Thoracic Trauma

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The initial management of the child with suspected thoracic trauma begins with Advanced Trauma Life Support (ATLS), specifically with management of airway, breathing, and circulation. Thoracic trauma has the potential to affect any combination of these physiological processes. The airway can be affected by a tracheal injury, pneumothorax, or blockage of the airway from bleeding due to a pulmonary laceration. Breathing is especially susceptible to compromise in a patient with pneumothorax or hemothorax. Circulation can be affected by severe occult blood loss in the pleural cavity and mediastinum. Due to the mobility of the mediastinum in children, a tension pneumothorax in a child can shift the mediastinum and reduce venous return to the heart, therefore affecting circulation. Most life-threatening thoracic injuries can be identified during the primary survey. These include airway obstruction, tension pneumothorax, open pneumothorax, flail chest, massive hemothorax, and cardiac tamponade.

The workup of the child with a suspected thoracic injury involves external inspection and palpation of the chest looking for tenderness, bruising, or bleeding. Physical examination involves evaluation of breathing, breath sounds, tracheal deviation, subcutaneous emphysema, and quality of the heart sounds. A standard anterior-posterior chest film should be obtained during the initial assessment of the trauma to help identify any immediately life-threatening injuries. In children aged less than 1-year-old, the thymic tissue is prominent and can confuse the interpretation of the trauma CXR—what looks like a widened mediastinum in an older child might represent the thymus in a normal infant. In most cases, a normal CXR is all that is needed to rule out life-threatening thoracic injuries.

There is no literature that clarifies the indications for chest CT or CT angiography after blunt injury in a pediatric patient. The indications for CT from the adult literature in blunt trauma include a widened mediastinum, fracture of the first or second rib, blunting of the aortic knob (which can be confusing because of the large thymus), apical capping, medial displacement of the left main-stem bronchus, displacement of the nasogastric tube to the right, and diaphragmatic elevation. In penetrating thoracic trauma, a chest CT can sometimes clarify the path of a bullet or implement and allow for better identification of injuries. Penetrating injury to the *cardiac box*—defined by the vertical nipple lines, the manubrium, and the inferior costal margin—suggests potential injury to the heart or mediastinal structures. A chest CT is indicated for further workup in a stable child. A pericardial window or subxiphoid exploration to confirm blood in the pericardial sac should also be strongly considered. If this is confirmed, then a formal sternotomy for exploration is indicated.

A penetrating thoracic injury can also potentially involve the abdominal cavity (Fig. 24.1). The abdominal cavity may be violated by any penetrating injury below the nipple line anteriorly on the chest wall and below the tip of the scapula posteriorly. An extended FAST (focused assessment with sonography in trauma) can be useful in identifying hemothorax, pneumothorax, and pericardial effusions in the trauma patient. Other ancillary tests include EKG, ABG, and pulse oximetry. If there is a concern for esophageal injury, an esophagram or esophagoscopy is indicated. If there is a concern for tracheal injury, a bronchoscopy is indicated. Emergency department thoracotomy in children is rarely indicated. In those patients presenting with penetrating thoracic injury and signs of life on arrival who then lose vital signs during resuscitation, an ED thoracotomy is indicated. But for children who present after a blunt traumatic injury with cardiac arrest and no signs of life during resuscitation ED, thoracotomy is futile.

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Fig. 24.1 Penetrating injury to thoracic cavity

Blunt Asphyxia

A large compressive force on a child's chest during deep inspiration can cause traumatic asphyxia. Capillaries and small veins are ruptured in the face, neck, and chest wall when the atrium is compressed, stopping blood return from the superior vena cava. Children present with petechial hemorrhages of the face and upper chest, conjunctival hemorrhages, and occasionally face swelling. Rarely, patients present with neurological or vision changes from cerebral edema. Care is mostly supportive.

Rib Fractures

Children <8 years old have a very compliant chest wall. Therefore, the presence of a rib fracture is a sign of a high-energy mechanism. Rib fractures are more common in older children. Rib fractures can be associated with pleural cavity injuries, such as pneumothorax and hemothorax. Fractures of the first rib, implying a very high-energy mechanism, are an indication for a CT angiogram of the chest to rule out injury to the great vessels. Fractures of ribs 10, 11, or 12 can be associated with abdominal injury, especially the spleen, liver, and kidneys. Rib fractures in children less than 2 years of age are often due to child abuse but are not always associated with physical findings of pain or bruising. When evaluating a patient with suspected physical abuse, the diagnosis of rib fractures is very important and may be associated with other clinically occult injuries. A skeletal survey or bone scan may be indicated for further evaluation. Management of rib fractures in children includes supportive care, pain control, and pulmonary hygiene. Flail chest is a very rare occurrence in children. The paradoxical motion of the flail segment causes depression of respiratory effort. Treatment is geared toward avoiding respiratory depression with good pain control and aggressive pulmonary hygiene. Occasionally positive pressure ventilation is required if the respiratory depression becomes severe.

