Thoracic injuries

Surgical anatomy

- Chest wall:
  - ribs, sternum, thoracic vertebral column, clavicles and scapula
  - muscular structures
  - intercostal and internal thoracic vessels

- Chest floor: diaphragm
  - hiatuses
    - esophagus (vagus n.)
    - aorta (thoracic duct and azygos vein)
    - and IVC
  - Maximum expiration: 5th ICS

- Chest contents

- Pleural spaces: tracheobronchial tree, lungs and pleurae

- Mediastinum:
  - anterior
  - middle
  - posterior
  - superior – connect with thoracic inlet

Introduction

- Chest injury: High morbidity and mortality

- Need for Thoracotomy:
  - Blunt injury 10%
  - Penetrating injury 25%

- 85% successful Rx with ICD only

Pathophysiology

- Impairment of ventilation
• Impairment of gas exchange at alveolar level
• Impairment of circulation due to hemodynamic changes
• Result in: Hypoxia, Hypercarbia, Acidosis

Lift-threatening chest injuries
• Acute airway obstruction
• Tension pneumothorax
• Open pneumothorax
• Flail chest
• Massive hemothorax
• Cardiac tamponade
• Air embolism

Potential life-threatening chest injuries
• Blunt cardiac injury or myocardial contusion
• Pulmonary contusion
• Traumatic rupture of aorta
• Diaphragmatic injury
• Tracheobronchial tree disruption
• Esophageal disruption
• Simple pneumothorax
• Simple hemothorax
• Mediastinal traversing wound
• Ribs fracture

Acute airway obstruction
• Laryngeal injury
• Maxillofacial injury
• Neck injury
• Posterior dislocation or fracture dislocation of SC joint
Airway assessment

- First Priority, with C-spine protection
- Assessment & frequent reassessment of airway patency and ventilation
- Inspection: FB, facial, mandibular, tracheal or laryngeal fracture
- Agitation or obtundant
- Listening: abnormal sound
  - Snoring, gurgling and crowding (stridor) sound: partial occlusion of pharynx or larynx
  - Hoarseness: laryngeal obstruction
- Palpation: trachea and larynx

Laryngeal injury

- Triads:
  - Hoarseness, Subcutaneous emphysema, Palpable fractures
- Immediate intubation in obstructed airway or respiratory distress options: flexible endoscopic-guided intubation
- If intubation is unsuccessful: Emergency tracheostomy
- Surgical cricothyroidotomy may be life-saving option
- Needle cricothyroidotomy with jet insufflation
- CT: helpful Dx in subtle clinical findings
- Definitive repair in OR: Anatomical repair with wires and sutures

Maxillofacial injuries

- Compromise nasopharynx and oropharynx
  - Additional problems: Bleeding, increase secretion, dislodged teeth
- Suction, remove FB, temporary airway maintenance
- Definitive airway:
  - contraindication for Nasotracheal intubation

Neck trauma
• Penetrating neck injury: vascular injury with significant hemorrhage
displacement and obstruction of airway
• Blunt and penetrating neck injury:
  tracheal or laryngeal disruption
• Need for definitive airway
• In partially obstruction: Endotracheal intubation with prompt surgical airway Rx
• Surgical exploration in operating room

**Posterior dislocation or fracture dislocation of SC joint**
• Injury to upper chest, can lead to airway obstruction
• May be associated with vascular injury to ipsilateral extremity
• Stridor, marked change in voice quality
• Obvious trauma at base of neck with palpable defect at SC joint
• RX: establish a patent airway
  Endotracheal intubation (that may be difficult)
• Close reduction of injury
  Extend shoulder & grasping clavicle with towel clip

**Tension pneumothorax**
• Collection of air in pleural space, result in shift of mediastinum away.
• Air leakage from lung laceration (direct injury, deceleration, rib fracture)
• S/S: chest pain, air hunger, respiratory distress, tachycardia, hypotension, tracheal
deviation, unilateral absence of breath sound, neck vein distention, cyanosis (late)
• Must be consider: most treatable life-threatening chest injury
• DDX to cardiac tamponade by hyperresonant percussion and absent breath sound
  in affected hemithorax
• Can occur in positive pressure ventilation
• RX: immediated decompression without radiologic confirmation
• Insert large-caliber needle (14 G) into 2nd ICS MCL (1 - 2 FB below clavicle)
• Tube thoracostomy at 5th ICS just anterior to Midaxillary line (nipple level)

