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Trauma management: Approach to the unstable child

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INTRODUCTION

The initial approach to the management of the unstable child with major traumatic injuries is presented here. The approach to the initially stable child with traumatic injury and the classification of trauma in the injured child are discussed separately. (See "Approach to the initially stable child with blunt or penetrating injury" and "Classification of trauma in children".)

EPIDEMIOLOGY

In the United States, over 12,000 children and adolescents 0 to 18 years old die annually of unintentional and intentional injuries, making trauma the leading cause of death for this population [1]. Injuries and poisoning are also the leading causes of emergency department (ED) visits [2], accounting for over 17 million ED visits in 2017, which is over one-third of the 48.5 million ED visits for children and youth <25 years old [3].

Blunt injury accounts for approximately 90 percent of all pediatric trauma. When blunt force is applied to a child's small body, multisystem trauma occurs frequently. Although the majority of injuries are mild to moderate in severity, the clinician caring for children should be prepared to rapidly evaluate and manage those patients with serious and life-threatening trauma. In addition, children have differing anatomy and physiology from adults, which requires specific attention during advanced trauma care. (See "Trauma management: Overview of unique pediatric considerations".)

OVERVIEW

A standardized approach to the initial management of trauma patients has been disseminated by the American College of Surgeons through the Advanced Trauma Life Support (ATLS) program (table 1 and table 2). The ATLS protocols are based on the concept of the Trimodal Death Distribution [4]:

- The first peak of death occurs in the seconds to minutes immediately after injury and only prevention can impact this mortality.
- The second peak occurs in the minutes to hours after injury. During this time, referred to as the "golden hour," rapid assessment and treatment decreases fatalities and improves outcomes.
- The third peak of death occurs days to weeks after the initial injury because of infection and multi-organ system failure. Definitive care in a center with pediatric expertise and resources mitigates this delayed mortality.

TERMINOLOGY

For this discussion, the unstable pediatric trauma patient refers to any child who has abnormal vital signs, disruption of vital functions (eg, airway, breathing, circulation, mental function), or apparent injuries of a critical nature. Knowledge of normal vital signs by age and awareness of the ability of children to sustain major hemorrhage without hypotension facilitates recognition of the critically injured child (table 3 and table 4). (See "Trauma management: Overview of unique pediatric considerations".)

INJURY CLASSIFICATION

Several methods for measuring severity of injury exist. In order to appropriately triage the management of the trauma patient, one useful method to categorize injuries uses the following parameters. (See "Classification of trauma in children".)

Injury extent — Multiple trauma is defined by apparent injury to two or more body areas. Localized trauma involves only one anatomic region (eg, head and neck, chest and back, abdomen, extremities) of the body. Sometimes the extent of injury may be obvious; at other times this may not be readily apparent, and the clinical picture may evolve over time.

Injury type — The expected injuries differ based on whether they occur as a result of blunt trauma (eg, fall, motor vehicle collision [MVC]) or penetrating trauma (eg, gunshot, stabbing, shrapnel from explosion).

Injury severity — The mechanism of injury and physical examination findings are useful in the determination of severity. Assessment of severity will dictate the initial management and disposition [5]. High risk trauma mechanisms predict patients who are more likely to be unstable or become unstable and, along with vital signs and physical findings, are often used to guide prehospital transport decisions (table 3 and table 5 and table 6). (See "Classification of trauma in children".)

INITIAL APPROACH

The goals of initial trauma management in children, as in adults, are to rapidly assess the injuries, determine management priorities, and provide critical interventions. Achieving these goals requires a systematic and logical approach according to the tenets of Advanced Trauma Life Support (ATLS), presented below in an expanded format to emphasize the importance of performing specific procedures rapidly in the emergency department (ED) and the crucial need to continuously reassess vital functions (table 1) [6]:

- Primary survey (rapid primary evaluation)
- Resuscitation of vital functions (eg, airway, breathing, circulation, mentation)
  - Utilization of adjuncts to the primary survey and resuscitation
- Secondary survey (more comprehensive secondary assessment)
  - Continued post resuscitation monitoring with further resuscitation as needed
  - Utilization of adjuncts to the secondary survey
- Transition to definitive care

Management of seriously injured children relies on two key principles:

- Assessment and management occur simultaneously during the primary survey. Any identified physiologic threat to life must be rapidly treated before moving on to the evaluation of the next priority area.
- If there is any deterioration of the patient during the evaluation, the primary survey should be repeated and any newly identified problems addressed before proceeding with the definitive care of the patient [4,7].

Clinicians should incorporate ATLS guidelines into the management of the pediatric trauma patient but with the understanding that this offers only a general construct. In reality, particularly when multiple clinicians are involved, many steps typically occur simultaneously.

Organization of the medical response around the concept of a pediatric trauma team may provide more timely identification of injury and more rapid treatment with improved outcomes [8].

The next section will discuss each of the key elements of the primary survey as if they were distinct entities occurring in a strict sequence, even though in centers with optimal pediatric trauma resources these steps typically occur simultaneously.

PRIMARY SURVEY

The order of priority in the initial assessment and treatment in ATLS is called the "primary survey" and includes:

- A - Airway maintenance with cervical spine (C-spine) protection
- B - Breathing and ventilation
- C - Circulation with hemorrhage control
- D - Disability (evaluation of neurologic status)
- E - Exposure (complete visualization)/environmental control (prevention of hypothermia)

During the primary survey, clinicians must identify and promptly address life-threatening conditions (table 1). Prior to the arrival of the patient, care providers should don eye protection, mask, gown, and gloves to prevent exposure to patient secretions (universal precautions). The care of the patient proceeds more effectively if participants know their role beforehand and if the leader of the resuscitation communicates clearly.

In trauma centers, advance notice to all participants and key units (eg, blood bank, operating room) facilitates collaborative and timely care of the critically injured child.

Upon arrival of the patient, clinicians should place the appropriate monitors, obtain vital signs (pulse, respirations, oxygen saturation, blood pressure, temperature), and provide supplemental oxygen. It is imperative for the trauma provider to assess pediatric vital signs in comparison to a readily available reference of normal values for age. (See 'Vital signs' below.)

The list below provides a brief overview of the approach and a more detailed discussion of each major category follows. Use of a trauma flow sheet with a dedicated recorder helps ensure that all aspects of assessment and care receive attention.

In the clinical setting, particularly when multiple clinicians are involved, many steps occur simultaneously. For example, intravenous (IV) access may precede chest tube placement, even though "breathing" comes before "circulation" in the algorithm. Also, clinical events will dictate the exact sequence of assessment and management. Some conditions are difficult to detect in young children based on physical findings (eg, cardiac tamponade), and others may evolve over time. For instance, a patient with initially symmetric breath sounds may become cyanotic from a tension pneumothorax in the middle of the secondary survey while receiving positive pressure ventilation and require an immediate thoracostomy tube.

Vital signs — Normal vital signs change with age in children (table 4). In general, heart and respiratory rates are higher than in adults, and blood pressure is lower. For children, the 5th percentile systolic blood pressure for age is defined by Pediatric Advanced Life Support as follows [9]:

- Term neonates (0 to 28 days): <60 mmHg
- Infants (1 to 12 months): <70 mmHg
- Children (1 to 10 years): <(70 mmHg + [child's age in years x 2])
- Children >10 years: <90 mmHg

Airway with cervical spine motion restriction

- **Airway assessment** – Airway obstruction with hypoxia and inadequate ventilation is the most common cause of pediatric cardiopulmonary arrest following trauma [10]. The clinician must rapidly determine airway patency, presence of foreign bodies in the mouth or pharynx, and evidence for facial/mandibular or tracheal/laryngeal fractures with potential for an unstable airway. Medical providers must remain alert for the potential loss of the airway. A patient who is able to cry or speak normally is unlikely to have impending airway obstruction, but should be reevaluated frequently [11]. (See "Basic airway management in children" and "Technique of emergency endotracheal intubation in children".)

