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ORIGINAL ARTICLE

# Potential Benefits of Rib Fracture Fixation in Patients with Flail Chest and Multiple Non-flail Rib Fractures

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**Abstract** The purpose of this study is to evaluate the potential benefits of rib fracture fixation in patients with flail chest and multiple non-flail rib fractures versus conventional treatment modalities. A retrospective reviewed study compared 86 cases which received surgical treatment between June 2009 and May 2013 to 76 cases which received conservative treatment between January 2006 and May 2009. The patients were divided into the flail chest ($n$=38) and multiple non-flail rib fracture groups ($n$=124). In the flail chest group, the mechanical ventilation time, ICU monitoring time, tracheostomies, thoracic deformity, and impaired pulmonary function and return to full-time employment were compared. In the multiple non-flail rib fracture group, fracture healing, visual analog scale (VAS) pain score, inpatient length of stay, atelectatic, pulmonary complications, and normal activity-returning time were compared. Patients in the flail chest operative fixation group had significantly shorter ICU stay, decreased ventilator requirements, fewer tracheostomies, less thoracic deformity and impaired pulmonary function, and more returned to full-time employment. Patients in the multiple non-flail rib fracture operative fixation had shorter hospital stay, less pain, earlier return to normal activity, more fracture healing, less atelectasis, and fewer pulmonary infections. This study demonstrates the potential benefits of surgical stabilization of flail chest and multiple non-flail rib fractures with plate fixation. When compared with conventional conservative management, operatively managed patients demonstrated improved clinical outcomes.

**Keywords** Flail chest · Non-flail chest · Conservative treatment · Internal fixation

## Introduction

Rib fractures are the most common form of thoracic injuries and account for 85 % of closed chest injuries [1]. Thoracic injuries have the second highest mortality among various injuries, which rank after cephalic injuries [2]. Concurrent pathophysiology after rib fractures is often neglected or underestimated, especially those serious respiratory and circulation pathophysiological changes caused by posterior chest wall instability and a flail chest. These changes can lead to respiratory and circulation dysfunctions, which pose great difficulties for clinical treatment [3]. Further, when proper treatment and follow-up is lacking, the complication incidence and death rates of rib fracture patients can increase, and what is worse is that the death risk increases with the increase in patients' age, the number of fractured ribs, and severity of complications and thorax-associated injuries [4, 5]. Many trauma centers maintain the belief that most patients with multiple rib fractures are satisfactorily managed without operative fixation. However, conservative treatment has serious drawbacks—nonoperative treatment algorithms can be complicated by prolonged ventilator support, posttraumatic pneumonia, respiratory insufficiency, and chronic pain from fracture

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nonunion. These outcomes have resulted in substantial hospital and societal costs [6–8].

Several studies have shown clinical benefits from surgical treatment of flail chest in certain patient populations [9–11]. But, operative rib fixation of multiple non-flail rib fractures is not considered standard management and is not practiced widely. Our study is different from all above studies since they address flail chest only. Most of the multiple non-flail rib fracture (number≥2) patients in our study are broken in one point but along a straight line. Actually, these are the major chunk of all thoracic trauma patients attending to outpatient department (OPD) rather than flail chest. The purpose of this study was to evaluate the potential benefits of rib fracture fixation in patients with flail chest and multiple non-flail rib fractures.

## Materials and Methods

### Study Design

We retrospectively reviewed 162 multiple rib fracture patients who received treatment at a single institution over a 6-year period. We compared 86 cases which received surgical treatment between June 2009 and May 2013 to 76 cases which received conservative treatment between January 2006 and May 2009. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Southern Medical University. Written informed consent was obtained from all participants. We excluded head trauma with disturbance of consciousness, associated injuries such as myocardial contusion, which might be adversely affected by general anesthesia, severe associated trauma to other systems, patients with a history of serious cardiac or respiratory disease, thoracic deformity, hepatic dysfunction, chronic renal failure on hemodialysis, cerebral infarction, pregnancy and bleeding diathesis.

