Thoracic trauma in children: Initial stabilization and evaluation

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INTRODUCTION

The initial evaluation and stabilization of children with thoracic trauma will be reviewed here. Thoracic trauma in adults and specific thoracic injuries in children are discussed separately. (See "Initial evaluation and management of blunt thoracic trauma in adults" and "Overview of intrathoracic injuries in children" and "Chest wall injuries after blunt trauma in children" and "Pulmonary contusion in children".)

EPIDEMIOLOGY

Among injured children, thoracic trauma occurs infrequently. In several observational series describing pediatric trauma victims, between 4 and 8 percent of children sustained thoracic injury [1-4].

Blunt mechanisms are involved in 85 percent or more of cases [1-4]. Most patients are injured as passengers or pedestrians in motor vehicle crashes. Other mechanisms include falls (8 to 10 percent) and abuse (7 to 8 percent). Children with inflicted injuries usually have rib fractures and are young (typically less than three years of age) [5,6]. (See "Orthopedic aspects of child abuse", section on 'Rib fractures'.)

Penetrating thoracic trauma may be caused by a gunshot wound or from stabbing/impalement:

- In the United States, gunshot wounds are the major cause of penetrating thoracic injury among children. A retrospective study describing reports to the National

Pediatric Trauma Registry noted that 60 percent of penetrating thoracic injuries were the result of gunshot wounds, while 33 percent were from stab wounds [3].

- In a study from Australia describing the management and outcome of penetrating trauma in children, 21 percent of injuries were caused by gunshot wounds, while 70 percent were the result of knife wounds or impalement [7].

The overall mortality rate for children with thoracic trauma is between 15 and 26 percent [1-3,8]. Most children who die after sustaining a blunt chest injury do so as a result of associated injuries, while the chest trauma itself is the cause of death in the majority of children who die after a penetrating thoracic injury [1-3,8].

ANATOMY

The thorax is composed of the following anatomic structures (see "Initial evaluation and management of blunt thoracic trauma in adults", section on 'Anatomy and Injury Patterns'):

- The chest wall is formed by ribs, costal cartilage, sternum, clavicles, and intercostal muscles, with additional support from the pectoralis muscles anteriorly and the scapula posteriorly. Functionally, the chest wall is an essential part of the mechanics of respiration and provides protection for intrathoracic organs. (See "Chest wall injuries after blunt trauma in children", section on 'Anatomy'.)

- The mediastinum is a division of the thorax that contains the heart, aorta, trachea, and esophagus.

- The diaphragm forms the floor of the thoracic cavity.

Injury patterns as the result of thoracic trauma in children are different from those seen in adults. This is because of the following anatomic and physiologic characteristics:

- The chest wall of a child is more compliant than that of an adult because the bones are less ossified and contain more cartilage [9]. As a result, the following injury patterns are noted in children:

  - Significant force is required to cause rib fractures in children, as compared with adults. As a result, intrathoracic injuries frequently occur without associated rib fractures. When rib fractures are present, they often indicate underlying organ injury or, in young children, abuse [10]. In one study, mortality increased linearly with the number of rib fractures present in children who underwent trauma. (See "Chest wall injuries after blunt trauma in children", section on 'Epidemiology' and "Chest wall injuries after blunt trauma in children", section on 'Rib fractures'.)

- Children may have serious intrathoracic trauma without obvious injuries to the chest wall [1-3].

- Traumatic asphyxia and commotio cordis are more common in children [11]. (See "Overview of intrathoracic injuries in children", section on 'Traumatic asphyxia'.)

- The mediastinum is more freely mobile in children than in adults. As a result, the heart and trachea may become displaced by pneumothorax, hemothorax, or diaphragmatic rupture, causing decreased venous return to the heart, decreased cardiac output, and hypotension [11].

- Although children have significant cardiac reserves, they also have higher metabolic demands than adults. Young children also have lower pulmonary reserves than healthy adults. Consequently, once children become hypoxic, their conditions may deteriorate rapidly [12].

TYPES OF THORACIC INJURY

Thoracic trauma can be characterized as blunt or penetrating. Due to the proximity of intrathoracic structures, many children with trauma to the chest will have more than one injury. In a retrospective report describing children who had sustained thoracic trauma, 44 percent had two or more chest injuries [1].

The types of injuries that occur as the result of thoracic trauma vary depending upon the mechanism of injury. In a series describing children with thoracic injuries reported to the National Pediatric Trauma Registry, the following patterns were noted [3]:

- Injuries that occurred commonly among children with blunt trauma included pulmonary contusions (49 percent), pneumothorax/hemothorax (38 percent), and rib fracture (35 percent).

- Among children with penetrating mechanisms, frequent injuries included pneumothorax/hemothorax (64 percent), pulmonary contusion (14 percent), pulmonary laceration (10 percent), and blood vessel injury (10 percent).

- Regardless of mechanism, mortality was highest for children with injuries to the heart or intrathoracic blood vessels and for those with associated head injury.

Life-threatening thoracic injuries are uncommon among children (table 1). Those that can be immediately life-threatening include tension pneumothorax, massive hemothorax, injuries to the great vessels, cardiac tamponade, and commotio cordis.

Of injuries that are potentially life threatening, the most common is pulmonary contusion, which occurs in nearly one-half of patients with identified intrathoracic injuries [1-3] (see "Pulmonary contusion in children"). Other potentially life-threatening injuries occur less frequently (see "Overview of intrathoracic injuries in children" and "Chest wall injuries after blunt trauma in children", section on 'Flail chest'). These include [3]:

- Flail chest (1 percent)
- Bronchial disruption (<1 percent)
- Intrathoracic vessel injury (3 percent)
- Myocardial contusion (3 percent)
- Diaphragmatic injury (4 percent)
- Esophageal rupture (<1 percent)

Traumatic asphyxia is a rare consequence of thoracic trauma that occurs in children because of greater flexibility of the chest wall. Direct compression of the chest from crushing injury, in conjunction with a deep inspiration and closed glottis, results in a marked increase in intrathoracic pressure that is transmitted directly through the superior and inferior vena cava. A rapid increase in intracranial pressure may also occur. (See "Overview of intrathoracic injuries in children", section on 'Traumatic asphyxia'.)

