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Plate of ribs: single institution's matched comparison of patients managed operatively and non-operatively for rib fractures

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ABSTRACT

Background Rib fractures are associated with significant morbidity and mortality in polytraumatized patients. There is considerable variability in the management (operative vs. non-operative) and timing of operative intervention. Although Eastern Association for the Surgery of Trauma (EAST) guidelines recommend early operative intervention in patients with flail chest, there are no strong recommendations regarding operative fixation in patients with a non-flail chest rib fracture pattern.

Methods We reviewed our Trauma Quality Improvement Program database for patients aged 18 to 99 who underwent operative intervention of ribs from January 2016 to July 2019. We examined hospital length of stay (LOS), intensive care unit (ICU) LOS, ventilator days, Injury Severity Score, age, discharge disposition and packed red blood cell transfusions. Similarly, we collected data from patients aged 18 to 99 who had one or more rib fractures in this time frame. We compared results in a 4:1 ratio of patients managed non-operatively to patients managed operatively. The patient groups were matched based on age, number of rib fractures and presence of bilateral rib fractures.

Results Between January 2016 and July 2019, 33 of 4189 total patients diagnosed with rib fractures underwent operative fixation; the matched non-operative group consisted of 132 patients. The statistically significant differences included presence of bilateral rib fractures, displaced rib fractures and flail chest segments. The median ICU days were longer in the operative group (6.0 vs. 3.5 days). A subgroup analysis of patients without flail segments demonstrated a significant presence of displaced rib fractures.

Our single-institution matched comparison of outcomes in operative intervention versus Non-operative Management (NOM) of rib fractures found an increased median number of ICU days. Patients who underwent operative intervention often stayed in the ICU preoperatively and postoperatively for aggressive pulmonary hygiene and pain control, suggesting observer bias. The increased incidence of displaced rib fractures and the presence of a flail segment in the operative group demonstrate congruence with EAST guidelines. A subgroup analysis of patients without flail segment did not demonstrate differences in outcomes nor shoulder girdle injury characteristics.

Level of evidence This article presents level III evidence that can be used by other clinicians to analyze eligibility for patients to undergo surgical stabilization of rib fracture (SSRF) and to provide counterarguments for performing SSRF in a heterogenous group of patients.

INTRODUCTION

Rib fractures constitute approximately 10% of all traumatic injuries.[1 2] Martin *et al* reviewed the Agency for Healthcare Research and Quality and found that the number of patients with rib fracture increased by 19.4% from 2006 to 2014,[3] suggesting that rib fractures have become more prevalent in the trauma population. Historically, rib fractures are managed non-operatively with pain control, deep inspiration and coughing exercises, and respiratory adjuncts such as high-flow nasal cannula or continuous positive airway pressure ventilation.[4] This strategy is outlined in guidelines from the Eastern Association for the Surgery of Trauma (EAST).[5] However, rib fractures are at high risk of morbidity, with estimates of pulmonary complications approximating 13%[3 6] and up to 33% in elderly patients over the age of 65 years.[7]

To reduce these pulmonary complications and quantify the degree of severity of rib fractures, several scoring systems have been created: RibScore, Rib Fracture Score, Organ Injury Scale (OIS) chest wall grade and Chest Trauma Score (CTS). Higher scores correlate with an increased incidence of complications and surgical interventions, including tracheostomy.[1] Parallel to this, there has been a growing concentration in recent years on surgical stabilization of rib fractures (SSRFs). EAST formulated guidelines recommending SSRF for patients with flail chest, as it reduced their mortality, duration of mechanical ventilation, and both hospital and intensive care unit (ICU) length of stay (LOS).[8] Due to a paucity of data, no recommendations concerning SSRF in patients without flail chest could be supported.

