8 Update in Pediatric Emergency Medicine: Pediatric Resuscitation, Pediatric Sepsis, Interfacility Transport of the Pediatric Patient, Pain and sedation in the Emergency Department, Pediatric Trauma

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Resuscitation

Cardiopulmonary arrest in the pediatric population is infrequent and it is thus important that physicians who deal with children are comfortable managing the pediatric airway and using Pediatric Advanced Life Support (PALS) algorithms. With improved evidence and management of pediatric cardiac arrests, the rates of survival for pediatric in- hospital arrest have considerably improved over the last 10 years from 24% to 39% (Girotra et al. 2013).

Airway

The most common cause of pediatric cardiac arrest is usually respiratory distress leading to respiratory failure (Shaw and Bachur 2016). Tracheal intubation is the definitive method to secure the airway and should be considered when the patient is unable to oxygenate, ventilate, lacks respiratory drive and/or has lost his/her airway protective reflexes. Pediatric airway management can be challenging due to the following differences in anatomy compared to the adult airway:

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Table 8.1 Suggested equipment for intubation

• Cardiac monitors with automated blood pressure measurements and continuous pulse oximetry
• Non-rebreather mask
• Bag-valve mask
• Functional suction device
• Functioning laryngoscope with various blades and sizes
• Endotracheal tubes with stylet, one size above and below desired tube size
• End-tidal CO_2 detector: capnography or colorimetery
• 10 mL syringe
• Nasopharyngeal and oropharyngeal airway
• Tape to secure the tube
• Laryngeal mask airway

larger occiput, large tongue in proportion to the oral airway, more anterior location of the vocal cords and floppy epiglottis (Singh and Frenkel 2013). Prior to intubation, all the necessary personnel and equipment must be readily accessible. Table 8.1 lists the necessary equipment for intubation; intravenous or intraosseous access should be obtained and all required medications drawn up prior to intubation.

Pre-oxygenation is important to minimize desaturation and to increase the safe apnea time during intubation. Ideally, the patient should be pre-oxygenated for at least 3 min (Weingart and Levitan 2012). If the patient is adequately breathing, oxygenation can be accomplished through a 100% non-rebreather mask with the rate of oxygen flow as high as possible. Bag Mask Ventilation (BMV) should be initiated in the apneic patients and in those with poor respiratory drive to ensure adequate pre-oxygenation. To further increase the safe apnea time and the success rate of the first intubation attempt, apneic oxygenation is used during rapid sequence intubation (RSI) in adults (Singh and Frenkel 2013; Weingart and Levitan 2012; Mittiga et al. 2015). This entails the application of oxygen via nasal prongs in addition to pre-oxygenation, and acts as an adjunct to pre-oxygenation by providing an oxygen filled pharynx used as a reservoir for alveolar ventilation (Weingart and Levitan 2012). Although the adult evidence shows promise (Singh and Frenkel 2013; Mittiga et al. 2015), pediatric research on this issue is limited (Steiner 2016).

Although uncuffed tubes were previously recommended in pediatrics due to airway narrowing at the glottis and concerns about mucosal injury, evidence suggests that pediatric cuffed endotracheal tubes are safe to use in the pediatric population. The use of cuffed tubes is associated with fewer tube changes, decreased risk of aspiration and allows for higher airway pressures during ventilation without an increased risk of complications (Kleinman et al. 2010a; Weiss et al. 2009; Shi et al. 2016). It is important that cuffed tubes are inflated to no more than 20 cm of water. The size of tube can be estimated by length-based tools or by using the following age-based formulas: age/4 + 3.5 for cuffed tubes or age/4 + 4 for uncuffed tubes (Kleinman et al. 2010a). An endotracheal tube one size above and below the estimated size should also be available, and consideration should be given to using a stylet. Successful placement should be confirmed through direct visualization, CO_2 detection, and chest x-ray or ultrasound confirmation in addition to auscultation (Mittiga et al. 2015; Kleinman et al. 2010a; Chou et al. 2015). Cricoid pressure is no longer routinely recommended during rapid sequence intubation as it has been shown to decrease the success of intubation with little effect on the risk of aspiration (Kleinman et al. 2010a; Ellis et al. 2007). If BMV is unsuccessful and intubation is not possible a Laryngeal-Mask Airway (LMA) may be used to provide a patent airway and ventilation support (de Caen et al. 2015a).

Medications

Medications should be used to help facilitate the success of intubation and decrease complications. Contrary to previous recommendation to use atropine to mitigate the risk of pediatric bradycardia, evidence to demonstrate this benefit has been lacking (Singh and Frenkel 2013; de Caen et al. 2015a). The most recent PALS guidelines do not support the routine use of atropine during pre-intubation in children (de Caen et al. 2015a). The use of atropine may be considered in children at increased risk of bradycardia (such as in infants under one year of age, when using succinylcholine in children under 5 years of age or in patients receiving multiple doses of succinylcholine) or in those who are bradycardic prior to intubation (Singh and Frenkel 2013). The recommended dose of atropine when used as a premedication agent for RSI is 0.02 mg/kg, with no minimum dose (de Caen et al. 2015a).

Common sedatives used for RSI in pediatrics include etomidate and ketamine. Etomidate, at a dose of 0.3 mg/kg is an excellent sedative medication for this purpose due to its minimal associated cardiovascular side effects. Given the risk of possible adrenal suppression, etomidate is not currently recommended in the septic patient (Kleinman et al. 2010a; den Brinker et al. 2008; Chan et al. 2012; Bruder et al. 2015). Ketamine is a dissociative sedative agent used at doses of 1–3 mg/kg. Ketamine is particularly useful in hypotensive patients or those with severe asthma. Since ketamine does not inhibit spontaneous respirations, it is a useful sedative for difficult intubations. Contrary to previous belief, recent evidence suggests that ketamine is safe to use in children with increased intracranial pressure. (Filanovsky et al. 2010; Hughes 2011). Although commonly used for intubation, the use of propofol in the emergency department should be limited to experienced personnel due to a significant risk of hypotension (Shaw and Bachur 2016; Singh and Frenkel 2013). Other medications such as benzodiazepines and opiates can also be used for sedation in RSI but these may not be as reliable or effective (Singh and Frenkel 2013; Stollings et al. 2014).

Rocuronium and succinylcholine are the most commonly used neuromuscular blocking agents. Succinylcholine at dose of 1–2 mg/kg provides a rapid onset of action with a short duration. It is contraindicated in patients with hyperkalemia, myopathies or a history of malignant hyperthermia and it can cause bradycardia with repeated doses (Singh and Frenkel 2013). Rocuronium is a longer-acting paralytic agent at doses of 0.6–1.2 mg/kg. Lower doses of rocuronium result in a shorter duration of action but require a longer time to take effect. Unlike succinylcholine, rocuronium does not have any contraindications but care should be taken in using rocuronium patients with difficult airways (Singh and Frenkel 2013; Stollings et al. 2014).

Cardiopulmonary Resuscitation

There in ongoing evidence that cardiopulmonary resuscitation (CPR) should be performed hard and fast. In infants and children; the chest should be compressed to one-third of the anterior-posterior diameter of the chest, at a rate of 100–120 compressions per minute (Atkins et al. 2015). Full recoil should occur between compressions and all efforts should be made to minimize interruptions in CPR. Compressions to ventilation should occur at a ratio of 15:2 until a definitive airway or LMA is present (Atkins et al. 2015). Respirations can be provided by BMV using adjuncts such as naso-pharyngeal or oro-pharyngeal airways to improve oxygenation. If skilled personal are present, tracheal intubation may be attempted while minimizing interruptions to chest compressions. If BMV is unsuccessful and intubation is not possible, ventilation via LMA should be considered (de Caen et al. 2015a). Early vascular access is important to allow for the administration of fluids and medications. Early insertion of an intraosseous needle provides timely and effective access during resuscitation; intraosseous medications can be given at the IV-recommended doses.

Defibrillation is the asynchronous delivery of an electrical current to the myocardium in an effort to established sinus rhythm. Defibrillation should be administered as soon as possible in patients with ventricular fibrillation or pulseless ventricular tachycardia at an initial dose of 2 J/kg (de Caen et al. 2015a). Adult size paddles should be used for patients older than a year of age or weighing more than 10 kg and can be placed on the right upper chest and apex. If unsuccessful, repeated doses can be given at 4 J/kg (de Caen et al. 2015a).

Cardioversion is the synchronous delivery of an electrical current to the myocardium in an effort to prevent ventricular fibrillation. It is indicated for the treatment of perfusing rhythms when a pulse is present, such as stable ventricular tachycardia or supraventricular tachycardia. The initial recommended cardioversion dose is 0.5–1 J/kg, which can be increased to 2 J/kg with subsequent attempts (Kleinman et al. 2010a).

In depth review of all the PALS algorithms are beyond the scope of this book. Please refer to PALS algorithms for further details.

Post-cardiac Arrest Hypothermia

After return to spontaneous circulation, every effort should be made to maintain normothermia and to treat any hyperthermia. Although there have been several studies evaluating the neuroprotective effects of hypothermia in pediatrics, a recent randomized controlled trial and meta-analysis both demonstrated lack of improved survival after permissive hypothermia (Moler et al. 2015; Bistritz et al. 2015).

Introduction

Sepsis is a systemic and often deleterious host response to infection. It is widely accepted that the onset and progression of sepsis results from a dysregulated inflammatory response that leads to widespread tissue injury and end organ dysfunction (Hotchkiss and Karl 2003). Practically speaking, sepsis represents a spectrum of disease ranging from the systemic inflammatory response (SIRS) to septic shock and multi-organ system dysfunction. The tendency to proceed along this spectrum is more likely determined by the host response to infection that the offending pathogen itself.

Definitions

Definitions for sepsis and organ dysfunction in children have been developed by the International Consensus Conference on Pediatric Sepsis (Goldstein et al. 2005). SIRS is a non-specific inflammatory reaction in response to insults such as infection, trauma, burns, pancreatitis and other diseases. *SIRS* in children is characterized by a temperature abnormality (fever or hypothermia) **or** an age-specific abnormality in the white blood cell count, **and** one of the following: tachycardia (or bradycardia in infants under 1 year of age), tachypnea or an acute respiratory condition requiring mechanical ventilation. SIRS in the presence of confirmed or suspected infection constitutes *sepsis*. *Severe sepsis* is defined as sepsis associated with cardiovascular dysfunction, acute respiratory distress syndrome (ARDS), or dysfunction in two or more other organ systems (specific definitions of respiratory, cardiovascular, neurologic, hematologic, hepatic and renal dysfunction are based on expert opinion). *Septic shock* is defined as sepsis in the presence of cardiovascular dysfunction. *Compensated shock* refers to a shock state in which the blood pressure remains in age-appropriate range. Hypotension represents a late and often ominous sign in pediatric patients. The presence of hypotension is the hallmark of *decompensated shock*.

Epidemiology and Risk Factors

The global burden of illness from pediatric sepsis is very high. Infectious diseases such as malaria, gastroenteritis and pneumonia, often culminating in severe sepsis and septic shock, are the most common cause of death in infants and children worldwide. In the United States the prevalence of severe sepsis has been rising over the past decade (Ruth et al. 2014; Balamuth et al. 2014), with estimated pediatric hospitalizations due to severe sepsis exceeding 75,000 cases annually (Hartman et al. 2013). Young infants, especially low birth weight neonates, are at the highest risk, and children with co-morbid medical conditions account for more than half the cases. This includes children with chronic lung disease, congenital heart disease, malignancy, and those with conditions impacting the immune system (Hartman et al. 2013). Children with indwelling devices and anatomic abnormalities are also at high risk for bacterial seeding and infection. In North America, the mortality rate from pediatric severe sepsis and septic shock is estimated to be 5–15% but approaches 30% in those with comorbid disorders and significant organ dysfunction (Ruth et al. 2014; Hartman et al. 2013; Watson et al. 2003; Kutko et al. 2003; Weiss et al. 2015a).

