Chest Wall Trauma & Rib Fractures

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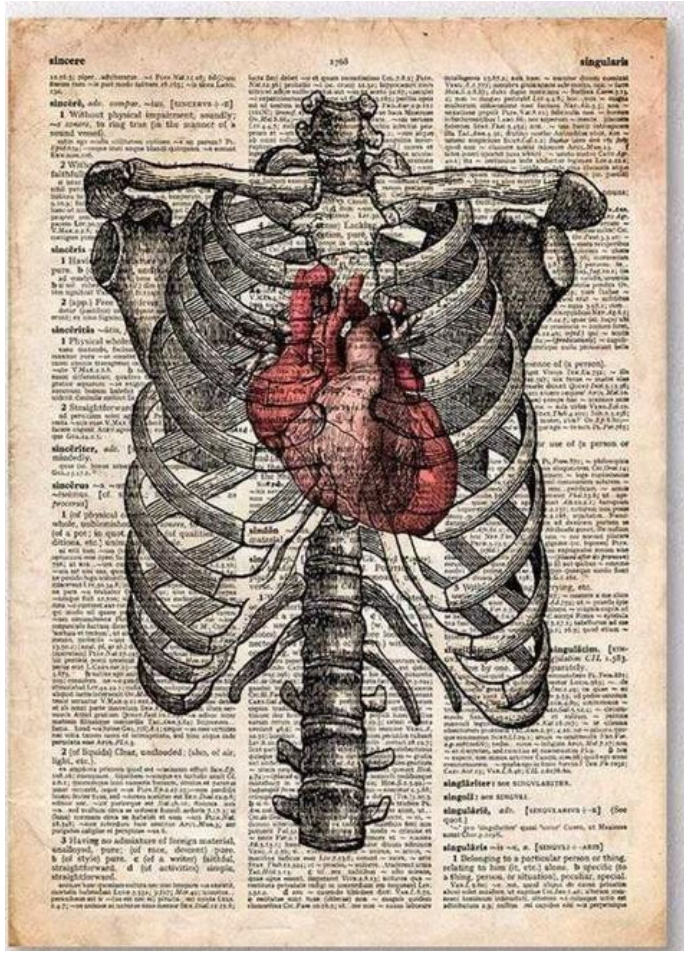
Objectives

- Definitions
- Background
- History
- Investigations
- Management
- Cases
- Summary
- Key References



Chest Injury - Background and Importance

- 10% of all injured have chest injury
- 39% of all thoracic trauma patients will have rib fractures
- **High morbidity and mortality**
  - Reported mortality in up to 22% in blunt chest injury
  - Pulmonary complications in isolated rib fractures in patients aged over 65 in 36%
    - High proportion of elderly require ICU and ~12% require mechanical ventilation
- **Can develop life threatening complications in first 72 hours**
- Mean hospital length of stay in elderly is 14 days
- *Isolated rib fracture patients unable to return to work for 50 days*

Chest Injury - Background and Importance

Primary mechanisms

- Motor vehicle crashes
  - Acceleration/deceleration injuries
  - Direct trauma from cabin/steering wheel
- Workplace injury
- Fall from height
- Assault
- Sporting injuries
- Low energy mechanism falls in the elderly

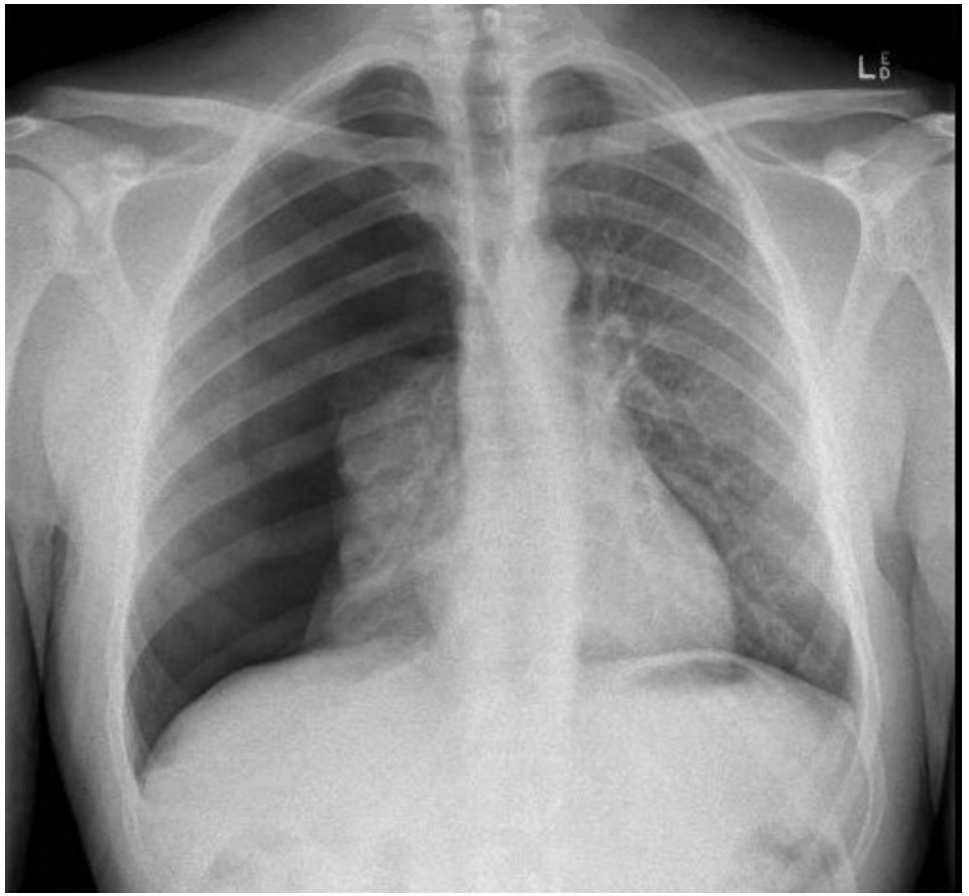
Chest Injury - Background and Importance

Increasing elderly trauma - *Poor respiratory reserve, decreased muscle mass and loss of bone density*

- Associated with increased morbidity and mortality
- Increase length of ICU stay
- Significant delayed complications
  - Pneumonia, pneumothorax, haemothorax, pulmonary contusion and chronic pain

Chest Injury - Pneumothorax

- Air leak from lung in to pleural cavity leading lung collapse
- Etiology: - blunt chest trauma – rib fracture
  - penetrating trauma – stab wounds
  - spontaneous
- Simple: variable clinical symptoms depending on size
- Tension: progressive increasing in size leading to mediastinal shift, hypoxia and hypotension
- Open: pleural cavity open to environment – mediastinal flutter



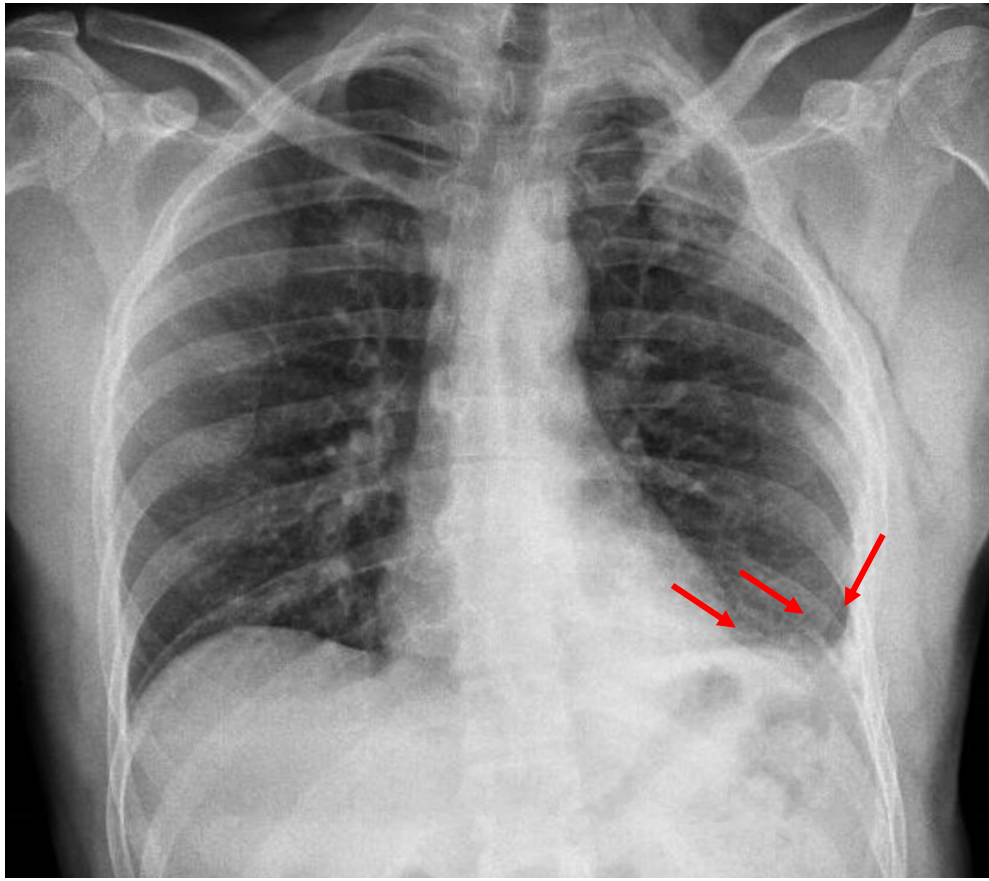
Chest Injury – Pneumothorax

Treatment

- Close observation
- Oxygen and supportive therapy
- Pain control
- Chest tube decompression
  - Hand hygiene
  - Aseptic technique
  - Insertion site 4/5th intercostal space just anterior to mid axillary line on upper border of the rib
  - Insert drain
  - Surgical closure of chest wall wound
  - Secure drain and Occlusive dressing
  - Secure connections

