Pediatric Blunt Thoracic Trauma

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Abstract

Thoracic injury in children deserves special attention because, although it accounts for less than 10% of traumatic injuries in children, there is a significant associated morbidity and mortality. This review discusses the anatomic and physiologic factors resulting in such injury severity with blunt thoracic trauma in children. Specific organ injuries, including most common chest wall injuries, hemo- and pneumothoraces, and pulmonary parenchymal injuries, are discussed, encompassing epidemiology, presentation, diagnosis, and management. Rare injuries including tracheobronchial tree injuries, cardiovascular injuries, esophageal injuries, and diaphragmatic injuries are also briefly discussed.

Keywords

- thoracic trauma
- chest trauma
- pulmonary injury
- children

Introduction

Basic evaluation of an injured patient follows the tenets of the advanced trauma life support course, regardless of the patient's age. The primary survey establishes logical and sequential treatment priorities and identifies life-threatening conditions in the severely injured patient,¹ and it speaks to the potential for life-threatening injury with thoracic trauma as the ABCs of the primary survey can all be disrupted by trauma to the chest.

Thoracic injury in children deserves special attention because, although it accounts for less than 10% of traumatic injuries in children, there is a significant associated morbidity and mortality.^{2–5} In fact, chest trauma is the second most likely cause of death in children with traumatic injuries,² and chest trauma in children is an indicator of increased mortality.⁵ Additionally, even though the small body surface area in children results in concomitant abdominal injuries, thoracic injuries are 20% more likely to be associated with death than abdominal injuries.² Penetrating injuries to the chest in children are rare, and not included in this review.

Although chest wall injuries, hemothorax and pneumothorax, and pulmonary parenchymal injury are the most common pediatric thoracic injuries,⁶ this review will include a brief discussion of the more rare injuries of the

tracheobronchial tree, great vessels, heart, esophagus and diaphragm, given their high morbidity and mortality.

Anatomic and Physiologic Considerations

The difference in morbidity and mortality between children and adults with thoracic trauma depends on several factors including anatomical and physiologic differences, differences in mechanism of injury, and differences in injury pattern. Children are more susceptible to thoracic trauma due to increased chest wall compliance as the ribs have not undergone complete ossification, and as they have decreased muscle mass.⁷ This results in increased transmission of force to the underlying organs during blunt force trauma, with relative preservation of the ribs as compared with adults.^{3,8,9} Additionally, the mediastinum is much more mobile in young children than in adults and accounts for an increased susceptibility to tension physiology and hypotension in the presence of pneumothorax, hemothorax, and diaphragmatic rupture.^{7,10}

General physiologic differences between adults and children, such as higher metabolic rates, decreased functional residual capacity, larger body surface area to weight ratio, and cardiac output that is dependent on preload and heart rate, all predispose to hypoxemia, hypotension, and hypothermia.^{7,10,11}

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resulting in significant morbidity and mortality in children with thoracic trauma.

Thoracic trauma in children most commonly results from motor vehicle related trauma, accounting for three quarters of blunt injuries to the chest,² and includes both passengers in motor vehicles as well as pedestrian struck patients. In both cases, pediatric specific anatomy such as the chest being at the level of the bumper for pedestrian struck cases,⁶ or use of shoulder lap restraints or car seats in passengers, accounts for substantial thoracic injuries in children.¹² Differences in injury pattern between children and adults also account for differences in thoracic trauma; children and adolescents are more likely to be involved in crashes with a higher change in velocity (Δv) than adults, and predominantly suffer lung contusions or pneumothoraces.¹² Both higher Δv and younger age are predictors of pulmonary injury.¹³ Additionally, although the increased chest compliance of children may be protective at crashes with lower Δv , at higher Δv this increased compliance results in injury to underlying organs and tissues without associated rib fracturing.¹² Since children are more likely to be involved in crashes with higher Δv , they are therefore more susceptible to thoracic injury.

