Blunt chest trauma: bony injury in the thorax

The management of blunt chest trauma is an evolving concept with no clear current guidelines. This article explores the bony injuries associated with this, focusing on rib fractures and flail segments and the themes around investigation and best management.

Blunt chest trauma causes injury to thoracic structures and is associated with significant morbidity and mortality (Unsworth et al, 2015). Injuries resulting from blunt chest trauma can be divided into those affecting bony and soft tissue structures.

The common bony injuries include rib, sternal or vertebral fractures. Rib fractures occur in 40% of patients who sustain severe non-penetrating chest trauma (Henry et al, 2014). This review of blunt chest trauma concentrates on fractures of the bony thorax, in particular rib fractures, and the evolving concepts regarding their management.

Anatomy

The chest wall has four primary functions:

1. It protects vital organs within both the thoracic (heart and lungs) and abdominal cavities (spleen, liver, kidneys)
2. It stabilizes the upper limbs by articulating with the scapulae
3. It aids ventilation by manipulating the volume of the thoracic cavity
4. It acts as the origin of many muscles of the chest, back, upper limbs and neck.

The bony anatomy of the chest wall (*Figure 1*) consists of the sternum and ribs. The sternum is in the anterior midline. In turn, three bones make up the sternum: the manubrium, sternal body and xiphoid process.

Mr Nasri H Zreik is Orthopaedic Registrar in the Department of Trauma and Orthopaedics, Aintree University Hospital, Liverpool L9 7AL

Miss Irene Francis is Medical Student in the Department of Medicine and Dentistry, Brighton University, Brighton

Mr Arun Ray is Orthopaedic Registrar in the Department of Trauma and Orthopaedics, Brighton and Sussex University Hospitals, Brighton, East Sussex

Mr Benedict A Rogers is Consultant Orthopaedic Surgeon in the Department of Trauma and Orthopaedics, Brighton and Sussex University Hospitals, Brighton, East Sussex

Mr David M Ricketts is Consultant Orthopaedic Surgeon in the Department of Trauma and Orthopaedics, Brighton and Sussex University Hospitals, Brighton, East Sussex

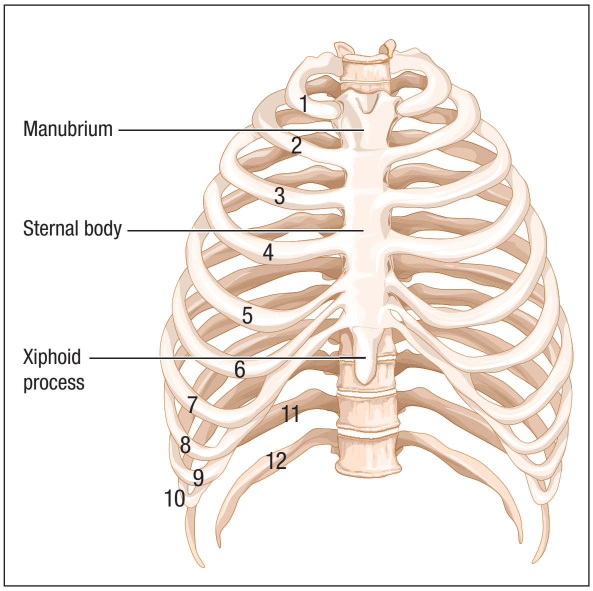
Correspondence to: Mr NH Zreik (nas_zreik@yahoo.co.uk)

There are twelve paired ribs. Ribs 1–7 are termed 'true' ribs and articulate directly with the sternum. The first pair is immobile. Pairs 2–7 articulate with the sternum as synovial joints, reinforced by sternocostal ligamentous attachments. This allows movement during ventilation in order to manipulate the volume of the thoracic cavity. The remaining ribs (8–12) are known as the 'false' ribs. These attach collectively via costal cartilages. Ribs 11 and 12 have no articulation anteriorly and are 'floating ribs'.

Posteriorly, the head of each rib articulates with the thoracic vertebra immediately above and below to form costovertebral joints (a gliding, synovial joint). The tubercle of each rib further articulates with the transverse process of the corresponding vertebra to form a synovial costotransverse joint, which is further reinforced by the anterior costotransverse ligament.