ASSOCIATED INJURIES

Children with thoracic trauma frequently have associated injuries. In one retrospective series describing children with thoracic trauma treated at a pediatric trauma center, 82 percent of patients had multisystem injury [1]. Head injuries were reported in 82 percent of children, extremity injuries in 40 percent, and abdominal injuries in 38 percent.

Among children who survive to emergency department (ED) admission, extrathoracic injuries are more often life-threatening than intrathoracic injuries. Because initial evaluation and stabilization may be focused on associated injuries, the diagnosis of potentially significant thoracic injuries is sometimes delayed.

EVALUATION

The goal of the evaluation of children with thoracic trauma is to identify those with significant injuries. Life-threatening conditions (such as airway compromise, impaired respiratory mechanics, and/or hemorrhagic shock) must be rapidly identified and stabilized (primary survey) (table 2). The full extent of the child's injuries can then be determined with a detailed history, careful physical examination, and diagnostic testing (secondary survey) (table 3).

An initial approach to the injured child that includes a description of the primary and secondary surveys, as well as prehospital preparation, is discussed elsewhere. (See "Trauma management: Approach to the unstable child", section on 'Initial approach'.)

The assessment of airway, ventilatory, and circulatory function in children is reviewed separately. (See "Initial assessment and stabilization of children with respiratory or circulatory compromise", section on 'Initial assessment' and "Technique of emergency endotracheal intubation in children" and "Assessment of systemic perfusion in children".)

The remainder of this discussion will focus on the evaluation specific to children with blunt and penetrating thoracic trauma.

Initial rapid assessment — Children with significant thoracic trauma who have respiratory or circulatory compromise at the time of initial presentation may have immediately life-threatening injuries such as tension pneumothorax, hemothorax, cardiac tamponade, or injury to the great vessels. Procedures (such as endotracheal intubation or needle thoracostomy) may be required to stabilize these injuries (algorithm 1), sometimes before imaging studies have been obtained. (See 'Diagnostic studies' below.)

Airway — Airway obstruction from secretions or blood can occur as the result of direct injury to the upper airway or in association with altered mental status, as with traumatic brain injury (TBI).

Immediate interventions may include suctioning of blood and secretions, repositioning with the jaw thrust maneuver, endotracheal intubation, and/or assisted ventilation. In rare cases of upper airway injury or obstruction in which endotracheal intubation is either contraindicated or impossible, cricothyrotomy may be necessary to establish a patent airway. (See "Basic airway management in children", section on 'Jaw thrust maneuver' and "Emergency evaluation of acute upper airway obstruction in children", section on 'Rapid assessment of the airway and breathing'.)

Breathing — Respiratory failure that develops immediately following a traumatic event is typically caused by tension pneumothorax, open pneumothorax, or hemothorax or is related to associated injuries (such as TBI). Children with pulmonary contusion or flail chest often have some evidence of respiratory distress (such as tachypnea), but respiratory failure usually develops later.

Stabilization may include assisted ventilation, needle chest decompression (to rapidly remove air), and/or tube thoracostomy (to remove air or blood) (algorithm 1). (See "Technique of emergency endotracheal intubation in children" and "Thoracostomy tubes and catheters: Indications and tube selection in adults and children" and "Initial evaluation and management of penetrating thoracic trauma in adults", section on 'Role of needle/finger chest decompression'.)

For a patient with an open chest wound, placement of an occlusive dressing (taped on three sides) may prevent development of an open pneumothorax [13].

Circulation — Children with major thoracic trauma with circulatory collapse may have tension pneumothorax, massive hemorrhage as the result of vascular injury, or cardiac injury. Indicated interventions may include needle chest decompression, rapid infusion of isotonic fluid or blood, pericardiocentesis, or (rarely) emergency thoracotomy. (See 'Emergency thoracotomy' below.)

History — Historical features that may identify children with significant injuries include:

- **Mechanism of injury** – Mechanisms that may result in serious injury include high impact acceleration-deceleration mechanisms (such as motor vehicle crashes) and penetrating injuries.
- **Vital signs at the scene** – Changes in respiratory rate and heart rate may indicate deterioration in the child's clinical condition as the result of a significant injury. Hypotension is a late finding of shock in children, occurring after tachycardia and tachypnea. As a result, clinicians should not be falsely reassured by a normal blood pressure in an injured child with other abnormal vital signs.
- **Chest pain** – Children with thoracic, cardiac, or esophageal injury commonly complain of chest pain.

Physical examination — A complete physical examination, including vital signs with pulse oximetry, should be performed. The presence of certain physical findings may indicate specific thoracic, cardiac, or intrathoracic vessel injuries.

The following findings are suggestive of chest injury:

- **Abnormal respiratory rate** – In two observational reports describing children with blunt trauma, abnormal respiratory rate correlated with thoracic injuries [4,14].
- **Hypoxemia** – In a study of 493 victims of multisystem blunt trauma, an oxygen saturation of <95 percent entailed a threefold risk of intrathoracic injury [15].
- **Signs of respiratory distress** – Signs of respiratory distress (including nasal flaring or retractions) suggest a significant chest injury such as pneumothorax, hemothorax, or pulmonary contusion.
- **Distended neck veins** – A patient with distended neck veins may have a tension pneumothorax or cardiac tamponade.

- **Chest wall findings** – Abnormalities to palpation over the chest wall have been correlated with thoracic injuries, as diagnosed by chest radiograph (CXR) [4,14,16]. Findings to note include:
  - Crepitus may indicate rib fractures or subcutaneous air. Subcutaneous air can develop as the result of a pneumothorax or pneumomediastinum.
  - Focal tenderness over the sternum, ribs, or scapula may indicate fracture. (See "Chest wall injuries after blunt trauma in children".)
  - Abrasions, ecchymoses, or lacerations over the chest wall may correlate with more significant rib or intrathoracic injuries.
  - Open wounds may represent the track of a penetrating wound. An open pneumothorax (sucking chest wound) can develop as air is drawn into the chest through the wound during inspiration.
- **Paradoxical chest wall movement** – This is indicative of flail chest, in which a flail segment bulges during expiration (figure 1). (See "Chest wall injuries after blunt trauma in children", section on 'Flail chest'.)
- **Abnormal lungs sounds on auscultation** – Decreased or absent breath sounds may indicate pneumothorax, hemothorax, or pulmonary contusion.

