Blunt chest wall trauma: an overview

ABSTRACT

Trauma affecting the chest wall, even in isolation, can carry a significant morbidity and mortality and thus appropriate management is vital. Consequences of chest wall trauma may include significant pain, altered chest wall mechanics, hypoventilation, infection and respiratory failure. In order to best determine the appropriate management, risk stratification tools have been developed to identify patients at highest risk of complications who would most benefit from more invasive management strategies. Early optimization of analgesia is vital both for patient experience and to reduce the risk of pulmonary complications. The analgesic options range from multimodal oral analgesia to invasive regional anaesthetic techniques such as thoracic epidurals, paravertebral catheters, intercostal nerve blocks and fascial plane blocks. Other important considerations include provision of appropriate oxygen therapy, ventilation support and physiotherapy. For a selected group of patients with the most significant injuries, surgical rib fixation may be appropriate if chest wall mechanics are sufficiently impaired.

Trauma is injury caused by physical force and makes up a significant proportion of the emergency department caseload globally, of which blunt chest trauma accounts for up to 15% of cases (Battle et al, 2014). The leading causes of blunt chest injury are falls from height and road traffic collisions (Barnea et al, 2002). Rib fractures are the most frequent injury following blunt chest trauma, affecting up to two thirds of patients (Simon et al, 2005). The true incidence may even be higher as some studies have reported that rib fractures often pass undetected on plain chest radiographs (Davis and Affatato, 2006).

Isolated rib fractures are associated with high morbidity and mortality, with complications seen in up to 36% of all cases (Barnea et al, 2002). Additionally, many patients with blunt chest trauma have associated injuries to underlying tissues including pneumothoraces, haemothoraces, lung contusions and solid organ injuries (Ziegler and Agarwal, 1994). Such patients require significant input in the acute setting, frequently require critical care support (Bergeron et al, 2003) and often need prolonged inpatient admissions. Mortality after blunt chest trauma is indirect and therefore harder to determine, but it has been estimated as 6–16%, and as high as 20% in patients with a flail segment (Ziegler and Agarwal, 1994; Sırmalı et al, 2003; Flagel et al, 2005; Simon et al, 2005; Battle et al, 2013).

A flail segment occurs when two or more fractures occur in at least two adjacent ribs, creating a section of the rib cage that moves independently of the rest of the chest wall. During normal ventilation, negative inspiratory pressure causes paradoxical inward movement of the flail segment. The underlying lung does not expand normally and therefore does not take part in gas exchange, creating an area of shunt and increasing the work of breathing.

Pain is the most common symptom from rib fractures and a key component in the generation of pulmonary complications. Pain restricts chest wall movement leading to hypoventilation, and impairs coughing ability leading to sputum retention; these combine to cause atelectasis and predispose to pneumonia. Additionally, injured lung tissue underlying the fractures has impaired ability to exchange gases, leading to shunt and VQ mismatch, and reduced compliance. Compensatory increases in respiratory rate may increase oxygen consumption. Pneumonia occurs in up to 30% of cases, with or without sepsis, causing further respiratory compromise. The combination of hypoventilation, atelectasis and/or lobar collapse and impaired gas exchange results in hypoxaemia, respiratory failure and, in some cases, a need for mechanical ventilation. These respiratory complications typically develop at 48–72 hours post injury. Other, less common, respiratory complications include pulmonary embolus, pulmonary effusions, empyema and acute respiratory distress syndrome (Simon et al, 2005; Jones et al, 2011; Battle et al, 2014; May et al, 2016; Witt and Bulger, 2017).

Risk stratification: the key to determining management

Given their high incidence, predicting the likelihood of complications is important to determine the appropriate management strategy for these patients. Multiple risk factors have been identified for poor outcomes in rib fractures, which can be classified as shown in *Table 1*.

