Thoracic Trauma

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Thoracic Trauma

Clinically significant thoracic trauma occurs in 4-6% of injured children. Although thoracic injury is uncommon in children, it is associated with mortality rates of 15-30% [2, 14]. Isolated thoracic injuries are rare in children. 60-80% of children sustaining thoracic trauma have associated injuries and nearly half of these children have a concomitant head injury.

There are several differences in the types of chest injuries sustained by children as compared to adults. The bones in children are more cartilaginous, therefore more pliable and can withstand considerable force without fracture. As a result, rib fractures occur less commonly in children than adults, but children are twice as likely to sustain pulmonary contusions. In fact, pulmonary contusion is the most common thoracic injury in children [16, 43].

The most common thoracic injuries are lung contusion, pneumothorax, hemothorax, and fractures to the ribs, sternum, or scapula. Injuries to the heart, aorta, trachea, bronchi, and diaphragm are much less common but potentially more dangerous.

The most common immediately life-threatening injuries to the chest are airway obstruction, tension pneumothorax, massive hemothorax, and cardiac tamponade. Open pneumothorax and massive flail chest are rare. The most common potentially life-threatening injuries of the chest are myocardial contusion, aortic disruption, ruptured diaphragm, and tracheobronchial disruption. Esophageal rupture is rare.

Diagnosis

A positive physical exam (stridor, chest pain, tracheal deviation, distended neck veins, abnormal or diminished breath sounds, crepitus or dullness to percussion) in the appropriate clinical setting is highly suggestive of thoracic injury, but is neither sensitive nor specific [43].

Most thoracic injuries can be identified and managed on the basis of standard plain film (erect posteroanterior chest radiograph). When the patient cannot get out of bed, mobile X-ray equipment is used to obtain a lying down chest x-ray (known as a "supine film"). As a result most supine films are anteroposterior.

Helical CT and CT angiography of the chest can better delineate injuries identified on plain radiographs [3, 6, 44]. These imaging modalities, however, are not necessary in the majority of children with blunt thoracic trauma and should not be used for screening purposes [8, 22, 43].

In hemodynamically stable children with penetrating injuries, CT can often better define injuries [3, 16]. A modified focused abdominal ultrasound for trauma (FAST) of the thorax has reported utility for the immediate diagnosis of life threatening injuries such as pericardial effusion, pneumothorax, and hemothorax in the unstable adult trauma patient.

An electrocardiogram should be obtained in all children to identify abnormalities in conduction, rhythm, and rate.

Serum creatine phosphokinase-MB (CPK-MB) and cardiac troponin levels (T and I) will demonstrate enzyme leak from injured myocardium but have limited clinical utility in routine patient management [14].
A water-soluble contrast esophagram is sometimes necessary in cases of suspected esophageal perforation.

**Treatment**

The initial management of a child with suspected thoracic injury should follow standard ATLS protocols.

The overall plan is as follows:
1. Primary survey
2. Resuscitation of vital functions
3. Detailed secondary survey
4. Definitive care

The treatment of thoracic injuries varies from supportive only (oxygen, analgesia), to simple interventions (endotracheal intubation, ventilation, tube thoracostomy) to operation (minimally invasive, open thoracotomy), depending on the specific structures injured and the severity of the injuries.

However, most patients do not require an operation and can be managed with supportive measures (oxygen, and analgesia), with or without tube thoracostomy.

Almost all children with thoracic trauma require large-bore intravenous lines for IV fluid replacement, hemostatic drugs and analgesic.

Infectious complications are less likely to develop when antibiotic prophylaxis is administered to patients with thoracic injuries requiring chest drains after penetrating injury, whereas in relatively small blunt trauma patients no effect of antibiotic prophylaxis after blunt thoracic injury was found in meta-analysis (Bosman A., de Jong M.B. and colleagues, 2012).

**Indications for Emergency Thoracotomy**

(David E. Wesson and Charles S. Cox, Jr., 2012) [43]:
1. Penetrating wound of the heart or great vessels
2. Massive or continuous intrathoracic bleeding
3. Open pneumothorax with major chest wall defect
4. Aortogram indicating injury to aorta or major branch
5. Massive or continuing air leak, indicating injury to a major airway
6. Cardiac tamponade
7. Esophageal perforation
8. Diaphragmatic rupture
9. Impalpable pulse with cardiac massage

Pulmonary contusions may be complicated by pneumothorax, hemothorax, or pleural effusion, all of which may require intercostal drainage.

These secondary phenomena are much more common in the presence of concomitant fractures of the bones of the chest wall and may be delayed as long as 48 hours.

