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Clinical Research

Surgical Rib Fracture Fixation: Early Operative Intervention Improves Outcomes

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Background: This study aimed to assess the outcomes of patients with complex rib fractures undergoing operative or nonoperative management at our major trauma center.
Methods: A retrospective review of all patients who were considered for surgical stabilization of rib fractures (SSRF) at a single major trauma center from May 2016 to September 2022 was performed.
Results: In total, 352 patients with complex rib fractures were identified. Thirty-seven patients (11%) fulfilled the criteria for surgical management and underwent SSRF. The SSRF group had a significantly higher proportion of patients with flail chest (32 [86%] vs. 94 [27%], p<0.001) or Injury Severity Score (ISS) >15 (37 [100%] vs. 129 [41%], p<0.001). No significant differences were seen between groups for 1-year mortality. Patients who underwent SSRF within 72 hours were 6 times less likely to develop pneumonia than those in whom SSRF was delayed for over 72 hours (2 [18%] vs. 15 [58%]; odds ratio, 0.163; 95% confidence interval, 0.029–0.909; p=0.036). Prompt SSRF showed non-significant associations with shorter intensive care unit length of stay (6 days vs. 10 days, p=0.140) and duration of mechanical ventilation (5 days vs. 8 days, p=0.177). SSRF was associated with a longer hospital length of stay compared to nonoperative patients with flail chest and/or ISS >15 (19 days vs. 13 days, p=0.012), whilst SSRF within 72 hours was not.
Conclusion: Surgical fixation of complex rib fractures improves outcomes in selected patient groups. Delayed surgical fixation was associated with increased rates of pneumonia and a longer hospital length of stay.

Keywords: Rib fractures, Fracture fixation, Thoracic injuries, Trauma centers

Introduction

Rib fractures are common, occurring in 55% of patients sustaining blunt chest wall trauma [1]. Around 6% of patients with rib fractures develop flail chest [2]. Mortality from flail chest injuries has been reported to be as high as 33% [3,4]. Of all trauma-related deaths, up to 25% are related to chest trauma [5,6].

There has been a recent shift towards surgical stabilization of rib fractures (SSRF) in selected patients [5,7]. The suggested benefits of SSRF are a shorter time to restoration of pulmonary function, reduced need for tracheostomy formation [8,9], decreased time of mechanical ventilation, and shorter intensive care unit (ICU) length of stay (LOS) and overall hospital LOS [10]. Previous retrospective studies have demonstrated a reduction in mortality with operative management; however, this was not shown in a recent meta-analysis of randomized controlled trials (RCTs) [11]. Although there is increasing evidence of the benefits of SSRF, questions persist about patient selection [12] and the timing of fixation [13].

This study aimed to review the outcomes of complex rib fracture patients admitted to a single major trauma center over a 6-year period (since acute rib fracture fixation was introduced in Aberdeen Royal Infirmary) who underwent SSRF or nonoperative management. Our hypotheses were that complex rib fracture patients with a flail chest or major trauma (Injury Severity Score >15) would have im-

proved outcome measures from SSRF [14], and that patients operated on within 72 hours following presentation would have more favorable outcome measures than those operated on after 72 hours.

Methods

A retrospective review of all patients who were considered for SSRF at our major trauma center from May 2016 to September 2022 was performed. The inclusion criteria were all patients who were referred directly to trauma and orthopaedics for consideration of SSRF, and all patients referred to the acute pain team for initial analgesic management (opioid analgesics or anesthetic block), of complex rib fractures. Complex rib fractures were defined as 3 or more rib fractures and/or a flail chest injury. All patients referred to the acute pain team with complex rib fractures were considered for onwards referral to our services for SSRF. This study was conducted in accordance with the principles set out in the Declaration of Helsinki, and local approval was granted by the NHS Grampian Research and Development Team (Project ID: 5821). The project was a retrospective case note review, using clinical information already present in patient records, for which patient consent was not required.

Care pathway

In our center, there are 4 orthopedic trauma surgeons who perform surgical fixation of rib fractures. Referrals are made electronically directly to all 4 surgeons. These referrals can be made by any clinician from the accident and emergency department, cardiothoracics, ICU, the major trauma team, or via the acute pain team services. Any patient admitted with multiple rib fractures can be referred for consideration of fixation. A multi-consultant discussion then occurs as to whether the patient should undergo SSRF and the timing of surgery. Surgery may be delayed due to a trial of conservative management, patient factors, theatre capacity, and/or surgeon availability.

