Part 1: Executive Summary

2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiac arrest | cardiopulmonary resuscitation | emergency | resuscitation

1 Introduction

Publication of the *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation* (CPR) *and Emergency Cardiovascular Care* (ECC) marks 49 years since the first CPR guidelines were published in 1966 by an Ad Hoc Committee on Cardiopulmonary Resuscitation established by the National Academy of Sciences of the National Research Council. Since that time, periodic revisions to the Guidelines have been published by the AHA in 1974,[1] 1980,[2] 1986,[3] 1992,[4] 2000,[5] 2005,[6] 2010,[7] and now 2015. The *2010 AHA Guidelines for CPR and ECC* provided a comprehensive review of evidence-based recommendations for resuscitation, ECC, and first aid. *The 2015 AHA Guidelines Update for CPR and ECC* focuses on topics with significant new science or ongoing controversy, and so serves as an update to the *2010 AHA Guidelines for CPR and ECC* rather than a complete revision of the Guidelines.

The purpose of this Executive Summary is to provide an overview of the new or revised recommendations contained in the 2015 Guidelines Update. This document does not contain extensive reference citations; the reader is referred to Parts 3 through 9 for more detailed review of the scientific evidence and the recommendations on which they are based.

There have been several changes to the organization of the 2015 Guidelines Update compared with 2010. "Part 4: Systems of Care and Continuous Quality Improvement" is an important new Part that focuses on the integrated structures and processes that are necessary to create systems of care for both in-hospital and out-of-hospital resuscitation capable of measuring and improving quality and patient outcomes. This Part replaces the "CPR Overview" Part of the 2010 Guidelines.

Another new Part of the 2015 Guidelines Update is "Part 14: Education," which focuses on evidence-based recommendations to facilitate widespread, consistent, efficient and effective implementation of the AHA Guidelines for CPR and ECC into practice. These recommendations will target resuscitation education of both lay rescuers and healthcare providers. This Part replaces the 2010 Part titled "Education, Implementation, and Teams." The 2015 Guidelines Update does not include a separate Part on adult stroke because the content would replicate that already offered in the most recent AHA/American Stroke Association guidelines for the management of acute stroke.[8,9] Finally, the 2015 Guidelines Update marks the beginning of a new era for the AHA Guidelines for CPR and ECC, because the Guidelines will transition from a 5-year cycle of periodic revisions and updates to a Web-based format that is continuously updated. The first release of the *Web-based Integrated Guidelines*, now available online at ECCguidelines.heart.org is based on the comprehensive 2010 Guidelines plus the 2015 Guidelines Update. Moving forward, these Guidelines will be updated by using a continuous evidence evaluation process to facilitate more rapid translation of new scientific discoveries into daily patient care.

Creation of practice guidelines is only one link in the chain of knowledge translation that starts with laboratory and clinical science and culminates in improved patient outcomes. The AHA ECC Committee has set an impact goal of doubling bystander CPR rates and doubling cardiac arrest survival by 2020. Much work will be needed across the entire spectrum of knowledge translation to reach this important goal.

2 Evidence Review and Guidelines Development Process

The process used to generate the *2015 AHA Guidelines Update for CPR and ECC* was significantly different from the process used in prior releases of the Guidelines, and marks the planned transition from a 5-year cycle of evidence review to a continuous evidence evaluation process. The AHA continues to partner with the International Liaison Committee on Resuscitation (ILCOR) in the evidence review process. However, for 2015, ILCOR prioritized topics for systematic review based on clinical significance and availability of new evidence.

Each priority topic was defined as a question in PICO (population, intervention, comparator, outcome) format. Many of the topics reviewed in 2010 did not have new published evidence or controversial aspects, so they were not rereviewed in 2015. In 2015, 165 PICO questions were addressed by systematic reviews, whereas in 2010, 274 PICO questions were addressed by evidence evaluation. In addition, ILCOR adopted the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) process for evidence evaluation and expanded the opportunity for public comment. The output of the GRADE process was used to generate the *2015 International Consensus on CPR and ECC Science With Treatment Recommendations* (CoSTR).[10,11]

The recommendations of the ILCOR 2015 CoSTR were used to inform the recommendations in the 2015 *AHA Guidelines Update for CPR and ECC*. The wording of these recommendations is based on the AHA classification system for evidentiary review (see "Part 2: Evidence Evaluation and Management of Conflicts of Interest").

The *2015 AHA Guidelines Update for CPR and ECC* contains 315 classified recommendations. There are 78 Class I recommendations (25%), 217 Class II recommendations (68%), and 20 Class III recommendations (7%). Overall, 3 (1%) are based on Level of Evidence (LOE) A, 50 (15%) are based on LOE B-R (randomized studies), 46 (15%) are based on LOE B-NR (nonrandomized studies), 145 (46%) are based on LOE C-LD (limited data), and 73 (23%) are based on LOE C-EO (consensus of expert opinion). These results highlight the persistent knowledge gap in resuscitation science that needs to be addressed through expanded research initiatives and funding opportunities.

As noted above, the transition from a 5-year cycle to a continuous evidence evaluation and Guidelines update process will be initiated by the 2015 online publication of the *AHA Integrated Guidelines for CPR and ECC* at ECCguidelines.heart.org. The initial content will be a compilation of the 2010 Guidelines and the 2015 Guidelines Update. In the future, the Scientific Evidence Evaluation and Review System (SEERS) Web-based resource will also be periodically updated with results of the ILCOR continuous evidence evaluation process at www.ilcor.org/seers.

3 Part 3: Ethical Issues

As resuscitation practice evolves, ethical considerations must also evolve. Managing the multiple decisions associated with resuscitation is challenging from many perspectives, especially when healthcare providers are dealing with the ethics surrounding decisions to provide or withhold emergency cardiovascular interventions.

Ethical issues surrounding resuscitation are complex and vary across settings (in or out of hospital), providers (basic or advanced), patient population (neonatal, pediatric, or adult), and whether to start or when to terminate CPR. Although the ethical principles involved have not changed dramatically since the 2010 Guidelines were published, the data that inform many ethical discussions have been updated through the evidence review process. The 2015 ILCOR evidence review process and resultant 2015 Guidelines Update include several recommendations that have implications for ethical decision making in these challenging areas.

3.1 Significant New and Updated Recommendations That May Inform Ethical Decisions

- The use of extracorporeal CPR (ECPR) for cardiac arrest
- Intra-arrest prognostic factors for infants, children, and adults
- Prognostication for newborns, infants, children, and adults after cardiac arrest
- Function of transplanted organs recovered after cardiac arrest

New resuscitation strategies, such as ECPR, have made the decision to discontinue cardiac arrest measures more complicated (see "Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation" and "Part 7: Adult Advanced Cardiovascular Life Support"). Understanding the appropriate use, implications, and likely benefits related to such new treatments will have an impact on decision making. There is new information regarding prognostication for newborns, infants, children, and adults with cardiac arrest and/or after cardiac arrest (see "Part 13: Neonatal Resuscitation," "Part 12: Pediatric Advanced Life Support," and "Part 8: Post-Cardiac Arrest Care"). The increased use of targeted temperature management has led to new challenges for predicting neurologic outcomes in comatose post-cardiac arrest patients, and the latest data about the accuracy of particular tests and studies should be used to guide decisions about goals of care and limiting interventions.

With new information about the success rate for transplanted organs obtained from victims of cardiac arrest, there is ongoing discussion about the ethical implications around organ donation in an emergency setting. Some of the different view-points on important ethical concerns are summarized in "Part 3: Ethical Issues." There is

also an enhanced awareness that although children and adolescents cannot make legally binding decisions, information should be shared with them to the extent possible, using appropriate language and information for their level of development. Finally, the phrase “limitations of care” has been changed to “limitations of interventions,” and there is increasing availability of the Physician Orders for Life-Sustaining Treatment (POLST) form, a new method of legally identifying people who wish to have specific limits on interventions at the end of life, both in and out of healthcare facilities.

4 Part 4: Systems of Care and Continuous Quality Improvement

Almost all aspects of resuscitation, from recognition of cardio-pulmonary compromise, through cardiac arrest and resuscitation and post-ardiac arrest care, to the return to productive life, can be discussed in terms of a system or systems of care. Systems of care consist of multiple working parts that are interdependent, each having an effect on every other aspect of the care within that system. To bring about any improvement, providers must recognize the interdependency of the various parts of the system. There is also increasing recognition that out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) systems of care must function differently. “Part 4: Systems of Care and Continuous Quality Improvement” in this 2015 Guidelines Update makes a clear distinction between the two systems, noting that OHCA frequently is the result of an unexpected event with a reactive element, whereas the focus on IHCA is shifting from reactive resuscitation to prevention. New Chains of Survival are suggested for in-hospital and out-of-hospital systems of care, with relatively recent in-hospital focus on prevention of arrests. Additional emphasis should be on continuous quality improvement by identifying the problem that is limiting survival, and then by setting goals, measuring progress toward those goals, creating accountability, and having a method to effect change in order to improve outcomes.

This new Part of the AHA Guidelines for CPR and ECC summarizes the evidence reviewed in 2015 with a focus on the systems of care for both IHCA and OHCA, and it lays the framework for future efforts to improve these systems of care. A universal taxonomy of systems of care is proposed for stakeholders. There are evidence-based recommendations on how to improve these systems.

4.1 Significant New and Updated Recommendations

In a randomized trial, social media was used by dispatchers to notify nearby potential rescuers of a possible cardiac arrest. Although few patients ultimately received CPR from volunteers dispatched by the notification system, there was a higher rate of bystander-initiated CPR (62% versus 48% in the control group).[12]

Given the low risk of harm and the potential benefit of such notifications, it may be reasonable for communities to incorporate, where available, social media technologies that summon rescuers who are willing and able to perform CPR and are in close proximity to a suspected victim of OHCA.
(Class IIb, LOE B-R)

Specialized cardiac arrest centers can provide comprehensive care to patients after resuscitation from cardiac arrest. These specialized centers have been proposed, and new evidence suggests that a regionalized approach to OHCA resuscitation may be considered that includes the use of cardiac resuscitation centers.

A variety of early warning scores are available to help identify adult and pediatric patients at risk for deterioration. Medical emergency teams or rapid response teams have been developed to help respond to patients who are deteriorating. Use of scoring systems to identify these patients and creation of teams to respond to those scores or other indicators of deterioration may be considered, particularly on general care wards for adults and for children with high-risk illnesses, and may help reduce the incidence of cardiac arrest.

Evidence regarding the use of public access defibrillation was reviewed, and the use of automated external defibrillators (AEDs) by laypersons continues to improve survival from OHCA. We continue to recommend implementation of public access defibrillation programs for treatment of patients with OHCA in communities who have persons at risk for cardiac arrest.

4.2 Knowledge Gaps

- What is the optimal model for rapid response teams in the prevention of IHCA, and is there evidence that rapid response teams improve outcomes?
- What are the most effective methods for increasing bystander CPR for OHCA?

- What is the best composition for a team that responds to IHCA, and what is the most appropriate training for that team?

5 Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality

5.1 New Developments in Basic Life Support Science Since 2010

The 2010 Guidelines were most notable for the reorientation of the universal sequence from A-B-C (Airway, Breathing, Compressions) to C-A-B (Compressions, Airway, Breathing) to minimize time to initiation of chest compressions. Since 2010, the importance of high-quality chest compressions has been reemphasized, and targets for compression rate and depth have been further refined by relevant evidence. For the untrained lay rescuer, dispatchers play a key role in the recognition of abnormal breathing or agonal gasps as signs of cardiac arrest, with recommendations for chest compression-only CPR.

This section presents the updated recommendations for the 2015 adult basic life support (BLS) guidelines for lay rescuers and healthcare providers. Key changes and continued points of emphasis in this 2015 Guidelines Update include the following: The crucial links in the adult Chain of Survival for OHCA are unchanged from 2010; however, there is increased emphasis on the rapid identification of potential cardiac arrest by dispatchers, with immediate provision of CPR instructions to the caller. These Guidelines take into consideration the ubiquitous presence of mobile phones that can allow the rescuer to activate the emergency response system without leaving the victim's side. For healthcare providers, these recommendations allow flexibility for activation of the emergency response to better match the provider's clinical setting. More data are available indicating that high-quality CPR improves survival from cardiac arrest. Components of high-quality CPR include

- Ensuring chest compressions of adequate rate
- Ensuring chest compressions of adequate depth
- Allowing full chest recoil between compressions
- Minimizing interruptions in chest compressions
- Avoiding excessive ventilation

Recommendations are made for a simultaneous, choreographed approach to performance of chest compressions, airway management, rescue breathing, rhythm detection, and shock delivery (if indicated) by an integrated team of highly trained rescuers in applicable settings.

5.2 Significant New and Updated Recommendations

Many studies have documented that the most common errors of resuscitation are inadequate compression rate and depth; both errors may reduce survival. New to this 2015 Guidelines Update are upper limits of recommended compression rate based on preliminary data suggesting that excessive rate may be associated with lower rate of return of spontaneous circulation (ROSC). In addition, an upper limit of compression depth is introduced based on a report associating increased non-life-threatening injuries with excessive compression depth.

- ***In adult victims of cardiac arrest, it is reasonable for rescuers to perform chest compressions at a rate of 100/min to 120/min. (Class IIa, LOE C-LD)***

  The addition of an upper limit of compression rate is the result of 1 large registry study associating extremely rapid compression rates with inadequate compression depth.

- ***During manual CPR, rescuers should perform chest compressions to a depth of at least 2 inches or 5 cm for an average adult, while avoiding excessive chest compression depths (greater than 2.4 inches or 6 cm). (Class I, LOE C-LD)***

  The addition of an upper limit of compression depth followed review of 1 publication suggesting potential harm from excessive chest compression depth (greater than 6 cm, or 2.4 inches). Compression depth may be difficult to judge without use of feedback devices, and identification of upper limits of compression depth may be challenging.

-

In adult cardiac arrest, total preshock and postshock pauses in chest compressions should be as short as possible. (Class I, LOE C-LD)

Shorter pauses can be associated with greater shock success, ROSC, and, in some studies, higher survival to hospital discharge. The need to reduce such pauses has received greater emphasis in this 2015 Guidelines Update.

- ***In adult cardiac arrest with an unprotected airway, it may be reasonable to perform CPR with the goal of a chest compression fraction as high as possible, with a target of at least 60%. (Class IIb, LOE C-LD)***

  The addition of this target compression fraction to the 2015 Guidelines Update is intended to limit interruptions in compressions and to maximize coronary perfusion and blood flow during CPR.

- ***For patients with known or suspected opioid overdose who have a definite pulse but no normal breathing or only gasping (ie, a respiratory arrest), in addition to providing standard BLS care, it is reasonable for appropriately trained BLS healthcare providers to administer IM or IN naloxone. (Class IIa, LOE C-LD)***

- ***It is reasonable to provide opioid overdose response education with or without naloxone distribution to persons at risk for opioid overdose (or those living with or in frequent contact with such persons). (Class IIa, LOE C-LD)***

  For more information, see “Part 10: Special Circumstances of Resuscitation”.

- ***For witnessed OHCA with a shockable rhythm, it may be reasonable for EMS systems with priority-based, multitiered response to delay positive-pressure ventilation by using a strategy of up to 3 cycles of 200 continuous compressions with passive oxygen insufflation and airway adjuncts. (Class IIb, LOE C-LD)***

- ***We do not recommend the routine use of passive ventilation techniques during conventional CPR for adults. (Class IIb, LOE C-LD)***

- ***However, in EMS systems that use bundles of care involving continuous chest compressions, the use of passive ventilation techniques may be considered as part of that bundle. (Class IIb, LOE C-LD)***

- ***It is recommended that emergency dispatchers determine if a patient is unconscious with abnormal breathing after acquiring the requisite information to determine the location of the event. (Class I, LOE C-LD)***

-

If the patient is unconscious with abnormal or absent breathing, it is reasonable for the emergency dispatcher to assume that the patient is in cardiac arrest. (Class IIa, LOE C-LD)

- ***Dispatchers should be educated to identify unconsciousness with abnormal and agonal gasps across a range of clinical presentations and descriptions. (Class I, LOE C-LD)***

- ***We recommend that dispatchers should provide chest compression-only CPR instructions to callers for adults with suspected OHCA. (Class I, LOE C-LD)***

- ***It is reasonable for healthcare providers to provide chest compressions and ventilation for all adult patients in cardiac arrest, from either a cardiac or noncardiac cause. (Class IIa, LOE C-LD)***

- ***When the victim has an advanced airway in place during CPR, rescuers no longer deliver cycles of 30 compressions and 2 breaths (ie, they no longer interrupt compressions to deliver 2 breaths). Instead, it may be reasonable for the provider to deliver 1 breath every 6 seconds (10 breaths per minute) while continuous chest compressions are being performed. (Class IIb, LOE C-LD)***

  This simple rate, rather than a range of breaths per minute, should be easier to learn, remember, and perform.

- ***There is insufficient evidence to recommend the use of artifact-filtering algorithms for analysis of ECG rhythm during CPR. Their use may be considered as part of a research protocol or if an EMS system, hospital, or other entity has already incorporated ECG artifact-filtering algorithms in its resuscitation protocols. (Class IIb, LOE C-EO)***

- ***It may be reasonable to use audiovisual feedback devices during CPR for real-time optimization of CPR performance. (Class IIb, LOE B-R)***

- ***For victims with suspected spinal injury, rescuers should initially use manual spinal motion restriction (eg, placing 1 hand on either side of the patient's head to hold it still) rather than immobilization devices, because use of immobilization devices by lay rescuers may be harmful. (Class III: Harm, LOE C-LD)***

5.3 Knowledge Gaps

- The optimal method for ensuring adequate depth of chest compressions during manual CPR
- The duration of chest compressions after which ventilation should be incorporated when using Hands-only CPR
- The optimal chest compression fraction
- Optimal use of CPR feedback devices to increase patient survival

6 Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation

High-quality conventional CPR (manual chest compressions with rescue breaths) generates about 25% to 33%

of normal cardiac output and oxygen delivery. A variety of alternatives and adjuncts to conventional CPR have been developed with the aim of enhancing coronary and cerebral perfusion during resuscitation from cardiac arrest. Since the 2010 AHA Guidelines for CPR and ECC were published, a number of clinical trials have provided new data regarding the effectiveness of these alternatives. Compared with conventional CPR, many of these techniques and devices require specialized equipment and training. Some have been tested in only highly selected subgroups of cardiac arrest patients; this selection must be noted when rescuers or healthcare systems consider implementation of the devices.

6.1 Significant New and Updated Recommendations

- The Resuscitation Outcomes Consortium (ROC) Prehospital Resuscitation Impedance Valve and Early Versus Delayed Analysis (PRIMED) study (n=8718)[13] failed to demonstrate improved outcomes with the use of an impedance threshold device (ITD) as an adjunct to conventional CPR when compared with use of a sham device. This negative high-quality study prompted a Class III: No Benefit recommendation regarding routine use of the ITD.

- One large randomized controlled trial evaluated the use of active compression-decompression CPR plus an ITD.[14] The writing group found interpretation of the true clinical effect of active compression-decompression CPR plus an ITD challenging because of wide confidence intervals around the effect estimate and also because of methodological concerns. The finding of improved neurologically intact survival in the study, however, supported a recommendation that this combination may be a reasonable alternative with available equipment and properly trained providers.

- Three randomized clinical trials comparing the use of mechanical chest compression devices with conventional CPR have been published since the 2010 Guidelines. None of these studies demonstrated superiority of mechanical chest compressions over conventional CPR. Manual chest compressions remain the standard of care for the treatment of cardiac arrest, but mechanical chest compression devices may be a reasonable alternative for use by properly trained personnel.

  The use of mechanical piston devices may be considered in specific settings where the delivery of high-quality manual compressions may be challenging or dangerous for the provider (eg, limited rescuers available, prolonged CPR, during hypothermic cardiac arrest, in a moving ambulance, in the angiography suite, during preparation for extracorporeal CPR [ECPR]), provided that rescuers strictly limit interruptions in CPR during deployment and removal of the devices.
  (Class IIb, LOE C-EO)

- Although several observational studies have been published documenting the use of ECPR, no randomized controlled trials have evaluated the effect of this therapy on survival.

6.2 Knowledge Gaps

- Are mechanical chest compression devices superior to manual chest compressions in special situations such as a moving ambulance, prolonged CPR, or procedures such as coronary angiography?
- What is the impact of implementing ECPR as part of the system of care for OHCA?

7 Part 7: Adult Advanced Cardiovascular Life Support

The major changes in the 2015 advanced cardiovascular life support (ACLS) guidelines include recommendations regarding prognostication during CPR based on end-tidal carbon dioxide measurements, use of vasopressin during resuscitation, timing of epinephrine administration stratified by shockable or nonshockable rhythms, and the possibility of bundling steroids, vasopressin, and epinephrine administration for treatment of IHCA. In addition, vasopressin has been removed from the pulseless arrest algorithm. Recommendations regarding physiologic monitoring of CPR were reviewed, although there is little new evidence.

7.1 Significant New and Updated Recommendations

- Based on new data, the recommendation for use of the maximal feasible inspired oxygen during CPR was strengthened. This recommendation applies only while CPR is ongoing and does not apply to care after ROSC.

- The new 2015 Guidelines Update continues to state that physiologic monitoring during CPR may be useful, but there has yet to be a clinical trial demonstrating that goal-directed CPR based on physiologic parameters improves outcomes.

- Recommendations for ultrasound use during cardiac arrest are largely unchanged, except for the explicit proviso that the use of ultrasound should not interfere with provision of high-quality CPR and conventional ACLS therapy.

- Continuous waveform capnography remained a Class I recommendation for confirming placement of an endotracheal tube. Ultrasound was added as an additional method for confirmation of endotracheal tube placement.

- The defibrillation strategies addressed by the 2015 ILCOR review resulted in minimal changes in defibrillation recommendations.

- The Class of Recommendation for use of standard dose epinephrine (1 mg every 3 to 5 minutes) was unchanged but reinforced by a single new prospective randomized clinical trial demonstrating improved ROSC and survival to hospital admission that was inadequately powered to measure impact on long-term outcomes.

- Vasopressin was removed from the ACLS Cardiac Arrest Algorithm as a vasopressor therapy in recognition of equivalence of effect with other available interventions (ig, epinephrine). This modification valued the simplicity of approach toward cardiac arrest when 2 therapies were found to be equivalent.

- The recommendations for timing of epinephrine administration were updated and stratified based on the initial presenting rhythm, recognizing the potential difference in pathophysiologic disease. For those with a nonshockable rhythm, it may be reasonable to administer epinephrine as soon as feasible. For those with a shockable rhythm, there is insufficient evidence to make a recommendation about the optimal timing of epinephrine administration, because defibrillation is a major focus of resuscitation.

- The use of steroids in cardiac arrest is controversial. In OHCA, administration of steroids did not improve survival to hospital discharge in 2 studies, and routine use is of uncertain benefit. The data regarding the use of steroids for IHCA were more vexing. In 2 randomized controlled trials led by the same investigators, a pharmacologic bundle that included methylprednisolone, vasopressin, and epinephrine administered during cardiac arrest followed by hydrocortisone given after ROSC improved survival. Whether the improved survival was a result of the bundle or of the steroid therapy alone could not be assessed

  In IHCA, the combination of intra-arrest vasopressin, epinephrine, and methylprednisolone and post-arrest hydrocortisone as described by Mentzelopoulos et al [15] may be considered; however, further studies are needed before recommending the routine use of this therapeutic strategy.

  (Class IIb, LOE C-LD)

- Prognostication during CPR was also a very active topic. There were reasonably good data indicating that low partial pressure of end-tidal carbon dioxide ($Petco_2$) in intubated patients after 20 minutes of CPR is strongly associated with failure of resuscitation. Importantly, this parameter should not be used in isolation and should not be used in nonintubated patients.

- ECPR, also known as venoarterial extracorporeal membrane oxygenation, may be considered as an alternative to conventional CPR for select patients with refractory cardiac arrest when the suspected etiology of the cardiac arrest is potentially reversible during a limited period of mechanical cardiorespiratory support.

7.2 Knowledge Gaps

- More knowledge is needed about the impact on survival and neurologic outcome when physiologic

targets and ultrasound are used to guide resuscitation during cardiac arrest.
- The dose-response curve for defibrillation of shockable rhythms is unknown, and the initial shock energy, subsequent shock energies, and maximum shock energies for each waveform are unknown.
- More information is needed to identify the ideal current delivery to the myocardium that will result in defibrillation, and the optimal way to deliver it. The selected energy is a poor comparator for assessing different waveforms, because impedance compensation and subtleties in waveform shape result in a different transmyocardial current among devices at any given selected energy.
- Is a hands-on defibrillation strategy with ongoing chest compressions superior to current hands-off strategies with pauses for defibrillation?
- What is the dose-response effect of epinephrine during cardiac arrest?
- The efficacy of bundled treatments, such as epinephrine, vasopressin, and steroids, should be evaluated, and further studies are warranted as to whether the bundle with synergistic effects or a single agent is related to any observed treatment effect.
- There are no randomized trials for any antiarrhythmic drug as a second-line agent for refractory ventricular fibrillation/pulseless ventricular tachycardia, and there are no trials evaluating the initiation or continuation of antiarrhythmics in the post-cardiac arrest period.
- Controlled clinical trials are needed to assess the clinical benefits of ECPR versus traditional CPR for patients with refractory cardiac arrest and to determine which populations would most benefit.

When ROSC is not rapidly achieved after cardiac arrest, several options exist to provide prolonged circulatory support. These options include mechanical CPR devices, and use of endovascular ventricular assist devices, intra-aortic balloon counterpulsation, and ECPR have all been described. The role of these modalities, alone or in combination, is not well understood. (For additional information, see, “Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation”)

8 Part 8: Post–Cardiac Arrest Care

Post–cardiac arrest care research has advanced significantly over the past decade. Multiple studies and trials detail the heterogeneity of patients and the spectrum of pathophysiology after cardiac arrest. Post–cardiac arrest care should be titrated based on arrest etiology, comorbid disease, and illness severity. Thus, the 2015 Guidelines Update integrates available data to help experienced clinicians make the complex set of therapeutic decisions required for these patients. The central principles of postarrest care are (1) to identify and treat the underlying etiology of the cardiac arrest, (2) to mitigate ischemia-reperfusion injury and prevent secondary organ injury, and (3) to make accurate estimates of prognosis to guide the clinical team and to inform the family when selecting goals of continued care.

8.1 New Developments

Early coronary angiography and coronary intervention are recommended for patients with ST elevation as well as for patients without ST elevation, when an acute coronary event is suspected. The decision to perform coronary angiography should not include consideration of neurologic status, because of the unreliability of early prognostic signs. Targeted temperature management is still recommended for at least 24 hours in comatose patients after cardiac arrest, but clinicians may choose a target temperature from the wider range of 32°C to 36°C. Estimating the prognosis of patients after cardiac arrest is best accomplished by using multiple modalities of testing: clinical examination, neurophysiological testing, and imaging.

8.2 Significant New and Updated Recommendations

One of the most common causes of cardiac arrest outside of the hospital is acute coronary occlusion. Quickly identifying and treating this cause is associated with better survival and better functional recovery. Therefore, coronary angiography should be performed emergently (rather than later in the hospital stay or not at all) for OHCA patients with suspected cardiac etiology of arrest and ST elevation on ECG. Emergency coronary angiography is reasonable for select (eg, electrically or hemodynamically unstable) adults who are without ST elevation on ECG but are comatose after OHCA of suspected cardiac origin. Emergency coronary angiography is also reasonable for post–cardiac arrest patients for whom coronary angiography is indicated, regardless of whether the patient is comatose or awake.

A high-quality randomized controlled trial did not identify any superiority of targeted temperature management at 36°C compared with management at 33°C. Excellent outcomes are possible when patients are actively managed at either temperature. All comatose (ie, lack of meaningful response to verbal commands) adult patients with

ROSC after cardiac arrest should have targeted temperature management, with providers selecting and maintaining a constant temperature between 32°C and 36°C for at least 24 hours after achieving target temperature. It is also reasonable to actively prevent fever in comatose patients after targeted temperature management.

- Multiple randomized controlled trials tested prehospital infusion of cold intravenous fluids to initiate hypothermia after OHCA. The absence of any benefit and the presence of some complications in these trials led to a recommendation against the routine prehospital cooling of patients after ROSC by using rapid infusion of cold saline. However, this recommendation does not preclude the use of cold intravenous fluids in more controlled or more selected settings and did not address other methods of inducing hypothermia.

- Specific management of patients during postresuscitation intensive care includes avoiding and immediately correcting hypotension and hypoxemia. It is reasonable to use the highest available oxygen concentration until the arterial oxyhemoglobin saturation or the partial pressure of arterial oxygen can be measured. However, the benefits of any specific target ranges for blood pressure, ventilator management, or glucose management are uncertain.

- Multiple studies examined methods to determine prognosis in patients after cardiac arrest, and the use of multiple modalities of testing is recommended. The earliest time to prognosticate a poor neurologic outcome by using clinical examination in patients not treated with targeted temperature management is 72 hours after ROSC, but this time can be even longer after cardiac arrest if the residual effect of sedation or paralysis is suspected to confound the clinical examination. In patients treated with targeted temperature management, where sedation or paralysis could confound clinical examination, it is reasonable to wait until 72 hours after return to normothermia.

- Useful clinical findings that are associated with poor neurologic outcome include
    - The absence of pupillary reflex to light at ?72 hours after cardiac arrest
    - The presence of status myoclonus during the first 72 hours after cardiac arrest
    - The absence of the N20 somatosensory evoked potential cortical wave 24 to 72 hours after cardiac arrest or after rewarming
    - The presence of a marked reduction of the gray-white ratio on brain computed tomography obtained within 2 hours after cardiac arrest
    - Extensive restriction of diffusion on brain magnetic resonance imaging at 2 to 6 days after cardiac arrest
    - Persistent absence of electroencephalographic reactivity to external stimuli at 72 hours after cardiac arrest
    - Persistent burst suppression or intractable status epilepticus on electroencephalogram after rewarming
    - *Note*: Absent motor movements, extensor posturing or myoclonus should not be used alone for predicting outcome.

- All patients who are resuscitated from cardiac arrest but who subsequently progress to death or brain death should be evaluated as potential organ donors. Patients who do not have ROSC after resuscitation efforts also may be considered candidates as kidney or liver donors in settings where programs exist.

8.3 Knowledge Gaps

- Which post-cardiac arrest patients without ST elevation are most likely to benefit from early coronary angiography?
- What are the optimal goals for blood pressure, ventilation, and oxygenation in specific groups of post-cardiac arrest patients?
- What are the optimal duration, timing, and methods for targeted temperature management?
- Will particular subgroups of patients benefit from management at specific temperatures?
- What strategies can be used to prevent or treat post–cardiac arrest cerebral edema and malignant electroencephalographic patterns (seizures, status myoclonus)?
- What is the most reliable strategy for prognostication of futility in comatose post–cardiac arrest survivors?

9 Part 9: Acute Coronary Syndromes

The 2015 Guidelines Update newly limits recommendations for the evaluation and management of acute

coronary syndromes (ACS) to the care rendered during the prehospital and emergency department phases of care only, and specifically does not address management of patients after emergency department disposition. Within this scope, several important components of care can be classified as diagnostic interventions in ACS, therapeutic interventions in ACS, reperfusion decisions in ST-segment elevation myocardial infarction (STEMI), and hospital reperfusion decisions after ROSC. Diagnosis is focused on ECG acquisition and interpretation and the rapid identification of patients with chest pain who are safe for discharge from the emergency department. Therapeutic interventions focus on prehospital adenosine diphosphate receptor antagonists in STEMI, prehospital anticoagulation, and the use of supplementary oxygen. Reperfusion decisions include when and where to use fibrinolysis versus percutaneous coronary intervention (PCI) and when post-ROSC patients may benefit from having access to PCI.

9.1 Significant New and Updated Recommendations

A well-organized approach to STEMI care still requires integration of community, EMS, physician, and hospital resources in a bundled STEMI system of care. Two studies published since the 2010 evidence review confirm the importance of acquiring a 12-lead ECG for patients with possible ACS as early as possible in the prehospital setting. These studies reaffirmed previous recommendations that when STEMI is diagnosed in the prehospital setting, prearrival notification of the hospital and/or prehospital activation of the catheterization laboratory should occur without delay. These updated recommendations place new emphasis on obtaining a prehospital ECG and on both the necessity for and the timing of receiving hospital notification.

- ***Prehospital 12-lead ECG should be acquired early for patients with possible ACS. (Class I, LOE B-NR)***

- ***Prehospital notification of the receiving hospital (if fibrinolysis is the likely reperfusion strategy) and/or prehospital activation of the catheterization laboratory should occur for all patients with a recognized STEMI on prehospital ECG. (Class I, LOE B-NR)***

Because the rate of false-negative results of 12-lead ECGs may be unacceptably high, a computer reading of the ECG should not be a sole means to diagnose STEMI, but may be used in conjunction with physician or trained provider interpretation. New studies examining the accuracy of ECG interpretation by trained nonphysicians have prompted a revision of the recommendation to explicitly permit trained nonphysicians to interpret ECGs for the presence of STEMI.

- ***We recommend that computer-assisted ECG interpretation may be used in conjunction with physician or trained provider interpretation to recognize STEMI . (Class IIb, LOE C-LD)***

- ***While transmission of the prehospital ECG to the ED physician may improve positive predictive value (PPV) and therapeutic decision-making regarding adult patients with suspected STEMI, if transmission is not performed, it may be reasonable for trained nonphysician ECG interpretation to be used as the basis for decision-making, including activation of the catheterization laboratory, administration of fibrinolysis, and selection of destination hospital. (Class IIa, LOE B-NR)***

High-sensitivity cardiac troponin is now widely available. The 2015 CoSTR review examined whether a negative troponin test could reliably exclude a diagnosis of ACS in patients who did not have signs of STEMI on ECG. For emergency department patients with a presenting complaint consistent with ACS, high-sensitivity cardiac troponin T (hs-cTnT) and cardiac troponin I (cTnI) measured at 0 and 2 hours should not be interpreted in isolation (without performing clinical risk stratification) to exclude the diagnosis of ACS. In contrast, high-sensitivity cardiac troponin I (hs-cTnI), cTnI, or cardiac troponin T (cTnT) may be used in conjunction with a number of clinical scoring systems to identify patients at low risk for 30-day major adverse cardiac events (MACE) who may be safely discharged from the emergency department.

-

We recommend that hs-cTnI measurements that are less than the 99th percentile, measured at 0 and 2 hours, may be used together with low-risk stratification (TIMI score of 0 or 1 or low risk per Vancouver rule) to predict a less than 1% chance of 30-day MACE. (Class IIa, LOE B-NR)

- ***We recommend that negative cTnI or cTnT measurements at 0 and between 3 and 6 hours may be used together with very low-risk stratification (TIMI score of 0, low-risk score per Vancouver rule, North American Chest Pain score of 0 and age less than 50 years, or low-risk HEART score) to predict a less than 1% chance of 30-day MACE. (Class IIa, LOE B-NR)***

New recommendations have been made regarding several therapeutic interventions in ACS. New data from a case-control study that compared heparin and aspirin administered in the prehospital to the hospital setting found blood flow rates to be higher in infarct-related arteries when heparin and aspirin are administered in the prehospital setting. Because of the logistical difficulties in introducing heparin to EMS systems that do not currently use this drug and the limitations in interpreting data from a single study, initiation of adenosine diphosphate (ADP) inhibition may be reasonable in either the prehospital or the hospital setting in patients with suspected STEMI who intend to undergo primary PCI.

- ***We recommend that EMS systems that do not currently administer heparin to suspected STEMI patients do not add this treatment, whereas those that do administer it may continue their current practice. (Class IIb, LOE B-NR)***

- ***In suspected STEMI patients for whom there is a planned PCI reperfusion strategy, administration of unfractionated heparin (UFH) can occur either in the prehospital or in-hospital setting. (Class IIb, LOE B-NR)***

Supplementary oxygen has been routinely administered to patients with suspected ACS for years. Despite this tradition, the usefulness of supplementary oxygen therapy has not been established in normoxemic patients.

- ***The usefulness of supplementary oxygen therapy has not been established in normoxic patients. In the prehospital, ED, and hospital settings, the withholding of supplementary oxygen therapy in normoxic patients with suspected or confirmed acute coronary syndrome may be considered. (Class IIb, LOE C-LD)***

Timely restoration of blood flow to ischemic myocardium in acute STEMI remains the highest treatment priority. While the Class of Recommendation regarding reperfusion strategies remains unchanged from 2010, the choice between fibrinolysis and PCI has been reexamined to focus on clinical circumstances, system capabilities, and timing, and the recommendations have been updated accordingly. The anticipated time to PCI has been newly examined in 2015, and new time-dependent recommendations regarding the most effective reperfusion strategy are made. In STEMI patients, when long delays to primary PCI are anticipated (more than 120 minutes), a strategy of immediate fibrinolysis followed by routine early angiography (within 3 to 24 hours) and PCI, if indicated, is reasonable. It is acknowledged that fibrinolysis becomes significantly less effective at more than 6 hours after symptom onset, and thus a longer delay to primary PCI is acceptable in patients at more than 6 hours after symptom onset. To facilitate ideal treatment, systems of care must factor information about hospital capabilities into EMS destination decisions and interfaculty transfers.

- ***In adult patients presenting with STEMI in the ED of a non-PCI-capable hospital, we recommend immediate transfer without fibrinolysis from the initial facility to a PCI center instead of immediate fibrinolysis at the initial hospital with transfer only for ischemia-driven PCI. (Class I, LOE B-R)***

-

When STEMI patients cannot be transferred to a PCI-capable hospital in a timely manner, fibrinolytic therapy with routine transfer for angiography may be an acceptable alternative to immediate transfer to PPCI. (Class IIb, LOE C-LD)

- ***When fibrinolytic therapy is administered to a STEMI patient in a non–PCI-capable hospital, it may be reasonable to transport all postfibrinolysis patients for early routine angiography in the first 3 to 6 hours and up to 24 hours rather than transport postfibrinolysis patients only when they require ischemia-guided angiography. (Class IIb, LOE B-R)***

9.2 Knowledge Gaps

- More knowledge is needed about the optimal diagnostic approach for patients with serial troponin levels lower than the 99th percentile who are identified as being at moderate or high risk based on clinical scoring rules.
- The role of a single troponin measurement in identifying patients who are safe for discharge from the emergency department is currently evolving.
- The time from symptom onset to first medical contact is highly variable. An ideal reperfusion strategy considering the contribution of this variability in time to presentation has yet to be determined.

10 Part 10: Special Circumstances of Resuscitation

"Part 10: Special Circumstances of Resuscitation" presents new guidelines for the prevention and management of resuscitation emergencies related to opioid toxicity, and for the role of intravenous lipid emulsion (ILE) therapy for treatment of cardiac arrest due to drug overdose. Updated guidelines for the management of cardiac arrest occurring during the second half of pregnancy, cardiac arrest caused by pulmonary embolism, and cardiac arrest occurring during PCI are included.

10.1 Significant New and Updated Recommendations

- The 2010 Guidelines included a Class I recommendation to perform bag-mask–assisted ventilation and administer naloxone for patients with known or suspected opioid overdose who have respiratory depression but are not in cardiac arrest. Since that time, significant experience has accumulated to show that naloxone can be administered with apparent safety and effectiveness in the first aid and BLS settings. Accordingly, the 2015 Guidelines Update contains new recommendations for naloxone administration by non–healthcare providers, with recommendations for simplified training. A new algorithm for management of unresponsive victims with suspected opioid overdose is provided.

- Administration of ILE for the treatment of local anesthetic systemic toxicity (LAST), particularly from bupivacaine, is supported by extensive animal research and human case reports. In the 2015 Guidelines Update, this science was reviewed and a weak recommendation supporting use of ILE for treatment of LAST was reaffirmed. Since 2010, animal studies and human case reports have been published that examined the use of ILE for patients with other forms of drug toxicity, with mixed results. The 2015 Guidelines Update contains a new recommendation that ILE may be considered in patients with cardiac arrest due to drug toxicity other than LAST who are failing standard resuscitative measures.

- Relief of aortocaval compression has long been recognized as an essential component of resuscitation for women who develop cardiac arrest in the latter half of pregnancy, and this remains an important area of emphasis in the Guidelines. In the 2010 Guidelines, relief of aortocaval compression with manual left uterine displacement was a Class IIb recommendation. Although no cardiac arrest outcome studies have been published that compared left uterine displacement to other strategies to relieve aortocaval compression during CPR, the critical importance of high-quality CPR has been further supported. Because alternative strategies to relieve aortocaval compression (eg, lateral tilt) do not seem to be compatible with delivery of high-quality CPR, the recommendation to perform left uterine displacement during CPR was strengthened.

  If the fundus height is at or above the level of the umbilicus, manual LUD can be beneficial in

relieving aortocaval compression during chest compressions. (Class IIa, LOE C-LD)

- In addition to providing the opportunity for separate resuscitation of a potentially viable fetus, perimortem cesarean delivery (PMCD) provides the ultimate relief of aortocaval compression and may improve maternal resuscitation outcomes. The 2010 Guidelines included a Class IIb recommendation to consider performing PMCD at 4 to 5 minutes after the onset of maternal cardiac arrest without ROSC. The 2015 Guidelines Update expands on these recommendations.

In situations such as nonsurvivable maternal trauma or prolonged pulselessness, in which maternal resuscitative efforts are obviously futile, there is no reason to delay performing PMCD. (Class I, LOE C-LD)

PMCD should be considered at 4 minutes after onset of maternal cardiac arrest or resuscitative efforts (for the unwitnessed arrest) if there is no ROSC. (Class IIa, LOE C-EO)

The complexity and need for clinical judgment in this decision making is explicitly acknowledged.

10.2 Knowledge Gaps

- Although the recommendation to consider PMCD after 4 minutes of unsuccessful maternal resuscitation attempts has been promulgated since 1986, it is based on scientific rationale rather than experimental evidence or critical analysis of prospectively collected data. A recent systematic review found that early time to PMCD (less than 10 minutes) was associated with improved survival of the mother but not of the child, and PMCD within 4 to 5 minutes may not be achievable in most settings. Although clinical trials are not feasible, large registry studies may be able to support evidence-based decision making in timing of PMCD to improve both maternal and neonatal outcomes.
- Since the first animal studies were published in 1998, a large body of literature has developed that describes the use of ILE in resuscitation from poisoning and drug toxicity. Although the experimental studies and human anecdotal reports are consistently positive for treatment of LAST from bupivacaine, more variable results are reported for treatment of LAST from other agents, and results achieved after ILE administration for other toxicants are mixed. Administration of ILE alters the effectiveness of epinephrine and vasopressin in animal resuscitation studies, may increase the absorption of lipophilic medications from the gastrointestinal tract, and sometimes interferes with the operation of venoarterial extracorporeal membrane oxygenation circuits. Further research is needed to determine the role of ILE in the management of cardiac arrest and refractory shock due to poisoning.

11 Part 11: Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality

The 2015 Guidelines Update for pediatric BLS concentrated on modifications in the algorithms for lone- and 2-rescuer CPR, initial actions of rescuers, and CPR quality process measures. Algorithms for 1- and 2-person healthcare provider CPR have been separated to better guide rescuers through the initial stages of resuscitation. In an era where handheld cellular telephones with speakers are common, this technology can allow a single rescuer to activate the emergency response system while beginning CPR. Healthcare providers should perform an assessment of breathing and pulse check simultaneously, to minimize delays in starting CPR if the child is unresponsive with no breathing or only gasping.

11.1 Significant New and Updated Recommendations

The 3 major CPR process characteristics that were evaluated included C-A-B (Compressions, Airway, Breathing) versus A-B-C (Airway, Breathing, Compressions), compression-only CPR, and compression depth and rate. No major changes were made for the 2015 Guidelines Update; however, new concepts in CPR delivery were examined for children.

-

Because of the limited amount and quality of the data, it may be reasonable to maintain the sequence from the 2010 Guidelines by initiating CPR with C-A-B over A-B-C sequence. (Class IIb, LOE C-EO)

There are no pediatric human studies to evaluate C-A-B versus A-B-C, but manikin studies do demonstrate a shorter time to fist chest compression. This recommendation was made to simplify training, provide consistency for teaching rescuers of adults and children, and hopefully increase the number of victims who receive bystander CPR.

- Compression depth of at least one third of the anterior-posterior diameter, approximately 1.5 inches (4 cm) for infants and approximately 2 inches (5 cm) for children, was affirmed (Updated). The Class of Recommendation was downgraded from Class I to Class IIa, primarily based on the rigor of the evidence evaluation. There are limited clinical data on the effect of compression depth on resuscitation outcomes, but 2 clinical studies suggest that compression depth is also associated with survival.

- Compression rate was not reviewed because of insufficient evidence, and we recommend that rescuers use the adult rate of 100 to 120/min (Updated).

- The asphyxial nature of the majority of pediatric cardiac arrests necessitates ventilation as part of effective CPR, and two large database studies documented worse 30-day outcomes with compression-only CPR compared with conventional CPR.

Conventional CPR (chest compressions and rescue breaths) should be provided for pediatric cardiac arrests. (Class I, LOE B-NR)

However, because compression-only CPR is effective in patients with a primary cardiac event, if rescuers are unwilling or unable to deliver breaths, we recommend rescuers perform compression-only CPR for infants and children in cardiac arrest. (Class I, LOE B-NR)

Conventional CPR (chest compressions and rescue breaths) is a Class I recommendation. (LOE B-NR)

11.2 Knowledge Gaps

- Much of the data supporting pediatric BLS is primarily extrapolated from studies in adults. Multicenter pediatric studies from both in-hospital and out-of hospital arrest are needed to optimize outcomes for children.
- More knowledge is needed about the optimal sequence, feedback techniques and devices, and effect of different surfaces on CPR delivery in children.

12 Part 12: Pediatric Advanced Life Support

12.1 Significant New and Updated Recommendations

The following are the most important changes and reinforcements to recommendations made in the 2010 Guidelines:

There is new evidence that when treating pediatric septic shock in specific settings, the use of restricted volume of isotonic crystalloid leads to improved survival, contrasting with the long-standing belief that all patients benefit from aggressive volume resuscitation. New guidelines suggest a cautious approach to fluid resuscitation, with frequent patient reassessment, to better tailor fluid therapy and supportive care to children with febrile illness.

- New literature suggests limited survival benefit to the routine use of atropine as a premedication for emergent tracheal intubation of non-neonates, and that any benefit in preventing arrhythmias is controversial. Recent literature also provides new evidence suggesting there is no minimum dose required for atropine use.

- Children in cardiac arrest may benefit from the titration of CPR to blood pressure targets, but this strategy is suggested only if they already have invasive blood pressure monitoring in place.
- New evidence suggests that either amiodarone or lidocaine is acceptable for treatment of shock-refractory pediatric ventricular fibrillation and pulseless ventricular tachycardia.
- Recent literature supports the need to avoid fever when caring for children remaining unconscious after OHCA.
- The writing group reviewed a newly published multicenter clinical trial of targeted temperature management that demonstrated that a period of either 2 days of moderate therapeutic hypothermia (32? to 34? C) or the strict maintenance of normothermia (36? to 37.5? C) were equally beneficial. As a result, the writing group feels either of these approaches are appropriate for infants and children remaining comatose after OHCA.
- Hemodynamic instability after cardiac arrest should be treated actively with fluids and/or inotropes/vasopressors to maintain systolic blood pressure greater than the fifth percentile for age. Continuous arterial pressure monitoring should be used when the appropriate resources are available.

12.2 Knowledge Gaps

- What clinical or physiologic parameters reflect high-quality pediatric CPR and improve outcome in children? Do devices to monitor these parameters improve survival?
- What is the role of targeted temperature management in the care of children who remain unconscious after in-hospital cardiac arrest?
- Does a postarrest bundle of care with specific targets for temperature, oxygenation and ventilation, and hemodynamic parameters improve outcomes after pediatric cardiac arrest?
- Does a combination of intra-arrest factors reliability predict successful resuscitation in children with either OHCA or IHCA?

13 Part 13: Neonatal Resuscitation

“Part 13: Neonatal Resuscitation” presents new guidelines for resuscitation of primarily newly born infants transitioning from intrauterine to extrauterine life. The recommendations are also applicable to neonates who have completed newborn transition and require resuscitation during the first weeks after birth.

Much of the neonatal resuscitation guidelines remains unchanged from 2010, but there is increasing focus on umbilical cord management, maintaining a normal temperature after birth, accurate determination of heart rate, optimizing oxygen use during resuscitation, and de-emphasis of routine suctioning for meconium in nonvigorous newborns. The etiology of neonatal arrest is almost always asphyxia, and therefore, establishing effective ventilation remains the most critical step.

13.1 Significant New and Updated Recommendations

Umbilical cord management: The 2015 Guidelines Update includes for the first time recommendations regarding umbilical cord management. Until recently, it was common practice to clamp the umbilical cord immediately after birth to facilitate rapid transfer of the baby to the pediatric provider for stabilization. A significant issue with the available evidence is that the published studies enrolled very few babies who were considered to need resuscitation.

- There is evidence, primarily in babies who do not require resuscitation, that delayed cord clamping is associated with less intraventricular hemorrhage, higher blood pressure and blood volume, less need for transfusion after birth, and less necrotizing enterocolitis. Delayed cord clamping conferred no benefit on mortality or severe intraventricular hemorrhage. The only negative consequence seems to be a slightly increased level of bilirubin, associated with more need for phototherapy.[16,17]
- ***Delayed cord clamping for longer than 30 seconds is reasonable for both term and preterm infants who do not require resuscitation at birth. (Class IIa, LOE C-LD)***

  There is still insufficient evidence to recommend an approach to cord clamping or cord “milking” for babies

who require resuscitation at birth.

Assessment of heart rate: Immediately after birth, assessment of the newborn's heart rate is used to evaluate the effectiveness of spontaneous respiratory effort and determine the need for subsequent interventions. An increase in the newborn's heart rate is considered the most sensitive indicator of a successful response to resuscitation interventions. Therefore, identifying a rapid, reliable, and accurate method to measure the newborn's heart rate is critically important.

- Available evidence comparing clinical assessment with ECG in the delivery room and simultaneous pulse oximetry and ECG heart rate determination found that clinical assessment was both unreliable and inaccurate.
- ECG (3-lead) displayed a reliable heart rate faster than pulse oximetry. Pulse oximetry tended to underestimate the newborn's heart rate and would have led to potentially unnecessary interventions.[16,17]
- ***During resuscitation of term and preterm newborns, the use of 3-lead ECG for the rapid and accurate measurement of the newborn's heart rate may be reasonable. (Class IIb, LOE C-LD)***

Maintaining normal temperature of the newborn after birth:

- ***It is recommended that the temperature of newly born nonasphyxiated infants be maintained between 36.5°C and 37.5°C after birth through admission and stabilization.[14] (Class I, LOE C-LD)***

  There is new evidence supporting a variety of interventions that may be used alone or in combination to reduce hypothermia. Temperature must be monitored to avoid hyperthermia as well.

Management of the meconium stained infant: For more than a decade, vigorous infants born through meconium stained amniotic fluid have been treated no differently than if they had been born through clear fluid. However, there remained a long standing practice to intubate and suction infants born through meconium stained amniotic fluid who have poor muscle tone and inadequate breathing efforts at birth.

- ***Routine intubation for tracheal suction in this setting is not suggested because there is insufficient evidence to continue recommending this practice.[16,17] (Class IIb, LOE C-LD)***
- In making this suggested change, greater value has been placed on harm avoidance (delays in providing positive-pressure ventilation, potential harm of the procedure) over the unknown benefit of the intervention of routine trachea intubation and suctioning.

Oxygen use for preterm infants in the delivery room: Since the release of the 2010 AHA Guidelines for CPR and ECC, additional randomized trials have been published that examine the use of oxygen during resuscitation and stabilization of preterm newborns. These additional publications have allowed an increase from Class IIb to a Class I recommendation.

- Meta-analysis of the randomized trials that compared initiating resuscitation of preterm newborns (less than 35 weeks of gestation) with high oxygen (65% or greater) versus low oxygen (21%–30%) showed no improvement in survival or morbidity to hospital discharge with the use of high oxygen.[16,17]
- ***Resuscitation of preterm newborns of less than 35 weeks of gestation should be initiated with low oxygen (21% to 30%), and the oxygen concentration should be titrated to achieve preductal oxygen saturation approximating the interquartile range measured in healthy term infants after vaginal birth at sea level.[18] (Class I, LOE B-R)***

  This recommendation reflects a preference for not exposing preterm newborns to additional oxygen without data demonstrating a proven benefit for important outcomes.

Oxygen use during neonatal cardiac compressions: The evidence for optimal oxygen use during neonatal cardiac compressions was not reviewed for the 2010 Guidelines. Unfortunately, there are no clinical studies to inform the neonatal guidelines, but the available animal evidence demonstrated no obvious advantage of 100% oxygen over air. However, by the time resuscitation of a newborn includes cardiac compressions, the steps of trying to improve the heart rate via effective ventilation with low concentrations of oxygen should have already been tried. Thus, the 2015 Guidelines Task Force thought it was reasonable to increase the supplementary oxygen concentration during cardiac compressions and then subsequently wean the oxygen as soon as the heart rate recovers (see "Part 13: Neonatal Resuscitation" in the 2015 Web-based Integrated Guidelines).

Structure of educational programs to teach neonatal resuscitation: Currently, neonatal resuscitation training that includes simulation and debriefing is recommended at 2-year intervals.

- Studies that examined how frequently healthcare providers or healthcare students should train showed no differences in patient outcomes, but demonstrated some advantages in psychomotor performance, knowledge, and confidence when focused task training occurred every 6 months or more frequently.[16,17]
- ***It is therefore suggested that neonatal resuscitation task training occur more frequently than the current 2-year interval.[14] (Class IIb, LOE B-R)***

13.2 Knowledge Gaps

Umbilical cord management for newborns needing resuscitation: As noted previously, the risks and benefits of delayed cord clamping for newborns who need resuscitation after birth remains unknown because such infants have thus far been excluded from the majority of trials. Concern remains that delay in establishing ventilation may be harmful. Further study is strongly endorsed.

- Some studies have suggested that cord milking might accomplish goals similar to delayed cord clamping.[17,19] Cord milking is rapid and can be accomplished within 15 seconds, before resuscitation might ordinarily be initiated. However, there is insufficient evidence of either the safety or utility of cord milking in babies requiring resuscitation.
- The effect of delayed cord clamping or cord milking on initial heart rate and oxygen saturations is also unknown. New normal ranges may need to be determined.
- The risks and benefits of inflating the lungs to establish breathing before clamping of the umbilical cord needs to be explored.

*Uti****lity of a sustained inflation during the initial breaths after birth***: Several recent animal studies suggested that a longer sustained inflation may be beneficial for establishing functional residual capacity during transition from a fluid-filled to an air-filled lung after birth. Some clinicians have suggested applying this technique for transition of human newborns.

- It was the consensus of the 2015 CoSTR and the 2015 Guidelines Task Force that there was inadequate study of the benefits and risks to recommend sustained inflation at this time. Further study using carefully designed protocols was endorsed (see "Part 13: Neonatal Resuscitation" in this 2015 Guidelines Update and Perlman et al[17,19]).

Determination of heart rate: Neonatal resuscitation success has classically been determined by detecting an increase in heart rate through auscultation. Heart rate also determines the need for changing interventions and escalating care. However, recent evidence demonstrates that auscultation of heart rate is inaccurate, and pulse oximetry takes several minutes to achieve a signal and also may be inaccurate during the early minutes after birth. Use of ECG in the delivery room has been suggested as a possible alternative.

- Although data suggest that the ECG provides a more accurate heart rate in the first 3 minutes of life, there are no available data to determine how outcomes would change by acting (or not acting) on the information.
- Some transient bradycardia may be normal and be reflective of timing of cord clamping. More studies are needed.

- The human factors issues associated with introducing ECG leads in the delivery room are unknown.
- In addition, improved technologies for rapid application of ECG are needed.

14 Part 14: Education

There remains strikingly low survival rates for both OHCA and IHCA despite scientific advances in the care of cardiac arrest victims. The Formula for Survival suggests that cardiac arrest survival is influenced by high-quality science, education of lay providers and healthcare professionals, and a well-functioning Chain of Survival.[19] Considerable opportunities exist for education to close the gap between actual and desired performance of lay providers and healthcare teams. For lay providers, this includes proficient CPR and AED skills and the self-efficacy to use them, along with immediate support such as dispatch-guided CPR. For healthcare providers, the goals remain to recognize and respond to patients at risk of cardiac arrest, deliver high-quality CPR whenever CPR is required, and improve the entire resuscitation process through improved teamwork. Additionally, there needs to be a feedback loop focused on continuous quality improvement that can help the system improve as well as identify needs for targeted learning/performance improvement. Optimizing the knowledge translation of what is known from the science of resuscitation to the victim's bedside is a key step to potentially saving many more lives.

Evidence-based instructional design is essential to improve training of providers and ultimately improve resuscitation performance and patient outcomes. The quality of rescuer performance depends on learners integrating, retaining, and applying the cognitive, behavioral, and psychomotor skills required to successfully perform resuscitation. "Part 14: Education" provides an overview of the educational principles that the AHA has implemented to maximize learning from its educational programs. It is important to note that the systematic reviews from which the Guidelines were derived assigned a hierarchy of outcomes for educational studies that considered patient-related outcomes as critical and outcomes in educational settings as important.

14.1 Significant New and Updated Recommendations

The key recommendations based on the systematic reviews include the following:

- The use of high-fidelity manikins for ALS training can be beneficial in programs that have the infrastructure, trained personnel, and resources to maintain the program. Standard manikins continue to be an appropriate choice for organizations that do not have this capacity.

Use of a CPR feedback device is recommended to learn the psychomotor skill of CPR. Devices that provide feedback on performance are preferred to devices that provide only prompts (such as a metronome). Instructors are not accurate at assessment of CPR quality by visual inspection, so an adjunctive tool is necessary to provide accurate guidance to learners developing these critical psychomotor skills. Improved manikins that better reflect patient characteristics may prove important for future training. Use of CPR quality feedback devices during CPR is reviewed in the Adult BLS and CPR Quality Part, "Part 5: Adult Basic Life Support and CPR Quality."

- Two-year retraining cycles are not optimal. More frequent training of BLS and advanced life support skills may be helpful for providers likely to encounter a cardiac arrest.

- Although prior CPR training is not required for potential rescuers to initiate CPR, training helps people learn the skills and develop the self-efficacy to provide CPR when necessary. BLS skills seem to be learned as well through self-instruction (video or computer based) with hands-on practice as with traditional instructor-led courses. The opportunity to train many more individuals to provide CPR while reducing the cost and resources required for training is important when considering the vast population of potential rescuers that should be trained.

- To reduce the time to defibrillation for cardiac arrest victims, the use of an AED should not be limited to trained individuals only (although training is still recommended). A combination of self-instruction and instructor-led teaching with hands-on training can be considered as an alternative to traditional instructor-led courses for lay providers.

- Precourse preparation, including review of appropriate content information, online/precourse testing, and/or practice of pertinent technical skills, may optimize learning from advanced life support courses.

- Given very small risk for harm and the potential benefit of team and leadership training, the inclusion of team and leadership training as part of ALS training is reasonable.

- Communities may consider training bystanders in compression-only CPR for adult OHCA as an alternative to training in conventional CPR.

14.2 Knowledge Gaps

- Research on resuscitation education needs higher-quality studies that address important educational questions. Outcomes from educational studies should focus on patient outcomes (where feasible), performance in the clinical environment, or at least long-term retention of psychomotor and behavioral skills in the simulated resuscitation environment. Too much of the current focus of educational research is on the immediate end-of-course performance, which may not be representative of participants' performance when they are faced with a resuscitation event months or years later. Assessment tools that have been empirically studied for evidence of validity and reliability are foundational to high-quality research. Standardizing the use of such tools across studies could potentially allow for meaningful comparisons when analyzing evidence in systematic reviews to more precisely determine the impact of certain interventions. Cost-effectiveness research is needed because many of the AHA education guidelines are developed in the absence of this information.
- The ideal methodology (ie, instructional design) and frequency of training required to enhance retention of skills and performance in simulated and real resuscitations needs to be determined.

15 Part 15: First Aid

"Part 15: First Aid" reaffirms the definition of first aid as the helping behaviors and initial care provided for an acute illness or injury. The provision of first aid has been expanded to include any person, from layperson to professional healthcare provider, in a setting where first aid is needed. Goals and competencies are now provided to give guidance and perspective beyond specific skills. While a basic tenet of first aid is the delivery of care using minimal or no equipment, it is increasingly recognized that in some cases first aid providers may have access to various adjuncts, such as commercial tourniquets, glucometers, epinephrine autoinjectors, or oxygen. The use of any such equipment mandates training, practice, and, in some cases, medical or regulatory oversight related to use and maintenance of that equipment.

Although there is a growing body of observational studies performed in the first aid setting, most recommendations set forth in "Part 15: First Aid" continue to be extrapolated from prehospital- and hospital-based studies. One important new development relates to the ability of a first aid provider to recognize the signs and symptoms of acute stroke. "Part 15: First Aid" describes the various stroke assessment systems that are available to first aid providers, and lists their sensitivities and specificities in identifying stroke based on included components. This new recommendation for use of a stroke assessment system complements previous recommendations for early stroke management by improving the recognition of stroke signs and symptoms at the first step of emergency care—first aid—thus potentially reducing the interval from symptom onset to definitive care.

15.1 Significant New and Updated Recommendations

- Evidence shows that the early recognition of stroke by using a stroke assessment system decreases the interval between the time of stroke onset and arrival at a hospital and definitive treatment. More than 94% of lay providers trained in a stroke assessment system are able to recognize signs and symptoms of a stroke, and this ability persists at 3 months after training.

  The use of a stroke assessment system by first aid providers is recommended. (Class I, LOE B-NR)

  Compared to stroke assessment systems without glucose measurement, assessment systems that include glucose measurement have similar sensitivity but higher specificity for recognition of stroke.

- Hypoglycemia is a condition that is commonly encountered by first aid providers. Severe hypoglycemia, which may present with loss of consciousness or seizures, typically requires management by EMS providers. If a person with diabetes reports low blood sugar or exhibits signs or symptoms of mild hypoglycemia and is able to follow simple commands and swallow, oral glucose should be given to attempt to resolve the hypoglycemia.

  Glucose tablets, if available, should be used to reverse hypoglycemia in a patient who is able to

take these orally. (Class I, LOE B-R)

If glucose tablets are not available, other forms of specifically evaluated forms of sucrose- and fructose-containing foods, liquids, and candy can be effective as an alternative to glucose tablets for reversal of mild symptomatic hypoglycemia.

- The first aid management of an open chest wound was evaluated for the 2015 ILCOR Consensus Conference. The improper use of an occlusive dressing or device with potential subsequent development of unrecognized tension pneumothorax is of great concern. There are no human studies comparing the application of an occlusive dressing to a nonocclusive dressing, and only a single animal study showed benefit to use of a nonocclusive dressing. As a result of the lack of evidence for use of an occlusive dressing and the risk of unrecognized tension pneumothorax, we recommend against the application of an occlusive dressing or device by first aid providers for an individual with an open chest wound.

- First aid providers often encounter individuals with a concussion (minor traumatic brain injury). The myriad of signs and symptoms of concussion can make recognition of this injury a challenge. Although a simple validated single-stage concussion scoring system could possibly help first aid providers in the recognition of concussion, there is no evidence to support the use of such a scoring system. There are sport concussion assessment tools for use by healthcare professionals that require a 2-stage assessment, before competition and after concussion, but these are not appropriate as a single assessment tool for first aid providers. Therefore, it is recommended that a healthcare provider evaluate as soon as possible any person with a head injury that has resulted in a change in level of consciousness, who has progressive development of signs or symptoms of a concussion or traumatic brain injury, or who is otherwise a cause for concern to the first aid provider.

- Dental avulsion can result in permanent loss of a tooth. Immediate reimplantation of the avulsed tooth is thought by the dental community to afford the greatest chance of tooth survival. First aid providers may not be able to reimplant an avulsed tooth because of lack of training, skill, or personal protective equipment, or they may be reluctant to perform a painful procedure. The storage of an avulsed tooth in a variety of solutions (compared with saliva or milk) has been shown to prolong viability of dental cells by 30 to 120 minutes. In situations that do not allow for immediate reimplantation, the temporary storage of an avulsed tooth in one of these solutions may afford time until the tooth can be reimplanted.

- Evidence shows that education in first aid can increase survival rates, improve recognition of acute illness, and resolve symptomatology.

  We recommend that first aid education be universally available. (Class I, LOE C-EO)

- Past Guidelines recommended that first aid providers assist the person with symptoms of anaphylaxis to administer that person’s epinephrine. Evidence supports the need for a second dose of epinephrine for acute anaphylaxis in persons not responding to a first dose.

  When a person with anaphylaxis does not respond to the initial dose, and arrival of advanced care will exceed 5 to 10 minutes, a repeat dose may be considered. (Class IIb, LOE C-LD)

- There is no evidence of any benefit from routine administration of supplementary oxygen by first aid providers. Limited evidence shows benefit from use of oxygen for decompression sickness in the first aid setting. The use of supplementary oxygen by first aid providers with specific training (eg, a diving first aid oxygen course) is reasonable for cases of decompression sickness. Limited evidence suggests that supplementary oxygen may be effective for relief of dyspnea in advanced lung cancer patients with dyspnea and associated hypoxia, but not for similar patients without hypoxia.

- Newer-generation hemostatic agent–impregnated dressings have been shown to cause fewer complications and adverse effects and are effective in providing hemostasis in up to 90% of subjects in case series. First aid providers may consider use of hemostatic dressings when standard bleeding control (with direct pressure) is not effective.

- The use of cervical collars as a component of spinal motion restriction for blunt trauma was reviewed for the 2015 ILCOR consensus. No evidence was identified that showed a decrease in neurologic injury with

use of a cervical collar. Evidence demonstrates adverse effects from use of a cervical collar, such as increased intracranial pressure and potential airway compromise. The ILCOR First Aid Task Force also expressed concern that proper technique for application of a cervical collar in high-risk individuals requires significant training and practice to be performed correctly and is not considered a standard first aid skill. Because of these concerns, and with a growing body of evidence demonstrating harmful effects and no good evidence showing clear benefit, we recommend against routine application of cervical collars by first aid providers.

15.2 Knowledge Gaps

- Control of severe bleeding is a topic that has gained public interest and importance with recent domestic terrorist attacks. The ideal order for the technique of bleeding control by first aid providers for severe bleeding of an extremity is not clear—ie, direct pressure ? tourniquet ? additional (double) tourniquet; direct pressure ? hemostatic dressing ? tourniquet. It is also unclear how tourniquets compare with hemostatic dressings (or double tourniquet) for control of bleeding in extremity wounds.
- First aid providers may have difficulty recognizing potentially life-threatening conditions. The development and validation of highly sensitive assessment systems or scales (such as for stroke) and other educational techniques may help first aid providers recognize these entities so that they can provide rapid, appropriate care. Conditions that may benefit from development of such assessment educational systems include anaphylaxis, hypoglycemia, chest pain of cardiac origin, high-risk cervical spine injury, concussion, poisoning or overdose, abnormal versus normal breathing, and shock.
- How should a first aid provider care for a person with a potential spinal injury while awaiting arrival of EMS? Is there a benefit to manual cervical spinal stabilization by a first aid provider, and, if so, which technique is best? If verbal instructions to not move are given to a conscious/responsive person with trauma and possible spine injury, are they effective or useful?

16 Summary

The 2015 AHA Guidelines Update for CPR and ECC incorporated the evidence from the systematic reviews completed as part of the 2015 International Consensus on CPR and ECC Science With Treatment Recommendations. This 2015 AHA Guidelines Update marks the transition from periodic review and publication of new science-based recommendation to a more continuous process of evidence evaluation and guideline optimization designed to more rapidly translate new science into resuscitation practice that will save more lives. The Appendix to this Part contains a list of all recommendations published in the 2015 Update and, in addition, lists the recommendations from the 2010 AHA Guidelines for CPR and ECC. The 2015 recommendations were made consistent with the new AHA Classification System for describing the risk:benefit ratio for each Class and the Levels of Evidence supporting them. (Please see Table 1, in "Part 2: Evidence Evaluation and Management of Conflicts of Interest.")

Survival from both IHCA and OHCA has increased over the past decade, but there is still tremendous potential for improvement. It is clear that successful resuscitation depends on coordinated systems of care that start with prompt rescuer actions, require delivery of high-quality CPR, and continue through optimized ACLS and post–cardiac arrest care. Systems that monitor and report quality-of-care metrics and patient-centered outcomes will have the greatest opportunity through quality improvement to save the most lives.

17 Authorship and Disclosures

17.1 2015 Writing Team

Robert W. Neumar; Michael Shuster; Clifton W. Callaway; Lana M. Gent; Dianne L. Atkins; Farhan Bhanji; Steven C. Brooks; Allan R. de Caen; Michael W. Donnino; Jose Maria Ferrer; Russell E. Griffin; Monica E. Kleinman; Steven L. Kronick; Eric J. Lavonas; Mark S. Link; Mary E. Mancini; Laurie J. Morrison; Robert E. O'Connor; Ricardo A. Samson; Steven M. Schexnayder; Eunice "Nici" M. Singletary; Andrew H. Travers; Myra H. Wyckoff; Mary Fran Hazinski

Table 1: 2015 - Part 1: Executive Summary: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 1: Executive Summary: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Robert W. Neumar	University of Michigan	NIH†	None	None	None	None	None	None
Dianne L. Atkins	University of Iowa	None	None	None	None	None	None	None
Farhan Bhanji	McGill University	None	None	None	None	None	None	None
Steven C. Brooks	Queen's University	Heart and Stroke Foundation of Canada†; CIHR†; NIH†	None	None	None	None	None	South Eastern Ontario Academic Medical Association†
Clifton W. Callaway	University of Pittsburgh	None	None	None	None	None	None	None
Allan R. de Caen	University of Alberta; Stollery Children's Hospital	None	None	None	None	None	None	None
Monica E. Kleinman	Children's Hospital Boston	None	None	None	None	None	None	None
Steven L. Kronick	University of Michigan	None	None	None	None	None	None	None
Eric J. Lavonas	Rocky Mountain Poison & Drug Center	None	None	None	None	None	None	None
Mark S. Link	Tufts Medical Center	None	None	None	None	None	None	None
Mary E. Mancini	University of Texas at Arlington	None	None	None	None	None	None	None
Laurie J. Morrison	University of Toronto	NIH†; CIHR†; HSFC†	None	None	None	None	None	None
Robert E. O'Connor	University of Virginia	None	None	None	None	None	None	None
Eunice M. Singletary	University of Virginia	None	None	None	None	None	American Red Cross Scientific Advisory Board*	None
Myra H. Wyckoff	UT Southwestern	None	None	None	None	None	None	None
Staff								
Jose Maria E. Ferrer	American Heart Association	None	None	None	None	None	None	None
Lana M. Gent	American Heart Association	None	None	None	None	None	None	None
Consultants								

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Michael W. Donnino	Beth Israel Deaconess Med Center	None	None	None	None	None	American Heart Association†	None
Mary Fran Hazinski	Vanderbilt University	None	None	None	None	None	American Heart Association†	None
Ricardo A. Samson	University of Arizona	None	None	None	None	None	American Heart Association†	None
Steven M. Schexnayder	University of Arkansas; Arkansas Children's Hospital	None	None	None	None	None	American Heart Association†	None
Michael Shuster	Mineral Springs Hospital Emergency Medicine	None	None	None	None	None	American Heart Association†	None
Elizabeth H. Sinz	Pennsylvania State University College of Medicine	None	None	None	None	None	American Heart Association†	None
Andrew H. Travers	Emergency Health Services, Nova Scotia	None	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

18 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 1: Executive Summary. ECCguidelines.heart.org.

References

1. Cardiopulmonary resuscitation. JAMA. 1966;198:372–379.
2. Standards for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC). 3. Advanced life support. JAMA. 1974;227:suppl:852–860.
3. Standards and guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC). JAMA. 1980;244:453–509.
4. Standards and guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiac Care (ECC). National Academy of Sciences - National Research Council. JAMA. 1986;255:2905–2989.
5. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. JAMA. 1992;268:2135–2302.

6. American Heart Association in collaboration with International Liaison Committee on Resuscitation. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care: International Consensus on Science. Circulation. 2000;102(suppl):I1–I384.

7. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2005; 112:IV1–203.

8. FieldJM,HazinskiMF,SayreMR,ChameidesL,SchexnayderSM,Hemphill R, Samson RA, Kattwinkel J, Berg RA, Bhanji F, Cave DM, Jauch EC, Kudenchuk PJ, Neumar RW, Peberdy MA, Perlman JM, Sinz E, Travers AH, Berg MD, Billi JE, Eigel B, Hickey RW, Kleinman ME, Link MS, Morrison LJ, O'Connor RE, Shuster M, Callaway CW, Cucchiara B, Ferguson JD, Rea TD, Vanden Hoek TL. Part 1: executive summary: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S640–S656. doi: 10.1161/CIRCULATIONAHA.110.970889.

9. Jauch EC, Saver JL, Adams HP Jr, Bruno A, Connors JJ, Demaerschalk BM, Khatri P, McMullan PW Jr, Qureshi AI, Rosenfield K, Scott PA, Summers DR, Wang DZ, Wintermark M, Yonas H; American Heart Association Stroke Council; Council on Cardiovascular Nursing; Council on Peripheral Vascular Disease; Council on Clinical Cardiology. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2013;44:870–947. doi: 10.1161/STR.0b013e318284056a.

10. Powers WJ, Derdeyn CP, Biller J, Coffey CS, Hoh BL, Jauch EC, Johnston KC, Johnston SC, Khalessi AA, Kidwell CS, Meschia JF, Ovbiagele B, Yavagal DR; on behalf of the American Heart Association Stroke Council. 2015 American Heart Association/American Stroke Association focused update of the 2013 guidelines for the early management of patients with acute ischemic stroke regarding endovascular treatment: a guideline for healthcare professionals from the American Heart Association/ American Stroke Association. Stroke. 2015;46:XXX–XXX. doi: 10.1161/ STR.0000000000000074.

11. HazinskiMF,NolanJP,AickinR,BhanjiF,BilliJE,CallawayCW,Castren M, de Caen AR, Ferrer JME, Finn JC, Gent LM, Griffin RE, Iverson S, Lang E, Lim SH, Maconochie IK, Montgomery WH, Morley PT, Nadkarni VM, Neumar RW, Nikolaou NI, Perkins GD, Perlman JM, Singletary EM, Soar J, Travers AH, Welsford M, Wylie J, Zideman DA. Part 1: executive summary: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S2–S39. doi: 10.1161/ CIR.0000000000000270.

12. Nolan JP, Hazinski MF, Aickin R, Bhanji F, Billi JE, Callaway CW, Castren M, de Caen AR, Ferrer JME, Finn JC, Gent LM, Griffin RE, Iverson S, Lang E, Lim SH, Maconochie IK, Montgomery WH, Morley PT, Nadkarni VM, Neumar RW, Nikolaou NI, Perkins GD, Perlman JM, Singletary EM, Soar J, Travers AH, Welsford M, Wyllie J, Zideman DA. Part 1: executive summary: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

13. Ringh M, Rosenqvist M, Hollenberg J, Jonsson M, Fredman D, Nordberg P, Järnbert-Pettersson H, Hasselqvist-Ax I, Riva G, Svensson L. Mobile- phone dispatch of laypersons for CPR in out-of-hospital cardiac arrest. N Engl J Med. 2015;372:2325–806. doi: 10.1056/NEJMoa1406038.

14. Aufderheide TP, Nichol G, Rea TD, Brown SP, Leroux BG, Pepe PE, Kudenchuk PJ, Christenson J, Daya MR, Dorian P, Callaway CW, Idris AH, Andrusiek D, Stephens SW, Hostler D, Davis DP, Dunford JV, Pirrallo RG, Stiell IG, Clement CM, Craig A, Van Ottingham L, Schmidt TA, Wang HE, Weisfeldt ML, Ornato JP, Sopko G; Resuscitation Outcomes Consortium (ROC) Investigators. A trial of an impedance threshold device in out-of-hospital cardiac arrest. N Engl J Med. 2011;365:798–806. doi: 10.1056/NEJMoa1010821.

15. Frascone RJ, Wayne MA, Swor RA, Mahoney BD, Domeier RM, Olinger ML, Tupper DE, Setum CM, Burkhart N, Klann L, Salzman JG, Wewerka SS, Yannopoulos D, Lurie KG, O'Neil BJ, Holcomb RG, Aufderheide TP. Treatment of non-traumatic out-of-hospital cardiac arrest with active compression decompression cardiopulmonary resuscitation plus an impedance threshold device. Resuscitation. 2013;84:1214–1222. doi: 10.1016/j. resuscitation.2013.05.002.

16. Mentzelopoulos SD, Malachias S, Chamos C, Konstantopoulos D, Ntaidou T, Papastylianou A, Kolliantzaki I, Theodoridi M, Ischaki H, Makris D, Zakynthinos E, Zintzaras E, Sourlas S, Aloizos S, Zakynthinos SG. Vasopressin, steroids, and epinephrine and neurologically favor- able survival after in-hospital cardiac arrest: a randomized clinical trial. JAMA. 2013;310:270–279. doi: 10.1001/jama.2013.7832.

17. Perlman JM, Wyllie J, Kattwinkel J, Wyckoff MH, Aziz K, Guinsburg R, Kim HS, Liley HG, Mildenhall L, Simon WM, Szyld E, Tamura M, Velaphi S; on behalf of the Neonatal Resuscitation Chapter Collaborators. Part 7: neonatal resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S204–S241. doi: 10.1161/ CIR.0000000000000276.

18. Wyllie J, Perlman JM, Kattwinkel J, Wyckoff MH, Aziz K, Guinsburg R, Kim HS, Liley HG, Mildenhall L, Simon WM, Szyld E, Tamura M, Velaphi S; on behalf of the Neonatal Resuscitation Chapter Collaborators. Part 7: neonatal resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

19. Mariani G, Dik PB, Ezquer A, Aguirre A, Esteban ML, Perez C, Fernandez Jonusas S, Fustiñana C. Pre-ductal and post-ductal O2 satura- tion in healthy term neonates after birth. J Pediatr. 2007;150:418–421. doi: 10.1016/j.jpeds.2006.12.015.

20. Søreide E, Morrison L, Hillman K, Monsieurs K, Sunde K, Zideman D, Eisenberg M, Sterz F, Nadkarni VM, Soar J, Nolan JP; Utstein Formula for Survival Collaborators. The formula for survival in resuscitation. Resuscitation. 2013;84:1487–1493. doi: 10.1016/j.resuscitation. 2013.07.020.

Part 2: Evidence Evaluation and Management of Conflicts of Interest

2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiac arrest | cardiopulmonary resuscitation | emergency | resuscitation

1 Introduction

This Part describes the process of creating the *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation* (CPR) and Emergency Cardiovascular Care (ECC), informed by the *2015 International Consensus on CPR and ECC Science With Treatment Recommendations* (CoSTR) publication.[1] The process for the 2015 International Liaison Committee on Resuscitation (ILCOR) systematic review is quite different when compared with the process used in 2010.[2] For the 2015 systematic review process, ILCOR used the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) (www.gradeworkinggroup.org) approach to systematic reviews and guideline development. For the development of this 2015 Guidelines Update, the AHA used the ILCOR reviews as well as the AHA definition of Classes of Recommendation (COR) and Levels of Evidence (LOE) (Table 1). This Part summarizes the application of the ILCOR GRADE process to inform the creation of 2015 Guidelines Update, and the process of assigning the AHA COR and LOE.

Table 1: 2015 - Applying Class of Recommendations and Level of Evidence to Clinical Strategies, Interventions, Treatments, or Diagnostic Testing in Patient Care*

Open table in a new window

Applying Class of Recommendations and Level of Evidence to Clinical Strategies, Interventions, Treatments, or Diagnostic Testing in Patient Care*
CLASS (STRENGTH) OF RECOMMENDATION
CLASS I (STRONG) Benefit >>> Risk

Suggested phrases for writing recommendations:
▪ Is recommended
▪ Is indicated/useful/effective/beneficial
▪ Should be performed/administered/other
▪ Comparative-Effectiveness Phrases†:
  ▪ Treatment/strategy A is recommended/indicated in preference to treatment B
  ▪ Treatment A should be chosen over treatment B

CLASS IIa (MODERATE) Benefit >> Risk

Suggested phrases for writing recommendations:

- Is reasonable
- Can be useful/effective/beneficial
- Comparative-Effectiveness Phrases†:
  - Treatment/strategy A is probably recommended/indicated in preference to treatment B
  - It is reasonable to choose treatment A over treatment B

CLASS IIb (WEAK) Benefit ? Risk

Suggested phrases for writing recommendations:

- May/might be reasonable
- May/might be considered
- Usefulness/effectiveness is unknown/unclear/uncertainor not well established

CLASS III: No Benefit (MODERATE) Benefit = Risk(Generally, LOE A or B use only)

Suggested phrases for writing recommendations:

- Is not recommended
- Is not indicated/useful/effective/beneficial
- Should not be performed/administered/other

CLASS III: Harm (STRONG) Risk > Benefit

Suggested phrases for writing recommendations:

- Potentially harmful
- Causes harm
- Associated with excess morbidity/mortality
- Should not be performed/administered/other

LEVEL (QUALITY) OF EVIDENCE‡

Level A

- High-quality evidence‡ from more than 1 RCTs
- Meta-analyses of high-quality RCTs
- One or more RCTs corroborated by high-quality registry studies

Level B-R (Randomized)

- Moderate-quality evidence‡ from 1 or more RCTs
- Meta-analyses of moderate-quality RCTs

Level B-NR (Nonrandomized)

- Moderate-quality evidence‡ from 1 or more well-designed, well-executed nonrandomized studies, observational studies, or registry studies
- Meta-analyses of such studies

Level C-LD (Limited Data)

- Randomized or nonrandomized observational or registry studies with limitations of design or execution
- Meta-analyses of such studies
- Physiological or mechanistic studies in human subjects

Level C-EO (Expert Opinion)

Consensus of expert opinion based on clinical experience

COR and LOE are determined independently (any COR may be paired with any LOE). A recommendation with LOE C does not imply that the recommendation is weak. Many important clinical questions addressed in guidelines do not lend themselves to clinical trials. Although RCTs are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective. * The outcome or result of the intervention should be specified (an improved clinical outcome or increased diagnostic accuracy or incremental prognostic information). † For comparative-effectiveness recommendations (COR I and IIa; LOE A and B only), studies that support the use of comparator verbs should involve direct comparisons of the treatments or strategies being evaluated. ‡ The method of assessing quality is evolving, including the application of standardized, widely used, and preferably validated evidence grading tools; and for systematic reviews, the incorporation of an Evidence Review Committee. COR indicates Class of Recommendation; EO, expert opinion; LD, limited data; LOE, Level of Evidence; NR, nonrandomized; R, randomized; and RCT, randomized controlled trial.

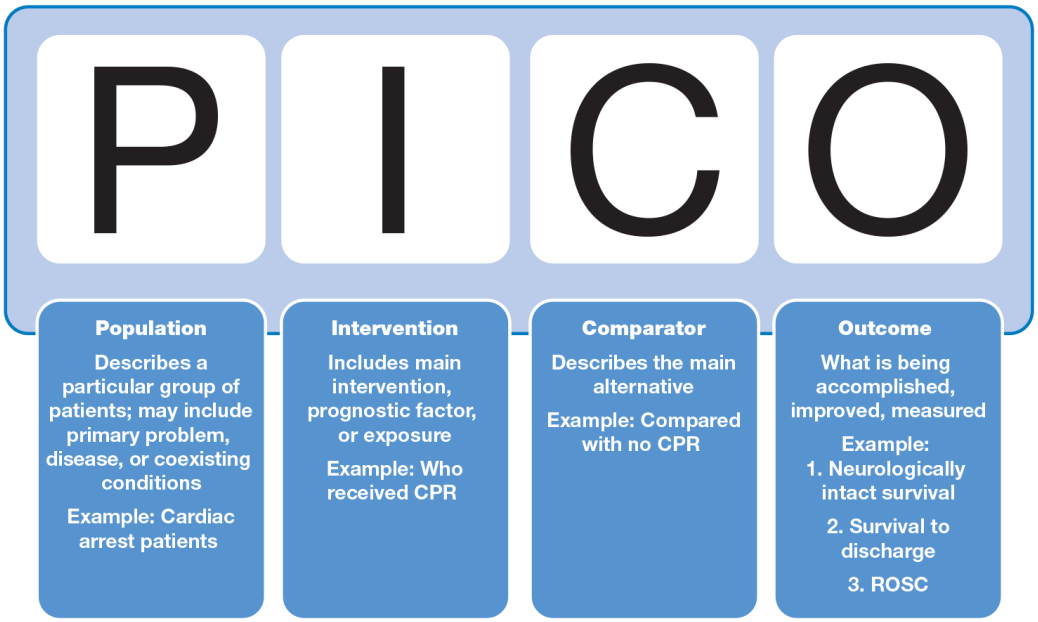
2 Development of the 2015 Consensus on Science with Treatment Recommendations

2.1 Grading of Recommendations Assessment, Development, and Evaluation (GRADE)

The 2015 CoSTR summarizes the published scientific evidence that was identified to answer specific resuscitation questions. ILCOR uses the GRADE system to summarize evidence and determine confidence in estimates of effect as well as to formulate treatment recommendations. GRADE is a consensus-crafted tool in wide use by many professional societies and reference organizations, including the American College of Physicians, the American Thoracic Society, and the Cochrane Collaboration, as well as the Centers for Disease Control and the World Health Organization. The choice of the GRADE approach was based on its increasingly ubiquitous use, practicality, and unique features. To our knowledge, the ILCOR evidence review process represents the largest application of the GRADE system in a healthcare-related review.

GRADE is a system to review evidence to determine the confidence in the estimate of effect of an intervention or the performance of a diagnostic test and to categorize the strength of a recommendation. GRADE requires explicit documentation of the evaluation of the evidence base specific to each outcome that was chosen and ranked as critical and important before the evidence review. The evidence is assessed by multiple criteria. Questions addressed in GRADE typically follow a PICO (population, intervention, comparator, outcome) structure for ease of mapping to available evidence (Figure 1).

Figure 1: Structure of questions for evidence evaluation



Structure of questions for evidence evaluation.

Confidence in the estimates of effect, synonymous with and reported more succinctly as quality, is reported by a synthesis of evidence informed by 1 or more studies as opposed to studies themselves. Quality is adjudicated by a 4-part ranking of our confidence in the estimate of effect (high, moderate, low, very low) informed by study methodology and the risk of bias. Studies start but do not necessarily end at high confidence for randomized controlled trials (RCTs), and they start but do not necessarily end at low confidence for observational studies. Studies may be downgraded for inconsistency, imprecision, indirectness, and publication bias and nonrandomized observational studies may be upgraded as the result of effect size, dose-response gradient, and plausible negative confounding; in other words, an underestimation of the association. The direction and strength of recommendations are driven by certainty of evidence effect estimates, values and preferences of patients, and, to some degree, clinicians' balance of positive and negative effects, costs and resources, equity, acceptability, and feasibility (Table 2).

Table 2: 2015 - From GRADE Evidence to Decision Factors for Making Strong Versus Weak Recommendations

Open table in a new window

From GRADE Evidence to Decision Factors for Making Strong Versus Weak Recommendations

Factor	Relevant Question	Notes
Priority of problem	Is the problem addressed by the question important enough to make a recommendation?	Many problems may not be identified a priori as high enough importance to justify strong recommendations when weighed against other problems.

Factor	Relevant Question	Notes
Balance of benefits and harms	Across outcomes, are the overall effects and confidence in those effects a net gain?	Most interventions, prognostications, and diagnostic tests have positive and negative consequences. Confidence in these estimates must be viewed in aggregate—do positive effects outweigh negative ones? Consideration must weigh outcomes by importance.
Certainty in the evidence	What is the overall certainty that these estimates will support a recommendation?	More certainty supports stronger recommendations, and vice versa.
Values and preferences	To what extent do the values and preferences of patients regarding outcomes or interventions vary?	Minimal variation and a strong endorsement of the outcomes or the interventions based on patients' values and preferences supports stronger recommendations. The lack of consistency in patients' values and preferences or a weak endorsement of the outcomes or the interventions supports weaker recommendations
Costs and resources	Are these net results proportionate to the expenditures and demands of the recommended measure?	Factors such as manpower, time, distraction from other tasks, and monetary investment are viewed through local values. Lower costs of an intervention and greater cost-effectiveness support strong recommendations, and vice versa. Analysis should account for uncertainty in the calculated costs.
Equity	Are the net positive effects of the measure distributed justly?	Measures that improve disparities or benefit fairly may drive a stronger recommendation, and vice versa.
Acceptability	Across stakeholders, is the measure tractable?	To be strong, a recommendation ideally appeals to most.
Feasibility	Can the recommendation be implemented from a practical standpoint?	Something that is practical to achieve may support a strong recommendation, and vice versa.
Summary: To what extent do positive and negative consequences balance in the settings in question?		
outweighs positive*clearly*Negative outweighs positive*probably*Negative Negative and positive consequences balanced outweighs negative*probably*Positive outweighs negative*clearly*Positive		

Factor	Relevant Question	Notes
	Strong recommendation against Weak recommendation against Weak recommendation for Strong recommendation for	
Considerations: Are there important subgroups that might be treated differently? Are there important concerns for implementation?		

2.2 The GRADE Development Tool

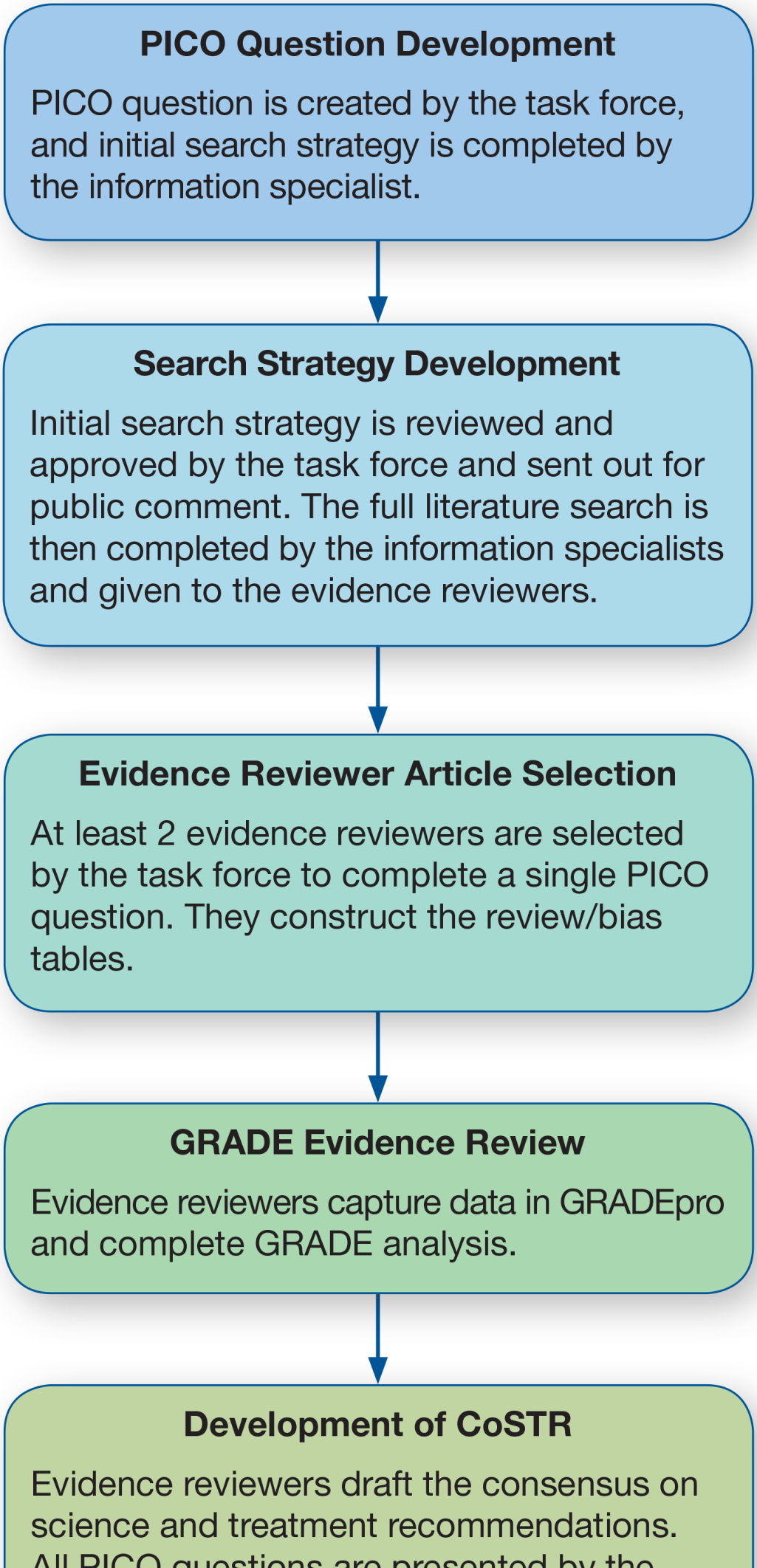
The GRADE Guideline Development Tool (www.guidelinedevelopment.org) provides a uniform interface in the form of standardized evidence profiles and sets forth a framework that enables the reviewer to synthesize the evidence and make a treatment recommendation.[3]

GRADE uniquely unlocks the often rigid linkage between one's confidence in the estimate of effect from the strength of a recommendation. Although the two are related, different factors (eg, costs, values, preferences) influence the strength of the recommendation independent of one's confidence in the estimate of effect. GRADE mandates explicit reasons for judgments in a transparent structure. The GRADE Guideline Development Tool[3] requires consideration of all of these factors and documentation for each decision. To qualify recommendations, an evidence-to-recommendation framework
is used to document all factors that shape the recommendation. Finally, with the GRADE Guideline Development Tool, summary of evidence and evidence profile tables are created. The tables summarize effect size, confidence in the estimates of effect (quality), and the judgments made to evaluate evidence at the level of outcomes. Quality is specified across each of multiple outcomes for the same population, intervention, and comparison, with judgments documented in explanatory notes.

2.3 Scientific Evidence and Evaluation Review System

In preparation for the 2015 systematic review process, ILCOR members, the AHA ECC staff, and compensated consultants collaborated to develop an online systematic review website. The Systematic Evidence Evaluation and Review System (SEERS) website was designed to support the management of workflow steps required to complete the ILCOR systematic reviews (in 2010, these were called worksheets) and capture the evidence extraction and evaluation data in reusable formats (Figure 2). The SEERS website facilitated the structured and consistent evidence review process, which enabled the task force members to finalize the CoSTR for each PICO question. Successful completion of the systematic review process ensured consistency in elements of the reviews from many different international reviewers.

Figure 2: ILCOR 2015 Consensus on Science work flow for all systematic reviews


PICO Question Development
PICO question is created by the task force, and initial search strategy is completed by the information specialist.
Search Strategy Development
Initial search strategy is reviewed and approved by the task force and sent out for public comment. The full literature search is then completed by the information specialists and given to the evidence reviewers.
Evidence Reviewer Article Selection
At least 2 evidence reviewers are selected by the task force to complete a single PICO question. They construct the review/bias tables.
GRADE Evidence Review
Evidence reviewers capture data in GRADEpro and complete GRADE analysis.
Development of CoSTR
Evidence reviewers draft the consensus on science and treatment recommendations.

2.4 Steps in the ILCOR 2015 Systematic Review Process

ILCOR created a comprehensive overview of the structured process that was used to support systematic reviews. The process was divided into 5 major categories, as outlined in Figure 2:

1.Question development: systematic review question development, using the PICO format (Figure 1)

2.Search strategy development

3.Evidence reviewer article selection

4.GRADE evidence review

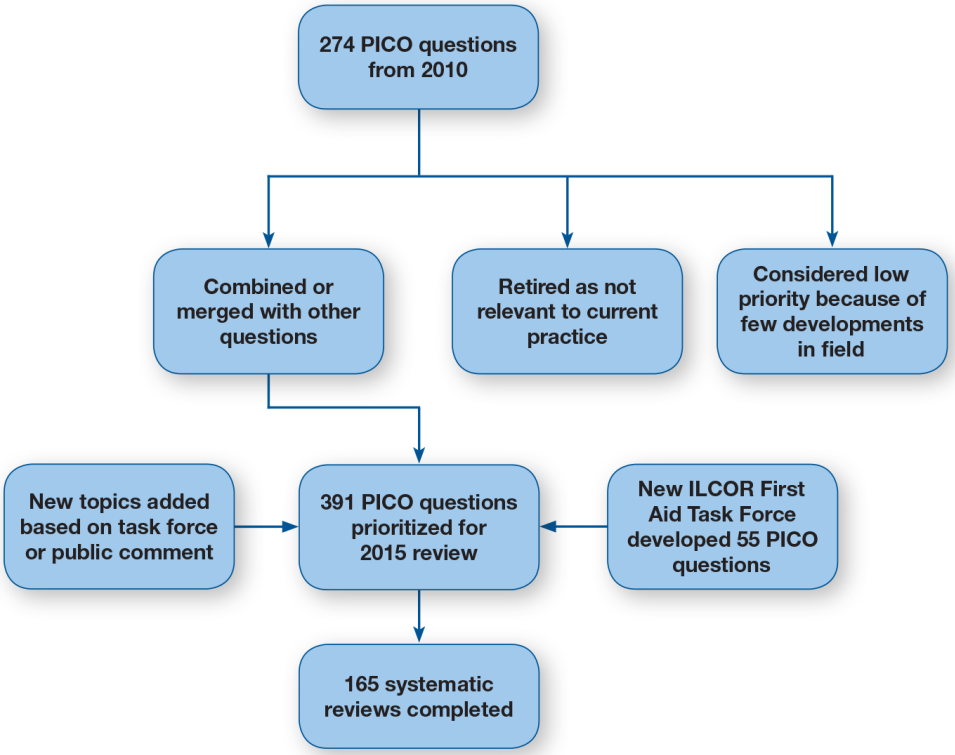
5.Development of CoSTR.

2.4.1 ILCOR PICO Question Development

Shortly after the *2010 International Consensus on CPR and ECC Science With Treatment Recommendations* and the *2010 AHA Guidelines for CPR and ECC* were published, the 2015 ILCOR task forces reviewed the 274 PICO questions that were addressed in 2010 and generated a comprehensive list of 336 questions for potential systematic reviews in 2015. In addition, the new ILCOR task force, First Aid, developed 55 PICO questions that were initially prioritized for review. Questions were prioritized based on clinical controversy, emerging literature, and previously identified knowledge gaps. ILCOR task forces debated and eventually voted to select a focused group of questions. Of the 391 potential PICO questions generated by the task forces, a total of 165 (42%) systematic reviews were completed for 2015 (Figure 3 and Figure 4). The number of PICO questions addressed by systematic reviews varied across task forces (Figure 4).

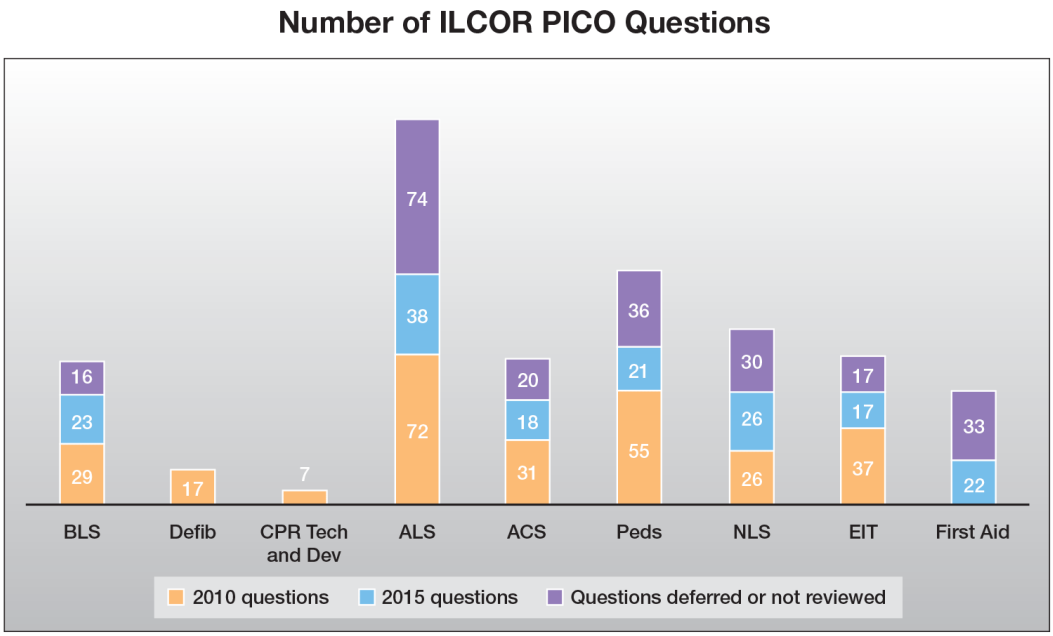
Consistent with adopting the GRADE guideline writing process, clinical outcomes for each PICO were selected and ranked on a 9-point scale as critical and important for decision making by each task force. The GRADE evidence tables were reported by outcome, based on the priority of the clinical outcome. After task force selection of PICO questions for review in 2015, individuals without any conflicts of interest (COIs) or relevant commercial relationships were identified and selected from task force members to serve as task force question owners. Task force question owners provided the oversight control to ensure progress and completion of each systematic review.

Figure 3: ILCOR process for prioritizing PICO questions for systematic reviews



ILCOR process for prioritizing PICO questions for systematic reviews.

Figure 4: Comparison of the number of systematic review questions (PICO questions)



Comparison of the number of systematic review questions (PICO questions) addressed or deferred/not reviewed in 2015 versus 2010 reported by Part in the ILCOR International Consensus on CPR and ECC Science With Treatment Recommendations (CoSTR) publication. BLS indicates Basic Life Support; Defib: Defibrillation*; CPR Tech and Dev: Cardiopulmonary Resuscitation Techniques and Devices; ALS: Advanced Life Support; ACS: Acute Coronary Syndromes; Peds: Pediatrics; NLS: Neonatal Resuscitation; EIT, Education, Implementation, and Teams. *Note that defibrillation content (Defib) of 2010 was absorbed within the 2015 Basic Life Support, Advanced Life Support, and Pediatric CoSTR parts, and the CPR Techniques and Devices questions of 2010 were absorbed by the Advanced Life Support CoSTR part in 2015.

2.4.2 ILCOR Search Strategy Development

Task force question owners worked in an iterative process with information specialists from St. Michael's Hospital Health Science Library in Toronto on contract as compensated consultants to the AHA. These information specialists created comprehensive literature search strategies. The information specialists collaborated with the task force question owners to create reproducible search strings that were customized for ease of use within the Cochrane Library (The Cochrane Collaboration, Oxford, England), PubMed (National Library of Medicine, Washington, DC), and Embase (Elsevier B.V., Amsterdam, Netherlands). Each search string was crafted with precision to meet the inclusion and exclusion criteria that were defined to balance the importance of sensitivity and specificity for a comprehensive literature search.

With commitment to a transparent systematic review process for 2015, ILCOR provided an opportunity for public comment on proposed literature search strategies. Members of the public were able to review search strategies and use the search strings to view the literature that would be captured. ILCOR received 18 public comments and suggestions based on the proposed search strategies and forwarded them to the task force chairs and task force question owners for consideration. This iterative process ensured that specific articles were captured during the evaluation process that may not have been initially retrieved by the search strategy.

2.4.3 ILCOR Evidence Reviewers' Article Selection

Upon completion of the public comment process, ILCOR invited topic experts from around the world to serve as evidence reviewers. Specialty organizations were also solicited to suggest potential evidence reviewers. The qualifications of each reviewer were assessed by the task force, and potential COIs were disclosed and evaluated by the task force co-chairs and COI co-chairs. Evidence reviewers could not have any significant COI issues pertaining to their assigned topics. If a COI was identified, the topic was assigned to a different reviewer who was free from conflict.

Two evidence reviewers were invited to complete independent reviews of the literature for each PICO question.

A total of 250 evidence reviewers from 39 countries completed 165 systematic reviews. The results of the search strategies were provided to the evidence reviewers. Each reviewer selected articles for inclusion, and the 2 reviewers came to agreement on articles to include before proceeding to the next step in the review process. If disagreement occurred in the selection process, the task force question owner served as a moderator to facilitate agreement between the reviewers. If necessary, the search strategy was modified and repeated based on feedback from the evidence reviewers. When final agreement was reached between the evidence reviewers on included studies, the systematic review process started.

2.4.4 ILCOR GRADE Evidence Review

The bias assessment process capitalized on existing frameworks for defining the risk of systematic error in research reporting through 3 distinct approaches. The Cochrane tool was used to evaluate risk of bias in randomized trials,[4,5] whereas the QUADAS-2 instrument[6] was used for included studies that supported diagnostic PICO questions. For non-RCTs that drew inferences on questions of therapy or prognosis, the GRADE working group risk-of-bias criteria[7] were used as a series of 4 questions that emphasized sampling bias, the integrity of predictor and outcome measurements, loss to follow-up, and adjusting for confounding influences.[7,8] Occasionally an existing systematic review would be uncovered that could formally address risk of bias as it pertained to a specific outcome. However, in most instances, the task forces used an empiric approach based on an amalgamation of risk from individual studies addressing a specific outcome. The 2 (or more) reviewers were encouraged to consolidate their judgments, with adjudication from the task force if needed. Agreed bias assessments were entered into a GRADE evidence profile table.

The GRADE Guideline Development Tool is a freely available online resource that includes the GRADE evidence profile table.[9] GRADE Guideline Development Tool served as an invaluable aid to summarize important features, strengths, and limitations of the selected studies. To complete each cell of the evidence profile table, reviewers needed to apply judgments on the 5 dimensions of quality, including risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias). Quantitative data that described effect sizes and confidence intervals were also entered into the evidence profiles, although a more descriptive approach was used when pooling was deemed inappropriate. The GRADE Guideline Development Tool software calculated the quality of evidence for critical and important outcomes by row and, when therapy questions (the most common type) were addressed, generated impact estimates for groups at high, moderate, or low baseline risk as a function of the relative risk.

2.4.5 2015 ILCOR Development of Draft Consensus on Science With Treatment Recommendations

ILCOR developed a standardized template for drafting the consensus on science to capture a narrative of the evidence profile and reflect the outcome-centric approach emphasized by GRADE. The consensus on science reported (1) the importance of each outcome, (2) the quality of the evidence and (3) the confidence in estimate of effect of the treatment (or diagnostic accuracy) on each outcome, (4) the GRADE reasons for downgrading or upgrading the quality rating of the study, and (5) the effect size with confidence intervals or a description of effects when pooling was not done.

The ILCOR task forces created treatment recommendations when consensus could be reached. Within the GRADE format, 4 recommendations are possible: (1) strong recommendation in favor of a treatment or diagnostic test, (2) strong recommendation against a treatment or diagnostic test, (3) weak recommendation in favor of a treatment or diagnostic test, or (4) weak recommendation against a treatment or diagnostic test. A strong recommendation is indicated by the words “we recommend” and a weak recommendation is indicated by the words “we suggest.”

Within the GRADE Guideline Development Tool, an evidence-to-recommendation framework assisted reviewers in making explicit the values and preferences that drove their recommendations, especially when evidence was either uncertain or was a weaker determinant of the optimal course of action. In doing so, resource considerations were invoked rarely when an economic analysis was identified and reviewed as germane or when the balance of risks and harms were considered by the task force to be weighed clearly against potential benefits. When there was inadequate or conflicting evidence, the task force would indicate this insufficient evidence with language such as, “The confidence in effect estimates is so low that the panel feels a recommendation to change current practice is too speculative.” If economic analyses were not available, or if the task forces thought that the appropriate recommendations could differ among the resuscitation councils based on training implications or structure or resources of out-of-hospital or in-hospital resuscitation systems, then the task forces occasionally made no recommendations, leaving that to the council guidelines.

The task force members reviewed, discussed and debated the evidence and developed wording on the summary consensus on science statements and on the treatment recommendations during in-person meetings and after the 2015 ILCOR International Consensus on CPR and ECC Science With Treatment Recommendations Conference, held in Dallas, Texas, in February 2015. In addition, the task forces met frequently by webinar to develop the draft documents that were submitted for peer review on June 1, 2015. As in 2005 and 2010, strict COI monitoring and management continued throughout the process of developing the consensus on science statements and the treatment recommendations, as described in “Part 2: Evidence Evaluation and Management of Conflicts of Interest” in the 2015 CoSTR.[10,11]

2.5 Public Comment on the ILCOR Draft Consensus on Science With Treatment Recommendations

All draft recommendations were posted to allow approximately 6 weeks of public comment, including COI disclosure from those commenting. In addition, the ILCOR draft consensus on science statements and treatment recommendations developed during the January 2015 conference were posted the week after the conference, and 492 public comments were received through February 28, 2015, when the comment period closed. The CoSTR drafts were reposted to remain available through April 2015 to allow optimal stakeholder engagement and familiarity with the proposed recommendations.

3 Development of the 2015 Guidelines Update

The 2015 Guidelines Update serves as an update to the 2010 Guidelines. The 2015 Guidelines Update addresses the new recommendations that arose from the 2015 ILCOR evidence reviews of the treatment of cardiac arrest and advanced life support for newborns, infants, children, and adults.

3.1 Formation of the AHA Guidelines Writing Groups

The AHA exclusively sponsors the 2015 Guidelines Update and does not accept commercial support for the development or publication. The AHA ECC Committee proposed 14 Parts of the Guidelines, which differ slightly from the 2010 Parts (Table 3).

Table 3: 2015 - Contents of 2010 Guidelines Compared With 2015 Guidelines Update

Open table in a new window

Contents of 2010 Guidelines Compared With 2015 Guidelines Update	
2010 Guidelines	**2015 Guidelines Update**
Executive Summary	Executive Summary
Evidence Evaluation and Management of Potential or Perceived Conflicts of Interest	Evidence Evaluation and Conflict of Interest

2010 Guidelines	2015 Guidelines Update
Ethics	Ethical Issues
CPR Overview	Systems of Care and Continuous Quality Improvement*†
Adult Basic Life Support	Adult Basic Life Support and Cardiopulmonary Resuscitation Quality*†
Electrical Therapies: Automated External Defibrillators, Defibrillation, Cardioversion and Pacing	Defibrillation content embedded in other Parts
CPR Techniques and Devices	Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation
Adult Advanced Cardiovascular Life Support	Adult Advanced Cardiovascular Life Support††
Post–Cardiac Arrest Care	Post–Cardiac Arrest Care
Acute Coronary Syndromes	Acute Coronary Syndromes
Adult Stroke	Relevant Stroke content embedded in other Parts
Cardiac Arrest in Special Situations	Special Circumstances of Resuscitation
Pediatric Basic Life Support	Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality†
Pediatric Advance Life Support	Pediatric Advanced Life Support††
Neonatal Resuscitation	Neonatal Resuscitation
Education, Implementation, and Teams	Education
First Aid	First Aid
Legend: CPR- Cardiopulmonary Resuscitation; AED - automated external defibrillator,*Includes prehospital stroke †Includes AED defibrillation ††Includes manual defibrillation	

In particular, content from 2010 Parts (electrical therapies, adult stroke) have been incorporated into other Parts, and a new Part that addresses systems of care and continuous quality improvement has been added. The committee nominated a slate of writing group chairs and writing group members for each Part. Writing group chairs were chosen based on their knowledge, expertise, and previous experience with the Guidelines development process. Writing group members were chosen for their knowledge and expertise relevant to their Part of the Guidelines. In addition, each writing group included at least 1 young investigator. The ECC Committee approved the composition of all writing groups before submitting them to the AHA Officers and Manuscript Oversight Committee for approval.

Part 15 of the Guidelines Update, "First Aid," is jointly sponsored by the AHA and the American Red Cross. The writing group chair was selected by the AHA and the American Red Cross, and writing group members were nominated by both the AHA and the American Red Cross and approved by the ECC Committee. The evidence review for this Part was conducted through the ILCOR GRADE evidence review process.

Before confirmation, all Guidelines writing group chairs and members were required to complete an AHA COI disclosure of all current healthcare-related relationships. The declarations were reviewed by AHA staff and the AHA officers. All writing group chairs and a minimum of 50% of the writing group members were required to be free of relevant COIs and relationships with industry. During the 2015 Guidelines development process, writing group members were requested to update their disclosure statements every 3 months.

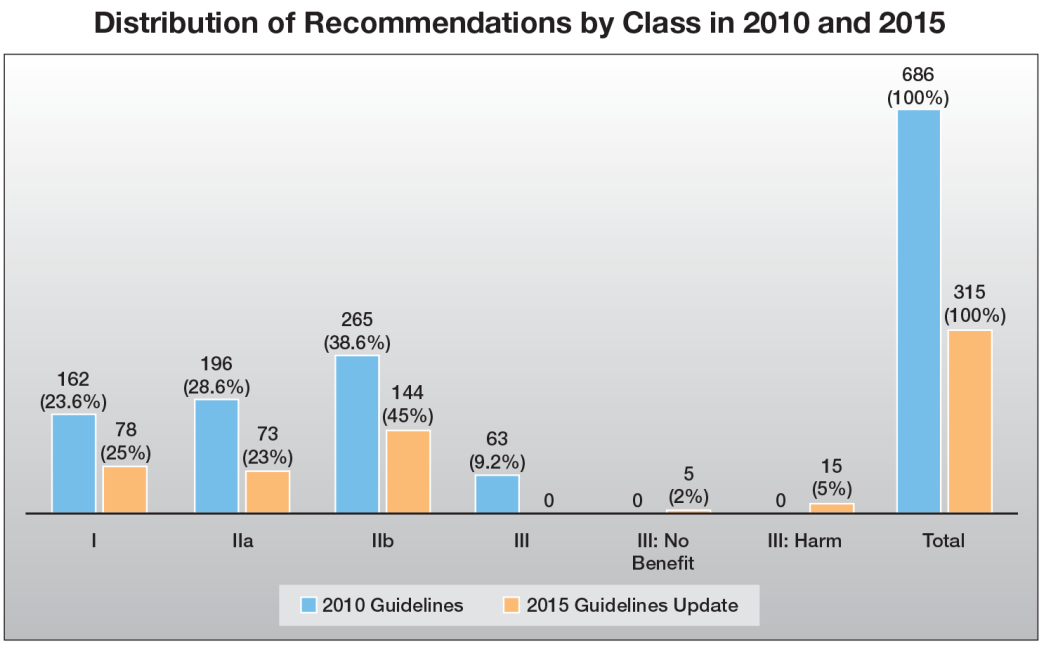
3.2 Classification of AHA Guidelines Recommendations

In developing the 2015 Guidelines Update, the writing groups used the latest version of the AHA format for COR and LOE (Table 1). The COR indicates the strength that the writing group assigns the recommendation, based on the anticipated magnitude and certainty of benefit relative to risk. The LOE is assigned based on the type, quality, quantity, and consistency of scientific evidence supporting the effect of the intervention.

3.2.1 2015 AHA Classes of Recommendation

Both the 2010 Guidelines and the 2015 Guidelines Update used the AHA Classification system that includes 3 main classes of positive recommendations: Class I, Class IIa, and Class IIb (Figure 5).

Figure 5: Class of Recommendation comparison between 2010 Guidelines and 2015 Guidelines Update



Class of Recommendation comparison between 2010 Guidelines and 2015 Guidelines Update.

A Class I recommendation is the strongest recommendation, indicating the writing group's judgment that the benefit of an intervention greatly outweighs its risk. Such recommendations are considered appropriate for the vast majority of clinicians to follow for the vast majority of patients, with infrequent exceptions based upon the judgment of practitioners in the context of the circumstances of individual cases; there is greater expectation of adherence to a Class I recommendation.

Class IIa recommendations are considered moderate in strength, indicating that an intervention is reasonable and generally useful. Most clinicians will follow these recommendations most of the time, although some notable exceptions exist. Class IIb recommendations are the weakest of the positive recommendations for interventions or diagnostic studies. Class IIb recommendations are identified by language (eg, "may/might be reasonable or may/might be considered") that indicates the intervention or diagnostic study is optional because its effect is unknown or unclear. Although the clinician may consider the treatment or diagnostic study with a Class IIb recommendation, it is also reasonable to consider other approaches.

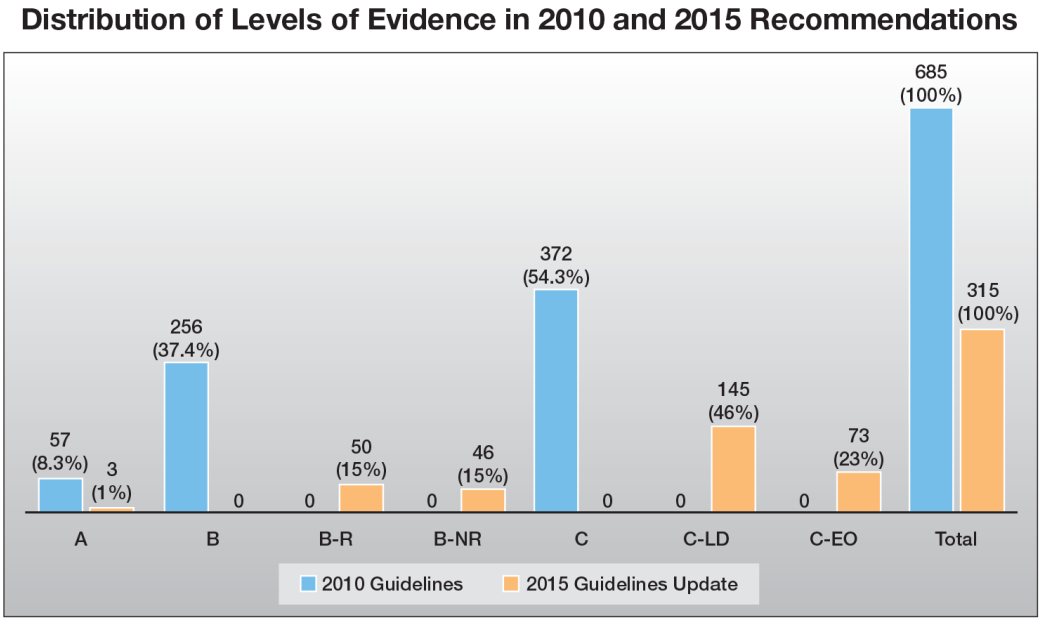
The past AHA format for COR contained only 1 negative classification, a Class III recommendation. This classification indicated that the therapy or diagnostic test was not helpful, could be harmful, and should not be used. In the 2015 Guidelines Update, there are 2 types of Class III recommendations, to clearly distinguish treatments or tests that may cause harm from those that have been disproven. A Class III: Harm recommendation is a strong one, signifying that the risk of the intervention (potential harm) outweighs the benefit, and the intervention or test should not be used. The second type of Class III recommendation, the Class III: No Benefit, is a moderate recommendation, generally reserved for therapies or tests that have been shown in high-level studies (generally LOE A or B) to provide no benefit when tested against a placebo or control. This recommendation signifies that there is equal likelihood of benefit and risk, and experts agree that the intervention or test should not be used.

3.2.2 2015 AHA Levels of Evidence

In the 2010 Guidelines, only 3 LOEs were used to indicate the quality of the data: LOEs A, B, and C. LOE A indicated evidence from multiple populations, specifically from multiple randomized clinical trials or meta-analyses. LOE B indicated that limited populations were evaluated, and evidence was derived from a single randomized trial or nonrandomized studies. LOE C indicated that either limited populations were studied or the

evidence consisted of case series or expert consensus. In this 2015 Guidelines Update, there are now 2 types of LOE B evidence, LOE B-R and LOE B-NR: LOE B-R (randomized) indicates moderate-quality evidence from 1 or more RCTs or meta-analyses of moderate-quality RCTs; LOE B-NR (nonrandomized) indicates moderate-quality evidence from 1 or more well-designed and executed nonrandomized studies, or observational or registry studies, or meta-analyses of such studies. LOE C-LD (limited data) now is used to indicate randomized or nonrandomized observational or registry studies with limitations of design or execution or meta-analyses of such studies, or physiologic or mechanistic studies in humans. LOE C-EO (expert opinion), indicates that evidence is based on consensus of expert opinion when evidence is insufficient, vague, or conflicting. Animal studies are also listed as LOE C-EO (Figure 6).

Figure 6: Level of Evidence comparison between 2010 and 2015 AHA Guidelines Update



Level of Evidence comparison between 2010 Guidelines and 2015 Guidelines Update. B-R indicates Level of Evidence B-Randomized; B-NR, Level of Evidence B-Nonrandomized; C-LD, Level of Evidence C-Limited Data; and C-EO, Level of Evidence C-Expert Opinion. (One recommendation in the 2010 Guidelines publication has no listed LOE.)

3.3 Development of AHA Classes of Recommendation and Levels of Evidence Informed by the 2015 ILCOR Evidence Review Using GRADE

The AHA COR and LOE framework (Table 1) differs from the framework used by GRADE. As a result, the leadership of the ECC Committee identified a group of experts in methodology to create tools for the 2015 Guidelines Update writing groups to use in developing recommendations informed by the ILCOR GRADE evidence review. Members of this writing group met by conference call weekly from October 27, 2014, to January 12, 2015, to validate the tools and ensure consistency in application. Frameworks for conversion were debated, settled by consensus, and then validated by applying them to specific ILCOR evidence reviews, again using a consensus process. Table 4 and Figure 7, Figure 8, and Figure 9 demonstrate the final tools that were used to guide the various guideline writing groups.

3.3.1 Identification of 2015 Guidelines Update Levels of Evidence, Informed by ILCOR Consensus on Science and GRADE Systematic Review

As the first step in the development of a guidelines recommendation, the writing group reviewed the studies cited in the GRADE evidence profile (Table 4) and assigned a Level of Evidence by using the AHA definitions for Levels of Evidence (Table 1). Evidence characterized as “high” by the GRADE process generally is consistent with an AHA LOE A. Evidence characterized as moderate in the GRADE process generally corresponds to an AHA LOE B-R for randomized or LOE B-NR for non-randomized, and evidence characterized by the GRADE process as low or very low generally meets the definitions of AHA LOE C-LD or LOE C-EO. Non-recommendations are not listed as a Level of Evidence. If the guidelines writing group determined that there was insufficient evidence, the writing group could make a recommendation noting that it was based on expert opinion (LOE C-EO) or could make no recommendation at all. It is important to note that this framework is not absolute; the writing group’s judgment may determine that the Level of Evidence is higher or lower than the ILCOR characterization of the evidence when a treatment or diagnostic test is applied to the population or under the conditions for which a Guidelines recommendation is made. In this circumstance, the writing group will explain the discrepancy between the GRADE analysis of evidence and the AHA LOE. This will help maintain transparency and make the process reproducible in the future (see Table 4).

Table 4: 2015 - Converting the GRADE Level of Evidence to the AHA ECC Level of Evidence

Open table in a new window

Converting the GRADE Level of Evidence to the AHA ECC Level of Evidence

GRADE Level of Evidence*	Starting Point for AHA ECC Level of Evidence (to be adjusted as determined by the Writing Group)
High GRADE LOE/confidence in the estimates of effect	**Convert to AHA ECC LOE A for:** High-quality evidence exists (well-designed, well- executed studies, each directly answers question, uses adequate randomization, blinding, allocation concealment, and is adequately powered, uses ITT analysis, with high follow-up rates). Evidence from >1 RCT, meta-analysis of high-quality RCTs, RCTs corroborated by high-quality registry studies.
Moderate GRADE LOE/confidence in the estimates of effect	**Convert to AHA ECC LOE B-R for:** Moderate-quality evidence from RCTs or meta- analysis of moderate quality RCTs.
Low GRADE LOE/confidence in the estimates of effect (low or very low confidence is caused by limitations in risk of bias for included studies, inconsistency, imprecision, indirectness, and publication bias)	**Convert to AHA ECC LOE B-NR for:** Moderate-quality evidence from well-designed and well-executed nonrandomized, observational, or registry studies or meta-analysis of same.
Very low GRADELOE/confidence in the estimate of effect (low or very low confidence is caused by limitations in risk of bias for included studies, inconsistency, imprecision, indirectness, and publication bias)	**Convert to AHA ECC LOE C-LD for:** Randomized or nonrandomized observational or registry studies with limitations of design or execution (including but not limited to inadequate randomization, lack of blinding, inadequate power, outcomes of interest are not pre-specified, inadequate follow-up, or based on subgroup analysis) or meta-analyses with such limitations; or if physiologic or mechanistic studies in human subjects.
GRADE non-recommendation	Convert to AHA ECC LOE C- EO for: Consensus of expert opinion based on clinical experience.

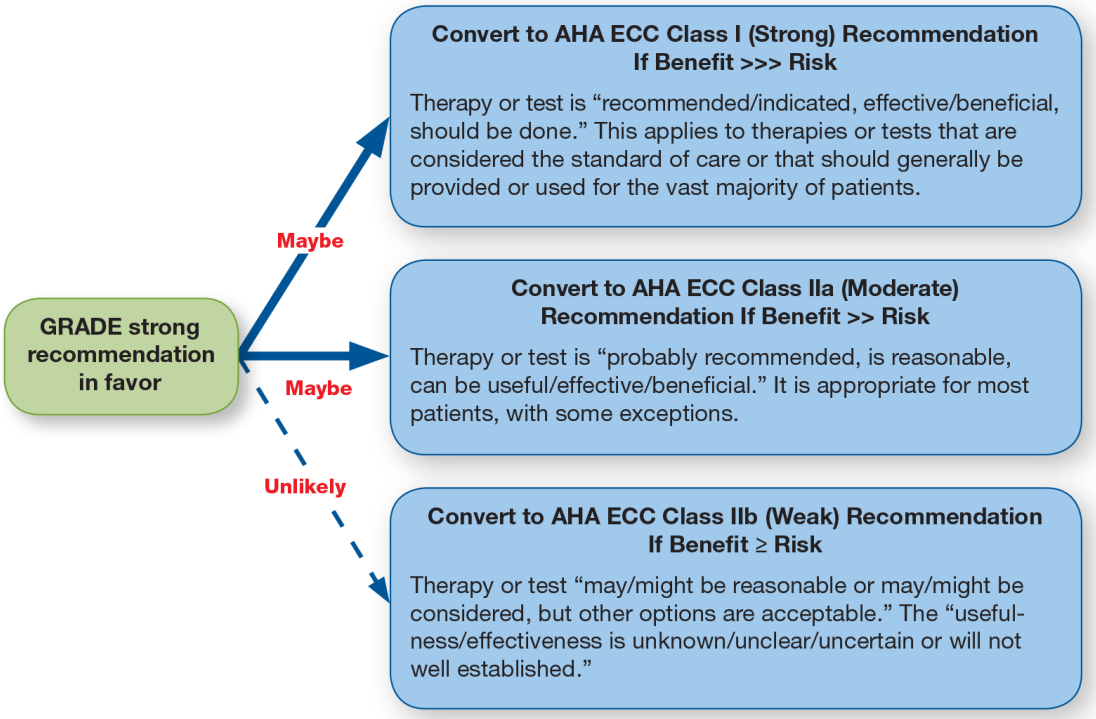
Clarification: The American Heart Association (AHA) classification is applied to the body of evidence supporting an individual recommendation, based largely on design and quality of studies addressing the clinical question (see above). Although the International Liaison Committee on Resuscitation (ILCOR) Grading of Recommendations Assessment, Development, and Evaluation (GRADE) recommendation attempts to consider factors such as resource allocation, the individual councils (eg, the AHA) are best able to identify the patients or subsets of patients, outcomes, and conditions that are most important to consider in the translation of science to guidelines.**Disclaimer:** The manuscript and its contents are confidential, intended for journal review purposes only, and not to be further disclosed. **Legend:** * The GRADE process labels a body of evidence across outcomes based on the lowest Level of Evidence (LOE) for the most critical outcome. ECC indicates Emergency Cardiovascular Care; ITT, intention-to-treat; and RCT, randomized controlled trial.

3.3.2 Identification of 2015 Guidelines Class of Recommendation, Informed by ILCOR Consensus Treatment Recommendation Based on GRADE

The second step in making a 2015 Guidelines Update recommendation is to determine the strength of the recommendation. In many cases, after an extensive evidence review such as that completed by ILCOR, the strength and direction of the ILCOR treatment recommendation will be similar to the strength and direction of the recommendation in the 2015 Guidelines Update. However, in its Clinical Practice Guidelines Methodology Summit Report, the AHA task force on practice guidelines [12] notes that the strength of recommendation and strength of evidence are each hierarchical but separate. The classification table itself notes “COR and LOE are determined independently, ie, any Class of Recommendation may be paired with any Level of Evidence” (Table 1).

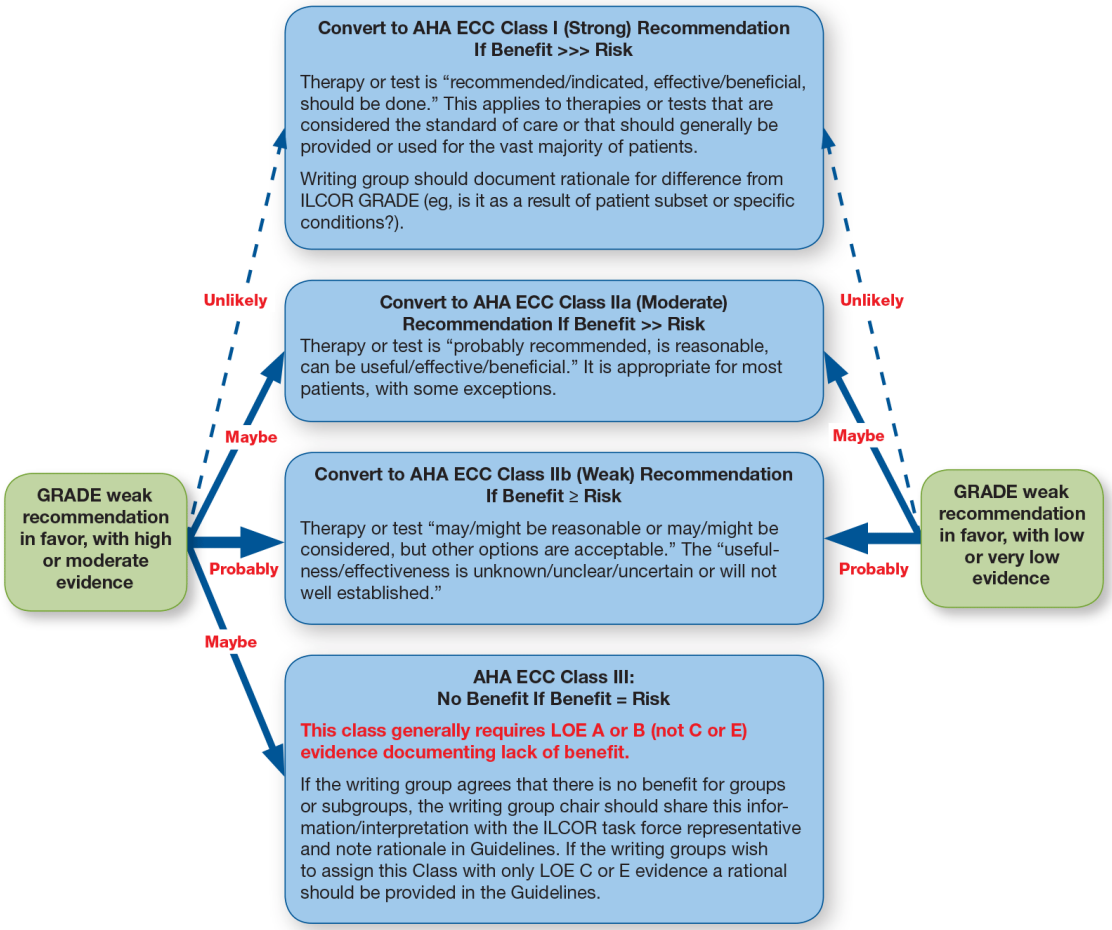
The writing groups for the 2015 Guidelines Update were charged to carefully consider the 2015 ILCOR evidence review and the ILCOR consensus treatment recommendations in light of local training systems and the structure and resources of out-of-hospital and in-hospital resuscitation systems. In addition, the writing groups weighed the balance between benefits and risks and the quality of studies providing the evidence. The writing group considered the precision, qualifications, conditions, setting, outcomes, and limitations of the evidence reviewed when making a final assessment. Generally, when strong ILCOR recommendations were in favor of a treatment or diagnostic test, the AHA Guidelines writing groups also provided Class I or IIa recommendations (Figure 7). When weak ILCOR recommendations were in favor of a treatment or diagnostic test, the AHA Guidelines writing groups typically provided a Class IIa, IIb, or a Class III: No Benefit recommendation (Figure 8). If the AHA Guidelines writing group reached a decision that significantly differed in either strength (eg, a strong GRADE recommendation conversion to an AHA Class IIb recommendation) or direction of a recommendation, from that reported by the ILCOR evidence review, the writing group typically included a brief explanation of the rationale for the difference.

Figure 7: Developing AHA ECC recommendation informed by GRADE strong recommendation in favor of therapy or diagnostic or prognostic test



Developing an AHA ECC recommendation that is informed by a GRADE strong recommendation in favor of a therapy or diagnostic or prognostic test.

Figure 8: Developing AHA ECC recommendation informed by GRADE weak recommendation in favor of therapy or diagnostic or prognostic test



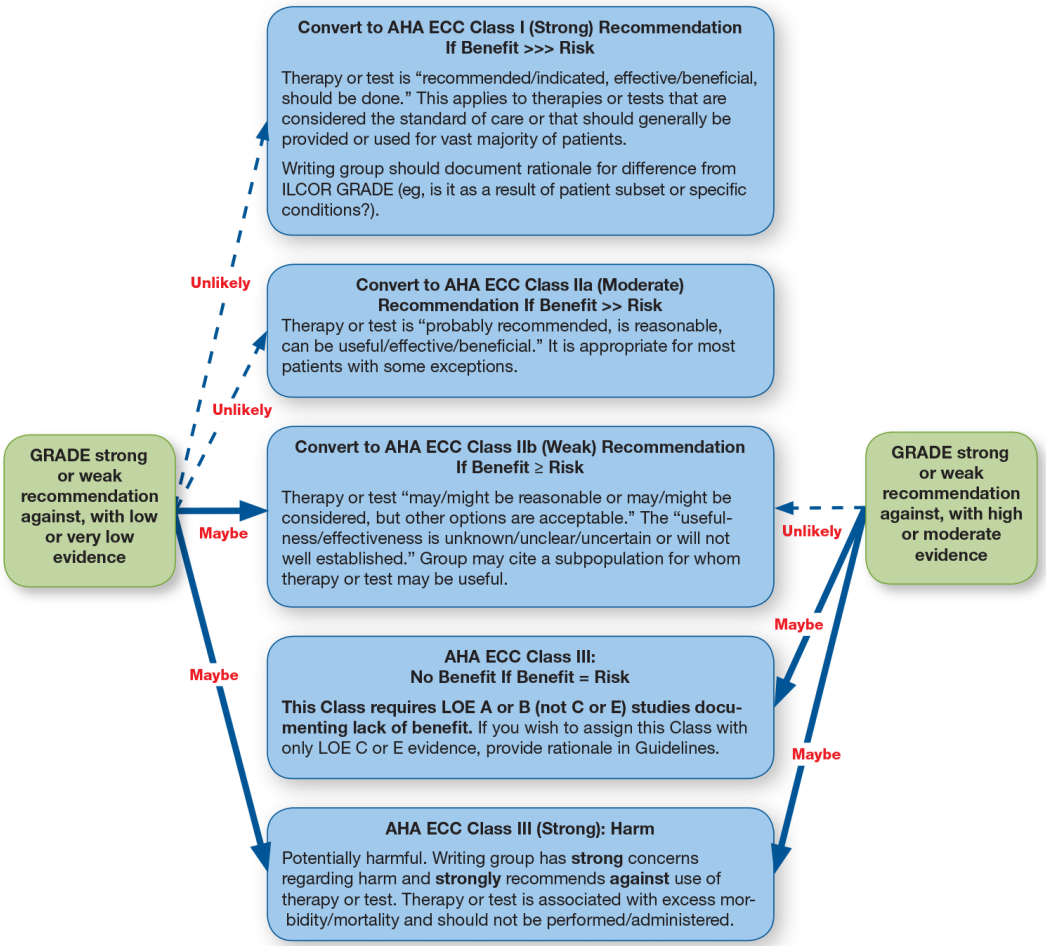
Developing an AHA ECC recommendation that is informed by a GRADE weak recommendation in favor of a therapy or diagnostic or prognostic test.

Ideally, strong recommendations from a scientific organization are supported by a high LOE. However, there are few prospective RCTs and blinded clinical trials conducted in resuscitation. As a result, it may be necessary for authors of this 2015 Guidelines Update to make recommendations to improve survival, even in the absence of such high-quality evidence. Such was the case in 2005, when the AHA and many other resuscitation councils changed the treatment of pulseless arrest associated with a shockable rhythm (ie, ventricular fibrillation [VF] or pulseless ventricular tachycardia [pVT]) from a recommendation of 3 stacked shocks to recommending delivery of single shocks followed by immediate CPR. Although there were no studies documenting improved survival from VF/pVT cardiac arrest with this approach, single shocks delivered by biphasic defibrillators had a much higher first-shock success than monophasic defibrillators, and experts felt strongly that reducing interruptions in compressions would improve survival. This change in 2005, coupled with emphasis to minimize interruptions in chest compressions, was associated with significant increases in survival from prehospital cardiac arrest associated with VF or pVT.[13,14]

It is important to note that the AHA CORs are generally positive, whereas the ILCOR recommendations based on the GRADE process may recommend for or against an intervention or diagnostic study. This will inevitably create some inconsistency between ILCOR recommendations and AHA Guidelines recommendations. For treatments and diagnostic tests that ILCOR provided a weak recommendation against, the AHA Guidelines writing groups might reach a decision to recommend for or against a therapy with a Class IIb (weak, permissive) recommendation for the therapy under particular circumstances or a Class III: No Benefit or Class III: Harm recommendation. When ILCOR provided no recommendation, the AHA Guidelines writing group often reached a decision to provide a Class IIb or a Class III: No Benefit recommendation (Figure 9). As noted previously, if the AHA Guidelines writing group reached a decision that significantly differed in either strength (eg, a weak GRADE

recommendation but a strong AHA COR) or direction of a recommendation from that reported by the ILCOR evidence review, the writing group typically included a brief explanation of the rationale for the difference. The writing group chair of any of the AHA Guidelines was free to direct questions to the ILCOR task force writing group co-chairs to clarify the evidence or even to suggest wording or qualification of a recommendation.

Figure 9: Developing AHA ECC recommendation informed by GRADE strong or weak recommendation against therapy or diagnostic or prognostic test



Developing an AHA ECC recommendation that is informed by a GRADE strong or weak recommendation against a therapy or diagnostic or prognostic test.

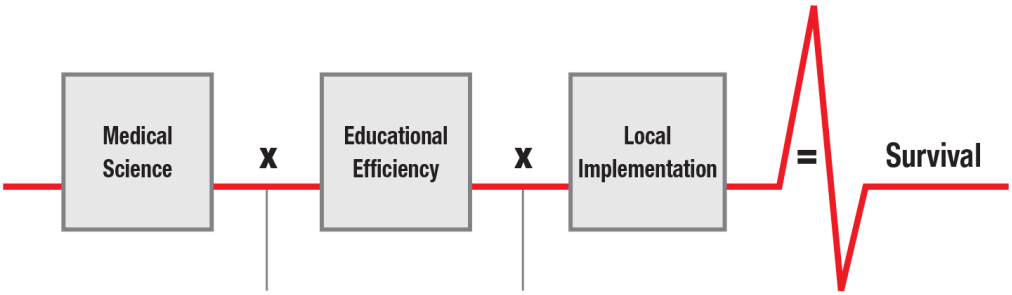
3.4 Writing Group Voting Procedures

During the writing of the 2015 Guidelines Update, writing group members were asked to express support for or disagreement with the wording of the recommendations, and the recommendations were reworded until consensus was reached. During every discussion, writing group members disclosed any COIs before they spoke on a topic. Writing group chairs were aware of the conflicts reported by the writing group members, and the chairs were charged with ensuring that such disclosure occurred consistently. The writing group also formally voted on every recommendation contained in the 2015 Guidelines Update, after review by the AHA Science Advisory Coordinating Committee. Writing group members recused themselves from voting on any recommendations that involve relevant relationships with industry or any other COI. A tracking sheet was developed and ballots maintained as part of the permanent files of the 2015 Guidelines Update.

4 Integrating Science Into Practice Guidelines

Implementation or knowledge translation is both a continuum and an iterative process, and it is integral to improving survival [15] (Figure 10).

Figure 10: The Utstein Formula of Survival, emphasizing the 3 components essential to improve survival



The Utstein Formula of Survival, emphasizing the 3 components essential to improve survival. Redrawn from Søreide E, Morrison LJ, Hillman K, Monsieurs K, Sunde K, Zideman D, Eisenberg M, Sterz F, Nadkarni VM, Soar J, Nolan JP. The formula for survival in resuscitation. *Resuscitation.* 2013;84:1487–1493, with permission from Elsevier. www.resuscitationjournal.com.

In the first instance, systematic review and synthesis are required to define the current state of knowledge. Results must then be conveyed in a manner that is appropriate and understandable to knowledge users, such as the 2015 Guidelines Update. Despite various societies investing heavily in evidence synthesis and guideline renewal, downstream translation of evidence into practice is frequently deficient and/or delayed.[16,17] The developing field of implementation science is the study of interventions aimed at addressing deficiencies in knowledge translation. The National Institutes of Health defines implementation science as "the study of methods to promote the integration of research findings and evidence into healthcare policy and practice. It seeks to understand the behavior of healthcare professionals and other stakeholders as a key variable in the sustainable uptake, adoption, and implementation of evidence-based interventions."[18] Both knowledge translation and implementation science are critical to continual quality improvement. It is not sufficient to define best practices; evaluation of implementation and adherence are needed (implementation science), and where gaps in evidence uptake exist, tools and strategies to remedy the situation are required (knowledge translation). Ultimately, an iterative plan-do-study-act process can help move policy and clinical care toward best practices over time.[19] More on continuous quality improvement and viewing resuscitation as a system of care can be found in "Part 4: Systems of Care."

Performance metrics are a crucial component of the iterative implementation cycle. Many common assessments of healthcare professionals' competence and performance have inherent strength and weaknesses.[20] Although challenging, the development and adoption of performance measures have been shown to improve processes of care linked to improvements in patient outcome.[21] The value of standardized performance measures lies in the ability to reliably assess clinical care and identify gaps. Metrics allow for self-assessment, regional and national benchmarking, and evaluation of clinical interventions. The importance of standardized performance measures has been recognized by The Joint Commission, Centers for Medicare and Medicaid Services, and the National Quality Forum,[22] and the recently released Institute of Medicine Report on Cardiac Arrest.[23] The AHA Get With The Guidelines® initiative builds on this by providing additional financial, educational, and analytical resources to facilitate performance measure adoption, data collection, and assessments of quality.[21] The AHA Get With The Guidelines program has led to improvements in the care of patients with cardiovascular disease that are significant and beyond what would typically be expected over time.[21] Additionally, the Get With The Guidelines program has been integral in identifying and reducing or eliminating disparities in care based on race and sex.[21] The success of in-hospital performance measures and the investment in prehospital clinical trials in cardiac arrest have led to the creation and adoption of national performance measures for care provided in the prehospital environment.[24] The Resuscitation Outcomes Consortium's focus on quality of CPR metrics as a requirement of the RCTs has led to a steady increase in survival across all participating sites.[14]

A variety of tools and strategies can be used to promote evidence uptake and guideline adherence. Protocol driven care bundles [25] and checklists [26] have been shown to reduce the incidence of serious complications [25,26] and mortality.[26] Simple interventions, such as institutional-specific protocols and order sets, are effective at improving guideline compliance..[27] Smart technology, such as real-time CPR feedback devices, provides data on factors such as chest compression rate, depth, and fraction, prompting provider self-correction and improved

performance [28] and improved survival.[29] Selection of knowledge translation tools and strategies for a given situation or setting should be informed by the best available evidence.

5 The Future of ECC Guidelines

In previous cycles, we conducted comprehensive literature reviews and systematic reviews in a batch-and-queue manner to update consensus on science with treatment recommendations every 5 years. The new recommendations then informed revision of training materials every 5 years. This model may not be optimal for responding to emerging peer-reviewed data and might delay implementation of new or emerging research findings. This 2015 cycle marks the transition from batch-and-queue to a continuous evidence-review process. A critical feature of this continuous-review process will be the creation of a transparent and easily accessible, editable version of the most recent systematic reviews and treatment recommendations. This format of comprehensive systematic review with treatment recommendations will occur in an online, living website that will be updated as ILCOR completes evidence reviews.

At any time, the ILCOR task forces may identify clinical questions as high priority for review based on new clinical trials, perceived controversies in patient care, emerging differences in constituent council training materials or algorithms, new publications, Cochrane Reviews, or feedback from the public. On an ongoing basis, the task force will conduct systematic reviews and evidence evaluations for the questions designated as highest priority. Any change in treatment recommendations resulting from these reviews that is endorsed by the task force and the ILCOR Resuscitation Councils will be incorporated into existing resuscitation recommendations and posted to the ILCOR online comprehensive treatment recommendations (http://www.ilcor.org/seers to follow these developments). Any change in treatment recommendation may be immediately peer reviewed and published as an interim Scientific Statement in traditional journals if the task force thinks that enhanced dissemination is required. If the treatment recommendation is not changed or not of critical impact for immediate implementation for patient care, the new recommendation will be updated simply by indicating the date of the most recent systematic review posted to the website and periodically summarized on a routine basis.

The continuous review process should allow more rapid translation of prioritized new science to treatment recommendations and, ultimately, implementation. This process also should improve the workflow for the task forces by allowing concentrated effort on the highest-priority clinical questions rather than an every-5-year effort to review a large number of selected clinical questions.

6 Summary

The process used to generate the 2015 Guidelines Update has been remarkably different from prior releases of the Guidelines. The combination of (1) ILCOR process of selecting a reduced number of priority topics for review, (2) using the GRADE process of evaluation, and (3) merging the Grade recommendations with the current prescribed AHA classification system to assign LOE and COR is unique to the 2015 Guidelines Update. Thus, the 2015 Guidelines Update is leaner compared with the 2010 Guidelines publication because fewer topics were addressed by the 2015 ILCOR evidence review process than were reviewed in 2010. There were a total of 685 recommendations in the 2010 Guidelines, and there are a total of 315 recommendations in the 2015 Guidelines Update. The number of systematic reviews is lower in 2015; however, the quality of the reviews may be higher and more consistent based on the involvement of information specialists, the rigorous oversight of the SEERS process, and the use of the GRADE process of review.

An examination of the data in Table 5 reveals a substantial gap in resuscitation science available to answer important resuscitation questions. Of all 315 recommendations made in the 2015 Guidelines Update, only 3 (1%) are based on Level A evidence, and only 78 (25%) are a Class I recommendation.

Table 5: Class of Recommendation and Levels of Evidence for the 2015 Guidelines Update: Demonstrating the Gap in Resuscitation Science

Open table in a new window

Class of Recommendation and Levels of Evidence for the 2015 Guidelines Update: Demonstrating the Gap in Resuscitation Science

Class of Recommendation	LOE A	LOE B-R	LOE B-NR	LOE C-LD	LOE C-EO	Total
I	0	8	17	27	28	80
IIa	0	12	12	40	10	74
IIb	0	23	11	80	26	140
III: No Benefit	2	3	0	0	0	5
III: Harm	0	1	4	3	7	15
Total	2	47	44	150	71	314

Legend: LOE, Level of Evidence; NR, non-randomized; R, randomized;

Most of the guidelines are based on Level C evidence (218/315, 69%) or Class II recommendations (217/315, 69%) (Table 5). When comparing levels of recommendations, there is a modest increase from 23.6% of Class I recommendations in 2010 to 25% in 2015 without much change in Class II recommendations, at 67% in 2010 and 68% in 2015 (Figure 5). There was a decrease in recommendations classified as Level B evidence from 37% in 2010 to 30% (LOE B-R and LOE B-NR) in 2015 (Figure 6). However, in contrast, **there was an increase in recommendations based on Level C evidence from 54% in 2010 to 69% in 2015**. These observations must be tempered with the fact that the PICO questions were selected by the task force in 2015 based on their critical or controversial nature or new science and, as such, their inclusion reflects a selection bias in the sample, whereas PICO questions in 2010 represented the true scope of work as determined by the task force. Nonetheless, even without comparative statistics, these data suggest a persistent huge knowledge gap for resuscitation science that has not been sufficiently addressed in the past 5 years. This gap in resuscitation science needs to be addressed through targeted future research funding. It is anticipated that new science will quickly be translated into Guideline Updates as a result of the continuous review process ILCOR will employ.

7 Authorship and Disclosures

7.1 2015 Writing Team

Laurie J. Morrison, Chair; Lana M. Gent, Eddy Lang, Mark E. Nunnally; Melissa J. Parker; Clifton W. Calloway; Vinay M. Nadkarni; Antonio R. Fernandez; John E. Billi; Jonathan R. Egan; Russell E. Griffin; Michael Shuster; Mary Fran Hazinski

Table 6: 2015 - AHA Guidelines for CPR & ECC Part 2: Evidence Evaluation & COI Writing Group Disclosures

Open table in a new window

AHA Guidelines for CPR & ECC Part 2: Evidence Evaluation & COI Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Category A Chair cannot have ANY relevant relationships (modest or significant) in the categories of ownership interest, equity interest, royalty income, stock, stock options speakers bureau, honoraria, expert witness, consultant/advisory board, or relevant research support from industry. Research funded by federal sources or not-for-profits is allowed on a case by case basis. The appropriate oversight committee (e.g., Guideline Task Force or Manuscript Oversight Committee) will review and evaluate the relationship. Government-sponsored or university managed DSMB allowed. Co-Chair can have modest or significant RWI in the categories of speakers' bureau, honoraria, consultant/advisory board, and expert witness. SIGNIFICANT relationships in category of personal investments (equity interest, royalty income, ownership, stock, stock options) are not allowed; modest RWI in this category is allowed.)								

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Laurie J. Morrison	Li Ka Shing Knowledge Institute; St Michael's Hospital, University of Toronto	Heart and Stroke Foundation of Canada† Canadian Institute of Health Research†	None	None	None	None	None	None
A majority of the writing group members must be free of a conflict in any category (modest or significant); if there's an even number of writing group members, at least 50% + 1 must be free of any conflicts.								
Category B (Proposed WG Members Who Have No Conflicts—must have a minimum of 6 currently have 7 including Chair)								
1. John E. Billi	The University of Michigan Medical School	None	None	None	None	None	None	None
2. Clifton W. Callaway	University of Pittsburgh	None	None	None	None	None	None	None
3. Yu-Feng	Mount Sinai	None	None	None	None	None	None	None
Yvonne Chan	Medical Center							
4. Jonathan R. Egan	The Children's Hospital at Westmead	None	None	None	None	None	None	None
5. Vinay M. Nadkarni	Children's Hospital of Philadelphia	None	None	None	None	None	None	None
6. Mark E. Nunnally	University of Chicago	None	None	None	None	None	None	None
7. Melissa J. Parker	Division of Pediatric Critical Care	None	None	None	None	None	None	None
Category C (Proposed WG Members Who Have Conflicts—cannot exceed 5 currently have 4)								

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
8. Antonio R. Fernandez	University of North Carolina	The Duke Endowment/ h Carolina Department of Health & Human Services, Department of Facility Services, Office of Emergency Medical Services† The Duke Endowment/ th Carolina Department of Health and Environment Control, Division of Emergency Medical Services & Trauma† Department of Homeland Security/Offi of Health Affairs†	None	None	None	None	None	None
Staff								
9. Lana M. Gent	AHA National Center	None	None	None	None	None	None	AHA Employee †
10. Russell E. Griffin	AHA National Center	None	None	None	None	None	None	AHA Employee †
Consultants								
11. Eddy Lang	University of Calgary	None	None	None	None	None	American Heart Association†	AHA Consultant

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
12. Mary Fran Hazinski	Vanderbilt University	None	None	None	None	None	AHA Paid Consultant†	AHA Consultant
13. Michael Shuster	Mineral Springs Hospital Emergency Medicine	None	None	None	None	None	AHA Paid Consultant†	AHA Consultant

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. * Modest. † Significant.

7.2 Acknowledgements

The authors on this writing group wish to acknowledge the 313 evidence reviewers contributing to the 2010 Guidelines and the additional 250 evidence reviewers contributing to the 2015 Guidelines Update, through the completion of the systematic reviews. In addition, the quality of this work is a reflection of the oversight of the GRADE expert, Dr. Eddy Lang, and the Evidence Evaluation expert, Dr. Peter T. Morley, with advice from a representative subgroup of ILCOR (the Methods Committee, under the leadership of Professor Ian G. Jacobs) as well as the countless hours of mentorship and oversight provided by the task force chairs and task force members.

8 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 2: Evidence Evaluation and Management of Conflicts of Interest. ECCguidelines.heart.org.

References

1. HazinskiMF,NolanJP,AickinR,BhanjiF,BilliJE,CallawayCW,CastrenM, de Caen AR, Ferrer JME, Finn JC, Gent LM, Griffin RE, Iverson S, Lang E, Lim SH, Maconochie IK, Montgomery WH, Morely PT, Nadkarni VM, Neumar RW, Nikolaou NI, Perkins GD, Perlman JM, Singletary EM, Soar J, Travers AH, Welsford M, Wyllie J, Zideman DA. Part 1: executive summary: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S2–S39. doi: 10.1161/CIR.0000000000000270.

2. Nolan JP, Hazinski MF, Aickin R, Bhanji F, Billi JE, Callaway CW, Castren M, de Caen AR, Ferrer JME, Finn JC, Gent LM, Griffin RE, Iverson S, Lang E, Lim SH, Maconochie IK, Montgomery WH, Morely PT, Nadkarni VM, Neumar RW, Nikolaou NI, Perkins GD, Perlman JM, Singletary EM, Soar J, Travers AH, Welsford M, Wyllie J, Zideman DA. Part 1: executive summary: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

3. Morley PT, Atkins DL, Billi JE, Bossaert L, Callaway CW, de Caen AR, Deakin CD, Eigel B, Hazinski MF, Hickey RW, Jacobs I, Kleinman ME, Koster RW, Mancini ME, Montgomery WH, Morrison LJ, Nadkarni VM, Nolan JP, O'Connor RE, Perlman JM, Sayre MR, Semenko TI, Shuster M, Soar J, Wyllie J, Zideman D. Part 3: evidence evaluation process: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122(suppl 2):S283–S290. doi: 10.1161/CIRCULATIONAHA.110.970947.

4. Schünemann H, Broz?ek J, Guyatt G, Oxman A. GRADE Handbook. 2013. http://www.guidelinedevelopment.org/handbook/. Accessed May 6, 2015.

5. Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions. Cochrane Book Series. Chichester, West Sussex, England: John Wiley & Sons Ltd; 2008.

6. The Cochrane Collaboration, Higgins JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0. 2013. http://handbook.cochrane.org/. Accessed May 6, 2015.

7. Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, Leeflang MM, Sterne JA, Bossuyt PM; QUADAS-2 Group. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med. 2011;155:529–536. doi: 10.7326/0003-4819-155-8-201110180-00009.

8. Schünemann H, Broz?ek J, Guyatt G, Oxman A. 5.2.1 Study limitations (risk of bias). GRADE Handbook. 2013. http://www.guidelinedevelopment.org/handbook/#h.m9385o5z3li7. Accessed May 6, 2015.

9. Evidence Prime Inc. GRADEpro Guideline Development Tool. 2015. http://www.guidelinedevelopment.org/. Accessed May 6, 2015.

10. GRADEpro. Computer program on http://www.gradepro.org. McMaster University. 2014.

11. Morley PT, Lang E, Aickin R, Billi JE, Eigel B, Ferrer JME, Finn JC, Gent LM, Griffin RE, Hazinski MF, Maconochie IK, Montgomery WH, Morrison LJ, Nadkarni VM, Nikolaou NI, Nolan JP, Perkins GD, Sayre MR, Travers AH, Wyllie J, Zideman DA. Part 2: evidence evaluation and management of conflicts of interest: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

12. Morley PT, Lang E, Aickin R, Billi JE, Eigel B, Ferrer JME, Finn JC, Gent LM, Griffin RE, Hazinski MF, Maconochie IK, Montgomery WH, Morrison LJ, Nadkarni VM, Nikolaou NI, Nolan JP, Perkins GD, Sayre MR, Travers AH, Wyllie J, Zideman DA. Part 2: evidence evaluation and management of conflicts of interest: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S40–S50. doi: 10.1161/CIR.0000000000000271.

13. Jacobs AK, Kushner FG, Ettinger SM, Guyton RA, Anderson JL, Ohman EM, Albert NM, Antman EM, Arnett DK, Bertolet M, Bhatt DL, Brindis RG, Creager MA, DeMets DL, Dickersin K, Fonarow GC, Gibbons RJ, Halperin JL, Hochman JS, Koster MA, Normand SL, Ortiz E, Peterson ED, Roach WH Jr, Sacco RL, Smith SC Jr, Stevenson WG, Tomaselli GF, Yancy CW, Zoghbi WA. ACCF/AHA clinical practice guideline methodology summit report: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2013;127:268–310. doi: 10.1161/CIR.0b013e31827e8e5f.

14. Rea TD, Helbock M, Perry S, Garcia M, Cloyd D, Becker L, Eisenberg M. Increasing use of cardiopulmonary resuscitation during out- of-hospital ventricular fibrillation arrest: survival implications of guideline changes. Circulation. 2006;114:2760–2765. doi: 10.1161/CIRCULATIONAHA.106.654715.

15. Daya MR, Schmicker RH, Zive DM, Rea TD, Nichol G, Buick JE, Brooks S, Christenson J, MacPhee R, Craig A, Rittenberger JC, Davis DP, May S, Wigginton J, Wang H; Resuscitation Outcomes Consortium Investigators. Out-of-hospital cardiac arrest survival improving over time: Results from the Resuscitation Outcomes Consortium (ROC). Resuscitation. 2015;91:108–115. doi: 10.1016/j.resuscitation.2015.02.003.

16. Søreide E, Morrison L, Hillman K, Monsieurs K, Sunde K, Zideman D, Eisenberg M, Sterz F, Nadkarni VM, Soar J, Nolan JP; Utstein Formula for Survival Collaborators. The formula for survival in resuscitation. Resuscitation. 2013;84:1487–1493. doi: 10.1016/j.resuscitation.2013.07.020.

17. Dainty KN, Brooks SC, Morrison LJ. Are the 2010 guidelines on cardiopulmonary resuscitation lost in translation? A call for increased focus on implementation science. Resuscitation. 2013;84:422–425. doi: 10.1016/j. resuscitation.2012.08.336.

18. Bigham BL, Koprowicz K, Aufderheide TP, Davis DP, Donn S, Powell J, Suffoletto B, Nafziger S, Stouffer J, Idris A, Morrison LJ; ROC Investigators. Delayed prehospital implementation of the 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiac care. Prehosp Emerg Care. 2010;14:355–360. doi: 10.3109/10903121003770639.

19. Fogarty International Center, National Institutes of Health. Implementation science information and resources. http://www.fic.nih.gov/researchtopics/ pages/implementationscience.aspx. Accessed May 13, 2015.

20. Berwick DM. A primer on leading the improvement of systems. BMJ. 1996;312:619–622.

21. Kane MT. The assessment of professional competence. Eval Health Prof. 1992;15:163–182.

22. Ellrodt AG, Fonarow GC, Schwamm LH, Albert N, Bhatt DL, Cannon CP, Hernandez AF, Hlatky MA, Luepker RV, Peterson PN, Reeves M, Smith EE. Synthesizing lessons learned from get with the guidelines: the value of disease-based registries in improving quality and outcomes. Circulation. 2013;128:2447–2460. doi: 10.1161/01.cir.0000435779.48007.5c.

23. The Joint Commission. Specifications Manual for National Hospital Inpatient Quality Measures. Version 4.4a. Discharges 01-01-15 (1q15) through 09-30-15 (3q15). http://www.jointcommission.org/specifications_manual_for_national_hospital_inpatient_quality_measures.aspx. Accessed May 13, 2015.

24. Graham R, McCoy MA, Schultz AM, Institute of Medicine. Strategies to Improve Cardiac Arrest Survival: A Time to Act. Washington, DC: The National Academies Press; 2015.

25. National Association of State EMS Officials. EMS performance measures: recommended attributes and indicators for system and service perfor- mance (December 2009). http://www.nasemso.org/projects/performance- measures/. Accessed May 13, 2015.

26. Jaber S, Jung B, Corne P, Sebbane M, Muller L, Chanques G, Verzilli D, Jonquet O, Eledjam JJ, Lefrant JY. An intervention to decrease complications related to endotracheal intubation in the intensive care unit: a prospective, multiple-center study. Intensive Care Med. 2010;36:248–255. doi: 10.1007/s00134-009-1717-8.

27. Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AH, Dellinger EP, Herbosa T, Joseph S, Kibatala PL, Lapitan MC, Merry AF, Moorthy K, Reznick RK, Taylor B, Gawande AA; Safe Surgery Saves Lives Study Group. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med. 2009;360:491–499. doi: 10.1056/ NEJMsa0810119.

28. Morrison LJ, Brooks SC, Dainty KN, Dorian P, Needham DM, Ferguson ND, Rubenfeld GD, Slutsky AS, Wax RS, Zwarenstein M, Thorpe K, Zhan C, Scales DC; Strategies for Post-Arrest Care Network. Improving use of targeted temperature management after out-of-hospital cardiac arrest: a stepped wedge cluster randomized controlled trial. Crit Care Med. 2015;43:954–964. doi: 10.1097/CCM.0000000000000864.

29. Kirkbright S, Finn J, Tohira H, Bremner A, Jacobs I, Celenza A. Audiovisual feedback device use by health care professionals during CPR: a systematic review and meta-analysis of randomised and non- randomised trials. Resuscitation. 2014;85:460–471. doi: 10.1016/j. resuscitation.2013.12.012.

30. Kilian BJ, Binder LS, Marsden J. The emergency physician and knowledge transfer: continuing medical education, continuing professional development, and self-improvement. Acad Emerg Med. 2007;14:1003– 1007. doi: 10.1197/j.aem.2007.07.008.

Part 3: Ethical Issues

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: advance directive DNAR life support organ donation

1 Highlights

As resuscitation practice evolves, ethical considerations must also evolve. Managing the multiple decisions associated with resuscitation is challenging from many perspectives, no more so than when healthcare providers (HCPs) are dealing with the ethics surrounding decisions to provide or withhold emergency cardiovascular interventions.

Ethical issues surrounding whether to start or when to terminate CPR are complex and may vary across settings (in- or out-of-hospital), providers (basic or advanced), and patient population (neonatal, pediatrics, adult). Although ethical principles have not changed since the 2010 Guidelines were published, the data that inform many ethical discussions have been updated through the evidence review process. The 2015 ILCOR evidence review process and resultant AHA Guidelines Update include several science updates that have implications for ethical decision making for periarrest, arrest, and postarrest patients.

Significant New and Updated Recommendations That May Inform Ethical Decisions

- The use of extracorporeal CPR (ECPR) for cardiac arrest
- Intra-arrest prognostic factors
- Review of evidence about prognostic scores for preterm infants
- Prognostication for children and adults after cardiac arrest
- Function of transplanted organs recovered after cardiac arrest

New resuscitation strategies such as ECPR have made decisions to discontinue resuscitation measures more complicated (see the Adult Advanced Cardiovascular Life Support section in this publication). Understanding the appropriate use, implications, and likely benefits related to such new treatments will have an impact on decision making. There is new information about prognostication for neonates, children, and adults in cardiac arrest and after cardiac arrest (see Neonatal Resuscitation, Pediatric Advanced Life Support, and Post–Cardiac Arrest Care). The increased use of targeted temperature management (TTM) has led to new challenges for predicting neurologic outcomes in comatose post–cardiac arrest patients, and the latest data about the usefulness of particular tests and studies should inform decisions about goals of care and limiting interventions.

There is greater awareness that although children and adolescents cannot make legally binding decisions, information should be shared with them to the extent, using appropriate language and information for each patient's level of development. In addition, the phrase *limitations of care* has been changed to *limitations of interventions*, and there is increasing availability of the Physician Orders for Life-Sustaining Treatment (POLST) form, a new method of legally identifying people with specific limits on interventions at the end of life, both in and out of healthcare facilities. Even with new information that the success of kidney and liver transplants from adult donors is unrelated to whether the donor receives CPR, the donation of organs after resuscitation remains controversial. Viewpoints on several important ethical concerns that are the topics of ongoing debate around organ donation in an emergency setting are summarized below in this Web-based Integrated Guidelines document.

2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

The goals of resuscitation are to preserve life; restore health; relieve suffering; limit disability; and respect individuals' decisions, rights, and privacy. Because cardiopulmonary resuscitation (CPR) efforts must be initiated

immediately at the time of arrest, a rescuer may not know who the victim is, what that individual's goals of care are, or if an advance directive exists. As a result, administration of CPR may be contrary to the individual's desires or best interests.[-2] This Part of the *2015 American Heart Association (AHA) Web-based Integrated Guidelines for CPR and Emergency Cardiovascular Care* provides updates to the 2010 AHA Guidelines[3] for healthcare providers who are faced with the difficult decision to provide or withhold emergency cardiovascular care.

3 Ethical Principles - Updated

Ethical, legal, and cultural factors influence decisions about resuscitation. Ideally, these decisions are guided by science, patient or surrogate preferences, local policies and legal requirements, and established ethical principles.

3.1 Principle of Respect for Autonomy - Updated

Respect for autonomy is an important social value in medical ethics and law.[4] This principle is based on society's respect for a competent individual's ability to make decisions about his or her own health care. Adults are presumed to have decision-making capability unless they are incapacitated or declared incompetent by a court of law. Informed decisions require that individuals receive and understand accurate information about their condition and prognosis as well as the nature, risks, benefits, and alternatives of any proposed interventions. Individuals must deliberate and choose among alternatives by linking their decisions to their values and personal goals of care.

When physicians strive to understand patients' goals of care, decisions can be made based on the likelihood that together they will achieve the patients' goals of care. The following 3-step process may assist healthcare providers in ensuring each patient understands and makes informed decisions: (1) the patient receives and understands accurate information about his or her condition, prognosis, nature of any proposed interventions, alternatives, and risks and benefits; (2) the patient is asked to paraphrase the information to give providers the opportunity to assess the patient's understanding and correct any misimpressions; and (3) the patient deliberates and chooses among alternatives and justifies his or her decisions.[5]

When decision-making capacity is temporarily impaired by conditions such as active illness, treatment of these conditions may restore capacity. When an individual's preferences are unknown or uncertain, it is ethically appropriate to treat emergency conditions until further information is available.

3.1.1 Advance Directives, Living Wills, and Patient Self-Determination

A recent study documented that more than a quarter of elderly patients require surrogate decision making at the end of life. Advance directives, living wills, and executing a durable power of attorney for health care ensure that when the patient is unable to make decisions, the preferences that the individual established in advance can guide care. These decisions are associated with less aggressive medical care near death, earlier hospice referrals for palliation, better quality of life, and caregiver's bereavement adjustment.[6]

A **healthcare advance directive** is a legal binding document that in the United States (US) is based on the Patient Self-Determination Act of 1990.[7] It communicates the thoughts, wishes, or preferences for healthcare decisions that might need to be made during periods of incapacity. The Patient Self-Determination Act mandated that healthcare institutions should facilitate the completion of advance directives if patients desire them.[7] Advance directives can be verbal or written and may be based on conversations, written directives, living wills, or durable power of attorney for health care. The legal validity of various forms of advance directives varies from jurisdiction to jurisdiction. Courts consider written advance directives to be more trustworthy than recollections of conversations.

A **living will** may be referred to as a "medical directive" or "declaration" or "directive to physicians," and it provides written direction to healthcare providers about the care that the individual approves should he or she become terminally ill and be unable to make decisions. A living will constitutes evidence of the individual's wishes, and in most areas it can be legally enforced.

A **durable power of attorney for health care** is a legal document that appoints an authorized person to make healthcare decisions (not limited to end-of-life decisions). Simply put, a living will affects the care received, and a durable power of attorney accounts for unforeseen circumstances. The latter decisions may be in conflict with the living will or advance directive; at the time of the unforeseen circumstances they are considered to be valid

expressions of the patient's best interests.[8]

A **comprehensive healthcare advance directive** combines the living will and the durable power of attorney for health care into one legally binding document.

As a patient's medical condition and desire for types of medical treatment may change over time, all types of advance directives should be revisited regularly. Most importantly the presence of an advance directive, a living will, or a durable power of attorney for health care is closely associated with ensuring that personal preferences match the actual care received, as documented in a survey of surrogates for patients of at least 60 years of age who died between 2000 and 2006 and required surrogate decision making at some point in their care.[8]

A **Do Not Attempt Resuscitation (DNAR) order** is given by a licensed physician or alternative authority as per local regulation, and it must be signed and dated to be valid.[9,10] In many settings, "Allow Natural Death" (AND) is becoming a preferred term to replace DNAR, to emphasize that the order is to allow natural consequences of a disease or injury, and to emphasize ongoing end-of-life care.[11] The DNAR order should explicitly describe the resuscitation interventions to be performed in the event of a life-threatening emergency. In most cases, a DNAR order is preceded by a documented discussion with the patient, family, or surrogate decision maker addressing the patient's wishes about resuscitation interventions. In addition, some jurisdictions may require confirmation by a witness or a second treating physician.

3.1.2 Surrogate Decision Makers

In the event of incapacity, an adult may require a surrogate decision maker to make medical decisions. In the event that the individual has a durable power of attorney for health care, the person appointed by that document is authorized to make medical decisions within the scope of authority granted by the document. If the individual has a court-appointed guardian with authority to make healthcare decisions, the guardian becomes the authorized surrogate.

If there is no court-appointed or other authority, a close relative or friend can become a surrogate decision maker. Most jurisdictions have laws that designate the legally authorized surrogate decision maker for an incompetent patient who has not identified a decision maker through a durable power of attorney for health care. Surrogate decision makers should base their decisions on the individual's previously expressed preferences, if known; otherwise, surrogates should make decisions based on their understanding of what constitutes the best interests of the individual.

3.1.3 Pediatric Decision Making - Updated

As a general rule, minors are considered incompetent to provide legally binding consent about their health care. Parents or guardians are generally empowered to make healthcare decisions on the behalf of minors, and in most situations, parents are given wide latitude in terms of the decisions they make on behalf of their children. Ethically, however, a child should be involved in decision making at a level appropriate for the child's maturity. Children under 14 years of age in Canada and under 18 years of age in the United States rarely possess the legal authority to consent to their health care except under specific legally defined situations (eg, emancipated minors; mature minors; minors who have specific health conditions, such as those with sexually transmitted diseases or in need of pregnancy-related care). However, as older children develop the capacity to make decisions, it is ethically appropriate to include them in discussions about their care and the treatments using language and explanations suitable for the child's level of maturity and cognitive function.

3.2 Principle of Futility

Patients or families may ask for care that is highly unlikely to improve health outcomes. Healthcare providers, however, are not obliged to provide such care when there is scientific and social consensus that the treatment is ineffective. If the purpose of a medical treatment cannot be achieved, the treatment can be considered futile.

An objective criterion for medical futility was defined in 1990 for interventions and drug therapy as imparting a <1% chance of survival.[12] Although this criterion may be controversial, it remains a basis for current futility research. An obvious example of an inappropriate or futile intervention is providing CPR for a patient who has suffered irreversible death.

Conditions such as irreversible brain damage or brain death cannot be reliably assessed or predicted at the time of cardiac arrest. Withholding resuscitation and the discontinuation of life-sustaining treatment during or after resuscitation are ethically equivalent. In situations where the prognosis is uncertain, a trial of treatment may be initiated while further information is gathered to help determine the likelihood of survival, the patient's preferences, and the expected clinical course. (Class IIb, LOE C)

4 Withholding and Withdrawing CPR (Termination of Resuscitative Efforts) - Updated

4.1 Out-of-Hospital Cardiac Arrest (OHCA) - Updated

4.1.1 Criteria for Not Starting CPR - Updated

While the general rule is to provide emergency treatment to a victim of cardiac arrest, there are a few exceptions where withholding CPR would be considered appropriate:

- Situations where attempts to perform CPR would place the rescuer at risk of serious injury or mortal peril (eg, exposure to infectious diseases).
- Obvious clinical signs of irreversible death (eg, rigor mortis, dependent lividity, decapitation, transection, decomposition).
- A valid advance directive, a Physician Orders for Life- Sustaining Treatment (POLST) form[13] (www.polst.org) indicating that resuscitation is not desired, or a valid Do Not Attempt Resuscitation (DNAR) order.

4.1.2 DNAR Orders in OHCA

Out-of-hospital DNAR protocols must be clearly written and easily implemented for all involved (all members of the healthcare team, patients, family members, and loved ones). DNAR documentation can take many forms (eg, written bedside orders, wallet identification cards, identification bracelets, or predefined paper documents approved by the local emergency medical services [EMS] authority). The ideal out-of-hospital DNAR documentation is portable and can be carried on the person, such as a POLST form.[10]

Delayed or token efforts such as so-called "slow-codes" (knowingly providing ineffective resuscitative efforts) are inappropriate. This practice compromises the ethical integrity of healthcare providers, uses deception to create a false impression, and may undermine the provider-patient relationship. The practice of "pseudo resuscitation" was self-reported by paramedics to occur in 27% of cardiac arrests in a community where a prehospital DNAR and termination-of-resuscitation protocols were not in place.[14]

Some EMS systems have extended the DNAR protocol to include verbal DNAR requests from family members as grounds to withhold therapy.[15,16] Paramedics withheld care to patients in cardiac arrest with a history of a terminal illness, who were under the care of a physician, and when at the time of the cardiac arrest the family requested that resuscitation not be attempted. The numbers of patients for whom resuscitation was withheld doubled after implementation (from 45 to 99 a year). This is an important first step in expanding the clinical decision rule pertaining to when to start resuscitation in OHCA, however there is insufficient evidence to support this approach without further validation.

4.1.3 Advance Directives in OHCA

Advance directives do not have to include a DNAR order, and a DNAR order is valid without an advance directive. A significant number of cardiac arrest victims for whom EMS is summoned have a terminal illness, and many have written advance directives. Laws detailing the actions of a prehospital provider in response to an out-of-hospital DNAR order vary across jurisdictions. In general, EMS professionals should initiate CPR and advanced life support if there is reasonable doubt about the validity of a DNAR order, if there is concern that the victim may have had a change of mind, or if there is a question about whether the patient intended the advance directive to be applied under the actual conditions for which EMS has been called.

The DNAR order should be shown to EMS responders as soon as they arrive on the scene. If the EMS professional cannot obtain clear information about the victim's wishes, they should not hesitate to start resuscitation. Sometimes within a few minutes of starting resuscitation, relatives or other medical personnel will arrive and confirm that the victim had clearly expressed a wish that resuscitation not be attempted. CPR or other

life-support measures may be discontinued by following local directives or protocols, which may include real-time consultation with medical direction.

4.1.4 Terminating Resuscitative Efforts in Neonatal, Pediatric, or Adult OHCA - Updated

The 2010 Guidelines contains a complete discussion of clinical decision rules for terminating resuscitative efforts.[3] This discussion is included in this integrated document.

In 2015, the International Liaison Committee on Resuscitation (ILCOR) Neonatal Life Support Task Force and the Pediatric Life Support Task Force completed systematic reviews to examine whether the presence of certain prognostic factors in the newly born or in infants or children enabled prediction of good neurologic outcome (see "Part 12: Pediatric Advanced Life Support" and "Part 13: Neonatal Resuscitation").

In the absence of clinical decision rules for the neonate, infant, child, or adult out-of-hospital cardiac arrest (OHCA) victim, CPR and advanced life support protocols are used by responsible prehospital providers in consultation with medical direction in real-time or as the victim is transported to the most appropriate facility per local directives. The impact of the availability of advanced hospital-based interventions, including extracorporeal membrane oxygenation (ECMO) during refractory CPR and the use of targeted temperature management (TTM), is now being considered in the local evaluation for continuing resuscitation and transport in some emergency medical service systems.[17-19]

The remainder of this section covers the 2010 content about Terminating Resuscitative Efforts in OHCA.

4.1.5 Terminating Resuscitative Efforts in Neonatal or Pediatric OHCA

No predictors of neonatal or pediatric (infant or child) out-of-hospital resuscitation success or failure have been established. No validated clinical decision rules have been derived and evaluated. Further research in this area is needed.

In the absence of clinical decision rules for the neonatal or pediatric OHCA victim, the responsible prehospital provider should follow BLS pediatric and advanced cardiovascular life support protocols and consult with real-time medical direction or transport the victim to the most appropriate facility per local directives.

4.1.6 Terminating Resuscitative Efforts in Adult OHCA

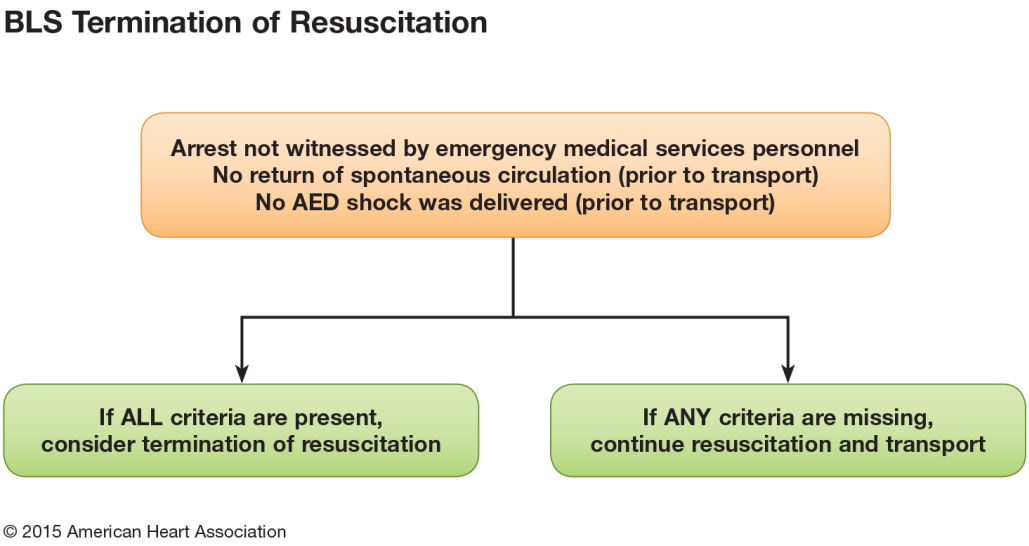
4.1.6.1 BLS Out-of-Hospital System

Rescuers who start BLS should continue resuscitation until one of the following occurs:

- Restoration of effective, spontaneous circulation
- Care is transferred to a team providing advanced life support
- The rescuer is unable to continue because of exhaustion, the presence of dangerous environmental hazards, or because continuation of the resuscitative efforts places others in jeopardy
- Reliable and valid criteria indicating irreversible death are met, criteria of obvious death are identified, or criteria for termination of resuscitation are met.

One set of reliable and valid criteria for termination of resuscitation is termed the "BLS termination of resuscitation rule" (see Figure 1.[20] All 3 of the following criteria must be present before moving to the ambulance for transport, to consider terminating BLS resuscitative attempts for adult victims of out-of-hospital cardiac arrest: (1) arrest was not witnessed by EMS provider or first responder; (2) no return of spontaneous circulation (ROSC) after 3 full rounds of CPR and automated external defibrillator (AED) analysis; and (3) no AED shocks were delivered.

Figure 1: BLS Termination of Resuscitation Rule for Adult OHCA



BLS termination-of-resuscitation rule for adult OHCA.

The BLS termination of resuscitation rule can reduce the rate of hospital transport to 37% of cardiac arrests without compromising the care of potentially viable patients. This was prospectively validated in rural and urban EMS services[20] and externally validated in additional locations in the US, Canada, and Europe.[21-26] The rule should be applied before moving to the ambulance for transport.[27] This clinical prediction rule consistently generates the highest specificity and positive predictive values when compared to previous guidelines.[26]

It is recommended that regional or local EMS authorities use the BLS termination rule to develop protocols for the termination of resuscitative efforts by BLS providers for adult victims of cardiac arrest in areas where advanced life support is not available or may be significantly delayed. (Class I, LOE A)

The reliability and validity of this rule is uncertain if modified. (Class IIb, LOE A)

Implementation of the rule includes real-time contacting of medical control when the rule suggests termination. Before the protocol is implemented, EMS providers require training in sensitive communication with the family about the outcome of the resuscitative attempt.[28] This strategy will help to ensure comfort of the provider and appropriate support of the grieving family. Support for the prehospital protocol should be sought from collaborating external agencies (eg, destination hospital emergency departments [EDs], coroner, medical directors, and police) before implementation.

4.1.6.2 ALS Out-of-Hospital System

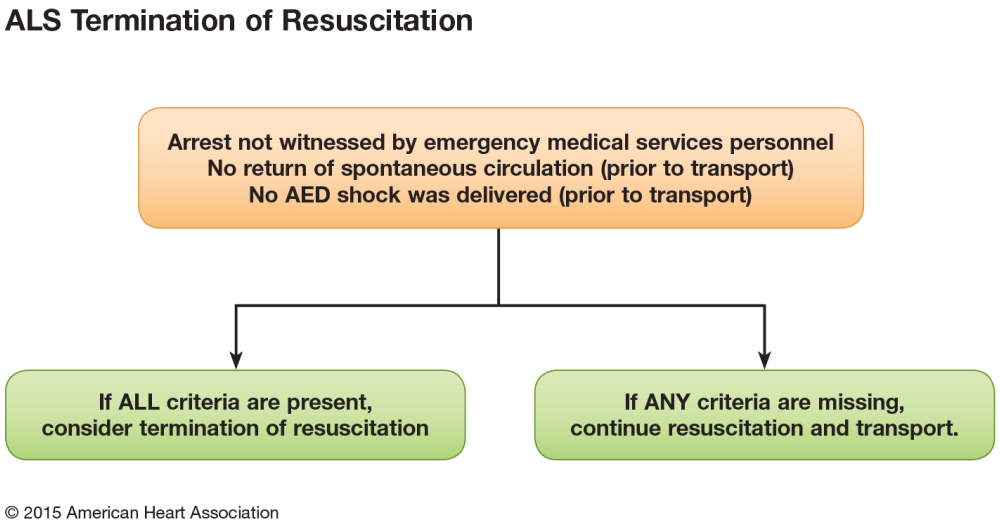
A different rule may be useful when the additional diagnostic and therapeutic capabilities of an advanced life support EMS response are available to the victim. The National Association of EMS Physicians (NAEMSP) suggested that resuscitative efforts could be terminated in patients who do not respond to at least 20 minutes of ALS care.[29]

An ALS termination of resuscitation rule was derived from a diverse population of rural and urban EMS settings.[30] This rule recommends considering terminating resuscitation when ALL of the following criteria apply before moving to the ambulance for transport (see Figure 2): (1) arrest was not witnessed;

(2) no bystander CPR was provided; (3) no ROSC after full ALS care in the field; and (4) no AED shocks were delivered. This rule has been retrospectively externally validated for adult patients in several regions in the US, Canada, and Europe,[22,24-26] and it is reasonable to employ this rule in all ALS services. (Class IIa, LOE B)

See Figure 2 in relation to this recommendation statement.

Figure 2: ALS Termination of Resuscitation Rule for Adult OHCA



ALS termination-of-resuscitation rule for adult OHCA.

4.1.6.3 Combined BLS and ALS Out-of-Hospital System

In a tiered ALS- and BLS-provider system, the use of a universal rule can avoid confusion at the scene of a cardiac arrest without compromising diagnostic accuracy.[22,25,26] The BLS rule is reasonable to use in these services. (Class IIa, LOE B)

4.1.6.4 Transport Implications

Field termination reduces unnecessary transport to the hospital by 60% with the BLS rule and 40% with the ALS rule,[22] reducing associated road hazards[31,32] that put the provider, patient, and public at risk. In addition field termination reduces inadvertent paramedic exposure to potential biohazards and the higher cost of ED pronouncement.[33-35] More importantly the quality of CPR is compromised during transport, and survival is linked to optimizing scene care rather than rushing to hospital.[36-38]

4.1.7 Use of Extracorporeal CPR for Adults with OHCA - Updated

The use of extracorporeal CPR (ECPR) may allow providers additional time to treat reversible underlying causes of cardiac arrest (eg, acute coronary artery occlusion, pulmonary embolism, refractory ventricular fibrillation, profound hypothermia, cardiac injury, myocarditis, cardiomyopathy, congestive heart failure, drug intoxication) or serve as a bridge for left ventricular assist device implantation or cardiac transplant.

4.1.7.1 2015 Evidence Summary

The 2015 ILCOR systematic review evaluated the use of ECPR techniques (including ECMO or cardiopulmonary bypass) compared with manual CPR or mechanical CPR. One post hoc analysis of data from a prospective, observational cohort of 162 OHCA patients who did not achieve return of spontaneous circulation (ROSC) with more than 20 minutes of conventional CPR, including propensity score matching, showed that at 3-month follow-up ECPR was associated with a higher rate of neurologically intact survival than continued conventional CPR.[39]

A single prospective, observational study that enrolled 454 patients with OHCA who were treated with ECPR if they did not achieve ROSC with more than 15 minutes of conventional CPR after hospital arrival demonstrated improved neurologic outcomes at 1-month and 6-month follow-ups.[40]

4.1.7.2 2015 Recommendation - Revised ALS 723

There is insufficient evidence to recommend the routine use of ECPR for patients with cardiac arrest.

In settings where it can be rapidly implemented, ECPR may be considered for select cardiac arrest patients for whom the suspected etiology of the cardiac arrest is potentially reversible during a limited period of mechanical cardiorespiratory support. (Class IIb, LOE C-LD)

4.1.8 Intra-arrest Prognostic Factors for Cardiac Arrest in Infants and Children - Updated

The ILCOR Pediatric Life Support Task Force reviewed the available evidence to determine if there were intra-arrest prognostic indicators that reliably predict survival with good neurologic outcome for OHCA.

4.1.8.1 2015 Evidence Summary

For infants and children with OHCA, age of less than 1 year,[41,42] longer duration of cardiac arrest,[43-45] and presentation with a nonshockable as opposed to a shockable rhythm[41,42,44] are all predictors of poor patient outcome.

4.1.8.2 2015 Recommendation - New PEDS 814

Multiple variables should be used when attempting to prognosticate outcomes during cardiac arrest. (Class I, LOE C-LD)

Although there are factors associated with better or worse outcomes, no single factor that was studied predicts outcome with sufficient accuracy to recommend termination or continuation of CPR.

4.2 In-Hospital Cardiac Arrest (IHCA) - Updated

4.2.1 Limitation of Interventions and Withdrawal of Life-Sustaining Therapies - Updated

This topic was last reviewed in 2010. Since that time, the term *limitation of interventions* has replaced *limitations of care*.[3] In the 2010 Guidelines, it was noted that not initiating resuscitation and discontinuing life-sustaining treatment of in-hospital cardiac arrest (IHCA) during or after resuscitation are ethically equivalent, and clinicians should not hesitate to withdraw support on ethical grounds when functional survival is highly unlikely.

The 2010 Guidelines are as follows:

Limitation of interventions or withdrawal of life-sustaining therapies is an emotionally complex decision for family and staff. Withholding and withdrawing life support are ethically similar. A decision to limit interventions or withdraw life support is justifiable if the patient is determined to be brain dead, if the physician and patient or surrogate agree that treatment goals cannot be met, or if the burden to the patient of continued treatment is believed to exceed any benefits.

Patients in the end stage of an incurable disease should receive care that ensures their autonomy, comfort, and dignity. Interventions that minimize suffering and pain, dyspnea, delirium, convulsions, and other terminal complications should always be provided. For such patients it is ethically acceptable to gradually increase the doses of narcotics and sedatives to relieve pain and other suffering, even to levels that might concomitantly shorten the patient's life. The care team should initiate plans for future care by collaborative discussions and the resolution of any conflicts with nurses, consultants, residents, fellows, the patient (when capable of participating), surrogate decision makers, and the family. Nursing and comfort care (eg, oral hygiene, skin care, patient positioning, and measures to relieve pain and suffering) must always be continued.

In the absence of evidence of an incurable disease in the end stage, decisions to withdraw or limit interventions in the post-arrest patient are often challenging, given the difficulties of accurate prognostication, especially in the era of treatment advances such as therapeutic hypothermia.

4.2.2 Criteria for Withholding and Discontinuing CPR in Newly Born Infant IHCA - Updated

There are prescribed recommendations to guide the initiation of resuscitative efforts in newly born infants. When gestational age, birth weight, or congenital anomalies are associated with almost certain early death and when unacceptably high morbidity is likely among the rare survivors, resuscitation is not indicated. Examples may include extreme prematurity (gestational age (Class IIb, LOE C)

In conditions associated with uncertain prognosis where survival is borderline, the morbidity rate is relatively high, and the anticipated burden to the child is high, parental desires concerning initiation of resuscitation should be supported. (Class IIb, LOE C)

There should be a consistent and coordinated approach from the obstetric and neonatal teams in applying these guidelines and in communicating with the parents in developing an agreed-upon management plan when possible.

As referenced above, in the 2010 Guidelines, the data regarding management of neonates born at the margins of viability or those with conditions that predict a high risk of mortality or morbidity were reviewed, and it was concluded that there was variation in attitudes and practice by region and availability of resources. Moreover, it was emphasized that parents desire a larger role in decisions related to initiation of resuscitation and continuation of support of severely compromised newborns. Guidelines were provided for when resuscitation is not indicated or when it is nearly always indicated. Under circumstances when the outcome remains unclear, the desires of the parents should be supported.[3]

4.2.3 Criteria for Not Starting CPR in Pediatric and Adult IHCA

Few criteria can accurately predict the futility of continued resuscitation. In light of this uncertainty, all pediatric and adult patients who suffer cardiac arrest in the hospital setting should have resuscitative attempts initiated unless the patient has a valid DNAR order or has objective signs of irreversible death (eg, dependent lividity).

4.2.4 DNAR Orders in IHCA

Unlike other medical interventions, CPR is initiated without a physician's order, based on implied consent for emergency treatment. A licensed physician's order is necessary to withhold CPR in the hospital setting. Physicians should initiate a discussion about the use of CPR with all patients admitted for medical and surgical care or with their surrogates. Terminally ill patients may fear abandonment and pain more than death, so physicians should also reassure the patient and family that control of pain and other symptoms as well as other aspects of support will continue even if resuscitation is withheld.

The attending physician should write the DNAR order in accordance with local policy in the patient's chart, with a note explaining the rationale for the DNAR order, other specific limitations of care, and documenting discussions with the patient, surrogate, and family. Oral DNAR orders are not acceptable. The limitation-of-treatment order should provide explicit instructions for specific emergency interventions that may arise, including the use of vasopressor agents, mechanical ventilation, blood products, or antibiotics. The scope of a DNAR order should specify which interventions are to be withheld.

It is important to emphasize that all other care should be administered without delay and as appropriate for all patients. A DNAR order does not automatically preclude interventions such as administration of parenteral fluids, nutrition, oxygen, analgesia, sedation, antiarrhythmics, or vasopressors, unless these are included in the order. Some patients may choose to accept defibrillation and chest compressions but not intubation and mechanical ventilation. DNAR orders carry no implications about other forms of treatment, and other aspects of the treatment plan should be documented separately and communicated to members of the healthcare team. DNAR orders should be reviewed periodically as per local protocol, particularly if the patient's condition changes.[46] DNAR orders should also be reviewed before surgery by the anesthesiologist, attending surgeon, and patient or surrogate to determine their applicability in the operating suite and during the immediate postoperative recovery period.[47]

4.2.5 Use of a Prognostic Score in the Delivery Room for Preterm Infants - Updated NRP 805

The 2015 ILCOR systematic review evaluated studies about prognostic scores applied to extremely preterm infants (below 25 weeks) compared with assessment of gestational age only.

4.2.5.1 2015 Recommendation - Updated

The data regarding prognostic scores are challenging to evaluate because of the difficulty in distinguishing between outcomes that are driven by practice and current belief about survivability, decision making by parents, and actual physiologic limitations of prematurity.

Antenatal assignment of prognosis for survival and/or disability of the neonate born extremely preterm has generally been made on the basis of gestational age alone. Scoring systems for including additional variables such as gender, use of maternal antenatal steroids, and multiplicity have been developed in an effort to improve prognostic accuracy. Indeed, it was suggested in the 2010 Guidelines that decisions regarding morbidity and risks of mortality may be augmented by the use of published tools based on data from specific populations.[48]

There is no evidence to support the prospective use of any particular delivery room prognostic score presently described, over gestational age assessment alone, in preterm infants at less than 25 weeks of gestation. Importantly, no score has been shown to improve the clinician's ability to estimate likelihood of survival through the first 18 to 22 months after birth.

However, in individual cases, when counseling a family and constructing a prognosis for survival at gestations below 25 weeks, it is reasonable to consider variables such as perceived accuracy of gestational age assignment, the presence or absence of chorioamnionitis, and the level of care available for the location of delivery. It is also recognized that decsions about appropriateness of resuscitation below 25 weeks of gestation will be influenced by region-specific guidelines. In making this statement, a higher value was placed on the lack of evidence for a generalized prospective approach to changing important outcomes over improved retrospective accuracy and locally validated counseling policies. The most useful data for antenatal counseling provides outcome figures for infants alive at the onset of labor, not only for those born alive or admitted to a neonatal intensive care unit.[49-54]
(Class IIb, LOE C-LD)

4.2.6 Terminating Resuscitative Efforts in Term Infants - Updated NRP 896

Noninitiation of resuscitation and discontinuation of life-sustaining treatment during or after resuscitation are ethically equivalent, and clinicians should not hesitate to withdraw support when functional survival is highly unlikely.[55] The following guidelines must be interpreted according to current regional outcomes.[56]

The 2015 ILCOR systematic review examined whether outcome is changed by continuing resuscitative efforts in late preterm and term infants with an Apgar score of 0 after 10 minutes of adequate resuscitation.

4.2.6.1 2015 Recommendation - Updated

An Apgar score of 0 at 10 minutes is a strong predictor of mortality and morbidity in late preterm and term infants.

We suggest that, in infants with an Apgar score of 0 after 10 minutes of resuscitation, if the heart rate remains undetectable, it may be reasonable to stop assisted ventilation; however, the decision to continue or discontinue resuscitative efforts must be individualized. Variables to be considered may include whether the resuscitation was considered optimal; availability of advanced neonatal care, such as therapeutic hypothermia; specific circumstances before delivery (eg, known timing of the insult); and wishes expressed by the family. [53,57-61] ***(Class IIb, LOE C-LD)***

For further information, see "Part 13: Neonatal Resuscitation."

4.2.7 Terminating Resuscitative Efforts in Pediatric or Adult IHCA - Updated

4.2.7.1 Use of ECPR in IHCA - Updated ALS 723 PEDS 407

To answer the question of whether outcome is changed by the use of ECPR for individuals in IHCA, the available

evidence was reviewed by the ILCOR Advanced Life Support and Pediatric Task Forces.

4.2.7.1.1 2015 Evidence Summary

The 2015 ILCOR review process evaluated the use of ECPR techniques (including ECMO or cardiopulmonary bypass) compared with manual CPR or mechanical CPR for adult survival from IHCA in any setting. One propensity-matched, prospective, observational study that enrolled 172 patients with IHCA reported greater likelihood of ROSC and improved survival at hospital discharge, 30-day follow-up, and 1-year follow-up with the use of ECPR among patients who received more than 10 minutes of CPR. However, this study showed no difference in neurologic outcomes.[62] A single propensity- matched, retrospective, observational study that enrolled 118 patients with IHCA who underwent more than 10 minutes of CPR and then ECPR after cardiac arrest of cardiac origin showed no survival or neurologic benefit over conventional CPR at the time of hospital discharge, 30-day follow-up, or 1-year follow-up.[62-64] A single retrospective, observational study that enrolled 120 patients with witnessed IHCA who underwent more than 10 minutes of CPR reported a modest benefit over historical controls with the use of ECPR over continued conventional CPR in both survival and neurologic outcome at discharge and 6-month follow-up.[64]

For infants and children in IHCA, the evidence comparing standard resuscitation with standard resuscitation plus ECMO was reviewed. Most studies were not robust, and there was little evidence of benefit overall; however, the outcome of some patients, such as those with underlying heart disease, may be improved.[65-70]

4.2.7.1.2 2015 Recommendations - New

There is insufficient evidence to recommend the routine use of ECPR for patients with cardiac arrest.

In settings where it can be rapidly implemented, ECPR may be considered for select cardiac arrest patients for whom the suspected etiology of the cardiac arrest is potentially reversible during a limited period of mechanical cardiorespiratory support. (Class IIb, LOE C-LD)

ECPR may be considered for pediatric patients with cardiac diagnoses who have IHCA in settings with existing ECMO protocols, expertise, and equipment. (Class IIb, LOE C-LD)

In making these recommendations, the reviewers noted that the published series used rigorous inclusion criteria to select patients for ECPR, and this recommendation should apply to similar populations. ECMO is a resource-intensive and invasive therapy with potential for harm that must be balanced against the potential for benefit based on individual clinical situations.

4.2.7.2 Terminating Cardiac Arrest Resuscitative Efforts in Pediatric IHCA - Updated PEDS 814

In the 2010 Guidelines, it was noted that no predictors of pediatric (infant or child) resuscitative success or failure have been established. The 2015 ILCOR systematic review examined whether there were any intra-arrest prognostic indicators that reliably predicted survival with good neurologic outcome for IHCA in infants and children and updated several of the prior recommendations.

4.2.7.2.1 2015 Evidence Summary

For infants and children with IHCA, negative predictive factors include age of over 1 year[71] and longer durations of cardiac arrest.[71-74] The evidence is contradictory as to whether a nonshockable (as opposed to shockable) initial cardiac arrest rhythm is a negative predictive factor in the in-hospital setting.[71,75,76]

4.2.7.2.2 2015 Recommendation - Updated

Multiple variables should be used when attempting to prognosticate outcomes during cardiac arrest. (Class I, LOE C-LD)

Although there are factors associated with better or worse outcomes, no single factor studied predicts outcome with sufficient accuracy to recommend termination or prolongation of CPR.

4.2.7.3 Prognostication During CPR - Updated

The 2015 ILCOR ALS systematic review considered one intra-arrest modality, end-tidal CO_2 ($ETCO_2$) measurement, in prognosticating outcome from cardiac arrest in adults. This section focuses on whether a specific $ETCO_2$ threshold can reliably predict ROSC and survival or inform a decision to terminate resuscitation efforts. For further information on the use of $ETCO_2$, see "Part 7: Adult Advanced Cardiovascular Life Support."

4.2.7.3.1 2015 Evidence Summary

Studies on the predictive capacity of $ETCO_2$ among intubated patients during cardiac arrest resuscitation are observational, and none have investigated survival with intact neurologic outcome. An $ETCO_2$ less than 10 mmHg immediately after intubation and 20 minutes after the initiation of resuscitation was associated with extremely poor chances for ROSC and survival in several observational studies.[77-81] Although these results suggest that $ETCO_2$ can be a valuable tool to predict futility during CPR, potential confounding reasons for a low $ETCO_2$ and the relatively small numbers of patients in these studies suggest that the $ETCO_2$ should not be used alone as an indication to terminate resuscitative efforts. However, the failure to achieve an $ETCO_2$ greater than 10 mmHg despite optimized resuscitation efforts may be a valuable component of a multimodal approach to deciding when to terminate resuscitation.

There are no studies that assess the prognostic value of $ETCO_2$ measurements sampled from a supraglottic airway or bag-mask device in predicting outcomes from a cardiac arrest.

4.2.7.3.2 2015 Recommendation - New ALS 459

In intubated patients, failure to achieve an ETCO2 of greater than 10 mm Hg by waveform capnography after 20 minutes of CPR may be considered as one component of a multimodal approach to decide when to end resuscitative efforts, but should not be used in isolation. (Class IIb, LOE C-LD)

The above recommendation is made with respect to $ETCO_2$ in patients who are intubated, because the studies examined included only those who were intubated.

In nonintubated patients, a specific ETCO2 cutoff value at any time during CPR should not be used as an indication to end resuscitative efforts. (Class III: Harm, LOE C-EO)

5 Providing Emotional Support to the Family

5.1 Providing Emotional Support to the Family During Resuscitative Efforts in Cardiac Arrest

In the past, family members have often been excluded from being present during the attempted resuscitation of a child or other relative. Surveys suggest that healthcare providers hold a range of opinions about the presence of family members during resuscitative attempts.[82-93] One theoretical concern is the potential for family members to become disruptive, interfere with resuscitative procedures, or develop syncope, and another is the possibility of increased exposure to legal liability; however, these are not reported in the literature.

Several surveys suggested that most family members wish to be present during a resuscitative attempt.[86-90] Family members with no medical background have reported that being at a loved one's side and saying goodbye during the final moments of life was comforting.[86,87,91] Family members have also reported that it helped them to adjust to the death of their loved one,[92,94] and most indicated that they would do so again.[91] Several retrospective reports note positive reactions from family members,[82-84] many of whom said that they felt a sense of having helped their loved one and of easing their own grieving.[85] Most parents surveyed indicated that they wanted to be offered the option of being present during the resuscitative effort for their child.[85,95-103]

In the absence of data documenting harm and in light of data suggesting that it may be helpful, offering

select family members the opportunity to be present during a resuscitation is reasonable and desirable (assuming that the patient, if an adult, has not raised a prior objection).
(Class IIa, LOE C for adults and Class I, LOE B for pediatric patients)

Parents and other family members seldom ask if they can be present unless they are encouraged to do so by healthcare providers. Resuscitation team members should be sensitive to the presence of family members during resuscitative efforts, assigning a team member to remain with the family to answer questions, clarify information, and otherwise offer comfort.[90]

5.2 Providing Emotional Support to the Family After Termination of Resuscitative Efforts in Cardiac Arrest

Notifying family members of the death of a loved one is an important aspect of a resuscitation that should be performed compassionately, with care taken to consider the family's culture, religious beliefs and preconceptions surrounding death, and any guilt they may feel associated with the event or circumstances preceding the event.[104]

6 Prognostication After Cardiac Arrest - Updated

6.1 Predicting Neurologic Outcome in Pediatric Patients After ROSC - Updated

There continues to be insufficient evidence to recommend or describe an approach to accurately predict the neurologic outcome of pediatric patients after cardiac arrest. Since the publication of the 2010 Guidelines, there have been an increasing number of publications associating a variety of findings with poor neurologic prognosis in these populations. Early and reliable prognostication of neurologic outcome in pediatric survivors of cardiac arrest is helpful for effective planning and family support and can inform decisions to continue or discontinue life-sustaining therapy.

6.2 Postresuscitation Use of Electroencephalography for Prognosis in Pediatric Survivors of Cardiac Arrest - Updated

The 2015 ILCOR Pediatric Life Support Task Force examined the usefulness of electroencephalography (EEG) or evoked potential assessment to predict long-term good neurologic outcome in infants and children who have survived cardiac arrest.

6.2.1 2015 Evidence Summary

Observational data from 2 small pediatric studies[105,106] showed that a continuous and reactive tracing on EEG performed in the first 7 days after cardiac arrest was associated with a significantly higher likelihood of good neurologic outcome at hospital discharge, whereas an EEG demonstrating a discontinuous or isoelectric tracing was associated with a poorer neurologic outcome at hospital discharge.

6.3 Predictive Factors After Cardiac Arrest in Pediatric Patients - Updated PEDS 822 PEDS 813

The 2015 systematic review examined whether there were factors that could assist with prognostication for pediatric patients who remained unconscious after cardiac arrest.

6.3.1 2015 Evidence Summary

Four observational studies supported the use of pupillary reactivity at 12 to 24 hours after cardiac arrest in predicting survival to discharge,[44,74,106,107] while 1 observational study found that reactive pupils 24 hours after cardiac arrest were associated with improved survival at 180 days with favorable neurologic outcome.[108]

Several serum biomarkers of neurologic injury have been considered for their prognostic value. Two small observational studies found that lower neuron-specific enolase (NSE) and S-100B serum levels post-arrest were associated with improved survival to hospital discharge and improved survival with favorable neurologic outcome.[108,109]

One observational study found that children with lower lactate levels in the first 12 hours after arrest had an improved survival to hospital discharge.[110]

6.3.2 2015 Recommendations - New

EEGs performed within the first 7 days after pediatric cardiac arrest may be considered in prognosticating neurologic outcome at the time of hospital discharge (Class IIb, LOE C-LD) but should not be used as the sole criterion.

The reliability of any 1 variable for prognostication in children after cardiac arrest has not been established.

Practitioners should consider multiple factors when predicting outcomes in infants and children who achieve ROSC after cardiac arrest. (Class I, LOE C-LD)

In situations where children have minimal prospects for recovery, we emphasize the use of multiple variables to inform treatment decisions. Given the greater neuroplasticity and potential for recovery in the developing brain, we place greater value on preserving opportunities for neonatal and pediatric recovery than on limiting therapy based on not-yet-validated prognostic tools. Accordingly, the decision to withdraw life-sustaining therapies is complex and continues to rest with the treating physician and family. Further research in this area is needed.

7 Predicting Neurologic Outcomes in Adult Patients After Cardiac Arrest - Updated

Scientists and clinicians continue to attempt to identify clinical, electrographic, radiographic, and biomarker data, which may be able to prognosticate neurologic outcome in patients. The primary purpose in accurately correlating specific data with poor neurologic outcome is to allow clinicians and families to make informed, but often difficult, choices for a patient who remains comatose after cardiac arrest with subsequent ROSC. There is a growing body of data that correlates specific findings with poor neurologic outcome after cardiac arrest. To date, however, there is no one specific test that can predict with certainty a poor neurologic recovery in this patient population. In making decisions, particularly the decision of whether to continue or withdraw life-sustaining therapies, clinicians and families need the most accurate information possible; typically, this information is an aggregate of clinical, electrographic, radiographic, and laboratory (eg, biomarkers) findings (see "Part 8: Post–Cardiac Arrest Care").

7.1 Timing of Prognostication in Post–Cardiac Arrest Adults - Updated ALS 450 ALS 713

In 2010, it was noted that there are no clinical neurologic signs, electrophysiologic studies, biomarkers, or imaging modalities that can reliably predict death or poor neurologic outcome (eg, Cerebral Performance Category of 3, 4, or 5) within the first 24 hours after cardiac arrest in patients treated with or without TTM. In 1 registry study,[111] it was noted that 63% of patients who survived an IHCA were given a DNAR status, and 43% had medical interventions actively withdrawn. These patients were often young and had no terminal illnesses but experienced death after withdrawal of life support in a time frame that was inadequate to allow thorough examination. This tendency to withdraw interventions prematurely in patients after cardiac arrest may have contributed to a selection bias in the current literature on prognostic testing. As the data are continuing to evolve, it is important to consider the potential for premature withdrawal of life support (see "Part 8: Post–Cardiac Arrest Care").

Sedatives or neuromuscular blockers received during TTM may be metabolized more slowly in patients after cardiac arrest, and injured brains may be more sensitive to the depressant effects of many drugs than normal brains. Residual sedation or paralysis can confound accurate clinical examinations.

7.1.1 2015 Recommendations - Updated

The earliest time for prognostication in patients treated with TTM using clinical examination where sedation or paralysis could be a confounder may be 72 hours after return to normothermia. (Class IIb, LOE C-EO)

We recommend the earliest time to prognosticate a poor neurologic outcome in patients not treated with TTM using clinical examination is 72 hours after cardiac arrest. (Class I, LOE B-NR)

This time can be even longer after cardiac arrest if the residual effect of sedation or paralysis confounds the clinical examination. (Class IIa, LOE C-LD)

Operationally, the timing for prognostication is typically 4.5 to 5 days after ROSC for patients treated with TTM. This approach minimizes the possibility of obtaining false-positive (ie, erroneously pessimistic) results because of drug-induced depression of neurologic function. In making this recommendation, it is recognized that in some instances, withdrawal of life support may occur appropriately before 72 hours because of underlying terminal disease, brain herniation, or other clearly nonsurvivable situations.

7.2 Prognostic Testing in Adult Patients After Cardiac Arrest - Updated ALS 713 ALS 450

The 2015 systematic evidence reviews examined numerous studies on the diagnostic accuracy of a wide range of tests for patients who did or did not receive TTM therapy.

The 2010 Guidelines recommended clinical examination, electrophysiologic measurements, imagining studies, and blood or cerebrospinal fluid markers of brain injury to estimate the prognosis for neurologic impairment in adult patients who remain comatose after cardiac arrest.[3] Updated guidelines for prognostication have been proposed by other international organizations[1,12] as well as the AHA in the 2015 Guidelines Update; for further information, see "Part 8: Post–Cardiac Arrest Care."

This topic continues to be an area of active research. The use of TTM has demonstrated the potential to improve the neurologic outcome in certain adult patients after cardiac arrest who might otherwise have a poor neurologic outcome. Although the data and literature are becoming more robust on this particular topic, there are few differences in the types of tests used in those who are and are not treated with TTM as relates to prognosticating neurologic outcome.

7.2.1 2015 Evidence Summary - New

For a full description of the evidence reviewed for each assessment of neurologic function and prognosis for adults who have had cardiac arrest, refer to "Part 8: Post–Cardiac Arrest Care."

7.2.2 2015 Recommendations: Clinical Examination Findings - New

In comatose patients who are not treated with TTM, the absence of pupillary reflex to light at 72 hours or more after cardiac arrest is a reasonable exam finding with which to predict poor neurologic outcome (FPR [false-positive rate], 0%; 95% CI, 0%–8%). (Class IIa, LOE B-NR)

In comatose patients who are treated with TTM, the absence of pupillary reflex to light at 72 hours or more after cardiac arrest is useful to predict poor neurologic outcome (FPR, 0%; 95% CI, 0%–3%). (Class I, LOE B-NR)

We recommend that, given their high FPRs, the findings of either absent motor movements or extensor posturing should not be used alone for predicting a poor neurologic outcome(FPR, 10%; 95% CI, 7%–15% to FPR, 15%; 95% CI, 5%– 31%). (Class III: Harm, LOE B-NR)

The motor examination may be a reasonable means to identify the population who need further prognostic testing to predict poor outcome. (Class IIb, LOE B-NR)

We recommend that the presence of myoclonus, which is distinct from status myoclonus, should not be

used to predict poor neurologic outcomes because of the high FPR(FPR, 5%; 95% CI, 3%–8% to FPR, 11%; 95% CI, 3%–26%). (Class III: Harm, LOE B-NR)

In combination with other diagnostic tests at 72 or more hours after cardiac arrest, the presence of status myoclonus during the first 72 hours after cardiac arrest is a reasonable finding to help predict poor neurologic outcomes(FPR, 0%; 95% CI, 0%–4%). (Class IIa, LOE B-NR)

7.2.3 2015 Recommendations: EEG - Updated ALS 450 ALS 713

In comatose post–cardiac arrest patients who are treated with TTM, it may be reasonable to consider persistent absence of EEG reactivity to external stimuli at 72 hours after cardiac arrest, and persistent burst suppression on EEG after rewarming, to predict a poor outcome (FPR, 0%; 95% CI, 0%–3%). (Class IIb, LOE B-NR)

Intractable and persistent (more than 72 hours) status epilepticus in the absence of EEG reactivity to external stimuli may be reasonable to predict poor outcome. (Class IIb, LOE B-NR)

In comatose post–cardiac arrest patients who are not treated with TTM, it may be reasonable to consider the presence of burst suppression on EEG at 72 hours or more after cardiac arrest, in combination with other predictors, to predict a poor neurologic outcome (FPR, 0%; 95% CI, 0%–11%). (Class IIb, LOE B-NR)

7.2.4 2015 Recommendations: Evoked Potentials - Updated ALS 450

In patients who are comatose after resuscitation from cardiac arrest regardless of treatment with TTM, it is reasonable to consider bilateral absence of the N20 somatosensory evoked potentials (SSEP) wave 24 to 72 hours after cardiac arrest or after rewarming a predictor of poor outcome (FPR, 1%; 95% CI, 0%–3%). (Class IIa, LOE B-NR)

SSEP recording requires appropriate skills and experience, and utmost care should be taken to avoid electrical interference from muscle artifacts or from the intensive care unit environment. However, sedative drugs or temperature manipulation affect SSEPs less than they affect the EEG and clinical examination.[113,114]

7.2.5 2015 Recommendations: Imaging Tests - New ALS 713

In patients who are comatose after resuscitation from cardiac arrest and are not treated with TTM, it may be reasonable to use the presence of a marked reduction of the gray-white ratio on brain computed tomography obtained within 2 hours after cardiac arrest to predict poor outcome. (Class IIb, LOE B-NR)

It may be reasonable to consider extensive restriction of diffusion on brain magnetic resonance imaging at 2 to 6 days after cardiac arrest in combination with other established predictors for predicting a poor neurologic outcome. (Class IIb, LOE B-NR)

Note that acquisition and interpretation of imaging studies have not been fully standardized and are affected by interobserver variability.[115] Therefore, brain imaging studies for prognostication should be performed only in centers where specific experience is available.

7.2.6 2015 Recommendations: Blood Markers - Updated ALS 713 ALS 450

Given the possibility of high FPRs, blood levels of NSE and S-100B should not be used alone to predict a poor neurologic outcome. (Class III: Harm, LOE C-LD)

When performed with other prognostic tests at 72 hours or more after cardiac arrest, it may be reasonable to consider high serum values of NSE at 48 to 72 hours after cardiac arrest to support the prognosis of a poor neurologic outcome (Class IIb, LOE B-NR), especially if repeated sampling reveals persistently high values. (Class IIb, LOE C-LD)

Laboratory standards for NSE and S-100B measurement vary between centers, making comparison of absolute values difficult. The kinetics of these markers have not been studied, particularly during or after TTM in cardiac arrest patients. Finally, NSE and S-100B are not specific to neuronal damage and can be produced by extra–central nervous system sources (hemolysis, neuroendocrine tumors, myenteric plexus, muscle and adipose tissue breakdown). If care is not taken when drawing NSE levels and if multiple time points are not assessed, false-positive results could occur secondary to hemolysis. All of these limitations led the writing group to conclude that NSE should be limited to a confirmatory test rather than a primary method for estimating prognosis.

8 Ethics of Organ and Tissue Donation - Updated

Situations that offer the opportunity for organ donation include donation after neurologic determination of death, controlled donation after circulatory determination of death, and uncontrolled donation after circulatory determination of death. Controlled donation after circulatory death usually takes place in the hospital after a patient whose advanced directives or surrogate, family, and medical team agree to allow natural death and withdraw life support. Uncontrolled donation usually takes place in an emergency department after exhaustive efforts at resuscitation have failed to achieve ROSC. In 2015, the ILCOR Advanced Life Support Task Force reviewed the evidence that might address the question of whether an organ retrieved from a donor who has had CPR that was initially successful (controlled donation) or unsuccessful (uncontrolled donation) would impact survival or complications compared with an organ from a donor who did not require CPR (controlled donation).

8.1 2015 Evidence Summary

Studies comparing transplanted organ function between those organs from donors who had received successful CPR before donation and those whose donors had not received CPR before donation have found no difference in transplanted organ function. This includes immediate graft function, 1-year graft function, and 5-year graft function. Studies have also shown no evidence of worse outcome in transplanted kidneys and livers from adult donors who have not had restoration of circulation after CPR compared with those from other types of donors.[116-119]

8.2 2015 Recommendation - Updated ALS 449

We recommend that all patients who are resuscitated from cardiac arrest but who subsequently progress to death or brain death be evaluated for organ donation. (Class I, LOE B-NR)

Patients who do not have ROSC after resuscitation efforts and who would otherwise have termination of efforts may be considered candidates for kidney or liver donation in settings where programs exist. (Class IIb, LOE B-NR)

In making this recommendation, the decisions for termination of resuscitative efforts and the pursuit of organ donation need to be independent processes (see “Part 8: Post–Cardiac Arrest Care”).

In 2010, it was noted that most communities do not optimize the retrieval of organ and tissue donations; this has created protracted waiting time and greater suffering for patients awaiting organ transplantation. The Emergency Cardiovascular Care community of the American Heart Association supports efforts to optimize the ethical acquisition of organ and tissue donations. Studies suggest no difference in functional outcomes of organs transplanted from patients who are determined to be brain dead as a consequence of cardiac arrest when

compared with donors who are brain dead from other causes.[120-123]

Therefore it is reasonable to suggest that all communities should optimize retrieval of tissue and organ donations in brain dead post–cardiac arrest patients (in-hospital) and those pronounced dead in the out-of-hospital setting. (Class IIa, LOE B)

Most important to this process is advance planning and infrastructure support to allow organ donation to occur in a manner sensitive to the needs of the donor's family and without undue burden on the staff.

Medical directors of EMS agencies, emergency departments (EDs), and critical care units (CCUs) should develop protocols and implementation plans with the regional organ and tissue donation program to optimize donation following a cardiac arrest death (Class I, LOE C), including:

A process by which permission for organ and tissue donations will be obtained
The establishment of clearly defined guidelines for organ and tissue procurement that will be available to all healthcare providers both in and out of the hospital
Information to address the possible differences between applicable laws and societal values in procedures for organ procurement
The emotional support to be offered to providers post event
A system to acquire organ and tissue donations from individuals pronounced dead in the out-of-hospital setting. This discussion should include input from the coroner, EMS, police, and lay people representing the target community

The 2010 Guidelines outlined the debate regarding the ethics of organ donation.[124] The debate continues today. Points to consider are outlined in **Table 1** below, with opposing viewpoints on the issue.[125-132] Although this material was not reviewed as part of the ILCOR review process, this section is intended to highlight some of the ethical issues around organ donation. A full discussion of the merits of each of these viewpoints is beyond the scope of this publication.

Table 1: 2015 - Ethical Questions and Issues Surrounding Organ Donation

Open table in a new window

Ethical Questions and Issues Surrounding Organ Donation

Ethical Question	Viewpoint	Alternative Viewpoint
How long after loss of circulation can a practitioner declare death?	Between 2 and 10 minutes, based on current literature documenting length of time that autoresuscitation has occurred, as long as the decision to allow natural death has been made.	Not until the point in time that resuscitative efforts could not restore spontaneous circulation. Currently we do not have evidence to support how long this would be.
	Between 7 and 10 minutes after resuscitative efforts have stopped in uncontrolled donation after circulatory determination of death.	

Ethical Question	Viewpoint	Alternative Viewpoint
Are individuals and surrogates truly and fully informed when consenting for organ donation?	Individuals may consent by designating the decision on a driver's license, in advance directives and wills, or through an online donor registry. If no previous consent by a patient exists, a surrogate will usually have to give consent if the patient is unable.	Individuals who consent to organ donation may not understand the dying process or be aware of the ethical dilemmas involved in organ donation.
Are there conflicts of interest?	Organ donation should not be considered until the decision has been made to allow natural death and withdraw support.	There is perception that those who care for patients and participate in withdrawal decisions are providers who care for organ recipients and may be biased.
	Organ procurement teams and transplant surgeons are not to be involved in the decisions or act of withdrawing support or declaring death.	
	Consent for donation should be requested by a trained individual who is not part of the care team.	Some believe that it is impossible to not consider organ donation as decisions to withdraw care are being made and, therefore, could influence the decision to withdraw support.
Should antemortem interventions be performed (eg, administration of heparin, vasodilators, bronchoscopy, cannulating large vessels—all for the purpose of preserving organ function)?	If the actual risk to the donor is low and is fully disclosed to patients and families, the procedure is ethically acceptable.	There is concern that these procedures pose risks to the donor and benefit only the recipient.
What postmortem procedures are ethically acceptable (eg, procedures such as extracorporeal membrane oxygenation that restore circulation and oxygenation)?	Restoring circulation to organs can result in better outcomes of transplanted organs. As long as oxygen and circulation are not supplied to the brain by the procedure, the diagnosis of death is still valid.	Procedures that restore oxygenation and circulation are unacceptable because they could reverse death.

9 Summary - Updated

Managing the multiple decisions associated with resuscitation is challenging from many perspectives, and no more so than when healthcare providers are dealing with the ethics surrounding decisions to provide or withhold emergency cardiovascular care. This is especially true with the increasing availability of technologies that hold the promise of improved outcomes after cardiac arrest, such as ECPR and TTM.

In the 2015 Guidelines Update, we have provided the evidence identified by 7 systematic reviews and the clarifying language to several other topics that were covered in the 2010 systematic review process but were not subjected to a full evidence review in 2015.

There is often insufficient evidence to recommend for or against specific interventions due to the uncertainty of determining a prognosis and predicting a particular outcome. As such, a solid understanding of the ethical principles surrounding autonomy and decision making must be coupled with the best information available at the time. Beyond decisions regarding the initiation and termination of life support, family presence during

resuscitations and organ donation also require healthcare providers to consider both science and ethics when providing patient-centered care.

As the science that informs resuscitation efforts continues to advance, so too must our efforts to understand the ethical implications that accompany them.

10 Authorship and Disclosures

10.1 2015 Writing Team

Mary E. Mancini, Chair; Douglas S. Diekema; Theresa A. Hoadley; Kelly D. Kadlec; Marygrace H. Leveille; Jane E. McGowan; Michele M. Munkwitz; Ashish R. Panchal; Michael R. Sayre; Elizabeth H. Sinz

Table 2: Part 3: Ethical Issues: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 3: Ethical Issues: 2015 Guidelines Update Writing Group Disclosures								
Writing Group Member	**Employment**	**Research Grant**	**Other Research Support**	**Speakers' Bureau/ Honoraria**	**Expert Witness**	**Ownership Interest**	**Consultant/Advisory Board**	**Other**
Mary E. Mancini	University of Texas at Arlington	None	None	None	None	None	None	None
Douglas S. Diekema	University of Washington School of Medicine	None	None	None	None	None	None	None
Theresa A. Hoadley	St. Francis Medical Center College of Nursing	None	None	None	None	None	None	None
Kelly D. Kadlec	Children's Hospital Medical Center	None	None	None	None	None	None	None
Marygrace H. Leveille	Baylor University Medical Center	None	None	None	None	None	None	None
Jane E. McGowan	St. Christopher's Hospital for Children	None	None	None	St. Christopher's Hospital*; USDOJ*	None	None	None
Michele M. Munkwitz	University of Arizona	None	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Ashish R. Panchal	Ohio State University	None	None	None	None	None	None	None
Michael R. Sayre	University of Washington	None	None	None	None	None	None	None
Consultant								
Elizabeth H. Sinz	University of Pennsylvania	None	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

10.2 2010 Writing Team

Laurie J. Morrison, Chair; Gerald Kierzek; Douglas S. Diekema; Michael R. Sayre; Scott M. Silvers; Ahamed H. Idris; Mary E. Mancini

Table 3: 2010 - Guidelines Part 3: Ethics: Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 3: Ethics: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Laurie J. Morrison	St Michael's Hospital–Clinician Scientist, Director Rescu Robert and Dorothy Pitts Chair in Acute Care & Emergency Medicine Keenan Research Centre Li Ka Shing Knowledge Institute St Michael's Hosp. Univ	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Gerald Kierzek	Assistance Publique Hopitaux de Paris & Univ of Paris, Emerg Dept & EMS & Forensic Med, Hotel-Dieu Cochin Hosp; MD	†Pitts Foundation/St Hosp Toronto, 1 yr research Fellow Emerg Med CCM	None	None	None	*Steering Com (Study LMWH in traumatic injury) GSK	None
Douglas S. Diekema	Children's University Medical Group-Professor of Pediatrics	None	None	None	None	None	None
Michael R. Sayre	The Ohio State University; Assoc Prof	None	None	None	None	None	None
Scott M. Silvers	Mayo Clinic Chair Emergency Medicine	None	None	None	None	None	None
Ahamed H. Idris	UT Southwestern Medical Center at Dallas–Profess of Surgery	†NIH grant for the Resuscitation Outcomes Consortium Dallas-Fort Worth Site. I serve as the site PI. All payments to UT SWMC, at which I'm employed	*In kind support from Philips, Medtronics, and ZOLL consisting of defibrillators, software, and manikins used for training purposes	None	None	None	None
Mary E. Mancini	Univ of Texas at Arlington, Professor	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

10.3 2010 Acknowledgements

Neonatal Task Force Chair Jeffrey M. Perlman for his contributions to the manuscript and Andrew H. Travers and Thomas D. Rea for their insightful review and editing.

11 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 3: Ethical Issues. ECCguidelines.heart.org.

References

1. Guru V, Verbeek PR, Morrison LJ. Response of paramedics to terminally ill patients with cardiac arrest: an ethical dilemma. CMAJ. 1999;161:1251–1254.
2. Wiese CH, Bartels UE, Zausig YA, Pfirstinger J, Graf BM, Hanekop GG. Prehospital emergency treatment of palliative care patients with cardiac arrest: a retrolective investigation. Support Care Cancer. 2010;18:1287– 1292. doi: 10.1007/s00520-009-0746-8.
3. Miller W, Levy P, Lamba S, Zalenski RJ, Compton S. Descriptive analysis of the in-hospital course of patients who initially survive out-of-hospital cardiac arrest but die in-hospital. J Palliat Med. 2010;13:19–22. doi: 10.1089/jpm.2009.0248.
4. Morrison LJ, Kierzek G, Diekema DS, Sayre MR, Silvers SM, Idris AH, Mancini ME. Part 3: ethics: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S665–S675. doi: 10.1161/ CIRCULATIONAHA.110.970905.
5. Beauchamp TL, Childress J. Principles of Biomedical Ethics. Oxford, England: Oxford University Press; 2008.
6. Simon JR. Refusal of care: the physician-patient relationship and decisionmaking capacity. Ann Emerg Med. 2007;50:456–461. doi: 10.1016/j. annemergmed.2007.04.016.
7. Wright AA, Zhang B, Ray A, Mack JW, Trice E, Balboni T, Mitchell SL, Jackson VA, Block SD, Maciejewski PK, Prigerson HG. Associations between end-of-life discussions, patient mental health, medical care near death, and caregiver bereavement adjustment. JAMA. 2008;300:1665–1673.
8. Omnibus Budget Reconciliation Act of 1990, Pub. Law No. 1990;101–508.
9. Silveira MJ, Kim SY, Langa KM. Advance directives and outcomes of surrogate decision making before death. N Engl J Med. 2010;362:1211–1218.

10. Cerminara KL, Bogin SM. A paper about a piece of paper. Regulatory action as the most effective way to promote use of physician orders for life-sustaining treatment. J Leg Med. 2008;29:479–503.

11. Payne JK, Thornlow DK. Clinical perspectives on portable do-not-resuscitate orders. J Gerontol Nurs. 2008;34:11–16.

12. Venneman SS, Narnor-Harris P, Perish M, Hamilton M. “Allow natural death” versus “do not resuscitate”: three words that can change a life. J Med Ethics. 2008;34:2–6.

13. Schneiderman LJ, Jecker NS, Jonsen AR. Medical futility: its meaning and ethical implications. Ann Intern Med. 1990;112:949–954.

14. Hickman SE, Keevern E, Hammes BJ. Use of the physician orders for life-sustaining treatment program in the clinical setting: a systematic review of the literature. J Am Geriatr Soc. 2015;63:341–350. doi: 10.1111/ jgs.13248.

15. Sherbino J, Guru V, Verbeek PR, Morrison LJ. Prehospital emergency medical services. CJEM. 2000;2:246–251.

16. Kellermann A, Lynn J. Withholding resuscitation in prehospital care. Ann Intern Med. 2006;144:692–693.

17. Feder S, Matheny RL, Loveless RS Jr., Rea TD. Withholding resuscitation: a new approach to prehospital end-of-life decisions. Ann Intern Med. 2006;144:634–640.

18. Avalli L, Maggioni E, Formica F, Redaelli G, Migliari M, Scanziani M, Celotti S, Coppo A, Caruso R, Ristagno G, Fumagalli R. Favourable sur- vival of in-hospital compared to out-of-hospital refractory cardiac arrest patients treated with extracorporeal membrane oxygenation: an Italian tertiary care centre experience. Resuscitation. 2012;83:579–583. doi: 10.1016/j.resuscitation.2011.10.013.

19. Wolf MJ, Kanter KR, Kirshbom PM, Kogon BE, Wagoner SF. Extracorporeal cardiopulmonary resuscitation for pediatric cardiac patients. Ann Thorac Surg. 2012;94:874–879; discussion 879. doi: 10.1016/j.athoracsur.2012.04.040.

20. Delmo Walter EM, Alexi-Meskishvili V, Huebler M, Redlin M, Boettcher W, Weng Y, Berger F, Hetzer R. Rescue extracorporeal membrane oxy- genation in children with refractory cardiac arrest. Interact Cardiovasc Thorac Surg. 2011;12:929–934. doi: 10.1510/icvts.2010.254193.

21. Morrison LJ, Visentin LM, Kiss A, Theriault R, Eby D, Vermeulen M, Sherbino J, Verbeek PR. Validation of a rule for termination of resuscitation in out-of-hospital cardiac arrest. N Engl J Med. 2006;355:478–487.

22. Richman PB, Vadeboncoeur TF, Chikani V, Clark L, Bobrow BJ. Independent evaluation of an out-of-hospital termination of resuscitation (TOR) clinical decision rule. Acad Emerg Med. 2008;15:517–521.

23. Morrison LJ, Verbeek PR, Zhan C, Kiss A, Allan KS. Validation of a universal prehospital termination of resuscitation clinical prediction rule for advanced and basic life support providers. Resuscitation. 2009;80:324–328.

24. Ong ME, Jaffey J, Stiell I, Nesbitt L. Comparison of termination-of-resuscitation guidelines for basic life support: defibrillator providers in out-of-hospital cardiac arrest. Ann Emerg Med. 2006;47:337–343.

25. Sasson C, Hegg AJ, Macy M, Park A, Kellermann A, McNally B. Prehospital termination of resuscitation in cases of refractory out-of-hospital cardiac arrest. JAMA. 2008;300:1432–1438.

26. Ruygrok ML, Byyny RL, Haukoos JS. Validation of 3 termination of resuscitation criteria for good neurologic survival after out-of-hospital cardiac arrest. Ann Emerg Med. 2009;54:239–247.

27. Skrifvars MB, Vayrynen T, Kuisma M, Castren M, Parr MJ, Silfverstople J, Svensson L, Jonsson L, Herlitz J. Comparison of Helsinki and European Resuscitation Council “do not attempt to resuscitate” guidelines, and a termination of resuscitation clinical prediction rule for out-of-hospital cardiac arrest patients found in asystole or pulseless electrical activity. Resuscitation. 2010.

28. Verbeek PR, Vermeulen MJ, Ali FH, Messenger DW, Summers J, Morrison LJ. Derivation of a termination-of-resuscitation guideline for emergency medical technicians using automated external defibrillators. Acad Emerg Med. 2002;9:671–678.

29. Morrison LJ, Visentin LM, Vermeulen M, Kiss A, Theriault R, Eby D, Sherbino J, Verbeek R. Inter-rater reliability and comfort in the application of a basic life support termination of resuscitation clinical prediction rule for out of hospital cardiac arrest. Resuscitation. 2007;74:150–157.

30. Bailey ED, Wydro GC, Cone DC. Termination of resuscitation in the prehospital setting for adult patients suffering nontraumatic cardiac arrest. National Association of EMS Physicians Standards and Clinical Practice Committee. Prehosp Emerg Care. 2000;4:190–195.

31. Morrison LJ, Verbeek PR, Vermeulen MJ, Kiss A, Allan KS, Nesbitt L, Stiell I. Derivation and evaluation of a termination of resuscitation clinical prediction rule for advanced life support providers. Resuscitation. 2007;74:266–275.

32. Auerbach PS, Morris JA Jr., Phillips JB Jr., Redlinger SR, Vaughn WK. An analysis of ambulance accidents in Tennessee. JAMA. 1987;258:1487–1490.

33. Kellermann AL, Hackman BB. Terminating unsuccessful advanced cardiac life support in the field. Am J Emerg Med. 1987;5:548–549.

34.

Morrison LJ, Cheung MC, Redelmeier DA. Evaluating paramedic comfort with field pronouncement: development and validation of an outcome measure. Acad Emerg Med. 2003;10:633–637.

35. Gray WA, Capone RJ, Most AS. Unsuccessful emergency medical resuscitation: are continued efforts in the emergency department justified? N Engl J Med. 1991;325:1393–1398.

36. Suchard JR, Fenton FR, Powers RD. Medicare expenditures on unsuccessful out-of-hospital resuscitations. J Emerg Med. 1999;17:801–805.

37. Olasveengen TM, Wik L, Steen PA. Quality of cardiopulmonary resuscitation before and during transport in out-of-hospital cardiac arrest. Resuscitation. 2008;76:185–190.

38. Eisenberg MS, Mengert TJ. Cardiac resuscitation. N Engl J Med. 2001;344:1304–1313.

39. Chung TN, Kim SW, Cho YS, Chung SP, Park I, Kim SH. Effect of vehicle speed on the quality of closed-chest compression during ambulance transport. Resuscitation. 2010.

40. Maekawa K, Tanno K, Hase M, Mori K, Asai Y. Extracorporeal cardiopulmonary resuscitation for patients with out-of-hospital cardiac arrest of cardiac origin: a propensity-matched study and pre- dictor analysis. Crit Care Med. 2013;41:1186–1196. doi: 10.1097/ CCM.0b013e31827ca4c8.

41. Sakamoto T, Morimura N, Nagao K, Asai Y, Yokota H, Nara S, Hase M, Tahara Y, Atsumi T; SAVE-J Study Group. Extracorporeal cardio- pulmonary resuscitation versus conventional cardiopulmonary resus- citation in adults with out-of-hospital cardiac arrest: a prospective observational study. Resuscitation. 2014;85:762–768. doi: 10.1016/j. resuscitation.2014.01.031.

42. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, Berg RA; Resuscitation Outcomes Consortium Investigators. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry- Cardiac Arrest. Circulation. 2009;119:1484–1491. doi: 10.1161/ CIRCULATIONAHA.108.802678.

43. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, Berg RA, Hiraide A; implementation working group for All-Japan Utstein Registry of the Fire and Disaster Management Agency. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nation- wide, population-based cohort study. Lancet. 2010;375:1347–1354. doi: 10.1016/S0140-6736(10)60064-5.

44. YoungKD,Gausche-HillM,McClungCD,LewisRJ.Aprospective,pop- ulation-based study of the epidemiology and outcome of out-of-hospital pediatric cardiopulmonary arrest. Pediatrics. 2004;114:157–164.

45. Moler FW, Donaldson AE, Meert K, Brilli RJ, Nadkarni V, Shaffner DH, Schleien CL, Clark RS, Dalton HJ, Statler K, Tieves KS, Hackbarth R, Pretzlaff R, van der Jagt EW, Pineda J, Hernan L, Dean JM; Pediatric Emergency Care Applied Research Network. Multicenter cohort study of out-of-hospital pediatric cardiac arrest. Crit Care Med. 2011;39:141–149. doi: 10.1097/CCM.0b013e3181fa3c17.

46. López-Herce J, García C, Domínguez P, Rodríguez-Núñez A, Carrillo A, Calvo C, Delgado MA; Spanish Study Group of Cardiopulmonary Arrest in Children. Outcome of out-of-hospital cardiorespiratory arrest in children. Pediatr Emerg Care. 2005;21:807–815.

47. Loertscher L, Reed DA, Bannon MP, Mueller PS. Cardiopulmonary resuscitation and do-not-resuscitate orders: a guide for clinicians. Am J Med. 2010;123:4–9.

48. Do Not Attempt Resuscitation (DNAR) Decisions in the Perioperative Period. London: The Association of Anaesthetists of Great Britain and Ireland; 2009.

49. Field JM, Hazinski MF, Sayre MR, Chameides L, Schexnayder SM, Hemphill R, Samson RA, Kattwinkel J, Berg RA, Bhanji F, Cave DM, Jauch EC, Kudenchuk PJ, Neumar RW, Peberdy MA, Perlman JM, Sinz E, Travers AH, Berg MD, Billi JE, Eigel B, Hickey RW, Kleinman ME, Link MS, Morrison LJ, O'Connor RE, Shuster M, Callaway CW, Cucchiara B, Ferguson JD, Rea TD, Vanden Hoek TL. Part 1: executive summary: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S640–S656. doi: 10.1161/CIRCULATIONAHA.110.970889.

50. Bottoms SF, Paul RH, Mercer BM, MacPherson CA, Caritis SN, Moawad AH, Van Dorsten JP, Hauth JC, Thurnau GR, Miodovnik M, Meis PM, Roberts JM, McNellis D, Iams JD. Obstetric determinants of neonatal survival: antenatal predictors of neonatal survival and mor- bidity in extremely low birth weight infants. Am J Obstet Gynecol. 1999;180(3 pt 1):665–669.

51. Ambalavanan N, Carlo WA, Bobashev G, Mathias E, Liu B, Poole K, Fanaroff AA, Stoll BJ, Ehrenkranz R, Wright LL; National Institute of Child Health and Human Development Neonatal Research Network. Prediction of death for extremely low birth weight neonates. Pediatrics. 2005;116:1367–1373. doi: 10.1542/peds.2004-2099.

52. Manktelow BN, Seaton SE, Field DJ, Draper ES. Population-based estimates of in-unit survival for very preterm infants. Pediatrics. 2013;131:e425–e432. doi: 10.1542/peds.2012-2189.

53. Medlock S, Ravelli AC, Tamminga P, Mol BW, Abu-Hanna A. Prediction of mortality in very premature infants: a systematic review of prediction models. PLoS One. 2011;6:e23441. doi: 10.1371/journal.pone.0023441.

54. Patel H, Beeby PJ. Resuscitation beyond 10 minutes of term babies born without signs of life. J Paediatr Child Health. 2004;40:136–138.

55. Tyson JE, Parikh NA, Langer J, Green C, Higgins RD; National Institute of Child Health and Human Development Neonatal Research Network. Intensive care for extreme prematurity–moving beyond gestational age. N Engl J Med. 2008;358:1672–1681. doi: 10.1056/NEJMoa073059.

56. Paris JJ. What standards apply to resuscitation at the borderline of gestational age? J Perinatol. 2005;25:683–684.

57. De Leeuw R, Cuttini M, Nadai M, Berbik I, Hansen G, Kucinskas A, Lenoir S, Levin A, Persson J, Rebagliato M, Reid M, Schroell M, de Vonderweid U. Treatment choices for extremely preterm infants: an international perspective. J Pediatr. 2000;137:608–616.

58. Casalaz DM, Marlow N, Speidel BD. Outcome of resuscitation follow- ing unexpected apparent stillbirth. Arch Dis Child Fetal Neonatal Ed. 1998;78:F112–F115.

59. Harrington DJ, Redman CW, Moulden M, Greenwood CE. The long-term outcome in surviving infants with Apgar zero at 10 minutes: a systematic review of the literature and hospital-based cohort. Am J Obstet Gynecol. 2007;196:463.e1–463.e5. doi: 10.1016/j.ajog.2006.10.877.

60. Kasdorf E, Laptook A, Azzopardi D, Jacobs S, Perlman JM. Improving infant outcome with a 10 min Apgar of 0. Arch Dis Child Fetal Neonatal Ed. 2015;100:F102–F105. doi: 10.1136/archdischild-2014-306687.

61. Laptook AR, Shankaran S, Ambalavanan N, Carlo WA, McDonald SA, Higgins RD, Das A; Hypothermia Subcommittee of the NICHD Neonatal Research Network. Outcome of term infants using apgar scores at 10 minutes following hypoxic-ischemic encephalopathy. Pediatrics. 2009;124:1619–1626. doi: 10.1542/peds.2009-0934.

62. Sarkar S, Bhagat I, Dechert RE, Barks JD. Predicting death despite thera- peutic hypothermia in infants with hypoxic-ischaemic encephalopathy. Arch Dis Child Fetal Neonatal Ed. 2010;95:F423–F428. doi: 10.1136/ adc.2010.182725.

63. Chen YS, Lin JW, Yu HY, Ko WJ, Jerng JS, Chang WT, Chen WJ, Huang SC, Chi NH, Wang CH, Chen LC, Tsai PR, Wang SS, Hwang JJ, Lin FY. Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in- hospital cardiac arrest: an observational study and propensity analysis. Lancet. 2008;372:554–561. doi: 10.1016/S0140-6736(08)60958-7.

64. Lin JW, Wang MJ, Yu HY, Wang CH, Chang WT, Jerng JS, Huang SC, Chou NK, Chi NH, Ko WJ, Wang YC, Wang SS, Hwang JJ, Lin FY, Chen YS. Comparing the survival between extracorporeal rescue and conven- tional resuscitation in adult in-hospital cardiac arrests: propensity analy- sis of three-year data. Resuscitation. 2010;81:796–803. doi: 10.1016/j. resuscitation.2010.03.002.

65. Shin TG, Choi JH, Jo IJ, Sim MS, Song HG, Jeong YK, Song YB, Hahn JY, Choi SH, Gwon HC, Jeon ES, Sung K, Kim WS, Lee YT. Extracorporeal cardiopulmonary resuscitation in patients with inhospital cardiac arrest: A comparison with conventional cardiopulmonary resuscitation. Crit Care Med. 2011;39:1–7. doi: 10.1097/CCM.0b013e3181feb339.

66. Wu ET, Li MJ, Huang SC, Wang CC, Liu YP, Lu FL, Ko WJ, Wang MJ, Wang JK, Wu MH. Survey of outcome of CPR in pediatric in-hospital car- diac arrest in a medical center in Taiwan. Resuscitation. 2009;80:443–448. doi: 10.1016/j.resuscitation.2009.01.006.

67. Moler FW, Meert K, Donaldson AE, Nadkarni V, Brilli RJ, Dalton HJ, Clark RS, Shaffner DH, Schleien CL, Statler K, Tieves KS, Hackbarth R, Pretzlaff R, van der Jagt EW, Levy F, Hernan L, Silverstein FS, Dean JM; Pediatric Emergency Care Applied Research Network. In-hospital versus out-of-hospital pediatric cardiac arrest: a multicenter cohort study. Crit Care Med. 2009;37:2259–2267. doi: 10.1097/CCM.0b013e3181a00a6a.

68. de Mos N, van Litsenburg RR, McCrindle B, Bohn DJ, Parshuram CS. Pediatric in-intensive-care-unit cardiac arrest: incidence, survival, and predictive factors. Crit Care Med. 2006;34:1209–1215. doi: 10.1097/01. CCM.0000208440.66756.C2.

69. Lowry AW, Morales DL, Graves DE, Knudson JD, Shamszad P, Mott AR, Cabrera AG, Rossano JW. Characterization of extracorporeal membrane oxygenation for pediatric cardiac arrest in the United States: analysis of the kids' inpatient database. Pediatr Cardiol. 2013;34:1422–1430. doi: 10.1007/s00246-013-0666-8.

70. Odegard KC, Bergersen L, Thiagarajan R, Clark L, Shukla A, Wypij D, Laussen PC. The frequency of cardiac arrests in patients with con- genital heart disease undergoing cardiac catheterization. Anesth Analg. 2014;118:175–182. doi: 10.1213/ANE.0b013e3182908bcb.

71. Ortmann L, Prodhan P, Gossett J, Schexnayder S, Berg R, Nadkarni V, Bhutta A; American Heart Association's Get With the Guidelines– Resuscitation Investigators. Outcomes after in-hospital cardiac arrest in children with cardiac disease: a report from Get With the Guidelines– Resuscitation. Circulation. 2011;124:2329–2337. doi: 10.1161/ CIRCULATIONAHA.110.013466.

72. Matos RI, Watson RS, Nadkarni VM, Huang HH, Berg RA, Meaney PA, Carroll CL, Berens RJ, Praestgaard A, Weissfeld L, Spinella PC; American Heart Association's Get With The Guidelines–Resuscitation (Formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Duration of cardiopulmonary resuscitation and illness category impact survival and neurologic outcomes for in-hospital pedi- atric cardiac arrests. Circulation. 2013;127:442–451. doi: 10.1161/ CIRCULATIONAHA.112.125625.

73. Reis AG, Nadkarni V, Perondi MB, Grisi S, Berg RA. A prospective investigation into the epidemiology of in-hospital pediatric cardiopulmonary resuscitation using the international Utstein reporting style. Pediatrics. 2002;109:200–209.

74. Haque A, Rizvi A, Bano S. Outcome of in-hospital pediatric cardiopulmonary arrest from a single center in Pakistan. Indian J Pediatr. 2011;78:1356–1360. doi: 10.1007/s12098-011-0439-4.

75. Meert KL, Donaldson A, Nadkarni V, Tieves KS, Schleien CL, Brilli RJ, Clark RS, Shaffner DH, Levy F, Statler K, Dalton HJ, van der Jagt EW, Hackbarth R, Pretzlaff R, Hernan L, Dean JM, Moler FW; Pediatric Emergency Care Applied Research Network. Multicenter cohort study of in-hospital pediatric cardiac arrest. Pediatr Crit Care Med. 2009;10:544– 553. doi: 10.1097/PCC.0b013e3181a7045c.

76. López-Herce J, Del Castillo J, Matamoros M, Cañadas S, Rodriguez- Calvo A, Cecchetti C, Rodriguez-Núñez A, Alvarez AC; Iberoamerican Pediatric Cardiac Arrest Study Network RIBEPCI. Factors associated with mortality in pediatric in-hospital cardiac arrest: a prospective multicenter multinational observational study. Intensive Care Med. 2013;39:309–318. doi: 10.1007/s00134-012-2709-7.

77. Tibballs J, Kinney S. A prospective study of outcome of in-patient pae- diatric cardiopulmonary arrest. Resuscitation. 2006;71:310–318. doi: 10.1016/j.resuscitation.2006.05.009.

78. Ahrens T, Schallom L, Bettorf K, Ellner S, Hurt G, O'Mara V, Ludwig J, George W, Marino T, Shannon W. End-tidal carbon dioxide measurements as a prognostic indicator of outcome in cardiac arrest. Am J Crit Care. 2001;10:391–398.

79. Callaham M, Barton C. Prediction of outcome of cardiopulmonary resus- citation from end-tidal carbon dioxide concentration. Crit Care Med. 1990;18:358–362.

80. Cantineau JP, Lambert Y, Merckx P, Reynaud P, Porte F, Bertrand C, Duvaldestin P. End-tidal carbon dioxide during cardiopulmonary resusci- tation in humans presenting mostly with asystole: a predictor of outcome. Crit Care Med. 1996;24:791–796.

81. Levine RL, Wayne MA, Miller CC. End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest. N Engl J Med. 1997;337:301–306. doi: 10.1056/NEJM199707313370503.

82. Wayne MA, Levine RL, Miller CC. Use of end-tidal carbon diox- ide to predict outcome in prehospital cardiac arrest. Ann Emerg Med. 1995;25:762–767.

83. Meyers TA, Eichhorn DJ, Guzzetta CE. Do families want to be present during CPR? A retrospective survey. J Emerg Nurs. 1998;24:400–405.

84. Robinson SM, Mackenzie-Ross S, Campbell Hewson GL, Egleston CV, Prevost AT. Psychological effect of witnessed resuscitation on bereaved relatives. Lancet. 1998;352:614–617.

85. Boie ET, Moore GP, Brummett C, Nelson DR. Do parents want to be present during invasive procedures performed on their children in the emergency department? A survey of 400 parents. Ann Emerg Med. 1999;34:70–74.

86. Adams S, Whitlock M, Higgs R, Bloomfield P, Baskett PJ. Should relatives be allowed to watch resuscitation? BMJ. 1994;308:1687–1692.

87. Boyd R. Witnessed resuscitation by relatives. Resuscitation. 2000;43:171–176.

88. Hampe SO. Needs of the grieving spouse in a hospital setting. Nurs Res. 1975;24:113–120.

89. Offord RJ. Should relatives of patients with cardiac arrest be invited to be present during cardiopulmonary resuscitation? Intensive Crit Care Nurs. 1998;14:288–293.

90. Shaner K, Eckle N. Implementing a program to support the option of family presence during resuscitation. The Association for the Care of Children's Health (ACCH) Advocate. 1997;3:3–7.

91. Eichhorn DJ, Meyers TA, Mitchell TG, Guzzetta CE. Opening the doors: family presence during resuscitation. J Cardiovasc Nurs. 1996;10:59–70.

92. Doyle CJ, Post H, Burney RE, Maino J, Keefe M, Rhee KJ. Family participation during resuscitation: an option. Ann Emerg Med. 1987;16:673–675.

93. Barratt F, Wallis DN. Relatives in the resuscitation room: their point of view. J Accid Emerg Med. 1998;15:109–111.

94. Compton S, Madgy A, Goldstein M, Sandhu J, Dunne R, Swor R. Emergency medical service providers' experience with family presence during cardiopulmonary resuscitation. Resuscitation. 2006;70:223–228.

95. Beckman AW, Sloan BK, Moore GP, Cordell WH, Brizendine EJ, Boie ET, Knoop KJ, Goldman MJ, Geninatti MR. Should parents be present during emergency department procedures on children, and who should make that decision? A survey of emergency physician and nurse attitudes. Acad Emerg Med. 2002;9:154–158.

96. Dudley NC, Hansen KW, Furnival RA, Donaldson AE, Van Wagenen KL, Scaife ER. The effect of family presence on the efficiency of pediatric trauma resuscitations. Ann Emerg Med. 2009;53:777–784. e773.

97.

Tinsley C, Hill JB, Shah J, Zimmerman G, Wilson M, Freier K, Abd-Allah S, Tinsley C, Hill JB, Shah J, Zimmerman G, Wilson M, Freier K, Abd-Allah S. Experience of families during cardiopulmonary resuscitation in a pediatric intensive care unit. Pediatrics. 2008;122:e799–e804.

98. Mangurten J, Scott SH, Guzzetta CE, Clark AP, Vinson L, Sperry J, Hicks B, Voelmeck W. Effects of family presence during resuscitation and invasive procedures in a pediatric emergency department. Journal of Emergency Nursing. 2006;32:225–233.

99. McGahey-Oakland PR, Lieder HS, Young A, Jefferson LS, McGahey-Oakland PR, Lieder HS, Young A, Jefferson LS. Family experiences during resuscitation at a children's hospital emergency department. Journal of Pediatric Health Care. 2007;21:217–225.

100. Jones M, Qazi M, Young KD. Ethnic differences in parent preference to be present for painful medical procedures. Pediatrics. 2005;116:e191–e197.

101. Andrews R, Andrews R. Family presence during a failed major trauma resuscitation attempt of a 15-year-old boy: lessons learned.[see comment]. Journal of Emergency Nursing. 2004;30:556–558.

102. Dill K, Gance-Cleveland B, Dill K, Gance-Cleveland B. With you until the end: family presence during failed resuscitation. Journal for Specialists in Pediatric Nursing: JSPN. 2005;10:204–207.

103. Gold KJ, Gorenflo DW, Schwenk TL, Bratton SL, Gold KJ, Gorenflo DW, Schwenk TL, Bratton SL. Physician experience with family presence during cardiopulmonary resuscitation in children. [see comment]. Pediatric Crit Care Med. 2006;7:428–433.

104. Duran CR, Oman KS, Abel JJ, Koziel VM, Szymanski D. Attitudes Toward and Beliefs About Family Presence: A Survey of Healthcare Providers, Patients' Families, and Patients. Am Journal of Critical Care. 2007;16:270–279.

105. Iserson KV. Notifying survivors about sudden, unexpected deaths. West J Med. 2000;173:261–265.

106. Kessler SK, Topjian AA, Gutierrez-Colina AM, Ichord RN, Donnelly M, Nadkarni VM, Berg RA, Dlugos DJ, Clancy RR, Abend NS. Short-term outcome prediction by electroencephalographic features in children treated with therapeutic hypothermia after cardiac arrest. Neurocrit Care. 2011;14:37–43. doi: 10.1007/s12028-010-9450-2.

107. Nishisaki A, Sullivan J 3rd, Steger B, Bayer CR, Dlugos D, Lin R, Ichord R, Helfaer MA, Nadkarni V. Retrospective analysis of the prognostic value of electroencephalography patterns obtained in pediatric in-hospital cardiac arrest survivors during three years. Pediatr Crit Care Med. 2007;8:10–17. doi: 10.1097/01.pcc.0000256621.63135.4b.

108. Abend NS, Topjian AA, Kessler SK, Gutierrez-Colina AM, Berg RA, Nadkarni V, Dlugos DJ, Clancy RR, Ichord RN. Outcome prediction by motor and pupillary responses in children treated with therapeutic hypo- thermia after cardiac arrest. Pediatr Crit Care Med. 2012;13:32–38. doi: 10.1097/PCC.0b013e3182196a7b.

109. Fink EL, Berger RP, Clark RS, Watson RS, Angus DC, Richichi R, Panigrahy A, Callaway CW, Bell MJ, Kochanek PM. Serum biomarkers of brain injury to classify outcome after pediatric cardiac arrest. Crit Care Med. 2014;42:664–674. doi: 10.1097/01.ccm.0000435668.53188.80.

110. Topjian AA, Lin R, Morris MC, Ichord R, Drott H, Bayer CR, Helfaer MA, Nadkarni V. Neuron-specific enolase and S-100B are associated with neurologic outcome after pediatric cardiac arrest. Pediatr Crit Care Med. 2009;10:479–490. doi: 10.1097/PCC.0b013e318198bdb5.

111. Topjian AA, Clark AE, Casper TC, Berger JT, Schleien CL, Dean JM, Moler FW; Pediatric Emergency Care Applied Research Network. Early lactate elevations following resuscitation from pediatric cardiac arrest are associated with increased mortality. Pediatr Crit Care Med. 2013;14:e380–e387. doi: 10.1097/PCC.0b013e3182976402.

112. Peberdy MA, Ornato JP. Post-resuscitation care: is it the missing link in the Chain of Survival? Resuscitation. 2005;64:135–137. doi: 10.1016/j. resuscitation.2004.09.015.

113. Sandroni C, Cariou A, Cavallaro F, Cronberg T, Friberg H, Hoedemaekers C, Horn J, Nolan JP, Rossetti AO, Soar J. Prognostication in coma- tose survivors of cardiac arrest: an advisory statement from the European Resuscitation Council and the European Society of Intensive Care Medicine. Resuscitation. 2014;85:1779–1789. doi: 10.1016/j. resuscitation.2014.08.011.

114. Tiainen M, Kovala TT, Takkunen OS, Roine RO. Somatosensory and brainstem auditory evoked potentials in cardiac arrest patients treated with hypothermia. Crit Care Med. 2005;33:1736–1740.

115. Kottenberg-Assenmacher E, Armbruster W, Bornfeld N, Peters J. Hypothermia does not alter somatosensory evoked potential amplitude and global cerebral oxygen extraction during marked sodium nitroprus- side-induced arterial hypotension. Anesthesiology. 2003;98:1112–1118.

116. Greer D, Scripko P, Bartscher J, Sims J, Camargo E, Singhal A, Parides M, Furie K. Clinical MRI interpretation for outcome predic- tion in cardiac arrest. Neurocrit Care. 2012;17:240–244. doi: 10.1007/ s12028-012-9716-y.

117. Orioles A, Morrison WE, Rossano JW, Shore PM, Hasz RD, Martiner AC, Berg RA, Nadkarni VM. An under-recognized benefit of cardiopulmonary resuscitation: organ transplantation. Crit Care Med. 2013;41:2794–2799. doi: 10.1097/CCM.0b013e31829a7202.

118.

Matsumoto CS, Kaufman SS, Girlanda R, Little CM, Rekhtman Y, Raofi V, Laurin JM, Shetty K, Fennelly EM, Johnson LB, Fishbein TM. Utilization of donors who have suffered cardiopulmonary arrest and resuscitation in intestinal transplantation. Transplantation. 2008;86:941–946. doi: 10.1097/TP.0b013e3181852f9a.

119. Asher J, Navarro A, Watson J, Wilson C, Robson L, Gupta A, Gok M, Balupuri S, Shenton B, Del Rio Martin J, Sen B, Jaques B, Soomro N, Rix D, Manas D, Talbot D. Does donor cardiopulmonary resuscita- tion time affect outcome in uncontrolled non-heart-beating donor renal transplants? Transplant Proc. 2005;37:3264–3265. doi: 10.1016/j. transproceed.2005.09.006.

120. Reynolds JC, Rittenberger JC, Callaway CW; Post Cardiac Arrest Service. Patterns of organ donation among resuscitated patients at a regional cardiac arrest center. Resuscitation. 2014;85:248–252. doi: 10.1016/j. resuscitation.2013.11.001.

121. Adrie C, Haouache H, Saleh M, Memain N, Laurent I, Thuong M, Darques L, Guerrini P, Monchi M. An underrecognized source of organ donors: patients with brain death after successfully resuscitated cardiac arrest. Intensive Care Med. 2008;34:132–137.

122. Ali AA, Lim E, Thanikachalam M, Sudarshan C, White P, Parameshwar J, Dhital K, Large SR. Cardiac arrest in the organ donor does not negatively influence recipient survival after heart transplantation. Eur J Cardiothorac Surg. 2007;31:929–933.

123. Matsumoto CS, Kaufman SS, Girlanda R, Little CM, Rekhtman Y, Raofi V, Laurin JM, Shetty K, Fennelly EM, Johnson LB, Fishbein TM. Utilization of donors who have suffered cardiopulmonary arrest and resuscitation in intestinal transplantation. Transplantation. 2008;86:941–946.

124. Mercatello A, Roy P, Ng-Sing K, Choux C, Baude C, Garnier JL, Colpart JJ, Finaz J, Petit P, Moskovtchenko JF, et al. Organ transplants from out-of-hospital cardiac arrest patients. Transplant Proc. 1988;20:749–750.

125. Peberdy MA, Callaway CW, Neumar RW, Geocadin RG, Zimmerman JL, Donnino M, Gabrielli A, Silvers SM, Zaritsky AL, Merchant R, Vanden Hoek TL, Kronick SL; American Heart Association. Part 9: post-cardiac arrest care: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S768–S786. doi: 10.1161/ CIRCULATIONAHA.110.971002.

126. Bernat JL. Point: are donors after circulatory death really dead, and does it matter? Yes and yes. Chest. 2010;138:13–16. doi: 10.1378/chest.10-0649.

127. Bernat JL, Capron AM, Bleck TP, Blosser S, Bratton SL, Childress JF, DeVita MA, Fulda GJ, Gries CJ, Mathur M, Nakagawa TA, Rushton CH, Shemie SD, White DB. The circulatory-respiratory determination of death in organ donation. Crit Care Med. 2010;38:963–970. doi: 10.1097/ CCM.0b013e3181c58916.

128. Committee on Hospital Care SoS, Section on Critical C. Policy state- ment?pediatric organ donation and transplantation. Pediatrics. 2010;125:822–828.

129. Gries CJ, White DB, Truog RD, Dubois J, Cosio CC, Dhanani S, Chan KM, Corris P, Dark J, Fulda G, Glazier AK, Higgins R, Love R, Mason DP, Nakagawa TA, Shapiro R, Shemie S, Tracy MF, Travaline JM, Valapour M, West L, Zaas D, Halpern SD; American Thoracic Society Health Policy Committee. An official American Thoracic Society/International Society for Heart and Lung Transplantation/Society of Critical Care Medicine/ Association of Organ and Procurement Organizations/United Network of Organ Sharing Statement: ethical and policy considerations in organ dona- tion after circulatory determination of death. Am J Respir Crit Care Med. 2013;188:103–109. doi: 10.1164/rccm.201304-0714ST.

130. Hornby K, Hornby L, Shemie SD. A systematic review of autoresus- citation after cardiac arrest. Crit Care Med. 2010;38:1246–1253. doi: 10.1097/CCM.0b013e3181d8caaa.

131. Joffe AR, Carcillo J, Anton N, deCaen A, Han YY, Bell MJ, Maffei FA, Sullivan J, Thomas J, Garcia-Guerra G. Donation after cardiocircula- tory death: a call for a moratorium pending full public disclosure and fully informed consent. Philos Ethics Humanit Med. 2011;6:17. doi: 10.1186/1747-5341-6-17.

132. Nakagawa TA, Rigby MR, Bratton S, Shemie S, Ajizian SJ, Berkowitz I, Bowens CD, Cosio CC, Curley MA, Dhanani S, Dobyns E, Easterling L, Fortenberry JD, Helfaer MA, Kolovos NS, Koogler T, Lebovitz DJ, Michelson K, Morrison W, Naim MY, Needle J, Nelson B, Rotta AT, Rowin ME, Serrao K, Shore PM, Smith S, Thompson AE, Vohra A, Weise K. A call for full public disclosure for donation after circulatory deter- mination of death in children. Pediatr Crit Care Med. 2011;12:375–377; author reply 377. doi: 10.1097/PCC.0b013e31820ac30c.

133. Truog RD, Miller FG. Counterpoint: are donors after circulatory death really dead, and does it matter? No and not really. Chest. 2010;138:16–18; discussion 18. doi: 10.1378/chest.10-0657.

Part 4: Systems of Care and Continuous Quality Improvement

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

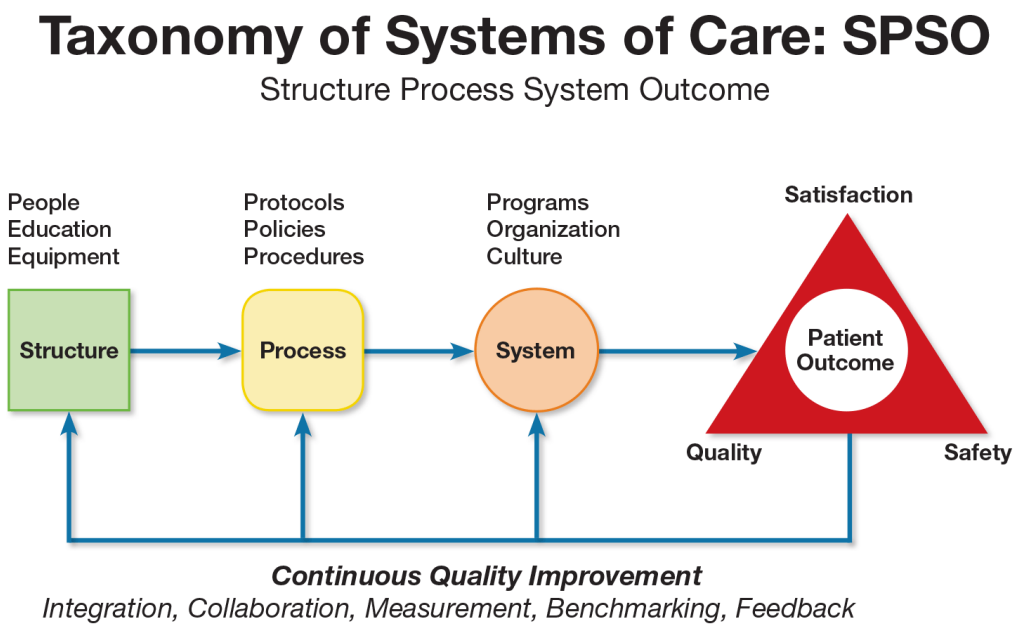
Key Words: cardiac arrest | cardiopulminary resuscitation | emergency | resuscitation

1 Highlights

The 2015 Guidelines Update provides stakeholders with a new perspective on systems of care, differentiating in-hospital cardiac arrests (IHCAs) from out-of-hospital cardiac arrests (OHCAs). Major highlights include

- A universal taxonomy of systems of care
- Separation of the AHA adult Chain of Survival into 2 chains: one for in-hospital and one for out-of-hospital systems of care
- Review of best evidence on how these cardiac arrest systems of care are reviewed, with a focus on cardiac arrest, ST-segment elevation myocardial infarction (STEMI), and stroke

Figure 1: Taxonomy of systems of care



Components of a System of Care

2015 (New): Universal elements of a system of care have been identified to provide stakeholders with a common framework with which to assemble an integrated resuscitation system (Figure 1).

Why: Healthcare delivery requires structure (eg, people, equipment, education) and process (eg, policies, protocols, procedures) that, when integrated, produce a system (e.g., programs, organizations, cultures) that leads to optimal outcomes (eg, patient survival and safety, quality, satisfaction). An effective system of care comprises all of these elements—structure, process, system, and patient outcomes—in a framework of continuous quality improvement.

Chains of Survival

2015 (New): Separate Chains of Survival (Figure 2) have been recommended that identify the different pathways of care for patients who experience cardiac arrest in the hospital as distinct from out-of-hospital settings.

Why: The care for all post–cardiac arrest patients, regardless of where their arrests occur, converges in the hospital, generally in an intensive care unit where post–cardiac arrest care is provided. The elements of structure and process that are required before that convergence are very different for the 2 settings. Patients who have an OHCA depend on their community for support. Lay rescuers must recognize the arrest, call for help, and initiate CPR and provide defibrillation (ie, public-access defibrillation [PAD]) until a team of professionally trained emergency medical service (EMS) providers assumes responsibility and then transports the patient to an emergency department and/or cardiac catheterization lab. The patient is ultimately transferred to a critical care unit for continued care. In contrast, patients who have an IHCA depend on a system of appropriate surveillance (eg, rapid response or early warning system) to prevent cardiac arrest. If cardiac arrest occurs, patients depend on the smooth interaction of the institution's various departments and services and on a multidisciplinary team of professional providers, including physicians, nurses, respiratory therapists, and others.

Figure 2: System-specific Chains of Survival

Use of Social Media to Summon Rescuers

2015 (New): It may be reasonable for communities to incorporate social media technologies that summon rescuers who are in close proximity to a victim of suspected OHCA and are willing and able to perform CPR.

Why: There is limited evidence to support the use of social media by dispatchers to notify potential rescuers of a possible cardiac arrest nearby, and activation of social media has not been shown to improve survival from OHCA. However, in a recent study in Sweden, there was a significant increase in the rate of bystander-initiated CPR when a mobile-phone dispatch system was used. Given the low harm and the potential benefit, as well as the ubiquitous presence of digital devices, municipalities could consider incorporating these technologies into their OHCA systems of care.

Team Resuscitation: Early Warning Sign Systems, Rapid Response Teams, and Medical Emergency Team Systems

2015 (Updated): For adult patients, rapid response team (RRT) or medical emergency team (MET) systems can be effective in reducing the incidence of cardiac arrest, particularly in the general care wards. Pediatric MET/RRT systems may be considered in facilities where children with high-risk illnesses are cared for in general in-patient units. The use of early warning sign systems may be considered for adults and children.

2010 (Old): Although conflicting evidence exists, expert consensus recommended the systematic identification of patients at risk of cardiac arrest, an organized response to such patients, and an evaluation of outcomes to foster continuous quality improvement.

Why: RRTs or METs were established to provide early intervention for patients with clinical deterioration, with the goal of preventing IHCA. Teams can be composed of varying combinations of physicians, nurses, and respiratory therapists. These teams are usually summoned to a patient bedside when acute deterioration is identified by hospital staff. The team typically brings emergency monitoring and resuscitation equipment and drugs. Although the evidence is still evolving, there is face validity in the concept of having teams trained in the complex choreography of resuscitation.

Continuous Quality Improvement for Resuscitation Programs

2015 (Reaffirmation of 2010): Resuscitation systems should establish ongoing assessment and improvement of systems of care.

Why: There is evidence of considerable regional variation in the reported incidence and outcome of cardiac arrest in the United States. This variation underscores the need for communities and systems to accurately identify each occurrence of treated cardiac arrest and to record outcomes. There are likely to be opportunities to improve survival rates in many communities.

Community- and hospital-based resuscitation programs should systematically monitor cardiac arrests, the level of resuscitation care provided, and outcome. Continuous quality improvement includes systematic evaluation and feedback, measurement or benchmarking, and analysis. Continuous efforts are needed to optimize resuscitation care so that the gaps between ideal and actual resuscitation performance can be narrowed.

Regionalization of Care

2015 (Reaffirmation of 2010): A regionalized approach to OHCA resuscitation that includes the use of cardiac resuscitation centers may be considered.

Why: A cardiac resuscitation center is a hospital that provides evidence-based care in resuscitation and post–cardiac arrest care, including 24-hour, 7-day percutaneous coronary intervention (PCI) capability, TTM with an adequate annual volume of cases, and commitment to ongoing performance improvement that includes measurement, benchmarking, and both feedback and process change. It is hoped that resuscitation systems of care will achieve the improved survival rates that followed establishment of other systems of care, such as trauma.

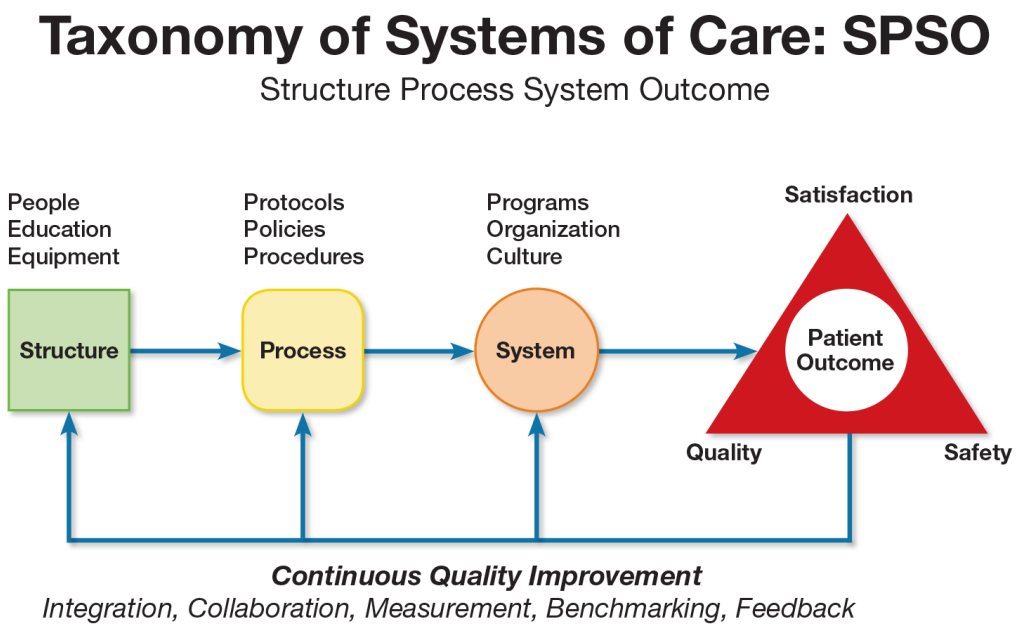
2 Introduction

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

The science and recommendations discussed in the other Parts of the *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation* (CPR) *and Emergency Cardiovascular Care* (ECC) form the backbone of resuscitation. They answer the “why”, “what,” and “when” of performing resuscitation steps. In a perfectly controlled and predictable environment, such as a laboratory setting, those answers often suffice, but the “how” of actual implementation depends on knowing the “who” and “where” as well. The ideal work flow to accomplish resuscitation successfully is highly dependent on the system of care as a whole.

Healthcare delivery requires structure (eg, people, equipment, education, prospective registry data collection) and process (eg, policies, protocols, procedures), which, when integrated, produce a system (eg, programs, organizations, cultures) leading to outcomes (eg, patient safety, quality, satisfaction). An effective system of care **(Figure 1)** comprises all of these elements—structure, process, system, and patient outcomes—in a framework of continuous quality improvement (CQI).

Figure 1: Taxonomy of systems of care



In this Part, we will focus on 2 distinct systems of care: the system for patients who arrest inside the hospital and the one for those who arrest outside it. We will set into context the building blocks for a system of care for cardiac arrest, with consideration of the setting, team, and available resources, as well as CQI from the moment the patient becomes unstable until after the patient is discharged.

The chain of survival metaphor, first used almost 25 years ago,[1] is still very relevant. However, it may be helpful to create 2 separate chains **(Figure 2)** to reflect the differences in the steps needed for response to cardiac arrest in the hospital (in-hospital cardiac arrest [IHCA]) and out of the hospital (out of hospital cardiac arrest [OHCA]). Regardless of where an arrest occurs, the care following resuscitation converges in the hospital, generally in an emergency department (ED) or intensive care unit (ICU). This post?cardiac arrest care is depicted as the final link in both chains, symbolized by a hospital bed with a monitor and thermometer, which represent advanced monitoring and targeted temperature management. As noted above, the structure and process elements before the convergence of the 2 chains, however, vary significantly.

Figure 2: System-specific Chains of Survival

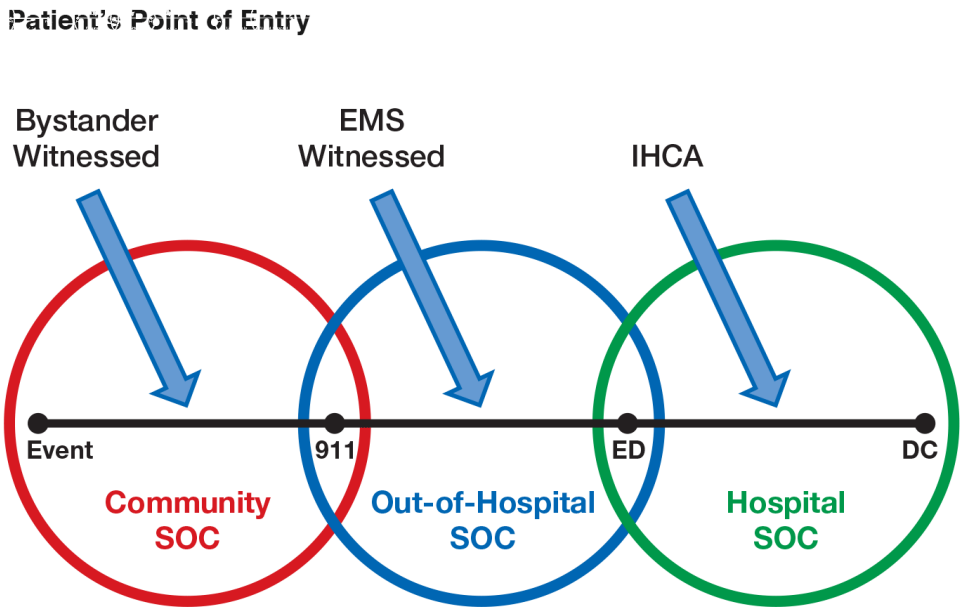
Patients with OHCA depend on elements within the community for support. Lay rescuers must recognize the patient's arrest, call for help, and initiate CPR and early defibrillation (public-access defibrillation [PAD]) until a team of professionally trained emergency medical services (EMS) providers assumes responsibility and then transports the patient to an ED and/or cardiac catheterization lab, and then on to an ICU for post?cardiac arrest care. Ideally, all victims of OHCA receive bystander CPR and defibrillation; if not, CPR and defibrillation won't occur until EMS personnel arrive, and the victim's chance of survival is then much lower.

In contrast, patients with IHCA depend on a system of appropriate surveillance and prevention of cardiac arrest, which is represented by a magnifying glass in the first link. When cardiac arrest occurs, prompt notification and response to a cardiac arrest should result in the smooth interaction of a multidisciplinary team of professional providers, including physicians, nurses, respiratory therapists, and others. This team provides high-quality CPR, prompt defibrillation, and advanced cardiovascular life support when appropriate. The chain metaphor endures: in any resuscitation, the chain is no stronger than its weakest link.

The level of complexity is high for both in-hospital and out-of-hospital systems. The challenges encountered, however, are different. Teamwork and coordination among responders is a critical determinant of patient outcomes. An in-hospital multidisciplinary team has immediate access to additional personnel as well as all the resources of the ED, ICU, and laboratories, whereas in out-of-hospital settings,[2] paramedics may find themselves alone with no resources except those they brought with them. Factors such as crowd control, family presence, space constraints, transportation, and device failures can be common to both settings. In both settings, systems must be in place to address expected and unexpected challenges and must be continually monitored and re-examined to address their flaws and failures.