- **Airway management** – Clinicians should restrict motion of the cervical spine. During the initial management, the clinician must assume a cervical spine injury in the patient with multiple trauma, especially with head/neck injury or with an altered level of consciousness. Padding under the shoulder and back and use of the "sniffing position" is important to open the airway maximally and maintain a neutral cervical spine position in the infant or young child. Note that this positioning is markedly different from adults where padding under the head is frequently required to achieve neutral cervical spine position. (See "Pediatric cervical spinal motion restriction".)

Indications for cervical spine motion restriction include (see "Evaluation and acute management of cervical spine injuries in children and adolescents"):

- Mechanism concerning for potential C-spine injury (motor vehicle-pedestrian collision, motor vehicle-bicycle collision, fall from a considerable height, motor vehicle collision [MVC] with unrestrained passenger, diving) (table 5)
- Anatomic predisposition to neck injury (eg, Down syndrome), prior neck injury, or history of cervical spine surgery
- Altered mental status (GCS <15) or intoxication
- Neck pain, torticollis, and/or guarding of the neck
- Neurologic deficit
- Substantial trauma to the torso defined as the following:
  - Observable injuries that appear to be life threatening, require surgical intervention, or warrant inpatient observation.
  - Injuries of the clavicles, abdomen, flanks, back (including the spine), or the pelvis (eg, rib fractures, visceral or solid organ injury, pelvic fracture).
- Anatomically remote distracting injury that may mask cervical spine instability because of pain such as a femoral fracture. To qualify as a distracting injury, the trauma must be sufficiently severe as to make the otherwise alert, verbal child unaware of neck pain. One possible method of assessment is to forcibly pinch the child on the neck to see if there is a reaction.

Cervical spine motion restriction is usually addressed by the application of a rigid cervical collar. One-person, manual in-line techniques to restrict motion must be used if immobilizing devices need to be removed for endotracheal intubation or other airway procedures (figure 1) [7]. (See "Pediatric cervical spinal motion restriction", section on 'Techniques'.)

Clinicians must establish an airway if the airway is inadequate. This may be accomplished by performing the following maneuvers/procedures in sequence. In most trauma patients, an inadequate airway means the patient requires rapid sequence intubation to manage or to prevent hypoxemia and hypercarbia and to prevent rapid respiratory decompensation. Establishing an airway, particularly in children <3 years of age may be challenging due to specific anatomical differences from adults (see "Basic airway management in children" and "Technique of emergency endotracheal intubation in children" and "Trauma management: Overview of unique pediatric considerations", section on 'Airway'):

- Chin lift or jaw thrust
- Suctioning of secretions
- Oropharyngeal/nasopharyngeal airway as adjuncts to bag-valve-mask ventilation or temporary measures prior to endotracheal intubation (nasopharyngeal airway is contraindicated if cribriform plate fracture is suspected)
- Endotracheal intubation
- Laryngeal mask airway (LMA) (if endotracheal intubation fails or difficult airway is anticipated)
- Needle or surgical cricothyroidotomy

Common reasons for endotracheal intubation in injured patients include impending or potential airway compromise (eg, airway trauma, inhalation injury, prolonged seizures), pulmonary contusion with hypoxemia, flail chest with inadequate chest wall movement (figure 2), hemorrhagic shock, and severe head injury (GCS <8) [4,10,11]. General indications for endotracheal intubation are discussed separately. (See "Technique of emergency endotracheal intubation in children".)

Endotracheal intubation in severe head trauma requires judicious choice of medications to prevent the abrupt increase in intracranial pressure associated with laryngoscopy and intubation. (See "Severe traumatic brain injury (TBI) in children: Initial evaluation and management", section on 'Rapid sequence intubation'.)

Breathing

- **Breathing assessment** – Assessment of breathing begins with inspection of the neck and thorax. Key findings include tracheal deviation, abnormal chest wall movement, the use of accessory muscles, and contusions or lacerations of the thorax or neck (see below). In addition the rate and depth of respirations should be determined and breath sounds auscultated (table 4) [4]. If bedside ultrasound is available and its application will not cause any delays, this modality may be helpful in the diagnosis of a pneumothorax [12]. Certain life-threatening injuries, which may impair ventilation, often are associated with specific physical examination findings (table 7):
  - Tension pneumothorax may present with tracheal deviation, a hyperresonant chest, and unilateral decreased or absent breath sounds.
  - Flail chest may present with an asymmetric rise and fall of the chest (figure 2).
  - Open pneumothorax may result from a large defect in the chest wall.
  - Massive hemothorax may cause unilateral decreased breath sounds and dullness to percussion.
- **Breathing management** – Management principles should focus on improvement of vital signs with the following interventions:
  - Administer a high concentration of oxygen.
  - Deliver bag-valve-mask ventilation in cases of inadequate respiratory effort.
  - Decompress tension pneumothorax either with a needle initially or by placing a thoracostomy tube. For a hemothorax, use a thoracostomy tube. (See "Thoracostomy tubes and catheters: Indications and tube selection in adults and children".)
  - Seal open pneumothorax and immediately place a chest tube.

- In addition to treating respiratory compromise, apply end-tidal CO_2 monitoring and consider arterial or venous blood gas measurements [7]. (See "Thoracic trauma in children: Initial stabilization and evaluation" and "Continuous oxygen delivery systems for the acute care of infants, children, and adults" and "Basic airway management in children" and "Technique of emergency endotracheal intubation in children".)

Circulation

- **Circulatory assessment** – Hypovolemia due to blood loss is the most common cause of shock in the pediatric trauma patient [7], and its early recognition and treatment are critical during trauma resuscitation. Compensated shock occurs when there has been significant blood loss, but the blood pressure has been maintained by tachycardia and vasoconstriction. Hypotensive shock manifests with hypotension in addition to tachycardia [13]. Cardiac tamponade is uncommon in children with trauma and difficult to diagnose on clinical examination. If bedside ultrasound is available and its application will not cause any delays, this modality may be helpful in identifying pericardial effusion [12].

  Tachycardia is usually the first sign of hypovolemia in the child. Due to the physiologic reserve in children, blood pressure may be maintained despite a loss of up to 45 percent of the circulating blood volume. Therefore, the trauma patient who is cool and tachycardic should be considered to be in shock until proven otherwise. Other signs of shock include delayed capillary refill, narrowing of the pulse pressure to less than 20 mmHg, skin mottling, cool extremities, decreased level of consciousness, and dulled response to pain (table 8) [11]. (See "Initial evaluation of shock in children" and "Trauma management: Overview of unique pediatric considerations".)

  The remainder of the assessment focuses on sources of bleeding and other causes of hemodynamic compromise:

  - External bleeding (eg, large vessel injury, limb amputation, large scalp laceration)

  - Significant chest trauma with possible tension pneumothorax, hemothorax, cardiac tamponade, or blunt cardiac injury (see 'Breathing' above and "Thoracic trauma in children: Initial stabilization and evaluation" and "Initial evaluation and management of blunt cardiac injury", section on 'Clinical features')

- Abdominal tenderness suggesting internal hemorrhage (eg, liver laceration, splenic laceration)
- Pelvic pain and/or instability indicating fracture
- Open fractures of the long bones
- Spinal cord injury with shock (see "Acute traumatic spinal cord injury")

- **Circulation management** – Hemorrhage control, IV access for administration of crystalloid or blood, and advanced procedures for persistent hemodynamic compromise constitute the primary management issues for the circulation phase of the primary survey.

