INTRODUCTION

In the United States, approximately 17,000 children and adolescents die annually of unintentional and intentional injuries.\(^1\) According to the National Center for Injury Prevention and Control, unintentional injury was the number 1 cause of death in children 1 to 18 years of age in 2007, accounting for 41.5% of childhood deaths, followed by homicide (11.2%), malignant neoplasms (9.0%), and suicide (6.1%). In infants under a year of age, unintentional injury accounts for 4.4% of deaths. When further broken down by injury type, injuries sustained in motor vehicle accidents account for more than half of these deaths. The leading causes of traumatic death in children and adolescents from 2007 are listed in Table 1.

Childhood injury is a major focus for trauma research, both for prevention and best practices for coordination of care from acute stabilization through rehabilitation. Several advancements in injury prevention have dramatically decreased unintentional

Disclosures: None.

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injury mortality, including enhanced child restraints for most states, pool fencing, and bicycle helmet laws, although universal compliance has not yet been achieved. A Centers for Disease Control and Prevention vital signs report renewed prevention efforts in research, education, and outreach programming when surveillance revealed unintentional injury remained the leading cause of childhood morbidity despite a 40% decrease since 2005. Suffocation and poisoning subsets have substantially increased in that time frame as well.2

### PHYSIOLOGIC CONSIDERATIONS IN THE PEDIATRIC PATIENT

Children have unique anatomy and physiology that must be taken into consideration when managing them as trauma patients. First and foremost, compared with adults, children are much more susceptible to multiple and more severe injuries given the same amount of force in any given trauma. This force is more widely distributed throughout their bodies, often resulting in more significant internal organ damage, sometimes without significant external signs. Additionally, the proportionately larger surface area of children’s bodies to their weight exposes them to significant heat loss and subsequent secondary negative effects. These effects include decreased cardiac function, cardiac inotropy, left ventricular contractility, catecholamine responsiveness, platelet function, renal and hepatic drug clearance, and a higher metabolic demand that potentiates metabolic acidemia.3

Knowledge of or access to a chart of normal vital signs broken down by age helps facilitate recognition of critically injured children (Table 2).4 Multiple platforms exist online and via electronic tablets or mobile devices to access this information in real time during a trauma resuscitation. Blood pressure is not listed to help reinforce a pediatric patient’s capacity to maintain a normal blood pressure despite significant loss of up to 25% to 30% of total blood volume.3 Changes in heart rate, respiratory rate, and peripheral perfusion can indicate imminent cardiopulmonary collapse and should be closely monitored throughout a patient’s stabilization period.

### Table 1

<table>
<thead>
<tr>
<th>Children &lt;1 y</th>
<th>Cause of Death</th>
<th>Number of Deaths</th>
<th>Percentage of Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unintentional suffocation</td>
<td>959</td>
<td>54.9</td>
<td></td>
</tr>
<tr>
<td>Homicide unspecified</td>
<td>174</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>Unintentional MVC</td>
<td>122</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Homicide other spec, classifiable</td>
<td>86</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Unintentional drowning</td>
<td>57</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Children 1–18 y</th>
<th>Cause of Death</th>
<th>Number of Deaths</th>
<th>Percentage of Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unintentional MVC</td>
<td>4910</td>
<td>40.1</td>
<td></td>
</tr>
<tr>
<td>Homicide firearm</td>
<td>1553</td>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>Unintentional drowning</td>
<td>918</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Unintentional poisoning</td>
<td>645</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Suicide suffocation</td>
<td>566</td>
<td>4.6</td>
<td></td>
</tr>
</tbody>
</table>

Lastly, when injured, pediatric patients have a significantly higher energy and caloric requirement than at baseline. Their oxygen extraction and consumption as well as glucose use is much higher per kilogram than their adult counterparts. Therefore, maintaining adequate oxygenation and consideration of early initiation of glucose-containing fluids are important in the management of injured children.

**INTRODUCTION TO THE PEDIATRIC PRIMARY SURVEY**

The initial assessment and survey of pediatric patients is not vastly different from those of adults. This brief and focused assessment is necessary to rule out the presence of life-threatening injury and set in motion life-saving interventions within 5 minutes of presentation. During the primary survey, vital signs should be continuously monitored, allowing for early notification of impending compromise for patients. The primary survey is composed of A for airway, B for breathing, C for circulation, D for disability, E for exposure, and F for family. If at any time during this initial assessment a patient begins to deteriorate, the provider should start at the top and reassess each step again to stabilize the patient.

**Primary Survey: Airway**

Effective management of a pediatric airway is challenging because it poses both anatomic and physiologic differences from the adult airway. Children become hypoxic much more quickly and thus require careful preparation and swift intervention. In pediatrics, effective airway management is a critical component to successful cardiopulmonary resuscitation. Respiratory arrest usually precedes cardiac arrest in children. When assessing the pediatric airway, the first priority is to ensure the airway is clear and patent. Can the child speak? Or is he or she crying if not yet verbal? If the voice seems muffled, the provider may consider an oral foreign body and should

### Table 2

<table>
<thead>
<tr>
<th>Age</th>
<th>Heart Rate</th>
<th>Respiratory Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 mo</td>
<td>139 (90–165)</td>
<td>43 (26–68)</td>
</tr>
<tr>
<td>1 mo</td>
<td>145 (110–182)</td>
<td>42 (25–67)</td>
</tr>
<tr>
<td>2 mo</td>
<td>143 (108–180)</td>
<td>42 (24–66)</td>
</tr>
<tr>
<td>3 mo</td>
<td>142 (105–178)</td>
<td>41 (23–65)</td>
</tr>
<tr>
<td>6 mo</td>
<td>136 (100–170)</td>
<td>40 (22–62)</td>
</tr>
<tr>
<td>9 mo</td>
<td>130 (95–165)</td>
<td>39 (22–60)</td>
</tr>
<tr>
<td>12 mo</td>
<td>125 (93–160)</td>
<td>38 (21–67)</td>
</tr>
<tr>
<td>2 y</td>
<td>110 (80–150)</td>
<td>30 (18–42)</td>
</tr>
<tr>
<td>4 y</td>
<td>105 (70–135)</td>
<td>25 (16–31)</td>
</tr>
<tr>
<td>6 y</td>
<td>95 (60–130)</td>
<td>22 (16–28)</td>
</tr>
<tr>
<td>8 y</td>
<td>90 (55–120)</td>
<td>20 (15–25)</td>
</tr>
<tr>
<td>10 y</td>
<td>85 (55–115)</td>
<td>20 (14–25)</td>
</tr>
<tr>
<td>12 y</td>
<td>80 (50–110)</td>
<td>19 (12–24)</td>
</tr>
<tr>
<td>14–18 y</td>
<td>75 (45–105)</td>
<td>15 (10–22)</td>
</tr>
</tbody>
</table>

sweep the mouth for debris, teeth, and other items. Additionally, evidence of facial fractures or tracheal injury should be noted as potential for a complicated airway. Once the airway has been deemed clear and intubation is eminent, the differences in the pediatric airway (summarized in Table 3) should be considered before intubation (Box 1).