**PNEUMOTHORAX**

Pneumothorax is defined as the presence of air or gas in the pleural cavity, which can impair oxygenation and/or ventilation.

Pneumothorax occurs when air enters the potential space between the visceral and parietal pleurae. Air enters into this space:
- from the inside due to a violation of the visceral pleura
- from the outside when the parietal pleura is torn or punctured
Classification of pneumothorax

Pneumothorax is classified according to:
A. Etiology.
B. Extent.
C. Mechanism.
D. Duration.

A. Classification by ‘Etiology’:
Basically:
- Primary pneumothorax
- Secondary pneumothorax

More fully
i. **Spontaneous pneumothorax** – It is the most common form of pneumothorax in clinical practice.
   - Primary spontaneous pneumothorax – occurs in apparently healthy persons due to leak of air through a weak area of the pleura.
   - Secondary spontaneous pneumothorax – is seen in cases with any underlying lung conditions, e.g., COPD usually.

   i. **Traumatic pneumothorax** (non-iatrogenic) – due to blunt or penetrating thoracic trauma

   ii. **Iatrogenic or artificial pneumothorax** – occurs as a result of any diagnostic or therapeutic procedure (postoperative; mechanical ventilation; thoracocentesis; central venous cannulation)

B. Classification by ‘Extent’:
§ **Simple pneumothorax** – without shift of the mediastinum
§ **Tension pneumothorax** – leads to shift of the mediastinum to opposite side and to significant impairment of respiration and/or blood circulation (inferior vena cava “kinks” on diaphragm ® decreased venous return ® cardiovascular collapse ® death)

- **Asymptomatic** – small pneumothorax (<20%) without any clinical signs.
- **Symptomatic** – with clinical signs

- Pneumothorax on right side
- Pneumothorax on left side
- Pneumothorax on both sides
C. Classification by ‘Mechanism’:

- **Open pneumothorax** – when there is movement of air in and out of the pleural cavity without any hinderance. This is due to communication between the pleural space and the airways and may lead to development of a broncho-pleural fistula (BPF).

- **Closed pneumothorax** – when there is no movement of air, i.e., air is trapped in the pleural space because the hole through which air entered has been obliterated.

- **Valvular pneumothorax** – when air is able to enter during inspiration, but is unable to exit during expiration. This type of pneumothorax becomes a medical emergency because the air pressure keeps on increasing gradually, and the lung deflates more and more, leading to pressure effects on the mediastinum and great veins. As an effect, the mediastinum is displaced and the great veins become kinked, leading to decreased venous return to the heart. This leads to increasing cardiac and respiratory embarrassment. At this stage it is usually termed a "tension pneumothorax" because of the rising pressure which builds up in the pleural cavity.

D. Classification by ‘Duration’:

- Acute
- Chronic
- Recurrent

**Etiology**

It most commonly arises:

- Spontaneously (most commonly in tall slim young males and in Marfan syndrome)
- Acute infections (due to complicated pneumonia)
- Following a penetrating chest wound
- Following barotrauma to the lungs

It may also be due to:

- Chronic lung pathologies including emphysema, asthma, tuberculosis
- Lung damage caused by cystic fibrosis
- Cancer

**Diagnosis**

Symptoms of pneumothorax will depend on its type and extent. Usually, the patient experiences severe pain. Often, a small pneumothorax is asymptomatic. But when there is progressive dyspnoea with pain and tightness in the affected side of the chest, then the possibility of tension pneumothorax has to be considered.
The absence of audible breath sounds through a stethoscope can indicate that the lung is not unfolded in the pleural cavity. This accompanied by hyperresonance (higher pitched sounds than normal) to percussion of the chest wall is suggestive of the diagnosis.

The “coin test” may be positive. **NB:** A coin test, which is also called a bell-metal resonance test, is used to determine whether a patient has a lung infection or a collapsed lung.

The test is simple to perform and requires only two coins and a stethoscope. A coin held against the chest is tapped by another coin on the side where the problem is suspected. A stethoscope is placed on the back to listen to breath sounds and the sound of the coins. If a tinkling sound is heard, it is likely that air or fluid has found its way into the pleural cavity. In healthy patients, this sound will not be audible.

If the signs and symptoms are doubtful, a chest X-ray can be performed, but in severe hypoxia, or evidence of tension pneumothorax emergency treatment has to be administered first.

**NB:** On a roentgenogram of the chest, a pneumothorax is classically seen as an area of “absent” lung markings between the bony thoracic cage and the edge of the lung (Image 1).

