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, suppress 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, O₂ 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

<table>
<thead>
<tr>
<th>Imaging Technique</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest X-Ray</td>
<td>Cost and time effective, Early identification of life threatening cardiopulmonary trauma, Readily available</td>
<td>Lacks sensitivity in identifying rib fractures and pneumothorax</td>
</tr>
<tr>
<td>Computed Tomography</td>
<td>High sensitivity for rib fracture, pneumothorax, contusion, major organ/vessel damage</td>
<td>Expensive, Time, Radiation exposure</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>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</td>
<td>Subscapular injuries inaccessible, Cannot quantify degree of pathology, Difficult with obese patients or those with large breasts</td>
</tr>
</tbody>
</table>
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

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

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Worse outcomes in relation to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &gt; 65 years</td>
<td>Mortality, Morbidity, Length of stay</td>
</tr>
<tr>
<td>3 or more rib fractures</td>
<td>Mortality, Morbidity, Length of stay</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>Mortality, Morbidity, Length of stay</td>
</tr>
<tr>
<td>Onset of pneumonia post injury</td>
<td>Mortality</td>
</tr>
<tr>
<td>Vital Capacity</td>
<td>Length of stay</td>
</tr>
<tr>
<td>Pre-injury anticoagulant use</td>
<td>Development of complications</td>
</tr>
<tr>
<td>BMI &gt; 25 kg/m²</td>
<td>Initiation/prolonged duration of mechanical ventilation</td>
</tr>
<tr>
<td>PaO₂/FiO₂ ratio &lt;250 on admission</td>
<td>Development of complications</td>
</tr>
<tr>
<td>Oxygen saturation &lt; 90% in the ED</td>
<td>Development of complications</td>
</tr>
</tbody>
</table>

## 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

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

### Evidence – Operative intervention

<table>
<thead>
<tr>
<th>Review Year</th>
<th>Country</th>
<th>Review aim</th>
<th>Search strategy</th>
<th>Studies and participants</th>
<th>Patient, Intervention, Comparator, Outcome and Study type (PICOS)</th>
<th>Risk of bias</th>
<th>Authors’ conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsworth et al 2015</td>
<td>Australia</td>
<td>To review the treatments for blunt chest trauma and their impact on patient and hospital outcomes. Specifically alludes to surgical stabilisation of flail chest.</td>
<td>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.</td>
<td>3 RCT n=123 5 Retrospective case-controls n=642. 1 Retrospective cohort n=21.</td>
<td>Population: Adult blunt chest trauma. Intervention: Flail chest. Comparator: Multidisciplinary intervention (models of care, management intervention, care practices, care protocols). Comparator: Other intervention not specified. Studies type: RCTs.</td>
<td>Some quality assessment completed but criteria and explanation unclear.</td>
<td>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.</td>
</tr>
</tbody>
</table>

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

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

- Needing intensive physical therapy to maintain to move secretions and maintain O₂ 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

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
Key References


Key References

3 RCTs

