



Challenges in plate fixation of chest wall injuries

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ABSTRACT

Unstable chest wall injuries can result from multiple rib fractures or a flail chest, and are associated with high rates of morbidity and mortality. Traditionally such injuries have been treated non-operatively, with mechanical ventilation when required, and pain management. Surgical treatment of these fractures is technically possible, and studies suggest improved outcomes, such as lower time on mechanical ventilation and length of time in the intensive care unit, compared to non-operative treatment. However, there are many challenges and controversies regarding indications for surgical fixation, patient selection, outcomes, and fixation strategy. Further research in this area is warranted to better answer these questions.

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Introduction

Rib fractures are common injuries and occur in up to 39% of patients with blunt chest trauma [1]. The majority of these are isolated single rib (58%) [2], which usually heal uneventfully. However, a significant proportion of patients with rib fractures suffer fractures of multiple ribs (41%), and a small fraction are diagnosed with a flail chest (1.5%) [2].

It has been reported that 10–15% of patients with blunt chest trauma can have chest wall instability [3]. Chest wall instability can be caused by a flail chest, which is defined as fractures of three or more consecutive ribs, in two or more places, creating a flail segment [4]. This definition also applies to ≥ 3 bilateral consecutive rib fractures; and ≥ 3 rib fractures associated with a sternal fracture, as both of these also lead to the creation of a flail segment [5]. Other causes of unstable chest wall can be a crush injury that causes a “caved in chest”, or severe displacement or overriding of ribs. These can lead to chest wall deformity, loss of thoracic volume, and impaling of lung or intra-thoracic structures by the fractured rib fragments [5].

Unstable chest wall injuries have high rates of short-term mortality (up to 33%) [1] and long-term morbidity. While surgical treatment of these fractures is technically possible, indications remain controversial and large multicentre clinical trials are lacking. There are several challenges in surgical fixation of chest wall injuries, including lack of high quality studies to assess outcomes compared to the current modern non-operative treatment. Other challenges include a lack of concise indications for surgery, identifying which

surgical subspecialty should be performing these procedures, and what is the best fixation strategy. This manuscript will examine each of these issues in more detail.

Understanding the injury: chest wall instability

Thoracic trauma can cause severe displacement of adjacent rib fractures, creating a deformity of the chest wall. It can also result in chest thoracic instability and paradoxical chest wall motion (as in a flail segment). These injuries have a high incidence of complications, including chest instability, severe pulmonary restriction, loss of lung volume, and inability to control pain [1,3,5,6]. The resulting chest wall instability, decreased lung volume and pain can lead to decreased pulmonary function and render patients dependent on long term mechanical ventilation. Such long term mechanical ventilation can lead to high rates of pneumonia, sepsis, tracheostomy, barotrauma, prolonged stay in the Intensive Care Unit (ICU), and high health care costs [1,3,5–8].

Patients with an unstable chest wall as a result of a flail segment can suffer compromised respiratory function, poor pulmonary toilet due to pain, and inability to clear secretions; which typically triggers the need for mechanical ventilation. A recent study in this area revealed that 43% of patients with a flail chest injury required mechanical ventilation, compared to only 7% in patients with multiple rib fractures without a flail segment, and 2% of those with an isolated rib fracture [2]. Chest wall instability no doubt contributes to poor outcomes and increases the risk of mechanical ventilation in these patients.

Prolonged mechanical ventilation in turn results in high rates of pneumonia, barotrauma, sepsis, ICU stay and death [1,3,5,8]. A recent study of patients with flail chest injuries revealed high rates of morbidity and mortality, including: admission to the ICU in 82%, tracheostomy in 21%, acute respiratory distress syndrome (ARDS) in

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14%, sepsis in 7%, and death in 16% [9]. Mortality has been shown to be as high as 10–36% [1] in patients with severe chest trauma, and despite the presence of extra thoracic injuries present in these patients, sepsis and pneumonia remain two of the most common causes of death [5]. In the long term, only 43% of such patients return to their previous full-time employment [10], and many complain of chronic pain, subjective dyspnea, chest tightness, chest wall deformity [10,11].

What are the benefits of surgical fixation?

Flail chest and unstable chest wall injuries have been traditionally treated non-operatively. While there has been an increased interest in operative treatment the last decade, a review of the National Trauma Databank from 2008–2009 revealed that 99% of flail chest injuries were treated non-operatively [9]. Such treatment includes invasive and non-invasive mechanical ventilation when required, intermittent positive pressure ventilation (internal pneumatic splint), appropriate analgesia (intercostal nerve blocks, epidural catheters), pulmonary toilet and chest physiotherapy [1,5,12]. However, such an approach may not produce optimal results, given the poor historical outcomes discussed in the previous section.

There has been an increased interest in surgical fixation of unstable chest wall injuries in recent years. To date there have been multiple retrospective and non-randomized comparative studies [3,7,13], as well as three randomized clinical trials (RCTs) [6,8,14] that demonstrate superior clinical outcomes in patients treated with surgical fixation, compared to the traditional non-operative treatment. This includes decreased days on mechanical ventilation (3.7–10.8 vs 15–30.7) [6–8,15], earlier discharge from ICU (6.8–16.5 vs 21–28.3) [3,6–8], decreased chest infection (7.6–24% vs 50–77%) [6–8], earlier return to work (95–100% vs 43%) [8], decreased chronic pain (5.5–11% vs 49%) [3], and decreased long term respiratory dysfunction [16,17].