Etiology and Microbiology

The most common primary sites of infection in children are respiratory (40–50%) and bloodstream (10–20%) (Weiss et al. 2015a), with abdominal, genitourinary, central nervous system and skin infections accounting for the majority of remaining cases. Although bacterial and viral pathogens are most common, fungal, parasitic, or rickettsial infections can also lead to sepsis. The most commonly implicated bacterial organisms are staphylococcal species (including *Staphylococcus aureus* in previously healthy patients and coagulase-negative staphylococci in those with indwelling catheters) and streptococcal species. Gram-negative organisms are frequently responsible for urinary tract infection (UTI)-related sepsis and sepsis in immunocompromised hosts. The most common viral pathogens include the respiratory viruses (influenza, parainfluenza, respiratory syncytial virus (RSV), adenovirus) (Gaines et al. 2012). It should be noted however, that in up to two thirds of septic shock cases, no infectious pathogen is identified. This is commonly referred to as "culture-negative" sepsis.

Pathophysiology

The longstanding pediatric mantra that "children are not little adults" certainly applies to sepsis. The differences between the pediatric and adult response to infection have important implications on the presentation and treatment of sepsis in children compared to older patients (Brierley et al. 2009). First, severe hypovolemia, likely due to a combination of dehydration and increased microvascular permeability, is a hallmark of pediatric septic shock. Therefore, children frequently respond well to aggressive fluid resuscitation. Second, the hemodynamic response to sepsis is significantly different in the two populations (Fig. 8.1). Up to 90% of adult patients present with a "hyperdynamic shock", otherwise known as "warm shock". Despite myocardial dysfunction, cardiac output (CO) is typically maintained by an increase in heart rate and decrease in systemic vascular resistance (SVR). Thus, the adult response to sepsis is characterized by tachycardia, hypotension and a normal, or increased, cardiac output. The predominant cause of mortality in adult septic shock is vasomotor paralysis (when SVR cannot be further increased with vasopressor agents). In contrast, at least 50% of infants and children present with "cold shock". Although an increase in heart rate is a child's principal means of maintaining CO, a predominant response to a decreased CO in children is vasoconstriction. Blood flow is redistributed from non-essential vascular beds such as the skin, to essential organs such as the heart, brain and lungs. This increase in SVR maintains a normal blood pressure, even with significant decreases in CO. Hypotension is therefore a late sign in pediatric septic shock, and often signifies impending cardiovascular collapse. Thus, the pediatric response to sepsis is often characterized by tachycardia, normal blood pressure and decreased cardiac output. In children, low CO is most often

Fig. 8.1 Comparison of cold and warm septic shock. *HR* heart rate, *SVR* systemic vascular resistance, *CO* cardiac output, *BP* blood pressure

	COLD SHOCK	WARM SHOCK
Hemodynamics	↑HR, ↑SVR, ↓CO, BP maintained until late	↑HR, ↓SVR, ↑CO, ↓BP
Clinical Features	Capillary refill >2sec, Cool, mottled skin, Weak pulses, Narrowed pulse pressure Altered mental status, Decreased urine output	Flash capillary refill <1sec, Warm, flushed skin, Bounding pulses, Widened pulse pressure, Altered mental status, Decreased urine output
First Line Vasoactive Support for fluid-refractory shock	Epinephrine (0.05-0.3mcg/kg/min); Can use Dopamine (5-10 mcg/kg/min) if epinephrine unavailable	Norepinephrine (0.03-0.05mcg/kg/min) Can use Dopamine (>10mcg/kg/min) if norepinephrine unavailable

associated with mortality, in contrast to adults who often succumb to low SVR. It should be noted however, that the clinical presentation of septic shock in children can be highly variable and can include a combination of hemodynamic abnormalities.

Diagnosis

Although the specific definitions of cardiovascular dysfunction set forth by the international consensus criteria help standardize patient populations for research purposes, they may be less pertinent in the everyday clinical setting (Weiss et al. 2012, 2015b). Clinical suspicion for septic shock should always supersede reliance on the presence of specific consensus criteria. The diagnosis of septic shock should be made in children with sepsis (SIRS with infection) and *signs of inadequate tissue perfusion* including any of the following: decreased or altered mental status, decreased urine output (<1 ml/kg/h), capillary refill >2 s (cold shock), cool or mottled extremities (cold shock), diminished pulses (cold shock), flash capillary refill (warm shock), bounding peripheral pulses (warm shock), and wide pulse pressure (warm shock) (Brierley et al. 2009). The presence of hypotension, although not necessary for diagnosis, is confirmatory in a child with suspected infection. Although no laboratory test is sensitive or specific enough to be used alone, some experts recommend using lactic acid (a by product of anaerobic metabolism and marker of tissue hypoperfusion) as a diagnostic adjunct. Elevated initial lactic acid levels (≥4.0 mmol/L), and failure of lactate levels to normalize (<2 mmol/L) or progressively clear with resuscitative efforts may be poor prognostic indicators in pediatric sepsis (Scott et al. 2012, 2016).

Management

Early recognition and aggressive treatment of septic shock are essential to reducing morbidity and mortality. The American College of Critical Care Medicine (ACCM) and the Pediatric Advanced Life Support (PALS) course have published internationally recognized guidelines for the management and hemodynamic support of pediatric septic shock (Brierley et al. 2009; Kleinman et al. 2010a, b). The two guidelines outline a similar step-wise approach to resuscitation directed at restoring physiologic indicators of perfusion: normal mental status, threshold heart rates, normal peripheral perfusion (cap refill <3 s), palpable distal pulses and

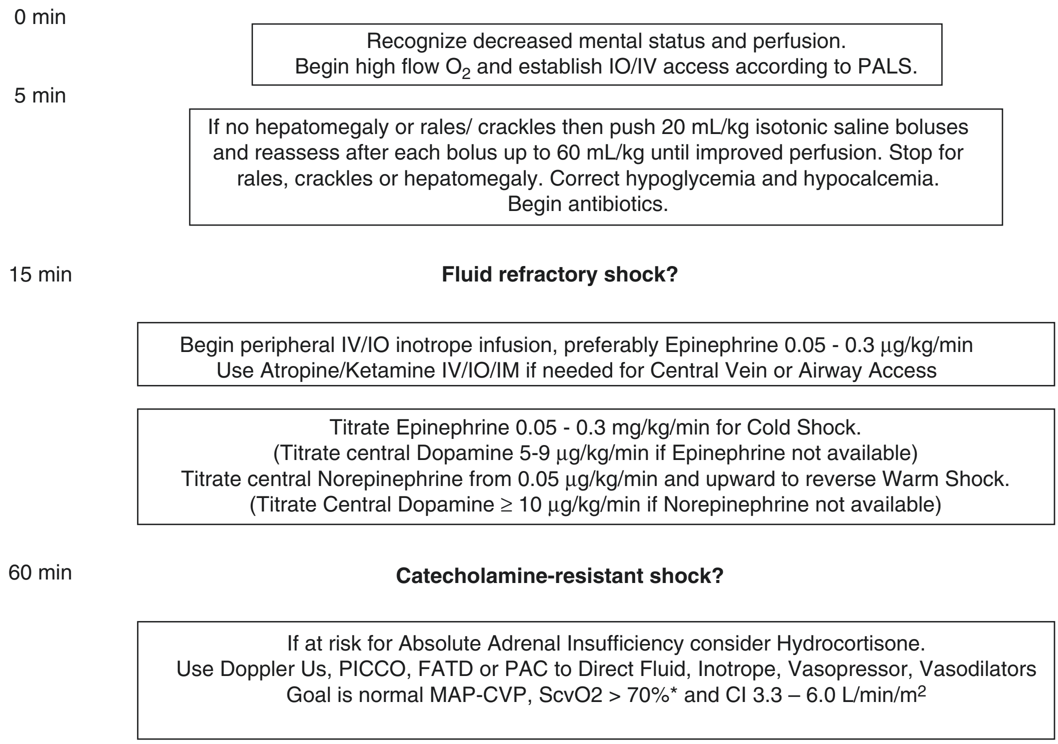

Fig. 8.2 First hour goals for the management of hemodynamic support in infants and children with septic shock (intensive care unit goals not shown). Reproduced with permission from from Brierley J, Carcillo JA, Choong K, Cornell T, DeCaen A, Deymann A et al. Clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine. Crit Care Med 2009;37:666. **Of note, this guideline and algorithm is undergoing review by the American College of Critical Care Medicine. The updated version of these guidelines is expected to support epinephrine as the first line vasoactive agent for cold shock

normal blood pressure. The 'first-hour' therapeutic actions outlined in the ACCM guidelines should be regarded as best practices for emergency department resuscitation (Fig. 8.2). It has been shown that adherence to PALS-ACCM guidelines significantly reduces mortality and hospital length of stay (Han et al. 2003; Paul et al. 2012; Carcillo et al. 2009; Oliveira et al. 2008).

Within the first 5 min of septic shock recognition, 100% oxygen via a non-rebreathing mask should be applied to maximize oxygen delivery to tissues. A significant amount of cardiac output supports work of breathing so ventilation should be supported as required. If rapid sequence intubation is necessary, hemodynamic stability should first be optimized with fluids. Ketamine is the sedative of choice. Etomidate should be avoided due to the potential for adrenocortical axis suppression (Brierley et al. 2009; den Brinker et al. 2008).

Intravenous access should be established within 5 min. If a peripheral IV cannot be established within this timeframe, an intraosseous catheter should be inserted. Laboratory tests, including blood cultures, should ideally be obtained at the time of intravenous access. Patients in septic shock are at risk for hypoglycaemia and hypocalcemia, so clinicians should be prepared to administer dextrose and calcium as needed. Children with hypoglycaemia should be administered and IV bolus of 0.25 g/kg of dextrose (2.5 mL/kg of D10W OR 1 mL/kg of D25W). Hypocalcemia can be corrected via infusion of calcium gluconate 10% solution in a dose of 50–100 mg/kg (0.5–1 mL/kg).

Volume resuscitation is the cornerstone of the ACCM management. Initial therapy should begin with a bolus of 20 mL/kg of isotonic crystalloid solution infused over 5 min or as rapidly as possible, preferably with a manual "push-pull" technique or rapid infuser. Repeated 20 mL/kg fluid boluses should be given until markers of tissue perfusion (discussed above) normalize, or signs of fluid overload (lung rales, gallop rhythm, hepatomegaly) develop. Many children require up to 60 mL/kg within the first hour. Recently, a large trial in sub-Saharan Africa demonstrated increased mortality from fluid boluses in children with compensated septic shock (Maitland et al. 2011). Although it is the only study of its kind to date, it highlights the potential for harm if fluid resuscitation is used indiscriminately in children in resource-poor settings with limited availability of mechanical ventilation and vasoactive support. The most recent PALS update maintains, that in resource rich settings, fluid resuscitation remains a key component of goal directed therapy but emphasizes the need for individualized clinical evaluation and frequent reassessments to determine the appropriate volume of fluid resuscitation in every patient (de Caen et al. 2015b, c). Studies are currently underway to determine whether children in developed countries might benefit from fluid-sparing strategies.

Intravenous antimicrobial therapy should be administered within 60 min of recognition. Appropriate antibiotic regimens depend on age, likely responsible pathogens and known local patterns of infection and resistance. Generally speaking, a third or fourth generation cephalosporin **plus** vancomycin for methicillin-resistant Staphylococcal aureus coverage represent an appropriate regimen for most children. In addition to the above, neonates should be treated with ampicillin to cover for Listeria. Immunocompromised children at risk for pseudomonas infections should also be treated with broader spectrum agents including carbapenems. Piperacillin with tazobactam, aminoglycosides and/or metronidazole should be used when enteric organisms are suspected, and clindamycin is recommended in cases of suspected toxic shock or necrotizing fasciitis.