Hemorrhage control — Sites of significant external hemorrhage require direct manual pressure to control bleeding (figure 3). The presence of nerves near vascular bundles argues against blind clamping of bleeding vessels except in the scalp. In patients whose bleeding does not abate with direct pressure or who have a sharp foreign body at the site of bleeding or an amputation, compression at the nearest vascular pressure point provides an alternative means for hemorrhage control. Finally, the medical provider may employ a blood pressure tourniquet or Penrose drain tourniquet for severe bleeding that is poorly controlled despite direct pressure or compression of pressure points (figure 4) [14].

Severe bleeding from a large scalp laceration often responds to rapid closure using a figure of eight suture, surgical staples, or scalp clips (Raney clips). A circumferential Penrose drain tourniquet can provide temporary control of scalp bleeding until repair is complete (figure 5). (See "Closure of minor skin wounds with staples".)

Reduction and splinting of long bone fractures may also provide hemostasis. (See "Basic techniques for splinting of musculoskeletal injuries".)

For patients with a suspected pelvic fracture and hemodynamic instability, clinicians should carefully examine the perineum and rectum and then place a pelvic stabilization device over the greater trochanter (prefabricated pelvic binder or a bed sheet tied tightly around the pelvis) (figure 6). External fixation devices are generally placed in the operating room because placement can be difficult and time consuming and may interfere with other components of resuscitation.

Persistent hemorrhage — Although limited evidence is available for children, studies in adult trauma victims suggest potential benefits from developing treatments for external hemorrhage that cannot be controlled by direct pressure and ongoing internal hemorrhage as follows:

- **Uncontrolled external hemorrhage** – A number of hemostatic products are being developed to control such bleeding, including chitosan dressing, kaolin-impregnated sponge powder, and fibrin sealant dressing. Although some of these products have been routinely used by military personnel in combat, few controlled studies with civilians have been performed, and it remains unclear how these products should be used by civilian emergency clinicians. No experience of their use in children has been reported. These agents are discussed separately. (See "Fibrin sealants".)

- **Ongoing internal hemorrhage** – Antifibrinolytics, specifically aminocaproic acid, tranexamic acid, and aprotinin have all been shown to be safe and effective at reducing bleeding during elective surgery. Of these, tranexamic acid has undergone the most use in adult trauma patients and has been associated with a significant reduction in mortality when given within three hours of blunt or penetrating trauma but an increased risk of death from hemorrhage if administered after three hours. (See "Initial management of moderate to severe hemorrhage in the adult trauma patient", section on 'Antifibrinolytic agents'.)

  Preliminary evidence suggests that tranexamic acid may have similar benefits in severely injured children as well. As an example, in an observational study of 766 pediatric trauma patients younger than 18 years of age with combat injuries (73 percent with penetrating trauma), the 66 patients who received tranexamic acid had a significantly lower mortality compared with all other patients (adjusted odds ratio [OR] 0.3, 95% CI 0.09-0.89). Also, tranexamic acid significantly improved neurologic outcomes among patients who received tranexamic acid and large volume transfusions compared with large volume transfusions alone (Glasgow Coma Score [GCS] of 14 to 15 at discharge, 90 versus 69 percent, respectively) [15]. No thromboembolic complications were seen in the patients who received tranexamic acid. Further study of tranexamic acid therapy in pediatric trauma patients with significant hemorrhage are needed to determine its safety and efficacy [16].

IV access — Ideally, vascular access involves placement of two large bore IVs in the upper extremities within 60 to 90 seconds of arrival, realizing that in young children the lower extremities provide a reasonable alternative and that in many cases two large bore IVs cannot be inserted in a timely fashion.

The most common type of peripheral venous catheter used in children is the over-the-needle catheter. Catheter size necessary for fluid resuscitation varies by age: 22 to 24 gauge in newborns and infants, 18 to 20 gauge for older children. The size of the cannula used in resuscitation should be the largest that can be inserted reliably. In shock or severe hypovolemia, a smaller cannula may be used for initial fluid resuscitation until a larger vein can be cannulated. Butterfly needles should be avoided because they infiltrate easily. (See "Emergency and elective venous access in children".)

If peripheral IV access is not rapidly achieved, the intraosseous (IO) route offers a rapid and easily obtainable alternative access. Percutaneous central access or venous cutdown are other options for establishing more permanent vascular access for ongoing care. Central access is accomplished more easily than a cutdown, which is rarely used. Among the sites for central access, the femoral vein is most frequently used and affords the lowest rate of complications in the short term [4,10,11] (see "Emergency and elective venous access in children" and "Intraosseous infusion"). When available, ultrasound guidance should be used to facilitate central venous catheterization.

Fluid resuscitation — In patients with compensated shock after blunt trauma, a fluid bolus of 20 mL/kg of warmed normal saline or Lactated Ringer should be rapidly given over 10 to 15 minutes. Patients generally need to receive crystalloid volume that is three times the estimated blood loss in order to become hemodynamically stable. In children, three boluses or 60 mL/kg of normal saline or Lactated Ringer (maximum dose: 3 L total volume) would balance a blood loss of 20 mL/kg (approximately one-third of blood volume), assuming that bleeding is controlled. A transfusion of 10 mL/kg of packed red blood cells (PRBC) should be considered if there is inadequate clinical improvement after IV boluses of 40 to 60 mL/kg of normal saline [4]. (See "Shock in children in resource-abundant settings: Initial management".)

There is some debate about whether NS or Lactated Ringer is the better initial resuscitation fluid. However, when limited to 60 mL/kg, it is unlikely there is a significant difference in outcome. Lactated Ringer should not be given with blood through the same venous access because it can cause clotting. (See "Initial management of moderate to severe hemorrhage in the adult trauma patient", section on 'Intravenous fluid resuscitation'.)

Blood products — Blunt trauma patients with hypotension require rapid restoration of blood volume. These patients often require blood transfusion if they show little to no improvement with initial crystalloid infusions. Type specific or unmatched O negative packed red blood cells (PRBCs, initial volume 10 to 20 mL/kg up to 2 units) administered through a rapid infusion system with an inline warmer may be lifesaving in these patients.

Patients with compensated shock not responsive to initial crystalloid infusions should receive type and cross-matched blood (10 mL/kg up to 1 unit).

The role of other blood products, such as fresh frozen plasma (FFP), platelets, and recombinant activated factor VII (rFVIIa) for the treatment of severely traumatized patients who require massive transfusion is evolving. While replacement therapy with plasma, platelets, and red cells should not generally be based upon any set formula, results from a number of observational studies in adults suggest that patients with severe trauma, massive blood replacement, and coagulopathy have improved survival when the ratio of transfused FFP (units) to transfused platelets (units) to red cells (units) approaches 1:1:1. (See "Initial management of moderate to severe hemorrhage in the adult trauma patient".)

Massive transfusion protocol — In children, a massive transfusion protocol [17] is indicated for patients who have profound hemorrhage or ongoing bleeding with an anticipated need to replace total blood volume over 24 hours. Use of such a transfusion protocol has been associated with better outcomes in adults although evidence in children is limited [18,19]. (See "Initial management of moderate to severe hemorrhage in the adult trauma patient", section on 'Management by clinical scenario'.)