Decreasing the length of time on mechanical ventilation in these patients is the key, as it can help reduce the risk of pneumonia, sepsis, barotrauma, and number of days spent in the ICU [3,6–8]. This in turn can help lower rates of morbidity and mortality, and dramatically decrease the medical costs. Decreasing the length of ICU stay by even a few days can produce dramatic savings in health care expenses.

While randomized control trials in this area are limited, they demonstrate improved outcomes in surgically treated patients: decrease in number of days on mechanical ventilation, a lower rate of morbidity, and lower health care costs. However, these studies have been criticized for their small sample size (about 20 patients in each arm for each of the three RCTs), outdated methods of surgical fixation (use of Kirschner wires [7], Judet struts [8], or absorbable plates [14]), and vague inclusion/exclusion criteria.

There have been multiple meta-analysis and systematic reviews published on this topic. A meta-analysis by Slobogean et al. included 11 studies with 753 patients. The authors reported that surgical fixation resulted in a substantial decrease in ventilator days (8 days, 95% CI 5–10 days), and ICU length of stay (5 days, 95% CI 2–8 days). Surgery was also associated with a decrease in mortality (odds ratio [OR] 0.31, 95% CI 0.20–0.48), septicemia (OR 0.36, 95% CI 0.19–0.71), tracheostomy (OR 0.06, 95% CI 0.02–0.20), pneumonia (OR 0.2, 95% CI 0.11–0.32), and chest deformity (OR 0.11, 95% CI 0.02–0.60) [18]. In a recently published meta-analysis of 22 studies with 986 patients, it was reported that patients undergoing surgical fixation had decreased rates of mortality, days on mechanical ventilation, hospital length of stay, ICU length of stay, and lower incidence of pneumonia and need for tracheostomy. However, the authors indicated that the quality of data was very low, with only three prospective randomized trials available [19].

What are the risks of surgery?

While studies report improved outcomes with operative intervention, patients undergoing surgical fixation of chest wall injuries are still at risk for all of the previously mentioned complications associated with this injury (need for mechanical ventilation, pneumonia, sepsis, death, etc.). While surgery is believed to be safe and effective, it also exposes patients to inherent risks, such as wound complications, infection, and hardware failure, loosening, and hardware irritation. The use of smooth intramedullary wires should be avoided due to the risk of migration into adjacent organs, and the use of absorbable plates is associated with foreign-body reaction and fluid accumulation.

Wound infections and deep infection leading to empyema are of great concern. The risk of empyema may be increased by the presence of a retained haemothorax, or by close proximity of the surgical incision adjacent to a chest tube placed pre-operatively. A study reported that of 650 operative cases, complications were rare, including 1.2% superficial wound infections, 1.2% fixation failure, and 1.4% plate removal due to discomfort and chest stiffness [5]. Another prospective study reported a 3% risk of serious infections with surgical treatment [20]. High quality data on long-term complications and long-term outcomes of patients treated with surgical fixation are lacking in the literature.

Indications for surgical intervention

According to the available literature, the current indications for surgical stabilization of acute unstable chest injuries include:

- 1) Presence of flail chest: with paradoxical chest wall motion, respiratory compromise, or severe displacement (Figs. 1 and 2)
- 2) Chest wall deformity: crush injury with loss of thoracic volume; severely displaced fractures impeding lung expansion; or rib fractures impaling the lung/liver
- 3) Multiple rib fractures with concomitant thoracotomy for intra-thoracic injury
- 4) Reduction of pain and disability: painful mobile rib fractures with failure of narcotics or epidural pain catheter [1,5,15].

Not all patients with an unstable chest wall may benefit from surgical intervention, such as patients who need long term mechanical ventilation unrelated to their chest injury [1,5,15]. These patients will require long-term mechanical ventilation due to other causes, and despite chest wall stabilization, may not see the benefits of early weaning from mechanical ventilation. A clear example of this is patients with severe head injury, defined as Acute Injury Severity Score (AIS) >3. A recent study reported that patients with a flail chest and concomitant severe head injury have significantly higher rate of mortality compared to patients with a flail chest without a severe head injury (40% versus 11%) [21].

The presence of pulmonary contusion as an exclusion for surgical fixation of a flail chest injury is controversial. Pulmonary contusion may be present due to injury to the lung alveoli, causing interstitial lung injury as opposed to a mechanical instability caused by the flail chest. Pulmonary contusion can cause ARDS, and can be diagnosed by the presence of acute infiltrate on chest radiographs, presence of contusions on CT scan, or with bronchoscopy. The study by Voggenreiter et al. in 1998 described poor outcomes in patients with concomitant pulmonary contusion and flail chest who underwent surgical fixation of the chest wall [15]. This study reported that patients with a flail chest and pulmonary contusion had a similar length of time on mechanical ventilation regardless of surgical or non-operative treatment (30.8 vs. 29.3 days). Given the lack of improvement in time on mechanical ventilation, the authors concluded that surgical intervention for this group was as

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