Thoracic Trauma

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11.1 Introduction

Injuries involving the chest are one of the most lethal, after the intracranial injuries. However, it is usually the associated injuries that determine the ultimate outcome.

Children <10 years are more likely to develop hypoxia because of lower functional residual capacity to total lung volume ratio, and a higher rate of tissue oxygen consumption.

The mediastinum is more mobile in children allowing rapid development of tension pneumothorax, and the increased mobility of viscera leads to a greater risk of kinking of the great vessels, reducing preload leading to shock.

By 13 years of age, the chest wall responds to trauma more like that of an adult.

11.2 Mechanisms of Injury

- Blunt (85%): MVA, Bicycle related, sports related, falls from height, and blast injury.
- Penetrating (15%): Knives, gunshot, impalement on railings, or fence posts.

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11.3 Anatomy

Cardiopulmonary structures are protected by the bones and muscle of the chest wall allowing just enough flexibility to breathe but resistance to most severe crushing or penetrating force. The pediatric thoracic wall is more compliant (due to thicker periosteum surrounding immature bone) allowing ribs to bend rather to break, and transfers a greater force to underlying thoracic organs. Visible rib fractures imply a greater degree of trauma in children than adults.

11.3.1 Surface Landmarks

• Manubriosternal Angle of Louis[1]—insertion of the 2nd rib	T4/5 level
• Vertebra prominens	Spine of C7
• Nipple line—Overlies the fourth intercostal space	
• Diaphragm—Right dome higher than left	T 9/10 level

11.4 Principles of Management

- **Primary survey** for *immediately* life-threatening injuries: Airway obstruction, tension pneumothorax, open pneumothorax, massive hemothorax, flail chest, and cardiac tamponade.
- **Secondary survey** for *potentially* life-threatening injuries: Pulmonary contusion, myocardial contusion, aortic disruption, traumatic diaphragmatic rupture, tracheobronchial disruption, and esophageal disruption.

11.5 Rib Cage Injury

These range from contusion, through actual rib fracture (commonest 4th–9th) to multiple segmental involvements and a flail chest. Such trauma increases the work of breathing, either through inhibition due to pain or by rendering the actual mechanics of breathing impossible. There is a degree of inherent elasticity in the structure (anteroposterior rather than lateral) in children. So, sometimes, this results in severe lung parenchymal crush injury, yet, the shell remains intact.

11.5.1 Flail Chest

- ≥3 ribs broken twice, or disarticulation of ribs from sternum.
- Paradoxical movement of the chest wall (i.e., moves inward on inspiration).

[1] Antoine Louis (1723—1792) French surgeon, also key figure in the development of guillotine!

11.5.2 Non-accidental Trauma/Child Abuse

Violent squeezing of the chest in non-accidental injury (NAI) can lead to multiple sequential rib fractures with less underlying lung injury. Often rib fractures due to NAI occurs in the posterior aspect of the rib, and may be difficult to diagnose. These can be key observations in the investigation of NAI. As posterior rib fractures are so difficult to diagnose in the acute phase, it is recommended that radiographs are repeated at about 10 days to look for the callus formation.

Note that rib fractures do not follow cardiopulmonary resuscitation (CPR) in children.

11.5.3 Investigation

1. CXR (AP and lateral)—are the first line investigations. N.B. cartilaginous ribs may not show injury. Ultrasound can diagnose rib fractures but it is very operator dependent.
2. Whole-body CT:
   (a) Unenhanced head and cervical spine, and contrast-enhanced chest, abdomen, and pelvis CTs, for severe multi-trauma patients in children is debatable.
3. Extended-Focused Abdominal Sonography for Trauma (eFAST)
   (a) Aimed to evaluate heart, abdominal organ, pelvis, and chest cavity and allows rapid identification of pneumothorax, hemothorax, and diaphragm rupture.
   (b) Can be done when access to CT is limited.

11.5.4 Caveats and Atypical Injury

- First and second rib fracture—should be well-protected, presence implies significant blunt force. Beware of the injury to underlying subclavian vessels.
- Sternal fracture—seen in association with seat-belt use and steering wheel. Uncommon in children (because of ↑elasticity). Obtain ECG and cardiac enzymes.
- 10–12th rib fracture—suspect underlying liver, spleen, or kidney injury.
- Care is needed in interpretation of the ossification centers (most are fused by adolescence).