Rapid sequence intubation with both sedation and a paralytic is the optimal setting for airway control. Prior to intubating a pediatric trauma patient, a contingency plan should be in place. Although rapid sequence intubation is safe and effective, especially in emergent situations, there are times when this method fails and a back-up method must be ready to be executed immediately, which may be in the form of a supraglottic airway adjunct or video laryngoscopy. More recently, there is evidence showing that, although the duration of intubation is slightly longer (36 seconds vs 23.8 seconds), video laryngoscopy provides a better view than direct laryngoscopy in the pediatric airway.8

There has been some controversy surrounding the consistent use of continuous cricoid pressure (Sellick maneuver) during intubation. Although this method may be considered during sedation and paralysis to aid in the reduction of gastric aspiration, it should be at the discretion of the intubating practitioner once airway manipulation begins9 because of the significant risk of obstruction and delayed tube placement if not used skillfully.10 In the pediatric airway, it takes as little as 0.2 lb of force to obstruct the airway; thus, careful steps must be taken when manipulating the cricoid externally.3

**Cervical spine considerations with intubation**

If intubating a pediatric patient who has been involved in trauma, the patient should have continuous attention to cervical spine (C-spine) immobilization during the procedure. During intubation there should be minimal to no movement of the neck. It is most helpful for another person to hold in-line C-spine immobilization while the front of the

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Anatomic differences in the pediatric airway</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airway Differences</strong></td>
<td><strong>Interventions</strong></td>
</tr>
<tr>
<td>Prominent occiput</td>
<td>Place a rolled towel under the shoulders May not be possible in cervical spine precautions</td>
</tr>
<tr>
<td>Larger tongue that falls against the hypopharynx</td>
<td>Use of an oropharyngeal airway, optimize head positioning, jaw-thrust position</td>
</tr>
<tr>
<td>Larger adenoid tissues contribute to obstruction5</td>
<td>Use of an oropharyngeal airway, optimize head positioning, jaw-thrust position</td>
</tr>
<tr>
<td>Floppy, U-shaped epiglottis</td>
<td>Use of a straight blade</td>
</tr>
<tr>
<td>Larynx more cephalad and anterior</td>
<td>May need to be closer to the patient at a 45° angle6</td>
</tr>
<tr>
<td>Cricoid ring is the narrowest portion of the airway</td>
<td>Have a size smaller tube ready because the larger may pass the cords but not the cricoid</td>
</tr>
<tr>
<td>Narrow tracheal diameter and distance between the rings</td>
<td>Must do needle cricothyrotomy rather than surgical</td>
</tr>
<tr>
<td>Shorter tracheal length resulting in frequent right-mainstem intubations or dislodgement</td>
<td>Use 3 times the tube size to estimate accurate depth of placement, minimize head movement once placed6</td>
</tr>
</tbody>
</table>
cervical collar is released to allow for mandibular manipulation. Often this is a situation where video laryngoscopy is considered first line; however, a small prospective case study in 2012 revealed a decreased view of the glottis entrance when used with C-spine precautions.\textsuperscript{11}

**Selecting equipment**

The endotracheal (ET) tube size should be determined by a length-based resuscitation tape or age-based calculation:

- Uncuffed: $4 + \left( \frac{\text{age in years}}{4} \right) $\textsuperscript{12}
- Cuffed: $3.5 + \left( \frac{\text{age in years}}{4} \right) $\textsuperscript{12}

It is important to prepare ET tubes both one-half size larger and one-half size smaller before initiating intubation. When considering a laryngoscope blade, the straight blade is usually preferred for children under 2 years of age due to its ability to manipulate the epiglottis. Additionally, a straight blade may be more useful in situations where there is concern for C-spine injury because it results in less motion of the neck.\textsuperscript{13} Depth of placement is most accurately estimated by multiplying the tube size by 3, resulting in correct placement more than 80\% of the time.\textsuperscript{14} Immediately after placement, typical methods of ET tube placement confirmation should be completed, such as equal chest rise and breath sounds, air fogging in the ET tube, absence of gastric sounds with bagging, and color change on colorimetric capnography. There is no substitute for direct visualization of the ET tube passing through the cords and a decompensating patient should always have airway placement reevaluated. Consideration of end-tidal capnography for the most accurate confirmation of continued correct placement is becoming a part of regular ongoing monitoring practice for intubated patients.\textsuperscript{9}

**Cuffed or uncuffed?**

Beyond the newborn period, a cuffed ET tube is a safe option for airway management.\textsuperscript{9} In some instances, placement of a cuffed tube is favorable because it helps reduce the risk of aspiration, allows for management of airway swelling, and helps those who may require higher ventilator settings. This practice is supported by the American Heart Association Pediatric Advanced Life Support guidelines.\textsuperscript{9} Traditionally, uncuffed ET tubes were preferred for children under 8 years of age because there was concern for pressure-induced ischemic damage to their tracheal mucosa from the cuff, mostly due in part to the cricoid cartilage being the narrowest part of the airway.

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**Box 1**

Indications for intubating pediatric trauma patients

- Glasgow Coma Scale (GCS) score <8 or obtunded
- Inadequate oxygenation or ventilation—poor effort or color
- Inability to maintain or protect airway—gag reflex not especially helpful because it does not correlate with GCS\textsuperscript{7}
- Inability to ventilate by bag-valve-mask (BVM) or need for prolonged control
- Severe head injury
- Potential for clinical deterioration (thermal inhalation injuries)
- Respiratory failure from flail chest
- Decompensated shock resistant to initial fluid resuscitation
as opposed to adults where the narrowest part is the vocal cords. Several studies have shown, however, there is no increase in postextubation stridor, need for racemic epinephrine, or long-term complications when cuffed tubes are used in pediatric airway control.\textsuperscript{15,16} It is important to keep cuff pressures no greater than 20 mm H\textsubscript{2}O to 25 mm H\textsubscript{2}O to avoid harm to a patient’s airway.\textsuperscript{9}

**Primary Survey: Breathing and Ventilation**

The breathing and ventilation assessment of trauma patients begins with observation of the neck and chest. Specific areas for inspection include tracheal deviation, abnormal chest wall movement, use of accessory muscles, and injury to the chest wall. Identification of these signs trigger recognition of the following life-threatening injuries: tension pneumothorax, flail chest, impending respiratory failure, and cardiothoracic injury, respectively. As the provider moves through this portion of the trauma assessment, action may be required before moving on to the next step to address life-threatening conditions. Considerations when managing breathing and ventilation in pediatric trauma patients are

**Physiologic considerations in pediatric breathing**

- Respiratory rate: age dependent. A chart with normal ranges should be readily available to the provider (see Table 2).
- Increased vagal tone: tendency to result in bradycardia with tongue blade manipulation. It is no longer standard practice, however, to pretreat with atropine for intubation.
- Smaller tidal volumes: for all children, set initial tidal volumes at 6–8 mL/kg. Careful setting of the ventilator helps avoid iatrogenic barotrauma.
- Lower functional residual capacity: children have little intrapulmonary oxygen reserve and become hypoxic more precipitously than adults. Optimal preoxygenation with BVM and passive oxygenation with a nasal cannula help avoid this phenomenon. Additionally, the nasal cannula should remain in place for passive oxygenation while intubating.\textsuperscript{17}
- Higher oxygen metabolism: leads to a shorter safe apnea time.\textsuperscript{18}
- Respiratory fatigue: children are diaphragmatic breathers at baseline. They do not possess the chest wall musculature to aid in respiration; therefore, fatigue happens more quickly.
- Positioning is of utmost importance. Anatomic alignment for both C-spine precautions and sniffing position is preferred; hyperextension often leads to obstruction.
- Jaw-thrust maneuvers help open the airway in unresponsive children. Consider placement of oral airway to lift the tongue and pharyngeal soft tissues to aid with BVM ventilation.

