The natural history of flail chest injuries

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A B S T R A C T

Purpose: Flail chest (FC) injuries represent a significant burden on trauma services because of its high morbidity and mortality. Current gold standard conservative management strategies for FC, are now being challenged by renewed interest in surgical rib fixation. This retrospective epidemiological study sets out to evaluate FC patients, and quantify the natural history of this injury by studying the injury patterns, epidemiology and mortality of patients sustaining FC injuries admitted to a major trauma centre (MTC). Methods: A retrospective cohort analysis has been conducted at an MTC with full trauma service. All patients (age > 16 years) sustaining FC were included. Patient demographics, injury characteristics and inpatient stay information were extracted. Results: Two hundred and ninety-three patients were identified, with a mean injury severity score (ISS) of 28.9 (range 9–75), average age of 56.1 years (range of 16–100), and a male predominance (78%). Road traffic accidents accounted for 45% (n = 132) of injuries, whilst 44% were fall or jump from height (n = 129). Associated lung contusion was present in 133 patients (45%) while 76% of patients were found to have 5 or more ribs involved in the flail segment (n = 223) with 96% (n = 281) having a unilateral FC. Inpatient treatment was required 19.9 days (range 0–150 days) with 59% of patients (n = 173) requiring intensive care unit (ICU) level care for 8.4 days (range 1–63) with 61.8% requiring mechanical ventilation (n = 107) for 10.5 days (range 1–54), and 7.8% underwent rib fixation with rib plates (n = 23). The mortality rate was found to be 14% (n = 42). A non-significant trend towards improved outcomes in the conservative group was found when compared with the fixation group; ventilation days (6.94 vs 10.06, p = 0.18) intensive treatment unit (ITU) length of stay (LOS) (12.56 vs 15.53, p = 0.28) and hospital LOS (32.62 vs 35.24, p = 0.69).

Conclusion: This study has successfully described the natural history of flail chest injuries, and has found a nonsignificant trend towards better outcomes with conservative management. With the cohort and management challenges now defined, work on outcome improvement can be targeted. In addition the comparability of results to other studies makes collaboration with other MTCs a realistic proposal.

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Introduction

A flail chest (FC) occurs when 3 or more consecutive ribs are fractured in 2 or more places, creating an independent segment, moving paradoxically from the chest wall. This leads to acute pain, lobar atelectasis and alveolar collapse.1 The resultant effect on ventilation and gas exchange, in addition to loss of chest wall integrity,2 predisposes to acute respiratory distress syndrome, prolonging mechanical ventilation requirements and increasing the injury burden.1,3 of the traumatised patient. Mortality rates vary between 20%,3,4 and 42%,5 accounting for 25% of all blunt trauma deaths.6

Ten percent of blunt trauma sustains FC injuries, representing a significant burden on trauma services.7 The Healthcare Cost and Utilisation Project8 found FC patients spent on average 10 days in the intensive care unit (ICU) at a cost of $4945 per day9 (£3,400) with over 30% of patients requiring ongoing hospital care. Furthermore, long term indirect costs result from chronic pain and reduced workplace productivity.5

The corner stone management is conservative; ICU facilitated analgesia with rescue mechanical ventilation for chest wall integrity (internal splinting).10 However, surgical management with rib
plate fixation is becoming an increasing popular option with numerous systematic reviews finding superior outcomes.11–14

With an increasing interest on this subject, and the debate continuing over surgical versus conservative management, it is important to better understand this cohort in order to improve outcomes. This retrospective epidemiological study sets out to evaluate these patients, and quantify the natural history of this injury by studying the injury patterns, epidemiology and mortality of patients sustaining FC injuries admitted to a major trauma centre (MTC). Furthermore patients surgically managed with locked rib plate fixation will be compared to those managed conservatively.

