CHAPTER 28
Thoracic Trauma

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Introduction

The physiological constitution of children differs substantially from that of adults. As a result, injured children often require specific management as compared to adults. This chapter focuses on the management of chest trauma.[1–3]

Chest injuries occur commonly in children and include damage to the chest wall, diaphragm, lungs, and mediastinal structures. The presence of chest injury often portends involvement of other organs, reflecting the transmission of substantial force to the child's compact body. The severity of chest trauma in children ranges from minor to rapidly fatal. It is therefore imperative to promptly diagnose and appropriately treat these injuries to ensure an optimal outcome.

Anatomic Considerations

The chest wall in children is elastic; therefore, energy can be transmitted to underlying organs without breaking the protective ribs. Severe pulmonary contusion or injuries to spleen and liver can occur without overlying rib fractures. Rib fractures and mediastinal injuries are distinctly uncommon in children, and when present they usually indicate the transfer of a massive amount of energy; multiple serious organ injuries should be suspected.[4] The mediastinum is highly mobile in children, and a tension pneumothorax can develop rapidly.[5]

Resuscitation

All resuscitations should strictly follow the general ABC pattern of basic life support, as discussed in Chapter 27.

Demographics

Chest injuries are the leading cause of childhood injury death. Approximately one million children globally die annually as a result of trauma. The most common cause of trauma is motor vehicle crashes. Thoracic trauma in children may be classified by mechanism, anatomical site, and severity (immediately or potentially life threatening). The vast majority of thoracic injuries result from blunt trauma, usually inflicted to a child pedestrian by a motor vehicle. Less than 5% are attributable to penetrating injuries.

Penetrating chest trauma in children, just as in adults, is often the result of knife stabs or gunshot wounds. These include BBs or pellets fired from recreational air guns that can produce life-threatening injuries. Other unusual causes of penetrating trauma seen in children 12 years of age or younger include impalement onto shards of broken glass or metal rods.

Most chest injuries occur as a part of multiple injuries, including head and abdominal injuries, and it is these associated injuries that expose these children to a high mortality. It is therefore crucial to assess the whole patient in the case of a chest injury. Paediatric trauma scores may help to identify mortality early in this patient population to facilitate and expedite treatment.

Clinical Presentations

Chest Wall Injuries

The elasticity and flexibility of a child's chest cage often protect the child from a serious injury. If rib fractures do occur, however, this is usually a sign of a major energy transfer to the child's chest and often indicative of a high-velocity injury. A flail segment is an unusual event in a child, and the underlying pulmonary contusion is much more important for the prognosis than the flail segment itself.

Rib fractures are extremely painful because immobilisation is practically impossible. Therefore, adequate analgesia is of the utmost importance to render the child pain-free and to ensure adequate breathing. Intravenous morphine is the drug of choice (as bolus: 0.1 mg/kg body weight). Oral analgesia is not often tolerated, and intramuscular (IM) or subcutaneous drugs often are poorly absorbed. Respiratory exercises are essential in the proper management. In the case of multiple rib fractures, admission to a specialised trauma unit with availability of continuous chest physiotherapy is preferred.

Traumatic Asphyxia

Traumatic asphyxia usually occurs as a result of major chest and sometimes abdominal trauma. The exact pathophysiology is not clearly understood, but the proposed mechanism is a closed glottis and tensed abdominal muscles, causing the force of the injury to be transferred to the superior vena cava and to the head and neck, with subsequent rupture of the superficial blood vessels. Usually, the child presents tachypnoeic with petechiae over the face, neck, and chest. Additionally, the face might be blue and swollen, and retinoscopy might reveal retinal haemorrhages.

Children suffering from traumatic asphyxia should be very carefully examined for underlying injuries of the vital organs. Treatment should be symptomatically; however, because these children are likely to develop respiratory insufficiency, they should be managed in a paediatric intensive care unit (PICU). Long-term follow-up of isolated traumatic asphyxia has proven to have an excellent prognosis.