**Bag-valve-mask ventilation**

BVM ventilation is a temporizing method of ventilating pediatric patients; it is commonly used in prehospital settings and has been shown to be even more effective than intubation for emergency medical services providers.\textsuperscript{19} It is important to ensure the proper size, and methods are used to reduce the risk of barotrauma to patients. All pediatric BVM units should be equipped with a safety pop-off valve along with a manometer that limits peak inspiratory pressures between 35 cm H\textsubscript{2}O and 40 cm H\textsubscript{2}O per breath. Each breath administered should be just enough to make the chest rise. The mask should only cover the mouth and nose to ensure a proper seal. Additionally, use of an oropharyngeal airway is particularly useful in children with
macroglossia or tonsillar hypertrophy. To select the correct size of the oral airway, hold it along the side of a child’s face with the flange at the corner of the mouth. The opposite end of the oropharyngeal airway should reach the angle of the mandible. With optimal use of BVM ventilation, children may be ventilated for long periods of time if necessary or until a more definitive airway is established.

Finally, once the airway is established and the child placed on the ventilator, it is important to understand the potential harm that hyperoxemia presents postintubation. In recent adult studies, hyperoxemia has been shown to significantly increase patient risk for in-hospital mortality. When subsequently studied in children, however, one group of researchers did not find a difference in mortality with hyperoxia after cardiac arrest. Hyperoxemia is likely to be studied more extensively in the future and should remain a consideration when managing intubated pediatric patients.

**Primary Survey: Circulation**

Assessment of pediatric patients’ circulation and volume status involves examination of central and peripheral pulses, skin color, and capillary refill. Blood pressure is not an initial measure of circulation because pediatric patients have excellent compensatory measures that allow for blood pressure maintenance even in the face of significant volume loss (Table 4). These measures include an increase in heart rate and systemic vascular resistance to aid in central shunting. When these fail, however, children quickly convert from compensated to decompensated shock and risk complete cardiopulmonary failure. Signs of decompensated shock in pediatric patients include cool pale extremities, weak peripheral pulses, mottled/cyanotic skin, altered mental status, and delayed capillary refill. The avoidance of decompensated shock is possible with attention to specific signs and symptoms that are aggressively addressed in this initial evaluation.

When treating shock in pediatric patients, it is helpful to understand the category of shock. Three types of shock exist in traumatized patients: hemorrhagic, cardiogenic, and distributive. Hemorrhagic shock may present externally or internally. Either way, until the source of blood loss is identified, temporarily compressed, and then stopped, other resuscitative efforts minimally improve a patient’s clinical status. Cardiogenic shock can occur in the setting of severe thoracic trauma from cardiac contusion or rupture inhibiting the heart from pumping normally. Finally, distributive shock typically occurs in the setting of poor circulation as a result of either obstruction of return or loss of vascular tone in the setting of spinal cord injuries. In each of these types of shock, fluid or blood product resuscitation likely is required in conjunction with specific interventions to address patient injuries.

Because hemorrhagic shock is most common in trauma, initial intervention should begin with a 20-mL/kg bolus of isotonic intravenous/intraosseous fluids for resuscitation. If no significant response has been achieved after 2 20-mL/kg fluid boluses, additional resuscitative efforts are required.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Systolic blood pressures—5th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonates (0–28 d)</td>
<td>60 mm Hg</td>
</tr>
<tr>
<td>1–12 mo</td>
<td>70 mm Hg</td>
</tr>
<tr>
<td>1–10 y</td>
<td>70 + (2 × age in years)</td>
</tr>
<tr>
<td>&gt;10 y</td>
<td>90 mm Hg</td>
</tr>
</tbody>
</table>

boluses, reassessment and consideration of packed red blood cell transfusion (10–20 mL/kg) follows. The overall goal is to improve oxygen delivery and reduce consumption to reverse the state of shock.

**Primary Survey: Disability**

Rapid identification of neurologic deficits takes place during the disability portion of the primary survey. Use of the GCS or another validated neurologic evaluation tool is the quickest way to complete this assessment. The American Heart Association Pediatric Advanced Life Support program recommends the use of the AVPU scale.9 This mnemonic stands for decreasing levels of consciousness: alert, responds to voice, responds to pain, and unresponsive. It should also be recognized that a child’s mental status can be dramatically affected by hypoglycemia in this setting. Rapid bedside evaluation of glucose and correction can help in accurately assessing a child’s disability.

**Primary Survey: Exposure**

In order to adequately examine pediatric trauma patients, they must be fully undressed, log rolled, and thoroughly examined for any hidden injuries. During this assessment, there is a potential for hypothermia and heat loss, so careful attention to maintaining normothermia is paramount, which can be done through use of warm blankets, warm humidified oxygen, warm ambient temperature in the room, and warmed resuscitative fluids.

**Primary Survey: Family**

In the resuscitation and evaluation of children, families should be given the opportunity to be present in the room with their children.9 In general, children do not cope well in unknown, loud, and scary environments. Because the emergency department trauma bay is usually all of these things, children’s assessments may be altered as a result. By allowing family to be present, emergency physicians allow comfort and guidance from a family directed to the child, providing a more accurate assessment of mental status. Families report that they wish to be present during their child’s resuscitation and would recommend it to other families when reflecting on their experience.22 In fact, their presence has shown to be beneficial to both the patient and the family in their grieving process.22 It is important, however, that there is a point person in the room who serves as home base for the family. Social work, chaplaincy, and child life specialists can be helpful in this role. These individuals can be instrumental in helping a family know what is going on, where they can stand, when they can touch their child, and any other questions that arise during the resuscitation. Preexisting family presence policies and procedures should be considered for any emergency department that has the potential to evaluate pediatric trauma patients. Medical provider comfort and experience have been shown to be major barriers to implementing this practice.

**INTRODUCTION TO THE PEDIATRIC SECONDARY SURVEY**

After the primary assessment and stabilization of pediatric trauma patients, the second portion of the evaluation serves to fully examine patients head to toe. Specific injuries are discussed with recommendations regarding clinical testing and treatment.

**Secondary Survey: Head Trauma**

Pediatric head trauma accounts for approximately 600,000 emergency department visits and 7400 fatalities annually in the United States, making it the leading cause
of death in children ages 0 to 18 years. Fortunately, most of these traumatic injuries are not life threatening. The evaluation of pediatric patients with reported head trauma must be thorough and systematic, because patients in this age range may not present with symptoms normally found in their adult counterparts with head injuries. The goal of a systematic approach is to limit the number of unnecessary CT scans performed on young children, without overlooking clinically significant injuries.