Signs of cardiac injury include the following:

- Distant or muffled heart tones suggest hemopericardium
- An irregular rhythm may develop as the result of a cardiac contusion
- A new murmur
- Signs of congestive heart failure (eg, gallop rhythm, pulmonary edema, elevated central venous pressure, or hepatomegaly)

Injury to the great vessels should be suspected with the following signs:

- Hypotension
- Asymmetric, diminished, or absent peripheral pulses
- Paraplegia

Children with bronchial, esophageal, or diaphragmatic injuries may have respiratory distress or decreased breath sounds. A scaphoid abdomen suggests traumatic diaphragmatic hernia.

Diagnostic studies — Patients with serious thoracic injury warrant the same diagnostic studies that are recommended for children with multiple trauma as discussed separately. (See "Trauma management: Approach to the unstable child", section on 'Laboratory studies'.)

Ancillary studies of particular importance in patients with thoracic injury may include:

- Serum cardiac troponin levels to evaluate for myocardial contusion
- Arterial or venous blood gas measurement
- Electrocardiogram (ECG)
- Bedside ultrasonography
- Anteroposterior plain CXR

Depending on clinical suspicion for great vessel or blunt cardiac injury, contrast computed tomography (CT) of the chest and/or formal echocardiography may also be indicated.

Cardiac troponins — Elevated cardiac troponin levels appear to be sensitive indicators of myocardial injury among patients with blunt thoracic trauma. The definition of clinically significant myocardial contusion remains elusive. In observational reports describing adults and children with myocardial contusions, the majority of patients had elevated troponin levels [17,18]. However, troponin levels may be elevated in patients with minor cardiac injury [19]. Patients who are hemodynamically stable and have normal troponin levels and normal ECGs at initial presentation are unlikely to have significant myocardial injury [18,19].

Electrocardiography — A 12-lead ECG should be performed for the child who has sustained anterior chest trauma, a sternal fracture, or has any arrhythmia (including unexplained sinus tachycardia) [20].

ECG findings that can be seen in patients with cardiac contusion include ST-T wave changes (injury pattern) and arrhythmia. In a retrospective report from the National Pediatric Trauma Registry describing children with blunt cardiac injury, ECG was abnormal in 57 percent of patients [21].

The ECG for patients with cardiac tamponade can show sinus tachycardia, low voltage, and, less commonly, electrical alternans (caused by swinging of the heart in the pericardial fluid) (waveform 1) [22].

Thoracic imaging — The approach to imaging for patients with thoracic trauma depends upon the severity of the trauma and the suspected underlying injury. Imaging modalities that can be used to evaluate children with thoracic trauma include plain CXR, bedside ultrasonography by an experienced clinician, echocardiography, and CT.

Minor trauma — Children who have sustained isolated minor thoracic trauma may not require imaging. Those who have normal blood pressures, Glasgow coma scale (GCS) scores of 15, and no localizing findings on chest examination are unlikely to have abnormal plain CXRs [4]. This was demonstrated in several observational series in which thoracic injuries identified on CXR correlated with the following [4,14,16]:

- Abnormal respiratory rate
- Palpation tenderness over the chest wall
- Abnormal auscultatory findings such as decreased or absent breath sounds or crackles

Major trauma — All children who are unstable or are victims of high-force trauma should undergo chest imaging. Imaging modalities may include:

- **Plain radiograph** — Plain CXR (anteroposterior view) is a routine part of the evaluation of children with major thoracic or multisystem trauma and should be performed as part of the primary survey [23]. CXRs are widely available, inexpensive, and may identify many life-threatening injuries, including clinically significant pneumo- or hemothorax, abnormalities of the mediastinum associated with injury to the thoracic aorta, or a retained foreign body in the case of penetrating trauma. (See "Trauma management: Approach to the unstable child", section on 'Screening radiographs'.)

- **Bedside ultrasonography** — Bedside ultrasonography of the thorax during the primary survey may be used to rapidly identify the presence of pericardial fluid, pneumothorax, and hemothorax. Limited evidence suggests that bedside ultrasound is sensitive in detection of atraumatic pneumothoraces in children [24]; however, it may not be as sensitive in the detection of traumatic pneumothorax [25]. Therefore, a negative bedside ultrasound should still be followed by a chest radiograph if there is concern for pneumothorax. (See "Overview of intrathoracic injuries in children", section on 'Pneumo- and hemothorax'.)

- **CT of the chest** — In children, the frequency of cardiac and great vessel injury is low [26], and the risk of missing such an injury may be less than the risk of radiation exposure from CT [27-29]. For these reasons, the routine use of chest CT in children with major trauma but a normal anteroposterior CXR is not indicated and may be harmful. For example, in a children's hospital database study of over 120,000 pediatric trauma patients who received chest CTs (40 percent of admitted trauma patients), there were 2 thoracic aortic injuries found per 10,000 chest CTs [29].

  For children with major thoracic injury, contrast chest CT rarely changes management compared with CXR alone [30]. For example, in two large observational studies, chest CT in addition to CXR altered management in <1 percent of pediatric patients with blunt chest injury [31,32].

  For children, CT is primarily indicated to identify vascular injury and should be performed for the following indications [23]:

  - Suspected aortic injuries, as suggested by physical examination (asymmetric, diminished, or absent peripheral pulses or paraplegia), and/or findings on CXR (wide mediastinum, obscured aortic knob, left apical cap, or large left hemothorax). The

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

- Suspicion for other significant vascular injury, which may be indicated by a large hemothorax or signs of ongoing hemorrhage.

- Suspicion for tracheobronchial injury. (See "Overview of intrathoracic injuries in children", section on 'Tracheobronchial injury'.)

- Echocardiography – Echocardiography should be performed for children with physical findings concerning for cardiac injury (such as muffled heart tones or arrhythmias), elevated troponin levels, or abnormal ECGs. (See "Overview of intrathoracic injuries in children", section on 'Blunt cardiac injury'.)

MANAGEMENT

Following the initial rapid assessment and stabilization (primary survey), potentially life-threatening injuries that have been identified by physical examination or diagnostic studies may require immediate treatment in the emergency department (ED) or the operating room. Children with significant thoracic injuries are typically hospitalized for medical management (as with pulmonary contusion) or observation, while those with mild or moderate injuries can often be discharged from the ED.