Sucking Chest Wound

An open chest wound can act as a one-way valve, with air being pulled into the pleural cavity by negative thoracic pressure. This can lead to a tension pneumothorax. Immediate management is placement of a three-sided dressing, which will allow air to leave the chest, but sucks the dressing down onto the wound with inspiration, preventing any further entry of air into the hemithorax. Definitive management of this injury requires the placement of a formal chest tube to drain the pneumothorax and the placement of an occlusive dressing or surgical closure to close the open chest wound and prevent further air from entering the chest cavity.

Pneumothorax

A simple pneumothorax occurs when a patient sustains an open chest wound from a penetrating injury or from a pulmonary laceration allowing air to escape the lung into the pleural cavity (Fig. 24.2). Pneumothoraces are common in pediatric chest trauma. They are often asymptomatic and identified on CXR or CT. The air can loculate in different locations of the chest cavity and will sometimes be missed on the initial radiograph. When identified on a trauma CXR, intervention should be considered. Tube thoracostomy is indicated for symptomatic pneumothorax or a patient with a >20% pneumothorax; otherwise, the child may be treated with supplemented oxygen and monitoring. Treatment is usually required for 24–48 h. A chest CT is more sensitive and will sometimes identify an occult pneumothorax not

Fig. 24.2 Right pneumothorax

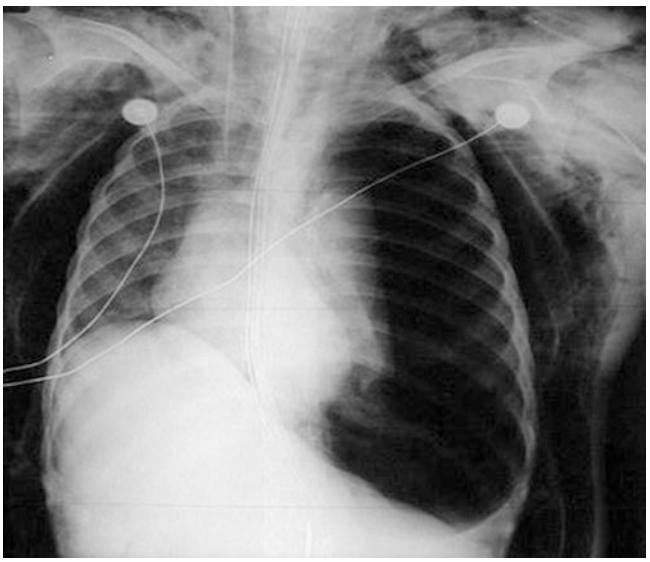

Fig. 24.3 Left tension pneumothorax

seen on CXR. If the pneumothorax is seen only on chest CT and the child is stable and asymptomatic, observation with no chest tube is usually sufficient. These patients must be monitored especially if they require positive pressure ventilation with consideration for serial CXRs to evaluate for progression of the pneumothorax over time. FAST examination can also be used to identify a pneumothorax in the acute setting. A tension pneumothorax with a mediastinal shift is a life-threatening injury (Fig. 24.3). This can present with shortness of breath, hypoxia, tachycardia, hypotension, absent breath sounds on the affected side, tracheal deviation, or distended neck veins. The diagnosis is clinical and immediate decompression is indicated. Needle decompression, at the midclavicular line in the second intercostal space, may be necessary to stabilize the child before placement of a chest tube.

Hemothorax

In a hemothorax, the source of blood can be the intercostal muscle or blood vessels, pulmonary parenchyma, the pleura, or, rarely, the great vessels. Hemothorax is often identified by CXR but a smaller volume hemothorax will be better visualized by chest CT. It can be difficult to estimate the volume of blood present in the chest on a CXR, so if a hemothorax is suspected, a chest tube should be considered. The volume of blood obtained from the chest tube is important as a large amount of blood loss (≥15 mL/kg) at the time of chest tube placement or ongoing blood loss (≥2–3 mL/kg/h for 3 or more hours) is an indication for a thoracotomy. Drainage of the hemothorax is important as the blood left in the chest cavity can become infected leading to an empyema or become a fibrothorax and cause restrictive lung disease.