Chest Injury - Haemothorax

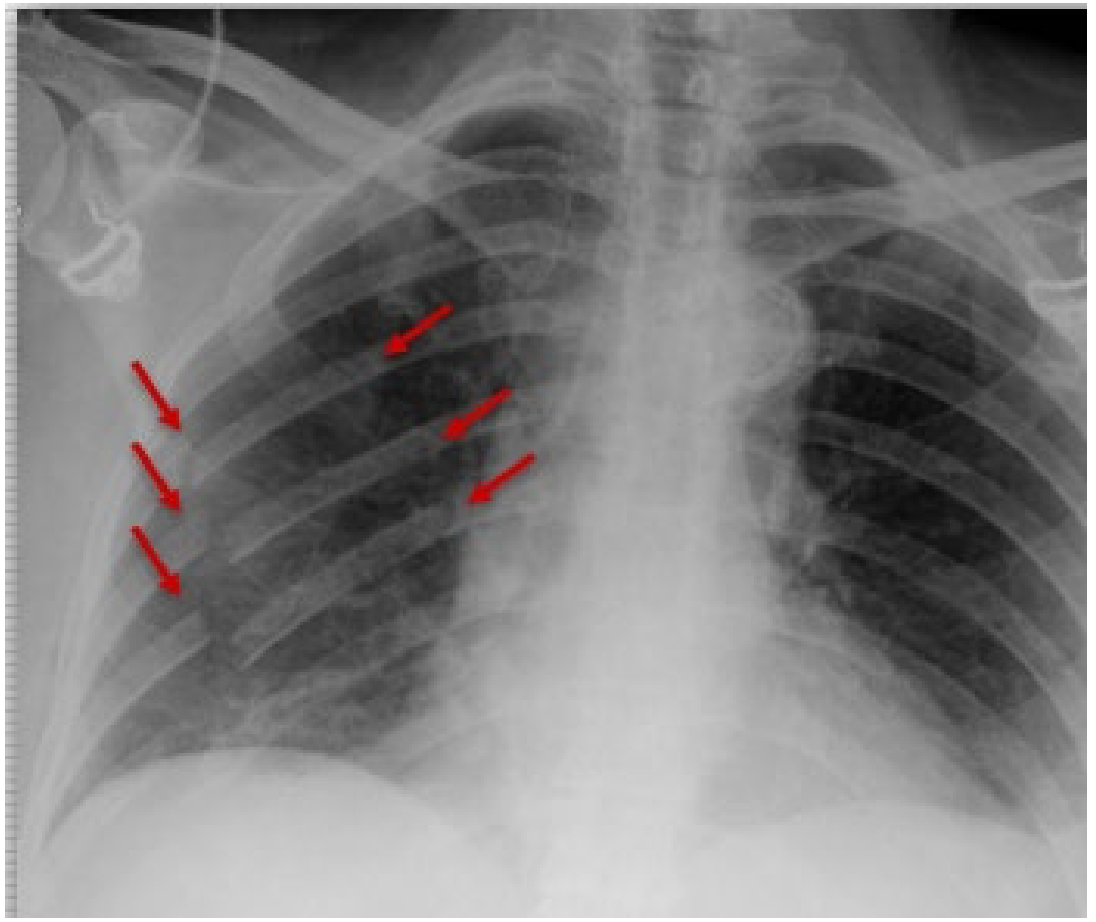
- Bleeding into pleural space
- Etiology: intercostal vessel laceration from trauma, rib fracture, penetrating wound
- Beware associated intrabdominal injury
- Hypotension, dyspnoea depending on extent of bleeding
- Treatment: decompression with chest tube and monitoring blood loss by vital signs and thoracotomy if unable to stabilize



Chest Injury - Pulmonary Contusion

- Alveolar, vascular and parenchymal lung damage with physiological loss of function
- Leads to dyspnea, hypoxia, tachypnea and tachycardia
- May be progressive leading to ARDS and death
- Treatment: maintain oxygenation including intubation and ventilation

Chest Injury – Rib fractures



Single Rib fractures

- Typically innocuous with little long term deficit

Multiple Rib fractures

- Adjacent unifocal fractures
- ≥3 displaced fractures
- Don’t fit flail definition

Flail

- Three or more contiguous ribs are fractured in two or more places
- Move paradoxically with the rest of the chest

Chest Injury – Rib Fractures

Complications

- Compromised respiratory function
- ARDS
- Poor pulmonary clearance
- Pneumonia
- Increase length of ICU stay
- Sepsis
- Need for mechanical ventilation
- Death

Associated Injuries

- Pneumothorax
- Haemothorax
- Sternal fracture
- Pulmonary contusion
- Myocardial contusion
- Decreased lung volume and function

Age and ≥3 rib fractures are the most important indicators of morbidity and mortality.

Flail Chest - History

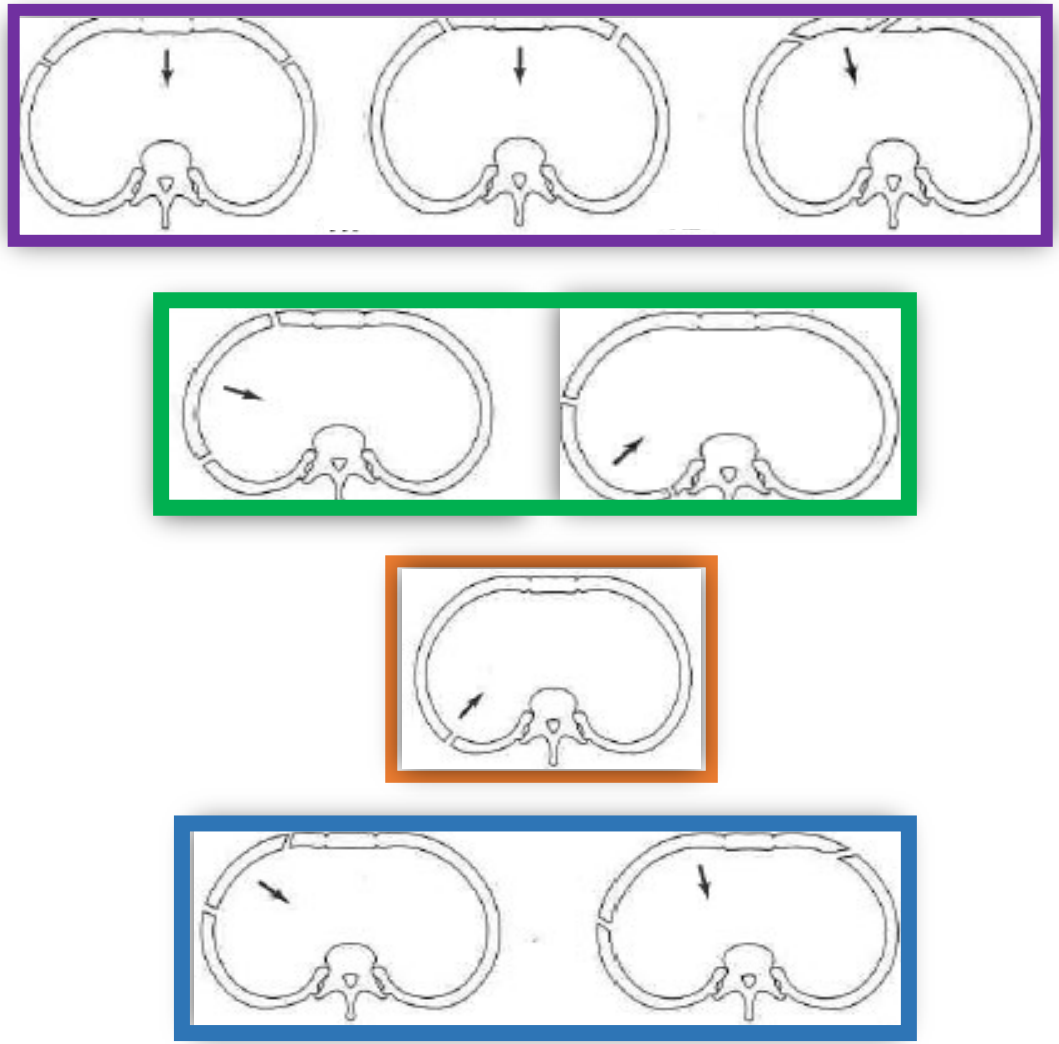
- Earliest reported chest trauma from ancient Egypt in 1600 BC
- Then, Hippocrates' writings in the 5th century contained a case series on trauma reports which included thoracic injuries.
  - Early management with linen was common
- Roman Surgeon Soranus (78-117AD) resected depressed rib fractures for relief of pleuritic pain
- WW II - External Stabilisation
  - First described 1926
  - Allegedly "good results"