Based on expert opinion, the ACCM recommends starting a vasoactive agent when a patient remains in shock despite 40–60 mL/kg of fluid resuscitation ('fluid-refractory shock'). Although central access is preferred, peripheral intravenous access can, and should be, used for initial vasoactive infusions (Brierley et al. 2009). Due to widespread availability and clinician familiarity, dopamine has traditionally been the first line vasoactive agent. However, recent evidence suggests that epinephrine is likely a safer and more effective first choice, especially for those with cold shock (Ventura et al. 2015). According to the most recent ACCM guidelines, peripheral epinephrine is the preferred first line agent for fluid-refractory shock. Thereafter, cold shock should be reversed by titrating epinephrine (or low dose central dopamine), and warm shock reversed by titrating central norepinephrine (or high dose central dopamine). Please see Fig 8.2. Patients with catecholamine-resistant shock often need a variety of vasodilators, afterload reducing agents and/or other vasopressors that should be titrated in an intensive care setting.

The use of corticosteroid therapy in those with catecholamine-resistant shock remains controversial as consistent, high quality evidence is lacking (Pizarro et al. 2005; Atkinson et al. 2014; Menon et al. 2013; Zimmerman and Williams 2011). Adjunctive steroid therapy is likely most important for patients at risk of adrenal insufficiency, children with purpura fulminans, those with a history of chronic steroid therapy or known hypothalamic, pituitary or adrenal abnormalities.

Summary

Signs and symptoms of shock may be subtle in children, leading to delays in recognition and underestimation of the severity of illness. The best approach to diagnosis involves a high level of clinical suspicion combined with the clinical history, vital signs and physical examination. Altered mental status and persistent tachycardia (often a sign of circulatory dysfunction) should not be overlooked. Standardized emergency department sepsis screening tools and protocols, which rely on abnormal vital signs and physical examination findings to help identify patients at risk, have been shown to reduce time to both fluid and antibiotic administration (Cruz et al. 2011; Larsen et al. 2011; Paul et al. 2014; Tuuri et al. 2016).

Emergency department nurses and physicians are in a unique position to affect sepsis outcomes since the therapies that a child receives during the initial treatment largely determine their prognosis. It is therefore crucial that every clinician who cares for children has a reliable approach to the recognition and resuscitation of pediatric septic shock.

Ill and injured children often seek medical care at physician offices and community hospitals (McPherson et al. 2008). Healthcare providers working in these settings must know how to safely transport a child who requires additional resources or an escalation in level of care. The regionalization of pediatric intensive care units and trauma services has made it imperative for providers to understand general principles of transport medicine (Lorch et al. 2010).

Despite existing recommendations by expert working groups, there are major variations in transport practice across North America and the world (Lorch et al. 2010; Whyte and Jefferies 2015). This chapter provides an overview of pediatric inter-facility transport and is divided into four sections, each exploring a different clinical question:

1. Which transport team should provide care for this child?
2. What is the best mode of transport?
3. How can medical care be optimized prior to transport?
4. What supplies and equipment should be prepared for transport?

References at the end provide additional information on the transport of neonates (Whyte and Jefferies, 2015) and pediatric trauma patients (Michailidou et al. 2014; Meyer et al. 2016).

Team Composition

Healthcare providers and parents often feel pressured to quickly move children to the centre where they will receive definitive care. However, most experts agree that the majority of children are best served by stabilization at the referral centre prior to departure (Ramnarayan et al. 2010; Barry and Leslie 2003). The child's expected clinical course is the most important factor in determining transport team composition and urgency of dispatch (Barry and Leslie 2003). For a critically ill child who is expected to deteriorate or require significant support, it is usually better to wait for dispatch of a specialized team than for an ad-hoc team to be hastily assembled.

Most evidence examining significant outcomes for children who require transport to a PICU comes from small retrospective and a few prospective studies. A Cochrane review found there is no high quality evidence from randomized controlled trials to support or refute that specialist teams for neonatal transport reduce mortality or morbidity among newborns requiring retrieval to a newborn intensive care unit (NICU) (Chang et al. 2008). Nevertheless, specialized transport teams are recommended as being the best option for most critically ill infants and children who require inter-facility transport (Whyte and Jefferies 2015). Ramnarayan et al. (2010) found that use of a specialized retrieval team was associated with decreased mortality risk in children transported to a pediatric intensive care unit (PICU). Orr et al. also found that children transported by specialized teams had a lower death rate of 9%, versus 23% for those transported by nonspecialized teams (Orr et al. 2009). They also found that nonspecialized teams who transport children have more significant adverse events including airway issues, cardiopulmonary arrest, sustained hypotension, loss of a crucial intravenous access and equipment failure with deterioration of patient status (Orr et al. 2009). Although the majority of critically ill children benefit from transport by a specialized team once they are stabilized at the referring centre, exceptions to this rule include children with epidural hematomas or bowel ischemia requiring emergent surgery. The relative benefits of immediate transport versus stabilization prior to departure should be carefully weighed in these children.

It is important to assess the transport team's comfort and experience with stabilizing children before transferring patient care. A clear team handover should take place with each team member's responsibilities being clearly outlined (Whyte and Jefferies 2015; Barry and Leslie 2003). The referring physician is generally responsible for patient care until arrival at the receiving, facility unless alternate arrangements have been made. Additional medication orders, supplies or resources should be anticipated and provided before departure.

Emergency medical services (EMS) teams are often appropriate for infants and children who require ongoing care, medications or fluids during transport e.g. an adolescent with suspected appendicitis who requires surgical consultation. EMS personnel and clinicians such as a nurse, respiratory therapist or physician may work together as a temporary team.

Parents and caregivers can transport stable children with no active airway or hemodynamic issues e.g. a child who requires foreign body removal from an ear, by a specialist physician.

Transport Mode

The relative merits of different transport modes are outlined in Table 8.2. Transport specialists in the PICU or NICU, emergency departments or

Table 8.2 Modes of transport

Transport mode	Advantage	Disadvantage
Private vehicle	No dispatch time Already has car seat or booster	No medical providers
Land ambulance	Easily available Fast dispatch time Can stop for procedures Accommodates extra team or family members Can be safer than helicopter for crew and patient (Meyer et al. 2016)	Slower than long distance flight Traffic can be slow Potholes and poor road conditions can worsen pain
Helicopter/rotor-wing	Faster than long distance drive Can do scene calls in remote and austere settings Can land on helipad at hospital	Affected by weather or night visibility Pressure at altitude can worsen some injuries and diseases May not be able to accommodate family members
Fixed wing	Can be faster than driving long distances	Requires additional transport leg to/from airport Affected by weather or night visibility Small work area, loud and turbulent Pressure at altitude can worsen some injuries and diseases May not be able to accommodate family members

regional air ambulance service should always be available to guide decisions about the safest and most effective way to transport children. This decision depends on many factors, including:

- The child's current condition and expected clinical course.
- Out-of-hospital time.
- Distance.
- Traffic conditions.
- Weather.
- Availability of specialized teams for air/land transport.

Pediatric trauma patients are frequently thought to require inter-facility transport by helicopter; although transport by helicopter is typically faster, the decreased transport time comes at the expense of increased risk to the patient and may not necessarily result in time-sensitive interventions at the receiving facility (Michailidou et al. 2014; Meyer et al. 2016).

Preparation for Transport

Critically ill children should be stabilized and trauma patients should have a full primary and secondary survey prior to departure, unless extenuating circumstances are present. Many transport teams now use pre-departure checklists or EMS protocols. These resources can be invaluable for ad-hoc teams tasked with infrequent pediatric transport.

Airway and Breathing Considerations

The airway should be patent or adequately protected, and the cervical spine should be immobilized in injured patients. Children may require intubation for oxygenation failure, ventilation failure, pulmonary toilet or expected clinical course. If the child is intubated, their endotracheal tube should be well secured after placement is confirmed according to local practice guidelines. A gastric tube should be left open to drainage in these children. A blood gas is strongly recommended to optimize oxygenation and ventilation parameters immediately before departure.

Oxygen saturation and end-tidal $C0_2$ should be continuously monitored in all ill infants and children. Before departure, oxygen tanks and suction should be checked to ensure adequate supply for the full duration of transport.

Tube thoracostomy should be considered for children with pulmonary injury or pleural effusion.

There are two special considerations in children who will be transported by air. First, *hypoxia* will worsen during flight as the fraction of inspired air ($Fi0_2$) decreases with altitude. Children with pulmonary injury or disease should receive supplemental oxygen during flight, and flight plans may need to be reconsidered for children with an $Fi0_2$ requirement >0.8 on the ground. Second, the possibility of *air entrapment* in a closed body cavity should be considered. Air expands at higher altitudes and this can cause pain and organ damage in children with pneumocephaly, pneumothorax and ocular, dental or bowel injury. The operations planner or flight team should be asked to limit altitude, or pressurize the cabin, when caring for children with either of these real or potential problems.

Circulatory Considerations

Adequate and/or ongoing volume resuscitation should be provided for children with tachycardia or signs of poor perfusion. At least one, and preferably two, reliable intravenous or intraosseous lines should be available for transport. The cannula sites must be visible with ports readily accessible and sufficient fluids, blood products and/or inotropic supports should be available for the duration of transport.

Pediatric trauma patients need to be inspected for signs of external bleeding, which should be managed with direct pressure, sutures, staples or other hemostatic controls. Sources of internal hemorrhage such as thoracic or abdominal injury, as well as significant external hemorrhages should be clearly delineated to the receiving facility. Urinary catheterization to monitor urine output in critically ill children should be considered.

Disability and Exposure Considerations

Blood glucose should be measured prior to departure and normoglycemia assured. A focused neurologic examination, including Glasgow Coma Scale, assessment of pupillary response, motor activity and tone in all limbs, should be performed prior to administration of sedatives or paralytic agents. Targeted treatments should be considered if increased intracranial pressure is suspected.

Temperature should be recorded for all children and measured continuously for infants, small children and unconscious patients. Thermoregulation can be maintained with a head covering, warm blankets or increasing the ambient temperature as needed. Fever and hyperthermia should be treated with antipyretics. A head-to-toe physical examination to document rashes, bruises or skin marks should be performed and recorded prior to departure.

Supplies and Equipment

Many transport teams use pre-departure packing lists to organize supplies and equipment prior to transport. One example of a simplified checklist is provided in Table 8.3. A variety of neonatal, pediatric and adult sizes should be available for all equipment listed.

Essential medications depend on the child's condition and expected course. Most regions have local EMS protocols for paramedics to deliver necessary and life-saving medications in the prehospital setting. As a general rule, most specialized teams carry cardiac drugs, antibiotics, anticonvulsants, analgesics, sedatives, paralytics and intravenous fluids on each transport. Blood products may also be prepared for transport of a trauma patient.