In a supine chest X-ray the deep sulcus sign is diagnostic, which is characterized by a low lateral costophrenic angle on the affected side. In neonates the use of a transilluminator to suspected area will help visualize the air as radiating rings from light source out [43].

**The assessment of the size of pneumothorax**

The estimated size of a pneumothorax is a key factor in determining the initial management.

For clinical practice, size is assessed on PA chest X-ray mainly by the Light index. There is an excellent correlation \( r = 0.84 \) between the Light index and the amount of air that can be aspirated from a pneumothorax.

The lung dehiscence over the whole length of lateral chest wall is defined as a large pneumothorax, in which case the Light index can be used with a cut-off point of 20% guiding therapeutic strategy.

The Light index is calculated as follows: size of pneumothorax (in %) = \[ 1 - \left( \frac{D_L}{D_H} \right)^3 \] \times 100 where \( D_L \) is the diameter of the lung measured at the hilar level and
D_H is the internal diameter of the hemithorax measured at the hilar level (Image 6.8). In general, a partial pneumothorax is defined as small.

**Differential diagnosis**

1. The sudden onset of chest pain and dyspnoea may simulate:
   - Myocardial infarction.
   - Pulmonary embolism.
   - Pulmonary infarction.
   - Perforated peptic ulcer.

2. Extensive bullous emphysema (“vanishing lung”).
3. Pneumomediastinum.
4. Pneumopericardium.

As air accumulates in the pleural space, the lung becomes compressed and the mediastinum shifts away from the side of pneumothorax – tension pneumothorax (Image 2). With severe mediastinal shift, the pressure in the chest cavity causes compression of the veins returning blood to the heart, leading to cardiovascular collapse and death [34].

Simple pneumothorax occurs in 30-40% of pediatric thoracic trauma victims [14]. Pneumothorax is most commonly identified in association with a rib fracture but also occurs after blunt or penetrating chest injuries without an associated fracture. Initial symptoms include ipsilateral chest pain, dyspnea, tachypnea and restlessness. Pulse oximetry is frequently normal despite the presence of a large pneumothorax.

Image 2 Upright chest X-ray. Tension pneumothorax on right side with mediastinal shift to the left.

Physical examination reveals absent or decreased breath sounds and hyperresonance to percussion on the affected side and tracheal shift away from the side of the pneumothorax. Jugular venous distension is sometimes observed with tension pneumothorax; however, this sign is frequently not present in children with hypovolemia.

The diagnosis of a tension pneumothorax is clinical; treatment is not delayed while awaiting radiologic confirmation [6, 7, 8]. Immediate treatment of a tension pneumothorax is needle decompression in the 2-3 intercostal space at the midclavicular line. Definitive treatment for any pneumothorax is tube thoracostomy in the 4th or 5th intercostal space at the anterior axillary line [1, 3, 16].

Open pneumothorax (sucking chest wound) should be initially managed with a semi-occlusive dressing prior to tube thoracostomy (Image 3).
Image 3. The semi-occlusive dressing used to treat open, or "sucking," chest wounds (open pneumothorax) to alleviate or prevent a tension pneumothorax (a serious complication of a simple pneumothorax).
Occasionally, an asymptomatic pneumothorax will be identified incidentally on the lower chest images obtained during an abdominal CT scan [14].

**Treatment**

Small pneumothoraces are often managed conservatively as they will resolve on their own. Repeat observation via chest X-rays and oxygen administered.

Larger pneumothoraces may require a needle aspiration or chest tube placement (tube thoracostomy).

**Treatment options**

1. **A small or shallow pneumothorax** – less than 20% collapse – can usually be left to absorb spontaneously; this takes about a month. A few days of rest or limitation of activity is all that is required, and it will absorb progressively.

2. **Any type of large pneumothorax** – more than 20% collapse and accompanied by dyspnoea needs to be aspirated using a suitable gauge needle, a large syringe, and a two-way tap.  
   **NB:** The puncture site is commonly in the second or third intercostal space in the midclavicular line or in the 4th or 5th intercostal space over the superior rib margin in the anterior axillary line

3. **In the presence of a continual leak.** A plastic or rubber catheter is inserted on the same site. The catheter is to be connected to an underwater-seal bottle. This helps evacuate the air. The intercostal tube is usually left in situ for 24 hours after full re-expansion of the lung has been achieved, i.e., a total period of 3 – 4 days in most cases. A tube in the chest is quite painful and analgesics are necessary – if there are no contraindications like asthma, severe bronchitis, or emphysema – to make the patient comfortable.

