DOI: 10.1097/JPN.0b013e318253e1aa

CE **Continuing Education**

J Perinat Neonat Nurs • Volume 26 Number 2, 158–163 • Copyright © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins

Neonatal Resuscitation Science, Education, and Practice

The Role of the Neonatal Resuscitation Program

Jane E. McGowan, MD

ABSTRACT

For almost 25 years, the Neonatal Resuscitation Program of the American Academy of Pediatrics has provided educational tools that are used in the United States and throughout the world to teach neonatal resuscitation. Over that time period, the guidelines for resuscitation have been increasingly evidence-based and a formal system has been established to determine which steps should be updated on the basis of available information. The most recent update occurred in 2010. This article describes the evidence review process and the specific evidence that lead to a number of significant changes in practice that were included in the 2010 guidelines.

Key Words: evidence-based medicine, oxygen, neonatal resuscitation, newborn

Effective resuscitation of the newborn with depression has been the subject of many publications, ranging from Victorian novels to entire textbooks. Yet until relatively recently, practice was guided primarily by empiric data and supposition rather than rigorous evaluation. Under the leadership of the American Academy of Pediatrics and the American Heart Association, practice guidelines for neonatal resuscitation were developed and have evolved over the past 25 years, becoming increasingly evidence-based over that period.

Author Affiliation: Department of Pediatrics, Drexel University College of Medicine, and St. Christopher's Hospital for Children, Philadelphia, Pennsylvania.

Disclosure: Dr McGowan receives a stipend from the American Academy of Pediatrics as associate editor of the Neonatal Resuscitation Textbook.

Correspoding Author: Jane E. McGowan, MD, Neonatology, St Christopher's Hospital for Children, 2nd Floor, 3601 A St, Philadelphia, PA 19134 (jane.mcgowan@drexelmed.edu).

Submitted for publication: November 30, 2011; accepted for publication: March 2, 2012.

The Neonatal Resuscitation Program (NRP) had its origins in the Neonatal Education Program developed at the Drew Postgraduate Medical School in Los Angeles in the mid-1970s. Shortly thereafter, in light of the increasing number of intensive care nurseries throughout the United States, the American Academy of Pediatrics asked Dr George Peckham to develop a standardized approach to the teaching and practice of neonatal resuscitation that could be disseminated to practitioners. With the support of the American Academy of Pediatrics Section on Perinatal Pediatrics and a grant from Mead Johnson, a modified version of the Neonatal Education Program was developed by a group of providers led by Dr Peckham as well as Dr Ronald Bloom and Cathy Cropley, MSN, RN, and was dubbed the "Neonatal Resuscitation Program." The first regional instructor courses were conducted in 1987 by some of the founding members, and the individuals who participated in these courses started the cascade that has continued to the present. As of 2008, there were more than 2 million providers who had been trained by more than 27 000 instructors.

Although material contained in the initial NRP courses was, in large part, based on what was then considered standard practice, one of the key principles of the NRP from the beginning was to base practice guidelines on evidence whenever possible. By the 1990s, the American Heart Association, along with other international resuscitation councils and the American Academy of Pediatrics (collectively known as the International Liaison Committee on Resuscitation, or ILCOR), had begun to develop a process for reviewing the literature on resuscitation and emergency cardiac care with the goal of evaluating current practice in the context of available evidence and modifying clinical care guidelines when indicated. The first set of comprehensive international guidelines was published in 2000.

THE ILCOR REVIEW PROCESS

The current process for evaluating available evidence to determine whether practice changes are warranted occurs on a 5-year cycle and requires rigorous evaluation of the literature and, often, heated discussion among those charged with completing the review process. For those in the ILCOR Neonatal Task Force, the process begins with a meeting of its members shortly after the publication of the previous guidelines to identify unanswered question and new topics to be investigated. The topics are assigned to task force members for review. The review process consists of a literature search, followed by a rigorous assessment of the relevant literature. The information from the review is synthesized to develop a Consensus on Science statement, and a Treatment Recommendation is made on the basis of the available evidence. The steps from the initial meeting of the task force to the final results take almost 5 years. This process is outlined in the following text (Figure 1).