Tracheobronchial Injuries

Like oesophageal injuries, tracheobronchial injuries are rare. Rupture of the trachea or bronchae is usually complete, associated with vascular and oesophageal injuries, and occurs mostly within 2.5 cm from the carina. Proper airway management takes priority; the injuries can usually be repaired primarily via a thoracotomy.

In the event of a tracheo-oesophageal injury, it is crucial to establish a muscular or pleura flap between the injuries to prevent a fistula.

Lung Injuries

Lung contusion is one of the most common childhood chest injuries, followed by infection and haematoma. It occurs in approximately two-thirds of all cases of chest trauma. Usually, it results from a rapid acceleration/deceleration injury (primarily motor vehicle collisions). Contusions occur within minutes after the injury, are mostly localised to a (lower) segment or lobe of the lung, and can be diagnosed on the initial chest radiograph.

Management is symptomatic, but intensive care is often required in the initial phase, where there is danger of respiratory collapse and ventilation might be indicated for adequate oxygenation. The prognosis is good if infection does not occur; healing can be expected within 1–2 weeks. Unfortunately, in two-thirds of these cases, infection occurs due to the extravasation of fluid and blood in interstitium and alveoli, which creates an excellent microbial culture medium. Ventilation efforts are often poor due to pain, and without active and passive chest physiotherapy, the prognosis is poor.

Pulmonary haematoma is rare. It is usually caused by an injury to a major blood vessel within the lung, creating a so-called coin-lesion in the lung tissue. Management is nonoperative, except in massive bleeds.

Simple Pneumothorax

Pneumothorax is a common occurrence in childhood chest injury. Collapse of the lung might be caused by a penetrating injury, a rupture of lung parenchyma, or a tear in the oesophagus or tracheobronchial tree.

Physical signs are diminished breath sounds, poor motion of the hemithorax, hyperresonance to percussion, subcutaneous emphysema, and deviation of the trachea to the ipsilateral site. Diagnosis is confirmed with an erect expiratory chest radiograph.

Treatment consists of a tube thoracostomy in the 4th intercostal space, in the anterior axillary line, under adequate analgesia. Care should be taken not to cause injury to the lung parenchyma or diaphragm during the insertion of the tube. An underwater seal should immediately be connected to the bottle. If the child is asymptomatic and can be closely monitored, aspiration or even observation of a simple pneumothorax may be appropriate, but the resources to rapidly insert a chest tube must be available in the event of any deterioration.[5]

Tension Pneumothorax

Progressive accumulation of air under pressure in the pleural space is usually due to a valve-effect tear in the lung parenchyma. It may lead to ipsilateral collapse of the lung and mediastinal shift, thereby compressing the (only properly ventilating) contralateral lung. This might result in severe impairment of ventilation as well as compromise the venous return to the heart, and is often a lethal condition if not acted upon rapidly.

Diagnosis should be made clinically. Decreased breathing sounds, a hyperinflated ipsilateral hemithorax, trachea deviation to the contralateral side, and a severely distressed patient all indicate that a fast needle-puncture of the anterior chest (2nd intercostal space, midclavicular line) will be life saving. The needle has to be replaced by a proper tube thoracostomy as soon as possible because blockage occurs frequently, and the excursions of an inflated lung will damage its visceral pleural surface against the sharp tip of the needle.

Haemothorax

Haemothorax is the accumulation of blood in the pleural space. Up to 40% of the blood volume can easily be lost in one pleural cavity. The blood loss usually arises from injury to a major artery, either from the chest wall or the lung, although this is not always the case. Persistent bleeding from an intercostal artery or a tear in the lung parenchyma can also produce major blood loss.

The diagnosis is made clinically and confirmed with an erect chest radiograph. Blood in the lower part of the pleural cavity often causes referred pain in the upper abdomen. Once the haemothorax is drained, the abdominal symptoms disappear.

Treatment consists of chest tube thoracostomy; only rarely is a thoracotomy indicated. The main indications for thoracotomy are ongoing active bleed while an intercostal drain is in place, or an infected haemothorax (usually 5–7 days after injury). On rare occasions, a massive haemothorax may lead to a tension haemothorax with deviation of the heart and mediastinum to the opposite side (Figure 28.1).