A number of different scoring systems have been created based on varying combinations of the above risk factors and these are often used to guide the management of patients. A well-validated score was created by Battle et al (2014), detailed in *Table 2*, and the probability of

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Table 1. Key risk factors associated with poor outcomes in patients with chest wall trauma

Anatomical	Number of ribs fractured	
	Presence of flail segment	
	Bilateral rib fractures	
	First rib fractured	
	Degree of fracture displacement	
	Fractures in the anterior, lateral and posterior regions	
	Presence of pulmonary contusions	
	Presence of two or more distant injuries	
Physiological	Reduced physiological reserve	Increasing age
		Premorbid respiratory disease
		Smoking
		Overweight or obese (body mass index >25 kg/m^2)
		Obstructive sleep apnoea
		Premorbid cardiovascular disease
		Premorbid diabetes
	Reduced peripheral oxygen saturations at presentation	
	Reduced vital capacity	
	Post injury pneumonia	
	Inadequate analgesia	
Other	Premorbid use of anticoagulants	
	Treated in low volume centres	
	Treated outside a pathway	

From Simon et al (2005), Jones et al (2011), Battle et al (2014), Unsworth et al (2015), May et al (2016), Witt and Bulger (2017)

Table 2. Risk score system to assess risk of complications

Variable	Score
Age	+1 per additional 10-year increase starting at 10 years of age
Number of rib fractures	+3 per rib fractured
Chronic lung disease	+5 if present
Pre-injury anticoagulant use	+4
Peripheral oxygen saturation levels	+2 per 5% decrease in peripheral oxygen saturation levels starting at 94% at time of assessment
Total	

adapted from Battle et al (2014)

Table 3. Risk factor score and probability of developing complications

Final risk score	Probability mean ± standard deviation of developing complications
0–10	13 ± 6%
11–15	29 ± 8%
16–20	52 ± 8%
21–25	70 ± 6%
26–30	80 ± 6%
31 and upwards	88 ± 7%

adapted from Battle et al (2014)

complications that the score predicts is shown in *Table 3*. For example, a 60-year-old man with chronic obstructive pulmonary disease, with five fractured ribs and who has oxygen saturations of 89%, would have a score of 22, and therefore a 70% (±6%) risk of developing complications.

The key elements of treatment of blunt chest injury are analgesia, ventilation management, physiotherapy and surgery.

Analgesic options for chest wall trauma

Optimizing analgesia is vital to prevent complications. There are many options for managing pain after blunt chest injury fractures including multimodal oral therapy, intravenous analgesia, topical treatments and a variety of regional anaesthetic techniques.

Acute pain severity and character should be assessed. Multimodal analgesic drugs including paracetamol, non-steroidal anti-inflammatory drugs and opioids are commonly used as initial treatment. These can be delivered orally or intravenously as appropriate and prescribed regularly or as required – either by request or via patient-controlled analgesia pumps. Patient-controlled analgesia is widely available, minimally invasive and has been shown to improve ventilation and pain scores in this patient group (Simon et al, 2005). However, issues arise with systemic side effects, including sedation, cough suppression and respiratory depression from opioids (Chau et al, 2008), as well as cardiovascular and gastrointestinal side effects from non-steroidal anti-inflammatory drugs (Marret et al, 2005). Adjunctive medications including anti-emetics, laxatives and gastric protection should be prescribed as appropriate. Other analgesic options in less severely injured patients include topical local anaesthetic patches, e.g. lidocaine, and transcutaneous electrical nerve stimulation. These have been shown to have some analgesic benefit (Oncel et al, 2002; Zink et al, 2011), but the evidence base is limited and they have only been used in patients with less extensive injury.

Epidural analgesia

Epidural analgesia is widely used, and recommended for blunt chest wall trauma (Simon et al, 2005). An 'epidural' involves the insertion of a fine bore catheter into the epidural space, at the level of the fractures, through which local anaesthetics and opioids can be administered to provide bilateral analgesia. When compared to intravenous analgesia, thoracic epidural analgesia is associated with reduced rates of pulmonary complications, requirement for invasive ventilation (Jarvis et al, 2009) and reduced mortality (Flagel et al, 2005). However, epidurals are an invasive procedure, can be technically challenging to insert and have a number of well-documented complications including failure to provide analgesia, hypotension, dural puncture, nerve damage, radicular pain, respiratory depression and epidural haematoma among others (Simon et al, 2005; Ahn et al, 2013). Additionally, availability of epidurals may be limited by a lack of appropriately trained staff to insert them and sufficiently trained nursing staff to provide subsequent care, although this holds for any regional anaesthetic technique. Epidurals may be contraindicated in patients with coagulopathy, spinal pathology, infection or drug allergy.

