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Chest Wall Stabilization in Trauma Patients with Rib Fractures: A Systematic Review

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Abstract

Background: The incidence of rib fractures remains high among trauma patients, serving as a significant source of morbidity and mortality. Outcomes are further impacted by the presence of a flail segment, multiple rib fractures, or in elderly patients. In recent years, there has been an increase in the utilization and research into chest wall stabilization. Due to heterogeneity of the rib fracture pathology, concomitant injuries and patient variability there has been challenges to develop strict indication guidelines that can be generalized in this patient population.

Method: We present a literature review of PubMed and Google Scholar. After review 30 papers met inclusion criteria. Outcomes of interest include mortality rates, length of stay in the intensive care unit (ICU) and hospital, post-operative pain, and post-operative complications.

Results: Data reports a decrease in in both the ICU and hospital length of stay. Studies show a decreased post-operative pain with chest wall stabilization when compared to non-operative management. Interestingly, these benefits appeared to be most prominent within 72 hours post-surgery.

Conclusion: Although some studies show no difference in these variables, most of the data shows a non-conclusive signal that chest wall stabilization surgeries might be a viable option with some impact on the morbidity and mortality in select patients with rib fractures.

Keywords: Rib fixation; Rib fracture; Rib Stabilization; Chest trauma; Outcomes

Introduction

Rib fractures are a prevalent source of morbidity and mortality among individuals who experience blunt thoracic

trauma. In fact, these fractures contribute to an estimated 248,000 emergency department visits annually in the United States.¹ Certain patient populations, such as those aged 65 years and older, individuals with a flail segment, or those with three or more rib fractures, face an elevated risk of complications resulting from rib fractures.^{2,3}

Traditionally, the management of rib fractures has primarily focused on providing analgesia for pain relief. However, in recent decades, there has been a growing acceptance and adoption of surgical stabilization of rib fractures (SSRF) as an alternative treatment approach.^{4,5} SSRF has gained traction and popularity as it offers promising outcomes.

Accepted indications for SSRF include cases of flail chest, the presence of three or more bi-cortically displaced ribs, impending respiratory failure or difficulties in weaning patients from ventilator support related to rib fractures.^{6,7} These specific scenarios warrant surgical intervention to stabilize the fractured ribs and mitigate associated complications.

While many experts endorse the use of rib plating for SSRF, it is important to note that there remains evidence that shows a lack of benefits. Therefore, it is imperative to critically evaluate the existing research on SSRF and its impact on patient outcomes. This paper aims to conduct a comprehensive review of the current literature in order to shed light on the efficacy and effectiveness of SSRF as a management option for rib fractures and ultimately inform clinical decision-making.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were utilized for the search criteria and data extraction in this study shown in figure 1. The search criteria were developed to compare non-operative (conservative) management of patients with rib fractures or flail chest to surgical management.

The databases PubMed and Google Scholar were searched, using keywords such as “Rib” or “Chest” in conjunction with “Fixation,” “ORIF” (open reduction and internal fixation), “Stabilization,” “Plating,” or “Management.” The full reference lists obtained from the database searches were examined for inclusion. Two reviewers evaluated the titles and abstracts of the papers. Case reports, case series without a control group, opinion papers, and abstracts were excluded from the analysis.

A total of 3,713 results were initially obtained. After

removing duplications, 3,646 unique records remained. After reviewing the abstracts, 31 results fulfilled our criteria. Each paper was independently analyzed and included or excluded based on predetermined criteria. One paper was excluded as it compared different types of plates without a control group. Two additional papers were removed as they focused on plating chronic non-union rather than acute fractures. This left a total of 28 papers listed in Table 1.