Table 8.3 Essential equipment and supplies

Type of intervention	Equipment and supplies
Airway and breathing	Bag-valve device, endotracheal tubes, laryngoscope Oxygen and nonrebreather masks Portable ventilator and circuit Portable oxygen and air cylinders Suction unit and catheters Chest tubes Difficult airway adjuncts – e.g. LMA, oropharyngeal airway Cervical immobilizers
Circulation	Intravenous cannulas Intraosseous needles Infusion pumps Extra tubing, stopcock, T-connectors Defibrillator Backboard
Monitoring and investigations	Pulse oximetry $EtC0_2$ monitors Cardiorespiratory monitors Blood pressure cuffs Thermometer Glucometer Point-of-care laboratory testing device and analyzer
Medications[a]	Useful medications to consider include: Analgesics and sedatives – e.g. ketamine, fentanyl, morphine, nitrous oxide Anaphylaxis – e.g. epinephrine 1:1000, epinephrine auto-injector Anti-arrhythmics and cardiac medications – e.g. epinephrine 1:10,000, adenosine, amiodarone, atropine, lidocaine, prostaglandin, inotropes and pressors Antimicrobials –e.g. ceftriaxone, ampicillin, cefotaxime and/or gentamycin Anti-epileptics – e.g. lorazepam, midazolam, diazepam, fosphenytoin, phenytoin, phenobarbital Blood products and fluids – e.g. normal saline, dextrose 10%, dextrose 50%, 3% hypertonic saline, sterile water, albumin Other – e.g. steroids (dexamethasone, hydrocortisone, methylprednisolone), paralytics (succinylcholine, rocuronium), activated charcoal, salbutamol, diphenhydramine, glucagon, insulin, magnesium sulphate, sodium bicarbonate

Table 8.3 (continued)

Type of intervention	Equipment and supplies
Moving the child safely	Stretcher or incubator Safety belts Metal pole or shelf to secure monitors, pumps and equipment
Record-keeping and communication	Patient transport record Resuscitation drug chart Mobile telephone Information package for parents with contact numbers Pen and medication/infusion labels
Additional supplies	Personal protective equipment—gowns, gloves, and masks Extra batteries for all electronics
Personal	Warm clothing and appropriate footwear Personal items Food and beverage

[a]Local EMS and specialized teams may carry a wide range of medications depending on their protocols and scope of practices. Never assume a given medication will be available. The child's expected clinical course should dictate which medications are prepared and drawn up prior to departure from the referring hospital

It is challenging and rewarding to care for an infant or child who requires inter-facility transport. An organized approach can be helpful to ensure the child, family and team are prepared for transport. The transport team should have the appropriate skills and expertise to care for the patient, based on the child's anticipated clinical trajectory. Choice of transport mode should be established collaboratively based on several extraneous factors, but including the child's clinical condition. Checklists are useful, if not essential, to ensure that all necessary supplies, equipment and medications are available for the entire transport. The references below provide additional checklists and further reading for those interested in neonatal, trauma and other specialized pediatric populations.

Acute pain in children is a common presenting symptom in the emergency setting, accounting for up to 78% of visits. (Dong et al. 2012; Grant 2006; Alexandre and Manno 2003; Krauss et al. 2016). An addition, fear of procedures is reported by children to be a significant anxiety-provoking aspect of their emergency room visit and the pain experience itself can have long term consequences (Kennedy et al. 2008). Pain and anxiety in infants and children can be successfully treated in the emergency room with use of age-appropriate pain assessment tools and implementation of non-pharmacologic and pharmacologic pain management strategies.

Pain Assessment

Pain assessment can be difficult particularly in younger children and infants as they are unable to verbalize their pain and often have associated anxiety related to fear of procedures or the emergency setting itself. Pain assessment tools are widely available and ideally should be used in triage as the first step in pain management (Srouji et al. 2010; Drendel et al. 2011). Early use of pain assessment scores has been shown to increase provision of analgesia and decrease time to provision of analgesia (Boyd and Stuart 2005; Nelson et al. 2004). Measures of pain include physiologic measures (e.g. heart rate and blood pressure), observational and behavioral measures and self-report. Self-report is the gold standard as behavioral measures may also reflect anxiety and fear. Physiologic measures may reflect stress reactions and hence are often used as adjuncts to other pain assessment tools. The Children's Hospital of Eastern Ontario pain scale is a widely used behavioral scale for younger infants and non-verbal children. Children as young as 3–4 years can self-report pain using visual scales such as the Faces Pain Scale (FPS-R), Wong-Baker FACES scale or the OUCHER pain scale. Numerical and 10-cm visual analogue scales are generally reserved for children older than 8 years with cognitive abilities to understand these abstract concepts (Srouji et al. 2010; Drendel et al. 2011).

Non-pharmacologic Management of Acute Pain

A child-centred approach is a key factor for successful management of pain in the emergency department. Parents and caregivers play a role in responding to their child's pain and should be encouraged to act as positive assistants for procedures rather than negatively restraining their child (Srouji et al. 2010). Open communication and preparation of the child and family for procedures with explanation of the procedure using non-medical jargon helps to reduce anxiety and fear. Cognitive or psychological measures such as age appropriate distraction techniques (e.g. bubbles, stories, videos and music) are useful adjuncts to reducing anxiety associated with procedures. Other behavioral strategies such as breastfeeding or non-nutritive sucking, kangaroo care (skin-to-skin contact), swaddling/tucking and rocking/holding have also been shown to be beneficial in neonates and young infants (Ali et al. 2016).

Pharmacologic Management of Acute Pain

Mild Pain

Oral analgesics such as acetaminophen or ibuprofen are safe and effective for the treatment of mild to moderate pain and are also used in conjunction with opioids for management of moderate to severe pain (Perrott et al. 2004). A higher initial loading dose of acetaminophen can be given, however, it is important to not exceed the recommended daily maximum doses. Ibuprofen is generally well tolerated in children with minimal adverse renal or gastrointestinal effects. More recently, alternating or simultaneous use of acetaminophen and ibuprofen strategies have been used if monotherapy is ineffective (Ong et al. 2010).

Moderate Pain

Oral opioid agents such as morphine in conjunction with NSAIDS (non-steroidal anti-inflammatory agents) and/or acetaminophen are generally used to treat moderate pain. Codeine, however often lacks analgesic potency as the enzyme necessary to metabolize the inactive pro-drug codeine (CYP 450 2D6) to morphine is missing in 10–12% of the Caucasian population (Le May et al. 2013). CYP2D6 polymorphisms can also result in ultra-rapid metabolism of codeine with potential for significant adverse effects including death (Kelly et al. 2012). NSAIDs can also be used for moderate pain and have been reported to be equally effective to low dose opioids with less side effects in some studies (Poonai et al. 2014).

Severe Pain

Intravenous morphine is the gold standard for management of severe pain. Fentanyl is a synthetic opioid, 100 times more potent than morphine. With a rapid onset of action (30 s), short duration of action (20–40 min) and lack of sedative properties at low dosing, fentanyl is an ideal agent for short painful procedures (Sahyoun and Krauss 2012). Intranasal fentanyl is well tolerated and has been shown to be equally effective for pain reduction to intravenous morphine (Borland et al. 2007). Hydromorphone is a potent opioid with a longer duration of action and generally used for patients with poor response or habituated response to morphine (e.g. sickle cell patients) (Sahyoun and Krauss 2012). Equipotent doses of all commonly used opioid agents produce similar degrees of nausea, vomiting, biliary tract spasm, pruritus, constipation and respiratory depression, however, individual responses may be variable and careful monitoring and titration of these agents is essential. Rigid chest syndrome with inability to ventilate a patient has been reported with large boluses of rapidly administered fentanyl, hence careful titration is necessary (Sahyoun and Krauss 2012). Dosage guidelines for use of opioid for acute pain management are listed in Table 8.4.

Procedural Pain

Fear of procedures is reported by children to be a significant anxiety-provoking aspect of their

Table 8.4 Dosage guidelines for use of opioid agents for acute pain in infants and older children

Opioid agent	Route of administration	Dosage
Morphine	PO	*Analgesia*: O.2–0.5 mg/kg/dose **Usual dose limit:** 15 mg/dose *Sedation*: 0.3 mg/kg, given 30–60 minutes prior to procedures
	IV	*Analgesia*: 0.05–0.1 mg/kg q2–4 h **Usual dose limit**: 5 mg/dose *Continuous infusion:* 10–40 µg/kg/h *Moderate Sedation*: 0.05–0.1 mg/kg IV, may repeat X 1 in 15 min prn
Fentanyl	IN	1.5 µg/kg, repeat q5 min prn for total of three doses Maximum volume: 0.5 mL per nostril in infants or 1 mL/nostril in children. Larger volumes should be divided between both nostrils
	IV	1–2 µg/kg/dose IV q30–60 min *Continuous infusion:* 0.5–2 µg/kg/h
Hydro-morphone	PO	Children ≤50 kg 0.04–0.08 mg/kg/dose q3–4 h prn Children >50 kg 2–4 mg/dose q3–4 h prn **Dose limit:** 4 mg/dose
	IV	0.015–0.2 mg/kg/dose q2–4 h *Continuous infusion:* 4–8 µg/kg/h **Dose limit**: 1 mg/dose

emergency room visit and the pain experience itself can have long term consequences (Kennedy et al. 2008). Although some procedures such as venipuncture and intravenous cannulation are viewed as minor, they often result in significant distress and anxiety for children and their caregivers (Kennedy et al. 2008). Even non-painful procedures for diagnostic imaging such as a CT scan which requires a child to lie motionless may provoke a high degree of anxiety. Other procedures such as fracture reduction and burn debridement are highly painful requiring a higher degree of analgesia and sedation.

Procedural sedation is a technique whereby sedative or dissociative agents with or without analgesic agents are used to induce a state that allows a patient to tolerate unpleasant procedures while maintaining cardiorespiratory function (American College of Emergency Physicians 2014). It has increasingly been adopted by emergency physicians skilled in advanced airway management and cardiopulmonary resuscitation. Safe sedation does require implementation of appropriate sedation guidelines and policies to minimize potential adverse effects (American College of Emergency Physicians 2014). Commonly used agents for minor procedures for anxiolysis with minimal sedative effects include midazolam (PO, IN) and inhaled nitrous oxide. Midazolam has no analgesic effects and hence requires additional analgesics for pain control. Intravenous midazolam is often combined with intravenous fentanyl and, with careful titration, produces more moderate sedation. Inhaled nitrous oxide is blended with oxygen and induces mild to moderate sedation and analgesia and has the advantage of onset and offset within 2–5 min. It is often used as an adjunctive agent for more painful procedures. Ketamine (IV, IM) is a dissociative agent characterized by potent analgesic and amnestic effects with relative lack of cardiopulmonary depression. It is a commonly used agent for procedural sedation in children and ideal for intensely painful procedures. Propofol is a deep anesthetic agent with rapid onset and pleasant recovery and is increasing being used in the emergency setting. It has a narrow therapeutic window and may result in significant respiratory depression and hypotension. It can be used alone for painless procedures requiring motion control such as CT scan and MRI, but additional analgesic agents are necessary for painful procedures (American College of Emergency Physicians 2014).

Sucrose Solution

Sucrose is a safe and effective method for reducing pain in infants for minor procedures such as venipuncture and heel lance (Stevens et al. 2013). This sweet solution can be prepared by pharmacy or available commercially and is generally instilled with a syringe in the infant's mouth 2 min prior to a procedure with or without a pacifier. Although the mechanism of action is unknown, pain reduction is thought to be mediated by both endogenous and non-opioid systems. While it appears most effective in neonates, it is often used in infants up to 12 months of age (Ali et al. 2016).

Topical Agents for Pain

Application of topical agents prior to needle insertion for venipuncture and intravenous cannulation are effective for reducing pain associated with these procedures. Comparison between commonly used topical agents including amethocaine (4% tetracaine, Ametop™), eutectic mixture of local anesthetics (lidocaine 2.5% and prilocaine 2.5%, EMLA™) and liposomal lidocaine (Maxilene™) are comparable in effectiveness with minimal side effects. Lidocaine-prilocaine requires an application time of 60 min and is associated with some blanching of the site, whereas amethocaine requires an application time of 30–45 min and can be associated with some erythema at the site (Ali et al. 2016). Concerns have been raised with use of lidocaine-prilocaine in young infants for methemoglobinemia due to a reduced level of methemoglobin reductase. Hence, alternative topical agents or a single dose of 1–2 g lidocaine-prilocaine cream with limited application time of 60 min should be considered (Taddio et al. 1998). Liposomal lidocaine is a newer topical anesthetic with a shorter application time of 30 min and has been associated with higher cannulation success rates (Taddio et al. 2005). Vapocoolant sprays are rapid acting evaporation-induced skin cooling agents that are also effective for reducing pain associated with IV cannulation (Farion et al. 2008).