### Outcome Parameters

Flail chest injuries have been defined by multiple authors as fractures of four or more ribs fractured at more than two sites [12]. In the flail chest group, the primary endpoints of the study were duration of mechanical ventilation and ICU stay. The secondary endpoints were rate of thoracic deformity, rate of tracheostomy, rate of impaired pulmonary function, and return to full-time employment.

In the multiple non-flail rib fracture group, we have repeatedly observed multiple ribs (number≥2) that are broken in one point but along a straight line, causing the patient to have chronic pain and pulmonary complications. Shahram and colleagues found that these patients usually do not have a huge floating segment and do not experience non-integrity of the chest wall and suggested using the phrase "multiple non-flail rib fractures or non-flail chest" in these cases [13]. The primary endpoints of the study were duration of hospital stay and returned to normal activity. The secondary endpoints were the number of respiratory complications (pneumonia, atelectasis), rate of fracture healing, and numerical visual analog scale (VAS) pain score 2 months after discharge.

Pain was assessed by VAS pain score 2 months after fixation. Radiologic confirmation of rib fracture and respiratory complications by chest radiography and computed tomographic scan was done. The patients in the outpatient clinic were followed with chest X-ray 2 months after fixation. Patients were examined for chest wall deformity in the form of stove-in chest after treatment and 2 months after discharge. In addition, pulmonary functions (spirometry, treadmill tests) were performed 2 months postoperatively. To know the duration of return to normal activity or full-time employment, we simply asked when the patient was able to return to usual daily activities or original work 6 months after discharge.

### Surgical Technique and Approaches

CT scan with three-dimensional reconstruction was particularly useful in evaluating costal cartilage fractures to delineate the surgical incision. A longitudinal incision was made according to different fracture segments (two longitudinal incisions could be made for multiple segmental fractures). Only rib fractures between the levels of ribs 3 and 10 were fixed [14]. Wherever possible, chest wall muscles were preserved, splitting them along the length of their fibers. The periosteum was also preserved, and injuries to the intercostal arteries and nerves were avoided. Repair of visceral lacerations and air leaks, control of bleeding, and evacuation of collections were performed [15]. The fractured ribs were fixed with AO standard 3.5 mm reconstruction plates, and cancellous screws were used. The plates were shaped while the lung was ventilated by use of high tidal volumes. Routine thoracic closed drainage was performed.

### Statistical Analysis

The data were analyzed with the SPSS13.0 statistical software. All variables were initially assessed for normality. Group comparisons of proportions were made using chi-square tests, Fisher's exact tests where numbers were small and were reported as numbers (%). Continuously normally distributed variables were compared using Student $t$ tests and reported as mean (standard deviation); non-normally distributed data were compared using Wilcoxon rank sum tests and reported as medians (interquartile range). The $P=0.05$ was considered statistically significant.

## Results

### The Data of the Patients on Admission

A total of 253 patients with rib fractures received treatment between January 2006 and March 2013, among which 162 suffered from multiple rib fractures. Participants included 109 males (67.28 %) and 53 females (32.72 %), ranging in age between 17 and 71 years. Mean age was 36.58±12.20. The leading cause of trauma was road traffic accidents (48.77 %). The second most common cause of trauma was fall (34.57 %), followed by assault (16.66 %). The patients were divided into the flail chest ($n$=38) and non-flail chest ($n$=124) groups. In the flail chest group, 21 patients received surgical treatment whereas 17 received non-surgical treatment. In the non-flail chest group, 65 received surgical treatment whereas 59 received non-surgical treatment. The characteristics of the patient groups were similar and were presented in Table 1.