Paravertebral blocks

The spinal nerves (*Figure 1*) can be blocked to provide unilateral analgesia as they pass through the paravertebral space. Paravertebral blocks, either as a single injection or insertion of a catheter, can be performed using a landmark technique or with ultrasound guidance. Paravertebral blocks have a similar analgesic efficacy to thoracic epidural analgesia in patients with unilateral rib fractures in some studies (Mohta et al, 2009). Theoretical advantages of paravertebral blocks over thoracic epidural analgesia include potential simplicity to perform and an improved side-effect profile, in particular a lower risk of neurological injury and reduced sympathetic block (Davies et al, 2006; Tighe et al, 2010). Complications include inadvertent epidural or intrathecal injection, pneumothorax, vascular puncture and hypotension (May et al, 2016). There is dispute over whether they are as effective as thoracic epidural analgesia and they are only of benefit if fractures are unilateral.

Fascial plane blocks

In recent years considerable interest has developed in fascial plane blocks, where local anaesthetic agents are infiltrated into the potential spaces that exist between muscle fasciae and therefore block any nerves which pass through. The serratus anterior plane block (Blanco et al, 2013) involves the infiltration of local anaesthetic into the potential space surrounding the serratus anterior muscle to block the intercostal nerves, which lie deep to and penetrate the serratus muscle (May et al, 2016). Serratus anterior plane blocks are considered safe, particularly in patients with abnormalities of coagulation, having been widely used in breast surgery, and compared against thoracic epidural analgesia for elective surgical thoracotomy (Khalil et al, 2017). However, they have not yet been robustly evaluated in patients who have had rib fractures, although studies are ongoing. Case reports and a retrospective series exist for the use of an erector spinae plane block for unilateral rib fracture analgesia (Hamilton and Manickam, 2017; Adhikary et al, 2019), but again, more robust evaluation is required before routine use is adopted.

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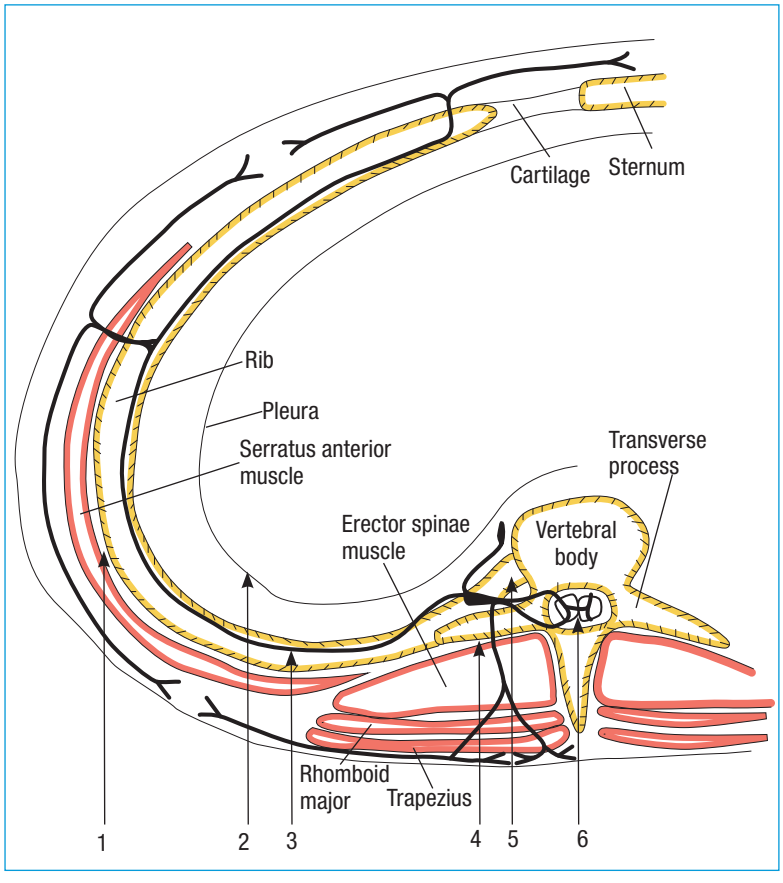
Other blocks

Less widely used blocks include intercostal nerve blocks and interpleural anaesthesia. Intercostal nerve blocks involve injection of local anaesthetic immediately below the rib into the intercostal space to block a single nerve and therefore provide analgesia to a single rib fracture. Multiple painful injections are required for multiple fractures, each carrying the risk of pneumothorax, vascular injury and local anaesthetic toxicity (May et al, 2016). Interpleural anaesthesia involves infiltrating the pleural space with

Figure 1. An illustration of a hemi-thorax with the intercostal nerve and its divisions supplying sensation to the chest wall demonstrated (black line). The numbers relate to sites of possible analgesic targets: 1. Serratus anterior plane block. 2. Interpleural block. 3. Intercostal nerve block. 4. Erector spinae plane block. 5. Paravertebral block. 6. Thoracic epidural.