LET (4% lidocaine, 0.1% epinephrine and 0.5% tetracaine) solution is a topical local anesthetic agent for laceration repair. It can be prepared by pharmacy or available commercially as a gel and is applied directly to wounds for 20–30 min. It is most effective on the scalp and face in producing wound anesthesia but also significantly reduces pain of subsequent injection of lidocaine if needed (Eidelman et al. 2011). Generally, use of LET on mucous membranes or end organs such as fingers is avoided, but small amounts applied with a cotton tip have been shown to be safe and effective (Bonadio 1996; White 2004). Pain associated with injection of lidocaine can also be reduced by slow injection, use of a fine needle and buffering with a solution of sodium bicarbonate (1 mL of 8.4% sodium bicarbonate to 9 mL of 1% or 2% lidocaine) (Fein et al. 2012).

Introduction

Trauma and injury are the biggest killers of children in the developed world. Although primary prevention is the best way to reduce casualties, robust and systematic management of traumatic injuries have been critical to reducing morbidity. This chapter reviews the basics of trauma management including the ABCDE approach ("primary survey"), with specific focus on pediatric physiology, interventions and management. We also provide an overview of the adjuncts to the primary survey, including, but not limited to radiography, ultrasound and CT scans. You will also find the basics of the "secondary survey", and a review of specific high yield injury topics, including C-spine injury, thoracic trauma, and abdominal trauma.

Scope of Pediatric Trauma

Traumatic injuries are the biggest killer of children in the developed world. Often referred to as 'accidents', most traumatic injuries represent discrete, potentially preventable events. Therefore, trauma has patterns, risk factors, and identifiable high-risk populations with preventative interventions. Traumatic injuries cost Canadian society millions of dollars annually (Public Health

Agency of Canada 2015); leading causes include include motor vehicle collisions (MVC), pedestrians and cyclists struck by vehicles, suffocation, falls from height, fires, and drowning. Blunt trauma accounts for >90% of injuries in children. Children are at greater risk of serious injury than adults when operating all-terrain vehicles and snowmobiles (Yanchar et al. 2012).

Pre-hospital Care

Trauma systems and regionalized trauma care have been shown to improve outcomes in severely injured trauma patients. Although critically ill injured children may have better outcomes when treated in designated pediatric trauma centers and tertiary intensive care units, specific criteria and age cut-offs for transfer to the pediatric trauma centers vary across the country. Pre-hospital triage scores used by pre-hospital care providers consider factors such as age, weight, airway compromise, hemodynamic instability, level of consciousness or Glasgow Coma Scale (GCS), and the presence of open or multiple fractures (Tepas et al. 1987).

The majority of traumatic injuries occur in adults, and thus the standard Advanced Trauma Life support (ATLS) course focuses primarily on adult trauma. While there are numerous differences in pediatric trauma management, the general approach to assessing the child with multiple injuries is the same.

ABCDE Approach

The traditional "ABCDE" (airway with cervical-spine [c-spine] control, breathing, circulation with hemorrhage control, disability, exposure) approach to trauma should be employed in all injured children.

Airway

A is for airway, which needs to be managed first. The oropharynx should be examined for foreign bodies such as loose teeth, and any debris removed. If the child is alert and crying, airway patency is usually not of concern, with the notable exception of neck trauma, where a rapidly expanding hematoma may occlude the airway if not identified early. Specific details related to the pediatric airway are beyond the scope of this chapter.

In trauma, 'A' includes c-spine control, as it is prudent to assume any blunt trauma victim has a c-spine injury until proven otherwise. This can be established through placement of a cervical collar until injury to the spine can be excluded (to be discussed below). Endotracheal intubation may be difficult due to distorted anatomy or due to blood, foreign bodies or teeth occluding the airway. Since in-line stabilization is initially required for all airway manipulation, airway support in trauma is considered 'difficult', with adjuncts such as laryngeal mask airways (LMAs), bougie, video laryngoscopy and surgical airways sometimes being required.

Breathing

Once a definitive airway is established, breathing adequacy must be assessed. A significant proportion of traumatic deaths occur due to hypoxia, and adequate oxygenation and ventilation of the trauma patient is of paramount importance. Immediate placement of all trauma patients on a non-rebreather face mask with 100% oxygen should be considered. The patient should be assessed for bilateral breath sounds and signs of hemo-pneumothorax, such as uneven or decreased breath sounds and subcutaneous emphysema. Progressive buildup of air in the pleural space, often from a lung laceration, can lead to a tension pneumothorax. The 'one-way valve' effect can be exacerbated by positive pressure ventilation. Classic signs of a tension pneumothorax are tracheal deviation away from the side of tension, hyper-expanded chest with poor chest wall movements, decreased breath sounds and increased percussion note on the affected side, although these signs can be difficult to appreciate in a busy trauma bay. Increasing tachypnea, tachycardia and hypoxia should raise the suspicion of a tension pneumothorax. Left untreated, ensuing circulatory collapse with hypotension may lead to traumatic arrest due to impaired venous return to the heart (obstructive shock).

Procedural interventions required include needle decompression of a tension pneumothorax and tube thoracostomy (chest tube) to drain air or blood from the chest. Needle decompression can be achieved using a large gauge (14–16 G) over the needle catheter inserted in the second intercostal space at a mid-clavicular line. The chest tube should be inserted between the anterior and mid-axillary lines of the fourth or fifth intercostal space. In trauma, the open procedure with a large size chest tube is preferable as blood may block smaller tubes.

Circulation and Hemorrhage Control

Hemodynamic status can be monitored clinically through frequent assessment of vital signs, mental status, skin color, pulses, capillary refill and urinary output. Tachycardia is the most sensitive sign of blood loss, with pain and fear also being major contributors. A fall in blood pressure is a late sign of blood loss in children who frequently maintain a perfusing pressure with up to 35–40% blood volume loss prior to becoming hypotensive. Since a drop in hemoglobin takes time, initial blood results are not reliable in identifying ongoing blood loss.

Two large bore intravenous lines (IV) are often needed for resuscitation, especially if there is hemodynamic compromise. As obtaining IV access can be difficult in young children, an intraosseus needle should be inserted if no IV access has been obtained within 90 seconds. Central venous access in young traumatized children is discouraged, as it can be procedurally difficult and time consuming and the length of catheter often precludes delivery of the high volumes of fluid/blood required.

Any obvious hemorrhage should be controlled with direct pressure. Although tourniquets have limited indications in trauma management, they can be considered if direct pressure does not stop the bleeding. Full exposure of the patient should be performed early to identify additional sources of blood loss. If there are signs of shock but no obvious external hemorrhage, internal bleeding sources must be identified. Massive hemorrhage can occur in the chest (hemothorax), in the abdomen and pelvis, in fractured long bones in adolescents and the scalp in infants. Obstructive shock from cardiac tamponade or tension pneumothorax (see 'B' above) must also be considered in the differential diagnosis of the hypotensive trauma patient.

Fluid Resuscitation and Hemorrhage

In patients with abnormal hemodynamics and signs of hemorrhagic shock, an initial bolus of normal saline or lactated Ringers' (20–40 ml/kg) is indicated. If the patient is unresponsive to the initial fluid bolus, blood products should be given, as excessive fluid resuscitation with crystalloids can be harmful.

Close monitoring of coagulation parameters is necessary, as disseminated intravascular coagulation (DIC) is a frequent result from trauma, with or without major hemorrhage. Massive transfusion protocols are becoming widely adopted by trauma centers to minimize the coagulopathy associated with trauma (Chidester et al. 2012; Hendrickson et al. 2011). Balanced blood resuscitation using packed red blood cells, fresh frozen plasma (FFP) and platelets has been advocated, although ideal ratios of these products remain unknown and the use of massive transfusion protocols varies considerably across the country (Horst et al. 2016). A foundation 2:1 ratio of red blood cells to platelets may be considered, along with goal directed therapy for replacement of platelets, cryoprecipitate and calcium (Dzik et al. 2011).

Tranexamic acid (TXA) has been shown to be safe and effective in high doses in pediatric surgery (Hasegawa et al. 2014). Although there is minimal evidence supporting its use in pediatric trauma, many experts feel that it should be considered within three hours of injury if there is obvious blood loss (Beno et al. 2014; Eckert et al. 2014), or if any blood transfusion is required.

Disability and GCS

A pediatric GCS (described elsewhere) and AVPU (alert, verbal, pain, unresponsive) scale should be used serially to describe all trauma patients. After establishing GCS or AVPU, a rapid assessment of neurologic status in all trauma patients is required. Pupils should be examined, and a brief neurologic exam should be performed if possible prior to intubation or use of drugs that may alter the neurologic exam. Significant bradycardia and hypotension refractory to fluid resuscitation should alert the trauma team to the possibility of an upper C-spine injury leading to neurogenic shock. Presence of hypertension and bradycardia may signal increased intracranial pressure.

Exposure and Temperature Control

The final step in the primary survey of all trauma patients is exposure, whereby the child should be fully exposed and log-rolled to assess for injuries to the back of the head and deformities or tenderness of the spine. Although an external genitourinary exam is an important, a digital rectal exam (DRE) should only be considered in select patients where there is concern about spinal injury. It has poor sensitivity in detecting spinal cord injuries, bowel and rectal injuries, pelvic fractures or urethral disruptions. It adds little to the assessment, can be falsely reassuring and may be upsetting for the pediatric patient (Shlamovitz et al. 2007). Since iatrogenic injury from prolonged stay on a backboard has been described, the patient should be removed from the backboard at this point (Totten and Sugarman 2009; Langevin 2016).

Keeping the patient warm is imperative as temperature instability and hypothermia are part of the 'trauma triad of death' (along with coagulopathy and acidosis) (Mikhail 1999). The trauma room should be appropriately warm, and warm blankets should be covering the patient. This is particularly true in children, who lose much more heat than adults due to increased body surface area to weight ratio. If the patient remains hypothermic or need for ongoing fluid resuscitation is anticipated, warmed crystalloids and blood products should be considered (this can be achieved through a level 1 infusion pump/rapid infuser if available).

Adjuncts to Primary Survey

Imaging, such as radiography and a focused assessment of sonography in trauma (FAST) are important adjuncts that may need to be considered. While there is no standard set of images to be done on every trauma patient, plain films of the c-spine, chest and pelvis are frequently performed. Recent evidence suggests that hemodynamically stable children with multiple trauma and GCS ≥13 who have normal examination of the pelvis and hip, no hematuria and do not have a femur fracture can safely forego pelvic imaging (Haasz et al. 2015). Radiographs for suspected skeletal injuries may be performed but should not delay definitive care for life threating injuries. Other imaging modalities can be employed, depending on clinical and radiographical findings. Although adult trauma patients often get 'pan CTs', this approach is strongly discouraged in children due to the long term effects of ionizing radiation (Nellensteijn et al. 2016; Pandit et al. 2016). Additionally, if the patient is being transferred to a trauma center, CT scan can usually be safely deferred (Fahy et al. 2016).