As with any emergency evaluation, patient history and physical examination should guide the work-up. It is important for physicians to elicit the mechanism of patient injury, especially in younger children who are preverbal. Most pediatric head traumas are caused by falls, whereas motor vehicle crashes (MVCs) and pedestrian injuries account for slightly less than 20% each of these types of injuries. The height from which a child fell and type of surface on which he or she landed are important prognostic factors. It is also important to ask if a child involved in an MVC was properly restrained in an appropriately sized car seat or booster seat. Lastly, nonaccidental trauma (NAT) in pediatric head injuries must always be considered, especially in newborns and infants.

Pediatric patients are more vulnerable to the forces of head trauma for several reasons. First, the relative size of a pediatric patient’s head compared with the trunk makes a patient more vulnerable to increased torque along the C-spine axis. Children under the age of 2 have more pliability to their skull, specifically due to sutures that may not be completely fused yet, accounting for the high number of intraparenchymal injuries without associated skull fractures. Finally, the pediatric brain is more vulnerable to shear injury because it is less myelinated and underdeveloped in size relative to the cranium.

The physical examination should be focused around assessment of a patient’s neurologic status along with any obvious extracranial injury to the head or neck. Focal neurologic defects, including unreactive pupils, the absence of a gag or corneal reflex, and any motor or sensory deficits, should increase provider suspicion of an intracranial injury. Nonfrontal scalp hematomas are particularly worrisome. Any temporal, parietal, or occipital scalp hematoma may be indicative of an intracranial abnormality, especially in children less than 2 years of age. In a study of head injuries in this age group, 93% of children with brain injuries had associated scalp hematomas. In younger children, physicians should palpate the anterior fontanelle, which generally closes at approximately 1 year of age. Any evidence of anterior fontanelle fullness or bulging should increase provider suspicion of elevated intracranial pressure as a result of hemorrhage.

Even within the pediatric population, age subcategories based on developmental milestones change the approach to trauma. Specifically, children under the age of 2 present a variety of challenges to providers. First, children this age are typically not able to express an accurate history of the traumatic event. Stranger anxiety is at its height between 6 months and 2 years of age, making the physical examination particularly difficult. Also, the anatomic differences (discussed previously) predispose children less than 2 years old to intracranial injuries with subtle to no findings on physical examination. GCS also has limited usefulness in the younger pediatric population because it is based on a patient’s ability to comprehend and cooperate with provider instructions.

In an attempt to decrease the amount of unnecessary radiation exposure to children, a prospective cohort study was published in 2009 to establish clinical guidelines for the use of CT in the setting of pediatric head trauma. This set of rules, known as the Pediatric Emergency Care Applied Research Network (PECARN) head injury guidelines, was developed between 2004 and 2006 after evaluating 42,412 patients between the ages of 0 and 18, with traumatic head injuries within 24 hours of
presentation. Table 5 outlines the results of this landmark study and provides guidelines for obtaining a CT scan based on symptomatology. These rules should not outweigh physician gestalt and experience. CT scans should also be considered if a child has any preexisting condition that increases risk for an intracranial hemorrhage, including hemophilia, a known arteriovenous malformation, use of anticoagulation, and indwelling hardware, such as a ventriculoperitoneal shunt. Table 5 lists the indications for obtaining a CT scan to assess for intracranial hemorrhage based on the PECARN head injury guidelines.

Children who do not meet these criteria for immediate CT scan but do have an intermediate risk for an acute intracranial injury should be observed for 4 to 6 hours in an emergency department. If a patient has any worsening clinical symptoms during the observation period, a CT scan should be obtained at that time.

A significant portion of children who have suffered isolated head trauma are sent home from the emergency department after a normal CT or suitable observation period. Prior to discharge, patients should be easily arousable with a normal neurologic examination. The provider should have a patient’s parents compare the child’s baseline mentation to his or her current state. The child should also be able to tolerate oral liquids without vomiting before discharge. Finally, provide strict and specific return precautions to the parents for any change in the child’s mental status or further concern. The provider should also attempt to establish follow-up with the patient’s primary pediatrician before a child is discharged. In the setting of a concussion, there is no need to instruct parents to wake their child from sleep after discharge.

Recently, there has been increased focus on concussions and their sequelae. Concussions are defined by the American Academy of Neurology as any traumatically

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Indications for CT scan in pediatric trauma patients based on PECARN</th>
</tr>
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<tbody>
<tr>
<td><strong>Children Less than 2 y of Age</strong></td>
<td><strong>Children Older than 2 y of Age</strong></td>
</tr>
<tr>
<td>Age &lt;3 mo</td>
<td>GCS &lt;14 or any signs of altered mental status</td>
</tr>
<tr>
<td>Palpable skull fracture</td>
<td>Signs of basilar skull fracture</td>
</tr>
<tr>
<td>GCS &lt;14 or any signs of altered mental status</td>
<td>Battle sign—ecchymosis of the mastoid process</td>
</tr>
<tr>
<td>Agitation/irritability</td>
<td>Raccoon eyes—periocular ecchymosis</td>
</tr>
<tr>
<td>Somnolence</td>
<td>CSF otorrhea or rhinorrhea</td>
</tr>
<tr>
<td>Slow response to verbal communication</td>
<td>Loss of consciousness</td>
</tr>
<tr>
<td>Occipital, parietal, or temporal scalp hematoma (any nonfrontal hematoma)</td>
<td>Vomiting</td>
</tr>
<tr>
<td>Loss of consciousness &gt;5 s</td>
<td>Severe headache</td>
</tr>
<tr>
<td>Not acting appropriately per parent</td>
<td>Severe mechanism</td>
</tr>
<tr>
<td>Severe mechanism</td>
<td>Falls &gt;3 feet</td>
</tr>
<tr>
<td>Falls &gt;3 feet</td>
<td>MVC with passenger ejection, rollover, or death of another passenger</td>
</tr>
<tr>
<td>MVC with passenger ejection, rollover, or death of another passenger</td>
<td>Pedestrian or bicycle passenger unhelmeted and hit by a motor vehicle</td>
</tr>
<tr>
<td>Pedestrian or bicycle passenger unhelmeted and hit by a motor vehicle</td>
<td>Struck in head by a high-impact object</td>
</tr>
</tbody>
</table>

induced disturbance of neurologic function and mental state, occurring with or without actual loss of consciousness. Concussions may present in a similar fashion as an intracranial lesion secondary to a traumatic event. Typically, patients with a concussion present with a headache and amnesia. Vomiting is not uncommon. These symptoms are generally short-lived and often resolve spontaneously. A CT scan is not indicated for simple concussive symptoms.