### Post-management Data in 38 Patients with Traumatic Flail Chest

The postoperative course, as well as the postoperative morbidity and mortality are listed in Table 2. Operatively treated patients had shorter intensive care unit stays (7.19±1.67 days vs. 10.29±2.31 days, $P$=0.016), decreased ventilator requirements (5.71±1.35 days vs. 9.06±3.58 days, $P$=0.005), and fewer tracheostomies (9.25 vs. 47.05 %, $P$=0.012). Pulmonary functions (spirometry, treadmill tests) performed 2 months postoperatively showed less impairment in the surgical group (19.04 vs. 58.82 %, $P$=0.014). Patients were examined for chest wall deformity in the form of stove-in chest after treatment and 2 months after discharge, which indicated less thoracic deformity in the surgical group (14.29 vs. 64.71 %, $P$=0.002). The patients were asked when they were able to return to usual daily activities or original work 6 months after discharge, which indicated more returned to full-time employment (85.71 vs. 47.06 %, $P$=0.014), demonstrating the statistically significant improved results with surgical fixation of flail chest.

As regards the causes of mortality, severe unresolving pneumonia was the causes of death of the one patient who received surgical treatment, while septic shock and pulmonary embolism were responsible for the mortalities in both patients who received non-surgical treatment.

### Post-management Data in 124 Patients with Multiple Non-flail Rib Fractures

The postoperative course, as well as the postoperative morbidity is listed in Table 3. Operatively treated patients had shorter hospital stay (11.09±1.88 vs. 15.93±2.75 days, $P$=0.013). Pain assessed by VAS pain score [16] 2 months after fixation showed less pain in the surgical group (1.45±0.65 vs. 4.50±1.05 score, $P$=0.003), and earlier return to normal activity (28.18±9.21 vs. 42.42±10.12 days, $P$=0.028). Patients examined with chest X-ray after treatment and 2 months after discharge showed more fracture healing in the surgical group (98.46 vs. 93.22 %, $P$=0.154), less atelectasis (6.15 vs. 22.03 %, $P$=0.01), and fewer pulmonary infection (4.62 vs. 16.95 %, $P$=0.025). No death case occurred in non-flail chest groups.

### Surgical Complications

In our study, one case of post-thoracotomy pain syndrome was reported. No case of fixation failure, fracture nonunion, wound infection, or osteomyelitis was found.

## Discussion

Rib fractures are common after trauma. The incidence is reported to be 4–10 % [17]. Patients can be treated at the cardiothoracic, trauma, or orthopedic department. Due to different degrees of attention paid to the disease, controversy on treatment methods still remains. Several physicians believe

**Table 1** Comparative demography of the surgical and non-surgical treatment in both groups

| Index | Flail chest group ($n$=38) | | | Non-flail chest group ($n$=124) | | |
|---|---|---|---|---|---|---|
| | Surgical ($n$=21) | Non-surgical ($n$=17) | $p$ | Surgical ($n$=65) | Non-surgical ($n$=59) | $p$ |
| Age (years) | 34.76±12.92 | 35.53±14.32 | 0.863 | 37.62±11.97 | 36.39±11.74 | 0.426 |
| Gender (M:F) $n$ | 15:6 | 12:5 | 0.955 | 46:19 | 42:17 | 0.765 |
| Body weight (kg) | 62.2±11.0 | 63.0±9.5 | 0.825 | 63.1±10.0 | 62.3±11.0 | 0.876 |
| Body mass index (kg/m$^2$) mean±SD | 25±2.6 | 26±2.3 | 0.902 | 28±3.2 | 27±2.5 | 0.756 |
| The fractured rib number mean±SD | 6.02±1.25 | 5.88±1.34 | 0.138 | 3.22±1.15 | 3.48±1.24 | 0.158 |

**Table 2** Results of surgical and non-surgical treatment of flail chest

| | Surgical | Non-surgical | *P* |
|---|---|---|---|
| ICU stay (*d*) mean±SD | 7.19±1.67 | 10.29±2.31 | 0.016 |
| Ventilatory support (*d*) mean±SD | 5.71±1.35 | 9.06±3.58 | 0.005 |
| Tracheostomy *n* (%) | 2 (9.52) | 8 (47.05) | 0.012 |
| Impaired pulmonary function *n* (%) | 4 (19.04) | 10 (58.82) | 0.014 |
| Thoracic deformity *n* (%) | 3 (14.29) | 11 (64.71) | 0.002 |
| Returned to full-time employment *n* (%) | 18 (85.71) | 8 (47.06) | 0.014 |
| Mortality *n* (%) | 1 (4.76) | 2 (11.76) | 0.491 |