Results

General Outcomes

Several studies have investigated the outcomes of surgical stabilization of rib fractures (SSRF) compared to medical management. An Craxford et al. study demonstrated a decrease in 30-day mortality and rates of tracheostomy, although it did find longer lengths of stay (LoS) both in the intensive care unit (ICU) and in the hospital.⁸ Another study by Hoepelman et al. showed no change in ICU LoS, duration of ventilation, or pain scores, but it did reveal a decrease in overall hospital LoS and improved quality of life at one year.⁹ Niziolek et al. reported a decrease in length of ventilation with both early SSRF and overall SSRF compared to medical management.¹⁰ On the other hand, Xiao et al. found no significant difference in mortality, hospital LoS, ventilation usage, or rates of pneumonia when comparing SSRF to medical management, whether for flail segment SSRF or non-flail segment SSRF.¹¹

A study that compared outcomes for patients with multicompart ment traumas found no difference in mortality with SSRF, but did observe longer hospital and ICU lengths of stay, as well as an increased number of ventilation days in SSRF patients with univariate analysis but showed no difference in multivariate analysis.¹² A small case series of 43 flail chest patients demonstrated a decreased ICU length of stay from 11.9 to 9.8 days with SSRF.¹³ Similarly, Yahn et al. also reported a significant decrease in ventilator days by approximately half in their case series of flail chest patients.¹³ Two studies examined readmission rates and found similar results with and without SSRF.^{14,15} Compared to a study by Shiroff who found lower rates of readmission and increase rates of discharging patients home.¹⁶

Interestingly, a study focusing solely on the number of rib fracture stabilizations per year revealed improved outcomes with each additional procedure and identified a significant threshold of 12.5 operations per year.¹⁷

Does timing matter?

Recent studies have investigated the timing of rib fracture fixation, and there is variation in the definitions used to define early fixation, typically ranging between 24 and 72 hours. Simmonds et al. conducted a study comparing early SSRF (<72 hours) to late SSRF and found that early fixation was associated with a decrease in ventilation days, ICU and hospital length of stay (LoS), as well as a reduction in unplanned intubations.¹⁸ Similarly, Wang et al. conducted a randomized controlled trial comparing early SSRF (<48 hours) to late SSRF and reported a significant decrease in hospital and ICU LoS, as well as a reduction in the number of ventilation days.¹⁹

A German trauma database study also examined the timing of rib plating, revealing a decrease in both hospital and ICU length of stay when rib plating was performed early (<48 hours) compared to late rib plating.²⁰ In the same study, the comparison of ventilation days showed a trend toward decreased ventilation days with early rib plating, although the difference was not statistically significant.²⁰ A study by Yasa et al. showed a decrease in hospital LoS but no change in ICU LoS, ventilation days or mortality.²¹

Another retrospective study, using a propensity-matched national trauma database, demonstrated that early SSRF was associated with a decreased need for prolonged ventilation in flail chest patients.²² Similarly, a study from Japan with 211 patients compared early SSRF (<6 days from admission) to late SSRF and found that early fixation was associated with a decrease in ventilation days, shorter hospital stay, and lower hospital cost. However, there was no difference in the 28-day mortality of patients.²³

Mortality

An interesting retrospective study conducted by Yeates et al. found a decrease in mortality with SSRF, but it also paradoxically revealed increased rates of ARDS, pneumonia, unplanned intubation, and length of hospital stay.²⁴ These findings are similar to those of Feyh et al., who reported decreased mortality but higher durations of mechanical ventilation, as well as increased ICU and hospital length of stay in the SSRF group. Furthermore, the SSRF group in their study had a higher overall ISS score.²⁵

A retrospective study based on the National Trauma Data Bank (NTDB) demonstrated that rib fixation in patients with flail chest resulted in a decrease in mortality

from 5.5% to 2.0%.²² Additionally, several other studies showed a significant decrease in 30-day mortality.^{8,15,19,24} Moreover, a retrospective study using the Trauma Quality Improvement Program (TQIP) data also showed decreased mortality rates in patients undergoing SSRF. In a retrospective post-hoc analysis of patients with traumatic brain injury (GCS<12) and concomitant rib fractures, no difference in mortality was found among patients undergoing SSRF.²⁶