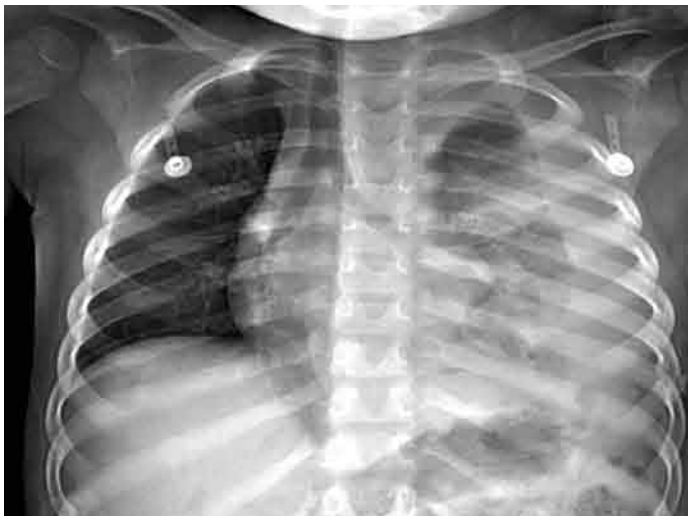

Figure 28.1: Chest radiograph of a ruptured left hemidiaphragm, with displacement of the heart and mediastinum to the right.

Oesophageal Injuries

Fortunately, due to the location of the oesophagus, injuries to it are rare. Transmitted pressure from the stomach may cause either Mallory-Weiss bleeding (if the lower oesophageal sphincter is closed) or the more sinister Boerhaave syndrome, characterised by perforation of the lower oesophagus into the left chest cavity (if the upper oesophageal sphincter is closed).

Penetrating injuries may cause oesophageal injuries if they are *transthoracic*. Radiographic contrast studies and/or endoscopies are strongly advocated in these cases. A nonionic contrast material should be used.

The management of the oesophageal injuries depends on the nature of the injury, the timing of presentation, and the location. With the exception of major (high-velocity) gunshot injuries, the majority can be repaired primarily within 24 hours of the injury. Beyond the first 24 hours, the operative strategy may include oesophageal diversion, exclusion, T-tube drainage, or even total oesophagectomy.

Cervical oesophageal injuries

Cervical oesophageal injuries rarely represent a large problem because leakage from a repair produces localised tissue infection or abscess, which can be drained externally.

Thoracic oesophageal injuries

Thoracic oesophageal injuries are notorious for the fast spread of saliva, food, and acid from the stomach through the injury into the chest, able to cause a rampant and usual lethal mediastinitis. Oesophageal diversion might be indicated in these cases.

Abdominal oesophageal injuries

Abdominal oesophageal injuries will usual present as an acute abdomen and will require a laparotomy for repair.

Diaphragmatic Injuries

Traumatic disruption of the diaphragm is usually caused by blunt trauma. It involves the left side in the majority of cases. The injury is high velocity in nature, such as from motor vehicle collisions and falls from a height. Because the force required to damage the diaphragm is considerable, associated injuries are common (about 80%) and include intrathoracic and intraabdominal as well as extratruncal injuries.

The clinical presentation varies according to the associated injuries; an isolated diaphragmatic rupture can easily be misdiagnosed. In children, the mechanism of injury might be slightly different from that in adults. Whereas in adults the typical injury involves the dome of

Figure 28.2: Chest radiograph of a ruptured left hemidiaphragm, with displacement of the heart and mediastinum to the right.

the diaphragm (as a blow-out), rupture in children seems to take place more often along the periphery of the diaphragm (probably due to the increased elasticity of the chest wall).

Diagnosis is made on an erect radiograph, which typically shows the nasogastric tube in the stomach above the diaphragm (Figure 28.2). However, herniation can involve nearly any intraabdominal organ, and the appearance of the stomach below the diaphragm does not exclude a diaphragmatic rupture.