- **Estimated volume trigger** – The optimal volume trigger for initiating a massive transfusion protocol in children is unknown but some experts use the following weight-based approach:

  - <5 kg (neonate) – 55 mL/kg
  - 5 to 25 kg (infant) – 50 mL/kg
  - 25 to 50 kg (child) – 45 mL/kg
  - >50 kg (adolescent) – 40 mL/kg or 6 units PRBC

  In support of a trigger of 40 mL/kg, one retrospective observational study of over 1,100 children (median age, 10 years) who sustained combat injuries found that patients who received 40 mL/kg or more of total blood products in the first 24 hours were at significantly higher risk of early and in-hospital death than those received <40 mL/kg (5 versus 2 percent for early death and 15 versus 6 percent for in-hospital death, respectively) [20].

- **Hemostatic resuscitation** – In addition to estimated blood loss, the presence of coagulopathy in severely traumatized children undergoing blood transfusion is significantly associated with mortality and is also used as a criterion for initiating a massive transfusion protocol by some centers [17,21,22].

  Patients with documented coagulopathy, especially those with significant head trauma, warrant FFP even in the absence of blood transfusion requirements and should also receive FFP if blood transfusion is necessary. Hemostatic resuscitation using blood component therapy resembling that of whole blood (PRBC:FFP:platelets in a 1:1:1 ratio) has been associated with improved outcomes. For example, in a retrospective cohort of over 1200 United States children undergoing massive transfusion and reported to a national pediatric trauma data registry, transfusion using a FFP:PRBC ratio of 1:1 compared with higher ratios (1:2, 1:3, and 1:3+) was associated with a significantly lower 24 hour mortality and lower PRBC transfusion requirements with no difference in complications [19].

Controlled hypotension — Questions remain whether reversal of hypovolemia or control of hemorrhage should take priority in some trauma patients. For example, controlled hypotension may be beneficial in patients with hemorrhagic shock due to torso injuries from gunshot or stab wounds. In this setting, titrating fluid resuscitation to regain a peripheral pulse but to maintain hypotension may allow lacerated blood vessels to spasm, form thrombi, and preserve blood volume prior to definitive surgical exploration and hemorrhage control. On the other hand, aggressive fluid administration prior to hemorrhage control in patients with penetrating trauma might, via augmentation of blood pressure, dilution of clotting factors, and production of hypothermia, disrupt thrombus formation and worsen bleeding. However, little data exists for this approach in children. (See "Initial management of moderate to severe hemorrhage in the adult trauma patient", section on 'Delayed fluid resuscitation/controlled hypotension'.)

Of note, controlled hypotension may be detrimental to blunt trauma patients with brain injury, as hypotension reduces cerebral perfusion and increases mortality. For this reason, we do not recommend controlled hypotension for pediatric blunt trauma victims, especially those with head injury.

Vasoactive pressor medications — Vasoactive pressor infusions are not appropriate for the treatment of hypovolemic shock but may be necessary to treat shock secondary to spinal cord injury. (See "Acute traumatic spinal cord injury".)

Refractory shock — Recalcitrant hypotension despite appropriate fluid therapy suggests massive hemorrhage or mechanical disruption of cardiac pumping ability.

Cardiac tamponade may manifest as Beck's triad (increased venous pressure [distended neck veins], muffled heart sounds, and hypotension), which may be absent with hypovolemia. Cardiac tamponade also may cause PEA (pulseless electrical activity) in the absence of hypovolemia and tension pneumothorax [4]. When available, bedside ultrasound reliably diagnoses or excludes significant cardiac tamponade and should be used, if time allows, prior to attempting pericardiocentesis. Pericardiocentesis, optimally performed with ultrasound guidance, may rapidly restore circulation, but thoracotomy will typically be required to control the source of bleeding. (See "Emergency pericardiocentesis".)

Open thoracotomy, though rarely successful in preventing mortality, provides access to the pericardium, heart, pulmonary vessels, and aorta for procedures that may address pericardial tamponade, exsanguinating intrathoracic hemorrhage, penetrating cardiac injury, or large vessel abdominal bleeding. Potential indications include (see "Thoracic trauma in children: Initial stabilization and evaluation", section on 'Emergency thoracotomy'):

- Patient had vital signs in the field but has cardiac arrest either on transport or while in the ED.

  or

- Patient has thoracic trauma and is hemodynamically unstable despite appropriate fluid resuscitation.

  and

- A thoracic or trauma surgeon is available within approximately 45 minutes.

Disability

Neurologic assessment — Rapid neurologic assessment encompasses determination of level of consciousness [11] using the Glasgow Coma Scale (GCS) or the pediatric GCS, a validated scale for children ≤2 years (table 9). (See "Classification of trauma in children", section on 'Glasgow Coma Scale'.)

Trauma patients with a GCS ≤8 or who are unresponsive or only respond to pain have severe altered mental status and require rapid resuscitative efforts. (See "Severe traumatic brain injury (TBI) in children: Initial evaluation and management", section on 'Initial assessment'.)

Additional neurologic findings to elicit during the primary survey include pupillary responsiveness and brainstem reflexes (eg, gag reflex). Unequal or fixed and dilated pupils indicate cerebral herniation and the need for aggressive measures to counteract increased intracranial hypertension. (See 'Disability management' below and "Elevated intracranial pressure (ICP) in children: Clinical manifestations and diagnosis".)

Disability management — Patients with concerns for significant intracranial injury or increased intracranial pressure (ICP) must be managed appropriately to reduce the likelihood of secondary brain injury from hypoxia, ischemia, and cerebral edema [4,10,11]:

- The clinician should provide supplemental oxygen to keep saturation >95 percent.
- Head injured patients with compromised airway, inadequate breathing, or a GCS ≤8 require early endotracheal intubation and controlled ventilation (table 9). Hyperventilation ($PaCO_2$ <35 mmHg) may cause cerebral ischemia as the result of decreased cerebral blood flow. Consequently, $PaCO_2$ should be maintained between 35 and 38 mmHg unless there are signs of impending herniation. (See "Elevated intracranial pressure (ICP) in children: Management", section on 'Breathing'.)
- Patients with hypotension require rapid fluid resuscitation to maintain cerebral perfusion. (See 'Circulation' above.)
- Patients with evidence of cerebral herniation should receive IV Mannitol 0.5 to 1 g per kg or IV hypertonic saline as 2 to 6 mL per kg of 3 percent NaCl (1 to 3 mEq per kg) to reduce ICP. Evidence is lacking regarding the best regimen for osmolar therapy in children with increased ICP. For most pediatric patients, osmolar therapy with either mannitol or hypertonic saline is initially effective. (See "Elevated intracranial pressure (ICP) in children: Management", section on 'Hyperosmolar therapy'.)

  Hypertonic saline has a theoretical advantage over mannitol because it does not exacerbate hypovolemia due to an osmotic diuresis in patients with brain injury and hemorrhagic shock. (See "Elevated intracranial pressure (ICP) in children: Management".)

  On the other hand, many experts prefer mannitol for treatment of acute herniation due to severe head trauma because it has a more rapid and sustained effect. (See "Elevated intracranial pressure (ICP) in children: Management", section on 'Mannitol'.)

Any child with a GCS ≤12 warrants consultation and evaluation by a neurosurgeon (table 9). In addition, children with a GCS ≤8 deserve invasive monitoring of ICP. Specific therapies targeted at increased ICP are discussed separately. (See "Severe traumatic brain injury (TBI) in children: Initial evaluation and management" and "Elevated intracranial pressure (ICP) in children: Clinical manifestations and diagnosis".)

Exposure and environment — Completely undressing the patient during the primary survey facilitates rapid identification and treatment of multiple injuries. After advanced procedures are completed, the medical providers may log roll the patient while maintaining cervical spine immobilization in order to fully assess the back for injuries to the flank or spine. Many providers chose to perform a rectal examination while the patient is in a lateral position during the log roll to assess anal sphincter tone and presence of gross blood in the rectal vault. Alternatively, the patient may be log rolled as part of the secondary survey (figure 7). (See 'Musculoskeletal' below.)