The most recent ILCOR review was completed in early 2010, and the Guidelines for Neonatal Resuscitation, developed by the members of the NRP Steering Committee using the Consensus on Science and Treatment Recommendations (CoSTR) document written by the ILCOR Neonatal Task Force, were published in October 2010.[1] On the basis of the evidence presented, a number of significant practice changes were recommended. Although the most significant changes deal with the use of supplementary oxygen, the changes in practice described impact all aspects of resuscitation, from the initial steps to educational methodology. Some of the most substantive changes are described here.

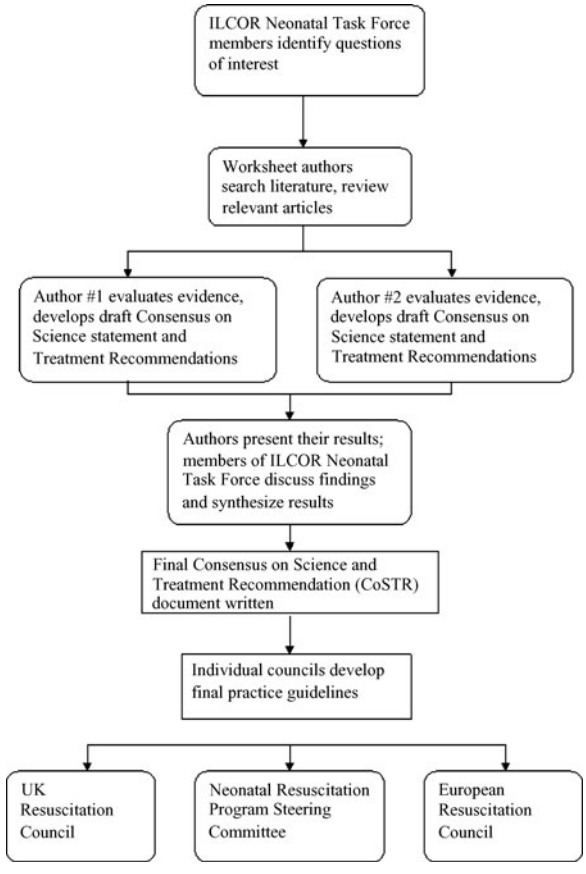

Figure 1. International Liaison Committee on Resuscitation (ILCOR) evidence review process.

Oxygen

The recommendations for use of supplementary oxygen during resuscitation of the newborn have changed significantly compared with previous guidelines. In the fifth edition of the *Neonatal Resuscitation Textbook*, providers were instructed to provide free-flow oxygen for babies who were breathing but had "persistent cyanosis." However, a study by O'Donnell et al[2] demonstrated that there is very little correlation between the perception of skin color by providers and actual oxygen saturation as measured by pulse oximetry. Furthermore, even brief exposure to oxygen has been associated with detrimental effects, including persistent evidence of oxidative stress, delay in taking the first spontaneous breath, and even an increase in the incidence of childhood leukemia.[3,4] Thus, the current recommendation is to use pulse oximetry to assess oxygenation in any infant in whom use of supplementary oxygen is considered, whether administered via a free-flow device or positive pressure ventilation (PPV). To provide sufficient but not excessive oxygen during the first few minutes after birth, providers should attempt to match the oxygen saturation (Spo_2) levels measured as those in healthy term infants.[5,6]

In cases where PPV is deemed necessary, the NRP has previously recommended the use of 100% oxygen. However, since the late 1990s, evidence has been growing to suggest that in many cases, 100% oxygen is not necessary for effective resuscitation and, in some instances, may be detrimental. Although there was considerable discussion during the 2005 consensus conference regarding the oxygen concentration (FIO_2) to use to initiate resuscitation in term infants, the members of the NRP Steering Committee came to the conclusion then that the evidence was not strong enough to warrant a change in practice. Additional evidence was reviewed by the neonatal task force for the 2010 guidelines, including several meta-analyses that showed similar or better outcomes[7,8] as well as less evidence of oxidative stress[9] in term infants resuscitated with 21% oxygen compared with those resuscitated with 100% oxygen. In addition, recent studies in animal models of pulmonary hypertension suggest that initial ventilation with 100% oxygen does not result in lower pulmonary

artery pressures than by use of 21% oxygen and may blunt the pulmonary vascular response to later treatment with inhaled nitric oxide.[10,11] On the basis of this evidence, the recommendations in the sixth edition textbook are to use 21% oxygen when initiating PPV in term infants, as well as in bradycardic infants, to increase the F_{IO_2} if there is no improvement in heart rate within 90 seconds.