Pain control and Quality of Life (QoL)

Pieracci et al. conducted a prospective randomized controlled trial (RCT) involving 110 patients with severely displaced rib fractures but without a flail segment.²⁷ The study demonstrated that patients who underwent SSRF experienced lower overall pain and improved quality of life (QoL) after two weeks. Although the results did not reach statistical significance, there was a clear trend towards reduced narcotic consumption in this group.²⁷ Similar findings regarding pain scores were observed in a small retrospective study by Monzou et al., which showed a decrease in pain scores among patients who underwent SSRF.²⁸ Another retrospective study conducted by Pieracci et al., specifically focusing on patients over 80 years old, revealed that those who underwent SSRF were less likely to be discharged with narcotic pain medication.²⁹

In contrast, Marasco et al. conducted an RCT involving 124 non-ventilated patients with at least three consecutive rib fractures. The study found no difference in terms of QoL or pain scores at three months between non-operative management and SSRF. However, they did observe an improvement in the return to work at both three and six months in the SSRF group.³⁰

Additionally, we found a study that compared the mean morphine equivalents for intrathoracic and extra thoracic rib plating, which showed no significant difference between the two groups.³¹

Elderly patients

We identified four studies that specifically examined rib fixation in the elderly population. Zhu et al. conducted a propensity score-matched study involving 758 patients aged over 65 years.³² The study showed that in-hospital mortality decreased from 7.3% to 4.2% with SSRF.³² They also observed reduced rates of ventilator-associated pneumonia (VAP), as well as decreased ICU and hospital length of stay, and ventilation days associated with early

rib fixation.³² Similar findings regarding mortality were reported in a study focusing on patients over 80 years old, which demonstrated a decrease in mortality with SSRF.²⁹ Two other retrospective studies found similar results in patients aged over 65 years, including decreased mortality, lower readmission rates, and reduced incidence of pneumonia and pleural effusion.^{33,34} Interestingly, in the study investigating SSRF in patients over 80 years old found that despite an increase in pneumonia and ventilation days, patients still experienced decreased mortality with SSRF.²⁹

Obese patients

We identified one article that met our search criteria and focused on patients with a BMI greater than 29.9. The study demonstrated significant reductions in overall mortality with SSRF, decreasing from 3.7% to 1.4%. The authors also reported decreased hospital and ICU length of stay, as well as a decrease in ventilation days. However, they did find an increased incidence of venous thromboembolism within the SSRF group.³⁵

Discussion

This study aimed to conduct a comprehensive review of the existing literature to evaluate the efficacy and effectiveness of SSRF as a management option for rib fractures and to inform clinical decision-making as there continues to be an increase in data within the field of rib fixation. This is imperative since the findings reported by Parra et al. suggest the likelihood of undergoing rib fixation is influenced more by surgeon characteristics and the medical center where the procedure was performed rather than clinical factors.¹⁵

The results of the reviewed studies indicate varying outcomes of SSRF compared to medical management. Some studies showed a decrease in 30-day mortality and rates of tracheostomy with SSRF, but longer lengths of stay in the intensive care unit (ICU) and the hospital. Other studies reported no change in ICU length of stay, duration of ventilation, or pain scores but demonstrated a decrease in overall hospital length of stay and improved quality of life at one year. Some studies found a decrease in length of ventilation and ICU length of stay with SSRF, while others showed no significant difference in mortality, hospital length of stay, ventilation usage, or rates of pneumonia.

Timing of rib fracture fixation has also been explored in recent studies. The results suggest that earlier SSRF, per-

formed within 24 to 72 hours, is associated with a decrease in ventilation days, ICU and hospital lengths of stay, and unplanned intubations. Studies comparing early SSRF (<48 hours) to late SSRF found significant decreases in hospital and ICU lengths of stay and ventilation days with early intervention. However, there was no consistent impact on 28-day mortality across these studies.