that thoracic wall collapse and paradoxical respiration are the indications for rib fracture surgery [12, 18]. Meanwhile, the idea of other literature [19] is that, the flail chest and thoracic wall collapse or defects are seen as surgical indications. Granetzny et al. and colleagues demonstrated shorter durations of mechanical ventilation, ICU stay, and hospital stay compared with nonoperative standard of care [20]. Balci et al. and colleagues found a reduction in duration of ventilation and mortality in flail chest patients when compared with conservative treatment [10]. Tanaka et al. and colleagues also found lower pneumonia rates and reduced medical expense compared with nonoperative standard of care [7]. In our study, the mechanical ventilation time and ICU stay time in the surgical group were significantly shorter than those in the non-surgical flail group. The incidence of thoracic deformity, tracheostomy, and impaired pulmonary function in the surgical group was significantly lower than that in the non-surgical group. The results in the current study were similar to these studies. Long-term disability is reported in over one third of these patients [21]. In our study, return to full-time employment was found to be 85.71 % in the surgical group, whereas it was only 47.06 % in the non-surgical group. This proves the potential benefits of rib fracture fixation in patients with flail chest.

However, multiple non-flail rib fracture (number≥2) patients that are broken in one point but along a straight line are the major chunk of all thoracic trauma patients attending to outpatient department (OPD) rather than flail chest. Most of these patients receive non-surgical treatment at an early stage. Although conventional wisdom and practitioner experience indicates that the majority of rib fractures heal without complications or permanent disability, a few clinical studies with short-term and long-term follow-up of nonoperative management have been published. In recent years, there are sporadic reports that nonoperative management has serious weaknesses. Conservative treatment can lead to more complications, a longer disease course and poorer fracture stability. Patients who receive conservative treatment always have a more serious respiratory pain and are reluctant to cough and expectorate, which can cause vital capacity reduction leading to complications such as pulmonary infection and atelectasis [8, 22]. Unstable fracture fixation can cause progressive fracture displacement in the recovery phase, leading to thoracic deformity, vital capacity reduction, and thorax capacity loss [15, 23]. At a later stage, intractable pains often occur in rib fracture patients, which is a main late complication of rib fractures [24, 25].

**Table 3** Results of surgical and non-surgical treatment of non-flail chest

| | Surgical | Non-surgical | *P* |
|---|---|---|---|
| Hospital stay (*d*) mean±SD | 11.09±1.88 | 15.93±2.75 | 0.013 |
| VAS pain score mean±SD | 1.45±0.65 | 4.50±1.05 | 0.003 |
| Return to normal activity (*d*) mean±SD | 28.18±9.21 | 42.42±10.12 | 0.028 |
| Fracture healing (*n*) (%) | 98.46 | 93.22 | 0.154 |
| Atelectasis *n* (%) | 4 (6.15) | 13 (22.03) | 0.010 |
| Pulmonary infection *n* (%) | 3 (4.62) | 10 (16.95) | 0.025 |

The above findings raise the issue of whether the acute management of these injuries, which typically involves pneumatic stabilization and pain control, yields the best short-term and long-term outcomes for these patients. Assessment of short-term outcomes, such as pneumonia, inpatient length of stay, and hospital costs, as well as long-term outcomes, including time loss from work or usual activity and pain and disability assessments, will be necessary [19]. Thus, it has been hypothesized that selected patients without flail chest may benefit from open reduction with internal fixation. In our current study, the non-flail fractured ribs were fixed with AO Standard 3.5 mm reconstruction plates, and cancellous screws were used. Overall, it appears that surgical stabilization with plating resulted in reduced pain, shorter hospital stay, earlier return to normal activity, faster fracture healing, and less complications than conventional treatment alone. In fact, most active academic trauma surgeons have neither performed nor observed a rib fracture operative procedure and are unfamiliar with the literature on surgical indications. We believe that any improvements in pain control and disability would have a proportionately positive effect on the health and economic status of a large number of patients.