Pressure sores on the buttocks and heels can develop quickly (within hours) in immobilized patients. Backboards should be used only to transport patients with potentially unstable spinal injury and discontinued as soon as possible. (See "Acute traumatic spinal cord injury".)

Hypothermia should be avoided with the use of increased ambient room temperature, radiant warmers, warmed IV fluids/blood, warm and humidified inspired oxygen, and covering the patient with warm blankets after full assessment [4,7].

Adjuncts to the primary survey

Laboratory studies — Hematologic studies, serum chemistries and urinalysis have low sensitivity for identifying serious injuries in children with blunt trauma. Clinicians should consider them adjuncts to diagnosis and not substitutes for clinical assessment of critically injured children [23]. Of the blood and urine studies typically obtained during the primary survey, the following have the greatest impact on patient management [11]:

- **Type and cross** – Type and cross for PRBC allows for rapid transition to blood product transfusion if crystalloid fluid resuscitation does not reverse shock. The emergency clinician should order a blood type and cross-match for any victim of significant trauma in anticipation of the need for transfusion. For the patient with a potentially life-threatening hemorrhage, the blood bank should be notified directly (ie, by telephone or in person) of the need for O negative uncross-matched blood and, when necessary, other blood products (eg, FFP, platelets, rVIIa) for immediate transfusion. (See 'Circulation' above.)

- **Hematocrit** – Hematocrit value <30 percent identifies low oxygen carrying capacity and may suggest intra-abdominal injury in blunt trauma patients [24]. The hematocrit can be useful as a baseline value in trauma patients. It must be interpreted in light of the clinical context, including the extent of hemorrhage, time since the injury, and the amount of exogenous fluid administration. As an example, the clinician should not be reassured by a normal hematocrit in the acute trauma victim with hypotension. The hematocrit is most helpful when measured serially to assess ongoing hemorrhage.

- **Blood glucose** – Rapid blood glucose diagnoses hypoglycemia in the patient with altered mental status. (See "Approach to hypoglycemia in infants and children".)

- **Liver enzyme studies** – Elevated liver enzyme values (AST >200 international unit/L or ALT >125 international unit/L) are highly associated with intra-abdominal injury following blunt trauma in children although values below this level do not exclude a significant injury in patients with a severe mechanism [23]. (See "Pediatric blunt abdominal trauma: Initial evaluation and stabilization", section on 'Liver transaminases'.)

- **Urinalysis** – Gross hematuria is highly suggestive of serious renal or urinary tract injury and warrants further investigation. Urinalysis demonstrating ≥50 red blood cells (RBCs) per high-powered field also suggests intra-abdominal injury after blunt trauma in children, which should be investigated with an abdominal computed tomography (CT) scan. Although some experts consider >5 to 50 RBCs to be abnormal, this finding would not mandate further imaging in otherwise well appearing children. (See "Blunt genitourinary trauma: Initial evaluation and management", section on 'Pediatric considerations'.)

- **Blood gas determination** – Arterial blood gas or venous blood gas combined with pulse oximetry identifies hypoxemia. In addition, metabolic acidosis associated with inadequate perfusion is common in the unstable trauma patient. It is important to interpret blood gas findings in light of the patient's current clinical condition. Some values (eg, pH, base deficit) may lag behind clinical improvement after an aggressive resuscitation.

In addition to the above, the unstable pediatric trauma victim often undergoes the following testing:

- Complete blood count (CBC) with differential
- Prothrombin time (PT)
- Partial thromboplastin time (PTT)
- International normalized ratio (INR)
- Serum electrolytes
- Serum blood urea nitrogen (BUN) and creatinine
- Serum lipase or amylase

Although these tests do not usually assist in the identification of specific injuries [23], they do serve as baseline values for comparison in the course of trauma resuscitation. For example, electrolytes and renal function may become abnormal after osmotherapy for increased ICP (see "Elevated intracranial pressure (ICP) in children: Clinical manifestations and diagnosis"). Similarly, thrombocytopenia and coagulopathy may occur in patients who have head trauma or receive multiple transfusions.

Selected patients should also have measurement of blood ethanol level (adolescents), rapid urine pregnancy test (postmenarchal females), or urine screen for drugs of abuse (adolescents and children with suspected exposure) [4]. Although the results of these will not typically alter acute trauma management they may have important ramifications for care after initial resuscitation.

Screening radiographs — Cross-table lateral cervical spine (C-spine), anteroposterior (AP) chest, and, in selected patients, AP pelvis help identify immediately life-threatening injuries during the primary survey [11]:

- A cross-table lateral C-spine film identifies up to 80 percent of fractures, dislocations, and subluxations. However, a negative C-spine radiograph does not exclude the possibility of serious spinal cord injury. Cervical immobilization should continue until complete clinical assessment and additional studies, as needed, rule out serious C-spine fracture or spinal cord trauma. In severely injured or comatose patients with a concerning mechanism of injury, the trauma physician may elect to maintain cervical spine immobilization, even after a complete radiographic C-spine evaluation shows no abnormality. (See "Evaluation and acute management of cervical spine injuries in children and adolescents", section on 'Cervical spine imaging'.)

- An AP chest radiograph may demonstrate pneumothorax, hemothorax, aortic dissection, pulmonary contusion, pneumomediastinum, rib fractures, and/or hemopericardium. In addition, it provides visualization of endotracheal and gastric tube placement.

- The AP pelvis radiograph is most often helpful in victims of high energy blunt trauma who are hemodynamically unstable, display pelvic pain, or have pelvic instability on physical examination. Identification of fracture in these unstable patients allows the emergency practitioner to initiate pelvic binding in anticipation of hypogastric artery embolization or operative external pelvic fixation. However, the sensitivity of an AP radiograph for pelvic fractures in children is limited, especially in patients younger than two years of age. Patients with negative plain radiographs in whom pelvic fracture is suspected should undergo CT of the pelvis once they are stable or, if performed, along with an abdominal CT. (See "Pelvic trauma: Initial evaluation and management", section on 'Imaging studies and fracture types' and 'Circulation' above and "Pelvic trauma: Initial evaluation and management", section on 'Initial stabilization and approach'.)

e-FAST (extended focused assessment with sonography for trauma) — e-FAST is a rapid ultrasound examination of four abdominal locations: right upper quadrant, left upper quadrant, subxiphoid region, and pelvis; lungs; and heart [25]. The primary utility of this examination for the unstable trauma patient is the detection of intraperitoneal fluid secondary to intra-abdominal injury, pneumo- or hemothorax, and/or hemopericardium.

We suggest e-FAST examination in hemodynamically unstable pediatric trauma patients as a rapid means to identify an underlying etiology and to focus further management and for stable patients, if performance of ultrasound will not cause any delays [12,26]. For example, hemodynamically unstable children with positive abdominal findings on e-FAST may warrant operative intervention in lieu of abdominal CT [26]. e-FAST may also have utility in a neurologically unstable child who is multiply injured and requires emergency surgery for an epidural hematoma. In this instance, a positive FAST examination may support the need for a laparoscopy or laparotomy at the time of craniotomy when there may not be time for other advanced imaging.

Although evidence is limited in children, e-FAST may also permit more timely detection of pneumothorax, hemothorax, or cardiac tamponade with greater sensitivity but lower specificity than a supine chest radiograph. (See "Overview of intrathoracic injuries in children", section on 'Diagnosis'.)