The classic resuscitation Chain of Survival concept linked the community to EMS and EMS to hospitals, with hospital care as the destination. [1] But patients with a cardiac emergency may enter the system of care at one of many different points **(Figure 3)**.

Figure 3: Patient's point of entry



A cardiac arrest can present anywhere, any time—on the street or at home, but also in the hospital's ED, inpatient bed, ICU, operating suite, catheterization suite, or imaging department. The system of care must be able to manage cardiac emergencies wherever they occur.

The concept of a system of care has been applied previously in emergency care, including regional systems of care for trauma, stroke, and ST-segment elevation myocardial infarction (STEMI). This Part addresses the idea that IHCA has similarities to, but is very different from,

OHCA. It also considers how the elements of a system of care apply to the comprehensive management of cardiac arrest.

3 In-Hospital Cardiac Arrest

3.1 Epidemiology

IHCA is a major patient safety and public health concern. Approximately 209 000 adults[2] and more than 6000 children[3] receive CPR for IHCAs in the United States annually. In contrast to adult OHCAs, which are mostly due to presumed cardiac etiologies and occur unexpectedly, most IHCAs are secondary to presumed acute respiratory compromise and/ or circulatory shock, with predictable progressive deterioration before the event.[4-6] Although CPR training programs have tended to focus on out-of-hospital CPR, professional in-hospital CPR is provided to similar numbers of adults and children each year as professional out-of-hospital CPR, and the patient characteristics, rescuers, and systems of care are quite different.

Outcomes from in-hospital CPR have improved over the past 10 to 15 years within hospitals participating in the AHA's Get With The Guidelines®-Resuscitation program. For adults, there has been improvement, with risk-adjusted rates of survival to discharge increased by 4% per year, from 13.7% in 2000 to 22.3% in 2009.[5] Importantly, more than 80% of these adult IHCA survivors had relatively favorable neurologic outcomes, with Cerebral Performance Category (CPC) scores of 1 or 2 at hospital discharge.5 For children, risk-adjusted rates of survival to discharge increased by 8% per year from 2000 to 2009, with unadjusted survival rates increasing from 14.3% to 39.4%.[6]

Notably, case-mix–adjusted IHCA incidence rates and survival rates vary considerably across hospitals. For example, case-mix–adjusted incidence of adult cardiac arrest was twice as high in the bottom quartile of Get

With The GuidelinesResuscitation hospitals compared with the top quartile (1.3/1000 bed-days versus 0.7/1000 bed-days).[7] Conversely, the case-mix–adjusted rates of survival to discharge were nearly double in the top decile of Get With The GuidelinesResuscitation hospitals compared with the bottom decile (22.7% versus 12.4%).[8] These data also showed a 42% greater likelihood of patients with identical covariates surviving to hospital discharge at one randomly selected Get With The Guidelines-Resuscitation hospital compared with another.8 Similarly, the range of risk-standardized survival rates for pediatric cardiac arrest varied from 29% to 48%.[9] These variabilities in incidences and outcomes suggest that more cardiac arrests can be prevented and that survival rates can be improved through effective quality improvement strategies.

Other IHCA data raise concerns about potential deficiencies in our systems for treatment of IHCAs in the United States. As with other medical issues, survival rates from IHCAs are substantially lower on nights and weekends compared with weekdays,[10] which suggests differential quality within hospitals by both time and day. In addition, lower-income patients and African-American patients have lower survival rates after an IHCA.[7,11] After controlling for the hospital site where the cardiac arrest occurred, the disparity was essentially ameliorated, which suggests differential quality across hospitals.[11]

Because most IHCAs are secondary to respiratory failure and/or circulatory shock, quality improvement efforts with rapid response teams and medical emergency teams have focused on early recognition of respiratory failure, shock, and neurologic deterioration of patients at risk, with targeted interventions and transfers to highly monitored intensive care settings. Perhaps as a result of such efforts, cardiac arrests and CPR on general wards are much less common than cardiac arrests and CPR in ICUs and other highly monitored units, such as the ED, operating suites, and cardiac catheterization suites. Only 5% of pediatric in-hospital CPR occurred on general wards in Get With The Guidelines-Resuscitation hospitals from 2000 to 2010, compared with 74% in ICUs, 10% in the ED, 5% in the operating suite, and 6% in a procedural suite, such as interventional radiology or cardiac catheterization suites. In addition, the relative frequency of ward CPR decreased substantially over that decade.[12] Similarly, 19% of adult CPR was provided on unmonitored wards, 16% in telemetry, 48% in ICUs units, and 18% in EDs or operating or procedural suites.[13] These data suggest that most in-hospital CPR is provided in ICUs, EDs, operating rooms, and other procedural units where teams and systems can be optimized to provide the highest level of care.

3.2 Prearrest Rapid Response Systems

3.2.1 Recognition EIT 638 PEDS 818

The wide variability in incidence and location of cardiac arrest in the hospital suggests potential areas for standardization of quality and prevention of at least some cardiac arrests. More than half of cardiac arrests in the hospital are the result of respiratory failure or hypovolemic shock, and the majority of these events are foreshadowed by changes in physiology, such as tachypnea, tachycardia, and hypotension. As such, cardiac arrest in the hospital often represents the progression of physiologic instability and a failure to identify and stabilize the patient in a timely manner. This scenario is more common on the general wards, outside of critical care and procedural areas, where patient-to-nurse ratios are higher and monitoring of patients less intense. In this setting, intermittent manual vital sign monitoring with less frequent direct observation by clinicians may increase the likelihood of delayed recognition. An observational study of both surgical and medical wards reported that approximately 1 in 5 patients developed abnormal vital signs, and more than 50% of these events went unnoticed by nursing staff. Patients with abnormal vital signs had a threefold higher 30-day mortality rate.[14]

Strategies to combat delayed recognition of patient deterioration include increased electronic monitoring of high-risk patients in the form of traditional electrocardiogram (ECG)-based telemetry, newer heart and respiratory rate sensors, or increased clinician surveillance. In addition, composite risk scores, such as the Modified Early Warning Score (MEWS) and more complex, statistically derived algorithms, which can include laboratory data, increase the discrimination for detection compared with single-parameter criteria.

3.2.2 Early Warning Sign Systems, Rapid Response Teams, and Medical Emergency Team Systems - Updated

Rapid response teams (RRTs) or medical emergency teams (METs) were established for early intervention in patients whose conditions were deteriorating, with the goal of preventing IHCA.[15,16] They can be composed of varying combinations of physicians, nurses, and respiratory therapists. These teams are usually summoned to patient bedsides when an acute deterioration is recognized by other hospital staff. Monitoring and resuscitation equipment and drug therapies often accompany the team. The 2015 ILCOR systematic review addressed the use of early warning sign systems (EWSS), RRTs, and METs in children and adults.

The evidence for EWSS was demonstrated in 1 before-after study by using an aggregated weighted scoring system (MEWS), which reported significantly higher cardiac arrest rates in MEWS bands 3 and 4 after intervention but not in MEWS bands 0 through 2 or 5 through 15; however, overall cardiac arrest rate significance was not reported.[17] The evidence for RRTs or METs in adults consists of a wardrandomized trial[18] and numerous observational studies. The introduction of a MET system was associated with a significant improvement in hospital survival[19-33] and a decrease in the incidence of IHCA.[19-29,31,33-40] A cluster-randomized trial and several other observational studies failed to confirm those results.[17,34,36,39,41-51]

The evidence for RRTs or METs and the usefulness of a Pediatric Early Warning System (PEWS) in children is observational but contradictory, and it is not as consistent in showing a decrease in either the incidence of cardiac and/or respiratory arrest outside of the ICU setting [52-54] or hospital mortality [53,55-59] for either PEWS or a MET. However, in a single observational study, PEWS use was associated with a reduction in cardiac arrest rate when used in a single hospital with an established MET system.[60]

3.2.3 2015 Recommendations - Modified

For adult patients, RRT or MET systems can be effective in reducing the incidence of cardiac arrest, particularly in general care wards. (Class IIa, LOE C-LD)

Pediatric MET/RRT systems may be considered in facilities where children with high-risk illnesses are cared for on general in-patient units. (Class IIb, LOE C-LD)

The use of EWSS may be considered for adults and children. (Class IIb, LOE C-LD)

3.2.4 Continuous Assessment

Once patients with acute decompensation or gradual deterioration are recognized and cared for by RRTs, these patients require continuous assessments until stabilized. Patients who are recognized to be at high risk of IHCA or who are refractory to early interventions are generally transferred to high-acuity hospital units (eg, ICUs). With more personnel and resources available (eg, technology, drug therapies), these high-acuity units enable improved monitoring and treatments. Further, there is increasing data indicating that delays in transfer to an ICU are associated with increased mortality. In 1 study, every hour of delay was associated with a 1.5% increase in hospital mortality.[61] Interestingly, the pediatric community of providers has had remarkable success in nearly eradicating cardiac arrest on the general wards and could serve as a model for the adult community. The focus on prevention has been emphasized for pediatrics, as evidenced by the 1998 departure from the traditional Chain of Survival to one that included prevention as a first link in the chain. Pediatric resuscitation experts also led this change in hospitals, and pediatric arrests that occur on general care wards are becoming a thing of the past.

3.2.5 Do Not Attempt Resuscitation and Palliative Care

One of the unintended consequences of the success in developing and promoting modern resuscitation is that, currently, many people who are in the natural process of dying receive CPR at the end of life. Resuscitation has become the default expectation for everyone and, unless specifically noted to the contrary as with an advanced directive or a Do Not Attempt Resuscitation (DNAR) order, is likely to be performed, at least for witnessed deaths. As such, another proposed mechanism for the decrease in cardiac arrest rates associated with RRTs is increased use of palliative care services and DNAR orders for patients who are dying and for whom resuscitation attempts are likely to be futile or inconsistent with their goals of care. Once a patient has a cardiac arrest, institution of a DNAR order to prevent further resuscitation attempts is frequently entertained. However, many of

these patients may have been appropriate for consideration of such an order before the arrest, and failure to properly consider it could result in an unwanted aggressive end to life and a waste of considerable resources. As such, it is consistent with a system of care to seek patient or family preferences regarding aggressive resuscitation measures, such as CPR and mechanical ventilation, in patients with advanced age or terminal condition and short life expectancy who are admitted to a hospital, and to issue a DNAR order based on patient or family preference as well as expectation of outcome, taking into account the clinical judgment of experienced providers.

3.3 Cardiac Arrest

Even in high-risk, in-hospital environments, cardiac arrests and CPR are relatively uncommon, and the members of the resuscitation teams may be different with each cardiac arrest. Therefore, optimal performance depends on rigorous preevent interdisciplinary collaborative planning and practice. Excellent outcomes can occur after well-choreographed, highquality CPR with effective chest compressions, ventilation and early defibrillation.[62] Hospital leaders have the opportunity to optimize outcomes with rigorous resuscitation programs that include the cycle of quality improvement: measurement of performance and outcomes, comparison, interventions to improve outcomes, and continuous measurement of performance and outcomes after interventions.

3.4 Activating the IHCA System of Care

Once IHCA is recognized, hospitals are expected to have a standardized method for promptly notifying and activating a team that specializes in treating cardiac arrest. A survey of hospitals revealed that 93% used a hospital-wide public address system, 53% paged or called team members, and 11% used a local alarm.[63]

3.5 Crisis Resource Management Principles for Resuscitation Teams

The quality of bedside resuscitation team leadership affects team performance.[64-68] Crisis resource management principles suggest that resuscitation teams will function best when the team knows who is leading the resuscitation efforts, what their individual roles are, and how to communicate and work together most effectively.[69,70] Crisis resource management techniques that have been incorporated for use during inhospital CPR efforts include training to be an advanced life support team leader, using checklists for leadership activities, standardizing communication, and performing cross-checks for safety of team members before defibrillation (eg, “all clear”).[70-74]

3.6 Resuscitation Team

Crisis resource management principles suggest that preparation for cardiac arrests and resuscitations include a designated, dedicated resuscitation team available 24 hours a day, 7 days a week, with adequate experience, expertise, and training and retraining to maintain skills, minimize errors, and optimize outcomes.[71,75-77] Although 77% of hospitals from a survey of US hospitals have a predesignated resuscitation team, nearly one quarter do not. Such teams usually consist of varying combinations of physicians, nurses, respiratory therapists, and pharmacists.[63] Some centers include security personnel, clergy, social workers, and others. Furthermore, just-in-time, just-in-place training is an excellent manner for the team members to practice so that they can be prepared to use the equipment and work with their colleagues in their own practice setting.[75] Just-in-time or just-in-place training ranges from activities as simple as training on a manikin in basic life support and the use of a defibrillator[78-80] to interdisciplinary advanced life support at a simulation room embedded in the clinical unit. Hospitals with training programs may require that resuscitation teams include an attending physician with resuscitation experience and expertise to supervise the physician in training on the resuscitation team during the resuscitation.

3.7 Training

Few studies have evaluated training programs that improve the early identification of prearrest patients. A longitudinal, multicenter study of the Acute Life-Threatening Events Recognition and Treatment (ALERT) course suggested an increase in prearrest calls, a reduction in the number of IHCAs, and an improved survival-to-discharge rate after IHCA.[81] After the initial training, interval training updates are necessary to maintain these important skills. Recognition of patient deterioration is an element of an IHCA system of care, with physicians, nurses, and staff being able to recognize that deterioration.

Standard advanced cardiovascular life support or pediatric advanced life support courses may not adequately train providers with specific processes unique to individual hospitals. Hospital-specific resuscitation training can

be contextualized for the individual wards and hospital settings to increase familiarity and effectiveness of the resuscitation team and responses to cardiac arrest.

3.8 Debriefing - Updated EIT 645

Acute debriefing for either an individual or the team immediately after the resuscitation event (“hot debriefing”) has been a time-honored approach to improve care and has been previously recommended in AHA Guidelines for CPR and ECC.[75] However, finding the time to do this properly in the highly intense and sometimes chaotic postarrest setting is problematic when practitioners are focused on postarrest care and/or communicating time-sensitive and emotionally sensitive information to families and staff. These acute postarrest debriefings may address several domains, including psychomotor skill issues, cognitive issues, team issues, family emotional issues, and professional staff emotional issues.

Another approach to debriefing an individual or the team is to communicate about the various domains at a later time (“cold debriefing”). The advantages of cold debriefing are adequate time for the debriefing personnel to prepare for optimal communication, availability of experienced debriefing personnel, and adequate time for the debriefing communication session to meet and discuss the resuscitation. However, it is often difficult to reconvene the same resuscitation team members at a later meeting.

Alternatively, cold debriefing can include both the resuscitation team that was present at the event and the broader multidisciplinary team of the entire unit so that all can learn from both their own and others’ experiences. This allows many more unit members to profit from the experience, and it can result in quality improvement in the unit-wide resuscitation culture. The 2015 ILCOR systematic review examined the utility of briefing and/or debriefing to determine if there was an impact on outcome.

3.8.1 2015 Evidence Review

Data from 2 in-hospital observational before-after studies, 1 in adults[82] and 1 in pediatrics[83] that involved a total 318 patients and 2494 epochs of chest compressions, demonstrated improved outcomes (eg, favorable neurologic outcome at discharge and compression depth, compression rate within target range) after implementation of a data-driven, performance-focused debriefing program for resuscitation team members using CPR-quality defibrillator transcripts.

3.8.2 2015 Treatment Recommendation - Updated

It is reasonable for in-hospital systems of care to implement performance-focused debriefing of rescuers after IHCA in both adults and children. (Class IIa, LOE C-LD)

3.9 Post–Cardiac Arrest

Patients who achieve return of spontaneous circulation (ROSC) after cardiac arrest in any setting have a complex combination of pathophysiologic processes described as post–cardiac arrest syndrome, which includes postarrest brain injury, postarrest myocardial dysfunction, systemic ischemia/ reperfusion response, and persistent acute and chronic pathology that may have precipitated the cardiac arrest.[84] Post–cardiac arrest syndrome plays a significant role in patient mortality. Survival rates in IHCA patients who achieve ROSC range from 32% to 54%.[85] Higher-volume hospitals and teaching hospitals have the highest survival rate, with an average survival of 38% for patients who have an arrest outside the ICU and 32% for patients who have an arrest in the ICU.[4]

Comprehensive post–cardiac arrest care requires optimization of hemodynamics, treatment and reversal of precipitating factors, and targeted temperature management and is discussed fully in “Part 8: Post–Cardiac Arrest Care.” Routine implementation of existing post–cardiac arrest protocols and order sets helps maintain consistent and optimal care to attenuate the detrimental effects of post–cardiac arrest syndrome. These patients also require access to a collaborative and multidisciplinary team of providers, including cardiologists, interventional cardiologists, cardiac electrophysiologists, intensivists, neurologists, nurses, respiratory therapists, and social workers. If these services are not readily available within the hospital, an effective system of care would include appropriate structures and processes for interhospital transfer to ensure access to these collaborative resources.

4 Out-of-Hospital Cardiac Arrest

4.1 Introduction

OHCA affects approximately 326 000 victims annually in the United States.[2] Given that OHCA has an annual incidence of 132/100 000 population, communities of all sizes should prepare a system of care for the eventual OHCA event.[2] Organized community programs that prepare the lay public to provide bystander CPR and early defibrillation offer the best opportunity for successful resuscitation in the initial minutes after OHCA and represent the community link in the OHCA Chain of Survival. This preparation begins with a surveillance system to measure the incidence and outcomes of OHCA. The AHA Scientific Statement "Essential Features of Designating Out-of-Hospital Cardiac Arrest as a Reportable Event"[86] makes recommendations to achieve the measurement of this public health burden as well as capture the data points needed to address quality improvements for continuous improvement in outcomes from OHCA.

4.2 Community

Bystander CPR is a potentially lifesaving procedure that can be performed by community members without equipment or professional credentials. Although bystander CPR plus early defibrillation can more than double the rate of survival from OHCA,[87] the number of OHCA victims who receive bystander CPR remains between 10% and 65%.[2] Recent evidence suggests that chest compression–only CPR is no less effective than traditional CPR when performed by bystanders for adult victims of cardiac arrest in the out-of-hospital setting.[87] CPR training can be accomplished via traditional classes or brief self-instruction media, public policy initiatives such as CPR training as a high school graduation requirement, training of likely rescuers (primarily family members and caregivers of populations at high risk for cardiac arrest), or mass community CPR training in large public venues. CPR training programs can help build a culture of expectation for chest compressions to be performed in whatever setting cardiac arrest occurs.

Further opportunities to provide community CPR training can coincide with the implementation of PAD initiatives. PAD programs provide bystanders with automatic electronic defibrillators (AEDs) that can be used by the lay public to deliver shocks to victims of ventricular fibrillation OHCA.

4.3 Public-Access Defibrillation - Updated BLS 347

The 2015 ILCOR systematic review compared the implementation of a PAD program with traditional EMS response to determine if there was an impact on outcome from OHCA.

4.3.1 2015 Evidence Review

The ILCOR Basic Life Support Task Force reviewed the evidence involving PAD and its effect on outcome from OHCA. This evidence is derived from many observational studies and 1 randomized controlled trial[88] with associated variations in rates of witnessed arrests, EMS programs, and recommended practice of bystander CPR.[89,90] Evidence from 3 observational studies[91-93] that enrolled 182 119 patients demonstrated improved survival to 30 days with favorable neurologic outcome with PAD compared with no community program. Improved clinical outcomes favoring PAD programs were seen consistently across the studies.[89,90] Some studies included in the *ILCOR 2015 International Consensus on CPR and ECC Science With Treatment Recommendations*[90,89] may involve repeat analysis and reporting of the same cardiac arrest population, which limits the ability to provide a summative effect measure in the reported analyses.

4.3.2 2015 Recommendation - Modified

It is recommended that PAD programs for patients with OHCA be implemented in communities with individuals at risk for OHCA. (Class I, LOE C-LD)

A system-of-care approach for OHCA might include public policy that encourages reporting of public AED locations to public service access points (PSAPs; PSAPs have replaced the less-precise term "EMS dispatch centers"). Such a policy would enable PSAPs to direct bystanders to retrieve nearby AEDs and assist in their use when OHCA occurs.

Many municipalities as well as the US federal government have enacted legislation to place AEDs in municipal buildings, large public venues, airports, casinos, and schools. For the 20% of OHCAs that occur in public, these community programs represent an important link in the Chain of Survival between recognition and activation of the emergency response system.

Victims of OHCAs that occur in private residences are much less likely to receive chest compressions than are victims who experience cardiac arrest in public settings. Real-time instructions provided by emergency dispatchers may help push in-home callers past the stress or fear that may be inhibiting their willingness to act. These improved outcomes can be achieved by having robust community CPR training programs for cardiac arrest in place in conjunction with effec- tive, prearrival dispatch protocols.

4.4 Emergency Medical Services BLS 740 BLS 359

PSAPs are the interface between EMS and the communities they serve. While individuals may be unsure of what to do in the setting of a cardiac arrest, the general population knows to call 9-1-1. Herein lies the opportunity to leverage the call for help into strategies for the initiation of early treatment as part of a larger system of care. Communities are best served by PSAPs that are designed to quickly recognize the occurrence of cardiac arrest, dispatch the nearest appropriate resources, and help bystanders provide immediate care before the arrival of EMS.

The link between the call for help to the PSAP and arrival of first medical care is the emergency dispatcher. In disease states that are time dependent, such as cardiac arrest, acute coronary syndrome (ACS), stroke, and trauma, recognition of symptoms and initiation of intervention can result in improved outcomes. In cardiac arrest, dispatcher-guided CPR has been extensively described.[94,95] In these descriptive studies, dispatcher-guided CPR has been shown to reduce time to first compression.

4.5 Dispatcher Recognition of Cardiac Arrest - Updated

The 2015 ILCOR systematic review addressed whether there are descriptions of any specific symptoms among adults and children who are in cardiac arrest outside a hospital compared with no description that helped emergency dispatchers identify cardiac arrest. Appropriate recognition of a patient in cardiac arrest is an important component of the discussion between a dispatcher and the bystanders with a cardiac arrest victim. This identification can lead to initiation of dispatcher-guided CPR and provide valuable information to EMS providers.

4.5.1 2015 Evidence Review

Evidence is derived from observational investigations that involve more than 17 000 patients from 27 different studies. In 2 studies that evaluated emergency dispatcher recognition alone, the sensitivity of recognition ranged from 18% to 83%.[96,97] In systems that currently have protocols to aid dispatchers in the recognition of cardiac arrest, the sensitivity when using protocols ranged from 38% to 96.9%, with a specificity exceeding 99%. Use of these scripted protocols has been shown to increase the rate of dispatcher-guided CPR.[98-100] The identification of abnormal breathing or agonal gasps is particularly important in the recognition of cardiac arrest by emergency dispatchers. This abnormal pattern is described by a wide range of heterogeneous words and phrases: difficulty breathing, poorly breathing, impaired breathing, occasional breathing, barely/hardly breathing, heavy breathing, labored breathing, sighing, and strange breathing.[96,101] The presence of agonal gasps is a factor that negatively affects the identification of cardiac arrest. One study reported agonal gasps were present in 50% of cardiac arrests that were not identified.[99] Training of emergency dispatchers in the recognition of agonal gasps has been associated with increased dispatcher-guided CPR.[102,103]

4.5.2 2015 Recommendations - Updated

It is recommended that emergency dispatchers determine if a patient is unconscious with abnormal breathing after acquiring the requisite information to determine the location of the event.
(Class I, LOE C-LD)

If the patient is unconscious with abnormal or absent breathing, it is reasonable for the emergency dispatcher to assume that the patient is in cardiac arrest. (Class IIa, LOE C-LD)

Dispatchers should be educated to identify unconsciousness with abnormal and agonal gasps across a range of clinical presentations and descriptions. (Class I, LOE C-LD)

There are limited data regarding the use of emergency dispatchers to appropriately identify patients with myocardial infarction. Using a protocol-driven approach, emergency dispatchers have been able to instruct patients with symptoms to self-administer aspirin, but there has not been a study that showed this improved outcomes.[104] However, in a system of care, identification by emergency dispatchers of symptoms that suggest a myocardial infarction may assist in the triage of these patients by EMS personnel and result in rapid transport to hospitals with adequate resources. In stroke patients, there is also evidence for reduced time from scene to hospital,[105] and identification of stroke symptoms by emergency dispatchers and prehospital providers is consistent with a system of care for the appropriate triage of stroke patients within that system of care.

4.6 Dispatcher Instruction in CPR - Updated

It has been hypothesized that dispatcher-initiated CPR instruction will improve outcomes, and the ILCOR systematic review sought to identify evidence of improved outcomes. Dispatcher-initiated CPR instruction has become integrated into many systems of care and viewed as an important link between the community and the EMS system.

4.6.1 2015 Evidence Review - Updated

Evidence related to this question was assessed in several studies (1 meta-analysis, 3 randomized clinical trials, and 11 observational studies). There was no statistical benefit in survival with favorable neurologic outcome at the time of hospital discharge to 1 year.[103,106-108] A meta-analysis showed an absolute survival benefit of 2.4% (95% confidence interval, 0.1%–4.9%) with the use of dispatcher instructions for continuous compressions over traditional CPR.[109] There is no evidence, however, to show that dispatcher instructions were associated with ROSC.[99,106] When the use of dispatcher instructions on CPR parameters was evaluated, dispatcher-guided CPR with bystander CPR initiation increased performance of chest compressions and ventilation.[107,110] There is no evidence that dispatcher-guided CPR decreases time to commence CPR.[98,100,103,111,112]

4.6.2 2015 Recommendation - Updated

We recommend that dispatchers should provide chest compression-only CPR instructions to callers for adults with suspected OHCA. (Class I, LOE C-LD)

4.7 Use of Social Media to Summon Rescuers - Updated EIT 878

Summoning rescuers to the scene of an OHCA may lead to initiation of CPR or defibrillation before the arrival of dispatched EMS providers. In a few localities, a system of care has been evaluated that includes emergency dispatcher activation of social media to summon nearby willing rescuers to provide bystander CPR until EMS providers arrive. The 2015 ILCOR systematic review addressed whether EMS dispatchers summoning rescuers with the use of technology or other social media improves patient outcomes.

4.7.1 2015 Evidence Review

Two case series examined the use of computer-generated phone calls and text messages sent to lay responders within 500 or 1000 meters of patients with suspected cardiac arrest. In one study, lay responders arrived first in 44.6% of episodes,[113] while in the second study, time to first shock was improved.[114] In a randomized trial, social media was used by dispatchers to notify nearby potential rescuers of a possible cardiac arrest. Although few patients ultimately received CPR from volunteers dispatched by the notification system, there was a higher rate of bystander-initiated CPR (62% vs 48% in control group).[115]

4.7.2 2015 Recommendation - New

Given the low risk of harm and the potential benefit of such notifications, it may be reasonable for communities to incorporate, where available, social media technologies that summon rescuers who are willing and able to perform CPR and are in close proximity to a suspected victim of OHCA.
(Class IIb, LOE B-R)

4.8 EMS and Transition to the Hospital

High-performance EMS is a key component of the OHCA system of care. An EMS culture of excellence reinforces itself through CQI, whereby successful OHCA resuscitations are considered the norm rather than the exception. Focused CQI review, supported by comprehensive data collection, seeks to evaluate what went right and what went wrong during the resuscitation and apply lessons learned to future resuscitation efforts.

4.9 OHCA Quality Metrics

Continuous efforts to improve resuscitation outcomes are impossible without data capture. The collection of resuscitation process measures is the underpinning of a system of care's quality improvement efforts. The ILCOR Consensus Statement "Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest"[116] includes recommendations for cardiac arrest data collection based on updated and simplified Utstein templates. The core Utstein data set capture is recommended as the minimum data required for CQI. These data form the data set for CPR registries at all levels. In addition, supplementary data are essential for further resuscitation research. Examples of supplementary data would be 12-lead ECG and CPR quality measurement—interventions available in some prehospital settings but not all.

High-performance EMS responders understand that high-quality CPR is the foundation on which all of their resuscitation efforts depend. Furthermore, when CPR quality is measured, responders strive to perform the highest quality of CPR. Actual CPR performance improves when providers know that their performance is being measured–the well-known Hawthorne effect. Chest compression fraction (the percent of total resuscitation time spent compressing the chest), chest compression quality (rate, depth, and chest recoil), and ventilation rate are fundamental metrics defining high-quality CPR. CPR quality measurement is needed to provide timely feedback to the responding providers.

Advanced life support (ALS) bridges the transition from OHCA care to the receiving facility. ALS can provide the OHCA patient with advanced cardiac monitoring, 12-lead ECG, additional defibrillation and cardioversion interventions, vascular access, appropriate pharmacologic interventions, and advanced airway care. This same broad scope of practice for ALS providers can be further leveraged to provide comprehensive postresuscitation care (eg, hemodynamic optimization, oxygen- and volume-limiting ventilation) once ROSC is achieved.

4.10 ACS and STEMI Systems of Care

A systems-of-care approach to STEMI encompasses a well-organized approach with system-wide integration that includes primary prevention and recognition, EMS, ED, in-hospital, specialty cardiac center, rehabilitation, and secondary prevention community resources. This approach has all of the required elements and characteristics of a system of care. The STEMI system of care starts with rapid identification by EMS providers in the field. The goal for the EMS system is early identification, initial management, and transport to an appropriate facility for definitive care.

The system begins with the community recognizing the signs of a potential ACS and calling 9-1-1 early. Approximately 40% to 60% of STEMI patients call 9-1-1, and the remaining patients present directly to the hospital.[117,118] Given the risk of sudden cardiac arrest in these patients, improving the rate of calling 9-1-1 is a clear goal. The dispatchers may provide prearrival advice (eg, early aspirin administration). On scene, the paramedics will assess quickly; perform a prehospital 12-lead ECG; and administer aspirin, nitrates, and other medications. Prompt identification of STEMI is the key that allows consideration of the method of reperfusion: prehospital fibrinolysis, notification of the hospital for early in-hospital fibrinolysis, and/or specific hospital destination with notification of the catheterization team for primary percutaneous coronary intervention (PPCI). Interpretation of the prehospital ECG is critical to the process. The methods to interpret that ECG, which are consistent with a system of care, are reviewed in "Part 9: Acute Coronary Syndromes."

Prehospital fibrinolysis requires a system including provider expertise, well-established protocols, comprehensive

training programs, medical oversight, and quality assurance. Not all systems may be able to support such a program. Similarly, PPCI requires an infrastructure of high-volume local or regional cardiac catheterization facilities and experienced providers. Thus, the decision regarding prehospital fibrinolysis, in-hospital fibrinolysis, or transport directly to a PPCI center is determined by the local system's resources.

The cardiac arrest and STEMI systems of care are linked in that a disproportionally high number of patients with ACS and STEMI also have sudden cardiac arrest. A key part of the postarrest management is consideration of patient evaluation in the catheterization laboratory. To achieve prompt recognition and treatment of ACS, the 2 systems of care—out of hospital care and in-hospital care—must be integrated.

4.11 Transport to Specialized Cardiac Arrest Centers EIT 624

The 2015 ILCOR systematic review addressed whether transport of OHCA patients by EMS directly to a specialist cardiac arrest center improves outcomes.

A cardiac resuscitation center is a hospital that provides evidence-based practice in resuscitation and post?cardiac arrest care, including 24-hour, 7-day PCI capability; targeted temperature management, cardiorespiratory and systems support with an adequate annual volume of cases; and commitment to ongoing performance improvement that includes measurement, benchmarking, and both feedback and process change.

4.11.1 2015 Evidence Review - Updated

Only 1 prospective study[119] compared survival outcomes in OHCA patients who were transported to a critical care medical center with those who were transported to a noncritical care hospital, while 20 observational studies performed comparisons of patient destination based on differences in hospital characteristics,[85,120-127] transport times,[128-132] or before-and-after implementation of regionalized systems of care.[133-138] These studies, reporting on more than 120 000 patients surviving to hospital discharge, suggest an association between improved survival (or neurologically intact survival when reported) and patient transport to specialist cardiac arrest centers.

4.11.2 2015 Recommendation

A regionalized approach to OHCA resuscitation that includes the use of cardiac resuscitation centers may be considered. (Class IIb, LOE C-LD)

5 Continuous Quality Improvement

Over the past 15 years, we have seen considerable improvements in the number of survivors from both IHCA and OHCA. These improvements have been associated with increased focus and attention in areas such as increasing bystander CPR, improving CPR quality, early defibrillation and optimizing rapid response systems and post?cardiac arrest care. The wide variability in survival that remains across systems, however, highlights the success that individual high-performing systems have accomplished and pushes the envelope on what is possible.

Certain qualities of a system of care make it effective and lead to desired outcomes. Whether it spans organizations or is located within 1 unit, systems benefit from conscious pursuit of clarity, focus, discipline, and engagement.[139] Successful systems of care in both the in-hospital and out-of-hospital settings engage in CQI. There are numerous approaches to quality improvement that have been used across industries, but all of them share several key concepts, including goal setting, a process-centric focus, measurement, and accountability.

5.1 Goal Setting

It is difficult to be successful without first defining what success is. And the definition of success, or the goal, has to be defined specifically enough that a person and/or system can be held accountable to it. For most quality improvement goals, that means specifying both the quantity of change expected and the date by which that change is to be completed. For example, the AHA ECC 2020 Impact Goals include doubling survival from cardiac arrests between 2010 and 2020 from 19% to 38% in hospitalized adults and from 7.9% to 15% for all out-of hospital arrests. The goals also set a target of doubling bystander CPR rates from 31% to 62% and increasing survival from cardiac arrests from 35% to 50% in hospitalized children.[140] These highly specific goals enable evaluation of the current survival and bystander CPR rates in the context of both the progress made and work

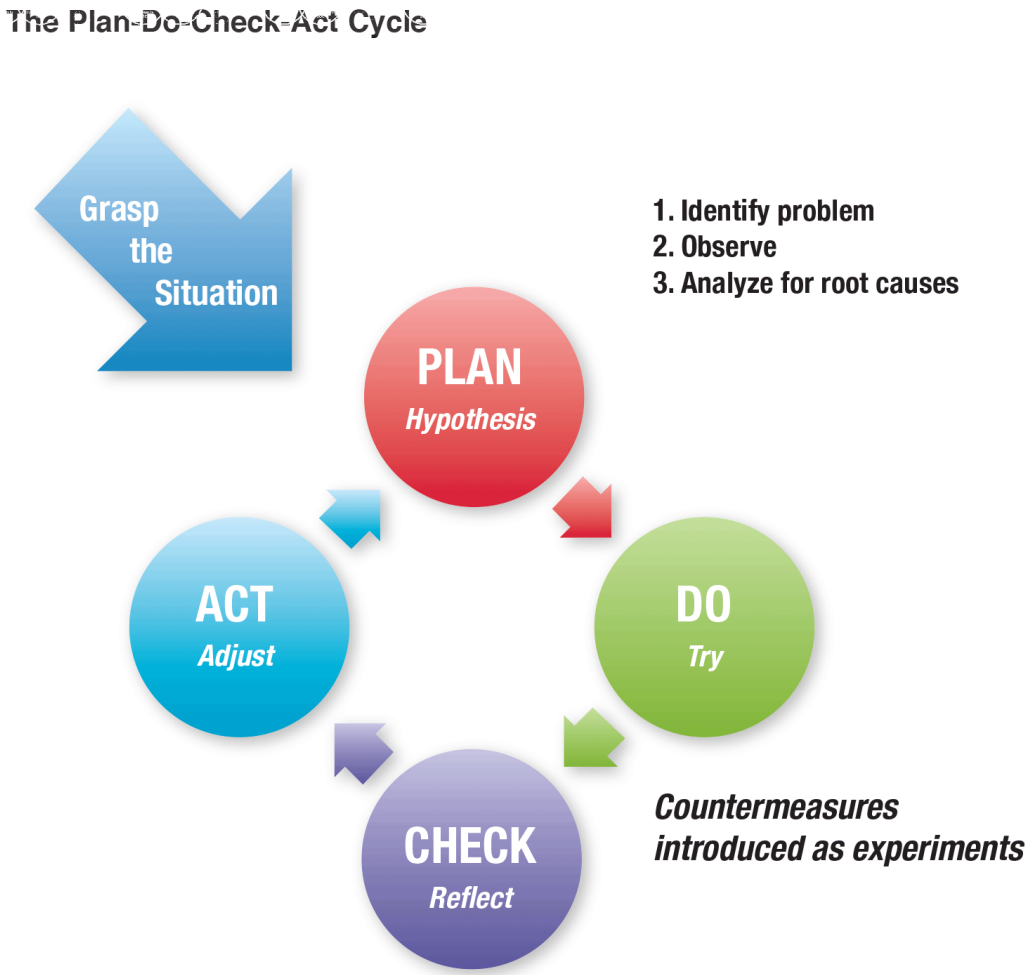
needed to achieve the stated goals by 2020.

Individual systems of care need to define their own goals based on their assessment of what the most important outcomes are. In their book, *The 4 Disciplines of Execution* (4DX), McChesney and colleagues termed these the "wildly important goals," or WIGs, and cautioned against focusing on more than 1 or 2 at a time to ensure success.[141] Subsystems can, in turn, focus on 1 to 2 WIGs in pursuit of system-wide WIGs. An example of a WIG is the ECC Systems of Care Subcommittee's including doubling of the number of states with CPR/AED training as a high school graduation requirement, a metric the advocacy committee has been working hard to achieve. Individual EMS systems may target the percentage of 9-1-1 calls for cardiac arrest with dispatcher instructions, enabling the caller to start CPR within 1 minute. Hospitals, in pursuit of the ultimate goal of decreasing cardiac arrest on the general wards, might target the number of RRT calls made for patients with physiologic evidence of deterioration. The key is that these process-oriented measures, or lead measures, as they are referred to in 4DX language, are in a system's control to modify and are the ones most expected to move the needle on the outcome metric of interest. The 4DX principle is to focus on the "wildly important" (but lagging) goals while acting on the leading measures.

5.2 Effecting Change

Those responsible for improving a resuscitation system can choose from a number of scientific problem-solving models to achieve continuous improvement (eg, Lean, Six Sigma, Total Quality Management, Plan-Do-Check-Act or Adjust, Plan-Do-Study-Act). While each has its own language and approach (eg, Lean, the continuous transformation of waste into customer value by workers; Six Sigma, the continuous decrease of variation; and PDCA, the iterative process of continuous small improvements; (Figure 4), each uses data to drive the process improvement.

Figure 4: The Plan-Do-Check-Act cycle



The framework used is not as important as an agreed-upon method and language and an established process whereby improvements are made after direct observation and analysis of root causes, with changes piloted as experiments, ideally by the workers who propose them. This drive—to improve continually a complex system's performance to meet its goal—characterizes the best systems, sometimes described as complex adaptive systems. The individuals and leaders in the system continually assess processes, form hypotheses, design possible improvements, run experiments, check results, and reflect—and then start again.[142]

5.2.1 Measurement

Goal setting and effecting change are data-driven processes. As such, they are dependent on regular and accurate measurement of the process and outcome variables. Candidate measures have been defined in Utstein guidelines and AHA consensus statements for the benefit of generalizability and to enable comparisons across systems, but they are not consistently used. Registries such as Get With The Guidelines-Resuscitation and the Cardiac Arrest Registry to Enhance Survival exist for this purpose as well, but they currently represent only a small fraction of existing hospitals and EMS systems.[143-145] Significant improvement in arrest outcomes depends on collection, analysis, feedback, and interventions based on data and observations. This includes measuring structure, process, and outcomes of the steps involved in the resuscitation system of care. Only once these data are routinely collected will it be possible to continuously evaluate and improve what is done.

5.2.2 Accountability

For data to be useful, it has to be fed back to the team and used to assess progress toward the goal. That

requires people to be accountable to that data for making the next round of changes. In the OHCA system of care, such stakeholders should come equally from the community, the EMS and the hospital systems of care. In the hospital, candidates for accountability include resuscitation team members; CPR committee members; and senior executives, including the chief quality, nursing, or medical officer. In the United Kingdom, every hospital is required to have a resuscitation officer for oversight of the IHCA program at that facility. The resuscitation officer's responsibilities include ensuring appropriate and timely recognition of cardiac arrest, effective and timely interventions, and the necessary processes and training to optimize outcome. Strong leadership is considered a necessary component for a highly performing enterprise. In light of the number of IHCAs, the variability of IHCA incidences and outcomes, and the potential to save more lives, perhaps it is time for US hospitals to have resuscitation officers with appropriate authority, responsibility, resources, and accountability to lead hospital resuscitation programs.

6 Conclusion

Using a systems-of-care approach as well as a rigorous process for CQI that is based on data can lead to improvements in the process for managing patients with cardiac arrest and improving their outcomes. We have learned a lot from high-performing systems and have made considerable progress over the past decade. But the current variability in survival from cardiac arrest shows that both IHCA and OHCA systems have the potential for substantial improvement. Continued improvement in the processes of managing patients before, during, and after cardiac arrest will require intense focus on consistent, clear goals aimed at decreasing incidence of and improving survival from cardiac arrest. Change will depend on engaged team members willing to be accountable for seeing those goals to fruition while actively working on improving process. And all of these aspects will demand high-quality data measurement, feedback, and comparison.

7 Authorship and Disclosures

7.1 2015 Writing Team

Steven L. Kronick, Chair; Michael C. Kurz; Steve Lin; Dana P. Edelson; Robert A. Berg; John E. Billi; Jose G. Cabanas; David C. Cone; Deborah B. Diercks; James K. Foster; Reylon A. Meeks; Andrew H. Travers; Michelle Welsford

Table 1: 2015 - Part 4: Systems of Care and Continuous Quality Improvement: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 4: Systems of Care and Continuous Quality Improvement: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Steven L. Kronick	University of Michigan	None	None	None	None	None	None	None
Robert A. Berg	Children's Hospital of Philadelphia	None	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
John E. Billi	The University of Michigan Medical School	None	None	None	None	None	None	None
Jose G. Cabanas	City of Austin	None	None	None	None	None	None	None
David C. Cone	Yale University School of Medicine	None	None	None	None	None	None	None
Deborah B. Diercks	University of California Davis Medical Center	Astra Zeneca*; PCORI*	None	None	None	None	None	Society of Cardiovascular Patient Care*
Dana P. Edelson	University of Chicago	American Heart Association/Laerdal Medical†; NIH†	None	None	None	QuantHC†; Patent Pending ARCD. P0535US.P2†	None	None
James (Jim) Foster	University of Alaska	None	None	None	None	None	None	None
Michael C. Kurz	University of Alabama at Birmingham	NIH†; RPS*	None	Zoll Medical Corporation*	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Steve Lin	Li Ka Shing Knowledge Institute of St. Michael's Hospital	Canadian Institutes None of Health Research†; Academic Health Sciences Centre (AHSC) Alternative Funding Plan Innovation Fund†; Physicians' Services Incorporated (PSI) Foundation† Canadian Association of Emergency Physicians*	None	None	None	None	None	None
Reylon A. Meeks	Blank Children's Hospital	None	None	None	None	None	None	None
Michelle Welsford	Centre for Paramedic Education and Research, Hamilton Health Sciences Centre	None	None	None	None	None	None	None
Consultant								
Andrew H. Travers	Emergency Health Services, Nova Scotia	None	None	None	None	None	American Heart Association†	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/Advis Board	Other

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

8 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 4: Systems of Care and Continuous Quality Improvement. ECCguidelines.heart.org.

References

1. Ringh M, Rosenqvist M, Hollenberg J, et al. Mobile-phone dispatch of laypersons for CPR in out-of-hospital cardiac arrest. *N Engl J Med.* 2015;372(24):2316-2325.

2. Cummins RO, Ornato JP, Thies WH, Pepe PE. Improving survival from sudden cardiac arrest: the "chain of survival" concept. A statement for health professionals from the Advanced Cardiac Life Support Subcommittee and the Emergency Cardiac Care Committee, American Heart Association. Circulation. 1991;83:1832–1847.

3. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, de Ferranti S, Després JP, Fullerton HJ, Howard VJ, Huffman MD, Judd SE, Kissela BM, Lackland DT, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Matchar DB, McGuire DK, Mohler ER 3rd, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G, Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Willey JZ, Woo D, Yeh RW, Turner MB; on behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2015 update: a report from the American Heart Association. Circulation. 2015;131:e29–e322. doi: 10.1161/CIR.0000000000000152.

4. Knudson JD, Neish SR, Cabrera AG, Lowry AW, Shamszad P, Morales DL, Graves DE, Williams EA, Rossano JW. Prevalence and outcomes of pediatric in-hospital cardiopulmonary resuscitation in the United States: an analysis of the Kids' Inpatient Database. Crit Care Med. 2012;40: 2940–2944. doi: 10.1097/CCM.0b013e31825feb3f.

5. Nadkarni VM, Larkin GL, Peberdy MA, Carey SM, Kaye W, Mancini ME, Nichol G, Lane-Truitt T, Potts J, Ornato JP, Berg RA; National Registry of Cardiopulmonary Resuscitation Investigators. First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. JAMA. 2006;295:50–57. doi: 10.1001/jama.295.1.50.

6. Girotra S, Nallamothu BK, Spertus JA, Li Y, Krumholz HM, Chan PS; American Heart Association Get with the Guidelines–Resuscitation Investigators. Trends in survival after in-hospital cardiac arrest. N Engl J Med. 2012;367:1912–1920. doi: 10.1056/NEJMoa1109148.

7. Girotra S, Spertus JA, Li Y, Berg RA, Nadkarni VM, Chan PS; American Heart Association Get With The Guidelines–Resuscitation Investigators. Survival trends in pediatric in-hospital cardiac arrests: an analysis from Get With The Guidelines-Resuscitation. Circ Cardiovasc Qual Outcomes. 2013;6:42–49. doi: 10.1161/CIRCOUTCOMES.112.967968.

8. Merchant RM, Yang L, Becker LB, Berg RA, Nadkarni V, Nichol G, Carr BG, Mitra N, Bradley SM, Abella BS, Groeneveld PW; American Heart Association Get With the Guideline-Resuscitation Investigators. Variability in case-mix adjusted in-hospital cardiac arrest rates. Med Care. 2012;50:124–130. doi: 10.1097/MLR.0b013e31822d5d17.

9. Merchant FM, Jones P, Wehrenberg S, Lloyd MS, Saxon LA. Incidence of defibrillator shocks after elective generator exchange following uneventful first battery life. J Am Heart Assoc. 2014;3:e001289. doi: 10.1161/ JAHA.114.001289.

10. Jayaram N, Spertus JA, Nadkarni V, Berg RA, Tang F, Raymond T, Guerguerian AM, Chan PS; American Heart Association's Get with the Guidelines-Resuscitation Investigators. Hospital variation in survival after pediatric in-hospital cardiac arrest. Circ Cardiovasc Qual Outcomes. 2014;7:517–523. doi: 10.1161/CIRCOUTCOMES.113.000691.

11. Peberdy MA, Ornato JP, Larkin GL, Braithwaite RS, Kashner TM, Carey SM, Meaney PA, Cen L, Nadkarni VM, Praestgaard AH, Berg RA; National Registry of Cardiopulmonary Resuscitation Investigators. Survival from in-hospital cardiac arrest during nights and weekends. JAMA. 2008;299:785–792. doi: 10.1001/jama.299.7.785.

12. Chan PS, Nichol G, Krumholz HM, Spertus JA, Jones PG, Peterson ED, Rathore SS, Nallamothu BK; American Heart Association National Registry of Cardiopulmonary Resuscitation (NRCPR) Investigators. Racial differences in survival after in-hospital cardiac arrest. JAMA. 2009;302:1195–1201. doi: 10.1001/jama.2009.1340.

13. Berg RA, Sutton RM, Holubkov R, Nicholson CE, Dean JM, Harrison R, Heidemann S, Meert K, Newth C, Moler F, Pollack M, Dalton H, Doctor A, Wessel D, Berger J, Shanley T, Carcillo J, Nadkarni VM; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network and for the American Heart Association's Get With The Guidelines- Resuscitation (formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Ratio of PICU versus ward cardiopulmonary resuscitation events is increasing. Crit Care Med. 2013;41:2292–2297. doi: 10.1097/CCM.0b013e31828cf0c0.

14. Girotra S, Cram P, Spertus JA, Nallamothu BK, Li Y, Jones PG, Chan PS; American Heart Association's Get With the Guidelines®-Resuscitation Investigators. Hospital variation in survival trends for in- hospital cardiac arrest. J Am Heart Assoc. 2014;3:e000871. doi: 10.1161/ JAHA.114.000871.

15. Fuhrmann L, Lippert A, Perner A, Østergaard D. Incidence, staff awareness and mortality of patients at risk on general wards. Resuscitation. 2008;77:325–330. doi: 10.1016/j.resuscitation.2008.01.009.

16. Peberdy MA, Cretikos M, Abella BS, DeVita M, Goldhill D, Kloeck W, Kronick SL, Morrison LJ, Nadkarni VM, Nichol G, Nolan JP, Parr M, Tibballs J, van der Jagt EW, Young L. Recommended guidelines for monitoring, reporting, and conducting research on medical emergency team, outreach, and rapid response systems: an Utstein-style scientific statement: a scientific statement from the International Liaison Committee on Resuscitation (American Heart Association, Australian Resuscitation Council, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, and the New Zealand Resuscitation Council); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiopulmonary, Perioperative, and Critical Care; and the Interdisciplinary Working Group on Quality of Care and Outcomes Research. Circulation. 2007;116:2481–2500. doi: 10.1161/ CIRCULATIONAHA.107.186227.

17. Devita MA, Bellomo R, Hillman K, Kellum J, Rotondi A, Teres D, Auerbach A, Chen WJ, Duncan K, Kenward G, Bell M, Buist M, Chen J, Bion J, Kirby A, Lighthall G, Ovreveit J, Braithwaite RS, Gosbee J, Milbrandt E, Peberdy M, Savitz L, Young L, Harvey M, Galhotra S. Findings of the first consensus conference on medical emergency teams. Crit Care Med. 2006;34:2463–2478. doi: 10.1097/01.CCM.0000235743.38172.6E.

18. Subbe CP, Davies RG, Williams E, Rutherford P, Gemmell L. Effect of introducing the Modified Early Warning score on clinical outcomes, cardio-pulmonary arrests and intensive care utilisation in acute medical admissions. Anaesthesia. 2003;58:797–802.

19. Priestley G, Watson W, Rashidian A, Mozley C, Russell D, Wilson J, Cope J, Hart D, Kay D, Cowley K, Pateraki J. Introducing Critical Care Outreach: a ward-randomised trial of phased introduction in a gen- eral hospital. Intensive Care Med. 2004;30:1398–1404. doi: 10.1007/ s00134-004-2268-7.

20. Al-Qahtani S, Al-Dorzi HM, Tamim HM, Hussain S, Fong L, Taher S, Al-Knawy BA, Arabi Y. Impact of an intensivist-led multidisciplinary extended rapid response team on hospital-wide cardiopulmonary arrests and mortality. Crit Care Med. 2013;41:506–517. doi: 10.1097/ CCM.0b013e318271440b.

21. Bellomo R, Goldsmith D, Uchino S, Buckmaster J, Hart GK, Opdam H, Silvester W, Doolan L, Gutteridge G. A prospective before-and-after trial of a medical emergency team. Med J Aust. 2003;179:283–287.

22. Buist MD, Moore GE, Bernard SA, Waxman BP, Anderson JN, Nguyen TV. Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: preliminary study. BMJ. 2002;324:387–390.

23. Laurens N, Dwyer T. The impact of medical emergency teams on ICU admission rates, cardiopulmonary arrests and mortality in a regional hospital. Resuscitation. 2011;82:707–712. doi: 10.1016/j. resuscitation.2010.11.031.

24. Moon A, Cosgrove JF, Lea D, Fairs A, Cressey DM. An eight year audit before and after the introduction of modified early warning score (MEWS) charts, of patients admitted to a tertiary referral intensive care unit after CPR. Resuscitation. 2011;82:150–154. doi: 10.1016/j.resuscitation.2010.09.480.

25. Sabahi M, Fanaei SA, Ziaee SA, Falsafi FS. Efficacy of a rapid response team on reducing the incidence and mortality of unexpected cardiac arrests. Trauma Mon. 2012;17:270–274. doi: 10.5812/traumamon.4170.

26. Dacey MJ, Mirza ER, Wilcox V, Doherty M, Mello J, Boyer A, Gates J, Brothers T, Baute R. The effect of a rapid response team on major clinical outcome measures in a community hospital. Crit Care Med. 2007;35:2076–2082.

27. Sarani B, Palilonis E, Sonnad S, Bergey M, Sims C, Pascual JL, Schweickert W. Clinical emergencies and outcomes in patients admitted to a surgical versus medical service. Resuscitation. 2011;82:415–418. doi: 10.1016/j.resuscitation.2010.12.005.

28. Beitler JR, Link N, Bails DB, Hurdle K, Chong DH. Reduction in hospital-wide mortality after implementation of a rapid response team: a long- term cohort study. Crit Care. 2011;15:R269. doi: 10.1186/cc10547.

29. Konrad D, Jäderling G, Bell M, Granath F, Ekbom A, Martling CR. Reducing in-hospital cardiac arrests and hospital mortality by introducing a medical emergency team. Intensive Care Med. 2010;36:100–106. doi: 10.1007/s00134-009-1634-x.

30. Chan PS, Khalid A, Longmore LS, Berg RA, Kosiborod M, Spertus JA. Hospital-wide code rates and mortality before and after implementation of a rapid response team. JAMA. 2008;300:2506–2513. doi: 10.1001/ jama.2008.715.

31. Bristow PJ, Hillman KM, Chey T, Daffurn K, Jacques TC, Norman SL, Bishop GF, Simmons EG. Rates of in-hospital arrests, deaths and intensive care admissions: the effect of a medical emergency team. Med J Aust. 2000;173:236–240.

32. Lighthall GK, Parast LM, Rapoport L, Wagner TH. Introduction of a rapid response system at a United States veterans affairs hospital reduced cardiac arrests. Anesth Analg. 2010;111:679–686. doi: 10.1213/ ANE.0b013e3181e9c3f3.

33. Howell MD, Ngo L, Folcarelli P, Yang J, Mottley L, Marcantonio ER, Sands KE, Moorman D, Aronson MD. Sustained effectiveness of a primary-team-based rapid response system. Crit Care Med. 2012;40:2562– 2568. doi: 10.1097/CCM.0b013e318259007b.

34. Santamaria J, Tobin A, Holmes J. Changing cardiac arrest and hospital mortality rates through a medical emergency team takes time and constant review. Crit Care Med. 2010;38:445–450. doi: 10.1097/ CCM.0b013e3181cb0ff1.

35. Baxter AD, Cardinal P, Hooper J, Patel R. Medical emergency teams at The Ottawa Hospital: the first two years. Can J Anaesth. 2008;55:223– 231. doi: 10.1007/BF03021506.

36. Benson L, Mitchell C, Link M, Carlson G, Fisher J. Using an advanced practice nursing model for a rapid response team. Jt Comm J Qual Patient Saf. 2008;34:743–747.

37. Campello G, Granja C, Carvalho F, Dias C, Azevedo LF, Costa-Pereira A. Immediate and long-term impact of medical emergency teams on cardiac arrest prevalence and mortality: a plea for periodic basic life-support training programs. Crit Care Med. 2009;37:3054–3061. doi: 10.1097/ CCM.0b013e3181b02183.

38. Offner PJ, Heit J, Roberts R. Implementation of a rapid response team decreases cardiac arrest outside of the intensive care unit. J Trauma. 2007;62:1223–1227; discussion 1227. doi: 10.1097/ TA.0b013e31804d4968.

39. Moldenhauer K, Sabel A, Chu ES, Mehler PS. Clinical triggers: an alternative to a rapid response team. Jt Comm J Qual Patient Saf. 2009;35:164–174.

40. Rothberg MB, Belforti R, Fitzgerald J, Friderici J, Keyes M. Four years' experience with a hospitalist-led medical emergency team: an interrupted time series. J Hosp Med. 2012;7:98–103. doi: 10.1002/jhm.953.

41. DeVita MA, Braithwaite RS, Mahidhara R, Stuart S, Foraida M, Simmons RL; Medical Emergency Response Improvement Team (MERIT). Use of medical emergency team responses to reduce hospital cardiopulmonary arrests. Qual Saf Health Care. 2004;13:251–254. doi: 10.1136/ qhc.13.4.251.

42. Hayani O, Al-Beihany A, Zarychanski R, Chou A, Kharaba A, Baxter A, Patel R, Allan DS. Impact of critical care outreach on hematopoietic stem cell transplant recipients: a cohort study. Bone Marrow Transplant. 2011;46:1138–1144. doi: 10.1038/bmt.2010.248.

43. Jones S, Mullally M, Ingleby S, Buist M, Bailey M, Eddleston JM. Bedside electronic capture of clinical observations and automated clinical alerts to improve compliance with an Early Warning Score protocol. Crit Care Resusc. 2011;13:83–88.

44. Kenward G, Castle N, Hodgetts T, Shaikh L. Evaluation of a medical emergency team one year after implementation. Resuscitation. 2004;61: 257–263. doi: 10.1016/j.resuscitation.2004.01.021.

45. Lim SY, Park SY, Park HK, Kim M, Park HY, Lee B, Lee JH, Jung EJ, Jeon K, Park CM, Ko MG, Park MR, Nam JM, Won SY, Jung JH, Cho SH, Suh GY. Early impact of medical emergency team implementation in a country with limited medical resources: a before-and-after study. J Crit Care. 2011;26:373–378. doi: 10.1016/j.jcrc.2010.08.019.

46. Patel MS, Jones MA, Jiggins M, Williams SC. Does the use of a "track and trigger" warning system reduce mortality in trauma patients? Injury. 2011;42:1455–1459. doi: 10.1016/j.injury.2011.05.030.

47. Scherr K, Wilson DM, Wagner J, Haughian M. Evaluating a new rapid response team: NP-led versus intensivist-led comparisons. AACN Adv Crit Care. 2012;23:32–42. doi: 10.1097/NCI.0b013e318240e2f9.

48. Shah SK, Cardenas VJ Jr, Kuo YF, Sharma G. Rapid response team in an academic institution: does it make a difference? Chest. 2011;139: 1361–1367. doi: 10.1378/chest.10-0556.

49. Simmes FM, Schoonhoven L, Mintjes J, Fikkers BG, van der Hoeven JG. Incidence of cardiac arrests and unexpected deaths in surgical patients before and after implementation of a rapid response system. Ann Intensive Care. 2012;2:20. doi: 10.1186/2110-5820-2-20.

50. Snyder CW, Patel RD, Roberson EP, Hawn MT. Unplanned intubation after surgery: risk factors, prognosis, and medical emergency team effects. Am Surg. 2009;75:834–838.

51. Vazquez R, Gheorghe C, Grigoriyan A, Palvinskaya T, Amoateng- Adjepong Y, Manthous CA. Enhanced end-of-life care associated with deploying a rapid response team: a pilot study. J Hosp Med. 2009;4:449– 452. doi: 10.1002/jhm.451.

52. Rothschild JM, Woolf S, Finn KM, Friedberg MW, Lemay C, Furbush KA, Williams DH, Bates DW. A controlled trial of a rapid response system in an academic medical center. Jt Comm J Qual Patient Saf. 2008;34: 417–425, 365.

53. Hunt EA, Zimmer KP, Rinke ML, Shilkofski NA, Matlin C, Garger C, Dickson C, Miller MR. Transition from a traditional code team to a medical emergency team and categorization of cardiopulmonary arrests in a children's center. Arch Pediatr Adolesc Med. 2008;162:117–122. doi: 10.1001/archpediatrics.2007.33.

54. Sharek PJ, Parast LM, Leong K, Coombs J, Earnest K, Sullivan J, Frankel LR, Roth SJ. Effect of a rapid response team on hospital-wide mortality and code rates outside the ICU in a Children's Hospital. JAMA. 2007;298:2267–2274. doi: 10.1001/jama.298.19.2267.

55. Anwar-ul-Haque, Saleem AF, Zaidi S, Haider SR. Experience of pediatric rapid response team in a tertiary care hospital in Pakistan. Indian J Pediatr. 2010;77:273–276. doi: 10.1007/s12098-010-0032-2.

56. Kotsakis A, Lobos AT, Parshuram C, Gilleland J, Gaiteiro R, Mohseni- Bod H, Singh R, Bohn D; Ontario Pediatric Critical Care Response Team Collaborative. Implementation of a multicenter rapid response system in pediatric academic hospitals is effective. Pediatrics. 2011;128:72–78. doi: 10.1542/peds.2010-0756.

57. Hanson CC, Randolph GD, Erickson JA, Mayer CM, Bruckel JT, Harris BD, Willis TS. A reduction in cardiac arrests and duration of clinical instability after implementation of a paediatric rapid response system. Postgrad Med J. 2010;86:314–318. doi: 10.1136/qshc.2007.026054.

58. Zenker P, Schlesinger A, Hauck M, Spencer S, Hellmich T, Finkelstein M, Thygeson MV, Billman G. Implementation and impact of a rapid response team in a children's hospital. Jt Comm J Qual Patient Saf. 2007;33:418–425.

59. Brilli RJ, Gibson R, Luria JW, Wheeler TA, Shaw J, Linam M, Kheir J, McLain P, Lingsch T, Hall-Haering A, McBride M. Implementation of a medical emergency team in a large pediatric teaching hospital prevents respiratory and cardiopulmonary arrests outside the intensive care unit. Pediatr Crit Care Med. 2007;8:236–246; quiz 247. doi: 10.1097/01. PCC.0000262947.72442.EA.

60. Tibballs J, Kinney S. Reduction of hospital mortality and of preventable cardiac arrest and death on introduction of a pediatric medical emergency team. Pediatr Crit Care Med. 2009;10:306–312. doi: 10.1097/ PCC.0b013e318198b02c.

61. Randhawa S, Roberts-Turner R, Woronick K, DuVal J. Implementing and sustaining evidence-based nursing practice to reduce pediatric cardiopulmonary arrest. West J Nurs Res. 2011;33:443–456. doi: 10.1177/0193945910379585.

62. Cardoso LT, Grion CM, Matsuo T, Anami EH, Kauss IA, Seko L, Bonametti AM. Impact of delayed admission to intensive care units on mortality of critically ill patients: a cohort study. Crit Care. 2011;15:R28. doi: 10.1186/cc9975.

63. Meaney PA, Bobrow BJ, Mancini ME, Christenson J, de Caen AR, Bhanji F, Abella BS, Kleinman ME, Edelson DP, Berg RA, Aufderheide TP, Menon V, Leary M; CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Cardiopulmonary resuscitation quality: [corrected] improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. Circulation. 2013;128:417–435. doi: 10.1161/ CIR.0b013e31829d8654.

64. Edelson DP, Yuen TC, Mancini ME, Davis DP, Hunt EA, Miller JA, Abella BS. Hospital cardiac arrest resuscitation practice in the United States: a nationally representative survey. J Hosp Med. 2014;9:353–357. doi: 10.1002/jhm.2174.

65. Mancini ME, Soar J, Bhanji F, Billi JE, Dennett J, Finn J, Ma MH, Perkins GD, Rodgers DL, Hazinski MF, Jacobs I, Morley PT; on behalf of the Education, Implementation, and Teams Chapter Collaborators. Part 12: education, implementation, and teams: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122(suppl 2):S539–S581. doi: 10.1161/CIRCULATIONAHA.110.971143.

66. Soar J, Mancini ME, Bhanji F, Billi JE, Dennett J, Finn J, Ma MH, Perkins GD, Rodgers DL, Hazinski MF, Jacobs I, Morley PT; Education, Implementation, and Teams Chapter Collaborators. Part 12: education, implementation, and teams: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e288–e330. doi: 10.1016/j.resuscitation.2010.08.030.

67. Hunziker S, Johansson AC, Tschan F, Semmer NK, Rock L, Howell MD, Marsch S. Teamwork and leadership in cardiopulmonary resuscitation. J Am Coll Cardiol. 2011;57:2381–2388. doi: 10.1016/j. jacc.2011.03.017.

68. Hunziker S, Bühlmann C, Tschan F, Balestra G, Legeret C, Schumacher C, Semmer NK, Hunziker P, Marsch S. Brief leadership instructions improve cardiopulmonary resuscitation in a high-fidelity simulation: a randomized controlled trial. Crit Care Med. 2010;38:1086–1091. doi: 10.1097/CCM.0b013e3181cf7383.

69. Ten Eyck RP, Tews M, Ballester JM, Hamilton GC. Improved fourth-year medical student clinical decision-making performance as a resuscitation team leader after a simulation-based curriculum. Simul Healthc. 2010;5:139–145. doi: 10.1097/SIH.0b013e3181cca544.

70. Fernandez Castelao E, Russo SG, Cremer S, Strack M, Kaminski L, Eich C, Timmermann A, Boos M. Positive impact of crisis resource management training on no-flow time and team member verbalisations during simulated cardiopulmonary resuscitation: a randomised controlled trial. Resuscitation. 2011;82:1338–1343. doi: 10.1016/j. resuscitation.2011.05.009.

71. Ornato JP, Peberdy MA. Applying lessons from commercial aviation safety and operations to resuscitation. Resuscitation. 2014;85:173–176. doi: 10.1016/j.resuscitation.2013.10.029.

72. Neumar RW, Otto CW, Link MS, Kronick SL, Shuster M, Callaway CW, Kudenchuk PJ, Ornato JP, McNally B, Silvers SM, Passman RS, White RD, Hess EP, Tang W, Davis D, Sinz E, Morrison LJ. Part 8: adult advanced cardiovascular life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S729–S767. doi: 10.1161/CIRCULATIONAHA.110.970988.

73. Kleinman ME, Chameides L, Schexnayder SM, Samson RA, Hazinski MF, Atkins DL, Berg MD, de Caen AR, Fink EL, Freid EB, Hickey RW, Marino BS, Nadkarni VM, Proctor LT, Qureshi FA, Sartorelli K, Topjian A, van der Jagt EW, Zaritsky AL. Part 14: pediatric advanced life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S876–S908. doi: 10.1161/ CIRCULATIONAHA.110.971101.

74. Cooper S. Developing leaders for advanced life support: evaluation of a training programme. Resuscitation. 2001;49:33–38.

75. DePriest J, Fee-Mulhearn AL, Teleron A. A novel ACLS team leader checklist implemented to improve resuscitation efforts. Resuscitation. 2013;84:e115. doi: 10.1016/j.resuscitation.2013.03.002.

76. Bhanji F, Mancini ME, Sinz E, Rodgers DL, McNeil MA, Hoadley TA, Meeks RA, Hamilton MF, Meaney PA, Hunt EA, Nadkarni VM, Hazinski MF. Part 16: education, implementation, and teams: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3): S920–S933. doi: 10.1161/CIRCULATIONAHA.110.971135.

77. Weidman EK, Bell G, Walsh D, Small S, Edelson DP. Assessing the impact of immersive simulation on clinical performance during actual in-hospital cardiac arrest with CPR-sensing technology: a randomized feasibility study. Resuscitation. 2010;81:1556–1561. doi: 10.1016/j. resuscitation.2010.05.021.

78. Yeung J, Meeks R, Edelson D, Gao F, Soar J, Perkins GD. The use of CPR feedback/prompt devices during training and CPR performance: A systematic review. Resuscitation. 2009;80:743–751. doi: 10.1016/j. resuscitation.2009.04.012.

79. Niles D, Sutton RM, Donoghue A, Kalsi MS, Roberts K, Boyle L, Nishisaki A, Arbogast KB, Helfaer M, Nadkarni V. “Rolling Refreshers”: a novel approach to maintain CPR psychomotor skill competence. Resuscitation. 2009;80:909–912. doi: 10.1016/j.resuscitation.2009.04.021.

80. Sutton RM, Niles D, Meaney PA, Aplenc R, French B, Abella BS, Lengetti EL, Berg RA, Helfaer MA, Nadkarni V. Low-dose, high-frequency CPR training improves skill retention of in-hospital pediatric providers. Pediatrics. 2011;128:e145–e151. doi: 10.1542/peds.2010-2105.

81. Wolfe H, Maltese MR, Niles DE, Fischman E, Legkobitova V, Leffelman J, Berg RA, Nadkarni VM, Sutton RM. Blood pressure directed booster trainings improve intensive care unit provider retention of excellent cardiopulmonary resuscitation skills. Pediatr Emerg Care. 2015:Epub ahead of print.

82. Spearpoint KG, Gruber PC, Brett SJ. Impact of the Immediate Life Support course on the incidence and outcome of in-hospital cardiac arrest calls: an observational study over 6 years. Resuscitation. 2009;80:638–643. doi: 10.1016/j.resuscitation.2009.03.002.

83. Edelson DP, Litzinger B, Arora V, Walsh D, Kim S, Lauderdale DS, Vanden Hoek TL, Becker LB, Abella BS. Improving in-hospital cardiac arrest process and outcomes with performance debriefing. Arch Intern Med. 2008;168:1063–1069. doi: 10.1001/archinte.168.10.1063.

84. Wolfe H, Zebuhr C, Topjian AA, Nishisaki A, Niles DE, Meaney PA, Boyle L, Giordano RT, Davis D, Priestley M, Apkon M, Berg RA, Nadkarni VM, Sutton RM. Interdisciplinary ICU cardiac arrest debriefing improves survival outcomes. Crit Care Med. 2014;42:1688–1695. doi: 10.1097/CCM.0000000000000327.

85. NeumarRW,NolanJP,AdrieC,AibikiM,BergRA,BöttigerBW,CallawayC, Clark RS, Geocadin RG, Jauch EC, Kern KB, Laurent I, Longstreth WT Jr, Merchant RM, Morley P, Morrison LJ, Nadkarni V, Peberdy MA, Rivers EP, Rodriguez-Nunez A, Sellke FW, Spaulding C, Sunde K, Vanden Hoek T. Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication: a consensus statement from the International Liaison Committee on Resuscitation (American Heart Association, Australian and New Zealand Council on Resuscitation, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Asia, and the Resuscitation Council of Southern Africa); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; and the Stroke Council. Circulation. 2008;118:2452–2483. doi: 10.1161/CIRCULATIONAHA.108.190652.

86. Carr BG, Kahn JM, Merchant RM, Kramer AA, Neumar RW. Inter-hospital variability in post-cardiac arrest mortality. Resuscitation. 2009;80:30–34. doi: 10.1016/j.resuscitation.2008.09.001.

87. Nichol G, Rumsfeld J, Eigel B, Abella BS, Labarthe D, Hong Y, O’Connor RE, Mosesso VN, Berg RA, Leeper BB, Weisfeldt ML. Essential features of designating out-of-hospital cardiac arrest as a reportable event: a scientific statement from the American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Perioperative, and Critical Care; Council on Cardiovascular Nursing; Council on Clinical Cardiology; and Quality of Care and Outcomes Research Interdisciplinary Working Group. Circulation. 2008;117:2299– 2308. doi: 10.1161/CIRCULATIONAHA.107.189472.

88. Sayre MR, Berg RA, Cave DM, Page RL, Potts J, White RD; American Heart Association Emergency Cardiovascular Care Committee. Hands-only (compression-only) cardiopulmonary resuscitation: a call to action for bystander response to adults who experience out- of-hospital sudden cardiac arrest: a science advisory for the public from the American Heart Association Emergency Cardiovascular Care Committee. Circulation. 2008;117:2162–2167. doi: 10.1161/ CIRCULATIONAHA.107.189380.

89. Hallstrom AP, Ornato JP, Weisfeldt M, Travers A, Christenson J, McBurnie MA, Zalenski R, Becker LB, Schron EB, Proschan M; Public Access Defibrillation Trial Investigators. Public-access defibrillation and survival after out-of-hospital cardiac arrest. N Engl J Med. 2004;351:637–646. doi: 10.1056/NEJMoa040566.

90. Perkins GD, Travers AH, Berg RA, Castren M, Considine J, Escalante R, Gazmuri RJ, Koster RW, Lim SH, Nation KJ, Olasveengen TM, Sakamoto T, Sayre MR, Sierra A, Smyth MA, Stanton D, Vaillancourt C; Part 3: adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

91. Travers AH, Perkins GD, Berg RA, Castren M, Considine J, Escalante R, Gazmuri RJ, Koster RW, Lim SH, Nation KJ, Olasveengen TM, Sakamoto T, Sayre MR, Sierra A, Smyth MA, Stanton D, Vaillancourt C; on behalf of the Basic Life Support Chapter Collaborators. Part 3: adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S51–S83. doi: 10.1161/CIR.0000000000000272.

92. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A; Implementation Working Group for the All-Japan Utstein Registry of the Fire and Disaster Management Agency. Nationwide public-access defibrillation in Japan. N Engl J Med. 2010;362:994–1004. doi: 10.1056/ NEJMoa0906644.

93. Kitamura T, Iwami T, Kawamura T, Nitta M, Nagao K, Nonogi H, Yonemoto N, Kimura T; Japanese Circulation Society Resuscitation Science Study Group. Nationwide improvements in survival from out- of-hospital cardiac arrest in Japan. Circulation. 2012;126:2834–2843. doi: 10.1161/CIRCULATIONAHA.112.109496.

94. Mitani Y, Ohta K, Yodoya N, Otsuki S, Ohashi H, Sawada H, Nagashima M, Sumitomo N, Komada Y. Public access defibrillation improved the outcome after out-of-hospital cardiac arrest in school-age children: a nationwide, population-based, Utstein registry study in Japan. Europace. 2013;15:1259–1266. doi: 10.1093/europace/eut053.

95. Van Vleet LM, Hubble MW. Time to first compression using Medical Priority Dispatch System compression-first dispatcher-assisted cardiopulmonary resuscitation protocols. Prehosp Emerg Care. 2012;16:242– 250. doi: 10.3109/10903127.2011.616259.

96. Fujie K, Nakata Y, Yasuda S, Mizutani T, Hashimoto K. Do dispatcher instructions facilitate bystander-initiated cardiopulmonary resuscitation and improve outcomes in patients with out-of-hospital cardiac arrest? A comparison of family and non-family bystanders. Resuscitation. 2014;85:315–319. doi: 10.1016/j.resuscitation.2013.11.013.

97. Bång A, Herlitz J, Martinell S. Interaction between emergency medical dispatcher and caller in suspected out-of-hospital cardiac arrest calls with focus on agonal breathing. A review of 100 tape recordings of true cardiac arrest cases. Resuscitation. 2003;56:25–34.

98. Nurmi J, Pettilä V, Biber B, Kuisma M, Komulainen R, Castrén M. Effect of protocol compliance to cardiac arrest identification by emergency medical dispatchers. Resuscitation. 2006;70:463–469. doi: 10.1016/j. resuscitation.2006.01.016.

99. Eisenberg MS, Hallstrom AP, Carter WB, Cummins RO, Bergner L, Pierce J. Emergency CPR instruction via telephone. Am J Public Health. 1985;75:47–50.

100. Vaillancourt C, Verma A, Trickett J, Crete D, Beaudoin T, Nesbitt L, Wells GA, Stiell IG. Evaluating the effectiveness of dispatch-assisted cardiopulmonary resuscitation instructions. Acad Emerg Med. 2007;14:877–883. doi: 10.1197/j.aem.2007.06.021.

101. Stipulante S, Tubes R, El Fassi M, Donneau AF, Van Troyen B, Hartstein G, D'Orio V, Ghuysen A. Implementation of the ALERT algorithm, a new dispatcher-assisted telephone cardiopulmonary resuscitation protocol, in non-Advanced Medical Priority Dispatch System (AMPDS) Emergency Medical Services centres. Resuscitation. 2014;85:177–181. doi: 10.1016/j.resuscitation.2013.10.005.

102. Berdowski J, Beekhuis F, Zwinderman AH, Tijssen JG, Koster RW. Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call. Circulation. 2009;119:2096– 2102. doi: 10.1161/CIRCULATIONAHA.108.768325.

103. Roppolo LP, Westfall A, Pepe PE, Nobel LL, Cowan J, Kay JJ, Idris AH. Dispatcher assessments for agonal breathing improve detection of cardiac arrest. Resuscitation. 2009;80:769–772. doi: 10.1016/j. resuscitation.2009.04.013.

104. Tanaka Y, Taniguchi J, Wato Y, Yoshida Y, Inaba H. The continuous quality improvement project for telephone-assisted instruction of cardiopulmonary resuscitation increased the incidence of bystander CPR and improved the outcomes of out-of-hospital cardiac arrests. Resuscitation. 2012;83:1235–1241. doi: 10.1016/j.resuscitation.2012.02.013.

105. Barron T, Clawson J, Scott G, Patterson B, Shiner R, Robinson D, Wrigley F, Gummett J, Olola CH. Aspirin administration by emergency medical dispatchers using a protocol-driven aspirin diagnostic and instruction tool. Emerg Med J. 2013;30:572–578. doi: 10.1136/ emermed-2012-201339.

106. Caceres JA, Adil MM, Jadhav V, Chaudhry SA, Pawar S, Rodriguez GJ, Suri MF, Qureshi AI. Diagnosis of stroke by emergency medical dispatchers and its impact on the prehospital care of patients. J Stroke Cerebrovasc Dis. 2013;22:e610–e614. doi: 10.1016/j.jstrokecerebrovasdis.2013.07.039.

107. Rea TD, Fahrenbruch C, Culley L, Donohoe RT, Hambly C, Innes J, Bloomingdale M, Subido C, Romines S, Eisenberg MS. CPR with chest compression alone or with rescue breathing. N Engl J Med. 2010;363:423–433. doi: 10.1056/NEJMoa0908993.

108. Akahane M, Ogawa T, Tanabe S, Koike S, Horiguchi H, Yasunaga H, Imamura T. Impact of telephone dispatcher assistance on the outcomes of pediatric out-of-hospital cardiac arrest. Crit Care Med. 2012;40:1410– 1416. doi: 10.1097/CCM.0b013e31823e99ae.

109. Hallstrom AP. Dispatcher-assisted “phone” cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. Crit Care Med. 2000;28(11 suppl):N190–N192.

110. Hüpfl M, Selig HF, Nagele P. Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. Lancet. 2010;376:1552–1557. doi: 10.1016/S0140-6736(10)61454-7.

111. Bray JE, Deasy C, Walsh J, Bacon A, Currell A, Smith K. Changing EMS dispatcher CPR instructions to 400 compressions before mouth- to-mouth improved bystander CPR rates. Resuscitation. 2011;82:1393– 1398. doi: 10.1016/j.resuscitation.2011.06.018.

112. Culley LL, Clark JJ, Eisenberg MS, Larsen MP. Dispatcher-assisted telephone CPR: common delays and time standards for delivery. Ann Emerg Med. 1991;20:362–366.

113. Rea TD, Eisenberg MS, Culley LL, Becker L. Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. Circulation. 2001;104:2513–2516.

114. Ringh M, Fredman D, Nordberg P, Stark T, Hollenberg J. Mobile phone technology identifies and recruits trained citizens to perform CPR on out-of-hospital cardiac arrest victims prior to ambulance arrival. Resuscitation. 2011;82:1514–1518. doi: 10.1016/j. resuscitation.2011.07.033.

115. Zijlstra JA, Stieglis R, Riedijk F, Smeekes M, van der Worp WE, Koster RW. Local lay rescuers with AEDs, alerted by text messages, contribute to early defibrillation in a Dutch out-of-hospital cardiac arrest dispatch system. Resuscitation. 2014;85:1444–1449. doi: 10.1016/j. resuscitation.2014.07.020.

116. Ringh M, Rosenqvist M, Hollenberg J, Jonsson M, Fredman D, Nordberg P, Järnbert-Pettersson H, Hasselqvist-Ax I, Riva G, Svensson L. Mobile- phone dispatch of laypersons for CPR in out-of-hospital cardiac arrest. N Engl J Med. 2015;24:2316–2325. doi: 10.1056/NEJMoa1406038.

117. Perkins GD, Jacobs IG, Nadkarni VM, Berg RA, Bhanji F, Biarent D, Bossaert LL, Brett SJ, Chamberlain D, de Caen AR, Deakin CD, Finn JC, Gräsner J-T, Hazinski MF, Iwami T, Koster RW, Lim SH, Huei-Ming Ma M, McNally BF, Morley PT, Morrison LJ, Monsieurs KG, Montgomery W, Nichol G, Okada K, Eng Hock Ong M, Ong M, Travers AH, Nolan JP; for the Utstein Collaborators. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Circulation. 2015;132:•••–•••. doi: 10.1161/CIR.0000000000000144.

118. Le May MR, So DY, Dionne R, Glover CA, Froeschl MP, Wells GA, Davies RF, Sherrard HL, Maloney J, Marquis JF, O’Brien ER, Trickett J, Poirier P, Ryan SC, Ha A, Joseph PG, Labinaz M. A citywide proto- col for primary PCI in ST-segment elevation myocardial infarction. N Engl J Med. 2008;358:231–240. doi: 10.1056/NEJMoa073102.

119. Mercuri M, Velianou JL, Welsford M, Gauthier L, Natarajan MK. Improving the timeliness of care for patients with acute ST-elevation myocardial infarction: implications of “self-transport” versus use of EMS. Healthc Q. 2010;13:105–109.

120. Kajino K, Iwami T, Daya M, Nishiuchi T, Hayashi Y, Kitamura T, Irisawa T, Sakai T, Kuwagata Y, Hiraide A, Kishi M, Yamayoshi S. Impact of transport to critical care medical centers on outcomes after out-of-hospital cardiac arrest. Resuscitation. 2010;81:549–554. doi: 10.1016/j.resuscitation.2010.02.008.

121. Callaway CW, Schmicker R, Kampmeyer M, Powell J, Rea TD, Daya MR, Aufderheide TP, Davis DP, Rittenberger JC, Idris AH, Nichol G; Resuscitation Outcomes Consortium (ROC) Investigators. Receiving hospital characteristics associated with survival after out-of-hospital cardiac arrest. Resuscitation. 2010;81:524–529. doi: 10.1016/j. resuscitation.2009.12.006.

122. Carr BG, Goyal M, Band RA, Gaieski DF, Abella BS, Merchant RM, Branas CC, Becker LB, Neumar RW. A national analysis of the relation- ship between hospital factors and post-cardiac arrest mortality. Intensive Care Med. 2009;35:505–511. doi: 10.1007/s00134-008-1335-x.

123. Cudnik MT, Sasson C, Rea TD, Sayre MR, Zhang J, Bobrow BJ, Spaite DW, McNally B, Denninghoff K, Stolz U. Increasing hospital volume is not associated with improved survival in out of hospital cardiac arrest of cardiac etiology. Resuscitation. 2012;83:862–868. doi: 10.1016/j. resuscitation.2012.02.006.

124. Engdahl J, Abrahamsson P, Bång A, Lindqvist J, Karlsson T, Herlitz J. Is hospital care of major importance for outcome after out-of-hospital cardiac arrest? Experience acquired from patients with out-of-hospital cardiac arrest resuscitated by the same Emergency Medical Service and admitted to one of two hospitals over a 16-year period in the municipal- ity of Göteborg. Resuscitation. 2000;43:201–211.

125.

Hansen M, Fleischman R, Meckler G, Newgard CD. The association between hospital type and mortality among critically ill children in US EDs. Resuscitation. 2013;84:488–491. doi: 10.1016/j. resuscitation.2012.07.032.

126. Herlitz J, Engdahl J, Svensson L, Angquist KA, Silfverstolpe J, Holmberg S. Major differences in 1-month survival between hospitals in Sweden among initial survivors of out-of-hospital cardiac arrest. Resuscitation. 2006;70:404–409. doi: 10.1016/j. resuscitation.2006.01.014.

127. Kjaergaard J, Bro-Jeppesen J, Rasmussen LS, Nielsen SL, Folke F, Lippert F, Wanscher MC, Hassager C. [Differences between hospitals in prognosis after resuscitated out-of-hospital cardiac arrest patients]. Ugeskr Laeger. 2009;171:2169–2173.

128. Stub D, Smith K, Bray JE, Bernard S, Duffy SJ, Kaye DM. Hospital characteristics are associated with patient outcomes following out-of-hospital cardiac arrest. Heart. 2011;97:1489–1494. doi: 10.1136/ hrt.2011.226431.

129. Davis DP, Fisher R, Aguilar S, Metz M, Ochs G, McCallum-Brown L, Ramanujam P, Buono C, Vilke GM, Chan TC, Dunford JV. The fea- sibility of a regional cardiac arrest receiving system. Resuscitation. 2007;74:44–51. doi: 10.1016/j.resuscitation.2006.11.009.

130. Heffner AC, Pearson DA, Nussbaum ML, Jones AE. Regionalization of post-cardiac arrest care: implementation of a cardiac resuscitation center. Am Heart J. 2012;164:493–501.e2. doi: 10.1016/j. ahj.2012.06.014.

131. Mooney MR, Unger BT, Boland LL, Burke MN, Kebed KY, Graham KJ, Henry TD, Katsiyiannis WT, Satterlee PA, Sendelbach S, Hodges JS, Parham WM. Therapeutic hypothermia after out-of-hospital cardiac arrest: evaluation of a regional system to increase access to cooling. Circulation. 2011;124:206–214. doi: 10.1161/ CIRCULATIONAHA.110.986257.

132. Spaite DW, Bobrow BJ, Vadeboncoeur TF, Chikani V, Clark L, Mullins T, Sanders AB. The impact of prehospital transport interval on survival in out-of-hospital cardiac arrest: implications for regionalization of post-resuscitation care. Resuscitation. 2008;79:61–66. doi: 10.1016/j. resuscitation.2008.05.006.

133. Spaite DW, Stiell IG, Bobrow BJ, de Boer M, Maloney J, Denninghoff K, Vadeboncoeur TF, Dreyer J, Wells GA. Effect of transport interval on out-of-hospital cardiac arrest survival in the OPALS study: implications for triaging patients to specialized cardiac arrest centers. Ann Emerg Med. 2009;54:248–255. doi: 10.1016/j. annemergmed.2008.11.020.

134. Bosson N, Kaji AH, Niemann JT, Eckstein M, Rashi P, Tadeo R, Gorospe D, Sung G, French WJ, Shavelle D, Thomas JL, Koenig W. Survival and neurologic outcome after out-of-hospital cardiac arrest: results one year after regionalization of post-cardiac arrest care in a large metropolitan area. Prehosp Emerg Care. 2014;18:217–223. doi: 10.3109/10903127.2013.856507.

135. Fothergill RT, Watson LR, Virdi GK, Moore FP, Whitbread M. Survival of resuscitated cardiac arrest patients with ST-elevation myocardial infarction (STEMI) conveyed directly to a Heart Attack Centre by ambulance clinicians. Resuscitation. 2014;85:96–98. doi: 10.1016/j. resuscitation.2013.09.010.

136. Lick CJ, Aufderheide TP, Niskanen RA, Steinkamp JE, Davis SP, Nygaard SD, Bemenderfer KK, Gonzales L, Kalla JA, Wald SK, Gillquist DL, Sayre MR, Osaki Holm SY, Oski Holm SY, Oakes DA, Provo TA, Racht EM, Olsen JD, Yannopoulos D, Lurie KG. Take Heart America: A comprehensive, community-wide, systems-based approach to the treatment of cardiac arrest. Crit Care Med. 2011;39:26–33. doi: 10.1097/CCM.0b013e3181fa7ce4.

137. Lund-Kordahl I, Olasveengen TM, Lorem T, Samdal M, Wik L, Sunde K. Improving outcome after out-of-hospital cardiac arrest by strengthen- ing weak links of the local Chain of Survival; quality of advanced life support and post-resuscitation care. Resuscitation. 2010;81:422–426. doi: 10.1016/j.resuscitation.2009.12.020.

138. Spaite DW, Bobrow BJ, Stolz U, Berg RA, Sanders AB, Kern KB, Chikani V, Humble W, Mullins T, Stapczynski JS, Ewy GA; Arizona Cardiac Receiving Center Consortium. Statewide regionalization of postarrest care for out-of-hospital cardiac arrest: association with survival and neurologic outcome. Ann Emerg Med. 2014;64:496–506. e1. doi: 10.1016/j.annemergmed.2014.05.028.

139. Tagami T, Hirata K, Takeshige T, Matsui J, Takinami M, Satake M, Satake S, Yui T, Itabashi K, Sakata T, Tosa R, Kushimoto S, Yokota H, Hirama H. Implementation of the fifth link of the chain of survival con- cept for out-of-hospital cardiac arrest. Circulation. 2012;126:589–597. doi: 10.1161/CIRCULATIONAHA.111.086173.

140. Martin K. The Outstanding Organization: Generate Business Results by Eliminating Chaos and Building the Foundation for Everyday Excellence. New York, NY: McGraw-Hill; 2012.

141. American HeartAssociation. Emergency Cardiovascular Care 2020 Impact Goals 2015. http://www.heart.org/HEARTORG/General/Emergency- Cardiovascular-Care-2020-Impact-Goals_UCM_435128_Article.jsp. Accessed May 9, 2015.

142. McChesney C, Covey S, Huling J. The 4 Disciplines of Execution: Achieving Your Wildly Important Goals. New York, NY: Free Press; 2012.

143. Womack JP, Shook J. Gemba Walks. Cambridge, MA: Lean Enterprises Institute, Inc; 2011.

144. American Heart Association Get With The Guidelines?Resuscitation. http://www.heart.org/HEARTORG/HealthcareResearch/GetWith TheGuidelines-Resuscitation/Get-With-The-GuidelinesResuscitation_ UCM_314496_SubHomePage.jsp. Accessed May 9, 2015.

145.

Peberdy MA, Kaye W, Ornato JP, Larkin GL, Nadkarni V, Mancini ME, Berg RA, Nichol G, Lane-Trultt T. Cardiopulmonary resuscitation of adults in the hospital: a report of 14 720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. Resuscitation. 2003;58:297–308.

146. Resuscitation Outcomes Consortium. https://roc.uwctc.org/tiki/tiki- index.php?page=roc-public-home. Accessed May 9, 2015.

Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiac arrest | cardiopulmonary resuscitation | defibrillation | emergency

1 Highlights & Introduction

1.1 Highlights: Lay Rescuer CPR

Summary of Key Issues and Major Changes

Key issues and major changes in the 2015 Guidelines Update recommendations for adult CPR by lay rescuers include the following:

- The crucial links in the out-of-hospital adult Chain of Survival are unchanged from 2010, with continued emphasis on the simplified universal Adult Basic Life Support (BLS) Algorithm.
- The Adult BLS Algorithm has been modified to reflect the fact that rescuers can activate an emergency response (ie, through use of a mobile telephone) without leaving the victim's side.
- It is recommended that communities with people at risk for cardiac arrest implement PAD programs.
- Recommendations have been strengthened to encourage immediate recognition of unresponsiveness, activation of the emergency response system, and initiation of CPR if the lay rescuer finds an unresponsive victim is not breathing or not breathing normally (eg, gasping).
- Emphasis has been increased about the rapid identification of potential cardiac arrest by dispatchers, with immediate provision of CPR instructions to the caller (ie, dispatch-guided CPR).
- The recommended sequence for a single rescuer has been confirmed: the single rescuer is to initiate chest compressions before giving rescue breaths (C-A-B rather than A-B-C) to reduce delay to first compression. The single rescuer should begin CPR with 30 chest compressions followed by 2 breaths.
- There is continued emphasis on the characteristics of high-quality CPR: compressing the chest at an adequate rate and depth, allowing complete chest recoil after each compression, minimizing interruptions in compressions, and avoiding excessive ventilation.
- The recommended chest compression rate is 100 to 120/min (updated from *at least* 100/min).
- The clarified recommendation for chest compression depth for adults is at least 2 inches (5 cm) but not greater than 2.4 inches (6 cm).
- Bystander-administered naloxone may be considered for suspected life-threatening opioid-associated emergencies.

These changes are designed to simplify lay rescuer training and to emphasize the need for early chest compressions for victims of sudden cardiac arrest. More information about these changes appears below.

> In the following topics, changes or points of emphasis that are similar for lay rescuers and HCPs are noted with an asterisk (*).

Community Lay Rescuer AED Programs

2015 (Updated): It is recommended that PAD programs for patients with OHCA be implemented in public locations where there is a relatively high likelihood of witnessed cardiac arrest (eg, airports, casinos, sports facilities).

2010 (Old): CPR and the use of automated external defibrillators (AEDs) by public safety first responders were recommended to increase survival rates for out-of-hospital sudden cardiac arrest. The 2010 Guidelines recommended the establishment of AED programs in public locations where there is a relatively high likelihood of witnessed cardiac arrest (eg, airports, casinos, sports facilities).

Why: There is clear and consistent evidence of improved survival from cardiac arrest when a bystander

performs CPR and rapidly uses an AED. Thus, immediate access to a defibrillator is a primary component of the system of care. The implementation of a PAD program requires 4 essential components: (1) a planned and practiced response, which ideally includes identification of locations and neighborhoods where there is high risk of cardiac arrest, placement of AEDs in those areas and ensuring that bystanders are aware of the location of the AEDs, and, typically, oversight by an HCP; (2) training of anticipated rescuers in CPR and use of the AED; (3) an integrated link with the local EMS system; and (4) a program of ongoing quality improvement.

A system-of-care approach for OHCA might include public policy that encourages reporting of public AED locations to public service access points (PSAPs; the term *public service access point* has replaced the less-precise *EMS dispatch center*). Such a policy would enable PSAPs to direct bystanders to retrieve nearby AEDs and assist in their use when OHCA occurs. Many municipalities as well as the US federal government have enacted legislation to place AEDs in municipal buildings, large public venues, airports, casinos, and schools. For the 20% of OHCAs that occur in public areas, these community programs represent an important link in the Chain of Survival between recognition and activation of the PSAPs. This information is expanded in "Part 4: Systems of Care and Continuous Quality Improvement" in the 2015 Guidelines Update.

There is insufficient evidence to recommend for or against the deployment of AEDs in homes. Victims of OHCAs that occur in private residences are much less likely to receive chest compressions than are patients who experience cardiac arrest in public settings. Real-time instructions provided by emergency dispatchers may help potential in-home rescuers to initiate action. Robust community CPR training programs for cardiac arrest, along with effective, prearrival dispatch protocols, can improve outcomes.

Dispatcher Identification of Agonal Gasps

Cardiac arrest victims sometimes present with seizure-like activity or agonal gasps that can confuse potential rescuers. Dispatchers should be specifically trained to identify these presentations of cardiac arrest to enable prompt recognition and immediate dispatcher-guided CPR.

2015 (Updated): To help bystanders recognize cardiac arrest, dispatchers should inquire about a victim's absence of responsiveness and quality of breathing (normal versus not normal). If the victim is unresponsive with absent or abnormal breathing, the rescuer and the dispatcher should assume that the victim is in cardiac arrest. Dispatchers should be educated to identify unresponsiveness with abnormal and agonal gasps across a range of clinical presentations and descriptions.

2010 (Old): To help bystanders recognize cardiac arrest, dispatchers should ask about an adult victim's responsiveness, if the victim is breathing, and if the breathing is normal, in an attempt to distinguish victims with agonal gasps (ie, in those who need CPR) from victims who are breathing normally and do not need CPR.

Why: This change from the 2010 Guidelines emphasizes the role that emergency dispatchers can play in helping the lay rescuer recognize absent or abnormal breathing.

Dispatchers should be specifically educated to help bystanders recognize that agonal gasps are a sign of cardiac arrest. Dispatchers should also be aware that brief generalized seizures may be the first manifestation of cardiac arrest. In summary, in addition to activating professional emergency responders, the dispatcher should ask straightforward questions about whether the patient is unresponsive and if breathing is normal or abnormal in order to identify patients with possible cardiac arrest and enable dispatcher-guided CPR.

Emphasis on Chest Compressions* 2015

2015 (Updated): Untrained lay rescuers should provide compression-only (Hands-Only) CPR, with or without dispatcher guidance, for adult victims of cardiac arrest. The rescuer should continue compression-only CPR until the arrival of an AED or rescuers with additional training. All lay rescuers should, at a minimum, provide chest compressions for victims of cardiac arrest. In addition, if the trained lay rescuer is able to perform rescue breaths, he or she should add rescue breaths in a ratio of 30 compressions to 2 breaths. The rescuer should continue CPR until an AED arrives and is ready for use, EMS providers take over care of the victim, or the victim starts to move.

2010 (Old): If a bystander is not trained in CPR, the bystander should provide compression-only CPR for the adult victim who suddenly collapses, with an emphasis to "push hard and fast" on the center of the chest, or follow the directions of the EMS dispatcher. The rescuer should continue compression-only CPR until an AED arrives and is ready for use or EMS providers take over care of the victim. All trained lay rescuers should, at a

minimum, provide chest compressions for victims of cardiac arrest. In addition, if the trained lay rescuer is able to perform rescue breaths, compressions and breaths should be provided in a ratio of 30 compressions to 2 breaths. The rescuer should continue CPR until an AED arrives and is ready for use or EMS providers take over care of the victim.

Why: Compression-only CPR is easy for an untrained rescuer to perform and can be more effectively guided by dispatchers over the telephone. Moreover, survival rates from adult cardiac arrests of cardiac etiology are similar with either compression only CPR or CPR with both compressions and rescue breaths when provided before EMS arrival. However, for the trained lay rescuer who is able, the recommendation remains for the rescuer to perform both compressions and breaths.

Chest Compression Rate*

2015 (Updated): In adult victims of cardiac arrest, it is reasonable for rescuers to perform chest compressions at a rate of 100 to 120/min.

2010 (Old): It is reasonable for lay rescuers and HCPs to perform chest compressions at a rate of at least 100/min.

Why: The number of chest compressions delivered per minute during CPR is an important determinant of return of spontaneous circulation (ROSC) and survival with good neurologic function. The actual number of chest compressions delivered per minute is determined by the rate of chest compressions and the number and duration of interruptions in compressions (eg, to open the airway, deliver rescue breaths, allow AED analysis). In most studies, more compressions are associated with higher survival rates, and fewer compressions are associated with lower survival rates. Provision of adequate chest compressions requires an emphasis not only on an adequate compression rate but also on minimizing interruptions to this critical component of CPR. An inadequate compression rate or frequent interruptions (or both) will reduce the total number of compressions delivered per minute. New to the 2015 Guidelines Update are upper limits of recommended compression rate and compression depth, based on preliminary data suggesting that excessive compression rate and depth adversely affect outcomes. The addition of an upper limit of compression rate is based on 1 large registry study analysis associating extremely rapid compression rates (greater than 140/min) with inadequate compression depth. Box 1 uses the analogy of automobile travel to explain the effect of compression rate and interruptions on total number of compressions delivered during resuscitation.

Box 1

Number of Compressions Delivered Affected by Compression Rate and by Interruptions

The total number of compressions delivered during resuscitation is an important determinant of survival from cardiac arrest.

- The number of compressions delivered is affected by the compression *rate* (the frequency of chest compressions per minute) and by the compression *fraction* (the portion of total CPR time during which compressions are performed). Increases in compression rate and fraction increase the total number of compressions delivered. Compression fraction is improved by reducing the number and duration of any interruptions in compressions.
- An analogy can be found in automobile travel. When traveling in an automobile, the number of miles traveled in a day is affected not only by the speed (rate of travel) but also by the number and duration of any stops (interruptions in travel). Traveling 60 mph without interruptions translates to an actual travel distance of 60 miles in an hour. Traveling 60 mph except for a 10-minute stop translates to an actual travel of 50 miles in that hour. The more frequent and the more prolonged the stops, the lower the actual miles traveled.
- During CPR, rescuers should deliver effective compressions at an appropriate rate (100 to 120/min) and depth while minimizing the number and duration of interruptions in chest compressions. Additional components of high-quality CPR include allowing complete chest recoil after each compression and avoiding excessive ventilation.

Chest Compression Depth*

2015 (Updated): During manual CPR, rescuers should perform chest compressions to a depth of at least 2 inches (5 cm) for an average adult, while avoiding excessive chest compression depths (greater than 2.4 inches [6 cm]).

2010 (Old): The adult sternum should be depressed at least 2 inches (5 cm).

Why: Compressions create blood flow primarily by increasing intrathoracic pressure and directly compressing the heart, which in turn results in critical blood flow and oxygen delivery to the heart and brain. Rescuers often do not compress the chest deeply enough despite the recommendation to “push hard.” While a compression depth of at least 2 inches (5 cm) is recommended, the 2015 Guidelines Update incorporates new evidence about the potential for an upper threshold of compression depth (greater than 2.4 inches [6 cm]), beyond which complications may occur. Compression depth may be difficult to judge without use of feedback devices, and identification of upper limits of compression depth may be challenging. It is important for rescuers to know that the recommendation about the upper limit of compression depth is based on 1 very small study that reported an association between excessive compression depth and injuries that were not life-threatening. Most monitoring via CPR feedback devices suggests that compressions are more often too shallow than they are too deep.

Bystander Naloxone in Opioid-Associated Life-Threatening Emergencies*

2015 (New): For patients with known or suspected opioid addiction who are unresponsive with no normal breathing but a pulse, it is reasonable for appropriately trained lay rescuers and BLS providers, in addition to providing standard BLS care, to administer intramuscular (IM) or intranasal (IN) naloxone. Opioid overdose response education with or without naloxone distribution to persons at risk for opioid overdose in any setting may be considered. This topic is also addressed in the Special Circumstances of Resuscitation section.

Why: There is substantial epidemiologic data demonstrating the large burden of disease from lethal opioid overdoses, as well as some documented success in targeted national strategies for bystander-administered naloxone for people at risk. In 2014, the naloxone autoinjector was approved by the US Food and Drug Administration for use by lay rescuers and HCPs. The resuscitation training network has requested information about the best way to incorporate such a device into the adult BLS guidelines and training. This recommendation incorporates the newly approved treatment.

1.2 Highlights: HCP BLS

Summary of Key Issues and Major Changes

Key issues and major changes in the 2015 Guidelines Update recommendations for HCPs include the following:

- These recommendations allow flexibility for activation of the emergency response system to better match the HCP's clinical setting.
- Trained rescuers are encouraged to simultaneously perform some steps (ie, checking for breathing and pulse at the same time), in an effort to reduce the time to first chest compression.
- Integrated teams of highly trained rescuers may use a choreographed approach that accomplishes multiple steps and assessments simultaneously rather than the sequential manner used by individual rescuers (eg, one rescuer activates the emergency response system while another begins chest compressions, a third either provides ventilation or retrieves the bag-mask device for rescue breaths, and a fourth retrieves and sets up a defibrillator).
- Increased emphasis has been placed on high-quality CPR using performance targets (compressions of adequate rate and depth, allowing complete chest recoil between compressions, minimizing interruptions in compressions, and avoiding excessive ventilation). See Table 1.
- Compression rate is modified to a range of 100 to 120/min.
- Compression depth for adults is modified to at least 2 inches (5 cm) but should not exceed 2.4 inches (6 cm).
- To allow full chest wall recoil after each compression, rescuers must avoid leaning on the chest between compressions.
- Criteria for minimizing interruptions is clarified with a goal of chest compression fraction as high as possible, with a target of at least 60%.
- Where EMS systems have adopted bundles of care involving continuous chest compressions, the use of passive ventilation techniques may be considered as part of that bundle for victims of OHCA.
- For patients with ongoing CPR and an advanced airway in place, a simplified ventilation rate of 1 breath every 6 seconds (10 breaths per minute) is recommended.

Table 1: BLS Dos and Don'ts of Adult High-Quality CPR

Open table in a new window

BLS Dos and Don'ts of Adult High-Quality CPR

Rescuers Should	Rescuers Should *Not*
Perform chest compressions at a rate of 100-120/min	Compress at a rate slower than 100/min or faster than 120/min
Compress to a depth of at least 2 inches (5 cm)	Compress to a depth of less than 2 inches (5 cm) or greater than 2.4 inches (6 cm)
Allow full recoil after each compression	Lean on the chest between compressions

Rescuers Should	Rescuers Should *Not*
Minimize pauses in compressions	Interrupt compressions for greater than 10 seconds
Ventilate adequately (2 breaths after 30 compressions, each breath delivered over 1 second, each causing chest rise)	Provide excessive ventilation (ie, too many breaths or breaths with excessive force)

These changes are designed to simplify training for HCPs and to continue to emphasize the need to provide early and high-quality CPR for victims of cardiac arrest. More information about these changes follows.

In the following topics for HCPs, an asterisk (*) marks those that are similar for HCPs and lay rescuers.

Immediate Recognition and Activation of Emergency Response System

2015 (Updated): HCPs must call for nearby help upon finding the victim unresponsive, but it would be practical for an HCP to continue to assess the breathing and pulse simultaneously before fully activating the emergency response system (or calling for backup).

2010 (Old): The HCP should check for response while looking at the patient to determine if breathing is absent or not normal.

Why: The intent of the recommendation change is to minimize delay and to encourage fast, efficient simultaneous assessment and response, rather than a slow, methodical, step-by-step approach.

Emphasis on Chest Compressions*

2015 (Updated): It is reasonable for HCPs to provide chest compressions and ventilation for all adult patients in cardiac arrest, whether from a cardiac or noncardiac cause. Moreover, it is realistic for HCPs to tailor the sequence of rescue actions to the most likely cause of arrest.

2010 (Old): It is reasonable for both EMS and in-hospital professional rescuers to provide chest compressions and rescue breaths for cardiac arrest victims.

Why: Compression-only CPR is recommended for untrained rescuers because it is relatively easy for dispatchers to guide with telephone instructions. It is expected that HCPs are trained in CPR and can effectively perform both compressions and ventilation. However, the priority for the provider, especially if acting alone, should still be to activate the emergency response system and to provide chest compressions. There may be circumstances that warrant a change of sequence, such as the availability of an AED that the provider can quickly retrieve and use.

Shock First vs CPR First

2015 (Updated): For witnessed adult cardiac arrest when an AED is immediately available, it is reasonable that the defibrillator be used as soon as possible. For adults with unmonitored cardiac arrest or for whom an AED is not immediately available, it is reasonable that CPR be initiated while the defibrillator equipment is being retrieved and applied and that defibrillation, if indicated, be attempted as soon as the device is ready for use

2010 (Old): When any rescuer witnesses an out-of-hospital arrest and an AED is immediately available on-site, the rescuer should start CPR with chest compressions and use the AED as soon as possible. HCPs who treat cardiac arrest in hospitals and other facilities with on-site AEDs or defibrillators should provide immediate CPR and should use the AED/defibrillator as soon as it is available. These recommendations are designed to support early CPR and early defibrillation, particularly when an AED or defibrillator is available within moments of the onset of sudden cardiac arrest. When an OHCA is not witnessed by EMS personnel, EMS may initiate CPR while checking the rhythm with the AED or on the electrocardiogram (ECG) and preparing for defibrillation. In such instances, 1½ to 3 minutes of CPR may be considered before attempted defibrillation. Whenever 2 or more rescuers are present, CPR should be provided while the defibrillator is retrieved.

With in-hospital sudden cardiac arrest, there is insufficient evidence to support or refute CPR before

defibrillation. However, in monitored patients, the time from ventricular fibrillation (VF) to shock delivery should be under 3 minutes, and CPR should be performed while the defibrillator is readied.

Why: While numerous studies have addressed the question of whether a benefit is conferred by providing a specified period (typically 1½ to 3 minutes) of chest compressions before shock delivery, as compared with delivering a shock as soon as the AED can be readied, no difference in outcome has been shown. CPR should be provided while the AED pads are applied and until the AED is ready to analyze the rhythm.

Chest Compression Rate: 100 to 120/min*

2015 (Updated): In adult victims of cardiac arrest, it is reasonable for rescuers to perform chest compressions at a rate of 100 to 120/min.

2010 (Old): It is reasonable for lay rescuers and HCPs to perform chest compressions at a rate of at least 100/min.

Why: The minimum recommended compression rate remains 100/min. The upper limit rate of 120/min has been added because 1 large registry series suggested that as the compression rate increases to more than 120/min, compression depth decreases in a dose-dependent manner. For example, the proportion of compressions of inadequate depth was about 35% for a compression rate of 100 to 119/min but increased to inadequate depth in 50% of compressions when the compression rate was 120 to 139/min and to inadequate depth in 70% of compressions when compression rate was more than 140/min.

Chest Compression Depth*

2015 (Updated): During manual CPR, rescuers should perform chest compressions to a depth of at least 2 inches (5 cm) for an average adult while avoiding excessive chest compression depths (greater than 2.4 inches [6 cm]).

2010 (Old): The adult sternum should be depressed at least 2 inches (5 cm).

Why: A compression depth of approximately 5 cm is associated with greater likelihood of favorable outcomes compared with shallower compressions. While there is less evidence about whether there is an upper threshold beyond which compressions may be too deep, a recent very small study suggests potential injuries (none life-threatening) from excessive chest compression depth (greater than 2.4 inches [6 cm]). Compression depth may be difficult to judge without use of feedback devices, and identification of upper limits of compression depth may be challenging. It is important for rescuers to know that chest compression depth is more often too shallow than too deep.

Chest Recoil*

2015 (Updated): It is reasonable for rescuers to avoid leaning on the chest between compressions, to allow full chest wall recoil for adults in cardiac arrest.

2010 (Old): Rescuers should allow complete recoil of the chest after each compression, to allow the heart to fill completely before the next compression.

Why: Full chest wall recoil occurs when the sternum returns to its natural or neutral position during the decompression phase of CPR. Chest wall recoil creates a relative negative intrathoracic pressure that promotes venous return and cardiopulmonary blood flow. Leaning on the chest wall between compressions precludes full chest wall recoil. Incomplete recoil raises intrathoracic pressure and reduces venous return, coronary perfusion pressure, and myocardial blood flow and can influence resuscitation outcomes.

Minimizing Interruptions in Chest Compressions*

2015 (Reaffirmation of 2010): Rescuers should attempt to minimize the frequency and duration of interruptions in compressions to maximize the number of compressions delivered per minute.

2015 (New): For adults in cardiac arrest who receive CPR without an advanced airway, it may be reasonable to perform CPR with the goal of a chest compression fraction as high as possible, with a target of at least 60%.

Why: Interruptions in chest compressions can be intended as part of required care (ie, rhythm analysis and

ventilation) or unintended (ie, rescuer distraction). Chest compression fraction is a measurement of the proportion of total resuscitation time that compressions are performed. An increase in chest compression fraction can be achieved by minimizing pauses in chest compressions. The optimal goal for chest compression fraction has not been defined. The addition of a target compression fraction is intended to limit interruptions in compressions and to maximize coronary perfusion and blood flow during CPR.

Comparison of Key Elements of Adult, Child, and Infant BLS

Table 2 lists the 2015 key elements of adult, child, and infant BLS (excluding CPR for newly born infants).

Table 2: Summary of High-Quality CPR Components for BLS Providers

Open table in a new window

Summary of High-Quality CPR Components for BLS Providers

*Compression depth should be no more than 2.4 inches (6 cm).
Abbreviations: AED, automated external defibrillator; AP, anteroposterior; CPR, cardiopulmonary resuscitation.

Component	Adults and Adolescents	Children (Age 1 Year to Puberty)	Infants (Age Less Than 1 Year, Excluding Newborns)
Scene safety	Make sure the environment is safe for rescuers and victim		
Recognition of cardiac arrest	Check for responsiveness No breathing or only gasping (ie, no normal breathing) No definite pulse felt within 10 seconds (Breathing and pulse check can be performed simultaneously in less than 10 seconds)		
Activation of emergency response system	If you are alone with no mobile phone, leave the victim to activate the emergency response system and get the AED before beginning CPR Otherwise, send someone and begin CPR immediately; use the AED as soon as it is available	***Witnessed collapse*** Follow steps for adults and adolescents on the left ***Unwitnessed collapse*** Give 2 minutes of CPR Leave the victim to activate the emergency response system and get the AED Return to the child or infant and resume CPR; use the AED as soon as it is available	
Compression-ventilation ratio *without advanced airway*	***1 or 2 rescuers*** 30:2	***1 rescuer*** 30:2 ***2 or more rescuers*** 15:2	
Compression-ventilation ratio *with advanced airway*	Continuous compressions at a rate of 100-120/min Give 1 breath every 6 seconds (10 breaths/min)		

Component	Adults and Adolescents	Children (Age 1 Year to Puberty)	Infants (Age Less Than 1 Year, Excluding Newborns)
Compression rate	100-120/min		
Compression depth	At least 2 inches (5 cm)*	At least one-third AP diameter of chest About 2 inches (5 cm)	At least one-third AP diameter of chest About 1 1?2 inches (4 cm)
Hand placement	2 hands on the lower half of the breastbone (sternum)	2 hands or 1 hand (optional for very small child) on the lower half of the breastbone (sternum)	***1 rescuer*** 2 fingers in the center of the chest, just below the nipple line ***2 or more rescuers*** 2 thumb–encircling hands in the center of the chest, just below the nipple line
Chest recoil	Allow full recoil of chest after each compression; do not lean on the chest after each compression		
Minimizing interruptions	Limit interruptions in chest compressions to less than 10 seconds		

Chest Compression Feedback

2015 (Updated): It may be reasonable to use audiovisual feedback devices during CPR for real-time optimization of CPR performance.

2010 (Old): New CPR prompt and feedback devices may be useful for training rescuers and as part of an overall strategy to improve the quality of CPR in actual resuscitations. Training for the complex combination of skills required to perform adequate chest compressions should focus on demonstrating mastery.

Why: Technology allows for real-time monitoring, recording, and feedback about CPR quality, including both physiologic patient parameters and rescuer performance metrics. These important data can be used in real time during resuscitation, for debriefing after resuscitation, and for system-wide quality improvement programs. Maintaining focus during CPR on the characteristics of compression rate and depth and chest recoil while minimizing interruptions is a complex challenge even for highly trained professionals. There is some evidence that the use of CPR feedback may be effective in modifying chest compression rates that are too fast, and there is separate evidence that CPR feedback decreases the leaning force during chest compressions. However, studies to date have not demonstrated a significant improvement in favorable neurologic outcome or survival to hospital discharge with the use of CPR feedback devices during actual cardiac arrest events.

Delayed Ventilation

2015 (New): For witnessed OHCA with a shockable rhythm, it may be reasonable for EMS systems with priority-based, multitiered response to delay positive-pressure ventilation (PPV) by using a strategy of up to 3 cycles of 200 continuous compressions with passive oxygen insufflation and airway adjuncts.

Why: Several EMS systems have tested a strategy of providing initial continuous chest compressions with delayed PPV for adult victims of OHCA. In all of these EMS systems, the providers received additional training with emphasis on provision of high-quality chest compressions. Three studies in systems that use priority-based, multitiered response in both urban and rural communities, and provide a bundled package of care that includes up to 3 cycles of passive oxygen insufflation, airway adjunct insertion, and 200 continuous chest compressions with interposed shocks, showed improved survival with favorable neurologic status for victims with witnessed

arrest or shockable rhythm.

Ventilation During CPR With an Advanced Airway

2015 (Updated): It may be reasonable for the provider to deliver 1 breath every 6 seconds (10 breaths per minute) while continuous chest compressions are being performed (ie, during CPR with an advanced airway).

2010 (Old): When an advanced airway (ie, endotracheal tube, Combitube, or laryngeal mask airway) is in place during 2-person CPR, give 1 breath every 6 to 8 seconds without attempting to synchronize breaths between compressions (this will result in delivery of 8 to 10 breaths per minute).

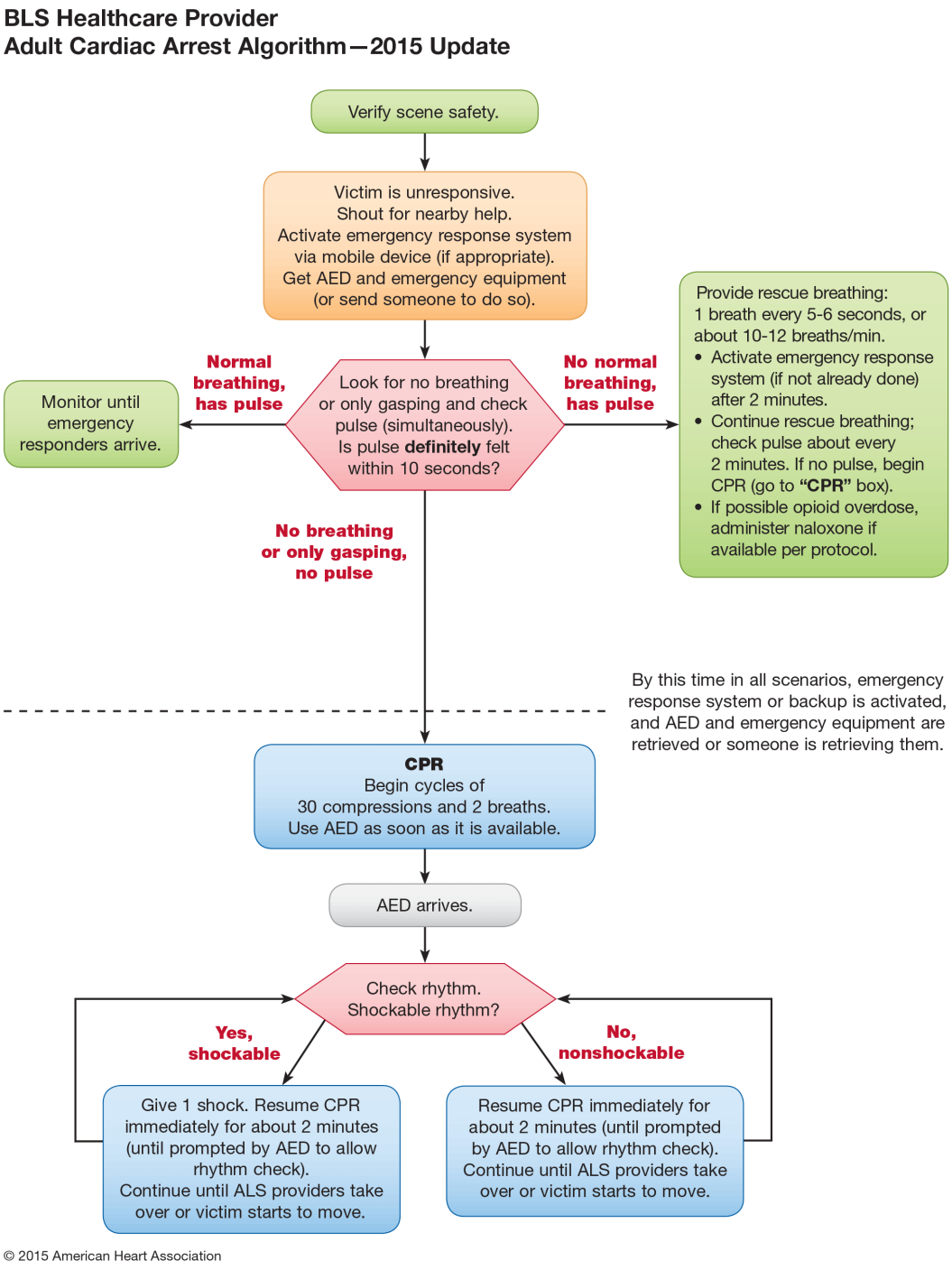
Why: This simple single rate for adults, children, and infants—rather than a range of breaths per minute—should be easier to learn, remember, and perform.

Team Resuscitation: Basic Principles

2015 (New): For HCPs, the 2015 Guidelines Update allows flexibility for activation of the emergency response and subsequent management in order to better match the provider's clinical setting (Figure 1).

Why: The steps in the BLS algorithms have traditionally been presented as a sequence in order to help a single rescuer prioritize actions. However, there are several factors in any resuscitation (eg, type of arrest, location, whether trained providers are nearby, whether the rescuer must leave a victim to activate the emergency response system) that may require modifications in the BLS sequence. The updated BLS HCP algorithms aim to communicate when and where flexibility in sequence is appropriate.

Figure 1: BLS Healthcare Provider Adult Cardiac Arrest Algorithm—2015 Update



1.3 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

As with other Parts of the *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation* (CPR) *and Emergency Cardiovascular Care* (ECC), Part 5 is based on the International Liaison Committee on Resuscitation (ILCOR) 2015 international evidence review process. ILCOR Basic Life Support (BLS) Task Force members identified and prioritized topics and questions with the newest or most controversial evidence, or those that were thought to be most important for resuscitation. This 2015 Guidelines Update is based on the systematic reviews and recommendations of the *2015 International Consensus on CPR and ECC Science With Treatment Recommendations*, "Part 3: Adult Basic Life Support and Automated External

Defibrillation."[1,2] In the online version of this document, live links are provided so the reader can connect directly to the systematic reviews on the ILCOR Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated by a combination of letters and numbers (eg, BLS 740). We encourage readers to use the links and review the evidence and appendix.

As with all AHA Guidelines, each 2015 recommendation is labeled with a Class of Recommendation (COR) and a Level of Evidence (LOE). New or updated recommendations use the newest AHA COR and LOE classification system, which contains modifications of the Class III recommendation and introduces LOE B-R (randomized studies) and B-NR (non-randomized studies) as well as LOE C-LD (based on limited data) and LOE C-EO (consensus of expert opinion).

The AHA process for identification and management of potential conflicts of interest was used, and potential conflicts for writing group members are listed at the end of each Part of the 2015 Guidelines Update. For additional information about the systematic review process or management of potential conflicts of interest, see "Part 2: Evidence Evaluation and Management of Conflicts of Interest" in the 2015 Guidelines Update and the related publication, "Part 2: Evidence Evaluation and Management of Conflicts of Interest" in the ILCOR *2015 International Consensus on CPR and ECC Science With Treatment Recommendations.*[3]

Because the 2015 publication represents the first Guidelines Update, it includes an appendix with all the 2015 recommendations for adult BLS as well as the recommendations from the 2010 Guidelines. If the 2015 ILCOR review resulted in a new or significantly revised Guidelines recommendation, that recommendation will be labeled *New* or *Updated*.

It is important to note that the 2010 recommendations used a previous version of the AHA COR and LOE classification system that was current in 2010. Any of the 2010 algorithms that have been revised as a result of recommendations in the 2015 Guidelines Update are contained in this publication. To emphasize that the algorithm has been modified, the words *2015 Update* will appear in the title of the algorithm.

2 Adult BLS and CPR Quality Overview - Updated

Sudden cardiac arrest remains a leading cause of death in the United States. Seventy percent of out-of-hospital cardiac arrests (OHCAs) occur in the home, and approximately 50% are unwitnessed. Outcome from OHCA remains poor: only 10.8% of adult patients with nontraumatic cardiac arrest who have received resuscitative efforts from emergency medical services (EMS) survive to hospital discharge.[4] In-hospital cardiac arrest (IHCA) has a better outcome, with 22.3% to 25.5% of adults surviving to discharge.[5]

BLS is the foundation for saving lives after cardiac arrest. Fundamental aspects of adult BLS include immediate recognition of sudden cardiac arrest and activation of the emergency response system, early CPR, and rapid defibrillation with an automated external defibrillator (AED). Initial recognition and response to heart attack and stroke are also considered part of BLS. This section presents the updated recommendations for adult BLS guidelines for lay rescuers and healthcare providers. Key changes and continued points of emphasis in this 2015 Guidelines Update include the following:

- The crucial links in the adult out-of-hospital Chain of Survival are unchanged from 2010; however, there is increased emphasis on the rapid identification of potential cardiac arrest by dispatchers, with immediate provision of CPR instructions to the caller.
- This Guidelines Update takes into consideration the ubiquitous presence of mobile phones that can allow the rescuer to activate the emergency response system without leaving the victim's side. For healthcare providers, these recommendations allow flexibility for activation of the emergency response to better match the provider's
  clinical setting.
- More data are available showing that high-quality CPR improves survival from cardiac arrest, including
  - Ensuring chest compressions of adequate rate
  - Ensuring chest compressions of adequate depth
  - Allowing full chest recoil between compressions
  - Minimizing interruptions in chest compressions
  - Avoiding excessive ventilation
- This Guidelines Update includes an updated recommendation for a simultaneous, choreographed approach to performance of chest compressions, airway management, rescue breathing, rhythm detection, and shocks (if indicated) by an integrated team of highly trained rescuers in applicable settings.

When the links in the Chain of Survival are implemented in an effective way, survival can approach 50% in EMS-treated patients after witnessed out-of-hospital ventricular fibrillation (VF) arrest.[6,7] Unfortunately, survival rates in many out-of-hospital and in-hospital settings fall far short of this figure. For example, survival rates after cardiac arrest due to VF vary from approximately 5% to 50% in both out-of-hospital and in-hospital settings.[8-10] This variation in outcome underscores the opportunity for improvement in many settings. The remaining links in the AHA Chain of Survival, namely advanced life support and integrated postarrest care, are covered in later Parts of this 2015 Guidelines Update (see "Part 7: Adult Advanced Cardiovascular Life Support" and "Part 8: Post–Cardiac Arrest Care").

3 Adult BLS Sequence - Updated

The steps of BLS consist of a series of sequential assessments and actions, which are illustrated in a simplified BLS algorithm that is unchanged from 2010.[11] The intent of the algorithm is to present the steps of BLS in a logical and concise manner that is easy for all types of rescuers to learn, remember, and perform. Integrated teams of highly trained rescuers may use a choreographed approach that accomplishes multiple steps and assessments simultaneously rather than in the sequential manner used by individual rescuers (eg, one rescuer activates the emergency response system while another begins chest compressions, a third either provides ventilation or retrieves the bag-mask device for rescue breaths, and a fourth retrieves and sets up a defibrillator). Moreover, trained rescuers are encouraged to simultaneously perform some steps (ie, checking for breathing and pulse at the same time) in an effort to reduce the time to first compressions. BLS assessments and actions for specific types of rescuers are summarized in (Table 3).

Table 3: 2015 - Basic Life Support Sequence

Open table in a new window

Basic Life Support Sequence			
Step	**Lay Rescuer Not Trained**	**Lay Rescuer Trained**	**Healthcare Provider**
1	Ensure scene safety.	Ensure scene safety.	Ensure scene safety.
2	Check for response.	Check for response.	Check for response.
3	Shout for nearby help. Phone or ask someone to phone 9-1-1 (the phone or caller with the phone remains at the victim's side, with the phone on speaker).	Shout for nearby help and activate the emergency response system (9-1-1, emergency response). If someone responds, ensure that the phone is at the side of the victim if at all possible.	Shout for nearby help/activate the resuscitation team; can activate the resuscitation team at this time or after checking breathing and pulse.
4	Follow the dispatcher's instructions.	Check for no breathing or only gasping; if none, begin CPR with compressions.	Check for no breathing or only gasping and check pulse (ideally simultaneously). Activation and retrieval of the AED/emergency equipment by either the lone healthcare provider or by the second person sent by the rescuer must occur no later than immediately after the check for no normal breathing and no pulse identifies cardiac arrest.

Step	Lay Rescuer Not Trained	Lay Rescuer Trained	Healthcare Provider
5	Look for no breathing or only gasping, at the direction of the dispatcher.	Answer the dispatcher's questions, and follow the dispatcher's instructions.	Immediately begin CPR, and use the AED/ defibrillator when available.
6	Follow the dispatcher's instructions.	Send the second person to retrieve an AED, if one is available.	When the second rescuer arrives, provide 2-person CPR and use AED/defibrillator.

AED indicates automated external defibrillator; and CPR, cardiopulmonary resuscitation.

3.1 Immediate Recognition and Activation of the Emergency Response System - Updated BLS 740 BLS 359

Emergency medical dispatch is an integral component of the EMS response.[12] Bystanders (lay responders) should immediately call their local emergency number to initiate a response any time they find an unresponsive adult victim. Healthcare providers should call for nearby help upon finding the victim unresponsive, but it would be practical for a healthcare provider to continue to assess for breathing and pulse simultaneously before fully activating the emergency response system.

For OHCA, a recent Scientific Statement recommended that all emergency dispatchers have protocols to guide the lay rescuer to check for breathing and to perform the steps of CPR, if needed.[13] When dispatchers ask bystanders to determine if breathing is present, bystanders often misinterpret agonal gasps or abnormal breathing as normal breathing. This erroneous information can result in failure by dispatchers to identify potential cardiac arrest and failure to instruct bystanders to initiate CPR immediately.[14-19] An important consideration is that brief, generalized seizures may be the first manifestation of cardiac arrest.[18,19]

3.1.1 2015 Evidence Review

Patients who are unresponsive and not breathing normally have a high likelihood of being in cardiac arrest.[16,19-26] Dispatcher CPR instructions substantially increase the likelihood of bystander CPR performance[27] and improve survival from cardiac arrest.[28-30]

3.1.2 2015 Recommendations - Updated

It is recommended that emergency dispatchers determine if a patient is unresponsive with abnormal breathing after acquiring the requisite information to determine the location of the event. (Class I, LOE C-LD)

If the patient is unresponsive with abnormal or absent breathing, it is reasonable for the emergency dispatcher to assume that the patient is in cardiac arrest. (Class IIa, LOE C-LD)

Dispatchers should be educated to identify unresponsiveness with abnormal breathing and agonal gasps across a range of clinical presentations and descriptions (Class I, LOE C-LD)

In order to increase bystander willingness to perform CPR, dispatchers should provide telephone CPR instructions to callers reporting an adult who is unresponsive and not breathing or not breathing normally (ie, only gasping). (Class I, LOE B)

The EMS system quality improvement process, including review of the quality of dispatcher CPR

instructions provided to specific callers, is considered an important component of a high-quality lifesaving program.[31-33] (Class IIa, LOE B)

The role of dispatcher-guided CPR and recommendations for dispatcher training are more fully described in "Part 4: Systems of Care and Continuous Quality Improvement."

3.2 Pulse Check - Updated

Studies have shown that both lay rescuers and healthcare providers have difficulty detecting a pulse.[34-43] Healthcare providers also may take too long to check for a pulse.[37,40]

The lay rescuer should not check for a pulse and should assume that cardiac arrest is present if an adult suddenly collapses or an unresponsive victim is not breathing normally.

The healthcare provider should take no more than 10 seconds to check for a pulse and, if the rescuer does not definitely feel a pulse within that time period, the rescuer should start chest compressions.[44,45] (Class IIa, LOE C)

Ideally, the pulse check is performed simultaneously with the check for no breathing or only gasping, to minimize delay in detection of cardiac arrest and initiation of CPR. Lay rescuers will not check for a pulse.

Interruptions of chest compressions to palpate for a spontaneous pulse or to otherwise check for return of spontaneous circulation (ROSC) can compromise vital organ perfusion.[46,47-52]

Accordingly lay rescuers should not interrupt chest compressions to palpate pulses or check for ROSC. (Class IIa, LOE C)

3.3 Early CPR - Updated BLS 661

Begin chest compressions as quickly as possible after recognition of cardiac arrest. The 2010 Guidelines included a major change for trained rescuers, who were instructed to begin the CPR sequence with chest compressions rather than breaths (C-A-B versus A-B-C) to minimize the time to initiation of chest compressions. The 2015 ILCOR BLS Task Force reviewed the most recent evidence evaluating the impact of this change in sequence on resuscitation.

3.3.1 2015 Evidence Review

Additional evidence published since 2010 showed that beginning the CPR sequence with compressions minimized time to first chest compression.[53-55]

3.3.2 2015 Recommendation - Updated

Similar to the 2010 Guidelines, it may be reasonable for rescuers to initiate CPR with chest compressions. (Class IIb, LOE C-LD)

The characteristics of effective chest compressions are described in the following section on BLS skills. As in the 2010 sequence, once chest compressions have been started, a trained rescuer delivers rescue breaths by mouth-to-mask or bag-mask device to provide oxygenation and ventilation. Recommendations regarding the duration of each breath and the need to make the chest rise were not updated in 2015.

3.4 Early Defibrillation With an AED - Updated

After activating the emergency response system, the lone rescuer retrieves an AED (if nearby and easily accessible) and then returns to the victim to attach and use the AED and provide CPR. When 2 or more trained rescuers are present, 1 rescuer begins CPR, starting with chest compressions, while a second rescuer activates the emergency response system and gets the AED (or a manual defibrillator in most hospitals) and other

emergency equipment. The AED or manual defibrillator is used as rapidly as possible, and both rescuers are expected to provide CPR with chest compressions and ventilation. The sequence for using an AED has not been updated from the 2010 Guidelines.

3.5 Rescuer-Specific CPR Strategies: Putting It All Together - Updated BLS 359 BLS 372

This section summarizes the sequence of CPR interventions to be performed by 3 types of prototypical rescuers after they activate the emergency response system. The specific steps for rescuers and healthcare providers (compression-only [Hands-Only™] CPR, conventional CPR with rescue breaths, and CPR with AED use) are determined by the rescuer's level of training.

3.6 Untrained Lay Rescuer - Updated

Bystander CPR may prevent VF from deteriorating to asystole, and it also increases the chance of defibrillation, contributes to preservation of heart and brain function, and improves survival from OHCA.[56] Bystander CPR rates remain unacceptably low in many communities. Because compression-only CPR is easier to teach, remember, and perform, it is preferred for "just-in-time" teaching for untrained lay rescuers.

3.6.1 2015 Evidence Review

When telephone guidance is needed, survival is improved when compression-only CPR is provided as compared with conventional CPR for adult victims of cardiac arrest.[57] Multiple studies have shown no difference in survival when adult victims of OHCA receive compression-only CPR versus conventional CPR.[28,30,58-65]

3.6.2 2015 Recommendations - Updated

Untrained lay rescuers should provide compression-only CPR, with or without dispatcher assistance. (Class I, LOE C-LD)

The rescuer should continue compression-only CPR until the arrival of an AED or rescuers with additional training. (Class I, LOE C-LD)

3.7 Trained Lay Rescuer - Updated

The 2010 Guidelines recommended that trained rescuers should provide rescue breaths in addition to chest compressions because they may encounter victims with asphyxial causes of cardiac arrest or they may be providing CPR for prolonged periods of time before additional help arrives.

3.7.1 2015 Recommendations - Updated

All lay rescuers should, at a minimum, provide chest compressions for victims of cardiac arrest. (Class I, LOE C-LD) In addition, if the trained lay rescuer is able to perform rescue breaths, he or she should add rescue breaths in a ratio of 30 compressions to 2 breaths.

The rescuer should continue CPR until an AED arrives and is ready for use or EMS providers take over care of the victim. (Class I, LOE C-LD)

3.8 Healthcare Provider - Updated

Optimally, all healthcare providers should be trained in BLS. As in past Guidelines, healthcare providers are trained to provide both compressions and ventilation.

3.8.1 2015 Evidence Review

There is concern that delivery of chest compressions without assisted ventilation for prolonged periods could be less effective than conventional CPR (compressions plus breaths) because the arterial oxygen content will decrease as CPR duration increases. This concern is especially pertinent in the setting of asphyxial cardiac

arrest.[59] For the 2015 ILCOR evidence review, the Adult BLS Task Force reviewed observational studies and randomized controlled trials (RCTs), including studies of dispatcher-guided CPR; much of the research involved patients whose arrests were presumed to be of cardiac origin and in settings with short EMS response times. It is likely that a time threshold exists beyond which the absence of ventilation may be harmful,[58,60] and the generalizability of the findings to all settings must be considered with caution.

3.8.2 2015 Recommendation - Updated

It is reasonable for healthcare providers to provide chest compressions and ventilation for all adult patients in cardiac arrest, from either a cardiac or noncardiac cause. (Class IIa, LOE C-LD)

In addition, it is realistic for healthcare providers to tailor the sequence of rescue actions to the most likely cause of arrest. For example, if a lone healthcare provider sees an adolescent suddenly collapse, the provider may assume that the victim has had a sudden arrhythmic arrest and call for help, get a nearby AED, return to the victim to use the AED, and then provide CPR.

The related 2010 recommendation is as follows:

If a lone healthcare provider aids an adult drowning victim or a victim of foreign body airway obstruction who becomes unconscious, the healthcare provider may give about 5 cycles (approximately 2 minutes) of CPR before activating the emergency response system. (Class IIa, LOE C)

3.9 Delayed Ventilation - Updated BLS 360

Several EMS systems have tested a strategy of initial continuous chest compressions with delayed positive-pressure ventilation for adult OHCA.

3.9.1 2015 Evidence Review

During adult OHCA, survival to hospital discharge was improved by the use of an initial period of continuous chest compressions.[66,67] Three observational studies showed improved survival with favorable neurologic status when EMS providers performed a set of continuous chest compressions with delayed ventilation for victims with witnessed arrest or shockable rhythm.[68-70] These studies were performed in systems that use priority-based, multitiered response in both urban and rural communities, and all included a “bundled” package of care that included up to 3 cycles of passive oxygen insufflation, airway adjunct insertion, and 200 continuous chest compressions with interposed shocks. Providers received additional training with emphasis on provision of high-quality chest compressions.

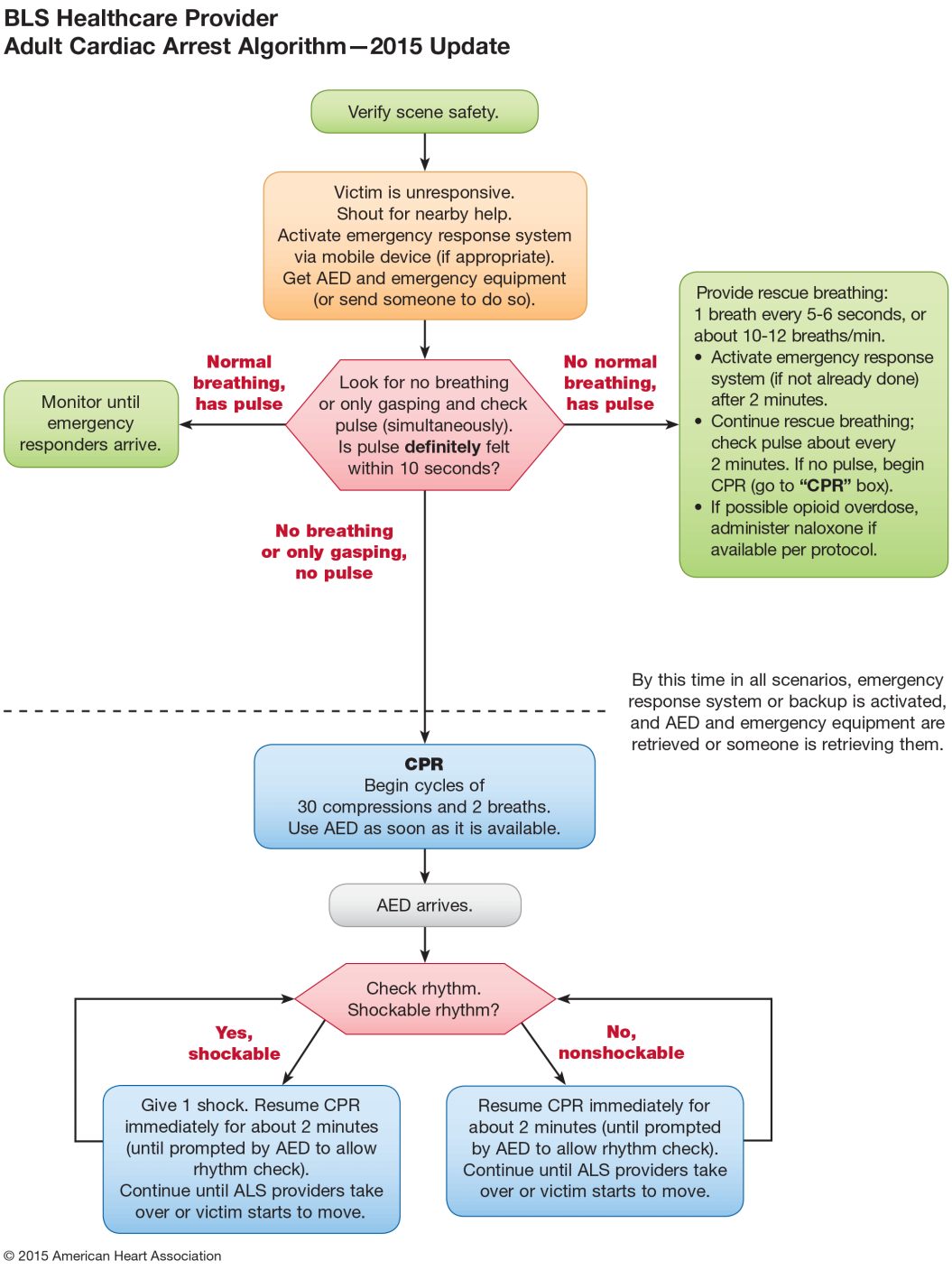
3.9.2 2015 Recommendation - New

For witnessed OHCA with a shockable rhythm, it may be reasonable for EMS systems with priority-based, multitiered response to delay positive-pressure ventilation by using a strategy of up to 3 cycles of 200 continuous compressions with passive oxygen insufflation and airway adjuncts. (Class IIb, LOE C-LD)

4 Adult BLS Skills - Updated

The sequence of BLS skills for the healthcare provider is depicted in the BLS Healthcare Provider Adult Cardiac Arrest Algorithm (Figure 1). There are minor changes to the 2010 Guidelines as the result of new evidence regarding compression rate, feedback received from the training network, and new evidence regarding the incidence of opioid overdose and the effects of naloxone-administration programs.

Figure 1: BLS Healthcare Provider Adult Cardiac Arrest Algorithm—2015 Update



4.1 Verify Scene Safety - Updated

Rescuers arriving on the scene of an emergency should verify that the environment in which they are approaching a patient is safe for the provider. This is accomplished by a quick scan of the patient's location and surroundings to make sure there are no imminent physical threats such as toxic or electrical hazards.

Because of the difficulty in providing effective chest compressions while moving the patient during CPR, the resuscitation should generally be conducted where the patient is found. (Class IIa, LOE C)

This may not be possible if the environment is dangerous.

4.2 Recognition of Arrest - Updated BLS 359 BLS 740

The necessary first step in the treatment of cardiac arrest is immediate recognition. Initial major steps for bystanders remain unchanged from the 2010 Guidelines and are provided below. CPR training, both formal classroom training and "just-in-time" training such as that given through a dispatch center, should emphasize how to recognize occasional gasps.

Dispatchers should instruct rescuers to provide CPR if the victim is unresponsive with no normal breathing, even when the victim demonstrates occasional gasps. (Class I, LOE C-LD)

The 2010 Guidelines are as follows:

Bystanders may witness the sudden collapse of a victim or find someone who appears lifeless. At that time several steps should be initiated. Before approaching a victim, the rescuer must ensure that the scene is safe and then check for response. To do this, tap the victim on the shoulder and shout, "Are you all right?" If the victim is responsive he or she will answer, move, or moan. If the victim remains unresponsive, the lay rescuer should activate the emergency response system.

When phoning 911 for help, the rescuer should be prepared to answer the dispatcher's questions about the location of the incident, the events of the incident, the number and condition of the victim(s), and the type of aid provided. If rescuers never learned or have forgotten how to do CPR, they should also be prepared to follow the dispatcher's instructions. Finally the rescuer making the phone call should hang up only when instructed to do so by the dispatcher.

After activation of the emergency response system, all rescuers should immediately begin CPR (see steps below) for adult victims who are unresponsive with no breathing or no normal breathing (only gasping).

Professional as well as lay rescuers may be unable to accurately determine the presence or absence of adequate or normal breathing in unresponsive victims[34,71] because the airway is not open[72] or because the victim has occasional gasps, which can occur in the first minutes after SCA and may be confused with adequate breathing. Occasional gasps do not necessarily result in adequate ventilation.

Studies have shown that both laypersons and healthcare providers have difficulty detecting a pulse.[34-43] For this reason pulse check was deleted from training for lay rescuers several years ago, and is deemphasized in training for healthcare providers. The lay rescuer should assume that cardiac arrest is present and should begin CPR if an adult suddenly collapses or an unresponsive victim is not breathing or not breathing normally (ie, only gasping).

Healthcare providers may take too long to check for a pulse[37,40] and have difficulty determining if a pulse is present or absent.[37,40,44] There is no evidence, however, that checking for breathing, coughing, or movement is superior for detection of circulation.[73]

The four related 2010 recommendations are as follows:

The rescuer should treat the victim who has occasional gasps as if he or she is not breathing. (Class I, LOE C)

If the victim also has absent or abnormal breathing (ie, only gasping), the rescuer should assume the victim is in cardiac arrest.[74,75,76] (Class I, LOE C)

The health care provider should also check for no breathing or no normal breathing (ie, only gasping) while checking for responsiveness; if the healthcare provider finds the victim is unresponsive with no breathing or no normal breathing (ie, only gasping), the rescuer should assume the victim is in cardiac arrest and immediately activate the emergency response system.[74,75,76] (Class I, LOE C)

Because delays in chest compressions should be minimized, the healthcare provider should take no more than 10 seconds to check for a pulse; and if the rescuer does not definitely feel a pulse within that time period the rescuer should start chest compressions. (Class IIa, LOE C)

4.2.1 Scenario: Pulse Present, Normal Breathing - Updated

Closely monitor the patient, and activate the emergency response system as indicated by location and patient condition.

4.2.2 Scenario: Pulse Present, No Normal Breathing - Updated BLS 811 BLS 891

This topic was last reviewed in 2010. The 2015 ILCOR systematic review addressed whether bystander-administered naloxone to patients with suspected opioid-associated cardio-pulmonary arrest affected resuscitation outcomes. The evaluation did not focus on opioid-associated respiratory arrest.

The authors acknowledge the epidemiologic data demonstrating the large burden of disease from lethal opioid overdoses as well as targeted national strategies for bystander-administered naloxone for people at risk. Since the 2014 US Food and Drug Administration approval of the use of a naloxone autoinjector by lay rescuers and healthcare providers,[77] the training network has requested information regarding the best way to incorporate such a device in the BLS sequence. In response to requests, the ILCOR BLS Task Force performed an additional search for evidence of effectiveness of the use of naloxone for opioid overdose.

4.2.2.1 2015 Summary of Evidence

There were no published studies to determine if adding intranasal or intramuscular naloxone to conventional CPR is superior to conventional CPR alone for the management of adults and children with suspected opioid-associated cardiac or respiratory arrest in the prehospital setting. However, the additional search for available evidence regarding overdose education and naloxone distribution programs yielded 3 observational before-and-after studies. One study observed a dose-response effect with 0.73 (95% confidence interval [CI], 0.57–0.91) and 0.54 (95% CI, 0.39–0.76) adjusted rate ratios for lethal overdose in communities with low and high implementation, respectively.[78] The remaining 2 observational studies reported reductions in rate ratios for lethal overdose of 0.62 (95% CI, 0.54–0.72)[79] and 0.70 (95% CI, 0.65–0.74) in individual communities that implemented programs to address opioid overdose.[80]

4.2.2.2 2015 Recommendations - New

For a patient with known or suspected opioid overdose who has a definite pulse but no normal breathing or only gasping (ie, a respiratory arrest), in addition to providing standard BLS care, it is reasonable for appropriately trained BLS healthcare providers to administer intramuscular or intranasal naloxone. (Class IIa, LOE C-LD)

For patients in cardiac arrest, medication administration is ineffective without concomitant chest compressions for drug delivery to the tissues, so naloxone administration may be considered after initiation of CPR if there is high suspicion for opiate overdose. (Class IIb, LOE C-EO)

It is reasonable to provide opioid overdose response education with or without naloxone distribution to persons at risk for opioid overdose (or those living with or in frequent contact with such persons). (Class IIa, LOE C-LD)

Information regarding lay rescuer education and the use of naloxone for known or suspected victims of opioid overdose is discussed in "Part 10: Special Circumstances of Resuscitation."

4.2.3 Scenario: Pulse Absent, No Breathing or Only Gasping - Updated

As in the 2010 Guidelines, rescuers should initiate CPR and use an AED as soon as possible. By this point in all potential scenarios, the emergency response system is activated, and a defibrillator and emergency equipment

are retrieved or requested.

4.3 Technique: Chest Compressions - Updated

Chest compressions are the key component of effective CPR. Chest compressions consist of forceful rhythmic applications of pressure over the lower half of the sternum. These compressions create blood flow by increasing intrathoracic pressure and directly compressing the heart. This generates blood flow and oxygen delivery to the myocardium and brain.

Characteristics of chest compressions include their depth, rate, and degree of recoil. The quality of CPR can also be characterized by the frequency and duration of interruptions in chest compressions—when such interruptions are minimized, the chest compression fraction (percent of total resuscitation time that compressions are performed) is higher. Finally, with high-quality CPR, the rescuer avoids excessive ventilation. These CPR performance elements affect intrathoracic pressure, coronary perfusion pressure, cardiac output, and, in turn, clinical outcomes.

Effective chest compressions are essential for providing blood flow during CPR. For this reason all patients in cardiac arrest should receive chest compressions. [81-85] ***(Class I, LOE B)***

4.3.1 Hand Position During Compressions - Updated BLS 357

The 2015 ILCOR systematic review addressed whether hand position placement for chest compressions affected resuscitation outcomes. Different rescuer hand positions alter the mechanics of chest compressions and may, in turn, influence their quality and effectiveness.

4.3.1.1 2015 Summary of Evidence

Only a few human studies involving a total of fewer than 100 cardiac arrest patients have evaluated hand position during CPR.[86-88] These investigations assessed hand placement on the lower third of the sternum compared with the center of the chest in a crossover design, and they measured physiologic endpoints, such as blood pressure and end-tidal carbon dioxide ($ETCO_2$). The studies have not provided conclusive or consistent results about the effects of hand placement on resuscitation outcomes.

4.3.1.2 2015 Recommendation - Unchanged

Consistent with the 2010 Guidelines, it is reasonable to position hands for chest compressions on the lower half of the sternum in adults with cardiac arrest. (Class IIa, LOE C-LD)

The full 2010 recommendation is as follows.

The rescuer should place the heel of one hand on the center (middle) of the victim's chest (which is the lower half of the sternum) and the heel of the other hand on top of the first so that the hands are overlapped and parallel. [89-92] ***(Class IIa, LOE B)***

4.3.2 Chest Compression Rate - Updated BLS 343

In the 2010 Guidelines, the recommended compression rate was *at least* 100 compressions per minute. The 2015 Guidelines Update incorporates new evidence about the potential for an upper threshold of rate beyond which outcome may be adversely affected.

The 2015 ILCOR systematic review addressed whether compression rates different from 100/min influence physiologic or clinical outcomes. Chest compression rate is defined as the actual rate used during each continuous period of chest compressions. This rate differs from the number of chest compressions delivered per unit of time, which takes into account any interruptions in chest compressions.

4.3.2.1 2015 Summary of Evidence

Evidence involving compression rate is derived from observational human studies that evaluate the relationship

between compression rate and outcomes including survival to hospital discharge, return of spontaneous circulation (ROSC), and various physiologic measures, such as blood pressure and end-tidal CO_2. These investigations suggest that there may be an optimal zone for the rate of manual chest compressions—between 100/min and 120/min—that on average is associated with improved survival.[93,94] Importantly, there is an interdependent relationship between compression rate and compression depth during manual chest compressions: as rate increases to greater than 120/min, depth decreases in a dose-dependent manner.[93] For example, the proportion of compressions less than 38 mm (less than 3.8 cm or 1.5 inches) was about 35% for a compression rate of 100 to 119/min but increased to 50% for a compression rate of 120 to 139/min and 70% for a compression rate of greater than 140/min.

4.3.2.2 2015 Recommendation - Updated

In adult victims of cardiac arrest, it is reasonable for rescuers to perform chest compressions at a rate of 100/min to 120/min. (Class IIa, LOE C-LD)

4.3.3 Chest Compression Depth - Updated BLS 366

The 2015 ILCOR systematic review addressed whether a chest compression depth different from 2 inches (5 cm) influences physiologic or clinical outcomes. The depth of chest compression can affect the relative increase in intrathoracic pressure and, in turn, influence forward blood flow from the heart and great vessels to the systemic circulation. In the 2010 Guidelines, the recommended compression depth was *at least* 2 inches (5 cm). The 2015 Guidelines Update incorporates new evidence about the potential for an upper threshold of compression depth beyond which outcomes may be adversely affected.

4.3.3.1 2015 Summary of Evidence

Evidence involving compression depth is derived from observational human studies that evaluate the relationship between compression depth and outcomes including survival with favorable neurologic outcome, survival to hospital discharge, and ROSC. Studies often classify compression depth differently, using distinct categories of depth or using an average depth for a given portion of the resuscitation.

Even with this heterogeneity, there is consistent evidence that achieving compression depth of approximately 5 cm is associated with greater likelihood of favorable outcomes compared with shallower compressions.[95-103] In the largest study to date (n=9136), the optimal compression depth with regard to survival occurred within the range of 41 to 55 mm (4.1 to 5.5 cm, or 1.61 to 2.2 inches).[98] Less evidence is available about whether there is an upper threshold beyond which compressions may be too deep. During manual CPR, injuries are more common when compression depth is greater than 6 cm (2.4 inches) than when it is between 5 and 6 cm (2 and 2.4 inches).[104] Importantly, chest compressions performed by professional rescuers are more likely to be too shallow (ie, less than 40 mm [4 cm] or 1.6 inches) and less likely to exceed 55 mm (5.5 cm or 2.2 inches).[98]

4.3.3.2 2015 Recommendation - Updated

During manual CPR, rescuers should perform chest compressions to a depth of at least 2 inches or 5 cm for an average adult, while avoiding excessive chest compression depths (greater than 2.4 inches or 6 cm). (Class I, LOE C-LD)

Additionally, the 2010 Guidelines further specified that chest compressions should be performed with chest compression and chest recoil/relaxation times approximately equal.[105,106] (Class IIb, LOE C)

4.3.4 Chest Wall Recoil - Updated BLS 367

The 2015 ILCOR systematic reviews addressed whether full chest wall recoil compared with incomplete recoil influenced physiologic or clinical outcomes. Full chest wall recoil occurs when the sternum returns to its natural or neutral position during the decompression phase of CPR. Chest wall recoil creates a relative negative intrathoracic pressure that promotes venous return and cardiopulmonary blood flow. Leaning on the chest wall between compressions precludes full chest wall recoil. Incomplete recoil could increase intrathoracic pressure and reduce venous return, coronary perfusion pressure, and myocardial blood flow and could potentially

influence resuscitation outcomes.[107,108] Observational studies indicate that leaning is common during CPR in adults and children.[109,110]

4.3.4.1 2015 Summary of Evidence

There are no human studies reporting the relationship between chest wall recoil and clinical outcomes. The evidence is derived from 2 animal studies and a pediatric study of patients not in cardiac arrest.[107,111,112] In all 3 studies, an increased force of leaning (incomplete recoil) was associated with a dose-dependent decrease in coronary perfusion pressure. Based on 2 studies, the relationship between leaning and cardiac output was inconsistent.[107,111]

4.3.4.2 2015 Recommendation - Updated

It is reasonable for rescuers to avoid leaning on the chest between compressions to allow full chest wall recoil for adults in cardiac arrest. (Class IIa, LOE C-LD)

4.4 Minimizing Interruptions in Chest Compressions - Updated BLS 358

As in the 2010 Guidelines, minimizing interruptions in chest compressions remains a point of emphasis. The 2015 ILCOR systematic review addressed whether shorter compared with longer interruptions in chest compressions influenced physiologic or clinical outcomes. Interruptions in chest compressions can be intended as part of required care (ie, rhythm analysis and ventilation) or unintended (ie, rescuer distraction).

Chest compression fraction is a measurement of the proportion of time that compressions are performed during a cardiac arrest. An increase in chest compression fraction can be achieved by minimizing pauses in chest compressions. The optimal goal for chest compression fraction has not been defined. The AHA expert consensus is that a chest compression fraction of 80% is achievable in a variety of settings.[113]

4.4.1 2015 Summary of Evidence

Evidence involving the consequences of compression interruptions is derived from observational and randomized human studies of cardiac arrest. These studies provide heterogeneous results. Observational studies demonstrate an association between a shorter duration of compression interruption for the perishock period and a greater likelihood of shock success,[100] ROSC,[114] and survival to hospital discharge.[115,116] Other observational studies have demonstrated an association between higher chest compression fraction and likelihood of survival among patients with shockable rhythms, and return of circulation among patients with nonshockable rhythms.[117,118] In contrast, the results of a randomized trial comparing a bundle of changes between the 2000 and 2005 Guidelines showed no survival difference when perishock pauses were reduced.[119] In an investigation of first responders equipped with AEDs, the duration of pauses specific to ventilation was not associated with survival.[120]

4.4.2 2015 Recommendations - Updated

In adult cardiac arrest, total preshock and postshock pauses in chest compressions should be as short as possible. (Class I, LOE C-LD)

For adults in cardiac arrest receiving CPR without an advanced airway, it is reasonable to pause compressions for less than 10 seconds to deliver 2 breaths. (Class IIa, LOE C-LD)

In adult cardiac arrest with an unprotected airway, it may be reasonable to perform CPR with the goal of a chest compression fraction as high as possible, with a target of at least 60%. (Class IIb, LOE C-LD)

4.4.3 Rescuer Fatigue

The 2010 Guidelines provided specific guidance for switching compressors:

Rescuer fatigue may lead to inadequate compression rates or depth.[121-123] Significant fatigue and shallow

compressions are common after 1 minute of CPR, although rescuers may not recognize that fatigue is present for ?5 minutes.[122]

When 2 or more rescuers are available it is reasonable to switch chest compressors approximately every 2 minutes (or after about 5 cycles of compressions and ventilations at a ratio of 30:2) to prevent decreases in the quality of compressions. (Class IIa, LOE B)

Consider switching compressors during any intervention associated with appropriate interruptions in chest compressions (eg, when an AED is delivering a shock). Every effort should be made to accomplish this switch in <5 seconds. If the 2 rescuers are positioned on either side of the patient, 1 rescuer will be ready and waiting to relieve the “working compressor” every 2 minutes.

4.5 Compression-to-Ventilation Ratio - Updated BLS 362

In 2005, the recommended compression-to-ventilation ratio for adults in cardiac arrest was changed from 15:2 to 30:2. The 2015 ILCOR systematic review addressed whether compression-to-ventilation ratios different from 30:2 influenced physiologic or clinical outcomes. In cardiac arrest patients without an advanced airway, chest compressions are briefly paused to provide rescue breaths in order to achieve adequate air entry.

4.5.1 2015 Summary of Evidence

Evidence involving the compression-to-ventilation ratio is derived from observational before-and-after human studies in the out-of-hospital setting.[124-127] These studies compared the compression-to-ventilation ratio of 30:2 with 15:2 for survival and other outcomes. However, the treatment of the comparison groups also differed in other respects that typically reflected changes from the 2000 to 2005 Guidelines, such as an increase in the duration of CPR cycles between rhythm analyses from 1 to 2 minutes. Overall, outcomes were typically better in the 30:2 group compared with the 15:2 group.

4.5.2 2015 Recommendation - Unchanged

Consistent with the 2010 Guidelines, it is reasonable for rescuers to provide a compression-to-ventilation ratio of 30:2 for adults in cardiac arrest. (Class IIa, LOE C-LD)

4.6 Layperson - Compression-Only CPR Versus Conventional CPR (Chest Compressions Plus Rescue Breaths) - Updated BLS 372

The 2015 ILCOR systematic review addressed whether lay-person CPR consisting of chest compressions alone compared with conventional CPR (compressions plus rescue breaths) influenced physiologic or clinical outcomes.

4.6.1 2015 Summary of Evidence

Evidence comparing layperson compression-only CPR with conventional CPR is derived from RCTs of dispatcher-guided CPR and observational studies. There were no short-term survival differences in any of the 3 individual randomized trials comparing the 2 types of dispatcher instructions.[28,30,128] Based on meta-analysis of the 2 largest randomized trials (total n=2496), dispatcher instruction in compression-only CPR was associated with long-term survival benefit compared with instruction in chest compressions and rescue breathing.[57] Among the observational studies, survival outcomes were not different when comparing the 2 types of CPR.[58-65,129-133]

4.6.2 2015 Recommendations - Updated

The following recommendations are consistent with 2010 Guidelines involving layperson CPR.

Dispatchers should provide chest compression-only CPR instructions to callers for adults with suspected OHCA. (Class I, LOE C-LD)

For lay rescuers, compression-only CPR is a reasonable alternative to conventional CPR in the adult cardiac arrest patient. (Class IIa, LOE C-LD)

For trained lay rescuers, it is reasonable to provide ventilation in addition to chest compressions for the adult in cardiac arrest. (Class IIa, LOE C-LD)

4.7 Managing the Airway - Updated

A significant change in the 2010 Guidelines was the initiation of chest compressions before ventilation (ie, a change in the sequence from A-B-C to C-A-B). The prioritization of circulation (C) over ventilation reflected the overriding importance of blood flow generation for successful resuscitation and practical delays inherent to initiation of rescue breaths (B). Physiologically, in cases of sudden cardiac arrest, the need for assisted ventilation is a lower priority because of the availability of adequate arterial oxygen content at the time of a sudden cardiac arrest. The presence of this oxygen and its renewal through gasping and chest compressions (provided there is a patent airway) also supported the use of compression-only CPR and the use of passive oxygen delivery.

4.7.1 Open the Airway: Lay Rescuer - Updated FA 772

The recommendation for trained and untrained lay rescuers remains the same as in 2010.

For victims with suspected spinal injury, rescuers should initially use manual spinal motion restriction (eg, placing 1 hand on either side of the patient's head to hold it still) rather than immobilization devices, because use of immobilization devices by lay rescuers may be harmful. (Class III: Harm, LOE C-LD)

Spinal immobilization devices may interfere with maintaining a patent airway,[134,135] but ultimately the use of such a device may be necessary to maintain spinal alignment during transport. This treatment recommendation is explored in depth in "Part 15: First Aid."

The trained lay rescuer who feels confident that he or she can perform both compressions and ventilations should open the airway using a head tilt–chin lift maneuver. (Class IIa, LOE B)

For the rescuer providing Hands-Only CPR, there is insufficient evidence to recommend the use of any specific passive airway (such as hyperextending the neck to allow passive ventilation).

4.7.2 Open the Airway: Healthcare Provider - Updated

A healthcare provider uses the head tilt–chin lift maneuver to open the airway of a victim with no evidence of head or neck trauma. The evidence for this was last reviewed in 2010. For victims with suspected spinal cord injury, this evidence was last reviewed in 2010 and there is no change in treatment recommendation.

A healthcare provider should use the head tilt–chin lift maneuver to open the airway of a victim with no evidence of head or neck trauma.

Although the head tilt–chin lift technique was developed using unconscious, paralyzed adult volunteers and has not been studied in victims with cardiac arrest, clinical[136] and radiographic evidence[137,138] and a case series[139] have shown it to be effective. (Class IIa, LOE B)

Between 0.12 and 3.7% of victims with blunt trauma have a spinal injury,[140-142] and the risk of spinal injury is increased if the victim has a craniofacial injury,[143,144] a Glasgow Coma Scale score of <8,[145,146] or both.[144,145]

If healthcare providers suspect a cervical spine injury, they should open the airway using a jaw thrust without head extension.[139] (Class IIb, LOE C)

Because maintaining a patent airway and providing adequate ventilation are priorities in CPR (Class I, LOE C), use the head tilt–chin lift maneuver if the jaw thrust does not adequately open the airway.

4.7.3 Rescue Breathing - Updated

The 2015 Guidelines Update makes many of the same recommendations regarding rescue breathing as were made in 2005 and 2010. Effective performance of rescue breathing or bag-mask or bag-tube ventilation is an essential skill and requires training and practice. During CPR without an advanced airway, a compression-to-ventilation ratio of 30:2 is used.

Deliver each rescue breath over 1 second. (Class IIa, LOE C)

Give a sufficient tidal volume to produce visible chest rise.[147] (Class IIa, LOE C)

Studies in anesthetized adults (with normal perfusion) suggest that a tidal volume of 8 to 10 mL/kg maintains normal oxygenation and elimination of CO2. During CPR, cardiac output is ?25% to 33% of normal, so oxygen uptake from the lungs and CO2 delivery to the lungs are also reduced. As a result, a low minute ventilation (lower than normal tidal volume and respiratory rate) can maintain effective oxygenation and ventilation.[147,148,149,150]

For that reason during adult CPR tidal volumes of approximately 500 to 600 mL (6 to 7 mL/kg) should suffice.[151-153] (Class IIa, LOE B)

This is consistent with a tidal volume that produces visible chest rise.

Patients with airway obstruction or poor lung compliance may require high pressures to be properly ventilated (to make the chest visibly rise). A pressure-relief valve on a resuscitation bag-mask may prevent the delivery of a sufficient tidal volume in these patients.[154] Ensure that the bag-mask device allows you to bypass the pressure-relief valve and use high pressures, if necessary, to achieve visible chest expansion.[155]

Excessive ventilation is unnecessary and can cause gastric inflation and its resultant complications, such as regurgitation and aspiration.[156-158] (Class III, LOE B)

More important, excessive ventilation can be harmful because it increases intrathoracic pressure, decreases venous return to the heart, and diminishes cardiac output and survival.[158]

In summary, rescuers should avoid excessive ventilation (too many breaths or too large a volume) during CPR. (Class III, LOE B)

During CPR the primary purpose of assisted ventilation is to maintain adequate oxygenation; the secondary purpose is to eliminate CO_2. However, the optimal inspired oxygen concentration, tidal volume and respiratory rate to achieve those purposes are not known. As noted above, during the first minutes of sudden VF cardiac arrest, rescue breaths are not as important as chest compressions[159,160,161] because the oxygen content in the noncirculating arterial blood remains unchanged until CPR is started; the blood oxygen content then continues to be adequate during the first several minutes of CPR. In addition, attempts to open the airway and give rescue breaths (or to access and set up airway equipment) may delay the initiation of chest compressions.[162] These issues support the CAB approach of the *2010 AHA Guidelines for CPR and ECC* (ie, starting with **C**hest Compressions prior to **A**irway and **B**reathing).

For victims of prolonged cardiac arrest both ventilations and compressions are important because over time oxygen in the blood is consumed and oxygen in the lungs is depleted (although the precise time course is unknown). Ventilations and compressions are also important for victims of asphyxial arrest, such as children and drowning victims, because they are hypoxemic at the time of cardiac arrest.[163,164]

4.7.3.1 Mouth-to-Mouth Rescue Breathing

The technique for mouth-to-mouth rescue breathing was last reviewed in 2010.[11]

Mouth-to-mouth rescue breathing provides oxygen and ventilation to the victim.[165] To provide mouth-to-mouth rescue breaths, open the victim's airway, pinch the victim's nose, and create an airtight mouth-to-mouth seal.

Give 1 breath over 1 second, take a "regular" (not a deep) breath, and give a second rescue breath over 1 second. (Class IIb, LOE C)

Taking a regular rather than a deep breath prevents the rescuer from getting dizzy or lightheaded and prevents overinflation of the victim's lungs. The most common cause of ventilation difficulty is an improperly opened airway,[72] so if the victim's chest does not rise with the first rescue breath, reposition the head by performing the head tilt–chin lift again and then give the second rescue breath.

If an adult victim with spontaneous circulation (ie, strong and easily palpable pulses) requires support of ventilation, the healthcare provider should give rescue breaths at a rate of about 1 breath every 5 to 6 seconds, or about 10 to 12 breaths per minute. (Class IIb, LOE C)

Each breath should be given over 1 second regardless of whether an advanced airway is in place. Each breath should cause visible chest rise.

4.7.3.2 Mouth–to–Barrier Device Breathing

The technique for mouth–to–barrier device breathing was last reviewed in 2010.[11]

Some healthcare providers[166-168] and lay rescuers state that they may hesitate to give mouth-to-mouth rescue breathing and prefer to use a barrier device. The risk of disease transmission through mouth to mouth ventilation is very low, and it is reasonable to initiate rescue breathing with or without a barrier device. When using a barrier device the rescuer should not delay chest compressions while setting up the device.

4.7.3.3 Mouth-to-Nose and Mouth-to-Stoma Ventilation

The technique for mouth-to-nose and mouth-to-stoma ventilation was last reviewed in 2010.[11]

Mouth-to-nose ventilation is recommended if ventilation through the victim's mouth is impossible (eg, the mouth is seriously injured), the mouth cannot be opened, the victim is in water, or a mouth-to-mouth seal is difficult to achieve. (Class IIa, LOE C)

A case series suggests that mouth-to-nose ventilation in adults is feasible, safe, and effective.[169] Give mouth-to-stoma rescue breaths to a victim with a tracheal stoma who requires rescue breathing.

A reasonable alternative is to create a tight seal over the stoma with a round, pediatric face mask. (Class IIb, LOE C)

There is no published evidence on the safety, effectiveness, or feasibility of mouth-to-stoma ventilation. One study of patients with laryngectomies showed that a pediatric face mask created a better peristomal seal than a standard ventilation mask.[170]

4.7.3.4 Ventilation With Bag-Mask Device - Updated

When using a self-inflating bag, rescuers can provide bag-mask ventilation with room air or oxygen. A bag-mask device can provide positive-pressure ventilation without an advanced airway and may result in gastric inflation and its potential complications.

4.7.3.4.1 The Bag-Mask Device - Updated

The elements of a bag-mask device are the same as those used in 2010.[11]

A bag-mask device should have the following[171]: a nonjam inlet valve; either no pressure relief valve or a pressure relief valve that can be bypassed; standard 15-mm/22-mm fittings; an oxygen reservoir to allow delivery of high oxygen concentrations; a nonrebreathing outlet valve that cannot be obstructed by foreign material and will not jam with an oxygen flow of 30 L/min; and the capability to function satisfactorily under common environmental conditions and extremes of temperature.

Masks should be made of transparent material to allow detection of regurgitation. They should be capable of creating a tight seal on the face, covering both mouth and nose. Masks should be fitted with an oxygen (insufflation) inlet and have a standard 15-mm/22-mm connector.[172] They should be available in one adult and several pediatric sizes.

4.7.3.4.2 Bag-Mask Ventilation

Bag-mask ventilation is a challenging skill that requires considerable practice for competency.[173,174] Bag-mask ventilation is not the recommended method of ventilation for a lone rescuer during CPR. It is most effective when provided by 2 trained and experienced rescuers. One rescuer opens the airway and seals the mask to the face while the other squeezes the bag. Both rescuers watch for visible chest rise.[173,175]

The rescuer should use an adult (1 to 2 L) bag to deliver approximately 600 mL tidal volume[176-178] for adult victims. This amount is usually sufficient to produce visible chest rise and maintain oxygenation and normocarbia in apneic patients.[151-153] (Class IIa, LOE C)

If the airway is open and a good, tight seal is established between face and mask, this volume can be delivered by squeezing a 1-L adult bag about two thirds of its volume or a 2-L adult bag about one third of its volume.

As long as the patient does not have an advanced airway in place, the rescuers should deliver cycles of 30 compressions and 2 breaths during CPR. The rescuer delivers breaths during pauses in compressions and delivers each breath over approximately 1 second. (Class IIa, LOE C-LD)

The healthcare provider should use supplementary oxygen (O2 concentration >40%, at a minimum flow rate of 10 to 12 L/min) when available.

4.7.3.5 Ventilation With a Supraglottic Airway

Supraglottic airway devices such as the LMA, the esophageal-tracheal combitube and the King airway device, are currently within the scope of BLS practice in a number of regions (with specific authorization from medical

control).

Ventilation with a bag through these devices provides an acceptable alternative to bag-mask ventilation for well-trained healthcare providers who have sufficient experience to use the devices for airway management during cardiac arrest.[179-184] (Class IIa, LOE B)

It is not clear that these devices are any more or less complicated to use than a bag and mask; training is needed for safe and effective use of both the bag-mask device and each of the advanced airways. These devices are discussed in greater detail in Part 7: Adult Advanced Cardiovascular Life Support of the Web-based Integrated Guidelines.

4.7.3.6 Ventilation With an Advanced Airway - Updated BLS 808

When the victim has an advanced airway in place during CPR, rescuers no longer deliver cycles of 30 compressions and 2 breaths (ie, they no longer interrupt compressions to deliver 2 breaths). Instead, it may be reasonable for the provider to deliver 1 breath every 6 seconds (10 breaths per minute) while continuous chest compressions are being performed. (Class IIb, LOE C-LD)

This represents a simplification of the 2010 Guidelines recommendations, to provide a single number that rescuers will need to remember for ventilation rate, rather than a range of numbers.

4.7.4 Passive Oxygen Versus Positive-Pressure Oxygen During CPR - Updated BLS 352

Some EMS systems have studied the use of passive oxygen flow during chest compressions without positive-pressure ventilation, an option known as passive oxygen administration.

4.7.4.1 2015 Evidence Summary

Two studies compared positive-pressure ventilation through an endotracheal tube to continuous delivery of oxygen or air directly into the trachea after intubation by using a modified endotracheal tube that had microcannulas inserted into its inner wall.[185,186] A third study compared bag-mask ventilation to high-flow oxygen delivery by nonrebreather face mask after oropharyngeal airway insertion as part of a resuscitation bundle that also included uninterrupted preshock and postshock chest compressions and early epinephrine administration.[68] Continuous tracheal delivery of oxygen or air through the modified endotracheal tube was associated with lower arterial PCO_2[185] but no additional improvement in ROSC,[185,186] hospital admission,[186] or ICU discharge[186] when compared with positive-pressure ventilation. High-flow oxygen delivery via a face mask with an oropharyngeal airway as part of a resuscitation bundle was associated with improved survival with favorable neurologic outcome. This study, however, included only victims who had witnessed arrest from VF or pulseless ventricular tachycardia (pVT).[68]

4.7.4.2 2015 Recommendations - New

We do not recommend the routine use of passive ventilation techniques during conventional CPR for adults. (Class IIb, LOE C-LD)

However, in EMS systems that use bundles of care involving continuous chest compressions, the use of passive ventilation techniques may be considered as part of that bundle. (Class IIb, LOE C-LD)

4.7.5 Cricoid Pressure

Cricoid pressure is a technique of applying pressure to the victim's cricoid cartilage to push the trachea posteriorly and compress the esophagus against the cervical vertebrae. Cricoid pressure can prevent gastric inflation and reduce the risk of regurgitation and aspiration during bag-mask ventilation, but it may also impede ventilation. Seven randomized, controlled studies demonstrated that cricoid pressure can delay or prevent the placement of an advanced airway and that aspiration can occur despite application of pressure.[187-193] Additional manikin studies[194-207] found training in the maneuver to be difficult for both expert and nonexpert

rescuers. Neither expert nor nonexpert rescuers demonstrated mastery of the technique, and the applied pressure was frequently inconsistent and outside of effective limits. Cricoid pressure might be used in a few special circumstances (eg, to aid in viewing the vocal cords during tracheal intubation).

However, the routine use of cricoid pressure in adult cardiac arrest is not recommended. ***(Class III, LOE B)***

5 AED Defibrillation - Updated

Ideally, all BLS providers are trained on use of an AED given that VF and pVT are treatable cardiac arrest rhythms with outcomes closely related to the rapidity of recognition and treatment.[208] Survival in victims of VF/pVT is highest when bystanders deliver CPR and defibrillation is attempted within 3 to 5 minutes of collapse.[9, 56,209-212] Accordingly, in 2010, we recommended that BLS providers immediately apply an AED in witnessed OHCA or for monitored patients who develop IHCA. In 2015, the review focused on (1) the evidence surrounding the clinical benefit of automatic external defibrillators in the out-of-hospital setting by laypeople and healthcare providers, and (2) the complex choreography of care needed to ensure high-quality CPR and effective defibrillation.

The 2010 Guidelines are as follows:

Rapid defibrillation is the treatment of choice for VF of short duration, such as for victims of witnessed out-of-hospital cardiac arrest or for hospitalized patients whose heart rhythm is monitored. ***(Class I, LOE A)***

There is insufficient evidence to recommend for or against delaying defibrillation to provide a period of CPR for patients in VF/pulseless VT out-of-hospital cardiac arrest. In settings with lay rescuer AED programs (AED onsite and available) and for in-hospital environments, or if the EMS rescuer witnesses the collapse, the rescuer should use the defibrillator as soon as it is available. ***(Class IIa, LOE C)***

5.1 CPR Before Defibrillation - Updated BLS 363

The 2015 ILCOR systematic review addressed whether a specified period (typically 1.5 to 3 minutes) of chest compressions before shock delivery compared with a short period of chest compressions before shock delivery affected resuscitation outcomes. When cardiac arrest is unwitnessed, experts have debated whether a period of CPR might be beneficial before attempting defibrillation, especially in the out-of-hospital setting when access to defibrillation may be delayed until arrival of professional rescuers. Observational clinical studies and mechanistic studies in animal models suggest that CPR under conditions of prolonged untreated VF might help restore metabolic conditions of the heart favorable to defibrillation. Others have suggested that prolonged VF is energetically detrimental to the ischemic heart, justifying rapid defibrillation attempts regardless of the duration of arrest.

5.1.1 2015 Evidence Summary

Five RCTs,[213-217] 4 observational cohort studies,[218-221] 3 meta-analyses,[222-224] and 1 subgroup analysis of an RCT[225] addressed the question of CPR before defibrillation. The duration of CPR before defibrillation ranged from 90 to 180 seconds, with the control group having a shorter CPR interval lasting only as long as the time required for defibrillator deployment, pad placement, initial rhythm analysis, and AED charging. These studies showed that outcomes were not different when CPR was provided for a period of up to 180 seconds before attempted defibrillation compared with rhythm analysis and attempted defibrillation first for the various outcomes examined, ranging from 1-year survival with favorable neurologic outcome to ROSC. Subgroup analysis suggested potential benefit from CPR before defibrillation in patients with prolonged EMS response intervals (4 to 5 minutes or longer)[213] and in EMS agencies with high baseline survival to hospital discharge,[225] but these findings conflict with other subset analyses.[216] Accordingly, the current evidence suggests that for unmonitored patients with cardiac arrest outside of the hospital and an initial rhythm of VF or pVT, there is no benefit from a period of CPR of 90 to 180 seconds before attempted defibrillation.

5.1.2 2015 Recommendations - Updated

For witnessed adult cardiac arrest when an AED is immediately available, it is reasonable that the defibrillator be used as soon as possible. (Class IIa, LOE C-LD)

For adults with unmonitored cardiac arrest or for whom an AED is not immediately available, it is reasonable that CPR be initiated while the defibrillator equipment is being retrieved and applied and that defibrillation, if indicated, be attempted as soon as the device is ready for use. (Class IIa, LOE B-R)

Additional guidance is given for either situation in the 2010 Guidelines recommendations where 2 or more rescuers are present:

When 2 or more rescuers are present, one rescuer should begin chest compressions while a second rescuer activates the emergency response system and gets the AED (or a manual defibrillator in most hospitals). (Class IIa, LOE C)

5.2 Analysis of Rhythm During Compressions - Updated BLS 373

The 2015 ILCOR systematic review addressed whether analysis of cardiac rhythm during chest compressions compared with analysis of cardiac rhythm during pauses in chest compressions affected resuscitation outcomes.

Although the performance of chest compressions during AED rhythm analysis would reduce the time that CPR is paused, motion artifacts currently preclude reliable AED assessment of heart rhythm during chest compressions and may delay VF/pVT identification and defibrillation.

5.2.1 2015 Evidence Summary

There are currently no published human studies that address whether compressions during manual defibrillator or AED rhythm analysis affect patient outcome. New technology to assess the potential benefit of filtering electrocardiogram (ECG) compression artifacts has not been evaluated in humans.

5.2.2 2015 Recommendation - New

There is insufficient evidence to recommend the use of artifact-filtering algorithms for analysis of ECG rhythm during CPR. Their use may be considered as part of a research protocol or if an EMS system, hospital, or other entity has already incorporated ECG artifact-filtering algorithms in its resuscitation protocols. (Class IIb, LOE C-EO)

5.3 Timing of Rhythm Check - Updated BLS 346

The 2015 ILCOR evidence review process considered whether the assessment of rhythm immediately after shock delivery, as opposed to immediate resumption of chest compressions, affected resuscitation outcomes. In 2010, the Guidelines emphasized the importance of avoiding pauses in cardiac compressions during CPR. Assessment of rhythm after shock delivery lengthens the period of time that chest compressions are not delivered.

5.3.1 2015 Evidence Summary

Three before-and-after observational studies of OHCA[67,70,226] evaluated the impact of omitting a rhythm check immediately after attempted defibrillation as part of a bundle of interventions to minimize pauses in chest compressions (eg, elimination of 3 stacked shocks and postshock rhythm and pulse checks). The observational studies documented improved survival with favorable neurologic outcome at hospital discharge associated with the bundle of care, including resumption of chest compressions immediately after shock delivery. One RCT[119] comparing immediate postshock CPR to rhythm checks failed to demonstrate improved ROSC or survival to hospital admission or discharge. One small, low-quality RCT evaluated the ability to identify recurrence of VF and showed no benefit to checking rhythm immediately after defibrillation.[227]

5.3.2 2015 Recommendation - Updated

It may be reasonable to immediately resume chest compressions after shock delivery for adults in cardiac arrest in any setting. (Class IIb, LOE C-LD)

6 CPR Quality, Accountability, and Healthcare Systems - Updated

The quality of CPR in both in-hospital and OHCA events is variable. CPR quality encompasses the traditional metrics of chest compression rate and depth and chest recoil, but it also includes parameters such as chest compression fraction and avoiding excessive ventilation. Other important aspects of CPR quality include resuscitation team dynamics, system performance, and quality monitoring.

Today, despite clear evidence that providing high-quality CPR significantly improves cardiac resuscitation outcomes, few healthcare organizations consistently apply strategies of systematically monitoring CPR quality.[228] As a consequence, there is an unacceptable disparity in the quality of resuscitation care and outcomes, as well an enormous opportunity to save more lives.[97]

Like other urgent healthcare conditions, the use of a relatively simple, iterative continuous quality improvement approach to CPR can dramatically improve CPR quality and optimize outcomes.[229-231] Similar to successful approaches toward mitigating medical errors, programs aimed at system-wide CPR data collection, implementation of best practices, and continuous feedback on performance have been shown to be effective.[113]

6.1 Chest Compression Feedback - Updated BLS 361

Technology allows for real-time monitoring, recording, and feedback about CPR quality, including both physiologic patient parameters and rescuer performance metrics. This important data can be used in real time during resuscitation, for debriefing after resuscitation, and for system-wide quality improvement programs.[113]

6.1.1 2015 Evidence Review

In studies to date, the use of CPR feedback devices has not been shown to significantly improve performance of chest compression depth, chest compression fraction, and ventilation rate.[96,99,103,232-234] There is some evidence that the use of CPR feedback may be effective in modifying chest compression rates that are too fast.[99,233] Additionally, there is evidence that CPR feedback decreases the leaning force during chest compressions.[110] For the outcome of ROSC, there is conflicting evidence,[99,103,232,233,235-237] with the majority of studies showing no difference in the number of patients that achieved ROSC and only 2 studies showing an increase in ROSC with the use of CPR feedback.[96,103,234,237] However, studies to date have not demonstrated a significant improvement in favorable neurologic outcome[96,233,234,237] or survival to hospital discharge[96,99,232-234,237] related to the use of CPR feedback devices during actual cardiac arrest events.

6.1.2 2015 Recommendation - Updated

It may be reasonable to use audiovisual feedback devices during CPR for real-time optimization of CPR performance. (Class IIb, LOE B-R)

6.2 Team-Based Resuscitation - Updated

Resuscitation from cardiac arrest most often involves a team of caregivers, with team composition and level of experience varying depending on location (in-versus out-of-hospital), setting (field, emergency department, hospital ward), and circumstances. Despite the varied environments and team members, a designated team leader is needed to direct and coordinate all components of the resuscitation with a central focus on delivering high-quality CPR. The team leader choreographs team activities with an aim to minimize interruptions in CPR and, through the use of real-time feedback, ensures delivery of adequate compression rate and depth, minimization of leaning, and interruptions in chest compressions, and avoidance of excessive ventilation.[113] More information on team training is available in “Part 14: Education” and “Part 4: Systems of Care and Continuous Quality Improvement.”

6.3 Duration of Resuscitation - Updated

Investigators have published relatively few studies that examine the impact of resuscitation duration on clinical

outcomes, and most of these studies have important limitations. In an older series of 313 IHCA patients, the percentage who survived to discharge was 45% when resuscitation lasted less than 5 minutes and less than 5% when the resuscitation extended beyond 20 minutes.[238] More recently, an analysis from a single-hospital registry in Taiwan suggested that the rate of achieving ROSC was higher than 90% among patients resuscitated for less than 10 minutes but approximately 50% for those resuscitated for 30 minutes or more.[239]

Two observational cohort studies of patients with in-hospital arrests from the Get With The Guidelines®-Resuscitation registry were recently published suggesting that extending the duration of resuscitation efforts may result in improved cardiac arrest survival. For adult patients, hospitals that systematically practiced longer durations of resuscitation had improved outcomes of ROSC and survival to discharge, with no apparent detriment in neurologic outcomes.[240] Another report of pediatric patients demonstrated an intact survival of 16.2% after more than 35 minutes of CPR in certain patient populations.[241] While investigators can define neither an optimal duration of resuscitation before the termination of efforts nor which patients may benefit from prolonged efforts at resuscitation, extending the duration of resuscitation may be a means of improving survival in selected hospitalized patients.

For information on ethical implications on termination of resuscitative efforts see Part 3: Ethical Issues.

6.4 CPR Registry Data - Updated

Ideally, RCTs will be used to advance the science and practice of resuscitation. However, conducting clinical trials in cardiac arrest patients is exceedingly challenging, given the small number of patients at single-center sites. Moreover, such research confers unique limitations and ethical concerns. Given these challenges, real-world observational data from registries can be a valuable resource for studying and reporting resuscitation processes and outcomes. Registries are available for both in-hospital and out-of-hospital arrests.[242]

Formerly known as the National Registry of Cardiopulmonary Resuscitation, the AHA's Get With The Guidelines-Resuscitation registry is the largest prospective, multicenter, observational registry of IHCA.[243,244] At present, more than 600 hospitals in the United States and Canada participate in the registry, and more than 200 000 index arrests have been recorded since 2000.

To date, the Get With The Guidelines-Resuscitation registry has provided important insights into several aspects of IHCA. Recent work has highlighted the survival gains by reducing time to defibrillation,[245] reducing racial differences and trends in IHCA incidence and survival,[246] and gathering evidence to support lengthier durations of CPR.[247]

The Resuscitation Outcomes Consortium (ROC) is a clinical research network designed to evaluate the effectiveness of prehospital emergency care for patients with OHCA or life-threatening injury.[248] Data collection began in 2007 and stems from 264 EMS agencies in 11 sites (8 in the United States and 3 in Canada), altogether representing 10% of the North American population. The ROC has afforded insights on several aspects of OHCA,[249-251] including regional variation in incidence and outcomes[8] and chest compression rates.[94]

The Cardiac Arrest Registry to Enhance Survival (CARES) is a central repository of OHCA events of presumed cardiac etiology treated with CPR and/or defibrillation throughout the United States.[4,252,253] CARES was designed as a quality improvement project, with the aims of providing performance indicators to EMS medical and administrative directors to improve processes and outcomes. As of 2011, it has collected data on more than 31 000 OHCAs from 46 EMS agencies in 36 communities in 20 states.[254] CARES has offered important insight into bystander CPR,[255] prehospital termination of resuscitation,[256] and variation in EMS systems of care.[257]

7 Family Presence During Resuscitation - Updated

Studies that explicitly examined the association between family presence and outcomes have shown mixed results. In an analysis of simulated resuscitations in an urban emergency department, investigators demonstrated that family presence may have a significant effect on physicians' ability to perform critical interventions as well as on resuscitation-based performance outcomes.[258] Specifically, the presence of a witness to resuscitation was associated with longer mean times to defibrillation (2.6 versus 1.7 minutes) and fewer shocks (4.0 versus 6.0).

A recent observational study using the Get With The Guidelines-Resuscitation registry demonstrated that implementing a hospital policy that allows family presence had no impact on survival or the processes of

attempted resuscitations.[259] Overall, given the evidence for improved psychological benefits for families present during out-of-hospital resuscitation, and without an apparent negative effect on outcomes at hospitals that allow families to be present, family presence represents an important dimension in the paradigm of resuscitation quality.

8 Recovery Position

The recovery position is used for unresponsive adult victims who clearly have normal breathing and effective circulation. This position is designed to maintain a patent airway and reduce the risk of airway obstruction and aspiration. The victim is placed on his or her side with the lower arm in front of the body.

There are several variations of the recovery position, each with its own advantages. No single position is perfect for all victims.[260,261]

The position should be stable, near a true lateral position, with the head dependent and with no pressure on the chest to impair breathing. (Class IIa, LOE C)

Studies in normal volunteers[262] show that extending the lower arm above the head and rolling the head onto the arm, while bending both legs, may be feasible for victims with known or suspected spinal injury.[263]

9 Special Resuscitation Situations - Updated

9.1 Acute Coronary Syndrome - Updated

Acute coronary syndrome (ACS) is a term that subtends a spectrum of diseases leading to myocardial ischemia or infarction. The subtypes of ACS are principally stratified through a combination of electrocardiographic changes and/ or the elevations of cardiac biomarkers, in the context of symptoms consistent with ACS (eg, substernal chest pain or discomfort with or without characteristic radiation, shortness of breath, weakness, diaphoresis, nausea or vomiting, light-headedness). ACS may manifest as an ST-segment elevation myocardial infarction (STEMI) or non–ST-segment elevation myocardial infarction (NSTEMI)/unstable angina (UA), now called *non?ST-segment acute coronary syndromes* (NSTE-ACS). Both diagnoses are pathophysiologically linked to varying degrees of a reduction in coronary blood flow due to atherosclerotic plaque progression, instability, or rupture with or without luminal thrombosis and vasospasm.

Since 2010, the American College of Cardiology and the AHA have published targeted clinical practice guidelines pertaining to the management of patients with STEMI[264] and NSTE-ACS.[265] These guidelines should be referred to for full details on the specific management of ACS. In addition, other parts of the *2015 AHA Guidelines Update for CPR and ECC* include updates on basic and advanced life support for prehospital providers who care for these patients ("Part 9: Acute Coronary Syndromes," "Part 4: Systems of Care and Continuous Quality Improvement," and "Part 10: Special Circumstances of Resuscitation"; aspirin and chest pain are presented in "Part 15: First Aid").

The 2010 Guidelines are as follows:

In the United States coronary heart disease was responsible for 1 of every 6 hospital admissions in 2005 and 1 in every 6 deaths in 2006.[266] The American Heart Association estimates that in 2010, 785 000 Americans will have a new coronary attack and 470 000 will have a recurrent attack.[266] Approximately 70% of deaths from acute myocardial infarction (AMI) occur outside of the hospital, most within the first 4 hours after the onset of symptoms.[266,267]

Early recognition, diagnosis, and treatment of AMI can improve outcome by limiting damage to the heart,[268] but treatment is most effective if provided within a few hours of the onset of symptoms.[269] Patients at risk for acute coronary syndromes (ACS) and their families should be taught to recognize the symptoms of ACS and to immediately activate the EMS system when symptoms appear, rather than delaying care by contacting family, calling a physician, or driving themselves to the hospital.

The classic symptoms associated with ACS are chest discomfort, discomfort in other areas of the upper body, shortness of breath, sweating, nausea, and lightheadedness. The symptoms of AMI characteristically last more than 15 minutes. Atypical symptoms of ACS may be more common in the elderly, women, and diabetic patients, but any patient may present with atypical signs and symptoms.[270-272] Signs and symptoms cannot be used to

confirm or exclude the diagnosis of ACS because reported sensitivity ranges from 35% to 92% and specificity ranges from 28% of 91%. Numerous studies do not support the use of any clinical signs and symptoms independent of electrocardiograph (ECG) tracings, cardiac biomarkers, or other diagnostic tests to rule in or rule out ACS in prehospital or emergency department (ED) settings.[273-286]

To improve ACS outcome, all dispatchers and EMS providers must be trained to recognize ACS symptoms, even if atypical.

It is reasonable for dispatchers to advise patients with potential cardiac symptoms to chew an aspirin (160 to 325 mg), providing the patient has no history of aspirin allergy and no signs of active or recent gastrointestinal bleeding.[287-291] (Class IIa, LOE C)

EMS providers should obtain a 12-lead ECG, determine onset of ACS symptoms, and provide prearrival notification to the destination hospital.[287,292] Clinical trials have shown improved outcomes in ST-segment elevation myocardial infarction (STEMI) patients transported by EMS directly to a percutaneous coronary intervention (PCI)–capable hospital.[293-295]

If the patient has a STEMI on ECG and if PCI is the chosen method of reperfusion, it is reasonable to transport the patient directly to a PCI facility, bypassing closer emergency departments as necessary, in systems where time intervals between first medical contact and balloon times are less than 90 minutes, and transport times are relatively short (ie, less than 30 minutes), or based on regional EMS protocols. (Class IIa, LOE B)

Common practice has been for basic EMT's to administer oxygen during the initial assessment of patients with suspected ACS. However, there is insufficient evidence to 'support or refute oxygen use in uncomplicated ACS.

If the patient is dyspneic, hypoxemic, has obvious signs of heart failure, or an oxyhemoglobin saturation <94%, providers should administer oxygen and titrate therapy to provide the lowest administered oxygen concentration that will maintain the oxyhemoglobin saturation ?94%.[296] (Class I, LOE C)

If the patient has not taken aspirin and has no history of aspirin allergy and no evidence of recent gastrointestinal bleeding, EMS providers should give the patient nonenteric aspirin (160 to 325 mg) to chew.[287,292,297,298] (Class I, LOE C)

EMS providers can administer nitroglycerin for patients with chest discomfort and suspected ACS.

Although it is reasonable to consider the early administration of nitroglycerin in select hemodynamically stable patients, insufficient evidence exists to support or refute the routine administration of nitroglycerin in the ED or prehospital setting in patients with a suspected ACS.[299-301] (Class IIb, LOE B)

Nitrates in all forms are contraindicated in patients with initial systolic blood pressure <90 mm Hg or ?30 mm Hg below baseline and in patients with right ventricular infarction (see Part 10). Caution is advised in patients with known inferior wall STEMI, and a right-sided ECG should be performed to evaluate right ventricular infarction. Administer nitrates with extreme caution, if at all, to patients with inferior STEMI and suspected RV involvement because these patients require adequate RV preload. Nitrates are contraindicated when patients have taken a phosphodiesterase-5 (PDE-5) inhibitor within 24 hours (48 hours for tadalafil).

For patients diagnosed with STEMI in the prehospital setting, EMS providers should administer appropriate analgesics, such as intravenous morphine, for persistent chest pain. (Class IIa, LOE C)

EMS providers may consider administering intravenous morphine for undifferentiated chest pain unresponsive to nitroglycerin. (Class IIb, LOE C)

However, morphine should be used with caution in unstable angina (UA)/NSTEMI due to an association with increased mortality in a large registry.

9.2 Stroke - Updated

Approximately 800 000 people have a stroke each year in the United States, and stroke is a leading cause of severe, long-term disability and death.[5] Fibrinolytic therapy administered within the first hours of the onset of symptoms limits neurologic injury and improves outcome in selected patients with acute ischemic stroke. Effective therapy requires early detection of the signs of stroke; prompt activation of the EMS system and dispatch of EMS personnel; appropriate triage to a stroke center; prearrival notification; rapid triage, evaluation, and management in the emergency department; and prompt delivery of fibrinolytic therapy to eligible patients. Since 2010, the AHA and the American Stroke Association have published clinical practice guidelines pertaining to the early management of patients with acute ischemic stroke.[302,303]

The 2010 CPR & ECC Guidelines are included below, but please view **Guidelines for the Early Management of Patients With Acute Ischemic Stroke** on Circulation to see the most current recommendations.

Patients at high risk for stroke, their family members, and BLS providers should learn to recognize the signs and symptoms of stroke and to call EMS as soon as any signs of stroke are present. (Class I, LOE C)

The signs and symptoms of stroke are sudden numbness or weakness of the face, arm, or leg, especially on one side of the body; sudden confusion, trouble speaking or understanding; sudden trouble seeing in one or both eyes; sudden trouble walking, dizziness, loss of balance or coordination; and sudden severe headache with no known cause.[304,305] Community and professional education is essential to improve stroke recognition and early EMS activation.[306-308]

EMS dispatchers should be trained to suspect stroke and rapidly dispatch emergency responders. EMS personnel should be able to perform an out-of-hospital stroke assessment*, establish the time of symptom onset when possible, provide cardiopulmonary support, and notify the receiving hospital that a patient with possible stroke is being transported.[309-311,312-314] (*Class I, LOE B)

EMS systems should have protocols that address triaging the patient when possible directly to a stroke center.[313,315,316] (Class I, LOE B)

It may be important for a family member to accompany the patient during transport to verify the time of symptom onset and provide consent for interventional therapy.

Patients with acute stroke are at risk for respiratory compromise, and the combination of poor perfusion and hypoxemia will exacerbate and extend ischemic brain injury leading to worse outcomes.[317]

Both out-of-hospital and in-hospital medical personnel should administer supplementary oxygen to hypoxemic (ie, oxygen saturation <94%) stroke patients (Class 1, LOE C) or those with unknown oxygen saturation.

There are no data to support initiation of hypertension intervention in the prehospital environment.

Unless the patient is hypotensive (systolic blood pressure <90 mm Hg), prehospital intervention for blood pressure is not recommended. (Class III, LOE C)

9.3 Drowning - Updated

Drowning is a leading cause of unintentional injury and death worldwide and a preventable cause of death for more than 4000 Americans annually.[318,319] The highest rates of morbidity and mortality are among children aged 1 to 4 years.[319] The incidence of fatal drowning has declined from 1.45 deaths per 100 000 population in 2000 to 1.26 in 2013.[319] Immediate resuscitation to restore oxygenation and ventilation—especially by bystanders—is essential for survival after a drowning incident.

This topic was last reviewed in 2010, and the treatment recommendations have not changed.

Since the 2010 Guidelines, there has been a growing appreciation for the fact that the response to the submersion victim often involves a multiagency approach with several different organizations responsible for different phases of the victim's care, from the initial aquatic rescue, on-scene resuscitation, transport to hospital, and in-hospital care. Attempting the rescue of a submerged victim has substantial resource implications and may place rescuers at risk themselves.

The 2010 Guidelines are as follows:

Rescuers should provide CPR, particularly rescue breathing, as soon as an unresponsive submersion victim is removed from the water. (Class I, LOE C)

When rescuing a drowning victim of any age, it is reasonable for the lone healthcare provider to give 5 cycles (about 2 minutes) of CPR before leaving the victim to activate the EMS system.

Mouth-to-mouth ventilation in the water may be helpful when administered by a trained rescuer.[320] (Class IIb, LOE C)

Chest compressions are difficult to perform in water; they may not be effective and they could potentially cause harm to both the rescuer and the victim. There is no evidence that water acts as an obstructive foreign body. Maneuvers to relieve foreign-body airway obstruction (FBAO) are not recommended for drowning victims because such maneuvers are not necessary and they can cause injury, vomiting, aspiration, and delay of CPR.[321]

Rescuers should remove drowning victims from the water by the fastest means available and should begin resuscitation as quickly as possible. Spinal cord injury is rare among fatal drowning victims.[322] Victims with obvious clinical signs of injury, alcohol intoxication, or a history of diving into shallow water are at a higher risk of spinal cord injury, and health care providers may consider stabilization and possible immobilization of the cervical and thoracic spine for these victims.[323]

9.4 Unintentional Hypothermia - Updated

This topic was last reviewed in 2010, and the treatment recommendations have not changed.

9.5 Foreign-Body Airway Obstruction (Choking)

This topic was last reviewed in 2010, and the treatment recommendations are as follows.

FBAO is an uncommon, but preventable, cause of death.[324] Most reported cases of FBAO occur in adults while they are eating.[325] Most reported episodes of choking in infants and children occur during eating or play when parents or childcare providers are present. The choking event is therefore commonly witnessed, and the rescuer usually intervenes while the victim is still responsive. Treatment is usually successful, and survival rates can exceed 95%.[326]

9.5.1 Recognition of Foreign-Body Airway Obstruction

Because recognition of FBAO is the key to successful outcome, it is important to distinguish this emergency from fainting, heart attack, seizure, or other conditions that may cause sudden respiratory distress, cyanosis, or loss of consciousness.

Foreign bodies may cause either mild or severe airway obstruction. The rescuer should intervene if the choking victim shows signs of severe airway obstruction. These include signs of poor air exchange and increased breathing difficulty, such as a silent cough, cyanosis, or inability to speak or breathe. The victim may clutch the neck, demonstrating the universal choking sign. Quickly ask, “Are you choking?” If the victim indicates “yes” by nodding his head without speaking, this will verify that the victim has severe airway obstruction.

9.5.2 Relief of Foreign-Body Airway Obstruction

When FBAO produces signs of severe airway obstruction, rescuers must act quickly to relieve the obstruction. If mild obstruction is present and the victim is coughing forcefully, do not interfere with the patient’s spontaneous coughing and breathing efforts. Attempt to relieve the obstruction only if signs of severe obstruction develop: the cough becomes silent, respiratory difficulty increases and is accompanied by stridor, or the victim becomes unresponsive. Activate the EMS system quickly if the patient is having difficulty breathing. If more than one rescuer is present, one rescuer should phone 911 while the other rescuer attends to the choking victim.

The clinical data about effectiveness of maneuvers to relieve FBAO are largely retrospective and anecdotal. For responsive adults and children >1 year of age with severe FBAO, case reports show the feasibility and effectiveness of back blows or “slaps,”[327-329] abdominal thrusts,[326-328,330,331] and chest thrusts.[327,332] In 1 case series of 513 choking episodes for which EMS was summoned,[326] approximately 50% of the episodes of airway obstruction were relieved prior to arrival of EMS. EMS intervention with abdominal thrusts successfully relieved the obstruction in more than 85% of the remaining cases. The few patients with persistent obstruction usually responded to suction or the use of Magill forceps. Less than 4% died.[326]

Although chest thrusts, back slaps, and abdominal thrusts are feasible and effective for relieving severe FBAO in conscious (responsive) adults and children ?1 year of age, for simplicity in training it is recommended that abdominal thrusts be applied in rapid sequence until the obstruction is relieved. (Class IIb, LOE B)

If abdominal thrusts are not effective, the rescuer may consider chest thrusts. (Class IIb, LOE B)

It is important to note that abdominal thrusts are not recommended for infants <1 year of age because thrusts may cause injuries.

Chest thrusts should be used for obese patients if the rescuer is unable to encircle the victim’s abdomen. If the choking victim is in the late stages of pregnancy, the rescuer should use chest thrusts instead of abdominal thrusts.

If the adult victim with FBAO becomes unresponsive, the rescuer should carefully support the patient to the ground, immediately activate (or send someone to activate) EMS, and then begin CPR. The healthcare provider should carefully lower the victim to the ground, send someone to activate the emergency response system and begin CPR (without a pulse check). After 2 minutes, if someone has not already done so, the healthcare provider should activate the emergency response system. A randomized trial of maneuvers to open the airway in cadavers [333] and 2 prospective studies in anesthetized volunteers[332,334] showed that higher sustained airway pressures can be generated using the chest thrust rather than the abdominal thrust. Each time the airway is opened during CPR, the rescuer should look for an object in the victim’s mouth and if found, remove it. Simply looking into the mouth should not significantly increase the time needed to attempt the ventilations and proceed to the 30 chest compressions.

No studies have evaluated the routine use of the finger sweep to clear an airway in the absence of visible airway obstruction. The recommendation to use the finger sweep in past guidelines was based on anecdotal reports that suggested that it was helpful for relieving an airway obstruction.[327,328,335] However, case reports have also documented harm to the victim[294,336,337] or rescuer.

10 Authorship and Disclosures - Updated

10.1 2015 Writing Team

Monica E. Kleinman, Chair; Erin E. Brennan; Zachary D. Goldberger; Robert A. Swor; Mark Terry; Bentley J. Bobrow; Raúl J. Gazmuri; Andrew H. Travers; Thomas Rea

Table 4: Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Monica E. Kleinman	Boston Children's Hospital	None	None	None	None	None	None	None
Bentley J. Bobrow	Arizona Department of Health Services	Medtronic Foundation†	None	None	None	None	None	None
Erin E. Brennan	Queen's University	None	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Rau?l J. Gazmuri	Rosalind Franklin University of Medicine and Science	VA Merit Review Grant†; Defense Medical Research and Developmen Program (DMRDP), Applied Research and Technology Developmen Award (ARADTA)†; Chicago Medical School and Advocate Lutheran General Hospital Translational Research Pilot Grant Program†; Baxter Healthcare Corporation† Friends Medical Research Institute†; ZOLL Medical Corporation†	None	None	None	None	None	None
Zachary D. Goldberger	University of Washington	None	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Thomas Rea	Department of Medicine, University of Washington; Public Health-Seattle and King County, Emergency Medical Services Division	Philips*; Medtronic Foundation*; NIH*; Laerdal Foundation*; Life Sciences Discovery Fund*	None	None	None	None	None	University of Washington*
Robert A. Swor	William Beaumont Hospital	None	None	None	None	None	None	None
Mark Terry	Johnson County MED-ACT	None	None	None	None	None	None	None
Consultant								
Andrew H. Travers	Emergency Health Services, Nova Scotia	None	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

10.2 2010 Writing Team

Robert A. Berg, Chair; Robin Hemphill; Benjamin S. Abella; Tom P. Aufderheide; Diana M. Cave; Mary Fran Hazinski; E. Brooke Lerner; Thomas D. Rea; Michael R. Sayre; Robert A. Swor

Table 5: 2010 - Guidelines Part 5: Adult Basic Life Support: Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 5: Adult Basic Life Support: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Robert A. Berg	University of Pennsylvania–Professor of Anesthesiology and Critical Care Medicine, Division Chief, Pediatric Critical Care	None	None	None	None	None	None
Robin Hemphill	Emory University, Dept. of Emergency Medicine–Asso Professor * Paid writer for AHA guidelines	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Benjamin S. Abella	University of Pennsylvania–Assistant Professor	†Philips Healthcare-research grant for study of CPR during inhospital cardiac arrest AHA Clinical Research Program grant-research grant for study of CPR training in the community Doris Duke Foundation-research grant for study of post resuscitation injury after cardiac arrest	*Laerdal Medical Corp-inkind support of equipment for CPR research	*CME lectures on topics of CPR and hypothermia after cardiac arrest	None	None	*legal review of two cardiac arrest cases, no trial appearances

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Tom P. Aufderheide	Medical College of Wisconsin–Pro of Emergency Medicine	†NIH-ROC Consortium-PI of Milwaukee site NETT-PI of Milwaukee site * ResQTrial (Advanced Circulatory Systems, Inc.)-PI of Oshkosh study site, In Kind NHLBI Trial-PI for Milwaukee site, In Kind Medtronics-Consultant JoLife-Consultant Take Heart America-Board Member	*Zoll Medical Corp.-Supplied AEDs and software capturing CPR performance data for ROC Consortium Advanced Circulatory Systems, Inc.-Supplied impedance threshold devices for ROC Consortium	*EMS Today-Compensated speaker, $2,000	None	*Take Heart *America-Board Member * Medtronic-Consultant * JoLife-Consultant	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Diana M. Cave	Legacy Health System, Emanuel Hospital, Emergency Services: Not-for-profit health system consists of 5 hospitals in the Portland, Oregon metro area. Emanuel Hospital is a Level I Trauma Center.–RN, MSN; Portland Com. College, Institute for Health Professionals–Faculty/Instructor	None	None	None	None	None	None
Mary Fran Hazinski	Vanderbilt University School of Nursing—Profe AHA ECC Product Development–Science Editor † Significant compensation from the AHA to write and edit the AHA Guidelines and resuscitation statements and training materials	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
E. Brooke Lerner	Medical College of Wisconsin–Associate Professor	None	†Title: Circulation Improving Resuscitation Care Trial Source: Zoll Medical Corporation Role: Consultant Principal Investigator: Lars Wik, M.D. Dates: 12/2006–8/2010 Total Funding to MCW: $345 000 (funding is received by my employer to support my time on this trial. My institution receives support for 20% of my time and the remaining funds are used for other members of our staff and supplies. My role is to advise them on human subject protection issues and to assist with data management and report generation for the trial)	None	*Stockholder in Medtronic, Pfizer, and General Electric	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Thomas D. Rea	University of Washington: Physician–Ass Professor of Medicine; Emergency Medical Services Division of Public Health-Seattle & King County–Progra Medical Director	*In the past, I have received unrestricted (modest) grant support from Philips Inc and PhysioControl. The topics were related to improving resuscitation generally (changing resuscitation protocols) and not specific to proprietary information or equipment. I am currently an investigator in the ROC. As part of this, I am directly involved in the Feedback Trial to evaluate dynamic fdbk available on the Philips MRX. The ROC is also evaluating the impedance threshold device. These studies are supported by the NIH primarily and I receive no support from Philips or the company that makes the impedance	*We conducted an AED training study that recently completed where Philips and PhysioControl contributed equipment for the research. I did not receive any of this equipment	None	None	None	*I serve on a DSMB for a trial sponsored by Philips to evaluate quantitative VF waveform algorhithm to guide care. I receive no support for this effort in order to minimize (eliminate) any conflict

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Michael R. Sayre	The Ohio State University-Associate Professor	None	None	None	None	None	None
Robert A. Swor	Beaumont Hospital–Direc EMS Programs	None	None	None	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

11 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality. ECCguidelines.heart.org.

References

1. FDA approves new hand-held auto-injector to reverse opioid overdose [news release]. Silver Spring, MD: US Food and Drug Administration; April 3, 2014. http://www.fda.gov/NewsEvents/ Newsroom/PressAnnouncements/ucm391465.htm . Accessed July 27, 2015.
2. Perkins GD, Travers AH, Berg RA, Castren M, Considine J, Escalante R, Gazmuri RJ, Koster RW, Lim SH, Nation KJ, Olasveengen TM, Sakamoto T, Sayre MR, Sierra A, Smyth MA, Stanton D, Vaillancourt C; on behalf of the Basic Life Support Chapter Collaborators. Part 3: adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S51–S83. doi: 10.1161/CIR.0000000000000272.
3. Travers AH, Perkins GD, Berg RA, Castren M, Considine J, Escalante R, Gazmuri RJ, Koster RW, Lim SH, Nation KJ, Olasveengen TM, Sakamoto T, Sayre MR, Sierra A, Smyth MA, Stanton D, Vaillancourt C; on behalf of the Basic Life Support Chapter Collaborators. Part 3: adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.
4.

Morley PT, Lang E, Aickin R, Billi JE, Eigel B, Ferrer JME, Finn JC, Gent LM, Griffin RE, Hazinski MF, Maconochie IK, Montgomery WH, Morrison LJ, Nadkarni VM, Nikolaou NI, Nolan JP, Perkins GD, Sayre MR, Travers AH, Wyllie J, Zideman DA. Part 2: evidence evaluation and management of conflicts of interest: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S40–S50. doi: 10.1161/CIR.0000000000000271.

5. Centers for Disease Control and Prevention. 2014 Cardiac Arrest Registry to Enhance Survival (CARES) National Summary Report. 2014. https:// mycares.net/sitepages/uploads/2015/2014%20Non-Traumatic%20 National%20Summary%20Report.pdf. Accessed April 30, 2015.

6. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, de Ferranti S, Després JP, Fullerton HJ, Howard VJ, Huffman MD, Judd SE, Kissela BM, Lackland DT, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Matchar DB, McGuire DK, Mohler ER 3rd, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G, Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Willey JZ, Woo D, Yeh RW, Turner MB; on behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2015 update: a report from the American Heart Association. Circulation. 2015;131:e29–e322. doi: 10.1161/CIR.0000000000000152.

7. Daya MR, Schmicker RH, Zive DM, Rea TD, Nichol G, Buick JE, Brooks S, Christenson J, MacPhee R, Craig A, Rittenberger JC, Davis DP, May S, Wigginton J, Wang H; Resuscitation Outcomes Consortium Investigators. Out-of-hospital cardiac arrest survival improving over time: Results from the Resuscitation Outcomes Consortium (ROC). Resuscitation. 2015;91:108–115. doi: 10.1016/j.resuscitation.2015.02.003.

8. Public Health, Seattle and King County, Division of Emergency Medical Services. 2014 Annual Report. http://www.kingcounty.gov/healthservices/ health/~/media/health/publichealth/documents/ems/2014AnnualReport. ashx. Accessed May 7, 2015.

9. Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, Rea T, Lowe R, Brown T, Dreyer J, Davis D, Idris A, Stiell I; Resuscitation Outcomes Consortium Investigators. Regional variation in out-of-hospital cardiac arrest incidence and outcome. JAMA. 2008;300:1423–1431. doi: 10.1001/jama.300.12.1423.

10. Chan PS, Nichol G, Krumholz HM, Spertus JA, Nallamothu BK; American Heart Association National Registry of Cardiopulmonary Resuscitation (NRCPR) Investigators. Hospital variation in time to defibrillation after in-hospital cardiac arrest. Arch Intern Med. 2009;169:1265–1273. doi: 10.1001/archinternmed.2009.196.

11. Chan PS, McNally B, Tang F, Kellermann A; CARES Surveillance Group. Recent trends in survival from out-of-hospital cardiac arrest in the United States. Circulation. 2014;130:1876–1882. doi: 10.1161/ CIRCULATIONAHA.114.009711.

12. Berg RA, Hemphill R, Abella BS, Aufderheide TP, Cave DM, Hazinski MF, Lerner EB, Rea TD, Sayre MR, Swor RA. Part 5: adult basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S685– S705. doi: 10.1161/CIRCULATIONAHA.110.970939.

13. Becker LB, Pepe PE. Ensuring the effectiveness of community-wide emergency cardiac care. Ann Emerg Med. 1993;22(2 pt 2):354–365.

14. Lerner EB, Rea TD, Bobrow BJ, Acker JE 3rd, Berg RA, Brooks SC, Cone DC, Gay M, Gent LM, Mears G, Nadkarni VM, O'Connor RE, Potts J, Sayre MR, Swor RA, Travers AH; American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Emergency medical service dispatch cardiopulmonary resuscitation prearrival instructions to improve survival from out-of-hospital cardiac arrest: a scientific statement from the American Heart Association. Circulation. 2012;125:648–655. doi: 10.1161/CIR.0b013e31823ee5fc.

15. Berdowski J, Beekhuis F, Zwinderman AH, Tijssen JG, Koster RW. Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call. Circulation. 2009;119:2096– 2102. doi: 10.1161/CIRCULATIONAHA.108.768325.

16. Hauff SR, Rea TD, Culley LL, Kerry F, Becker L, Eisenberg MS. Factors impeding dispatcher-assisted telephone cardiopulmonary resuscitation. Ann Emerg Med. 2003;42:731–737. doi: 10.1016/S0196064403004232.

17. Vaillancourt C, Verma A, Trickett J, Crete D, Beaudoin T, Nesbitt L, Wells GA, Stiell IG. Evaluating the effectiveness of dispatch-assisted cardiopulmonary resuscitation instructions. Acad Emerg Med. 2007;14:877–883. doi: 10.1197/j.aem.2007.06.021.

18. Bohm K, Rosenqvist M, Hollenberg J, Biber B, Engerström L, Svensson L. Dispatcher-assisted telephone-guided cardiopulmonary resuscitation: an underused lifesaving system. Eur J Emerg Med. 2007;14:256–259. doi: 10.1097/MEJ.0b013e32823a3cd1.

19. Hallstrom AP, Cobb LA, Johnson E, Copass MK. Dispatcher assisted CPR: implementation and potential benefit. A 12-year study. Resuscitation. 2003;57:123–129.

20. Nurmi J, Pettilä V, Biber B, Kuisma M, Komulainen R, Castrén M. Effect of protocol compliance to cardiac arrest identification by emergency medical dispatchers. Resuscitation. 2006;70:463–469. doi: 10.1016/j. resuscitation.2006.01.016.

21. Eisenberg MS, Hallstrom AP, Carter WB, Cummins RO, Bergner L, Pierce J. Emergency CPR instruction via telephone. Am J Public Health. 1985;75:47–50.

22.

Garza AG, Gratton MC, Chen JJ, Carlson B. The accuracy of predicting cardiac arrest by emergency medical services dispatchers: the calling party effect. Acad Emerg Med. 2003;10:955–960.

23. Flynn J, Archer F, Morgans A. Sensitivity and specificity of the medical priority dispatch system in detecting cardiac arrest emergency calls in Melbourne. Prehosp Disaster Med. 2006;21:72–76.

24. Ma MH, Lu TC, Ng JC, Lin CH, Chiang WC, Ko PC, Shih FY, Huang CH, Hsiung KH, Chen SC, Chen WJ. Evaluation of emergency medi- cal dispatch in out-of-hospital cardiac arrest in Taipei. Resuscitation. 2007;73:236–245. doi: 10.1016/j.resuscitation.2006.09.005.

25. Cairns KJ, Hamilton AJ, Marshall AH, Moore MJ, Adgey AA, Kee F. The obstacles to maximising the impact of public access defibrillation: an assessment of the dispatch mechanism for out-of-hospital cardiac arrest. Heart. 2008;94:349–353. doi: 10.1136/hrt.2006.109785.

26. Deakin CD, Evans S, King P. Evaluation of telephone-cardiopulmonary resuscitation advice for paediatric cardiac arrest. Resuscitation. 2010;81:853–856. doi: 10.1016/j.resuscitation.2010.02.007.

27. Bång A, Herlitz J, Martinell S. Interaction between emergency medical dispatcher and caller in suspected out-of-hospital cardiac arrest calls with focus on agonal breathing. A review of 100 tape recordings of true cardiac arrest cases. Resuscitation. 2003;56:25–34.

28. Akahane M, Ogawa T, Tanabe S, Koike S, Horiguchi H, Yasunaga H, Imamura T. Impact of telephone dispatcher assistance on the outcomes of pediatric out-of-hospital cardiac arrest. Crit Care Med. 2012;40:1410– 1416. doi: 10.1097/CCM.0b013e31823e99ae.

29. Svensson L, Bohm K, Castrèn M, Pettersson H, Engerström L, Herlitz J, Rosenqvist M. Compression-only CPR or standard CPR in out-of- hospital cardiac arrest. N Engl J Med. 2010;363:434–442. doi: 10.1056/ NEJMoa0908991.

30. Hallstrom AP. Dispatcher-assisted “phone” cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. Crit Care Med. 2000;28(11 suppl):N190–N192.

31. Rea TD, Fahrenbruch C, Culley L, Donohoe RT, Hambly C, Innes J, Bloomingdale M, Subido C, Romines S, Eisenberg MS. CPR with chest compression alone or with rescue breathing. N Engl J Med. 2010;363:423– 433. doi: 10.1056/NEJMoa0908993.

32. Heward A, Damiani M, Hartley-Sharpe C. Does the use of the Advanced Medical Priority Dispatch System affect cardiac arrest detection? Emerg Med J. 2004;21:115–118.

33. Roppolo LP, Westfall A, Pepe PE, Nobel LL, Cowan J, Kay JJ, Idris AH. Dispatcher assessments for agonal breathing improve detection of cardiac arrest. Resuscitation. 2009;80:769–772.

34. Bohm K, Stalhandske B, Rosenqvist M, Ulfvarson J, Hollenberg J, Svensson L. Tuition of emergency medical dispatchers in the recognition of agonal respiration increases the use of telephone assisted CPR. Resuscitation. 2009;80:1025–1028.

35. Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. Resuscitation. 1997;35:23–26.

36. Brennan RT, Braslow A. Skill mastery in public CPR classes. Am J Emerg Med. 1998;16:653–657.

37. Chamberlain D, Smith A, Woollard M, Colquhoun M, Handley AJ, Leaves S, Kern KB. Trials of teaching methods in basic life support : comparison of simulated CPR performance after first training and at 6 months, with a note on the value of re-training. Resuscitation. 2002;53:179–187.

38. Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. Resuscitation. 1996;33:107–116.

39. Frederick K, Bixby E, Orzel MN, Stewart-Brown S, Willett K. Will changing the emphasis from ‘pulseless’ to ‘no signs of circulation’ improve the recall scores for effective life support skills in children? Resuscitation. 2002;55:255–261.

40. Lapostolle F, Le Toumelin P, Agostinucci JM, Catineau J, Adnet F. Basic cardiac life support providers checking the carotid pulse: performance, degree of conviction, and influencing factors. Acad Emerg Med. 2004;11:878–880.

41. Moule P. Checking the carotid pulse: diagnostic accuracy in students of the healthcare professions. Resuscitation. 2000;44:195–201.

42. Nyman J, Sihvonen M. Cardiopulmonary resuscitation skills in nurses and nursing students. Resuscitation. 2000;47:179–184.

43. Owen CJ, Wyllie JP. Determination of heart rate in the baby at birth. Resuscitation. 2004;60:213–217.

44. Sarti A, Savron F, Ronfani L, Pelizzo G, Barbi E. Comparison of three sites to check the pulse and count heart rate in hypotensive infants. Paediatr Anaesth. 2006;16:394–398.

45. Ochoa FJ, Ramalle-Gomara E, Carpintero JM, Garcia A, Saralegui I. Competence of health professionals to check the carotid pulse. Resuscitation. 1998;37:173–175.

46. Mather C, O'Kelly S. The palpation of pulses. Anaesthesia. 1996;51:189–191.

47.

Rea TD, Helbock M, Perry S, Garcia M, Cloyd D, Becker L, Eisenberg M. Increasing use of cardiopulmonary resuscitation during out-of-hospital ventricular fibrillation arrest: survival implications of guideline changes. Circulation. 2006;114:2760–2765.

48. Berg RA, Hilwig RW, Berg MD, Berg DD, Samson RA, Indik JH, Kern KB. Immediate post-shock chest compressions improve outcome from prolonged ventricular fibrillation. Resuscitation. 2008;78:71–76.

49. Tang W, Snyder D, Wang J, Huang L, Chang YT, Sun S, Weil MH. One-shock versus three-shock defibrillation protocol significantly improves outcome in a porcine model of prolonged ventricular fibrillation cardiac arrest. Circulation. 2006;113:2683–2689.

50. Garza AG, Gratton MC, Salomone JA, Lindholm D, McElroy J, Archer R. Improved patient survival using a modified resuscitation protocol for out-of-hospital cardiac arrest. Circulation. 2009;119:2597–2605.

51. Bobrow BJ, Clark LL, Ewy GA, Chikani V, Sanders AB, Berg RA, Richman PB, Kern KB. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. JAMA. 2008;299:1158–1165.

52. Kellum MJ, Kennedy KW, Barney R, Keilhauer FA, Bellino M, Zuercher M, Ewy GA. Cardiocerebral resuscitation improves neurologically intact survival of patients with out-of-hospital cardiac arrest. Ann Emerg Med. 2008;52:244–252.

53. Sayre MR, Cantrell SA, White LJ, Hiestand BC, Keseg DP, Koser S. Impact of the 2005 American Heart Association cardiopulmonary resuscitation and emergency cardiovascular care guidelines on out-of-hospital cardiac arrest survival. Prehosp Emerg Care. 2009;13:469–477.

54. Lubrano R, Cecchetti C, Bellelli E, Gentile I, Loayza Levano H, Orsini F, Bertazzoni G, Messi G, Rugolotto S, Pirozzi N, Elli M. Comparison of times of intervention during pediatric CPR maneuvers using ABC and CAB sequences: a randomized trial. Resuscitation. 2012;83:1473–1477. doi: 10.1016/j.resuscitation.2012.04.011.

55. Sekiguchi H, Kondo Y, Kukita I. Verification of changes in the time taken to initiate chest compressions according to modified basic life support guidelines. Am J Emerg Med. 2013;31:1248–1250. doi: 10.1016/j.ajem.2013.02.047.

56. Marsch S, Tschan F, Semmer NK, Zobrist R, Hunziker PR, Hunziker S. ABC versus CAB for cardiopulmonary resuscitation: a prospective, ran- domized simulator-based trial. Swiss Med Wkly. 2013;143:w13856. doi: 10.4414/smw.2013.13856.

57. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of sur- vival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes. 2010;3:63–81. doi: 10.1161/CIRCOUTCOMES.109.889576.

58. Hüpfl M, Selig HF, Nagele P. Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. Lancet. 2010;376:1552–1557. doi: 10.1016/S0140-6736(10)61454-7.

59. Iwami T, Kawamura T, Hiraide A, Berg RA, Hayashi Y, Nishiuchi T, Kajino K, Yonemoto N, Yukioka H, Sugimoto H, Kakuchi H, Sase K, Yokoyama H, Nonogi H. Effectiveness of bystander-ini- tiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation. 2007;116:2900–2907. doi: 10.1161/ CIRCULATIONAHA.107.723411.

60. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A; Implementation Working Group for All-Japan Utstein Registry of the Fire and Disaster Management Agency. Bystander-initiated rescue breath- ing for out-of-hospital cardiac arrests of noncardiac origin. Circulation. 2010;122:293–299. doi: 10.1161/CIRCULATIONAHA.109.926816.

61. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Berg RA, Hiraide A; Implementation Working Group for All-Japan Utstein Registry of the Fire and Disaster Management Agency. Time-dependent effectiveness of chest compression-only and conventional cardiopulmonary resusci- tation for out-of-hospital cardiac arrest of cardiac origin. Resuscitation. 2011;82:3–9. doi: 10.1016/j.resuscitation.2010.09.468.

62. Ong ME, Ng FS, Anushia P, Tham LP, Leong BS, Ong VY, Tiah L, Lim SH, Anantharaman V. Comparison of chest compression only and standard car- diopulmonary resuscitation for out-of-hospital cardiac arrest in Singapore. Resuscitation. 2008;78:119–126. doi: 10.1016/j.resuscitation.2008.03.012.

63. SOS-KANTO Study Group. Cardiopulmonary resuscitation by bystand- ers with chest compression only (SOS-KANTO): an observational study. Lancet. 2007;369:920–926.

64. Bobrow BJ, Spaite DW, Berg RA, Stolz U, Sanders AB, Kern KB, Vadeboncoeur TF, Clark LL, Gallagher JV, Stapczynski JS, LoVecchio F, Mullins TJ, Humble WO, Ewy GA. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. JAMA. 2010;304:1447–1454. doi: 10.1001/jama.2010.1392.

65. Olasveengen TM, Wik L, Steen PA. Standard basic life support vs. continuous chest compressions only in out-of-hospital cardiac arrest. Acta Anaesthesiol Scand. 2008;52:914–919. doi: 10.1111/j.1399-6576.2008.01723.x.

66. Panchal AR, Bobrow BJ, Spaite DW, Berg RA, Stolz U, Vadeboncoeur TF, Sanders AB, Kern KB, Ewy GA. Chest compression-only cardiopul- monary resuscitation performed by lay rescuers for adult out-of-hospital cardiac arrest due to non-cardiac aetiologies. Resuscitation. 2013;84:435– 439. doi: 10.1016/j.resuscitation.2012.07.038.

67. Mosier J, Itty A, Sanders A, Mohler J, Wendel C, Poulsen J, Shellenberger J, Clark L, Bobrow B. Cardiocerebral resuscitation is associated with improved survival and neurologic outcome from out-of-hospi- tal cardiac arrest in elders. Acad Emerg Med. 2010;17:269–275. doi: 10.1111/j.1553-2712.2010.00689.x.

68. Bobrow BJ, Clark LL, Ewy GA, Chikani V, Sanders AB, Berg RA, Richman PB, Kern KB. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. JAMA. 2008;299:1158–1165. doi: 10.1001/jama.299.10.1158.

69. Bobrow BJ, Ewy GA, Clark L, Chikani V, Berg RA, Sanders AB, Vadeboncoeur TF, Hilwig RW, Kern KB. Passive oxygen insufflation is superior to bag-valve-mask ventilation for witnessed ventricular fibrilla- tion out-of-hospital cardiac arrest. Ann Emerg Med. 2009;54:656–662.e1. doi: 10.1016/j.annemergmed.2009.06.011.

70. Kellum MJ, Kennedy KW, Barney R, Keilhauer FA, Bellino M, Zuercher M, Ewy GA. Cardiocerebral resuscitation improves neurologically intact survival of patients with out-of-hospital cardiac arrest. Ann Emerg Med. 2008;52:244–252. doi: 10.1016/j.annemergmed.2008.02.006.

71. Kellum MJ, Kennedy KW, Ewy GA. Cardiocerebral resuscitation improves survival of patients with out-of-hospital cardiac arrest. Am J Med. 2006;119:335–340. doi: 10.1016/j.amjmed.2005.11.014.

72. Ruppert M, Reith MW, Widmann JH, Lackner CK, Kerkmann R, Schweiberer L, Peter K. Checking for breathing: evaluation of the diagnostic capability of emergency medical services personnel, physicians, medical students, and medical laypersons. Ann Emerg Med. 1999;34:720–729.

73. Safar P, Escarraga LA, Chang F. Upper airway obstruction in the unconscious patient. J Appl Physiol. 1959;14:760–764.

74. Perkins GD, Stephenson B, Hulme J, Monsieurs KG. Birmingham assessment of breathing study (BABS). Resuscitation. 2005;64:109–113.

75. Berdowski J, Beekhuis F, Zwinderman AH, Tijssen JG, Koster RW. Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call. Circulation. 2009;119:2096–2102.

76. Bohm K, Rosenqvist M, Hollenberg J, Biber B, Engerstrom L, Svensson L. Dispatcher-assisted telephone-guided cardiopulmonary resuscitation: an underused lifesaving system. Eur J Emerg Med. 2007;14:256–259.

77. Clawson J, Olola C, Scott G, Heward A, Patterson B. Effect of a Medical Priority Dispatch System key question addition in the seizure/convulsion/fitting protocol to improve recognition of ineffective (agonal) breathing. Resuscitation. 2008;79:257–264.

78. US Food and Drug Administration. FDA News Release: FDA approves new hand-held auto-injector to reverse opioid overdose. 2015. http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ ucm391465.htm. Accessed May 11, 2015.

79. Walley AY, Doe-Simkins M, Quinn E, Pierce C, Xuan Z, Ozonoff A. Opioid overdose prevention with intranasal naloxone among people who take methadone. J Subst Abuse Treat. 2013;44:241–247. doi: 10.1016/j. jsat.2012.07.004.

80. Albert S, Brason FW 2nd, Sanford CK, Dasgupta N, Graham J, Lovette B. Project Lazarus: community-based overdose prevention in rural North Carolina. Pain Med. 2011;12 suppl 2:S77–S85. doi: 10.1111/j.1526-4637.2011.01128.x.

81. Maxwell S, Bigg D, Stanczykiewicz K, Carlberg-Racich S. Prescribing nal- oxone to actively injecting heroin users: a program to reduce heroin over- dose deaths. J Addict Dis. 2006;25:89–96. doi: 10.1300/J069v25n03_11.

82. Olasveengen TM, Wik L, Steen PA. Standard basic life support vs. continuous chest compressions only in out-of-hospital cardiac arrest. Acta Anaesthesiol Scand. 2008;52:914–919.

83. Ong ME, Ng FS, Anushia P, Tham LP, Leong BS, Ong VY, Tiah L, Lim SH, Anantharaman V. Comparison of chest compression only and standard cardiopulmonary resuscitation for out-of-hospital cardiac arrest in Singapore. Resuscitation. 2008;78:119–126.

84. Bohm K, Rosenqvist M, Herlitz J, Hollenberg J, Svensson L. Survival is similar after standard treatment and chest compression only in out-of-hospital bystander cardiopulmonary resuscitation. Circulation. 2007;116:2908–2912.

85. Iwami T, Kawamura T, Hiraide A, Berg RA, Hayashi Y, Nishiuchi T, Kajino K, Yonemoto N, Yukioka H, Sugimoto H, Kakuchi H, Sase K, Yokoyama H, Nonogi H. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation. 2007;116:2900–2907.

86. SOS-KANTO Study Group. Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): an observational study. Lancet. 2007;369:920–926.

87. Cha KC, Kim HJ, Shin HJ, Kim H, Lee KH, Hwang SO. Hemodynamic effect of external chest compressions at the lower end of the sternum in cardiac arrest patients. J Emerg Med. 2013;44:691–697. doi: 10.1016/j. jemermed.2012.09.026.

88. Qvigstad E, Kramer-Johansen J, Tømte Ø, Skålhegg T, Sørensen Ø, Sunde K, Olasveengen TM. Clinical pilot study of different hand positions during manual chest compressions monitored with capnography. Resuscitation. 2013;84:1203–1207. doi: 10.1016/j.resuscitation.2013.03.010.

89. Orlowski JP. Optimum position for external cardiac compression in infants and young children. Ann Emerg Med. 1986;15:667–673.

90. Kundra P, Dey S, Ravishankar M. Role of dominant hand position during external cardiac compression. Br J Anaesth. 2000;84:491–493.

91.

Nikandish R, Shahbazi S, Golabi S, Beygi N. Role of dominant versus non-dominant hand position during uninterrupted chest compression CPR by novice rescuers: a randomized double-blind crossover study. Resuscitation. 2008;76:256–260.

92. Shin J, Rhee JE, Kim K. Is the inter-nipple line the correct hand position for effective chest compression in adult cardiopulmonary resuscitation? Resuscitation. 2007;75:305–310.

93. Kusunoki S, Tanigawa K, Kondo T, Kawamoto M, Yuge O. Safety of the inter-nipple line hand position landmark for chest compression. Resuscitation. 2009;80:1175–1180.

94. Idris AH, Guffey D, Pepe PE, Brown SP, Brooks SC, Callaway CW, Christenson J, Davis DP, Daya MR, Gray R, Kudenchuk PJ, Larsen J, Lin S, Menegazzi JJ, Sheehan K, Sopko G, Stiell I, Nichol G, Aufderheide TP; Resuscitation Outcomes Consortium Investigators. Chest compression rates and survival following out-of-hospital cardiac arrest. Crit Care Med. 2015;43:840–848. doi: 10.1097/CCM.0000000000000824.

95. Idris AH, Guffey D, Aufderheide TP, Brown S, Morrison LJ, Nichols P, Powell J, Daya M, Bigham BL, Atkins DL, Berg R, Davis D, Stiell I, Sopko G, Nichol G; Resuscitation Outcomes Consortium (ROC) Investigators. Relationship between chest compression rates and outcomes from cardiac arrest. Circulation. 2012;125:3004–3012. doi: 10.1161/ CIRCULATIONAHA.111.059535.

96. Vadeboncoeur T, Stolz U, Panchal A, Silver A, Venuti M, Tobin J, Smith G, Nunez M, Karamooz M, Spaite D, Bobrow B. Chest compression depth and survival in out-of-hospital cardiac arrest. Resuscitation. 2014;85:182– 188. doi: 10.1016/j.resuscitation.2013.10.002.

97. Hostler D, Everson-Stewart S, Rea TD, Stiell IG, Callaway CW, Kudenchuk PJ, Sears GK, Emerson SS, Nichol G; Resuscitation Outcomes Consortium Investigators. Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial. BMJ. 2011;342:d512.

98. Stiell IG, Brown SP, Christenson J, Cheskes S, Nichol G, Powell J, Bigham B, Morrison LJ, Larsen J, Hess E, Vaillancourt C, Davis DP, Callaway CW; Resuscitation Outcomes Consortium (ROC) Investigators. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? Crit Care Med. 2012;40:1192–1198. doi: 10.1097/ CCM.0b013e31823bc8bb.

99. Stiell IG, Brown SP, Nichol G, Cheskes S, Vaillancourt C, Callaway CW, Morrison LJ, Christenson J, Aufderheide TP, Davis DP, Free C, Hostler D, Stouffer JA, Idris AH; Resuscitation Outcomes Consortium Investigators. What is the optimal chest compression depth during out-of-hospital car- diac arrest resuscitation of adult patients? Circulation. 2014;130:1962– 1970. doi: 10.1161/CIRCULATIONAHA.114.008671.

100. Kramer-Johansen J, Myklebust H, Wik L, Fellows B, Svensson L, Sørebø H, Steen PA. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective inter- ventional study. Resuscitation. 2006;71:283–292. doi: 10.1016/j. resuscitation.2006.05.011.

101. Edelson DP, Abella BS, Kramer-Johansen J, Wik L, Myklebust H, Barry AM, Merchant RM, Hoek TL, Steen PA, Becker LB. Effects of com- pression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. Resuscitation. 2006;71:137–145. doi: 10.1016/j. resuscitation.2006.04.008.

102. Edelson DP, Litzinger B, Arora V, Walsh D, Kim S, Lauderdale DS, Vanden Hoek TL, Becker LB, Abella BS. Improving in-hospital cardiac arrest process and outcomes with performance debriefing. Arch Intern Med. 2008;168:1063–1069. doi: 10.1001/archinte.168.10.1063.

103. Babbs CF, Kemeny AE, Quan W, Freeman G. A new paradigm for human resuscitation research using intelligent devices. Resuscitation. 2008;77:306–315. doi: 10.1016/j.resuscitation.2007.12.018.

104. Bohn A, Weber TP, Wecker S, Harding U, Osada N, Van Aken H, Lukas RP. The addition of voice prompts to audiovisual feedback and debriefing does not modify CPR quality or outcomes in out of hospital cardiac arrest–a prospective, randomized trial. Resuscitation. 2011;82:257–262. doi: 10.1016/j.resuscitation.2010.11.006.

105. Hellevuo H, Sainio M, Nevalainen R, Huhtala H, Olkkola KT, Tenhunen J, Hoppu S. Deeper chest compression - more complications for cardiac arrest patients? Resuscitation. 2013;84:760–765. doi: 10.1016/j. resuscitation.2013.02.015.

106. Talley DB, Ornato JP, Clarke AM. Computer-aided characterization and optimization of the Thumper compression waveform in closed-chest CPR. Biomed Instrum Technol. 1990;24:283–288.

107. Handley AJ, Handley SA. Improving CPR performance using an audible feedback system suitable for incorporation into an automated external defibrillator. Resuscitation. 2003;57:57–62.

108. Zuercher M, Hilwig RW, Ranger-Moore J, Nysaether J, Nadkarni VM, Berg MD, Kern KB, Sutton R, Berg RA. Leaning during chest compres- sions impairs cardiac output and left ventricular myocardial blood flow in piglet cardiac arrest. Crit Care Med. 2010;38:1141–1146. doi: 10.1097/CCM.0b013e3181ce1fe2.

109. Niles DE, Sutton RM, Nadkarni VM, Glatz A, Zuercher M, Maltese MR, Eilevstjønn J, Abella BS, Becker LB, Berg RA. Prevalence and hemo-dynamic effects of leaning during CPR. Resuscitation. 2011;82 suppl 2:S23–S26. doi: 10.1016/S0300-9572(11)70147-2.

110. Fried DA, Leary M, Smith DA, Sutton RM, Niles D, Herzberg DL, Becker LB, Abella BS. The prevalence of chest compression leaning during in- hospital cardiopulmonary resuscitation. Resuscitation. 2011;82:1019– 1024. doi: 10.1016/j.resuscitation.2011.02.032.

111. Niles D, Nysaether J, Sutton R, Nishisaki A, Abella BS, Arbogast K, Maltese MR, Berg RA, Helfaer M, Nadkarni V. Leaning is common during in-hospital pediatric CPR, and decreased with automated cor- rective feedback. Resuscitation. 2009;80:553–557. doi: 10.1016/j. resuscitation.2009.02.012.

112. Yannopoulos D, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie KG. Effects of incomplete chest wall decompres- sion during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2005;64:363–372. doi: 10.1016/j.resuscitation.2004.10.009.

113. Glatz AC, Nishisaki A, Niles DE, Hanna BD, Eilevstjonn J, Diaz LK, Gillespie MJ, Rome JJ, Sutton RM, Berg RA, Nadkarni VM. Sternal wall pressure comparable to leaning during CPR impacts intrathoracic pressure and haemodynamics in anaesthetized children during cardiac catheterization. Resuscitation. 2013;84:1674–1679. doi: 10.1016/j. resuscitation.2013.07.010.

114. Meaney PA, Bobrow BJ, Mancini ME, Christenson J, de Caen AR, Bhanji F, Abella BS, Kleinman ME, Edelson DP, Berg RA, Aufderheide TP, Menon V, Leary M; CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Cardiopulmonary resuscitation quality: [corrected] improv- ing cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. Circulation. 2013;128:417–435. doi: 10.1161/CIR.0b013e31829d8654.

115. Sell RE, Sarno R, Lawrence B, Castillo EM, Fisher R, Brainard C, Dunford JV, Davis DP. Minimizing pre- and post-defibrillation pauses increases the likelihood of return of spontaneous circulation (ROSC). Resuscitation. 2010;81:822–825. doi: 10.1016/j.resuscitation.2010.03.013.

116. Cheskes S, Schmicker RH, Christenson J, Salcido DD, Rea T, Powell J, Edelson DP, Sell R, May S, Menegazzi JJ, Van Ottingham L, Olsufka M, Pennington S, Simonini J, Berg RA, Stiell I, Idris A, Bigham B, Morrison L; Resuscitation Outcomes Consortium (ROC) Investigators. Perishock pause: an independent predictor of survival from out-of-hospi- tal shockable cardiac arrest. Circulation. 2011;124:58–66. doi: 10.1161/ CIRCULATIONAHA.110.010736.

117. Cheskes S, Schmicker RH, Verbeek PR, Salcido DD, Brown SP, Brooks S, Menegazzi JJ, Vaillancourt C, Powell J, May S, Berg RA, Sell R, Idris A, Kampp M, Schmidt T, Christenson J; Resuscitation Outcomes Consortium (ROC) investigators. The impact of peri-shock pause on survival from out- of-hospital shockable cardiac arrest during the Resuscitation Outcomes Consortium PRIMED trial. Resuscitation. 2014;85:336–342. doi: 10.1016/j.resuscitation.2013.10.014.

118. Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J, Callaway CW, Bishop D, Vaillancourt C, Davis D, Aufderheide TP, Idris A, Stouffer JA, Stiell I, Berg R; Resuscitation Outcomes Consortium Investigators. Chest compression fraction determines sur- vival in patients with out-of-hospital ventricular fibrillation. Circulation. 2009;120:1241–1247. doi: 10.1161/CIRCULATIONAHA.109.852202.

119. Vaillancourt C, Everson-Stewart S, Christenson J, Andrusiek D, Powell J, Nichol G, Cheskes S, Aufderheide TP, Berg R, Stiell IG; Resuscitation Outcomes Consortium Investigators. The impact of increased chest com- pression fraction on return of spontaneous circulation for out-of-hospi- tal cardiac arrest patients not in ventricular fibrillation. Resuscitation. 2011;82:1501–1507. doi: 10.1016/j.resuscitation.2011.07.011.

120. Jost D, Degrange H, Verret C, Hersan O, Banville IL, Chapman FW, Lank P, Petit JL, Fuilla C, Migliani R, Carpentier JP; DEFI 2005 Work Group. DEFI 2005: a randomized controlled trial of the effect of automated exter- nal defibrillator cardiopulmonary resuscitation protocol on outcome from out-of-hospital cardiac arrest. Circulation. 2010;121:1614–1622. doi: 10.1161/CIRCULATIONAHA.109.878389.

121. Beesems SG, Wijmans L, Tijssen JG, Koster RW. Duration of ventilations during cardiopulmonary resuscitation by lay rescuers and first responders: relationship between delivering chest compressions and outcomes. Circulation. 2013;127:1585–1590. doi: 10.1161/CIRCULATIONAHA.112.000841.

122. Sugerman NT, Edelson DP, Leary M, Weidman EK, Herzberg DL, Vanden Hoek TL, Becker LB, Abella BS. Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: a prospective multicenter study. Resuscitation. 2009;80:981–984.

123. Manders S, Geijsel FE. Alternating providers during continuous chest compressions for cardiac arrest: every minute or every two minutes? Resuscitation. 2009;80:1015–1018.

124. Heidenreich JW, Berg RA, Higdon TA, Ewy GA, Kern KB, Sanders AB. Rescuer fatigue: standard versus continuous chest-compression cardiopulmonary resuscitation. Acad Emerg Med. 2006;13:1020–1026.

125. Hinchey PR, Myers JB, Lewis R, De Maio VJ, Reyer E, Licatese D, Zalkin J, Snyder G; Capital County Research Consortium. Improved out-of-hos- pital cardiac arrest survival after the sequential implementation of 2005 AHA guidelines for compressions, ventilations, and induced hypothermia: the Wake County experience. Ann Emerg Med. 2010;56:348–357. doi: 10.1016/j.annemergmed.2010.01.036.

126. Olasveengen TM, Vik E, Kuzovlev A, Sunde K. Effect of implementa- tion of new resuscitation guidelines on quality of cardiopulmonary resus- citation and survival. Resuscitation. 2009;80:407–411. doi: 10.1016/j. resuscitation.2008.12.005.

127. Sayre MR, Cantrell SA, White LJ, Hiestand BC, Keseg DP, Koser S. Impact of the 2005 American Heart Association cardiopulmonary resus- citation and emergency cardiovascular care guidelines on out-of-hospital cardiac arrest survival. Prehosp Emerg Care. 2009;13:469–477. doi: 10.1080/10903120903144965.

128.

Steinmetz J, Barnung S, Nielsen SL, Risom M, Rasmussen LS. Improved survival after an out-of-hospital cardiac arrest using new guidelines. Acta Anaesthesiol Scand. 2008;52:908–913. doi: 10.1111/j.1399-6576.2008.01657.x.

129. HallstromA,CobbL,JohnsonE,CopassM.Cardiopulmonaryresuscitation by chest compression alone or with mouth-to-mouth ventilation. N Engl J Med. 2000;342:1546–1553. doi: 10.1056/NEJM200005253422101.

130. Bohm K, Rosenqvist M, Herlitz J, Hollenberg J, Svensson L. Survival is similar after standard treatment and chest compres- sion only in out-of-hospital bystander cardiopulmonary resus- citation. Circulation. 2007;116:2908–2912. doi: 10.1161/ CIRCULATIONAHA.107.710194.

131. Holmberg M, Holmberg S, Herlitz J; Swedish Cardiac Arrest Registry. Factors modifying the effect of bystander cardiopulmonary resuscitation on survival in out-of-hospital cardiac arrest patients in Sweden. Eur Heart J. 2001;22:511–519.

132. Bossaert L, Van Hoeyweghen R. Evaluation of cardiopulmonary resus- citation (CPR) techniques. The Cerebral Resuscitation Study Group. Resuscitation. 1989;17 suppl:S99–S109; discussion S199.

133. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardio- pulmonary resuscitation and survival following out-of-hospital cardiac arrest. JAMA. 1995;274:1922–1925.

134. Mohler MJ, Wendel CS, Mosier J, Itty A, Fain M, Clark L, Bobrow B, Sanders AB. Cardiocerebral resuscitation improves out-of-hospi- tal survival in older adults. J Am Geriatr Soc. 2011;59:822–826. doi: 10.1111/j.1532-5415.2011.03400.x.

135. Hastings RH, Wood PR. Head extension and laryngeal view during laryn- goscopy with cervical spine stabilization maneuvers. Anesthesiology. 1994;80:825–831.

136. Gerling MC, Davis DP, Hamilton RS, Morris GF, Vilke GM, Garfin SR, Hayden SR. Effects of cervical spine immobilization technique and laryngoscope blade selection on an unstable cervical spine in a cadaver model of intubation. Ann Emerg Med. 2000;36:293–300. doi: 10.1067/ mem.2000.109442.

137. Guildner CW. Resuscitation: opening the airway. A comparative study of techniques for opening an airway obstructed by the tongue. JACEP. 1976;5:588–590.

138. Greene DG, Elam JO, Dobkin AB, Studley CL. Cinefluorographic study of hyperextension of the neck and upper airway patency. JAMA. 1961;176:570–573.

139. Ruben HM, Elam JO, al. e. Investigations of pharyngeal xrays and perfomance by laymen. Anesthesiology. 1961;22:271–279.

140. Elam JO, Greene DG, Schneider MA, Ruben HM, Gordon AS, Hustead RF, Benson DW, Clements JA, Ruben A. Head-tilt method of oral resuscitation. JAMA. 1960;172:812–815.

141. Rhee P, Kuncir EJ, Johnson L, Brown C, Velmahos G, Martin M, Wang D, Salim A, Doucet J, Kennedy S, Demetriades D. Cervical spine injury is highly dependent on the mechanism of injury following blunt and penetrating assault. J Trauma. 2006;61:1166–1170.

142. Lowery DW, Wald MM, Browne BJ, Tigges S, Hoffman JR, Mower WR. Epidemiology of cervical spine injury victims. Ann Emerg Med. 2001;38:12–16.

143. Milby AH, Halpern CH, Guo W, Stein SC. Prevalence of cervical spinal injury in trauma. Neurosurg Focus. 2008;25:E10.

144. Mithani SK, St-Hilaire H, Brooke BS, Smith IM, Bluebond-Langner R, Rodriguez ED. Predictable patterns of intracranial and cervical spine injury in craniomaxillofacial trauma: analysis of 4786 patients. Plast Reconstr Surg. 2009;123:1293–1301.

145. Hackl W, Hausberger K, Sailer R, Ulmer H, Gassner R. Prevalence of cervical spine injuries in patients with facial trauma. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2001;92:370–376.

146. Holly LT, Kelly DF, Counelis GJ, Blinman T, McArthur DL, Cryer HG. Cervical spine trauma associated with moderate and severe head injury: incidence, risk factors, and injury characteristics. J Neurosurg Spine. 2002;96:285–291.

147. Demetriades D, Charalambides K, Chahwan S, Hanpeter D, Alo K, Velmahos G, Murray J, Asensio J. Nonskeletal cervical spine injuries: epidemiology and diagnostic pitfalls. J Trauma. 2000;48:724–727.

148. Baskett P, Nolan J, Parr M. Tidal volumes which are perceived to be adequate for resuscitation. Resuscitation. 1996;31:231–234.

149. Berg RA, Kern KB, Hilwig RW, Berg MD, Sanders AB, Otto CW, Ewy GA. Assisted ventilation does not improve outcome in a porcine model of single-rescuer bystander cardiopulmonary resuscitation. Circulation. 1997;95:1635–1641.

150. Berg RA, Kern KB, Hilwig RW, Ewy GA. Assisted ventilation during ‘bystander’ CPR in a swine acute myocardial infarction model does not improve outcome. Circulation. 1997;96:4364–4371.

151. Tang W, Weil MH, Sun S, Kette D, Gazmuri RJ, O'Connell F, Bisera J. Cardiopulmonary resuscitation by precordial compression but without mechanical ventilation. Am J Respir Crit Care Med. 1994;150():1709–1713.

152.

Wenzel V, Keller C, Idris AH, Dorges V, Lindner KH, Brimacombe JR. Effects of smaller tidal volumes during basic life support ventilation in patients with respiratory arrest: good ventilation, less risk? Resuscitation. 1999;43:25–29.

153. Dorges V, Ocker H, Hagelberg S, Wenzel V, Idris AH, Schmucker P. Smaller tidal volumes with room-air are not sufficient to ensure adequate oxygenation during bag-valve-mask ventilation. Resuscitation. 2000;44:37–41.

154. Dorges V, Ocker H, Hagelberg S, Wenzel V, Schmucker P. Optimisation of tidal volumes given with self-inflatable bags without additional oxygen. Resuscitation. 2000;43:195–199.

155. Finer NN, Barrington KJ, Al-Fadley F, Peters KL. Limitations of self-inflating resuscitators. Pediatrics. 1986;77:417–420.

156. Hirschman AM, Kravath RE. Venting vs ventilating. A danger of manual resuscitation bags. Chest. 1982;82:369–370.

157. Berg MD, Idris AH, Berg RA. Severe ventilatory compromise due to gastric distention during pediatric cardiopulmonary resuscitation. Resuscitation. 1998;36:71–73.

158. Garnett AR, Ornato JP, Gonzalez ER, Johnson EB. End-tidal carbon dioxide monitoring during cardiopulmonary resuscitation. JAMA. 1987;257:512–515.

159. Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004;109:1960–1965.

160. Sayre MR, Berg RA, Cave DM, Page RL, Potts J, White RD. Hands-only (compression-only) cardiopulmonary resuscitation: a call to action for bystander response to adults who experience out-of-hospital sudden cardiac arrest: a science advisory for the public from the American Heart Association Emergency Cardiovascular Care Committee. Circulation. 2008;117:2162–2167.

161. Berg RA, Sanders AB, Kern KB, Hilwig RW, Heidenreich JW, Porter ME, Ewy GA. Adverse hemodynamic effects of interrupting chest compressions for rescue breathing during cardiopulmonary resuscitation for ventricular fibrillation cardiac arrest. Circulation. 2001;104:2465–2470.

162. Kern KB, Hilwig RW, Berg RA, Sanders AB, Ewy GA. Importance of continuous chest compressions during cardiopulmonary resuscitation: improved outcome during a simulated single lay-rescuer scenario. Circulation. 2002;105:645–649.

163. Wang HE, Simeone SJ, Weaver MD, Callaway CW. Interruptions in cardiopulmonary resuscitation from paramedic endotracheal intubation. Ann Emerg Med. 2009;54:645–652 e641.

164. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, Berg RA, Hiraide A. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet. 2010.

165. Berg RA, Hilwig RW, Kern KB, Ewy GA. “Bystander” chest compressions and assisted ventilation independently improve outcome from piglet asphyxial pulseless “cardiac arrest.” Circulation. 2000;101:1743–1748.

166. Wenzel V, Idris AH, Banner MJ, Fuerst RS, Tucker KJ. The composition of gas given by mouth-to-mouth ventilation during CPR. Chest. 1994;106:1806–1810.

167. Ornato JP, Hallagan LF, McMahan SB, Peeples EH, Rostafinski AG. Attitudes of BCLS instructors about mouth-to-mouth resuscitation during the AIDS epidemic. Ann Emerg Med. 1990;19:151–156.

168. Brenner BE, Van DC, Cheng D, Lazar EJ. Determinants of reluctance to perform CPR among residents and applicants: the impact of experience on helping behavior. Resuscitation. 1997;35:203–211.

169. Hew P, Brenner B, Kaufman J. Reluctance of paramedics and emergency medical technicians to perform mouth-to-mouth resuscitation. J Emerg Med. 1997;15:279–284.

170. Ruben H. The immediate treatment of respiratory failure. Br J Anaesth. 1964;36:542–549.

171. Bhalla RK, Corrigan A, Roland NJ. Comparison of two face masks used to deliver early ventilation to laryngectomized patients. Ear Nose Throat J. 2004;83:414, 416.

172. Barnes TA. Emergency ventilation techniques and related equipment. Respir Care. 1992;37:673–690, discussion 690–674.

173. Johannigman JA, Branson RD, Davis K Jr., Hurst JM. Techniques of emergency ventilation: a model to evaluate tidal volume, airway pressure, and gastric insufflation. J Trauma. 1991;31:93–98.

174. Elam JO. Bag-valve-mask O2 ventilation. In: Safar P, Elam JO, eds. Advances in Cardiopulmonary Resuscitation: The Wolf Creek Conference on Cardiopulmonary Resuscitation. New York, NY: Springer-Verlag, Inc.; 1977:73–79.

175. Dailey R, Young G, Simon B, Stewart R. The Airway: Emergency Management: C.V. Mosby; 1992.

176. Elling R, Politis J. An evaluation of emergency medical technicians' ability to use manual ventilation devices. Ann Emerg Med. 1983;12:765–768.

177. von Goedecke A, Bowden K, Wenzel V, Keller C, Gabrielli A. Effects of decreasing inspiratory times during simulated bag-valve-mask ventilation. Resuscitation. 2005;64:321–325.

178. von Goedecke A, Bowden K, Keller C, Voelckel WG, Jeske HC, Wenzel V. [Decreased inspiratory time during ventilation of an unprotected airway. Effect on stomach inflation and lung ventilation in a bench model.] Anaesthesist. 2005;54:117–122.

179. von Goedecke A, Paal P, Keller C, Voelckel WG, Herff H, Lindner KH, Wenzel V. [Ventilation of an unprotected airway: evaluation of a new peak-inspiratory-flow and airway-pressure-limiting bag-valve-mask.] Anaesthesist. 2006;55:629–634.

180. Rumball CJ, MacDonald D. The, PTL Combitube, laryngeal mask, and oral airway: a randomized prehospital comparative study of ventilatory device effectiveness and cost-effectiveness in 470 cases of cardiorespiratory arrest. Prehosp Emerg Care. 1997;1:1–10.

181. Comparison of arterial blood gases of laryngeal mask airway and bag-valve-mask ventilation in out-of-hospital cardiac arrests. Circ J. 2009;73:490–496.

182. Stone BJ, Chantler PJ, Baskett PJ. The incidence of regurgitation during cardiopulmonary resuscitation: a comparison between the bag valve mask and laryngeal mask airway. Resuscitation. 1998;38:3–6.

183. Atherton GL, Johnson JC. Ability of paramedics to use the Combitube in prehospital cardiac arrest. Ann Emerg Med. 1993;22:1263–1268.

184. Kette F, Reffo I, Giordani G, Buzzi F, Borean V, Cimarosti R, Codiglia A, Hattinger C, Mongiat A, Tararan S. The use of laryngeal tube by nurses in out-of-hospital emergencies: Preliminary experience. Resuscitation. 2005;66:21–25.

185. Timmermann A, Russo SG, Rosenblatt WH, Eich C, Barwing J, Roessler M, Graf BM. Intubating laryngeal mask airway for difficult out-of-hospital airway management: a prospective evaluation. Br J Anaesth. 2007;99:286–291.

186. Saïssy JM, Boussignac G, Cheptel E, Rouvin B, Fontaine D, Bargues L, Levecque JP, Michel A, Brochard L. Efficacy of continuous insuf- flation of oxygen combined with active cardiac compression-decom- pression during out-of-hospital cardiorespiratory arrest. Anesthesiology. 2000;92:1523–1530.

187. Bertrand C, Hemery F, Carli P, Goldstein P, Espesson C, Rüttimann M, Macher JM, Raffy B, Fuster P, Dolveck F, Rozenberg A, Lecarpentier E, Duvaldestin P, Saissy JM, Boussignac G, Brochard L; Boussignac Study Group. Constant flow insufflation of oxygen as the sole mode of ventilation during out-of-hospital cardiac arrest. Intensive Care Med. 2006;32:843–851. doi: 10.1007/s00134-006-0137-2.

188. McNelis U, Syndercombe A, Harper I, Duggan J. The effect of cricoid pressure on intubation facilitated by the gum elastic bougie. Anaesthesia. 2007;62:456–459.

189. Harry RM, Nolan JP. The use of cricoid pressure with the intubating laryngeal mask. Anaesthesia. 1999;54:656–659.

190. Noguchi T, Koga K, Shiga Y, Shigematsu A. The gum elastic bougie eases tracheal intubation while applying cricoid pressure compared to a stylet. Can J Anaesth. 2003;50:712–717.

191. Asai T, Murao K, Shingu K. Cricoid pressure applied after placement of laryngeal mask impedes subsequent fibreoptic tracheal intubation through mask. Br J Anaesth. 2000;85:256–261.

192. Snider DD, Clarke D, Finucane BT. The “BURP” maneuver worsens the glottic view when applied in combination with cricoid pressure. Can J Anaesth. 2005;52:100–104.

193. Smith CE, Boyer D. Cricoid pressure decreases ease of tracheal intubation using fibreoptic laryngoscopy (WuScope System). Can J Anaesth. 2002;49:614–619.

194. Asai T, Barclay K, Power I, Vaughan RS. Cricoid pressure impedes placement of the laryngeal mask airway and subsequent tracheal intubation through the mask. Br J Anaesth. 1994;72:47–51.

195. Domuracki KJ, Moule CJ, Owen H, Kostandoff G, Plummer JL. Learning on a simulator does transfer to clinical practice. Resuscitation. 2009;80:346–349.

196. Beavers RA, Moos DD, Cuddeford JD. Analysis of the application of cricoid pressure: implications for the clinician. J Perianesth Nurs. 2009;24:92–102.

197. Meek T, Gittins N, Duggan JE. Cricoid pressure: knowledge and performance amongst anaesthetic assistants. Anaesthesia. 1999;54:59–62.

198. Clark RK, Trethewy CE. Assessment of cricoid pressure application by emergency department staff. Emerg Med Australas. 2005;17:376–381.

199. Kopka A, Robinson D. The 50 ml syringe training aid should be utilized immediately before cricoid pressure application. Eur J Emerg Med. 2005;12:155–158.

200.

Flucker CJ, Hart E, Weisz M, Griffiths R, Ruth M. The 50-millilitre syringe as an inexpensive training aid in the application of cricoid pressure. Eur J Anaesthesiol. 2000;17:443–447.

201. Shimabukuro A, Kawatani M, Nagao N, Inoue Y, Hayashida M, Hikawa Y. [Training in application of cricoid pressure.] Masui. 2006;55:742–744.

202. Schmidt A, Akeson J. Practice and knowledge of cricoid pressure in southern Sweden. Acta Anaesthesiol Scand. 2001;45:1210–1214.

203. Patten SP. Educating nurses about correct application of cricoid pressure. AORN J. 2006;84:449–461.

204. Koziol CA, Cuddeford JD, Moos DD. Assessing the force generated with application of cricoid pressure. AORN J. 2000;72:1018–1028, 1030.

205. Clayton TJ, Vanner RG. A novel method of measuring cricoid force. Anaesthesia. 2002;57:326–329.

206. Owen H, Follows V, Reynolds KJ, Burgess G, Plummer J. Learning to apply effective cricoid pressure using a part task trainer. Anaesthesia. 2002;57:1098–1101.

207. Kopka A, Crawford J. Cricoid pressure: a simple, yet effective biofeedback trainer. Eur J Anaesthesiol. 2004;21:443–447.

208. Quigley P, Jeffrey P. Cricoid pressure: assessment of performance and effect of training in emergency department staff. Emerg Med Australas. 2007;19:218–222.

209. Hallstrom AP, Ornato JP, Weisfeldt M, Travers A, Christenson J, McBurnie MA, Zalenski R, Becker LB, Schron EB, Proschan M; Public Access Defibrillation Trial Investigators. Public-access defibrillation and survival after out-of-hospital cardiac arrest. N Engl J Med. 2004;351:637–646. doi: 10.1056/NEJMoa040566.

210. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. N Engl J Med. 2000;343:1206–1209. doi: 10.1056/ NEJM200010263431701.

211. Agarwal DA, Hess EP, Atkinson EJ, White RD. Ventricular fibrilla- tion in Rochester, Minnesota: experience over 18 years. Resuscitation. 2009;80:1253–1258. doi: 10.1016/j.resuscitation.2009.07.019.

212. Rea TD, Cook AJ, Stiell IG, Powell J, Bigham B, Callaway CW, Chugh S, Aufderheide TP, Morrison L, Terndrup TE, Beaudoin T, Wittwer L, Davis D, Idris A, Nichol G; Resuscitation Outcomes Consortium Investigators. Predicting survival after out-of-hospital cardiac arrest: role of the Utstein data elements. Ann Emerg Med. 2010;55:249–257. doi: 10.1016/j.annemergmed.2009.09.018.

213. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. N Engl J Med. 2002;347:1242–1247. doi: 10.1056/NEJMoa020932.

214. Wik L, Hansen TB, Fylling F, Steen T, Vaagenes P, Auestad BH, Steen PA. Delaying defibrillation to give basic cardiopulmonary resuscitation to patients with out-of-hospital ventricular fibrillation: a randomized trial. JAMA. 2003;289:1389–1395.

215. Jacobs IG, Finn JC, Oxer HF, Jelinek GA. CPR before defibrillation in out-of-hospital cardiac arrest: a randomized trial. Emerg Med Australas. 2005;17:39–45. doi: 10.1111/j.1742-6723.2005.00694.x.

216. Baker PW, Conway J, Cotton C, Ashby DT, Smyth J, Woodman RJ, Grantham H; Clinical Investigators. Defibrillation or cardiopulmonary resuscitation first for patients with out-of-hospital cardiac arrests found by paramedics to be in ventricular fibrillation? A randomised control trial. Resuscitation. 2008;79:424–431. doi: 10.1016/j.resuscitation.2008.07.017.

217. Stiell IG, Nichol G, Leroux BG, Rea TD, Ornato JP, Powell J, Christenson J, Callaway CW, Kudenchuk PJ, Aufderheide TP, Idris AH, Daya MR, Wang HE, Morrison LJ, Davis D, Andrusiek D, Stephens S, Cheskes S, Schmicker RH, Fowler R, Vaillancourt C, Hostler D, Zive D, Pirrallo RG, Vilke GM, Sopko G, Weisfeldt M; ROC Investigators. Early versus later rhythm analysis in patients with out-of-hospital cardiac arrest. N Engl J Med. 2011;365:787–797. doi: 10.1056/NEJMoa1010076.

218. Ma MH, Chiang WC, Ko PC, Yang CW, Wang HC, Chen SY, Chang WT, Huang CH, Chou HC, Lai MS, Chien KL, Lee BC, Hwang CH, Wang YC, Hsiung GH, Hsiao YW, Chang AM, Chen WJ, Chen SC. A randomized trial of compression first or analyze first strategies in patients with out-of-hospital cardiac arrest: results from an Asian community. Resuscitation. 2012;83:806–812. doi: 10.1016/j.resuscitation.2012.01.009.

219. Cobb LA, Fahrenbruch CE, Walsh TR, Copass MK, Olsufka M, Breskin M, Hallstrom AP. Influence of cardiopulmonary resuscitation prior to defibrillation in patients with out-of-hospital ventricular fibrillation. JAMA. 1999;281:1182–1188.

220. Hayakawa M, Gando S, Okamoto H, Asai Y, Uegaki S, Makise H. Shortening of cardiopulmonary resuscitation time before the defibrilla- tion worsens the outcome in out-of-hospital VF patients. Am J Emerg Med. 2009;27:470–474. doi: 10.1016/j.ajem.2008.03.043.

221. Bradley SM, Gabriel EE, Aufderheide TP, Barnes R, Christenson J, Davis DP, Stiell IG, Nichol G; Resuscitation Outcomes Consortium Investigators. Survival increases with CPR by Emergency Medical Services before defibrillation of out-of-hospital ventricular fibrillation or ventricular tachycardia: observations from the Resuscitation Outcomes Consortium. Resuscitation. 2010;81:155–162. doi: 10.1016/j.resuscitation.2009.10.026.

222. Koike S, Tanabe S, Ogawa T, Akahane M, Yasunaga H, Horiguchi H, Matsumoto S, Imamura T. Immediate defibrillation or defibrillation after cardiopulmonary resuscitation. Prehosp Emerg Care. 2011;15:393–400. doi: 10.3109/10903127.2011.569848.

223. Meier P, Baker P, Jost D, Jacobs I, Henzi B, Knapp G, Sasson C. Chest compressions before defibrillation for out-of-hospital cardiac arrest: a meta-analysis of randomized controlled clinical trials. BMC Med. 2010;8:52. doi: 10.1186/1741-7015-8-52.

224. Simpson PM, Goodger MS, Bendall JC. Delayed versus immedi- ate defibrillation for out-of-hospital cardiac arrest due to ventricular fibrillation: A systematic review and meta-analysis of randomised controlled trials. Resuscitation. 2010;81:925–931. doi: 10.1016/j. resuscitation.2010.04.016.

225. Huang Y, He Q, Yang LJ, Liu GJ, Jones A. Cardiopulmonary resuscitation (CPR) plus delayed defibrillation versus immediate defibrillation for out-of-hospital cardiac arrest. Cochrane Database Syst Rev. 2014;9:CD009803. doi: 10.1002/14651858.CD009803.pub2.

226. Rea T, Prince D, Morrison L, Callaway C, Aufderheide T, Daya M, Stiell I, Christenson J, Powell J, Warden C, van Ottingham L, Kudenchuk P, Weisfeldt M. Association between survival and early versus later rhythm analysis in out-of-hospital cardiac arrest: do agency-level fac- tors influence outcomes? Ann Emerg Med. 2014;64:1–8. doi: 10.1016/j. annemergmed.2014.01.014.

227. Rea TD, Helbock M, Perry S, Garcia M, Cloyd D, Becker L, Eisenberg M. Increasing use of cardiopulmonary resuscitation during out-of-hospital ventricular fibrillation arrest: survival implications of guideline changes. Circulation. 2006;114:2760–2765. doi: 10.1161/CIRCULATIONAHA.106.654715.

228. Berdowski J, Tijssen JG, Koster RW. Chest compressions cause recurrence of ventricular fibrillation after the first successful conversion by defibrillation in out-of-hospital cardiac arrest. Circ Arrhythm Electrophysiol. 2010;3:72–78. doi: 10.1161/CIRCEP.109.902114.

229. Vadeboncoeur T, Bobrow BJ, Cone DC, Chikani V, Abella BS. Instant replay: perform CPR with immediate feedback. JEMS. 2011;36:50–63. doi: 10.1016/S0197-2510(11)70057-2.

230. Jollis JG, Granger CB, Henry TD, Antman EM, Berger PB, Moyer PH, Pratt FD, Rokos IC, Acuña AR, Roettig ML, Jacobs AK. Systems of care for ST-segment-elevation myocardial infarction: a report From the American Heart Association's Mission: Lifeline. Circ Cardiovasc Qual Outcomes. 2012;5:423–428. doi: 10.1161/CIRCOUTCOMES.111.964668.

231. Nestler DM, Noheria A, Haro LH, Stead LG, Decker WW, Scanlan- Hanson LN, Lennon RJ, Lim CC, Holmes DR Jr, Rihal CS, Bell MR, Ting HH. Sustaining improvement in door-to-balloon time over 4 years: the Mayo clinic ST-elevation myocardial infarction protocol. Circ Cardiovasc Qual Outcomes. 2009;2:508–513. doi: 10.1161/ CIRCOUTCOMES.108.839225.

232. Santana MJ, Stelfox HT. Quality indicators used by trauma centers for performance measurement. J Trauma Acute Care Surg. 2012;72:1298– 1302; discussion 12303. doi: 10.1097/TA.0b013e318246584c.

233. Abella BS, Edelson DP, Kim S, Retzer E, Myklebust H, Barry AM, O'Hearn N, Hoek TL, Becker LB. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation. 2007;73:54–61. doi: 10.1016/j. resuscitation.2006.10.027.

234. Bobrow BJ, Vadeboncoeur TF, Stolz U, Silver AE, Tobin JM, Crawford SA, Mason TK, Schirmer J, Smith GA, Spaite DW. The influence of scenario-based training and real-time audiovisual feedback on out-of- hospital cardiopulmonary resuscitation quality and survival from out- of-hospital cardiac arrest. Ann Emerg Med. 2013;62:47–56.e1. doi: 10.1016/j.annemergmed.2012.12.020.

235. Sutton RM, Niles D, French B, Maltese MR, Leffelman J, Eilevstjønn J, Wolfe H, Nishisaki A, Meaney PA, Berg RA, Nadkarni VM. First quanti- tative analysis of cardiopulmonary resuscitation quality during in-hospi- tal cardiac arrests of young children. Resuscitation. 2014;85:70–74. doi: 10.1016/j.resuscitation.2013.08.014.

236. Chiang WC, Chen WJ, Chen SY, Ko PC, Lin CH, Tsai MS, Chang WT, Chen SC, Tsan CY, Ma MH. Better adherence to the guidelines during cardiopulmonary resuscitation through the provision of audio-prompts. Resuscitation. 2005;64:297–301. doi: 10.1016/j. resuscitation.2004.09.010.

237. Lukas RP, Gräsner JT, Seewald S, Lefering R, Weber TP, Van Aken H, Fischer M, Bohn A. Chest compression quality management and return of spontaneous circulation: a matched-pair registry study. Resuscitation. 2012;83:1212–1218. doi: 10.1016/j.resuscitation.2012.03.027.

238. Sainio M, Kämäräinen A, Huhtala H, Aaltonen P, Tenhunen J, Olkkola KT, Hoppu S. Real-time audiovisual feedback system in a physician- staffed helicopter emergency medical service in Finland: the quality results and barriers to implementation. Scand J Trauma Resusc Emerg Med. 2013;21:50. doi: 10.1186/1757-7241-21-50.

239. Ballew KA, Philbrick JT, Caven DE, Schorling JB. Predictors of survival following in-hospital cardiopulmonary resuscitation. A moving target. Arch Intern Med. 1994;154:2426–2432.

240. Shih CL, Lu TC, Jerng JS, Lin CC, Liu YP, Chen WJ, Lin FY. A web- based Utstein style registry system of in-hospital cardiopulmonary resuscitation in Taiwan. Resuscitation. 2007;72:394–403. doi: 10.1016/j. resuscitation.2006.07.020.

241. Bradley SM, Huszti E, Warren SA, Merchant RM, Sayre MR, Nichol G. Duration of hospital participation in Get With the Guidelines-Resuscitation and survival of in-hospital cardiac arrest. Resuscitation. 2012;83:1349–1357. doi: 10.1016/j.resuscitation.2012.03.014.

242.

Matos RI, Watson RS, Nadkarni VM, Huang HH, Berg RA, Meaney PA, Carroll CL, Berens RJ, Praestgaard A, Weissfeld L, Spinella PC; American Heart Association's Get With The Guidelines–Resuscitation (Formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Duration of cardiopulmonary resuscitation and illness category impact survival and neurologic outcomes for in-hospital pedi- atric cardiac arrests. Circulation. 2013;127:442–451. doi: 10.1161/ CIRCULATIONAHA.112.125625.

243. Goldberger ZD, Nichol G. Registries to measure and improve out- comes after cardiac arrest. Curr Opin Crit Care. 2013;19:208–213. doi: 10.1097/MCC.0b013e328360ad06.

244. American Heart Association. Get With The Guidelines?Resuscitation. http://www.heart.org/HEARTORG/HealthcareResearch/GetWithThe Guidelines-Resuscitation/Get-With-The-GuidelinesResuscitation_UCM_314496_SubHomePage.jsp. Accessed May 9, 2015.

245. Peberdy MA, Kaye W, Ornato JP, Larkin GL, Nadkarni V, Mancini ME, Berg RA, Nichol G, Lane-Trultt T. Cardiopulmonary resuscitation of adults in the hospital: a report of 14 720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. Resuscitation. 2003;58:297–308.

246. Chan PS, Krumholz HM, Nichol G, Nallamothu BK; American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators. Delayed time to defibrillation after in-hospital cardiac arrest. N Engl J Med. 2008;358:9–17. doi: 10.1056/NEJMoa0706467.

247. Chan PS, Nichol G, Krumholz HM, Spertus JA, Jones PG, Peterson ED, Rathore SS, Nallamothu BK; American Heart Association National Registry of Cardiopulmonary Resuscitation (NRCPR) Investigators. Racial differences in survival after in-hospital cardiac arrest. JAMA. 2009;302:1195–1201. doi: 10.1001/jama.2009.1340.

248. Goldberger ZD, Chan PS, Berg RA, Kronick SL, Cooke CR, Lu M, Banerjee M, Hayward RA, Krumholz HM, Nallamothu BK; American Heart Association Get With The Guidelines—Resuscitation (formerly National Registry of Cardiopulmonary Resuscitation) Investigators. Duration of resus- citation efforts and survival after in-hospital cardiac arrest: an observational study. Lancet. 2012;380:1473–1481. doi: 10.1016/S0140-6736(12)60862-9.

249. Resuscitation Outcomes Consortium. https://roc.uwctc.org/tiki/tiki- index.php?page=roc-public-home. Accessed May 6, 2015.

250. Aufderheide TP, Nichol G, Rea TD, Brown SP, Leroux BG, Pepe PE, Kudenchuk PJ, Christenson J, Daya MR, Dorian P, Callaway CW, Idris AH, Andrusiek D, Stephens SW, Hostler D, Davis DP, Dunford JV, Pirrallo RG, Stiell IG, Clement CM, Craig A, Van Ottingham L, Schmidt TA, Wang HE, Weisfeldt ML, Ornato JP, Sopko G; Resuscitation Outcomes Consortium (ROC) Investigators. A trial of an imped- ance threshold device in out-of-hospital cardiac arrest. N Engl J Med. 2011;365:798–806. doi: 10.1056/NEJMoa1010821.

251. Kim F, Nichol G, Maynard C, Hallstrom A, Kudenchuk PJ, Rea T, Copass MK, Carlbom D, Deem S, Longstreth WT Jr, Olsufka M, Cobb LA. Effect of prehospital induction of mild hypothermia on survival and neurological status among adults with cardiac arrest: a randomized clinical trial. JAMA. 2014;311:45–52. doi: 10.1001/ jama.2013.282173.

252. Newgard CD, Koprowicz K, Wang H, Monnig A, Kerby JD, Sears GK, Davis DP, Bulger E, Stephens SW, Daya MR; ROC Investigators. Variation in the type, rate, and selection of patients for out-of-hospital airway procedures among injured children and adults. Acad Emerg Med. 2009;16:1269–1276. doi: 10.1111/j.1553-2712. 2009.00604.x.