In any pediatric head trauma, the provider must consider NAT, which is especially true in children less than 1 year of age because these patients are more vulnerable and physical findings of injury may be more obscure. It is important for providers to elicit a detailed history and complete a thorough physical examination with a child completely undressed. The provider must determine if the reported mechanism is compatible with the child’s injury given a child’s age and correlating developmental milestones. Classically, the injury pattern associated with nonaccidental head trauma includes subdural hemorrhages, retinal hemorrhages, and diffuse brain injury.27,28 The provider must be judicious and search for other injuries in a child with suspected NAT, because approximately 20% to 50% of children with abusive head trauma have extracranial skeletal fractures.29–34 The American Academy of Pediatrics recommends a full skeletal survey in any child less than 2 years of age with suspected NAT. Between the ages of 2 and 5 years old, the use of a skeletal survey diminishes but can still provide useful information if there is a presence of any injury consistent with abuse. There is little value in obtaining a skeletal survey in children greater than 5 years of age because these children are often verbal and can express specific areas of pain or injury.35 Box 2 outlines the specific radiographic films to be obtained in a skeletal survey as outlined by the American College of Radiology. In any cases where NAT is suspected, physicians must be proactive in involving the appropriate resources, including Child Protective Services.

### Box 2
Plain radiographs to be obtained in a complete skeletal survey

<table>
<thead>
<tr>
<th>Appendicular skeleton</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Arms (anteroposterior [AP])</td>
</tr>
<tr>
<td>• Forearms (AP)</td>
</tr>
<tr>
<td>• Hands (AP)</td>
</tr>
<tr>
<td>• Thighs (AP)</td>
</tr>
<tr>
<td>• Legs (AP)</td>
</tr>
<tr>
<td>• Feet (AP or posteroanterior)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Axial skeleton</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Chest/thorax (AP and lateral)</td>
</tr>
<tr>
<td>• AP abdomen, lumbar spine, and bony pelvis</td>
</tr>
<tr>
<td>• Lumbar spine (lateral)</td>
</tr>
<tr>
<td>• C-spine (AP and lateral)</td>
</tr>
<tr>
<td>• Skull (frontal and lateral)</td>
</tr>
</tbody>
</table>

**Secondary Survey: Cervical Spine**

The stabilization, evaluation, and subsequent clearance of the C-spine are of utmost importance in a pediatric trauma. C-spine injuries are rare in children although they must be considered and properly evaluated in an emergency department.

There are approximately 1100 pediatric spinal injuries annually in the United States. A majority of these injuries are attributed to a small number of mechanisms, which are mostly age dependent. MVCs make up the highest percentage of pediatric C-spine injuries in all age groups, whereas contact sports make up a more significant percentage of C-spine injuries in children older than 8 years of age.

**Anatomic differences in the pediatric cervical spine**

C-spine injuries in children vary from their adult counterparts due to anatomic differences. Specifically, children under the age of 8 are more susceptible to injuries of the upper C-spine. These anatomic differences are illustrated in Box 3.

Certain pediatric populations also have genetic predisposition to C-spine injuries. Up to 15% of children with Down syndrome have atlantoaxial instability along the C1-C2 interface. Less common genetic disorders, including Klippel-Feil syndrome and Morquio syndrome, also have increased risk of C-spine injury. The C-spine does not fully mature until approximately 16 years of age in developmentally normal children.

**Initial evaluation of the pediatric cervical spine**

Any child involved in a trauma with the potential for a C-spine injury should be treated as if the injury exists until proved otherwise, either by physical examination or radiography. The C-spine should be adequately immobilized as soon as possible, ideally in a prehospital setting. Failure to immobilize the C-spine during resuscitation and transport has lead to neurologic deficits in an estimated 3% to 25% of patients with a spinal cord injury. If concern exists after the initial evaluation for a C-spine injury, patients ought to remain immobilized until an injury is excluded both clinically and radiographically. Box 4 illustrates indications for spinal cord immobilization.

Pediatric C-spine collars are available in multiple sizes for ideal immobilization of the neck in a neutral position. The child’s head should be place in a supine position relative to their torso and a properly positioned backboard. The Advanced Trauma Life Support (ATLS) guidelines define the neutral position as “supine without rotating or bending the spinal column.”

Determining a C-spine injury is difficult in children, especially those who are unable to give a reliable history. ATLS protocol should be followed in all trauma cases, with

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**Box 3**

Anatomic differences in pediatric patients predisposing them to cervical spine injury

- Larger head size and weight compared with the neck and trunk
- Weaker C-spine musculature
- Increased laxity of the spinal ligaments
- Immature vertebral joints and ossification centers
- Increased elasticity of the spinal column
- Lack of uncinate processes until approximately age 10

*Data from Refs. 37, 41-45*
evaluation of the C-spine taking place in the secondary survey. Most spinal cord injuries are a result of direct compression on the cord itself or disruption of the cord by a fractured or subluxed vertebrae.\textsuperscript{56} Symptoms of a C-spine injury are extremely variable. Neurologic complaints may be vague or transient. In some cases, children with spinal cord injuries are asymptomatic. The evaluation of a C-spine injury on physical examination focuses on vital signs, neck examination, and neurologic examination. A child who presents with apnea or hypoventilation may have damage to the phrenic nerve (C3-C5), which controls the movement of the diaphragm. Spinal shock, also known as distributive shock, may be the presenting sign in some cases of spinal cord injury, with hypotension and bradycardia most commonly found on examination.

Physical examination should center on a thorough neck and neurologic evaluation. The C-spine should be palpated down the midline. This can be safely completed with the removal of the immobilization collar; however, it is recommended that a second provider hold the patient’s head in a neutral position during the examination. Any midline deformities or point tenderness are concerning for a C-spine injury. Second, a thorough neurologic examination is an integral part of the assessment for a spinal cord injury. Isolated sensory deficits are far more common than motor deficits. It is also important to assess and document muscle tone, muscle strength, and deep tendon reflexes. In patients with abnormal vital signs and an abnormal neurologic examination, a rectal examination may help rule out spinal shock. The lack of a bulbocavernous reflex is indicative of an injury leading to spinal shock. This particular reflex is elicited and measured by squeezing the glans penis or pulling on an indwelling Foley catheter while monitoring anal sphincter tone.

The assessment of children with a C-spine injury is challenging to providers. Because of the likelihood of a high mechanism causing the injury, children are often scared and uncooperative during a physician’s physical examination. It is important for physicians to use the available resources to thoroughly examine patients. Early and aggressive pain management techniques, including the use of intranasal or intravenous opioids, allow practitioners to provide adequate analgesia while assessing a child’s injury. Other resources, including child life specialists, are valuable when available, because they can provide distraction and comforting measures to patients. Finally, a patient’s family should be allowed to accompany the child during the evaluation as long as they do not impede the examination or necessary resuscitation.