Fewer data are available regarding the use of oxygen during resuscitation of preterm infants, although optimization of oxygen administration is even more critical in these babies since they are more susceptible to oxidant injury. Several studies have been published that compare resuscitation of preterm infants with various initial oxygen concentrations ranging from 21% to 100% and subsequent titration of the F_{IO_2} up or down based on S_{PO_2} and response to resuscitation.[12,13] The results of these studies suggest that starting resuscitation of preterm infants with 100% oxygen may result in periods of hyperoxemia whereas initial resuscitation with 21% oxygen may be associated with marked hypoxemia during the first few minutes after birth in some preterm infants. Clearly, further studies are needed to further refine the management of oxygen use during resuscitation in the preterm population, particularly in those infants who are less than 28 weeks' gestation. In the absence of additional data, the recommendation in the sixth edition is to use blended oxygen to resuscitate preterm infants, titrating the F_{IO_2} up or down as needed to achieve the same target S_{PO_2} levels as those in term infants. There currently is insufficient evidence to allow identification of the optimal starting oxygen level between 30% and 90%, the minimum and maximum levels of blended oxygen used in studies to date.

It is important to keep in mind that the sixth edition guidelines for the use of oxygen are based on investigations completed as of mid-2010 and reflect only the conditions and populations investigated by the authors of those studies. For example, there have been no published studies comparing resuscitation with an oxygen concentration greater than 21% (eg, 40%) with use of 21% or 100% oxygen in term infants. In addition, the degree of compromise in the subjects studied varied widely. Thus, it is not possible to draw conclusions regarding the potential risks or benefits of using specific oxygen concentrations in infants with severe asphyxia, due to the likelihood that the number of such infants was not high enough to make this determination, even in the largest studies.

Ensuring effective ventilation

The NRP has always emphasized that the key to resuscitation of the newborn with depression is effective ventilation. In most cases, bradycardia and respiratory depression in the newborn result from decreased or absent respiratory drive with subsequent failure to adequately clear fetal lung fluid and establish the functional residual volume.[14] This leads to hypoxemia and prevents the normal increase in blood oxygen levels and resulting decrease in pulmonary artery pressures. If PPV is provided in an effective and timely fashion, the situation can be reversed quickly and the baby's respiratory status and heart rate will increase.[14] However, ensuring adequate ventilation can be difficult in the newborn. There are no current readily available methods for measuring the volume delivered with each positive pressure breath or to determine whether functional residual capacity has been established in the absence of a clinical response. However, if chest compressions are initiated in response to the presence of a heart rate of less than 60 breaths per minute when ventilation is not being provided effectively, the heart rate is unlikely to improve.[1] This dilemma likely occurs more often than realized during resuscitation, particularly when the providers do not participate in neonatal resuscitations on a regular basis.

In previous editions of the NRP, initiation of chest compressions was recommended if the heart rate remained low after 30 seconds of effective ventilation. If the expected response to PPV does not occur, a series of corrective actions should be taken, including adjusting the mask on the face to ensure a good seal, repositioning the baby's head to make sure the airway is open, suctioning the oropharynx to remove any secretions that might be preventing adequate air entry, opening the baby's mouth slightly, and increasing the amount of positive pressure being delivered with each breath. If there is still no improvement, placement of a secure airway such as an endotracheal tube or laryngeal mask airway should be considered. Only after all of the ventilation corrective steps have been taken without an improvement in heart rate should a member of the team begin chest compressions. It is important to remember that chest compressions are not effective in improving circulation if oxygen delivery to the myocardium is inadequate, as is the case if the baby is not being ventilated properly. Thus, even after chest compressions are started, ongoing assessment of ventilation, including repeating some or all of the steps of the MRSOPA pathway (depending on airway status), may be necessary to ensure that effective ventilation is still being provided, especially if the baby is not improving.