Penetrating injuries in the lower half of the chest as well as the upper part of the abdomen can involve the diaphragm. In these cases, herniation will rarely occur in the acute phase, but an undiagnosed hole in the diaphragm can lead to complications on the long term. Repair should be performed via a laparotomy, during which the state of the intraabdominal organs also can be assessed.

Heart and Pericardium

Blunt chest trauma can produce several types of cardiac injuries, including contusions, concussions, and frank rupture of the myocardium, a valve, a septum, and—very rarely—a coronary artery. Pericardial tears leading to herniation of the heart often lead to diminished cardiac function and a low output state. Occult structural cardiac injuries (i.e., atrial or ventricular septal defects, valvular insufficiency, and ventricular aneurysm formation) may also occur and present without physiologic signs of injury. Often, these injuries are identified only after a new murmur is noted or a change in the electrocardiogram (ECG) occurs. Echocardiography, when available, can assist to confirm the diagnosis.

Myocardial contusion

The most common type of blunt cardiac injury is the myocardial contusion. Unlike myocardial concussions, myocardial contusions produce focal damage to the heart that can be demonstrated histologically. Patients with myocardial contusions often have an associated chest wall injury. Many tests have been proposed to diagnose a contusion (e.g., echocardiography, electrocardiography, enzyme determinations, and nuclear imaging), but still no definitive diagnostic test exists. A 12-lead ECG is the simplest test and may show reversible changes in the ST and T waves. Symptomatic myocardial contusions are diagnosed by echocardiography based on finding a reduced ejection fraction, localised systolic wall motion abnormalities, and an area of increased end-diastolic wall thickness and echogenicity.

Myocardial contusions may be silent and asymptomatic, can present with cardiovascular collapse from reduced cardiac output, or cause arrhythmias that may be life threatening.

The treatment of myocardial contusions remains supportive, with 12- to 24-hour electrocardiographic monitoring and inotropic support as needed. Most authors recommend cardiac monitoring in an intensive care unit to identify arrhythmias. Patients with arrhythmias and obvious thoracic injuries should be monitored with ECG, serum cardiac enzymes, and echocardiogram as needed.

Myocardial rupture and valve injury

Traumatic rupture of any chamber of the heart usually results in rapid death. The most common cause of death from thoracic injury is myocardial rupture. The majority of these are due to high-energy impacts such as motor vehicle collisions or falls from great heights. The majority of these patients die at the scene. The right ventricle is the most commonly ruptured cardiac chamber. Children with myocardial rupture present *in extremis* with pericardial tamponade. Patients with traumatic atrial or ventricular septal defects may be clinically stable, with the only finding being that of a new murmur. Early diagnosis and repair is mandatory for survival from these lethal injuries.

Valvular injuries may occur following severe blunt chest trauma, but these are rare. The atrioventricular valves are most susceptible to injury, and the damage often occurs to the valve apparatus (i.e., annulus, ruptured chorda tendinae, or papillary muscle). These injuries in clinically stable patients may be repaired electively.

Pericardial tamponade

The accumulation of blood within the pericardial sac from blunt or penetrating trauma can produce pericardial tamponade. Although a range of clinical signs may be seen, the most common presentations are tachycardia; peripheral vasoconstriction; and the Beck's triad of jugular venous distention, persistent hypotension unresponsive to aggressive fluid resuscitation, and muffled heart sounds. In resource-poor environments, the tools needed to establish an accurate diagnosis, such as an ECG or focused abdominal sonography for trauma (FAST), often are not available. Although pericardiocentesis can be life saving, it should not be done by those without the proper training and skill.

Resuscitative Thoracotomy

Immediate resuscitative thoracotomy may be life saving when performed in children with penetrating trauma who arrive pulseless, but with myocardial electrical activity.[5] However, even when myocardial function is restored, survival ultimately requires additional operative procedures and intensive care, which are generally not available in resource-poor African subregions. Under these conditions, resuscitative thoracotomy becomes a futile exercise. In any case, such heroic measures are rarely effective following blunt trauma, which is far more common than penetrating trauma in children.[6]

Pitfalls in the Management of Paediatric Thoracic Trauma

Several pitfalls exist in the management of paediatric thoracic trauma, as outlined here.