Open pneumothorax
• Sucking chest wound
• If chest wall defect > 2/3 of tracheal diameter: air pass preferentially through defect
• Impair ventilation: hypoxia & hypercarbia
• Initial management: closure defect with 3-sided sterile occlusive dressing
• Tube thoracostomy remote to defect
• Temporary closure of defect
  Suturing,
  Taping all edges of dressing,
  Occlusive dressing with plastic wrap or petrolatum gauze
• Debridement, definitive closure of defect in OR
• Once positive pressure ventilation is instituted:
  temporary closure chest defect is unnecessary
• Hemodynamic unstable:
  ERT, emergency thoracotomy, damage control, packing and temporary closure, follow by Angiographic embolization

Flail chest
• Multiple segmental rib fractures (2 or more ribs in 2 or more places):
  esp: anterior or anterolateral part
• Paradoxical chest movement
• Hypoxia due
  pain (restricted chest movement) and underlying lung contusion
• S/S: patient moves air poorly, asymmetrical and uncoordinated movement of thorax, palpation of abnormal respiratory motion and crepitus of rib or cartilage fractures
• CXR: suggest multiple rib fractures but may not show costochondral separation
• Definitive treatment
Re-expand lung
Ensure oxygenation
Careful fluid administration (Avoid crystalloid fluid overload)
Provide analgesia to improve ventilation
- Assessment of RR, ABG and estimate work of breathing
- May need intubation with mechanical ventilation
- Increase interest in ORIF of multiple rib fractures with pins, plates, wires, rods or absorbable plates.

shortening of hospital stay and improve morbidity in Uncontrolled trials
(with selection bias & risk of operation)

Lung contusion
- Common potential lethal chest injury
direct injury to lung parenchyma
- VIQ mismatch : result in acute hypoxia
- Respiratory failure may be subtle and develop overtime, require careful monitoring and reevaluation

Management
- Close observation, repeat CXR, monitor respiration, O2sat and ABG
- Patients with significant hypoxia ($P_{aO2} \leq 60$ mmHg or $O2sat \leq 90\%$ on room air) should be intubate and ventilated within first hour after injury
- Some patients with stable condition : selective Rx without intubation and ventilation
- Carefully fluid administration : avoid crystalloid solution overload

worsening pulmonary contusion
- ARDS

Massive hemothorax
- By definition : blood drain from chest tube $> 1,500$ cc

($> 1/3$ blood volume, hemodynamic unstable)
• 50% die immediately after injury,
  25% live for 5 – 6 min
  25% live upto 30 min , arrive ER
• Sources :
  85% from intercostal vessels or IMA
  15% from pulmonary laceration,
  few from hilum, heart, vascular injury of thoracic outlet
• May be from intraabdominal organ with diaphragmatic injury
• S/S : shock associated with absence breath sound and/or dullness on percussion
  on side of the chest
• Flat neck vein secondary to hypovolemia
• Treatment
  Fluid resuscitation
  Tube thoracostomy
  Consider for ERT, emergency thoracotomy
  Autotransfusion (contraindication : contamination eg. hollow viscus injury)

ACUTE INDICATION FOR THORACOTOMY
- Drainage of more than 1,500 cc from chest tube in 1st insert
- Continuous hemorrhage > 200 cc for ≥ 3 consecutive hours
- Vascular injury of thoracic outlet
- Acute clinical deterioration
- Loss of chest wall substance
- Caked hemothorax
- Large air leak with inadequate ventilation or persistent collapse of lung
- Esophageal perforation
- Pericardial tamponade
Cardiac tamponade

- Blood accumulate in pericardial sac - increase pressure in pericardial sac - impair RA filling / decrease RV preload - decrease RV output and increase CVP
- Most common from penetrating injury (but also with blunt injury)
- S/S
- Beck's tirads (hypotension, distend NV, muffled heart sound)
  Not reliable indicator for acute tamponade at ER
- Consider in partial or non-responder, suspected HX
- Insertion of CVP line may aid diagnosis
- Diagnostic tools
  - FAST: accuracy 90% in experienced hand
  - Pericardiocentesis: DX and RX
temporary hemodynamic improvement (only release 15 - 20 cc)
  - Alternative: subxiphoid window
- If cardiac tamponade is demonstrated \( \Rightarrow \) Immediated transfer to OR:
  Thoracotomy
  Median sternotomy
- ERT in Extremis patients