Chest compressions

One of the major differences between the algorithm for resuscitation in neonates and those used to guide resuscitation in older children and adults is the ratio of

chest compressions to ventilations used. In the latter 2 groups, the standard compressions to ventilations ratio is 15:2; in contrast, the NRP guidelines call for the compressions to ventilation ratio of 3:1. Although there has been considerable discussion regarding whether neonates would benefit from a higher compression to ventilation ratio, there is currently no evidence to support a change in practice. The rationale for suggesting a higher ratio comes from studies that show that in adult animal models, giving a greater number of compressions before stopping to ventilate improves coronary artery perfusion and therefore myocardial function. However, there is a significant difference between the neonate requiring resuscitation and other patient populations, that is, in the vast majority of cases, the etiology of cardiac arrest or bradycardia in a neonate is respiratory in origin.[15] This is in contrast to the situation in the adult with cardiac arrest, where by far the most common cause is ventricular fibrillation or another acute cardiac event. In children greater than 6 months of age, there is a greater incidence of respiratory disease contributing to the need for resuscitation than in the adult, but a significant percentage of arrests are also due to a primary cardiac problem.[16] Another difference between resuscitation in the newborn (ie, delivery room resuscitation) and resuscitation in other patient populations is that the apneic infant in the delivery room may have been hypoxemic and bradycardic for some period of time before birth and therefore is more likely to be hypercarbic than the adult who, up until the moment of cardiac arrest, may have had normal respiratory function and normal blood gases.[17] These differences, combined with the absence of any data showing benefit to increasing the number of consecutive chest compressions per cycle in the neonate, support the continued use of the compressions to ventilation ratio of 3:1.

There are also some changes in the procedure for providing chest compressions in the sixth edition *Neonatal Resuscitation Textbook*. Several studies have shown that the 2-thumb technique is more effective than the 2-finger technique with regard to depth of compressions, pressure delivered, and consistency.[18,19] In addition, because there is an as yet unresolved question regarding the potential benefit of fewer interruptions in providing chest compressions, the time line in the algorithm has been modified. Although evaluation at approximately 30-second intervals is still recommended during the initial steps and when PPV is started, once chest compressions are being performed, the interval for assessing heart rate changes to 45 to 60 seconds in order to decrease the frequency of interruptions of chest compressions which, in adult animal models, has been shown to decrease diastolic blood pressure and coronary perfusion pressure.[20] However, a study of 5 adults with cardiac arrest found that blood pressure increased during pauses to assess cardiac rhythm[21]; thus, there is no conclusive evidence to support a change to a longer interval of chest compressions at present. Since most infants who reach the point of requiring chest compressions will have a pulse oximeter in place, it may be possible to assess heart rate without stopping compressions. However, if the baby is severely bradycardic and/or hypotensive, the pulse oximeter may not be able to detect adequate signal to provide a heart rate value. Thus, there will still be times when compressions must be interrupted to auscultate for heart rate.

The guidelines for administration of epinephrine in infants with severe bradycardia or undetectable heart rate remain the same, that is, epinephrine should be administered via the intravenous route. There is ongoing research to determine the optimal dosing of epinephrine as well as whether higher doses given via the endotracheal route might be effective. However, no new evidence has been published to support a change in the currently recommended dosing.

EDUCATION

Although the tendency is to focus on the steps of the resuscitation algorithm in any discussion of neonatal resuscitation, one cannot forget that no matter what techniques are recommended, they are effective only if delivered correctly. Thus, the most critical component of the algorithm may well be the NRP instructor. The NRP has relied on thousands of hospital-based and regional trainers to disseminate the educational program to providers throughout the country and around the world. Feedback from instructors and providers has guided some of the changes in the course materials and the approach to teaching for more than 20 years. For example, the fourth edition reflected a change to an educational approach that embraced principles of adult learning. The sixth edition brings even more significant changes in the way in which NRP education will be provided.

The changes in how NRP courses are taught resulted from looking at the process of adult education from a different perspective. In addition to cognitive skills, evaluated by the examination, and hands-on skills, evaluated by the skills stations and Megacode, there has been increasing recognition that the ability to successfully resuscitate a newborn also requires communication and teamwork skills. The last group of skills is much more difficult to teach and requires a different approach to learning. Whereas there is a right way and a wrong way to answer a factual questions (eg, " What is the compression to ventilation ratio?") or how to perform bag-mask ventilation, there are many different

approaches to working as a team during the resuscitation of a newborn. Determining the best way to facilitate the development of teamwork skills is a challenge faced by the members of the NRP Steering Committee and has been a topic of discussion for a number of years. On the basis of these discussions, as well as information derived from the NRP instructor survey and conversations with long-time instructors and regional trainers, some major changes in course format have been implemented.