- Underestimating the degree of chest injury at the initial survey because of little external evidence and performing only a supine chest radiograph.
- Administration of excess intravenous fluid during resuscitation, aggravating pulmonary contusion and oedema.
- Inadequate analgesia and chest physiotherapy, promoting retention of secretions, which leads to pulmonary infection.
- Iatrogenic damage through emergency (and faulty) procedures such as endotracheal intubation, chest drain insertion, and central line insertion.

Prevention of Thoracic Trauma

The top three causes of child mortality from unintentional injury are road traffic collisions (32%), drowning (17%), and burns (9%).[7] All of these causes are highly preventable.[2] Factors that influence injuries are

supervision, particularly of small children; a single caregiver; a home with multiple siblings; and substance abuse by the caregiver and in large families. Although these risk factors are located within particular households, the larger context in which they operate cannot be ignored; child safety is ultimately a matter of crucial concern for all societies. Some studies have demonstrated the feasibility of interventions to reduce child mortality and morbidity from unintentional injury.

Risk factors for child abuse include the demographic characteristics of the child (e.g., younger age); caregiver characteristics (e.g., prior history of abuse); family structure and resources; and community factors (e.g., increased poverty, decreased social capital).[8–9]

Evidence-Based Research

Table 28.1 presents a retrospective review of paediatric blunt chest trauma.

Table 28.1: Evidence-based research.

Title	Blunt chest trauma in childhood
Authors	Inan M, Ayvaz S, Sut N, et al.
Institution	Departments of Pediatric Surgery and Biostatistics, Faculty of Medicine, Trakya University, Edirne, Turkey
Reference	ANZ J Surg 2007; 77:682–685
Problem	Evaluate the clinical features of children with blunt chest injury and investigate the predictive accuracy of their paediatric trauma scores.
Methods	Retrospective review evaluating children with blunt thoracic trauma.
Outcomes	Forty-four patients were identified, of which 27 were male and 17 were female. The mean paediatric trauma score was 7.6 ± 2.4. Causes of injury consisted of motor vehicle/pedestrian collisions, 19 cases; motor vehicle collisions, 11; falls, 8; and motor vehicle/bicycle or motorbike accidents, 6. Injuries included pulmonary contusions, 28; pneumothoraxes, 12; haemothoraxes, 10; rib fractures, 9; haemopneumothoraxes, 7; clavicle fractures, 5; flail chest, 2; diaphragmatic rupture, 1; and pneumatocele, 1. In this cohort, 27 patients were managed nonoperatively, 17 were treated with tube thoracostomy, and 2 required thoracotomy. Four patients (9.09%) had concomitant abdominal injuries.
Comments	Thoracic injuries are rare in children and are a predictor of severe and multiple—frequently fatal—injuries.
Historical significance/ comments	This well-written article takes the reader through the historical development of some trauma scoring systems and provides a very good overview of frequently used systems. The authors even inform readers about an ideal scoring system: it should correlate well with the desired outcome (e.g., death, disability, costs, etc.); it should be reasonable to clinicians and correlate with their judgement; it should use available data; it should be reliable among different users; and it should be simple. This is, in fact, what all scoring systems should be.

Key Summary Points

1. The majority of thoracic injuries can be diagnosed by a good clinical exam and a plain chest x-ray.
2. The majority of chest trauma in children can be treated nonoperatively, often with a well-placed chest tube.
3. Life-threatening injuries from thoracic trauma are relatively uncommon in children, and when they occur, they are related to associated head and abdominal injuries.
4. Optimum treatment and outcomes can be achieved only by having a thorough understanding of the unique anatomy and physiology of children.
5. Even the most severe of injuries requiring operative therapy can, if recognised early, be managed successfully.

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