Flail Chest

- Main problems: Parenchymal injury and the pain caused by the rib fractures
  - Reduced tidal volume, supress cough reflex – leading to atelectasis and infection
  - Paradoxical movement makes breathing progressively more difficult
- Flail chest also can cause chronic persistent chest pain and restricted lung function.
- Additional injuries common – organ injuries, shock and blood loss
  - Parenchymal contusion
  - Haemothorax and pneumothorax common

Flail Chest - Types

- Anterior
- Lateral
- Cartilage
- Anterolateral



In patients managed surgically with flail chest;

Anterior rib fracture more likely to lead to deformity if not fixed. Majority of anterior ribs are fixed as per current evidence

Lateral fractures tend to heal well without new overlapping, displacement or angulation. They tend to improve with fracture fixation at the other end of the rib.

Posterior ribs are well padded by the scapula and muscles and protected. Those that are displaced, are likely to stay displaced if not fixed

Flail Chest – Internal Stabilization

- Open Reduction Internal Fixation first introduced 1943
- Internal pneumatic stabilization introduced by Avery in 1956
  - Positive pressure ventilation became the standard treatment of choice
    - Mortality rates began to fall
    - But incidence of complications associated with ventilator use increased
- 1970's introduction of multidisciplinary management
  - Multimodal care
    - Optimal pain control
    - Pain catheters
    - Chest physiotherapy
    - Non invasive positive pressure ventilation
- 1990's forward
  - Reintroduction of ORIF

Management of Chest Trauma

Pre-hospital: Severe chest trauma

- **ATLS principles**
- Monitor observations
- Continuous pulse oximetry monitoring

- **Retrieval Medical team, potential for life saving intervention:**
  - Intubation
  - Insertion of field Intercostal catheters (chest tubes)

- **Trauma Centres if safe and feasible**

Assessment

- **Primary Survey**
  - ABCDE
  - Work of breathing
  - RR, HR, O_2 saturations, BP, Auscultate
  - ABG/VBG + ECG

- **6 life threatening chest conditions**
  - Airway obstruction
  - Tension pneumothorax
  - Open pneumothorax
  - Massive haemothorax
  - Flail chest
  - Pericardial tamponade

Assessment

OTHER associated conditions

- Pulmonary contusion
- Tracheobronchial injuries
- Diaphragmatic injuries
- Myocardial injury
- Thoracic aorta disruption
- Oesophageal injury

DO NOT FORGET THE OTHER SYSTEMS

Investigations

- **eFAST (Ultrasound)**
  - Able to identify rib fractures as well as pneumothorax
- **CXR**
  - High proportion of fractures missed (33-50%)
  - 36% sensitivity in identifying traumatic pneumothoraces
  - Help in identifying other pathology and complications however…
    - Unrecognised/unreported rib fractures increase mortality/morbidity
- **Computed tomography**
  - Important to image with 3D reconstruction rib cage
    - Gold Standard
  - Assess anatomic severity
  - Accurate and helps with planning for intervention

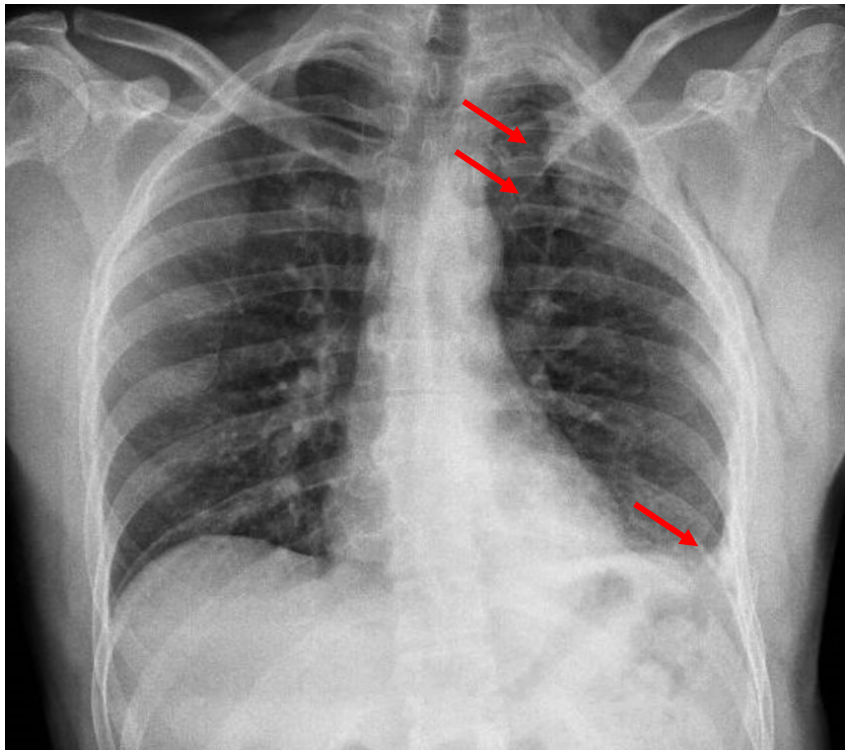
Investigation - Imaging

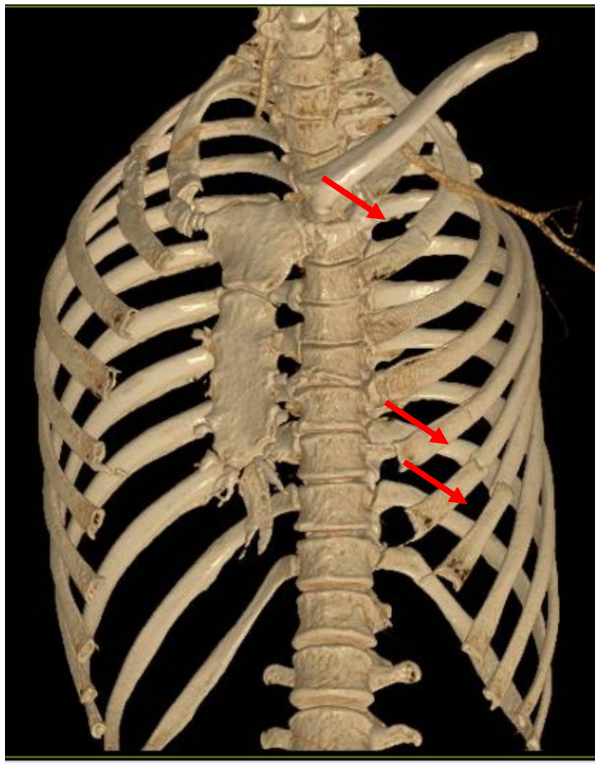
Imaging Technique	Strengths	Weaknesses
Chest X-Ray	Cost and time effective Early identification of life threatening cardiopulmonary trauma Readily available	Lacks sensitivity in identifying rib fractures and pneumothorax
Computed Tomography	High sensitivity for rib fracture, pneumothorax, contusion, major organ/vessel damage	Expensive Time Radiation exposure
Ultrasound	Small/portable Can include as part of extended focused assessment with sonography for trauma (eFAST) High sensitivity for identifying rib fractures, pleural fluid and pneumothorax	Subscapular injuries inaccessible Cannot quantify degree of pathology Difficult with obese patients or those with large breasts