Uchida *et al* compared patients who underwent SSRF with propensity-matched cohorts to demonstrate benefit for both patients with flail chest and severely fractured ribs, but this study was underpowered with only 10 patients in the operative group and 10 patients in the non-operative group.[9] Wada *et al* and Shibahashi *et al* compared operative to non-operative patients in 4:1 propensity-matched ratios for data extracted from the Diagnosis Procedure Combination database and Japan Trauma Data Bank, respectively.[2 10] Because both of these studies compared many different hospitals and different

surgical teams, there is confounding of the outcomes and statistical analyses performed. We completed a similar matched comparison of patients undergoing SSRF to those managed non-operatively within a single institution with a single group of trauma surgeons using the same protocol. We hypothesized that SSRF would reduce mechanical ventilator duration, ICU LOS, hospital length of stay (HLOS), rate of pneumonia and rate of acute respiratory distress syndrome (ARDS), for patients with and without flail chest. Secondarily we attempted to identify other factors that describe patients benefiting from SSRF, such as concurrent clavicle fractures, bilaterality, and the presence of first rib fractures or sternal fractures.

METHODS

Study population

A retrospective cohort from our institution's Trauma Quality Improvement Program database was compiled of patients aged 18–100 years admitted from January 2015 to July 2019 with at least one rib fracture. The data extracted included age, sex, Injury Severity Score (ISS), ICU LOS, ventilator days, HLOS, discharge disposition and packed red blood cell (PRBC) transfusion.

We identified 4198 patients with a diagnosis of at least one rib fracture. Thirty-nine patients underwent SSRF during this time frame. In accordance with the current guidelines, SSRF was considered for patients with a flail segment, as well as patients with severely displaced rib fractures and worsening respiratory insufficiency or respiratory failure. The decision to perform SSRF was at the discretion of the attending surgeon caring for the patient. One patient was not initially seen at our institution and did not have presentation data available, and another underwent reoperation, leading to their exclusion. Another four patients were excluded because they had their SSRF performed more than 7 days after admission, creating a cohort of 33 patients who underwent SSRF within 7 days of admission.

Demographic and clinical data were extracted from our hospital electronic medical records—CT thorax radiology reports, diagnosis of ARDS and pneumonia, and time to surgical fixation (if applicable). We used the CT thorax radiology reports to analyze the number of rib fractures, bilaterality, presence of first rib fracture, presence of a flail segment (three or more contiguous rib fractures with at least two separate fractures), concurrent sternal fracture and concurrent clavicle fracture.

Outcomes

The primary outcomes were mechanical ventilator duration, ICU LOS, HLOS, development of pneumonia and diagnosis of severe ARDS. The secondary outcomes are discharge disposition and PRBC transfusion. All patients in the study population were treated similarly, regardless of SSRF status, with multimodal pain control, ventilator management and pulmonary care.

During this time frame, patients were treated by a single trauma surgery group with institutional guidelines for employing multimodal pain control and admission criteria to the ICU. Admission criteria to the ICU consisted of elderly trauma patients over the age of 65, respiratory insufficiency, inability to inspire greater than 1000 cc on incentive spirometer, mechanical ventilation, or any other concerning signs or symptoms at the discretion of the attending physician. Multimodal pain control consisted of use of scheduled Tylenol and narcotic medications as needed; these could be supplemented by scheduled gabapentin, scheduled muscle relaxants, scheduled intravenous ketorolac and/or epidural catheter analgesia. In 2017, our institution began using a low-dose lidocaine peripheral intravenous infusion for pain control in rib fracture pathological findings. The decision to pursue SSRF did not alter the patient's pain regimen plan, as the patient was still treated according to our guidelines in both operative and non-operative groups.

Patient matching

We matched the operative patients with four non-operative patients with similar ages (±2 years) and similar number of rib fractures within one rib fracture difference while staying within the age range, up to eight rib fractures. Patients in the operative arm with 8 to 12 rib fractures were matched to non-operative patients within two rib fractures due to difficulty in finding matches otherwise and the lack of evidence suggesting statistical difference in outcomes for patients with more than eight rib fractures. For operative patients with 13 or more rib fractures, we matched to non-operative patients within the age range that had 13 to 24 rib fractures, as both patients would have bilateral rib fractures and also due to the difficulty in matching otherwise. This resulted in 132 patients who were matched to the 33 patients in the operative group (figure 1).