KEY POINTS

- Chest wall trauma is associated with a high incidence of complications, which lead to morbidity, mortality and prolonged hospital admissions.
- The risk of developing complications should be identified to ensure appropriate management can be instituted to minimize the risk and severity of these complications.
- Analgesia is crucial to enable appropriate ventilation and allow secretion clearance; there are many options but the modality with the largest evidence base for improving outcomes is currently the thoracic epidural.
- Physiotherapy and management of ventilation are also important to consider when managing patients with significant chest wall injury.
- Some patients with significant chest wall deformity or flail segments may be considered for surgical rib fixation to improve their chest wall mechanics.

local anaesthetics. It requires an indwelling catheter and is often limited by local anaesthetic agent loss via any chest drain. There is also variable and unpredictable spread in the pleural cavity, particularly if blood or an effusion is present (Simon et al, 2005).

Ventilation management

Many patients will require supplemental oxygen after blunt chest wall injury. Oxygen should be titrated to the lowest concentration that achieves oxygen saturations of 94–98% unless the patient is at risk of carbon dioxide retention. Humidification of supplemental oxygen is important to prevent airway drying and help to loosen secretions. Sitting upright, early mobilisation and use of 0.9% sodium chloride nebulisers can assist expectoration. Some patients will develop significant respiratory failure, which will require more advanced support including continuous positive airway pressure, non-invasive ventilation, nasal high flow oxygen or invasive ventilation. Decisions regarding advanced ventilatory support should be individualised and taken in conjunction with critical care teams, but a preventative rather than reactive approach is ideal.

Physiotherapy

Physiotherapists play a crucial role in the care of patients with chest wall trauma and should be involved within 24 hours of admission. Physiotherapists can support early mobilisation, bed-based exercises, active cycle breathing techniques and assisted coughing techniques. Participation in physiotherapy requires adequate non-sedating analgesia.

Surgical management

Surgical rib fixation is the internal reduction and stabilisation of broken ribs using metal plates, screws or wires (National Institute for Health and Care Excellence, 2010). The indications for surgical fixation are flail segment associated with significant respiratory compromise, especially in those who require mechanical ventilation (National Institute for Health and Care Excellence, 2010), severe chest wall deformity, non-union or uncontrolled pain (Battle et al, 2013).

Ribs have a thin cortex, curved structure and tend to fracture obliquely, meaning that surgical fixation can be technically challenging (Nirula et al, 2009). Furthermore, the rib moves with every breath and so any surgical fixation device will be expected to tolerate the movement of breathing thousands of times each day. Typically, surgical fixation is only applied to ribs from T4 to T10. Fixation of the ribs between T1 and T3 carries a high risk of subclavian vessel injury, while fractures of ribs at T11 and T12 rarely lead to any significant compromise (National Institute for Health and Care Excellence, 2010). The procedure is performed under general anaesthesia in the lateral or supine position. Regional anaesthetic techniques as described above are also frequently used in conjunction with surgery for postoperative care (May et al, 2016).

Multiple small studies have demonstrated the benefits of surgical fixation to include lower rates of pneumonia and chronic pain, reduced durations of mechanical ventilation and a lower risk of tracheostomy and higher chances of returning to work post injury (Tanaka et al, 2002). The National Institute for Health and Care Excellence (2010) supports the use of surgical rib fixation and has guidelines available.

Conclusions

Patients with blunt chest wall trauma present frequently and are at high risk of morbidity and mortality. It is vital that the patients at highest risk of complications are identified and appropriately managed. The use of appropriate analgesic options, both invasive and non-invasive, may help prevent respiratory complications, while in some patients surgical fixation may prove to be necessary. **BJHM**

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