253. National Center for Chronic Disease Prevention and Health Promotion, Division for Heart Disease and Stroke Prevention. Improving Emergency Cardiac Care Saves Lives: CARES Brochure. 2015. http://www.cdc.gov/ dhdsp/docs/CARES_Brochure.pdf. Accessed May 9, 2015.

254. Centers for Disease and Control Prevention, Emory Woodruff Health Sciences Center. CARES: Cardiac Arrest Registry to Enhance Survival. 2015. https://mycares.net/. Accessed May 19, 2015.

255. McNally B, Robb R, Mehta M, Vellano K, Valderrama AL, Yoon PW, Sasson C, Crouch A, Perez AB, Merritt R, Kellermann A; Centers for Disease Control and Prevention. Out-of-hospital cardiac arrest surveil- lance—Cardiac Arrest Registry to Enhance Survival (CARES), United States, October 1, 2005–December 31, 2010. MMWR Surveill Summ. 2011;60:1–19.

256. Sasson C, Magid DJ, Haukoos JS. Neighborhood characteristics and bystander-initiated CPR. N Engl J Med. 2013;368:391–392. doi: 10.1056/NEJMc1214188.

257. Sasson C, Hegg AJ, Macy M, Park A, Kellermann A, McNally B; CARES Surveillance Group. Prehospital termination of resuscitation in cases of refractory out-of-hospital cardiac arrest. JAMA. 2008;300:1432–1438. doi: 10.1001/jama.300.12.1432.

258. Govindarajan P, Lin L, Landman A, McMullan JT, McNally BF, Crouch AJ, Sasson C. Practice variability among the EMS systems participating in Cardiac Arrest Registry to Enhance Survival (CARES). Resuscitation. 2012;83:76–80. doi: 10.1016/j.resuscitation.2011.06.026.

259. Fernandez R, Compton S, Jones KA, Velilla MA. The presence of a family witness impacts physician performance during simulated medical codes. Crit Care Med. 2009;37:1956–1960. doi: 10.1097/ CCM.0b013e3181a00818.

260. Goldberger ZD, Nallamothu BK, Nichol G, Chan PS, Curtis JR, Cooke CR; American Heart Association's Get With the Guidelines–Resuscitation Investigators. Policies allowing family presence dur- ing resuscitation and patterns of care during in-hospital cardiac arrest. Circ Cardiovasc Qual Outcomes. 2015;8:226–234. doi: 10.1161/ CIRCOUTCOMES.114.001272.

261. Handley AJ. Recovery Position. Resuscitation. 1993;26:93–95.

262. Turner S, Turner I, Chapman D, Howard P, Champion P, Hatfield J, James A, Marshall S, Barber S. A comparative study of the 1992 and 1997 recovery positions for use in the UK. Resuscitation. 1998;39:153–160.

263. Gunn BD, Eizenberg N, Silberstein M, McMeeken JM, Tully EA, Stillman BC, Brown DJ, Gutteridge GA. How should an unconscious person with a suspected neck injury be positioned? Prehospital Disaster Med. 1995;10:239–244.

264. Blake WE, Stillman BC, Eizenberg N, Briggs C, McMeeken JM. The position of the spine in the recovery position–an experimental comparison between the lateral recovery position and the modified HAINES position. Resuscitation. 2002;53:289–297.

265. O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso JE, Tracy CM, Woo YJ, Zhao DX. 2013 ACCF/AHA guideline for the manage- ment of ST-elevation myocardial infarction: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2013;127:529–555. doi: 10.1161/CIR.0b013e3182742c84.

266. Amsterdam EA, Wenger NK, Brindis RG, Casey DE Jr, Ganiats TG, Holmes DR Jr, Jaffe AS, Jneid H, Kelly RF, Kontos MC, Levine GN, Liebson PR, Mukherjee D, Peterson ED, Sabatine MS, Smalling RW, Zieman SJ. 2014 AHA/ACC guideline for the management of patients with non-ST-elevation acute coronary syndromes: a report of the American College of Cardiology/ American Heart Association Task Force on Practice Guidelines. Circulation. 2014;130:e344–e426. doi: 10.1161/CIR.0000000000000134.

267. WRITING GROUP MEMBERS Lloyd-Jones D, Adams RJ, Brown TM, Carnethon M, Dai S, De Simone G, Ferguson TB, Ford E, Furie K, Gillespie C, Go A, Greenlund K, Haase N, Hailpern S, Ho PM, Howard V, Kissela B, Kittner S, Lackland D, Lisabeth L, Marelli A, McDermott MM, Meigs J, Mozaffarian D, Mussolino M, Nichol G, Roger VL, Rosamond W, Sacco R, Sorlie P, Stafford R, Thom T, Wasserthiel-Smoller S, Wong ND, Wylie-Rosett J. Committee obotAHAS, Stroke Statistics Subcommittee. Heart Disease and Stroke Statistics–2010 Update: A Report From the American Heart Association. Circulation. 2010;121:e46–e215.

268. Chiriboga D, Yarzebski J, Goldberg RJ, Gore JM, Alpert JS. Temporal trends (1975 through 1990) in the incidence and case-fatality rates of primary ventricular fibrillation complicating acute myocardial infarction: a communitywide perspective. Circulation. 1994;89:998–1003.

269. Anderson JL, Karagounis LA, Califf RM. Metaanalysis of five reported studies on the relation of early coronary patency grades with mortality and outcomes after acute myocardial infarction. Am J Cardiol. 1996;78:1–8.

270. Raitt MH, Maynard C, Wagner GS, Cerqueira MD, Selvester RH, Weaver WD. Relation between symptom duration before thrombolytic therapy and final myocardial infarct size. Circulation. 1996;93:48–53.

271. Douglas PS, Ginsburg GS. The evaluation of chest pain in women. N Engl J Med. 1996;334:1311–1315.

272. Solomon CG, Lee TH, Cook EF, Weisberg MC, Brand DA, Rouan GW, Goldman L. Comparison of clinical presentation of acute myocardial infarction in patients older than 65 years of age to younger patients: the Multicenter Chest Pain Study experience. Am J Cardiol. 1989;63:772–776.

273. Peberdy MA, Ornato JP. Coronary artery disease in women. Heart Dis Stroke. 1992;1:315–319.

274. Body R, Carley S, Wibberley C, McDowell G, Ferguson J, Mackway-Jones K. The value of symptoms and signs in the emergent diagnosis of acute coronary syndromes. Resuscitation. 2010;81:281–286.

275. Goodacre SW, Angelini K, Arnold J, Revill S, Morris F. Clinical predictors of acute coronary syndromes in patients with undifferentiated chest pain. QJM. 2003;96:893–898.

276. Goodacre S, Locker T, Morris F, Campbell S. How useful are clinical features in the diagnosis of acute, undifferentiated chest pain? Acad Emerg Med. 2002;9:203–208.

277. Everts B, Karlson BW, Wahrborg P, Hedner T, Herlitz J. Localization of pain in suspected acute myocardial infarction in relation to final diagnosis, age and sex, and site and type of infarction. Heart Lung. 1996;25:430–437.

278. McSweeney JC, Cody M, O'Sullivan P, Elberson K, Moser DK, Garvin BJ. Women's early warning symptoms of acute myocardial infarction. Circulation. 2003;108:2619–2623.

279. Panju AA, Hemmelgarn BR, Guyatt GG, Simel DL. Is this patient having a myocardial infarction? JAMA. 1998;280:1256–1263.

280. Mant J, McManus RJ, Oakes RA, Delaney BC, Barton PM, Deeks JJ, Hammersley L, Davies RC, Davies MK, Hobbs FD. Systematic review and modelling of the investigation of acute and chronic chest pain presenting in primary care. Health Technol Assess. 2004;8:iii,1–158.

281. Berger JP, Buclin T, Haller E, Van Melle G, Yersin B. Right arm involvement and pain extension can help to differentiate coronary diseases from chest pain of other origin: a prospective emergency ward study of 278 consecutive patients admitted for chest pain. J Intern Med. 1990;227:165–172.

282.

Jonsbu J, Rollag A, Aase O, Lippestad CT, Arnesen KE, Erikssen J, Koss A. Rapid and correct diagnosis of myocardial infarction: standardized case history and clinical examination provide important information for correct referral to monitored beds. J Intern Med. 1991;229:143–149.

283. Hargarten KM, Aprahamian C, Stueven H, Olson DW, Aufderheide TP, Mateer JR. Limitations of prehospital predictors of acute myocardial infarction and unstable angina. Ann Emerg Med. 1987;16:1325–1329.

284. Herlitz J, Hansson E, Ringvall E, Starke M, Karlson BW, Waagstein L. Predicting a life-threatening disease and death among ambulance-transported patients with chest pain or other symptoms raising suspicion of an acute coronary syndrome. Am J Emerg Med. 2002;20:588–594.

285. Lee TH, Pearson SD, Johnson PA, Garcia TB, Weisberg MC, Guadagnoli E, Cook EF, Goldman L. Failure of information as an intervention to modify clinical management. A time-series trial in patients with acute chest pain. Ann Intern Med. 1995;122:434–437.

286. Henrikson CA, Howell EE, Bush DE, Miles JS, Meininger GR, Friedlander T, Bushnell AC, Chandra-Strobos N. Chest pain relief by nitroglycerin does not predict active coronary artery disease. Ann Intern Med. 2003;139:979–986.

287. Lee TH, Rouan GW, Weisberg MC, Brand DA, Acampora D, Stasiulewicz C, Walshon J, Terranova G, Gottlieb L, Goldstein-Wayne B, et al. Clinical characteristics and natural history of patients with acute myocardial infarction sent home from the emergency room. Am J Cardiol. 1987;60:219–224.

288. Freimark D, Matetzky S, Leor J, Boyko V, Barbash IM, Behar S, Hod H. Timing of aspirin administration as a determinant of survival of patients with acute myocardial infarction treated with thrombolysis. Am J Cardiol. 2002;89:381–385.

289. Barbash IM, Freimark D, Gottlieb S, Hod H, Hasin Y, Battler A, Crystal E, Matetzky S, Boyko V, Mandelzweig L, Behar S, Leor J. Outcome of myocardial infarction in patients treated with aspirin is enhanced by pre-hospital administration. Cardiology. 2002;98:141–147.

290. Randomised trial of intravenous streptokinase, oral aspirin, both, or neither among 17 187 cases of suspected acute myocardial infarction: ISIS-2. ISIS-2 (Second International Study of Infarct Survival) Collaborative Group. Lancet. 1988;2:349–360.

291. Casaccia M, Bertello F, De Bernardi A, Sicuro M, Scacciatella P. Prehospital management of acute myocardial infarct in an experimental metropolitan system of medical emergencies [in Italian]. G Ital Cardiol. 1996;26:657–672.

292. Quan D, LoVecchio F, Clark B, Gallagher JV III.. Prehospital use of aspirin rarely is associated with adverse events. Prehosp Disaster Med. 2004;19:362–365.

293. Verheugt FW, van der Laarse A, Funke-Kupper AJ, Sterkman LG, Galema TW, Roos JP. Effects of early intervention with low-dose aspirin (100 mg) on infarct size, reinfarction and mortality in anterior wall acute myocardial infarction. Am J Cardiol. 1990;66:267–270.

294. Le May MR, So DY, Dionne R, Glover CA, Froeschl MP, Wells GA, Davies RF, Sherrard HL, Maloney J, Marquis JF, O'Brien ER, Trickett J, Poirier P, Ryan SC, Ha A, Joseph PG, Labinaz M. A citywide protocol for primary PCI in ST-segment elevation myocardial infarction. N Engl J Med. 2008;358:231–240.

295. Stenestrand U, Lindback J, Wallentin L. Long-term outcome of primary percutaneous coronary intervention vs prehospital and in-hospital thrombolysis for patients with ST-elevation myocardial infarction. JAMA. 2006;296:1749–1756.

296. Le May MR, Davies RF, Dionne R, Maloney J, Trickett J, So D, Ha A, Sherrard H, Glover C, Marquis JF, O'Brien ER, Stiell IG, Poirier P, Labinaz M. Comparison of early mortality of paramedic-diagnosed ST-segment elevation myocardial infarction with immediate transport to a designated primary percutaneous coronary intervention center to that of similar patients transported to the nearest hospital. Am J Cardiol. 2006;98:1329–1333.

297. Wijesinghe M, Perrin K, Ranchord A, Simmonds M, Weatherall M, Beasley R. Routine use of oxygen in the treatment of myocardial infarction: systematic review. Heart. 2009;95:198–202.

298. Haynes BE, Pritting J. A rural emergency medical technician with selected advanced skills. Prehosp Emerg Care. 1999;3:343–346.

299. Funk D, Groat C, Verdile VP. Education of paramedics regarding aspirin use. Prehosp Emerg Care. 2000;4:62–64.

300. Bussmann WD, Passek D, Seidel W, Kaltenbach M. Reduction of CK and CK-MB indexes of infarct size by intravenous nitroglycerin. Circulation. 1981;63:615–622.

301. Charvat J, Kuruvilla T, al Amad H. Beneficial effect of intravenous nitroglycerin in patients with non-Q myocardial infarction. Cardiologia. 1990;35:49–54.

302. Jugdutt BI, Warnica JW. Intravenous nitroglycerin therapy to limit myocardial infarct size, expansion, and complications. Effect of timing, dosage, and infarct location. Circulation. 1988;78:906–919.

303.

Jauch EC, Saver JL, Adams HP Jr, Bruno A, Connors JJ, Demaerschalk BM, Khatri P, McMullan PW Jr, Qureshi AI, Rosenfield K, Scott PA, Summers DR, Wang DZ, Wintermark M, Yonas H; American Heart Association Stroke Council; Council on Cardiovascular Nursing; Council on Peripheral Vascular Disease; Council on Clinical Cardiology. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2013;44:870–947. doi: 10.1161/STR.0b013e318284056a.

304. Powers WJ, Derdeyn CP, Biller J, Coffey CS, Hoh BL, Jauch EC, Johnston KC, Johnston SC, Khalessi AA, Kidwell CS, Meschia JF, Ovbiagele B; Yavagal DR; on behalf of the American Heart Association Stroke Council. 2015 American Heart Association/ American Stroke Association focused update of the 2013 guide- lines for the early management of patients with acute ischemic stroke regarding endovascular treatment: a guideline for health- care professionals from the American Heart Association/American Stroke Association. Stroke. 2015;46:XXX–XXX. doi: 10.1161/ STR.0000000000000074.

305. Barsan WG, Brott TG, Olinger CP, Adams HP Jr., Haley EC Jr., Levy DE. Identification and entry of the patient with acute cerebral infarction. Ann Emerg Med. 1988;17:1192–1195.

306. Barsan WG, Brott TG, Broderick JP, Haley EC, Levy DE, Marler JR. Time of hospital presentation in patients with acute stroke. Arch Intern Med. 1993;153:2558–2561.

307. Morgenstern LB, Bartholomew LK, Grotta JC, Staub L, King M, Chan W. Sustained benefit of a community and professional intervention to increase acute stroke therapy. Arch Intern Med. 2003;163:2198–2202.

308. Scott PA. Enhancing community delivery of tissue plasminogen activator in stroke through community-academic collaborative clinical knowledge translation. Emerg Med Clin North Am. 2009;27:115–136, ix.

309. Kleindorfer D, Khoury J, Broderick JP, Rademacher E, Woo D, Flaherty ML, Alwell K, Moomaw CJ, Schneider A, Pancioli A, Miller R, Kissela BM. Temporal trends in public awareness of stroke: warning signs, risk factors, and treatment. Stroke. 2009;40:2502–2506.

310. Smith WS, Isaacs M, Corry MD. Accuracy of paramedic identification of stroke and transient ischemic attack in the field. Prehosp Emerg Care. 1998;2:170–175.

311. Kidwell CS, Starkman S, Eckstein M, Weems K, Saver JL. Identifying stroke in the field. Prospective validation of the Los Angeles prehospital stroke screen (LAPSS). Stroke. 2000;31:71–76.

312. Smith WS, Corry MD, Fazackerley J, Isaacs SM. Improved paramedic sensitivity in identifying stroke victims in the prehospital setting. Prehosp Emerg Care. 1999;3:207–210.

313. Kim SK, Lee SY, Bae HJ, Lee YS, Kim SY, Kang MJ, Cha JK. Pre-hospital notification reduced the door-to-needle time for iv t-PA in acute ischaemic stroke. Eur J Neurol. 2009;16:1331–1335.

314. Quain DA, Parsons MW, Loudfoot AR, Spratt NJ, Evans MK, Russell ML, Royan AT, Moore AG, Miteff F, Hullick CJ, Attia J, McElduff P, Levi CR. Improving access to acute stroke therapies: a controlled trial of organised pre-hospital and emergency care. Med J Aust. 2008;189:429–433.

315. Abdullah AR, Smith EE, Biddinger PD, Kalenderian D, Schwamm LH. Advance hospital notification by EMS in acute stroke is associated with shorter door-to-computed tomography time and increased likelihood of administration of tissue-plasminogen activator. Prehosp Emerg Care. 2008;12:426–431.

316. Gropen TI, Gagliano PJ, Blake CA, Sacco RL, Kwiatkowski T, Richmond NJ, Leifer D, Libman R, Azhar S, Daley MB. Quality improvement in acute stroke: the New York State Stroke Center Designation Project. Neurology. 2006;67:88–93.

317. Gladstone DJ, Rodan LH, Sahlas DJ, Lee L, Murray BJ, Ween JE, Perry JR, Chenkin J, Morrison LJ, Beck S, Black SE. A citywide prehospital protocol increases access to stroke thrombolysis in Toronto. Stroke. 2009;40:3841–3844.

318. Langhorne P, Tong BL, Stott DJ. Association between physiological homeostasis and early recovery after stroke. Stroke. 2000;31:2518–2519.

319. Centers for Disease Control and Prevention. Drowning?United States, 2005–2009. MMWR Morb Mortal Wkly Rep. 2012;61:344–347.

320. Centers for Disease, Control, and Prevention. Fatal Injury Reports. Injury Prevention & Control: Data & Statistics (WISQARS). 2015. http://www.cdc.gov/injury/wisqars/fatal_injury_reports.html. Accessed May 9, 2015.

321. Perkins GD. In-water resuscitation: a pilot evaluation. Resuscitation. 2005;65:321–324.

322. Rosen P, Stoto M, Harley J. The use of the Heimlich maneuver in near-drowning: Institute of Medicine report. J Emerg Med. 1995;13:397–405.

323. Watson RS, Cummings P, Quan L, Bratton S, Weiss NS. Cervical spine injuries among submersion victims. J Trauma. 2001;51:658–662.

324. Hwang V, Shofer FS, Durbin DR, Baren JM. Prevalence of traumatic injuries in drowning and near drowning in children and adolescents. Arch Pediatr Adolesc Med. 2003;157:50–53.

325. Fingerhut LA, Cox CS. Warner M International comparative analysis of injury mortality. Findings from the ICE on injury statistics. International Collaborative Effort on Injury Statistics. Adv Data. 1998():1–20.

326. Dolkas L, Stanley C, Smith AM, Vilke GM. Deaths associated with choking in San Diego county. J Forensic Sci. 2007;52:176–179.

327. Soroudi A, Shipp HE, Stepanski BM, Ray LU, Murrin PA, Chan TC, Davis DP, Vilke GM. Adult foreign body airway obstruction in the prehospital setting. Prehosp Emerg Care. 2007;11:25–29.

328. Redding JS. The choking controversy: critique of evidence on the Heimlich maneuver. Crit Care Med. 1979;7:475–479.

329. Vilke GM, Smith AM, Ray LU, Steen PJ, Murrin PA, Chan TC. Airway obstruction in children aged less than 5 years: the prehospital experience. Prehosp Emerg Care. 2004;8:196–199.

330. Ingalls TH. Heimlich versus a slap on the back. N Engl J Med. 1979;300:990.

331. Heimlich HJ, Hoffmann KA, Canestri FR. Food-choking and drowning deaths prevented by external subdiaphragmatic compression. Physiological basis. Ann Thorac Surg. 1975;20:188–195.

332. Boussuges S, Maitrerobert P, Bost M. [Use of the Heimlich Maneuver on children in the Rhone-Alpes area.] Arch Fr Pediatr. 1985;42:733–736.

333. Guildner CW, Williams D, Subitch T. Airway obstructed by foreign material: the Heimlich maneuver. JACEP. 1976;5:675–677.

334. Langhelle A, Sunde K, Wik L, Steen PA. Airway pressure with chest compressions versus Heimlich manoeuvre in recently dead adults with complete airway obstruction. Resuscitation. 2000;44:105–108.

335. Ruben H, Macnaughton FI. The treatment of food-choking. Practitioner. 1978;221:725–729.

336. Brauner DJ. The Heimlich maneuver: procedure of choice? J Am Geriatr Soc. 1987;35:78.

337. Hartrey R, Bingham RM. Pharyngeal trauma as a result of blind finger sweeps in the choking child. J Accid Emerg Med. 1995;12:52–54.

338. Kabbani M, Goodwin SR. Traumatic epiglottis following blind finger sweep to remove a pharyngeal foreign body. Clin Pediatr (Phila). 1995;34:495–497.

Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiac arrest | cardiopulmonary resuscitation | emergency | ventricular fibrillation

1 Highlights

Summary of Key Issues and Major Changes

Conventional CPR consisting of manual chest compressions interspersed with rescue breaths is inherently inefficient with respect to generating significant cardiac output. A variety of alternatives and adjuncts to conventional CPR have been developed with the aim of enhancing cardiac output resuscitation from cardiac arrest. Since the 2010 Guidelines were published, a number of clinical trials have provided new data on the effectiveness of these alternatives.

Compared with conventional CPR, many of these techniques and devices require specialized equipment and training. When rescuers or healthcare systems are considering implementation, it must be noted that some techniques and devices have been tested only in highly selected subgroups of cardiac arrest patients.

- The routine use of the impedance threshold device (ITD) as an adjunct to conventional CPR is not recommended.
- A recent randomized controlled trial suggests that the use of the ITD plus active compression-decompression CPR is associated with improved neurologically intact survival for patients with OHCA.
- The routine use of mechanical chest compression devices is not recommended, but special settings where this technology may be useful are identified.
- The use of ECPR may be considered for selected patients in settings where a reversible cause of cardiac arrest is suspected.

Impedance Threshold Devices

2015 (Updated): The routine use of the ITD as an adjunct during conventional CPR is not recommended. The combination of ITD with active compression-decompression CPR may be a reasonable alternative to conventional CPR in settings with available equipment and properly trained personnel.

2010 (Old): The use of the ITD may be considered by trained personnel as a CPR adjunct in adult cardiac arrest.

Why: Two large randomized controlled trials have provided new information about the use of the ITD in OHCA. One large multicenter randomized clinical trial failed to demonstrate any improvement associated with the use of an ITD (compared with a sham device) as an adjunct to conventional CPR. Another clinical trial demonstrated a benefit with the use of active compression-decompression CPR plus an ITD when compared with conventional CPR and no ITD. However, confidence intervals around the primary outcome point estimate were very broad, and there is a high risk of bias on the basis of co-intervention (the group receiving active compression-decompression CPR plus the ITD also had CPR delivered using CPR quality feedback devices, while the control arm did not have the use of such feedback devices).

Mechanical Chest Compression Devices

2015 (Updated): The evidence does not demonstrate a benefit with the use of mechanical piston devices for chest compressions versus manual chest compressions in patients with cardiac arrest. Manual chest compressions remain the standard of care for the treatment of cardiac arrest. However, such a device may be a reasonable alternative to conventional CPR in specific settings where the delivery of high-quality manual compressions may be challenging or dangerous for the provider (eg, limited rescuers available, prolonged CPR,

CPR during hypothermic cardiac arrest, CPR in a moving ambulance, CPR in the angiography suite, CPR during preparation for ECPR).

2010 (Old): Mechanical piston devices may be considered for use by properly trained personnel in specific settings for the treatment of adult cardiac arrest in circumstances (e.g., during diagnostic and interventional procedures) that make manual resuscitation difficult. The load-distributing band may be considered for use by properly trained personnel in specific settings for the treatment of cardiac arrest.

Why: Three large randomized controlled trials comparing mechanical chest compression devices have not demonstrated improved outcomes for patients with OHCA when compared with manual chest compressions. For this reason, manual chest compressions remain the standard of care.

Extracorporeal Techniques and Invasive Perfusion Devices

2015 (Updated): ECPR may be considered an alternative to conventional CPR for select patients who have a cardiac arrest and for whom the suspected etiology of the cardiac arrest is potentially reversible.

2010 (Old): There was insufficient evidence to recommend the routine use of ECPR for patients in cardiac arrest. However, in settings where ECPR is readily available, it may be considered when the time without blood flow is brief and the condition leading to the cardiac arrest is reversible (e.g., accidental hypothermia, drug intoxication) or amenable to heart transplantation (e.g., myocarditis) or revascularization (eg, acute myocardial infarction).

Why: The term *extracorporeal* CPR is used to describe the initiation of extracorporeal circulation and oxygenation during the resuscitation of a patient in cardiac arrest. ECPR involves the emergency cannulation of a large vein and artery (e.g., femoral vessels). The goal of ECPR is to support patients in cardiac arrest while potentially reversible conditions are treated. ECPR is a complex process that requires a highly trained team, specialized equipment, and multidisciplinary support within the local healthcare system. There are no clinical trials on ECPR, and available published series have used rigorous inclusion and exclusion criteria to select patients for ECPR. Although these inclusion criteria are highly variable, most included only patients aged 18 to 75 years with limited comorbidities, with arrest of cardiac origin, after conventional CPR for more than 10 minutes without ROSC. These inclusion criteria should be considered in a provider's selection of potential candidates for ECPR.

2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

Conventional cardiopulmonary resuscitation (CPR) consisting of manual chest compressions with rescue breaths is inherently inefficient with respect to generating cardiac output. A variety of alternatives and adjuncts to conventional CPR have been developed, with the aim of enhancing perfusion during resuscitation from cardiac arrest. Since the publication of the *2010 American Heart Association* (AHA) *Guidelines for CPR and Emergency Cardiovascular Care* (ECC), a number of clinical trials have provided additional data on the effectiveness of these alternatives and adjuncts. Compared with conventional CPR, many of these techniques and devices require specialized equipment and training. Some have only been tested in highly selected subgroups of cardiac arrest patients; this context must be considered when rescuers or healthcare systems are considering implementation.

The 2010 Guidelines add these cautions:

2.1 Methodology - Updated

The updated or new recommendations in the *2015 AHA Guidelines Update for CPR and ECC* are based on an extensive evidence review process that was begun by the International Liaison Committee on Resuscitation (ILCOR) after the publication of the ILCOR *2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations*[1,2] and was completed in February 2015.[3,4]

In this in-depth evidence review process, the ILCOR Advanced Life Support (ALS) Task Force examined topics and then generated a prioritized list of questions for systematic review. Questions were first formulated in PICO (population, intervention, comparator, outcome) format,[5] search strategies and criteria for inclusion and exclusion of articles were defined, and then a search for relevant articles was performed. The evidence was evaluated by the ILCOR ALS Task Force by using the standardized methodological approach proposed by the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group.[6]

The quality of the evidence was categorized based on the study methodologies and the 5 core GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias). Then, where possible, consensus-based treatment recommendations were created.

To create the *2015 AHA Guidelines Update for CPR and ECC*, the AHA formed 15 writing groups, with careful attention to manage conflicts of interest, to assess the ILCOR treatment recommendations, and to write AHA Guidelines and treatment recommendations by using the AHA Class of Recommendation and Level of Evidence (LOE) system. The recommendations made in the *2015 AHA Guidelines Update for CPR and ECC* are informed by the ILCOR recommendations and GRADE classification, in the context of the delivery of medical care in North America. Throughout the online version of this publication, live links are provided so the reader can connect directly to the systematic reviews on the ILCOR Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated by a superscript combination of letters and numbers (eg, ALS 579). We encourage readers to use the links and review the evidence and appendixes, such as the GRADE tables. For further information, please see Part 2 of this supplement, “Evidence Evaluation and Management of Conflicts of Interest.”

The following CPR techniques and devices were last reviewed in 2010 [1,2]: open-chest CPR, interposed abdominal compression, “cough” CPR, prone CPR, precordial thump, percussion pacing, and devices to assist ventilation. The reader is referred to the 2010 Guidelines for details of those recommendations. A listing of all of the recommendations in this 2015 Guidelines Update and the recommendations from “Part 7: CPR Techniques and Devices” of the 2010 Guidelines can be found in the Appendix. The 2010 recommendations are included below in this Web-based Integrated Guideline document.

3 CPR Techniques

3.1 Open-Chest CPR

In open-chest CPR the heart is accessed through a thoracotomy (typically created through the 5th left intercostal space) and compression is performed using the thumb and fingers, or with the palm and extended fingers against the sternum. Use of this technique generates forward blood flow and coronary perfusion pressure that typically exceed those generated by closed chest compressions.

There are few human studies comparing open-chest CPR to conventional CPR in cardiac arrest and no prospective randomized trials. Several studies of open-chest CPR have demonstrated improved coronary perfusion pressure and/or return of spontaneous circulation (ROSC) for both the in-hospital (eg, following cardiac surgery)[7-9] and out-of-hospital environments. [10-13]

Several small case series of cardiac arrest patients treated with thoracotomy and open-chest CPR after blunt [14,15] or penetrating trauma[15-17] reported survivors with mild or no neurological deficit.

There is insufficient evidence of benefit or harm to recommend the routine use of open-chest CPR.

However, open-chest CPR can be useful if cardiac arrest develops during surgery when the chest or abdomen is already open, or in the early postoperative period after cardiothoracic surgery. (Class IIa, LOE C2)

A resuscitative thoracotomy to facilitate open-chest CPR may be considered in very select circumstances of adults and children with out-of-hospital cardiac arrest from penetrating trauma with short transport times to a trauma facility.[18,19] (Class IIb, LOE C)

3.2 Interposed Abdominal Compression-CPR

The interposed abdominal compression (IAC)-CPR is a 3-rescuer technique (an abdominal compressor plus the chest compressor and the rescuer providing ventilations) that includes conventional chest compressions combined with alternating abdominal compressions. The dedicated rescuer who provides manual abdominal compressions will compress the abdomen midway between the xiphoid and the umbilicus during the relaxation phase of chest compression. Hand position, depth, rhythm, and rate of abdominal compressions are similar to those for chest compressions and the force required is similar to that used to palpate the abdominal aorta. In most reports, an endotracheal tube is placed before or shortly after initiation of IAC-CPR. IAC-CPR increases diastolic aortic pressure and venous return, resulting in improved coronary perfusion pressure and blood flow to other vital organs.

In 2 randomized in-hospital trials, IAC-CPR performed by trained rescuers improved short-term survival[20] and survival to hospital discharge[21] compared with conventional CPR for adult cardiac arrest. The data from these studies were combined in 2 positive meta-analyses.[22,23] However, 1 randomized controlled trial of adult out-of-hospital cardiac arrest[24] did not show any survival advantage to IAC-CPR. Although there were no complications reported in adults,[22] 1 pediatric case report[25] documented traumatic pancreatitis following IAC-CPR.

IAC-CPR may be considered during in-hospital resuscitation when sufficient personnel trained in its use are available. (Class IIb, LOE B)

There is insufficient evidence to recommend for or against the use of IAC-CPR in the out-of-hospital setting or in children.

3.3 “Cough” CPR

“Cough” CPR describes the use of forceful voluntary coughs every 1 to 3 seconds in conscious patients shortly after the onset of a witnessed nonperfusing cardiac rhythm in a controlled environment such as the cardiac catheterization laboratory. Coughing episodically increases the intrathoracic pressure and can generate systemic blood pressures higher than those usually generated by conventional chest compressions,[26,27] allowing patients to maintain consciousness[26-29] for a brief arrhythmic interval (up to 92 seconds documented in humans).[28]

“Cough” CPR has been reported exclusively in awake, monitored patients (predominantly in the cardiac catheterization laboratory) when arrhythmic cardiac arrest can be anticipated, the patient remains conscious and can be instructed before and coached during the event, and cardiac activity can be promptly restored.[26-36] However, not all victims are able to produce hemodynamically effective coughs.[30]

“Cough” CPR is not useful for unresponsive victims and should not be taught to lay rescuers. “Cough” CPR may be considered in settings such as the cardiac catheterization laboratory for conscious, supine, and monitored patients if the patient can be instructed and coached to cough forcefully every 1 to 3 seconds during the initial seconds of an arrhythmic cardiac arrest. It should not delay definitive treatment. (Class IIb, LOE C)

3.4 Prone CPR

When the patient cannot be placed in the supine position, it may be reasonable for rescuers to provide CPR with the patient in the prone position, particularly in hospitalized patients with an advanced airway in place.[37-40] (Class IIb, LOE C)

3.5 Precordial Thump

A precordial thump has been reported to convert ventricular tachyarrhythmias in 1 study with concurrent controls,[41] single-patient case reports, and small case series.[42-46] However, 2 larger case series found that the precordial thump was ineffective in 79 (98.8%) of 80 cases[47] and in 153 (98.7%) of 155 cases of malignant

ventricular arrhythmias.[48] Case reports and case series[49-51] have documented complications associated with precordial thump including sternal fracture, osteomyelitis, stroke, and triggering of malignant arrhythmias in adults and children.

The precordial thump should not be used for unwitnessed out-of-hospital cardiac arrest. (Class III, LOE C)

The precordial thump may be considered for patients with witnessed, monitored, unstable ventricular tachycardia including pulseless VT if a defibrillator is not immediately ready for use, but it should not delay CPR and shock delivery. (Class IIb, LOE C)

There is insufficient evidence to recommend for or against the use of the precordial thump for witnessed onset of asystole.

3.6 Percussion Pacing

Percussion (eg, fist) pacing refers to the use of regular, rhythmic and forceful percussion of the chest with the rescuer's fist in an attempt to pace the myocardium. There is little evidence supporting fist or percussion pacing in cardiac arrest based on 6 single-patient case reports[52-57] and a moderate-sized case series.[58] There is insufficient evidence to recommend percussion pacing during typical attempted resuscitation from cardiac arrest.

4 CPR Devices - Updated

4.1 Devices to Assist Ventilation

4.1.1 Automatic and Mechanical Transport Ventilators

4.1.1.1 Automatic Transport Ventilators

There are very few studies evaluating the use of automatic transport ventilators (ATVs) during attempted resuscitation in patients with endotracheal intubation.

During prolonged resuscitation efforts, the use of an ATV (pneumatically powered and time- or pressure-cycled) may provide ventilation and oxygenation similar to that possible with the use of a manual resuscitation bag, while allowing the Emergency Medical Services (EMS) team to perform other tasks.[59], [60] (Class IIb, LOE C)

Disadvantages of ATVs include the need for an oxygen source and a power source. Thus, providers should always have a bag-mask device available for manual backup. For additional information regarding support of airway and ventilation in the adult, see "Part 7:Adult Advanced Cardiovascular Life Support."

4.1.1.2 Manually Triggered, Oxygen-Powered, Flow-Limited Resuscitators

In a study of 104 anesthetized nonarrest patients without an advanced airway in place (ie, no endotracheal tube; patients were ventilated through a mask), patients ventilated by firefighters with manually triggered, oxygen-powered, flow-limited resuscitators had less gastric inflation than those ventilated with a bag-mask device.[61]

Manually triggered, oxygen-powered, flow-limited resuscitators may be considered for the management of patients who do not have an advanced airway in place and for whom a mask is being used for ventilation during CPR. (Class IIb, LOE C)

Rescuers should avoid using the automatic mode of the oxygen-powered, flow-limited resuscitator during CPR because it may generate high positive end-expiratory pressure (PEEP) that may impede venous return during chest compressions and compromise forward blood flow.[62] (Class III, LOE C)

4.2 Devices to Support Circulation - Updated

4.2.1 Active Compression-Decompression CPR

Active compression-decompression CPR (ACD-CPR) is performed with a device that includes a suction cup to actively lift the anterior chest during decompression. The application of external negative suction during the decompression phase of CPR creates negative intrathoracic pressure and thus potentially enhances venous return to the heart. When used, the device is positioned at midsternum on the chest.

Results from the use of ACD-CPR have been mixed. In several studies[63-68] ACD-CPR improved ROSC and short-term survival compared with conventional CPR. Of these studies, 3 showed improvement in neurologically intact survival.[63,66,67] In contrast, 1 Cochrane meta-analysis of 10 studies involving both in-hospital arrest (826 patients) and out-of-hospital arrest (4162 patients)[69] and several other controlled trials[70-76] comparing ACD-CPR to conventional CPR showed no difference in ROSC or survival. The meta-analysis[69] did not find any increase in ACD-CPR–related complications.

There is insufficient evidence to recommend for or against the routine use of ACD-CPR. ACD-CPR may be considered for use when providers are adequately trained and monitored. (Class IIb, LOE B)

4.2.2 Phased Thoracic-Abdominal Compression-Decompression CPR With a Handheld Device

Phased thoracic-abdominal compression-decompression CPR (PTACD-CPR) combines the concepts of IAC-CPR and ACD-CPR. A handheld device alternates chest compression and abdominal decompression with chest decompression and abdominal compression. Evidence from 1 prospective randomized clinical study of adults in cardiac arrest[77] demonstrated no improvement in survival to hospital discharge with use of PTACD-CPR during out-of-hospital cardiac arrest. There is insufficient evidence to support or refute the use of PTACD-CPR for the treatment of cardiac arrest.

4.2.3 Impedance Threshold Device - Updated ALS 579

The impedance threshold device (ITD) is a pressure-sensitive valve that is attached to an endotracheal tube (ETT), supraglottic airway, or face mask. The ITD limits air entry into the lungs during the decompression phase of CPR, enhancing the negative intrathoracic pressure generated during chest wall recoil, thereby improving venous return to the heart and cardiac output during CPR. It does so without impeding positive-pressure ventilation or passive exhalation. The ITD is removed after return of spontaneous circulation (ROSC) is achieved. The ITD has been used alone as a circulatory adjunct as well as in conjunction with active compression-decompression CPR (ACD-CPR) devices. The ITD and ACD-CPR are thought to act synergistically to enhance venous return and improve cardiac output during CPR.[78,79] Although initially used as part of a circuit with a cuffed ETT during bag-tube ventilation, the ITD can also be used with a face mask, provided that a tight seal is maintained between the face and mask.

4.2.3.1 2015 Evidence Summary

Three randomized controlled trials (RCTs) in humans have examined the benefits of incorporating the ITD as an adjunct to conventional CPR in out-of-hospital cardiac arrest (OHCA). One small single-site RCT of 22 patients with femoral artery catheters demonstrated that a functioning ITD applied to an ETT significantly increased systolic blood pressures as compared with a sham device, although there was no difference in ROSC rates.[80] The second RCT examined the safety and survival to intensive care unit admission of a functioning versus sham ITD in 230 patients.[81] The ITD was initially placed on a face mask and was relocated to the ETT after intubation. This study found no difference in ROSC, intensive care unit admission, or 24-hour survival between the 2 groups. The third and largest RCT examined the impact of a functioning ITD versus a sham device at 10 sites in the United States and Canada as part of the Resuscitation Outcomes Consortium (ROC) Prehospital Resuscitation Impedance Valve and Early Versus Delayed Analysis (PRIMED) study.[82] Of the 8718 patients

included in this high-quality RCT, 4345 were randomized to resuscitation with a sham ITD and 4373 were assigned to resuscitation with the functioning ITD. The ROC PRIMED study permitted placement of the ITD on a face mask, supraglottic airway, or ETT. This large multicenter RCT did not show a benefit from the addition of the ITD to conventional CPR for neurologically intact survival to hospital discharge or survival to hospital discharge. There were no differences in adverse events (pulmonary edema or airway bleeding) between the 2 groups.

4.2.3.2 2015 Recommendation—New

The routine use of the ITD as an adjunct during conventional CPR is not recommended.
(Class III: No Benefit, LOE A)

This Class of Recommendation, new in 2015, indicates that high-quality evidence did not demonstrate benefit or harm associated with the ITD when used as an adjunct to conventional CPR.

4.2.4 Active Compression-Decompression CPR and Impedance Threshold Device - Updated ALS 579

ACD-CPR is performed by using a handheld device with a suction cup applied over the midsternum of the chest. After chest compression, the device is used to actively lift up the anterior chest during decompressions. The application of external negative suction during decompression enhances the negative intrathoracic pressure (vacuum) generated by chest recoil, thereby increasing venous return (preload) to the heart and cardiac output during the next chest compression. ACDCPR is believed to act synergistically with the ITD to enhance venous return during chest decompression and improves blood flow to vital organs during CPR. Commercially available ACD-CPR devices have a gauge meter to guide compression and decompression forces and a metronome to guide duty cycle and chest compression rate. The use of ACD-CPR in comparison with conventional CPR was last reviewed for the 2010 Guidelines. Since the 2010 Guidelines, new evidence is available regarding the use of ACD-CPR in combination with the ITD.

4.2.4.1 2015 Evidence Summary

The combination of ACD-CPR with an ITD has been studied in 4 RCTs reported in 5 publications.[79,83-86] Two of these trials evaluated ACD-CPR with the ITD in comparison with ACDCPR alone.[79,83] The first of these used femoral artery catheters to measure improved hemodynamic parameters but found no difference in ROSC, 24-hour survival, or survival to hospital discharge.[79] In a follow-up RCT of 400 patients, the ACD-CPR with a functioning ITD increased 24-hour survival, but again there was no difference in survival to hospital discharge or survival with good neurologic function as compared with the ACD-CPR with sham ITD group.[83]

The remaining 2 RCTs compared ACD-CPR with the ITD versus conventional CPR. The first was a single-center RCT in which 210 patients were randomly assigned to ACD-CPR+ITD or conventional CPR after intubation by the advanced life support team, which arrived on scene a mean of 9.5 minutes after the 9-1-1 call.[84] The chest compression and ventilation rates in both arms were 100/min and 10 to 12 breaths/min, respectively. The ROSC, 1-hour, and 24-hour rates of survival were all significantly improved in the ACDCPR+ITD group as compared with conventional CPR, but survival to hospital discharge and survival with favorable neurologic outcome were not significantly different. The second trial is the ResQ trial, which was conducted in 7 distinct geographic regions of the United States. In the ResQ trial, conventional CPR was performed with compressions at 100/min, with a compression-to-ventilation ratio of 30:2 during basic life support and ventilation rate of 10/min after intubation. In the ACD-CPR+ITD group, compressions were performed at a rate of 80/min and ventilation at a rate of 10/min. In the intervention arm, a metronome was used to guide the compression rate, a force gauge was used to guide compression depth and recoil, and timing lights on the ITD were used to guide ventilation rate. Two analyses of data from the ResQ trial have been published; the first was restricted to OHCA of presumed cardiac etiology,[85] and the second included all enrolled patients.[86] The complete trial enrolled 2738 patients (conventional CPR=1335, ACD-CPR+ITD=1403) before it was terminated early because of funding constraints.[86] Survival to hospital discharge with favorable neurologic function (modified Rankin Scale score of 3 or less) was greater in the ACD-CPR+ITD group as compared with the conventional CPR group: 7.9% versus 5.7% (odds ratio, 1.42; 95% confidence interval, 1.04–1.95), and this difference was maintained out to 1 year. For survival to hospital discharge with favorable neurologic function, this translates into a number needed to treat of 45 with very wide confidence limits (95% confidence interval, 25–333), making interpretation of the true clinical effect challenging. There was no difference in the overall incidence of adverse events, although pulmonary edema was more common with ACD-CPR+ITD as compared with conventional CPR (11.3% versus 7.9%; P=0.002). The ResQ

Trial had a number of important limitations, including lack of blinding, different CPR feedback elements between the study arms (ie, co-intervention), lack of CPR quality assessment, and early termination. Although improved neurologic function was noted with the use of the ACD-CPR+ITD combination at both hospital discharge and 1-year follow-up, additional trials are needed to confirm these findings.

4.2.4.2 2015 Recommendation—New

The existing evidence, primarily from 1 large RCT of low quality, does not support the routine use of ACD-CPR+ITD as an alternative to conventional CPR. The combination may be a reasonable alternative in settings with available equipment and properly trained personnel. (Class IIb, LOE C-LD)

4.2.5 Mechanical Chest Compression Devices:Piston Device - Updated ALS 782

A mechanical piston device consists of an automated compressed gas- or electric-powered plunger positioned over the sternum, which compresses the chest at a set rate. Some devices incorporate a suction cup at the end of the piston that is designed to actively decompress the chest after each compression, whereas others do not.

4.2.5.1 2015 Evidence Review

The Lund University Cardiac Arrest System (LUCAS) is a gas- (oxygen or air) or electric-powered piston device that produces a consistent chest compression rate and depth. It incorporates a suction cup on the end of the piston that attaches to the sternum and returns the sternum to the starting position when it retracts. A small pilot RCT found similar survival in patients randomly assigned to mechanical versus manual chest compressions.[87] Subsequently, 2 large RCTs, the Prehospital Randomised Assessment of a Mechanical Compression Device in Cardiac Arrest (PARAMEDIC)[88] and LUCAS in Cardiac Arrest (LINC)[89] trials, have compared the use of LUCAS against manual compressions for patients with OHCA. Together, these studies enrolled 7060 patients, and neither demonstrated a benefit for mechanical CPR over manual CPR with respect to early (4-hour) and late (1- and 6-month) survival.[88,89] The PARAMEDIC study demonstrated a negative association between mechanical chest compressions and survival with good neurologic outcome (Cerebral Performance Category 1–2) at 3 months as compared with manual compressions.

A number of other mechanical piston devices have been compared with manual chest compressions in studies of OHCA. There are no large-scale RCTs with these devices. Three small (largest sample size of 50 patients) RCTs found no differences in early survival[90-92] despite improvements in end-tidal CO2 in patients randomly assigned to mechanical piston devices in 2 of these 3 studies.[91,92] However, in neither of these studies did any patient survive to hospital discharge. Time-motion analysis of manual versus mechanical chest compressions showed that it took considerable time to deploy the mechanical piston device, prolonging the no-chest compression interval during CPR.[93]

4.2.5.2 2015 Recommendation—New

The evidence does not demonstrate a benefit with the use of mechanical piston devices for chest compressions versus manual chest compressions in patients with cardiac arrest. Manual chest compressions remain the standard of care for the treatment of cardiac arrest, but mechanical piston devices may be a reasonable alternative for use by properly trained personnel. (Class IIb, LOE B-R)

The use of mechanical piston devices may be considered in specific settings where the delivery of high-quality manual compressions may be challenging or dangerous for the provider (eg, limited rescuers available, prolonged CPR, during hypothermic cardiac arrest, in a moving ambulance, in the angiography suite, during preparation for extracorporeal CPR [ECPR]), provided that rescuers strictly limit interruptions in CPR during deployment and removal of the devices. (Class IIb, LOE C-EO)

4.2.6 Load-Distributing Band Devices - Updated ALS 782

The load-distributing band (LDB) is a circumferential chest compression device composed of a pneumatically or electrically actuated constricting band and backboard.

4.2.6.1 2015 Evidence Summary

While early case series[94-96] of patients treated with LDB-CPR were encouraging, an observational study exploring a number of treatments related to new guideline implementation suggested that the use of LDB-CPR was associated with lower odds of 30-day survival when compared with concurrent patients receiving only manual CPR.[97] One multicenter prospective RCT[98] comparing LDB-CPR (Autopulse device) with manual CPR for OHCA demonstrated no improvement in 4-hour survival and worse neurologic outcome when the device was compared with manual CPR. Site-specific factors[99] and experience with deployment of the device[100] may have influenced the outcomes in this study. In a high-quality multicenter RCT of 4753 OHCA patients, LDB-CPR (Autopulse device) and manual chest compressions were shown to be equivalent with respect to the outcome of survival to hospital discharge. Both approaches in this study were carefully monitored to minimize hands-off time and to optimize compression technique.[101]

4.2.6.2 2015 Recommendation—New

The evidence does not demonstrate a benefit with the use of LDB-CPR for chest compressions versus manual chest compressions in patients with cardiac arrest. Manual chest compressions remain the standard of care for the treatment of cardiac arrest, but LDB-CPR may be a reasonable alternative for use by properly trained personnel. (Class IIb, LOE B-R)

The use of LDB-CPR may be considered in specific settings where the delivery of high-quality manual compressions may be challenging or dangerous for the provider (eg, limited rescuers available, prolonged CPR, during hypothermic cardiac arrest, in a moving ambulance, in the angiography suite, during preparation for ECPR), provided that rescuers strictly limit interruptions in CPR during deployment and removal of the devices. (Class IIb, LOE C-EO)

5 Extracorporeal Techniques and Invasive Perfusion Devices - Updated

5.1 Extracorporeal CPR - Updated ALS 723

For the purpose of this Guidelines Update, the term ECPR is used to describe the initiation of cardiopulmonary bypass during the resuscitation of a patient in cardiac arrest. This involves the emergency cannulation of a large vein and artery (eg, femoral vessels) and initiation of venoarterial extracorporeal circulation and oxygenation. The goal of ECPR is to support patients between cardiac arrest and restoration of spontaneous circulation while potentially reversible conditions are addressed. ECPR is a complex process that requires a highly trained team, specialized equipment, and multidisciplinary support within the local healthcare system.

5.1.1 2015 Evidence Summary

There are no data on the use of ECPR from RCTs. Early observational studies in small numbers of witnessed in-hospital cardiac arrest (IHCA) and OHCA patients younger than 75 years with potentially reversible conditions suggested improved survival when compared with conventional CPR.[102-106] Patients receiving ECPR in these studies tended to be younger, with more witnessed arrests and bystander CPR.

The 2015 ILCOR ALS Task Force reviewed several observational studies, some of which used propensity matching. The results of the studies are mixed. One propensity-matched prospective observational study enrolling 172 IHCA patients reported greater likelihood of return of spontaneous beating in the ECPR group (compared with ROSC in the conventional CPR group) and improved survival at hospital discharge, 30-day, and 1-year follow-up with the use of ECPR. However, this study showed no difference in neurologic outcomes.[107] A retrospective observational study including 120 IHCA patients with historic control reported a modest benefit in both survival and neurologic outcome at discharge and 6-month follow-up with the use of ECPR versus

conventional CPR.[108] A propensity-matched retrospective observational study enrolling 118 IHCA patients showed no survival or neurologic benefit with ECPR at the time of hospital discharge, 30-day, or 1-year follow-up.[106] One post hoc analysis of data from a prospective, observational cohort of 162 OHCA patients, including propensity score matching, showed that ECPR was associated with a higher rate of neurologically intact survival at 3-month follow-up.[109] A prospective observational study enrolling 454 OHCA patients demonstrated improved neurologic outcomes with the use of ECPR at 1-month and 6-month follow-up after arrest.[110]

5.1.2 2015 Recommendation—New

There is insufficient evidence to recommend the routine use of ECPR for patients with cardiac arrest.

In settings where it can be rapidly implemented, ECPR may be considered for select patients for whom the suspected etiology of the cardiac arrest is potentially reversible during a limited period of mechanical cardiorespiratory support. (Class IIb, LOE C-LD)

Published series have used rigorous inclusion and exclusion criteria to select patients for ECPR. Although these inclusion criteria are highly variable, most included only patients aged 18 to 75 years, with arrest of cardiac origin, after conventional CPR for more than 10 minutes without ROSC. Such inclusion criteria should be considered in a provider's selection of potential candidates for ECPR.

6 Authorship and Disclosures

6.1 2015 Writing Team

Steven C. Brooks, Chair; Monique L. Anderson; Eric Bruder; Mohamud R. Daya; Alan Gaffney; Charles W. Otto; Adam J. Singer; Ravi R. Thiagarajan; Andrew H. Travers

Table 1: Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Steven C. Brooks	Queen's University	Heart and Stroke Foundation†; South Eastern Ontario Academic Medical Organization†; Canadian Institutes of Health Research†; National Institutes of Health Research†; Department of Defense, Canada†; US Military†;	None	None	None	None	None	Eastern Ontario Academic Medicine Organization†

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Monique L. Anderson	Duke Clinical Research Institute	None	None	None	None	None	None	None
Eric Bruder	Emergency Medicine	None	None	None	None	None	None	None
Mohamud R. Daya	Oregon Health and Science University	NIH-NHLBI†; NIH*; NIH-NINR*	None	None	None	None	Philips Health Care –Uncompens	None
Alan Gaffney	Columbia University Medical Center; University of Arizona	None	None	None	None	None	None	None
Charles W. Otto	University of Arizona College of Medicine	None	None	None	None	None	None	None
Adam J. Singer	Stony Brook University	AHA*; NY State*	None	None	None	None	None	None
Ravi R. Thiagarajan	Children's Hospital, Boston	NHLBI*	None	None	None	None	None	None
Consultant								
Andrew H. Travers	Emergency Health Services, Nova Scotia	None	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

6.2 2010 Writing Team

Diana M. Cave, Chair; Raul J. Gazmuri; Charles W. Otto; Vinay M. Nadkarni; Adam Cheng; Steven C. Brooks; Mohamud Daya; Robert M. Sutton; Richard Branson; Mary Fran Hazinski

Table 2: 2010 - Guidelines Part 7: CPR Techniques and Devices: Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 7: CPR Techniques and Devices: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Diana M. Cave	Legacy Health System, Emanuel Hospital, Emergency Services–RN, MSN; Portland Com. College–Institute for Health Prof.-Faculty/Instructor	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Raul Gazmuri	North Chicago VA Medical Center–Sectio Chief, Critical Care and Professor of Medicine	†Volume-Controlled Manual Ventilation during Resuscitation from Cardiac Arrest. Funded by Dessinier Corporation. Funds come to my institution (Rosalind Franklin UniversityRFU Vitamin-C Preserves Myocardial Distensibility during Resuscitation from CA. Funded by Maribor University, Slovenia. Funds come to my institution (RFU)	None	None	†Patent titled “Facilitation of Resuscitation from Cardiac Arrest by Erythropoietin” (pending)	None	None
Charles W. Otto	University of Arizona–Professor	None	None	None	None	None	None
Vinay M. Nadkarni	University of Pennsylvania/T Children's Hospital of Philadelphia–A Physician, Departement of Anesthesia, Critical Care and Pediatrics	None	None	None	None	None	*Voluntary (Unpaid) member of Data Safety Monitoring Committee for Automated CPR device trial

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Adam Cheng	British Columbia Children's Hospital: University Affiliated–Director, Pediatric Simulation Program	†American Heart Association RFP - educational grant. Money comes to my institution, and is distributed to our group of collaborative pediatric hospitals	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Steven C. Brooks	University of Toronto–Clinic Scientist	†PI-1. Univ.of Toronto Faculty of Medicine New Staff Grant. 01/07/2009–01 A pilot study to explore missed opportunities for public access defibrillation in OHCA and to determine the potential impact of emergency medical dispatchers. Role: PI $10 000 unrestricted grant administered through the research institute 2. University of Toronto Connaught New Staff Matching Grant 2009–2010. 04/05/2009–03 Development of Centres of Excellence to Improve Outcomes after OHCAt: A Pilot Study. Role: PI $23 700 unrestricted grant administered through the research institute 3. Ontario Ministry of Health and Long Term Care and					

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Mohamud Daya	Oregon Health & Science University: Attending Physician–Associate Professor of Emergency Medicine	†PI Resuscitation Outcomes Consoritum - Portland Site, NHLBI, grant is awarded directly to the insitution (OHSU)	None	*Lectures at local, regional and national meetings, income is directly to me, last lectures CPR update at the Timberline EMS conference, there was no honorarium but conference paid for my lodging Stroke Update in Corvallis at Samaritan Health, Honorarium fee was 500 dollars Advanced 12 lead ECG diagnostic algoritms, Lecutre for Philips Healthcare at EMS today, honoarium for 2 lectures was 1000 dollars	*Stock held in the following health care companies; Johnson and Johnson - 250 shares Amgen - 100 shares Roche - 100 shares	*Philips Health Care - Consultant on 12 lead ECG diagnostic algorithms and resuscitation products, no reimbursement for this activity	†I am an EMS medical director for 2 fire departments and one 911 agency, this is a private contract and the money comes directly to me, this is independent of my employment at OHSU which is at an 80% FTE level, my EMS activities are 20% FTE

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Robert M. Sutton	The Children's Hospital of Philadelphia–C Care Attending	* Unrestricted Research Grant Support through a Center of Excellence Grant from the Laerdal Found	None	None	None	None	
Richard Branson	University of Cincinnati-Associate Professor	None	†SeQual. Sponsor of laboratory study of the use of oxygen concentrators in conjunction with mechanical ventilators for military and mass casualty scenarios. $40 000. All monies are paid to the Univ. I have no financial interest in the company and do not receive any personal income	†Cardinal - makers of ICU and home care ventialtors. I am paid directly for speaking. Newport Medical makers of ICU and home care ventilators. I am paid directly for speaking. * IKARIA - manufactures and distributes inhaled nitric oxide. I am paid directly	None	*Bayer Pharmaceuticals Treatment of ventilator associated pneumonia	*KIngs Daughters Hospital Ashalnd KY. Paid directly to me

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Mary Fran Hazinski	Vanderbilt University School of Nursing—Profe American Heart Association–Senior Science Editor † Significant AHA compensation for my editing responsibilities writing and editing of the 2010 AHA Guidelines for CPR and ECC	None	None	None	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

7 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation. ECCguidelines.heart.org

References

1. Cave DM, Gazmuri RJ, Otto CW, Nadkarni VM, Cheng A, Brooks SC, Daya M, Sutton RM, Branson R, Hazinski MF. Part 7: CPR techniques and devices: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S720–S728. doi: 10.1161/ CIRCULATIONAHA.110.970970.

2. Shuster M, Lim SH, Deakin CD, Kleinman ME, Koster RW, Morrison LJ, Nolan JP, Sayre MR; CPR Techniques and Devices Collaborators. Part 7: CPR techniques and devices: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122(suppl 2):S338–S344. doi: 10.1161/CIRCULATIONAHA.110.971036.

3. Lim SH, Shuster M, Deakin CD, Kleinman ME, Koster RW, Morrison LJ, Nolan JP, Sayre MR; CPR Techniques, Devices Collaborators. Part 7: CPR techniques and devices: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e86–e92. doi: 10.1016/j.resuscitation.2010.08.026.

4. Callaway CW, Soar J, Aibiki M, Böttiger BW, Brooks SC, Deakin CD, Donnino MW, Drajer S, Kloeck W, Morley PT, Morrison LJ, Neumar RW, Nicholson TC, Nolan JP, Okada K, O'Neil BJ, Paiva EF, Parr MJ, Wang TL, Witt J; on behalf of the Advanced Life Support Chapter Collaborators. Part 4: advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132 (suppl 1):S84–S145. doi: 10.1161/CIR.0000000000000273.

5. Soar J, Callaway CW, Aibiki M, Böttiger BW, Brooks SC, Deakin CD, Donnino MW, Drajer S, Kloeck W, Morley PT, Morrison LJ, Neumar RW, Nicholson TC, Nolan JP, Okada K, O'Neil BJ, Paiva EF, Parr MJ, Wang TL, Witt J; on behalf of the Advanced Life Support Chapter Collaborators. Part 4: advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

6. The Cochrane Collaboration. Higgins JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0. 2011. http://handbook.cochrane.org/. Accessed May 6, 2015.

7. Schünemann H, Broz?ek J, Guyatt G, Oxman A. GRADE Handbook. 2013. http://www.guidelinedevelopment.org/handbook/. Accessed May 6, 2015.

8. Raman J, Saldanha RF, Branch JM, Esmore DS, Spratt PM, Farnsworth AE, Harrison GA, Chang VP, Shanahan MX. Open cardiac compression in the postoperative cardiac intensive care unit. Anaesth Intensive Care. 1989;17:129–135.

9. Anthi A, Tzelepis GE, Alivizatos P, Michalis A, Palatianos GM, Geroulanos S. Unexpected cardiac arrest after cardiac surgery: incidence, predisposing causes, and outcome of open chest cardiopulmonary resuscitation. Chest. 1998;113:15–19.

10. Pottle A, Bullock I, Thomas J, Scott L. Survival to discharge following Open Chest Cardiac Compression (OCCC): a 4-year retrospective audit in a cardiothoracic specialist centre–Royal Brompton and Harefield NHS Trust, United Kingdom. Resuscitation. 2002;52:269–272.

11. Takino M, Okada Y. The optimum timing of resuscitative thoracotomy for non-traumatic out-of-hospital cardiac arrest. Resuscitation. 1993;26:69–74.

12. Boczar ME, Howard MA, Rivers EP, Martin GB, Horst HM, Lewandowski C, Tomlanovich MC, Nowak RM. A technique revisited: hemodynamic comparison of closed- and open-chest cardiac massage during human cardiopulmonary resuscitation. Crit Care Med. 1995;23:498–503.

13. Hachimi-Idrissi S, Leeman J, Hubloue Y, Huyghens L, Corne L. Open chest cardiopulmonary resuscitation in out-of-hospital cardiac arrest. Resuscitation. 1997;35:151–156.

14. Calinas-Correia J, Phair I. Physiological variables during open chest cardiopulmonary resuscitation: results from a small series. J Accid Emerg Med. 2000;17:201–204.

15. Fialka C, Sebok C, Kemetzhofer P, Kwasny O, Sterz F, Vecsei V. Open-chest cardiopulmonary resuscitation after cardiac arrest in cases of blunt chest or abdominal trauma: a consecutive series of 38 cases. J Trauma. 2004;57:809–814.

16. Powell DW, Moore EE, Cothren CC, Ciesla DJ, Burch JM, Moore JB, Johnson JL. Is emergency department resuscitative thoracotomy futile care for the critically injured patient requiring prehospital cardiopulmonary resuscitation? J Am Coll Surg. 2004;199:211–215.

17. Sheppard FR, Cothren CC, Moore EE, Orfanakis A, Ciesla DJ, Johnson JL, Burch JM. Emergency department resuscitative thoracotomy for nontorso injuries. Surgery. 2006;139:574–576.

18. Seamon MJ, Fisher CA, Gaughan JP, Kulp H, Dempsey DT, Goldberg AJ. Emergency department thoracotomy: survival of the least expected. World J Surg. 2008;32:604–612.

19. Powell RW, Gill EA, Jurkovich GJ, Ramenofsky ML. Resuscitative thoracotomy in children and adolescents. Am Surg. 1988;54:188–191.

20. Rothenberg SS, Moore EE, Moore FA, Baxter BT, Moore JB, Cleveland HC. Emergency Department thoracotomy in children–a critical analysis. J Trauma. 1989;29:1322–1325.

21. Sack JB, Kesselbrenner MB, Jarrad A. Interposed abdominal compression-cardiopulmonary resuscitation and resuscitation outcome during asystole and electromechanical dissociation. Circulation. 1992;86:1692–1700.

22. Sack JB, Kesselbrenner MB, Bregman D. Survival from in-hospital cardiac arrest with interposed abdominal counterpulsation during cardiopulmonary resuscitation. JAMA. 1992;267:379–385.

23. Babbs CF. Interposed abdominal compression CPR: a comprehensive evidence based review. Resuscitation. 2003;59:71–82.

24. Babbs CF. Simplified meta-analysis of clinical trials in resuscitation. Resuscitation. 2003;57:245–255.

25. Mateer JR, Stueven HA, Thompson BM, Aprahamian C, Darin JC. Pre-hospital IAC-CPR versus standard CPR: paramedic resuscitation of cardiac arrests. Am J Emerg Med. 1985;3:143–146.

26. Waldman PJ, Walters BL, Grunau CF. Pancreatic injury associated with interposed abdominal compressions in pediatric cardiopulmonary resuscitation. Am J Emerg Med. 1984;2:510–512.

27. Miller B, Cohen A, Serio A, Bettock D. Hemodynamics of cough cardiopulmonary resuscitation in a patient with sustained torsades de pointes/ventricular flutter. J Emerg Med. 1994;12:627–632.

28. Keeble W, Tymchak WJ. Triggering of the Bezold Jarisch Reflex by reperfusion during primary PCI with maintenance of consciousness by cough CPR: a case report and review of pathophysiology. J Invasive Cardiol. 2008;20:E239–E242.

29. Niemann JT, Rosborough J, Hausknecht M, Brown D, Criley JM. Cough-CPR: documentation of systemic perfusion in man and in an experimental model: a “window” to the mechanism of blood flow in external CPR. Crit Care Med. 1980;8:141–146.

30. Saba SE, David SW. Sustained consciousness during ventricular fibrillation: case report of cough cardiopulmonary resuscitation. Cathet Cardiovasc Diagn. 1996;37:47–48.

31. Criley JM, Blaufuss AH, Kissel GL. Cough-induced cardiac compression: self-administered form of cardiopulmonary resuscitation. JAMA. 1976;236:1246–1250.

32. Wei JY, Greene HL, Weisfeldt ML. Cough-facilitated conversion of ventricular tachycardia. Am J Cardiol. 1980;45:174–176.

33. Caldwell G, Millar G, Quinn E, Vincent R, Chamberlain DA. Simple mechanical methods for cardioversion: defence of the precordial thump and cough version. Br Med J (Clin Res Ed). 1985;291:627–630.

34. Miller B, Lesnefsky E, Heyborne T, Schmidt B, Freeman K, Breckinridge S, Kelley K, Mann D, Reiter M. Cough-cardiopulmonary resuscitation in the cardiac catheterization laboratory: hemodynamics during an episode of prolonged hypotensive ventricular tachycardia. Cathet Cardiovasc Diagn. 1989;18:168–171.

35. Rieser MJ. The use of cough-CPR in patients with acute myocardial infarction. J Emerg Med. 1992;10:291–293.

36. Petelenz T, Iwinski J, Chlebowczyk J, Czyz Z, Flak Z, Fiutowski L, Zaorski K, Zeman S. Self-administered cough cardiopulmonary resuscitation (c-CPR) in patients threatened by MAS events of cardiovascular origin. Wiad Lek. 1998;51():326–336.

37. Girsky MJ, Criley JM. Images in cardiovascular medicine. Cough cardiopulmonary resuscitation revisited. Circulation. 2006;114:e530–531.

38. Mazer SP, Weisfeldt M, Bai D, Cardinale C, Arora R, Ma C, Sciacca RR, Chong D, Rabbani LE. Reverse, CPR: a pilot study of CPR in the prone position. Resuscitation. 2003;57:279–285.

39. Sun WZ, Huang FY, Kung KL, Fan SZ, Chen TL. Successful cardiopulmonary resuscitation of two patients in the prone position using reversed precordial compression. Anesthesiology. 1992;77:202–204.

40. Tobias JD, Mencio GA, Atwood R, Gurwitz GS. Intraoperative cardiopulmonary resuscitation in the prone position. J Pediatr Surg. 1994;29:1537–1538.

41. Brown J, Rogers J, Soar J. Cardiac arrest during surgery and ventilation in the prone position: a case report and systematic review. Resuscitation. 2001;50:233–238.

42. Pellis T, Kette F, Lovisa D, Franceschino E, Magagnin L, Mercante WP, Kohl P. Utility of pre-cordial thump for treatment of out of hospital cardiac arrest: a prospective study. Resuscitation. 2009;80:17–23.

43. Bornemann C, Scherf D. Electrocardiogram of the month. Paroxysmal ventricular tachycardia abolished by a blow to the precordium. Dis Chest. 1969;56:83–84.

44. Dale KM, Lertsburapa K, Kluger J, White CM. Moxifloxacin and torsade de pointes. Ann Pharmacother. 2007;41:336–340.

45. De Maio VJ, Stiell IG, Spaite DW, Ward RE, Lyver MB, Field BJ III., Munkley DP, Wells GA. CPR-only survivors of out-of-hospital cardiac arrest: implications for out-of-hospital care and cardiac arrest research methodology. Ann Emerg Med. 2001;37:602–608.

46. Pennington JE, Taylor J, Lown B. Chest thump for reverting ventricular tachycardia. N Engl J Med. 1970;283:1192–1195.

47. Rahner E, Zeh E. Die Regularisierung von Kammertachykardien durch präkordialen Faustschlag. (“The Regularization of Ventricular Tachycardias by Precordial Thumping.”) Med Welt. 1978;29:1659–1663.

48.

Amir O, Schliamser JE, Nemer S, Arie M. Ineffectiveness of precordial thump for cardioversion of malignant ventricular tachyarrhythmias. Pacing Clin Electrophysiol. 2007;30:153–156.

49. Haman L, Parizek P, Vojacek J. Precordial thump efficacy in termination of induced ventricular arrhythmias. Resuscitation. 2009;80:14–16.

50. Ahmar W, Morley P, Marasco S, Chan W, Aggarwal A. Sternal fracture and osteomyelitis: an unusual complication of a precordial thump. Resuscitation. 2007;75:540–542.

51. Miller J, Tresch D, Horwitz L, Thompson BM, Aprahamian C, Darin JC. The precordial thump. Ann Emerg Med. 1984;13():791–794.

52. Muller GI, Ulmer HE, Bauer JA. Complications of chest thump for termination of supraventricular tachycardia in children. Eur J Pediatr. 1992;151:12–14.

53. Chan L, Reid C, Taylor B. Effect of three emergency pacing modalities on cardiac output in cardiac arrest due to ventricular asystole. Resuscitation. 2002;52:117–119.

54. Dowdle JR. Ventricular standstill and cardiac percussion. Resuscitation. 1996;32:31–32.

55. Eich C, Bleckmann A, Schwarz SK. Percussion pacing–an almost forgotten procedure for haemodynamically unstable bradycardias? A report of three case studies and review of the literature. Br J Anaesth. 2007;98:429–433.

56. Eich C, Bleckmann A, Paul T. Percussion pacing in a three-year-old girl with complete heart block during cardiac catheterization. Br J Anaesth. 2005;95:465–467.

57. Iseri LT, Allen BJ, Baron K, Brodsky MA. Fist pacing, a forgotten procedure in bradyasystolic cardiac arrest. Am Heart J. 1987;113:1545–1550.

58. Tucker KJ, Shaburihvili TS, Gedevanishvili AT. Manual external (fist) pacing during high-degree atrioventricular block: a lifesaving intervention. Am J Emerg Med. 1995;13:53–54.

59. Zeh E, Rahner E. [The manual extrathoracal stimulation of the heart. Technique and effect of the precordial thump (author's transl)]. Z Kardiol. 1978;67:299–304.

60. Weiss SJ, Ernst AA, Jones R, Ong M, Filbrun T, Augustin C, Barnum M, Nick TG. Automatic transport ventilator versus bag valve in the EMS setting: a prospective, randomized trial. South Med J. 2005;98:970–976.

61. Johannigman JA, Branson RD, Johnson DJ, Davis K Jr., Hurst JM. Out-of-hospital ventilation: bag–valve device vs transport ventilator. Acad Emerg Med. 1995;2:719–724.

62. Noordergraaf GJ, van Dun PJ, Kramer BP, Schors MP, Hornman HP, de Jong W, Noordergraaf A. Can first responders achieve and maintain normocapnia when sequentially ventilating with a bag-valve device and two oxygen-driven resuscitators? A controlled clinical trial in 104 patients. Eur J Anaesthesiol. 2004;21:367–372.

63. Hevesi ZG, Thrush DN, Downs JB, Smith RA. Cardiopulmonary resuscitation: effect of CPAP on gas exchange during chest compressions. Anesthesiology. 1999;90:1078–1083.

64. Cohen TJ, Goldner BG, Maccaro PC, Ardito AP, Trazzera S, Cohen MB, Dibs SR. A comparison of active compression-decompression cardiopulmonary resuscitation with standard cardiopulmonary resuscitation for cardiac arrests occurring in the hospital. N Engl J Med. 1993;329:1918–1921.

65. Lurie KG, Shultz JJ, Callaham ML, Schwab TM, Gisch T, Rector T, Frascone RJ, Long L. Evaluation of active compression-decompression CPR in victims of out-of-hospital cardiac arrest. JAMA. 1994;271:1405–1411.

66. Tucker KJ, Galli F, Savitt MA, Kahsai D, Bresnahan L, Redberg RF. Active compression-decompression resuscitation: effect on resuscitation success after in-hospital cardiac arrest. J Am Coll Cardiol. 1994;24:201–209.

67. Plaisance P, Adnet F, Vicaut E, Hennequin B, Magne P, Prudhomme C, Lambert Y, Cantineau JP, Leopold C, Ferracci C, Gizzi M, Payen D. Benefit of active compression-decompression cardiopulmonary resuscitation as a prehospital advanced cardiac life support: a randomized multicenter study. Circulation. 1997;95:955–961.

68. Plaisance P, Lurie KG, Vicaut E, Adnet F, Petit JL, Epain D, Ecollan P, Gruat R, Cavagna P, Biens J, Payen D. A comparison of standard cardiopulmonary resuscitation and active compression-decompression resuscitation for out-of-hospital cardiac arrest. French Active Compression-Decompression Cardiopulmonary Resuscitation Study Group. N Engl J Med. 1999;341:569–575.

69. He Q, Wan Z, Wang L. [Random control trial of the efficacy of cardiopump on pre-hospital cardiac arrest]. Zhongguo Wei Zhong Bing Ji Jiu Yi Xue. 2003;15:292–294.

70. Lafuente-Lafuente C, Melero-Bascones M. Active chest compression-decompression for cardiopulmonary resuscitation. Cochrane Database Syst Rev. 2004;:CD002751.

71.

Mauer D, Schneider T, Dick W, Withelm A, Elich D, Mauer M. Active compression-decompression resuscitation: a prospective, randomized study in a two-tiered EMS system with physicians in the field. Resuscitation. 1996;33:125–134.

72. Stiell IG, Hebert PC, Wells GA, Laupacis A, Vandemheen K, Dreyer JF, Eisenhauer MA, Gibson J, Higginson LA, Kirby AS, Mahon JL, Maloney JP, Weitzman BN. The Ontario trial of active compression-decompression cardiopulmonary resuscitation for in-hospital and prehospital cardiac arrest. JAMA. 1996;275:1417–1423.

73. Goralski M, Villeger JL, Cami G, Linassier P, Guilles-Des-Buttes P, Fabbri P, Venot P, Tazarourte K, Cami M. Evaluation of active compression-decompression cardiopulmonary resuscitation in out-of-hospital cardiac arrest. Reanimation Urgences. 1998;7:543–550.

74. Skogvoll E, Wik L. Active compression-decompression cardiopulmonary resuscitation: a population-based, prospective randomised clinical trial in out-of-hospital cardiac arrest. Resuscitation. 1999;42:163–172.

75. Schwab TM, Callaham ML, Madsen CD, Utecht TA. A randomized clinical trial of active compression-decompression CPR vs standard CPR in out-of-hospital cardiac arrest in two cities. JAMA. 1995;273:1261–1268.

76. Luiz T, Ellinger K, Denz C. Active compression-decompression cardiopulmonary resuscitation does not improve survival in patients with prehospital cardiac arrest in a physician-manned emergency medical system. J Cardiothorac Vasc Anesth. 1996;10:178–186.

77. Nolan J, Smith G, Evans R, McCusker K, Lubas P, Parr M, Baskett P. The United Kingdom pre-hospital study of active compression-decompression resuscitation. Resuscitation. 1998;37:119–125.

78. Arntz HR, Agrawal R, Richter H, Schmidt S, Rescheleit T, Menges M, Burbach H, Schroder J, Schultheiss HP. Phased chest and abdominal compression-decompression versus conventional cardiopulmonary resuscitation in out-of-hospital cardiac arrest. Circulation. 2001;104:768–772.

79. Lurie KG, Coffeen P, Shultz J, McKnite S, Detloff B, Mulligan K. Improving active compression-decompression cardiopulmo- nary resuscitation with an inspiratory impedance valve. Circulation. 1995;91:1629–1632.

80. Plaisance P, Lurie KG, Payen D. Inspiratory impedance during active com- pression-decompression cardiopulmonary resuscitation: a randomized evaluation in patients in cardiac arrest. Circulation. 2000;101:989–994.

81. Pirrallo RG, Aufderheide TP, Provo TA, Lurie KG. Effect of an inspira- tory impedance threshold device on hemodynamics during conventional manual cardiopulmonary resuscitation. Resuscitation. 2005;66:13–20. doi: 10.1016/j.resuscitation.2004.12.027.

82. Aufderheide TP, Pirrallo RG, Provo TA, Lurie KG. Clinical evaluation of an inspiratory impedance threshold device during standard cardiopulmo- nary resuscitation in patients with out-of-hospital cardiac arrest. Crit Care Med. 2005;33:734–740.

83. Aufderheide TP, Nichol G, Rea TD, Brown SP, Leroux BG, Pepe PE, Kudenchuk PJ, Christenson J, Daya MR, Dorian P, Callaway CW, Idris AH, Andrusiek D, Stephens SW, Hostler D, Davis DP, Dunford JV, Pirrallo RG, Stiell IG, Clement CM, Craig A, Van Ottingham L, Schmidt TA, Wang HE, Weisfeldt ML, Ornato JP, Sopko G; Resuscitation Outcomes Consortium (ROC) Investigators. A trial of an impedance threshold device in out-of-hospital cardiac arrest. N Engl J Med. 2011;365:798–806. doi: 10.1056/NEJMoa1010821.

84. Plaisance P, Lurie KG, Vicaut E, Martin D, Gueugniaud PY, Petit JL, Payen D. Evaluation of an impedance threshold device in patients receiv- ing active compression-decompression cardiopulmonary resuscitation for out of hospital cardiac arrest. Resuscitation. 2004;61:265–271. doi: 10.1016/j.resuscitation.2004.01.032.

85. Wolcke BB, Mauer DK, Schoefmann MF, Teichmann H, Provo TA, Lindner KH, Dick WF, Aeppli D, Lurie KG. Comparison of standard cardiopulmonary resuscitation versus the combination of active compres- sion-decompression cardiopulmonary resuscitation and an inspiratory impedance threshold device for out-of-hospital cardiac arrest. Circulation. 2003;108:2201–2205. doi: 10.1161/01.CIR.0000095787.99180.B5.

86. Aufderheide TP, Frascone RJ, Wayne MA, Mahoney BD, Swor RA, Domeier RM, Olinger ML, Holcomb RG, Tupper DE, Yannopoulos D, Lurie KG. Standard cardiopulmonary resuscitation versus active compression- decompression cardiopulmonary resuscitation with augmentation of nega- tive intrathoracic pressure for out-of-hospital cardiac arrest: a randomised trial. Lancet. 2011;377:301–311. doi: 10.1016/S0140-6736(10)62103-4.

87. Frascone RJ, Wayne MA, Swor RA, Mahoney BD, Domeier RM, Olinger ML, Tupper DE, Setum CM, Burkhart N, Klann L, Salzman JG, Wewerka SS, Yannopoulos D, Lurie KG, O'Neil BJ, Holcomb RG, Aufderheide TP. Treatment of non-traumatic out-of-hospital cardiac arrest with active compression decompression cardiopulmonary resuscitation plus an imped- ance threshold device. Resuscitation. 2013;84:1214–1222. doi: 10.1016/j. resuscitation.2013.05.002.

88. Smekal D, Johansson J, Huzevka T, Rubertsson S. A pilot study of mechanical chest compressions with the LUCASTM device in cardiopul- monary resuscitation. Resuscitation. 2011;82:702–706. doi: 10.1016/j. resuscitation.2011.01.032.

89. Perkins GD, Lall R, Quinn T, Deakin CD, Cooke MW, Horton J, Lamb SE, Slowther AM, Woollard M, Carson A, Smyth M, Whitfield R, Williams A, Pocock H, Black JJ, Wright J, Han K, Gates S; PARAMEDIC trial collab- orators. Mechanical versus manual chest compression for out-of-hospital cardiac arrest (PARAMEDIC): a pragmatic, cluster randomised controlled trial. Lancet. 2015;385:947–955. doi: 10.1016/S0140-6736(14)61886-9.

90.

Rubertsson S, Lindgren E, Smekal D, Östlund O, Silfverstolpe J, Lichtveld RA, Boomars R, Ahlstedt B, Skoog G, Kastberg R, Halliwell D, Box M, Herlitz J, Karlsten R. Mechanical chest compressions and simultaneous defibrillation vs conventional cardiopulmonary resuscitation in out-of- hospital cardiac arrest: the LINC randomized trial. JAMA. 2014;311:53– 61. doi: 10.1001/jama.2013.282538.

91. Taylor GJ, Rubin R, Tucker M, Greene HL, Rudikoff MT, Weisfeldt ML. External cardiac compression. A randomized comparison of mechanical and manual techniques. JAMA. 1978;240:644–646.

92. Ward KR, Menegazzi JJ, Zelenak RR, Sullivan RJ, McSwain NE Jr. A comparison of chest compressions between mechanical and manual CPR by monitoring end-tidal PCO2 during human cardiac arrest. Ann Emerg Med. 1993;22:669–674.

93. Dickinson ET, Verdile VP, Schneider RM, Salluzzo RF. Effectiveness of mechanical versus manual chest compressions in out-of-hospital cardiac arrest resuscitation: a pilot study. Am J Emerg Med. 1998;16:289–292.

94. Wang HC, Chiang WC, Chen SY, Ke YL, Chi CL, Yang CW, Lin PC, Ko PC, Wang YC, Tsai TC, Huang CH, Hsiung KH, Ma MH, Chen SC, Chen WJ, Lin FY. Video-recording and time-motion analyses of manual versus mechanical cardiopulmonary resuscitation during ambulance transport. Resuscitation. 2007;74:453–460. doi: 10.1016/j. resuscitation.2007.01.018.

95. Timerman S, Cardoso LF, Ramires JA, Halperin H. Improved hemody- namic performance with a novel chest compression device during treat- ment of in-hospital cardiac arrest. Resuscitation. 2004;61:273–280. doi: 10.1016/j.resuscitation.2004.01.025.

96. Casner M, Andersen D, Isaacs SM. The impact of a new CPR assist device on rate of return of spontaneous circulation in out-of-hospital cardiac arrest. Prehosp Emerg Care. 2005;9:61–67. doi: 10.1080/10903120590891714.

97. Ong ME, Ornato JP, Edwards DP, Dhindsa HS, Best AM, Ines CS, Hickey S, Clark B, Williams DC, Powell RG, Overton JL, Peberdy MA. Use of an automated, load-distributing band chest compression device for out- of-hospital cardiac arrest resuscitation. JAMA. 2006;295:2629–2637. doi: 10.1001/jama.295.22.2629.

98. SteinmetzJ,BarnungS,NielsenSL,RisomM,RasmussenLS.Improvedsurvival after an out-of-hospital cardiac arrest using new guidelines. Acta Anaesthesiol Scand. 2008;52:908–913. doi: 10.1111/j.1399-6576.2008.01657.x.

99. Hallstrom A, Rea TD, Sayre MR, Christenson J, Anton AR, Mosesso VN Jr, Van Ottingham L, Olsufka M, Pennington S, White LJ, Yahn S, Husar J, Morris MF, Cobb LA. Manual chest compression vs use of an automated chest compression device during resuscitation following out-of-hospital cardiac arrest: a randomized trial. JAMA. 2006;295:2620–2628. doi: 10.1001/jama.295.22.2620.

100. Paradis NA, Young G, Lemeshow S, Brewer JE, Halperin HR. Inhomogeneity and temporal effects in AutoPulse Assisted Prehospital International Resuscitation–an exception from consent trial termi- nated early. Am J Emerg Med. 2010;28:391–398. doi: 10.1016/j.ajem. 2010.02.002.

101. Tomte O, Sunde K, Lorem T, Auestad B, Souders C, Jensen J, Wik L. Advanced life support performance with manual and mechanical chest compressions in a randomized, multicentre manikin study. Resuscitation. 2009;80:1152–1157. doi: 10.1016/j.resuscitation.2009.07.001.

102. Wik L, Olsen JA, Persse D, Sterz F, Lozano M Jr, Brouwer MA, Westfall M, Souders CM, Malzer R, van Grunsven PM, Travis DT, Whitehead A, Herken UR, Lerner EB. Manual vs. integrated automatic load-distributing band CPR with equal survival after out of hospital cardiac arrest. The randomized CIRC trial. Resuscitation. 2014;85:741–748. doi: 10.1016/j. resuscitation.2014.03.005.

103. Thiagarajan RR, Brogan TV, Scheurer MA, Laussen PC, Rycus PT, Bratton SL. Extracorporeal membrane oxygenation to support cardiopul- monary resuscitation in adults. Ann Thorac Surg. 2009;87:778–785. doi: 10.1016/j.athoracsur.2008.12.079.

104. Chen YS, Chao A, Yu HY, Ko WJ, Wu IH, Chen RJ, Huang SC, Lin FY, Wang SS. Analysis and results of prolonged resuscitation in cardiac arrest patients rescued by extracorporeal membrane oxygenation. J Am Coll Cardiol. 2003;41:197–203.

105. Athanasuleas CL, Buckberg GD, Allen BS, Beyersdorf F, Kirsh MM. Sudden cardiac death: directing the scope of resuscitation towards the heart and brain. Resuscitation. 2006;70:44–51. doi: 10.1016/j. resuscitation.2005.11.017.

106. Tanno K, Itoh Y, Takeyama Y, Nara S, Mori K, Asai Y. Utstein style study of cardiopulmonary bypass after cardiac arrest. Am J Emerg Med. 2008;26:649–654. doi: 10.1016/j.ajem.2007.09.019.

107. Huang SC, Wu ET, Chen YS, Chang CI, Chiu IS, Wang SS, Lin FY, Ko WJ. Extracorporeal membrane oxygenation rescue for cardiopulmonary resuscitation in pediatric patients. Crit Care Med. 2008;36:1607–1613. doi: 10.1097/CCM.0b013e318170b82b.

108. Chen YS, Lin JW, Yu HY, Ko WJ, Jerng JS, Chang WT, Chen WJ, Huang SC, Chi NH, Wang CH, Chen LC, Tsai PR, Wang SS, Hwang JJ, Lin FY. Cardiopulmonary resuscitation with assisted extracor- poreal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis. Lancet. 2008;372:554–561. doi: 10.1016/S0140-6736(08)60958-7.

109. Shin TG, Choi JH, Jo IJ, Sim MS, Song HG, Jeong YK, Song YB, Hahn JY, Choi SH, Gwon HC, Jeon ES, Sung K, Kim WS, Lee YT. Extracorporeal cardiopulmonary resuscitation in patients with inhospital cardiac arrest: A comparison with conventional cardiopulmonary resuscitation. Crit Care Med. 2011;39:1–7. doi: 10.1097/CCM.0b013e3181feb339.

110.

Maekawa K, Tanno K, Hase M, Mori K, Asai Y. Extracorporeal cardiopulmonary resuscitation for patients with out-of-hospital cardiac arrest of cardiac origin: a propensity-matched study and pre- dictor analysis. Crit Care Med. 2013;41:1186–1196. doi: 10.1097/CCM.0b013e31827ca4c8.

111. Sakamoto T, Morimura N, Nagao K, Asai Y, Yokota H, Nara S, Hase M, Tahara Y, Atsumi T; SAVE-J Study Group. Extracorporeal cardio- pulmonary resuscitation versus conventional cardiopulmonary resus- citation in adults with out-of-hospital cardiac arrest: a prospective observational study. Resuscitation. 2014;85:762–768. doi: 10.1016/j. resuscitation.2014.01.031.

Part 7: Adult Advanced Cardiovascular Life Support

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: arrhythmia cardiac arrest drugs ventricular arrhythmia ventricular fibrillation

1 Highlights

Summary of Key Issues and Major Changes

Key issues and major changes in the 2015 Guidelines Update recommendations for advanced cardiac life support include the following:

- The combined use of vasopressin and epinephrine offers no advantage to using standard-dose epinephrine in cardiac arrest. Also, vasopressin does not offer an advantage over the use of epinephrine alone. Therefore, to simplify the algorithm, vasopressin has been removed from the Adult Cardiac Arrest Algorithm–2015 Update.
- Low end-tidal carbon dioxide ($ETCO_2$) in intubated patients after 20 minutes of CPR is associated with a very low likelihood of resuscitation. While this parameter should not be used in isolation for decision making, providers may consider low $ETCO_2$ after 20 minutes of CPR in combination with other factors to help determine when to terminate resuscitation.
- Steroids may provide some benefit when bundled with vasopressin and epinephrine in treating IHCA. While routine use is not recommended pending follow-up studies, it would be reasonable for a provider to administer the bundle for IHCA.
- When rapidly implemented, ECPR can prolong viability, as it may provide time to treat potentially reversible conditions or arrange for cardiac transplantation for patients who are not resuscitated by conventional CPR.
- In cardiac arrest patients with nonshockable rhythm and who are otherwise receiving epinephrine, the early provision of epinephrine is suggested.
- Studies about the use of lidocaine after ROSC are conflicting, and routine lidocaine use is not recommended. However, the initiation or continuation of lidocaine may be considered immediately after ROSC from VF/pulseless ventricular tachycardia (pVT) cardiac arrest.
- One observational study suggests that ß-blocker use after cardiac arrest may be associated with better outcomes than when ß-blockers are not used. Although this observational study is not strong-enough evidence to recommend routine use, the initiation or continuation of an oral or intravenous (IV) ß-blocker may be considered early after hospitalization from cardiac arrest due to VF/pVT.

Vasopressors for Resuscitation: Vasopressin

2015 (Updated): Vasopressin in combination with epinephrine offers no advantage as a substitute for standard-dose epinephrine in cardiac arrest.

2010 (Old): One dose of vasopressin 40 units IV/ intraosseously may replace either the first or second dose of epinephrine in the treatment of cardiac arrest.

Why: Both epinephrine and vasopressin administration during cardiac arrest have been shown to improve ROSC. Review of the available evidence shows that efficacy of the 2 drugs is similar and that there is no demonstrable benefit from administering both epinephrine and vasopressin as compared with epinephrine alone. In the interest of simplicity, vasopressin has been removed from the Adult Cardiac Arrest Algorithm.

Vasopressors for Resuscitation: Epinephrine

2015 (New): It may be reasonable to administer epinephrine as soon as feasible after the onset of cardiac arrest due to an initial nonshockable rhythm.

Why: A very large observational study of cardiac arrest with nonshockable rhythm compared epinephrine given

at 1 to 3 minutes with epinephrine given at 3 later time intervals (4 to 6, 7 to 9, and greater than 9 minutes). The study found an association between early administration of epinephrine and increased ROSC, survival to hospital discharge, and neurologically intact survival.

$ETCO_2$ for Prediction of Failed Resuscitation

2015 (New): In intubated patients, failure to achieve an $ETCO_2$ of greater than 10 mm Hg by waveform capnography after 20 minutes of CPR may be considered as one component of a multimodal approach to decide when to end resuscitative efforts but should not be used in isolation.

Why: Failure to achieve an $ETCO_2$ of 10 mm Hg by waveform capnography after 20 minutes of resuscitation has been associated with an extremely poor chance of ROSC and survival. However, the studies to date are limited in that they have potential confounders and have included relatively small numbers of patients, so it is inadvisable to rely solely on $ETCO_2$ in determining when to terminate resuscitation.

Extracorporeal CPR

2015 (New): ECPR may be considered among select cardiac arrest patients who have not responded to initial conventional CPR, in settings where it can be rapidly implemented.

Why: Although no high-quality studies have compared ECPR to conventional CPR, a number of lower-quality studies suggest improved survival with good neurologic outcome for select patient populations. Because ECPR is resource intensive and costly, it should be considered only when the patient has a reasonably high likelihood of benefit—in cases where the patient has a potentially reversible illness or to support a patient while waiting for a cardiac transplant.

Post–Cardiac Arrest Drug Therapy: Lidocaine

2015 (New): There is inadequate evidence to support the routine use of lidocaine after cardiac arrest. However, the initiation or continuation of lidocaine may be considered immediately after ROSC from cardiac arrest due to VF/pVT.

2Why: While earlier studies showed an association between giving lidocaine after myocardial infarction and increased mortality, a recent study of lidocaine in cardiac arrest survivors showed a decrease in the incidence of recurrent VF/pVT but did not show either long-term benefit or harm.

Post–Cardiac Arrest Drug Therapy: ß-Blockers

2015 (New): There is inadequate evidence to support the routine use of a ß-blocker after cardiac arrest. However, the initiation or continuation of an oral or IV ß-blocker may be considered early after hospitalization from cardiac arrest due to VF/pVT.

Why: In an observational study of patients who had ROSC after VF/pVT cardiac arrest, ß-blocker administration was associated with higher survival rates. However, this finding is only an associative relationship, and the routine use of ß-blockers after cardiac arrest is potentially hazardous because ß-blockers can cause or worsen hemodynamic instability, exacerbate heart failure, and cause bradyarrhythmias. Therefore, providers should evaluate patients individually for their suitability for ß-blockers.

2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

Basic life support (BLS), advanced cardiovascular life support (ACLS), and post–cardiac arrest care are labels of convenience that each describe a set of skills and knowledge that are applied sequentially during the treatment of patients who have a cardiac arrest. There is overlap as each stage of care progresses to the next, but generally ACLS comprises the level of care between BLS and post–cardiac arrest care.

ACLS training is recommended for advanced providers of both prehospital and in-hospital medical care. In the past, much of the data regarding resuscitation was gathered from out-of-hospital arrests, but in recent years, data have also been collected from in-hospital arrests, allowing for a comparison of cardiac arrest and resuscitation in these 2 settings. While there are many similarities, there are also some differences between in-

and out-of-hospital cardiac arrest etiology, which may lead to changes in recommended resuscitation treatment or in sequencing of care. The consideration of steroid administration for in-hospital cardiac arrest (IHCA) versus out-of-hospital cardiac arrest (OHCA) is one such example discussed in this Part.

The recommendations in this *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation* (CPR) *and Emergency Cardiovascular Care* (ECC) are based on an extensive evidence review process that was begun by the International Liaison Committee on Resuscitation (ILCOR) after the publication of the ILCOR *2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations* and was completed in February 2015.[1]

In this in-depth evidence review process, the ILCOR task forces examined topics and then generated prioritized lists of questions for systematic review. Questions were first formulated in PICO (population, intervention, comparator, outcome) format,[2] and then a search strategy and inclusion and exclusion criteria were defined and a search for relevant articles was performed. The evidence was evaluated by using the standardized methodological approach proposed by the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group.[3]

The quality of the evidence was categorized based on the study methodologies and the 5 core GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias). Then, where possible, consensus-based treatment recommendations were created.

To create the 2015 Guidelines Update, the AHA formed 15 writing groups, with careful attention to avoid or manage conflicts of interest, to assess the ILCOR treatment recommendations and to write AHA treatment recommendations by using the AHA Class of Recommendation and Level of Evidence (LOE) system.

The recommendations made in this 2015 Guidelines Update are informed by the ILCOR recommendations and GRADE classification, in the context of the delivery of medical care in North America. The AHA ACLS writing group made new recommendations only on topics specifically reviewed by ILCOR in 2015. This chapter delineates any instances where the AHA writing group developed recommendations that are substantially different than the ILCOR statements. In the online version of this document, live links are provided so the reader can connect directly to the systematic reviews on the Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated by a superscript combination of letters and numbers (eg, ALS 433).

This update uses the newest AHA COR and LOE classification system, which contains modifications of the Class III recommendation and introduces LOE B-R (randomized studies) and B-NR (nonrandomized studies) as well as LOE C-LD (limited data) and LOE C-EO (consensus of expert opinion). All recommendations made in this 2015 Guidelines Update, as well as in the 2010 Guidelines, are listed in the Appendix. For further information, see "Part 2: Evidence Evaluation and Management of Conflicts of Interest." The ILCOR ACLS Task Force addressed 37 PICO questions related to ACLS care (presented in this Part) in 2015. These questions included oxygen dose during CPR, advanced airway devices, ventilation rate during CPR, exhaled carbon dioxide (CO_2) detection for confirmation of airway placement, physiologic monitoring during CPR, prognostication during CPR, defibrillation, antiarrhythmic drugs, and vasopressors. The 2 new topics are steroids and hormones in cardiac arrest, and extracorporeal CPR (ECPR), perhaps better known to the inpatient provider community as extracorporeal life support (ECMO). The 2010 Guidelines Part on electrical therapies (defibrillation and emergency pacing) has been eliminated, and relevant material from it is now included in this ACLS Part.

The major changes in the 2015 ACLS guidelines include recommendations about prognostication during CPR based on exhaled CO_2 measurements, timing of epinephrine administration stratified by shockable or nonshockable rhythms, and the possibility of bundling treatment of steroids, vasopressin, and epinephrine for treatment of in-hospital arrests. In addition, the administration of vasopressin as the sole vasoactive drug during CPR has been removed from the algorithm.

3 Adjuncts to CPR - Updated

3.1 Oxygen Dose During CPR - Updated ALS 889

The 2015 ILCOR systematic review considered inhaled oxygen delivery both during CPR and in the post–cardiac arrest period. This 2015 Guidelines Update evaluates the optimal inspired concentration of oxygen during CPR. The immediate goals of CPR are to restore the energy state of the heart so it can resume mechanical work and to maintain the energy state of the brain to minimize ischemic injury. Adequate oxygen delivery is necessary to achieve these goals. Oxygen delivery is dependent on both blood flow and arterial oxygen content. Because

blood flow is typically the major limiting factor to oxygen delivery during CPR, it is theoretically important to maximize the oxygen content of arterial blood by maximizing inspired oxygen concentration. Maximal inspired oxygen can be achieved with high-flow oxygen into a resuscitation bag device attached to a mask or an advanced airway.

3.1.1 2015 Evidence Summary

There were no adult human studies identified that directly compared maximal inspired oxygen with any other inspired oxygen concentration. However, 1 observational study of 145 OHCA patients evaluated arterial Po2 measured during CPR and cardiac arrest outcomes.[4] In this study, during which all patients received maximal inspired oxygen concentration, patients were divided into low, intermediate, and high arterial Po2 ranges (less than 61, 61–300, and greater than 300 mmHg, respectively). The higher ranges of arterial Po2 during CPR were associated with an increase in hospital admission rates (low, 18.8%; intermediate, 50.6%; and high, 83.3%). However, there was no statistical difference in overall neurologic survival (low, 3.1%; intermediate, 13.3%; and high, 23.3%). Of note, this study did not evaluate the provision of various levels of inspired oxygen, so differences between groups likely reflect patient-level differences in CPR quality and underlying pathophysiology. This study did not find any association between hyperoxia during CPR and poor outcome.

3.1.2 2015 Recommendation - Updated

When supplementary oxygen is available, it may be reasonable to use the maximal feasible inspired oxygen concentration during CPR. (Class IIb, LOE C-EO)

Evidence for detrimental effects of hyperoxia that may exist in the immediate post–cardiac arrest period should not be extrapolated to the low-flow state of CPR where oxygen delivery is unlikely to exceed demand or cause an increase in tissue Po_2 . Therefore, until further data are available, physiology and expert consensus support providing the maximal inspired oxygen concentration during CPR.

3.2 Passive Oxygen Delivery During CPR

This topic was updated in 2015 and is discussed in Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality.

3.3 Monitoring Physiologic Parameters During CPR - Updated ALS 656

Monitoring both provider performance and patient physiologic parameters during CPR is essential to optimizing CPR quality. The 2010 Guidelines put a strong emphasis on CPR quality. In 2013, the AHA published a Consensus Statement focused on strategies to improve CPR quality.[5] In 2015, the ILCOR ACLS Task Force evaluated the available clinical evidence to determine whether using physiologic feedback to guide CPR quality improved survival and neurologic outcome.

3.3.1 2015 Evidence Summary

Animal and human studies indicate that monitoring physiologic parameters during CPR provides valuable information about the patient's condition and response to therapy. Most important, end-tidal CO2 (etco2), coronary perfusion pressure, arterial relaxation pressure, arterial blood pressure, and central venous oxygen saturation correlate with cardiac output and myocardial blood flow during CPR, and threshold values have been reported below which return of spontaneous circulation (ROSC) is rarely achieved.[6-12] These parameters can be monitored continuously, without interrupting chest compressions. An abrupt increase in any of these parameters is a sensitive indicator of ROSC.[13-30] There is evidence that these and other physiologic parameters can be modified by interventions aimed at improving CPR quality.[6,31-42]

The 2015 ILCOR systematic review was unable to identify any clinical trials that have studied whether titrating resuscitative efforts to a single or combined set of physiologic parameters during CPR results in improved survival or neurologic outcome.

3.3.2 2015 Recommendation - Updated

Although no clinical study has examined whether titrating resuscitative efforts to physiologic

parameters during CPR improves outcome, it may be reasonable to use physiologic parameters (quantitative waveform capnography, arterial relaxation diastolic pressure, arterial pressure monitoring, and central venous oxygen saturation) when feasible to monitor and optimize CPR quality, guide vasopressor therapy, and detect ROSC. (Class IIb, LOE C-EO)

Previous guidelines specified physiologic parameter goals; however, because the precise numerical targets for these parameters during resuscitation have not as yet been established, these were not specified in 2015.

3.4 Ultrasound During Cardiac Arrest - Updated ALS 658

Bedside cardiac and noncardiac ultrasound are frequently used as diagnostic and prognostic tools for critically ill patients.[43] Ultrasound may be applied to patients receiving CPR to help assess myocardial contractility and to help identify potentially treatable causes of cardiac arrest such as hypovolemia, pneumothorax, pulmonary thromboembolism, or pericardial tamponade.[44] However, it is unclear whether important clinical outcomes are affected by the routine use of ultrasound among patients experiencing cardiac arrest.

3.4.1 2015 Evidence Summary

One limited study with a small sample size was identified that specifically addressed the utility of ultrasound during cardiac arrest. This study evaluated bedside cardiac ultrasound use during ACLS among adult patients in pulseless electrical activity arrest and found no difference in the incidence of ROSC when ultrasound was used.[45]

3.4.2 2015 Recommendations - Updated

Ultrasound (cardiac or noncardiac) may be considered during the management of cardiac arrest, although its usefulness has not been well established. (Class IIb, LOE C-EO)

If a qualified sonographer is present and use of ultrasound does not interfere with the standard cardiac arrest treatment protocol, then ultrasound may be considered as an adjunct to standard patient evaluation. (Class IIb, LOE C-EO)

4 Adjuncts for Airway Control and Ventilation - Updated

4.1 Overview of Airway Management

This section highlights recommendations for the support of ventilation and oxygenation during CPR and the peri-arrest period. The purpose of ventilation during CPR is to maintain adequate oxygenation and sufficient elimination of carbon dioxide. However, research has not identified the optimal tidal volume, respiratory rate, and inspired oxygen concentration required during resuscitation from cardiac arrest.

Both ventilation and chest compressions are thought to be important for victims of prolonged ventricular fibrillation (VF) cardiac arrest and for all victims with other presenting rhythms. Because both systemic and pulmonary perfusion are substantially reduced during CPR, normal ventilation-perfusion relationships can be maintained with a minute ventilation that is much lower than normal. During CPR with an advanced airway in place, a lower rate of rescue breathing is needed to avoid hyperventilation.

4.2 Ventilation and Oxygen Administration During CPR

During low blood flow states such as CPR, oxygen delivery to the heart and brain is limited by blood flow rather than by arterial oxygen content.[46, 47] Therefore, rescue breaths are less important than chest compressions during the first few minutes of resuscitation from witnessed VF cardiac arrest and could reduce CPR efficacy due to interruption in chest compressions and the increase in intrathoracic pressure that accompanies positive-pressure ventilation.

Thus, during the first few minutes of witnessed cardiac arrest a lone rescuer should not interrupt chest compressions for ventilation. Advanced airway placement in cardiac arrest should not delay initial CPR

and defibrillation for VF cardiac arrest. (Class I, LOE C)

4.3 Bag-Mask Ventilation - Updated

Bag-mask ventilation is an acceptable method of providing ventilation and oxygenation during CPR but is a challenging skill that requires practice for continuing competency. All healthcare providers should be familiar with the use of the bag-mask device.[48,49] Use of bag-mask ventilation is not recommended for a lone provider. When ventilations are performed by a lone provider, mouth-to-mouth or mouth-to-mask are more efficient. When a second provider is available, bag-mask ventilation may be used by a trained and experienced provider. But bag-mask ventilation is most effective when performed by 2 trained and experienced providers. One provider opens the airway and seals the mask to the face while the other squeezes the bag. Bag-mask ventilation is particularly helpful when placement of an advanced airway is delayed or unsuccessful. The desirable components of a bag-mask device are listed in "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality."

The provider should use an adult (1 to 2 L) bag and the provider should deliver approximately 600 mL of tidal volume sufficient to produce chest rise over 1 second.13 This volume of ventilation is adequate for oxygenation and minimizes the risk of gastric inflation. The provider should be sure to open the airway adequately with a head tilt–chin lift, lifting the jaw against the mask and holding the mask against the face, creating a tight seal. During CPR give 2 breaths (each 1 second) during a brief (about 3 to 4 seconds) pause after every 30 chest compressions.

Bag-mask ventilation can produce gastric inflation with complications, including regurgitation, aspiration, and pneumonia. Gastric inflation can elevate the diaphragm, restrict lung movement, and decrease respiratory system compliance.[50-52]

4.3.1 Bag-Mask Ventilation Compared With Any Advanced Airway During CPR - Updated ALS 783

As stated above, bag-mask ventilation is a commonly used method for providing oxygenation and ventilation in patients with respiratory insufficiency or arrest. When cardiac arrest occurs, providers must determine the best way to support ventilation and oxygenation. Options include standard bag-mask ventilation versus the placement of an advanced airway (ie, endotracheal tube [ETT], supraglottic airway device [SGA]). Previous guidelines recommended that prolonged interruptions in chest compressions should be avoided during transitions from bag-mask ventilation to an advanced airway device. In 2015, ILCOR evaluated the evidence comparing the effect of bagmask ventilation versus advanced airway placement on overall survival and neurologic outcome from cardiac arrest.

4.3.1.1 2015 Evidence Summary

There is inadequate evidence to show a difference in survival or favorable neurologic outcome with the use of bag-mask ventilation compared with endotracheal intubation[53-59] or other advanced airway devices.[53,55-57,60] The majority of these retrospective observational studies demonstrated slightly worse survival with the use of an advanced airway when compared with bag-mask ventilation. However, interpretation of these results is limited by significant concerns of selection bias. Two additional observational studies[60,61] showed no difference in survival.

4.4 Airway Adjuncts

4.4.1 Cricoid Pressure

Cricoid pressure in nonarrest patients may offer some measure of protection to the airway from aspiration and gastric insufflation during bag-mask ventilation.[62-65] However, it also may impede ventilation and interfere with placement of a supraglottic airway or intubation.[66-72] The role of cricoid pressure during out-of-hospital cardiac arrest and in-hospital cardiac arrest has not been studied. If cricoid pressure is used in special circumstances during cardiac arrest, the pressure should be adjusted, relaxed, or released if it impedes ventilation or advanced airway placement.

The routine use of cricoid pressure in cardiac arrest is not recommended. (Class III, LOE C)

4.4.2 Oropharyngeal Airways

Although studies have not specifically considered the use of oropharyngeal airways in patients with cardiac

arrest, airways may aid in the delivery of adequate ventilation with a bag-mask device by preventing the tongue from occluding the airway. Incorrect insertion of an oropharyngeal airway can displace the tongue into the hypopharynx, causing airway obstruction.

To facilitate delivery of ventilations with a bag-mask device, oropharyngeal airways can be used in unconscious (unresponsive) patients with no cough or gag reflex and should be inserted only by persons trained in their use. (Class IIa, LOE C)

4.4.3 Nasopharyngeal Airways

Nasopharyngeal airways are useful in patients with airway obstruction or those at risk for developing airway obstruction, particularly when conditions such as a clenched jaw prevent placement of an oral airway. Nasopharyngeal airways are better tolerated than oral airways in patients who are not deeply unconscious. Airway bleeding can occur in up to 30% of patients following insertion of a nasopharyngeal airway.[73] Two case reports of inadvertent intracranial placement of a nasopharyngeal airway in patients with basilar skull fractures[74, 75] suggest that nasopharyngeal airways should be used with caution in patients with severe craniofacial injury.

As with all adjunctive equipment, safe use of the nasopharyngeal airway requires adequate training, practice, and retraining. No studies have specifically examined the use of nasopharyngeal airways in cardiac arrest patients. To facilitate delivery of ventilations with a bag-mask device, the nasopharyngeal airway can be used in patients with an obstructed airway.

In the presence of known or suspected basal skull fracture or severe coagulopathy, an oral airway is preferred. (Class IIa, LOE C)

4.5 Advanced Airways - Updated

Ventilation with a bag and mask or with a bag through an advanced airway (eg, endotracheal tube or supraglottic airway) is acceptable during CPR. All healthcare providers should be trained in delivering effective oxygenation and ventilation with a bag and mask. Because there are times when ventilation with a bag-mask device is inadequate, ideally ACLS providers also should be trained and experienced in insertion of an advanced airway.

Providers must be aware of the risks and benefits of insertion of an advanced airway during a resuscitation attempt. Such risks are affected by the patient's condition and the provider's expertise in airway control. There are no studies directly addressing the timing of advanced airway placement and outcome during resuscitation from cardiac arrest. Although insertion of an endotracheal tube can be accomplished during ongoing chest compressions, intubation frequently is associated with interruption of compressions for many seconds.

The provider should weigh the need for minimally interrupted compressions against the need for insertion of an endotracheal tube or supraglottic airway. There is inadequate evidence to define the optimal timing of advanced airway placement in relation to other interventions during resuscitation from cardiac arrest. In a registry study of 25 006 in-hospital cardiac arrests, earlier time to invasive airway (<5 minutes) was not associated with improved ROSC but was associated with improved 24-hour survival.[76] In an urban out-of-hospital setting, intubation that was achieved in <12 minutes was associated with better survival than intubation achieved in ?13 minutes.[77]

In out-of-hospital urban and rural settings, patients intubated during resuscitation had a better survival rate than patients who were not intubated,[78] whereas in an in-hospital setting, patients who required intubation during CPR had a worse survival rate.[79] A recent study[80] found that delayed endotracheal intubation combined with passive oxygen delivery and minimally interrupted chest compressions was associated with improved neurologically intact survival after out-of-hospital cardiac arrest in patients with adult witnessed VF/pulseless VT.

If advanced airway placement will interrupt chest compressions, providers may consider deferring insertion of the airway until the patient fails to respond to initial CPR and defibrillation attempts or demonstrates ROSC. (Class IIb, LOE C)

For a patient with perfusing rhythm who requires intubation, pulse oximetry and electrocardiographic (ECG) status should be monitored continuously during airway placement. Intubation attempts should be interrupted to

provide oxygenation and ventilation as needed.

To use advanced airways effectively, healthcare providers must maintain their knowledge and skills through frequent practice. It may be helpful for providers to master one primary method of airway control. Providers should have a second (backup) strategy for airway management and ventilation if they are unable to establish the first-choice airway adjunct. Bag-mask ventilation may serve as that backup strategy.

Once an advanced airway is inserted, providers should immediately perform a thorough assessment to ensure that it is properly positioned. This assessment should not interrupt chest compressions. Assessment by physical examination consists of visualizing chest expansion bilaterally and listening over the epigastrium (breath sounds should not be heard) and the lung fields bilaterally (breath sounds should be equal and adequate). A device also should be used to confirm correct placement (see the section “Endotracheal Intubation” below).

Providers should observe a persistent capnographic waveform with ventilation to confirm and monitor endotracheal tube placement in the field, in the transport vehicle, on arrival at the hospital, and after any patient transfer to reduce the risk of unrecognized tube misplacement or displacement.

The use of capnography to confirm and monitor correct placement of supraglottic airways has not been studied, and its utility will depend on airway design. However, effective ventilation through a supraglottic airway device should result in a capnograph waveform during CPR and after ROSC.

Once an advanced airway is in place, the 2 providers should no longer deliver cycles of CPR (ie, compressions interrupted by pauses for ventilation) unless ventilation is inadequate when compressions are not paused. Instead the compressing provider should give continuous chest compressions at a rate of 100/min to 120/min, without pauses for ventilation. The provider delivering ventilation should provide 1 breath every 6 seconds (10 breaths per minute). Providers should avoid delivering an excessive ventilation rate because doing so can compromise venous return and cardiac output during CPR. The 2 providers should change compressor and ventilator roles approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions. When multiple providers are present, they should rotate the compressor role about every 2 minutes.

4.5.1 Advanced Airway Placement Choice - Updated

Advanced airway devices are frequently placed by experienced providers during CPR if bag-mask ventilation is inadequate or as a stepwise approach to airway management. Placement of an advanced airway may result in interruption of chest compressions, and the ideal timing of placement to maximize outcome has not been adequately studied. The use of an advanced airway device such as an ETT or SGA and the effect of ventilation technique on overall survival and neurologic outcome was evaluated in 2015.

4.5.1.1 2015 Evidence Summary

4.5.1.1.1 Endotracheal Intubation Versus Bag-Mask Ventilation - Updated

There is no high-quality evidence favoring the use of endotracheal intubation compared with bag-mask ventilation or an advanced airway device in relation to overall survival or favorable neurologic outcome.[53-59] Evaluating retrospective studies that compare bag-mask ventilation to endotracheal intubation is challenging because patients with more severe physiologic compromise will typically receive more invasive care (including endotracheal intubation) than patients who are less compromised and more likely to survive. Within that context, a number of retrospective studies show an association of worse outcome in those who were intubated as compared with those receiving bag-mask ventilation. While the studies did attempt to control for confounders, bias still may have been present, limiting the interpretation of these investigations. These studies illustrate that endotracheal intubation can be associated with a number of complications and that the procedure requires skill and experience. Risks of endotracheal intubation during resuscitation include unrecognized esophageal intubation and increased hands-off time.

4.5.1.1.2 Supraglottic Airway Devices - Updated

Several retrospective studies compared a variety of supraglottic devices (laryngeal mask airway, laryngeal tube, Combitube, esophageal obturator airway) to both bag-mask ventilation and endotracheal intubation. There is no high-quality evidence demonstrating a difference in survival rate or favorable neurologic outcome from use of an SGA compared with bagmask ventilation[53,55-57] or endotracheal intubation.[53,55,56,60,81-86] Three

observational studies demonstrated a lower rate of both overall survival and favorable neurologic outcome when SGA use was compared with bag-mask ventilation,[53,55,57] whereas another observational study demonstrated similar survival rates.[56]

In studies comparing SGA insertion to endotracheal intubation, no high-quality studies have demonstrated a difference in overall survival or favorable neurologic outcome.[56,60,81-83,86] Several retrospective observational studies show more favorable outcome with the use of an SGA device, whereas other studies favor the use of endotracheal intubation.[53,55,56,84-86]

4.5.1.2 2015 Recommendations - Updated

Either a bag-mask device or an advanced airway may be used for oxygenation and ventilation during CPR in both the in-hospital and out-of-hospital setting. (Class IIb, LOE C-LD)

For healthcare providers trained in their use, either an SGA device or an ETT may be used as the initial advanced airway during CPR. (Class IIb, LOE C-LD)

Recommendations for advanced airway placement presume that the provider has the initial training and skills as well as the ongoing experience to insert the airway and verify proper position with minimal interruption in chest compressions. Bag-mask ventilation also requires skill and proficiency. The choice of bag-mask device versus advanced airway insertion, then, will be determined by the skill and experience of the provider.

Frequent experience or frequent retraining is recommended for providers who perform endotracheal intubation.[76,87] (Class I, LOE B)

EMS systems that perform prehospital intubation should provide a program of ongoing quality improvement to minimize complications. (Class IIa, LOE B)

4.5.2 Clinical Assessment of Tracheal Tube Placement - Updated ALS 469

The 2015 ILCOR systematic review considered tracheal tube placement during CPR. This section evaluates methods for confirming correct tracheal tube placement.

Attempts at endotracheal intubation during CPR have been associated with unrecognized tube misplacement or displacement as well as prolonged interruptions in chest compression. Inadequate training, lack of experience, patient physiology (eg, low pulmonary blood flow, gastric contents in the trachea, airway obstruction), and patient movement may contribute to tube misplacement. After correct tube placement, tube displacement or obstruction may develop. In addition to auscultation of the lungs and stomach, several methods (eg, waveform capnography, CO2 detection devices, esophageal detector device, tracheal ultrasound, fiberoptic bronchoscopy) have been proposed to confirm successful tracheal intubation in adults during cardiac arrest.

4.5.2.1 2015 Evidence Summary

The evidence regarding the use of tracheal detection devices during cardiac arrest is largely observational. Observational studies and 1 small randomized study of waveform capnography to verify ETT position in victims of cardiac arrest report a specificity of 100% for correct tube placement.[88-90] Although the sensitivity of waveform capnography for detecting tracheal tube placement immediately after prehospital intubation was 100% in 1 study,[88] several other studies showed that the sensitivity of waveform capnography decreases after a prolonged cardiac arrest. [88-90] Differences in sensitivity can be explained by the low pulmonary blood flow during cardiac arrest, which will decrease ETCO2 concentration.

Although exhaled CO2 detection suggests correct tracheal tube placement, false-positive results (CO2 detection with esophageal intubation) can occur after ingestion of carbonated liquids.66 False-negative results (ie, absent exhaled CO2 in the presence of tracheal intubation) can occur in the setting of pulmonary embolism, significant hypotension, contamination of the detector with gastric contents, and severe airflow obstruction.[14,91,92] The use

of CO2 -detecting devices to determine the correct placement of other advanced airways (eg, Combitube, laryngeal mask airway) has not been studied, but, as with an ETT, effective ventilation should produce a capnography waveform during CPR and after ROSC.

Colorimetric and nonwaveform CO2 detectors can identify the presence of exhaled CO2 from the respiratory tract, but there is no evidence that these devices are accurate for continued monitoring of ETT placement.[14,88,93-97] Moreover, because a minimal threshold of CO2 must be reached to activate the detector and exhaled CO2 is low in cardiac arrest, proper placement of an ETT may not be confirmed with this qualitative methodology.

While observational studies and a small randomized controlled trial (RCT) of esophageal detector devices report a low false-positive rate for confirming tracheal placement, there is no evidence that these devices are accurate or practical for the continued monitoring of ETT placement.[89-98,93,99,100]

An ultrasound transducer can be placed transversely on the anterior neck above the suprasternal notch to identify endotracheal or esophageal intubation. In addition, ultrasound of the thoracic cavity can identify pleural movement as lung sliding. Unlike capnography, confirmation of ETT placement via ultrasonography is not dependent on adequate pulmonary blood flow and CO2 in exhaled gas.[101-103] One small prospective study of experienced clinicians compared tracheal ultrasound to waveform capnography and auscultation during CPR and reported a positive predictive value for ultrasound of 98.8% and negative predictive value of 100%.[103] The usefulness of tracheal and pleural ultrasonography, like fiberoptic bronchoscopy, may be limited by abnormal anatomy, availability of equipment, and operator experience.

4.5.2.2 2015 Recommendations - Updated

Continuous waveform capnography is recommended in addition to clinical assessment as the most reliable method of confirming and monitoring correct placement of an ETT. (Class I, LOE C-LD)

If continuous waveform capnometry is not available, a nonwaveform CO2 detector, esophageal detector device, or ultrasound used by an experienced operator is a reasonable alternative. (Class IIa, LOE C-LD)

4.5.3 Postintubation Airway Management

After inserting and confirming correct placement of an endotracheal tube, the provider should record the depth of the tube as marked at the front teeth or gums and secure it. There is significant potential for endotracheal tube movement with head flexion and extension[104-106] and when the patient is moved from one location to another.[107,108] Continuous monitoring of endotracheal tube placement with waveform capnography is recommended as discussed above.

The endotracheal tube should be secured with tape or a commercial device. (Class I, LOE C)

Devices and tape should be applied in a manner that avoids compression of the front and sides of the neck, which may impair venous return from the brain.

One out-of-hospital study[109] and 2 studies in an intensive-care setting[110,111] indicate that backboards, commercial devices for securing the endotracheal tube, and other strategies provide equivalent methods for preventing inadvertent tube displacement when compared with traditional methods of securing the tube (tape). These devices may be considered during patient transport. (Class IIb, LOE C)

After tube confirmation and fixation, obtain a chest x-ray (when feasible) to confirm that the end of the endotracheal tube is properly positioned above the carina.

4.5.4 Ventilation After Advanced Airway Placement - Updated ALS 808

The 2015 ILCOR systematic review addressed the optimal ventilation rate during continuous chest compressions among adults in cardiac arrest with an advanced airway. The 2015 Guidelines Update for ACLS applies only to patients who have been intubated and are in cardiac arrest. The effect of tidal volume and any other ventilation

parameters during CPR are not addressed in this recommendation.

Except for respiratory rate, it is unknown whether monitoring ventilatory parameters (eg, minute ventilation, peak pressure) during CPR can influence outcome. However, positive pressure ventilation increases intrathoracic pressure and may reduce venous return and cardiac output, especially in patients with hypovolemia or obstructive airway disease. Ventilation at inappropriately high respiratory rates (greater than 25 breaths/ min) is common during resuscitation from cardiac arrest.[112,113] There is concern that excessive ventilation in the setting of cardiac arrest may be associated with worse outcome.

4.5.4.1 2015 Evidence Summary

No human clinical trials were found addressing whether a ventilation rate of 10 breaths/min, compared with any other ventilation rate, changes survival with favorable neurologic or functional outcome. Although there have been a number of animal studies[112,114-122] and 1 human observational study[123] evaluating ventilation rates during CPR, the design and data from these studies did not allow for the assessment of the effect of a ventilation rate of 10 per minute compared with any other rate for ROSC or other outcomes.

4.5.4.2 2015 Recommendation - Updated

After placement of an advanced airway, it may be reasonable for the provider to deliver 1 breath every 6 seconds (10 breaths/min) while continuous chest compressions are being performed.
(Class IIb, LOE C-LD)

4.5.5 Automatic Transport Ventilators

In both out-of-hospital and in-hospital settings, automatic transport ventilators (ATVs) can be useful for ventilation of adult patients in noncardiac arrest who have an advanced airway in place.
(Class IIb, LOE C)

There are very few studies evaluating the use of ATVs attached to advanced airways during ongoing resuscitative efforts.

During prolonged resuscitative efforts the use of an ATV (pneumatically powered and time- or pressure-cycled) may allow the EMS team to perform other tasks while providing adequate ventilation and oxygenation.[124,125](Class IIb, LOE C)

Providers should always have a bag-mask device available for backup.

4.6 Suction Devices

Both portable and installed suction devices should be available for resuscitation emergencies. Portable units should provide adequate vacuum and flow for pharyngeal suction. The suction device should be fitted with large-bore, nonkinking suction tubing and semirigid pharyngeal tips. Several sterile suction catheters of various sizes should be available for suctioning the lumen of the advanced airway, along with a nonbreakable collection bottle and sterile water for cleaning tubes and catheters. The installed suction unit should be powerful enough to provide an airflow of >40 L/min at the end of the delivery tube and a vacuum of >300 mm Hg when the tube is clamped. The amount of suction should be adjustable for use in children and intubated patients.

5 Management of Cardiac Arrest - Updated

5.1 Overview

This section details the general care of a patient in cardiac arrest and provides an overview of the ACLS Adult Cardiac Arrest Algorithms (Figure 1 and Figure 2). Cardiac arrest can be caused by 4 rhythms: ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), pulseless electric activity (PEA), and asystole. VF represents disorganized electric activity, whereas pulseless VT represents organized electric activity of the ventricular myocardium. Neither of these rhythms generates significant forward blood flow. PEA encompasses a

heterogeneous group of organized electric rhythms that are associated with either absence of mechanical ventricular activity or mechanical ventricular activity that is insufficient to generate a clinically detectable pulse. Asystole (perhaps better described as ventricular asystole) represents absence of detectable ventricular electric activity with or without atrial electric activity.

Figure 1: Adult Cardiac Arrest Algorithm?2015 Update

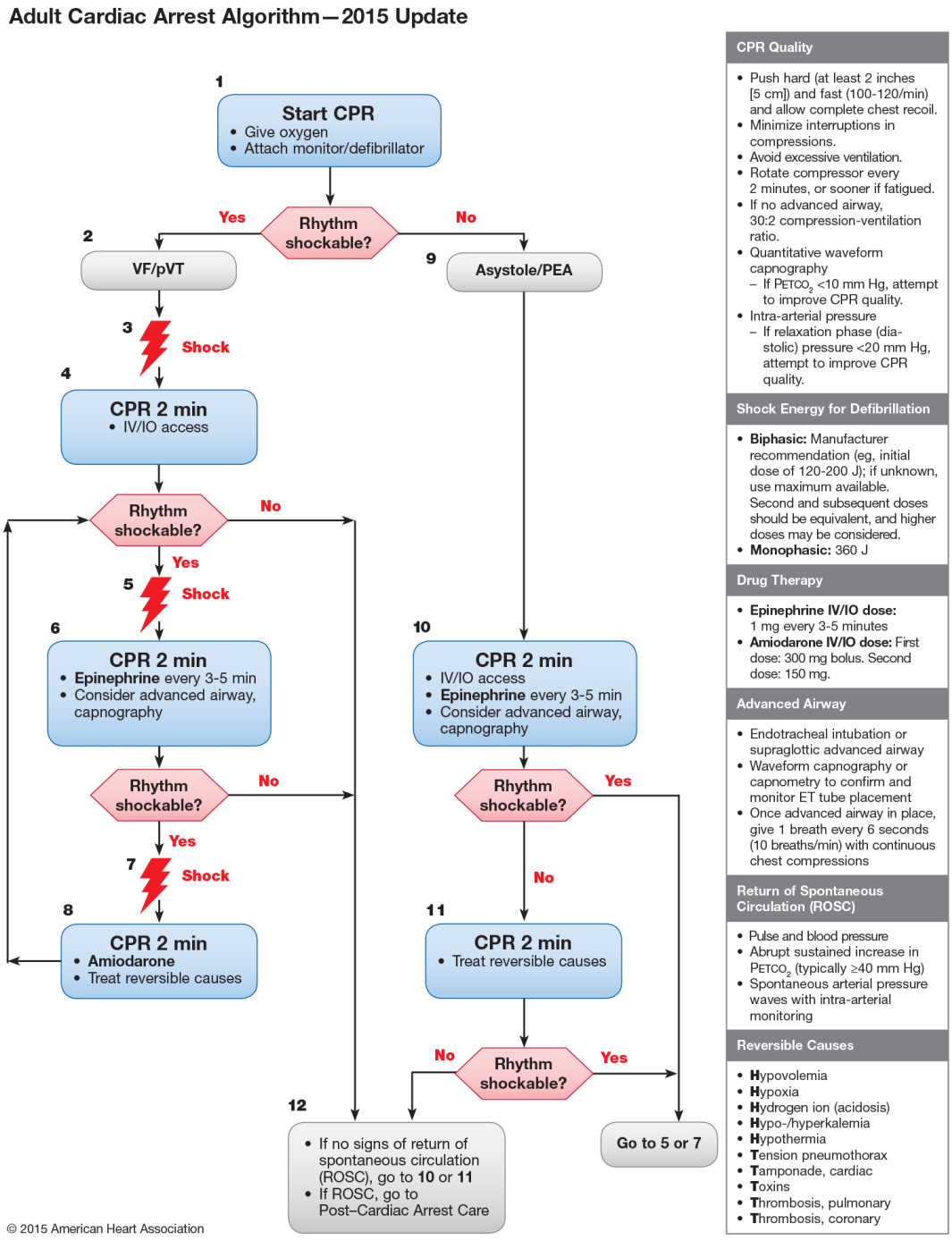
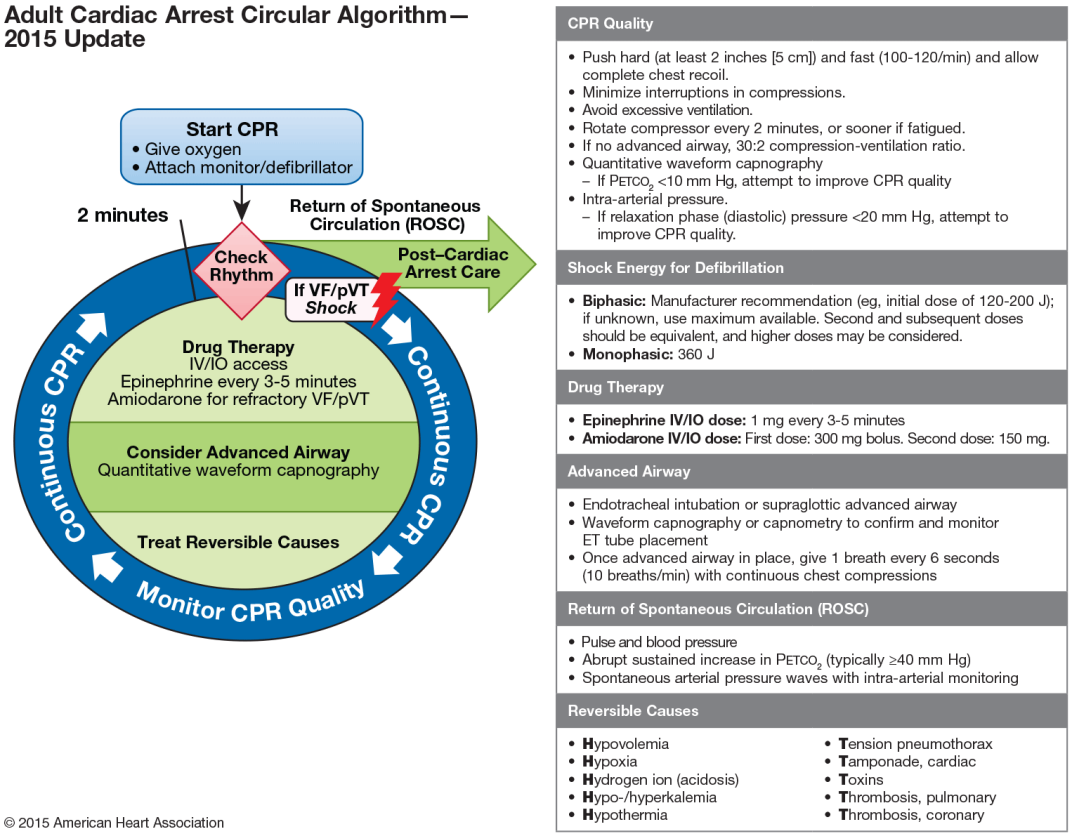


Figure 2: ACLS Cardiac Arrest Circular Algorithm - 2015 Update



Survival from these cardiac arrest rhythms requires both basic life support (BLS) and a system of advanced cardiovascular life support (ACLS) with integrated post–cardiac arrest care. The foundation of successful ACLS is high-quality CPR, and, for VF/pulseless VT, attempted defibrillation within minutes of collapse. For victims of witnessed VF arrest, early CPR and rapid defibrillation can significantly increase the chance for survival to hospital discharge.[126-131] In comparison, other ACLS therapies such as some medications and advanced airways, although associated with an increased rate of ROSC, have not been shown to increase the rate of survival to hospital discharge.[76,78,132-136]The majority of clinical trials testing these ACLS interventions, however, preceded the recently renewed emphasis on high-quality CPR and advances in post–cardiac arrest care (see “Part 8: Post–Cardiac Arrest Care”). Therefore, it remains to be determined if improved rates of ROSC achieved with ACLS interventions might better translate into improved long-term outcomes when combined with higher-quality CPR and post–cardiac arrest interventions such as therapeutic hypothermia and early percutaneous coronary intervention (PCI).

The ACLS Adult Cardiac Arrest Algorithms (Figure 1) are presented in the traditional box-and-line format and a new circular format. The 2 formats are provided to facilitate learning and memorization of the treatment recommendations discussed below. Overall these algorithms have been simplified and redesigned to emphasize the importance of high-quality CPR that is fundamental to the management of all cardiac arrest rhythms. Periodic pauses in CPR should be as brief as possible and only as necessary to assess rhythm, shock VF/VT, perform a pulse check when an organized rhythm is detected, or place an advanced airway. Monitoring and optimizing quality of CPR on the basis of either mechanical parameters (chest compression rate and depth, adequacy of relaxation, and minimization of pauses) or, when feasible, physiologic parameters (partial pressure of end-tidal CO_2 [$PETCO_2$], arterial pressure during the relaxation phase of chest compressions, or central venous oxygen saturation [$ScvO_2$]) are encouraged (see “Monitoring During CPR” below). In the absence of an advanced airway, a synchronized compression–ventilation ratio of 30:2 is recommended at a compression rate of at least 100 per minute. After placement of a supraglottic airway or an endotracheal tube, the provider performing chest compressions should deliver at least 100 compressions per minute continuously without pauses for ventilation. The provider delivering ventilations should give 1 breath every 6 seconds (10 breaths per minute) and should be particularly careful to avoid delivering an excessive number of ventilations.

In addition to high-quality CPR, the only rhythm-specific therapy proven to increase survival to hospital discharge is defibrillation of VF/pulseless VT. Therefore, this intervention is included as an integral part of the CPR cycle when the rhythm check reveals VF/pulseless VT. Other ACLS interventions during cardiac arrest may be associated with an increased rate of ROSC but have not yet been proven to increase survival to hospital discharge. Therefore, they are recommended as considerations and should be performed without compromising quality of CPR or timely defibrillation. In other words, vascular access, drug delivery, and advanced airway placement should not cause significant interruptions in chest compression or delay defibrillation. There is insufficient evidence to recommend a specific timing or sequence (order) of drug administration and advanced airway placement during cardiac arrest. In most cases the timing and sequence of these secondary interventions will depend on the number of providers participating in the resuscitation and their skill levels. Timing and sequence will also be affected by whether vascular access has been established or an advanced airway placed before cardiac arrest.

Understanding the importance of diagnosing and treating the underlying cause is fundamental to management of all cardiac arrest rhythms. During management of cardiac arrest the provider should consider the H’s and T’s to identify and treat any factor that may have caused the arrest or may be complicating the resuscitative effort (Table 1).

Table 1: 2010 - Treatable Causes of Cardiac Arrest: The H's and T's

Open table in a new window

Treatable Causes of Cardiac Arrest: The H's and T's

H's	T's
Hypoxia	Toxins
Hypovolemia	Tamponade (cardiac)
Hydrogen ion (acidosis)	Tension pneumothorax
Hypo-/hyperkalemia	Thrombosis, pulmonary
Hypothermia	Thrombosis, coronary

H's	T's
• For further explanation of the H's and T's, see Part 12: “Special Resuscitation Situations.”	

It is common for the arrest rhythm to evolve during the course of resuscitation. In such cases management should shift smoothly to the appropriate rhythm-based strategy. In particular, providers should be prepared to deliver a timely shock when a patient who presented with asystole or PEA is found to be in VF/pulseless VT during a rhythm check. There is no evidence that the resuscitation strategy for a new cardiac arrest rhythm should necessarily be altered based on the characteristics of the previous rhythm. Medications administered during resuscitation should be monitored and total doses tabulated to avoid potential toxicity.

If the patient achieves ROSC, it is important to begin post–cardiac arrest care immediately to avoid rearrest and optimize the patient’s chance of long-term survival with good neurologic function (see “Part 8: Post–Cardiac Arrest Care”). Finally, the reality is that the majority of resuscitative efforts do not result in ROSC. Criteria for ending unsuccessful resuscitative efforts are addressed in *Part 3: Ethical Issues*.

5.2 Rhythm-Based Management of Cardiac Arrest

In most cases of witnessed and unwitnessed cardiac arrest the first provider should start CPR with chest compressions and the second provider should get or turn on the defibrillator, place the adhesive pads or paddles, and check the rhythm. Paddles and electrode pads should be placed on the exposed chest in an anterior-lateral position. Acceptable alternative positions are anterior-posterior, anterior-left infrascapular, and anterior-right infrascapular. Rhythm checks should be brief, and if an organized rhythm is observed, a pulse check should be performed. If there is any doubt about the presence of a pulse, chest compressions should be resumed immediately. If a cardiac monitor is attached to the patient at the time of arrest, the rhythm can be diagnosed before CPR is initiated.

5.2.1 VF/Pulseless VT

When a rhythm check by an automated external defibrillator (AED) reveals VF/VT, the AED will typically prompt to charge, “clear” the victim for shock delivery, and then deliver a shock, all of which should be performed as quickly as possible. CPR should be resumed immediately after shock delivery (without a rhythm or pulse check and beginning with chest compressions) and continue for 2 minutes before the next rhythm check.

When a rhythm check by a manual defibrillator reveals VF/VT, the first provider should resume CPR while the second provider charges the defibrillator. Once the defibrillator is charged, CPR is paused to “clear” the patient for shock delivery. After the patient is “clear,” the second provider gives a single shock as quickly as possible to minimize the interruption in chest compressions (“hands-off interval”). The first provider resumes CPR immediately after shock delivery (without a rhythm or pulse check and beginning with chest compressions) and continues for 2 minutes. After 2 minutes of CPR the sequence is repeated, beginning with a rhythm check.

The provider giving chest compressions should switch at every 2-minute cycle to minimize fatigue. CPR quality should be monitored based on mechanical or physiologic parameters **(see “Monitoring During CPR” below)**.

5.2.1.1 Defibrillation Strategies for Ventricular Fibrillation or Pulseless Ventricular Tachycardia: Waveform Energy and First-Shock Success ALS 470

Currently manufactured manual and automated external defibrillators use biphasic waveforms of 3 different designs: biphasic truncated exponential (BTE), rectilinear biphasic (RLB), and pulsed biphasic waveforms; they deliver different peak currents at the same programmed energy setting and may adjust their energy output in relation to patient impedance in differing ways. These factors can make comparisons of shock efficacy between devices from different manufacturers challenging even when the same programmed energy setting is used. A substantial body of evidence now exists for the efficacy of BTE and RLB waveforms, with a smaller body of evidence for the pulsed waveform. An impedance-compensated version of the pulsed biphasic waveform is now clinically available, but no clinical studies were identified to define its performance characteristics.

5.2.1.1.1 2015 Evidence Summary

There is no evidence indicating superiority of one biphasic waveform or energy level for the termination of ventricular fibrillation (VF) with the first shock (termination is defined as absence of VF at 5 seconds after shock). All published studies support the effectiveness (consistently in the range of 85%–98%)[137] of biphasic shocks using 200 J or less for the first shock.[137] Defibrillators using the RLB waveform typically deliver more shock energy than selected, based on patient impedance. Thus, in the single study in which a manufacturer's nonescalating energy device was programmed to deliver 150 J shocks, comparison with other devices was not possible because shock energy delivery in other devices is adjusted for measured patient impedance. For the RLB, a selected energy dose of 120 J typically provides nearly 150 J for most patients.

5.2.1.1.2 2015 Recommendations - Updated

Defibrillators (using BTE, RLB, or monophasic waveforms) are recommended to treat atrial and ventricular arrhythmias. (Class I, LOE B-NR)

Based on their greater success in arrhythmia termination, defibrillators using biphasic waveforms (BTE or RLB) are preferred to monophasic defibrillators for treatment of both atrial and ventricular arrhythmias. (Class IIa, LOE B-R)

In the absence of conclusive evidence that 1 biphasic waveform is superior to another in termination of VF, it is reasonable to use the manufacturer's recommended energy dose for the first shock. If this is not known, defibrillation at the maximal dose may be considered. (Class IIb, LOE C-LD)

5.2.1.2 Defibrillation Strategies for Ventricular Fibrillation or Pulseless Ventricular Tachycardia: Energy Dose for Subsequent Shocks

The 2010 Guidelines regarding treatment of VF/pulseless ventricular tachycardia (pVT) recommended that if the first shock dose did not terminate VF/pVT, the second and subsequent doses should be equivalent, and higher doses may be considered. The evidence supporting energy dose for subsequent shocks was evaluated for the 2015 Guidelines Update.

5.2.1.2.1 2015 Evidence Summary

Observational data indicate that an automated external defibrillator administering a high peak current at 150 J biphasic fixed energy can terminate initial, as well as persistent or recurrent VF, with a high rate of conversion.[138] In fact, the high conversion rate achieved with all biphasic waveforms for the first shock makes it difficult to study the energy requirements for second and subsequent shocks when the first shock is not successful. A 2007 study attempted to determine if a fixed lower energy dose or escalating higher doses were associated with better outcome in patients requiring more than 1 shock. Although termination of VF at 5 seconds after shock was higher in the escalating higher-energy group (82.5% versus 71.2%), there were no significant differences in ROSC, survival to discharge, or survival with favorable neurologic outcome between the 2 groups. In this study, only 1 manufacturer's nonescalating energy device, programmed to deliver 150-J shocks, was used. Thus, it is not possible to compare this 150-J shock with that delivered by any other device set to deliver 150 J.

There is a decline in shock success with repeated shocks. One nonrandomized trial that used a BTE waveform reported a decline in shock success when repeated shocks at the same energy were administered.[139] For the

RLB waveform, 1 observational study reported an initial VF termination rate of 87.8% at a selected energy setting of 120 J and an 86.4% termination rate for persistent VF. Recurrence of VF did not affect ultimate shock success, ROSC, or discharge survival.[140]

5.2.1.2.2 2015 Recommendations - Updated

It is reasonable that selection of fixed versus escalating energy for subsequent shocks be based on the specific manufacturer's instructions. (Class IIa, LOE C-LD)

If using a manual defibrillator capable of escalating energies, higher energy for second and subsequent shocks may be considered. (Class IIb, LOE C-LD)

5.2.1.3 Defibrillation Strategies for Ventricular Fibrillation or Pulseless Ventricular Tachycardia: Single Shocks Versus Stacked Shocks

The 2010 Guidelines recommended a 2-minute period of CPR after each shock instead of immediate successive shocks for persistent VF. The rationale for this is at least 3-fold: First, VF is terminated with a very high rate of success with biphasic waveforms. Second, when VF is terminated, a brief period of asystole or pulseless electrical activity (PEA) typically ensues and a perfusing rhythm is unlikely to be present immediately. Third, this provides for a period of uninterrupted CPR following a shock before repeat rhythm analysis. The evidence for single versus stacked shocks was reviewed again in 2015.

5.2.1.3.1 2015 Evidence Summary

One RCT that comprised 845 OHCA patients found no difference in 1-year survival when a single shock protocol with 2 minutes of CPR between successive shocks was compared against a previous resuscitation protocol employing 3 initial stacked shocks with 1 minute of CPR between subsequent shocks (odds ratio, 1.64; 95% confidence interval, 0.53– 5.06).[141] An RCT published in 2010 showed no difference in frequency of VF recurrence when comparing the 2 treatment protocols.[142] In that study, increased time in recurrent VF was associated with decreased favorable neurologic survival under either protocol.

There is evidence that resumption of chest compressions immediately after a shock can induce recurrent VF, but the benefit of CPR in providing myocardial blood flow is thought to outweigh the benefit of immediate defibrillation for the VF.[143] Another study of patients presenting in VF after a witnessed arrest concluded that recurrence of VF within 30 seconds of a shock was not affected by the timing of resumption of chest compressions.[144] Thus, the effect of chest compressions on recurrent VF is not clear. It is likely that in the future, algorithms that recognize recurrent VF during chest compressions with high sensitivity and specificity will allow us to deliver a shock earlier in the CPR cycle, thereby reducing the length of time the myocardium is fibrillating and the duration of postshock CPR.[145]

5.2.1.3.2 2015 Recommendation - Updated

A single-shock strategy (as opposed to stacked shocks) is reasonable for defibrillation. (Class IIa, LOE B-NR)

5.2.1.4 Automatic Versus Manual Modes for Multimodal Defibrillators

Use of a multimodal defibrillator in manual mode may reduce the duration of interruption of CPR required for rhythm analysis compared with automatic mode but could increase the frequency of inappropriate shock.[146,147]

Current evidence indicates that the benefit of using a multimodal defibrillator in manual instead of automatic mode during cardiac arrest is uncertain. (Class IIb, LOE C)

5.2.1.5 CPR Before Defibrillation

This topic now covered in Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality.

5.2.1.6 VF Waveform Analysis to Predict Defibrillation Success

Retrospective analysis of VF waveforms in multiple clinical studies suggests that it is possible to predict the success of defibrillation from the fibrillation waveform with varying reliability.[148,149-168] No prospective human studies have specifically evaluated whether treatment altered by predicting success of defibrillation can improve successful defibrillation, rate of ROSC, or survival from cardiac arrest.

The value of VF waveform analysis to guide management of defibrillation in adults with in-hospital and out-of-hospital cardiac arrest is uncertain. (Class IIb, LOE C)

5.2.2 PEA/Asystole

When a rhythm check by an AED reveals a nonshockable rhythm, CPR should be resumed immediately, beginning with chest compressions, and should continue for 2 minutes before the rhythm check is repeated. When a rhythm check using a manual defibrillator or cardiac monitor reveals ***an organized rhythm***, a pulse check is performed. If a pulse is detected, post–cardiac arrest care should be initiated immediately (see Part 8: Post–Cardiac Arrest Care). If the rhythm is asystole or the pulse is absent (eg, PEA), CPR should be resumed immediately, beginning with chest compressions, and should continue for 2 minutes before the rhythm check is repeated. The provider performing chest compressions should switch every 2 minutes. CPR quality should be monitored on the basis of mechanical or physiologic parameters (see “Monitoring During CPR” below).

5.2.2.1 Treating Potentially Reversible Causes of PEA/Asystole

PEA is often caused by reversible conditions and can be treated successfully if those conditions are identified and corrected. During each 2-minute period of CPR the provider should recall the H’s and T’s to identify factors that may have caused the arrest or may be complicating the resuscitative effort (see Table 1 and “Part 10: Special Circumstances of Resuscitation”). Given the potential association of PEA with hypoxemia, placement of an advanced airway is theoretically more important than during VF/pulseless VT and might be necessary to achieve adequate oxygenation or ventilation. PEA caused by severe volume loss or sepsis will potentially benefit from administration of empirical IV/IO crystalloid. A patient with PEA caused by severe blood loss will potentially benefit from a blood transfusion.

When pulmonary embolism is presumed or known to be the cause of cardiac arrest, empirical fibrinolytic therapy can be considered. (Class IIa, LOE B)

Finally, if tension pneumothorax is clinically suspected as the cause of PEA, initial management includes needle decompression. If available, echocardiography can be used to guide management of PEA because it provides useful information about intravascular volume status (assessing ventricular volume), cardiac tamponade, mass lesions (tumor, clot), left ventricular contractility, and regional wall motion.[169] See “Part 10: Special Circumstances of Resuscitation” for management of toxicological causes of cardiac arrest.

Asystole is commonly the end-stage rhythm that follows prolonged VF or PEA, and for this reason the prognosis is generally much worse.

5.2.2.2 ROSC After PEA/Asystole

If the patient has ROSC, post–cardiac arrest care should be initiated (see Part 8: Post–Cardiac Arrest Care). Of particular importance is treatment of hypoxemia and hypotension and early diagnosis and treatment of the underlying cause of cardiac arrest.

Therapeutic hypothermia may be considered when the patient is comatose. (Class IIb, LOE C)

5.3 Medications for Arrest Rhythms

The primary goal of pharmacologic therapy during cardiac arrest is to facilitate restoration and maintenance of a perfusing spontaneous rhythm. Toward this goal, ACLS drug therapy during CPR is often associated with increased rates of ROSC and hospital admission but not increased rates of long-term survival with good neurologic outcome. One study [136] randomized patients to IV or no IV medications during management of adult out-of-hospital cardiac arrest. The study demonstrated higher rates of ROSC in the IV group (40% IV versus 25% no IV [odds ratio (OR) 1.99; 95% confidence interval (CI) 1.48 to 2.67]), but there was no statistical difference in survival to hospital discharge (10.5% IV versus 9.2% no IV [OR 1.16; 95% CI 0.74 to 1.82]) or survival with favorable neurologic outcome (9.8% IV versus 8.1% no IV [OR 1.24; 95% CI 0.77 to 1.98]). This study was not adequately powered to detect clinically important differences in long-term outcomes. Evidence from one nonrandomized trial [135] found that the addition of ACLS interventions including IV drugs in a previously optimized BLS system with rapid defibrillation resulted in an increased rate of ROSC (18.0% with ACLS versus 12.9% before ACLS, P<0.001) and hospital admission (14.6% with ACLS versus 10.9% before ACLS, P<0.001) but no statistical difference in survival to hospital discharge (5.1% with ACLS versus 5.0% before ACLS). Whether optimized high-quality CPR and advances in post–cardiac arrest care will enable the increased rates of ROSC with ACLS medications to be translated into increased long-term survival remains to be determined.

5.3.1 Ventricular Fibrillation (VF) or Pulseless Ventricular Tachycardia (pVT)

5.3.1.1 Treating Potentially Reversible Causes of VF/pVT

The importance of diagnosing and treating the underlying cause of VF/pVT is fundamental to the management of all cardiac arrest rhythms. As always, the provider should recall the H's and T's to identify a factor that may have caused the arrest or may be complicating the resuscitative effort (see Table 1 and "Part 10: Special Circumstances of Resuscitation"). In the case of refractory VF/pulseless VT, acute coronary ischemia or myocardial infarction should be considered as a potential etiology. Reperfusion strategies such as coronary angiography and PCI during CPR or emergency cardiopulmonary bypass have been demonstrated to be feasible in a number of case studies and case series but have not been evaluated for their effectiveness in RCTs.[170-179] Fibrinolytic therapy administered during CPR for acute coronary occlusion has not been shown to improve outcome.[180]

5.3.1.2 ROSC After VF/pVT

If the patient has ROSC, post–cardiac arrest care should be started. Of particular importance are treatment of hypoxemia and hypotension, early diagnosis and treatment of ST-elevation myocardial infarction (STEMI) (Class I, LOE B)

and therapeutic hypothermia in comatose patients. (Class I, LOE B)

5.3.2 Antiarrhythmic Drugs During and Immediately After Cardiac Arrest - Updated ALS 428

The 2015 ILCOR systematic review addressed whether the administration of antiarrhythmic drugs for cardiac arrest due to refractory VF or pVT results in better outcome.

5.3.2.1 Antiarrhythmic Drugs During and Immediately After Cardiac Arrest: Antiarrhythmic Therapy for Refractory VF/pVT Arrest - Updated

Refractory VF/pVT refers to VF or pVT that persists or recurs after 1 or more shocks. It is unlikely that an antiarrhythmic drug will itself pharmacologically convert VF/pVT to an organized perfusing rhythm. Rather, the principal objective of antiarrhythmic drug therapy in shock-refractory VF/pVT is to facilitate the restoration and maintenance of a spontaneous perfusing rhythm in concert with the shock termination of VF. Some antiarrhythmic drugs have been associated with increased rates of ROSC and hospital admission, but none have yet been proven to increase long-term survival or survival with good neurologic outcome. Thus, establishing vascular access to enable drug administration should not compromise the quality of CPR or timely defibrillation, which are known to improve survival. The optimal sequence of ACLS interventions, including administration of antiarrhythmic drugs during resuscitation and the preferred manner and timing of drug administration in relation to shock delivery, is not known. Previous ACLS guidelines addressed the use of magnesium in cardiac arrest with polymorphic ventricular tachycardia (ie, torsades de pointes) or suspected hypomagnesemia, and this has

not been reevaluated in the 2015 Guidelines Update. These previous guidelines recommended defibrillation for termination of polymorphic VT (ie, torsades de pointes), followed by consideration of intravenous magnesium sulfate when secondary to a long QT interval.

The 2015 ILCOR systematic review did not specifically address the selection or use of second-line antiarrhythmic medications in patients who are unresponsive to a maximum therapeutic dose of the first administered drug, and there are limited data available to direct such treatment.

5.3.2.1.1 2015 Evidence Summary

5.3.2.1.1.1 Amiodarone - Updated

Intravenous amiodarone is available in 2 approved formulations in the United States, one containing polysorbate 80, a vasoactive solvent that can provoke hypotension, and one containing captisol, which has no vasoactive effects. In blinded RCTs in adults with refractory VF/pVT in the out-of-hospital setting, paramedic administration of amiodarone in polysorbate (300 mg or 5 mg/kg) after at least 3 failed shocks and administration of epinephrine improved hospital admission rates when compared to placebo with polysorbate[181] or 1.5 mg/kg lidocaine with polysorbate.[182] Survival to hospital discharge and survival with favorable neurologic outcome, however, was not improved by amiodarone compared with placebo or amiodarone compared with lidocaine, although these studies were not powered for survival or favorable neurologic outcome.

5.3.2.1.1.2 Lidocaine - Updated

Intravenous lidocaine is an alternative antiarrhythmic drug of long-standing and widespread familiarity. Compared with no antiarrhythmic drug treatment, lidocaine did not consistently increase ROSC and was not associated with improvement in survival to hospital discharge in observational studies.[183,184] In a prospective, blinded, randomized clinical trial, lidocaine was less effective than amiodarone in improving hospital admission rates after OHCA due to shock-refractory VF/pVT, but there were no differences between the 2 drugs in survival to hospital discharge.[182]

5.3.2.1.1.3 Procainamide - Updated

Procainamide is available only as a parenteral formulation in the United States. In conscious patients, procainamide can be given only as a controlled infusion (20 mg/min) because of its hypotensive effects and risk of QT prolongation, making it difficult to use during cardiac arrest. Procainamide was recently studied as a second-tier antiarrhythmic agent in patients with OHCA due to VF/pVT that was refractory to lidocaine and epinephrine. In this study, the drug was given as a rapid infusion of 500 mg (repeated as needed up to 17 mg/kg) during ongoing CPR. An unadjusted analysis showed lower rates of hospital admission and survival among the 176 procainamide recipients as compared with 489 nonrecipients. After adjustment for patients' clinical and resuscitation characteristics, no association was found between use of the drug and hospital admission or survival to hospital discharge, although a modest survival benefit from the drug could not be excluded.[185]

5.3.2.1.1.4 Magnesium - Updated

Magnesium acts as a vasodilator and is an important cofactor in regulating sodium, potassium, and calcium flow across cell membranes. In 3 randomized clinical trials, magnesium was not found to increase rates of ROSC for cardiac arrest due to any presenting rhythm,[186] including VF/pVT.[187,188] In these RCTs and in 1 additional randomized clinical trial, the use of magnesium in cardiac arrest for any rhythm presentation of cardiac arrest[186,189] or strictly for VF arrest[187,188] did not improve survival to hospital discharge or neurologic outcome.[189]

5.3.2.1.2 2015 Recommendations - Unchanged

Amiodarone may be considered for VF/pVT that is unresponsive to CPR, defibrillation, and a vasopressor therapy. (Class IIb, LOE B-R)

Lidocaine may be considered as an alternative to amiodarone for VF/pVT that is unresponsive to CPR, defibrillation, and vasopressor therapy. (Class IIb, LOE C-LD)

The routine use of magnesium for VF/pVT is not recommended in adult patients. (Class III: No Benefit, LOE B-R)

No antiarrhythmic drug has yet been shown to increase survival or neurologic outcome after cardiac arrest due to VF/pVT. Accordingly, recommendations for the use of antiarrhythmic medications in cardiac arrest are based primarily on the potential for benefit on short-term outcome until more definitive studies are performed to address their effect on survival and neurologic outcome.

5.3.2.2 Antiarrhythmic Drugs During and Immediately After Cardiac Arrest: Antiarrhythmic Drugs After Resuscitation - Updated ALS 493

The 2015 ILCOR systematic review addressed whether, after successful termination of VF or pVT cardiac arrest, the prophylactic administration of antiarrhythmic drugs for cardiac arrest results in better outcome. The only medications studied in this context are ?-adrenergic blocking drugs and lidocaine, and the evidence for their use is limited.

5.3.2.2.1 2015 Evidence Summary

5.3.2.2.1.1 ?-Adrenergic Blocking Drugs - Updated

?-Adrenergic blocking drugs blunt heightened catecholamine activity that can precipitate cardiac arrhythmias. The drugs also reduce ischemic injury and may have membrane-stabilizing effects. In 1 observational study of oral or intravenous metoprolol or bisoprolol during hospitalization after cardiac arrest due to VF/pVT, recipients had a significantly higher adjusted survival rate than nonrecipients at 72 hours after ROSC and at 6 months.[190] Conversely, ?-blockers can cause or worsen hemodynamic instability, exacerbate heart failure, and cause bradyarrhythmias, making their routine adminis- tration after cardiac arrest potentially hazardous. There is no evidence addressing the use of ?-blockers after cardiac arrest precipitated by rhythms other than VF/pVT.

5.3.2.2.1.2 Lidocaine - Updated

Early studies in patients with acute myocardial infarction found that lidocaine suppressed premature ventricular complexes and nonsustained VT, rhythms that were believed to presage VF/pVT. Later studies noted a disconcerting association between lidocaine and higher mortality after acute myocardial infarction, possibly due to a higher incidence of asystole and bradyarrhythmias; the routine practice of administering prophylactic lidocaine during acute myocardial infarction was abandoned.[191,192] The use of lidocaine was explored in a multivariate and propensity score–adjusted analysis of patients resuscitated from out-of-hospital VF/pVT arrest. In this observational study of 1721 patients, multivariate analysis found the prophylactic administration of lidocaine before hospitalization was associated with a significantly lower rate of recurrent VF/ pVT and higher rates of hospital admission and survival to hospital discharge. However, in a propensity score–adjusted analysis, rates of hospital admission and survival to hospital discharge did not differ between recipients of prophylactic lidocaine as compared with nonrecipients, although lidocaine was associated with less recurrent VF/pVT and there was no evidence of harm.[193] Thus, evidence supporting a role for prophylactic lidocaine after VF/pVT arrest is weak at best, and nonexistent for cardiac arrest initiated by other rhythms.

5.3.2.2.2 Recommendations - Updated

There is inadequate evidence to support the routine use of lidocaine after cardiac arrest. However, the initiation or continuation of lidocaine may be considered immediately after ROSC from cardiac arrest due to VF/pVT. (Class IIb, LOE C-LD)

There is inadequate evidence to support the routine use of a ?-blocker after cardiac arrest. However, the initiation or continuation of an oral or intravenous ?-blocker may be considered early after hospitalization from cardiac arrest due to VF/pVT. (Class IIb, LOE C-LD)

Available evidence suggests that the routine use of atropine during PEA or asystole is unlikely to have a

therapeutic benefit. (Class IIb, LOE B)

There is insufficient evidence to recommend for or against the routine initiation or continuation of other antiarrhythmic medications after ROSC from cardiac arrest.

5.3.3 Vasopressors in Cardiac Arrest - Updated

The 2015 ILCOR systematic review addresses the use of the vasopressors epinephrine and vasopressin during cardiac arrest. The new recommendations in this 2015 Guidelines Update apply only to the use of these vasopressors for this purpose.

In 2010 it was noted that, no placebo-controlled trials have shown that administration of any vasopressor agent at any stage during management of VF, pulseless VT, PEA, or asystole increases the rate of neurologically intact survival to hospital discharge. There is evidence, however, that the use of vasopressor agents is associated with an increased rate of ROSC.

5.3.3.1 Vasopressors in Cardiac Arrest: Standard-Dose Epinephrine - Updated ALS 788

Epinephrine produces beneficial effects in patients during cardiac arrest, primarily because of its ?-adrenergic (ie, vasoconstrictor) effects. These ?-adrenergic effects of epinephrine can increase coronary perfusion pressure and cerebral perfusion pressure during CPR. The value and safety of the ?-adrenergic effects of epinephrine are controversial because they may increase myocardial work and reduce subendocardial perfusion. The 2010 Guidelines stated that it is reasonable to consider administering a 1-mg dose of IV/IO epinephrine every 3 to 5 minutes during adult cardiac arrest.

5.3.3.1.1 2015 Evidence Summary

One trial[194] assessed short-term and longer-term outcomes when comparing standard-dose epinephrine to placebo. Standard-dose epinephrine was defined as 1 mg given IV/ IO every 3 to 5 minutes. For both survival to discharge and survival to discharge with good neurologic outcome, there was no benefit with standard-dose epinephrine; however, the study was stopped early and was therefore underpowered for analysis of either of these outcomes (enrolled approximately 500 patients as opposed to the target of 5000). There was, nevertheless, improved survival to hospital admission and improved ROSC with the use of standard-dose epinephrine. Observational studies were performed that evaluated epinephrine, with conflicting results.[195,196]

5.3.3.1.2 2015 Recommendation - Updated

Standard-dose epinephrine (1 mg every 3 to 5 minutes) may be reasonable for patients in cardiac arrest. (Class IIb, LOE B-R)

5.3.3.2 Vasopressors in Cardiac Arrest: Standard Dose Epinephrine Versus High-Dose Epinephrine - Updated ALS 778 ALS 778

High doses of epinephrine are generally defined as doses in the range of 0.1 to 0.2 mg/kg. In theory, higher doses of epinephrine may increase coronary perfusion pressure, resulting in increased ROSC and survival from cardiac arrest. However, the adverse effects of higher doses of epinephrine in the postarrest period may negate potential advantages during the intraarrest period. Multiple case series followed by randomized trials have been performed to evaluate the potential benefit of higher doses of epinephrine. In the 2010 Guidelines, the use of high-dose epinephrine was not recommended except in special circumstances, such as for ?-blocker overdose, calcium channel blocker overdose, or when titrated to real-time physiologically monitored parameters. In 2015, ILCOR evaluated the use of high-dose epinephrine compared with standard doses.

5.3.3.2.1 2015 Evidence Summary

A number of trials have compared outcomes from standard-dose epinephrine with those of high-dose epinephrine. These trials did not demonstrate any benefit for high-dose epinephrine over standard-dose epinephrine for survival to discharge with a good neurologic recovery (ie, Cerebral Performance Category score),[197,198] survival to discharge,[197-201] or survival to hospital admission.[197-199,202] There was, however, a demonstrated ROSC advantage with highdose epinephrine.[197-202]

5.3.3.2.2 2015 Recommendation—New

High-dose epinephrine is not recommended for routine use in cardiac arrest.
(Class III: No Benefit, LOE B-R)

5.3.3.3 Vasopressors in Cardiac Arrest: Epinephrine Versus Vasopressin - Updated ALS 659

Vasopressin is a nonadrenergic peripheral vasoconstrictor that also causes coronary[203,204] and renal vasoconstriction.[205]

5.3.3.3.1 2015 Evidence Summary

A single RCT[206] enrolling 336 patients compared multiple doses of standard-dose epinephrine with multiple doses of standard dose vasopressin (40 units IV) in the emergency department after OHCA. The trial had a number of limitations but showed no benefit with the use of vasopressin for ROSC or survival to discharge with or without good neurologic outcome.

5.3.3.3.2 2015 Recommendation—Updated

Vasopressin offers no advantage as a substitute for epinephrine in cardiac arrest. (Class IIb, LOE B-R)

The removal of vasopressin has been noted in the Adult Cardiac Arrest Algorithm above (Figure 1).

5.3.3.4 Vasopressors in Cardiac Arrest: Epinephrine Versus Vasopressin in Combination With Epinephrine - Updated ALS 789

5.3.3.4.1 2015 Evidence Summary

A number of trials have compared outcomes from standard dose epinephrine to those using the combination of epinephrine and vasopressin. These trials showed no benefit with the use of the epinephrine/vasopressin combination for survival to hospital discharge with Cerebral Performance Category score of 1 or 2 in 2402 patients,[207-209] no benefit for survival to hospital discharge or hospital admission in 2438 patients,[207-211] and no benefit for ROSC.[207-212]

5.3.3.4.2 2015 Recommendation—New

Vasopressin in combination with epinephrine offers no advantage as a substitute for standard-dose epinephrine in cardiac arrest. (Class IIb, LOE B-R)

The removal of vasopressin has been noted in the Adult Cardiac Arrest Algorithm above (Figure 1).

5.3.3.5 Vasopressors in Cardiac Arrest: Timing of Administration of Epinephrine - Updated ALS 784

5.3.3.5.1 2015 Evidence Summary: IHCA

One large (n=25 905 patients) observational study of IHCA with nonshockable rhythms was identified,[213] in which outcomes from early administration of epinephrine (1 to 3 minutes) were compared with outcomes from administration of epinephrine at 4 to 6 minutes, 7 to 9 minutes, and greater than 9 minutes. In this study, the early administration of epinephrine in nonshockable rhythms was associated with increased ROSC, survival to hospital discharge, and neurologically intact survival. No studies were identified specifically examining the effect of timing of administration of epinephrine after IHCA with shockable rhythms.

5.3.3.5.2 2015 Evidence Summary: OHCA

For nonshockable rhythms, 3 studies showed improved survival to hospital discharge with early administration of epinephrine. A study of 209 577 OHCA patients[214] showed improved 1-month survival when outcomes from administration of epinephrine at less than 9 minutes of EMS-initiated CPR were compared with those in which epinephrine was administered at greater than 10 minutes. Another study enrolling 212 228 OHCA patients[215] showed improved survival to discharge with early epinephrine (less than 10 minutes after EMS-initiated CPR) compared with no epinephrine. A smaller study of 686 OHCA patients[216] showed improved rates of ROSC with early epinephrine (less than 10 minutes after 9-1-1 call) when the presenting rhythm was pulseless electrical activity. For shockable rhythms, there was no benefit with early administration of epinephrine, but there was a negative association of outcome with late administration. When neurologically intact survival to discharge was assessed,[214,215,217] however, there was variable benefit with early administration of epinephrine for both shockable and nonshockable rhythms. Later administration of epinephrine was associated with a worse outcome. ROSC was generally improved with early administration of epinephrine in studies of more than 210 000 patients.[201,214,216,218] Design flaws in the majority of these observational OHCA studies, however, included the use of a “no epinephrine” control arm as the comparator (thus not allowing for estimates on the effect of timing), and the lack of known timing of epinephrine administration upon arrival in the emergency department. In addition, the relationship of timing of defibrillation to timing of epinephrine is unknown for studies that included shockable rhythms.

5.3.3.5.3 2015 Recommendations—Updated

It may be reasonable to administer epinephrine as soon as feasible after the onset of cardiac arrest due to an initial non- shockable rhythm. (Class IIb, LOE C-LD)

There is insufficient evidence to make a recommendation as to the optimal timing of epinephrine, particularly in relation to defibrillation, when cardiac arrest is due to a shockable rhythm, because optimal timing may vary based on patient factors and resuscitation conditions.

5.3.4 Steroids - Updated ALS 433

The use of steroids in cardiac arrest has been assessed in 2 clinical settings: IHCA and OHCA. In IHCA, steroids were combined with a vasopressor bundle or cocktail of epinephrine and vasopressin. Because the results of IHCA and OHCA were so different, these situations are discussed separately.

5.3.4.1 2015 Evidence Summary: IHCA

In an initial RCT involving 100 IHCA patients at a single center, the use of a combination of methylprednisolone, vasopressin, and epinephrine during cardiac arrest and hydrocortisone after ROSC for those with shock significantly improved survival to hospital discharge compared with the use of only epinephrine and placebo.[219] In a subsequent 3-center study published in 2013,[219] of 268 patients with IHCA (the majority coming from the same center as in the first study), the same combination of methylprednisolone, vasopressin, and epinephrine during cardiac arrest, and hydrocortisone for those with post-ROSC shock, significantly improved survival to discharge with good neurologic outcome compared with only epinephrine and placebo.

The same 2 RCTs provided evidence that the use of methylprednisolone and vasopressin in addition to epinephrine improved ROSC compared with the use of placebo and epinephrine alone.[219,220]

5.3.4.2 2015 Evidence Summary: OHCA

In OHCA, steroids have been evaluated in 1 RCT[221] and 1 observational study.[222] In these studies, steroids were not bundled as they were in the IHCA but studied as a sole treatment. When dexamethasone was given

during cardiac arrest, it did not improve survival to hospital discharge or ROSC as compared with placebo.[221] The observational study[222] showed no benefit in survival to discharge but did show an association of improved ROSC with hydrocortisone compared with no hydrocortisone.

5.3.4.3 2015 Recommendations—New

There are no data to recommend for or against the routine use of steroids alone for IHCA patients.

In IHCA, the combination of intra-arrest vasopressin, epinephrine, and methylprednisolone and post-arrest hydrocortisone as described by Mentzelopoulos et al [220] may be considered; however, further studies are needed before recommending the routine use of this therapeutic strategy.

(Class IIb, LOE C-LD)

For patients with OHCA, use of steroids during CPR is of uncertain benefit. (Class IIb, LOE C-LD)

5.4 Access for Parenteral Medications During Cardiac Arrest

5.4.1 Timing of IV/IO Access

During cardiac arrest, provision of high-quality CPR and rapid defibrillation are of primary importance and drug administration is of secondary importance. After beginning CPR and attempting defibrillation for identified VF or pulseless VT, providers can establish IV or IO access. This should be performed without interrupting chest compressions. The primary purpose of IV/IO access during cardiac arrest is to provide drug therapy. Two clinical studies[132,134] reported data suggesting worsened survival for every minute that antiarrhythmic drug delivery was delayed (measured from time of dispatch). However, this finding was potentially biased by a concomitant delay in onset of other ACLS interventions. In one study[134] the interval from first shock to administration of an antiarrhythmic drug was a significant predictor of survival. One animal study[223] reported lower CPP when delivery of a vasopressor was delayed. Time to drug administration was also a predictor of ROSC in a retrospective analysis of swine cardiac arrest.[224] Thus, although time to drug treatment appears to have importance, there is insufficient evidence to specify exact time parameters or the precise sequence with which drugs should be administered during cardiac arrest.

5.4.2 Peripheral IV Drug Delivery

If a resuscitation drug is administered by a peripheral venous route, it should be administered by bolus injection and followed with a 20-mL bolus of IV fluid to facilitate the drug flow from the extremity into the central circulation.[225] Briefly elevating the extremity during and after drug administration theoretically may also recruit the benefit of gravity to facilitate delivery to the central circulation but has not been systematically studied.

5.4.3 IO Drug Delivery

IO cannulation provides access to a noncollapsible venous plexus, enabling drug delivery similar to that achieved by peripheral venous access at comparable doses. Two prospective trials in children[226] and adults[227] and 6 other studies[228-234] suggest that IO access can be established efficiently; is safe and effective for fluid resuscitation, drug delivery, and blood sampling for laboratory evaluation; and is attainable in all age groups. However, many of these studies were conducted during normal perfusion states or hypovolemic shock or in animal models of cardiac arrest. Although virtually all ACLS drugs have been given intraosseously in the clinical setting without known ill effects, there is little information on the efficacy and effectiveness of such administration in clinical cardiac arrest during ongoing CPR.

It is reasonable for providers to establish IO access if IV access is not readily available. (Class IIa, LOE C)

Commercially available kits can facilitate IO access in adults.

5.4.4 Central IV Drug Delivery

The appropriately trained provider may consider placement of a central line (internal jugular or subclavian) during cardiac arrest, unless there are contraindications. (Class IIb, LOE C)

The primary advantage of a central line is that peak drug concentrations are higher and drug circulation times shorter compared with drugs administered through a peripheral IV catheter.[235-237] In addition, a central line extending into the superior vena cava can be used to monitor ScvO2 and estimate CPP during CPR, both of which are predictive of ROSC.[238,239] However, central line placement can interrupt CPR. Central venous catheterization is a relative (but not absolute) contraindication for fibrinolytic therapy in patients with acute coronary syndromes.

5.4.5 Endotracheal Drug Delivery

One study in children,[240] 5 studies in adults,[241-245] and multiple animal studies[246-248] have shown that lidocaine,[242,249] epinephrine,[250] atropine,[251] naloxone, and vasopressin[248] are absorbed via the trachea. There are no data regarding endotracheal administration of amiodarone. Administration of resuscitation drugs into the trachea results in lower blood concentrations than when the same dose is given intravascularly. Furthermore, the results of recent animal studies[252,253] suggest that the lower epinephrine concentrations achieved when the drug is delivered endotracheally may produce transient ?-adrenergic effects, resulting in vasodilation. These effects can be detrimental, causing hypotension, lower CPP and flow, and reduced potential for ROSC. Thus, although endotracheal administration of some resuscitation drugs is possible, IV or IO drug administration is preferred because it will provide more predictable drug delivery and pharmacologic effect.

In one nonrandomized cohort study of out-of-hospital cardiac arrest in adults[254] using a randomized control, IV administration of atropine and epinephrine was associated with a higher rate of ROSC and survival to hospital admission than administration by the endotracheal route. Five percent of those who received IV drugs survived to hospital discharge, but no patient survived in the group receiving drugs by the endotracheal route.

If IV or IO access cannot be established, epinephrine, vasopressin, and lidocaine may be administered by the endotracheal route during cardiac arrest. (Class IIb, LOE B)

The optimal endotracheal dose of most drugs is unknown, but typically the dose given by the endotracheal route is 2 to 2½ times the recommended IV dose. In 2 animal CPR studies the equipotent epinephrine dose given endotracheally was approximately 3 to 10 times higher than the IV dose.[255,256] Providers should dilute the recommended dose in 5 to 10 mL of sterile water or normal saline and inject the drug directly into the endotracheal tube.[250] Studies with epinephrine[257] and lidocaine[245] showed that dilution with sterile water instead of 0.9% saline may achieve better drug absorption.

5.5 Prognostication During CPR:End-Tidal CO2 - Updated ALS 459 ALS 459

The 2015 ILCOR systematic review considered one intraarrest modality, $ETCO_2$ measurement, in prognosticating outcome from cardiac arrest. This section focuses on whether a specific $ETCO_2$ threshold can reliably predict ROSC and survival or inform a decision to terminate resuscitation efforts. The potential value of using $ETCO_2$ as a physiologic monitor to optimize resuscitation efforts is discussed elsewhere (See Monitoring Physiologic Parameters During CPR, earlier in this Part).

$ETCO_2$ is the partial pressure of exhaled carbon dioxide at the end of expiration and is determined by CO_2 production, alveolar ventilation, and pulmonary blood flow. It is most reliably measured using waveform capnography, where the visualization of the actual CO_2 waveform during ventilation ensures accuracy of the measurement. During low-flow states with relatively fixed minute ventilation, pulmonary blood flow is the primary determinant of $ETCO_2$. During cardiac arrest, $ETCO_2$ levels reflect the cardiac output generated by chest compression. Low $ETCO_2$ values may reflect inadequate cardiac output, but $ETCO_2$ levels can also be low as a result of bronchospasm, mucous plugging of the ETT, kinking of the ETT, alveolar fluid in the ETT, hyperventilation, sampling of an SGA, or an airway with an air leak. It is particularly important to recognize that all of the prognostication studies reviewed in this section included only intubated patients. In nonintubated patients (those with bag-mask ventilation or SGA), $ETCO_2$ may not consistently reflect the true value, making the measurement less reliable as a prognostication tool.

5.5.1 2015 Evidence Summary

Studies on the predictive capacity of $ETCO^2$ among intubated patients during cardiac arrest resuscitation are observational, and none have investigated survival with intact neurologic outcome. An $ETCO_2$ less than 10 mmHg immediately after intubation and 20 minutes after the initial resuscitation is associated with extremely poor chances for ROSC and survival.[8,12,15,18,258]

A prospective observational study of 127 IHCA patients found that an $ETCO_2$ less than 10 mmHg at any point during the resuscitation was predictive of mortality, and only 1 patient with an $ETCO_2$ value less than 10 mmHg survived to discharge.[258] In that same study, an $ETCO_2$ greater than 20 mmHg after 20 minutes of resuscitation was associated with improved survival to discharge.[258] Another prospective observational study of 150 OHCA patients reported no survival to hospital admission when the $ETCO_2$ was less than 10 mmHg after 20 minutes of resuscitation.[8] Although these results suggest that $ETCO_2$ can be a valuable tool to predict futility during CPR, potential confounding reasons for a low $ETCO_2$ as listed above and the relatively small numbers of patients in these studies suggest that the $ETCO_2$ should not be used alone as an indication to terminate resuscitative efforts. However, the failure to achieve an $ETCO_2$ greater than 10 mmHg despite optimized resuscitation efforts may be a valuable component of a multimodal approach to deciding when to terminate resuscitation.

There are no studies that assess the prognostic value of $ETCO_2$ measurements sampled from an SGA or bag-mask airway in predicting outcomes from a cardiac arrest.

5.5.2 2015 Recommendations—New

In intubated patients, failure to achieve an ETCO2 of greater than 10 mm Hg by waveform capnography after 20 minutes of CPR may be considered as one component of a multimodal approach to decide when to end resuscitative efforts, but it should not be used in isolation. (Class IIb, LOE C-LD)

The above recommendation is made with respect to $ETCO_2$ in patients who are intubated, because the studies examined included only those who were intubated.

In nonintubated patients, a specific ETCO2 cutoff value at any time during CPR should not be used as an indication to end resuscitative efforts. (Class III: Harm, LOE C-EO)

5.6 Overview of Extracorporeal CPR - Updated ALS 723

The 2015 ILCOR systematic review compared the use of ECPR (or ECMO) techniques for adult patients with IHCA and OHCA to conventional (manual or mechanical) CPR, in regard to ROSC, survival, and good neurologic outcome. The recommendations in this update apply only to the use of ECPR in this context.

ECPR refers to venoarterial extracorporeal membrane oxygenation during cardiac arrest, including extracorporeal membrane oxygenation and cardiopulmonary bypass. These techniques require adequate vascular access and specialized equipment. The use of ECPR may allow providers additional time to treat reversible underlying causes of cardiac arrest (eg, acute coronary artery occlusion, pulmonary embolism, refractory VF, profound hypothermia, cardiac injury, myocarditis, cardiomyopathy, congestive heart failure, drug intoxication etc) or serve as a bridge for left ventricular assist device implantation or cardiac transplantation.

5.6.1 2015 Evidence Summary

All of the literature reviewed in the 2015 ILCOR systematic review comparing ECPR to conventional CPR was in the form of reviews, case reports, and observational studies. The low-quality evidence suggests a benefit in regard to survival and favorable neurologic outcome with the use of ECPR when compared with conventional CPR. There are currently no data from RCTs to support the use of ECPR for cardiac arrest in any setting.

One propensity-matched prospective observational study enrolling 172 patients with IHCA reported greater likelihood of ROSC and improved survival at hospital discharge, 30-day follow-up, and 1-year follow-up with the use of ECPR among patients who received more than 10 minutes of CPR. However, this study showed no difference in neurologic outcomes.[259]

A single retrospective, observational study enrolling 120 patients with witnessed IHCA who underwent more than 10 minutes of CPR reported a modest benefit over historic controls with the use of ECPR over continued

conventional CPR in both survival and neurologic outcome at discharge and 6-month follow-up.[260]

A single propensity-matched, retrospective, observational study enrolling 118 patients with IHCA who underwent more than 10 minutes of CPR and then ECPR after cardiac arrest of cardiac origin showed no survival or neurologic benefit over conventional CPR at the time of hospital discharge, 30-day follow-up, or 1-year follow-up.[261]

One post hoc analysis of data from a prospective, observational cohort of 162 patients with OHCA who did not achieve ROSC with more than 20 minutes of conventional CPR, including propensity score matching, showed that ECPR was associated with a higher rate of neurologically intact survival than continued conventional CPR at 3-month follow-up.[262]

A single prospective, observational study enrolling 454 patients with OHCA who were treated with ECPR if they did not achieve ROSC with more than 15 minutes of conventional CPR after hospital arrival demonstrated improved neurologic outcomes at 1-month and 6-month follow-up.[263]

The key articles reviewed in the 2015 ILCOR systematic review comparing ECPR to conventional CPR feature some variability in their inclusion and exclusion criteria (Table 2), which may affect the generalizability of their results and could explain some of the inconsistencies in outcomes between studies.

Table 2: 2015 - Inclusion and Exclusion Criteria for Key Extracorporeal CPR Articles

Open table in a new window

Inclusion and Exclusion Criteria for Key Extracorporeal CPR Articles

Study	CA Type	Inclusion Criteria	Exclusion Criteria
Chen, 2008[reference id="1291" range="" /]	IHCA	Witnessed CA of cardiac origin (elevated cardiac enzymes before CA, sudden collapse without obvious cause, or sudden collapse with pre-existing cardiovascular disease)	Age less than 18 years or greater than 75 years Known severe irreversible brain damage Terminal malignancy
		No ROSC during first 10 minutes of conventional CPR	Traumatic origin with uncontrolled bleeding Postcardiotomy shock with inability to be weaned from cardiopulmonary bypass

Study	CA Type	Inclusion Criteria	Exclusion Criteria
Shin, 2011[reference id="1292" range="" /]	IHCA	Witnessed CA of cardiac origin No ROSC during first 10 minutes of conventional CPR	Age less than 18 years or greater than 80 years No sustained (20 minutes or more) ROSC during first 10 minutes of conventional CPR Known severe neurologic damage Current intracranial hemorrhage Terminal malignancy Traumatic origin with uncontrolled bleeding Noncardiac origin* (submersion, drug overdose, asphyxia, exsanguination, sepsis) Irreversible organ failure (liver failure, late stage of adult respiratory distress syndrome, etc)
Lin, 2010[reference id="1293" range="" /]	IHCA	• Witnessed CA of cardiac origin • No ROSC during first 10 minutes of conventional CPR	Age less than 18 years or greater than 75 years Known severe irreversible brain damage Terminal malignancy Severe trauma Uncontrolled bleeding
Maekawa, 2013[reference id="1294" range="" /]	OHCA	Witnessed CA of presumed cardiac origin	Age less than 16 years Terminal malignancy
		No ROSC during first 20 minutes of conventional CPR	Poor level of activities of daily living before onset of CA Noncardiac origin (trauma, submersion, hypothermia, drug overdose, asphyxia, exsanguination, intracranial hemorrhage, acute aortic dissection)

Study	CA Type	Inclusion Criteria	Exclusion Criteria
Sakamoto, 2014[reference id="1295" range="" /]	OHCA	VF/pVT on initial ECG CA of presumed cardiac origin on hospital arrival with or without prehospital ROSC Arrival to hospital 45 minutes or less after reception of emergency call or onset of CA No ROSC (1 minute or more of continuing confirmation of pulsation) during first 15 minutes of conventional CPR in hospital	Age less than 20 years or 75 years or older Poor level of activities of daily living before onset of CA Noncardiac origin (trauma, drug intoxication, primary cerebral disorders, acute aortic dissection, terminal malignancy) Core body temperature less than 30°C

CA indicates cardiac arrest; CPR, cardiopulmonary resuscitation; ECG, electrocardiogram; IHCA, in-hospital cardiac arrest; OHCA, out-of-hospital cardiac arrest; pVT, pulseless ventricular tachycardia; ROSC, return of spontaneous circulation; and VF, ventricular fibrillation.*Postcardiotomy bleeding considered to be of cardiac origin.

5.6.2 2015 Recommendation—New

There is insufficient evidence to recommend the routine use of ECPR for patients with cardiac arrest. In settings where it can be rapidly implemented, ECPR may be considered for select cardiac arrest patients for whom the suspected etiology of the cardiac arrest is potentially reversible during a limited period of mechanical cardiorespiratory support. (Class IIb, LOE C-LD)

5.7 Interventions Not Recommended for Routine Use During Cardiac Arrest

5.7.1 Atropine

Atropine sulfate reverses cholinergic-mediated decreases in heart rate and atrioventricular nodal conduction. No prospective controlled clinical trials have examined the use of atropine in asystole or bradycardic PEA cardiac arrest. Lower-level clinical studies provide conflicting evidence of the benefit of routine use of atropine in cardiac arrest.[79,264-273] There is no evidence that atropine has detrimental effects during bradycardic or asystolic cardiac arrest.

Available evidence suggests that routine use of atropine during PEA or asystole is unlikely to have a therapeutic benefit. (Class IIb, LOE B)

5.7.2 Sodium Bicarbonate

Tissue acidosis and resulting acidemia during cardiac arrest and resuscitation are dynamic processes resulting from no blood flow during arrest and low blood flow during CPR. These processes are affected by the duration of cardiac arrest, level of blood flow, and arterial oxygen content during CPR. Restoration of oxygen content with appropriate ventilation with oxygen, support of some tissue perfusion and some cardiac output with high-quality chest compressions, then rapid ROSC are the mainstays of restoring acid-base balance during cardiac arrest.

Two studies demonstrated [274,275] increased ROSC, hospital admission, and survival to hospital discharge associated with use of bicarbonate. However, the majority of studies showed no benefit [276-278] or found a relationship with poor outcome.[273,279-281]

There are few data to support therapy with buffers during cardiac arrest. There is no evidence that bicarbonate improves the likelihood of defibrillation or survival rates in animals with VF cardiac arrest. A wide variety of adverse effects have been linked to administration of bicarbonate during cardiac arrest. Bicarbonate may compromise CPP by reducing systemic vascular resistance.[282] It can create extracellular alkalosis that will shift the oxyhemoglobin saturation curve and inhibit oxygen release. It can produce hypernatremia and therefore hyperosmolarity. It produces excess CO

$_2$, which freely diffuses into myocardial and cerebral cells and may paradoxically contribute to intracellular acidosis.[283] It can exacerbate central venous acidosis and may inactivate simultaneously administered catecholamines.

In some special resuscitation situations, such as preexisting metabolic acidosis, hyperkalemia, or tricyclic antidepressant overdose, bicarbonate can be beneficial (see Part 10: Special Circumstances of Resuscitation).

However, routine use of sodium bicarbonate is not recommended for patients in cardiac arrest. (Class III, LOE B)

When bicarbonate is used for special situations, an initial dose of 1 mEq/kg is typical. Whenever possible, bicarbonate therapy should be guided by the bicarbonate concentration or calculated base deficit obtained from blood gas analysis or laboratory measurement. To minimize the risk of iatrogenically induced alkalosis, providers should not attempt complete correction of the calculated base deficit. Other non–CO_2-generating buffers such as carbicarb, THAM, or tribonate have shown potential for minimizing some adverse effects of sodium bicarbonate, including CO_2 generation, hyperosmolarity, hypernatremia, hypoglycemia, intracellular acidosis, myocardial acidosis, and “overshoot” alkalosis.[284-286] But clinical experience is greatly limited and outcome studies are lacking.

5.7.3 Calcium

Studies of calcium during cardiac arrest have found variable results on ROSC, and no trial has found a beneficial effect on survival either in or out of hospital.[270,273,287-292]

Routine administration of calcium for treatment of in-hospital and out-of-hospital cardiac arrest is not recommended. (Class III, LOE B)

5.7.4 Fibrinolysis

Fibrinolytic therapy was proposed for use during cardiac arrest to treat both coronary thrombosis (acute coronary syndrome) with presumably complete occlusion of a proximal coronary artery and major life-threatening pulmonary embolism. Ongoing CPR is not an absolute contraindication to fibrinolysis. Initial studies were promising [293-299] and suggested benefit from fibrinolytic therapy in the treatment of victims of cardiopulmonary arrest unresponsive to standard therapy. But 2 large clinical trials [180,300] failed to show any improvement in outcome with fibrinolytic therapy during CPR. One of these showed an increased risk of intracranial bleeding associated with the routine use of fibrinolytics during cardiac arrest.[180]

Fibrinolytic therapy should not be routinely used in cardiac arrest. (Class III, LOE B)

5.7.5 IV Fluids

No published human study directly compares the outcome of routine IV fluid administration to no fluid administration during CPR. Most human and animal studies of fluid infusion during CPR did not have a control group,[301-312] and 2 animal studies showed that normothermic fluid infusion during CPR caused a decrease in CPP.[313-315] In addition to normothermic fluid, hypertonic and chilled fluids have been studied in animal and small human studies without a survival benefit.[301,303,305-307,310-312] If cardiac arrest is associated with extreme volume losses, hypovolemic arrest should be suspected. These patients present with signs of circulatory shock advancing to PEA. In these settings intravascular volume should be promptly restored.

5.8 Pacing

Electric pacing is generally not effective in cardiac arrest, and no studies have observed a survival benefit from pacing in cardiac arrest.[316-319] Existing evidence suggests that pacing by transcutaneous, transvenous, or transmyocardial means in cardiac arrest does not improve the likelihood of ROSC or survival outcome regardless of the timing of pacing administration (early or delayed in established asystole), location of arrest (in-hospital or out-of-hospital), or primary cardiac rhythm (asystole, PEA) targeted for treatment.

Electric pacing is not recommended for routine use in cardiac arrest. (Class III, LOE B)

5.9 Precordial Thump

The potential utility of precordial thump in cardiac arrest has not been well studied. When hemodynamically unstable ventricular tachyarrhythmias were induced during electrophysiological testing, initial administration of a precordial thump appeared to be safe but rarely effective in terminating ventricular arrhythmias.[320] In a prospective observational study of patients with out-of-hospital cardiac arrest, precordial thump was associated with ROSC when administered promptly to patients with responder-witnessed asystolic arrest. When administered for VF/VT or PEA arrest it was ineffective but resulted in no apparent harm.[321] In 3 case series[322-324] VF or pulseless VT was converted to a perfusing rhythm by a precordial thump. Conversely, other case series documented deterioration in cardiac rhythm, such as rate acceleration of VT, conversion of VT to VF, or development of complete AV block or asystole following the thump.[323,325-330]

The precordial thump may be considered for termination of witnessed monitored unstable ventricular tachyarrhythmias when a defibrillator is not immediately ready for use(Class IIb, LOE B), but should not delay CPR and shock delivery.

There is insufficient evidence to recommend for or against the use of the precordial thump for witnessed onset of asystole, and there is insufficient evidence to recommend percussion pacing during typical attempted resuscitation from cardiac arrest.

5.10 When Should Resuscitative Efforts Stop?

The final decision to stop can never rest on a single parameter, such as duration of resuscitative efforts. Rather, clinical judgment and respect for human dignity must enter into decision making. In the out-of-hospital setting, cessation of resuscitative efforts in adults should follow system-specific criteria under direct medical control. There are limited clinical data to guide this decision in neonatal and pediatric out-of-hospital or in-hospital cardiac arrest. A more detailed discussion is provided in Part 3: Ethical Issues.

5.11 Summary

Intervention to prevent cardiac arrest in critically ill patients is ideal. When cardiac arrest occurs, high-quality CPR is fundamental to the success of any subsequent ACLS intervention. During resuscitation healthcare providers must perform chest compressions of adequate rate and depth, allow complete recoil of the chest after each compression, minimize interruptions in chest compressions, and avoid excessive ventilation, especially with an advanced airway. Quality of CPR should be continuously monitored. Physiologic monitoring may prove useful to optimize resuscitative efforts. For patients in VF/pulseless VT, shocks should be delivered promptly with minimal interruptions in chest compressions. The increased rates of ROSC associated with ACLS drug therapy have yet to be translated into long-term survival benefits. However, improved quality of CPR, advances in post–cardiac arrest care, and improved overall implementation through comprehensive systems of care may provide a pathway to optimize the outcomes of cardiac arrest patients treated with ACLS interventions.

6 Management of Symptomatic Bradycardia and Tachycardia

6.1 Overview

This section highlights recommendations for management of patients with acute symptomatic arrhythmias. Electrocardiographic (ECG) and rhythm information should be interpreted within the context of total patient assessment. Errors in diagnosis and treatment are likely to occur if advanced cardiovascular life support (ACLS) providers base treatment decisions solely on rhythm interpretation and neglect clinical evaluation. Providers must evaluate the patient's symptoms and clinical signs, including ventilation, oxygenation, heart rate, blood pressure, level of consciousness, and signs of inadequate organ perfusion.

Unstable and *symptomatic* are terms typically used to describe the condition of patients with arrhythmias. Generally, *unstable* refers to a condition in which vital organ function is acutely impaired or cardiac arrest is ongoing or imminent. When an arrhythmia causes a patient to be unstable, immediate intervention is indicated. *Symptomatic* implies that an arrhythmia is causing symptoms, such as palpitations, lightheadedness, or dyspnea, but the patient is stable and not in imminent danger. In such cases more time is available to decide on the most appropriate intervention. In both unstable and symptomatic cases the provider must make an

assessment as to whether it is the arrhythmia that is causing the patient to be unstable or symptomatic. For example, a patient in septic shock with sinus tachycardia of 140 beats per minute is unstable; however, the arrhythmia is a physiologic compensation rather than the cause of instability. Therefore, electric cardioversion will not improve this patient's condition. Additionally, if a patient with respiratory failure and severe hypoxemia becomes hypotensive and develops a bradycardia, the bradycardia is not the primary cause of instability. Treating the bradycardia without treating the hypoxemia is unlikely to improve the patient's condition. It is critically important to determine the cause of the patient's instability in order to properly direct treatment. In general, sinus tachycardia is a response to other factors and, thus, it rarely (if ever) is the cause of instability in and of itself.

The *2010 AHA Guidlines for CPR and ECC* emphasize the importance of clinical evaluation and highlight principles of therapy with algorithms that have been refined and streamlined since publication of the *2005 AHA Guidelines for CPR and ECC*.[331] The key principles of arrhythmia recognition and management in adults are as follows:

If bradycardia produces signs and symptoms of instability (eg, acutely altered mental status, ischemic chest discomfort, acute heart failure, hypotension, or other signs of shock that persist despite adequate airway and breathing), the initial treatment is atropine. (Class IIa, LOE B)

If bradycardia is unresponsive to atropine, intravenous (IV) infusion of ?-adrenergic agonists with rate-accelerating effects (dopamine, epinephrine) or transcutaneous pacing (TCP) can be effective(Class IIa, LOE B) while the patient is prepared for emergent transvenous temporary pacing if required.

If the tachycardic patient is unstable with severe signs and symptoms related to a suspected arrhythmia (eg, acute altered mental status, ischemic chest discomfort, acute heart failure, hypotension, or other signs of shock), immediate cardioversion should be performed (with prior sedation in the conscious patient). (Class I, LOE B)

In select cases of regular narrow-complex tachycardia with unstable signs or symptoms, a trial of adenosine before cardioversion is reasonable to consider. (Class IIb, LOE C)

If the patient with tachycardia is stable, determine if the patient has a narrow-complex or wide-complex tachycardia, whether the rhythm is regular or irregular, and for wide complexes whether the QRS morphology is monomorphic or polymorphic. Therapy is then tailored accordingly (Table 3).

Table 3: 2010 - IV Drugs Used for Tachycardia

Open table in a new window

IV Drugs Used for Tachycardia					
Drug	**Characteristics**	**Indication(s)**	**Dosing**	**Side Effects**	**Precautions or Special Considerations**
Intravenous Drugs Used to Treat Supraventricular Tachyarrhythmias					

Drug	Characteristics	Indication(s)	Dosing	Side Effects	Precautions or Special Considerations
Adenosine	Endogenous purine nucleoside; briefly depresses sinus node rate and AV node conduction; vasodilator	• Stable, narrow-complex regular tachycardias • Unstable narrow-complex regular tachycardias while preparations are made for electrical cardioversio • Stable, regular, monomorphi wide complex tachycardia as a therapeutic and diagnostic maneuver	6 mg IV as a rapid IV push followed by a 20 mL saline flush; repeat if required as 12 mg IV push	Hypotension, bronchospasm, chest discomfort	Contraindicated in patients with asthma; may precipitate atrial fibrillation, which may be very rapid in patients with WPW; thus a defibrillator should be readily available; reduce dose in post–cardiac transplant patients, those taking dipyridamole or carbamazepine and when administered via a central vein

Drug	Characteristics	Indication(s)	Dosing	Side Effects	Precautions or Special Considerations
Diltiazem, Verapamil	Non-dihydropyridine calcium channel blockers; slow AV node conduction and increase AV node refractoriness; vasodilators, negative inotropes	• Stable, narrow-complex tachycardias if rhythm remains uncontrolled or unconverted by adenosine or vagal maneuvers or if SVT is recurrent • Control ventricular rate in patients with atrial fibrillation or atrial flutter	Diltiazem: Initial dose 15 to 20 mg (0.25 mg/kg) IV over 2 minutes; additional 20 to 25 mg (0.35 mg/kg) IV in 15 minutes if needed; 5 to 15 mg/h IV maintenance infusion (titrated to AF heart rate if given for rate control) Verapamil: Initial dose 2.5 to 5 mg IV given over 2 minutes; may repeat as 5 to 10 mg every 15 to 30 minutes to total dose of 20 to 30 mg	Hypotension, bradycardia, precipitation of heart failure	Should only be given to patients with narrow-complex tachycardias (regular or irregular). Avoid in patients with heart failure and pre-excited AF or flutter or rhythms consistent with VT

Drug	Characteristics	Indication(s)	Dosing	Side Effects	Precautions or Special Considerations
Atenolol, Esmolol, Metoprolol, Propranolol	?-Blockers; reduce effects of circulating catecholamines; reduce heart rate, AV node conduction and blood pressure; negative inotropes	• Stable, narrow-complex tachycardias if rhythm remains uncontrolled or unconverted by adenosine or vagal maneuvers or if SVT is recurrent • Control ventricular rate in patients with atrial fibrillation or atrial flutter • Certain forms of polymorphic VT (associated with acute ischemia, familial LQTS, catecholami	Atenolol (?1 specific blocker) 5 mg IV over 5 minutes; repeat 5 mg in 10 minutes if arrhythmia persists or recurs Esmolol (?1 specific blocker with 2- to 9-minute half-life) IV loading dose 500 mcg/kg (0.5 mg/kg) over 1 minute, followed by an infusion of 50 mcg/kg per minute (0.05 mg/kg per minute); if response is inadequate, infuse second loading bolus of 0.5 mg/kg over 1 minute and increase maintenance infusion to 100 mcg/kg (0.1 mg/kg) per minute; increment; increase in this manner if required to maximum infusion rate of 300 mcg/kg [0.3 mg/kg] per minute Metoprolol (?1 specific blocker) 5 mg over 1 to 2 minutes repeated as required every 5 minutes to maximum dose of 15 mg Propranolol (nonselective ?-blocker) 0.5 to 1 mg over 1 minute, repeated up to a total dose of 0.1 mg/kg if required	Hypotension, bradycardia, precipitation of heart failure	Avoid in patients with asthma, obstructive airway disease, decompensated heart failure and pre-excited artrial fibrillation or flutter

Drug	Characteristics	Indication(s)	Dosing	Side Effects	Precautions or Special Considerations
Procainamide	Sodium and potassium channel blocker	• Pre-excited atrial fibrillation	20 to 50 mg/min until arrhythmia suppressed, hypotension ensues, or QRS prolonged by 50%, or total cumulative dose of 17 mg/kg; or 100 mg every 5 minutes until arrhythmia is controlled or other conditions described above are met	Bradycardia, hypotension, torsades de pointes	Avoid in patients with QT prolongation and CHF
Amiodarone	Multichannel blocker (sodium, potassium, calcium channel, and noncompetitive ?/?-blocker)	• Stable irregular narrow complex tachycardia (atrial fibrillation) • Stable regular narrow-complex tachycardia • To control rapid ventricular rate due to accessory pathway conduction in pre-excited atrial arrhythmias	150 mg given over 10 minutes and repeated if necessary, followed by a 1 mg/min infusion for 6 hours, followed by 0.5 mg/min. Total dose over 24 hours should not exceed 2.2 g.	Bradycardia, hypotension, phlebitis	

Drug	Characteristics	Indication(s)	Dosing	Side Effects	Precautions or Special Considerations
Digoxin	Cardiac glycoside with positive inotropic effects; slows AV node conduction by enhancing parasympathetic tone; slow onset of action	• Stable, narrow-complex regular tachycardias if rhythm remains uncontrolled or unconverted by adenosine or vagal maneuvers or if SVT is recurrent • Control ventricular rate in patients with atrial fibrillation or atrial flutter	8 to 12 mcg/kg total loading dose, half of which is administered initially over 5 minutes, and remaining portion as 25% fractions at 4- to 8- hour intervals	Bradycardia	Slow onset of action and relative low potency renders it less useful for treatment of acute arrhythmias
Intravenous Drugs Used to Treat Ventricular Tachyarrhythmias					
Procainamide	Sodium and potassium channel blocker	• Hemodynamically stable monomorphic VT	20 to 50 mg/min until arrhythmia suppressed, hypotension ensues, or QRS prolonged by 50%, or total cumulative dose of 17 mg/kg; or 100 mg every 5 minutes until arrhythmia is controlled or other conditions described above are met	Bradycardia, hypotension, torsades de pointes	Avoid in patients with QT prolongation and CHF

Drug	Characteristics	Indication(s)	Dosing	Side Effects	Precautions or Special Considerations
Amiodarone	Multichannel blocker (sodium, potassium, calcium channel, ?- and noncompetitive ?-blocker)	• Hemodynam stable monomorphi VT • Polymorphic VT with normal QT interval	150 mg given over 10 minutes and repeated if necessary, followed by a 1 mg/min infusion for 6 hours, followed by 0.5 mg/min. Total dose over 24 hours should not exceed 2.2 g.	Bradycardia, hypotension, phlebitis	
Sotalol	Potassium channel blocker and nonselective ?-blocker	• Hemodynamically stable monomorphic VT	In clinical studies 1.5 mg/kg infused over 5 minutes; however, US package labeling recommends any dose of the drug should be infused slowly over a period of 5 hours	Bradycardia, hypotension, torsades de pointes	Avoid in patients with QT prolongation and CHF
Lidocaine	Relatively weak sodium channel blocker	• Hemodynam stable monomorphi VT	Initial dose range from 1 to 1.5 mg/kg IV; repeated if required at 0.5 to 0.75 mg/kg IV every 5 to 10 minutes up to maximum cumulative dose of 3 mg/kg; 1 to 4 mg/min (30 to 50 mcg/kg per minute) maintenance infusion	Slurred speech, altered consciousness, seizures, bradycardia	

Drug	Characteristics	Indication(s)	Dosing	Side Effects	Precautions or Special Considerations
Magnesium	Cofactor in variety of cell processes including control of sodium and potassium transport	• Polymorphic VT associated with QT prolongation (torsades de pointes)	1 to 2 g IV over 15 minutes	Hypotension, CNS toxicity, respiratory depression	Follow magnesium levels if frequent or prolonged dosing required, particularly in patients with impaired renal function

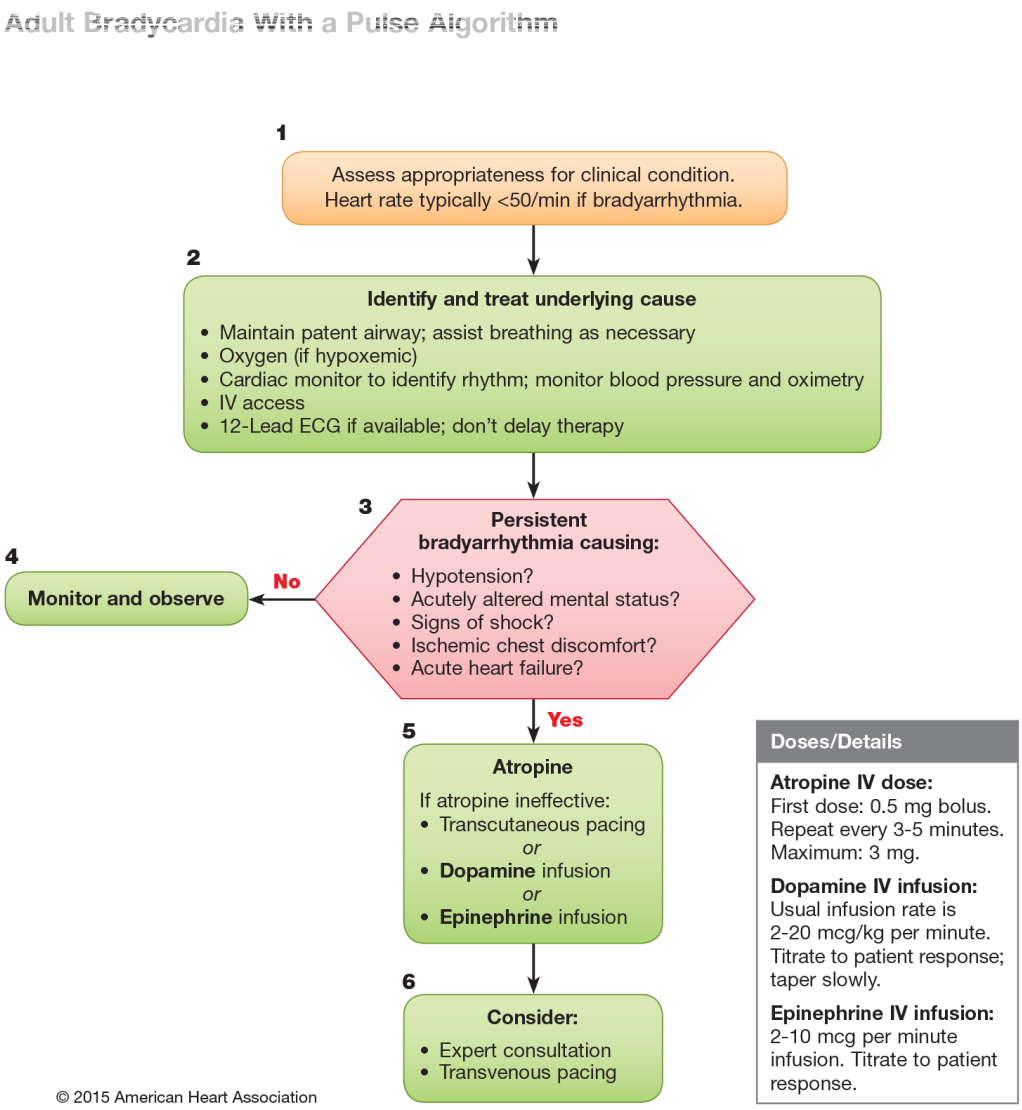
Know when to call for expert consultation regarding complicated rhythm interpretation, drugs, or management decisions.

A comprehensive presentation of the evaluation and management of bradyarrhythmias and tachyarrhythmias is beyond the scope of this document. The following selected rhythm scenarios are meant to aid with the management of periarrest rhythm disorders. If cardiac arrest develops at any time, see the ACLS Cardiac Arrest Algorithms above (Figure 1,Figure 2).

6.1.1 Bradycardia

This section summarizes the management of bradyarrhythmias. Following the overview of bradyarrhythmias and summary of the initial evaluation and treatment of bradycardia, drugs used in the treatment of bradycardia are presented. See the Bradycardia Algorithm, Figure 3. Box numbers in the text refer to the numbered boxes in the algorithm.

Figure 3: Adult Bradycardia With a Pulse Algorithm



6.1.1.1 Evaluation

Bradycardia is defined as a heart rate of <60 beats per minute. However, when bradycardia is the cause of symptoms, the rate is generally <50 beats per minute, which is the working definition of bradycardia used here (Figure 3: Bradycardia Algorithm, Box 1). A slow heart rate may be physiologically normal for some patients, whereas a heart rate of >50 beats per minut1e may be inadequate for others. The Bradycardia Algorithm focuses on management of clinically significant bradycardia (ie, bradycardia that is inappropriate for the clinical condition).

Because hypoxemia is a common cause of bradycardia, initial evaluation of any patient with bradycardia should focus on signs of increased work of breathing (tachypnea, intercostal retractions, suprasternal retractions, paradoxical abdominal breathing) and oxyhemoglobin saturation as determined by pulse oximetry (**Box 2**). If oxygenation is inadequate or the patient shows signs of increased work of breathing, provide supplementary oxygen. Attach a monitor to the patient, evaluate blood pressure, and establish IV access. If possible, obtain a 12-lead ECG to better define the rhythm. While initiating treatment, evaluate the patient's clinical status and identify potentially reversible causes.

The provider must identify signs and symptoms of poor perfusion and determine if those signs are likely to be caused by the bradycardia (**Box 3**). If the signs and symptoms are not due to bradycardia, the provider should reassess the underlying cause of the patient's symptoms. Remember that signs and symptoms of bradycardia may be mild; asymptomatic or minimally symptomatic patients do not necessarily require treatment (**Box 4**) unless there is suspicion that the rhythm is likely to progress to symptoms or become life-threatening (eg,

Mobitz type II second-degree AV block in the setting of acute myocardial infarction [AMI]). If the bradycardia is suspected to be the cause of acute altered mental status, ischemic chest discomfort, acute heart failure, hypotension, or other signs of shock, the patient should receive immediate treatment.

Atrioventricular (AV) blocks are classified as first-, second-, and third-degree. Blocks may be caused by medications or electrolyte disturbances, as well as structural problems resulting from AMI or other myocardial diseases. A first-degree AV block is defined by a prolonged PR interval (>0.20 second) and is generally benign. Second-degree AV block is divided into Mobitz types I and II. In Mobitz type I block, the block is at the AV node; the block is often transient and asymptomatic. In Mobitz type II block, the block is usually below the AV node within the His-Purkinje system; this block is often symptomatic, with the potential to progress to complete (third-degree) AV block. Third-degree AV block may occur at the AV node, bundle of His, or bundle branches. When third-degree AV block is present, no impulses pass between the atria and ventricles. Third-degree AV block can be permanent or transient, depending on the underlying cause.

6.1.1.2 Therapy (Figure 3 Box 5)

6.1.1.2.1 Atropine

Atropine remains the first-line drug for acute symptomatic bradycardia. (Class IIa, LOE B)

Clinical trials in adults[332-336] showed that IV atropine improved heart rate, symptoms, and signs associated with bradycardia. Atropine sulfate reverses cholinergic-mediated decreases in heart rate and should be considered a temporizing measure while awaiting a transcutaneous or transvenous pacemaker for patients with symptomatic sinus bradycardia, conduction block at the level of the AV node, or sinus arrest.[336]

The recommended atropine dose for bradycardia is 0.5 mg IV every 3 to 5 minutes to a maximum total dose of 3 mg. Doses of atropine sulfate of <0.5 mg may paradoxically result in further slowing of the heart rate.[337] Atropine administration should not delay implementation of external pacing for patients with poor perfusion.

Use atropine cautiously in the presence of acute coronary ischemia or MI; increased heart rate may worsen ischemia or increase infarction size. Atropine will likely be ineffective in patients who have undergone cardiac transplantation because the transplanted heart lacks vagal innervation. One small uncontrolled study documented paradoxical slowing of the heart rate and high-degree AV block when atropine was administered to patients after cardiac transplantation.[338]

Avoid relying on atropine in type II second-degree or third-degree AV block or in patients with third-degree AV block with a new wide-QRS complex where the location of block is likely to be in non-nodal tissue (such as in the bundle of His or more distal conduction system). These bradyarrhythmias are not likely to be responsive to reversal of cholinergic effects by atropine and are preferably treated with TCP or ?-adrenergic support as temporizing measures while the patient is prepared for transvenous pacing (Figure 3, **Box 6**).

6.1.1.2.2 Pacing

TCP may be useful for the treatment of symptomatic bradycardias. There are limited studies comparing TCP with drug therapy for the treatment of symptomatic bradycardia. A randomized controlled trial in which atropine and glycopyrrolate were compared with TCP showed few differences in outcome and survival, although the TCP group obtained a more consistent heart rate.[332] In a study evaluating the feasibility of treatment with dopamine as compared with TCP, no differences were observed between treatment groups in survival to hospital discharge.[339] TCP is, at best, a temporizing measure. TCP is painful in conscious patients, and, whether effective or not (achieving inconsistent capture), the patient should be prepared for transvenous pacing and expert consultation should be obtained.

It is reasonable for healthcare providers to initiate TCP in unstable patients who do not respond to atropine. (Class IIa, LOE B)

Immediate pacing might be considered in unstable patients with high-degree AV block when IV access is

not available. (Class IIb, LOE C)

If the patient does not respond to drugs or TCP, transvenous pacing is probably indicated (Figure 3, Box 6). (Class IIa, LOE C)

6.1.1.2.3 Alternative Drugs to Consider

Although not first-line agents for treatment of symptomatic bradycardia, dopamine, epinephrine, and isoproterenol are alternatives when a bradyarrhythmia is unresponsive to or inappropriate for treatment with atropine, or as a temporizing measure while awaiting the availability of a pacemaker. Alternative drugs may also be appropriate in special circumstances such as the overdose of a ?-blocker or calcium channel blocker.

6.1.1.2.3.1 Dopamine

Dopamine hydrochloride is a catecholamine with both ?- and ?-adrenergic actions. It can be titrated to more selectively target heart rate or vasoconstriction. At lower doses dopamine has a more selective effect on inotropy and heart rate; at higher doses (>10 mcg/kg per minute), it also has vasoconstrictive effects.

Dopamine infusion may be used for patients with symptomatic bradycardia, particularly if associated with hypotension, in whom atropine may be inappropriate or after atropine fails. (Class IIb, LOE B)

Begin dopamine infusion at 2 to 10 mcg/kg per minute and titrate to patient response.[339] Use of vasoconstrictors requires that the recipient be assessed for adequate intravascular volume and volume status supported as needed.

6.1.1.2.3.2 Epinephrine

Epinephrine is a catecholamine with ?- and ?-adrenergic actions.

Epinephrine infusion may be used for patients with symptomatic bradycardia, particularly if associated with hypotension, for whom atropine may be inappropriate or after atropine fails. (Class IIb, LOE B)

Begin the infusion at 2 to 10 mcg/min and titrate to patient response. Use of vasoconstrictors requires that the recipient be assessed for adequate intravascular volume and volume status supported as needed.

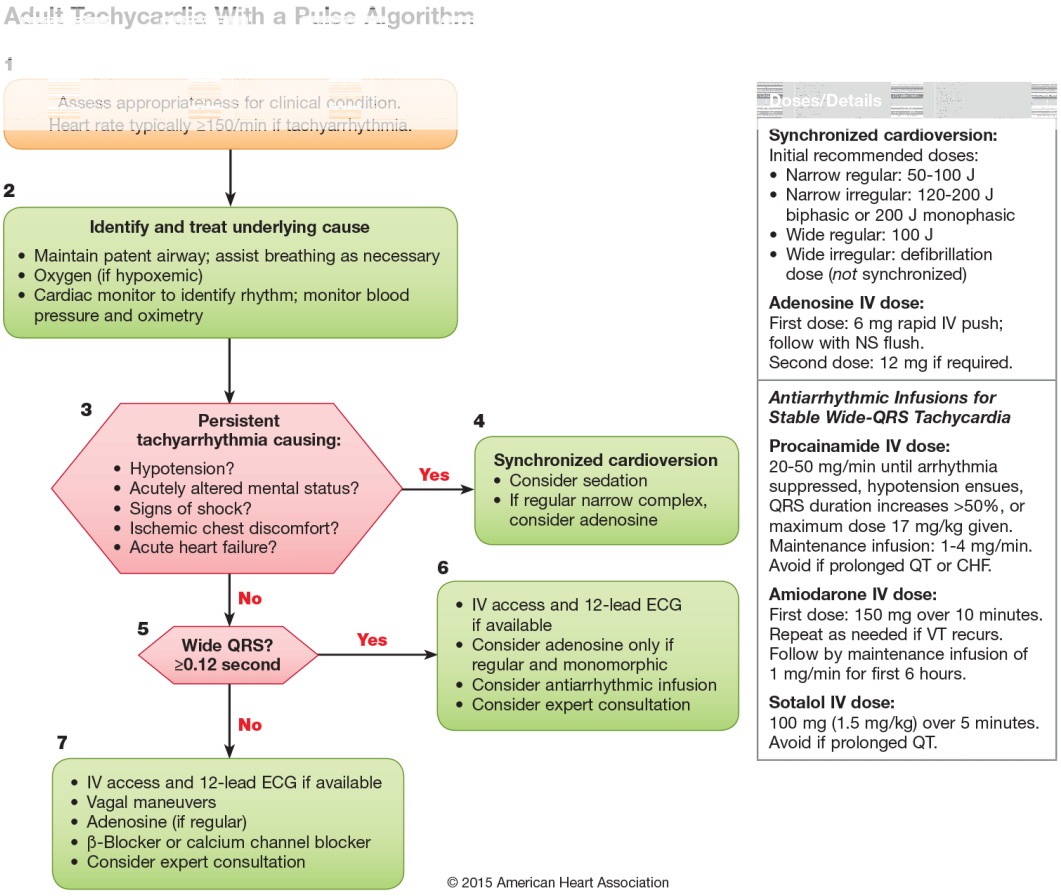
6.1.1.2.3.3 Isoproterenol

Isoproterenol is a ?-adrenergic agent with ?-1 and ?-2 effects, resulting in an increase in heart rate and vasodilation. The recommended adult dose is 2 to 10 mcg/min by IV infusion, titrated according to heart rate and rhythm response.

6.2 Tachycardia

This section summarizes the management of a wide variety of tachyarrhythmias. Following the overview of tachyarrhythmias and summary of the initial evaluation and treatment of tachycardia, common antiarrhythmic drugs used in the treatment of tachycardia are presented. See the Tachycardia Algorithm, Figure 4. Box numbers in the text refer to the numbered boxes in the algorithm.

Figure 4: Adult Tachycardia With a Pulse Algorithm



6.2.1 Classification of Tachyarrhythmias

Tachycardias can be classified in several ways, based on the appearance of the QRS complex, heart rate, and regularity. ACLS professionals should be able to recognize and differentiate between sinus tachycardia, narrow-complex supraventricular tachycardia (SVT), and wide-complex tachycardia. Because ACLS providers may be unable to distinguish between supraventricular and ventricular rhythms, they should be aware that most wide-complex (broad-complex) tachycardias are *ventricular* in origin.

Narrow–QRS-complex (SVT) tachycardias (QRS <0.12 second), in order of frequency

Sinus tachycardia

Atrial fibrillation

Atrial flutter

AV nodal reentry

Accessory pathway–mediated tachycardia

Atrial tachycardia (including automatic and reentry forms)

Multifocal atrial tachycardia (MAT)

Junctional tachycardia (rare in adults)

Wide–QRS-complex tachycardias (QRS ?0.12 second)

Ventricular tachycardia (VT) and ventricular fibrillation (VF)

SVT with aberrancy

Pre-excited tachycardias (Wolff-Parkinson-White [WPW] syndrome)

Ventricular paced rhythms

Irregular narrow-complex tachycardias are likely atrial fibrillation or MAT; occasionally atrial flutter is irregular. The management of atrial fibrillation and flutter is discussed in the section “Irregular Tachycardias” below.

6.2.2 Initial Evaluation and Treatment of Tachyarrhythmias

Tachycardia is defined as an arrhythmia with a rate of >100 beats per minute, although, as with defining bradycardia, the rate of a tachycardia takes on clinical significance at its greater extremes and is more likely attributable to an arrhythmia rate of ?150 beats per minute (Figure 4: Tachycardia Algorithm, **Box 1**). A rapid heart rate is an appropriate response to a physiologic stress (eg, fever, dehydration) or other underlying conditions. When encountering patients with tachycardia, efforts should be made to determine whether the tachycardia is the primary cause of the presenting symptoms or secondary to an underlying condition that is causing both the presenting symptoms and the faster heart rate. Many experts suggest that when a heart rate is <150 beats per minute, it is unlikely that symptoms of instability are caused primarily by the tachycardia unless there is impaired ventricular function.

The evaluation and management of tachyarrhythmias is depicted in the ACLS Tachycardia With Pulse Algorithm (Figure 4: Tachycardia Algorithm). Box numbers in the text refer to numbered boxes in this algorithm. If cardiac arrest develops at any time, see the ACLS Cardiac Arrest Algorithms in this document above under 4.1: “Management of Cardiac Arrest.”

Because hypoxemia is a common cause of tachycardia, initial evaluation of any patient with tachycardia should focus on signs of increased work of breathing (tachypnea, intercostal retractions, suprasternal retractions, paradoxical abdominal breathing) and oxyhemoglobin saturation as determined by pulse oximetry (**Box 2**). If oxygenation is inadequate or the patient shows signs of increased work of breathing, provide supplementary oxygen. Attach a monitor to the patient, evaluate blood pressure, and establish IV access. If available, obtain a 12-lead ECG to better define the rhythm, but this should not delay immediate cardioversion if the patient is unstable. While initiating treatment, evaluate the patient’s clinical status and identify potential reversible causes of the tachycardia.

If signs and symptoms persist despite provision of supplementary oxygen and support of airway and ventilation, the provider should assess the patient’s degree of instability and determine if the instability is related to the tachycardia (**Box 3**). If the patient demonstrates rate-related cardiovascular compromise with signs and symptoms such as acute altered mental status, ischemic chest discomfort, acute heart failure, hypotension, or other signs of shock suspected to be due to a tachyarrhythmia, proceed to immediate synchronized cardioversion (**Box 4**). However, with ventricular rates <150 beats per minute in the absence of ventricular dysfunction, it is more likely that the tachycardia is secondary to the underlying condition rather than the cause of the instability.

If not hypotensive, the patient with a regular narrow-complex SVT (likely due to suspected reentry, paroxysmal supraventricular tachycardia, as described below) may be treated with adenosine while preparations are made for synchronized cardioversion. (Class IIb, LOE C)

If the patient with tachycardia is stable (ie, no serious signs related to the tachycardia), the provider has time to obtain a 12-lead ECG, evaluate the rhythm, determine if the width of the QRS complex is ?0.12 second (**Box 5**), and determine treatment options. Stable patients may await expert consultation because treatment has the potential for harm.

6.2.3 Cardioversion

If possible, establish IV access before cardioversion and administer sedation if the patient is conscious. Do not delay cardioversion if the patient is extremely unstable.

6.2.3.1 Synchronized Cardioversion and Unsynchronized Shocks

Refer to Figure 4: Tachycardia Algorithm – **Box 4**.

Synchronized cardioversion is shock delivery that is timed (synchronized) with the QRS complex. This synchronization avoids shock delivery during the relative refractory period of the cardiac cycle when a shock could produce VF.[340] If cardioversion is needed and it is impossible to synchronize a shock, use high-energy unsynchronized shocks (defibrillation doses).

Synchronized cardioversion is recommended to treat (1) unstable SVT, (2) unstable atrial fibrillation, (3) unstable atrial flutter, and (4) unstable monomorphic (regular) VT. Shock can terminate these tachyarrhythmias by interrupting the underlying reentrant pathway that is responsible for them.

6.2.3.2 Waveform and Energy

The recommended initial biphasic energy dose for cardioversion of atrial fibrillation is 120 to 200 J.[341-345] (Class IIa, LOE A)

If the initial shock fails, providers should increase the dose in a stepwise fashion.

Cardioversion of atrial flutter and other SVTs generally requires less energy; an initial energy of 50 J to 100 J is often sufficient.[345] If the initial 50-J shock fails, the provider should increase the dose in a stepwise fashion.[346]

Cardioversion of atrial fabrillation with monophasic waveforms should begin at 200 J and increase in stepwise fashion if not successful.[341-343] (Class IIa, LOE B)

Monomorphic VT (regular form and rate) with a pulse responds well to monophasic or biphasic waveform cardioversion (synchronized) shocks at initial energies of 100 J.

If there is no response to the first shock, it may be reasonable to increase the dose in a stepwise fashion. No studies were identified that addressed this issue. Thus, this recommendation represents expert opinion. (Class IIb, LOE C)

Arrhythmias with a polymorphic QRS appearance (such as torsades de pointes) will usually not permit synchronization. Thus, if a patient has polymorphic VT, treat the rhythm as VF and deliver high-energy *unsynchronized* shocks (ie, defibrillation doses). If there is any doubt whether monomorphic or polymorphic VT is present in the *unstable* patient, do not delay shock delivery to perform detailed rhythm analysis: provide high-energy unsynchronized shocks (ie, defibrillation doses). Use the ACLS Cardiac Arrest Algorithms in this document above under 4.1: “Management of Cardiac Arrest.”

6.2.4 Regular Narrow-Complex Tachycardia

6.2.4.1 Sinus Tachycardia

Sinus tachycardia is common and usually results from a physiologic stimulus, such as fever, anemia, or hypotension/shock. Sinus tachycardia is defined as a heart rate >100 beats per minute. The upper rate of sinus tachycardia is age-related (calculated as approximately 220 beats per minute, minus the patient’s age in years) and may be useful in judging whether an apparent sinus tachycardia falls within the expected range for a patient’s age. If judged to be sinus tachycardia, no specific drug treatment is required. Instead, therapy is directed toward identification and treatment of the underlying cause. When cardiac function is poor, cardiac output can be dependent on a rapid heart rate. In such compensatory tachycardias, stroke volume is limited, so “normalizing” the heart rate can be detrimental.

6.2.4.2 Supraventricular Tachycardia (Reentry SVT)

6.2.4.2.1 Evaluation

Most SVTs are regular tachycardias that are caused by reentry, an abnormal rhythm circuit that allows a wave of depolarization to repeatedly travel in a circle in cardiac tissue. The rhythm is considered to be of supraventricular origin if the QRS complex is narrow (<120 milliseconds or <0.12 second) or if the QRS complex is wide (broad) and preexisting bundle branch block or rate-dependent aberrancy is *known* to be present. Reentry circuits resulting in SVT can occur in atrial myocardium (resulting in atrial fibrillation, atrial flutter, and some forms of atrial tachycardia). The reentry circuit may also reside in whole or in part in the AV node itself. This results in AV nodal reentry tachycardia (AVNRT) if both limbs of the reentry circuit involve AV nodal tissue. Alternatively, it may result in AV reentry tachycardia (AVRT) if one limb of the reentry circuit involves an accessory pathway and the other involves the AV node. The characteristic abrupt onset and termination of each of the latter groups of reentrant tachyarrhythmias (AVNRT and AVRT) led to the original name, paroxysmal supraventricular tachycardia (PSVT). This subgroup of reentry arrhythmias, due to either AVNRT or AVRT, is characterized by abrupt onset and termination and a regular rate that exceeds the typical upper limits of sinus tachycardia at rest (usually >150 beats per minute) and, in the case of an AVNRT, often presents without readily identifiable P waves on the ECG.

Distinguishing the forms of reentrant SVTs that are based in atrial myocardium (such as atrial fibrillation) versus those with a reentry circuit partly or wholly based in the AV node itself (PSVT) is important because each will respond differently to therapies aimed at impeding conduction through the AV node. The ventricular rate of reentry arrhythmias based in atrial myocardium will be slowed but not terminated by drugs that slow conduction through the AV node. Conversely, reentry arrhythmias for which at least one limb of the circuit resides in the AV node (PSVT attributable to AVNRT or AVRT) can be terminated by such drugs.

Yet another group of SVTs is referred to as automatic tachycardias. These arrhythmias are not due to a circulating circuit but to an excited automatic focus. Unlike the abrupt pattern of reentry, the characteristic onset and termination of these tachyarrhythmias are more gradual and analogous to how the sinus node behaves in gradually accelerating and slowing heart rate. These automatic arrhythmias include ectopic atrial tachycardia, MAT, and junctional tachycardia. These arrhythmias can be difficult to treat, are not responsive to cardioversion, and are usually controlled acutely with drugs that slow conduction through the AV node and thereby slow ventricular rate.

6.2.4.2.2 Therapy

6.2.4.2.2.1 Vagal Maneuvers

Vagal maneuvers and adenosine are the preferred initial therapeutic choices for the termination of stable PSVT (Figure 4: Tachycardia Algorithm, **Box 7**). Vagal maneuvers alone (Valsalva maneuver or carotid sinus massage) will terminate up to 25% of PSVTs.[347-349] For other SVTs, vagal maneuvers and adenosine may transiently slow the ventricular rate and potentially assist rhythm diagnosis but will not usually terminate such arrhythmias.

6.2.4.2.2.2 Adenosine

If PSVT does not respond to vagal maneuvers, give 6 mg of IV adenosine as a rapid IV push through a large (eg, antecubital) vein followed by a 20 mL saline flush. (Class I, LOE B)

If the rhythm does not convert within 1 to 2 minutes, give a 12 mg rapid IV push using the method above. Because of the possibility of initiating atrial fibrillation with rapid ventricular rates in a patient with WPW, a defibrillator should be available when adenosine is administered to any patient in whom WPW is a consideration. As with vagal maneuvers, the effect of adenosine on other SVTs (such as atrial fibrillation or flutter) is to transiently slow ventricular rate (which may be useful diagnostically) but not afford their termination or meaningful lasting rate control.

A number of studies[350-367] support the use of adenosine in the treatment of stable PSVT. Although 2 randomized clinical trials[352,355] documented a similar PSVT conversion rate between adenosine and calcium channel blockers, adenosine was more rapid and had fewer severe side effects than verapamil. Amiodarone as well as other antiarrhythmic agents can be useful in the termination of PSVT, but the onset of action of amiodarone is slower than that of adenosine,[368] and the potential proarrhythmic risks of these agents favor the use of safer treatment alternatives.

Adenosine is safe and effective in pregnancy.[369] However, adenosine does have several important drug interactions. Larger doses may be required for patients with a significant blood level of theophylline, caffeine, or theobromine. The initial dose should be reduced to 3 mg in patients taking dipyridamole or carbamazepine, those with transplanted hearts, or if given by central venous access. Side effects with adenosine are common but transient; flushing, dyspnea, and chest discomfort are the most frequently observed.[370] Adenosine should not be given to patients with asthma.

After conversion, monitor the patient for recurrence and treat any recurrence of PSVT with adenosine or a longer-acting AV nodal blocking agent (eg, diltiazem or ?-blocker). If adenosine or vagal maneuvers disclose another form of SVT (such as atrial fibrillation or flutter), treatment with a longer-acting AV nodal blocking agent should be considered to afford more lasting control of ventricular rate.

6.2.4.2.2.3 Calcium Channel Blockers and ?-Blockers

If adenosine or vagal maneuvers fail to convert PSVT, PSVT recurs after such treatment, or these treatments disclose a different form of SVT (such as atrial fibrillation or flutter), it is reasonable to use longer-acting AV nodal blocking agents, such as the nondihydropyridine calcium channel blockers (verapamil and diltiazem)(Class IIa, LOE B) or ?-blockers. (Class IIa, LOE C)

These drugs act primarily on nodal tissue either to terminate the reentry PSVTs that depend on conduction through the AV node or to slow the ventricular response to other SVTs by blocking conduction through the AV node. The alternate mechanism of action and longer duration of these drugs may result in more sustained termination of PSVT or afford more sustained rate control of atrial arrhythmias (such as atrial fibrillation or flutter). A number of studies have established the effectiveness of verapamil[350,352,353,355,363, 367,371-374] and diltiazem[371,375,376] in converting PSVT to normal sinus rhythm.

For verapamil, give a 2.5 mg to 5 mg IV bolus over 2 minutes (over 3 minutes in older patients). If there is no therapeutic response and no drug-induced adverse event, repeated doses of 5 mg to 10 mg may be administered every 15 to 30 minutes to a total dose of 20 mg. An alternative dosing regimen is to give a 5 mg bolus every 15 minutes to a total dose of 30 mg. Verapamil should be given *only* to patients with narrow-complex reentry SVT or arrhythmias known with certainty to be of supraventricular origin. Verapamil should not be given to patients with wide-complex tachycardias. It should not be given to patients with impaired ventricular function or heart failure.

For diltiazem, give a dose of 15 mg to 20 mg (0.25 mg/kg) IV over 2 minutes; if needed, in 15 minutes give an additional IV dose of 20 mg to 25 mg (0.35 mg/kg). The maintenance infusion dose is 5 mg/hour to 15 mg/hour, titrated to heart rate.

A wide variety of IV ?-blockers are available for treatment of supraventricular tachyarrhythmias. These include metoprolol, atenolol, propranolol, esmolol, and labetolol (the latter more commonly used for acute management of hypertension than for arrhythmias). In principle these agents exert their effect by antagonizing sympathetic tone in nodal tissue, resulting in slowing of conduction. Like calcium channel blockers, they also have negative inotropic effects and further reduce cardiac output in patients with heart failure. More detailed information is provided below. Side effects of ?-blockers can include bradycardias, AV conduction delays, and hypotension. ?-blockers should be used with caution in patients with obstructive pulmonary disease or congestive heart failure.

Caution is advised when encountering pre-excited atrial fibrillation or flutter that conducts to the ventricles via both the AV node and an accessory pathway. Treatment with an AV nodal blocking agent (including adenosine, calcium blockers, ?-blockers, or digoxin) is unlikely to slow the ventricular rate and in some instances may accelerate the ventricular response.

Therefore, AV nodal blocking drugs should not be used for pre-excited atrial fibrillation or flutter. (Class III, LOE C)

Caution is also advised to avoid the combination of AV nodal blocking agents that have a longer duration of action. For example, the short elimination half-life of adenosine affords follow-up treatment, if required, with a calcium channel blocker or ?-blocker. Conversely the longer half-life of a calcium channel or ?-blocker means their effects will overlap; profound bradycardia can develop if they are given serially.

Although antiarrhythmic medications (eg, amiodarone, procainamide, or sotalol) can also be used to treat SVTs, the higher toxicity and risk for proarrhythmia make these medications less desirable alternatives to the described AV nodal blocking agents. A possible exception is in patients with pre-excited atrial arrhythmias; the typical AV nodal blocking drugs are contraindicated in these patients and rate control may be achieved with antiarrhythmic medications. Importantly, use of these agents for atrial-based SVTs, such as atrial fibrillation and flutter can result in their termination, which may be undesirable in the absence of precautions to prevent the thromboembolic complications that may result from such conversion.

6.2.5 Wide-Complex Tachycardia

6.2.5.1 Evaluation

The first step in the management of any tachycardia is to determine if the patient's condition is stable or unstable (Figure 4: Tachycardia Algorithm, **Box 3**). An unstable patient with a wide-complex tachycardia should be presumed to have VT and immediate cardioversion should be performed (**Box 4** and see above).

Precordial thump may be considered for patients with witnessed, monitored, unstable ventricular tachycardia if a defibrillator is not immediately ready for use. (Class IIb, LOE C)

If the patient is stable, the second step in management is to obtain a 12-lead ECG (**Boxes 6 and 7**) to evaluate the rhythm. At this point the provider should consider the need to obtain expert consultation. If the patient becomes unstable at any time, proceed with synchronized cardioversion or unsynchronized defibrillation should the arrhythmia deteriorate to VF or be due to a polymorphic VT.

Wide-complex tachycardias are defined as those with a QRS ?0.12 second. The most common forms of wide-complex tachycardia are

VT or VF

SVT with aberrancy

Pre-excited tachycardias (associated with or mediated by an accessory pathway)

Ventricular paced rhythms

The third step in management of a tachycardia is to determine if the rhythm is regular or irregular. A *regular* wide-complex tachycardia is likely to be VT or SVT with aberrancy. An *irregular* wide-complex tachycardia may be atrial fibrillation with aberrancy, pre-excited atrial fibrillation (ie, atrial fibrillation using an accessory pathway for antegrade conduction), or polymorphic VT/torsades de pointes. Providers should consider the need for expert consultation when treating wide-complex tachycardias.

6.2.5.2 Therapy for Regular Wide-Complex Tachycardias

In patients with stable undifferentiated wide-QRS complex tachycardia, a reasonable approach is to try to identify the wide-complex tachycardia as SVT or VT and treat based on the algorithm for that rhythm.

If the etiology of the rhythm cannot be determined, the rate is regular, and the QRS is monomorphic, recent evidence suggests that IV adenosine is relatively safe for both treatment and diagnosis.[377] (Class IIb, LOE B)

However, adenosine should not be given for unstable or for irregular or polymorphic wide-complex tachycardias, as it may cause degeneration of the arrhythmia to VF. (Class III, LOE C)

If the wide-complex tachycardia proves to be SVT with aberrancy, it will likely be transiently slowed or converted by adenosine to sinus rhythm; if due to VT there will be no effect on rhythm (except in rare cases of idiopathic VT), and the brevity of the transient adenosine effect should be reasonably tolerated hemodynamically. Because close attention to these varying responses may help to diagnose the underlying rhythm, whenever possible, continuous ECG recording is strongly encouraged to provide such written documentation. This documentation can be invaluable in helping to establish a firm rhythm diagnosis even if after the fact. Typically, adenosine is administered in a manner similar to treatment of PSVT: as a 6 mg rapid IV push; providers may follow the first dose with a 12 mg bolus and a second 12 mg bolus if the rate fails to convert. When adenosine is given for undifferentiated wide-complex tachycardia, a defibrillator should be available.

Depending on the underlying rhythm, the response to adenosine challenge can be variable. Some studies[378-382] showed that adenosine converted an undifferentiated wide-complex tachycardia to sinus rhythm. Another study [383] showed poor rates of conversion to sinus rhythm in patients known to have VT. The following adverse effects were reported in patients with pre-excited atrial fibrillation treated with adenosine: conversion to atrial fibrillation with a rapid ventricular response in one patient later found to have preexcitation, conversion to VF in one patient with known WPW,[384] conversion to VF in 4 patients with pre-excited atrial fibrillation,[385] conversion to VF in 2 patients with WPW,[386] and a single case of VF in a patient with VT.[387]

Verapamil is contraindicated for wide-complex tachycardias unless known to be of supraventricular origin. (Class III, LOE B)

Adverse effects when the rhythm was due to VT were shown in 5 small case series.[384-388] Profound hypotension was reported in 11 of 25 patients known to have VT treated with verapamil.[388]

For patients who are stable with likely VT, IV antiarrhythmic drugs or elective cardioversion is the preferred treatment strategy.

If IV antiarrhythmics are administered, procainamide,(Class IIa, LOE B) amiodarone, or sotalol can be considered. (Class IIb, LOE B)

Procainamide and sotalol should be avoided in patients with prolonged QT. If one of these antiarrhythmic agents is given, a second agent should not be given without expert consultation. (Class III, LOE B)

If antiarrhythmic therapy is unsuccessful, cardioversion or expert consultation should be considered. (Class IIa, LOE C)

One randomized comparison found procainamide (10 mg/kg) to be superior to lidocaine (1.5 mg/kg) for termination of hemodynamically stable monomorphic VT.[389] Procainamide can be administered at a rate of 20 to 50 mg/min until the arrhythmia is suppressed, hypotension ensues, QRS duration increases >50%, or the maximum dose of 17 mg/kg is given. Maintenance infusion is 1 to 4 mg/min. Procainamide should be avoided in patients with prolonged QT and congestive heart failure.

IV sotalol (100 mg IV over 5 minutes) was found to be more effective than lidocaine (100 mg IV over 5 minutes) when administered to patients with spontaneous hemodynamically stable sustained monomorphic VT in a double-blind randomized trial within a hospital setting.[390]

In a separate study of 109 patients with a history of spontaneous and inducible sustained ventricular tachyarrhythmias, infusing 1.5 mg/kg of sotalol over ?5 minutes was found to be relatively safe and effective, causing hypotension in only 2 patients, both of whom responded to IV fluid.[391] Package insert recommends slow infusion, but the literature supports more rapid infusion of 1.5 mg/kg over 5 minutes or less. Sotalol should be avoided in patients with a prolonged QT interval.

Amiodarone is also effective in preventing recurrent monomorphic VT or treating refractory ventricular arrhythmias[392,393-395] in patients with coronary artery disease and poor ventricular function. It is given 150 mg IV over 10 minutes; dosing should be repeated as needed to a maximum dose of 2.2 g IV per 24 hours. Higher doses (300 mg) were associated with an increased frequency of hypotension, although some reports[393,395] attributed the hypotension to the vasoactive solvents that are not present in a new form of the drug recently approved for use in the US.

By comparison, lidocaine is less effective in terminating VT than procainamide, sotalol, and amiodarone,[392,389,390] and when given to patients with or without a history of MI with spontaneous sustained stable VT in the hospital setting.[383,396,397] Lidocaine has been reported to variably terminate VT when administered intramuscularly to patients with AMI and VT in the out-of-hospital setting.[398,399] Thus, while occasionally effective, lidocaine should be considered second-line antiarrhythmic therapy for monomorphic VT. Lidocaine can be administered at a dose of 1 to 1.5 mg/kg IV bolus. Maintenance infusion is 1 to 4 mg/min (30 to 50 mcg/kg per minute).

6.3 Irregular Tachycardias

6.3.1 Atrial Fibrillation and Flutter

6.3.1.1 Evaluation

An irregular narrow-complex or wide-complex tachycardia is most likely atrial fibrillation (with or without aberrant conduction) with an uncontrolled ventricular response. Other diagnostic possibilities include MAT or sinus rhythm/tachycardia with frequent atrial premature beats. When there is doubt about the rhythm diagnosis and the patient is stable, a 12-lead ECG with expert consultation is recommended.

6.3.1.2 Therapy

General management of atrial fibrillation should focus on control of the rapid ventricular rate (rate control), conversion of hemodynamically unstable atrial fibrillation to sinus rhythm (rhythm control), or both. Patients with an atrial fibrillation duration of >48 hours are at increased risk for cardioembolic events, although shorter durations of atrial fibrillation do not exclude the possibility of such events. Electric or pharmacologic cardioversion (conversion to normal sinus rhythm) should *not be attempted* in these patients unless the patient is unstable. An alternative strategy is to perform cardioversion following anticoagulation with heparin *and* performance of transesophageal echocardiography to ensure the absence of a left atrial thrombus; see the ACC/AHA Guidelines for Management of Patients with Atrial Fibrillation.[400]

6.3.1.3 Rate Control

Patients who are hemodynamically unstable should receive prompt electric cardioversion. More stable patients require ventricular rate control as directed by patient symptoms and hemodynamics.

IV ?-blockers and nondihydropyridine calcium channel blockers such as diltiazem[401-404] are the drugs of choice for acute rate control in most individuals with atrial fibrillation and rapid ventricular response. (Class IIa, LOE A)

Digoxin[405-407] and amiodarone[408,409] may be used for rate control in patients with congestive heart failure; however, the potential risk of conversion to sinus rhythm with amiodarone should be considered before treating with this agent.

A wide-complex irregular rhythm should be considered pre-excited atrial fibrillation. Expert consultation is advised. Avoid AV nodal blocking agents such as adenosine, calcium channel blockers, digoxin, and possibly ?-blockers in patients with pre-excitation atrial fibrillation because these drugs may cause a paradoxical increase in the ventricular response. Typically, patients with pre-excited atrial fibrillation present with very rapid heart rates and require emergent electric cardioversion. When electric cardioversion is not feasible or effective, or atrial fibrillation is recurrent, use of rhythm control agents (discussed below) may be useful for both rate control and

stabilization of the rhythm.

6.3.1.4 Rhythm Control

A variety of agents have been shown to be effective in terminating atrial fibrillation (pharmacologic or chemical cardioversion), although success between them varies and not all are available as parenteral formulations. Expert consultation is recommended.

6.3.2 Polymorphic (Irregular) VT

Polymorphic (irregular) VT requires immediate defibrillation with the same strategy used for VF.

Pharmacologic treatment to prevent recurrent polymorphic VT should be directed by the underlying cause of VT and the presence or absence of a long QT interval during sinus rhythm.

If a long QT interval is observed during sinus rhythm (ie, the VT is torsades de pointes), the first step is to stop medications known to prolong the QT interval. Correct electrolyte imbalance and other acute precipitants (eg, drug overdose or poisoning: see Part 12.7: “Cardiac Arrest Associated With Toxic Ingestions”). Although magnesium is commonly used to treat torsades de pointes VT (polymorphic VT associated with long QT interval), it is supported by only 2 observational studies[410,411] that showed effectiveness in patients with prolonged QT interval. One adult case series[412] showed that isoproterenol or ventricular pacing can be effective in terminating torsades de pointes associated with bradycardia and drug-induced QT prolongation. Polymorphic VT associated with familial long QT syndrome may be treated with IV magnesium, pacing, and/or ?-blockers; isoproterenol should be avoided. Polymorphic VT associated with acquired long QT syndrome may be treated with IV magnesium. The addition of pacing or IV isoproterenol may be considered when polymorphic VT is accompanied by bradycardia or appears to be precipitated by pauses in rhythm.

In the absence of a prolonged QT interval, the most common cause of polymorphic VT is myocardial ischemia. In this situation IV amiodarone and ?-blockers may reduce the frequency of arrhythmia recurrence. (Class IIb, LOE C)

Myocardial ischemia should be treated with ?-blockers and consideration be given to expeditious cardiac catheterization with revascularization.

Magnesium is unlikely to be effective in preventing polymorphic VT in patients with a normal QT interval,[410] but amiodarone may be effective.[413] (Class IIb, LOE C)

Other causes of polymorphic VT apart from ischemia and long QT syndrome are catecholaminergic VT (which may be responsive to ?-blockers) and Brugada syndrome (which may be responsive to isoproterenol).

6.4 Summary

The goal of therapy for bradycardia or tachycardia is to rapidly identify and treat patients who are hemodynamically unstable or symptomatic due to the arrhythmia. Drugs or, when appropriate, pacing may be used to control unstable or symptomatic bradycardia. Cardioversion or drugs or both may be used to control unstable or symptomatic tachycardia. ACLS providers should closely monitor stable patients pending expert consultation and should be prepared to aggressively treat those with evidence of decompensation.

7 Authorship and Disclosures

7.1 2015 Writing Team

Mark S. Link, Chair; Lauren C. Berkow; Peter J. Kudenchuk; Henry R. Halperin; Erik P. Hess; Vivek K. Moitra; Robert W. Neumar; Brian J. O’Neil; James H. Paxton; Scott M. Silvers; Roger D. White; Demetris Yannopoulos; Michael W. Donnino

Table 4: Part 7: Adult Advanced Cardiovascular Life Support: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 7: Adult Advanced Cardiovascular Life Support: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Mark S. Link	Tufts Medical Center	None	None	None	None	None	None	None
Lauren C. Berkow	Johns Hopkins Anesthesia	None	None	None	Bonezzi Switzer Polito & Hupp Co. L.P.A.*	None	Teleflex*	None
Henry R. Halperin	Johns Hopkins University	Zoll Circulation†	None	None	Zoll Medical†	None	Zoll Circulation†	None
Erik P. Hess	Mayo Clinic	None	None	None	None	None	None	None
Peter J. Kudenchuk	University of Washington Medical Center	NIH-NHLBI†	None	None	None	None	None	Public Health - Seattle/ King County†
Vivek K. Moitra	Columbia University Medical Center	None	None	None	Reviewed records for plaintiff and defense on perioperative managemen	None	None	None
Robert W. Neumar	University of Michigan	NIH/NHLBI†; AHA†	None	None	None	None	None	None
Brian J. O'Neil	Wayne State University	Zoll*	None	None	None	None	None	None
James H. Paxton	Wayne State University School of Medicine	Vidacare / Teleflex LLC†	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Scott M. Silvers	Mayo Clinic	None	None	None	None	None	None	None
Roger D. White	Mayo Clinic	None	None	None	None	None	None	None
Demetris Yannopoulos	University of Minnesota	NIH*	None	None	None	None	None	None
Consultant								
Michael W. Donnino	Beth Israel Deaconess Med Center	None	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.*Modest. †Significant.

7.2 2010 Writing Team

Robert W. Neumar, Chair; Charles W. Otto; Mark S. Link; Steven L. Kronick; Michael Shuster; Clifton W. Callaway; Peter J. Kudenchuk; Joseph P. Ornato; Bryan McNally; Scott M. Silvers; Rod S. Passman; Roger D. White; Erik P. Hess; Wanchun Tang; Daniel Davis; Elizabeth Sinz; Laurie J. Morrison

Table 5: 2010 - Guidelines Part 7: CPR Techniques and Devices: Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 7: CPR Techniques and Devices: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Diana M. Cave	Legacy Health System, Emanuel Hospital, Emergency Services–RN, MSN; Portland Com. College–Institute for Health Prof.-	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Raul Gazmuri	North Chicago VA Medical Center–Sectio Chief, Critical Care and Professor of Medicine	†Volume-Controlled Manual Ventilation during Resuscitation from Cardiac Arrest. Funded by Dessinier Corporation. Funds come to my institution (Rosalind Franklin UniversityRFU Vitamin-C Preserves Myocardial Distensibility during Resuscitation from CA. Funded by Maribor University, Slovenia. Funds come to my institution (RFU)	None	None	†Patent titled “Facilitation of Resuscitation from Cardiac Arrest by Erythropoietin” (pending)	None	None
Charles W. Otto	University of Arizona–Professor	None	None	None	None	None	None
Vinay M. Nadkarni	University of Pennsylvania/T Children's Hospital of Philadelphia–A Physician, Departement of Anesthesia, Critical Care and Pediatrics	None	None	None	None	None	*Voluntary (Unpaid) member of Data Safety Monitoring Committee for Automated CPR device trial

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Adam Cheng	British Columbia Children's Hospital: University Affiliated–Director, Pediatric Simulation Program	†American Heart Association RFP - educational grant. Money comes to my institution, and is distributed to our group of collaborative pediatric hospitals	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Steven C. Brooks	University of Toronto–Clinic Scientist	†PI-1. Univ.of Toronto Faculty of Medicine New Staff Grant. 01/07/2009–01 A pilot study to explore missed opportunities for public access defibrillation in OHCA and to determine the potential impact of emergency medical dispatchers. Role: PI $10 000 unrestricted grant administered through the research institute 2. University of Toronto Connaught New Staff Matching Grant 2009–2010. 04/05/2009–03 Development of Centres of Excellence to Improve Outcomes after OHCAt: A Pilot Study. Role: PI $23 700 unrestricted grant administered through the research institute 3. Ontario Ministry of Health and Long Term Care and					

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Mohamud Daya	Oregon Health & Science University: Attending Physician–Associate Professor of Emergency Medicine	†PI Resuscitation Outcomes Consoritum - Portland Site, NHLBI, grant is awarded directly to the insitution (OHSU)	None	*Lectures at local, regional and national meetings, income is directly to me, last lectures CPR update at the Timberline EMS conference, there was no honorarium but conference paid for my lodging Stroke Update in Corvallis at Samaritan Health, Honorarium fee was 500 dollars Advanced 12 lead ECG diagnostic algoritms, Lecutre for Philips Healthcare at EMS today, honoarium for 2 lectures was 1000 dollars	*Stock held in the following health care companies; Johnson and Johnson - 250 shares Amgen - 100 shares Roche - 100 shares	*Philips Health Care - Consultant on 12 lead ECG diagnostic algorithms and resuscitation products, no reimbursement for this activity	†I am an EMS medical director for 2 fire departments and one 911 agency, this is a private contract and the money comes directly to me, this is independent of my employment at OHSU which is at an 80% FTE level, my EMS activities are 20% FTE

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Robert M. Sutton	The Children's Hospital of Philadelphia–C Care Attending	* Unrestricted Research Grant Support through a Center of Excellence Grant from the Laerdal Found	None	None	None	None	
Richard Branson	University of Cincinnati-Associate Professor	None	†SeQual. Sponsor of laboratory study of the use of oxygen concentrators in conjunction with mechanical ventilators for military and mass casualty scenarios. $40 000. All monies are paid to the Univ. I have no financial interest in the company and do not receive any personal income	†Cardinal - makers of ICU and home care ventialtors. I am paid directly for speaking. Newport Medical makers of ICU and home care ventilators. I am paid directly for speaking. * IKARIA - manufactures and distributes inhaled nitric oxide. I am paid directly	None	*Bayer Pharmaceuticals Treatment of ventilator associated pneumonia	*KIngs Daughters Hospital Ashalnd KY. Paid directly to me

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Mary Fran Hazinski	Vanderbilt University School of Nursing—Profe American Heart Association–Senior Science Editor † Significant AHA compensation for my editing responsibilities writing and editing of the 2010 AHA Guidelines for CPR and ECC	None	None	None	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

8 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 7: Adult Advanced Cardiovascular Life Support. ECCguidelines.heart.org

References

1. MorrisonLJ,DeakinCD,MorleyPT,CallawayCW,KerberRE,Kronick SL, Lavonas EJ, Link MS, Neumar RW, Otto CW, Parr M, Shuster M, Sunde K, Peberdy MA, Tang W, Hoek TL, Böttiger BW, Drajer S, Lim SH, Nolan JP; Advanced Life Support Chapter Collaborators. Part 8: advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122 (suppl 2):S345–S421. doi: 10.1161/CIRCULATIONAHA.110.971051.

2. Callaway CW, Soar J, Aibiki M, Böttiger BW, Brooks SC, Deakin CD, Donnino MW, Drajer S, Kloeck W, Morley PT, Morrison LJ, Neumar RW, Nicholson TC, Nolan JP, Okada K, O'Neil BJ, Paiva EF, Parr MJ, Wang TL, Witt J; on behalf of the Advanced Life Support Chapter Collaborators. Part 4: advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S84–S145. doi: 10.1161/CIR.0000000000000273.

3. O'Connor D, Green S, Higgins J, eds. Chapter 5: defining the review questions and developing criteria for including studies. In: The Cochrane Collaboration. Higgans JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0. 2011. http://handbook. cochrane.org/. Accessed May 6, 2015.

4. Schünemann H, Broz?ek J, Guyatt G, Oxman A. GRADE Handbook. 2013. http://www.guidelinedevelopment.org/handbook/. Accessed May 6, 2015.

5. Spindelboeck W, Schindler O, Moser A, Hausler F, Wallner S, Strasser C, Haas J, Gemes G, Prause G. Increasing arterial oxygen partial pressure during cardiopulmonary resuscitation is associated with improved rates of hospital admission. Resuscitation. 2013;84:770–775. doi: 10.1016/j. resuscitation.2013.01.012.

6. Meaney PA, Bobrow BJ, Mancini ME, Christenson J, de Caen AR, Bhanji F, Abella BS, Kleinman ME, Edelson DP, Berg RA, Aufderheide TP, Menon V, Leary M; CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Cardiopulmonary resuscitation quality: [corrected] improv- ing cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. Circulation. 2013;128:417–435. doi: 10.1161/CIR.0b013e31829d8654.

7. Halperin HR, Tsitlik JE, Gelfand M, Weisfeldt ML, Gruben KG, Levin HR, Rayburn BK, Chandra NC, Scott CJ, Kreps BJ. A preliminary study of cardiopulmonary resuscitation by circumferential compression of the chest with use of a pneumatic vest. N Engl J Med. 1993;329:762–768. doi: 10.1056/NEJM199309093291104.

8. Kern KB, Hilwig RW, Berg RA, Ewy GA. Efficacy of chest compres- sion-only BLS CPR in the presence of an occluded airway. Resuscitation. 1998;39:179–188.

9. Levine RL, Wayne MA, Miller CC. End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest. N Engl J Med. 1997;337:301–306. doi: 10.1056/NEJM199707313370503.

10. Lindner KH, Prengel AW, Pfenninger EG, Lindner IM, Strohmenger HU, Georgieff M, Lurie KG. Vasopressin improves vital organ blood flow during closed-chest cardiopulmonary resuscitation in pigs. Circulation. 1995;91:215–221.

11. Little CM, Angelos MG, Paradis NA. Compared to angiotensin II, epi- nephrine is associated with high myocardial blood flow following return of spontaneous circulation after cardiac arrest. Resuscitation. 2003;59:353–359.

12. Paradis NA, Martin GB, Rivers EP, Goetting MG, Appleton TJ, Feingold M, Nowak RM. Coronary perfusion pressure and the return of sponta- neous circulation in human cardiopulmonary resuscitation. JAMA. 1990;263:1106–1113.

13. Wayne MA, Levine RL, Miller CC. Use of end-tidal carbon diox- ide to predict outcome in prehospital cardiac arrest. Ann Emerg Med. 1995;25:762–767.

14. Bhende MS, Thompson AE. Evaluation of an end-tidal CO2 detector dur- ing pediatric cardiopulmonary resuscitation. Pediatrics. 1995;95:395–399.

15. Ornato JP, Shipley JB, Racht EM, Slovis CM, Wrenn KD, Pepe PE, Almeida SL, Ginger VF, Fotre TV. Multicenter study of a portable, hand- size, colorimetric end-tidal carbon dioxide detection device. Ann Emerg Med. 1992;21:518–523.

16. Callaham M, Barton C. Prediction of outcome of cardiopulmonary resus- citation from end-tidal carbon dioxide concentration. Crit Care Med. 1990;18:358–362.

17. Sanders AB, Ogle M, Ewy GA. Coronary perfusion pressure during cardio- pulmonary resuscitation. Am J Emerg Med. 1985;3:11–14.

18. Rivers EP, Martin GB, Smithline H, Rady MY, Schultz CH, Goetting MG, Appleton TJ, Nowak RM. The clinical implications of continuous central venous oxygen saturation during human CPR. Ann Emerg Med. 1992;21:1094–1101.

19. Cantineau JP, Lambert Y, Merckx P, Reynaud P, Porte F, Bertrand C, Duvaldestin P. End-tidal carbon dioxide during cardiopulmonary resusci- tation in humans presenting mostly with asystole: a predictor of outcome. Crit Care Med. 1996;24:791–796.

20. Grmec S, Kupnik D. Does the Mainz Emergency Evaluation Scoring (MEES) in combination with capnometry (MEESc) help in the prognosis of outcome from cardiopulmonary resuscitation in a prehospital setting? Resuscitation. 2003;58:89–96.

21. Grmec S, Lah K, Tusek-Bunc K. Difference in end-tidal CO2 between asphyxia cardiac arrest and ventricular fibrillation/pulseless ventricu- lar tachycardia cardiac arrest in the prehospital setting. Crit Care. 2003;7:R139–R144. doi: 10.1186/cc2369.

22. Grmec S, Klemen P. Does the end-tidal carbon dioxide (EtCO2) concen- tration have prognostic value during out-of-hospital cardiac arrest? Eur J Emerg Med. 2001;8:263–269.

23.

Kolar M, Krizmaric M, Klemen P, Grmec S. Partial pressure of end-tidal carbon dioxide successful predicts cardiopulmonary resuscitation in the field: a prospective observational study. Crit Care. 2008;12:R115. doi: 10.1186/cc7009.

24. Steedman DJ, Robertson CE. Measurement of end-tidal carbon dioxide concentration during cardiopulmonary resuscitation. Arch Emerg Med. 1990;7:129–134.

25. Pokorná M, Necas E, Kratochvíl J, Skripský R, Andrlík M, Franek O. A sudden increase in partial pressure end-tidal carbon dioxide (P(ET) CO(2)) at the moment of return of spontaneous circulation. J Emerg Med. 2010;38:614–621. doi: 10.1016/j.jemermed.2009.04.064.

26. Sehra R, Underwood K, Checchia P. End tidal CO2 is a quantitative mea- sure of cardiac arrest. Pacing Clin Electrophysiol. 2003;26(1 Pt 2):515–517.

27. Grmec S, Krizmaric M, Mally S, Kozelj A, Spindler M, Lesnik B. Utstein style analysis of out-of-hospital cardiac arrest–bystander CPR and end expired carbon dioxide. Resuscitation. 2007;72:404–414. doi: 10.1016/j. resuscitation.2006.07.012.

28. Entholzner E, Felber A, Mielke L, Hargasser S, Breinbauer B, Hundelshausen VB, Hipp R. Assessment of end-tidal CO2 measure- ment in reanimation. Anasthesiol Intensivmed Notfallmed Schmerzther. 1992;27:473–476.

29. Garnett AR, Ornato JP, Gonzalez ER, Johnson EB. End-tidal car- bon dioxide monitoring during cardiopulmonary resuscitation. JAMA. 1987;257:512–515.

30. Bhende MS, Karasic DG, Karasic RB. End-tidal carbon dioxide changes during cardiopulmonary resuscitation after experimental asphyxial cardiac arrest. Am J Emerg Med. 1996;14:349–350. doi: 10.1016/ S0735-6757(96)90046-7.

31. Falk JL, Rackow EC, Weil MH. End-tidal carbon dioxide concentration during cardiopulmonary resuscitation. N Engl J Med. 1988;318:607–611. doi: 10.1056/NEJM198803103181005.

32. Axelsson C, Karlsson T, Axelsson AB, Herlitz J. Mechanical active com- pression-decompression cardiopulmonary resuscitation (ACD-CPR) ver- sus manual CPR according to pressure of end tidal carbon dioxide (P(ET) CO2) during CPR in out-of-hospital cardiac arrest (OHCA). Resuscitation. 2009;80:1099–1103. doi: 10.1016/j.resuscitation.2009.08.006.

33. Berryman CR, Phillips GM. Interposed abdominal compression-CPR in human subjects. Ann Emerg Med. 1984;13:226–229.

34. Cha KC, Kim HJ, Shin HJ, Kim H, Lee KH, Hwang SO. Hemodynamic effect of external chest compressions at the lower end of the sternum in cardiac arrest patients. J Emerg Med. 2013;44:691–697. doi: 10.1016/j. jemermed.2012.09.026.

35. Duchateau FX, Gueye P, Curac S, Tubach F, Broche C, Plaisance P, Payen D, Mantz J, Ricard-Hibon A. Effect of the AutoPulse automated band chest compression device on hemodynamics in out-of-hospital car- diac arrest resuscitation. Intensive Care Med. 2010;36:1256–1260. doi: 10.1007/s00134-010-1784-x.

36. Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans. The importance of rate-directed chest compressions. Arch Intern Med. 1992;152:145–149.

37. Manning JE. Feasibility of blind aortic catheter placement in the pre- hospital environment to guide resuscitation in cardiac arrest. J Trauma Acute Care Surg. 2013;75(2 suppl 2):S173–S177. doi: 10.1097/ TA.0b013e318299d9ee.

38. Orliaguet GA, Carli PA, Rozenberg A, Janniere D, Sauval P, Delpech P. End-tidal carbon dioxide during out-of-hospital cardiac arrest resuscita- tion: comparison of active compression-decompression and standard CPR. Ann Emerg Med. 1995;25:48–51.

39. Plaisance P, Lurie KG, Payen D. Inspiratory impedance during active com- pression-decompression cardiopulmonary resuscitation: a randomized evaluation in patients in cardiac arrest. Circulation. 2000;101:989–994.

40. Segal N, Parquette B, Ziehr J, Yannopoulos D, Lindstrom D. Intrathoracic pressure regulation during cardiopulmonary resuscitation: a feasibility case-series. Resuscitation. 2013;84:450–453. doi: 10.1016/j. resuscitation.2012.07.036.

41. Timerman S, Cardoso LF, Ramires JA, Halperin H. Improved hemody- namic performance with a novel chest compression device during treat- ment of in-hospital cardiac arrest. Resuscitation. 2004;61:273–280. doi: 10.1016/j.resuscitation.2004.01.025.

42. Ward KR, Sullivan RJ, Zelenak RR, Summer WR. A comparison of inter- posed abdominal compression CPR and standard CPR by monitoring end- tidal PCO2. Ann Emerg Med. 1989;18:831–837.

43. Ward KR, Menegazzi JJ, Zelenak RR, Sullivan RJ, McSwain NE Jr. A comparison of chest compressions between mechanical and manual CPR by monitoring end-tidal PCO2 during human cardiac arrest. Ann Emerg Med. 1993;22:669–674.

44. Narasimhan M, Koenig SJ, Mayo PH. Advanced echocardiography for the critical care physician: part 1. Chest. 2014;145:129–134. doi: 10.1378/ chest.12-2441.

45. Breitkreutz R, Walcher F, Seeger FH. Focused echocardiographic evaluation in resuscitation management: concept of an advanced life support-conformed algorithm. Crit Care Med. 2007;35(5 suppl):S150–S161. doi: 10.1097/01.CCM.0000260626.23848.FC.

46.

Chardoli M, Heidari F, Rabiee H, Sharif-Alhoseini M, Shokoohi H, Rahimi-Movaghar V. Echocardiography integrated ACLS protocol ver- sus conventional cardiopulmonary resuscitation in patients with pulseless electrical activity cardiac arrest. Chin J Traumatol. 2012;15:284–287.

47. Ornato JP, Garnett AR, Glauser FL. Relationship between cardiac output and the end-tidal carbon dioxide tension. Ann Emerg Med. 1990; 19:1104–1106.

48. Chandra NC, Gruben KG, Tsitlik JE, Brower R, Guerci AD, Halperin HH, Weisfeldt ML, Permutt S. Observations of ventilation during resuscitation in a canine model. Circulation. 1994;90:3070–3075.

49. Bailey AR, Hett DA. The laryngeal mask airway in resuscitation. Resuscitation. 1994;28:107–110.

50. Dorges V, Wenzel V, Knacke P, Gerlach K. Comparison of different airway management strategies to ventilate apneic, nonpreoxygenated patients. Crit Care Med. 2003;31:800–804.

51. Doerges V, Sauer C, Ocker H, Wenzel V, Schmucker P. Airway management during cardiopulmonary resuscitation—a comparative study of bag-valve-mask, laryngeal mask airway and combitube in a bench model. Resuscitation. 1999;41:63–69.

52. Weiler N, Heinrichs W, Dick W. Assessment of pulmonary mechanics and gastric inflation pressure during mask ventilation. Prehosp Disaster Med. 1995;10:101–105.

53. Ocker H, Wenzel V, Schmucker P, Dorges V. Effectiveness of various airway management techniques in a bench model simulating a cardiac arrest patient. J Emerg Med. 2001;20:7–12.

54. Hasegawa K, Hiraide A, Chang Y, Brown DF. Association of prehospital advanced airway management with neurologic outcome and survival in patients with out-of-hospital cardiac arrest. JAMA. 2013;309:257–266. doi: 10.1001/jama.2012.187612.

55. Holmberg M, Holmberg S, Herlitz J. Low chance of survival among patients requiring adrenaline (epinephrine) or intubation after out-of-hos- pital cardiac arrest in Sweden. Resuscitation. 2002;54:37–45.

56. McMullan J, Gerecht R, Bonomo J, Robb R, McNally B, Donnelly J, Wang HE; CARES Surveillance Group. Airway management and out- of-hospital cardiac arrest outcome in the CARES registry. Resuscitation. 2014;85:617–622. doi: 10.1016/j.resuscitation.2014.02.007.

57. Shin SD, Ahn KO, Song KJ, Park CB, Lee EJ. Out-of-hospital air- way management and cardiac arrest outcomes: a propensity score matched analysis. Resuscitation. 2012;83:313–319. doi: 10.1016/j. resuscitation.2011.10.028.

58. Hanif MA, Kaji AH, Niemann JT. Advanced airway management does not improve outcome of out-of-hospital cardiac arrest. Acad Emerg Med. 2010;17:926–931. doi: 10.1111/j.1553-2712.2010.00829.x.

59. Adams JN, Sirel J, Marsden K, Cobbe SM. Heartstart Scotland: the use of paramedic skills in out of hospital resuscitation. Heart. 1997;78:399–402.

60. Studnek JR, Thestrup L, Vandeventer S, Ward SR, Staley K, Garvey L, Blackwell T. The association between prehospital endotracheal intuba- tion attempts and survival to hospital discharge among out-of-hospi- tal cardiac arrest patients. Acad Emerg Med. 2010;17:918–925. doi: 10.1111/j.1553-2712.2010.00827.x.

61. Takei Y, Enami M, Yachida T, Ohta K, Inaba H. Tracheal intubation by paramedics under limited indication criteria may improve the short-term outcome of out-of-hospital cardiac arrests with noncardiac origin. J Anesth. 2010;24:716–725. doi: 10.1007/s00540-010-0974-6.

62. Yeung J, Chilwan M, Field R, Davies R, Gao F, Perkins GD. The impact of airway management on quality of cardiopulmonary resuscitation: an observational study in patients during cardiac arrest. Resuscitation. 2014;85:898–904. doi: 10.1016/j.resuscitation.2014.02.018.

63. Petito SP, Russell WJ. The prevention of gastric inflation—a neglected benefit of cricoid pressure. Anaesth Intensive Care. 1988;16:139–143.

64. Lawes EG, Campbell I, Mercer D. Inflation pressure, gastric insufflation and rapid sequence induction. Br J Anaesth. 1987;59:315–318.

65. Salem MR, Wong AY, Mani M, Sellick BA. Efficacy of cricoid pressure in preventing gastric inflation during bag-mask ventilation in pediatric patients. Anesthesiology. 1974;40:96–98.

66. Moynihan RJ, Brock-Utne JG, Archer JH, Feld LH, Kreitzman TR. The effect of cricoid pressure on preventing gastric insufflation in infants and children. Anesthesiology. 1993;78:652–656.

67. Asai T, Goy RW, Liu EH. Cricoid pressure prevents placement of the laryngeal tube and laryngeal tube-suction II. Br J Anaesth. 2007;99:282–285.

68. Turgeon AF, Nicole PC, Trepanier CA, Marcoux S, Lessard MR. Cricoid pressure does not increase the rate of failed intubation by direct laryngoscopy in adults. Anesthesiology. 2005;102:315–319.

69. Allman KG. The effect of cricoid pressure application on airway patency. J Clin Anesth. 1995;7:197–199.

70. Brimacombe J, White A, Berry A. Effect of cricoid pressure on ease of insertion of the laryngeal mask airway. Br J Anaesth. 1993;71:800–802.

71. McNelis U, Syndercombe A, Harper I, Duggan J. The effect of cricoid pressure on intubation facilitated by the gum elastic bougie. Anaesthesia. 2007;62:456–459.

72. Hartsilver EL, Vanner RG. Airway obstruction with cricoid pressure. Anaesthesia. 2000;55:208–211.

73. Hocking G, Roberts FL, Thew ME. Airway obstruction with cricoid pressure and lateral tilt. Anaesthesia. 2001;56:825–828.

74. Stoneham MD. The nasopharyngeal airway. Assessment of position by fibreoptic laryngoscopy. Anaesthesia. 1993;48:575–580.

75. Schade K, Borzotta A, Michaels A. Intracranial malposition of nasopharyngeal airway. J Trauma. 2000;49:967–968.

76. Muzzi DA, Losasso TJ, Cucchiara RF. Complication from a nasopharyngeal airway in a patient with a basilar skull fracture. Anesthesiology. 1991;74:366–368.

77. Wong ML, Carey S, Mader TJ, Wang HE. Time to invasive airway placement and resuscitation outcomes after inhospital cardiopulmonary arrest. Resuscitation. 2010;81:182–186.

78. Shy BD, Rea TD, Becker LJ, Eisenberg MS. Time to intubation and survival in prehospital cardiac arrest. Prehosp Emerg Care. 2004;8:394–399.

79. Jennings PA, Cameron P, Walker T, Bernard S, Smith K. Out-of-hospital cardiac arrest in Victoria: rural and urban outcomes. Med J Aust. 2006;185:135–139.

80. Dumot JA, Burval DJ, Sprung J, Waters JH, Mraovic B, Karafa MT, Mascha EJ, Bourke DL. Outcome of adult cardiopulmonary resuscitations at a tertiary referral center including results of “limited” resuscitations. Arch Intern Med. 2001;161:1751–1758.

81. Bobrow BJ, Ewy GA, Clark L, Chikani V, Berg RA, Sanders AB, Vadeboncoeur TF, Hilwig RW, Kern KB. Passive oxygen insufflation is superior to bag-valve-mask ventilation for witnessed ventricular fibrillation out-of-hospital cardiac arrest. Ann Emerg Med. 2009;54:656–662.

82. Goldenberg IF, Campion BC, Siebold CM, McBride JW, Long LA. Esophageal gastric tube airway vs endotracheal tube in prehospital cardio- pulmonary arrest. Chest. 1986;90:90–96.

83. Rabitsch W, Schellongowski P, Staudinger T, Hofbauer R, Dufek V, Eder B, Raab H, Thell R, Schuster E, Frass M. Comparison of a conventional tracheal airway with the Combitube in an urban emergency medical ser- vices system run by physicians. Resuscitation. 2003;57:27–32.

84. Cady CE, Weaver MD, Pirrallo RG, Wang HE. Effect of emergency medical technician-placed Combitubes on outcomes after out-of-hospital cardiopulmonary arrest. Prehosp Emerg Care. 2009;13:495–499. doi: 10.1080/10903120903144874.

85. Kajino K, Iwami T, Kitamura T, Daya M, Ong ME, Nishiuchi T, Hayashi Y, Sakai T, Shimazu T, Hiraide A, Kishi M, Yamayoshi S. Comparison of supraglottic airway versus endotracheal intubation for the pre-hospital treatment of out-of-hospital cardiac arrest. Crit Care. 2011;15:R236. doi: 10.1186/cc10483.

86. Wang HE, Szydlo D, Stouffer JA, Lin S, Carlson JN, Vaillancourt C, Sears G, Verbeek RP, Fowler R, Idris AH, Koenig K, Christenson J, Minokadeh A, Brandt J, Rea T; ROC Investigators. Endotracheal intubation versus supra- glottic airway insertion in out-of-hospital cardiac arrest. Resuscitation. 2012;83:1061–1066. doi: 10.1016/j.resuscitation.2012.05.018.

87. Tanabe S, Ogawa T, Akahane M, Koike S, Horiguchi H, Yasunaga H, Mizoguchi T, Hatanaka T, Yokota H, Imamura T. Comparison of neu- rological outcome between tracheal intubation and supraglottic airway device insertion of out-of-hospital cardiac arrest patients: a nationwide, population-based, observational study. J Emerg Med. 2013;44:389–397. doi: 10.1016/j.jemermed.2012.02.026.

88. Warner KJ, Carlbom D, Cooke CR, Bulger EM, Copass MK, Sharar SR. Paramedic training for proficient prehospital endotracheal intubation. Prehosp Emerg Care. 2010;14:103–108.

89. Grmec S. Comparison of three different methods to confirm tracheal tube placement in emergency intubation. Intensive Care Med. 2002;28:701– 704. doi: 10.1007/s00134-002-1290-x.

90. Takeda T, Tanigawa K, Tanaka H, Hayashi Y, Goto E, Tanaka K. The assessment of three methods to verify tracheal tube placement in the emer- gency setting. Resuscitation. 2003;56:153–157.

91. Tanigawa K, Takeda T, Goto E, Tanaka K. Accuracy and reliability of the self-inflating bulb to verify tracheal intubation in out-of-hospital cardiac arrest patients. Anesthesiology. 2000;93:1432–1436.

92. Ward KR, Yealy DM. End-tidal carbon dioxide monitoring in emergency medicine, Part 2: Clinical applications. Acad Emerg Med. 1998;5:637–646.

93. Tobias JD, Meyer DJ. Noninvasive monitoring of carbon dioxide during respiratory failure in toddlers and infants: end-tidal versus transcutaneous carbon dioxide. Anesth Analg. 1997;85:55–58.

94. Bozeman WP, Hexter D, Liang HK, Kelen GD. Esophageal detector device versus detection of end-tidal carbon dioxide level in emergency intubation. Ann Emerg Med. 1996;27:595–599.

95. Hayden SR, Sciammarella J, Viccellio P, Thode H, Delagi R. Colorimetric end-tidal CO2 detector for verification of endotracheal tube placement in out-of-hospital cardiac arrest. Acad Emerg Med. 1995;2:499–502.

96. MacLeod BA, Heller MB, Gerard J, Yealy DM, Menegazzi JJ. Verification of endotracheal tube placement with colorimetric end-tidal CO2 detection. Ann Emerg Med. 1991;20:267–270.

97. Anton WR, Gordon RW, Jordan TM, Posner KL, Cheney FW. A disposable end-tidal CO2 detector to verify endotracheal intubation. Ann Emerg Med. 1991;20:271–275.

98. Sanders KC, Clum WB 3rd, Nguyen SS, Balasubramaniam S. End-tidal carbon dioxide detection in emergency intubation in four groups of patients. J Emerg Med. 1994;12:771–777.

99. Tanigawa K, Takeda T, Goto E, Tanaka K. The efficacy of esophageal detector devices in verifying tracheal tube placement: a randomized cross-over study of out-of-hospital cardiac arrest patients. Anesth Analg. 2001;92:375–378.

100. Oberly D, Stein S, Hess D, Eitel D, Simmons M. An evaluation of the esophageal detector device using a cadaver model. Am J Emerg Med. 1992;10:317–320.

101. Pelucio M, Halligan L, Dhindsa H. Out-of-hospital experience with the syringe esophageal detector device. Acad Emerg Med. 1997;4:563–568.

102. Chou HC, Tseng WP, Wang CH, Ma MH, Wang HP, Huang PC, Sim SS, Liao YC, Chen SY, Hsu CY, Yen ZS, Chang WT, Huang CH, Lien WC, Chen SC. Tracheal rapid ultrasound exam (T.R.U.E.) for confirming endotracheal tube placement during emergency intubation. Resuscitation. 2011;82:1279–1284. doi: 10.1016/j.resuscitation.2011.05.016.

103. Zadel S, Strnad M, Prosen G, Mekiš D. Point of care ultrasound for orotra- cheal tube placement assessment in out-of hospital setting. Resuscitation. 2015;87:1–6. doi: 10.1016/j.resuscitation.2014.11.006.

104. Chou HC, Chong KM, Sim SS, Ma MH, Liu SH, Chen NC, Wu MC, Fu CM, Wang CH, Lee CC, Lien WC, Chen SC. Real-time tracheal ultrasonography for confirmation of endotracheal tube placement during cardiopulmonary resuscitation. Resuscitation. 2013;84:1708–1712. doi: 10.1016/j.resuscitation.2013.06.018.

105. Yap SJ, Morris RW, Pybus DA. Alterations in endotracheal tube position during general anaesthesia. Anaesth Intensive Care. 1994;22:586–588.

106. Sugiyama K, Yokoyama K. Displacement of the endotracheal tube caused by change of head position in pediatric anesthesia: evaluation by fiberoptic bronchoscopy. Anesth Analg. 1996;82:251–253.