Patients and methods

Setting and data source

The study has been conducted at the Royal London Hospital, an MTC with a full trauma service, including air ambulance helipad, experienced trauma surgeons, orthopaedic surgeons and ITU physicians and facilities capable of delivering gold standard care for flail chest injuries. The in-hospital trauma service database was used to identify patients for this study from January 2014 to June 2016.

Study design

A retrospective cohort analysis has been conducted with a view to characterizing the cohort of patients sustaining FC, injury patterns, and morality. Patients treated with operative fixation with locked rib plates were subsequently compared with those managed conservatively. Outcomes compared included ventilation days, ITU length of stay (LOS), and hospital length of stay (LOS).

Cohort

All adult patients (age > 16 years) sustaining FC were included, with the accepted definition of FC being 3 or more consecutive rib fractures in 2 or more places.1

Characteristics

Patient characteristics extracted included age, sex, injury severity score (ISS), mechanism of injury, number of ribs fractured, unilateral or bilateral FC, management of FC (whether surgical or conservative) associated injuries, presence of lung contusion, ICU length of stay, mechanical ventilation days, hospital length of stay, and mortality.

Results

Epidemiological characteristics

This study has identified 293 patients sustaining FC injuries with a mean ISS of 28.9 (range 9–75). The average age at time of injury was 56.1 years (range of 16–100) with 78% male and 22% female patients.

A total 45.1% of patients sustained the FC through road traffic incidents (n = 132). Of these, 44% of patients were pedestrians (n = 58), 24% were motorcyclists (n = 31), 15% were cyclists (n = 20) and 17% were vehicle drivers (n = 23). The mechanisms of injury included 44% (n = 129) of falling or jumping from height, 10.2% (n = 30) crush injuries at work, etc (Fig. 1). For two patients (0.7%), the mechanisms of injury were unknown.

Associated lung contusion was present in 133 patients (45%) while 76% of patients were found to have 5 or more ribs involved in the flail segment (n = 223) with 96% (n = 218) having a unilateral FC. Twelve patients (4%) were found to have bilateral flail segments. Patients required inpatient treatment for an average of 19.9 days (range 0–150 days) with 59% of patients (n = 173) requiring ITU level care. Patients spent on average 8.4 days in ITU (range 1–63) with 61.8% requiring mechanical ventilation (n = 107) for an average of 10.5 days (range 1–54).

Of the 293 patients identified, only 7.8% underwent rib fixation with rib plates (n = 23). The mortality rate was found to be 14% (n = 42). All of the surgical fixation cohort survived. These results have been summarized in Tables 1–3.

Statistical comparison

Patients operatively managed with locked rib plate fixation were compared with that receiving gold standard conservative management. Statistical analysis with T squared testing found no significant difference between the potential confounding factors of ISS and age (Table 4).

Comparison of the data using T testing found a nonsignificant trend towards improved outcomes in the conservative group compared with the fixation group (Table 4); ventilation days (6.94 vs 10.6, p = 0.18) ITU LOS (12.56 vs 15.53, p = 0.28) and hospital LOS (32.62 vs 35.24, p = 0.69).

Discussion

The results enable a better understanding of the epidemiology and natural history of FC. The majority of patients sustaining FC are males (78%) in the 50–60 year old age group. Furthermore, one can see that a large, inner-city MTC, such as the Royal London Hospital, is likely to see approximately 75 patients per year. This information is important, as it can aid the trauma department to plan resources

**Table 1**

| Variables     | n   | Percentage (%) | Mean | Range |
|---------------|-----|----------------|------|-------|
| Age (Years)   | –   | –              | 56.1 | 16–100|
| Male          | 228 | 78             | –    | –     |
| Female        | 65  | 22             | –    | –     |
| ISS           | –   | –              | 28.9 | 9–75  |
| Survived      | 251 | 86             | –    | –     |
| Mortality     | 42  | 14             | –    | –     |
including ward and ITU beds, and experienced trauma staff appropriately. It also gives insight into the patient demographic with the likely preexisting morbidity in this age group. We can see that FC represents a significant use of resources, with the average hospital stay being 29.9 days.