Between consecutive ribs three layers of muscles occupy the intercostal space. The external intercostal muscles elevate the ribs during respiration. The internal intercostal muscles are split into two layers by the neurovascular bundle: middle and innermost fibres. These run in an opposing orientation to the external intercostal muscles and depress the ribs.

Figure 1. Bony thoracic anatomy with ribs numbered.



Mechanism of injury

Blunt chest trauma is commonly caused by sudden deceleration injuries, such as in road traffic accidents or a fall from a height. The chest wall undergoes sudden deceleration, causing the mobile intrathoracic viscera to impact upon the bony structures adjacent to them. A wide range of injuries may ensue (*Table 1*).

The management of blunt chest trauma

The management of blunt chest trauma starts with ATMIST trauma room handover (*Table 2*) and advanced trauma life support (ATLS) guided primary and secondary surveys. The assessment and immediate management of life-threatening injuries in blunt chest trauma directly affects breathing and circulation. A careful examination should include:

- Evidence of tracheal deviation
- Evidence of paradoxical chest movement
- Auscultation
- Respiratory rate
- Oxygen saturation
- Pulse rate
- Blood pressure.

Clinical examination should guide which investigations may be necessary and reduce over-reliance on radiological investigations. A high index of suspicion and understanding of the mechanism of injury ought to guide assessment and decision making. The primary ATLS survey should identify and treat the following five life-threatening thoracic conditions:

1. Tension pneumothorax
2. Open pneumothorax
3. Massive haemothorax
4. Flail chest
5. Cardiac tamponade.

Following initial emergency management several risk factors increase mortality and morbidity in blunt chest trauma (*Table 3*). A validated prognostic model based on these factors was developed by Battle et al (2014).

An established hospital protocol for management of blunt chest trauma appears to reduce complications and hospital stay without affecting cost (Unsworth et al, 2015).

A number of pathways for management of blunt chest trauma has been evaluated. Todd et al (2006) found that multidisciplinary management centred on analgesia, respiratory support, anticoagulation, nutrition and early mobilization reduced the complication rate in high-risk patients with blunt chest trauma. A triage protocol for patients over 65 years of age with blunt chest trauma demonstrated significant reduction in length of hospital stay, suggesting that pre-defined clinical pathways improve outcomes (Sahr et al, 2013).

Rib fractures and flail segments

The most common cause of rib fractures is blunt chest trauma in motor vehicle accidents. Other causes include falls, assaults and industrial accidents (Sirmali et al, 2003).

Table 1. Common thoracic injuries

Soft tissues of the chest wall	Skin laceration Haematoma
Sternum	Fracture
Ribs	Fracture Flail segment
Pleura	Puncture by fracture ends Haemothorax Pneumothorax (simple or tension)
Lungs	Puncture Contusion Collapse
Tracheobronchial tree	Puncture Rupture
Diaphragm	Puncture Rupture
Heart and great vessels	Tear/transection of the vessels Contusion Cardiac tamponade
Oesophagus	Tear Rupture
Vertebrae	Fracture Spondylolithesis

Table 2. ATMIST trauma room handover

Age
Time of accident
Mechanism
Injuries
Signs (physiological, vital and limb)
Treatment carried out so far

Table 3. Risk factors increasing mortality and morbidity in blunt chest trauma

Age
Number of rib fractures
Oxygen saturations
Respiratory rate
Pre-injury anticoagulants
Smoking status
Chronic lung disease
Existing cardiovascular disease

Figure 2. Left-sided flail segment with fractures of ribs 4–7. Note the small pneumothorax in the upper zone.