Each patient is discussed on a case-by-case basis; however, the departmental indications for fixation are mechanical flail/paradoxical breathing, significant deformity, respiratory failure/failure to ventilate, and failure to extubate/wean from ventilator. A relative indication is patients with a flail chest requiring thoracic surgery (e.g., penetrating trauma, massive hemothorax, or pneumothorax) and intractable pain.

For those patients who undergo surgery, most cases are performed in conjunction with a cardiothoracic surgeon. All cases are managed using the same MATRIX Synthes locking plates (DePuy Synthes, Raynham, MA, USA), which are intraoperatively contoured to fit the curvature of the ribs. A chest radiograph is performed postoperatively in the anesthetic recovery area.

Complex rib fracture patients managed nonoperatively are admitted under cardiothoracics with input from the acute pain team. The acute pain team consists of an anesthetic consultant and specialist nurses, with nonoperative management ranging from simple analgesics to regional blocks.

Outcome measures

Retrospective data collection was performed using electronic patient records. Outcome measures included mortality (30-day and 1-year), ICU LOS, total hospital LOS, days ventilated (if intubated), tracheostomy formation, and pneumonia. Additional data collected included demographics, associated injuries, and Injury Severity Score (ISS).

Outcome measures were compared between the SSRF and nonoperative groups. To minimize heterogeneity between the operative and nonoperative groups, a subsequent sub-group analysis was performed for patients who underwent SSRF versus nonoperative treatment (ISS >15); a minimum cut-off ISS score of 15 was chosen to ensure that isolated flail chest patients would be included within the analysis. To assess the impact of time to surgery on outcome measures, a further subgroup analysis was performed for SSRF in <72 hours versus SSRF in >72 hours, SSRF in <72 hours versus nonoperative treatment, and SSRF in <72 hours versus nonoperative (ISS >15).

Statistical analysis

Data analysis was performed using IBM SPSS ver. 27.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were described using means with standard deviations for parametric data, and median with ranges for non-parametric data. Comparisons for continuous variables were performed using the Mann-Whitney U test. Cross-tabulation with Pearson's chi-square test was used to assess the significance of differences in categorical variables. Odds ratios (ORs) with 95% confidence intervals (CIs) were used to assess the risk associated with statistically significant variables. Multivariate analysis was performed with logistic regression to assess for potential confounders of the outcome measures, with significance set at $p<0.05$.

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Results

All patients

In total, 352 patients with complex rib fractures were identified, and 315 patients were managed nonoperatively, of whom 129 had a flail chest or ISS >15. Thirty-seven patients underwent SSRF. Eleven patients underwent SSRF within 72 hours. The most common indications for SSRF were failure to wean from ventilator (40.5%) and mechanical flail/paradoxical breathing (32.4%) (Table 1). Several patients had 2 indications. Common Indications in the delayed group included failure to extubate (6 patients), failure to ventilate (9 patients), mechanical flail/paradoxical breathing (8 patients), and deformity (6 patients). Common indications in the early group included deformity (4 patients) mechanical flail/paradoxical breathing (4 patients), failure to ventilate (4 patients), and failure to extubate (1 patient).

Patient demographics, injury patterns and outcome measures across all groups are displayed in Table 2. Of the patients undergoing SSRF, 31 patients did so in a combined case with an orthopedic surgeon and cardiothoracic surgeon (combined group). In the combined group, 10 patients received early fixation and 21 received delayed fixation. Six patients underwent fixation by an orthopedic surgeon alone (orthopedic group). Only 1 patient in the orthopedic group underwent early fixation and 5 underwent delayed fixation. There was no significant difference in time to fixation or the presence of a cardiothoracic surgeon (p=0.45).

Table 1. Indications for surgery

Indication for surgery	No. of frequency
Mechanical flail/paradoxical breathing	12
Failure to ventilate/respiratory failure	15
Significant deformity	10
Failure to extubate/wean from ventilator	5
Flail+requiring thoracic surgery	2
Intractable pain	3

SSRF versus nonoperative treatment

SSRF patients were significantly more likely to have a flail chest (32 [86%] versus 94 [30%], p<0.001), ISS >15 (37 [100%] versus 129 [41%], p<0.001), require ICU admission (30 [81%] versus 19 [6%], p<0.001), and require intubation with ventilatory support (24 [65%] versus 17 [5%], p<0.001) than the nonoperative group. No statistically significant differences were seen for 30-day mortality, 1-year mortali-