The data shows that FC is seldom a benign or isolated injury. With a high mean ISS of 28.9, patients with FC often have other serious injuries, including head, chest, abdomen and long bone injuries. Furthermore, nearly all have been admitted with high energy trauma; road traffic incidents or falling/jumping from a height (45% and 44% respectively). This is significant as it alerts the clinician to the co-existing injury burden. The high injury burden of these patients necessitates over half the cohort (59%) to require ITU facilitated care. These unwell patients require an average of 8.4 days in ITU.

The high energy nature of the trauma is also reflected in the anatomy of the FC injuries; 76% of FC involved 5 or more ribs in the flail segment. It is clear that the large flail segment causes significant management difficulties; the stave-in chest wall will cause significant pain and reduced lung volume, making autonomous ventilation challenging. Indeed, 37.5% of all FC patients required mechanical ventilation for an average of 10.5 days. Whilst this is similar to the conservative management group (61.8%), the rib fixation patients were mechanically ventilated for longer (mean 3.12, \( p = 0.18 \)). It is also interesting to note that all the rib fixation cohort survived. Patients in the conservative group spent fewer days in the ITU and in hospital (mean 2.97, \( p = 0.28 \) and 2.62, \( p = 0.69 \) respectively), which is against the trend of recent research. This study has attempted to reduce selection bias by analyzing the main confounding factors, age and ISS, and has found no significant difference between the cohorts.

There is currently much debate and ongoing research into rib fixation. Despite these only 23 patients (7.8% of the cohort) underwent rib fixation since January 2014. Twenty of the 23 patients required ITU care and 60% (\( n = 14 \)) required mechanical ventilation. Whilst this is similar to the conservative management group (61.8%), the rib fixation patients were mechanically ventilated for longer (mean 3.12, \( p = 0.18 \)). It is also interesting to note that all the rib fixation cohort survived. Patients in the conservative group spent fewer days in the ITU and in hospital (mean 2.97, \( p = 0.28 \) and 2.62, \( p = 0.69 \) respectively), which is against the trend of recent research. This study has attempted to reduce selection bias by analyzing the main confounding factors, age and ISS, and has found no significant difference between the cohorts.

A large multi-centre study from Dehghan et al. analysing the Canadian National Trauma Data Bank identified over 3400 FC patients. Their data search analysed similar outcomes to this study, including patient demographics, ITU admissions, mechanical ventilation, ITU and hospital length of stay, presence of lung contusion, mechanism of injury and mortality. Their data went further to include presence of head injury and complications (which included ARDS, tracheostomy, sepsis and epidural use). It is important to note the similarities between this study and Dehghan’s. The cohort demographics are comparable, with similar mean age (56.1 vs 52.5), male sex (78% vs 77%), mean ISS (28.9 vs 30.4), presence of lung contusion (45% vs 54%) and mortality (14% vs 16%).

Differences seen between cohorts include mean hospital length of stay (29.9 vs 16.6 days), and ITU history. However, without further details on ITU admission criteria, mechanical ventilation indications, and strict extubation criteria, these differences may be of minimal significance and thus not comparable.

Other interesting differences include rib fixation as a treatment modality (7.8% vs 0.7%). However, selection bias may account for this; Dehghan et al. looked at patients from 2007 to 2009, whilst this study has been performed when rib fixation is increasing popular. Indeed, with further analysis, of the 23 patients surgical managed, only 4 occurred in the first half of the study period. The comparison between these studies indicates that the natural history and epidemiology of FC is similar in other centres, importantly, makes this a useful and relevant baseline study as the outcomes are transferable.
Limitations

The authors acknowledge the limitations of this study; its retrospective design, lack of case controls and population bias given the nature of the poly-traumatised patient. Furthermore although some confounding variables have been accounted for, the comparison has been made on unmatched cohorts.

