

Pediatric Trauma: A Review

July thru September

2017

This continuing education packet covers pediatric trauma, head injuries, and pediatric sports related injuries. The content covers theory and practice that relates to the first responder thru critical care paramedics, including nursing, in pediatric trauma. The completion of this packet and associated quiz will give the participant 2 hours of medical director approved education in pediatric trauma.

**EMS
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Series**

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July 2017

Trauma is the most common cause of mortality and morbidity in the US pediatric population. Caring for the injured child requires special knowledge, precise management, and scrupulous attention to details. All clinicians who are responsible for the care of a pediatric trauma patient, including pediatricians, emergency room clinicians, pediatric emergency room clinicians, and trauma surgeons, must be familiar with every tenet of modern trauma care. The special considerations, characteristics, and unique needs of injured children must also be recognized. (Brian J Daley & Ramanathan Raju, 2015)

Epidemiology

Injury is the leading cause of death among children older than 1 year. In fact, for children, injury exceeds all other causes of death combined. Death from unintentional injury accounts for 65% of all injury deaths in children younger than 19 years. From 1972-1992, motor vehicle accidents (MVAs) were the leading cause of death in children aged 1-19 years, followed by homicide or suicide (predominantly with firearms) and drowning. Each year, approximately 20,000 children and teenagers die as a result of injury. Moreover, for every child who dies from an injury, 40 others are hospitalized and 1120 are treated in emergency departments. An estimated 50,000 children acquire permanent disabilities each year, most of which are the result of closed head injuries. Thus, pediatric trauma continues to be one of the major threats to the health and well-being of children.

Several factors influence childhood injuries, including age, sex, behavior, and environment. Of these, age and sex are the most important factors affecting the patterns of injury. Male children younger than 18 years have higher injury and mortality rates, perhaps in part because of their more aggressive behavior and exposure to contact sports. (Fabricant PD, 2013) In the infant and toddler age group, falls are a common cause of severe injury, whereas bicycle-related mishaps, with or without the interaction of motor vehicles, are the main culprits for injury of older children and adolescents. Use of helmets results in fewer head injuries and decreases the severity of them as well. Tragically, the home environment is the next most common scene of pediatric injury. Approximately 35% of significant injuries occur as the result of accidents in the very environment that should be the most sheltering and nurturing to children.

Most pediatric trauma occurs as a result of blunt trauma, with penetrating injury accounting for 10-20% of all pediatric trauma admissions at most centers. (Sheehan B, 2013) Gunshot wounds are responsible for most penetrating injuries and carry a significantly higher mortality compared with blunt mechanism injuries. A rising incidence of pediatric penetrating trauma, particularly penetrating thoracic

trauma, has occurred in recent years. Unfortunately, the proliferation of handguns and increased proclivity to urban violence in our society has increased the frequency of penetrating injury in children aged 13-18 years. Regardless of the classification, the 2 mechanisms of injuries are interrelated in that blunt mechanical force can result in penetrating injury, such as that caused by fender edges, door handles, or shrapnel. Thus, treating clinicians must be thorough and must proceed with a rational plan with scrupulous attention to detail.

A review by Guice and colleagues queried the Healthcare Cost and Utilization Project Kids' Inpatient Database to define contemporary trends in pediatric trauma epidemiology (Guice KS, 2007). Trauma continues to remain the leading cause of death for children aged 1-17 years. The average age in this review was about 10 years, and, for every year, male gender was more prevalent than female gender. This disparity increases toward adolescence, with boys having a significantly higher incidence of traumatic injury. Burns were found to be most common in children aged 1-4 years, upper limb fractures were found to be common in children aged 5-9 years, and lower limb fractures and traumatic brain injuries were found to be more common in adolescents.

Specific Injuries

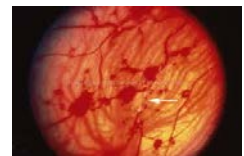
Approach Considerations

Developmental milestones correlate with mechanisms of childhood injuries. Head injuries, either alone or in association with multiple system injuries, are the most severe and cause the most deaths. Head injuries also account for most disability in children. All factors considered, clinicians must become aware of the anatomic and physiologic characteristics that make children unique.

CNS Injuries

Among children, the CNS is the most commonly injured isolated system. Because CNS injury is the leading cause of death among injured children, it is the principal determinant of outcome. However, numerous observations have shown that patients from the pediatric population recover more frequently and more fully than similarly injured adults. Although this might be euphemistically ascribed to the "physiologic reserve" of the child, it suggests that injured children respond exceedingly well to preservation of cerebral oxygenation and perfusion. Therefore, management of the whole patient must focus on preservation of cerebral perfusion and elimination of potential detrimental effects of extracranial lesions to it.

In children aged 2 years or younger, physical abuse is the most common cause of serious head injury. Shaken baby syndrome (SBS) is characterized by retinal hemorrhage¹, subdural or subarachnoid hemorrhage, and little evidence of external



¹ Retinal hemorrhage is a disorder of the eye in which bleeding occurs into the light sensitive tissue on the back wall of the eye.

trauma. In children aged 3 years and older, falls and motor vehicle, bicycle, and pedestrian accidents are responsible for most traumatic brain injuries.

Children tend to sustain injuries that produce diffuse edema rather than those that cause focal space-occupying lesions. At this point, precise management makes the difference between disaster and success. Judicious fluid resuscitation, precise ventilatory care, and careful titration of cerebral perfusion pressure are the keys to success.

The Glasgow Coma Scale (GCS) score is the universal tool for the rapid assessment of the consciousness level of injured children. A modified verbal and motor version has been developed to aid in the evaluation of consciousness level in infants and young children. The GCS score and its modified version (with scores of 3-15) are based on children's best response in 3 areas: (1) motor activity, (2) verbal response, and (3) eye opening. Traumatic brain injury in children is classified as mild (GCS 13-15), moderate (GCS 9-12), or severe (GCS 3-8). Regardless of the GCS score, a head CT scan should be performed on any child with a history of trauma and loss of consciousness longer than 5 minutes or an altered level of consciousness.

Several factors predict mortality with head injury. A presenting GCS score of less than 8, unilateral dilated pupil, and transcranial gunshot wound are associated with mortality of almost 70-98%. Hypotension and hypoxia should be aggressively avoided and are known to produce secondary injury. This secondary injury, when present, is a substantial cause of morbidity, and aggressive protocols to prevent it should be in place.

Mild Head Injury

A concussion is defined by the American Academy of Neurology as "trauma-induced alteration in mental status that may or may not involve loss of consciousness."

Children with a mild head injury (GCS 14-15)² with a history of transient loss of consciousness or amnesia of the events and normal findings on a head CT scan can be discharged and observed at home

² General Symptoms of Concussion

- Headaches or neck pain that do not go away
- Difficulty remembering, concentrating, or making decisions
- Slowness in thinking, speaking, acting, or reading
- Getting lost or easily confused
- Feeling tired all of the time, having no energy or motivation
- Mood changes (feeling sad or angry for no reason)
- Changes in sleep patterns (sleeping a lot more or having a hard time sleeping)
- Light-headedness, dizziness, or loss of balance
- Urge to vomit (nausea)

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after at least 6 hours of uneventful observation in the pediatric emergency department. Caretakers should be provided with specific discharge instructions. Warn caretakers of a possible post-concussion syndrome, which includes the constellation of headaches, memory loss, behavior disturbances, and impaired concentration. This should prompt reevaluation and possibly a repeat head CT scan.

The post-concussive symptoms can last up to months after the injury but only rarely extend beyond 3 months. No specific treatment exists for these symptoms other than symptomatic support; however, with severe mood alteration, psychiatric treatment may be indicated.

Determining which pediatric patients with mild head injury need neuroimaging studies has been difficult. It has been reported that less than 5% of children with mild head injury (variably defined) have CT findings indicative of traumatic brain injury. Also, the concern for limiting radiation exposure has led to scrutiny of this practice. A meta-analysis of 16 studies, including over 20,000 children with mild head injury, defined associated risk factors for traumatic brain injury. Skull fracture, focal neurologic signs, GCS less than 15, and loss of consciousness were all associated with traumatic brain injury. Headache and vomiting were not associated with traumatic brain injury with a presentation of mild head injury.

The very young child (< 2 y) with mild head injury is perhaps the most difficult evaluation. The limitations of the neurologic examination often present a decision-making dilemma as to the appropriate imaging studies. The key point to remember in this evaluation is that a higher index of suspicion is required in a young child as compared with an older child because there is a higher incidence of skull fracture and traumatic brain injury in a child younger than 2 years after mild head

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- Increased sensitivity to lights, sounds, or distractions
 - Blurred vision or eyes that tire easily
 - Loss of sense of smell or taste
 - Ringing in the ears

Children Concussion Symptoms

Children with a concussion can have the same symptoms as adults, but it is often harder for them to share how they feel.

- Tiredness or listlessness
- Irritability or crankiness (will not stop crying or cannot be consoled)
- Changes in eating (will not eat or nurse)
- Changes in sleep patterns
- Changes in the way the child plays
- Changes in performance at school
- Lack of interest in favorite toys or activities
- Loss of new skills, such as toilet training
- Loss of balance or unsteady walking
- Vomiting

injury. Up to 30% of children younger than 2 years with a skull fracture may have traumatic brain injury demonstrable on CT scan.