<table>
<thead>
<tr>
<th>Box 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indications for immobilizing the pediatric cervical spine in a trauma</td>
</tr>
<tr>
<td>• High-risk mechanism (MVCs, diving, contact sports, acceleration-deceleration injury)</td>
</tr>
<tr>
<td>• Altered mental status</td>
</tr>
<tr>
<td>• C-spine midline tenderness</td>
</tr>
<tr>
<td>• Decreased range of motion</td>
</tr>
<tr>
<td>• Neurologic deficits</td>
</tr>
<tr>
<td>• Distracting injury</td>
</tr>
<tr>
<td>• Multiple system trauma</td>
</tr>
</tbody>
</table>

Common cervical spine injuries in pediatric trauma

Given the anatomic differences in pediatric patients, clinical presentations of C-spine injuries can vary widely. Hyperflexion injuries are the most common type of C-spine injury. Such injuries include the clay-shoveler’s fracture, which is an avulsion fracture of a single spinous process, usually located within the lower cervical vertebrae. Clay-shoveler’s fractures are stable; however, neurosurgical consultation is warranted in any vertebral fracture. The teardrop fracture is another common C-spine fracture that occurs when extreme flexion causes a vertebral body to come in contact with the vertebral body below. This particular mechanism leads to a fracture of the anteroinferior vertebral body, resembling a teardrop. The teardrop fracture of the C-spine is considered unstable and can present with anterior cord symptoms including paralysis and loss of pain sensation.

Radiology for assessment of a cervical spine injury

Any child with a suspected C-spine injury must undergo radiographic evaluation. Many of the C-spine decision rules for imaging do not apply to the pediatric population. The National Emergency X-Radiography Utilization Study must be applied with caution to children less than 8 years of age, because only 2.5% of the study population was under the age of 8 years old and thus is not validated for this age group. Preverbal children are notoriously difficult to clear clinically because the surroundings, stress, and nature of their emergency department visits make a calm environment difficult to attain. Also, ambulation is not a predictor of C-spine injury in pediatric patients. The Canadian C-spine rule is a second well-known clinical decision rule that has been validated in adult populations; however, this particular study excluded patients under the age of 16 and, therefore, cannot be applied to a majority of the pediatric population.57

If indicated after the initial assessment, radiographic evaluation should include AP, cross-table lateral, and open-mouth odontoid views of the patient’s C-spine. Cross-table lateral plain films identify approximately 80% of fractures, dislocations, and subluxations.58 Adding the AP and open-mouth odontoid views increases the sensitivity of the evaluation to approximately 90%.59 Flexion-extension and oblique views provide minimal information and are not recommended.60,61

CT scan has increased sensitivity and specificity of 98% or higher for the detection of C-spine fractures or injuries but is not recommended as the initial radiographic modality.62,63 Children are at a much higher risk of developing malignancy of soft tissues, including the skin and thyroid, when exposed to the radiation of a helical CT scan. CT scans do have a place in the evaluation of pediatric C-spine injuries in certain instances. CT of the C-spine should be obtained in the following instances: inadequate plain films, suspicious findings on plain films, fracture or displacement seen on plain films, or if the provider has a high clinical suspicion of C-spine injury.64,65

MRI is the imaging modality recommended in any patient with persistent neurologic symptoms and normal plain films or CT. MRI is more sensitive for identifying injuries, including soft tissue abnormalities, vertebral disk herniation, ligamentous injury, or acute spinal cord injury.66–73 MRI does have a limited use in the acute setting because it is not readily available, expensive, and time-intensive.

Spinal cord injuries without radiographic abnormality

Not all C-spine injuries are detected on plain film or CT. Spinal cord injuries without radiographic abnormality (SCIWORA) is the term used to describe spinal cord injuries without radiographic abnormality. SCIWORA is suspected in patients with neurologic deficits, including transient parasthesias, numbness, or paralysis, without any
pathology found on plain radiographs, flexion-extension radiographs, and/or CT scan. MRI has greatly decreased the number of such cases, because this particular modality better assesses the soft tissue components of the spinal column and is recommended in any child who displays transient or persistent neurologic deficits despite having no abnormalities with other imaging modalities. Transient neurologic complaints are especially worrisome because approximately 25% of children with transient neurologic complaints or deficits can develop permanent symptoms ranging from complete paralysis to distinct neurologic deficits. SCIWORA continues to be a controversial entity, with few well-powered or long-term studies to assess the true incidence and outcome of this injury. Current literature suggests it is more likely to occur in children less than 8 years old, with incidence ranging between 4.5% and 35% of children with spinal cord injuries.

Secondary Survey: Cardiothoracic Injury

In pediatric trauma, thoracic injury occurs infrequently and is generally the result of forceful mechanisms that tend to cause other concomitant injuries. In an observational study from 1990, only 4.4% of traumatic victims had intrathoracic injuries. The most common injuries include pulmonary contusion (48%); pneumothorax, hemothorax, or pneumohemothorax (39%); and rib fractures (32%). Of those children with thoracic injury, 82% had other involved systems and significantly higher trauma severity scores. Blunt trauma, generally from MVCs, is responsible for most thoracic injuries. Penetrating injury to the chest often results, however, in higher mortality with gunshot wounds, making up 60% of these injuries. Overall, the mortality rate for children with thoracic trauma is between 15% and 26%.

Anatomic and physiologic considerations

Injury patterns as the result of thoracic trauma in children are different from those seen in adults, mostly due to the differences in pediatric anatomy and physiology (Box 5). Most importantly, children have a more compliant chest wall that is able to absorb and distribute forces, resulting in fewer rib fractures than seen in their adult counterparts. Conversely, this compliance can often mask serious underlying injury because patients exhibit minimal signs externally. Additionally, the mediastinum is more freely

<table>
<thead>
<tr>
<th>Box 5</th>
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<tbody>
<tr>
<td><strong>Physical evaluation—what to look for in pediatric thoracic trauma</strong></td>
</tr>
<tr>
<td><strong>Respiratory</strong></td>
</tr>
<tr>
<td>• Abnormal rate</td>
</tr>
<tr>
<td>• Nasal flaring or retractions</td>
</tr>
<tr>
<td>• Paradoxic chest wall movement</td>
</tr>
<tr>
<td>• Chest wall injuries or defects</td>
</tr>
<tr>
<td>• Abnormal lung sounds on auscultation</td>
</tr>
<tr>
<td><strong>Cardiac</strong></td>
</tr>
<tr>
<td>• Distant or muffled heart tones</td>
</tr>
<tr>
<td>• Murmur</td>
</tr>
<tr>
<td>• Irregular rhythm</td>
</tr>
<tr>
<td>• Distended neck veins</td>
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</table>
mobile often, resulting in greater displacement with intrathoracic injury, leading to decreased venous return to the heart and subsequently decreased cardiac output and hypotension with the risk of complete circulatory collapse.

In a study from 2002, researchers looked for a clinical decision rule for predicting thoracic injury in children after blunt trauma. They found that significant predictors included low systolic blood pressure, elevated respiratory rate, abnormal findings on thoracic examination, abnormal auscultation findings, and a GCS score of less than 15. Of the patients they reviewed, 98% had at least 1 of these predictive factors. These findings should be used to guide laboratory and radiologic investigation in traumatic patients suspected of intrathoracic injury.

**Diagnostic evaluation of cardiothoracic injury**

After a thorough historical and physical evaluation, diagnostic studies are the next step in identifying a patient’s injuries. There is a growing use of CT for evaluating children in the setting of trauma. As a result, there is also a growing concern that CT is unnecessarily overused in traumatic evaluation, especially given the concern for excessive radiation exposure at a young age. When considering thoracic trauma specifically, there is significant evidence that a plain film chest radiograph remains an effective screening tool for significant injury in pediatric patients. It is recommended that a chest CT not be the primary imaging tool but, rather, an adjunct to clinical evaluation and plain film imaging.