Table 2. Patient demographics, injury patterns, and outcome measures of surgical fixation of rib fractures and nonoperative treatment

Characteristic	All complex rib fractures (n=352)	Surgical fixation of rib fractures (n=37)	Surgical fixation of rib fractures (within 72 hr) (n=11)	Surgical fixation of rib fractures (over 72 hr) (n=26)	Nonoperative complex rib fractures (n=315)	Nonoperative complex rib fractures (ISS >15) (n=129)
Sex (male)	230 (65)	30 (81)	9 (82)	21 (81)	201 (64)	85 (66)
Age (yr)	66	59.5	60	59	66	66
ISS	13	29	34	22.5	13	16
Major trauma patient (ISS >15)	166 (47)	37 (100)	11 (100)	26 (100)	129 (41)	129 (100)
Flail chest	126 (36)	32 (86)	10 (91)	22 (85)	94 (30)	94 (73)
ICU admission	49 (14)	30 (81)	10 (91)	20 (77)	19 (6)	9 (7)
ICU length of stay (day)	8	10	6	10	6	6
Intubated	41 (12)	24 (65)	8 (73)	16 (61)	17 (5)	9 (7)
Median days intubated	7	8	5	8	6	5
Tracheostomy	9 (3)	8 (22)	3 (27)	5 (19)	1 (0)	0
Pneumonia	101 (29)	17 (46)	2 (18)	15 (58)	84 (27)	48 (37)
Total hospital length of stay	11 (1–552)	19 (6–83)	18 (11–39)	19 (6–83)	10 (1–552)	13 (4–119)
30-Day mortality	8 (2)	0	0	0	12 (4)	6 (5)
1-Year mortality	16 (5)	1 (3)	0	1 (4)	16 (5)	5 (4)

Values are presented as number (%), median, or median (range), unless otherwise stated.
ISS, Injury Severity Score; ICU, intensive care unit.

ty, tracheostomy, days intubated, or ICU LOS when comparing the SSRF and nonoperative groups. The SSRF group had a significantly longer hospital LOS than the nonoperative group (19 days versus 10 days, p<0.001).

The SSRF group was significantly more likely to have pneumonia than the nonoperative group (17 [46%] versus 84 [27%], p<0.001). Logistic regression identified ISS >15 as a confounder for statistical significance for pneumonia (p<0.001; OR, 2.436; 95% CI, 1.463–4.057). Other potential confounders included in the logistic regression model were age, sex, ICU admission, tracheostomy, intubation, mortality, and LOS, for which no significance was seen. SSRF was no longer significantly associated with pneumonia when this was accounted for. Specifically, a statistical analysis comparing SSRF to nonoperative treatment in patients with an ISS >15 showed no significant difference for pneumonia (OR, 0.697; 95% CI, 0.333–1.459; p=0.338).

SSRF versus nonoperative treatment (flail chest and/or ISS >15)

No statistically significant differences were seen for 30-day mortality, 1-year mortality, tracheostomy, pneumonia, days of intubation, or ICU LOS when comparing the SSRF and nonoperative groups (flail chest and/or ISS >15). The SSRF group had a significantly longer hospital LOS than the nonoperative group (19 versus 13 days, p=0.012). Logistic regression analysis identified no significant difference assessing confounders of hospital LOS when including the variables of age, sex, ICU admission, tracheostomy, intubation, mortality, and pneumonia.

SSRF in <72 hours versus SSRF in >72 hours

Patients who underwent SSRF within 72 hours post-injury were 6 times less likely to develop pneumonia than those in whom SSRF was delayed for more than 72 hours (2 [18%] versus 15 [58%]; OR, 0.163; 95% CI, 0.029–0.909; p=0.036). Logistic regression analysis identified no significant difference when assessing confounders of pneumonia between these groups (SSRF <72 hours versus SSRF >72 hours), when including the variables of age, sex, ICU admission, tracheostomy, intubation, mortality, and LOS. A non-significant trend was noted for SSRF within 72 hours to be associated with a shorter ICU LOS (6 days versus 10 days, p=0.140) and duration of mechanical ventilation (5 days versus 8 days, p=0.177). No statistically significant differences were seen for 30-day mortality, 1-year mortality, tracheostomy, or hospital LOS.