11.5.5 Management

1. Analgesia—multimodal
   (a) NSAI, opiate-based regimen (including patient-controlled analgesia (PCA)).

(b) Local infiltration at the fracture site.
(c) Epidural anesthesia.
2. Underlying lung contusional injury (see later).
3. Treatment of a flail chest depends on its severity and functional impact; but endotracheal intubation and intermittent positive pressure ventilation (IPPV) removes the mechanical element of lung dysfunction, and analgesics. N.B. flail "stabilization" is controversial but ranges from simple "strapping," to operative fixation.

11.6 Parenchymal Injury

Wide range of pathology from simple contusion through laceration, and segmental vessel injury to major hilar injury involving bronchus, tracheal, and pulmonary vessels. The effect of injury is manifest in three interrelated ways:

- Contusion—↓ventilation/perfusion (i.e., $\downarrow pO_2$, $\uparrow pCO_2$)
- Air leak (i.e., pneumothorax)
  - Open—penetrating
  - Closed
  - Tension—valve effect leading to accumulation under pressure
- Bleeding (i.e., hemothorax)

11.6.1 Clinical Features

Lung contusion is the commonest type of thoracic injury in children and results from blunt force trauma. The injury evolves from simple blood and edema inside alveoli to a widespread inflammatory reaction (*Adult* Respiratory Distress Syndrome—ARDS) over about 24 h. Secondary bacterial pneumonia is possible after 3–5 days.

11.6.2 Investigation

1. Chest XR—usually underestimates the degree of parenchymal injury. Alveolar bleeding pushes air out of the lung giving a similar appearance to liver tissue (*hepatization*). Non-segmental consolidation, often sparing the peripheral fields.
   (a) Serial CXR needed to look for delayed appearing consolidation or the development of ARDS.
2. Chest CT scan—may overestimate the injury as it is able to diagnose small contusions of limited clinical significance.

3. Ultrasound may diagnose pulmonary contusions more rapidly because B lines from edema and alveolar disruption appear rapidly.
4. Arterial blood gas—↓ O_2 saturation (<90%), ↓pO_2, ↑pCO_2 (late).

11.6.3 Treatment

- Supportive—supplemental O_2, CPAP, IPPV
- Avoidance of fluid overload, caution with blood products (exacerbates ARDS)

11.7 Pneumothorax

A "sucking" wound may be obvious, but a tension pneumothorax needs to be looked for. The key signs are hyperresonance, mediastinal shift (trachea, cardiac impulse), and ↓breath sounds. If untreated, this will cause impairment of venous return, caval kinking, hypotension, and death.

Surgical emphysema and crepitus imply that air is leaking from the pleural space into the subcutaneous tissues via fascial planes.

11.7.1 Investigation

1. Chest XR (in expiration if possible) is a better predictor of clinically significant injuries and outcomes. In the ventilated patients signs of a pneumothorax in the supine position are hyperlucency of affected hemithorax, a sharp heart border, a deep costophrenic sulcus with sharp margins, and a double diaphragm sign.
2. Chest CT scan—may overdiagnose clinically insignificant contusion and hemothoraces.
3. e-FAST—"*Lung sliding*" appears if the visceral and parietal pleura are free to slide over each other with respiration. Additionally, "*comet tail artifacts*" require the parietal and visceral pleura to be aligned for visualization. These occur when water under the visceral pleura vibrates. Both "*lung sliding*" and "comet tails" will be interrupted and abolished by subcutaneous emphysema, pleural adhesions, or air or blood distending the pleural and suggest the presence of a pneumothorax.

11.7.2 Treatment

- Urgent needle thoracostomy (followed by formal tube thoracostomy).
  - Second intercostal space, midclavicular line.

- Tube thoracostomy.
  - "Large-bore" but compatible with rib-space (~32 Fg. in an adolescent).
  - 4/5th intercostal space—anterior/midaxillary line.
  - Incise skin, blunt dissection through rib-space with artery forceps. Enter pleural cavity. N.B. "*Finger sweep*" is usually impossible in a child.
  - Insert tube (**Apex for Air, Base for Blood**).
- Open pneumothorax/ sucking—implies single-lung ventilation only.
  - Close/occlude defect in the chest wall via Vaseline© gauze, three-way occlusion dressing or actual suture closure and insertion of a chest tube at a different site.