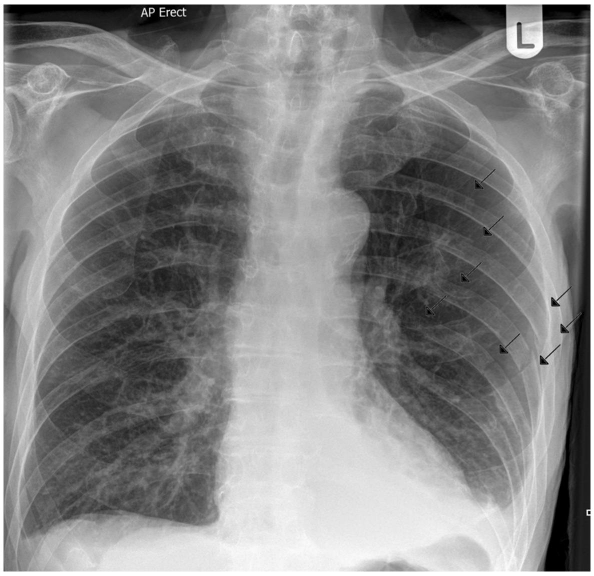
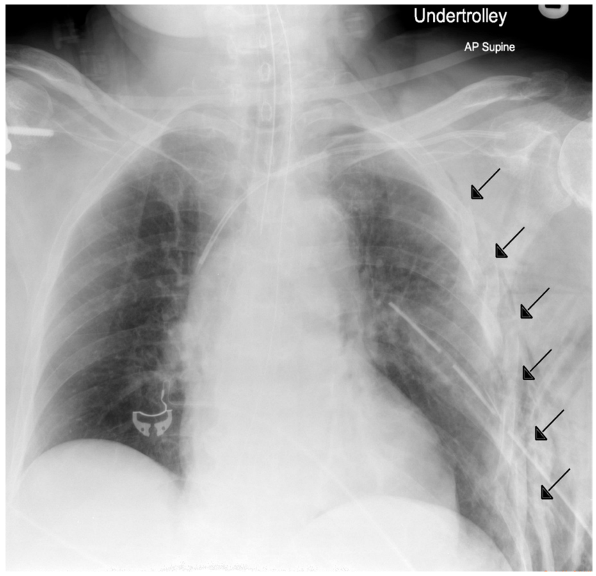


Figure 3. Left flail segment with comminuted fractures of ribs 2–7.



The nature of chest and rib injury differs with age. Children have a more compliant chest wall allowing greater deformity before failure; therefore more energy is required to fracture children's ribs. Because of this the incidence of pulmonary contusions after blunt chest trauma is doubled in children (Bliss and Silen, 2002).

Adults have less rib compliance. In adults blunt chest trauma is associated with a higher incidence of rib fracture on impact and associated morbidity and mortality (Kent et al, 2008). Localized thoracic loading (i.e. by seatbelts in motor vehicle accidents) can generate displaced rib fractures and potential soft tissue penetration of the pleura and lung.

In both children and adults rib fractures may be isolated or multiple. A fracture of two or more consecutive ribs in two or more places results in a flail segment (*Figures 2* and *3*). This occurs in 10% of patients with blunt chest trauma and is associated with significantly increased mortality (Ciraulo et al, 1994). Flail segments present with paradoxical motion of the chest wall during ventilation. During inspiration, negative intrathoracic pressure pulls the flail segment inward. On expiration, the positive pressure causes the segment to move outward.

Pain secondary to rib fractures results in splinting of the thorax, hypoventilation and a potential ventilation–perfusion mismatch that may be exacerbated by concurrent lung contusions. Without appropriate management this may deteriorate to respiratory failure. The common complications of rib fractures are outlined in *Table 4*.

Regarding the radiological investigation of bony injuries, plain chest radiography is the first-line investigation for rib fracture but has low accuracy. Computed tomography is widely used in assessing bony injuries in blunt chest trauma as it has higher accuracy in assessing rib fracture and other sequelae of blunt chest trauma (Sangster et al, 2007).

The management of rib fractures and flail chest

Following ATLS management the aim of further treatment is to avoid associated complications.

Single rib fractures without associated injuries are managed by analgesia, physiotherapy and mobilization. Effective pain control can prevent secondary complications such as atelectasis and pneumonia. The options for pain management include non-steroidal anti-inflammatory agents, opioids (avoiding respiratory depression) and topical local anaesthetic patches. More aggressive analgesia can include intercostal nerve blocks, intrapleural catheters and thoracic epidurals.