107. King HK. A new device: Tube Securer. An endotracheal tube holder with integrated bite-block. Acta Anaesthesiol Sin. 1997;35:257–259.

108. Falk JL, Sayre MR. Confirmation of airway placement. Prehosp Emerg Care. 1999;3:273–278.

109. Wang HE, Kupas DF, Paris PM, Bates RR, Yealy DM. Preliminary experience with a prospective, multi-centered evaluation of out-of-hospital endotracheal intubation. Resuscitation. 2003;58:49–58.

110. Kupas DF, Kauffman KF, Wang HE. Effect of airway-securing method on prehospital endotracheal tube dislodgment. Prehosp Emerg Care. 2010;14:26–30.

111. Levy H, Griego L. A comparative study of oral endotracheal tube securing methods. Chest. 1993;104:1537–1540.

112. Tasota FJ, Hoffman LA, Zullo TG, Jamison G. Evaluation of two methods used to stabilize oral endotracheal tubes. Heart Lung. 1987;16:140–146.

113. Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004;109:1960–1965. doi: 10.1161/01.CIR.0000126594.79136.61.

114. O'Neill JF, Deakin CD. Do we hyperventilate cardiac arrest patients? Resuscitation. 2007;73:82–85. doi: 10.1016/j.resuscitation.2006.09.012.

115. Sanders AB, Kern KB, Berg RA, Hilwig RW, Heidenrich J, Ewy GA. Survival and neurologic outcome after cardiopulmonary resuscitation with four differ- ent chest compression-ventilation ratios. Ann Emerg Med. 2002;40:553–562.

116. Aufderheide TP, Lurie KG. Death by hyperventilation: a common and life-threatening problem during cardiopulmonary resuscitation. Crit Care Med. 2004;32(9 suppl):S345–S351.

117. Yannopoulos D, Sigurdsson G, McKnite S, Benditt D, Lurie KG. Reducing ventilation frequency combined with an inspiratory impedance device improves CPR efficiency in swine model of cardiac arrest. Resuscitation. 2004;61:75–82. doi: 10.1016/j.resuscitation.2003.12.006.

118. Yannopoulos D, Aufderheide TP, Gabrielli A, Beiser DG, McKnite SH, Pirrallo RG, Wigginton J, Becker L, Vanden Hoek T, Tang W, Nadkarni VM, Klein JP, Idris AH, Lurie KG. Clinical and hemodynamic compari- son of 15:2 and 30:2 compression-to-ventilation ratios for cardiopulmo- nary resuscitation. Crit Care Med. 2006;34:1444–1449. doi: 10.1097/01. CCM.0000216705.83305.99.

119. Hayes MM, Ewy GA, Anavy ND, Hilwig RW, Sanders AB, Berg RA, Otto CW, Kern KB. Continuous passive oxygen insufflation results in a similar outcome to positive pressure ventilation in a swine model of out- of-hospital ventricular fibrillation. Resuscitation. 2007;74:357–365. doi: 10.1016/j.resuscitation.2007.01.004.

120. Cavus E, Meybohm P, Bein B, Steinfath M, Pöppel A, Wenzel V, Scholz J, Dörges V. Impact of different compression-ventilation ratios during basic life support cardiopulmonary resuscitation. Resuscitation. 2008;79:118– 124. doi: 10.1016/j.resuscitation.2008.04.015.

121. Hwang SO, Kim SH, Kim H, Jang YS, Zhao PG, Lee KH, Choi HJ, Shin TY. Comparison of 15:1, 15:2, and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation in a canine model of a simu- lated, witnessed cardiac arrest. Acad Emerg Med. 2008;15:183–189. doi: 10.1111/j.1553-2712.2008.00026.x.

122. Gazmuri RJ, Ayoub IM, Radhakrishnan J, Motl J, Upadhyaya MP. Clinically plausible hyperventilation does not exert adverse hemodynamic effects during CPR but markedly reduces end-tidal PCO2. Resuscitation. 2012;83:259–264. doi: 10.1016/j.resuscitation.2011.07.034.

123. Kill C, Hahn O, Dietz F, Neuhaus C, Schwarz S, Mahling R, Wallot P, Jerrentrup A, Steinfeldt T, Wulf H, Dersch W. Mechanical ventilation during cardiopulmonary resuscitation with intermittent positive-pressure ventilation, bilevel ventilation, or chest compression synchronized ven- tilation in a pig model. Crit Care Med. 2014;42:e89–e95. doi: 10.1097/ CCM.0b013e3182a63fa0.

124. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resusci- tation during in-hospital cardiac arrest. JAMA. 2005;293:305–310. doi: 10.1001/jama.293.3.305.

125. Weiss SJ, Ernst AA, Jones R, Ong M, Filbrun T, Augustin C, Barnum M, Nick TG. Automatic transport ventilator versus bag valve in the EMS setting: a prospective, randomized trial. South Med J. 2005;98:970–976.

126. Johannigman JA, Branson RD, Johnson DJ, Davis K Jr., Hurst JM. Out-of-hospital ventilation: bag-valve device vs transport ventilator. Acad Emerg Med. 1995;2:719–724.

127. Rea TD, Cook AJ, Stiell IG, Powell J, Bigham B, Callaway CW, Chugh S, Aufderheide TP, Morrison L, Terndrup TE, Beaudoin T, Wittwer L, Davis D, Idris A, Nichol G. Predicting survival after out-of-hospital cardiac arrest: role of the Utstein data elements. Ann Emerg Med. 2010;55:249–257.

128. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes. 2010;3:63–81.

129. Agarwal DA, Hess EP, Atkinson EJ, White RD. Ventricular fibrillation in Rochester, Minnesota: experience over 18 years. Resuscitation. 2009;80:1253–1258.

130. Chan PS, Nichol G, Krumholz HM, Spertus JA, Nallamothu BK. Hospital variation in time to defibrillation after in-hospital cardiac arrest. Arch Intern Med. 2009;169:1265–1273.

131. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. N Engl J Med. 2002;347:1242–1247.

132. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. N Engl J Med. 2000;343:1206–1209.

133. Kudenchuk PJ, Cobb LA, Copass MK, Cummins RO, Doherty AM, Fahrenbruch CE, Hallstrom AP, Murray WA, Olsufka M, Walsh T. Amiodarone for resuscitation after out-of-hospital cardiac arrest due to ventricular fibrillation. N Engl J Med. 1999;341:871–878.

134. Vandycke C, Martens P. High dose versus standard dose epinephrine in cardiac arrest—a meta-analysis. Resuscitation. 2000;45:161–166.

135. Dorian P, Cass D, Schwartz B, Cooper R, Gelaznikas R, Barr A. Amiodarone as compared with lidocaine for shock-resistant ventricular fibrillation. N Engl J Med. 2002;346:884–890.

136. Stiell IG, Wells GA, Field B, Spaite DW, Nesbitt LP, De Maio VJ, Nichol G, Cousineau D, Blackburn J, Munkley D, Luinstra-Toohey L, Campeau T, Dagnone E, Lyver M. Advanced cardiac life support in out-of-hospital cardiac arrest. N Engl J Med. 2004;351:647–656.

137. Olasveengen TM, Sunde K, Brunborg C, Thowsen J, Steen PA, Wik L. Intravenous drug administration during out-of-hospital cardiac arrest: a randomized trial. JAMA. 2009;302:2222–2229.

138. Morrison LJ, Henry RM, Ku V, Nolan JP, Morley P, Deakin CD. Single-shock defibrillation success in adult cardiac arrest: a sys- tematic review. Resuscitation. 2013;84:1480–1486. doi: 10.1016/j. resuscitation.2013.07.008.

139. Hess EP, Russell JK, Liu PY, White RD. A high peak current 150-J fixed-energy defibrillation protocol treats recurrent ventricular fibrillation (VF) as effectively as initial VF. Resuscitation. 2008;79:28–33. doi: 10.1016/j.resuscitation.2008.04.028.

140. Koster RW, Walker RG, Chapman FW. Recurrent ventricular fibril- lation during advanced life support care of patients with prehospi- tal cardiac arrest. Resuscitation. 2008;78:252–257. doi: 10.1016/j. resuscitation.2008.03.231.

141. Hess EP, Agarwal D, Myers LA, Atkinson EJ, White RD. Performance of a rectilinear biphasic waveform in defibrillation of presenting and recurrent ventricular fibrillation: a prospective multicenter study. Resuscitation. 2011;82:685–689. doi: 10.1016/j.resuscitation.2011.02.008.

142. Jost D, Degrange H, Verret C, Hersan O, Banville IL, Chapman FW, Lank P, Petit JL, Fuilla C, Migliani R, Carpentier JP; DEFI 2005 Work Group. DEFI 2005: a randomized controlled trial of the effect of automated external defibrillator cardiopulmonary resuscitation pro- tocol on outcome from out-of-hospital cardiac arrest. Circulation. 2010;121:1614–1622. doi: 10.1161/CIRCULATIONAHA.109.878389.

143. Berdowski J, ten Haaf M, Tijssen JG, Chapman FW, Koster RW. Time in recurrent ventricular fibrillation and survival after out-of-hospital cardiac arrest. Circulation. 2010;122:1101–1108. doi: 10.1161/ CIRCULATIONAHA.110.958173.

144. Berdowski J, Tijssen JG, Koster RW. Chest compressions cause recurrence of ventricular fibrillation after the first successful conversion by defibrillation in out-of-hospital cardiac arrest. Circ Arrhythm Electrophysiol. 2010;3:72–78. doi: 10.1161/CIRCEP.109.902114.

145. Conover Z, Kern KB, Silver AE, Bobrow BJ, Spaite DW, Indik JH. Resumption of chest compressions after successful defibrillation and risk for recurrence of ventricular fibrillation in out-of-hospital cardiac arrest. Circ Arrhythm Electrophysiol. 2014;7:633–639. doi: 10.1161/CIRCEP.114.001506.

146. Hoogendijk MG, Schumacher CA, Belterman CN, Boukens BJ, Berdowski J, de Bakker JM, Koster RW, Coronel R. Ventricular fibrillation hampers the restoration of creatine-phosphate levels during simu- lated cardiopulmonary resuscitations. Europace. 2012;14:1518–1523. doi: 10.1093/europace/eus078.

147. Pytte M, Pedersen TE, Ottem J, Rokvam AS, Sunde K. Comparison of hands-off time during CPR with manual and semi-automatic defibrillation in a manikin model. Resuscitation. 2007;73:131–136.

148. Kramer-Johansen J, Edelson DP, Abella BS, Becker LB, Wik L, Steen PA. Pauses in chest compression and inappropriate shocks: a comparison of manual and semi-automatic defibrillation attempts. Resuscitation. 2007;73:212–220.

149. Eftestol T, Wik L, Sunde K, Steen PA. Effects of cardiopulmonary resuscitation on predictors of ventricular fibrillation defibrillation success during out-of-hospital cardiac arrest. Circulation. 2004;110:10–15.

150. Box MS, Watson JN, Addison PS, Clegg GR, Robertson CE. Shock outcome prediction before and after CPR: a comparative study of manual and automated active compression-decompression CPR. Resuscitation. 2008;78:265–274.

151. Brown CG, Dzwonczyk R, Martin DR. Physiologic measurement of the ventricular fibrillation ECG signal: estimating the duration of ventricular fibrillation. Ann Emerg Med. 1993;22:70–74.

152. Callaway CW, Sherman LD, Mosesso VN Jr., Dietrich TJ, Holt E, Clarkson MC. Scaling exponent predicts defibrillation success for out-of-hospital ventricular fibrillation cardiac arrest. Circulation. 2001;103:1656–1661.

153. Eftestol T, Sunde K, Aase SO, Husoy JH, Steen PA. Predicting outcome of defibrillation by spectral characterization and nonparametric classification of ventricular fibrillation in patients with out-of-hospital cardiac arrest. Circulation. 2000;102:1523–1529.

154. Eftestol T, Losert H, Kramer-Johansen J, Wik L, Sterz F, Steen PA. Independent evaluation of a defibrillation outcome predictor for out-of-hospital cardiac arrested patients. Resuscitation. 2005;67:55–61.

155. Gundersen K, Kvaloy JT, Kramer-Johansen J, Olasveengen TM, Eilevstjonn J, Eftestol T. Using within-patient correlation to improve the accuracy of shock outcome prediction for cardiac arrest. Resuscitation. 2008;78:46–51.

156. Gunderson EP. Breast-feeding and diabetes: long-term impact on mothers and their infants. Curr Diab Rep. 2008;8:279–286.

157. Gundersen K, Kvaloy JT, Kramer-Johansen J, Steen PA, Eftestol T. Development of the probability of return of spontaneous circulation in intervals without chest compressions during out-of-hospital cardiac arrest: an observational study. BMC Med. 2009;7:6.

158. Jekova I, Mougeolle F, Valance A. Defibrillation shock success estimation by a set of six parameters derived from the electrocardiogram. Physiol Meas. 2004;25:1179–1188.

159. Neurauter A, Eftestol T, Kramer-Johansen J, Abella BS, Sunde K, Wenzel V, Lindner KH, Eilevstjonn J, Myklebust H, Steen PA, Strohmenger HU. Prediction of countershock success using single features from multiple ventricular fibrillation frequency bands and feature combinations using neural networks. Resuscitation. 2007;73:253–263.

160. Olasveengen TM, Eftestol T, Gundersen K, Wik L, Sunde K. Acute ischemic heart disease alters ventricular fibrillation waveform characteristics in out-of hospital cardiac arrest. Resuscitation. 2009;80:412–417.

161.

Ristagno G, Gullo A, Berlot G, Lucangelo U, Geheb E, Bisera J. Prediction of successful defibrillation in human victims of out-of-hospital cardiac arrest: a retrospective electrocardiographic analysis. Anaesth Intensive Care. 2008;36:46–50.

162. Russell ME, Friedman MI, Mascioli SR, Stolz LE. Off-label use: an industry perspective on expanding use beyond approved indications. J Interv Cardiol. 2006;19:432–438.

163. Snyder DE, White RD, Jorgenson DB. Outcome prediction for guidance of initial resuscitation protocol: shock first or CPR first. Resuscitation. 2007;72:45–51.

164. Watson JN, Uchaipichat N, Addison PS, Clegg GR, Robertson CE, Eftestol T, Steen PA. Improved prediction of defibrillation success for out-of-hospital VF cardiac arrest using wavelet transform methods. Resuscitation. 2004;63:269–275.

165. Watson JN, Addison PS, Clegg GR, Steen PA, Robertson CE. Practical issues in the evaluation of methods for the prediction of shock outcome success in out-of-hospital cardiac arrest patients. Resuscitation. 2006;68:51–59.

166. Weaver WD, Cobb LA, Dennis D, Ray R, Hallstrom AP, Copass MK. Amplitude of ventricular fibrillation waveform and outcome after cardiac arrest. Ann Intern Med. 1985;102:53–55.

167. Yang Z, Lu W, Harrison RG, Eftestol T, Steen PA. A probabilistic neural network as the predictive classifier of out-of-hospital defibrillation outcomes. Resuscitation. 2005;64:31–36.

168. Jagric T, Marhl M, Stajer D, Kocjancic ST, Podbregar M, Perc M. Irregularity test for very short electrocardiogram (ECG) signals as a method for predicting a successful defibrillation in patients with ventricular fibrillation. Transl Res. 2007;149:145–151.

169. Strohmenger HU, Lindner KH, Brown CG. Analysis of the ventricular fibrillation ECG signal amplitude and frequency parameters as predictors of countershock success in humans. Chest. 1997;111:584–589.

170. Porter TR, Ornato JP, Guard CS, Roy VG, Burns CA, Nixon JV. Transesophageal echocardiography to assess mitral valve function and flow during cardiopulmonary resuscitation. Am J Cardiol. 1992;70:1056–1060.

171. Agostoni P, Cornelis K, Vermeersch P. Successful percutaneous treatment of an intraprocedural left main stent thrombosis with the support of an automatic mechanical chest compression device. Int J Cardiol. 2008;124:e19–e21.

172. Grogaard HK, Wik L, Eriksen M, Brekke M, Sunde K. Continuous mechanical chest compressions during cardiac arrest to facilitate restoration of coronary circulation with percutaneous coronary intervention. J Am Coll Cardiol. 2007;50:1093–1094.

173. Steen S, Sjoberg T, Olsson P, Young M. Treatment of out-of-hospital cardiac arrest with LUCAS, a new device for automatic mechanical compression and active decompression resuscitation. Resuscitation. 2005;67:25–30.

174. Larsen AI, Hjornevik AS, Ellingsen CL, Nilsen DW. Cardiac arrest with continuous mechanical chest compression during percutaneous coronary intervention. A report on the use of the LUCAS device. Resuscitation. 2007;75:454–459.

175. Wagner H, Terkelsen CJ, Friberg H, Harnek J, Kern K, Lassen JF, Olivecrona GK. Cardiac arrest in the catheterisation laboratory: a 5-year experience of using mechanical chest compressions to facilitate PCI during prolonged resuscitation efforts. Resuscitation. 2010;81:383–387.

176. Criley JM, Blaufuss AH, Kissel GL. Cough-induced cardiac compression: self-administered form of cardiopulmonary resuscitation. JAMA. 1976;236:1246–1250.

177. Criley JM, Blaufuss AH, Kissel GL. Self-administered cardiopulmonary resuscitation by cough-induced cardiac compression. Trans Am Clin Climatol Assoc. 1976;87:138–146.

178. Miller B, Lesnefsky E, Heyborne T, Schmidt B, Freeman K, Breckinridge S, Kelley K, Mann D, Reiter M. Cough-cardiopulmonary resuscitation in the cardiac catheterization laboratory: hemodynamics during an episode of prolonged hypotensive ventricular tachycardia. Cathet Cardiovasc Diagn. 1989;18:168–171.

179. Keeble W, Tymchak WJ. Triggering of the Bezold Jarisch Reflex by reperfusion during primary PCI with maintenance of consciousness by cough CPR: a case report and review of pathophysiology. J Invasive Cardiol. 2008;20:E239–E242.

180. Saba SE, David SW. Sustained consciousness during ventricular fibrillation: case report of cough cardiopulmonary resuscitation. Cathet Cardiovasc Diagn. 1996;37:47–48.

181. Bottiger BW, Arntz HR, Chamberlain DA, Bluhmki E, Belmans A, Danays T, Carli PA, Adgey JA, Bode C, Wenzel V. Thrombolysis during resuscitation for out-of-hospital cardiac arrest. N Engl J Med. 2008;359:2651–2662.

182. Kudenchuk PJ, Cobb LA, Copass MK, Cummins RO, Doherty AM, Fahrenbruch CE, Hallstrom AP, Murray WA, Olsufka M, Walsh T. Amiodarone for resuscitation after out-of-hospital cardiac arrest due to ventricular fibrillation. N Engl J Med. 1999;341:871–878. doi: 10.1056/ NEJM199909163411203.

183. Dorian P, Cass D, Schwartz B, Cooper R, Gelaznikas R, Barr A. Amiodarone as compared with lidocaine for shock-resistant ventricular fibrillation. N Engl J Med. 2002;346:884–890. doi: 10.1056/ NEJMoa013029.

184. Herlitz J, Ekström L, Wennerblom B, Axelsson A, Bång A, Lindkvist J, Persson NG, Holmberg S. Lidocaine in out-of-hospital ventricular fibril- lation. Does it improve survival? Resuscitation. 1997;33:199–205.

185. Harrison EE. Lidocaine in prehospital countershock refractory ventricu- lar fibrillation. Ann Emerg Med. 1981;10:420–423.

186. Markel DT, Gold LS, Allen J, Fahrenbruch CE, Rea TD, Eisenberg MS, Kudenchuk PJ. Procainamide and survival in ventricular fibrillation out-of-hospital cardiac arrest. Acad Emerg Med. 2010;17:617–623. doi: 10.1111/j.1553-2712.2010.00763.x.

187. Fatovich DM, Prentice DA, Dobb GJ. Magnesium in cardiac arrest (the magic trial). Resuscitation. 1997;35:237–241.

188. Allegra J, Lavery R, Cody R, Birnbaum G, Brennan J, Hartman A, Horowitz M, Nashed A, Yablonski M. Magnesium sulfate in the treatment of refractory ventricular fibrillation in the prehospital setting. Resuscitation. 2001;49:245–249.

189. Hassan TB, Jagger C, Barnett DB. A randomised trial to investigate the efficacy of magnesium sulphate for refractory ventricular fibrillation. Emerg Med J. 2002;19:57–62.

190. Thel MC, Armstrong AL, McNulty SE, Califf RM, O'Connor CM. Randomised trial of magnesium in in-hospital cardiac arrest. Duke Internal Medicine Housestaff. Lancet. 1997;350:1272–1276.

191. Skrifvars MB, Pettilä V, Rosenberg PH, Castrén M. A multiple logistic regression analysis of in-hospital factors related to survival at six months in patients resuscitated from out-of-hospital ventricular fibrillation. Resuscitation. 2003;59:319–328.

192. Sadowski ZP, Alexander JH, Skrabucha B, Dyduszynski A, Kuch J, Nartowicz E, Swiatecka G, Kong DF, Granger CB. Multicenter random- ized trial and a systematic overview of lidocaine in acute myocardial infarction. Am Heart J. 1999;137:792–798.

193. Teo KK, Yusuf S, Furberg CD. Effects of prophylactic antiarrhythmic drug therapy in acute myocardial infarction. An overview of results from randomized controlled trials. JAMA. 1993;270:1589–1595.

194. Kudenchuk PJ, Newell C, White L, Fahrenbruch C, Rea T, Eisenberg M. Prophylactic lidocaine for post resuscitation care of patients with out-of-hospital ventricular fibrillation cardiac arrest. Resuscitation. 2013;84:1512–1518. doi: 10.1016/j.resuscitation.2013.05.022.

195. Jacobs IG, Finn JC, Jelinek GA, Oxer HF, Thompson PL. Effect of adrenaline on survival in out-of-hospital cardiac arrest: A randomised double-blind placebo-controlled trial. Resuscitation. 2011;82:1138– 1143. doi: 10.1016/j.resuscitation.2011.06.029.

196. Hagihara A, Hasegawa M, Abe T, Nagata T, Wakata Y, Miyazaki S. Prehospital epinephrine use and survival among patients with out- of- hospital cardiac arrest. JAMA. 2012;307:1161–1168. doi: 10.1001/ jama.2012.294.

197. Machida M, Miura S, Matsuo K, Ishikura H, Saku K. Effect of intrave- nous adrenaline before arrival at the hospital in out-of-hospital cardiac arrest. J Cardiol. 2012;60:503–507. doi: 10.1016/j.jjcc.2012.07.001.

198. Callaham M, Madsen CD, Barton CW, Saunders CE, Pointer J. A randomized clinical trial of high-dose epinephrine and norepineph- rine vs standard-dose epinephrine in prehospital cardiac arrest. JAMA. 1992;268:2667–2672.

199. Gueugniaud PY, Mols P, Goldstein P, Pham E, Dubien PY, Deweerdt C, Vergnion M, Petit P, Carli P. A comparison of repeated high doses and repeated standard doses of epinephrine for cardiac arrest out- side the hospital. European Epinephrine Study Group. N Engl J Med. 1998;339:1595–1601. doi: 10.1056/NEJM199811263392204.

200. Brown CG, Martin DR, Pepe PE, Stueven H, Cummins RO, Gonzalez E, Jastremski M. A comparison of standard-dose and high-dose epineph- rine in cardiac arrest outside the hospital. The Multicenter High-Dose Epinephrine Study Group. N Engl J Med. 1992;327:1051–1055. doi: 10.1056/NEJM199210083271503.

201. Sherman BW, Munger MA, Foulke GE, Rutherford WF, Panacek EA. High-dose versus standard-dose epinephrine treatment of car- diac arrest after failure of standard therapy. Pharmacotherapy. 1997;17:242–247.

202. Stiell IG, Hebert PC, Weitzman BN, Wells GA, Raman S, Stark RM, Higginson LA, Ahuja J, Dickinson GE. High-dose epinephrine in adult cardiac arrest. N Engl J Med. 1992;327:1045–1050. doi: 10.1056/ NEJM199210083271502.

203. Choux C, Gueugniaud PY, Barbieux A, Pham E, Lae C, Dubien PY, Petit P. Standard doses versus repeated high doses of epinephrine in cardiac arrest outside the hospital. Resuscitation. 1995;29:3–9.

204. Maturi MF, Martin SE, Markle D, Maxwell M, Burruss CR, Speir E, Greene R, Ro YM, Vitale D, Green MV. Coronary vasoconstric- tion induced by vasopressin. Production of myocardial ischemia in dogs by constriction of nondiseased small vessels. Circulation. 1991;83:2111–2121.

205. Asfar P, Radermacher P. Vasopressin and ischaemic heart disease: more than coronary vasoconstriction? Crit Care. 2009;13:169. doi: 10.1186/cc7954.

206. Feng JJ, Arendshorst WJ. Enhanced renal vasoconstriction induced by vasopressin in SHR is mediated by V1 receptors. Am J Physiol. 1996;271(2 pt 2):F304–F313.

207.

Mukoyama T, Kinoshita K, Nagao K, Tanjoh K. Reduced effective- ness of vasopressin in repeated doses for patients undergoing prolonged cardiopulmonary resuscitation. Resuscitation. 2009;80:755–761. doi: 10.1016/j.resuscitation.2009.04.005.

208. Gueugniaud PY, David JS, Chanzy E, Hubert H, Dubien PY, Mauriaucourt P, Bragança C, Billères X, Clotteau-Lambert MP, Fuster P, Thiercelin D, Debaty G, Ricard-Hibon A, Roux P, Espesson C, Querellou E, Ducros L, Ecollan P, Halbout L, Savary D, Guillaumée F, Maupoint R, Capelle P, Bracq C, Dreyfus P, Nouguier P, Gache A, Meurisse C, Boulanger B, Lae C, Metzger J, Raphael V, Beruben A, Wenzel V, Guinhouya C, Vilhelm C, Marret E. Vasopressin and epinephrine vs. epinephrine alone in cardiopulmonary resuscitation. N Engl J Med. 2008;359:21–30. doi: 10.1056/NEJMoa0706873.

209. Ong ME, Tiah L, Leong BS, Tan EC, Ong VY, Tan EA, Poh BY, Pek PP, Chen Y. A randomised, double-blind, multi-centre trial comparing vasopressin and adrenaline in patients with cardiac arrest presenting to or in the Emergency Department. Resuscitation. 2012;83:953–960. doi: 10.1016/j.resuscitation.2012.02.005.

210. Wenzel V, Krismer AC, Arntz HR, Sitter H, Stadlbauer KH, Lindner KH; European Resuscitation Council Vasopressor during Cardiopulmonary Resuscitation Study Group. A comparison of vasopressin and epineph- rine for out-of-hospital cardiopulmonary resuscitation. N Engl J Med. 2004;350:105–113. doi: 10.1056/NEJMoa025431.

211. Ducros L, Vicaut E, Soleil C, Le Guen M, Gueye P, Poussant T, Mebazaa A, Payen D, Plaisance P. Effect of the addition of vasopressin or vasopressin plus nitroglycerin to epinephrine on arterial blood pres- sure during cardiopulmonary resuscitation in humans. J Emerg Med. 2011;41:453–459. doi: 10.1016/j.jemermed.2010.02.030.

212. Lindner KH, Dirks B, Strohmenger HU, Prengel AW, Lindner IM, Lurie KG. Randomised comparison of epinephrine and vasopressin in patients with out-of-hospital ventricular fibrillation. Lancet. 1997;349:535–537. doi: 10.1016/S0140-6736(97)80087-6.

213. Callaway CW, Hostler D, Doshi AA, Pinchalk M, Roth RN, Lubin J, Newman DH, Kelly LJ. Usefulness of vasopressin administered with epinephrine during out-of-hospital cardiac arrest. Am J Cardiol. 2006;98:1316–1321. doi: 10.1016/j.amjcard.2006.06.022.

214. Donnino MW, Salciccioli JD, Howell MD, Cocchi MN, Giberson B, Berg K, Gautam S, Callaway C; American Heart Association's Get With The Guidelines-Resuscitation Investigators. Time to administration of epinephrine and outcome after in-hospital cardiac arrest with non-shock- able rhythms: retrospective analysis of large in-hospital data registry. BMJ. 2014;348:g3028.

215. Goto Y, Maeda T, Goto Y. Effects of prehospital epinephrine during out- of-hospital cardiac arrest with initial non-shockable rhythm: an observa- tional cohort study. Crit Care. 2013;17:R188. doi: 10.1186/cc12872.

216. Nakahara S, Tomio J, Nishida M, Morimura N, Ichikawa M, Sakamoto T. Association between timing of epinephrine administration and intact neurologic survival following out-of-hospital cardiac arrest in Japan: a population-based prospective observational study. Acad Emerg Med. 2012;19:782–792. doi: 10.1111/j.1553-2712.2012.01387.x.

217. Koscik C, Pinawin A, McGovern H, Allen D, Media DE, Ferguson T, Hopkins W, Sawyer KN, Boura J, Swor R. Rapid epineph- rine administration improves early outcomes in out-of-hospital cardiac arrest. Resuscitation. 2013;84:915–920. doi: 10.1016/j.resuscitation.2013.03.023.

218. Hayashi Y, Iwami T, Kitamura T, Nishiuchi T, Kajino K, Sakai T, Nishiyama C, Nitta M, Hiraide A, Kai T. Impact of early intravenous epinephrine administration on outcomes following out-of-hospital cardiac arrest. Circ J. 2012;76:1639–1645.

219. Cantrell CL Jr, Hubble MW, Richards ME. Impact of delayed and infrequent administration of vasopressors on return of spontaneous circulation during out-of-hospital cardiac arrest. Prehosp Emerg Care. 2013;17:15–22. doi: 10.3109/10903127.2012.702193.

220. Mentzelopoulos SD, Zakynthinos SG, Tzoufi M, Katsios N, Papastylianou A, Gkisioti S, Stathopoulos A, Kollintza A, Stamataki E, Roussos C. Vasopressin, epinephrine, and corticosteroids for in- hospital cardiac arrest. Arch Intern Med. 2009;169:15–24. doi: 10.1001/ archinternmed.2008.509.

221. Mentzelopoulos SD, Malachias S, Chamos C, Konstantopoulos D, Ntaidou T, Papastylianou A, Kolliantzaki I, Theodoridi M, Ischaki H, Makris D, Zakynthinos E, Zintzaras E, Sourlas S, Aloizos S, Zakynthinos SG. Vasopressin, steroids, and epinephrine and neurologically favor- able survival after in-hospital cardiac arrest: a randomized clinical trial. JAMA. 2013;310:270–279. doi: 10.1001/jama.2013.7832.

222. Paris PM, Stewart RD, Deggler F. Prehospital use of dexamethasone in pulseless idioventricular rhythm. Ann Emerg Med. 1984;13:1008–1010.

223. Tsai MS, Huang CH, Chang WT, Chen WJ, Hsu CY, Hsieh CC, Yang CW, Chiang WC, Ma MH, Chen SC. The effect of hydrocortisone on the outcome of out-of-hospital cardiac arrest patients: a pilot study. Am J Emerg Med. 2007;25:318–325. doi: 10.1016/j.ajem.2006.12.007.

224. Wenzel V, Lindner KH, Krismer AC, Miller EA, Voelckel WG, Lingnau W. Repeated administration of vasopressin but not epinephrine maintains coronary perfusion pressure after early and late administration during prolonged cardiopulmonary resuscitation in pigs. Circulation. 1999;99:1379–1384.

225. Rittenberger JC, Menegazzi JJ, Callaway CW. Association of delay to first intervention with return of spontaneous circulation in a swine model of cardiac arrest. Resuscitation. 2007;73:154–160.

226. Emerman CL, Pinchak AC, Hancock D, Hagen JF. The effect of bolus injection on circulation times during cardiac arrest. Am J Emerg Med. 1990;8:190–193.

227. Banerjee S, Singhi SC, Singh S, Singh M. The intraosseous route is a suitable alternative to intravenous route for fluid resuscitation in severely dehydrated children. Indian Pediatr. 1994;31:1511–1520.

228. Brickman KR, Krupp K, Rega P, Alexander J, Guinness M. Typing and screening of blood from intraosseous access. Ann Emerg Med. 1992;21:414–417.

229. Fiser RT, Walker WM, Seibert JJ, McCarthy R, Fiser DH. Tibial length following intraosseous infusion: a prospective, radiographic analysis. Pediatr Emerg Care. 1997;13:186–188.

230. Ummenhofer W, Frei FJ, Urwyler A, Drewe J. Are laboratory values in bone marrow aspirate predictable for venous blood in paediatric patients? Resuscitation. 1994;27:123–128.

231. Glaeser PW, Hellmich TR, Szewczuga D, Losek JD, Smith DS. Five-year experience in prehospital intraosseous infusions in children and adults. Ann Emerg Med. 1993;22:1119–1124.

232. Guy J, Haley K, Zuspan SJ. Use of intraosseous infusion in the pediatric trauma patient. J Pediatr Surg. 1993;28:158–161.

233. Macnab A, Christenson J, Findlay J, Horwood B, Johnson D, Jones L, Phillips K, Pollack C Jr., Robinson DJ, Rumball C, Stair T, Tiffany B, Whelan M. A new system for sternal intraosseous infusion in adults. Prehosp Emerg Care. 2000;4:173–177.

234. Ellemunter H, Simma B, Trawoger R, Maurer H. Intraosseous lines in preterm and full term neonates. Arch Dis Child Fetal Neonatal Ed. 1999;80:F74–F75.

235. Mader TJ, Kellogg AR, Walterscheid JK, Lodding CC, Sherman LD. A randomized comparison of cardiocerebral and cardiopulmonary resuscitation using a swine model of prolonged ventricular fibrillation. Resuscitation. 2010;81:596–602.

236. Barsan WG, Levy RC, Weir H. Lidocaine levels during CPR: differences after peripheral venous, central venous, and intracardiac injections. Ann Emerg Med. 1981;10:73–78.

237. Kuhn GJ, White BC, Swetnam RE, Mumey JF, Rydesky MF, Tintinalli JE, Krome RL, Hoehner PJ. Peripheral vs central circulation times during CPR: a pilot study. Ann Emerg Med. 1981;10:417–419.

238. Emerman CL, Pinchak AC, Hancock D, Hagen JF. Effect of injection site on circulation times during cardiac arrest. Crit Care Med. 1988;16:1138–1141.

239. Paradis NA, Martin GB, Rivers EP, Goetting MG, Appleton TJ, Feingold M, Nowak RM. Coronary perfusion pressure and the return of spontaneous circulation in human cardiopulmonary resuscitation. JAMA. 1990;263:1106–1113.

240. Rivers EP, Martin GB, Smithline H, Rady MY, Schultz CH, Goetting MG, Appleton TJ, Nowak RM. The clinical implications of continuous central venous oxygen saturation during human CPR. Ann Emerg Med. 1992;21:1094–1101.

241. Howard RF, Bingham RM. Endotracheal compared with intravenous administration of atropine. Arch Dis Child. 1990;65:449–450.

242. Lee PL, Chung YT, Lee BY, Yeh CY, Lin SY, Chao CC. The optimal dose of atropine via the endotracheal route. Ma Zui Xue Za Zhi. 1989;27:35–38.

243. Prengel AW, Lindner KH, Hahnel J, Ahnefeld FW. Endotracheal and endobronchial lidocaine administration: effects on plasma lidocaine concentration and blood gases. Crit Care Med. 1991;19:911–915.

244. Schmidbauer S, Kneifel HA, Hallfeldt KK. Endobronchial application of high dose epinephrine in out of hospital cardiopulmonary resuscitation. Resuscitation. 2000;47:89.

245. Raymondos K, Panning B, Leuwer M, Brechelt G, Korte T, Niehaus M, Tebbenjohanns J, Piepenbrock S. Absorption and hemodynamic effects of airway administration of adrenaline in patients with severe cardiac disease. Ann Intern Med. 2000;132:800–803.

246. Hahnel JH, Lindner KH, Schurmann C, Prengel A, Ahnefeld FW. Plasma lidocaine levels and PaO2 with endobronchial administration: dilution with normal saline or distilled water? Ann Emerg Med. 1990;19:1314–1317.

247. Brown LK, Diamond J. The efficacy of lidocaine in ventricular fibrillation due to coronary artery ligation: endotracheal vs intravenous use. Proc West Pharmacol Soc. 1982;25:43–45.

248. Jasani MS, Nadkarni VM, Finkelstein MS, Hofmann WT, Salzman SK. Inspiratory-cycle instillation of endotracheal epinephrine in porcine arrest. Acad Emerg Med. 1994;1:340–345.

249. Wenzel V, Lindner KH, Prengel AW, Lurie KG, Strohmenger HU. Endobronchial vasopressin improves survival during cardiopulmonary resuscitation in pigs. Anesthesiology. 1997;86:1375–1381.

250. Prengel AW, Rembecki M, Wenzel V, Steinbach G. A comparison of the endotracheal tube and the laryngeal mask airway as a route for endobronchial lidocaine administration. Anesth Analg. 2001;92:1505–1509.

251.

Jasani MS, Nadkarni VM, Finkelstein MS, Mandell GA, Salzman SK, Norman ME. Effects of different techniques of endotracheal epinephrine administration in pediatric porcine hypoxic-hypercarbic cardiopulmonary arrest. Crit Care Med. 1994;22:1174–1180.

252. Johnston C. Endotracheal drug delivery. Pediatr Emerg Care. 1992;8:94–97.

253. Efrati O, Ben-Abraham R, Barak A, Modan-Moses D, Augarten A, Manisterski Y, Barzilay Z, Paret G. Endobronchial adrenaline: should it be reconsidered? Dose response and haemodynamic effect in dogs. Resuscitation. 2003;59:117–122.

254. Elizur A, Ben-Abraham R, Manisterski Y, Barak A, Efrati O, Lotan D, Barzilay Z, Paret G. Tracheal epinephrine or norepinephrine preceded by beta blockade in a dog model. Can beta blockade bestow any benefits? Resuscitation. 2003;59:271–276.

255. Niemann JT, Stratton SJ, Cruz B, Lewis RJ. Endotracheal drug administration during out-of-hospital resuscitation: where are the survivors? Resuscitation. 2002;53:153–157.

256. Schuttler J, Bartsch A, Ebeling BJ, Hornchen U, Kulka P, Suhling B, Stoeckel H. [Endobronchial administration of adrenaline in preclinical cardiopulmonary resuscitation]. Anasth Intensivther Notfallmed. 1987;22:63–68.

257. Hornchen U, Schuttler J, Stoeckel H, Eichelkraut W, Hahn N. Endobronchial instillation of epinephrine during cardiopulmonary resuscitation. Crit Care Med. 1987;15:1037–1039.

258. Naganobu K, Hasebe Y, Uchiyama Y, Hagio M, Ogawa H. A comparison of distilled water and normal saline as diluents for endobronchial administration of epinephrine in the dog. Anesth Analg. 2000;91:317–321.

259. Ahrens T, Schallom L, Bettorf K, Ellner S, Hurt G, O'Mara V, Ludwig J, George W, Marino T, Shannon W. End-tidal carbon dioxide measure- ments as a prognostic indicator of outcome in cardiac arrest. Am J Crit Care. 2001;10:391–398.

260. Chen YS, Lin JW, Yu HY, Ko WJ, Jerng JS, Chang WT, Chen WJ, Huang SC, Chi NH, Wang CH, Chen LC, Tsai PR, Wang SS, Hwang JJ, Lin FY. Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in- hospital cardiac arrest: an observational study and propensity analysis. Lancet. 2008;372:554–561. doi: 10.1016/S0140-6736(08)60958-7.

261. Shin TG, Choi JH, Jo IJ, Sim MS, Song HG, Jeong YK, Song YB, Hahn JY, Choi SH, Gwon HC, Jeon ES, Sung K, Kim WS, Lee YT. Extracorporeal cardiopulmonary resuscitation in patients with inhospital cardiac arrest: A comparison with conventional cardiopulmonary resuscitation. Crit Care Med. 2011;39:1–7. doi: 10.1097/CCM.0b013e3181feb339.

262. Lin JW, Wang MJ, Yu HY, Wang CH, Chang WT, Jerng JS, Huang SC, Chou NK, Chi NH, Ko WJ, Wang YC, Wang SS, Hwang JJ, Lin FY, Chen YS. Comparing the survival between extracorporeal rescue and conventional resuscitation in adult in-hospital cardiac arrests: propen- sity analysis of three-year data. Resuscitation. 2010;81:796–803. doi: 10.1016/j.resuscitation.2010.03.002.

263. Maekawa K, Tanno K, Hase M, Mori K, Asai Y. Extracorporeal cardio- pulmonary resuscitation for patients with out-of-hospital cardiac arrest of cardiac origin: a propensity-matched study and predictor analysis. Crit Care Med. 2013;41:1186–1196. doi: 10.1097/CCM.0b013e31827ca4c8.

264. Sakamoto T, Morimura N, Nagao K, Asai Y, Yokota H, Nara S, Hase M, Tahara Y, Atsumi T; SAVE-J Study Group. Extracorporeal cardio- pulmonary resuscitation versus conventional cardiopulmonary resus- citation in adults with out-of-hospital cardiac arrest: a prospective observational study. Resuscitation. 2014;85:762–768. doi: 10.1016/j. resuscitation.2014.01.031.

265. Brown DC, Lewis AJ, Criley JM. Asystole and its treatment: the possible role of the parasympathetic nervous system in cardiac arrest. JACEP. 1979;8:448–452.

266. Sorensen M, Engbaek J, Viby-Mogensen J, Guldager H, Molke Jensen F. Bradycardia and cardiac asystole following a single injection of suxamethonium. Acta Anaesthesiol Scand. 1984;28:232–235.

267. Lovstad RZ, Granhus G, Hetland S. Bradycardia and asystolic cardiac arrest during spinal anaesthesia: a report of five cases. Acta Anaesthesiol Scand. 2000;44:48–52.

268. Stueven HA, Tonsfeldt DJ, Thompson BM, Whitcomb J, Kastenson E, Aprahamian C. Atropine in asystole: human studies. Ann Emerg Med. 1984;13:815–817.

269. Coon GA, Clinton JE, Ruiz E. Use of atropine for brady-asystolic prehospital cardiac arrest. Ann Emerg Med. 1981;10:462–467.

270. Tortolani AJ, Risucci DA, Powell SR, Dixon R. In-hospital cardiopulmonary resuscitation during asystole. Therapeutic factors associated with 24-hour survival. Chest. 1989;96:622–626.

271. Stiell IG, Wells GA, Hebert PC, Laupacis A, Weitzman BN. Association of drug therapy with survival in cardiac arrest: limited role of advanced cardiac life support drugs. Acad Emerg Med. 1995;2:264–273.

272. Engdahl J, Bang A, Lindqvist J, Herlitz J. Can we define patients with no and those with some chance of survival when found in asystole out of hospital? Am J Cardiol. 2000;86:610–614.

273. Engdahl J, Bang A, Lindqvist J, Herlitz J. Factors affecting short- and long-term prognosis among 1069 patients with out-of-hospital cardiac arrest and pulseless electrical activity. Resuscitation. 2001;51:17–25.

274. van Walraven C, Stiell IG, Wells GA, Hebert PC, Vandemheen K. Do advanced cardiac life support drugs increase resuscitation rates from in-hospital cardiac arrest? The OTAC Study Group. Ann Emerg Med. 1998;32:544–553.

275. Bar-Joseph G, Abramson NS, Kelsey SF, Mashiach T, Craig MT, Safar P. Improved resuscitation outcome in emergency medical systems with increased usage of sodium bicarbonate during cardiopulmonary resuscitation. Acta Anaesthesiol Scand. 2005;49:6–15.

276. Weaver WD, Fahrenbruch CE, Johnson DD, Hallstrom AP, Cobb LA, Copass MK. Effect of epinephrine and lidocaine therapy on outcome after cardiac arrest due to ventricular fibrillation. Circulation. 1990;82:2027–2034.

277. Dybvik T, Strand T, Steen PA. Buffer therapy during out-of-hospital cardiopulmonary resuscitation. Resuscitation. 1995;29:89–95.

278. Vukmir RB, Katz L. Sodium bicarbonate improves outcome in prolonged prehospital cardiac arrest. Am J Emerg Med. 2006;24:156–161.

279. Aufderheide TP, Martin DR, Olson DW, Aprahamian C, Woo JW, Hendley GE, Hargarten KM, Thompson B. Prehospital bicarbonate use in cardiac arrest: a 3-year experience. Am J Emerg Med. 1992;10:4–7.

280. Skovron ML, Goldberg E, Suljaga-Petchel K. Factors predicting survival for six months after cardiopulmonary resuscitation: multivariate analysis of a prospective study. Mt Sinai J Med. 1985;52:271–275.

281. Delooz HH, Lewi PJ. Are inter-center differences in EMS-management and sodium-bicarbonate administration important for the outcome of CPR? The Cerebral Resuscitation Study Group. Resuscitation. 1989; 17 suppl:S161–S172; discussion S199–S206.

282. Roberts D, Landolfo K, Light R, Dobson K. Early predictors of mortality for hospitalized patients suffering cardiopulmonary arrest. Chest. 1990;97:413–419.

283. Kette F, Weil MH, Gazmuri RJ. Buffer solutions may compromise cardiac resuscitation by reducing coronary perfusion presssure. JAMA. 1991;266:2121–2126.

284. Graf H, Leach W, Arieff AI. Evidence for a detrimental effect of bicarbonate therapy in hypoxic lactic acidosis. Science. 1985;227:754–756.

285. Katz LM, Wang Y, Rockoff S, Bouldin TW. Low-dose Carbicarb improves cerebral outcome after asphyxial cardiac arrest in rats. Ann Emerg Med. 2002;39:359–365.

286. Sun S, Weil MH, Tang W, Fukui M. Effects of buffer agents on postresuscitation myocardial dysfunction. Crit Care Med. 1996;24:2035–2041.

287. Blecic S, De Backer D, Deleuze M, Vachiery JL, Vincent JL. Correction of metabolic acidosis in experimental CPR: a comparative study of sodium bicarbonate, carbicarb, and dextrose. Ann Emerg Med. 1991;20:235–238.

288. Stueven HA, Thompson BM, Aprahamian C, Tonsfeldt DJ. Calcium chloride: reassessment of use in asystole. Ann Emerg Med. 1984;13:820–822.

289. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. The effectiveness of calcium chloride in refractory electromechanical dissociation. Ann Emerg Med. 1985;14:626–629.

290. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. Lack of effectiveness of calcium chloride in refractory asystole. Ann Emerg Med. 1985;14:630–632.

291. Gando S, Tedo I, Tujinaga H, Kubota M. Variation in serum ionized calcium on cardiopulmonary resuscitation. J Anesth. 1988;2:154–160.

292. Stueven H, Thompson BM, Aprahamian C, Darin JC. Use of calcium in prehospital cardiac arrest. Ann Emerg Med. 1983;12:136–139.

293. Harrison EE, Amey BD. The use of calcium in cardiac resuscitation. Am J Emerg Med. 1983;1:267–273.

294. Bottiger BW, Bode C, Kern S, Gries A, Gust R, Glatzer R, Bauer H, Motsch J, Martin E. Efficacy and safety of thrombolytic therapy after initially unsuccessful cardiopulmonary resuscitation: a prospective clinical trial. Lancet. 2001;357:1583–1585.

295. Kurkciyan I, Meron G, Sterz F, Janata K, Domanovits H, Holzer M, Berzlanovich A, Bankl HC, Laggner AN. Pulmonary embolism as a cause of cardiac arrest: presentation and outcome. Arch Intern Med. 2000;160:1529–1535.

296. Janata K, Holzer M, Kurkciyan I, Losert H, Riedmuller E, Pikula B, Laggner AN, Laczika K. Major bleeding complications in cardiopulmonary resuscitation: the place of thrombolytic therapy in cardiac arrest due to massive pulmonary embolism. Resuscitation. 2003;57:49–55.

297. Lederer W, Lichtenberger C, Pechlaner C, Kroesen G, Baubin M. Recombinant tissue plasminogen activator during cardiopulmonary resuscitation in 108 patients with out-of-hospital cardiac arrest. Resuscitation. 2001;50:71–76.

298. Bozeman WP, Kleiner DM, Ferguson KL. Empiric tenecteplase is associated with increased return of spontaneous circulation and short term survival in cardiac arrest patients unresponsive to standard interventions. Resuscitation. 2006;69:399–406.

299. Stadlbauer KH, Krismer AC, Arntz HR, Mayr VD, Lienhart HG, Bottiger BW, Jahn B, Lindner KH, Wenzel V. Effects of thrombolysis during out-of-hospital cardiopulmonary resuscitation. Am J Cardiol. 2006;97:305–308.

300. Fatovich DM, Dobb GJ, Clugston RA. A pilot randomised trial of thrombolysis in cardiac arrest (the TICA trial). Resuscitation. 2004;61:309–313.

301. Abu-Laban RB, Christenson JM, Innes GD, van Beek CA, Wanger KP, McKnight RD, MacPhail IA, Puskaric J, Sadowski RP, Singer J, Schechter MT, Wood VM. Tissue plasminogen activator in cardiac arrest with pulseless electrical activity. N Engl J Med. 2002;346:1522–1528.

302. Bender R, Breil M, Heister U, Dahmen A, Hoeft A, Krep H, Fischer M. Hypertonic saline during CPR: feasibility and safety of a new protocol of fluid management during resuscitation. Resuscitation. 2007;72:74–81.

303. Breil M, Krep H, Sinn D, Hagendorff A, Dahmen A, Eichelkraut W, Hoeft A, Fischer M. Hypertonic saline improves myocardial blood flow during CPR, but is not enhanced further by the addition of hydroxy ethyl starch. Resuscitation. 2003;56:307–317.

304. Bruel C, Parienti JJ, Marie W, Arrot X, Daubin C, Du Cheyron D, Massetti M, Charbonneau P. Mild hypothermia during advanced life support: a preliminary study in out-of-hospital cardiac arrest. Crit Care. 2008;12:R31.

305. D'Alecy LG, Lundy EF, Barton KJ, Zelenock GB. Dextrose containing intravenous fluid impairs outcome and increases death after eight minutes of cardiac arrest and resuscitation in dogs. Surgery. 1986;100:505–511.

306. Fischer M, Dahmen A, Standop J, Hagendorff A, Hoeft A, Krep H. Effects of hypertonic saline on myocardial blood flow in a porcine model of prolonged cardiac arrest. Resuscitation. 2002;54:269–280.

307. Kamarainen A, Virkkunen I, Tenhunen J, Yli-Hankala A, Silfvast T. Prehospital induction of therapeutic hypothermia during CPR: a pilot study. Resuscitation. 2008;76:360–363.

308. Krep H, Breil M, Sinn D, Hagendorff A, Hoeft A, Fischer M. Effects of hypertonic versus isotonic infusion therapy on regional cerebral blood flow after experimental cardiac arrest cardiopulmonary resuscitation in pigs. Resuscitation. 2004;63:73–83.

309. Longstreth WT Jr., Copass MK, Dennis LK, Rauch-Matthews ME, Stark MS, Cobb LA. Intravenous glucose after out-of-hospital cardiopulmonary arrest: a community-based randomized trial. Neurology. 1993;43:2534–2541.

310. Miclescu A, Basu S, Wiklund L. Methylene blue added to a hypertonic-hyperoncotic solution increases short-term survival in experimental cardiac arrest. Crit Care Med. 2006;34:2806–2813.

311. Nordmark J, Rubertsson S. Induction of mild hypothermia with infusion of cold (4 degrees C) fluid during ongoing experimental CPR. Resuscitation. 2005;66:357–365.

312. Nozari A, Safar P, Stezoski SW, Wu X, Kostelnik S, Radovsky A, Tisherman S, Kochanek PM. Critical time window for intra-arrest cooling with cold saline flush in a dog model of cardiopulmonary resuscitation. Circulation. 2006;113:2690–2696.

313. Ujhelyi MR, Winecoff AP, Schur M, Frede T, Bottorff MB, Gabel M, Markel ML. Influence of hypertonic saline solution infusion on defibrillation efficacy. Chest. 1996;110:784–790.

314. Ditchey RV, Lindenfeld J. Potential adverse effects of volume loading on perfusion of vital organs during closed-chest resuscitation. Circulation. 1984;69:181–189.

315. Voorhees WD, Ralston SH, Kougias C, Schmitz PM. Fluid loading with whole blood or Ringer's lactate solution during CPR in dogs. Resuscitation. 1987;15:113–123.

316. Yannopoulos D, Zviman M, Castro V, Kolandaivelu A, Ranjan R, Wilson RF, Halperin HR. Intra-cardiopulmonary resuscitation hypothermia with and without volume loading in an ischemic model of cardiac arrest. Circulation. 2009;120:1426–1435.

317. Barthell E, Troiano P, Olson D, Stueven HA, Hendley G. Prehospital external cardiac pacing: a prospective, controlled clinical trial. Ann Emerg Med. 1988;17:1221–1226.

318. Cummins RO, Graves JR, Larsen MP, Hallstrom AP, Hearne TR, Ciliberti J, Nicola RM, Horan S. Out-of-hospital transcutaneous pacing by emergency medical technicians in patients with asystolic cardiac arrest. N Engl J Med. 1993;328:1377–1382.

319. Hedges JR, Syverud SA, Dalsey WC, Feero S, Easter R, Shultz B. Prehospital trial of emergency transcutaneous cardiac pacing. Circulation. 1987;76:1337–1343.

320. White JD, Brown CG. Immediate transthoracic pacing for cardiac asystole in an emergency department setting. Am J Emerg Med. 1985;3:125–128.

321. Haman L, Parizek P, Vojacek J. Precordial thump efficacy in termination of induced ventricular arrhythmias. Resuscitation. 2009;80:14–16.

322.

Pellis T, Kette F, Lovisa D, Franceschino E, Magagnin L, Mercante WP, Kohl P. Utility of pre-cordial thump for treatment of out of hospital cardiac arrest: a prospective study. Resuscitation. 2009;80:17–23.

323. Befeler B. Mechanical stimulation of the heart: its therapeutic value in tachyarrhythmias. Chest. 1978;73:832–838.

324. Volkmann H, Klumbies A, Kuhnert H, Paliege R, Dannberg G, Siegert K. [Terminating ventricular tachycardias by mechanical heart stimulation with precordial thumps]. Z Kardiol. 1990;79:717–724.

325. Caldwell G, Millar G, Quinn E, Vincent R, Chamberlain DA. Simple mechanical methods for cardioversion: defence of the precordial thump and cough version. BMJ (Clin Res Ed). 1985;291:627–630.

326. Morgera T, Baldi N, Chersevani D, Medugno G, Camerini F. Chest thump and ventricular tachycardia. Pacing Clin Electrophysiol. 1979;2:69–75.

327. Rahner E, Zeh E. Die Regularisierung von Kammertachykardien durch präkordialen Faustschlag. [Regulation of ventricular tachycardia with precordial fist blow]. Med Welt. 1978;29:1659–1663.

328. Gertsch M, Hottinger S, Hess T. Serial chest thumps for the treatment of ventricular tachycardia in patients with coronary artery disease. Clin Cardiol. 1992;15:181–188.

329. Krijne R. Rate acceleration of ventricular tachycardia after a precordial chest thump. Am J Cardiol. 1984;53:964–965.

330. Sclarovsky S, Kracoff OH, Agmon J. Acceleration of ventricular tachycardia induced by a chest thump. Chest. 1981;80:596–599.

331. Yakaitis RW, Redding JS. Precordial thumping during cardiac resuscitation. Crit Care Med. 1973;1:22–26.

332. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2005;112(24 suppl):IV1–IV203.

333. Smith I, Monk TG, White PF. Comparison of transesophageal atrial pacing with anticholinergic drugs for the treatment of intraoperative bradycardia. Anesth Analg. 1994;78:245–252.

334. Brady WJ, Swart G, DeBehnke DJ, Ma OJ, Aufderheide TP. The efficacy of atropine in the treatment of hemodynamically unstable bradycardia and atrioventricular block: prehospital and emergency department considerations. Resuscitation. 1999;41:47–55.

335. Swart G, Brady WJJ, DeBehnke DJ, John OM, Aufderheide TP. Acute myocardial infarction complicated by hemodynamically unstable bradyarrhythmia: prehospital and ED treatment with atropine. Am J Emerg Med. 1999;17:647–652.

336. Chadda KD, Lichstein E, Gupta PK, Choy R. Bradycardia-hypotension syndrome in acute myocardial infarction. Reappraisal of the overdrive effects of atropine. Am J Med. 1975;59:158–164.

337. Chadda KD, Lichstein E, Gupta PK, Kourtesis P. Effects of atropine in patients with bradyarrhythmia complicating myocardial infarction: usefulness of an optimum dose for overdrive. Am J Med. 1977;63:503–510.

338. Dauchot P, Gravenstein JS. Effects of atropine on the electrocardiogram in different age groups. Clin Pharmacol Ther. 1971;12:274–280.

339. Bernheim A, Fatio R, Kiowski W, Weilenmann D, Rickli H, Rocca HP. Atropine often results in complete atrioventricular block or sinus arrest after cardiac transplantation: an unpredictable and dose-independent phenomenon. Transplantation. 2004;77:1181–1185.

340. Morrison LJ, Long J, Vermeulen M, Schwartz B, Sawadsky B, Frank J, Cameron B, Burgess R, Shield J, Bagley P, Mausz V, Brewer JE, Dorian P. A randomized controlled feasibility trial comparing safety and effectiveness of prehospital pacing versus conventional treatment: 'PrePACE.' Resuscitation. 2008;76:341–349.

341. Lown B. Electrical reversion of cardiac arrhythmias. Br Heart J. 1967;29:469–489.

342. Mittal S, Ayati S, Stein KM, Schwartzman D, Cavlovich D, Tchou PJ, Markowitz SM, Slotwiner DJ, Scheiner MA, Lerman BB. Transthoracic cardioversion of atrial fibrillation: comparison of rectilinear biphasic versus damped sine wave monophasic shocks. Circulation. 2000;101:1282–1287.

343. Page RL, Kerber RE, Russell JK, Trouton T, Waktare J, Gallik D, Olgin JE, Ricard P, Dalzell GW, Reddy R, Lazzara R, Lee K, Carlson M, Halperin B, Bardy GH. Biphasic versus monophasic shock waveform for conversion of atrial fibrillation: the results of an international randomized, double-blind multicenter trial. J Am Coll Cardiol. 2002;39:1956–1963.

344. Scholten M, Szili-Torok T, Klootwijk P, Jordaens L. Comparison of monophasic and biphasic shocks for transthoracic cardioversion of atrial fibrillation. Heart. 2003;89:1032–1034.

345. Glover BM, Walsh SJ, McCann CJ, Moore MJ, Manoharan G, Dalzell GW, McAllister A, McClements B, McEneaney DJ, Trouton TG, Mathew TP, Adgey AA. Biphasic energy selection for transthoracic cardioversion of atrial fibrillation. The BEST AF Trial. Heart. 2008;94:884–887.

346.

Reisinger J, Gstrein C, Winter T, Zeindlhofer E, Hollinger K, Mori M, Schiller A, Winter A, Geiger H, Siostrzonek P. Optimization of initial energy for cardioversion of atrial tachyarrhythmias with biphasic shocks. Am J Emerg Med. 2010;28:159–165.

347. Kerber RE, Martins JB, Kienzle MG, Constantin L, Olshansky B, Hopson R, Charbonnier F. Energy, current, and success in defibrillation and cardioversion: clinical studies using an automated impedance-based method of energy adjustment. Circulation. 1988;77:1038–1046.

348. Lim SH, Anantharaman V, Teo WS, Goh PP, Tan AT. Comparison of treatment of supraventricular tachycardia by Valsalva maneuver and carotid sinus massage. Ann Emerg Med. 1998;31:30–35.

349. Wen ZC, Chen SA, Tai CT, Chiang CE, Chiou CW, Chang MS. Electrophysiological mechanisms and determinants of vagal maneuvers for termination of paroxysmal supraventricular tachycardia. Circulation. 1998;98:2716–2723.

350. Ornato JP, Hallagan LF, Reese WA, Clark RF, Tayal VS, Garnett AR, Gonzalez ER. Treatment of paroxysmal supraventricular tachycardia in the emergency department by clinical decision analysis. Am J Emerg Med. 1988;6:555–560.

351. DiMarco JP, Miles W, Akhtar M, Milstein S, Sharma AD, Platia E, McGovern B, Scheinman MM, Govier WC. Adenosine for paroxysmal supraventricular tachycardia: dose ranging and comparison with verapamil: assessment in placebo-controlled, multicenter trials. The Adenosine for PSVT Study Group [published correction appears in Ann Intern Med. 1990;113:996]. Ann Intern Med. 1990;113:104–110.

352. Lim SH, Anantharaman V, Teo WS, Chan YH. Slow infusion of calcium channel blockers compared with intravenous adenosine in the emergency treatment of supraventricular tachycardia. Resuscitation. 2009;80:523–528.

353. Cheng KA. [A randomized, multicenter trial to compare the safety and efficacy of adenosine versus verapamil for termination of paroxysmal supraventricular tachycardia]. Zhonghua Nei Ke Za Zhi. 2003;42:773–776.

354. Hood MA, Smith WM. Adenosine versus verapamil in the treatment of supraventricular tachycardia: a randomized double-crossover trial. Am Heart J. 1992;123:1543–1549.

355. Rankin AC, Oldroyd KG, Chong E, Dow JW, Rae AP, Cobbe SM. Adenosine or adenosine triphosphate for supraventricular tachycardias? Comparative double-blind randomized study in patients with spontaneous or inducible arrhythmias. Am Heart J. 1990;119:316–323.

356. Brady WJ Jr., DeBehnke DJ, Wickman LL, Lindbeck G. Treatment of out-of-hospital supraventricular tachycardia: adenosine vs verapamil. Acad Emerg Med. 1996;3:574–585.

357. Morrison LJ, Allan R, Vermeulen M, Dong SL, McCallum AL. Conversion rates for prehospital paroxysmal supraventricular tachycardia (PSVT) with the addition of adenosine: a before-and-after trial. Prehosp Emerg Care. 2001;5:353–359.

358. Glatter K, Cheng J, Dorostkar P, Modin G, Talwar S, Al-Nimri M, Lee R, Saxon L, Lesh M, Scheinman M. Electrophysiologic effects of adenosine in patients with supraventricular tachycardia. Circulation. 1999;99:1034–1040.

359. Cairns CB, Niemann JT. Intravenous adenosine in the emergency department management of paroxysmal supraventricular tachycardia. Ann Emerg Med. 1991;20:717–721.

360. Davis R, Spitalnic SJ, Jagminas L. Cost-effective adenosine dosing for the treatment of PSVT. Am J Emerg Med. 1999;17:633–634.

361. Gausche M, Persse DE, Sugarman T, Shea SR, Palmer GL, Lewis RJ, Brueske PJ, Mahadevan S, Melio FR, Kuwata JH, Niemann JT. Adenosine for the prehospital treatment of paroxysmal supraventricular tachycardia. Ann Emerg Med. 1994;24:183–189.

362. McIntosh-Yellin NL, Drew BJ, Scheinman MM. Safety and efficacy of central intravenous bolus administration of adenosine for termination of supraventricular tachycardia. J Am Coll Cardiol. 1993;22:741–745.

363. Riccardi A, Arboscello E, Ghinatti M, Minuto P, Lerza R. Adenosine in the treatment of supraventricular tachycardia: 5 years of experience (2002–2006). Am J Emerg Med. 2008;26:879–882.

364. Sellers TD, Kirchhoffer JB, Modesto TA. Adenosine: a clinical experience and comparison with verapamil for the termination of supraventricular tachycardias. Prog Clin Biol Res. 1987;230:283–299.

365. Marco CA, Cardinale JF. Adenosine for the treatment of supraventricular tachycardia in the ED. Am J Emerg Med. 1994;12:485–488.

366. Seet CM. Efficacy of intravenous adenosine in treatment of paroxysmal supraventricular tachycardia in the local population. Singapore Med J. 1997;38:525–528.

367. Tan H, Spekhorst H, Peters R, Wilde A. Adenosine induced ventricular arrhythmias in the emergency room. Pacing Clin Electrophysiol. 2001;24:450–455.

368. Madsen CD, Pointer JE, Lynch TG. A comparison of adenosine and verapamil for the treatment of supraventricular tachycardia in the prehospital setting. Ann Emerg Med. 1995;25:649–655.

369.

Cybulski J, Kulakowski P, Makowska E, Czepiel A, Sikora-Frac M, Ceremuzynski L. Intravenous amiodarone is safe and seems to be effective in termination of paroxysmal supraventricular tachyarrhythmias. Clin Cardiol. 1996;19:563–566.

370. Gowda RM, Khan IA, Mehta NJ, Vasavada BC, Sacchi TJ. Cardiac arrhythmias in pregnancy: clinical and therapeutic considerations. Int J Cardiol. 2003;88:129–133.

371. Camm AJ, Garratt CJ. Adenosine and supraventricular tachycardia. N Engl J Med. 1991;325:1621–1629.

372. Lim SH, Anantharaman V, Teo WS. Slow-infusion of calcium channel blockers in the emergency management of supraventricular tachycardia. Resuscitation. 2002;52:167–174.

373. Ferreira JF, Pamplona D, Cesar LA, Leite PF, Sosa EA, da Luz PL, Bellotti G. [Comparative study between verapamil and adenosine triphosphate in the treatment of paroxysmal supraventricular tachycardia]. Arq Bras Cardiol. 1996;66:55–57.

374. Rankin AC, Rae AP, Oldroyd KG, Cobbe SM. Verapamil or adenosine for the immediate treatment of supraventricular tachycardia. Q J Med. 1990;74:203–208.

375. Joshi PP, Deshmukh PK, Salkar RG. Efficacy of intravenous magnesium sulphate in supraventricular tachyarrhythmias. J Assoc Physicians India. 1995;43:529–531.

376. Gupta A, Naik A, Vora A, Lokhandwala Y. Comparison of efficacy of intravenous diltiazem and esmolol in terminating supraventricular tachycardia. J Assoc Physicians India. 1999;47:969–972.

377. Boudonas G, Lefkos N, Efthymiadis AP, Styliadis IG, Tsapas G. Intravenous administration of diltiazem in the treatment of supraventricular tachyarrhythmias. Acta Cardiol. 1995;50:125–134.

378. Staudinger T, Brugger S, Roggla M, Rintelen C, Atherton GL, Johnson JC, Frass M. [Comparison of the Combitube with the endotracheal tube in cardiopulmonary resuscitation in the prehospital phase]. Wien Klin Wochenschr. 1994;106:412–415.

379. Marill KA, Wolfram S, Desouza IS, Nishijima DK, Kay D, Setnik GS, Stair TO, Ellinor PT. Adenosine for wide-complex tachycardia: efficacy and safety. Crit Care Med. 2009;37:2512–2518.

380. Domanovits H, Laske H, Stark G, Sterz F, Schmidinger H, Schreiber W, Mullner M, Laggner AN. Adenosine for the management of patients with tachycardias—a new protocol. Eur Heart J. 1994;15:589–593.

381. Ilkhanipour K, Berrol R, Yealy DM. Therapeutic and diagnostic efficacy of adenosine in wide-complex tachycardia. Ann Emerg Med. 1993;22:1360–1364.

382. Rankin AC, Oldroyd KG, Chong E, Rae AP, Cobbe SM. Value and limitations of adenosine in the diagnosis and treatment of narrow and broad complex tachycardias. Br Heart J. 1989;62:195–203.

383. Wilber DJ, Baerman J, Olshansky B, Kall J, Kopp D. Adenosine-sensitive ventricular tachycardia. Clinical characteristics and response to catheter ablation. Circulation. 1993;87:126–134.

384. Armengol RE, Graff J, Baerman JM, Swiryn S. Lack of effectiveness of lidocaine for sustained, wide QRS complex tachycardia. Ann Emerg Med. 1989;18:254–257.

385. Exner DV, Muzyka T, Gillis AM. Proarrhythmia in patients with the Wolff-Parkinson-White syndrome after standard doses of intravenous adenosine. Ann Intern Med. 1995;122:351–352.

386. Gupta AK, Shah CP, Maheshwari A, Thakur RK, Hayes OW, Lokhandwala YY. Adenosine induced ventricular fibrillation in Wolff-Parkinson-White syndrome. Pacing Clin Electrophysiol. 2002;25:477–480.

387. Shah CP, Gupta AK, Thakur RK, Hayes OW, Mehrotra A, Lokhandwala YY. Adenosine-induced ventricular fibrillation. Indian Heart J. 2001;53:208–210.

388. Parham WA, Mehdirad AA, Biermann KM, Fredman CS. Case report: adenosine induced ventricular fibrillation in a patient with stable ventricular tachycardia. J Interv Card Electrophysiol. 2001;5:71–74.

389. Buxton AE, Marchlinski FE, Doherty JU, Flores B, Josephson ME. Hazards of intravenous verapamil for sustained ventricular tachycardia. Am J Cardiol. 1987;59:1107–1110.

390. Gorgels AP, van den Dool A, Hofs A, Mulleneers R, Smeets JL, Vos MA, Wellens HJ. Comparison of procainamide and lidocaine in terminating sustained monomorphic ventricular tachycardia. Am J Cardiol. 1996;78:43–46.

391. Ho DS, Zecchin RP, Richards DA, Uther JB, Ross DL. Double-blind trial of lignocaine versus sotalol for acute termination of spontaneous sustained ventricular tachycardia. Lancet. 1994;344:18–23.

392. Ho DSW, Zecchin RP, Cooper MJ, Richards DAB, Uther JB, Ross DL. Rapid intravenous infusion of d-1 sotalol: time to onset of effects on ventricular refractoriness, and safety. Eur Heart J. 1995;16:81–86.

393.

Somberg JC, Bailin SJ, Haffajee CI, Paladino WP, Kerin NZ, Bridges D, Timar S, Molnar J. Intravenous lidocaine versus intravenous amiodarone (in a new aqueous formulation) for incessant ventricular tachycardia. Am J Cardiol. 2002;90:853–859.

394. Marill KA, deSouza IS, Nishijima DK, Stair TO, Setnik GS, Ruskin JN. Amiodarone is poorly effective for the acute termination of ventricular tachycardia. Ann Emerg Med. 2006;47:217–224.

395. Schutzenberger W, Leisch F, Kerschner K, Harringer W, Herbinger W. Clinical efficacy of intravenous amiodarone in the short term treatment of recurrent sustained ventricular tachycardia and ventricular fibrillation. Br Heart J. 1989;62:367–371.

396. Tomlinson DR, Cherian P, Betts TR, Bashir Y. Intravenous amiodarone for the pharmacological termination of haemodynamically-tolerated sustained ventricular tachycardia: is bolus dose amiodarone an appropriate first-line treatment? Emerg Med J. 2008;25:15–18.

397. Nasir N Jr., Taylor A, Doyle TK, Pacifico A. Evaluation of intravenous lidocaine for the termination of sustained monomorphic ventricular tachycardia in patients with coronary artery disease with or without healed myocardial infarction. Am J Cardiol. 1994;74:1183–1186.

398. Marill KA, Greenberg GM, Kay D, Nelson BK. Analysis of the treatment of spontaneous sustained stable ventricular tachycardia. Acad Emerg Med. 1997;4:1122–1128.

399. Koster RW, Dunning AJ. Intramuscular lidocaine for prevention of lethal arrhythmias in the prehospitalization phase of acute myocardial infarction. N Engl J Med. 1985;313:1105–1110.

400. Roth A, Malov N, Bloch Y, Schlesinger Z, Laniado S, Kaplinski E. Usefulness of self-administration of intramuscular lidocaine in the prehospital setting for ventricular tachyarrhythmias unassociated with acute myocardial infarction (The “SHAHAL” experience in Israel). Am J Cardiol. 1997;79:611–614.

401. Fuster V, Ryden LE, Cannom DS, Crijns HJ, Curtis AB, Ellenbogen KA, Halperin JL, Le Heuzey JY, Kay GN, Lowe JE, Olsson SB, Prystowsky EN, Tamargo JL, Wann S, Smith SC Jr., Jacobs AK, Adams CD, Anderson JL, Antman EM, Halperin JL, Hunt SA, Nishimura R, Ornato JP, Page RL, Riegel B, Priori SG, Blanc JJ, Budaj A, Camm AJ, Dean V, Deckers JW, Despres C, Dickstein K, Lekakis J, McGregor K, Metra M, Morais J, Osterspey A, Tamargo JL, Zamorano JL. ACC/AHA/ESC 2006 Guidelines for the Management of Patients with Atrial Fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Revise the 2001 Guidelines for the Management of Patients With Atrial Fibrillation): developed in collaboration with the European Heart Rhythm Association and the Heart Rhythm Society. Circulation. 2006;114:e257–e354.

402. Sticherling C, Tada H, Hsu W, Bares AC, Oral H, Pelosi F, Knight BP, Strickberger SA, Morady F. Effects of diltiazem and esmolol on cycle length and spontaneous conversion of atrial fibrillation. J Cardiovasc Pharmacol Ther. 2002;7:81–88.

403. Chiladakis JA, Stathopoulos C, Davlouros P, Manolis AS. Intravenous magnesium sulfate versus diltiazem in paroxysmal atrial fibrillation. Int J Cardiol. 2001;79:287–291.

404. Schreck DM, Rivera AR, Tricarico VJ. Emergency management of atrial fibrillation and flutter: intravenous diltiazem versus intravenous digoxin. Ann Emerg Med. 1997;29:135–140.

405. Siu CW, Lau CP, Lee WL, Lam KF, Tse HF. Intravenous diltiazem is superior to intravenous amiodarone or digoxin for achieving ventricular rate control in patients with acute uncomplicated atrial fibrillation. Crit Care Med. 2009;37:2174–2179, quiz 2180.

406. Intravenous digoxin in acute atrial fibrillation. Results of a randomized, placebo-controlled multicentre trial in 239 patients. The Digitalis in Acute Atrial Fibrillation (DAAF) Trial Group. Eur Heart J. 1997;18:649–654.

407. Jordaens L, Trouerbach J, Calle P, Tavernier R, Derycke E, Vertongen P, Bergez B, Vandekerckhove Y. Conversion of atrial fibrillation to sinus rhythm and rate control by digoxin in comparison to placebo. Eur Heart J. 1997;18:643–648.

408. Wattanasuwan N, Khan IA, Mehta NJ, Arora P, Singh N, Vasavada BC, Sacchi TJ. Acute ventricular rate control in atrial fibrillation: IV combination of diltiazem and digoxin vs IV diltiazem alone. Chest. 2001;119:502–506.

409. Galve E, Rius T, Ballester R, Artaza MA, Arnau JM, Garcia-Dorado D, Soler-Soler J. Intravenous amiodarone in treatment of recent-onset atrial fibrillation: results of a randomized, controlled study. J Am Coll Cardiol. 1996;27:1079–1082.

410. Thomas SP, Guy D, Wallace E, Crampton R, Kijvanit P, Eipper V, Ross DL, Cooper MJ. Rapid loading of sotalol or amiodarone for management of recent onset symptomatic atrial fibrillation: a randomized, digoxin-controlled trial. Am Heart J. 2004;147:E3.

411. Kramer-Johansen J, Wik L, Steen PA. Advanced cardiac life support before and after tracheal intubation—direct measurements of quality. Resuscitation. 2006;68:61–69.

412. Cantineau JP, Lambert Y, Merckx P, Reynaud P, Porte F, Bertrand C, Duvaldestin P. End-tidal carbon dioxide during cardiopulmonary resuscitation in humans presenting mostly with asystole: a predictor of outcome. Crit Care Med. 1996;24:791–796.

413. Keren A, Tzivoni D, Gavish D, Levi J, Gottlieb S, Benhorin J, Stern S. Etiology, warning signs and therapy of torsade de pointes: a study of 10 patients. Circulation. 1981;64:1167–1174.

414. Nguyen PT, Scheinman MM, Seger J. Polymorphous ventricular tachycardia: clinical characterization, therapy, and the QT interval. Circulation. 1986;74:340–349.

Part 8: Post-Cardiac Arrest Care

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiac arrest drug imaging moderate hypothermia

1 Highlights

Summary of Key Issues and Major Changes

Key issues and major changes in the 2015 Guidelines Update recommendations for post–cardiac arrest care include the following:

- Emergency coronary angiography is recommended for all patients with ST elevation and for hemodynamically or electrically unstable patients without ST elevation for whom a cardiovascular lesion is suspected.
- TTM recommendations have been updated with new evidence suggesting that a range of temperatures may be acceptable to target in the post–cardiac arrest period.
- After TTM is complete, fever may develop. While there are conflicting observational data about the harm of fever after TTM, the prevention of fever is considered benign and therefore is reasonable to pursue.
- Identification and correction of hypotension is recommended in the immediate post–cardiac arrest period.
- Prognostication is now recommended no sooner than 72 hours after the completion of TTM; for those who do not have TTM, prognostication is not recommended any sooner than 72 hours after ROSC.
- All patients who progress to brain death or circulatory death after initial cardiac arrest should be considered potential organ donors.

Coronary Angiography

2015 (Updated): Coronary angiography should be performed emergently (rather than later in the hospital stay or not at all) for OHCA patients with suspected cardiac etiology of arrest and ST elevation on ECG. Emergency coronary angiography is reasonable for select (eg, electrically or hemodynamically unstable) adult patients who are comatose after OHCA of suspected cardiac origin but without ST elevation on ECG. Coronary angiography is reasonable in post–cardiac arrest patients for whom coronary angiography is indicated, regardless of whether the patient is comatose or awake.

2010 (Old): Primary PCI (PPCI) after ROSC in subjects with arrest of presumed ischemic cardiac etiology may be reasonable, even in the absence of a clearly defined STEMI. Appropriate treatment of acute coronary syndromes (ACS) or STEMI, including PCI or fibrinolysis, should be initiated regardless of coma.

Why: Multiple observational studies found positive associations between emergency coronary revascularization and both survival and favorable functional outcome. In the absence of cardiac arrest, guidelines already recommend emergency treatment of STEMI and emergency treatment of non–ST-segment elevation ACS with electrical or hemodynamic instability. Because the outcome of coma may be improved by correction of cardiac instability, and the prognosis of coma cannot be reliably determined in the first few hours after cardiac arrest, emergency treatment of post–cardiac arrest patients should follow identical guidelines.

Targeted Temperature Management

2015 (Updated): All comatose (ie, lacking meaningful response to verbal commands) adult patients with ROSC after cardiac arrest should have TTM, with a target temperature between 32°C and 36°C selected and achieved, then maintained constantly for at least 24 hours.

2010 (Old): Comatose (ie, lacking of meaningful response to verbal commands) adult patients with ROSC after out-of-hospital VF cardiac arrest should be cooled to 32°C to 34°C for 12 to 24 hours. Induced hypothermia also may be considered for comatose adult patients with ROSC after IHCA of any initial rhythm or after OHCA with an initial rhythm of pulseless electrical activity or asystole.

Why: Initial studies of TTM examined cooling to temperatures between 32°C and 34°C compared with no well-defined TTM and found improvement in neurologic outcome for those in whom hypothermia was induced. A recent high-quality study compared temperature management at 36°C and at 33°C and found outcomes to be similar for both. Taken together, the initial studies suggest that TTM is beneficial, so the recommendation remains to select a single target temperature and perform TTM. Given that 33°C is no better than 36°C, clinicians can select from a wider range of target temperatures. The selected temperature may be determined by clinician preference or clinical factors.

Continuing Temperature Management Beyond 24 Hours

2015 (New): Actively preventing fever in comatose patients after TTM is reasonable.

Why: In some observational studies, fever after rewarming from TTM is associated with worsened neurologic injury, although studies are conflicting. Because preventing fever after TTM is relatively benign and fever may be associated with harm, preventing fever is suggested.

Out-of-Hospital Cooling

2015 (New): The routine prehospital cooling of patients with rapid infusion of cold IV fluids after ROSC is not recommended.

Why: Before 2010, cooling patients in the prehospital setting had not been extensively evaluated. It had been assumed that earlier initiation of cooling might provide added benefits and also that prehospital initiation might facilitate and encourage continued in-hospital cooling. Recently published high-quality studies demonstrated no benefit to prehospital cooling and also identified potential complications when using cold IV fluids for prehospital cooling.

Hemodynamic Goals After Resuscitation

2015 (New): It may be reasonable to avoid and immediately correct hypotension (systolic blood pressure less than 90 mm Hg, mean arterial pressure less than 65 mm Hg) during post–cardiac arrest care.

Why: Studies of patients after cardiac arrest have found that a systolic blood pressure less than 90 mm Hg or a mean arterial pressure of less than 65 mm Hg is associated with higher mortality and diminished functional recovery, while systolic arterial pressures of greater than 100 mm Hg are associated with better recovery. While higher pressures appear superior, specific systolic or mean arterial pressure targets could not be identified, because trials typically studied a bundle of many interventions, including hemodynamic control. Also, because baseline blood pressure varies from patient to patient, different patients may have different requirements to maintain optimal organ perfusion.

Prognostication After Cardiac Arrest

2015 (New): The earliest time to prognosticate a poor neurologic outcome using clinical examination in patients *not* treated with TTM is 72 hours after cardiac arrest, but this time can be even longer after cardiac arrest if the residual effect of sedation or paralysis is suspected to confound the clinical examination.

2015 (Updated): In patients treated *with* TTM, where sedation or paralysis could confound clinical examination, it is reasonable to wait until 72 hours after return to normothermia before predicting outcome.

2010 (Old): While times for usefulness of specific tests were identified, no specific overall recommendation was made about time to prognostication.

Why: Clinical findings, electrophysiologic modalities, imaging modalities, and blood markers are all useful for predicting neurologic outcome in comatose patients, but each finding, test, and marker is affected differently by sedation and neuromuscular blockade. In addition, the comatose brain may be more sensitive to medications, and medications may take longer to metabolize after cardiac arrest.

No single physical finding or test can predict neurologic recovery after cardiac arrest with 100% certainty. Multiple modalities of testing and examination used together to predict outcome after the effects of hypothermia and medications have been allowed to resolve, are most likely to provide accurate prediction of outcome (**Box 1**).

Box 1

Useful Clinical Findings That Are Associated With Poor Neurologic Outcome*

- Absence of pupillary reflex to light at 72 hours or more after cardiac arrest
- Presence of status myoclonus (different from isolated myoclonic jerks) during the first 72 hours after cardiac arrest
- Absence of the N20 somatosensory evoked potential cortical wave 24 to 72 hours after cardiac arrest or after rewarming
- Presence of a marked reduction of the gray-white ratio on brain CT obtained within 2 hours after cardiac arrest
- Extensive restriction of diffusion on brain MRI at 2 to 6 days after cardiac arrest
- Persistent absence of EEG reactivity to external stimuli at 72 hours after cardiac arrest
- Persistent burst suppression or intractable status epilepticus on EEG after rewarming

Absent motor movements, extensor posturing, or myoclonus should not be used alone for predicting outcome.

*Shock, temperature, metabolic derangement, prior sedatives or neuromuscular blockers, and other clinical factors should be considered carefully because they may affect results or interpretation of some tests.

Abbreviations: CT, computed tomography; EEG, electroencephalogram; MRI, magnetic resonance imaging.

Organ Donation

2015 (Updated): All patients who are resuscitated from cardiac arrest but who subsequently progress to death or brain death should be evaluated as potential organ donors. Patients who do not achieve ROSC and who would otherwise have resuscitation terminated may be considered as potential kidney or liver donors in settings where rapid organ recovery programs exist.

2010 (Old): Adult patients who progress to brain death after resuscitation from cardiac arrest should be considered for organ donation.

Why: There has been no difference reported in immediate or long-term function of organs from donors who reach brain death after cardiac arrest when compared with donors who reach brain death from other causes. Organs transplanted from these donors have success rates comparable to organs recovered from similar donors with other conditions.

2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

The recommendations in the *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care* are based on an extensive evidence review process that was begun by the International Liaison Committee on Resuscitation (ILCOR) after the publication of the *2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations*,[1] and was completed in February 2015.[2,3]

In this in-depth evidence review process, ILCOR examined topics and then generated a prioritized list of questions for systematic review. Questions were first formulated in PICO (population, intervention, comparator, outcome) format,[4] and then search strategies and inclusion and exclusion criteria were defined and a search for relevant articles was performed. The evidence was evaluated by the ILCOR task forces by using the standardized methodological approach proposed by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group.[5]

The quality of the evidence was categorized based on the study methodologies and the 5 core GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias). Then, where possible, consensus-based treatment recommendations were created.

To create the 2015 Guidelines Update, the AHA formed 15 writing groups, with careful attention to manage conflicts of interest, to assess the ILCOR treatment recommendations and to write AHA treatment recommendations by using the AHA Class of Recommendation (COR) and Level of Evidence (LOE) system. The recommendations made in the Guidelines are informed by the ILCOR recommendations and GRADE classification, in the context of the delivery of medical care in North America. The AHA writing group made new recommendations only on topics specifically reviewed by ILCOR in 2015. This chapter delineates instances where the AHA writing group developed recommendations that are significantly stronger or weaker than the ILCOR statements. In the online version of this publication, live links are provided so the reader can connect directly to the systematic reviews on the Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated by a combination of letters and numbers (eg, ALS 790). We encourage readers to use the links and review the evidence and appendixes, including the GRADE tables.

The 2015 recommendations use the newest AHA COR and LOE classification system, which contains modifications of the Class III recommendation and introduces LOE B-R (randomized studies) and B-NR (nonrandomized studies) as well as LOE C-LD (limited data) and LOE C-EO (consensus of expert opinion). All recommendations made in the 2015 Guidelines Update, as well as in the 2010 Guidelines for post?cardiac arrest care, are listed in the Appendix. For further information, see "Part 2: Evidence Evaluation and Management of Conflicts of Interest."

2.1 Systems of Care for Improving Post–Cardiac Arrest Outcomes

Post–cardiac arrest care is a critical component of advanced life support (Figure 1). Most deaths occur during the first 24 hours after cardiac arrest.[6,7] The best hospital care for patients with ROSC after cardiac arrest is not completely known, but there is increasing interest in identifying and optimizing practices that are likely to improve outcomes (Table 1).[8] Positive associations have been noted between the likelihood of survival and the number of cardiac arrest cases treated at any individual hospital.[9,10] Because multiple organ systems are affected after cardiac arrest, successful post–cardiac arrest care will benefit from the development of system-wide plans for proactive treatment of these patients. For example, restoration of blood pressure and gas exchange does not ensure survival and functional recovery. Significant cardiovascular dysfunction can develop, requiring support of blood flow and ventilation, including intravascular volume expansion, vasoactive and inotropic drugs, and invasive devices. Therapeutic hypothermia and treatment of the underlying cause of cardiac arrest impacts survival and neurological outcomes. Protocolized hemodynamic optimization and multidisciplinary early goal-directed therapy protocols have been introduced as part of a bundle of care to improve survival rather than single interventions.[11-13] The data suggests that proactive titration of post–cardiac arrest hemodynamics to levels intended to ensure organ perfusion and oxygenation may improve outcomes. There are multiple specific options

for achieving these goals, and it is difficult to distinguish between the benefit of protocols or any specific component of care that is most important.

Figure 1: Adult Immediate Post–Cardiac Arrest Care Algorithm - 2015 Update

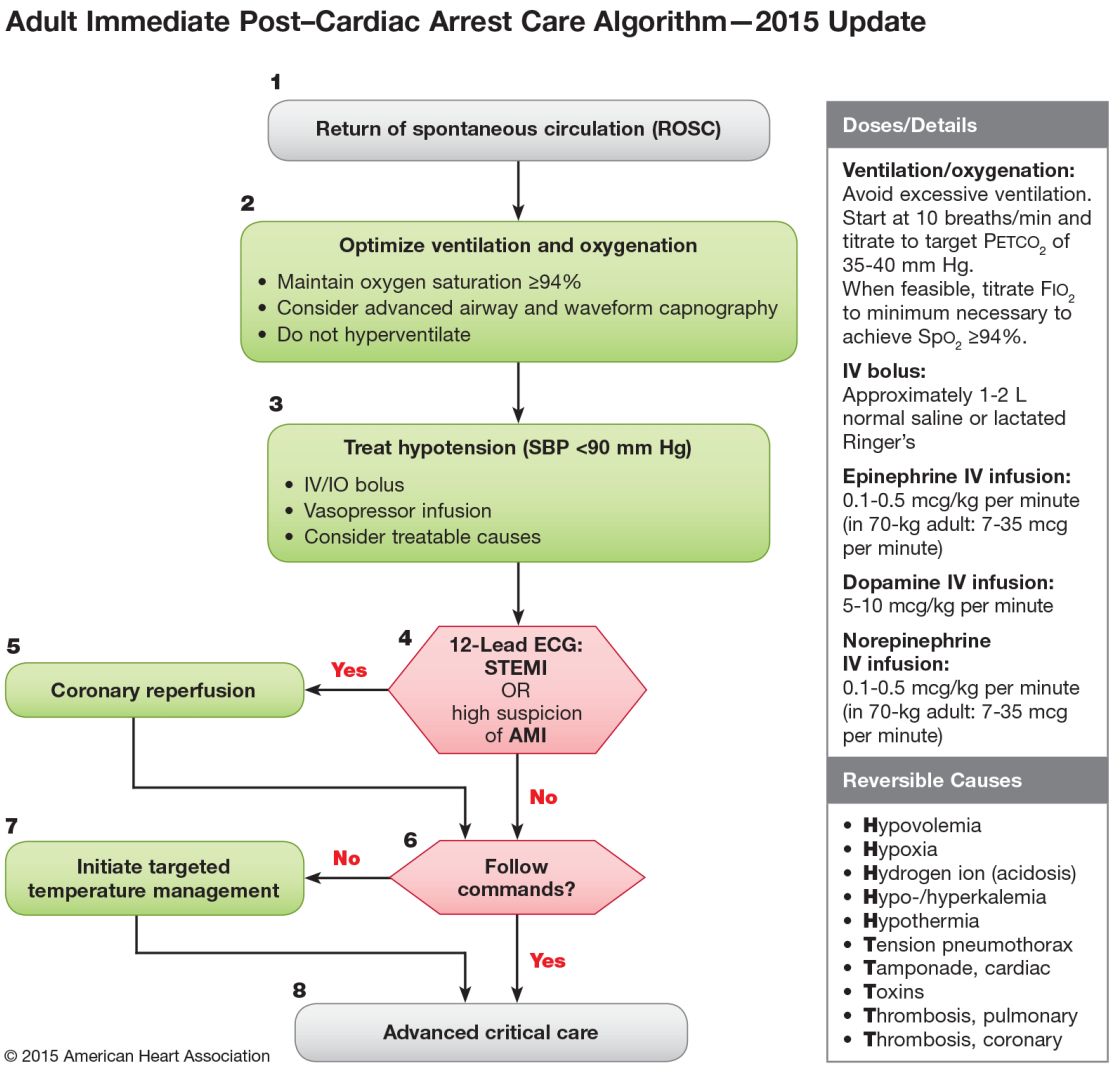


Table 1: 2010 - Multiple System Approach to Post–Cardiac Arrest Care

Open table in a new window

Multiple System Approach to Post–Cardiac Arrest Care				
Ventilation	**Hemodynamics**	**Cardiovascular**	**Neurological**	**Metabolic**

• Capnography ◦ Rationale: Confirm secure airway and titrate ventilation ◦ Endotracheal tube when possible for comatose patients ◦ $Petco_2$?35–40 mm Hg ◦ $Paco_2$?40–45 mm Hg	• Frequent Blood Pressure Monitoring/Arterial-line ◦ Rationale: Maintain perfusion and prevent recurrent hypotension ◦ Mean arterial pressure ?65 mm Hg or systolic blood pressure ?90 mm Hg	• Continuous Cardiac Monitoring ◦ Rationale: Detect recurrent arrhythmia ◦ No prophylactic antiarrhythmics ◦ Treat arrhythmias as required ◦ Remove reversible causes	• Serial Neurological Exam ◦ Rationale: Serial examinations define coma, brain injury, and prognosis ◦ Response to verbal commands or physical stimulation ◦ Pupillary light and corneal reflex, spontaneous eye movement ◦ Gag, cough, spontaneous breaths	• Serial Lactate ◦ Rationale: Confirm adequate perfusion

• Chest X-ray ○ Rationale: Confirm secure airway and detect causes or complications of arrest: pneumonia, pneumothorax, pulmonary edema	• Treat Hypotension ○ Rationale: Maintain perfusion ○ Fluid bolus if tolerated ○ Dopamine 5–10 mcg/kg per min ○ Norepinephrine 0.1–0.5 mcg/kg per min ○ Epinephrine 0.1–0.5 mcg/kg per min	• 12-lead ECG/Troponin ○ Rationale: Detect Acute Coronary Syndrome, ST-Elevation Myocardial Infarction, Assess QT interval	• EEG Monitoring If Comatose ○ Rationale: Exclude seizures ○ Anticonvulsants if seizing	• Serum Potassium ○ Rationale: Avoid hypokalemia which promotes arrhythmias ○ Replace to maintain K >3.5 mEq/L

• Pulse Oximetry/ABG ◦ Rationale: Maintain adequate oxygenation and minimize FiO_2 ◦ SpO_2 ?94% ◦ PaO_2 ?100 mm Hg ◦ Reduce FiO_2 as tolerated ◦ PaO_2/FiO_2 ratio to follow acute lung injury	…	• Treat Acute Coronary Syndrome ◦ Aspirin/heparin ◦ Transfer to acute coronary treatment center ◦ Consider emergent PCI or fibrinolysis	• Core Temperature Measurement If Comatose ◦ Rationale: Minimize brain injury and improve outcome ◦ Prevent hyperpyrexia >37.7°C ◦ Induce therapeutic hypothermia if no contraindications ◦ Cold IV fluid bolus 30 mL/kg if no contraindication ◦ Surface or endovascular cooling for 32°C–34°C×24 hours ◦ After 24 hours, slow rewarming 0.25°C/hr	• Urine Output, Serum Creatinine ◦ Rationale: Detect acute kidney injury ◦ Maintain euvolemia ◦ Renal replacement therapy if indicated

• Mechanical Ventilation ◦ Rationale: Minimize acute lung injury, potential oxygen toxicity ◦ Tidal Volume 6–8 mL/kg ◦ Titrate minute ventilation to P_{etCO_2} ?35–40 mm Hg $Paco_2$?40–45 mm Hg ◦ Reduce Fio_2 as tolerated to keep Spo_2 or Sao_2 ?94%	…	• Echocardiogram ◦ Rationale: Detect global stunning, wall-motion abnormalities, structural problems, or cardiomyopathy	• Consider Non-enhanced CT Scan ◦ Rationale: Exclude primary intracranial process	• Serum Glucose ◦ Rationale: Detect hyperglycemia and hypoglycemia ◦ Treat hypoglycemia (<80 mg/dL) with dextrose ◦ Treat hyperglycemia to target glucose 144–180 mg/dL ◦ Local insulin protocols

	…	• Treat Myocardial Stunning ○ Fluids to optimize volume status (requires clinical judgment) ○ Dobutamine 5–10 mcg/kg per min ○ Mechanical augmentation (IABP)	• Sedation/Muscle Relaxation ○ Rationale: To control shivering, agitation, or ventilator desynchrony as needed	• Avoid Hypotonic Fluids ○ Rationale: May increase edema, including cerebral edema

A comprehensive, structured, multidisciplinary system of care should be implemented in a consistent manner for the treatment of post-cardiac arrest patients. (Class I, LOE B)

Programs should include as part of structured interventions therapeutic hypothermia; optimization of hemodynamics and gas exchange; immediate coronary reperfusion when indicated for restoration of coronary blood flow with percutaneous coronary intervention (PCI); glycemic control; and neurological diagnosis, management, and prognostication.

2.2 Overview of Post-Cardiac Arrest Care - Updated

The 2010 Guidelines emphasized that cardiac arrest can result from many different diseases. Regardless of cause, the hypoxemia, ischemia, and reperfusion that occur during cardiac arrest and resuscitation may cause damage to multiple organ systems.[14] The severity of damage can vary widely among patients and among organ systems within individual patients. Therefore, effective post–cardiac arrest care consists of identification and treatment of the precipitating cause of cardiac arrest combined with the assessment and mitigation of ischemia-reperfusion injury to multiple organ systems. Care must be tailored to the particular disease and dysfunction that affect each patient. Therefore, individual patients may require few, many, or all of the specific interventions discussed in the remainder of this Part.

3 Cardiovascular Care - Updated

3.1 Acute Cardiovascular Interventions - Updated ACS 340 ACS 885

The 2010 Guidelines recommended obtaining a 12-lead electrocardiogram (ECG) as soon as possible after return of spontaneous circulation (ROSC) to identify if acute ST elevation is present, and to perform urgent coronary angiography with prompt recanalization of any infarct-related artery in select post–cardiac arrest patients in whom ST-segment elevation was identified. Acute coronary syndromes are a common etiology for out-of-hospital cardiac arrest (OHCA) in adults with no obvious extracardiac cause of arrest[15-17] and also can precipitate some in-hospital cardiac arrest. In series in which consecutive post–cardiac arrest patients with suspected cardiovascular cause were taken to coronary angiography, a coronary artery lesion amenable to emergency treatment was found in 96% of patients with ST elevation and in 58% of patients without ST elevation.[17]

The 2015 ILCOR systematic review examined immediate coronary angiography for patients after cardiac arrest.

3.1.1 2015 Evidence Summary

Numerous observational studies evaluate the relationship between coronary angiography, survival, and functional outcome in post–cardiac arrest patients, but there are no prospective randomized trials evaluating an interventional strategy in postarrest patients. The timing of immediate coronary angiography was defined in various ways in different studies, but all studies considered immediate angiography as a procedure performed on the same day as the cardiac arrest, as opposed to later in the hospital stay. Fifteen observational studies reported improved survival to hospital discharge associated with emergency coronary angiography in patients with ST elevation after cardiac arrest.[18-32] Nine observational studies showed improved neurologically favorable outcome associated with emergency coronary angiography in patients with ST elevation after cardiac arrest.[18-20,23,25-28,30]

Fewer data are available to evaluate coronary angiography in patients without ST elevation on the initial ECG. Two observational studies reported improved survival to hospital discharge and improved neurologically favorable outcome associated with emergency coronary angiography in patients without ST elevation on initial ECG.[18,23]

3.1.2 Recommendations - Updated

A 12-lead ECG should be obtained as soon as possible after ROSC to determine whether acute ST elevation is present. (Class I, LOE B)

Coronary angiography should be performed emergently (rather than later in the hospital stay or not at all) for OHCA patients with suspected cardiac etiology of arrest and ST elevation on ECG. (Class I, LOE B-NR)

Emergency coronary angiography is reasonable for select (eg, electrically or hemodynamically unstable) adult patients who are comatose after OHCA of suspected cardiac origin but without ST elevation on ECG. (Class IIa, LOE B-NR)

Coronary angiography is reasonable in post-cardiac arrest patients for whom coronary angiography is indicated regardless of whether the patient is comatose or awake. (Class IIa, LOE C-LD)

Early invasive approaches are preferred for patients with ST-segment elevation myocardial infarction (STEMI), making these recommendations for post–cardiac arrest patients consistent with global recommendations for all patients with STEMI.[33] Early invasive approaches also are suggested for treatment of select post–cardiac arrest patients with acute coronary syndromes without ST elevation. Considerations for selecting patients are complex and may consider factors such as hemodynamic or electrical instability as well as comorbidities, evidence of ongoing ischemia, and other patient characteristics.[34] Knowledge of coronary anatomy and opportunity for placement of temporary support devices are other potential benefits derived from early catheterization. Therefore, these recommendations for post–cardiac arrest care are consistent with recommendations for all patients with non-STEMI acute coronary syndromes. Both the European Society of Cardiology and the combined entity of the American College of Cardiology Foundation and the AHA have published STEMI guidelines recommending immediate coronary angiography, and percutaneous coronary intervention when indicated, for resuscitated OHCA patients whose ECGs show STEMI.[33,35] None of these guidelines recommended different

treatment of patients based on the initial cardiac arrest rhythm (ventricular fibrillation [VF] or non-VF).

Previous consensus statements have discussed how public reporting of postprocedure death creates an incentive to avoid emergency coronary angiography in comatose patients who are at higher risk of death as a consequence of poor neurologic recovery.[36] However, the probability of neurologic recovery cannot be determined reliably at the time that emergency cardiovascular interventions are performed (see Prognostication of Outcome section in this Part). Therefore, the best care for the patient requires separation of decisions about cardiovascular intervention from assessment of neurologic prognosis.

3.2 Hemodynamic Goals - Updated ALS 570

Post–cardiac arrest patients are often hemodynamically unstable, which can occur for multiple reasons that include the underlying etiology of the arrest as well as the ischemia-reperfusion injury from the arrest. Management of these patients can be challenging, and optimal hemodynamic goals remain undefined. In 2015, ILCOR evaluated the optimal hemodynamic targets in post–cardiac arrest patients, primarily considering blood pressure goals.

3.2.1 2015 Evidence Summary

There are several observational studies evaluating the relationship between blood pressure and outcome in post–cardiac arrest patients, but there are no interventional studies targeting blood pressure in isolation and no trials evaluating one specific strategy for improving blood pressure over another (ie, fluids, vasopressors). Observational studies found that post–cardiac arrest systolic blood pressure less than 90 mmHg[37,38] or greater than 100 mmHg[39] was associated with higher mortality and diminished functional recovery. One observational study found that mean arterial pressure (MAP) greater than 100 mmHg during 2 hours after ROSC was associated with better neurologic recovery at hospital discharge.[40] Another observational study found that survivors, compared with nonsurvivors, had higher MAP at 1 hour (96 versus 84 mmHg) and at 6 hours (96 versus 90 mmHg).[41]

While no studies evaluated blood pressure in isolation, several before-and-after studies implemented bundles of care that included blood pressure goals. In these studies, the individual effect of blood pressure was impossible to separate from the effects of the remainder of the bundle. One bundle with a MAP target of greater than 80 mmHg improved mortality and neurologic outcome at hospital discharge.[42] One bundle with a goal of MAP over 75 mmHg found no change in functional recovery at hospital discharge.[43] One bundle with MAP greater than 65 mmHg increased survival to hospital discharge, with a favorable neurologic outcome at 1 year.[44] Another bundle with a goal MAP greater than 65 mmHg within 6 hours found no change in in-hospital mortality or functional recovery at hospital discharge.[45]

3.2.2 2015 Recommendation - New

Avoiding and immediately correcting hypotension (systolic blood pressure less than 90 mm Hg, MAP less than 65 mm Hg) during postresuscitation care may be reasonable. (Class IIb, LOE C-LD)

A specific MAP or systolic blood pressure that should be targeted as part of the bundle of postresuscitation interventions could not be identified, although published protocols targeted MAP goals of greater than 65 mmHg to greater than 80 mmHg. Moreover, identifying an optimal MAP goal for the overall patient population may be complicated by individual patient variability, because baseline blood pressures vary among patients. The true optimal blood pressure would be that which allows for optimal organ and brain perfusion, and different patients and different organs may have different optimal pressures.

Targets for other hemodynamic or perfusion measures (such as cardiac output, mixed/central venous oxygen saturation, and urine output) remain undefined in post–cardiac arrest patients. The systematic reviews did not identify specific targets for other variables, and individual goals likely vary based on patient-specific comorbidities and underlying physiology. In the absence of evidence for specific targets, the writing group made no recommendations to target any hemodynamic goals other than those that would be used for other critically ill patients.

3.3 Vasopressors

Vasoactive drugs may be administered after ROSC to support cardiac output, especially blood flow to the heart and brain. Drugs may be selected to improve heart rate (chronotropic effects), myocardial contractility (inotropic effects), or arterial pressure (vasoconstrictive effects), or to reduce afterload (vasodilator effects). Unfortunately

many adrenergic drugs are not selective and may increase or decrease heart rate and afterload, increase cardiac arrhythmias, and increase myocardial ischemia by creating a mismatch between myocardial oxygen demand and delivery. Myocardial ischemia, in turn, may further decrease heart function. Some agents may also have metabolic effects that increase blood glucose, lactate, and metabolic rate. There is a paucity of data about which vasoactive drug to select first, although providers should become familiar with the differing adverse effects associated with these drugs, which might make a particular agent more or less appropriate for a specific patient.[46]

Specific drug infusion rates cannot be recommended because of variations in pharmacokinetics (relation between drug dose and concentration) and pharmacodynamics (relation between drug concentration and effect) in critically ill patients,[47,48] so commonly used initial dose ranges are listed in (Table 2). Vasoactive drugs must be titrated at the bedside to secure the intended effect while limiting side effects. Providers must also be aware of the concentrations delivered and compatibilities with previously and concurrently administered drugs.

Table 2: 2010 - Common Vasoactive Drugs

Open table in a new window

Common Vasoactive Drugs	
Drug	**Typical Starting Dose (Then Titrate to Effect)**
Epinephrine	0.1–0.5 mcg/kg/min (In 70-kg adult, 7–35 mcg/min) • Useful for symptomatic bradycardia if atropine and transcutaneous pacing fail or if pacing is not available • Used to treat severe hypotension (eg, systolic blood pressure <70 mm Hg) • Useful for anaphylaxis associated with hemodynamic instability or respiratory distress[reference id="3971" range="" /]

Drug	Typical Starting Dose (Then Titrate to Effect)
Norepinephrine	0.1–0.5 mcg/kg/min (In 70-kg adult, 7–35 mcg/min) • Used to treat severe hypotension (eg, systolic blood pressure <70 mm Hg) and a low total peripheral resistance • Relatively contraindicated in patients with hypovolemia. It may increase myocardial oxygen requirements, mandating cautious use in patients with ischemic heart disease • Usually induces renal and mesenteric vasoconstriction; in sepsis, however, norepinephrine improves renal blood flow and urine output[reference id="3972" range="" /]·[reference id="3973" range="" /]
Phenylephrine	0.5–2.0 mcg/kg/min (In 70-kg adult, 35–140 mcg/min) • Used to treat severe hypotension (eg, systolic blood pressure <70 mm Hg) and a low total peripheral resistance
Dopamine	5–10 mcg/kg/min • Used to treat hypotension, especially if it is associated with symptomatic bradycardia • Although low-dose dopamine infusion has frequently been recommended to maintain renal blood flow or improve renal function, more recent data have failed to show a beneficial effect from such therapy[reference id="3974" range="" /]·[reference id="3975" range="" /]
Dobutamine	5–10 mcg/kg/min • The (+) isomer is a potent beta-adrenergic agonist, whereas the (–) isomer is a potent alpha-1-agonist[reference id="3976" range="" /] • The vasodilating beta2-adrenergic effects of the (+) isomer counterbalance the vasoconstricting alpha-adrenergic effects, often leading to little change or a reduction in systemic vascular resistance

Drug	Typical Starting Dose (Then Titrate to Effect)
Milrinone	Load 50 mcg/kg over 10 minutes then infuse at 0.375 mcg/kg/min • Used to treat low cardiac output • May cause less tachycardia than dobutamine

In general, adrenergic drugs should not be mixed with sodium bicarbonate or other alkaline solutions in the IV line because there is evidence that adrenergic agents are inactivated in alkaline solutions.[49,50] Norepinephrine (levarterenol) and other catecholamines that activate ?-adrenergic receptors may produce tissue necrosis if extravasation occurs. Therefore, administration through a central line is preferred whenever possible. If extravasation develops, infiltrate 5 to 10 mg of phentolamine diluted in 10 to 15 mL of saline into the site of extravasation as soon as possible to prevent tissue death and sloughing.

4 Targeted Temperature Management - Updated

The 2010 Guidelines strongly advised induced hypothermia (32ºC to 34ºC) for the subgroup of patients with out-of-hospital VF/pulseless ventricular tachycardia (pVT) cardiac arrest and post-ROSC coma (the absence of purposeful movements), and encouraged that induced hypothermia be considered for most other comatose patients after cardiac arrest. Precise duration and optimal temperature targets were unknown, and the Guidelines recommended 12 to 24 hours at 32ºC to 34ºC based on the regimens studied in prior trials. The 2015 ILCOR systematic review identified multiple new randomized controlled trials testing different target temperatures and different timing for initiation of temperature control after cardiac arrest.[51] Reflecting that a variety of temperature targets are now used, the term *targeted temperature management* (TTM) has been adopted to refer to induced hypothermia as well as to active control of temperature at any target.

4.1 Induced Hypothermia - Updated ALS 790 ALS 791

4.1.1 2015 Evidence Summary

For patients with VF/pVT OHCA, combined outcome data from 1 randomized and 1 quasi-randomized clinical trial reported increased survival and increased functional recovery with induced hypothermia to 32ºC to 34ºC.[52, 53]

For patients with OHCA and nonshockable rhythms, observational data were conflicting and no randomized data were available. Three observational studies found no difference in neurologic outcome at hospital discharge in patientstreated with induced hypothermia.[54-56] One study reported an increase in poor neurologic outcome at hospital discharge; however, the analysis of this study was confounded perhaps most notably by lack of information on whether analyzed patients were eligible for induced hypothermia (ie, unknown if patients were following commands).[57] One study reported reduced mortality at 6 months with induced hypothermia.[55]

For patients with in-hospital cardiac arrest, no randomized data were available. One observational study found no association between induced hypothermia and survival or functionally favorable status at hospital discharge. However, the analysis of this study was also confounded by multiple factors, including the lack of information on which patients were comatose and, therefore, potential candidates for induced hypothermia.[58]

One well-conducted randomized controlled trial found that neurologic outcomes and survival at 6 months after OHCA were not superior when temperature was controlled at 36ºC versus 33ºC.[59] Both arms of this trial involved a form of TTM as opposed to no TTM.

There are no direct comparisons of different durations of TTM in post–cardiac arrest patients. The largest trials and studies of TTM maintained temperatures for 24 hours[52] or 28 hours[59] followed by a gradual (approximately 0.25ºC/hour) return to normothermia.

4.1.2 2015 Recommendations - Updated

We recommend that comatose (ie, lack of meaningful response to verbal commands) adult patients with ROSC after cardiac arrest have TTM (Class I, LOE B-R for VF/pVT OHCA; for non-VF/pVT (ie, "nonshockable") and in-hospital cardiac arrest). (Class I, LOE C-EO)

We recommend selecting and maintaining a constant temperature between 32ºC and 36ºC during TTM. (Class I, LOE B-R)

In making these strong recommendations, the writing group was influenced by the recent clinical trial data enrolling patients with all rhythms, the rarity of adverse effects in trials, the high neurologic morbidity and mortality without any specific interventions, and the preponderance of data suggesting that temperature is an important variable for neurologic recovery. Of note, there are essentially no patients for whom temperature control somewhere in the range between 32º C and 36º C is contraindicated. Specific features of the patient may favor selection of one temperature over another for TTM. Higher temperatures might be preferred in patients for whom lower temperatures convey some risk (eg, bleeding),[60,61] and lower temperatures might be preferred when patients have clinical features that are worsened at higher temperatures (eg, seizures, cerebral edema).[62-64] Therefore, all patients in whom intensive care is continued are eligible. The initial temperature of the patient may influence selection of the temperature for TTM. For example, those who present at the lower end of the TTM range might be maintained at that lower temperature (as opposed to warming them to a higher target). Alternatively, passive warming to a maximum temperature of 36º C might be acceptable as well. Of note is that the recent randomized trial did not use active warming for the 36ºC group.[59] Therefore, while it is stated that choosing a temperature within the 32ºC to 36ºC range is acceptable, actively or rapidly warming patients is not suggested. Conversely, patients who present on the higher end of the TTM range might be kept at 36ºC without much additional effort. Providers should note that allowing patients to warm to temperatures above 36ºC would be more akin to the control group of the earlier trials and not consistent with the current TTM recommendations.

The recommendations for TTM for nonshockable rhythms and for patients following in-hospital arrest are stronger than those made in 2015 by ILCOR[2,3] and are stronger than the recommendations in "Part 9: Post–Cardiac Arrest Care" in the 2010 Guidelines. The writing group felt that the option for TTM at 36ºC diminished theoretical concerns about side effects of TTM for these populations. In addition, the writing group was influenced by the high rate of neurologic morbidity in historical cohorts that did not use TTM.

It is reasonable that TTM be maintained for at least 24 hours after achieving target temperature. (Class IIa, LOE C-EO)

Even if the selected target temperature is not achieved during this time frame, clinicians should still try to control temperature for at least 24 hours after cardiac arrest. Temperature sensitivity of the brain after cardiac arrest may continue for as long as brain dysfunction (ie, coma) is present, making the upper limit of duration for temperature management unknown. The duration of at least 24 hours was used in 2 of the largest trials, although there are no comparative data for this duration. For these reasons, 24 hours was selected as the minimum recommended time for TTM.

4.2 Hypothermia in the Prehospital Setting - Updated ALS 802

The initiation of hypothermia has been popularized in the prehospital setting, though the original studies showing efficacy from induced hypothermia did not systematically study the prehospital setting. A logical assumption for the widespread implementation of this practice stemmed from the concept that earlier provision of an effective intervention would be more beneficial. However, induction of prehospital hypothermia was not extensively evaluated by large-scale randomized trials in 2010. Since that time, a number of additional trials have been published, including at least 1 large-scale investigation. In 2015, ILCOR examined the question of whether early provision of TTM was beneficial, with a focus on the prehospital period.

4.2.1 2015 Evidence Summary

Five randomized controlled trials[65-69] compared the post ROSC use of cold intravenous fluids to induce

hypothermia to no fluids. One trial compared cold intravenous fluid during resuscitation to no cooling,[70] and another trial compared intra-arrest intranasal cooling to no cooling.[71] When cooling maneuvers were initiated in the prehospital setting, neither survival nor neurologic recovery differed for any of these trials alone or when combined in a meta-analysis. One trial found an increase in pulmonary edema and rearrest among patients treated with a goal of prehospital infusion of 2 L of cold fluids[69].

4.2.2 2015 Recommendation - New

We recommend against the routine prehospital cooling of patients after ROSC with rapid infusion of cold intravenous fluids. (Class III: No Benefit, LOE A)

During the past few years, infusion of cold intravenous fluids has become a popular prehospital intervention that may influence the system of care. Initiation of a temperature management strategy en route to the hospital may increase the probability that temperature management continues during the hospitalization. Adverse effects of the rapid infusion of cold intravenous fluids in the prehospital setting must be weighed against this potential positive effect of earlier intervention. Current evidence indicates that there is no direct patient benefit from these interventions and that the intravenous fluid administration in the prehospital setting may have some potential harm, albeit with no increase in overall mortality. Whether different methods or devices for temperature control outside of the hospital are beneficial is unknown.

4.3 Avoidance of Hyperthermia - Updated ALS 879

After the completion of TTM for a set duration (such as 24 hours), the optimal approach to subsequent temperature management remains unknown. In 2015, the ILCOR systematic review evaluated both the approach to hyperthermia on presentation (before initiation of TTM) and after rewarming. The treatment recommendation to maintain a targeted temperature between 32ºC and 36ºC for postarrest patients will prevent early hyperthermia. Therefore, treatment recommendations for the avoidance of hyperthermia focus on the post-rewarming period.

4.3.1 2015 Evidence Summary

Observational studies consistently report that fever in the post–cardiac arrest patient who is not treated with TTM is associated with poor outcome.[72-76]

After rewarming to normothermia from TTM, many studies have noted that fever occurs in a significant proportion of patients.[76-83] Occurrence of hyperthermia during the first few days after cardiac arrest was associated with worse outcome in 2 studies[82,83] but not in others.[76-81]

4.3.2 2015 Recommendation - New

It may be reasonable to actively prevent fever in comatose patients after TTM. (Class IIb, LOE C-LD)

Fever will not occur during the first 24 to 48 hours after cardiac arrest when patients are treated with TTM. Though the evidence that supports avoiding hyperthermia is weak in postarrest patients, the intervention is relatively benign. In addition, fever is associated with worsened neurologic injury in comatose patients receiving intensive care for other conditions.[84,85] Therefore, the recommendation of the avoidance of fever is based on expert opinion that a relatively benign procedure is reasonable to perform in the face of a potential for worsening ischemic brain injury. The simplest method to accomplish prolonged hyperthermia prevention may be to leave the devices or strategies used for TTM in place.

5 Other Neurologic Care - Updated

Brain injury is a common cause of morbidity and mortality in post–cardiac arrest patients. Brain injury is the cause of death in 68% of patients after out-of-hospital cardiac arrest and in 23% after in-hospital cardiac arrest.[86] The pathophysiology of post–cardiac arrest brain injury involves a complex cascade of molecular events that are triggered by ischemia and reperfusion and then executed over hours to days after ROSC. Events and conditions in the post–cardiac arrest period have the potential to exacerbate or attenuate these injury pathways and impact ultimate outcomes. Clinical manifestations of post–cardiac arrest brain injury include coma, seizures, myoclonus, various degrees of neurocognitive dysfunction (ranging from memory deficits to persistent vegetative state), and brain death.[87]

The 2010 Guidelines emphasized advanced neurocritical care for patients who have brain injury after cardiac arrest, including electroencephalography (EEG) for detection of seizures, and prompt treatment of seizures. The 2015 ILCOR systematic review considered detection and treatment of seizures.

5.1 Seizure Management - Updated ALS 868 ALS 431

5.1.1 2015 Evidence Summary

The prevalence of seizures, nonconvulsive status epilepticus, and other epileptiform activity among patients who are comatose after cardiac arrest is estimated to be 12% to 22%.[88-90] Nonconvulsive status epilepticus may be a reason that patients are not awakening from coma. Three case series looked at 47 post–cardiac arrest patients who were treated for seizures or status epilepticus and found that only 1 patient survived with good neurologic function.[91-93]

Available evidence does not support prophylactic administration of anticonvulsant drugs. Two randomized clinical trials comparing anticonvulsants (thiopental[94] in one study and diazepam[88] in the other study) to placebo found no difference in any outcome when these drugs were administered shortly after ROSC. In addition, 1 nonrandomized clinical trial with historic controls did not find outcome differences when a combination of thiopental and phenobarbital[95] was provided after ROSC.

Prolonged epileptiform discharges are associated with secondary brain injury in other situations, making detection and treatment of nonconvulsive status epilepticus a priority.[96] However, there are no direct comparative studies in post–cardiac arrest patients of treating seizures versus not treating seizures. The 2015 ILCOR systematic review did not identify any evidence that 1 specific drug or combination of drugs was superior for treatment of epileptiform activity after cardiac arrest.

5.1.2 2015 Recommendations - Updated

An EEG for the diagnosis of seizure should be promptly performed and interpreted, and then should be monitored frequently or continuously in comatose patients after ROSC. (Class I, LOE C-LD)

The same anticonvulsant regimens for the treatment of status epilepticus caused by other etiologies may be considered after cardiac arrest. (Class IIb, LOE C-LD)

5.2 Neuroprotective Drugs

The molecular events that cause neurodegeneration after cardiac arrest occur over hours to days after ROSC. This time course suggests a potentially broad therapeutic window for neuroprotective drug therapy. However, the number of clinical trials performed to date is limited and has failed to demonstrate improved neurological outcome with potential neuroprotective drugs given after cardiac arrest.

Few neuroprotective drugs have been tested in clinical trials, and only one published randomized trial[97] was performed in which a neuroprotective drug was combined with therapeutic hypothermia. No neuroprotection benefit was observed when patients (without hypothermia) were treated with thiopental, glucocorticoids, nimodipine, lidoflazine, diazepam, and magnesium sulfate. One trial using coenzyme Q10 in patients receiving hypothermia failed to show improved survival with good neurological outcome.[97]

The routine use of coenzyme Q10 in patients treated with hypothermia is uncertain. (Class IIb, LOE B)

6 Respiratory Care - Updated

The 2010 Guidelines emphasized the identification of pulmonary dysfunction after cardiac arrest. The 2015 ILCOR systematic review evaluated whether a particular strategy of ventilator management should be employed for postarrest patients, with a specific focus on a target range for $Paco_2$.

6.1 Ventilation - Updated ALS 571

6.1.1 2015 Evidence Summary

Systematic reviews examined whether ventilation to achieve and maintain a particular $Paco_2$ was associated with improved outcome. Two observational studies[98,99] found hypocapnia to be associated with a worse neurologic outcome, and 1 observational study found hypocapnia was associated with failure to be discharged home.[100] Observational studies did not find any consistent association between hypercapnia and outcome.[98-101]

6.1.2 2015 Recommendation - Updated

Maintaining the Paco2 within a normal physiological range, taking into account any temperature correction, may be reasonable. (Class IIb, LOE B-NR)

Normocarbia (end-tidal CO_2 30–40 mmHg or $Paco_2$ 35– 45 mmHg) may be a reasonable goal unless patient factors prompt more individualized treatment. Other $Paco_2$ targets may be tolerated for specific patients. For example, a higher $Paco_2$ may be permissible in patients with acute lung injury or high airway pressures. Likewise, mild hypocapnia might be useful as a temporizing measure when treating cerebral edema, but hyperventilation might cause cerebral vasoconstriction. The need to avoid potential hyperventilation-induced cerebral vasoconstriction needs to be weighed against the correction of metabolic acidosis by hyperventilation. Providers should note that when patient temperature is below normal, laboratory values reported for $Paco_2$ might be higher than the actual values in the patient.

6.2 Oxygenation - Updated ALS 448

Previous guidelines suggested that the optimal titration of supplementary oxygen targets avoidance of prolonged hyperoxia. Episodes of hypoxia that can add to organ injury should also be prevented.

6.2.1 2015 Evidence Summary

The systematic review identified recent observational studies suggesting that excessively high arterial oxygen concentrations (hyperoxia) may harm various organs or worsen outcomes.[102-104] Other studies did not confirm this finding.[98,101,105-107] One small randomized trial comparing 30% inspired oxygen for 60 minutes after ROSC versus 100% inspired oxygen for 60 minutes after ROSC found no difference in either survival to hospital discharge or survival with favorable neurologic outcome.[108] Most studies defined hypoxia as Pao_2 less than 60 mmHg, and hyperoxia as a Pao_2 greater than 300 mmHg. However, the optimum upper and lower limits of Pao_2 are not known.

The 2010 Guidelines defined an arterial oxygen saturation (Sao_2) of less than 94% as hypoxemia, and there were no new data to suggest modifying this threshold. Minimizing risk of hyperoxia must be weighed against the need to avoid hypoxia, which has a well established detrimental effect.[103,106,109] Preventing hypoxic episodes is considered more important than avoiding any potential risk of hyperoxia.

6.2.2 2015 Recommendations - New and Updated

To avoid hypoxia in adults with ROSC after cardiac arrest, it is reasonable to use the highest available oxygen concentration until the arterial oxyhemoglobin saturation or the partial pressure of arterial oxygen can be measured. (Class IIa, LOE C-EO)

When resources are available to titrate the Fio2 and to monitor oxyhemoglobin saturation, it is reasonable to decrease the Fio2 when oxyhemoglobin saturation is 100%, provided the oxyhemoglobin saturation can be maintained at 94% or greater. (Class IIa, LOE C-LD)

Shortly after ROSC, patients may have peripheral vasoconstriction that makes measurement of oxyhemoglobin saturation by pulse oximetry difficult or unreliable. In those situations, arterial blood sampling may be required before titration of Fio_2 . Attempts to limit the concentration of inspired oxygen rely on having proper equipment available. For example, oxygen blenders may not be available immediately after return of pulses, and these recommendations remind providers using bag-mask devices and oxygen cylinders to simply provide the highest available oxygen concentration until titration is possible.

7 Treatment of Pulmonary Embolism After CPR

Fibrinolytic use may benefit patients with massive pulmonary emboli who have not had CPR,[110] and use of fibrinolytics to treat pulmonary embolism after CPR has been reported.[111] The use of fibrinolytics during CPR has been studied, and CPR itself does not appear to pose an unacceptable risk of bleeding.[112-120] Alternatively, surgical embolectomy has also been used successfully in some patients after PE-induced cardiac arrest.[116,121-124] Mechanical thrombectomy was employed in a small case series and only one of seven patients died and pulmonary perfusion was restored in the majority (85.7%).[114]

In post–cardiac arrest patients with arrest due to presumed or known pulmonary embolism, fibrinolytics may be considered. (Class IIb, LOE C)

8 Sedation After Cardiac Arrest

Patients with coma or respiratory dysfunction after ROSC are routinely intubated and maintained on mechanical ventilation for a period of time, which results in discomfort, pain, and anxiety. Intermittent or continuous sedation and/or analgesia can be used to achieve specific goals. Patients with post–cardiac arrest cognitive dysfunction may display agitation or frank delirium with purposeless movement and are at risk of self-injury. Opioids, anxiolytics, and sedative-hypnotic agents can be used in various combinations to improve patient-ventilator interaction and blunt the stress-related surge of endogenous catecholamines. Other agents with sedative and antipsychotic-tranquilizer properties, such as $?_2$-adrenergic agonists,[125] and butyrophenones[126] are also used based on individual clinical circumstances.

If patient agitation is life-threatening, neuromuscular blocking agents can be used for short intervals with adequate sedation. Caution should be used in patients at high risk of seizures unless continuous electroencephalographic (EEG) monitoring is available. In general sedative agents should be administered cautiously with daily interruptions and titrated to the desired effect. A number of sedation scales[127-132] and motor activity scales[133] were developed to titrate these pharmacological interventions to a clinical goal.

Shorter-acting medications that can be used as a single bolus or continuous infusion are usually preferred. There is little evidence to guide sedation/analgesia therapy immediately after ROSC. One observational study[134] found an association between use of sedation and development of pneumonia in intubated patients during the first 48 hours of therapy. However, the study was not designed to investigate sedation as a risk factor for either pneumonia or death in patients with cardiac arrest.

Although minimizing sedation allows a better clinical estimate of neurological status, sedation, analgesia, and occasionally neuromuscular relaxation are routinely used to facilitate induced hypothermia and to control shivering. The duration of neuromuscular blocker use should be minimized and the depth of neuromuscular blockade should be monitored with a nerve twitch stimulator.

It is reasonable to consider the titrated use of sedation and analgesia in critically ill patients who require mechanical ventilation or shivering suppression during induced hypothermia after cardiac arrest. (Class IIb, LOE C)

Duration of neuromuscular blocking agents should be kept to a minimum or avoided altogether.

9 Other Critical Care Interventions - Updated

Cardiac arrest is thought to involve multiorgan ischemic injury and microcirculatory dysfunction.[135,136,137] Implementing a protocol for goal-directed therapy using fluid and vasoactive drug administration along with monitoring of central venous oxygen saturation may improve survival from sepsis,[138] suggesting that a similar approach may benefit post–cardiac arrest patients. By analogy, studies have explored several other interventions believed to be beneficial in sepsis or other critical illness.

9.1 Glucose Control - Updated ALS 580

The 2010 Guidelines acknowledged that the optimum blood glucose concentration and interventional strategy to manage blood glucose in the post–cardiac arrest period are unknown. Glycemic control in critically ill patients is controversial, and efforts to tightly control glucose at low levels have been associated with increased frequency of hypoglycemic episodes that may be detrimental.

9.1.1 2015 Evidence Summary

The 2015 ILCOR systematic review found no new evidence that a specific target range for blood glucose management improved relevant clinical outcomes after cardiac arrest. One randomized trial in post–cardiac arrest patients comparing strict (72 to 108 mg/dL) versus moderate (108 to 144 mg/dL) glucose control found no difference in 30-day mortality.[139] One before-and-after study of a bundle of care that included a target glucose range (90 to 144 mg/dL) reported better survival and functional recovery at hospital discharge, but the effects of glucose control could not be separated from the remainder of the bundle.[44] No data suggest that the approach to glucose management chosen for other critically ill patients should be modified for cardiac arrest patients.[140-142]

9.1.2 2015 Recommendation - Updated

The benefit of any specific target range of glucose management is uncertain in adults with ROSC after cardiac arrest. (Class IIb, LOE B-R)

9.2 Steroids

Corticosteroids have an essential role in the physiological response to severe stress, including maintenance of vascular tone and capillary permeability. In the post–cardiac arrest phase, several authors report a relative adrenal insufficiency compared with the metabolic demands of the body.[143,144] Relative adrenal insufficiency in the post–cardiac arrest phase was associated with higher rates of mortality.[143-145]

At present there are no human randomized trials investigating corticosteroid use after ROSC. One investigation combined steroid therapy with use of vasopressin, which made interpretation of results specific to steroids impossible.[146] The post–cardiac arrest syndrome has similarities to septic shock, but the efficacy of corticosteroids remains controversial in patients with sepsis as well.[135,147-149] Whether the provision of corticosteroids in the post–cardiac arrest phase improves outcome remains unknown and the value of the routine use of corticosteroids for patients with ROSC following cardiac arrest is uncertain.

9.3 Hemofiltration

Hemofiltration has been proposed as a method to modify the humoral response to the ischemic-reperfusion injury that occurs after cardiac arrest. In a single randomized controlled trial there was no significant difference in 6-month survival among the groups.[150] Future investigations are required to determine whether hemofiltration will improve outcome in post–cardiac arrest patients.

10 Prognostication of Outcome - Updated

The 2010 Guidelines discussed the use of clinical examination, electrophysiologic measurements, imaging studies, and evaluation of blood or cerebrospinal fluid markers of brain injury to estimate the prognosis for neurologic improvement in patients who are comatose after cardiac arrest. The 2015 ILCOR systematic review examined numerous studies of the diagnostic accuracy of clinical findings, electrophysiologic modalities, imaging

modalities, and blood markers for predicting neurologic outcome in comatose post–cardiac arrest patients who receive TTM, and examined recent studies of these modalities in comatose post–cardiac arrest patients who do not receive TTM. Updated guidelines for prognostication have also been proposed by other international organizations.[151]

Most studies examined the accuracy of diagnostic tests for predicting a poor outcome (as defined by a Cerebral Performance Category score of 3 to 5) and focused on patients receiving TTM with a goal of 32°C to 34°C. The writing group assumed that the accuracy of prognostic tests is similar in patients receiving TTM with a goal of 36°C when similar sedation and paralysis are used as in patients receiving TTM with a goal of 32°C to 34°C. Recognizing the need for high certainty when predicting that outcomes will be poor, the writing group focused recommendations on diagnostic tests for which the systematic review identified false-positive rates (FPRs) close to 0%, with narrow 95% confidence intervals (CIs; 0%–10%).

Experienced clinicians should select the proper tests and studies for individual patients. Some patients will recoverquickly and will require no special testing. For other patients, prediction of their recovery trajectory may be impossible despite collecting every available test and imaging study. The following recommendations are designed to provide guidance to clinicians about the performance of specific findings and tests, recognizing that not every patient will require every study.

10.1 Timing of Outcome Prediction - Updated ALS 450 ALS 713

It is important to consider the optimal timing for prognostication in post–cardiac arrest patients. In 2015, the ILCOR task force evaluated the timing of prognostication for patients receiving TTM and for those not receiving TTM.

10.1.1 2015 Evidence Summary

Sedatives or neuromuscular blockers received during TTM may be metabolized more slowly in post–cardiac arrest patients, and injured brains may be more sensitive to the depressant effects of various medications. Residual sedation or paralysis can confound the accuracy of clinical examinations.[152,153] The optimal time for prognostication is when the FPRs of the various prognostic tools approach zero. Multiple investigations suggest that it is necessary to wait to prognosticate for a minimum of 72 hours after ROSC to minimize the rate of false-positive results in patients who had not undergone TTM[154] and to wait for some period of time after return of normothermia for those using TTM.[155]

10.1.2 2015 Recommendations - New and Updated

The earliest time for prognostication using clinical examination in patients treated with TTM, where sedation or paralysis could be a confounder, may be 72 hours after return to normothermia. (Class IIb, LOE C-EO)

We recommend the earliest time to prognosticate a poor neurologic outcome using clinical examination in patients not treated with TTM is 72 hours after cardiac arrest. (Class I, LOE B-NR)

This time until prognostication can be even longer than 72 hours after cardiac arrest if the residual effect of sedation or paralysis confounds the clinical examination. (Class IIa, LOE C-LD)

Operationally, the timing for prognostication is typically 4.5 to 5 days after ROSC for patients treated with TTM. This approach minimizes the possibility of obtaining false-positive results (ie, inaccurately suggesting a poor outcome) because of drug-induced depression of neurologic function. In making this recommendation, it is recognized that in some instances, withdrawal of life support may occur appropriately before 72 hours because of underlying terminal disease, brain herniation, or other clearly nonsurvivable situations.

10.2 Clinical Examination Findings That Predict Outcome - Updated ALS 450 ALS 713

Prediction of outcome based on clinical examination may be challenging. In 2015, the ILCOR Advanced Life Support Task Force evaluated a series of clinical exam findings to determine their value in outcome prediction.

10.2.1 2015 Evidence Summary

The 2015 ILCOR systematic review examined pupillary light reflexes, corneal reflexes, and motor response for predictionof poor functional recovery in patients treated with TTM. Bilaterally absent pupillary light reflex at 72 to 108 hours after cardiac arrest predicted poor outcome, with an FPR of 1% (95% CI, 0%–3%).[156-160] Bilaterally absent corneal reflexes at 72 to 120 hours after cardiac arrest predicted poor outcome, with a 2% FPR (95% CI, 0%–7%).[158-161] Extensor posturing or no motor response to pain at 36 to 108 hours after cardiac arrest predicted poor outcome, with a 10% FPR (95% CI, 7%–15%).[156,158,160,162-164] Only the absent pupillary light reflex at 72 to 108 hours achieved an FPR of 0% (95% CI, 0%–3%).

In patients not treated with TTM, absent pupillary light reflex 72 hours after cardiac arrest predicts poor outcome, with 0% FPR (95% CI, 0%–8%).[165,166] Absent corneal reflex at 24 hours and 48 hours after cardiac arrest predicted poor outcome, with an FPR of 17% (95% CI, 9%–27%) and an FPR of 7% (95% CI, 2%–20%), respectively.[166-168] Extensor posturing or no motor response to pain at 72 hours after cardiac arrest predicted a poor outcome, with 15% FPR (95% CI, 5%–31%).[166,169] As in TTM-treated patients, only the absent pupillary light reflex at 72 to 108 hours achieved 0% FPR (95% CI, 0%–8%).

The 2015 ILCOR systematic review distinguished myoclonus from status myoclonus (continuous, repetitive myoclonic jerks lasting more than 30 minutes) in patients treated with TTM. Any myoclonus within 72 hours after cardiac arrest predicted a poor outcome, with a 5% FPR (95% CI, 3%–8%).[92,156,162,163,170,171] In 1 study,[164] presence of myoclonus within 7 days after ROSC predicted poor outcome, with 11% FPR (95% CI, 3%–26%) and 54% FPR (95% CI, 41%–66%) sensitivity. In 3 studies,[89,159,160] presence of status myoclonus (defined as a continuous prolonged and generalized myoclonus) within 72 to 120 hours after ROSC predicted poor outcome, with a 0% FPR (95% CI, 0%–4%). However, some series report good neurologic recovery in which an earlyonset and prolonged myoclonus evolved into a chronic action myoclonus (Lance-Adams syndrome).[170,172-174] Therefore, the presence of any myoclonus is not a reliable predictor of poor functional recovery, but status myoclonus during the first 72 hours after cardiac arrest achieved an FPR of 0% (95% CI, 0%–4%).

In patients not treated with TTM, status myoclonus on admission (FPR, 0%; 95% CI, 0%–5%)[175] at 24 hours after cardiac arrest[168] (FPR, 0%; 95% CI, 0%–7%) or within 72 hours of cardiac arrest[166,176] (FPR, 0%; 95% CI, 0%–14%) is associated with poor outcome. The older studies were less precise in distinguishing myoclonus from status myoclonus, lowering confidence in their estimated predictive value.

10.2.2 2015 Recommendations - New and Updated

In comatose patients who are not treated with TTM, the absence of pupillary reflex to light at 72 hours or more after cardiac arrest is a reasonable exam finding with which to predict poor neurologic outcome (FPR, 0%; 95% CI, 0%–8%). (Class IIa, LOE B-NR)

In comatose patients who are treated with TTM, the absence of pupillary reflex to light at 72 hours or more after cardiac arrest is useful to predict poor neurologic outcome (FPR, 1%; 95% CI, 0%–3%). (Class I, LOE B-NR)

We recommend that, given their unacceptable FPRs, the findings of either absent motor movements or extensor posturing should not be used alone for predicting a poor neurologic outcome (FPR, 10%; 95% CI, 7%–15% to FPR, 15%; 95% CI, 5%–31%). (Class III: Harm, LOE B-NR)

The motor examination may be a reasonable means to identify the population who need further prognostic testing to predict poor outcome. (Class IIb, LOE B-NR)

We recommend that the presence of myoclonus, which is distinct from status myoclonus, should not be used to predict poor neurologic outcomes because of the high FPR (FPR, 5%; 95% CI, 3%–8% to FPR, 11%; 95% CI, 3%–26%). (Class III: Harm, LOE B-NR)

In combination with other diagnostic tests at 72 or more hours after cardiac arrest, the presence of status myoclonus during the first 72 to 120 hours after cardiac arrest is a reasonable finding to help predict poor neurologic outcomes (FPR, 0%; 95% CI, 0%–4%). (Class IIa, LOE B-NR)

10.3 EEG Findings to Predict Outcome - Updated ALS 450 ALS 713

EEG is a widely used tool to assess brain cortical activity and diagnose seizures. EEG is the standard tool used to assess brain electrical activity (ie, EEG rhythms) and paroxysmal activity (ie, seizures and bursts). While EEG has been used widely in the diagnosis of seizures and prognostication after cardiac arrest, the lack of standardized EEG terminology continues to be a major limitation in research and practice.[177]

10.3.1 2015 Evidence Summary

In patients treated with TTM, the 2015 ILCOR systematic review identified EEG with burst suppression, epileptiform activity, and reactivity as potential predictors of poor outcome. Two studies reported that burst suppression on initial EEG predicted poor outcome, with a 0% FPR (95% CI, 0%–5%),[178,179] but 2 other studies reported that EEG during TTM predicted poor outcome, with a 6% FPR (95% CI, 1%– 15%).[163,180] Burst suppression after rewarming was associated with poor outcome[179] (FPR, 0%; 95% CI, 0%–5%). Some studies reported good outcome despite the presence of epileptiform discharges during TTM.[162,181] In several case series, no patients with electrographic seizures during or after TTM had good outcome,[92,162,181-183] but other studies reported cases with good outcome when seizures occurred in the presence of a reactive EEG background.[170,179] Absence of EEG reactivity during TTM predicted poor outcome, with an FPR of 2% (95% CI, 1%–7%),[92,163,171] and absence of EEG reactivity after rewarming predicted poor outcome, with an FPR of 0% (95% CI, 0%–3%).[92,162,163] Low-voltage EEG,[179] low bispectral index,[184] and EEG grades[92] were not reliably associated with poor outcome.

In patients not treated with TTM, the 2015 ILCOR systematic review identified EEG grades, burst suppression, and amplitude as potential predictors of poor outcome. EEG grades 4 to 5 at 72 hours or less after cardiac arrest predicted poor outcome, with a 0% FPR (95% CI, 0%–8%),[185-187] and burst suppression at 72 hours after cardiac arrest predicted poor outcome, with a 0% FPR (95% CI, 0%–11%).[166] EEG grades were not defined consistently between studies. Low-voltage EEG (?20 to 21 ?V) predicted poor outcome, with 0%FPR (95% CI, 0%–5%) within 48 hours after cardiac arrest (1 study)[168] and with 0% FPR (95% CI, 0%–11%) at 72 hours after cardiac arrest.[166] However, low-voltage EEG is not reliable, because a variety of technical factors can affect EEG amplitude.

10.3.2 2015 Recommendations - Updated

In comatose post–cardiac arrest patients who are treated with TTM, it may be reasonable to consider persistent absence of EEG reactivity to external stimuli at 72 hours after cardiac arrest, and persistent burst suppression on EEG after rewarming, to predict a poor outcome (FPR, 0%; 95% CI, 0%–3%). (Class IIb, LOE B-NR)

Intractable and persistent (more than 72 hours) status epilepticus in the absence of EEG reactivity to external stimuli may be reasonable to predict poor outcome. (Class IIb, LOE B-NR)

In comatose post–cardiac arrest patients who are not treated with TTM, it may be reasonable to consider the presence of burst suppression on EEG at 72 hours or more after cardiac arrest, in combination with other predictors, to predict a poor neurologic outcome (FPR, 0%; 95% CI, 0%–11%). (Class IIb, LOE B-NR)

10.4 Evoked Potentials to Predict Outcome - Updated ALS 450 ALS 713

The 2010 Guidelines advised that somatosensory evoked potentials (SSEPs) could be used as a prognostic tool in cardiac arrest survivors. The N20 waveform recorded from the primary cortical somatosensory area after median nerve stimulation was evaluated as a predictor of neurologic recovery in post–cardiac arrest patients.

10.4.1 2015 Evidence Summary

The 2015 systematic review found that in patients who are comatose after resuscitation from cardiac arrest and who are treated with TTM, bilaterally absent N20 was highly predictive of poor outcome. Absent N20 during TTM predicted poor outcome, with a 2% FPR (95% CI, 0%–4%).[156,180,188,189] Absent N20 after rewarming predicted poor outcome, with a 1% FPR (95% CI, 0%–3%).[156-158,160,162-164,171,190,191] One caution about these data is that SSEP has been used by healthcare providers and families as the parameter for withdrawal of life-sustaining therapies both in studies[155] and in bedside care, a practice that may inflate the apparent predictive accuracy of the test.

In patients not treated with TTM, bilateral absence of the N20 predicts poor outcome at 24, 48, or 72 hours after cardiac arrest (FPR, 0%; 95% CI, 0%–3% and 0%–12%).[167,189,192-200] Only 1 case of a false-positive result from absent SSEP in a patient not treated with TTM was identified.[168] Again, these studies may have allowed treating teams to act on the results of the SSEP, potentially inflating the accuracy of this test.

10.4.2 2015 Recommendations - Updated

In patients who are comatose after resuscitation from cardiac arrest regardless of treatment with TTM, it is reasonable to consider bilateral absence of the N20 SSEP wave 24 to 72 hours after cardiac arrest or after rewarming a predictor of poor outcome (FPR, 1%; 95% CI, 0%–3%). (Class IIa, LOE B-NR)

SSEP recording requires appropriate skills and experience, and utmost care should be taken to avoid electrical interference from muscle artifacts or from the intensive care unit environment. However, sedative drugs or temperature manipulation affect SSEPs less than they affect the EEG or clinical examination.[189,201]

10.5 Imaging Tests to Predict Outcome - Updated ALS 450 ALS 713

Previous guidelines did not suggest specific imaging tests for prognosis in post–cardiac arrest coma. Brain imaging studies, including computed tomography (CT) or magnetic resonance imaging (MRI) can define structural brain injury or detect focal injury. On brain CT, some post–cardiac arrest patients exhibit brain edema, which can be quantified as the graywhite ratio (GWR), defined as the ratio between the x-ray attenuation measured in Hounsfield units of the gray matter and the white matter. Normal brain has GWR around 1.3, and this number decreases with edema.[157] Brain edema on MRI is a sensitive marker of focal injury and is detected by restricted diffusion on diffusion-weighted imaging (DWI) sequences[202] and can be quantified by using apparent diffusion coefficient (ADC). Normal ADC values range between 700 and 800 × 10?6 mm2 /s and decrease with edema.[203]

10.5.1 2015 Evidence Summary

The 2015 ILCOR systematic review identified 4 studies of CT scan performed within 2 hours after cardiac arrest in patients treated with TTM. A reduced GWR at the level of the basal ganglia on brain CT predicted poor outcome, with FPR ranging from 0% to 8%.[157,204-206] Measurement techniques and thresholds for GWR varied among studies. Global cerebral edema on brain CT at a median of 1 day after cardiac arrest also predicted poor outcome[159] (FPR, 0%; 95% CI, 0%–5%).

The 2015 ILCOR systematic review found 3 studies of CT scan on patients not treated with TTM. At 72 hours after cardiac arrest, the presence of diffuse brain swelling on CT predicted a poor outcome, with a 0% FPR (95% CI, 0%–45%).[207] In 2 studies, a GWR between the caudate nucleus and the posterior limb of internal capsule below 1.22 within 24 hours (FPR, 0%; 95% CI, 0%–28%) or below 1.18 within 48 hours (FPR, 17%; 95% CI, 0%–64%) after cardiac arrest predicted poor outcome.[208,209]

In patients treated with TTM, the 2015 systematic review identified two studies relating MRI findings to outcome. Presence of more than 10% of brain volume with ADC less than 650 × $10^{?6}$ mm^2/s predicted poor outcome[210] (FPR, 0%; 95% CI, 0%–78%). Low ADC at the level of putamen, thalamus, or occipital cortex predicted poor outcome, with 0% FPR[211] (95% CIs, from 0%–24%), although the ADC threshold in each region varied.

In patients not treated with TTM, 6 studies related MRI findings to poor outcome. Diffuse DWI abnormalities in cortex or brainstem at a median of 80 hours after cardiac arrest predicted poor outcome, with a 0% FPR (95% CI, 0%–35%).[202] Extensive (cortex, basal ganglia, and cerebellum) DWI changes predicted poor outcome, with a 0% FPR (95% CI, 0%–45%).[212] Whole-brain ADC less than 665 × $10^{?6}$ mm^2/s predicted poor outcome, with 0% FPR (95% CI, 0%–21%).[213] More than 10% of brain volume with ADC less than 650 × $10^{?6}$ mm^2/s predicted poor outcome, with 0% FPR (95% CI, 0%–28%).[210] ADC below various thresholds at the level of putamen, thalamus, or occipital cortex at less than 120 hours after cardiac arrest predicted poor outcome, with 0% FPR (95% CI, 0%–31%). The presence of extensive cortical global DWI or fluid-attenuated inversion recovery changes within 7 days from arrest-predicted poor outcome, with a 0% FPR (95% CI, 0%–78%).[169,203]

MRI testing may be difficult in unstable patients, which may lead to selection bias. Studies report that DWI changes are most apparent more than 48 hours after cardiac arrest,[210] with most studies examining patients 3 to 7 days after cardiac arrest.

10.5.2 2015 Recommendations - New

In patients who are comatose after resuscitation from cardiac arrest and not treated with TTM, it may be reasonable to use the presence of a marked reduction of the GWR on brain CT obtained within 2 hours after cardiac arrest to predict poor outcome. (Class IIb, LOE B-NR)

It may be reasonable to consider extensive restriction of diffusion on brain MRI at 2 to 6 days after cardiac arrest in combination with other established predictors to predict a poor neurologic outcome. (Class IIb, LOE B-NR)

Acquisition and interpretation of imaging studies have not been fully standardized and are subject to interobserver variability.[214] In addition, the recommendations for brain imaging studies for prognostication are made with the assumption that images are performed in centers with expertise in this area.

10.6 Blood Markers to Predict Outcome - Updated ALS 450 ALS 713

Many blood markers have been examined for the prognostication of post–cardiac arrest patients. In 2015, the ILCOR Advanced Life Support Task Force evaluated whether blood markers can be used alone or in conjunction with other neurologic testing to prognosticate outcome in postarrest patients.

10.6.1 2015 Evidence Summary

The 2015 ILCOR systematic review examined many studies of blood markers to predict neurologic outcomes at various times after cardiac arrest, both in patients treated and not treated with TTM.[156,158-160,163,166,171,183,184,196,198,206,211,215-227] Neuron-specific enolase (NSE) and S-100B are the 2 most commonly examined blood markers.

Studies of NSE and S-100B reported that initial S-100B levels were higher in patients with poor outcome compared to patients with good outcome, and that NSE levels would increase over 72 hours in patients with poor outcome relative to patients with good outcome. However, studies did not identify specific blood levels of these proteins that enable prediction of poor neurologic outcome with perfect specificity and narrow confidence intervals. Therefore, no threshold values that enable prediction of poor outcome with confidence were identified.

10.6.2 2015 Recommendations - Updated

Given the possibility of high FPRs, blood levels of NSE and S-100B should not be used alone to predict a poor neurologic outcome. (Class III: Harm, LOE C-LD)

When performed with other prognostic tests at 72 hours or more after cardiac arrest, it may be reasonable to consider high serum values of NSE at 48 to 72 hours after cardiac arrest to support the prognosis of a poor neurologic outcome (Class IIb, LOE B-NR), especially if repeated sampling reveals persistently high values. (Class IIb, LOE C-LD)

Laboratory standards for NSE and S-100B measurement vary between centers, making comparison of absolute values difficult. The kinetics of these markers have not been studied, particularly during or after TTM in cardiac arrest patients. Finally, NSE and S-100B are not specific to neuronal damage and can be produced by extra–central nervous system sources (hemolysis, neuroendocrine tumors, myenteric plexus, muscle, and adipose tissue breakdown). If care is not taken when drawing NSE levels and if multiple time points are not assessed, false-positive results could occur secondary to hemolysis. All of these limitations led the writing group to conclude that NSE should be limited to a confirmatory test rather than a primary method for estimating prognosis.

11 Organ Donation - Updated ALS 449

The 2010 Guidelines emphasized that adult patients who progress to brain death after resuscitation from cardiac arrest should be considered as potential organ donors.

11.1 2015 Evidence Summary

The 2015 ILCOR systematic reviews considered the success rate of transplants when organs are taken from adult and pediatric donors who progressed to death or brain death after cardiac arrest. Post–cardiac arrest patients are an increasing proportion of the pool of organ donors.[228] When patients who have previously had cardiopulmonary resuscitation proceed to become organ donors, each donor provides a mean of 3.9[229] or 2.9[228] organs. Multiple studies found no difference in immediate or long-term function of organs from donors who reach brain death after cardiac arrest when compared with donors who reach brain death from other causes. In addition, some patients have withdrawal of life support after cardiac arrest as a consequence of failure to improve neurologically or as part of advanced directives, which can lead to cardiovascular death in a predictable time frame that may allow donation of kidney or liver. Organs transplanted from these donors also have success rates comparable to similar donors with other conditions. These studies examined adult hearts,[228,230-236] pediatric hearts,[228,237-240] adult lungs,[228,234,241] pediatric lungs,[228] adult kidneys,[228,242] pediatric kidneys,[228,239] adult livers,[228,230] pediatric livers,[228,239] adult intestines,[228,243] and pediatric intestines.[228] Finally, tissue donation (cornea, skin, and bone) is almost always possible if post-cardiac arrest patients die.

A few programs have developed procedures for recovery of kidney and liver when return of pulses cannot be achieved. Existing programs rely on continued mechanical circulatory support and very rapid mobilization of surgeons and transplant teams after a patient is unexpectedly pronounced dead. The resources to accomplish these donations require significant institutional preparation. These programs also require careful and thoughtful safeguards to prevent donation efforts from interfering with ongoing resuscitation efforts. A mean of 1.5[244] or 3.2[245] organs were procured from each donor in these programs. Function of adult kidneys[246-248] or adult livers[244,247,249] from these donors was similar immediately, 1 year, and 5 years after transplantation.

11.2 2015 Recommendations - Updated and New

We recommend that all patients who are resuscitated from cardiac arrest but who subsequently progress to death or brain death be evaluated for organ donation. (Class I, LOE B-NR)

Patients who do not have ROSC after resuscitation efforts and who would otherwise have termination of efforts may be considered candidates for kidney or liver donation in settings where programs exist. (Class IIb, LOE B-NR)

The ethics and practical aspects of these programs are quite complex and beyond the scope of this review.

12 Conclusions and Future Directions - Updated

The field of post–cardiac arrest care has increased in rigor and depth over the past decade. Investigations over this period illustrate the heterogeneity of patients hospitalized after cardiac arrest in terms of etiology, comorbid disease, and illness severity. Future interventional trials should ideally be designed to take into account patient heterogeneity and focus interventions on the specific subgroups most likely to benefit. By tailoring interventions to patient physiology and disease, a greater chance exists that the right therapies will be matched to the patients who will benefit.

13 Authorship and Disclosures

13.1 2015 Writing Team

Clifton W. Callaway, Chair; Michael W. Donnino; Ericka L. Fink; Romergryko G. Geocadin; Eyal Golan; Karl B. Kern; Marion Leary; William J. Meurer; Mary Ann Peberdy; Trevonne M. Thompson; Janice L. Zimmerman

Table 3: Part 8: Post–Cardiac Arrest Care: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 8: Post–Cardiac Arrest Care: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Clifton W. Callaway	University of Pittsburgh; UPMC Health System	None	None	None	None	None	None	None
Ericka L. Fink	Children's Hospital of Pittsburgh of UPMC	NIH†; Laerdal Foundation†	None	None	None	None	None	None
Romergryko G. Geocadin	Johns Hopkins University School of Medicine	NIH†	None	None	Medicolegal consulting*	None	None	None
Eyal Golan	University Health Network	None	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Karl B. Kern	University of Arizona	Zoll Medical†; PhysioControl†; Arizona Biomedical Research Association†	None	BARD, Inc.	None	None	None	None
Marion Leary	University of Pennsylvania	American Heart Association† Laerdal†	None	None	None	Resuscor*	PhysioContr Laerdal*	None
William J. Meurer	University of Michigan	None	None	None	None	None	None	None
Mary Ann Peberdy	Virginia Commonwea University	Zoll Medical†	None	None	None	None	None	None
Trevonne M. Thompson	University of Illinois at Chicago	None	None	None	None	None	None	None
Janice L. Zimmerman	The Methodist Hospital Physician Organization	None	None	None	None	None	Decisio Health, Inc*	None
Consultant								
Michael W. Donnino	Beth Israel Deaconess Med Center	American Heart Association†	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.*Modest.†Significant.

13.2 2010 Writing Team

Mary Ann Peberdy, Co-Chair*; Clifton W. Callaway, Co-Chair*; Robert W. Neumar; Romergryko G. Geocadin; Janice L. Zimmerman; Michael Donnino; Andrea Gabrielli; Scott M. Silvers; Arno L. Zaritsky; Raina Merchant; Terry L. Vanden Hoek; Steven L. Kronick

Table 4: 2010 - Guidelines Part 9: Post–Cardiac Arrest Care: Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 9: Post–Cardiac Arrest Care: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Mary Ann Peberdy	Virginia Commonwealth University–Professor of Medicine & Emergency Medicine	None	None	None	None	None	None
Clifton W. Callaway	University of Pittsburgh School of Medicine–Assc Professor; UPMC Health System–Physi	†Grants to University of Pittsburgh: NHLBI-Resuscitation Outcomes Consortium HRSA-Development and Dissemination of Program Tools for Uncontrolled Donation After Cardiac Death (UDCD)	*Loan of an Arctic Sun cooling device (without disposables) to human physiology laboratory for experiments on hypothermia by Medivance, Inc.	None	†Co-inventor on patent about ventricular fibrillation waveform analysis, licensed by University of Pittsburgh to Medtronic ERS, Inc.	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Robert W. Neumar	University of Pennsylvania–Associate Professor of Emergency Medicine	†Funding Source: NIH/NINDS Grant Number: R21 NS054654 Funding Period 06/01/07 to 06/31/2010 Role on Project: Principal Investigator Title: Optimizing Therapeutic Hypothermia After Cardiac Arrest Description: The goal of this project is to evaluate how the onset and duration of therapeutic hypothermia after cardiac arrest impacts survival and neuroprotection	None	None	None	None	None
Romergryko G. Geocadin	Johns Hopkins University School of Medicine–Asso Professor of Neurology, Anesthesiology Critical Care Medicine and Neurosurgery	†NIH RO1 Grant: “Consequence of Cardiac Arrest: Brain Injury” *NIH R44 Grant: “Cortical Injury Monitor Phase IIB”	None	*Academic Grand Rounds American Academy of Neurology	None	None	*Guest Editor: Neurology Clinics, Emergency Medicine Clinics, and Seminars in Neurology

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Janice L. Zimmerman	The Methodist Hospital Physician Organization–Head, Critical Care Division and Director, MICU	None	None	*Society of Critical Care Medicine American College of Chest Physicians Center for Biomedical Communications	None	None	*Callaway and Associates Andrews and Kurth
Michael Donnino	Harvard Medical Faculty Physicians–Ph	† Corticosteroids in Post-cardiac Arrest Patients [Scientist Development Grant, American Heart Association] Thiamine as a Metabolic Resuscitator in Septic Shock [Pending] * Thiamine Deficiency in Septic Shock [completed, NIH through Harvard Medical School] Statin Therapy in Sepsis [Eleanor Shores Grant-nonindustry]	None	None	None	None	None
Andrea Gabrielli	University of Florida–Professor of Anesthesiology and Surgery	†NIH-Biomarkers and Traumatic Brain Injury	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Scott M. Silvers	Mayo Clinic Florida–Chair, Department of Emergency Medicine	None	None	None	None	None	None
Arno L. Zaritsky	Children's Hospital of the King's Daughters–Sr. VP for Clinical Services	None	None	None	None	*Data Safety Monitoring Board for NIH-sponsored clinical trial of therapeutic hypothermia after pediatric cardiac arrest	None
Raina Merchant	University of Pennsylvania–fellow	None	None	None	None	None	None
Terry L. Vanden Hoek	University of Chicago–Associate Professor	*Principal Investigator 09/06/04–04/30/10 DOD/Office of Naval Research $885 639 Proteomic Development of Molecular Vital Signs: Mapping a Mitochondrial Injury Severity Score to Triage and Guide Resuscitation of Hemorrhagic Shock. This research grant is awarded to the University of Chicago	None	None	*Hypothermia Induction Patents (3 approved, 3 pending) no income	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Steven L. Kronick	University of Michigan Health System Healthcare institution Assistant Professor	None	None	None	None	None	*Expert Witness: Reviewed a single case for an attorney. Less than 4 hours work total

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

14 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 8: Post-Cardiac Arrest Care. ECCguidelines.heart.org.

References

1. Morrison LJ, Deakin CD, Morley PT, Callaway CW, Kerber RE, Kronick SL, Lavonas EJ, Link MS, Neumar RW, Otto CW, Parr M, Shuster M, Sunde K, Peberdy MA, Tang W, Hoek TL, Böttiger BW, Drajer S, Lim SH, Nolan JP; Advanced Life Support Chapter Collaborators. Part 8: advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122(suppl 2):S345– S421. doi: 10.1161/CIRCULATIONAHA.110.971051.

2. Deakin CD, Morrison LJ, Morley PT, Callaway CW, Kerber RE, Kronick SL, Lavonas EJ, Link MS, Neumar RW, Otto CW, Parr M, Shuster M, Sunde K, Peberdy MA, Tang W, Hoek TL, Böttiger BW, Drajer S, Lim SH, Nolan JP; Advanced Life Support Chapter Collaborators. Part 8: advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e93–e174. doi: 10.1016/j.resuscitation.2010.08.027.

3. Callaway CW, Soar J, Aibiki M, Böttiger BW, Brooks SC, Deakin CD, Donnino MW, Drajer S, Kloeck W, Morley PT, Morrison LJ, Neumar RW, Nicholson TC, Nolan JP, Okada K, O’Neil BJ, Paiva EF, Parr MJ, Wang TL, Witt J; on behalf of the Advanced Life Support Chapter Collaborators. Part 4: advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S84–S145. doi: 10.1161/CIR.0000000000000273.

4.

Soar J, Callaway CW, Aibiki M, Böttiger BW, Brooks SC, Deakin CD, Donnino MW, Drajer S, Kloeck W, Morley PT, Morrison LJ, Neumar RW, Nicholson TC, Nolan JP, Okada K, O'Neil BJ, Paiva EF, Parr MJ, Wang TL, Witt J; on behalf of the Advanced Life Support Chapter Collaborators. Part 4: advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

5. O'Connor D, Green S, Higgins JPT, eds. Chapter 5: defining the review questions and developing criteria for including studies. In: The Cochrane Collaboration. Higgins JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0. 2011. http://handbook. cochrane.org/. Accessed May 6, 2015.

6. Schünemann H, Broz?ek J, Guyatt G, Oxman A. GRADE Handbook. 2013. http://www.guidelinedevelopment.org/handbook/. Accessed May 6, 2015.

7. Negovsky VA. The second step in resuscitation–the treatment of the 'post-resuscitation disease.' Resuscitation. 1972;1:1–7.

8. Laurent I, Monchi M, Chiche JD, Joly LM, Spaulding C, Bourgeois B, Cariou A, Rozenberg A, Carli P, Weber S, Dhainaut JF. Reversible myocardial dysfunction in survivors of out-of-hospital cardiac arrest. J Am Coll Cardiol. 2002;40:2110–2116.

9. Skrifvars MB, Pettila V, Rosenberg PH, Castren M. A multiple logistic regression analysis of in-hospital factors related to survival at six months in patients resuscitated from out-of-hospital ventricular fibrillation. Resuscitation. 2003;59:319–328.

10. Carr BG, Kahn JM, Merchant RM, Kramer AA, Neumar RW. Inter-hospital variability in post-cardiac arrest mortality. Resuscitation. 2009;80:30–34.

11. Callaway CW, Schmicker R, Kampmeyer M, Powell J, Rea TD, Daya MR, Aufderheide TP, Davis DP, Rittenberger JC, Idris AH. Nichol G Receiving hospital characteristics associated with survival after out-of-hospital cardiac arrest. Resuscitation; 2010;81:524–529.

12. Kirves H, Skrifvars MB, Vahakuopus M, Ekstrom K, Martikainen M, Castren M. Adherence to resuscitation guidelines during prehospital care of cardiac arrest patients. Eur J Emerg Med. 2007;14:75–81.

13. Sunde K, Pytte M, Jacobsen D, Mangschau A, Jensen LP, Smedsrud C, Draegni T, Steen PA. Implementation of a standardised treatment protocol for post resuscitation care after out-of-hospital cardiac arrest. Resuscitation. 2007;73:29–39.

14. Gaieski DF, Band RA, Abella BS, Neumar RW, Fuchs BD, Kolansky DM, Merchant RM, Carr BG, Becker LB, Maguire C, Klair A, Hylton J, Goyal M. Early goal-directed hemodynamic optimization combined with therapeutic hypothermia in comatose survivors of out-of-hospital cardiac arrest. Resuscitation. 2009;80:418–424.

15. Neumar RW, Nolan JP, Adrie C, Aibiki M, Berg RA, Böttiger BW, Callaway C, Clark RS, Geocadin RG, Jauch EC, Kern KB, Laurent I, Longstreth WT Jr, Merchant RM, Morley P, Morrison LJ, Nadkarni V, Peberdy MA, Rivers EP, Rodriguez-Nunez A, Sellke FW, Spaulding C, Sunde K, Vanden Hoek T. Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication: a consensus statement from the International Liaison Committee on Resuscitation (American Heart Association, Australian and New Zealand Council on Resuscitation, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Asia, and the Resuscitation Council of Southern Africa); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; and the Stroke Council. Circulation. 2008;118:2452–2483. doi: 10.1161/CIRCULATIONAHA.108.190652.

16. Davies MJ. Anatomic features in victims of sudden coronary death. Coronary artery pathology. Circulation. 1992;85(1 suppl):I19–I24.

17. Spaulding CM, Joly LM, Rosenberg A, Monchi M, Weber SN, Dhainaut JF, Carli P. Immediate coronary angiography in survivors of out-of-hos- pital cardiac arrest. N Engl J Med. 1997;336:1629–1633. doi: 10.1056/NEJM199706053362302.

18. Dumas F, Cariou A, Manzo-Silberman S, Grimaldi D, Vivien B, Rosencher J, Empana JP, Carli P, Mira JP, Jouven X, Spaulding C. Immediate per- cutaneous coronary intervention is associated with better survival after out-of-hospital cardiac arrest: insights from the PROCAT (Parisian Region Out of hospital Cardiac ArresT) registry. Circ Cardiovasc Interv. 2010;3:200–207. doi: 10.1161/CIRCINTERVENTIONS.109.913665.

19. Hollenbeck RD, McPherson JA, Mooney MR, Unger BT, Patel NC, McMullan PW Jr, Hsu CH, Seder DB, Kern KB. Early cardiac catheter- ization is associated with improved survival in comatose survivors of car- diac arrest without STEMI. Resuscitation. 2014;85:88–95. doi: 10.1016/j. resuscitation.2013.07.027.

20. Mooney MR, Unger BT, Boland LL, Burke MN, Kebed KY, Graham KJ, Henry TD, Katsiyiannis WT, Satterlee PA, Sendelbach S, Hodges JS, Parham WM. Therapeutic hypothermia after out-of-hospital cardiac arrest: evaluation of a regional system to increase access to cooling. Circulation. 2011;124:206–214. doi: 10.1161/ CIRCULATIONAHA.110.986257.

21. Gräsner JT, Meybohm P, Lefering R, Wnent J, Bahr J, Messelken M, Jantzen T, Franz R, Scholz J, Schleppers A, Böttiger BW, Bein B, Fischer M; German Resuscitation Registry Study Group. ROSC after cardiac arrest–the RACA score to predict outcome after out-of-hospital cardiac arrest. Eur Heart J. 2011;32:1649–1656. doi: 10.1093/eurheartj/ehr107.

22. Cronier P, Vignon P, Bouferrache K, Aegerter P, Charron C, Templier F, Castro S, El Mahmoud R, Lory C, Pichon N, Dubourg O, Vieillard-Baron A. Impact of routine percutaneous coronary intervention after out-of-hos- pital cardiac arrest due to ventricular fibrillation. Crit Care. 2011;15:R122. doi: 10.1186/cc10227.

23. Bulut S, Aengevaeren WR, Luijten HJ, Verheugt FW. Successful out-of- hospital cardiopulmonary resuscitation: what is the optimal in-hospital treatment strategy? Resuscitation. 2000;47:155–161.

24. Bro-Jeppesen J, Kjaergaard J, Wanscher M, Pedersen F, Holmvang L, Lippert FK, Møller JE, Køber L, Hassager C. Emergency coronary angi- ography in comatose cardiac arrest patients: do real-life experiences sup- port the guidelines? Eur Heart J Acute Cardiovasc Care. 2012;1:291–301. doi: 10.1177/2048872612465588.

25. Aurore A, Jabre P, Liot P, Margenet A, Lecarpentier E, Combes X. Predictive factors for positive coronary angiography in out-of-hospital cardiac arrest patients. Eur J Emerg Med. 2011;18:73–76. doi: 10.1097/ MEJ.0b013e32833d469a.

26. Nanjayya VB, Nayyar V. Immediate coronary angiogram in comatose sur- vivors of out-of-hospital cardiac arrest–an Australian study. Resuscitation. 2012;83:699–704. doi: 10.1016/j.resuscitation.2011.12.004.

27. Reynolds JC, Callaway CW, El Khoudary SR, Moore CG, Alvarez RJ, Rittenberger JC. Coronary angiography predicts improved outcome fol- lowing cardiac arrest: propensity-adjusted analysis. J Intensive Care Med. 2009;24:179–186. doi: 10.1177/0885066609332725.

28. Strote JA, Maynard C, Olsufka M, Nichol G, Copass MK, Cobb LA, Kim F. Comparison of role of early (less than six hours) to later (more than six hours) or no cardiac catheterization after resuscitation from out-of- hospital cardiac arrest. Am J Cardiol. 2012;109:451–454. doi: 10.1016/j. amjcard.2011.09.036.

29. Tømte O, Andersen GØ, Jacobsen D, Drægni T, Auestad B, Sunde K. Strong and weak aspects of an established post-resuscitation treatment protocol-A five-year observational study. Resuscitation. 2011;82:1186– 1193. doi: 10.1016/j.resuscitation.2011.05.003.

30. Waldo SW, Armstrong EJ, Kulkarni A, Hoffmayer K, Kinlay S, Hsue P, Ganz P, McCabe JM. Comparison of clinical characteristics and outcomes of cardiac arrest survivors having versus not having coronary angiography. Am J Cardiol. 2013;111:1253–1258. doi: 10.1016/j.amjcard.2013.01.267.

31. Nielsen N, Hovdenes J, Nilsson F, Rubertsson S, Stammet P, Sunde K, Valsson F, Wanscher M, Friberg H; Hypothermia Network. Outcome, timing and adverse events in therapeutic hypothermia after out-of-hos- pital cardiac arrest. Acta Anaesthesiol Scand. 2009;53:926–934. doi: 10.1111/j.1399-6576.2009.02021.x.

32. Werling M, Thorén AB, Axelsson C, Herlitz J. Treatment and outcome in post-resuscitation care after out-of-hospital cardiac arrest when a modern therapeutic approach was introduced. Resuscitation. 2007;73:40–45. doi: 10.1016/j.resuscitation.2006.08.018.

33. Zanuttini D, Armellini I, Nucifora G, Carchietti E, Trillò G, Spedicato L, Bernardi G, Proclemer A. Impact of emergency coronary angiogra- phy on in-hospital outcome of unconscious survivors after out-of-hos- pital cardiac arrest. Am J Cardiol. 2012;110:1723–1728. doi: 10.1016/j. amjcard.2012.08.006.

34. O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso CL, Tracy CM, Woo YJ, Zhao DX. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2013;127:529–555. doi: 10.1161/CIR.0b013e3182742c84.

35. Jneid H, Anderson JL, Wright RS, Adams CD, Bridges CR, Casey DE Jr, Ettinger SM, Fesmire FM, Ganiats TG, Lincoff AM, Peterson ED, Philippides GJ, Theroux P, Wenger NK, Zidar JP. 2012 ACCF/AHA focused update of the guideline for the management of patients with unstable angina/non–ST-elevation myocardial infarction (updating the 2007 guideline and replacing the 2011 focused update): a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2012;126:875–910. DOI: 10.1161/CIR.0b013e318256f1e0.

36. Task Force on the Management of ST-Segment Elevation Acute Myocardial Infarction of the European Society of Cardiology, Steg PG, James SK, Atar D, Badano LP, Blomstrom-Lundqvist C, Borger MA, Di Mario C, Dickstein K, Ducrocq G, Fernandez-Aviles F, Gershlick AH, Giannuzzi P, Halvorsen S, Huber K, Juni P, Kastrati A, Knuuti J, Lenzen MJ, Mahaffey KW, Valgimigli M, van 't Hof A, Widimsky P, Zahger D. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Eur Heart J. 2012;33:2569–2619.

37. Peberdy MA, Donnino MW, Callaway CW, Dimaio JM, Geocadin RG, Ghaemmaghami CA, Jacobs AK, Kern KB, Levy JH, Link MS, Menon V, Ornato JP, Pinto DS, Sugarman J, Yannopoulos D, Ferguson TB Jr; on behalf of the American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Impact of percutaneous coronary intervention performance reporting on cardiac resuscitation centers: a scientific statement from the American Heart Association. Circulation. 2013;128:762–773. doi: 10.1161/CIR.0b013e3182a15cd2.

38. Trzeciak S, Jones AE, Kilgannon JH, Milcarek B, Hunter K, Shapiro NI, Hollenberg SM, Dellinger P, Parrillo JE. Significance of arterial hypoten- sion after resuscitation from cardiac arrest. Crit Care Med. 2009;37:2895– 903; quiz 2904.

39. Bray JE, Bernard S, Cantwell K, Stephenson M, Smith K; VACAR Steering Committee. The association between systolic blood pressure on arrival at hospital and outcome in adults surviving from out-of-hospital cardiac arrests of presumed cardiac aetiology. Resuscitation. 2014;85:509–515. doi: 10.1016/j.resuscitation.2013.12.005.

40.

Kilgannon JH, Roberts BW, Reihl LR, Chansky ME, Jones AE, Dellinger RP, Parrillo JE, Trzeciak S. Early arterial hypotension is common in the post-cardiac arrest syndrome and associated with increased in-hospital mortality. Resuscitation. 2008;79:410–416. doi: 10.1016/j. resuscitation.2008.07.019.

41. Müllner M, Sterz F, Binder M, Hellwagner K, Meron G, Herkner H, Laggner AN. Arterial blood pressure after human cardiac arrest and neu- rological recovery. Stroke. 1996;27:59–62.

42. Beylin ME, Perman SM, Abella BS, Leary M, Shofer FS, Grossestreuer AV, Gaieski DF. Higher mean arterial pressure with or without vasoac- tive agents is associated with increased survival and better neurological outcomes in comatose survivors of cardiac arrest. Intensive Care Med. 2013;39:1981–1988. doi: 10.1007/s00134-013-3075-9.

43. Gaieski DF, Band RA, Abella BS, Neumar RW, Fuchs BD, Kolansky DM, Merchant RM, Carr BG, Becker LB, Maguire C, Klair A, Hylton J, Goyal M. Early goal-directed hemodynamic optimization com- bined with therapeutic hypothermia in comatose survivors of out-of-hospital cardiac arrest. Resuscitation. 2009;80:418–424. doi: 10.1016/j. resuscitation.2008.12.015.

44. Laurent I, Monchi M, Chiche JD, Joly LM, Spaulding C, Bourgeois B, Cariou A, Rozenberg A, Carli P, Weber S, Dhainaut JF. Reversible myo- cardial dysfunction in survivors of out-of-hospital cardiac arrest. J Am Coll Cardiol. 2002;40:2110–2116.

45. Sunde K, Pytte M, Jacobsen D, Mangschau A, Jensen LP, Smedsrud C, Draegni T, Steen PA. Implementation of a standardised treatment protocol for post resuscitation care after out-of-hospital cardiac arrest. Resuscitation. 2007;73:29–39. doi: 10.1016/j.resuscitation.2006.08.016.

46. Walters EL, Morawski K, Dorotta I, Ramsingh D, Lumen K, Bland D, Clem K, Nguyen HB. Implementation of a post-cardiac arrest care bundle including therapeutic hypothermia and hemodynamic optimization in comatose patients with return of spontaneous circulation after out-of- hospital cardiac arrest: a feasibility study. Shock. 2011;35:360–366. doi: 10.1097/SHK.0b013e318204c106.

47. De Backer D, Biston P, Devriendt J, Madl C, Chochrad D, Aldecoa C, Brasseur A, Defrance P, Gottignies P, Vincent JL. Comparison of dopamine and norepinephrine in the treatment of shock. N Engl J Med. 2010;362:779–789.

48. Kellum JA, Pinsky MR. Use of vasopressor agents in critically ill patients. Curr Opin Crit Care. 2002;8:236–241.

49. Zaritsky AL. Catecholamines, inotropic medications, and vasopressor agents. In: Chernow B ed. The Pharmacologic Approach to the Critically Ill Patient. III ed. Baltimore, MD: Williams & Wilkins;1994:387–404.

50. Grillo JA, Gonzalez ER, Ramaiya A, Karnes HT, Wells B. Chemical compatibility of inotropic and vasoactive agents delivered via a multiple line infusion system. Crit Care Med. 1995;23:1061–1066.

51. Bonhomme L, Benhamou D, Comoy E, Preaux N. Stability of epinephrine in alkalinized solutions. Ann Emerg Med. 1990;19:1242–1244.

52. Donnino M, Andersen LW, Berg KM, et al. Temperature management after cardiac arrest: an advisory statement by the Advanced Life Support (ALS) Task Force of the International Liaison Committee on Resuscitation (ILCOR). Circulation. In press.

53. Mild therapeutic hypothermia to improve the neurologic outcome after cardiac arrest. N Engl J Med. 2002;346:549–556.

54. Bernard SA, Gray TW, Buist MD, Jones BM, Silvester W, Gutteridge G, Smith K. Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia. N Engl J Med. 2002;346:557–563. doi: 10.1056/NEJMoa003289.

55. Dumas F, Grimaldi D, Zuber B, Fichet J, Charpentier J, Pène F, Vivien B, Varenne O, Carli P, Jouven X, Empana JP, Cariou A. Is hypothermia after cardiac arrest effective in both shockable and nonshockable patients?: insights from a large registry. Circulation. 2011;123:877–886. doi: 10.1161/CIRCULATIONAHA.110.987347.

56. Testori C, Sterz F, Behringer W, Haugk M, Uray T, Zeiner A, Janata A, Arrich J, Holzer M, Losert H. Mild therapeutic hypothermia is associ- ated with favourable outcome in patients after cardiac arrest with non- shockable rhythms. Resuscitation. 2011;82:1162–1167. doi: 10.1016/j. resuscitation.2011.05.022.

57. Vaahersalo J, Hiltunen P, Tiainen M, Oksanen T, Kaukonen KM, Kurola J, Ruokonen E, Tenhunen J, Ala-Kokko T, Lund V, Reinikainen M, Kiviniemi O, Silfvast T, Kuisma M, Varpula T, Pettilä V; FINNRESUSCI Study Group. Therapeutic hypothermia after out-of-hospital cardiac arrest in Finnish intensive care units: the FINNRESUSCI study. Intensive Care Med. 2013;39:826–837. doi: 10.1007/s00134-013-2868-1.

58. Mader TJ, Nathanson BH, Soares WE 3rd, Coute RA, McNally BF. Comparative Effectiveness of Therapeutic Hypothermia After Out-of-Hospital Cardiac Arrest: Insight from a Large Data Registry. Ther Hypothermia Temp Manag. 2014;4:21–31. doi: 10.1089/ther.2013.0018.

59. Nichol G, Huszti E, Kim F, Fly D, Parnia S, Donnino M, Sorenson T, Callaway CW; American Heart Association Get With The Guideline- Resuscitation Investigators. Does induction of hypothermia improve out- comes after in-hospital cardiac arrest? Resuscitation. 2013;84:620–625. doi: 10.1016/j.resuscitation.2012.12.009.

60.

Nielsen N, Wetterslev J, Cronberg T, Erlinge D, Gasche Y, Hassager C, Horn J, Hovdenes J, Kjaergaard J, Kuiper M, Pellis T, Stammet P, Wanscher M, Wise MP, Åneman A, Al-Subaie N, Boesgaard S, Bro- Jeppesen J, Brunetti I, Bugge JF, Hingston CD, Juffermans NP, Koopmans M, Køber L, Langørgen J, Lilja G, Møller JE, Rundgren M, Rylander C, Smid O, Werer C, Winkel P, Friberg H; TTM Trial Investigators. Targeted temperature management at 33°C versus 36°C after cardiac arrest. N Engl J Med. 2013;369:2197–2206. doi: 10.1056/NEJMoa1310519.

61. Watts DD, Trask A, Soeken K, Perdue P, Dols S, Kaufmann C. Hypothermic coagulopathy in trauma: effect of varying levels of hypothermia on enzyme speed, platelet function, and fibrinolytic activity. J Trauma. 1998;44:846–854.

62. Lavinio A, Scudellari A, Gupta AK. Hemorrhagic shock resulting in cardiac arrest: is therapeutic hypothermia contraindicated? Minerva Anestesiol. 2012;78:969–970.

63. Guilliams K, Rosen M, Buttram S, Zempel J, Pineda J, Miller B, Shoykhet M. Hypothermia for pediatric refractory status epilepticus. Epilepsia. 2013;54:1586–1594. doi: 10.1111/epi.12331.

64. Corry JJ, Dhar R, Murphy T, Diringer MN. Hypothermia for refrac- tory status epilepticus. Neurocrit Care. 2008;9:189–197. doi: 10.1007/ s12028-008-9092-9.

65. Guluma KZ, Oh H, Yu SW, Meyer BC, Rapp K, Lyden PD. Effect of endovascular hypothermia on acute ischemic edema: morphometric analysis of the ICTuS trial. Neurocrit Care. 2008;8:42–47. doi: 10.1007/ s12028-007-9009-z.

66. Kim F, Olsufka M, Longstreth WT Jr, Maynard C, Carlbom D, Deem S, Kudenchuk P, Copass MK, Cobb LA. Pilot randomized clinical trial of prehospital induction of mild hypothermia in out-of-hospital cardiac arrest patients with a rapid infusion of 4 degrees C normal saline. Circulation. 2007;115:3064–3070. doi: 10.1161/CIRCULATIONAHA.106.655480.

67. Kämäräinen A, Virkkunen I, Tenhunen J, Yli-Hankala A, Silfvast T. Prehospital therapeutic hypothermia for comatose survivors of cardiac arrest: a randomized controlled trial. Acta Anaesthesiol Scand. 2009;53:900–907. doi: 10.1111/j.1399-6576.2009.02015.x.

68. Bernard SA, Smith K, Cameron P, Masci K, Taylor DM, Cooper DJ, Kelly AM, Silvester W; Rapid Infusion of Cold Hartmanns (RICH) Investigators. Induction of therapeutic hypothermia by paramedics after resuscitation from out-of-hospital ventricular fibrillation cardiac arrest: a randomized controlled trial. Circulation. 2010;122:737–742. doi: 10.1161/CIRCULATIONAHA.109.906859.

69. Bernard SA, Smith K, Cameron P, Masci K, Taylor DM, Cooper DJ, Kelly AM, Silvester W; Rapid Infusion of Cold Hartmanns Investigators. Induction of prehospital therapeutic hypothermia after resuscitation from nonventricular fibrillation cardiac arrest. Crit Care Med. 2012;40:747– 753. doi: 10.1097/CCM.0b013e3182377038.

70. Kim F, Nichol G, Maynard C, Hallstrom A, Kudenchuk PJ, Rea T, Copass MK, Carlbom D, Deem S, Longstreth WT Jr, Olsufka M, Cobb LA. Effect of prehospital induction of mild hypothermia on survival and neurological status among adults with cardiac arrest: a randomized clinical trial. JAMA. 2014;311:45–52. doi: 10.1001/jama.2013.282173.

71. Debaty G, Maignan M, Savary D, Koch FX, Ruckly S, Durand M, Picard J, Escallier C, Chouquer R, Santre C, Minet C, Guergour D, Hammer L, Bouvaist H, Belle L, Adrie C, Payen JF, Carpentier F, Gueugniaud PY, Danel V, Timsit JF. Impact of intra-arrest therapeutic hypothermia in out- comes of prehospital cardiac arrest: a randomized controlled trial. Intensive Care Med. 2014;40:1832–1842. doi: 10.1007/s00134-014-3519-x.

72. Castrén M, Nordberg P, Svensson L, Taccone F, Vincent JL, Desruelles D, Eichwede F, Mols P, Schwab T, Vergnion M, Storm C, Pesenti A, Pachl J, Guérisse F, Elste T, Roessler M, Fritz H, Durnez P, Busch HJ, Inderbitzen B, Barbut D. Intra-arrest transnasal evaporative cooling: a ran- domized, prehospital, multicenter study (PRINCE: Pre-ROSC IntraNasal Cooling Effectiveness). Circulation. 2010;122:729–736. doi: 10.1161/ CIRCULATIONAHA.109.931691.

73. ZeinerA,HolzerM,SterzF,SchörkhuberW,EisenburgerP,HavelC,Kliegel A, Laggner AN. Hyperthermia after cardiac arrest is associated with an unfa- vorable neurologic outcome. Arch Intern Med. 2001;161:2007–2012.

74. Langhelle A, Tyvold SS, Lexow K, Hapnes SA, Sunde K, Steen PA. In-hospital factors associated with improved outcome after out-of-hospital cardiac arrest. A comparison between four regions in Norway. Resuscitation. 2003;56:247–263.

75. Nolan JP, Laver SR, Welch CA, Harrison DA, Gupta V, Rowan K. Outcome following admission to UK intensive care units after cardiac arrest: a second- ary analysis of the ICNARC Case Mix Programme Database. Anaesthesia. 2007;62:1207–1216. doi: 10.1111/j.1365-2044.2007.05232.x.

76. Suffoletto B, Peberdy MA, van der Hoek T, Callaway C. Body temperature changes are associated with outcomes following in-hospital cardiac arrest and return of spontaneous circulation. Resuscitation. 2009;80:1365–1370. doi: 10.1016/j.resuscitation.2009.08.020.0

77. Gebhardt K, Guyette FX, Doshi AA, Callaway CW, Rittenberger JC; Post Cardiac Arrest Service. Prevalence and effect of fever on outcome follow- ing resuscitation from cardiac arrest. Resuscitation. 2013;84:1062–1067. doi: 10.1016/j.resuscitation.2013.03.038.

78. Aldhoon B, Melenovsky V, Kettner J, Kautzner J. Clinical predictors of outcome in survivors of out-of-hospital cardiac arrest treated with hypo- thermia. Cor et Vasa. 2012;54:e68–e75.

79. Benz-Woerner J, Delodder F, Benz R, Cueni-Villoz N, Feihl F, Rossetti AO, Liaudet L, Oddo M. Body temperature regulation and outcome after cardiac arrest and therapeutic hypothermia. Resuscitation. 2012;83:338– 342. doi: 10.1016/j.resuscitation.2011.10.026.

80. Bouwes A, Robillard LB, Binnekade JM, de Pont AC, Wieske L, Hartog AW, Schultz MJ, Horn J. The influence of rewarming after therapeutic hypothermia on outcome after cardiac arrest. Resuscitation. 2012;83:996– 1000. doi: 10.1016/j.resuscitation.2012.04.006.

81. Leary M, Grossestreuer AV, Iannacone S, Gonzalez M, Shofer FS, Povey C, Wendell G, Archer SE, Gaieski DF, Abella BS. Pyrexia and neurologic outcomes after therapeutic hypothermia for cardiac arrest. Resuscitation. 2013;84:1056–1061. doi: 10.1016/j.resuscitation.2012.11.003.

82. Cocchi MN, Boone MD, Giberson B, Giberson T, Farrell E, Salciccioli JD, Talmor D, Williams D, Donnino MW. Fever after rewarming: inci- dence of pyrexia in postcardiac arrest patients who have undergone mild therapeutic hypothermia. J Intensive Care Med. 2014;29:365–369. doi: 10.1177/0885066613491932.

83. Bro-Jeppesen J, Hassager C, Wanscher M, Søholm H, Thomsen JH, Lippert FK, Møller JE, Køber L, Kjaergaard J. Post-hypothermia fever is associated with increased mortality after out-of-hospital cardiac arrest. Resuscitation. 2013;84:1734–1740. doi: 10.1016/j.resuscitation.2013.07.023.

84. Winters SA, Wolf KH, Kettinger SA, Seif EK, Jones JS, Bacon-Baguley T. Assessment of risk factors for post-rewarming “rebound hyperthermia” in cardiac arrest patients undergoing therapeutic hypothermia. Resuscitation. 2013;84:1245–1249. doi: 10.1016/j.resuscitation.2013.03.027.

85. Bohman LE, Levine JM. Fever and therapeutic normothermia in severe brain injury: an update. Curr Opin Crit Care. 2014;20:182–188. doi: 10.1097/MCC.0000000000000070.

86. Badjatia N. Hyperthermia and fever control in brain injury. Crit Care Med. 2009;37(7 suppl):S250–S257. doi: 10.1097/CCM.0b013e3181aa5e8d.

87. Laver S, Farrow C, Turner D, Nolan J. Mode of death after admission to an intensive care unit following cardiac arrest. Intensive Care Med. 2004;30:2126–2128.

88. Neumar RW, Nolan JP, Adrie C, Aibiki M, Berg RA, Bottiger BW, Callaway C, Clark RS, Geocadin RG, Jauch EC, Kern KB, Laurent I, Longstreth WT Jr.., Merchant RM, Morley P, Morrison LJ, Nadkarni V, Peberdy MA, Rivers EP, Rodriguez-Nunez A, Sellke FW, Spaulding C, Sunde K, Vanden Hoek T. Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication. A consensus statement from the International Liaison Committee on Resuscitation (American Heart Association, Australian and New Zealand Council on Resuscitation, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Asia, and the Resuscitation Council of Southern Africa); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; and the Stroke Council. Circulation. 2008;118:2452–2483.

89. Longstreth WT Jr, Fahrenbruch CE, Olsufka M, Walsh TR, Copass MK, Cobb LA. Randomized clinical trial of magnesium, diazepam, or both after out-of-hospital cardiac arrest. Neurology. 2002;59:506–514.

90. Rittenberger JC, Popescu A, Brenner RP, Guyette FX, Callaway CW. Frequency and timing of nonconvulsive status epilepticus in comatose post-cardiac arrest subjects treated with hypothermia. Neurocrit Care. 2012;16:114–122. doi: 10.1007/s12028-011-9565-0.

91. Tomte O, Draegni T, Mangschau A, Jacobsen D, Auestad B, Sunde K. A comparison of intravascular and surface cooling techniques in comatose cardiac arrest survivors. Crit Care Med. 2011;39:443–449.

92. Hofmeijer J, Tjepkema-Cloostermans MC, Blans MJ, Beishuizen A, van Putten MJ. Unstandardized treatment of electroencephalographic status epilepticus does not improve outcome of comatose patients after cardiac arrest. Front Neurol. 2014;5:39. doi: 10.3389/fneur.2014.00039.

93. Crepeau AZ, Rabinstein AA, Fugate JE, Mandrekar J, Wijdicks EF, White RD, Britton JW. Continuous EEG in therapeutic hypothermia after cardiac arrest: prognostic and clinical value. Neurology. 2013;80:339–344. doi:10.1212/WNL.0b013e31827f089d.

94. Knight WA, Hart KW, Adeoye OM, Bonomo JB, Keegan SP, Ficker DM, Szaflarski JP, Privitera MD, Lindsell CJ. The incidence of seizures in patients undergoing therapeutic hypothermia after resuscitation from cardiac arrest. Epilepsy Res. 2013;106:396–402. doi: 10.1016/j.eplepsyres.2013.06.018.

95. Randomized clinical study of thiopental loading in comatose survivors of cardiac arrest. Brain Resuscitation Clinical Trial I Study Group. N Engl J Med. 1986;314:397–403.

96. Monsalve F, Rucabado L, Ruano M, Cuñat J, Lacueva V, Viñuales A. The neurologic effects of thiopental therapy after cardiac arrest. Intensive Care Med. 1987;13:244–248.

97. Friedman D, Claassen J, Hirsch LJ. Continuous electroencephalogram monitoring in the intensive care unit. Anesth Analg. 2009;109:506–523. doi: 10.1213/ane.0b013e3181a9d8b5.

98. Damian MS, Ellenberg D, Gildemeister R, Lauermann J, Simonis G, Sauter W, Georgi C. Coenzyme Q10 combined with mild hypothermia after cardiac arrest: a preliminary study. Circulation. 2004;110:3011–3016.

99. Roberts BW, Kilgannon JH, Chansky ME, Mittal N, Wooden J, Trzeciak S. Association between postresuscitation partial pressure of arterial car- bon dioxide and neurological outcome in patients with post-cardiac arrest syndrome. Circulation. 2013;127:2107–2113. doi: 10.1161/ CIRCULATIONAHA.112.000168.

100. Lee BK, Jeung KW, Lee HY, Lee SJ, Jung YH, Lee WK, Heo T, Min YI. Association between mean arterial blood gas tension and outcome in cardiac arrest patients treated with therapeutic hypothermia. Am J Emerg Med. 2014;32:55–60. doi: 10.1016/j.ajem.2013.09.044.

101. Schneider AG, Eastwood GM, Bellomo R, Bailey M, Lipcsey M, Pilcher D, Young P, Stow P, Santamaria J, Stachowski E, Suzuki S, Woinarski NC, Pilcher J. Arterial carbon dioxide tension and outcome in patients admitted to the intensive care unit after cardiac arrest. Resuscitation. 2013;84:927– 934. doi: 10.1016/j.resuscitation.2013.02.014.

102. Vaahersalo J, Bendel S, Reinikainen M, Kurola J, Tiainen M, Raj R, Pettilä V, Varpula T, Skrifvars MB; FINNRESUSCI Study Group. Arterial blood gas tensions after resuscitation from out-of-hospital cardiac arrest: associ- ations with long-term neurologic outcome. Crit Care Med. 2014;42:1463– 1470. doi: 10.1097/CCM.0000000000000228.

103. Janz DR, Hollenbeck RD, Pollock JS, McPherson JA, Rice TW. Hyperoxia is associated with increased mortality in patients treated with mild therapeutic hypothermia after sudden cardiac arrest. Crit Care Med. 2012;40:3135–3139. doi: 10.1097/CCM.0b013e3182656976.

104. Kilgannon JH, Jones AE, Shapiro NI, Angelos MG, Milcarek B, Hunter K, Parrillo JE, Trzeciak S; Emergency Medicine Shock Research Network (EMShockNet) Investigators. Association between arterial hyperoxia fol- lowing resuscitation from cardiac arrest and in-hospital mortality. JAMA. 2010;303:2165–2171. doi: 10.1001/jama.2010.707.

105. Elmer J, Scutella M, Pullalarevu R, Wang B, Vaghasia N, Trzeciak S, Rosario-Rivera BL, Guyette FX, Rittenberger JC, Dezfulian C; Pittsburgh Post-Cardiac Arrest Service (PCAS). The association between hyperoxia and patient outcomes after cardiac arrest: analysis of a high-resolution database. Intensive Care Med. 2015;41:49–57. doi: 10.1007/s00134-014-3555-6.

106. Rachmale S, Li G, Wilson G, Malinchoc M, Gajic O. Practice of excessive F(IO(2)) and effect on pulmonary outcomes in mechanically ventilated patients with acute lung injury. Respir Care. 2012;57:1887–1893. doi: 10.4187/respcare.01696.

107. Bellomo R, Bailey M, Eastwood GM, Nichol A, Pilcher D, Hart GK, Reade MC, Egi M, Cooper DJ; Study of Oxygen in Critical Care (SOCC) Group. Arterial hyperoxia and in-hospital mortality after resuscitation from cardiac arrest. Crit Care. 2011;15:R90. doi: 10.1186/cc10090.

108. Nelskylä A, Parr MJ, Skrifvars MB. Prevalence and factors correlating with hyperoxia exposure following cardiac arrest–an observational sin- gle centre study. Scand J Trauma Resusc Emerg Med. 2013;21:35. doi: 10.1186/1757-7241-21-35.

109. Kuisma M, Boyd J, Voipio V, Alaspää A, Roine RO, Rosenberg P. Comparison of 30 and the 100% inspired oxygen concentrations dur- ing early post-resuscitation period: a randomised controlled pilot study. Resuscitation. 2006;69:199–206. doi: 10.1016/j.resuscitation.2005.08.010.

110. Ihle JF, Bernard S, Bailey MJ, Pilcher DV, Smith K, Scheinkestel CD. Hyperoxia in the intensive care unit and outcome after out-of-hospital ventricular fibrillation cardiac arrest. Crit Care Resusc. 2013;15:186–190.

111. Wan S, Quinlan DJ, Agnelli G, Eikelboom JW. Thrombolysis compared with heparin for the initial treatment of pulmonary embolism: a meta-analysis of the randomized controlled trials. Circulation. 2004;110:744–749.

112. Scholz KH, Hilmer T, Schuster S, Wojcik J, Kreuzer H, Tebbe U. Thrombolysis in resuscitated patients with pulmonary embolism. Dtsch Med Wochenschr. 1990;115:930–935.

113. Bottiger BW, Bode C, Kern S, Gries A, Gust R, Glatzer R, Bauer H, Motsch J, Martin E. Efficacy and safety of thrombolytic therapy after initially unsuccessful cardiopulmonary resuscitation: a prospective clinical trial. Lancet. 2001;357():1583–1585.

114. Fatovich DM, Dobb GJ, Clugston RA. A pilot randomised trial of thrombolysis in cardiac arrest (The TICA trial). Resuscitation. 2004;61:309–313.

115. Fava M, Loyola S, Bertoni H, Dougnac A. Massive pulmonary embolism: percutaneous mechanical thrombectomy during cardiopulmonary resuscitation. J Vasc Interv Radiol. 2005;16:119–123.

116. Janata K, Holzer M, Kurkciyan I, Losert H, Riedmuller E, Pikula B, Laggner AN, Laczika K. Major bleeding complications in cardiopulmonary resuscitation: the place of thrombolytic therapy in cardiac arrest due to massive pulmonary embolism. Resuscitation. 2003;57:49–55.

117. Konstantinov IE, Saxena P, Koniuszko MD, Alvarez J, Newman MA. Acute massive pulmonary embolism with cardiopulmonary resuscitation: management and results. Tex Heart Inst J. 2007;34:41–45; discussion 45–46.

118. Lederer W, Lichtenberger C, Pechlaner C, Kroesen G, Baubin M. Recombinant tissue plasminogen activator during cardiopulmonary resuscitation in 108 patients with out-of-hospital cardiac arrest. Resuscitation. 2001;50:71–76.

119. Lederer W, Lichtenberger C, Pechlaner C, Kinzl J, Kroesen G, Baubin M. Long-term survival and neurological outcome of patients who received recombinant tissue plasminogen activator during out-of-hospital cardiac arrest. Resuscitation. 2004;61:123–129.

120. Zahorec R. Rescue systemic thrombolysis during cardiopulmonary resuscitation. Bratisl Lek Listy. 2002;103():266–269.

121. Spohr F, Bottiger BW. Thrombolytic therapy during or after cardiopulmonary resuscitation: efficacy and safety of a new therapeutic approach. Minerva Anestesiol. 2003;69:357–364.

122. Schmid C, Zietlow S, Wagner TO, Laas J, Borst HG. Fulminant pulmonary embolism: symptoms, diagnostics, operative technique, and results. Ann Thorac Surg. 1991;52:1102–1105.

123. Dauphine C, Omari B. Pulmonary embolectomy for acute massive pulmonary embolism. Ann Thorac Surg. 2005;79:1240–1244.

124. Doerge HC, Schoendube FA, Loeser H, Walter M, Messmer BJ. Pulmonary embolectomy: review of a 15-year experience and role in the age of thrombolytic therapy. Eur J Cardiothorac Surg. 1996;10:952–957.

125. Ullmann M, Hemmer W, Hannekum A. The urgent pulmonary embolectomy: mechanical resuscitation in the operating theatre determines the outcome. Thorac Cardiovasc Surg. 1999;47:5–8.

126. Hall JE, Uhrich TD, Barney JA, Arain SR, Ebert TJ. Sedative, amnestic, and analgesic properties of small-dose dexmedetomidine infusions. Anesth Analg. 2000;90:699–705.

127. Milbrandt EB, Kersten A, Kong L, Weissfeld LA, Clermont G, Fink MP, Angus DC. Haloperidol use is associated with lower hospital mortality in mechanically ventilated patients. Crit Care Med. 2005;33:226–229, discussion 263–225.

128. De Jonghe B, Cook D, Griffith L, Appere-de-Vecchi C, Guyatt G, Theron V, Vagnerre A, Outin H. Adaptation to the Intensive Care Environment (ATICE): development and validation of a new sedation assessment instrument. Crit Care Med. 2003;31:2344–2354.

129. Weinert C, McFarland L. The state of intubated ICU patients: development of a two-dimensional sedation rating scale for critically ill adults. Chest. 2004;126:1883–1890.

130. Ramsay MA, Savege TM, Simpson BR, Goodwin R. Controlled sedation with alphaxalone-alphadolone. Br Med J. 1974;2():656–659.

131. Sessler CN, Gosnell MS, Grap MJ, Brophy GM, O'Neal PV, Keane KA, Tesoro EP, Elswick RK. The Richmond Agitation-Sedation Scale: validity and reliability in adult intensive care unit patients. Am J Respir Crit Care Med. 2002;166:1338–1344.

132. Riker RR, Fraser GL, Cox PM. Continuous infusion of haloperidol controls agitation in critically ill patients. Crit Care Med. 1994;22:433–440.

133. de Lemos J, Tweeddale M, Chittock D. Measuring quality of sedation in adult mechanically ventilated critically ill patients: the Vancouver Interaction and Calmness Scale. Sedation Focus Group. J Clin Epidemiol. 2000;53:908–919.

134. Devlin JW, Boleski G, Mlynarek M, Nerenz DR, Peterson E, Jankowski M, Horst HM, Zarowitz BJ. Motor Activity Assessment Scale: a valid and reliable sedation scale for use with mechanically ventilated patients in an adult surgical intensive care unit. Crit Care Med. 1999;27:1271–1275.

135. Rello J, Diaz E, Roque M, Valles J. Risk factors for developing pneumonia within 48 hours of intubation. Am J Respir Crit Care Med. 1999;159:1742–1746.

136. Adrie C, Adib-Conquy M, Laurent I, Monchi M, Vinsonneau C, Fitting C, Fraisse F, Dinh-Xuan AT, Carli P, Spaulding C, Dhainaut JF, Cavaillon JM. Successful cardiopulmonary resuscitation after cardiac arrest as a “sepsis-like” syndrome. Circulation. 2002;106:562–568.

137. Adrie C, Laurent I, Monchi M, Cariou A, Dhainaou JF, Spaulding C. Postresuscitation disease after cardiac arrest: a sepsis-like syndrome? Curr Opin Crit Care. 2004;10:208–212.

138. Dellinger RP, Carlet JM, Masur H, Gerlach H, Calandra T, Cohen J, Gea-Banacloche J, Keh D, Marshall JC, Parker MM, Ramsay G, Zimmerman JL, Vincent JL, Levy MM. Surviving Sepsis Campaign guidelines for management of severe sepsis and septic shock. Crit Care Med. 2004;32:858–873.

139. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, Peterson E, Tomlanovich M. Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med. 2001;345:1368–1377.

140. Oksanen T, Skrifvars MB, Varpula T, Kuitunen A, Pettilä V, Nurmi J, Castrén M. Strict versus moderate glucose control after resuscitation from ventricular fibrillation. Intensive Care Med. 2007;33:2093–2100. doi: 10.1007/s00134-007-0876-8.

141. Wiener RS, Wiener DC, Larson RJ. Benefits and risks of tight glucose control in critically ill adults: a meta-analysis. JAMA. 2008;300:933– 944. doi: 10.1001/jama.300.8.933.

142. Marik PE, Preiser JC. Toward understanding tight glycemic control in the ICU: a systematic review and metaanalysis. Chest. 2010;137:544–551. doi: 10.1378/chest.09-1737.

143. Moghissi ES, Korytkowski MT, DiNardo M, Einhorn D, Hellman R, Hirsch IB, Inzucchi SE, Ismail-Beigi F, Kirkman MS, Umpierrez GE; American Association of Clinical Endocrinologists; American Diabetes Association. American Association of Clinical Endocrinologists and American Diabetes Association consensus statement on inpatient gly- cemic control. Diabetes Care. 2009;32:1119–1131. doi: 10.2337/ dc09-9029.

144. Schultz CH, Rivers EP, Feldkamp CS, Goad EG, Smithline HA, Martin GB, Fath JJ, Wortsman J, Nowak RM. A characterization of hypothalamic-pituitary-adrenal axis function during and after human cardiac arrest. Crit Care Med. 1993;21:1339–1347.

145.

Kim JJ, Lim YS, Shin JH, Yang HJ, Kim JK, Hyun SY, Rhoo I, Hwang SY, Lee G. Relative adrenal insufficiency after cardiac arrest: impact on postresuscitation disease outcome. Am J Emerg Med. 2006;24:684–688.

146. Pene F, Hyvernat H, Mallet V, Cariou A, Carli P, Spaulding C, Dugue MA, Mira JP. Prognostic value of relative adrenal insufficiency after out-of-hospital cardiac arrest. Intensive Care Med. 2005;31:627–633.

147. Mentzelopoulos SD, Zakynthinos SG, Tzoufi M, Katsios N, Papastylianou A, Gkisioti S, Stathopoulos A, Kollintza A, Stamataki E, Roussos C. Vasopressin, epinephrine, and corticosteroids for in-hospital cardiac arrest. Arch Intern Med. 2009;169:15–24.

148. Minneci PC, Deans KJ, Banks SM, Eichacker PQ, Natanson C. Corticosteroids for septic shock. Ann Intern Med. 2004;141:742–743.

149. Sprung CL, Annane D, Keh D, Moreno R, Singer M, Freivogel K, Weiss YG, Benbenishty J, Kalenka A, Forst H, Laterre PF, Reinhart K, Cuthbertson BH, Payen D, Briegel J. Hydrocortisone therapy for patients with septic shock. N Engl J Med. 2008;358:111–124.

150. Annane D, Sebille V, Charpentier C, Bollaert PE, Francois B, Korach JM, Capellier G, Cohen Y, Azoulay E, Troche G, Chaumet-Riffaud P, Bellissant E. Effect of treatment with low doses of hydrocortisone and fludrocortisone on mortality in patients with septic shock. JAMA. 2002;288:862–871.

151. Laurent I, Adrie C, Vinsonneau C, Cariou A, Chiche JD, Ohanessian A, Spaulding C, Carli P, Dhainaut JF, Monchi M. High-volume hemofiltration after out-of-hospital cardiac arrest: a randomized study. J Am Coll Cardiol. 2005;46:432–437.

152. Sandroni C, Cariou A, Cavallaro F, Cronberg T, Friberg H, Hoedemaekers C, Horn J, Nolan JP, Rossetti AO, Soar J. Prognostication in comatose survivors of cardiac arrest: an advisory statement from the European Resuscitation Council and the European Society of Intensive Care Medicine. Resuscitation. 2014;85:1779–1789. doi: 10.1016/j. resuscitation.2014.08.011.

153. Empey PE, de Mendizabal NV, Bell MJ, Bies RR, Anderson KB, Kochanek PM, Adelson PD, Poloyac SM; Pediatric TBI Consortium: Hypothermia Investigators. Therapeutic hypothermia decreases phenyt- oin elimination in children with traumatic brain injury. Crit Care Med. 2013;41:2379–2387. doi: 10.1097/CCM.0b013e318292316c.

154. Hostler D, Zhou J, Tortorici MA, Bies RR, Rittenberger JC, Empey PE, Kochanek PM, Callaway CW, Poloyac SM. Mild hypothermia alters midazolam pharmacokinetics in normal healthy volunteers. Drug Metab Dispos. 2010;38:781–788. doi: 10.1124/dmd.109.031377.

155. Sandroni C, Cavallaro F, Callaway CW, Sanna T, D'Arrigo S, Kuiper M, Della Marca G, Nolan JP. Predictors of poor neurological out- come in adult comatose survivors of cardiac arrest: a systematic re- view and meta-analysis. Part 1: patients not treated with therapeutic hypothermia. Resuscitation. 2013;84:1310–1323. doi: 10.1016/j. resuscitation.2013.05.013.

156. Sandroni C, Cavallaro F, Callaway CW, D'Arrigo S, Sanna T, Kuiper MA, Biancone M, Della Marca G, Farcomeni A, Nolan JP. Predictors of poor neurological outcome in adult comatose survivors of cardiac arrest: a systematic review and meta-analysis. Part 2: Patients treated with thera- peutic hypothermia. Resuscitation. 2013;84:1324–1338. doi: 10.1016/j. resuscitation.2013.06.020.

157. Bouwes A, Binnekade JM, Kuiper MA, Bosch FH, Zandstra DF, Toornvliet AC, Biemond HS, Kors BM, Koelman JH, Verbeek MM, Weinstein HC, Hijdra A, Horn J. Prognosis of coma after therapeutic hypothermia: a prospective cohort study. Ann Neurol. 2012;71:206–212. doi: 10.1002/ana.22632.

158. Choi SP, Youn CS, Park KN, Wee JH, Park JH, Oh SH, Kim SH, Kim JY. Therapeutic hypothermia in adult cardiac arrest because of drowning. Acta Anaesthesiol Scand. 2012;56:116–123. doi: 10.1111/j.1399-6576.2011.02562.x.

159. Cronberg T, Rundgren M, Westhall E, Englund E, Siemund R, Rosén I, Widner H, Friberg H. Neuron-specific enolase correlates with other prognostic markers after cardiac arrest. Neurology. 2011;77:623–630. doi: 10.1212/WNL.0b013e31822a276d.

160. Fugate JE, Wijdicks EF, Mandrekar J, Claassen DO, Manno EM, White RD, Bell MR, Rabinstein AA. Predictors of neurologic outcome in hypo- thermia after cardiac arrest. Ann Neurol. 2010;68:907–914. doi: 10.1002/ ana.22133.

161. Samaniego EA, Mlynash M, Caulfield AF, Eyngorn I, Wijman CA. Sedation confounds outcome prediction in cardiac arrest survivors treat- ed with hypothermia. Neurocrit Care. 2011;15:113–119. doi: 10.1007/ s12028-010-9412-8.

162. Bouwes A, van Poppelen D, Koelman JH, Kuiper MA, Zandstra DF, Weinstein HC, Tromp SC, Zandbergen EG, Tijssen MA, Horn J. Acute posthypoxic myoclonus after cardiopulmonary resuscitation. BMC Neurol. 2012;12:63. doi: 10.1186/1471-2377-12-63.

163. Rossetti AO, Oddo M, Logroscino G, Kaplan PW. Prognostication af- ter cardiac arrest and hypothermia: a prospective study. Ann Neurol. 2010;67:301–307. doi: 10.1002/ana.21984.

164. Rossetti AO, Carrera E, Oddo M. Early EEG correlates of neuronal injury after brain anoxia. Neurology. 2012;78:796–802. doi: 10.1212/WNL.0b013e318249f6bb.

165. Bisschops LL, van Alfen N, Bons S, van der Hoeven JG, Hoedemaekers CW. Predictors of poor neurologic outcome in patients after cardiac arrest treated with hypothermia: a retrospective study. Resuscitation. 2011;82:696–701. doi: 10.1016/j.resuscitation.2011.02.020.

166. Bertini G, Margheri M, Giglioli C, Cricelli F, De Simone L, Taddei T, Marchionni N, Zini G, Gensini GF. Prognostic significance of early clinical manifestations in postanoxic coma: a retrospective study of 58 patients resuscitated after prehospital cardiac arrest. Crit Care Med. 1989;17:627–633.

167. Zandbergen EG, Hijdra A, Koelman JH, Hart AA, Vos PE, Verbeek MM, de Haan RJ; PROPAC Study Group. Prediction of poor outcome within the first 3 days of postanoxic coma. Neurology. 2006;66:62–68. doi: 10.1212/01.wnl.0000191308.22233.88.

168. Edgren E, Hedstrand U, Nordin M, Rydin E, Ronquist G. Prediction of outcome after cardiac arrest. Crit Care Med. 1987;15:820–825.

169. Young GB, Doig G, Ragazzoni A. Anoxic-ischemic encephalopathy: clinical and electrophysiological associations with outcome. Neurocrit Care. 2005;2:159–164. doi: 10.1385/NCC:2:2:159.

170. Topcuoglu MA, Oguz KK, Buyukserbetci G, Bulut E. Prognostic value of magnetic resonance imaging in post-resuscitation encephalopathy. Intern Med. 2009;48:1635–1645.

171. Legriel S, Hilly-Ginoux J, Resche-Rigon M, Merceron S, Pinoteau J, Henry-Lagarrigue M, Bruneel F, Nguyen A, Guezennec P, Troché G, Richard O, Pico F, Bédos JP. Prognostic value of electrographic postan- oxic status epilepticus in comatose cardiac-arrest survivors in the thera- peutic hypothermia era. Resuscitation. 2013;84:343–350. doi: 10.1016/j. resuscitation.2012.11.001.

172. Oddo M, Rossetti AO. Early multimodal outcome prediction after cardiac arrest in patients treated with hypothermia. Crit Care Med. 2014;42:1340–1347. doi: 10.1097/CCM.0000000000000211.

173. Accardo J, De Lisi D, Lazzerini P, Primavera A. Good functional outcome after prolonged postanoxic comatose myoclonic status epilepticus in a patient who had undergone bone marrow transplantation. Case Rep Neurol Med. 2013;2013:872127. doi: 10.1155/2013/872127.

174. Greer DM. Unexpected good recovery in a comatose post-cardiac arrest patient with poor prognostic features. Resuscitation. 2013;84:e81–e82. doi: 10.1016/j.resuscitation.2013.02.011.

175. Lucas JM, Cocchi MN, Salciccioli J, Stanbridge JA, Geocadin RG, Herman ST, Donnino MW. Neurologic recovery after therapeutic hypo- thermia in patients with post-cardiac arrest myoclonus. Resuscitation. 2012;83:265–269. doi: 10.1016/j.resuscitation.2011.09.017.

176. Wijdicks EF, Parisi JE, Sharbrough FW. Prognostic value of myoclonus status in comatose survivors of cardiac arrest. Ann Neurol. 1994;35:239– 243. doi: 10.1002/ana.410350219.

177. Krumholz A, Stern BJ, Weiss HD. Outcome from coma after cardiopul- monary resuscitation: relation to seizures and myoclonus. Neurology. 1988;38:401–405.

178. Hirsch LJ, LaRoche SM, Gaspard N, Gerard E, Svoronos A, Herman ST, Mani R, Arif H, Jette N, Minazad Y, Kerrigan JF, Vespa P, Hantus S, Claassen J, Young GB, So E, Kaplan PW, Nuwer MR, Fountain NB, Drislane FW. American Clinical Neurophysiology Society's Standardized Critical Care EEG Terminology: 2012 version. J Clin Neurophysiol. 2013;30:1–27. doi: 10.1097/WNP.0b013e3182784729.

179. Kawai M, Thapalia U, Verma A. Outcome from therapeutic hypother- mia and EEG. J Clin Neurophysiol. 2011;28:483–488. doi: 10.1097/ WNP.0b013e318231bfef.

180. Rundgren M, Westhall E, Cronberg T, Rosén I, Friberg H. Continuous amplitude-integrated electroencephalogram predicts outcome in hypo- thermia-treated cardiac arrest patients. Crit Care Med. 2010;38:1838– 1844. doi: 10.1097/CCM.0b013e3181eaa1e7.

181. Cloostermans MC, van Meulen FB, Eertman CJ, Hom HW, van Putten MJ. Continuous electroencephalography monitoring for early prediction of neurological outcome in postanoxic patients after cardiac arrest: a pro- spective cohort study. Crit Care Med. 2012;40:2867–2875. doi: 10.1097/ CCM.0b013e31825b94f0.

182. Mani R, Schmitt SE, Mazer M, Putt ME, Gaieski DF. The frequency and timing of epileptiform activity on continuous electroencephalogram in comatose post-cardiac arrest syndrome patients treated with thera- peutic hypothermia. Resuscitation. 2012;83:840–847. doi: 10.1016/j. resuscitation.2012.02.015.

183. Legriel S, Bruneel F, Sediri H, Hilly J, Abbosh N, Lagarrigue MH, Troche G, Guezennec P, Pico F, Bedos JP. Early EEG monitoring for detecting postanoxic status epilepticus during therapeutic hypother- mia: a pilot study. Neurocrit Care. 2009;11:338–344. doi: 10.1007/ s12028-009-9246-4.

184. Wennervirta JE, Ermes MJ, Tiainen SM, Salmi TK, Hynninen MS, Särkelä MO, Hynynen MJ, Stenman UH, Viertiö-Oja HE, Saastamoinen KP, Pettilä VY, Vakkuri AP. Hypothermia-treated cardiac arrest patients with good neurological outcome differ early in quantitative variables of EEG suppression and epileptiform activity. Crit Care Med. 2009;37:2427–2435. doi: 10.1097/CCM.0b013e3181a0ff84.

185. Stammet P, Wagner DR, Gilson G, Devaux Y. Modeling serum level of s100? and bispectral index to predict outcome after cardiac arrest. J Am Coll Cardiol. 2013;62:851–858. doi: 10.1016/j.jacc.2013.04.039.

186. Bassetti C, Bomio F, Mathis J, Hess CW. Early prognosis in coma af- ter cardiac arrest: a prospective clinical, electrophysiological, and biochemical study of 60 patients. J Neurol Neurosurg Psychiatry. 1996;61:610–615.

187. Rothstein TL, Thomas EM, Sumi SM. Predicting outcome in hypoxic- ischemic coma. A prospective clinical and electrophysiologic study. Electroencephalogr Clin Neurophysiol. 1991;79:101–107.

188. Scollo-Lavizzari G, Bassetti C. Prognostic value of EEG in post-anoxic coma after cardiac arrest. Eur Neurol. 1987;26:161–170.

189. Bouwes A, Binnekade JM, Zandstra DF, Koelman JH, van Schaik IN, Hijdra A, Horn J. Somatosensory evoked potentials during mild hypo- thermia after cardiopulmonary resuscitation. Neurology. 2009;73:1457– 1461. doi: 10.1212/WNL.0b013e3181bf98f4.

190. Tiainen M, Kovala TT, Takkunen OS, Roine RO. Somatosensory and brainstem auditory evoked potentials in cardiac arrest patients treated with hypothermia. Crit Care Med. 2005;33:1736–1740.

191. Leithner C, Ploner CJ, Hasper D, Storm C. Does hypothermia influ- ence the predictive value of bilateral absent N20 after cardiac arrest? Neurology. 2010;74:965–969. doi: 10.1212/WNL.0b013e3181d5a631.

192. Zanatta P, Messerotti Benvenuti S, Baldanzi F, Bosco E. Pain-related mid- dle-latency somatosensory evoked potentials in the prognosis of post an- oxic coma: a preliminary report. Minerva Anestesiol. 2012;78:749–756.

193. Brunko E, Zegers de Beyl D. Prognostic value of early cortical so- matosensory evoked potentials after resuscitation from cardiac arrest. Electroencephalogr Clin Neurophysiol. 1987;66:15–24.

194. Stelzl T, von Bose MJ, Hogl B, Fuchs HH, Flugel KA. A comparison of the prognostic value of neuron-specific enolase serum levels and somato- sensory evoked potentials in 13 reanimated patients. Eur J Emerg Med. 1995;2:24–27.

195. Rothstein TL. The role of evoked potentials in anoxic-ischemic coma and severe brain trauma. J Clin Neurophysiol. 2000;17:486–497.

196. Berek K, Lechleitner P, Luef G, Felber S, Saltuari L, Schinnerl A, Traweger C, Dienstl F, Aichner F. Early determination of neurologi- cal outcome after prehospital cardiopulmonary resuscitation. Stroke. 1995;26:543–549.

197. Zandbergen EG, Koelman JH, de Haan RJ, Hijdra A; PROPAC-Study Group. SSEPs and prognosis in postanoxic coma: only short or also long latency responses? Neurology. 2006;67:583–586. doi: 10.1212/01. wnl.0000230162.35249.7f.

198. Madl C, Kramer L, Domanovits H, Woolard RH, Gervais H, Gendo A, Eisenhuber E, Grimm G, Sterz F. Improved outcome prediction in uncon- scious cardiac arrest survivors with sensory evoked potentials compared with clinical assessment. Crit Care Med. 2000;28:721–726.

199. Zingler VC, Krumm B, Bertsch T, Fassbender K, Pohlmann-Eden B. Early prediction of neurological outcome after cardiopulmonary resus- citation: a multimodal approach combining neurobiochemical and elec- trophysiological investigations may provide high prognostic certainty in patients after cardiac arrest. Eur Neurol. 2003;49:79–84. doi: 68503.

200. Gendo A, Kramer L, Häfner M, Funk GC, Zauner C, Sterz F, Holzer M, Bauer E, Madl C. Time-dependency of sensory evoked poten- tials in comatose cardiac arrest survivors. Intensive Care Med. 2001;27:1305–1311.

201. Zhang Y, Su YY, Haupt WF, Zhao JW, Xiao SY, Li HL, Pang Y, Yang QL. Application of electrophysiologic techniques in poor outcome prediction among patients with severe focal and diffuse ischemic brain injury. J Clin Neurophysiol. 2011;28:497–503. doi: 10.1097/ WNP.0b013e318231c852.

202. Kottenberg-Assenmacher E, Armbruster W, Bornfeld N, Peters J. Hypothermia does not alter somatosensory evoked potential amplitude and global cerebral oxygen extraction during marked sodium nitroprus- side-induced arterial hypotension. Anesthesiology. 2003;98:1112–1118.

203. Mlynash M, Campbell DM, Leproust EM, Fischbein NJ, Bammer R, Eyngorn I, Hsia AW, Moseley M, Wijman CA. Temporal and spatial profile of brain diffusion-weighted MRI after cardiac arrest. Stroke. 2010;41:1665–1672. doi: 10.1161/STROKEAHA.110.582452.

204. Wijdicks EF, Campeau NG, Miller GM. MR imaging in coma- tose survivors of cardiac resuscitation. AJNR Am J Neuroradiol. 2001;22:1561–1565.

205. Inamasu J, Miyatake S, Suzuki M, Nakatsukasa M, Tomioka H, Honda M, Kase K, Kobayashi K. Early CT signs in out-of-hospital cardiac arrest survivors: Temporal profile and prognostic significance. Resuscitation. 2010;81:534–538. doi: 10.1016/j.resuscitation.2010.01.012.

206. Kim SH, Choi SP, Park KN, Youn CS, Oh SH, Choi SM. Early brain com- puted tomography findings are associated with outcome in patients treated with therapeutic hypothermia after out-of-hospital cardiac arrest. Scand J Trauma Resusc Emerg Med. 2013;21:57. doi: 10.1186/1757-7241-21-57.

207. Lee BK, Jeung KW, Lee HY, Jung YH, Lee DH. Combining brain com- puted tomography and serum neuron specific enolase improves the prognostic performance compared to either alone in comatose cardiac arrest survivors treated with therapeutic hypothermia. Resuscitation. 2013;84:1387–1392. doi: 10.1016/j.resuscitation.2013.05.026.

208. Morimoto Y, Kemmotsu O, Kitami K, Matsubara I, Tedo I. Acute brain swelling after out-of-hospital cardiac arrest: pathogenesis and outcome. Crit Care Med. 1993;21:104–110.

209. Choi SP, Park HK, Park KN, Kim YM, Ahn KJ, Choi KH, Lee WJ, Jeong SK. The density ratio of grey to white matter on computed tomogra- phy as an early predictor of vegetative state or death after cardiac arrest. Emerg Med J. 2008;25:666–669. doi: 10.1136/emj.2007.053306.

210. Torbey MT, Geocadin R, Bhardwaj A. Brain arrest neurological out- come scale (BrANOS): predicting mortality and severe disability following cardiac arrest. Resuscitation. 2004;63:55–63. doi: 10.1016/j. resuscitation.2004.03.021.

211. Wijman CA, Mlynash M, Caulfield AF, Hsia AW, Eyngorn I, Bammer R, Fischbein N, Albers GW, Moseley M. Prognostic value of brain dif- fusion-weighted imaging after cardiac arrest. Ann Neurol. 2009;65:394– 402. doi: 10.1002/ana.21632.

212. Kim J, Choi BS, Kim K, Jung C, Lee JH, Jo YH, Rhee JE, Kim T, Kang KW. Prognostic performance of diffusion-weighted MRI combined with NSE in comatose cardiac arrest survivors treated with mild hypothermia. Neurocrit Care. 2012;17:412–420. doi: 10.1007/s12028-012-9773-2.

213. Els T, Kassubek J, Kubalek R, Klisch J. Diffusion-weighted MRI during early global cerebral hypoxia: a predictor for clinical outcome? Acta Neurol Scand. 2004;110:361–367. doi: 10.1111/j.1600-0404.2004.00342.x.

214. Wu O, Sorensen AG, Benner T, Singhal AB, Furie KL, Greer DM. Comatose patients with cardiac arrest: predicting clinical outcome with diffusion-weighted MR imaging. Radiology. 2009;252:173–181. doi: 10.1148/radiol.2521081232.

215. Greer D, Scripko P, Bartscher J, Sims J, Camargo E, Singhal A, Parides M, Furie K. Clinical MRI interpretation for outcome predic- tion in cardiac arrest. Neurocrit Care. 2012;17:240–244. doi: 10.1007/ s12028-012-9716-y.

216. Hachimi-Idrissi S, Van der Auwera M, Schiettecatte J, Ebinger G, Michotte Y, Huyghens L. S-100 protein as early predictor of regain- ing consciousness after out of hospital cardiac arrest. Resuscitation. 2002;53:251–257.

217. Rosén H, Rosengren L, Herlitz J, Blomstrand C. Increased serum levels of the S-100 protein are associated with hypoxic brain damage after car- diac arrest. Stroke. 1998;29:473–477.

218. Steffen IG, Hasper D, Ploner CJ, Schefold JC, Dietz E, Martens F, Nee J, Krueger A, Jörres A, Storm C. Mild therapeutic hypothermia alters neuron specific enolase as an outcome predictor after resuscitation: 97 prospective hypothermia patients compared to 133 historical non-hypo- thermia patients. Crit Care. 2010;14:R69. doi: 10.1186/cc8975.

219. Reisinger J, Höllinger K, Lang W, Steiner C, Winter T, Zeindlhofer E, Mori M, Schiller A, Lindorfer A, Wiesinger K, Siostrzonek P. Prediction of neurological outcome after cardiopulmonary resuscitation by serial determination of serum neuron-specific enolase. Eur Heart J. 2007;28:52–58. doi: 10.1093/eurheartj/ehl316.

220. Tiainen M, Roine RO, Pettilä V, Takkunen O. Serum neuron-spe- cific enolase and S-100B protein in cardiac arrest patients treated with hypothermia. Stroke. 2003;34:2881–2886. doi: 10.1161/01. STR.0000103320.90706.35.

221. Rosén H, Sunnerhagen KS, Herlitz J, Blomstrand C, Rosengren L. Serum levels of the brain-derived proteins S-100 and NSE predict long- term outcome after cardiac arrest. Resuscitation. 2001;49:183–191.

222. Mussack T, Biberthaler P, Kanz KG, Wiedemann E, Gippner-Steppert C, Mutschler W, Jochum M. Serum S-100B and interleukin-8 as pre- dictive markers for comparative neurologic outcome analysis of patients after cardiac arrest and severe traumatic brain injury. Crit Care Med. 2002;30:2669–2674. doi: 10.1097/01.CCM.0000037963.51270.44.

223. Mörtberg E, Zetterberg H, Nordmark J, Blennow K, Rosengren L, Rubertsson S. S-100B is superior to NSE, BDNF and GFAP in predicting outcome of resuscitation from cardiac arrest with hypothermia treatment. Resuscitation. 2011;82:26–31. doi: 10.1016/j.resuscitation.2010.10.011.

224. Huntgeburth M, Adler C, Rosenkranz S, Zobel C, Haupt WF, Dohmen C, Reuter H. Changes in neuron-specific enolase are more suitable than its absolute serum levels for the prediction of neurologic outcome in hy- pothermia-treated patients with out-of-hospital cardiac arrest. Neurocrit Care. 2014;20:358–366. doi: 10.1007/s12028-013-9848-8.

225. Oksanen T, Tiainen M, Skrifvars MB, Varpula T, Kuitunen A, Castrén M, Pettilä V. Predictive power of serum NSE and OHCA score regarding 6-month neurologic outcome after out-of-hospital ventricular fibrilla- tion and therapeutic hypothermia. Resuscitation. 2009;80:165–170. doi: 10.1016/j.resuscitation.2008.08.017.

226. Rundgren M, Karlsson T, Nielsen N, Cronberg T, Johnsson P, Friberg H. Neuron specific enolase and S-100B as predictors of outcome after car- diac arrest and induced hypothermia. Resuscitation. 2009;80:784–789. doi: 10.1016/j.resuscitation.2009.03.025.

227. Storm C, Nee J, Jörres A, Leithner C, Hasper D, Ploner CJ. Serial mea- surement of neuron specific enolase improves prognostication in cardiac arrest patients treated with hypothermia: a prospective study. Scand J Trauma Resusc Emerg Med. 2012;20:6. doi: 10.1186/1757-7241-20-6.

228. Zellner T, Gärtner R, Schopohl J, Angstwurm M. NSE and S-100B are not sufficiently predictive of neurologic outcome after therapeutic hy- pothermia for cardiac arrest. Resuscitation. 2013;84:1382–1386. doi: 10.1016/j.resuscitation.2013.03.021.

229. Orioles A, Morrison WE, Rossano JW, Shore PM, Hasz RD, Martiner AC, Berg RA, Nadkarni VM. An under-recognized benefit of car- diopulmonary resuscitation: organ transplantation. Crit Care Med. 2013;41:2794–2799. doi: 10.1097/CCM.0b013e31829a7202.

230. Faucher A, Savary D, Jund J, Dorez D, Debaty G, Gaillard A, Atchabahian A, Tazarourte K. Out-of-hospital traumatic cardiac arrest: an underrecog- nized source of organ donors. Transpl Int. 2014;27:42–48. doi: 10.1111/ tri.12196.

231. Adrie C, Haouache H, Saleh M, Memain N, Laurent I, Thuong M, Darques L, Guerrini P, Monchi M. An underrecognized source of organ donors: patients with brain death after successfully resuscitated cardiac arrest. Intensive Care Med. 2008;34:132–137. doi: 10.1007/s00134-007-0885-7.

232. Ali AA, Lim E, Thanikachalam M, Sudarshan C, White P, Parameshwar J, Dhital K, Large SR. Cardiac arrest in the organ donor does not nega- tively influence recipient survival after heart transplantation. Eur J Cardiothorac Surg. 2007;31:929–933. doi: 10.1016/j.ejcts.2007.01.074.

233. Hsu RB, Chu SH, Chien CY, Chou NK, Chen YS, Ko WJ, Wang SS. Heart transplantation with marginal recipients and donors. J Formos Med Assoc. 1999;98:663–667.

234. Quader MA, Wolfe LG, Kasirajan V. Heart transplantation outcomes from cardiac arrest-resuscitated donors. J Heart Lung Transplant. 2013;32:1090–1095. doi: 10.1016/j.healun.2013.08.002.

235. Pilarczyk K, Osswald BR, Pizanis N, Tsagakis K, Massoudy P, Heckmann J, Jakob HG, Kamler M. Use of donors who have suffered cardiopulmonary arrest and resuscitation in lung transplantation. Eur J Cardiothorac Surg. 2011;39:342–347. doi: 10.1016/j.ejcts.2010.06.038.

236. Sánchez-Lázaro IJ, Almenar-Bonet L, Martínez-Dolz L, Buendía- Fuentes F, Agüero J, Navarro-Manchón J, Raso-Raso R, Salvador-Sanz A. Can we accept donors who have suffered a resuscitated cardiac arrest? Transplant Proc. 2010;42:3091–3092. doi: 10.1016/j.transproceed.2010.05.054.

237. Southerland KW, Castleberry AW, Williams JB, Daneshmand MA, Ali AA, Milano CA. Impact of donor cardiac arrest on heart transplantation. Surgery. 2013;154:312–319. doi: 10.1016/j.surg.2013.04.028.

238. Conway J, Chin C, Kemna M, Burch M, Barnes A, Tresler M, Scheel JN, Naftel DC, Beddow K, Allain-Rooney T, Dipchand AI; Pediatric Heart Transplant Study Investigators. Donors' characteristics and impact on outcomes in pediatric heart transplant recipients. Pediatr Transplant. 2013;17:774–781. doi: 10.1111/petr.12149.

239. de Begona JA, Gundry SR, Razzouk AJ, Boucek MM, Kawauchi M, Bailey LL. Transplantation of hearts after arrest and resuscitation. Early and long-term results. J Thorac Cardiovasc Surg. 1993;106:1196–1201; discussion 1200.

240. Finfer S, Bohn D, Colpitts D, Cox P, Fleming F, Barker G. Intensive care management of paediatric organ donors and its effect on post-transplant organ function. Intensive Care Med. 1996;22:1424–1432.

241. L'Ecuyer T, Sloan K, Tang L. Impact of donor cardiopulmonary re- suscitation on pediatric heart transplant outcome. Pediatr Transplant. 2011;15:742–745. doi: 10.1111/j.1399-3046.2011.01565.x.

242. Castleberry AW, Worni M, Osho AA, Snyder LD, Palmer SM, Pietrobon R, Davis RD, Hartwig MG. Use of lung allografts from brain-dead do- nors after cardiopulmonary arrest and resuscitation. Am J Respir Crit Care Med. 2013;188:466–473. doi: 10.1164/rccm.201303-0588OC.

243. Mercatello A, Roy P, Ng-Sing K, Choux C, Baude C, Garnier JL, Colpart JJ, Finaz J, Petit P, Moskovtchenko JF. Organ transplants from out-of- hospital cardiac arrest patients. Transplant Proc. 1988;20:749–750.

244. Matsumoto CS, Kaufman SS, Girlanda R, Little CM, Rekhtman Y, Raofi V, Laurin JM, Shetty K, Fennelly EM, Johnson LB, Fishbein TM. Utilization of donors who have suffered cardiopulmonary arrest and re- suscitation in intestinal transplantation. Transplantation. 2008;86:941– 946. doi: 10.1097/TP.0b013e3181852f9a.

245. Fondevila C, Hessheimer AJ, Flores E, Ruiz A, Mestres N, Calatayud D, Paredes D, Rodríguez C, Fuster J, Navasa M, Rimola A, Taurá P, García- Valdecasas JC. Applicability and results of Maastricht type 2 donation after cardiac death liver transplantation. Am J Transplant. 2012;12:162– 170. doi: 10.1111/j.1600-6143.2011.03834.x.

246. Mateos-Rodríguez AA, Navalpotro-Pascual JM, Del Rio Gallegos F, Andrés-Belmonte A. Out-hospital donors after cardiac death in Madrid, Spain: a 5-year review. Australas Emerg Nurs J. 2012;15:164–169. doi: 10.1016/j.aenj.2012.05.002.

247. Alonso A, Fernández-Rivera C, Villaverde P, Oliver J, Cillero S, Lorenzo D, Valdés F. Renal transplantation from non-heart-beating donors: a single-center 10-year experience. Transplant Proc. 2005;37:3658–3660. doi: 10.1016/j.transproceed.2005.09.104.

248. Casavilla A, Ramirez C, Shapiro R, Nghiem D, Miracle K, Bronsther O, Randhawa P, Broznick B, Fung JJ, Starzl T. Experience with liver and kidney allografts from non-heart-beating donors. Transplantation. 1995;59:197–203.

249. Nicholson ML, Metcalfe MS, White SA, Waller JR, Doughman TM, Horsburgh T, Feehally J, Carr SJ, Veitch PS. A comparison of the re- sults of renal transplantation from non-heart-beating, conventional cadaveric, and living donors. Kidney Int. 2000;58:2585–2591. doi: 10.1046/j.1523-1755.2000.00445.x.

250. Otero A, Gómez-Gutiérrez M, Suárez F, Arnal F, Fernández-García A, Aguirrezabalaga J, García-Buitrón J, Alvarez J, Máñez R. Liver trans- plantation from maastricht category 2 non-heart-beating donors: a source to increase the donor pool? Transplant Proc. 2004;36:747–750. doi: 10.1016/j.transproceed.2004.03.027.

Part 9: Acute Coronary Syndromes

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: acute coronary syndrome | electrocardiogram | fibrinolytics | myocardial infarction | ST-segment elevation | unstable angina | non-ST-segment elevation

1 Highlights

The 2015 Guidelines Update marks a change in the scope of the AHA guidelines for the evaluation and management of ACS. Starting with this update, recommendations will be limited to the prehospital and emergency department phases of care. In-hospital care is addressed by guidelines for the management of myocardial infarction published jointly by the AHA and the American College of Cardiology Foundation.

Summary of Key Issues and Major Changes

Key issues with major changes in the 2015 Guidelines Update recommendations for ACS include the following:

- Prehospital ECG acquisition and interpretation
- Choosing a reperfusion strategy when prehospital fibrinolysis is available
- Choosing a reperfusion strategy at a non–PCI-capable hospital
- Troponin to identify patients who can be safely discharged from the emergency department
- Interventions that may or may not be of benefit if given before hospital arrival

Prehospital ECG Acquisition and Interpretation

2015 (New): Prehospital 12-lead ECG should be acquired early for patients with possible ACS.

2015 (New): Trained nonphysicians may perform ECG interpretation to determine whether or not the tracing shows evidence of STEMI.

2015 (Updated): Computer-assisted ECG interpretation may be used in conjunction with interpretation by a physician or trained provider to recognize STEMI.

2015 (Updated): Prehospital notification of the receiving hospital and/or prehospital activation of the catheterization laboratory should occur for all patients with a STEMI identified on prehospital ECG.

2010 (Old): If providers are not trained to interpret the 12-lead ECG, field transmission of the ECG or a computer report to the receiving hospital was recommended.

2010 (Old): Advance notification should be provided to the receiving hospital for patients identified as having STEMI.

Why: A 12-lead ECG is inexpensive, is easy to perform, and can rapidly provide evidence of acute ST elevation. Concern that nonphysician interpretation of ECGs could lead to either overdiagnosis with a resulting overuse of resources or, alternately, underdiagnosis, which could result in a delay to treatment, has inhibited expansion of ECG programs to EMS systems. Similar concerns existed with computer interpretation of ECGs. A review of the literature shows that when fibrinolysis is not given in the prehospital setting, early hospital notification of the impending arrival of a patient with ST elevation or prehospital activation of the catheterization laboratory reduces time to reperfusion and reduces morbidity and mortality. Because it may take time for the inexperienced provider to develop skill with 12-lead ECG interpretation, computer interpretation can be expected to increase the accuracy of interpretation when used in conjunction with trained nonphysician interpretation.

Reperfusion

2015 (New): Where prehospital fibrinolysis is available as part of the STEMI system of care and direct transport to a PCI center is available, prehospital triage and transport directly to a PCI center may be preferred because it results in a small relative decrease in the incidence of intracranial hemorrhage. There is, however, no evidence of mortality benefit of one therapy over the other.

2015 (New): In adult patients presenting with STEMI in the emergency department of a non–PCI-capable hospital, we recommend immediate transfer without fibrinolysis from the initial facility to a PCI center, instead of immediate fibrinolysis at the initial hospital with transfer only for ischemia-driven PCI.

2015 (New): When STEMI patients cannot be transferred to a PCI-capable hospital in a timely manner, fibrinolytic therapy with routine transfer for angiography (see below) may be an acceptable alternative to immediate transfer to primary PCI.

2015 (New): When fibrinolytic therapy is administered to a STEMI patient in a non–PCI-capable hospital, it may be reasonable to transport all postfibrinolysis patients for early routine angiography in the first 3 to 6 hours and up to 24 hours rather than transport postfibrinolysis patients only when they require ischemia-guided angiography.

2010 (Old): Transfer of high-risk patients who have received primary reperfusion with fibrinolytic therapy is reasonable.

Why: Fibrinolysis has been the standard of care for STEMI for more than 30 years. In the past 15 years, PPCI has become more readily available in most parts of North America and has been shown to modestly improve outcomes, compared with fibrinolysis, when PPCI can be provided in a timely manner by experienced practitioners. However, when there is a delay to PPCI, depending on the length of that delay, immediate fibrinolysis may overcome any additional benefits of PCI. Direct transfer to a PCI-capable hospital compared with prehospital fibrinolysis does not produce any difference in mortality, but transfer for PPCI does result in a small relative decrease in the incidence of intracranial hemorrhage. A fresh look at the evidence has allowed stratification of treatment recommendations according to time from *symptom onset* and anticipated delay to PPCI, and has enabled recommendations specifically for clinicians at non–PCI-capable hospitals. Immediate PCI after treating with fibrinolysis provides no added benefit, but routine angiography within the first 24 hours after giving fibrinolysis does reduce the incidence of reinfarction.

Troponin to Identify Patients Who Can Be Safely Discharged From the Emergency Department

2015 (New): High-sensitivity troponin T and troponin I alone measured at 0 and 2 hours (without performing clinical risk stratification) should not be used to exclude the diagnosis of ACS, but high-sensitivity troponin I measurements that are less than the 99th percentile, measured at 0 and 2 hours, may be used together with low-risk stratification (Thrombolysis in Myocardial Infarction [TIMI] score of 0 or 1, or low risk per Vancouver rule) to predict a less than 1% chance of 30-day major adverse cardiac event (MACE). Also, negative troponin I or troponin T measurements at 0 and between 3 and 6 hours may be used together with very low-risk stratification (TIMI score of 0, low risk score per Vancouver rule, North American Chest Pain score of 0 and age less than 50 years, or low-risk HEART score) to predict a less than 1% chance of 30-day MACE.

2010 (Old): If biomarkers are initially negative within 6 hours of symptom onset, it was recommended that biomarkers should be remeasured between 6 to 12 hours after
symptom onset.

Why: Relying on a negative troponin test result, either alone or in combination with *unstructured* risk assessment, results in an unacceptably high rate of MACE at 30 days. However, predictions based on negative troponin test results, combined with *structured* risk assessment, carry a risk of less than 1% of MACE at 30 days.

Other Interventions

When a medication reduces morbidity or mortality, prehospital compared with hospital administration of that medication allows the drug to begin its work sooner and may further decrease morbidity or mortality. However, when urban EMS response and transport times are short, the opportunity for beneficial drug effect may not be great. Moreover, adding medications increases the complexity of prehospital care, which may in turn produce negative effects.

- Adenosine diphosphate inhibition for hospital patients with suspected STEMI has been recommended for many years. Administration of an adenosine diphosphate inhibitor in the prehospital setting provides neither additional benefit nor harm compared with waiting to administer it in the hospital.
- Unfractionated heparin (UFH) administered to patients with STEMI in the prehospital setting has not been shown to provide additional benefits to giving it in the hospital. In systems where prehospital administration of UFH already occurs, it is reasonable to continue to use it. Where it is not already used in the prehospital setting, it is just as reasonable to wait to give UFH until hospital arrival.
- Before the 2010 recommendations, oxygen was routinely administered to all patients with suspected ACS regardless of oxygen saturation or respiratory condition. In 2010, weak evidence of no benefit and possible harm prompted a recommendation that supplementary oxygen was not needed for patients with ACS who had an oxyhemoglobin saturation of 94% or greater (i.e., no hypoxemia) and no evidence of respiratory distress. Further evidence that the routine administration of supplementary oxygen may be harmful, supported by a multicenter randomized controlled trial published since the 2015 systematic review, strengthens the recommendation that oxygen be withheld from patients with possible ACS who have a normal oxygen saturation (ie, who are without hypoxemia).
- For STEMI patients, prehospital administration of UFH or bivalirudin is reasonable.
- For suspected STEMI patients who are being transferred for PPCI, enoxaparin is a reasonable alternative to UFH.

2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

Clinicians often struggle with uncertainty and complexity in deciding which course of treatment will likely lead to an optimal outcome for an individual patient. Scientific research provides information on how patient populations have responded to treatment regimens, and this information, combined with a knowledge of the individual patient, can help guide the clinician’s decisions.

The recommendations in the *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation* (CPR) *and Emergency Cardiovascular Care* (ECC) are based on an extensive evidence review process that was begun by the International Liaison Committee on Resuscitation (ILCOR) after the publication of the ILCOR *2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations*[1,2] and was completed in February 2015.[3,4]

In this in-depth evidence review process, ILCOR examined topics and then generated a prioritized list of questions for systematic review. Questions were first formulated in PICO (population, intervention, comparator, outcome) format,[5] and then a search for relevant articles was performed. The evidence was evaluated by the ILCOR task forces by using the standardized methodologic approach proposed by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group.[6]

The quality of the evidence was categorized based on the study methodologies and the 5 core GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias). Then, where possible, consensus-based treatment recommendations were created.

To create this *2015 AHA Guidelines Update for CPR and ECC*, the AHA formed 15 writing groups, with careful attention to avoid conflicts of interest, to assess the ILCOR treatment recommendations, and to write AHA treatment recommendations by using the AHA Class of Recommendation and Level of Evidence (LOE) system. The recommendations made in the *2015 Guidelines Update for CPR and ECC* are informed by the ILCOR recommendations and GRADE classification, in the context of the delivery of medical care in North America. In the online version of this publication, live links are provided so the reader can connect directly to the systematic reviews on the Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated

by a superscript combination of letters and numbers (eg, ACS 873).

This 2015 Guidelines Update offers recommendations for the care of patients with acute coronary syndromes (ACS). The recommendations in this Web-based Integrated Guidelines include issues that were reviewed in 2015 as well as the recommendations from the the 2010 Guidelines that are still relevant.

The ILCOR ACS Task Force did not review areas in which it found a paucity of new evidence between 2010 and 2015; therefore, the 2010 Guidelines for these unreviewed areas remain current. For example, acetylsalicylic acid administration has been shown to be of benefit in ACS and was recommended by the 2010 Guidelines.[7] Acetylsalicylic acid was not reviewed by the ACS Task Force in 2015, so the recommendations from 2010 should be used. (Note: The First Aid section of this 2015 Guidelines Update makes recommendations on acetylsalicylic acid administration by nonmedical personnel—see "Part 15: First Aid"). The recommendations that were not reviewed in 2015 will either be reviewed and included in future *AHA Guidelines for CPR and ECC* or will be in the most recent ACC/AHA Guidelines.[8-10]

A table of recommendations made in this update, as well as the recommendations made in "Part 10: Acute Coronary Syndromes" of the 2010 Guidelines,[7] can be found in the Appendix.

The 2015 Guidelines for ACS are directed toward practitioners who provide care for patients with suspected ACS from the time of first medical contact until disposition from the emergency department (ED). Care providers during this time may include emergency medical service (EMS) dispatchers, first responders, EMT-Bs, paramedics, nurses, physicians, and other independent practitioners.

3 Methodology - Updated

ILCOR performed 18 systematic reviews (14 based on meta-analyses) on more than 110 relevant studies that span 40 years. Based on these reviews, the ACS Writing Group assessed the evidence and assigned an LOE by using AHA definitions. The LOE for a given intervention supports the class or "strength" of recommendation that the writing group assigned. This update uses the newest AHA Class of Recommendation and LOE classification system, which contains modifications to the Class III recommendation and introduces LOE B-R (randomized studies) and B-NR (nonrandomized studies), as well as LOE C-LD (limited data) and LOE C-EO (consensus of expert opinion). For further information, see "Part 2: Evidence Evaluation and Management of Conflicts of Interest."

4 Patient and Healthcare Provider Recognition of ACS

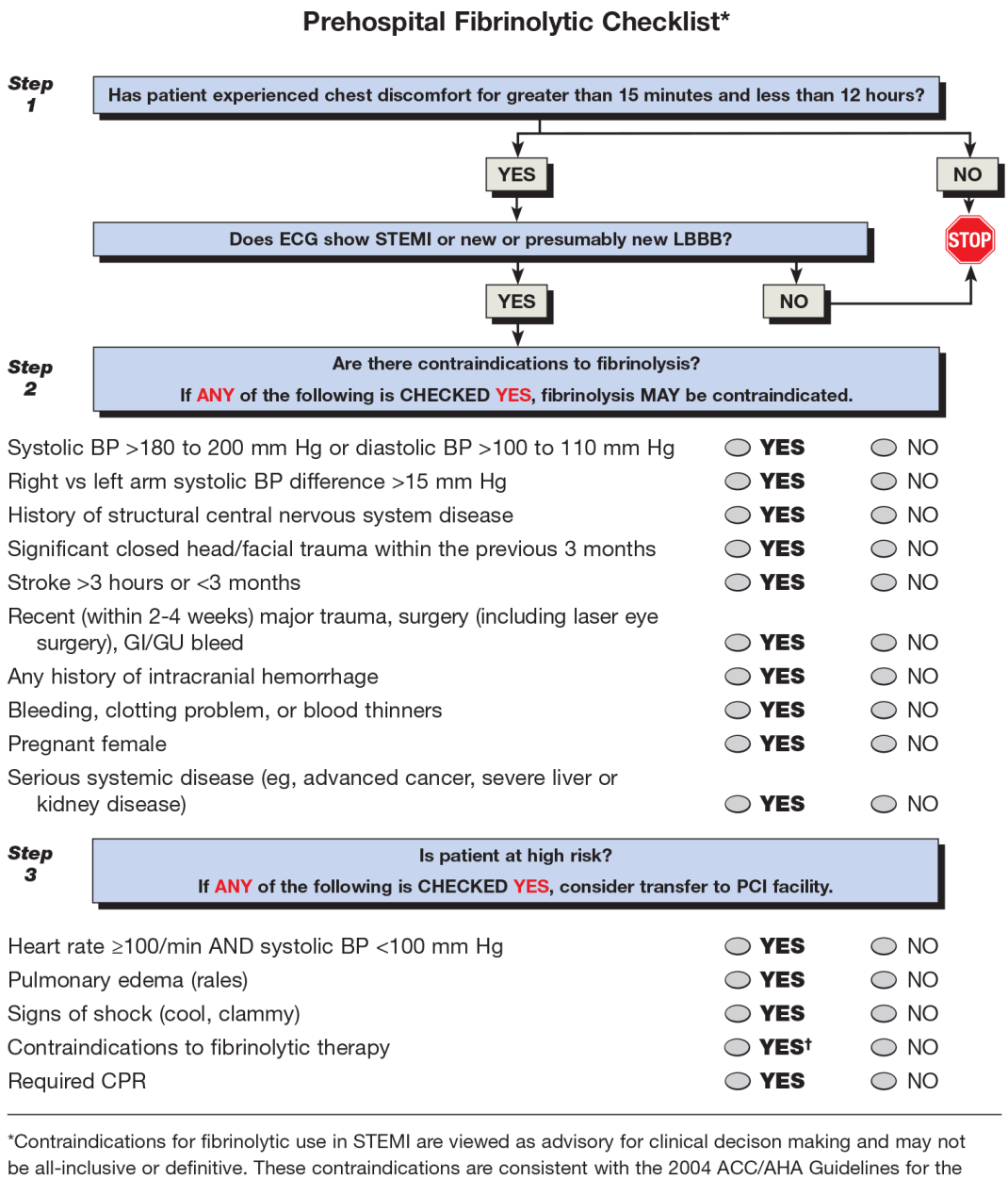
Prompt diagnosis and treatment offers the greatest potential benefit for myocardial salvage in the first hours of STEMI; and early, focused management of unstable angina and NSTEMI reduces adverse events and improves outcome.[11] Thus, it is imperative that healthcare providers recognize patients with potential ACS in order to initiate the evaluation, appropriate triage, and management as expeditiously as possible; in the case of STEMI, this recognition also allows for prompt notification of the receiving hospital and preparation for emergent reperfusion therapy. Potential delays to therapy occur during 3 intervals: from onset of symptoms to patient recognition, during prehospital transport, and during emergency department (ED) evaluation.

Patient-based delay in recognition of ACS and activation of the emergency medical services (EMS) system often constitutes the longest period of delay to treatment.[12] With respect to the prehospital recognition of ACS, numerous issues have been identified as independent factors for prehospital treatment delay (ie, symptom-to-door time), including older age,[13] racial and ethnic minorities,[14,15] female gender,[16] lower socioeconomic status,[17,18] and solitary living arrangements.[14,19]

Hospital-based delays in ACS recognition range from nonclassical patient presentations and other confounding diagnostic issues to provider misinterpretation of patient data and inefficient in-hospital system of care.[16,20-23]

Symptoms of ACS may be used in combination with other important information (biomarkers, risk factors, ECG, and other diagnostic tests) in making triage and some treatment decisions in the out-of-hospital and ED settings. The symptoms of AMI may be more intense than angina and most often persist for longer periods of time (eg, longer than 15–20 minutes). The classic symptom associated with ACS is chest discomfort, but symptoms may also include discomfort in other areas of the upper body, shortness of breath, sweating, nausea, vomiting, and dizziness. Most often the patient will note chest or upper body discomfort and dyspnea as the predominant presenting symptoms accompanied by diaphoresis, nausea, vomiting, and dizziness.[24-26] Isolated diaphoresis, nausea, vomiting, or dizziness are unusual predominant presenting symptoms.[27] Atypical or unusual symptoms are more common in women, the elderly, and diabetic patients.[28-30] The physical examination of the patient with ACS is often normal.

Figure 1: Prehospital Fibrinolytic Checklist



Prehospital fibrinolytic checklist. Adapted from Antman EM, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Revise the 1999 Guidelines for the Management of Patients with Acute Myocardial Infarction). *Circulation.* 2004;110:e82-e292, with permission from Lippincott Williams & Wilkins. Copyright 2004, American Heart Association.

(Figure 1). Prehospital Fibrinolytic Checklist. Adapted from Antman EM, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Revise the 1999 Guidelines for the Management of Patients with Acute Myocardial Infarction). Circulation. 2004;110:e82-e292, with permission from Lippincott Williams & Wilkins. Copyright 2004, American Heart Association.

Public education campaigns increase patient awareness and knowledge of the symptoms of ACS, yet have only transient effects on time to presentation.[31,32] For patients at risk for ACS (and for their families), primary care physicians and other healthcare providers should consider discussing the appropriate use of aspirin and activation of EMS system. Furthermore, an awareness of the location of the nearest hospital that offers 24-hour

emergency cardiovascular care can also be included in this discussion. Previous guidelines have recommended that the patient, family member, or companion activate the EMS system rather than call their physician or drive to the hospital if chest discomfort is unimproved or worsening 5 minutes after taking 1 nitroglycerin treatment.[33]

5 Initial EMS Care

Half the patients who die of ACS do so before reaching the hospital. VF or pulseless VT is the precipitating cardiac arrest rhythm in most of these deaths,[34,35] and it is most likely to develop in the early phase of ACS evolution.[36] Communities should develop programs to respond to cardiac emergencies that include the prompt recognition of ACS symptoms by patients and their companions as well as by healthcare and public safety providers and early activation of the EMS system. Additional features of such a program include high-quality CPR for patients in cardiac arrest (see Part 5: “Adult Basic Life Support”) and rapid access to and use of an automated external defibrillator (AED) through community AED programs (see Part 6: “Electrical Therapies”).[37] Emergency dispatch center personnel should be educated in the provision of CPR instructions for lay rescuers before the arrival of EMS. EMS providers should be trained to respond to cardiovascular emergencies, including ACS and its acute complications.

Emergency dispatch center personnel can provide instructions to the patient or caller before EMS arrival.

Because aspirin should be administered as soon as possible after symptom onset to patients with suspected ACS, it is reasonable for EMS dispatchers to instruct patients with no history of aspirin allergy and without signs of active or recent gastrointestinal bleeding to chew an aspirin (160 to 325 mg) while awaiting the arrival of EMS providers.[38-43] (Class IIa, LOE C)

EMS providers should be familiar with the presentation of ACS and trained to determine the time of symptom onset. EMS providers should monitor vital signs and cardiac rhythm and be prepared to provide CPR and defibrillation if needed.

EMS providers administer oxygen during the initial assessment of patients with suspected ACS. However, there is insufficient evidence to support its routine use in uncomplicated ACS.

If the patient is dyspneic, hypoxemic, or has obvious signs of heart failure, providers should titrate therapy, based on monitoring of oxyhemoglobin saturation, to ?94%.[44] (Class I, LOE C)

EMS providers should administer nonenteric aspirin (160* to 325* mg). (Class I, LOE B Class I, LOE C)

The patient should chew the aspirin tablet to hasten absorption.[38,45-47] EMS providers should administer up to 3 nitroglycerin doses (tablets or spray) at intervals of 3 to 5 minutes. Nitrates in all forms are contraindicated in patients with initial systoloic blood pressure <90 mm Hg or ?30 mm Hg below baseline and in patients with right ventricular infarction.[48-50] Caution is advised in patients with known inferior wall STEMI, and a right-sided ECG should be performed to evaluate RV infarction. Administer nitrates with extreme caution, if at all, to patients with inferior STEMI and suspected right ventricular (RV) involvement because these patients require adequate RV preload. Nitrates are contraindicated when patients have taken a phosphodiesterase-5 (PDE-5) inhibitor within 24 hours (48 hours for tadalafil).[51]

Morphine is indicated in STEMI when chest discomfort is unresponsive to nitrates. (Class I, LOE C)

Morphine should be used with caution in unstable angina (UA)/NSTEMI due to an association with increased mortality in a large registry.[52] (Class IIa, LOE C)

The efficacy of other analgesics is unknown.

6 Diagnostic Interventions in ACS - Updated

6.1 Prehospital ECG and Prehospital STEMI Activation of the Catheterization Laboratory - Updated ACS 873 ACS 336

Prehospital 12-lead ECGs speed the diagnosis, shorten the time to reperfusion (fibrinolytics [53-60] or primary percutaneous coronary intervention [PPCI][61-68]). EMS personnel should routinely acquire a 12-lead electrocardiogram (ECG) as soon as possible for all patients exhibiting signs and symptoms of ACS. The ECG may be transmitted for remote interpretation by a physician or screened for STEMI by properly trained paramedics, with or without the assistance of computer-interpretation.

Prehospital acquisition of 12-lead electrocardiograms (ECGs) has been recommended by the AHA Guidelines for CPR and Emergency Cardiovascular Care since 2000. The 2015 ILCOR systematic review examined whether acquisition of a prehospital ECG with transmission of the ECG to the hospital, notification of the hospital of the need for fibrinolysis, or activation of the catheterization laboratory changes any major outcome.

6.1.1 2015 Evidence Summary

Obtaining an ECG early in the assessment of patients with possible ACS ensures that dynamic ECG changes suggestive of cardiac ischemia and ACS will be identified, even if they normalize before initial treatment.[69]

An early ECG may also enable ST elevation myocardial infarction (STEMI) to be recognized earlier. Acquiring a prehospital ECG and determining the presence of STEMI effectively makes the prehospital provider the first medical contact. The prehospital ECG can reliably enable identification of STEMI before arrival at the hospital,[70] but if notification of the receiving facility does not occur, any benefit to prehospital STEMI recognition is lost.

Prehospital ECG acquisition coupled with hospital notification if STEMI is identified consistently reduces the time to reperfusion in-hospital (first medical contact–to–balloon time, first medical contact–to–needle time, door-to-balloon time, door-to-needle time).[71] To reduce time to STEMI reperfusion in-hospital, rapid transport and early treatment must occur in parallel with hospital preparation for the arriving patient.

Prehospital ECGs reduce the time to reperfusion with fibrinolytic therapy and also reduce the time to primary percutaneous coronary intervention (PPCI) and facilitate triage of STEMI patients to specific hospitals.[4] Prehospital activation of the catheterization laboratory (as opposed to delaying cardiac catheterization laboratory activation until the patient arrives at the hospital) is independently associated with improved times to PPCI and reduced mortality.[4]

Prehospital ECG acquisition and hospital notification reduce mortality by 32% when PPCI is the reperfusion strategy (benefit is accentuated when prehospital activation occurs) and by 24% when ED fibrinolysis is the reperfusion strategy.[4]

6.1.2 2015 Recommendations - Updated

Prehospital 12-lead ECG should be acquired early for patients with possible ACS. (Class I, LOE B-NR)

Prehospital notification of the receiving hospital (if fibrinolysis is the likely reperfusion strategy) and/or prehospital activation of the catheterization laboratory should occur for all patients with a recognized STEMI on prehospital ECG. (Class I, LOE B-NR)

Implementation of 12-lead ECG diagnostic programs with concurrent medically-directed quality assurance is recommended. (Class I, LOE B)

Prehospital personnel can accurately identify ST-segment elevation from the 12-lead ECG.[55,58,72-85]

If providers are not trained to interpret the 12-lead ECG, field transmission of the ECG or a computer report to the receiving hospital is recommended. (Class I, LOE B)

6.2 ED Evaluation and Risk Stratification (Figure 1, Boxes 3 and 4)

6.2.1 Focused Assessment and ECG Risk Stratification

ED providers should quickly assess patients with possible ACS. Ideally within 10 minutes of ED arrival providers should obtain a targeted history while a monitor is attached to the patient and a 12-lead ECG is obtained (if not done in the prehospital setting).[86] The evaluation should focus on chest discomfort, associated signs and symptoms, prior cardiac history, risk factors for ACS, and historical features that may preclude the use of fibrinolytics or other therapies.

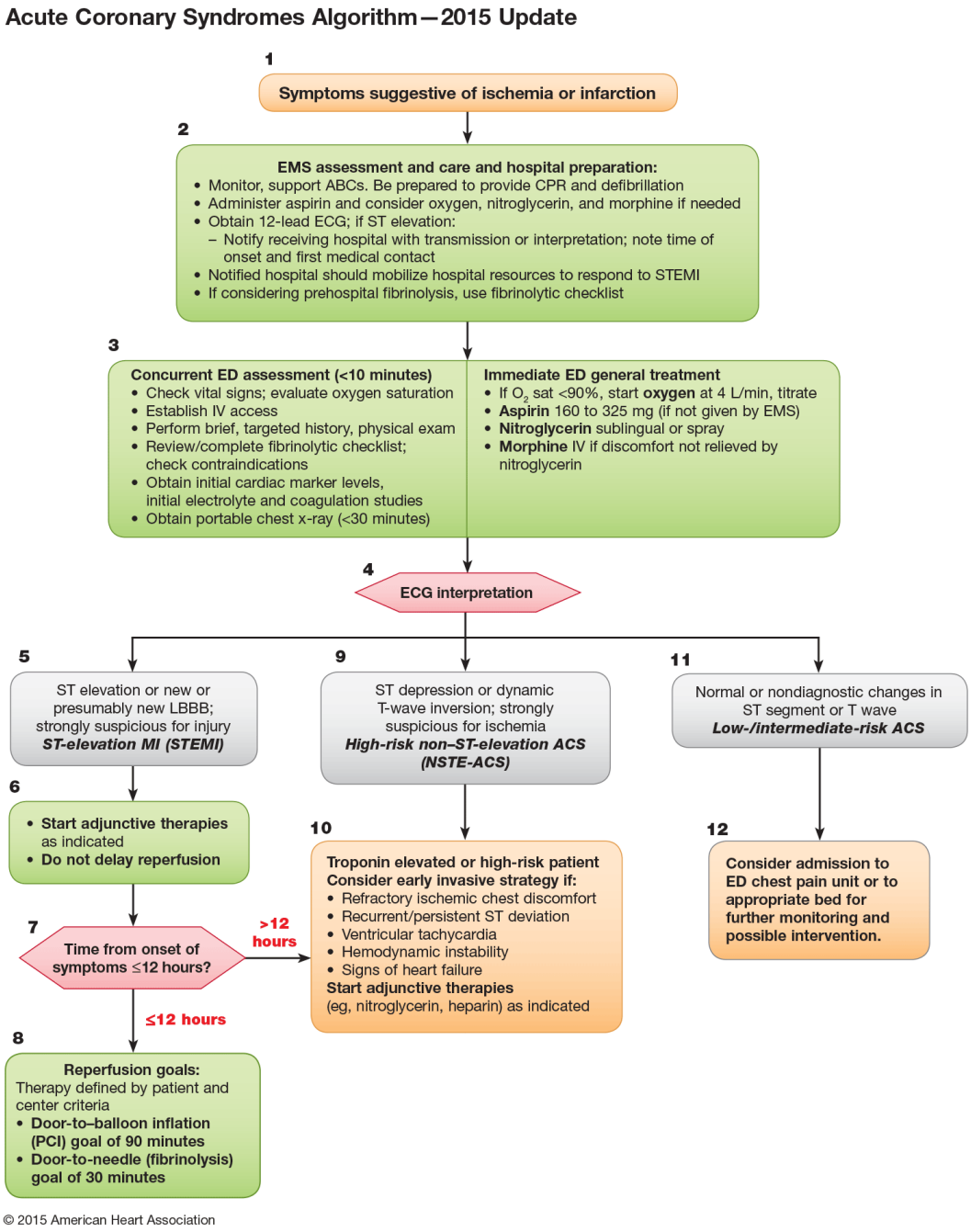
This initial evaluation must be efficient because if the patient has STEMI, the goals of reperfusion are to administer fibrinolytics within 30 minutes of arrival (30-minute interval "door-to-drug") or to provide PCI within 90 minutes of arrival (90-minute interval "door-to-balloon"). (Class I, LOE A)

Potential delay during the in-hospital evaluation period may occur from door to data, from data (ECG) to decision, and from decision to drug (or PCI). These 4 major points of in-hospital therapy are commonly referred to as the "4 D's."[87] All providers must focus on minimizing delays at each of these points. Prehospital transport time constitutes only 5% of delay to treatment time; ED evaluation constitutes 25% to 33% of this delay.[88,87-90]

The physical examination is performed to aid diagnosis, rule out other causes of the patient's symptoms, and evaluate the patient for complications related to ACS. Although the presence of clinical signs and symptoms may increase suspicion of ACS, evidence does not support the use of any single sign or combination of clinical signs and symptoms alone to confirm the diagnosis.[24-26,91]

When the patient presents with symptoms and signs of potential ACS, the clinician uses ECG findings (Figure 2 : Acute Coronary Syndromes, Box 4) to classify the patient into 1 of 3 groups:

Figure 2: Acute Coronary Syndromes Algorithm - 2015 Update



1. ST-segment elevation or presumed new LBBB (Box 5) is characterized by ST-segment elevation in 2 or more contiguous leads and is classified as *ST-segment elevation MI (STEMI*). Threshold values for ST-segment elevation consistent with STEMI are J-point elevation 0.2 mV (2 mm) in leads V2 and V3 and 0.1 mV (1 mm) in all other leads (men ?40 years old); J-point elevation 0.25 mV (2.5 mm) in leads V2 and V3 and 0.1 mV (1 mm) in all other leads (men <40 years old); J-point elevation 0.15 mV (1.5 mm) in leads V2 and V3 and 0.1 mV (1 mm) in all other leads (women).[92]

2. Ischemic ST-segment depression >0.5 mm (0.05 mV) or dynamic T-wave inversion with pain or discomfort (Box 9) is classified as UA/NSTEMI. Nonpersistent or transient ST-segment elevation ?0.5 mm for <20 minutes is also included in this category. Threshold values for ST-segment depression consistent with ischemia are J-point depression 0.05 mV (-.5 mm) in leads V2 and V3 and -0.1 mV (-1 mm) in all other leads (men and women).[92]

3. The nondiagnostic ECG with either normal or minimally abnormal (ie, nonspecific ST-segment or T-wave changes, Box 13). This ECG is nondiagnostic and inconclusive for ischemia, requiring further risk stratification. This classification includes patients with normal ECGs and those with ST-segment deviation of <0.5 mm (0.05

mV) or T-wave inversion of ?0.2 mV. This category of ECG is termed *nondiagnostic*.

The interpretation of the 12-lead ECG is a key step in this process, allowing not only for this classification but also the selection of the most appropriate diagnostic and management strategies.

6.2.2 Cardiac Biomarkers

Serial cardiac biomarkers are often obtained during evaluation of patients suspected of ACS. Cardiac troponin is the preferred biomarker and is more sensitive than creatine kinase isoenzyme (CK-MB). Cardiac troponins are useful in diagnosis, risk stratification, and determination of prognosis. An elevated level of *troponin* correlates with an increased risk of death, and greater elevations predict greater risk of adverse outcome.[93]

Clinicians should take into account the timing of symptom onset and the sensitivity, precision, and institutional norms of the assay, as well as the release kinetics and clearance of the measured biomarker.

A diagnosis of myocardial infarction can be made when clinical symptoms or new ECG abnormalities are consistent with ischemia and one biomarker is elevated above the 99th percentile of the upper reference limit (URL) using a test with optimal precision defined as a CV ?10%.

There is insufficient evidence to support the use of troponin point-of-care testing (POCT) either in or out of hospital. There is also insufficient evidence to support the use of myoglobin, ?-natriuretic peptide (BNP), NT-proBNP, D-dimer, C-reactive protein, ischemia-modified albumin pregnancy-associated plasma protein A (PAPP-A) or interleukin-6 in isolation.

6.2.3 STEMI (Figure 1, Boxes 5 Through 8)

Patients with STEMI usually have complete occlusion of an epicardial coronary artery. The primary goal of initial treatment is early reperfusion therapy through administration of fibrinolytics (pharmacological reperfusion) or PPCI (mechanical reperfusion). Providers should rapidly identify patients with STEMI and quickly screen them for indications and contraindications to fibrinolytic therapy and PCI. Patients who are ineligible for fibrinolytic therapy should be considered for transfer to a PCI facility regardless of delay.

Within a STEMI system of care, the first physician who encounters a patient with STEMI determines the need and strategy (fibrinolytic or PPCI) for reperfusion therapy (see Table 1: ST-Segment Elevation or New or Presumably New LBBB: Evaluation for Reperfusion).

If the patient meets the criteria for fibrinolytic therapy, a door-to-needle time (initiation of fibrinolytic agent) (Class I, LOE A)

Routine consultation with a cardiologist or another physician is not recommended except in equivocal or uncertain cases.[94,95]

Consultation delays therapy and is associated with increased hospital mortality rates. (Class III, LOE B)

Table 1: 2010 - ST-Segment Elevation or New or Presumably New LBBB: Evaluation for Reperfusion

Open table in a new window

ST-Segment Elevation or New or Presumably New LBBB: Evaluation for Reperfusion
Step 1: Assess time and risk
Time since onset of symptoms

Risk of STEMI
Risk of fibrinolysis
Time required to transport to skilled PCI catheterization suite
Step 2: Select reperfusion (fibrinolysis or invasive) strategy
Note: If presentation <3 hours and no delay for PCI, then no preference for either strategy.

Fibrinolysis is generally preferred if:	An invasive strategy is generally preferred if:

• Early presentation (?3 hours from symptom onset)
• Invasive strategy is not an option (eg, lack of access to skilled PCI facility or difficult vascular access) or would be delayed
  ○ - Medical contact-to-balloon or door-balloon >90 minutes
  ○ - (Door-to-balloon) minus (door-to-needle) is >1 hour
• No contraindications to fibrinolysis
	• Late presentation (symptom onset >3 hours ago)
	• Skilled PCI facility available with surgical backup
	• Medical contact-to-balloon or door-to-balloon <90 minutes
	• (Door-to-balloon) minus (door-to-needle) is <1 hour
	• Contraindications to fibrinolysis, including increased risk of bleeding and ICH
	• High risk from STEMI (CHF, Killip class is ?3)
	• Diagnosis of STEMI is in doubt

• Modified from ACC/AHA 2004 Update Recommendations.[reference id="4607" range="" /]

6.2.4 UA and NSTEMI (Figure 1, Boxes 9 Through 12)

Unstable angina (UA) and NSTEMI are difficult to distinguish initially. These patients usually have a partially or intermittently occluding thrombus. Both ACS syndromes may present with similar symptoms and ECG. Clinical features can correlate with the dynamic nature of clot formation and degradation (eg, waxing and waning clinical symptoms). The ECG will demonstrate a range of findings short of diagnostic ST-segment deviation; these ECG presentations include normal, minimal nonspecific ST-segment/T-wave changes, and significant ST-segment depression and T-wave inversions.

An elevated biomarker separates NSTEMI from UA and has incremental value in addition to the ECG. Elevation of cardiac troponin indicates increased risk for major adverse cardiac events and benefit from an invasive strategy. Cardiac troponins indicate myocardial necrosis, although numerous conditions other than ACS may cause elevated biomarkers (eg, myocarditis, heart failure, and pulmonary embolism).

Management strategies for UA/NSTEMI include antiplatelet, antithrombin, and antianginal therapy and are based on risk stratification. Fibrinolysis is contraindicated in this heterogenous group of patients and may be harmful; an invasive strategy is indicated in patients with positive biomarkers or unstable clinical features.

6.2.4.1 The Process of Risk Stratification

Diagnosis of ACS and risk stratification become an integrated process in patients presenting to an acute care setting with possible ACS and an initially nondiagostic evaluation. This nondiagnostic evaluation includes a normal or nondiagnostic 12-lead ECG and normal serum cardiac biomarker concentrations. The majority of these patients will not be experiencing an ACS, but many may have underlying CAD or other clinical features putting them at subsequent risk for major adverse cardiac events over the course of a few days to several months.

A major goal of the risk stratification process is to identify those patients who do not appear to have high-risk features on initial assessment but are found, through the course of the diagnostic process, to have ACS and clinically significant CAD. This strategy allows physicians to target patients who would benefit from guidelines-based ACS therapies while avoiding unnecessary procedural and pharmacological risks (eg, anticoagulation therapy and invasive cardiac catheterization) in patients with low risk for major adverse cardiac events.

Although the diagnosis of ACS is important and will help to guide immediate therapy, the estimation of risk for major adverse cardiac events in the immediate, short-term, and long-term time frames helps the physician determine the urgency in completing the diagnostic workup not just for ACS but also for CAD. Many patients can be managed in the outpatient setting once it is determined that they are at very low risk for short-term (30 days) major adverse cardiac events.

6.2.4.1.1 Braunwald Risk Stratification

ACC/AHA Guidelines recommend that all patients be risk stratified for the selection of an initial management strategy and site of care.[88] A well-recognized approach is the one initially proposed and later refined by Braunwald and colleagues and published in ACC/AHA Guidelines on the Management of Patients With Unstable Angina and Non-ST Segment Elevation MI.[96-100] This approach is based on a combination of historical, clinical, laboratory, and ECG variables and answers two questions: what is the likelihood that signs and symptoms represent ACS secondary to obstructive CAD, and what is the likelihood of an adverse clinical outcome?

Table 2[101] is a modified version of Braunwald and colleagues' approach updated over several publications.[98,100,102] Patients are initially risk-stratified according to the likelihood that symptoms are due to unstable CAD. Patients at intermediate or high risk for CAD are further classified by their risk of major adverse cardiac events. This second classification is useful for prospectively identifying patients at intermediate or high risk who can benefit from an invasive strategy and more aggressive pharmacology with antiplatelet and antithrombin agents. Other risk stratification schemes include the TIMI, GRACE, and PURSUIT risk scores developed for short- and longer-term risk assessment.[103-107] Stratification tools cannot be used to determine discharge from the ED.

Table 2: 2010 - Likelihood That Signs and Symptoms Represent ACS Secondary to CAD

Open table in a new window

Likelihood That Signs and Symptoms Represent ACS Secondary to CAD			
Feature	**High Likelihood** ***Any of the following:***	**Intermediate Likelihood** ***Absence of high-likelihood features and presence of any of the following:***	**Low Likelihood** ***Absence of high- or intermediate-likelihood features but may have the following:***
History	Chest or left arm pain or discomfort as chief symptom reproducing prior documented angina; known history of CAD including MI	Chest or left arm pain or discomfort as chief symptom; age >70 years; male sex; diabetes mellitus	Probable ischemic symptoms in absence of any intermediate-likelihood characteristics; recent cocaine use

Feature	High Likelihood *Any of the following:*	Intermediate Likelihood *Absence of high-likelihood features and presence of any of the following:*	Low Likelihood *Absence of high- or intermediate-likelihood features but may have the following:*
Examination	Transient MR murmur, hypotension, diaphoresis, pulmonary edema, or rales	Extracardiac vascular disease	Chest discomfort reproduced by palpation
ECG	New or presumably new transient ST-segment deviation (?1 mm) or T-wave inversion in multiple precordial leads	Fixed Q waves ST depression 0.5 to 1 mm or T-wave inversion >1 mm	T-wave flattening or inversion <1 mm in leads with dominant R waves Normal ECG
Cardiac markers	Elevated cardiac TnI, TnT, or CK-MB	Normal	Normal

- CAD indicates coronary artery disease; CK-MB, MB fraction of creatine kinase; ECG, electrocardiogram; MI, myocardial infarction; MR, mitral regurgitation; TnI, troponin I; and TnT, troponin T.

  Modified from Braunwald E, et al. *Unstable Angina: Diagnosis and Management*. 1994;3-1-AHCPR Publication No 94-0602:1-154. In the public domain.[reference id="4732" range="" /]

6.2.4.1.2 TIMI Risk Score

Recommendations concerning TIMI Risk Scores were not reviewed in 2015. Please refer to the *2014 AHA/ACC Guideline for the Management of Patients With Non–ST-Elevation Acute Coronary Syndromes* or the *2013 ACCF/AHA Guideline for the Management of ST-Elevation Myocardial Infarction* for information on this topic.

6.2.5 Indicators for Early Invasive Strategies

Risk stratification (Figure 2, Boxes 9, 13, 14, 15) helps the clinician identify patients with non–ST-elevation ACS who should be managed with an early invasive strategy versus a selectively invasive one. Early coronary angiography may allow the clinician to determine whether patients are appropriate candidates for revascularization with PCI or coronary artery bypass grafting (CABG).

The 2007 Focused Update of the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention contains the following recommendations related to the selection of early invasive PCI versus conservative strategies.

1. An early invasive PCI strategy is indicated for patients with non–ST-elevation ACS who have no serious comorbidity and who have coronary lesions amenable to PCI and an elevated risk for clinical events. (Class I, LOE A)

(See Table 3 and Section 3.3 of the ACC/AHA 2007 UA/NSTEMI Guidelines).