Supportive care — General management considerations for children with thoracic trauma who are symptomatic (such as with chest pain or abnormal physical examination), those with multiple injuries, or those with high-impact mechanisms include the following:

- Supplemental oxygen
- Monitoring of vital signs, including pulse oximetry
- Prompt surgical consultation

Advanced airway management, including endotracheal intubation, should be considered for the following indications:

- Severe respiratory distress
- Hemodynamic instability
- Glasgow coma scale (GCS) score <9

Cervical spine motion restriction should be maintained for patients with thoracic trauma who have multiple injuries, particularly those with head trauma. (See "Pediatric cervical spinal

motion restriction", section on 'Motion restriction during airway management'.)

Fluids should be provided as needed to support blood pressure and improve end-organ perfusion. Although patients with pulmonary contusions may develop pulmonary edema with excessive fluid administration, this is rarely a consideration during initial management and never takes precedent over supporting circulation.

Chest decompression — Interventions that may be required in the ED for children who have serious thoracic injuries include the following:

- **Needle decompression** – For patients who are unstable, needle decompression to relieve tension pneumothorax is typically performed while preparations are made for pigtail catheter placement or tube thoracostomy. (See "Initial evaluation and management of penetrating thoracic trauma in adults", section on 'Role of needle/finger chest decompression'.)

- **Pigtail catheter placement** – Pigtail catheter placement, rather than tube thoracostomy, may be appropriate for symptomatic simple pneumothoraces without associated hemothorax. Evidence suggests the pigtail catheter provides similar efficacy with less pain than a thoracostomy tube [33,34].

  Asymptomatic patients with clinical evidence of a pneumothorax warrant pediatric surgical consultation prior to pigtail catheter placement; limited evidence suggests that observation without catheter placement may be beneficial for some of these patients although criteria are not well established. (See "Overview of intrathoracic injuries in children", section on 'Management'.)

- **Tube thoracostomy** – Tube thoracostomy is indicated for patients with traumatic hemothorax. The technique for performing the procedure is described separately. (See "Thoracostomy tubes and catheters: Indications and tube selection in adults and children".)

  The appropriate tube size during resuscitation of an unstable patient with thoracic trauma is determined by the child's age and/or weight with larger sizes potentially required for patients with a hemothorax (table 4).

Emergency thoracotomy — Whenever possible, children who present to the ED in decompensated shock caused by penetrating chest trauma should be taken immediately to the operating room for resuscitative thoracotomy [2,35].

Emergency department (ED) thoracotomy is rarely performed for patients in extremis (cardiac arrest or severe decompensated shock) to release pericardial tamponade, control hemorrhage, control massive air embolism, or perform open cardiac massage. ED

thoracotomy should only be performed by experienced clinicians when a thoracic or trauma surgeon is available in a timely manner to perform operative intervention and definitive stabilization. Following the procedure, the patient must be taken immediately to the operating room for definitive surgery:

- **Indications** – Potential indications for ED thoracotomy in children are not well defined. Adult data, small case series, anecdotal reports and expert opinion suggest the following indications [36,37] (see "Initial evaluation and management of penetrating thoracic trauma in adults", section on 'Indications and contraindications'):

  - 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

- **Contraindications** – ED thoracotomy is contraindicated due to futility of the procedure in the following situations:

  - Patient has no pulse or blood pressure in the field
  - Asystole is the presenting rhythm and there is no pericardial tamponade
  - Prolonged pulselessness (over 15 minutes) during resuscitation
  - Massive, nonsurvivable injuries have occurred
  - No thoracic or trauma surgeon is available within approximately 45 minutes

ED thoracotomy entails risk: transmission of communicable diseases such as HIV and hepatitis can occur, and multiple sharp instruments, suture needles, and open rib fractures can cause iatrogenic injury. Given the resources required and risks entailed in ED thoracotomy, we strongly encourage hospitals to develop policies to determine the circumstances under which the procedure is to be performed.

Among adults, survival rates are best among patients with isolated stab wounds to the heart (17 percent). Survival after ED thoracotomy is rare among blunt trauma victims, patients without signs of life in the field, or patients with multiple gunshot wounds to the chest (1 percent or less for each group). (See "Initial evaluation and management of penetrating thoracic trauma in adults", section on 'Overview and survival'.)

Evidence is limited for outcomes of ED thoracotomy in children, with survival rates that range from approximately 10 percent to 30 percent in different cohorts [13,38,39]. In one study of prehospital or ED resuscitation of children with penetrating or blunt thoracic trauma in a combat zone, 4 of 13 children who underwent resuscitative thoracotomy survived compared with 6 of 66 age- and injury-matched children who underwent cardiopulmonary resuscitation (CPR) without thoracotomy [38]. Signs of life in the field or in the ED were associated with survival in the thoracotomy group. In another observational study of over 300 children (mean age 15 years) who underwent thoracotomy within one hour of emergency presentation and were treated in a level one trauma center, approximately one-third survived to discharge, including almost 20 percent of patients with blunt trauma [36]. Survivors were more likely to have higher heart rates and blood pressures and lower injury severity scores. Survival dropped to 5 percent among patients whose presenting heart rate was ≤70 beats per minute or whose systolic blood pressure was ≤50 mmHg. Similar to adults, these results show improved survival after ED thoracotomy among adolescents with penetrating trauma when compared with blunt trauma. However, they also suggest that vital signs on emergency presentation are more important factors than the type of trauma when deciding whether thoracotomy should be performed in children.

Emergency surgery — Some patients with serious thoracic injuries may be transferred from the ED to the operating room; however, most thoracic injuries in children do not require surgical intervention. In one retrospective report describing children with thoracic trauma, 7 percent had surgical procedures to treat their thoracic injuries [1]. Most patients require surgery for associated injuries. Many children are hospitalized for observation, while some may be discharged from the ED.

Indications for emergency surgical intervention include the following [11,40]:

- Massive hemorrhage identified at thoracostomy placement (20 to 30 percent of blood volume for a child or 1000 to 1500 cc for an adolescent)
- Persistent hemorrhage (bleeding from thoracostomy at rate of 2 to 3 mL/kg per hour over four hours)
- Tracheobronchial rupture
- Esophageal disruption
- Diaphragmatic rupture
- Cardiac tamponade
- Great vessel injury

DISPOSITION

Admission to the hospital for further evaluation and observation is generally indicated for children with the following:

- Abnormal vital signs, respiratory symptoms, or severe pain
- Abnormal chest radiograph (CXR; other than rib fracture)
- Associated injuries
- High-impact mechanism
- Suspicion of inflicted injury

Children who can typically be managed as outpatients include:

- Those with isolated thoracic injuries who are asymptomatic, have normal vital signs (with GCS score 15), and no other abnormalities on physical examination.
- Those with chest wall injuries such as rib fracture or contusions who have normal vital signs, good pain control, and no other injuries noted on examination or imaging studies.

