Trauma is the leading cause of death and acquired disability in children and adolescents, resulting in more deaths in children than all other causes combined.1,2 Because children with severe injuries can rapidly deteriorate, resources for rapidly identifying and treating injuries are needed immediately on arrival at the receiving hospital. The initial evaluation of injured children in the emergency department (“trauma resuscitation”) has two main goals: (1) identify and immediately treat potentially life-threatening injuries, and (2) determine disposition after the trauma resuscitation based on known or suspected injuries. The trauma team must stabilize the child, determine the extent of the injury, and develop an initial treatment plan for the child’s hospitalization.

Advanced Trauma Life Support (ATLS) is a protocol developed to standardize the initial evaluation and management of injured patients and avoid omission of potentially lifesaving interventions. The ATLS training program was initiated by an orthopedic surgeon in 1978 in response to suboptimal care that he and his family received in a rural hospital after an airplane crash in a Nebraska cornfield. After 30 years of refinement, ATLS serves as the standard for initial management of injured patients and is now taught to providers around the world.2 The impact of ATLS on reducing morbidity and mortality after injury has been affirmed in several studies.3,4 ATLS training is mainly focused on treating the injured adult, but includes modules that emphasize the anatomic, physiologic, and psychological features that make management of the injured child unique.

The first phase of ATLS is the primary survey and is a rapid evaluation for identifying life-threatening injuries. The steps include evaluation and treatment of airway injuries (A, airway) followed by evaluation of respiratory dynamics (B, breathing), evaluation of the patient’s hemodynamic status (C, circulation), followed by a neurological assessment (D, disability). The final phase of the primary survey (E, exposure) is removing the patient’s clothing to identify concealed injuries and to ensure that the patient is protected from environmental heat loss. The primary survey is then followed by the secondary survey—a detailed head-to-toe evaluation that identifies other injuries. The steps within the primary survey are repeated as needed if the patient’s status changes and to monitor treatments given. The initial evaluation and treatment period can usually be accomplished within the first 20 to 60 minutes after arrival to the emergency department. The patient’s disposition from the emergency department depends on the type of injuries and the need for treatment and may range from admission to an inpatient or intensive care unit to transport directly to the operating room, transfer to a higher level facility, or discharge.

The initial management of injured adults has been the domain of trauma surgeons; however, the jurisdiction of care for the injured child is not as well defined at many centers. Frequently, pediatricians have an active role in the initial
management and treatment of injured children.\textsuperscript{5} While formal ATLS training is not needed for most pediatric providers, this training should be mandatory for those actively involved in the initial evaluation of injured children. At the least, a working knowledge of the evaluation and management steps of ATLS is needed for pediatricians and pediatric specialists who encounter injured patients in an acute care setting. The goal of this chapter is to provide a focused introduction to the initial resuscitation of injured children. This chapter does not serve as a replacement for ATLS training but will instead highlight aspects of the resuscitation that are unique to injured children or may not be emphasized in the ATLS curriculum.

**Prehospital Care and Trauma Team Activation**

Initial field care, appropriate triage and rapid transport are all aspects of prehospital care that can have an important impact on the outcome in pediatric trauma. Cities and regions have developed trauma systems that coordinate these aspects of care by creating networks of prehospital and hospital providers. The most severely injured children are triaged to the centers within each trauma system that have the personnel, facilities, and equipment to manage these patients. Equally important, minimally injured patients can be directed to nontrauma hospitals to avoid burdening pediatric trauma centers with these patients. Field triage is based on several components including physiological criteria, anatomic injury, mechanism of injury, and underlying medical conditions. Triage criteria have been designed to minimize inappropriate transport of severely injured patients to non-trauma hospitals (undertriage) but achieve this goal at the cost of directing some patients to trauma centers who are only minimally injured (overtriage). Because of the limited time and resources available for evaluation in the prehospital setting, overtriage is an unavoidable aspect of current trauma systems. Injured children who have met criteria for transport to high-level trauma centers by current criteria may be minimally injured and require no specific interventions before discharge from the emergency department. A key aspect of the initial management of the injured child in the emergency department is effectively continuing the care started in the field while avoiding unneeded care for those with minimal injuries.

One approach that has been used in many centers to address the problem of overtriage is the use of a tiered team response in the emergency department.\textsuperscript{5} Based on prehospital criteria, patients who are identified as being most at risk for severe injury are met by a full team upon arrival, including a trauma surgeon, emergency department physicians, critical care physicians, anesthesiologists, nurses, and radiology technicians. Patients with a lower likelihood of severe injury are initially met by a smaller team with the option of summoning a larger team if the initial evaluation suggests a severe injury. Centers that have used this approach for team activation have significantly reduced the expenditure of resources on minimally injured patients without any impact on the care received for more severely injured patients.\textsuperscript{7}

**Trauma Resuscitation**

Similar to medical codes, trauma resuscitations are among the most resource-intensive and time-pressured events in any hospital. The severity of the patient’s injuries, the number of team members required, and the number of simultaneous evaluation and management steps needed contribute to the complexity of the environment. To manage the complexity of trauma resuscitation, a systematic team-based and process-focused approach is needed to rapidly identify and treat life-threatening injuries and minimize team errors.

Designating a specific room and team for trauma resuscitations helps ensure needed resources are immediately available. A single location ensures that supplies (e.g., emergency airway kits, chest tube and thoracotomy trays, and central or intraosseous vascular access kits) are available and that team members know to gather at a specific site. Physicians, nurses, radiography technicians, respiratory therapists, and other hospital personnel needed for trauma resuscitation are identified in advance as trauma team members and assemble and assume their roles in the resuscitation area upon arrival of the injured child (Figure 112-1). These seemingly simple preparations ensure that the arriving patient has the maximal resources available at the receiving hospital.