2. An early invasive strategy (ie, diagnostic angiography with intent to perform revascularization) is indicated in non–ST-elevation ACS patients who have refractory angina or hemodynamic or electric instability (without serious comorbidities or contraindications to such procedures). (Class I, LOE B)

3. In initially stabilized patients, an initially conservative (ie, a selectively invasive) strategy may be considered as a treatment strategy for non–ST-elevation ACS patients (without serious comorbidities or contraindications to such procedures) who have an elevated risk for clinical events including those with abnormal troponin elevations. (Class IIb, LOE B)

4. The decision to implement an initial conservative (versus initial invasive) strategy in these patients may be made by considering physician and patient preference. (Class IIb, LOE C)

Table 3: 2010 - Selection of Initial Treatment Strategy for Patients With Non-ST-Elevation ACS: Invasive Versus Conservative Strategy

Open table in a new window

Selection of Initial Treatment Strategy for Patients With Non-ST-Elevation ACS: Invasive Versus Conservative Strategy*	
Preferred Strategy	**Patient Characteristics**

Invasive	• Recurrent angina or ischemia at rest or with low-level activities despite intensive medical therapy • Elevated cardiac biomarkers (TnT or TnI) • New or presumably new ST-segment depression • Signs or symptoms of HF or new or worsening mitral regurgitation • High-risk findings from noninvasive testing • Hemodynamic instability • Sustained ventricular tachycardia • PCI within 6 months • Prior CABG • High-risk score (eg, TIMI, GRACE) • Reduced LV function (LVEF less than 40%)
Conservative	• Low-risk score (eg, TIMI, GRACE) • Patient or physician preference in absence of high-risk features

- CABG indicates coronary artery bypass graft surgery; GRACE, Global Registry of Acute Coronary Events; HF, heart failure; LV, left ventricular; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; TIMI, Thrombolysis in Myocardial Infarction; TnI, troponin I; and TnT, troponin T.
- ?* Adapted from the ACC/AHA 2007 UA/NSTEMI Guidelines.

6.2.6 Normal or Nondiagnostic ECG Changes (Figure 1, Boxes 13 Through 17)

The majority of patients with normal or nondiagnostic ECGs do not have ACS. Patients in this category with ACS are most often at low or intermediate risk. The physician's goal involves risk stratification (see above) to provide appropriate diagnostic or treatment strategies for an individual patient. These strategies then target patients at increased risk for benefit while avoiding risk (eg, anticoagulation therapy and invasive cardiac catheterization) in patients with low or minimal risk.

6.2.6.1 The Chest Pain Unit Model

Chest pain observation protocols may be employed in a dedicated space (ie, a physical chest pain unit [CPU]) or throughout an ED/hospital (ie, virtual CPU). These chest pain observation protocols are a rapid system of patient

assessment that should generally include a history and physical examination, a period of observation, serial electrocardiography, and serial measurement of serum cardiac markers. In selected patients, an evaluation for inducible myocardial ischemia or anatomic coronary disease after AMI is excluded when indicated. Eleven randomized trials[108-118] suggest that these protocols may be used to improve accuracy in identifying patients requiring inpatient admission or further diagnostic testing and, thereby, reduce length of stay, rate of hospital admission, and health care costs while improving quality of life measures.

In patients with suspicion for ACS, normal initial biomarkers, and nonischemic ECG, chest pain observation protocols may be recommended as a safe and effective strategy for evaluating patients in the ED. (Class I, LOE A)

There is no direct evidence demonstrating that CPUs/observation protocols reduce adverse cardiovascular outcomes, including mortality for patients presenting with possible ACS, normal serum cardiac biomarkers, and a nondiagnostic ECG.

6.2.6.2 Advanced Testing to Detect Coronary Ischemia and CAD

For ED/CPU patients who are suspected of having ACS, have nonischemic ECG's and negative biomarkers, a noninvasive test for inducible myocardial ischemia or anatomic evaluation of the coronary arteries (eg, computed tomography [CT] angiography, cardiac magnetic resonance, myocardial perfusion imaging, stress echocardiography) can be useful in identifying patients suitable for discharge from the ED. (Class IIa, LOE B)

This strategy may be considered to increase diagnostic accuracy for ACS thereby decreasing costs, length of stay, time to diagnosis, and can provide valuable short-term and long-term prognostic information of future major cardiac events.

Myocardial perfusion scintigraphy (MPS) has a high negative predictive value (NPV) for ruling out ACS; 99% in patients presenting to the ED with acute chest pain, nondiagnostic ECG, and negative cardiac markers.

MPS can also be used for risk stratification, especially in low- to intermediate-likelihood of cardiac events according to traditional cardiac markers.[119-122] (Class IIa, LOE B)

MPS is best utilized in patients with an intermediate probability or LOE of risk stratification.

The use of multidetector computed tomography (MDCT) angiography (64-slice scanner) after presentation to the ED with chest discomfort, a nondiagnostic ECG, and negative cardiac biomarkers has also been demonstrated to have high sensitivity and specificity for CAD and ACS.[123,124]

The use of MDCT angiography for selected low-risk patients can be useful to allow for safe early discharge from the ED.[125-127] (Class IIa, LOE B)

It is reasonable to consider both the exposure to radiation and iodinated contrast agents when using MDCT angiography and myocardial perfusion imaging. Little evidence is available to support the use of MRI in this patient population.

6.2.6.3 Safety of Discharge and Risk of Major Adverse Cardiac Events After Discharge From the ED/CPU

The final step in the CPU risk-stratification process is the decision to discharge or admit the patient. No simple clinical decision rule is adequate and appropriate to identify ED chest discomfort patients with suspected ACS who can be safely discharged from the ED.[128]

The use of inpatient-derived risk scoring systems are useful for prognosis* but are not recommended to

identify patients who may be safely discharged from the ED. (*Class I, LOE A; **Class III, LOE C)

The Bayesian process of serial assignment of pretest risk, diagnostic testing, and reclassification into post-test risk levels based on the test results is the most reliable method to identify patients at the lowest risk for short term major adverse cardiac events and those patients in need of further evaluation for underlying CAD.

Patients at low and intermediate clinical risk for ACS who have remained stable in the CPU and have negative serial ECGs, serial cardiac biomarker measurements, and noninvasive physiological or anatomic testing for ACS have very low rates of major adverse cardiac events at 30 days from ED discharge.[129-133] Patients younger than 40 years-of-age with nonclassical presentations and no significant past medical history have very low short-term rates of major adverse cardiac events when serial biomarkers and 12-lead ECGs are normal. These patients may be discharged directly from the ED/CPU if appropriate outpatient testing can be arranged within 72 hours.[88,129-131,133-135] Any system that attempts to facilitate outpatient testing should include mechanisms to ensure patient access to outpatient clinics and testing facilities and should consider nonmedical barriers to discharge from the ED that may require inpatient admission.

6.3 Computer-Assisted ECG STEMI Interpretation - Updated ACS 559

The identification of STEMI in patients with suspected STEMI is often made on clinical grounds in combination with ECG findings as interpreted by a physician. The 2015 ILCOR systematic review addressed whether computer-assisted ECG interpretation improves identification of STEMI while minimizing unnecessary intervention.

6.3.1 2015 Evidence Summary

Studies examined both underdiagnosis (false-negative results) and overdiagnosis (false-positive results)[136,137] or overdiagnosis alone[138-142] by computer ECG interpretation. There was wide variation in the proportion of false-positive results (0% to 42%) and of false-negative results (22% to 42%).

These variations in accuracy seemed to occur because different ECG machines use different algorithms and because the computer interpretations are compared variously with interpretation by cardiologists, emergency physicians, and discharge diagnosis of STEMI. Moreover, the sensitivity and specificity of the test will differ depending on the prevalence of STEMI.

Both studies that examined false-negative results suggest that computer interpretation of ECG tracing produces unacceptably high rates of false-negative results in the identification of STEMI. A few studies show that computer interpretation can produce an unacceptably high rate of false-positive diagnoses. Interpretation by trained personnel in conjunction with computer interpretation may lower the rate of false results obtained when using computer interpretation alone.

6.3.2 2015 Recommendations - New

Because of high false-negative rates, we recommend that computer-assisted ECG interpretation not be used as a sole means to diagnose STEMI. (Class III: Harm, LOE B-NR)

We recommend that computer-assisted ECG interpretation may be used in conjunction with physician or trained provider interpretation to recognize STEMI . (Class IIb, LOE C-LD)

6.4 Nonphysician STEMI ECG Interpretation - Updated ACS 884

When physicians are not present or not available to interpret an ECG, other methods for interpretation must be used so that timely patient care is not adversely affected. The 2015 ILCOR systematic review examined whether nonphysicians such as paramedics and nurses could identify STEMI on an ECG so that earlier identification of STEMI could be made with acceptable rates of either underdiagnosis (false-negative results) or overdiagnosis (false-positive results).

6.4.1 2015 Evidence Summary

Three observational studies compared the diagnostic accuracy of the interpretation of ECGs as either STEMI or No STEMIby physicians and paramedics.[143-145] While the studies used different methods to adjudicate the diagnosis, including World Health Organization criteria,[143] discharge diagnosis,[144] and catheterization laboratory activation,[145] all 3 studies showed a fairly high rate of agreement between physician and paramedic rates of distinguishing STEMI from No STEMI.

Overidentification of STEMI may have a significant adverse effect on resource utilization. An additional 6 studies examined the accuracy of paramedic identification of STEMI and reported false-positive rates (patients incorrectly diagnosed with STEMI by paramedics when no STEMI was present) ranging from 8% to 40%.[139,146-150] One study reported that transmission of the ECG to the ED for emergency physician interpretation, compared with paramedic interpretation alone, improves the positive predictive value of the prehospital 12-lead ECG for triage and therapeutic decision making.[146] The time from hospital arrival to percutaneous coronary intervention (PCI) with balloon inflation was significantly shorter if EMS activated the catheterization laboratory than if the laboratory was activated by hospital staff[147,148,150] or if the patient was directly admitted to the catheterization laboratory.[149]

6.4.2 2015 Recommendation - New

While transmission of the prehospital ECG to the ED physician may improve positive predictive value (PPV) and therapeutic decision-making regarding adult patients with suspected STEMI, if transmission is not performed, it may be reasonable for trained nonphysician ECG interpretation to be used as the basis for decision-making, including activation of the catheterization laboratory, administration of fibrinolysis, and selection of destination hospital. (Class IIa, LOE B-NR)

6.5 Biomarkers in ACS - Updated ACS 737

Cardiac troponin measurement, along with the ECG, is an integral part of the evaluation of patients with signs and symptoms suspicious for ACS. The detection of an elevated troponin (Tn) above the 99th percentile upper reference limit is highly sensitive and specific for myocardial necrosis, and is required in the universal definition of myocardial infarction (MI).[151]

Contemporary troponin assays are termed “high-sensitivity” (hs) if they are able to detect measurable troponin levels even in healthy individuals, with a threshold of detection of 0.006 ng/ml for hs-cTnI and 0.005 for hs-cTnT. Positive results are an order of magnitude higher than the threshold for detection and are usually defined as exceeding the 99th percentile of values with a coefficient of variation of less than 10%.[152]

More than 8 million patients are evaluated for potential ischemic chest pain in US EDs each year, with troponin measurement serving as one of the crucial diagnostic tests.[153] Because of this vast number of patients with potential ischemic chest pain, it is highly desirable to find some combination of diagnostic testing that can reliably identify patients who are not experiencing ischemia and can be safely discharged from the ED.

The 2015 ILCOR systematic review examined whether a negative troponin test could be used to identify patients at low risk for ACS when they did not have signs of STEMI,ischemia, or changes on the ECG that could mask signs of acute ischemia or MI.

The clinician should bear in mind that unstable angina can present without any objective data of myocardial ischemic injury (ie, with normal ECG and normal troponin), in which case the initial diagnosis depends solely on the patient’s clinical history and the clinician’s interpretation and judgment.

6.5.1 2015 Evidence Summary

Two observational studies used troponin (cTnI, cTnT, or hscTnT) measured at 0 and 2 hours to assess whether patients could be safely discharged from the ED.[154,155] In these studies, 2.5% to 7.8% of patients with ACS had (false-) negative tests. That is, ACS would have been missed in 2.5% to 7.8% of the patients studied. With an unstructured risk assessment used in addition to the troponin testing, 2.3% of patients identified as being at low risk have a major adverse cardiac event (MACE) on 30-day follow-up. A formal risk assessment instrument was not used in either of these 2 studies.

Six additional observational studies combined troponin testing (using cTnI, cTnT, hs-cTnI, or hs-cTnT) with use

of clinical decision rules such as TIMI, Vancouver, North American, or HEART. The proportion of false-negative results among patients with 30-day MACE ranged from 0% to 1.2%.[156-161] When the age cutoff for low-risk patients was increased from 50 years to 60 years for the North American Chest Pain Rule, the proportion of false-negative results rose from 0% to 1.1%.[159] Because the rules were used in combination with different troponin measurements, and each test identified 99% of patients with ACS as defined by 30-day MACE, it was difficult to directly compare rule or assay performance. One study[158] identified 1 additional ACS patient by using the Vancouver rule when the hs-cTnI was used instead of the cTnI.

6.5.2 2015 Recommendations - New

We recommend against using hs-cTnT and cTnI alone measured at 0 and 2 hours (without performing clinical risk stratification) to identify patients at low risk for ACS. (Class III: Harm, LOE B-NR)

We recommend that hs-cTnI measurements that are less than the 99th percentile, measured at 0 and 2 hours, may be used together with low-risk stratification (TIMI score of 0 or 1 or low risk per Vancouver rule) to predict a less than 1% chance of 30-day MACE. (Class IIa, LOE B-NR)

We recommend that negative cTnI or cTnT measurements at 0 and between 3 and 6 hours may be used together with very low-risk stratification (TIMI score of 0, low-risk score per Vancouver rule, North American Chest Pain score of 0 and age less than 50 years, or low-risk HEART score) to predict a less than 1% chance of 30-day MACE. (Class IIa, LOE B-NR)

7 Therapeutic Interventions in ACS - Updated

Several initial therapeutic measures are appropriate for all patients with suspected ACS in the ED setting. These include continuous cardiac monitoring, establishment of intravenous (IV) access, and consideration of several medications discussed below.

7.1 ADP Inhibition: Adjunctive Therapy in Patients With Suspected STEMI—ADP Inhibitors - Updated ACS 335

The 2015 ILCOR systematic review addressed the clinical impact of the timing of administration of adenosine diphosphate (ADP) inhibition in the treatment of patients with suspected STEMI. The relative merit of early prehospital as compared with hospital administration of ADP inhibition as ageneral treatment strategy was assessed. Differences between individual ADP inhibitors were not examined.

The preferred reperfusion strategy for patients with STEMI is identification and restoration of normal flow in the infarct-related artery using primary percutaneous intervention. The use of potent dual antiplatelet therapy in STEMI patients undergoing PPCI is associated with improved clinical outcomes as well as lower rates of acute stent thrombosis.[162,163] Given the short time from first medical contact to balloon inflation, treatment with oral ADP inhibitors in a prehospital setting has the potential to enhance platelet inhibition and improve procedural and clinical outcomes after PCI.

7.1.1 2015 Evidence Summary

Three randomized controlled trials (RCTs)[164-166] showed no additional benefit to the outcome of 30-day mortality and no additional benefit or harm with respect to major bleeding with prehospital administration compared with in-hospital administration of an ADP-receptor antagonist.

7.1.2 2015 Recommendation - New

In patients with suspected STEMI intending to undergo PPCI, initiation of ADP inhibition may be reasonable in either the prehospital or in-hospital setting. (Class IIb, LOE C-LD)

7.2 Prehospital Anticoagulants Versus None in STEMI - Updated ACS 562

In patients with suspected STEMI, anticoagulation is standard treatment recommended by the American College

of Cardiology Foundation/AHA Guidelines.[9,10] The 2015 ILCOR systematic review sought to determine if any important outcome measure was affected if an anticoagulant was administered prehospital compared with whether that same anticoagulant was administered in-hospital.

7.2.1 2015 Evidence Summary

A single nonrandomized, case-control study found that while flow rates were higher in an infarct-related artery when heparin and aspirin were administered in the prehospital setting versus the ED, there was no significant difference in death, PCI success rate, major bleeding, or stroke.[167]

7.2.2 2015 Recommendations - New

While there seems to be neither benefit nor harm to administering heparin to patients with suspected STEMI before their arrival at the hospital, prehospital administration of medication adds complexity to patient care.

We recommend that EMS systems that do not currently administer heparin to suspected STEMI patients do not add this treatment, whereas those that do administer it may continue their current practice. (Class IIb, LOE B-NR)

In suspected STEMI patients for whom there is a planned PCI reperfusion strategy, administration of unfractionated heparin (UFH) can occur either in the prehospital or in-hospital setting. (Class IIb, LOE B-NR)

7.3 Prehospital Anticoagulation for STEMI - Updated ACS 568

The 2015 ILCOR systematic review examined whether the prehospital administration of an anticoagulant such as bivalirudin, dalteparin, enoxaparin, or fondaparinux instead of UFH, in suspected STEMI patients who are transferred for PPCI, changes any major outcome.

7.3.1 2015 Evidence Summary

One RCT provided evidence in patients transferred for PCI for STEMI that there was no significant difference between prehospital bivalirudin compared with prehospital UFH with respect to 30-day mortality, stroke, or reinfarction. However, this same study did demonstrate a decreased incidence of major bleeding with bivalirudin.[168] Another study (this one a non-RCT) also demonstrated no difference between prehospital bivalirudin compared with prehospital UFH with respect to 30-day mortality, stroke, and reinfarction. In contrast to the RCT, this study did not find a difference in major bleeding.[169]

Although stent thrombosis was not considered as an a priori outcome, bivalirudin was strongly associated with the risk of acute stent thrombosis (relative risk, 6.11; 95% confidence interval, 1.37–27.24).[168] Such association is also consistently reported in other published in-hospital studies and meta-analyses of this agent in patients undergoing PCI.[170-172] While the benefit of bivalirudin over UFH alone in reducing bleeding complications has been shown, this benefit may be offset by the risk of stent thrombosis.

We have identified 1 RCT[173] enrolling 910 patients transferred for PPCI for STEMI that showed no significant difference between prehospital enoxaparin compared with prehospital UFH with respect to 30-day mortality, stroke, reinfarction, or major bleeding.

It is important to consider the results of the comparison between anticoagulants given in prehospital versus in-hospital settings in STEMI patients. Only UFH has been evaluated directly in this setting, and because there is no clear evidence of benefit, we are not recommending that EMS systems implement anticoagulant administration in the prehospital setting.

7.3.2 2015 Recommendations - New

It may be reasonable to consider the prehospital administration of UFH in STEMI patients or the prehospital administration of bivalirudin in STEMI patients who are at increased risk of bleeding. (Class IIb, LOE B-R)

In systems in which UFH is currently administered in the prehospital setting for patients with suspected STEMI who are being transferred for PPCI, it is reasonable to consider prehospital administration of enoxaparin as an alternative to UFH. (Class IIa, LOE B-R)

7.4 Routine Supplementary Oxygen Therapy in Patients Suspected of ACS - Updated ACS 887

The *2010 AHA Guidelines for CPR and ECC* noted that there was insufficient evidence to recommend the routine use of oxygen therapy in patients who had an uncomplicated ACS without signs of hypoxemia or heart failure and that older literature suggested harm with supplementary oxygen administration in uncomplicated ACS without demonstrated need for supplementary oxygen.[174•175] The 2010 Guidelines, however, did recommend that oxygen be administered to patients with breathlessness, signs of heart failure, shock, or an oxygen saturation less than 94%.[7]

In 2015, the ILCOR systematic review specifically addressed the use of oxygen as an adjunctive medication in thetreatment of patients who had normal oxygen saturation but had suspected ACS. The 2 treatment approaches (either providing or withholding oxygen) were compared with respect to outcomes: rate of death, infarction size, resolution of chest pain, and ECG abnormality resolution. The new recommendation in this 2015 Guidelines Update applies only to the use of oxygen for patients suspected of ACS who have normal oxygen saturations.

7.5 Adjunctive Therapy in Patients Suspected of ACS: Oxygen - Updated

Respiratory compromise, manifested by oxygen desaturation, can occur during ACS, most often as a result of either acute pulmonary edema or chronic pulmonary disease. Supplementary oxygen has previously been considered standard therapy for the patient suspected of ACS, even in patients with normal oxygen saturation. The rationale for oxygen therapy was a belief that maximization of oxygen saturation may improve delivery of oxygen to the tissues and thus reduce the ischemic process and related negative outcomes. In other patient groups, such as resuscitated cardiac arrest patients, hyperoxia has been associated with worse outcomes as compared with normoxia.[176-178]

7.5.1 2015 Evidence Summary

There is limited evidence regarding the use of supplementary oxygen therapy in suspected ACS patients with normal oxygen saturation. The practice of administering oxygen to all patients regardless of their oxygen saturation is based on both rational conjecture and research performed before the current reperfusion era in acute cardiac care.[174] More recent study of this issue is also limited,[179,180] although 2 trials addressing this question are in progress or are recently completed. The AVOID trial,[181] a multicentered prospective RCT published since the 2015 ILCOR systematic review, compared oxygen administration with no oxygen administration in suspected STEMI patients without respiratory compromise. When oxygen was administered, the patients experienced increased myocardial injury at presentation and larger infarction size at 6 months. Reinfarction and the incidence of cardiac arrhythmias were also increased in the oxygen therapy group.[181] Because this study was published after the ILCOR systematic review, it was not considered in our treatment recommendation.

There is no evidence that withholding supplementary oxygen therapy in normoxic patients suspected of ACS affects the rate of death and/or resolution of chest pain; there is only a very low level of evidence that withholding supplementary oxygen reduces infarction size, and there is no evidence that withholding supplementary oxygen therapy affects the resolution of ECG abnormality.[174,175,179,180]

7.5.2 2015 Recommendation - Updated

The provision of supplementary oxygen to patients with suspected ACS who are normoxic has not been shown to reduce mortality or hasten the resolution of chest pain. Withholding supplementary oxygen in these patients has been shown to minimally reduce infarct size.

The usefulness of supplementary oxygen therapy has not been established in normoxic patients. In the prehospital, ED, and hospital settings, the withholding of supplementary oxygen therapy in normoxic patients with suspected or confirmed acute coronary syndrome may be considered. (Class IIb, LOE C-LD)

7.6 Aspirin and Nonsteroidal Anti-Inflammatory Drugs

Early administration of aspirin (acetylsalicylic acid [ASA]), has been associated with decreased mortality rates in several clinical trials.[38,40,182,183] Multiple studies support the safety of aspirin administration.

Therefore, unless the patient has a known aspirin allergy or active gastrointestinal hemorrhage, nonenteric aspirin should be given as soon as possible to all patients with suspected ACS. (Class I, LOE A)

Aspirin produces a rapid clinical antiplatelet effect with near-total inhibition of thromboxane A2 production. It reduces coronary reocclusion and recurrent ischemic events after fibrinolytic therapy. Aspirin alone reduced death from AMI in the Second International Study of Infarct Survival (ISIS-2), and its effect was additive to that of streptokinase.[40] Aspirin was found to substantially reduce vascular events in all patients with AMI, and in high-risk patients it reduced nonfatal AMI and vascular death.[184] Aspirin is also effective in patients with NSTEMI. The recommended dose is 160 to 325 mg. Chewable or soluble aspirin is absorbed more quickly than swallowed tablets.[185,186]

Aspirin suppositories (300 mg) are safe and can be considered for patients with severe nausea, vomiting, or disorders of the upper gastrointestinal tract.

Other nonsteroidal anti-inflammatory medications (NSAIDS) are contraindicated and should be discontinued in patients who are taking these medications. NSAIDs (except for aspirin), both nonselective as well as COX-2 selective agents, should not be administered during hospitalization for STEMI because of the increased risk of mortality, reinfarction, hypertension, heart failure, and myocardial rupture associated with their use. (Class III, LOE C)

(Research related to this recommendation statements can be found in the linked references.[187-189])

7.7 Nitroglycerin (or Glyceryl Trinitrate)

Nitroglycerin has beneficial hemodynamic effects, including dilation of the coronary arteries (particularly in the region of plaque disruption), the peripheral arterial bed, and venous capacitance vessels. The treatment benefits of nitroglycerin are limited, however, and no conclusive evidence has been shown to support the routine use of IV, oral, or topical nitrate therapy in patients with AMI.[190] With this in mind, these agents should be carefully considered, especially in the patient with low blood pressure and when their use would preclude the use of other agents known to be beneficial, such as angiotensin-converting enzyme (ACE) inhibitors.

Patients with ischemic discomfort should receive up to 3 doses of sublingual or aerosol nitroglycerin at 3- to 5-minute intervals until pain is relieved or low blood pressure limits its use. (Class I, LOE B)

Topical nitrates are acceptable alternatives for patients who require anti-anginal therapy but who are hemodynamically stable and do not have ongoing refractory ischemic symptoms. Parenteral formulations, rather than long acting oral preparations, can be used acutely to enable titration in patients with obvious ACS, objective test abnormality, and ongoing discomfort. In patients with recurrent ischemia, nitrates are indicated in the first 24 to 48 hours.

The use of nitrates in patients with hypotension (SBP (Class III, LOE C)

Caution is advised in patients with known inferior wall STEMI, and a right-sided ECG should be performed to evaluate RV infarction. Administer nitrates with extreme caution, if at all, to patients with inferior-wall MI and suspected right ventricular (RV) involvement because these patients require adequate RV preload. Nitroglycerin should not be administered to patients who had taken a phosphodiesterase inhibitor (eg, sildenafil) for erectile dysfunction within 24 hours (48 hours if tadalafil use).

Relief of chest discomfort with nitroglycerin is neither sensitive nor specific for ACS; gastrointestinal etiologies as well as other causes of chest discomfort can “respond” to nitroglycerin administration.[25,191-193]

7.8 Analgesia

Providers should administer analgesics, such as intravenous morphine, for chest discomfort unresponsive to nitrates. Morphine is the preferred analgesic for patients with STEMI. (Class I, LOE C)

However, analysis of retrospective registry data raised a question about the potentially adverse effects of morphine in patients with UA/NSTEMI.[52] As a result, the ACC AHA UA/NSTEMI writing group reduced morphine use to a ***Class IIa*** recommendation for that patient population.[88]

8 Reperfusion Decisions in STEMI Patients - Updated

Acute reperfusion therapy using PPCI or fibrinolytic therapy in patients with STEMI restores flow in the infarct-related artery, limits infarct size, and translates into early mortality benefit that is sustained over the next decade.[194,195] While optimal fibrinolysis restores normal coronary flow (TIMI 3) in 50% to 60% of subjects, PPCI is able to achieve restored flow in >90% of subjects. The patency rates achieved with PPCI translates into reduced mortality and reinfarction rates as compared to fibrinolytic therapy.[196] This benefit is even greater in patients presenting with cardiogenic shock. PPCI also results in a decreased risk of intracranial hemorrhage and stroke, making it the reperfusion strategy of choice in the elderly and those at risk for bleeding complications.

The 2010 ILCOR systematic review addressed the use of reperfusion therapy, including fibrinolysis and PPCI, in patients with STEMI who present initially to non–PCI-capable hospitals. The *2015 AHA Guidelines Update for CPR and ECC* examines the most appropriate reperfusion therapy in STEMI patients presenting to non–PCI-capable hospitals as well as the need for hospital transfer for PCI, or ischemiaguided (ie, rescue) coronary angiography and/or PCI.

In summary, for patients presenting within 12 hours of symptom onset and electrocardiographic findings consistent with STEMI, reperfusion should be initiated as soon as possible – independent of the method chosen. (Class I, LOE A)

8.1 Fibrinolytics & Percutaneous Coronary Intervention (PCI) Overview

A cooperative and interdisciplinary effort between emergency medicine and cardiology, as well as among the EMS agencies, the catheterization laboratory, and the CCU, has the potential to reduce markedly the door-to-therapy time in STEMI patients and therefore limit delays in providing this time-sensitive treatment. Prior agreement between the ED and cardiovascular physicians at institutions with invasive capability must be obtained so that consideration of PCI does not introduce further delays in fibrinolytic drug administration; such cooperation can limit additional delays in the administration of fibrinolytic agents in patients who are considered for PCI in AMI.

A systems of care approach involving a reperfusion team or “STEMI alert” system mobilizes hospital-based resources, optimizing the approach to the patient. This system, whether activated by data gathered in the ED or prehospital-based information, has the potential to offer time-sensitive therapies in a rapid fashion to these ill patients.

8.1.1 Fibrinolytics

Early fibrinolytic therapy is a well-established treatment modality for patients with STEMI who present within 12 hours of the onset of symptoms and who lack contraindications to its use.[195,197-200]

Patients are evaluated for risk and benefit; for absolute and relative contraindications to therapy (see Table 4).

Table 4: 2010 - Fibrinolytic Therapy

Open table in a new window

Fibrinolytic Therapy
Contraindications and cautions for fibrinolytic use in STEMI from ACC/AHA 2004 Guideline Update*
Absolute Contraindications • Any prior intracranial hemorrhage • Known structural cerebral vascular lesion (eg, AVM) • Known malignant intracranial neoplasm (primary or metastatic) • Ischemic stroke within 3 months EXCEPT acute ischemic stroke within 3 hours • Suspected aortic dissection • Active bleeding or bleeding diathesis (excluding menses) • Significant closed head trauma or facial trauma within 3 months

Relative Contraindications

- History of chronic, severe, poorly controlled hypertension
- Severe uncontrolled hypertension on presentation (SBP >180 mm Hg or DBP >110 mm Hg)†
- History of prior ischemic stroke >3 months, dementia, or known intracranial pathology not covered in contraindications
- Traumatic or prolonged (>10 minutes) CPR or major surgery (<3 weeks)
- Recent (within 2 to 4 weeks) internal bleeding
- Noncompressible vascular punctures
- For streptokinase/anistreplase: prior exposure (>5 days ago) or prior allergic reaction to these agents
- Pregnancy
- Active peptic ulcer
- Current use of anticoagulants: the higher the INR, the higher the risk of bleeding

- CPR, cardiopulmonary resuscitation; AVM indicates arteriovenous malformation; SBP, systolic blood pressure; DBP, diastolic blood pressure; INR, International Normalized Ratio.
- ?* Viewed as advisory for clinical decision making and may not be all-inclusive or definitive.
- ?† Could be an absolute contraindication in low-risk patients with myocardial infarction.

If fibrinolysis is chosen for reperfusion, the ED physician should administer fibrinolytics to eligible patients as early as possible according to a predetermined process of care developed by the ED and cardiology staff. (Class I, LOE A)

Patients with STEMI presenting at later times in the myocardial infarction evolution are much less likely to benefit from fibrinolysis.

In fact, fibrinolytic therapy is generally not recommended for patients presenting between 12 and 24 hours after onset of symptoms based on the results of the LATE and EMERAS trials,[201],[202] unless continuing ischemic pain is present with continuing ST-segment elevation. (Class IIb, LOE B)

Fibrinolytic therapy should not be administered* to patients who present greater than 24 hours after the onset of symptoms. (*Class III, LOE B)

8.1.1.1 Risks of Fibrinolytic Therapy

Physicians who administer fibrinolytic agents must be aware of the indications, contraindications, benefits, and major risks of administration so that they are able to weigh the net clinical benefit for each patient (see Table 4).[203,202] This net clinical benefit requires integration of relative and absolute contraindications versus overall potential clinical gain.

Patients who present early after symptom onset with extensive ECG changes (consistent with a large AMI) and a low risk of intracranial bleeding receive the greatest benefit from fibrinolytic therapy.[197] Patients who have symptoms highly suggestive of ACS and ECG findings consistent with LBBB are also appropriate candidates for intervention because they have the highest mortality rate when LBBB is due to extensive AMI. Inferior wall STEMI also benefits from fibrinolysis, yet the magnitude of this outcome improvement is markedly less robust. More extensive inferior STEMI presentations, of course, demonstrate more robust benefit when undergoing fibrinolysis; inferior wall STEMI with RV involement is such an example. Fibrinolytics have been shown to be beneficial across a spectrum of patient subgroups with comorbidities such as previous MI, diabetes, tachycardia, and hypotension.[197] Although superior to placebo, the lack of efficacy in the setting of cardiogenic shock makes referral for PPCI an optimal strategy in this setting.

Although older patients (>75 years) have a higher risk of death, their absolute benefit appears to be similar to that of younger patients. The incidence of stroke does increase with advancing age,[204,205] reducing the relative benefit of fibrinolytic therapy. Older age is the most important baseline variable predicting nonhemorrhagic stroke.[205] Although 1 large trial reported lower early and 1-year mortality rates with accelerated administration of tissue plasminogen activator (rtPA) in patients <85 years of age,[206] a retrospective analysis found no specific survival advantage and possible risk for patients >75 years of age.[207]

8.1.1.1.1 Intracranial Hemorrhage

Fibrinolytic therapy is associated with a small but definite increase in the risk of hemorrhagic stroke, which contributes to increased mortality.[197] More intensive fibrinolytic regimens using rtPA (alteplase) and heparin pose a greater risk than streptokinase and aspirin.[208,209] Clinical factors that may help risk-stratify patients at the time of presentation are age (?65 years), low body weight (<70 kg), hypertension on presentation (>180/110 mm Hg), and use of rtPA. The number of risk factors can be used to estimate the frequency of stroke, which ranges from 0.25% with no risk factors to 2.5% with 3 risk factors.[202] Several risk factor estimates are available for use by clinicians, including Simoons,[202] the Co-Operative Cardiovascular Project,[210] and the In-Time 2 trial.[211]

8.1.2 Percutaneous Coronary Intervention (PCI)

Coronary angioplasty with or without stent placement is the treatment of choice for the management of STEMI when it can be performed effectively with a door-to-balloon time 75 PCIs per year) at a skilled PCI facility (performing >200 PCIs annually, of which at least 36 are primary PCI for STEMI).[33,212,213] (Class I, LOE A)

Primary PCI (PPCI) may also be offered to patients presenting to non-PCI centers when prompt transfer can result in an effective ballon time of <90 minutes from first medical contact as a systems goal.[214] The TRANSFER AMI trial supports the transfer of high-risk patients who receive fibrinolysis in a non-PCI center to a PCI center within 6 hours of presentation to receive routine early PCI.[215]

Primary PCI performed at a high-volume center within 90 minutes of first medical contact by an experienced operator that maintains an appropriate expert status is reasonable, as it improves morbidity and mortality as compared with immediate fibrinolysis ((Class I, LOE A)

For those patients with a contraindication to fibrinolysis, PCI is recommended despite the delay, rather than foregoing reperfusion therapy. (Class I, LOE A)

For those STEMI patients presenting in shock, PCI (or CABG) is the preferred reperfusion treatment. Fibrinolysis should only be considered in consultation with the cardiologist if there is a substantial delay to PCI.

8.2 Prehospital Fibrinolysis, Hospital Fibrinolysis, and Prehospital Triage to PCI Center - Updated ACS 338 ACS 341

Prehospital fibrinolysis requires a sophisticated system of provider expertise, well-established protocols, comprehensive training programs, medical oversight, and quality assurance.[4] In many European systems, a physician provides prehospital fibrinolysis, but nonphysicians can also safely administer fibrinolytics.[216] The 2015 ILCOR systematic review evaluated whether prehospital fibrinolysis is preferred to reperfusion inhospital where the prehospital fibrinolysis expertise, education, and system support exists.

8.2.1 2015 Evidence Summary

Prehospital fibrinolysis will achieve earlier treatment as compared with ED fibrinolysis. Where transport times are more than 30 to 60 minutes, the time advantage conferred by prehospital fibrinolysis provides a mortality benefit.[4] This benefit from prehospital fibrinolysis was found consistently by 3 RCTs performed more than 20 years ago.[217-219] However, these studies were performed at a time when hospital fibrinolytic administration typically took well in excess of 60 minutes. It is not clear the extent to which that mortality benefit would be maintained today when the hospital time to fibrinolytic treatment is typically considerably shorter than it was 20 years ago. The only recent evidence for this therapy comes from a non-RCT that confirms a small mortality benefit to prehospital fibrinolysis.[220] When transport times are shorter than 30 to 60 minutes, the mortality benefit from administering fibrinolytics before hospital arrival may be lost and may no longer outweigh the relative complexity of providing this therapy outside of a hospital.

However, PPCI is generally preferred to in-hospital fibrinolysis for STEMI reperfusion.[221] Prehospital providers can transport STEMI patients directly to PCI centers, and activation of the team before arrival allows the team to assemble and prepare in parallel with transport. Several studies in the past 15 years have compared transport directly for PPCI with prehospital fibrinolysis and found no mortality benefit of either therapy, although the relatively rare harm from intracranial hemorrhage is greater with fibrinolysis.[222-225]

8.2.2 2015 Recommendations - Updated

Where prehospital fibrinolysis is available as part of a STEMI system of care, and in-hospital fibrinolysis is the alternative treatment strategy, it is reasonable to administer prehospital fibrinolysis when transport times are more than 30 minutes. (Class IIa, LOE B-R)

It is strongly recommended that systems which administer fibrinolytics in the prehospital setting include the following features: protocols using fibrinolytic checklists, 12-lead ECG acquisition and interpretation, experience in advanced life support, communication with the receiving institution, medical director with training and experience in STEMI management, and continuous quality improvement. (Class I, LOE C)

Where prehospital fibrinolysis is available as part of the STEMI system of care and direct transport to a PCI center is available, prehospital triage and transport directly to a PCI center may be preferred because of the small relative decrease in the incidence of intracranial hemorrhage without evidence of mortality benefit to either therapy. (Class IIb, LOE B-R)

If PCI is the chosen method of reperfusion for the prehospital STEMI patient, it is reasonable to transport patients directly to the nearest PCI facility, bypassing closer EDs as necessary, in systems where time intervals between first medical contact and balloon times are (Class IIa, LOE B)

8.3 ED Fibrinolysis and Immediate PCI Versus Immediate PCI Alone - Updated ACS 882

Delays in the performance of PPCI are commonly observed in clinical practice. In many regions, the delay arises because of the relative paucity of dedicated PPCI centers, resulting in the need for prolonged transfer times. In this context, combining the availability and ease of administration of fibrinolytic with the downstream certainty of mechanical reperfusion with facilitated PCI was an attractive concept, with its promise of both restoring early flow to the infarct-related artery while addressing the concerns of pharmacologic failure and need for rescue. This was counterbalanced by the concern for a heightened risk of bleeding complications and detrimental procedural outcomes in this prothrombotic milieu.

The 2015 ILCOR systematic review addressed the merits for reperfusion in STEMI patients with a strategy of initial fibrinolysis followed by immediate PCI versus immediate PCI alone.

8.3.1 2015 Evidence Summary

A number of randomized clinical trials have addressed clinical outcomes after initial treatment with a half- or full-dose fibrinolytic agent followed by dedicated immediate PCI compared with immediate PCI alone.

The studies showed no benefit to mortality,[226-230] nonfatal MI,[226-230] or target vessel revascularization[226-229] when fibrinolytic administration is combined with immediate PCI as compared with immediate PCI alone.

The studies did, however, identify harm from intracranial hemorrhage[226-228] or major bleeding[226-230] when fibrinolytic administration is combined with immediate PCI versus immediate PCI alone.

8.3.2 2015 Recommendation - New

In the treatment of patients with suspected STEMI, the combined application of fibrinolytic therapy followed by immediate PCI (as contrasted with immediate PCI alone) is not recommended. (Class III: Harm, LOE B-R)

8.4 Delayed PCI Versus Fibrinolysis Stratified by Time From Symptom Onset - Updated ACS 337

Although the overall survivability benefits of reperfusion therapy are time dependent, the loss of efficacy caused by delay is more pronounced with fibrinolysis than with PCI.[231] The success of PCI in achieving TIMI-3 flow in the early hours after STEMI does not change with time, whereas the ability of fibrinolytic therapy to achieve TIMI-3 flow decreases significantly with increasing ischemic time.[232] In this context, the choice of reperfusion therapy for a STEMI patient when access to PCI is delayed is a challenging one. The clinician has to weigh the advantages of immediate fibrinolysis, which includes ease of administration and potential to open the infarct-related artery in a timely manner versus the limitations of fibrinolysis, which include the risk of intracranial hemorrhage and bleeding and the time sensitivity of the intervention's efficacy to open the infarct-related artery. Thus, total ischemic time is an important variable in weighing the merits of delayed PCI versus immediate fibrinolysis.

In the *2010 AHA Guidelines for CPR and ECC*,[7] the recommendations were directed at patients in whom PCI could not be accomplished within 90 minutes of first medical contact.

The 2015 ILCOR systematic review compared the relative benefits of immediate fibrinolysis versus primary but delayed PCI in treating STEMI patients, stratifying patients by time from initial medical contact.

8.4.1 2015 Evidence Summary

In STEMI patients presenting less than 2 hours after symptom onset in whom immediate PPCI will delay treatment 60 to 160 minutes compared with fibrinolysis, 2 RCTs (combined into a single analysis) using an outcome of 30-day mortality[233] and 1 RCT using an outcome of 5-year mortality showed greater harm with delayed PPCI compared with fibrinolysis.[234] No differences were found to incidence of reinfarction[233] or severe

bleeding.[235]

For STEMI patients presenting 2 to 6 hours after symptom onset in whom PPCI will delay treatment 60 to 160 minutes compared with fibrinolysis, 2 RCTs using an outcome of 1-year mortality[233] and 1 RCT using an outcome of 5-year mortality showed no benefit of delayed PPCI over fibrinolysis.[234] There was also no difference in the incidence of reinfarction,[233] but 1 RCT[235] showed more severe bleeding with fibrinolysis as compared with delayed PPCI.

In STEMI patients presenting 3 to 12 hours after symptom onset in whom PPCI will delay treatment 60 to 120 minutes as compared with fibrinolysis, 1 RCT[236] using a 30-day mortality outcome showed that delayed PPCI conferred a benefit as compared with immediate fibrinolysis.

A reanalysis of the raw data from 16 RCTs[237] has suggested that the acceptable fibrinolysis to PPCI delay varies depending on the patient's baseline risk and delay to presentation. A pragmatic simplification of the formula derived in the analysis has been suggested in an editorial[238] associated with the publication of the analysis: Patients older than 65 years and all patients in Killip class greater than 1 should be treated with PPCI. Patients older than 65 years in Killip class 1 should have PPCI unless delay is greater than 35 minutes.

8.4.2 2015 Recommendations - Updated

The following recommendations are not in conflict with, and do not replace, the 2013 ACC/AHA STEMI Guidelines, which are endorsed by this ACS Writing Group. These 2015 Guidelines Update recommendations are derived from a different set of studies that examined the interval between *symptom onset* and reperfusion, rather than the interval between *first medical contact* and reperfusion. The symptom onset interval is appropriate to consider when time of symptom onset is known. However, time from symptom onset may be difficult to ascertain or may be unreliable. When time from symptom onset is uncertain, it is appropriate to follow the ACC/AHA STEMI Guidelines recommendation that PPCI is the preferred reperfusion strategy when time from symptom onset is less than 12 hours and time to PPCI from first medical contact in these patients is anticipated to be less than 120 minutes.

Regardless of whether time of symptom onset is known, the interval between first medical contact and reperfusion should not exceed 120 minutes. (Class I, LOE C-EO)

In STEMI patients presenting within 2 hours of symptom onset, immediate fibrinolysis rather than PPCI may be considered when the expected delay to PPCI is more than 60 minutes. (Class IIb, LOE C-LD)

In STEMI patients presenting within 2 to 3 hours after symptom onset, either immediate fibrinolysis or PPCI involving a possible delay of 60 to 120 minutes might be reasonable. (Class IIb, LOE C-LD)

In STEMI patients presenting within 3 to 12 hours after symptom onset, performance of PPCI involving a possible delay of up to 120 minutes may be considered rather than initial fibrinolysis. (Class IIb, LOE C-LD)

It is acknowledged that fibrinolysis becomes significantly less effective more than 6 hours after symptom onset, and thus a longer delay to PPCI may be the better option for patients more than 6 hours after symptom onset.

In STEMI patients, when delay from first medical contact to PPCI is anticipated to exceed 120 minutes, a strategy of immediate fibrinolysis followed by routine early (within 3 to 24 hours) angiography and PCI if indicated may be reasonable for patients with STEMI. (Class IIb, LOE B-R)

8.5 Interfacility Transfer

Hospital and ED protocols should clearly identify criteria for expeditious transfer of patients to PCI facilities.

These include patients who are ineligible for fibrinolytic therapy or who are in cardiogenic shock. (Class I, LOE C)

(Research related to this recommendation statements can be found in the linked references.[239])

A door-to-departure time <30 minutes is recommended by ACC/AHA Guidelines.[33]

Transfer of high-risk patients who have received primary reperfusion with fibrinolytic therapy is reasonable. (Class IIa, LOE B)

(Research related to this recommendation statements can be found in the linked references.[215,240])

8.6 Reperfusion Therapy for STEMI in Non–PCI-Capable Hospitals - Updated ACS 332 ACS 334 ACS 779

The rapid restoration of perfusion in the infarct-related coronary artery, using either fibrinolytic therapy or PPCI, provides the opportunity for an optimal outcome.

Fibrinolytic therapy unequivocally improves survival in patients presenting with STEMI and has widespread availability.[241] STEMI patients with contraindications to fibrinolytic therapy and who are in cardiogenic shock are not appropriate candidates for this form of reperfusion therapy.[242] PPCI is superior to fibrinolytic therapy in the management of STEMI,[243] because PPCI also improves survival rates and enhances other important outcomes in the STEMI patient. However, this form of reperfusion therapy is not widely available.

The superiority of PPCI over fibrinolytic therapy is not absolute. For STEMI patients presenting to a non–PCIcapable hospital, the decision to administer fibrinolytic therapy at the initial facility as compared with immediate-transfer PPCI requires consideration of several factors, including the location of the MI, patient age, the duration of STEMI at time of initial ED presentation, time required to complete transfer for and performance of PPCI, and the abilities of the PPCI cardiologist and hospital.[243] Furthermore, the hemodynamic status of the patient is important; specifically, patients in cardiogenic shock are most appropriately managed with PPCI.[242]

8.6.1 2015 Evidence Summary

8.6.1.1 Fibrinolysis Versus Transfer for PPCI - Updated

In a non–PCI-capable hospital, the choice of reperfusion therapy in the STEMI patient is either immediate fibrinolytic therapy or transfer for PPCI; the time required for transfer of the patient to a PCI-capable hospital must be considered in making the choice. Comparison studies showed benefit of immediate transfer to a PCI center with respect to 30-day mortality, stroke, and/or reinfarction.[236,244-250] There was no difference in major hemorrhage.[246,249]

8.6.1.2 Fibrinolysis and Routine Transfer for Angiography Versus Immediate Transfer for PPCI - Updated

When immediate fibrinolysis in a non–PCI-capable hospital followed by routine transfer for angiography was compared with immediate transfer to a PCI center for PPCI, 3 studies showed no benefit to 30-day mortality, stroke, and/or reinfarction and no difference in the rates of intracranial hemorrhage or major bleeding.[223,251,252]

8.6.1.3 Fibrinolysis and Routine Transfer for Angiography Versus No Routine Transfer: 30-Day Mortality - Updated

In patients who received a fibrinolytic agent for STEMI in a non–PCI-capable hospital, studies comparing either routine transfer for angiography at 3 to 6 hours and up to 24 hours or no transfer except for ischemia-driven PCI (rescue PCI) in the first 24 hours showed no benefit with respect to 30-day mortality[223,250,253-257] or 1-year mortality.[223,253,254,257-259]

8.6.1.4 Fibrinolysis and Routine Transfer for Angiography Versus No Routine Transfer: Intracranial Hemorrhage or Major Bleeding - Updated

In patients who received a fibrinolytic agent for STEMI in a non–PCI-capable hospital, studies comparing either routine transfer for angiography at 3 to 6 hours and up to 24 hours or no transfer except for ischemia-driven PCI (rescue PCI) in the first 24 hours demonstrated no difference in incidence of intracranial hemorrhage,[223,253-257] major bleeding,[223,253-257] or stroke.[250,253,255,257]

8.6.1.5 Fibrinolysis and Routine Transfer for Angiography Versus No Routine Transfer: Reinfarction - Updated

When immediate fibrinolysis for STEMI was followed by routine transfer for angiography at 3 to 6 hours and up to 24 hours as compared with no transfer except for ischemia-driven PCI (rescue PCI) in the first 24 hours, a decrease in the rate of reinfarction was demonstrated.[223,250,253-257]

8.6.2 2015 Recommendations - New

In adult patients presenting with STEMI in the ED of a non-PCI-capable hospital, we recommend immediate transfer without fibrinolysis from the initial facility to a PCI center instead of immediate fibrinolysis at the initial hospital with transfer only for ischemia-driven PCI. (Class I, LOE B-R)

When STEMI patients cannot be transferred to a PCI-capable hospital in a timely manner, fibrinolytic therapy with routine transfer for angiography may be an acceptable alternative to immediate transfer to PPCI. (Class IIb, LOE C-LD)

When fibrinolytic therapy is administered to a STEMI patient in a non–PCI-capable hospital, it may be reasonable to transport all postfibrinolysis patients for early routine angiography in the first 3 to 6 hours and up to 24 hours rather than transport postfibrinolysis patients only when they require ischemia-guided angiography. (Class IIb, LOE B-R)

It is recognized that there may be practical and logistical circumstances, including geographic limitations, where transfer for angiography within 24 hours is difficult or impossible. In these cases, the small but measurable decrease in reinfarction rates may not justify a prolonged or difficult transfer.

9 Hospital Reperfusion Decisions After ROSC - Updated

9.1 PCI After ROSC With and Without ST Elevation - Updated ACS 340 ACS 885

In 2010, the ILCOR systematic review combined ST-elevation and non–ST-elevation patients after ROSC. However, the *2010 AHA Guidelines for CPR and ECC* did make separate recommendations for each of these distinct groups of patients, recommending emergency coronary angiography for ST-elevation patients after ROSC, while supporting the consideration of coronary angiography for non–ST-elevation patients after ROSC.

The 2015 ILCOR systematic review examined whether immediate coronary angiography (angiography performed within 24 hours after ROSC) for patients with and without ST elevation after cardiac arrest improved outcomes.

9.1.1 2015 Evidence Summary

Evidence regarding the timing of coronary angiography immediately after cardiac arrest (defined variously, but within 24 hours) is limited to observational studies.

Aggregated data from 15 studies of 3800 patients having ST elevation on ECG after ROSC after cardiac arrest demonstrated a benefit of immediate coronary angiography, favoring survival to hospital discharge,[260-274] while 9 of these studies enrolling a total of 2819 patients also demonstrated a benefit favoring neurologically favorable outcomes.[260-262,265,267-269,272,275]

In patients without ST elevation on initial postarrest ECG, 2 studies demonstrated a benefit favoring improved survival to hospital discharge and improved neurologically favorable outcome when patients received immediate coronary angiography.[260,265]

In these studies, the decision to undertake the intervention was influenced by a variety of factors such as patient age, duration of CPR, hemodynamic instability, presenting cardiac rhythm, neurologic status upon hospital arrival, and perceived likelihood of cardiac etiology.

9.1.2 2015 Recommendations - Updated

Coronary angiography should be performed emergently (rather than later in the hospital stay or not at all) for OHCA patients with suspected cardiac etiology of arrest and ST elevation on ECG). (Class I, LOE B-NR)

Emergency coronary angiography is reasonable for select (eg, electrically or hemodynamically unstable) adult patients who are comatose after OHCA of suspected cardiac origin but without ST elevation on ECG. (Class IIa, LOE B-NR)

It is reasonable to include cardiac catheterization and coronary angiography in standardized post–cardiac arrest protocols as part of an overall strategy to improve neurologically intact survival in this patient group (Class IIa, LOE B) and appropriate treatment of ACS or STEMI, including PCI or fibrinolysis, should be initiated regardless of coma. (Class I, LOE B)

Angiography and/or PCI need not preclude or delay other therapeutic strategies including therapeutic hypothermia. (Class IIa, LOE B)

Coronary angiography is reasonable in post–cardiac arrest patients where coronary angiography is indicated regardless of whether the patient is comatose or awake. (Class IIa, LOE C-LD)

A 12-lead ECG should be performed as soon as possible after ROSC. (Class I, LOE A)

10 Complicated Acute Myocardial Infarction (AMI)

10.1 Cardiogenic Shock, LV Failure, and Congestive Heart Failure

Infarction of ?40% of the LV myocardium usually results in cardiogenic shock and carries a high mortality rate. Of those who developed shock,[276] patients with ST-segment elevation developed shock significantly earlier than patients without ST-segment elevation. Cardiogenic shock and congestive heart failure are not contraindications to fibrinolysis, but PCI is preferred if the patient is at a facility with PCI capabilities. Based on the results of the SHOCK trial ACC/AHA guidelines note that PPCI is reasonable in those who develop shock within 36 hours of symptom onset and who are suitable candidates for revascularization that can be performed within 18 hours of the onset of shock.[88] Although the benefits in the SHOCK trial were observed only in patients ?75 years of age, selected elderly patients also appear to benefit from this strategy. The guidelines also support the use of hemodynamic support with intra-aortic balloon counterpulsation (IABP) in this setting as part of aggressive medical treatment. The IABP works synergistically with fibrinolytic agents in this setting, and the benefits observed with early revascularization strategy in the SHOCK trial were also obtained in the setting of IABP support. The use of PPCI for patients with cardiogenic shock has increased over time and contributes to the observed decrease in hospital mortality.[277,278] The majority of survivors following cardiogenic shock experience a good quality of life, and the early mortality benefit with revascularization is sustained over time.[279-281] In hospitals without PCI facilities, fibrinolytic administration needs to be considered with prompt transfer to a tertiary care facility where adjunct PCI can be performed if cardiogenic shock or ongoing ischemia ensues.[282] The ACC/AHA STEMI guidelines recommend a door-to-departure time of ?30 minutes for transfer to a PCI-capable center.[88]

10.2 Right Ventricular (RV) Infarction

RV infarction or ischemia may occur in up to 50% of patients with inferior wall MI. The clinician should suspect RV infarction in patients with inferior wall infarction, hypotension, and clear lung fields. In patients with inferior wall infarction, obtain an ECG with right-sided leads. ST-segment elevation (>1 mm) in lead V4R is sensitive (sensitivity, 88%; specificity, 78%; diagnostic accuracy, 83%) for RV infarction and is a strong predictor of increased in-hospital complications and mortality.[283]

The in-hospital mortality rate of patients with RV dysfunction is 25% to 30%, and these patients should be routinely considered for reperfusion therapy. Fibrinolytic therapy reduces the incidence of RV dysfunction.[284] Similarly PCI is an alternative for patients with RV infarction and is preferred for patients in shock. Patients with shock caused by RV failure have a mortality rate similar to that for patients with shock due to LV failure.

Patients with RV dysfunction and acute infarction are dependent on maintenance of RV “filling” pressure (RV end-diastolic pressure) to maintain cardiac output.[285] Thus, nitrates, diuretics, and other vasodilators (ACE inhibitors) should be avoided because severe hypotension may result. Hypotension is initially treated with an IV fluid bolus.

11 ACE Inhibitors in the Prehospital Setting

Despite multiple studies that have shown a benefit of ACE inhibitors and ARBs in patients with a myocardial infarction when therapy is started during the first 24 hours of the index hospitalization, no trial specifically evaluates patients in the ED or prehospital settings. An older randomized trial showed a reduction in mortality with an increased risk of hypotension in patients treated soon after presentation in the inpatient setting.[190] Several trials showed a reduction in the rate of heart failure and mortality in patients treated soon after fibrinolysis,[286-288] and several others showed no benefit with the early or prehospital use of angiotensin converting enzyme.[287,289,290]

In conclusion, although ACE inhibitors and ARBs have been shown to reduce long-term risk of mortality in patients suffering an AMI, there is insufficient evidence to support the routine initiation of ACE inhibitors and ARBs in the prehospital or ED setting. (Class IIb, LOE C)

Other recommendations concerning ACE Inhibitors in the hospital setting were not reviewed in 2015. Please refer to the ***2014 AHA/ACC Guideline for the Management of Patients With Non–ST-Elevation Acute Coronary Syndromes*** or the ***2013 ACCF/AHA Guideline for the Management of ST-Elevation Myocardial Infarction*** *for information on this topic.*

12 Management of Arrhythmias

This section discusses management of arrhythmias during acute ischemia and infarction.

12.1 Ventricular Rhythm Disturbances

Treatment of ventricular arrhythmias during and after AMI has been a controversial topic for three decades. Primary VF accounts for the majority of early deaths during AMI.[291-293] The incidence of primary VF is highest during the first 4 hours after onset of symptoms [36,294-296] but remains an important contributor to mortality during the first 24 hours. Secondary VF occurring in the setting of CHF or cardiogenic shock can also contribute to death from AMI. VF is a less common cause of death in the hospital setting with the use of fibrinolytics and percutaneous revascularization as early reperfusion strategies. Broad use of ?-blockers also contributes significantly in the reduction of VF incidence in the after AMI.

Although prophylaxis with lidocaine reduces the incidence of VF, an analysis of data from ISIS-3 and a meta-analysis suggest that lidocaine increased all-cause mortality rates.[297]

Thus, the practice of prophylactic administration of lidocaine is not recommended. (Class III, LOE A)

Sotalol has not been adequately studied. (Class IIb, LOE C)

Amiodarone in a single RCT did not appear to improve survival in low doses and may increase mortality in high doses when used early in patients with suspected myocardial infarction.[298] (Class IIb, LOE C)

Twenty published studies including 14 RCTs and 4 meta-analyses/reviews provide no good evidence that prophylactic antiarrhythmics improve outcomes (survival to discharge, 30/60 day mortality) and despite a documented decrease in the incidence of malignant ventricular arrhythmias, they may cause harm.

Therefore prophylactic antiarrhythmics are not recommended for patients with suspected ACS or myocardial infarction in the prehospital or ED. (Class III, LOE A)

Routine IV administration of ?-blockers to patients without hemodynamic or electric contraindications is associated with a reduced incidence of primary VF. (Class IIb, LOE C)

Low serum potassium, but not magnesium, has been associated with ventricular arrhythmias.

It is prudent clinical practice to maintain serum potassium >4 mEq/L and magnesium >2 mEq/L. (Class IIB, LOE A)

Routine administration of magnesium to patients with MI has no significant clinical mortality benefit, particularly in patients receiving fibrinolytic therapy.[190] ISIS-4 enrolled >58 000 patients and showed a trend toward increased mortality rates when magnesium was given in-hospital for primary prophylaxis to patients within the first 4 hours of known or suspected AMI.

Following an episode of VF, there is no conclusive data to support the use of lidocaine or any particular strategy for preventing VF recurrence. Further management of ventricular rhythm disturbances is discussed in Part 7: Adult Advanced Cardiovascular Life Support.

13 Authorship and Disclosures

13.1 2015 Writing Team

Robert E. O'Connor, Chair; Abdulaziz S. Alali; William J. Brady; Chris A. Ghaemmaghami; Venu Menon; Michelle Welsford; Michael Shuster

Table 5: 2015 - Part 9: Acute Coronary Syndromes: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 9: Acute Coronary Syndromes: 2015 Guidelines Update Writing Group Disclosures								
Writing Group Member	**Employment**	**Research Grant**	**Other Research Support**	**Speakers' Bureau/Honora**	**Expert Witness**	**Ownership Interest**	**Consultant/Advis Board**	**Other**
Robert E. O'Connor	University of Virginia	None	None	None	None	None	None	None
Abdulaziz S. Al Ali	McMaster University	None	None	None	None	None	None	None
William J. Brady	University of Virginia	Siemens Medical Diagnostics*	None	None	Medicolegal consulting*	None	EvidenceCare†	None
Chris A. Ghaemmagh	University of Virginia	None	None	None	None	None	None	None
Venu Menon	Cleveland Clinic	Astra Zeneca*	None	None	None	None	Astra Zeneca*; Takeda Pharmaceuticals†	None
Michelle Welsford	Centre for Paramedic Education and Research	None	None	None	None	None	None	None
Consultant								
Michael Shuster	Mineral Springs Hospital	None	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

13.2 2010 Writing Team

Robert E. O'Connor, Chair; William Brady; Steven C. Brooks; Deborah Diercks; Jonathan Egan; Chris Ghaemmaghami; Venu Menon; Brian J. O'Neil; Andrew H. Travers; Demetris Yannopoulos

Table 6: 2010 - Guidelines Part 10: ACS Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 10: ACS Writing Group Disclosures							
Writing Group Member	**Employment**	**Research Grant**	**Other Research Support**	**Speakers' Bureau/Honorari**	**Ownership Interest**	**Consultant/Advisc Board**	**Other**
Robert E. O'Connor	University of Virginia Health System–Professor and Chair of Emergency Medicine	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
William Brady	University of Virginia	None	None	None	None	None	*Expert Witness: If contacted by attorneys, I will consider reviewing cases under litigation/potentially under litigation. I am not affiliated with any agency or business entity in this regard. When paid, the money is paid to my department at the University of Virginia–I can then use the money for professional issues and/or receive a certain amount in my personal pay check from the University.
Steven C. Brooks	University of Toronto–Clinician-Scientist	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Deborah Diercks	University of California, Davis Medical Center–Profes of Emergency Medicine	* Collaborator on Research Grant Nanosphere and Heartscape with money going to the University	None	*Speakers Bureau for Sanofi-Aventis and Bristol Myer Squibb * Sanofi Aventis, Heartscape, Bristol Myers Squibb, and Schering Plough	None	*Scheuring Plough, Heartscape, Sanofi-Aventis	None
Jonathan Egan	Children's hopital at Westmead, Sydney–Paediatric Intensivist	None	None	None	None	None	None
Chris Ghaemmagha	University of Virginia School of medicine Faculty Department of Emergency Medicine Associate Professor and Vice Chair	**None**	None	*Speaker and program chair for the 2010 national meeting of the Society of Chest Pain Centers	None	None	None
Venu Menon	Cleveland Clinic–Director CCU	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Brian J. O'Neil	Wayne State, Associate Chair	†Medivance Corporation, Zoll Circulation, Heartscape Technologies	* Somanetics Corp	Speakers bureau † Sanofi-Aventis, Bristol Meyer Squibb * Glaxo-Smith Kline; Medivance Corp; Heartscape Technologies Honoraria* Heartscape Technologies	None	Advisory board- * Heartscape Technologies; *Zoll Circulation	Expert witness- * Seimien Huckabay law offices
Andrew H. Travers	Emergency Health Services–Provincial Medical Director; Dalhousie University–Associate Professor; QE-II Hospital–Attending Physician	None	None	None	None	None	None
Demetris Yannopoulos	University of Minnesota–Int cardiologist	None	None	None	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition
- ?* Modest.
- ?† Significant.

14 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 9: Acute Coronary Syndromes. ECCguidelines.heart.org.

References

1. Stub D, Smith K, Bernard S, et al. Air versus oxygen in ST-segment-elevation myocardial infarction. *Circulation.* 2015;131(24):2143-2150.

2. Bossaert L, O'Connor RE, Arntz HR, Brooks SC, Diercks D, Feitosa- Filho G, Nolan JP, Hoek TL, Walters DL, Wong A, Welsford M, Woolfrey K; Acute Coronary Syndrome Chapter Collaborators. Part 9: acute coro- nary syndromes: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e175–e212. doi: 10.1016/j.resuscitation.2010.09.001.

3. O'Connor RE, Bossaert L, Arntz HR, Brooks SC, Diercks D, Feitosa- Filho G, Nolan JP, Vanden Hoek TL, Walters DL, Wong A, Welsford M, Woolfrey K; Acute Coronary Syndrome Chapter Collaborators. Part 9: acute coronary syndromes: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122(suppl 2):S422–S465. doi: 10.1161/CIRCULATIONAHA.110.985549.

4. Nikolaou NI, Welsford M, Beygui F, Bossaert L, Ghaemmaghami C, Nonogi H, O'Connor RE, Pichel DR, Scott T, Walters DL, Woolfrey KGH; on behalf of the Acute Coronary Syndrome Chapter Collaborators. Part 5: acute coronary syndromes: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

5. Welsford M, Nikolaou NI, Beygui F, Bossaert L, Ghaemmaghami C, Nonogi H, O'Connor RE, Pichel DR, Scott T, Walters DL, Woolfrey KGH; on behalf of the Acute Coronary Syndrome Chapter Collaborators. Part 5: acute coronary syndromes: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S146–S176. doi: 10.1161/CIR.0000000000000274.

6. O'Connor D, Higgins JPT, Green S, eds. Chapter 5: Defining the review questions and developing criteria for including studies. In: The Cochrane Collaboration. Higgins JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0. 2011. http://handbook. cochrane.org/. Accessed May 6, 2015.

7. Schünemann H, Broz?ek J, Guyatt G, Oxman A. GRADE Handbook. 2013. http://www.guidelinedevelopment.org/handbook/. Accessed May 6, 2015.

8. O'Connor RE, Brady W, Brooks SC, Diercks D, Egan J, Ghaemmaghami C, Menon V, O'Neil BJ, Travers AH, Yannopoulos D. Part 10: acute coronary syndromes: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S787–S817. doi: 10.1161/ CIRCULATIONAHA.110.971028.

9. Amsterdam EA, Wenger NK, Brindis RG, Casey DE Jr, Ganiats TG, Holmes DR Jr, Jaffe AS, Jneid H, Kelly RF, Kontos MC, Levine GN, Liebson PR, Mukherjee D, Peterson ED, Sabatine MS, Smalling RW, Zieman SJ. 2014 ACC/AHA guideline for the management of patients with non–ST-elevation acute coronary syndromes: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation. 2014;130:e344–e426. doi: 10.1161/ CIR.0000000000000134.

10. O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso CL, Tracy CM, Woo YJ, Zhao DX. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2013;61:e78–e140.

11. O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso CL, Tracy CM, Woo YJ, Zhao DX. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2013;127:e362–e425. doi: 10.1161/CIR.0b013e3182742cf6.

12. Steg PG, Bonnefoy E, Chabaud S, Lapostolle F, Dubien PY, Cristofini P, Leizorovicz A, Touboul P. Impact of time to treatment on mortality after prehospital fibrinolysis or primary angioplasty: data from the CAPTIM randomized clinical trial. Circulation. 2003;108:2851–2856.

13. Nallamothu BK, Bates ER, Herrin J, Wang Y, Bradley EH, Krumholz HM. Times to treatment in transfer patients undergoing primary percutaneous coronary intervention in the United States: National Registry of Myocardial Infarction (NRMI)-3/4 analysis. Circulation. 2005;111:761–767.

14. Saczynski JS, Yarzebski J, Lessard D, Spencer FA, Gurwitz JH, Gore JM, Goldberg RJ. Trends in prehospital delay in patients with acute myocardial infarction (from the Worcester Heart Attack Study). Am J Cardiol. 2008;102:1589–1594.

15. Lefler LL, Bondy KN. Women's delay in seeking treatment with myocardial infarction: a meta-synthesis. J Cardiovasc Nurs. 2004;19:251–268.

16.

McGinn AP, Rosamond WD, Goff DC Jr., Taylor HA, Miles JS, Chambless L. Trends in prehospital delay time and use of emergency medical services for acute myocardial infarction: experience in 4 US communities from 1987–2000. Am Heart J. 2005;150:392–400.

17. Jneid H, Fonarow GC, Cannon CP, Hernandez AF, Palacios IF, Maree AO, Wells Q, Bozkurt B, Labresh KA, Liang L, Hong Y, Newby LK, Fletcher G, Peterson E, Wexler L. Sex differences in medical care and early death after acute myocardial infarction. Circulation. 2008;118:2803–2810.

18. Foraker RE, Rose KM, McGinn AP, Suchindran CM, Goff DC Jr., Whitsel EA, Wood JL, Rosamond WD. Neighborhood income, health insurance, and prehospital delay for myocardial infarction: the atherosclerosis risk in communities study. Arch Intern Med. 2008;168:1874–1879.

19. Sari I, Acar Z, Ozer O, Erer B, Tekbas E, Ucer E, Genc A, Davutoglu V, Aksoy M. Factors associated with prolonged prehospital delay in patients with acute myocardial infarction. Turk Kardiyol Dern Ars. 2008;36:156–162.

20. Gibler WB, Armstrong PW, Ohman EM, Weaver WD, Stebbins AL, Gore JM, Newby LK, Califf RM, Topol EJ. Persistence of delays in presentation and treatment for patients with acute myocardial infarction: The GUSTO-I and GUSTO-III experience. Ann Emerg Med. 2002;39:123–130.

21. Mehta RH, Bufalino VJ, Pan W, Hernandez AF, Cannon CP, Fonarow GC, Peterson ED. Achieving rapid reperfusion with primary percutaneous coronary intervention remains a challenge: insights from Am Heart Association's Get With the Guidelines program. Am Heart J. 2008;155:1059–1067.

22. Rathore SS, Curtis JP, Chen J, Wang Y, Nallamothu BK, Epstein AJ, Krumholz HM. Association of door-to-balloon time and mortality in patients admitted to hospital with ST elevation myocardial infarction: national cohort study. BMJ. 2009;338:b1807.

23. Song YB, Hahn JY, Gwon HC, Kim JH, Lee SH, Jeong MH. The impact of initial treatment delay using primary angioplasty on mortality among patients with acute myocardial infarction: from the Korea acute myocardial infarction registry. J Korean Med Sci. 2008;23:357–364.

24. Moser DK, Kimble LP, Alberts MJ, Alonzo A, Croft JB, Dracup K, Evenson KR, Go AS, Hand MM, Kothari RU, Mensah GA, Morris DL, Pancioli AM, Riegel B, Zerwic JJ. Reducing delay in seeking treatment by patients with acute coronary syndrome and stroke: a scientific statement from the Am Heart Association Council on cardiovascular nursing and stroke council. Circulation. 2006;114:168–182.

25. Goodacre SW, Angelini K, Arnold J, Revill S, Morris F. Clinical predictors of acute coronary syndromes in patients with undifferentiated chest pain. QJM. 2003;96:893–898.

26. Goodacre S, Locker T, Morris F, Campbell S. How useful are clinical features in the diagnosis of acute, undifferentiated chest pain? Acad Emerg Med. 2002;9:203–208.

27. Everts B, Karlson BW, Wahrborg P, Hedner T, Herlitz J. Localization of pain in suspected acute myocardial infarction in relation to final diagnosis, age and sex, and site and type of infarction. Heart Lung. 1996;25:430–437.

28. Panju AA, Hemmelgarn B.R., Guyatt G.G., Simel DL. Is this patient having a myocardial infarction? JAMA. 1998;280:1256–1263.

29. Douglas PS, Ginsburg GS. The evaluation of chest pain in women. N Engl J Med. 1996;334:1311–1315.

30. Solomon CG, Lee TH, Cook EF, Weisberg MC, Brand DA, Rouan GW, Goldman L. Comparison of clinical presentation of acute myocardial infarction in patients older than 65 years of age to younger patients: the Multicenter Chest Pain Study experience. Am J Cardiol. 1989;63:772–776.

31. Peberdy MA, Ornato JP. Coronary artery disease in women. Heart Dis Stroke. 1992;1:315–319.

32. Blohm M, Herlitz J, Schroder U, Hartford M, Karlson BW, Risenfors M, Larsson E, Luepker R, Wennerblom B, Holmberg S. Reaction to a media campaign focusing on delay in acute myocardial infarction. Heart Lung. 1991;20:661–666.

33. Hedges JR, Feldman HA, Bittner V, Goldberg RJ, Zapka J, Osganian SK, Murray DM, Simons-Morton DG, Linares A, Williams J, Luepker RV, Eisenberg MS. Impact of community intervention to reduce patient delay time on use of reperfusion therapy for acute myocardial infarction: rapid early action for coronary treatment (REACT) trial. REACT Study Group. Acad Emerg Med. 2000;7:862–872.

34. Antman EM, Anbe DT, Armstrong PW, Bates ER, Green LA, Hand M, Hochman JS, Krumholz HM, Kushner FG, Lamas GA, Mullany CJ, Ornato JP, Pearle DL, Sloan MA, Smith SC Jr., Alpert JS, Anderson JL, Faxon DP, Fuster V, Gibbons RJ, Gregoratos G, Halperin JL, Hiratzka LF, Hunt SA, Jacobs AK. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction–executive summary: a report of the Am College of Cardiology/Am Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 1999 Guidelines for the Management of Patients With Acute Myocardial Infarction). Circulation. 2004;110:588–636.

35. Antman EM, Berlin JA. Declining incidence of ventricular fibrillation in myocardial infarction: implications for the prophylactic use of lidocaine. Circulation. 1992;86:764–773.

36. Wyman MG, Wyman RM, Cannom DS, Criley JM. Prevention of primary ventricular fibrillation in acute myocardial infarction with prophylactic lidocaine. Am J Cardiol. 2004;94:545–551.

37. Chiriboga D, Yarzebski J, Goldberg RJ, Gore JM, Alpert JS. Temporal trends (1975 through 1990) in the incidence and case-fatality rates of primary ventricular fibrillation complicating acute myocardial infarction: a communitywide perspective. Circulation. 1994;89:998–1003.

38. The Public Access Defibrillation Trial Investigators. Public-access defibrillation and survival after out-of-hospital cardiac arrest. N Engl J Med. 2004;351:637–646.

39. Freimark D, Matetzky S, Leor J, Boyko V, Barbash IM, Behar S, Hod H. Timing of aspirin administration as a determinant of survival of patients with acute myocardial infarction treated with thrombolysis. Am J Cardiol. 2002;89:381–385.

40. Barbash IM, Freimark D, Gottlieb S, Hod H, Hasin Y, Battler A, Crystal E, Matetzky S, Boyko V, Mandelzweig L, Behar S, Leor J. Outcome of myocardial infarction in patients treated with aspirin is enhanced by pre-hospital administration. Cardiology. 2002;98:141–147.

41. Randomised trial of intravenous streptokinase, oral aspirin, both, or neither among 17 187 cases of suspected acute myocardial infarction: ISIS-2. ISIS-2 (Second International Study of Infarct Survival) Collaborative Group. Lancet. 1988;2():349–360.

42. Casaccia M, Bertello F, De Bernardi A, Sicuro M, Scacciatella P. Prehospital management of acute myocardial infarct in an experimental metropolitan system of medical emergencies [in Italian]. G Ital Cardiol. 1996;26:657–672.

43. Quan D, LoVecchio F, Clark B, Gallagher JV III.. Prehospital use of aspirin rarely is associated with adverse events. Prehosp Disaster Med. 2004;19:362–365.

44. Eisenberg MJ, Topol EJ. Prehospital administration of aspirin in patients with unstable angina and acute myocardial infarction. Arch Intern Med. 1996;156:1506–1510.

45. Wijesinghe M, Perrin K, Ranchord A, Simmonds M, Weatherall M, Beasley R. Routine use of oxygen in the treatment of myocardial infarction: systematic review. Heart. 2009;95:198–202.

46. Haynes BE, Pritting J. A rural emergency medical technician with selected advanced skills. Prehosp Emerg Care. 1999;3:343–346.

47. Funk D, Groat C, Verdile VP. Education of paramedics regarding aspirin use. Prehosp Emerg Care. 2000;4:62–64.

48. Verheugt FW, van der Laarse A, Funke-Kupper AJ, Sterkman LG, Galema TW, Roos JP. Effects of early intervention with low-dose aspirin (100 mg) on infarct size, reinfarction and mortality in anterior wall acute myocardial infarction. Am J Cardiol. 1990;66:267–270.

49. Bussmann WD, Passek D, Seidel W, Kaltenbach M. Reduction of CK and CK-MB indexes of infarct size by intravenous nitroglycerin. Circulation. 1981;63:615–622.

50. Charvat J, Kuruvilla T, al Amad H. Beneficial effect of intravenous nitroglycerin in patients with non-Q myocardial infarction. Cardiologia. 1990;35:49–54.

51. Jugdutt BI, Warnica JW. Intravenous nitroglycerin therapy to limit myocardial infarct size, expansion, and complications. Effect of timing, dosage, and infarct location. Circulation. 1988;78:906–919.

52. Madsen JK, Chevalier B, Darius H, Rutsch W, Wojcik J, Schneider S, Allikmets K. Ischaemic events and bleeding in patients undergoing percutaneous coronary intervention with concomitant bivalirudin treatment. EuroIntervention. 2008;3:610–616.

53. Meine TJ, Roe MT, Chen AY, Patel MR, Washam JB, Ohman EM, Peacock WF, Pollack CV Jr., Gibler WB, Peterson ED. Association of intravenous morphine use and outcomes in acute coronary syndromes: results from the CRUSADE Quality Improvement Initiative. Am Heart J. 2005;149:1043–1049.

54. Karagounis L, Ipsen SK, Jessop MR, Gilmore KM, Valenti DA, Clawson JJ, Teichman S, Anderson JL. Impact of field-transmitted electrocardiography on time to in-hospital thrombolytic therapy in acute myocardial infarction. Am J Cardiol. 1990;66:786–791.

55. Kereiakes DJ, Gibler WB, Martin LH, Pieper KS, Anderson LC. Relative importance of emergency medical system transport and the prehospital electrocardiogram on reducing hospital time delay to therapy for acute myocardial infarction: a preliminary report from the Cincinnati Heart Project. Am Heart J. 1992;123():835–840.

56. Foster DB, Dufendach JH, Barkdoll CM, Mitchell BK. Prehospital recognition of AMI using independent nurse/paramedic 12-lead ECG evaluation: impact on in-hospital times to thrombolysis in a rural community hospital. The Am journal of emergency medicine. 1994;12:25–31.

57. Banerjee S, Rhoden WE. Fast-tracking of myocardial infarction by paramedics. J R Coll Physicians Lond. 1998;32:36–38.

58. Melville MR, Gray Dal. e. The potential impact of prehospital electrocardiography and telemetry on time to thrombolysis in a United Kingdom center. Ann Noninvasive Electrocardiol. 1998;3:327–333.

59. Millar-Craig MW, Joy AV, Adamowicz M, Furber R, Thomas B. Reduction in treatment delay by paramedic ECG diagnosis of myocardial infarction with direct CCU admission. Heart. 1997;78:456–461.

60.

Brainard AH, Raynovich W, Tandberg D, Bedrick EJ. The prehospital 12-lead electrocardiogram's effect on time to initiation of reperfusion therapy: a systematic review and meta-analysis of existing literature. Am J Emerg Med. 2005;23:351–356.

61. Morrison LJ, Brooks S, Sawadsky B, McDonald A, Verbeek PR. Prehospital 12-lead electrocardiography impact on acute myocardial infarction treatment times and mortality: a systematic review. Acad Emerg Med. 2006;13:84–89.

62. Adams GL, Campbell PT, Adams JM, Strauss DG, Wall K, Patterson J, Shuping KB, Maynard C, Young D, Corey C, Thompson A, Lee BA, Wagner GS. Effectiveness of prehospital wireless transmission of electrocardiograms to a cardiologist via hand-held device for patients with acute myocardial infarction (from the Timely Intervention in Myocardial Emergency, NorthEast Experience [TIME-NE]). Am J Cardiol. 2006;98:1160–1164.

63. Afolabi BA, Novaro GM, Pinski SL, Fromkin KR, Bush HS. Use of the prehospital ECG improves door-to-balloon times in ST segment elevation myocardial infarction irrespective of time of day or day of week. Emerg Med J. 2007;24:588–591.

64. Terkelsen CJ, Lassen JF, Norgaard BL, Gerdes JC, Poulsen SH, Bendix K, Ankersen JP, Gotzsche LB, Romer FK, Nielsen TT, Andersen HR. Reduction of treatment delay in patients with ST-elevation myocardial infarction: impact of pre-hospital diagnosis and direct referral to primary percutanous coronary intervention. Eur Heart J. 2005;26:770–777.

65. Wall T, Albright J, Livingston B, Isley L, Young D, Nanny M, Jacobowitz S, Maynard C, Mayer N, Pierce K, Rathbone C, Stuckey T, Savona M, Leibrandt P, Brodie B, Wagner G. Prehospital ECG transmission speeds reperfusion for patients with acute myocardial infarction. North Carolina Medical Journal. 2000;61:104–108.

66. Dhruva VN, Abdelhadi SI, Anis A, Gluckman W, Hom D, Dougan W, Kaluski E, Haider B, Klapholz M. ST-Segment Analysis Using Wireless Technology in Acute Myocardial Infarction (STAT-MI) trial. J Am Coll Cardiol. 2007;50:509–513.

67. Sekulic M, Hassunizadeh B, McGraw S, David S. Feasibility of early emergency room notification to improve door-to-balloon times for patients with acute ST segment elevation myocardial infarction. Catheter Cardiovasc Interv. 2005;66:316–319.

68. Swor R, Hegerberg S, McHugh-McNally A, Goldstein M, McEachin CC. Prehospital 12-lead ECG: efficacy or effectiveness? Prehosp Emerg Care. 2006;10:374–377.

69. Campbell PT, Patterson J, Cromer D, Wall K, Adams GL, Albano A, Corey C, Fox P, Gardner J, Hawthorne B, Lipton J, Sejersten M, Thompson A, Wilfong S, Maynard C, Wagner G. Prehospital triage of acute myocardial infarction: wireless transmission of electrocardiograms to the on-call cardiologist via a handheld computer. J Electrocardiol. 2005;38():300–309.

70. Davis M, Lewell M, McLeod S, Dukelow A. A prospective evaluation of the utility of the prehospital 12-lead electrocardiogram to change patient management in the emergency department. Prehosp Emerg Care. 2014;18:9–14. doi: 10.3109/10903127.2013.825350.

71. Le May MR, Dionne R, Maloney J, Trickett J, Watpool I, Ruest M, Stiell I, Ryan S, Davies RF. Diagnostic performance and potential clinical impact of advanced care paramedic interpretation of ST-segment elevation myo- cardial infarction in the field. CJEM. 2006;8:401–407.

72. Nam J, Caners K, Bowen JM, Welsford M, O'Reilly D. Systematic review and meta-analysis of the benefits of out-of-hospital 12-lead ECG and advance notification in ST-segment elevation myocardial infarc- tion patients. Ann Emerg Med. 2014;64:176–86, 186.e1. doi: 10.1016/j. annemergmed.2013.11.016.

73. Feldman JA, Brinsfield K, Bernard S, White D, Maciejko T. Real-time paramedic compared with blinded physician identification of ST-segment elevation myocardial infarction: results of an observational study. Am J Emerg Med. 2005;23:443–448.

74. Le May MR, Dionne R, Maloney J, Trickett J, Watpool I, Ruest M, Stiell I, Ryan S, Davies RF. Diagnostic performance and potential clinical impact of advanced care paramedic interpretation of ST-segment elevation myocardial infarction in the field. CJEM. 2006;8:401–407.

75. van't Hof AW, Rasoul S, van de Wetering H, Ernst N, Suryapranata H, Hoorntje JC, Dambrink JH, Gosselink M, Zijlstra F, Ottervanger JP, de Boer MJ Feasibility and benefit of prehospital diagnosis, triage, and therapy by paramedics only in patients who are candidates for primary angioplasty for acute myocardial infarction. Am heart journal. 2006;151:1255 e1251–1255.

76. Pitt K. Prehospital selection of patients for thrombolysis by paramedics. Emerg Med J. 2002;19:260–263.

77. Trivedi K, Schuur JD, Cone DC. Can paramedics read ST-segment elevation myocardial infarction on prehospital 12-lead electrocardiograms? Prehosp Emerg Care. 2009;13:207–214.

78. Whitbread M, Leah V, Bell T, Coats TJ. Recognition of ST elevation by paramedics. Emerg Med J. 2002;19:66–67.

79. Lloyd G, Roberts A, Bashir I, Mumby M, Kamalvand K, Cooke R. An audit of clinical nurse practitioner led thrombolysis to improve the treatment of acute myocardial infarction. J Public Health Med. 2000;22:462–465.

80. Qasim A, Malpass K, O'Gorman DJ, Heber ME. Safety and efficacy of nurse initiated thrombolysis in patients with acute myocardial infarction. BMJ. 2002;324():1328–1331.

81. Heath SM, Bain RJ, Andrews A, Chida S, Kitchen SI, Walters MI. Nurse initiated thrombolysis in the accident and emergency department: safe, accurate, and faster than fast track. Emerg Med J. 2003;20:418–420.

82. Bouten MJ, Simoons ML, Hartman JA, van Miltenburg AJ, van der Does E, Pool J. Prehospital thrombolysis with alteplase (rt-PA) in acute myocardial infarction. Eur Heart J. 1992;13:925–931.

83. Kremser AK, Lyneham J. Can Australian nurses safely assess for thrombolysis on EKG criteria? J Emerg Nurs. 2007;33:102–109.

84. Wilmshurst P, Purchase A, Webb C, Jowett C, Quinn T. Improving door to needle times with nurse initiated thrombolysis. Heart. 2000;84:262–266.

85. Quinn T. Can nurses safely assess suitability for thrombolytic therapy? A pilot study. Intensive Crit Care Nurs. 1995;11:126–129.

86. Ioannidis JP, Salem D, Chew PW, Lau J. Accuracy and clinical effect of out-of-hospital electrocardiography in the diagnosis of acute cardiac ischemia: a meta-analysis. Ann Emerg Med. 2001;37:461–470.

87. Emergency department: rapid identification and treatment of patients with acute myocardial infarction. National Heart Attack Alert Program Coordinating Committee, 60 Minutes to Treatment Working Group. Ann Emerg Med. 1994;23:311–329.

88. Lambrew CT, Bowlby LJ, Rogers WJ, Chandra NC, Weaver WD. Factors influencing the time to thrombolysis in acute myocardial infarction. Time to Thrombolysis Substudy of the National Registry of Myocardial Infarction-1. Arch Intern Med. 1997;157:2577–2582.

89. Anderson JL, Adams CD, Antman EM, Bridges CR, Califf RM, Casey DE Jr., Chavey WE II., Fesmire FM, Hochman JS, Levin TN, Lincoff AM, Peterson ED, Theroux P, Wenger NK, Wright RS, Smith SC Jr., Jacobs AK, Halperin JL, Hunt SA, Krumholz HM, Kushner FG, Lytle BW, Nishimura R, Ornato JP, Page RL, Riegel B. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non ST-elevation myocardial infarction: a report of the Am College of Cardiology/Am Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines for the Management of Patients With Unstable Angina/Non ST-Elevation Myocardial Infarction): developed in collaboration with the Am College of Emergency Physicians, the Society for Cardiovascular Angiography and Interventions, and the Society of Thoracic Surgeons: endorsed by the Am Association of Cardiovascular and Pulmonary Rehabilitation and the Society for Academic Emergency Medicine. Circulation. 2007;116:e148–e304.

90. Bleeker JK, Simoons ML, Erdman RA, Leenders CM, Kruyssen HA, Lamers LM, van der Does E. Patient and doctor delay in acute myocardial infarction: a study in Rotterdam, The Netherlands. Br J Gen Pract. 1995;45():181–184.

91. Goldberg RJ, McGovern PG, Guggina T, Savageau J, Rosamond WD, Luepker RV. Prehospital delay in patients with acute coronary heart disease: concordance between patient interviews and medical records. Am Heart J. 135():293–299, 1998.

92. McSweeney JC, Cody M, O'Sullivan P, Elberson K, Moser DK, Garvin BJ. Women's early warning symptoms of acute myocardial infarction. Circulation. 2003;108:2619–2623.

93. Wagner GS, Macfarlane P, Wellens H, Josephson M, Gorgels A, Mirvis DM, Pahlm O, Surawicz B, Kligfield P, Childers R, Gettes LS, Bailey JJ, Deal BJ, Gorgels A, Hancock EW, Kors JA, Mason JW, Okin P, Rautaharju PM, van Herpen G. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part VI: acute ischemia/infarction: a scientific statement from the Am Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the Am College of Cardiology Foundation; and the Heart Rhythm Society. Endorsed by the International Society for Computerized Electrocardiology. Journal of the Am College of Cardiology. 2009;53:1003–1011.

94. Antman EM, Tanasijevic MJ, Thompson B, Schactman M, McCabe CH, Cannon CP, Fischer GA, Fung AY, Thompson C, Wybenga D, Braunwald E. Cardiac-specific troponin I levels to predict the risk of mortality in patients with acute coronary syndromes. N Engl J Med. 1996;335:1342–1349.

95. Bradley EH, Herrin J, Wang Y, Barton BA, Webster TR, Mattera JA, Roumanis SA, Curtis JP, Nallamothu BK, Magid DJ, McNamara RL, Parkosewich J, Loeb JM, Krumholz HM. Strategies for reducing the door-to-balloon time in acute myocardial infarction. N Engl J Med. 2006;355:2308–2320.

96. Al-Mubarak N, Rogers WJ, Lambrew CT, Bowlby LJ, French WJ Consultation before thrombolytic therapy in acute myocardial infarction. Second National Registry of Myocardial Infarction (NRMI 2) Investigators. The Am journal of cardiology. 1999;83:89–93, A88.

97. Braunwald E, Antman EM, Beasley JW, Califf RM, Cheitlin MD, Hochman JS, Jones RH, Kereiakes D, Kupersmith J, Levin TN, Pepine CJ, Schaeffer JW, Smith EE III., Steward DE, Theroux P, Gibbons RJ, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Smith SC Jr.. ACC/AHA 2002 guideline update for the management of patients with unstable angina and non-ST-segment elevation myocardial infarction–summary article: a report of the Am College of Cardiology/Am Heart Association task force on practice guidelines (Committee on the Management of Patients With Unstable Angina). J Am Coll Cardiol. 2002;40:1366–1374.

98. Braunwald E, Antman EM, Beasley JW, Califf RM, Cheitlin MD, Hochman JS, Jones RH, Kereiakes D, Kupersmith J, Levin TN, Pepine CJ, Schaeffer JW, Smith EE III., Steward DE, Theroux P, Gibbons RJ, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Smith SC Jr.. ACC/AHA guideline update for the management of patients with unstable angina and non-ST-segment elevation myocardial infarction–2002: summary article: a report of the Am College of Cardiology/Am Heart Association Task Force on Practice Guidelines (Committee on the Management of Patients With Unstable Angina). Circulation. 2002;106:1893–1900.

99. Braunwald E, Antman EM, Beasley JW, Califf RM, Cheitlin MD, Hochman JS, Jones RH, Kereiakes D, Kupersmith J, Levin TN, Pepine CJ, Schaeffer JW, Smith EE III., Steward DE, Theroux P, Alpert JS, Eagle KA, Faxon DP, Fuster V, Gardner TJ, Gregoratos G, Russell RO, Smith SC Jr.. ACC/AHA guidelines for the management of patients with unstable angina and non-ST-segment elevation myocardial infarction. A report of the Am College of Cardiology/Am Heart Association Task Force on Practice Guidelines (Committee on the Management of Patients With Unstable Angina). J Am Coll Cardiol. 2000;36:970–1062.

100. Effects of tissue plasminogen activator and a comparison of early invasive and conservative strategies in unstable angina and non-Q-wave myocardial infarction. Results of the TIMI IIIB Trial. Thrombolysis in Myocardial Ischemia. Circulation. 1994;89:1545–1556.

101. Scanlon PJ, Faxon DP, Audet AM, Carabello B, Dehmer GJ, Eagle KA, Legako RD, Leon DF, Murray JA, Nissen SE, Pepine CJ, Watson RM, Ritchie JL, Gibbons RJ, Cheitlin MD, Gardner TJ, Garson A Jr., Russell RO Jr., Ryan TJ, Smith SC Jr.. ACC/AHA guidelines for coronary angiography: executive summary and recommendations. A report of the Am College of Cardiology/Am Heart Association Task Force on Practice Guidelines (Committee on Coronary Angiography) developed in collaboration with the Society for Cardiac Angiography and Interventions. Circulation. 1999;99:2345–2357.

102. King SB III., Smith SC Jr., Hirshfeld JW Jr., Jacobs AK, Morrison DA, Williams DO, Feldman TE, Kern MJ, O'Neill WW, Schaff HV, Whitlow PL, Adams CD, Anderson JL, Buller CE, Creager MA, Ettinger SM, Halperin JL, Hunt SA, Krumholz HM, Kushner FG, Lytle BW, Nishimura R, Page RL, Riegel B, Tarkington LG, Yancy CW. 2007 Focused Update of the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention: a report of the Am College of Cardiology/Am Heart Association Task Force on Practice Guidelines: 2007 Writing Group to Review New Evidence and Update the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention, Writing on Behalf of the 2005 Writing Committee. Circulation. 2008;117:261–295.

103. Alpert JS, Thygesen K, Antman E, Bassand JP. Myocardial infarction redefined–a consensus document of The Joint European Society of Cardiology/Am College of Cardiology Committee for the redefinition of myocardial infarction. Journal of the Am College of Cardiology. 2000;36:959–969.

104. Pollack CV Jr., Sites FD, Shofer FS, Sease KL, Hollander JE. Application of the TIMI risk score for unstable angina and non-ST elevation acute coronary syndrome to an unselected emergency department chest pain population. Acad Emerg Med. 2006;13:13–18.

105. Antman EM, Cohen M, Bernink PJ, McCabe CH, Horacek T, Papuchis G, Mautner B, Corbalan R, Radley D, Braunwald E. The TIMI risk score for unstable angina/non-ST elevation MI: A method for prognostication and therapeutic decision making. JAMA. 2000;284:835–842.

106. Boersma E, Pieper KS, Steyerberg EW, Wilcox RG, Chang WC, Lee KL, Akkerhuis KM, Harrington RA, Deckers JW, Armstrong PW, Lincoff AM, Califf RM, Topol EJ, Simoons ML. Predictors of outcome in patients with acute coronary syndromes without persistent ST-segment elevation. Results from an international trial of 9461 patients. The PURSUIT Investigators. Circulation. 2000;101:2557–2567.

107. Granger CB, Goldberg RJ, Dabbous O, Pieper KS, Eagle KA, Cannon CP, Van De Werf F, Avezum A, Goodman SG, Flather MD, Fox KA. Predictors of hospital mortality in the global registry of acute coronary events. Archives of internal medicine. 2003;163:2345–2353.

108. Eagle KA, Lim MJ, Dabbous OH, Pieper KS, Goldberg RJ, Van de Werf F, Goodman SG, Granger CB, Steg PG, Gore JM, Budaj A, Avezum A, Flather MD, Fox KAA for the GRACE Investigators. A validated prediction model for all forms of acute coronary syndrome: estimating the risk of 6-month postdischarge death in an international registry. JAMA. 2004;291:2727–2733.

109. Farkouh ME, Smars PA, Reeder GS, Zinsmeister AR, Evans RW, Meloy TD, Kopecky SL, Allen M, Allison TG, Gibbons RJ, Gabriel SE. A clinical trial of a chest-pain observation unit for patients with unstable angina. Chest Pain Evaluation in the Emergency Room (CHEER) Investigators. N Engl J Med. 1998;339:1882–1888.

110. Udelson JE, Beshansky JR, Ballin DS, Feldman JA, Griffith JL, Handler J, Heller GV, Hendel RC, Pope JH, Ruthazer R, Spiegler EJ, Woolard RH, Selker HP. Myocardial perfusion imaging for evaluation and triage of patients with suspected acute cardiac ischemia: a randomized controlled trial. JAMA. 2002;288:2693–2700.

111. Bedetti G, Pasanisi EM, Tintori G, Fonseca L, Tresoldi S, Minneci C, Jambrik Z, Ghelarducci B, Orlandini A, Picano E. Stress echo in chest pain unit: the SPEED trial. International journal of cardiology. 2005;102:461–467.

112. Caragher TE, Fernandez BB, Barr LA. Long-term experience with an accelerated protocol for diagnosis of chest pain. Archives of pathology & laboratory medicine. 2000;124:1434–1439.

113. deFilippi CR, Rosanio S, Tocchi M, Parmar RJ, Potter MA, Uretsky BF, Runge MS. Randomized comparison of a strategy of predischarge coronary angiography versus exercise testing in low-risk patients in a chest pain unit: in-hospital and long-term outcomes. Journal of the Am College of Cardiology. 2001;37:2042–2049.

114. Gomez MA, Anderson JL, Karagounis LA, Muhlestein JB, Mooers FB. An emergency department-based protocol for rapidly ruling out myocardial ischemia reduces hospital time and expense: results of a randomized study (ROMIO). J Am Coll Cardiol. 1996;28:25–33.

115. Lee TH, Juarez G, Cook EF, Weisberg MC, Rouan GW, Brand DA, Goldman L. Ruling out acute myocardial infarction. A prospective multicenter validation of a 12-hour strategy for patients at low risk. N Engl J Med. 1991;324:1239–1246.

116. Nucifora G, Badano LP, Sarraf-Zadegan N, Karavidas A, Trocino G, Scaffidi G, Pettinati G, Astarita C, Vysniauskas V, Gregori D, Ilerigelen B, Fioretti PM. Effect on quality of life of different accelerated diagnostic protocols for management of patients presenting to the emergency department with acute chest pain. The Am journal of cardiology. 2009;103:592–597.

117. Ramakrishna G, Milavetz JJ, Zinsmeister AR, Farkouh ME, Evans RW, Allison TG, Smars PA, Gibbons RJ. Effect of exercise treadmill testing and stress imaging on the triage of patients with chest pain: CHEER substudy. Mayo Clinic proceedings. 2005;80:322–329.

118. Roberts RR, Zalenski RJ, Mensah EK, Rydman RJ, Ciavarella G, Gussow L, Das K, Kampe LM, Dickover B, McDermott MF, Hart A, Straus HE, Murphy DG, Rao R. Costs of an emergency department-based accelerated diagnostic protocol vs hospitalization in patients with chest pain: a randomized controlled trial. JAMA. 1997;278:1670–1676.

119. Zalenski RJ, McCarren M, Roberts R, Rydman RJ, Jovanovic B, Das K, Mendez J, el-Khadra M, Fraker L, McDermott M. An evaluation of a chest pain diagnostic protocol to exclude acute cardiac ischemia in the emergency department. Archives of internal medicine. 1997;157:1085–1091.

120. Paventi S, Parafati MA, Luzio ED, Pellegrino CA. Usefulness of two-dimensional echocardiography and myocardial perfusion imaging for immediate evaluation of chest pain in the emergency department. Resuscitation. 2001;49:47–51.

121. Conti A, Sammicheli L, Gallini C, Costanzo EN, Antoniucci D, Barletta G. Assessment of patients with low-risk chest pain in the emergency department: Head-to-head comparison of exercise stress echocardiography and exercise myocardial SPECT. Am Heart J. 2005;149:894–901.

122. Gallagher MJ, Ross MA, Raff GL, Goldstein JA, O'Neill WW, O'Neil B. The diagnostic accuracy of 64-slice computed tomography coronary angiography compared with stress nuclear imaging in emergency department low-risk chest pain patients. Ann Emerg Med. 2007;49:125–136.

123. Forberg JL, Hilmersson CE, Carlsson M, Arheden H, Bjork J, Hjalte K, Ekelund U. Negative predictive value and potential cost savings of acute nuclear myocardial perfusion imaging in low risk patients with suspected acute coronary syndrome: a prospective single blinded study. BMC Emerg Med. 2009;9:12.

124. Athappan G, Habib M, Ponniah T, Jeyaseelan L Multi-detector computerized tomography angiography for evaluation of acute chest pain - A meta analysis and systematic review of literature. Int J Cardiol. 2009.

125. Vanhoenacker PK, Decramer I, Bladt O, Sarno G, Bevernage C, Wijns W. Detection of non-ST-elevation myocardial infarction and unstable angina in the acute setting: meta-analysis of diagnostic performance of multi-detector computed tomographic angiography. BMC Cardiovasc Disord. 2007;7:39.

126. Hoffmann U, Bamberg F, Chae CU, Nichols JH, Rogers IS, Seneviratne SK, Truong QA, Cury RC, Abbara S, Shapiro MD, Moloo J, Butler J, Ferencik M, Lee H, Jang IK, Parry BA, Brown DF, Udelson JE, Achenbach S, Brady TJ, Nagurney JT. Coronary computed tomography angiography for early triage of patients with acute chest pain: the ROMICAT (Rule Out Myocardial Infarction using Computer Assisted Tomography) trial. J Am Coll Cardiol. 2009;53:1642–1650.

127. Hollander JE, Litt HI, Chase M, Brown AM, Kim W, Baxt WG. Computed tomography coronary angiography for rapid disposition of low-risk emergency department patients with chest pain syndromes. Acad Emerg Med. 2007;14:112–116.

128. Goldstein JA, Gallagher MJ, O'Neill WW, Ross MA, O'Neil BJ, Raff GL. A randomized controlled trial of multi-slice coronary computed tomography for evaluation of acute chest pain. J Am Coll Cardiol. 2007;49:863–871.

129. Hess EP, Thiruganasambandamoorthy V, Wells GA, Erwin P, Jaffe AS, Hollander JE, Montori VM, Stiell IG. Diagnostic accuracy of clinical prediction rules to exclude acute coronary syndrome in the emergency department setting: a systematic review. Cjem. 2008;10:373–382.

130. Hamm CW, Goldmann BU, Heeschen C, Kreymann G, Berger J, Meinertz T. Emergency room triage of patients with acute chest pain by means of rapid testing for cardiac troponin T or troponin I. N Engl J Med. 1997;337:1648–1653.

131. Lai C, Noeller TP, Schmidt K, King P, Emerman CL. Short-term risk after initial observation for chest pain. J Emerg Med. 2003;25:357–362.

132. Marsan RJ Jr., Shaver KJ, Sease KL, Shofer FS, Sites FD, Hollander JE. Evaluation of a clinical decision rule for young adult patients with chest pain. Acad Emerg Med. 2005;12:26–31.

133. Christenson J, Innes G, McKnight D, Thompson CR, Wong H, Yu E, Boychuk B, Grafstein E, Rosenberg F, Gin K, Anis A, Singer J. A clinical prediction rule for early discharge of patients with chest pain. Ann Emerg Med. 2006;47:1–10.

134. Challa PK, Smith KM, Conti CR. Initial presenting electrocardiogram as determinant for hospital admission in patients presenting to the emergency department with chest pain: a pilot investigation. Clin Cardiol. 2007;30:558–561.

135. Schillinger M, Sodeck G, Meron G, Janata K, Nikfardjam M, Rauscha F, Laggner AN, Domanovits H. Acute chest pain–identification of patients at low risk for coronary events. The impact of symptoms, medical history and risk factors. Wien Klin Wochenschr. 2004;116:83–89.

136. Bassan R, Pimenta L, Scofano M, Gamarski R, Volschan A. Probability stratification and systematic diagnostic approach for chest pain patients in the emergency department. Crit Pathw Cardiol. 2004;3:1–7.

137. Bhalla MC, Mencl F, Gist MA, Wilber S, Zalewski J. Prehospital elec- trocardiographic computer identification of ST-segment elevation myocardial infarction. Prehosp Emerg Care. 2013;17:211–216. doi: 10.3109/10903127.2012.722176.

138. Clark EN, Sejersten M, Clemmensen P, Macfarlane PW. Automated elec- trocardiogram interpretation programs versus cardiologists' triage deci- sion making based on teletransmitted data in patients with suspected acute coronary syndrome. Am J Cardiol. 2010;106:1696–1702. doi: 10.1016/j. amjcard.2010.07.047.

139.

de Champlain F, Boothroyd LJ, Vadeboncoeur A, Huynh T, Nguyen V, Eisenberg MJ, Joseph L, Boivin JF, Segal E. Computerized interpretation of the prehospital electrocardiogram: predictive value for ST segment elevation myocardial infarction and impact on on-scene time. CJEM. 2014;16:94–105.

140. Squire BT, Tamayo-Sarver JH, Rashi P, Koenig W, Niemann JT. Effect of prehospital cardiac catheterization lab activation on door-to-balloon time, mortality, and false-positive activation. Prehosp Emerg Care. 2014;18:1– 8. doi: 10.3109/10903127.2013.836263.

141. Youngquist ST, Shah AP, Niemann JT, Kaji AH, French WJ. A com- parison of door-to-balloon times and false-positive activations between emergency department and out-of-hospital activation of the coro- nary catheterization team. Acad Emerg Med. 2008;15:784–787. doi: 10.1111/j.1553-2712.2008.00186.x.

142. Brown JP, Mahmud E, Dunford JV, Ben-Yehuda O. Effect of prehospi- tal 12-lead electrocardiogram on activation of the cardiac cathetheriza- tion laboratory and door-to-balloon time in ST-segment elevation acute myocardial infarction. Am J Cardiol. 2008;101:158–161. doi: 10.1016/j. amjcard.2007.07.082.

143. van ‘t Hof AW, Rasoul S, van de Wetering H, Ernst N, Suryapranata H, Hoorntje JC, Dambrink JH, Gosselink M, Zijlstra F, Ottervanger JP, de Boer MJ; On-TIME study group. Feasibility and benefit of prehospital diagnosis, triage, and therapy by paramedics only in patients who are can- didates for primary angioplasty for acute myocardial infarction. Am Heart J. 2006;151:1255.e1–1255.e5. doi: 10.1016/j.ahj.2006.03.014.

144. Feldman JA, Brinsfield K, Bernard S, White D, Maciejko T. Real-time paramedic compared with blinded physician identification of ST-segment elevation myocardial infarction: results of an observational study. Am J Emerg Med. 2005;23:443–448.

145. Ducas RA, Wassef AW, Jassal DS, Weldon E, Schmidt C, Grierson R, Tam JW. To transmit or not to transmit: how good are emergency medical per- sonnel in detecting STEMI in patients with chest pain? Can J Cardiol. 2012;28:432–437. doi: 10.1016/j.cjca.2012.04.008.

146. Trivedi K, Schuur JD, Cone DC. Can paramedics read ST-segment elevation myocardial infarction on prehospital 12-lead electrocardiograms? Prehosp Emerg Care. 2009;13:207–214. doi: 10.1080/10903120802706153.

147. Davis DP, Graydon C, Stein R, Wilson S, Buesch B, Berthiaume S, Lee DM, Rivas J, Vilke GM, Leahy DR. The positive predictive value of paramedic versus emergency physician interpretation of the prehospital 12-lead electrocardiogram. Prehosp Emerg Care. 2007;11:399–402. doi: 10.1080/10903120701536784.

148. Lee CH, Van Gelder CM, Cone DC. Early cardiac catheterization labo- ratory activation by paramedics for patients with ST-segment elevation myocardial infarction on prehospital 12-lead electrocardiograms. Prehosp Emerg Care. 2010;14:153–158. doi: 10.3109/10903120903537213.

149. Young DR, Murinson M, Wilson C, Hammond B, Welch M, Block V, Booth S, Tedder W, Dolby K, Roh J, Beaton R, Edmunds J, Young M, Rice V, Somers C, Edwards R, Maynard C, Wagner GS. Paramedics as decision makers on the activation of the catheterization laboratory in the presence of acute ST-elevation myocardial infarction. J Electrocardiol. 2011;44:18–22. doi: 10.1016/j.jelectrocard.2010.06.010.

150. Dorsch MF, Greenwood JP, Priestley C, Somers K, Hague C, Blaxill JM, Wheatcroft SB, Mackintosh AF, McLenachan JM, Blackman DJ. Direct ambulance admission to the cardiac catheterization laboratory significantly reduces door-to-balloon times in primary percutaneous coronary interven- tion. Am Heart J. 2008;155:1054–1058. doi: 10.1016/j.ahj.2008.01.014.

151. Strauss DG, Sprague PQ, Underhill K, Maynard C, Adams GL, Kessenich A, Sketch MH Jr, Berger PB, Marcozzi D, Granger CB, Wagner GS. Paramedic transtelephonic communication to cardiologist of clinical and electrocardiographic assessment for rapid reperfusion of ST-elevation myocardial infarction. J Electrocardiol. 2007;40:265–270. doi: 10.1016/j. jelectrocard.2006.11.006.

152. Thygesen K, Alpert JS, Jaffe AS, Simoons ML, Chaitman BR, White HD; the Writing Group on behalf of the Joint ESC/ACCF/AHA/WHF Task Force for the Universal Definition of Myocardial Infarction. Third univer- sal definition of myocardial infarction. Circulation. 2012;126:2020–2035. doi: 10.1161/CIR.0b013e31826e1058.

153. Mahajan VS, Jarolim P. How to interpret elevated cardiac tro- ponin levels. Circulation. 2011;124:2350–2354. doi: 10.1161/CIRCULATIONAHA.111.023697.

154. Pitts SR, Niska RW, Xu J, Burt CW. National Hospital Ambulatory Medical Care Survey: 2006 emergency department summary. Natl Health Stat Report. 2008:1–38.

155. Aldous SJ, Richards AM, Cullen L, Than MP. Early dynamic change in high-sensitivity cardiac troponin T in the investigation of acute myocardial infarction. Clin Chem. 2011;57:1154–1160. doi: 10.1373/ clinchem.2010.161166.

156. Parsonage WA, Greenslade JH, Hammett CJ, Lamanna A, Tate JR, Ungerer JP, Chu K, Than M, Brown AF, Cullen L. Validation of an accel- erated high-sensitivity troponin T assay protocol in an Australian cohort with chest pain. Med J Aust. 2014;200:161–165.

157. Cullen L, Mueller C, Parsonage WA, Wildi K, Greenslade JH, Twerenbold R, Aldous S, Meller B, Tate JR, Reichlin T, Hammett CJ, Zellweger C, Ungerer JP, Rubini Gimenez M, Troughton R, Murray K, Brown AF, Mueller M, George P, Mosimann T, Flaws DF, Reiter M, Lamanna A, Haaf P, Pemberton CJ, Richards AM, Chu K, Reid CM, Peacock WF, Jaffe AS, Florkowski C, Deely JM, Than M. Validation of high-sensitivity troponin I in a 2-hour diagnostic strategy to assess 30-day outcomes in emergency department patients with possible acute coronary syndrome. J Am Coll Cardiol. 2013;62:1242–1249. doi: 10.1016/j.jacc.2013.02.078.

158. Kelly AM, Klim S. Prospective external validation of an accelerated (2-h) acute coronary syndrome rule-out process using a contemporary troponin assay. Int J Emerg Med. 2014;7:42. doi: 10.1186/s12245-014-0042-3.

159. Cullen L, Greenslade JH, Than M, Brown AF, Hammett CJ, Lamanna A, Flaws DF, Chu K, Fowles LF, Parsonage WA. The new Vancouver Chest Pain Rule using troponin as the only biomarker: an external validation study. Am J Emerg Med. 2014;32:129–134. doi: 10.1016/j. ajem.2013.10.021.

160. Hess EP, Brison RJ, Perry JJ, Calder LA, Thiruganasambandamoorthy V, Agarwal D, Sadosty AT, Silvilotti ML, Jaffe AS, Montori VM, Wells GA, Stiell IG. Development of a clinical prediction rule for 30-day car- diac events in emergency department patients with chest pain and pos- sible acute coronary syndrome. Ann Emerg Med. 2012;59:115–25.e1. doi: 10.1016/j.annemergmed.2011.07.026.

161. Mahler SA, Miller CD, Hollander JE, Nagurney JT, Birkhahn R, Singer AJ, Shapiro NI, Glynn T, Nowak R, Safdar B, Peberdy M, Counselman FL, Chandra A, Kosowsky J, Neuenschwander J, Schrock JW, Plantholt S, Diercks DB, Peacock WF. Identifying patients for early discharge: per- formance of decision rules among patients with acute chest pain. Int J Cardiol. 2013;168:795–802. doi: 10.1016/j.ijcard.2012.10.010.

162. Xavier Scheuermeyer F, Wong H, Yu E, Boychuk B, Innes G, Grafstein E, Gin K, Christenson J. Development and validation of a prediction rule for early discharge of low-risk emergency department patients with potential ischemic chest pain. CJEM. 2014;16:106–119.

163. Montalescot G, Wiviott SD, Braunwald E, Murphy SA, Gibson CM, McCabe CH, Antman EM; TRITON-TIMI 38 investigators. Prasugrel compared with clopidogrel in patients undergoing percutaneous coronary intervention for ST-elevation myocardial infarction (TRITON-TIMI 38): double-blind, randomised controlled trial. Lancet. 2009;373:723–731. doi: 10.1016/S0140-6736(09)60441-4.

164. Steg PG, James S, Harrington RA, Ardissino D, Becker RC, Cannon CP, Emanuelsson H, Finkelstein A, Husted S, Katus H, Kilhamn J, Olofsson S, Storey RF, Weaver WD, Wallentin L; PLATO Study Group. Ticagrelor versus clopidogrel in patients with ST-elevation acute coronary syn- dromes intended for reperfusion with primary percutaneous coronary intervention: A Platelet Inhibition and Patient Outcomes (PLATO) trial subgroup analysis. Circulation. 2010;122:2131–2141. doi: 10.1161/ CIRCULATIONAHA.109.927582.

165. Zeymer U, Arntz HR, Mark B, Fichtlscherer S, Werner G, Schöller R, Zahn R, Diller F, Darius H, Dill T, Huber K. Efficacy and safety of a high loading dose of clopidogrel administered prehospitally to improve primary percutaneous coronary intervention in acute myocardial infarc- tion: the randomized CIPAMI trial. Clin Res Cardiol. 2012;101:305–312. doi: 10.1007/s00392-011-0393-1.

166. Ducci K, Grotti S, Falsini G, Angioli P, Liistro F, Mandò M, Porto I, Bolognese L. Comparison of pre-hospital 600 mg or 900 mg vs. peri-inter- ventional 300 mg clopidogrel in patients with ST-elevation myocardial infarction undergoing primary coronary angioplasty. The Load&Go randomized trial. Int J Cardiol. 2013;168:4814–4816. doi: 10.1016/j. ijcard.2013.07.012.

167. Montalescot G, van 't Hof AW, Lapostolle F, Silvain J, Lassen JF, Bolognese L, Cantor WJ, Cequier A, Chettibi M, Goodman SG, Hammett CJ, Huber K, Janzon M, Merkely B, Storey RF, Zeymer U, Stibbe O, Ecollan P, Heutz WM, Swahn E, Collet JP, Willems FF, Baradat C, Licour M, Tsatsaris A, Vicaut E, Hamm CW; ATLANTIC Investigators. Prehospital ticagrelor in ST-segment elevation myocardial infarction. N Engl J Med. 2014;371:1016–1027. doi: 10.1056/NEJMoa1407024.

168. Zijlstra F, Ernst N, de Boer MJ, Nibbering E, Suryapranata H, Hoorntje JC, Dambrink JH, van 't Hof AW, Verheugt FW. Influence of prehospi- tal administration of aspirin and heparin on initial patency of the infarct- related artery in patients with acute ST elevation myocardial infarction. J Am Coll Cardiol. 2002;39:1733–1737.

169. Steg PG, van 't Hof A, Hamm CW, Clemmensen P, Lapostolle F, Coste P, Ten Berg J, Van Grunsven P, Eggink GJ, Nibbe L, Zeymer U, Campo dell' Orto M, Nef H, Steinmetz J, Soulat L, Huber K, Deliargyris EN, Bernstein D, Schuette D, Prats J, Clayton T, Pocock S, Hamon M, Goldstein P; EUROMAX Investigators. Bivalirudin started during emergency trans- port for primary PCI. N Engl J Med. 2013;369:2207–2217. doi: 10.1056/ NEJMoa1311096.

170. Sejersten M, Nielsen SL, Engstrøm T, Jørgensen E, Clemmensen P. Feasibility and safety of prehospital administration of bivalirudin in patients with ST-elevation myocardial infarction. Am J Cardiol. 2009;103:1635–1640. doi: 10.1016/j.amjcard.2009.02.015.

171. Bangalore S, Toklu B, Kotwal A, Volodarskiy A, Sharma S, Kirtane AJ, Feit F. Anticoagulant therapy during primary percutaneous coronary inter- vention for acute myocardial infarction: a meta-analysis of randomized trials in the era of stents and P2Y12 inhibitors. BMJ. 2014;349:g6419.

172. Cavender MA, Sabatine MS. Bivalirudin versus heparin in patients planned for percutaneous coronary intervention: a meta-analysis of ran- domised controlled trials. Lancet. 2014;384:599–606. doi: 10.1016/ S0140-6736(14)61216-2.

173. Stone GW, Mehran R, Goldstein P, Witzenbichler B, Van't Hof A, Guagliumi G, Hamm CW, Généreux P, Clemmensen P, Pocock SJ, Gersh BJ, Bernstein D, Deliargyris EN, Steg PG. Bivalirudin versus heparin with or without glycoprotein IIb/IIIa inhibitors in patients with STEMI under- going primary percutaneous coronary intervention: pooled patient-level analysis from the HORIZONS-AMI and EUROMAX trials. J Am Coll Cardiol. 2015;65:27–38. doi: 10.1016/j.jacc.2014.10.029.

174. Montalescot G, Zeymer U, Silvain J, Boulanger B, Cohen M, Goldstein P, Ecollan P, Combes X, Huber K, Pollack C Jr, Bénezet JF, Stibbe O, Filippi E, Teiger E, Cayla G, Elhadad S, Adnet F, Chouihed T, Gallula S, Greffet A, Aout M, Collet JP, Vicaut E; ATOLL Investigators. Intravenous enoxaparin or unfractionated heparin in primary percutaneous coronary intervention for ST-elevation myocardial infarction: the international randomised open-label ATOLL trial. Lancet. 2011;378:693–703. doi: 10.1016/S0140-6736(11)60876-3.

175. Rawles JM, Kenmure AC. Controlled trial of oxygen in uncomplicated myocardial infarction. Br Med J. 1976;1:1121–1123.

176. Wilson AT, Channer KS. Hypoxaemia and supplemental oxygen therapy in the first 24 hours after myocardial infarction: the role of pulse oximetry. J R Coll Physicians Lond. 1997;31:657–661.

177. Kilgannon JH, Jones AE, Shapiro NI, Angelos MG, Milcarek B, Hunter K, Parrillo JE, Trzeciak S; Emergency Medicine Shock Research Network (EMShockNet) Investigators. Association between arterial hyperoxia fol- lowing resuscitation from cardiac arrest and in-hospital mortality. JAMA. 2010;303:2165–2171. doi: 10.1001/jama.2010.707.

178. Janz DR, Hollenbeck RD, Pollock JS, McPherson JA, Rice TW. Hyperoxia is associated with increased mortality in patients treated with mild therapeutic hypothermia after sudden cardiac arrest. Crit Care Med. 2012;40:3135–3139. doi: 10.1097/CCM.0b013e3182656976.

179. Wang CH, Chang WT, Huang CH, Tsai MS,Yu PH, Wang AY, Chen NC, Chen WJ. The effect of hyperoxia on survival following adult cardiac arrest: a sys- tematic review and meta-analysis of observational studies. Resuscitation. 2014;85:1142–1148. doi: 10.1016/j.resuscitation.2014.05.021.

180. Ukholkina GB, Kostianov IIu, Kuchkina NV, Grendo EP, Gofman IaB. [Effect of oxygenotherapy used in combination with reperfusion in patients with acute myocardial infarction]. Kardiologiia. 2005;45:59.

181. Ranchord AM, Argyle R, Beynon R, Perrin K, Sharma V, Weatherall M, Simmonds M, Heatlie G, Brooks N, Beasley R. High-concentration versus titrated oxygen therapy in ST-elevation myocardial infarction: a pilot ran- domized controlled trial. Am Heart J. 2012;163:168–175. doi: 10.1016/j. ahj.2011.10.013.

182. Stub D, Smith K, Bernard S, Nehme Z, Stephenson M, Bray JE, Cameron P, Barger B, Ellims AH, Taylor AJ, Meredith IT, Kaye DM; AVOID Investigators. Air Versus Oxygen in ST-Segment-Elevation Myocardial Infarction. Circulation. 2015;131:2143–2150. doi: 10.1161/ CIRCULATIONAHA.114.014494.

183. Gurfinkel EP, Manos EJ, Mejail RI, Cerda MA, Duronto EA, Garcia CN, Daroca AM, Mautner B. Low molecular weight heparin versus regular heparin or aspirin in the treatment of unstable angina and silent ischemia. J Am Coll Cardiol. 1995;26:313–318.

184. Collaborative meta-analysis of randomised trials of antiplatelet therapy for prevention of death, myocardial infarction, and stroke in high risk patients. BMJ. 2002;324():71–86.

185. Collaborative overview of randomised trials of antiplatelet therapy–I: Prevention of death, myocardial infarction, and stroke by prolonged antiplatelet therapy in various categories of patients. Antiplatelet Trialists' Collaboration. BMJ. 1994;308():81–106.

186. Feldman M, Cryer B. Aspirin absorption rates and platelet inhibition times with 325-mg buffered aspirin tablets (chewed or swallowed intact) and with buffered aspirin solution. Am J Cardiol. 1999;84:404–409.

187. Sagar KA, Smyth MR. A comparative bioavailability study of different aspirin formulations using on-line multidimensional chromatography. J Pharm Biomed Anal. 1999;21:383–392.

188. McGettigan P, Henry D. Cardiovascular risk and inhibition of cyclooxygenase: a systematic review of the observational studies of selective and nonselective inhibitors of cyclooxygenase 2. Jama. 2006;296:1633–1644.

189. Kearney PM, Baigent C, Godwin J, Halls H, Emberson JR, Patrono C. Do selective cyclo-oxygenase-2 inhibitors and traditional non-steroidal anti-inflammatory drugs increase the risk of atherothrombosis? Meta-analysis of randomised trials. BMJ (Clinical research ed. 2006;332():1302–1308.

190. Gibson IR, Bonfield W. Novel synthesis and characterization of an AB-type carbonate-substituted hydroxyapatite. J Biomed Mater Res. 2002;59:697–708.

191. ISIS-4: a randomised factorial trial assessing early oral captopril, oral mononitrate, and intravenous magnesium sulphate in 58 050 patients with suspected acute myocardial infarction. ISIS-4 (Fourth International Study of Infarct Survival) Collaborative Group. Lancet. 1995;345():669–685.

192. Diercks DB, Boghos E, Guzman H, Amsterdam EA, Kirk JD. Changes in the numeric descriptive scale for pain after sublingual nitroglycerin do not predict cardiac etiology of chest pain. Annals of emergency medicine. 2005;45:581–585.

193. Henrikson CA, Howell EE, Bush DE, Miles JS, Meininger GR, Friedlander T, Bushnell AC, Chandra-Strobos N. Chest pain relief by nitroglycerin does not predict active coronary artery disease. Ann Intern Med. 2003;139:979–986.

194. Steele R, McNaughton T, McConahy M, Lam J. Chest pain in emergency department patients: if the pain is relieved by nitroglycerin, is it more likely to be cardiac chest pain? CJEM. 2006;8:164–169.

195. Baigent C, Collins R, Appleby P, Parish S, Sleight P, Peto R. ISIS-2: 10 year survival among patients with suspected acute myocardial infarction in randomised comparison of intravenous streptokinase, oral aspirin, both, or neither. The ISIS-2 (Second International Study of Infarct Survival) Collaborative Group. Bmj. 1998;316():1337–1343.

196. Franzosi MG, Santoro E, De Vita C, Geraci E, Lotto A, Maggioni AP, Mauri F, Rovelli F, Santoro L, Tavazzi L, Tognoni G. Ten-year follow-up of the first megatrial testing thrombolytic therapy in patients with acute myocardial infarction: results of the Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto-1 study. The GISSI Investigators. Circulation. 1998;98:2659–2665.

197. Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. Lancet. 2003;361():13–20.

198. Indications for fibrinolytic therapy in suspected acute myocardial infarction: collaborative overview of early mortality and major morbidity results from all randomised trials of more than 1000 patients. Fibrinolytic Therapy Trialists' (FTT) Collaborative Group. Lancet. 1994;343():311–322.

199. A comparison of reteplase with alteplase for acute myocardial infarction. The Global Use of Strategies to Open Occluded Coronary Arteries (GUSTO III) Investigators. N Engl J Med. 1997;337:1118–1123.

200. Single-bolus tenecteplase compared with front-loaded alteplase in acute myocardial infarction: the ASSENT-2 double-blind randomised trial. Assessment of the Safety and Efficacy of a New Thrombolytic Investigators. Lancet. 1999;354():716–722.

201. Effectiveness of intravenous thrombolytic treatment in acute myocardial infarction. Gruppo Italiano per lo Studio della Streptochinasi nell'Infarto Miocardico (GISSI). Lancet. 1986;1():397–402.

202. Randomised trial of late thrombolysis in patients with suspected acute myocardial infarction. EMERAS (Estudio Multicentrico Estreptoquinasa Republicas de America del Sur) Collaborative Group. Lancet. 1993;342():767–772.

203. Simoons ML, Maggioni AP, Knatterud G, Leimberger JD, de Jaegere P, van Domburg R, Boersma E, Franzosi MG, Califf R, Schroder Ral. e. Individual risk assessment for intracranial haemorrhage during thrombolytic therapy. Lancet. 1993;342(8886–8887):1523–1528.

204. Hillis LD, Forman S, Braunwald E. Risk stratification before thrombolytic therapy in patients with acute myocardial infarction. The Thrombolysis in Myocardial Infarction (TIMI) Phase II Co-Investigators. J Am Coll Cardiol. 1990;16:313–315.

205. Mahaffey KW, Granger CB, Sloan MA, Thompson TD, Gore JM, Weaver WD, White HD, Simoons ML, Barbash GI, Topol EJ, Califf RM. Risk factors for in-hospital nonhemorrhagic stroke in patients with acute myocardial infarction treated with thrombolysis: results from GUSTO-I. Circulation. 1998;97:757–764.

206. Gore JM, Granger CB, Simoons ML, Sloan MA, Weaver WD, White HD, Barbash GI, Van de Werf F, Aylward PE, Topol EJ, et al. Stroke after thrombolysis. Mortality and functional outcomes in the GUSTO-I trial. Global Use of Strategies to Open Occluded Coronary Arteries. Circulation. 1995;92:2811–2818.

207. White HD, Barbash GI, Califf RM, Simes RJ, Granger CB, Weaver WD, Kleiman NS, Aylward PE, Gore JM, Vahanian A, Lee KL, Ross AM, Topol EJ. Age and outcome with contemporary thrombolytic therapy. Results from the GUSTO-I trial. Global Utilization of Streptokinase and TPA for Occluded coronary arteries trial. Circulation. 1996;94:1826–1833.

208. Thiemann DR, Coresh J, Schulman SP, Gerstenblith G, Oetgen WJ, Powe NR. Lack of benefit for intravenous thrombolysis in patients with myocardial infarction who are older than 75 years. Circulation. 2000;101:2239–2246.

209. An international randomized trial comparing four thrombolytic strategies for acute myocardial infarction. The GUSTO investigators. N Engl J Med. 1993;329:673–682.

210. Collins R, Peto R, Parish S, Sleight P. ISIS-3 and GISSI-2: no survival advantage with tissue plasminogen activator over streptokinase, but a significant excess of strokes with tissue plasminogen activator in both trials. Am J Cardiol. 1993;71:1127–1130.

211. Randomised placebo-controlled and balloon-angioplasty-controlled trial to assess safety of coronary stenting with use of platelet glycoprotein-IIb/IIIa blockade. The EPISTENT Investigators. Evaluation of Platelet IIb/IIIa Inhibitor for Stenting. Lancet. 1998;352():87–92.

212. Selker HP, Griffith JL, D'Agostino RB. A tool for judging coronary care unit admission appropriateness, valid for both real-time and retrospective use. A time-insensitive predictive instrument (TIPI) for acute cardiac ischemia: a multicenter study. Med Care. 1991;29:610–627.

213. Magid DJ, Calonge BN, Rumsfeld JS, Canto JG, Frederick PD, Every NR, Barron HV. Relation between hospital primary angioplasty volume and mortality for patients with acute MI treated with primary angioplasty vs thrombolytic therapy. JAMA. 2000;284:3131–3138.

214. Canto JG, Every NR, Magid DJ, Rogers WJ, Malmgren JA, Frederick PD, French WJ, Tiefenbrunn AJ, Misra VK, Kiefe CI, Barron HV. The volume of primary angioplasty procedures and survival after acute myocardial infarction. National Registry of Myocardial Infarction 2 Investigators. N Engl J Med. 2000;342:1573–1580.

215. Dalby M, Bouzamondo A, Lechat P, Montalescot G. Transfer for primary angioplasty versus immediate thrombolysis in acute myocardial infarction: a meta-analysis. Circulation. 2003;108:1809–1814.

216. Cantor WJ, Fitchett D, Borgundvaag B, Ducas J, Heffernan M, Cohen EA, Morrison LJ, Langer A, Dzavik V, Mehta SR, Lazzam C, Schwartz B, Casanova A, Goodman SG. Routine early angioplasty after fibrinolysis for acute myocardial infarction. N Engl J Med. 2009;360:2705–2718.

217. Welsh RC, Travers A, Senaratne M, Williams R, Armstrong PW. Feasibility and applicability of paramedic-based prehospital fibrinolysis in a large North American center. Am Heart J. 2006;152:1007–1014. doi: 10.1016/j.ahj.2006.06.022.

218.

Castaigne AD, Hervé C, Duval-Moulin AM, Gaillard M, Dubois-Rande JL, Boesch C, Wolf M, Lellouche D, Jan F, Vernant P. Prehospital use of APSAC: results of a placebo-controlled study. Am J Cardiol. 1989;64:30A–33A; discussion 41A.

219. Schofer J, Büttner J, Geng G, Gutschmidt K, Herden HN, Mathey DG, Moecke HP, Polster P, Raftopoulo A, Sheehan FH. Prehospital thromboly- sis in acute myocardial infarction. Am J Cardiol. 1990;66:1429–1433.

220. Weaver WD, Cerqueira M, Hallstrom AP, Litwin PE, Martin JS, Kudenchuk PJ, Eisenberg M. Prehospital-initiated vs hospital-initiated thrombolytic therapy. The Myocardial Infarction Triage and Intervention Trial. JAMA. 1993;270:1211–1216.

221. Zeymer U, Arntz HR, Dirks B, Ellinger K, Genzwürker H, Nibbe L, Tebbe U, Senges J, Schneider S; PREMIR-Investigators. Reperfusion rate and inhospital mortality of patients with ST segment elevation myocardial infarction diagnosed already in the prehospital phase: results of the German Prehospital Myocardial Infarction Registry (PREMIR). Resuscitation. 2009;80:402–406. doi: 10.1016/j.resuscitation.2008.12.004.

222. Hartwell D, Colquitt J, Loveman E, Clegg AJ, Brodin H, Waugh N, Royle P, Davidson P, Vale L, MacKenzie L. Clinical effectiveness and cost-effectiveness of immediate angioplasty for acute myocardial infarc- tion: systematic review and economic evaluation. Health Technol Assess. 2005;9:1–99, iii.

223. Bonnefoy E, Lapostolle F, Leizorovicz A, Steg G, McFadden EP, Dubien PY, Cattan S, Boullenger E, Machecourt J, Lacroute JM, Cassagnes J, Dissait F, Touboul P; Comparison of Angioplasty and Prehospital Thromboysis in Acute Myocardial Infarction study group. Primary angioplasty versus prehospital fibrinolysis in acute myocardial infarc- tion: a randomised study. Lancet. 2002;360:825–829. doi: 10.1016/ S0140-6736(02)09963-4.

224. Armstrong PW; WEST Steering Committee. A comparison of pharmaco- logic therapy with/without timely coronary intervention vs. primary per- cutaneous intervention early after ST-elevation myocardial infarction: the WEST (Which Early ST-elevation myocardial infarction Therapy) study. Eur Heart J. 2006;27:1530–1538. doi: 10.1093/eurheartj/ehl088.

225. Thiele H, Eitel I, Meinberg C, Desch S, Leuschner A, Pfeiffer D, Hartmann A, Lotze U, Strauss W, Schuler G; LIPSIA-STEMI Trial Group. Randomized comparison of pre-hospital-initiated facilitated percutaneous coronary intervention versus primary percutaneous coronary interven- tion in acute myocardial infarction very early after symptom onset: the LIPSIA-STEMI trial (Leipzig immediate prehospital facilitated angio- plasty in ST-segment myocardial infarction). JACC Cardiovasc Interv. 2011;4:605–614. doi: 10.1016/j.jcin.2011.01.013.

226. Armstrong PW, Gershlick AH, Goldstein P, Wilcox R, Danays T, Lambert Y, Sulimov V, Rosell Ortiz F, Ostojic M, Welsh RC, Carvalho AC, Nanas J, Arntz HR, Halvorsen S, Huber K, Grajek S, Fresco C, Bluhmki E, Regelin A, Vandenberghe K, Bogaerts K, Van de Werf F; STREAM Investigative Team. Fibrinolysis or primary PCI in ST-segment elevation myocardial infarction. N Engl J Med. 2013;368:1379–1387. doi: 10.1056/NEJMoa1301092.

227. Primary versus tenecteplase-facilitated percutaneous coronary interven- tion in patients with ST-segment elevation acute myocardial infarction (ASSENT-4 PCI): randomised trial. Lancet. 2006;367:569–578.

228. Ellis SG, Tendera M, de Belder MA, van Boven AJ, Widimsky P, Janssens L, Andersen HR, Betriu A, Savonitto S, Adamus J, Peruga JZ, Kosmider M, Katz O, Neunteufl T, Jorgova J, Dorobantu M, Grinfeld L, Armstrong P, Brodie BR, Herrmann HC, Montalescot G, Neumann FJ, Effron MB, Barnathan ES, Topol EJ; FINESSE Investigators. Facilitated PCI in patients with ST-elevation myocardial infarction. N Engl J Med. 2008;358:2205–2217. doi: 10.1056/NEJMoa0706816.

229. Itoh T, Fukami K, Suzuki T, Kimura T, Kanaya Y, Orii M, Goto I, Matsui H, Sugawara S, Nakajima S, Fusazaki T, Nakamura M; IMPORTANT investigators. Comparison of long-term prognostic evaluation between pre-intervention thrombolysis and primary coronary intervention: a pro- spective randomized trial: five-year results of the IMPORTANT study. Circ J. 2010;74:1625–1634.

230. Kurihara H, Matsumoto S, Tamura R, Yachiku K, Nakata A, Nakagawa T, Yoshino T, Matsuyama T. Clinical outcome of percutaneous coronary intervention with antecedent mutant t-PA administration for acute myocardial infarction. Am Heart J. 2004;147:E14. doi: 10.1016/j.ahj.2003.10.028.

231. Thiele H, Scholz M, Engelmann L, Storch WH, Hartmann A, Dimmel G, Pfeiffer D, Schuler G; Leipzig Prehospital Fibrinolysis Group. ST-segment recovery and prognosis in patients with ST-elevation myocar- dial infarction reperfused by prehospital combination fibrinolysis, prehos- pital initiated facilitated percutaneous coronary intervention, or primary percutaneous coronary intervention. Am J Cardiol. 2006;98:1132–1139. doi: 10.1016/j.amjcard.2006.05.044.

232. Zijlstra F, Patel A, Jones M, Grines CL, Ellis S, Garcia E, Grinfeld L, Gibbons RJ, Ribeiro EE, Ribichini F, Granger C, Akhras F, Weaver WD, Simes RJ. Clinical characteristics and outcome of patients with early (4 h) presentation treated by primary coronary angioplasty or thrombolytic therapy for acute myocardial infarc- tion. Eur Heart J. 2002;23:550–557. doi: 10.1053/euhj.2001.2901.

233. Grines CL, Serruys P, O'Neill WW. Fibrinolytic therapy: is it a treat- ment of the past? Circulation. 2003;107:2538–2542. doi: 10.1161/01. CIR.0000075292.29458.BB.

234. Westerhout CM, Bonnefoy E, Welsh RC, Steg PG, Boutitie F, Armstrong PW. The influence of time from symptom onset and reperfusion strategy on 1-year survival in ST-elevation myocardial infarction: a pooled analy- sis of an early fibrinolytic strategy versus primary percutaneous coronary intervention from CAPTIM and WEST. Am Heart J. 2011;161:283–290. doi: 10.1016/j.ahj.2010.10.033.

235.

Bonnefoy E, Steg PG, Boutitie F, Dubien PY, Lapostolle F, Roncalli J, Dissait F, Vanzetto G, Leizorowicz A, Kirkorian G, Mercier C, McFadden EP, Touboul P; CAPTIM Investigators. Comparison of primary angio- plasty and pre-hospital fibrinolysis in acute myocardial infarction (CAPTIM) trial: a 5-year follow-up. Eur Heart J. 2009;30:1598–1606. doi: 10.1093/eurheartj/ehp156.

236. Steg PG, Bonnefoy E, Chabaud S, Lapostolle F, Dubien PY, Cristofini P, Leizorovicz A, Touboul P; Comparison of Angioplasty and Prehospital Thrombolysis In acute Myocardial infarction (CAPTIM) Investigators. Impact of time to treatment on mortality after prehospital fibrinolysis or primary angioplasty: data from the CAPTIM randomized clinical trial. Circulation. 2003;108:2851–2856. doi: 10.1161/01.CIR.0000103122.10021.F2.

237. Widimský P, Budesínský T, Vorác D, Groch L, Zelízko M, Aschermann M, Branny M, St'ásek J, Formánek P; 'PRAGUE' Study Group Investigators. Long distance transport for primary angioplasty vs immediate thromboly- sis in acute myocardial infarction. Final results of the randomized national multicentre trial–PRAGUE-2. Eur Heart J. 2003;24:94–104.

238. Tarantini G, Razzolini R, Napodano M, Bilato C, Ramondo A, Iliceto S. Acceptable reperfusion delay to prefer primary angioplasty over fibrin- specific thrombolytic therapy is affected (mainly) by the patient's mortal- ity risk: 1 h does not fit all. Eur Heart J. 2010;31:676–683. doi: 10.1093/ eurheartj/ehp506.

239. Widimsky P. Primary angioplasty vs. thrombolysis: the end of the contro- versy? Eur Heart J. 2010;31:634–636. doi: 10.1093/eurheartj/ehp535.

240. Kushner FG, Hand M, Smith SC Jr., King SB III., Anderson JL, Antman EM, Bailey SR, Bates ER, Blankenship JC, Casey DE Jr., Green LA, Hochman JS, Jacobs AK, Krumholz HM, Morrison DA, Ornato JP, Pearle DL, Peterson ED, Sloan MA, Whitlow PL, Williams DO. 2009 Focused Updates: ACC/AHA Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction (updating the 2004 Guideline and 2007 Focused Update) and ACC/AHA/SCAI Guidelines on Percutaneous Coronary Intervention (updating the 2005 Guideline and 2007 Focused Update): a report of the Am College of Cardiology Foundation/Am Heart Association Task Force on Practice Guidelines. Circulation. 2009;120:2271–2306.

241. Di Mario C, Dudek D, Piscione F, Mielecki W, Savonitto S, Murena E, Dimopoulos K, Manari A, Gaspardone A, Ochala A, Zmudka K, Bolognese L, Steg PG, Flather M. Immediate angioplasty versus standard therapy with rescue angioplasty after thrombolysis in the Combined Abciximab REteplase Stent Study in Acute Myocardial Infarction (CARESS-in-AMI): an open, prospective, randomised, multicentre trial. Lancet. 2008;371():559–568.

242. Fibrinolytic Therapy Trialists' (FTT) Collaborative Group. Indications for fibrinolytic therapy in suspected acute myocardial infarction: collabora- tive overview of early mortality and major morbidity results from all ran- domised trials of more than 1000 patients. Lancet. 1994;343:311–322.

243. Hochman JS, Sleeper LA, Webb JG, Sanborn TA, White HD, Talley JD, Buller CE, Jacobs AK, Slater JN, Col J, McKinlay SM, LeJemtel TH. Early revascularization in acute myocardial infarction complicated by cardiogenic shock. SHOCK Investigators. Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock. N Engl J Med. 1999;341:625–634. doi: 10.1056/NEJM199908263410901.

244. Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intrave- nous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. Lancet. 2003;361:13–20. doi: 10.1016/ S0140-6736(03)12113-7.

245. Andersen HR, Nielsen TT, Rasmussen K, Thuesen L, Kelbaek H, Thayssen P, Abildgaard U, Pedersen F, Madsen JK, Grande P, Villadsen AB, Krusell LR, Haghfelt T, Lomholt P, Husted SE, Vigholt E, Kjaergard HK, Mortensen LS; DANAMI-2 Investigators. A comparison of coronary angioplasty with fibrinolytic therapy in acute myocardial infarction. N Engl J Med. 2003;349:733–742. doi: 10.1056/NEJMoa025142.

246. Dieker HJ, van Horssen EV, Hersbach FM, Brouwer MA, van Boven AJ, van 't Hof AW, Aengevaeren WR, Verheugt FW, Bär FW. Transport for abciximab facilitated primary angioplasty versus on-site thrombolysis with a liberal rescue policy: the randomised Holland Infarction Study (HIS). J Thromb Thrombolysis. 2006;22:39–45. doi: 10.1007/s11239-006-7731-6.

247. Dobrzycki S, Kralisz P, Nowak K, Prokopczuk P, Kochman W, Korecki J, Poniatowski B, Zuk J, Sitniewska E, Bachorzewska-Gajewska H, Sienkiewicz J, Musial WJ. Transfer with GP IIb/IIIa inhibitor tirofiban for primary percutaneous coronary intervention vs. on-site thrombolysis in patients with ST-elevation myocardial infarction (STEMI): a randomized open-label study for patients admitted to community hospitals. Eur Heart J. 2007;28:2438–2448. doi: 10.1093/eurheartj/ehm369.

248. Grines CL, Westerhausen DR Jr, Grines LL, Hanlon JT, Logemann TL, Niemela M, Weaver WD, Graham M, Boura J, O'Neill WW, Balestrini C; Air PAMI Study Group. A randomized trial of transfer for primary angio- plasty versus on-site thrombolysis in patients with high-risk myocardial infarction: the Air Primary Angioplasty in Myocardial Infarction study. J Am Coll Cardiol. 2002;39:1713–1719.

249. Svensson L, Aasa M, Dellborg M, Gibson CM, Kirtane A, Herlitz J, Ohlsson A, Karlsson T, Grip L. Comparison of very early treatment with either fibrinolysis or percutaneous coronary intervention facilitated with abciximab with respect to ST recovery and infarct-related artery epicardial flow in patients with acute ST-segment elevation myocardial infarction: the Swedish Early Decision (SWEDES) reperfusion trial. Am Heart J. 2006;151:798.e1–798.e7. doi: 10.1016/j.ahj.2005.09.013.

250. Vermeer F, Oude Ophuis AJ, vd Berg EJ, Brunninkhuis LG, Werter CJ, Boehmer AG, Lousberg AH, Dassen WR, Bär FW. Prospective ran- domised comparison between thrombolysis, rescue PTCA, and primary PTCA in patients with extensive myocardial infarction admitted to a hospital without PTCA facilities: a safety and feasibility study. Heart. 1999;82:426–431.

251.

Widimský P, Groch L, Zelízko M, Aschermann M, Bednár F, Suryapranata H. Multicentre randomized trial comparing transport to primary angio- plasty vs immediate thrombolysis vs combined strategy for patients with acute myocardial infarction presenting to a community hospital without a catheterization laboratory. The PRAGUE study. Eur Heart J. 2000;21:823–831. doi: 10.1053/euhj.1999.1993.

252. Fernández-Avilés F, Alonso JJ, Peña G, Blanco J, Alonso-Briales J, López- Mesa J, Fernández-Vázquez F, Moreu J, Hernández RA, Castro-Beiras A, Gabriel R, Gibson CM, Sánchez PL; GRACIA-2 (Groupo de Análisis de Cardiopatía Isquémica Aguda) Investigators. Primary angioplasty vs. early routine post-fibrinolysis angioplasty for acute myocardial infarction with ST-segment elevation: the GRACIA-2 non-inferiority, randomized, con- trolled trial. Eur Heart J. 2007;28:949–960. doi: 10.1093/eurheartj/ehl461.

253. Danchin N, Coste P, Ferrières J, Steg PG, Cottin Y, Blanchard D, Belle L, Ritz B, Kirkorian G, Angioi M, Sans P, Charbonnier B, Eltchaninoff H, Guéret P, Khalife K, Asseman P, Puel J, Goldstein P, Cambou JP, Simon T; FAST-MI Investigators. Comparison of thrombolysis followed by broad use of percuta- neous coronary intervention with primary percutaneous coronary intervention for ST-segment-elevation acute myocardial infarction: data from the french registry on acute ST-elevation myocardial infarction (FAST-MI). Circulation. 2008;118:268–276. doi: 10.1161/CIRCULATIONAHA.107.762765.

254. Scheller B, Hennen B, Hammer B, Walle J, Hofer C, Hilpert V, Winter H, Nickenig G, Böhm M; SIAM III Study Group. Beneficial effects of immediate stenting after thrombolysis in acute myocardial infarction. J Am Coll Cardiol. 2003;42:634–641.

255. Fernandez-Avilés F, Alonso JJ, Castro-Beiras A, Vázquez N, Blanco J, Alonso-Briales J, López-Mesa J, Fernández-Vazquez F, Calvo I, Martínez-Elbal L, San Román JA, Ramos B; GRACIA (Grupo de Análisis de la Cardiopatía Isquémica Aguda) Group. Routine invasive strategy within 24 hours of thrombolysis versus ischaemia-guided conservative approach for acute myocardial infarction with ST-segment elevation (GRACIA-1): a randomised controlled trial. Lancet. 2004;364:1045– 1053. doi: 10.1016/S0140-6736(04)17059-1.

256. Le May MR, Wells GA, Labinaz M, Davies RF, Turek M, Leddy D, Maloney J, McKibbin T, Quinn B, Beanlands RS, Glover C, Marquis JF, O'Brien ER, Williams WL, Higginson LA. Combined angioplasty and pharmacological intervention versus thrombolysis alone in acute myocardial infarction (CAPITAL AMI study). J Am Coll Cardiol. 2005;46:417–424. doi: 10.1016/j.jacc.2005.04.042.

257. Cantor WJ, Fitchett D, Borgundvaag B, Ducas J, Heffernan M, Cohen EA, Morrison LJ, Langer A, Dzavik V, Mehta SR, Lazzam C, Schwartz B, Casanova A, Goodman SG; TRANSFER-AMI Trial Investigators. Routine early angioplasty after fibrinolysis for acute myo-cardial infarction. N Engl J Med. 2009;360:2705–2718. doi: 10.1056/ NEJMoa0808276.

258. Bøhmer E, Hoffmann P, Abdelnoor M, Arnesen H, Halvorsen S. Efficacy and safety of immediate angioplasty versus ischemia-guided manage- ment after thrombolysis in acute myocardial infarction in areas with very long transfer distances results of the NORDISTEMI (NORwegian study on DIstrict treatment of ST-elevation myocardial infarction). J Am Coll Cardiol. 2010;55:102–110. doi: 10.1016/j.jacc.2009.08.007.

259. Bednár F, Widimský P, Krupicka J, Groch L, Aschermann M, Zelízko M; PRAGUE Study Group Investigators. Interhospital transport for primary angioplasty improves the long-term outcome of acute myocar- dial infarction compared with immediate thrombolysis in the nearest hospital (one-year follow-up of the PRAGUE-1 study). Can J Cardiol. 2003;19:1133–1137.

260. Bagai A, Cantor WJ, Tan M, Tong W, Lamy A, Fitchett D, Cohen EA, Mehta SR, Borgundvaag B, Ducas J, Heffernan M, Džavík V, Morrison L, Schwartz B, Lazzam C, Langer A, Goodman SG. Clinical outcomes and cost implications of routine early PCI after fibrinolysis: one- year follow-up of the Trial of Routine Angioplasty and Stenting after Fibrinolysis to Enhance Reperfusion in Acute Myocardial Infarction (TRANSFER-AMI) study. Am Heart J. 2013;165:630–637.e2. doi: 10.1016/j.ahj.2012.12.016.

261. Hollenbeck RD, McPherson JA, Mooney MR, Unger BT, Patel NC, McMullan PW Jr, Hsu CH, Seder DB, Kern KB. Early cardiac cath-eterization is associated with improved survival in comatose survivors of cardiac arrest without STEMI. Resuscitation. 2014;85:88–95. doi: 10.1016/j.resuscitation.2013.07.027.

262. Mooney MR, Unger BT, Boland LL, Burke MN, Kebed KY, Graham KJ, Henry TD, Katsiyiannis WT, Satterlee PA, Sendelbach S, Hodges JS, Parham WM. Therapeutic hypothermia after out-of-hospital cardiac arrest: evaluation of a regional system to increase access to cooling. Circulation. 2011;124:206–214. doi: 10.1161/CIRCULATIONAHA.110.986257.

263. Gräsner JT, Meybohm P, Lefering R, Wnent J, Bahr J, Messelken M, Jantzen T, Franz R, Scholz J, Schleppers A, Böttiger BW, Bein B, Fischer M; German Resuscitation Registry Study Group. ROSC after cardiac arrest–the RACA score to predict outcome after out-of-hospital cardiac arrest. Eur Heart J. 2011;32:1649–1656. doi: 10.1093/eurheartj/ehr107.

264. Cronier P, Vignon P, Bouferrache K, Aegerter P, Charron C, Templier F, Castro S, El Mahmoud R, Lory C, Pichon N, Dubourg O, Vieillard- Baron A. Impact of routine percutaneous coronary intervention after out-of-hospital cardiac arrest due to ventricular fibrillation. Crit Care. 2011;15:R122. doi: 10.1186/cc10227.

265. Bulut S, Aengevaeren WR, Luijten HJ, Verheugt FW. Successful out-of- hospital cardiopulmonary resuscitation: what is the optimal in-hospital treatment strategy? Resuscitation. 2000;47:155–161.

266. Bro-Jeppesen J, Kjaergaard J, Wanscher M, Pedersen F, Holmvang L, Lippert FK, Møller JE, Køber L, Hassager C. Emergency coronary an- giography in comatose cardiac arrest patients: do real-life experiences support the guidelines? Eur Heart J Acute Cardiovasc Care. 2012;1:291– 301. doi: 10.1177/2048872612465588.

267. Aurore A, Jabre P, Liot P, Margenet A, Lecarpentier E, Combes X. Predictive factors for positive coronary angiography in out-of-hospital cardiac arrest patients. Eur J Emerg Med. 2011;18:73–76. doi: 10.1097/MEJ.0b013e32833d469a.

268. Nanjayya VB, Nayyar V. Immediate coronary angiogram in comatose survivors of out-of-hospital cardiac arrest–an Australian study. Resuscitation. 2012;83:699–704. doi: 10.1016/j.resuscitation.2011.12.004.

269. Reynolds JC, Callaway CW, El Khoudary SR, Moore CG, Alvarez RJ, Rittenberger JC. Coronary angiography predicts improved outcome fol- lowing cardiac arrest: propensity-adjusted analysis. J Intensive Care Med. 2009;24:179–186. doi: 10.1177/0885066609332725.

270. Strote JA, Maynard C, Olsufka M, Nichol G, Copass MK, Cobb LA, Kim F. Comparison of role of early (less than six hours) to later (more than six hours) or no cardiac catheterization after resuscitation from out-of- hospital cardiac arrest. Am J Cardiol. 2012;109:451–454. doi: 10.1016/j. amjcard.2011.09.036.

271. Tømte O, Andersen GØ, Jacobsen D, Drægni T, Auestad B, Sunde K. Strong and weak aspects of an established post-resuscitation treatment protocol-A five-year observational study. Resuscitation. 2011;82:1186– 1193. doi: 10.1016/j.resuscitation.2011.05.003.

272. Waldo SW, Armstrong EJ, Kulkarni A, Hoffmayer K, Kinlay S, Hsue P, Ganz P, McCabe JM. Comparison of clinical characteristics and outcomes of cardiac arrest survivors having versus not having coro- nary angiography. Am J Cardiol. 2013;111:1253–1258. doi: 10.1016/j. amjcard.2013.01.267.

273. Nielsen N, Hovdenes J, Nilsson F, Rubertsson S, Stammet P, Sunde K, Valsson F, Wanscher M, Friberg H; Hypothermia Network. Outcome, timing and adverse events in therapeutic hypothermia after out-of-hos- pital cardiac arrest. Acta Anaesthesiol Scand. 2009;53:926–934. doi: 10.1111/j.1399-6576.2009.02021.x.

274. Werling M, Thorén AB, Axelsson C, Herlitz J. Treatment and outcome in post-resuscitation care after out-of-hospital cardiac arrest when a modern therapeutic approach was introduced. Resuscitation. 2007;73:40–45. doi: 10.1016/j.resuscitation.2006.08.018.

275. Zanuttini D, Armellini I, Nucifora G, Carchietti E, Trillò G, Spedicato L, Bernardi G, Proclemer A. Impact of emergency coronary angiogra- phy on in-hospital outcome of unconscious survivors after out-of-hos- pital cardiac arrest. Am J Cardiol. 2012;110:1723–1728. doi: 10.1016/j. amjcard.2012.08.006.

276. Tømte O, Andersen GØ, Jacobsen D, Drægni T, Auestad B, Sunde K. Strong and weak aspects of an established post-resuscitation treatment protocol-A five-year observational study. Resuscitation. 2011;82:1186– 1193. doi: 10.1016/j.resuscitation.2011.05.003.

277. Holmes DR Jr., Bates ER, Kleiman NS, Sadowski Z, Horgan JH, Morris DC, Califf RM, Berger PB, Topol EJ. Contemporary reperfusion therapy for cardiogenic shock: the GUSTO-I trial experience. The GUSTO-I Investigators. Global Utilization of Streptokinase and Tissue Plasminogen Activator for Occluded Coronary Arteries. J Am Coll Cardiol. 1995;26:668–674.

278. Babaev A, Frederick PD, Pasta DJ, Every N, Sichrovsky T, Hochman JS. Trends in management and outcomes of patients with acute myocardial infarction complicated by cardiogenic shock. Jama. 2005;294:448–454.

279. Goldberg RJ, Spencer FA, Gore JM, Lessard D, Yarzebski J. Thirty-year trends (1975 to 2005) in the magnitude of, management of, and hospital death rates associated with cardiogenic shock in patients with acute myocardial infarction: a population-based perspective. Circulation. 2009;119:1211–1219.

280. Hochman JS, Sleeper LA, Webb JG, Dzavik V, Buller CE, Aylward P, Col J, White HD. Early revascularization and long-term survival in cardiogenic shock complicating acute myocardial infarction. Jama. 2006;295:2511–2515.

281. Singh M, White J, Hasdai D, Hodgson PK, Berger PB, Topol EJ, Califf RM, Holmes DR Jr.. Long-term outcome and its predictors among patients with ST-segment elevation myocardial infarction complicated by shock: insights from the GUSTO-I trial. J Am Coll Cardiol. 2007;50:1752–1758.

282. Sleeper LA, Ramanathan K, Picard MH, Lejemtel TH, White HD, Dzavik V, Tormey D, Avis NE, Hochman JS. Functional status and quality of life after emergency revascularization for cardiogenic shock complicating acute myocardial infarction. J Am Coll Cardiol. 2005;46:266–273.

283. Califf RM, Bengtson JR. Cardiogenic shock. N Engl J Med. 1994;330:1724–1730.

284. Zehender M, Kasper W, Kauder E, Schonthaler M, Geibel A, Olschewski M, Just H. Right ventricular infarction as an independent predictor of prognosis after acute inferior myocardial infarction. N Engl J Med. 1993;328:981–988.

285. Berger PB, Ruocco NA Jr., Ryan TJ, Jacobs AK, Zaret BL, Wackers FJ, Frederick MM, Faxon DP. Frequency and significance of right ventricular dysfunction during inferior wall left ventricular myocardial infarction treated with thrombolytic therapy (results from the thrombolysis in myocardial infarction [TIMI] II trial). The TIMI Research Group. Am J Cardiol. 1993;71:1148–1152.

286. Goldstein JA, Barzilai B, Rosamond TL, Eisenberg PR, Jaffe AS. Determinants of hemodynamic compromise with severe right ventricular infarction. Circulation. 1990;82:359–368.

287. Di Pasquale P, Bucca V, Scalzo S, Cannizzaro S, Giubilato A, Paterna S. Does the addition of losartan improve the beneficial effects of ACE inhibitors in patients with anterior myocardial infarction? A pilot study. Heart (British Cardiac Society). 1999;81:606–611.

288. Kingma JH, van Gilst WH, Peels CH, Dambrink JH, Verheugt FW, Wielenga RP. Acute intervention with captopril during thrombolysis in patients with first anterior myocardial infarction. Results from the Captopril and Thrombolysis Study (CATS). Eur Heart J. 1994;15:898–907.

289. van Gilst WH, Kingma JH, Peels KH, Dambrink JH, St John Sutton M. Which patient benefits from early angiotensin-converting enzyme inhibition after myocardial infarction? Results of one-year serial echocardiographic follow-up from the Captopril and Thrombolysis Study (CATS). J Am Coll Cardiol. 1996;28:114–121.

290. de Kam PJ, Voors AA, van den Berg MP, van Veldhuisen DJ, Brouwer J, Crijns HJ, Borghi C, Ambrosioni E, Hochman JS, LeJemtel TH, Kingma JH, Sutton MS, van Gilst WH. Effect of very early angiotensin-converting enzyme inhibition on left ventricular dilation after myocardial infarction in patients receiving thrombolysis: results of a meta-analysis of 845 patients. FAMIS, CAPTIN and CATS Investigators. Journal of the Am College of Cardiology. 2000;36:2047–2053.

291. Voors AA, de Kam PJ, van den Berg MP, Borghi C, Hochman JS, van Veldhuisen DJ, van Gilst WH. Acute administration of angiotensin converting enzyme inhibitors in thrombolysed myocardial infarction patients is associated with a decreased incidence of heart failure, but an increased re-infarction risk. Cardiovasc Drugs Ther. 2005;19:119–124.

292. Pantridge JF, Geddes JS. A mobile intensive-care unit in the management of myocardial infarction. Lancet. 1967;2():271–273.

293. Cohen MC, Rohtla KM, Lavery CE, Muller JE, Mittleman MA. Meta-analysis of the morning excess of acute myocardial infarction and sudden cardiac death [published correction appears in Am J Cardiol. 1998;81:260]. Am J Cardiol. 1997;79:1512–1516.

294. Colquhoun MC, Julien DG Sudden death in the community–the arrhythmia causing cardiac arrest and results of immediate resuscitation. Resuscitation. 1992;24:177A.

295. Campbell RW, Murray A, Julian DG. Ventricular arrhythmias in first 12 hours of acute myocardial infarction: natural history study. Br Heart J. 1981;46:351–357.

296. O'Doherty M, Tayler DI, Quinn E, Vincent R, Chamberlain DA. Five hundred patients with myocardial infarction monitored within one hour of symptoms. BMJ. 1983;286():1405–1408.

297. Lie KI, Wellens HJ, Downar E, Durrer D. Observations on patients with primary ventricular fibrillation complicating acute myocardial infarction. Circulation. 1975;52:755–759.

298. MacMahon S, Collins R, Peto R, Koster RW, Yusuf S. Effects of prophylactic lidocaine in suspected acute myocardial infarction: an overview of results from the randomized, controlled trials. JAMA. 1988;260:1910–1916.

299. Elizari MV, Martinez JM, Belziti C, Ciruzzi M, Perez de la Hoz R, Sinisi A, Carbajales J, Scapin O, Garguichevich J, Girotti L, Cagide A. Morbidity and mortality following early administration of amiodarone in acute myocardial infarction. GEMICA study investigators, GEMA Group, Buenos Aires, Argentina. Grupo de Estudios Multicentricos en Argentina. Eur Heart J. 2000;21:198–205. Copyright 2010 American Heart Association, Inc., European Resuscitation Council, and International Liaison Committee on Resuscitation.

Part 10: Special Circumstances of Resuscitation

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiac arrest defibrillation emergency

1 Highlights & Introduction

1.1 Highlights

Summary of Key Issues and Major Changes

- Experience with treatment of patients with known or suspected opioid overdose has demonstrated that naloxone can be administered with apparent safety and effectiveness in the first aid and BLS settings. For this reason, naloxone administration by lay rescuers and HCPs is now recommended, and simplified training is being offered. In addition, a new algorithm for management of unresponsive victims with suspected opioid overdose is provided.
- Intravenous lipid emulsion (ILE) may be considered for treatment of local anesthetic systemic toxicity. In addition, a new recommendation is provided, supporting a possible role for ILE in patients who have cardiac arrest and are failing standard resuscitative measures as the result of drug toxicity other than local anesthetic systemic toxicity.
- The importance of high-quality CPR during any cardiac arrest has led to a reassessment of the recommendations about relief of aortocaval compression during cardiac arrest in pregnancy. This reassessment has resulted in refined recommendations about strategies for uterine displacement.

Opioid Overdose Education and Naloxone Training and Distribution

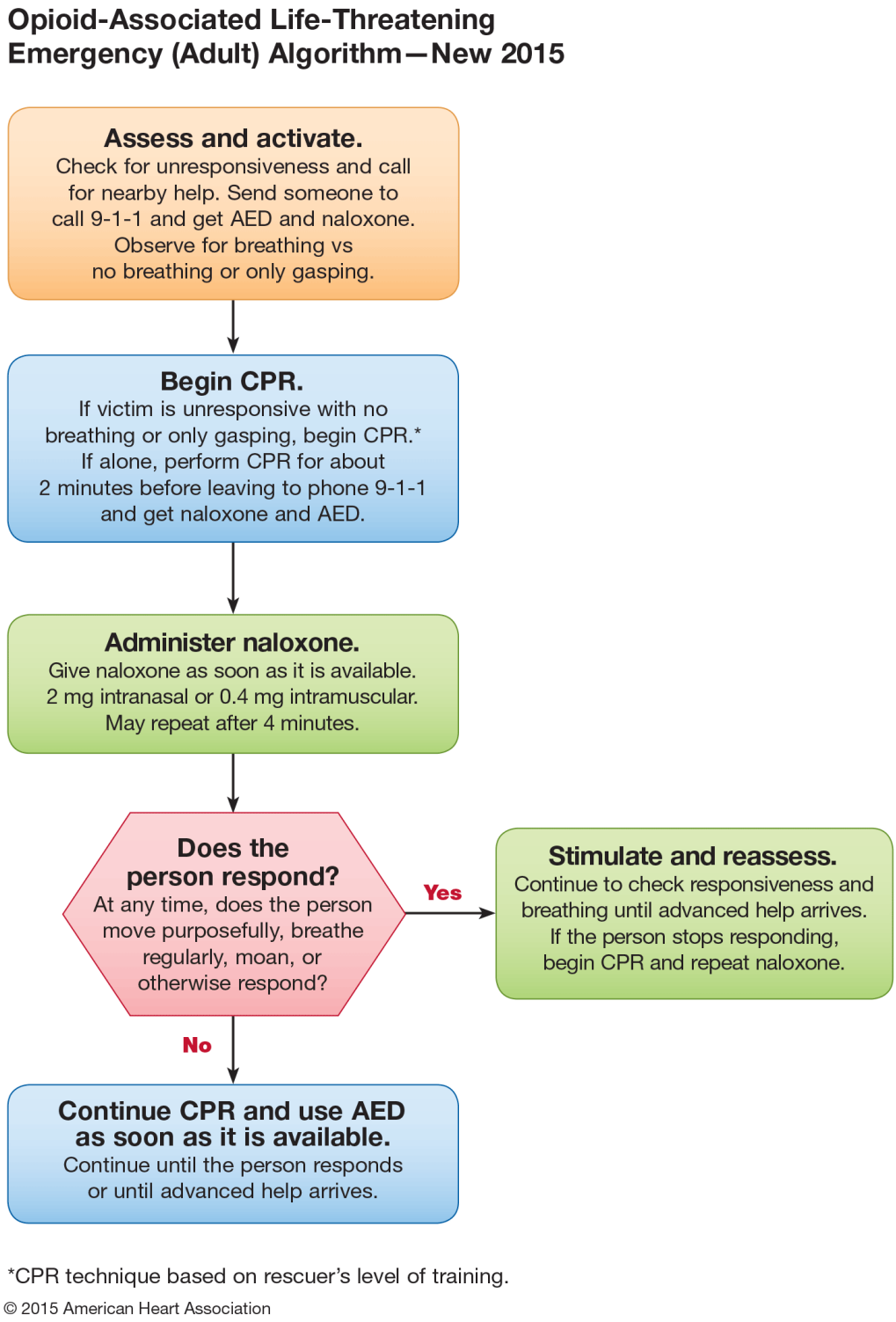
2015 (New): It is reasonable to provide opioid overdose response education, either alone or coupled with naloxone distribution and training, to persons at risk for opioid overdose (or those living with or in frequent contact with such persons). It is reasonable to base this training on first aid and non-HCP BLS recommendations rather than on more advanced practices intended for HCPs.

Opioid Overdose Treatment

2015 (New): Empiric administration of IM or IN naloxone to all unresponsive victims of possible opioid-associated life-threatening emergency may be reasonable as an adjunct to standard first aid and non-HCP BLS protocols. For patients with known or suspected opioid overdose who have a definite pulse but no normal breathing or only gasping (ie, a respiratory arrest), in addition to providing standard care, it is reasonable for appropriately trained rescuers to administer IM or IN naloxone to patients with an opioid-associated respiratory emergency (Figure 1). Responders
should not delay access to more advanced medical services while awaiting the patient's response to naloxone or other interventions.

Empiric administration of IM or IN naloxone to all unresponsive opioid-associated resuscitative emergency patients may be reasonable as an adjunct to standard first aid and non-HCP BLS protocols. Standard resuscitation procedures, including EMS activation, should not be delayed for naloxone administration.

Figure 1: Opioid-Associated Life-Threatening Emergency (Adult) Algorithm



Cardiac Arrest in Patients With Known or Suspected Opioid Overdose

2015 (New): Patients with no definite pulse may be in cardiac arrest or may have an undetected weak or slow pulse. These patients should be managed as cardiac arrest patients. Standard resuscitative measures should take priority over naloxone administration, with a focus on high-quality CPR (compressions plus ventilation). It may be reasonable to administer IM or IN naloxone based on the possibility that the patient is in respiratory arrest, not in cardiac arrest. Responders should not delay access to more-advanced medical services while awaiting the patient's response to naloxone or other interventions.

Why: Naloxone administration has not previously been recommended for first aid providers, non-HCPs, or BLS providers. However, naloxone administration devices intended for use by lay rescuers are now approved and available for use in the United States, and the successful implementation of lay rescuer naloxone programs has been highlighted by the Centers for Disease Control. While it is not expected that naloxone is beneficial in cardiac arrest, whether or not the cause is opioid overdose, it is recognized that it may be difficult to distinguish cardiac arrest from severe respiratory depression in victims of opioid overdose. While there is no evidence that administration of naloxone will help a patient in cardiac arrest, the provision of naloxone may help an unresponsive patient with severe respiratory depression who only appears to be in cardiac arrest (ie, it is difficult to determine if a pulse is present).

Intravenous Lipid Emulsion

2015 (Updated): It may be reasonable to administer ILE, concomitant with standard resuscitative care, to patients who have premonitory neurotoxicity or cardiac arrest due to local anesthetic toxicity. It may be reasonable to administer ILE to patients with other forms of drug toxicity who are failing standard resuscitative measures.

2010 (Old): It may be reasonable to consider ILE for local anesthetic toxicity.

Why: Since 2010, published animal studies and human case reports have examined the use of ILE for patients with drug toxicity that is not the result of local anesthetic infusion. Although the results of these studies and reports are mixed, there may be clinical improvement after ILE administration. As the prognosis of patients who are failing standard resuscitative measures is very poor, empiric administration of ILE in this situation may be reasonable despite the very weak and conflicting evidence.

Cardiac Arrest in Pregnancy: Provision of CPR

2015 (Updated): Priorities for the pregnant woman in cardiac arrest are provision of high-quality CPR and relief of aortocaval compression. If the fundus height is at or above the level of the umbilicus, manual left uterine displacement can be beneficial in relieving aortocaval compression during chest compressions.

2010 (Old): To relieve aortocaval compression during chest compressions and optimize the quality of CPR, it is reasonable to perform manual left uterine displacement in the supine position first. If this technique is unsuccessful, and an appropriate wedge is readily available, then providers may consider placing the patient in a left lateral tilt of 27° to 30°, using a firm wedge to support the pelvis and thorax.

Why: Recognition of the critical importance of high-quality CPR and the incompatibility of the lateral tilt with high-quality CPR has prompted the elimination of the recommendation for using the lateral tilt and the strengthening of the recommendation for lateral uterine displacement.

Cardiac Arrest in Pregnancy: Emergency Cesarean Delivery

2015 (Updated): In situations such as nonsurvivable maternal trauma or prolonged maternal pulselessness, in which maternal resuscitative efforts are obviously futile, there is no reason to delay performing perimortem cesarean delivery (PMCD). PMCD should be considered at 4 minutes after onset of maternal cardiac arrest or resuscitative efforts (for the unwitnessed arrest) if there is no maternal ROSC. The clinical decision to perform a PMCD—and its timing with respect to maternal cardiac arrest—is complex because of the variability in level of practitioner and team training, patient factors (eg, etiology of arrest, gestational age of the fetus), and system resources.

2010 (Old): Emergency cesarean delivery may be considered at 4 minutes after onset of maternal cardiac arrest if there is no ROSC.

Why: PMCD provides the opportunity for separate resuscitation of the potentially viable fetus and the ultimate

relief of aortocaval compression, which may improve maternal resuscitation outcomes. The clinical scenario and circumstances of the arrest should inform the ultimate decision around the timing of emergency cesarean delivery.

1.2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

Part 10 of the *2015 American Heart Association* (AHA) *Guidelines Update for Cardiopulmonary Resuscitation* (CPR) *and Emergency Cardiovascular Care* (ECC) addresses cardiac arrest in situations that require special treatments or procedures other than those provided during basic life support (BLS) and advanced cardiovascular life support (ACLS).

This Part summarizes recommendations for the management of resuscitation in several critical situations, including cardiac arrest associated with pregnancy (Part 10.1), pulmonary embolism (PE) (10.2), and opioid-associated resuscitative emergencies, with or without cardiac arrest (10.3). Part 10.4 provides recommendations on intravenous lipid emulsion (ILE) therapy, an emerging therapy for cardiac arrest due to drug intoxication. Finally, updated guidance for the management of cardiac arrest during percutaneous coronary intervention (PCI) is presented in Part 10.5. A table of all recommendations made in this 2015 Guidelines Update as well as those made in the 2010 Guidelines is contained in the Appendix.

The special situations of resuscitation section (Part 12) of the *2010 AHA Guidelines for CPR and ECC*[1] covered 15 distinct topic areas. The following topics were last updated in 2010, and are included in this Web-based integrated Guidelines document:

- Management of cardiac arrest associated with asthma (Part 12.1)
- Anaphylaxis (12.2)
- Morbid obesity (12.4)
- Electrolyte imbalance (12.6)
- Trauma (12.8)
- Accidental hypothermia (12.9)
- Avalanche (12.10)
- ACLS treatment of cardiac arrest due to drowning (12.11)
- Electric shock or lightning strikes (12.12)
- Cardiac tamponade (12.14)
- Cardiac surgery (12.15)
- Toxic effects of benzodiazepines, ?-blockers, calcium channel blockers, digoxin, cocaine, cyclic antidepressants, carbon monoxide, and cyanide (12.7)

Additional information about drowning is presented in Part 5, “Adult Basic Life Support and Cardiopulmonary Resuscitation Quality.”

The recommendations in the 2015 Guidelines Update are based on an extensive evidence review process that was begun by the International Liaison Committee on Resuscitation (ILCOR) with the publication of the ILCOR *2010 International Consensus on CPR and ECC Science With Treatment Recommendations* (CoSTR)[2] and was completed with the preparation of the 2015 CoSTR publication.[3,4]

In the in-depth international evidence review process, the ILCOR task forces examined topics and then generated prioritized lists of questions for systematic review. The process by which topics were prioritized for review are described in the CoSTR publication.[5,6] Questions were first formulated in PICO (population,

intervention, comparator, outcome) format,[7] the search strategy and inclusion and exclusion criteria were defined, and then a search for relevant articles was performed. The evidence was evaluated by using the standardized methodological approach proposed by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group.[8]

The quality of the evidence was categorized based on the study methodologies and the 5 core GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias). Then, where possible, consensus-based treatment recommendations were created. Further information about this international evidence evaluation process can be found in the 2015 CoSTR, "Part 2: Evidence Evaluation and Management of Conflicts of Interest."[9,10]

To create the 2015 Guidelines Update, the AHA formed 15 writing groups, with careful attention to avoid or manage conflicts of interest, to assess the ILCOR treatment recommendations and to write AHA treatment recommendations by using the AHA Class of Recommendation and Level of Evidence (LOE) system. The recommendations made in the 2015 Guidelines Update are informed by the ILCOR recommendations and GRADE classification of the systematic reviews in the context of the delivery of medical care in North America. In the online version of this publication, live links are provided so the reader can connect directly to those systematic reviews on the ILCOR Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated by a combination of letters and numbers (eg, ALS 436). We encourage readers to use the links and review the evidence and appendixes, such as the GRADE tables. Further information about this evidence evaluation process can be found in "Part 2: Evidence Evaluation and Management of Conflicts of Interest" of this 2015 Guidelines Update.

Contemporaneous with the ILCOR evidence-review process, the AHA ECC Committee; Council on Cardiopulmonary, Critical Care, Perioperative, and Resuscitation; Council on Cardiovascular Diseases in the Young; and Council on Clinical Cardiology have developed an AHA Scientific Statement on cardiac arrest in pregnancy.[11] While this document provides treatment recommendations for the intra-arrest management of pregnant patients, a full discussion of preparation, prevention, resuscitation, emergency delivery, and postresuscitation care are beyond the scope of this article. Readers are directed to the full Scientific Statement for more complete recommendations.

2 Cardiac Arrest Associated With Pregnancy - Updated ALS 436

Cardiac arrest associated with pregnancy is rare in highincome countries. Maternal cardiac arrest occurs in approximately 1:12 000 admissions for delivery in the United States.[12] Maternal cardiac arrest rates appear to be increasing in the United States, from 7.2 deaths per 100 000 live births in 1987 to 17.8 deaths per 100 000 live births in 2009.[13] Maternal mortality rates are lower in Canada, where maternal mortality is reported as 6.1 deaths per 100 000 deliveries, with a decreasing trend from 2001 until 2011.[14,15]

The best outcomes for both mother and fetus are likely to be achieved by successful maternal resuscitation. The most common causes of maternal cardiac arrest are hemorrhage, cardiovascular diseases (including myocardial infarction, aortic dissection, and myocarditis), amniotic fluid embolism, sepsis, aspiration pneumonitis, PE, and eclampsia.[12,16] Important iatrogenic causes of maternal cardiac arrest include hypermagnesemia from magnesium sulfate administration and anesthetic complications.

The 2015 ILCOR systematic review addressed the questions of patient positioning during CPR and the role of perimortem cesarean delivery (PMCD) in the management of pregnant women in cardiac arrest during the second half of pregnancy.

2.1 2015 Evidence Summary

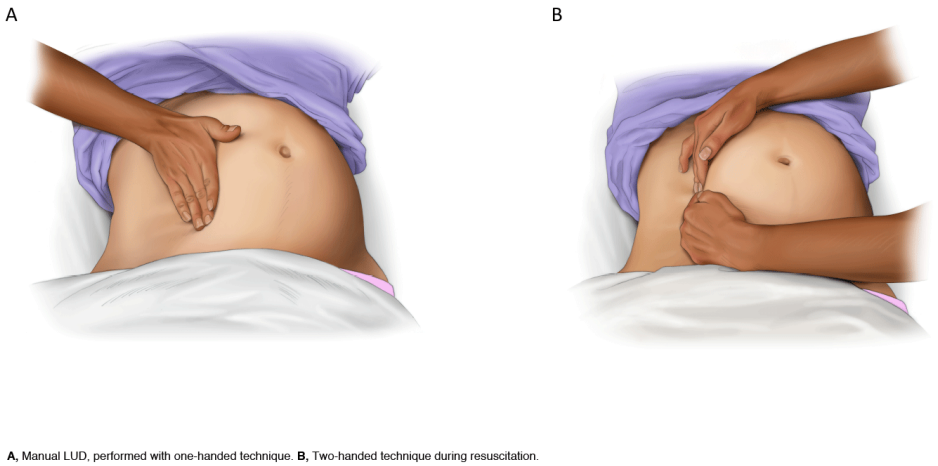
The evidence regarding advanced treatment strategies for cardiac arrest in pregnancy is largely observational. As a result, the recommendations are based on application of physiologic principles and on close examination of observational studies that are susceptible to bias. The lack of high-quality studies examining treatment of cardiac arrest in late pregnancy represents a major scientific gap.

2.1.1 Patient Positioning During CPR - Updated

Patient position has emerged as an important strategy to improve the quality of CPR and resultant compression

force and cardiac output. The gravid uterus can compress the inferior vena cava, impeding venous return, thereby reducing stroke volume and cardiac output. In general, aortocaval compression can occur for singleton pregnancies at approximately 20 weeks of gestational age,[17] at about the time when the fundus is at or above the umbilicus. Although chest compressions in the left lateral tilt position are feasible in a manikin study,[18] they result in decreased CPR quality (less forceful chest compressions) than is possible in the supine position.[19] Manual left lateral uterine displacement (LUD) effectively relieves aortocaval pressure in patients with hypotension[20] (Figure 2). No cardiac arrest outcome studies have been published examining the effect of LUD or other strategies to relieve aortocaval compression during resuscitation.

Figure 2: A, Manual LUD, performed with one-handed technique. B, Two-handed technique during resuscitation



A, Manual LUD, performed with one-handed technique. **B,** Two-handed technique during resuscitation.

2.1.1.1 Emergency Cesarean Delivery in Cardiac Arrest - Updated

Evacuation of the gravid uterus relieves aortocaval compression and may improve resuscitative efforts.[21-25] In the latter half of pregnancy, PMCD may be considered part of maternal resuscitation, regardless of fetal viability.[26] In a case series, 12 of 20 women for whom maternal outcome was recorded who underwent PMCD during resuscitation had return of spontaneous circulation (ROSC) immediately after delivery, and no cases of worsening maternal status were reported.[27] A systematic review of the literature evaluated all case reports of cardiac arrest in pregnancy, but the wide range of case heterogeneity and reporting bias does not allow for any conclusions regarding the timing of PMCD.[28] Survival of the mother has been reported up to 15 minutes after the onset of maternal cardiac arrest.[21,29-31] Neonatal survival has been documented with PMCD performed up to 30 minutes after the onset of maternal cardiac arrest.[21]

2.2 2015 Recommendations—New and Updated

2.2.1 BLS Modification: Relief of Aortocaval Compression - Updated

Priorities for the pregnant woman in cardiac arrest are provision of high-quality CPR and relief of aortocaval compression. (Class I, LOE C-LD)

If the fundus height is at or above the level of the umbilicus, manual LUD can be beneficial in relieving aortocaval compression during chest compressions. (Class IIa, LOE C-LD)

2.2.2 ALS Modification: Emergency Cesarean Delivery in Cardiac Arrest - Updated

Because immediate ROSC cannot always be achieved, local resources for a PMCD should be summoned as soon as cardiac arrest is recognized in a woman in the second half of pregnancy. (Class I, LOE C-LD)

Systematic preparation and training are the keys to a successful response to such rare and complex events.

Care teams that may be called upon to manage these situations should develop and practice standard institutional responses to allow for smooth delivery of resuscitative care. (Class I, LOE C-EO)

During cardiac arrest, if the pregnant woman with a fundus height at or above the umbilicus has not achieved ROSC with usual resuscitation measures plus manual LUD, it is advisable to prepare to evacuate the uterus while resuscitation continues. (Class I, LOE C-LD)

In situations such as nonsurvivable maternal trauma or prolonged pulselessness, in which maternal resuscitative efforts are obviously futile, there is no reason to delay performing PMCD. (Class I, LOE C-LD)

PMCD should be considered at 4 minutes after onset of maternal cardiac arrest or resuscitative efforts (for the unwitnessed arrest) if there is no ROSC. (Class IIa, LOE C-EO)

The clinical decision to perform a PMCD?and its timing with respect to maternal cardiac arrest?is complex because of the variability in level of practitioner and team training, patient factors (eg, etiology of arrest, gestational age), and system resources.

3 Cardiac Arrest Associated With Pulmonary Embolism - Updated ALS 435 ALS 435

PE is a potentially reversible cause of shock and cardiac arrest. Acute increase in right ventricular pressure due to pulmonary artery obstruction and liberation of vasoactive mediators produces cardiogenic shock that may rapidly progress to cardiovascular collapse. Management of acute PE is determined by disease severity.[32] Fulminant PE, characterized by cardiac arrest or severe hemodynamic instability, defines the subset of massive PE that is the focus of these recommendations.[33]

Less than 5% of patients with acute PE progress to cardiac arrest. Disease of this severity is associated with mortality of 65% to 90%.[34-36] PE-related cardiac arrests may occur within hours of symptom onset. Between 5% and 13% of unexplained cardiac arrests are associated with fulminant PE.[37,38]

Because establishing the diagnosis of acute PE in cardiac arrest situations is often difficult, separate systematic reviews were performed for management of patients with suspected and confirmed PE. Although clinical markers specific to fulminant PE are limited, acute symptoms frequently prompt medical attention before cardiac arrest. Conventional thromboembolism risk factors, prodromal dyspnea or respiratory distress, and witnessed arrest are features associated with cardiac arrest due to PE.[37,39] Pulseless electrical activity is the presenting rhythm in 36% to 53% of PE-related cardiac arrests, while primary shockable rhythms are uncommon.[37,40,41] Specific recommendations about the use of diagnostic ultrasonography during resuscitation can be found in “Part 7: Adult Advanced Cardiovascular Life Support” in this 2015 Guidelines Update.

Prompt systemic anticoagulation is generally indicated for patients with massive and submassive PE to prevent clot propagation and support endogenous clot dissolution over weeks.[42] Anticoagulation alone is inadequate for patients with fulminant PE. Pharmacologic and mechanical therapies to rapidly reverse pulmonary artery occlusion and restore adequate pulmonary and systemic circulation have emerged as primary therapies for massive PE, including fulminant PE.[32,43] Current advanced treatment options include systemic thrombolysis, surgical or percutaneous mechanical embolectomy, and extracorporeal cardiopulmonary resuscitation (ECPR).

The 2015 ILCOR systematic review addressed the treatment of PE as the known or suspected cause of cardiac arrest. The role of thrombolytic medications in the management of undifferentiated cardiac arrest was last reviewed in the 2010 Guidelines and is not reviewed again here.[44]

3.1 2015 Evidence Summary

The evidence regarding advanced treatment strategies for fulminant PE is largely observational. The lack of high-quality studies examining treatment of cardiac arrest due to PE represents a major scientific gap.

3.1.1 Confirmed Pulmonary Embolism - Updated

Systemic thrombolysis is associated with ROSC and shortterm survival in PE-related cardiac arrest in nonrandomized observational studies.[37,45-54]

There is no consensus on the ideal dose of thrombolytic therapy in PE-associated cardiac arrest. Contemporary examples of accelerated emergency thrombolysis dosing regimens for fulminant PE include alteplase 50 mg intravenous (IV) bolus with an option for repeat bolus in 15 minutes, or single-dose weight-based tenecteplase; thrombolytics are administered with or followed by systemic anticoagulation.[55-57] Early administration of systemic thrombolysis is associated with improved resuscitation outcomes compared with use after failure of conventional ACLS.[46]

Successful surgical and percutaneous mechanical embolectomy in cases of PE-related cardiac arrest have been reported in limited series.[58-60] Many of these patients developed cardiac arrest before or during embolectomy. The feasibility of embolectomy under uncontrolled CPR conditions is not known.

3.1.2 Suspected Pulmonary Embolism - Updated

No evidence is available to support or refute the effectiveness of empiric thrombolysis in suspected but unconfirmed PE.

3.2 2015 Recommendations—New and Updated

3.2.1 ALS Modification: Confirmed Pulmonary Embolism - Updated

In patients with confirmed PE as the precipitant of cardiac arrest, thrombolysis, surgical embolectomy, and mechanical embolectomy are reasonable emergency treatment options. (Class IIa, LOE C-LD)

Comparative data are not available to recommend one strategy over another. Patient location, local intervention options, and patient factors (including thrombolysis contraindications) are recognized elements to be considered.

Thrombolysis can be beneficial even when chest compressions have been provided. (Class IIa, LOE C-LD)

Given the poor outcomes associated with fulminant PE in the absence of clot-directed therapy, standard contraindications to thrombolysis may be superseded by the need for potentially lifesaving intervention.

In patients with cardiac arrest and without known PE, routine fibrinolytic treatment given during CPR shows no benefit[61,62] and is not recommended. (Class III, LOE A)

3.2.2 ALS Modifications: Suspected Pulmonary Embolism - Updated

Thrombolysis may be considered when cardiac arrest is suspected to be caused by PE. (Class IIb, LOE C-LD)

There is no consensus on inclusion criteria (eg, risk factors, signs, or symptoms that constitute suspected PE), thrombolytic timing, drug, or dose in this situation. There are insufficient data on surgical and mechanical embolectomy to evaluate these therapies for cardiac arrest associated with suspected but unconfirmed PE.

4 Cardiac or Respiratory Arrest Associated With Opioid Overdose - Updated ALS 441 BLS 811 BLS 891

In the United States in 2013, 16 235 people died of prescription opioid toxicity, and an additional 8257 died of heroin overdose.[63,64] In the United States in 2012, opioid overdose became the leading cause of unintentional injurious death in people aged 25 to 60 years, accounting for more deaths than motor vehicle collisions.[65] A majority of these deaths are associated with prescription opioids. Statistics are similar in Canada.[66]

Isolated opioid toxicity is associated with central nervous system (CNS) and respiratory depression that can progress to respiratory and cardiac arrest. Most opioid deaths involve the co-ingestion of multiple drugs or medical and mental health comorbidities.[67-70] In addition, methadone and propoxyphene can cause torsades de pointes, and cardiotoxicity has been reported with other opioids.[71-77] Except in specific clinical settings (eg,

unintended opioid overdose during a medical procedure), rescuers cannot be certain that the patient's clinical condition is due to opioidinduced CNS and respiratory depression toxicity alone, and might therefore misidentify opioid-associated cardiac arrest as unconsciousness or vice versa. This is particularly true in the first aid and BLS contexts, where determination of the presence or absence of a pulse is unreliable.[78,79] Any treatment recommendations intended for use in the first aid or BLS settings must therefore have benefit that exceeds harm when applied to a mixed patient population that may include people with severe CNS and respiratory depression, respiratory arrest, and cardiac arrest.

In creating the 2015 Guidelines Update, the writing group considered the difficulty in accurately differentiating opioid-associated resuscitative emergencies from other causes of cardiac and respiratory arrest. Opioid-associated resuscitative emergencies are defined by the presence of cardiac arrest; respiratory arrest; or severe life-threatening instability (such as severe CNS or respiratory depression, hypotension, or cardiac arrhythmia) that is suspected to be due to opioid toxicity. The term "opioid-associated life-threatening emergency" is used for first aid and non-healthcare providers.

Naloxone is a potent opioid receptor antagonist in the brain, spinal cord, and gastrointestinal system. Naloxone has an excellent safety profile and can rapidly reverse CNS and respiratory depression in a patient with an opioid-associated resuscitative emergency. Based on the rescuer's training and clinical circumstance, naloxone can be administered intravenously,[80-83] intramuscularly,[80,81,84] intranasally,[82,84-88] or subcutaneously[89]; nebulized for inhalation[90,91]; or instilled into the bronchial tree via endotracheal tube.[92] Appropriate dose and concentrations differ by route.

There are no known harms or major clinical effects associated with the administration of naloxone in typical doses to patients who are not opioid-intoxicated or dependent.[93,94] Naloxone administration may precipitate acute withdrawal syndrome in patients with opioid dependency, with signs and symptoms including hypertension, tachycardia, piloerection, vomiting, agitation, and drug cravings. These signs and symptoms are rarely life-threatening, and they may be minimized by using the lowest effective dose of naloxone.[95] Pulmonary edema has been reported with naloxone administration, but it also may be caused primarily by opioid toxicity.[95]

The ideal dose of naloxone is not known. In the 2010 Guidelines, an empiric starting dose of 0.04 to 0.4 mg IV or intramuscular (IM) was recommended to avoid provoking severe opioid withdrawal in patients with opioid dependency and to allow for consideration of a range of doses, depending on the clinical scenario.[1] Repeat doses or dose escalation to 2 mg IV or IM was recommended if the initial response was inadequate. Few comparative data exist about the appropriate dose of intranasal (IN) naloxone; most studies used a fixed dose of 2 mg, repeated in 3 to 5 minutes if necessary.[82,84-88,96] Nebulized naloxone has been studied and well-tolerated in opioid-intoxicated patients at a dose of 2 mg diluted in 3 mL normal saline.[90,91] Regardless of the care setting and route of administration, the initial goal of therapy is to restore and maintain patent airway and ventilation, preventing respiratory and cardiac arrest, without provoking severe opioid withdrawal.

The 2015 ILCOR systematic review addressed the questions of whether opioid overdose response education (with or without naloxone distribution) improves outcomes related to opioid overdose and whether naloxone administration or any other therapy improves outcomes in the patients with opioidassociated cardio/respiratory arrest in the first aid, BLS, or ACLS settings.

4.1 2015 Evidence Summary

4.1.1 Opioid Overdose Response Education and Naloxone Training and Distribution - Updated

Several studies have shown that community-based opioid overdose response education and naloxone distribution programs are feasible and that naloxone administration occurs frequently by persons trained by these programs.[97] Because patients who have CNS and respiratory depression from opioid overdose cannot self-administer naloxone, naloxone is typically administered in the first aid setting by friends, family, or bystanders.[98,99]

In 2014, the US Food and Drug Administration approved of the use of a naloxone autoinjector by lay rescuers[100] as well as healthcare providers. Both the IM and IN[97] routes of administration have been successfully used in first aid settings, with commercially available devices or kits containing a naloxone vial or prefilled syringe and a nasal atomizer or other administration device. IM, IN, and nebulized routes of administration have also been used to treat opioid-associated resuscitative emergencies in the BLS and ACLS settings.[81,82,90,101] Recent recommendations by an international working group called for uniform training standards based on simplified (first aid) resuscitation principles for community-based naloxone distribution programs.[102]

4.1.2 Administration of Naloxone in Opioid-Associated Resuscitation Emergencies - Updated

4.1.2.1 Respiratory Arrest - Updated

Two clinical trials and 12 observational studies examined outcomes after naloxone treatment for opioid-induced respiratory arrest or severe CNS and respiratory depression. Of these, 5 studies compared routes of naloxone administration,[82,84,85,89,103] and 9 assessed the safety of naloxone use or were observational studies of naloxone use alone.[81,104-111] All studies reported improvement in level of consciousness and spontaneous breathing after naloxone administration in the majority of patients treated, and complication rates were low. No study compared resuscitation outcomes achieved with naloxone with those achieved through standard therapy alone (eg, manual or mechanical ventilation).

4.1.2.2 Cardiac Arrest - Updated

One small observational study noted an improvement in cardiac rhythm in some patients after naloxone administration, but it did not compare outcomes in patients managed with and without naloxone administration.[112]

4.2 2015 Recommendations—New

4.2.1 Opioid Overdose Response Education and Naloxone Training and Distribution - Updated

It is reasonable to provide opioid overdose response education, either alone or coupled with naloxone distribution and training, to persons at risk for opioid overdose. (Class IIa, LOE C-LD)

Some populations that may benefit from opioid overdose response interventions are listed in Table 1.

It is reasonable to base this training on first aid and non-healthcare provider BLS recommendations rather than on more advanced practices intended for healthcare providers. (Class IIa, LOE C-EO)

Table 1: 2015 - Groups That May Benefit From Opioid Overdose Response Education and/or Naloxone Distribution and Training (100,111–119)

Open table in a new window

Groups That May Benefit From Opioid Overdose Response Education and/or Naloxone Distribution and Training [reference id="1798" range="" /]·[reference id="1809,1810,1811,1812,1813,1814,1815,1816,1817" range="9" /]

- Persons who abuse prescription opioids or heroin
- Patients who have required emergency care for opioid overdose
- Patients enrolled in opioid dependence treatment programs, including methadone and buprenorphine maintenance programs, particularly at high-risk periods, such as induction or discharge
- Persons with a history of opioid abuse or dependence who are being released from prison
- Patients receiving prescription opioid therapy with risk factors for adverse effects
    - Coprescriptions of benzodiazepines or other sedatives
    - Ongoing alcohol use
    - High-dose prescription opioid therapy
- Persons living with or in frequent contact with those listed above

4.2.2 First Aid and Non–Healthcare Provider BLS Modification: Administration of Naloxone - Updated

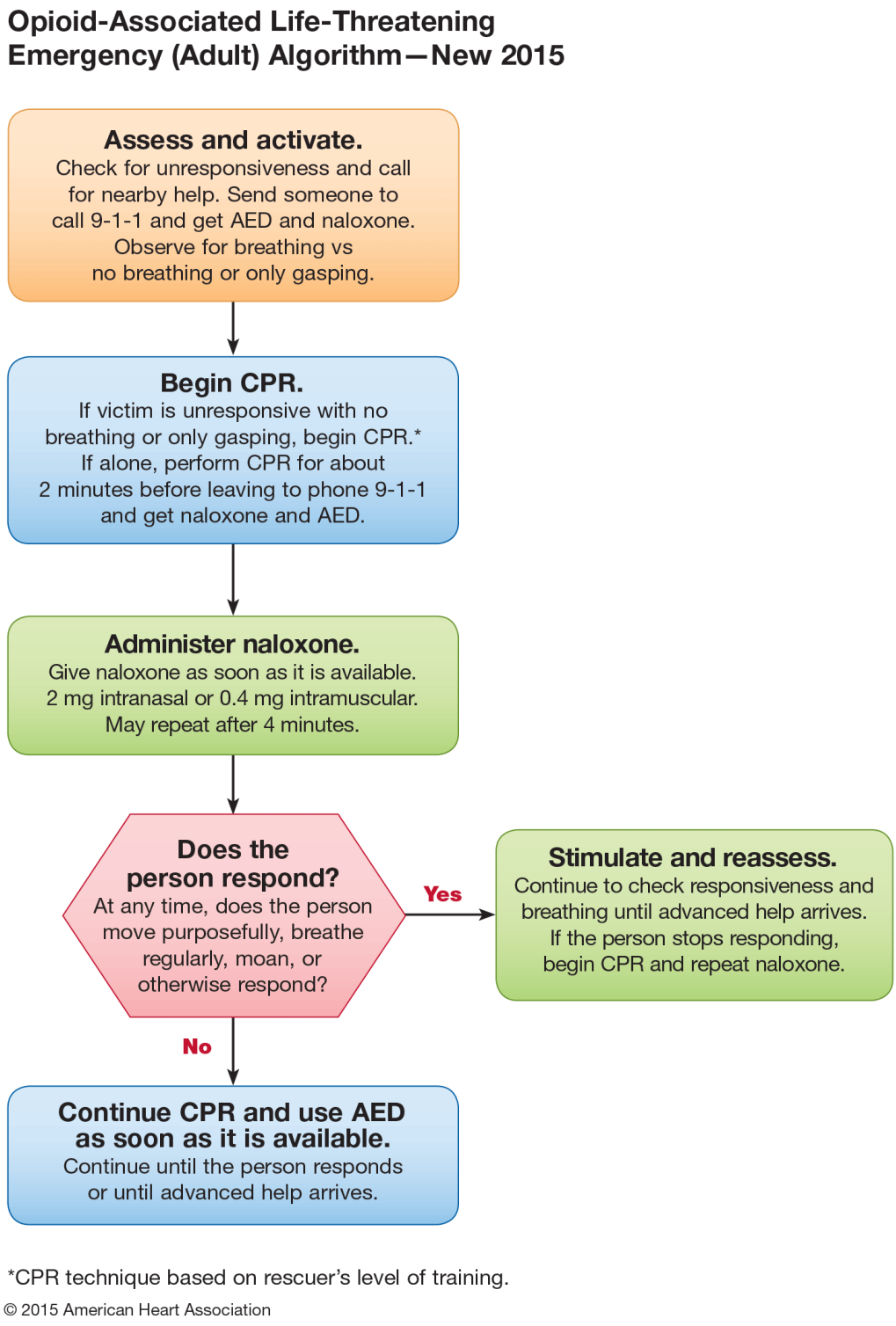
Although naloxone has no clear role in the management of confirmed cardiac arrest, first aid and other non-healthcare providers are not instructed to attempt to determine whether an unresponsive person is pulseless.

Empiric administration of IM or IN naloxone to all unresponsive opioid-associated life-threatening emergency patients may be reasonable as an adjunct to standard first aid and non–healthcare provider BLS protocols. (Class IIb, LOE C-EO)

Standard resuscitation, including activation of emergency medical services, should not be delayed for naloxone administration. However, family members and friends of those known to be addicted to opiates are likely to have naloxone available and ready to use if someone known or suspected to be addicted to opiates is found unresponsive and not breathing normally or only gasping (see sequence in Figure 1).

Victims who respond to naloxone administration should access advanced healthcare services. (Class I, LOE C-EO)

Figure 1: Opioid-Associated Life-Threatening Emergency (Adult) Algorithm



4.2.3 Healthcare Provider BLS Modification: Administration of Naloxone - Updated

4.2.3.1 Respiratory Arrest - Updated

For patients with known or suspected opioid overdose who have a definite pulse but no normal breathing or only gasping (ie, a respiratory arrest), in addition to providing standard BLS care, it is reasonable for appropriately trained BLS healthcare providers to administer IM or IN naloxone. (Class IIa, LOE C-LD)

For further information, see "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality."

4.2.3.2 Cardiac Arrest - Updated

Patients with no definite pulse may be in cardiac arrest or may have an undetected weak or slow pulse. These patients should be managed as cardiac arrest patients.

Standard resuscitative measures should take priority over naloxone administration, with a focus on high-quality CPR (compressions plus ventilation). (Class I, LOE C-EO)

It may be reasonable to administer IM or IN naloxone based on the possibility that the patient is not in cardiac arrest. (Class IIb, LOE C-EO)

Responders should not delay access to more-advanced medical services while awaiting the patient's response to naloxone or other interventions. (Class I, LOE C-EO)

Unless the patient refuses further care, victims who respond to naloxone administration should access advanced healthcare services. (Class I, LOE C-EO)

4.2.4 ACLS Modification: Administration of Naloxone - Updated

4.2.4.1 Respiratory Arrest - Updated

ACLS providers should support ventilation and administer naloxone to patients with a perfusing cardiac rhythm and opioid-associated respiratory arrest or severe respiratory depression. Bag-mask ventilation should be maintained until spontaneous breathing returns, and standard ACLS measures should continue if return of spontaneous breathing does not occur. (Class I, LOE C-LD)

4.2.4.2 Cardiac Arrest - Updated

We can make no recommendation regarding the administration of naloxone in confirmed opioid-associated cardiac arrest. Patients with opioid-associated cardiac arrest are managed in accordance with standard ACLS practices.

4.2.4.3 Observation and Post-Resuscitation Care - Updated

After ROSC or return of spontaneous breathing, patients should be observed in a healthcare setting until the risk of recurrent opioid toxicity is low and the patient's level of consciousness and vital signs have normalized. (Class I, LOE C-LD)

If recurrent opioid toxicity develops, repeated small doses or an infusion of naloxone can be beneficial in healthcare settings. (Class IIa, LOE C-LD)

Patients who respond to naloxone administration may develop recurrent CNS and/or respiratory depression. Although abbreviated observation periods may be adequate for patients with fentanyl, morphine, or heroin overdose,[104,111,113-116] longer periods of observation may be required to safely discharge a patient with life-

threatening overdose of a long-acting or sustained-release opioid.[95,117,118]

Naloxone administration in post–cardiac arrest care may be considered in order to achieve the specific therapeutic goals of reversing the effects of long-acting opioids. (Class IIb, LOE C-EO)

5 Role of Intravenous Lipid Emulsion Therapy in Management of Cardiac Arrest Due to Poisoning - Updated ALS 834

The use of ILE therapy was first developed as a treatment for cardiac arrest resulting from the local anesthetic bupivacaine.[119-121] Local anesthetics inhibit voltage at the cell membrane sodium channels, limiting action potential and the conduction of nerve signals. Local anesthetic systemic toxicity (LAST) can present with fulminant cardiovascular collapse that is refractory to standard resuscitative measures. A CNS toxicity phase (agitation evolving to frank seizures or CNS depression) may precede cardiovascular collapse. A recent review of peripheral nerve anesthetic blocks estimated the incidence of LAST equal to 0.87/1000 patients.[122] When a local anesthetic is administered, professional organizations recommend continuous neurologic and cardiovascular monitoring, dose fractionation, slow injection, concurrent use of an intravascular marker of systemic absorption (epinephrine 10 to 15 ?g), and the use of ultrasound techniques.[123]

Administration of ILE creates a lipid compartment in the serum, reducing by sequestration the concentration of lipophilic medications in the tissues.[124] Administration of ILE also increases cardiac inotropy by other mechanisms.[125-127]

Over time, common use of this modality has been expanded to include poisoning by other local anesthetics and other medications.[128-131]

The 2015 ILCOR systematic review addressed the question of whether administration of lipid emulsion improves outcomes for patients who develop cardiac arrest due to drug toxicity, including that caused by local anesthetics and other drugs.

5.1 2015 Evidence Summary

To date, we identified no human studies that compared outcomes of patients in cardiac arrest treated with ILE plus supportive care versus supportive care alone. A small controlled trial of adults with poisoning from drugs other than local anesthetics showed a more rapid improvement in level of consciousness in the group that received ILE, but all patients survived in both groups.[132] Patients with glyphosate-surfactant herbicide ingestion treated with ILE had less hypotension and fewer arrhythmias than historic controls, but there was no difference in survival outcomes.[133] Registry studies of patients receiving ILE are difficult to interpret because of a lack of comparison groups.[134,135]

Animal studies in rats consistently show a benefit of ILE in LAST caused by bupivacaine.[130,136] Studies are less consistently positive in porcine models of LAST and from poisoning by drugs other than local anesthetics.[131] In a recent systematic review of human case reports, the majority (81/103) reported clinical improvement, such as ROSC, relief of hypotension, resolution of dysrhythmia, improved mental status, or termination of status epilepticus, after ILE administration.[131] In this review, all 21 published cases of the use of ILE to treat LAST from bupivacaine demonstrated clinical improvement after ILE administration.

Comparative dose studies are not available. The most commonly reported strategy is to use a 20% emulsion of long-chain triglycerides, giving an initial bolus of 1.5 mL/kg lean body mass over 1 minute followed by an infusion of 0.25 mL/kg per minute for 30 to 60 minutes. The bolus can be repeated once or twice as needed for persistent cardiovascular collapse; the suggested maximum total dose is 10 mL/kg over the first hour.[130,137-139] The safety of prolonged infusions (beyond 1 hour) has not been established.[140]

The most common adverse effect of ILE therapy is interference with diagnostic laboratory testing[141]; rare cases of pancreatitis[141] and pulmonary changes similar to those observed with acute respiratory distress syndrome[142] have also been reported. There appear to be complex pharmacodynamic interactions between ILE and epinephrine given during resuscitation, and in some situations, treatment with ILE alters the effectiveness of epinephrine and vasopressin in animal resuscitation studies.[143] Although some organizations recommend modification of the pharmacologic treatment of cardiac arrest after ILE administration,[144,145] there are no human data to support a modification in ACLS recommendations. More recently, concern has been raised that ILE administration may increase the absorption of lipophilic medications from the gastrointestinal tract[146] and

interfere with the operation of venoarterial extracorporeal membrane oxygenation circuits.[147]

5.2 2015 Recommendations—New and Updated

5.2.1 ACLS Modifications - Updated

It may be reasonable to administer ILE, concomitant with standard resuscitative care, to patients with local anesthetic systemic toxicity and particularly to patients who have premonitory neurotoxicity or cardiac arrest due to bupivacaine toxicity. (Class IIb, LOE C-EO)

It may be reasonable to administer ILE to patients with other forms of drug toxicity who are failing standard resuscitative measures. (Class IIb, LOE C-EO)

6 Cardiac Arrest Associated With Other Toxic Ingestions

Poisoning has been likened to trauma on the cellular level, destroying the natural workings of a victim's physiology.[148] Severe poisoning alters the function of a cellular receptor, ion channel, organelle, or chemical pathway to the extent that critical organ systems can no longer support life.

As with any patient in cardiac arrest, management of the patient with a toxic exposure begins with support of airway, breathing, and circulation. Cardiac arrest due to toxicity is managed in accordance with the current standards of BLS and ACLS. With few exceptions, there are no unique antidotes or toxin-specific interventions that are recommended during resuscitation from cardiac arrest.

Once return of spontaneous circulation is achieved, urgent consultation with a medical toxicologist or certified regional poison center is recommended, as the postarrest management of the critically poisoned patient may benefit from a thorough understanding of the toxic agent. Consultation is also recommended early in the management of a patient with potentially life-threatening poisoning, when appropriate interventions might prevent deterioration to cardiac arrest. In the United States a certified poison center can be reached by calling 1-800-222-1222; in Canada, call 1-800-268-9017.

It is extremely difficult to conduct clinical trials of acute life-threatening poisoning. Challenges include the infrequency with which most specific conditions occur, the heterogeneity of presentation, and ethical challenges related to withholding established care from patients who are unable to provide informed consent because the patient has an altered mental status, the patient is suicidal, or there is a lack of time to explain treatment alternatives.[149]

The majority of questions addressing cardiac arrest due to drug toxicity remain unanswered. Epidemiological studies are required to document the incidence rate of cardiac arrests secondary to drug toxicity and the safety and efficacy baseline rates for current therapeutic strategies. This section presents recommendations for the care of the patient with a toxicological problem causing cardiac arrest or severe cardiovascular instability (respiratory depression, hypotension, life-threatening alterations of cardiac conduction, etc). Some recommendations are evidence-based, but most research in this area consists of case reports, small case series, animal studies, and pharmacokinetic studies in healthy volunteers. Virtually no toxicology research involves human cardiac arrest. Thus, many of these recommendations are based on expert consensus, and further research is needed to validate them.

6.1 Initial Approach to the Critically Poisoned Patient

Management of the critically poisoned patient begins with airway protection, support of respiration and circulation, and rapid assessment. Patients may or may not be able to provide an accurate history of exposure to a toxic substance. Whenever possible, history gathering should include questioning of persons who accompany the patient, evaluation of containers, review of pharmacy records, and examination of the patient's prior medical record.[150] Many patients who ingest medications in a suicide attempt take more than 1 substance, and the number of substances ingested is greater in fatal than in nonfatal suicide attempts.[151] Comprehensive toxicology laboratory testing is virtually never available in a time frame that supports early resuscitation decisions.[152]

Poisoned patients may deteriorate rapidly. Care for all adult patients who are critically ill or under evaluation for possible toxin exposure or ingestion, particularly when the history is uncertain, should begin in a monitored treatment area where the development of central nervous system depression, hemodynamic instability, or

seizures can be rapidly recognized and addressed.[153]

Gastrointestinal decontamination, once a mainstay in the management of ingested toxins, has a less significant role in poisoning treatment today. With rare exceptions, gastric lavage, whole bowel irrigation, and administration of syrup of ipecac are no longer recommended.[154-156] Administration of single-dose activated charcoal to adsorb ingested toxins is generally recommended for the ingestion of life-threatening poisons for which no adequate antidotal therapy is available and when the charcoal can be administered within 1 hour of poisoning.[157] Multiple-dose activated charcoal should be considered for patients who have ingested a life-threatening amount of specific toxins (eg, carbamazepine, dapsone, phenobarbital, quinine, or theophylline) for which a benefit of this strategy has been established.[158] Charcoal should not be administered for ingestions of caustic substances, metals, or hydrocarbons.[157]

Charcoal should only be administered to patients with an intact or protected airway. In patients who are at risk for aspiration, endotracheal intubation and head-of-bed elevation should be performed before charcoal administration.[158,159] Because the decision to perform gastrointestinal decontamination is complex, multifactorial, and associated with risk, expert advice can be helpful.

6.2 Toxidromes

A “toxidrome” is a clinical syndrome—a constellation of signs, symptoms, and laboratory findings—suggestive of the effects of a specific toxin. By recognizing these presentations, the clinician can establish a working diagnosis that guides initial management. Some common toxidromes are presented in Table 2: Common Toxidromes . Practically every sign and symptom observed in poisoning can be produced by natural disease, and many clinical presentations associated with natural disease can be mimicked by some poison.[160] It is important to maintain a broad differential diagnosis, particularly when the history of toxic chemical exposure is unclear.

Table 2: 2010 - Common Toxidromes

Open table in a new window

Common Toxidromes*		
Cardiac Signs		
Tachycardia and/or Hypertension	Bradycardia and/or Hypotension	Cardiac Conduction Delays (Wide QRS)
Amphetamines	Beta blockers	Cocaine
Anticholinergic drugs	Calcium channel blockers	Cyclic antidepressants
Antihistamines	Clonidine	Local anesthetics
Cocaine	Digoxin and related glycosides	Propoxyphene
Theophylline/caffeine	Organophosphates and carbamates	Antiarrhythmics (e.g., quinidine, flecainide)
Withdrawal states		
CNS/Metabolic Signs		
Seizures	CNS and/or Respiratory Depression	Metabolic Acidosis

Cardiac Signs		
Cyclic antidepressants	Antidepressants (several classes)	Cyanide
Isoniazid	Benzodiazepines	Ethylene glycol
Selective and non-selective norepinephrine reuptake inhibitors (eg, bupropion)	Carbon monoxide	Metformin
Withdrawal states	Ethanol	Methanol
	Methanol	Salicylates
	Opioids	
	Oral hypoglycemics	

- ?* Differential diagnosis lists are partial.

6.3 Benzodiazepines

There are no data to support the use of specific antidotes in the setting of cardiac arrest due to benzodiazepine overdose. Resuscitation from cardiac arrest should follow standard BLS and ACLS algorithms.

Flumazenil is a potent antagonist of the binding of benzodiazepines to their central nervous system receptors. Administration of flumazenil can reverse central nervous system and respiratory depression caused by benzodiazepine overdose. Flumazenil has no role in the management of cardiac arrest.

The administration of flumazenil to patients with undifferentiated coma confers risk and is not recommended. (Class III, LOE B)

Flumazenil administration can precipitate seizures in benzodiazepine-dependent patients and has been associated with seizures, arrhythmia, and hypotension in patients with coingestion of certain medications, such as tricyclic antidepressants.[161,162] However, flumazenil may be used safely to reverse excessive sedation known to be due to the use of benzodiazepines in a patient without known contraindications (eg, procedural sedation).[163]

6.4 ?-Blockers

There are no data to support the use of specific antidotes in the setting of cardiac arrest due to ?-blocker overdose. Resuscitation from cardiac arrest should follow standard BLS and ACLS algorithms.

?-Blocker medication overdose may cause such severe inhibition of ?-adrenergic receptors that high-dose vasopressors cannot effectively restore blood pressure, cardiac output, or perfusion. Therapeutic options in the treatment of refractory hemodynamic instability due to ?-blocker overdose include administration of glucagon, high-dose insulin, or IV calcium salts.

6.4.1 Glucagon

Administration of glucagon may be helpful for severe cardiovascular instability associated with ?-blocker toxicity that is refractory to standard measures, including vasopressors.

The recommended dose of glucagon is a bolus of 3 to 10 mg, administered slowly over 3 to 5 minutes, followed by an infusion of 3 to 5 mg/h (0.05 to 0.15 mg/kg followed by an infusion of 0.05 to 0.10 mg/kg per hour).[164-176] (Class IIb, LOE C)

The infusion rate is titrated to achieve an adequate hemodynamic response (appropriate mean arterial pressure and evidence of good perfusion). Because the amount of glucagon required to sustain this therapy may exceed 100 mg in a 24-hour period, plans should be made early to ensure that an adequate supply of glucagon is available. Glucagon commonly causes vomiting. In patients with central nervous system depression, the airway must be protected before glucagon administration. Animal studies have suggested that the concomitant use of dopamine alone or in combination with isoproterenol and milrinone may decrease the effectiveness of glucagon.[177-179]

6.4.2 Insulin

Animal studies suggest that high-dose IV insulin, accompanied by IV dextrose supplementation and electrolyte monitoring, may improve hemodynamic stability and survival in ?-blocker overdose by improving myocardial energy utilization.[180,181] A single human case report[182] showed improved hemodynamic stability and survival to discharge following administration of high-dose insulin in refractory shock due to a massive overdose of metoprolol.

Administration of high-dose insulin in patients with shock refractory to other measures may be considered. (ClassIIb, LOE C)

Although the ideal human dose has not been determined, a commonly used protocol calls for IV administration of 1 U/kg regular insulin as a bolus, accompanied by 0.5 g/kg dextrose, followed by continuous infusions of 0.5 to 1 U/kg per hour of insulin and 0.5 g/kg per hour of dextrose.[183] The insulin infusion is titrated as needed to achieve adequate hemodynamic response, whereas the dextrose infusion is titrated to maintain serum glucose concentrations of 100 to 250 mg/dL (5.5 to 14 mmol/L). Very frequent serum glucose monitoring (up to every 15 minutes) may be needed during the initial phase of dextrose titration. Sustained infusions of concentrated dextrose solutions (>10%) require central venous access. Insulin causes potassium to shift into the cells. Moderate hypokalemia is common during high-dose insulin-euglycemia therapy, and animals treated with aggressive potassium repletion developed asystole.[180] To avoid overly aggressive potassium repletion, 1 human protocol targets potassium levels of 2.5 to 2.8 mEq/L.[183]

6.4.3 Calcium

One human case report[184] and a large-animal study[185] suggest that calcium may be helpful in ?-blocker overdose. Administration of calcium in patients with shock refractory to other measures may be considered. (Class IIb, LOE C)

One approach is to administer 0.3 mEq/kg of calcium (0.6 mL/kg of 10% calcium gluconate solution or 0.2 mL/kg of 10% calcium chloride solution) IV over 5 to 10 minutes, followed by an infusion of 0.3 mEq/kg per hour.[183] The infusion rate is titrated to adequate hemodynamic response. Serum ionized calcium levels should be monitored, and severe hypercalcemia (ionized calcium levels greater than twice the upper limits of normal) should be avoided. Sustained infusions of IV calcium require central venous access.

6.4.4 Other Therapies

Case reports have suggested that in patients who remain critically hypotensive despite maximal vasopressor therapy, specific interventions using intra-aortic balloon counterpulsation, ventricular assist devices, and extracorporeal membrane oxygenation or other extra corporeal life support (ECLS) devices may be lifesaving.[186-188] While evidence remains weak, at least two human case reports indicate a possible benefit from lipid emulsion infusion for overdose by ?-blockers.[189,190] Animal studies are mixed.[191-194] Because this area of therapy is rapidly evolving,[195-197] prompt consultation with a medical toxicologist or other specialists with up-to-date knowledge is recommended when managing treatment-refractory hypotension from ?-blocker overdosage.

6.5 Calcium Channel Blockers

There are no data to support the use of specific antidotes in the setting of cardiac arrest due to calcium channel blocker overdose. Resuscitation from cardiac arrest should follow standard BLS and ACLS algorithms.

Calcium channel blocker overdose also may cause life-threatening hypotension and bradycardia that are refractory to standard agents. Treatment with high-dose insulin has been described in a number of clinical case reports[198-209] and animal studies.[210-213]

High-dose insulin, in the doses listed in the ?-blocker section above, may be effective for restoring hemodynamic stability and improving survival in the setting of severe cardiovascular toxicity associated with toxicity from a calcium channel blocker overdose. (Class IIb, LOE B)

Limited evidence supports the use of calcium in the treatment of hemodynamically unstable calcium channel blocker overdose refractory to other treatments.[199,200,203,204,206-208,211,214-217]

Administration of calcium in patients with shock refractory to other measures may be considered. (Class IIb, LOE C)

There is insufficient and conflicting evidence to recommend the use of glucagon[203,204,208,210,211,214,217-220] in the treatment of hemodynamically unstable calcium channel blocker overdose.

6.6 Digoxin and Related Cardiac Glycosides

Digoxin poisoning can cause severe bradycardia and life-threatening arrhythmias, including ventricular tachycardia, ventricular fibrillation, and high degrees of AV nodal blockade. Other plant- and animal-derived cardiac glycosides may produce similar effects, including those found in oleander, lily-of-the-valley, toad skin, and some herbal medications. There are no data to support the use of specific antidotes in the setting of cardiac arrest due to digoxin overdose. Resuscitation from cardiac arrest should follow standard BLS and ACLS algorithms, with specific antidotes used in the post-cardiac arrest phase if severe cardiotoxicity is encountered.

Antidigoxin Fab antibodies should be administered to patients with severe life-threatening cardiac glycoside toxicity.[221-230] (Class I, LOE B)

One vial of antidigoxin Fab is standardized to neutralize 0.5 mg of digoxin. Although the ideal dose is unknown, a reasonable strategy is as follows:

If the ingested dose of digoxin is known, administer 2 vials of Fab for every milligram of digoxin ingested.

In cases of chronic digoxin toxicity or when the ingested dose is not known, calculate the number of vials to administer by using the following formula: serum digoxin concentration (ng/mL)×weight (kg)/100.

In critical cases in which therapy is required before a serum digoxin level can be obtained or in cases of life-threatening toxicity due to cardiac glycosides, administer empirically 10 to 20 vials.

Hyperkalemia is a marker of severity in acute cardiac glycoside poisoning and is associated with poor prognosis.[231] Antidigoxin Fab may be administered empirically to patients with acute poisoning from digoxin or related cardiac glycosides whose serum potassium level exceeds 5.0 mEq/L.[232]

6.7 Cocaine

There are no data to support the use of cocaine-specific interventions in the setting of cardiac arrest due to cocaine overdose. Resuscitation from cardiac arrest should follow standard BLS and ACLS algorithms, with specific antidotes used in the postresuscitation phase if severe cardiotoxicity or neurotoxicity is encountered. A single case series demonstrated excellent overall and neurologically intact survival (55%) in patients with cardiac arrest associated with cocaine overdose who were treated with standard therapy.[233]

Cocaine-induced tachycardia and hypertension are predominantly caused by central nervous system stimulation. Treatment strategies are extrapolated from acute coronary syndrome studies, small case series, and experiments in cocaine-naïve human volunteers.

It may be reasonable to try agents that have shown efficacy in the management of acute coronary syndrome in patients with severe cardiovascular toxicity. ?-Blockers (phentolamine),[234] benzodiazepines (lorazepam, diazepam),[235] calcium channel blockers (verapamil),[236] morphine,[237] and sublingual nitroglycerin[238,239] may be used as needed to control hypertension, tachycardia, and agitation. (Class IIb, LOE B)

The available data do not support the use of 1 agent over another in the treatment of cardiovascular toxicity due to cocaine. (Class IIb, LOE B)

There is clear evidence that cocaine can precipitate acute coronary syndromes.[240] For cocaine-induced hypertension or chest discomfort, benzodiazepines, nitroglycerin, and/or morphine can be beneficial.[235,238,241] (Class IIa, LOE B)

Because the effects of cocaine and other stimulant medications are transient, drugs and doses should be chosen carefully to minimize the risk of producing hypotension after the offending agent has been metabolized. Catheterization laboratory studies demonstrate that cocaine administration leads to reduced coronary artery diameter. This effect is reversed by morphine,[237] nitroglycerin,[239] phentolamine,[234] and verapamil[236]; is not changed by labetalol[242]; and is exacerbated by propranolol.[243] Several studies suggest that administration of ?-blockers may worsen cardiac perfusion and/or produce paradoxical hypertension when cocaine is present.[243,244]

Although contradictory evidence exists,[245,246] current recommendations are that pure ?-blocker medications in the setting of cocaine are not indicated.[247] (Class IIb, LOE C)

In severe overdose, cocaine acts as a Vaughan-Williams class Ic antiarrhythmic, producing wide-complex tachycardia through several mechanisms, including blockade of cardiac sodium channels.[248] Although there is no human evidence in cocaine poisoning, extrapolation from evidence in the treatment of wide-complex tachycardia caused by other class Ic agents (flecainide) and tricyclic antidepressants suggests that administration of hypertonic sodium bicarbonate may be beneficial.[249] A typical treatment strategy used for these other sodium channel blockers involves administration of 1 mL/kg of sodium bicarbonate solution (8.4%, 1 mEq/mL) IV as a bolus, repeated as needed until hemodynamic stability is restored and QRS duration is ?120 ms.[250-257] Current evidence neither supports nor refutes a role for lidocaine in the management of wide-complex tachycardia caused by cocaine.

6.8 Cyclic Antidepressants

Many drugs can prolong the QRS interval in overdose. These include Vaughan-Williams class Ia and Ic antiarrhythmics (eg, procainamide, quinidine, flecainide), cyclic antidepressants (eg, amitriptyline), and cocaine. Type Ia and Ic antiarrhythmics were not reviewed in 2010. Similar to the type Ia antiarrhythmics, cyclic antidepressants block cardiac sodium channels, leading to hypotension and wide-complex arrhythmia in overdose.

Cardiac arrest caused by cyclic antidepressant toxicity should be managed by current BLS and ACLS treatment guidelines. A small case series of cardiac arrest patients demonstrated improvement with sodium bicarbonate and epinephrine,[258] but the concomitant use of physostigmine in the prearrest period in this study reduces the ability to generalize this study.

Administration of sodium bicarbonate for cardiac arrest due to cyclic antidepressant overdose may be considered. (Class IIb, LOE C)

Therapeutic strategies for treatment of severe cyclic antidepressant cardiotoxicity include increasing serum sodium, increasing serum pH, or doing both simultaneously. The relative contributions of hypernatremia and alkalemia are controversial, but in practice most experience involves administration of hypertonic sodium bicarbonate solution (8.4% solution, 1 mEq/mL).

Sodium bicarbonate boluses of 1 mL/kg may be administered as needed to achieve hemodynamic stability (adequate mean arterial blood pressure and perfusion) and QRS narrowing.[250-257] (Class IIb, LOE C)

Serum sodium levels and pH should be monitored, and severe hypernatremia (sodium >155 mEq/L) and alkalemia (pH >7.55) should be avoided. A number of vasopressors and inotropes have been associated with improvement in the treatment of tricyclic-induced hypotension, ie, epinephrine,[259,260,261] norepinephrine,[261-264] dopamine,[264-266] and dobutamine.[265]

6.9 Carbon Monoxide

Apart from complications from deliberate drug abuse, carbon monoxide is the leading cause of unintentional poisoning death in the United States.[267] In addition to reducing the ability of hemoglobin to deliver oxygen, carbon monoxide causes direct cellular damage to the brain and myocardium.[268] Survivors of carbon monoxide poisoning are at risk for lasting neurological injury.[268]

Several studies have suggested that very few patients who develop cardiac arrest from carbon monoxide poisoning survive to hospital discharge, regardless of treatment administered following return of spontaneous circulation.[269-271] Routine care of patients in cardiac arrest and severe cardiotoxicity from carbon monoxide poisoning should comply with standard BLS and ACLS recommendations.

6.9.1 Hyperbaric Oxygen

Two studies suggest that neurological outcomes were improved in patients with carbon monoxide toxicity of all severity (excluding “moribund” patients)[272] and mild to moderate severity (excluding loss of consciousness and cardiac instability)[273] who received hyperbaric oxygen therapy for carbon monoxide poisoning. Other studies found no difference in neurologically intact survival.[274,275] A systematic review[276,277] and a recent evidence-based clinical policy review[278] concluded that, based on the available evidence, improvement in neurologically intact survival following treatment for carbon monoxide poisoning with hyperbaric oxygen is possible but unproven.

Hyperbaric oxygen therapy is associated with a low incidence of severe side effects. Because hyperbaric oxygen therapy appears to confer little risk,[278] the available data suggest that hyperbaric oxygen therapy may be helpful in treatment of acute carbon monoxide poisoning in patients with severe toxicity. (Class IIb, LOE C)

Patients with carbon monoxide poisoning who develop a cardiac injury have an increased risk of cardiovascular and all-cause mortality for at least 7 years after the event, even if hyperbaric oxygen is administered.[279,280] Although data about effective interventions in this population are lacking, it is reasonable to advise enhanced follow-up for these patients.

On the basis of this conflicting evidence, the routine transfer of patients to a hyperbaric treatment facility following resuscitation from severe cardiovascular toxicity should be carefully considered, weighing the risk of transport against the possible improvement in neurologically intact survival.

6.10 Cyanide

Cyanide is a surprisingly common chemical. In addition to industrial sources, cyanide can be found in jewelry cleaners, electroplating solutions, and as a metabolic product of the putative antitumor drug amygdalin (laetrile). Cyanide is a major component of fire smoke, and cyanide poisoning must be considered in victims of smoke

inhalation who have hypotension, central nervous system depression, metabolic acidosis, or soot in the nares or respiratory secretions.[281] Cyanide poisoning causes rapid cardiovascular collapse, which manifests as hypotension, lactic acidosis, central apnea, and seizures.

Patients in cardiac arrest[281-283] or those presenting with cardiovascular instability[281-287] caused by known or suspected cyanide poisoning should receive cyanide-antidote therapy with a cyanide scavenger (either IV hydroxocobalamin or a nitrate such as IV sodium nitrite and/or inhaled amyl nitrite), followed as soon as possible by IV sodium thiosulfate.[285,288,289]

Both hydroxocobalamin[281-287] and sodium nitrite[285,288,289] serve to rapidly and effectively bind cyanide in the serum and reverse the effects of cyanide toxicity. Because nitrites induce methemoglobin formation[288] and can cause hypotension,[290] hydroxocobalamin has a safety advantage, particularly in children and victims of smoke inhalation who might also have carbon monoxide poisoning. A detailed comparison of these measures has been recently published.[291]

Sodium thiosulfate serves as a metabolic cofactor, enhancing the detoxification of cyanide to thiocyanate. Thiosulfate administration enhances the effectiveness of cyanide scavengers in animal experimentation[292-295] and has been used successfully in humans with both hydroxocobalamin[281,287] and sodium nitrite.[285,288,289] Sodium thiosulfate is associated with vomiting but has no other significant toxicity.[296]

Therefore, based on the best evidence available, a treatment regimen of 100% oxygen and hydroxocobalamin, with or without sodium thiosulfate, is recommended (Class I, LOE B)

7 Cardiac Arrest During Percutaneous Coronary Intervention - Updated ALS 479

Cardiac arrest during PCI is rare, occurring in approximately 1.3% of catheterization procedures.[297,298] Although the risk of cardiac arrest during PCI is present in both elective and emergency procedures, the incidence is higher in emergency cases.[299]

In general, patients who develop cardiac arrest during PCI have superior outcomes to patients in cardiac arrest that occurs in other settings, including in-hospital units.[300] Many patients will respond to standard ACLS resuscitation, including high-quality CPR and rapid defibrillation. Rapid defibrillation (within 1 minute) is associated with survival to hospital discharge rates as high as 100% in this population.[301]

A subset of patients who develop cardiac arrest during PCI will require prolonged resuscitation efforts. Providing effective prolonged resuscitation in the catheterization laboratory has unique challenges, and a number of interventions and adjuncts for management of cardiac arrest during PCI have been described. Inconsistent availability and lack of comparative studies limit recommendations of one approach over another.

The 2015 ILCOR systematic review addressed the question of whether any special interventions or changes in care, compared with standard ACLS resuscitation alone, can improve outcomes in patients who develop cardiac arrest during PCI.

There are a number of mechanical devices available to provide hemodynamic support during cardiac catheterization in high-risk patients presenting with cardiogenic shock. The use of these devices in cardiogenic shock was not reviewed by ILCOR in 2015. Therefore, the *2015 AHA Guidelines Update for CPR and ECC* does not make recommendations on the use of mechanical support devices in patients presenting in cardiogenic shock who undergo PCI. Recent recommendations for the use of mechanical support devices in these situations can be found in the *2013 American College of Cardiology Foundation (ACCF)/AHA Guideline for the Management of ST-Elevation Myocardial Infarction.* [302]

7.1 2015 Evidence Summary

The feasibility of using mechanical CPR devices during PCI has been demonstrated in both animal[303] and human[304-307] studies. No comparative studies have examined the use of mechanical CPR devices compared with manual chest compressions during PCI procedures. However, a number of case reports[303,304,308] and case series[306,307] have reported the use of mechanical CPR devices to facilitate prolonged resuscitation in patients who have a cardiac arrest during PCI. One study demonstrated that the use of a mechanical CPR device for cardiac arrest during PCI was feasible; however, no patients survived to hospital discharge.[306] Other studies have reported good patient outcomes, including ROSC, survival to discharge, and functional outcome at

hospital discharge, after use of mechanical devices in resuscitation from cardiac arrest during PCI.[303,307] Mechanical CPR devices may also allow the use of fluoroscopy during chest compressions without direct irradiation of personnel.

Patients in cardiogenic shock or with other high-risk features (eg, multivessel coronary disease) may be at increased risk for adverse outcomes during or after PCI. Ventricular assist devices, intraaortic balloon pumps (IABP), and ECPR are all rescue treatment options available to support circulation and permit completion of the PCI. Not all interventions are available or can be rapidly deployed in all centers.

Rapid initiation of ECPR or cardiopulmonary bypass is associated with good patient outcomes in patients with hemodynamic collapse and cardiac arrest in the catheterization lab.[309-315] The use of ECPR is also feasible and associated with good outcomes when used as a bridge to coronary artery bypass grafting.[309,315-317] The combination of ECPR and IABP has been associated with increased survival when compared with IABP alone for patients who present with cardiogenic shock, including those who have a cardiac arrest while undergoing PCI.[310,314,318] Available observational studies often implement ECPR 20 to 30 minutes after cardiac arrest.[310,312]

IABP counterpulsation increases coronary perfusion, decreases myocardial oxygen demand, and improves hemodynamics in cardiogenic shock states, but it is not associated with improved patient survival in cardiogenic shock.[319-327] The role of IABP in patients who have a cardiac arrest in the catheterization laboratory is not known.

Several case series have reported on the use of emergency coronary artery bypass graft surgery after failed PCI.[328,329] In patients with cardiogenic shock or cardiac arrest and failed PCI, mechanical CPR devices and/ or ECPR have been used as rescue bridges to coronary artery bypass graft. Although no comparison studies have examined the use of this therapy as an adjunct to PCI, survival to hospital discharge rates as high as 64% have been reported.[309,310,315,317]

7.2 2015 Recommendations—New and Updated

7.2.1 ACLS Modifications - Updated

It may be reasonable to use mechanical CPR devices to provide chest compressions to patients in cardiac arrest during PCI. (Class IIb, LOE C-EO)

It may be reasonable to use ECPR as a rescue treatment when initial therapy is failing for cardiac arrest that occurs during PCI. (Class IIb, LOE C-LD)

Because patients can remain on ECPR support for extended periods of time without possibility of recovery, practical and ethical considerations must be taken into account in determining which victims of cardiac arrest should receive ECPR support.

Institutional guidelines should include the selection of appropriate candidates for use of mechanical support devices to ensure that these devices are used as a bridge to recovery, surgery or transplant, or other device. (Class I, LOE C-EO)

Due to a lack of comparative studies, it is not possible to recommend one approach (manual CPR, mechanical CPR, or ECPR) over another when options exist.

8 Cardiac Arrest Associated With Asthma

Asthma is responsible for more than 2 million visits to the emergency department (ED) in the United States each year, with 1 in 4 patients requiring admission to a hospital.[330] Annually there are 5,000 to 6,000 asthma-related deaths in the United States, many occurring in the prehospital setting.[331] Severe asthma accounts for approximately 2% to 20% of admissions to intensive care units, with up to one third of these patients requiring intubation and mechanical ventilation.[332] This section focuses on the evaluation and treatment of patients with near-fatal asthma.

Several consensus groups have developed excellent guidelines for the management of asthma that are available on the World Wide Web:

http://www.nhlbi.nih.gov/health-pro/guidelines/current/asthma-guidelines/full-report

http://www.ginasthma.com

8.1 Pathophysiology

The pathophysiology of asthma consists of 3 key abnormalities:

- Bronchoconstriction
- Airway inflammation
- Mucous plugging

Complications of severe asthma, such as tension pneumothorax, lobar atelectasis, pneumonia, and pulmonary edema, can contribute to fatalities. Severe asthma exacerbations are commonly associated with hypercarbia and acidemia, hypotension due to decreased venous return, and depressed mental status, but the most common cause of death is asphyxia. Cardiac causes of death are less common.[333]

8.2 Clinical Aspects of Severe Asthma

Wheezing is a common physical finding, although the severity of wheezing does not correlate with the degree of airway obstruction. The absence of wheezing may indicate critical airway obstruction, whereas increased wheezing may indicate a positive response to bronchodilator therapy.

Oxygen saturation (SaO_2) levels may not reflect progressive alveolar hypoventilation, particularly if oxygen is being administered. Note that SaO_2 may fall initially during therapy because ?2-agonists produce both bronchodilation and vasodilation and initially may increase intrapulmonary shunting.

Other causes of wheezing are pulmonary edema,[334] chronic obstructive pulmonary disease (COPD), pneumonia, anaphylaxis,[335] foreign bodies, PE, bronchiectasis, and subglottic mass.[336]

8.3 Initial Stabilization

Patients with severe life-threatening asthma require urgent and aggressive treatment with simultaneous administration of oxygen, bronchodilators, and steroids. Healthcare providers must monitor these patients closely for deterioration. Although the pathophysiology of life-threatening asthma consists of bronchoconstriction, inflammation, and mucous plugging, only bronchoconstriction and inflammation are amenable to drug treatment.

8.4 Primary Therapy

8.4.1 Oxygen

Oxygen should be provided to all patients with severe asthma, even those with normal oxygenation. As noted above, successful treatment with ?2-agonists may cause an initial decrease in oxygen saturation because the resultant bronchodilation can initially increase the ventilation-perfusion mismatch.

8.4.2 Inhaled ?2-Agonists

Short-acting ?-agonists provide rapid, dose-dependent bronchodilation with minimal side effects. Because the dose delivered depends on the patient's lung volume and inspiratory flow rate, the same dose can be used in most patients regardless of age or size. Studies have shown no difference in the effects of continuous versus intermittent administration of nebulized albuterol[337,338]; however, continuous administration was more effective in a subset of patients with severe exacerbations of asthma.[337] A Cochrane meta-analysis showed no overall difference between the effects of albuterol delivered by metered-dose inhaler spacer or nebulizer.[339] If prior use of a metered-dose inhaler has not been effective, use of a nebulizer is reasonable.

Although albuterol is sometimes administered intravenously (IV) in severe asthma, a systematic review of 15 clinical trials found that IV ?2-agonists, administered by either bolus or infusion, did not lead to significant improvements in any clinical outcome measure.[338]

Levalbuterol is the R-isomer of albuterol. Comparisons with albuterol have produced mixed results, with some studies showing a slightly improved bronchodilator effect in the treatment of acute asthma in the ED.[340]

There is no evidence that levalbuterol should be favored over albuterol.

One of the most common adjuncts used with ?-agonist treatment, particularly in the first hours of treatment, include anticholinergic agents (see “Adjunctive Therapies” below for more detail). When combined with short-acting ?-agonists, anticholinergic agents such as ipratropium can produce a clinically modest improvement in lung function compared with short-acting ?-agonists alone.[341,342]

8.4.3 Corticosteroids

Systemic corticosteroids are the only treatment for the inflammatory component of asthma proven to be effective for acute asthma exacerbations. Because the antiinflammatory effects after administration may not be apparent for 6 to 12 hours, corticosteroids should be administered early. The early use of systemic steroids hastens the resolution of airflow obstruction and may reduce admission to the hospital.[343] Although there may be no difference in clinical effects between oral and IV formulations of corticosteroids,[344,345] the IV route is preferable in patients with severe asthma. In adults a typical initial dose of methylprednisolone is 125 mg (dose range: 40 mg to 250 mg); a typical dose of dexamethasone is 10 mg.

8.5 Adjunctive Therapies

8.5.1 Anticholinergics

Ipratropium bromide is an anticholinergic bronchodilator pharmacologically related to atropine. The nebulizer dose is 500 mcg.[344,345] Ipratropium bromide has a slow onset of action (approximately 20 minutes), with peak effectiveness at 60 to 90 minutes and no systemic side effects. The drug is typically given only once because of its prolonged onset of action, but some studies have shown that repeat doses of 250 mcg or 500 mcg every 20 minutes may be beneficial.[346] A recent meta-analysis indicated a reduced number of hospital admissions associated with treatment with ipratropium bromide, particularly in patients with severe exacerbations.[347]

8.5.2 Magnesium Sulfate

When combined with nebulized ?-adrenergic agents and corticosteroids, IV magnesium sulfate can moderately improve pulmonary function in patients with asthma.[348] Magnesium causes relaxation of bronchial smooth muscle independent of serum magnesium level, with only minor side effects (flushing, lightheadedness). A Cochrane meta-analysis of 7 studies concluded that IV magnesium sulfate improves pulmonary function and reduces hospital admissions, particularly for patients with the most severe exacerbations of asthma.[349] The use of nebulized magnesium sulfate as an adjunct to nebulized ?-adrenergic agents has been reported in a small case series to improve FEV1 and SpO2,[350] although a prior meta-analysis demonstrated only a trend toward improved pulmonary function with nebulized magnesium.[351] For those with severe refractory asthma, providers may consider IV magnesium at the standard adult dose of 2 g administered over 20 minutes.

8.5.3 Epinephrine or Terbutaline

Epinephrine and terbutaline are adrenergic agents that can be given subcutaneously to patients with acute severe asthma. The dose of subcutaneous epinephrine (concentration 1:1000) is 0.01 mg/kg, divided into 3 doses of approximately 0.3 mg administered at 20-minute intervals. Although the nonselective adrenergic properties of epinephrine may cause an increase in heart rate, myocardial irritability, and increased oxygen demand, its use is well-tolerated, even in patients >35 years of age.[352] Terbutaline is given in a subcutaneous dose of 0.25 mg, which can be repeated every 20 minutes for 3 doses. There is no evidence that subcutaneous epinephrine or terbutaline has advantages over inhaled ?2-agonists. Epinephrine has been administered IV (initiated at 0.25 mcg/min to 1 mcg/min continuous infusion) in severe asthma; however, 1 retrospective investigation indicated a 4% incidence of serious side effects. There is no evidence of improved outcomes with IV epinephrine compared with selective inhaled ?2-agonists.[353]

8.5.4 Ketamine

Ketamine is a parenteral, dissociative anesthetic with bronchodilatory properties that also can stimulate copious bronchial secretions. One case series[354] suggested substantial efficacy, whereas 2 published randomized trials in children[355,356] found no benefit of ketamine when compared with standard care. Ketamine has sedative and analgesic properties that may be useful if intubation is planned.

8.5.5 Heliox

Heliox is a mixture of helium and oxygen (usually a 70:30 helium to oxygen ratio mix) that is less viscous than ambient air. Heliox has been shown to improve the delivery and deposition of nebulized albuterol[357]

; however, a recent meta-analysis of clinical trials did not support its use as initial treatment for patients with acute asthma.[358] Because the heliox mixture requires at least 70% helium for effect, it cannot be used if the patient requires >30% oxygen.

8.5.6 Methylxanthines

Although once considered a mainstay in the treatment of acute asthma, methylxanthines are no longer recommended because of their erratic pharmacokinetics, known side effects, and lack of evidence of benefit.[359]

8.5.7 Leukotriene Antagonists

Leukotriene antagonists improve lung function and decrease the need for short-acting ?2-agonists for long-term asthma therapy, but their effectiveness during acute exacerbations of asthma is unproven.

8.5.8 Inhaled Anesthetics

Case reports in adults[360] and children[361] suggest a benefit of the potent inhalation anesthetics sevoflurane and isoflurane for patients with life-threatening asthma unresponsive to maximal conventional therapy. These agents may have direct bronchodilator effects. In addition, the anesthetic effect of these drugs increases the ease of mechanical ventilation and reduces oxygen demand and carbon dioxide production. This therapy requires expert consultation in an intensive care setting, and its effectiveness has not been evaluated in randomized clinical studies.

8.6 Assisted Ventilation

8.6.1 Noninvasive Positive-Pressure Ventilation

Noninvasive positive-pressure ventilation (NIPPV) may offer short-term support for patients with acute respiratory failure and may delay or eliminate the need for endotracheal intubation.[362-364] This therapy requires that the patient is alert and has adequate spontaneous respiratory effort. Bilevel positive airway pressure (BiPAP), the most common method of delivering NIPPV, allows for separate control of inspiratory and expiratory pressures.

8.6.2 Endotracheal Intubation With Mechanical Ventilation

Endotracheal intubation is indicated for patients who present with apnea, coma, persistent or increasing hypercapnia, exhaustion, severe distress, and depression of mental status. Clinical judgment is necessary to assess the need for immediate endotracheal intubation for these critically ill patients. Endotracheal intubation does not solve the problem of small airway constriction in patients with severe asthma; thus, therapy directed toward relief of bronchoconstriction should be continued. Mechanical ventilation in the asthmatic patient can be difficult and associated risks require careful management. Intubation and positive-pressure ventilation can trigger further bronchoconstriction and complications such as breath stacking that result from incomplete expiration, air trapping, and buildup of positive end-expiratory pressure (ie, intrinsic or auto-PEEP). This breath stacking can cause barotrauma. Decreasing tidal volume may avoid auto-PEEP and high peak airway pressures. Optimal ventilator management requires expert consultation and ongoing careful review of ventilation flow and pressure curves. Although endotracheal intubation introduces risks, it should be performed when necessary based on clinical condition.

Rapid sequence intubation is the technique of choice and should be performed by an expert in airway management. The provider should use the largest endotracheal tube available (usually 8 or 9 mm) to decrease airway resistance. Immediately after intubation, endotracheal tube placement should be confirmed by clinical examination and waveform capnography. A chest radiograph should then be performed.

8.7 Troubleshooting After Intubation

When severe bronchoconstriction is present, breath stacking (so-called auto-PEEP) can develop during positive-pressure ventilation, leading to complications such as hyperinflation, tension pneumothorax, and hypotension. During manual or mechanical ventilation, a slower respiratory rate should be used with smaller tidal volumes (eg, 6 to 8 mL/kg),[365] shorter inspiratory time (eg, adult inspiratory flow rate 80 to 100 L/min), and longer expiratory time (eg, inspiratory to expiratory ratio 1:4 or 1:5) than generally would be provided to patients without asthma.[366] Management of mechanical ventilation will vary based on patient-ventilation characteristics. Expert consultation should be obtained.

Mild hypoventilation (permissive hypercapnia) reduces the risk of barotrauma. Hypercapnia is typically well tolerated.[367,368] Sedation is often required to optimize ventilation, decrease ventilator dyssynchrony (and therefore auto-PEEP), and minimize barotrauma after intubation. Because delivery of inhaled medications may be inadequate before intubation, the provider should continue to administer inhaled albuterol treatments through the endotracheal tube.

Four common causes of acute deterioration in any intubated patient are recalled by the mnemonic **DOPE** (tube **D**isplacement, tube **O**bstruction, **P**neumothorax, **E**quipment failure). Auto-PEEP is another common cause of deterioration in patients with asthma. If the asthmatic patient's condition deteriorates or if it is difficult to ventilate the patient, check the ventilator for leaks or malfunction; verify endotracheal tube position; eliminate tube obstruction (eliminate any mucous plugs and kinks); evaluate for auto-PEEP; and rule out a pneumothorax.

High-end expiratory pressure can be reduced quickly by separating the patient from the ventilator circuit; this will allow PEEP to dissipate during passive exhalation. If auto-PEEP results in significant hypotension, assisting with exhalation by pressing on the chest wall after disconnection of the ventilator circuit will allow active exhalation and should lead to immediate resolution of hypotension. To minimize auto-PEEP, decrease the respiratory rate or tidal volume or both. If auto-PEEP persists and the patient displays ventilator dyssynchrony despite adequate sedation, paralytic agents may be considered.

In exceedingly rare circumstances, aggressive treatment for acute respiratory failure due to severe asthma will not provide adequate gas exchange. There are case reports that describe successful use of extracorporeal membrane oxygenation (ECMO) in adult and pediatric patients[369-372] with severe asthma after other aggressive measures have failed to reverse hyoxemia and hypercarbia.

8.8 BLS Modifications

BLS treatment of cardiac arrest in asthmatic patients is unchanged.

8.9 ACLS Modifications

When cardiac arrest occurs in the patient with acute asthma, standard ACLS guidelines should be followed.

Case series and case reports describe a novel technique of cardiopulmonary resuscitation (CPR) termed "lateral chest compressions"; however, there is insufficient evidence to recommend this technique over standard techniques.[373-379]

The adverse effect of auto-PEEP on coronary perfusion pressure and capacity for successful defibrillation has been described in patients in cardiac arrest without asthma.[380,381] Moreover, the adverse effect of auto-PEEP on hemodynamics in asthmatic patients who are not in cardiac arrest has also been well-described.[382-385]

Therefore, since the effects of auto-PEEP in an asthmatic patient with cardiac arrest are likely quite severe, a ventilation strategy of low respiratory rate and tidal volume is reasonable. (Class IIa, LOE C)

During arrest a brief disconnection from the bag mask or ventilator may be considered, and compression of the chest wall to relieve air-trapping can be effective. (Class IIa, LOE C)

For all asthmatic patients with cardiac arrest, and especially for patients in whom ventilation is difficult, the possible diagnosis of a tension pneumothorax should be considered and treated. (Class I, LOE C)

9 Cardiac Arrest Associated With Anaphylaxis

Anaphylaxis is an allergic reaction characterized by multisystem involvement, including skin, airway, vascular system, and gastrointestinal tract. Severe cases may result in complete obstruction of the airway and cardiovascular collapse from vasogenic shock. Anaphylaxis accounts for about 500 to 1000 deaths per year in the United States.[386]

The term *classic anaphylaxis* refers to hypersensitivity reactions mediated by the immunoglobulins IgE and IgG. Prior sensitization to an allergen produces antigen-specific immunoglobulins. Subsequent reexposure to the allergen provokes the anaphylactic reaction, although many anaphylactic reactions occur with no documented prior exposure. Pharmacological agents, latex, foods, and stinging insects are among the most common causes of anaphylaxis described.

9.1 Signs and Symptoms

The initial symptoms of anaphylaxis are often nonspecific and include tachycardia, faintness, cutaneous flushing, urticaria, diffuse or localized pruritus, and a sensation of impending doom. Urticaria is the most common physical finding. The patient may be agitated or anxious and may appear either flushed or pale.

A common early sign of respiratory involvement is rhinitis. As respiratory compromise becomes more severe, serious upper airway (laryngeal) edema may cause stridor and lower airway edema (asthma) may cause wheezing. Upper airway edema can also be a sign in angiotensin converting enzyme inhibitor-induced angioedema or C1 esterase inhibitor deficiency with spontaneous laryngeal edema.[387-389]

Cardiovascular collapse is common in severe anaphylaxis. If not promptly corrected, vasodilation and increased capillary permeability, causing decreased preload and relative hypovolemia of up to 37% of circulating blood volume, can rapidly lead to cardiac arrest.[390,391] Myocardial ischemia and acute myocardial infarction, malignant arrhythmias, and cardiovascular depression can also contribute to rapid hemodynamic deterioration and cardiac arrest.[392] Additionally, cardiac dysfunction may result from underlying disease or development of myocardial ischemia due to hypotension or following administration of epinephrine.[393,394]

There are no randomized controlled trials evaluating alternative treatment algorithms for cardiac arrest due to anaphylaxis. Evidence is limited to case reports and extrapolations from nonfatal cases, interpretation of pathophysiology, and consensus opinion. Providers must be aware that urgent support of airway, breathing, and circulation is essential in suspected anaphylactic reactions.

Because of limited evidence, the management of cardiac arrest secondary to anaphylaxis should be treated with standard BLS and ACLS. The following therapies are largely consensus-based but commonly used and widely accepted in the management of the patient with anaphylaxis who is not in cardiac arrest.

9.2 BLS Modifications

9.2.1 Airway

Early and rapid advanced airway management is critical and should not be unnecessarily delayed.

Given the potential for the rapid development of oropharyngeal or laryngeal edema,[395] immediate referral to a health professional with expertise in advanced airway placement is recommended. (Class I, LOE C)

9.2.2 Circulation

The intramuscular (IM) administration of epinephrine (epinephrine autoinjectors, eg, the EpiPen™) in the anterolateral aspect of the middle third of the thigh provides the highest peak blood levels.[396] Absorption and subsequent achievement of maximum plasma concentration after subcutaneous administration is slower than the IM route and may be significantly delayed with shock.[396]

Epinephrine[397] should be administered early by IM injection to all patients with signs of a systemic allergic reaction, especially hypotension, airway swelling, or difficulty breathing. (Class I, LOE C))

The recommended dose is 0.2 to 0.5 mg (1:1000) IM to be repeated every 5 to 15 minutes in the absence of clinical improvement.[398] (Class I, LOE C)

The adult epinephrine IM auto-injector will deliver 0.3 mg of epinephrine and the pediatric epinephrine IM auto-injector will deliver 0.15 mg of epinephrine.

In both anaphylaxis and cardiac arrest the immediate use of an epinephrine autoinjector is recommended if available. (Class I, LOE C)

9.3 ACLS Modifications

9.3.1 Airway

Early recognition of the potential for a difficult airway in anaphylaxis is paramount in patients who develop hoarseness, lingual edema, stridor, or oropharyngeal swelling.

Planning for advanced airway management, including a surgical airway,[399] is recommended. (Class I, LOE C)

9.3.2 Fluid Resuscitation

In a prospective evaluation of volume resuscitation after diagnostic sting challenge, repeated administration of 1000-mL bolus doses of isotonic crystalloid (eg, normal saline) titrated to systolic blood pressure above 90 mm Hg was used successfully in patients whose hypotension did not respond immediately to vasoactive drugs.[390, 400]

Vasogenic shock from anaphylaxis may require aggressive fluid resuscitation. (Class IIa, LOE C)

9.3.3 Vasopressors

There are no human trials establishing the role of epinephrine or preferred route of administration in anaphylactic shock managed by ACLS providers.[397] In an animal study of profound anaphylactic shock, IV epinephrine restored blood pressure to baseline; however, the effect was limited to the first 15 minutes after shock, and no therapeutic effect was observed with the same dose of epinephrine administered IM or subcutaneously.[401]

Therefore, when an IV line is in place, it is reasonable to consider the IV route as an alternative to IM administration of epinephrine in anaphylactic shock. (Class IIa, LOE C)

For patients not in cardiac arrest, IV epinephrine 0.05 to 0.1 mg (5% to 10% of the epinephrine dose used routinely in cardiac arrest) has been used successfully in patients with anaphylactic shock.[402]

Because fatal overdose of epinephrine has been reported,[393,400,403,404] close hemodynamic monitoring

is recommended. (Class I, LOE B)

In a study of animals sensitized by ragweed, a continuous IV infusion of epinephrine maintained a mean arterial pressure at 70% of preshock levels better than no treatment or bolus epinephrine treatment (IV, subcutaneous, or IM).[405] Furthermore, a recent human study suggests that careful titration of a continuous infusion of IV epinephrine (5 to 15 mcg/min), based on severity of reaction and in addition to crystalloid infusion, may be considered in treatment of anaphylactic shock.[400]

Therefore, IV infusion of epinephrine is a reasonable alternative to IV boluses for treatment of anaphylaxis in patients not in cardiac arrest (Class IIa, LOE C) and may be considered in postarrest management. (Class IIb, LOE C)

Recently vasopressin has been used successfully in patients with anaphylaxis (with or without cardiac arrest) who did not respond to standard therapy.[406-408] Other small case series described successful results with administration of alternative ?-agonists such as norepinephrine,[409] methoxamine,[410,411] and metaraminol.[412-414]

Alternative vasoactive drugs (vasopressin, norepinephrine, methoxamine, and metaraminol) may be considered in cardiac arrest secondary to anaphylaxis that does not respond to epinephrine. (Class IIb, LOE C)

No randomized controlled trials have evaluated epinephrine versus the use of alternative vasoactive drugs for cardiac arrest due to anaphylaxis.

9.3.4 Other Interventions

There are no prospective randomized clinical studies evaluating the use of other therapeutic agents in anaphylactic shock or cardiac arrest.

Adjuvant use of antihistamines (H1 and H2 antagonist),[415,416] inhaled ?-adrenergic agents,[417] and IV corticosteroids [418] has been successful in management of the patient with anaphylaxis and may be considered in cardiac arrest due to anaphylaxis. (Class IIb, LOE C)

9.3.5 Extracorporeal Support of Circulation

Cardiopulmonary bypass has been successful in isolated case reports of anaphylaxis followed by cardiac arrest.[419,420]

Use of these advanced techniques may be considered in clinical situations where the required professional skills and equipment are immediately available. (Class IIb, LOE C)

10 Cardiac Arrest in the Morbidly Obese

Morbid obesity can provide challenges during the resuscitation attempt. Airway management may be more challenging, and changes to the thorax may make resuscitative efforts more demanding. Evidence from 2 case studies,[421,422] 1 case series,[423] and 1 related clinical study[424] indicated no differences in survival based on patient weight. However, one large case series demonstrated lower survival for morbidly obese children who required in-hospital pediatric CPR.[425]

10.1 BLS and ACLS Modifications

No modifications to standard BLS or ACLS care have been proven efficacious, although techniques may need to be adjusted due to the physical attributes of individual patients.

11 Cardiac Arrest Associated With Life-Threatening Electrolyte Disturbances

Electrolyte abnormalities can be associated with cardiovascular emergencies and may cause or contribute to cardiac arrest, hinder resuscitative efforts, and affect hemodynamic recovery after cardiac arrest. An evidence-based review in 2010 focused on electrolyte abnormalities most often associated with cardiac arrest.

Early consideration may be given to using selective methods of therapeutic management in addition to standard ACLS protocols that can be provided rapidly and have been shown to be effective in patients with cardiovascular instability as outlined below. Current BLS and ACLS should be used to manage cardiac arrest associated with all electrolyte disturbances.

11.1 Potassium (K+)

Potassium is maintained mainly in the intracellular compartment through the action of the Na+/K+ ATPase pump. The magnitude of the potassium gradient across cell membranes determines excitability of nerve and muscle cells, including the myocardium.

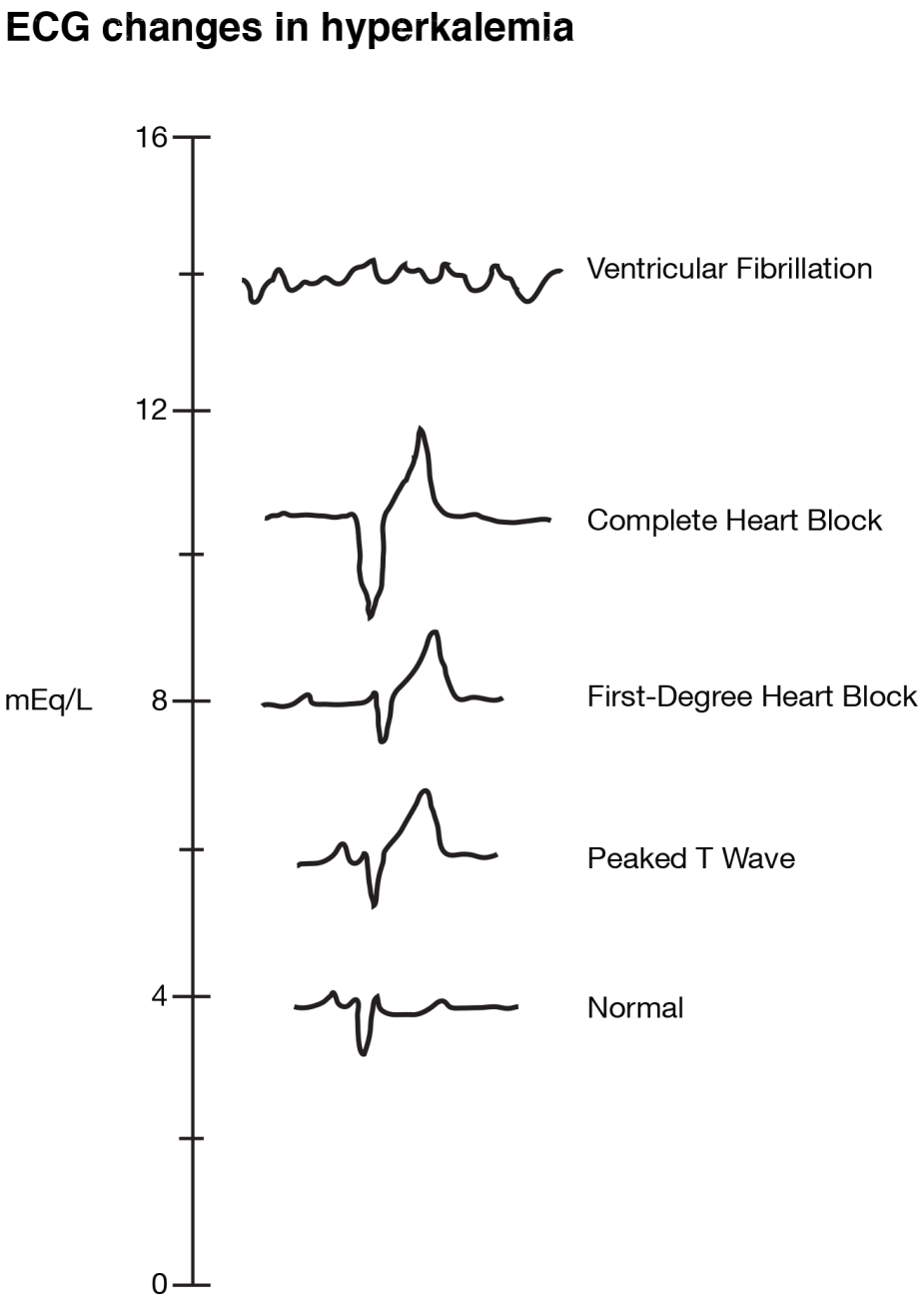
Potassium is tightly regulated. Under normal conditions potential differences across membranes, especially cardiac, are not affected by alterations in potassium level. Rapid or significant changes in serum concentrations of potassium result from the shifting of potassium from one space to another and may have life-threatening consequences.

11.2 Hyperkalemia

Hyperkalemia is one of the few potentially lethal electrolyte disturbances. Severe hyperkalemia (defined as a serum potassium concentration >6.5 mmol/L) occurs most commonly from renal failure or from release of potassium from cells and can cause cardiac arrhythmias and cardiac arrest. In 1 retrospective in-hospital study of 29 063 patients, hyperkalemia was found to be directly responsible for sudden cardiac arrest in 7 cases.[426] Acute kidney injury was present in all the arrest cases, accompanied by acute pancreatitis in 3 cases and acute hepatic failure in 2 cases. Overall renal failure and drug treatment were the most common causes of hyperkalemia, with the most severe cases occurring when excessive IV potassium was administered to a patient with renal insufficiency.

Although severe hyperkalemia may cause flaccid paralysis, paresthesia, depressed deep tendon reflexes, or respiratory difficulties,[427-429] the first indicator of hyperkalemia may be the presence of peaked T waves (tenting) on the electrocardiogram (ECG). As serum potassium rises, the ECG may progressively develop flattened or absent P waves, a prolonged PR interval, widened QRS complex, deepened S waves, and merging of S and T waves (Figure 3). If hyperkalemia is left untreated, a sine-wave pattern, idioventricular rhythms, and asystolic cardiac arrest may develop.[430,431]

Figure 3: 2010 ECG Changes Hyperkalemia



11.2.1 ACLS Modifications in Management of Severe Cardiotoxicity or Cardiac Arrest Due to Hyperkalemia

Treatment of severe hyperkalemia aims at protecting the heart from the effects of hyperkalemia by antagonizing the effect of potassium on excitable cell membranes, forcing potassium into cells to remove it promptly from the circulation, and removing potassium from the body. Therapies that shift potassium will act rapidly but are temporary and thus may need to be repeated. In order of urgency, treatment includes the following:

· Stabilize myocardial cell membrane:

· Calcium chloride (10%): 5 to 10 mL (500 to 1000 mg) IV over 2 to 5 minutes or calcium gluconate (10%): 15 to 30 mL IV over 2 to 5 minutes

· Shift potassium into cells:

· Sodium bicarbonate: 50 mEq IV over 5 minutes

· Glucose plus insulin: mix 25 g (50 mL of D50) glucose and 10 U regular insulin and give IV over 15 to 30 minutes

· Nebulized albuterol: 10 to 20 mg nebulized over 15 minutes

· Promote potassium excretion:

· Diuresis: furosemide 40 to 80 mg IV

· Kayexalate: 15 to 50 g plus sorbitol per oral or per rectum

· Dialysis

When cardiac arrest occurs secondary to hyperkalemia, it may be reasonable to administer adjuvant IV therapy as outlined above for cardiotoxicity in addition to standard ACLS. (Class IIb, LOE C)

11.2.2 ACLS Modifications in Management of Severe Cardiotoxicity Due to Hypokalemia

Life-threatening hypokalemia is uncommon but can occur in the setting of gastrointestinal and renal losses and is associated with hypomagnesemia. Severe hypokalemia will alter cardiac tissue excitability and conduction. Hypokalemia can produce ECG changes such as U waves, T-wave flattening, and arrhythmias (especially if the patient is taking digoxin), particularly ventricular arrhythmias,[432,433] which, if left untreated, deteriorate to PEA or asystole.

Several studies reported an association with hypokalemia and development of ventricular fibrillation,[434-437] whereas a single animal study reported that hypokalemia lowered the ventricular fibrillation threshold.[438] However, the management of hypokalemia in the setting of cardiotoxicity, specifically torsades de pointes, is largely based on historical case reports that report slow infusion of potassium over hours.[439]

The effect of bolus administration of potassium for cardiac arrest suspected to be secondary to hypokalemia is unknown and ill advised. (Class III, LOE C)

11.3 Sodium (Na+)

Sodium is the major intravascular ion that influences serum osmolality. Sodium abnormalities are unlikely to lead to cardiac arrest, and there are no specific recommendations for either checking or treating sodium during cardiac arrest. Disturbances in sodium level are unlikely to be the primary cause of severe cardiovascular instability.

11.4 Magnesium (Mg++)

Magnesium is an essential electrolyte and an important cofactor for multiple enzymes, including ATPase. Magnesium is necessary for the movement of sodium, potassium, and calcium into and out of cells and plays an important role in stabilizing excitable membranes. The presence of a low plasma magnesium concentration has been associated with poor prognosis in cardiac arrest patients.[435,440-443]

11.5 Hypermagnesemia

Hypermagnesemia is defined as a serum magnesium concentration >2.2 mEq/L (normal: 1.3 to 2.2 mEq/L). Neurological symptoms of hypermagnesemia include muscular weakness, paralysis, ataxia, drowsiness, and confusion. Hypermagnesemia can produce vasodilation and hypotension.[444] Extremely high serum magnesium levels may produce a depressed level of consciousness, bradycardia, cardiac arrhythmias, hypoventilation, and cardiorespiratory arrest.[435,442,443]

11.5.1 ACLS Modifications in Management of Cardiac Arrest and Severe Cardiotoxicity Due to Hypermagnesemia

Administration of calcium (calcium chloride [10%] 5 to 10 mL or calcium gluconate [10%] 15 to 30 mL IV over 2 to 5 minutes) may be considered during cardiac arrest associated with hypermagnesemia. (Class IIb, LOE C)

11.6 Hypomagnesemia

Hypomagnesemia, defined as a serum magnesium concentration <1.3 mEq/L, is far more common than hypermagnesemia. Hypomagnesemia usually results from decreased absorption or increased loss of magnesium from either the kidneys or intestines (diarrhea). Alterations in thyroid hormone function, certain medications (eg, pentamidine, diuretics, alcohol), and malnourishment can also induce hypomagnesemia.

11.6.1 ACLS Modifications in Management of Cardiac Arrest and Severe Cardiotoxicity Due to Hypomagnesemia

Hypomagnesemia can be associated with polymorphic ventricular tachycardia, including torsades de pointes, a pulseless form (polymorphic) of ventricular tachycardia. For cardiotoxicity and cardiac arrest, IV magnesium 1 to 2 g of MgSO4 bolus IV push is recommended. (Class I, LOE C)

11.7 Calcium (Ca++)

Calcium abnormality as an etiology of cardiac arrest is rare. There are no studies evaluating the treatment of hypercalcemia or hypocalcemia during arrest.

However, empirical use of calcium (calcium chloride [10%] 5 to 10 mL OR calcium gluconate [10%] 15 to 30 mL IV over 2 to 5 minutes) may be considered when hyperkalemia or hypermagnesemia is suspected as the cause of cardiac arrest. (Class IIb, LOE C)

12 Cardiac Arrest Associated With Trauma

BLS and ACLS for the trauma patient are fundamentally the same as that for the patient with primary cardiac arrest, with focus on support of airway, breathing, and circulation. In addition, reversible causes of cardiac arrest need to considered. While CPR in the pulseless trauma patient has overall been considered futile, several reversible causes of cardiac arrest in the context of trauma are correctible and their prompt treatment could be life-saving. These include hypoxia, hypovolemia, diminished cardiac output secondary to pneumothorax or pericardial tamponade, and hypothermia.

12.1 BLS Modifications

When multisystem trauma is present or trauma involves the head and neck, the cervical spine must be stabilized. A jaw thrust should be used instead of a head tilt–chin lift to establish a patent airway. If breathing is inadequate and the patient’s face is bloody, ventilation should be provided with a barrier device, a pocket mask, or a bag-mask device while maintaining cervical spine stabilization. Stop any visible hemorrhage using direct compression and appropriate dressings. If the patient is completely unresponsive despite rescue breathing, provide standard CPR and defibrillation as indicated.

12.2 ACLS Modifications

After initiation of BLS care, if bag-mask ventilation is inadequate, an advanced airway should be inserted while maintaining cervical spine stabilization. If insertion of an advanced airway is not possible and ventilation remains inadequate, experienced providers should consider a cricothyrotomy.

A unilateral decrease in breath sounds during positive-pressure ventilation should prompt the rescuer to consider the possibility of pneumothorax, hemothorax, or rupture of the diaphragm.

When the airway, oxygenation, and ventilation are adequate, evaluate and support circulation. Control ongoing bleeding where possible and replace lost volume if the losses appear to have significantly compromised circulating blood volume. Cardiac arrest resuscitation will likely be ineffective in the presence of uncorrected severe hypovolemia.

Treatment of PEA requires identification and treatment of reversible causes, such as severe hypovolemia, hypothermia, cardiac tamponade, or tension pneumothorax.[445] Development of bradyasystolic rhythms often indicates the presence of severe hypovolemia, severe hypoxemia, or cardiorespiratory failure. Ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT) are treated with CPR and defibrillation. For treatment recommendations regarding cardiac tamponade in traumatic cardiac arrest, see "Cardiac Arrest Caused by Cardiac Tamponade."

Resuscitative thoracotomy may be indicated in selected patients. A review of the literature from 1966 to 1999, carried out by the American College of Surgeons Committee on Trauma, found a survival rate of 7.8% (11.2% for penetrating injuries and 1.6% for blunt lesions) in trauma victims who would otherwise have 100% mortality.[446] Practitioners should consult the guidelines for withholding or terminating resuscitation, which were developed for victims of traumatic cardiac arrest by a joint committee of the National Association of EMS Physicians and the American College of Surgeons Committee on Trauma.[447,448]

12.3 Commotio Cordis

Commotio cordis is VF triggered by a blow to the anterior chest during a cardiac repolarization.[449,450] Blunt cardiac injury may result in cardiac contusion with injured myocardium and risk of ECG changes and arrhythmias. Even a small blow to the anterior chest during a cardiac repolarization, such as that imparted by the strike of a baseball or hockey puck, may trigger VF, so-called commotio cordis.[451] Events causing commotio cordis are most commonly seen in young persons up to 18 years of age who are engaged in sports but may occur during daily activities. Prompt recognition that a precordial blow may cause VF is critical. Rapid defibrillation is often life-saving for these frequently young victims of cardiac arrest. Provision of immediate BLS care using an automated external defibrillator (AED) and ACLS for VF in this setting is appropriate.

13 Cardiac Arrest in Accidental Hypothermia

Unintentional or accidental hypothermia is a serious and preventable health problem. Severe hypothermia (body temperature <30°C [86°F]) is associated with marked depression of critical body functions, which may make the victim appear clinically dead during the initial assessment. Therefore, lifesaving procedures should be initiated unless the victim is obviously dead (eg, rigor mortis, decomposition, hemisection, decapitation). The victim should be transported as soon as possible to a center where aggressive rewarming during resuscitation is possible.

13.1 Initial Care for Victims of Accidental Hypothermia

When the victim is extremely cold but has maintained a perfusing rhythm, the rescuer should focus on interventions that prevent further loss of heat and begin to rewarm the victim immediately. Additional interventions include the following:

Prevent additional evaporative heat loss by removing wet garments and insulating the victim from further environmental exposures. Passive rewarming is generally adequate for patients with mild hypothermia (temperature >34°C [93.2°F]).

For patients with moderate (30°C to 34°C [86°F to 93.2°F]) hypothermia with a perfusing rhythm, external warming techniques are appropriate.[452] Passive rewarming alone will be inadequate for these patients.[453]

For patients with severe hypothermia (<30°C [86°F]) with a perfusing rhythm, core rewarming is often used, although some have reported successful rewarming with active external warming techniques.[454,455] Active external warming techniques include forced air or other efficient surface-warming devices.

Patients with severe hypothermia and cardiac arrest can be rewarmed most rapidly with cardiopulmonary bypass.[452,456-461] Alternative effective core rewarming techniques include warm-water lavage of the thoracic cavity[459,462-466] and extracorporeal blood warming with partial bypass.[467-469]

Adjunctive core rewarming techniques include warmed IV or intraosseous (IO) fluids and warm humidified oxygen.[470] Heat transfer with these measures is not rapid, and should be considered supplementary to active warming techniques.

Do not delay urgent procedures such as airway management and insertion of vascular catheters. Although these patients may exhibit cardiac irritability, this concern should not delay necessary interventions.

Beyond these critical initial steps, the treatment of severe hypothermia (temperature <30°C [86°F]) in the field remains controversial. Many providers do not have the time or equipment to assess core body temperature or to institute aggressive rewarming techniques, although these methods should be initiated when available.

13.1.1 BLS Modifications

When the victim is hypothermic, pulse and respiratory rates may be slow or difficult to detect,[471,472] and the ECG may even show asystole. If the hypothermic victim has no signs of life, begin CPR without delay. If the victim is not breathing, start rescue breathing immediately.

The temperature at which defibrillation should first be attempted in the severely hypothermic patient and the number of defibrillation attempts that should be made have not been established. There are case reports of refractory ventricular arrhythmias with severe hypothermia; however, in a recent animal model it was found that an animal with a temperature of as low as 30°C had a better response to defibrillation than did normothermic animals in arrest.[473,474]

If VT or VF is present, defibrillation should be attempted. If VT or VF persists after a single shock, the value of deferring subsequent defibrillations until a target temperature is achieved is uncertain.

It may be reasonable to perform further defibrillation attempts according to the standard BLS algorithm concurrent with rewarming strategies. (Class IIb, LOE C)

To prevent further loss of core heat, remove wet garments and protect the victim from additional environmental exposure. Insofar as possible, this should be done while providing initial BLS therapies. Rewarming should be attempted when feasible.

13.1.2 ACLS Modifications

For unresponsive patients or those in arrest, advanced airway insertion is appropriate as recommended in the standard ACLS guidelines. Advanced airway management enables effective ventilation with warm, humidified oxygen and reduces the likelihood of aspiration in patients in periarrest.

ACLS management of cardiac arrest due to hypothermia focuses on aggressive active core rewarming techniques as the primary therapeutic modality. Conventional wisdom indicates that the hypothermic heart may be unresponsive to cardiovascular drugs, pacemaker stimulation, and defibrillation; however, the data to support this are essentially theoretical.[475] In addition, drug metabolism may be reduced, and there is a theoretical concern that medications could accumulate to toxic levels in the peripheral circulation if given repeatedly to the severely hypothermic victim. For these reasons, previous guidelines suggest withholding IV drugs if the victim's core body temperature is <30°C (86°F).

In the last decade a number of animal investigations have been performed evaluating both vasopressors and antiarrhythmic medications that could challenge some of this conventional wisdom.[476-481] In a meta-analysis of these studies, Wira et al[482] found that vasopressor medications (ie, epinephrine or vasopressin) increased rates of return of spontaneous circulation (ROSC) when compared with placebo (62% versus 17%; *P*<0.0001, n=77). Coronary perfusion pressures were increased in groups that received vasopressors compared with placebo. But groups given antiarrhythmics showed no improvement in ROSC when compared with control groups, although sample sizes were relatively small (n=34 and n=40, respectively).

One small-animal investigation suggested that the application of standard normothermic ACLS algorithms using both drugs (ie, epinephrine and amiodarone) and defibrillation improved ROSC compared with a placebo arm of defibrillation only (91% versus 30%; *P*<0.01; n=21). Human trials of medication use in accidental hypothermia do not exist, although case reports of survival with use of intra-arrest medication have been reported.[460,464,483]

Given the lack of human evidence and relatively small number of animal investigations, the recommendation for administration or withholding of medications is not clear.

It may be reasonable to consider administration of a vasopressor during cardiac arrest according to the standard ACLS algorithm concurrent with rewarming strategies. (Class IIb, LOE C)

13.1.3 After ROSC

After ROSC, patients should continue to be warmed to a goal temperature of approximately 32° to 34°C; this can be maintained according to standard postarrest guidelines for mild to moderate hypothermia in patients for whom induced hypothermia is appropriate. For those with contraindications to induced hypothermia, rewarming can continue to normal temperatures.

Because severe hypothermia is frequently preceded by other disorders (eg, drug overdose, alcohol use, or trauma), the clinician must look for and treat these underlying conditions while simultaneously treating hypothermia.

13.1.4 Withholding and Cessation of Resuscitative Efforts

Multiple case reports indicate survival from accidental hypothermia even with prolonged CPR and downtimes.[456,468] Thus, patients with severe accidental hypothermia and cardiac arrest may benefit from resuscitation even in cases of prolonged downtime and prolonged CPR. Low serum potassium may indicate hypothermia, and not hypoxemia, as the primary cause of the arrest.[484] Patients should not be considered dead before warming has been provided.

14 Cardiac Arrest in Avalanche Victims

Avalanche-related deaths are on the rise in North America due to winter recreational activities, including backcountry skiing and snowboarding, helicopter and snowcat skiing, snowmobiling, out-of-bounds skiing, ice climbing, mountaineering, and snowshoeing. The most common causes of avalanche-related death are asphyxia, trauma, and hypothermia, or combinations of the 3. Rescue and resuscitation strategies focus on management of asphyxia and hypothermia, because most field research has been done on these 2 conditions.

Avalanches occur in areas that are difficult to access by rescuers in a timely manner, and burials frequently involve multiple victims. The decision to initiate full resuscitative measures should be determined by the number of victims, resources available, and likelihood of survival. Studies of avalanche victims demonstrate a progressive nonlinear reduction in survival as the time of avalanche burial lengthens.[485-488] The likelihood of survival is minimal when avalanche victims are buried >35 minutes with an obstructed airway and in cardiac arrest on extrication[486,487,489-495] or are buried for any length of time and in cardiac arrest on extrication with an obstructed airway and an initial core temperature of <32°C.[487-489,493,496]

It may be difficult to know with any certainty how long an avalanche victim has been buried. The core temperature at time of extrication provides a proxy for duration of burial. A case series[496] of buried avalanche victims showed a maximum cooling rate of 8°C per hour, whereas a case report[493] described a maximum cooling rate of 9°C per hour. These cooling rates suggest that at 35 minutes of burial, the core temperature may drop as low as 32°C.

If information on the duration of burial or the state of the airway on extrication is not available to the receiving physician, a serum potassium level of <8 mmol/L on hospital admission is a prognostic marker for ROSC[490] and survival to hospital discharge.[489,496] High potassium values are associated with asphyxia,[489,496-498] and there is an inverse correlation between admission K+ and survival to discharge in all-cause hypothermic patients.[489,499-502] In a series of 32 avalanche survivors the highest serum K+ was 6.4 mmol/L,[496] but there is a single case report of a 31- month-old child with a K+ of 11.8 mmol/L presenting with hypothermia from exposure unrelated to an avalanche who survived.[503] This suggests that the upper survivable limit of potassium is unknown for children who are hypothermic and victims of avalanche.

Full resuscitative measures, including extracorporeal rewarming when available, are recommended for all avalanche victims without the characteristics outlined above that deem them unlikely to survive or with any obvious lethal traumatic injury. (Class I, LOE C)

15 Cardiac Arrest Due to Drowning

Each year drowning is responsible for more than 500 000 deaths worldwide.[504] Drowning is a leading preventable cause of unintentional morbidity and mortality.[505,506]

All victims of drowning who require any form of resuscitation (including rescue breathing alone) should be transported to the hospital for evaluation and monitoring, even if they appear to be alert and demonstrate effective cardiorespiratory function at the scene. (Class I, LOE C)

A number of terms are used to describe drowning.[507] To aid in use of consistent terminology and uniform reporting of data, use of the Utstein definitions and style of data reporting specific to drowning is recommended.[508,509]

Although survival is uncommon in victims who have undergone prolonged submersion and require prolonged resuscitation,[510,511] successful resuscitation with full neurological recovery has occurred occasionally after prolonged submersion in icy water[512-515] and, in some instances, warm water.[516,517] For this reason, scene resuscitation should be initiated and the victim transported to the ED unless there is obvious death (eg, rigor mortis, decomposition, hemisection, decapitation, lividity).