4. In a case of **tension pneumothorax** – it is a life-threatening emergency that requires instant action. Severe symptoms and signs of respiratory distress suggest the presence of tension pneumothorax.
Treatment is with oxygen and emergency needle decompression [1, 3, 34].

Insert a large-bore needle into the pleural space through the second or third anterior intercostal space. A gush of air confirms the diagnosis.

Typical clinical situations where tension pneumothorax arises include:

- Ventilated patients
- Trauma patients
- Resuscitation patients (CPR)
- Lung disease, especially acute presentations of asthma and COPD
- Blocked, clamped or displaced chest drains
- Patients receiving non-invasive ventilation
- Patients undergoing hyperbaric oxygen treatment

If the valvular mechanism continues to function, the tension element will recur and the needle must then be replaced with either an indwelling needle of the Foster-Carter type, or by an intercostal catheter (Malecot type), connected to a water-sealed suction until the lung re-expands and seals off the leak [14, 34, 43].
5. When there is a **large air leak and aspiration proves inadequate** – a thoracoscopy (or thoracotomy) with suturing of the damaged lung / bronchus is necessary.

**NB:** In all cases where a chest tube has been inserted, the rule of thumb is that the tube should not be removed till bubbling in the underwater-seal bottle is absent on coughing, and the lung has re-expanded. Also, the tube should not be left in one position for more than seven days. But if the tube is still required, it should be replaced through a new puncture 2 cm away [43, 34].

**HEMOTHORAX**

Hemothorax occurs in 10-15% of pediatric thoracic injuries. *The most common cause of a hemothorax is injury to a systemic vessel* (i.e., intercostal vessel, internal mammary artery, etc.). Other causes include hemorrhage from the great vessels or the pulmonary hilum (often fatal) and bleeding from the lung parenchyma (5%).

As with the diagnosis of pneumothorax, the anterior-posterior radiograph is helpful in diagnosing hemothorax.

Initial treatment consists of **tube thoracostomy** to evacuate the blood from the pleural space and to expand the lung [1, 5, 8, 36, 43]. In addition to improving oxygenation and ventilation, this maneuver provides a tamponade effect and reduces the bleeding.

Placement of two large bore intravenous lines with fluid warmers, the immediate availability of type specific blood and an autotransfusion device are recommended **prior** to tube thoracostomy for a massive bleed.

In most cases, intercostal drainage is the only treatment needed. However, exploratory thoracotomy (minimally invasive, open thoracotomy) may be indicated for the following reasons [14, 43]:

Auto-transfusion may be helpful during surgery for massive intrathoracic bleeding.

**NB:** The new data define the indications, morbidity, and mortality of thoracoscopy and suggest that thoracoscopy may emerge as the procedure of choice in the diagnosis and management of thoracic injury.

Failure to evacuate the majority of blood in the pleural space sometimes results in empyema or fibrothorax (“trapped lung”) and requires prolonged hospitalization and thoracotomy for treatment.

**AORTIC INJURY**

Thoracic aortic injury is an uncommon injury in children and is almost always due to severe deceleration or crush type injury [16, 36]. Injury to the aorta accounts for approximately 2% of the unintentional deaths in children.

Although the risk of traumatic aortic rupture is higher in adults than children, the risk of death from this injury is higher in children. The most common location of aortic injury due to blunt trauma is similar in children and adults. It occurs immediately distal to the take off of the left subclavian artery, generally where the ductus arteriosus previously entered the aorta. The descending aorta is fixed at this point; therefore, the shear stress encountered during a sudden deceleration is greatest at this point.

Aortic injuries in children are frequently accompanied by multisystem trauma. The overall mortality for this injury is 90%.

The diagnosis of aortic injury is suspected when there is a history of significant deceleration or crush injury, accompanied by findings of profound shock, chest pain and possible paraplegia. Other signs that suggest aortic transaction include hoarseness, dysphagia, or thoracic spinal injury.

Chest X-ray findings suggestive of aortic injury include [14]:

1. mediastinal widening;
2. prominent aortic knob;
3. left first rib fracture or scapular fracture;
4. elevated left mainstem bronchus;
5. deviated esophagus (deviated nasogastric tube);
6. left pleural effusion and obliterated aortopulmonary window.

Children suspected of having aortic injury should undergo immediate aortography. Recently, dynamic thoracic computed tomography has gained acceptance in some centers as a sensitive diagnostic modality [36, 43].

Treatment includes emergent thoracotomy, usually through a left posterolateral incision and direct suture repair.
PERICARDIAL TAMPONADE

Pericardial tamponade is very rare in children. A history of a penetrating wound or severe deceleration is common.