Pulmonary Contusion

Pulmonary contusions in children are very common. Larger pulmonary contusions can be identified by CXR. Chest CT is more sensitive and will identify smaller contusions, but the presence of lung contusions on CXR is adequate to make a diagnosis—CT is not required. Pulmonary contusions tend to be very well tolerated in children and often no treatment is required. Many become more prominent after fluid resuscitation. Treatment involves supplemental oxygen and pulmonary hygiene to minimize atelectasis. A child with a severe pulmonary contusion or multiple injuries might progress to pulmonary compromise or pneumonia and require ventilator support. This can progress in rare instances to ARDS. Another late complication is a pneumatocele, which can usually be observed without surgical intervention as long as the patient continues to improve.

Pulmonary Laceration

A pulmonary laceration can lead to development of a pneumothorax, in which case a chest tube will be required. If the pulmonary laceration is large and the lung is severely compromised, the child might develop a continuous air leak in which case a thoracotomy for lung repair or segmental lung resection is indicated (Fig. 24.4).

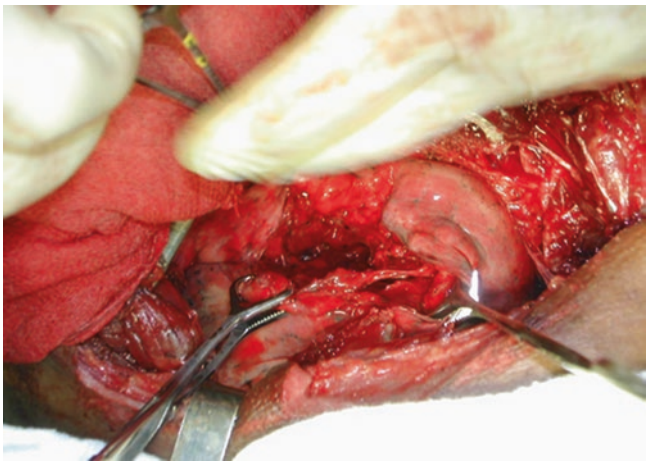

Fig. 24.4 Pulmonary laceration secondary to a gunshot wound to the chest in a 13-year-old child

Bronchial Injury

Bronchial injuries are rare. If the injury is in the distal segment of the bronchus, the patient may present with a simple pneumothorax and a chest tube will be sufficient for treatment. If the injury is located in the more proximal bronchus, the patient may present with tension pneumothorax, a continuous air leak, or a persistent pneumothorax after placement of a chest tube. The placement of a second chest tube often confirms the diagnosis. A chest CT with three-dimensional reconstruction can be helpful in visualizing the injury. Bronchoscopy is also potentially helpful. This injury requires a thoracotomy for the repair of the bronchial injury or pulmonary resection to remove the injured area.

Mediastinum

An injury to the mediastinum can involve the trachea, great vessels, heart, esophagus, or thoracic duct. Evaluation of penetrating thoracic trauma involving the mediastinum begins with a CXR. If the child is stable, chest CT can help identify further injuries. Some combination of esophagram, arteriogram, bronchoscopy, or echocardiography might also be indicated depending on the path of the penetrating mechanism. If the child is unstable following a penetrating injury, immediate operative exploration is indicated.

Tracheal Injury

A child with a tracheal injury will often present with respiratory compromise and subcutaneous emphysema of the chest or neck. Most will also have mediastinal air on CXR, but some can present with a tension pneumothorax if the injury is located distally on the trachea. As with a bronchial injury, the pneumothorax may persist even after adequate tube thoracostomy and should alert the physician that a tracheobronchial injury may be present. Mechanical ventilation might be necessary, and the workup includes a chest CT with three-dimensional reconstruction. Fiber-optic bronchoscopy might be needed for intubation. Tracheal injuries are also diagnosed with rigid bronchoscopy, which can clarify the degree of tracheal involvement. Once an injury is identified, surgical repair is most likely indicated. If the injury is minor, nonoperative management can be considered; however, this can result in airway stenosis or the formation of granulation tissue in the airway, eventually necessitating operative intervention.