The FAST exam, traditionally incorporated into adult trauma activations, is a recent addition to pediatric trauma care. Since the utility of this exam is currently being investigated in children, a negative FAST in children does not rule out intra-abdominal injury (Scaife et al. 2013) and a positive FAST does not necessarily indicate the need for operative intervention (Berona et al. 2016), and it is insufficiently sensitive to replace CT (Menaker et al. 2014). Extending the FAST exam may be useful, as it can detect small pneumothoraces, heart function and more (Marin et al. 2015). These examinations should only be performed in conjunction with traditional imaging, and interpreted within appropriate clinical context.

Blood work, often referred to as a 'trauma panel' can be drawn upon insertion of the two large bore IVs (see Circulation). Suggested bloodwork includes complete blood count, blood gas, group and screen/crossmatch, amylase and/or lipase, liver function tests (AST, ALT), coagulation profile including fibrinogen, renal function, electrolytes, glucose as well as βHCG and toxicology screen. Urinalysis should be assessed for macroscopic hematuria (>50 red blood cells/hpf) to screen for renal or genitourinary injury (Santucci et al. 2004; Perez-Brayfield et al. 2002).

Secondary Survey

After the primary survey is completed and the child stabilized, a secondary survey should be performed. The secondary survey is a comprehensive examination of the patient's history, a detailed physical examination and the completion of any adjunctive laboratory or imaging tests not yet performed. An AMPLE history should be performed: **A**llergies, any relevant **M**edications, **P**ast medical history, time of **L**ast meal and **E**vents leading up to the trauma.

Specifically, the head and face should be examined for hematomas (boggy or firm), depressed skull fractures, and scalp lacerations. Signs of a basilar skull fracture such as hemotympanum, periorbital ecchymosis ('raccoon eyes'), bruising over the mastoid ('Battles's sign') and cerebrospinal fluid rhinorrhea/otorrhea should be noted. Pupillary diameter and reactivity should be documented, the facial bones palpated, and the oral cavity examined for missing teeth or signs of malocclusion. The chest should be re-examined for respiratory effort, heart/breath sounds, flail chest or other injuries. Any bruising on the abdomen (especially in seatbelt distribution, abdominal tenderness or peritoneal irritation) should be noted. The genitourinary system should be examined for vaginal bleeding, blood at the urethral meatus or perineal or scrotal bruising, which may suggest injury to the genitourinary system. Extremities should be examined for deformity, open fracture or neurovascular compromise. Finally, a mental status assessment and peripheral neurologic exam should be performed, including sensation, motor function (power, tone), deep tendon reflexes, and paresthesias, with special attention to focal neurologic deficits. This examination aspect may be challenging in young children.

Children and infants are at a much higher risk for spinal ligamentous injury, due to ligamentous laxity and skeletal immaturity. Additionally, spinal cord injury without radiographic abnormality (SCIWORA) is much more common in children compared to adults.

Radiography of c-spine rules out the majority of related injuries (Connelly et al. 2016). However, given the higher incidence of SCIWORA in children compared to adults, MRI may be required in select cases. Important anatomic differences that predispose children to C-spine injury include: ligamentous laxity, shallow angle of facet joints, relatively larger head leading to a higher rate of axial injuries in young children, and multiple vertebral ossification centers, all of which make radiological interpretation challenging. Risk factors for c-spine injury include: altered mental status, focal neurological deficit, neck pain, torticollis, substantial torso injury, predisposing condition (e.g. arthritis, Trisomy 21), diving, high risk MVC (Leonard et al. 2011). Although a detailed discussion about clearing the pediatric cervical spine is beyond the scope of this text, clinical decision rules such as the NEXUS criteria may be helpful to aid in clinical clearance in a cooperative child (Vinson 2001; Michaleff et al. 2012). Plain films in children are about 90% sensitive for C-spine injury, and therefore should be the first imaging modality in alert, non-intubated children who cannot be cleared clinically. (Nigrovic et al. 2012). If the cervical spine cannot be evaluated as normal, it is advisable to keep the patient in a soft collar (or bags besides his/her head if the child is too small for a traditional collar) until detailed imaging (usually MRI) can be performed.

Traumatic Brain Injury

Compared to adults, children are more susceptible to intracranial injuries due to their larger head-to-body size ratio, open sutures and thinner cranial bones. Additionally, a high brain water content and relative paucity of myelinated tissue predispose children to cerebral edema and diffuse axonal injury.

Mild head injury is defined as a GCS score >13. Although this may result in concussion, detailed discussion about concussion is beyond the scope of this chapter. A number of clinical decision rules exist to help risk stratify children with respect to the need for neurological intervention and likelihood of brain injury on CT scan (CATCH rules) (Osmond et al. 2010) as well as to identify children at low risk of clinically important traumatic brain injury (PECARN and CHALICE rules) (Kuppermann et al. 2007; Harty and Bellis 2010). Based on previous studies, factors that warrant consideration for a CT scan to rule out a clinically important traumatic brain injury in children >2 years old include GCS <15, altered metal status and signs of a basal skull fracture. Vomiting more than once, loss of consciousness for more than five seconds, severe headache or severe mechanism of injury (fall >5 ft, MVC with rollover, ejection or fatality, pedestrian/bicycle without helmet versus vehicle or struck by high velocity object) should also raise suspicion of a possible intracranial bleed (Kuppermann et al. 2007). In children <2 years old, palpable skull fractures, the presence of a scalp hematoma (other than frontal), and abnormal behavior as per parents may also suggest significant head trauma.

After a traumatic head injury has occurred, the primary management goal is to minimize secondary injury to the brain, the most common of which are hypoxia, hypotension and hypothermia. Coagulopathy, acidosis and GCS have also been associated with increased mortality, and may help identify high risk patients (Davis et al. 2017).

Hypoxia is minimized by timely provision of 100% supplemental oxygen via a non-rebreather mask and by early consideration of intubation with significant neurologic deterioration. Children should be intubated by the most experienced individual, as multiple intubation attempts can create spikes in intracranial pressure. Ketamine can be used as a sedative agent for intubation in trauma, as the previously held belief regarding its contraindication has been disproven (Wang et al. 2014; Bar-Joseph et al. 2009; Chang et al. 2013).

Physicians need to be aware of the possibility of brainstem herniation, classically presenting with Cushing's triad of hypertension, irregular respirations and bradycardia. Asymmetric pupils and progressive obtundation are the hallmark of herniation and warrant urgent intervention and an immediate neurosurgical consultation. Management consists of elevating the head of the bed to 30°, assuring that venous drainage is not blocked by a tight cervical collar, administration of IV mannitol (1 g/kg) and/or IV 3% hypertonic saline (3–5 ml/kg), sedation and appropriate airway management with ventilation parameters targeting a low normal end tidal CO_2 (approximately 35 mmHg). Hyperventilating the patient below the lower limit of normocapnia may reduce cerebral blood flow to the point of impaired oxygen delivery, leading to brain ischemia (Skippen et al. 1997), and, is therefore reserved for refractory patients with a 'blown' pupil while awaiting definitive operative management.

Temperature must be strictly monitored, and the patient should be warmed to normothermia.

There is currently no role for therapeutic hypothermia in children with traumatic brain injuries (Hutchison et al. 2008, 2010).

Thoracic Trauma

After head injury, thoracic trauma is the second most common cause of injured related mortality in children. Children are less likely to have rib fractures than adults due to increased chest wall compliance, with forces preferentially transmitted to internal organs. This results in more pulmonary contusions and hemo/pneumothorax. Tension pneumothorax can also develop more rapidly. Children are more prone to hypoxia due to higher metabolic rate, increased oxygen consumption per kg body weight and reduced functional residual capacity.

High energy mechanisms can still lead to rib fractures. A flail chest occurs when two or more ribs are fractured in two or more places, leaving a 'floating' segment which in turn results in paradoxical chest movement with respiratory pressure changes. If associated with an underlying pulmonary contusion, this scenario can lead to respiratory insufficiency or failure requiring respiratory support.

Abdominal Trauma

Eight to twelve percent of seriously injured children sustain an intra-abdominal injury and the most common causes are MVCs, pedestrian collisions and falls (Cooper et al. 1994). Abdominal trauma needs to be strongly considered in children with seatbelt and handlebar injuries, and those with non-accidental injuries. Management of children with solid organ injuries has evolved markedly over the last two decades and most solid organ abdominal injuries are now treated non-operatively. (Dodgion et al. 2014; Wisner et al. 2015). The most commonly injured abdominal organs are the spleen and the liver. Compared to adults: children are smaller and their ribs are more pliable which results in transfer of greater kinetic energy to thoracic and upper abdominal organs, and their weaker abdominal musculature and thinner abdominal wall provides less organ protection. Furthermore, intra-abdominal organs in children are in closer proximity to each other increasing the risk of multiple organ injury.

Clinical predictors of blunt abdominal injury include: (in order of importance): (1) Evidence of abdominal wall trauma or seat belt sign, (2) GCS score <14, (3) Abdominal tenderness, (4) Evidence of thoracic wall trauma, (5) Abdominal pain, (6) Decreased breath sounds, (7) Vomiting.

Penetrating abdominal injuries involve the gastrointestinal tract more often than the solid organs—most children with these injuries require operative management. A seatbelt sign (transverse abdominal ecchymosis caused by acute flexion over a lapbelt) should raise suspicion of injury of the small bowel and duodenum, mesenteric avulsions, and associated lumbar distraction injuries (Chance fracture). As these may be missed on initial imaging, they warrant close monitoring as well as serial exams.

References

Alexandre J, Manno M. Under use of analgesia in very young pediatric patients with isolated painful injuries. Annu Emerg Med. 2003;41(5):617–22.

Ali S, McGrath T, Drendel AL. An evidence-based approach to minimizing acute procedural pain in the emergency department. Pediatr Emerg Care. 2016;32(1):36–42.

American College of Emergency Physicians. Clinical policy: procedural sedation and analgesia in the emergency department. Ann Emerg Med. 2014;63(2):247–57.

Atkins DL, et al. Part 11: Pediatric basic life support and cardiopulmonary resuscitation quality: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2015;132(18 Suppl 2):S519–25.

Atkinson SJ, Cvijanovich NZ, Thomas NJ, et al. Corticosteroids and pediatric septic shock outcomes: a risk stratified analysis. PLoS One. 2014;9(11):e112702.

Balamuth F, Weiss SL, Neuman MI, et al. Pediatric severe sepsis in U.S. children's hospitals. Pediatr Crit Care Med. 2014;15:798.