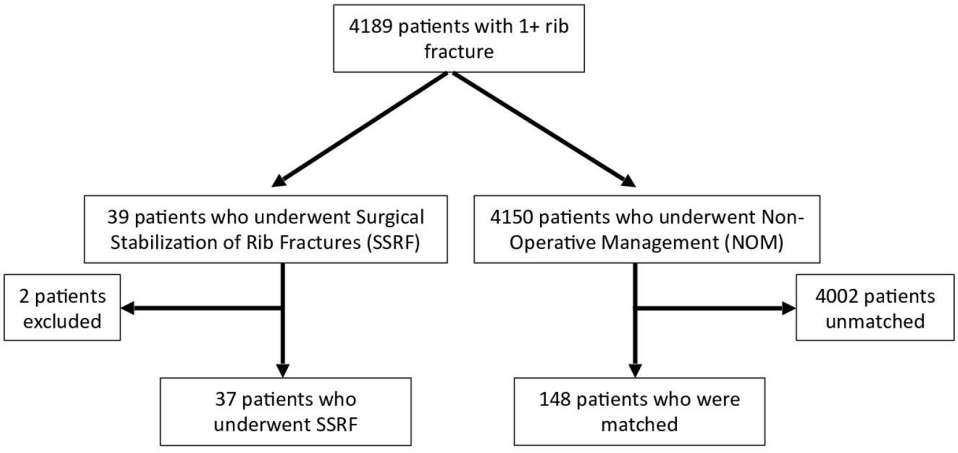

Figure 1 Study design of patients identified in our database with at least one rib fracture and patients identified as undergoing SSRF, with those eliminated from the study in each arm shown. Cohorts of patients were compared in a 4:1 ratio of those managed non-operatively versus those who underwent SSRF. SSRF, surgical stabilization of rib fracture.

Table 1 Study populations

Variable	Operative (n=33)	Non-operative (n=132)	P value	Test
Descriptive characteristics				
Age (years)	59 (48 to 68)	59 (46.5 to 69)	0.974	Mann-Whitney U
ISS	17 (17 to 25)	19.5 (17 to 29)	0.258	Mann-Whitney U
Number of rib fractures	9 (7 to 14)	9 (7 to 13)	0.512	Mann-Whitney U
Flail chest segment (n=33, n=128)	15 (45.5)	33 (25.8)	0.028	χ^2
Bilateral rib fractures	15 (45.5)	87 (65.9)	0.031	χ^2
Displaced rib fracture	30 (90.9)	85 (65.4)	0.003	χ^2
First rib fracture	11 (33.3)	35 (26.5)	0.435	χ^2
Sternum fracture	3 (9.1)	28 (21.2)	0.110	χ^2
Clavicle fracture	8 (24.2)	19 (14.4)	0.171	χ^2
Outcomes				
Ventilator days	0 (0 to 4)	0 (0 to 4)	0.641	Mann-Whitney U
Hospital days	11 (7 to 16)	9 (4 to 18)	0.136	Mann-Whitney U
ICU days	6 (3 to 9)	3 (2 to 9)	0.040	Mann-Whitney U
Number of RBC units administered	0 (0 to 1.5)	0 (0 to 1)	0.397	Mann-Whitney U
Severe ARDS	1 (3.0)	7 (5.3)	>0.999	Fisher's exact
Pneumonia	7 (21.2)	14 (10.7)	0.142	Fisher's exact

ARDS, acute respiratory distress syndrome; ICU, intensive care unit; ISS, Injury Severity Score; RBC, red blood cell.

Table 2 Non-flail segment study population

Variable	Operative (n=18)	Non-operative (n=72)	P value	Test
Characteristics				
Age (years)	60 (46 to 68)	60 (45.5 to 68.5)	>0.999	Mann-Whitney U
ISS	17 (17 to 21)	19 (16 to 29)	0.347	Mann-Whitney U
Number of rib fractures	10 (6 to 15)	10 (6 to 14)	0.565	Mann-Whitney U
Bilateral rib fractures	11 (61.1)	49 (68.1)	0.576	χ^2
Displaced rib fracture	16 (88.9)	47 (65.3)	0.050	χ^2
First Rib Fracture	7 (38.9)	20 (27.8)	0.358	χ^2
Sternum Fracture	2 (11.1)	21 (29.2)	0.142	Fisher's exact
Clavicle fracture	6 (33.3)	10 (13.9)	0.081	Fisher's exact
Outcomes				
Ventilator days	0 (0 to 6)	0 (0 to 7)	0.8553	Mann-Whitney U
Hospital days	12 (8 to 19)	9 (3.5 to 20)	0.21	Mann-Whitney U
ICU days	7 (4 to 12)	4 (2 to 12)	0.1523	Mann-Whitney U
Number of RBC units administered	0 (0 to 0)	0 (0 to 1.5)	0.5244	Mann-Whitney U
Severe ARDS	0 (0)	6 (8.3)	0.3427	Fisher's exact
Pneumonia	5 (27.8)	11 (15.3)	0.2985	Fisher's exact

ARDS, acute respiratory distress syndrome; ICU, intensive care unit; ISS, Injury Severity Score; RBC, red blood cell.