15.1 BLS Modifications

The most important and detrimental consequence of submersion is hypoxia; therefore, oxygenation, ventilation, and perfusion should be restored as rapidly as possible. This will require immediate bystander CPR plus activation of the EMS system. With the *2010 AHA Guidelines for CPR and ECC*, CPR now begins with chest compressions in a C-A-B sequence. However, the guidelines recommend that healthcare providers tailor the sequence based upon the presumed etiology of the arrest. Healthcare provider CPR for drowning victims should use the traditional A-B-C approach in view of the hypoxic nature of the arrest. Victims with only respiratory arrest usually respond after a few artificial breaths are given.

15.2 Recovery From the Water

When attempting to rescue a drowning victim, the rescuer should get to the victim as quickly as possible. It is crucial, however, that the rescuer pays constant attention to his or her own personal safety during the rescue process.

The reported incidence of cervical spine injury in drowning victims is low (0.009%).[518,519] Unnecessary cervical spine immobilization can impede adequate opening of the airway and delay delivery of rescue breaths.

Routine stabilization of the cervical spine in the absence of circumstances that suggest a spinal injury is not recommended.[519,520] (Class III, LOE B)

15.3 Rescue Breathing

The first and most important treatment of the drowning victim is the immediate provision of ventilation. Prompt initiation of rescue breathing increases the victim's chance of survival.[521] Rescue breathing is usually performed once the unresponsive victim is in shallow water or out of the water. Mouth-to-nose ventilation may be used as

an alternative to mouth-to-mouth ventilation if it is difficult for the rescuer to pinch the victim's nose, support the head, and open the airway in the water.

Management of the drowning victim's airway and breathing is similar to that recommended for any victim of cardiopulmonary arrest. Some victims aspirate no water because they develop laryngospasm or breath-holding.[511,522] Even if water is aspirated, there is no need to clear the airway of aspirated water, because only a modest amount of water is aspirated by the majority of drowning victims, and aspirated water is rapidly absorbed into the central circulation.[511,523] Attempts to remove water from the breathing passages by any means other than suction (eg, abdominal thrusts or the Heimlich maneuver) are unnecessary and potentially dangerous.[523]

The routine use of abdominal thrusts or the Heimlich maneuver for drowning victims is not recommended. (Class III, LOE C)

15.4 Chest Compressions

As soon as the unresponsive victim is removed from the water, the rescuer should open the airway, check for breathing, and if there is no breathing, give 2 rescue breaths that make the chest rise (if this was not done previously in the water). After delivery of 2 effective breaths, if a pulse is not definitely felt, the healthcare provider should begin chest compressions and provide cycles of compressions and ventilations according to the BLS guidelines. Once the victim is out of the water, if he or she is unresponsive and not breathing after delivery of 2 rescue breaths and is pulseless, rescuers should attach an AED and attempt defibrillation if a shockable rhythm is identified. It is only necessary to dry the chest area before applying the defibrillation pads and using the AED. If hypothermia is present, follow the recommendations in "Cardiac Arrest in Accidental Hypothermia."

15.5 Vomiting by the Victim During Resuscitation

The victim may vomit when the rescuer performs chest compressions or rescue breathing. In fact, in a 10-year study in Australia, two thirds of victims who received rescue breathing and 86% of those who required compressions and ventilations vomited.[524] If vomiting occurs, turn the victim to the side and remove the vomitus using your finger, a cloth, or suction. If spinal cord injury is suspected, the victim should be logrolled so that the head, neck, and torso are turned as a unit to protect the cervical spine.

15.6 ACLS Modifications

Victims in cardiac arrest may present with asystole, PEA, or pulseless VT/VF. For treatment of these rhythms, follow the appropriate PALS or ACLS guidelines. Case reports of pediatric patients document the use of surfactant for fresh water–induced respiratory distress, but further research is needed.[525-528] The use of extracorporeal membrane oxygenation in patients with severe hypothermia after submersion has been documented in case reports.[514,515,529]

16 Cardiac Arrest Associated With Electric Shock and Lightning Strikes

Injuries from electric shock and lightning strike result from the direct effects of current on the heart and brain, cell membranes, and vascular smooth muscle. Additional injuries result from the conversion of electric energy into heat energy as current passes through body tissues.[530]

16.1 Electric Shock

Fatal electrocutions may occur with household current; however, high-tension current generally causes the most serious injuries.[531] Contact with alternating current (the type of current commonly present in most North American households and commercial settings) may cause tetanic skeletal muscle contractions, "locking" the victim to the source of the electricity and thereby leading to prolonged exposure. The frequency of alternating current increases the likelihood of current flow through the heart during the relative refractory period, which is the "vulnerable period" of the cardiac cycle. This exposure can precipitate VF, which is analogous to the R-on-T phenomenon that occurs in nonsynchronized cardioversion.[532]

16.2 Lightning Strike

The National Weather Service estimates that an average of 70 deaths and 630 injuries occur due to lightning strikes in the United States each year.[533] Lightning strike injuries can vary widely, even among groups of people struck at the same time. Symptoms are mild in some victims, whereas fatal injuries occur in others.[534,535]

The primary cause of death in victims of lightning strike is cardiac arrest, which may be associated with primary VF or asystole.[534-537] Lightning acts as an instantaneous, massive direct-current shock, simultaneously depolarizing the entire myocardium.[535,538] In many cases intrinsic cardiac automaticity may spontaneously restore organized cardiac activity and a perfusing rhythm. However, concomitant respiratory arrest due to thoracic muscle spasm and suppression of the respiratory center may continue after ROSC. Unless ventilation is supported, a secondary hypoxic (asphyxial) cardiac arrest will develop.[539]

Lightning also can have myriad effects on the cardiovascular system, producing extensive catecholamine release or autonomic stimulation. The victim may develop hypertension, tachycardia, nonspecific ECG changes (including prolongation of the QT interval and transient T-wave inversion), and myocardial necrosis with release of creatinine kinase-MB fraction.

Lightning can produce a wide spectrum of peripheral and central neurological injuries. The current can produce brain hemorrhages, edema, and small-vessel and neuronal injury. Hypoxic encephalopathy can result from cardiac arrest.

Victims are most likely to die of lightning injury if they experience immediate respiratory or cardiac arrest and no treatment is provided. Patients who do not suffer respiratory or cardiac arrest, and those who respond to immediate treatment, have an excellent chance of recovery. Therefore, when multiple victims are struck simultaneously by lightning, rescuers should give the highest priority to patients in respiratory or cardiac arrest.

For victims in cardiac arrest, treatment should be early, aggressive, and persistent. Victims with respiratory arrest may require only ventilation and oxygenation to avoid secondary hypoxic cardiac arrest. Resuscitation attempts may have high success rates and efforts may be effective even when the interval before the resuscitation attempt is prolonged.[539]

16.3 BLS Modifications

The rescuer must first be certain that rescue efforts will not put him or her in danger of electric shock. When the scene is safe (ie, the danger of shock has been removed), determine the victim's cardiorespiratory status. If spontaneous respiration or circulation is absent, immediately initiate standard BLS resuscitation care, including the use of an AED to identify and treat VT or VF.

Maintain spinal stabilization during extrication and treatment if there is a likelihood of head or neck trauma.[540,541] Both lightning and electric shock often cause multiple trauma, including injury to the spine,[541] muscular strains, internal injuries from being thrown, and fractures caused by the tetanic response of skeletal muscles.[542] Remove smoldering clothing, shoes, and belts to prevent further thermal damage.

16.4 ACLS Modifications

No modification of standard ACLS care is required for victims of electric injury or lightning strike, with the exception of paying attention to possible cervical spine injury. Establishing an airway may be difficult for patients with electric burns of the face, mouth, or anterior neck. Extensive soft-tissue swelling may develop rapidly, complicating airway control measures. Thus, early intubation should be performed for patients with evidence of extensive burns even if the patient has begun to breathe spontaneously.

For victims with significant tissue destruction and in whom a pulse is regained, rapid IV fluid administration is indicated to counteract distributive/hypovolemic shock and to correct ongoing fluid losses due to third spacing. Fluid administration should be adequate to maintain diuresis and facilitate excretion of myoglobin, potassium, and other byproducts of tissue destruction (this is particularly true for patients with electric injury).[538] Regardless of the extent of external injuries after electrothermal shock, the underlying tissue damage can be far more extensive.

17 Cardiac Arrest Caused by Cardiac Tamponade

Cardiac tamponade can be a life-threatening event. Increasing fluid and pressure in the pericardium reduces atrial and ventricular filling. As filling is reduced, stroke volume and cardiac output fall, with associated hypotension leading to cardiac arrest. Rapid diagnosis and drainage of the pericardial fluid are required to avoid cardiovascular collapse.

Pericardiocentesis guided by echocardiography is a safe and effective method of relieving tamponade in a nonarrest setting, especially when used in conjunction with a pericardial drain, and may obviate the need for subsequent operating room treatment.[543-547]

In the arrest setting, in the absence of echocardiography, emergency pericardiocentesis without imaging guidance can be beneficial. (Class IIa, LOE C)

Emergency department thoracotomy may improve survival compared with pericardiocentesis in patients with pericardial tamponade secondary to trauma who are in cardiac arrest or who are prearrest,[548-550] especially if gross blood causes clotting that blocks a pericardiocentesis needle.[551] (Class IIb, LOE C)

18 Cardiac Arrest Following Cardiac Surgery

The incidence of cardiac arrest following cardiac surgery is in the range of 1–3%. Causes include conditions that may be readily reversed such as ventricular fibrillation, hypovolemia, cardiac tamponade, or tension pneumothorax. Pacing wires, if present, may reverse symptomatic bradycardia or asystole. A recent review may be helpful for those seeking additional information.[552]

18.1 Resternotomy

Studies of patients with cardiac arrest after cardiac surgery who are treated with resternotomy and internal cardiac compression have reported improved outcome compared with a standard protocol[553-563] when patients are treated by experienced personnel in intensive care units. Findings of similar quality studies[564-568] reported no difference in outcomes when resternotomy was compared with standard management of cardiac arrest after cardiac surgery. Resternotomy performed outside an intensive care unit generally has a very poor outcome.[553,560,567]

For patients with cardiac arrest following cardiac surgery, it is reasonable to perform resternotomy in an appropriately staffed and equipped intensive care unit. (Class IIa, LOE B)

Despite rare case reports describing damage to the heart possibly due to external chest compressions,[569,570] chest compressions should not be withheld if emergency resternotomy is not immediately available. (Class IIa, LOE C)

18.2 Mechanical Circulatory Support

Nine case series have reported survival of some post–cardiac surgery patients during cardiac arrest refractory to standard resuscitation measures following the use of extracorporeal membrane oxygenation[571-575] and cardiopulmonary bypass.[563,576-578]

In post-cardiac surgery patients who are refractory to standard resuscitation procedures, mechanical circulatory support (eg, extracorporeal membrane oxygenation and cardiopulmonary bypass) may be effective in improving outcome. (Class IIb, LOE B)

18.3 Pharmacological Intervention

Rebound hypertension following administration of pressors during resuscitation has the potential to induce significant bleeding in this group of patients. Results from a single study of epinephrine[579] and another study evaluating the choice of antiarrhythmics[580]

in patients with cardiac arrest following cardiac surgery were neutral. There is insufficient evidence on epinephrine dose, antiarrhythmic use, and other routine pharmacological interventions to recommend deviating from standard resuscitation guidelines when cardiac arrest occurs after cardiac surgery.

19 Authorship and Disclosures

19.1 2015 Writing Team

Eric J. Lavonas, Chair; Ian R. Drennan; Andrea Gabrielli; Alan C. Heffner; Christopher O. Hoyte; Aaron M. Orkin; Kelly N. Sawyer; Michael W. Donnino

Table 3: Part 10: Special Circumstances of Resuscitation: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 10: Special Circumstances of Resuscitation: 2015 Guidelines Update Writing Group Disclosures								
Writing Group Member	**Employment**	**Research Grant**	**Other Research Support**	**Speakers' Bureau/Honora**	**Expert Witness**	**Ownership Interest**	**Consultant/Advis Board**	**Other**
Eric J. Lavonas	Rocky Mountain Poison & Drug Center; Denver Health and Hospital Authority	None	None	None	None	None	None	BTG International, Inc. – relationship between Employer and BTG†
Ian R. Drennan	St. Michael's Hospital Rescu	None	None	None	None	None	None	None
Andrea Gabrielli	University of Florida College of Medicine	None	None	None	For intraoperative cardiac ischemia*	None	None	None
Alan C. Heffner	UNC School of Medicine	None	None	Edwards Lifesciences	Defense and plaintiff consultant and causation expert in cases focused on airway managemen and CPR*	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Christopher O. Hoyte	University of Colorado School of Medicine	None	None	None	None	None	None	None
Aaron M. Orkin	University of Toronto	Canadian Institutes of Health Research*	None	None	None	None	None	Remote Health Initiative*
Kelly N. Sawyer	William Beaumont Hospital	None	None	None	None	None	None	None
Consultants								
Michael W. Donnino	Beth Israel Deaconess Med Center	None	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it the preceding definition.*Modest. †Significant.

19.2 2010 Writing Team

Terry L. Vanden Hoek, Chair; Laurie J. Morrison; Michael Shuster; Michael Donnino; Elizabeth Sinz; Eric J. Lavonas; Farida M. Jeejeebhoy; Andrea Gabrielli

Table 4: 2010 - Guidelines Part 12: Cardiac Arrest in Special Situations: Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 12: Cardiac Arrest in Special Situations: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Terry L. Vanden Hoek	The University of Chicago-Associate Professor	*Vanden Hoek, Principal Investigator, Department of Defense, Office of Naval Research,					

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Laurie J. Morrison	St. Michaels Clinician scientist	None	None	None	None	None	None
Michael Shuster	Self-employed–emergency physician	None	None	None	None	None	None
Michael Donnino	Harvard Medical Faculty Physicians–Ph	† Corticosteroids in Post-arrest Shock (American Heart Association, Scientist Development Grant); Thiamine as a Metabolic Resuscitator in Septic Shock (NIH pending); * Statins in Sepsis (Eleanor Shore) Clinical Correlates to Influenza Genome (NIH); Thiamine Deficiency in Critically Ill (Harvard Medical School/NIH); Thiamine for Congestive Heart Failure (Baystate Incubator Fund-NON-industry, academic hospital funding)	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Elizabeth Sinz	Penn State Hershey Medical Center–Professor of Anesthesiology and Neurosurgery; AHA–Associate Science Editor	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Eric J. Lavonas	Rocky Mountain Poison & Drug Center; (RMPDC) Denver, Colo. Associate Director	†RMPDC performed research related to hydroxocobala prior to its licensure in the United States. This occurred prior to my arrival at RMPDC. RMPDC-DH performed work related to the development of hydroxocobala (CyanoKit, Dey LP) as a cyanide antidote. Various projects were completed in 2001, 2005, and 2006. Some of the sponsors of this research (EMD; Merck KGA) either no longer exist or no longer have an interest in hydroxocobala I was not involved in this research, which was performed long before my arrival. RMPDC-DH does not have any current or pending hydroxocobala related projects. Neither I nor any other	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Farida M. Jeejeebhoy	Self employed cardiologist, affiliate with University Health Network/Mt Sinai and University of Toronto	None	None	None	None	None	None
Andrea Gabrielli	University of Florida–Profes of Anesthesiology and Surgery	†NIH-Biomarkers in Traumatic Brain Injury	None	None	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

20 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 10: Special Circumstances of Resuscitation. ECCguidelines.heart.org.

References

1. Wheeler E, Jones TS, Gilbert MK, Davidson PJ. Opioid overdose prevention programs providing naloxone to laypersons—United States, 2014. *MMWR Morb Mortal Wkly Rep.* 2015;64(23): 631-635.

2. Vanden Hoek TL, Morrison LJ, Shuster M, Donnino M, Sinz E, Lavonas EJ, Jeejeebhoy FM, Gabrielli A. Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S829–S861. doi: 10.1161/ CIRCULATIONAHA.110.971069.

3. Deakin CD, Morrison LJ, Morley PT, Callaway CW, Kerber RE, Kronick SL, Lavonas EJ, Link MS, Neumar RW, Otto CW, Parr M, Shuster M, Sunde K, Peberdy MA, Tang W, Hoek TL, Böttiger BW, Drajer S, Lim SH, Nolan JP; Advanced Life Support Chapter Collaborators. Part 8: advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e93–e174. doi: 10.1016/j.resuscitation.2010.08.027.

4. Hazinski MF, Nolan JP, Aickin R, Bhanji F, Billi JE, Callaway CW, Castren M, de Caen AR, Ferrer JME, Finn JC, Gent LM, Griffin RE, Iverson S, Lang E, Lim SH, Maconochie IK, Montgomery WH, Morley PT, Nadkarni VM, Neumar RW, Nikolaou NI, Perkins GD, Perlman JM, Singletary EM, Soar J, Travers AH, Welsford M, Wyllie J, Zideman DA. Part 1: executive summary: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S2–S39. doi: 10.1161/CIR.0000000000000270.

5. Nolan JP, Hazinski MF, Aickin R, Bhanji F, Billi JE, Callaway CW, Castren M, de Caen AR, Ferrer JME, Finn JC, Gent LM, Griffin RE, Iverson S, Lang E, Lim SH, Maconochie IK, Montgomery WH, Morley PT, Nadkarni VM, Neumar RW, Nikolaou NI, Perkins GD, Perlman JM, Singletary EM, Soar J, Travers AH, Welsford M, Wyllie J, Zideman DA. Part 1: executive summary: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

6. Callaway CW, Soar J, Aibiki M, Böttiger BW, Brooks SC, Deakin CD, Donnino MW, Drajer S, Kloeck W, Morley PT, Morrison LJ, Neumar RW, Nicholson TC, Nolan JP, Okada K, O'Neil BJ, Paiva EF, Parr MJ, Wang TL, Witt J; on behalf of the Advanced Life Support Chapter Collaborators. Part 4: advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S84–S145. doi: 10.1161/CIR.0000000000000273.

7. Soar J, Callaway CW, Aibiki M, Böttiger BW, Brooks SC, Deakin CD, Donnino MW, Drajer S, Kloeck W, Morley PT, Morrison LJ, Neumar RW, Nicholson TC, Nolan JP, Okada K, O'Neil BJ, Paiva EF, Parr MJ, Wang TL, Witt J; on behalf of the Advanced Life Support Chapter Collaborators. Part 4: advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

8. O'Connor D, Green S, Higgins J, eds. Chapter 5: defining the review questions and developing criteria for including studies. In: The Cochrane Collaboration. Higgins JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0. 2011. http://hand- book.cochrane.org/. Accessed May 6, 2015.

9. Schünemann H, Broz?ek J, Guyatt G, Oxman A. GRADE Handbook. 2013. http://www.guidelinedevelopment.org/handbook/. Accessed May 6, 2015.

10. Morley PT, Lang E, Aickin R, Billi JE, Eigel B, Ferrer JME, Finn JC, Gent LM, Griffin RE, Hazinski MF, Maconochie IK, Montgomery WH, Morrison LJ, Nadkarni VM, Nikolaou NI, Nolan JP, Perkins GD, Sayre MR, Travers AH, Wyllie J, Zideman DA. Part 2: evidence evaluation and management of conflicts of interest: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1): S40–S50. doi: 10.1161/CIR.0000000000000271.

11. Lang E, Morley PT, Aickin R, Billi JE, Eigel B, Ferrer JME, Finn JC, Gent LM, Griffin RE, Hazinski MF, Maconochie IK, Montgomery WH, Morrison LJ, Nadkarni VM, Nikolaou NI, Nolan JP, Perkins GD, Sayre MR, Travers AH, Wyllie J, Zideman DA. Part 2: evidence evaluation and management of conflicts of interest: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

12. Jeejeebhoy FM, Zelop CM, Lipman S, Carvalho B, Joglar J, Mhyre JM, Katz VL, Lapinsky SE, Einav S, Warnes CA, Page RL, Griffin RE, Jain A, Dainty KN, Arafeh J, Windrim R, Koren G, Callaway C; on behalf of the American Heart Association Emergency Cardiovascular Care Committee, Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation, Council on Cardiovascular Diseases in the Young, and Council on Clinical Cardiology. Cardiac arrest in pregnancy: a scientific statement from the American Heart Association. Circulation. 2015. In press. doi: 10.1161/CIR.0000000000000300.

13. Mhyre JM, Tsen LC, Einav S, Kuklina EV, Leffert LR, Bateman BT. Cardiac arrest during hospitalization for delivery in the United States, 1998-2011. Anesthesiology. 2014;120:810–818. doi: 10.1097/ ALN.0000000000000159.

14. Centers for Disease Control and Prevention. Pregnancy mortality sur- veillance system http://www.cdc.gov/reproductivehealth/maternalin- fanthealth/pmss.html. Accessed April 2, 2015.

15. Public Health Agency of Canada. Maternal mortality in Canada. http:// sogc.org/wp-content/uploads/2014/05/REVISEDMortality-EN-Final- PDF.pdf. Accessed April 2, 2015.

16. Hogan MC, Foreman KJ, Naghavi M, Ahn SY, Wang M, Makela SM, Lopez AD, Lozano R, Murray CJL. Maternal mortality for 181 coun- tries, 1980–2008: a systematic analysis of progress towards Millennium Development Goal 5. 2010. http://cdrwww.who.int/pmnch/topics/mater- nal/20100402_ihmearticle.pdf. Accessed April 2, 2015.

17. Creanga AA, Berg CJ, Ko JY, Farr SL, Tong VT, Bruce FC, Callaghan WM. Maternal mortality and morbidity in the United States: where are we now? J Womens Health (Larchmt). 2014;23:3–9. doi: 10.1089/ jwh.2013.4617.

18. Ueland K, Novy MJ, Peterson EN, Metcalfe J. Maternal cardiovascu- lar dynamics. IV. The influence of gestational age on the maternal car- diovascular response to posture and exercise. Am J Obstet Gynecol. 1969;104:856–864.

19. Goodwin AP, Pearce AJ. The human wedge. A manoeuvre to relieve aor- tocaval compression during resuscitation in late pregnancy. Anaesthesia. 1992;47:433–434.

20. Rees GA, Willis BA. Resuscitation in late pregnancy. Anaesthesia. 1988;43:347–349.

21.

Cyna AM, Andrew M, Emmett RS, Middleton P, Simmons SW. Techniques for preventing hypotension during spinal anaesthesia for caesarean sec- tion. Cochrane Database Syst Rev. 2006:CD002251.

22. Dijkman A, Huisman CM, Smit M, Schutte JM, Zwart JJ, van Roosmalen JJ, Oepkes D. Cardiac arrest in pregnancy: increasing use of perimortem caesarean section due to emergency skills training? BJOG. 2010;117:282– 287. doi: 10.1111/j.1471-0528.2009.02461.x.

23. Page-Rodriguez A, Gonzalez-Sanchez JA. Perimortem cesarean section of twin pregnancy: case report and review of the literature. Acad Emerg Med. 1999;6:1072–1074.

24. Cardosi RJ, Porter KB. Cesarean delivery of twins during maternal cardio- pulmonary arrest. Obstet Gynecol. 1998;92(4 Pt 2):695–697.

25. Rees SG, Thurlow JA, Gardner IC, Scrutton MJ, Kinsella SM. Maternal cardiovascular consequences of positioning after spinal anaesthesia for Caesarean section: left 15 degree table tilt vs. left lateral. Anaesthesia. 2002;57:15–20.

26. Mendonca C, Griffiths J, Ateleanu B, Collis RE. Hypotension following combined spinal-epidural anaesthesia for Caesarean section. Left lateral position vs. tilted supine position. Anaesthesia. 2003;58:428–431.

27. Svinos H. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. BET 1. Emergency caesarean section in cardiac arrest before the third trimester. Emerg Med J. 2008;25:764–765. doi: 10.1136/emj.2008.066860.

28. Katz V, Balderston K, DeFreest M. Perimortem cesarean delivery: were our assumptions correct? Am J Obstet Gynecol. 2005;192:1916–1920; dis- cussion 1920. doi: 10.1016/j.ajog.2005.02.038.

29. Einav S, Kaufman N, Sela HY. Maternal cardiac arrest and perimor- tem caesarean delivery: evidence or expert-based? Resuscitation. 2012;83:1191–1200. doi: 10.1016/j.resuscitation.2012.05.005.

30. Kam CW. Perimortem caesarean sections (PMCS). J Accid Emerg Med. 1994;11:57–58.

31. Kupas DF, Harter SC, Vosk A. Out-of-hospital perimortem cesarean sec- tion. Prehosp Emerg Care. 1998;2:206–208.

32. Oates S, Williams GL, Rees GA. Cardiopulmonary resuscitation in late pregnancy. BMJ. 1988;297:404–405.

33. Jaff MR, McMurtry MS, Archer SL, Cushman M, Goldenberg N, Goldhaber SZ, Jenkins JS, Kline JA, Michaels AD, Thistlethwaite P, Vedantham S, White RJ, Zierler BK; American Heart Association Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; American Heart Association Council on Peripheral Vascular Disease; American Heart Association Council on Arteriosclerosis, Thrombosis and Vascular Biology. Management of massive and submassive pulmonary embolism, iliofemoral deep vein thrombosis, and chronic thromboem- bolic pulmonary hypertension: a scientific statement from the American Heart Association. Circulation. 2011;123:1788–1830. doi: 10.1161/ CIR.0b013e318214914f.

34. Schmid C, Zietlow S, Wagner TO, Laas J, Borst HG. Fulminant pulmo- nary embolism: symptoms, diagnostics, operative technique, and results. Ann Thorac Surg. 1991;52:1102–1105; discussion 1105.

35. Kucher N, Rossi E, De Rosa M, Goldhaber SZ. Massive pulmo- nary embolism. Circulation. 2006;113:577–582. doi: 10.1161/ CIRCULATIONAHA.105.592592.

36. Kasper W, Konstantinides S, Geibel A, Olschewski M, Heinrich F, Grosser KD, Rauber K, Iversen S, Redecker M, Kienast J. Management strategies and determinants of outcome in acute major pulmonary embolism: results of a multicenter registry. J Am Coll Cardiol. 1997;30:1165–1171.

37. Janata K. Managing pulmonary embolism. BMJ. 2003;326:1341–1342. doi: 10.1136/bmj.326.7403.1341.

38. Kürkciyan I, Meron G, Sterz F, Janata K, Domanovits H, Holzer M, Berzlanovich A, Bankl HC, Laggner AN. Pulmonary embolism as a cause of cardiac arrest: presentation and outcome. Arch Intern Med. 2000;160:1529–1535.

39. Hess EP, Campbell RL, White RD. Epidemiology, trends, and outcome of out-of-hospital cardiac arrest of non-cardiac origin. Resuscitation. 2007;72:200–206. doi: 10.1016/j.resuscitation.2006.06.040.

40. Courtney DM, Kline JA. Identification of prearrest clinical factors asso- ciated with outpatient fatal pulmonary embolism. Acad Emerg Med. 2001;8:1136–1142.

41. Courtney DM, Kline JA. Prospective use of a clinical decision rule to identify pulmonary embolism as likely cause of outpa- tient cardiac arrest. Resuscitation. 2005;65:57–64. doi: 10.1016/j. resuscitation.2004.07.018.

42. Comess KA, DeRook FA, Russell ML, Tognazzi-Evans TA, Beach KW. The incidence of pulmonary embolism in unexplained sudden cardiac arrest with pulseless electrical activity. Am J Med. 2000;109:351–356.

43. Aghayev A, Furlan A, Patil A, Gumus S, Jeon KN, Park B, Bae KT. The rate of resolution of clot burden measured by pulmonary CT angiogra- phy in patients with acute pulmonary embolism. AJR Am J Roentgenol. 2013;200:791–797. doi: 10.2214/AJR.12.8624.

44. Wood KE. Major pulmonary embolism: review of a pathophysiologic approach to the golden hour of hemodynamically significant pulmonary embolism. Chest. 2002;121:877–905.

45. Neumar RW, Otto CW, Link MS, Kronick SL, Shuster M, Callaway CW, Kudenchuk PJ, Ornato JP, McNally B, Silvers SM, Passman RS, White RD, Hess EP, Tang W, Davis D, Sinz E, Morrison LJ. Part 8: adult advanced cardiovascular life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S729–S767. doi: 10.1161/CIRCULATIONAHA.110.970988.

46. Böttiger BW, Böhrer H, Bach A, Motsch J, Martin E. Bolus injection of thrombolytic agents during cardiopulmonary resuscitation for massive pulmonary embolism. Resuscitation. 1994;28:45–54.

47. Er F, Nia AM, Gassanov N, Caglayan E, Erdmann E, Hoppe UC. Impact of rescue-thrombolysis during cardiopulmonary resuscitation in patients with pulmonary embolism. PLoS One. 2009;4:e8323. doi: 10.1371/jour- nal.pone.0008323.

48. Lederer W, Lichtenberger C, Pechlaner C, Kroesen G, Baubin M. Recombinant tissue plasminogen activator during cardiopulmonary resuscitation in 108 patients with out-of-hospital cardiac arrest. Resuscitation. 2001;50:71–76.

49. Böttiger BW, Martin E. Thrombolytic therapy during cardiopulmonary resuscitation and the role of coagulation activation after cardiac arrest. Curr Opin Crit Care. 2001;7:176–183.

50. Ruiz-Bailén M, Aguayo-de-Hoyos E, Serrano-Córcoles MC, Díaz- Castellanos MA, Fierro-Rosón JL, Ramos-Cuadra JA, Rodríguez-Elvira M, Torres-Ruiz JM. Thrombolysis with recombinant tissue plasminogen activator during cardiopulmonary resuscitation in fulminant pulmonary embolism. A case series. Resuscitation. 2001;51:97–101.

51. Janata K, Holzer M, Kürkciyan I, Losert H, Riedmüller E, Pikula B, Laggner AN, Laczika K. Major bleeding complications in cardiopulmo- nary resuscitation: the place of thrombolytic therapy in cardiac arrest due to massive pulmonary embolism. Resuscitation. 2003;57:49–55.

52. Lederer W, Lichtenberger C, Pechlaner C, Kinzl J, Kroesen G, Baubin M. Long-term survival and neurological outcome of patients who received recombinant tissue plasminogen activator during out-of-hos- pital cardiac arrest. Resuscitation. 2004;61:123–129. doi: 10.1016/j. resuscitation.2003.12.016.

53. Stadlbauer KH, Krismer AC, Arntz HR, Mayr VD, Lienhart HG, Böttiger BW, Jahn B, Lindner KH, Wenzel V. Effects of thrombolysis during out- of-hospital cardiopulmonary resuscitation. Am J Cardiol. 2006;97:305– 308. doi: 10.1016/j.amjcard.2005.08.045.

54. Renard A, Verret C, Jost D, Meynard JB, Tricehreau J, Hersan O, Fontaine D, Briche F, Benner P, de Stabenrath O, Bartou C, Segal N, Domanski L. Impact of fibrinolysis on immediate prognosis of patients with out-of- hospital cardiac arrest. J Thromb Thrombolysis. 2011;32:405–409. doi: 10.1007/s11239-011-0619-0.

55. Dirican A, Ozkaya S, Atas AE, Ulu EK, Kitapci I, Ece F. Thrombolytic treatment (alteplase; rt-Pa) in acute massive pulmonary embolism and cardiopulmonary arrest. Drug Des Devel Ther. 2014;8:759–763. doi: 10.2147/DDDT.S61679.

56. Böttiger BW, Arntz HR, Chamberlain DA, Bluhmki E, Belmans A, Danays T, Carli PA, Adgey JA, Bode C, Wenzel V; TROICA Trial Investigators; European Resuscitation Council Study Group. Thrombolysis during resus- citation for out-of-hospital cardiac arrest. N Engl J Med. 2008;359:2651– 2662. doi: 10.1056/NEJMoa070570.

57. Böttiger BW, Bode C, Kern S, Gries A, Gust R, Glätzer R, Bauer H, Motsch J, Martin E. Efficacy and safety of thrombolytic therapy after initially unsuccessful cardiopulmonary resuscitation: a prospective clinical trial. Lancet. 2001;357:1583–1585. doi: 10.1016/S0140-6736(00)04726-7.

58. Logan JK, Pantle H, Huiras P, Bessman E, Bright L. Evidence-based diagnosis and thrombolytic treatment of cardiac arrest or periarrest due to suspected pulmonary embolism. Am J Emerg Med. 2014;32:789–796. doi: 10.1016/j.ajem.2014.04.032.

59. Konstantinov IE, Saxena P, Koniuszko MD, Alvarez J, Newman MA. Acute massive pulmonary embolism with cardiopulmonary resuscitation: management and results. Tex Heart Inst J. 2007;34:41–45; discussion 45.

60. Doerge HC, Schoendube FA, Loeser H, Walter M, Messmer BJ. Pulmonary embolectomy: review of a 15-year experience and role in the age of thrombolytic therapy. Eur J Cardiothorac Surg. 1996;10:952–957.

61. Fava M, Loyola S, Bertoni H, Dougnac A. Massive pulmonary embo- lism: percutaneous mechanical thrombectomy during cardiopulmonary resuscitation. J Vasc Interv Radiol. 2005;16:119–123. doi: 10.1097/01. RVI.0000146173.85401.BA.

62. Bottiger BW, Arntz HR, Chamberlain DA, Bluhmki E, Belmans A, Danays T, Carli PA, Adgey JA, Bode C, Wenzel V. Thrombolysis during resuscitation for out-of-hospital cardiac arrest. N Engl J Med. 2008;359:2651–2662.

63. Abu-Laban RB, Christenson JM, Innes GD, van Beek CA, Wanger KP, McKnight RD, MacPhail IA, Puskaric J, Sadowski RP, Singer J, Schechter MT, Wood VM. Tissue plasminogen activator in cardiac arrest with pulseless electrical activity. N Engl J Med. 2002;346:1522–1528.

64. Centers for Disease Control and Prevention. Injury prevention and control: prescription drug overdose. http://www.cdc.gov/drugoverdose/index.html. Accessed March 17, 2015.

65. Hedegaard H, Chen LH, Warner M. Drug-poisoning deaths involving her- oin: United States, 2000–2013. http://www.cdc.gov/nchs/data/databriefs/ db190.htm. Accessed March 17, 2015.

66. Centers for Disease Control and Prevention. Fatal injury data. http://www. cdc.gov/injury/wisqars/fatal.html. Accessed April 4, 2015.

67. Carter CI, Graham B. Opioid overdose prevention and response in Canada. http://drugpolicy.ca/wp-content/uploads/2014/07/CDPC_Overdose PreventionPolicy_Final_July2014.pdf. Accessed March 17, 2015.

68. Jones CM, Paulozzi LJ, Mack KA; Centers for Disease Control and Prevention (CDC). Alcohol involvement in opioid pain reliever and ben- zodiazepine drug abuse-related emergency department visits and drug- related deaths - United States, 2010. MMWR Morb Mortal Wkly Rep. 2014;63:881–885.

69. Madadi P, Hildebrandt D, Lauwers AE, Koren G. Characteristics of opi- oid-users whose death was related to opioid-toxicity: a population-based study in Ontario, Canada. PLoS One. 2013;8:e60600. doi: 10.1371/jour- nal.pone.0060600.

70. Webster LR, Cochella S, Dasgupta N, Fakata KL, Fine PG, Fishman SM, Grey T, Johnson EM, Lee LK, Passik SD, Peppin J, Porucznik CA, Ray A, Schnoll SH, Stieg RL, Wakeland W. An analysis of the root causes for opioid-related overdose deaths in the United States. Pain Med. 2011;12 suppl 2:S26–S35. doi: 10.1111/j.1526-4637.2011.01134.x.

71. Paulozzi LJ, Logan JE, Hall AJ, McKinstry E, Kaplan JA, Crosby AE. A comparison of drug overdose deaths involving methadone and other opioid analgesics in West Virginia. Addiction. 2009;104:1541–1548. doi: 10.1111/j.1360-0443.2009.02650.x.

72. Krantz MJ, Kutinsky IB, Robertson AD, Mehler PS. Dose-related effects of methadone on QT prolongation in a series of patients with torsade de pointes. Pharmacotherapy. 2003;23:802–805.

73. Eap CB, Crettol S, Rougier JS, Schläpfer J, Sintra Grilo L, Déglon JJ, Besson J, Croquette-Krokar M, Carrupt PA, Abriel H. Stereoselective block of hERG channel by (S)-methadone and QT interval prolongation in CYP2B6 slow metabolizers. Clin Pharmacol Ther. 2007;81:719–728. doi: 10.1038/sj.clpt.6100120.

74. Krantz MJ, Martin J, Stimmel B, Mehta D, Haigney MC. QTc interval screening in methadone treatment. Ann Intern Med. 2009;150:387–395.

75. Stallvik M, Nordstrand B, Kristensen Ø, Bathen J, Skogvoll E, Spigset O. Corrected QT interval during treatment with methadone and buprenor- phine–relation to doses and serum concentrations. Drug Alcohol Depend. 2013;129:88–93. doi: 10.1016/j.drugalcdep.2012.09.016.

76. Chou R, Weimer MB, Dana T. Methadone overdose and cardiac arrhyth- mia potential: findings from a review of the evidence for an American Pain Society and College on Problems of Drug Dependence clinical practice guideline. J Pain. 2014;15:338–365. doi: 10.1016/j.jpain.2014.01.495.

77. Lipski J, Stimmel B, Donoso E. The effect of heroin and multiple drug abuse on the electrocardiogram. Am Heart J. 1973;86:663–668.

78. Labi M. Paroxysmal atrial fibrillation in heroin intoxication. Ann Intern Med. 1969;71:951–959.

79. Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. Resuscitation. 1997;35:23–26.

80. Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. Resuscitation. 1996;33:107–116.

81. Leach M. Naloxone: a new therapeutic and diagnostic agent for emer- gency use. JACEP. 1973;2:21–23.

82. Sporer KA, Firestone J, Isaacs SM. Out-of-hospital treatment of opioid overdoses in an urban setting. Acad Emerg Med. 1996;3:660–667.

83. Robertson TM, Hendey GW, Stroh G, Shalit M. Intranasal nalox- one is a viable alternative to intravenous naloxone for prehospi- tal narcotic overdose. Prehosp Emerg Care. 2009;13:512–515. doi: 10.1080/10903120903144866.

84. Evans LE, Swainson CP, Roscoe P, Prescott LF. Treatment of drug overdosage with naloxone, a specific narcotic antagonist. Lancet. 1973;1:452–455.

85. Kelly AM, Kerr D, Dietze P, Patrick I, Walker T, Koutsogiannis Z. Randomised trial of intranasal versus intramuscular naloxone in prehospital treatment for suspected opioid overdose. Med J Aust. 2005;182:24–27.

86. Barton ED, Colwell CB, Wolfe T, Fosnocht D, Gravitz C, Bryan T, Dunn W, Benson J, Bailey J. Efficacy of intranasal naloxone as a needleless alternative for treatment of opioid overdose in the pre- hospital setting. J Emerg Med. 2005;29:265–271. doi: 10.1016/j.jemermed.2005.03.007.

87. Wolfe TR, Braude DA. Intranasal medication delivery for children: a brief review and update. Pediatrics. 2010;126:532–537. doi: 10.1542/ peds.2010-0616.

88. Loimer N, Hofmann P, Chaudhry HR. Nasal administration of naloxone is as effective as the intravenous route in opiate addicts. Int J Addict. 1994;29:819–827.

89.

Doe-Simkins M, Walley AY, Epstein A, Moyer P. Saved by the nose: bystander-administered intranasal naloxone hydrochloride for opioid overdose. Am J Public Health. 2009;99:788–791. doi: 10.2105/ AJPH.2008.146647.

90. Wanger K, Brough L, Macmillan I, Goulding J, MacPhail I, Christenson JM. Intravenous vs subcutaneous naloxone for out-of-hospital manage- ment of presumed opioid overdose. Acad Emerg Med. 1998;5:293–299.

91. Baumann BM, Patterson RA, Parone DA, Jones MK, Glaspey LJ, Thompson NM, Stauss MP, Haroz R. Use and efficacy of nebulized nal- oxone in patients with suspected opioid intoxication. Am J Emerg Med. 2013;31:585–588. doi: 10.1016/j.ajem.2012.10.004.

92. Weber JM, Tataris KL, Hoffman JD, Aks SE, Mycyk MB. Can nebulized naloxone be used safely and effectively by emergency medical services for suspected opioid overdose? Prehosp Emerg Care. 2012;16:289–292. doi: 10.3109/10903127.2011.640763.

93. Greenberg MI, Roberts JR, Baskin SI. Endotracheal naloxone reversal of morphine-induced respiratory depression in rabbits. Ann Emerg Med. 1980;9:289–292.

94. Posner J, Burke CA. The effects of naloxone on opiate and pla- cebo analgesia in healthy volunteers. Psychopharmacology (Berl). 1985;87:468–472.

95. Borras MC, Becerra L, Ploghaus A, Gostic JM, DaSilva A, Gonzalez RG, Borsook D. fMRI measurement of CNS responses to naloxone infu- sion and subsequent mild noxious thermal stimuli in healthy volunteers. J Neurophysiol. 2004;91:2723–2733. doi: 10.1152/jn.00249.2003.

96. Clarke SF, Dargan PI, Jones AL. Naloxone in opioid poisoning: walk- ing the tightrope. Emerg Med J. 2005;22:612–616. doi: 10.1136/ emj.2003.009613.

97. Walley AY, Doe-Simkins M, Quinn E, Pierce C, Xuan Z, Ozonoff A. Opioid overdose prevention with intranasal naloxone among people who take methadone. J Subst Abuse Treat. 2013;44:241–247. doi: 10.1016/j. jsat.2012.07.004.

98. Clark AK, Wilder CM, Winstanley EL. A systematic review of com- munity opioid overdose prevention and naloxone distribution programs. J Addict Med. 2014;8:153–163. doi: 10.1097/ADM.0000000000000034.

99. Lagu T, Anderson BJ, Stein M. Overdoses among friends: drug users are willing to administer naloxone to others. J Subst Abuse Treat. 2006;30:129–133. doi: 10.1016/j.jsat.2005.05.010.

100. Tracy M, Piper TM, Ompad D, Bucciarelli A, Coffin PO, Vlahov D, Galea S. Circumstances of witnessed drug overdose in New York City: implications for intervention. Drug Alcohol Depend. 2005;79:181–190. doi: 10.1016/j.drugalcdep.2005.01.010.

101. US Food and Drug Administration. FDA News Release: FDA approves new hand-held auto-injector to reverse opioid overdose. 2015. http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ ucm391465.htm. Accessed May 11, 2015.

102. Tataris KL, Weber JM, Stein-Spencer L, Aks SE. The effect of prehospi- tal nebulized naloxone on suspected heroin-induced bronchospasm. Am J Emerg Med. 2013;31:717–718. doi: 10.1016/j.ajem.2012.11.025.

103. Bingham K, Klaiman M, Leece P, Orkin A, Buick J. An agenda for nal- oxone distribution research and practice: Meeting report of the Surviving Opioid Overdose with Naloxone (SOON) International Working Group. J Addict Res Ther. 2015;6:212.

104. Kerr D, Kelly AM, Dietze P, Jolley D, Barger B. Randomized controlled trial comparing the effectiveness and safety of intranasal and intramus- cular naloxone for the treatment of suspected heroin overdose. Addiction. 2009;104:2067–2074. doi: 10.1111/j.1360-0443.2009.02724.x.

105. Boyd JJ, Kuisma MJ, Alaspää AO, Vuori E, Repo JV, Randell TT. Recurrent opioid toxicity after pre-hospital care of presumed heroin overdose patients. Acta Anaesthesiol Scand. 2006;50:1266–1270. doi: 10.1111/j.1399-6576.2006.01172.x.

106. Buajordet I, Naess AC, Jacobsen D, Brørs O. Adverse events after nal- oxone treatment of episodes of suspected acute opioid overdose. Eur J Emerg Med. 2004;11:19–23.

107. Cantwell K, Dietze P, Flander L. The relationship between naloxone dose and key patient variables in the treatment of non-fatal heroin overdose in the prehospital setting. Resuscitation. 2005;65:315–319. doi: 10.1016/j. resuscitation.2004.12.012.

108. Cetrullo C, Di Nino GF, Melloni C, Pieri C, Zanoni A. [Naloxone antagonism toward opiate analgesic drugs. Clinical experimental study]. Minerva Anestesiol. 1983;49:199–204.

109. Nielsen K, Nielsen SL, Siersma V, Rasmussen LS. Treatment of opioid overdose in a physician-based prehospital EMS: frequency and long- term prognosis. Resuscitation. 2011;82:1410–1413. doi: 10.1016/j. resuscitation.2011.05.027.

110. Osterwalder JJ. Naloxone–for intoxications with intravenous heroin and heroin mixtures–harmless or hazardous? A prospective clinical study. J Toxicol Clin Toxicol. 1996;34:409–416.

111. Stokland O, Hansen TB, Nilsen JE. [Prehospital treatment of heroin intox- ication in Oslo in 1996]. Tidsskr Nor Laegeforen. 1998;118:3144–3146.

112.

Wampler DA, Molina DK, McManus J, Laws P, Manifold CA. No deaths associated with patient refusal of transport after naloxone-reversed opioid overdose. Prehosp Emerg Care. 2011;15:320–324. doi: 10.3109/10903127.2011.569854.

113. Saybolt MD, Alter SM, Dos Santos F, Calello DP, Rynn KO, Nelson DA, Merlin MA. Naloxone in cardiac arrest with suspected opi- oid overdoses. Resuscitation. 2010;81:42–46. doi: 10.1016/j. resuscitation.2009.09.016.

114. Vilke GM, Sloane C, Smith AM, Chan TC. Assessment for deaths in out- of-hospital heroin overdose patients treated with naloxone who refuse transport. Acad Emerg Med. 2003;10:893–896.

115. Rudolph SS, Jehu G, Nielsen SL, Nielsen K, Siersma V, Rasmussen LS. Prehospital treatment of opioid overdose in Copenhagen–is it safe to discharge on-scene? Resuscitation. 2011;82:1414–1418. doi: 10.1016/j. resuscitation.2011.06.027.

116. Moss ST, Chan TC, Buchanan J, Dunford JV, Vilke GM. Outcome study of prehospital patients signed out against medical advice by field para- medics. Ann Emerg Med. 1998;31:247–250.

117. Christenson J, Etherington J, Grafstein E, Innes G, Pennington S, Wanger K, Fernandes C, Spinelli JJ, Gao M. Early discharge of patients with pre- sumed opioid overdose: development of a clinical prediction rule. Acad Emerg Med. 2000;7:1110–1118.

118. Etherington J, Christenson J, Innes G, Grafstein E, Pennington S, Spinelli JJ, Gao M, Lahiffe B, Wanger K, Fernandes C. Is early dis- charge safe after naloxone reversal of presumed opioid overdose? CJEM. 2000;2:156–162.

119. Zuckerman M, Weisberg SN, Boyer EW. Pitfalls of intranasal naloxone. Prehosp Emerg Care. 2014;18:550–554. doi: 10.3109/10903127.2014.896961.

120. Weinberg GL, VadeBoncouer T, Ramaraju GA, Garcia-Amaro MF, Cwik MJ. Pretreatment or resuscitation with a lipid infusion shifts the dose-response to bupivacaine-induced asystole in rats. Anesthesiology. 1998;88:1071–1075.

121. Weinberg G, Ripper R, Feinstein DL, Hoffman W. Lipid emulsion infu- sion rescues dogs from bupivacaine-induced cardiac toxicity. Reg Anesth Pain Med. 2003;28:198–202. doi: 10.1053/rapm.2003.50041.

122. Rosenblatt MA, Abel M, Fischer GW, Itzkovich CJ, Eisenkraft JB. Successful use of a 20% lipid emulsion to resuscitate a patient after a presumed bupivacaine-related cardiac arrest. Anesthesiology. 2006;105:217–218.

123. Barrington MJ, Kluger R. Ultrasound guidance reduces the risk of local anesthetic systemic toxicity following peripheral nerve blockade. Reg Anesth Pain Med. 2013;38:289–297. doi: 10.1097/AAP.0b013e318292669b.

124. Neal JM, Mulroy MF, Weinberg GL; American Society of Regional Anesthesia and Pain Medicine. American Society of Regional Anesthesia and Pain Medicine checklist for managing local anesthetic systemic tox- icity: 2012 version. Reg Anesth Pain Med. 2012;37:16–18. doi: 10.1097/ AAP.0b013e31822e0d8a.

125. Weinberg G, Lin B, Zheng S, Di Gregorio G, Hiller D, Ripper R, Edelman L, Kelly K, Feinstein D. Partitioning effect in lipid resuscitation: further evidence for the lipid sink. Crit Care Med. 2010;38:2268–2269. doi: 10.1097/CCM.0b013e3181f17d85.

126. Weinberg GL, Palmer JW, VadeBoncouer TR, Zuechner MB, Edelman G, Hoppel CL. Bupivacaine inhibits acylcarnitine exchange in cardiac mitochondria. Anesthesiology. 2000;92:523–528.

127. Fettiplace MR, Akpa BS, Ripper R, Zider B, Lang J, Rubinstein I, Weinberg G. Resuscitation with lipid emulsion: dose-dependent recovery from cardiac pharmacotoxicity requires a cardiotonic effect. Anesthesiology. 2014;120:915–925. doi: 10.1097/ALN.0000000000000142.

128. Harvey M, Cave G. Lipid rescue: does the sink hold water? And other controversies. Br J Anaesth. 2014;112:622–625. doi: 10.1093/bja/aeu010.

129. Turner-Lawrence DE, Kerns Ii W. Intravenous fat emulsion: a potential novel antidote. J Med Toxicol. 2008;4:109–114.

130. Jamaty C, Bailey B, Larocque A, Notebaert E, Sanogo K, Chauny JM. Lipid emulsions in the treatment of acute poisoning: a systematic review of human and animal studies. Clin Toxicol (Phila). 2010;48:1–27. doi: 10.3109/15563650903544124.

131. Weinberg GL. Lipid emulsion infusion: resuscitation for local anes- thetic and other drug overdose. Anesthesiology. 2012;117:180–187. doi: 10.1097/ALN.0b013e31825ad8de.

132. Cao H, Zhou X, Zhang J, Huang X, Zhai Y, Zhang X, Chu L. Hydrogen sulfide protects against bleomycin-induced pulmonary fibrosis in rats by inhibiting NF-?B expression and regulating Th1/Th2 balance. Toxicol Lett. 2014;224:387–394. doi: 10.1016/j.toxlet.2013.11.008.

133. Taftachi F, Sanaei-Zadeh H, Sepehrian B, Zamani N. Lipid emulsion improves Glasgow coma scale and decreases blood glucose level in the setting of acute non-local anesthetic drug poisoning–a randomized controlled trial. Eur Rev Med Pharmacol Sci. 2012;16 suppl 1:38–42.

134. Gil HW, Park JS, Park SH, Hong SY. Effect of intravenous lipid emul- sion in patients with acute glyphosate intoxication. Clin Toxicol (Phila). 2013;51:767–771. doi: 10.3109/15563650.2013.821129.

135.

Cave G, Harvey M, Willers J, Uncles D, Meek T, Picard J, Weinberg G. LIPAEMIC report: results of clinical use of intravenous lipid emul- sion in drug toxicity reported to an online lipid registry. J Med Toxicol. 2014;10:133–142. doi: 10.1007/s13181-013-0375-y.

136. Downes MA, Calver LA, Isbister GK. Intralipid therapy does not improve level of consciousness in overdoses with sedating drugs: a case series. Emerg Med Australas. 2014;26:286–290. doi: 10.1111/1742-6723.12237.

137. Weinberg GL, Di Gregorio G, Ripper R, Kelly K, Massad M, Edelman L, Schwartz D, Shah N, Zheng S, Feinstein DL. Resuscitation with lipid ver- sus epinephrine in a rat model of bupivacaine overdose. Anesthesiology. 2008;108:907–913. doi: 10.1097/ALN.0b013e31816d91d2.

138. Weinberg G. LipidRescue resuscitation for drug toxicity. http://www. lipidrescue.org/. Accessed March 19, 2015.

139. American Society of Regional Anesthesia and Pain Medicine. Checklist for treatment of local anesthetic systemic toxicity. https://www.asra. com/advisory-guidelines/article/3/checklist-for-treatment-of-local-anes- thetic-systemic-toxicity. Accessed March 19, 2015.

140. American College of Medical Toxicology. ACMT position statement: interim guidance for the use of lipid resuscitation therapy. J Med Toxicol. 2011;7:81–82.

141. Fettiplace MR, Akpa BS, Rubinstein I, Weinberg G. Confusion about infusion: rational volume limits for intravenous lipid emulsion during treatment of oral overdoses. Ann Emerg Med. 2015;66:185–188. doi: 10.1016/j.annemergmed.2015.01.020.

142. Levine M, Skolnik AB, Ruha AM, Bosak A, Menke N, Pizon AF. Complications following antidotal use of intravenous lipid emulsion ther- apy. J Med Toxicol. 2014;10:10–14. doi: 10.1007/s13181-013-0356-1.

143. Carreiro S, Blum J, Jay G, Hack JB. Intravenous lipid emulsion alters the hemodynamic response to epinephrine in a rat model. J Med Toxicol. 2013;9:220–225. doi: 10.1007/s13181-013-0291-1.

144. Harvey M, Cave G, Prince G, Lahner D. Epinephrine injection in lipid- based resuscitation from bupivacaine-induced cardiac arrest: transient circulatory return in rabbits. Anesth Analg. 2010;111:791–796. doi: 10.1213/ANE.0b013e3181e66050.

145. Neal JM, Bernards CM, Butterworth JF 4th, Di Gregorio G, Drasner K, Hejtmanek MR, Mulroy MF, Rosenquist RW, Weinberg GL. ASRA prac- tice advisory on local anesthetic systemic toxicity. Reg Anesth Pain Med. 2010;35:152–161. doi: 10.1097/AAP.0b013e3181d22fcd.

146. American Society of Regional Anesthesia and Pain Medicine. Checklist for Treatment of Local Anesthetic Systemic Toxicity. 2011. https://www. asra.com/content/documents/checklist-for-local-anesthetic-toxicity- treatment-1-18-12.pdf. Accessed May 11, 2015.

147. Cole JB, Stellpflug SJ, Engebretsen KM. Asystole immediately follow- ing intravenous fat emulsion for overdose. J Med Toxicol. 2014;10:307– 310. doi: 10.1007/s13181-014-0382-7.

148. Lee HM, Archer JR, Dargan PI, Wood DM. What are the adverse effects associated with the combined use of intravenous lipid emulsion and extra- corporeal membrane oxygenation in the poisoned patient? Clin Toxicol (Phila). 2015;53:145–150. doi: 10.3109/15563650.2015.1004582.

149. Trestrail JH. Criminal Poisoning: Investigational Guide for Law Enforcement, Toxicologists, Forensic Scientists, and Attorneys. 2nd ed. Totowa, NJ: Humana; 2007.

150. Courtney DM, Neumar RW, Venkatesh AK, Kaji AH, Cairns CB, Lavonas E, Richardson LD. Unique characteristics of emergency care research: scope, populations, and infrastructure. Acad Emerg Med. 2009;16:990–994.

151. Matsika MD, Tournier M, Lagnaoui R, Pehourcq F, Molimard M, Begaud B, Verdoux H, Moore N. Comparison of patient questionnaires and plasma assays in intentional drug overdoses. Basic Clin Pharmacol Toxicol. 2004;95:31–37.

152. Neeleman J, Wessely S. Drugs taken in fatal and non-fatal self-poisoning: a study in south London. Acta Psychiatr Scand. 1997;95:283–287.

153. Wu AH, McKay C, Broussard LA, Hoffman RS, Kwong TC, Moyer TP, Otten EM, Welch SL, Wax P. National Academy of Clinical Biochemistry Laboratory Medicine Practice Guidelines: recommendations for the use of laboratory tests to support poisoned patients who present to the emergency department. Clin Chem. 2003;49:357–379.

154. Shannon MW. A general approach to poisoning. In: Shannon MW, Borron SW, Burns MJ eds. Haddad and Winchester's Clinical Management of Poisoning and Drug Overdose. 4th ed. Philadelphia, Pa: Saunders/Elsevier; 2007:13–30.

155. Position paper: ipecac syrup. J Toxicol Clin Toxicol. 2004;42:133–143.

156. Vale JA, Kulig K; American Academy of Clinical Toxicology; European Association of Poisons Centres and Clinical Toxicologists. Position paper: gastric lavage. J Toxicol Clin Toxicol. 2004;42:933–943.

157. Position paper: whole bowel irrigation. J Toxicol Clin Toxicol. 2004;42:843–854.

158.

Chyka PA, Seger D, Krenzelok EP, Vale JA; American Academy of Clinical Toxicology; European Association of Poisons Centres and Clinical Toxicologists. Position paper: single-dose activated charcoal. Clin Toxicol (Phila). 2005;43:61–87.

159. American Academy of Clinical Toxicology; European Association of Poisons Centres and Clinical Toxicologists. Position statement and practice guidelines on the use of multi-dose activated charcoal in the treatment of acute poisoning. J Toxicol Clin Toxicol. 1999;37:731–751.

160. Metheny NA. Preventing respiratory complications of tube feedings: evidence-based practice. Am J Crit Care. 2006;15:360–369.

161. Adelson L. Poison and the pathologist. JAMA. 1964;187:918–920.

162. The Flumazenil in Benzodiazepine Intoxication Multicenter Study Group. Treatment of benzodiazepine overdose with flumazenil. Clin Ther. 1992;14:978–995.

163. Lheureux P, Vranckx M, Leduc D, Askenasi R. Flumazenil in mixed benzodiazepine/tricyclic antidepressant overdose: a placebo-controlled study in the dog. Am J Emerg Med. 1992;10:184–188.

164. Pitetti RD, Singh S, Pierce MC. Safe and efficacious use of procedural sedation and analgesia by nonanesthesiologists in a pediatric emergency department. Arch Pediatr Adolesc Med. 2003;157:1090–1096.

165. Fahed S, Grum DF, Papadimos TJ. Labetalol infusion for refractory hypertension causing severe hypotension and bradycardia: an issue of patient safety. Patient Saf Surg. 2008;2:13.

166. Fernandes CM, Daya MR. Sotalol-induced bradycardia reversed by glucagon. Can Fam Physician. 1995;41:659–660, 663–665.

167. Frishman W, Jacob H, Eisenberg E, Ribner H. Clinical pharmacology of the new beta-adrenergic blocking drugs, part 8: self-poisoning with beta-adrenoceptor blocking agents: recognition and management. Am Heart J. 1979;98:798–811.

168. Gabry AL, Pourriat JL, Hoang TD, Lapandry C. Cardiogenic shock caused by metoprolol poisoning: reversibility with high doses of glucagon and isoproterenol [in French]. Presse Med. 1985;14:229.

169. Hazouard E, Ferrandiere M, Lesire V, Joye F, Perrotin D, de Toffol B. Peduncular hallucinosis related to propranolol self-poisoning: efficacy of intravenous glucagon. Intensive Care Med. 1999;25:336–337.

170. Khan MI, Miller MT. Beta-blocker toxicity: the role of glucagon: report of 2 cases. S Afr Med J. 1985;67:1062–1063.

171. Moller BH. Massive intoxication with metoprolol. BMJ. 1976;1:222. Letter.

172. O'Mahony D, O'Leary P, Molloy MG. Severe oxprenolol poisoning: the importance of glucagon infusion. Hum Exp Toxicol. 1990;9:101–103.

173. Wallin CJ, Hulting J. Massive metoprolol poisoning treated with prenalterol. Acta Med Scand. 1983;214:253–255.

174. Weinstein RS. Recognition and management of poisoning with beta-adrenergic blocking agents. Ann Emerg Med. 1984;13:1123–1131.

175. Alderfliegel F, Leeman M, Demaeyer P, Kahn RJ. Sotalol poisoning associated with asystole. Intensive Care Med. 1993;19:57–58.

176. Kenyon CJ, Aldinger GE, Joshipura P, Zaid GJ. Successful resuscitation using external cardiac pacing in beta adrenergic antagonist-induced bradyasystolic arrest. Ann Emerg Med. 1988;17:711–713.

177. Freestone S, Thomas HM, Bhamra RK, Dyson EH. Severe atenolol poisoning: treatment with prenalterol. Hum Toxicol. 1986;5:343–345.

178. Toet AE, Wemer J, Vleeming W, te Biesebeek JD, Meulenbelt J, de Wildt DJ. Experimental study of the detrimental effect of dopamine/glucagon combination in d,l-propranolol intoxication. Hum Exp Toxicol. 1996;15:411–421.

179. Toet AE, te Biesebeek JD, Vleeming W, Wemer J, Meulenbelt J, de Wildt DJ. Reduced survival after isoprenaline/dopamine in d,l-propranolol intoxicated rats. Hum Exp Toxicol. 1996;15:120–128.

180. Sato S, Tsuji MH, Okubo N, Nishimoto C, Naito H. Combined use of glucagon and milrinone may not be preferable for severe propranolol poisoning in the canine model. J Toxicol Clin Toxicol. 1995;33:337–342.

181. Kerns W II., Schroeder D, Williams C, Tomaszewski C, Raymond R. Insulin improves survival in a canine model of acute beta-blocker toxicity. Ann Emerg Med. 1997;29:748–757.

182. Holger JS, Engebretsen KM, Fritzlar SJ, Patten LC, Harris CR, Flottemesch TJ. Insulin versus vasopressin and epinephrine to treat beta-blocker toxicity. Clin Toxicol (Phila). 2007;45:396–401.

183. Page C, Hacket LP, Isbister GK. The use of high-dose insulin-glucose euglycemia in beta-blocker overdose: a case report. J Med Toxicol. 2009;5:139–143.

184. Kerns W II.. Management of beta-adrenergic blocker and calcium channel antagonist toxicity. Emerg Med Clin North Am. 2007;25:309–331.

185. Pertoldi F, D'Orlando L, Mercante WP. Electromechanical dissociation 48 hours after atenolol overdose: usefulness of calcium chloride. Ann Emerg Med. 1998;31:777–781.

186. Love JN, Hanfling D, Howell JM. Hemodynamic effects of calcium chloride in a canine model of acute propranolol intoxication. Ann Emerg Med. 1996;28:1–6.

187. McVey FK, Corke CF. Extracorporeal circulation in the management of massive propranolol overdose. Anaesthesia. 1991;46:744–746.

188. Lane AS, Woodward AC, Goldman MR. Massive propranolol overdose poorly responsive to pharmacologic therapy: use of the intra-aortic balloon pump. Ann Emerg Med. 1987;16:1381–1383.

189. Rooney M, Massey KL, Jamali F, Rosin M, Thomson D, Johnson DH. Acebutolol overdose treated with hemodialysis and extracorporeal membrane oxygenation. J Clin Pharmacol. 1996;36:760–763.

190. Stellpflug SJ, Harris CR, Engebretsen KM, Cole JB, Holger JS. Intentional overdose with cardiac arrest treated with intravenous fat emulsion and high-dose insulin. Clin Toxicol. 2010:48:227–229.

191. Zimmer BW, Marcus RJ, Sawyer K, Harchelroad F. Salicylate intoxication as a cause of pseudohyperchloremia. Am J Kidney Dis. 2008;51():346–347.

192. Cave G, Harvey M. Lipid emulsion may augment early blood pressure recovery in a rabbit model of atenolol toxicity. J Med Toxicol. 2009;5:50–51.

193. Cave G, Harvey MG, Castle CD. The role of fat emulsion therapy in a rodent model of propranolol toxicity: a preliminary study. J Med Toxicol. 2006;2():4–7.

194. Harvey MG, Cave GR. Intralipid infusion ameliorates propranolol-induced hypotension in rabbits. J Med Toxicol. 2008;4:71–76.

195. Browne A, Harvey M, Cave G. Intravenous lipid emulsion does not augment blood pressure recovery in a rabbit model of metoprolol toxicity. J Med Toxicol. 2010:ePub.

196. Turner-Lawrence DE, Kerns Ii W. Intravenous fat emulsion: a potential novel antidote. J Med Toxicol. 2008;4:109–114.

197. Cave G, Harvey M. Intravenous lipid emulsion as antidote beyond local anesthetic toxicity: a systematic review. Acad Emerg Med. 2009;16:815–824.

198. Jamaty C, Bailey B, Larocque A, Notebaert E, Sanogo K, Chauny JM. Lipid emulsions in the treatment of acute poisoning: a systematic review of human and animal studies. Clin Toxicol. 2010:48:1–27.

199. Boyer EW, Duic PA, Evans A. Hyperinsulinemia/euglycemia therapy for calcium channel blocker poisoning. Pediatr Emerg Care. 2002;18:36–37.

200. Cohen E, Du D, Joyce D, Kapernick EA, Volovik Y, Kelly JW, Dillin A. Temporal requirements of insulin/IGF-1 signaling for proteotoxicity protection. Aging Cell. 2010;9:126–134.

201. Greene SL, Gawarammana I, Wood DM, Jones AL, Dargan PI. Relative safety of hyperinsulinaemia/euglycaemia therapy in the management of calcium channel blocker overdose: a prospective observational study. Intensive Care Med. 2007;33:2019–2024.

202. Harris NS. Case records of the Massachusetts General Hospital: case 24–2006: a 40-year-old woman with hypotension after an overdose of amlodipine. N Engl J Med. 2006;355:602–611.

203. Johansen KK, Belhage B. A 48-year-old woman's survival from a massive verapamil overdose [in Danish]. Ugeskr Laeger. 2007;169:4074–4075.

204. Kanagarajan K, Marraffa JM, Bouchard NC, Krishnan P, Hoffman RS, Stork CM. The use of vasopressin in the setting of recalcitrant hypotension due to calcium channel blocker overdose. Clin Toxicol (Phila). 2007;45:56–59.

205. Marques M, Gomes E, de Oliveira J. Treatment of calcium channel blocker intoxication with insulin infusion: case report and literature review. Resuscitation. 2003;57:211–213.

206. Ortiz-Munoz L, Rodriguez-Ospina LF, Figueroa-Gonzalez M. Hyperinsulinemic-euglycemic therapy for intoxication with calcium channel blockers. Bol Asoc Med P R. 2005;97():182–189.

207. Patel NP, Pugh ME, Goldberg S, Eiger G. Hyperinsulinemic euglycemia therapy for verapamil poisoning: case report. Am J Crit Care. 2007;16:518–529.

208. Rasmussen L, Husted SE, Johnsen SP. Severe intoxication after an intentional overdose of amlodipine. Acta Anaesthesiol Scand. 2003;47:1038–1040.

209. Smith SW, Ferguson KL, Hoffman RS, Nelson LS, Greller HA. Prolonged severe hypotension following combined amlodipine and valsartan ingestion. Clin Toxicol (Phila). 2008;46:470–474.

210. Yuan TH, Kerns WPI, Tomaszewski CA, Ford MD, Kline JA. Insulin-glucose as adjunctive therapy for severe calcium channel antagonist poisoning. J Toxicol Clin Toxicol. 1999;37:463–474.

211. Kline JA, Tomaszewski CA, Schroeder JD, Raymond RM. Insulin is a superior antidote for cardiovascular toxicity induced by verapamil in the anesthetized canine. J Pharmacol Exp Ther. 1993;267:744–750.

212. Kline JA, Leonova E, Raymond RM. Beneficial myocardial metabolic effects of insulin during verapamil toxicity in the anesthetized canine. Crit Care Med. 1995;23:1251–1263.

213. Kline JA, Leonova E, Williams TC, Schroeder JD, Watts JA. Myocardial metabolism during graded intraportal verapamil infusion in awake dogs. J Cardiovasc Pharmacol. 1996;27:719–726.

214. Kline JA, Raymond RM, Schroeder JD, Watts JA. The diabetogenic effects of acute verapamil poisoning. Toxicol Appl Pharmacol. 1997;145:357–362.

215. Durward A, Guerguerian AM, Lefebvre M, Shemie SD. Massive diltiazem overdose treated with extracorporeal membrane oxygenation. Pediatr Crit Care Med. 2003;4:372–376.

216. Fiszer M, Kolacinski Z, Rechcinski T. The application of 4-aminopyridine in calcium channel inhibitors acute poisoning [in Polish]. Przegl Lek. 2007;64:293–297.

217. Pfaender M, Casetti PG, Azzolini M, Baldi ML, Valli A. Successful treatment of a massive atenolol and nifedipine overdose with CVVHDF. Minerva Anestesiol. 2008;74:97–100.

218. Sabatier J, Pouyet T, Shelvey G, Cavero I. Antagonistic effects of epinephrine, glucagon and methylatropine but not calcium chloride against atrio-ventricular conduction disturbances produced by high doses of diltiazem, in conscious dogs. Fundam Clin Pharmacol. 1991;5:93–106.

219. Stone CK, May WA, Carroll R. Treatment of verapamil overdose with glucagon in dogs. Ann Emerg Med. 1995;25:369–374.

220. Stone CK, Thomas SH. Cardiopulmonary resuscitation (CPR) performance. Prehosp Disaster Med. 1996;11:120.

221. Tuncok Y, Apaydin S, Kalkan S, Ates M, Guven H. The effects of amrinone and glucagon on verapamil-induced cardiovascular toxicity in anaesthetized rats. Int J Exp Pathol. 1996;77:207–212.

222. Eddleston M, Rajapakse S, Rajakanthan, Jayalath S, Sjostrom L, Santharaj W, Thenabadu PN, Sheriff MH, Warrell DA. Anti-digoxin Fab fragments in cardiotoxicity induced by ingestion of yellow oleander: a randomised controlled trial. Lancet. 2000;355:967–972.

223. Smith TW, Butler VP Jr., Haber E, Fozzard H, Marcus FI, Bremner WF, Schulman IC, Phillips A. Treatment of life-threatening digitalis intoxication with digoxin-specific Fab antibody fragments: experience in 26 cases. N Engl J Med. 1982;307:1357–1362.

224. Wenger TL, Butler VPJ, Haber E, Smith TW. Treatment of 63 severely digitalis-toxic patients with digoxin-specific antibody fragments. J Am Coll Cardiol. 1985;5(suppl):118A–123A.

225. Antman EM, Wenger TL, Butler VP Jr., Haber E, Smith TW. Treatment of 150 cases of life-threatening digitalis intoxication with digoxin-specific Fab antibody fragments: final report of a multicenter study. Circulation. 1990;81:1744–1752.

226. Woolf AD, Wenger T, Smith TW, Lovejoy FHJ. The use of digoxin-specific Fab fragments for severe digitalis intoxication in children. N Engl J Med. 1992;326:1739–1744.

227. Hickey AR, Wenger TL, Carpenter VP, Tilson HH, Hlatky MA, Furberg CD, Kirkpatrick CH, Strauss HC, Smith TW. Digoxin immune Fab therapy in the management of digitalis intoxication: safety and efficacy results of an observational surveillance study. J Am Coll Cardiol. 1991;17:590–598.

228. Wenger TL. Experience with digoxin immune Fab (ovine) in patients with renal impairment. Am J Emerg Med. 1991;9(suppl 1):21–23.

229. Woolf AD, Wenger TL, Smith TW, Lovejoy FHJ. Results of multicenter studies of digoxin-specific antibody fragments in managing digitalis intoxication in the pediatric population. Am J Emerg Med. 1991;9(suppl 1):16–20.

230. Taboulet P, Baud FJ, Bismuth C, Vicaut E. Acute digitalis intoxication: is pacing still appropriate? J Toxicol Clin Toxicol. 1993;31:261–273.

231. Lapostolle F, Borron SW, Verdier C, Taboulet P, Guerrier G, Adnet F, Clemessy JL, Bismuth C, Baud FJ. Digoxin-specific Fab fragments as single first-line therapy in digitalis poisoning. Crit Care Med. 2008;36:3014–3018.

232. Bismuth C, Gaultier M, Conso F, Efthymiou ML. Hyperkalemia in acute digitalis poisoning: prognostic significance and therapeutic implications. Clin Toxicol. 1973;6:153–162.

233.

Lapostolle F, Borron SW. Digitalis. In: Shannon MW, Borron SW, Burns MJ eds. Haddad and Winchester's Clinical Management of Poisoning and Drug Overdose. Philadelphia, Pa: Saunders/Elsevier; 2007:949–962.

234. Hsue PY, McManus D, Selby V, Ren X, Pillutla P, Younes N, Goldschlager N, Waters DD. Cardiac arrest in patients who smoke crack cocaine. Am J Cardiol. 2007;99:822–824.

235. Lange RA, Cigarroa RG, Yancy CW Jr., Willard JE, Popma JJ, Sills MN, McBride W, Kim AS, Hillis LD. Cocaine-induced coronary-artery vasoconstriction. N Engl J Med. 1989;321:1557–1562.

236. Baumann BM, Perrone J, Hornig SE, Shofer FS, Hollander JE. Randomized, double-blind, placebo-controlled trial of diazepam, nitroglycerin, or both for treatment of patients with potential cocaine-associated acute coronary syndromes. Acad Emerg Med. 2000;7:878–885.

237. Negus BH, Willard JE, Hillis LD, Glamann DB, Landau C, Snyder RW, Lange RA. Alleviation of cocaine-induced coronary vasoconstriction with intravenous verapamil. Am J Cardiol. 1994;73:510–513.

238. Saland KE, Hillis LD, Lange RA, Cigarroa JE. Influence of morphine sulfate on cocaine-induced coronary vasoconstriction. Am J Cardiol. 2002;90:810–811.

239. Hollander JE, Hoffman RS, Gennis P, Fairweather P, DiSano MJ, Schumb DA, Feldman JA, Fish SS, Dyer S, Wax P, Whelan C, Schwarzwald E. Nitroglycerin in the treatment of cocaine associated chest pain: clinical safety and efficacy. J Toxicol Clin Toxicol. 1994;32:243–256.

240. Brogan WCI, Lange RA, Kim AS, Moliterno DJ, Hillis LD. Alleviation of cocaine-induced coronary vasoconstriction by nitroglycerin. J Am Coll Cardiol. 1991;18:581–586.

241. Mittleman MA, Mintzer D, Maclure M, Tofler GH, Sherwood JB, Muller JE. Triggering of myocardial infarction by cocaine. Circulation. 1999;99:2737–2741.

242. Honderick T, Williams D, Seaberg D, Wears R. A prospective, randomized, controlled trial of benzodiazepines and nitroglycerine or nitroglycerine alone in the treatment of cocaine-associated acute coronary syndromes. Am J Emerg Med. 2003;21:39–42.

243. Boehrer JD, Moliterno DJ, Willard JE, Hillis LD, Lange RA. Influence of labetalol on cocaine-induced coronary vasoconstriction in humans. Am J Med. 1993;94:608–610.

244. Lange RA, Cigarroa RG, Flores ED, McBride W, Kim AS, Wells PJ, Bedotto JB, Danziger RS, Hillis LD. Potentiation of cocaine-induced coronary vasoconstriction by beta-adrenergic blockade. Ann Intern Med. 1990;112:897–903.

245. Sand IC, Brody SL, Wrenn KD, Slovis CM. Experience with esmolol for the treatment of cocaine-associated cardiovascular complications. Am J Emerg Med. 1991;9:161–163.

246. Dattilo PB, Hailpern SM, Fearon K, Sohal D, Nordin C. Beta-blockers are associated with reduced risk of myocardial infarction after cocaine use. Ann Emerg Med. 2008;51:117–125.

247. Vongpatanasin W, Mansour Y, Chavoshan B, Arbique D, Victor RG. Cocaine stimulates the human cardiovascular system via a central mechanism of action. Circulation. 1999;100:497–502.

248. McCord J, Jneid H, Hollander JE, de Lemos JA, Cercek B, Hsue P, Gibler WB, Ohman EM, Drew B, Philippides G, Newby LK. Management of cocaine-associated chest pain and myocardial infarction: a scientific statement from the American Heart Association Acute Cardiac Care Committee of the Council on Clinical Cardiology. Circulation. 2008;117:1897–1907.

249. Ellington C, Katz VL, Watson WJ, Spielman FJ. The effect of lateral tilt on maternal and fetal hemodynamic variables. Obstet Gynecol. 1991;77:201–203.

250. Wood DM, Dargan PI, Hoffman RS. Management of cocaine-induced cardiac arrhythmias due to cardiac ion channel dysfunction. Clin Toxicol (Phila). 2009;47:14–23.

251. Hoffman JR, Votey SR, Bayer M, Silver L. Effect of hypertonic sodium bicarbonate in the treatment of moderate-to-severe cyclic antidepressant overdose. Am J Emerg Med. 1993;11:336–341.

252. Koppel C, Wiegreffe A, Tenczer J. Clinical course, therapy, outcome and analytical data in amitriptyline and combined amitriptyline/chlordiazepoxide overdose. Hum Exp Toxicol. 1992;11:458–465.

253. Brown TC. Tricyclic antidepressant overdosage: experimental studies on the management of circulatory complications. Clin Toxicol. 1976;9:255–272.

254. Hedges JR, Baker PB, Tasset JJ, Otten EJ, Dalsey WC, Syverud SA. Bicarbonate therapy for the cardiovascular toxicity of amitriptyline in an animal model. J Emerg Med. 1985;3:253–260.

255. Knudsen K, Abrahamsson J. Epinephrine and sodium bicarbonate independently and additively increase survival in experimental amitriptyline poisoning. Crit Care Med. 1997;25:669–674.

256. Nattel S, Mittleman M. Treatment of ventricular tachyarrhythmias resulting from amitriptyline toxicity in dogs. J Pharmacol Exp Ther. 1984;231:430–435.

257. Pentel P, Benowitz N. Efficacy and mechanism of action of sodium bicarbonate in the treatment of desipramine toxicity in rats. J Pharmacol Exp Ther. 1984;230:12–19.

258. Sasyniuk BI, Jhamandas V, Valois M. Experimental amitriptyline intoxication: treatment of cardiac toxicity with sodium bicarbonate. Ann Emerg Med. 1986;15:1052–1059.

259. Pentel P, Peterson CD. Asystole complicating physostigmine treatment of tricyclic antidepressant overdose. Ann Emerg Med. 1980;9:588–590.

260. Clarke SF, Dargan PI, Jones AL. Naloxone in opioid poisoning: walking the tightrope. Emerg Med J. 2005;22:612–616.

261. Knudsen K, Abrahamsson J. Effects of epinephrine and norepinephrine on hemodynamic parameters and arrhythmias during a continuous infusion of amitriptyline in rats. J Toxicol Clin Toxicol. 1993;31:461–471.

262. Knudsen K, Abrahamsson J. Effects of epinephrine, norepinephrine, magnesium sulfate, and milrinone on survival and the occurrence of arrhythmias in amitriptyline poisoning in the rat. Crit Care Med. 1994;22:1851–1855.

263. Tran TP, Panacek EA, Rhee KJ, Foulke GE. Response to dopamine vs norepinephrine in tricyclic antidepressant-induced hypotension. Acad Emerg Med. 1997;4:864–868.

264. Tobis JM, Aronow WS. Effect of amitriptyline antidotes on repetitive extrasystole threshold. Clin Pharmacol Ther. 1980;27:602–606.

265. Vernon DD, Banner W Jr., Garrett JS, Dean JM. Efficacy of dopamine and norepinephrine for treatment of hemodynamic compromise in amitriptyline intoxication. Crit Care Med. 1991;19:544–549.

266. Follmer CH, Lum BK. Protective action of diazepam and of sympathomimetic amines against amitryptyline-induced toxicity. J Pharmacol Exp Ther. 1982;222:424–429.

267. Sangster B, de Groot G, Borst C, de Wildt D. Dopamine and isoproterenol in imipramine intoxication in the dog. J Toxicol Clin Toxicol. 1985;23:407–420.

268. Centers for Disease Control and Prevention. Unintentional poisoning deaths: United States, 1999–2004. MMWR Morb Mortal Wkly Rep. 2007;56:93–96.

269. Weaver LK. Clinical practice: carbon monoxide poisoning. N Engl J Med. 2009;360:1217–1225.

270. Hampson NB, Zmaeff JL. Outcome of patients experiencing cardiac arrest with carbon monoxide poisoning treated with hyperbaric oxygen. Ann Emerg Med. 2001;38:36–41.

271. Sloan EP, Murphy DG, Hart R, Cooper MA, Turnbull T, Barreca RS, Ellerson B. Complications and protocol considerations in carbon monoxide-poisoned patients who require hyperbaric oxygen therapy: report from a ten-year experience. Ann Emerg Med. 1989;18:629–634.

272. Chou KJ, Fisher JL, Silver EJ. Characteristics and outcome of children with carbon monoxide poisoning with and without smoke exposure referred for hyperbaric oxygen therapy. Pediatr Emerg Care. 2000;16:151–155.

273. Weaver LK, Hopkins RO, Chan KJ, Churchill S, Elliott CG, Clemmer TP, Orme JF Jr., Thomas FO, Morris AH. Hyperbaric oxygen for acute carbon monoxide poisoning. N Engl J Med. 2002;347:1057–1067.

274. Thom SR, Taber RL, Mendiguren II, Clark JM, Hardy KR, Fisher AB. Delayed neuropsychologic sequelae after carbon monoxide poisoning: prevention by treatment with hyperbaric oxygen. Ann Emerg Med. 1995;25:474–480.

275. Scheinkestel CD, Bailey M, Myles PS, Jones K, Cooper DJ, Millar IL, Tuxen DV. Hyperbaric or normobaric oxygen for acute carbon monoxide poisoning: a randomised controlled clinical trial. Med J Aust. 1999;170:203–210.

276. Raphael JC, Elkharrat D, Jars-Guincestre MC, Chastang C, Chasles V, Vercken JB, Gajdos P. Trial of normobaric and hyperbaric oxygen for acute carbon monoxide intoxication. Lancet. 1989;2:414–419.

277. Juurlink DN, Buckley NA, Stanbrook MB, Isbister GK, Bennett M, McGuigan MA. Hyperbaric oxygen for carbon monoxide poisoning. Cochrane Database Syst Rev. 2005;No. 1:CD002041.

278. Buckley NA, Isbister GK, Stokes B, Juurlink DN. Hyperbaric oxygen for carbon monoxide poisoning: a systematic review and critical analysis of the evidence. Toxicol Rev. 2005;24:75–92.

279. Wolf SJ, Lavonas EJ, Sloan EP, Jagoda AS. Clinical policy: critical issues in the management of adult patients presenting to the emergency department with acute carbon monoxide poisoning. Ann Emerg Med. 2008;51:138–152.

280.

Satran D, Henry CR, Adkinson C, Nicholson CI, Bracha Y, Henry TD. Cardiovascular manifestations of moderate to severe carbon monoxide poisoning. J Am Coll Cardiol. 2005;45:1513–1516.

281. Henry CR, Satran D, Lindgren B, Adkinson C, Nicholson CI, Henry TD. Myocardial injury and long-term mortality following moderate to severe carbon monoxide poisoning. JAMA. 2006;295:398–402.

282. Baud FJ, Barriot P, Toffis V, Riou B, Vicaut E, Lecarpentier Y, Bourdon R, Astier A, Bismuth C. Elevated blood cyanide concentrations in victims of smoke inhalation. N Engl J Med. 1991;325:1761–1766.

283. Borron SW, Baud FJ, Barriot P, Imbert M, Bismuth C. Prospective study of hydroxocobalamin for acute cyanide poisoning in smoke inhalation. Ann Emerg Med. 2007;49:794–801, 801.e1–e2.

284. Fortin JL, Giocanti JP, Ruttimann M, Kowalski JJ. Prehospital administration of hydroxocobalamin for smoke inhalation-associated cyanide poisoning: 8 years of experience in the Paris Fire Brigade. Clin Toxicol (Phila). 2006;44(suppl 1):37–44.

285. Borron SW, Baud FJ, Megarbane B, Bismuth C. Hydroxocobalamin for severe acute cyanide poisoning by ingestion or inhalation. Am J Emerg Med. 2007;25:551–558.

286. Espinoza OB, Perez M, Ramirez MS. Bitter cassava poisoning in eight children: a case report. Vet Hum Toxicol. 1992;34:65.

287. Houeto P, Hoffman JR, Imbert M, Levillain P, Baud FJ. Relation of blood cyanide to plasma cyanocobalamin concentration after a fixed dose of hydroxocobalamin in cyanide poisoning. Lancet. 1995;346:605–608.

288. Pontal P, Bismuth C, Garnier R. Therapeutic attitude in cyanide poisoning: retrospective study of 24 non-lethal cases. Vet Hum Toxicol. 1982;24:286–287.

289. Kirk MA, Gerace R, Kulig KW. Cyanide and methemoglobin kinetics in smoke inhalation victims treated with the cyanide antidote kit. Ann Emerg Med. 1993;22:1413–1418.

290. Chen KK, Rose CL. Nitrite and thiosulfate therapy in cyanide poisoning. JAMA. 1952;149:113–119.

291. Kiese M, Weger N. Formation of ferrihaemoglobin with aminophenols in the human for the treatment of cyanide poisoning. Eur J Pharmacol. 1969;7:97–105.

292. Hall AH, Saiers J, Baud F. Which cyanide antidote? Critical Reviews in Toxicology. 2009;39:541–552.

293. Hobel M, Engeser P, Nemeth L, Pill J. The antidote effect of thiosulphate and hydroxocobalamin in formation of nitroprusside intoxication of rabbits. Arch Toxicol. 1980;46:207–213.

294. Mengel K, Kramer W, Isert B, Friedberg KD. Thiosulphate and hydroxocobalamin prophylaxis in progressive cyanide poisoning in guinea-pigs. Toxicology. 1989;54:335–342.

295. Friedberg KD, Shukla UR. The efficiency of aquocobalamine as an antidote in cyanide poisoning when given alone or combined with sodium thiosulfate. Arch Toxicol. 1975;33:103–113.

296. Hall AH, Rumack BH. Hydroxycobalamin/sodium thiosulfate as a cyanide antidote. J Emerg Med. 1987;5:115–121.

297. Forsyth JC, Mueller PD, Becker CE, Osterloh J, Benowitz NL, Rumack BH, Hall AH. Hydroxocobalamin as a cyanide antidote: safety, efficacy and pharmacokinetics in heavily smoking normal volunteers. J Toxicol Clin Toxicol. 1993;31:277–294.

298. Webb JG, Solankhi NK, Chugh SK, Amin H, Buller CE, Ricci DR, Humphries K, Penn IM, Carere R. Incidence, correlates, and outcome of cardiac arrest associated with percutaneous coronary intervention. Am J Cardiol. 2002;90:1252–1254.

299. Mehta RH, Harjai KJ, Grines L, Stone GW, Boura J, Cox D, O'Neill W, Grines CL; Primary Angioplasty in Myocardial Infarction (PAMI) Investigators. Sustained ventricular tachycardia or fibrillation in the cardiac catheterization laboratory among patients receiving primary percutaneous coronary intervention: incidence, predictors, and outcomes. J Am Coll Cardiol. 2004;43:1765–1772. doi: 10.1016/j.jacc.2003.09.072.

300. Martin-Yuste V, Alvarez-Contreras L, Brugaletta S, Ferreira-Gonzalez I, Cola C, Garcia-Picart J, Martí V, Sabate M. Emergent versus elective percu- taneous stent implantation in the unprotected left main: long-term outcomes from a single-center registry. J Invasive Cardiol. 2011;23:392–397.

301. Sprung J, Ritter MJ, Rihal CS, Warner ME, Wilson GA, Williams BA, Stevens SR, Schroeder DR, Bourke DL, Warner DO. Outcomes of cardiopul- monary resuscitation and predictors of survival in patients undergoing coro- nary angiography including percutaneous coronary interventions. Anesth Analg. 2006;102:217–224. doi: 10.1213/01.ane.0000189082.54614.26.

302. Addala S, Kahn JK, Moccia TF, Harjai K, Pellizon G, Ochoa A, O'Neill WW. Outcome of ventricular fibrillation developing during percutaneous coronary interventions in 19 497 patients without cardiogenic shock. Am J Cardiol. 2005;96:764–765. doi: 10.1016/j.amjcard.2005.04.057.

303.

O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso CL, Tracy CM, Woo YJ, Zhao DX. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2013;127:e362–e425. doi: 10.1161/CIR.0b013e3182742cf6.

304. Grogaard HK, Wik L, Eriksen M, Brekke M, Sunde K. Continuous mechanical chest compressions during cardiac arrest to facilitate resto- ration of coronary circulation with percutaneous coronary intervention. J Am Coll Cardiol. 2007;50:1093–1094. doi: 10.1016/j.jacc.2007.05.028.

305. Agostoni P, Cornelis K, Vermeersch P. Successful percutaneous treat- ment of an intraprocedural left main stent thrombosis with the support of an automatic mechanical chest compression device. Int J Cardiol. 2008;124:e19–e21. doi: 10.1016/j.ijcard.2006.11.175.

306. Steen S, Sjöberg T, Olsson P, Young M. Treatment of out-of-hospital cardiac arrest with LUCAS, a new device for automatic mechanical compression and active decompression resuscitation. Resuscitation. 2005;67:25–30. doi: 10.1016/j.resuscitation.2005.05.013.

307. Larsen AI, Hjørnevik AS, Ellingsen CL, Nilsen DW. Cardiac arrest with continuous mechanical chest compression during percutaneous coronary intervention. A report on the use of the LUCAS device. Resuscitation. 2007;75:454–459. doi: 10.1016/j.resuscitation.2007.05.007.

308. Wagner H, Terkelsen CJ, Friberg H, Harnek J, Kern K, Lassen JF, Olivecrona GK. Cardiac arrest in the catheterisation laboratory: a 5-year experience of using mechanical chest compressions to facilitate PCI dur- ing prolonged resuscitation efforts. Resuscitation. 2010;81:383–387. doi: 10.1016/j.resuscitation.2009.11.006.

309. Linder R, Abdollahi P, Wennersten G. [Life-saving mechanical compression during percutaneous coronary intervention]. Lakartidningen. 2006;103:2390–2392.

310. Ladowski JS, Dillon TA, Deschner WP, DeRiso AJ 2nd, Peterson AC, Schatzlein MH. Durability of emergency coronary artery bypass for complications of failed angioplasty. Cardiovasc Surg. 1996;4:23–27.

311. Redle J, King B, Lemole G, Doorey AJ. Utility of rapid percutaneous cardiopulmonary bypass for refractory hemodynamic collapse in the cardiac catheterization laboratory. Am J Cardiol. 1994;73:899–900.

312. Overlie PA. Emergency use of portable cardiopulmonary bypass. Cathet Cardiovasc Diagn. 1990;20:27–31.

313. Shawl FA, Domanski MJ, Wish MH, Davis M, Punja S, Hernandez TJ. Emergency cardiopulmonary bypass support in patients with car-diac arrest in the catheterization laboratory. Cathet Cardiovasc Diagn. 1990;19:8–12.

314. Bagai J, Webb D, Kasasbeh E, Crenshaw M, Salloum J, Chen J, Zhao D. Efficacy and safety of percutaneous life support during high-risk percu- taneous coronary intervention, refractory cardiogenic shock and in-labo- ratory cardiopulmonary arrest. J Invasive Cardiol. 2011;23:141–147.

315. SheuJJ,TsaiTH,LeeFY,FangHY,SunCK,LeuS,YangCH,ChenSM, Hang CL, Hsieh YK, Chen CJ, Wu CJ, Yip HK. Early extracorporeal mem- brane oxygenator-assisted primary percutaneous coronary intervention improved 30-day clinical outcomes in patients with ST-segment elevation myocardial infarction complicated with profound cardiogenic shock. Crit Care Med. 2010;38:1810–1817. doi: 10.1097/CCM.0b013e3181e8acf7.

316. Arlt M, Philipp A, Voelkel S, Schopka S, Husser O, Hengstenberg C, Schmid C, Hilker M. Early experiences with miniaturized extracorporeal life-support in the catheterization laboratory. Eur J Cardiothorac Surg. 2012;42:858–863. doi: 10.1093/ejcts/ezs176.

317. Grambow DW, Deeb GM, Pavlides GS, Margulis A, O'Neill WW, Bates ER. Emergent percutaneous cardiopulmonary bypass in patients having cardiovascular collapse in the cardiac catheterization laboratory. Am J Cardiol. 1994;73:872–875.

318. Mooney MR, Arom KV, Joyce LD, Mooney JF, Goldenberg IF, Von Rueden TJ, Emery RW. Emergency cardiopulmonary bypass support in patients with cardiac arrest. J Thorac Cardiovasc Surg. 1991;101:450–454.

319. Tsao NW, Shih CM, Yeh JS, Kao YT, Hsieh MH, Ou KL, Chen JW, Shyu KG, Weng ZC, Chang NC, Lin FY, Huang CY. Extracorporeal mem- brane oxygenation-assisted primary percutaneous coronary interven- tion may improve survival of patients with acute myocardial infarction complicated by profound cardiogenic shock. J Crit Care. 2012;27:530. e1–530.11. doi: 10.1016/j.jcrc.2012.02.012.

320. Thiele H, Zeymer U, Neumann FJ, Ferenc M, Olbrich HG, Hausleiter J, de Waha A, Richardt G, Hennersdorf M, Empen K, Fuernau G, Desch S, Eitel I, Hambrecht R, Lauer B, Böhm M, Ebelt H, Schneider S, Werdan K, Schuler G; Intraaortic Balloon Pump in cardiogenic shock II (IABP- SHOCK II) trial investigators. Intra-aortic balloon counterpulsation in acute myocardial infarction complicated by cardiogenic shock (IABP- SHOCK II): final 12 month results of a randomised, open-label trial. Lancet. 2013;382:1638–1645. doi: 10.1016/S0140-6736(13)61783-3.

321. Ohman EM, George BS, White CJ, Kern MJ, Gurbel PA, Freedman RJ, Lundergan C, Hartmann JR, Talley JD, Frey MJ. Use of aortic coun- terpulsation to improve sustained coronary artery patency during acute myocardial infarction. Results of a randomized trial. The Randomized IABP Study Group. Circulation. 1994;90:792–799.

322.

Kaul U, Sahay S, Bahl VK, Sharma S, Wasir HS, Venugopal P. Coronary angioplasty in high risk patients: comparison of elective intraaortic bal- loon pump and percutaneous cardiopulmonary bypass support–a ran- domized study. J Interv Cardiol. 1995;8:199–205.

323. Stone GW, Marsalese D, Brodie BR, Griffin JJ, Donohue B, Costantini C, Balestrini C, Wharton T, Esente P, Spain M, Moses J, Nobuyoshi M, Ayres M, Jones D, Mason D, Grines L, O'Neill WW, Grines CL. A prospective, randomized evaluation of prophylactic intraaortic bal- loon counterpulsation in high risk patients with acute myocardial infarc- tion treated with primary angioplasty. Second Primary Angioplasty in Myocardial Infarction (PAMI-II) Trial Investigators. J Am Coll Cardiol. 1997;29:1459–1467.

324. Ohman EM, Nanas J, Stomel RJ, Leesar MA, Nielsen DW, O'Dea D, Rogers FJ, Harber D, Hudson MP, Fraulo E, Shaw LK, Lee KL; TACTICS Trial. Thrombolysis and counterpulsation to improve survival in myocardial infarction complicated by hypotension and suspected car- diogenic shock or heart failure: results of the TACTICS Trial. J Thromb Thrombolysis. 2005;19:33–39. doi: 10.1007/s11239-005-0938-0.

325. Prondzinsky R, Lemm H, Swyter M, Wegener N, Unverzagt S, Carter JM, Russ M, Schlitt A, Buerke U, Christoph A, Schmidt H, Winkler M, Thiery J, Werdan K, Buerke M. Intra-aortic balloon counterpulsation in patients with acute myocardial infarction complicated by cardiogenic shock: the prospective, randomized IABP SHOCK Trial for attenuation of multiorgan dysfunction syndrome. Crit Care Med. 2010;38:152–160. doi: 10.1097/CCM.0b013e3181b78671.

326. Unverzagt S, Buerke M, de Waha A, Haerting J, Pietzner D, Seyfarth M, Thiele H, Werdan K, Zeymer U, Prondzinsky R. Intra-aortic balloon pump counterpulsation (IABP) for myocardial infarction complicated by cardiogenic shock. Cochrane Database Syst Rev. 2015;3:CD007398. doi: 10.1002/14651858.CD007398.pub3.

327. Sjauw KD, Engström AE, Vis MM, van der Schaaf RJ, Baan J Jr, Koch KT, de Winter RJ, Piek JJ, Tijssen JG, Henriques JP. A systematic review and meta-analysis of intra-aortic balloon pump therapy in ST-elevation myocardial infarction: should we change the guidelines? Eur Heart J. 2009;30:459–468. doi: 10.1093/eurheartj/ehn602.

328. LeeJM,ParkJ,KangJ,JeonKH,JungJH,LeeSE,HanJK,KimHL,Yang HM, Park KW, Kang HJ, Koo BK, Kim SH, Kim HS. The efficacy and safety of mechanical hemodynamic support in patients undergoing high- risk percutaneous coronary intervention with or without cardiogenic shock: Bayesian approach network meta-analysis of 13 randomized controlled tri- als. Int J Cardiol. 2015;184:36–46. doi: 10.1016/j.ijcard.2015.01.081.

329. Reul GJ, Cooley DA, Hallman GL, Duncan JM, Livesay JJ, Frazier OH, Ott DA, Angelini P, Massumi A, Mathur VS. Coronary artery bypass for unsuccessful percutaneous transluminal coronary angioplasty. J Thorac Cardiovasc Surg. 1984;88(5 Pt 1):685–694.

330. Andreasen JJ, Mortensen PE, Andersen LI, Arendrup HC, Ilkjaer LB, Kjøller M, Thayssen P. Emergency coronary artery bypass surgery after failed percutaneous transluminal coronary angioplasty. Scand Cardiovasc J. 2000;34:242–246.

331. Kenyon N, Albertson TE. Status asthmaticus: from the emergency department to the intensive care unit. Clin Rev Allergy Immunol. 2001;20:271–292.

332. Division of Data Services. New Asthma Estimates: Tracking Prevalence, Health Care, and Mortality. Hyattsville, Md: National Center for Health Statistics; 2001.

333. McFadden ER Jr.. Acute severe asthma. Am J Respir Crit Care Med. 2003;168:740–759.

334. McFadden ER Jr., Warren EL. Observations on asthma mortality. Ann Intern Med. 1997;127:142–147.

335. Jorge S, Becquemin MH, Delerme S, Bennaceur M, Isnard R, Achkar R, Riou B, Boddaert J, Ray P. Cardiac asthma in elderly patients: incidence, clinical presentation and outcome. BMC Cardiovasc Disord. 2007;7:16.

336. Rainbow J, Browne GJ. Fatal asthma or anaphylaxis? Emerg Med J. 2002;19:415–417.

337. Kokturk N, Demir N, Kervan F, Dinc E, Koybasioglu A, Turktas H. A subglottic mass mimicking near-fatal asthma: a challenge of diagnosis. J Emerg Med. 2004;26:57–60.

338. Camargo CA Jr., Spooner CH, Rowe BH. Continuous versus intermittent beta-agonists in the treatment of acute asthma. Cochrane Database Syst Rev. 2003;No. 4:CD001115.

339. Travers A, Jones AP, Kelly K, Barker SJ, Camargo CA, Rowe BH. Intravenous beta2-agonists for acute asthma in the emergency department. Cochrane Database Syst Rev. 2001:CD002988.

340. Cates CJ, Crilly JA, Rowe BH. Holding chambers (spacers) versus nebulisers for beta-agonist treatment of acute asthma. Cochrane Database Syst Rev. 2006;No. 2:CD000052.

341. Kelly HW. Levalbuterol for asthma: a better treatment? Curr Allergy Asthma Rep. 2007;7:310–314.

342. Aaron SD. The use of ipratropium bromide for the management of acute asthma exacerbation in adults and children: a systematic review. J Asthma. 2001;38:521–530.

343. Rodrigo G, Rodrigo C, Burschtin O. A meta-analysis of the effects of ipratropium bromide in adults with acute asthma. Am J Med. 1999;107:363–370.

344. Edmonds ML, Camargo CA Jr., Pollack CV Jr., Rowe BH. Early use of inhaled corticosteroids in the emergency department treatment of acute asthma. Cochrane Database Syst Rev. 2003;No. 3:CD002308.

345. Harrison BD, Stokes TC, Hart GJ, Vaughan DA, Ali NJ, Robinson AA. Need for intravenous hydrocortisone in addition to oral prednisolone in patients admitted to hospital with severe asthma without ventilatory failure. Lancet. 1986;1:181–184.

346. Ratto D, Alfaro C, Sipsey J, Glovsky MM, Sharma OP. Are intravenous corticosteroids required in status asthmaticus? JAMA. 1988;260:527–529.

347. Plotnick LH, Ducharme FM. Acute asthma in children and adolescents: should inhaled anticholinergics be added to beta(2)-agonists? Am J Respir Med. 2003;2:109–115.

348. Rodrigo GJ, Castro-Rodriguez JA. Anticholinergics in the treatment of children and adults with acute asthma: a systematic review with meta-analysis. Thorax. 2005;60:740–746.

349. Silverman RA, Osborn H, Runge J, Gallagher EJ, Chiang W, Feldman J, Gaeta T, Freeman K, Levin B, Mancherje N, Scharf S. IV magnesium sulfate in the treatment of acute severe asthma: a multicenter randomized controlled trial. Chest. 2002;122:489–497.

350. Rowe BH, Bretzlaff JA, Bourdon C, Bota GW, Camargo CA Jr.. Magnesium sulfate for treating exacerbations of acute asthma in the emergency department. Cochrane Database Syst Rev. 2000;No. 1:CD001490.

351. Gallegos-Solózanó MC, Pérez-Padilla R, Hernández-Zenteno RJ. “Usefulness of inhaled magnesium sulfate in the coadjuvant management of severe asthma crisis in an emergency department. Pulm Pharmacol Ther. 2010;23:432–437.

352. Blitz M, Blitz S, Hughes R, Diner B, Beasley R, Knopp J, Rowe BH. Aerosolized magnesium sulfate for acute asthma: a systematic review. Chest. 2005;128:337–344.

353. Cydulka R, Davison R, Grammer L, Parker M, Mathews JIV. The use of epinephrine in the treatment of older adult asthmatics. Ann Emerg Med. 1988;17:322–326.

354. Putland M, Kerr D, Kelly AM. Adverse events associated with the use of intravenous epinephrine in emergency department patients presenting with severe asthma. Ann Emerg Med. 2006;47:559–563.

355. Petrillo TM, Fortenberry JD, Linzer JF, Simon HK. Emergency department use of ketamine in pediatric status asthmaticus. J Asthma. 2001;38:657–664.

356. Howton JC, Rose J, Duffy S, Zoltanski T, Levitt MA. Randomized, double-blind, placebo-controlled trial of intravenous ketamine in acute asthma. Ann Emerg Med. 1996;27:170–175.

357. Allen JY, Macias CG. The efficacy of ketamine in pediatric emergency department patients who present with acute severe asthma. Ann Emerg Med. 2005;46:43–50.

358. Hess DR, Acosta FL, Ritz RH, Kacmarek RM, Camargo CA Jr.. The effect of heliox on nebulizer function using a beta-agonist bronchodilator. Chest. 1999;115:184–189.

359. Rodrigo G, Pollack C, Rodrigo C, Rowe BH. Heliox for nonintubated acute asthma patients. Cochrane Database Syst Rev. 2006;No. 4:CD002884.

360. Parameswaran K, Belda J, Rowe BH. Addition of intravenous aminophylline to ?2-agonists in adults with acute asthma. Cochrane Database Syst Rev. 2000;No. 4:CD002742.

361. Schultz TE. Sevoflurane administration in status asthmaticus: a case report. AANA J. 2005;73:35–36.

362. Wheeler DS, Clapp CR, Ponaman ML, Bsn HM, Poss WB. Isoflurane therapy for status asthmaticus in children: a case series and protocol. Pediatr Crit Care Med. 2000;1:55–59.

363. British Thoracic Society Standards of Care Committee. Non-invasive ventilation in acute respiratory failure. Thorax. 2002;57:192–211.

364. Soroksky A, Stav D, Shpirer I. A pilot prospective, randomized, placebo-controlled trial of bilevel positive airway pressure in acute asthmatic attack. Chest. 2003;123:1018–1025.

365. Ram FS, Wellington S, Rowe BH, Wedzicha JA. Non-invasive positive pressure ventilation for treatment of respiratory failure due to severe acute exacerbations of asthma. Cochrane Database Syst Rev. 2005;No. 3:CD004360.

366. Marik PE, Varon J, Fromm R Jr.. The management of acute severe asthma. J Emerg Med. 2002;23:257–268.

367. Brenner B, Corbridge T, Kazzi A. Intubation and mechanical ventilation of the asthmatic patient in respiratory failure. Proc Am Thorac Soc. 2009;6:371–379.

368. Darioli R, Perret C. Mechanical controlled hypoventilation in status asthmaticus. Am Rev Respir Dis. 1984;129:385–387.

369.

Tuxen DV. Permissive hypercapnic ventilation. Am J Respir Crit Care Med. 1994;150:870–874.

370. Mikkelsen ME, Woo YJ, Sager JS, Fuchs BD, Christie JD. Outcomes using extracorporeal life support for adult respiratory failure due to status asthmaticus. Asaio J. 2009;55():47–52.

371. Leiba A, Bar-Yosef S, Bar-Dayan Y, Weiss Y, Segal E, Paret G, Vardi A. Early administration of extracorporeal life support for near fatal asthma. Isr Med Assoc J. 2003;5():600–602.

372. Conrad SA, Green R, Scott LK. Near-fatal pediatric asthma managed with pumpless arteriovenous carbon dioxide removal. Criti Care Med. 2007;35:2624–2629.

373. Elliot SC, Paramasivam K, Oram J, Bodenham AR, Howell SJ, Mallick A. Pumpless extracorporeal carbon dioxide removal for life-threatening asthma. Crit Care Med. 2007;35:945–948.

374. Barker P. Resuscitation in status asthmaticus. Med J Aust. 1985;142:238.

375. Diament RH, Sloan JP. Failed resuscitation in acute severe asthma: a medical indication for emergency thoracotomy? Arch Emerg Med. 1987;4:233–235.

376. Eason J, Tayler D, Cottam S, Edwards R, Beard C, Peachey T, Lanigan C, Knibb A, Dimond J. Manual chest compression for total bronchospasm. Lancet. 1991;337:366.

377. Fisher MM, Bowey CJ, Ladd-Hudson K. External chest compression in acute asthma: a preliminary study. Crit Care Med. 1989;17:686–687.

378. Fisher MM, Whaley AP, Pye RR. External chest compression in the management of acute severe asthma: a technique in search of evidence. Prehosp Disaster Med. 2001;16:124–127.

379. Mostert JW. Lung massage for total bronchospasm: a case report. S Afr Med J. 1960;34:703–704.

380. Smolnikoff VP. Total bronchospasm and lung massage. Anaesthesia. 1960;15:40–44.

381. Deakin CD, McLaren RM, Petley GW, Clewlow F, Dalrymple-Hay MJ. Effects of positive end-expiratory pressure on transthoracic impedance: implications for defibrillation. Resuscitation. 1998;37:9–12.

382. Voelckel WG, Lurie KG, Zielinski T, McKnite S, Plaisance P, Wenzel V, Lindner KH. The effects of positive end-expiratory pressure during active compression decompression cardiopulmonary resuscitation with the inspiratory threshold valve. Anesth Analg. 2001;92:967–974.

383. Tuxen DV. Detrimental effects of positive end-expiratory pressure during controlled mechanical ventilation of patients with severe airflow obstruction. Am Rev Respir Dis. 1989;140:5–9.

384. Myles PS, Madder H, Morgan EB. Intraoperative cardiac arrest after unrecognized dynamic hyperinflation. Br J Anaesth. 1995;74:340–342.

385. Mercer M. Cardiac arrest after unrecognized dynamic inflation. Br J Anaesth. 1995;75:252.

386. Rosengarten PL, Tuxen DV, Dziukas L, Scheinkestel C, Merrett K, Bowes G. Circulatory arrest induced by intermittent positive pressure ventilation in a patient with severe asthma. Anaesth Intensive Care. 1991;19:118–121.

387. Neugut AI, Ghatak AT, Miller RL. Anaphylaxis in the United States: an investigation into its epidemiology. Arch Intern Med. 2001;161:15–21.

388. Banerji A, Clark S, Blanda M, LoVecchio F, Snyder B, Camargo CA Jr.. Multicenter study of patients with angiotensin-converting enzyme inhibitor-induced angioedema who present to the emergency department. Ann Allergy Asthma Immunol. 2008;100:327–332.

389. Agah R, Bandi V, Guntupalli KK. Angioedema: the role of ACE inhibitors and factors associated with poor clinical outcome. Intensive Care Med. 1997;23:793–796.

390. Bork K, Hardt J, Schicketanz KH, Ressel N. Clinical studies of sudden upper airway obstruction in patients with hereditary angioedema due to C1 esterase inhibitor deficiency. Arch Intern Med. 2003;163:1229–1235.

391. Fisher M. Blood volume replacement in acute anaphylactic cardiovascular collapse related to anaesthesia. Br J Anaesth. 1977;49:1023–1026.

392. Nicolas F, Villers D, Blanloeil Y. Hemodynamic pattern in anaphylactic shock with cardiac arrest. Crit Care Med. 1984;12:144–145.

393. Raper RF, Fisher MM. Profound reversible myocardial depression after anaphylaxis. Lancet. 1988;1:386–388.

394. Pumphrey RS. Lessons for management of anaphylaxis from a study of fatal reactions. Clin Exp Allergy. 2000;30:1144–1150.

395. Pumphrey RS. Fatal anaphylaxis in the UK, 1992–2001. Novartis Found Symp. 2004;257:116–128.

396. Yilmaz R, Yuksekbas O, Erkol Z, Bulut ER, Arslan MN. Postmortem findings after anaphylactic reactions to drugs in Turkey. Am J Forensic Med Pathol. 2009;30:346–349.

397. Simons FE, Gu X, Simons KJ. Epinephrine absorption in adults: intramuscular versus subcutaneous injection. J Allergy Clin Immunol. 2001;108:871–873.

398. Sheikh A, Shehata YA, Brown SG, Simons FE. Adrenaline (epinephrine) for the treatment of anaphylaxis with and without shock. Cochrane Database Syst Rev. 2008;No. 4:CD006312.

399. Korenblat P, Lundie MJ, Dankner RE, Day JH. A retrospective study of epinephrine administration for anaphylaxis: how many doses are needed? Allergy Asthma Proc. 1999;20:383–386.

400. Yunginger JW, Sweeney KG, Sturner WQ, Giannandrea LA, Teigland JD, Bray M, Benson PA, York JA, Biedrzycki L, Squillace DL, Helm RM. Fatal food-induced anaphylaxis. JAMA. 1988;260:1450–1452.

401. Brown SG, Blackman KE, Stenlake V, Heddle RJ. Insect sting anaphylaxis; prospective evaluation of treatment with intravenous adrenaline and volume resuscitation. Emerg Med J. 2004;21:149–154.

402. Bautista E, Simons FE, Simons KJ, Becker AB, Duke K, Tillett M, Kepron W, Mink SN. Epinephrine fails to hasten hemodynamic recovery in fully developed canine anaphylactic shock. Int Arch Allergy Immunol. 2002;128:151–164.

403. Bochner BS, Lichtenstein LM. Anaphylaxis. N Engl J Med. 1991;324:1785–1790.

404. Pumphrey R. Anaphylaxis: can we tell who is at risk of a fatal reaction? Curr Opin Allergy Clin Immunol. 2004;4:285–290.

405. Johnston SL, Unsworth J, Gompels MM. Adrenaline given outside the context of life threatening allergic reactions. BMJ. 2003;326:589–590.

406. Mink SN, Simons FE, Simons KJ, Becker AB, Duke K. Constant infusion of epinephrine, but not bolus treatment, improves haemodynamic recovery in anaphylactic shock in dogs. Clin Exp Allergy. 2004;34:1776–1783.

407. Kill C, Wranze E, Wulf H. Successful treatment of severe anaphylactic shock with vasopressin: two case reports. Int Arch Allergy Immunol. 2004;134:260–261.

408. Williams SR, Denault AY, Pellerin M, Martineau R. Vasopressin for treatment of shock following aprotinin administration. Can J Anaesth. 2004;51:169–172.

409. Schummer C, Wirsing M, Schummer W. The pivotal role of vasopressin in refractory anaphylactic shock. Anesth Analg. 2008;107:620–624.

410. Kluger MT. The Bispectral Index during an anaphylactic circulatory arrest. Anaesth Intensive Care. 2001;29:544–547.

411. McBrien ME, Breslin DS, Atkinson S, Johnston JR. Use of methoxamine in the resuscitation of epinephrine-resistant electromechanical dissociation. Anaesthesia. 2001;56:1085–1089.

412. Rocq N, Favier JC, Plancade D, Steiner T, Mertes PM. Successful use of terlipressin in post-cardiac arrest resuscitation after an epinephrine-resistant anaphylactic shock to suxamethonium. Anesthesiology. 2007;107:166–167.

413. Green R, Ball A. Alpha-agonists for the treatment of anaphylactic shock. Anaesthesia. 2005;60:621–622.

414. Heytman M, Rainbird A. Use of alpha-agonists for management of anaphylaxis occurring under anaesthesia: case studies and review. Anaesthesia. 2004;59:1210–1215.

415. Higgins DJ, Gayatri P. Methoxamine in the management of severe anaphylaxis. Anaesthesia. 1999;54:1126.

416. Simons FE. Advances in H1-antihistamines. N Engl J Med. 2004;351:2203–2217.

417. Sheikh A, Ten Broek V, Brown SG, Simons FE. H1-antihistamines for the treatment of anaphylaxis: Cochrane systematic review. Allergy. 2007;62:830–837.

418. Gibbs MW, Kuczkowski KM, Benumof JL. Complete recovery from prolonged cardio-pulmonary resuscitation following anaphylactic reaction to readministered intravenous cefazolin. Acta Anaesthesiol Scand. 2003;47:230–232.

419. Choo KJ, Simons FE, Sheikh A. Glucocorticoids for the treatment of anaphylaxis. Cochrane Database Syst Rev. 2010;3:CD007596.

420. Allen SJ, Gallagher A, Paxton LD. Anaphylaxis to rocuronium. Anaesthesia. 2000;55:1223–1224.

421. Lafforgue E, Sleth JC, Pluskwa F, Saizy C. Successful extracorporeal resuscitation of a probable perioperative anaphylactic shock due to atracurium [in French]. Ann Fr Anesth Reanim. 2005;24:551–555.

422. Bunch TJ, White RD, Lopez-Jimenez F, Thomas RJ. Association of body weight with total mortality and with ICD shocks among survivors of ventricular fibrillation in out-of-hospital cardiac arrest. Resuscitation. 2008;77:351–355.

423. White RD, Blackwell TH, Russell JK, Jorgenson DB. Body weight does not affect defibrillation, resuscitation, or survival in patients with out-of-hospital cardiac arrest treated with a nonescalating biphasic waveform defibrillator. Crit Care Med. 2004;32:S387–S392.

424. DeSilva RA, Lown B. Energy requirement for defibrillation of a markedly overweight patient. Circulation. 1978;57:827–830.

425. White RD, Blackwell TH, Russell JK, Snyder DE, Jorgenson DB. Transthoracic impedance does not affect defibrillation, resuscitation or survival in patients with out-of-hospital cardiac arrest treated with a non-escalating biphasic waveform defibrillator. Resuscitation. 2005;64:63–69.

426. Srinivasan V, Nadkarni VM, Helfaer MA, Carey SM, Berg RA. Childhood obesity and survival after in-hospital pediatric cardiopulmonary resuscitation. Pediatrics. 2010:125:e481–e488.

427. Paice B, Gray JM, McBride D, Donnelly T, Lawson DH. Hyperkalaemia in patients in hospital. Br Med J (Clin Res Ed). 1983;286:1189–1192.

428. Weiner ID, Wingo CS. Hyperkalemia: a potential silent killer. J Am Soc Nephrol. 1998;9:1535–1543.

429. Weiner M, Epstein FH. Signs and symptoms of electrolyte disorders. Yale J Biol Med. 1970;43:76–109.

430. Rastegar A, Soleimani M. Hypokalaemia and hyperkalaemia. Postgrad Med J. 2001;77:759–764.

431. Mattu A, Brady WJ, Robinson DA. Electrocardiographic manifestations of hyperkalemia. Am J Emerg Med. 2000;18:721–729.

432. Frohnert PP, Giuliani ER, Friedberg M, Johnson WJ, Tauxe WN. Statistical investigation of correlations between serum potassium levels and electrocardiographic findings in patients on intermittent hemodialysis therapy. Circulation. 1970;41:667–676.

433. Gennari FJ. Hypokalemia. N Engl J Med. 1998;339:451–458.

434. Slovis C, Jenkins R. ABC of clinical electrocardiography: conditions not primarily affecting the heart [published corrections appear in BMJ. 2007;334(7603) doi: 10.1136/bmj.39219.615243.AE and BMJ. 2002;325:259]. BMJ. 2002;324:1320–1323.

435. Clausen TG, Brocks K, Ibsen H. Hypokalemia and ventricular arrhythmias in acute myocardial infarction. Acta Med Scand. 1988;224:531–537.

436. Higham PD, Adams PC, Murray A, Campbell RW. Plasma potassium, serum magnesium and ventricular fibrillation: a prospective study. Q J Med. 1993;86:609–617.

437. Nordrehaug JE. Malignant arrhythmia in relation to serum potassium in acute myocardial infarction. Am J Cardiol. 1985;56:20D–23D.

438. Nordrehaug JE, von der Lippe G. Hypokalaemia and ventricular fibrillation in acute myocardial infarction. Br Heart J. 1983;50:525–529.

439. Obeid AI, Verrier RL, Lown B. Influence of glucose, insulin, and potassium on vulnerability to ventricular fibrillation in the canine heart. Circ Res. 1978;43:601–608.

440. Curry P, Fitchett D, Stubbs W, Krikler D. Ventricular arrhythmias and hypokalaemia. Lancet. 1976;2:231–233.

441. Buylaert WA, Calle PA, Houbrechts HN. Serum electrolyte disturbances in the post-resuscitation period. Resuscitation. 1989;17(suppl):S189–S196.

442. Cannon LA, Heiselman DE, Dougherty JM, Jones J. Magnesium levels in cardiac arrest victims: relationship between magnesium levels and successful resuscitation. Ann Emerg Med. 1987;16:1195–1199.

443. McDonnell NJ, Muchatuta NA, Paech MJ. Acute magnesium toxicity in an obstetric patient undergoing general anaesthesia for caesarean delivery. Int J Obstet Anesth. 2010;19:226–231.

444. James MF. Cardiopulmonary arrest in pregnancy. Br J Anaesth. 2010;104:115.

445. Mordes JP, Swartz R, Arky RA. Extreme hypermagnesemia as a cause of refractory hypotension. Ann Intern Med. 1975;83:657–658.

446. Kloeck WG. A practical approach to the aetiology of pulseless electrical activity: a simple 10-step training mnemonic. Resuscitation. 1995;30:157–159.

447. Working Group, Ad Hoc Subcommittee on Outcomes, American College of Surgeons–Committee on Trauma. Practice management guidelines for emergency department thoracotomy. J Am Coll Surg. 2001;193:303–309.

448. Hopson LR, Hirsh E, Delgado J, Domeier RM, McSwain NE, Krohmer J. Guidelines for withholding or termination of resuscitation in prehospital traumatic cardiopulmonary arrest: joint position statement of the National Association of EMS Physicians and the American College of Surgeons Committee on Trauma. J Am Coll Surg. 2003;196:106–112.

449. Advanced Trauma Life Support for Doctors. 7th Ed. Chicago: American College of Surgeons; 2004.

450. Maron BJ, Estes NA III.. Commotio cordis. N Engl J Med. 2010;362:917–927.

451. Maron BJ, Doerer JJ, Haas TS, Estes NA, Hodges JS, Link MS. Commotio cordis and the epidemiology of sudden death in competitive lacrosse. Pediatrics. 2009;124:966–971.

452. Link MS, Maron BJ, Wang PJ, VanderBrink BA, Zhu W, Estes NA III.. Upper and lower limits of vulnerability to sudden arrhythmic death with chest-wall impact (commotio cordis). J Am Coll Cardiol. 2003;41:99–104.

453. Sheridan RL, Goldstein MA, Stoddard FJ Jr., Walker TG. Case records of the Massachusetts General Hospital: case 41–2009: a 16-year-old boy with hypothermia and frostbite. N Engl J Med. 2009;361:2654–2662.

454. Larach MG. Accidental hypothermia. Lancet. 1995;345:493–498.

455. Kornberger E, Schwarz B, Lindner KH, Mair P. Forced air surface rewarming in patients with severe accidental hypothermia. Resuscitation. 1999;41:105–111.

456. Roggla M, Frossard M, Wagner A, Holzer M, Bur A, Roggla G. Severe accidental hypothermia with or without hemodynamic instability: rewarming without the use of extracorporeal circulation. Wien Klin Wochenschr. 2002;114:315–320.

457. Gilbert M, Busund R, Skagseth A, Nilsen PÅ, Solb? JP. Resuscitation from accidental hypothermia of 13.7°C with circulatory arrest. Lancet. 2000;355:375–376.

458. Coleman E, Doddakula K, Meeke R, Marshall C, Jahangir S, Hinchion J. An atypical case of successful resuscitation of an accidental profound hypothermia patient, occurring in a temperate climate. Perfusion. 2010;25:103–106.

459. Walpoth BH, Walpoth-Aslan BN, Mattle HP, Radanov BP, Schroth G, Schaeffler L, Fischer AP, von Segesser L, Althaus U. Outcome of survivors of accidental deep hypothermia and circulatory arrest treated with extracorporeal blood warming. N Engl J Med. 1997;337:1500–1505.

460. Althaus U, Aeberhard P, Schupbach P, Nachbur BH, Muhlemann W. Management of profound accidental hypothermia with cardiorespiratory arrest. Ann Surg. 1982;195:492–495.

461. Dobson JA, Burgess JJ. Resuscitation of severe hypothermia by extracorporeal rewarming in a child. J Trauma. 1996;40:483–485.

462. Farstad M, Andersen KS, Koller ME, Grong K, Segadal L, Husby P. Rewarming from accidental hypothermia by extracorporeal circulation: a retrospective study. Eur J Cardiothorac Surg. 2001;20:58–64.

463. Kangas E, Niemela H, Kojo N. Treatment of hypothermic circulatory arrest with thoracotomy and pleural lavage. Ann Chir Gynaecol. 1994;83:258–260.

464. Plaisier BR. Thoracic lavage in accidental hypothermia with cardiac arrest: report of a case and review of the literature. Resuscitation. 2005;66:99–104.

465. Winegard C. Successful treatment of severe hypothermia and prolonged cardiac arrest with closed thoracic cavity lavage. J Emerg Med. 1997;15:629–632.

466. Walters DT. Closed thoracic cavity lavage for hypothermia with cardiac arrest. Ann Emerg Med. 1991;20:439–440.

467. Hall KN, Syverud SA. Closed thoracic cavity lavage in the treatment of severe hypothermia in human beings. Ann Emerg Med. 1990;19:204–206.

468. Oberhammer R, Beikircher W, Hormann C, Lorenz I, Pycha R, Adler-Kastner L, Brugger H. Full recovery of an avalanche victim with profound hypothermia and prolonged cardiac arrest treated by extracorporeal re-warming. Resuscitation. 2008;76:474–480.

469. Tiruvoipati R, Balasubramanian SK, Khoshbin E, Hadjinikolaou L, Sosnowski AW, Firmin RK. Successful use of venovenous extracorporeal membrane oxygenation in accidental hypothermic cardiac arrest. ASAIO J. 2005;51:474–476.

470. Scaife ER, Connors RC, Morris SE, Nichol PF, Black RE, Matlak ME, Hansen K, Bolte RG. An established extracorporeal membrane oxygenation protocol promotes survival in extreme hypothermia. J Pediatr Surg. 2007;42:2012–2016.

471. Weinberg AD. The role of inhalation rewarming in the early management of hypothermia. Resuscitation. 1998;36:101–104.

472. Steinman AM. Cardiopulmonary resuscitation and hypothermia. Circulation. 1986;74():IV-29–IV-32.

473. Danzl DF, Pozos RS, Auerbach PS, Glazer S, Goetz W, Johnson E, Jui J, Lilja P, Marx JA, Miller J, Mills W Jr., Nowak R, Shields R, Vicario S, Wayne M. Multicenter hypothermia survey. Ann Emerg Med. 1987;16:1042–1055.

474. Incagnoli P, Bourgeois B, Teboul A, Laborie JM. Resuscitation from accidental hypothermia of 22 degrees C with circulatory arrest: importance of prehospital management [in French]. Ann Fr Anesth Reanim. 2006;25:535–538.

475. Boddicker KA, Zhang Y, Zimmerman MB, Davies LR, Kerber RE. Hypothermia improves defibrillation success and resuscitation outcomes from ventricular fibrillation. Circulation. 2005;111:3195–3201.

476. Reuler JB. Hypothermia: pathophysiology, clinical settings, and management. Ann Intern Med. 1978;89:519–527.

477. Elenbaas RM, Mattson K, Cole H, Steele M, Ryan J, Robinson W. Bretylium in hypothermia-induced ventricular fibrillation in dogs. Ann Emerg Med. 1984;13:994–999.

478. Kornberger E, Lindner KH, Mayr VD, Schwarz B, Rackwitz KS, Wenzel V, Krismer AC, Mair P. Effects of epinephrine in a pig model of hypothermic cardiac arrest and closed-chest cardiopulmonary resuscitation combined with active rewarming. Resuscitation. 2001;50:301–308.

479. Schwarz B, Mair P, Raedler C, Deckert D, Wenzel V, Lindner KH. Vasopressin improves survival in a pig model of hypothermic cardiopulmonary resuscitation. Crit Care Med. 2002;30:1311–1314.

480. Schwarz B, Mair P, Wagner-Berger H, Stadlbauer KH, Girg S, Wenzel V, Lindner KH. Neither vasopressin nor amiodarone improve CPR outcome in an animal model of hypothermic cardiac arrest. Acta Anaesthesiol Scand. 2003;47:1114–1118.

481. Stoner J, Martin G, O'Mara K, Ehlers J, Tomlanovich M. Amiodarone and bretylium in the treatment of hypothermic ventricular fibrillation in a canine model. Acad Emerg Med. 2003;10:187–191.

482. Wira C, Martin G, Stoner J, Margolis K, Donnino M. Application of normothermic cardiac arrest algorithms to hypothermic cardiac arrest in a canine model. Resuscitation. 2006;69:509–516.

483. Wira CR, Becker JU, Martin G, Donnino MW. Anti-arrhythmic and vasopressor medications for the treatment of ventricular fibrillation in severe hypothermia: a systematic review of the literature. Resuscitation. 2008;78:21–29.

484. Lienhart HG, John W, Wenzel V. Cardiopulmonary resuscitation of a near-drowned child with a combination of epinephrine and vasopressin. Pediatr Crit Care Med. 2005;6:486–488.

485. Kjaergaard B, Jakobsen LK, Nielsen C, Knudsen PJ, Kristensen SR, Larsson A. Low plasma potassium in deep hypothermic cardiac arrest indicates that cardiac arrest is secondary to hypothermia: a porcine study. Eur J Emerg Med. 2010;17:131–135.

486. Falk M, Brugger H, Adler-Kastner L. Avalanche survival chances. Nature. 1994;368:21.

487. Buser O, Etter HJ, Jaccard C. Probability of dying in an avalanche [in German]. Z Unfallchir Versicherungsmed. 1993;suppl 1:263–271.

488. Brugger H, Falk M. New perspectives of avalanche disasters: phase classification using pathophysiologic considerations [in German]. Wien Klin Wochenschr. 1992;104:167–173.

489. Brugger H, Durrer B, Adler-Kastner L, Falk M, Tschirky F. Field management of avalanche victims. Resuscitation. 2001;51:7–15.

490. Locher T, Walpoth B, Pfluger D, Althaus U. Accidental hypothermia in Switzerland (1980–1987): case reports and prognostic factors [in German]. Schweiz Med Wochenschr. 1991;121:1020–1028.

491. Mair P, Kornberger E, Furtwaengler W, Balogh D, Antretter H. Prognostic markers in patients with severe accidental hypothermia and cardiocirculatory arrest. Resuscitation. 1994;27:47–54.

492. Grosse AB, Grosse CA, Steinbach LS, Zimmermann H, Anderson S. Imaging findings of avalanche victims. Skeletal Radiol. 2007;36:515–521.

493. Stalsberg H, Albretsen C, Gilbert M, Kearney M, Moestue E, Nordrum I, Rostrup M, Orbo A. Mechanism of death in avalanche victims. Virchows Arch A Pathol Anat Histopathol. 1989;414:415–422.

494. Oberhammer R, Beikircher W, Hormann C, Lorenz I, Pycha R, Adler-Kastner L, Brugger H. Full recovery of an avalanche victim with profound hypothermia and prolonged cardiac arrest treated by extracorporeal re-warming. Resuscitation. 2008;76:474–480.

495. Radwin MI, Grissom CK. Technological advances in avalanche survival. Wilderness Environ Med. 2002;13:143–152.

496. Paal P, Ellerton J, Sumann G, Demetz F, Mair P, Brugger H. Basic life support ventilation in mountain rescue: official recommendations of the International Commission for Mountain Emergency Medicine (ICAR MEDCOM). High Alt Med Biol. 2007;8:147–154.

497. Locher T, Walpoth BH. Differential diagnosis of circulatory failure in hypothermic avalanche victims: retrospective analysis of 32 avalanche accidents [in German]. Praxis (Bern 1994). 1996;85:1275–1282.

498. Farstad M, Andersen KS, Koller ME, Grong K, Segadal L, Husby P. Rewarming from accidental hypothermia by extracorporeal circulation: a retrospective study. Eur J Cardiothorac Surg. 2001;20:58–64.

499. Schaller MD, Fischer AP, Perret CH. Hyperkalemia: a prognostic factor during acute severe hypothermia. JAMA. 1990;264:1842–1845.

500.

Danzl DF, Pozos RS, Auerbach PS, Glazer S, Goetz W, Johnson E, Jui J, Lilja P, Marx JA, Miller J, Mills W Jr., Nowak R, Shields R, Vicario S, Wayne M. Multicenter hypothermia survey. Ann Emerg Med. 1987;16:1042–1055.

501. Ruttmann E, Weissenbacher A, Ulmer H, Muller L, Hofer D, Kilo J, Rabl W, Schwarz B, Laufer G, Antretter H, Mair P. Prolonged extracorporeal membrane oxygenation-assisted support provides improved survival in hypothermic patients with cardiocirculatory arrest. J Thorac Cardiovasc Surg. 2007;134:594–600.

502. Silfvast T, Pettila V. Outcome from severe accidental hypothermia in Southern Finland: a 10-year review. Resuscitation. 2003;59:285–290.

503. Hauty MG, Esrig BC, Hill JG, Long WB. Prognostic factors in severe accidental hypothermia: experience from the Mt. Hood tragedy. J Trauma. 1987;27:1107–1112.

504. Dobson JA, Burgess JJ. Resuscitation of severe hypothermia by extracorporeal rewarming in a child. J Trauma. 1996;40:483–485.

505. Peden MM, McGee K. The epidemiology of drowning worldwide. Inj Control Saf Promot. 2003;10:195–199.

506. Warner DS, Bierens JJ, Beerman SB, Katz LM. Drowning: a cry for help. Anesthesiology. 2009;110:1211–1213.

507. Joost JLM Handbook on Drowning. Berlin: Springer; 2004.

508. Papa L, Hoelle R, Idris A. Systematic review of definitions for drowning incidents. Resuscitation. 2005;65:255–264.

509. Idris AH, Berg RA, Bierens J, Bossaert L, Branche CM, Gabrielli A, Graves SA, Handley AJ, Hoelle R, Morley PT, Papa L, Pepe PE, Quan L, Szpilman D, Wigginton JG, Modell JH. Recommended guidelines for uniform reporting of data from drowning: the “Utstein style.” Resuscitation. 2003;59:45–57.

510. Youn CS, Choi SP, Yim HW, Park KN. Out-of-hospital cardiac arrest due to drowning: an Utstein Style report of 10 years of experience from St. Mary's Hospital. Resuscitation. 2009;80:778–783.

511. Quan L, Wentz KR, Gore EJ, Copass MK. Outcome and predictors of outcome in pediatric submersion victims receiving prehospital care in King County, Washington. Pediatrics. 1990;86:586–593.

512. Modell JH, Davis JH. Electrolyte changes in human drowning victims. Anesthesiology. 1969;30:414–420.

513. Southwick FS, Dalglish PH Jr.. Recovery after prolonged asystolic cardiac arrest in profound hypothermia: a case report and literature review. JAMA. 1980;243:1250–1253.

514. Siebke H, RØd T, Breivik H, Lind B. Survival after 40 minutes' submersion without cerebral sequelae. Lancet. 1975;1:1275–1277.

515. Bolte RG, Black PG, Bowers RS, Thorne JK, Corneli HM. The use of extracorporeal rewarming in a child submerged for 66 minutes. JAMA. 1988;260:377–379.

516. Gilbert M, Busund R, Skagseth A, Nilsen PÅ, Solb? JP. Resuscitation from accidental hypothermia of 13.7°C with circulatory arrest. Lancet. 2000;355:375–376.

517. Szpilman D, Soares M. In-water resuscitation: is it worthwhile? Resuscitation. 2004;63:25–31.

518. Allman FD, Nelson WB, Pacentine GA, McComb G. Outcome following cardiopulmonary resuscitation in severe pediatric near-drowning. Am J Dis Child. 1986;140:571–575.

519. Weinstein MD, Krieger BP. Near-drowning: epidemiology, pathophysiology, and initial treatment. J Emerg Med. 1996;14:461–467.

520. Watson RS, Cummings P, Quan L, Bratton S, Weiss NS. Cervical spine injuries among submersion victims. J Trauma. 2001;51:658–662.

521. Hwang V, Shofer FS, Durbin DR, Baren JM. Prevalence of traumatic injuries in drowning and near drowning in children and adolescents. Arch Pediatr Adolesc Med. 2003;157:50–53.

522. Kyriacou DN, Arcinue EL, Peek C, Kraus JF. Effect of immediate resuscitation on children with submersion injury. Pediatrics. 1994;94():137–142.

523. Modell JH. Drowning. N Engl J Med. 1993;328:253–256.

524. Rosen P, Stoto M, Harley J. The use of the Heimlich maneuver in near-drowning: Institute of Medicine report. J Emerg Med. 1995;13:397–405.

525. Manolios N, Mackie I. Drowning and near-drowning on Australian beaches patrolled by life-savers: a 10-year study, 1973–1983. Med J Aust. 1988;148:165–167, 170–171.

526.

Onarheim H, Vik V. Porcine surfactant (Curosurf) for acute respiratory failure after near-drowning in 12 year old. Acta Anaesthesiol Scand. 2004;48:778–781.

527. Staudinger T, Bankier A, Strohmaier W, Weiss K, Locker GJ, Knapp S, Roggla M, Laczika K, Frass M. Exogenous surfactant therapy in a patient with adult respiratory distress syndrome after near drowning. Resuscitation. 1997;35:179–182.

528. Suzuki H, Ohta T, Iwata K, Yamaguchi K, Sato T. Surfactant therapy for respiratory failure due to near-drowning. Eur J Pediatr. 1996;155:383–384.

529. Cubattoli L, Franchi F, Coratti G. Surfactant therapy for acute respiratory failure after drowning: two children victim of cardiac arrest. Resuscitation. 2009;80:1088–1089.

530. Thalmann M, Trampitsch E, Haberfellner N, Eisendle E, Kraschl R, Kobinia G. Resuscitation in near drowning with extracorporeal membrane oxygenation. Ann Thorac Surg. 2001;72:607–608.

531. Fish RM, Geddes LA. Conduction of electrical current to and through the human body: a review. Eplasty. 2009;9:e44.

532. Budnick LD. Bathtub-related electrocutions in the United States, 1979 to 1982. JAMA. 1984;252:918–920.

533. Geddes LA, Bourland JD, Ford G. The mechanism underlying sudden death from electric shock. Med Instrum. 1986;20:303–315.

534. Medical aspects of lightning. National Weather Service Web site. Available at: www.lightningsafety.noaa.gov/medical.html. Accessed May 7, 2010.

535. Patten BM. Lightning and electrical injuries. Neurol Clin. 1992;10:1047–1058.

536. Browne BJ, Gaasch WR. Electrical injuries and lightning. Emerg Med Clin North Am. 1992;10:211–229.

537. Kleiner JP, Wilkin JH. Cardiac effects of lightning stroke. JAMA. 1978;240:2757–2759.

538. Lichtenberg R, Dries D, Ward K, Marshall W, Scanlon P. Cardiovascular effects of lightning strikes. J Am Coll Cardiol. 1993;21:531–536.

539. Cooper MA. Emergent care of lightning and electrical injuries. Semin Neurol. 1995;15:268–278.

540. Milzman DP, Moskowitz L, Hardel M. Lightning strikes at a mass gathering. South Med J. 1999;92:708–710.

541. Duclos PJ, Sanderson LM. An epidemiological description of lightning-related deaths in the United States. Int J Epidemiol. 1990;19:673–679.

542. Epperly TD, Stewart JR. The physical effects of lightning injury. J Fam Pract. 1989;29:267–272.

543. Whitcomb D, Martinez JA, Daberkow D. Lightning injuries. South Med J. 2002;95:1331–1334.

544. Maggiolini S, Bozzano A, Russo P, Vitale G, Osculati G, Cantu E, Achilli F, Valagussa F. Echocardiography-guided pericardiocentesis with probe-mounted needle: report of 53 cases. J Am Soc Echocardiogr. 2001;14:821–824.

545. Salem K, Mulji A, Lonn E. Echocardiographically guided pericardiocentesis: the gold standard for the management of pericardial effusion and cardiac tamponade. Can J Cardiol. 1999;15:1251–1255.

546. Susini G, Pepi M, Sisillo E, Bortone F, Salvi L, Barbier P, Fiorentini C. Percutaneous pericardiocentesis versus subxiphoid pericardiotomy in cardiac tamponade due to postoperative pericardial effusion. J Cardiothorac Vasc Anesth. 1993;7:178–183.

547. Tsang TS, Barnes ME, Gersh BJ, Bailey KR, Seward JB. Outcomes of clinically significant idiopathic pericardial effusion requiring intervention. Am J Cardiol. 2003;91:704–707.

548. Tsang TS, Enriquez-Sarano M, Freeman WK, Barnes ME, Sinak LJ, Gersh BJ, Bailey KR, Seward JB. Consecutive 1127 therapeutic echocardiographically guided pericardiocenteses: clinical profile, practice patterns, and outcomes spanning 21 years. Mayo Clin Proc. 2002;77:429–436.

549. Coats TJ, Keogh S, Clark H, Neal M. Prehospital resuscitative thoracotomy for cardiac arrest after penetrating trauma: rationale and case series. J Trauma. 2001;50:670–673.

550. Powell DW, Moore EE, Cothren CC, Ciesla DJ, Burch JM, Moore JB, Johnson JL. Is emergency department resuscitative thoracotomy futile care for the critically injured patient requiring prehospital cardiopulmonary resuscitation? J Am Coll Surg. 2004;199:211–215.

551. Lewis G, Knottenbelt JD. Should emergency room thoracotomy be reserved for cases of cardiac tamponade? Injury. 1991;22:5–6.

552. Wang JC, Jiang P, Huang J, Qian GS. The protective effects and mechanisms of peroxisome proliferator-activated receptor-gamma agonist in rats with acute lung injury [in Chinese]. Zhonghua Jie He He Hu Xi Za Zhi. 2008;31:425–430.

553. Dunning J, Fabbri A, Kohl PH, Levine A, Lockowandt U, Mackay J, Pavie AJ, Strang T, Versteegh MI, Nashef SA EACTS Clinical Guidelines Committee. Guideline for resuscitation in cardiac arrest after cardiac surgery. Eur J Cardiothorac Surg. 2009;36:3–28.

554. Mackay JH, Powell SJ, Charman SC, Rozario C. Resuscitation after cardiac surgery: are we ageist? Eur J Anaesthesiol. 2004;21:66–71.

555. Raman J, Saldanha RF, Branch JM, Esmore DS, Spratt PM, Farnsworth AE, Harrison GA, Chang VP, Shanahan MX. Open cardiac compression in the postoperative cardiac intensive care unit. Anaesth Intensive Care. 1989;17:129–135.

556. Karhunen JP, Sihvo EI, Suojaranta-Ylinen RT, Ramo OJ, Salminen US. Predictive factors of hemodynamic collapse after coronary artery bypass grafting: a case-control study. J Cardiothorac Vasc Anesth. 2006;20:143–148.

557. Anthi A, Tzelepis GE, Alivizatos P, Michalis A, Palatianos GM, Geroulanos S. Unexpected cardiac arrest after cardiac surgery: incidence, predisposing causes, and outcome of open chest cardiopulmonary resuscitation. Chest. 1998;113:15–19.

558. Dimopoulou I, Anthi A, Michalis A, Tzelepis GE. Functional status and quality of life in long-term survivors of cardiac arrest after cardiac surgery. Crit Care Med. 2001;29:1408–1411.

559. el-Banayosy A, Brehm C, Kizner L, Hartmann D, Kortke H, Korner MM, Minami K, Reichelt W, Korfer R. Cardiopulmonary resuscitation after cardiac surgery: a two-year study. J Cardiothorac Vasc Anesth. 1998;12:390–392.

560. Fairman RM, Edmunds LH Jr.. Emergency thoracotomy in the surgical intensive care unit after open cardiac operation. Ann Thorac Surg. 1981;32:386–391.

561. Mackay JH, Powell SJ, Osgathorp J, Rozario CJ. Six-year prospective audit of chest reopening after cardiac arrest. Eur J Cardiothorac Surg. 2002;22:421–425.

562. Ngaage DL, Cowen ME. Survival of cardiorespiratory arrest after coronary artery bypass grafting or aortic valve surgery. Ann Thorac Surg. 2009;88:64–68.

563. Kriaras I, Anthi A, Michelopoulos A, Karakatsani A, Tzelepis G, Papadimitriou L, Geroulanos S. Antimicrobial protection in cardiac surgery patients undergoing open chest CPR. Resuscitation. 1996;31:10–11.

564. Rousou JA, Engelman RM, Flack JE III., Deaton DW, Owen SG. Emergency cardiopulmonary bypass in the cardiac surgical unit can be a lifesaving measure in postoperative cardiac arrest. Circulation. 1994;90():II-280–II-284.

565. Beyersdorf F, Kirsh M, Buckberg GD, Allen BS. Warm glutamate/aspartate-enriched blood cardioplegic solution for perioperative sudden death. J Thorac Cardiovasc Surg. 1992;104:1141–1147.

566. Feng WC, Bert AA, Browning RA, Singh AK. Open cardiac massage and periresuscitative cardiopulmonary bypass for cardiac arrest following cardiac surgery. J Cardiovasc Surg. 1995;36:319–321.

567. Wahba A, Gotz W, Birnbaum DE. Outcome of cardiopulmonary resuscitation following open heart surgery. Scand Cardiovasc J. 1997;31:147–149.

568. Pottle A, Bullock I, Thomas J, Scott L. Survival to discharge following open chest cardiac compression (OCCC): a 4-year retrospective audit in a cardiothoracic specialist centre: Royal Brompton and Harefield NHS Trust, United Kingdom. Resuscitation. 2002;52:269–272.

569. Kaiser GC, Naunheim KS, Fiore AC, Harris HH, McBride LR, Pennington DG, Barner HB, Willman VL. Reoperation in the intensive care unit. Ann Thorac Surg. 1990;49:903–907.

570. Bohrer H, Gust R, Bottiger BW. Cardiopulmonary resuscitation after cardiac surgery. J Cardiothorac Vasc Anesth. 1995;9:352.

571. Ricci M, Karamanoukian HL, D'Ancona G, Jajkowski MR, Bergsland J, Salerno TA. Avulsion of an H graft during closed-chest cardiopulmonary resuscitation after minimally invasive coronary artery bypass graft surgery. J Cardiothorac Vasc Anesth. 2000;14:586–587.

572. Chen YS, Chao A, Yu HY, Ko WJ, Wu IH, Chen RJ, Huang SC, Lin FY, Wang SS. Analysis and results of prolonged resuscitation in cardiac arrest patients rescued by extracorporeal membrane oxygenation. J Am Coll Cardiol. 2003;41:197–203.

573. Dalton HJ, Siewers RD, Fuhrman BP, Del Nido P, Thompson AE, Shaver MG, Dowhy M. Extracorporeal membrane oxygenation for cardiac rescue in children with severe myocardial dysfunction. Crit Care Med. 1993;21:1020–1028.

574. Ghez O, Feier H, Ughetto F, Fraisse A, Kreitmann B, Metras D. Postoperative extracorporeal life support in pediatric cardiac surgery: recent results. ASAIO J. 2005;51:513–516.

575. del Nido PJ, Dalton HJ, Thompson AE, Siewers RD. Extracorporeal membrane oxygenator rescue in children during cardiac arrest after cardiac surgery. Circulation. 1992;86(suppl):II-300–II-304.

576.

Duncan BW, Ibrahim AE, Hraska V, del Nido PJ, Laussen PC, Wessel DL, Mayer JE Jr., Bower LK, Jonas RA. Use of rapid-deployment extracorporeal membrane oxygenation for the resuscitation of pediatric patients with heart disease after cardiac arrest. J Thorac Cardiovasc Surg. 1998;116:305–311.

577. Newsome LR, Ponganis P, Reichman R, Nakaji N, Jaski B, Hartley M. Portable percutaneous cardiopulmonary bypass: use in supported coronary angioplasty, aortic valvuloplasty, and cardiac arrest. J Cardiothorac Vasc Anesth. 1992;6:328–331.

578. Parra DA, Totapally BR, Zahn E, Jacobs J, Aldousany A, Burke RP, Chang AC. Outcome of cardiopulmonary resuscitation in a pediatric cardiac intensive care unit. Crit Care Med. 2000;28:3296–3300.

579. Overlie PA. Emergency use of cardiopulmonary bypass. J Interv Cardiol. 1995;8:239–247.

580. Cipolotti G, Paccagnella A, Simini G. Successful cardiopulmonary resuscitation using high doses of epinephrine. Int J Cardiol. 1991;33:430–431.

581. Kron IL, DiMarco JP, Harman PK, Crosby IK, Mentzer RM Jr., Nolan SP, Wellons HA Jr.. Unanticipated postoperative ventricular tachyarrhythmias. Ann Thorac Surg. 1984;38:317–322.

Part 11: Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality

Key Words: automatic external defibrillator | cardiopulmonary resuscitation | pediatrics

1 Highlights

Summary of Key Issues and Major Changes

The changes for pediatric BLS parallel changes in adult BLS. The topics reviewed here include the following:

- Reaffirming the C-A-B sequence as the preferred sequence for pediatric CPR
- New algorithms for 1-rescuer and multiple-rescuer pediatric HCP CPR in the cell phone era
- Establishing an upper limit of 6 cm for chest compression depth in an adolescent
- Mirroring the adult BLS recommended chest compression rate of 100 to 120/min
- Strongly reaffirming that compressions and ventilation are needed for pediatric BLS

C-A-B Sequence

2015 (Updated): Although the amount and quality of supporting data are limited, it may be reasonable to maintain the sequence from the 2010 Guidelines by initiating CPR with C-A-B over A-B-C. Knowledge gaps exist, and specific research is required to examine the best sequence for CPR in children.

2010 (Old): Initiate CPR for infants and children with chest compressions rather than rescue breaths (C-A-B rather than A-B-C). CPR should begin with 30 compressions (by a single rescuer) or 15 compressions (for resuscitation of infants and children by 2 HCPs) rather than with 2 ventilations.

Why: In the absence of new data, the 2010 sequence has not been changed. Consistency in the order of compressions, airway, and breathing for CPR in victims of all ages may be easiest for rescuers who treat people of all ages to remember and perform. Maintaining the same sequence for adults and children offers consistency in teaching.

New Algorithms for 1-Rescuer and Multiple-Rescuer HCP CPR

Algorithms for 1-rescuer and multiple-rescuer HCP pediatric CPR have been separated (Figure 1 and Figure 2) to better guide rescuers through the initial stages of resuscitation in an era in which handheld cellular telephones with speakers are common. These devices can enable a single rescuer to activate an emergency response while beginning CPR; the rescuer can continue conversation with a dispatcher during CPR. These algorithms continue to emphasize the high priority for high-quality CPR and, in the case of sudden, witnessed collapse, for obtaining an AED quickly because such an event is likely to have a cardiac etiology.

Figure 1: BLS Healthcare Provider Pediatric Cardiac Arrest Algorithm for the Single Rescuer—2015 Update

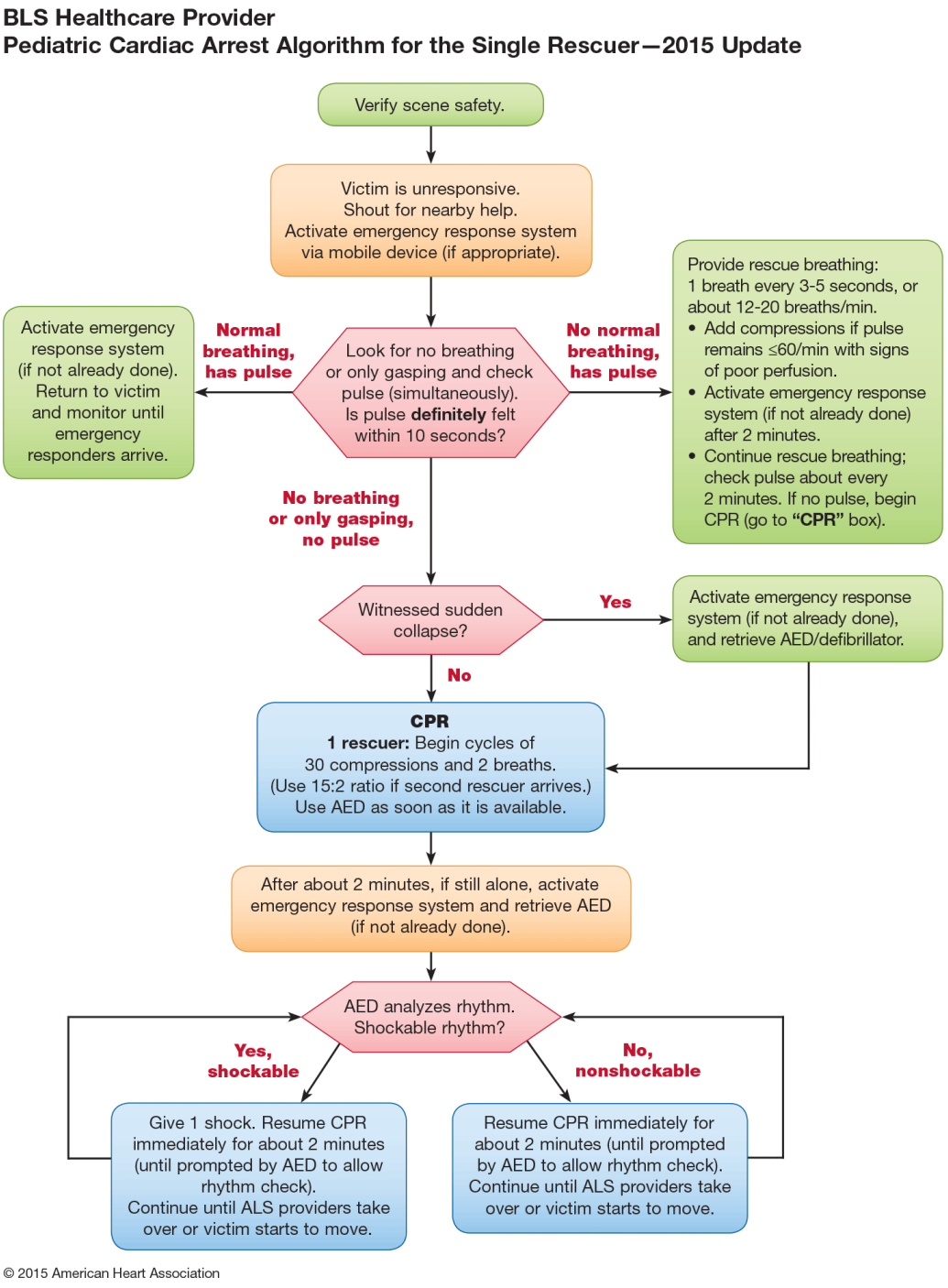
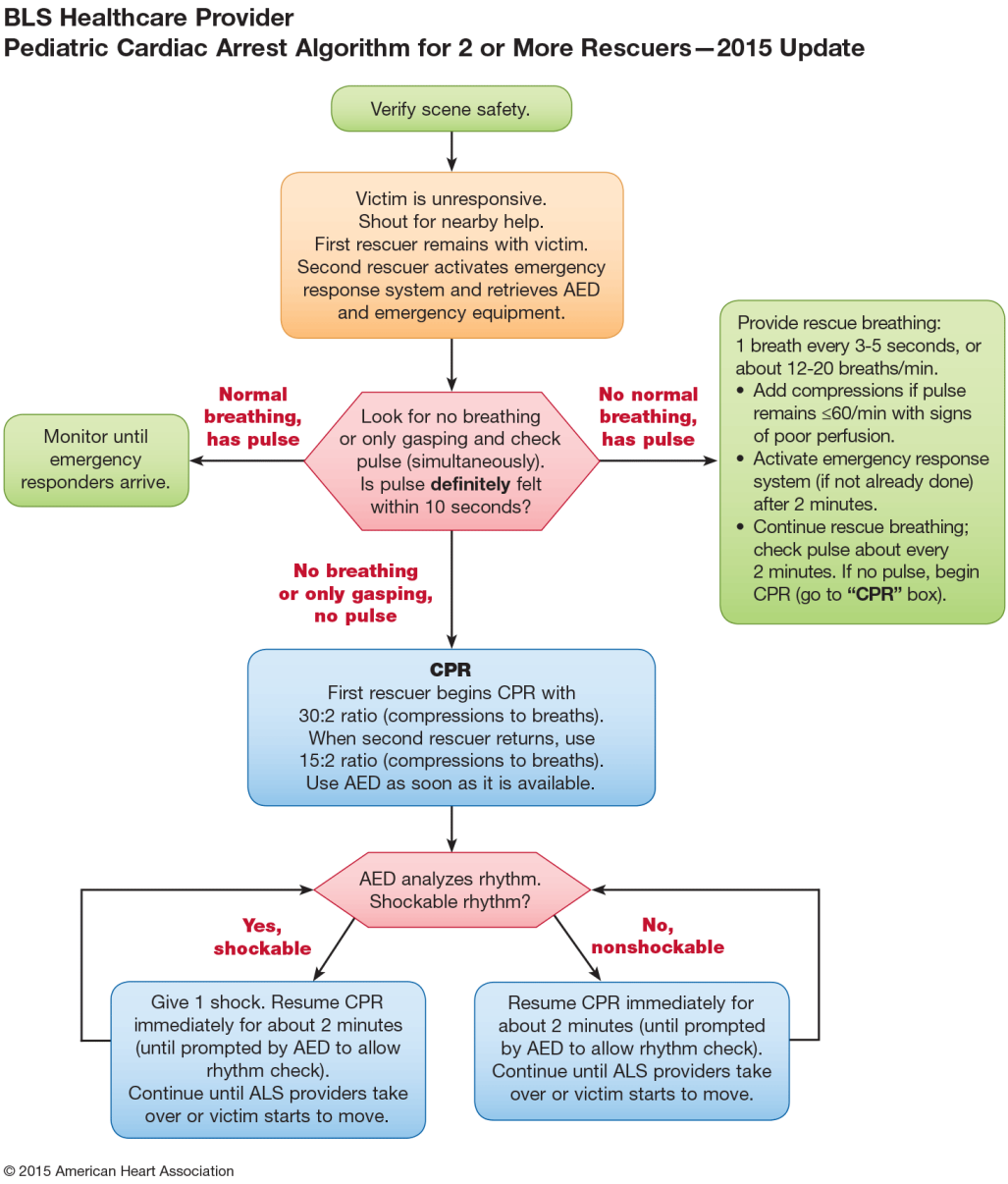


Figure 2: BLS Healthcare Provider Pediatric Cardiac Arrest Algorithm for 2 or More Rescuers—2015 Update



Chest Compression Depth

2015 (Updated): It is reasonable that rescuers provide chest compressions that depress the chest at least one third the anteroposterior diameter of the chest in pediatric patients (infants [younger than 1 year] to children up to the onset of puberty). This equates to approximately 1.5 inches (4 cm) in infants to 2 inches (5 cm) in children. Once children have reached puberty (ie, adolescents), the recommended adult compression depth of at least 2 inches (5 cm) but no greater than 2.4 inches (6 cm) is used.

2010 (Old): To achieve effective chest compressions, rescuers should compress at least one third of the anteroposterior diameter of the chest. This corresponds to approximately 1.5 inches (about 4 cm) in most infants and about 2 inches (5 cm) in most children.

Why: One adult study suggested harm with chest compressions deeper than 2.4 inches (6 cm). This resulted in a change in the adult BLS recommendation to include an upper limit for chest compression depth; the pediatric experts accepted this recommendation for adolescents beyond puberty. A pediatric study observed improved 24-hour survival when compression depth was greater than 2 inches (51 mm). Judgment of compression depth is difficult at the bedside, and the use of a feedback device that provides such information may be useful if

available.

Chest Compression Rate

2015 (Updated): To maximize simplicity in CPR training, in the absence of sufficient pediatric evidence, it is reasonable to use the recommended adult chest compression rate of 100 to 120/min for infants and children.

2010 (Old): "Push fast": Push at a rate of at least 100 compressions per minute.

Why: One adult registry study demonstrated inadequate chest compression depth with extremely rapid compression rates. To maximize educational consistency and retention, in the absence of pediatric data, pediatric experts adopted the same recommendation for compression rate as is made for adult BLS. See the Adult BLS and CPR Quality section of this publication for more detail.

Compression-Only CPR

2015 (Updated): Conventional CPR (rescue breaths and chest compressions) should be provided for infants and children in cardiac arrest. The asphyxial nature of most pediatric cardiac arrests necessitates ventilation as part of effective CPR. However, because compression-only CPR can be effective in patients with a primary cardiac arrest, if rescuers are unwilling or unable to deliver breaths, we recommend rescuers perform compression-only CPR for infants and children in cardiac arrest.

2010 (Old): Optimal CPR in infants and children includes both compressions and ventilations, but compressions alone are preferable to no CPR.

Why: Large registry studies have demonstrated worse outcomes for presumed asphyxial pediatric cardiac arrests (which compose the vast majority of out-of-hospital pediatric cardiac arrests) treated with compression-only CPR. In 2 studies, when conventional CPR (compressions plus breaths) was not given in presumed asphyxial arrest, outcomes were no different from when victims did not receive any bystander CPR. When a presumed cardiac etiology was present, outcomes were similar whether conventional or compression-only CPR was provided.

2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

The 2015 American Heart Association (AHA) Guidelines Update for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) section on pediatric basic life support (BLS) differs substantially from previous versions of the AHA Guidelines. This publication updates the 2010 AHA Guidelines on pediatric BLS for several key questions related to pediatric CPR. The Pediatric ILCOR Task Force reviewed the topics covered in the 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations and the 2010 council-specific guidelines for CPR and ECC (including those published by the AHA) and formulated 3 priority questions to address for the 2015 systematic reviews. In the online version of this document, live links are provided so the reader can connect directly to those systematic reviews on the International Liaison Committee on Resuscitation (ILCOR) Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated by a superscript combination of letters and numbers (eg, Peds 709). We encourage readers to use the links and review the evidence and appendices.

A rigorous systematic review process was undertaken to review the relevant literature to answer those questions, resulting in the 2015 International Consensus on CPR and ECC Science With Treatment Recommendations, "Part 6: Pediatric Basic Life Support and Pediatric Advanced Life Support."[1,2] This 2015 Guidelines Update covers only those topics reviewed as part of the 2015 systematic review process. Other recommendations published in the 2010 AHA Guidelines remain the official recommendations of the AHA ECC scientists. As stated above, this Web-based Integrated Guideline document includes relevant 2010 recommendations as well as the new or updated recommendations from 2015. When making AHA treatment recommendations, we used the AHA Class of Recommendation and Level of Evidence (LOE) systems. New or updated recommendations use the newest AHA COR and LOE classification system, which contains modifications of the Class III recommendation and introduces LOE B-R (randomized studies) and B-NR (nonrandomized studies) as well as LOE C-LD (limited data) and LOE C-EO (consensus of expert opinion).

Recommendations from 2010 display the original classification system from 2010.

Outcomes from pediatric in-hospital cardiac arrest (IHCA) have markedly improved over the past decade. From 2001 to 2009, rates of pediatric IHCA survival to hospital discharge improved from 24% to 39%.[3] Recent unpublished 2013 data from the AHA's Get With The Guidelines®-Resuscitation program observed 36% survival to hospital discharge for pediatric IHCA (Paul S. Chan, MD, personal communication, April 10, 2015). Prolonged CPR is not always futile, with 12% of patients who receive CPR for more than 35 minutes surviving to discharge and 60% of those survivors having a favorable neurologic outcome.[4]

Unlike IHCA, survival from out-of-hospital cardiac arrest (OHCA) remains poor. Data from 2005 to 2007 from the Resuscitation Outcomes Consortium, a registry of 11 US and Canadian emergency medical systems, showed age-dependent discharge survival rates of 3.3% for infants (younger than 1 year), 9.1% for children (1 to 11 years), and 8.9% for adolescents (12 to 19 years).[5] More recently published data from this network demonstrate 8.3% survival to hospital discharge across all age groups.[6]

For the purposes of these guidelines:

• Infant BLS guidelines apply to infants younger than approximately 1 year of age.

• Child BLS guidelines apply to children approximately 1 year of age until puberty. For teaching purposes, puberty is defined as breast development in females and the presence of axillary hair in males.

• Adult BLS guidelines apply at and beyond puberty (see "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality" in this *Web-based Integrated Guidelines* regarding the use of the AED and methods to achieve high-quality CPR).

The following subjects are addressed in the 2015 pediatric BLS guidelines update:

• Pediatric BLS Healthcare Provider Pediatric Cardiac Arrest Algorithms for a single rescuer and for 2 or more rescuers

• The sequence of compressions, airway, breathing (C-A-B) versus airway, breathing, compressions (A-B-C)

• Chest compression rate and depth

• Compression-only (Hands-Only) CPR

Pediatric Advanced Life Support topics reviewed by the ILCOR Pediatric Task Force are covered in "Part 12: Pediatric Advanced Life Support."

3 Prevention of Cardiopulmonary Arrest

In infants, the leading causes of death are congenital malformations, complications of prematurity, and SIDS. In children over 1 year of age, injury is the leading cause of death. Survival from traumatic cardiac arrest is rare, emphasizing the importance of injury prevention in reducing deaths.[7,8] Motor vehicle crashes are the most common cause of fatal childhood injuries; targeted interventions, such as the use of child passenger safety seats, can reduce the risk of death. Resources for the prevention of motor vehicle-related injuries are detailed on the US National Highway Traffic Safety Administration's website at www.nhtsa.gov. The World Health Organization provides information on the prevention of violence and injuries at www.who.int/violence_injury_prevention/en/.

4 Algorithms - Updated

Algorithms for 1- and 2-person healthcare provider CPR have been separated to better guide rescuers through the initial stages of resuscitation (Figure 1 andFigure 2). In an era where cellular telephones with speakers are common, this technology can allow a single rescuer to activate the emergency response system while beginning CPR. These algorithms continue to emphasize the high priority for obtaining an AED quickly in a sudden, witnessed collapse, because such an event is likely to have a cardiac etiology.

Figure 1: BLS Healthcare Provider Pediatric Cardiac Arrest Algorithm for the Single Rescuer—2015 Update

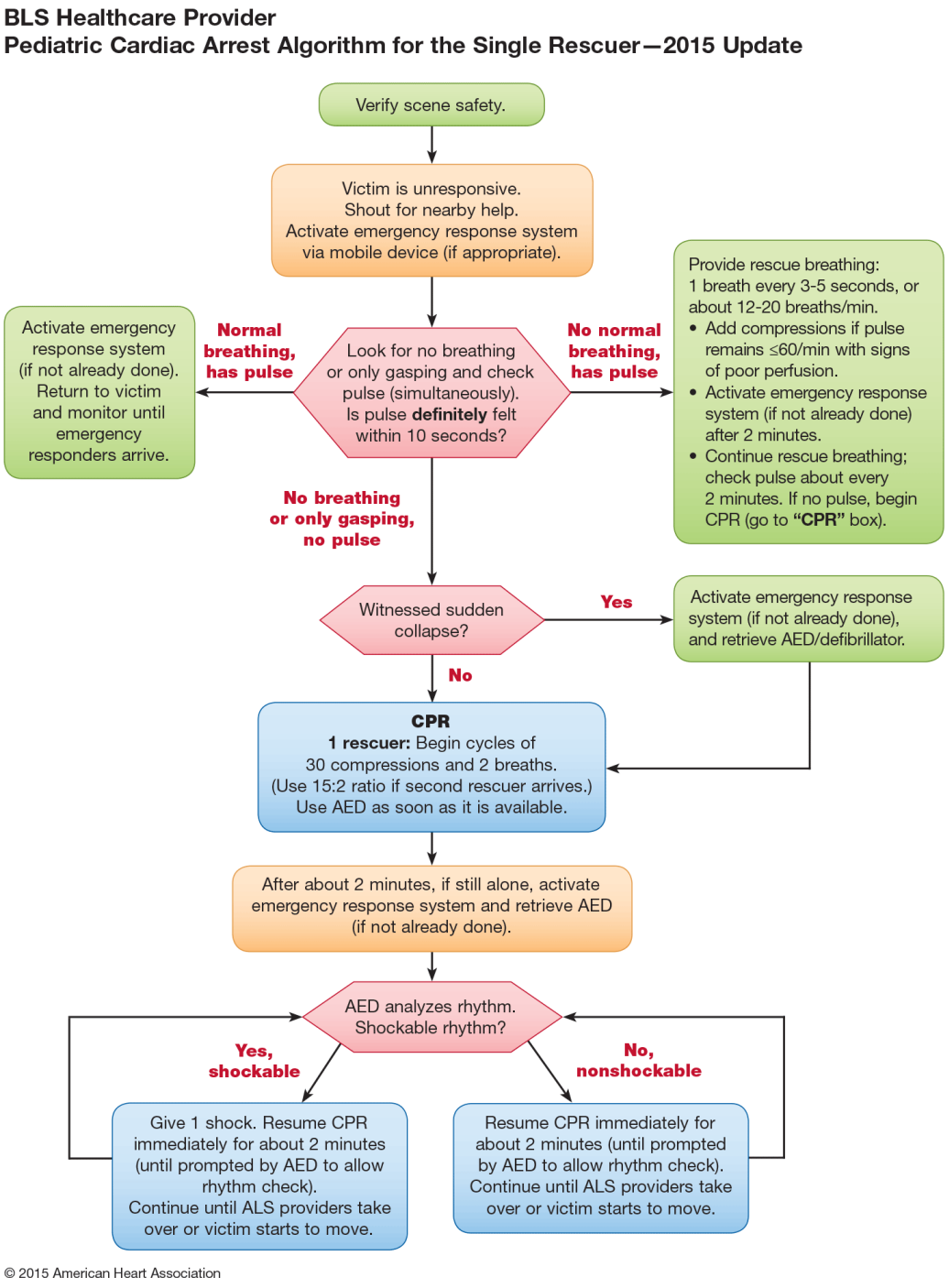
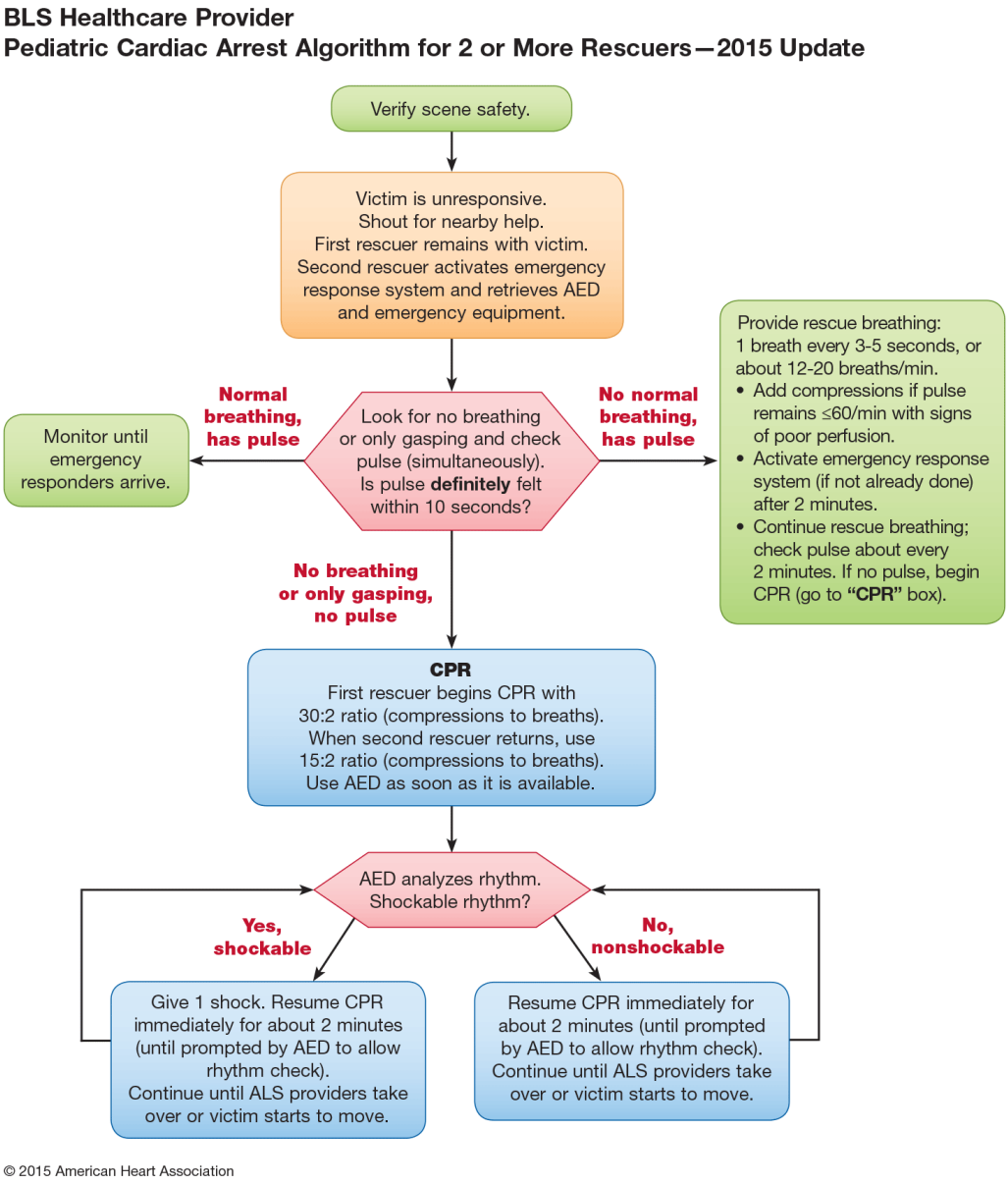


Figure 2: BLS Healthcare Provider Pediatric Cardiac Arrest Algorithm for 2 or More Rescuers—2015 Update



5 BLS Sequence for Lay Rescuers

5.1 Safety of Rescuer and Victim

Always make sure that the area is safe for you and the victim. Although provision of CPR carries a theoretical risk of transmitting infectious disease, the risk to the rescuer is very low.[9]

5.2 Assess Need for CPR

To assess the need for CPR, the lay rescuer should assume that cardiac arrest is present if the victim is unresponsive and not breathing or only gasping.

5.3 Check for Response

Gently tap the victim and ask loudly, "Are you okay?" Call the child's name if you know it. If the child is responsive, he or she will answer, move, or moan. Quickly check to see if the child has any injuries or needs medical assistance. If you are alone and the child is breathing, leave the child to phone the emergency response system, but return quickly and recheck the child's condition frequently. Children with respiratory distress often

assume a position that maintains airway patency and optimizes ventilation. Allow the child with respiratory distress to remain in a position that is most comfortable. If the child is unresponsive, shout for help.

5.4 Check for Breathing

If you see regular breathing, the victim does not need CPR. If there is no evidence of trauma, turn the child onto the side (recovery position), which helps maintain a patent airway and decreases risk of aspiration.

If the victim is unresponsive and not breathing (or only gasping), begin CPR. Sometimes victims who require CPR will gasp, which may be misinterpreted as breathing. Treat the victim with gasps as though there is no breathing and begin CPR.

Formal training as well as "just in time" training, such as that provided by an emergency response system dispatcher, should emphasize how to recognize the difference between gasping and normal breathing; rescuers should be instructed to provide CPR even when the unresponsive victim has occasional gasps. (Class IIa, LOE C)

5.5 Start Chest Compressions

During cardiac arrest, high-quality chest compressions generate blood flow to vital organs and increase the likelihood of ROSC. For details on chest compression see the section in this document entitled: "Components of High-Quality CPR."

5.6 Open the Airway and Give Ventilations

For the lone rescuer a compression-to-ventilation ratio of 30:2 is recommended. After the initial set of 30 compressions, open the airway and give 2 breaths. In an unresponsive infant or child, the tongue may obstruct the airway and interfere with ventilations.[10-12]

Open the airway using a head tilt–chin lift maneuver for both injured and noninjured victims. (Class I, LOE B)

To give breaths to an infant, use a mouth-to-mouth-and-nose technique; to give breaths to a child, use a mouth-to-mouth technique.[13] Make sure the breaths are effective (ie, the chest rises). Each breath should take about 1 second. If the chest does not rise, reposition the head, make a better seal, and try again.[13] It may be necessary to move the child's head through a range of positions to provide optimal airway patency and effective rescue breathing.

In an infant, if you have difficulty making an effective seal over the mouth and nose, try either mouth-to-mouth or mouth-to-nose ventilation.[14-16] (Class IIb, LOE C)

If you use the mouth-to-mouth technique, pinch the nose closed. If you use the mouth-to-nose technique, close the mouth.

In either case make sure the chest rises when you give a breath. If you are the only rescuer, provide 2 effective ventilations using as short a pause in chest compressions as possible after each set of 30 compressions. (Class IIa, LOE C)

5.7 Coordinate Chest Compressions and Breathing

After giving 2 breaths, immediately give 30 compressions. The lone rescuer should continue this cycle of 30 compressions and 2 breaths for approximately 2 minutes (about 5 cycles) before leaving the victim to activate the emergency response system and obtain an automated external defibrillator (AED) if one is nearby.

The ideal compression-to-ventilation ratio in infants and children is unknown. The following have been considered in recommending a compression-to-ventilation ratio of 30:2 for single rescuers:

Evidence from manikin studies shows that lone rescuers cannot deliver the desired number of compressions per minute with the compression-to-ventilation ratio of 5:1 that was previously recommended (2000 and earlier).[17-20] For the lone rescuer, manikin studies show that a ratio of 30:2 yields more chest compressions than a 15:2 ratio with no, or minimal, increase in rescuer fatigue.[21-25]

Volunteers recruited at an airport to perform single-rescuer layperson CPR on an adult manikin had less “no flow time” (ie, arrest time without chest compressions, when no blood flow is generated) with 30:2 compared with a 15:2 ratio.[26]

An observational human study[27] comparing resuscitations by firefighters prior to and following the change from 15:2 to 30:2 compression-to-ventilation ratio reported more chest compressions per minute with a 30:2 ratio; ROSC was unchanged.

Animal studies[28-30] show that coronary perfusion pressure, a major determinant of success in resuscitation, rapidly declines when chest compressions are interrupted; once compressions are resumed, several chest compressions are needed to restore coronary perfusion pressure. Thus, frequent interruptions of chest compressions prolong the duration of low coronary perfusion pressure and flow.

Manikin studies,[31,26,32] as well as in- and out-of-hospital adult human studies,[33,34,35] have documented long interruptions in chest compressions. Adult studies[36-38] have also demonstrated that these interruptions reduce the likelihood of ROSC.

5.8 Activate Emergency Response System

If there are 2 rescuers, one should start CPR immediately and the other should activate the emergency response system (in most locales by phoning 911) and obtain an AED, if one is available. Most infants and children with cardiac arrest have an asphyxial rather than a VF arrest[39,40,41]; therefore 2 minutes of CPR are recommended before the lone rescuer activates the emergency response system and gets an AED if one is nearby. The lone rescuer should then return to the victim as soon as possible and use the AED (if available) or resume CPR, starting with chest compressions. Continue with cycles of 30 compressions to 2 ventilations until emergency response rescuers arrive or the victim starts breathing spontaneously.

6 BLS Sequence for Healthcare Providers and Others Trained in 2-Rescuer CPR

As stated previously, in 2015 the algorithms for 1- and 2-person pediatric HCP CPR have been separated to better guide rescuers through the initial stages of resuscitation (Figure 1 and Figure 2).

For the most part the sequence of BLS for healthcare providers is similar to that for laypeople with some variation as indicated (Figure 1 and Figure 2). Healthcare providers are more likely to work in teams and less likely to be lone rescuers. Activities described as a series of individual sequences are often performed simultaneously (eg, chest compressions and preparing for rescue breathing) so there is less significance regarding which is performed first.

It is reasonable for healthcare providers to tailor the sequence of rescue actions to the most likely cause of arrest. For example, if the arrest is witnessed and sudden (eg, sudden collapse in an adolescent or a child identified at high risk for arrhythmia or during an athletic event), the healthcare provider may assume that the victim has suffered a sudden VF–cardiac arrest and as soon as the rescuer verifies that the child is unresponsive and not breathing (or only gasping) the rescuer should immediately phone the emergency response system, get the AED and then begin CPR and use the AED.[42,43,44] (Class IIa LOE C)

Figure 1: BLS Healthcare Provider Pediatric Cardiac Arrest Algorithm for the Single Rescuer—2015 Update

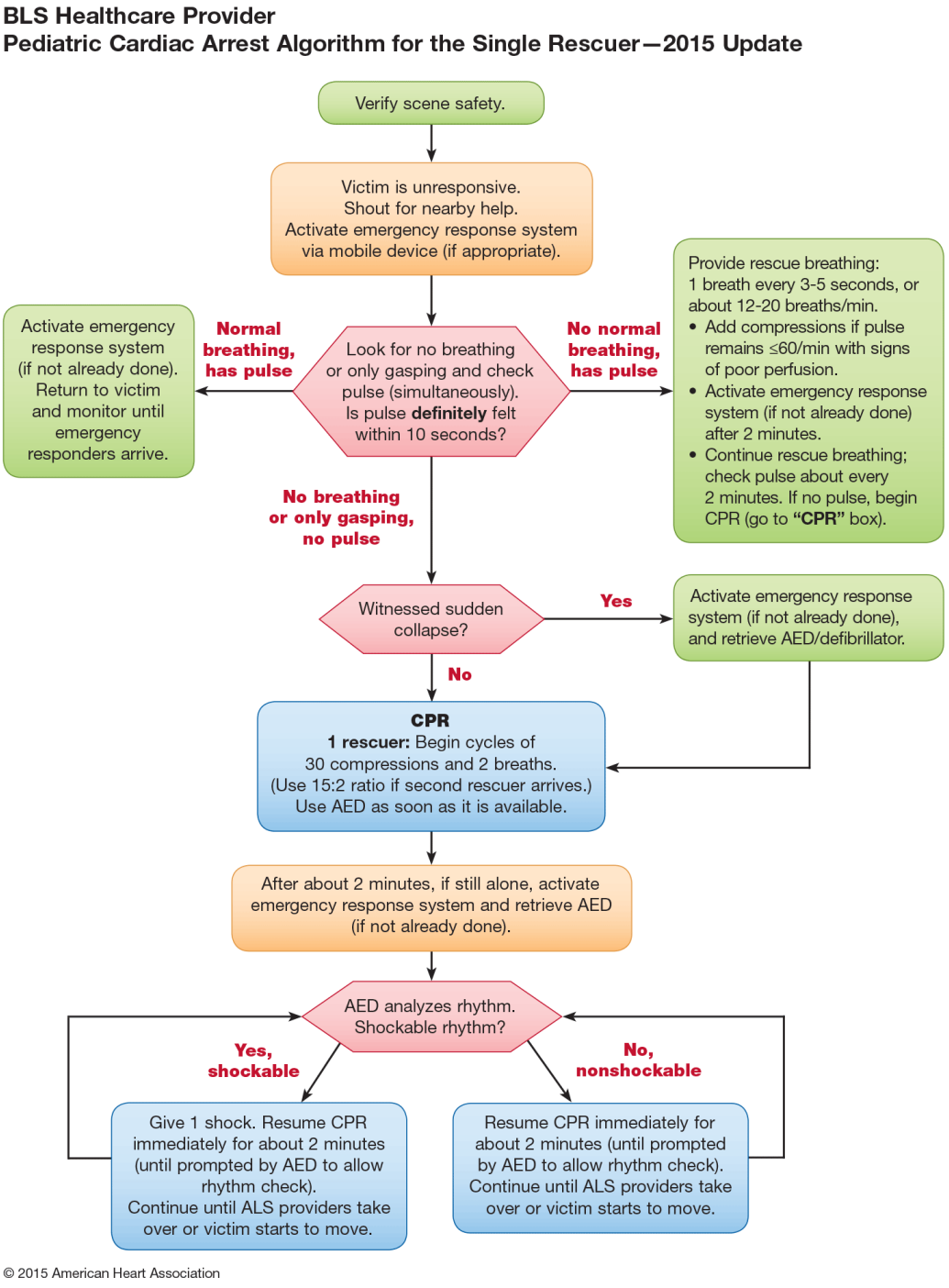
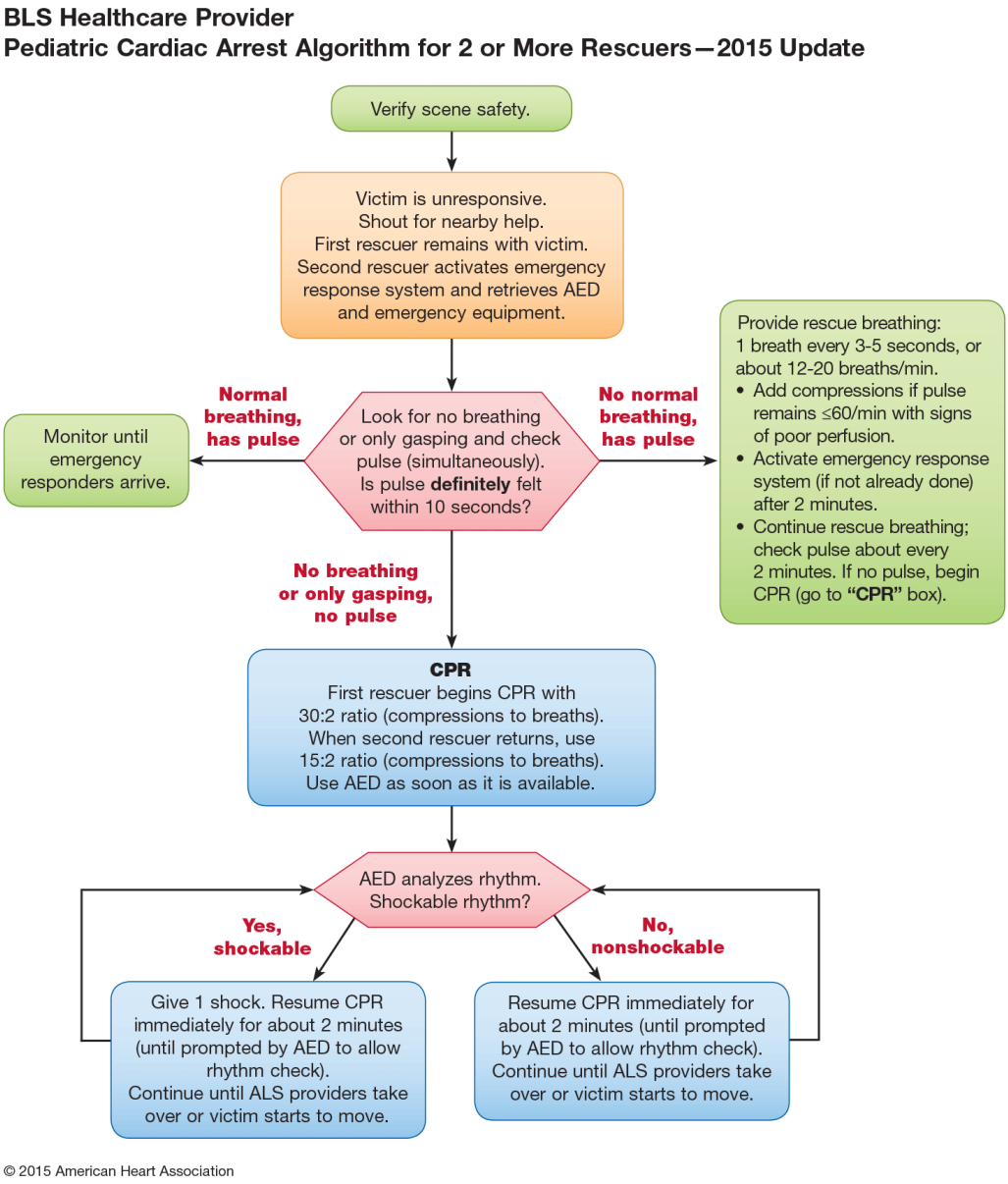


Figure 2: BLS Healthcare Provider Pediatric Cardiac Arrest Algorithm for 2 or More Rescuers—2015 Update



6.1 Assess the Need for CPR

If the victim is unresponsive and is not breathing (or only gasping), send someone to activate the emergency response system.

6.2 Pulse Check

If the infant or child is unresponsive and not breathing (gasps do not count as breathing), healthcare providers may take up to 10 seconds to attempt to feel for a pulse (brachial in an infant and carotid or femoral in a child).

If, within 10 seconds, you don't feel a pulse or are not sure if you feel a pulse, begin chest compressions. (Class IIa, LOE C)

It can be difficult to feel a pulse, especially in the heat of an emergency, and studies show that healthcare providers,[45] as well as lay rescuers, are unable to reliably detect a pulse.[46-60]

6.3 Inadequate Breathing With Pulse

If there is a palpable pulse ?60 per minute but there is inadequate breathing, give rescue breaths at a rate of about 12 to 20 breaths per minute (1 breath every 3 to 5 seconds) until spontaneous breathing resumes.

Reassess the pulse about every 2 minutes but spend no more than 10 seconds doing so.
(Class IIa, LOE B)

6.4 Bradycardia With Poor Perfusion

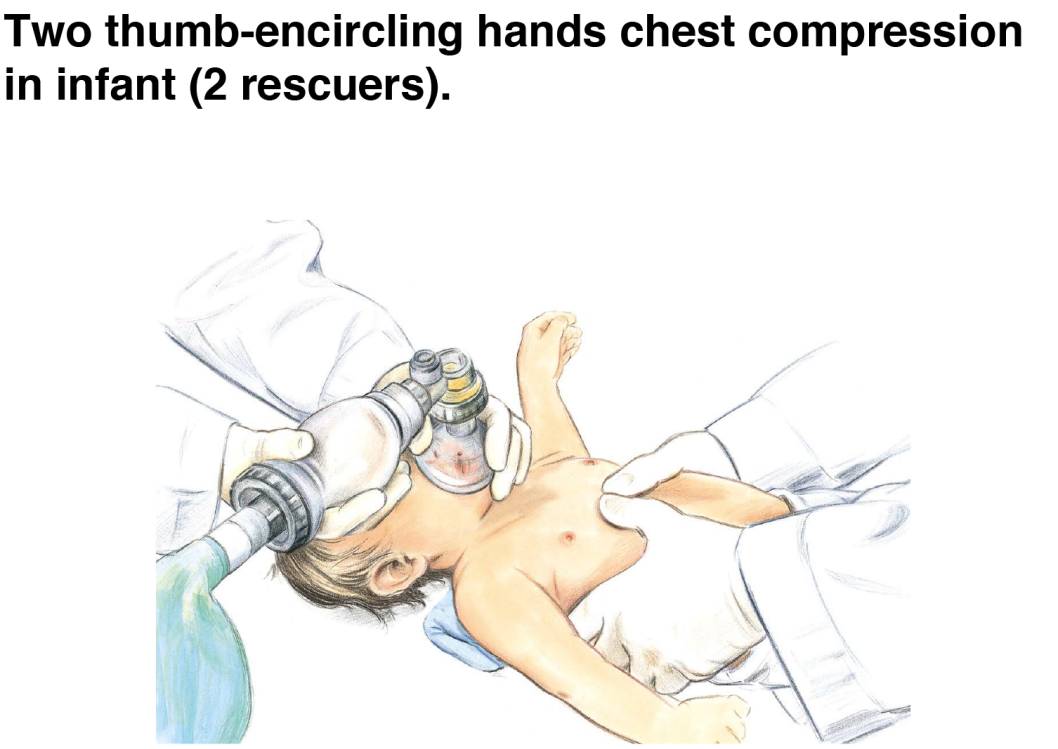
If the pulse is <60 per minute and there are signs of poor perfusion (ie, pallor, mottling, cyanosis) despite support of oxygenation and ventilation, begin chest compressions. Because cardiac output in infancy and childhood largely depends on heart rate, profound bradycardia with poor perfusion is an indication for chest compressions because cardiac arrest is imminent and beginning CPR prior to full cardiac arrest results in improved survival.[61] The absolute heart rate at which chest compressions should be initiated is unknown; the recommendation to provide chest compressions for a heart rate <60 per minute with signs of poor perfusion is based on ease of teaching and retention of skills. For additional information see Bradycardia in Part 12: Pediatric Advanced Life Support.

6.5 Chest Compressions

If the infant or child is unresponsive, not breathing, and has no pulse (or you are unsure whether there is a pulse), start chest compressions (see the section in this document entitled: “Components of High-Quality CPR.”). The only difference in chest compressions for the healthcare provider is in chest compression for infants.

The lone healthcare provider should use the 2-finger chest compression technique for infants. The 2-thumb–encircling hands technique (Figure 3) is recommended when CPR is provided by 2 rescuers. Encircle the infant’s chest with both hands; spread your fingers around the thorax, and place your thumbs together over the lower third of the sternum.[62-66,67-73] Forcefully compress the sternum with your thumbs. In the past, it has been recommended that the thorax be squeezed at the time of chest compression, but there is no data that show benefit from a circumferential squeeze. The 2-thumb–encircling hands technique is preferred over the 2-finger technique because it produces higher coronary artery perfusion pressure, results more consistently in appropriate depth or force of compression,[69-72] and may generate higher systolic and diastolic pressures.[67,68,73,74] If you cannot physically encircle the victim’s chest, compress the chest with 2 fingers, see the section in this document entitled: “Components of High-Quality CPR.”

Figure 3: Two thumb-encircling hands chest compression in infant (2 rescuers)



6.6 Ventilations

After 30 compressions (15 compressions if 2 rescuers), open the airway with a head tilt–chin lift and give 2 breaths.

Ventilations
If there is evidence of trauma that suggests spinal injury, use a jaw thrust without head tilt to open the airway. (Class IIb LOE C)

Because maintaining a patent airway and providing adequate ventilation is important in pediatric CPR, use a head tilt–chin lift maneuver if the jaw thrust does not open the airway.

6.7 Coordinate Chest Compressions and Ventilations

A lone rescuer uses a compression-to-ventilation ratio of 30:2. For 2-rescuer infant and child CPR, one provider should perform chest compressions while the other keeps the airway open and performs ventilations at a ratio of 15:2.

Deliver ventilations with minimal interruptions in chest compressions. (Class IIa, LOE C)

If an advanced airway is in place, cycles of compressions and ventilations are no longer delivered. Instead the compressing rescuer should deliver at least 100 compressions per minute continuously without pauses for ventilation. The ventilation rescuer delivers 8 to 10 breaths per minute (a breath every 6 to 8 seconds), being careful to avoid excessive ventilation in the stressful environment of a pediatric arrest.

6.8 Defibrillation

VF can be the cause of sudden collapse[43,75] or may develop during resuscitation attempts.[76,77] Children with sudden witnessed collapse (eg, a child collapsing during an athletic event) are likely to have VF or pulseless VT

and need immediate CPR and rapid defibrillation. VF and pulseless VT are referred to as “shockable rhythms” because they respond to electric shocks (defibrillation).

Many AEDs have high specificity in recognizing pediatric shockable rhythms, and some are equipped to decrease (or attenuate) the delivered energy to make them suitable for infants and children <8 years of age.[78-80]

For infants a manual defibrillator is preferred when a shockable rhythm is identified by a trained healthcare provider. (Class IIb, LOE C)

The recommended first energy dose for defibrillation is 2 J/kg. If a second dose is required, it should be doubled to 4 J/kg. If a manual defibrillator is not available, an AED equipped with a pediatric attenuator is preferred for infants.

An AED with a pediatric attenuator is also preferred for children (Class IIb, LOE C)

AEDs that deliver relatively high energy doses have been successfully used in infants with minimal myocardial damage and good neurological outcomes.[81,82]

Rescuers should coordinate chest compressions and shock delivery to minimize the time between compressions and shock delivery and to resume CPR, beginning with compressions, immediately after shock delivery. The AED will prompt the rescuer to re-analyze the rhythm about every 2 minutes. Shock delivery should ideally occur as soon as possible after compressions.

6.9 Defibrillation Sequence Using an AED

Turn the AED on.

Follow the AED prompts.

End CPR cycle (for analysis and shock) with compressions, if possible

Resume chest compressions immediately after the shock. Minimize interruptions in chest compressions.

6.10 Breathing Adjuncts

6.10.1 Barrier Devices

Despite its safety,[9] some healthcare providers[83-85] and lay rescuers[40,86,87] may hesitate to give mouth-to-mouth rescue breathing without a barrier device. Barrier devices have not reduced the low risk of transmission of infection,[9] and some may increase resistance to air flow.[88,89] If you use a barrier device, do not delay rescue breathing. If there is any delay in obtaining a barrier device or ventilation equipment, give mouth-to-mouth ventilation (if willing and able) or continue chest compressions alone.

6.10.2 Bag-Mask Ventilation (Healthcare Providers)

Bag-mask ventilation is an essential CPR technique for healthcare providers. Bag-mask ventilation requires training and periodic retraining in the following skills: selecting the correct mask size, opening the airway, making a tight seal between the mask and face, delivering effective ventilation, and assessing the effectiveness of that ventilation.

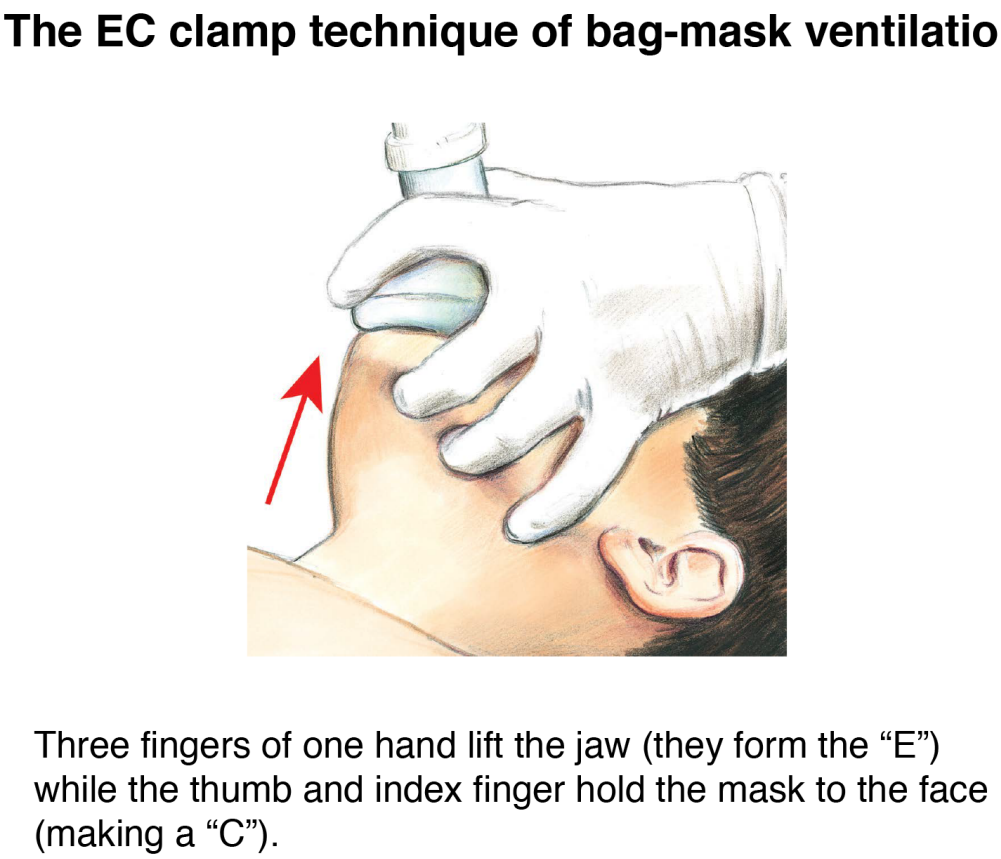
Use a self-inflating bag with a volume of at least 450 to 500 mL[90] for infants and young children, as smaller bags may not deliver an effective tidal volume or the longer inspiratory times required by full-term neonates and infants.[91] In older children or adolescents, an adult self-inflating bag (1000 mL) may be needed to reliably achieve chest rise.

A self-inflating bag delivers only room air unless supplementary oxygen is attached, but even with an oxygen inflow of 10 L/min, the concentration of delivered oxygen varies from 30% to 80% and is affected by the tidal volume and peak inspiratory flow rate.[92] To deliver a high oxygen concentration (60% to 95%), attach an oxygen reservoir to the self-inflating bag. Maintain an oxygen flow of 10 to 15 L/min into a reservoir attached to a pediatric bag[92] and a flow of at least 15 L/min into an adult bag.

Effective bag-mask ventilation requires a tight seal between the mask and the victim's face. Open the airway by lifting the jaw toward the mask making a tight seal and squeeze the bag until the chest rises (Figure 4) . Because effective bag-mask ventilation requires complex steps, bag-mask ventilation is not recommended for a lone rescuer during CPR. During CPR the lone rescuer should use mouth-to-barrier device techniques for ventilation. Bag-mask ventilation can be provided effectively during 2-person CPR.

Three fingers of one hand lift the jaw (they form the "E") while the thumb and index finger hold the mask to the face (making a "C").

Figure 4: The EC clamp technique of bag-mask ventilations.



6.10.3 Precautions

Healthcare providers often deliver excessive ventilation during CPR,[34,93,94] particularly when an advanced airway is in place. Excessive ventilation is harmful because it

Increases intrathoracic pressure and impedes venous return and therefore decreases cardiac output, cerebral blood flow, and coronary perfusion.[94]

Causes air trapping and barotrauma in patients with small-airway obstruction.

Increases the risk of regurgitation and aspiration in patients without an advanced airway.

Avoid excessive ventilation; use only the force and tidal volume necessary to just make the chest rise. (Class III, LOE C)

Give each breath slowly, over approximately 1 second, and watch for chest rise. If the chest does not rise, reopen the airway, verify that there is a tight seal between the mask and the face (or between the bag and the advanced airway), and reattempt ventilation.

Because effective bag-mask ventilation requires complex steps, bag-mask ventilation is not recommended for ventilation by a lone rescuer during CPR.

Patients with airway obstruction or poor lung compliance may require high inspiratory pressures to be properly ventilated (sufficient to produce chest rise). A pressure-relief valve may prevent the delivery of a sufficient tidal volume in these patients.[92] Make sure that the bag-mask device allows you to bypass the pressure-relief valve and use high pressures, if necessary, to achieve visible chest expansion.[95]

6.10.4 Two-Person Bag-Mask Ventilation

If skilled rescuers are available, a 2-person technique may provide more effective bag-mask-ventilation than a single-person technique.[96]

A 2-person technique may be required to provide effective bag-mask ventilation when there is significant airway obstruction, poor lung compliance,[95] or difficulty in creating a tight seal between the mask and the face. One rescuer uses both hands to open the airway and maintain a tight mask-to-face seal while the other compresses the ventilation bag. Both rescuers should observe the chest to ensure chest rise. Because the 2-person technique may be more effective, be careful to avoid delivering too high a tidal volume that may contribute to excessive ventilation.

6.10.5 Gastric Inflation and Cricoid Pressure

Gastric inflation may interfere with effective ventilation[97] and cause regurgitation. To minimize gastric inflation

Avoid creation of excessive peak inspiratory pressures by delivering each breath over approximately 1 second.[98]

Cricoid pressure may be considered, but only in an unresponsive victim if there is an additional healthcare provider.[99-101] Avoid excessive cricoid pressure so as not to obstruct the trachea.[102]

6.10.6 Oxygen

Animal and theoretical data suggest possible adverse effects of 100% oxygen,[103-106] but studies comparing various concentrations of oxygen during resuscitation have been performed only in the newborn period.[104,106-112] Until additional information becomes available, it is reasonable for healthcare providers to use 100% oxygen during resuscitation. Once circulation is restored, monitor systemic oxygen saturation, It may be reasonable, when appropriate equipment is available, to titrate oxygen administration to maintain the oxyhemoglobin saturation ?94%. Provided appropriate equipment is available, once ROSC is achieved, adjust the FIO_2 to the minimum concentration needed to achieve transcutaneous or arterial oxygen saturation of at least 94% with the goal of avoiding hypreroxia while ensuring adequate oxygen delivery.

Since an oxygen saturation of 100% may correspond to a PaO2 anywhere between ?80 and 500 mm Hg, in general it is appropriate to wean the FIO2 for a saturation of 100%, provided the oxyhemoglobin saturation can be maintained ?94%. (Class IIb, LOE C)

Whenever possible, humidify oxygen to prevent mucosal drying and thickening of pulmonary secretions.

6.10.7 Oxygen Masks

Simple oxygen masks can provide an oxygen concentration of 30% to 50% to a victim who is breathing spontaneously. To deliver a higher concentration of oxygen, use a tight-fitting nonrebreathing mask with an oxygen inflow rate of approximately 15 L/min to maintain inflation of the reservoir bag.

6.10.8 Nasal Cannulas

Infant- and pediatric-size nasal cannulas are suitable for children with spontaneous breathing. The concentration of delivered oxygen depends on the child's size, respiratory rate, and respiratory effort,[113] but the concentration of inspired oxygen is limited unless a high-flow device is used.

6.11 Other CPR Techniques and Adjuncts

There is insufficient data in infants and children to recommend for or against the use of the following: mechanical devices to compress the chest, active compression-decompression CPR, interposed abdominal compression CPR (IAC-CPR), the impedance threshold device, or pressure sensor accelerometer (feedback) devices. For further information, see Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation for adjuncts in adults.

6.12 Foreign-Body Airway Obstruction (Choking) (FBAO)

6.12.1 Epidemiology and Recognition

More than 90% of childhood deaths from foreign-body aspiration occur in children <5 years of age; 65% of the victims are infants. Liquids are the most common cause of choking in infants,[114] whereas balloons, small objects, and foods (eg, hot dogs, round candies, nuts, and grapes) are the most common causes of foreign-body airway obstruction (FBAO) in children.[115-118]

Signs of FBAO include a *sudden* onset of respiratory distress with coughing, gagging, stridor, or wheezing. Sudden onset of respiratory distress in the absence of fever or other respiratory symptoms (eg, antecedent cough, congestion) suggests FBAO rather than an infectious cause of respiratory distress, such as croup.

6.12.2 Relief of FBAO

FBAO may cause mild or severe airway obstruction. When the airway obstruction is mild, the child can cough and make some sounds. When the airway obstruction is severe, the victim cannot cough or make any sound.

If FBAO is mild, do not interfere. Allow the victim to clear the airway by coughing while you observe for signs of severe FBAO.

If the FBAO is severe (ie, the victim is unable to make a sound) you must act to relieve the obstruction.

For a child perform subdiaphragmatic abdominal thrusts (Heimlich maneuver)[119,120] until the object is expelled or the victim becomes unresponsive. For an infant, deliver repeated cycles of 5 back blows (slaps) followed by 5 chest compressions[121-123] until the object is expelled or the victim becomes unresponsive. Abdominal thrusts are not recommended for infants because they may damage the infant's relatively large and unprotected liver.

If the victim becomes unresponsive, start CPR with chest compressions (do not perform a pulse check). After 30 chest compressions, open the airway. If you see a foreign body, remove it but do not perform blind finger sweeps because they may push obstructing objects farther into the pharynx and may damage the oropharynx.[124-126] Attempt to give 2 breaths and continue with cycles of chest compressions and ventilations until the object is expelled. After 2 minutes, if no one has already done so, activate the emergency response system.

6.13 Special Resuscitation Situations

6.13.1 Children With Special Healthcare Needs

Children with special healthcare needs may require emergency care for complications of chronic conditions (eg, obstruction of a tracheostomy), failure of support technology (eg, ventilator malfunction), progression of underlying disease, or events unrelated to those special needs.[127]Care is often complicated by a lack of medical information, a comprehensive plan of medical care, a list of current medications, and lack of clarity in limitation of resuscitation orders such as "Do Not Attempt Resuscitation (DNAR)" or "Allow Natural Death (AND)." Parents and child-care providers of children with special healthcare needs are encouraged to keep copies of medical information at home, with the child, and at the child's school or child-care facility. School nurses should have copies and should maintain a readily available list of children with DNAR/AND orders.[127,128] An Emergency Information Form (EIF) developed by the American Academy of Pediatrics and the American College of Emergency Physicians[129] is available online (www2.aap.org/advocacy/blankform.pdf).

6.13.2 Advanced Directives

If a decision to limit or withhold resuscitative efforts is made, the physician must write an order clearly detailing the limits of any attempted resuscitation. A separate order must be written for the out-of-hospital setting. Regulations regarding out-of-hospital DNAR or AND directives vary from state to state.

When a child with a chronic or potentially life-threatening condition is discharged from the hospital, parents, school nurses, and home healthcare providers should be informed about the reason for hospitalization, a summary of the hospital course, and how to recognize signs of deterioration. They should receive specific instructions about CPR and whom to contact.[128]

6.13.3 Ventilation With a Tracheostomy or Stoma

Everyone involved with the care of a child with a tracheostomy (parents, school nurses, and home healthcare providers) should know how to assess patency of the airway, clear the airway, change the tracheostomy tube, and perform CPR using the artificial airway.

Use the tracheostomy tube for ventilation and verify adequacy of airway and ventilation by watching for chest expansion. If the tracheostomy tube does not allow effective ventilation even after suctioning, replace it. If you are still unable to achieve chest rise, remove the tracheostomy tube and attempt alternative ventilation methods, such as mouth-to-stoma ventilation or bag-mask ventilation through the nose and mouth (while you or someone else occludes the tracheal stoma).

6.13.4 Trauma

The principles of BLS resuscitation for the injured child are the same as those for the ill child, but some aspects require emphasis.

The following are important aspects of resuscitation of pediatric victims of trauma:

Anticipate airway obstruction by dental fragments, blood, or other debris. Use a suction device if necessary.

Stop all external bleeding with direct pressure.

When the mechanism of injury is compatible with spinal injury, minimize motion of the cervical spine and movement of the head and neck.

Professional rescuers should open and maintain the airway with a jaw thrust and try not to tilt the head. If a jaw thrust does not open the airway, use a head tilt–chin lift, because a patent airway is necessary. If there are 2 rescuers, 1 can manually restrict cervical spine motion while the other rescuer opens the airway.

To limit spine motion, secure at least the thighs, pelvis, and shoulders to the immobilization board. Because of the disproportionately large size of the head in infants and young children, optimal positioning may require recessing the occiput[130] or elevating the torso to avoid undesirable backboard-induced cervical flexion.[130,131]

If possible, transport children with potential for serious trauma to a trauma center with pediatric expertise.

6.13.5 Drowning

Outcome after drowning is determined by the duration of submersion, the water temperature, and how promptly and effectively CPR is provided.[132,133,134] Neurologically intact survival has been reported after prolonged submersion in icy waters.[135,136] Start resuscitation by safely removing the victim from the water as rapidly as possible. If you have special training, start rescue breathing while the victim is still in the water[137] if doing so will not delay removing the victim from the water. Do not attempt chest compressions in the water.

After removing the victim from the water start CPR if the victim is unresponsive and is not breathing. If you are alone, continue with 5 cycles (about 2 minutes) of compressions and ventilations before activating the emergency response system and getting an AED. If 2 rescuers are present, send the second rescuer to activate the emergency response system immediately and get the AED while you continue CPR.

7 Sequence of CPR - Updated

7.1 C-A-B Versus A-B-C - Updated PEDS 709

Historically, the preferred sequence of CPR was A-B-C (Airway-Breathing-Compressions). The 2010 AHA Guidelines recommended a change to the C-A-B sequence (Compressions-Airway-Breathing) to decrease the time to initiation of chest compressions and reduce “no blood flow” time. The 2015 ILCOR systematic review addressed evidence to support this change.[1,2]

Pediatric cardiac arrest has inherent differences when compared with adult cardiac arrest. In infants and children, asphyxial cardiac arrest is more common than cardiac arrest from a primary cardiac event; therefore, ventilation may have greater importance during resuscitation of children. Data from animal studies[138,139] and 2 pediatric studies[140,141] suggest that resuscitation outcomes for asphyxial arrest are better with a combination of ventilation and chest compressions.

Manikin studies demonstrated that starting CPR with 30 chest compressions followed by 2 breaths delays the first ventilation by 18 seconds for a single rescuer and less (by about 9 seconds or less) for 2 rescuers. A universal CPR algorithm for victims of all ages minimizes the complexity of CPR and offers consistency in teaching CPR to rescuers who treat infants, children, or adults. Whether resuscitation beginning with ventilations (A-B-C) or with chest compressions (C-AB) impacts survival is unknown. To increase bystander CPR rates as well as knowledge and skill retention, the use of the same sequence for infants and children as for adults has potential benefit.

7.1.1 2015 Evidence Summary

No human studies with clinical outcomes were identified that compared C-A-B and A-B-C approaches for initial management of cardiac arrest. The impact of time to first chest compression for C-A-B versus A-B-C sequence has been evaluated. Adult [142,143] and pediatric [144] manikin studies showed a significantly reduced time to first chest compression with the use of a C-A-B approach compared with an A-B-C approach. Data from 2 of these 3 studies demonstrated that time to first ventilation is delayed by only approximately 6 seconds when using a C-A-B sequence compared with an A-B-C sequence.[142,144]

7.1.2 2015 Recommendation—New

Because of the limited amount and quality of the data, it may be reasonable to maintain the sequence from the 2010 Guidelines by initiating CPR with C-A-B over A-B-C sequence. (Class IIb, LOE C-EO)

Knowledge gaps exist, and specific research is required to examine the best approach to initiating CPR in children.

8 Components of High-Quality CPR - Updated

The 5 components of high-quality CPR are

- Ensuring chest compressions of adequate rate
- Ensuring chest compressions of adequate depth
- Allowing full chest recoil between compressions
- Minimizing interruptions in chest compressions
- Avoiding excessive ventilation

The ILCOR Pediatric Task Force systematic review addressed the optimal depth of chest compressions in infants and children. Because there was insufficient evidence for a systemic review of chest compression rate in children, the ILCOR Pediatric Task Force and this writing group reviewed and accepted the recommendations of the ILCOR BLS Task Force regarding chest compression rate so that the recommended compression rate would be consistent for victims of all age groups.

8.1 Chest Compression Rate and Depth - Updated BLS 343 PEDS 394

8.1.1 2015 Evidence Summary

Insufficient data were available for a systematic review of chest compression rate in children. As noted above, the writing group reviewed the evidence and recommendations made for adult BLS and agreed to recommend the same compression rate during resuscitation of children. For the review of chest compression rate in adults, see “Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality.”

Limited pediatric evidence suggests that chest compression depth is a target for improving resuscitation. One observational study demonstrated that chest compression depth is often inadequate during pediatric cardiac arrest.[145] Adult data have demonstrated the importance of adequate chest compression depth to the outcome of resuscitation,[146] but such data in children are very limited. A case series of 6 infants with heart disease examined blood pressure during CPR in relation to chest compression depth and observed a higher systolic blood pressure during CPR in association with efforts to increase chest compression depth.[147] Another report of 87 pediatric resuscitation events, most involving children older than 8 years, found that compression depth greater than 51 mm for more than 60% of the compressions during 30-second epochs within the first 5 minutes was associated with improved 24-hour survival.[148]

8.1.2 2015 Recommendations—New

For simplicity in CPR training, in the absence of sufficient pediatric evidence, it is reasonable to use the adult BLS recommended chest compression rate of 100/min to 120/min for infants and children. (Class IIa, LOE C-EO)

Although the effectiveness of CPR feedback devices was not reviewed by this writing group, the consensus of the group is that the use of feedback devices likely helps the rescuer optimize adequate chest compression rate and depth, and we suggest their use when available. (Class IIb, LOE C-EO)

See also Part 14: Education.

It is reasonable that for pediatric patients (birth to the onset of puberty) rescuers provide chest compressions that depress the chest at least one third the anterior-posterior diameter of the chest. This equates to approximately 1.5 inches (4 cm) in infants to 2 inches (5 cm) in children. (Class IIa, LOE C-LD)

Once children have reached puberty, the recommended adult compression depth of at least 5 cm, but no more than 6 cm, is used for the adolescent of average adult size.[146] (Class I, LOE C-LD)

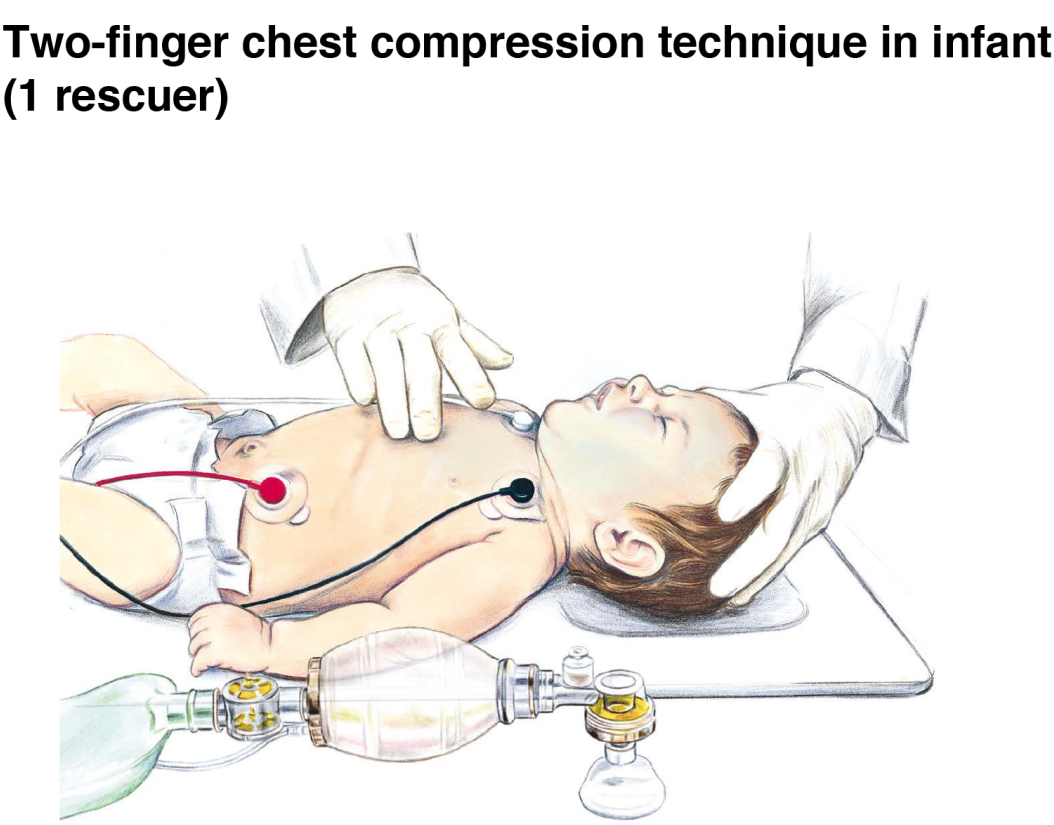
Inadequate compression depth is common [149-34] even by health care providers. For best results, deliver chest compressions on a firm surface.[150,151]

8.2 Finger and Hand Placement

For an infant, lone rescuers (whether lay rescuers or healthcare providers) should compress the sternum with 2 fingers placed just below the intermammary line.[62-66] (Class IIb, LOE C)

Do not compress over the xiphoid or ribs. Rescuers should compress at least one third the depth of the chest, or about 4 cm (1.5 inches).

Figure 5: Two-finger chest compression technique in infant (1 rescuer)



For a child, lay rescuers and healthcare providers should compress the lower half of the sternum at least one third of the AP dimension of the chest or approximately 5 cm (2 inches) with the heel of 1 or 2 hands. Do not press on the xiphoid or the ribs.

There are no data to determine if the 1- or 2-hand method produces better compressions and better outcome. (Class IIb, LOE C)

In a child manikin study, higher chest compression pressures were obtained [152] with less rescuer fatigue [153] with the 2-hand technique. Because children and rescuers come in all sizes, rescuers may use either 1 or 2 hands to compress the child's chest. Whichever you use, make sure to achieve an adequate compression depth with complete release after each compression.

8.3 Chest Recoil

Allow complete chest recoil after each compression to allow the heart to refill with blood.

After each compression, allow the chest to recoil completely (Class IIb, LOE B) because complete chest re-expansion improves the flow of blood returning to the heart and thereby blood flow to the body during CPR. [154-156]

During pediatric CPR incomplete chest wall recoil is common, particularly when rescuers become fatigued.[149, 157,158] Incomplete recoil during CPR is associated with higher intrathoracic pressures and significantly decreased venous return, coronary perfusion, blood flow, and cerebral perfusion.[155,156] Manikin studies suggest that techniques to lift the heel of the hand slightly, but completely, off the chest can improve chest recoil, but this technique has not been studied in humans.[154,159]

8.4 Minimizing Interruptions

Minimize interruptions of chest compressions.

8.4.1 Rescuer fatigue

Rescuer fatigue can lead to inadequate compression rate, depth, and recoil.[149,157,160] The quality of chest compressions may deteriorate within minutes even when the rescuer denies feeling fatigued.[161,162] Rescuers should therefore rotate the compressor role approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions. Recent data suggest that when feedback devices are used and compressions are effective, some rescuers may be able to effectively continue past the 2-minute interval.[157] The switch should be accomplished as quickly as possible (ideally in less than 5 seconds) to minimize interruptions in chest compressions.

8.5 Avoiding Excessive Ventilation

Avoid excessive ventilation.

8.6 Compression-Only CPR Peds 414[PEDS 414]

The 2015 ILCOR pediatric systematic review addressed the use of compression-only CPR for cardiac arrest in infants and children. Compression-only CPR is an alternative for lay rescuer CPR in adults.

8.6.1 2015 Evidence Summary

In a large observational study examining data from a Japanese national registry of pediatric OHCA, the use of compression only CPR, when compared with conventional CPR, was associated with worse 30-day intact neurologic survival.[140] When analyzed by arrest etiology, although the numbers are small, in patients with presumed nonasphyxial arrest (ie, a presumed arrest of cardiac etiology), compression-only CPR was as effective as conventional CPR. However, in patients with presumed asphyxial cardiac arrest, outcomes after compression-only CPR were no better than those for patients receiving no bystander CPR.

A second large observational study using a more recent data set from the same Japanese registry examined the effect of dispatcher-assisted CPR in pediatric OHCA. In this study, the use of compression-only CPR was associated with worse 30-day intact neurologic survival compared with patients who received conventional CPR.[141] Although not stratified for etiology of arrest, outcomes after compression-only CPR were no better than for patients who received no bystander CPR.

8.6.2 2015 Recommendations - New

Conventional CPR (chest compressions and rescue breaths) should be provided for pediatric cardiac arrests. (Class I, LOE B-NR)

The asphyxial nature of the majority of pediatric cardiac arrests necessitates ventilation as part of effective CPR.

However, because compression-only CPR is effective in patients with a primary cardiac event, if rescuers are unwilling or unable to deliver breaths, we recommend rescuers perform compression-only CPR for infants and children in cardiac arrest. (Class I, LOE B-NR)

9 The Quality of BLS

Immediate CPR can improve survival from cardiac arrest in children, but not enough children receive high-quality CPR. We must increase the number of laypersons who learn, remember, and perform CPR, and must improve the quality of CPR provided by lay rescuers and healthcare providers alike.

Healthcare systems that deliver CPR should implement processes of performance improvement. These include monitoring the time required for recognition and activation of the emergency response system, the quality of CPR delivered at the scene of cardiac arrest, other process-of-care measures (eg, initial rhythm, bystander CPR, and response intervals), and patient outcome up to hospital discharge (see additional information in Part 4: Systems of Care and Continuous Quality Improvement). This evidence should be used to optimize the quality of CPR delivered.

10 Authorship and Disclosures

10.1 2015 Writing Team

Dianne L. Atkins, Chair; Stuart Berger; Jonathan P. Duff; John C. Gonzales; Elizabeth A. Hunt; Benny L. Joyner; Peter A. Meaney; Dana E. Niles; Ricardo A. Samson; Stephen M. Schexnayder

Table 1: Part 11: Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 11: Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Dianne L. Atkins	University of Iowa	None	None	None	None	None	None	None
Stuart Berger	University of California	None	None	None	Entity: Defense and plaintiff expert testimony but none that have involved the subject of the AHA Scientific Statement in question. Relationship: Myself. Compensatic Compensate	None	None	None
Jonathan P. Duff	University of Alberta and Stollery Children's Hospital	None	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
John C. Gonzales	Williamson County EMS	None	None	None	None	None	None	None
Elizabeth A. Hunt	Johns Hopkins University School of Medicine	None	Laerdal Foundation for Acute Care Medicine*	None	I have filed several patents on inventions related to simulators to be used in teaching and studying resuscitation*	None	None	None
Benny L. Joyner	University of North Carolina	None	None	None	None	None	None	None
Peter A. Meaney	The Children's Hospital of Philadelphia	None	None	None	None	None	None	None
Dana E. Niles	The Children's Hospital of Philadelphia	None	None	None	None	None	None	None
Consultants								
Ricardo A. Samson	University of Arizona	None	None	None	None	None	American Heart Association†	None
Stephen M. Schexnayder	University of Arkansas; Arkansas Children's Hospital	None	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it the preceding definition. *Modest. †Significant.

10.2 2010 Writing Team

Marc D. Berg, Chair; Stephen M. Schexnayder; Leon Chameides; Mark Terry; Aaron Donoghue; Robert W. Hickey; Robert A. Berg; Robert M. Sutton; Mary Fran Hazinski

Table 2: 2010 - Guidelines Part 13: Pediatric BLS Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 13: Pediatric BLS Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/ Advisory Board	Other
Marc D. Berg	University of Arizona/University Physician's Healthcare (UPH)– Associate Professor of Clinical Pediatrics and Member, Board of Directors	None	None	None	None	None	None
Stephen M. Schexnayder	University of Arkansas for Medical Sciences—Professor/ Division Chief; AHA Compensated Consultant as Associate Senior Science Editor.†	*Pharmacokinetics of Proton Pump Inhibitors	None	*Contemporary Forums	None	None	
Leon Chameides	Emeritus Director Pediatric Cardiology, Connecticut Children's Medical Center Clinical Professor, University of Connecticut	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/ Advisory Board	Other
Mark Terry	Johnson County Med-Act–Deputy Chief Operations	None	None	None	None	None	None
Aaron DonoghuePennsylvania–Assistant	University of Professor of Pediatrics	None	None	None	None	None	None
Robert W. Hickey	University of Pittsburgh—MD	†Salary support on NIH grant to investigate the role of cylcopentenone prostaglandins in hypoxic-ischemic brain injury	None	None	None	None	
Robert A. Berg	University of Pennsylvania Professor	None	None	None	None	None	None
Robert M. Sutton	The Children's Hospital of Philadelphia–Critical Care Attending	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/ Advisory Board	Other
Mary Fran Hazinski	Vanderbilt University School of Nursing—Professor; AHA ECC Product Development—Senior Science Editor. † Significant compensation from the AHA to provide protected time to edit, review, write for the development of the 2010 AHA Guidelines for CPR and ECC and the 2010 International Liaison Committee on Resuscitation Consensus on CPR and ECC Science with Treatment Recommendation	None	None	None	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

11 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 11: Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality. ECCguidelines.heart.org.

References

1. Berg MD, Schexnayder SM, Chameides L, Terry M, Donoghue A, Hickey RW, Berg RA, Sutton RM, Hazinski MF. Part 13: pediat- ric basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S862–S875. doi: 10.1161/ CIRCULATIONAHA.110.971085.

2. de Caen AR, Maconochie IK, Aickin R, Atkins DL, Biarent D, Guerguerian AM, Kleinman ME, Kloeck DA, Meaney PA, Nadkarni VM, Ng KC, Nuthall G, Reis AG, Shimizu N, Tibballs J, Veliz Pintos R; on behalf of the Pediatric Basic Life Support and Pediatric Advanced Life Support Chapter Collaborators. Part 6: pediatric basic life support and pediatric advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132 (suppl 1):S177–S203. doi: 10.1161/CIR.0000000000000275.

3. Maconochie IK, de Caen AR, Aickin R, Atkins DL, Biarent D, Guerguerian AM, Kleinman ME, Kloeck DA, Meaney PA, Nadkarni VM, Ng KC, Nuthall G, Reis AG, Shimizu N, Tibballs J, Veliz Pintos R; on behalf of the Pediatric Basic Life Support and Pediatric Advanced Life Support Chapter Collaborators. Part 6: pediatric basic life support and pediatric advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

4. Girotra S, Spertus JA, Li Y, Berg RA, Nadkarni VM, Chan PS; American Heart Association Get With The Guidelines–Resuscitation Investigators. Survival trends in pediatric in-hospital cardiac arrests: an analysis from Get With The Guidelines-Resuscitation. Circ Cardiovasc Qual Outcomes. 2013;6:42–49. doi: 10.1161/CIRCOUTCOMES.112.967968.

5. Matos RI, Watson RS, Nadkarni VM, Huang HH, Berg RA, Meaney PA, Carroll CL, Berens RJ, Praestgaard A, Weissfeld L, Spinella PC; American Heart Association's Get With The Guidelines–Resuscitation (Formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Duration of cardiopulmonary resuscitation and illness category impact survival and neurologic outcomes for in-hospital pedi- atric cardiac arrests. Circulation. 2013;127:442–451. doi: 10.1161/ CIRCULATIONAHA.112.125625.

6. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, Berg RA; Resuscitation Outcomes Consortium Investigators. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry- Cardiac Arrest. Circulation. 2009;119:1484–1491. doi: 10.1161/ CIRCULATIONAHA.108.802678.

7. Sutton RM, Case E, Brown SP, Atkins DL, Nadkarni VM, Kaltman J, Callaway C, Idris A, Nichol G, Hutchison J, Drennan IR, Austin M, Daya M, Cheskes S, Nuttall J, Herren H, Christenson J, Andrusiek D, Vaillancourt C, Menegazzi JJ, Rea TD, Berg RA; ROC Investigators. A quantitative analysis of out-of-hospital pediatric and adolescent resuscita- tion quality - A report from the ROC epistry-cardiac arrest. Resuscitation. 2015;93:150–157. doi: 10.1016/j.resuscitation.2015.04.010.

8. Crewdson K, Lockey D, Davies G. Outcome from paediatric cardiac arrest associated with trauma. Resuscitation. 2007;75:29–34.

9. Donoghue AJ, Nadkarni V, Berg RA, Osmond MH, Wells G, Nesbitt L, Stiell IG. Out-of-hospital pediatric cardiac arrest: an epidemiologic review and assessment of current knowledge. Ann Emerg Med. 2005;46:512–522.

10. Mejicano GC, Maki DG. Infections acquired during cardiopulmonary resuscitation: estimating the risk and defining strategies for prevention. Ann Intern Med. 1998;129:813–828.

11. Ruben HM, Elam JO, et al. Investigations of pharyngeal xrays and perfomance by laymen. Anesthesiology. 1961;22:271–279.

12. Safar P, Aguto-Escarraga L. Compliance in apneic anesthetized adults. Anesthesiology. 1959;20:283–289.

13. Elam JO, Greene DG, Schneider MA, Ruben HM, Gordon AS, Hustead RF, Benson DW, Clements JA, Ruben A. Head-tilt method of oral resuscitation. JAMA. 1960;172:812–815.

14. Zideman DA. Paediatric and neonatal life support. Br J Anaesth. 1997;79:178–187.

15. Tonkin SL, Davis SL, Gunn TR. Nasal route for infant resuscitation by mothers. Lancet. 1995;345:1353–1354.

16. Segedin E, Torrie J, Anderson B. Nasal airway versus oral route for infant resuscitation. Lancet. 1995;346:382.

17. Tonkin SL, Gunn AJ. Failure of mouth-to-mouth resuscitation in cases of sudden infant death. Resuscitation. 2001;48:181–184.

18.

Dorph E, Wik L, Steen PA. Effectiveness of ventilation-compression ratios 1:5 and 2:15 in simulated single rescuer paediatric resuscitation. Resuscitation. 2002;54:259–264.

19. Greingor JL. Quality of cardiac massage with ratio compression-ventilation 5/1 and 15/2. Resuscitation. 2002;55:263–267.

20. Kinney SB, Tibballs J. An analysis of the efficacy of bag-valve-mask ventilation and chest compression during different compression-ventilation ratios in manikin-simulated paediatric resuscitation. Resuscitation. 2000;43:115–120.

21. Srikantan SK, Berg RA, Cox T, Tice L, Nadkarni VM. Effect of one-rescuer compression/ventilation ratios on cardiopulmonary resuscitation in infant, pediatric, and adult manikins. Pediatr Crit Care Med. 2005;6:293–297.

22. Betz AE, Callaway CW, Hostler D, Rittenberger JC. Work of CPR during two different compression to ventilation ratios with real-time feedback. Resuscitation. 2008;79:278–282.

23. Haque IU, Udassi JP, Udassi S, Theriaque DW, Shuster JJ, Zaritsky AL. Chest compression quality and rescuer fatigue with increased compression to ventilation ratio during single rescuer pediatric CPR. Resuscitation. 2008;79:82–89.

24. Bjorshol CA, Soreide E, Torsteinbo TH, Lexow K, Nilsen OB, Sunde K. Quality of chest compressions during 10 min of single-rescuer basic life support with different compression: ventilation ratios in a manikin model. Resuscitation. 2008;77:95–100.

25. Deschilder K, De Vos R, Stockman W. The effect on quality of chest compressions and exhaustion of a compression–ventilation ratio of 30:2 versus 15:2 during cardiopulmonary resuscitation–a randomised trial. Resuscitation. 2007;74:113–118.

26. Yannopoulos D, Aufderheide TP, Gabrielli A, Beiser DG, McKnite SH, Pirrallo RG, Wigginton J, Becker L, Vanden Hoek T, Tang W, Nadkarni VM, Klein JP, Idris AH, Lurie KG. Clinical and hemodynamic comparison of 15:2 and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation. Crit Care Med. 2006;34:1444–1449.

27. Odegaard S, Saether E, Steen PA, Wik L. Quality of lay person CPR performance with compression: ventilation ratios 15:2, 30:2 or continuous chest compressions without ventilations on manikins. Resuscitation. 2006;71:335–340.

28. Hostler D, Rittenberger JC, Roth R, Callaway CW. Increased chest compression to ventilation ratio improves delivery of CPR. Resuscitation. 2007;74:446–452.

29. Berg RA, Sanders AB, Kern KB, Hilwig RW, Heidenreich JW, Porter ME, Ewy GA. Adverse hemodynamic effects of interrupting chest compressions for rescue breathing during cardiopulmonary resuscitation for ventricular fibrillation cardiac arrest. Circulation. 2001;104:2465–2470.

30. Kern KB, Hilwig RW, Berg RA, Sanders AB, Ewy GA. Importance of continuous chest compressions during cardiopulmonary resuscitation: improved outcome during a simulated single lay-rescuer scenario. Circulation. 2002;105:645–649.

31. Ewy GA, Zuercher M, Hilwig RW, Sanders AB, Berg RA, Otto CW, Hayes MM, Kern KB. Improved neurological outcome with continuous chest compressions compared with 30:2 compressions-to-ventilations cardiopulmonary resuscitation in a realistic swine model of out-of-hospital cardiac arrest. Circulation. 2007;116:2525–2530.

32. Assar D, Chamberlain D, Colquhoun M, Donnelly P, Handley AJ, Leaves S, Kern KB. Randomised controlled trials of staged teaching for basic life support, 1: skill acquisition at bronze stage. Resuscitation. 2000;45:7–15.

33. Heidenreich JW, Sanders AB, Higdon TA, Kern KB, Berg RA, Ewy GA. Uninterrupted chest compression CPR is easier to perform and remember than standard CPR. Resuscitation. 2004;63:123–130.

34. Wik L, Kramer-Johansen J, Myklebust H, Sorebo H, Svensson L, Fellows B, Steen PA. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. JAMA. 2005;293:299–304.

35. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. JAMA. 2005;293:305–310.

36. Valenzuela TD, Kern KB, Clark LL, Berg RA, Berg MD, Berg DD, Hilwig RW, Otto CW, Newburn D, Ewy GA. Interruptions of chest compressions during emergency medical systems resuscitation. Circulation. 2005;112:1259–1265.

37. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, Hoffman P, Tynus K, Vanden Hoek TL, Becker LB. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation. 2005;111:428–434.

38. Eftestol T, Sunde K, Steen PA. Effects of interrupting precordial compressions on the calculated probability of defibrillation success during out-of-hospital cardiac arrest. Circulation. 2002;105:2270–2273.

39. Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J, Callaway CW, Bishop D, Vaillancourt C, Davis D, Aufderheide TP, Idris A, Stouffer JA, Stiell I, Berg R. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. Circulation. 2009;120:1241–1247.

40.

Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, Berg RA, Hiraide A. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet. 2010;375():1347–1354.

41. Sirbaugh PE, Pepe PE, Shook JE, Kimball KT, Goldman MJ, Ward MA, Mann DM. A prospective, population-based study of the demographics, epidemiology, management, and outcome of out-of-hospital pediatric cardiopulmonary arrest. Ann Emerg Med. 1999;33:174–184.

42. Young KD, Seidel JS. Pediatric cardiopulmonary resuscitation: a collective review. Ann Emerg Med. 1999;33:195–205.

43. Hickey RW, Cohen DM, Strausbaugh S, Dietrich AM. Pediatric patients requiring CPR in the prehospital setting. Ann Emerg Med. 1995;25:495–501.

44. Mogayzel C, Quan L, Graves JR, Tiedeman D, Fahrenbruch C, Herndon P. Out-of-hospital ventricular fibrillation in children and adolescents: causes and outcomes. Ann Emerg Med. 1995;25:484–491.

45. Appleton GO, Cummins RO, Larson MP, Graves JR. CPR and the single rescuer: at what age should you “call first” rather than “call fast”? Ann Emerg Med. 1995;25:492–494.

46. Tibballs J, Russell P. Reliability of pulse palpation by healthcare personnel to diagnose paediatric cardiac arrest. Resuscitation. 2009;80:61–64.

47. Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. Resuscitation. 1997;35:23–26.

48. Brearley S, Shearman CP, Simms MH. Peripheral pulse palpation: an unreliable physical sign. Ann R Coll Surg Engl. 1992;74:169–171.

49. Cavallaro DL, Melker RJ. Comparison of two techniques for detecting cardiac activity in infants. Crit Care Med. 1983;11:189–190.

50. Inagawa G, Morimura N, Miwa T, Okuda K, Hirata M, Hiroki K. A comparison of five techniques for detecting cardiac activity in infants. Paediatr Anaesth. 2003;13:141–146.

51. Kamlin CO, O'Donnell CP, Everest NJ, Davis PG, Morley CJ. Accuracy of clinical assessment of infant heart rate in the delivery room. Resuscitation. 2006;71:319–321.

52. Lee CJ, Bullock LJ. Determining the pulse for infant CPR: time for a change? Mil Med. 1991;156:190–193.

53. Mather C, O'Kelly S. The palpation of pulses. Anaesthesia. 1996;51:189–191.

54. Ochoa FJ, Ramalle-Gomara E, Carpintero JM, Garcia A, Saralegui I. Competence of health professionals to check the carotid pulse. Resuscitation. 1998;37:173–175.

55. Owen CJ, Wyllie JP. Determination of heart rate in the baby at birth. Resuscitation. 2004;60:213–217.

56. Sarti A, Savron F, Casotto V, Cuttini M. Heartbeat assessment in infants: a comparison of four clinical methods. Pediatr Crit Care Med. 2005;6:212–215.

57. Sarti A, Savron F, Ronfani L, Pelizzo G, Barbi E. Comparison of three sites to check the pulse and count heart rate in hypotensive infants. Paediatr Anaesth. 2006;16:394–398.

58. Tanner M, Nagy S, Peat JK. Detection of infant's heart beat/pulse by caregivers: a comparison of 4 methods. J Pediatr. 2000;137:429–430.

59. Whitelaw CC, Goldsmith LJ. Comparison of two techniques for determining the presence of a pulse in an infant. Acad Emerg Med. 1997;4:153–154.

60. Dick WF, Eberle B, Wisser G, Schneider T. The carotid pulse check revisited: what if there is no pulse? Crit Care Med. 2000;28(11 Suppl):N183–185.

61. Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. Resuscitation. 1996;33:107–116.

62. Donoghue A, Berg RA, Hazinski MF, Praestgaard AH, Roberts K, Nadkarni VM. Cardiopulmonary resuscitation for bradycardia with poor perfusion versus pulseless cardiac arrest. Pediatrics. 2009;124:1541–1548.

63. Clements F, McGowan J. Finger position for chest compressions in cardiac arrest in infants. Resuscitation. 2000;44:43–46.

64. Finholt DA, Kettrick RG, Wagner HR, Swedlow DB. The heart is under the lower third of the sternum: implications for external cardiac massage. Am J Dis Child. 1986;140:646–649.

65. Phillips GW, Zideman DA. Relation of infant heart to sternum: its significance in cardiopulmonary resuscitation. Lancet. 1986;1:1024–1025.

66. Orlowski JP. Optimum position for external cardiac compression in infants and young children. Ann Emerg Med. 1986;15:667–673.

67. Shah NM, Gaur HK. Position of heart in relation to sternum and nipple line at various ages. Indian Pediatr. 1992;29:49–53.

68. David R. Closed chest cardiac massage in the newborn infant. Pediatrics. 1988;81:552–554.

69. Todres ID, Rogers MC. Methods of external cardiac massage in the newborn infant. J Pediatr. 1975;86:781–782.

70. Menegazzi JJ, Auble TE, Nicklas KA, Hosack GM, Rack L, Goode JS. Two-thumb versus two-finger chest compression during CRP in a swine infant model of cardiac arrest. Ann Emerg Med. 1993;22:240–243.

71. Houri PK, Frank LR, Menegazzi JJ, Taylor R. A randomized, controlled trial of two-thumb vs two-finger chest compression in a swine infant model of cardiac arrest. Prehosp Emerg Care. 1997;1:65–67.

72. Dorfsman ML, Menegazzi JJ, Wadas RJ, Auble TE. Two-thumb vs two-finger chest compression in an infant model of prolonged cardiopulmonary resuscitation. Acad Emerg Med. 2000;7:1077–1082.

73. Whitelaw CC, Slywka B, Goldsmith LJ. Comparison of a two-finger versus two-thumb method for chest compressions by healthcare providers in an infant mechanical model. Resuscitation. 2000;43:213–216.

74. Thaler MM, Stobie GH. An improved technique of external caridac compression in infants and young children. N Engl J Med. 1963;269:606–610.

75. Ishimine P, Menegazzi J, Weinstein D. Evaluation of two-thumb chest compression with thoracic squeeze in a swine model of infant cardiac arrest. Acad Emerg Med. 1998;5:397.

76. Atkins DL, Jorgenson DB. Attenuated pediatric electrode pads for automated external defibrillator use in children. Resuscitation. 2005;66:31–37.

77. Nadkarni VM, Larkin GL, Peberdy MA, Carey SM, Kaye W, Mancini ME, Nichol G, Lane-Truitt T, Potts J, Ornato JP, Berg RA. First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. JAMA. 2006;295:50–57.

78. Samson RA, Nadkarni VM, Meaney PA, Carey SM, Berg MD, Berg RA. Outcomes of in-hospital ventricular fibrillation in children. N Engl J Med. 2006;354:2328–2339.

79. Atkinson E, Mikysa B, Conway JA, Parker M, Christian K, Deshpande J, Knilans TK, Smith J, Walker C, Stickney RE, Hampton DR, Hazinski MF. Specificity and sensitivity of automated external defibrillator rhythm analysis in infants and children. Ann Emerg Med. 2003;42:185–196.

80. Cecchin F, Jorgenson DB, Berul CI, Perry JC, Zimmerman AA, Duncan BW, Lupinetti FM, Snyder D, Lyster TD, Rosenthal GL, Cross B, Atkins DL. Is arrhythmia detection by automatic external defibrillator accurate for children? Sensitivity and specificity of an automatic external defibrillator algorithm in 696 pediatric arrhythmias. Circulation. 2001;103:2483–2488.

81. Atkins DL, Scott WA, Blaufox AD, Law IH, Dick M II., Geheb F, Sobh J, Brewer JE. Sensitivity and specificity of an automated external defibrillator algorithm designed for pediatric patients. Resuscitation. 2008;76:168–174.

82. Bar-Cohen Y, Walsh EP, Love BA, Cecchin F. First appropriate use of automated external defibrillator in an infant. Resuscitation. 2005;67:135–137.

83. Konig B, Benger J, Goldsworthy L. Automatic external defibrillation in a 6 year old. Arch Dis Child. 2005;90:310–311.

84. Ornato JP, Hallagan LF, McMahan SB, Peeples EH, Rostafinski AG. Attitudes of BCLS instructors about mouth-to-mouth resuscitation during the AIDS epidemic. Ann Emerg Med. 1990;19:151–156.

85. Brenner BE, Van DC, Cheng D, Lazar EJ. Determinants of reluctance to perform CPR among residents and applicants: the impact of experience on helping behavior. Resuscitation. 1997;35:203–211.

86. Hew P, Brenner B, Kaufman J. Reluctance of paramedics and emergency medical technicians to perform mouth-to-mouth resuscitation. J Emerg Med. 1997;15:279–284.

87. Locke CJ, Berg RA, Sanders AB, Davis MF, Milander MM, Kern KB, Ewy GA. Bystander cardiopulmonary resuscitation. Concerns about mouth-to-mouth contact. Arch Intern Med. 1995;155:938–943.

88. Shibata K, Taniguchi T, Yoshida M, Yamamoto K. Obstacles to bystander cardiopulmonary resuscitation in Japan. Resuscitation. 2000;44:187–193.

89. Terndrup TE, Warner DA. Infant ventilation and oxygenation by basic life support providers: comparison of methods. Prehospital Disaster Med. 1992;7:35–40.

90. Hess D, Ness C, Oppel A, Rhoads K. Evaluation of mouth-to-mask ventilation devices. Respir Care. 1989;34:191–195.

91.

Terndrup TE, Kanter RK, Cherry RA. A comparison of infant ventilation methods performed by prehospital personnel. Ann Emerg Med. 1989;18:607–611.

92. Field D, Milner AD, Hopkin IE. Efficiency of manual resuscitators at birth. Arch Dis Child. 1986;61:300–302.
93. Finer NN, Barrington KJ, Al-Fadley F, Peters KL. Limitations of self-inflating resuscitators. Pediatrics. 1986;77:417–420.
94. Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. Arch Intern Med. 1992;152:145–149.
95. Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004;109:1960–1965.
96. Hirschman AM, Kravath RE. Venting vs ventilating. A danger of manual resuscitation bags. Chest. 1982;82:369–370.
97. Davidovic L, LaCovey D, Pitetti RD. Comparison of 1- versus 2-person bag-valve-mask techniques for manikin ventilation of infants and children. Ann Emerg Med. 2005;46:37–42.
98. Berg MD, Idris AH, Berg RA. Severe ventilatory compromise due to gastric distention during pediatric cardiopulmonary resuscitation. Resuscitation. 1998;36:71–73.
99. Gausche M, Lewis RJ, Stratton SJ, Haynes BE, Gunter CS, Goodrich SM, Poore PD, McCollough MD, Henderson DP, Pratt FD, Seidel JS. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. JAMA. 2000;283:783–790.
100. Moynihan RJ, Brock-Utne JG, Archer JH, Feld LH, Kreitzman TR. The effect of cricoid pressure on preventing gastric insufflation in infants and children. Anesthesiology. 1993;78:652–656.
101. Salem MR, Wong AY, Mani M, Sellick BA. Efficacy of cricoid pressure in preventing gastric inflation during bag- mask ventilation in pediatric patients. Anesthesiology. 1974;40:96–98.
102. Sellick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anaesthesia. Lancet. 1961;2:404–406.
103. Hartsilver EL, Vanner RG. Airway obstruction with cricoid pressure. Anaesthesia. 2000;55:208–211.
104. Lipinski CA, Hicks SD, Callaway CW. Normoxic ventilation during resuscitation and outcome from asphyxial cardiac arrest in rats. Resuscitation. 1999;42:221–229.
105. Liu Y, Rosenthal RE, Haywood Y, Miljkovic-Lolic M, Vanderhoek JY, Fiskum G. Normoxic ventilation after cardiac arrest reduces oxidation of brain lipids and improves neurological outcome. Stroke. 1998;29:1679–1686.
106. Lefkowitz W. Oxygen and resuscitation: beyond the myth. Pediatrics. 2002;109:517–519.
107. Zwemer CF, Whitesall SE, D'Alecy LG. Cardiopulmonary-cerebral resuscitation with 100% oxygen exacerbates neurological dysfunction following nine minutes of normothermic cardiac arrest in dogs. Resuscitation. 1994;27:159–170.
108. Balan IS, Fiskum G, Hazelton J, Cotto-Cumba C, Rosenthal RE. Oximetry-guided reoxygenation improves neurological outcome after experimental cardiac arrest. Stroke. 2006;37:3008–3013.
109. Marsala J, Marsala M, Vanicky I, Galik J, Orendacova J. Post cardiac arrest hyperoxic resuscitation enhances neuronal vulnerability of the respiratory rhythm generator and some brainstem and spinal cord neuronal pools in the dog. Neurosci Lett. 1992;146:121–124.
110. Richards EM, Rosenthal RE, Kristian T, Fiskum G. Postischemic hyperoxia reduces hippocampal pyruvate dehydrogenase activity. Free Radic Biol Med. 2006;40:1960–1970.
111. Richards EM, Fiskum G, Rosenthal RE, Hopkins I, McKenna MC. Hyperoxic reperfusion after global ischemia decreases hippocampal energy metabolism. Stroke. 2007;38:1578–1584.
112. Vereczki V, Martin E, Rosenthal RE, Hof PR, Hoffman GE, Fiskum G. Normoxic resuscitation after cardiac arrest protects against hippocampal oxidative stress, metabolic dysfunction, and neuronal death. J Cereb Blood Flow Metab. 2006;26:821–835.
113. Feet BA, Yu XQ, Rootwelt T, Oyasaeter S, Saugstad OD. Effects of hypoxemia and reoxygenation with 21% or 100% oxygen in newborn piglets: extracellular hypoxanthine in cerebral cortex and femoral muscle. Crit Care Med. 1997;25:1384–1391.
114. Finer NN, Bates R, Tomat P. Low flow oxygen delivery via nasal cannula to neonates. Pediatr Pulmonol. 1996;21:48–51.
115. Vilke GM, Smith AM, Ray LU, Steen PJ, Murrin PA, Chan TC. Airway obstruction in children aged less than 5 years: the prehospital experience. Prehosp Emerg Care. 2004;8:196–199.
116. Morley RE, Ludemann JP, Moxham JP, Kozak FK, Riding KH. Foreign body aspiration in infants and toddlers: recent trends in British Columbia. J Otolaryngol. 2004;33:37–41.

117. Harris CS, Baker SP, Smith GA, Harris RM. Childhood asphyxiation by food. A national analysis and overview. JAMA. 1984;251:2231–2235.

118. Rimell FL, Thome AJ, Stool S, Reilly JS, Rider G, Stool D, Wilson CL. Characteristics of objects that cause choking in children. JAMA. 1995;274:1763–1766.

119. Prevention of choking among children. Pediatrics. 2010;125:601–607.

120. Heimlich HJ. A life-saving maneuver to prevent food-choking. JAMA. 1975;234:398–401.

121. Sternbach G, Kiskaddon RT. Henry Heimlich: a life-saving maneuver for food choking. J Emerg Med. 1985;3:143–148.

122. Langhelle A, Sunde K, Wik L, Steen PA. Airway pressure with chest compressions versus Heimlich manoeuvre in recently dead adults with complete airway obstruction. Resuscitation. 2000;44:105–108.

123. Redding JS. The choking controversy: critique of evidence on the Heimlich maneuver. Crit Care Med. 1979;7:475–479.

124. Guildner CW, Williams D, Subitch T. Airway obstructed by foreign material: the Heimlich maneuver. JACEP. 1976;5:675–677.

125. Kabbani M, Goodwin SR. Traumatic epiglottis following blind finger sweep to remove a pharyngeal foreign body. Clin Pediatr (Phila). 1995;34:495–497.

126. Hartrey R, Bingham RM. Pharyngeal trauma as a result of blind finger sweeps in the choking child. J Accid Emerg Med. 1995;12:52–54.

127. Gjoni D, Mbamalu D, Banerjee A, James K. An unusual complication of an attempt to open the airway in a choking child. Br J Hosp Med (Lond). 2009;70:595.

128. Spaite DW, Conroy C, Tibbitts M, Karriker KJ, Seng M, Battaglia N, Criss EA, Valenzuela TD, Meislin HW. Use of emergency medical services by children with special health care needs. Prehosp Emerg Care. 2000;4:19–23.

129. Schultz-Grant LD, Young-Cureton V, Kataoka-Yahiro M. Advance directives and do not resuscitate orders: nurses' knowledge and the level of practice in school settings. J Sch Nurs. 1998;14:4–10, 12–13.

130. Policy statement–emergency information forms and emergency preparedness for children with special health care needs. Pediatrics. 2010;125:829–837.

131. Herzenberg JE, Hensinger RN, Dedrick DK, Phillips WA. Emergency transport and positioning of young children who have an injury of the cervical spine. The standard backboard may be hazardous. J Bone Joint Surg Am. 1989;71:15–22.

132. Nypaver M, Treloar D. Neutral cervical spine positioning in children. Ann Emerg Med. 1994;23:208–211.

133. Kyriacou DN, Arcinue EL, Peek C, Kraus JF. Effect of immediate resuscitation on children with submersion injury. Pediatrics. 1994;94():137–142.

134. Suominen P, Baillie C, Korpela R, Rautanen S, Ranta S, Olkkola KT. Impact of age, submersion time and water temperature on outcome in near-drowning. Resuscitation. 2002;52:247–254.

135. Graf WD, Cummings P, Quan L, Brutocao D. Predicting outcome in pediatric submersion victims. Ann Emerg Med. 1995;26:312–319.

136. Modell JH, Idris AH, Pineda JA, Silverstein JH. Survival after prolonged submersion in freshwater in Florida. Chest. 2004;125:1948–1951.

137. Mehta SR, Srinivasan KV, Bindra MS, Kumar MR, Lahiri AK. Near drowning in cold water. J Assoc Physicians India. 2000;48:674–676.

138. Szpilman D, Soares M. In-water resuscitation–is it worthwhile? Resuscitation. 2004;63:25–31.

139. Berg RA, Hilwig RW, Kern KB, Babar I, Ewy GA. Simulated mouth- to-mouth ventilation and chest compressions (bystander cardiopulmonary resuscitation) improves outcome in a swine model of prehospital pediatric asphyxial cardiac arrest. Crit Care Med. 1999;27:1893–1899.

140. Yannopoulos D, Matsuura T, McKnite S, Goodman N, Idris A, Tang W, Aufderheide TP, Lurie KG. No assisted ventilation cardiopulmonary resusci- tation and 24-hour neurological outcomes in a porcine model of cardiac arrest. Crit Care Med. 2010;38:254–260. doi: 10.1097/CCM.0b013e3181b42f6c.

141. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, Berg RA, Hiraide A; implementation working group for All-Japan Utstein Registry of the Fire and Disaster Management Agency. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet. 2010;375:1347–1354. doi: 10.1016/ S0140-6736(10)60064-5.

142.

Goto Y, Maeda T, Goto Y. Impact of dispatcher-assisted bystander cardio- pulmonary resuscitation on neurological outcomes in children with out-of- hospital cardiac arrests: a prospective, nationwide, population-based cohort study. J Am Heart Assoc. 2014;3:e000499. doi: 10.1161/JAHA.113.000499.

143. Marsch S, Tschan F, Semmer NK, Zobrist R, Hunziker PR, Hunziker S. ABC versus CAB for cardiopulmonary resuscitation: a prospective, random- ized simulator-based trial. Swiss Med Wkly. 2013;143:w13856. doi: 10.4414/ smw.2013.13856.

144. SekiguchiH,KondoY,KukitaI.Verificationofchangesinthetimetakento initiate chest compressions according to modified basic life support guidelines. Am J Emerg Med. 2013;31:1248–1250. doi: 10.1016/j.ajem.2013.02.047.

145. Lubrano R, Cecchetti C, Bellelli E, Gentile I, Loayza Levano H, Orsini F, Bertazzoni G, Messi G, Rugolotto S, Pirozzi N, Elli M. Comparison of times of intervention during pediatric CPR maneuvers using ABC and CAB sequences: a randomized trial. Resuscitation. 2012;83:1473–1477. doi: 10.1016/j.resuscitation.2012.04.011.

146. Sutton RM, Wolfe H, Nishisaki A, Leffelman J, Niles D, Meaney PA, Donoghue A, Maltese MR, Berg RA, Nadkarni VM. Pushing harder, pushing faster, minimizing interruptions... but falling short of 2010 cardiopulmonary resuscitation targets during in-hospital pediatric and adolescent resuscitation. Resuscitation. 2013;84:1680–1684. doi: 10.1016/j.resuscitation.2013.07.029.

147. Kleinman ME, Brennan EE, Goldberger ZD, Swor RA, Terry M, Bobrow BJ, Gazmuri RJ, Travers AH, Rea T. Part 5: adult basic life support and cardiopulmonary resuscitation quality: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2015;132(suppl 2):S000–S000.

148. Maher KO, Berg RA, Lindsey CW, Simsic J, Mahle WT. Depth of sternal compression and intra-arterial blood pressure during CPR in infants fol- lowing cardiac surgery. Resuscitation. 2009;80:662–664. doi: 10.1016/j. resuscitation.2009.03.016.

149. Sutton RM, French B, Niles DE, Donoghue A, Topjian AA, Nishisaki A, Leffelman J, Wolfe H, Berg RA, Nadkarni VM, Meaney PA. 2010 American Heart Association recommended compression depths during pediatric in-hospital resuscitations are associated with survival. Resuscitation. 2014;85:1179–1184. doi: 10.1016/j.resuscitation.2014.05.007.

150. Sutton RM, Niles D, Nysaether J, Abella BS, Arbogast KB, Nishisaki A, Maltese MR, Donoghue A, Bishnoi R, Helfaer MA, Myklebust H, Nadkarni V. Quantitative analysis of CPR quality during in-hospital resuscitation of older children and adolescents. Pediatrics. 2009;124:494–499.

151. Nishisaki A, Nysaether J, Sutton R, Maltese M, Niles D, Donoghue A, Bishnoi R, Helfaer M, Perkins GD, Berg R, Arbogast K, Nadkarni V. Effect of mattress deflection on CPR quality assessment for older children and adolescents. Resuscitation. 2009;80:540–545.

152. Noordergraaf GJ, Paulussen IW, Venema A, van Berkom PF, Woerlee PH, Scheffer GJ, Noordergraaf A. The impact of compliant surfaces on in-hospital chest compressions: effects of common mattresses and a backboard. Resuscitation. 2009;80:546–552.

153. Stevenson AG, McGowan J, Evans AL, Graham CA. CPR for children: one hand or two? Resuscitation. 2005;64:205–208.

154. Peska E, Kelly AM, Kerr D, Green D. One-handed versus two-handed chest compressions in paediatric cardio-pulmonary resuscitation. Resuscitation. 2006;71:65–69.

155. Aufderheide TP, Pirrallo RG, Yannopoulos D, Klein JP, von Briesen C, Sparks CW, Deja KA, Conrad CJ, Kitscha DJ, Provo TA, Lurie KG. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. Resuscitation. 2005;64:353–362.

156. Yannopoulos D, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, Lurie KG. Effects of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2005;64:363–372.

157. Zuercher M, Hilwig RW, Ranger-Moore J, Nysaether J, Nadkarni VM, Berg MD, Kern KB, Sutton R, Berg RA. Leaning during chest compressions impairs cardiac output and left ventricular myocardial blood flow in piglet cardiac arrest. Crit Care Med. 2010;38:1141–1146.

158. Sutton RM, Maltese MR, Niles D, French B, Nishisaki A, Arbogast KB, Donoghue A, Berg RA, Helfaer MA, Nadkarni V. Quantitative analysis of chest compression interruptions during in-hospital resuscitation of older children and adolescents. Resuscitation. 2009;80:1259–1263.

159. Niles D, Nysaether J, Sutton R, Nishisaki A, Abella BS, Arbogast K, Maltese MR, Berg RA, Helfaer M, Nadkarni V. Leaning is common during in-hospital pediatric CPR, and decreased with automated corrective feedback. Resuscitation. 2009;80:553–557.

160. Aufderheide TP, Pirrallo RG, Yannopoulos D, Klein JP, von Briesen C, Sparks CW, Deja KA, Kitscha DJ, Provo TA, Lurie KG. Incomplete chest wall decompression: A clinical evaluation of CPR performance by trained laypersons and an assessment of alternative manual chest compression-decompression techniques. Resuscitation. 2006;71:341–351.

161. Ashton A, McCluskey A, Gwinnutt CL, Keenan AM. Effect of rescuer fatigue on performance of continuous external chest compressions over 3 min. Resuscitation. 2002;55:151–155.

162. Ochoa FJ, Ramalle-Gomara E, Lisa V, Saralegui I. The effect of rescuer fatigue on the quality of chest compressions. Resuscitation. 1998;37:149–152.

163. Hightower D, Thomas SH, Stone CK, Dunn K, March JA. Decay in quality of closed-chest compressions over time. Ann Emerg Med. 1995;26:300–303.

Part 12: Pediatric Advanced Life Support

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: arrhythmia cardiopulmonary resuscitation pediatrics

1 Highlights & Introduction

1.1 Highlights

Summary of Key Issues and Major Changes

Many key issues in the review of the pediatric advanced life support literature resulted in refinement of existing recommendations rather than in new recommendations. New information or updates are provided about fluid resuscitation in febrile illness, atropine use before tracheal intubation, use of amiodarone and lidocaine in shock-refractory VF/pVT, TTM after resuscitation from cardiac arrest in infants and children, and post–cardiac arrest management of blood pressure.

- In specific settings, when treating pediatric patients with febrile illnesses, the use of restrictive volumes of isotonic crystalloid leads to improved survival. This contrasts with traditional thinking that routine aggressive volume resuscitation is beneficial.
- Routine use of atropine as a premedication for emergency tracheal intubation in non-neonates, specifically to prevent arrhythmias, is controversial. Also, there are data to suggest that there is no minimum dose required for atropine for this indication.
- If invasive arterial blood pressure monitoring is already in place, it may be used to adjust CPR to achieve specific blood pressure targets for children in cardiac arrest.
- Amiodarone *or* lidocaine is an acceptable antiarrhythmic agent for shock-refractory pediatric VF and pVT in children.
- Epinephrine continues to be recommended as a vasopressor in pediatric cardiac arrest.
- For pediatric patients with cardiac diagnoses and IHCA in settings with existing extracorporeal membrane oxygenation protocols, ECPR may be considered.
- Fever should be avoided when caring for comatose children with ROSC after OHCA. A large randomized trial of therapeutic hypothermia for children with OHCA showed no difference in outcomes whether a period of moderate therapeutic hypothermia (with temperature maintained at 32°C to 34°C) or the strict maintenance of normothermia (with temperature maintained 36°C to 37.5°C) was provided.
- Several intra-arrest and post–cardiac arrest clinical variables were examined for prognostic significance. No single variable was identified to be sufficiently reliable to predict outcomes. Therefore, caretakers should consider multiple factors in trying to predict outcomes during cardiac arrest and in the post-ROSC setting.
- After ROSC, fluids and vasoactive infusions should be used to maintain a systolic blood pressure above the fifth percentile for age.
- After ROSC, normoxemia should be targeted. When the necessary equipment is available, oxygen administration should be weaned to target an oxyhemoglobin saturation of 94% to 99%. Hypoxemia should be strictly avoided. Ideally, oxygen should be titrated to a value appropriate to the specific patient condition. Likewise, after ROSC, the child's $Paco_2$ should be targeted to a level appropriate to each patient's condition. Exposure to severe hypercapnia or hypocapnia should be avoided.

Recommendations for Fluid Resuscitation

2015 (New): Early, rapid IV administration of isotonic fluids is widely accepted as a cornerstone of therapy for septic shock. Recently, a large randomized controlled trial of fluid resuscitation conducted in children with severe febrile illnesses in a resource-limited setting found worse outcomes to be associated with IV fluid boluses. For children in shock, an initial fluid bolus of 20 mL/kg is reasonable. However, for children with febrile illness in settings with limited access to critical care resources (ie, mechanical ventilation and inotropic support), administration of bolus IV fluids should be undertaken with extreme caution, as it may be harmful. Individualized

treatment and frequent clinical reassessment are emphasized.

Why: This recommendation continues to emphasize the administration of IV fluid for children with septic shock. Additionally, it emphasizes individualized treatment plans for each patient, based on frequent clinical assessment before, during, and after fluid therapy is given, and it presumes the availability of other critical care therapies. In certain resource-limited settings, excessive fluid boluses given to febrile children may lead to complications where the appropriate equipment and expertise might not be present to effectively address them.

Atropine for Endotracheal Intubation

2015 (Updated): There is no evidence to support the *routine* use of atropine as a premedication to prevent bradycardia in emergency pediatric intubations. It may be considered in situations where there is an increased risk of bradycardia. There is no evidence to support a minimum dose of atropine when used as a premedication for emergency intubation.

2010 (Old): A minimum atropine dose of 0.1 mg IV was recommended because of reports of paradoxical bradycardia occurring in very small infants who received low doses of atropine.

Why: Recent evidence is conflicting as to whether atropine prevents bradycardia and other arrhythmias during emergency intubation in children. However, these recent studies did use atropine doses less than 0.1 mg without an increase in the likelihood of arrhythmias.

Invasive Hemodynamic Monitoring During CPR

2015 (Updated): If invasive hemodynamic monitoring is in place at the time of a cardiac arrest in a child, it may be reasonable to use it to guide CPR quality.

2010 (Old): If the patient has an indwelling arterial catheter, the waveform can be used as feedback to evaluate hand position and chest compression depth. Compressing to a specific systolic blood pressure target has not been studied in humans but may improve outcomes in animals.

Why: Two randomized controlled trials in animals found improvements in ROSC and survival to completion of the experiment when CPR technique was adjusted on the basis of invasive hemodynamic monitoring. This has yet to be studied in humans.

Antiarrhythmic Medications for Shock-Refractory VF or Pulseless VT

2015 (Updated): Amiodarone or lidocaine is equally acceptable for the treatment of shock refractory VF or pVT in children.

2010 (Old): Amiodarone was recommended for shock-refractory VF or pVT. Lidocaine can be given if amiodarone is not available.

Why: A recent, retrospective, multi-institution registry of in-patient pediatric cardiac arrest showed that, compared with amiodarone, lidocaine was associated with higher rates of ROSC and 24-hour survival. However, neither lidocaine nor amiodarone administration was associated with improved survival to hospital discharge.

Vasopressors for Resuscitation

2015 (Updated): It is reasonable to give epinephrine during cardiac arrest.

2010 (Old): Epinephrine should be given for pulseless cardiac arrest.

Why: The recommendation about epinephrine administration during cardiac arrest was downgraded slightly in Class of Recommendation. There are no high-quality pediatric studies showing the effectiveness of any vasopressors in cardiac arrest. Two pediatric observational studies were inconclusive, and 1 randomized, out-of-hospital adult study found that epinephrine was associated with improved ROSC and survival to hospital admission but not to hospital discharge.

ECPR Compared With Standard Resuscitation

2015 (Updated): ECPR may be considered for children with underlying cardiac conditions who have an IHCA,

provided appropriate protocols, expertise, and equipment are available.

2010 (Old): Consider early activation of extracorporeal life support for a cardiac arrest that occurs in a highly supervised environment, such as an intensive care unit, with the clinical protocols in place and the expertise and equipment available to initiate it rapidly. Extracorporeal life support should be considered only for children in cardiac arrest refractory to standard resuscitation attempts, with a potentially reversible cause of arrest.

Why: OHCA in children was not considered. For pediatric IHCA, there was no difference in overall survival comparing ECPR to CPR without extracorporeal membrane oxygenation. One retrospective registry review showed better outcome with ECPR for patients with cardiac disease than for those with noncardiac disease.

Targeted Temperature Management

2015 (Updated): For children who are comatose in the first several days after cardiac arrest (in-hospital or out-ofhospital), temperature should be monitored continuously and fever should be treated aggressively.

For comatose children resuscitated from OHCA, it is reasonable for caretakers to maintain either 5 days of normothermia (36°C to 37.5°C) or 2 days of initial continuous hypothermia (32°C to 34°C) followed by 3 days of normothermia.

For children remaining comatose after IHCA, there are insufficient data to recommend hypothermia over normothermia.

2010 (Old): Therapeutic hypothermia (32°C to 34°C) may be considered for children who remain comatose after resuscitation from cardiac arrest. It is reasonable for adolescents resuscitated from witnessed out-of-hospital VF arrest.

Why: A prospective, multicenter study of pediatric OHCA victims randomized to receive either therapeutic hypothermia (32°C to 34°C) or normothermia (36°C to 37.5°C) showed no difference in functional outcome at 1 year between the 2 groups. This and other observational studies demonstrated no additional complications in the group treated with therapeutic hypothermia. Results are currently pending from a large, multicenter, randomized controlled trial of therapeutic hypothermia for patients who are comatose after ROSC following pediatric IHCA (see Therapeutic Hypothermia After Pediatric Cardiac Arrest website: www.THAPCA.org.

Intra-arrest and Postarrest Prognostic Factors

2015 (Updated): Multiple factors should be considered when trying to predict outcomes of cardiac arrest. Multiple factors play a role in the decision to continue or terminate resuscitative efforts during cardiac arrest and in the estimation of potential for recovery after cardiac arrest.

2010 (Old): Practitioners should consider multiple variables to prognosticate outcomes and use judgment to titrate efforts appropriately.

Why: No single intra-arrest or post–cardiac arrest variable has been found that reliably predicts favorable or poor outcomes

Post–Cardiac Arrest Fluids and Inotropes

2015 (New): After ROSC, fluids and inotropes/vasopressors should be used to maintain a systolic blood pressure above the fifth percentile for age. Intra-arterial pressure monitoring should be used to continuously monitor blood pressure and identify and treat hypotension.

Why: No studies were identified that evaluated specific vasoactive agents in post-ROSC pediatric patients. Recent observational studies found that children who had post-ROSC hypotension had worse survival to hospital discharge and worse neurologic outcome.

Post–Cardiac Arrest Pao_2 and $Paco_2$

2015 (Updated): After ROSC in children, it may be reasonable for rescuers to titrate oxygen administration to achieve normoxemia (oxyhemoglobin saturation of 94% or above). When the requisite equipment is available, oxygen should be weaned to target an oxyhemoglobin saturation within the range of 94% to 99%. The goal should be to strictly avoid hypoxemia while maintaining normoxemia. Likewise, post-ROSC ventilation strategies

in children should target a $PaCO_2$ that is appropriate for each patient while avoiding extremes of hypercapnia or hypocapnia.

2010 (Old): Once circulation is restored, if appropriate equipment is in place, it may be reasonable to wean the fraction of inspired oxygen to maintain an oxyhemoglobin saturation of 94% or greater. No recommendations were made about $PaCO_2$.

Why: A large observational pediatric study of IHCA and OHCA found that normoxemia (defined as PaO_2 60 to 300 mm Hg) was associated with improved survival to pediatric intensive care unit discharge, compared with hyperoxemia (PaO_2 greater than 300 mm Hg). Adult and animal studies show increased mortality associated with hyperoxemia. Likewise, adult studies after ROSC demonstrate worse patient outcomes associated with hypocapnia.

1.2 Introduction - Updated

These *Web-based Integrated Guidelines* incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

Over the past 13 years, survival to discharge from pediatric inhospital cardiac arrest (IHCA) has markedly improved. From 2001 to 2013, rates of return of spontaneous circulation (ROSC) from IHCA increased significantly from 39% to 77%, and survival to hospital discharge improved from 24% to 36% to 43% (Girotra et al and personal communication with Paul Chan, MD, MSc, April 3, 2015). In a single center, implementation of an intensive care unit (ICU)–based interdisciplinary debriefing program improved survival with favorable neurologic outcome from 29% to 50%.[1] Furthermore, new data show that prolonged cardiopulmonary resuscitation (CPR) is not futile: 12% of patients receiving CPR in IHCA for more than 35 minutes survived to discharge, and 60% of the survivors had a favorable neurologic outcome.[2] This improvement in survival rate from IHCA can be attributed to multiple factors, including emphasis on high-quality CPR and advances in post-resuscitation care. Over the past decade, the percent of cardiac arrests occurring in an ICU setting has increased (87% to 91% in 2000 to 2003 to 94% to 96% in 2004 to 2010).[3] While rates of survival from pulseless electrical activity and asystole have increased, there has been no change in survival rates from in-hospital ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT).

Conversely, survival from out-of-hospital cardiac arrest (OHCA) has not improved as dramatically over the past 5 years. Data from 11 US and Canadian hospital emergency medical service systems (the Resuscitation Outcomes Consortium) during 2005 to 2007 showed age-dependent discharge survival rates of 3.3% for infants (less than 1 year), 9.1% for children (1 to 11 years), and 8.9% for adolescents (12 to 19 years).[4] More recently published data (through 2012) from this network demonstrate 8.3% survival to hospital discharge across all age groups, with 10.5% survival for children aged 1 to 11 years and 15.8% survival for adolescents aged 12 to 18 years.[5]

2 Evidence Evaluation Process Informing The Guidelines Update - Updated

The American Heart Association (AHA) Emergency Cardiovascular Care (ECC) Committee uses a rigorous process to review and analyze the peer-reviewed published scientific evidence supporting the AHA Guidelines for CPR and ECC, including this update. In 2000, the AHA began collaborating with other resuscitation councils throughout the world, via the International Liaison Committee on Resuscitation (ILCOR), in a formal international process to evaluate resuscitation science. This process resulted in the publication of the International Consensus on CPR and ECC Science With Treatment Recommendations (CoSTR) in 2005 and 2010 [6,7] These publications provided the scientific support for AHA Guidelines revisions in those years.

In 2011, the AHA created an online evidence review process, the Scientific Evidence Evaluation and Review System (SEERS), to support ILCOR systematic reviews for 2015 and beyond. This new process includes the use of Grading of Recommendations Assessment, Development, and Evaluation (GRADE) software to create systematic reviews that will be available online and used by resuscitation councils to develop their guidelines for CPR and ECC. The drafts of the online reviews were posted for public comment, and ongoing reviews will be accessible to the public (https://volunteer.heart.org/ apps/pico/Pages/default.aspx).

The AHA process for identification and management of potential conflicts of interest was used, and potential conflicts for writing group members are listed at the end of each Part of the *2015 AHA Guidelines Update for CPR and ECC*. For additional information about this systematic review or management of the potential conflicts of interest, see “Part 2: Evidence Evaluation and Management of Conflicts of Interest” in this supplement and the

related article "Part 2: Evidence Evaluation and Management of Conflict of Interest" in the 2015 CoSTR publication.[8,9]

This update to the *2010 AHA Guidelines for CPR and ECC* for pediatric advanced life support (PALS) targets key questions related to pediatric resuscitation. Areas of update were selected by a group of international pediatric resuscitation experts from ILCOR, and the questions encompass resuscitation topics in prearrest care, intra-arrest care, and postresuscitation care. The ILCOR Pediatric Life Support Task Force experts reviewed the topics addressed in the 2010 Guidelines for PALS and, based on in-depth knowledge of new research developments, formulated 18 questions for further systematic evaluation.[10] Three questions that address pediatric basic life support appear in "Part 11: Pediatric Basic Life Support and Cardiopulmonary Resuscitation Quality."

Beginning with the publication of the 2015 CoSTR, the ILCOR evidence evaluation process will be continuous, rather than "batched" into 5-year cycles. The goal of this continuous evidence review is to improve survival from cardiac arrest by shortening the time between resuscitation science discoveries and their application in resuscitation practice. As additional resuscitation topics are prioritized and reviewed, these Guidelines may be updated again. When the evidence supports sufficient changes to the Guidelines or a change in sequence or treatments that must be woven throughout the Guidelines, then the Guidelines will be revised completely.

Because the *2015 AHA Guidelines Update for CPR and ECC* represents the first update to the previous Guidelines, recommendations from both this 2015 Guidelines Update and the 2010 Guidelines are contained in the Appendix. If the 2015 ILCOR review resulted in a new or significantly revised Guidelines recommendation, that recommendation will be labeled as *New or Updated*.

As with all AHA Guidelines, each 2015 recommendation is labeled with a Class of Recommendation (COR) and a Level of Evidence (LOE). This update uses the newest AHA COR and LOE classification system, which contains modifications of the Class III recommendation and introduces LOE B-R (randomized studies) and B-NR (nonrandomized studies) as well as LOE C-LD (limited data) and LOE C-EO (consensus of expert opinion).

These PALS recommendations are informed by the rigorous systematic review and consensus recommendations of the ILCOR Pediatric Task Force, and readers are referred to the complete consensus document in the 2015 CoSTR.[11,12] In the online version of this document, live links are provided so the reader can connect directly to the systematic reviews on the SEERS website. These links are indicated by a superscript combination of letters and numbers (eg, Peds 397). We encourage readers to use the links and review the evidence and appendixes, including the GRADE tables.

The 2015 Guidelines Update for PALS includes science review in the following subjects:

Prearrest Care

• Effectiveness of **medical emergency teams or rapid response teams** to improve outcomes

• Effectiveness of a **pediatric early warning score (PEWS)** to improve outcomes

• **Restrictive volume of isotonic crystalloid** for resuscitation from septic shock

• **Use of atropine as a premedication** in infants and children requiring emergency tracheal intubation

• Treatment for infants and children with **myocarditis or dilated cardiomyopathy and impending cardiac arrest**

Intra-arrest Care

• Effectiveness of **extracorporeal membrane oxygenation (ECMO) resuscitation** compared to standard resuscitation without ECMO

• Targeting a **specific end-tidal CO_2 ($ETCO_2$) threshold** to improve chest compression technique

• Reliability of **intra-arrest prognostic factors** to predict outcome

• Use of **invasive hemodynamic monitoring during CPR** to titrate to a specific systolic/diastolic blood pressure to improve outcomes

• Effectiveness of NO **vasopressor** compared with ANY vasopressors for resuscitation from cardiac arrest

• Use of amiodarone compared with **lidocaine** for **shockrefractory VF or pVT**

• Optimal **energy dose** for **defibrillation**

Postarrest Care

• Use of **targeted temperature management** to improve outcomes

• Use of a **targeted Pao_2 strategy** to improve outcomes

• Use of a **specific $Paco_2$ target** to improve outcomes

• Use of **parenteral fluids and inotropes and/or vasopressors** to maintain targeted measures of perfusion such as blood pressure to improve outcomes

• Use of **electroencephalograms (EEGs)** to accurately predict outcomes

• Use of any **specific post–cardiac arrest factors** to accurately predict outcomes

As noted above, these Web-based Integrated Guidelines incorporate all the recommendations from both 2010 Guidelines and the 2015 Guidelines Update.