Other modalities to consider using to evaluate chest trauma in children include ECG, cardiac troponins, and a cardiac view on bedside ultrasound via the Focused Assessment with Sonography for Trauma (FAST) examination. ECG should be considered in any child with anterior chest trauma, sternal fracture, or any arrhythmia. In the setting of possible cardiac contusion, a 12-lead ECG and cardiac troponin levels are helpful, although not routinely recommended. In a recent study, stable patients with suspected intrathoracic trauma with normal troponin levels and normal ECGs were unlikely to have significant myocardial injury; however, this is not standard practice in most pediatric trauma centers. Additionally, the bedside FAST examination can reveal cardiac tamponade and, in the hands of a skilled ultrasonographer, pneumothorax.

**Specific cardiothoracic injuries common in pediatric trauma**

**Diaphragmatic injury** Although a rare event in pediatric patients, a diaphragmatic injury can result in rapid respiratory deterioration and failure if not quickly addressed. Often this injury is a predictor of other serious associated injuries in trauma. These children often present with chest pain and tachypnea but tend to lack external signs of injury unless caused by a penetrating wound that suggests diaphragmatic involvement. In general, this injury is easily identified on plain film chest radiograph where loops of intestine are seen above the diaphragm, the tip of the nasogastric tube lies above the diaphragm, or the hemidiaphragm appears elevated or obscured. Definitive treatment requires surgical intervention. Therefore, the focus in an emergency department should include resuscitation, definitive airway control, gastric decompression, and stabilization of other injuries.

**Traumatic asphyxia** A unique and rare injury to the pediatric population, traumatic asphyxia occurs as a result of the increased compliance of pediatric the chest wall. Typically, this entity follows a marked increase in intrathoracic pressure due to direct chest compression in conjunction with deep inspiration against a closed glottis experienced during a crush injury. This dramatic increase in pressure is transmitted directly to the superior and inferior vena cava, resulting in significant facial and neck petechial
hemorrhages, cyanosis, subconjunctival hemorrhages, and facial swelling. Occasionally, neurologic and ocular involvement is seen in severe cases. Neurologic findings include altered mental status, brachial plexus injuries, and coma, although ocular findings, including hemorrhage into the retina, vitreous body, or optic nerve, can result in vision loss. Generally speaking, this injury does not result in significant morbidity and mortality, but is often associated with other severe injuries. Treatment involves elevating the head of the bed and addressing other associated injuries.

**Commotio cordis** This disease entity, commotio cordis, described almost solely in pediatric trauma, is a combination of ventricular fibrillation and sudden cardiac death secondary to a sudden impact to the anterior chest wall. Frequently it is described in association with sudden cardiac death that occurs after direct impact to the chest when playing sports, specifically baseball. According to the National Commotio Cordis Registry, victims have a mean age of 15 years, with a 95% male predominance, and are frequently struck in the chest with projectiles rather than blunt bodily contact. Although usually a fatal event, the survival rate has risen to 35% over the past decade due to improved public awareness, increased availability of automatic external defibrillators, and earlier activation of first responders.

There are several factors that contribute to the risk of commotio cordis. These relate to the timing, location, and velocity of impact to the chest wall. Most importantly, there is only a 20-millisecond to 40-millisecond window during the cardiac cycle in which the trauma must occur to result in ventricular fibrillation. Commotio cordis is best diagnosed by the appropriate clinical scenario, ECG data demonstrating ventricular fibrillation, and the absence of structural heart damage on subsequent studies after resuscitation.

One study in 2006 aimed at looking at the effectiveness of commercially available chest wall protectors in the prevention of commotio cordis. Unfortunately, it found these protectors were mostly ineffective in preventing ventricular fibrillation in pig models. A study from 1998, however, found that the likelihood of ventricular fibrillation was proportional to the hardness of the ball, with soft safety baseballs providing the lowest risk of ventricular fibrillation. As a result, it has been recommended that age-appropriate baseballs be used to help reduce the incidence of this potentially fatal event.

**Secondary Survey: Blunt Abdominal Trauma**

Blunt abdominal trauma in pediatric patients is the third leading cause of traumatic death behind head and chest injuries. The mechanism of blunt abdominal trauma is especially important in the pediatric population, because certain mechanisms often correlate with specific injuries. Motor vehicle collisions are the most common cause of lethal blunt abdominal trauma in this age group. The mortality of these traumatic events is directly proportional to the number of intra-abdominal organs injured. Children are inherently more susceptible to serious intra-abdominal injuries because of their anatomic structure. Children have larger solid organs, less-protective subcutaneous fat and abdominal musculature, more-flexible rib cages, and a smaller torso, allowing for wide transmission of significant force.

The extent of injury in a child with blunt abdominal trauma is often difficult to determine. Generally, patients with severe abdominal trauma also present with other traumatic injuries, which can make obtaining a detailed history difficult. Children who present with obvious traumatic injuries should be considered as having an intra-abdominal injury until proved otherwise; this is especially true in patients who are hemodynamically unstable. It is important to remember that the assessment of
The abdomen is part of the secondary survey, and serial examinations of the abdomen aid in ongoing evaluation.

The physical examination is an important part of the evaluation of abdominal trauma and can provide clues to clinicians regarding specific injuries that may be potentially life threatening. On initial evaluation, a patient’s vital signs should be obtained. A child found tachycardic, hypotensive, or tachypneic may have significant intra-abdominal injuries.

In children who are hemodynamically stable, the physical examination can yield clues to potential injuries. It is important to completely undress children to do a thorough examination, specifically looking for bruising, tire tracks, or any missed injuries. Patients with presumed abdominal trauma and subsequent abdominal distension should have an orogastric or nasogastric tube placed for abdominal decompression. Doing so improves ventilatory abilities of the child and decreases the risk for aspiration. Any ecchymosis of the abdominal wall should greatly increase provider suspicion of severe intra-abdominal injury. The seat belt sign is a transverse bruise over the inferior portion of the abdomen. This particular bruising pattern may be associated with small bowel injuries, Chance fractures of the lumbar spine, and, rarely, injuries of the abdominal aorta. A seat belt sign may be present in up to 10% of motor vehicle collisions.93–95 Bruising of the flank may be indicative of injuries to retroperitoneal structures, including the kidney. Point tenderness of the abdomen may also increase the probability of injury to the underlying structure but is unreliable in younger children. Potentially dangerous splenic injuries may be manifested only by pain in the left shoulder, known as Kehr sign.