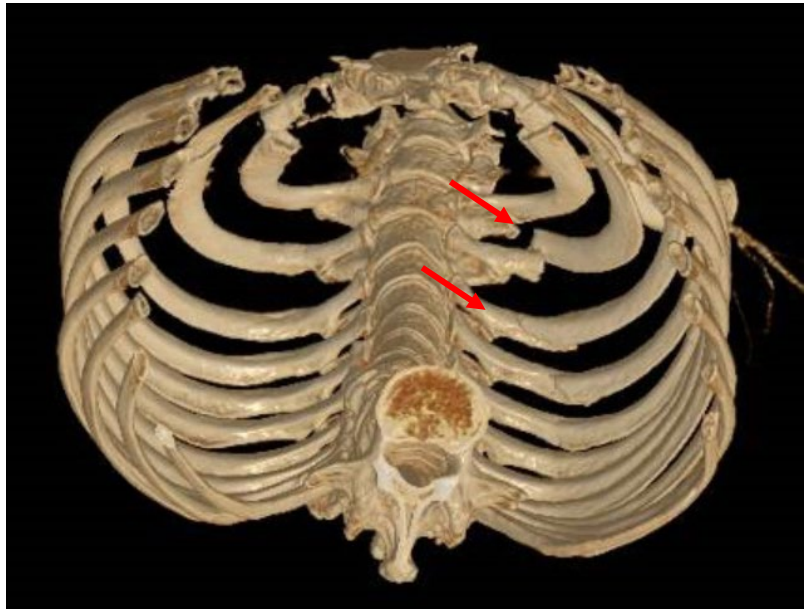
Example: Haemothorax

55yo Motor Bike Collision – Handlebars into chest

Initial Imaging



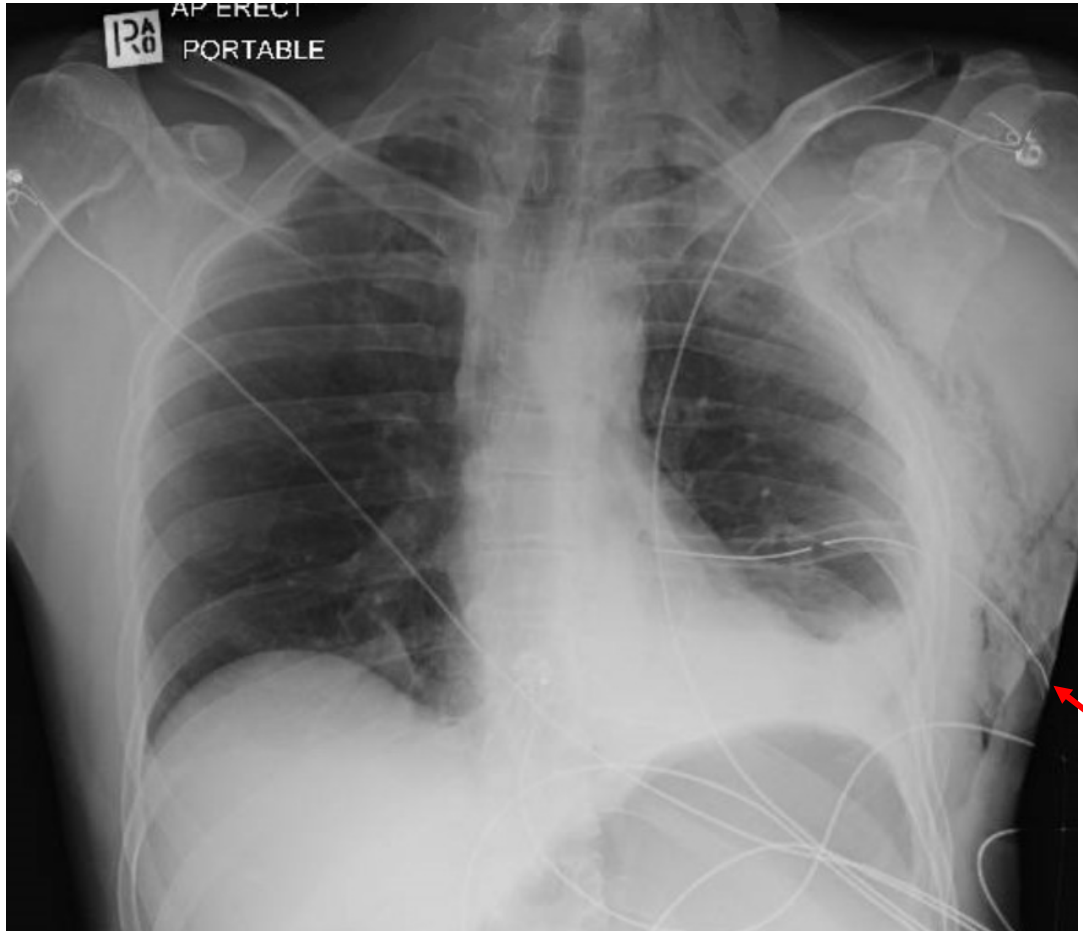




Example: Haemothorax

Rapid Response day 1 admission

Post chest tube and 1.5 litres drained



Management – Factors to Consider

Patient

- Age, gender, BMI, ASA, tobacco, comorbidities, medications

Injury related

- Mechanism, chest tube insertion, number and location of rib fractures, sternum fractures, associated injuries, AIS/ISS.

Management – Factors to Consider

Personnel and Institutional

- Expertise, surgical approach, number of plates, surgical delay, wound drain, intraoperative chest tube, duration of surgery

Situational

- Associated injuries
- Head injury
- Prolong ventilation

Patient wishes

Management – Multimodal Pain Relief

- Paracetamol (acetaminophen) + NSAIDs
- Local
  - Rib blocks
- Regional anesthesia
  - Epidural or paravertebral
    - Improves pain control, especially in the elderly
    - Intercostal block
  - Contraindications
    - Hypovolaemia, increased ICP, allergy, infection
    - Other medications: DVT prophylaxis

Management – Multimodal Pain Relief

Technique	Advantages	Disadvantages
NSAIDs	Non invasive Orally administered Nil systemic side effects	Poor analgesic effect in severe pain Risk of GIT ulcers Risk of renal impairment
Opioids	Easy to administer Effective for severe pain	Risk of respiratory/CNS depression Nausea
Thoracic Epidural	Reduced risk of systemic sedation Immediate and substantial effect Minimal local anaesthetic toxicity	Oral supplementation often required Invasive and painful Risk of spinal cord injury Risk of hypotension Risk of urinary retention
Thoracic paravertebral block	Easier than epidural Immediate and substantial effect Can be used with moderate degree of haemostatic deficiency	Risk of Pneumothorax Risk of local anaesthetic toxicity Less accurate than epidural
Intercostal nerve block	Extremely effective No CNS depression	Only lasts 4-8 hours Risk of local anaesthetic toxicity Risk of pneumothorax
Intrapleural block	Effective pain relief No CNS depression	Loss of analgesia if chest drain present Presence of blood in space dilutes analgesia

Management – Chest Injury

- Chest Physio
- Regular Chest X-ray imaging
- Early mobilization
- Role of prophylactic antibiotics → Controversial
  - Use in thoracostomy, prolonged ICU/intubation, lung contusion, retained haemothorax
- ***+/- Surgical Management***

Chest Physio

- *Anecdotal evidence*
- Includes
  - Pulmonary hygiene
  - Cough
  - Deep breath
  - Sitting out of bed
  - Incentive spirometry

Management - Ventilation

- Non Invasive mechanical – upright, CPAP, pressure support
- Intubation and invasive mechanical ventilation in severe cases
  - Blunt chest wall trauma with poor gas exchange and respiratory effort
- Positive Pressure Ventilation
  - Early use resulted in prolonged mechanical ventilation time, increasing VAP and mortality.

Management – Surgical

- **Open Reduction Internal Fixation First introduced 1943**
- 99% of flail chest in UK pre 2010 were managed conservatively
- **Last 10-20 years, rebirth with new techniques and equipment**
- Fixation must withstand 25,000 breathing cycles per day as well as coughing

Management – Surgical

Aims of surgery:

- Stabilize chest wall and restore chest wall continuity
- Accelerated restoration of pulmonary function
- Reduced morbidity associated with prolonged mechanical ventilation
- Shortened stays in ICU and in hospital
- Decrease pneumonia rate
- Improve pain management
- ?cost effective component

Management – Surgical (Flail Chest)

Surgery:

- Should occur early (<48 hours)
- Decreases pain by minimizing movement
- Can be minimally invasive or formal thoracotomy
  - Standard thoracotomy curvilinear incision centred over fractured ribs
    - Muscle sparing
    - 3 ribs can be fixed through each window
- Ultimate aim to get off ventilator early

Management – Surgical (Flail Chest)

Surgery: Results

3 small RCTs, larger observational studies and a meta-analysis shows added benefit

- Fewer ventilated days, less rates of pneumonia and tracheostomy with shorter ICU stay
- Impact on pain more variable

No large evidence to show advantage over standard treatment for pain, ventilator free days, overall length of stay, quality of life or mortality

Chest Wall Stabilization

Indications

- Flail chest with paradoxical chest wall motion
  - ***Independent predictors of poor outcome in patients with blunt chest wall trauma***
  - ***30 day early mortality flail chest 9.8% non operative vs 2.6% with surgery***
    - *(Adjusted for age, pneumonia, mechanical ventilation, ICU admission and length of stay)*
- Chest Wall deformity
- Pain Management
- Prolonged intubation or immobilisation
- Thoracotomy for other indication
- Pulmonary contusion: controversial
- NO Clear guidelines/indications

Management – Surgical

Who should perform?