Up to now, many devices can work for fixation. Different materials and methods involved in surgical fixation for fractured ribs have been reported [16, 26, 27]. But actually, reliable and effective materials and methods proved by clinical trials are still few. An extensive review by Nirula et al. [12] showed that rib fixation is being performed using six main methods (anterior plates with wire cerclage, anterior plating with bicortical screws, intramedullary fixation, judet strut, U-plates, and absorbable plates). Surgical complications included superficial wound infections, pleural empyemas, wound hematoma, pleural effusion, and osteomyelitis. Fixation

failure, including plate loosening and postoperative chest wall "stiffness", "rigidity," or "pain" necessitates plate removal [28]. We believe that it is the team approach and adherence to principles of orthopedic instrumentation, minimal tissue stripping, protection of intercostals muscles, pleura, and lung tissue that makes for a successful outcome. In our study, one case of post-thoracotomy pain syndrome was reported. No case of fixation failure, hardware prominence, fracture nonunion, wound infection, or osteomyelitis was found.

We acknowledge several limitations of our study. First, this is a retrospective, non-randomized study. Although there was no difference in patient characteristics in the two groups, selection bias was not completely excluded. This has still been further confirmed by cohort comparison or multicenter randomized trial. Second, we did not give optimal time to surgery after injury. This may affect our therapeutic effect. The optimal number of days after injury at which to perform repair whether early or delayed, remains controversial. Several recent reports recommend early intervention in selected patients [19, 29]. Third, our study did not take into account the increased cost for surgical patients. However, it was assessed in the current study that improvements in quality of life could reduce the use of hospital and outpatient resources and increase the potential societal benefit through earlier return to work that has been identified in other studies [30].

We suggest that surgical fixation is a method of great value in the treatment of flail chest and non-flail rib fractures. In this modality of treatment, stability without deformity of the chest wall was achieved, and patients had less impairment in pulmonary functions, a significantly decreased rate of complications, shorter intensive care unit stays, decreased ventilator requirements, fewer tracheostomies, more returned to full-time employment, earlier return to normal activity, shorter hospital stay, and less pain as compared to the conservatively managed patients.

#### Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no competing interests.

**Ethical Approval** This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Southern Medical University. Written informed consent was obtained from all participants.