11.8 Hemothorax

One side of chest can hold up to half of a child's total blood volume. The key signs are dullness to percussion, ↓breath sounds, mediastinal shift (rarely), together with evidence of shock and impaired ventilation.

Retained blood in the pleural space may initiate a fibrotic reaction leading to atelectasis, lung entrapment, pneumonia, empyema, and ventilation/perfusion mismatch.

11.8.1 Investigation

1. Chest XR—may show fluid in pleural space (interpret supine and erect films differently).
   (a) Air/fluid level or a "white-out."
2. e-FAST

11.8.2 Treatment

- Tube thoracostomy (large bore) (as above).
- **Thoracotomy**:
  - Major vascular injury suggested by either massive hemothorax **(15 mL/kg initially after chest tube insertion)** or ongoing bleeding (>7 mL/h in first hour or 3–4 mL/kg/h or >4% of the body blood volume).
  - Possible intervention includes oversewing of lacerations, repair of central bronchovascular injury, etc.
- **Video-assisted thoracoscopy (VATS)**
  - Is indicated in non-critical, and in persistent non-major vessel-bleeding hemothorax for pleural space debridement. VATS is considered to have lower ARDS rates in comparison to an open thoracotomy.

11.9 Great Vessel Injury

- Rare but still possible.
  - Usually seen in sudden profound deceleration injury causing swinging of heart on great vessels (*"bell clanger" effect).* The ligamentous attachment of the descending aorta to the left pulmonary artery is the most common site. Possible signs include evidence of aortic dissection (e.g., impalpable distal limb pulses).
- CT angiography is indicated for mediastinal or cervical inlet hematoma.
- Intervention remains the province of the cardiothoracic surgeon.

11.9.1 Aortic Injury

- MVA is most common, followed by penetrating trauma.
- Thoracic aorta is most commonly injured.
- Chest X-ray may show a widened mediastinum. Angiography is diagnostic.
  - Open repair on cardiopulmonary bypass (gold standard).
  - Endovascular aortic stent graft repair.
- Overall survival ~50%.

11.10 Tracheobronchial Injury

- Very rare incidence ≤0.05%.
- Due to either penetrating injury or a crush injury of the thorax.
- -80% occurs within 2 cm of the carina in the trachea or mainstem bronchus.
- Suggested by non-resolving air leak with pneumomediastinum and features of hemopneumothorax.
- Diagnosis by flexible /rigid bronchoscopy or virtual bronchoscopy.
- Most pneumomediastinum resolves spontaneously. But may need:
  - Low flow oxygen supplementation (enhances air absorption), prophylactic antibiotics, and absolute bed rest.
  - For unstable and major air leaks a thoracotomy and primary repair with flap coverage of pleura/ muscle.

11.11 Cardiac Injury

This is seen either with penetrating injuries (right > left ventricle), or as a result of severe central blunt force trauma (±sternal fracture). Possible injuries ranging from contusion, pericardial effusion, and tamponade to laceration, septal defects, and acute valve dysfunction.

Pericardial tamponade causes muffled heart sounds, impaired venous return (distended neck veins), and diminished cardiac output (Beck's Triad). The pulse pressure narrows as the degree of tamponade increases.

11.11.1 Commotio Cordis[2]

A severe direct blow to the precordium triggers ventricular fibrillation or other fatal arrhythmias that quickly deteriorate. Typically seen in sports injury (e.g., cricket, baseball, soccer, lacrosse, and karate) or steering wheel trauma. The treatment is urgent defibrillation within 1–2 min and anti-arrhythmic drugs.

11.11.1.1 Investigations

1. ECG (arrhythmias, ST elevation, etc.)
2. Troponin 1
3. Sub-xiphoid view in eFAST
4. Echocardiography if hemodynamic instability and arrhythmia

Specific treatment is outside the remit of this book, but needle pericardiocentesis of the tamponade is an achievable object (ECG controlled, sub-xiphoid approach—aiming for the tip of left scapula).