The current American Academy of Pediatrics consensus guideline for CT evaluation of children younger than 2 years after mild head trauma include signs of depressed or basilar skull fracture, acute skull fracture, altered mental status, focal neurologic findings, bulging fontanel, loss of consciousness for 1 minute or longer, and multiple episodes of emesis; these findings are indications to proceed with CT scan. In the absence of these findings, plain skull radiographs are a reasonable evaluation method, with the finding of skull fracture prompting further evaluation with CT scan given the high association of underlying brain injury with skull fracture in this population.

A study by Königs et al investigated the impact of pediatric traumatic brain injury (TBI) on attention, a prerequisite for behavioral and neurocognitive functioning. The study concluded that lapses of attention represent a core attention deficit in children with mild TBI or moderate/severe TBI, and relate to daily life problems after pediatric TBI. (Königs M, 2015) (K., 2015)

Severe Head Injury

The goal of initial resuscitation must be to limit or prevent secondary brain injury by maximizing cerebral perfusion and oxygen delivery while minimizing increased intracranial pressure (ICP). Hypoxia and hypotension should be aggressively treated. ICP monitoring is recommended in infants and children with a GCS score of 8 or less. Epidural hematoma occurs in about 2% of pediatric head trauma admissions. The characteristic lucid interval³ occurs in about 20 to 50% of patients with epidural hematoma.

Prospective data is limited in pediatric traumatic brain injury. Posttraumatic seizures may occur in up to 30%, and a lower GCS score portends a higher risk. There is insufficient data on prophylactic treatment in the pediatric population. When present, seizures should be treated to decrease metabolic demand and elevation of ICP that may extend an insult.

Spinal Cord Injury

Although spinal cord injury is relatively uncommon in the pediatric population, cervical spine injury must be presumed until proven otherwise. The most common cause of spinal cord injury (SCI) in the pediatric population is motor vehicle collision, accounting for about 40%. The common cervical fracture usually involves the first 2 vertebrae. If it remains undetected, cervical fracture can result in devastating injuries. Other common spinal fractures among pediatric patients with trauma are

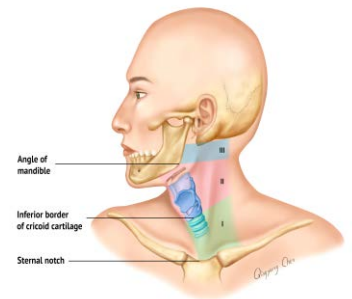
³ In emergency medicine, a lucid interval is a temporary improvement in a patient's condition after a traumatic brain injury, after which the condition deteriorates. A lucid interval is especially indicative of an epidural hematoma.

compression fractures and flexion-distraction (Chance) fractures of the lumbar spine, usually from inappropriate use of a lap seat belt.

Spinal cord injury without radiologic abnormality (SCIWORA) syndrome is a problem unique to the pediatric population. SCIWORA has been reported in 10-20% of children with SCI. The incompletely calcified vertebral column of the child may transiently deform and allow stretching of the cord or nerve roots with no residual anatomic evidence of injury. The hallmark of this syndrome is documented⁴ neurologic deficit that may have changed or resolved by the time the child has arrived in the emergency department. Immediate re-injury of the same area may produce permanent disability, so thorough neurosurgical evaluation is essential whenever reliable evidence of even a transient neurologic deficit is present.

Neck Injuries

There are 3 horizontal zones of the neck for classification of injury location. Zone 1 extends from the sternal notch to the cricoid cartilage. Zone 2 extends from the cricoid cartilage to the angle of the mandible. Zone 3



⁴ EMS providers must document all neurological deficits in the Patient Care Record (PCR) after a thorough examination paying close attention to the signs & symptoms of a spinal cord injury.

Spinal cord injuries of any kind may result in one or more of the following signs and symptoms:

- Loss of movement
- Loss of sensation, including the ability to feel heat, cold and touch
- Loss of bowel or bladder control
- Exaggerated reflex activities or spasms
- Changes in sexual function, sexual sensitivity and fertility
- Pain or an intense stinging sensation caused by damage to the nerve fibers in your spinal cord
- Difficulty breathing, coughing or clearing secretions from your lungs

Emergency signs and symptoms of spinal cord injury after an accident may include:

- Extreme back pain or pressure in your neck, head or back
- Weakness, incoordination or paralysis in any part of your body
- Numbness, tingling or loss of sensation in your hands, fingers, feet or toes
- Loss of bladder or bowel control
- Difficulty with balance and walking
- Impaired breathing after injury
- An oddly positioned or twisted neck or back

extends from the angle of the mandible to the skull base. Early airway control is paramount. Gross laryngotracheal injury, stridor, pulsatile bleeding, or expanding hematoma requires urgent operative treatment. Local exploration or probing of wounds is not recommended.

A 5-year retrospective study of pediatric admissions with penetrating neck injury was conducted by Abjorama et al., in this study, 31 children (mean age, 9.5 y) were examined. Most of these injuries (84%) were in zone 2. The 3 deaths had major findings on presentation and were characterized to be in extremis. A major physical examination finding was defined as shock, neurologic deficit, pulsatile hematoma, bruit/thrill, absence of pulses, or crepitus. Surgical exploration was conducted in 31% (8 patients), and all yielded negative findings. (Abujamra L, 2003)

Oropharyngeal injury represents a complex array of injury, and most are due to falls in the pediatric population. The generous blood supply to this area usually leads to excellent healing but also can result in copious bleeding from wounds.

Ocular Trauma

Half of pediatric eye injuries occur during sporting events. Significant morbidity may result from pediatric eye trauma because of the continued development of the visual system up to age 9 years. (Similarly, the full adult complement of pulmonary alveoli is not present until about age 7 years.) If a rupture of the globe is suspected, the examination should cease; the eye should be covered with a protective device, and urgent ophthalmologic consultation is indicated.

In evaluation of a foreign body, topical anesthetic may be useful for a complete examination. The lid should be everted with a cotton swab for a thorough evaluation. Examination should include an assessment of visual acuity and extraocular motion⁵. Eyelid lacerations deserve careful evaluation for lacrimal duct involvement. Orbital floor fractures may result in entrapment of extraocular muscles with complaints of diplopia⁶.

Thoracic Injuries

Thoracic injury is the second leading cause of death in pediatric trauma. Thoracic injury occurs in about 5% of children hospitalized for trauma. Blunt trauma, particularly from MVAs, is responsible for most thoracic injuries. Not surprisingly, isolated thoracic injuries seen commonly in adults are relatively

⁵ Check extraocular movements (eye movements) by having the patient look in all directions without moving their head and ask them if they experience any double vision.

⁶ Diplopia is the subjective complaint of seeing two images instead of one and is often referred to as double-vision in lay parlance. An accurate, clear description of the symptoms (eg, constant or intermittent; variable or unchanging; at near or at far; with one eye [monocular] or with both eyes [binocular]; horizontal, vertical, or oblique) is critical to appropriate diagnosis and management.

uncommon in children. The pediatric thorax has a greater cartilage content and incomplete ossification⁷ of the ribs. Due to the pliability of the pediatric rib cage and mediastinal mobility, significant intrathoracic injury may exist in the absence of external signs of trauma. Pulmonary contusion and pneumothorax are frequently present without rib fractures. Pulmonary contusion, pneumothorax, and rib fractures are the most common injuries. Hemothorax and pneumothorax are the most common thoracic injuries from penetrating trauma. Physical examination of the traumatized pediatric thorax is notoriously unreliable and requires careful assessment.

Over half of rib fractures in children younger than 3 years may be due to child abuse. Pain control and aggressive pulmonary toilet are the mainstays of treatment of rib fractures. Fixation of flail segments is rarely required. With pulmonary contusion, progressive inflammation may lead to edema, atelectasis⁸, and consolidation⁹. Hypoxemia, hypercarbia, and tachypnea may result. Most respond to supportive treatment and heal in 7-10 days.

Parenchymal cavitation¹⁰ from blunt trauma may cause pneumatocele¹¹. They may become infected or expand requiring surgical intervention, while most resolve slowly. Pulmonary laceration can be a source of persistent bleeding and air leak. Tube thoracostomy¹² allows small lacerations to seal spontaneously, while larger lacerations require surgical treatment. Tracheobronchial injury usually occurs near the carina and is thought to stem from anterior-posterior compression of the pliable pediatric chest. Multiple findings may be present including pneumothorax, hemothorax, pneumomediastinum, subcutaneous emphysema, and hemorrhage. Persistent air leak is common. If the injury involves less than one third of the diameter of the bronchus, nonoperative therapy may be suitable; otherwise, most require open repair.

⁷ Ossification (or osteogenesis) in bone remodeling is the process of laying down new bone material by cells called osteoblasts. It is synonymous with bone tissue formation.

⁸ Atelectasis is the collapse or closure of a lung resulting in reduced or absent gas exchange. It may affect part or all of a lung. It is usually not bilateral.

⁹ A pulmonary consolidation is a region of (normally compressible) lung tissue that has filled with liquid, a condition marked by induration (swelling or hardening of normally soft tissue) of a normally aerated lung.

¹⁰ Parenchyma is the functional tissue of an organ as distinguished from the connective and supporting tissue. Cavitation is the formation of an empty space within a solid object or body.

¹¹ Pneumatoceles are thin-walled, air-filled cysts that develop within the lung parenchyma. They can be single emphysematous lesions but are more often multiple, thin-walled, air-filled, cystlike cavities.

¹² A thoracostomy is a small incision of the chest wall, with maintenance of the opening for drainage. It is most commonly used for the treatment of a pneumothorax.