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

- **Evaluation** – Thoracic injuries in children are potentially life-threatening and require rapid identification and treatment as part of initial evaluation and stabilization; major thoracic injuries require emergency involvement of a trauma surgeon with pediatric expertise. (See 'Evaluation' above.)
- **Primary survey** – During the primary survey, hemodynamically unstable patients and those with marked respiratory distress or respiratory failure may require emergency interventions (eg, chest decompression, endotracheal intubation with cervical spine motion restriction, fluid resuscitation, pericardiocentesis, and, rarely, emergency thoracotomy) before completion of all diagnostic testing (table 2 and algorithm 1). (See 'Initial rapid assessment' above.)

  Important findings of serious chest injury include (see 'Physical examination' above):

  - Tachypnea with decreased oxygen saturation (eg, pulse oximetry <95 percent)
  - Respiratory distress (grunting, flaring, or retractions)
  - Paradoxical chest wall movement
  - Focal chest wall signs (eg, crepitus, focal tenderness, ecchymoses, lacerations, or a sucking chest wound) although life-threatening injury may be present without any

chest wall findings in children
- Abnormal lung sounds (eg, asymmetric decreased or absent breath sounds)
- Distended neck veins

Cardiac injury is suggested by an irregular rhythm, distant or muffled heart tones, a new murmur, or signs of heart failure.

Great vessel injury may be associated with hypotension, abnormal pulses (asymmetric, diminished, or absent), and/or paraplegia.

- **Secondary survey** – During the secondary survey, the chest exam is repeated to identify response to any emergency interventions during the primary survey and to ensure identification of all significant thoracic injuries (table 3). (See 'Physical examination' above.)

- **Diagnostic studies** – Patients with serious thoracic injury warrant the same diagnostic studies that are recommended for children with multiple trauma as discussed separately (see "Trauma management: Approach to the unstable child", section on 'Laboratory studies'). Ancillary studies of particular importance in patients with thoracic injury may include (see 'Diagnostic studies' above):

  - Serum cardiac troponin levels to evaluate for myocardial contusion
  - Arterial or venous blood gas measurement
  - Electrocardiogram (ECG)

- **Imaging** – During the primary survey, children with findings of major thoracic trauma should routinely undergo plain chest radiograph (CXR; anteroposterior view) and, where available, bedside thoracic ultrasonography. The routine use of chest computed tomography (CT) for pediatric patients with a normal anteroposterior CXR is **not** indicated and may be harmful. (See 'Minor trauma' above and 'Major trauma' above.)

  Chest CT with angiography is warranted for stable children with suspected blunt aortic injury (BAI). Hemodynamically unstable patients should undergo emergency surgical or endovascular repair rather than additional imaging. (See "Overview of intrathoracic injuries in children", section on 'Traumatic aortic injury'.)

  Children who have sustained isolated minor thoracic trauma, have a normal blood pressure, a Glasgow coma scale (GCS) score of 15, and no localizing findings on chest examination may not require any imaging. (See 'Minor trauma' above.)

- **Definitive management**

  - Emergency surgery – Indications for emergency surgical intervention include the following (see 'Emergency surgery' above):

  - Massive hemorrhage identified at thoracostomy placement (20 to 30 percent of blood volume for a child or 1000 to 1500 cc for an adolescent)
  - Persistent hemorrhage (bleeding from thoracostomy at rate of 2 to 3 mL/kg per hour over four hours)
  - Tracheobronchial rupture
  - Esophageal disruption
  - Diaphragmatic rupture
  - Cardiac tamponade
  - Great vessel injury

- Hospital admission – Most thoracic injuries in children do **not** require surgery. Admission to a pediatric trauma surgery service is typically indicated for children with (see 'Disposition' above):

  - Abnormal vital signs, respiratory symptoms, or severe pain
  - Abnormal CXR (other than rib fracture)
  - Associated injuries (children with multiple trauma)
  - High-impact mechanism
  - Suspicion of child abuse

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Topic 6568 Version 26.0

GRAPHICS

Pediatric thoracic injuries

Immediately life-threatening (usually suspected on initial assessment)
Airway obstruction
Open pneumothorax
Flail chest
Tension pneumothorax
Massive hemothorax
Cardiac tamponade
Potentially life-threatening (usually noted on secondary survey, chest radiograph, ECG, or reevaluation)
Tracheobronchial tear
Pulmonary contusion
Myocardial contusion
Ruptured diaphragm
Esophageal rupture
Aortic transection
Generally not life-threatening
Simple pneumothorax
Small hemothorax
Rib fracture
Chest wall laceration/contusion

ECG: electrocardiogram.

Graphic 79921 Version 2.0

Initial trauma management in children with severe multiple trauma

Assessment	Management
0 up to 5 minutes	
Mobilize trauma resources	***Immobilize cervical spine***
	Assess vital signs
Airway – Identify:	
Obstruction	***Open airway; suction secretions***
	Administer 100% O_2
Midface fracture/difficult airway **or** Direct airway injury	Surgical airway
Breathing – Identify:	
Tension pneumothorax	Needle decompression; place chest tube or pigtai catheter
Massive hemothorax	Place chest tube
Open pneumothorax	Apply 3-sided occlusive dressing
Flail chest	Perform bag-valve-mask ventilation
Impaired oxygenation/ventilation	Rapid sequence endotracheal intubation
Circulation – Identify:	
Absent circulation	Cardiac compressions, thoracotomy **if** witnessed arrest
External hemorrhage	Control external hemorrhage
Signs of shock	***Secure IV access; obtain laboratory studies***
	Fluid resuscitation*
Cardiac tamponade	Pericardiocentesis followed by thoracotomy
Pelvic fracture	Wrap or bind pelvis
Disability – Identify:	
Level of consciousness (GCS)	Endotracheal intubation for rapidly declining GCS GCS ≤8 or herniation¶
Pupillary response	Elevate head of bed to 30° if no signs of shock
Signs of spinal cord injury	
Signs of impending herniation	Moderate hyperventilation (pCO_2 30 to 35)
	Neurosurgical consultation
	Administer osmotic agents if normotensive