Cardiac injury

- Definitive Rx: cardiorrhaphy in OR
- APPROACH
  - Median sternotomy: superb exposure of heart, great vessels and hila
  - Left anterior or anterolateral thoracotomy: ERT, posterior cardiac injury
- Open pericardial sac, relief tamponade
- Identify injury at myocardium
- temporary control the hemorrhage: digital occlusion (or skin stapler)
- Large wound: temporary occlusion with foley's catheter
• partial occlusion: temporary control of atria, cavae or aorta
• Suture wound with prolene 3/0, horizontal matress with pledgets (or strips of pericardium)
• Wound close to coronary vessels: horizontal matress under vessels

Air embolism
• Infrequently, 4% of major chest injury
• Mostly (65%) from penetrating injury
• Pathophysiology: fistula between pulmonary vein and bronchus cause systemic air embolism
• Focal neurodeficit, sudden collapse (esp after positive pressure ventilation), froth in ABG
• DX: aware of possibility, confirmation by fundoscopic exam
• In Extremis with suspected air embolism: ERT
  cross-clamp hilar, internal cardiac massage, vent LA, LV & aorta
• RX: immediate thoracotomy in OR
  hilar clamping and definitive repair of injury or lobectomy

Emergency room thoracotomy
• Strong indication:
  penetrating chest injury that cardiac arrest at ER, cardiac arrest before arrival < 30 min along with resuscitation and persistent severe hypotension
• Position: supine with left arm elevation
• Incision: left anterolateral thoracotomy incision, 5th ICS from left sternocostal junction to latissimus dorsi muscle (Spangaro incision)
• Release cardiac tamponade
• Control intra-thoracic bleeding
• Control air-embolism or bronchopleural fistula
• Permit open cardiac massage
• Allow temporary occlusion of descending thoracic aorta
• Extend to right anterolateral thoracotomy: control injury in right chest bilateral trans-sternal thoracotomy "clampshell's incision"
• Immediately transport to OR after successful resuscitation
• Use of universal precautions and the selective use of ERT
• Minimize risks of blood-borne pathogens: HIV, hepatitis
• Result of ERT (survival) : penetrating chest injury 1 – 50%, blunt < 1%

Secondary survey
• History taking
• Complete physical examination: from head to toe
• Chest examination
  inspection
  palpation
  percussion
  auscultation
• Adjunct : CXR, pulse oximetry, ABG
• Most injury Dx or suggestive Dx by PE and CXR
• Blunt injury involve :
  chest wall, thoracic spine, heart, lung, aorta and great vessels & rarely with esophagus
• Penetrating injury :
  PE, CXR (PA, lateral), CVP

Rib fractures
• Most common chest trauma
• S/S : localized pain, tenderness, crepitus, palpable or visible deformity
• CXR: for identify rib fracture and exclude other intrathoracic injury
• Pain:
  limit chest movement
  impair ventilation, oxygenation and effective cough
• Upper (1st – 3rd) rib fractures: risk of injury to head, neck, spinal cord, lungs and great vessels
• Middle (4th – 9th) rib fractures:
  AP compression: mid-shaft fracture
  Direct force: ribs tend to fracture with potential for intrathoracic injury
• Lower (10th – 12th) rib fractures:
  suspicion of hepatic or splenic injury
• Young patients: flexible chest wall, less likely to rib fractures
• Managements
  • Adequate pain control:
    NSAIDs, parenteral narcotics (with titration and monitor)
    intercostal nerve block
    0.25% bupivacaine
    epidural anesthesia
  • Oxygenation

Sternal fracture
• Uncommon
• Direct impact of the sternum
• Mostly: upper or midportion
• Hallmark of severe injury: rib fractures, head injury and blunt myocardial injury
• S/S: anterior chest pain, tenderness, ecchymosis, swelling, palpable deformity and motion of fracture segment
• Additional Dx: CT, lateral sternal films
• Treatment:
  Associated injury
  ECG monitoring
  pain control
  avoid motion
  ORIF – severe pain and displaced fracture