3 Prearrest Care - Updated

3.1 Medical Emergency Team/Rapid Response Team - Updated PEDS 397

Medical emergency team or rapid response team activation by caregivers or parents ideally occurs as a response to changes noted in a patient's condition and may prevent cardiac or respiratory arrest. Several variables, including the composition of the team, the type of patient, the hospital setting, and the confounder of a wider "system benefit," further complicate objective analyses.

3.1.1 2015 Evidence Summary

Observational data have been contradictory and have not consistently shown a decreased incidence of cardiac and/or respiratory arrest outside of the ICU setting.[13-15] The data addressing effects on hospital mortality were inconclusive.[15-20]

3.1.2 2015 Recommendation—Updated

Pediatric medical emergency team/rapid response team systems may be considered in facilities where children with high-risk illnesses are cared for on general in-patient units. (Class IIb, LOE C-LD)

3.2 Pediatric Early Warning Scores - Updated PEDS 818

In-hospital pediatric cardiac or respiratory arrest can potentially be averted by early recognition of and intervention for the deteriorating patient. The use of scoring systems might help to identify such patients sufficiently early so as to enable effective intervention.

3.2.1 2015 Evidence Summary

There is no evidence that the use of PEWS outside of the pediatric ICU setting reduces hospital mortality. In 1 observational study, PEWS use was associated with a reduction in cardiac arrest rate when used in a single hospital with an established medical emergency team system.[21]

3.2.2 2015 Recommendation—New

The use of PEWS may be considered, but its effectiveness in the in-hospital setting is not well established. (Class IIb, LOE C-LD)

3.3 Fluid Resuscitation in Septic Shock - Updated PEDS 545

This update regarding intravenous fluid resuscitation in infants and children in septic shock in all settings addressed 2 specific therapeutic elements: (1) Withholding the use of bolus fluids was compared with the use of bolus fluids, and (2) noncrystalloid was compared with crystalloid fluids.

Early and rapid administration of intravenous fluid to reverse decompensated shock, and to prevent progression from compensated to decompensated shock, has been widely accepted based on limited observational studies.[22] Mortality from pediatric sepsis has declined in recent years, during which guidelines and publications have emphasized the role of early rapid fluid administration (along with early antibiotic and vasopressor therapy, and careful cardiovascular monitoring) in treating septic shock.[23,24] Since the 2010 Guidelines, a large randomized controlled trial of fluid resuscitation in pediatric severe febrile illness in a resource-limited setting found intravenous fluid boluses to be harmful.[25]This new information, contradicting long-held beliefs and practices, prompted careful analysis of the effect of fluid resuscitation on many outcomes in specific infectious illnesses.

3.3.1 2015 Evidence Summary

Specific infection-related shock states appear to behave differently with respect to fluid bolus therapy. Evidence was not considered to be specific to a particular setting, after determining that “resource-limited setting” is difficult to define and can vary greatly even within individual health systems and small geographic regions.

The evidence regarding the impact of restricting fluid boluses during resuscitation on outcomes in pediatric septic shock is summarized in Table 1. There were no studies for many specific combinations of presenting illness and outcome. In the majority of scenarios, there was no benefit to restricting fluid boluses during resuscitation.

Table 1: Evidence for the Use of Restrictive Volume of Intravenous Fluid Resuscitation, Compared With Unrestrictive Volume

Open table in a new window

Evidence for the Use of Restrictive Volume of Intravenous Fluid Resuscitation, Compared With Unrestrictive Volume

	Studies	Survival to Hospital Discharge	Need for Transfusion or Diuretics	Need for Rescue Fluid	Mechanical Ventilation or Vasopressor	Time to Resolution of Shock	Total IV Fluids
Severe sepsis/septic shock	Santhanam 2008; Carcillo 1991	No Benefit	No Benefit	No Studies Available	No Benefit	No Benefit	No Studies Available
Severe malaria	Maitland 2005; Maitland 2005	No Benefit	No Benefit	Harm	No Studies Available	No Benefit	No Benefit

	Studies	Survival to Hospital Discharge	Need for Transfusion or Diuretics	Need for Rescue Fluid	Mechanical Ventilation or Vasopressor	Time to Resolution of Shock	Total IV Fluids
Severe febrile illness with some but not all signs of shock	Maitland 2011; Maitland 2013	Benefit	No Benefit	No Studies Available	No Studies Available	Harm	No Benefit

Evidence for the use of restrictive volume of intravenous fluid resuscitation, compared with unrestrictive volume, by presenting illness and outcome. Benefit indicates that studies show a benefit to restricting fluid volume, No Benefit indicates that there is no benefit to restricting fluid volume, and Harm indicates that there is harm associated with restricting fluid volume. No Studies Available indicates no studies are available for a particular illness/outcome combination.

The most important exception is that in 1 large study, restriction of fluid boluses conveyed a benefit for survival to both 48 hours and 4 weeks after presentation. This study was conducted in sub-Saharan Africa, and inclusion criteria were severe febrile illness complicated by impaired consciousness (prostration or coma), respiratory distress (increased work of breathing), or both, and with impaired perfusion, as evidenced by 1 or more of the following: a capillary refill time of 3 or more seconds, lower limb temperature gradient, weak radialpulse volume, or severe tachycardia. In this study, administration of 20 mL/kg or 40 mL/kg in the first hour was associated with decreased survival compared with the use of maintenance fluids alone.[25] Therefore, it appears that in this specific patient population, where critical care resources including inotropic and mechanical ventilator support were limited, bolus fluid therapy resulted in higher mortality.

The use of noncrystalloid fluid was compared with crystalloid fluid for the same diseases and outcomes listed in the preceding paragraph.[25-31] Evidence is summarized in Table 2. In most scenarios, there was no benefit to noncrystalloids over crystalloids. In patients with Dengue shock, a benefit was conferred in using noncrystalloid compared with crystalloid fluid for the outcome of time to resolution of shock.[30]

Table 2: 2015 - Noncrystalloid vs Crystalloid IV Fluid

Open table in a new window

Noncrystalloid vs Crystalloid IV Fluid								
	Studies	**Survival to Hospital Discharge**	**Need for Other Treatment**	**Need for Rescue Fluid**	**Mechanical Ventilation or Vasopressor**	**Time to Resolution of Shock**	**Total IV Fluids**	**Hospital Duration of Stay**
Severe sepsis/ septic shock	Upadhyay 2005	No Benefit	No Benefit	No Studies Available	No Benefit	No Benefit	No Studies Available	No Studies Available
Severe malaria	Maitland 2003; Maitland 2005	No Studies Available	No Benefit	No Studies Available	No Studies Available	No Benefit	No Studies Available	No Studies Available

	Studies	Survival to Hospital Discharge	Need for Other Treatment	Need for Rescue Fluid	Mechanical Ventilation or Vasopressor	Time to Resolution of Shock	Total IV Fluids	Hospital Duration of Stay
Dengue shock	Cifra 2003; Dung 1999; Ngo 2001; Wills 2005	No Benefit	No Benefit	No Benefit	No Studies Available	Benefit	No Benefit	No Benefit
Severe febrile illness with some but not all signs of shock	Maitland 2011	No Benefit	No Benefit	No Benefit	No Studies Available	No Benefit	No Benefit	No Studies Available

Evidence for the use of noncrystalloid intravenous fluid resuscitation, compared with crystalloid, by presenting illness and outcome. *Benefit* indicates that studies show a benefit to the use of noncrystalloid intravenous fluid resuscitation compared with crystalloid, and *No Benefit* indicates that there is no benefit to the use of noncrystalloid intravenous fluid resuscitation compared with crystalloid. *No Studies Available* indicates no studies are available for a particular illness/outcome combination.

3.3.2 2015 Recommendations—New

Administration of an initial fluid bolus of 20 mL/kg to infants and children with shock is reasonable, including those with conditions such as severe sepsis (Class IIa, LOE C-LD), severe malaria and Dengue. (Class IIb, LOE B-R)

When caring for children with severe febrile illness (such as those included in the FEAST trial26) in settings with limited access to critical care resources (ie, mechanical ventilation and inotropic support), administration of bolus intravenous fluids should be undertaken with extreme caution because it may be harmful. (Class IIb, LOE B-R)

Providers should reassess the patient after every fluid bolus. (Class I, LOE C-EO)

Either isotonic crystalloids or colloids can be effective as the initial fluid choice for resuscitation. (Class IIa, LOE B-R)

This recommendation takes into consideration the important work of Maitland et al,[25] which found that fluid boluses as part of resuscitation are not safe for all patients in all settings. This study showed that the use of fluid boluses as part of resuscitation increased mortality in a specific population in a resource-limited setting, without access to some critical care interventions such as mechanical ventilation and inotrope support.

The spirit of this recommendation is a continued emphasis on fluid resuscitation for both compensated (detected by physical examination) and decompensated (hypotensive) septic shock. Moreover, emphasis is also placed on the use of individualized patient evaluation before the administration of intravenous fluid boluses, including physical examination by a clinician and frequent reassessment to determine the appropriate volume of fluid resuscitation. The clinician should also integrate clinical signs with patient and locality-specific information about prevalent diseases, vulnerabilities (such as severe anemia and malnutrition), and available critical care

resources.

Early assisted ventilation may be considered as part of a protocol-driven strategy for septic shock. (Class IIb, LOE C)

Etomidate has been shown to facilitate endotracheal intubation in infants and children with minimal hemodynamic effect, but do not use it routinely in pediatric patients with evidence of septic shock. (Class III, LOE B)

Adrenal suppression is seen after administration of etomidate in children[32] and adults.[33] In children and adults with septic shock, etomidate administration is associated with a higher mortality rate.[32,34]

3.4 Hypovolemic Shock

Use an isotonic crystalloid solution (eg, lactated Ringer's solution or normal saline) as the initial fluid for the treatment of shock. (Class I, LOE A)

There is no added benefit in using colloid (eg, albumin) during the early phase of resuscitation.[35,36]

Treat signs of shock with a bolus of 20 mL/kg of isotonic crystalloid even if blood pressure is normal. (Class IIb, LOE C)

Crystalloids may have an associated survival benefit over colloid for children with shock secondary to general trauma, traumatic brain injury, and burns.[36-39] There is no evidence to support the use of a specific isotonic crystalloid. Give additional boluses (20 mL/kg) if systemic perfusion fails to improve. There are insufficient data to make a recommendation for or against use of hypertonic saline for shock associated with head injuries or hypovolemia.[40,41]

There is insufficient evidence in infants and children to make a recommendation about the best timing or extent of volume resuscitation for children with hemorrhagic shock following trauma.

3.5 Dilated Cardiomyopathy or Myocarditis - Updated PEDS 819

Optimal care of a critically ill infant or child with dilated cardiomyopathy or myocarditis should avert cardiac arrest. While significant global experience exists with the care of these patients, the evidence base is limited. The ILCOR systematic review ultimately restricted its analysis to patients with myocarditis and did not include the use of ventricular assist devices.

3.5.1 2015 Evidence Summary

No literature was identified evaluating best prearrest management strategies (including anesthetic technique) for infants and children with dilated cardiomyopathy or myocarditis. Limited observational data support the pre-cardiac arrest use of ECMO in children with acute fulminant myocarditis.[42]

3.5.3 2015 Recommendation—New

Venoarterial ECMO use may be considered in patients with acute fulminant myocarditis who are at high risk of imminent cardiac arrest. (Class IIb, LOE C-EO)

Optimal outcomes from ECMO are achieved in settings with existing ECMO protocols, expertise, and equipment.

3.6 Toxicological Emergencies

Overdose with local anesthetics, cocaine, narcotics, tricyclic antidepressants, calcium channel blockers, and ?-adrenergic blockers may require specific treatment modalities in addition to the usual resuscitative measures.

3.6.1 Local Anesthetic

Local anesthetics are used topically, intravenously, subcutaneously, and in epidural or other catheters for delivery of regional analgesia. The toxicity of local anesthetics is well recognized in children; they may cause changes in mental status, seizures, arrhythmias, or even cardiac arrest in settings of overdose or inadvertent vascular administration. Multiple case reports, including some pediatric reports, have described successful treatment of local anesthetic toxicity with intravenous lipid emulsion.[43]

3.6.2 Cocaine

Acute coronary syndrome, manifested by chest pain and cardiac rhythm disturbances (including VT and VF), is the most frequent cocaine-related reason for hospitalization in adults.[44,45] Cocaine also may prolong the action potential and QRS duration and impairs myocardial contractility.[46,47]

3.6.2.1 Treatment

Hyperthermia, which may result from cocaine-induced hypermetabolism, is associated with an increase in toxicity;[48] therefore treat elevated temperature aggressively.

For coronary vasospasm consider nitroglycerin (Class IIa, LOE C), a benzodiazepine, and phentolamine (an ?-adrenergic antagonist). (Class IIb, LOE C)

Do not give ?-adrenergic blockers. (Class III, LOE C)

For ventricular arrhythmia, consider sodium bicarbonate (1 to 2 mEq/kg) administration in addition to standard treatment. (Class IIb, LOE C)

3.6.3 Tricyclic Antidepressants and Other Sodium Channel Blockers

Toxic doses cause cardiovascular abnormalities, including intraventricular conduction delays, heart block, bradycardia, prolongation of the QT interval, ventricular arrhythmias (including torsades de pointes, VT, and VF), hypotension, seizures,[47,49] and a depressed level of consciousness.

3.6.3.1 Treatment

Give 1 to 2 mEq/kg intravenous boluses of sodium bicarbonate until arterial pH is >7.45; then provide an infusion of 150 mEq NaHCO3 per liter of D5W to maintain alkalosis. In cases of severe intoxication increase the pH to 7.50 to 7.55.[47,50]

Do not administer Class IA (quinidine, procainamide), Class IC (flecainide, propafenone), or Class III (amiodarone and sotalol) antiarrhythmics, which may exacerbate cardiac toxicity. (Class III, LOE C)

For hypotension, give boluses (10 mL/kg each) of normal saline. If hypotension persists, epinephrine and norepinephrine are more effective than dopamine in raising blood pressure.[51,52]

Consider ECMO if high-dose vasopressors do not maintain blood pressure.[53,54]

3.6.4 Calcium Channel Blockers

Manifestations of toxicity include hypotension, ECG changes (prolongation of the QT interval, widening of the QRS, and right bundle branch block), arrhythmias (bradycardia, SVT, VT, torsades de pointes, and VF),[55] seizures, and altered mental status.

3.6.4.1 Treatment

Treat mild hypotension with small boluses (5 to 10 mL/kg) of normal saline because myocardial depression may limit the amount of fluid the patient can tolerate.

The effectiveness of calcium administration is variable. (Class IIb, LOE C)

Infuse 20 mg/kg (0.2 mL/kg) of 10% calcium chloride intravenously over 5 to 10 minutes; if there is a beneficial effect, give an infusion of 20 to 50 mg/kg per hour. Monitor serum ionized calcium concentration to prevent hypercalcemia. It is preferable to administer calcium chloride via a central venous catheter; use caution when infusing into a peripheral IV because infiltration can cause severe tissue injury. If no central venous catheter is available, infuse calcium gluconate through a secure peripheral IV.

For bradycardia and hypotension, consider vasopressors and inotropes such as norepinephrine or epinephrine. (Class IIb, LOE C)

There are insufficient data to recommend for or against an infusion of insulin and glucose[56-59] or sodium bicarbonate.

3.6.5 Beta-Adrenergic Blockers

Toxic doses of ?-adrenergic blockers cause bradycardia, heart block, and decreased cardiac contractility, and some (eg, propranolol and sotalol) may also prolong the QRS and the QT intervals.[59-62]

3.6.5.1 Treatment

High-dose epinephrine infusion may be effective. (Class IIb, LOE C)

Consider glucagon. In adolescents infuse 5 to 10 mg of glucagon over several minutes followed by an IV infusion of 1 to 5 mg/hour. (Class IIb, LOE C)

Consider an infusion of glucose and insulin. (Class IIb, LOE C)

There are insufficient data to make a recommendation for or against using calcium. (Class IIb, LOE C)

Calcium may be considered if glucagon and catecholamines are ineffective. (Class IIb, LOE C)

3.6.6 Opioids

Narcotics may cause hypoventilation, apnea, bradycardia, and hypotension in addition to depressed responsiveness.

3.6.6.1 Treatment

Support of oxygenation and ventilation is the initial treatment for severe respiratory depression from any

cause. (Class I)

Naloxone reverses the respiratory depression of narcotic overdose, but in persons with long-term addictions or cardiovascular disease, naloxone may markedly increase heart rate and blood pressure and cause acute pulmonary edema, cardiac arrhythmias (including asystole), and seizures. (Class I, LOE B)

Ventilation before administration of naloxone appears to reduce these adverse effects.[63] Intramuscular administration of naloxone may lower the risk by slowing the onset of drug effect.

3.7 Atropine for Premedication During Emergency Intubation - Updated PEDS 821

Bradycardia commonly occurs during emergency pediatric intubation, resulting from hypoxia/ischemia, as a vagal response to laryngoscopy, as a reflex response to positive pressure ventilation, or as a pharmacologic effect of some drugs (eg, succinylcholine or fentanyl). Practitioners have often tried to blunt this bradycardia with prophylactic premedication with atropine.

3.7.1 2015 Evidence Summary

The evidence regarding the use of atropine during emergency intubation has largely been observational, including extrapolation from experience with elective intubation in the operating suite. More recent in-hospital literature involves larger case series of critically ill neonates, infants, and children undergoing emergency intubation.[64-66]

There is no evidence that preintubation use of atropine improves survival or prevents cardiac arrest in infants and children. Observational data suggest that it increases the likelihood of survival to ICU discharge in children older than 28 days.[64] Evidence is conflicting as to whether preintubation atropine administration reduces the incidence of arrhythmias or postintubation shock.[65, 66]

In past Guidelines, a minimum atropine dose of 0.1 mg IV was recommended after a report of paradoxical bradycardia observed in very small infants who received very low atropine doses.[67] However, in 2 of the most recent case series cited above, preintubation doses of 0.02 mg/kg, with no minimum dose, were shown to be effective.[64,65]

3.7.2 2015 Recommendations—New

The available evidence does not support the routine use of atropine preintubation of critically ill infants and children.

It may be reasonable for practitioners to use atropine as a premedication in specific emergency intubations when there is higher risk of bradycardia (eg, when giving succinylcholine as a neuromuscular blocker to facilitate intubation). (Class IIb, LOE C-LD)

A dose of 0.02 mg/kg of atropine with no minimum dose may be considered when atropine is used as a premedication for emergency intubation. (Class IIb, LOE C-LD)

This new recommendation applies only to the use of atropine as a premedication for infants and children during emergency intubation.

4 Intra-arrest Care - Updated

4.1 BLS Considerations During PALS

Pediatric advanced life support (PALS) usually takes place in the setting of an organized response in an advanced healthcare environment. In these circumstances, multiple responders are rapidly mobilized and are capable of simultaneous coordinated action. Resuscitation teams may also have access to invasive patient monitoring that may provide additional information during the performance of basic life support (BLS).

4.1.1 Simultaneous Actions

BLS (whether for a child or adult) is presented as a series of sequential events with the assumption that there is only one responder, but PALS usually takes place in an environment where many rescuers are rapidly mobilized and actions are performed simultaneously. The challenge is to organize the rescuers into an efficient team. Important considerations for the greatest chance of a successful resuscitation from cardiac arrest include the following:

Chest compressions should be immediately started by one rescuer, while a second rescuer prepares to start ventilations with a bag and mask. Ventilation is extremely important in pediatrics because of the large percentage of asphyxial arrests in which best results are obtained by a combination of chest compressions and ventilations.[68] Unfortunately ventilations are sometimes delayed because equipment (bag, mask, oxygen, airway) must be mobilized. Chest compressions require only the hands of a willing rescuer.

Therefore, start CPR with chest compressions immediately, while a second rescuer prepares to provide ventilations. (Class I, LOE C)

The effectiveness of PALS is dependent on high-quality CPR, which requires an adequate compression rate (at least 100 compressions/min), an adequate compression depth (at least one third of the AP diameter of the chest or approximately 1 ½ inches [4 cm] in infants and approximately 2 inches [5 cm] in children), allowing complete recoil of the chest after each compression, minimizing interruptions in compressions, and avoiding excessive ventilation. Reasons for not performing high-quality CPR include rescuer inattention to detail, rescuer fatigue, and long or frequent interruptions to secure the airway, check the heart rhythm, and move the patient.[69] Optimal chest compressions are best delivered with the victim on a firm surface.[70,71]

While one rescuer performs chest compressions and another performs ventilations, other rescuers should obtain a monitor/defibrillator, establish vascular access, and calculate and prepare the anticipated medications.

4.1.2 Monitored Patients

Many in-hospital patients, especially if they are in an ICU, are monitored and some have an advanced airway and are receiving mechanical ventilation. If the patient has an indwelling arterial catheter, use the waveform as feedback to evaluate hand position and chest compression depth. A minor adjustment of hand position or depth of compression can significantly improve the amplitude of the arterial waveform, reflecting better chest compression-induced stroke volume. The arterial waveform may also be useful in identification of return of spontaneous circulation (ROSC). If the patient's end-tidal CO_2 ($ETCO_2$) is being monitored, it can be used to evaluate the quality of chest compressions; it can also provide an indication of ROSC (see below).

4.1.3 Respiratory Failure

Respiratory failure is characterized by inadequate ventilation, insufficient oxygenation, or both. Anticipate respiratory failure if any of the following signs is present:

An increased respiratory rate, particularly with signs of distress (eg, increased respiratory effort including nasal flaring, retractions, seesaw breathing, or grunting)

An inadequate respiratory rate, effort, or chest excursion (eg, diminished breath sounds or gasping), especially if mental status is depressed

Cyanosis with abnormal breathing despite supplementary oxygen

4.1.4 Shock

Shock results from inadequate blood flow and oxygen delivery to meet tissue metabolic demands. The most common type of shock in children is hypovolemic, including shock due to hemorrhage. Distributive, cardiogenic, and obstructive shock occur less frequently. Shock progresses over a continuum of severity, from a

compensated to a decompensated state. Compensatory mechanisms include tachycardia and increased systemic vascular resistance (vasoconstriction) in an effort to maintain cardiac output and perfusion pressure respectively. Decompensation occurs when compensatory mechanisms fail and results in hypotensive shock.

Typical signs of compensated shock include

– Tachycardia

– Cool and pale distal extremities

– Prolonged (>2 seconds) capillary refill (despite warm ambient temperature)

– Weak peripheral pulses compared with central pulses

– Normal systolic blood pressure

As compensatory mechanisms fail, signs of inadequate end-organ perfusion develop. In addition to the above, these signs include

– Depressed mental status

– Decreased urine output

– Metabolic acidosis

– Tachypnea

– Weak central pulses

– Deterioration in color (eg, mottling, see below)

Decompensated shock is characterized by signs and symptoms consistent with inadequate delivery of oxygen to tissues (pallor, peripheral cyanosis, tachypnea, mottling of the skin, decreased urine output, metabolic acidosis, depressed mental status), weak or absent peripheral pulses, weak central pulses, and hypotension.

Learn to integrate the signs of shock because no single sign confirms the diagnosis. For example:

Capillary refill time alone is not a good indicator of circulatory volume, but a capillary refill time >2 seconds is a useful indicator of moderate dehydration when combined with decreased urine output, absent tears, dry mucous membranes, and a generally ill appearance. Capillary refill time is influenced by ambient temperature,[72] site, and age and its interpretation can be influenced by lighting.[73]

Tachycardia is a common sign of shock, but it can also result from other causes, such as pain, anxiety, and fever.

Pulses are weak in hypovolemic and cardiogenic shock, but may be bounding in anaphylactic, neurogenic, and septic shock.

Blood pressure may be normal in a child with compensated shock but may decline rapidly when the child decompensates. Like the other signs, hypotension must be interpreted within the context of the entire clinical picture.

There are several sources of data that use large populations to identify the 5th percentile for systolic blood pressure at various ages.[74,75] For purposes of these guidelines, hypotension is defined as a ***systolic*** blood pressure:

<60 mm Hg in term neonates (0 to 28 days)

<70 mm Hg in infants (1 month to 12 months)

<70 mm Hg + (2 × age in years) in children 1 to 10 years

<90 mm Hg in children ?10 years of age

4.1.5 Airway

4.1.5.1 Oropharyngeal and Nasopharyngeal Airways

Oropharyngeal and nasopharyngeal airways help maintain an open airway by displacing the tongue or soft palate from the pharyngeal air passages. Oropharyngeal airways are used in unresponsive victims who do not have a gag reflex. Make sure to select the correct size: an oropharyngeal airway that is too small may push the base of the tongue farther into the airway; one that is too large may obstruct the airway.

Nasopharyngeal airways can be used in children who do have a gag reflex. Pay careful attention to proper diameter and length. A nasopharyngeal airway that is too short may not maintain an open airway, while one that is too long may obstruct it. A small-diameter nasopharyngeal airway may be obstructed easily by secretions. It may therefore require frequent suctioning.

4.1.5.2 Laryngeal Mask Airway (LMA)

Although several supraglottic devices have been used in children, clinical studies of devices other than the LMA in pediatric patients are limited.

When bag-mask ventilation (see "Bag-Mask Ventilation," below) is unsuccessful and when endotracheal intubation is not possible, the LMA is acceptable when used by experienced providers to provide a patent airway and support ventilation. (Class IIa, LOE C)

LMA insertion is associated with a higher incidence of complications in young children compared with older children and adults.[76-81]

4.1.6 Oxygen

It is reasonable to ventilate with 100% oxygen during CPR because there is insufficient information on the optimal inspired oxygen concentration. (Class IIa, LOE C)

Once the circulation is restored, monitor systemic oxygen saturation. It may be reasonable, when the appropriate equipment is available, to titrate oxygen administration to maintain the oxyhemoglobin saturation ?94%. Provided appropriate equipment is available, once ROSC is achieved, adjust the FIO_2 to the minimum concentration needed to achieve an arterial oxyhemoglobin saturation at least 94%, with the goal of avoiding hyperoxia while ensuring adequate oxygen delivery.

Since an arterial oxyhemoglobin saturation of 100% may correspond to a PaO2 anywhere between ?80 and 500 mmHg, in general it is appropriate to wean the FIO2 when saturation is 100%, provided the oxyhemoglobin saturation can be maintained ?94%. (Class IIb, LOE C)

Remember that adequate oxygen delivery requires not only adequate arterial oxyhemoglobin saturation but also adequate hemoglobin concentration and cardiac output.

4.1.7 Pulse Oximetry

If the patient has a perfusing rhythm, monitor oxyhemoglobin saturation continuously with a pulse oximeter because clinical recognition of hypoxemia is not reliable.[82] Pulse oximetry may, however, also be unreliable in patients with poor peripheral perfusion, carbon monoxide poisoning, or methemoglobinemia.

4.1.7.1 Bag-Mask Ventilation

Bag-mask ventilation can be as effective, and may be safer, than endotracheal tube ventilation for short periods during out-of-hospital resuscitation.[83-90]

In the prehospital setting it is reasonable to ventilate and oxygenate infants and children with a bag-mask device, especially if transport time is short. (Class IIa, LOE B)

Bag-mask ventilation requires training and periodic retraining in selecting a correct mask size, maintaining an open airway, providing a tight seal between mask and face, providing ventilation, and assessing effectiveness of ventilation (see Part 11, Pediatric Basic Life Support).

4.1.7.1.1 Precautions

Use only the force and tidal volume needed to just make the chest rise visibly (Class I, LOE C); avoid delivering excessive ventilation during cardiac arrest. (Class III, LOE C)

Evidence shows that cardiac arrest victims frequently receive excessive ventilation.[69,91-93] Excessive ventilation during cardiac arrest increases intrathoracic pressure, which impedes venous return, thus reducing cardiac output and cerebral and coronary blood flow. These effects will reduce the likelihood of ROSC.[92] In addition, excessive ventilation may cause air trapping and barotrauma in patients with small airway obstruction. It also increases the risk of stomach inflation, regurgitation, and aspiration.

If the infant or child is not intubated, pause after 30 chest compressions (1 rescuer) or after 15 chest compressions (2 rescuers) to give 2 ventilations (mouth-to-mouth, mouth-to-mask, or bag-mask).

Deliver each breath with an inspiratory time of approximately 1 second. If the infant or child is intubated, ventilate at a rate of about 1 breath every 6 seconds (10 times per minute) without interrupting chest compressions.

It may be reasonable to do the same if an LMA is in place. (Class IIb, LOE C)

In the victim with a perfusing rhythm but absent or inadequate respiratory effort, give 1 breath every 3 to 5 seconds (12 to 20 breaths per minute), using the higher rate for the younger child. (Class I, LOE C)

One way to achieve that rate with a ventilating bag is to use the mnemonic “squeeze-release-release” at a normal speaking rate.[83,94]

4.1.8 Two-Person Bag-Mask Ventilation

A 2-person ventilation technique may be preferable when personnel are available and may be more effective than ventilation by a single rescuer if the patient has significant airway obstruction, poor lung compliance, or the rescuer has difficulty in creating a tight mask-to-face seal.[95,96] One rescuer uses both hands to maintain an open airway with a jaw thrust and a tight mask-to-face seal while the other compresses the ventilation bag. Both rescuers should observe the victim’s chest to ensure chest rise.

4.1.9 Gastric Inflation

Gastric inflation may interfere with effective ventilation[97] and cause regurgitation, aspiration of stomach contents, and further ventilatory compromise. The risk of gastric inflation can be decreased by

Avoiding excessive peak inspiratory pressures by ventilating slowly and giving only enough tidal volume to just achieve visible chest rise.[83]

Applying cricoid pressure in an unresponsive victim to reduce air entry into the stomach. (Class IIa, LOE B)

This may require a third rescuer if cricoid pressure cannot be applied by the rescuer who is securing the bag to the face.

Avoid excessive cricoid pressure so as not to obstruct the trachea. (Class III, LOE B)

Passing a nasogastric or orogastric tube to relieve gastric inflation, especially if oxygenation and ventilation are compromised. Pass the tube after intubation because a gastric tube interferes with gastroesophageal sphincter function, allowing regurgitation during intubation. If a gastrostomy tube is present, vent it during bag-mask ventilation to allow gastric decompression.

4.1.10 Ventilation With an Endotracheal Tube

Endotracheal intubation in infants and children requires special training because the pediatric airway anatomy differs from that of the adult. The likelihood of successful endotracheal tube placement with minimal complications is related to the length of training, supervised experience in the operating room and in the field,[98, 99] adequate ongoing experience,[100] and use of rapid sequence intubation (RSI).[101,102]

4.1.11 Ventilation With a Tracheostomy or Stoma

Parents, school nurses, and home healthcare providers should know how to assess patency of the airway, clear the airway, replace the tracheostomy tube, and perform CPR using the artificial airway in a child with a tracheostomy.

Parents and providers should be able to ventilate via a tracheostomy tube and verify effectiveness by assessing chest expansion. If, after suctioning, the chest does not expand with ventilation, remove the tracheostomy tube and replace it or insert a same-sized endotracheal tube, if available, into the tracheal stoma. If a clean tube is unavailable, perform mouth-to-stoma or mask-to-stoma ventilations. If the upper airway is patent, bag-mask ventilation via the nose and mouth may be effective if the tracheal stoma is manually occluded.

4.1.12 Rapid Sequence Intubation (RSI)

To facilitate emergency intubation and reduce the incidence of complications, skilled, experienced providers may use sedatives, neuromuscular blocking agents, and other medications to rapidly sedate and neuromuscularly block the pediatric patient.[103]

Use RSI only if you are trained, and have experience using these medications and are proficient in the evaluation and management of the pediatric airway. If you use RSI you must have a secondary plan to manage the airway in the event that you cannot achieve intubation.

Actual body weight, rather than ideal body weight, should be used for some non-resuscitation medications (eg, succinylcholine).[104-119]

4.1.13 Cricoid Pressure During Intubation

There is insufficient evidence to recommend routine cricoid pressure application to prevent aspiration during endotracheal intubation in children.

Do not continue cricoid pressure if it interferes with ventilation or the speed or ease of intubation. (Class III, LOE C)

4.1.14 Cuffed Versus Uncuffed Endotracheal Tubes

Both cuffed and uncuffed endotracheal tubes are acceptable for intubating infants and children. (Class IIa, LOE C)

In the operating room, cuffed endotracheal tubes are associated with a higher likelihood of correct selection of tube size, thus achieving a lower reintubation rate with no increased risk of perioperative complications.[120-122] In intensive care settings the risk of complications in infants and in children is no greater with cuffed tubes than with noncuffed tubes.[123-125] Cuffed endotracheal tubes may decrease the risk of aspiration.[126] If cuffed endotracheal tubes are used, cuff inflating pressure should be monitored and limited according to manufacturer's instruction (usually less than 20 to 25 cm H_2O).

In certain circumstances (eg, poor lung compliance, high airway resistance, or a large glottic air leak) a cuffed endotracheal tube may be preferable to an uncuffed tube, provided that attention is paid to endotracheal tube size, position, and cuff inflation pressure. (Class IIa, LOE B)

4.1.15 Endotracheal Tube Size

Length-based resuscitation tapes are helpful and more accurate than age-based formula estimates of endotracheal tube size for children up to approximately 35 kg,[111,127,128] even for children with short stature.[129]

In preparation for intubation with either a cuffed or an uncuffed endotracheal tube, confirm that tubes with an internal diameter (ID) 0.5 mm smaller and 0.5 mm larger than the estimated size are available. During intubation, if the endotracheal tube meets resistance, place a tube 0.5 mm smaller instead. Following intubation, if there is a large glottic air leak that interferes with oxygenation or ventilation, consider replacing the tube with one that is 0.5 mm larger, or place a cuffed tube of the same size if an uncuffed tube was used originally. Note that replacement of a functional endotracheal tube is associated with risk; the procedure should be undertaken in an appropriate setting by experienced personnel.

If an uncuffed endotracheal tube is used for emergency intubation, it is reasonable to select a 3.5-mm ID tube for infants up to one year of age and a 4.0-mm ID tube for patients between 1 and 2 years of age. After age 2, uncuffed endotracheal tube size can be estimated by the following formula:

Uncuffed endotracheal tube ID (mm) = 4+(age/4)

If a cuffed tube is used for emergency intubation of an infant less than 1 year of age, it is reasonable to select a 3.0 mm ID tube.

For children between 1 and 2 years of age, it is reasonable to use a cuffed endotracheal tube with an internal diameter of 3.5 mm. (Class IIa, LOE B)

After age 2 it is reasonable to estimate tube size with the following formula. (Class IIa, LOE B)

Cuffed endotracheal tube ID (mm) = 3.5+(age/4)

4.1.16 Verification of Endotracheal Tube Placement

There is a risk of endotracheal tube misplacement (ie, in the esophagus, the pharynx above the vocal cords, or a mainstem bronchus) and an ongoing risk of displacement or obstruction,[83,130] especially during patient transport.[131]

Since no single confirmation technique, including clinical signs or the presence of water vapor in the tube, is completely reliable, use both clinical assessment and confirmatory devices to verify proper tube placement immediately after intubation, again after securing the endotracheal tube, during transport, and each time the patient is moved (eg, from gurney to bed). (Class I, LOE B)

The following are methods for confirming correct position:

Look for bilateral chest movement and listen for equal breath sounds over both lung fields, especially over the axillae.

Listen for gastric insufflation sounds over the stomach. They should *not* be present if the tube is in the trachea.[132]

Check for exhaled CO_2 (see "Exhaled or End-Tidal CO_2 Monitoring," below).

If there is a perfusing rhythm, check oxyhemoglobin saturation with a pulse oximeter. Remember that following hyperoxygenation, the oxyhemoglobin saturation detected by pulse oximetry may not decline for as long as 3 minutes even without effective ventilation.[133,134]

If you are still uncertain, perform direct laryngoscopy and visualize the endotracheal tube to confirm that it lies between the vocal cords.

In hospital settings, perform a chest x-ray to verify that the tube is not in a bronchus and to identify proper position in the midtrachea.

After intubation, secure the tube; there is insufficient evidence to recommend any single method. After securing the tube, maintain the patient's head in a neutral position; neck flexion may push the tube farther into the airway, and extension may pull the tube out of the airway.[135,136]

If an intubated patient's condition deteriorates, consider the following possibilities (mnemonic DOPE):

Displacement of the tube

Obstruction of the tube

Pneumothorax

Equipment failure

4.1.17 Exhaled or End-Tidal CO2 ($ETCO_2$) Monitoring

When available, exhaled CO2 detection (capnography or colorimetry) is recommended as confirmation of tracheal tube position for neonates, infants, and children with a perfusing cardiac rhythm in all settings (eg, prehospital, emergency department [ED], ICU, ward, operating room) (Class I, LOE C) and during intrahospital or interhospital transport. (Class IIb, LOE C)

Remember that a color change or the presence of a capnography waveform confirms tube position in the airway but does not rule out right mainstem bronchus intubation.

During cardiac arrest, if exhaled CO2 is not detected, confirm tube position with direct laryngoscopy because the absence of CO2 may reflect very low pulmonary blood flow rather than tube misplacement. (Class IIa, LOE C)

Confirmation of endotracheal tube position by colorimetric end-tidal CO_2 detector may be altered by the following:

If the detector is contaminated with gastric contents or acidic drugs (eg, endotracheally administered epinephrine), a consistent color rather than a breath-to-breath color change may be seen.

An intravenous (IV) bolus of epinephrine[137] may transiently reduce pulmonary blood flow and exhaled CO_2 below the limits of detection.[138]

Severe airway obstruction (eg, status asthmaticus) and pulmonary edema may impair CO_2 elimination below the limits of detection.[138,139-141]

A large glottic air leak may reduce exhaled tidal volume through the tube and dilute CO_2 concentration.

4.1.18 Esophageal Detector Device (EDD)

If capnography is not available, an esophageal detector device (EDD) may be considered to confirm endotracheal tube placement in children weighing >20 kg with a perfusing rhythm), but the data are insufficient to make a recommendation for or against its use in children during cardiac arrest. (Class IIb, LOE B)

4.1.19 Transtracheal Catheter Oxygenation and Ventilation

Transtracheal catheter oxygenation and ventilation may be considered for patients with severe airway obstruction above the level of the cricoid cartilage if standard methods to manage the airway are unsuccessful. Note that transtracheal ventilation primarily supports oxygenation as tidal volumes are usually too small to effectively remove carbon dioxide.

This technique is intended for temporary use while a more effective airway is obtained. Attempt this procedure only after proper training and with appropriate equipment. (Class IIb, LOE C)

4.1.20 Suction Devices

A properly sized suction device with an adjustable suction regulator should be available. Do not insert the suction catheter beyond the end of the endotracheal tube to avoid injuring the mucosa. Use a maximum suction force of -80 to -120 mm Hg for suctioning the airway via an endotracheal tube. Higher suction pressures applied through large-bore noncollapsible suction tubing and semirigid pharyngeal tips are used to suction the mouth and pharynx.

4.1.21 CPR Guidelines for Newborns With Cardiac Arrest of Cardiac Origin

Recommendations for infants differ from those for the newly born (ie, in the delivery room and during the first hours after birth) and newborns (during their initial hospitalization and in the NICU). The compression-to-ventilation ratio differs (newly born and newborns – 3:1; infant two rescuer – 15:2) and how to provide ventilations in the presence of an advanced airway differs (newly born and newborns – pause after 3 compressions; infants – no pauses for ventilations). This presents a dilemma for healthcare providers who may also care for newborns outside the NICU. Because there are no definitive scientific data to help resolve this dilemma, for ease of training we recommend that newborns (intubated or not) who require CPR in the newborn nursery or NICU receive CPR using the same technique as for the newly born in the delivery room (ie, 3:1 compression-to-ventilation ratio with a pause for ventilation).

Newborns who require CPR in other settings (eg, prehospital, ED, pediatric intensive care unit [PICU], etc.), should receive CPR according to infant guidelines: 2 rescuers provide continuous chest compressions with asynchronous ventilations if an advanced airway is in place and a 15:2 ventilation-to-compression ratio if no advanced airway is in place. (Class IIb, LOE C)

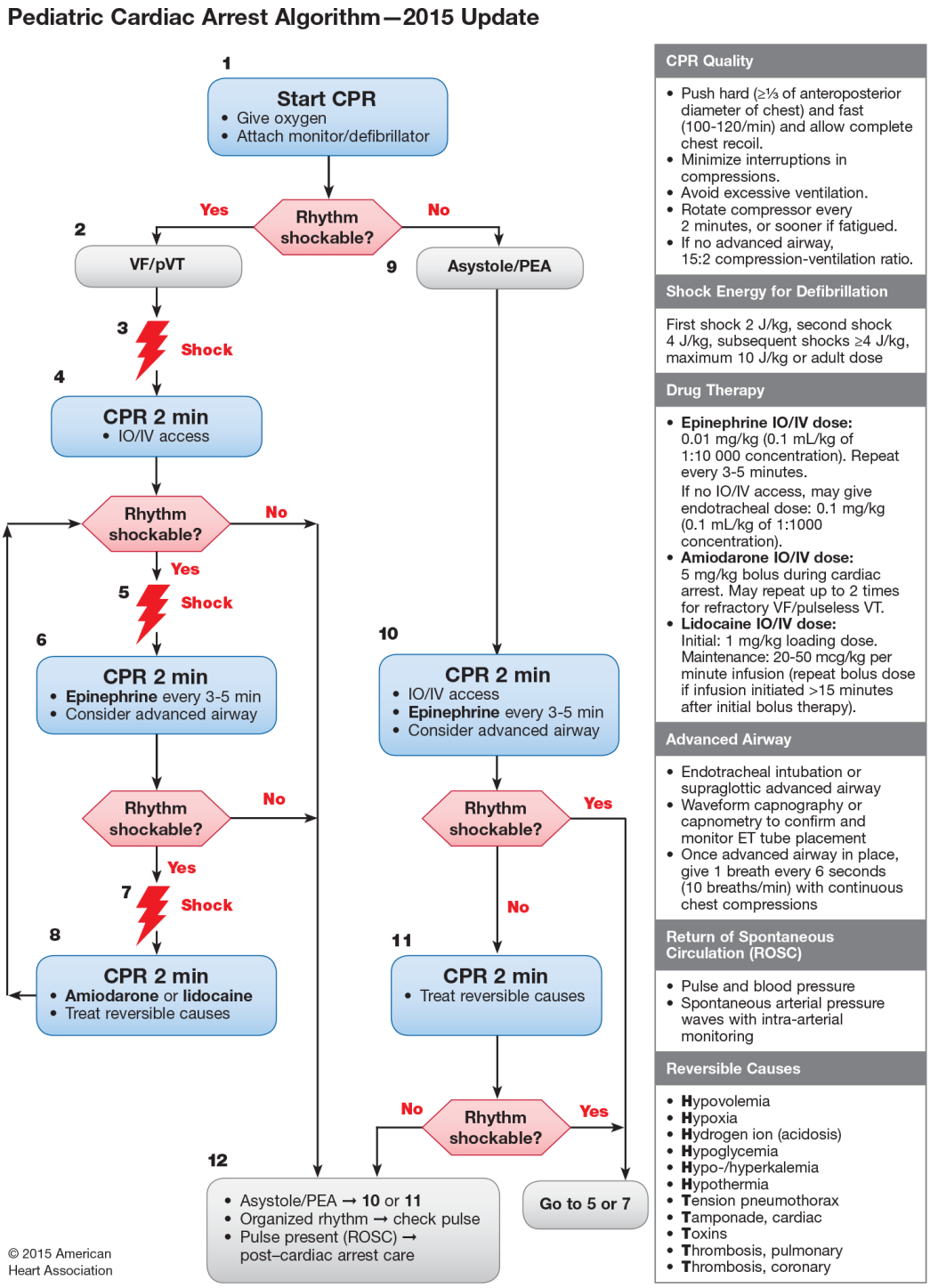
It is reasonable to resuscitate newborns with a primary cardiac etiology of arrest, regardless of location, according to infant guidelines, with emphasis on chest compressions. (Class IIa, LOE C)

For further information, please refer to Part 11: Pediatric Basic Life Support, and Part 13: Neonatal Resuscitation.

4.2 Pulseless Arrest

In the text below, box numbers identify the corresponding step in the algorithm (Figure 1).

Figure 1: Pediatric Cardiac Arrest Algorithm—2015 Update



(Step 1) As soon as the child is found to be unresponsive with no breathing, call for help, send for a defibrillator (manual or AED), and start CPR (with supplementary oxygen if available). Attach ECG monitor or AED pads as soon as available. Throughout resuscitation, emphasis should be placed on provision of high-quality CPR (providing chest compressions of adequate rate and depth, allowing complete chest recoil after each compression, minimizing interruptions in compressions and avoiding excessive ventilation).

While CPR is being given, determine the child's cardiac rhythm from the ECG or, if you are using an AED, the device will tell you whether the rhythm is "shockable" (eg, VF or rapid pVT) or "not shockable" (eg, asystole or PEA). It may be necessary to temporarily interrupt chest compressions to determine the child's rhythm. Asystole and bradycardia with a wide QRS are most common in asphyxial arrest.[142] VF and PEA are less common[143] but VF is more likely to be present in older children with sudden witnessed arrest.

4.2.1 "Nonshockable Rhythm": Asystole/PEA (Step 9)

PEA is an organized electric activity-most commonly slow, wide QRS complexes-without palpable pulses. Less frequently there is a sudden impairment of cardiac output with an initially normal rhythm but without pulses and with poor perfusion. This subcategory, formerly known as electromechanical dissociation (EMD), may be more reversible than asystole. For asystole and PEA:

(Step 10) Continue CPR with as few interruptions in chest compressions as possible. A second rescuer obtains vascular access and delivers epinephrine, 0.01 mg/kg (0.1 mL/kg of 1:10 000 solution) maximum of 1 mg (10 mL), while CPR is continued.

The same epinephrine dose is repeated every 3 to 5 minutes. (Class I, LOE B)

There is no survival benefit from high-dose epinephrine, and it may be harmful, particularly in asphyxia. (Class III, LOE B)

High-dose epinephrine may be considered in exceptional circumstances, such as ?-blocker overdose. (Class IIb, LOE C)

Once an advanced airway is in place, 1 rescuer should give continuous chest compressions at a rate of at least 100 per minute without pause for ventilation. The second rescuer delivers ventilations at a rate of 1 breath every 6 seconds (10 breaths per minute). Rotate the compressor role approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions. Check rhythm every 2 minutes with minimal interruptions in chest compressions. If the rhythm is "nonshockable" continue with cycles of CPR and epinephrine administration until there is evidence of ROSC or you decide to terminate the effort. If at any time the rhythm becomes "shockable," give a shock (Step 7) and immediately resume chest compressions for 2 minutes before rechecking the rhythm. Minimize time between chest compressions and shock delivery (ie, check rhythm and deliver shocks immediately after compressions rather than after rescue breaths, if possible) and between shock delivery and resumption of chest compressions.

Search for and treat reversible causes.

4.2.2 "Shockable Rhythm": VF/Pulseless VT (Step 2)

Defibrillation is the definitive treatment for VF with an overall survival rate of 17% to 20%. (Class I, LOE B)

Survival is better in primary than in secondary VF.[144] In adults, the probability of survival declines by 7% to 10% for each minute of arrest without CPR and defibrillation.[145] Survival is better if early, high-quality CPR is provided with minimal interruptions. Outcome of shock delivery is best if rescuers minimize the time between last compression and shock delivery, so rescuers should be prepared to coordinate (brief) interruptions in chest compressions to deliver shocks, and should resume compressions immediately after shock delivery.

4.3 Monitoring

4.3.1 End-Tidal CO2 Monitoring to Guide CPR Quality - Updated PEDS 827

High-quality CPR is associated with improved outcomes after cardiac arrest. Animal data support a direct association between $ETCO_2$ and cardiac output. Capnography is used during pediatric cardiac arrest to monitor

for ROSC as well as CPR quality. The 2010 Guidelines recommended that if the partial pressure of $ETCO_2$ is consistently less than 15 mmHg, efforts should focus on improving CPR quality, particularly improving chest compressions and ensuring that the victim does not receive excessive ventilation.

4.3.1.1 2015 Evidence Summary

There is no pediatric evidence that $ETCO_2$ monitoring improves outcomes from cardiac arrest. One pediatric animal study showed that $ETCO_2$ -guided chest compressions are as effective as standard chest compressions optimized by marker, video, and verbal feedback for achieving ROSC.[146] A recent study in adults found that $ETCO_2$ values generated during CPR were significantly associated with chest compression depth and ventilation rate.[147]

4.3.1.2 2015 Recommendation—New

ETCO2 monitoring may be considered to evaluate the quality of chest compressions, but specific values to guide therapy have not been established in children. (Class IIb, LOE C-LD)

4.3.2 Electrocardiography

Monitor cardiac rhythm as soon as possible so both normal and abnormal cardiac rhythms are identified and followed. Continuous monitoring is helpful in tracking responses to treatment and changes in clinical condition.

4.3.3 Echocardiography

There is insufficient evidence for or against the routine use of echocardiography in pediatric cardiac arrest.

When appropriately trained personnel are available, echocardiography may be considered to identify patients with potentially treatable causes of the arrest, particularly pericardial tamponade and inadequate ventricular filling. (Class IIb, LOE C)

Minimize interruption of CPR while performing echocardiography.

4.3.4 Invasive Hemodynamic Monitoring During CPR - Updated PEDS 826

Children often have cardiac arrests in settings where invasive hemodynamic monitoring already exists or is rapidly obtained. If a patient has an indwelling arterial catheter, the waveform can be used as feedback to evaluate chest compressions.

4.3.4.1 2015 Evidence Summary

Adjusting chest compression technique to a specific systolic blood pressure target has not been studied in humans. Two randomized controlled animal studies showed increased likelihood of ROSC and survival to completion of experiment with the use of invasive hemodynamic monitoring.[148,149]

4.3.4.2 2015 Recommendation—New

For patients with invasive hemodynamic monitoring in place at the time of cardiac arrest, it may be reasonable for rescuers to use blood pressure to guide CPR quality. (Class IIb, LOE C-EO)

Specific target values for blood pressure during CPR have not been established in children.

4.3.5 Vascular Access

Vascular access is essential for administering medications and drawing blood samples. Obtaining peripheral venous access can be challenging in infants and children during an emergency; intraosseous (IO) access can be quickly established with minimal complications by providers with varied levels of training.[150-157] Limit the time spent attempting to establish peripheral venous access in a critically ill or injured child.[158]

4.3.6 Intraosseous (IO) Access

IO access is a rapid, safe, effective, and acceptable route for vascular access in children, and it is useful as the initial vascular access in cases of cardiac arrest. (Class I, LOE C)

All intravenous medications can be administered intraosseously, including epinephrine, adenosine, fluids, blood products,[159,160] and catecholamines.[161] Onset of action and drug levels for most drugs are comparable to venous administration.[162] IO access can be used to obtain blood samples for analysis including for type and cross match and blood gases during CPR,[163]but acid-base analysis is inaccurate after sodium bicarbonate administration via the IO cannula.[164] Use manual pressure or an infusion pump to administer viscous drugs or rapid fluid boluses;[165,166] follow each medication with a saline flush to promote entry into the central circulation.

4.3.7 Venous Access

Peripheral IV access is acceptable during resuscitation if it can be placed rapidly, but placement may be difficult in a critically ill child. Although a central venous catheter can provide more secure long-term access, its placement requires training and experience, and the procedure can be time-consuming. Therefore central venous access is not recommended as the initial route of vascular access during an emergency. If both central and peripheral accesses are available, administer medications into the central circulation since some medications (eg, adenosine) are more effective when administered closer to the heart, and others (eg, calcium, amiodarone, procainamide, sympathomimetics) may be irritating when infused into a peripheral vein. The length of a central catheter can contribute to increased resistance, making it more difficult to push boluses of fluid rapidly through a multilumen central than a peripheral catheter.

4.3.8 Endotracheal Drug Administration

Vascular access (IO or IV) is the preferred method for drug delivery during CPR, but if it is not possible, lipid-soluble drugs, such as lidocaine, epinephrine, atropine, and naloxone (mnemonic “LEAN”)[167,168] can be administered via an endotracheal tube.[169] However, the effects may not be uniform with tracheal as compared with intravenous administration. One study of children in cardiac arrest[170] demonstrated similar ROSC and survival rates regardless of the method of drug delivery, while three studies of adults in cardiac arrest[171-173] demonstrated reduced ROSC and survival to hospital discharge with tracheal administration of epinephrine compared to vascular delivery. If CPR is in progress, stop chest compressions briefly, administer the medications, and follow with a flush of at least 5 mL of normal saline and 5 consecutive positive-pressure ventilations.[174] Optimal endotracheal doses of medications are unknown; in general expert consensus recommends doubling or tripling the dose of lidocaine, atropine or naloxone given via the ETT. For epinephrine, a dose ten times the intravenous dose (0.1 mg/kg or 0.1 mL/kg of 1:1,000 concentration) is recommended (see Table 3).

Table 3: 2010 - Medications for Pediatric Resuscitation

Open table in a new window

Medications for Pediatric Resuscitation		
Medication	**Dose**	**Remarks**
Adenosine	0.1 mg/kg (maximum 6 mg) Second dose: 0.2 mg/kg (maximum 12 mg)	Monitor ECG Rapid IV/IO bolus with flush

Medication	Dose	Remarks
Amiodarone	5 mg/kg IV/IO; may repeat twice up to 15 mg/kg Maximum single dose 300 mg	Monitor ECG and blood pressure; adjust administration rate to urgency (IV push during cardiac arrest, more slowly–over 20–60 minutes with perfusing rhythm). Expert consultation strongly recommended prior to use when patient has a perfusing rhythmUse caution when administering with other drugs that prolong QT (obtain expert consultation)
Atropine	0.02 mg/kg IV/IO 0.04–0.06 mg/kg ET* Repeat once if neededMaximum single dose: 0.5 mg	Higher doses may be used with organophosphate poisoning
Calcium Chloride (10%)	20 mg/kg IV/IO (0.2 mL/kg) Maximum single dose 2 g	Administer slowly
Epinephrine	0.01 mg/kg (0.1 mL/kg 1:10 000) IV/IO 0.1 mg/kg (0.1 mL/kg 1:1000) ET* Maximum dose 1 mg IV/IO; 2.5 mg ET	May repeat every 3–5 minutes
Glucose	0.5–1 g/kg IV/IO	Newborn: 5–10 mL/kg $D_{10}W$ Infants and Children: 2–4 mL/kg $D_{25}W$ Adolescents: 1–2 mL/kg $D_{50}W$
Lidocaine	Bolus: 1 mg/kg IV/IO Infusion: 20–50 mcg/kg/minute	
Magnesium Sulfate	25–50 mg/kg IV/IO over 10–20 minutes, faster in torsades de pointes Maximum dose 2 g	
Naloxone	Full Reversal: <5 y or ?20 kg: 0.1 mg/kg IV/IO/ET* ?5y or >20 kg: 2 mg IV/IO/ET*	Use lower doses to reverse respiratory depression associated with therapeutic opioid use (1–5 mcg/kg titrate to effect)
Procainamide	15 mg/kg IV/IO Adult Dose: 20 mg/min IV infusion to total maximum dose of 17 mg/kg	Monitor ECG and blood pressure; Give slowly–over 30–60 minutes. Use caution when administering with other drugs that prolong QT (obtain expert consultation)
Sodium bicarbonate	1 mEq/kg per dose IV/IO slowly	After adequate ventilation

- IV indicates intravenous; IO, intraosseous; and ET, via endotracheal tube.
- ?* Flush with 5 mL of normal saline and follow with 5 ventilations.

The effectiveness of endotracheal epinephrine during cardiac arrest is controversial. Some studies showed it to be as effective as vascular administration[170,175,176] while other studies have not found it to be as effective.[171-173,177] Animal studies[178-183] suggested that a higher dose of epinephrine is required for endotracheal than for intravascular administration because the lower epinephrine concentrations achieved when the drug is delivered by the endotracheal route may produce predominant transient peripheral ?2-adrenergic vasodilating effects. These effects can be detrimental, and cause hypotension, lower coronary artery perfusion pressure and flow,

and a reduced potential for ROSC.

Non-lipid-soluble drugs (eg, sodium bicarbonate and calcium) may injure the airway; they should not be administered via the endotracheal route.

4.4 Extracorporeal CPR for In-Hospital Pediatric Cardiac Arrest - Updated PEDS 407

The 2010 AHA PALS Guidelines suggested the use of ECMO when dealing with pediatric cardiac arrest refractory to conventional interventions and when managing a reversible underlying disease process. Pediatric OHCA was not considered for the 2015 ILCOR systematic review.

4.4.1 2015 Evidence Summary

Evidence from 4 observational studies of pediatric IHCA has shown no overall benefit to the use of CPR with ECMO (ECPR) compared to CPR without ECMO.[184-187] Observational data from a registry of pediatric IHCA showed improved survival to hospital discharge with the use of ECPR in patients with surgical cardiac diagnoses.[188] For children with underlying cardiac disease, when ECPR is initiated in a critical care setting, long-term survival has been reported even after more than 50 minutes of conventional CPR.[189] When ECPR is used during cardiac arrest, the outcome for children with underlying cardiac disease is better than for those with noncardiac disease.[190]

4.4.2 2015 Recommendation—New

ECPR may be considered for pediatric patients with cardiac diagnoses who have IHCA in settings with existing ECMO protocols, expertise, and equipment. (Class IIb, LOE C-LD)

4.5 Intra-arrest Prognostic Factors for Cardiac Arrest - Updated PEDS 814

Accurate and reliable prognostication during pediatric cardiac arrest would allow termination of CPR in patients where CPR is futile, while encouraging continued CPR in patients with a potential for good recovery.

4.5.1 2015 Evidence Summary

For infants and children with OHCA, age less than 1 year,[4,191] longer durations of cardiac arrest[192-194] and presentation with a nonshockable as opposed to a shockable rhythm[4,191,193] are all predictors of poor patient outcome. For infants and children with IHCA, negative predictive factors include age greater than 1 year[2] and longer durations of cardiac arrest.[2,195-197] The evidence is contradictory as to whether a nonshockable (as opposed to shockable) initial cardiac arrest rhythm is a negative predictive factor in the in-hospital setting.[2,198,199]

4.5.2 2015 Recommendation—New

Multiple variables should be used when attempting to prognosticate outcomes during cardiac arrest. (Class I, LOE C-LD)

Although there are factors associated with better or worse outcomes, no single factor studied predicts outcome with sufficient accuracy to recommend termination or continuation of CPR.

4.6 Vasopressors During Cardiac Arrest - Updated PEDS 424

During cardiac arrest, vasopressors are used to restore spontaneous circulation by optimizing coronary perfusion and to help maintain cerebral perfusion. However, they also cause intense vasoconstriction and increase myocardial oxygen consumption, which might be detrimental.

4.6.1 2015 Evidence Summary

There are no pediatric studies that demonstrate the effectiveness of any vasopressors (epinephrine, or combination of vasopressors) in cardiac arrest. Two pediatric observational out-of-hospital studies[200,201] had too many confounders to determine if vasopressors were beneficial. One adult OHCA randomized controlled trial [202] showed epinephrine use was associated with increased ROSC and survival to hospital admission but no

improvement in survival to hospital discharge.

4.6.2 2015 Recommendation—New

It is reasonable to administer epinephrine in pediatric cardiac arrest. (Class IIa, LOE C-LD)

4.7 Amiodarone and Lidocaine for Shock-Refractory VF and pVT - Updated PEDS 825

The 2005 and 2010 Guidelines recommended administering amiodarone in preference to lidocaine for the management of VF or pVT. This recommendation was based predominantly on pediatric case series or extrapolation from adult studies that used short-term outcomes.

4.7.1 2015 Evidence Summary

New pediatric observational data[203] showed improved ROSC with the use of lidocaine as compared with amiodarone. Use of lidocaine compared with no lidocaine was significantly associated with an increased likelihood of ROSC. The same study did not show an association between lidocaine or amiodarone use and survival to hospital discharge.

4.7.2 2015 Recommendation—New

For shock-refractory VF or pVT, either amiodarone or lidocaine may be used. (Class IIb, LOE C-LD)

The Pediatric Cardiac Arrest Algorithm (Figure 1) reflects this change.

4.8 Defibrillators (2015/2010)

Defibrillators are either manual or automated (AED), with monophasic or biphasic waveforms.

AEDs in institutions caring for children at risk for arrhythmias and cardiac arrest (eg, hospitals, EDs) must be capable of recognizing pediatric cardiac rhythms and should ideally have a method of adjusting the energy level for children.

The following should be considered when using a manual defibrillator:

4.8.1 Paddle Size

In general, manual defibrillators have two sizes of hand-held paddles: adult and infant. The infant paddles may slide over or be located under the adult paddles. Manual defibrillators can also be used with hands-free pads that are self adhesive. Use the largest paddles or self-adhering electrodes[204-206] that will fit on the child's chest without touching (when possible, leave about 3 cm between the paddles or electrodes). Paddles and self-adhering pads appear to be equally effective.[207] Self-adhering pads should be pressed firmly on the chest so that the gel on the pad completely touches the child's chest. An appropriate paddle or self-adhesive pad size is

"Adult" size (8 to 10 cm) for children >10 kg (> approximately 1 year)

"Infant" size for infants <10 kg

4.8.2 Interface

The electrode-chest wall interface is part of the self-adhesive pad; in contrast, electrode gel must be applied liberally on manually applied paddles. Do not use saline-soaked pads, ultrasound gel, bare paddles, or alcohol pads

4.8.3 Paddle Position

Follow package directions for placement of self-adhesive AED or monitor/defibrillator pads.

Place manual paddles over the right side of the upper chest and the apex of the heart (to the left of the nipple over the left lower ribs) so the heart is between the two paddles. Apply firm pressure. There is no advantage in an anterior-posterior position of the paddles.[207]

4.8.4 Energy Doses for Defibrillation - Updated PEDS 405

The 2015 ILCOR systematic review addressed the dose of energy for pediatric manual defibrillation during cardiac arrest. Neither the energy dose specifically related to automated external defibrillators, nor the energy dose for cardioversion was evaluated in this evidence review.

4.8.4.1 2015 Evidence Summary

Two small case series demonstrated termination of VF/pVT with either 2 J/kg[208] or 2 to 4 J/kg.[209] In 1 observational study of IHCA,[210] a higher initial energy dose of more than 3 to 5 J/kg was less effective than 1 to 3 J/kg in achieving ROSC. One small observational study of IHCA[211] showed no benefit in achieving ROSC with a specific energy dose for initial defibrillation. Three small observational studies of IHCA and OHCA[209,211,212] showed no survival to discharge advantage of any energy dose compared with 2 to 4 J/kg for initial defibrillation.

4.8.4.2 2015 Recommendations—Updated

It is reasonable to use an initial dose of 2 to 4 J/kg of monophasic or biphasic energy for defibrillation (Class IIa, LOE C-LD), but for ease of teaching, an initial dose of 2 J/kg may be considered. (Class IIb, LOE C-EO)

For refractory VF, it is reasonable to increase the dose to 4 J/kg. (Class IIa, LOE C-LD)

For subsequent energy levels, a dose of 4 J/kg may be reasonable and higher energy levels may be considered, though not to exceed 10 J/kg or the adult maximum dose. (Class IIb, LOE C-LD)

4.8.5 AEDs

Many AEDs can accurately detect VF in children of all ages.[213,214-216] They can differentiate “shockable” from “nonshockable” rhythms with a high degree of sensitivity and specificity.[214,215] It is recommended that systems and institutions that have AED programs and that care for children should use AEDs with a high specificity to recognize pediatric shockable rhythms and a pediatric attenuating system that can be used for infants and children up to approximately 25 kg (approximately 8 years of age).[217,218]

If an AED with an attenuator is not available, use an AED with standard electrodes. (Class IIa, LOE C)

In infants <1 year of age a manual defibrillator is preferred. If a manual defibrillator is not available, an AED with a dose attenuator may be used.

An AED without a dose attenuator may be used if neither a manual defibrillator nor one with a dose attenuator is available. (Class IIb, LOE C)

4.8.6 Integration of Defibrillation With Resuscitation Sequence

Please refer to Figure 1: Pediatric Cardiac Arrest Algorithm—2015 Update.

The following are important considerations:

Provide CPR until the defibrillator is ready to deliver a shock; after shock delivery, resume CPR, beginning with chest compressions. Minimize interruptions of chest compressions. In adults with prolonged arrest[219,220] and in animal models,[221] defibrillation is more likely to be successful after a period of effective chest compressions. Ideally chest compressions should be interrupted only for ventilations (until an advanced airway is in place), rhythm check, and shock delivery. If a “shockable” rhythm is still present, continue chest compressions after a

rhythm check (when possible) while the defibrillator is charging (so chest compressions are delivered until shock delivery).

(Step 3) Give 1 shock (2 J/kg) as quickly as possible and immediately resume CPR, beginning with chest compressions. If 1 shock fails to eliminate VF, the incremental benefit of another immediate shock is low, and resumption of CPR is likely to confer a greater value than another shock. CPR may provide coronary perfusion, increasing the likelihood of defibrillation with a subsequent shock. It is important to minimize the time between chest compressions and shock delivery and between shock delivery and resumption of postshock compressions.

(Step 4) Continue CPR for about 2 minutes. In in-hospital settings with continuous invasive monitoring, this sequence may be modified at the expert provider's discretion. If sufficient rescuers are present, obtain vascular (IO or IV) access.

After 2 minutes of CPR, check the rhythm; recharge the defibrillator to a higher dose (4 J/kg).

(Step 5) If a "shockable" rhythm persists, give another shock (4 J/kg). If rhythm is "nonshockable," continue with the asystole/PEA algorithm (Steps 10 and 11).

(Step 6) Immediately resume chest compressions. Continue CPR for approximately 2 minutes. During CPR give epinephrine 0.01 mg/kg (0.1 mL/kg of 1:10 000 concentration), maximum of 1 mg every 3 to 5 minutes. (Class I, LOE B)

It is helpful if a third rescuer prepares the drug doses *before* the rhythm is checked so epinephrine can be administered as soon as possible. Epinephrine should be administered during chest compressions, but the timing of drug administration is less important than the need to minimize interruptions in chest compressions. Just prior to the rhythm check, the rescuer operating the defibrillator should prepare to recharge the defibrillator (4 J/kg or more with a maximum dose not to exceed 10 J/kg or the adult dose, whichever is lower).

Check the rhythm

(Step 7) If the rhythm is "shockable," deliver another shock (4 J/kg or more with a maximum dose not to exceed 10 J/kg or the adult dose, whichever is lower) and immediately resume CPR (beginning with chest compressions).

(Step 8) While continuing CPR, give either amiodarone or lidocaine.

If at any time the rhythm check shows a "nonshockable" rhythm, proceed to the "Pulseless Arrest" sequence (Steps 10 or 11).

Once an advanced airway is in place, 2 rescuers no longer deliver cycles of CPR (ie, compressions interrupted by pauses for ventilation). Instead, the compressing rescuer gives continuous chest compressions at a rate of at least 100 per minute without pause for ventilation. The rescuer delivering ventilation provides about 1 breath every 6 seconds (10 breaths per minute). Two or more rescuers should rotate the compressor role approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions.

If defibrillation successfully restores an organized rhythm (or there is other evidence of ROSC, such as an abrupt rise in $ETCO_2$ or visible pulsations on an arterial waveform), check the child's pulse to determine if a perfusing rhythm is present. If a pulse is present, continue with postresuscitation care.

If defibrillation is successful but VF recurs, resume CPR and give another bolus of amiodarone before trying to defibrillate with the previously successful shock dose.

Search for and treat reversible causes

4.8.7 Torsades de Pointes

This polymorphic VT is associated with a long QT interval, which may be congenital or may result from toxicity with type IA antiarrhythmics (eg, procainamide, quinidine, and disopyramide) or type III antiarrhythmics (eg, sotalol and amiodarone), tricyclic antidepressants (see below), digitalis, or drug interactions.[222,223]

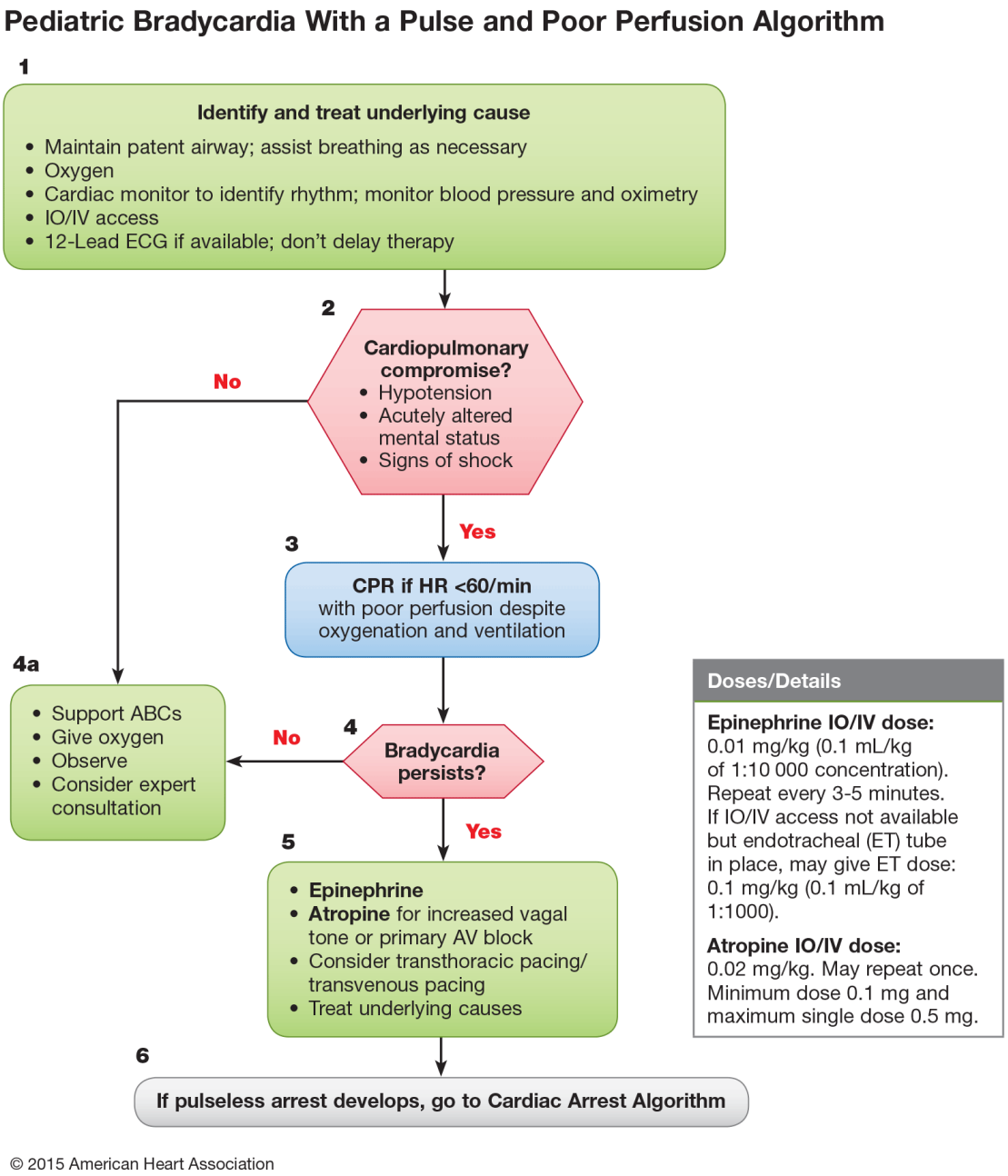
4.8.7.1 Treatment

Torsades de pointes VT typically deteriorates rapidly to VF or pulseless VT, so providers should initiate CPR and proceed with defibrillation when pulseless arrest develops (see above). Regardless of the cause, treat torsades de pointes with a rapid (over several minutes) IV infusion of magnesium sulfate (25 to 50 mg/kg; maximum single dose 2 g).

4.8.8 Bradycardia

Box numbers in the text below refer to the corresponding boxes in the PALS Bradycardia Algorithm (see Figure 2 : PALS Bradycardia Algorithm). This algorithm applies to the care of the infant or child with bradycardia and cardiorespiratory compromise, but a palpable pulse. If at any time the patient develops pulseless arrest, see the PALS Pulseless Arrest Algorithm.

Figure 2: Pediatric Bradycardia With a Pulse and Poor Perfusion Algorithm



Emergency treatment of bradycardia is indicated when the rhythm results in hemodynamic compromise.

(**Box 1**) Support a patent airway, breathing, and circulation as needed. Administer oxygen, attach an ECG monitor/defibrillator, and obtain vascular access.

(**Box 2**) Reassess the patient to determine if bradycardia persists and is still causing cardiorespiratory symptoms despite adequate oxygenation and ventilation.

(**Box 4a**) If pulses, perfusion, and respirations are adequate, no emergency treatment is necessary. Monitor and proceed with evaluation.

(**Box 3**) If heart rate is <60 beats per minute with poor perfusion despite effective ventilation with oxygen, start CPR.

(**Box 4**) After 2 minutes reevaluate the patient to determine if bradycardia and signs of hemodynamic compromise persist. Verify that the support is adequate (eg, check airway, oxygen source, and effectiveness of ventilation).

(**Box 5**) Medications and pacing:

Continue to support airway, ventilation, oxygenation, and chest compressions. (Class I, LOE B)

If bradycardia persists or responds only transiently, give epinephrine IV (or IO) 0.01 mg/kg (0.1 mL/kg of 1:10 000 solution) or if IV/IO access not available, give endotracheally 0.1 mg/kg (0.1 mL/kg of 1:1 000 solution). (Class I, LOE B)

If bradycardia is due to increased vagal tone or primary AV conduction block (ie, not secondary to factors such as hypoxia), give IV/IO atropine 0.02 mg/kg or an endotracheal dose of 0.04 to 0.06 mg/kg. (Class I, LOE C)

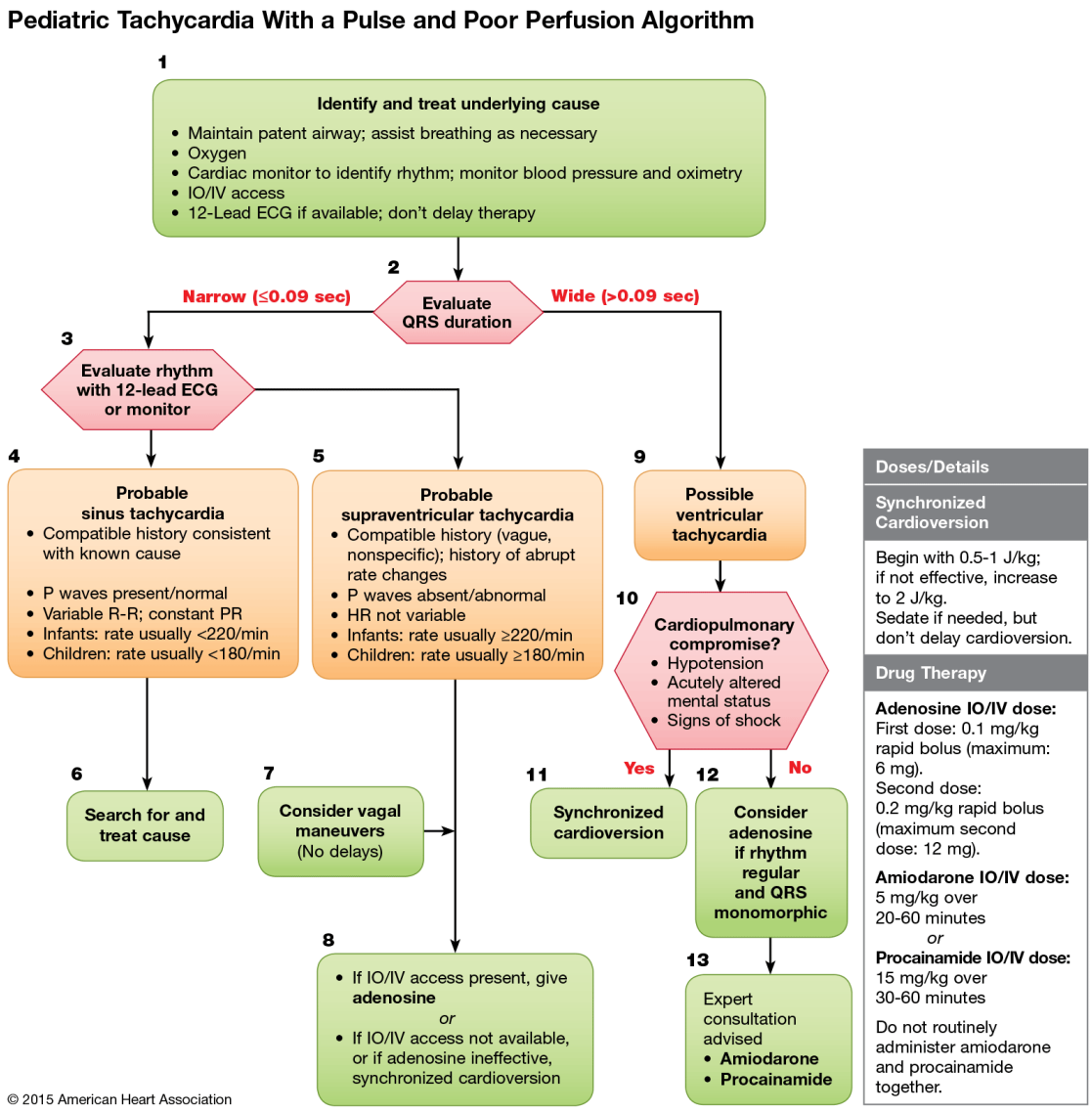
Emergency transcutaneous pacing may be lifesaving if the bradycardia is due to complete heart block or sinus node dysfunction unresponsive to ventilation, oxygenation, chest compressions, and medications, especially if it is associated with congenital or acquired heart disease. (Class IIb, LOE C)

Pacing is not useful for asystole[224,225] or bradycardia due to postarrest hypoxic/ischemic myocardial insult or respiratory failure.

4.8.9 Tachycardia

The box numbers in the text below correspond to the numbered boxes in the Tachycardia Algorithm (see Figure 3 : PALS Tachycardia Algorithm).

Figure 3: Pediatric Tachycardia With a Pulse and Poor Perfusion Algorithm



If there are signs of poor perfusion and pulses are not palpable, proceed with the PALS Pulseless Arrest Algorithm (see Figure 1).

(Figure 3 **Box 1**) If pulses are palpable and the patient has adequate perfusion

–Assess and support airway, breathing, and circulation

–Provide oxygen.

–Attach monitor/defibrillator.

–Obtain vascular access.

–Evaluate 12-lead ECG and assess QRS duration (Figure 3 **Box 2**).

4.8.9.1 Narrow-Complex (?0.09 Second) Tachycardia

Evaluation of a 12-lead ECG (Box 3) and the patient's clinical presentation and history (Boxes 4 and 5) should help differentiate sinus tachycardia from supraventricular tachycardia (SVT). If the rhythm is sinus tachycardia, search for and treat reversible causes.

4.8.9.2 Supraventricular Tachycardia (Box 5)

Monitor rhythm during therapy to evaluate the effect of interventions. The choice of therapy is determined by the patient's degree of hemodynamic instability.

Attempt vagal stimulation (Box 7) first, unless the patient is hemodynamically unstable or the procedure will unduly delay chemical or electric cardioversion. (Class IIa, LOE C)

In infants and young children, apply ice to the face without occluding the airway.[226,227]

In older children, carotid sinus massage or Valsalva maneuvers are safe.[228-230]

One method for performing a Valsalva maneuver is to have the child blow through a narrow straw.[229]Do not apply pressure to the eye because this can damage the retina.

Pharmacologic cardioversion with adenosine (Box 8) is very effective with minimal and transient side effects.[231-235]

If IV/IO access is readily available, adenosine is the drug of choice. (Class I, LOE C)

Side effects are usually transient.[231-235]Administer IV/IO adenosine 0.1 mg/kg using 2 syringes connected to a T-connector or stopcock; give adenosine rapidly with 1 syringe and immediately flush with ?5 mL of normal saline with the other.

An IV/IO dose of Verapamil, 0.1 to 0.3 mg/kg is also effective in terminating SVT in older children, but it should not be used in infants without expert consultation because it may cause potential myocardial depression, hypotension, and cardiac arrest. (Class III, LOE C)

If the patient is hemodynamically unstable or if adenosine is ineffective, perform electric synchronized cardioversion (Box 8).

Use sedation, if possible. Start with a dose of 0.5 to 1 J/kg. If unsuccessful, increase the dose to 2 J/kg. (Class IIb, LOE C)

If a second shock is unsuccessful or the tachycardia recurs quickly, consider amiodarone or procainamide before a third shock.

Consider amiodarone 5 mg/kg IO/IV or procainamide 15 mg/kg IO/IV236 for a patient with SVT unresponsive to vagal maneuvers and adenosine and/or electric cardioversion; for hemodynamically stable patients, expert consultation is strongly recommended prior to administration. (Class IIb, LOE C)

Both amiodarone and procainamide must be infused slowly (amiodarone over 20 to 60 minutes and procainamide over 30 to 60 minutes), depending on the urgency, while the ECG and blood pressure are monitored. If there is no effect and there are no signs of toxicity, give additional doses (Table 3). Avoid the simultaneous use of amiodarone and procainamide without expert consultation.

4.8.9.3 Wide-Complex (>0.09 Second) Tachycardia (Box 9)

Wide-complex tachycardia often originates in the ventricles (ventricular tachycardia) but may be supraventricular in origin.[236]

Because all arrhythmia therapies have a potential for serious adverse effects, consultation with an expert in pediatric arrhythmias is strongly recommended before treating children who are hemodynamically stable.

The following are important considerations in treating wide-complex tachycardia in hemodynamically stable patients:

Adenosine may be useful in differentiating SVT from VT and converting wide-complex tachycardia of supraventricular origin (Box 12). Adenosine should be considered only if the rhythm is regular and the QRS is monomorphic. Do not use adenosine in patients with known Wolff-Parkinson-White syndrome and wide-complex tachycardia.

Consider electric cardioversion after sedation using a starting energy dose of 0.5 to 1 J/kg. If that fails, increase the dose to 2 J/kg (Box 11). (Class IIb, LOE C)

Consider pharmacologic conversion with either intravenous amiodarone (5 mg/kg over 20 to 60 minutes) or procainamide (15 mg/kg given over 30 to 60 minutes) while monitoring ECG and blood pressure. Stop or slow the infusion if there is a decline in blood pressure or the QRS widens (Box 13). Expert consultation is strongly recommended prior to administration.

In hemodynamically unstable patients:

Electric cardioversion is recommended using a starting energy dose of 0.5 to 1 J/kg. If that fails, increase the dose to 2 J/kg. (Class 1, LOE C)

4.9 Special Resuscitation Situations

4.9.1 Trauma

Some aspects of trauma resuscitation require emphasis because improperly performed resuscitation is a major cause of preventable pediatric deaths.[237]

Common errors in pediatric trauma resuscitation include failure to open and maintain the airway, failure to provide appropriate fluid resuscitation, and failure to recognize and treat internal bleeding. Involve a qualified surgeon early and, if possible, transport a child with multisystem trauma to a trauma center with pediatric expertise.

The following are special aspects of trauma resuscitation:

When the mechanism of injury is compatible with cervical spinal injury, restrict motion of the cervical spine and avoid traction or movement of the head and neck. Open and maintain the airway with a jaw thrust, and do not tilt the head.

If the airway cannot be opened with a jaw thrust, use a head tilt–chin lift because you must establish a patent airway. Because of the disproportionately large head of infants and young children, optimal positioning may require recessing the occiput[238] or elevating the torso to avoid undesirable backboard-induced cervical flexion.[238,239]

Do not routinely hyperventilate even in case of head injury. (Class III, LOE C)

Intentional brief hyperventilation may be used as a temporizing rescue therapy if there are signs of impending brain herniation (eg, sudden rise in measured intracranial pressure, dilation of one or both pupils with decreased response to light, bradycardia, and hypertension).

Suspect thoracic injury in all thoraco-abdominal trauma, even in the absence of external injuries. Tension pneumothorax, hemothorax, or pulmonary contusion may impair oxygenation and ventilation.

If the patient has maxillofacial trauma or if you suspect a basilar skull fracture, insert an orogastric rather than a nasogastric tube. (Class IIa, LOE C)

In the very select circumstances of children with cardiac arrest from penetrating trauma with short transport times, consider performing resuscitative thoracotomy. (Class IIb, LOE C)

Consider intra-abdominal hemorrhage, tension pneumothorax, pericardial tamponade, and spinal cord injury in infants and children, and intracranial hemorrhage in infants, as causes of shock.[240,241]

4.9.2 Single Ventricle

Standard prearrest and arrest resuscitation procedures should be followed for infants and children with single ventricle anatomy following Stage I palliation or in the infant or neonate with a univentricular heart and a shunt to augment pulmonary blood flow. Heparin may be considered for infants with a systemic-pulmonary artery shunt or right ventricular-pulmonary artery shunt. Following resuscitation from cardiac arrest, oxygen administration should be adjusted to balance systemic and pulmonary blood flow, targeting an oxyhemoglobin saturation (SpO_2) of approximately 80%. End-tidal CO_2 ($ETCO_2$) in the single-ventricle patient during cardiac arrest may not be a reliable indicator of CPR quality because pulmonary blood flow changes rapidly and does not necessarily reflect cardiac output during CPR.[242]

Neonates in a prearrest state due to elevated pulmonary-to-systemic flow ratio prior to Stage I repair might benefit from a PaCO2 of 50 to 60 mm Hg, which can be achieved during mechanical ventilation by reducing minute ventilation, increasing the inspired fraction of CO2, or administering opioids with or without chemical paralysis. (Class IIb, LOE B)

Neonates in a low cardiac output state following stage I repair may benefit from systemic vasodilators such as ?-adrenergic antagonists (eg, phenoxybenzamine) to treat or ameliorate increased systemic vascular resistance, improve systemic oxygen delivery, and reduce the likelihood of cardiac arrest. (Class IIa, LOE B)

Other drugs that reduce systemic vascular resistance (eg, milrinone or nipride) may also be considered for patients with excessive Qp:Qs. (Class IIa, LOE B)

Following Stage I repair, evaluation of oxygen delivery and extraction (eg, using central venous oxygen saturation [ScvO2] and near-infrared spectroscopy) may help identify evolving changes in hemodynamics that may herald impending cardiac arrest.[243-245]

During cardiopulmonary arrest, it is reasonable to consider extracorporeal membrane oxygenation (ECMO) for patients with single ventricle anatomy who have undergone Stage I procedure. (Class IIa, LOE B)

Hypoventilation may improve oxygen delivery in patients in a prearrest state with Fontan or hemi-Fontan/bidirectional Glenn (BDG) physiology. (Class IIa, LOE B)

Negative-pressure ventilation may improve cardiac output. (Class IIa, LOE C)

During cardiopulmonary arrest, it is reasonable to consider extracorporeal membrane oxygenation (ECMO) for patients with Fontan physiology. (Class IIa, LOE C)

It is unclear at this time whether patients with hemi-Fontan/BDG physiology in cardiac arrest might benefit from ECMO.

4.9.3 Pulmonary Hypertension

Standard PALS, including oxygenation and ventilation, should be provided to patients with pulmonary hypertension and a cardiopulmonary arrest. It may be beneficial to attempt to correct hypercarbia. Administration of a bolus of isotonic fluid may be useful to maintain preload to the systemic ventricle.

If intravenous or inhaled therapy to decrease pulmonary hypertension has been interrupted, reinstitute it. (Class IIa, LOE C)

Consider administering inhaled nitric oxide (iNO) or aerosolized prostacyclin or analogue to reduce pulmonary vascular resistance. (Class IIa, LOE C))

If iNO is not available, consider giving an intravenous bolus of prostacyclin. (Class IIa, LOE C)

ECMO may be beneficial if instituted early in the resuscitation. (Class IIa, LOE C)

4.10 Family Presence During Resuscitation

Family presence during CPR is increasingly common, and most parents would like to be given the opportunity to be present during resuscitation of their child.[246-255] Studies show that family members who are present at a resuscitation would recommend it to others.[246,247,249,255,256] Parents of chronically ill children are comfortable with medical equipment and emergency procedures, but even family members with no medical background who were at the side of a loved one to say goodbye during the final moments of life believe that their presence was beneficial to the patient,[246-248,250] comforting for them,[246-249,252-255,257] and helpful in their adjustment[247-249,256,258,257,259] and grieving process.[259] Standardized psychological examinations suggest that, compared with those not present, family members present during attempted resuscitations have less anxiety and depression and more constructive grieving behavior.[259] Parents or family members often fail to ask, but healthcare providers should offer the opportunity in most situations.[260,261,262]

Whenever possible, provide family members with the option of being present during resuscitation of an infant or child) (Class I, LOE B)

Family presence during resuscitation, in general, is not disruptive,[248,256,263,257,264,265] and does not create stress among staff or negatively affect their performance.[246,248,264,266]

If the presence of family members creates undue staff stress or is considered detrimental to the resuscitation, then family members should be respectfully asked to leave. (Class IIa, LOE C)

Members of the resuscitation team must be sensitive to the presence of family members, and one person should be assigned to remain with the family to comfort, answer questions, and support the family.[267]

4.11 Termination of Resuscitative Efforts

There are no reliable predictors of outcome to guide when to terminate resuscitative efforts in children.

Clinical variables associated with survival include length of CPR, number of doses of epinephrine, age, witnessed versus unwitnessed cardiac arrest, and the first and subsequent rhythm.

[144,268,269-143,271,272,273,274-278] None of these associations, however, predict outcome. Witnessed collapse, bystander CPR, and a short interval from collapse to arrival of professionals improve the chances of a successful resuscitation. Intact survival has been documented after unusually prolonged in-hospital resuscitation.[143,279,280,273,281,282]

5 Postarrest Care Updates - Updated

5.1 Postresuscitation Stabilization (Post Cardiac Arrest Care) - Updated

The goals of postresuscitation care are to preserve neurologic function, prevent secondary organ injury, diagnose and treat the cause of illness, and enable the patient to arrive at a pediatric tertiary-care facility in an optimal physiologic state. Frequent reassessment of the patient is necessary because cardiorespiratory status may deteriorate.

5.1.1 Respiratory System - Updated

5.1.1.1 Post–Cardiac Arrest Oxygenation - Updated PEDS 544

Animal studies suggest that elevated levels of tissue Po2 after ROSC (hyperoxia) contribute to oxidative stress that may potentiate the postresuscitation syndrome, while some adult studies show associations between hyperoxemia and increased mortality.[283,284]

5.1.1.1.1 2015 Evidence Summary

Three small observational studies of pediatric IHCA and OHCA survivors[285-287] did not show an association between elevated Pao2 and outcome. In a larger observational study of 1427 pediatric IHCA and OHCA victims who survived to pediatric ICU admission,[288] after adjustment of confounders, the presence of normoxemia (defined as a Pao2 60 mmHg or greater and less than 300 mmHg) when compared with hyperoxemia (Pao2 greater than 300 mmHg) after ROSC was associated with improved survival to pediatric ICU discharge.

5.1.1.1.2 2015 Recommendations—New

It may be reasonable for rescuers to target normoxemia after ROSC. (Class IIb, LOE B-NR)

Because an arterial oxyhemoglobin saturation of 100% may correspond to a Pao_2 anywhere between 80 and approximately 500 mmHg, it may be reasonable—when the necessary equipment is available—for rescuers to wean oxygen to target an oxyhemoglobin saturation of less than 100%, but 94% or greater. The goal of such an approach is to achieve normoxemia while ensuring that hypoxemia is strictly avoided. Ideally, oxygen is titrated to a value appropriate to the specific patient condition.

5.1.1.2 Post–Cardiac Arrest $Paco_2$ - Updated PEDS 815

Cerebral vascular autoregulation may be abnormal after ROSC. Adult data show an association between post-ROSC hypocapnia and worse patient outcomes.[289,290] In other types of pediatric brain injury, hypocapnia is associated with worse clinical outcomes.[291-294]

5.1.1.2.1 2015 Evidence Summary

There were no studies in children after cardiac arrest specifically comparing ventilation with a predetermined Paco2 target. One small observational study of both pediatric IHCA and OHCA[285] demonstrated no association between hypercapnia (Paco2 greater than 50 mmHg) or hypocapnia (Paco2 less than 30 mmHg) and outcome. However, in an observational study of pediatric IHCA,[287] hypercapnia (Paco2 50 mmHg or greater) was associated with worse survival to hospital discharge.

5.1.1.2.2 2015 Recommendation-Updated

It is reasonable for practitioners to target a Paco2 after ROSC that is appropriate to the specific patient condition, and limit exposure to severe hypercapnia or hypocapnia. (Class IIb, LOE C-LD)

Monitor exhaled CO2 (ETCO2), especially during transport and diagnostic procedures. (Class IIa, LOE B)

5.1.2 Cardiovascular System - Updated

Monitor heart rate and blood pressure. Repeat clinical evaluations at frequent intervals until the patient is stable. Consider monitoring urine output with an indwelling catheter. A 12-lead ECG may be helpful in establishing the cause of the cardiac arrest.

Remove the IO access after alternative (preferably 2) secure venous catheters are placed. Monitor venous or arterial blood gas analysis and serum electrolytes, glucose, and calcium concentrations. A chest x-ray should be performed to evaluate endotracheal tube position, heart size, and pulmonary status. Consider obtaining arterial lactate and central venous oxygen saturation to assess adequacy of tissue oxygen delivery.

5.1.2.1 Post–Cardiac Arrest Fluids and Inotropes - Updated PEDS 820

Myocardial dysfunction and vascular instability are common after resuscitation from cardiac arrest.[295-301]

5.1.2.1.1 2015 Evidence Summary

Three small observational studies involving pediatric IHCA and OHCA[302-304] demonstrated worse survival to hospital discharge when children were exposed to post-ROSC hypotension. One of these studies[302] associated post-ROSC hypotension (defined as a systolic blood pressure less than fifth percentile for age) after IHCA with lower likelihood of survival to discharge with favorable neurologic outcome. There are no studies evaluating the benefit of specific vasoactive agents after ROSC in infants and children.

5.1.2.1.2 2015 Recommendations—New

After ROSC, we recommend that parenteral fluids and/or inotropes or vasoactive drugs be used to maintain a systolic blood pressure greater than fifth percentile for age. (Class I, LOE C-LD)

When appropriate resources are available, continuous arterial pressure monitoring is recommended to identify and treat hypotension. (Class I, LOE C-EO)

5.1.2.2 Drugs Used to Maintain Cardiac Output

Table 4: 2010 - Medications to Maintain Cardiac Output and for Postresuscitation Stabilization

Open table in a new window

Medications to Maintain Cardiac Output and for Postresuscitation Stabilization		
Medication	**Dose Range**	**Comment**
Inamrinone	0.75–1 mg/kg IV/IO over 5 minutes; may repeat × 2 then: 5–10 mcg/kg per minute	Inodilator
Dobutamine	2–20 mcg/kg per minute IV/IO	Inotrope; vasodilator

Medication	Dose Range	Comment
Dopamine	2–20 mcg/kg per minute IV/IO	Inotrope; chronotrope; renal and splanchnic vasodilator in low doses; pressor in high doses
Epinephrine	0.1–1 mcg/kg per minute IV/IO	Inotrope; chronotrope; vasodilator in low doses; pressor in higher doses
Milrinone	Loading dose: 50 mcg/kg IV/IO over 10–60 min then 0.25–0.75 mcg/kg per minute	Inodilator
Norepinephrine	0.1–2 mcg/kg per minute	Vasopressor
Sodium nitroprusside	Initial: 0.5–1 mcg/kg per minute; titrate to effect up to 8 mcg/kg per minute	Vasodilator Prepare only in D_5W

- IV indicates intravenous; and IO, intraosseous.
- Alternative formula for verifying dose during continuous infusion:
- Infusion rate

$$(\text{mL/h}) = \frac{[\text{weight (kg)} \times \text{dose (mcg/kg per min)} \times 60\ (\text{min/hour})]}{\text{concentration(mcg/mL)}}.$$

Systemic and pulmonary vascular resistances are often increased initially, except in some cases of septic shock.[305] The postarrest effects on the cardiovascular system may evolve over time, with an initial hyperdynamic state replaced by worsening cardiac function. Therefore in infants and children with documented or suspected cardiovascular dysfunction after cardiac arrest, it is reasonable to administer vasoactive drugs titrated to improve myocardial function and organ perfusion.

5.1.2.2.1 Epinephrine

Low-dose infusions (<0.3 mcg/kg per minute) generally produce ?-adrenergic actions (tachycardia, potent inotropy, and decreased systemic vascular resistance). Higher-dose infusions (>0.3 mcg/kg per minute) cause ?-adrenergic vasoconstriction.[306,307] Because there is great interpatient variability in response,[308,309] titrate the drug to the desired effect. Epinephrine or norepinephrine may be preferable to dopamine in patients (especially infants) with marked circulatory instability and decompensated shock.[310]

5.1.2.2.2 Dopamine

Dopamine can produce direct dopaminergic effects and indirect ?- and ?-adrenergic effects through stimulation of norepinephrine release.

Titrate dopamine to treat shock that is unresponsive to fluids and when systemic vascular resistance is low. (Class IIb, LOE C)

Titrate dopamine to treat shock that is unresponsive to fluids and when systemic vascular resistance is low (

***Class IIb, LOE C*)**.[420,435]

Typically a dose of 2 to 20 mcg/kg per minute is used. Although low-dose dopamine infusion has been frequently recommended to maintain renal blood flow or improve renal function, data do not show benefit from such therapy.[311,312] At higher doses (>5 mcg/kg per minute), dopamine stimulates cardiac ?-adrenergic receptors, but this effect may be reduced in infants and in patients with chronic congestive heart failure. Infusion rates >20 mcg/kg per minute may result in excessive vasoconstriction.[306,307] In one study in single ventricle postoperative cardiac patients, dopamine increased oxygen consumption while not improving blood pressure or cardiac output.[313]

5.1.2.2.3 Dobutamine Hydrochloride

Dobutamine has a relatively selective effect on ?1- and ?2-adrenergic receptors due to effects of the two isomers; one is an ?-adrenergic agonist, and the other is an ?-adrenergic antagonist.[314]Dobutamine increases myocardial contractility and can decrease peripheral vascular resistance. Titrate the infusion[308,315,316] to improve cardiac output and blood pressure due to poor myocardial function.[316]

5.1.2.2.4 Norepinephrine

Norepinephrine is a potent vasopressor promoting peripheral vasoconstriction. Titrate the infusion to treat shock with low systemic vascular resistance (septic, anaphylactic, spinal, or vasodilatory) unresponsive to fluid.

5.1.2.2.5 Sodium Nitroprusside

Sodium nitroprusside increases cardiac output by decreasing vascular resistance (afterload). If hypotension is related to poor myocardial function, consider using a combination of sodium nitroprusside to reduce afterload and an inotrope to improve contractility. Fluid administration may be required secondary to vasodilatory effects.

5.1.2.2.6 Inodilators

Inodilators (inamrinone and milrinone) augment cardiac output with little effect on myocardial oxygen demand.

It is reasonable to use an inodilator in a highly monitored setting for treatment of myocardial dysfunction with increased systemic or pulmonary vascular resistance. (Class IIa, LOE B)

Administration of fluids may be required secondary to vasodilatory effects.

Inodilators have a long half-life with a delay in reaching a steady-state hemodynamic effect after the infusion rate is changed (18 hours with inamrinone and 4.5 hours with milrinone). In cases of toxicity the cardiovascular effects may persist for several hours even after the infusion is discontinued.

5.1.3 Neurologic System - Updated

5.1.3.1 Post–Cardiac Arrest Temperature Management - Updated PEDS 387

Data suggest that fever after pediatric cardiac arrest is common and is associated with poor outcomes.[317] The 2010 AHA PALS Guidelines suggested a role for targeted temperature management after pediatric cardiac arrest (fever control for all patients, therapeutic hypothermia for some patients), but the recommendations were based predominantly on extrapolation from adult and asphyxiated newborn data.

5.1.3.1.1 2015 Evidence Summary

A large multi-institutional, prospective, randomized study of pediatric patients (aged 2 days to 18 years) with OHCA found no difference in survival with good functional outcome at 1 year and no additional complications in comatose patients who were treated with therapeutic hypothermia (32°C to 34°C), compared to those treated with normothermia (36°C to 37.5°C).[318]Observational data of pediatric patients resuscitated from IHCA or OHCA [319,320] have also shown that ICU duration of stay, neurologic outcomes, and mortality are unchanged with the use of therapeutic hypothermia. Only 1 small study of therapeutic hypothermia in survivors of pediatric asphyxial cardiac arrest[321] showed an improvement in mortality at hospital discharge, but with no difference in neurologic outcomes. Results are pending from a large multicenter randomized controlled trial of targeted temperature management for pediatric patients with IHCA (see Therapeutic Hypothermia After Cardiac Arrest).

5.1.3.1.2 2015 Recommendations—New

For infants and children remaining comatose after OHCA, it is reasonable either to maintain 5 days of continuous normothermia (36°C to 37.5°C) or to maintain 2 days of initial continuous hypothermia (32°C to 34°C) followed by 3 days of continuous normothermia. (Class IIa, LOE B-R)

Continuous measurement of temperature during this time period is recommended. (Class I, LOE B-NR)

For infants and children remaining comatose after IHCA, there is insufficient evidence to recommend cooling over normothermia.

Fever (temperature 38°C or higher) should be aggressively treated after ROSC. (Class I, LOE B-NR)

5.1.4 Renal System

Decreased urine output (<1 mL/kg per hour in infants and children or <30 mL/hour in adolescents) may be caused by prerenal conditions (eg, dehydration, inadequate systemic perfusion), renal ischemic damage, or a combination of factors. Avoid nephrotoxic medications and adjust the dose of medications excreted by the kidneys until you have checked renal function.

5.2 Prognostication - Updated

5.2.1 Postresuscitation Use of EEG for Prognosis - Updated PEDS 822

Early and reliable prognostication of neurologic outcome in pediatric survivors of cardiac arrest is essential to enable effective planning and family support (whether it be to continue or discontinue life-sustaining therapy).

5.2.1.1 2015 Evidence Summary

Observational data from 2 small pediatric studies[322,323] showed that a continuous and reactive tracing on an EEG performed in the first 7 days after cardiac arrest was associated with a significantly higher likelihood of good neurologic outcome at hospital discharge, while an EEG demonstrating a discontinuous or isoelectric tracing was associated with a poorer neurologic outcome at hospital discharge. There are no data correlating EEG findings with neurologic outcome after hospital discharge.

5.2.1.2 2015 Recommendation—New

EEGs performed within the first 7 days after pediatric cardiac arrest may be considered in prognosticating neurologic outcome at the time of hospital discharge but should not be used as the sole criterion. (Class IIb, LOE C-LD)

5.2.2 Predictive Factors After Cardiac Arrest - Updated PEDS 813

Several post-ROSC factors have been studied as possible predictors of survival and neurologic outcome after pediatric cardiac arrest. These include pupillary responses, the presence of hypotension, serum neurologic biomarkers, and serum lactate.

5.2.2.1 2015 Evidence Summary

Four observational studies supported the use of pupillary reactivity at 12 to 24 hours after cardiac arrest in predicting survival to discharge,[193,197,323,324] while 1 observational study found that reactive pupils 24 hours after cardiac arrest were associated with improved survival at 180 days with favorable neurologic outcome.[325]

Several serum biomarkers of neurologic injury have been considered for their prognostic value. Two small

observational studies found that lower neuron-specific enolase and S100B serum levels after arrest were associated with improved survival to hospital discharge and with improved survival with favorable neurologic outcome.[325,326]

One observational study found that children with lower lactate levels in the first 12 hours after arrest had an improved survival to hospital discharge.[327]

5.2.2.2 2015 Recommendation—New

The reliability of any 1 variable for prognostication in children after cardiac arrest has not been established. Practitioners should consider multiple factors when predicting outcomes in infants and children who achieve ROSC after cardiac arrest. (Class I, LOE C-LD)

5.3 Interhospital Transport

Ideally postresuscitation care should be provided by a trained team from a pediatric tertiary care facility. Contact such a team as early as possible during the resuscitation attempt and coordinate transportation with the receiving unit.[328]Transport team members should be trained and experienced in the care of critically ill and injured children[131,329] and supervised by a pediatric emergency medicine or pediatric critical care physician. The mode of transport and composition of the team should be established for each system based on the care required by each patient.[330]

Monitor exhaled CO2 (qualitative colorimetric detector or capnography) during interhospital or intrahospital transport of intubated patients. (Class IIa, LOE B)

5.4 Sudden Unexplained Deaths

Increasing evidence demonstrates that some cases of sudden infant death syndrome (SIDS) and sudden death in older children and young adults may be associated with genetic mutations causing cardiac ion channelopathies. Channelopathies are dysfunctional myocyte ion channels that result in abnormal movement of electrolytes into and/or out of the cell and predispose the heart to arrhythmia.[331-340] Mutations causing cardiac ion channelopathies are found in 2% to 10% of victims[331-337] and in 14% to 20% of young adults with sudden death in whom the cause of death is not evident in a routine autopsy.[338-340] Clinical and laboratory (eg, ECG, molecular-genetic screening) investigations of first- and second-degree relatives of patients with sudden unexplained death reported inherited, arrhythmogenic disease in 22% to 53% of families.[341-344]

Therefore when sudden unexplained cardiac arrest occurs in children and young adults, obtain a complete past medical and family history (including a history of syncopal episodes, seizures, unexplained accidents or drownings, or sudden unexpected death at <50 years old) and review previous ECGs.

All infants, children, and young adults with sudden unexpected death should, where resources allow, have an unrestricted, complete autopsy, preferably performed by a pathologist with training and experience in cardiovascular pathology. Consider appropriate preservation and genetic analysis of tissue to determine the presence of a channelopathy.

Refer families of patients that do not have a cause of death found on autopsy to a healthcare provider or center with expertise in arrhythmias. (Class I, LOE C)

6 Emergency Fluids and Medications

6.1 Estimating Weight

In the out-of-hospital setting, a child's weight is often unknown, and even experienced personnel may not be able to estimate it accurately.[108]Tapes with precalculated doses printed at various patient lengths have been clinically validated[108,111,127] and are more accurate than age-based or observer (parent or provider) estimate-based methods in the prediction of body weight.[104-111] Body habitus may also be an important consideration.[104,106,112,113]

6.2 Medication Dose Calculation

To calculate the dose of resuscitation medications, use the child's weight if it is known.

If the child's weight is unknown, it is reasonable to use a body length tape with precalculated doses. (Class IIa, LOE C)

It is unclear if an adjustment in the calculation of resuscitation medications is needed in obese children. Use of the actual body weight in calculation of drug doses in obese patients may result in potentially toxic doses. Length-based tapes estimate the 50th percentile weight for length (ie, ideal body weight), which may, theoretically, result in inadequate doses of some medications in obese patients. Despite these theoretical considerations, there are no data regarding the safety or efficacy of adjusting the doses of resuscitation medications in obese patients.

Therefore, regardless of the patient's habitus, use the actual body weight for calculating initial resuscitation drug doses or use a body length tape with precalculated doses. (Class IIb, LOE C)

For subsequent doses of resuscitation drugs in both nonobese and obese patients, expert providers may consider adjusting doses to achieve the desired therapeutic effect. In general, the dose administered to a child should not exceed the standard dose recommended for adult patients.

6.3 Medications

See Table 3

Table 3: 2010 - Medications for Pediatric Resuscitation

Open table in a new window

Medications for Pediatric Resuscitation		
Medication	**Dose**	**Remarks**
Adenosine	0.1 mg/kg (maximum 6 mg) Second dose: 0.2 mg/kg (maximum 12 mg)	Monitor ECG Rapid IV/IO bolus with flush
Amiodarone	5 mg/kg IV/IO; may repeat twice up to 15 mg/kg Maximum single dose 300 mg	Monitor ECG and blood pressure; adjust administration rate to urgency (IV push during cardiac arrest, more slowly–over 20–60 minutes with perfusing rhythm). Expert consultation strongly recommended prior to use when patient has a perfusing rhythmUse caution when administering with other drugs that prolong QT (obtain expert consultation)
Atropine	0.02 mg/kg IV/IO 0.04–0.06 mg/kg ET* Repeat once if neededMaximum single dose: 0.5 mg	Higher doses may be used with organophosphate poisoning
Calcium Chloride (10%)	20 mg/kg IV/IO (0.2 mL/kg) Maximum single dose 2 g	Administer slowly

Medication	Dose	Remarks
Epinephrine	0.01 mg/kg (0.1 mL/kg 1:10 000) IV/IO 0.1 mg/kg (0.1 mL/kg 1:1000) ET* Maximum dose 1 mg IV/IO; 2.5 mg ET	May repeat every 3–5 minutes
Glucose	0.5–1 g/kg IV/IO	Newborn: 5–10 mL/kg $D_{10}W$ Infants and Children: 2–4 mL/kg $D_{25}W$ Adolescents: 1–2 mL/kg $D_{50}W$
Lidocaine	Bolus: 1 mg/kg IV/IO Infusion: 20–50 mcg/kg/minute	
Magnesium Sulfate	25–50 mg/kg IV/IO over 10–20 minutes, faster in torsades de pointes Maximum dose 2 g	
Naloxone	Full Reversal: <5 y or ?20 kg: 0.1 mg/kg IV/IO/ET* ?5y or >20 kg: 2 mg IV/IO/ET*	Use lower doses to reverse respiratory depression associated with therapeutic opioid use (1–5 mcg/kg titrate to effect)
Procainamide	15 mg/kg IV/IO Adult Dose: 20 mg/min IV infusion to total maximum dose of 17 mg/kg	Monitor ECG and blood pressure; Give slowly–over 30–60 minutes. Use caution when administering with other drugs that prolong QT (obtain expert consultation)
Sodium bicarbonate	1 mEq/kg per dose IV/IO slowly	After adequate ventilation

- IV indicates intravenous; IO, intraosseous; and ET, via endotracheal tube.
- ?* Flush with 5 mL of normal saline and follow with 5 ventilations.

6.3.1 Adenosine

Adenosine causes a temporary atrioventricular (AV) nodal conduction block and interrupts reentry circuits that involve the AV node. The drug has a wide safety margin because of its short half-life. Adenosine should be given only IV or IO, followed by a rapid saline flush to promote drug delivery to the central circulation. If adenosine is given IV, it should be administered as close to the heart as possible. (See also “Arrhythmia.”)

6.3.2 Amiodarone

Amiodarone slows AV conduction, prolongs the AV refractory period and QT interval, and slows ventricular conduction (widens the QRS). Expert consultation is strongly recommended prior to administration of amiodarone to a pediatric patient with a perfusing rhythm. (See also “Arrhythmia.”)

6.3.2.1 Precautions

Monitor blood pressure and electrocardiograph (ECG) during intravenous administration of amiodarone. If the patient has a perfusing rhythm, administer the drug as slowly (over 20 to 60 minutes) as the patient's clinical condition allows; if the patient is in VF/pulseless VT, give the drug as a rapid bolus. Amiodarone causes hypotension through its vasodilatory property, and the severity is related to the infusion rate; hypotension is less common with the aqueous form of amiodarone.[345] Decrease the infusion rate if there is prolongation of the QT interval or heart block; stop the infusion if the QRS widens to >50% of baseline or hypotension develops. Other potential complications of amiodarone include bradycardia and torsades de pointes ventricular tachycardia. Amiodarone should not be administered together with another drug that causes QT prolongation, such as procainamide, without expert consultation.

6.3.3 Atropine

Atropine sulfate is a parasympatholytic drug that accelerates sinus or atrial pacemakers and increases the speed of AV conduction.

6.3.3.1 Precautions

Larger than recommended doses may be required in special circumstances such as organophosphate poisoning [346] or exposure to nerve gas agents.

6.3.4 Calcium

Calcium administration is not recommended for pediatric cardiopulmonary arrest in the absence of documented hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia. (Class III, LOE B)

Routine calcium administration in cardiac arrest provides no benefit[347-358] and may be harmful.[347-349]

If calcium administration is indicated during cardiac arrest, either calcium chloride or calcium gluconate may be considered. Hepatic dysfunction does not appear to alter the ability of calcium gluconate to raise serum calcium levels.[359] In critically ill children, calcium chloride may be preferred because it results in a greater increase in ionized calcium during the treatment of hypocalcemia.[360] In the nonarrest setting, if the only venous access is peripheral, calcium gluconate is recommended because it has a lower osmolality than calcium chloride and is therefore less irritating to the vein.

6.3.5 Epinephrine

The ?-adrenergic-mediated vasoconstriction of epinephrine increases aortic diastolic pressure and thus coronary perfusion pressure, a critical determinant of successful resuscitation from cardiac arrest.[361,362] At low doses, the ?-adrenergic effects may predominate, leading to decreased systemic vascular resistance; in the doses used during cardiac arrest, the vasoconstrictive ?-effects predominate.

6.3.5.1 Precautions

Do not administer catecholamines and sodium bicarbonate simultaneously through an IV catheter or tubing because alkaline solutions such as the bicarbonate inactivate the catecholamines.

In patients with a perfusing rhythm, epinephrine causes tachycardia; it may also cause ventricular ectopy, tachyarrhythmias, vasoconstriction, and hypertension.

6.3.6 Glucose

Because infants have a relatively high glucose requirement and low glycogen stores, they may develop hypoglycemia when energy requirements rise.[363]

Check blood glucose concentration during the resuscitation and treat hypoglycemia promptly. (Class I, LOE C)

6.3.7 Lidocaine

Lidocaine decreases automaticity and suppresses ventricular arrhythmias.[364]

6.3.7.1 Precautions

Lidocaine toxicity includes myocardial and circulatory depression, drowsiness, disorientation, muscle twitching, and seizures, especially in patients with poor cardiac output and hepatic or renal failure.[365,366]

6.3.8 Magnesium

Magnesium is indicated for the treatment of documented hypomagnesemia or for torsades de pointes (polymorphic VT associated with long QT interval). There is insufficient evidence to recommend for or against the routine administration of magnesium during cardiac arrest.[367-369]

6.3.8.1 Precautions

Magnesium produces vasodilation and may cause hypotension if administered rapidly.

6.3.9 Procainamide

Procainamide prolongs the refractory period of the atria and ventricles and depresses conduction velocity.

6.3.9.1 Precautions

There is limited clinical data on using procainamide in infants and children.[370-372] Infuse procainamide very slowly (over 30 to 60 minutes) while monitoring the ECG and blood pressure. Decrease the infusion rate if there is prolongation of the QT interval, or heart block; stop the infusion if the QRS widens to >50% of baseline or hypotension develops. Do not administer together with another drug causing QT prolongation, such as amiodarone, without expert consultation. Prior to using procainamide for a hemodynamically stable patient, expert consultation is strongly recommended.

6.3.10 Sodium Bicarbonate

Routine administration of sodium bicarbonate is not recommended in cardiac arrest. (Class III, LOE B)

Sodium bicarbonate may be administered for treatment of some toxidromes (see “Toxicological Emergencies,” below) or special resuscitation situations such as hyperkalemic cardiac arrest.

6.3.10.1 Precautions

During cardiac arrest or severe shock, arterial blood gas analysis may not accurately reflect tissue and venous acidosis.[373,374] Excessive sodium bicarbonate may impair tissue oxygen delivery;[375]cause hypokalemia, hypocalcemia, hypernatremia, and hyperosmolality;[376,377] decrease the VF threshold;[378]and impair cardiac function.

6.3.11 Vasopressin

There is insufficient evidence to make a recommendation for or against the routine use of vasopressin during cardiac arrest. Pediatric[379-381] and adult[382,383] case series/reports suggested that vasopressin[379] or its long-acting analog, terlipressin,[380,381] may be effective in refractory cardiac arrest when standard therapy fails. A large pediatric NRCPR case series, however, suggested that vasopressin is associated with lower ROSC, and a trend toward lower 24-hour and discharge survival.[384]A preponderance of controlled trials in adults do not demonstrate a benefit.[385-390]

7 Authorship and Disclosures - Updated

7.1 2015 Writing Team

Allan R. de Caen, Chair; Marc D. Berg; Leon Chameides; Cheryl K. Gooden; Robert W. Hickey; Halden F. Scott; Robert M. Sutton; Janice A. Tijssen; Alexis Topjian; Élise W. van der Jagt; Stephen M. Schexnayder; Ricardo A. Samson

Table 5: Part 12: Pediatric Advanced Life Support: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 12: Pediatric Advanced Life Support: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Allan R. de Caen	University of Alberta Stollery Children's Hospital	None	None	None	None	None	None	None
Marc D. Berg	University of Arizona	None	None	None	None	None	None	None
Leon Chameides	Connecticut Children's Medical Center	None	None	None	None	None	None	None
Cheryl K. Gooden	Mount Sinai Medical Center	None	None	None	None	None	None	None
Robert W. Hickey	Children's Hospital of Pittsburgh	None	None	None	None	None	None	None
Halden F. Scott	Children's Hospital Colorado	None	None	None	None	None	None	None
Robert M. Sutton	The Children's Hospital of Philadelphia; University of Pennsylvania School of Medicine	NIH†	None	Zoll Medical Sales Meeting Lecture (Speaking Honoraria)*	Webber and Gallagher*	None	None	None
Janice A. Tijssen	London Health Services Center	AMOSO Opportunities Fund*	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Alexis Topjian	The Children's Hospital of Philadelphia; University of Pennsylvania School of Medicine	NIH†	None	None	Expert witness for defense and plantiff*	None	None	None
E?lise W. van der Jagt	University of Rochester School of Medicine	NHLBI*	None	None	None	None	None	None
Consultants								
Ricardo A. Samson	The University of Arizona	None	None	None	None	None	American Heart Association†	None
Stephen M. Schexnayder	University of Arkansas; Arkansas Children's Hospital	None	None	None	Arkansas Dept. of Human Services*; Lewis Thomason*; University of Chicago*	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

7.2 2010 Writing Team

Monica E. Kleinman, Chair; Leon Chameides; Stephen M. Schexnayder; Ricardo A. Samson; Mary Fran Hazinski; Dianne L. Atkins; Marc D. Berg; Allan R. de Caen; Ericka L. Fink; Eugene B. Freid; Robert W. Hickey; Bradley S. Marino; Vinay M. Nadkarni; Lester T. Proctor; Faiqa A. Qureshi; Kennith Sartorelli; Alexis Topjian; Elise W. van der Jagt; Arno L. Zaritsky

Table 6: 2010 - Guidelines Part 14: PALS Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 14: PALS Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Monica E. Kleinman	Children's Hospital Anesthesia Foundation–Senior Associate in Critical Care Medicine	None	None	None	None	None	None
Leon Chameides	Emeritus Director Pediatric Cardiology, Clinical Professor, University of Connecticut	None	None	None	None	None	None
Stephen M. Schexnayder	University of Arkansas for Medical Sciences—Professor/ Division Chief; †AHA Compensated Consultant as Associate Senior Science Editor	*Pharmacokinetics of Proton Pumps inhibitors in Critically Ill patients	None	None	None	None	*Expert witness in several cases involving pediatric critical care & emergency medicine
Ricardo A. Samson	The University of Arizona: clinical care, teaching and research related to the field of Pediatric Cardiology in academic setting- Professor	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Mary Fran Hazinski	Vanderbilt University School of Nursing—Professor; AHA ECC Product Development—Senior Science Editor- † Significant compensation as a paid AHA consultant to help develop and edit the 2010 AHA Guidelines for CPR and ECC.	None	None	None	None	None	None
Dianne L. Atkins	University of Iowa—Profess * Compensated worksheet editor for the 2010 AHA Guidelines. Money is divided 2/3 to my institution and 1/3 to me.	None	None	None	None	None	*Defense expert witness for episode of ventricular fibrillation in a 2 year old child. Attorney are Buckley and Thereoux of Princeton, New Jersey
Marc D. Berg	University of Arizona - Staff Intensivist; Asso. Prof. Clinical Pediatrics, Attending Intensivist, Pediatric Critical Care Medicine	None	None	Travel expenses defrayed with an honorarium of $4000 for speaking at 13th Asian Australasian Congress of Anesthesiologists, Fukuoka, Japan 6/2010	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Allan R. de Caen	Self employed, pediatric intensivist	None	None	None	None	None	*Medical expert for Canadian Medical ProtectiveAssoc
Ericka L. Fink	Children's Hospital of Pittsburgh of UPMC–Assistant Professor	†National Institutes of Health, NINDS K23, Laerdal Foundation, and Children's Hospital of Pittsburgh Clinical and Translational Science Institute grants to study duration of hypothermia after pediatric cardiac arrest.	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Eugene B. Freid	Nemours Childrens Clinics–Anesth and Intensivist	None	None	*$1500.00 from University of North Carolina to Nemours Childrens Clinics for 3 lectures at annual anesthesiology conference-lectures related to anesthesia management of patients with cancer, operating room ventilators & postoperative nausea/vomitir No direct conflicts with Pediatric Life support topics	None	None	None
Robert W. Hickey	University of Pittsburgh–Pediatric Emergency Medicine Physician	†NIH sponsored research on the effect of cyclopentenone prostaglandins upon post-ischemic brain.	None	None	None	None	*Occasional expert witness (1–2 times per year)
Bradley S. Marino	Cincinnati Children's Hospital Medical Center–Associ Professor of Pediatrics	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Vinay M. Nadkarni	University of Pennsylvania, Children's Hospital of Philadelphia–Attending Physician, Pediatric Critical Care	†NIH RO1: Coinvestigator, Therapeutic Hypothermia After Pediatric Cardiac Arrest Center of Excellence Grant, PI, Laerdal Foundation for Acute Care Medicine AHRQ: Agency for Healthcare Research and Quality: PI, Tracheal Intubation Safety in Pediatric ICUs * NHTSA: Coinvestigator, Chest compression characteristics in children	None	None	None	None	*Volunteer (no salary or remuneration), World Federation of Pediatric Intensive and Critical Care Societies Volunteer (no salary), Data Safety and Monitoring Board, CIRC study
Lester T. Proctor	University of Wisconsin-Madison College of Medicine and Public Health–Profes	None	None	None	None	None	None
Faiqa A. Qureshi	Children's Specialty Group—Partner	None	None	None	None	None	None
Kennith Sartorelli	University of Vermont–Assc Professor of Surgery	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Alexis Topjian	University of Pennsylvania–Assistant Professor	*Site principal investigator at the Children's hospital of Philadelphia for the "Therpaeutic Hypothermia after Pediatric Cardiac Arrest" funded via an NIH U01	None	None	None	None	None
Elise W. van der Jagt	University of Rochester–Prof of Pediatrics and Critical Care	None	None	None	None	None	None
Arno L. Zaritsky	Childen's Hospital of The King's Daughters-Sr. VP for Clinical Services	None	None	None	None	*Data Safety Monitoring Board for NIH-funded pediatric hypothermia after cardiac arrest research project	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.
- ?* Modest.
- ?† Significant.

8 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and

Emergency Cardiovascular Care – Part 12: Pediatric Advanced Life Support. ECCguidelines.heart.org.

References

1. Girotra S, Spertus JA, Li Y, Berg RA, Nadkarni VM, Chan PS; American Heart Association Get With The Guidelines–Resuscitation Investigators. Survival trends in pediatric in-hospital cardiac arrests: an analysis from Get With The Guidelines-Resuscitation. Circ Cardiovasc Qual Outcomes. 2013;6:42–49. doi: 10.1161/CIRCOUTCOMES.112.967968.

2. Wolfe H, Zebuhr C, Topjian AA, Nishisaki A, Niles DE, Meaney PA, Boyle L, Giordano RT, Davis D, Priestley M, Apkon M, Berg RA, Nadkarni VM, Sutton RM. Interdisciplinary ICU cardiac arrest debriefing improves survival outcomes. Crit Care Med. 2014;42:1688–1695. doi: 10.1097/CCM.0000000000000327.

3. Matos RI, Watson RS, Nadkarni VM, Huang HH, Berg RA, Meaney PA, Carroll CL, Berens RJ, Praestgaard A, Weissfeld L, Spinella PC; American Heart Association's Get With The Guidelines–Resuscitation (Formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Duration of cardiopulmonary resuscitation and illness category impact survival and neurologic outcomes for in-hospital pediatric cardiac arrests. Circulation. 2013;127:442–451. doi: 10.1161/CIRCULATIONAHA.112.125625.

4. Berg RA, Sutton RM, Holubkov R, Nicholson CE, Dean JM, Harrison R, Heidemann S, Meert K, Newth C, Moler F, Pollack M, Dalton H, Doctor A, Wessel D, Berger J, Shanley T, Carcillo J, Nadkarni VM; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network and for the American Heart Association's Get With The Guidelines- Resuscitation (formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Ratio of PICU versus ward cardiopulmonary resuscitation events is increasing. Crit Care Med. 2013;41:2292–2297. doi: 10.1097/CCM.0b013e31828cf0c0.

5. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, Berg RA; Resuscitation Outcomes Consortium Investigators. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry- Cardiac Arrest. Circulation. 2009;119:1484–1491. doi: 10.1161/ CIRCULATIONAHA.108.802678.

6. Sutton RM, Case E, Brown SP, Atkins DL, Nadkarni VM, Kaltman J, Callaway C, Idris A, Nichol G, Hutchison J, Drennan IR, Austin M, Daya M, Cheskes S, Nuttall J, Herren H, Christenson J, Andrusiek D, Vaillancourt C, Menegazzi JJ, Rea TD, Berg RA, ROC Investigators. A quantitative analysis of out-of-hospital pediatric and adolescent resuscitation quality. A report from the ROC Epistry?Cardiac Arrest. Resuscitation. 2015;93:150–157. doi: 10.1016/j.resuscitation.2015.04.010.

7. InternationalLiaisonCommitteeonResuscitation.Part6:paediatricbasicand advanced life support: 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2005;67:271–291.

8. de Caen AR, Kleinman ME, Chameides L, Atkins DL, Berg RA, Berg MD, Bhanji F, Biarent D, Bingham R, Coovadia AH, Hazinski MF, Hickey RW, Nadkarni VM, Reis AG, Rodriguez-Nunez A, Tibballs J, Zaritsky AL, Zideman D; Paediatric Basic and Advanced Life Support Chapter Collaborators. Part 10: Paediatric basic and advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e213–e259. doi: 10.1016/j.resuscitation.2010.08.028.

9. Morley PT, Lang E, Aickin R, Billi JE, Eigel B, Ferrer JME, Finn Jc, Gent LM, Nadkarni VM, Nikolaou NI, Nolan JP, Perkins GD, Sayre MR, Travers AH, Wyllie J, Zideman DA, Part 2: evidence evaluation and management of conflicts of interest: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S40–S50. doi: 10.1161/CIR.0000000000000271.

10. Lang E, Morley PT, Aickin R, Billi JE, Eigel B, Ferrer JME, Finn JC, Gent LM, Griffin RE, Hazinski MF, Maconochie IK, Montgomery WH, Morrison LJ, Nadkarni VM, Nikolaou NI, Nolan JP, Perkins GD, Sayre MR, Travers AH, Wyllie J, Zideman DA. Part 2: evidence evaluation and management of conflicts of interest: 2015 International Liaison Committee on Resuscitation Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science and Treatment Recommendations. Resuscitation. 2015. In press.

11. Kleinman ME, Chameides L, Schexnayder SM, Samson RA, Hazinski MF, Atkins DL, Berg MD, de Caen AR, Fink EL, Freid EB, Hickey RW, Marino BS, Nadkarni VM, Proctor LT, Qureshi FA, Sartorelli K, Topjian A, van der Jagt EW, Zaritsky AL. Part 14: pediatric advanced life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S876–S908. doi: 10.1161/CIRCULATIONAHA.110.971101.

12. de Caen AR, Maconochie IK, Aickin R, Atkins DL, Biarent D, Guerguerian AM, Kleinman ME, Kloeck DA, Meaney PA, Nadkarni VM, Ng KC, Nuthall G, Reis AG, Shimizu N, Tibballs J, Veliz Pintos R; on behalf of the Pediatric Basic Life Support and Pediatric Advanced Life Support Chapter Collaborators. Part 6: pediatric basic life support and pediatric advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S177–S203. doi: 10.1161/CIR.0000000000000275.

13.

Maconochie IK, de Caen AR, Aickin R, Atkins DL, Biarent D, Guerguerian AM, Kleinman ME, Kloeck DA, Meaney PA, Nadkarni VM, Ng KC, Nuthall G, Reis AG, Shimizu N, Tibballs J, Veliz Pintos R; on behalf of the Pediatric Basic Life Support and Pediatric Advanced Life Support Chapter Collaborators. Part 6: pediatric basic life support and pediatric advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

14. Anwar-ul-Haque, Saleem AF, Zaidi S, Haider SR. Experience of pediatric rapid response team in a tertiary care hospital in Pakistan. Indian J Pediatr. 2010;77:273–276.

15. Hunt EA, Zimmer KP, Rinke ML, Shilkofski NA, Matlin C, Garger C, Dickson C, Miller MR. Transition from a traditional code team to a medical emergency team and categorization of cardiopulmonary arrests in a children's center. Arch Pediatr Adolesc Med. 2008;162:117–122. doi: 10.1001/archpediatrics.2007.33.

16. Sharek PJ, Parast LM, Leong K, Coombs J, Earnest K, Sullivan J, Frankel LR, Roth SJ. Effect of a rapid response team on hospital-wide mortality and code rates outside the ICU in a Children's Hospital. JAMA. 2007;298:2267–2274. doi: 10.1001/jama.298.19.2267.

17. Kotsakis A, Lobos AT, Parshuram C, Gilleland J, Gaiteiro R, Mohseni- Bod H, Singh R, Bohn D; Ontario Pediatric Critical Care Response Team Collaborative. Implementation of a multicenter rapid response system in pediatric academic hospitals is effective. Pediatrics. 2011;128:72–78. doi: 10.1542/peds.2010-0756.

18. Hanson CC, Randolph GD, Erickson JA, Mayer CM, Bruckel JT, Harris BD, Willis TS. A reduction in cardiac arrests and duration of clinical instability after implementation of a paediatric rapid response system. Postgrad Med J. 2010;86:314–318. doi: 10.1136/qshc.2007.026054.

19. Zenker P, Schlesinger A, Hauck M, Spencer S, Hellmich T, Finkelstein M, Thygeson MV, Billman G. Implementation and impact of a rapid response team in a children's hospital. Jt Comm J Qual Patient Saf. 2007;33:418–425.

20. Brilli RJ, Gibson R, Luria JW, Wheeler TA, Shaw J, Linam M, Kheir J, McLain P, Lingsch T, Hall-Haering A, McBride M. Implementation of a medical emergency team in a large pediatric teaching hospital prevents respiratory and cardiopulmonary arrests outside the intensive care unit. Pediatr Crit Care Med. 2007;8:236–146; quiz 247. doi: 10.1097/01. PCC.0000262947.72442.EA.

21. TibballsJ,KinneyS.Reductionofhospitalmortalityandofpreventablecardiac arrest and death on introduction of a pediatric medical emergency team. Pediatr Crit Care Med. 2009;10:306–312. doi: 10.1097/PCC.0b013e318198b02c.

22. Randhawa S, Roberts-Turner R, Woronick K, DuVal J. Implementing and sustaining evidence-based nursing practice to reduce pediatric cardiopulmonary arrest. West J Nurs Res. 2011;33:443–456. doi: 10.1177/0193945910379585.

23. Carcillo JA, Davis AL, Zaritsky A. Role of early fluid resuscitation in pediatric septic shock. JAMA. 1991;266:1242–1245.

24. Hartman ME, Linde-Zwirble WT, Angus DC, Watson RS. Trends in the epidemiology of pediatric severe sepsis. Pediatr Crit Care Med. 2013;14:686–693. doi: 10.1097/PCC.0b013e3182917fad.

25. Balamuth F, Weiss SL, Neuman MI, Scott H, Brady PW, Paul R, Farris RW, McClead R, Hayes K, Gaieski D, Hall M, Shah SS, Alpern ER. Pediatric severe sepsis in U.S. children's hospitals. Pediatr Crit Care Med. 2014;15:798–805. doi: 10.1097/PCC.0000000000000225.

26. Maitland K, Kiguli S, Opoka RO, Engoru C, Olupot-Olupot P, Akech SO, Nyeko R, Mtove G, Reyburn H, Lang T, Brent B, Evans JA, Tibenderana JK, Crawley J, Russell EC, Levin M, Babiker AG, Gibb DM; FEAST Trial Group. Mortality after fluid bolus in African children with severe infection. N Engl J Med. 2011;364:2483–2495. doi: 10.1056/NEJMoa1101549.

27. Upadhyay M, Singhi S, Murlidharan J, Kaur N, Majumdar S. Randomized evaluation of fluid resuscitation with crystalloid (saline) and colloid (polymer from degraded gelatin in saline) in pediatric septic shock. Indian Pediatr. 2005;42:223–231.

28. Maitland K, Pamba A, Newton CR, Levin M. Response to volume resuscitation in children with severe malaria. Pediatr Crit Care Med. 2003;4:426– 431. doi: 10.1097/01.PCC.0000090293.32810.4E.

29. Cifra H, Velasco J. A comparative study of the efficacy of 6% Haes-Steril and Ringer's lactate in the management of dengue shock syndrome. Crit Care Shock. 2003;6:95–100.

30. Dung NM, Day NP, Tam DT, Loan HT, Chau HT, Minh LN, Diet TV, Bethell DB, Kneen R, Hien TT, White NJ, Farrar JJ. Fluid replacement in dengue shock syndrome: a randomized, double-blind comparison of four intravenous-fluid regimens. Clin Infect Dis. 1999;29:787–794. doi: 10.1086/520435.

31. Ngo NT, Cao XT, Kneen R, Wills B, Nguyen VM, Nguyen TQ, Chu VT, Nguyen TT, Simpson JA, Solomon T, White NJ, Farrar J. Acute management of dengue shock syndrome: a randomized double-blind comparison of 4 intravenous fluid regimens in the first hour. Clin Infect Dis. 2001;32:204–213. doi: 10.1086/318479.

32. Wills BA, Nguyen MD, Ha TL, Dong TH, Tran TN, Le TT, Tran VD, Nguyen TH, Nguyen VC, Stepniewska K, White NJ, Farrar JJ. Comparison of three fluid solutions for resuscitation in dengue shock syndrome. N Engl J Med. 2005;353:877–889. doi: 10.1056/NEJMoa044057.

33.

den Brinker M, Hokken-Koelega AC, Hazelzet JA, de Jong FH, Hop WC, Joosten KF. One single dose of etomidate negatively influences adrenocortical performance for at least 24h in children with meningococcal sepsis. Intensive Care Med. 2008;34:163–168.

34. Jabre P, Combes X, Lapostolle F, Dhaouadi M, Ricard-Hibon A, Vivien B, Bertrand L, Beltramini A, Gamand P, Albizzati S, Perdrizet D, Lebail G, Chollet-Xemard C, Maxime V, Brun-Buisson C, Lefrant JY, Bollaert PE, Megarbane B, Ricard JD, Anguel N, Vicaut E, Adnet F. Etomidate versus ketamine for rapid sequence intubation in acutely ill patients: a multicentre randomised controlled trial. Lancet. 2009;374:293–300.

35. Sprung CL, Annane D, Keh D, Moreno R, Singer M, Freivogel K, Weiss YG, Benbenishty J, Kalenka A, Forst H, Laterre PF, Reinhart K, Cuthbertson BH, Payen D, Briegel J. Hydrocortisone therapy for patients with septic shock. N Engl J Med. 2008;358:111–124.

36. Alderson P, Schierhout G, Roberts I, Bunn F. Colloids versus crystalloids for fluid resuscitation in critically ill patients. In: The Cochrane Library. Oxford: Update Software. 2003().

37. Finfer S, Bellomo R, Boyce N, French J, Myburgh J, Norton R. A comparison of albumin and saline for fluid resuscitation in the intensive care unit. N Engl J Med. 2004;350:2247–2256.

38. Choi PT, Yip G, Quinonez LG, Cook DJ. Crystalloids vs. colloids in fluid resuscitation: a systematic review. Crit Care Med. 1999;27:200–210.

39. Myburgh J, Cooper DJ, Finfer S, Bellomo R, Norton R, Bishop N, Kai Lo S, Vallance S. Saline or albumin for fluid resuscitation in patients with traumatic brain injury. N Engl J Med. 2007;357:874–884.

40. Huang PP, Stucky FS, Dimick AR, Treat RC, Bessey PQ, Rue LW. Hypertonic sodium resuscitation is associated with renal failure and death. Ann Surg. 221:543–554, 1995; discussion 554–547.

41. Simma B, Burger R, Falk M, Sacher P, Fanconi S. A prospective, randomized, and controlled study of fluid management in children with severe head injury: lactated Ringer's solution versus hypertonic saline. Crit Care Med. 1998;26:1265–1270.

42. Bunn F, Roberts I, Tasker R, Akpa E. Hypertonic versus isotonic crystalloid for fluid resuscitation in critically ill patients. In: The Cochrane Library. Oxford: Update Software. 2003().

43. Teele SA, Allan CK, Laussen PC, Newburger JW, Gauvreau K, Thiagarajan RR. Management and outcomes in pediatric patients presenting with acute fulminant myocarditis. J Pediatr. 2011;158:638–643.e1. doi: 10.1016/j. jpeds.2010.10.015.

44. Ludot H, Tharin JY, Belouadah M, Mazoit JX, Malinovsky JM. Successful resuscitation after ropivacaine and lidocaine-induced ventricular arrhythmia following posterior lumbar plexus block in a child [published erratum appears in Anesth Analg. 2008;107:238]. Anesth Analg. 2008;106:1572–1574.

45. Hollander JE, Hoffman RS, Gennis P, Fairweather P, DiSano MJ, Schumb DA, Feldman JA, Fish SS, Dyer S, Wax P, et al. Prospective multicenter evaluation of cocaine-associated chest pain. Cocaine Associated Chest Pain (COCHPA) Study Group. Acad Emerg Med. 1994;1:330–339.

46. Brody SL, Slovis CM, Wrenn KD. Cocaine-related medical problems: consecutive series of 233 patients. Am J Med. 1990;88:325–331.

47. Bauman JL, Grawe JJ, Winecoff AP, Hariman RJ. Cocaine-related sudden cardiac death: a hypothesis correlating basic science and clinical observations. J Clin Pharmacol. 1994;34:902–911.

48. Kolecki PF, Curry SC. Poisoning by sodium channel blocking agents. Crit Care Clin. 1997;13:829–848.

49. Lange RA, Cigarroa RG, Flores ED, McBride W, Kim AS, Wells PJ, Bedotto JB, Danziger RS, Hillis LD. Potentiation of cocaine-induced coronary vasoconstriction by beta-adrenergic blockade. Ann Intern Med. 1990;112:897–903.

50. Dziukas LJ, Vohra J. Tricyclic antidepressant poisoning. Med J Aust. 1991;154:344–350.

51. Liebelt EL. Targeted management strategies for cardiovascular toxicity from tricyclic antidepressant overdose: the pivotal role for alkalinization and sodium loading. Pediatr Emerg Care. 1998;14:293–298.

52. Teba L, Schiebel F, Dedhia HV, Lazzell VA. Beneficial effect of norepinephrine in the treatment of circulatory shock caused by tricyclic antidepressant overdose. Am J Emerg Med. 1988;6:566–568.

53. Tran TP, Panacek EA, Rhee KJ, Foulke GE. Response to dopamine vs norepinephrine in tricyclic antidepressant-induced hypotension. Acad Emerg Med. 1997;4:864–868.

54. Williams JM, Hollingshed MJ, Vasilakis A, Morales M, Prescott JE, Graeber GM. Extracorporeal circulation in the management of severe tricyclic antidepressant overdose. Am J Emerg Med. 1994;12:456–458.

55. Larkin GL, Graeber GM, Hollingsed MJ. Experimental amitriptyline poisoning: treatment of severe cardiovascular toxicity with cardiopulmonary bypass. Ann Emerg Med. 1994;23:480–486.

56.

Ramoska EA, Spiller HA, Winter M, Borys D. A one-year evaluation of calcium channel blocker overdoses: toxicity and treatment. Ann Emerg Med. 1993;22:196–200.

57. Kerns W II., Schroeder D, Williams C, Tomaszewski C, Raymond R. Insulin improves survival in a canine model of acute beta-blocker toxicity. Ann Emerg Med. 1997;29:748–757.

58. Kline JA, Tomaszewski CA, Schroeder JD, Raymond RM. Insulin is a superior antidote for cardiovascular toxicity induced by verapamil in the anesthetized canine. J Pharmacol Exp Ther. 1993;267:744–750.

59. Yuan TH, Kerns WPI, Tomaszewski CA, Ford MD, Kline JA. Insulin-glucose as adjunctive therapy for severe calcium channel antagonist poisoning. J Toxicol Clin Toxicol. 1999;37:463–474.

60. Kerns W II., Kline J, Ford MD. Beta-blocker and calcium channel blocker toxicity. Emerg Med Clin North Am. 1994;12:365–390.

61. Lewis M, Kallenbach J, Germond C, Zaltzman M, Muller F, Steyn J, Zwi S. Survival following massive overdose of adrenergic blocking agents (acebutolol and labetalol). Eur Heart J. 1983;4:328–332.

62. Cruickshank JM, Neil-Dwyer G, Cameron MM, McAinsh J. beta-Adrenoreceptor-blocking agents and the blood-brain barrier. Clin Sci. 1980;59(suppl 6):453s–455s.

63. Weinstein RS. Recognition and management of poisoning with beta-adrenergic blocking agents. Ann Emerg Med. 1984;13:1123–1131.

64. Mills CA, Flacke JW, Flacke WE, Bloor BC, Liu MD. Narcotic reversal in hypercapnic dogs: comparison of naloxone and nalbuphine. Can J Anaesth. 1990;37:238–244.

65. Jones P, Peters MJ, Pinto da Costa N, Kurth T, Alberti C, Kessous K, Lode N, Dauger S. Atropine for critical care intubation in a cohort of 264 chil- dren and reduced mortality unrelated to effects on bradycardia. PLoS One. 2013;8:e57478. doi: 10.1371/journal.pone.0057478.

66. Jones P, Dauger S, Denjoy I, Pinto da Costa N, Alberti C, Boulkedid R, Peters MJ. The effect of atropine on rhythm and conduction disturbances during 322 critical care intubations. Pediatr Crit Care Med. 2013;14:e289– e297. doi: 10.1097/PCC.0b013e31828a8624.

67. Fastle RK, Roback MG. Pediatric rapid sequence intubation: incidence of reflex bradycardia and effects of pretreatment with atropine. Pediatr Emerg Care. 2004;20:651–655.

68. Dauchot P, Gravenstein JS. Effects of atropine on the electrocardiogram in different age groups. Clin Pharmacol Ther. 1971;12:274–280.

69. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, Berg RA, Hiraide A. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet. 2010;375:1347–1354.

70. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. JAMA. 2005;293:305–310.

71. Nishisaki A, Nysaether J, Sutton R, Maltese M, Niles D, Donoghue A, Bishnoi R, Helfaer M, Perkins GD, Berg R, Arbogast K, Nadkarni V. Effect of mattress deflection on CPR quality assessment for older children and adolescents. Resuscitation. 2009;80:540–545.

72. Noordergraaf GJ, Paulussen IW, Venema A, van Berkom PF, Woerlee PH, Scheffer GJ, Noordergraaf A. The impact of compliant surfaces on in-hospital chest compressions: effects of common mattresses and a backboard. Resuscitation. 2009;80:546–552.

73. Raju NV, Maisels MJ, Kring E, Schwarz-Warner L. Capillary refill time in the hands and feet of normal newborn infants. Clin Pediatr. 1999;38:139–144.

74. Brown LH, Prasad NH, Whitley TW. Adverse lighting condition effects on the assessment of capillary refill. Am J Emerg Med. 1994;12:46–47.

75. Haque IU, Zaritsky AL. Analysis of the evidence for the lower limit of systolic and mean arterial pressure in children. Pediatr Crit Care Med. 2007;8:138–144.

76. Zubrow AB, Hulman S, Kushner H, Falkner B. Determinants of blood pressure in infants admitted to neonatal intensive care units: a prospective multicenter study. Philadelphia Neonatal Blood Pressure Study Group. J Perinatol. 1995;15:470–479.

77. Lopez-Gil M, Brimacombe J, Alvarez M. Safety and efficacy of the laryngeal mask airway. A prospective survey of 1400 children. Anaesthesia. 1996;51:969–972.

78. Lopez-Gil M, Brimacombe J, Cebrian J, Arranz J. Laryngeal mask airway in pediatric practice: a prospective study of skill acquisition by anesthesia residents. Anesthesiology. 1996;84:807–811.

79. Park C, Bahk JH, Ahn WS, Do SH, Lee KH. The laryngeal mask airway in infants and children. Can J Anaesth. 2001;48:413–417.

80.

Bagshaw O. The size 1.5 laryngeal mask airway (LMA) in paediatric anaesthetic practice. Paediatr Anaesth. 2002;12:420–423.

81. Harnett M, Kinirons B, Heffernan A, Motherway C, Casey W. Airway complications in infants: comparison of laryngeal mask airway and the facemask-oral airway. Can J Anaesth. 2000;47:315–318.

82. Flick RP, Wilder RT, Pieper SF, van Koeverden K, Ellison KM, Marienau ME, Hanson AC, Schroeder DR, Sprung J. Risk factors for laryngospasm in children during general anesthesia. Paediatr Anaesth. 2008;18:289–296.

83. Brown LH, Manring EA, Kornegay HB, Prasad NH. Can prehospital personnel detect hypoxemia without the aid of pulse oximeters? Am J Emerg Med. 1996;14:43–44.

84. Gausche M, Lewis RJ, Stratton SJ, Haynes BE, Gunter CS, Goodrich SM, Poore PD, McCollough MD, Henderson DP, Pratt FD, Seidel JS. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. JAMA. 2000;283:783–790.

85. Stockinger ZT, McSwain NE Jr.. Prehospital endotracheal intubation for trauma does not improve survival over bag-valve-mask ventilation. J Trauma. 2004;56:531–536.

86. Pitetti R, Glustein JZ, Bhende MS. Prehospital care and outcome of pediatric out-of-hospital cardiac arrest. Prehosp Emerg Care. 2002;6:283–290.

87. Gerritse BM, Draaisma JM, Schalkwijk A, van Grunsven PM, Scheffer GJ. Should EMS-paramedics perform paediatric tracheal intubation in the field? Resuscitation. 2008;79:225–229.

88. A prospective multicenter evaluation of prehospital airway management performance in a large metropolitan region. Prehosp Emerg Care. 2009;13:304–310.

89. Garza AG, Algren DA, Gratton MC, Ma OJ. Populations at risk for intubation nonattempt and failure in the prehospital setting. Prehosp Emerg Care. 2005;9:163–166.

90. Hon KL, Olsen H, Totapally B, Leung TF. Hyperventilation at referring hospitals is common before transport in intubated children with neurological diseases. Pediatr Emerg Care. 2005;21:662–666.

91. Wang HE, Lave JR, Sirio CA, Yealy DM. Paramedic intubation errors: isolated events or symptoms of larger problems? Health Aff (Millwood). 2006;25:501–509.

92. Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. Arch Intern Med. 1992;152:145–149.

93. Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004;109:1960–1965.

94. Wik L, Kramer-Johansen J, Myklebust H, Sorebo H, Svensson L, Fellows B, Steen PA. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. JAMA. 2005;293:299–304.

95. Gausche-Hill M, Lewis RJ, Gunter CS, Henderson DP, Haynes BE, Stratton SJ. Design and implementation of a controlled trial of pediatric endotracheal intubation in the out-of-hospital setting. Ann Emerg Med. 2000;36:356–365.

96. Jesudian MC, Harrison RR, Keenan RL, Maull KI. Bag-valve-mask ventilation; two rescuers are better than one: preliminary report. Crit Care Med. 1985;13:122–123.

97. Davidovic L, LaCovey D, Pitetti RD. Comparison of 1- versus 2-person bag-valve-mask techniques for manikin ventilation of infants and children. Ann Emerg Med. 2005;46:37–42.

98. Berg MD, Idris AH, Berg RA. Severe ventilatory compromise due to gastric distention during pediatric cardiopulmonary resuscitation. Resuscitation. 1998;36:71–73.

99. Sirbaugh PE, Pepe PE, Shook JE, Kimball KT, Goldman MJ, Ward MA, Mann DM. A prospective, population-based study of the demographics, epidemiology, management, and outcome of out-of-hospital pediatric cardiopulmonary arrest. Ann Emerg Med. 1999;33:174–184.

100. Brownstein DR, Quan L, Orr R, Wentz KR, Copass MK. Paramedic intubation training in a pediatric operating room. Am J Emerg Med. 1992;10:418–420.

101. Vilke GM, Steen PJ, Smith AM, Chan TC. Out-of-hospital pediatric intubation by paramedics: the San Diego experience. J Emerg Med. 2002;22:71–74.

102. Ma OJ, Atchley RB, Hatley T, Green M, Young J, Brady W. Intubation success rates improve for an air medical program after implementing the use of neuromuscular blocking agents. Am J Emerg Med. 1998;16:125–127.

103.

Sing RF, Rotondo MF, Zonies DH, Schwab CW, Kauder DR, Ross SE, Brathwaite CC. Rapid sequence induction for intubation by an aeromedical transport team: a critical analysis. Am J Emerg Med. 1998;16:598–602.

104. Sagarin MJ, Chiang V, Sakles JC, Barton ED, Wolfe RE, Vissers RJ, Walls RM. Rapid sequence intubation for pediatric emergency airway management. Pediatr Emerg Care. 2002;18:417–423.

105. Black K, Barnett P, Wolfe R, Young S. Are methods used to estimate weight in children accurate? Emerg Med (Fremantle). 2002;14:160–165.

106. Chan GM, Moyer-Mileur L, Rallison L. An easy and accurate method of estimating newborn birthweight for resuscitation. Am J Perinatol. 9():371–373, 1992.

107. Garland JS, Kishaba RG, Nelson DB, Losek JD, Sobocinski KA. A rapid and accurate method of estimating body weight. Am J Emerg Med. 1986;4:390–393.

108. Krieser D, Nguyen K, Kerr D, Jolley D, Clooney M, Kelly AM. Parental weight estimation of their child's weight is more accurate than other weight estimation methods for determining children's weight in an emergency department? Emerg Med J. 2007;24:756–759.

109. Lubitz DS, Seidel JS, Chameides L, Luten RC, Zaritsky AL, Campbell FW. A rapid method for estimating weight and resuscitation drug dosages from length in the pediatric age group. Ann Emerg Med. 1988;17:576–581.

110. Varghese A, Vasudevan VK, Lewin S, Indumathi CK, Dinakar C, Rao SD. Do the length-based (Broselow) Tape, APLS, Argall and Nelson's formulae accurately estimate weight of Indian children? Indian Pediatr. 2006;43:889–894.

111. Vilke GM, Marino A, Fisher R, Chan TC. Estimation of pediatric patient weight by EMT-PS. J Emerg Med. 2001;21:125–128.

112. Hofer CK, Ganter M, Tucci M, Klaghofer R, Zollinger A. How reliable is length-based determination of body weight and tracheal tube size in the paediatric age group? The Broselow tape reconsidered. Br J Anaesth. 2002;88:283–285.

113. DuBois D, Baldwin S, King WD. Accuracy of weight estimation methods for children. Pediatr Emerg Care. 2007;23:227–230.

114. Yamamoto LG, Inaba AS, Young LL, Anderson KM. Improving length-based weight estimates by adding a body habitus (obesity) icon. Am J Emerg Med. 2009;27:810–815.

115. Johnson TN. The problems in scaling adult drug doses to children. Arch Dis Child. 2008;93:207–211.

116. Mahmood I. Prediction of drug clearance in children: impact of allometric exponents, body weight, and age. Ther Drug Monit. 2007;29:271–278.

117. Edginton AN, Schmitt W, Willmann S. Development and evaluation of a generic physiologically based pharmacokinetic model for children. Clin Pharmacokinet. 2006;45:1013–1034.

118. Gill MA, Ueda CT. Novel method for the determination of pediatric dosages. Am J Hosp Pharm. 1976;33:389–392. Abstract

119. Rodriguez W, Selen A, Avant D, Chaurasia C, Crescenzi T, Gieser G, Di Giacinto J, Huang SM, Lee P, Mathis L, Murphy D, Murphy S, Roberts R, Sachs HC, Suarez S, Tandon V, Uppoor RS. Improving pediatric dosing through pediatric initiatives: what we have learned. Pediatrics. 2008;121:530–539.

120. Traub SL, Kichen L. Estimating ideal body mass in children. Am J Hosp Pharm. 1983;40:107–110. Abstract

121. Khine HH, Corddry DH, Kettrick RG, Martin TM, McCloskey JJ, Rose JB, Theroux MC, Zagnoev M. Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia. Anesthesiology. 1997;86:627–631; discussion 627A.

122. Weiss M, Dullenkopf A, Fischer JE, Keller C, Gerber AC. Prospective randomized controlled multi-centre trial of cuffed or uncuffed endotracheal tubes in small children. Br J Anaesth. 2009;103:867–873.

123. Bordet F, Allaouchiche B, Lansiaux S, Combet S, Pouyau A, Taylor P, Bonnard C, Chassard D. Risk factors for airway complications during general anaesthesia in paediatric patients. Paediatr Anaesth. 2002;12:762–769.

124. Newth CJ, Rachman B, Patel N, Hammer J. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. J Pediatr. 2004;144:333–337.

125. Deakers TW, Reynolds G, Stretton M, Newth CJ. Cuffed endotracheal tubes in pediatric intensive care. J Pediatr. 1994;125:57–62.

126. Mhanna MJ, Zamel YB, Tichy CM, Super DM. The “air leak” test around the endotracheal tube, as a predictor of postextubation stridor, is age dependent in children. Crit Care Med. 2002;30:2639–2643.

127. Browning DH, Graves SA. Incidence of aspiration with endotracheal tubes in children. J Pediatr. 1983;102:582–584.

128. Luten RC, Wears RL, Broselow J, Zaritsky A, Barnett TM, Lee T, Bailey A, Vally R, Brown R, Rosenthal B. Length-based endotracheal tube and emergency equipment in pediatrics. Ann Emerg Med. 1992;21:900–904.

129. Davis D, Barbee L, Ririe D. Pediatric endotracheal tube selection: a comparison of age-based and height-based criteria. AANA J. 1998;66:299–303.

130. Daugherty RJ, Nadkarni V, Brenn BR. Endotracheal tube size estimation for children with pathological short stature. Pediatr Emerg Care. 2006;22:710–717.

131. Katz SH, Falk JL. Misplaced endotracheal tubes by paramedics in an urban emergency medical services system. Ann Emerg Med. 2001;37:32–37.

132. Beyer AJd, Land G, Zaritsky A. Nonphysician transport of intubated pediatric patients: a system evaluation. Crit Care Med. 1992;20:961–966.

133. Andersen KH, Schultz-Lebahn T. Oesophageal intubation can be undetected by auscultation of the chest. Acta Anaesthesiol Scand. 1994;38:580–582.

134. Poirier MP, Gonzalez Del-Rey JA, McAneney CM, DiGiulio GA. Utility of monitoring capnography, pulse oximetry, and vital signs in the detection of airway mishaps: a hyperoxemic animal model. Am J Emerg Med. 1998;16:350–352.

135. Birmingham PK, Cheney FW, Ward RJ. Esophageal intubation: a review of detection techniques. Anesth Analg. 1986;65:886–891.

136. Donn SM, Kuhns LR. Mechanism of endotracheal tube movement with change of head position in the neonate. Pediatr Radiol. 1980;9:37–40.

137. Hartrey R, Kestin IG. Movement of oral and nasal tracheal tubes as a result of changes in head and neck position. Anaesthesia. 1995;50:682–687.

138. Cantineau JP, Merckx P, Lambert Y, Sorkine M, Bertrand C, Duvaldestin P. Effect of epinephrine on end-tidal carbon dioxide pressure during prehospital cardiopulmonary resuscitation. Am J Emerg Med. 1994;12:267–270.

139. Ornato JP, Shipley JB, Racht EM, Slovis CM, Wrenn KD, Pepe PE, Almeida SL, Ginger VF, Fotre TV. Multicenter study of a portable, hand-size, colorimetric end-tidal carbon dioxide detection device. Ann Emerg Med. 1992;21:518–523.

140. Ward KR, Yealy DM. End-tidal carbon dioxide monitoring in emergency medicine. Part 2: Clinical applications. Acad Emerg Med. 1998;5:637–646.

141. Hand IL, Shepard EK, Krauss AN, Auld PA. Discrepancies between transcutaneous and end-tidal carbon dioxide monitoring in the critically ill neonate with respiratory distress syndrome. Crit Care Med. 1989;17:556–559.

142. Tobias JD, Meyer DJ. Noninvasive monitoring of carbon dioxide during respiratory failure in toddlers and infants: end-tidal versus transcutaneous carbon dioxide. Anesth Analg. 1997;85:55–58.

143. Young KD, Seidel JS. Pediatric cardiopulmonary resuscitation: a collective review. Ann Emerg Med. 1999;33:195–205.

144. Reis AG, Nadkarni V, Perondi MB, Grisi S, Berg RA. A prospective investigation into the epidemiology of in-hospital pediatric cardiopulmonary resuscitation using the international Utstein reporting style. Pediatrics. 2002;109:200–209.

145. Samson RA, Nadkarni VM, Meaney PA, Carey SM, Berg MD, Berg RA. Outcomes of in-hospital ventricular fibrillation in children. N Engl J Med. 2006;354:2328–2339.

146. Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: a graphic model. Ann Emerg Med. 1993;22:1652–1658.

147. Hamrick JL, Hamrick JT, Lee JK, Lee BH, Koehler RC, Shaffner DH. Efficacy of chest compressions directed by end-tidal CO2 feedback in a pediatric resuscitation model of basic life support. J Am Heart Assoc. 2014;3:e000450. doi: 10.1161/JAHA.113.000450.

148. Sheak KR, Wiebe DJ, Leary M, Babaeizadeh S, Yuen TC, Zive D, Owens PC, Edelson DP, Daya MR, Idris AH, Abella BS. Quantitative relationship between end-tidal carbon dioxide and CPR quality during both in-hospital and out-of-hospital cardiac arrest. Resuscitation. 2015;89:149–154. doi: 10.1016/j.resuscitation.2015.01.026.

149. Sutton RM, Friess SH, Bhalala U, Maltese MR, Naim MY, Bratinov G, Niles D, Nadkarni VM, Becker LB, Berg RA. Hemodynamic directed CPR improves short-term survival from asphyxia-associ- ated cardiac arrest. Resuscitation. 2013;84:696–701. doi: 10.1016/j.resuscitation.2012.10.023.

150. Friess SH, Sutton RM, Bhalala U, Maltese MR, Naim MY, Bratinov G, Weiland TR 3rd, Garuccio M, Nadkarni VM, Becker LB, Berg RA. Hemodynamic directed cardiopulmonary resuscitation improves short- term survival from ventricular fibrillation cardiac arrest. Crit Care Med. 2013;41:2698–2704. doi: 10.1097/CCM.0b013e318298ad6b.

151. Rosetti VA, Thompson BM, Miller J, Mateer JR, Aprahamian C. Intraosseous infusion: an alternative route of pediatric intravascular access. Ann Emerg Med. 1985;14:885–888.

152. Brunette DD, Fischer R. Intravascular access in pediatric cardiac arrest. Am J Emerg Med. 1988;6:577–579.

153. Seigler RS, Tecklenburg FW, Shealy R. Prehospital intraosseous infusion by emergency medical services personnel: a prospective study. Pediatrics. 1989;84:173–177.

154. Glaeser PW, Hellmich TR, Szewczuga D, Losek JD, Smith DS. Five-year experience in prehospital intraosseous infusions in children and adults. Ann Emerg Med. 1993;22:1119–1124.

155. Ellemunter H, Simma B, Trawoger R, Maurer H. Intraosseous lines in preterm and full term neonates. Arch Dis Child Fetal Neonatal Ed. 1999;80:F74–F75.

156. Claudet I, Baunin C, Laporte-Turpin E, Marcoux MO, Grouteau E, Cahuzac JP. Long-term effects on tibial growth after intraosseous infusion: a prospective, radiographic analysis. Pediatr Emerg Care. 2003;19:397–401.

157. Fiorito BA, Mirza F, Doran TM, Oberle AN, Cruz EC, Wendtland CL, Abd-Allah SA. Intraosseous access in the setting of pediatric critical care transport. Pediatr Crit Care Med. 2005;6:50–53.

158. Horton MA, Beamer C. Powered intraosseous insertion provides safe and effective vascular access for pediatric emergency patients. Pediatr Emerg Care. 2008;24:347–350.

159. Kanter RK, Zimmerman JJ, Strauss RH, Stoeckel KA. Pediatric emergency intravenous access. Evaluation of a protocol. Am J Dis Child. 1986;140:132–134.

160. Fiser DH. Intraosseous infusion. N Engl J Med. 1990;322:1579–1581.

161. Guy J, Haley K, Zuspan SJ. Use of intraosseous infusion in the pediatric trauma patient. J Pediatr Surg. 1993;28:158–161.

162. Berg RA. Emergency infusion of catecholamines into bone marrow. Am J Dis Child. 1984;138:810–811.

163. Andropoulos DB, Soifer SJ, Schreiber MD. Plasma epinephrine concentrations after intraosseous and central venous injection during cardiopulmonary resuscitation in the lamb. J Pediatr. 1990;116:312–315.

164. Johnson L, Kissoon N, Fiallos M, Abdelmoneim T, Murphy S. Use of intraosseous blood to assess blood chemistries and hemoglobin during cardiopulmonary resuscitation with drug infusions. Crit Care Med. 1999;27:1147–1152.

165. Abdelmoneim T, Kissoon N, Johnson L, Fiallos M, Murphy S. Acid-base status of blood from intraosseous and mixed venous sites during prolonged cardiopulmonary resuscitation and drug infusions. Crit Care Med. 1999;27:1923–1928.

166. Orlowski JP, Porembka DT, Gallagher JM, Lockrem JD, VanLente F. Comparison study of intraosseous, central intravenous, and peripheral intravenous infusions of emergency drugs. Am J Dis Child. 1990;144:112–117.

167. Warren DW, Kissoon N, Sommerauer JF, Rieder MJ. Comparison of fluid infusion rates among peripheral intravenous and humerus, femur, malleolus, and tibial intraosseous sites in normovolemic and hypovolemic piglets. Ann Emerg Med. 1993;22:183–186.

168. Ward JTJ. Endotracheal drug therapy. Am J Emerg Med. 1983;1:71–82.

169. Johnston C. Endotracheal drug delivery. Pediatr Emerg Care. 1992;8:94–97.

170. Efrati O, Ben-Abraham R, Barak A, Modan-Moses D, Augarten A, Manisterski Y, Barzilay Z, Paret G. Endobronchial adrenaline: should it be reconsidered? Dose response and haemodynamic effect in dogs. Resuscitation. 2003;59:117–122.

171. Guay J, Lortie L. An evaluation of pediatric in-hospital advanced life support interventions using the pediatric Utstein guidelines: a review of 203 cardiorespiratory arrests. Can J Anaesth. 2004;51:373–378.

172. Niemann JT, Stratton SJ. Endotracheal versus intravenous epinephrine and atropine in out-of-hospital “primary” and postcountershock asystole. Crit Care Med. 2000;28:1815–1819.

173. Niemann JT, Stratton SJ, Cruz B, Lewis RJ. Endotracheal drug administration during out-of-hospital resuscitation: where are the survivors? Resuscitation. 2002;53:153–157.

174. Quinton DN, O'Byrne G, Aitkenhead AR. Comparison of endotracheal and peripheral intravenous adrenaline in cardiac arrest: is the endotracheal route reliable? Lancet. 1987;1:828–829.

175. Jasani MS, Nadkarni VM, Finkelstein MS, Mandell GA, Salzman SK, Norman ME. Effects of different techniques of endotracheal epinephrine administration in pediatric porcine hypoxic-hypercarbic cardiopulmonary arrest. Crit Care Med. 1994;22:1174–1180.

176. Battin M, Page B, Knight D. Is there still a place for endotracheal adrenaline in neonatal resuscitation? J Paediatr Child Health. 2007;43:504.

177. Lindemann R. Resuscitation of the newborn. Endotracheal administration of epinephrine. Acta Paediatr Scand. 1984;73:210–212.

178. Barber CA, Wyckoff MH. Use and efficacy of endotracheal versus intravenous epinephrine during neonatal cardiopulmonary resuscitation in the delivery room. Pediatrics. 2006;118:1028–1034.

179. Efrati O, Barak A, Ben-Abraham R, Modan-Moses D, Berkovitch M, Manisterski Y, Lotan D, Barzilay Z, Paret G. Should vasopressin replace adrenaline for endotracheal drug administration? Crit Care Med. 2003;31:572–576.

180. Elizur A, Ben-Abraham R, Manisterski Y, Barak A, Efrati O, Lotan D, Barzilay Z, Paret G. Tracheal epinephrine or norepinephrine preceded by beta blockade in a dog model. Can beta blockade bestow any benefits? Resuscitation. 2003;59:271–276.

181. Manisterski Y, Vaknin Z, Ben-Abraham R, Efrati O, Lotan D, Berkovitch M, Barak A, Barzilay Z, Paret G. Endotracheal epinephrine: a call for larger doses. Anesth Analg. 2002;95:1037–1041.

182. Orlowski JP, Gallagher JM, Porembka DT. Endotracheal epinephrine is unreliable. Resuscitation. 1990;19:103–113.

183. Paret G, Vaknin Z, Ezra D, Peleg E, Rosenthal T, Vardi A, Mayan H, Barzilay Z. Epinephrine pharmacokinetics and pharmacodynamics following endotracheal administration in dogs: the role of volume of diluent. Resuscitation. 1997;35:77–82.

184. Vaknin Z, Manisterski Y, Ben-Abraham R, Efrati O, Lotan D, Barzilay Z, Paret G. Is endotracheal adrenaline deleterious because of the beta adrenergic effect? Anesth Analg. 2001;92:1408–1412.

185. de Mos N, van Litsenburg RR, McCrindle B, Bohn DJ, Parshuram CS. Pediatric in-intensive-care-unit cardiac arrest: incidence, survival, and predictive factors. Crit Care Med. 2006;34:1209–1215. doi: 10.1097/01. CCM.0000208440.66756.C2.

186. Wu ET, Li MJ, Huang SC, Wang CC, Liu YP, Lu FL, Ko WJ, Wang MJ, Wang JK, Wu MH. Survey of outcome of CPR in pediatric in-hospital car- diac arrest in a medical center in Taiwan. Resuscitation. 2009;80:443–448. doi: 10.1016/j.resuscitation.2009.01.006.

187. Lowry AW, Morales DL, Graves DE, Knudson JD, Shamszad P, Mott AR, Cabrera AG, Rossano JW. Characterization of extracorporeal membrane oxygenation for pediatric cardiac arrest in the United States: analysis of the kids' inpatient database. Pediatr Cardiol. 2013;34:1422–1430. doi: 10.1007/s00246-013-0666-8.

188. Odegard KC, Bergersen L, Thiagarajan R, Clark L, Shukla A, Wypij D, Laussen PC. The frequency of cardiac arrests in patients with con- genital heart disease undergoing cardiac catheterization. Anesth Analg. 2014;118:175–182. doi: 10.1213/ANE.0b013e3182908bcb.

189. Ortmann L, Prodhan P, Gossett J, Schexnayder S, Berg R, Nadkarni V, Bhutta A; American Heart Association's Get With The Guidelines–Resuscitation Investigators. Outcomes after in-hospital cardiac arrest in children with cardiac disease: a report from Get With The Guidelines–Resuscitation. Circulation. 2011;124:2329–2337. doi: 10.1161/CIRCULATIONAHA.110.013466.

190. Morris MC, Wernovsky G, Nadkarni VM. Survival outcomes after extra- corporeal cardiopulmonary resuscitation instituted during active chest compressions following refractory in-hospital pediatric cardiac arrest. Pediatr Crit Care Med. 2004;5:440–446.

191. Raymond TT, Cunnyngham CB, Thompson MT, Thomas JA, Dalton HJ, Nadkarni VM; American Heart Association National Registry of CPR Investigators. Outcomes among neonates, infants, and children after extra- corporeal cardiopulmonary resuscitation for refractory inhospital pediatric cardiac arrest: a report from the National Registry of Cardiopulmonary Resuscitation. Pediatr Crit Care Med. 2010;11:362–371. doi: 10.1097/ PCC.0b013e3181c0141b.

192. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, Berg RA, Hiraide A; implementation working group for All-Japan Utstein Registry of the Fire and Disaster Management Agency. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nation- wide, population-based cohort study. Lancet. 2010;375:1347–1354. doi: 10.1016/S0140-6736(10)60064-5.

193. Young KD, Gausche-Hill M, McClung CD, Lewis RJ. A prospective, pop- ulation-based study of the epidemiology and outcome of out-of-hospital pediatric cardiopulmonary arrest. Pediatrics. 2004;114:157–164.

194. Moler FW, Donaldson AE, Meert K, Brilli RJ, Nadkarni V, Shaffner DH, Schleien CL, Clark RS, Dalton HJ, Statler K, Tieves KS, Hackbarth R, Pretzlaff R, van der Jagt EW, Pineda J, Hernan L, Dean JM; Pediatric Emergency Care Applied Research Network. Multicenter cohort study of out-of-hospital pediatric cardiac arrest. Crit Care Med. 2011;39:141–149. doi: 10.1097/CCM.0b013e3181fa3c17.

195. López-Herce J, García C, Rodríguez-Núñez A, Domínguez P, Carrillo A, Calvo C, Delgado MA; Spanish Study Group of Cardiopulmonary Arrest in Children. Long-term outcome of paediatric cardiorespiratory arrest in Spain. Resuscitation. 2005;64:79–85. doi: 10.1016/j.resuscitation.2004.07.010.

196. Reis AG, Nadkarni V, Perondi MB, Grisi S, Berg RA. A prospective inves- tigation into the epidemiology of in-hospital pediatric cardiopulmonary resuscitation using the international Utstein reporting style. Pediatrics. 2002;109:200–209.

197. Haque A, Rizvi A, Bano S. Outcome of in-hospital pediatric cardio- pulmonary arrest from a single center in Pakistan. Indian J Pediatr. 2011;78:1356–1360. doi: 10.1007/s12098-011-0439-4.

198. Meert KL, Donaldson A, Nadkarni V, Tieves KS, Schleien CL, Brilli RJ, Clark RS, Shaffner DH, Levy F, Statler K, Dalton HJ, van der Jagt EW, Hackbarth R, Pretzlaff R, Hernan L, Dean JM, Moler FW; Pediatric Emergency Care Applied Research Network. Multicenter cohort study of in-hospital pediatric cardiac arrest. Pediatr Crit Care Med. 2009;10:544– 553. doi: 10.1097/PCC.0b013e3181a7045c.

199. López-Herce J, Del Castillo J, Matamoros M, Cañadas S, Rodriguez- Calvo A, Cecchetti C, Rodriguez-Núñez A, Alvarez AC; Iberoamerican Pediatric Cardiac Arrest Study Network RIBEPCI. Factors associated with mortality in pediatric in-hospital cardiac arrest: a prospective multicenter multinational observational study. Intensive Care Med. 2013;39:309–318. doi: 10.1007/s00134-012-2709-7.

200. Tibballs J, Kinney S. A prospective study of outcome of in-patient pae- diatric cardiopulmonary arrest. Resuscitation. 2006;71:310–318. doi: 10.1016/j.resuscitation.2006.05.009.

201. Enright K, Turner C, Roberts P, Cheng N, Browne G. Primary cardiac arrest following sport or exertion in children presenting to an emergency department: chest compressions and early defibrillation can save lives, but is intravenous epinephrine always appropriate? Pediatr Emerg Care. 2012;28:336–339. doi: 10.1097/PEC.0b013e31824d8c78.

202. Dieckmann RA, Vardis R. High-dose epinephrine in pediatric out-of-hos- pital cardiopulmonary arrest. Pediatrics. 1995;95:901–913.

203. Jacobs IG, Finn JC, Jelinek GA, Oxer HF, Thompson PL. Effect of adrena- line on survival in out-of-hospital cardiac arrest: a randomised double- blind placebo-controlled trial. Resuscitation. 2011;82:1138–1143. doi: 10.1016/j.resuscitation.2011.06.029.

204. Valdes SO, Donoghue AJ, Hoyme DB, Hammond R, Berg MD, Berg RA, Samson RA; American Heart Association Get With The Guidelines- Resuscitation Investigators. Outcomes associated with amiodarone and lidocaine in the treatment of in-hospital pediatric cardiac arrest with pulseless ventricular tachycardia or ventricular fibrillation. Resuscitation. 2014;85:381–386. doi: 10.1016/j.resuscitation.2013.12.008.

205. Atkins DL, Sirna S, Kieso R, Charbonnier F, Kerber RE. Pediatric defibrillation: importance of paddle size in determining transthoracic impedance. Pediatrics. 1988;82:914–918.

206. Atkins DL, Kerber RE. Pediatric defibrillation: current flow is improved by using “adult” electrode paddles. Pediatrics. 1994;94:90–93.

207. Samson RA, Atkins DL, Kerber RE. Optimal size of self-adhesive preapplied electrode pads in pediatric defibrillation. Am J Cardiol. 1995;75:544–545.

208. Tibballs J, Carter B, Kiraly NJ, Ragg P, Clifford M. External and internal biphasic direct current shock doses for pediatric ventricular fibrillation and pulseless ventricular tachycardia. Pediatr Crit Care Med. 2010. In press.

209. Gutgesell HP, Tacker WA, Geddes LA, Davis S, Lie JT, McNamara DG. Energy dose for ventricular defibrillation of children. Pediatrics. 1976;58:898–901.

210. Berg MD, Samson RA, Meyer RJ, Clark LL, Valenzuela TD, Berg RA. Pediatric defibrillation doses often fail to terminate prolonged out- of- hospital ventricular fibrillation in children. Resuscitation. 2005;67:63–67. doi: 10.1016/j.resuscitation.2005.04.018.

211. Meaney PA, Nadkarni VM, Atkins DL, Berg MD, Samson RA, Hazinski MF, Berg RA; American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators. Effect of defibrilla- tion energy dose during in-hospital pediatric cardiac arrest. Pediatrics. 2011;127:e16–e23. doi: 10.1542/peds.2010-1617.

212. Rodríguez-Núñez A, López-Herce J, del Castillo J, Bellón JM; Iberian-American Paediatric Cardiac Arrest Study Network RIBEPCI. Shockable rhythms and defibrillation during in-hospital pediatric cardiac arrest. Resuscitation. 2014;85:387–391. doi: 10.1016/j. resuscitation.2013.11.015.

213. Rossano JW, Quan L, Kenney MA, Rea TD, Atkins DL. Energy doses for treatment of out-of-hospital pediatric ventricular fibril- lation. Resuscitation. 2006;70:80–89. doi: 10.1016/j.resuscitation. 2005.10.031.

214. Atkins DL, Hartley LL, York DK. Accurate recognition and effective treatment of ventricular fibrillation by automated external defibrillators in adolescents. Pediatrics. 1998;101():393–397.

215. Atkinson E, Mikysa B, Conway JA, Parker M, Christian K, Deshpande J, Knilans TK, Smith J, Walker C, Stickney RE, Hampton DR, Hazinski MF. Specificity and sensitivity of automated external defibrillator rhythm analysis in infants and children. Ann Emerg Med. 2003;42:185–196.

216. Cecchin F, Jorgenson DB, Berul CI, Perry JC, Zimmerman AA, Duncan BW, Lupinetti FM, Snyder D, Lyster TD, Rosenthal GL, Cross B, Atkins DL. Is arrhythmia detection by automatic external defibrillator accurate for children? Sensitivity and specificity of an automatic external defibrillator algorithm in 696 pediatric arrhythmias. Circulation. 2001;103:2483–2488.

217. Atkins DL, Scott WA, Blaufox AD, Law IH, Dick M II., Geheb F, Sobh J, Brewer JE. Sensitivity and specificity of an automated external defibrillator algorithm designed for pediatric patients. Resuscitation. 2008;76:168–174.

218. Atkins DL, Jorgenson DB. Attenuated pediatric electrode pads for automated external defibrillator use in children. Resuscitation. 2005;66:31–37.

219. Samson RA, Berg RA, Bingham R, Biarent D, Coovadia A, Hazinski MF, Hickey RW, Nadkarni V, Nichol G, Tibballs J, Reis AG, Tse S, Zideman D, Potts J, Uzark K, Atkins D. Use of automated external defibrillators for children: an update: an advisory statement from the pediatric advanced life support task force, International Liaison Committee on Resuscitation. Circulation. 2003;107:3250–3255.

220. Cobb LA, Fahrenbruch CE, Walsh TR, Copass MK, Olsufka M, Breskin M, Hallstrom AP. Influence of cardiopulmonary resuscitation prior to defibrillation in patients with out-of-hospital ventricular fibrillation. JAMA. 1999;281:1182–1188.

221. Wik L, Hansen TB, Fylling F, Steen T, Vaagenes P, Auestad BH, Steen PA. Delaying defibrillation to give basic cardiopulmonary resuscitation to patients with out-of-hospital ventricular fibrillation: a randomized trial. JAMA. 2003;289:1389–1395.

222. Yakaitis RW, Ewy GA, Otto CW, Taren DL, Moon TE. Influence of time and therapy on ventricular defibrillation in dogs. Crit Care Med. 1980;8:157–163.

223. van Haarst AD, van 't Klooster GA, van Gerven JM, Schoemaker RC, van Oene JC, Burggraaf J, Coene MC, Cohen AF. The influence of cisapride and clarithromycin on QT intervals in healthy volunteers. Clin Pharmacol Ther. 1998;64:542–546.

224. Ray WA, Murray KT, Meredith S, Narasimhulu SS, Hall K, Stein CM. Oral erythromycin and the risk of sudden death from cardiac causes. N Engl J Med. 2004;351:1089–1096.

225. Beland MJ, Hesslein PS, Finlay CD, Faerron-Angel JE, Williams WG, Rowe RD. Noninvasive transcutaneous cardiac pacing in children. Pacing Clin Electrophysiol. 1987;10:1262–1270.

226. Quan L, Graves JR, Kinder DR, Horan S, Cummins RO. Transcutaneous cardiac pacing in the treatment of out-of-hospital pediatric cardiac arrests. Ann Emerg Med. 1992;21:905–909.

227. Sreeram N, Wren C. Supraventricular tachycardia in infants: response to initial treatment. Arch Dis Child. 1990;65:127–129.

228. Aydin M, Baysal K, Kucukoduk S, Cetinkaya F, Yaman S. Application of ice water to the face in initial treatment of supraventricular tachycardia. Turk J Pediatr. 1995;37:15–17.

229. Ornato JP, Hallagan LF, Reese WA, Clark RF, Tayal VS, Garnett AR, Gonzalez ER. Treatment of paroxysmal supraventricular tachycardia in the emergency department by clinical decision analysis [published correction appears in Am J Emerg Med. 1990;8:85]. Am J Emerg Med. 1988;6:555–560.

230. Lim SH, Anantharaman V, Teo WS, Goh PP, Tan AT. Comparison of treatment of supraventricular tachycardia by Valsalva maneuver and carotid sinus massage. Ann Emerg Med. 1998;31:30–35.

231. Waxman MB, Wald RW, Sharma AD, Huerta F, Cameron DA. Vagal techniques for termination of paroxysmal supraventricular tachycardia. Am J Cardiol. 1980;46:655–664.

232. Balaguer Gargallo M, Jordan Garcia I, Caritg Bosch J, Cambra Lasaosa FJ, Prada Hermogenes F, Palomaque Rico A. [Supraventricular tachycardia in infants and children]. An Pediatr (Barc). 2007;67:133–138.

233. Dixon J, Foster K, Wyllie J, Wren C. Guidelines and adenosine dosing in supraventricular tachycardia. Arch Dis Child. 2005;90:1190–1191.

234. Moghaddam M, Mohammad Dalili S, Emkanjoo Z. Efficacy of Adenosine for Acute Treatment of Supraventricular Tachycardia in Infants and Children. J Teh Univ Heart Ctr. 2008;3:157–162.

235. Riccardi A, Arboscello E, Ghinatti M, Minuto P, Lerza R. Adenosine in the treatment of supraventricular tachycardia: 5 years of experience (2002–2006). Am J Emerg Med. 2008;26:879–882.

236. Ertan C, Atar I, Gulmez O, Atar A, Ozgul A, Aydinalp A, Muderrisoglu H, Ozin B. Adenosine-induced ventricular arrhythmias in patients with supraventricular tachycardias. Ann Noninvasive Electrocardiol. 2008;13:386–390.

237. Benson D Jr.., Smith W, Dunnigan A, Sterba R, Gallagher J. Mechanisms of regular wide QRS tachycardia in infants and children. Am J Cardiol. 1982;49:1778–1788.

238. Dykes EH, Spence LJ, Young JG, Bohn DJ, Filler RM, Wesson DE. Preventable pediatric trauma deaths in a metropolitan region. J Pediatr Surg. 1989;24:107–110.

239. Herzenberg JE, Hensinger RN, Dedrick DK, Phillips WA. Emergency transport and positioning of young children who have an injury of the cervical spine. The standard backboard may be hazardous. J Bone Joint Surg Am. 1989;71:15–22.

240. Nypaver M, Treloar D. Neutral cervical spine positioning in children. Ann Emerg Med. 1994;23:208–211.

241. Ramenofsky ML, Luterman A, Quindlen E, Riddick L, Curreri PW. Maximum survival in pediatric trauma: the ideal system. J Trauma. 1984;24:818–823.

242. Luterman A, Ramenofsky M, Berryman C, Talley MA, Curreri PW. Evaluation of prehospital emergency medical service (EMS): defining areas for improvement. J Trauma. 1983;23:702–707.

243. Matthews IL, Bjornstad PG, Kaldestad RH, Heiberg L, Thaulow E, Gronn M. The impact of shunt size on lung function in infants with univentricular heart physiology. Pediatr Crit Care Med. 2009;10:60–65.

244. Charpie JR, Dekeon MK, Goldberg CS, Mosca RS, Bove EL, Kulik TJ. Postoperative hemodynamics after Norwood palliation for hypoplastic left heart syndrome. Am J Cardiol. 2001;87:198–202.

245. Hoffman GM, Mussatto KA, Brosig CL, Ghanayem NS, Musa N, Fedderly RT, Jaquiss RD, Tweddell JS. Systemic venous oxygen saturation after the Norwood procedure and childhood neurodevelopmental outcome. J Thorac Cardiovasc Surg. 2005;130:1094–1100.

246.

Johnson BA, Hoffman GM, Tweddell JS, Cava JR, Basir M, Mitchell ME, Scanlon MC, Mussatto KA, Ghanayem NS. Near-infrared spectroscopy in neonates before palliation of hypoplastic left heart syndrome. Ann Thorac Surg. 87:571–577, 2009; discussion 577–579.

247. Dudley NC, Hansen KW, Furnival RA, Donaldson AE, Van Wagenen KL, Scaife ER. The effect of family presence on the efficiency of pediatric trauma resuscitations. Ann Emerg Med. 2009;53:777–784 e773.

248. Tinsley C, Hill JB, Shah J, Zimmerman G, Wilson M, Freier K, Abd-Allah S, Tinsley C, Hill JB, Shah J, Zimmerman G, Wilson M, Freier K, Abd-Allah S. Experience of families during cardiopulmonary resuscitation in a pediatric intensive care unit. Pediatrics. 2008;122:e799–804.

249. Mangurten J, Scott SH, Guzzetta CE, Clark AP, Vinson L, Sperry J, Hicks B, Voelmeck W, Mangurten J, Scott SH, Guzzetta CE, Clark AP, Vinson L, Sperry J, Hicks B, Voelmeck W. Effects of family presence during resuscitation and invasive procedures in a pediatric emergency department. Journal of Emergency Nursing. 2006;32:225–233.

250. McGahey-Oakland PR, Lieder HS, Young A, Jefferson LS, McGahey-Oakland PR, Lieder HS, Young A, Jefferson LS. Family experiences during resuscitation at a children's hospital emergency department. Journal of Pediatric Health Care. 2007;21:217–225.

251. Jones M, Qazi M, Young KD. Ethnic differences in parent preference to be present for painful medical procedures. Pediatrics. 2005;116:e191–197.

252. Boie ET, Moore GP, Brummett C, Nelson DR. Do parents want to be present during invasive procedures performed on their children in the emergency department? A survey of 400 parents. Ann Emerg Med. 1999;34:70–74.

253. Andrews R, Andrews R. Family presence during a failed major trauma resuscitation attempt of a 15-year-old boy: lessons learned.[see comment]. Journal of Emergency Nursing. 2004;30:556–558.

254. Dill K, Gance-Cleveland B, Dill K, Gance-Cleveland B. With you until the end: family presence during failed resuscitation. Journal for Specialists in Pediatric Nursing: JSPN. 2005;10:204–207.

255. Gold KJ, Gorenflo DW, Schwenk TL, Bratton SL, Gold KJ, Gorenflo DW, Schwenk TL, Bratton SL. Physician experience with family presence during cardiopulmonary resuscitation in children.[see comment]. Pediatric Crit Care Med. 2006;7:428–433.

256. Duran CR, Oman KS, Abel JJ, Koziel VM, Szymanski D. Attitudes Toward and Beliefs About Family Presence: A Survey of Healthcare Providers, Patients' Families, and Patients. Am Journal of Critical Care. 2007;16:270–279.

257. Doyle CJ, Post H, Burney RE, Maino J, Keefe M, Rhee KJ. Family participation during resuscitation: an option. Ann Emerg Med. 1987;16:673–675.

258. Holzhauser K, Finucane J, De Vries S. Family Presence During Resuscitation: A Randomised Controlled Trial Of The Impact Of Family Presence. Australasian Emergency Nursing Journal. 2005;8:139–147.

259. Hanson C, Strawser D. Family presence during cardiopulmonary resuscitation: Foote Hospital emergency department's nine-year perspective. J Emerg Nurs. 1992;18:104–106.

260. Robinson SM, Mackenzie-Ross S, Campbell Hewson GL, Egleston CV, Prevost AT. Psychological effect of witnessed resuscitation on bereaved relatives. Lancet. 1998;352:614–617.

261. Meyers TA, Eichhorn DJ, Guzzetta CE. Do families want to be present during CPR? A retrospective survey. J Emerg Nurs. 1998;24:400–405.

262. Boyd R. Witnessed resuscitation by relatives. Resuscitation. 2000;43:171–176.

263. Offord RJ. Should relatives of patients with cardiac arrest be invited to be present during cardiopulmonary resuscitation? Intensive Crit Care Nurs. 1998;14:288–293.

264. Meyers TA, Eichhorn DJ, Guzzetta CE, Clark AP, Klein JD, Taliaferro E, Calvin A. Family presence during invasive procedures and resuscitation. Am J Nurs. 100:32–42, 2000; quiz 43.

265. O'Connell KJ, Farah MM, Spandorfer P, Zorc JJ, O'Connell KJ, Farah MM, Spandorfer P, Zorc JJ. Family presence during pediatric trauma team activation: an assessment of a structured program. Pediatrics. 2007;120:e565–574.

266. Engel KG, Barnosky AR, Berry-Bovia M, Desmond JS, Ubel PA, Engel KG, Barnosky AR, Berry-Bovia M, Desmond JS, Ubel PA. Provider experience and attitudes toward family presence during resuscitation procedures. Journal of Palliative Medicine. 2007;10:1007–1009.

267. Boyd R, White S. Does witnessed cardiopulmonary resuscitation alter perceived stress in accident and emergency staff? Eur J Emerg Med. 2000;7:51–53.

268. Eichhorn DJ, Meyers TA, Mitchell TG, Guzzetta CE. Opening the doors: family presence during resuscitation. J Cardiovasc Nurs. 1996;10:59–70.

269. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, Berg RA. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. Circulation. 2009;119:1484–1491.

270. Zaritsky A, Nadkarni V, Getson P, Kuehl K. CPR in children. Ann Emerg Med. 1987;16:1107–1111.

271. Gillis J, Dickson D, Rieder M, Steward D, Edmonds J. Results of inpatient pediatric resuscitation. Crit Care Med. 1986;14:469–471.

272. Nadkarni VM, Larkin GL, Peberdy MA, Carey SM, Kaye W, Mancini ME, Nichol G, Lane-Truitt T, Potts J, Ornato JP, Berg RA. First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. JAMA. 2006;295:50–57.

273. Meaney PA, Nadkarni VM, Cook EF, Testa M, Helfaer M, Kaye W, Larkin GL, Berg RA. Higher survival rates among younger patients after pediatric intensive care unit cardiac arrests. Pediatrics. 2006;118:2424–2433.

274. Parra DA, Totapally BR, Zahn E, Jacobs J, Aldousany A, Burke RP, Chang AC. Outcome of cardiopulmonary resuscitation in a pediatric cardiac intensive care unit. Crit Care Med. 2000;28:3296–3300.

275. Innes PA, Summers CA, Boyd IM, Molyneux EM. Audit of paediatric cardiopulmonary resuscitation. Arch Dis Child. 1993;68:487–491.

276. Slonim AD, Patel KM, Ruttimann UE, Pollack MM. Cardiopulmonary resuscitation in pediatric intensive care units. Crit Care Med. 1997;25:1951–1955.

277. Young KD, Gausche-Hill M, McClung CD, Lewis RJ. A prospective, population-based study of the epidemiology and outcome of out-of-hospital pediatric cardiopulmonary arrest. Pediatrics. 2004;114:157–164.

278. Suominen P, Baillie C, Korpela R, Rautanen S, Ranta S, Olkkola KT. Impact of age, submersion time and water temperature on outcome in near-drowning. Resuscitation. 2002;52:247–254.

279. Rodriguez-Nunez A, Lopez-Herce J, Garcia C, Carrillo A, Dominguez P, Calvo C, Delgado MA. Effectiveness and long-term outcome of cardiopulmonary resuscitation in paediatric intensive care units in Spain. Resuscitation. 2006;71:301–309.

280. del Nido PJ, Dalton HJ, Thompson AE, Siewers RD. Extracorporeal membrane oxygenator rescue in children during cardiac arrest after cardiac surgery. Circulation. 1992;86(5 Suppl):II300–304.

281. Duncan BW, Ibrahim AE, Hraska V, del Nido PJ, Laussen PC, Wessel DL, Mayer JE Jr.., Bower LK, Jonas RA. Use of rapid-deployment extracorporeal membrane oxygenation for the resuscitation of pediatric patients with heart disease after cardiac arrest. J Thorac Cardiovasc Surg. 1998;116:305–311.

282. Lopez-Herce J, Garcia C, Dominguez P, Carrillo A, Rodriguez-Nunez A, Calvo C, Delgado MA. Characteristics and outcome of cardiorespiratory arrest in children. Resuscitation. 2004;63:311–320.

283. Lopez-Herce J, Garcia C, Rodriguez-Nunez A, Dominguez P, Carrillo A, Calvo C, Delgado MA. Long-term outcome of paediatric cardiorespiratory arrest in Spain. Resuscitation. 2005;64:79–85.

284. Kilgannon JH, Jones AE, Shapiro NI, Angelos MG, Milcarek B, Hunter K, Parrillo JE, Trzeciak S; Emergency Medicine Shock Research Network (EMShockNet) Investigators. Association between arterial hyperoxia fol- lowing resuscitation from cardiac arrest and in-hospital mortality. JAMA. 2010;303:2165–2171. doi: 10.1001/jama.2010.707.

285. Kilgannon JH, Jones AE, Parrillo JE, Dellinger RP, Milcarek B, Hunter K, Shapiro NI, Trzeciak S; Emergency Medicine Shock Research Network (EMShockNet) Investigators. Relationship between supranormal oxygen tension and outcome after resuscitation from cardiac arrest. Circulation. 2011;123:2717–2722. doi: 10.1161/ CIRCULATIONAHA.110.001016.

286. Bennett KS, Clark AE, Meert KL, Topjian AA, Schleien CL, Shaffner DH, Dean JM, Moler FW; Pediatric Emergency Care Medicine Applied Research Network. Early oxygenation and ventilation measurements after pediatric cardiac arrest: lack of association with outcome. Crit Care Med. 2013;41:1534–1542. doi: 10.1097/CCM.0b013e318287f54c.

287. Guerra-Wallace MM, Casey FL III, Bell MJ, Fink EL, Hickey RW. Hyperoxia and hypoxia in children resuscitated from cardiac arrest. Pediatr Crit Care Med. 2013;14:e143–e148. doi: 10.1097/ PCC.0b013e3182720440.

288. Del Castillo J, López-Herce J, Matamoros M, Cañadas S, Rodriguez- Calvo A, Cechetti C, Rodriguez-Núñez A, Alvarez AC; Iberoamerican Pediatric Cardiac Arrest Study Network RIBEPCI. Hyperoxia, hypo- capnia and hypercapnia as outcome factors after cardiac arrest in chil- dren. Resuscitation. 2012;83:1456–1461. doi: 10.1016/j.resuscitation. 2012.07.019.

289. Ferguson LP, Durward A, Tibby SM. Relationship between arte- rial partial oxygen pressure after resuscitation from cardiac arrest and mortality in children. Circulation. 2012;126:335–342. doi: 10.1161/CIRCULATIONAHA.111.085100.

290. Roberts BW, Kilgannon JH, Chansky ME, Mittal N, Wooden J, Trzeciak S. Association between postresuscitation partial pressure of arterial car- bon dioxide and neurological outcome in patients with post-cardiac arrest syndrome. Circulation. 2013;127:2107–2113. doi: 10.1161/ CIRCULATIONAHA.112.000168.

291. Lee BK, Jeung KW, Lee HY, Lee SJ, Jung YH, Lee WK, Heo T, Min YI. Association between mean arterial blood gas tension and outcome in cardiac arrest patients treated with therapeutic hypothermia. Am J Emerg Med. 2014;32:55–60. doi: 10.1016/j.ajem.2013.09.044.

292. Muizelaar JP, Marmarou A, Ward JD, Kontos HA, Choi SC, Becker DP, Gruemer H, Young HF. Adverse effects of prolonged hyperventilation in patients with severe head injury: a randomized clinical trial. J Neurosurg. 1991;75:731–739. doi: 10.3171/jns.1991.75.5.0731.

293. Buunk G, van der Hoeven JG, Meinders AE. Cerebrovascular reac- tivity in comatose patients resuscitated from a cardiac arrest. Stroke. 1997;28:1569–1573.

294. Skippen P, Seear M, Poskitt K, Kestle J, Cochrane D, Annich G, Handel J. Effect of hyperventilation on regional cerebral blood flow in head-injured children. Crit Care Med. 1997;25:1402–1409.

295. Pappas A, Shankaran S, Laptook AR, Langer JC, Bara R, Ehrenkranz RA, Goldberg RN, Das A, Higgins RD, Tyson JE, Walsh MC; Eunice Kennedy Shriver National Institute of Child Health and Human Development Neonatal Research Network. Hypocarbia and adverse outcome in neonatal hypoxic-ischemic encephalopathy. J Pediatr. 2011;158:752–758.e1. doi: 10.1016/j.jpeds.2010.10.019.

296. Hildebrand CA, Hartmann AG, Arcinue EL, Gomez RJ, Bing RJ. Cardiac performance in pediatric near-drowning. Crit Care Med. 1988;16:331–335.

297. Checchia PA, Sehra R, Moynihan J, Daher N, Tang W, Weil MH. Myocardial injury in children following resuscitation after cardiac arrest. Resuscitation. 2003;57:131–137.

298. Laurent I, Monchi M, Chiche JD, Joly LM, Spaulding C, Bourgeois B, Cariou A, Rozenberg A, Carli P, Weber S, Dhainaut JF. Reversible myo- cardial dysfunction in survivors of out-of-hospital cardiac arrest. J Am Coll Cardiol. 2002;40:2110–2116.

299. Mayr V, Luckner G, Jochberger S, Wenzel V, Ulmer H, Pajk W, Knotzer H, Friesenecker B, Lindner K, Hasibeder W, Dünser M. Arginine vaso- pressin in advanced cardiovascular failure during the post-resuscitation phase after cardiac arrest. Resuscitation. 2007;72:35–44. doi: 10.1016/j. resuscitation.2006.06.003.

300. Kern KB, Hilwig RW, Berg RA, Rhee KH, Sanders AB, Otto CW, Ewy GA. Postresuscitation left ventricular systolic and diastolic dysfunction. Treatment with dobutamine. Circulation. 1997;95:2610–2613.

301. Meyer RJ, Kern KB, Berg RA, Hilwig RW, Ewy GA. Post-resuscitation right ventricular dysfunction: delineation and treatment with dobutamine. Resuscitation. 2002;55:187–191.

302. Conlon TW, Falkensammer CB, Hammond RS, Nadkarni VM, Berg RA, Topjian AA. Association of left ventricular systolic function and vasopressor support with survival following pediatric out-of-hospital cardiac arrest. Pediatr Crit Care Med. 2015;16:146–154. doi: 10.1097/ PCC.0000000000000305.

303. Topjian AA, French B, Sutton RM, Conlon T, Nadkarni VM, Moler FW, Dean JM, Berg RA. Early postresuscitation hypotension is associated with increased mortality following pediatric cardiac arrest. Crit Care Med. 2014;42:1518–1523. doi: 10.1097/CCM.0000000000000216.

304. Lin YR, Li CJ, Wu TK, Chang YJ, Lai SC, Liu TA, Hsiao MH, Chou CC, Chang CF. Post-resuscitative clinical features in the first hour after achiev- ing sustained ROSC predict the duration of survival in children with non- traumatic out-of-hospital cardiac arrest. Resuscitation. 2010;81:410–417. doi: 10.1016/j.resuscitation.2010.01.006.

305. Lin YR, Wu HP, Chen WL, Wu KH, Teng TH, Yang MC, Chou CC, Chang CF, Li CJ. Predictors of survival and neurologic outcomes in children with traumatic out-of-hospital cardiac arrest during the early postresuscita- tive period. J Trauma Acute Care Surg. 2013;75:439–447. doi: 10.1097/ TA.0b013e31829e2543.

306. Ceneviva G, Paschall JA, Maffei F, Carcillo JA. Hemodynamic support in fluid-refractory pediatric septic shock. Pediatrics. 1998;102:e19.

307. Zaritsky A, Chernow B. Use of catecholamines in pediatrics. J Pediatr. 1984;105:341–350.

308. Steinberg C, Notterman DA. Pharmacokinetics of cardiovascular drugs in children. Inotropes and vasopressors. Clin Pharmacokinet. 1994;27:345–367.

309. Berg RA, Padbury JF. Sulfoconjugation and renal excretion contribute to the interpatient variation of exogenous catecholamine clearance in critically ill children. Crit Care Med. 1997;25:1247–1251.

310. Fisher DG, Schwartz PH, Davis AL. Pharmacokinetics of exogenous epinephrine in critically ill children. Crit Care Med. 1993;21:111–117.

311. De Backer D, Biston P, Devriendt J, Madl C, Chochrad D, Aldecoa C, Brasseur A, Defrance P, Gottignies P, Vincent JL. Comparison of dopamine and norepinephrine in the treatment of shock. N Engl J Med. 2010;362:779–789.

312. Bellomo R, Chapman M, Finfer S, Hickling K, Myburgh J. Low-dose dopamine in patients with early renal dysfunction: a placebo-controlled randomised trial. Australian and New Zealand Intensive Care Society (ANZICS) Clinical Trials Group. Lancet. 2000;356:2139–2143.

313. Zacharias M, Conlon NP, Herbison GP, Sivalingam P, Walker RJ, Hovhannisyan K. Interventions for protecting renal function in the perioperative period. Cochrane Database Syst Rev. 2008;:CD003590.

314. Li J, Zhang G, Holtby H, Humpl T, Caldarone CA, Van Arsdell GS, Redington AN. Adverse effects of dopamine on systemic hemodynamic status and oxygen transport in neonates after the Norwood procedure. J Am Coll Cardiol. 2006;48:1859–1864.

315. Ruffolo RR Jr.., Spradlin TA, Pollock GD, Waddell JE, Murphy PJ. Alpha and beta adrenergic effects of the stereoisomers of dobutamine. J Pharmacol Exp Ther. 1981;219:447–452.

316. Habib DM, Padbury JF, Anas NG, Perkin RM, Minegar C. Dobutamine pharmacokinetics and pharmacodynamics in pediatric intensive care patients. Crit Care Med. 1992;20:601–608.

317. Martinez AM, Padbury JF, Thio S. Dobutamine pharmacokinetics and cardiovascular responses in critically ill neonates. Pediatrics. 1992;89:47–51.

318. Bembea MM, Nadkarni VM, Diener-West M, Venugopal V, Carey SM, Berg RA, Hunt EA; American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators. Temperature pat- terns in the early postresuscitation period after pediatric inhospital car- diac arrest. Pediatr Crit Care Med. 2010;11:723–730. doi: 10.1097/ PCC.0b013e3181dde659.

319. Moler FW, Silverstein FS, Holubkov R, Slomine BS, Christensen JR, Nadkarni VM, Meert KL, Clark AE, Browning B, Pemberton VL, Page K, Shankaran S, Hutchison JS, Newth CJ, Bennett KS, Berger JT, Topjian A, Pineda JA, Koch JD, Schleien CL, Dalton HJ, Ofori-Amanfo G, Goodman DM, Fink EL, McQuillen P, Zimmerman JJ, Thomas NJ, van der Jagt EW, Porter MB, Meyer MT, Harrison R, Pham N, Schwarz AJ, Nowak JE, Alten J, Wheeler DS, Bhalala US, Lidsky K, Lloyd E, Mathur M, Shah S, Wu T, Theodorou AA, Sanders RC Jr, Dean JM; THAPCA Trial Investigators. Therapeutic hypothermia after out-of-hospital cardiac arrest in children. N Engl J Med. 2015;372:1898–1908. doi: 10.1056/ NEJMoa1411480.

320. Doherty DR, Parshuram CS, Gaboury I, Hoskote A, Lacroix J, Tucci M, Joffe A, Choong K, Farrell R, Bohn DJ, Hutchison JS; Canadian Critical Care Trials Group. Hypothermia therapy after pediat- ric cardiac arrest. Circulation. 2009;119:1492–1500. doi: 10.1161/ CIRCULATIONAHA.108.791384.

321. Fink EL, Clark RS, Kochanek PM, Bell MJ, Watson RS. A tertiary care center's experience with therapeutic hypothermia after pediatric cardiac arrest. Pediatr Crit Care Med. 2010;11:66–74. doi: 10.1097/ PCC.0b013e3181c58237.

322. Lin JJ, Hsia SH, Wang HS, Chiang MC, Lin KL. Therapeutic hypothermia associated with increased survival after resuscitation in children. Pediatr Neurol. 2013;48:285–290. doi: 10.1016/j.pediatrneurol.2012.12.021.

323. Kessler SK, Topjian AA, Gutierrez-Colina AM, Ichord RN, Donnelly M, Nadkarni VM, Berg RA, Dlugos DJ, Clancy RR, Abend NS. Short- term outcome prediction by electroencephalographic features in children treated with therapeutic hypothermia after cardiac arrest. Neurocrit Care. 2011;14:37–43. doi: 10.1007/s12028-010-9450-2.

324. Nishisaki A, Sullivan J 3rd, Steger B, Bayer CR, Dlugos D, Lin R, Ichord R, Helfaer MA, Nadkarni V. Retrospective analysis of the prog- nostic value of electroencephalography patterns obtained in pediatric in-hospital cardiac arrest survivors during three years. Pediatr Crit Care Med. 2007;8:10–17. doi: 10.1097/01.pcc.0000256621.63135.4b.

325. Abend NS, Topjian AA, Kessler SK, Gutierrez-Colina AM, Berg RA, Nadkarni V, Dlugos DJ, Clancy RR, Ichord RN. Outcome prediction by motor and pupillary responses in children treated with therapeutic hypo- thermia after cardiac arrest. Pediatr Crit Care Med. 2012;13:32–38. doi: 10.1097/PCC.0b013e3182196a7b.

326. Fink EL, Berger RP, Clark RS, Watson RS, Angus DC, Richichi R, Panigrahy A, Callaway CW, Bell MJ, Kochanek PM. Serum biomarkers of brain injury to classify outcome after pediatric cardiac arrest. Crit Care Med. 2014;42:664–674. doi: 10.1097/01.ccm.0000435668.53188.80.

327. Topjian AA, Lin R, Morris MC, Ichord R, Drott H, Bayer CR, Helfaer MA, Nadkarni V. Neuron-specific enolase and S-100B are associated with neurologic outcome after pediatric cardiac arrest. Pediatr Crit Care Med. 2009;10:479–490. doi: 10.1097/PCC.0b013e318198bdb5.

328. Topjian AA, Clark AE, Casper TC, Berger JT, Schleien CL, Dean JM, Moler FW; Pediatric Emergency Care Applied Research Network. Early lactate elevations following resuscitation from pediatric cardiac arrest are associated with increased mortality. Pediatr Crit Care Med. 2013;14:e380–e387. doi: 10.1097/PCC.0b013e3182976402.

329. Henning R. Emergency transport of critically ill children: stabilisation before departure. Med J Aust. 1992;156:117–124.

330. Edge WE, Kanter RK, Weigle CG, Walsh RF. Reduction of morbidity in interhospital transport by specialized pediatric staff. Crit Care Med. 1994;22:1186–1191.

331. Woodward G ed. Guidelines for Air and Ground Transport of Neonatal and Pediatric Patients. III ed; 2006. Am Academy of Pediatrics Section on Transport Medicine.

332. Ackerman MJ, Siu BL, Sturner WQ, Tester DJ, Valdivia CR, Makielski JC, Towbin JA. Postmortem molecular analysis of SCN5A defects in sudden infant death syndrome. JAMA. 2001;286:2264–2269.

333. Arnestad M, Crotti L, Rognum TO, Insolia R, Pedrazzini M, Ferrandi C, Vege A, Wang DW, Rhodes TE, George AL Jr.., Schwartz PJ. Prevalence of long-QT syndrome gene variants in sudden infant death syndrome. Circulation. 2007;115:361–367.

334.

Cronk LB, Ye B, Kaku T, Tester DJ, Vatta M, Makielski JC, Ackerman MJ. Novel mechanism for sudden infant death syndrome: persistent late sodium current secondary to mutations in caveolin-3. Heart Rhythm. 2007;4:161–166.

335. Millat G, Kugener B, Chevalier P, Chahine M, Huang H, Malicier D, Rodriguez-Lafrasse C, Rousson R. Contribution of long-QT syndrome genetic variants in sudden infant death syndrome. Pediatr Cardiol. 2009;30:502–509.

336. Otagiri T, Kijima K, Osawa M, Ishii K, Makita N, Matoba R, Umetsu K, Hayasaka K. Cardiac ion channel gene mutations in sudden infant death syndrome. Pediatr Res. 2008;64:482–487.

337. Plant LD, Bowers PN, Liu Q, Morgan T, Zhang T, State MW, Chen W, Kittles RA, Goldstein SA. A common cardiac sodium channel variant associated with sudden infant death in African Americans, SCN5A S1103Y. J Clin Invest. 2006;116:430–435.

338. Tester DJ, Dura M, Carturan E, Reiken S, Wronska A, Marks AR, Ackerman MJ. A mechanism for sudden infant death syndrome (SIDS): stress-induced leak via ryanodine receptors. Heart Rhythm. 2007;4:733–739.

339. Albert CM, Nam EG, Rimm EB, Jin HW, Hajjar RJ, Hunter DJ, MacRae CA, Ellinor PT. Cardiac sodium channel gene variants and sudden cardiac death in women. Circulation. 2008;117:16–23.

340. Chugh SS, Senashova O, Watts A, Tran PT, Zhou Z, Gong Q, Titus JL, Hayflick SJ. Postmortem molecular screening in unexplained sudden death. J Am Coll Cardiol. 2004;43:1625–1629.

341. Tester DJ, Spoon DB, Valdivia HH, Makielski JC, Ackerman MJ. Targeted mutational analysis of the RyR2-encoded cardiac ryanodine receptor in sudden unexplained death: a molecular autopsy of 49 medical examiner/coroner's cases. Mayo Clin Proc. 2004;79:1380–1384.

342. Behr E, Wood DA, Wright M, Syrris P, Sheppard MN, Casey A, Davies MJ, McKenna W. Cardiological assessment of first-degree relatives in sudden arrhythmic death syndrome. Lancet. 2003;362:1457–1459.

343. Behr ER, Dalageorgou C, Christiansen M, Syrris P, Hughes S, Tome Esteban MT, Rowland E, Jeffery S, McKenna WJ. Sudden arrhythmic death syndrome: familial evaluation identifies inheritable heart disease in the majority of families. Eur Heart J. 2008;29:1670–1680.

344. Hofman N, Tan HL, Clur SA, Alders M, van Langen IM, Wilde AA. Contribution of inherited heart disease to sudden cardiac death in childhood. Pediatrics. 2007;120:e967–973.

345. Tan HL, Hofman N, van Langen IM, van der Wal AC, Wilde AA. Sudden unexplained death: heritability and diagnostic yield of cardiological and genetic examination in surviving relatives. Circulation. 2005;112:207–213.

346. Somberg JC, Bailin SJ, Haffajee CI, Paladino WP, Kerin NZ, Bridges D, Timar S, Molnar J. Intravenous lidocaine versus intravenous amiodarone (in a new aqueous formulation) for incessant ventricular tachycardia. Am J Cardiol. 2002;90:853–859.

347. Zwiener RJ, Ginsburg CM. Organophosphate and carbamate poisoning in infants and children [published correction appears in Pediatrics. 1988;81:683]. Pediatrics. 1988;81:121–126.

348. Srinivasan V, Morris MC, Helfaer MA, Berg RA, Nadkarni VM. Calcium use during in-hospital pediatric cardiopulmonary resuscitation: a report from the National Registry of Cardiopulmonary Resuscitation. Pediatrics. 2008;121:e1144–1151.

349. de Mos N, van Litsenburg RR, McCrindle B, Bohn DJ, Parshuram CS. Pediatric in-intensive-care-unit cardiac arrest: incidence, survival, and predictive factors. Crit Care Med. 2006;34:1209–1215.

350. Meert KL, Donaldson A, Nadkarni V, Tieves KS, Schleien CL, Brilli RJ, Clark RS, Shaffner DH, Levy F, Statler K, Dalton HJ, van der Jagt EW, Hackbarth R, Pretzlaff R, Hernan L, Dean JM, Moler FW. Multicenter cohort study of in-hospital pediatric cardiac arrest. Pediatr Crit Care Med. 2009;10:544–553.

351. Blecic S, De Backer D, Huynh CH, Deleuze M, Domb M, Luypaert P, Vincent JL. Calcium chloride in experimental electromechanical dissociation: a placebo-controlled trial in dogs. Crit Care Med. 1987;15:324–327.

352. Harrison EE, Amey BD. The use of calcium in cardiac resuscitation. Am J Emerg Med. 1983;1:267–273.

353. Niemann JT, Adomian GE, Garner D, Rosborough JP. Endocardial and transcutaneous cardiac pacing, calcium chloride, and epinephrine in postcountershock asystole and bradycardias. Crit Care Med. 1985;13:699–704.

354. Ornato JP, Gonzales ER, Morkunas AR, Coyne MR, Beck CL. Treatment of presumed asystole during pre-hospital cardiac arrest: superiority of electrical countershock. Am J Emerg Med. 1985;3:395–399.

355. Redding JS, Haynes RR, Thomas JD. Drug therapy in resuscitation from electromechanical dissociation. Crit Care Med. 1983;11:681–684.

356. Redding JS, Pearson JW. Evaluation of drugs for cardiac resuscitation. Anesthesiology. 1963;24:203–207.

357. Stueven H, Thompson BM, Aprahamian C, Darin JC. Use of calcium in prehospital cardiac arrest. Ann Emerg Med. 1983;12:136–139.

358. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. The effectiveness of calcium chloride in refractory electromechanical dissociation. Ann Emerg Med. 1985;14:626–629.

359. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. Lack of effectiveness of calcium chloride in refractory asystole. Ann Emerg Med. 1985;14:630–632.

360. Martin TJ, Kang Y, Robertson KM, Virji MA, Marquez JM. Ionization and hemodynamic effects of calcium chloride and calcium gluconate in the absence of hepatic function. Anesthesiology. 1990;73:62–65.

361. Broner CW, Stidham GL, Westenkirchner DF, Watson DC. A prospective, randomized. double-blind comparison of calcium chloride and calcium gluconate therapies for hypocalcemia in critically ill children. J Pediatr. 1990;117:986–989.

362. Niemann JT, Criley JM, Rosborough JP, Niskanen RA, Alferness C. Predictive indices of successful cardiac resuscitation after prolonged arrest and experimental cardiopulmonary resuscitation. Ann Emerg Med. 1985;14:521–528.

363. Sanders A, Ewy G, Taft T. Prognostic and therapeutic importance of the aortic diastolic pressure in resuscitation from cardiac arrest. Crit Care Med. 1984;12:871–873.

364. Losek JD. Hypoglycemia and the ABC'S (sugar) of pediatric resuscitation. Ann Emerg Med. 2000;35:43–46.

365. Bigger JT Jr.., Mandel WJ. Effect of lidocaine on the electrophysiological properties of ventricular muscle and purkinje fibers. J Clin Invest. 1970;49:63–77.

366. Wilson FC, Harpur J, Watson T, Morrow JI. Adult survivors of severe cerebral hypoxia–case series survey and comparative analysis. Neuro Rehabilitation. 2003;18:291–298.

367. Thomson PD, Melmon KL, Richardson JA, Cohn K, Steinbrunn W, Cudihee R, Rowland M. Lidocaine pharmacokinetics in advanced heart failure, liver disease, and renal failure in humans. Ann Intern Med. 1973;78:499–508.

368. Allegra J, Lavery R, Cody R, Birnbaum G, Brennan J, Hartman A, Horowitz M, Nashed A, Yablonski M. Magnesium sulfate in the treatment of refractory ventricular fibrillation in the prehospital setting. Resuscitation. 2001;49:245–249.

369. Hassan TB, Jagger C, Barnett DB. A randomised trial to investigate the efficacy of magnesium sulphate for refractory ventricular fibrillation. Emerg Med J. 2002;19:57–62.

370. Thel MC, Armstrong AL, McNulty SE, Califf RM, O'Connor CM. Randomised trial of magnesium in in-hospital cardiac arrest. Duke Internal Medicine Housestaff. Lancet. 1997;350:1272–1276.

371. Luedtke SA, Kuhn RJ, McCaffrey FM. Pharmacologic management of supraventricular tachycardias in children. Part 1: Wolff-Parkinson-White and atrioventricular nodal reentry. Ann Pharmacother. 1997;31:1227–1243.

372. Luedtke SA, Kuhn RJ, McCaffrey FM. Pharmacologic management of supraventricular tachycardias in children, part 2: atrial flutter, atrial fibrillation, and junctional and atrial ectopic tachycardia. Ann Pharmacother. 1997;31:1347–1359.

373. Chang PM, Silka MJ, Moromisato DY, Bar-Cohen Y. Amiodarone versus procainamide for the acute treatment of recurrent supraventricular tachycardia in pediatric patients. Circ Arrhythm Electrophysiol. 2010;3:134–140.

374. Weil MH, Rackow EC, Trevino R, Grundler W, Falk JL, Griffel MI. Difference in acid-base state between venous and arterial blood during cardiopulmonary resuscitation. N Engl J Med. 1986;315:153–156.

375. Steedman DJ, Robertson CE. Acid-base changes in arterial and central venous blood during cardiopulmonary resuscitation. Arch Emerg Med. 1992;9:169–176.

376. Wayne MA, Delbridge TR, Ornato JP, Swor RA, Blackwell T. Concepts and application of prehospital ventilation. Prehosp Emerg Care. 2001;5:73–78.

377. Mattar JA, Weil MH, Shubin H, Stein L. Cardiac arrest in the critically ill. II. Hyperosmolal states following cardiac arrest. Am J Med. 1974;56:162–168.

378. Aufderheide TP, Martin DR, Olson DW, Aprahamian C, Woo JW, Hendley GE, Hargarten KM, Thompson B. Prehospital bicarbonate use in cardiac arrest: a 3-year experience. Am J Emerg Med. 1992;10:4–7.

379. Bishop RL, Weisfeldt ML. Sodium bicarbonate administration during cardiac arrest. Effect on arterial pH PCO2, and osmolality. JAMA. 1976;235:506–509.

380. Mann K, Berg RA, Nadkarni V. Beneficial effects of vasopressin in prolonged pediatric cardiac arrest: a case series. Resuscitation. 2002;52:149–156.

381. Matok I, Vardi A, Augarten A, Efrati O, Leibovitch L, Rubinshtein M, Paret G. Beneficial effects of terlipressin in prolonged pediatric cardiopulmonary resuscitation: a case series. Crit Care Med. 2007;35:1161–1164.

382.

Gil-Anton J, Lopez-Herce J, Morteruel E, Carrillo A, Rodriguez-Nunez A. Pediatric cardiac arrest refractory to advanced life support: is there a role for terlipressin? Pediatr Crit Care Med. 2010;11:139–141.

383. Lindner KH, Prengel AW, Brinkmann A, Strohmenger HU, Lindner IM, Lurie KG. Vasopressin administration in refractory cardiac arrest. Ann Intern Med. 1996;124:1061–1064.

384. Lee CC, Kim GW, Kim SH, Crupi RS. Cases of aminophylline and vasopressin use after failed prehospital resuscitation of cardiac arrest. Prehosp Emerg Care. 2001;5:304–307.

385. Duncan JM, Meaney P, Simpson P, Berg RA, Nadkarni V, Schexnayder S. Vasopressin for in-hospital pediatric cardiac arrest: results from the American Heart Association National Registry of Cardiopulmonary Resuscitation. Pediatr Crit Care Med. 2009;10:191–195.

386. Callaway CW, Hostler D, Doshi AA, Pinchalk M, Roth RN, Lubin J, Newman DH, Kelly LJ. Usefulness of vasopressin administered with epinephrine during out-of-hospital cardiac arrest. Am J Cardiol. 2006;98:1316–1321.

387. Gueugniaud PY, David JS, Chanzy E, Hubert H, Dubien PY, Mauriaucourt P, Braganca C, Billeres X, Clotteau-Lambert MP, Fuster P, Thiercelin D, Debaty G, Ricard-Hibon A, Roux P, Espesson C, Querellou E, Ducros L, Ecollan P, Halbout L, Savary D, Guillaumee F, Maupoint R, Capelle P, Bracq C, Dreyfus P, Nouguier P, Gache A, Meurisse C, Boulanger B, Lae C, Metzger J, Raphael V, Beruben A, Wenzel V, Guinhouya C, Vilhelm C, Marret E. Vasopressin and epinephrine vs. epinephrine alone in cardiopulmonary resuscitation. N Engl J Med. 2008;359:21–30.

388. Lindner KH, Dirks B, Strohmenger HU, Prengel AW, Lindner IM, Lurie KG. Randomised comparison of epinephrine and vasopressin in patients with out-of-hospital ventricular fibrillation. Lancet. 1997;349:535–537.

389. Mukoyama T, Kinoshita K, Nagao K, Tanjoh K. Reduced effectiveness of vasopressin in repeated doses for patients undergoing prolonged cardiopulmonary resuscitation. Resuscitation. 2009;80:755–761.

390. Stiell IG, Hebert PC, Wells GA, Vandemheen KL, Tang AS, Higginson LA, Dreyer JF, Clement C, Battram E, Watpool I, Mason S, Klassen T, Weitzman BN. Vasopressin versus epinephrine for inhospital cardiac arrest: a randomised controlled trial. Lancet. 2001;358:105–109.

391. Wenzel V, Krismer AC, Arntz HR, Sitter H, Stadlbauer KH, Lindner KH. A comparison of vasopressin and epinephrine for out-of-hospital cardiopulmonary resuscitation. N Engl J Med. 2004;350:105–113.

Part 13: Neonatal Resuscitation

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiopulmonary resuscitation neonatal

1 Highlights & Introduction

1.1 Highlights

Summary of Key Issues and Major Changes

Neonatal cardiac arrest is predominantly asphyxial, so initiation of ventilation remains the focus of initial resuscitation. The following were the major neonatal topics in 2015:

- The order of the 3 assessment questions has changed to (1) Term gestation? (2) Good tone? and (3) Breathing or crying?
- The Golden Minute (60-second) mark for completing the initial steps, reevaluating, and beginning ventilation (if required) is retained to emphasize the importance of avoiding unnecessary delay in initiation of ventilation, the most important step for successful resuscitation of the newly born who has not responded to the initial steps.
- There is a new recommendation that delayed cord clamping for longer than 30 seconds is reasonable for both term and preterm infants who do not require resuscitation at birth, but there is insufficient evidence to recommend an approach to cord clamping for infants who require resuscitation at birth, and a suggestion against the routine use of cord milking (outside of a research setting) for infants born at less than 29 weeks of gestation, until more is known of benefits and complications.
- Temperature should be recorded as a predictor of outcomes and as a quality indicator.
- Temperature of newly born nonasphyxiated infants should be maintained between 36.5°C and 37.5°C after birth through admission and stabilization.
- A variety of strategies (radiant warmers, plastic wrap with a cap, thermal mattress, warmed humidified gases, and increased room temperature plus cap plus thermal mattress) may be reasonable to prevent hypothermia in preterm infants. Hyperthermia (temperature greater than 38°C) should be avoided because it introduces potential associated risks.
- In resource-limited settings, simple measures to prevent hypothermia in the first hours of life (use of plastic wraps, skinto-skin contact, and even placing the infant after drying in a clean food-grade plastic bag up to the neck) may reduce mortality.
- If an infant is born through meconium-stained amniotic fluid and presents with poor muscle tone and inadequate breathing efforts, the infant should be placed under a radiant warmer and PPV should be initiated if needed. Routine intubation for tracheal suction is no longer suggested because there is insufficient evidence to continue this recommendation. Appropriate intervention to support ventilation and oxygenation should be initiated as indicated for each individual infant. This may include intubation and suction if the airway is obstructed.
- Assessment of heart rate remains critical during the first minute of resuscitation and the use of a 3-lead ECG may be reasonable, because providers may not assess heart rate accurately by auscultation or palpation, and pulse oximetry may underestimate heart rate. Use of the ECG does not replace the need for pulse oximetry to evaluate the newborn's oxygenation.
- Resuscitation of *preterm* newborns of less than 35 weeks of gestation should be initiated with low oxygen (21% to 30%) and the oxygen titrated to achieve preductal oxygen saturation approximating the range achieved in healthy term infants.
- There are insufficient data about the safety and the method of application of sustained inflation of greater than 5 seconds' duration for the transitioning newborn.
- A laryngeal mask may be considered as an alternative to tracheal intubation if face-mask ventilation is unsuccessful, and a laryngeal mask is recommended during resuscitation of newborns 34 weeks or more of gestation when tracheal intubation is unsuccessful or not feasible.
- Spontaneously breathing preterm infants with respiratory distress may be supported with continuous

positive airway pressure initially rather than with routine intubation for administering PPV.

- Recommendations about chest compression technique (2 thumb–encircling hands) and compression-to-ventilation ratio (3:1 with 90 compressions and 30 breaths per minute) remain unchanged. As in the 2010 recommendations, rescuers may consider using higher ratios (e.g., 15:2) if the arrest is believed to be of cardiac origin.
- Although there are no available clinical studies about oxygen use during CPR, the Neonatal Guidelines Writing Group continues to endorse the use of 100% oxygen whenever chest compressions are provided. It is reasonable to wean the oxygen concentration as soon as the heart rate recovers.
- Recommendations about use of epinephrine during CPR and volume administration were not reviewed in 2015, so the 2010 recommendations remain in effect.
- Induced therapeutic hypothermia in resource-abundant areas, for infants born at more than 36 weeks of gestation with evolving moderate to severe hypoxic-ischemic encephalopathy, was not reviewed in 2015, so the 2010 recommendations remain in effect.
- In resource-limited settings, use of therapeutic hypothermia may be considered under clearly defined protocols similar to those used in clinical trials and in facilities with the capabilities for multidisciplinary care and follow-up.
- In general, no new data have been published to justify a change in the 2010 recommendations about withholding or withdrawing resuscitation. An Apgar score of 0 at 10 minutes is a strong predictor of mortality and morbidity in late preterm and term infants, but decisions to continue or discontinue resuscitation efforts must be individualized.
- It is suggested that neonatal resuscitation task training occur more frequently than the current 2-year interval.

Umbilical Cord Management: Delayed Cord Clamping

2015 (Updated): Delayed cord clamping after 30 seconds is suggested for both term and preterm infants who do not require resuscitation at birth. There is insufficient evidence to recommend an approach to cord clamping for infants who require resuscitation at birth.

2010 (Old): There is increasing evidence of benefit of delaying cord clamping for at least 1 minute in term and preterm infants not requiring resuscitation. There is insufficient evidence to support or refute a recommendation to delay cord clamping in infants requiring resuscitation.

Why: In infants who do not require resuscitation, delayed cord clamping is associated with less intraventricular hemorrhage, higher blood pressure and blood volume, less need for transfusion after birth, and less necrotizing enterocolitis. The only adverse consequence found was a slightly increased level of bilirubin, associated with more need for phototherapy.

Suctioning Nonvigorous Infants Through Meconium-Stained Amniotic Fluid

2015 (Updated): If an infant born through meconiumstained amniotic fluid presents with poor muscle tone and inadequate breathing efforts, the initial steps of resuscitation should be completed under the radiant warmer. PPV should be initiated if the infant is not breathing or the heart rate is less than 100/min after the initial steps are completed. Routine intubation for tracheal suction in this setting is not suggested, because there is insufficient evidence to continue recommending this practice. However, a team that includes someone skilled in intubation of the newborn should still be present in the delivery room.

2010 (Old): There was insufficient evidence to recommend a change in the current practice of performing endotracheal suctioning of nonvigorous infants with meconium-stained amniotic fluid.

Why: Review of the evidence suggests that resuscitation should follow the same principles for infants with meconium-stained fluid as for those with clear fluid; that is, if poor muscle tone and inadequate breathing effort are present, the initial steps of resuscitation (warming and maintaining temperature, positioning the infant, clearing the airway of secretions if needed, drying, and stimulating the infant) should be completed under an overbed warmer. PPV should be initiated if the infant is not breathing or the heart rate is less than 100/min after the initial steps are completed. Experts placed greater value on harm avoidance (ie, delays in providing bag-mask ventilation, potential harm of the procedure) over the unknown benefit of the intervention of routine tracheal intubation and suctioning. Appropriate intervention to support ventilation and oxygenation should be initiated as indicated for each individual infant. This may include intubation and suction if the airway is obstructed.

Assessment of Heart Rate: Use of 3-Lead ECG

2015 (Updated): During resuscitation of term and preterm newborns, the use of 3-lead ECG for the rapid and accurate measurement of the newborn's heart rate may be useful. The use of ECG does not replace the need for pulse oximetry to evaluate the newborn's oxygenation.

2010 (Old): Although use of ECG was not mentioned in 2010, the issue of how to assess the heart rate was addressed: Assessment of heart rate should be done by intermittently auscultating the precordial pulse. When a pulse is detectable, palpation of the umbilical pulse can also provide a rapid estimate of the pulse and is more accurate than palpation at other sites. A pulse oximeter can provide a continuous assessment of the pulse without interruption of other resuscitation measures, but the device takes 1 to 2 minutes to apply and may not function during states of very poor cardiac output or perfusion.

Why: Clinical assessment of heart rate in the delivery room has been found to be both unreliable and inaccurate. Underestimation of the heart rate may lead to unnecessary resuscitation. The ECG has been found to display an accurate heart rate faster than pulse oximetry. Pulse oximetry more often displayed a lower rate in the first 2 minutes of life, often at levels that suggest the need for intervention.

Administration of Oxygen to Preterm Newborns

2015 (Updated): Resuscitation of preterm newborns of less than 35 weeks of gestation should be initiated with low oxygen (21% to 30%), and the oxygen concentration should be titrated to achieve a preductal oxygen saturation approximating the interquartile range measured in healthy term infants after vaginal birth at sea level. Initiating resuscitation of preterm newborns with high oxygen (65% or greater) is not recommended. This recommendation reflects a preference for not exposing preterm newborns to additional oxygen without data demonstrating a proven benefit for important outcomes.

2010 (Old): It is reasonable to initiate resuscitation with air (21% oxygen at sea level). Supplementary oxygen may be administered and titrated to achieve a preductal oxygen saturation approximating the interquartile range measured in healthy term infants after vaginal birth at sea level. Most data were from term infants not during resuscitation, with a single study of preterm infants during resuscitation.

Why: Data are now available from a meta-analysis of 7 randomized studies demonstrating no benefit in survival to hospital discharge, prevention of bronchopulmonary dysplasia, intraventricular hemorrhage, or retinopathy of prematurity when preterm newborns (less than 35 weeks of gestation) were resuscitated with high (65% or greater) compared with low (21% to 30%) oxygen concentration.

Postresuscitation Therapeutic Hypothermia: Resource-Limited Settings

2015 (Updated): It is suggested that the use of therapeutic hypothermia in resource-limited settings (ie, lack of qualified staff, inadequate equipment, etc) may be considered and offered under clearly defined protocols similar to those used in published clinical trials and in facilities with the capabilities for multidisciplinary care and longitudinal follow-up.

2010 (Old): It is recommended that infants born at 36 weeks or more of gestation with evolving moderate to severe hypoxic-ischemic encephalopathy should be offered therapeutic hypothermia. Therapeutic hypothermia should be administered under clearly defined protocols similar to those used in published clinical trials and in facilities with the capabilities for multidisciplinary care and longitudinal follow-up.

Why: While the recommendation for therapeutic hypothermia in the treatment of moderate to severe hypoxicischemic encephalopathy in resource-abundant settings remains unchanged, a recommendation was added to guide the use of this modality in settings where resources may limit options for some therapies.

1.2 Introduction

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

The new or updated guidelines are a summary of the evidence presented in the *2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations* (CoSTR).[1] Throughout the online version of this publication, live links are provided so the reader can connect directly to systematic reviews on the International Liaison Committee on Resuscitation

(ILCOR) Scientific Evidence Evaluation and Review System (SEERS) website. These links are indicated by a combination of letters and numbers (eg, NRP 787). We encourage readers to use the links and review the evidence and appendices.

These guidelines apply primarily to newly born infants transitioning from intrauterine to extrauterine life. The recommendations are also applicable to neonates who have completed newborn transition and require resuscitation during the first weeks after birth.[2] Practitioners who resuscitate infants at birth or at any time during the initial hospitalization should consider following these guidelines. For purposes of these guidelines, the terms *newborn* and *neonate* apply to any infant during the initial hospitalization. The term *newly born* applies specifically to an infant at the time of birth.[2]

Immediately after birth, infants who are breathing and crying may undergo delayed cord clamping (see Umbilical Cord Management section). However, until more evidence is available, infants who are not breathing or crying should have the cord clamped (unless part of a delayed cord clamping research protocol), so that resuscitation measures can commence promptly.

Approximately 10% of newborns require some assistance to begin breathing at birth. Less than 1% require extensive resuscitation measures,[3] such as cardiac compressions and medications. Although most newly born infants successfully transition from intrauterine to extrauterine life without special help, because of the large total number of births, a significant number will require some degree of resuscitation.[2]

Newly born infants who do not require resuscitation can be generally identified upon delivery by rapidly assessing the answers to the following 3 questions:

- Term gestation?
- Good tone?
- Breathing or crying?

If the answer to all 3 questions is “yes,” the newly born infant may stay with the mother for routine care. Routine care means the infant is dried, placed skin to skin with the mother, and covered with dry linen to maintain a normal temperature. Observation of breathing, activity, and color must be ongoing.

If the answer to any of these assessment questions is “no,” the infant should be moved to a radiant warmer to receive 1 or more of the following 4 actions in sequence:

A. Initial steps in stabilization (warm and maintain normal temperature, position, clear secretions only if copious and/or obstructing the airway, dry, stimulate)

B. Ventilate and oxygenate

C. Initiate chest compressions

D. Administer epinephrine and/or volume

Approximately 60 seconds (“the Golden Minute”) are allotted for completing the initial steps, reevaluating, and beginning ventilation if required (Figure 1). Although the 60-second mark is not precisely defined by science, it is important to avoid unnecessary delay in initiation of ventilation, because this is *the* most important step for successful resuscitation of the newly born who has not responded to the initial steps. The decision to progress beyond the initial steps is determined by simultaneous assessment of 2 vital characteristics: respirations (apnea, gasping, or labored or unlabored breathing) and heart rate (less than 100/min). Methods to accurately assess the heart rate will be discussed in detail in the section on Assessment of Heart Rate. Once positive-pressure ventilation (PPV) or supplementary oxygen administration is started, assessment should consist of simultaneous evaluation of 3 vital characteristics: heart rate, respirations, and oxygen saturation, as determined by pulse oximetry and discussed under Assessment of Oxygen Need and Administration of Oxygen. The most sensitive indicator of a successful response to each step is an increase in heart rate.[2]

2 Anticipation of Resuscitation Need

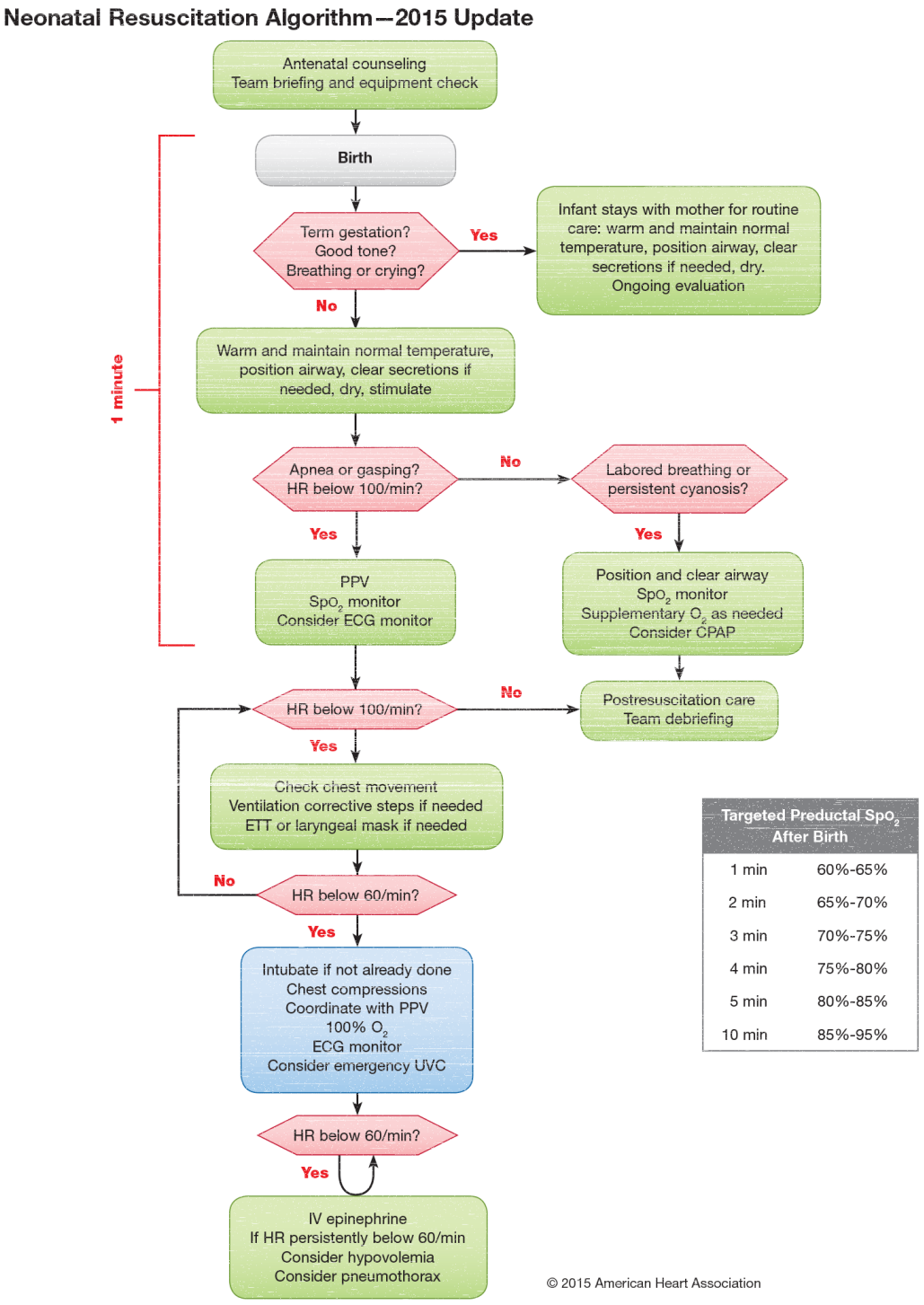
Readiness for neonatal resuscitation requires assessment of perinatal risk, a system to assemble the appropriate personnel based on that risk, an organized method for ensuring immediate access to supplies and equipment, and standardization of behavioral skills that help assure effective teamwork and communication.

Every birth should be attended by at least 1 person who can perform the initial steps of newborn resuscitation and PPV, and whose only responsibility is care of the newborn. In the presence of significant perinatal risk factors that increase the likelihood of the need for resuscitation,[4,5] additional personnel with resuscitation skills, including chest compressions, endotracheal intubation, and umbilical vein catheter insertion, should be immediately available. Furthermore, because a newborn without apparent risk factors may unexpectedly require resuscitation, each institution should have a procedure in place for rapidly mobilizing a team with complete newborn resuscitation skills for any birth.

The neonatal resuscitation provider and/or team is at a major disadvantage if supplies are missing or equipment is not functioning. A standardized checklist to ensure that all necessary supplies and equipment are present and functioning may be helpful. A known perinatal risk factor, such as preterm birth, requires preparation of supplies specific to thermoregulation and respiratory support for this vulnerable population.

When perinatal risk factors are identified, a team should be mobilized and a team leader identified. As time permits, the leader should conduct a preresuscitation briefing, identify interventions that may be required, and assign roles and responsibilities to the team members.[6,7] During resuscitation, it is vital that the team demonstrates effective communication and teamwork skills to help ensure quality and patient safety.

Figure 1: Neonatal Resuscitation Algorithm—2015 Update



3 Umbilical Cord Management - NRP 787 NRP 849

Until recent years, a common practice has been to clamp the umbilical cord soon after birth to quickly transfer the infant to the neonatal team for stabilization. This immediate clamping was deemed particularly important for infants at high risk for difficulty with transition and those most likely to require resuscitation, such as infants born preterm. During the 2010 CoSTR review, evidence began to emerge suggesting that delayed cord clamping (DCC) might be beneficial for infants who did not need immediate resuscitation at birth.[6]

The 2015 ILCOR systematic review[NRP 787] confirms that DCC is associated with less intraventricular hemorrhage (IVH) of any grade, higher blood pressure and blood volume, less need for transfusion after birth, and less necrotizing enterocolitis. There was no evidence of decreased mortality or decreased incidence of severe IVH.[1]

The studies were judged to be very low quality (downgraded for imprecision and very high risk of bias). The only negative consequence appears to be a slightly increased level of bilirubin, associated with more need for phototherapy. These findings have led to national recommendations that DCC be practiced when possible.[8,9] A major problem with essentially all of these studies has been that infants who were thought to require resuscitation were either withdrawn from the randomized controlled trials or electively were not enrolled. Therefore, there is no evidence regarding safety or utility of DCC for infants requiring resuscitation and some concern that the delay in establishing ventilation may be harmful. Some studies have suggested that cord "milking" might accomplish goals similar to DCC,[10-12] but there is insufficient evidence of either its safety or utility to suggest its routine use in the newly born, particularly in extremely preterm infants.

In summary, from the evidence reviewed in the 2010 CoSTR[6] and subsequent review of DCC and cord milking in preterm newborns in the 2015 ILCOR systematic review,,[1] DCC for longer than 30 seconds is reasonable for both term and preterm infants who do not require resuscitation at birth. (Class IIa, LOE C-LD)

There is insufficient evidence to recommend an approach to cord clamping for infants who require resuscitation at birth, and more randomized trials involving such infants are encouraged. In light of the limited information regarding the safety of rapid changes in blood volume for extremely preterm infants, we suggest against the routine use of cord milking for infants born at less than 29 weeks of gestation outside of a research setting. Further study is warranted because cord milking may improve initial mean blood pressure and hematologic indices and reduce intracranial hemorrhage, but thus far there is no evidence for improvement in long-term outcomes. (Class IIb, LOE C-LD)

4 Initial Steps

The initial steps of newborn resuscitation are to maintain normal temperature of the infant, position the infant in a "sniffing" position to open the airway, clear secretions if needed with a bulb syringe or suction catheter, dry the infant (unless preterm and covered in plastic wrap), and stimulate the infant to breathe. Current examination of the evidence for these practices is summarized below.

4.1 Importance of Maintaining Normal Temperature in the Delivery Room - Updated NRP 589

It has long been recognized (since Budin's 1907 publication of The Nursling)[13] that the admission temperature of newly born nonasphyxiated infants is a strong predictor of mortality at all gestational ages.[14-48] Preterm infants are especially vulnerable. Hypothermia is also associated with serious morbidities, such as increased risk of IVH,[18,25,38,49-53] respiratory issues,[14,18,20,49,54-59] hypoglycemia,[14,43,59-63] and late-onset sepsis.[32,64]

Because of this, admission temperature should be recorded as a predictor of outcomes as well as a quality indicator. (Class I, LOE B-NR)

It is recommended that the temperature of newly born nonasphyxiated infants be maintained between 36.5°C and 37.5°C after birth through admission and stabilization.[65] (Class I, LOE C-LD)

4.1.1 Interventions to Maintain Newborn Temperature in the Delivery Room - Updated NRP 599

The use of radiant warmers and plastic wrap with a cap has improved but not eliminated the risk of hypothermia in preterm infants in the delivery room. Other strategies have been introduced, which include increased room temperature, thermal mattresses, and the use of warmed humidified resuscitation gases. Various combinations of these strategies may be reasonable to prevent hypothermia in infants born at less than 32 weeks of gestation. (Class IIb, LOE B-R, B-NR, C-LD)

All resuscitation procedures, including endotracheal intubation, chest compression, and insertion of intravenous lines, can be performed with these temperature-controlling interventions in place. (Class IIb, LOE C)

Compared with plastic wrap and radiant warmer, the addition of a thermal mattress,[66-70] warmed humidified gases,[71,72] and increased room temperature plus cap plus thermal mattress[54,56,58,73] were all effective in reducing hypothermia. For all the studies, hyperthermia was a concern, but harm was not shown.

Hyperthermia (greater than 38.0°C) should be avoided due to the potential associated risks. (Class III: Harm, LOE C-EO)

4.1.1.1 Warming Hypothermic Newborns to Restore Normal Temperature - Updated NRP 858

The traditional recommendation for the method of rewarming neonates who are hypothermic after resuscitation has been that slower is preferable to faster rewarming to avoid complications such as apnea and arrhythmias. However, there is insufficient current evidence to recommend a preference for either rapid (0.5°C/h or greater) or slow rewarming (less than 0.5°C/h) of unintentionally hypothermic newborns (temperature less than 36°C) at hospital admission. Either approach to rewarming may be reasonable (Class IIb, LOE C-LD)

4.1.1.2 Effect of Maternal Hypothermia and Hyperthermia on the Neonate - Updated NRP 804

Maternal hyperthermia in labor is associated with adverse neonatal effects. These include increased mortality,[74,75] neonatal seizures,[74-80] and adverse neurologic states like encephalopathy.[81-84] Maternal hypothermia in labor has not been shown to be associated with clinically significant adverse neonatal outcomes at the time of birth.[85-89] Although maternal hyperthermia is associated with adverse neonatal outcomes, there is insufficient evidence to make a recommendation on the management of maternal hyperthermia.

4.1.2 Maintaining Normothermia in Resource-Limited Settings - Updated NRP 793

The ability to maintain temperature in resource-limited settings after birth is a significant problem,[39] with a dose-dependent increase in mortality for temperatures below 36.5°C. Premature newborns are at much higher risk than those born at term. Simple interventions to prevent hypothermia during transition (birth until 1 to 2 hours of life) reduce mortality. During transition, the use of plastic wraps[90-92] and the use of skin-to-skin contact[93-100] reduce hypothermia.

In resource-limited settings, to maintain body temperature or prevent hypothermia during transition (birth until 1 to 2 hours of life) in well newborn infants, it may be reasonable to put them in a clean food-grade plastic bag up to the level of the neck and swaddle them after drying. (Class IIb, LOE C-LD)

Another option that may be reasonable is to nurse such newborns with skin-to-skin contact or kangaroo mother care. (Class IIb, LOE C-LD)

There are no data examining the use of plastic wraps or skin-to-skin contact during resuscitation/stabilization in resource-limited settings.

4.2 Clearing the Airway

4.2.1 When Amniotic Fluid is Clear - Updated

This topic was last reviewed in 2010.[2] Suctioning immediately after birth, whether with a bulb syringe or suction catheter, may be considered only if the airway appears obstructed or if PPV is required.

Therefore it is recommended that suctioning immediately following birth (including suctioning with a bulb syringe) should be reserved for babies who have obvious obstruction to spontaneous breathing or who require positive-pressure ventilation (PPV). (Class IIb, LOE C)

Avoiding unnecessary suctioning helps prevent the risk of induced bradycardia due to suctioning of the nasopharynx.[101,102] Deterioration of pulmonary compliance, oxygenation, and cerebral blood flow velocity shown to accompany tracheal suction in intubated infants in the neonatal intensive care unit also suggests the need for caution in the use of suction immediately after birth.[103-105] This recommendation remains unchanged. Please refer to the 2010 CoSTR for the latest science review.[6,7]

4.2.2 When Meconium is Present - Updated NRP 865

Since the mid-1970s, interventions to decrease the mortality and morbidity of meconium aspiration syndrome in infants who are born through meconium-stained amniotic fluid have been recommended. The practice of universal oropharyngeal suctioning of the fetus on the perineum followed by routine intubation and suctioning of the trachea at birth was generally practiced for many years. This practice was abandoned over a decade ago after a large multicenter, multinational randomized clinical trial provided evidence that newborns born through meconium-stained amniotic fluid who were vigorous at birth did not benefit from intervention and could avoid the risk of intubation.[106]

Because the presence of meconium-stained amniotic fluid may indicate fetal distress and increases the risk that the infant will require resuscitation after birth, a team that includes an individual skilled in tracheal intubation should be present at the time of birth. If the infant is vigorous with good respiratory effort and muscle tone, the infant may stay with the mother to receive the initial steps of newborn care. Gentle clearing of meconium from the mouth and nose with a bulb syringe may be done if necessary.

However, if the infant born through meconium-stained amniotic fluid presents with poor muscle tone and inadequate breathing efforts, the initial steps of resuscitation should be completed under the radiant warmer. PPV should be initiated if the infant is not breathing or the heart rate is less than 100/min after the initial steps are completed. Routine intubation for tracheal suction in this setting is not suggested, because there is insufficient evidence to continue recommending this practice. (Class IIb, LOE C-LD)

In making this suggested change, greater value has been placed on harm avoidance (ie, delays in providing bag-mask ventilation, potential harm of the procedure) over the unknown benefit of the intervention of routine tracheal intubation and suctioning. Therefore, emphasis should be made on initiating ventilation within the first minute of life in nonbreathing or ineffectively breathing infants.

Although a definitive randomized clinical trial is still needed, current published human evidence does not support a recommendation for routine intervention of intubation and suction for the nonvigorous newborn with meconium-stained amniotic fluid.[107-116] Appropriate intervention to support ventilation and oxygenation should be initiated as indicated for each individual infant. This may include intubation and suction if the airway is obstructed.

4.3 Assessment of Heart Rate - Updated NRP 898

Immediately after birth, assessment of the newborn's heart rate is used to evaluate the effectiveness of spontaneous respiratory effort and determine the need for subsequent interventions. During resuscitation, an increase in the newborn's heart rate is considered the most sensitive indicator of a successful response to each intervention. Therefore, identifying a rapid, reliable, and accurate method to measure the newborn's heart rate is critically important. In previous treatment guidelines, auscultation of the precordium was recommended as the preferred physical examination method, and pulse oximetry was recommended as an adjunct to provide a noninvasive, rapid, and continuous assessment of heart rate during resuscitation.[2]

The 2015 ILCOR systematic review evaluated 1 study comparing clinical assessment with electrocardiography (ECG) in the delivery room[117] and 5 studies comparing simultaneous pulse oximetry and ECG.[118-122] Clinical assessment was found to be both unreliable and inaccurate. Among healthy newborns, providers frequently could not palpate the umbilical pulse and underestimated the newborn's heart rate by auscultation or palpation.[117] Four studies found that 3-lead ECG displayed a reliable heart rate faster than pulse oximetry.[118,120-122] In 2 studies, ECG was more likely to detect the newborn's heart rate during the first minute of life.[120,121] Although

the mean differences between the series of heart rates measured by ECG and pulse oximetry were small, pulse oximetry tended to underestimate the newborn's heart rate and would have led to potentially unnecessary interventions.[118,119,122] During the first 2 minutes of life, pulse oximetry frequently displayed the newborn's heart rate below either 60/ min or 100/min, while a simultaneous ECG showed the heart rate greater than 100/min.[122]

Many of the newborns included in the studies did not require resuscitation, and very few required chest compressions. The majority of the studies did not report any difficulties with applying the leads.[118-120]

During resuscitation of term and preterm newborns, the use of 3-lead ECG for the rapid and accurate measurement of the newborn's heart rate may be reasonable. (Class IIb, LOE C-LD)

The use of ECG does not replace the need for pulse oximetry to evaluate the newborn's oxygenation.

4.4 Assessment of Oxygen Need and Administration of Oxygen - Updated

There is a large body of evidence that blood oxygen levels in uncompromised babies generally do not reach extrauterine values until approximately 10 minutes following birth. Oxyhemoglobin saturation may normally remain in the 70% to 80% range for several minutes following birth, thus resulting in the appearance of cyanosis during that time. Other studies have shown that clinical assessment of skin color is a very poor indicator of oxyhemoglobin saturation during the immediate neonatal period and that lack of cyanosis appears to be a very poor indicator of the state of oxygenation of an uncompromised baby following birth.

Optimal management of oxygen during neonatal resuscitation becomes particularly important because of the evidence that either insufficient or excessive oxygenation can be harmful to the newborn infant. Hypoxia and ischemia are known to result in injury to multiple organs. Conversely there is growing experimental evidence, as well as evidence from studies of babies receiving resuscitation, that adverse outcomes may result from even brief exposure to excessive oxygen during and following resuscitation.

4.4.1 Use of Pulse Oximetry - Updated

This topic was last reviewed in 2010.[2]

It is recommended that oximetry be used when resuscitation can be anticipated, when PPV is administered, when central cyanosis persists beyond the first 5 to 10 minutes of life, or when supplementary oxygen is administered.

To appropriately compare oxygen saturations to similar published data, the probe should be attached to a preductal location (ie, the right upper extremity, usually the wrist or medial surface of the palm).[123]

4.4.2 Administration of Oxygen - Updated

4.4.2.1 Term Infants - Updated

This topic was last reviewed in 2010.[2]

Two meta-analyses of several randomized controlled trials comparing neonatal resuscitation initiated with room air versus 100% oxygen showed increased survival when resuscitation was initiated with air.[124,125] There are no studies in term infants comparing outcomes when resuscitations are initiated with different concentrations of oxygen other than 100% or room air.

It is reasonable to initiate resuscitation with air (21% oxygen at sea level).

If blended oxygen is not available, resuscitation should be initiated with air. (Class IIb, LOE B)

In the absence of studies comparing outcomes of neonatal resuscitation initiated with other oxygen concentrations or targeted at various oxyhemoglobin saturations, it is recommended that the goal in babies being resuscitated at birth, whether born at term or preterm, should be an oxygen saturation value in the interquartile range of preductal saturations (see table in Figure) measured in healthy term babies following vaginal birth at sea level. (Class IIb, LOE B)

These targets may be achieved by initiating resuscitation with air or a blended oxygen and titrating the oxygen concentration to achieve an SpO2 in the target range as described above using pulse oximetry. (Class IIb, LOE C)

If the baby is bradycardic (HR (Class IIb, LOE B)

4.4.2.2 Preterm - Updated NRP 864

Meta-analysis of 7 randomized trials that compared initiating resuscitation of preterm newborns (less than 35 weeks of gestation) with high oxygen (65% or greater) and low oxygen (21% to 30%) showed no improvement in survival to hospital discharge with the use of high oxygen.[126-132] Similarly, in the subset of studies that evaluated these outcomes, no benefit was seen for the prevention of bronchopulmonary dysplasia,[127,129-132] IVH,[127,130,131] or retinopathy of prematurity.[127,130,131] When oxygen targeting was used as a cointervention, the oxygen concentration of resuscitation gas and the preductal oxygen saturation were similar between the high-oxygen and low-oxygen groups within the first 10 minutes of life.[127,130,131]

In all studies, irrespective of whether air or high oxygen (including 100%) was used to initiate resuscitation, most infants were in approximately 30% oxygen by the time of stabilization.

Resuscitation of preterm newborns of less than 35 weeks of gestation should be initiated with low oxygen (21% to 30%), and the oxygen concentration should be titrated to achieve preductal oxygen saturation approximating the interquartile range measured in healthy term infants after vaginal birth at sea level.[133] (Class I, LOE B-R)

Initiating resuscitation of preterm newborns with high oxygen (65% or greater) is not recommended. (Class III—No Benefit, LOE B-R)

This recommendation reflects a preference for not exposing preterm newborns to additional oxygen without data demonstrating a proven benefit for important outcomes.

5 Positive Pressure Ventilation (PPV)

5.1 Initial Breaths NRP 809

Several recent animal studies have suggested that a longer sustained inflation may be beneficial for establishing functional residual capacity during transition from fluid-filled to air-filled lungs after birth.[134,135] Some clinicians have suggested applying this technique for transition of human newborns. Review of the literature in 2015 identified 3 randomized controlled trials[136-138] and 2 cohort studies[139,140] that demonstrated a benefit of sustained inflation for reducing need for mechanical ventilation (very low quality of evidence, downgraded for variability of interventions). However, no benefit was found for reduction of mortality, bronchopulmonary dysplasia, or air leak. One cohort study[139] suggested that the need for intubation was less after sustained inflation.

There is insufficient data regarding short and long-term safety and the most appropriate duration and pressure of inflation to support routine application of sustained inflation of greater than 5 seconds' duration to the transitioning newborn. (Class IIb, LOE B-R)

Further studies using carefully designed protocols are needed.

The 2010 recommendations are as follows:

Initial inflations following birth, either spontaneous or assisted, create a functional residual capacity (FRC).[141-144] The optimal pressure, inflation time, and flow rate required to establish an effective FRC when PPV is administered during resuscitation have not been determined. Evidence from animal studies indicates that preterm lungs are easily injured by large-volume inflations immediately after birth.[145,146] Assisted ventilation rates of 40 to 60 breaths per minute are commonly used, but the relative efficacy of various rates has not been investigated.

The primary measure of adequate initial ventilation is prompt improvement in heart rate.[147] Chest wall movement should be assessed if heart rate does not improve. The initial peak inflating pressures needed are variable and unpredictable and should be individualized to achieve an increase in heart rate or movement of the chest with each breath.

Inflation pressure should be monitored; an initial inflation pressure of 20 cm H2O may be effective, but ?30 to 40 cm H2O may be required in some term babies without spontaneous ventilation.[142,144,148] (Class IIb, LOE C)

If circumstances preclude the use of pressure monitoring, the minimal inflation required to achieve an increase in heart rate should be used. There is insufficient evidence to recommend an optimum inflation time.

In summary, assisted ventilation should be delivered at a rate of 40 to 60 breaths per minute to promptly achieve or maintain a heart rate >100 per minute. (Class IIb, LOE C)

The use of colorimetric CO_2 detectors during mask ventilation of small numbers of preterm infants in the intensive care unit and in the delivery room has been reported, and such detectors may help to identify airway obstruction.[149,150]

However, it is unclear whether the use of CO2 detectors during mask ventilation confers additional benefit above clinical assessment alone. (Class IIb, LOE C)

5.2 End-Expiratory Pressure NRP 897

Administration of PPV is the standard recommended treatment for both preterm and term infants who are apneic. A flow-inflating or self-inflating resuscitation bag or T-piece resuscitator are appropriate devices to use for PPV. In the 2010 Guidelines[2] and based on experience with delivering PPV in the neonatal intensive care unit, the use of positive end-expiratory pressure (PEEP) was speculated to be beneficial when PPV is administered to the newly born, but no published evidence was available to support this recommendation. PEEP was evaluated again in 2015, and 2 randomized controlled trials[151,152] suggested that addition of PEEP during delivery room resuscitation of preterm newborns resulted in no improvement in mortality, no less need for cardiac drugs or chest compressions, no more rapid improvement in heart rate, no less need for intubation, no change in pulmonary air leaks, no less chronic lung disease, and no effect on Apgar scores, although the studies were underpowered to have sufficient confidence in a no-difference conclusion. However, 1 of the trials[152] provided low-quality evidence that the maximum amount of supplementary oxygen required to achieve target oxygen saturation may be slightly less when using PEEP.

In 2015, the Neonatal Resuscitation ILCOR and Guidelines Task Forces repeated their 2010

recommendation that, when PPV is administered to preterm newborns, approximately 5 cm H2O PEEP is suggested. (Class IIb, LOE B-R)

This will require the addition of a PEEP valve for self-inflating bags.

5.3 Assisted-Ventilation Devices and Advanced Airways NRP 870, NRP 806

PPV can be delivered effectively with a flow-inflating bag, self-inflating bag, or T-piece resuscitator.[151], [152](Class IIa, LOE B-R)

PPV can be delivered effectively with a flow-inflating bag, self-inflating bag, or T-piece resuscitator.138,139 (Class IIa, LOE B-R)

The most appropriate choice may be guided by available resources, local expertise, and preferences. The self-inflating bag remains the only device that can be used when a compressed gas source is not available. Unlike flow-inflating bags or T-piece resuscitators, self-inflating bags cannot deliver continuous positive airway pressure (CPAP) and may not be able to achieve PEEP reliably during PPV, even with a PEEP valve.[153-156] However, it may take more practice to use a flow-inflating bag effectively. In addition to ease of use, T-piece resuscitators can consistently provide target inflation pressures and longer inspiratory times in mechanical models,[157-159] but there is insufficient evidence to suggest that these qualities result in improved clinical outcomes.[151,152]

It is likely that inflation pressures will need to change as compliance improves following birth, but the relationship of pressures to delivered volume and the optimal volume to deliver with each breath as FRC is being established have not been studied.

Resuscitators are insensitive to changes in lung compliance, regardless of the device being used.[160] (Class IIb, LOE C)

Use of respiratory mechanics monitors have been reported to prevent excessive pressures and tidal volumes[161] and exhaled CO2 monitors may help assess that actual gas exchange is occurring during face-mask PPV attempts.[162] Although use of such devices is feasible, thus far their effectiveness, particularly in changing important outcomes, has not been established. (Class IIb, LOE C-LD)

5.3.1 Laryngeal Mask - Updated NRP 618

Laryngeal masks, which fit over the laryngeal inlet, can achieve effective ventilation in term and preterm newborns at 34 weeks or more of gestation. Data are limited for their use in preterm infants delivered at less than 34 weeks of gestation or who weigh less than 2000 g. A laryngeal mask may be considered as an alternative to tracheal intubation if face-mask ventilation is unsuccessful in achieving effective ventilation.[163](Class IIb, LOE B-R)

A laryngeal mask is recommended during resuscitation of term and preterm newborns at 34 weeks or more of gestation when tracheal intubation is unsuccessful or is not feasible. (Class I, LOE C-EO)

Use of the laryngeal mask has not been evaluated during chest compressions or for administration of emergency medications.

5.3.2 Endotracheal Tube Placement

During neonatal resuscitation, endotracheal intubation may be indicated when bag-mask ventilation is ineffective or prolonged, when chest compressions are performed, or for special circumstances such as congenital diaphragmatic hernia. When PPV is provided through an endotracheal tube, the best indicator of successful

endotracheal intubation with successful inflation and aeration of the lungs is a prompt increase in heart rate. Although last reviewed in 2010,[2] exhaled CO detection remains the most reliable method of confirmation of endotracheal tube placement.[6,7]

Exhaled CO2 detection is effective for confirmation of endotracheal tube placement in infants, including very low-birth-weight infants.[164-167] (Class IIa, LOE B)

A positive test result (detection of exhaled CO_2) in patients with adequate cardiac output confirms placement of the endotracheal tube within the trachea, whereas a negative test result (ie, no CO_2 detected) strongly suggests esophageal intubation.[164-168]

Exhaled CO2 detection is the recommended method of confirmation of endotracheal tube placement. (Class IIa, LOE B)

Failure to detect exhaled CO2 in neonates with adequate cardiac output strongly suggests esophageal intubation. Poor or absent pulmonary blood flow (eg, during cardiac arrest) may result in failure to detect exhaled CO2 despite correct tube placement in the trachea and may result in unnecessary extubation and reintubation in these critically ill newborns.[2] Clinical assessment such as chest movement, presence of equal breath sounds bilaterally, and condensation in the endotracheal tube are additional indicators of correct endotracheal tube placement.

Clinical assessment such as chest movement, presence of equal breath sounds bilaterally, and condensation in the endotracheal tube are additional indicators of correct endotracheal tube placement.

5.4 Continuous Positive Airway Pressure (CPAP) NRP 590

Three randomized controlled trials enrolling 2358 preterm infants born at less than 30 weeks of gestation demonstrated that starting newborns on CPAP may be beneficial when compared with endotracheal intubation and PPV.[169-171] Starting CPAP resulted in decreased rate of intubation in the delivery room, decreased duration of mechanical ventilation with potential benefit of reduction of death and/or bronchopulmonary dysplasia, and no significant increase in air leak or severe IVH.

Based on this evidence, spontaneously breathing preterm infants with respiratory distress may be supported with CPAP initially rather than routine intubation for administering PPV. (Class IIb, LOE B-R)

6 Chest Compressions NRP 605 NRP 895 NRP 738 NRP 862

If the heart rate is less than 60/min despite adequate ventilation (via endotracheal tube if possible), chest compressions are indicated. Because ventilation is the most effective action in neonatal resuscitation and because chest compressions are likely to compete with effective ventilation, rescuers should ensure that assisted ventilation is being delivered optimally before starting chest compressions.[2]

Compressions are delivered on the lower third of the sternum[172-175] to a depth of approximately one third of the anterior-posterior diameter of the chest.[176] (Class IIb, LOE C-LD)

Two techniques have been described: compression with 2 thumbs with the fingers encircling the chest and supporting the back (the 2-thumb technique) or compression with 2 fingers with a second hand supporting the back (the 2-finger technique).

Because the 2-thumb technique generates higher blood pressures and coronary perfusion pressure with less rescuer fatigue, the 2 thumb–encircling hands technique is suggested as the preferred method.[177-191] (Class IIb, LOE C-LD)

Because the 2-thumb technique can be continued from the head of the bed while the umbilicus is accessed for insertion of an umbilical catheter, the 2-finger technique is no longer needed.

It is still suggested that compressions and ventilations be coordinated to avoid simultaneous delivery. The chest should be allowed to re-expand fully during relaxation, but the rescuer's thumbs should not leave the chest. The Neonatal Resuscitation ILCOR and Guidelines Task Forces continue to support use of a 3:1 ratio of compressions to ventilation, with 90 compressions and 30 breaths to achieve approximately 120 events per minute to maximize ventilation at an achievable rate.[192-197] (Class IIa, LOE C-LD)

Thus each event will be allotted approximately 1/2 second, with exhalation occurring during the first compression after each ventilation. (Class IIb, LOE C)

A 3:1 compression-to-ventilation ratio is used for neonatal resuscitation where compromise of gas exchange is nearly always the primary cause of cardiovascular collapse, but rescuers may consider using higher ratios (eg, 15:2) if the arrest is believed to be of cardiac origin. (Class IIb, LOE C-EO)

Respirations, heart rate, and oxygenation should be reassessed periodically, and coordinated chest compressions and ventilations should continue until the spontaneous heart rate is ?60 per minute. (Class IIb, LOE C)

However, frequent interruptions of compressions should be avoided, as they will compromise artificial maintenance of systemic perfusion and maintenance of coronary blood flow. (Class IIb, LOE C)

The Neonatal Guidelines Writing Group endorses increasing the oxygen concentration to 100% whenever chest compressions are provided. (Class IIa, LOE C-EO)

There are no available clinical studies regarding oxygen use during neonatal CPR. Animal evidence shows no advantage to 100% oxygen during CPR.[198-205] However, by the time resuscitation of a newborn infant has reached the stage of chest compressions, efforts to achieve return of spontaneous circulation using effective ventilation with low-concentration oxygen should have been attempted. Thus, it would appear sensible to try increasing the supplementary oxygen concentration.

To reduce the risks of complications associated with hyperoxia the supplementary oxygen concentration should be weaned as soon as the heart rate recovers. (Class I, LOE C-LD)

The current measure for determining successful progress in neonatal resuscitation is to assess the heart rate response. Other devices, such as end-tidal CO2 monitoring and pulse oximetry, may be useful techniques to determine when return of spontaneous circulation occurs.[206-210]

However, in asystolic/bradycardic neonates, we suggest against the routine use of any single feedback device such as ETCO2 monitors or pulse oximeters for detection of return of spontaneous circulation as their usefulness for this purpose in neonates has not been well established. (Class IIb, LOE C-LD)

7 Medications

Drugs are rarely indicated in resuscitation of the newly born infant. Bradycardia in the newborn infant is usually the result of inadequate lung inflation or profound hypoxemia, and establishing adequate ventilation is the most important step to correct it. However, if the heart rate remains less than 60/min despite adequate ventilation with 100% oxygen (preferably through an endotracheal tube) and chest compressions, administration of epinephrine or volume, or both, is indicated.[2]

7.1 Epinephrine

This topic was last reviewed in 2010.[2] Dosing recommendations remain unchanged from 2010.[6,7] Intravenous administration of epinephrine may be considered at a dose of 0.01 to 0.03 mg/kg of 1:10 000 epinephrine. If endotracheal administration is attempted while intravenous access is being established, higher dosing at 0.05 to 0.1 mg/kg may be reasonable. Given the lack of supportive data for endotracheal epinephrine, it is reasonable to provide drugs by the intravenous route as soon as venous access is established.

The 2010 Guidelines are as follows:

Epinephrine is recommended to be administered intravenously. (Class IIb, LOE C)

Given the lack of supportive data for endotracheal epinephrine, the IV route should be used as soon as venous access is established. (Class IIb, LOE C)

The recommended IV dose is 0.01 to 0.03 mg/kg per dose. Higher IV doses are not recommended because animal[211,212] and pediatric[213,214] studies show exaggerated hypertension, decreased myocardial function, and worse neurological function after administration of IV doses in the range of 0.1 mg/kg. If the endotracheal route is used, doses of 0.01 or 0.03 mg/kg will likely be ineffective.

Therefore, IV administration of 0.01 to 0.03 mg/kg per dose is the preferred route. While access is being obtained, administration of a higher dose (0.05 to 0.1 mg/kg) through the endotracheal tube may be considered, but the safety and efficacy of this practice have not been evaluated. (Class IIb, LOE C)

The concentration of epinephrine for either route should be 1:10 000 (0.1 mg/mL).

8 Volume Expansion

This topic was last reviewed in 2010.[2] Dosing recommendations remain unchanged from 2010. [6,7]

Volume expansion should be considered when blood loss is known or suspected (pale skin, poor perfusion, weak pulse) and the infant's heart rate has not responded adequately to other resuscitative measures.[215] (Class IIb, LOE C)

An isotonic crystalloid solution or blood may be useful for volume expansion in the delivery room. (Class IIb, LOE C)

The recommended dose is 10 mL/kg, which may need to be repeated. When resuscitating premature infants, care should be taken to avoid giving volume expanders rapidly, because rapid infusions of large volumes have been associated with IVH. (Class IIb, LOE C)

9 Postresuscitation Care

Infants who require resuscitation are at risk of deterioration after their vital signs have returned to normal. Once effective ventilation and/or the circulation has been established, the infant should be maintained in or transferred to an environment where close monitoring and anticipatory care can be provided.

9.1 Glucose - Updated

In the 2010 Guidelines, the potential role of glucose in modulating neurologic outcome after hypoxia-ischemia was identified. Lower glucose levels were associated with an increased risk for brain injury, while increased glucose levels may be protective. However, it was not possible to recommend a specific protective target glucose concentration range. There are no new data to change this recommendation.[6,7]

Intravenous glucose infusion should be considered as soon as practical after resuscitation, with the goal of avoiding hypoglycemia. (Class IIb, LOE C)

9.2 Induced Therapeutic Hypothermia

9.2.1 Resource-Abundant Areas

Induced therapeutic hypothermia was last reviewed in 2010.

It is recommended that infants born at more than 36 weeks of gestation with evolving moderate-to-severe hypoxic-ischemic encephalopathy should be offered therapeutic hypothermia under clearly defined protocols similar to those used in published clinical trials and in facilities with the capabilities for multidisciplinary care and longitudinal follow-up.[6,7] (Class IIa, LOE A)

This recommendation remains unchanged.

9.2.2 Resource-Limited Areas NRP 734

Evidence suggests that use of therapeutic hypothermia in resource-limited settings (ie, lack of qualified staff, inadequate equipment, etc) may be considered and offered under clearly defined protocols similar to those used in published clinical trials and in facilities with the capabilities for multidisciplinary care and longitudinal follow-up.[216-219] (Class IIb, LOE-B-R)

10 Guidelines for Withholding and Discontinuing

Data reviewed for the 2010 Guidelines regarding management of neonates born at the margins of viability or those with conditions that predict a high risk of mortality or morbidity document wide variation in attitudes and practice by region and availability of resources. Additionally, parents desire a larger role in decisions related to initiation of resuscitation and continuation of support of severely compromised newborns. Noninitiation of resuscitation and discontinuation of life-sustaining treatment during or after resuscitation are considered ethically equivalent. The 2010 Guidelines provide suggestions for when resuscitation is not indicated, when it is nearly always indicated, and that under circumstances when outcome remains unclear, that the desires of the parents should be supported. No new data have been published that would justify a change to these guidelines as published in 2010.[6,7]

Antenatal assignment of prognosis for survival and/or disability of the neonate born extremely preterm has generally been made on the basis of gestational age alone. Scoring systems for including additional variables such as gender, use of maternal antenatal steroids, and multiplicity have been developed in an effort to improve prognostic accuracy. Indeed, it was suggested in the 2010 Guidelines that decisions regarding morbidity and

risks of morbidity may be augmented by the use of published tools based on data from specific populations.

The 2010 Guidelines are as follows:

It is possible to identify conditions associated with high mortality and poor outcome in which withholding resuscitative efforts may be considered reasonable, particularly when there has been the opportunity for parental agreement.[220,221] (Class IIb, LOE C)

A consistent and coordinated approach to individual cases by the obstetric and neonatal teams and the parents is an important goal. Noninitiation of resuscitation and discontinuation of life-sustaining treatment during or after resuscitation are ethically equivalent, and clinicians should not hesitate to withdraw support when functional survival is highly unlikely.[222] The following guideline must be interpreted according to current regional outcomes:

When gestation, birth weight, or congenital anomalies are associated with almost certain early death and when unacceptably high morbidity is likely among the rare survivors, resuscitation is not indicated (Class IIb, LOE C)

10.1 Withholding Resuscitation NRP 805

There is no evidence to support the prospective use of any particular delivery room prognostic score presently available over gestational age assessment alone, in preterm infants at less than 25 weeks of gestation. Importantly, no score has been shown to improve the clinician's ability to estimate likelihood of survival through the first 18 to 22 months after birth.

However, in individual cases, when counseling a family and constructing a prognosis for survival at gestations below 25 weeks, it is reasonable to consider variables such as perceived accuracy of gestational age assignment, the presence or absence of chorioamnionitis, and the level of care available for location of delivery. It is also recognized that decisions about appropriateness of resuscitation below 25 weeks of gestation will be influenced by region-specific guidelines. In making this statement, a higher value was placed on the lack of evidence for a generalized prospective approach to changing important outcomes over improved retrospective accuracy and locally validated counseling policies. The most useful data for antenatal counseling provides outcome figures for infants alive at the onset of labor, not only for those born alive or admitted to a neonatal intensive care unit.[223-227] (Class IIb, LOE C-LD)

10.2 Discontinuing Resuscitative Efforts NRP 896

An Apgar score of 0 at 10 minutes is a strong predictor of mortality and morbidity in late preterm and term infants.

We suggest that, in infants with an Apgar score of 0 after 10 minutes of resuscitation, if the heart rate remains undetectable, it may be reasonable to stop assisted ventilation; however, the decision to continue or discontinue resuscitative efforts must be individualized. Variables to be considered may include whether the resuscitation was considered optimal; availability of advanced neonatal care, such as therapeutic hypothermia; specific circumstances before delivery (eg, known timing of the insult); and wishes expressed by the family.[228-233] (Class IIb, LOE C-LD)

11 Briefing/Debriefing

This topic was last reviewed in 2010.[2] It is still suggested that briefing and debriefing techniques be used whenever possible for neonatal resuscitation.

Also, studies examining briefings or debriefings of resuscitation team performance have generally shown improved knowledge or skills.[234-239] Interpretation of data is complicated by the heterogeneity and limitations of the studies, including a paucity of data about clinical outcomes.