Great vessel injury is rare. The diagnosis is suggested by a finding of widened mediastinum on plain film. Most thoracic aortic injury occurs via blunt mechanism (eg, MVA, pedestrian, falls), in older children (mean age, 12 y), and at the ligamentum arteriosum¹³ (77-90%). This injury is highly morbid and requires rapid diagnosis and treatment. Preoperative blunt aortic injury management should include aggressive blood pressure control with beta blockade. Blunt cardiac injury is rare in children. Traumatic cardiac rupture is uniformly fatal. Traumatic cardiac contusion may result in arrhythmia, myocardial hypokinesia, and abnormal cardiac serum enzymes.

Sudden unexpected cardiac death that occurs in young people during sports participation is usually associated with previously diagnosed or undiagnosed structural or primary electrical cardiac abnormalities. Examples of such abnormalities include hypertrophic cardiomyopathy, anomalous origin of a coronary artery, arrhythmogenic right ventricular cardiomyopathy, and primary electrical disorders, such as congenital prolongation of the QTc interval and catecholaminergic, polymorphic ventricular tachycardia (CPVT). Sudden death due to ventricular fibrillation may also occur following a blunt, nonpenetrating blow to the chest, specifically the precordial area, in an individual with no underlying cardiac disease. This is termed commotio cordis.

Commotio cordis typically involves young, predominantly male, athletes in whom a sudden, blunt, nonpenetrating and innocuous-appearing trauma to the anterior chest results in cardiac arrest and sudden death from ventricular fibrillation. The rate of successful resuscitation remains relatively low but is improving slowly. Although commotio cordis usually involves impact from a baseball, it has also been reported during hockey, softball, lacrosse, karate, and other sports activities in which a relatively hard and compact projectile or bodily contact caused impact to the person's precordium.

Traumatic Asphyxia

Traumatic asphyxia is a unique injury in pediatric trauma because of the compliance of the chest wall. This injury is commonly the result of blunt compressing thoracic trauma, with sudden airway obstruction and abrupt retrograde high pressure in the superior vena cava. Patients with traumatic asphyxia have a dramatic physical presentation characterized by cervical and facial petechial hemorrhages or cyanosis associated with vascular engorgement and subconjunctival hemorrhage. Despite its dramatic presentation, this injury has a good prognosis. CNS injuries, pulmonary contusions, and intra-abdominal injuries are common associated injuries.

¹³ Several mechanisms have been postulated as to why the isthmus portion is the most common site of aortic rupture. The most widely accepted theory suggests that in nonpenetrating chest traumas, sudden high-velocity deceleration is accompanied by hyperflexion of the spine leading to sudden chest compression and traction on the aortic isthmus, the point at which the mobile aortic arch meets the fixed proximal descending thoracic aorta. Another theory suggests a "shoveling effect," as a lower thoracic impact results in cranial displacement of the mediastinum and torsion of the isthmus. The "osseous pinch" theory suggests that the proximal descending aorta is pinched between the sternum, upper ribs, and clavicles anteriorly and the vertebral column posteriorly. A less favorable theory suggests a "water-hammer" effect, where an acute rise in aortic pressure exerts maximum stress on the aortic isthmus.

Abdominal Injuries

Anatomical differences in children make them more vulnerable to major abdominal injuries with very minor forces. In children, the abdomen begins at the level of the nipple. Children's small, pliable rib cages and undeveloped abdominal muscles provide little protection of major organs. Solid organs (eg, spleen, liver, kidneys) are vulnerable to injury.

Abdominal Wall Bruising

Bruising of the abdominal wall after a motor vehicle collision is an important finding. This is usually the result of a lap seat belt or a restraint device. A seat belt syndrome has been described as the concurrent findings of abdominal wall bruising, intra-abdominal injury, and vertebral fracture. (Achildi O, 2007)

The most common intra-abdominal injury associated with abdominal wall bruising is a hollow viscus. Vertebral fracture is also highly associated with abdominal wall bruising and may be present in up to 50% of patients. Chest and/or abdominal abrasion at the site of seat belt contact are commonly seen, and with the exception of subcutaneous bruising, the sternal fracture is the most common injury caused by the seat belt.

Stomach Injuries

The great majority of abdominal injuries are secondary to blunt trauma, and blunt injuries to the stomach occur more frequently in children than in adults. The injury is usually a blowout or perforation of the greater curvature. Children who are struck by a vehicle or who fall across bicycle handlebars shortly after eating a meal are at greater risk. Consider injury to the stomach if the child has peritoneal signs and/or bloody nasogastric drainage.

Duodenal Injuries

These injuries are relatively uncommon in children compared to adults. Most pediatric duodenal injuries, such as intramural duodenal hematoma¹⁴, are from blunt trauma and are often associated with child abuse. Intramural duodenal hematoma has many clinical and therapeutic puzzling aspects. Bicycle handlebar, road accidents and sports trauma are the main etiologic factors in children, but child abuse should be kept in mind.

¹⁴ Blunt trauma to the upper abdomen may cause bleeding into the wall of the proximal small intestine resulting in occlusion of the bowel lumen by an expanding hematoma. This unusual mechanism of high intestinal obstruction is more common in children than in adults. The diagnosis of traumatic intestinal hematoma should be strongly suspected when a child presents with evidence of high small intestinal obstruction and a history of recent trauma to the abdomen.

Associated injuries - The scope of injuries associated with pancreatic and duodenal trauma is illustrated in the following retrospective reviews:

In a review of 1153 cases of duodenal injury, there were 3047 associated injuries. The liver was the most commonly injured organ, accounting for 17 percent of associated injuries. Other organs injured along with the duodenum included the pancreas (12 percent), small bowel (12 percent), colon (12 percent), and stomach (9 percent). (Paul Maggio, 2016)

In another review of 3465 injuries involving the pancreas, there were 7526 associated injuries [9]. The liver was also the most commonly injured, accounting for 19 percent of associated injuries. Other organs injured along with the pancreas included the stomach (16 percent), spleen (11 percent), colon (8 percent), and duodenum (8 percent). (Paul Maggio, 2016)

Because of the proximity of the major vascular structures including the aorta, vena cava, and portal vein, injury to the duodenum and pancreas can be associated with exsanguinating hemorrhage. In the first review discussed above, major abdominal veins were injured in 10 percent of patients, mostly involving the inferior vena cava, and major arteries were injured in 7 percent of patients, mostly involving the aorta. Penetrating injury is more likely to result in vascular injury, with one review documenting that 37 percent of patients with penetrating pancreatic injury had major vascular injuries. Major venous injuries were present in 20 percent of patients with blunt duodenal injury, but there were no associated arterial injuries. (Paul Maggio, 2016)

Small Intestinal Injury

The most common intra-abdominal organs injured in restrained children involved in MVAs are hollow viscus type. Several mechanisms have been proposed for this type of injury. Rapid deceleration may cause the lap belt to compress the intestines against the spine. An increase in intraluminal pressure may lead to rupture or tear. This is the most common mechanism of injury to the pediatric duodenum. Duodenal hematoma may result and cause obstruction. Luminal stricture¹⁵ may present several weeks after blunt intestinal injury as persistent nausea and bilious emesis. Mesenteric¹⁶ hematoma is also possible.

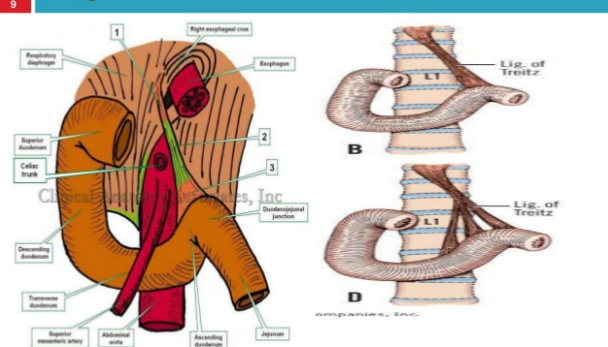
The incidence of intestinal injury in children with blunt trauma is estimated to be 1-15%. In comparison, colon injury from blunt trauma is rare.

¹⁵ Luminal stricture is an abnormal narrowing of a bodily duct or passage in the inner open space or cavity of a tubular organ, as of a blood vessel or an intestine.

¹⁶ Mesenteric - pertaining to the mesentery, the double layer of peritoneum suspending the intestine from the posterior abdominal wall.

As with adults, small intestinal injury in children occurs in the areas of fixation at the Treitz ligament or at the ileocecal valve. The most common site of the intestinal tract to be injured is the jejunum in the area of the area of the Treitz ligament. Such injury occurs in association with lap seat belt use or rapid deceleration. Up to 50% of children with lap seat belt injuries have associated retroperitoneal injuries. Associated injuries, such as flexion-distraction lumbar spine injury, may also occur. Penetrating intestinal injury presents unique diagnostic and therapeutic challenges. If the peritoneum has been violated by such an injury, exploratory laparotomy is generally recommended.

Suspensory ligament of duodenum or ligament of Treitz



With blunt or penetrating abdominal trauma, a high index of suspicion should be maintained for small intestine injury, because a delay in diagnosis or an unrecognized injury can result in substantial morbidity. Fewer than 50% of children with blunt intestinal perforation have peritonitis on initial examination. Abdominal tenderness is a consistent finding. Pneumoperitoneum or contrast extralumination on imaging study should prompt exploration as well.