Chest Wall Injury

Rib fractures occur in 20 to 60% of children with thoracic trauma, but account for only 1 to 2% of trauma victims overall.^{2,3,5,14-18} Flail chest occurs in only 1% of children with rib fractures,² and operative repair is extremely uncommon. Patients may present with crepitus and subcutaneous emphysema, but more commonly with tenderness to palpation. Diagnosis can be made with plain X-ray and/or computed tomography (CT) of the thorax for definitive localization. Isolated rib fractures rarely require intervention other than aggressive pain management and pulmonary toilet to deter respiratory compromise secondary to limitation of ventilation by pain. Pain control maneuvers include systemic intravenous (IV) pain control and local transdermal analgesic patches; rarely more aggressive options are utilized such as intercostal regional blocks and epidural analgesia, depending on the extent of fracturing.

An important consideration with rib fractures in young children is the potential for nonaccidental trauma and physical abuse. In children younger than 3 years with rib fractures, particularly when other high energy mechanisms of trauma or predisposing medical pathology have been excluded, the workup should include evaluation by child abuse specialists after stabilization from a trauma standpoint: the positive predictive value of rib fractures for child abuse in this setting is 100%.¹⁹

Hemothorax and Pneumothorax

Up to 29% of children with chest trauma will sustain a hemothorax, up to 37% will sustain a pneumothorax, and up to 11% will have both.^{2,3,14} These injuries typically occur in conjunction with injuries to the lung parenchyma. As previously discussed, children with these injuries are particularly

susceptible to cardiorespiratory compromise due to their increased chest wall compliance and mediastinal mobility. Minor pneumothoraces and hemothoraces may present with minor or no clinical symptoms. These are typically due to pulmonary parenchymal injury.²⁰ They may be difficult to diagnose with chest X-ray, and are more commonly seen with CT scan; however, occult injuries that are only noted on CT scan rarely need intervention if there is no progression. Ultrasound diagnosis of simple pneumothoraces not seen on chest X-ray is nearly as sensitive as CT scan and can also be used for diagnosis.⁷ Moderate pneumothorax is diagnosed by chest X-ray and may require evacuation with tube thoracostomy, based on the clinical condition of the child.²¹ Hemothorax that has failed drainage with tube thoracostomy should be evacuated after 7 days, given the increased risk of posttraumatic empyema and restrictive lung disease^{7,22}; thoracotomy or video assisted thoracoscopy can be performed,²³ although the use of thrombolytics via the tube thoracostomy has also been suggested.⁷

Patients with tension pneumothorax present with respiratory distress, absent breath sounds, hyperresonance on percussion, jugular venous distension, and may have hemodynamic compromise from lack of venous return. These patients require immediate decompression with tube thoracostomy, and treatment should not be delayed for diagnostic imaging. A more significant pneumothorax-like symptom may be secondary to parenchymal injury, but clinicians should have a low threshold of suspicion for injury to the tracheobronchial tree.²⁰

Patients with massive hemothorax will also have respiratory distress and absent breath sounds, however they will have dullness to percussion. They too may have the immediate symptoms of hypovolemia and hemorrhagic shock. Tube thoracostomy is required for decompression and treatment of respiratory distress, as well as to quantify blood loss and potential need for operative management.^{3,20} Transfusion of blood products should be initiated. Massive hemothorax is typically due to injury to intercostal vessels or significant parenchymal injury, but may be indicative of major vascular or cardiac injuries.

Pulmonary Injury

Direct lung injury from thoracic trauma is common in children due to the transmission of force through the relatively thin and compliant chest wall to the underlying organs; this results in pulmonary contusions, lacerations and traumatic pneumatoceles. Pulmonary contusions occur in 34 to 100% of children with thoracic trauma,^{2,3,5,14-18} although they range in severity from being an isolated asymptomatic radiographic finding, to resulting in significant respiratory failure requiring mechanical ventilation. The pulmonary contusion results in damage at the level of the alveoli with hemorrhage and edema resulting in poor gas exchange.^{4,7} Diagnosis should be obtained by chest X-ray; although CT scan is more sensitive, it does capture clinically insignificant pulmonary contusions. Only the severity of lung contusion determined by chest X-ray, not CT scan, correlates with impairment of