11.11.2 Myocardial contusion

- The most common pediatric cardiac injury.
- Substernal chest pain following blunt chest trauma is indicative of myocardial contusion.
- Dyspnea, hypotension, and cardiac arrhythmias.
- Late complications can be aneurysm formation and possibly cardiac rupture.

11.11.2.1 Investigations

- ↑ troponin (debatable in pediatric patients)
- ECG shows S-T changes, arrhythmias, or heart block
- Echocardiography

11.11.3 Treatment

- Treat arrhythmia
- Thoracotomy and repair of structural defect

[2] Latin—agitation of the heart.

11.12 Diaphragm Injury

Penetrating injury and severe blunt trauma to the abdomen can cause a blow-out injury (left >>right) causing posterolateral tearing. Right-sided injuries are almost inevitably associated with severe liver injury (often caval) and frequently fatal.

Diaphragm injuries are frequently missed during the first 24 h and sometimes only diagnosed intraoperatively.

Delayed presentation is possible as visceral herniation is a secondary phenomenon, and may lead to small bowel obstruction, presenting some weeks after the initial trauma.

11.12.1 Investigation

1. Chest XR and abdominal XR—blurring of hemidiaphragm is the first clue, but ~50% appear "normal." If the stomach is herniated, the nasogastric tube may be deviated in the thorax.
2. US and CT scan—70–100% sensitive to identify visceral herniation, or lack of muscular integrity.

11.12.2 Treatment

- Nasogastric decompression.
- Diaphragm repair—abdominal approach if associated visceral injury. If demonstrably an isolated injury then thoracoscopic repair could be considered.
- Indications for VATS in severely injured patients:
  - Penetrating injury with little blood loss in a stable patient.
  - Persistent hemothorax.
  - Delayed developing empyema.
  - Persistent air leakage.
  - Suspicion of diaphragmatic rupture.
- Contraindications to VATS: Hemodynamic unstable patient with severe chest wall or cardiac vessels injuries and need for massive transfusion.

11.13 Esophageal Rupture

This may be due to a penetrating wound or gunshot injury. Alternatively, a sudden increase in intra-abdominal pressure may cause lower esophageal injury. This usually presents as a left pleural effusion with chest pain, fever, subcutaneous emphysema, dysphagia, tachycardia, and leukocytosis. Mediastinitis can be fatal if ignored.

11.13.1 Investigation

1. Chest X-ray—wide mediastinum, subcutaneous emphysema, pneumomediastinum, pneumothorax, and pleural effusion.
2. Neck X-ray—visible air under the pretracheal fascia.
3. Water-soluble contrast esophagogram (dye leak).
4. Diagnostic rigid esophagoscopy or endoscopy.

11.13.2 Treatment

- Small contained perforation: IV antibiotics, total parenteral nutrition, pleural drainage. Most children respond to conservative management.
- Mediastinitis: First stabilize the patient with IV fluids and antibiotics. Consider **thoracotomy** to drain the mediastinal contamination.
- Early (<24 h)—primary repair.
- Delayed (>24 h)—an exclusion procedure, i.e., cervical esophagostomy and feeding gastrostomy/ jejunostomy. This mandates a reconstructive second operation.

11.14 Traumatic Asphyxia (a.k.a. Crush Asphyxia) (Perthes[3] Syndrome)

This is global hypoxia due to inability to expand the chest against external compression by heavy object in conjunction with deep inspiration against a closed glottis. It typically occurs during a crush injury.

- Clinical features include:
  - Facial/ neck/ chest petechiae; facial edema, cyanosis, and subconjunctival hemorrhage.
- Neurologic findings include:
  - Altered mental status, brachial plexus injuries, and even coma.
- Ocular signs:
  - Hemorrhage into retina, vitreous body, or optic nerve, and can result in vision loss.

Immediate removal of the compressive forces allows resumption of breathing and recovery and is the first stage to recovery. Adequate oxygenation and adequate cerebral perfusion needed to promote healing and avoid secondary neurological injury.

[3] Georg Clemens Perthes (1869–1927) German surgeon. Also, named for the femoral necrosis seen in young boys.

Further Reading

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