- Trauma Surgeons
- General Surgeons
- Cardiothoracic Surgeons
- Orthopaedic Surgeons

Equipment

- Nails, wires, struts, metal or absorbable plates
- Both rigid and non rigid systems (plates)
- Plates placed directly on periosteum
- Human rib thickness ranges from 8 to 12mm with a relatively thin (1-2mm) cortex surrounding soft marrow.
  - Drill sets come set at 6,8,10,12mm
- Chest tube +- surgical drains

Injury Risks

Risk Factor	Worse outcomes in relation to:
Age > 65 years	Mortality, Morbidity, Length of stay
3 or more rib fractures	Mortality, Morbidity, Length of stay
Chronic lung disease	Mortality, Morbidity, Length of stay
Onset of pneumonia post injury	Mortality
Vital Capacity	Length of stay
Pre-injury anticoagulant use	Development of complications
BMI >25 kg/m^2	Initiation/prolonged duration of mechanical ventilation
PaO_2/FiO_2 ratio <250 on admission	Development of complications
Oxygen saturation < 90% in the ED	Development of complications

Surgical Risks

- Wound complications
- Infection
- Hardware failure
- Loosening
- Irritation
- Same as non-operative
  - Need for mechanical ventilation
  - Pneumonia
  - Sepsis
  - Death

Evidence – Operative intervention

3 RCTs and 19 non-randomized studies

Outcome	Flail Chest	Multiple Rib Fractures
Mortality	Non-statistically significant reduction in mortality	Not assessed
Length of ICU stay	In favour of fixation (-3.2 to -6.5 days)	1 study included – no statistically significant difference
Length of mechanical ventilation	Surgery reduced length (between -3.5 to – 7.5 days)	Statistically significant reduction in postoperative ventilator days in favour of ventilation group but no statistically significant difference in total ventilator days
Length of hospital stay	Pooled RCT showed -11.4 days Non randomised showed -3.8 days	No difference
Pneumonia	RR 0.36 (95% CI 0.15-0.85) in favour of fixation	
Sepsis	Statistically significant favour of surgery	
Spirometry	No difference	

Evidence – Operative intervention

Review Year Country	Review aim	Search strategy	Studies and participants	Patient, Intervention, Comparator, Outcome and Study type (PICOS)	Risk of bias	Authors' conclusions
Swart *et al*[17] 2017 USA	To perform a meta-analysis of high quality literature to evaluate both economic and medical benefits of early fixation of rib fractures in severe chest trauma.	PubMed, Embase, Medline and Scopus. No search start date. Last search date 1 June 2016. Search terms defined, No limitations described. Evidence of hand searching. Eligibility criteria: over 18 years of age and studies comparing operative versus non-operative treatment,	3 RCT n=123 14 Case–control 3 Case series	**Population** Acute flail chest 18 years or older. **Intervention** Operative fixation. **Comparator** Non-operative. **Studies type** All study designs.	No evidence of quality assessment.	Acute ORIF of rib fractures in patients with flail chest injuries results in reduced mortality and medical complications in conjunction with being cost effective intervention.
Schuurmans *et al*[18] 2017 The Netherlands	Investigate how operative management improves patient care for adults with flail chest.	PubMed, Trip database, Google Scholar. No search start date. Last search date November 2015. Search terms defined, No limitations described. Evidence of reference checking. Eligibility criteria: studies comparing operative versus non-operative treatment, RCT only and English.	3 RCT n=123	**Population** Acute flail chest. **Intervention** Operative fixation. **Comparator** Non-operative. **Studies type** RCTs.	Quality assessment completed but criteria and explanation unclear.	The operative management group showed a significant lower incidence of pneumonia, whereas mortality rate did not differ between treatment groups.
Schulte *et al*[13] 2016 UK	In patients with acute flail chest does surgical rib fixation improve outcomes in terms of morbidity and mortality?	OVID MEDLINE. Search start date 1946. Last search date January 2016. Search terms defined. Search strategy description minimal, no limitations described. No evidence of reference checking. No specific inclusion or exclusion criteria defined.	1 Meta-analysis by separate author. 1 RCT n=123 (2 further coded as RCT which are non-randomised studies). 3 Retrospective cohort studies.	**Population** Acute flail chest. **Intervention** Operative fixation. **Comparator** Non-operative. **Studies type** Unclear.	No evidence of quality assessment.	Surgical stabilisation of flail chest in thoracic trauma patients has beneficial effects with respect to reduced ventilatory support, shorter intensive care and hospital stay, reduced incidence of pneumonia and septicaemia, decreased risk of chest deformity and an overall reduced mortality when compared with patients who received non-operative management.

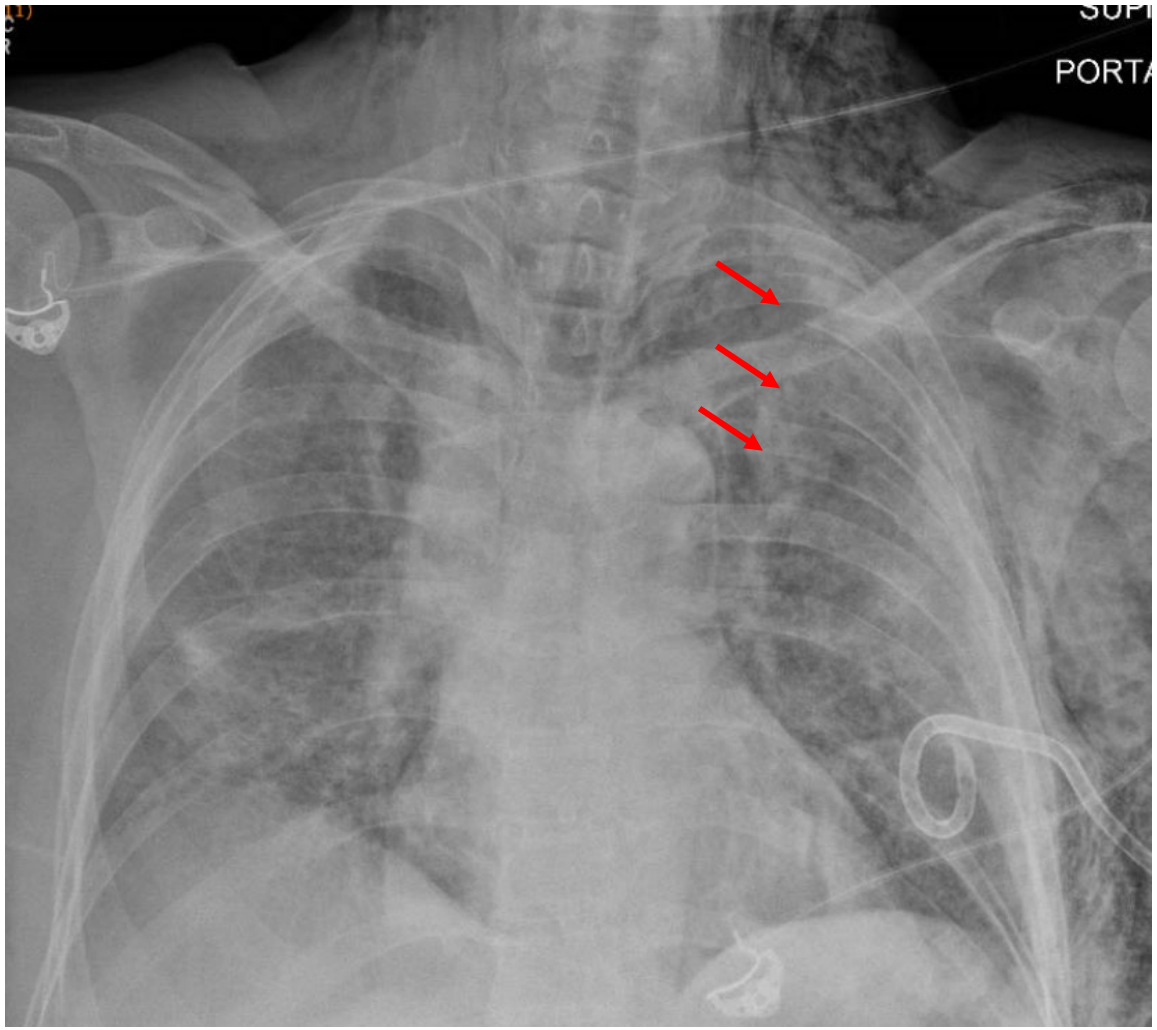
Ingoe HM, Coleman E, Eardley W, et al. Systematic review of systematic reviews for effectiveness of internal fixation for flail chest and rib fractures in adults. *BMJ Open* 2019; 9: e023444. doi: 10.1136/bmjopen-2018-023444