SSRF <72 hours versus no SSRF (flail chest and/or ISS >15)

No statistically significant differences were seen for 30-day mortality, 1-year mortality, tracheostomy, pneumonia, days of intubation, ICU length of stay, or hospital LOS when comparing the SSRF and nonoperative groups. In contrast to all SSRF patients, the SSRF <72 hours subgroup did not show a significantly longer hospital LOS than the flail chest and/or ISS >15 nonoperative group.

Discussion

In the current study, no statistically significant difference in mortality was seen according to whether the management of rib fractures was operative or nonoperative. This mirrors the findings of a recent meta-analysis of 2 RCTs, in which 86 SSRF patients were included [11]. One hypothesis for this finding in our study is that the patients in the SSRF group were more severely injured (ISS >15) on presentation (with an associated increased expectation of mortality) for which SSRF resulted in an equal mortality rate to that of the less severely injured nonoperative group. A subgroup analysis was performed to reduce heterogeneity between groups; however, when accounting for nonoperative patients with an ISS >15, there were few cases of mortality and a type II error of non-significance should be considered.

Early operative intervention within 72 hours demonstrated improved outcomes with a decreased rate of pneumonia and shorter LOS. The benefit of early fixation has been demonstrated in a large retrospective study of 102 patients, in which those who underwent surgery within 48 hours had statistically significant reductions in ICU LOS, days of mechanical ventilation, total hospital LOS, pneumonia, and tracheostomy formation [13]. In our study, no statistically significant differences were seen in ICU LOS or the need for tracheostomy formation; however, the incidence of tracheostomy was low in both groups (3 in the early group versus 5 in the delayed surgery group), and similarly, a type II error of non-significance should be considered. The potential implication of this may be that with larger numbers, the incidence of tracheostomy formation might be significantly lower in patients who undergo early fixation. This was the case in the study by Iqbal et al. [13], who reported lower tracheostomy rates in 65 patients undergoing SSRF in under 48 hours.

There was large variation in the severity of injuries in patients referred for consideration of fixation. This can be

attributed to the absence of an established formal referral pathway in our center. The most common characteristics of patients in the nonoperative group were an isolated thoracic injury with an ISS of 9. The evidence for more severely injured patients, such as those with a flail chest, supports operative fixation [15,16]. Our study demonstrated similar outcomes between operative and nonoperative fixation for all patients with a flail chest, which is not in keeping with current evidence. On reviewing the comparative flail chest groups, however, the overall ISS in the SSRF group was significantly higher (29 versus 16 as the highest score of any nonoperative flail patient). The similarity in mortality, ICU LOS, and hospital LOS between the 2 groups, despite an overall higher ISS score in the SSRF flail chest patients, may account for the lack of significant difference seen between these 2 groups. A study by Karev [17] demonstrated benefits of surgical fixation when flail chest is present, for which reason the authors concluded that further research was required into the selection of patients with other indications. Our study supports this conclusion, and we suggest future prospective studies assessing less severely injured patients who may benefit from SSRF.

Complications from operative fixation were uncommon. Pneumonia occurred in 46% of patients, though this rate was significantly lower in the early fixation group (18%). The nonoperative ISS >15 group showed a similar rate of pneumonia (37%). Only 1 patient (2.7%) developed a wound infection, which is lower than the rate of 19% reported in a previous study [18].

Inherent limitations are associated with retrospective analyses. Patients were not randomized to operative or nonoperative management. Within the operative group, patients were not randomized into early or delayed fixation groups. Heterogeneity was present between the operative and nonoperative groups due to the lack of a referral pathway and the fact that the inclusion criteria in this study encompassed all patients who were referred to our service for SSRF. A further limitation of the present study is the small sample size within the operative group, which limits the statistical power of our findings. Further higher-powered studies or meta-analyses are suggested to strengthen the power of these findings. Due to sample size limitations, SSRF <72 hours was chosen as the earliest timeframe for which statistical analysis could be performed. We were unable to perform a further sub-group analysis on alternative time periods, such as <48 hours (only 5 patients fulfilled this criterion). Subsequent higher-powered studies should investigate different time intervals and their associations with outcome measures. We were similarly unable to perform an additional analysis on potential confounders for which there were insufficient events, including traumatic brain injury.

In conclusion, the current study demonstrated that patients who underwent SSRF within 72 hours post-injury were 6 times less likely to develop pneumonia than those in whom SSRF was delayed for more than 72 hours. No differences were seen between the SSRF and nonoperative groups for ICU LOS or mortality.