Paravertebral or intrapleural blocks are beneficial for unilateral rib fractures. For multiple bilateral fractures, epidural catheters with continuous infusion of anaesthetics and opioids have a longer duration of action (Rauchwerger et al, 2013). However, these require intensive monitoring to prevent complications such as spinal toxicity. Carrier et al (2009) concluded that the use of epidural analgesics offered no benefit regarding length of stay in intensive care but can reduce the duration of mechanical ventilation.

Surgical intervention in blunt chest trauma is indicated to manage either rib fracture or the soft tissue complications (such as haemothoraces and pneumothoraces). Tube

Table 4. Complications of rib fractures and flail segment
Visceral injuries (including haemothorax or pneumothorax)
Respiratory failure
Acute respiratory distress syndrome
Atelectasis
Pneumonia

thoracostomy can be the definitive procedure for haemothorax or pneumothorax, whereas video-assisted thoracic surgery is used successfully in draining pleural haematomas (Sirmali et al, 2003).

Debate exists regarding the benefits of operative *vs* non-operative management for flail segment (Nirula et al, 2008). Currently there are no widely accepted guidelines for surgical fixation of ribs for flail segment. Early surgical intervention may reduce the associated risks of prolonged intubation. Evidence suggests early surgical stabilization may benefit patients needing mechanical ventilation for more than 48 hours (de Lesquen et al, 2014).

Some studies demonstrate clear benefits of surgical intervention for flail segments, such as:

- Reduced mechanical ventilation (Doben et al, 2014)
- Improved postoperative quality of life and cost saving (Marasco et al, 2013)
- Decreased mortality compared to ventilator management alone (Leinicke et al, 2013).

Although surgical stabilization of multiple rib fractures is uncommon, it is associated with decreased morbidity and number of days on mechanical ventilation (Karmy-Jones and Jurkovich, 2004). Nirula et al (2008) suggested indications for operative fixation (*Table 5*).

The techniques used for surgical fixation of flail segments include plates (metal and biodegradable), wires, struts or sutures. Suture techniques include pericostal sutures through the ribs with a figure-of-8 or through plates.

The complications of rib fracture fixation are outlined in *Table 6*. Osteoporotic ribs are at risk of metalwork failure as normal respiratory effort places a variety of tension forces on the ribs during expansion and contraction (Karmy-Jones and Jurkovich, 2004). A disadvantage of metal prostheses in the chest is migration, necessitating removal. Further, stress shielding by the metal may reduce bone growth and cause delayed union.

A survey of trauma and thoracic surgeons in America found that while the majority advocated rib fracture fixation, few had performed the procedure as a result of a lack of expertise, research or randomized trials on optimal technique (Mayberry et al, 2009).

Table 5. Relative indications for operative fixation of rib fractures

Open fracture
Flail chest
New chest wall deformity
To reduce pain and disability
Symptomatic rib fracture non-union

Table 6. Complications of rib fracture fixation

Increased pain and splinting
Pneumothorax and/or haemothorax
Damage to viscera
Metalwork migration
Wrong rib surgery
Chronic pain
Malunion or non-union
Need for further surgery (e.g. metalwork removal)

Sternal fractures

Sternal fractures may result from direct or indirect trauma. Direct trauma such as with blunt chest trauma from deceleration injuries in vehicles has a reported incidence of sternal fracture of 3–6.8% (Brookes et al, 1993). Indirect sternal fractures are uncommon and tend to occur in higher risk groups such as the elderly, post-menopausal women and patients on long-term steroid therapy (Horikawa et al, 2007).

Isolated sternal fractures tend to have good prognosis (de Oliveira et al, 1998). Most sternal fractures occur in multiply injured patients with polytrauma and may be associated with a higher mortality rate. The most common associated injuries are to the chest wall.

Investigation

The investigation of choice for sternal fractures is a lateral chest X-ray (Von Garrel et al, 2004). This is not usually practical in a trauma setting and a computed tomography scan should be obtained if a pneumothorax is suspected. Three-dimensional reconstruction of computed tomography images may help in preoperative planning for fixation.

Management

During the secondary survey, a high index of suspicion to concomitant injuries such as flail chest and vertebral injuries should guide investigation and management.