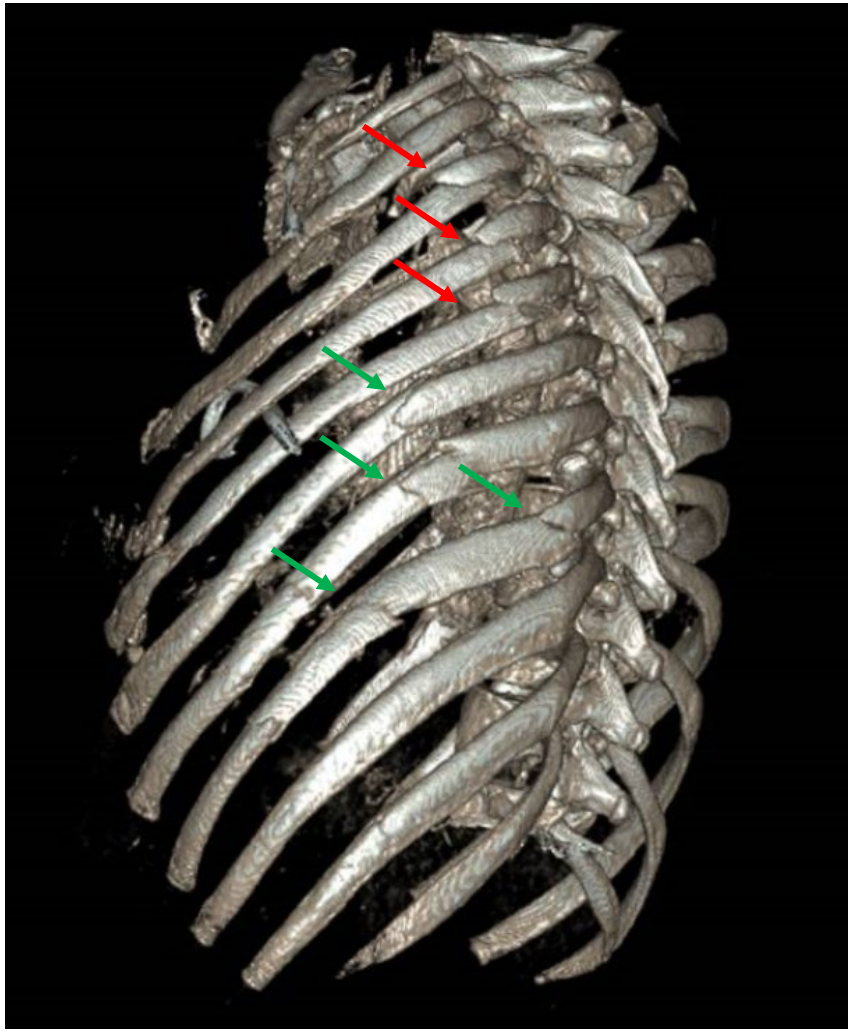
Evidence – Operative intervention

Review Year Country	Review aim	Search strategy	Studies and participants	Patient, Intervention, Comparator, Outcome and Study type (PICOS)	Risk of bias	Authors' conclusions
Coughlin *et al*[19] 2016 UK	Compare the efficacy of flail chest surgical stabilisation to non-operative management.	PubMed MEDLINE, Embase, Cochrane Library, clinical trials.gov. No search start date. Last search date February 2015. Search terms defined, No limitations. Evidence of reference checking. Eligibility criteria: studies comparing operative versus non-operative treatment in flail chest and RCT only.	3 RCT n=123	**Population** Traumatic flail chest. **Intervention** Surgical stabilisation of any kind. **Comparator** Patients treated non-operatively by any other means. **Studies type** RCTs only.	Clear quality appraisal of the studies.	Surgical stabilisation for a traumatic flail chest is associated with significant clinical benefits including rate of pneumonia, length of hospital an ICU stay and duration of mechanical ventilation in this meta-analysis of three relatively small RCTs.
Unsworth *et al*[24] 2015 Australia	To review the treatments for blunt chest trauma and their impact on patient and hospital outcomes. Specifically alludes to surgical stabilisation of flail chest.	Cochrane, Medline, EMBASE and CINAHL databases. Search limited to 1990 onwards. Last search date March 2014. Search terms defined. Limited to humans and adults. Evidence of reference checking. Eligibility criteria: original research, blunt chest trauma, intervention for blunt chest trauma including a comparator and contained measured outcomes.	3 RCT n=123 5 Retrospective case–controls n=642. 1 Retrospective cohort n=21.	**Population** Adult blunt chest trauma. Flail chest. **Intervention** Multidisciplinary intervention (models of care, management intervention, care practices, care protocols). **Comparator** Other intervention not specified. **Studies type** RCTs.	Some quality assessment completed but criteria and explanation unclear.	Across the literature there were consistent improvements in patients with flail chest and surgical fixation with fewer days of mechanical ventilation, ICU-LOS and cost savings compared with non-operative techniques. Three out of nine studies were randomised controlled trials, and the level of evidence in all studies was primarily fair or good.

Ingoe HM, Coleman E, Eardley W, et al. Systematic review of systematic reviews for effectiveness of internal fixation for flail chest and rib fractures in adults. *BMJ Open* 2019; 9: e023444. doi: 10.1136/bmjopen-2018-023444

Case 1 – Displaced multiple fractures





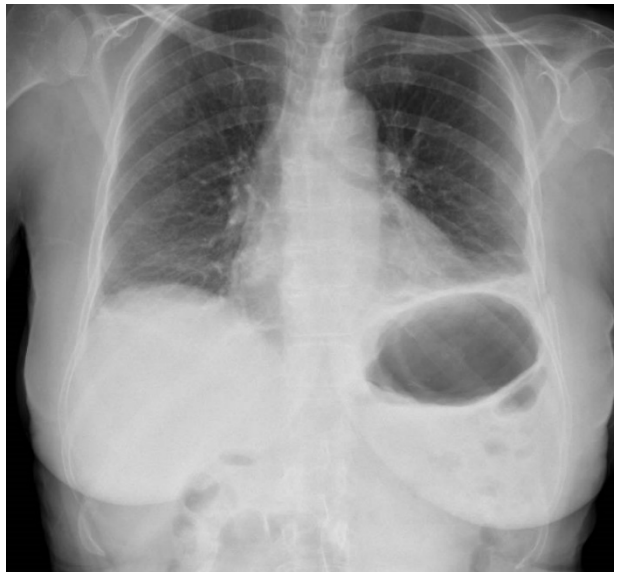
Case 1 – Displaced multiple rib fractures

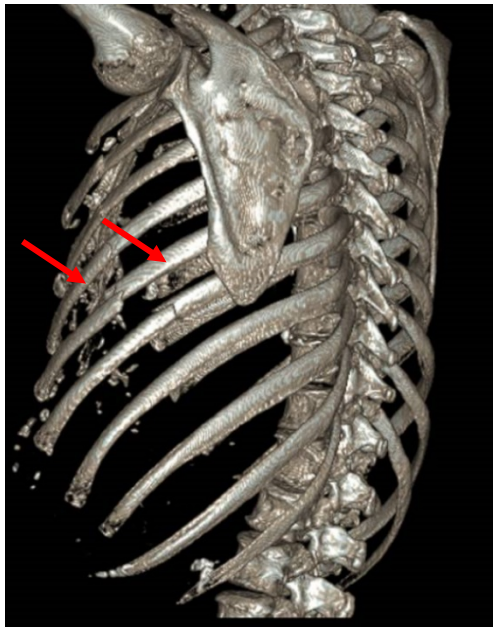
40yo Male. Multiple Orthopaedic Injuries

- Open plate fixation of 5 ribs
- CXR improved
- Off ventilatory support in 48 hours

Case 2 – Pain

- Continuous pain
- No relief with non operative modalities
- Pain in dermatomal pattern





Case 2 – Pain

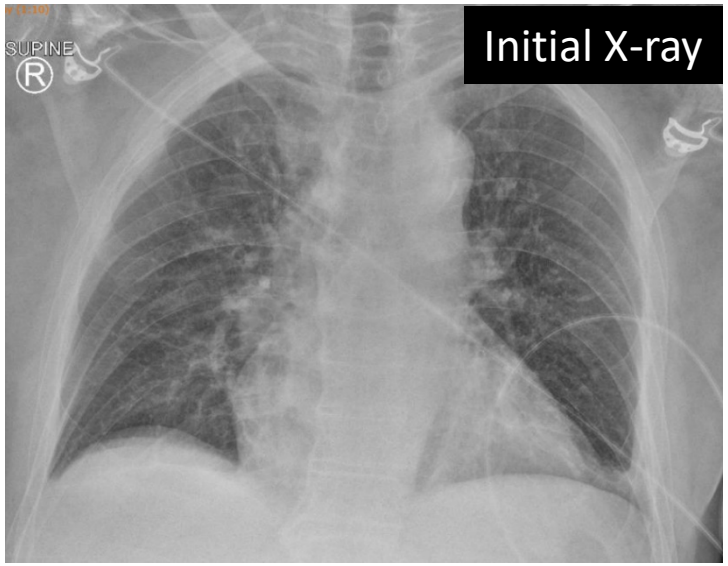
65 year old Female. Low energy fall.