The utility of e-FAST for the detection of intra-abdominal injury in hemodynamically stable children with blunt abdominal trauma and no other injury that requires emergency surgery is less clear:

- Although FAST has been associated with improved outcomes in adult trauma patients (see "Emergency ultrasound in adults with abdominal and thoracic trauma", section on 'Clinical studies'), its use in the evaluation of children is not routine because the nature of pediatric injuries, primarily the common presence of solid organ lacerations, makes FAST an insensitive means for detecting important intra-abdominal injury [27]. As an example, in a metaanalysis of 25 studies (over 3800 injured children), FAST had a sensitivity of 66 percent and a specificity of 95 percent for the detection of hemoperitoneum using CT as the gold standard [28]. Given this low sensitivity, hemodynamically stable children with a moderate to high pretest probability for intra-abdominal injury warrant abdominal CT, regardless of findings on FAST.

- FAST may also **not** have an impact on potentially important clinical outcomes or resource use in hemodynamically stable children with a low clinical suspicion for intra-abdominal injury. For example, in an unblinded randomized trial of 925 hemodynamically stable children evaluated for blunt torso trauma at a single center, FAST was **not** associated with significant differences in missed intra-abdominal injury (0 to 0.2 percent), frequency of abdominal CT (52 to 55 percent), mean emergency department length of stay (six hours), and hospital charges compared with standard care without FAST [29,30]. Negative results on ultrasonography did lower the clinical suspicion for intra-abdominal injury by managing physician but did not decrease the use of abdominal CT. However, the study did not provide a specified approach to positive or negative FAST results and the sensitivity of FAST in this study (33 percent) was low compared with prior studies [31].

On the other hand, in a retrospective observational study of 354 children with blunt torso trauma (14 percent with intra-abdominal injury), e-FAST combined with physical examination had a sensitivity of 88 percent (95% CI, 76 to 96 percent) and a negative predictive value of 97 percent (95% CI, 95 to 99 percent) for intra-abdominal injury and a sensitivity of 100 percent (95% CI, 75 to 100 percent) and a negative predictive value of 100 percent for intra-abdominal injury requiring acute intervention [32]. Larger prospective studies are needed to confirm these findings.

Given the significant potential for false negative results, e-FAST alone should **not** be used to limit the use of abdominal CT in children with blunt abdominal trauma [33]. However, preliminary evidence suggests that e-FAST in combination with physical examination findings may provide useful information to guide clinical decisions.

Urinary catheter — A urinary catheter should be placed to monitor urinary output and to obtain urine for diagnostic testing. Patients with suspected urethral transection (blood at the urethral meatus, perineal ecchymosis, blood in the scrotum, or pelvic fracture) should undergo a retrograde urethrogram to evaluate urethral integrity before urinary catheterization is attempted. Alternatively, a suprapubic tube offers an option for emergent decompression of the bladder [4]. Retrograde urethrogram should be deferred when significant pelvic vascular injury is suspected as extravasated contrast dye from the retrograde urethrogram or cystogram may obscure computed tomography and angiography images thereby interfering with study interpretation and subsequent embolization attempts. (See "Blunt genitourinary trauma: Initial evaluation and management", section on 'History, examination, and approach to testing'.)

Gastric tube — Major trauma often results in gastroparesis and significant stomach enlargement. When this occurs, an orogastric or nasogastric tube should be placed for stomach decompression to reduce the risk of aspiration. Placement of a gastric tube may also facilitate endotracheal intubation.

Nasogastric insertion is contraindicated in patients with oromaxillary trauma and possible cribriform plate fracture, either diagnosed radiographically or if suspected on the basis of epistaxis, watery discharge from the nares, or mobility of the maxilla [11]. In this setting, the orogastric route is preferred.

SECONDARY SURVEY

The secondary survey is a systematic head-to-toe evaluation of the trauma patient, which must be performed after the primary survey has been completed and resuscitation begun, as needed, with the stabilization of vital functions. This part of the evaluation includes the patient history, comprehensive physical examination, and additional studies and procedures (table 2) [4,7].

Although the goal of the secondary survey is to be complete, the need for rapid treatment requires a compromise in some cases. For instance, in a hypotensive child who has sustained multiple pelvic fractures due to a compression injury of the lower body, one would not ordinarily check visual acuity before moving on to interventional radiology.

When the physical examination is truncated due to patient condition, it is incumbent upon the team to ensure that the examination is completed after the necessary interventions or diagnostic studies are performed. If the patient is transferred to another service or hospital, the missing components of the examination should be specifically communicated.

History — The AMPLE mnemonic may be used to obtain a quick, focused history from prehospital personnel, patients, or family members [11]:

- A – Allergies
- M – Medications
- P – Past medical history/pregnancy
- L – Last meal
- E – Events/environment leading to the injury

Physical examination and management — The components of the physical examination that deserve special focus in the secondary survey are summarized below (table 2).

Head — The scalp and head should be examined and palpated for lacerations, hematomas, or bony step-offs.

- **Eyes** – The eyes should be evaluated for pupillary size, conjunctival/fundal hemorrhage, penetrating injury, ocular mobility/entrapment, or periorbital ecchymosis (Raccoon's eyes). Contact lenses, if present, should be removed. Awake patients should have visual acuity assessed.

- **Ears** – Hemotympanum (picture 1) or blood or clear drainage from the ear canal suggests basilar fracture with CSF leakage, as does retroauricular ecchymosis (Battle's sign). (See "Skull fractures in children: Clinical manifestations, diagnosis, and management", section on 'Basilar skull fracture'.)

- **Maxillofacial** – The emergency practitioner should inspect the nose for cerebrospinal fluid leakage or blood. When placing a gastric tube in patients with midface fractures, as indicated by deformity, tenderness, or mobility of the maxilla, the clinician should pass an orogastric rather than a nasogastric tube because of the risk of penetration of the cribriform plate with intracranial placement of the gastric tube. The mouth should be inspected for soft tissue lacerations, malocclusion, or loose teeth [4,7]. Jaw pain or deformity indicates possible jaw fracture. Significant maxillofacial injury is a marker for possible cervical spine injury.

Cervical spine and neck — Cervical spine protection and motion restriction should be maintained throughout the examination [7]. The neck should be inspected for tracheal deviation, contusions, hematomas, or penetrating injuries, which may affect the airway, the spinal cord, or major vessels. Palpation should assess for cervical spine tenderness (in the awake and cooperative patient), or stepoff that suggests vertebral fracture or dislocation. Crepitus indicates subcutaneous emphysema, which may result from laryngeal fracture, esophageal rupture, or pneumothorax [11]. (See "Evaluation and acute management of cervical spine injuries in children and adolescents".)

Chest — Inspection and auscultation of the chest should be repeated as described previously. In addition, the entire chest, including the clavicles, sternum, and ribs, should be palpated for crepitus, step-offs, or tenderness. Children may sustain significant internal injury to the intrathoracic structures (eg, pulmonary or cardiac contusion) without evidence of skeletal trauma [4,11]. (See "Thoracic trauma in children: Initial stabilization and evaluation" and "Initial evaluation and management of blunt cardiac injury", section on 'Pediatric considerations'.)

Abdomen — Inspection, auscultation, and palpation of the abdomen with reevaluation is important for the pediatric trauma patient as examination findings may change over time. The physician should evaluate the abdomen for distention, ecchymosis, presence/quality of bowel sounds, abdominal tenderness, rebound, guarding, or palpable masses. (See "Pediatric blunt abdominal trauma: Initial evaluation and stabilization".)

The presence of a "seat belt sign" (a linear contusion across the abdomen), especially when coupled with abdominal pain and tenderness, is associated with a substantially increased risk of intra-abdominal injury, specifically, gastrointestinal injury. (See "Pediatric blunt abdominal trauma: Initial evaluation and stabilization", section on 'Seat belt sign'.)