Statistical analysis

Continuous variables were checked for normality using the Shapiro-Wilk test, Komogorov-Smirnov test and visual inspection of histograms. None of the continuous variables were found to be normal; thus, all results are presented as medians with IQRs. A Mann-Whitney U test was used for between-group comparisons. All categorical variables are presented as count (percent). A χ^2 or Fisher's exact test was used for between-group comparisons.

All of the raw data were collected into a Microsoft Excel version 16 spreadsheet and converted to a Comma Separated Variables (CSV) file. All statistics were generated using SAS V.9.4 (TS1M4), and a p value of <0.05 was considered statistically significant.

RESULTS

A total of 165 patients were analyzed, 33 SSRF and 132 non-operative. Both the operative and non-operative groups were similar with regard to age, ISS, number of rib fractures, first rib fracture, sternum fracture and clavicle fracture. The median age for both groups was 59 years, and the median ISS was 17 and 19.5, respectively (table 1).

Flail chest segments and displaced rib fractures were more common in the operative group (p values of 0.0276 and 0.003, respectively). The SSRF group had 15 (45.5%) patients with flail segments compared with 33 patients in the non-operative group (25.8%), and displaced rib fractures were present in 90.9% of the operative group and 65.4% of the non-operative group. Bilateral rib fractures were more common in the non-operative group at 65.9% versus 45.5% (p value of 0.0305). First rib fractures had similar rates between the two groups (33.3% vs. 26.5%, p=0.4346). Concurrent sternum and clavicle fractures were not similar and did not have statistically significant differences (p values of 0.1108 and 0.1714, respectively).

There was no significant difference between the operative and non-operative groups in ventilator days (p=0.641) or hospital days with 11 days versus 9 days (p=0.1358). There was no difference in the prevalence of pneumonia or severe ARDS between the groups (p values of 0.1416 and 0.999, respectively). SSRF had a statistically significant longer ICU LOS at 6 days (IQR 4 to 9) compared with 3.5 days (IQR 2 to 9) (p=0.0217). Discharge dispositions were similar and did not demonstrate any difference, regardless of the category.

In the non-flail segmental rib fractures subgroup (table 2), the presence of displaced rib fracture was more common in the operative group (p=0.050). All other characteristics did not reach statistical significance, including the number of rib fractures, median of 10 (IQR of 6 to 15) in the operative group and 10 (IQR 6 to 14) in the non-operative group (p value of 0.5657). There were no statistically significant outcome differences between these two groups, despite SSRF having an increased median number of ICU days and hospital days with 7 days versus 4 days and 12 days versus 9 days, respectively.

DISCUSSION

In our retrospective, cohort-matched study comparing the characteristics and outcomes of surgical rib fixation and current practice of non-operative support, we did not demonstrate a significantly statistical difference in the rates of severe ARDS or pneumonia, hospital LOS, or ventilator days. We observed a longer ICU LOS in the operative group. This may be biased, as both groups had similar IQRs (4 to 9 operative vs. 2 to 9 non-operative). It may also be affected by the majority of patients being admitted to the ICU prior to SSRF and remaining in the ICU for postoperative care. This increased number of ICU days is in concordance with the results of Kane *et al*, who demonstrated a median length of ICU days of 3 days in the surgical group compared with 0 in the non-operative group.[11]

This is worrisome not just clinically but also financially, as an increased ICU LOS consumes healthcare resources. Each 24-hour day spent in the ICU can result in a charge of approximately $5500 at our institution; by our LOS, this equals $19 000 more in charges for an SSRF patient compared with a non-operative. This is in addition to the cost of SSRF itself, which can range from $3200 to $9000, depending on the number of

ribs that require fixation.[12] Our results suggest that SSRF does not decrease ventilator days, incidence of pneumonia or incidence of severe ARDS. We think this is partially due to our robust non-operative management strategies of rib fractures: we use a continuous low-dose intravenous infusion of lidocaine, in addition to multimodal pain control strategies and early mobilization, and we use our non-trauma iCough protocol across the house, which includes aggressive training of patients to use incentive spirometers and flutter valves to encourage deep breathing and coughing.