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

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References

1. Haines KL, Zens T, Warner-Hillard C, DeSouza E, Jung HS, Agarwal S. Rib fracture location should be evaluated when predicting morbidity and mortality in trauma patients. Am Surg 2018;84:1462-5. https://doi.org/10.1177/000313481808400950
2. Sirmali M, Turut H, Topcu S, et al. A comprehensive analysis of traumatic rib fractures: morbidity, mortality and management. Eur J Cardiothorac Surg 2003;24:133-8. https://doi.org/10.1016/s1010-7940(03)00256-2
3. Ciraulo DL, Elliott D, Mitchell KA, Rodriguez A. Flail chest as a

marker for significant injuries. J Am Coll Surg 1994;178:466-70.
4. Kim HY, Kim MY. Management of patients with rib fractures: analysis of the risk factors affecting the outcome. Korean J Thorac Cardiovasc Surg 2010;43:285-91. https://doi.org/10.5090/kjtcs.2010.43.3.285
5. Lafferty PM, Anavian J, Will RE, Cole PA. Operative treatment of chest wall injuries: indications, technique, and outcomes. J Bone Joint Surg Am 2011;93:97-110. https://doi.org/10.2106/JBJS.I.00696
6. Bemelman M, de Kruijf MW, van Baal M, Leenen L. Rib fractures: to fix or not to fix?: an evidence-based algorithm. Korean J Thorac Cardiovasc Surg 2017;50:229-34. https://doi.org/10.5090/kjtcs.2017.50.4.229
7. Kim SH, I H. Commentary: thoracoscopic-assisted rib plating: where we are and what we have learned. J Chest Surg 2023;56:126-7. https://doi.org/10.5090/jcs.23.017
8. Craxford S, Marson BA, Nightingale J, Forward DP, Taylor A, Ollivere B. Surgical fixation of rib fractures improves 30-day survival after significant chest injury: an analysis of ten years of prospective registry data from England and Wales. Bone Joint J 2022;104-B:729-35. https://doi.org/10.1302/0301-620X.104B6.BJJ-2021-1502.R1
9. Ahmed Z, Mohyuddin Z. Management of flail chest injury: internal fixation versus endotracheal intubation and ventilation. J Thorac Cardiovasc Surg 1995;110:1676-80. https://doi.org/10.1016/S0022-5223(95)70030-7
10. Tanaka H, Yukioka T, Yamaguti Y, et al. Surgical stabilization of internal pneumatic stabilization?: a prospective randomized study of management of severe flail chest patients. J Trauma 2002;52:727-32. https://doi.org/10.1097/00005373-200204000-00020
11. Coughlin TA, Ng JW, Rollins KE, Forward DP, Ollivere BJ. Management of rib fractures in traumatic flail chest: a meta-analysis of randomised controlled trials. Bone Joint J 2016;98-B:1119-25. https://doi.org/10.1302/0301-620X.98B8.37282
12. Forward DP, Ollivere BJ, Ng JW, Coughlin TA, Rollins KE. Current concepts in rib fracture fixation. Bone Joint 360 2016;5:2-7. https://doi.org/10.1302/2048-0105.55.360464
13. Iqbal HJ, Alsousou J, Shah S, et al. Early surgical stabilization of complex chest wall injuries improves short-term patient outcomes. J Bone Joint Surg Am 2018;100:1298-308. https://doi.org/10.2106/JBJS.17.01215
14. Copes WS, Champion HR, Sacco WJ, Lawnick MM, Keast SL, Bain LW. The Injury Severity Score revisited. J Trauma 1988;28:69-77. https://doi.org/10.1097/00005373-198801000-00010
15. Marasco SF, Davies AR, Cooper J, et al. Prospective randomized controlled trial of operative rib fixation in traumatic flail chest. J Am Coll Surg 2013;216:924-32. https://doi.org/10.1016/j.jamcollsurg.2012.12.024
16. Granetzny A, Abd El-Aal M, Emam E, Shalaby A, Boseila A. Surgical versus conservative treatment of flail chest: evaluation of the pulmonary status. Interact Cardiovasc Thorac Surg 2005;4:583-7. https://doi.org/10.1510/icvts.2005.111807
17. Karev DV. Operative management of the flail chest. Wiad Lek 1997;50 Suppl 1 Pt 2:205-8.
18. Campbell N, Conaglen P, Martin K, Antippa P. Surgical stabilization of rib fractures using Inion OTPS wraps: techniques and quality of life follow-up. J Trauma 2009;67:596-601. https://doi.org/10.1097/TA.0b013e3181ad8cb7