Penetrating Abdominal Injuries - The bowel was the most commonly injured organ (51.7%), with omentum/bowel evisceration through the wound in 7 patients, none of whom had organ injury. Of the 39 children who were managed surgically, 6 (15%) had no significant organ injury found during surgery; of the 51 patients who initially received conservative therapy, 2 children (3.9%) required surgery. The investigators concluded that in the absence of hemodynamic instability or signs of hollow viscus perforation, the majority of abdominal stab wounds and many gunshot wounds in children can initially be managed nonoperatively. (Cigdem MK, 2009 Dec.)

Rectal Injuries

Except for the occasional straddle injury, child abuse or deviant sexual activity causes most isolated rectal injuries in children. Examine rectal injuries while the patient is under anesthesia because tissues are frequently painful. Examination under anesthesia also decreases the psychologic trauma of such an invasive examination. Rectal mucosal or superficial anal injuries usually resolve with conservative treatment, but full-thickness injuries or internal sphincteric injury may require surgical repair. If child abuse is a possibility, contact the appropriate agency¹⁷.

¹⁷ Mandatory reporting to the appropriate Law Enforcement Agency that has jurisdiction or to the Department of Health and Human Services; Kenosha County call the ACCESS number at 262-605-6582, Racine County call 262-638-7720, Rock County call 608-757-5401, and Walworth County call 262-741-3200 or call toll free 800-365-1587. Mandated reporters include physicians, nurses, EMT's, and Paramedics.

Solid Organ Injury Management

Nonoperative management is considered the standard of care for most children with blunt solid organ injury who are clinically stable. This approach was pioneered in children and has led to a dramatic change in practice in adult patients regarding management of solid organ injury.

The data emphasize the importance of early vigilance in the care of the child with a solid organ injury. Those who will fail nonoperative management will likely do so early, within the first 12 hours. An important finding is that pancreatic injuries do not behave like other injured solid organs and are associated with a higher need for operative intervention. A key distinction between adult and pediatric nonoperative management of solid organ injury is that adults are more prone to late failure (eg, >5 d), whereas 98% of pediatric failure is within 72 hours. The reasons for declaration of failure were shock, peritonitis, persistent hemorrhage, pancreatic injury, hollow viscus injury, and ruptured diaphragm. (Holmes JH 4th, 2005 Dec.)

For isolated liver or spleen injury, current recommendations for length of stay and observation are per Stylianos and the American Pediatric Surgical Association (APSA). [14] These recommendations are based on CT grade of injury. For grade 1 injury, no ICU stay, 2 total hospital days, and 3 weeks activity restriction. For grade 2 injury, no ICU stay, 3 total hospital days, and 4 weeks activity restriction. For grade 3 injury, no ICU stay, 4 total hospital days, and 5 weeks activity restriction. For grade 4 injury, 1 day of ICU stay, 5 total hospital days, and 6 weeks of activity restriction. These guidelines have been prospectively evaluated and demonstrate significant reduction in length of stay without adverse sequelae. (Holmes JH 4th, 2005 Dec.)

Splenic Injuries

Splenic injuries are relatively common in pediatric trauma. Successful conservative management of splenic injury was reported in 1968 by Upadhyaya et al. Because of the risk of overwhelming sepsis following splenectomy (OPSS), the current philosophy is to manage splenic injuries conservatively unless the spleen is hemodynamically compromised. OPSS occurs slightly more frequently after splenectomy in the treatment of hematologic disease compared with the lower incidence after traumatic splenectomy. Age younger than 5 years at the time of splenectomy also increases the risk. (Upadhyaya, 2003 Nov.) A child's spleen stops bleeding spontaneously; therefore, most patients with splenic injuries respond to nonoperative management.

Hepatic Injury

Isolated hepatic injury, without disruption of the portal vein, hepatic vein, or suprarenal inferior vena cava, behaves clinically like a splenic injury. Most patients with these injuries respond to nonoperative management. The same criteria for selecting nonoperative or operative treatment for patients with splenic injury are now being selectively used for patients with documented hepatic

injuries. The success rate for nonoperative management of blunt hepatic injury is about 85-90%. The exception, of course, is for children with a massive hepatic injury or with perihepatic vascular involvement who are not hemodynamically stable and transfusion requirements of greater than 25-40 mL/kg/d.

Pancreatic Injury

Blunt trauma causes most pancreatic injuries. A frequently cited mechanism involves falling into bicycle handlebars. Timely diagnosis of major pancreatic injuries and prompt surgical treatment are essential to decrease mortality and morbidity rates in pediatric patients.

Renal Injury

Blunt abdominal trauma involves renal injury in 10-20% of cases. Renal trauma comprises 1.6% of total injuries, and 90% of these injuries are from a blunt mechanism of injury. The pediatric kidney is more susceptible to blunt injury due to the relative lack of perirenal fat and decreased protection from incompletely ossified ribs. Contusion is the most common renal injury encountered in children. Disruption of the ureteropelvic junction from transient axial torsion and parenchymal injury due to preexisting renal abnormalities are the next most common renal injuries. These lesions are commonly associated with direct blows to the back or flank.

The concept of nonoperative management has been expanded to include renal injuries as well. Conservative management is standard for low-grade renal injury (grades I-III). A treatment strategy adopted by some level I trauma centers includes bed rest for 24 hours, serial hematocrit, heart rate monitoring, and frequent physical examinations.

Vascular Injuries

Vascular injuries in children require early diagnosis and aggressive operative management to prevent serious sequelae. An injury to a major artery in a child's extremity can result in ischemia and growth retardation of that limb if not detected in a timely manner.

Most vascular injury is associated with orthopedic injuries, such as supracondylar fracture or long-bone fracture. The presence of hard signs mandates operative exploration and repair. These signs are pulsatile bleeding, expanding hematoma, absent pulses, cold limb, and bruit/thrill. If a vascular injury is thought to be present, objective studies (eg, Doppler studies, arteriography) may be required. The most important differential diagnosis in pediatric vascular trauma is between thrombosis and spasm of the injured vessel. Spasm usually lasts less than 3 hours. When the pulses remain absent longer than 6 hours, thrombosis or transection of the vessel must be excluded. A delay in diagnosing vascular injury

could lead to prolonged ischemia, compartment syndrome, and Volkmann contractures¹⁸, with consequent long-term disability.

Penetrating Injuries

The lethality of penetrating injuries is about 3 times that of blunt injury. Several factors having prognostic value have been identified. An arrival systolic blood pressure of less than 90 mm Hg and an initial core temperature of less than 34°C (93.2° F) correlate with mortality of penetrating trauma patients. Specific injuries are discussed in other sections within this article. Impalement injuries are uncommon, and the recommendation is to leave them in place until they can be removed in the operating room because of the potential for hemorrhage.

Orthopedic Injuries

Approximately 30-45% of children with trauma have multiple injuries and at least 1 skeletal fracture. Careful evaluation of every extremity is essential, and the possibility of deformity or associated fracture must be excluded. Splint fractured limbs effectively¹⁹ to prevent ongoing hemorrhage and to reduce occurrence of fat emboli syndrome. Carefully assess every limb for the presence of distal pulses. Adequate documentation of intact sensation is critical. Pediatric bone is relatively soft and prone to incomplete fracture, such as greenstick type. Inappropriate use of a seat belt in children can also result in associated lumbar spine fractures (Chance fractures) and hollow visceral injuries, primarily of the small bowel. The clinician must be aware of associated injuries when lap seat belts are involved.

Air Bag Injuries

Air bags can save lives and prevent injuries when seat belts and car seats are used correctly. Failure to adhere to safety regulations can result in childhood fatalities. The American Academy of Pediatrics has recommended that children aged 12 years and younger ride in the back seat. Most pediatric injuries are a result of proximity to air bag deployment and unused or improperly used seat belts. A deploying air bag can reach speeds of more than 240 km/h (150 mph), so it is not surprising that internal organ injuries have been reported. In children facing forward, injuries include abrasions and friction burns to the face, neck, chest, inner arms, and upper thighs. As the child moves closer, more severe head and neck injuries can occur, such as basilar skull fractures and/or SCIWORA. The



¹⁸ Volkmann ischemic contracture is a deformity of the hand, fingers, and wrist caused by injury to the muscles of the forearm. Volkmann contracture occurs when there is a lack of blood flow (ischemia) to the forearm.

¹⁹ A basic rule of splinting is that the joint above and below the broken bone should be immobilized to protect the fracture site. Protect open wounds, including open fractures.

safest place for a child is in the middle of the back seat, either in a safety seat or in a 3-point restraint.

Child Abuse

Child abuse includes physical abuse, sexual abuse, emotional abuse, and child neglect. Child abuse involves children of all ages and crosses all socioeconomic boundaries, although poverty, a young single parent, and substance abuse contribute to the risk factors. Most abused children are younger than 3 years, with one third being younger than 6 months.

Because signs and symptoms of abuse can be subtle, maintain a high level of clinical awareness when evaluating these children. The history and mechanism of alleged trauma must be consistent. Infants and children younger than 2 years are more prone to present with closed-head trauma as a result of SBS. Older children, as they begin to explore their surroundings, are more likely to sustain physical abuse as a form of discipline, so abdominal trauma, skeletal trauma, and cutaneous injuries are more commonly observed. Prepubescent children and adolescents often experience sexual abuse and are less likely to report such assaults. Certain characteristic findings may suggest child abuse. Fundoscopic²⁰ examination may reveal retinal hemorrhages suggesting SBS. Radiographic skeletal survey may demonstrate multiple fractures in various stages of healing.