Simple pneumothorax

• Both penetrating and blunt injury
• Most common: Lung laceration with air leakage from blunt trauma
  Air in pleural space collapse lung
• S/S: decrease breath sound on affected side, hyperresonance on percussion, subcutaneous emphysema
• Dx: CXR (expiration/upright or AP) - most commonly used
  CT (occult pneumothorax)
• Estimates of the size of pneumothorax
• Treatment:
  tube thoracostomy (ICD) – with CXR confirmation
  aspiration - not recommend
  observe & F/U in 6 – 24 hrs - in occult pneumothorax only
  (except in positive pressure ventilation)
  oxygen supplementation
• Simple pneumothorax can convert to tension pneumothorax: esp. with positive pressure ventilation

Simple hemothorax

• Presence of blood in pleural space
• Source of bleeding
• CXR:
  AP – haziness
upright - increase sensitivity (penetrating, stable patient)

- FAST, CT
- Treatments
  - evacuate blood and reexpand lung with chest tube (no. 36)
  - F/U CXR: confirm position of ICD and lung expansion
  - consider amount and continuous bleeding, patient's status
- Treatments
  - Factors involve decision for operations: patient's physiologic status and volume of blood drainage
    - Immediately obtain 1500 cc
    - Drainage < 200 cc/hr for 2-4 hrs
    - Persistent blood transfusion is required
- Most of simple hemothorax Rx with chest tube
- Complication:
  - clotted or caked hemothorax
- Rx: Insert another ICD,
  - video-assisted thoracoscopy (VATS)
  - thoracotomy

**Tube thoracostomy (ICD)**
- For pneumo and/or hemothorax
- Position: 4th or 5th ICS just anterior to midaxillary line
  - point supero-posteriorly
- Connect to underwater seal apparatus with or without suction
- CXR after insertion
- Avoid error in apparatus: kinking, leakage
- Left in place until
  - lung is fully expanded
  - no air leakage
  - fluid drainage < 100 - 150 cc/24 hrs (straw color)
Blunt myocardial injury

- Direct injury to myocardium
- In significant blunt chest injury
- Associated with: sternal fracture
- S/S: chest discomfort
  
  often attributed to chest wall contusion or ribs/sternal fracture
- True Dx only by inspection of injured myocardium
- Clinical sequelae of myocardial contusion:
  
  hypotension, EKG: significant conductive abnormality ECHO: wall motion abnormality
- EKG: variable, most common with multiple PVC, unexplained sinus tachycardia, AF, RBBB, ST segment change
- Elevation of CVP in absence of obvious cause indicate right ventricular dysfunction secondary to contusion
- Cardiac enzyme: not helpful for Dx
- in old patient: S/S may be due to true MI
- Treatment:
  
  monitor ECG
  Rx cardiac arrhythmia
  supportive treatment (inotrop drugs, swan-ganz catheter, IABP)

Tracheobronchial tree injury

- Unusual but potential fatal
- S/S: hemoptysis, subcutaneous emphysema or tension pneumothorax, pneumothorax with persistent air leakage after chest tube insertion
- Bronchoscopy: confirm diagnosis
- Treatment: Thoracotomy
  
  repair bronchus, may required segmentectomy or lobectomy
**Traumatic aortic disruption**

- Common cause of death after MVA or fall from great height
- Penetrating injury
- Blunt injury: shearing force - tear at fixation point
  
  ligamentum arteriosum and diaphragm
- Free rupture – usually fatal
- Survival - Contained rupture or partial thickness (dissection)
- Unstable or stable patients
- Clinical findings : no specific S/S
  
  hypotension
  massive hemothorax
  unequal BP or pulses in extermity
  evidence of major blunt chest injury
  suggestive findings from CXR
- Dx by high index of suspicion, history of decelerating force, radiologic change,
- Initial Rx
  
  ERT (as indicated)
  tube thoracostomy
  IV access and fluid administration
- Radiologic signs : likelihood of major vascular injury
  
  - Widened mediastinum
  - Obliteration of aortic knob
  - Deviation of trachea to the right
  - Obliteration of space between pulmonary artery and aorta (obscuration of AP window)
  - Depression of left main stem bronchus
  - Deviation of esophagus (NG tube) to the right
• Widened paratracheal stripe
• Widened paraspinal interface
• Presence of pleural or apical cap
• Left hemothorax
• Fracture of 1st or 2nd rib or scapula