Exposure – Identify:	
Hypothermia	***Remove clothing***
	Initiate rewarming
5 up to 15 minutes	
Repeat vital signs every 5 minutes	Continue care of airway, breathing, circulation, and disability
Reassess response to interventions	Proceed to intraosseous or central venous access if peripheral IV access unsuccessful
Intubated patients:	
Monitor end-tidal CO_2	Gastric tube placement
Obtain blood gas	Perform thoracotomy in patients who lose vital signs during resuscitation
Persistently hypotensive patients:	
FAST examination, if available	
15 up to 20 minutes	
Reassess response to interventions	***Continue care of airway, breathing, circulation, and disability***
Reassess level of consciousness	***Logroll patient and remove spine board***
Examine head, neck, chest, abdomen, pelvis, and extremities	***Provide analgesia***
	Place urinary catheter **if** no signs of urethral disruption
Obtain screening radiographs, as indicated	Operative management for patients who remain hemodynamically unstable despite rapid blood infusion per trauma surgeon
20 up to 60 minutes	
Reassess response to interventions	***Provide analgesia***
	Splint fractures
Reassess level of consciousness	Update tetanus immunization, as needed
Perform complete PE (secondary survey)	Antibiotics for open fracture, contaminated wounds, or suspected bowel perforation
Repeat selected laboratory studies (eg, hematocrit, blood gas, glucose)	Determine need for emergency life- or limb-saving operative procedures
CT of head, neck, chest, abdomen, or pelvis, as indicated by clinical findings	***Transition to definitive care at a regional pediatric trauma center***

Clinicians should always perform actions in the bold italicized ***red*** text. Refer to UpToDate topics on management of trauma in the unstable child.

O_2: oxygen; CO_2: carbon dioxide; GCS: Glasgow coma scale; pCO_2: partial pressure of carbon dioxide; IV: intravenous; FAST: focused abdominal sonography for trauma; PE: physical examination; CT: computed tomography.

* Administer 20 mL/kg of warmed normal saline or Ringer's lactate as rapidly as possible using a rapid infuser or the push/pull method via stopcock. In children with severe head injury, the aim is to ensure normal, but not excessive, circulating volume.

¶ Signs of herniation include coma, unilateral pupillary dilation with outward eye deviation followed by hemiplegia, hyperventilation, Cheyne-Stokes respirations, and/or decerebrate or decorticate posturing. Refer to UpToDate topics on severe traumatic brain injury in children for more specific guidance.

Graphic 64241 Version 11.0

Secondary survey physical examination in the pediatric trauma patient

Head
Inspect and palpate face and scalp
Eye examination
Visual acuity (if alert)
Pupillary size
Hemorrhage (conjunctiva, fundi)
Penetrating injury
Contact lenses (remove if indicated)
Ocular entrapment
Periorbital ecchymosis (Raccoon eyes)
Ear examination
Hemotympanum, bleeding, perforation
Retro-auricular ecchymosis (Battle's sign)
Midface examination
Inspect for nasal swelling, deformity, bleeding, or clear rhinorrhea
Inspect for oral trauma, malocclusion, intraoral lacerations
Palpate maxilla for evidence of LeFort fracture (palatal instability with anterior to posterior pressure on the upper teeth)
Cervical spine and neck
If maxillofacial/head trauma sustained, presume unstable cervical spine injury and immobilize neck until c-spine adequately evaluated
Inspect and palpate neck
Tracheal deviation
Distended neck veins
C-spine tenderness
Subcutaneous emphysema

Abdomen
Inspect and palpate abdomen
Seat belt sign/bruises (Cullen's sign)
Distention
Focal tenderness
Peritoneal signs
Masses
Auscultate for bowel sounds
Perineum/rectum/vagina
Inspection
Contusions/lacerations/hematomas
Males-urethral bleeding
Females-vaginal bleeding
Rectal examination
May be performed at the end of spinal examination when the body is already turned onto the side
Assess for blood in bowel lumen
Sphincter tone
Males (teenage/adult)--palpate for high-riding prostate
Musculoskeletal
Inspect and palpate extremities
Identify fractures/dislocations
Assess pulses for presence and strength
Inspect and palpate pelvis
Pain on palpation of pelvic ring
Mobility of pelvis with anterior-to-posterior pressure with heels of hands on both anterior iliac spines
Logroll patient to inspect and palpate back
Examine for step-offs or focal tenderness
Inspect under the axillae

Crepitus over larynx (concerning for laryngeal fracture)
Carotid artery bruits
Active range of motion (in awake, cooperative patient without distracting injuries)
Penetrating neck injury
Inspect to determine if injury may be through the platysma
Chest
Inspect and palpate chest, including the clavicle, ribs, and sternum
Open pneumothorax/large flail segment
Crepitus
Tenderness/bony deformity
Auscultate
Breath sounds
Heart sounds

Neurologic
Comprehensive neurological examination
Re-evaluation of patient's level of consciousness
Re-evaluation of patient's pupillary size
Motor evaluation
Sensory evaluation