Before arrival to the hospital, prehospital providers transmit information to hospital providers about the mechanism of injury, the status of the patient, and initial treatments given. This information can alert the team to prepare specific equipment or resources or to summon other essential personnel. Before the patient arrives, it is good practice for the team to review prehospital information to ensure all team members are aware of the patient’s status and anticipated needs. A “time out” or quiet period facilitates this information transfer. Upon arrival to the emergency department, an additional and final exchange of information between the prehospital providers and the trauma team occurs. Essential elements that should be obtained in this report include details about the injury event, vital signs obtained at the scene and during transport, pertinent physical findings, and the initial treatments administered and response to these treatments.\textsuperscript{8} Allowing the prehospital providers to give their report before starting the patient evaluation or even transferring the patient to the emergency department gurney improves information exchange and prevents repetitive questions later in the resuscitation. Obtaining a record of the prehospital event completes the formal information exchange between prehospital and in-hospital providers. These records can contain critical information for early in-hospital management but often are not immediately obtained because prehospital providers are moving on to their next assignment and the trauma team is focused on direct care of the patient.

**The Primary Survey**

**Overview**

The primary survey, as defined by ATLS, is a prioritized evaluation and management protocol focused on identifying and treating the most life-threatening injuries first. This approach is different from the traditional initial evaluation in a patient where an extensive history and physical exam is performed before diagnosis and treatment. The steps of the primary survey are taught in the ATLS course as a sequence followed by one provider with one nurse assistant. In actual practice, most centers have a team of providers rather than only two, allowing the evaluation and management steps to proceed forward even if one step leads to a delay. For example, a relatively more time-consuming step such as placing an intravenous catheter...
can be performed by one team member while others move on to subsequent steps in the primary survey. The typical model used at many trauma centers is to have a single provider on the team perform and report the components of the primary survey, supported by other team members as it is conducted. A designated team leader stands at the foot of the bed, receives information reported by the team and provides higher level direction of the conduct of the resuscitation. While the steps of the primary survey provide the framework for the initial assessment, new information may be obtained in later phases, or a patient’s status may change, requiring iterative performance of each step. It is often a challenge to ensure the team retains its focus on the underlying prioritization scheme of the primary survey and does not omit or minimize steps in this process (Figure 112-2). When resuscitations are evaluated, compliance with ATLS protocols is often low, mandating continued training and retraining to ensure the well-established benefits of this protocol are realized.

**Establish an Airway with Cervical Spine Stabilization (A)**

Establishment of a patent airway with cervical spine stabilization is the first step of the primary survey. All patients should immediately receive oxygen as the evaluation is begun. After oxygen is placed, evaluation of the airway can proceed. Injured children who present to the emergency department can be placed into three categories with respect to initial airway management: (1) those with a patent airway requiring no manipulation, (2) those who have undergone intervention in the field or at another hospital to establish a patent airway, and (3) those who will need an intervention to establish a patent airway. Most children evaluated by the trauma team are in the first group. For these patients, evaluation should include several simple steps including asking the patient’s name, inspection for craniofacial injuries, assessment for voice changes, and listening for obvious stridor. These steps can be performed easily and rapidly in most children. A simple statement that “the airway is patent” will communicate to the team these confirmatory steps have been accomplished. Because most injured children will not require any specific airway management, omission of elements of the airway assessment are common in pediatric trauma resuscitation. In a study of pediatric trauma resuscitations analyzed by video review, the most common omission in airway evaluation was not providing supplemental oxygen (omitted in 67% of resuscitations). Fewer than one quarter of resuscitations included a complete assessment of the airway along with assessment of ‘breathing,’ the second component of the primary survey. Although the patent of the airway may seem “obvious” in many patients, subtle and early signs of pending airway compromise will be missed if a formal airway evaluation is not completed (Table 112-1).
The second category is children with an airway already established in the field or other hospital, usually by endotracheal intubation. Airway interventions performed prior to a patient’s arrival should not be interpreted as an adequate airway and additional steps should be performed to assess airway patency, especially in light of the relative tenuous nature of pediatric airways placed under emergency situations. The key steps to evaluating an endotracheal tube placed outside the emergency department are assessing the appropriateness of tube size, evaluating tube depth, assessing adequacy of ventilation by auscultation and inspection of the chest, measurement of end tidal CO₂, and confirmation of tube position with a chest radiograph. The appropriate tube size can be evaluated using age-specific formulas and charts or by comparing the tube with the child’s fifth (little) finger. Deep placement of an endotracheal tube in a prehospital setting is common especially among younger children. Most prehospital providers have more experience with intubating adults, leading to a tendency toward deeper tube placement. In addition, the shorter airway of children increases the likelihood that an endotracheal tube will migrate from the proper position during transport. An easy rule for rapidly assessing tube depth is that the length of the tube at the teeth should be three times the tube size. Age-specific formulas for evaluating endotracheal tube depth are available and are more easily used by providers with greater experience in management of airways. Assessment that the endotracheal tube is an adequate airway should include steps that are more formally part of the breathing (B) phase of the primary survey, including assessment of ventilation by auscultation and inspection and measurement of end tidal CO₂. Because of a shorter airway and relatively less margin for movement of an endotracheal tube in younger child, correct endotracheal tube position cannot be reliably confirmed by auscultation of bilateral breath sounds alone. Final confirmation of endotracheal tube position requires obtaining a chest radiograph. In most cases, the chest radiograph should be deferred until later in the resuscitation because simpler and more rapid evaluations can be performed to verify tube position that do not interrupt the conduct of the primary survey. However, a chest radiograph should be performed in the emergency department before transport to other areas of the hospital to avoid the need for airway management in less optimal hospital settings.