Sports Injuries

Although sports participation provides numerous physical and social benefits, it also has a downside: the risk of sports-related injuries. According to the Centers for Disease Control and Prevention, more than 2.6 million children 0 to 19 years old are treated in the emergency department each year for sports and recreation-related injuries.

These injuries are by far the most common cause of musculoskeletal injuries in children treated in emergency departments. They are also the single most common cause of injury-related primary care office visits. Although sports injuries can range from scrapes and bruises to serious brain and spinal cord injuries, most fall somewhere between the two extremes. Here are some of the more common types of injuries.

Sprains and Strains

A sprain is an injury to a ligament, one of the bands of tough, fibrous tissue that connects two or more bones at a joint and prevents excessive movement of the joint. An ankle sprain is the most common athletic injury.

²⁰ Ophthalmoscopy, also called funduscopy, is a test that allows a health professional to see inside the fundus of the eye and other structures using an ophthalmoscope (or funduscope).

A strain is an injury to either a muscle or a tendon. A muscle is a tissue composed of bundles of specialized cells that, when stimulated by nerve messages, contract and produce movement. A tendon is a tough, fibrous cord of tissue that connects muscle to bone. Muscles in any part of the body can be injured.

Growth Plate Injuries

In some sports accidents and injuries, the growth plate may be injured. The growth plate is the area of developing tissues at the end of the long bones in growing children and adolescents. When growth is complete, sometime during adolescence, the growth plate is replaced by solid bone. The long bones in the body include:

- the long bones of the hand and fingers (metacarpals and phalanges)
- both bones of the forearm (radius and ulna)
- the bone of the upper leg (femur)
- the lower leg bones (tibia and fibula)
- the foot bones (metatarsals and phalanges)

If any of these areas becomes injured, it's important to seek professional help from an orthopaedic surgeon, a doctor who specializes in bone injuries.

Repetitive Motion Injuries

Painful injuries such as stress fractures (a hairline fracture of the bone that has been subjected to repeated stress) and tendinitis (inflammation of a tendon) can occur from overuse of muscles and tendons. Some of these injuries don't always show up on x-rays, but they do cause pain and discomfort. The injured area usually responds to rest, ice, compression, and elevation (RICE). Other treatments can include crutches, cast immobilization, and physical therapy.

Traumatic Brain Injury

Traumatic brain injury (TBI) is one of the leading causes of acquired disability and death in infants and children. Falls and motor vehicle collisions are common unintentional causes, whereas child abuse in infants and young children and assaults in adolescents are unfortunate inflicted causes of TBI. Management focuses on limiting progression of the primary brain injury and minimizing secondary brain injury. Research has revealed important age-dependent responses following pediatric traumatic brain injury.

Primary brain injury

Primary injury to the brain occurs as an immediate consequence of the force of the trauma. Linear forces as a result of direct blows to the head generate focal injuries such as intracranial hemorrhages and contusions. Intracranial hemorrhage resulting from trauma typically occurs in 4 locations: epidural, subdural, subarachnoid, and intraparenchymal.

Contusions are bruises of the brain parenchyma²¹ as a result of blunt head injury that causes the brain surface to impact the bony ridges of the skull. Injury patterns include acceleration-deceleration injuries, where the brain strikes the skull in a “coup-contracoup” fashion, with the “coup” contusion occurring at the site of impact and the “contracoup” contusion located directly opposite the site of impact.

Clinical symptoms relate to the severity and location of injury. Contusions may lead to local edema and ischemia with resultant neurologic deterioration, increased intracranial pressure (ICP) and intracranial hypertension, and brain herniation.

Acceleration-deceleration injuries can also generate inertial, angular forces resulting in physical shearing or tearing of axons termed primary axotomy. Rotational forces on the brain during acceleration-deceleration injuries cause widespread damage to axons in the white matter of the brain and should be suspected in a child when the degree of neurologic deterioration is associated with a relatively unremarkable CT scan.

Secondary brain injury

Secondary brain injury develops in the initial minutes to weeks following primary brain injury and occurs in two forms. The first form of secondary brain injury is potentiated by a myriad of physiologic and metabolic alterations, including but not limited to, the following:

- Hypoxemia
- Hypotension
- Elevated intracranial pressure and intracranial hypertension
- Hypercarbia or hypocarbia
- Hyperglycemia or hypoglycemia
- Electrolyte abnormalities
- Enlarging hematomas
- Coagulopathy
- Seizures
- Hyperthermia

²¹ Parenchyma - the functional tissue of an organ as distinguished from the connective and supporting tissue.

This form of secondary brain injury is potentially avoidable and is amenable to treatment. Currently, the primary focus in the acute management of traumatic brain injury is to prevent or ameliorate²² these events that promote secondary brain injury.

The second form of secondary brain injury includes a cascade of cellular events that occur in the initial minutes and extend into the weeks following the primary injury, leading to neuronal cell degeneration, ongoing or secondary traumatic axonal injury (TAI), and, ultimately, neuronal cell death. Some of these mechanisms include cerebrovascular dysregulation, cerebral swelling, traumatic axonal injury, necrosis and apoptosis, and inflammation. Although vigorous research continues in these areas, no treatment for this type of secondary brain injury is available. (Felice Su, 2015 Nov)

Age-Dependent Etiology

Age-dependent injury patterns exist. Abusive or intentional injury is a major cause of morbidity and mortality in infants and young children. Unintentional injuries in this age group occur as a result of falls and motor vehicle collisions. Falls become the predominant mechanism of injury by the toddler age. Among motor vehicle–related injuries in this age group, motor-pedestrian injuries are more common than motor vehicle occupant injuries. School-aged children exhibit a rise in bicycle-related injuries. Adolescents experience a rise in motor vehicle injuries, sports-related injuries, and assaults. (Felice Su, 2015 Nov)

Children appear to experience age-dependent pathology following pediatric TBI. In infants and young children, subdural hematomas and diffuse injury (eg, diffuse cerebral swelling) are more common than focal injuries (eg, contusions). Hypoxic-ischemic injuries appear to be less common in unintentional TBI.

Treatment & Management

In 2012, the Society of Critical Care Medicine and World Federation of Pediatric Intensive and Critical Care Societies published the second edition of the Guidelines for the Acute Management of Severe Traumatic Brain Injury for Infants, Children, and Adolescents, based on a review of the pediatric TBI literature. (Society of Critical Care Medicine, 2012 Jan.) A brief synopsis of the guidelines is discussed below, but the reader is urged to read the actual guidelines for complete details.

Initial intervention for patients with TBI focuses on detection of primary injury and prevention or treatment of secondary brain injury. The following treatable conditions can exacerbate secondary brain injury:

- Hypoxemia

²² Ameliorate - make (something bad or unsatisfactory) better.

- Hypotension
- Elevated intracranial pressure leading to intracranial hypertension
- Hypercarbia or hypocarbia
- Hyperglycemia or hypoglycemia
- Electrolyte abnormalities
- Enlarging hematomas
- Coagulopathy
- Seizures
- Hyperthermia

Primary interventions

Treatment of severe TBI (Glasgow coma scale [GCS] score, 3-8) follows current trauma life-support guidelines. Stabilization begins with applying the basic elements of resuscitation: securing the airway, achieving adequate oxygenation and ventilation, and avoiding or rapidly treating hypotension.

Early airway management involves providing proper airway position, clearance of debris while keeping cervical spine precautions in place, and orotracheal intubation. Hypercarbia and hypoxia must be avoided because they are both potent cerebral vasodilators that result in increased cerebral blood flow and volume and, potentially, increased ICP and intracranial hypertension. Orotracheal intubation allows for airway protection in patients who are severely obtunded and allows for better control of oxygenation and ventilation.

In the initial resuscitation period, efforts should be made to maintain eucapnia²³ at the low end of the normal reference range (PaCO₂ of 35-39 mm Hg) and prevent hypoxia (PaO₂ < 60-65 mm Hg) to prevent or to limit secondary brain injury. Nasotracheal intubation should be avoided because of the risk of cervical spine injury and direct intracranial injury, especially in patients with basilar skull fractures.

Special neuroprotective considerations must be given to the choice of medications used to facilitate endotracheal intubation. These considerations are as follows:

- Prevent elevated ICP
- Minimize cerebral metabolic rate of oxygen consumption
- Avoid hypotension

Common medications used in the intubation of patients with traumatic brain injury include midazolam, fentanyl, etomidate, and/or lidocaine along with neuromuscular blockade. Potential specific side effects of these medications include (but are not limited to) hypotension, chest wall rigidity, adrenal suppression, and myoclonus.

²³ Eucapnia - the condition of having a normal, healthy concentration of carbon dioxide in the blood.

Propofol is not currently recommended, because of the risk of propofol infusion syndrome, which consists principally of cardiac failure, rhabdomyolysis, severe metabolic acidosis, and renal failure. (Society of Critical Care Medicine, 2012 Jan.) Although the syndrome is rare and is typically associated with prolonged use of high doses of propofol, it is often fatal.

Ketamine is commonly avoided because it is thought to have the potential for elevating ICP. However, a recent prospective, controlled, clinical trial of 82 ketamine administrations in 30 intubated and mechanically ventilated children with elevated ICP revealed that ketamine effectively decreased ICP and prevented untoward elevation of ICP during potentially distressing interventions, without lowering blood pressure and cerebral perfusion pressure (CPP). However, these patients were already on continuous infusions of IV sedative medications and some received hyperosmolar therapy or decompressive craniectomy prior to the administration of ketamine. (Bar-Joseph G, 2009 Jul.) As a result, further studies need to be done on the isolated effect of ketamine on ICP.