The first major change is that there is no longer a paper test to be administered by instructors at the beginning of each course. Instead, each learner reviews the textbook and takes an online examination to demonstrate mastery of the cognitive material. The decision to make the change was due, in part, to responses to several questions on the instructor survey. Most instructors said they spent the biggest percentage of time during a provider course teaching the cognitive material using the slides provided. However, they also responded that lecturing was the least effective way to learn the NRP material. These responses suggested that instructor time is better spent teaching skills that cannot be learned easily by studying at home and that self-study was an appropriate route to mastering the cognitive material. Since an online examination has been available for a number of years, some instructors and learners have been using this format and so it is not completely unfamiliar.

Another significant change in the format of an NRP provider course is the addition of a simulation-based education component. This allows the learners to participate in resuscitation scenarios while working as a member of a team, an experience that is not provided by the Megacode. An important concept that is part of the simulation experience is that it is okay, and even beneficial, to make mistakes in a simulated learning environment. By discussing mistakes that occurred during the post–scenario debriefing, learners can reflect on what went wrong and discuss ways to prevent the same errors from occurring in a real-life situation. The use of simulation in resuscitation training is supported by studies that show simulation-based learning results in better performance in simulated resuscitation situations than traditional learning methods.[22,23] There are, understandably, fewer studies that show that simulation education results in improved performance and patient outcomes in the clinical setting, although this has been suggested by research on resuscitation of adults in the emergency department.[24]

The simulation and debriefing exercises have no specific "pass/fail" criteria or scoring system. Rather, the goal is for all of the team members to participate in their various roles during the resuscitation and to be able to assess the performance of the team from the point of view of specific teamwork behaviors. A crucial concept is that the role of the instructor during a debriefing is to facilitate the discussion by the members of the team rather than to point out errors or suggest changes. This is in alignment with concepts of adult education since it fosters self-directed learning and allows the participants to relate the simulations exercise to their own experiences, resulting in better internalization of the concepts and behaviors discussed than would occur when learners are "told" what they need to correct.

The addition of the simulation component to the NRP course has also resulted in a modification of the role of the Megacode. Rather than being the final "test" of mastery of the material, it is now the last component of the hands-on skills station section of the course. Its role in the sixth edition course structure is to provide a framework for the learner to demonstrate that he or she can put together all of the individual skills in the correct order during an ongoing resuscitation. Given this change, the Megacode has been relabeled the "Integrated Skills Station," reflecting the new purpose of completion of this exercise. Instructors can use checklists provided in the NRP materials to facilitate assessment of each learner's performance. Learners who, based on the instructor's assessment, do not succeed in completing the integrated skills station will be required to review the material and/or spend more time practicing the individual skills before repeating the Integrated Skills Station. Thus, the role of the instructor in assessing mastery of the second and third components of the course is more important than ever.

THE FUTURE OF THE NRP

Throughout its almost 25-year history, the NRP has been a dynamic educational program, adapting in response to new evidence, changes in clinical practice, and changes in learning strategies and available tools. Going forward, it is likely that the NRP will continue to change in response to the needs of its instructors and learners, embracing new technology and educational concepts, and changing practice guidelines as new data become available. In the future, modeling technology may be available that would allow learners to practice procedures such as intubation using a haptic simulator and instructors may receive modules on new instructional techniques via e-mail to be reviewed on their home computers. No matter what the practice guidelines state, or what the course format is, the goal will remain the same: to provide an educational program in neonatal resuscitation so that at each delivery there is an individual present who can resuscitate the newborn baby quickly and effectively.