## References


1. Bulger EM, Arneson MA, Mock CN, Jurkovich GJ (2000) Rib fractures in the elderly. J Trauma 48(6):1040–1046
2. Wang SC, Schneider L (1999) An aging population: fragile, handle with care, Proceedings of the National Highway Traffic Safety Administration
3. Borrelly J, Aazami MH (2005) New insights into the pathophysiology of flail segment: the implications of anterior serratus muscle in parietal failure. Eur J Cardio-Thorac Surg 28(5):742–749
4. Kulshrestha P, Munshi I, Wait R (2004) Profile of chest trauma in a level I trauma center. J Trauma 57(3):576–581
5. Laron D, Pandya NK (2013) Advances in the orthopedic management of osteogenesis imperfecta. Orthop Clin North Am 44(4): 565–573
6. Pettiford BL, Luketich JD, Landreneau RJ (2007) The management of flail chest. Thorac Surg Clin 17(1):25–33
7. Tanaka H, Yukioka T, Yamaguti Y, Shimizu S, Goto H, Matsuda H, Shimazaki S (2002) Surgical stabilization of internal pneumatic stabilization? A prospective randomized study of management of severe flail chest patients. J Trauma 52(4):727–732
8. Lafferty PM, Anavian J, Will RE, Cole PA (2011) Operative treatment of chest wall injuries: indications, technique, and outcomes. J Bone Joint Surg Am 93(1):97–110
9. Nirula R, Allen B, Layman R, Falimirski ME, Somberg LB (2006) Rib fracture stabilization in patients sustaining blunt chest injury. Am Surg 72(4):307–309
10. Balci AE, Eren S, Cakir O, Eren MN (2004) Open fixation in flail chest review of 64 patients. Asian Cardiovasc Thorac Ann 12(1): 11–15
11. Richardson JD, Franklin GA, Heffley S, Seligson D (2007) Operative fixation of chest wall fractures: an underused procedure? Am Surg 73(6):591–596, **discussion 596–597**
12. Nirula R, Diaz JJ Jr, Trunkey DD, Mayberry JC (2009) Rib fracture repair: indications, technical issues, and future directions. World J Surg 33(1):14–22
13. Paydar S, Mousavi SM, Niakan H, Abbasi HR, Bolandparvaz S (2012) Appropriate management of flail chest needs proper injury classification. J Am Coll Surg 215(5):743–744
14. Marasco SF, Davies AR, Cooper J, Varma D, Bennett V, Nevill R, Lee G, Bailey M, Fitzgerald M (2013) Prospective randomized controlled trial of operative rib fixation in traumatic flail chest. J Am Coll Surg 216(5):924–932
15. Marasco SF, Liovic P, Šutalo ID (2012) Structural integrity of intramedullary rib fixation using a single bioresorbable screw. Acute Care Surg 73(3):668–673
16. Wallerstein SL (1984) Scaling clinical pain and pain relief. In: Bromm B (ed) Pain measurement in man: neurophysiological correlates of pain. Elsevier, New York, pp 389–396
17. Mayberry JC, Trunkey DD (1997) The fractured rib in chest wall trauma. Chest Surg Clin N Am 7(2):239–261
18. Bastos R, Calhoon JH, Baisden CE (2008) Flail chest and pulmonary contusion. Semin Thorac Cardiovasc Surg 20(1):39–45
19. Mayberry JC, Terhes JT, Ellis TJ, Wanek S, Mullins RJ (2003) Absorbable plates for rib fracture repair: preliminary experience. J Trauma 55(5):835–839
20. Granetzny A, Abd El-Aal MA, Emam E, Shalaby A, Boseila A (2005) Surgical versus conservative treatment of flail chest. Evaluation of the pulmonary status. Interact Cardiovasc Thorac Surg 4(6):583–587
21. Mayberry JC, Ham LB, Schipper PH, Ellis TJ, Mullins RJ (2009) Surveyed opinion of American trauma, orthopedic, and thoracic surgeons on rib and sternal fracture repair. J Trauma 66(3):875–879
22. Khandelwal G, Mathur RK, Shukla S, Maheshwari A (2011) A prospective single center study to assess the impact of surgical stabilization in patients with rib fracture. Int J Surg 9(6):478–481
23. Cacchione RN, Richardson JD, Seligson D (2000) Painful nonunion of multiple rib fractures managed by operative stabilization. J Trauma 48(2):319–321
24. Slater MS, Mayberry JC, Trunkey DD (2001) Operative stabilization of a flail chest six years after injury. Ann Thorac Surg 72(2): 600–601

25. Mayberry JC, Kroeker AD, Ham LB, Mullins RJ, Trunkey DD (2009) Long-term morbidity, pain, and disability after repair of severe chest wall injuries. Am Surg 75(5):389–394
26. Bottlang M, Helzel I, Long WB, Madey S (2010) Anatomically contoured plates for fixation of rib fractures. J Trauma 68(3):611–615
27. Althausen PL, Shannon S, Watts C, Thomas K, Bain MA, Coll D, O'mara TJ, Bray TJ (2011) Early surgical stabilization of flail chest with locked plate fixation. J Orthop Trauma 25(11):641–647
28. Carbognani P, Cattelani L, Bellini G, Rusca M (2000) A technical proposal for the complex flail chest. Ann Thorac Surg 70(1):342–343
29. Lardinois D, Krueger T, Dusmet M, Ghisletta N, Gugger M, Ris HB (2001) Pulmonary function testing after operative stabilisation of the chest wall for flail chest. Eur J Cardiothorac Surg 20(3):496–501
30. Bhatnagar A, Mayberry J, Nirula R (2012) Rib fracture fixation for flail chest: what is the benefit? J Am Coll Surg 215(5):201–205