Mortality rates were a key focus of several studies. While some studies demonstrated a decrease in mortality with SSRF, others showed increased rates of complications such as acute respiratory distress syndrome (ARDS), pneumonia, unplanned intubation, and longer hospital stays. SSRF was found to decrease mortality in flail chest patients, and several studies reported a significant decrease in 30-day mortality. However, there was variability in the results, and some studies did not find a significant difference in mortality rates.

Pain control and quality of life (QoL) outcomes were assessed in a few studies. SSRF was associated with lower overall pain and improved QoL in patients with severely displaced rib fractures. Some studies also showed a decrease in pain scores, narcotic consumption, and discharge with narcotic pain medication in elderly patients who underwent SSRF. However, a randomized controlled trial did not find a significant difference in QoL or pain scores between SSRF and non-operative management at three months, although there was an improvement in return to work at three and six months with SSRF.

Limited studies focused on specific populations, such as elderly or obese patients. The available evidence suggests that SSRF in elderly patients is associated with decreased mortality, shorter lengths of stay, and decreased rates of complications, although effects on pneumonia rates vary. Only one study specifically examined SSRF in obese patients and found decreased mortality, shorter lengths of stay, and decreased ventilation days, but an increased risk of venous thromboembolism.

Conclusion:

Surgical rib fixation is increasingly employed as a treatment for rib fractures. This study highlights significant benefits associated with this approach, particularly in terms of improved patient outcomes. These advantages encompass reduced mortality, shorter length of hospital stay, and lower complication rates. Furthermore, optimal benefits seem to be achieved when surgical fixation is performed early in the patient's presentation. Although there may be certain individuals who do not derive

substantial benefits from surgical rib fixation, further research is essential to identify and understand these specific subgroups.

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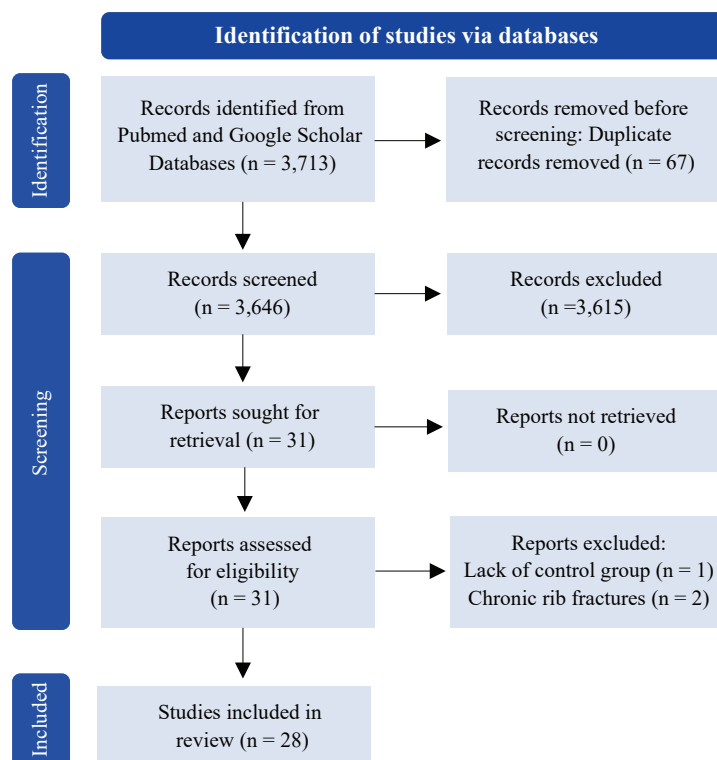
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Figure 1. PRISMA flow diagram