Every effort should be made to avoid hypotension in these patients, because hypotension has been shown to increase morbidity and mortality. Euvolemia²⁴ should be maintained. Isolated TBI rarely leads to severe hypotension. Other causes of trauma-related hypotension include, but are not limited to:

- Intra-abdominal injuries
- Pericardial tamponade
- Hemothorax
- Pneumothorax
- Spinal cord injury causing spinal shock

Raising the head of the bed to decrease venous obstruction may help to control ICP. Traditionally, elevation of the head to 30° in the midline position is recommended, but titration of head elevation to achieve the lowest ICP would be optimal. Again, care of the cervical spine must always be a consideration when moving patients with traumatic brain injury.

Posttraumatic hyperthermia (core body temperature ≥ 38.0 - 38.5°C) is not uncommon in patients with TBI. [43] Fever increases cerebral metabolic requirements and oxygen consumption and can promote intracranial hypertension. Fever also decreases the seizure threshold. Consequently, efforts should be made to avoid hyperthermia. The patient should also be investigated and treated for other etiologies of fever, such as infection and atelectasis.

Sedation and analgesia are also important adjuncts to minimize increases in ICP. Painful stimuli and stress increase metabolic demands and increase blood pressure and ICP. However, sedatives and analgesics must be judiciously chosen to prevent unwanted side effects, such as hypotension. Short-

²⁴ Euvolemia - having a normal amount of body fluids.

acting and reversible analgesics, such as fentanyl, are commonly used. Short-acting benzodiazepines, such as midazolam, are also commonly used and have the added benefit of increasing the seizure threshold.

Pediatric Trauma Resuscitation: an Update

Trauma continues to be the leading cause of mortality in children and contemporary evidence suggests that in developed countries trauma is also the major cause of disability in the pediatric population. Pediatric trauma resuscitation constitutes the first of the multiple steps that are needed to achieve full recovery of the traumatized child; a feasible goal that should always be taken into consideration given the remarkable degree of recovery observed in polytrauma children. The vast majority of literature pertaining to the acute trauma care is derived from studies in adults. Nevertheless, the pediatric trauma population represents a unique challenge due to differences in anatomy, physiology and age-specific considerations. In this narrative review of the literature, we attempt to summarize the advances that have taken place over the last 5 years in pediatric trauma resuscitation with emphasis on fluid resuscitation, massive transfusion, permissive resuscitation, management of coagulopathy and use of tranexamic acid and evidence pertaining to implementation of transfusion protocols in the pediatric population. Considering the importance and inherent difficulties in education related to pediatric resuscitation, we also present some of new evidences regarding the use of simulation in pediatric resuscitation. (Tosounidis & Giannoudis, 2016)

Fluid Management

Fluid resuscitation necessitates a potent vascular access. It has recently been highlighted that vascular access for adequate fluid resuscitation can be a challenge in the pre-hospital setting. A retrospective review evaluating the emergency medical service interventions including endotracheal intubation, intravenous access and fluid resuscitation demonstrated that the pre-hospital care of children was substantially deficient in comparison to the one provided to adults. In particular, compared to adults more children required venous access upon their arrival to the hospital. The authors attributed the above finding to hypovolemia at presentation and observed increased number of adverse events related to unsuccessful attempts such as bruises and hematomas.

Fluid resuscitation in the pediatric population should be physiology-driven and at the same time, respect the different aspects of age-related differences in this population. Excessive fluid resuscitation might be harmful and up-to-date there are no firm guidelines regarding the optimal resuscitation fluid volume in pediatric trauma. In a retrospective review of the practice of a designated pediatric trauma center in Canada, Al-Sarif et al. studied the practice of fluid resuscitation and the associated complications in non-hemorrhagic blunt trauma pediatric patients. The authors concluded that the administered fluid volume was excessive and that 12 % of the 139 patients that were included in the study developed “fluid resuscitation attributable complications” such as ascites and/or pleural effusions.

The authors concluded that over-resuscitation is a common and potentially harmful phenomenon in non-hemorrhagic pediatric trauma. In the same line, Edwards et al. in a recent retrospective review of Department of Defense Trauma Registry (US military) of 907 children 14 years old or younger, concluded that crystalloid-predominant resuscitation had a negative effect on mortality, hospital and intensive care length of stay and increased ventilator days. The above effect was also evident even when adjusted for age and Injury Severity Score. Interestingly, balanced component resuscitation with FFP and RPBCs or whole blood did not yield better results as well. The authors point out that further studies are needed to determine the effects of balanced resuscitation in the bleeding pediatric patients and suggest that future research should focus on delineation of appropriate physiologic triggers of resuscitation strategies based on the age of the patient.

Massive Transfusion

Massive transfusion is a strategy to deal with the bleeding critically ill trauma patient by administering large volume of blood products in a short period of time. It is a well-established practice in the adult population and over the last years it has been clearly proven beneficial for the adult trauma patient. Massive transfusion protocols for children are not yet fully developed but this field has recently gained attention and massive transfusion protocols for the pediatric population have started emerging. Nevertheless, the vast majority of the existing studies are retrospective in nature and the level of evidence is low.

Defining massive transfusion is of paramount importance. In the adult population various definitions exist. Similarly several different definitions have been created for the pediatric trauma population with none being universally accepted. Recently, Diab et al. suggested the following dynamic definition of massive transfusion in children and neonates: “transfusion of >50 % TBV in 3 h, transfusion >100 % TBV in 24 h or transfusion support to replace ongoing blood loss of >10 % TBV per min”. Moreover, Neff et al. utilized data from the Department of Defense Trauma Registry (US Military) and retrospectively reviewed 1113 pediatric (<18 years of age) trauma (combat-injured) patients that were transfused during the resuscitation process. The authors concluded that 40 ml/kg of all blood products administered at any time within the first day could identify the critically traumatized patients who are at increased risk for early and in-hospital death. Consequently, the authors considered the above cut off point as critical in defining massive transfusion in pediatric population and suggested that since this definition is irrelevant to the injury mechanism and also takes into account contemporary transfusion practices, it could be reliably used in future clinical research. Livingston et al. reviewed the incidence, patients’ characteristic and outcomes of massive transfusion in a pediatric trauma cohort of 435 patients. The authors aimed to evaluate the outcomes of massive transfusion when it was used prior to the implementation of a specific protocol. Massive transfusion took place in 3 % of the patients and was correlated to poor outcome, severe injuries, and higher incidence of head trauma and longer duration of hospital stay. Coagulopathy occurred more frequently when massive transfusion was implemented. The

authors concluded that better coordination and attention to the correct amounts of frozen plasma, cryoprecipitate and platelets is needed when this tactic is used.

Transfusion Protocols

The evidence in relation to the implementation of massive transfusion protocols in pediatric trauma is sparse. Hendrickson et al. described the efficiency of the implementation of the transfusion protocol (fixed ratio of red blood cells: fresh frozen plasma: platelets). The authors compared demographics, resuscitation volumes and outcomes of patients managed with the transfusion protocol in historical control of patients that were managed before the implementation of this protocol. The authors came to the conclusion that mortality rates were not significantly altered after the implementation of the transfusion protocol. Nevertheless, they acknowledge the fact that the cross-sectional character of the study and the small number of patients enrolled constitute inherent weaknesses of their study and that better designed studies are needed to reach safe conclusions. In another recent retrospective review, Nosanov et al. reported on the impact of plasma and platelet ratios on mortality of 105 pediatric and adolescent patients (<18 years) who received massive transfusion. Interestingly, no decrease in mortality was observed in patients who were transfused with higher plasma/RBC and plasma/platelets ratio. Again the authors underpinned the need for additional high quality research in the field. In a prospective cohort of 55 patients, Chidester et al. found that coagulopathy was a predictor of initiation of the protocol and fewer thromboembolic complications were observed in the patients who received massive transfusion.

Permissive Resuscitation

Permissive or low volume resuscitation is a concept that has evolved over the last years in the management of adult trauma patient and has gained considerable attention both in clinical setting and the related basic research. This practice has not gained wide acceptance in the management of pediatric patients and some authors advocate extreme vigilance, questioning the non-validated theoretical benefits of such an approach in children.

Coagulopathy and Tranexamic Acid

Trauma-induced coagulopathy is one of the most commonly encountered complications of trauma during the resuscitation process. The main causative factor behind the development of coagulopathy is the local activation of the coagulation system after trauma and the subsequent acidosis, hypothermia, hemodilution and coagulation factor consumption. Current thinking in the field suggests that the basic mechanisms of this phenomenon differ between the adults and children. The two main potential mechanisms in the trauma-induced coagulopathy in pediatric population include the so-called acute traumatic coagulopathy and the iatrogenic coagulopathy. Without the undisputable evidence available, it is thought that in children the former pathway is mediated by activation of protein C, glyocalyx shedding and degradation of Weibel–Palade body. Nevertheless, the classic factors

(hypothermia, volume depletion, hemodilution and coagulation factor depletion) are considered as the main mechanisms of coagulopathy.