The final category of injured children undergoing airway evaluation is those who present with airway compromise requiring intervention. Because this category of injured children is least common, clearly defined personnel and procedures are needed to prepare the team to efficiently and safely establish an airway. Indications for endotracheal intubation in pediatric trauma include apnea, inability to maintain a patent airway by other means, need to protect the lower airway

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Table 112-1 Missed Components of the Primary and Secondary Survey in Pediatric Trauma Resuscitation: Management Errors Among All Patients (N = 90)

<table>
<thead>
<tr>
<th>Errors Identified</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIRWAY AND BREATHING</td>
<td></td>
</tr>
<tr>
<td>Delay in oxygen therapy</td>
<td>60 (67)</td>
</tr>
<tr>
<td>Chest not auscultated</td>
<td>40 (44)</td>
</tr>
<tr>
<td>Oxygen saturation not measured</td>
<td>33 (37)</td>
</tr>
<tr>
<td>Neck not adequately examined</td>
<td>71 (79)</td>
</tr>
<tr>
<td>CERVICAL SPINE</td>
<td></td>
</tr>
<tr>
<td>No head stabilization on transfer</td>
<td>18 (20)</td>
</tr>
<tr>
<td>CIRCULATION</td>
<td></td>
</tr>
<tr>
<td>Inappropriate intravenous access</td>
<td>18 (20)</td>
</tr>
<tr>
<td>Pulse not assessed</td>
<td>37 (41)</td>
</tr>
<tr>
<td>Central capillary refill not assessed</td>
<td>59 (66)</td>
</tr>
<tr>
<td>Blood pressure not measured</td>
<td>28 (31)</td>
</tr>
<tr>
<td>Fluid bolus not warmed</td>
<td>33 (89)</td>
</tr>
<tr>
<td>DISABILITY</td>
<td></td>
</tr>
<tr>
<td>Pupils</td>
<td>22 (25)</td>
</tr>
<tr>
<td>Posture</td>
<td>22 (25)</td>
</tr>
<tr>
<td>SECONDARY SURVEY</td>
<td></td>
</tr>
<tr>
<td>Perineum not examined</td>
<td>41 (45)</td>
</tr>
<tr>
<td>Head not examined</td>
<td>13 (15)</td>
</tr>
<tr>
<td>Ears not examined</td>
<td>16 (18)</td>
</tr>
<tr>
<td>Mouth not examined</td>
<td>41 (45)</td>
</tr>
<tr>
<td>Back not examined</td>
<td>13 (15)</td>
</tr>
<tr>
<td>Chest not examined</td>
<td>3 (3)</td>
</tr>
<tr>
<td>Abdomen not examined</td>
<td>2 (2)</td>
</tr>
</tbody>
</table>

from aspiration of blood or vomitus, impending or potential compromise of the airway, presence of a closed head injury (Glasgow Coma Scale [GCS] score ≤8), and inability to maintain adequate oxygenation with face-mask oxygen supplementation. An altered level of consciousness, usually due to an intracranial injury, is the most commonly observed reason for emergency airway intervention in the acutely injured child. Although a neurological assessment is performed later in the primary survey, early recognition of children requiring a formal airway because of an altered level of consciousness is essential. The AVPU scale (awake, responds to verbal stimuli, responds to painful stimuli, and unresponsive) is one model for assessing consciousness that has been found to correlate with the GCS scale and which may be useful for identifying children who are at risk for a compromised airway because of an altered level of consciousness. Patients with an AVPU score of “P” or “U” can be anticipated to have a GCS score of 8 or 3, respectively, and should receive early airway intervention.

Once the trauma team has confirmed the need to establish an airway, the least invasive method for achieving this goal should be chosen. A chin lift and jaw thrust may be sufficient for initially opening the airway in some patients and are simple and rapid steps that can facilitate bag mask ventilation. However, in the presence of a suspected cervical spine injury, only a jaw thrust should be used. Because these maneuvers are not sufficient for long-term airway management, further interventions are usually needed to establish a definitive airway. Small children on a flat spine board may have a partially occluded airway because their proportionately large head forces the neck into a kyphotic position, resulting in upper airway obstruction. Simple manipulation of the young child’s head to maintain the plane of the face with the plane of the spine board can improve airway patency, particularly among infants.

When a more definitive airway is needed, the preferred method for establishing an airway in pediatric trauma is orotracheal intubation. A rapid-sequence technique is preferred for most injured children, because intubation is made easier by eliminating protective airway reflexes and safer by preventing aspiration and decreasing physiological stress that can lead to increased intracranial pressure in children with severe head injuries. During intubation, steps should be taken to account for the short length and narrow diameter of the trachea and the narrowing of the trachea at the cricoid ring, including choosing an appropriately sized tube and confirming tube position. While it can be a good option in other settings, nasotracheal intubation is usually not performed for injured children because this technique is more difficult due to the acute angle of the posterior pharynx of the child. Nasotracheal intubation has not been recommended in patients with facial trauma, cerebrospinal fluid leaks, or suggestions of basilar skull fractures, because these injuries suggest the possibility of a disruption between the cranial vault and nasopharynx. Laryngeal mask airway (LMA) is also an option for emergency airway management in situations in which endotracheal intubation cannot be accomplished. However, as the LMA does not protect against aspiration and cannot be used effectively to provide positive pressure ventilation in patients with altered respiratory compliance or resistance, it should be used only as a rescue technique if the patient cannot be intubated.

![Figure 112-3](#)

Fewer than 1% of all adult patients who require an emergency airway in the emergency department require a surgical airway.

If bag-mask ventilation is successful, the team has time to find alternative routes of securing an airway. Examples include attempting fiberoptic intubation or bringing a more experienced physician to the trauma bay to assist with establishing an airway. If bag-mask ventilation is not successful, an appropriate invasive procedure may be required. Among injured children, appropriate options include surgical or needle cricothyrotomy, depending on the child’s size. Among children with a larger airway whose cricothyroid membrane is easily palpated, a surgical cricothyrotoomy is preferred. If small neck size or other anatomic features preclude the safe placement of a cricothyrotomy, a needle cricothyrotoomy with needle jet insufflation of oxygen into the airway is the recommended approach. Surgical cricothyrotoomy should be performed by members of the team with experience with this technique. This procedure has four main steps: (1) identification of the cricothyroid membrane, (2) making an incision through the skin and cricothyroid membrane, (3) stabilization of the larynx with a tracheal hook at the inferior aspect of the ostomy, and (4) placement of a tube in the trachea. Training in this technique is now included as part of the ATLS course.