Further diagnostic tools:
- Angiogram – gold standard
- TEE – less invasive
- Helical CT scan or CT angiography

• Perform in stable patients
• Treatment: urgent surgical repair of aorta

**Esophageal disruption**

- Penetrating injury or blunt (uncommon)
- S/S of thoracic esophageal injury: pain, fever, dyspnea, hematemesis, Late – posterior mediastinitis, sepsis
- CXR: pneumomediastinum, persistent pneumothorax, pleural effusion
- Dx: esophagography with gastrograffin and followed by Barium contrast
- Treatment: operative management
  - Early (< 24 hrs.): primary closure with tissue buttress (pericardium, pleura, intercostal muscle, diaphragm)
  - Late (> 24 hrs.):
    - esophageal diversion
    - total esophageal exclusion
    - esophagectomy
    - T-tube drainage
- IV antibiotics and nutritional support
Mediastinal traversing wound

- Can injury the major mediastinal structures: Heart, great vessels, tracheobronchial tree or esophagus
- Dx: careful PE
  CXR: reveal entrance wound in one hemithorax and exit wound or missile lodged in contralateral hemithorax
- Treatment
  Bilateral tube thoracostomy
- Hemodynamic abnormal:
  consider massive exsanguinating thoracic hemorrhage, tension pneumothorax or pericardial tamponade
- Emergency thoracotomy
- In hemodynamic stable, asymptomatic
  Tube thoracostomy as indicated
  Contrast-enhanced helical CT or angiography
  Water-soluble esophagography (complementary with esophagoscopy)
  Bronchoscopy should be performed
  Heart and pericardium: best evaluated by CT or U/S

Diaphragmatic injury

- Anatomy:
  dome-shaped musculoaponeurotic structure, central tendon
  floor of chest wall
  insertion: anterior - 6th rib, posterior - 12th rib
  3 hiatus
  phrenic nerves: C3 - C5 nerve root
- Maximum superior position during expiration
  anterior: left - 5th ICS, right - 4th ICS
posterior – 8th ICS

- Blunt or penetrating injury
- Associated injury: rarely injury alone
- Incidence: left (75%), right (23%), bilaterally (2%)
- Diagnosis: require high index of suspicion
- Hx: thoracoabdominal injury (transnipple line – costal margin)
- No specific presentation
  - Hemodynamic stable without abnormal - S/S severe destruction of chest wall with hemodynamic unstable
- S/S: dyspnea, chest pain, abdominal pain
- Late presentation of organ herniation – unrecognized acute injury
- Diagnostic tools
  - CXR (with NG tube insertion): accuracy ~ 40%
    - NG tube in the left chest (pathognomonic)
    - Abnormal bowel gas in left chest
    - Obliteration of normal contour
    - Hemothorax
- Contrast study: UGI series, BE
  - Only in hemodynamic stable patient or chronic phase
- Spiral CT scan
  - Discontinuation of diaphragm
  - Hemoperitoneum with hemothorax
  - Associated organ injury
  - Dependent visceral signs
  - Useful esp. in blunt mechanism or right - sided penetrating injury
- DPL: rarely use, low sensitivity
- Laparoscopy or thoracoscopy
  - Increase Dx role in penetrating injury of thoracoabdominal region
choice depend on surgeon's preference

- Treatment
  - surgical repair of diaphragm
  - with large nonabsorbable monofilament (prolene no 0 or 1)
  - laparotomy
  - thoracotomy (during chronic phase)

Access to thorax

Anterolateral thoracotomy

- Approach of choice for most unstable patients
- Utilized for ERT
- Extension:
  - Bilateral thoracotomy
  - Thoracoabdominal incision
  - Trap-door incision

Median sternotomy

- Approach of choice for penetrating injury at base of neck (zone I) & thoracic outlet
- Access to heart, arch of aorta and origin of great vessels
- Extension:
  - Neck incision
  - Laparotomy
  - Supraclavicular incision

"Trap door" thoracotomy

- Combination of anterolateral thoracotomy, partial sternotomy and clavicular incision.
- Allow access to proximal left subclavian a.
- Difficult, time consuming: not recommend

Posterolateral thoracotomy

- Use in elective setting for definitive lung and esophageal surgery
- Require appropriated position, time-consuming, Not recommend in acute setting