Coagulopathy in pediatric trauma is of paramount importance and there are recent reports in the literature suggesting that it is associated with mortality. Hendrickson et al., in a study evaluating the prevalence of coagulopathy of 102 traumatized children presented to the emergency department of a level-2 trauma center, concluded that almost half of the studied patients were coagulopathic during the first 24 hours and that was related to increased mortality and morbidity (longer intensive care stay and number of days requiring ventilation). The authors stressed the fact that more research is needed to clarify the role of coagulation factor replacement and massive transfusion practice. Moreover, Whittaker et al. retrospectively reviewed 803 patients with severe trauma admitted in Level-1 civilian trauma center. Early coagulopathy was correlated with significant increase in mortality when associated with traumatic brain injury. The authors suggested that early correction of coagulopathy could lead to substantial decrease in mortality.

The safety and efficiency of tranexamic acid in adult trauma has been well documented and its use as a first line medication is established and considered a “standard practice”. The use of tranexamic acid in perioperative setting in children has been studied in cardiac, spinal and craniofacial surgery. Beno et al. in a narrative review of the contemporary literature concluded that there is lack of strong evidence to support its use in adolescent trauma resuscitation. On the other hand, the authors suggested that its use is likely to be beneficial in pediatric trauma, given the robust clinical evidence of its use in adult resuscitation, its proven safety and efficacy in other fields of pediatric surgery and its documented cost-effectiveness. Nevertheless, the authors recognized that further research is necessary in the field to substantiate their suggestions. Additionally in a retrospective review of 766 pediatric patients presented in a four year period (2008–2012) to the North Atlantic Treaty Organization Role 3 hospital, Camp Bastion, Afghanistan, Eckert et al. reported on the factors related to tranexamic acid use and mortality. Tranexamic acid was used in 10 % of the cases and especially in cases with severe abdominal and extremity trauma. The use of tranexamic acid was independently associated with increased mortality and no adverse safety or medication-related complications (i.e. cardiovascular or other thromboembolic phenomena) were observed. Up-to-date there is no robust evidence for the use of tranexamic acid in severe pediatric trauma but current expert opinion suggests its use.

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Aurora Lakeland Medical Center & Aurora Memorial Hospital of Burlington Pediatric Specific Protocols:

Pediatric Child Abuse or Neglect (Suspected)

LEVEL	Suspected Child Abuse or Neglect:
FR B A I P	<ol style="list-style-type: none"> 1. Initial Medical Care – Special Considerations: <ul style="list-style-type: none"> • Environmental factors that could adversely affect a child's welfare. • The child’s interactions with parents/guardians. • Discrepancies in the history obtained from the child and caregivers. • Injury patterns that do not correlate with the history or anticipated motor skills based on the child’s growth and developmental stage. • Any signs of intentional injury or neglect. 2. Treat obvious injuries per appropriate protocol. 3. Prepare to transport. If parent/guardian refuses to allow removal of the child, remain at the scene and contact law enforcement for assistance. Request law enforcement take the child into secure custody for medical evaluation at the hospital. 1. If law enforcement refuses to take the child into secure custody, request that they remain at the scene. Contact local Child Protective Services (see numbers below) and request they respond to the scene and take the child into custody. If EMS remains unsuccessful in removing child, contact a medical control physician and seek guidance. If law enforcement or Child Protective Services assists in securing custody of the child, transport the child against the parent/guardian wishes. CPS contact numbers for respective counties are as follows: <ul style="list-style-type: none"> ▪ Kenosha County (262) 605-6582 (After hours, weekends and holidays call Crisis Intervention: (262) 657-7188) • Racine County (262)-638-6321 or (800)-924-5137 • Walworth County DHS (262)-741-3200 • Waukesha County (262) 548-7212 or 211 5. Children suffering from suspected abuse or neglect should not remain in an environment of suspected abuse unless #4 of the protocol has been pursued in vain to remove the child. 6. Notify the receiving physician or nurse of the suspected abuse upon arrival to the hospital. 7. Suspicions of child abuse or neglect must be reported to the local law enforcement agency having jurisdiction OR the Department of Children and Family Services (DCFS) per State Law. Reports must be filed, even if the EMT is aware that the hospital will also be reporting the incident. This includes both living and deceased children encountered by prehospital personnel. An EMS Provider who has reasonable cause to suspect that a child seen by the person in the course of professional duties has been abused or neglected or who has reason to believe that a child seen by the person in the course of professional duties has been threatened with abuse or neglect and that abuse or neglect of the child will occur is required to report., 8. Thoroughly document the child’s history and physical exam findings on the run sheet. Note relevant environmental/circumstantial data in the comments section of the run sheet or supplemental reports.

Pediatric (Initial Care)

I. Special Considerations:

- Children have different responses to blood volume loss. They often maintain their systolic BP until a 30% volume loss has occurred, then, crash rapidly.
- Children are also prone to heat loss and cold stress, which results in acidosis, hypoxia, and bradycardia.
- Gastric dilation develops from crying, which leads to ventilatory impairment.
- Conditions Requiring Rapid Cardiopulmonary Assessment and Potential Cardiopulmonary Support:
 - Respiratory Rate greater than 60 breaths/min
 - Heart rate
 - Child greater than 1 year of age, less than 60 beats/min or greater than 180 beats/min.
 - Infants less than 1 year of age, less than 60 beats/min or greater than 220 beats/min.
 - Increased work of breathing (retractions, nasal flaring, grunting)
 - Cyanosis or a decrease in oxygen saturation
 - Altered level of consciousness (unusual irritability or lethargy, or failure to respond to parents or painful procedures)
 - Seizures
 - Fever with petechiae
 - Trauma
 - Burns involving more than 10% of body surface area
- Use of Pediatric Measuring Tape (e.g. Broselow) along with the corresponding Pediatric Color coded supplies is encouraged for quick and easy identification of drug doses and supply sizes.

II. Formula for Estimating Normal Weight in Children (kilograms)

- Under 12 months $(\text{Age in months}/2) + 4 = \text{Weight in kg}$
- 1 to 10 Years $(\text{Age in Years} \times 2) + 10 = \text{Weight in kg}$

Age*	Typical Systolic BP (Age x 2) + 90	Lower Limits of SBP (Age x 2) + 70	Awake Pulse (Range)	Sleeping Pulse	Resp. Rate
Neo to 3 months	90	70	140 (85-205)	80-160	30-60
3 mos.to 2 yrs	90-92	70-72	130 (100-190)	75-160	24-40
2 to 10 yrs	94-110	74-90	80 (60-140)	60-90	18-30
Over 10 yrs	Over 110	90	75 (60-100)	50-90	12-20

Note: Age is all in years unless otherwise indicated.

Typical Systolic Blood Pressure in children 1 to 10 years of age are:

90 mmHg + (Child’s age in years x 2) mmHg.

Lower limits of Systolic Blood Pressure in children 1 to 10 years of age:

70 mmHg + (Child’s age in years x 2) mmHg

Estimating Normal Weight in Children (Kg)

12 months [Age(months)/2 +4]

1 – 10 years [2 x age (years)] + 10

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Suggested Sizes for ET Tubes, Blades, Suction Catheters								
Age Averages	Newborn	6 Months	18 Months	3 Years	5 Years	6 Years	8 Years	12 Years
ET Tube	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
Blade Size	0-1 Straight	1 Straight	1.5 Straight	2 Straight	2 Straight	2 Straight	2 Straight or Curved	3 Straight or Curved
Suction Cath	6 Fr	6 Fr	8 Fr	8 Fr	10 Fr	10 Fr	10 Fr	10 Fr

Notes:

- Select tube size based on size of the child, not his/her chronological age.
- Prepare additional tubes one size larger and one size smaller than the one you initially select.
- Use cuffed ET Tube if available in appropriate size.

Fast References:

- Match tube size to size of nail on patient's little finger, or
- Calculate using formula $(16 + \text{age in years}) / 4$.

Pediatric Glasgow Coma Scale									
Eye Opening		Best Verbal Response Age older than 5 Yrs		Best Verbal Response Age 2-5 Years		Best Verbal Response Age Less than 2 Years		Best Motor Response	
Spontaneous	4	Oriented / Converses	5	Appropriate Words/Phrases	5	Smiles/Coos/Cries Appropriately	5	Moves Spontaneously/ Purposefully	6
To Speech	3	Disoriented / Converses	4	Inappropriate Words	4	Cries/Is Consolable	4	Localizes Pain/Withdraws to Touch	5
To Pain	2	Inappropriate Words	3	Cries/Screams	3	Persistent Screaming/Crying/ Inconsolable	3	Withdraws to Pain	4
None	1	Incomprehensible	2	Moans/Grunts to Pain	2	Moans/Grunts to Pain	2	Abnormal Flexion	3
		None	1	None	1	None	1	Abnormal Extension	2
								None	1

CPR Modifications for Children and Infants		
Technique	Child Age 1-8 Years	Infant Under 1 Year
Airway Opening	Modified Head Tilt/Chin Lift	Slight Head Tilt/Chin Lift
Breathing	Mouth-to-Mouth	Mouth-to-Mouth-and-Nose
Foreign Body Airway Obstruction	Abdominal Thrusts	Back Slaps/Chest Thrusts
Ventilation Rate without Compressions	12-20 per minute/every 3 to 5 seconds	
Ventilation Rate with CPR and Advanced Airway	8-10 breaths per minute/every 6 to 8 seconds	