Although controversy surrounds whether needle cricothyrotoomy should be used at all in pediatric patients, it is still
advocated by some authorities as a rescue technique in specific clinical scenarios. Needle cricothyrotomy can be performed using commercially available kits. When one is not available, the procedure can be carried out by inserting a large bore (12 to 18 gauge) angiocatheter in a caudal direction at a 30- to 45-degree angle through the cricothyroid membrane. During needle advancement, constant negative pressure is applied to the plunger of the syringe to aspirate air and confirm its endotracheal position. After confirmation of endotracheal placement, the syringe and stylet are removed and the cannula is connected to an oxygen source. Among larger children and adolescents, the cannula should be connected to an unregulated oxygen supply of 30 psi, because ventilation cannot be adequately provided using an ambu bag. When pediatric evidence is limited, a flow of 25 to 35 psi from a standard regulator set at 10 to 12 L/min for most children has been recommended. Another approach that can be used is based on flow rates and estimated tidal volumes (TV): 10 to 25 psi with TV of 340 to 625 mL for children 8 years and older; 5 to 10 psi with TV of 240 to 340 mL for children 5 to 8 years old; and 5 psi with TV of 100 mL for patients who are 5 years and younger. Standard intravenous tubing can be connected to the cannula and a Y connector placed between the intravenous tubing and the oxygen tubing. Intermittent occlusion for 1 second and release of the Y-connector for 4 to 5 seconds provides some passive ventilation. A needle cricothyrotomy is a highly tenuous airway and should be carefully secured after placement and converted to a more stable airway as soon as possible. This approach is only sufficient for 30 to 45 minutes because of the progressive respiratory acidosis that results from underventilation. Because surgical airway management is rarely performed in pediatric patients, centers that manage injured children should have the equipment and adequately trained personnel for performing these procedures when needed.

Cervical spine stabilization should be viewed as part of the “A” step and is included as part of airway management in ATLS. In contrast to intubation in other hospital settings such as the intensive care unit, intubation in the trauma bay should proceed with the assumption that a cervical spine injury is present until this type of injury has been formally ruled out. This step is needed in patients with any mechanism of injury that can be associated with cervical spine trauma. Many injured children present to the emergency department with a cervical collar that was placed in the field because of the mechanism of injury. The initial evaluation of the airway should be immediately followed or simultaneously performed with an assessment of the proper size and fitting of the cervical collar or placement of a cervical collar when one is not present. When endotracheal intubation is required, in-line cervical spine stabilization should be used. A member of the team holds the neck on each side with his or her hands and forearms maintaining the stability of the spine during airway manipulation. Despite the importance of this step, neck inspection and palpation while maintaining C-spine precautions and head stabilization during transfer to the trauma gurney are steps omitted in 80% and 20% of trauma resuscitation performed for injured children, respectively.

Breathing (B)
Establishment of a patent airway is an important initial step but is not sufficient to ensure adequate oxygen delivery. The breathing (B) step of the primary survey is the immediate assessment of ventilation and performance of measures to establish adequate ventilation if it is compromised. The three most effective, objective, and rapid steps in evaluating ventilation are auscultation of the chest, application of a pulse oximeter for measuring oxygen saturation, and assessment of respiratory rate. Because patients are supine during the primary survey, auscultation is limited to sites on the anterior and lateral chest. Auscultation should be performed in both these areas to obtain the most accurate evaluation of ventilation. Localizing abnormal auscultatory findings to a specific region of the chest can be more difficult in younger children because of smaller chest size and the usual supine position of the injured patient during the primary survey. However, in most children, auscultation can be used to identify significant compromise in ventilation requiring lifesaving intervention. These steps can be supplemented by a subjective evaluation of the adequacy and symmetry of chest wall movement and an evaluation for evidence of chest wall trauma. Because of the pliability of the chest wall of younger children, significant chest injury may be present even in the absence of any chest wall deformity.

A main focus of the B phase of the primary survey is on identifying four specific thoracic injuries that can significantly impair ventilation and that require immediate treatment: (1) tension pneumothorax, (2) open pneumothorax, (3) flail chest with pulmonary contusion, and (4) massive hemothorax. The diagnosis of a tension pneumothorax should be made on clinical criteria, including tracheal deviation, unilateral absence of breath sounds, neck vein distention, tachycardia, hypotension, and respiratory distress. Delaying treatment to obtain a confirmatory chest radiograph should be avoided because of the time delay associated with processing, and interpreting this study. When the clinical diagnosis of a tension pneumothorax is made, the chest should immediately be decompressed by placing a 14 to 18 gauge, 5-cm needle into the second intercostal space at the midclavicular line. The needle should be sufficiently long to penetrate the chest wall and enter the pleural space. A minimum length of 5 cm is recommended in other children and adults, but shorter needles may suffice in infants and younger children. Proper intrathoracic placement of the needle can be partly confirmed by an audible rush of air when entering the chest. Because needle decompression will convert a tension pneumothorax into a simple pneumothorax, a chest tube will be needed regardless of the response to needle decompression. Advanced prehospital providers are often trained in needle decompression of the chest in the field. If a child arrives after needle decompression, tube thoracostomy placement is also needed for definitive treatment.

An open pneumothorax or “sucking chest wound” occurs when the size of a chest wall injury approaches two thirds the area of the tracheal lumen, causing a preferential pull of air into the pleural space and out of the wound. This injury can lead to mediastinal shift, decreased venous return, and eventual cardiopulmonary collapse. Open pneumothorax is rare in children and is usually the result of a penetrating injury. Airflow through the wound will be audible or can be visualized by bubbling of blood at the wound. A rectangular petroleum jelly/gauze dressing that is occlusive on three sides beyond the wound edge will produce a one-way valve effect that will allow air to escape on expiration but inhibit air from entering the thoracic cavity on inspiration.