References

1. Kattwinkel J, Perlman JM, Aziz K, et al. Neonatal resuscitation: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Pediatrics*. 2010;126:e1400–e1413.
2. O'Donnell CP, Kamlin CO, Davis PG, Carlin JB, Morley CJ. Clinical assessment of infant colour at delivery. *Arch Dis Child Fetal Neonatal Ed*. 2007;92:F465–F467.
3. Richmond S, Goldsmith J. Refining the role of oxygen administration during delivery room resuscitation: what are the future goals? *Semin Fetal Neonatal Med*. 2008;13:368–374.
4. Naumburg E, Bellocco R, Cnattingius S, Jonzon A, Ekbom A. Supplementary oxygen and risk of childhood lymphatic leukaemia. *Acta Paediatr*. 2002;91:1328–1333.
5. Mariani G, Dik PB, Ezquer A, et al. Pre-ductal and post-ductal O_2 saturation in healthy term neonates after birth. *J Pediatr*. 2007;150:4.
6. Dawson JA, Kamlin CO, Vento M, et al. Changes in heart rate in the first minutes after birth. *Pediatrics*. 2010;125:e1340–e1347.
7. Tan A, Schulze A, O'Donnell CP, Davis PG. Air versus oxygen for resuscitation of infants at birth. *Cochrane Database Syst Rev*. 2005;(2):CD002273.
8. Rabi Y, Rabi D, Yee W. Room air resuscitation of the depressed newborn: a systematic review and meta-analysis. *Resuscitation*. 2007;72:353–356.
9. Vento M, Asensi M, Sastre J, Lloret A, García-Sala F, Viña J. Oxidative stress in asphyxiated term infants resuscitated with 100% oxygen. *J Pediatr*. 2003;142:240–246.
10. Lakshminrusimha S, Swartz DD, Gugino SF, et al. Oxygen concentration and pulmonary hemodynamics in newborn lambs with pulmonary hypertension. *Pediatr Res*. 2009;66:539–544.
11. Steinhorn RH. Nitric oxide and beyond: new insights and therapies for pulmonary hypertension. *J Perinatol*. 2008;28(suppl 3):S67–S71.
12. 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.
13. Escrig R, Arruza L, Izquierdo I, et al. Achievement of targeted saturation values in extremely low gestational age neonates resuscitated with low or high oxygen concentrations: a prospective, randomized trial. *Pediatrics*. 2008;121:875–881.
14. Dawes GS. *Birth Asphyxia, Resuscitation, and Brain Damage*. Chicago, IL: Foetal and Neonatal Physiology, Yearbook Medical Publishers; 1968:141–159.
15. Perlman JM, Wyllie J, Kattwinkel J, et al. Neonatal resuscitation: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Pediatrics*. 2010;126:e1319.
16. Berens RJ, Cassidy LD, Matchey J, et al. Probability of survival based on etiology of cardiopulmonary arrest in pediatric patients. *Paediatr Anaesth*. 2011;21:834–840.
17. Bloom RS. Delivery room resuscitation of the newborn. In Fanaroff AR, Martin RJ, eds. *Neonatal-Perinatal Medicine*. 7th ed. Philadelphia, PA: Mosby Inc; 2002:376–402.
18. Udassi JP, Udassi S, Theriaque DW, Shuster JJ, Zaritsky AL, Haque IU. Effect of alternative chest compression techniques in infant and child on rescuer performance. *Pediatr Crit Care Med*. 2009;10(3):328–333.
19. Christman C, Hemway RJ, Wyckoff MH, Perlman JM. The two-thumb is superior to the two-finger method for administering chest compressions in a manikin model of neonatal resuscitation. *Arch Dis Child Fetal Neonatal Ed*. 2011;96:F99–F101.
20. Wang S, Li C, Ji X, Yang L, Su Z, Wu J. Effect of continuous compressions and 30:2 cardiopulmonary resuscitation on global ventilation/perfusion values during resuscitation in a porcine model. *Crit Care Med*. 2010;38:2024–2030.
21. Hoppu S, Sainio M, Huhtala H, Eilevstjønn J, Tenhunen J, Olkkola KT. Blood pressure during resuscitation in man—the effect of pause during rhythm analysis revisited. *Resuscitation*. 2011;82:1460–1463.
22. Kory PD, Eisen LA, Adachi M, Ribaudo VA, Rosenthal ME, Mayo PH. Initial airway management skills of senior residents: simulation training compared with traditional training. *Chest*. 2007;132:1927–1931.
23. Langhan TS, Rigby IJ, Walker IW, Howes D, Donnon T, Lord JA. Simulation-based training in critical resuscitation procedures improves residents' competence. *CJEM*. 2009;11:535–539.
24. 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.