Conclusion

This study has set out to define the cohort of patients sustain FC and has successfully described the natural history of this injury. Furthermore, a comparison has been made between conservative and fixation groups, finding a nonsignificant benefit to conservative management. However, due to the limitations, this study cannot conclude with certainty whether outcomes are improved with surgical fixation.

With the patient and management challenges now identified one can begin to tackle the bigger question on how to improve the outcomes of FC. The similarity of this study to others makes collaboration with other MTC’s a realistic proposal. Furthermore, the longer term follow up of these patients is needed to identify areas of continuing morbidity associated with flail chest injuries.

References

1. Xu J-Q, Qiu P-L, Yu R-G, et al. Better short-term efficacy of treating severe flail chest with internal fixation surgery compared with conservative treatments. *Eur J Med Res*. 2015;20:55. http://dx.doi.org/10.1186/s40001-015-0146-0.
2. Davignon K, Kwo J, Bigatello LM. Pathophysiology and management of the flail chest. *Minerva Anestesiol*. 2004;70:193–199.
3. Sirmali M, Turut H, Topcu S, et al. A comprehensive analysis of traumatic rib fractures: morbidity, mortality and management. *Eur J Cardiothorac Surg*. 2003;24:133–138.
4. Simon B, Ebert J, Bokhara F, et al. Management of pulmonary contusion and flail chest: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg*. 2012;73:5351–5361. http://dx.doi.org/10.1097/TA.0b013e3182701960.
5. Althausen PL, Shannon S, Watts C, et al. Early surgical stabilization of flail chest with locked plate fixation. *J Orthop Trauma*. 2011;25:641–648. http://dx.doi.org/10.1097/BOT.0b013e318234d479.
6. Clark GC, Schecter WP, Trunkey DD. Variables affecting outcome in blunt chest trauma: flail chest vs. pulmonary contusion. *J Trauma*. 1988;28:298–304.
7. Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: a systematic review and meta-analysis. *Injury*. 2012;43:8–17. http://dx.doi.org/10.1016/j.injury.2011.01.004.
8. Hospital discharges with International Classification of Diseases. Clinical Modification, 9th Revision (ICD-9-CM) for flail chest (807.4) as a primary diagnosis. Healthcare Cost and Utilization Project. 2010.
9. Dasta JF, McLaughlin TP, Mody SH, et al. Daily cost of an intensive care unit day: the contribution of mechanical ventilation. *Crit Care Med*. 2005;33:1266–1271.
10. Karmakar MK, Ho AM. Acute pain management of patients with multiple fractured ribs. *J Trauma*. 2003;54:615–625.
11. Cataneo AJ, Cataneo DC, de Oliveira FH, et al. Surgical versus nonsurgical interventions for flail chest. *Cochrane database Syst Rev*. 2015;7:CD009919. http://dx.doi.org/10.1002/14651858.CD009919.pub2.
12. Lennicke JA, Elmore L, Freeman BD, et al. Operative management of rib fractures in the setting of flail chest: a systematic review and meta-analysis. *Ann Surg*. 2013;258:914–921. http://dx.doi.org/10.1097/SLA.0b013e3182895b00.
13. de Jong MB, Kokke NG, Hietbrink F, et al. Surgical management of rib fractures: strategies and literature review. *Scand J Surg*. 2014;103:120–125.
14. Slobogean GP, MacPherson CA, Sun T, et al. Surgical fixation vs nonoperative management of flail chest: a meta-analysis. *J Am Coll Surg*. 2013;216:302–311. http://dx.doi.org/10.1016/j.jamcollsurg.2012.10.010.
15. Dehghan N, de Mestral C, McKee MD, et al. Flail chest injuries: a review of outcomes and treatment practices from the National Trauma Data Bank. *J Trauma Acute Care Surg*. 2014;76:462–468. http://dx.doi.org/10.1097/TA.0000000000000860.