Blunt Cardiac Injury

Blunt cardiac injury—myocardial contusion, cardiac rupture, laceration, or tamponade—is uncommon. Of these, a cardiac contusion is the most common. Most pediatric cardiac contusions are asymptomatic. A blunt cardiac injury should be considered in any patient with significant chest trauma. The patient may present with an arrhythmia, new onset of a murmur, or, in severe cases, heart failure. Workup includes a CXR, FAST, EKG, and cardiac enzymes including CPK-MB and troponin. Echocardiography is indicated when the patient is found to have EKG abnormalities or elevated cardiac enzymes. Patients with a confirmed cardiac contusion should be monitored with frequent vital signs and continuous electrocardiography. Management is mostly supportive. Cardiac laceration is extremely rare and if suspected an immediate echocardiogram in the emergency room should be diagnostic. Beck's triad (hypotension, distended neck veins, muffled heart sounds) is indicative of cardiac tamponade. These findings can be difficult to appreciate in a noisy trauma bay. If tamponade is confirmed by FAST, then pericardiocentesis or subxiphoid window may be indicated, followed by a formal surgical exploration.

Great Vessel Injury

Aortic and great vessel injuries most often occurs after a rapid deceleration blunt injury such as a high-speed motor vehicle collision or falls from a great height. CXR findings may include a widened mediastinum, abnormal aortic knob contour, depression of the left main-stem bronchus, deviation of the nasogastric tube to the right, or apical pleural hematoma. A chest CT is indicated if the CXR is abnormal

and the mechanism fits the potential injury. Operative management of these injuries includes endovascular stenting or open repair.

Esophageal Injury

Blunt and penetrating esophageal injuries are very rare. Presenting symptoms can be vague but include dysphagia, subcutaneous emphysema, and dyspnea. Mediastinal air and pleural effusion may also indicate an esophageal injury. Esophagram with a water-soluble agent or esophagoscopy should be performed. If the esophagus is perforated and the injury is identified early (<24 h), antibiotics and operative repair with aggressive drainage of the mediastinum and pleural cavity is indicated. Esophageal diversion with a cervical esophagostomy may be required if the perforation is identified late (>24 h). Endoluminal stenting to cover a leak or endoluminal clip application or suturing are options for treatment in some centers with advanced endoscopic resources. In some stable patients with a small contained leak, nonoperative management with IV antibiotics and withholding of oral feedings can be successful.

Thoracic Duct Injury

Thoracic duct injury is very rare in children. These patients will present with a non-bloody pleural effusion high in lymphocytes and lipid content. The effusion can develop days after injury. Treatment includes a chest tube placement for drainage and diagnosis. Bowel rest with parenteral nutrition or feeding with medium-chain triglycerides is also indicated to facilitate spontaneous closure of the injury. Octreotide given IV to limit chylous drainage is controversial but has been reported. Most injuries will heal with these measures. Operative intervention via thoracic duct ligation by thoracotomy or thoracoscopy is indicated after weeks of failed conservative management and chest tube drainage. The repair involves administering cream into the patient's stomach to help identify the chylous leak in the thoracic cavity. If this fails to identify an exact location of the leak, a mass ligation of the soft tissues between the aorta and the esophagus may be performed. Interventional techniques with lymphatic duct ligation may also be an option in some centers. Of note, thoracic duct injury in the absence of a known mechanism has been associated with child abuse.

Diaphragm Injury

A patient with a diaphragmatic injury may be asymptomatic or present with chest pain, abdominal pain, or shortness of breath. Blunt injury is most often on the left as the liver is protective on the right. A CXR may confirm a diaphragmatic injury with herniated loops of bowel in the chest cavity, elevated hemidiaphragm, or nasogastric tube tip in the chest (Fig. 24.5). A chest CT is indicated in questionable cases when the CXR is non-diagnostic. When diagnosed in the acute setting, operative repair is indicated with an abdominal approach and a search for associated injuries, though repair might be amenable to a minimally invasive approach. If the diagnosis of a diaphragmatic injury is delayed, repair via thoracotomy or thoracoscopy is recommended.