We found that there was a statistically significant difference in the presence of a flail segment, bilateral rib fractures and displaced rib fractures in our SSRF group, paralleling current EAST practice guidelines,[8] but were unable to impact outcomes. Witt and Bulger recommend offering SSRF for patients with >3 displaced rib fractures but do not address the presence of bilateral rib fractures that can have a substantial effect on chest wall mechanics.[13 14] From our data, we can only recommend broadening the current considerations for SSRF of rib fractures to include presence of a flail segment, displacement of at least one rib fracture and bilateral rib fractures after further study.

When comparing the outcomes and injury characteristics of patients without flail segments, we only demonstrated a significantly significant difference in the presence of a displaced rib fracture. This finding confirms we used the presence of a displaced rib fracture as an indication for SSRF. Unfortunately, our data do not establish an improvement in outcomes for patients in the non-flail segment population, which is congruent with the current practice guidelines from EAST.[8] We hope that further study of our trauma population can better delineate a benefit for patients without flail segments in the future.

Based on our results, we did not demonstrate a clear benefit from performing SSRF on our patient populations. At our institution, SSRF did not decrease the ventilator days nor the ICU LOS compared with a cohort of non-operatively managed rib fractures, contrary to benefits described in the literature.[8 11] The incidence of pneumonia was higher in the SSRF group compared with the non-operative group, and this difference trended towards significance (p value of 0.1416). Overall, our data suggest that SSRF may not be as beneficial as current literature suggests compared with aggressive non-operative management with multimodal pain control, ventilator management,and pulmonary care.

The greatest strength of our study is that it compares a patient population within a single institution. During the study period, the patients were managed with similar protocols, multimodal treatment plans and the same group of trauma surgeons. There have been several multi-institutional propensity-scored analyses performed, but these studies are at risk of confounding due to the heterogeneity of providers, treatment plans, institutional protocols and regional differences.[2 10 15] Kane *et al* evaluated operative patients at their institution but compared their outcomes to a national database of non-operative patients.[11] Our study resembles that performed by Uchida *et al*, but their study was limited in evaluating only 10 operative patients and 10 non-operative patients for comparison of outcomes.[9]

The main limitation of this study is the patient population size; we evaluated 33 patients who underwent SSRF, but this is still a small sample size. We plan to continue to collect data on our outcomes and hope to define our SSRF program to identify in whom a benefit is achieved from SSRF.

CONCLUSION

In recent years, SSRF has become a popular topic of study. The most recent practice guidelines from EAST recommend offering this to patients with flail segments, as it demonstrated clinical benefit. Based on our institution's outcomes, we did not find data to support this. Expansion of indications to include the presence of displaced rib fractures and the presence of bilateral rib fractures for SSRF requires more study. In our study population, SSRF may lead to an increased ICU stay, which has clinical, financial and societal impact in the use of healthcare resources.

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Contributors JG participated in the study design, literature search, data analysis, data interpretation, writing and critical revisions of the article. BD, MC, and JT participated in the study design and critical revisions of the article. DM participated in the study design and literature search of the article. SR participated in the data analysis, data interpretation, writing and critical revisions of the article. ZB participated in writing and critical revisions of the article.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval Approval for this retrospective study was obtained from the institutional review board (IRB) at the University of Tennessee Graduate School of Medicine in Knoxville, Tennessee. Due to the retrospective nature of the study and the minimal use of protected health information, it was exempt from a full IRB review. Consent was not obtained from the subjects, as the information had already been collected in the electronic health record for clinical purposes, and it was not feasible to call and obtain consent from all of the subjects in the 4-year time frame studied. The IRB number associated with this study is 4504.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. Deidentified data are available within the article and the original data set is on a secure server location at the University of Tennessee Medical Center and can be obtained by contacting JG.

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