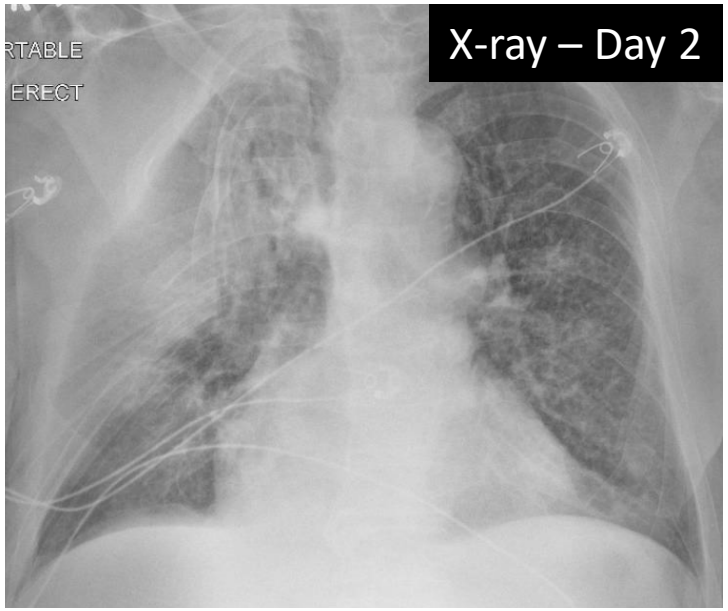
- # ribs plated in open technique
- Intercostal nerve entrapped in fracture site
- Removed and rib stabilized
- Excellent relief of pain

Case 3 – Fracture Instability

24year old male. Motor vehicle crash with multiple rib fractures. Polytrauma

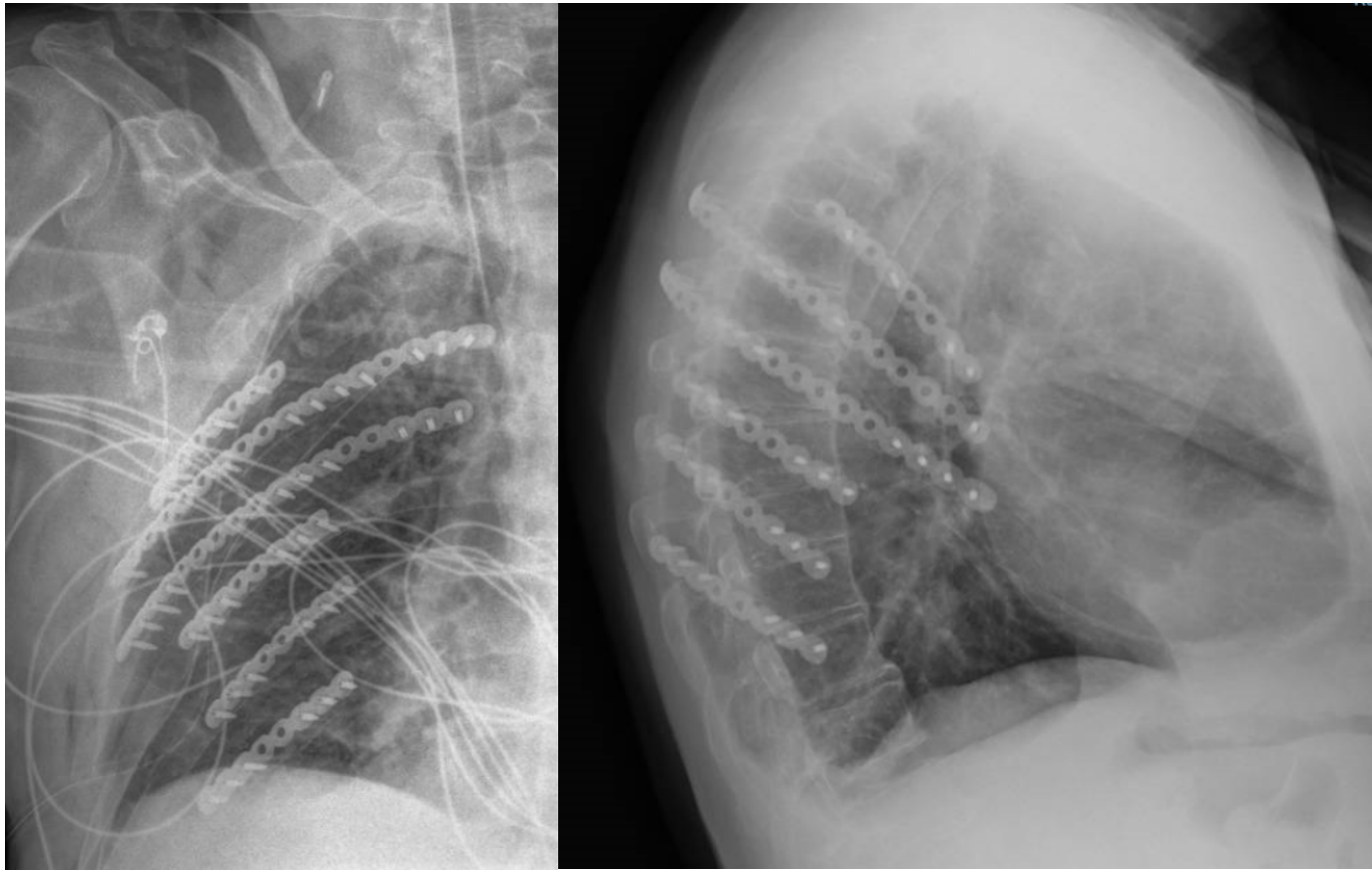
- Needing intensive physical therapy to maintain to move secretions and maintain O_2 saturations
- Severe pain with attempts to roll patient for chest therapy
- Patient having difficulty cooperating with therapy
- CXR and oxygenation worsening





Case 3 – Fracture Instability

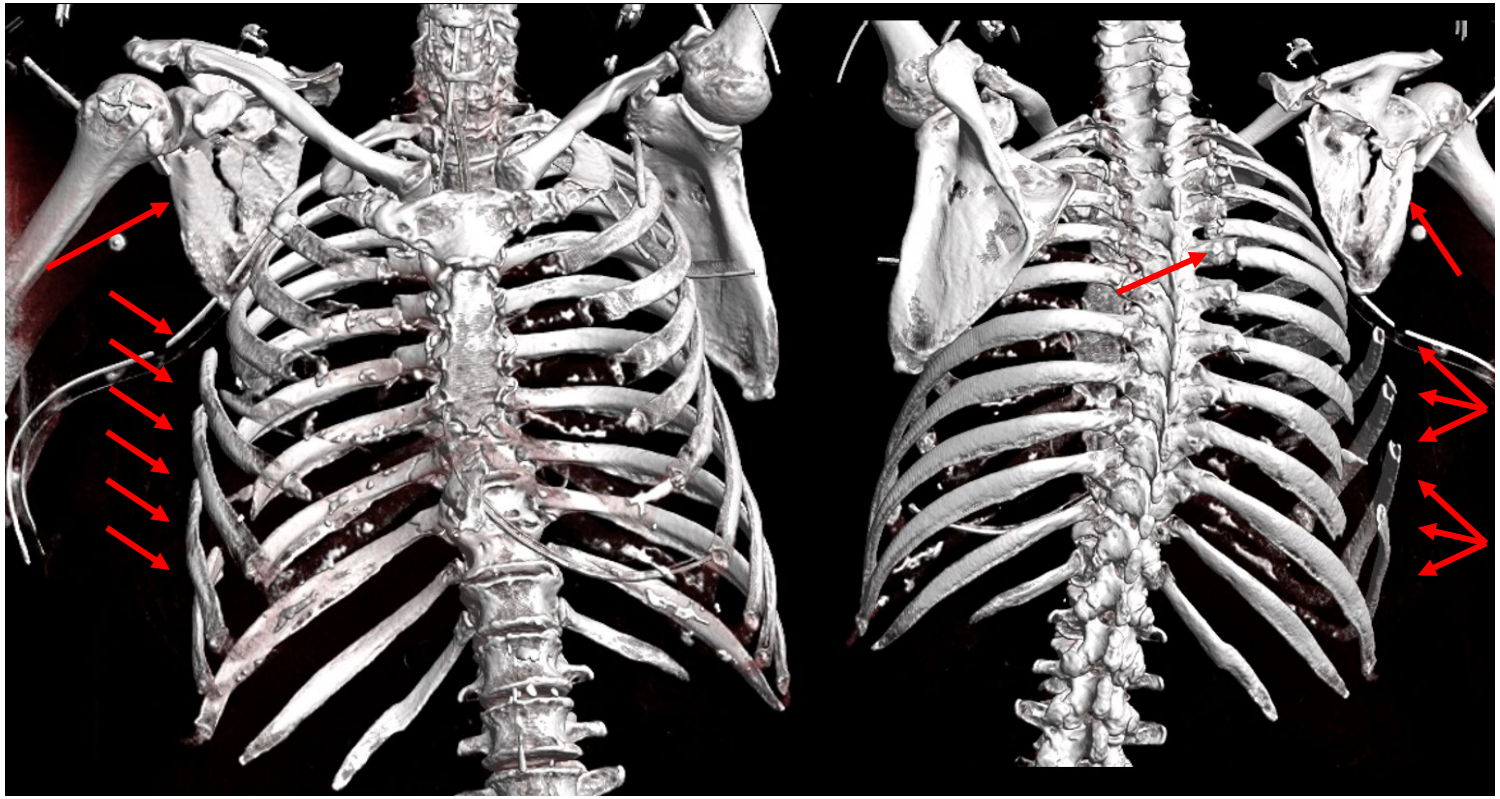
- Open plate fixation of ribs
- O_2 saturation improved
- Pain improved
- Able to tolerate therapy and upright position