Flail chest occurs when a segment of the chest wall has lost continuity with the movement of the thoracic cage, occurring
when two or more ribs are fractured in two or more positions. The pediatric thoracic cage is more compliant than adults and rib fractures are not always present when parenchymal injuries exist. When occurring in infants and young children, rib fractures suggest a significant amount of blunt force to the chest and the possibility of an underlying pulmonary injury. Because fractured ribs can lead to direct lung injury, the presence of a flail chest segment should raise the suspension of a pneumothorax and hemothorax. Due to compromised ventilatory function and underlying pulmonary injury, management of flail chest is focused on providing temporary ventilatory support until the injury heals. Intubation may be immediately needed in the emergency department when ventilation is significantly compromised by this injury.

Significant bleeding may occur with thoracic trauma from intercostal vessels, internal mammary vessels, lung parenchyma, or cardiopulmonary vessels, leading to massive hemothorax. Children with this injury will present with decreased breath sounds and dullness to percussion on the affected side. Eliciting the finding of dullness to percussion can be difficult in a noisy trauma resuscitation area but is a diagnostic feature that can be used to distinguish this injury from a pneumothorax. While the diagnosis is optimally made with a chest radiograph, the team should proceed with immediate chest tube placement if clinical evidence suggests the presence of a large amount of intrathoracic blood. When a massive hemothorax is present, fluid resuscitation or blood transfusion will often be needed. After chest tube placement, the amount of blood initially obtained and the rate of continued bleeding from the tube should be evaluated. A definitive thoracotomy for controlling bleeding from the chest wall, lung, or heart may be indicated if the initial volume exceeds 20% to 25% of estimated blood volume, bleeding continues at a rate exceeding 2 to 4 mL/kg/hr, the rate of bleeding is increasing, or the pleural space cannot be drained of blood and clots. The latter three criteria may be observed after the child is initially stabilized and has been admitted to the hospital.

About 75% of traumatic chest injuries can be treated expectantly or with placement of a chest tube and volume resuscitation. While placement of a chest tube in an injured child is similar to placement in other settings, additional steps should be considered in the injured child. When placing a chest tube for trauma, the tube should be directed posteriorly to allow for adequate drainage of blood in a supine patient. A sufficiently large tube should be selected to allow drainage of blood and fluid without becoming clogged with blood clot. The fifth intercostal space in the anterior midaxillary line is ideal in most patients to prevent placement of the tube through the diaphragm or abdomen but allows sufficient length in the chest for drainage and avoiding later dislodgement. While it is often taught that the lung should be palpated with a gloved digit before tube placement, this verification step may be difficult to perform in infants and small children with smaller intercostal spaces. Confirmation of tube placement in the pleural space can be confirmed in infants and smaller children by the egress of air or blood after placement. Proper tube placement in the thoracic cavity can also be evaluated by observing air condensation on the internal surface of the tube and movement of fluid in the water-seal chamber in time with the patient’s respirations when connected to a pressure regulated collection device. When palpating the lung in larger children, the use of double gloves will avoid cross contamination of the patient and the person placing the chest tube that may result from glove tears from broken ribs when palpating a track through the chest wall. A chest radiograph should be performed to verify placement of the tube before leaving the resuscitation area.

Circulation (C)

The “C” step of the primary survey is the assessment, recognition, and management of shock. Because of greater physiological reserve, early identification of cardiovascular compromise can be more difficult in children than adults (Table 112-2). Assessment and management of circulatory status in the primary survey is focused on early identification and treatment rather than defining the specific etiology of the shock state. Determining the site of internal hemorrhage and defining the specific type of shock state are steps that are deferred until after the primary survey. Objective assessment of circulation is done by measuring heart rate and blood pressure, and assessing pulses and capillary refill. In addition to cardiovascular compromise, tachycardia after injury can indicate pain, fear, or other psychological stress. Tachycardia therefore cannot be used as the sole criteria for diagnosing cardiovascular compromise and needs to be combined with other clinical criteria before treatment is initiated. A manual blood pressure measurement should be obtained, using the appropriate size cuff, upon arrival to the resuscitation area. Periodic reassessment of blood pressure should continue throughout the resuscitation to verify the child’s hemodynamic status. Palpation of central and peripheral pulses is a rapid method for

<table>
<thead>
<tr>
<th>Table 112-2 Systemic Response to Blood Loss in Pediatric Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
</tr>
<tr>
<td>Cardiovascular</td>
</tr>
<tr>
<td>Central nervous system</td>
</tr>
<tr>
<td>Skin</td>
</tr>
<tr>
<td>Urinary output</td>
</tr>
</tbody>
</table>

Data from Committee on Trauma, American College of Surgeons: Advanced trauma life support for doctors, student course manual, ed 7, Chicago, 2004, American College of Surgeons.
detecting hypotension and often can be accomplished before a cuff blood pressure is obtained. Because pulses are most likely to be lost in progressive hypotension in the wrist or feet followed by the groin followed by the neck, palpation for pulses in each of these areas can provide a crude estimate of the level of hypotension. Assessment of peripheral perfusion can also include an estimate of capillary refill in addition to a visual evaluation of skin perfusion. Because these latter assessments are more subjective, these should be used only in conjunction with more objective measurements in directing treatment. While assessment of circulatory status is essential to the initial evaluation of an injured child, these steps are often omitted or delayed until later in the resuscitation. During video review of pediatric trauma resuscitations, blood pressure was not measured in 31% of patients, pulses not assessed in 41%, and central capillary refill not assessed in 66% during the initial evaluation.10

The two main interventions for managing cardiovascular compromise during the primary survey are controlling external hemorrhage and administration of fluid. Active hemorrhage is easy to recognize and can usually be treated by direct manual pressure or the application of compression bandages. Scalp lacerations are a common source of external bleeding in injured children and the blood loss from this site should not be underestimated. A full evaluation for external hemorrhage, however, is only complete after the child has been exposed completely later in the primary survey.