oxygenation, carbon dioxide exchange and duration of mechanical ventilation.^{24,25} Bedside ultrasonography to diagnose pulmonary contusion has also been described.^{26,27} Additionally, a negative chest X-ray does not preclude a significant pulmonary contusion, as these may develop several hours after injury.²⁸ Minor pulmonary contusions require supportive care in the form of supplemental oxygen, pulmonary toilet and fluid restriction, however severe contusions may require mechanical ventilation in up to 30% of children.^{14,17,29,30} Additional strategies to maximize gas exchange may be required such as high positive end-expiratory pressures, inhaled nitric oxide, high frequency oscillating ventilation or even extra-corporeal membrane oxygenation.^{31–33} Controversy exists in the literature regarding the morbidity of pulmonary contusions in children as compared with adults; some studies suggest that the morbidity in children is not as severe as in adults^{34,35}; however, others show a similarly severe morbidity in terms of their overall injury severity, associated injuries, and outcomes.³⁰ Nonetheless, long-term outcomes in children with pulmonary contusions show spontaneous resolution, and normal lung function in most children.^{17,36}

When discussing pulmonary injury in the setting of trauma, adult respiratory distress syndrome often comes up. Although rare in children with traumatic injuries, it can occur and is most commonly due to polytrauma, shock or sepsis, rather than a result of direct trauma on the lung.³⁰ When adult respiratory distress syndrome does develop, it carries an associated mortality of 62% in the pediatric population.³⁷

Traumatic pneumatoceles are typically asymptomatic and can be diagnosed with visualization on chest X-ray or CT scan. They vary in size and typically require no intervention other than expectant management and repeat chest X-ray demonstrating a decrease in the size of the lesion, as they can sometimes increase in size for several days following injury.^{17,38,39} If they cause respiratory compromise due to significant increase in size, surgical resection is warranted.⁴⁰

Tracheobronchial Injury

Injury to the tracheobronchial tree occurs in <3% of children with thoracic trauma, but death occurs in about a third of these patients.^{41–43} The mechanism of this injury is usually from anteroposterior compression of the compliant chest wall pressing the sternum against the spine and resulting in lateral displacement of the lungs and injuring the bronchi or trachea at the carina. Additionally, there can be direct tracheal injury, or tracheobronchial injury from rapid rise in intratracheal pressure against a closed glottis from the force of the thoracic trauma.³

Patients may present asymptotically, which can delay diagnosis, or they may present with pneumothorax, hemothorax, pneumomediastinum, hemoptysis, subcutaneous emphysema, and respiratory distress.^{3,43} Radiographic imaging is rarely helpful in diagnosing these injuries. Diagnosis is usually made when a continuous or large air leak develops and fails to resolve after tube thoracostomy, and flexible bronchoscopy confirms an injury.³ Bronchoscopy also guides

management by allowing determination of location and extent of injury. If the patient remains stable from a respiratory point of view, if the airway can be secured (and the endotracheal tube passed beyond the injury), if the pneumothorax is evacuated, and the injury involves less than a third of the tracheal diameter, then the child can be managed non-operatively.^{42,43} If thoracotomy and operative repair is required, the repair must be tension free to ensure success, and a vascularized tissue flap as reinforcement is recommended.³

Cardiovascular Injury

Injury to the great vessels and heart are rare in children, and occur less commonly than in adults.³ Thoracic aortic injuries occur in 1 to 7.4% of children with thoracic trauma,^{2,3,14} and blunt cardiac injury is even rarer occurring in 0.3 to 4.6% of children.^{44,45} These injuries have significant mortality with 30% mortality within 6 hours of arrival at the hospital with blunt aortic trauma and 40% in hospital mortality with cardiac trauma.^{3,46} Children with thoracic aortic injury present with first rib and sternal fractures, paraplegia, upper extremity hypertension, or pulse or blood pressure differentials in extremities.^{47,48} Aortic injury can be diagnosed with chest X-ray findings of widened mediastinum or loss of the aortic knob, and a CT scan with IV contrast should be performed in anyone with a suspicion of aortic injury. Transesophageal echocardiography and intravascular ultrasound can also be used.³ Prompt operative management with either open or endovascular approaches are mandatory (although in growing children endovascular stent grafts are less preferable), and aggressive blood pressure control should be implemented preoperatively.