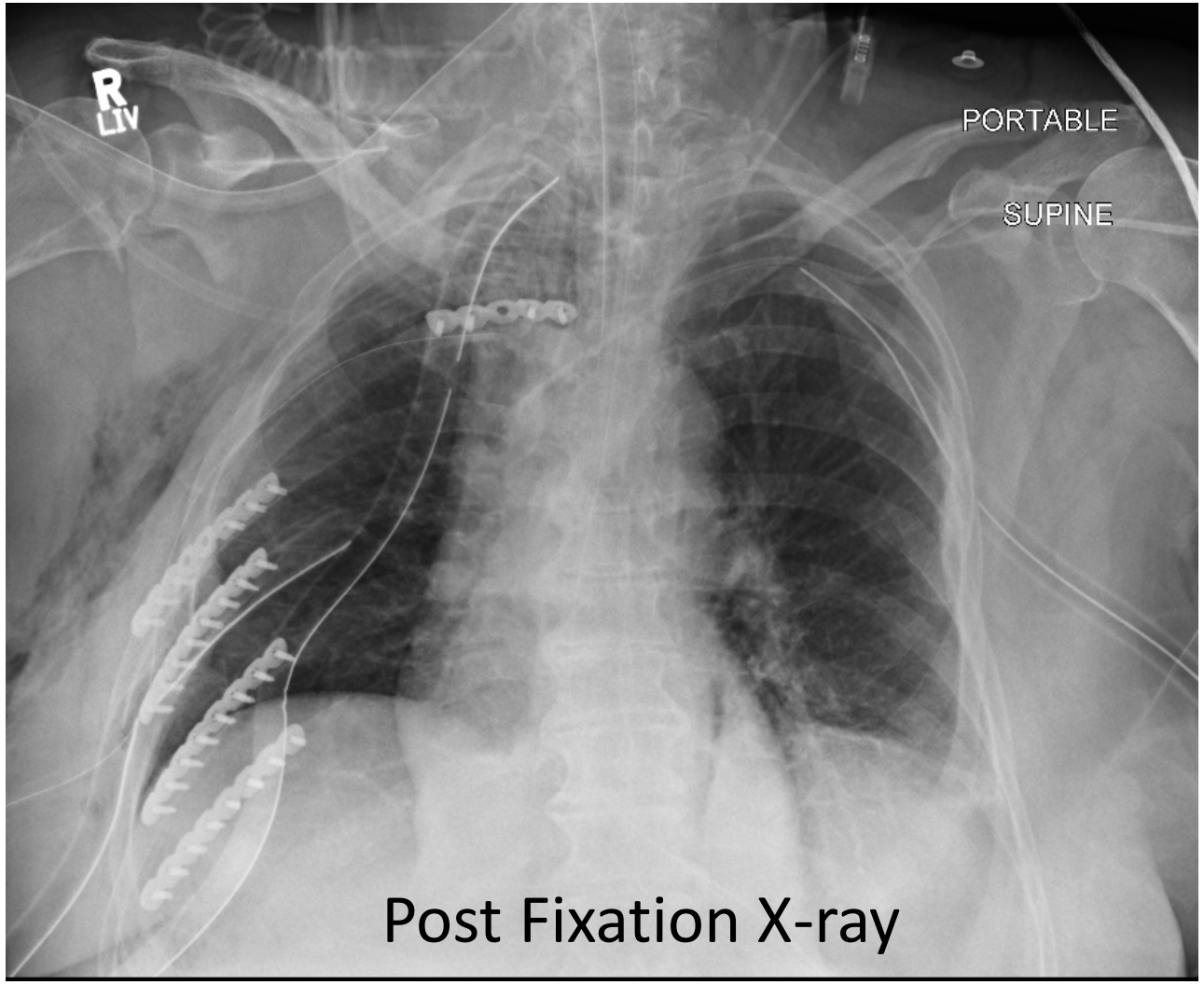
Case 4 – MVA Rollover: Chest and Upper Limb

29 year old patient has a severe scapula fracture associated with multiple rib fractures resulting in difficulty to mobilize upper extremity and breath due to pain from fractures and soft tissue injury

Stabilization of rib fractures improved pain on the scapular fracture side to allow improved respiratory parameters and mobilization of patient and upper extremity



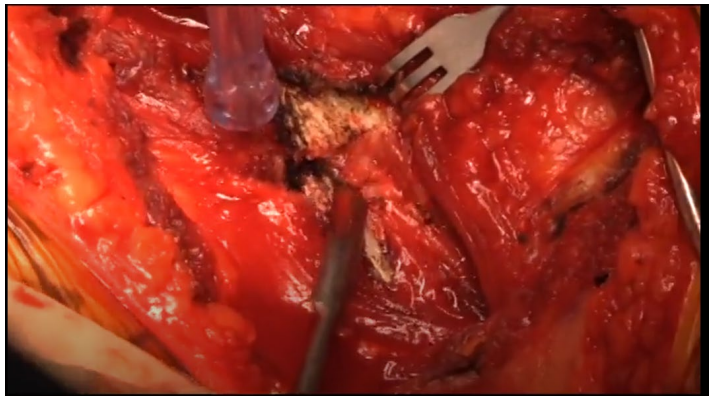
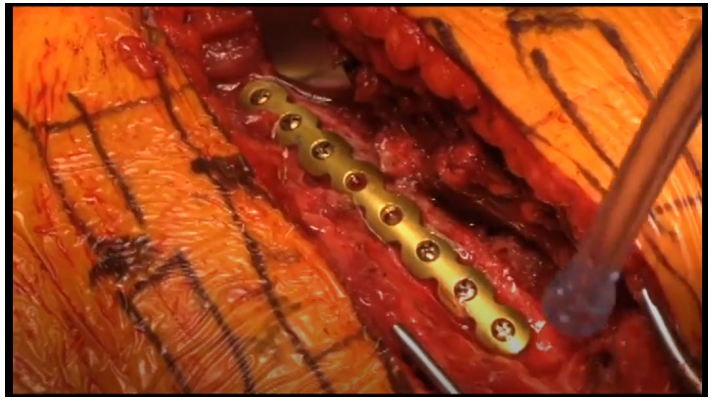
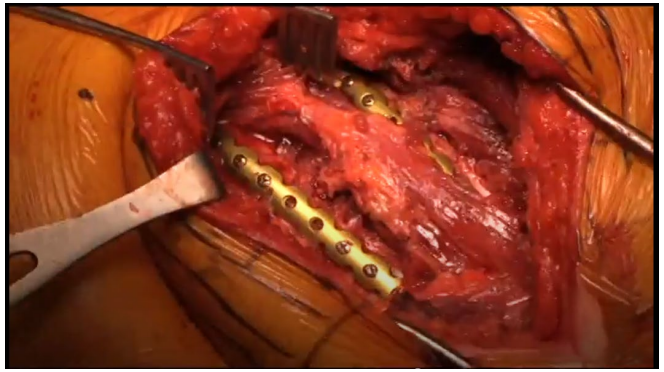
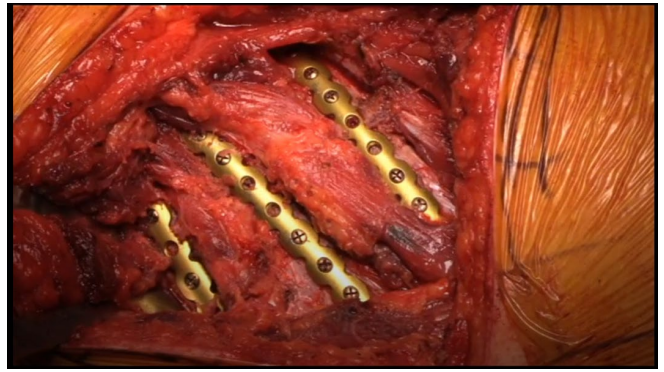
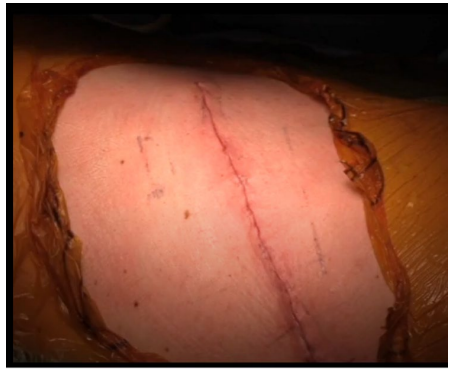
Case 4 MVA Rollover: Chest and Upper Limb



Post Fixation X-ray

OTA Video
Multiple Rib Non-Union: ORIF and Iliac Crest Bone Graft Aspirate

https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16731377/multiple-rib-non-union-orif-and-iliac-crest-bone

Summary

- Vast majority of rib fracture are appropriately managed nonoperatively
  - However, operative stabilisation should be considered for certain patients.
  - Indications currently for flail chest
  - Emerging procedure with evolving indications that requires careful patient selection
- Gold standard imaging is 3D reconstruction of chest wall
- Multimodal approach
- CXR prior to discharge

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