Bar-Joseph G, Guilburd Y, Tamir A, Guilburd JN. Effectiveness of ketamine in decreasing intracra-

nial pressure in children with intracranial hypertension. J Neurosurg Pediatr. 2009;4(1):40–6.
Barry P, Leslie A. Paediatric and neonatal critical care transport. London: BMJ Publishing Group; 2003.
Batton DG, Barrington KJ, Wallman C, American Academy of Pediatrics, Committee on Fetus and Newborn, Section of Anesthesiology and Pain Medicine; Canadian Paediatric Society Fetus and Newborn Committee. Prevention and management of pain the neonate: an update. Pediatrics. 2006;118(5):2231–41.
Beno S, Ackery AD, Callum J, Rizoli S. Tranexamic acid in pediatric trauma: why not? Crit Care. 2014;18(4):313.
Berona K, Kang T, Rose E. Pelvic free fluid in asymptomatic pediatric blunt abdominal trauma patients: a case series and review of the literature. J Emerg Med. 2016;50(5):753–8.
Bistritz JF, Horton LM, Smaldone A. Therapeutic hypothermia in children after cardiac arrest: a systematic review and meta-analysis. Pediatr Emerg Care. 2015;31(4):296–303.
Bonadio WA. Safe and effective method for application of tetracaine, adrenaline and cocaine to oral lacerations. Ann Emerg Med. 1996;28(4):396–8.
Borland M, Jacobs I, King B, et al. A randomized controlled trial comparing intranasal fentanyl to intravenous morphine for managing acute pain in children in the emergency department. Ann Emerg Med. 2007;49(3):335–40.
Boyd JR, Stuart P. The efficacy of structured assessment and analgesia provision in the paediatric emergency department. Emerg Med J. 2005;22:30–2.
Brierley J, Carcillo JA, Choong K, et al. Clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine. Crit Care Med. 2009;37:666.
Bruder EA, et al. Single induction dose of etomidate versus other induction agents for endotracheal intubation in critically ill patients. Cochrane Database Syst Rev. 2015;1:CD010225.
Carcillo JA, Kuch BA, Han YY, et al. Mortality and functional morbidity after use of PALS/APLS by community physicians. Pediatrics. 2009;124(2):500.
Chan CM, Mitchell AL, Shorr AF. Etomidate is associated with mortality and adrenal insufficiency in sepsis: a meta-analysis. Crit Care Med. 2012;40(11):2945–53.
Chang A, Berry A, Jones LJ, Sivasangari S. Specialist teams for neonatal transport to neonatal intensive care units for prevention of morbidity and mortality. Cochrane Database Syst Rev. 2008;4:CD007485.
Chang LC, Raty SR, Ortiz J, Bailard NS, Mathew SJ. The emerging use of ketamine for anesthesia and sedation in traumatic brain injuries. CNS Neurosci Ther. 2013;19(6):390–5.
Chidester SJ, Williams N, Wang W, Groner JI. A pediatric massive transfusion protocol. J Trauma Acute Care Surg. 2012;73(5):1273–7.
Chou EH, et al. Ultrasonography for confirmation of endotracheal tube placement: a systematic review and meta-analysis. Resuscitation. 2015;90:97–103.
Connelly CR, Yonge JD, Eastes LE, Bilyeu PE, Kemp Bohan PM, Schreiber MA, et al. Performance improvement and patient safety program (PIPS) guided quality improvement initiatives can significantly reduce CT imaging in pediatric trauma patients. J Trauma Acute Care Surg. 2016;81(2):278–84.
Cooper A, Barlow B, DiScala C, String D. Mortality and truncal injury: the pediatric perspective. J Pediatr Surg. 1994;29(1):33–8.
Cruz AT, Perry AM, Williams EA, et al. Implementation of goal-directed therapy for children with suspected sepsis in the emergency department. Pediatrics. 2011;127:e758.
Davis AL, Wales PW, Malik T, Stephens D, Razik F, Schuh S. The BIG score and prediction of mortality in pediatric blunt trauma. Crit Care Med. 2017;45:1061–93.
de Caen AR, et al. Part 12: Pediatric advanced life support: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Pediatrics. 2015a;136(Suppl 2):S176–95.
de Caen AR, Berg MD, Chameides L, et al. Part 12: pediatric advanced life support 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2015b;132(Suppl 2):S526–42.
de Caen AR, Maconochie IK, Aickin R, et al. Part 6: Pediatric basic life support and pediatric advanced life support 2015 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation. 2015c;132(suppl 1):S177–203.
den Brinker M, et al. One single dose of etomidate negatively influences adrenocortical performance for at least 24 h in children with meningococcal sepsis. Intensive Care Med. 2008;34(1):163–8.
Dodgion CM, Gosain A, Rogers A, St Peter SD, Nichol PF, Ostlie DJ. National trends in pediatric blunt spleen and liver injury management and potential benefits of an abbreviated bed rest protocol. J Pediatr Surg. 2014;49(6):1004–8. discussion 1008
Dong L, Donaldson A, Metzger R, Keenan H. Analgesic administration in the emergency department for children requiring hospitalization for long bone fractures. Pediatr Emerg Care. 2012;28:109–14.
Drendel AL, Kelly BT, Ali S. Pain assessment for children: overcoming challenges and optimizing care. Pediatr Emerg Care. 2011;27(8):773–80.
Dzik WH, Blajchman MA, Fergusson D, Hameed M, Henry B, Kirkpatrick AW, et al. Clinical review: Canadian National Advisory Committee on Blood and Blood Products – massive transfusion consensus conference 2011: report of the panel. Crit Care. 2011;15(6):242.
Eckert MJ, Wertin TM, Tyner SD, Nelson DW, Izenberg S, Martin MJ. Tranexamic acid administration to pedi-

atric trauma patients in a combat setting: the pediatric trauma and tranexamic acid study (PED-TRAX). J Trauma Acute Care Surg. 2014;77(6):852–8. discussion 858

Eidelman A, Weiss JM, Baldwin CL, et al. Topical anaesthetics for repair of dermal laceration. Cochrane Database Syst Rev. 2011;6:CD005364.

Ellis DY, Harris T, Zideman D. Cricoid pressure in emergency department rapid sequence tracheal intubations: a risk-benefit analysis. Ann Emerg Med. 2007;50(6): 653–65.

Fahy AS, Antiel RM, Polites SF, Ishitani MB, Moir CR, Zielinski MD. Pretransfer computed tomography delays arrival to definitive care without affecting pediatric trauma outcomes. J Pediatr Surg. 2016;51(2): 323–5.

Farion KJ, Splinter KL, Newhook K, et al. The effect of vapocoolant spray on pain due to intravenous cannulation in children: a randomized controlled trial. CMAJ. 2008;179(1):31–6.

Fein JA, Zempsky WT, Cravero JP, The Committee on Pediatric Emergency Medicine and Section on Anesthesiology and Pain Medicine. Relief of pain and anxiety in pediatric patients in emergency medical systems. Pediatrics. 2012;130(5):e1391–405.

Filanovsky Y, Miller P, Kao J. Myth: ketamine should not be used as an induction agent for intubation in patients with head injury. CJEM. 2010;12(02):154–7.

Gaines NN, Patel B, Williams EA, Cruz AT. Etiologies of septic shock in a pediatric emergency department population. Pediatr Infect Dis J. 2012;31:1203.

Girotra S, et al. Survival trends in pediatric in-hospital cardiac arrests: an analysis from get with the guidelines-resuscitation. Circulation. 2013;6(1):42–9.

Goldstein B, Giroir B, Randolph A. International consensus conference on pediatric sepsis. International pediatric sepsis consensus conference: definitions for sepsis and organ dysfunction in pediatrics. Pediatr Crit Care Med. 2005;6:2.

Grant PS. Analgesia delivery in the emergency department. Am J Emerg Med. 2006;24:806–9.

Haasz M, Simone LA, Wales PW, Stimec J, Stephens D, Beno S, et al. Which pediatric blunt trauma patients do not require pelvic imaging? J Trauma Acute Care Surg. 2015;79(5):828–32.

Han YY, Carcillo JA, Dragotta MA, et al. Early reversal of pediatric-neonatal septic shock by community physicians is associated with improved outcome. Pediatrics. 2003;112:793.

Hartman ME, Linde-Zwirble WT, Angus DC, Watson RS. Trends in the epidemiology of pediatric severe sepsis. Pediatr Crit Care Med. 2013;14:686.

Harty E, Bellis F. CHALICE head injury rule: an implementation study. Emerg Med J. 2010;27(10): 750–2.

Hasegawa T, Oshima Y, Maruo A, Matsuhisa H, Tanaka A, Noda R, et al. Intraoperative tranexamic acid in pediatric bloodless cardiac surgery. Asian Cardiovasc Thorac Ann. 2014;22(9):1039–45.

Hendrickson JE, Shaz BH, Pereira G, Parker PM, Jessup P, Atwell F, et al. Implementation of a pediatric trauma massive transfusion protocol: one institution's experience. Transfusion. 2011;52(6): 1228–36.

Horst J, Leonard JC, Vogel A, Jacobs R, Spinella PC. A survey of US and Canadian hospitals' paediatric massive transfusion protocol policies. Transfus Med. 2016;26(1):49–56.

Hotchkiss RS, Karl IE. The pathophysiology and treatment of sepsis. N Engl J Med. 2003;348:138.

Hughes S. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. BET 3: is ketamine a viable induction agent for the trauma patient with potential brain injury. Emerg Med J. 2011;28(12):1076–7.

Hutchison JS, Ward RE, Lacroix J, Hébert PC, Barnes MA, Bohn DJ, et al. Hypothermia therapy after traumatic brain injury in children. N Engl J Med. 2008;358(23):2447–56.

Hutchison JS, Frndova H, Lo T-YM, Guerguerian A-M. Hypothermia Pediatric Head Injury Trial Investigators, Canadian Critical Care Trials Group. Impact of hypotension and low cerebral perfusion pressure on outcomes in children treated with hypothermia therapy following severe traumatic brain injury: a post hoc analysis of the Hypothermia Pediatric Head Injury Trial. Dev Neurosci. 2010;32(5–6):406–12.

Kelly LE, Rieder M, van den Anker J, et al. More codeine fatalities after tonsillectomy in North American Children. Pediatrics. 2012;129:e1324–7.

Kennedy RM. Sedation in the emergency department: a complex and multifactorial challenge. In: Mason KP, editor. Pediatric sedation outside of the operating room. New York, NY: Springer; 2015. p. 367–422.

Kennedy RM, Luhmann J, Zempsky WT. Clinical implications of unmanaged needle-insertion pain and distress in children. Pediatrics. 2008;122:S130–3.

Kleinman ME, et al. Part 14: pediatric advanced life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2010a;122(18 Suppl 3):S876–908.

Kleinman ME, de Caen AR, Chameides L, et al. Pediatric basic and advanced life support: 2010 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Pediatrics. 2010b;126:e1261.

Krauss BS, Calligari L, Green SM, Barbi E. Current concepts in management of pain in children in the emergency department. Lancet. 2016;387:83–92.

Kuppermann N, Holmes J, Dayan P, Hoyle J, Atabaki S, Dean J, et al. Blunt head trauma in the pediatric emergency care applied research network (PECARN). Acad Emerg Med. 2007;14(5 Suppl 1):S94–5.

Kutko MC, Calarco MP, Flaherty MB, et al. Mortality rates in pediatric septic shock with and without multiple organ system failure. Pediatr Crit Care Med. 2003;4:333.

Langevin M. Ditch the spine board – emergency physicians monthly. Bel Air, MD: Emergency Physicians Monthly; 2016. p. 1–6.

Larsen GY, Mecham N, Greenberg R. An emergency department septic shock protocol and care guideline for children initiated at triage. Pediatrics. 2011;127:e1585–92.

Le May S, Gouin S, Fortin C, et al. Efficacy of an ibuprofen/codeine combination for pain management in children presenting to the emergency department with a limb injury: a pilot study. J Emerg Med. 2013;33(2):536–41.

Leonard JC, Kuppermann N, Olsen C, Babcock-Cimpello L, Brown K, Mahajan P, et al. Factors associated with cervical spine injury in children after blunt trauma. Ann Emerg Med. 2011;58(2):145–55.

Lorch S, Myers S, Carr B. The regionalization of pediatric health care. Pediatrics. 2010;126(6):1182–90.

Maitland K, Kiguli S, Opoka RO, et al. Mortality after fluid bolus in African children with severe infection. N Engl J Med. 2011;364:2483.

Marin JR, Lewiss RE, American Academy of Pediatrics, Committee on Pediatric Emergency Medicine, Society for Academic Emergency Medicine, Academy of Emergency Ultrasound, American College of Emergency Physicians, Pediatric Emergency Medicine Committee, World Interactive Network Focused on Critical Ultrasound. Point-of-care ultrasonography by pediatric emergency medicine physicians. Pediatrics. 2015;135(4):e1113–22.

McPherson ML, Jefferson LS, Graf JM. A validated pediatric transport survey: how is your team performing? Air Med J. 2008;27(1):40–5.