Administration of fluids requires the establishment of intravenous access. In pediatric trauma, the preferred order of sites depends on the child’s age and the urgency of establishing intravenous access. If a percutaneous peripheral intravenous line cannot be established, intraosseous access, percutaneous central venous access, or cutdown on a vein should be considered. Intraosseous access is achieved by placing a needle into the marrow cavity of a long bone in an uninjured extremity. This procedure is rapid, requires minimal training, and is the preferred alternate method of vascular access in infants and younger children. The availability of new equipment and techniques has expanded the use of intraosseous infusions to older children and even adults. Percutaneous placement of a central venous catheter can be pursued as alternate access in older children when equipment for intraosseous access in older patients is not available or when ossification of the long bones precludes placement of an intraosseous needle. Femoral placement of a central line in the injured child has advantages over placement in a jugular or subclavian vein position because it can be performed in most patients without interfering with ongoing assessment and management of other components of the primary survey. However, the femoral route is not recommended if there is a concern of the potential for intra-abdominal injuries. Despite the importance of establishing intravenous access in the injured child for fluid resuscitation and administration of medications, vascular access was not performed or inadequate access was obtained in 20% of recorded pediatric resuscitations.10

The goal of fluid resuscitation is to rapidly replace intravascular volume, initially with warmed crystalloid solution and then moving to blood products based on the child’s response to crystalloid boluses (Figure 112-4). When cardiovascular compromise is detected, an initial bolus of 20 mL/kg of warmed isotonic crystalloid fluid (lactated Ringer’s solution or normal saline) should be administered. Given that it is relatively hypotonic, Ringer’s solution is not recommended for fluid resuscitation in patients with evidence of traumatic brain injury. Fluid administration should not be delayed by slow-rate drip infusion, but instead should be administered as a bolus using a hand-pump device, a syringe, or a pressure bag to ensure that the effect of the bolus and assessment of need for additional fluid proceeds rapidly. If a second bolus of crystalloid is needed, preparations for the potential administration of blood products should begin. If the child responds to fluid administration, intravenous fluid is continued at a maintenance rate as further investigations concerning the need for fluid are performed. If there continues to be no response or transient response to crystalloid, blood administration should be considered. During the primary survey, cross-matched, type-specific blood is often not yet available, and O-negative blood should be administered. Blood should be administered in boluses of 10 mL/kg. The four sites of hemorrhage that can lead to major blood loss after injury include external sites (e.g., scalp laceration), intrathoracic injury, intraabdominal injury, and pelvic or multiple long-bone (usually femur) fractures. While external bleeding can be easily detected, bleeding in other sites is evaluated after the primary survey has been completed.

Disability (D)

The primary survey continues with a neurologic assessment of the child, the disability (D) component of the primary survey. This assessment includes two main components, calculating the GCS and assessment of pupillary responses (Figure 112-5). More extensive neurological evaluation should be deferred to the secondary survey to avoid slowing the primary survey. As with airway assessment, a formal evaluation of GCS is often omitted when it is “obvious” that no neurologic injury is present. This practice should be avoided because subtle changes may be missed with only a cursory assessment. In addition,
establishment of a baseline GCS may have prognostic value among children with an evolving intracranial injury. To account for variations in response related to age, the GCS should be calculated using age-specific criteria. Among the three main components of the GCS, the motor score has been shown to be the best predictor of outcome after injury.27 Particular attention should be paid to ensure that this component is accurately assessed and recorded. Pupillary assessment includes an evaluation of pupil size and response to light and can easily and rapidly be assessed, reported, and recorded. Findings from the neurological assessment are used to plan additional evaluation and management steps, including the need for endotracheal intubation, the requirements of additional imaging, and the final disposition after leaving the emergency department. Despite the importance of obtaining a GCS and assessing pupils, these steps were both omitted in 20% of observed pediatric trauma resuscitations.

**Exposure (E)**

The final step in the primary survey is exposure of the patient, the “E” component of the primary survey. In this phase, clothing is removed to visually inspect all body regions to minimize the chance of missing an obvious injury. A team-coordinated log roll of the child, maintaining cervical spine stabilization, can be used to assess the back and spine for external injury. When rolled on their side, patients are in an ideal position for assessing the spinal column for deformities and tenderness and for undergoing a rectal examination if indicated. While not all of these steps are formally part of the primary survey, the additional time required for them is minimal, leading to the inclusion of these steps as part of exposure in many centers. Immediately after exposing the injured child, the child should be covered again with warm blankets to minimize heat loss. Infants and younger children are particularly vulnerable to heat loss because of a relatively large surface area in relation to body volume. Other measures for warming or maintaining an injured child’s temperature include warming the room and the use of overhead warmers or a Bair hugger. The patient’s temperature should be obtained at this point, a step that is frequently omitted in the initial evaluation of the injured child.

### The Secondary Survey

After completion of the primary survey, the secondary survey is then performed. This includes a medical and event history, a more complete physical examination, and additional adjunct interventions. The secondary survey is less structured than the primary survey and its components and sequence can be modified to reflect patient needs, provider preferences, and institutional practices. The secondary survey should not be performed until the components of the primary survey have been completed and interventions needed to address issues identified in the primary survey have been implemented. It is a common pitfall to move to components of the secondary survey or to mix components of the secondary survey during performance of the primary survey. This practice should be discouraged so as to avoid losing focus on the primary survey and the life-threatening injuries that it is designed to identify.