Solid organs, including the liver and spleen, are the most commonly injured structures in the setting of blunt trauma in children. These particular organs are highly vascularized, and injury can cause significant blood loss with rapid decompensation. Pancreatic injuries are far less common than hepatic or splenic insults but may be present, especially in patients with epigastric pain. Hollow viscous organ injury is less common than solid organ injuries but potentially life threatening. In descending order, the jejunum, duodenum, colon, and stomach are the most commonly injured hollow viscous organs damaged in pediatric abdominal trauma. Duodenal injuries are often associated with bicycle accidents, specifically by handlebars contacting the epigastric and right upper quadrant regions of the abdomen. Hematomas of the duodenum occur when the structure is compressed against the vertebral column, momentarily interrupting the blood flow. Duodenal hematomas can expand causing partial or complete small bowel obstructions. These particular obstructions may be manifested as bilious vomiting and often occur 24 to 48 hours after the injury. Duodenal hematomas and their subsequent obstructions generally resolve with conservative management including nothing by mouth status, bowel rest, gastric decompression, and parenteral nutrition.

Beyond the physical examination, there are a few laboratory and radiographic tests that may aid providers in determining the extent of underlying abdominal injury. During the initial assessment, intravenous access should ideally be established. Laboratory tests, including a complete blood cell count (CBC), lipase, and comprehensive metabolic panel (including electrolytes and liver function tests), are particularly useful. Other laboratory tests, including coagulation studies, and a urinalysis may also aid physicians but are not as sensitive nor specific for intra-abdominal injuries. The CBC provides physicians with patients’ intravascular blood volume. Abnormally low hemoglobin may indicate internal hemorrhage requiring emergent intervention by pediatric surgeons or interventional radiologists. A blood type and crossmatch should also be obtained quickly as to not delay any potential surgical
care. Elevated transaminases have been shown sensitive and specific for the presence of intra-abdominal injury in the setting of blunt trauma.\textsuperscript{96,97} Specifically, patients with an aspartate aminotransferase (AST) greater than 200 IU/L or alanine aminotransferase (ALT) greater than 125 IU/L should raise clinician suspicion of injury and warrant further investigation of his abdomen with imaging. Pancreatic enzymes, such as amylase and lipase, are not sensitive for acute pancreatic or other intra-abdominal organ injury. They are useful as a baseline when monitoring the development of a pancreatic complication or unexplained abdominal pain in trauma patients. An elevated lipase is fairly specific for pancreatic injury, but an elevated level is not a clear indication for imaging, especially without epigastric pain. A urinalysis is another routinely obtained laboratory test in trauma patients, and the presence of gross blood may indicate injury to the genitourinary system. No single laboratory test has acceptable sensitivity or negative predictive value to safely and effectively screen patients after undergoing blunt abdominal trauma when used alone (Box 6).\textsuperscript{98}

The gold standard radiographic method for identifying intra-abdominal injury after a traumatic event is the abdominal CT with intravenous contrast in hemodynamically stable patients. Box 7 lists indications for obtaining an abdominal CT. Patients who are hemodynamically unstable with suspected abdominal injury should be evaluated by a surgeon immediately. The FAST examination is another modality often used in the emergency department to assess for free fluid in the peritoneum or pericardium secondary to trauma. The FAST examines 4 specific locations: Morison pouch (hepatorenal interface in the right upper quadrant), subxyphoid cardiac view, splenorenal interface, and bladder. A positive FAST that indicates free fluid in a patient’s abdomen or pericardium should prompt a physician to obtain an abdominal CT with intravenous contrast if the patient is hemodynamically stable. Patients with a positive FAST examination and hemodynamic instability should undergo prompt surgical evaluation. A negative FAST does not rule out serious intra-abdominal injury. Patients with a high suspicion of solid organ injury should undergo an abdominal CT (Box 7).

In hemodynamically unstable children with suspected intra-abdominal injury who are unable to go to CT scan, a diagnostic peritoneal lavage (DPL) may be useful. The discussion of performing a DPL versus an emergent laparotomy should be held with a pediatric surgeon. The DPL is much less invasive than laparotomy. The DPL, however, is less specific, cannot detect retroperitoneal injury, has potentially harmful side effects, and may lead to unnecessary exploratory laparotomy because many children with intra-abdominal blood are safely observed without surgical intervention.\textsuperscript{99} Because of the aforementioned risks and the availability of high-resolution

<table>
<thead>
<tr>
<th>Box 6</th>
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<tbody>
<tr>
<td><strong>Laboratory testing indicated in pediatric abdominal trauma</strong></td>
</tr>
<tr>
<td>CBC</td>
</tr>
<tr>
<td>Comprehensive metabolic panel, including transaminases</td>
</tr>
<tr>
<td>Blood type and crossmatch</td>
</tr>
<tr>
<td>Urinalysis</td>
</tr>
<tr>
<td>Serum amylase and lipase</td>
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<tr>
<td>Urine pregnancy test</td>
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CT scanners, the DPL has mostly fallen out of favor with most pediatric surgeons when assessing the need for operative management. Box 8 outlines the indications for emergency laparotomy in pediatric patients who present after blunt abdominal trauma.

A substantial portion of children with acute abdominal trauma are managed without surgical intervention. Children who have any indication of hemodynamic instability or required volume resuscitation should be admitted to an intensive care unit for continuous monitoring. Patients with stable vital signs and physical examination or laboratory findings suggestive of acute intra-abdominal injury can be safely monitored on a pediatric ward. In both settings, patients should undergo serial abdominal examinations to assess for clinical worsening and the need for subsequent intervention. Specifically, the American Pediatric Surgical Association has developed guidelines for the management of clinically stable patients who have isolated liver or spleen injuries. The guidelines recommend that all pediatric patients who are hemodynamically stable with grades I to IV liver or splenic lacerations secondary to blunt abdominal trauma should receive nonoperative management. In addition, immunization against encapsulated organisms is standard practice and should be given during the hospital stay for children with severe splenic injuries. Pediatric studies that indicate the optimal timing of immunization as it relates to the grade of liver injury are limited, but two randomized trials suggest that two weeks post-splenectomy generates the best immune response.

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**Box 7**

**Indications for obtaining an abdominal CT in pediatric trauma in hemodynamically stable patients trauma**

- History suggestive of severe intra-abdominal injury
- Physical examination concerning for intra-abdominal injury (ie, abdominal tenderness, guarding, or rebound tenderness)
- Presence of the seat belt sign or other abdominal bruising
- AST >200 or ALT >125
- Decline in hemoglobin or hematocrit <30% from baseline
- Gross or microscopic blood on urinalysis (≥50 red blood cells)
- Positive FAST examination

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**Box 8**

**Indications for emergency laparotomy after blunt abdominal trauma**

- Intra-abdominal bleeding with persistent hemodynamic instability despite aggressive crystalloid and blood transfusion (transfusion >20 mL/kg packed red blood cells),
- Perforation of a hollow viscous injury leading to pneumoperitoneum
- Increasing abdominal tenderness or the development of peritoneal signs on examination
- Solid organ injury with persistent bleeding
- Pancreatic injury with ductal disruption

*Data from Refs. 24,100–102*
SUMMARY

The evaluation of pediatric trauma patients involves several various nuances, differentiating it from that of an adult counterpart. It is important to develop a structured yet focused approach when dealing with children with traumatic injuries. With the completion of a thorough physical examination, appropriate laboratory and radiographic adjuncts, and adherence to ATLS protocol, the evaluation of pediatric patients involved in a trauma can be managed in a safe and efficient manner.

REFERENCES