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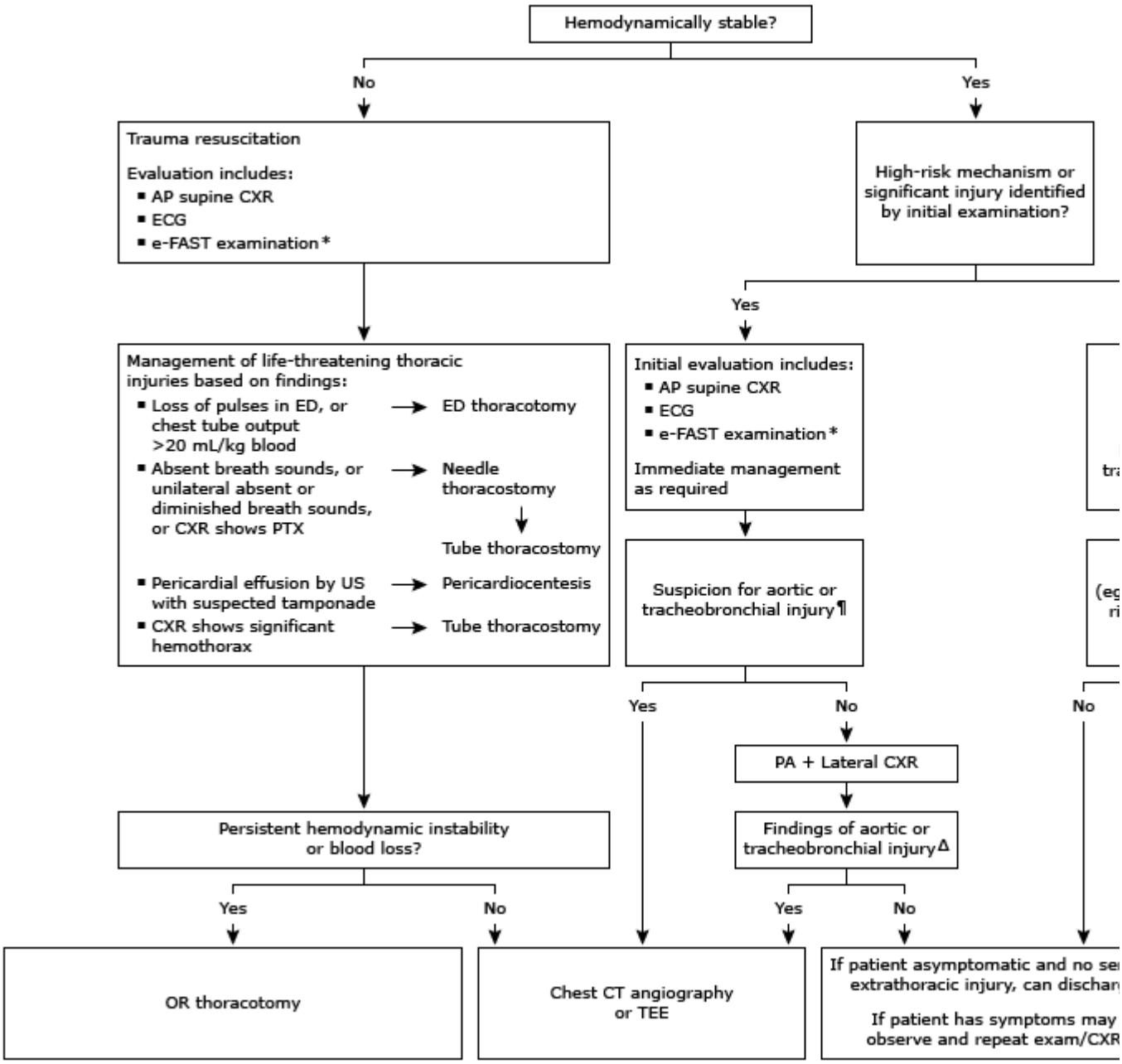
Graphic 65952 Version 5.0

Blunt chest trauma in children ED management



AP: anterior-posterior; CT: computed tomography; CXR: chest x-ray; ECG: electrocardiogram; ED: emergency department; e-FAST: Extended Focused Assessment with Sonography in Trauma; OR: operating room; PA: posterior-anterior; PTX: pneumothorax; TEE: transesophageal echocardiography; US: ultrasound.

* e-FAST includes is a rapid bedside ultrasound examination of four abdominal locations: right upper quadrant, left upper quadrant, subxiphoid region, and pelvis; lungs; and heart.

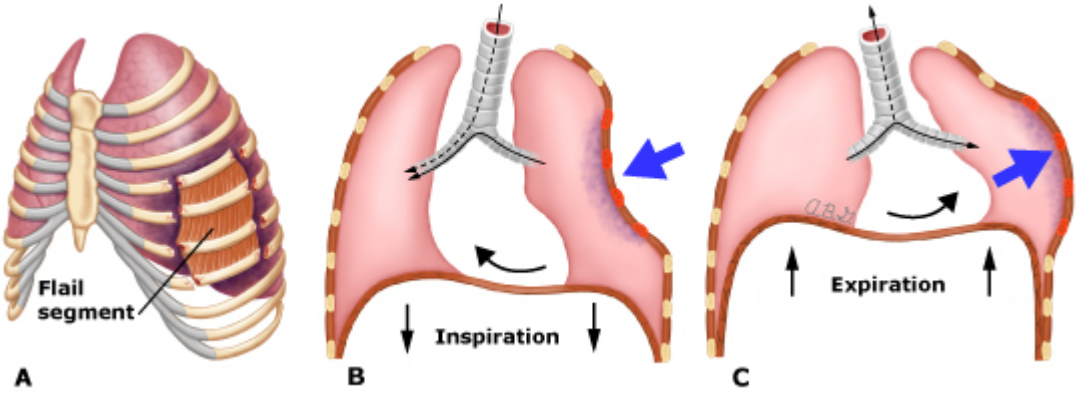
¶ Aortic injury should be suspected in children with a rapid deceleration injury (eg, high-speed motor vehicle crash or fall from a significant height), hypotension, diminished blood pressure or pulses in the lower extremities compared to the upper extremities, or paraplegia. Tracheobronchial injury should be suspected in children with subcutaneous emphysema, stridor, and/or a persistent high volume air leak from a chest tube placed for a pneumothorax. Refer to UpToDate topics on intrathoracic injuries in children.

Δ Chest radiograph findings of aortic injury include a widened superior mediastinum, a left apical cap (fluid from left mediastinum to the apex), abnormal aortic knob contour, and/or a left hemothorax or

pleural effusion. Chest radiograph findings of a tracheobronchial injury include air within soft tissue surrounding a bronchus or pneumothorax, hyoid bone elevation suggesting tracheal transection, or obstruction of an air-filled bronchus. Refer to UpToDate topics on intrathoracic injuries in children.