Menaker J, Blumberg S, Wisner DH, Dayan PS, Tunik M, Garcia M, et al. Use of the focused assessment with sonography for trauma (FAST) examination and its impact on abdominal computed tomography use in hemodynamically stable children with blunt torso trauma. J Trauma Acute Care Surg. 2014;77(3):427–32.

Menon K, McNally D, Choong K, Sampson M. A systematic review and meta-analysis on the effect of steroids in pediatric shock. Pediatr Crit Care Med. 2013;14(5):474.

Meyer MT, Gourlay DM, Weitze KC, Ship MD, Drayna PC, Wener C, Lerner EB. Helicopter interfacility transport of pediatric trauma patients: are we overusing a costly resource? J Trauma Acute Care Surg. 2016;80(2):313–7.

Michailidou M, Goldstein SD, Salazar J, Aboagye J, Steward D, Efron D, Abdullah F, Haut ER. Helicopter overtriage in pediatric trauma. J Pediatr Surg. 2014;49(110):1673–7.

Michaleff ZA, Maher CG, Verhagen AP, Rebbeck T, Lin C-WC. Accuracy of the Canadian C-spine rule and NEXUS to screen for clinically important cervical spine injury in patients following blunt trauma: a systematic review. CMAJ Can Med Assoc. 2012; 184(16):E867–76.

Mikhail J. The trauma triad of death: hypothermia, acidosis, and coagulopathy. AACN Clin Issues. 1999;10(1): 85–94.

Mittiga MR, Rinderknecht AS, Kerrey BT. A modern and practical review of rapid-sequence intubation in pediatric emergencies. Clin Pediatr Emerg Med. 2015;16(3):172–85.

Moler FW, et al. Therapeutic hypothermia after out-of-hospital cardiac arrest in children. N Engl J Med. 2015;372(20):1898–908.

Nellensteijn DR, Greuter MJ, Moumni El M, Hulscher JB. The use of CT scan in hemodynamically stable children with blunt abdominal trauma: look before you leap. Eur J Pediatr Surg. 2016;26(4):332–5.

Nelson BP, Cohen D, Lander O, et al. Mandated pain scores improves frequency of ED analgesic administration. Am J Emerg Med. 2004;22(7):582–5.

Nigrovic LE, Rogers AJ, Adelgais KM, Olsen CS, Leonard JR, Jaffe DM, et al. Utility of plain radiographs in detecting traumatic injuries of the cervical spine in children. Pediatr Emerg Care. 2012;28(5):426–32.

Oliveira CF, Nogueira de Sá FR, Oliveira DS, et al. Time- and fluid-sensitive resuscitation for hemodynamic support of children in septic shock: barriers to the implementation of the American College of Critical Care Medicine/pediatric advanced life support guidelines in a pediatric intensive care unit in a developing world. Pediatr Emerg Care. 2008;24(12):810.

Ong CK, Seymour RA, Lirk P, Merry AF. Combining paracetamol (acetaminophen) with nonsteroidal anti-inflammatory drugs: a qualitative systematic review of analgesic efficacy for acute postoperative pain. Anesth Analg. 2010;110(4):1170–9.

Orr RA, Felmet KA, Han Y, McCloskey KA, Dragotta MA, Bills DM, Kuch BA, Watson RS. Pediatric specialized transport teams are associated with improved outcomes. Pediatrics. 2009;124(1):40–8.

Osmond MH, Klassen TP, Wells GA, Correll R, Jarvis A, Joubert G, et al. CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. Can Med Assoc J. 2010;182(4): 341–8.

Pandit V, Michailidou M, Rhee P, Zangbar B, Kulvatunyou N, Khalil M, et al. The use of whole body computed tomography scans in pediatric trauma patients: Are there differences among adults and pediatric centers? J Pediatr Surg. 2016;51(4):649–53.

Paul R, Neuman MI, Monuteaux MC, Melendez E. Adherence to PALS sepsis guides decreases hospital length of stay. Pediatrics. 2012;130:e273–80.

Paul R, Melendez E, Stack A, et al. Improving adherence to PALS septic shock guidelines. Pediatrics. 2014;133(5):e1358–66.

Perez-Brayfield MR, Gatti JM, Smith EA, Broecker B, Massad D, Scherz H, et al. Blunt traumatic hematuria in children. is a simplified algorithm justified? J Urol. 2002;167:2543–7.

Perrott DA, Piira T, Goodenough B, Champion GD. Efficacy and safety of acetaminophen vs. ibu-

profen for treating children's pain and fever. JAMA Pediatr. 2004;15(6):521–6.
Pizarro CF, Troster EJ, Damiani D, Carcillo JA. Absolute and relative adrenal insufficiency in children with septic shock. Crit Care Med. 2005;33(4):855.
Poonai N, Bhullar G, Kangrui L, et al. Oral administration of morphine versus ibuprophen to manage postfracture pain in children: a randomized trial. CMAJ. 2014;186(18):1358–63.
Public Health Agency of Canada. The cost of injury in Canada. Ottawa, ON: Public Health Agency of Canada; 2015. p. 1–177.
Ramnarayan P, Thiru K, Parslow RC, Harrison DA, Draper ES, Rowan KM. Effect of specialist retrieval teams on outcomes in children admitted to paediatric intensive care units in England and Wales: a retrospective cohort study. Lancet. 2010;376:698–704.
Ruth A, McCracken CE, Fortenberry JD, et al. Pediatric severe sepsis: current trends and outcomes from the pediatric health information systems database. Pediatr Crit Care Med. 2014;15:828.
Sahyoun C, Krauss B. Clinical implications of pharmacokinetics and pharmacodynamics of procedural sedation agents in children. Curr Opin Pediatr. 2012;24:225–32.
Santucci RA, Langenburg SE, Zachareas MJ. Traumatic hematuria in children can be evaluated as in adults. J Urol. 2004;171(2 Pt 1):822–5.
Scaife ER, Rollins MD, Barnhart DC, Downey EC, Black RE, Meyers RL, et al. The role of focused abdominal sonography for trauma (FAST) in pediatric trauma evaluation. J Pediatr Surg. 2013;48(6):1377–83.
Scott HF, Donoghue AJ, Gaieski DF, et al. The utility of early lactate testing in undifferentiated pediatric systemic inflammatory response syndrome. Acad Emerg Med. 2012;19:1276.
Scott HF, Brou L, Deakyne SJ, et al. Lactate clearance and normalization and prolonged organ dysfunction in pediatric sepsis. J Pediatr. 2016;170:149–55.e1–4. https://doi.org/10.1016/j.jpeds.2015.11.071.
Shaw KN, Bachur RG, editors. Fleisher and Ludwig's textbook of pediatric emergency medicine. 17th ed. Philidelphia, PA: Wolters Kluwer; 2016.
Shi F, et al. Cuffed versus uncuffed endotracheal tubes in children: a meta-analysis. J Anesth. 2016;30:3–11.
Shlamovitz GZ, Mower WR, Bergman J, Crisp J, DeVore HK, Hardy D, et al. Lack of evidence to support routine digital rectal examination in pediatric trauma patients. Pediatr Emerg Care. 2007;23(8):537–43.
Singh A, Frenkel O. Evidence-based emergency management of the pediatric airway. Pediatr Emerg Med Pract. 2013;10(1):1–25.
Skippen P, Seear M, Poskitt K, Kestle J, Cochrane D, Annich G, et al. Effect of hyperventilation on regional cerebral blood flow in head-injured children. Crit Care Med. 1997;25(8):1402–9.
Srouji R, Ratnapalan S, Schneeweiss S. Pain in children: assessment and non-pharmacologic management. Int J Pediatr. 2010;2010:Article ID: 474838.
Steiner, J. The use of apneic oxygenation during prolonged intubation in pediatric patients: a randomized clinical trial. 2016.; https://clinicaltrials.gov/ct2/show/NCT01886807?term=apneic+oxygenation&rank=3. Accessed 24 Mar 2016.
Stevens B, Yamada J, Lee GY, et al. Sucrose for analgesia in newborn infants undergoing painful procedures. Cochrane Database Syst Rev. 2013;1:CD001069.
Stollings JL, et al. Rapid-sequence intubation a review of the process and considerations when choosing medications. Ann Pharmacother. 2014;48(1):62–76.
Taddio A, Ohlsson A, Einarson TR, Stevens B, Koren G. A systematic review of lidocaine-prilocaine cream (EMLA) in the treatment of acute pain in neonates. Pediatrics. 1998;101(2):E1.
Taddio A, Kaur Soin H, Schuh S, et al. Liposomal lidocaine to improve procedural success rates and reduce procedural pain among children: a randomized controlled trial. CMAJ. 2005;172(13):1691–5.
Tepas JJ III, Mollitt DL, Talbert JL, Bryant M. The pediatric trauma score as a predictor of injury severity in the injured child. J Pediatr Surg. 1987;22(1):14–8.
Totten VY, Sugarman DB. Respiratory effects of spinal immobillzatlon. Prehosp Emerg Care. 2009;3(4):347–52.
Tuuri RE, Gehrig MG, Busch CE, et al. "Beat the shock clock": an interprofessional team improves pediatric septic shock care. Clin Pediatr (Phila). 2016;55(7):626–38.
Ventura AM, Shieh HH, Bousso A, et al. Double-blind prospective randomized controlled trial of dopamine versus epinephrine as first-line vasoactive drugs in pediatric septic shock. Crit Care Med. 2015;43:2292.
Vinson DR. NEXUS cervical spine criteria. Ann Emerg Med. 2001;37(2):237–8.
Wang X, Ding X, Tong Y, Zong J, Zhao X, Ren H, et al. Ketamine does not increase intracranial pressure compared with opioids: meta-analysis of randomized controlled trials. J Anesth. 2014;28(6):821–7.
Watson RS, Carcillo JA, Linde-Zwirble WT, et al. The epidemiology of severe sepsis in children in the United States. Am J Respir Crit Care Med. 2003;167:695.
Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. Ann Emerg Med. 2012;59(3):165–75. e1
Weiss M, et al. Prospective randomized controlled multicentre trial of cuffed or uncuffed endotracheal tubes in small children. Br J Anaesth. 2009;103(6):867–73.
Weiss SL, Parker B, Bullock ME, et al. Defining pediatric sepsis by different criteria: discrepancies in populations and implications for clinical practice. Pediatr Crit Care Med. 2012;13:e219.
Weiss SL, Fitzgerald JC, Pappachan J, et al. Global epidemiology of pediatric severe sepsis: the sepsis prevalence, outcomes, and therapies study. Am J Respir Crit Care Med. 2015a;191:1147.
Weiss SL, Fitzgerald JC, Maffei FA, et al. SPROUT Study Investigators and Pediatric Acute Lung Injury and

Sepsis Investigators Network. Discordant identification of pediatric severe sepsis by research and clinical definitions in the SPROUT international point prevalence study. Crit Care. 2015b;19:325.

White NJ. Kim Mk, Brousseau DC et al. The anesthetic effectiveness of lidocaine-adrenaline-tetracaine gel on finger lacerations. Pediatr Emerg Care. 2004;20(12):812–5.

Whyte HE, Jefferies AL. The interfacility transport of critically ill newborns. Paediatr Child Health. 2015;20(5):265–75.

Wisner DH, Kuppermann N, Cooper A, Menaker J, Ehrlich P, Kooistra J, et al. Management of children with solid organ injuries after blunt torso trauma. J Trauma Acute Care Surg. 2015;79(2):206–14.

Yanchar NL, Warda LJ, Fuselli P. Child and youth injury prevention: a public health approach. Paediatr Child Health. 2012;17(9):511–2.

Zimmerman JJ, Williams MD. Adjunctive corticosteroid therapy in pediatric severe sepsis: observations from the RESOLVE study. Pediatr Crit Care Med. 2011;12(1):2.