During the secondary survey, attention should be intermittently refocused on vital signs and other monitoring steps of the primary survey. When changes are observed, the primary survey evaluation and treatment steps should be reinitiated to ensure that potentially life-threatening injuries are addressed.

In contrast to a typical history performed during evaluations in other settings, the history performed in the secondary survey is more focused and follows rather than precedes the performance of the physical examination. It is common practice to obtain this information while simultaneously performing the physical examination components of the secondary survey. The most important history elements to obtain are those that most directly impact injured patients and the evaluation and treatments needed for them. The acronym AMPLEx is useful for remembering these key elements (allergies,
Missed injuries have been shown to be reduced with admission GCS, and those with an injury severity score greater than 15.  

Missed injuries do occur in trauma resuscitations, which may lead to preventable morbidity during the patient’s hospital stay. About 4% of injured children will have an injury missed in the primary and secondary survey. The risk of a missed injury is higher in children with more severe injuries, including those transported by air, those who undergo endotracheal intubation in the emergency department, those with a low admission GCS, and those with an injury severity score greater than 15. Missed injuries have been shown to be reduced with the implementation of a designated pediatric trauma response team, supporting a focused and stepwise approach to the initial evaluation of the injured children. Critical care providers should be alert to the possibility of missed injuries in patients admitted to their unit and not rely on the emergency department evaluation for detecting all injuries.

**Diagnostic Assessment**

The secondary survey is supplemented by diagnostic testing that focuses on identifying and treating injuries not found in the primary survey. Performance of a standard set of tests is discouraged to avoid unnecessary discomfort, exposure to radiation from excessive imaging, and cost. Injured children may be overtriaged to the resuscitation area and require no additional testing after the primary and secondary survey has been completed. Observation in the emergency department before discharge and close outpatient follow-up is an appropriate option for children identified as low-risk for injury.

**Laboratory Studies**

Routine laboratory evaluations in pediatric trauma have been shown to be of little value in the management of injured children. Among children injured from a significant blunt mechanism, a focused screening set of laboratory studies to identify occult intraabdominal or retroperitoneal injury and hemorrhage has been shown to be sufficient. Based on the current literature, a screening panel that includes aspartate aminotransferase (AST) and alanine aminotransferase (ALT), urinalysis, and hemoglobin will effectively screen for most intraabdominal injuries. The ALT, AST, and urinalysis are screening tests to determine the need for an abdominal CT scan and can be omitted if other clinical indications suggest the need for abdominal imaging. Threshold values of greater than 100 U/L for AST and ALT and more than 5 red blood cells/hpf suggest the presence of an intraabdominal injury and suggest the need for abdominal imaging.

Among children with major head injuries, penetrating trauma, multiple extremity fractures, and significant mechanisms of injury, this panel of laboratory studies may be expanded to include coagulation studies, electrolytes, and blood for cross-matching. Coagulation studies in pediatric trauma are most often abnormal in the presence of severe traumatic brain injury. If obtained early after injury, electrolyte studies are most often normal and serve only as a baseline for a patient who will require aggressive management of severe head injuries or aggressive resuscitation. Blood should be obtained for cross-matching if significant fluid resuscitation has been required, the child has a preexisting condition causing a predisposition to bleeding, has a major head injury, or will undergo a surgical procedure with a potential for a blood loss. Early after injury, pancreatic enzymes do not need to be obtained as a screen for pancreatic injury because of the low diagnostic yield of these studies. Screening tests for alcohol or drug use may be appropriate in older children and adolescent patients.

**Radiographic Imaging**

Radiographs may be needed to rule out specific injuries or to evaluate known injuries. Imaging in the resuscitation area is often performed with a portable system or with a built-in...
system within the trauma room to avoid moving the child. The three most common radiographs obtained are cervical spine, chest, and pelvic radiographs. While these studies are commonly referred to as a trauma series and ordered as a set, the performance of all three is often not necessary. The need for each radiograph should be evaluated based on the mechanism of injury and patient symptoms and examination.\(^{35}\)

A cervical spine injury should be suspected in any child sustaining a significant head injury or injured by a major blunt mechanism. Although cervical spine injuries are rare, these injuries can be devastating and can have worse outcomes when adequate spine precautions are not taken early after injury. A systematic and efficient approach using both clinical and diagnostic modalities is needed to ensure that a cervical spine injury is not present. Implementation of standards for cervical spine assessment and clearance have been shown to decrease the time for cervical spine clearance.\(^{36}\) Each institution should develop an institution-specific protocol for managing the initial and subsequent imaging of the cervical spine to avoid either incomplete evaluations or excessive imaging. Criteria for cervical spine imaging include midline cervical tenderness, altered level of consciousness, evidence of intoxication, neurological abnormalities potentially attributable to a spine injury, and presence of a distracting injury precluding a reliable clinical assessment.\(^{37}\) The cervical spine evaluation in nonverbal children is particularly difficult to assess. A recent study of this subgroup identified GCS less than 14, GCS eye component of 1, an injury sustained in a motor vehicle crash, and age less than 2 years as important variables associated with the presence of a cervical spine injury.\(^{38}\)

A cervical spine series consists of a cross-table lateral, an anterior-posterior view, and an open-mouth view to assess the dens process of C1. With adequate films, a three-view series has a high sensitivity (89%) and a negative predictive value of 99.9%.\(^{39}\) Among these views, the lateral cervical spine film is most useful and has been adopted as the initial screening film at many institutions.\(^{40}\) If an injury is noted on screening cervical spine imaging, a cervical spine CT or MRI may be needed to further evaluate the injury. If either the clinical or radiographic findings cannot be used to safely rule out a cervical spine injury in the resuscitation area, the child should remain in a cervical spine collar and be evaluated later for the need for further imaging.