Patients with isolated sternal fractures may be discharged within 24 hours provided that cardiac injury markers, in particular electrocardiography and cardiac enzymes, are normal (Sadaba et al, 2000). Patients with multiple comorbidities or polytrauma normally require admission for analgesia and assessment for ventilatory and cardiothoracic capacity.

Most sternal fractures are managed non-operatively with adequate analgesia. Non-union of these can lead to chronic painful instability. Surgical management may include various techniques for open reduction internal fixation such as plating or circlage wiring of the sternum. Rigid plate fixation has the advantage of inducing bone healing faster and reduces complications of non-union, malunion and infection when compared to wiring. Wound healing problems following surgical fixation can be a serious complication and may require plastic surgery reconstruction.

KEY POINTS

- Evidence is strong for the use of an established protocol for blunt chest trauma management for improving patient outcomes. The development of new British Orthopaedic Association Standards for Trauma (BOAST) guidelines, in association with cardiothoracic surgeons and intensivists, might be a logical step.
- Single uncomplicated rib fractures should be management with adequate analgesia and chest physiotherapy advice.
- Multiple rib fractures and flail chest benefit from early surgical intervention to restore chest wall integrity to improved respiratory function. It can reduce stay on intensive care, requirement for ventilatory support and overall length of hospital stay. It should be noted that surgical fixation is not without risk and specialist surgeons should undertake this.
- Sternal fractures should be discussed with the appropriate team regarding whether and/or when to fix.
- Management of vertebral fractures and suspected spinal cord injury should follow BOAST-2 guidelines and be discussed with orthopaedic and spinal surgeons.

Vertebral injuries

Spinal injuries occur in 2–6% of blunt chest trauma (Hsu et al, 2003). Common mechanisms of injury include falls from a height, ejection from a vehicle and pedestrians struck by vehicles. These produce different patterns of fracture. Falls from height are commonly associated with burst or wedge fracture. With blunt chest trauma, a lap seatbelt restraint may result in a Chance fracture; a flexion-distraction injury where energy is transferred horizontally through the vertebra or intervertebral disc and soft tissue.

Vertebral fractures may be stable or unstable. With high velocity trauma there is an associated 20% risk of non-contiguous fractures (British Orthopaedic Association Standards for Trauma (BOAST 2), 2008) in the spine. Unstable fractures may result in spinal cord injury, especially in the presence of retropulsed bony fragments in the spinal canal.

A clearly documented neurological exam is essential. Hsu et al (2003) demonstrated that the following show high specificity for thoracolumbar fractures:

- Presence of back pain or midline tenderness
- Palpable midline step
- Back ecchymosis
- Abnormal neurological signs.

The British Orthopaedic Association published standards of trauma (BOAST 2) on spinal clearance in trauma patients. These recommendations include the assumption that all patients presenting with blunt trauma have a spinal injury until proven otherwise and that a hospital protocol for spinal immobilization is important. They also recommend computed tomography imaging as this has high sensitivity and specificity for unstable injuries. Magnetic resonance imaging has a high sensitivity for spinal cord injury, although it is more difficult to conduct, especially in intensive care patients (BOAST 2).

Management

The management of isolated vertebral injuries varies with the neurological deficit and mechanical instability. This can be assessed radiologically with the Denis three-column theory (Denis, 1978) – dividing the vertebrae and soft tissues into anterior, middle and posterior columns; with two or more columns affected, the fracture is mechanically unstable.

Stable injuries may be managed with analgesia and mobilization. A thoraco-lumbar support orthotic may be beneficial. Surgical stabilization, with or without surgical decompression, may be used for unstable fractures. The stabilization techniques vary between the cervical and thoracolumbar spines, including a variety of fixation options, e.g. struts or pedicular screws.

Conclusions

The caseload of blunt chest trauma is increasing and management options are evolving with an incomplete evidence base. Surgical fixation of multiple rib fractures and flail chest may decrease hospital stay and patient disability, and improve pulmonary status requiring less time on mechanical ventilation. Conservative management of rib fractures can be beneficial in patients who are unfit for surgery.

Close collaboration between emergency department, surgical and intensive care teams is essential to identify blunt chest trauma early and expedite appropriate management. **BJHM**

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