Graphic 59720 Version 6.0

Flail chest pathophysiology



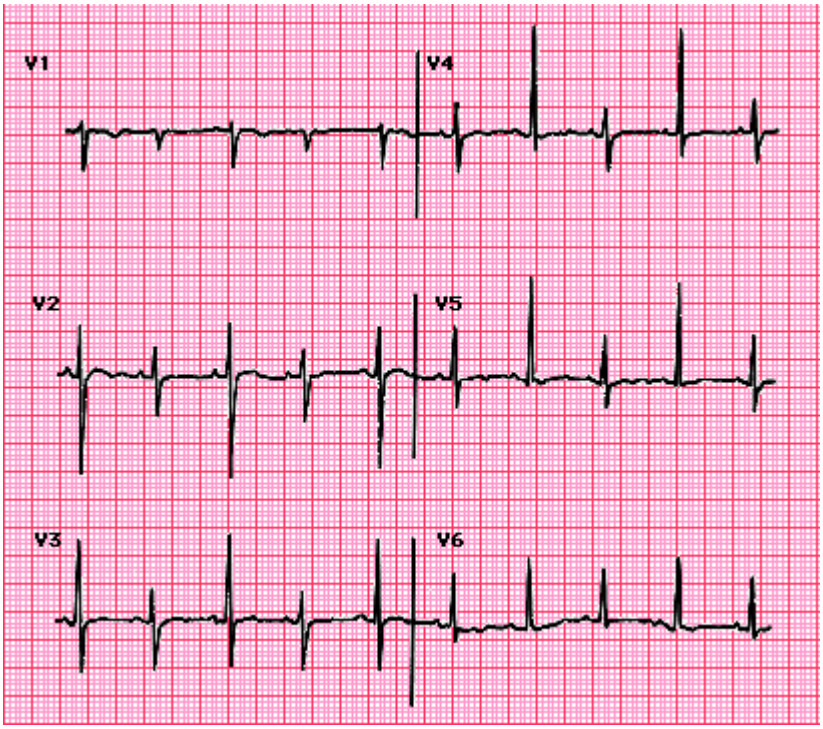
(A) Flail chest occurs when multiple rib fractures result in a loss of stability of the chest wall. The loss of continuity with the remainder of the rib cage causes the flail segment to move paradoxically.

(B) Pressure within the chest is negative during inspiration, causing the flail segment to retract.

(C) With expiration, intrathoracic pressure becomes positive and the flail segment bulges.

Graphic 79746 Version 4.0

Electrical alternans



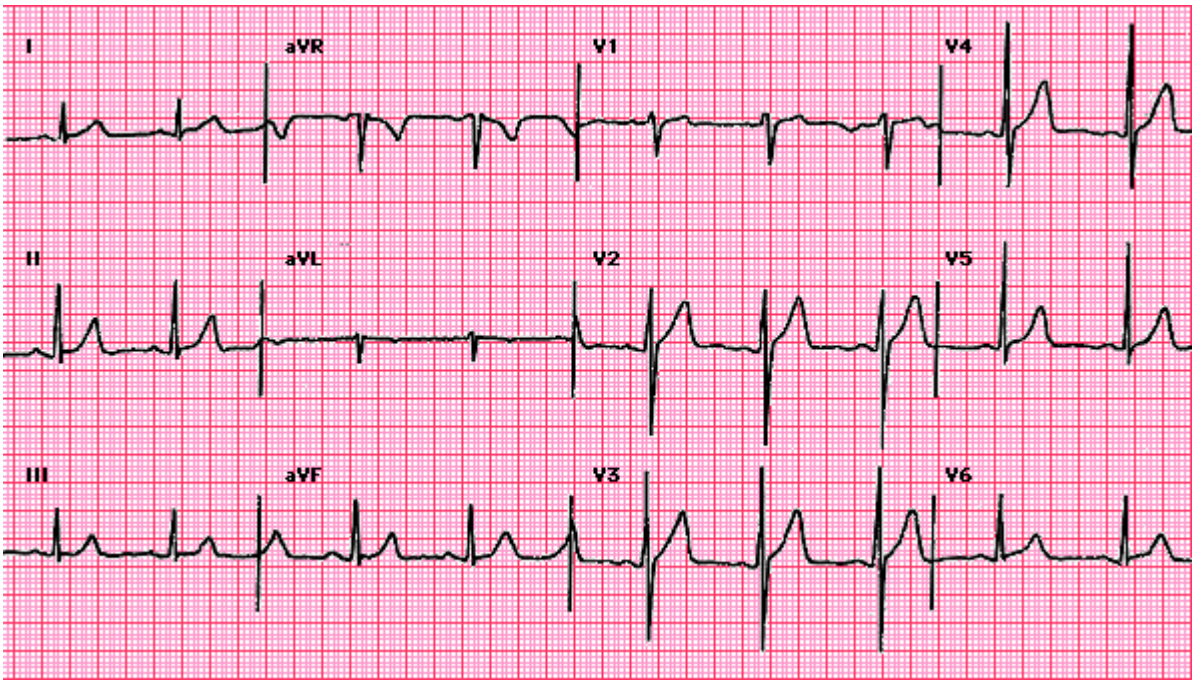
Sinus tachycardia with electrical alternans which is characterized by beat-to-beat alternation in the QRS appearance (best seen in leads V2 to V4). These findings are strongly suggestive of pericardial effusion, usually with cardiac tamponade. The alternating ECG pattern is related to back-and-forth swinging motion of the heart in the pericardial fluid.

ECG: electrocardiogram.

Courtesy of Ary Goldberger, MD.

Graphic 72525 Version 5.0

Normal ECG



Normal electrocardiogram showing normal sinus rhythm at a rate of 75 beats/minute, a PR interval of 0.14 seconds, a QRS interval of 0.10 seconds, and a QRS axis of approximately 75°.

Courtesy of Ary Goldberger, MD.

Graphic 76183 Version 4.0

Chest tube sizes for pediatric trauma

Age	Weight (kg)	Chest tube (French)*
Infant (up to 1 year)	3 to 9	10 to 12
Toddler (1 to 3 years)	10 to 11	16 to 20
Preschool child (3 to 5 years)	12 to 18	20 to 24
School-aged child (5 to 12 years)	19 to 29	24 to 32
Over 12 years	≥30	32 to 38

* In addition to considering age and weight, the clinician should evaluate the distance between the ribs to arrive at the correctly sized chest tube for placement. Larger sizes within the range are potentially required for patients with a hemothorax.

Data from: 2010 Handbook of Emergency Cardiovascular Care for Healthcare Providers, Hazinski MF, Samson R, Schexnayder S (Eds), American Heart Association, Dallas TX 2010.

Graphic 81970 Version 6.0

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