Blunt cardiac injury may present as asymptomatic electrocardiography changes, arrhythmias, or profound hemodynamic compromise, depending on the severity of the injury. Echocardiography should be obtained in any patient with electrocardiography changes or who are symptomatic, and treatment remains supportive.^{44–46}

Esophageal Injury

Esophageal perforation from blunt thoracic injury is very rare in children resulting in only a few cases having been described in the English language literature.^{49–54} Associated injuries are common and diagnosis can be difficult. Diagnosis is often delayed, because with blunt injury, as opposed to penetrating injury, the index of suspicion for esophageal injuries is typically low, and the associated signs and symptoms often also present in a delayed and nonspecific fashion, particularly if the injury is contained and presents later as an acquired tracheoesophageal fistula. The more common findings associated with esophageal perforations after blunt thoracic trauma include nonspecific neck and chest pain, dyspnea, fever, crepitance, subcutaneous air on plain film, pneumomediastinum and more rarely pleural effusions and pneumothoraces.^{54,55} These findings are nonspecific and can commonly be seen in other thoracic injuries, thereby, often resulting in delayed diagnosis of esophageal injuries.

A high index of suspicion is required in these cases and full diagnostic work up should be undertaken if there is any concern for esophageal injury, or if there is an already diagnosed mediastinal injury; an almost 60% incidence of concurrent tracheolaryngeal injury has been described in patients with an injury to the cervicothoracic esophagus, which is the most common site of esophageal injury.^{53,54} The potential for a delayed presentation, up to 74 days after injury in one pediatric case report,⁵⁶ mandates that a previously negative diagnostic work up must be repeated if the suspicion for an injury persists.

Suspicion for esophageal injury should result in a water-soluble esophagram as the first diagnostic step as this avoids the potential inflammatory reaction of barium sulfate contrast; however, a negative study should be repeated with barium given a false negative rate of up to 10 to 38% with water-soluble contrast.^{55,57} Overall, the sensitivity of contrast radiographs for esophageal injuries (resulting from penetrating and blunt trauma) is reported at 97.4%.⁵⁸ A negative contrast study, however, should be complemented with endoscopy. Furthermore, it is acceptable to perform endoscopy as the first diagnostic study depending on the stability of the patient and feasibility of transporting to the fluoroscopy suite, however, again using the contrast study as a complementary diagnostic modality if the esophagoscopy is negative.

Flexible endoscopy has the advantage of not requiring general anesthesia, being technically less challenging, and having a smaller complication rate than rigid esophagoscopy, however, rigid esophagoscopy has been reported to have a higher sensitivity (82% versus 37.5% in one of the largest published series, although, studies with smaller patient numbers have shown a sensitivity of 100% with flexible esophagoscopy).⁵⁸ In children, rigid esophagoscopy is typically used as part of the armamentarium of the pediatric trauma surgeon. More recently, CT esophagography with the use of low-osmolar IV contrast material as the oral contrast agent has been suggested as a diagnostic modality instead of, or in conjunction with a negative fluoroscopic study. The advantage of this modality is that it evaluates for esophageal injury, but also for any other thoracic injury in the setting of trauma, that may result in the patient's presenting symptoms.⁵⁷

Once the diagnosis has been made, nonoperative therapy should be used for stable patients with contained leaks.^{59,60} For those that fail nonoperative management, primary esophageal repair with live tissue reinforcement is ideal; however, in children with mediastinitis, a damage control operation with exclusion of the esophagus and drainage of the mediastinum should be performed.⁵³

Diaphragmatic Injury

Diaphragmatic injuries are rare, but when they do occur, the left side is involved more frequently than the right due to the protection provided by the liver on the right.^{7,61–63} Children present with chest and shoulder pain, absent breath sounds on side of the injury, bowel sounds in the chest, respiratory distress, and abdominal pain.^{7,64}

Diagnosis can be made with chest X-ray, however these injuries sometimes become apparent over time and so repeat imaging may be needed.^{61–63} Additionally, a normal chest X-ray does not rule out the injury, so in patients with a suspicion for diaphragmatic injury but no clear evidence on chest X-ray, chest CT with oral contrast can confirm the diagnosis, or if needed laparoscopy or thoracoscopy can be performed for diagnosis and treatment.^{3,61–63} Management entails operative repair typically via an abdominal approach in the acute setting, and a thoracic approach in the delayed setting.³ These injuries can be addressed with minimally invasive techniques (laparoscopy or thoracoscopy) in the stable patient.

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