Hollow viscus and retroperitoneal injuries, including to the pancreas, are often occult initially on a clinical basis, and a high index of suspicion based on the mechanism of injury is important for the identification of these injuries. (See "Hollow viscus blunt abdominal trauma in children", section on 'Lap seat belt injury'.)

Perineum — Inspection of the perineum is important for the identification of contusions, hematomas, lacerations, or urethral bleeding (in the male). Although the utility of the rectal examination in trauma patients has been questioned [34], we believe that it can add information regarding blood from the bowel lumen and sphincter tone in the unstable patient. In teenage or adult males a high-riding prostate suggesting transurethral transection may be palpated. In the female patient the vagina should be inspected for the presence of blood or lacerations [4]. Postpubertal women with pelvic fractures should undergo vaginal examination. (See "Blunt genitourinary trauma: Initial evaluation and management", section on 'History, examination, and approach to testing'.)

Musculoskeletal — The emergency provider should inspect the extremities for swelling or contusion and palpate for deformity, tenderness, presence/absence of pulses, and quality of pulses. Any potential fracture should undergo splinting. In addition, limbs with neurovascular compromise require rapid involvement of orthopedic and vascular subspecialists. (See 'Orthopedic management' below and "Basic techniques for splinting of musculoskeletal injuries".)

Ecchymosis over the iliac wings, pubis, labia, or scrotum is suspicious for pelvic fractures. In the alert patient, pain on palpation of the pelvic ring suggests the presence of a fracture. In the unconscious patient, mobility of the pelvis in response to anterior-to-posterior pressure on both anterior iliac spines and symphysis pubis is suggestive of pelvic ring disruption. "Rocking" of the pelvis back and forth should be avoided as it may increase hemorrhage due to pelvic fracture. The patient must be rolled and the back inspected and palpated for tenderness or step-offs if not already performed during patient exposure. The axillae should also be examined [11].

Neurologic — A brief but thorough neurologic evaluation including motor and sensory function as well as reevaluation of the patient's level of consciousness and pupillary response to light must be performed as part of the secondary survey. If any spinal cord injury is suspected, the patient must be immobilized using cervical spine immobilization devices. (See "Severe traumatic brain injury (TBI) in children: Initial evaluation and management", section on 'Secondary survey'.)

Pressure sores on the buttocks and heels can develop quickly (within hours) in immobilized patients. Backboards should be used only to transport patients with potentially unstable spinal injury and discontinued as soon as possible. (See "Acute traumatic spinal cord injury".)

Adjuncts to the secondary survey — After the pediatric trauma patient has been assessed, resuscitated, and stabilized, imaging can be performed to identify specific injuries not detected or fully characterized on the screening radiographs. Computed tomography (CT) is the modality of choice to identify intracranial and abdominal injuries when indicated by physical findings. (See "Severe traumatic brain injury (TBI) in children: Initial evaluation and management", section on 'Imaging' and "Pediatric blunt abdominal trauma: Initial evaluation and stabilization", section on 'Indications' and "Minor blunt head trauma in infants and young children (<2 years): Clinical features and evaluation", section on 'Neuroimaging' and "Minor blunt head trauma in children (≥2 years): Clinical features and evaluation", section on 'Neuroimaging'.)

CT may also be useful to evaluated selected children with suspected cervical spine injuries (algorithm 1 and algorithm 2). (See "Evaluation and acute management of cervical spine injuries in children and adolescents", section on 'Computed tomography'.)

To avoid excess radiation exposure with subsequent cancer risk, injury mechanism and clinical factors must be carefully considered when determining if a CT scan should be performed in the pediatric trauma patient. (See "Ischemic stroke in children: Clinical presentation, evaluation, and diagnosis", section on 'CT safety considerations'.)

Radiographs — After stabilization, the cervical spine radiographic series may be completed with AP and, in the older child, open mouth odontoid views. Due to the possibility of spinal cord injury without radiologic or CT evidence of trauma (SCIWORA or SCIWOCTET) in the pediatric population, trauma patients with brief or sustained sensory or motor deficits with no plain radiologic or CT abnormality and decreased level of consciousness must be assumed to have a cervical spine injury, and cervical spine protection and motion restriction must be maintained until proven otherwise. (See "Spinal cord injury without radiographic abnormality (SCIWORA) in children", section on 'Clinical features and diagnosis'.)

Based on physical examination findings, extremity radiographs should also be performed for the evaluation of suspected fractures. (See "Evaluation and acute management of cervical spine injuries in children and adolescents", section on 'Cervical spine imaging'.)

Head CT — Intracranial imaging should be performed for normotensive patients with GCS scores <14 (table 9) or signs of a basilar skull fracture. In a hypotensive patient with depressed mental status, every effort should be made with fluid resuscitation to improve the hypotension, which may also improve mental status and obviate the need for a head CT [4]. (See "Severe traumatic brain injury (TBI) in children: Initial evaluation and management".)

The indications for obtaining imaging for children with minor head trauma are discussed separately. (See "Minor blunt head trauma in infants and young children (<2 years): Clinical features and evaluation", section on 'Neuroimaging' and "Minor blunt head trauma in children (≥2 years): Clinical features and evaluation", section on 'Neuroimaging'.)

Neck CT — Although CT of the neck with sagittal and coronal three-dimensional (3D) reconstruction is highly sensitive and specific for cervical spine fractures, the radiation risk does **not** justify routine use of neck CT in pediatric trauma patients. Screening cervical spine radiographs, which identify most life-threatening cervical spine injuries, remain the initial imaging modality. An anatomically focused CT on the cervical spine level of concern should be obtained in any of the following circumstances (see "Evaluation and acute management of cervical spine injuries in children and adolescents", section on 'Cervical spine imaging'):

- Inadequate cervical spine radiographs (three-views)
- Suspicious plain radiographic findings
- Fracture/displacement seen on plain radiographs
- High clinical index of suspicion of injury despite normal radiographs

Chest CT — For children, chest CT is primarily indicated to identify vascular or tracheo-bronchial injury in hemodynamically stable patients with the following findings:

- Physical examination evidence of great vessel injury (asymmetric pulses, diminished pulses throughout with associated major chest trauma, paralysis, or large hemothorax with ongoing hemorrhage)

- Abnormal screening chest radiograph with findings that suggest great vessel injury (eg, wide mediastinum, obscured aortic knob, left apical cap, or large left hemothorax)

- Suspected tracheo-bronchial injury

Hemodynamically unstable patients with suspected aortic injury should undergo emergency surgical or endovascular repair rather than additional imaging. For children with suspected blunt aortic injury (BAI), the approach to diagnosis and treatment is similar to the approach in adults (algorithm 3). (See "Overview of intrathoracic injuries in children", section on 'Traumatic aortic injury'.)

We restrict the use of chest CT to the above indications because a normal chest radiograph has a high negative predictive value for significant thoracic injury that requires intervention. Furthermore, the incidence of cardiac and great vessel injury in children is significantly lower than the risk of radiation exposure in children. The initial stabilization and evaluation of thoracic trauma is discussed in more detail separately. (See "Thoracic trauma in children: Initial stabilization and evaluation", section on 'Thoracic imaging'.)

Abdominal CT — Abdominal CT with intravenous contrast is the preferred diagnostic imaging modality to detect intra-abdominal injury in hemodynamically stable children who have sustained blunt abdominal trauma. CT is sensitive and specific in diagnosing liver, spleen, and retroperitoneal injuries, which may be managed nonoperatively. (See "Pediatric blunt abdominal trauma: Initial evaluation and stabilization", section on 'Abdominal and pelvic CT' and "Liver, spleen, and pancreas injury in children with blunt abdominal trauma", section on 'Imaging'.)