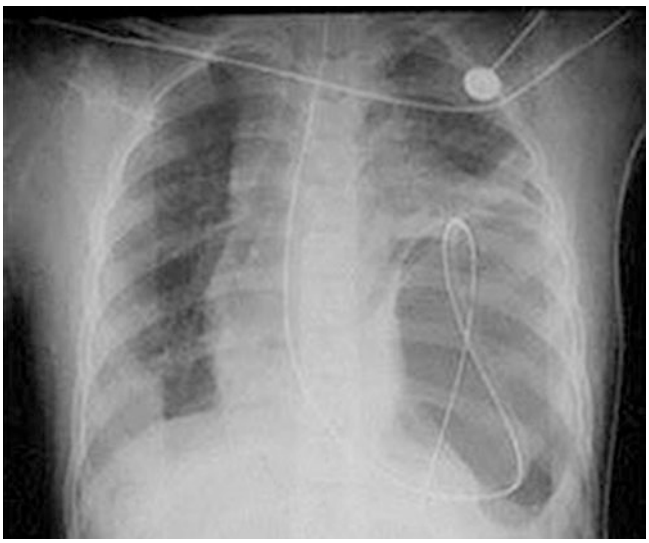

Fig. 24.5 Left diaphragmatic rupture after motor vehicle collision in a restrained child with an abdominal seat belt sign

Editor's Comment

The common life-threatening injuries we see in adults after a blunt thoracic trauma—aortic dissection, myocardial contusion, pericardial tamponade, pulmonary contusion, sternal fracture, flail chest—are rarely seen in children, perhaps a result of their superior tissue resiliency, a more favorable dissipation of kinetic energy due to size differences, and, in the case of a head-on automobile collision, the absence of steering wheel-induced injuries. Nevertheless, these injuries are occasionally seen and easily missed in children. A proper diagnostic algorithm should be followed whenever the mechanism is suggestive. A small amount of mediastinal air or a tiny pneumothorax will sometimes be identified by chest CT after blunt trauma, but in the absence of other signs of significant organ injury, these can generally be regarded as incidental. Nevertheless, they should prompt a meticulous evaluation and a period of careful observation.

Penetrating injuries are becoming more common and require a meticulous approach to identify latent injuries. Trajectories based on the location of entry and exit wounds are notoriously inaccurate because the victim is often in a

contorted position at the moment of impact, missiles can follow tissue planes and therefore fail to travel in a straight line, and bullets can ricochet within the bony cage of the thorax. Not every patient with a gunshot or knife injury to the chest will require an operation, but a pediatric trauma surgeon needs to be involved in every aspect of the care of these children. The most important diagnostic and therapeutic maneuver in a child with a gunshot wound to the chest is the placement of a chest tube. The stable child with a stab wound should have a chest radiograph and could potentially avoid a chest tube if there is no evidence of pneumo- or hemothorax. Placing a chest tube in a child should be done using a gentle technique, under sterile conditions, and after sedation and injection of a local anesthetic. In young children, a small incision that passes through the chest wall obliquely is all that is necessary (if it is big enough to insert your finger, it is probably too big), but it is surprisingly easy to inadvertently place the tube into the subcutaneous tissues and for it to mistakenly appear to be in perfect position on a chest film.

The primary indication for operative intervention in a child with a thoracic injury is bleeding. There is no absolute amount of frankly bloody chest tube effluent that can be used to decide if an operation is needed; this must be based on good judgment. Lung injuries can be over-sewn or repaired with a linear stapler using a vascular cartridge. Esophageal injuries can usually be repaired primarily provided there is healthy tissue to work with and good drainage can be established. The same is true for most tracheal injuries, but when there are injuries to both the airway and the esophagus, viable tissue (pleural or pericardial flap, ligated azygos vein) should be placed between the two suture lines to prevent the formation of a tracheoesophageal fistula. The vagus and phrenic nerves should be carefully identified and protected throughout the procedure. Major vascular injuries should be repaired using standard vascular techniques, including proximal and distal control of the vessels and the use of side-biting clamps, when necessary. Major aortic or cardiac injuries will usually require cardiopulmonary bypass and the assistance of a cardiac surgeon, a decision best made ahead of time rather than in the heat of the moment. In the adult world, aortic injuries are often repaired using endovascular techniques, but stents small enough for children are largely unavailable as of yet. High-volume centers should consider having a protocol in place ahead of time for the very rare but potentially survivable aortic deceleration injury they may see from time to time.

Finally, many thoracic injuries result in diaphragmatic or abdominal injuries that are easily missed if one does not think to rule them out. We still see the occasional diaphragmatic hernia that was missed after a visit to the trauma bay years earlier. We have also found projectiles that have magically found their way into the abdomen after what was thought to have been a through-and-through gunshot wound to the chest. Likewise, a penetrating abdominal or flank injury can easily violate the thoracic cavity.

Further Reading

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