Chest radiographs can be often be omitted for children without physical examination findings or symptoms suggesting a thoracic injury.\(^{35}\) This study, however, should be obtained for children who are injured by a major blunt mechanism such as a high-speed motor vehicle crash or those who have sustained other significant torso injuries. Pelvic radiographs can be safely omitted among children who are awake, alert, and have no physical examination findings or proximity injuries (e.g., a proximal femur fracture) to suggest a pelvic injury. Radiographs of the extremities or other areas may also be needed in the resuscitation area depending on the findings of the primary and secondary survey.

Computed tomography is a powerful and accurate diagnostic tool and has become an integral component of the evaluation of injured patients. Although CT scans can be essential in the evaluation of many children, excessive use is discouraged because of the higher radiation exposure associated with CT scans, rare but important complications such as contrast reactions, and added costs. CT scans are a growing source of medical radiation exposure in children and may contribute to the occurrence of radiation-related malignancy, particularly when performed among younger children.\(^{41}\)

The two most common body regions imaged with a CT scan in pediatric trauma are the head and abdomen. A non-contrast head CT is performed to assess for closed head injuries and fractures that may require additional treatment such as a depressed skull fracture. The most common indication for a head CT scan after pediatric injury is a history of loss of consciousness or altered mental status. A head CT scan may also be needed for preverbal children whose injury was not observed or those who have received endotracheal intubation or are sedated as they cannot reliably be assessed for a potential head injury.\(^{42,44}\) A large multicenter trial derived and validated predictive rules to identify children at very low risk of clinically important traumatic brain injury after blunt trauma where a head CT scan may be unnecessary. These prediction rules had a sensitivity of 100% in children less than or equal to 2 years old and 96.8% in children older than 2; negative predictive value was 100% for all ages (Figure 112-6).\(^{45}\)

Recent emphasis on developing approaches to reduce the need for screening abdominal CT scans in pediatric trauma continues to evolve. Abdominal imaging is indicated when an injury is suggested by physical examination findings such as major abdominal ecchymoses or abdominal tenderness. Among children who sustain a significant blunt injury but do not have physical examination findings suggesting an abdominal injury, the yield of screening abdominal CT scans is low. Screening laboratory tests, however, can be used to reduce unneeded imaging for these children. A multicenter trial is underway that will define the specific studies and study parameters that are optimal for directing abdominal imaging.

While focused abdominal sonogram for trauma (FAST) has been widely adopted as a diagnostic tool for adult trauma patients, its value in pediatric trauma is less certain. FAST is focused on identifying fluid in four areas, the presence of which is suggestive of hemopericardium or intraabdominal injury: the pericardial sac, hepatorenal fossa, splenorenal fossa, and pouch of Douglas. Current evidence suggests that the role of FAST for evaluating children after blunt abdominal injury is limited. When used in children, FAST has only modest sensitivity (80%) for the detection of hemoperitoneum, and a negative ultrasound has questionable utility as the only test to exclude an intra-abdominal injury.\(^{46}\) Recent studies have suggested that FAST may be combined with screening laboratory studies to increase sensitivity, specificity, positive predictive value, and negative predictive value.\(^{47}\) The utility of FAST in the assessment of pediatric trauma still needs to be defined.

### Emergency Department Thoracotomy

Emergency department thoracotomy can be a lifesaving intervention among some children presenting in extremis after injury. This procedure, however, should be used very selectively, because its effectiveness has been shown to be limited to specific patient subsets, including those who have received a brief period of cardiopulmonary resuscitation after sustaining a blunt injury or witnessed penetrating injury. Patients who sustain a penetrating injury are more likely to benefit from an emergency department thoracotomy, because the higher potential for identifying injuries that can be treated after a thoracotomy has been performed. Data defining the role of
emergency department thoracotomy in children are limited to small patient series and dated retrospective reviews. Available evidence suggests that this procedure should be reserved for pediatric patients who present with detectable vital signs and deteriorate despite maximal resuscitation. Each institution should establish guidelines for the use of emergency department thoracotomy to aid in decision-making when this rare procedure needs to be performed.

Emergency department thoracotomy should only be performed by a surgeon with appropriate training in this technique. A left anterolateral thoracotomy incision is made extending from left of the sternum in the fifth intercostal space to the table. A large incision is needed to aid visualization and therapeutic interventions. This incision may be extended across to the right side of the chest if needed. The next step is to control hemorrhage by digital compression, suture control, or clamping of bleeding blood vessels. A pericardiectomy is performed using a longitudinal incision to evacuate blood and inspect the heart for injuries. Open cardiac massage can be performed if needed. Cross-clamping the descending aorta will stop blood loss below the diaphragm and allow cardiac filling to achieve cardiac and brain perfusion. The pulmonary hilum can be clamped or manually compressed to control bleeding from the lung and pulmonary vessels.

**Stabilization and Definitive Care**

Following the initial resuscitation, a plan for the next step in care is defined. Children can be discharged from the emergency department if no injuries requiring inpatient observation or management are identified and there is a low suspicion of injury based on the clinical evaluation and mechanism of injury. Other children may require inpatient admission to either the general hospital ward or intensive care unit depending on the injuries identified. Some children may have injuries that require immediate operative repair and need to be moved directly to the operating room. Transfer to a higher level of care facility after evaluation and stabilization may be needed if injuries are identified that cannot be treated at the receiving hospital. The period from the time of injury until a definitive emergency department disposition is an active period of medical decision-making in the care of all injured patients.

**Conclusions**

Pediatric trauma care requires an efficient team-based approach from prehospital care until the time of discharge. Within current trauma systems, patient care is optimized for efficiency and outcomes when each team member has a defined role and effective communication is established within the team. By understanding the prioritized sequence of ATLS, rapid recognition and treatment of life-threatening injuries will occur efficiently within the team and greatly improve the outcome of these injured patients. Pediatric critical care providers will continue to take an active role in the management of the most severely injured pediatric trauma patients. Pediatric critical care physicians proficient in emergent procedures and knowledgeable of resuscitative measures in trauma care will augment the multidisciplinary approach to pediatric trauma care.