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Circulation (Compression Point)	Lower 1/3 of Sternum (Same as adult)	Lower 1/3 of Sternum (Below nipple line)
Compress With	Heel of one hand, add second hand on top as needed to push fast and hard	2 to 3 fingers
Compression Depth	$\frac{1}{3}$ to $\frac{1}{2}$ the depth of the chest	
Compression Rate	At least 100 per minute	
Compression-to-Ventilation Ratio		
Single Rescue Provider	30 : 2	
Multiple Rescue Providers	15 : 2	

Resuscitation Medication Dosages											
Age	Weight		ET Size	Epinephrine 1:10,000 0.01 mg/kg IV/IO ¹		Atropine 0.1mg/mL 0.02 mg/kg IV/IO ¹		Lidocaine 20 mg/mL 1 mg/kg IV/IO ¹		Amiodarone 50 mg/mL 5mg/kg/dose IV/IO ¹	
	Kg	Lbs		mm	mg	mL	mg	mL	mg	mL	mg
Newborn	3	7	3	0.03	0.3	0.1	1	3	0.15	15	0.3
1 month	4	8	3	0.04	0.4	0.1	1	4	0.2	20	0.4
3 months	5	11	3.5	0.05	0.5	0.1	1	5	0.25	25	0.5
6 months	7	15	3.5	0.07	0.7	0.14	1.4	7	0.35	35	0.7
1 year	10	22	4	0.1	1	0.2	2	10	0.5	50	1
2 years	12	26	4	0.12	1.2	0.24	2.4	12	0.6	60	1.2
3 years	14	31	4.5	0.14	1.4	0.28	2.8	14	0.7	70	1.4
4 years	16	35	5	0.16	1.6	0.32	3.2	16	0.8	80	1.6
5 years	18	40	5	0.18	1.8	0.36	3.6	18	1	90	1.8
6 years	20	44	5.5	0.2	2	0.4	4	20	1	100	2
7 years	22	48	6	0.22	2.2	0.44	4.4	22	1.1	110	2.2
8 years	25	55	6	0.25	2.5	0.5	5	25	1.25	125	2.5
9 years	28	63	6	0.28	2.8	0.5	5	28	1.4	140	2.8
10 years	34	75	6.5	0.34	3.4	0.5	5	34	1.7	170	3.4

Notes:

¹ IV/IO flush drugs with 5 mL Normal Saline.

Pediatric Shock

LEVEL	Pediatric Shock		
FR B A I P	<ol style="list-style-type: none"> 1. Initial Medical Care; special considerations: <ul style="list-style-type: none"> * Shock is decreased effective circulation causing inadequate delivery of oxygen to tissues * Signs of early(compensated) shock in children include tachycardia, poor skin color, cool/dry skin and delayed capillary refill. Hypotension is a late sign. *Hypovolemia is most common cause of shock in children. *Distributive shock (loss of vascular tone) is usually due to sepsis. Other causes include anaphylaxis, toxins, and spinal cord injury. *Cardiogenic shock is rare in children. 2. Potential causes of hypovolemia and shock include: <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;"> <ul style="list-style-type: none"> * Infections/sepsis * Burns * Hemorrhage (Internal, External) * Spinal cord injury * Pump Failure * Heart Rhythm Disturbances </td> <td style="width: 50%; vertical-align: top;"> <ul style="list-style-type: none"> * Dehydration/Heat emergencies * Drugs and Toxins * Metabolic Disturbances * Anaphylaxis * Pulmonary Embolism </td> </tr> </table> 3. Place the patient in supine position. Ensure ABC's, oxygenation, ventilation; suction as needed 4. Control external bleeding and keep child warm. 5. Initiate cardiac monitor and apply oxygen as needed 6. Establish vascular access. Do not delay transport to obtain vascular access. Refer to intraosseous protocol if unable to start IV. 	<ul style="list-style-type: none"> * Infections/sepsis * Burns * Hemorrhage (Internal, External) * Spinal cord injury * Pump Failure * Heart Rhythm Disturbances 	<ul style="list-style-type: none"> * Dehydration/Heat emergencies * Drugs and Toxins * Metabolic Disturbances * Anaphylaxis * Pulmonary Embolism
<ul style="list-style-type: none"> * Infections/sepsis * Burns * Hemorrhage (Internal, External) * Spinal cord injury * Pump Failure * Heart Rhythm Disturbances 	<ul style="list-style-type: none"> * Dehydration/Heat emergencies * Drugs and Toxins * Metabolic Disturbances * Anaphylaxis * Pulmonary Embolism 		
A I P	<ol style="list-style-type: none"> 7. If evidence of shock, administer IV fluid 20 mL/kg IV/IO. May repeat times 2 if necessary up to maximum of 60 mL/kg. Reassess patient after each bolus. 8. If Blood Glucose less than 60 see appropriate protocol <ul style="list-style-type: none"> • Adult Diabetic/Glucose Emergencies • Pediatric Diabetic/Glucose Emergencies 9. If child is in anaphylactic shock, please also see Allergic Reaction/Anaphylaxis Shock protocol 		
P	<ol style="list-style-type: none"> 10. ➔ If child does not respond to IV fluids or is in cardiogenic shock, consider Dopamine drip at 2-5 mcg/kg per min 		

Pediatric Unconscious – Unknown Etiology

LEVEL	Unconscious – Unknown Etiology
FR B A I P	<p>Possible etiology mnemonic AEIOU TIPS-V:</p> <p>A: Alcohol, arrhythmias, ingestions; E: Endocrine, exocrine, electrolyte imbalance; I: Insulin shock, DKA; O: Oxygen deficit, opiates, overdose; U: Uremia, renal problems including hypertension; T: Trauma, temperature (hypothermia/hyperthermia); I: Infection; P: Psychological; S: Space occupying lesion (SAH), stroke, shock, seizures; V: Vascular</p>
FR B A I P	<p>2. Initial Assessment & General Standing Orders. 3. Consider possible causes and treat.</p> <ul style="list-style-type: none"> • Evaluate for hypoxia/hypercarbia and give oxygen and establish an airway as indicated. • If the patient is in SHOCK, attempt to determine the etiology and refer to the appropriate protocol, give IV fluids by IV protocol. • Consider Hypoglycemia- See Protocol - Hypoglycemia. <p>4. If spontaneous ventilations inadequate</p> <ol style="list-style-type: none"> a. Narcan 0.5mg IN (IM B only. Repeat every 5 min as necessary. Max dose 2mg. b. If weight is over 20 kg: Narcan 0.4 - 2mg IV/IO/IN/IM and/or c. If weight is under 20 kg: Narcan 0.1 mg/kg IV/IO/IN/IM <p>Consider restraints before Narcan is given. Refer to Patient Restraint Protocol. Narcan may precipitate narcotic withdrawal. Document response. May repeat every 5 minutes as needed.</p>

Bibliography of Works Cited

- Abujamra L, J. M. (2003). Penetrating neck injuries in children: a retrospective review. . *Pediatr Emerg Care.*, 308-13.
- Achildi O, B. R. (2007). Lapbelt injuries and the seatbelt syndrome in pediatric spinal cord injury. . *J Spinal Cord Med.* , Suppl 1:S21-4.
- author, T. H. (2016). Paediatric trauma resuscitation: an update. *Eur J Trauma Emerg Surg.*, 42: 297–301.
- Bar-Joseph G, G. Y. (2009 Jul.). Effectiveness of ketamine in decreasing intracranial pressure in children with intracranial hypertension. *J Neurosurg Pediatr.* , 4(1):40-6.
- Brian J Daley, M. M., & Ramanathan Raju, M. M. (2015). *Considerations in Pediatric Trauma.* medscape.
- Cigdem MK, O. A. (2009 Dec.). Selective nonoperative management of penetrating abdominal injuries in children. . *J Trauma.* , 67(6):1284-6; discussion 1287. .
- Fabricant PD, R. A.-Z. (2013). Development and Validation of a Pediatric Sports Activity Rating Scale: The Hospital for Special Surgery Pediatric Functional Activity Brief Scale (HSS Pedi-FABS). *Am J Sports Med.* .
- Felice Su, M. F. (2015 Nov). Traumatic Brain Injury in Children. *Medscape.*
- Guice KS, C. L. (2007). Traumatic injury and children: a national assessment. *J Trauma.*, S81-6.
- Holmes JH 4th, W. D. (2005 Dec.). The failure of nonoperative management in pediatric solid organ injury: a multi-institutional experience. . *J Trauma.* , 59(6):1309-13. .
- Jennifer Cuske, R. E.-P. (2008 Jun). The Lost Art of Splinting: How to properly immobilize extremities & manage pain. *JEMS.*
- K., D. (2015). Pediatric Brain Injury May Lead to Attention Problems.
- Königs M, H. H. (2015). Pediatric Traumatic Brain Injury and Attention Deficit. . *Pediatrics.*, 534-41.
- Paul Maggio, M. (2016). *Management of duodenal and pancreatic trauma in adults.* UpToDate.
- Sheehan B, N. L. (2013). Informing the design of clinical decision support services for evaluation of children with minor blunt head trauma in the emergency department: A sociotechnical analysis. *J Biomed Inform.* .

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Society of Critical Care Medicine. (2012 Jan.). Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents. *Pediatr Crit Care Med.* , 13(1 Suppl):S1-82. .

Tosounidis, T., & Giannoudis, P. (2016). Paediatric trauma resuscitation: an update. *Eur J Trauma Emerg Surg.*, 42: 297–301.

Upadhyaya, P. (2003 Nov.). Conservative management of splenic trauma: history and current trends. *Pediatr Surg Int.*, 19(9-10):617-27.