Physical signs include tachycardia, hypotension, muffled heart tones and distended neck veins. Children who present in hypovolemic shock will not manifest distended neck veins until resuscitation, if at all. Although pulsus paradoxus is a prominent feature in adults with this condition, it is often difficult to demonstrate in an injured child.

The diagnosis of pericardial tamponade is suggested by an abnormally elevated or steadily increasing central venous pressure. In the hemodynamically stable child, transthoracic echocardiogram confirms the diagnosis [14, 36, 43].

The chest X-ray frequently demonstrates a left pleural effusion or an abnormal cardiac silhouette. In the unstable child, pericardiocentesis provides dramatic relief of symptoms and provides definitive diagnosis.

Aspiration of blood that does not easily clot confirms the diagnosis and produces rapid clinical improvement.

PULMONARY CONTUSION

Pulmonary contusion is an injury to the lung parenchyma resulting from direct trauma that causes hemorrhage, edema and dysfunction.

NB: Pulmonary contusion is the most common thoracic injury in children.

In children, the compliant chest walls decreased thoracic musculature and cartilaginous ribs allow a significant transfer of kinetic energy to the lung parenchyma without overlying rib or chest wall injury.

Pulmonary contusions are commonly identified by chest X-ray and confirmed by CT. Clinically, children with pulmonary contusion exhibit hypoxia, ventilation-perfusion mismatch and atelectasis.

Extrathoracic injuries associated with pulmonary contusion include splenic/hepatic lacerations and closed head injury. Associated intrathoracic injuries include mainly hemothorax and pneumothorax that occur in over 50% of the children with significant pulmonary contusion [3, 6, 14].

Children with severe pulmonary contusion are tachypneic, hypoxic and dyspneic. Yet, the initial physical examination is often misleading and these findings are absent in over 50% of cases [14].

The initial chest radiograph usually reveals patchy infiltrates or a small pleural effusion. The radiographic findings typically worsen over the ensuing **48 hours** and correlate with the clinical findings.

Treatment is primarily supportive and involves **aggressive pain management and antibiotics**. Most children with pulmonary contusion do not require intubation or mechanical ventilation. Children who do require mechanical ventilation have a 2-fold increased risk of pneumonia and an increased incidence of respiratory distress syndrome [14].

DIAPHRAGMATIC INJURY

Traumatic diaphragmatic injury is very uncommon in children and accounts for less than 2% of all pediatric thoracic injuries [14].

Over 90% of blunt injuries to the diaphragm occur on the left side. Associated injuries are common, especially to the abdominal viscera and pelvis. In children with blunt diaphragmatic rupture, there is also an increased incidence of head injuries [14, 43].

Diaphragmatic injury is suspected and ruled out in all cases of penetrating trauma below the level of the tip of the scapula or the nipples.

**Radiologic findings suggestive of diaphragmatic rupture include:**

1. the tip of the nasogastric tube above the diaphragm
2. bowel gas or gastric bubble in the chest
3. obscured or elevated left hemidiaphragm

Ultrasonography, CT and contrast studies have all been used to make the diagnosis of diaphragmatic perforation, but all have high false-negative rates for small perforations. DPL, thoracoscopy, or laparotomy are the more sensitive methods to identify diaphragmatic injuries. Treatment is surgical repair. Although thoracoscopic repair has been described, laparotomy is favored due to the high (greater than 50%) likelihood of associated hollow viscus injury [14].

TRACHEOBRONCHIAL RUPTURE

Tracheobronchial rupture (TBR) occurs in less than 2% of children with thoracic trauma. TBR affects older children with males greatly outnumbering females. The mortality rate in children with TBR is approximately 30% and over half of these children sustain severe associated injuries [14].

The mechanism of injury is thought to be either a sudden shearing force or compression causing a rapid increase in transverse thoracic diameter and disruption of the tracheobronchial tree at fixed points near the carina and cricoid cartilage.

NB: Bronchial injuries are characterized by persistent pneumothorax and often massive air leak following tube thoracostomy.

Nearly 80% of cases of TBR occur within 2 cm of the carina and another 15% occur in the more proximal trachea.

The immediate management of children with TBR includes securing the airway, ensuring adequate ventilation and tube thoracostomy.

Definitive treatment usually requires surgery and direct repair of the disrupted bronchus or tracheal tear [4, 5, 43]. In cases with severe air leak compromising ventilation, a double lumen endotracheal tube or selective contralateral mainstem intubation is often helpful [14, 43].