CT with intravenous (IV) contrast alone is less sensitive in detecting injuries of the pancreas, intestinal tract, bladder, and lumbar spine. (See "Liver, spleen, and pancreas injury in children with blunt abdominal trauma", section on 'Imaging' and "Hollow viscus blunt abdominal trauma in children", section on 'Imaging' and "Blunt genitourinary trauma: Initial evaluation and management", section on 'CT scanning'.)

Patients with hypotension are also at high risk for intra-abdominal injury. Those children who do not respond to fluid resuscitation require direct operative intervention; a FAST examination may be helpful in characterizing the injury in this situation. Those who become hemodynamically stable after fluid repletion should have an abdominal CT performed. (See 'e-FAST (extended focused assessment with sonography for trauma)' above.)

A low-risk rule for intra-abdominal injury can identify children and adolescents who may undergo emergency department observation rather than abdominal and pelvic CT and is discussed in detail separately. (See "Pediatric blunt abdominal trauma: Initial evaluation and stabilization".)

The accuracy of CT imaging may be increased with the use of oral or intravenous contrast. The routine use of oral contrast is controversial; it is rarely of benefit in the diagnosis of acute distal bowel injuries, but may be helpful in the diagnosis of duodenal and pancreatic injuries. The use of oral contrast media can increase scanning time and cause vomiting although low rates of aspiration have been documented in retrospective studies. In addition, oral contrast may inadequately penetrate the small or large bowel. For these reasons, many trauma centers no longer use oral contrast. (See "Pediatric blunt abdominal trauma: Initial evaluation and stabilization", section on 'Abdominal and pelvic CT'.)

Laparoscopy — In patients with suspected bowel injury, who are hemodynamically stable, emergent laparoscopy may be considered as a diagnostic and therapeutic procedure. This may be useful for selected patients who have sustained blunt or penetrating abdominal injuries as an alternative to laparotomy [35]. (See "Hollow viscus blunt abdominal trauma in children", section on 'Suspected hollow viscus injury'.)

Orthopedic management — Fractures resulting in neurovascular compromise may be gently reduced and splinted while awaiting orthopedic consultation. If the pulses are present, the extremity may be maintained in the position in which it is found. Splints should be placed to immobilize the joint above and below the injury site, if possible. The neurovascular status of the extremity should be evaluated before and after splint placement. (See "Basic techniques for splinting of musculoskeletal injuries".)

Pelvic fractures may be temporarily managed by wrapping a sheet around the pelvis at the level of the greater trochanter to reduce pelvic volume and control hemorrhage (figure 6). (See 'Circulation' above.)

Open wounds should have appropriate wound care, and IV antibiotics should be given for open fractures. The choice of prophylactic antibiotics is derived from evidence in adults and depends upon the type of open fracture and the degree of contamination as described in the table (table 10) and is discussed separately. (See "Osteomyelitis associated with open fractures in adults", section on 'Antibiotics after open fracture'.)

Tetanus immunization (table 11) and pain control should also be addressed [11,36]. (See "Pain in children: Approach to pain assessment and overview of management principles".)

Definitive care — Level 1 pediatric trauma centers (PTCs) have the greatest amount of personnel and resources devoted to the care of critically injured children (table 12) and are the preferred sites for initial resuscitation and ongoing management of pediatric trauma patients [8,37]. When a level 1 PTC is not available, injured children should receive care at a hospital that has the highest level of pediatric trauma expertise and resources. Depending upon the region, this site may be a level II pediatric trauma center, an adult trauma center with pediatric capability sometimes called a combined trauma center (CTC), an adult trauma center (ATC), or a children's hospital without trauma verification. In the US, just over half of children had timely access (ie, ground or air transport time < 60 minutes) to a level 1 or 2 PTC by ground transport in 2020 [38].

Experts have developed a field triage guideline that identifies those patients who warrant direct prehospital transportation to a US trauma center. This critical field transport decision requires evaluation of vital signs, level of consciousness, injury anatomy, injury mechanism, and special patient or local emergency medical systems considerations. This guidance recommends that children "should be triaged preferentially to pediatric-capable trauma centers" (figure 8) [39].

For injured infants, children, and younger adolescents who require admission, treatment in a PTC is associated with better clinical outcomes than an ATC. For example, in a meta-analysis of 34 studies that evaluated hospitalized pediatric trauma patients, treatment in a PTC for children < 14 years old was associated with lower mortality than in an ATC (23 studies; OR 0.59, 95% CI 0.46 to 0.76) or in an ATC with additional pediatric capability referred to as a combined trauma center (CTC, 11 studies; OR 0.73, 95% CI 0.53 to 0.99) [37]. Compared with an ATC, care of children with blunt trauma in a PTC was also associated with a lower likelihood of undergoing computed tomography or operative management for a blunt solid organ injury. There was significant heterogeneity in the metaanalyses, and the overall quality of the evidence was rated as low. In a separate large retrospective cohort study of over 88,000 children <18 years old treated in 146 US trauma centers, high ED pediatric readiness was independently associated with a lower risk of death at one year [40].

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Pediatric trauma".)

SUMMARY AND RECOMMENDATIONS

- **Terminology** – For this discussion, the unstable pediatric trauma patient refers to any child who has abnormal vital signs, disruption of vital functions, or apparent injuries of a critical nature. Knowledge of normal vital signs by age and awareness of the ability of children to sustain major hemorrhage without hypotension facilitates recognition of the critically injured child (table 3 and table 4). (See 'Terminology' above and "Trauma management: Overview of unique pediatric considerations".)

- **Initial approach** – The initial trauma management in the pediatric trauma patient are summarized in the tables provided (table 1 and table 2). The phases of treatment are (see 'Initial approach' above):

  - **Primary survey (rapid primary evaluation)** (see 'Primary survey' above) – Assessment and management occur simultaneously during the primary survey. Any identified physiologic threat to life must be rapidly addressed and treated before moving on to the evaluation of the next priority area including:

    - Resuscitation of vital functions (eg, airway, breathing, circulation, mentation) (see 'Airway with cervical spine motion restriction' above and 'Breathing' above and 'Circulation' above and 'Disability' above and 'Exposure and environment' above)

    - Utilization of adjuncts to the primary survey and resuscitation such as laboratory studies, screening radiographs, extended focused assessment with sonography for trauma (FAST or e-FAST), and placement of a urinary catheter and gastric tube (see 'Laboratory studies' above and 'Screening radiographs' above and 'e-FAST (extended focused assessment with sonography for trauma)' above and 'Urinary catheter' above and 'Gastric tube' above)

  - **Secondary survey (more comprehensive secondary assessment)** (see 'Secondary survey' above) – The secondary survey is performed after the primary survey and consists of a head to toe physical examination with continued postresuscitation monitoring. Adjuncts to the secondary survey include completion of cervical spine imaging, more detailed imaging of the head and abdomen in stabilized patients, and laparoscopy. Key orthopedic interventions include external wrapping of pelvic fractures and splinting of fractures. (See 'Adjuncts to the secondary survey' above.)

If there is any deterioration of the patient during the evaluation, the primary survey should be repeated and any newly identified problems addressed before proceeding with the definitive care of the patient. (See 'Primary survey' above and 'Secondary survey' above.)

- **Definitive care** – Level 1 pediatric trauma centers have the greatest amount of personnel and resources devoted to the care of critically injured children (table 12) and are the preferred sites for initial resuscitation and ongoing management of pediatric trauma patients. (See 'Definitive care' above.)

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