Based on available evidence, it is recommended that the AAP/AHA Neonatal Resuscitation Program adopt simulation, briefing, and debriefing techniques in designing an education program for the acquisition and maintenance of the skills necessary for effective neonatal resuscitation. (Class IIb, LOE C)

12 Structure of Educational Programs to Teach Neonatal Resuscitation

12.1 Instructors NRP 867

In studies that looked at the preparation of instructors for the training of healthcare providers, there was no association between the preparation provided and instructor or learner performance.[240-247]

Until more research is available to clarify the optimal instructor training methodology, it is suggested that neonatal resuscitation instructors be trained using timely, objective, structured, and individually targeted verbal and/or written feedback (Class IIb, LOE C-EO)

12.2 Resuscitation Providers NRP 859

The 2010 Guidelines suggested that simulation should become a standard component in neonatal resuscitation training.[2,5,248]

Studies that explored how frequently healthcare providers or healthcare students should train showed no differences in patient outcomes (LOE C-EO) but were able to show some advantages in psychomotor performance (LOE B-R) and knowledge and confidence (LOE C-LD) when focused training occurred every 6 months or more frequently.[249-264] (Class IIb, LOE B-R)

It is therefore suggested that neonatal resuscitation task training occur more frequently than the current 2-year interval.[65] (Class IIb, LOE B-R)

13 Authorship and Disclosures

13.1 2015 Writing Team

Myra H. Wyckoff, Chair; Khalid Aziz; Marilyn B. Escobedo; Vishal S. Kapadia; John Kattwinkel; Jeffrey M. Perlman; Wendy M. Simon; Gary M. Weiner; Jeanette G. Zaichkin

Table 1: Part 13: Neonatal Resuscitation: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 13: Neonatal Resuscitation: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Myra H. Wyckoff	UT Southwestern Medical School	None	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Khalid Aziz	Royal Alexandra Hospital	None	None	None	None	None	None	None
Marilyn B. Escobedo	University of Oklahoma Medical School	None	None	None	None	None	None	None
Vishal S. Kapadia	UT Southwester	None	Neonatal Resuscitatio Program*; NIH/NCATS KL2TR0011(	None	None	None	None	None
John Kattwinkel	University of Virginia Health System	None	None	None	None	None	None	None
Jeffrey M. Perlman	Weill Cornell Medical College	None	Laerdal Foundation for Global Health*	None	None	None	None	None
Wendy M. Simon	American Academy of Pediatrics	None	None	None	None	None	None	None
Gary M. Weiner	University of Michigan	None	None	None	None	None	American Academy of Pediatrics†	None
Jeannette G. Zaichkin	Self-employed	None	None	None	None	None	American Academy of Pediatrics†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

13.2 2010 Writing Team

John Kattwinkel, Co-Chair; Jeffrey M. Perlman, Co-Chair; Khalid Aziz; Christopher Colby; Karen Fairchild; John Gallagher; Mary Fran Hazinski; Louis P. Halamek; Praveen Kumar; George Little; Jane E. McGowan; Barbara Nightengale; Mildred M. Ramirez; Steven Ringer; Wendy M. Simon; Gary M. Weiner; Myra Wyckoff; Jeanette

Zaichkin

Table 2: 2010 - Guidelines Part 15: Neonatal Resuscitation Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 15: Neonatal Resuscitation Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
John Kattwinkel	University of Virginia–Professor of Pediatrics	None	None	None	None	None	None
Jeffrey M. Perlman	Weill Cornell-Professor of Pediatrics	†NIH-NIH-Improving antimicrobial prescribing practices in the NICU	None	None	None	None	None
Khalid Aziz	University of Alberta–Associate Professor of Pediatrics	None	None	None	None	None	None
Christopher Colby	Mayo Clinic–physicia	None	None	None	None	None	None
Karen Fairchild	University of Virginia Health System–Associate Professor of Pediatrics	None	None	None	None	None	None
John Gallagher	Univ. Hosp of Cleveland-Crit Care Coordinator of Ped.Resp Care	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Mary Fran Hazinski	Vanderbilt University School of Nursing—Professor; AHA ECC Product Development-Senior Science Editor † Significant AHA compensation to write, edit and review documents such as the 2010 AHA Guidelines for CPR and ECC.	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Louis P. Halamek	Stanford University–Ass Professor	†Laerdal Foundation: The Laerdal Foundation (not company) provided a grant to the Center for Advanced Pediatric and Perinatal Education at Packard Children's Hospital at Stanford during the academic years 2006–07, 2007–08, 2008–09; I develop simulation-based training programs and conduct research at CAPE. This support was provided directly to my institution.	None	*I have received < 10 honoraria in amounts of $500 or less from speaking at various academic meetings in the past 24 months; none of these meetings were conducted by for-profit entities.	None	*Laerdal Medical Advanced Medical Simulation Both of these companies reimburse me directly.	*I provide medical consultation to the legal profession for which I am reimbursed directly.
Praveen Kumar	PEDIATRIC FACULTY FOUNDATION-ATTENDING NEONATOLOGIST	None	None	None	None	None	None
George Little	Dartmouth College-Ped. Professor; Dartmouth Hitchcock Medfont. Center Neonatologist	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Jane E. McGowan	St Christopher's Pediatric Associate/Tenet Healthcare–Attending neonatologist; medical director, NICU	None	None	None	None	None	* reviewed records of cases involving neonatal resuscitation on one or two occasions over the past 5 years. *As co-editor for Textbook of Neonatal Resuscitation 6th edition, to be published by the AAP, being paid a total of $4000 over 3 years by the AAP.
Barbara Nightengale	Univ.Health Assoc,Nurse Practitioner	None	None	None	None	None	None
Mildred M. Ramirez	Univ of Texas Med School Houston-Physician	None	None	*Signed as consultant for Cytokine Pharmasciences, Inc., for a lecture in Mexico City. Product Propress for cervical rippening. $2,000 Money to Univ.	None	None	*Expert for Current expert case of triplets and preterm delivery. Money to the university &lquote;09

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Steven Ringer	Brigham and Women's Hospital–Chief Newborn Medicine	None	None	*Vermont Oxford Neonatal Network, $1000, comes to me	None	*Alere $2000, consultation Dey Pharamaceutic $1000 Consultation Forrest Pharmaceutica $1500 Grant Review Committee	†Several Attorneys, serving as expert witness in Medical malpractice cases
Wendy M. Simon	American Academy of Pediatrics–Director, Life Support Programs	None	None	None	None	None	None
Gary M. Weiner	St. Joseph Mercy Hospital-Ann Arbor Michigan–Atte Neonatologist	None	†Received equipment on-loan (3 resuscitation mannequins, 2 sets of video recording equipment) from Laerdal Medical Corporation to be used to complete a research project evaluating educational methods for teaching neonatal resuscitation. The value of the on-loan equipment is approximately $35,000.	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
Myra Wyckoff	UT Southwestern Medical Center–Associate Professor of Pediatrics	†American Academy of Pediatrics Neonatal Research Grant-Ergonomics of Neonatal CPR 2008–2009	†Received a SimNewB neonatal simulator for help in Beta testing prior to final production	*Speaker at Symposia on Neonatal Care from University of Miami-honoraria paid to me Speaker at Symposia on Neonatal Care from Columbia/Cornell-honoraria paid directly to me Speaker for Grand Rounds from University of Oklahoma-honoraria paid directly to me	None	None	None
Jeanette Zaichkin	Seattle Children's Hospital–Neon Outreach Coordinator	None	None	*I receive honoraria directly to me from the AAP as compensation for editorial activities for NRP instructor ms.	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

14 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 13: Neonatal Resuscitation. ECCguidelines.heart.org.

References

1. Perlman JM, Wyllie J, Kattwinkel J, Wyckoff MH, Aziz K, Guinsburg R, Kim HS, Liley HG, Mildenhall L, Simon WM, Szyld E, Tamura M, Velaphi S; on behalf of the Neonatal Resuscitation Chapter Collaborators. Part 7: neonatal resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S204–S241. doi: 10.1161/CIR.0000000000000276.

2. WyllieJ,PerlmanJM,KattwinkelJ,WyckoffMH,AzizK,GuinsburgR,Kim HS, Liley HG, Mildenhall L, Simon WM, Szyld E, Tamura M, Velaphi S; on behalf of the Neonatal Resuscitation Chapter Collaborators. Part 7: neonatal resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

3. Kattwinkel J, Perlman JM, Aziz K, Colby C, Fairchild K, Gallagher J, Hazinski MF, Halamek LP, Kumar P, Little G, McGowan JE, Nightengale B, Ramirez MM, Ringer S, Simon WM, Weiner GM, Wyckoff M, Zaichkin J. Part 15: neonatal resuscitation: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3):S909–S919. doi: 10.1161/CIRCULATIONAHA.110.971119.

4. BarberCA,WyckoffMH.Useandefficacyofendotrachealversusintrave- nous epinephrine during neonatal cardiopulmonary resuscitation in the deliv- ery room. Pediatrics. 2006;118:1028–1034. doi: 10.1542/peds.2006-0416.

5. Aziz K, Chadwick M, Baker M, Andrews W. Ante- and intra-partum fac- tors that predict increased need for neonatal resuscitation. Resuscitation. 2008;79:444–452. doi: 10.1016/j.resuscitation.2008.08.004.

6. Zaichkin J, ed. Instructor Manual for Neonatal Resuscitation. Chicago, IL: American Academy of Pediatrics;2011.

7. Perlman JM, Wyllie J, Kattwinkel J, Atkins DL, Chameides L, Goldsmith JP, Guinsburg R, Hazinski MF, Morley C, Richmond S, Simon WM, Singhal N, Szyld E, Tamura M, Velaphi S; Neonatal Resuscitation Chapter Collaborators. Part 11: neonatal resuscitation: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122(suppl 2): S516–S538. doi: 10.1161/CIRCULATIONAHA.110.971127.

8. Wyllie J, Perlman JM, Kattwinkel J, Atkins DL, Chameides L, Goldsmith JP, Guinsburg R, Hazinski MF, Morley C, Richmond S, Simon WM, Singhal N, Szyld E, Tamura M, Velaphi S; Neonatal Resuscitation Chapter Collaborators. Part 11: neonatal resuscitation: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e260–e287. doi: 10.1016/j.resuscitation.2010.08.029.

9. Committee Opinion No.543: Timing of umbilical cord clamping after birth. Obstet Gynecol. 2012;120:1522–1526.

10. American Academy of Pediatrics. Statement of endorsement: timing of umbilical cord clamping after birth. Pediatrics. 2013;131:e1323.

11. Hosono S, Mugishima H, Fujita H, Hosono A, Minato M, Okada T, Takahashi S, Harada K. Umbilical cord milking reduces the need for red cell transfusions and improves neonatal adaptation in infants born at less than 29 weeks' gestation: a randomised controlled trial. Arch Dis Child Fetal Neonatal Ed. 2008;93:F14–F19. doi: 10.1136/adc.2006.108902.

12. Katheria AC, Leone TA, Woelkers D, Garey DM, Rich W, Finer NN. The effects of umbilical cord milking on hemodynamics and neonatal out- comes in premature neonates. J Pediatr. 2014;164:1045–1050.e1. doi: 10.1016/j.jpeds.2014.01.024.

13. MarchMI,HackerMR,ParsonAW,ModestAM,deVecianaM.Theeffects of umbilical cord milking in extremely preterm infants: a randomized con- trolled trial. J Perinatol. 2013;33:763–767. doi: 10.1038/jp.2013.70.

14. BudinP.TheNursling.TheFeedingandHygieneofPrematureandFull-term Infants. Translation by WJ Maloney. London: The Caxton Publishing Co;1907.

15. A Abd-El Hamid S, Badr-El Din MM, Dabous NI, Saad KM. Effect of the use of a polyethylene wrap on the morbidity and mortality of very low birth weight infants in Alexandria University Children's Hospital. J Egypt Public Health Assoc. 2012;87:104–108.

16. AcoletD,ElbourneD,McIntoshN,WeindlingM,KorkodilosM,HavilandJ, Modder J, Macintosh M; Confidential Enquiry Into Maternal and Child Health. Project 27/28: inquiry into quality of neonatal care and its effect on the survival of infants who were born at 27 and 28 weeks in England, Wales, and Northern Ireland. Pediatrics. 2005;116:1457–1465. doi: 10.1542/peds.2004-2691.

17. Bateman DA, O'Bryan L, Nicholas SW, Heagarty MC. Outcome of unattended out-of-hospital births in Harlem. Arch Pediatr Adolesc Med. 1994;148:147–152.

18. Bhoopalam PS, Watkinson M. Babies born before arrival at hospital. Br J Obstet Gynaecol. 1991;98:57–64.

19. Boo NY, Guat-Sim Cheah I; Malaysian National Neonatal Registry. Admission hypothermia among VLBW infants in Malaysian NICUs. J Trop Pediatr. 2013;59:447–452. doi: 10.1093/tropej/fmt051.

20. Buetow KC, Kelein SW. Effects of maintenenance of “normal” skin temperature on survival of infants of low birth weight. Pediatr. 1964;33:163–169.

21. Costeloe K, Hennessy E, Gibson AT, Marlow N, Wilkinson AR. The EPICure study: outcomes to discharge from hospital for infants born at the threshold of viability. Pediatrics. 2000;106:659–671.

22. Costeloe KL, Hennessy EM, Haider S, Stacey F, Marlow N, Draper ES. Short term outcomes after extreme preterm birth in England: compari- son of two birth cohorts in 1995 and 2006 (the EPICure studies). BMJ. 2012;345:e7976.

23. da Mota Silveira SM, Gonçalves de Mello MJ, de Arruda Vidal S, de Frias PG, Cattaneo A. Hypothermia on admission: a risk factor for death in new- borns referred to the Pernambuco Institute of Mother and Child Health. J Trop Pediatr. 2003;49:115–120.

24. Daga AS, Daga SR, Patole SK. Determinants of death among admissions to intensive care unit for newborns. J Trop Pediatr. 1991;37:53–56.

25. de Almeida MF, Guinsburg R, Sancho GA, Rosa IR, Lamy ZC, Martinez FE, da Silva RP, Ferrari LS, de Souza Rugolo LM, Abdallah VO, Silveira Rde C; Brazilian Network on Neonatal Research. Hypothermia and early neonatal mortality in preterm infants. J Pediatr. 2014;164:271–5.e1. doi: 10.1016/j.jpeds.2013.09.049.

26. García-Muñoz Rodrigo F, Rivero Rodríguez S, Siles Quesada C. [Hypothermia risk factors in the very low weight newborn and associ- ated morbidity and mortality in a neonatal care unit]. An Pediatr (Barc). 2014;80:144–150. doi: 10.1016/j.anpedi.2013.06.029.

27. Harms K, Osmers R, Kron M, Schill M, Kuhn W, Speer CP, Schröter W. [Mortality of premature infants 1980-1990: analysis of data from the Göttingen perinatal center]. Z Geburtshilfe Perinatol. 1994;198:126–133.

28. Hazan J, Maag U, Chessex P. Association between hypothermia and mortality rate of premature infants–revisited. Am J Obstet Gynecol. 1991;164(1 pt 1):111–112.

29. Jones P, Alberti C, Julé L, Chabernaud JL, Lodé N, Sieurin A, Dauger S. Mortality in out-of-hospital premature births. Acta Paediatr. 2011;100:181–187. doi: 10.1111/j.1651-2227.2010.02003.x.

30. Kalimba E, Ballot D. Survival of extremely low-birth-weight infants. South African Journal of Child Health. 2013;7:13–16.

31. Kambarami R, Chidede O. Neonatal hypothermia levels and risk factors for mortality in a tropical country. Cent Afr J Med. 2003;49:103–106.

32. Kent AL, Williams J. Increasing ambient operating theatre temperature and wrapping in polyethylene improves admission temperature in premature infants. J Paediatr Child Health. 2008;44:325–331. doi: 10.1111/j.1440-1754.2007.01264.x.

33. Laptook AR, Salhab W, Bhaskar B; Neonatal Research Network. Admission temperature of low birth weight infants: predictors and associated morbidities. Pediatrics. 2007;119:e643–e649. doi: 10.1542/ peds.2006-0943.

34. Lee HC, Ho QT, Rhine WD. A quality improvement project to improve admission temperatures in very low birth weight infants. J Perinatol. 2008;28:754–758. doi: 10.1038/jp.2008.92.

35. Levi S, Taylor W, Robinson LE, Levy LI. Analysis of morbidity and outcome of infants weighing less than 800 grams at birth. South Med J. 1984;77:975–978.

36. Manani M, Jegatheesan P, DeSandre G, Song D, Showalter L, Govindaswami B. Elimination of admission hypothermia in preterm very low-birth-weight infants by standardization of delivery room manage- ment. Perm J. 2013;17:8–13. doi: 10.7812/TPP/12-130.

37. Manji KP, Kisenge R. Neonatal hypothermia on admission to a special care unit in Dar-es-Salaam, Tanzania: a cause for concern. Cent Afr J Med. 2003;49:23–27.

38. Mathur NB, Krishnamurthy S, Mishra TK. Evaluation of WHO classifica- tion of hypothermia in sick extramural neonates as predictor of fatality. J Trop Pediatr. 2005;51:341–345. doi: 10.1093/tropej/fmi049.

39. Miller SS, Lee HC, Gould JB. Hypothermia in very low birth weight infants: distribution, risk factors and outcomes. J Perinatol. 2011;31 suppl 1:S49–S56. doi: 10.1038/jp.2010.177.

40. Mullany LC, Katz J, Khatry SK, LeClerq SC, Darmstadt GL, Tielsch JM. Risk of mortality associated with neonatal hypothermia in south- ern Nepal. Arch Pediatr Adolesc Med. 2010;164:650–656. doi: 10.1001/ archpediatrics.2010.103.

41. Nayeri F, Nili F. Hypothermia at birth and its associated complications in newborn infants: a follow-up study. Iran J Public Health. 2006;35:48–52.

42.

Obladen M, Heemann U, Hennecke KH, Hanssler L. [Causes of neona- tal mortality 1981-1983: a regional analysis]. Z Geburtshilfe Perinatol. 1985;189:181–187.

43. Ogunlesi TA, Ogunfowora OB, Adekanmbi FA, Fetuga BM, Olanrewaju DM. Point-of-admission hypothermia among high-risk Nigerian new- borns. BMC Pediatr. 2008;8:40. doi: 10.1186/1471-2431-8-40.

44. Pal DK, Manandhar DS, Rajbhandari S, Land JM, Patel N, de L Costello AM. Neonatal hypoglycaemia in Nepal 1. Prevalence and risk factors. Arch Dis Child Fetal Neonatal Ed. 2000;82:F46–F51.

45. Shah S, Zemichael O, Meng HD. Factors associated with mortality and length of stay in hospitalised neonates in Eritrea, Africa: a cross-sectional study. BMJ Open. 2012;2. doi: 10.1136/bmjopen-2011-000792.

46. Singh A, Yadav A, Singh A. Utilization of postnatal care for newborns and its association with neonatal mortality in India: an analytical appraisal. BMC Pregnancy Childbirth. 2012;12:33. doi: 10.1186/1471-2393-12-33.

47. Sodemann M, Nielsen J, Veirum J, Jakobsen MS, Biai S, Aaby P. Hypothermia of newborns is associated with excess mortality in the first 2 months of life in Guinea-Bissau, West Africa. Trop Med Int Health. 2008;13:980–986. doi: 10.1111/j.1365-3156.2008.02113.x.

48. Stanley FJ, Alberman EV. Infants of very low birthweight. I: Perinatal fac- tors affecting survival. Dev Med Child Neurol. 1978;20:300–312.

49. Wyckoff MH, Perlman JM. Effective ventilation and temperature control are vital to outborn resuscitation. Prehosp Emerg Care. 2004;8:191–195.

50. Bartels DB, Kreienbrock L, Dammann O, Wenzlaff P, Poets CF. Population based study on the outcome of small for gestational age new- borns. Arch Dis Child Fetal Neonatal Ed. 2005;90:F53–F59. doi: 10.1136/ adc.2004.053892.

51. Carroll PD, Nankervis CA, Giannone PJ, Cordero L. Use of polyethylene bags in extremely low birth weight infant resuscitation for the prevention of hypothermia. J Reprod Med. 2010;55:9–13.

52. Gleissner M, Jorch G, Avenarius S. Risk factors for intraventricular hemorrhage in a birth cohort of 3721 premature infants. J Perinat Med. 2000;28:104–110. doi: 10.1515/JPM.2000.013.

53. Herting E, Speer CP, Harms K, Robertson B, Curstedt T, Halliday HL, Compagnone D, Gefeller O, McClure G, Reid M. Factors influencing morbidity and mortality in infants with severe respiratory distress syn- drome treated with single or multiple doses of a natural porcine surfactant. Biol Neonate. 1992;61 suppl 1:26–30.

54. Van de Bor M, Van Bel F, Lineman R, Ruys JH. Perinatal factors and periventricular-intraventricular hemorrhage in preterm infants. Am J Dis Child. 1986;140:1125–1130.

55. DeMauro SB, Douglas E, Karp K, Schmidt B, Patel J, Kronberger A, Scarboro R, Posencheg M. Improving delivery room management for very preterm infants. Pediatrics. 2013;132:e1018–e1025. doi: 10.1542/ peds.2013-0686.

56. Harms K, Herting E, Kron M, Schill M, Schiffmann H. [Importance of pre- and perinatal risk factors in respiratory distress syndrome of prema- ture infants. A logical regression analysis of 1100 cases]. Z Geburtshilfe Neonatol. 1997;201:258–262.

57. Lee HC, Powers RJ, Bennett MV, Finer NN, Halamek LP, Nisbet C, Crockett M, Chance K, Blackney D, von Köhler C, Kurtin P, Sharek PJ. Implementation methods for delivery room management: a quality improvement comparison study. Pediatrics. 2014;134:e1378–e1386. doi: 10.1542/peds.2014-0863.

58. Reilly MC, Vohra S, Rac VE, Dunn M, Ferrelli K, Kiss A, Vincer M, Wimmer J, Zayack D, Soll RF; Vermont Oxford Network Heat Loss Prevention (HeLP) Trial Study Group. Randomized trial of occlusive wrap for heat loss prevention in preterm infants. J Pediatr. 2015;166:262–8.e2. doi: 10.1016/j.jpeds.2014.09.068.

59. Russo A, McCready M, Torres L, Theuriere C, Venturini S, Spaight M, Hemway RJ, Handrinos S, Perlmutter D, Huynh T, Grunebaum A, Perlman J. Reducing hypothermia in preterm infants following delivery. Pediatrics. 2014;133:e1055–e1062. doi: 10.1542/peds.2013-2544.

60. Zayeri F, Kazemnejad A, Ganjali M, Babaei G, Khanafshar N, Nayeri F. Hypothermia in Iranian newborns. Incidence, risk factors and related com- plications. Saudi Med J. 2005;26:1367–1371.

61. Anderson S, Shakya KN, Shrestha LN, Costello AM. Hypoglycaemia: a common problem among uncomplicated newborn infants in Nepal. J Trop Pediatr. 1993;39:273–277.

62. Lazic?-Mitrovic? T, Djukic? M, Cutura N, Andjelic? S, Curkovic? A, Soldo V, Radlovic? N. [Transitory hypothermia as early prognostic factor in term newborns with intrauterine growth retardation]. Srp Arh Celok Lek. 2010;138:604–608.

63. Lenclen R, Mazraani M, Jugie M, Couderc S, Hoenn E, Carbajal R, Blanc P, Paupe A. [Use of a polyethylene bag: a way to improve the thermal envi- ronment of the premature newborn at the delivery room]. Arch Pediatr. 2002;9:238–244.

64. Sasidharan CK, Gokul E, Sabitha S. Incidence and risk factors for neona- tal hypoglycaemia in Kerala, India. Ceylon Med J. 2004;49:110–113.

65. Mullany LC. Neonatal hypothermia in low-resource settings. Semin Perinatol. 2010;34:426–433. doi: 10.1053/j.semperi.2010.09.007.

66. Frascone RJ, Wayne MA, Swor RA, Mahoney BD, Domeier RM, Olinger ML, Tupper DE, Setum CM, Burkhart N, Klann L, Salzman JG, Wewerka SS, Yannopoulos D, Lurie KG, O'Neil BJ, Holcomb RG, Aufderheide TP. Treatment of non-traumatic out-of-hospital cardiac arrest with active compression decompression cardiopulmonary resuscitation plus an impedance threshold device. Resuscitation. 2013;84:1214–1222. doi: 10.1016/j. resuscitation.2013.05.002.

67. McCarthy LK, Molloy EJ, Twomey AR, Murphy JF, O'Donnell CP. A ran- domized trial of exothermic mattresses for preterm newborns in polyethyl- ene bags. Pediatrics. 2013;132:e135–e141. doi: 10.1542/peds.2013-0279.

68. Billimoria Z, Chawla S, Bajaj M, Natarajan G. Improving admission temperature in extremely low birth weight infants: a hospital-based multi- intervention quality improvement project. J Perinat Med. 2013;41:455–460. doi: 10.1515/jpm-2012-0259.

69. Chawla S, Amaram A, Gopal SP, Natarajan G. Safety and efficacy of Trans-warmer mattress for preterm neonates: results of a randomized controlled trial. J Perinatol. 2011;31:780–784. doi: 10.1038/jp.2011.33.

70. Ibrahim CP, Yoxall CW. Use of self-heating gel mattresses eliminates admission hypothermia in infants born below 28 weeks gestation. Eur J Pediatr. 2010;169:795–799. doi: 10.1007/s00431-009-1113-y.

71. Singh A, Duckett J, Newton T, Watkinson M. Improving neonatal unit admission temperatures in preterm babies: exothermic mattresses, poly- thene bags or a traditional approach? J Perinatol. 2010;30:45–49. doi: 10.1038/jp.2009.94.

72. Meyer MP, Payton MJ, Salmon A, Hutchinson C, de Klerk A. A clinical comparison of radiant warmer and incubator care for preterm infants from birth to 1800 grams. Pediatrics. 2001;108:395–401.

73. te Pas AB, Lopriore E, Dito I, Morley CJ, Walther FJ. Humidified and heated air during stabilization at birth improves temperature in preterm infants. Pediatrics. 2010;125:e1427–e1432. doi: 10.1542/peds.2009-2656.

74. Pinheiro JM, Furdon SA, Boynton S, Dugan R, Reu-Donlon C, Jensen S. Decreasing hypothermia during delivery room stabilization of preterm neonates. Pediatrics. 2014;133:e218–e226. doi: 10.1542/peds.2013-1293.

75. Petrova A, Demissie K, Rhoads GG, Smulian JC, Marcella S, Ananth CV. Association of maternal fever during labor with neonatal and infant morbidity and mortality. Obstet Gynecol. 2001;98:20–27.

76. Alexander JM, McIntire DM, Leveno KJ. Chorioamnionitis and the prognosis for term infants. Obstet Gynecol. 1999;94:274–278.

77. Greenwell EA, Wyshak G, Ringer SA, Johnson LC, Rivkin MJ, Lieberman E. Intrapartum temperature elevation, epidural use, and adverse out- come in term infants. Pediatrics. 2012;129:e447–e454. doi: 10.1542/ peds.2010-2301.

78. Goetzl L, Manevich Y, Roedner C, Praktish A, Hebbar L, Townsend DM. Maternal and fetal oxidative stress and intrapartum term fever. Am J Obstet Gynecol. 2010;202:363.e1–363.e5. doi: 10.1016/j.ajog.2010.01.034.

79. Glass HC, Pham TN, Danielsen B, Towner D, Glidden D, Wu YW. Antenatal and intrapartum risk factors for seizures in term newborns: a population-based study, California 1998-2002. J Pediatr. 2009;154:24–28.e1. doi: 10.1016/j.jpeds.2008.07.008.

80. Lieberman E, Lang J, Richardson DK, Frigoletto FD, Heffner LJ, Cohen A. Intrapartum maternal fever and neonatal outcome. Pediatrics. 2000;105(1 pt 1):8–13.

81. Lieberman E, Eichenwald E, Mathur G, Richardson D, Heffner L, Cohen A. Intrapartum fever and unexplained seizures in term infants. Pediatrics. 2000;106:983–988.

82. Badawi N, Kurinczuk JJ, Keogh JM, Alessandri LM, O'Sullivan F, Burton PR, Pemberton PJ, Stanley FJ. Intrapartum risk factors for new- born encephalopathy: the Western Australian case-control study. BMJ. 1998;317:1554–1558.

83. Impey L, Greenwood C, MacQuillan K, Reynolds M, Sheil O. Fever in labour and neonatal encephalopathy: a prospective cohort study. BJOG. 2001;108:594–597.

84. Impey LW, Greenwood CE, Black RS, Yeh PS, Sheil O, Doyle P. The rela- tionship between intrapartum maternal fever and neonatal acidosis as risk factors for neonatal encephalopathy. Am J Obstet Gynecol. 2008;198:49. e1–49.e6. doi: 10.1016/j.ajog.2007.06.011.

85. Linder N, Fridman E, Makhoul A, Lubin D, Klinger G, Laron-Kenet T, Yogev Y, Melamed N. Management of term newborns following maternal intrapartum fever. J Matern Fetal Neonatal Med. 2013;26:207–210. doi: 10.3109/14767058.2012.722727.

86. Butwick AJ, Lipman SS, Carvalho B. Intraoperative forced air-warming during cesarean delivery under spinal anesthesia does not prevent mater- nal hypothermia. Anesth Analg. 2007;105:1413–1419, table of contents. doi: 10.1213/01.ane.0000286167.96410.27.

87. Fallis WM, Hamelin K, Symonds J, Wang X. Maternal and new- born outcomes related to maternal warming during cesarean delivery. J Obstet Gynecol Neonatal Nurs. 2006;35:324–331. doi: 10.1111/ j.1552-6909.2006.00052.x.

88. Horn EP, Schroeder F, Gottschalk A, Sessler DI, Hiltmeyer N, Standl T, Schulte am Esch J. Active warming during cesarean delivery. Anesth Analg. 2002;94:409–414, table of contents.

89. Woolnough M, Allam J, Hemingway C, Cox M, Yentis SM. Intra- operative fluid warming in elective caesarean section: a blinded randomised controlled trial. Int J Obstet Anesth. 2009;18:346–351. doi: 10.1016/j.ijoa.2009.02.009.

90. Yokoyama K, Suzuki M, Shimada Y, Matsushima T, Bito H, Sakamoto A. Effect of administration of pre-warmed intravenous flu- ids on the frequency of hypothermia following spinal anesthesia for Cesarean delivery. J Clin Anesth. 2009;21:242–248. doi: 10.1016/j.jclinane.2008.12.010.

91. Belsches TC, Tilly AE, Miller TR, Kambeyanda RH, Leadford A, Manasyan A, Chomba E, Ramani M, Ambalavanan N, Carlo WA. Randomized trial of plastic bags to prevent term neonatal hypothermia in a resource-poor setting. Pediatrics. 2013;132:e656–e661. doi: 10.1542/ peds.2013-0172.

92. Leadford AE, Warren JB, Manasyan A, Chomba E, Salas AA, Schelonka R, Carlo WA. Plastic bags for prevention of hypothermia in preterm and low birth weight infants. Pediatrics. 2013;132:e128–e134. doi: 10.1542/ peds.2012-2030.

93. Raman S, Shahla A. Temperature drop in normal term newborn infants born at the University Hospital, Kuala Lumpur. Aust N Z J Obstet Gynaecol. 1992;32:117–119.

94. Bergman NJ, Linley LL, Fawcus SR. Randomized controlled trial of skin-to-skin contact from birth versus conventional incubator for physi- ological stabilization in 1200- to 2199-gram newborns. Acta Paediatr. 2004;93:779–785.

95. Fardig JA. A comparison of skin-to-skin contact and radiant heat- ers in promoting neonatal thermoregulation. J Nurse Midwifery. 1980;25:19–28.

96. Christensson K, Siles C, Moreno L, Belaustequi A, De La Fuente P, Lagercrantz H, Puyol P, Winberg J. Temperature, metabolic adaptation and crying in healthy full-term newborns cared for skin-to-skin or in a cot. Acta Paediatr. 1992;81:488–493.

97. Christensson K. Fathers can effectively achieve heat conservation in healthy newborn infants. Acta Paediatr. 1996;85:1354–1360.

98. Bystrova K, Widström AM, Matthiesen AS, Ransjö-Arvidson AB, Welles-Nyström B, Wassberg C, Vorontsov I, Uvnäs-Moberg K. Skin-to-skin contact may reduce negative consequences of “the stress of being born”: a study on temperature in newborn infants, subjected to different ward routines in St. Petersburg. Acta Paediatr. 2003;92:320–326.

99. Gouchon S, Gregori D, Picotto A, Patrucco G, Nangeroni M, Di Giulio P. Skin-to-skin contact after cesarean delivery: an experimental study. Nurs Res. 2010;59:78–84. doi: 10.1097/NNR.0b013e3181d1a8bc.

100. Marín Gabriel MA, Llana Martín I, López Escobar A, Fernández Villalba E, Romero Blanco I, Touza Pol P. Randomized controlled trial of early skin-to-skin contact: effects on the mother and the newborn. Acta Paediatr. 2010;99:1630–1634. doi: 10.1111/j.1651-2227.2009.01597.x.

101. Nimbalkar SM, Patel VK, Patel DV, Nimbalkar AS, Sethi A, Phatak A. Effect of early skin-to-skin contact following normal delivery on inci- dence of hypothermia in neonates more than 1800 g: randomized control trial. J Perinatol. 2014;34:364–368. doi: 10.1038/jp.2014.15.

102. Gungor S, Kurt E, Teksoz E, Goktolga U, Ceyhan T, Baser I. Oronasopharyngeal suction versus no suction in normal and term infants delivered by elective cesarean section: a prospective random- ized controlled trial. Gynecol Obstet Invest. 2006;61:9–14. doi: 10.1159/000087604.

103. Waltman PA, Brewer JM, Rogers BP, May WL. Building evidence for practice: a pilot study of newborn bulb suctioning at birth. J Midwifery Womens Health. 2004;49:32–38. doi: 10.1016/j.jmwh.2003.10.003.

104. Carrasco M, Martell M, Estol PC. Oronasopharyngeal suction at birth: effects on arterial oxygen saturation. J Pediatr. 1997;130:832–834.

105. Perlman JM, Volpe JJ. Suctioning in the preterm infant: effects on cerebral blood flow velocity, intracranial pressure, and arterial blood pressure. Pediatrics. 1983;72:329–334.

106. Simbruner G, Coradello H, Fodor M, Havelec L, Lubec G, Pollak A. Effect of tracheal suction on oxygenation, circulation, and lung mechanics in newborn infants. Arch Dis Child. 1981;56:326–330.

107. Vain NE, Szyld EG, Prudent LM, Wiswell TE, Aguilar AM, Vivas NI. Oropharyngeal and nasopharyngeal suctioning of meconium-stained neonates before delivery of their shoulders: multicentre, ran- domised controlled trial. Lancet. 2004;364:597–602. doi: 10.1016/S0140-6736(04)16852-9.

108. Al Takroni AM, Parvathi CK, Mendis KB, Hassan S, Reddy I, Kudair HA. Selective tracheal suctioning to prevent meconium aspiration syn- drome. Int J Gynaecol Obstet. 1998;63:259–263.

109. Chettri S, Adhisivam B, Bhat BV. Endotracheal suction for nonvigor- ous neonates born through meconium stained amniotic fluid: a random- ized controlled trial. J Pediatr. 2015;166:1208–1213.e1. doi: 10.1016/j. jpeds.2014.12.076.

110. Davis RO, Philips JB 3rd, Harris BA Jr, Wilson ER, Huddleston JF. Fatal meconium aspiration syndrome occurring despite airway management considered appropriate. Am J Obstet Gynecol. 1985;151:731–736.

111. Dooley SL, Pesavento DJ, Depp R, Socol ML, Tamura RK, Wiringa KS. Meconium below the vocal cords at delivery: correlation with intrapar- tum events. Am J Obstet Gynecol. 1985;153:767–770.

112. Hageman JR, Conley M, Francis K, Stenske J, Wolf I, Santi V, Farrell EE. Delivery room management of meconium staining of the amniotic fluid and the development of meconium aspiration syndrome. J Perinatol. 1988;8:127–131.

113. Manganaro R, Mamì C, Palmara A, Paolata A, Gemelli M. Incidence of meconium aspiration syndrome in term meconium-stained babies managed at birth with selective tracheal intubation. J Perinat Med. 2001;29:465–468. doi: 10.1515/JPM.2001.065.

114. Peng TC, Gutcher GR, Van Dorsten JP. A selective aggressive approach to the neonate exposed to meconium-stained amniotic fluid. Am J Obstet Gynecol. 1996;175:296–301; discussion 301.

115. Rossi EM, Philipson EH, Williams TG, Kalhan SC. Meconium aspiration syndrome: intrapartum and neonatal attributes. Am J Obstet Gynecol. 1989;161:1106–1110.

116. Suresh GK, Sarkar S. Delivery room management of infants born through thin meconium stained liquor. Indian Pediatr. 1994;31:1177–1181.

117. Yoder BA. Meconium-stained amniotic fluid and respiratory complications: impact of selective tracheal suction. Obstet Gynecol. 1994;83:77–84.

118. Kamlin CO, O'Donnell CP, Everest NJ, Davis PG, Morley CJ. Accuracy of clinical assessment of infant heart rate in the delivery room. Resuscitation. 2006;71:319–321. doi: 10.1016/j.resuscitation.2006.04.015.

119. Dawson JA, Saraswat A, Simionato L, Thio M, Kamlin CO, Owen LS, Schmölzer GM, Davis PG. Comparison of heart rate and oxygen satura- tion measurements from Masimo and Nellcor pulse oximeters in newly born term infants. Acta Paediatr. 2013;102:955–960. doi: 10.1111/ apa.12329.

120. Kamlin CO, Dawson JA, O'Donnell CP, Morley CJ, Donath SM, Sekhon J, Davis PG. Accuracy of pulse oximetry measurement of heart rate of newborn infants in the delivery room. J Pediatr. 2008;152:756–760. doi: 10.1016/j.jpeds.2008.01.002.

121. Katheria A, Rich W, Finer N. Electrocardiogram provides a continuous heart rate faster than oximetry during neonatal resuscitation. Pediatrics. 2012;130:e1177–e1181. doi: 10.1542/peds.2012-0784.

122. Mizumoto H, Tomotaki S, Shibata H, Ueda K, Akashi R, Uchio H, Hata D. Electrocardiogram shows reliable heart rates much earlier than pulse oximetry during neonatal resuscitation. Pediatr Int. 2012;54:205–207. doi: 10.1111/j.1442-200X.2011.03506.x.

123. van Vonderen JJ, Hooper SB, Kroese JK, Roest AA, Narayen IC, van Zwet EW, te Pas AB. Pulse oximetry measures a lower heart rate at birth compared with electrocardiography. J Pediatr. 2015;166:49–53. doi: 10.1016/j.jpeds.2014.09.015.

124. Dawson JA, Kamlin CO, Wong C, te Pas AB, O'Donnell CP, Donath SM, Davis PG, Morley CJ. Oxygen saturation and heart rate during delivery room resuscitation of infants h30 weeks' gestation with air or 100% oxygen. Arch Dis Child Fetal Neonatal Ed. 2009;94:F87–F91.

125. Davis PG, Tan A, O'Donnell CP, Schulze A. Resuscitation of newborn infants with 100% oxygen or air: a systematic review and meta-analysis. Lancet. 2004;364:1329–1333.

126. Rabi Y, Rabi D, Yee W. Room air resuscitation of the depressed newborn: a systematic review and meta-analysis. Resuscitation. 2007;72:353–363.

127. Armanian AM, Badiee Z. Resuscitation of preterm newborns with low concentration oxygen versus high concentration oxygen. J Res Pharm Pract. 2012;1:25–29. doi: 10.4103/2279-042X.99674.

128. Kapadia VS, Chalak LF, Sparks JE, Allen JR, Savani RC, Wyckoff MH. Resuscitation of preterm neonates with limited versus high oxygen strat- egy. Pediatrics. 2013;132:e1488–e1496. doi: 10.1542/peds.2013-0978.

129. Lundstrøm KE, Pryds O, Greisen G. Oxygen at birth and prolonged cere- bral vasoconstriction in preterm infants. Arch Dis Child Fetal Neonatal Ed. 1995;73:F81–F86.

130. Rabi Y, Singhal N, Nettel-Aguirre A. Room-air versus oxygen adminis- tration for resuscitation of preterm infants: the ROAR study. Pediatrics. 2011;128:e374–e381. doi: 10.1542/peds.2010-3130.

131. Rook D, Schierbeek H, Vento M, Vlaardingerbroek H, van der Eijk AC, Longini M, Buonocore G, Escobar J, van Goudoever JB, Vermeulen MJ. Resuscitation of preterm infants with different inspired oxygen fractions. J Pediatr. 2014;164:1322–6.e3. doi: 10.1016/j.jpeds.2014.02.019.

132. Vento M, Moro M, Escrig R, Arruza L, Villar G, Izquierdo I, Roberts LJ 2nd, Arduini A, Escobar JJ, Sastre J, Asensi MA. Preterm resusci- tation with low oxygen causes less oxidative stress, inflammation, and chronic lung disease. Pediatrics. 2009;124:e439–e449. doi: 10.1542/ peds.2009-0434.

133. Wang CL, Anderson C, Leone TA, Rich W, Govindaswami B, Finer NN. Resuscitation of preterm neonates by using room air or 100% oxygen. Pediatrics. 2008;121:1083–1089. doi: 10.1542/peds.2007-1460.

134. Mariani G, Dik PB, Ezquer A, Aguirre A, Esteban ML, Perez C, Fernandez Jonusas S, Fustiñana C. Pre-ductal and post-ductal O2 satura- tion in healthy term neonates after birth. J Pediatr. 2007;150:418–421. doi: 10.1016/j.jpeds.2006.12.015.

135. Klingenberg C, Sobotka KS, Ong T, Allison BJ, Schmölzer GM, Moss TJ, Polglase GR, Dawson JA, Davis PG, Hooper SB. Effect of sus- tained inflation duration; resuscitation of near-term asphyxiated lambs. Arch Dis Child Fetal Neonatal Ed. 2013;98:F222–F227. doi: 10.1136/ archdischild-2012-301787.

136. te Pas AB, Siew M, Wallace MJ, Kitchen MJ, Fouras A, Lewis RA, Yagi N, Uesugi K, Donath S, Davis PG, Morley CJ, Hooper SB. Effect of sustained inflation length on establishing functional residual capacity at birth in ventilated premature rabbits. Pediatr Res. 2009;66:295–300. doi: 10.1203/PDR.0b013e3181b1bca4.

137. Harling AE, Beresford MW, Vince GS, Bates M, Yoxall CW. Does sus- tained lung inflation at resuscitation reduce lung injury in the preterm infant? Arch Dis Child Fetal Neonatal Ed. 2005;90:F406–F410. doi: 10.1136/adc.2004.059303.

138. Lindner W, Högel J, Pohlandt F. Sustained pressure-controlled inflation or intermittent mandatory ventilation in preterm infants in the delivery room? A randomized, controlled trial on initial respiratory support via nasopharyngeal tube. Acta Paediatr. 2005;94:303–309.

139. Lista G, Boni L, Scopesi F, Mosca F, Trevisanuto D, Messner H, Vento G, Magaldi R, Del Vecchio A, Agosti M, Gizzi C, Sandri F, Biban P, Bellettato M, Gazzolo D, Boldrini A, Dani C; SLI Trial Investigators. Sustained lung inflation at birth for preterm infants: a randomized clini- cal trial. Pediatrics. 2015;135:e457–e464. doi: 10.1542/peds.2014-1692.

140. Lindner W, Vossbeck S, Hummler H, Pohlandt F. Delivery room manage- ment of extremely low birth weight infants: spontaneous breathing or intubation? Pediatrics. 1999;103(5 pt 1):961–967.

141. Lista G, Fontana P, Castoldi F, Cavigioli F, Dani C. Does sustained lung inflation at birth improve outcome of preterm infants at risk for respiratory distress syndrome? Neonatology. 2011;99:45–50. doi: 10.1159/000298312.

142. Karlberg P, Koch G. Respiratory studies in newborn infants. III. Development of mechanics of breathing during the first week of life. A longitudinal study. Acta Paediatr. 1962;(Suppl 135):121–129.

143. Vyas H, Milner AD, Hopkin IE, Boon AW. Physiologic responses to prolonged and slow-rise inflation in the resuscitation of the asphyxiated newborn infant. J Pediatr. 1981;99:635–639.

144. Vyas H, Field D, Milner AD, Hopkin IE. Determinants of the first inspiratory volume and functional residual capacity at birth. Pediatr Pulmonol. 1986;2:189–193.

145. Boon AW, Milner AD, Hopkin IE. Lung expansion, tidal exchange, and formation of the functional residual capacity during resuscitation of asphyxiated neonates. J Pediatr. 1979;95:1031–1036.

146. Hillman NH, Moss TJ, Kallapur SG, Bachurski C, Pillow JJ, Polglase GR, Nitsos I, Kramer BW, Jobe AH. Brief, large tidal volume ventilation initiates lung injury and a systemic response in fetal sheep. Am J Respir Crit Care Med. 2007;176:575–581.

147. Polglase GR, Hooper SB, Gill AW, Allison BJ, McLean CJ, Nitsos I, Pillow JJ, Kluckow M. Cardiovascular and pulmonary consequences of airway recruitment in preterm lambs. J Appl Physiol. 2009;106:1347–1355.

148. Dawes GS. Foetal and Neonatal Physiology. A Comparative Study of the Changes at Birth. Chicago: Year Book Medical Publishers, Inc; 1968.

149. Lindner W, Vossbeck S, Hummler H, Pohlandt F. Delivery room management of extremely low birth weight infants: spontaneous breathing or intubation? Pediatrics. 1999;103():961–967.

150. Leone TA, Lange A, Rich W, Finer NN. Disposable colorimetric carbon dioxide detector use as an indicator of a patent airway during noninvasive mask ventilation. Pediatrics. 2006;118:e202–204.

151. Finer NN, Rich W, Wang C, Leone T. Airway obstruction during mask ventilation of very low birth weight infants during neonatal resuscitation. Pediatrics. 2009;123:865–869.

152. Dawson JA, Schmölzer GM, Kamlin CO, Te Pas AB, O'Donnell CP, Donath SM, Davis PG, Morley CJ. Oxygenation with T-piece versus self-inflating bag for ventilation of extremely preterm infants at birth: a randomized controlled trial. J Pediatr. 2011;158:912–918.e1. doi: 10.1016/j.jpeds.2010.12.003.

153. Szyld E, Aguilar A, Musante GA, Vain N, Prudent L, Fabres J, Carlo WA; Delivery Room Ventilation Devices Trial Group. Comparison of devices for newborn ventilation in the delivery room. J Pediatr. 2014;165: 234–239.e3. doi: 10.1016/j.jpeds.2014.02.035.

154. Dawson JA, Gerber A, Kamlin CO, Davis PG, Morley CJ. Providing PEEP during neonatal resuscitation: which device is best? J Paediatr Child Health. 2011;47:698–703. doi: 10.1111/j.1440-1754.2011.02036.x.

155. Morley CJ, Dawson JA, Stewart MJ, Hussain F, Davis PG. The effect of a PEEP valve on a Laerdal neonatal self-inflating resusci- tation bag. J Paediatr Child Health. 2010;46:51–56. doi: 10.1111/ j.1440-1754.2009.01617.x.

156. Bennett S, Finer NN, Rich W, Vaucher Y. A comparison of three neonatal resuscitation devices. Resuscitation. 2005;67:113–118. doi: 10.1016/j. resuscitation.2005.02.016.

157. Kelm M, Proquitté H, Schmalisch G, Roehr CC. Reliability of two common PEEP-generating devices used in neonatal resuscitation. Klin Padiatr. 2009;221:415–418. doi: 10.1055/s-0029-1233493.

158. Oddie S, Wyllie J, Scally A. Use of self-inflating bags for neona- tal resuscitation. Resuscitation. 2005;67:109–112. doi: 10.1016/j.resuscitation.2005.05.004.

159. Hussey SG, Ryan CA, Murphy BP. Comparison of three manual ven- tilation devices using an intubated mannequin. Arch Dis Child Fetal Neonatal Ed. 2004;89:F490–F493. doi: 10.1136/adc.2003.047712.

160. Finer NN, Rich W, Craft A, Henderson C. Comparison of methods of bag and mask ventilation for neonatal resuscitation. Resuscitation. 2001;49:299–305.

161. Kattwinkel J, Stewart C, Walsh B, Gurka M, Paget-Brown A. Responding to compliance changes in a lung model during manual ventilation: perhaps volume, rather than pressure, should be displayed. Pediatrics. 2009;123:e465–470.

162. Schmölzer GM, Morley CJ, Wong C, Dawson JA, Kamlin CO, Donath SM, Hooper SB, Davis PG. Respiratory function monitor guidance of mask ventilation in the delivery room: a feasibility study. J Pediatr. 2012;160:377–381.e2. doi: 10.1016/j.jpeds.2011.09.017.

163. Kong JY, Rich W, Finer NN, Leone TA. Quantitative end-tidal carbon dioxide monitoring in the delivery room: a randomized controlled trial. J Pediatr. 2013;163:104–8.e1. doi: 10.1016/j.jpeds.2012.12.016.

164. Esmail N, Saleh M, et al. Laryngeal mask airway versus endotracheal intubation for Apgar score improvement in neonatal resuscitation. Egypt J Anesth. 2002;18:115–121.

165. Hosono S, Inami I, Fujita H, Minato M, Takahashi S, Mugishima H. A role of end-tidal CO monitoring for assessment of tracheal intubations in very low birth weight infants during neonatal resuscitation at birth. J Perinat Med. 2009;37:79–84.

166. Repetto JE, Donohue P-CP, Baker SF, Kelly L, Nogee LM. Use of capnography in the delivery room for assessment of endotracheal tube placement. J Perinatol. 2001;21:284–287.

167. Roberts WA, Maniscalco WM, Cohen AR, Litman RS, Chhibber A. The use of capnography for recognition of esophageal intubation in the neonatal intensive care unit. Pediatr Pulmonol. 1995;19:262–268.

168. Aziz HF, Martin JB, Moore JJ. The pediatric disposable end-tidal carbon dioxide detector role in endotracheal intubation in newborns. J Perinatol. 1999;19:110–113.

169. Garey DM, Ward R, Rich W, Heldt G, Leone T, Finer NN. Tidal volume threshold for colorimetric carbon dioxide detectors available for use in neonates. Pediatrics. 2008;121:e1524–1527.

170. Morley CJ, Davis PG, Doyle LW, Brion LP, Hascoet JM, Carlin JB; COIN Trial Investigators. Nasal CPAP or intubation at birth for very preterm infants. N Engl J Med. 2008;358:700–708. doi: 10.1056/ NEJMoa072788.

171. SUPPORT Study Group of the Eunice Kennedy Shriver NICHD Neonatal Research Network, Finer NN, Carlo WA, Walsh MC, Rich W, Gantz MG, Laptook AR, Yoder BA, Faix RG, Das A, Poole WK, Donovan EF, Newman NS, Ambalavanan N, Frantz ID 3rd, Buchter S, Sanchez PJ, Kennedy KA, Laroia N, Poindexter BB, Cotten CM, Van Meurs KP, Duara S, Narendran V, Sood BG, O'Shea TM, Bell EF, Bhandari V, Watterberg KL, Higgins RD. Early CPAP versus surfactant in extremely preterm infants. N Engl J Med. 2010;362:1970–1979.

172. Dunn MS, Kaempf J, de Klerk A, de Klerk R, Reilly M, Howard D, Ferrelli K, O'Conor J, Soll RF; Vermont Oxford Network DRM Study Group. Randomized trial comparing 3 approaches to the initial respi- ratory management of preterm neonates. Pediatrics. 2011;128:e1069– e1076. doi: 10.1542/peds.2010-3848.

173. Orlowski JP. Optimum position for external cardiac compression in infants and young children. Ann Emerg Med. 1986;15:667–673.

174. Phillips GW, Zideman DA. Relation of infant heart to sternum: its signifi- cance in cardiopulmonary resuscitation. Lancet. 1986;1:1024–1025.

175. Saini SS, Gupta N, Kumar P, Bhalla AK, Kaur H. A comparison of two- fingers technique and two-thumbs encircling hands technique of chest compression in neonates. J Perinatol. 2012;32:690–694. doi: 10.1038/ jp.2011.167.

176. You Y. Optimum location for chest compressions during two-rescuer infant cardiopulmonary resuscitation. Resuscitation. 2009;80:1378– 1381. doi: 10.1016/j.resuscitation.2009.08.013.

177. Meyer A, Nadkarni V, Pollock A, Babbs C, Nishisaki A, Braga M, Berg RA, Ades A. Evaluation of the Neonatal Resuscitation Program's recommended chest compression depth using computerized tomog- raphy imaging. Resuscitation. 2010;81:544–548. doi: 10.1016/j.resuscitation.2010.01.032.

178. Christman C, Hemway RJ, Wyckoff MH, Perlman JM. The two-thumb is superior to the two-finger method for administering chest compres- sions in a manikin model of neonatal resuscitation. Arch Dis Child Fetal Neonatal Ed. 2011;96:F99–F101. doi: 10.1136/adc.2009.180406.

179. David R. Closed chest cardiac massage in the newborn infant. Pediatrics. 1988;81:552–554.

180. Dellimore K, Heunis S, Gohier F, Archer E, de Villiers A, Smith J, Scheffer C. Development of a diagnostic glove for unobtrusive measurement of chest compression force and depth during neonatal CPR. Conf Proc IEEE Eng Med Biol Soc. 2013;2013:350–353. doi: 10.1109/ EMBC.2013.6609509.

181. Dorfsman ML, Menegazzi JJ, Wadas RJ, Auble TE. Two-thumb vs. two- finger chest compression in an infant model of prolonged cardiopulmo- nary resuscitation. Acad Emerg Med. 2000;7:1077–1082.

182. Houri PK, Frank LR, Menegazzi JJ, Taylor R. A randomized, con- trolled trial of two-thumb vs two-finger chest compression in a swine infant model of cardiac arrest [see comment]. Prehosp Emerg Care. 1997;1:65–67.

183. Martin PS, Kemp AM, Theobald PS, Maguire SA, Jones MD. Do chest compressions during simulated infant CPR comply with international recommendations? Arch Dis Child. 2013;98:576–581. doi: 10.1136/ archdischild-2012-302583.

184. Martin PS, Kemp AM, Theobald PS, Maguire SA, Jones MD. Does a more “physiological” infant manikin design effect chest compression quality and create a potential for thoracic over-compression during simulated infant CPR? Resuscitation. 2013;84:666–671. doi: 10.1016/j. resuscitation.2012.10.005.

185. Martin P, Theobald P, Kemp A, Maguire S, Maconochie I, Jones M. Real-time feedback can improve infant manikin cardiopulmonary resus- citation by up to 79%–a randomised controlled trial. Resuscitation. 2013;84:1125–1130. doi: 10.1016/j.resuscitation.2013.03.029.

186. Menegazzi JJ, Auble TE, Nicklas KA, Hosack GM, Rack L, Goode JS. Two-thumb versus two-finger chest compression during CRP in a swine infant model of cardiac arrest. Ann Emerg Med. 1993;22:240–243.

187. MOYA F, JAMES LS, BURNARD ED, HANKS EC. Cardiac massage in the newborn infant through the intact chest. Am J Obstet Gynecol. 1962;84:798–803.

188. Park J, Yoon C, Lee JC, Jung JY, Kim do K, Kwak YH, Kim HC. Manikin-integrated digital measuring system for assessment of infant cardiopulmonary resuscitation techniques. IEEE J Biomed Health Inform. 2014;18:1659–1667. doi: 10.1109/JBHI.2013.2288641.

189. Thaler MM, Stobie GH. An improved technic of external cardiac compression in infants and young children. N Engl J Med. 1963;269: 606–610. doi: 10.1056/NEJM196309192691204.

190. Todres ID, Rogers MC. Methods of external cardiac massage in the newborn infant. J Pediatr. 1975;86:781–782.

191. Udassi S, Udassi JP, Lamb MA, Theriaque DW, Shuster JJ, Zaritsky AL, Haque IU. Two-thumb technique is superior to two-finger technique dur- ing lone rescuer infant manikin CPR. Resuscitation. 2010;81:712–717. doi: 10.1016/j.resuscitation.2009.12.029.

192. Whitelaw CC, Slywka B, Goldsmith LJ. Comparison of a two-finger ver- sus two-thumb method for chest compressions by healthcare providers in an infant mechanical model. Resuscitation. 2000;43:213–216.

193. Dannevig I, Solevåg AL, Saugstad OD, Nakstad B. Lung injury in asphyxiated newborn pigs resuscitated from cardiac arrest—the impact of supplementary oxygen, longer ventilation intervals and chest com- pressions at different compression-to-ventilation ratios. Open Respir Med J. 2012;6:89–96. doi: 10.2174/1874306401206010089.

194. Dannevig I, Solevåg AL, Sonerud T, Saugstad OD, Nakstad B. Brain inflammation induced by severe asphyxia in newborn pigs and the impact of alternative resuscitation strategies on the newborn central nervous sys- tem. Pediatr Res. 2013;73:163–170. doi: 10.1038/pr.2012.167.

195. Hemway RJ, Christman C, Perlman J. The 3:1 is superior to a 15:2 ratio in a newborn manikin model in terms of quality of chest compres- sions and number of ventilations. Arch Dis Child Fetal Neonatal Ed. 2013;98:F42–F45. doi: 10.1136/archdischild-2011-301334.

196. Solevåg AL, Dannevig I, Wyckoff M, Saugstad OD, Nakstad B. Extended series of cardiac compressions during CPR in a swine model of perinatal asphyxia. Resuscitation. 2010;81:1571–1576. doi: 10.1016/j. resuscitation.2010.06.007.

197. Solevåg AL, Dannevig I, Wyckoff M, Saugstad OD, Nakstad B. Return of spontaneous circulation with a compression:ventilation ratio of 15:2 versus 3:1 in newborn pigs with cardiac arrest due to asphyxia. Arch Dis Child Fetal Neonatal Ed. 2011;96:F417–F421. doi: 10.1136/ adc.2010.200386.

198. Solevåg AL, Madland JM, Gjærum E, Nakstad B. Minute ventilation at different compression to ventilation ratios, different ventilation rates, and continuous chest compressions with asynchronous ventilation in a newborn manikin. Scand J Trauma Resusc Emerg Med. 2012;20:73. doi: 10.1186/1757-7241-20-73.

199. Lakshminrusimha S, Steinhorn RH, Wedgwood S, Savorgnan F, Nair J, Mathew B, Gugino SF, Russell JA, Swartz DD. Pulmonary hemodynam- ics and vascular reactivity in asphyxiated term lambs resuscitated with 21 and 100% oxygen. J Appl Physiol (1985). 2011;111:1441–1447. doi: 10.1152/japplphysiol.00711.2011.

200. Linner R, Werner O, Perez-de-Sa V, Cunha-Goncalves D. Circulatory recovery is as fast with air ventilation as with 100% oxygen after asphyxia-induced cardiac arrest in piglets. Pediatr Res. 2009;66:391– 394. doi: 10.1203/PDR.0b013e3181b3b110.

201. Lipinski CA, Hicks SD, Callaway CW. Normoxic ventilation dur- ing resuscitation and outcome from asphyxial cardiac arrest in rats. Resuscitation. 1999;42:221–229.

202. Perez-de-Sa V, Cunha-Goncalves D, Nordh A, Hansson S, Larsson A, Ley D, Fellman V, Werner O. High brain tissue oxygen tension during ventilation with 100% oxygen after fetal asphyxia in newborn sheep. Pediatr Res. 2009;65:57–61.

203. Solevåg AL, Dannevig I, Nakstad B, Saugstad OD. Resuscitation of severely asphyctic newborn pigs with cardiac arrest by using 21% or 100% oxygen. Neonatology. 2010;98:64–72. doi: 10.1159/000275560.

204. Temesvári P, Karg E, Bódi I, Németh I, Pintér S, Lazics K, Domoki F, Bari F. Impaired early neurologic outcome in newborn piglets reoxygenated with 100% oxygen compared with room air after pneu- mothorax-induced asphyxia. Pediatr Res. 2001;49:812–819. doi: 10.1203/00006450-200106000-00017.

205. Walson KH, Tang M, Glumac A, Alexander H, Manole MD, Ma L, Hsia CJ, Clark RS, Kochanek PM, Kagan VE, Bayr H. Normoxic versus hyperoxic resuscitation in pediatric asphyxial cardiac arrest: effects on oxidative stress. Crit Care Med. 2011;39:335–343. doi: 10.1097/ CCM.0b013e3181ffda0e.

206. Yeh ST, Cawley RJ, Aune SE, Angelos MG. Oxygen requirement dur- ing cardiopulmonary resuscitation (CPR) to effect return of sponta- neous circulation. Resuscitation. 2009;80:951–955. doi: 10.1016/j. resuscitation.2009.05.001.

207. Berg RA, Henry C, Otto CW, Sanders AB, Kern KB, Hilwig RW, Ewy GA. Initial end-tidal CO2 is markedly elevated during cardiopulmonary resuscitation after asphyxial cardiac arrest. Pediatr Emerg Care. 1996;12:245–248.

208. Bhende MS, Karasic DG, Menegazzi JJ. Evaluation of an end-tidal CO2 detector during cardiopulmonary resuscitation in a canine model for pediatric cardiac arrest. Pediatr Emerg Care. 1995;11:365–368.

209. Bhende MS, Thompson AE. Evaluation of an end-tidal CO2 detec- tor during pediatric cardiopulmonary resuscitation. Pediatrics. 1995;95:395–399.

210. Bhende MS, Karasic DG, Karasic RB. End-tidal carbon dioxide changes during cardiopulmonary resuscitation after experimental asphyxial cardiac arrest. Am J Emerg Med. 1996;14:349–350. doi: 10.1016/ S0735-6757(96)90046-7.

211. Chalak LF, Barber CA, Hynan L, Garcia D, Christie L, Wyckoff MH. End-tidal CO2 detection of an audible heart rate during neonatal cardio- pulmonary resuscitation after asystole in asphyxiated piglets. Pediatr Res. 2011;69(5 pt 1):401–405. doi: 10.1203/PDR.0b013e3182125f7f.

212. Berg RA, Otto CW, Kern KB, Hilwig RW, Sanders AB, Henry CP, Ewy GA. A randomized, blinded trial of high-dose epinephrine versus standard-dose epinephrine in a swine model of pediatric asphyxial cardiac arrest. Crit Care Med. 1996;24:1695–1700.

213. Burchfield DJ, Preziosi MP, Lucas VW, Fan J. Effects of graded doses of epinephrine during asphxia-induced bradycardia in newborn lambs. Resuscitation. 1993;25:235–244.

214. Perondi MB, Reis AG, Paiva EF, Nadkarni VM, Berg RA. A comparison of high-dose and standard-dose epinephrine in children with cardiac arrest. N Engl J Med. 2004;350:1722–1730.

215. Patterson MD, Boenning DA, Klein BL, Fuchs S, Smith KM, Hegenbarth MA, Carlson DW, Krug SE, Harris EM. The use of high-dose epinephrine for patients with out-of-hospital cardiopulmonary arrest refractory to prehospital interventions. Pediatr Emerg Care. 2005;21:227–237.

216. Wyckoff MH, Perlman JM, Laptook AR. Use of volume expansion during delivery room resuscitation in near-term and term infants. Pediatrics. 2005;115:950–955.

217. Jacobs SE, Morley CJ, Inder TE, Stewart MJ, Smith KR, McNamara PJ, Wright IM, Kirpalani HM, Darlow BA, Doyle LW; Infant Cooling Evaluation Collaboration. Whole-body hypothermia for term and near- term newborns with hypoxic-ischemic encephalopathy: a randomized controlled trial. Arch Pediatr Adolesc Med. 2011;165:692–700. doi: 10.1001/archpediatrics.2011.43.

218. Bharadwaj SK, Bhat BV. Therapeutic hypothermia using gel packs for term neonates with hypoxic ischaemic encephalopathy in resource-lim- ited settings: a randomized controlled trial. J Trop Pediatr. 2012;58:382– 388. doi: 10.1093/tropej/fms005.

219. Robertson NJ, Hagmann CF, Acolet D, Allen E, Nyombi N, Elbourne D, Costello A, Jacobs I, Nakakeeto M, Cowan F. Pilot randomized trial of therapeutic hypothermia with serial cranial ultrasound and 18-22 month follow-up for neonatal encephalopathy in a low resource hospital setting in Uganda: study protocol. Trials. 2011;12:138. doi: 10.1186/1745-6215-12-138.

220. Thayyil S, Shankaran S, Wade A, Cowan FM, Ayer M, Satheesan K, Sreejith C, Eyles H, Taylor AM, Bainbridge A, Cady EB, Robertson NJ, Price D, Balraj G. Whole-body cooling in neonatal encephalopa- thy using phase changing material. Arch Dis Child Fetal Neonatal Ed. 2013;98:F280–F281. doi: 10.1136/archdischild-2013-303840.

221. Field DJ, Dorling JS, Manktelow BN, Draper ES. Survival of extremely premature babies in a geographically defined population: prospective cohort study of 1994–9 compared with 2000–5. BMJ. 2008;336:1221–1223.

222. Tyson JE, Parikh NA, Langer J, Green C, Higgins RD. Intensive care for extreme prematurity–moving beyond gestational age. N Engl J Med. 2008;358:1672–1681.

223. Paris JJ. What standards apply to resuscitation at the borderline of gestational age? J Perinatol. 2005;25:683–684.

224. Bottoms SF, Paul RH, Mercer BM, MacPherson CA, Caritis SN, Moawad AH, Van Dorsten JP, Hauth JC, Thurnau GR, Miodovnik M, Meis PM, Roberts JM, McNellis D, Iams JD. Obstetric determinants of neonatal survival: antenatal predictors of neonatal survival and morbidity in extremely low birth weight infants. Am J Obstet Gynecol. 1999;180 (3 pt 1):665–669.

225. Ambalavanan N, Carlo WA, Bobashev G, Mathias E, Liu B, Poole K, Fanaroff AA, Stoll BJ, Ehrenkranz R, Wright LL; National Institute of Child Health and Human Development Neonatal Research Network. Prediction of death for extremely low birth weight neonates. Pediatrics. 2005;116:1367–1373. doi: 10.1542/peds.2004-2099.

226. Manktelow BN, Seaton SE, Field DJ, Draper ES. Population-based estimates of in-unit survival for very preterm infants. Pediatrics. 2013;131:e425–e432. doi: 10.1542/peds.2012-2189.

227. Medlock S, Ravelli AC, Tamminga P, Mol BW, Abu-Hanna A. Prediction of mortality in very premature infants: a systematic review of prediction models. PLoS One. 2011;6:e23441. doi: 10.1371/journal.pone.0023441.

228. Tyson JE, Parikh NA, Langer J, Green C, Higgins RD; National Institute of Child Health and Human Development Neonatal Research Network. Intensive care for extreme prematurity–moving beyond gestational age. N Engl J Med. 2008;358:1672–1681. doi: 10.1056/NEJMoa073059.

229. Casalaz DM, Marlow N, Speidel BD. Outcome of resuscitation follow- ing unexpected apparent stillbirth. Arch Dis Child Fetal Neonatal Ed. 1998;78:F112–F115.

230. Harrington DJ, Redman CW, Moulden M, Greenwood CE. The long- term outcome in surviving infants with Apgar zero at 10 minutes: a sys- tematic review of the literature and hospital-based cohort. Am J Obstet Gynecol. 2007;196:463.e1–463.e5. doi: 10.1016/j.ajog.2006.10.877.

231. Kasdorf E, Laptook A, Azzopardi D, Jacobs S, Perlman JM. Improving infant outcome with a 10 min Apgar of 0. Arch Dis Child Fetal Neonatal Ed. 2015;100:F102–F105. doi: 10.1136/archdischild-2014-306687.

232. Laptook AR, Shankaran S, Ambalavanan N, Carlo WA, McDonald SA, Higgins RD, Das A; Hypothermia Subcommittee of the NICHD Neonatal Research Network. Outcome of term infants using apgar scores at 10 minutes following hypoxic-ischemic encephalopathy. Pediatrics. 2009;124:1619–1626. doi: 10.1542/peds.2009-0934.

233. Patel H, Beeby PJ. Resuscitation beyond 10 minutes of term babies born without signs of life. J Paediatr Child Health. 2004;40:136–138.

234. Sarkar S, Bhagat I, Dechert RE, Barks JD. Predicting death despite thera- peutic hypothermia in infants with hypoxic-ischaemic encephalopathy. Arch Dis Child Fetal Neonatal Ed. 2010;95:F423–F428. doi: 10.1136/ adc.2010.182725.

235. Savoldelli GL, Naik VN, Park J, Joo HS, Chow R, Hamstra SJ. Value of debriefing during simulated crisis management: oral versus video-assisted oral feedback. Anesthesiology. 2006;105:279–285.

236. Edelson DP, Litzinger B, Arora V, Walsh D, Kim S, Lauderdale DS, Vanden Hoek TL, Becker LB, Abella BS. Improving in-hospital cardiac arrest process and outcomes with performance debriefing. Arch Intern Med. 2008;168:1063–1069.

237. DeVita MA, Schaefer J, Lutz J, Wang H, Dongilli T. Improving medical emergency team (MET) performance using a novel curriculum and a computerized human patient simulator. Qual Saf Health Care. 2005;14:326–331.

238. Wayne DB, Butter J, Siddall VJ, Fudala MJ, Linquist LA, Feinglass J, Wade LD, McGaghie WC. Simulation-based training of internal medicine residents in advanced cardiac life support protocols: a randomized trial. Teach Learn Med. 2005;17:210–216.

239. Clay AS, Que L, Petrusa ER, Sebastian M, Govert J. Debriefing in the intensive care unit: a feedback tool to facilitate bedside teaching. Crit Care Med. 2007;35:738–754.

240. Blum RH, Raemer DB, Carroll JS, Dufresne RL, Cooper JB. A method for measuring the effectiveness of simulation-based team training for improving communication skills. Anesth Analg. 2005;100:1375–1380,.

241. Breckwoldt J, Svensson J, Lingemann C, Gruber H. Does clinical teacher training always improve teaching effectiveness as opposed to no teacher training? A randomized controlled study. BMC Med Educ. 2014;14:6. doi: 10.1186/1472-6920-14-6.

242. Boerboom TB, Jaarsma D, Dolmans DH, Scherpbier AJ, Mastenbroek NJ, Van Beukelen P. Peer group reflection helps clinical teachers to critically reflect on their teaching. Med Teach. 2011;33:e615–e623. doi: 10.3109/0142159X.2011.610840.

243. Litzelman DK, Stratos GA, Marriott DJ, Lazaridis EN, Skeff KM. Beneficial and harmful effects of augmented feedback on physicians' clinical-teaching performances. Acad Med. 1998;73:324–332.

244. Naji SA, Maguire GP, Fairbairn SA, Goldberg DP, Faragher EB. Training clinical teachers in psychiatry to teach interviewing skills to medical stu- dents. Med Educ. 1986;20:140–147.

245. Schum TR, Yindra KJ. Relationship between systematic feedback to fac- ulty and ratings of clinical teaching. Acad Med. 1996;71:1100–1102.

246.

Skeff KM, Stratos G, Campbell M, Cooke M, Jones HW III. Evaluation of the seminar method to improve clinical teaching. J Gen Intern Med. 1986;1:315–322.

247. Lye P, Heidenreich C, Wang-Cheng R, Bragg D, Simpson D; Advanced Faculty Development Group. Experienced clinical educators improve their clinical teaching effectiveness. Ambul Pediatr. 2003;3:93–97.

248. Regan-Smith M, Hirschmann K, Iobst W. Direct observation of faculty with feedback: an effective means of improving patient-centered and learner-centered teaching skills. Teach Learn Med. 2007;19:278–286. doi: 10.1080/10401330701366739.

249. American Academy of Pediatrics, American Heart Association. Textbook of Neonatal Resuscitation (NRP). Chicago, IL: American Academy of Pediatrics;2011.

250. Berden HJ, Willems FF, Hendrick JM, Pijls NH, Knape JT. How fre- quently should basic cardiopulmonary resuscitation training be repeated to maintain adequate skills? BMJ. 1993;306:1576–1577.

251. Ernst KD, Cline WL, Dannaway DC, Davis EM, Anderson MP, Atchley CB, Thompson BM. Weekly and consecutive day neonatal intubation training: comparable on a pediatrics clerkship. Acad Med. 2014;89:505– 510. doi: 10.1097/ACM.0000000000000150.

252. Kaczorowski J, Levitt C, Hammond M, Outerbridge E, Grad R, Rothman A, Graves L. Retention of neonatal resuscitation skills and knowledge: a randomized controlled trial. Fam Med. 1998;30:705–711.

253. Kovacs G, Bullock G, Ackroyd-Stolarz S, Cain E, Petrie D. A ran- domized controlled trial on the effect of educational interventions in promoting airway management skill maintenance. Ann Emerg Med. 2000;36:301–309. doi: 10.1067/mem.2000.109339.

254. Montgomery C, Kardong-Edgren SE, Oermann MH, Odom-Maryon T. Student satisfaction and self report of CPR competency: HeartCode BLS courses, instructor-led CPR courses, and monthly voice advisory manikin practice for CPR skill maintenance. Int J Nurs Educ Scholarsh. 2012;9. doi: 10.1515/1548-923X.2361.

255. Oermann MH, Kardong-Edgren SE, Odom-Maryon T. Effects of monthly practice on nursing students' CPR psychomotor skill perfor- mance. Resuscitation. 2011;82:447–453. doi: 10.1016/j.resuscitation. 2010.11.022.

256. Stross JK. Maintaining competency in advanced cardiac life support skills. JAMA. 1983;249:3339–3341.

257. Su E, Schmidt TA, Mann NC, Zechnich AD. A randomized con- trolled trial to assess decay in acquired knowledge among paramed- ics completing a pediatric resuscitation course. Acad Emerg Med. 2000;7:779–786.

258. Sutton RM, Niles D, Meaney PA, Aplenc R, French B, Abella BS, Lengetti EL, Berg RA, Helfaer MA, Nadkarni V. "Booster" training: evaluation of instructor-led bedside cardiopulmonary resuscitation skill training and automated corrective feedback to improve cardiopulmonary resuscitation compliance of Pediatric Basic Life Support providers dur- ing simulated cardiac arrest. Pediatr Crit Care Med. 2011;12:e116–e121. doi: 10.1097/PCC.0b013e3181e91271.

259. Turner NM, Scheffer R, Custers E, Cate OT. Use of unan- nounced spaced telephone testing to improve retention of knowl- edge after life-support courses. Med Teach. 2011;33:731–737. doi: 10.3109/0142159X.2010.542521.

260. Lubin J, Carter R. The feasibility of daily mannequin practice to improve intubation success. Air Med J. 2009;28:195–197. doi: 10.1016/j.amj. 2009.03.006.

261. Mosley CM, Shaw BN. A longitudinal cohort study to investigate the retention of knowledge and skills following attendance on the Newborn Life support course. Arch Dis Child. 2013;98:582–586. doi: 10.1136/ archdischild-2012-303263.

262. Nadel FM, Lavelle JM, Fein JA, Giardino AP, Decker JM, Durbin DR. Teaching resuscitation to pediatric residents: the effects of an interven- tion. Arch Pediatr Adolesc Med. 2000;154:1049–1054.

263. Niles D, Sutton RM, Donoghue A, Kalsi MS, Roberts K, Boyle L, Nishisaki A, Arbogast KB, Helfaer M, Nadkarni V. "Rolling Refreshers": a novel approach to maintain CPR psychomotor skill competence. Resuscitation. 2009;80:909–912. doi: 10.1016/j.resuscitation.2009.04.021.

264. Nishisaki A, Donoghue AJ, Colborn S, Watson C, Meyer A, Brown CA 3rd, Helfaer MA, Walls RM, Nadkarni VM. Effect of just-in-time simu- lation training on tracheal intubation procedure safety in the pediatric intensive care unit. Anesthesiology. 2010;113:214–223. doi: 10.1097/ ALN.0b013e3181e19bf2.

265. O'Donnell CM, Skinner AC. An evaluation of a short course in resuscitation training in a district general hospital. Resuscitation. 1993;26:193–201.

Part 14: Education

Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Key Words: cardiopulmonary resuscitation

1 Highlights & Introduction

1.1 Highlights

Despite significant scientific advances in the care of cardiac arrest victims, there remains considerable variability in survival rates that cannot be attributed to patient characteristics alone. To optimize the likelihood that cardiac arrest victims receive the highest-quality evidence-based care, resuscitation education must use sound educational principles supported by empirical educational research to translate scientific knowledge into practice. While the 2010 AHA education guidelines included implementation and teams in its recommendations, the 2015 AHA education guidelines now focus strictly on education, with implementation and teams being included in other parts of the 2015 Guidelines Update.

Summary of Key Issues and Major Changes

Key recommendations and points of emphasis include the following:

- Use of a CPR feedback device is recommended to assist in learning the psychomotor skill of CPR. Devices that provide corrective feedback on performance are preferred over devices that provide only prompts (such as a metronome).
- The use of high-fidelity manikins is encouraged for programs that have the infrastructure, trained personnel, and resources to maintain the program. Standard manikins continue to be an appropriate choice for organizations that do not have this capacity.
- BLS skills seem to be learned as easily through self-instruction (video or computer based) with hands-on practice as through traditional instructor-led courses.
- Although prior CPR training is not essential for potential rescuers to initiate CPR, training helps people to learn the skills and develop the confidence to provide CPR when encountering a cardiac arrest victim.
- To minimize the time to defibrillation for cardiac arrest victims, the deployment of an AED should not be limited to trained individuals (although training is still recommended).
- A combination of self-instruction and instructor-led courses with hands-on training can be considered as an alternative to traditional instructor-led courses for lay providers.
- Precourse preparation that includes review of appropriate content information, online/precourse testing, and/or practice of pertinent technical skills may optimize learning from adult and pediatric advanced life support courses.
- Given the importance of team dynamics in resuscitation, training with a focus on leadership and teamwork principles should be incorporated into advanced life support courses.
- Communities may consider training bystanders in compression-only CPR for adult OHCA as an alternative to training in conventional CPR.
- Two-year retraining cycles are not optimal. More-frequent training of basic and advanced life support skills may be helpful for providers who are likely to encounter a cardiac arrest.

The 2015 AHA ECC Education Guidelines Writing Group agreed on several core concepts to guide the development of courses and course materials (Table 1).

Table 1: Core AHA ECC Educational Concepts

Open table in a new window

Core AHA ECC Educational Concepts

Abbreviations: AHA, American Heart Association; CPR, cardiopulmonary resuscitation; ECC, emergency cardiovascular care.

Simplification	Course content should be simplified in both the presentation of the content and the breadth of content to facilitate accomplishment of course objectives.[reference id="11246" range="" /],[reference id="11247" range="" /]
Consistency	Course content and skill demonstrations should be presented in a consistent manner. Video-mediated, practice?while?watching instruction is the preferred method for basic psychomotor skill training because it reduces instructor variability that deviates from the intended course agenda.[reference id="11247,11248,11249,11250" range="4" /]
Contextual	Adult learning principles[reference id="11251" range="" /] should be applied to all ECC courses, with emphasis on creating relevant training scenarios that can be applied practically to the learners' real?world setting, such as having hospital-based learners practice CPR on a bed instead of the floor.
Hands-on practice	Substantial hands-on practice is needed to meet psychomotor and nontechnical/leadership skill performance objectives.[reference id="11247" range="" /],[reference id="11248" range="" /],[reference id="11252,11253,11256" range="3" /]
Practice to mastery	Learners should have opportunities for repetitive performance of key skills coupled with rigorous assessment and informative feedback in a controlled setting.[reference id="11257,11258,11259,11260" range="4" /] This deliberate practice should be based on clearly defined objectives[reference id="11261,11262,11263" range="3" /] and not time spent, to promote student development toward mastery.[reference id="11264,11265,11266,11267,11268" range="5" /]
Debriefing	The provision of feedback and/or debriefing is a critical component of experiential learning.[reference id="11269" range="" /] Feedback and debriefing after skills practice and simulations allow learners (and groups of learners) the opportunity to reflect on their performance and to receive structured feedback on how to improve their performance in the future.[reference id="11270" range="" /]
Assessment	Assessment of learning in resuscitation courses serves to both ensure achievement of competence and provide the benchmarks that students will strive toward. Assessment also provides the basis for student feedback (assessment for learning). Assessment strategies should evaluate competence and promote learning. Learning objectives[reference id="11271" range="" /] must be clear and measurable and serve as the basis of evaluation.

Course/program evaluation	This is an integral component of resuscitation education, with the appraisal of resuscitation courses including learner, individual instructor, course and program performance.[reference id="11272" range="" /] Training organizations should use this information to drive the continuous quality improvement process.

CPR Feedback Devices

2015 (Updated): Use of feedback devices can be effective in improving CPR performance during training.

2015 (New): If feedback devices are not available, auditory guidance (eg, metronome, music) may be considered to improve adherence to recommendations for chest compression rate.

2010 (Old): The use of a CPR feedback device can be effective for training.

Why: New evidence differentiates the benefit of different types of feedback for training, with a slight advantage given to feedback that is more comprehensive.

Use of High-Fidelity Manikins

2015 (Updated): The use of high-fidelity manikins for advanced life support training can be beneficial for improving skills performance at course conclusion.

2010 (Old): Realistic manikins may be useful for integrating the knowledge, skills, and behaviors in advanced life support training.

Why: In the 2010 evidence review, there was insufficient evidence to recommend the routine use of more realistic manikins to improve skills performance in actual resuscitations, particularly given the additional costs and resources required. Considering both the potential benefit of having more realistic manikins as well as the increased costs and resources involved, newly published literature supports the use of high-fidelity manikins, particularly in programs where resources (eg, human and financial resources) are already in place.

Blended Learning Formats

2015 (Updated): CPR self-instruction through video and/or computer-based modules with hands-on practice may be a reasonable alternative to instructor-led courses.

2015 (New): It may be reasonable to use alternative instructional modalities for basic and advanced life support teaching in resource-limited environments.

2010 (Old): Short video instruction combined with synchronous hands-on practice is an effective alternative to instructor-led BLS courses.

Why: Learner outcomes are more important than course formats. Knowledge and skill acquisition and retention and, ultimately, clinical performance and patient outcome should guide resuscitation education. There is new evidence that specific formats, such as CPR self-instruction using video or computer-based modules, can provide similar outcomes to instructor-led courses. The ability to effectively use alternative course formats is particularly important in resource-limited environments where instructor-led courses may be cost prohibitive. Self-instruction courses offer the opportunity to train many more individuals to provide CPR while reducing the cost and resources required for training—important factors when considering the vast population of potential rescuers that should be trained.

Targeted Training

2015 (New): Training primary caregivers and/or family members of high-risk patients may be reasonable.

Why: Studies consistently show high scores for CPR performance by trained family members and/or caregivers of high-risk cardiac patients as compared with those who were untrained.

Expanded Training for AEDs

2015 (Updated): A combination of self-instruction and instructor-led teaching with hands-on training can be considered as an alternative to traditional instructor-led courses for lay providers. If instructor-led training is not available, self-directed training may be considered for lay providers learning AED skills.

2015 (New): Self-directed methods can be considered for healthcare professionals learning AED skills.

2010 (Old): Because even minimal training in AED use has been shown to improve performance in simulated cardiac arrests, training opportunities should be made available and promoted for lay rescuers.

Why: AEDs can be correctly operated without any prior training: There is no need for a requirement for training to be placed on the use of AEDs by the public. Nevertheless, even minimal training improves performance, timeliness, and efficacy. Self-directed training broadens the opportunities for training for both lay providers and healthcare professionals.

Teamwork and Leadership

2015 (Updated): Given the very small risk for harm and the potential benefit of team and leadership training, the inclusion of team and leadership training as part of advanced life support training is reasonable.

2010 (Old): Teamwork and leadership skills training should be included in advanced life support courses.

Why: Resuscitation is a complex process that often involves the cooperation of many individuals. Teamwork and leadership are important components of effective resuscitation. Despite the importance of these factors, there is limited evidence that teamwork and leadership training affects patient outcomes.

Compression-Only CPR

2015 (New): Communities may consider training bystanders in compression-only CPR for adult OHCA as an alternative to training in conventional CPR.

Why: Compression-only CPR is simpler for lay providers to learn than conventional CPR (compressions with breaths) and can even be coached by a dispatcher during an emergency. Studies performed after a statewide educational campaign for bystander compression-only CPR showed that the prevalence of both overall CPR and compression-only CPR by bystanders increased.

BLS Retraining Intervals

2015 (Updated): Given the rapidity with which BLS skills decay after training, coupled with the observed improvement in skill and confidence among students who train more frequently, it may be reasonable for BLS retraining to be completed more frequently by individuals who are likely to encounter cardiac arrest.

2015 (New): Given the potential educational benefits of short, frequent retraining sessions coupled with the potential for cost savings from reduced training time and removal of staff from clinical environment for standard refresher training, it is reasonable that individuals who are likely to encounter a cardiac arrest victim perform more frequent manikin-based retraining. There is insufficient evidence to recommend the optimal time interval.

2010 (Old): Skill performance should be assessed during the 2-year certification with reinforcement provided as needed.

Why: While growing evidence continues to show that recertification in basic and advanced life support every 2 years is inadequate for most people, the optimal timing of retraining has not been determined. Factors that affect the optimal retraining interval include the quality of initial training, the fact that some skills may be more likely to decay than others, and the frequency with which skills are used in clinical practice. Although data are limited, there is an observed improvement in skills and confidence among students who train more frequently. Also, frequent refreshers with manikin-based simulation may provide cost savings by using less total retraining time as compared with standard retraining intervals.

1.2 Introduction - Updated

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or

updated recommendations from 2015.

Cardiac arrest is a major public health issue, with more than 500 000 deaths of children and adults per year in the United States.[-2] Despite significant scientific advances in the care of cardiac arrest victims, there remain striking disparities in survival rates for both out-of-hospital and in-hospital cardiac arrest. Survival can vary among geographic regions by as much as 6-fold for victims in the prehospital setting.[3,4] Significant variability in survival outcomes also exists for cardiac arrest victims in the hospital setting, particularly when the time of day or the location of the cardiac arrest is considered.[5] Inconsistencies in performance of both healthcare professionals and the systems in which they work likely contribute to these differences in outcome.[6]

For out-of-hospital cardiac arrest victims, the key determinants of survival are the timely performance of bystander cardiopulmonary resuscitation (CPR) and defibrillation for those in ventricular fibrillation or pulseless ventricular tachycardia. Only a minority of cardiac arrest victims receive potentially lifesaving bystander CPR, thus indicating room for improvement from a systems and educational point of view. For in-hospital cardiac arrest, the important provider-dependent determinants of survival are early defibrillation for shockable rhythms and high-quality CPR, along with recognition and response to deteriorating patients before an arrest.

Defining the optimal means of delivering resuscitation education to address these critical determinants of survival may help to improve outcomes from cardiac arrest.

Resuscitation education is primarily focused on ensuring widespread and uniform implementation of the science of resuscitation (eg, the Scientific Statements and Guidelines) into practice by lay and healthcare CPR providers. It aims to close the gap between actual and desired performance by providing lay providers with CPR skills and the self-efficacy to use them; supplementing training with in-the-moment support, such as dispatch-assisted CPR; improving healthcare professionals' ability to recognize and respond to patients at risk of cardiac arrest; improving resuscitation performance (including CPR); and ensuring continuous quality improvement activities to optimize future performance through targeted education. Simply ensuring that cardiac arrest victims receive care consistent with the current state of scientific knowledge has the potential to save thousands of lives every year in the United States.

1.3 Development of the Evidence-Based Education Guidelines - Updated

The American Heart Association (AHA) Emergency Cardiovascular Care (ECC) Committee uses a rigorous process to review and analyze the peer-reviewed published scientific evidence supporting the AHA Guidelines for CPR and ECC, including the 2015 update. In 2000, the AHA began collaborating with other resuscitation councils throughout the world, via the International Liaison Committee on Resuscitation (ILCOR), in a formal international process to evaluate resuscitation science. This process resulted in the publication of the International Consensus on CPR and ECC Science With Treatment Recommendations in 2005 and in 2010.[7] These publications provided the scientific support for AHA Guidelines revisions in those years.[8,9]

In 2011, the AHA created an online evidence review process, the Scientific Evidence Evaluation and Review System (SEERS), to support ILCOR systematic reviews for 2015 and beyond. This new process includes the use of Grading of Recommendations Assessment, Development, and Evaluation (GRADE) software to create systematic reviews that will be available online and used by resuscitation councils to develop their guidelines for CPR and ECC. The drafts of the online reviews were posted for public comment, and ongoing reviews will be accessible to the public.[10] Throughout the online version of this publication, live links are provided so the reader can connect directly to the systematic reviews on the SEERS website. These links are indicated by a combination of letters and numbers (eg, EIT 647). We encourage readers to use the links and review the evidence and appendixes, such as the GRADE tables.

For the 2015 international evidence review, members of the ILCOR Education, Implementation, and Teams Task Force [11,12] identified topics through consensus, based on their perceived relevance, potential impact on saving lives, and the likelihood for new evidence since the 2010 Guidelines. They also sought recommendations about topics from ILCOR member resuscitation councils through their council chairs and individual task force members. The systematic reviews of these high-priority topics provided the evidence base for these 2015 education guidelines.

Each review seeks to determine the answer to a question regarding the effect in a population of an intervention (evaluated against a control or other comparison group) on an outcome. The Education, Implementation, and Teams Task Force identified patient-related outcomes and actual performance in the clinical setting as the critical outcomes, with learningrelated outcomes (immediate and longer retention) considered to be important

outcomes. This approach is consistent with other recognized program evaluation paradigms, such as Kirkpatrick's model,[13] where "results" (or patient outcome) are considered more important than "transfer" of learning to the clinical setting, which is in turn more important than evidence of "learning." McGaghie's model describing translational outcomes for medical education research follows a similar logic.[14] The implication is that treatment recommendations based strictly on studies demonstrating improved learning will be weaker than if differences in critical patient related outcomes are demonstrated.

These Web-based Integrated Guidelines incorporate the relevant recommendations from 2010 and the new or updated recommendations from 2015.

As with all AHA Guidelines, each 2015 recommendation is labeled with a Class of Recommendation (COR) and a Level of Evidence (LOE). The updated 2015 recommendations use the newest AHA COR and LOE classification system, which contains modifications of the Class III recommendation and introduces LOE B-R (randomized studies) and B-NR (nonrandomized studies) as well as LOE C-LD (limited data) and C-EO (expert opinion/consensus). For further information, please see "Part 2: Evidence Evaluation and Management of Conflicts of Interest."

These 2015 AHA education guidelines differ from the 2010 AHA Guidelines on education, implementation, and teams because the focus of this publication is strictly on training, with important related topics covered in other Parts (eg, dispatch-guided CPR in "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality" and continuous quality improvement in "Part 4: Systems of Care and Continuous Quality Improvement").

Key recommendations in the 2015 update to the 2010 Guidelines include the following:

- Use of high-fidelity manikins is encouraged at training centers and organizations that have the infrastructure, trained personnel, and resources to maintain the program.
- Use of CPR feedback devices can help to learn the psychomotor skill of CPR.
- Two-year retraining cycles are not optimal. More frequent training in basic life support (BLS) and retraining in advanced life support (ALS) may be helpful for providers who are likely to encounter a cardiac arrest.

2 Willingness to Perform

Without immediate initiation of CPR, most victims of cardiac arrest will die. Bystander CPR can significantly improve survival rates from cardiac arrest,[15] but evidence indicates that only 15% to 30% of victims of out-of-hospital arrest receive CPR before EMS arrival.[16] Strategies to increase the incidence of bystander-initiated CPR and the use of automated external defibrillators (AEDs) are addressed in this section.

2.1 Barriers to Bystander CPR

Commonly cited reasons for reluctance to perform lifesaving maneuvers include concern for injuring the victim,[17-19] fear of performing CPR incorrectly,[18,20-23] physical limitations,[24] fear of liability,[24] fear of infection,[22] or victim characteristics.[25-28] Opportunities exist to overcome many of these barriers through education and encouragement to perform when the bystander is faced with a victim in cardiac arrest.

In a study of actual bystanders interviewed following a 911 call in which the EMS dispatcher encouraged performance of CPR, nonresponders most frequently cited panic (37.5%) and fear of hurting the patient (9.1%) as the reasons they were unable to perform.[18] In 2 studies reviewing actual emergencies, bystanders encountered practical and understandable barriers to performance (eg, physical limitations, inability to listen to instructions and perform skills at the same time, and system delays) more often than panic or stress, although both were important factors.[29,30]

Because panic can significantly impair a bystander's ability to perform in an emergency, it may be reasonable for CPR training to address the possibility of panic and encourage learners to consider how they will overcome it. (Class IIb LOE C)

Actual bystanders[18] and surveys of the general public report that people more recently trained in CPR techniques expressed greater willingness to attempt resuscitation than those without recent training.[28,31-33] Short, self-directed video instruction is an effective and cost-efficient strategy for training rescuers.[34-45]

Fear of harming the victim or fear of personal harm (i.e. infection or injury) may reduce willingness to undertake

basic life support training or to perform CPR. However infection resulting from CPR performance is extremely rare and limited to a few case reports.[46-56] Educating the public about the low risks to the rescuer and victim may increase willingness to perform CPR.

Some rescuers, including healthcare providers, may be more likely to initiate CPR if they have access to barrier devices.

Despite the low risk of infections, it is reasonable to teach rescuers about the use of barrier devices emphasizing that CPR should not be delayed for their use. (Class IIa, LOE C)

Rescuers who are not willing to perform mouth-to-mouth ventilations may be willing to perform Hands-Only (chest compression-only) CPR.[17,21,22,25,31,33,57-59]

CPR training programs should teach compression-only CPR as an alternative to conventional CPR for rescuers when they are unwilling or unable to provide conventional CPR. (Class I, LOE B)

2.2 Barriers to Recognition of Cardiac Arrest

Victims of out-of-hospital cardiac arrest who are gasping have a higher survival rate compared to victims who are not gasping.[60] Gasping is commonly misinterpreted as a sign of life that may prevent rescuers from initiating resuscitation. Potential rescuers can be taught to recognize gasping and initiate CPR.[61]

Rescuers should be taught to initiate CPR if the adult victim is unresponsive and is not breathing or not breathing normally (eg, only gasping). (Class I, LOE B)

Dispatcher telephone instructions and support has been shown to increase willingness to perform CPR.[28,62,63]

Because dispatcher CPR instructions substantially increase the likelihood of bystander CPR performance and improve survival from cardiac arrest, all dispatchers should be appropriately trained to provide telephone CPR instructions.[64-70] (Class I, LOE B)

2.3 Barriers to AED Use

Some rescuers may be intimidated by the idea of delivering a shock, but AEDs are safe,[71,72] and adverse events are rare.[73,74-78] Although AEDs can be used effectively with no prior training, even brief training increases the willingness of a bystander to use an AED and improves his or her performance.[79-81]

To maximize willingness to use an AED, public-access defibrillation training should continue to be encouraged for the lay public. (Class I, LOE B)

In summary, although the factors influencing willingness to perform CPR are myriad, many obstacles can be overcome with education. Although the precise number of trained volunteers needed to optimize the chance that a specific victim will receive CPR is not known, it is reasonable to assume that maximizing the number of people trained in a community and providing instructions and encouragement at the time an event occurs will improve the odds that a bystander will engage in resuscitation efforts.

For more information about automated external defibrillator training, please refer to section 4.2 of this document: Automated External Defibrillator (AED) Training Methods.

3 Educational Design - Updated

Evidence-based instructional design is essential to improve training of providers and ultimately improve resuscitation performance and patient outcomes. The quality of rescuer performance depends on learners integrating, retaining, and applying the cognitive, behavioral, and psychomotor skills required to perform

resuscitation successfully. Learners need to develop the self-efficacy to use the skills they learned when faced with a resuscitation scenario. [82,83] Well-designed resuscitation education informed by adult learning theories and educational science increases the likelihood that this will occur. The appropriate application of learning theories combined with research into program effectiveness has resulted in substantial changes to AHA ECC courses over the past quarter century.[84] In 2013, the AHA established the ECC Educational Sciences and Programs Subcommittee to help inform the creation of courses by using the best available evidence in education science. The development of the AHA courses are guided by core educational principles (Table 2), including deliberate, hands-on practice, where feedback and debriefing should support participants' development toward mastery.[84-86]

Consistent with established methodologies for program evaluation,[87] the effectiveness of resuscitation courses should be evaluated. (Class I, LOE C)

Table 2: 2015 - Core AHA Emergency Cardiovascular Care Educational Concepts

Open table in a new window

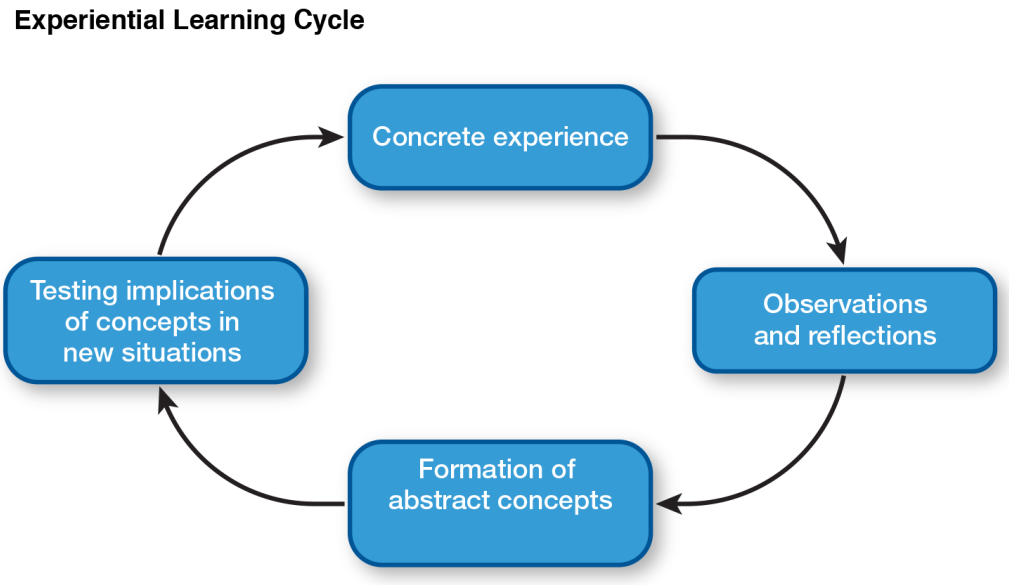
Core AHA Emergency Cardiovascular Care Educational Concepts	
Simplification	Course content should be simplified in both the presentation of the content and the breadth of content to facilitate accomplishment of course objectives.[reference id="2166" range="" /],[reference id="2167" range="" /]
Consistency	Course content and skill demonstrations should be presented in a consistent manner. Video-mediated, practice-while-watching instruction is the preferred method for basic psychomotor skill training because it reduces instructor variability that deviates from the intended course agenda.[reference id="2167,2168,2169,2170" range="4" /]
Contextual	Adult learning principles[reference id="2171" range="" /] should be applied to all ECC courses, with emphasis on creating relevant training scenarios that can be applied practically to the learners' real-world setting, such as having hospital-based learners practice CPR on a bed instead of the floor.
Hands-on practice	Substantial hands-on practice is needed to meet psychomotor and nontechnical/leadership skill performance objectives.[reference id="2167" range="" /],[reference id="2168" range="" /],[reference id="2172,2173,2174" range="3" /]
Practice to mastery	Learners should have opportunities for repetitive performance of key skills coupled with rigorous assessment and informative feedback in a controlled setting.[reference id="2175,2176,2177,2178" range="4" /] This deliberate practice should be based on clearly defined objectives[reference id="2179,2180,2181" range="3" /] and not time spent, to promote student development toward mastery.[reference id="2182,2183,2184,2185,2186" range="5" /]

Debriefing	The provision of feedback and/or debriefing is a critical component of experiential learning.[reference id="2165" range="" /] Feedback and debriefing after skills practice and simulations allow learners (and groups of learners) the opportunity to reflect on their performance and to receive structured feedback on how to improve their performance in the future.[reference id="2163" range="" /]
Assessment	Assessment of learning in resuscitation courses serves to both ensure achievement of competence and provide the benchmarks that students will strive toward. Assessment also provides the basis for student feedback (assessment for learning). Assessment strategies should evaluate competence and promote learning. Learning objectives[reference id="2187" range="" /] must be clear and measurable and serve as the basis of evaluation.
Course/program evaluation	This is an integral component of resuscitation education, with the appraisal of resuscitation courses including learner, individual instructor, course, and program performance.[reference id="2188" range="" /] Training organizations should use this information to drive the continuous quality improvement process.

AHA indicates American Heart Association; CPR, cardiopulmonary resuscitation; and ECC, emergency cardiovascular care.

An essential component of resuscitation education is the experiential learning that occurs through simulation and the associated debriefing. Kolb's experiential learning cycle provides a framework of 4 stages that are required to consolidate learning (Figure 1).[88] For most individuals participating in resuscitation courses, clinical resuscitations are rare events, emphasizing the importance of learning from simulated scenarios so that they are able to act when the real-life events occur.[89] By engaging learners in scenarios and guiding them through a constructive debriefing, instructors can maximize knowledge transfer to real-life events. Critical to this learning process is the notion that the experience is not enough to promote practice change. Experience needs to be coupled with a constructive debriefing, allowing for guided reflection that can promote change in performance.[8,86,90] AHA courses promote the use of structured and supported debriefing by using the GAS (gather-analyze-summarize) model of debriefing paired with evidence-based scripted debriefing tools.[84,91]

Figure 1: Experiential learning cycle



Kolb, David A., Experiential Learning: Experience as a Source of Learning & Development, 1st, ©1984, 21. Reprinted by permission of Pearson Education, Inc., New York, New York.44

As a part of this educational process, attention to functional task alignment is necessary to ensure that learners take away the appropriate skills.[92] By aligning the nature and degree of realism with the predetermined learning objectives and/or tasks, the instructor is deliberately targeting realism to the learning need. Taking shortcuts within the educational design of these courses can result in significant unintended consequences. As an example, a study by Krogh et al demonstrated poor adherence to the recommended 2-minute CPR time cycles when learners practiced CPR with abbreviated cycles.[93] Greater attention to promoting realism of the simulation scenario with respect to timing, duration, and integration of tasks with accompanying feedback creates a learning environment best suited to improving learning outcomes.[94] To quote the legendary coach Vince Lombardi, “Practice doesn’t make perfect. Only perfect practice makes perfect.”

There is substantial evidence to suggest that mastery learning is the key to skill retention and the prevention of rapid decay in skills and knowledge after simulation-based learning.[89,95-97] The goal of mastery learning is to have learners achieve the highest standards for all educational outcomes instead of simply meeting the minimum standard.[98] Although this is not a new educational concept, this represents a shift in the way resuscitation courses are taught. Flexibility is necessary for mastery learning to occur because the time required for learners to meet this mastery standard may vary.[97]

Assessment within AHA courses needs to play an important dual role. Summative assessment (ie, assessment conducted at the end of training that is compared with a standard or benchmark) is required to ensure that intended learning outcomes are met. Formative assessment (ie, low stakes assessment with little to no “point” value in the course) provides clarity to learners about what the important desired outcomes are and provides practical advice to learners on where they can improve and how to do it (so-called assessment for learning). Assessment is deliberately aligned to the learning objectives and instructional programs within the AHA courses. In recognizing that successful resuscitation requires the integration of cognitive, psychomotor, and behavioral skills, there is an increasing emphasis on focusing learner evaluation on the higher levels of Miller’s classic description of assessment (ie, above the level of knowledge). The simulated setting readily allows such an approach.[99] Optimal learning depends heavily on the assessment skills of the instructor; therefore, early and ongoing faculty development is a priority, as are the development and implementation of appropriate assessment tools with evidence of validity and reliability.

The degree to which a learner masters the material depends on the instructor’s expertise and the debriefing process.[86,100] Helping learners understand why the course is important (ie, the relevance) and how it applies to

their situation is critical in motivating adult learners. Respecting their prior experience and defining how their learning in the course can help them care for loved ones or their patients can be particularly useful. During debriefing, learners reflect on their performance during the simulation, performance gaps are identified and corrected, and “take-home” messages are generalized to maximize learning.[101] Without this step, learners are unlikely to improve nontechnical skills, decision-making abilities, situational awareness, and team coordination.[90] Future work should aim to establish competency and performance standards for resuscitation instructors that will help to standardize quality of instruction across training programs.[102]

4 Basic Life Support Training - Updated

4.1 CPR Instruction Methods - Updated EIT 647

Studies on CPR instruction methods (video- and/or computer-based with hands-on practice versus instructor-led courses) are heterogeneous with regard to instruction delivery and learner outcomes. Although instructor-led courses have been considered the gold-standard, multiple studies have demonstrated no difference in learning outcomes (cognitive performance, skill performance at course conclusion, and skill decay) when courses with self-instruction are compared with traditional instructor-led courses.[103-106,107,108-115]

CPR self-instruction through video- and/or computer-based modules paired with hands-on practice may be a reasonable alternative to instructor-led courses. (Class IIb, LOE C-LD)

This recommendation is based on the absence of differences in learner outcomes, the benefits of increased standardization, plus the likely reduction of time and resources required for training.

4.2 Automated External Defibrillator (AED) Training Methods - Updated EIT 651

Allowing the use of automated external defibrillators (AEDs) by untrained bystanders can potentially be lifesaving and should be encouraged when trained individuals are not immediately available.

Allowing the use of AEDs by untrained bystanders can be beneficial and may be lifesaving. (Class IIa, LOE B)

Although AEDs can be used effectively without prior training, even brief training increases the willingness of a bystander to use an AED and improves individual performance,[116-118] although the most effective method of instruction is not known.

None of the studies identified in the literature review addressed patient-related outcomes (ie, they were manikin-based with learning outcomes assessed within 6 months of training).

In lay providers, 4 studies examined self-instruction without instructor involvement versus a traditional instructor-led course.[119,107,120,121] There was no significant difference between these methods.[119,107,120,121] Two studies evaluated self-instruction combined with instructor-led training versus traditional courses; one study showed equivalent results,[120] whereas the other demonstrated that self-instruction combined with instructor-led AED training was inferior to traditional methods.[119]

A combination of self-instruction and instructor-led teaching with hands-on training can be considered as an alternative to traditional instructor-led courses for lay providers. If instructor-led training is not available, self-directed training may be considered for lay providers learning AED skills. (Class IIb, LOE C-EO)

Potential to increase the numbers of lay providers trained and cost implications were important considerations in the development of this recommendation.

In healthcare providers, 3 studies compared self-instruction without instructor involvement[106,122,123] versus an instructor-led course and demonstrated either no difference in performance[106,122] or inferior performance in the self-instruction group.[123] When compared with instructor-led training alone, self-instruction combined with instructor-led AED training led to slight reductions in performance but significant reductions in training time.[106,122]

Self-directed methods can be considered for healthcare professionals learning AED skills. (Class IIb, LOE C-EO)

4.3 CPR Feedback/Prompt Devices in Training - New and Updated EIT 648

Mastery learning requires accurate assessment of CPR skills and feedback to help learners improve subsequent performance. Unfortunately, inadequate performance of CPR is common yet challenging for providers and instructors to detect,[124,125] thereby making it difficult to appropriately focus feedback and improve future performance. Technology could theoretically help address this problem by assessing CPR performance and providing feedback. In conducting this analysis, we separated CPR feedback devices that provide corrective feedback to the learner from prompt devices that provide only a tone or rate for the rescuer to follow (with no feedback on how the learner is actually performing).

Learners who used devices that provided corrective feedback during CPR training had improved compression rate, depth, and recoil compared with learners performing CPR without feedback devices.[94,126-146] Evidence on the effect of feedback devices on CPR skill retention is limited, with 1 of 3 studies demonstrating improved retention.[132,135,136]

Use of feedback devices can be effective in improving CPR performance during training. (Class IIa, LOE A)

Three randomized trials examined the use of auditory guidance (ie, use of a metronome or music) to guide CPR performance. All 3 studies found that compression rate was more appropriate when auditory guidance was used, although there was a negative impact on compression depth in 1 study.[144-146]

If feedback devices are not available, auditory guidance (eg, metronome, music) may be considered to improve adherence to recommendations for chest compression rate only. (Class IIb, LOE B-R)

These recommendations are made, balancing the potential benefit of improved CPR performance with the cost of the use of such devices during training.

4.4 Debriefing

Debriefing is a learner-focused, nonthreatening technique to assist individual rescuers or teams to reflect on, and improve, performance.[147] In manikin-based studies, debriefing as part of the learning strategy resulted in improved performance in post-debriefing simulated scenarios,[148,149,150-152] and it improved adherence to resuscitation guidelines in clinical settings.[153]

Debriefing as a technique to facilitate learning should be included in all advanced life support courses. (Class I, LOE B)

Additional research on how best to teach and implement postevent debriefing is warranted.

4.5 Retraining Intervals for BLS - Updated EIT 628

The standard retraining period for BLS is every 2 years, despite growing evidence that BLS knowledge and skills decay rapidly after initial training. Studies have demonstrated the deterioration of BLS skills in as little as 3 months after initial training.[8,154,155]

Three studies evaluated the impact of 1 additional episode of BLS retraining 6 to 9 months after BLS certification and found no difference in chest compression performance or time to defibrillation.[156-158] Two studies examined the effect of brief, more frequent training sessions; both studies demonstrated slight improvement in chest compression performance, and 1 study found a shorter time to defibrillation.[136,159] These same studies also found that students reported improved confidence and willingness to perform CPR after additional or high-frequency training.

There is insufficient evidence to determine the optimal method and timing of BLS recertification.

Given the rapidity with which BLS skills decay after training, coupled with the observed improvement in skill and confidence among students who train more frequently, it may be reasonable for BLS retraining to be completed more often by individuals who are likely to encounter cardiac arrest.
(Class IIb, LOE C-LD)

It should be emphasized that BLS skill maintenance needs to be appropriately tailored for potential provider groups on the basis of their setting and the feasibility of more frequent training.

5 Advanced Life Support Training - Updated

5.1 Precourse Preparation - Updated EIT 637

To maximize learning from an ALS training program, an adult learner should be well prepared before attending such a program. Similarly, instructors have the responsibility of providing an optimal learning environment that will facilitate the acquisition and refinement of skills in motivated trainees. In view of the resources (time, equipment, supplies, money, etc) required and the potential impact (life or death) on patients, this duty is paramount. During the past decade, many life support programs have mandated independent review of content knowledge, via study of the pertinent provider manual, and successful completion of an online examination before attendance at the program. Unfortunately, trainee preparation has not been extensively studied. A single multicenter randomized controlled trial[160] compared extensive precourse preparation using an interactive compact disc and additional course materials (intervention group) with the use of course materials alone (control group). Subjects exhibited no differences in performance during a simulated cardiac arrest, and no differences were noted in knowledge acquisition or performance of the technical skills required during resuscitation. Although this study revealed no benefit of trainee preparation, it is important to acknowledge that the type of skill(s) practiced during preprogram preparation and the skill(s) assessed during the program may not have been directly aligned and thus may have confounded the results. Therefore, any conclusions from this study must be tempered by its limitations. Precourse preparation is consistent with theories of learning and current practices in other professional education. It has the potential to improve learning and improve the care delivered to patients.

Precourse preparation, including review of appropriate content information, online/precourse testing, and practice of pertinent technical skills is reasonable before attending ALS training programs.
(Class IIa, LOE C-EO)

5.2 Team and Leadership Training - Updated EIT 631

Effective management of a cardiac arrest patient requires a team-based approach with providers who have the knowledge, clinical skills, interpersonal communication skills, and leadership skills to perform effectively in a high-stakes environment. This also requires a team leader who has the ability to provide oversight of the team, provide guidance for specific tasks, and maintain a heightened level of situational awareness to avoid fixation on certain aspects of care. Given that team-based skills are different from clinical care skills, specific team and leadership training may have a role in the effective performance of resuscitation teams and patient outcomes after cardiac arrest.

A systematic review of the resuscitation education literature identified several studies assessing the impact of team training for healthcare professionals in a cardiac arrest setting. In 1 observational study, the implementation of a hospital-wide mock code program with team training resulted in a survival increase for pediatric cardiac arrest during the study period.[161]

In another observational study, the implementation of surgical team training resulted in a decrease in surgical patient mortality in hospitals that implemented the program when compared with those that did not.[162]

A number of additional studies demonstrated better performance of patient tasks, teamwork, and/or leadership behaviors in the immediate postcourse time period up to 1 year after training.[145-163]

Given very small risk for harm and the potential benefit of team and leadership training, the inclusion of team and leadership training as part of ALS training is reasonable. (Class IIa, LOE C-LD)

5.3 Manikin Fidelity - Updated EIT 623

Many training programs use high-fidelity manikins for adult and pediatric ALS training.[163-165] The use of high-fidelity manikins can encourage learners to engage physically and emotionally with the manikin and the environment, thus helping to promote teamwork, clinical decision making, and full participant immersion within the experiential learning environment. High-fidelity manikins have a wide range of functionality depending on make and model type, but generally they are defined as manikins that provide physical findings (such as heart and breath sounds, pulses, chest rise and fall, and blinking eyes), display vital signs that correlate with physical findings, and "physiologically" respond to medical intervention through an operator-controlled computer interface.[164] Many of these manikins also allow participants to actually perform some critical care procedures, including bag-mask ventilation, intubation, intraosseous needle insertion, and/or chest tube insertion.

A meta-analysis of 12 randomized controlled trials showed improvement of skills at course conclusion with the use of high-fidelity manikins.[91,166-176] A meta-analysis of 8 randomized controlled trials assessing knowledge at course conclusion demonstrated no significant benefit of training with high-fidelity manikins compared with low-fidelity manikins.[91,167,168,173-175,177,178] This is supported by 1 additional nonrandomized trial demonstrating no substantial benefit of high-fidelity training on knowledge acquisition.[122] With regard to skill retention, 1 study showed no benefit of high-fidelity training on skills performance (in the simulated environment) at 1 year after training,[109] and another demonstrated similar results for skills performance between course conclusion and 1 year.[175]

The use of high-fidelity manikins for ALS training can be beneficial for improving skills performance at course conclusion. (Class IIa, LOE B-R)

The usefulness of high-fidelity manikins for improving knowledge at course conclusion and skills performance beyond course conclusion is uncertain. Given the increased cost associated with high-fidelity training, the use of high-fidelity manikins is particularly appropriate in programs where existing resources (ie, human and financial resources) are already in place.

6 Training Intervals - Updated EIT 633

Retraining intervals for AHA basic and advanced life support programs have traditionally been time-specific, with a maximum 2-year interval recommended, despite evidence that core skills and knowledge decay within 3 to 12 months after initial training.[8,154] Unfortunately, the literature directly assessing the question of the retraining intervals is limited. In 1 pediatric ALS study,[179] frequent refreshers with manikin-based simulation showed better clinical performance scores and equivalent behavioral performance scores, using less total time of retraining, when compared with standard retraining intervals. Recent literature in resuscitation education also demonstrates improved learning from "frequent, low-dose" versus "comprehensive, all-at-once" instruction and a learner preference for this format.[180]

Given the potential educational benefits of short, frequent retraining sessions coupled with the potential for cost savings from reduced training time and removal of staff from the clinical environment for standard refresher training, it is reasonable that individuals who are likely to encounter a cardiac arrest victim perform more frequent manikin-based retraining. (Class IIa, LOE C-LD)

There is insufficient evidence to recommend the optimum time interval.

7 Checklists/Cognitive Aids

The quality of resuscitation is a major determinant of patient outcome. Simulation studies of basic life support,[181-185] advanced life support,[186,187] and anesthetic emergencies[193,194] demonstrated improved performance when checklists or cognitive aids were used. However, 1 simulation study demonstrated delayed completion of 2 cycles of CPR [188] when individuals not adept at cell phone operation used a cell phone-based cognitive aid. In clinical practice, physicians perceived checklists to be useful.[189,190] The impact of cognitive aids or checklists on patient outcomes is unknown.

Checklists or cognitive aids, such as the AHA algorithms, may be considered for use during actual resuscitation. (Class IIb, LOE C)

Specific checklists and cognitive aids should be evaluated to determine if they achieve the desired effect and do not result in negative consequences such as delayed response. Further research on the optimal design is warranted.

8 Special Considerations - Updated

8.1 Compression-Only CPR Training in Communities - New EIT 881

Compression-only (Hands-Only™) CPR has been advocated as a method of training laypeople that is simpler to learn and may increase bystander willingness to provide CPR. Most published studies on bystander compression-only CPR have involved dispatcher-guided CPR by lay rescuers. Life support course students, when surveyed, have reported a greater willingness to provide compression-only CPR than conventional CPR with assisted ventilations.[191-195] Two studies published after a state-wide educational campaign for bystander compression-only CPR showed that the prevalence of both overall bystander CPR and compression-only CPR by bystanders increased over time, but no effect on patient survival was demonstrated.[196,197]

Communities may consider training bystanders in compression-only CPR for adult out-of-hospital cardiac arrest as an alternative to training in conventional CPR. (Class IIb, LOE C-LD)

Communities should consider existing bystander CPR rates and other factors, such as local epidemiology of out-of-hospital cardiac arrest and cultural preferences, when deciding on the optimal community CPR training strategy.

8.2 CPR Training in Resource-Limited Environments - New EIT 634

Studies examining CPR training in resource-limited environments are heterogeneous in design and training outcomes. Studies comparing traditional course format with training using computer-based instruction, self-directed learning, video-based instruction, and varied instructor-to-student ratios showed mixed results with regard to knowledge and skill at course completion and at reassessment up to 6 months after course completion.[198-204] These studies varied in course composition (paramedic students, medical students at various levels, nursing students, and credentialed healthcare providers), type of course (BLS or ALS), and instructional methods.

It may be reasonable to use alternative instructional modalities for BLS and/or ALS teaching in resource-limited environments. (Class IIb, LOE C-LD)

In making this recommendation, we considered the cost of and access to training as major impediments to training BLS and ALS for healthcare workers in resource-limited areas. Additionally, the intent is to promote research and initiatives around creative teaching strategies that lower both cost and human resources needed to achieve more widespread BLS and ALS training that meets the desired learning objectives in resource-limited environments.

8.3 CPR for High-Risk Populations - New EIT 649

There are many studies evaluating the effectiveness of BLS training in family members and/or caregivers of high-risk cardiac patients, including some that measure the frequency at which CPR is performed by family members[191]

,[205-213]; their retention of knowledge, skills, and adequacy of performance[191,205,206,208,214,215]; and the survival rates of cardiac arrest victims receiving CPR from family members.[115,205,206,208,216-219] Despite the heterogeneity and generally low quality, these studies consistently showed high scores for CPR performance in those who were trained compared with those who were untrained. Most studies examining retention of skills showed a decline in CPR performance over time without retraining.

Training primary caregivers and/or family members of high-risk patients may be reasonable, (Class IIb, LOE C-LD) although further work needs to help define which groups to preferentially target.

This recommendation is predicated on the significant potential benefit and low potential for harm in patients receiving bystander CPR by a trained family member or caregiver.

8.4 Resuscitation Training in Limited-Resource Communities

Many AHA instructors are involved in training in limited-resource environments in the United States and throughout the world. The vast majority of participants enjoy training and feel more comfortable after educational programs regardless of the type of training provided.[220-232]

Improvements in provider performance and patient outcomes following training in resource-limited environments are inconsistent, and important characteristics of students and training environment, as well as outcomes (cognitive, psychomotor skills, operational performance, patient outcome, and cost-effectiveness), are inconsistently measured. Resuscitation training, when appropriately adapted to the local providers' clinical environment and resources, has significantly reduced mortality in developing countries.[226,233-236] The evidence from the trauma education is most compelling, and less clear with neonatal[237,238] and adult cardiac resuscitation training programs.[239] Patient outcome studies were often limited by study design, but 1 large, multicenter trial failed to show improvement in neonatal survival after newborn resuscitation training.[240]

There is no strong evidence to support any specific instruction method as preferable for all clinical environments and training subject experience. There is anecdotal evidence that successful resuscitation training in developing countries requires local adaptation to clinical environments,[222,241-243] utilizing existing and sustainable resources for both care and training,[224,242-244] and a dedicated local infrastructure.[231,241]

9 Knowledge Gaps - Updated

Implementing resuscitation science into clinical practice requires educational practice based on high-quality educational research. To date, the resuscitation education literature has been limited by outcomes that focus on short-term learning rather than patient outcome or transfer of provider performance into the clinical environment (or even long-term retention of critical skills), variable quality of research design, and the use of assessment tools that lack validity and reliability evidence. With that in mind, the writing group for the AHA education guidelines suggests the following general concepts to advance educational research and educational practice, along with a series of specific themes of research that warrant further exploration (Table 3).

Table 3: 2015 - Specific Themes for Future Resuscitation Education Research

Open table in a new window

Specific Themes for Future Resuscitation Education Research	
Basic Life Support Training	
CPR instruction methods	• Determine the impact of short, video-based practice on long-term CPR performance as well as patient outcomes • Determine the optimal design of these short courses

AED training methods	• Define the optimal instructional strategies and retraining intervals, including the methods of retraining, to improve performance and self-efficacy
CPR feedback/prompt devices in training	• Determine the impact of CPR feedback devices on future (long-term) performance of CPR • Explore the additional or reduced costs of training with feedback devices
Retraining intervals for basic life support	• Determine the ideal frequency of retraining required to enhance retention of skills and performance in simulated and real resuscitations • Assess if real resuscitation events, coupled with appropriate feedback and/or assessment, can serve as an adjunct or replacement for more frequent retraining
Compression-only CPR training in communities	• Define the optimal community bystander CPR training strategy based on cultural and local variables
CPR training in resource-limited environments	• Determine the optimal method of low-cost instruction while enhancing learning and patient outcomes
CPR for high-risk populations	• Determine which populations are best suited for targeted training, including the cost-effectiveness of this intervention
Advanced Life Support Training	
Precourse preparation	• Determine the content, timing, and importance of precourse preparation for various life support courses on learning outcomes
Team and leadership training	• Determine the optimal methodology (ie, instructional design), frequency, and context of team and leadership training for acquisition and retention of key resuscitation skills • Define how individual leadership and team skills influence and/or relate to specific clinical performance metrics during resuscitation

Manikin fidelity	• Determine the relative impact of different types of manikin fidelity (physical, emotional, conceptual) on learning, performance, and real clinical outcomes • Determine which aspects of manikin fidelity are important for achieving improved learning outcomes for specific objectives (eg, technical versus cognitive versus behavioral)
Training intervals	• Determine the ideal methodology (ie, instructional design) and frequency of retraining required to enhance retention of skills and performance in simulated and real resuscitations • Assess if real resuscitation events, coupled with appropriate feedback and/or assessment, can serve as an adjunct or replacement for more frequent retraining
Other Topics	
Repetitive practice/mastery learning	• Determine how repetitive practice and mastery learning can be applied to enhance the acquisition and retention of the various critical resuscitation competencies
Briefing/debriefing	• Determine how the various aspects of briefing (eg, content, duration) influence learning outcomes from simulation-based resuscitation education • Determine how various aspects of debriefing (eg, duration, method, framework, facilitator, use of video) can be tailored to improve the quality of simulation-based resuscitation education
Data-informed feedback	• Determine the value of data-informed feedback (eg, quantitative CPR data, video review) during advanced life support courses
Blended learning	• Determine how different learning methods and models (eg, screen-based learning, mastery learning, high-fidelity simulation) can be blended to enhance learning and patient outcomes
Instructor training and competencies	• Determine the key instructor competencies that influence positive learning outcomes • Determine the optimal means of coaching, training, and assessing instructors

AED indicates automated external defibrillator; and CPR, cardiopulmonary resuscitation.

9.1 General Concepts - Updated

Research on resuscitation education needs higher-quality studies that are adequately powered and that address important educational questions. Multicenter collaborative studies may be of benefit to support both quality in study design and enrolling adequate numbers of participants. Ideally, the outcomes from educational studies should focus on patient outcomes (where feasible), transfer of learning into performance in the clinical environment, or at least long-term retention of psychomotor and behavioral skills in the simulated resuscitation environment. Too much of the current focus of educational research is exclusively on the immediate end-of-course performance, which may not be representative of participants' performance when they are faced with a resuscitation event months to years later. Because much of the training for resuscitation events uses manikin-based simulation, research is needed to reflect important patient characteristics in training devices, such as chest compliance and clinical signs of distress. Assessment tools that have been empirically studied for evidence of validity and reliability are foundational to high-quality research. Standardizing the use of such tools across studies could potentially allow for meaningful comparisons when evidence is synthesized in systematic reviews to more precisely determine the impact of certain interventions. Finally, there is a clear need for cost-effectiveness research because many of the AHA education guidelines are developed in the absence of this information.

10 Authorship and Disclosures

10.1 2015 Writing Team

Farhan Bhanji, Chair; Aaron J. Donoghue; Margaret S. Wolff; Gustavo E. Flores; Louis P. Halamek; Jeffrey M. Berman; Elizabeth H. Sinz; Adam Cheng

Table 4: Part 14: Education: 2015 Guidelines Update Writing Group Disclosures

Open table in a new window

Part 14: Education: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Farhan Bhanji	McGill University	None	None	None	None	None	None	None
Jeffrey M. Berman	UNC Hospitals	None	None	None	None	None	None	None
Adam Cheng	Alberta Children's Hospital	Heart and Stroke Foundation of Canada*	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honora	Expert Witness	Ownership Interest	Consultant/Advis Board	Other
Aaron J. Donoghue	The Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine	Zoll Foundation*	None	None	None	None	None	None
Gustavo E. Flores	Emergency & Critical Care Trainings, LLC	None	None	None	None	None	None	None
Louis P. Halamek	Stanford University School of Medicine	None	None	None	None	None	None	None
Margaret S. Wolff	University of Michigan	None	None	None	None	None	None	None
Consultant								
Elizabeth H. Sinz	Pennsylvania State University College of Medicine	AHRQ*	None	None	None	None	American Heart Association†	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition. *Modest. †Significant.

10.2 2010 Writing Team

Farhan Bhanji, Chair; Mary E. Mancini; Elizabeth Sinz; David L. Rodgers; Mary Ann McNeil; Theresa A. Hoadley; Reylon A. Meeks; Melinda Fiedor Hamilton; Peter A. Meaney; Elizabeth A. Hunt; Vinay M. Nadkarni; Mary Fran Hazinski

Table 5: 2010 - Guidelines Part 16: Education Implementation and Teams Writing Group Disclosures

Open table in a new window

2010 Guidelines Part 16: Education Implementation and Teams Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Farhan Bhanji	Montreal Children's Hospital, McGill University–Assistant Professor of Pediatrics	None	None	None	None	None	None
Mary E. Mancini	University of Texas at Arlington—Pro	None	None	*In the past two years have received honoraria from Datascope for presentations at two national teaching institutes for the American Association of Critical Care Nurses and Emergency Nursing Association–T = Improving The Chain of Survival.	*I am listed on a patent held by my University for a sensing device that could be used for CPR. Device has not been produced. I receive no royalties.	None	None
Elizabeth Sinz	Penn State Hershey Medical Center–Professor of Anesthesiology and Neurosurgery; *American Heart Association; Associate Science Editor	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
David L. Rodgers		Clinical Educator, the Center for Simulation, Advanced Education and Innovation, Children's Hospital of Philadelphia	None	None	None	None	†Spouse (Robin Roberts) is an employee of the American Heart Association.
Mary Ann McNeil	University of Minnesota Medical school-Director, Department of Emergency Medicine	None	None	None	None	None	None
Theresa A. Hoadley	OSF St Francis College of Nursing; Assist. Professor; Proctor Hosp-TC coordinator	None	None	None	None	None	None
Reylon A. Meeks	Blank Children's Hosp./Pleasant Hill FD/Southwest CC, DMACC	None	None	None	None	None	None
Melinda Fiedor Hamilton	Children's Hospital of Pittsburgh of UPMC–Assista Professor of CCM and Pediatrics	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Peter A. Meaney	University of Pennsylvania, Children's Hospital of Philadelphia–Assistant Professor	*Laerdal Foundation, Research grant “Development and Validation of a Quantitative Measurement Device to Assess Technical Basic Life Support Skills in Resource Limited Settings.” No direct support to investigator Operation Smile, Educational development grant, “Pilot Training Proposal: Acute Care Training for the Peri-Operative Pediatrician”. No direct support to investigator	*Laerdal Corporation, Research equipment (study mankins) for “Development and Validation of a Quantitative Measurement Device to Assess Technical Basic Life Support Skills in Resource Limited Settings.” No direct support to investigator	None	None	None	None
Elizabeth A. Hunt	Johns Hopkins University School of Medicine–Director, Johns Hopkins Medicine Simulation Center	None	None	None	None	None	None

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honorari	Ownership Interest	Consultant/Advisc Board	Other
Vinay M. Nadkarni	University of Pennsylvania School of Medicine, Children's Hospital of Philadelphia–Attending Physician, Anesthesia, Critical Care and Pediatrics	†AHRQ: Agency for Healthcare, Research and Quality: PI, Grant for Evaluation of Safety of Pediatric Tracheal Intubation and Just in Time Simulation Education Intervention	None	None	None	None	None
Mary Fran Hazinski	Vanderbilt Univ. School of Nursing—Profe AHA ECC Product Development–Science Editor †I receive significant compensation as a consultant and senior science editor for the AHA ECC Product Development	None	None	None	None	None	None

- This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.
- ?* Modest.
- ?† Significant.

11 Footnotes

The American Heart Association requests that this document be cited as follows:

American Heart Association. Web-based Integrated Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – Part 14: Education. ECCguidelines.heart.org.

References

1. Meaney PA, Bobrow BJ, Mancini ME, Christenson J, de Caen AR, Bhanji F, Abella BS, Kleinman ME, Edelson DP, Berg RA, Aufderheide TP, Menon V, Leary M; CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Cardiopulmonary resuscitation quality: [corrected] improv- ing cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. Circulation. 2013;128:417–435. doi: 10.1161/CIR.0b013e31829d8654.

2. Stiell IG, Brown SP, Christenson J, Cheskes S, Nichol G, Powell J, Bigham B, Morrison LJ, Larsen J, Hess E, Vaillancourt C, Davis DP, Callaway CW; Resuscitation Outcomes Consortium (ROC) Investigators. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? Crit Care Med. 2012;40:1192–1198. doi: 10.1097/ CCM.0b013e31823bc8bb.

3. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, Hoffman P, Tynus K, Vanden Hoek TL, Becker LB. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation. 2005;111:428–434. doi: 10.1161/01.CIR.0000153811.84257.59.

4. Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, Rea T, Lowe R, Brown T, Dreyer J, Davis D, Idris A, Stiell I; Resuscitation Outcomes Consortium Investigators. Regional variation in out-of-hospital cardiac arrest incidence and outcome. JAMA. 2008;300:1423–1431. doi: 10.1001/jama.300.12.1423.

5. Perkins GD, Cooke MW. Variability in cardiac arrest survival: the NHS Ambulance Service Quality Indicators. Emerg Med J. 2012;29:3–5. doi: 10.1136/emermed-2011-200758.

6. Peberdy MA, Ornato JP, Larkin GL, Braithwaite RS, Kashner TM, Carey SM, Meaney PA, Cen L, Nadkarni VM, Praestgaard AH, Berg RA; National Registry of Cardiopulmonary Resuscitation Investigators. Survival from in-hospital cardiac arrest during nights and weekends. JAMA. 2008;299:785–792. doi: 10.1001/jama.299.7.785.

7. Idris AH, Guffey D, Pepe PE, Brown SP, Brooks SC, Callaway CW, Christenson J, Davis DP, Daya MR, Gray R, Kudenchuk PJ, Larsen J, Lin S, Menegazzi JJ, Sheehan K, Sopko G, Stiell I, Nichol G, Aufderheide TP; Resuscitation Outcomes Consortium Investigators. Chest compression rates and survival following out-of-hospital cardiac arrest. Crit Care Med. 2015;43:840–848. doi: 10.1097/CCM.0000000000000824.

8. International Liaison Committee on Resuscitation. Part 8: interdis- ciplinary topics: 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2005;67:305–314.

9. Bhanji F, Mancini ME, Sinz E, Rodgers DL, McNeil MA, Hoadley TA, Meeks RA, Hamilton MF, Meaney PA, Hunt EA, Nadkarni VM, Hazinski MF. Part 16: education, implementation, and teams: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122(suppl 3): S920–S933. doi: 10.1161/CIRCULATIONAHA.110.971135.

10. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2005;112:IV1–IV203.

11. American Heart Association, American Stroke Assocation, International Liaison Committee on Resuscitation (ILCOR). ILCOR Scientific Evidence Evaluation and Review System. https://volunteer.heart.org/apps/ pico/Pages/default.aspx. Accessed May 10, 2015.

12. Bhanji F, Finn JC, Lockey A, Monsieurs K, Frengley R, Iwami T, Lang E, Ma MH, Mancini ME, McNeil MA, Greif R, Billi JE, Nadkarni VM, Bigham B; on behalf of the Education, Implementation, and Teams Chapter Collaborators. Part 8: education, implementation, and teams: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2015;132(suppl 1):S242–S268. doi: 10.1161/CIR.0000000000000277.

13. Finn JC, Bhanji F, Lockey A, Monsieurs K, Frengley R, Iwami T, Lang E, Ma MH, Mancini ME, McNeil MA, Greif R, Billi JE, Nadkarni VM, Bigham B; on behalf of the Education, Implementation, and Teams Chapter Collaborators. Part 8: education, implementation, and teams: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2015. In press.

14. Kirkpatrick DL, Kirkpatrick JD. Evaluating Training Programs: The Four Levels. San Francisco, CA: Berrett-Koehler Publishers; 1994.

15. McGaghie WC. Medical education research as translational science. Sci Transl Med. 2010;2:19cm8. doi: 10.1126/scitranslmed.3000679.

16.

Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes. 2010;3:63–81.

17. Abella BS, Aufderheide TP, Eigel B, Hickey RW, Longstreth WT Jr., Nadkarni V, Nichol G, Sayre MR, Sommargren CE, Hazinski MF. Reducing barriers for implementation of bystander-initiated cardiopulmonary resuscitation: a scientific statement from the American Heart Association for healthcare providers, policymakers, and community leaders regarding the effectiveness of cardiopulmonary resuscitation. Circulation. 2008;117:704–709.

18. Hubble MW, Bachman M, Price R, Martin N, Huie D. Willingness of high school students to perform cardiopulmonary resuscitation and automated external defibrillation. Prehosp Emerg Care. 2003;7:219–224.

19. Swor R, Khan I, Domeier R, Honeycutt L, Chu K, Compton S. CPR training and CPR performance: do CPR-trained bystanders perform CPR? Acad Emerg Med. 2006;13:596–601.

20. Moser DK, Dracup K, Doering LV. Effect of cardiopulmonary resuscitation training for parents of high-risk neonates on perceived anxiety, control, and burden. Heart Lung. 1999;28:326–333.

21. Omi W, Taniguchi T, Kaburaki T, Okajima M, Takamura M, Noda T, Ohta K, Itoh H, Goto Y, Kaneko S, Inaba H. The attitudes of Japanese high school students toward cardiopulmonary resuscitation. Resuscitation. 2008;78:340–345.

22. Shibata K, Taniguchi T, Yoshida M, Yamamoto K. Obstacles to bystander cardiopulmonary resuscitation in Japan. Resuscitation. 2000;44:187–193.

23. Taniguchi T, Omi W, Inaba H. Attitudes toward the performance of bystander cardiopulmonary resuscitation in Japan. Resuscitation. 2007;75:82–87.

24. Dwyer T. Psychological factors inhibit family members' confidence to initiate CPR. Prehosp Emerg Care. 2008;12:157–161.

25. Coons SJ, Guy MC. Performing bystander CPR for sudden cardiac arrest: behavioral intentions among the general adult population in Arizona. Resuscitation. 2009;80:334–340.

26. Caves ND, Irwin MG. Attitudes to basic life support among medical students following the 2003 SARS outbreak in Hong Kong. Resuscitation. 2006;68:93–100.

27. Johnston TC, Clark MJ, Dingle GA, FitzGerald G. Factors influencing Queenslanders' willingness to perform bystander cardiopulmonary resuscitation. Resuscitation. 2003;56:67–75.

28. Boucek CD, Phrampus P, Lutz J, Dongilli T, Bircher NG. Willingness to perform mouth-to-mouth ventilation by health care providers: a survey. Resuscitation. 2009;80:849–853.

29. Axelsson A, Thoren A, Holmberg S, Herlitz J. Attitudes of trained Swedish lay rescuers toward CPR performance in an emergency: a survey of 1012 recently trained CPR rescuers. Resuscitation. 2000;44:27–36.

30. Riegel B, Mosesso VN, Birnbaum A, Bosken L, Evans LM, Feeny D, Holohan J, Jones CD, Peberdy MA, Powell J. Stress reactions and perceived difficulties of lay responders to a medical emergency. Resuscitation. 2006;70:98–106.

31. Lerner EB, Sayre MR, Brice JH, White LJ, Santin AJ, Billittier AJ IV., Cloud SD. Cardiac arrest patients rarely receive chest compressions before ambulance arrival despite the availability of pre-arrival CPR instructions. Resuscitation. 2008;77:51–56.

32. Donohoe RT, Haefeli K, Moore F. Public perceptions and experiences of myocardial infarction, cardiac arrest and CPR in London. Resuscitation. 2006;71:70–79.

33. Kuramoto N, Morimoto T, Kubota Y, Maeda Y, Seki S, Takada K, Hiraide A. Public perception of and willingness to perform bystander CPR in Japan. Resuscitation. 2008;79:475–481.

34. Jelinek GA, Gennat H, Celenza T, O'Brien D, Jacobs I, Lynch D. Community attitudes towards performing cardiopulmonary resuscitation in Western Australia. Resuscitation. 2001;51:239–246.

35. Lynch B, Einspruch EL, Nichol G, Becker LB, Aufderheide TP, Idris A. Effectiveness of a 30-min CPR self-instruction program for lay responders: a controlled randomized study. Resuscitation. 2005;67:31–43.

36. Todd KH, Braslow A, Brennan RT, Lowery DW, Cox RJ, Lipscomb LE, Kellermann AL. Randomized, controlled trial of video self-instruction versus traditional CPR training. Ann Emerg Med. 1998;31:364–369.

37. Einspruch EL, Lynch B, Aufderheide TP, Nichol G, Becker L. Retention of CPR skills learned in a traditional AHA Heartsaver course versus 30-min video self-training: a controlled randomized study. Resuscitation. 2007;74:476–486.

38. Todd KH, Heron SL, Thompson M, Dennis R, O'Connor J, Kellermann AL. Simple, CPR: a randomized, controlled trial of video self-instructional cardiopulmonary resuscitation training in an African American church congregation. Ann Emerg Med. 1999;34:730–737.

39.

Reder S, Cummings P, Quan L. Comparison of three instructional methods for teaching cardiopulmonary resuscitation and use of an automatic external defibrillator to high school students. Resuscitation. 2006;69:443–453.

40. Roppolo LP, Pepe PE, Campbell L, Ohman K, Kulkarni H, Miller R, Idris A, Bean L, Bettes TN, Idris AH. Prospective, randomized trial of the effectiveness and retention of 30-min layperson training for cardiopulmonary resuscitation and automated external defibrillators: the American Airlines Study. Resuscitation. 2007;74:276–285.

41. Batcheller AM, Brennan RT, Braslow A, Urrutia A, Kaye W. Cardiopulmonary resuscitation performance of subjects over forty is better following half-hour video self-instruction compared to traditional four-hour classroom training. Resuscitation. 2000;43:101–110.

42. Isbye DL, Rasmussen LS, Lippert FK, Rudolph SF, Ringsted CV. Laypersons may learn basic life support in 24 min using a personal resuscitation manikin. Resuscitation. 2006;69:435–442.

43. Moule P, Albarran JW, Bessant E, Brownfield C, Pollock J. A non-randomized comparison of e-learning and classroom delivery of basic life support with automated external defibrillator use: a pilot study. Int J Nurs Pract. 2008;14:427–434.

44. Liberman M, Golberg N, Mulder D, Sampalis J. Teaching cardiopulmonary resuscitation to CEGEP students in Quebec: a pilot project. Resuscitation. 2000;47:249–257.

45. Jones I, Handley AJ, Whitfield R, Newcombe R, Chamberlain D. A preliminary feasibility study of a short DVD-based distance-learning package for basic life support. Resuscitation. 2007;75:350–356.

46. Braslow A, Brennan RT, Newman MM, Bircher NG, Batcheller AM, Kaye W. CPR training without an instructor: development and evaluation of a video self-instructional system for effective performance of cardiopulmonary resuscitation. Resuscitation. 1997;34:207–220.

47. Ahmad F, Senadhira DCA, Charters J, Acquilla S. Transmission of salmonella via mouth-to-mouth resuscitation. Lancet. 1990;335:787–788.

48. Chalumeau M, Bidet P, Lina G, Mokhtari M, Andre MC, Gendrel D, Bingen E, Raymond J. Transmission of Panton-Valentine leukocidin-producing Staphylococcus aureus to a physician during resuscitation of a child. Clin Infect Dis. 2005;41:e29–e30.

49. Christian MD, Loutfy M, McDonald LC, Martinez KF, Ofner M, Wong T, Wallington T, Gold WL, Mederski B, Green K, Low DE. Possible SARS coronavirus transmission during cardiopulmonary resuscitation. Emerg Infect Dis. 2004;10:287–293.

50. Feldman HA. Some recollections of the meningococcal diseases: the first Harry, F. Dowling lecture. JAMA. 1972;220:1107–1112.

51. Finkelhor RS, Lampman JH. Herpes simplex infection following cardiopulmonary resuscitation. JAMA. 1980;243:650.

52. Heilman KM, Muschenheim C. Primary cutaneous tuberculosis resulting from mouth-to-mouth respiration. N Engl J Med. 1965;273:1035–1036.

53. Hendricks AA, Shapiro EP. Primary herpes simplex infection following mouth-to-mouth resuscitation. JAMA. 1980;243:257–258.

54. Todd MA, Bell JS. Shigellosis from cardiopulmonary resuscitation. JAMA. 1980;243:331.

55. Valenzuela TD, Hooton TM, Kaplan EL, Schlievert P. Transmission of “toxic strep” syndrome from an infected child to a firefighter during CPR. Ann Emerg Med. 1991;20:90–92.

56. Neiman R. Post manikin resuscitation stomatitis. J Ky Med Assoc. 1982;80:813–814.

57. Nicklin G. Manikin tracheitis. JAMA. 1980;244:2046–2047.

58. Lam KK, Lau FL, Chan WK, Wong WN. Effect of severe acute respiratory syndrome on bystander willingness to perform cardiopulmonary resuscitation (CPR): is compression-only preferred to standard CPR? Prehosp Disaster Med. 2007;22:325–329.

59. Locke CJ, Berg RA, Sanders AB, Davis MF, Milander MM, Kern KB, Ewy GA. Bystander cardiopulmonary resuscitation: concerns about mouth-to-mouth contact. Arch Intern Med. 1995;155:938–943.

60. Hamasu S, Morimoto T, Kuramoto N, Horiguchi M, Iwami T, Nishiyama C, Takada K, Kubota Y, Seki S, Maeda Y, Sakai Y, Hiraide A. Effects of BLS training on factors associated with attitude toward CPR in college students. Resuscitation. 2009;80:359–364.

61. Bobrow BJ, Zuercher M, Ewy GA, Clark L, Chikani V, Donahue D, Sanders AB, Hilwig RW, Berg RA, Kern KB. Gasping during cardiac arrest in humans is frequent and associated with improved survival. Circulation. 2008;118:2550–2554.

62. Perkins GD, Walker G, Christensen K, Hulme J, Monsieurs KG. Teaching recognition of agonal breathing improves accuracy of diagnosing cardiac arrest. Resuscitation. 2006;70:432–437.

63. Culley LL, Clark JJ, Eisenberg MS, Larsen MP. Dispatcher-assisted telephone CPR: common delays and time standards for delivery. Ann Emerg Med. 1991;20:362–366.

64.

Vaillancourt C, Stiell IG, Wells GA. Understanding and improving low bystander CPR rates: a systematic review of the literature. CJEM. 2008;10:51–65.

65. Calle PA, Lagaert L, Vanhaute O, Buylaert WA. Do victims of an out-of-hospital cardiac arrest benefit from a training program for emergency medical dispatchers? Resuscitation. 1997;35:213–218.

66. Emergency medical dispatching: rapid identification and treatment of acute myocardial infarction. National Heart Attack Alert Program Coordinating Committee Access to Care Subcommittee. Am J Emerg Med. 1995;13:67–73.

67. Hallstrom A, Cobb L, Johnson E, Copass M. Cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. N Engl J Med. 2000;342:1546–1553.

68. Culley LL, Clark JJ, Eisenberg MS, Larsen MP. Dispatcher-assisted telephone CPR: common delays and time standards for delivery. Ann Emerg Med. 1991;20:362–366.

69. Berdowski J, Beekhuis F, Zwinderman AH, Tijssen JG, Koster RW. Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call. Circulation. 2009;119:2096–2102.

70. Kuisma M, Boyd J, Vayrynen T, Repo J, Nousila-Wiik M, Holmstrom P. Emergency call processing and survival from out-of-hospital ventricular fibrillation. Resuscitation. 2005;67:89–93.

71. Rea TD, Eisenberg MS, Culley LL, Becker L. Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. Circulation. 2001;104:2513–2516.

72. Lyster T, Jorgenson D, Morgan C. The safe use of automated external defibrillators in a wet environment. Prehosp Emerg Care. 2003;7:307–311.

73. Lloyd MS, Heeke B, Walter PF, Langberg JJ. Hands-on defibrillation: an analysis of electrical current flow through rescuers in direct contact with patients during biphasic external defibrillation. Circulation. 2008;117:2510–2514.

74. Peberdy MA, Ottingham LV, Groh WJ, Hedges J, Terndrup TE, Pirrallo RG, Mann NC, Sehra R. Adverse events associated with lay emergency response programs: the Public Access Defibrillation Trial experience. Resuscitation. 2006;70:59–65.

75. Capucci A, Aschieri D, Piepoli MF. Improving survival with early defibrillation. Cardiol Rev. 2003;20:12–14.

76. Page RL, Joglar JA, Kowal RC, Zagrodzky JD, Nelson LL, Ramaswamy K, Barbera SJ, Hamdan MH, McKenas DK. Use of automated external defibrillators by a U.S. airline. N Engl J Med. 2000;343:1210–1216.

77. Jorgenson DB, Skarr T, Russell JK, Snyder DE, Uhrbrock K. AED use in businesses, public facilities and homes by minimally trained first responders. Resuscitation. 2003;59:225–233.

78. Hoke RS, Heinroth K, Trappe HJ, Werdan K. Is external defibrillation an electric threat for bystanders? Resuscitation. 2009;80:395–401.

79. Schratter A, Weihs W, Holzer M, Janata A, Behringer W, Losert UM, Ohley WJ, Schock RB, Sterz F. External cardiac defibrillation during wet-surface cooling in pigs. Am J Emerg Med. 2007;25:420–424.

80. Beckers S, Fries M, Bickenbach J, Derwall M, Kuhlen R, Rossaint R. Minimal instructions improve the performance of laypersons in the use of semiautomatic and automatic external defibrillators. Crit Care. 2005;9:R110–R116.

81. Beckers SK, Fries M, Bickenbach J, Skorning MH, Derwall M, Kuhlen R, Rossaint R. Retention of skills in medical students following minimal theoretical instructions on semi and fully automated external defibrillators. Resuscitation. 2007;72:444–450.

82. Mitchell KB, Gugerty L, Muth E. Effects of brief training on use of automated external defibrillators by people without medical expertise. Hum Factors. 2008;50:301–310.

83. Bandura A. Self-Efficacy: The Exercise of Control. New York, NY: WH Freeman and Co; 1997.

84. Turner NM, Lukkassen I, Bakker N, Draaisma J, ten Cate OT. The effect of the APLS-course on self-efficacy and its relationship to behavioural decisions in paediatric resuscitation. Resuscitation. 2009;80:913–918. doi: 10.1016/j.resuscitation.2009.03.028.

85. Cheng A, Rodgers DL, van der Jagt É, Eppich W, O'Donnell J. Evolution of the Pediatric Advanced Life Support course: enhanced learning with a new debriefing tool and Web-based module for Pediatric Advanced Life Support instructors. Pediatr Crit Care Med. 2012;13:589–595. doi: 10.1097/PCC.0b013e3182417709.

86. van de Ridder JM, Stokking KM, McGaghie WC, ten Cate OT. What is feedback in clinical education? Med Educ. 2008;42:189–197.

87. Cheng A, Eppich W, Grant V, Sherbino J, Zendejas B, Cook DA. Debriefing for technology-enhanced simulation: a systematic review and meta-analysis. Med Educ. 2014;48:657–666. doi: 10.1111/medu.12432.

88. Kirkpatrick D, Kirkpatrick J. Implementing the Four Levels: A Practical Guide for the Evaluation of Training Programs. San Francisco, Calif: Berrett-Koehler; 2007.

89. Kolb DA. Experiential Learning: Experience as the Source of Learning Development. Englewood Cliffs, NJ: Prentice-Hall Inc; 1984.

90. Moazed F, Cohen ER, Furiasse N, Singer B, Corbridge TC, McGaghie WC, Wayne DB. Retention of critical care skills after simulation-based mastery learning. J Grad Med Educ. 2013;5:458–463. doi: 10.4300/ JGME-D-13-00033.1.

91. Savoldelli GL, Naik VN, Park J, Joo HS, Chow R, Hamstra SJ. Value of debriefing during simulated crisis management: oral versus video-assisted oral feedback. Anesthesiology. 2006;105:279–285.

92. ChengA,HuntEA,DonoghueA,Nelson-McMillanK,NishisakiA,LefloreJ, Eppich W, Moyer M, Brett-Fleegler M, Kleinman M, Anderson J, Adler M, Braga M, Kost S, Stryjewski G, Min S, Podraza J, Lopreiato J, Hamilton MF, Stone K, Reid J, Hopkins J, Manos J, Duff J, Richard M, Nadkarni VM; EXPRESS Investigators. Examining pediatric resuscitation education using simulation and scripted debriefing: a multicenter randomized trial. JAMA Pediatr. 2013;167:528–536. doi: 10.1001/jamapediatrics.2013.1389.

93. Hamstra SJ, Brydges R, Hatala R, Zendejas B, Cook DA. Reconsidering fidelity in simulation-based training. Acad Med. 2014;89:387–392. doi: 10.1097/ACM.0000000000000130.

94. Krogh KB, Høyer CB, Ostergaard D, Eika B. Time matters–realism in resuscitation training. Resuscitation. 2014;85:1093–1098. doi: 10.1016/j. resuscitation.2014.05.008.

95. Cheng A, Brown LL, Duff JP, Davidson J, Overly F, Tofil NM, Peterson DT, White ML, Bhanji F, Bank I, Gottesman R, Adler M, Zhong J, Grant V, Grant DJ, Sudikoff SN, Marohn K, Charnovich A, Hunt EA, Kessler DO, Wong H, Robertson N, Lin Y, Doan Q, Duval-Arnould JM, Nadkarni VM; International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) CPR Investigators. Improving cardio- pulmonary resuscitation with a CPR feedback device and refresher simu- lations (CPR CARES Study): a randomized clinical trial. JAMA Pediatr. 2015;169:137–144. doi: 10.1001/jamapediatrics.2014.2616.

96. WayneDB,SiddallVJ,ButterJ,FudalaMJ,WadeLD,FeinglassJ,McGaghie WC. A longitudinal study of internal medicine residents' retention of advanced cardiac life support skills. Acad Med. 2006;81(10 suppl):S9–S12.

97. Ahya SN, Barsuk JH, Cohen ER, Tuazon J, McGaghie WC, Wayne DB. Clinical performance and skill retention after simulation-based education for nephrology fellows. Semin Dial. 2012;25:470–473. doi: 10.1111/j.1525-139X.2011.01018.x.

98. McGaghie WC, Issenberg SB, Barsuk JH, Wayne DB. A critical review of simulation-based mastery learning with translational outcomes. Med Educ. 2014;48:375–385. doi: 10.1111/medu.12391.

99. McGaghie WC, Miller GE, Sajid AW, Telder TV. Competency-based curriculum development on medical education: an introduction. Public Health Pap. 1978:11–91.

100. Miller GE. The assessment of clinical skills/competence/performance. Acad Med. 1990;65(9 suppl):S63–S67.

101. Mort T, Donahue S. Debriefing: the basics. In: Dunn WF, ed. Simulators in Critical Care And Beyond. Mount Prospect, IL: Society of Critical Care Medicine; 2004:130.

102. Eppich W, Cheng A. Promoting Excellence and Reflective Learning in Simulation (PEARLS): development and rationale for a blended approach to health care simulation debriefing. Simul Healthc. 2015;10:106–115. doi: 10.1097/SIH.0000000000000072.

103. Eppich W, Cheng A. Competency-based simulation education: should competency standards apply for simulation educators? BMJ Simulation and Technology Enhanced Learning. 2015:bmjstel-2014-000013.

104. Lynch B, Einspruch EL, Nichol G, Becker LB, Aufderheide TP, Idris A. Effectiveness of a 30-min CPR self-instruction program for lay respond- ers: a controlled randomized study. Resuscitation. 2005;67:31–43. doi: 10.1016/j.resuscitation.2005.04.017.

105. Einspruch EL, Lynch B, Aufderheide TP, Nichol G, Becker L. Retention of CPR skills learned in a traditional AHA Heartsaver course versus 30-min video self-training: a controlled randomized study. Resuscitation. 2007;74:476–486. doi: 10.1016/j.resuscitation.2007.01.030.

106. Mancini ME, Cazzell M, Kardong-Edgren S, Cason CL. Improving work- place safety training using a self-directed CPR-AED learning program. AAOHN J. 2009;57:159–167; quiz 168.

107. RoppoloLP,HeymannR,PepeP,WagnerJ,CommonsB,MillerR,AllenE, Horne L, Wainscott MP, Idris AH. A randomized controlled trial comparing traditional training in cardiopulmonary resuscitation (CPR) to self-directed CPR learning in first year medical students: the two-person CPR study. Resuscitation. 2011;82:319–325. doi: 10.1016/j.resuscitation.2010.10.025.

108. Roppolo LP, Pepe PE, Campbell L, Ohman K, Kulkarni H, Miller R, Idris A, Bean L, Bettes TN, Idris AH. Prospective, randomized trial of the effectiveness and retention of 30-min layperson training for car- diopulmonary resuscitation and automated external defibrillators: the American Airlines Study. Resuscitation. 2007;74:276–285. doi: 10.1016/j. resuscitation.2006.12.017.

109. Fabius DB, Grissom EL, Fuentes A. Recertification in cardiopulmonary resuscitation. A comparison of two teaching methods. J Nurs Staff Dev. 1994;10:262–268.

110. Todd KH, Heron SL, Thompson M, Dennis R, O'Connor J, Kellermann AL. Simple CPR: a randomized, controlled trial of video self-instructional cardiopulmonary resuscitation training in an African American church congregation. Ann Emerg Med. 1999;34:730–737.

111. Todd KH, Braslow A, Brennan RT, Lowery DW, Cox RJ, Lipscomb LE, Kellermann AL. Randomized, controlled trial of video self-instruction versus traditional CPR training. Ann Emerg Med. 1998;31:364–369.

112. Nelson M, Brown CG. CPR instruction: modular versus lecture course. Ann Emerg Med. 1984;13:118–121.

113. Chung CH, Siu AY, Po LL, Lam CY, Wong PC. Comparing the effective- ness of video self-instruction versus traditional classroom instruction tar- geted at cardiopulmonary resuscitation skills for laypersons: a prospective randomised controlled trial. Hong Kong Med J. 2010;16:165–170.

114. CasonCL,Kardong-EdgrenS,CazzellM,BehanD,ManciniME.Innovations in basic life support education for healthcare providers: improving compe- tence in cardiopulmonary resuscitation through self-directed learning. J Nurses Staff Dev. 2009;25:E1–E13. doi: 10.1097/NND.0b013e3181a56f92.

115. Batcheller AM, Brennan RT, Braslow A, Urrutia A, Kaye W. Cardiopulmonary resuscitation performance of subjects over forty is bet- ter following half-hour video self-instruction compared to traditional four- hour classroom training. Resuscitation. 2000;43:101–110.

116. Dracup K, Moser DK, Doering LV, Guzy PM. Comparison of cardiopul- monary resuscitation training methods for parents of infants at high risk for cardiopulmonary arrest. Ann Emerg Med. 1998;32:170–177.

117. Beckers S, Fries M, Bickenbach J, Derwall M, Kuhlen R, Rossaint R. Minimal instructions improve the performance of laypersons in the use of semiautomatic and automatic external defibrillators. Crit Care. 2005;9:R110–R116. doi: 10.1186/cc3033.

118. Beckers SK, Fries M, Bickenbach J, Skorning MH, Derwall M, Kuhlen R, Rossaint R. Retention of skills in medical students follow- ing minimal theoretical instructions on semi and fully automated exter- nal defibrillators. Resuscitation. 2007;72:444–450. doi: 10.1016/j. resuscitation.2006.08.001.

119. Mitchell KB, Gugerty L, Muth E. Effects of brief training on use of auto- mated external defibrillators by people without medical expertise. Hum Factors. 2008;50:301–310.

120. Reder S, Cummings P, Quan L. Comparison of three instructional methods for teaching cardiopulmonary resuscitation and use of an automatic exter- nal defibrillator to high school students. Resuscitation. 2006;69:443–453. doi: 10.1016/j.resuscitation.2005.08.020.

121. de Vries W, Turner NM, Monsieurs KG, Bierens JJ, Koster RW. Comparison of instructor-led automated external defibrillation train- ing and three alternative DVD-based training methods. Resuscitation. 2010;81:1004–1009. doi: 10.1016/j.resuscitation.2010.04.006.

122. Meischke HW, Rea T, Eisenberg MS, Schaeffer SM, Kudenchuk P. Training seniors in the operation of an automated external defibrillator: a randomized trial comparing two training methods. Ann Emerg Med. 2001;38:216–222. doi: 10.1067/mem.2001.115621.

123. de Vries W, Schelvis M, Rustemeijer I, Bierens JJ. Self-training in the use of automated external defibrillators: the same results for less money. Resuscitation. 2008;76:76–82. doi: 10.1016/j.resuscitation.2007.06.030.

124. Miotto HC, Camargos FR, Ribeiro CV, Goulart EM, Moreira Mda C. Effects of the use of theoretical versus theoretical-practical training on CPR. Arq Bras Cardiol. 2010;95:328–331.

125. Cheng A, Overly F, Kessler D, Nadkarni VM, Lin Y, Doan Q, Duff JP, Tofil NM, Bhanji F, Adler M, Charnovich A, Hunt EA, Brown LL; International Network for Simulation-based Pediatric Innovation, Research, Education (INSPIRE) CPR Investigators. Perception of CPR quality: influence of CPR feedback, just-in-time CPR training and provider role. Resuscitation. 2015;87:44–50. doi: 10.1016/j.resuscitation.2014.11.015.

126. Lynch B, Einspruch EL, Nichol G, Aufderheide TP. Assessment of BLS skills: optimizing use of instructor and manikin measures. Resuscitation. 2008;76:233–243. doi: 10.1016/j.resuscitation.2007.07.018.

127. Yeung J, Davies R, Gao F, Perkins GD. A randomised control trial of prompt and feedback devices and their impact on quality of chest com- pressions–a simulation study. Resuscitation. 2014;85:553–559. doi: 10.1016/j.resuscitation.2014.01.015.

128. Fischer H, Gruber J, Neuhold S, Frantal S, Hochbrugger E, Herkner H, Schöchl H, Steinlechner B, Greif R. Effects and limitations of an AED with audiovisual feedback for cardiopulmonary resuscitation: a random- ized manikin study. Resuscitation. 2011;82:902–907. doi: 10.1016/j. resuscitation.2011.02.023.

129. Mpotos N, Yde L, Calle P, Deschepper E, Valcke M, Peersman W, Herregods L, Monsieurs K. Retraining basic life support skills using video, voice feedback or both: a randomised controlled trial. Resuscitation. 2013;84:72–77. doi: 10.1016/j.resuscitation.2012.08.320.

130. Noordergraaf GJ, Drinkwaard BW, van Berkom PF, van Hemert HP, Venema A, Scheffer GJ, Noordergraaf A. The quality of chest com- pressions by trained personnel: the effect of feedback, via the CPREzy, in a randomized controlled trial using a manikin model. Resuscitation. 2006;69:241–252. doi: 10.1016/j.resuscitation.2005.08.008.

131. Sutton RM, Niles D, Meaney PA, Aplenc R, French B, Abella BS, Lengetti EL, Berg RA, Helfaer MA, Nadkarni V. “Booster” training: evaluation of instructor-led bedside cardiopulmonary resuscitation skill training and automated corrective feedback to improve cardiopulmonary resuscitation compliance of Pediatric Basic Life Support providers during simulated cardiac arrest. Pediatr Crit Care Med. 2011;12:e116–e121. doi: 10.1097/ PCC.0b013e3181e91271.

132.

Wik L, Thowsen J, Steen PA. An automated voice advisory manikin system for training in basic life support without an instructor. A novel approach to CPR training. Resuscitation. 2001;50:167–172.

133. Spooner BB, Fallaha JF, Kocierz L, Smith CM, Smith SC, Perkins GD. An evaluation of objective feedback in basic life support (BLS) training. Resuscitation. 2007;73:417–424. doi: 10.1016/j.resuscitation.2006.10.017.

134. Beckers SK, Skorning MH, Fries M, Bickenbach J, Beuerlein S, Derwall M, Kuhlen R, Rossaint R. CPREzy improves performance of external chest compressions in simulated cardiac arrest. Resuscitation. 2007;72:100– 107. doi: 10.1016/j.resuscitation.2006.05.020.

135. Perkins GD, Augré C, Rogers H, Allan M, Thickett DR. CPREzy: an eval- uation during simulated cardiac arrest on a hospital bed. Resuscitation. 2005;64:103–108. doi: 10.1016/j.resuscitation.2004.08.011.

136. Mpotos N, Lemoyne S, Calle PA, Deschepper E, Valcke M, Monsieurs KG. Combining video instruction followed by voice feedback in a self- learning station for acquisition of Basic Life Support skills: a randomised non-inferiority trial. Resuscitation. 2011;82:896–901. doi: 10.1016/j. resuscitation.2011.02.024.

137. Oermann MH, Kardong-Edgren SE, Odom-Maryon T. Effects of monthly practice on nursing students' CPR psychomotor skill performance. Resuscitation. 2011;82:447–453. doi: 10.1016/j.resuscitation.2010.11.022.

138. Skorning M, Derwall M, Brokmann JC, Rörtgen D, Bergrath S, Pflipsen J, Beuerlein S, Rossaint R, Beckers SK. External chest compressions using a mechanical feedback device: cross-over simulation study. Anaesthesist. 2011;60:717–722. doi: 10.1007/s00101-011-1871-6.

139. Dine CJ, Gersh RE, Leary M, Riegel BJ, Bellini LM, Abella BS. Improving cardiopulmonary resuscitation quality and resuscitation training by combining audiovisual feedback and debriefing. Crit Care Med. 2008;36:2817–2822. doi: 10.1097/CCM.0b013e318186fe37.

140. Handley AJ, Handley SA. Improving CPR performance using an audible feedback system suitable for incorporation into an automated external defibrillator. Resuscitation. 2003;57:57–62.

141. Skorning M, Beckers SK, Brokmann JCh, Rörtgen D, Bergrath S, Veiser T, Heussen N, Rossaint R. New visual feedback device improves performance of chest compressions by professionals in simu- lated cardiac arrest. Resuscitation. 2010;81:53–58. doi: 10.1016/j. resuscitation.2009.10.005.

142. Elding C, Baskett P, Hughes A. The study of the effectiveness of chest compressions using the CPR-plus. Resuscitation. 1998;36:169–173.

143. Sutton RM, Donoghue A, Myklebust H, Srikantan S, Byrne A, Priest M, Zoltani Z, Helfaer MA, Nadkarni V. The voice advisory manikin (VAM): an innovative approach to pediatric lay provider basic life sup- port skill education. Resuscitation. 2007;75:161–168. doi: 10.1016/j. resuscitation.2007.02.007.

144. Isbye DL, Høiby P, Rasmussen MB, Sommer J, Lippert FK, Ringsted C, Rasmussen LS. Voice advisory manikin versus instructor facilitated train- ing in cardiopulmonary resuscitation. Resuscitation. 2008;79:73–81. doi: 10.1016/j.resuscitation.2008.06.012.

145. Oh JH, Lee SJ, Kim SE, Lee KJ, Choe JW, Kim CW. Effects of audio tone guidance on performance of CPR in simulated cardiac arrest with an advanced airway. Resuscitation. 2008;79:273–277. doi: 10.1016/j. resuscitation.2008.06.022.

146. Rawlins L, Woollard M, Williams J, Hallam P. Effect of listening to Nellie the Elephant during CPR training on performance of chest compressions by lay people: randomised crossover trial. BMJ. 2009;339:b4707.

147. Woollard M, Poposki J, McWhinnie B, Rawlins L, Munro G, O'Meara P. Achy breaky makey wakey heart? A randomised crossover trial of musical prompts. Emerg Med J. 2012;29:290–294. doi: 10.1136/ emermed-2011-200187.

148. O'Donnell J, Rodgers D, Lee W, Edelson D, Haag J, Hamilton M, Hoadley T, McCullough A, Meeks R. Structured and Supported Debriefing. Dallas, Tex: American Heart Association; 2009.

149. DeVita MA, Schaefer J, Lutz J, Wang H, Dongilli T. Improving medical emergency team (MET) performance using a novel curriculum and a computerized human patient simulator. Qual Saf Health Care. 2005;14:326–331.

150. Dine CJ, Gersh RE, Leary M, Riegel BJ, Bellini LM, Abella BS. Improving cardiopulmonary resuscitation quality and resuscitation training by combining audiovisual feedback and debriefing. Crit Care Med. 2008;36:2817–2822.

151. Savoldelli GL, Naik VN, Park J, Joo HS, Chow R, Hamstra SJ. Value of debriefing during simulated crisis management: oral versus video-assisted oral feedback. Anesthesiology. 2006;105:279–285.

152. Morgan PJ, Tarshis J, LeBlanc V, Cleave-Hogg D, DeSousa S, Haley MF, Herold-McIlroy J, Law JA. Efficacy of high-fidelity simulation debriefing on the performance of practicing anaesthetists in simulated scenarios. Br J Anaesth. 2009;103:531–537.

153. Falcone RA Jr., Daugherty M, Schweer L, Patterson M, Brown RL, Garcia VF. Multidisciplinary pediatric trauma team training using high-fidelity trauma simulation. J Pediatr Surg. 2008;43:1065–1071.

154. Wayne DB, Didwania A, Feinglass J, Fudala MJ, Barsuk JH, McGaghie WC. Simulation-based education improves quality of care during cardiac arrest team responses at an academic teaching hospital: a case-control study. Chest. 2008;133:56–61.

155. Soar J, Mancini ME, Bhanji F, Billi JE, Dennett J, Finn J, Ma MH, Perkins GD, Rodgers DL, Hazinski MF, Jacobs I, Morley PT; Education, Implementation, and Teams Chapter Collaborators. Part 12: education, implementation, and teams: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation. 2010;81 suppl 1:e288–e330. doi: 10.1016/j.resuscitation.2010.08.030.

156. Mancini ME, Soar J, Bhanji F, Billi JE, Dennett J, Finn J, Ma MH, Perkins GD, Rodgers DL, Hazinski MF, Jacobs I, Morley PT; Education, Implementation, and Teams Chapter Collaborators. Part 12: education, implementation, and teams: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2010;122(suppl 2):S539–S581. doi: 10.1161/ CIRCULATIONAHA.110.971143.

157. Woollard M, Whitfield R, Newcombe RG, Colquhoun M, Vetter N, Chamberlain D. Optimal refresher training intervals for AED and CPR skills: a randomised controlled trial. Resuscitation. 2006;71:237–247. doi: 10.1016/j.resuscitation.2006.04.005.

158. Frkovic V, Sustic A, Zeidler F, Protic A, Desa K. A brief reeducation in cardiopulmonary resuscitation after six months?the benefit from timely repetition. Signa Vitae. 2008;3:24–28.

159. Chamberlain D, Smith A, Woollard M, Colquhoun M, Handley AJ, Leaves S, Kern KB. Trials of teaching methods in basic life support (3): comparison of simulated CPR performance after first training and at 6 months, with a note on the value of re-training. Resuscitation. 2002;53:179–187.

160. Ahn JY, Cho GC, Shon YD, Park SM, Kang KH. Effect of a reminder video using a mobile phone on the retention of CPR and AED skills in lay responders. Resuscitation. 2011;82:1543–1547. doi: 10.1016/j. resuscitation.2011.08.029.

161. Perkins GD, Fullerton JN, Davis-Gomez N, Davies RP, Baldock C, Stevens H, Bullock I, Lockey AS. The effect of pre-course e-learning prior to advanced life support training: a randomised controlled trial. Resuscitation. 2010;81:877–881. doi: 10.1016/j.resuscitation.2010.03.019.

162. Andreatta P, Saxton E, Thompson M, Annich G. Simulation-based mock codes significantly correlate with improved pediatric patient cardiopul- monary arrest survival rates. Pediatr Crit Care Med. 2011;12:33–38. doi: 10.1097/PCC.0b013e3181e89270.

163. Neily J, Mills PD, Young-Xu Y, Carney BT, West P, Berger DH, Mazzia LM, Paull DE, Bagian JP. Association between implementa- tion of a medical team training program and surgical mortality. JAMA. 2010;304:1693–1700. doi: 10.1001/jama.2010.1506.

164. Mundell WC, Kennedy CC, Szostek JH, Cook DA. Simulation technology for resuscitation training: a systematic review and meta-analysis. Resuscitation. 2013;84:1174–1183. doi: 10.1016/j. resuscitation.2013.04.016.

165. Cheng A, Lang TR, Starr SR, Pusic M, Cook DA. Technology-enhanced simulation and pediatric education: a meta-analysis. Pediatrics. 2014;133:e1313–e1323. doi: 10.1542/peds.2013-2139.

166. Ilgen JS, Sherbino J, Cook DA. Technology-enhanced simulation in emergency medicine: a systematic review and meta-analysis. Acad Emerg Med. 2013;20:117–127. doi: 10.1111/acem.12076.

167. Lo BM, Devine AS, Evans DP, Byars DV, Lamm OY, Lee RJ, Lowe SM, Walker LL. Comparison of traditional versus high-fidelity simulation in the retention of ACLS knowledge. Resuscitation. 2011;82:1440–1443. doi: 10.1016/j.resuscitation.2011.06.017.

168. Cherry RA, Williams J, George J, Ali J. The effectiveness of a human patient simulator in the ATLS shock skills station. J Surg Res. 2007;139:229–235. doi: 10.1016/j.jss.2006.08.010.

169. Conlon LW, Rodgers DL, Shofer FS, Lipschik GY. Impact of levels of simulation fidelity on training of interns in ACLS. Hosp Pract (1995). 2014;42:135–141. doi: 10.3810/hp.2014.10.1150.

170. Coolen EH, Draaisma JM, Hogeveen M, Antonius TA, Lommen CM, Loeffen JL. Effectiveness of high fidelity video-assisted real-time simu- lation: a comparison of three training methods for acute pediatric emer- gencies. Int J Pediatr. 2012;2012:709569. doi: 10.1155/2012/709569.

171. Curran V, Fleet L, White S, Bessell C, Deshpandey A, Drover A, Hayward M, Valcour J. A randomized controlled study of manikin simulator fidel- ity on neonatal resuscitation program learning outcomes. Adv Health Sci Educ Theory Pract. 2015;20:205–218. doi: 10.1007/s10459-014-9522-8.

172. Donoghue AJ, Durbin DR, Nadel FM, Stryjewski GR, Kost SI, Nadkarni VM. Effect of high-fidelity simulation on Pediatric Advanced Life Support training in pediatric house staff: a randomized trial. Pediatr Emerg Care. 2009;25:139–144. doi: 10.1097/PEC.0b013e31819a7f90.

173. Finan E, Bismilla Z, Whyte HE, Leblanc V, McNamara PJ. High-fidelity simulator technology may not be superior to traditional low-fidelity equipment for neonatal resuscitation training. J Perinatol. 2012;32:287– 292. doi: 10.1038/jp.2011.96.

174. Hoadley TA. Learning advanced cardiac life support: a comparison study of the effects of low- and high-fidelity simulation. Nurs Educ Perspect. 2009;30:91–95.

175. Owen H, Mugford B, Follows V, Plummer JL. Comparison of three sim- ulation-based training methods for management of medical emergencies. Resuscitation. 2006;71:204–211. doi: 10.1016/j.resuscitation.2006.04.007.

176. Settles J, Jeffries PR, Smith TM, Meyers JS. Advanced cardiac life sup- port instruction: do we know tomorrow what we know today? J Contin Educ Nurs. 2011;42:271–279. doi: 10.3928/00220124-20110315-01.

177. Thomas EJ, Williams AL, Reichman EF, Lasky RE, Crandell S, Taggart WR. Team training in the neonatal resuscitation program for interns: teamwork and quality of resuscitations. Pediatrics. 2010;125:539–546. doi: 10.1542/peds.2009-1635.

178. Campbell DM, Barozzino T, Farrugia M, Sgro M. High-fidelity simula- tion in neonatal resuscitation. Paediatr Child Health. 2009;14:19–23.

179. King JM, Reising DL. Teaching advanced cardiac life support protocols: the effectiveness of static versus high-fidelity simulation. Nurse Educ. 2011;36:62–65. doi: 10.1097/NNE.0b013e31820b5012.

180. Kurosawa H, Ikeyama T, Achuff P, Perkel M, Watson C, Monachino A, Remy D, Deutsch E, Buchanan N, Anderson J, Berg RA, Nadkarni VM, Nishisaki A. A randomized, controlled trial of in situ pediatric advanced life support recertification ("pediatric advanced life support recon- structed") compared with standard pediatric advanced life support recer- tification for ICU frontline providers. Crit Care Med. 2014;42:610–618. doi: 10.1097/CCM.0000000000000024.

181. Patocka C, Khan F, Dubrovsky AS, Brody D, Bank I, Bhanji F. Pediatric resuscitation training-instruction all at once or spaced over time? Resuscitation. 2015;88:6–11. doi: 10.1016/j.resuscitation.2014.12.003.

182. Choa M, Park I, Chung HS, Yoo SK, Shim H, Kim S. The effectiveness of cardiopulmonary resuscitation instruction: animation versus dispatcher through a cellular phone. Resuscitation. 2008;77:87–94.

183. Choa M, Cho J, Choi YH, Kim S, Sung JM, Chung HS. Animation-assisted CPRII program as a reminder tool in achieving effective one-person-CPR performance. Resuscitation. 2009;80:680–684.

184. Ertl L, Christ F. Significant improvement of the quality of bystander first aid using an expert system with a mobile multimedia device. Resuscitation. 2007;74:286–295.

185. Ward P, Johnson LA, Mulligan NW, Ward MC, Jones DL. Improving cardiopulmonary resuscitation skills retention: effect of two checklists designed to prompt correct performance. Resuscitation. 1997;34:221–225.

186. Merchant RM, Abella BS, Abotsi EJ, Smith TM, Long JA, Trudeau ME, Leary M, Groeneveld PW, Becker LB, Asch DA. Cell telephone cardiopulmonary resuscitation: audio instructions when needed by lay rescuers: a randomized, controlled trial. Ann Emerg Med. 2010;55:538–543.e1.

187. Lerner C, Gaca AM, Frush DP, Hohenhaus S, Ancarana A, Seelinger TA, Frush K. Enhancing pediatric safety: assessing and improving resident competency in life-threatening events with a computer-based interactive resuscitation tool. Pediatr Radiol. 2009;39:703–709.

188. Schneider AJ, Murray WB, Mentzer SC, Miranda F, Vaduva S. "Helper": a critical events prompter for unexpected emergencies. J Clin Monit. 1995;11:358–364.

189. Zanner R, Wilhelm D, Feussner H, Schneider G. Evaluation of M-AID, a first aid application for mobile phones. Resuscitation. 2007;74:487–494.

190. Mills PD, DeRosier JM, Neily J, McKnight SD, Weeks WB, Bagian JP. A cognitive aid for cardiac arrest: you can't use it if you don't know about it. Jt Comm J Qual Saf. 2004;30:488–496.

191. Neily J, DeRosier JM, Mills PD, Bishop MJ, Weeks WB, Bagian JP. Awareness and use of a cognitive aid for anesthesiology. Jt Comm J Qual Patient Saf. 2007;33:502–511.

192. Blewer AL, Leary M, Esposito EC, Gonzalez M, Riegel B, Bobrow BJ, Abella BS. Continuous chest compression cardiopulmonary resuscita- tion training promotes rescuer self-confidence and increased secondary training: a hospital-based randomized controlled trial. Crit Care Med. 2012;40:787–792. doi: 10.1097/CCM.0b013e318236f2ca.

193. Lam KK, Lau FL, Chan WK, Wong WN. Effect of severe acute respi- ratory syndrome on bystander willingness to perform cardiopulmonary resuscitation (CPR)–is compression-only preferred to standard CPR? Prehosp Disaster Med. 2007;22:325–329.

194. Cho GC, Sohn YD, Kang KH, Lee WW, Lim KS, Kim W, Oh BJ, Choi DH, Yeom SR, Lim H. The effect of basic life support education on laypersons' willingness in performing bystander hands only cardiopul- monary resuscitation. Resuscitation. 2010;81:691–694. doi: 10.1016/j. resuscitation.2010.02.021.

195. Shibata K, Taniguchi T, Yoshida M, Yamamoto K. Obstacles to bystander cardiopulmonary resuscitation in Japan. Resuscitation. 2000;44:187–193.

196. Taniguchi T, Omi W, Inaba H. Attitudes toward the performance of bystander cardiopulmonary resuscitation in Japan. Resuscitation. 2007;75:82–87. doi: 10.1016/j.resuscitation.2007.02.019.

197. Bobrow BJ, Spaite DW, Berg RA, Stolz U, Sanders AB, Kern KB, Vadeboncoeur TF, Clark LL, Gallagher JV, Stapczynski JS, LoVecchio F, Mullins TJ, Humble WO, Ewy GA. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. JAMA. 2010;304:1447–1454. doi: 10.1001/jama.2010.1392.

198. Panchal AR, Bobrow BJ, Spaite DW, Berg RA, Stolz U, Vadeboncoeur TF, Sanders AB, Kern KB, Ewy GA. Chest compression-only cardio- pulmonary resuscitation performed by lay rescuers for adult out-of- hospital cardiac arrest due to non-cardiac aetiologies. Resuscitation. 2013;84:435–439. doi: 10.1016/j.resuscitation.2012.07.038.

199. Delasobera BE, Goodwin TL, Strehlow M, Gilbert G, D'Souza P, Alok A, Raje P, Mahadevan SV. Evaluating the efficacy of simulators and multimedia for refreshing ACLS skills in India. Resuscitation. 2010;81: 217–223. doi: 10.1016/j.resuscitation.2009.10.013.

200. Meaney PA, Sutton RM, Tsima B, Steenhoff AP, Shilkofski N, Boulet JR, Davis A, Kestler AM, Church KK, Niles DE, Irving SY, Mazhani L, Nadkarni VM. Training hospital providers in basic CPR skills in Botswana: acquisition, retention and impact of novel training techniques. Resuscitation. 2012;83:1484–1490. doi: 10.1016/j. resuscitation.2012.04.014.

201. Jain A, Agarwal R, Chawla D, Paul V, Deorari A. Tele-education vs classroom training of neonatal resuscitation: a randomized trial. J Perinatol. 2010;30:773–779. doi: 10.1038/jp.2010.42.

202. Jenko M, Frangez M, Manohin A. Four-stage teaching technique and chest compression performance of medical students compared to conventional technique. Croat Med J. 2012;53:486–495.

203. Li Q, Ma EL, Liu J, Fang LQ, Xia T. Pre-training evaluation and feed- back improve medical students' skills in basic life support. Med Teach. 2011;33:e549–e555. doi: 10.3109/0142159X.2011.600360.

204. Shavit I, Peled S, Steiner IP, Harley DD, Ross S, Tal-Or E, Lemire A. Comparison of outcomes of two skills-teaching methods on lay-res- cuers' acquisition of infant basic life support skills. Acad Emerg Med. 2010;17:979–986. doi: 10.1111/j.1553-2712.2010.00849.x.

205. Nilsson C, Sørensen BL, Sørensen JL. Comparing hands-on and video training for postpartum hemorrhage management. Acta Obstet Gynecol Scand. 2014;93:517–520. doi: 10.1111/aogs.12372.

206. Dracup K, Guzy PM, Taylor SE, Barry J. Cardiopulmonary resuscitation (CPR) training. Consequences for family members of high-risk cardiac patients. Arch Intern Med. 1986;146:1757–1761.

207. Dracup K, Moser DK, Doering LV, Guzy PM, Juarbe T. A controlled trial of cardiopulmonary resuscitation training for ethnically diverse par- ents of infants at high risk for cardiopulmonary arrest. Crit Care Med. 2000;28:3289–3295.

208. Moser DK, Dracup K, Doering LV. Effect of cardiopulmonary resuscita- tion training for parents of high-risk neonates on perceived anxiety, con- trol, and burden. Heart Lung. 1999;28:326–333. doi: 10.1053/hl.1999. v28.a101053.

209. Dracup K, Moser DK, Guzy PM, Taylor SE, Marsden C. Is cardiopul- monary resuscitation training deleterious for family members of cardiac patients? Am J Public Health. 1994;84:116–118.

210. Haugk M, Robak O, Sterz F, Uray T, Kliegel A, Losert H, Holzer M, Herkner H, Laggner AN, Domanovits H. High acceptance of a home AED programme by survivors of sudden cardiac arrest and their families. Resuscitation. 2006;70:263–274. doi: 10.1016/j. resuscitation.2006.03.010.

211. Komelasky AL. The effect of home nursing visits on parental anxiety and CPR knowledge retention of parents of apnea-monitored infants. J Pediatr Nurs. 1990;5:387–392.

212. Kliegel A, Scheinecker W, Sterz F, Eisenburger P, Holzer M, Laggner AN. The attitudes of cardiac arrest survivors and their family members towards CPR courses. Resuscitation. 2000;47:147–154.

213. Knight LJ, Wintch S, Nichols A, Arnolde V, Schroeder AR. Saving a life after discharge: CPR training for parents of high-risk children. J Healthc Qual. 2013;35:9–16; quiz 17. doi: 10.1111/j.1945-1474.2012.00221.x.

214. Schneider L, Sterz F, Haugk M, Eisenburger P, Scheinecker W, Kliegel A, Laggner AN. CPR courses and semi-automatic defibrillators–life sav- ing in cardiac arrest? Resuscitation. 2004;63:295–303. doi: 10.1016/j. resuscitation.2004.06.005.

215. Dracup K, Doering LV, Moser DK, Evangelista L. Retention and use of cardiopulmonary resuscitation skills in parents of infants at risk for cardiopulmonary arrest. Pediatr Nurs. 1998;24:219–225; quiz 226.

216. Brannon TS, White LA, Kilcrease JN, Richard LD, Spillers JG, Phelps CL. Use of instructional video to prepare parents for learn- ing infant cardiopulmonary resuscitation. Proc (Bayl Univ Med Cent). 2009;22:133–137.

217. Higgins SS, Hardy CE, Higashino SM. Should parents of children with congenital heart disease and life-threatening dysrhythmias be taught car- diopulmonary resuscitation? Pediatrics. 1989;84:1102–1104.

218. McLauchlan CA, Ward A, Murphy NM, Griffith MJ, Skinner DV, Camm AJ. Resuscitation training for cardiac patients and their relatives–its effect on anxiety. Resuscitation. 1992;24:7–11.

219. Pierick TA, Van Waning N, Patel SS, Atkins DL. Self-instructional CPR training for parents of high risk infants. Resuscitation. 2012;83:1140– 1144. doi: 10.1016/j.resuscitation.2012.02.007.

220. Sanna T, Fedele F, Genuini I, Puglisi A, Azzolini P, Altamura G, Lobianco F, Ruzzolini M, Perna F, Micò M, Roscio G, Mottironi P, Saraceni C, Pistolese M, Bellocci F. Home defibrillation: a feasibility study in myo- cardial infarction survivors at intermediate risk of sudden death. Am Heart J. 2006;152:685.e1–685.e7. doi: 10.1016/j.ahj.2006.07.008.

221. Ali J, Adam R, Stedman M, Howard M, Williams J. Cognitive and attitudinal impact of the Advanced Trauma Life Support program in a developing country. J Trauma. 1994;36:695–702.

222. Bergman S, Deckelbaum D, Lett R, Haas B, Demyttenaere S, Munthali V, Mbembati N, Museru L, Razek T. Assessing the impact of the trauma team training program in Tanzania. J Trauma. 2008;65:879–883.

223. Bhat BV, Biswal N, Bhatia BD, Nalini P. Undergraduate training in neonatal resuscitation: a modified approach. Indian J Matern Child Health. 1993;4:87–88.

224. Carlo WA, Wright LL, Chomba E, McClure EM, Carlo ME, Bann CM, Collins M, Harris H. Educational impact of the neonatal resuscitation program in low-risk delivery centers in a developing country. J Pediatr. 2009;154:504–508.e5.

225. Couper ID, Thurley JD, Hugo JF. The neonatal resuscitation training project in rural South Africa. Rural Remote Health. 2005;5:459.

226. Ergenekon E, Koc E, Atalay Y, Soysal S. Neonatal resuscitation course experience in Turkey. Resuscitation. 2000;45:225–227.

227. Husum H, Gilbert M, Wisborg T. Training pre-hospital trauma care in low-income countries: the “Village University” experience. Med Teach. 2003;25:142–148.

228. Jabir MM, Doglioni N, Fadhil T, Zanardo V, Trevisanuto D. Knowledge and practical performance gained by Iraqi residents after participation to a neonatal resuscitation program course. Acta Paediatr. 2009;98:1265–1268.

229. Kimura A, Okada K, Kobayashi K, Inaka A, Hagiwara Y, Sakamoto T, Sugimoto N, Nakamura M, Nakamura K, Horiuchi K, Hujii Y, Murota C, Emoto M. Introductory adult cardiac life support course for Vietnamese healthcare workers. Resuscitation. 2008;79:511–512.

230. McClure EM, Carlo WA, Wright LL, Chomba E, Uxa F, Lincetto O, Bann C. Evaluation of the educational impact of the WHO Essential Newborn Care course in Zambia. Acta Paediatr. 2007;96:1135–1138.

231. Trevisanuto D, Ibrahim SA, Doglioni N, Salvadori S, Ferrarese P, Zanardo V. Neonatal resuscitation courses for pediatric residents: comparison between Khartoum (Sudan) and Padova (Italy). Paediatr Anaesth. 2007;17:28–31.

232. Urbano J, Matamoros MM, Lopez-Herce J, Carrillo AP, Ordonez F, Moral R, Mencia S. A paediatric cardiopulmonary resuscitation training project in Honduras. Resuscitation. 2010;81:472–476.

233. Zaeem ul H, Qureshi F, Hafeez A, Zafar S, Mohamud BK, Southal DP. Evidence for improvement in the quality of care given during emergencies in pregnancy, infancy and childhood following training in life-saving skills: a postal survey. J Pak Med Assoc. 2009;59:22–26.

234. Ali J, Adam R, Butler AK, Chang H, Howard M, Gonsalves D, Pitt-Miller P, Stedman M, Winn J, Williams JI. Trauma outcome improves following the advanced trauma life support program in a developing country. J Trauma. 1993;34:890–898.

235. Ali J, Adam RU, Gana TJ, Williams JI. Trauma patient outcome after the Prehospital Trauma Life Support program. J Trauma. 1997;42:1018–1021.

236. Arreola-Risa C, Mock C, Herrera-Escamilla AJ, Contreras I, Vargas J. Cost-effectiveness and benefit of alternatives to improve training for prehospital trauma care in Mexico. Prehosp Disaster Med. 2004;19:318–325.

237. Husum H, Gilbert M, Wisborg T, Van Heng Y, Murad M. Rural prehospital trauma systems improve trauma outcome in low-income countries: a prospective study from North Iraq and Cambodia. J Trauma. 2003;54:1188–1196.

238. Chomba E, McClure EM, Wright LL, Carlo WA, Chakraborty H, Harris H. Effect of WHO newborn care training on neonatal mortality by education. Ambul Pediatr. 2008;8:300–304.

239. Zhu XY, Fang HQ, Zeng SP, Li YM, Lin HL, Shi SZ. The impact of the Neonatal Resuscitation Program Guidelines (NRPG) on the neonatal mortality in a hospital in Zhuhai, China. Singapore Med J. 1997;38:485–487.

240. Moretti MA, Cesar LA, Nusbacher A, Kern KB, Timerman S, Ramires JA. Advanced cardiac life support training improves long-term survival from in-hospital cardiac arrest. Resuscitation. 2007;72:458–465.

241. Carlo WA, Goudar SS, Jehan I, Chomba E, Tshefu A, Garces A, Parida S, Althabe F, McClure EM, Derman RJ, Goldenberg RL, Bose C, Krebs NF, Panigrahi P, Buekens P, Chakraborty H, Hartwell TD, Wright LL. Newborn-care training and perinatal mortality in developing countries. N Engl J Med. 2010;362:614–623.

242. Smith MK, Ross C. Teaching cardiopulmonary resuscitation in a developing country: using Nicaragua as a model. Crit Care Nurs Q. 1997;20:15–21.

243. Tennant C. Resuscitation training in Uganda. Emerg Nurse. 2000;8:10–14.

244. Young S, Hutchinson A, Nguyen VT, Le TH, Nguyen DV, Vo TK. Teaching paediatric resuscitation skills in a developing country: introduction of the Advanced Paediatric Life Support course into Vietnam. Emerg Med Australas. 2008;20:271–275.

245.

Zafar S, Hafeez A, Qureshi F, Arshad N, Southall D. Structured training in the management of emergencies in mothers, babies and children in a poorly resourced health system: logbooks to document skill use. Resuscitation. 2009;80:449–452.

Part 15: First Aid

2015 American Heart Association and American Red Cross Guidelines Update for First Aid

Eunice M. Singletary, Chair; Nathan P. Charlton; Jonathan L. Epstein; Jeffrey D. Ferguson; Jan L. Jensen; Andrew I. MacPherson; Jeffrey L. Pellegrino; William "Will" R. Smith; Janel M. Swain; Luis F. Lojero-Wheatley; David A. Zideman

Introduction

The International Liaison Committee on Resuscitation (ILCOR) First Aid Task Force was formed in 2013 to review and evaluate the scientific literature on first aid in preparation for development of international first aid guidelines, including the *2015 American Heart Association* (AHA) *and American Red Cross Guidelines Update for First Aid*. The 14 members of the task force represent 6 of the international member organizations of ILCOR. Before 2015, evidence evaluation for first aid was conducted by the International First Aid Science Advisory Board and the National First Aid Advisory Board. Although the group responsible for evidence evaluation has changed, the goals remain the same: to reduce morbidity and mortality due to emergency events by making recommendations based on an analysis of the scientific evidence.

A critical review of the scientific literature by appointed ILCOR First Aid Task Force members and evidence evaluators resulted in consensus on science statements with treatment recommendations for 22 selected questions addressing first aid interventions. These findings are presented in "Part 9: First Aid" of the *2015 ILCOR International Consensus on First Aid Science With Treatment Recommendations*,[1,2] and they include a list of identified knowledge gaps that may be filled through future research. The ILCOR treatment recommendations are intended for the international first aid community, with the understanding that local, state, or provincial regulatory requirements may limit the ability to implement recommended first aid interventions. The current AHA/American Red Cross First Aid guidelines are derived from this work. New topics found in the 2015 First Aid Guidelines Update include first aid education, recognition of stroke, recognition of concussion, treatment of mild symptomatic hypoglycemia, and management of open chest wounds. Other topics have been updated based on findings from the corresponding ILCOR reviews.

Background

The roots of first aid have been recorded throughout history, particularly as related to warfare or battlefield care. Images on classical Greek pottery from circa 500 BC depict bandaging of battle wounds.[3] A system of first aid existed in the Roman army, with *capsarii* responsible for first aid, including bandaging, and resembling modern day combat medics.[4] In the 1870s, Johannes Friedrich August von Esmarch, a Prussian military surgeon, was the first to use the term *Erste Hilfe* ("first aid") and taught soldiers to use a standard set of bandaging and splinting skills to care for their wounded comrades on the battlefield.[3] During that same decade, the English Priory of the Order of St John was changed from a religious and fraternal body to a charitable organization with the goal of alleviating human suffering. They later established Britain's first ambulance service and the wheeled transport litter (the St John Ambulance) followed by the St John Ambulance Association "to train men and women for the benefit of the sick and wounded."[5] In the United States, organized training in first aid started in 1903, when Clara Barton, president of the Red Cross, formed a committee to establish instruction in first aid among industrial workers, who were frequently subject to dangerous conditions, accidents, and deaths.[6]

The Evidence Evaluation Process

The recommendations in this 2015 Guidelines Update are based on an extensive evidence review process that was begun by ILCOR after the publication of the *2010 American Heart Association and American Red Cross International Consensus on First Aid Science With Treatment Recommendations*[7] and was completed in February 2015.[1,2]

In this in-depth evidence review process, ILCOR examined topics and then generated a prioritized list of questions for systematic review. Questions were first formulated in PICO (population, intervention, comparator, outcome) format,[8] search strategies and inclusion and exclusion criteria were defined, and then a search for relevant articles was performed. The evidence was evaluated by the ILCOR task forces by using the standardized methodological approach proposed by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group.[9]

The American Heart Association and the American Red Cross request that this document be cited as follows: Singletary EM, Charlton NP, Epstein JL, Ferguson JD, Jensen JL, MacPherson AI, Pellegrino JL, Smith WR, Swain JM, Lojero-Wheatley LF, Zideman DA. Part 15: first aid: 2015 American Heart Association and American Red Cross Guidelines Update for First Aid. *Circulation*. 2015;132(suppl 2):S574–S589.

(*Circulation*. 2015;132[suppl 2]:S574–S589. DOI: 10.1161/CIR.0000000000000269.)

***Circulation* is available at http://circ.ahajournals.org** **DOI: 10.1161/CIR.0000000000000269**

The quality of the evidence was categorized based on the study methodologies and the 5 core GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias). Where possible, consensus-based treatment recommendations were created.

To create this 2015 First Aid Guidelines Update, the AHA and the American Red Cross formed a joint writing group, with careful attention to avoiding conflicts of interest, to assessing the ILCOR treatment recommendations, and to writing AHA and American Red Cross treatment recommendations by using the AHA Class of Recommendation and Level of Evidence (LOE) system. The recommendations made in the 2015 Guidelines Update are informed by the ILCOR recommendations and GRADE classification, in the context of the delivery of medical care in North America. Throughout the online version of this document, live links are provided so the reader can connect directly to the systematic review on the ILCOR website, the Scientific Evidence Evaluation and Review System (SEERS) site. These links are indicated by a superscript combination of letters and numbers (eg, FA 517). We encourage readers to review the evidence and appendixes, such as the GRADE tables. For further information, please see "Part 2: Evidence Evaluation and Management of Conflicts of Interest."

A paucity of research in the field of first aid is present, although certain topics have received recent attention (eg, tourniquets for traumatic amputations, hemostatic dressings, identification of stroke symptoms). Without research into first aid interventions, all recommendations must be derived indirectly from hospital-based, animal, or, at best, emergency medical services (EMS) studies.

Definition of First Aid

We define *first aid* as helping behaviors and initial care provided for an acute illness or injury. The goals of a first aid provider include preserving life, alleviating suffering, preventing further illness or injury, and promoting recovery. First aid can be initiated by anyone in any situation and includes self-care. First aid assessments and interventions should be medically sound and based on scientific evidence or, in the absence of such evidence, on expert consensus. First aid competencies include, at any level of training,

- Recognizing, assessing, and prioritizing the need for first aid
- Providing care by using appropriate knowledge, skills, and behaviors
- Recognizing limitations and seeking additional care when needed

The scope of first aid is not purely scientific; it is influenced by both training and regulatory constraints. The definition of scope is therefore variable and should be defined according to circumstances, need, and regulatory requirements.

First Aid Education[FA 773]—New

First aid education can be accomplished through a variety of means, including online courses, classes, and public health campaigns. First aid education can increase survival rates, reduce injury severity, and resolve symptoms over a spectrum of approaches, including public health campaigns,[10,11] focused health topics, or courses that result in certification.[12] Education and training in first aid can be useful to improve morbidity and mortality from injury and illness (Class IIa, LOE C-LD). We recommend that first aid education be universally available (Class I, LOE C-EO).

Calling for Help

The goal of first aid intervention is to recognize when help is needed and how to get it. This goal includes learning how and when to access the EMS system (9-1-1), how to activate the on-site emergency response plan, and how to contact the Poison Control Center (1-800-222-1222).

Providing care for someone who is ill or injured should not usually delay calling for more advanced care if needed. However, if the first aid provider is alone with an injured or ill person and there are imminent threats to life involving the ABCs (airway, breathing, circulation), then basic care—such as opening an airway or applying pressure to the site of severe bleeding—should be provided before leaving the victim to activate the emergency response system or phone for help (EMS or 9-1-1).

Positioning the Ill or Injured Person[FA 517]—Updated

Generally, an ill or injured person should not need to be moved. This is especially important if you suspect, from the person's position or the nature of the injury, that the person may have a pelvic or spine injury. There are times, however, when the person should be moved:

- If the area is unsafe for the first aid provider or the person, move to a safe location if possible (Class I, LOE C-EO).
- If a person is unresponsive and breathing normally, it may be reasonable to place him or her in a lateral side-lying recovery position (Class IIb, LOE C-LD). There is evidence that this position will help increase total airway volume[13] and decrease stridor severity.[14] Extend one of the person's arms above the head and roll the body to the side so that the person's head rests on the extended arm. Once the person is on his or her side, bend both legs to stabilize the body. There is little evidence to suggest an alternative optimal recovery position.[1] If a person is unresponsive and not breathing normally, proceed with basic life support guidelines (see "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality").
- If a person has been injured and the nature of the injury suggests a neck, back, hip, or pelvic injury, the person should not be rolled onto his or her side and instead should be left in the position in which they were found, to avoid potential further injury (Class I, LOE C-EO). If leaving the person in the position found is causing the person's airway to be blocked, or if the area is unsafe, move the person only as needed to open the airway and to reach a safe location (Class I, LOE C-EO).

Position for Shock[FA 520]—Updated

The ILCOR 2015 International Consensus on CPR and ECC Science With Treatment Recommendations (C2015) reviewed the published evidence in support of various body positions that might be used by a first aid provider for a person in shock. Studies included normotensive volunteers; healthy individuals who underwent phlebotomy; and patients with septic, cardiogenic, or hypovolemic shock. Study results were sometimes conflicting.[15–20] One observational study found a lower cardiac index and higher heart rate for individuals following phlebotomy when placed in a standing position compared with the supine position.[20] Other studies found that the addition of passive leg raising alone compared to the supine position in hypotensive patients resulted in an improvement in various vital signs and indicators of cardiac output, but this effect was temporary, lasting no more than 7 minutes.[16,17,20] There were no reported adverse effects due to raising the feet.

If a person shows evidence of shock and is responsive and breathing normally, it is reasonable to place or maintain the person in a supine position (Class IIa, LOE C-LD). If there is no evidence of trauma or injury (eg, simple fainting, shock from nontraumatic bleeding, sepsis, dehydration), raising the feet about 6 to 12 inches (about 30° to 60°) from the supine position is an option that may be considered while awaiting arrival of EMS (Class IIb, LOE C-LD). Do not raise the feet of a person in shock if the movement or the position causes pain (Class III: Harm, LOE C-EO).

Oxygen Use in First Aid[FA 519]—Updated

Despite the common use of supplementary oxygen in various medical conditions, there is little evidence to support its use in the first aid setting. Administration of oxygen is not considered a standard first aid skill. However, oxygen may be available in some first aid environments and requires specific training in its use.

The 2015 ILCOR evidence review of oxygen in the first aid setting sought to determine the impact of oxygen supplementation, as compared with no oxygen supplementation, on outcomes of patients with shortness of breath, difficulty breathing, or hypoxia. The review attempted to identify specific medical conditions, other than chest pain, that may benefit from supplementary oxygen administration by first aid providers. Supplementary oxygen for adults with chest pain, during CPR and after return of spontaneous circulation, is addressed in "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality," "Part 7: Adult Advanced Cardiovascular Life Support," "Part 8: Post–Cardiac Arrest Care," and "Part 9: Acute Coronary Syndromes." No evidence was found in the C2015 review for or against the routine administration of supplementary oxygen by first aid providers.[1]

Evidence was identified showing a beneficial effect with the use of supplementary oxygen for the relief of decompression sickness.[21] The use of supplementary oxygen by first aid providers with specific training is reasonable for cases of decompression sickness (Class IIa, LOE C-LD).

Patients with advanced cancer may use oxygen at home. One meta-analysis[22] found that the use of oxygen for patients with advanced cancer who had normoxia and dyspnea was not of benefit in relieving dyspnea. Two small, randomized controlled trials demonstrated relief of dyspnea in patients with advanced cancer who had hypoxemia and dyspnea.[23,24] For first aid providers with specific training in the use of oxygen, the administration of supplementary oxygen to persons with known advanced cancer with dyspnea *and* hypoxemia may be reasonable (Class IIb, LOE B-R).

Although no evidence was identified to support the use of oxygen, it might be reasonable to provide oxygen to spontaneously breathing persons who are exposed to carbon monoxide while waiting for advanced medical care (Class IIb, LOE C-EO).

Oxygen delivery mechanisms and amounts will vary with the individual's underlying health problems. Specialized courses are available for persons who may potentially need to use oxygen in the settings described above.

Medical Emergencies

Bronchodilators for Asthma With Shortness of Breath[FA 534]

There are many causes of shortness of breath. Some people carry inhaled medications to relieve certain causes of shortness of breath and wheezing, such as bronchitis, asthma, reactive airway disease or chronic obstructive pulmonary disease. The incidence of severe asthma and deaths from asthma are increasing.[25] First aid providers will likely encounter persons with a previous diagnosis of asthma and prescribed inhaled medication who have acute difficulty breathing and/or wheezing.

Inhaled bronchodilators have been shown to be effective in patients with asthma and acute shortness of breath.[26–36] Evidence from included studies was extrapolated from the prehospital and emergency department settings.

The incidence of adverse events related to the use of inhaled bronchodilators is low: multiple studies show that treatment with albuterol/salbutamol causes no significant change in heart rate,[26,31–33] blood pressure,[33] serum potassium, tremor, headache, nervousness, weakness, palpitation, or dry mouth.[26] However, a single study showed a statistically significant difference in heart rate with different treatment regimens of salbutamol/albuterol.[26]

It is reasonable for first aid providers to be familiar with the available inhaled bronchodilator devices and to assist as needed with the administration of prescribed bronchodilators when a person with asthma is having difficulty breathing (Class IIa, LOE B-R).

Stroke Recognition[FA 801]—New

Worldwide, 15 million individuals are estimated to have a stroke each year. Some areas have achieved great success in decreasing the incidence and long-term effects of stroke through prevention, recognition, treatment, and rehabilitation programs. Early stroke recognition through the use of stroke-assessment systems decreases the interval between the time of stroke onset and arrival at the hospital and definitive treatment.[37–42] This is associated with better outcomes, such as improved neurologic function. From a first aid education

perspective, it has been shown that 94.4% of lay providers trained in a stroke-assessment system are able to recognize signs and symptoms of a stroke, compared with 76.4% of those without training. The ability to recognize stroke with a stroke-assessment system persists at 3 months after training.[43]

The Face, Arm, Speech, Time (FAST) and Cincinnati Prehospital Stroke Scale (CPSS) stroke assessment systems are the simplest of these tools, with high sensitivity for the identification of stroke.[1] If glucose measurement is available to the first aid provider, stroke assessment systems such as the Los Angeles Prehospital Stroke Screen (LAPSS), Ontario Prehospital Stroke Scale (OPSS), Recognition of Stroke in the Emergency Room (ROSIER), and Kurashiki Prehospital Stroke Scale (KPSS) show increased specificity.[1,37–42,44–60]

The use of a stroke assessment system by first aid providers is recommended (Class I, LOE B-NR).

Chest Pain[FA 871, FA 586]

Chest pain is a common health problem with a myriad of causes, ranging from minor chest wall strains to pneumonia, angina, or myocardial infarction. It can be very difficult to differentiate chest pain of cardiac origin, such as a heart attack or myocardial infarction, from other origins. Common signs and symptoms associated with chest pain or discomfort of cardiac origin include shortness of breath, nausea, sweating, or pain in the arm(s) or back.

Aspirin has been found to significantly decrease mortality due to myocardial infarction in several large studies[61–63] and is therefore recommended for persons with chest pain due to suspected myocardial infarction (Class I, LOE B-R). There was no evidence of allergic reactions in 1 small study,[64] but there was an increased risk of bleeding among recipients of aspirin in 1 large study.[61]

The 2015 ILCOR systematic review for the use of aspirin in chest pain did not find any evidence to support the use of aspirin for undifferentiated chest pain.[1] When early aspirin administration (ie, in the first few hours after onset of symptoms) is compared with late aspirin administration (eg, after hospital arrival) for chest pain due to myocardial infarction, a reduction of mortality is found.[61,65,66]

Call EMS immediately for anyone with chest pain or other signs of heart attack, rather than trying to transport the person to a healthcare facility yourself (Class I, LOE C-EO).

While waiting for EMS to arrive, the first aid provider may encourage a person with chest pain to take aspirin if the signs and symptoms suggest that the person is having a heart attack and the person has no allergy or contraindication to aspirin, such as recent bleeding (Class IIa, LOE B-NR). The suggested dose of aspirin is 1 adult 325-mg tablet, or 2 to 4 low-dose "baby" aspirins (81 mg each), chewed and swallowed. If a person has chest pain that does not suggest that the cause is cardiac in origin, or if the first aid provider is uncertain or uncomfortable with administration of aspirin, then the first aid provider should not encourage the person to take aspirin (Class III: Harm, LOE C-EO). The decision to administer aspirin in these cases may be deferred to an EMS provider with physician oversight.

Anaphylaxis[FA 500]—Updated

Allergic reactions do not require epinephrine, but a small portion of reactions can progress to anaphylaxis. Epinephrine is recommended for anaphylaxis, and persons at risk are typically prescribed and carry an epinephrine autoinjector. An anaphylactic reaction involves 2 or more body systems and can be life-threatening. Symptoms may include respiratory difficulty (such as wheezing), cutaneous manifestations (such as hives or swelling of the lips and eyes), cardiovascular effects (such as hypotension, cardiovascular collapse, or shock), or gastrointestinal cramping and diarrhea. This update does not change the 2010 Guidelines recommendation that first aid providers assist with or administer to persons with symptoms of anaphylaxis their own epinephrine when they are having a reaction.[6] The recommended dose of epinephrine is 0.3 mg intramuscularly for adults and children greater than 30 kg, 0.15 mg intramuscularly for children 15 to 30 kg, or as prescribed by the person's physician. First aid providers should call 9-1-1 immediately when caring for a person with suspected anaphylaxis or a severe allergic reaction (Class I, LOE C-EO).

A second dose of epinephrine has been found to be beneficial for persons not responding to a first dose.[67–75] When a person with anaphylaxis does not respond to the initial dose, and arrival of advanced care will exceed 5 to 10 minutes, a repeat dose may be considered (Class IIb, LOE C-LD).

Hypoglycemia[FA 795]—New

Hypoglycemia can manifest as a variety of symptoms, including confusion, altered behavior, diaphoresis, or tremulousness. Diabetics who display these symptoms should be assumed by the first aid provider to have hypoglycemia. If the person is unconscious, exhibits seizures, or is unable to follow simple commands or swallow safely, the first aid provider should call for EMS immediately (Class I, LOE C-EO).

Evidence from the 2015 ILCOR systematic review demonstrates more rapid clinical relief of symptomatic hypoglycemia with glucose tablets compared with various evaluated dietary sugars, such as sucrose- or fructose-containing candies or foods, orange juice, or milk (Table 1).[76–78] If a person with diabetes reports low blood sugar or exhibits signs or symptoms of mild hypoglycemia and is able to follow simple commands and swallow, oral glucose should be given to attempt to resolve the hypoglycemia. Glucose tablets, if available, should be used to reverse hypoglycemia in a person who is able to take these orally (Class I, LOE B-R).

If glucose tablets are not available, other forms of dietary sugars, as depicted in Table 1, have been found to be effective as a substitute for glucose tablets to reverse hypoglycemia.[76–79] It is reasonable to use these dietary sugars as an alternative to glucose tablets (when not available) for reversal of mild symptomatic hypoglycemia (Class IIa, LOE B-R).

For diabetics with symptoms of hypoglycemia, symptoms may not resolve until 10 to 15 minutes after ingesting glucose tablets or dietary sugars (Table 1).[76–79] First aid providers should therefore wait at least 10 to 15 minutes before calling EMS and re-treating a diabetic with mild symptomatic hypoglycemia with additional oral sugars (Class I, LOE

Table 1. Types of Food Representing 20 g of Carbohydrates and Number of People With Improvement in Hypoglycemia Within 15 Minutes (Based on Included Evidence)[1]

Type of Food or Fluid	Carbohydrates/Serving	Measure Representing 20 g Carbohydrates*	Clinical Relief 15 min or Less After Ingestion
Glucose tablets	Varies	Varies	194/223 (87.0%)
Glucose 71%/oligosaccharides 29% candy (Mentos)	2.8 g/mint	5–10 mints	44/48 (91.7%)
Sucrose candy (Skittles)	0.9 g/candy	20–25 candies	150/177 (84.7%)
Jelly beans	1.1 g/jelly bean	15–20 jelly beans	33/45 (73.3%)
Orange juice (unsweetened, from concentrate)	1 g/10 mL	200 mL	35/50 (70.0%)
Fructose (fruit leather, such as Stretch Island)	10 g/strip	2 strips	111/165 (67.3%)
Whole milk	21.75 g/mL	435 mL	Not reported

*These measurements may differ from those in the evaluated studies, as the amount was not standardized across studies.

B-R). If the person's status deteriorates during that time or does not improve, the first aid provider should call EMS (Class I, LOE C-EO).

Exertional Dehydration[FA 584]—Updated

First aid providers are often called upon to assist at "hydration stations" at sporting events. Vigorous exercise, particularly in hot and humid environments, can lead to significant dehydration with loss of water and electrolytes through sweat.

Evidence from the 2015 ILCOR systematic review shows that ingestion of 5% to 8% carbohydrate-electrolyte (CE) solutions facilitates rehydration after exercise-induced dehydration and is generally well tolerated.[80,81] Studies in this review looked at the specific percentage CE solutions described and did not evaluate oral rehydration therapy or salts that are sometimes used for diarrheal illness. In the absence of shock, confusion, or inability to swallow, it is reasonable for first aid providers to assist or encourage individuals with exertional dehydration to orally rehydrate with CE drinks (Class IIa, LOE B-R). For individuals with severe dehydration with shock, confusion or symptoms of heat stroke, or symptoms of heat exhaustion or cramps, refer to the 2010 First Aid Guidelines.[6] Lemon tea-based CE drinks and Chinese tea with caffeine have been found to be similar to water for rehydration.[82] Other beverages, such as coconut water and 2% milk, have also been found to promote rehydration after exercise-associated dehydration, but they may not be as readily available.[80,82,83] If these alternative beverages are not available, potable water may be used (Class IIb, LOE B-R).

Toxic Eye Injury[FA 540]

Chemical injury to the eye occurs most commonly from chemicals in powder and liquid form. Evidence limited to a single study of eye exposure to an alkali showed improvement in ocular pH following irrigation with tap water compared with normal saline. In this study, irrigation with 1.5 L of solution occurred over 15 minutes.[84] It can be beneficial to rinse eyes exposed to toxic chemicals immediately and with a copious amount of tap water for at least 15 minutes or until advanced medical care arrives (Class IIa, LOE C-LD). If tap water is not available, normal saline or another commercially available eye irrigation solution may be reasonable (Class IIb, LOE C-LD). First aid providers caring for individuals with chemical eye injury should contact their local poison control center or, if a poison control center is not available, seek help from a medical provider or 9-1-1 (Class I, LOE C-EO).

Trauma Emergencies

Bleeding[FA 530]

Control of bleeding is an important first aid skill. Standard first aid bleeding control includes applying direct pressure with or without gauze. The 2015 ILCOR systematic review evaluated the use of pressure points, elevation, local application of ice, tourniquets, and hemostatic dressings for the control of bleeding compared with direct pressure.

Direct Pressure, Pressure Points, and Elevation

There continues to be no evidence to support the use of pressure points or elevation of an injury to control external bleeding. The use of pressure points or elevation of an extremity to control external bleeding is not indicated (Class III: No Benefit, LOE C-EO). The standard method for first aid providers to control open bleeding is to apply direct pressure to the bleeding site until it stops. Control open bleeding by applying direct pressure to the bleeding site (Class I, LOE B-NR).

Localized Cold Therapy

There are limited data from the hospital setting demonstrating a benefit from application of localized cold therapy compared to direct pressure alone to closed bleeding, such as a bruise or hematoma.[85,86] Local cold therapy, such as an instant cold pack, can be useful for these types of injuries to the extremity or scalp (Class IIa, LOE C-LD). Cold therapy should be used with caution in children because of the risk of hypothermia in this population (Class I, LOE C-EO).

Tourniquets[FA 768]

Tourniquets can be effective for severe external limb bleeding. The use of tourniquets in the prehospital setting for severe external limb bleeding has been studied in the military setting[87–94] and civilian EMS setting.[95,96] The effectiveness and complications of different types of tourniquets, such as military tourniquets compared with commercial or improvised tourniquets, was not reviewed for 2015. However, tourniquets have been found to control bleeding effectively in most cases.[87,89,93,95] Potential complications include compartment syndrome,[88] nerve damage,[88,90,93,95] damage to blood vessels,[95]

and amputation or limb shortening.[87,88,90,93] Complications may be related to tourniquet pressure and duration of occlusion, but there is insufficient evidence to determine a minimal critical time beyond which irreversible complications may occur. Because the rate of complications is low and the rate of hemostasis is high, first aid providers may consider the use of a tourniquet when standard first aid hemorrhage control does not control severe external limb bleeding (Class IIb, LOE C-LD).

A tourniquet may be considered for initial care when a first aid provider is unable to use standard first aid hemorrhage control, such as during a mass casualty incident, with a person who has multisystem trauma, in an unsafe environment, or with a wound that cannot be accessed (Class IIb, LOE C-EO). Although maximum time for tourniquet use was not reviewed by a 2015 ILCOR systematic review, it has been recommended that the first aid provider note the time that a tourniquet is first applied and communicate this information with EMS providers.[6] It is reasonable for first aid providers to be trained in the proper application of tourniquets, both manufactured and improvised (Class IIa, LOE C-EO).

Hemostatic Dressings[FA 769]—Updated

Hemostatic dressings are becoming more commonly used to control bleeding, especially in the military setting.[97–99] Early-generation powder or granular hemostatic agents were poured directly into the wound and were associated with exothermic reactions that could worsen tissue injury. Because of the potential for adverse effects and the variability of effectiveness of early hemostatic agents and dressings, routine use has not previously been advised. Newer-generation hemostatic agent–impregnated dressings are safer and effective in providing hemostasis in up to 90% of participants in case series.[97–100] Both complications and adverse effects are now uncommon but may include wound infection and exothermic burns.[97] Use of newer-generation hemostatic dressings is increasing in the civilian setting.[100]

Hemostatic dressings may be considered by first aid providers when standard bleeding control (direct pressure with or without gauze or cloth dressing) is not effective for severe or life-threatening bleeding (Class IIb, LOE C-LD). Hemostatic dressings are likely of greatest use for severe external bleeding in locations where standard hemorrhage control is not effective, when a tourniquet cannot be applied (trunk or junctional areas such as the abdomen or axilla/groin), when a tourniquet is not available, or when a tourniquet is not effective to stop bleeding. Proper application of hemostatic dressings requires training (Class I, LOE C-EO).

Open Chest Wounds[FA 525]—New

Management of an open chest wound in out-of-hospital settings is challenging and requires immediate activation of EMS. The greatest concern is the improper use of a dressing or device that could lead to fatal tension pneumothorax. There are no human studies comparing the application of an occlusive device versus a nonocclusive device.[1] We recommend against the application of an occlusive dressing or device by first aid providers for individuals with an open chest wound (Class III: Harm, LOE C-EO). In the first aid situation, it is reasonable to leave an open chest wound exposed to ambient air without a dressing or seal (Class IIa, LOE C-EO). If a nonocclusive dressing, such as a dry gauze dressing, is applied for active bleeding, care must be taken to ensure that saturation of the dressing does not lead to partial or complete occlusion.

Concussion[FA 799]—New

The signs and symptoms of concussion (mild traumatic brain injury) are complex. The classic signs of concussion after head trauma include feeling stunned or dazed, or experiencing headache, nausea, dizziness and unsteadiness (difficulty in balance), visual disturbance, confusion, or loss of memory (from either before or after the injury).[101] The various grades and combinations of these symptoms make the recognition of concussion difficult.[102] Furthermore, changes may be subtle and yet progressive.

First aid providers are often faced with the decision as to what advice to give to a person after minor head trauma, and it is now widely recognized that an incorrect decision can have long-term serious or even fatal consequences.[103]

There are no clinical studies to support the use of a simple concussion scoring system by first aid providers. Any person with a head injury that has resulted in a change in level of consciousness, has progressive development of signs or symptoms as described above, or is otherwise a cause for concern should be evaluated by a healthcare provider or EMS personnel as soon as possible (Class I, LOE C-EO). Using any mechanical machinery, driving, cycling, or continuing to participate in sports after a head injury should be deferred by these individuals until they are assessed by a healthcare provider and cleared to participate in those activities (Class I, LOE C-EO).

Spinal Motion Restriction[FA 772]

The terms *spinal immobilization* and *spinal motion restriction* have been used synonymously in the past. Because true spinal immobilization is not possible, the term *spinal motion restriction* is now being used to describe the practice of attempting to maintain the spine in anatomical alignment and minimize gross movement, with or without the use of specific adjuncts such as collars.

In the 2010 review, no published studies were identified to support or refute the benefit of spinal immobilization and/or the method by which to apply spinal motion restriction (SMR) by first aid providers.[7] For the 2015 ILCOR systematic review, cervical SMR in injured persons without penetrating trauma, as a component of total SMR, was the specific focus for evidence review. Thus, the evidence evaluation was limited to the use of cervical collars. Potential adverse effects from the use of a cervical collar include increased intracranial pressure[104–109] and potential airway compromise.[110] Once again, no studies were found that demonstrated a decrease in neurologic injury with the use of a cervical collar.[111]

While complete SMR may be indicated for individuals who have blunt mechanism of injury and who meet high-risk criteria as recommended in the 2010 Guidelines,[6] the proper technique for SMR requires extensive training and practice to be performed properly and is thus not considered a skill for first aid providers.

With a growing body of evidence showing more actual harm and no good evidence showing clear benefit, we

recommend against routine application of cervical collars by first aid providers (Class III: Harm, LOE C-LD). If a first aid provider suspects a spinal injury, he or she should have the person remain as still as possible and await the arrival of EMS providers (Class I, LOE C-EO).

Musculoskeletal Trauma

Suspected Long Bone Fractures[FA 503]

Long bone fractures may at times be severely angulated. The 2015 ILCOR systematic review attempted to compare straightening of angulated long bone fractures before splinting with splinting in the position found. No studies were identified that evaluate straightening of angulated long bone fractures before splinting. Thus, there is no evidence in the first aid setting for or against the straightening or gentle realignment of a suspected angulated long bone fracture before splinting, including in the presence of neurovascular compromise, for outcomes of incidence of neurologic or vascular injury, ability to splint, pain experienced, or time to medical transportation.[1]

In general, first aid providers should not move or try to straighten an injured extremity (Class III: Harm, LOE C-EO). Based on training and circumstance (such as remote distance from EMS or wilderness settings, presence of vascular compromise), some first aid providers may need to move an injured limb or person. In such situations, providers should protect the injured person, including splinting in a way that limits pain, reduces the chance for further injury, and facilitates safe and prompt transport (Class I, LOE C-EO).

If an injured extremity is blue or extremely pale, activate EMS immediately (Class I, LOE C-EO).

Burns

Thermal Burns: Cooling[FA 770]

Burns can come from a variety of sources such as hot water (scalds) and fire. It is known that applying ice directly to a burn can cause tissue ischemia.[6,7] The 2015 ILCOR systematic review of the evidence for cooling of burns evaluated agents that were cool or cold, but not frozen. Cooling was found to reduce risk of injury and depth of injury.[11,112,113] Cool thermal burns with cool or cold potable water as soon as possible and for at least 10 minutes (Class I, LOE B-NR). If cool or cold water is not available, a clean cool or cold, but not freezing, compress can be useful as a substitute for cooling thermal burns (Class IIa, LOE B-NR). Care should be taken to monitor for hypothermia when cooling large burns (Class I, LOE C-EO). This is particularly important in children, who have a larger body surface area for their weight than adults have.

Burn Dressings[FA 771]

It is common for first aid providers to cover a burn with a dressing after it has been cooled; however, based on limited data, there is no evidence that a wet dressing compared with a dry dressing is beneficial for care of a burn.[1] One study showed no benefit for a topical penetrating antibacterial versus petrolatum gauze or for a topical nonpenetrating antibacterial versus dry dressing.[114] After cooling of a burn, it may be reasonable to loosely cover the burn with a sterile, dry dressing (Class IIb, LOE C-LD).

Honey, when used as a dressing, has been shown in 2 randomized controlled trials to decrease the risk of infection and mean duration of time to healing when compared with an antibiotic–impregnated gauze dressings.[115,116] Both of these studies were downgraded for risk of bias, imprecision, and indirectness. In general, it may be reasonable to avoid natural remedies, such as honey or potato peel dressings (Class IIb, LOE C-LD). However, in remote or wilderness settings where commercially made topical antibiotics are not available, it may be reasonable to consider applying honey topically as an antimicrobial agent (Class IIb, LOE C-LD).

Burns: When Advanced Care Is Needed

Burns associated with or involving (1) blistering or broken skin; (2) difficulty breathing; (3) the face, neck, hands, or genitals; (4) a larger surface area, such as trunk or extremities; or (5) other cause for concern should be evaluated by a healthcare provider (Class I, LOE C-EO).

Dental Avulsion[FA 794] —Updated

Dental avulsion injury can damage both the tooth and the supporting soft tissue and bone, resulting in permanent loss of the tooth. Immediate reimplantation of an avulsed tooth is believed by the dental community to result in the greatest chance of tooth survival.[117] In situations that do not allow for immediate reimplantation, it can be beneficial to temporarily store an avulsed tooth in a variety of solutions shown to prolong viability of dental cells (Class IIa, LOE C-LD). The following solutions have demonstrated efficacy at prolonging dental cell viability from 30 to 120 minutes, and they may be available to first aid providers (listed in order of preference based on the C2015 evidence review): Hank's Balanced Salt Solution (containing calcium, potassium chloride and phosphate, magnesium chloride and sulfate, sodium chloride, sodium bicarbonate, sodium phosphate dibasic and glucose), propolis, egg white, coconut water, Ricetral, or whole milk.[118–128]

If none of these solutions are available, it may be reasonable to store an avulsed tooth in the injured persons saliva (not in the mouth) pending reimplantation (Class IIb, LOE C-LD). Viability of an avulsed tooth stored in any of the above solutions is limited. Reimplantation of the tooth within an hour after avulsion affords the greatest chance for tooth survival. Following dental avulsion, it is essential to seek rapid assistance with reimplantation (Class I, LOE C-EO).

Disclosures

Part 15: First Aid: 2015 Guidelines Update Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Eunice M. Singletary	University of Virginia; University Physicians Group	None	None	None	None	None	None	None
Nathan P. Charlton	University of Virginia	None	None	None	None	None	None	None
Jonathan L. Epstein	American Red Cross	None	None	None	None	None	None	None
Jeffrey D. Ferguson	Virginia Commonwealth University	None	None	None	None	None	None	None
Jan L. Jenson	Emergency Health Services, Dalhousie University	None	Nova Scotia Health Research Foundation*; Canadian Institutes of Health Research*	None	None	None	None	None
Luis F. Lojero-Wheatley	Swiss Hospital	None	None	None	None	None	None	None
Andrew I. MacPherson	Canadian Red Cross	None	None	None	None	None	None	None
Jeffrey L. Pellegrino	Kent State University	None	None	None	None	None	None	None
William "Will" R. Smith	Wilderness and Emergency Medicine Consulting (WEMC), LLC	None	None	None	Medicolegal consulting†	None	Chinook Medical Gear*	National Park Service*
Janel M. Swain	Emergency Health Services	None	Capital District Health Authority*	None	None	None	None	Emergency Health Services/ Emergency Medical Care Inc.†
David A. Zideman	Imperial College Healthcare NHS	None	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

Appendix

2015 Guidelines Update: Part 15 Recommendations

Year Last Reviewed	Topic	Recommendation	Comments
2015	First Aid Education	Education and training in first aid can be useful to improve morbidity and mortality from injury and illness (Class IIa, LOE C-LD).	new for 2015
2015	First Aid Education	We recommend that first aid education be universally available (Class I, LOE C-EO).	new for 2015
2015	Positioning the Ill or Injured Person	If the area is unsafe for the first aid provider or the person, move to a safe location if possible (Class I, LOE C-EO).	updated for 2015
2015	Positioning the Ill or Injured Person	If a person is unresponsive and breathing normally, it may be reasonable to place him or her in a lateral side-lying recovery position (Class IIb, LOE C-LD).	updated for 2015
2015	Positioning the Ill or Injured Person	If a person has been injured and the nature of the injury suggests a neck, back, hip, or pelvic injury, the person should not be rolled onto his or her side and instead should be left in the position in which they were found, to avoid potential further injury (Class I, LOE C-EO).	updated for 2015
2015	Positioning the Ill or Injured Person	If leaving the person in the position found is causing the person's airway to be blocked, or if the area is unsafe, move the person only as needed to open the airway and to reach a safe location (Class I, LOE C-EO).	updated for 2015
2015	Position for Shock	If a person shows evidence of shock and is responsive and breathing normally, it is reasonable to place or maintain the person in a supine position (Class IIa, LOE C-LD)	updated for 2015
2015	Position for Shock	If there is no evidence of trauma or injury (eg, simple fainting, shock from nontraumatic bleeding, sepsis, dehydration), raising the feet about 6 to 12 inches (about 30° to 60°) from the supine position is an option that may be considered while awaiting arrival of EMS (Class IIb, LOE C-LD)	updated for 2015
2015	Position for Shock	Do not raise the feet of a person in shock if the movement or the position causes pain (Class III: Harm, LOE C-EO).	new for 2015
2015	Oxygen Use in First Aid	The use of supplementary oxygen by first aid providers with specific training is reasonable for cases of decompression sickness (Class IIa, LOE C-LD)	updated for 2015
2015	Oxygen Use in First Aid	For first aid providers with specific training in the use of oxygen, the administration of supplementary oxygen to persons with known advanced cancer with dyspnea and hypoxemia may be reasonable (Class IIb, LOE B-R).	new for 2015
2015	Oxygen Use in First Aid	Although no evidence was identified to support the use of oxygen, it might be reasonable to provide oxygen to spontaneously breathing persons who are exposed to carbon monoxide while waiting for advanced medical care (Class IIb, LOE C-EO).	new for 2015
2015	Medical Emergencies: Asthma	It is reasonable for first aid providers to be familiar with the available inhaled bronchodilator devices and to assist as needed with the administration of prescribed bronchodilators when a person with asthma is having difficulty breathing (Class IIa, LOE B-R).	updated for 2015
2015	Medical Emergencies: Stroke	The use of a stroke assessment system by first aid providers is recommended (Class I, LOE B-NR).	new for 2015
2015	Medical Emergencies: Chest Pain	Aspirin has been found to significantly decrease mortality due to myocardial infarction in several large studies and is therefore recommended for persons with chest pain due to suspected myocardial infarction (Class I, LOE B-R).	updated for 2015
2015	Medical Emergencies: Chest Pain	Call EMS immediately for anyone with chest pain or other signs of heart attack, rather than trying to transport the person to a healthcare facility yourself (Class I, LOE C-EO).	new for 2015
2015	Medical Emergencies: Chest Pain	While waiting for EMS to arrive, the first aid provider may encourage a person with chest pain to take aspirin if the signs and symptoms suggest that the person is having a heart attack and the person has no allergy or contraindication to aspirin, such as recent bleeding (Class IIa, LOE B-NR).	updated for 2015
2015	Medical Emergencies: Chest Pain	If a person has chest pain that does not suggest that the cause is cardiac in origin, or if the first aid provider is uncertain or uncomfortable with administration of aspirin, then the first aid provider should not encourage the person to take aspirin (Class III: Harm, LOE C-EO).	new for 2015
2015	Medical Emergencies: Anaphylaxis	The recommended dose of epinephrine is 0.3 mg intramuscularly for adults and children greater than 30 kg, 0.15 mg intramuscularly for children 15 to 30 kg, or as prescribed by the person's physician. First aid providers should call 9-1-1 immediately when caring for a person with suspected anaphylaxis or a severe allergic reaction (Class I, LOE C-EO).	new for 2015
2015	Medical Emergencies: Anaphylaxis	When a person with anaphylaxis does not respond to the initial dose, and arrival of advanced care will exceed 5 to 10 minutes, a repeat dose may be considered (Class IIb, LOE C-LD).	updated for 2015

(*Continued*)

2015 Guidelines Update: Part 15 Recommendations, *Continued*

Year Last Reviewed	Topic	Recommendation	Comments
2015	Medical Emergencies: Hypoglycemia	If the person is unconscious, exhibits seizures, or is unable to follow simple commands or swallow safely, the first aid provider should call for EMS immediately (Class I, LOE C-EO).	new for 2015
2015	Medical Emergencies: Hypoglycemia	If a person with diabetes reports low blood sugar or exhibits signs or symptoms of mild hypoglycemia and is able to follow simple commands and swallow, oral glucose should be given to attempt to resolve the hypoglycemia. Glucose tablets, if available, should be used to reverse hypoglycemia in a person who is able to take these orally (Class I, LOE B-R).	new for 2015
2015	Medical Emergencies: Hypoglycemia	It is reasonable to use these dietary sugars as an alternative to glucose tablets (when not available) for reversal of mild symptomatic hypoglycemia (Class IIa, LOE B-R).	new for 2015
2015	Medical Emergencies: Hypoglycemia	First aid providers should therefore wait at least 10 to 15 minutes before calling EMS and re-treating a diabetic with mild symptomatic hypoglycemia with additional oral sugars (Class I, LOE B-R).	new for 2015
2015	Medical Emergencies: Hypoglycemia	If the person's status deteriorates during that time or does not improve, the first aid provider should call EMS (Class I, LOE C-EO).	new for 2015
2015	Medical Emergencies: Dehydration	In the absence of shock, confusion, or inability to swallow, it is reasonable for first aid providers to assist or encourage individuals with exertional dehydration to orally rehydrate with CE drinks (Class IIa, LOE B-R).	new for 2015
2015	Medical Emergencies: Dehydration	If these alternative beverages are not available, potable water may be used (Class IIb, LOE B-R).	new for 2015
2015	Medical Emergencies: Toxic Eye Injury	It can be beneficial to rinse eyes exposed to toxic chemicals immediately and with a copious amount of tap water for at least 15 minutes or until advanced medical care arrives (Class IIa, LOE C-LD).	updated for 2015
2015	Medical Emergencies: Toxic Eye Injury	If tap water is not available, normal saline or another commercially available eye irrigation solution may be reasonable (Class IIb, LOE C-LD).	new for 2015
2015	Medical Emergencies: Chemical Eye Injury	First aid providers caring for individuals with chemical eye injury should contact their local poison control center or, if a poison control center is not available, seek help from a medical provider or 9-1-1 (Class I, LOE C-EO).	new for 2015
2015	Trauma Emergencies: Control of Bleeding	There continues to be no evidence to support the use of pressure points or elevation of an injury to control external bleeding. The use of pressure points or elevation of an extremity to control external bleeding is not indicated (Class III: No Benefit, LOE C-EO).	updated for 2015
2015	Trauma Emergencies: Control of Bleeding	The standard method for first aid providers to control open bleeding is to apply direct pressure to the bleeding site until it stops. Control open bleeding by applying direct pressure to the bleeding site (Class I, LOE B-NR).	updated for 2015
2015	Trauma Emergencies: Control of Bleeding	Local cold therapy, such as an instant cold pack, can be useful for these types of injuries to the extremity or scalp (Class IIa, LOE C-LD).	new for 2015
2015	Trauma Emergencies: Control of Bleeding	Cold therapy should be used with caution in children because of the risk of hypothermia in this population (Class I, LOE C-EO).	new for 2015
2015	Trauma Emergencies: Control of Bleeding	Because the rate of complications is low and the rate of hemostasis is high, first aid providers may consider the use of a tourniquet when standard first aid hemorrhage control does not control severe external limb bleeding (Class IIb, LOE C-LD).	updated for 2015
2015	Trauma Emergencies: Control of Bleeding	A tourniquet may be considered for initial care when a first aid provider is unable to use standard first aid hemorrhage control, such as during a mass casualty incident, with a person who has multisystem trauma, in an unsafe environment, or with a wound that cannot be accessed (Class IIb, LOE C-EO).	new for 2015
2015	Trauma Emergencies: Control of Bleeding	Although maximum time for tourniquet use was not reviewed by a 2015 ILCOR systematic review, it has been recommended that the first aid provider note the time that a tourniquet is first applied and communicate this information with EMS providers. It is reasonable for first aid providers to be trained in the proper application of tourniquets, both manufactured and improvised (Class IIa, LOE C-EO).	new for 2015
2015	Trauma Emergencies: Control of Bleeding	Hemostatic dressings may be considered by first aid providers when standard bleeding control (direct pressure with or without gauze or cloth dressing) is not effective for severe or life-threatening bleeding (Class IIb, LOE C-LD).	updated for 2015
2015	Trauma Emergencies: Control of Bleeding	Proper application of hemostatic dressings requires training (Class I, LOE C-EO).	updated for 2015
2015	Trauma Emergencies: Open Chest Wounds	We recommend against the application of an occlusive dressing or device by first aid providers for individuals with an open chest wound (Class III: Harm, LOE C-EO).	new for 2015

(*Continued*)

2015 Guidelines Update: Part 15 Recommendations, *Continued*

Year Last Reviewed	Topic	Recommendation	Comments
2015	Trauma Emergencies: Open Chest Wounds	In the first aid situation, it is reasonable to leave an open chest wound exposed to ambient air without a dressing or seal (Class IIa, LOE C-EO).	new for 2015
2015	Trauma Emergencies: Concussion	Any person with a head injury that has resulted in a change in level of consciousness, has progressive development of signs or symptoms as described above, or is otherwise a cause for concern should be evaluated by a healthcare provider or EMS personnel as soon as possible (Class I, LOE C-EO).	new for 2015
2015	Trauma Emergencies: Concussion	Using any mechanical machinery, driving, cycling, or continuing to participate in sports after a head injury should be deferred by these individuals until they are assessed by a healthcare provider and cleared to participate in those activities (Class I, LOE C-EO).	new for 2015
2015	Trauma Emergencies: Spinal Motion Restriction	With a growing body of evidence showing more actual harm and no good evidence showing clear benefit, we recommend against routine application of cervical collars by first aid providers (Class III: Harm, LOE C-LD).	updated for 2015
2015	Trauma Emergencies: Spinal Motion Restriction	If a first aid provider suspects a spinal injury, he or she should have the person remain as still as possible and await the arrival of EMS providers (Class I, LOE C-EO).	new for 2015
2015	Musculoskeletal Trauma	In general, first aid providers should not move or try to straighten an injured extremity (Class III: Harm, LOE C-EO).	updated for 2015
2015	Musculoskeletal Trauma	In such situations, providers should protect the injured person, including splinting in a way that limits pain, reduces the chance for further injury, and facilitates safe and prompt transport (Class I, LOE C-EO).	updated for 2015
2015	Musculoskeletal Trauma	If an injured extremity is blue or extremely pale, activate EMS immediately (Class I, LOE C-EO).	new for 2015
2015	Burns	Cool thermal burns with cool or cold potable water as soon as possible and for at least 10 minutes (Class I, LOE B-NR).	updated for 2015
2015	Burns	If cool or cold water is not available, a clean cool or cold, but not freezing, compress can be useful as a substitute for cooling thermal burns (Class IIa, LOE B-NR).	new for 2015
2015	Burns	Care should be taken to monitor for hypothermia when cooling large burns (Class I, LOE C-EO).	new for 2015
2015	Burns	After cooling of a burn, it may be reasonable to loosely cover the burn with a sterile, dry dressing (Class IIb, LOE C-LD).	updated for 2015
2015	Burns	In general, it may be reasonable to avoid natural remedies, such as honey or potato peel dressings (Class IIb, LOE C-LD).	new for 2015
2015	Burns	However, in remote or wilderness settings where commercially made topical antibiotics are not available, it may be reasonable to consider applying honey topically as an antimicrobial agent (Class IIb, LOE C-LD).	new for 2015
2015	Burns	Burns associated with or involving (1) blistering or broken skin; (2) difficulty breathing; (3) the face, neck, hands, or genitals; (4) a larger surface area, such as trunk or extremities; or (5) other cause for concern should be evaluated by a healthcare provider (Class I, LOE C-EO).	new for 2015
2015	Dental Injury	In situations that do not allow for immediate reimplantation, it can be beneficial to temporarily store an avulsed tooth in a variety of solutions shown to prolong viability of dental cells (Class IIa, LOE C-LD).	updated for 2015
2015	Dental Injury	If none of these solutions are available, it may be reasonable to store an avulsed tooth in the injured persons saliva (not in the mouth) pending reimplantation (Class IIb, LOE C-LD).	new for 2015
2015	Dental Injury	Following dental avulsion, it is essential to seek rapid assistance with reimplantation (Class I, LOE C-EO).	new for 2015
The following recommendations were not reviewed in 2015. For more information, see the *2010 AHA and American Red Cross Guidelines for First Aid*, "Part 17: First Aid."			
2010	Oxygen	There is insufficient evidence to recommend routine use of supplementary oxygen by a first aid provider for victims complaining of chest discomfort or shortness of breath (Class IIb, LOE C).	not reviewed in 2015
2010	Anaphylaxis	First aid providers should also know how to administer the auto-injector if the victim is unable to do so, provided that the medication has been prescribed by a physician and state law permits it (Class IIb, LOE B).	not reviewed in 2015
2010	Tourniquets	Specifically designed tourniquets appear to be better than ones that are improvised, but tourniquets should only be used with proper training (Class IIa, LOE B).	not reviewed in 2015
2010	Thermal Burns	Don't apply ice directly to a burn; it can produce tissue ischemia (Class III, LOE B).	not reviewed in 2015
2010	Spine Stabilization	Because of the dire consequences if secondary injury does occur, maintain spinal motion restriction by manually stabilizing the head so that the motion of head, neck, and spine is minimized (Class IIb, LOE C).	not reviewed in 2015

(*Continued*)

2015 Guidelines Update: Part 15 Recommendations, *Continued*

Year Last Reviewed	Topic	Recommendation	Comments
2010	Sprains and Strains	Place a barrier, such as a thin towel, between the cold container and the skin (Class IIb, LOE C).	not reviewed in 2015
2010	Hypothermia	If the hypothermia victim is far from definitive health care, begin active rewarming (Class IIa, LOE B) although the effectiveness of active rewarming has not been evaluated.	not reviewed in 2015
2010	Seizures	Placing an object in the victim's mouth may cause dental damage or aspiration (Class IIa, LOE C).	not reviewed in 2015
2010	Wounds and Abrasions	Superficial wounds and abrasions should be thoroughly irrigated with a large volume of warm or room temperature potable water with or without soap until there is no foreign matter in the wound (Class I, LOE A).	not reviewed in 2015
2010	Wounds and Abrasions	Wounds heal better with less infection if they are covered with an antibiotic ointment or cream and a clean occlusive dressing (Class IIa, LOE A).	not reviewed in 2015
2010	Burn Blisters	Loosely cover burn blisters with a sterile dressing but leave blisters intact because this improves healing and reduces pain (Class IIa, LOE B).	not reviewed in 2015
2010	Electric Injuries	Do not place yourself in danger by touching an electrocuted victim while the power is on (Class III, LOE C).	not reviewed in 2015
2010	Human and Animal Bites	Irrigate human and animal bites with copious amounts of water (Class I, LOE B).	not reviewed in 2015
2010	Snakebites	Do not apply suction as first aid for snakebites (Class III, LOE C).	not reviewed in 2015
2010	Snakebites	Applying a pressure immobilization bandage with a pressure between 40 and 70 mm Hg in the upper extremity and between 55 and 70 mm Hg in the lower extremity around the entire length of the bitten extremity is an effective and safe way to slow the dissemination of venom by slowing lymph flow (Class IIa, LOE C).	not reviewed in 2015
2010	Jellyfish Stings	To inactivate venom load and prevent further envenomation, jellyfish stings should be liberally washed with vinegar (4% to 6% acetic acid solution) as soon as possible for at least 30 seconds (Class IIa, LOE B).	not reviewed in 2015
2010	Jellyfish Stings	For the treatment of pain, after the nematocysts are removed or deactivated, jellyfish stings should be treated with hot-water immersion when possible (Class IIa, LOE B).	not reviewed in 2015
2010	Jellyfish Stings	If hot water is not available, dry hot packs or, as a second choice, dry cold packs may be helpful in decreasing pain but these are not as effective as hot water (Class IIb, LOE B).	not reviewed in 2015
2010	Jellyfish Stings	Topical application of aluminum sulfate or meat tenderizer, commercially available aerosol products, fresh water wash, and papain, an enzyme derived from papaya used as a local medicine, are even less effective in relieving pain (Class IIb, LOE B).	not reviewed in 2015
2010	Jellyfish Stings	Pressure immobilization bandages are not recommended for the treatment of jellyfish stings because animal studies show that pressure with an immobilization bandage causes further release of venom, even from already fired nematocysts (Class III, LOE C).	not reviewed in 2015
2010	Frostbite	Do not try to rewarm the frostbite if there is any chance that it might refreeze or if you are close to a medical facility (Class III, LOE C).	not reviewed in 2015
2010	Frostbite	Severe or deep frostbite should be rewarmed within 24 hours of injury and this is best accomplished by immersing the frostbitten part in warm (37° to 40°C or approximately body temperature) water for 20 to 30 minutes (Class IIb, LOE C).	not reviewed in 2015
2010	Frostbite	Chemical warmers should not be placed directly on frostbitten tissue because they can reach temperatures that can cause burns (Class III, LOE C).	not reviewed in 2015
2010	Chemical Burns	In case of exposure to an acid or alkali on the skin or eye, immediately irrigate the affected area with copious amounts of water (Class I, LOE B).	not reviewed in 2015
2010	Treatment With Milk or Water	Do not administer anything by mouth for any poison ingestion unless advised to do so by a poison control center or emergency medical personnel because it may be harmful (Class III, LOE C).	not reviewed in 2015
2010	Activated Charcoal	Do not administer activated charcoal to a victim who has ingested a poisonous substance unless you are advised to do so by poison control center or emergency medical personnel (Class IIb, LOE C).	not reviewed in 2015
2010	Ipecac	Do not administer syrup of ipecac for ingestions of toxins (Class III, LOE B).	not reviewed in 2015

References

1. Singletary EM, Zideman DA, De Buck EDJ, Chang WT, Jensen JL, Swain JM, Woodin JA, Blanchard IE, Herrington RA, Pellegrino JL, Hood NA, Lojero-Wheatley LF, Markenson DS, Yang HJ; on behalf of the First Aid Chapter Collaborators. Part 9: first aid: 2015 International Consensus on First Aid Science With Treatment Recommendations. *Circulation*. 2015;132(suppl 1):S269–S311. doi: 10.1161/CIR.0000000000000278.
2. Zideman DA, Singletary EM, De Buck EDJ, Chang WT, Jensen JL, Swain JM, Woodin JA, Blanchard IE, Herrington RA, Pellegrino JL, Hood NA, Lojero-Wheatley LF, Markenson DS, Yang HJ; on behalf of the First Aid Chapter Collaborators. Part 9: first aid: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*. 2015. In press.
3. Pearn J. The earliest days of first aid. *BMJ*. 1994;309:1718–1720.
4. Griffin K. The evolution and role changes of the Australian military medic: a review of the literature. *Journal of Military and Veterans' Health*. 2014;22:50–54.
5. Fletcher NC. *The St John Ambulance Association: Its History and Its Past in the Ambulance Movement*. London, England: St John Ambulance Association; 1929.
6. Markenson D, Ferguson JD, Chameides L, Cassan P, Chung KL, Epstein J, Gonzales L, Herrington RA, Pellegrino JL, Ratcliff N, Singer A. Part 17: first aid: 2010 American Heart Association and American Red Cross Guidelines for First Aid. *Circulation*. 2010;122(suppl 3):S934–S946. doi: 10.1161/CIRCULATIONAHA.110.971150.
7. Markenson D, Ferguson JD, Chameides L, Cassan P, Chung KL, Epstein JL, Gonzales L, Hazinski MF, Herrington RA, Pellegrino JL, Ratcliff N, Singer AJ; First Aid Chapter Collaborators. Part 13: first aid: 2010 American Heart Association and American Red Cross International Consensus on First Aid Science With Treatment Recommendations. *Circulation*. 2010;122(suppl 2):S582–S605. doi: 10.1161/CIRCULATIONAHA.110.971168.
8. O'Connor D, Green S, Higgins JPT, eds. Chapter 5: Defining the review question and developing criteria for including studies. In: The Cochrane Collaboration. Higgins JPT, Green S, eds. *Cochrane Handbook for Systematic Reviews of Interventions*. Version 5.1.0. 2011. http://handbook.cochrane.org/. Accessed May 6, 2015.
9. Schünemann H, Brożek J, Guyatt G, Oxman A. *GRADE Handbook*. 2013. http://www.guidelinedevelopment.org/handbook/. Accessed May 6, 2015.
10. Skinner AM, Brown TL, Peat BG, Muller MJ. Reduced hospitalisation of burns patients following a multi-media campaign that increased adequacy of first aid treatment. *Burns*. 2004;30:82–85.
11. Sunder S, Bharat R. Industrial burns in Jamshedpur, India: epidemiology, prevention and first aid. *Burns*. 1998;24:444–447.
12. Murad MK, Husum H. Trained lay first responders reduce trauma mortality: a controlled study of rural trauma in Iraq. *Prehosp Disaster Med*. 2010;25:533–539.
13. Litman RS, Wake N, Chan LM, McDonough JM, Sin S, Mahboubi S, Arens R. Effect of lateral positioning on upper airway size and morphology in sedated children. *Anesthesiology*. 2005;103:484–488.
14. Arai YC, Fukunaga K, Hirota S, Fujimoto S. The effects of chin lift and jaw thrust while in the lateral position on stridor score in anesthetized children with adenotonsillar hypertrophy. *Anesth Analg*. 2004;99:1638–1641, table of contents. doi: 10.1213/01.ANE.0000135637.95853.1C.
15. Boulain T, Achard JM, Teboul JL, Richard C, Perrotin D, Ginies G. Changes in BP induced by passive leg raising predict response to fluid loading in critically ill patients. *Chest*. 2002;121:1245–1252.
16. Gaffney FA, Bastian BC, Thal ER, Atkins JM, Blomqvist CG. Passive leg raising does not produce a significant or sustained autotransfusion effect. *J Trauma*. 1982;22:190–193.
17. Jabot J, Teboul JL, Richard C, Monnet X. Passive leg raising for predicting fluid responsiveness: importance of the postural change. *Intensive Care Med*. 2009;35:85–90. doi: 10.1007/s00134-008-1293-3.
18. Kamran H, Salciccioli L, Kumar P, Pushilin S, Namana V, Trotman S, Lazar J. The relation between blood pressure changes induced by passive leg raising and arterial stiffness. *J Am Soc Hypertens*. 2010;4:284–289. doi: 10.1016/j.jash.2010.09.002.
19. Kyriakides ZS, Koukoulas A, Paraskevaidis IA, Chrysos D, Tsiapras D, Galiotos C, Kremastinos DT. Does passive leg raising increase cardiac performance? A study using Doppler echocardiography. *Int J Cardiol*. 1994;44:288–293.
20. Wong DH, O'Connor D, Tremper KK, Zaccari J, Thompson P, Hill D. Changes in cardiac output after acute blood loss and position change in man. *Crit Care Med*. 1989;17:979–983.
21. Longphre JM, Denoble PJ, Moon RE, Vann RD, Freiberger JJ. First aid normobaric oxygen for the treatment of recreational diving injuries. *Undersea Hyperb Med*. 2007;34:43–49.
22. Uronis HE, Currow DC, McCrory DC, Samsa GP, Abernethy AP. Oxygen for relief of dyspnoea in mildly- or non-hypoxaemic patients with cancer: a systematic review and meta-analysis. *Br J Cancer*. 2008;98:294–299. doi: 10.1038/sj.bjc.6604161.
23. Bruera E, de Stoutz N, Velasco-Leiva A, Schoeller T, Hanson J. Effects of oxygen on dyspnoea in hypoxaemic terminal-cancer patients. *Lancet*. 1993;342:13–14.
24. Booth S, Kelly MJ, Cox NP, Adams L, Guz A. Does oxygen help dyspnea in patients with cancer? *Am J Respir Crit Care Med*. 1996;153:1515–1518. doi: 10.1164/ajrccm.153.5.8630595.
25. Part 10: first aid: 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2005;112(suppl):III115–III125.
26. Karpel JP, Aldrich TK, Prezant DJ, Guguchev K, Gaitan-Salas A, Pathiparti R. Emergency treatment of acute asthma with albuterol metered-dose inhaler plus holding chamber: how often should treatments be administered? *Chest*. 1997;112:348–356.
27. Weiss SJ, Anand P, Ernst AA, Orgeron D, May WL. Effect of out-of-hospital albuterol inhalation treatments on patient comfort and morbidity. *Ann Emerg Med*. 1994;24:873–878.
28. Osmond MH, Klassen TP. Efficacy of ipratropium bromide in acute childhood asthma: a meta-analysis. *Acad Emerg Med*. 1995;2:651–656.
29. Hermansen MN, Nielsen KG, Buchvald F, Jespersen JJ, Bengtsson T, Bisgaard H. Acute relief of exercise-induced bronchoconstriction by inhaled formoterol in children with persistent asthma. *Chest*. 2006;129:1203–1209. doi: 10.1378/chest.129.5.1203.
30. Amirav I, Yacobov R, Luder AS. Formoterol turbuhaler is as effective as salbutamol diskus in relieving adenosine-induced bronchoconstriction in children. *J Aerosol Med*. 2007;20:1–6. doi: 10.1089/jam.2006.0561.
31. Bentur L, Canny GJ, Shields MD, Kerem E, Schuh S, Reisman JJ, Fakhoury K, Pedder L, Levison H. Controlled trial of nebulized albuterol in children younger than 2 years of age with acute asthma. *Pediatrics*. 1992;89:133–137.
32. Emerman CL, Shade B, Kubincanek J. A controlled trial of nebulized isoetharine in the prehospital treatment of acute asthma. *Am J Emerg Med*. 1990;8:512–514.
33. Littner MR, Tashkin DP, Siegel SC, Katz R. Double-blind comparison of acute effects of inhaled albuterol, isoproterenol and placebo on cardiopulmonary function and gas exchange in asthmatic children. *Ann Allergy*. 1983;50:309–316.
34. Berger WE, Milgrom H, Skoner DP, Tripp K, Parsey MV, Baumgartner RA; Xopenex Pediatric Asthma Group. Evaluation of levalbuterol metered dose inhaler in pediatric patients with asthma: a double-blind, randomized, placebo- and active-controlled trial. *Curr Med Res Opin*. 2006;22:1217–1226. doi: 10.1185/030079906X112534.
35. Politiek MJ, Boorsma M, Aalbers R. Comparison of formoterol, salbutamol and salmeterol in methacholine-induced severe bronchoconstriction. *Eur Respir J*. 1999;13:988–992.
36. van der Woude HJ, Postma DS, Politiek MJ, Winter TH, Aalbers R. Relief of dyspnoea by beta2-agonists after methacholine-induced bronchoconstriction. *Respir Med*. 2004;98:816–820.
37. Chenkin J, Gladstone DJ, Verbeek PR, Lindsay P, Fang J, Black SE, Morrison L. Predictive value of the Ontario prehospital stroke screening tool for the identification of patients with acute stroke. *Prehosp Emerg Care*. 2009;13:153–159. doi: 10.1080/10903120802706146.
38. Frendl DM, Strauss DG, Underhill BK, Goldstein LB. Lack of impact of paramedic training and use of the cincinnati prehospital stroke scale on stroke patient identification and on-scene time. *Stroke*. 2009;40:754–756. doi: 10.1161/STROKEAHA.108.531285.
39. Harbison J, Hossain O, Jenkinson D, Davis J, Louw SJ, Ford GA. Diagnostic accuracy of stroke referrals from primary care, emergency room physicians, and ambulance staff using the face arm speech test. *Stroke*. 2003;34:71–76.
40. Iguchi Y, Kimura K, Watanabe M, Shibazaki K, Aoki J. Utility of the Kurashiki Prehospital Stroke Scale for hyperacute stroke. *Cerebrovasc Dis*. 2011;31:51–56. doi: 10.1159/000320854.
41. O'Brien W, Crimmins D, Donaldson W, Risti R, Clarke TA, Whyte S, Sturm J. FASTER (Face, Arm, Speech, Time, Emergency Response): experience of Central Coast Stroke Services implementation of a pre-hospital notification system for expedient management of acute stroke. *J Clin Neurosci*. 2012;19:241–245. doi: 10.1016/j.jocn.2011.06.009.

42. Wojner-Alexandrov AW, Alexandrov AV, Rodriguez D, Persse D, Grotta JC. Houston paramedic and emergency stroke treatment and outcomes study (HoPSTO). *Stroke*. 2005;36:1512–1518. doi: 10.1161/01.STR.0000170700.45340.39.
43. Wall HK, Beagan BM, O'Neill J, Foell KM, Boddie-Willis CL. Addressing stroke signs and symptoms through public education: the Stroke Heroes Act FAST campaign. *Prev Chronic Dis*. 2008;5:A49.
44. You JS, Chung SP, Chung HS, Lee HS, Park JW, Kim HJ, Lee SH, Park I, Lee HS. Predictive value of the Cincinnati Prehospital Stroke Scale for identifying thrombolytic candidates in acute ischemic stroke. *Am J Emerg Med*. 2013;31:1699–1702. doi: 10.1016/j.ajem.2013.08.029.
45. Bergs J, Sabbe M, Moons P. Prehospital stroke scales in a Belgian prehospital setting: a pilot study. *Eur J Emerg Med*. 2010;17:2–6. doi: 10.1097/MEJ.0b013e32831040ec.
46. Bray JE, Martin J, Cooper G, Barger B, Bernard S, Bladin C. Paramedic identification of stroke: community validation of the melbourne ambulance stroke screen. *Cerebrovasc Dis*. 2005;20:28–33. doi: 10.1159/000086201.
47. Bray JE, Coughlan K, Barger B, Bladin C. Paramedic diagnosis of stroke: examining long-term use of the Melbourne Ambulance Stroke Screen (MASS) in the field. *Stroke*. 2010;41:1363–1366. doi: 10.1161/STROKEAHA.109.571836.
48. Buck BH, Starkman S, Eckstein M, Kidwell CS, Haines J, Huang R, Colby D, Saver JL. Dispatcher recognition of stroke using the National Academy Medical Priority Dispatch System. *Stroke*. 2009;40:2027–2030. doi: 10.1161/STROKEAHA.108.545574.
49. Chen S, Sun H, Lei Y, Gao D, Wang Y, Wang Y, Zhou Y, Wang A, Wang W, Zhao X. Validation of the Los Angeles pre-hospital stroke screen (LAPSS) in a Chinese urban emergency medical service population. *PLoS One*. 2013;8:e70742. doi: 10.1371/journal.pone.0070742.
50. De Luca A, Giorgi Rossi P, Villa GF; Stroke group Italian Society pre hospital emergency Services. The use of Cincinnati Prehospital Stroke Scale during telephone dispatch interview increases the accuracy in identifying stroke and transient ischemic attack symptoms. *BMC Health Serv Res*. 2013;13:513. doi: 10.1186/1472-6963-13-513.
51. Fothergill RT, Williams J, Edwards MJ, Russell IT, Gompertz P. Does use of the recognition of stroke in the emergency room stroke assessment tool enhance stroke recognition by ambulance clinicians? *Stroke*. 2013;44:3007–3012. doi: 10.1161/STROKEAHA.13.000851.
52. Kidwell CS, Starkman S, Eckstein M, Weems K, Saver JL. Identifying stroke in the field. Prospective validation of the Los Angeles prehospital stroke screen (LAPSS). *Stroke*. 2000;31:71–76.
53. Kleindorfer DO, Miller R, Moomaw CJ, Alwell K, Broderick JP, Khoury J, Woo D, Flaherty ML, Zakaria T, Kissela BM. Designing a message for public education regarding stroke: does FAST capture enough stroke? *Stroke*. 2007;38:2864–2868. doi: 10.1161/STROKEAHA.107.484329.
54. Kothari RU, Pancioli A, Liu T, Brott T, Broderick J. Cincinnati Prehospital Stroke Scale: reproducibility and validity. *Ann Emerg Med*. 1999;33:373–378.
55. Nazliel B, Starkman S, Liebeskind DS, Ovbiagele B, Kim D, Sanossian N, Ali L, Buck B, Villablanca P, Vinuela F, Duckwiler G, Jahan R, Saver JL. A brief prehospital stroke severity scale identifies ischemic stroke patients harboring persisting large arterial occlusions. *Stroke*. 2008;39:2264–2267. doi: 10.1161/STROKEAHA.107.508127.
56. Nor AM, Davis J, Sen B, Shipsey D, Louw SJ, Dyker AG, Davis M, Ford GA. The Recognition of Stroke in the Emergency Room (ROSIER) scale: development and validation of a stroke recognition instrument. *Lancet Neurol*. 2005;4:727–734. doi: 10.1016/S1474-4422(05)70201-5.
57. Ramanujam P, Guluma KZ, Castillo EM, Chacon M, Jensen MB, Patel E, Linnick W, Dunford JV. Accuracy of stroke recognition by emergency medical dispatchers and paramedics–San Diego experience. *Prehosp Emerg Care*. 2008;12:307–313. doi: 10.1080/10903120802099526.
58. Studnek JR, Asimos A, Dodds J, Swanson D. Assessing the validity of the Cincinnati prehospital stroke scale and the medic prehospital assessment for code stroke in an urban emergency medical services agency. *Prehosp Emerg Care*. 2013;17:348–353. doi: 10.3109/10903127.2013.773113.
59. Whiteley WN, Wardlaw JM, Dennis MS, Sandercock PA. Clinical scores for the identification of stroke and transient ischaemic attack in the emergency department: a cross-sectional study. *J Neurol Neurosurg Psychiatry*. 2011;82:1006–1010. doi: 10.1136/jnnp.2010.235010.
60. Yock-Corrales A, Babl FE, Mosley IT, Mackay MT. Can the FAST and ROSIER adult stroke recognition tools be applied to confirmed childhood arterial ischemic stroke? *BMC Pediatr*. 2011;11:93. doi: 10.1186/1471-2431-11-93.
61. Randomised trial of intravenous streptokinase, oral aspirin, both, or neither among 17,187 cases of suspected acute myocardial infarction: ISIS-2. ISIS-2 (Second International Study of Infarct Survival) Collaborative Group. *Lancet*. 1988;2:349–360.
62. Verheugt FW, van der Laarse A, Funke-Küpper AJ, Sterkman LG, Galema TW, Roos JP. Effects of early intervention with low-dose aspirin (100 mg) on infarct size, reinfarction and mortality in anterior wall acute myocardial infarction. *Am J Cardiol*. 1990;66:267–270.
63. Frilling B, Schiele R, Gitt AK, Zahn R, Schneider S, Glunz HG, Gieseler U, Baumgärtel B, Asbeck F, Senges J; Maximum Individual Therapy in Acute Myocardial Infarction (MITRA); Myocardial Infarction Registry (MIR) Study Groups. Characterization and clinical course of patients not receiving aspirin for acute myocardial infarction: results from the MITRA and MIR studies. *Am Heart J*. 2001;141:200–205. doi: 10.1067/mhj.2001.112681.
64. Quan D, LoVecchio F, Clark B, Gallagher JV 3rd. Prehospital use of aspirin rarely is associated with adverse events. *Prehosp Disaster Med*. 2004;19:362–365.
65. Barbash I, Freimark D, Gottlieb S, Hod H, Hasin Y, Battler A, Crystal E, Matetzky S, Boyko V, Mandelzweig L, Behar S, Leor J; Israeli working group on intensive cardiac care, Israel heart society. Outcome of myocardial infarction in patients treated with aspirin is enhanced by pre-hospital administration. *Cardiology*. 2002;98:141–147. doi: 66324.
66. Freimark D, Matetzky S, Leor J, Boyko V, Barbash IM, Behar S, Hod H. Timing of aspirin administration as a determinant of survival of patients with acute myocardial infarction treated with thrombolysis. *Am J Cardiol*. 2002;89:381–385.
67. Inoue N, Yamamoto A. Clinical evaluation of pediatric anaphylaxis and the necessity for multiple doses of epinephrine. *Asia Pac Allergy*. 2013;3:106–114. doi: 10.5415/apallergy.2013.3.2.106.
68. Järvinen KM, Sicherer SH, Sampson HA, Nowak-Wegrzyn A. Use of multiple doses of epinephrine in food-induced anaphylaxis in children. *J Allergy Clin Immunol*. 2008;122:133–138. doi: 10.1016/j.jaci.2008.04.031.
69. Noimark L, Wales J, Du Toit G, Pastacaldi C, Haddad D, Gardner J, Hyer W, Vance G, Townshend C, Alfaham M, Arkwright PD, Rao R, Kapoor S, Summerfield A, Warner JO, Roberts G. The use of adrenaline autoinjectors by children and teenagers. *Clin Exp Allergy*. 2012;42:284–292. doi: 10.1111/j.1365-2222.2011.03912.x.
70. Korenblat P, Lundie MJ, Dankner RE, Day JH. A retrospective study of epinephrine administration for anaphylaxis: how many doses are needed? *Allergy Asthma Proc*. 1999;20:383–386.
71. Oren E, Banerji A, Clark S, Camargo CA Jr. Food-induced anaphylaxis and repeated epinephrine treatments. *Ann Allergy Asthma Immunol*. 2007;99:429–432. doi: 10.1016/S1081-1206(10)60568-6.
72. Banerji A, Rudders SA, Corel B, Garth AM, Clark S, Camargo CA Jr. Repeat epinephrine treatments for food-related allergic reactions that present to the emergency department. *Allergy Asthma Proc*. 2010;31:308–316. doi: 10.2500/aap.2010.31.3375.
73. Rudders SA, Banerji A, Corel B, Clark S, Camargo CA Jr. Multicenter study of repeat epinephrine treatments for food-related anaphylaxis. *Pediatrics*. 2010;125:e711–e718. doi: 10.1542/peds.2009-2832.
74. Tsuang A, Menon N, Setia N, Geyman L, Nowak-Wegrzyn AH. Multiple epinephrine doses in food-induced anaphylaxis in children. *J. Allergy Clin. Immunol*. 2013;131:AB90.
75. Rudders SA, Banerji A, Katzman DP, Clark S, Camargo CA Jr. Multiple epinephrine doses for stinging insect hypersensitivity reactions treated in the emergency department. *Ann Allergy Asthma Immunol*. 2010;105:85–93. doi: 10.1016/j.anai.2010.05.004.
76. Slama G, Traynard PY, Desplanque N, Pudar H, Dhunputh I, Letanoux M, Bornet FR, Tchobroutsky G. The search for an optimized treatment of hypoglycemia. Carbohydrates in tablets, solutin, or gel for the correction of insulin reactions. *Arch Intern Med*. 1990;150:589–593.
77. Husband AC, Crawford S, McCoy LA, Pacaud D. The effectiveness of glucose, sucrose, and fructose in treating hypoglycemia in children with type 1 diabetes. *Pediatr Diabetes*. 2010;11:154–158. doi: 10.1111/j.1399-5448.2009.00558.x.
78. McTavish L, Wiltshire E. Effective treatment of hypoglycemia in children with type 1 diabetes: a randomized controlled clinical trial. *Pediatr Diabetes*. 2011;12(4 Pt 2):381–387. doi: 10.1111/j.1399-5448.2010.00725.x.
79. Brodows RG, Williams C, Amatruda JM. Treatment of insulin reactions in diabetics. *JAMA*. 1984;252:3378–3381.

80. Chang CQ, Chen YB, Chen ZM, Zhang LT. Effects of a carbohydrate-electrolyte beverage on blood viscosity after dehydration in healthy adults. *Chin Med J (Engl)*. 2010;123:3220–3225.
81. Kalman DS, Feldman S, Krieger DR, Bloomer RJ. Comparison of coconut water and a carbohydrate-electrolyte sport drink on measures of hydration and physical performance in exercise-trained men. *J Int Soc Sports Nutr*. 2012;9:1. doi: 10.1186/1550-2783-9-1.
82. Wong SH, Chen Y. Effect of a carbohydrate-electrolyte beverage, lemon tea, or water on rehydration during short-term recovery from exercise. *Int J Sport Nutr Exerc Metab*. 2011;21:300–310.
83. Ismail I, Singh R, Sirisinghe RG. Rehydration with sodium-enriched coconut water after exercise-induced dehydration. *Southeast Asian J Trop Med Public Health*. 2007;38:769–785.
84. Kompa S, Redbrake C, Hilgers C, Wüstemeyer H, Schrage N, Remky A. Effect of different irrigating solutions on aqueous humour pH changes, intraocular pressure and histological findings after induced alkali burns. *Acta Ophthalmol Scand*. 2005;83:467–470. doi: 10.1111/j.1600-0420.2005.00458.x.
85. King NA, Philpott SJ, Leary A. A randomized controlled trial assessing the use of compression versus vasoconstriction in the treatment of femoral hematoma occurring after percutaneous coronary intervention. *Heart Lung*. 2008;37:205–210. doi: 10.1016/j.hrtlng.2007.05.008.
86. Levy AS, Marmar E. The role of cold compression dressings in the postoperative treatment of total knee arthroplasty. *Clin Orthop Relat Res*. 1993:174–178.
87. Beekley AC, Sebesta JA, Blackbourne LH, Herbert GS, Kauvar DS, Baer DG, Walters TJ, Mullenix PS, Holcomb JB; 31st Combat Support Hospital Research Group. Prehospital tourniquet use in Operation Iraqi Freedom: effect on hemorrhage control and outcomes. *J Trauma*. 2008;64(2 suppl):S28–S37; discussion S37. doi: 10.1097/TA.0b013e318160937e.
88. Brodie S, Hodgetts TJ, Ollerton J, McLeod J, Lambert P, Mahoney P. Tourniquet use in combat trauma: U.K. military experience. *J Spec Oper Med*. 2009;9:74–77.
89. King DR, van der Wilden G, Kragh JF Jr, Blackbourne LH. Forward assessment of 79 prehospital battlefield tourniquets used in the current war. *J Spec Oper Med*. 2012;12:33–38.
90. Kragh JF Jr, Littrel ML, Jones JA, Walters TJ, Baer DG, Wade CE, Holcomb JB. Battle casualty survival with emergency tourniquet use to stop limb bleeding. *J Emerg Med*. 2011;41:590–597. doi: 10.1016/j.jemermed.2009.07.022.
91. Kragh JF Jr, Nam JJ, Berry KA, Mase VJ Jr, Aden JK 3rd, Walters TJ, Dubick MA, Baer DG, Wade CE, Blackbourne LH. Transfusion for shock in US military war casualties with and without tourniquet use. *Ann Emerg Med*. 2015;65:290–296. doi: 10.1016/j.annemergmed.2014.10.021.
92. Kragh JF Jr, Cooper A, Aden JK, Dubick MA, Baer DG, Wade CE, Blackbourne LH. Survey of trauma registry data on tourniquet use in pediatric war casualties. *Pediatr Emerg Care*. 2012;28:1361–1365. doi: 10.1097/PEC.0b013e318276c260.
93. Lakstein D, Blumenfeld A, Sokolov T, Lin G, Bssorai R, Lynn M, Ben-Abraham R. Tourniquets for hemorrhage control on the battlefield: a 4-year accumulated experience. *J Trauma*. 2003;54(5 suppl):S221–S225. doi: 10.1097/01.TA.0000047227.33395.49.
94. Tien HC, Jung V, Rizoli SB, Acharya SV, MacDonald JC. An evaluation of tactical combat casualty care interventions in a combat environment. *J Am Coll Surg*. 2008;207:174–178. doi: 10.1016/j.jamcollsurg.2008.01.065.
95. Kue RC, Temin ES, Weiner SG, Gates J, Coleman MH, Fisher J, Dyer S. Tourniquet Use in a Civilian Emergency Medical Services Setting: A Descriptive Analysis of the Boston EMS Experience. *Prehosp Emerg Care*. 2015;19:399–404. doi: 10.3109/10903127.2014.995842.
96. Passos E, Dingley B, Smith A, Engels PT, Ball CG, Faidi S, Nathens A, Tien H; Canadian Trauma Trials Collaborative. Tourniquet use for peripheral vascular injuries in the civilian setting. *Injury*. 2014;45:573–577. doi: 10.1016/j.injury.2013.11.031.
97. Cox ED, Schreiber MA, McManus J, Wade CE, Holcomb JB. New hemostatic agents in the combat setting. *Transfusion*. 2009;49 suppl 5:248S–255S. doi: 10.1111/j.1537-2995.2008.01988.x.
98. Ran Y, Hadad E, Daher S, Ganor O, Kohn J, Yegorov Y, Bartal C, Ash N, Hirschhorn G. QuikClot Combat Gauze use for hemorrhage control in military trauma: January 2009 Israel Defense Force experience in the Gaza Strip–a preliminary report of 14 cases. *Prehosp Disaster Med*. 2010;25:584–588.
99. Wedmore I, McManus JG, Pusateri AE, Holcomb JB. A special report on the chitosan-based hemostatic dressing: experience in current combat operations. *J Trauma*. 2006;60:655–658. doi: 10.1097/01.ta.0000199392.91772.44.
100. Brown MA, Daya MR, Worley JA. Experience with chitosan dressings in a civilian EMS system. *J Emerg Med*. 2009;37:1–7. doi: 10.1016/j.jemermed.2007.05.043.
101. McCrory P, Meeuwisse WH, Echemendia RJ, Iverson GL, Dvorák J, Kutcher JS. What is the lowest threshold to make a diagnosis of concussion? *Br J Sports Med*. 2013;47:268–271. doi: 10.1136/bjsports-2013-092247.
102. Delaney JS, Abuzeyad F, Correa JA, Foxford R. Recognition and characteristics of concussions in the emergency department population. *J Emerg Med*. 2005;29:189–197. doi: 10.1016/j.jemermed.2005.01.020.
103. Maroon JC, Mathyssek C, Bost J. Cerebral concussion: a historical perspective. *Prog Neurol Surg*. 2014;28:1–13. doi: 10.1159/000358746.
104. Davies G, Deakin C, Wilson A. The effect of a rigid collar on intracranial pressure. *Injury*. 1996;27:647–649.
105. Hunt K, Hallworth S, Smith M. The effects of rigid collar placement on intracranial and cerebral perfusion pressures. *Anaesthesia*. 2001;56:511–513.
106. Mobbs RJ, Stoodley MA, Fuller J. Effect of cervical hard collar on intracranial pressure after head injury. *ANZ J Surg*. 2002;72:389–391.
107. Kolb JC, Summers RL, Galli RL. Cervical collar-induced changes in intracranial pressure. *Am J Emerg Med*. 1999;17:135–137.
108. Raphael JH, Chotai R. Effects of the cervical collar on cerebrospinal fluid pressure. *Anaesthesia*. 1994;49:437–439.
109. Stone MB, Tubridy CM, Curran R. The effect of rigid cervical collars on internal jugular vein dimensions. *Acad Emerg Med*. 2010;17:100–102. doi: 10.1111/j.1553-2712.2009.00624.x.
110. Dodd FM, Simon E, McKeown D, Patrick MR. The effect of a cervical collar on the tidal volume of anaesthetised adult patients. *Anaesthesia*. 1995;50:961–963.
111. Lin HL, Lee WC, Chen CW, Lin TY, Cheng YC, Yeh YS, Lin YK, Kuo LC. Neck collar used in treatment of victims of urban motorcycle accidents: over- or underprotection? *Am J Emerg Med*. 2011;29:1028–1033. doi: 10.1016/j.ajem.2010.06.003.
112. Yava A, Koyuncu A, Tosun N, Kiliç S. Effectiveness of local cold application on skin burns and pain after transthoracic cardioversion. *Emerg Med J*. 2012;29:544–549. doi: 10.1136/emj.2010.098053.
113. Nguyen NL, Gun RT, Sparnon AL, Ryan P. The importance of immediate cooling–a case series of childhood burns in Vietnam. *Burns*. 2002;28:173–176.
114. Heinrich JJ, Brand DA, Cuono CB. The role of topical treatment as a determinant of infection in outpatient burns. *J Burn Care Rehabil*. 1988;9:253–257.
115. Subrahmanyam M. Topical application of honey in treatment of burns. *Br J Surg*. 1991;78:497–498.
116. Subrahmanyam M. Honey dressing versus boiled potato peel in the treatment of burns: a prospective randomized study. *Burns*. 1996;22:491–493.
117. Diangelis AJ, Andreasen JO, Ebeleseder KA, Kenny DJ, Trope M, Sigurdsson A, Andersson L, Bourguignon C, Flores MT, Hicks ML, Lenzi AR, Malmgren B, Moule AJ, Pohl Y, Tsukiboshi M; International Association of Dental Traumatology. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 1. Fractures and luxations of permanent teeth. *Dent Traumatol*. 2012;28:2–12. doi: 10.1111/j.1600-9657.2011.01103.x.
118. Khademi AA, Saei S, Mohajeri MR, Mirkheshti N, Ghassami F, Torabi nia N, Alavi SA. A new storage medium for an avulsed tooth. *J Contemp Dent Pract*. 2008;9:25–32.
119. Ahangari Z, Alborzi S, Yadegari Z, Dehghani F, Ahangari L, Naseri M. The effect of propolis as a biological storage media on periodontal ligament cell survival in an avulsed tooth: an *in vitro* study. *Cell J*. 2013;15:244–249.
120. Rajendran P, Varghese NO, Varughese JM, Murugaian E. Evaluation, using extracted human teeth, of Ricetral as a storage medium for avulsions–an *in vitro* study. *Dent Traumatol*. 2011;27:217–220. doi: 10.1111/j.1600-9657.2011.00988.x.
121. Gopikrishna V, Thomas T, Kandaswamy D. A quantitative analysis of coconut water: a new storage media for avulsed teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;105:e61–e65. doi: 10.1016/j.tripleo.2007.08.003.

122. Lekic PC, Kenny DJ, Barrett EJ. The influence of storage conditions on the clonogenic capacity of periodontal ligament cells: implications for tooth replantation. *Int Endod J*. 1998;31:137–140.
123. Martin MP, Pileggi R. A quantitative analysis of Propolis: a promising new storage media following avulsion. *Dent Traumatol*. 2004;20:85–89. doi: 10.1111/j.1600-4469.2004.00233.x.
124. Patel S, Dumsha TC, Sydiskis RJ. Determining periodontal ligament (PDL) cell vitality from exarticulated teeth stored in saline or milk using fluorescein diacetate. *Int Endod J*. 1994;27:1–5.
125. Werder P, von Arx T, Chappuis V. Treatment outcome of 42 replanted permanent incisors with a median follow-up of 2.8 years. *Schweiz Monatsschr Zahnmed*. 2011;121:312–320.
126. Chen H, Huang B. (-)-Epigallocatechin-3-gallate: a novel storage medium for avulsed teeth. *Dent Traumatol*. 2012;28:158–160. doi: 10.1111/j.1600-9657.2011.01066.x.
127. Andreasen JO, Borum MK, Jacobsen HL, Andreasen FM. Replantation of 400 avulsed permanent incisors. 2. Factors related to pulpal healing. *Endod Dent Traumatol*. 1995;11:59–68.
128. Andreasen JO, Borum MK, Jacobsen HL, Andreasen FM. Replantation of 400 avulsed permanent incisors. 4. Factors related to periodontal ligament healing. *Endod Dent Traumatol*. 1995;11:76–89.

KEY WORDS: emergency ■ injury

Part 15: First Aid: 2015 American Heart Association and American Red Cross Guidelines Update for First Aid

Eunice M. Singletary, Nathan P. Charlton, Jonathan L. Epstein, Jeffrey D. Ferguson, Jan L. Jensen, Andrew I. MacPherson, Jeffrey L. Pellegrino, William "Will" R. Smith, Janel M. Swain, Luis F. Lojero-Wheatley and David A. Zideman

Circulation. 2015;132:S574-S589
doi: 10.1161/CIR.0000000000000269
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0009-7322. Online ISSN: 1524-4539