First Author (Year)	Title	Sample size	Findings
Craxford (2022)	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.	Total: 86,838pt SSRF: 1,042pt	- Decreased 30-day mortality - Decreased tracheostomy rates
Hoepelman (2023)	Non-operative vs. operative treatment for multiple rib fractures after blunt thoracic trauma: a multicenter prospective cohort study.	Total: 142pt SSRF: 71pt Medical Management: 71pt	- Decreased hospital LoS - Improved quality of life at 1 year
Niziolek (2022)	Early results after initiation of a rib fixation program: A propensity score matched analysis.	Total: 81pt Early SSRF: 22pt Late SSRF: 23pt Medical management: 36pt	- Decreased ventilation days - Decreased rates of tracheostomy Early SSRF: - Decreased ventilation days - Decreased rates of discharge to LTAC
Xiao (2020)	Surgical fixation of rib fractures decreases intensive care length of stay in flail chest patients.	Total: 1,201pt SSRF: 563pt Medical management: 638pt	- Decreased ICU LoS
Harfouche (2023)	Surgical Stabilization of Rib Fractures in Severe Injury Is Not Associated With Worse Outcomes.	Total: 140pt SSRF: 42pt Medical management: 98pt	- Longer hospital LoS - Longer ICU LoS - Increased ventilation days
Yahn (2022)	Outcomes of Trauma Patients with Flail Chest and Surgical Rib Stabilization.	Total: 43pt SSRF: 27pt Medical Management: 16pt	- Decreased ventilation days - Decreased ICU LOS
Green (2021)	Surgical stabilization of traumatic rib fractures is associated with reduced readmissions and increased survival.	Total: 864,485pt SSRF: 13,701pt Medical management: 850,784pt	Improved survival in patients that underwent thoracotomy for retained hemothorax.
Parra (2022)	The where, when, and why of surgical rib fixation: Utilization patterns, outcomes, and readmissions.	Total: 1,790pt SSRF: 599pt Medical management: 1,191pt	- Decreased 30-day mortality
Shiroff (2023)	Outcomes of surgical versus nonsurgical treatment for multiple rib fractures: A US hospital matched cohort database analysis.	Total: 203,450pt SSRF: 2,870pt Medical Management: 200,580pt	- Higher rates of discharge home - Lower rates of readmission at both 6 and 12 months
Tillman (2022)	Lucky number 13: Association between center-specific chest wall stabilization volumes and patient outcomes.	Total: 3207 pt Total Hospitals: 430	-Decrease in composite outcome for high volume center
Simmonds (2023)	Early surgical stabilization of rib fractures for flail chest is associated with improved patient outcomes: An ACS-TQIP review.	Total: 418pt Early SSRF (<72hr): 209pt Late SSRF(>72hr): 209pt	With Early SSRF: - Decreased ICU LoS - Decreased hospital LoS - Decreased ventilation Days - Ventilation associated pneumonia rates - Decreased DVTs
Wang (2023)	The effectiveness of early surgical stabilization for multiple rib fractures: a multicenter randomized controlled trial.	Total: 403pt Early SSRF (<48hr): 201pt Delayed SSRF (>48hr) 202pt	With Early SSRF: - Decrease ICU LoS - Decrease hospital LoS - Decrease ventilation Days - Decreased hospital cost
Becker (2022)	Impact of Time of Surgery on the Outcome after Surgical Stabilization of Rib Fractures in Severely Injured Patients with Severe Chest Trauma-A Matched-Pairs Analysis of the German Trauma Registry.	Total: 284pt Early SSRF (<48hr): 142pt Late SSRF (>48hr): 142pt	With Early SSRF: - Decrease ICU LOS - Decrease Hospital LOS
Yasa (2023)	Early Surgical Fixation of Traumatic Rib Fractures Affects the In-hospital Outcomes	Total: 89pt Early SSRF (<72hr): 31 pt Late SSRF (>72hr) 58pt	With Early SSRF: - Decrease in hospital LoS - Decrease in chest tube duration
Owattanapanich (2022)	Surgical Rib Fixation in Isolated Flail Chest Improves Survival.	Total: 5293pt SSRF: 575pt Medical Management: 4,718pt	- Decrease in mortality With Early SSRF: - Decrease prolonged ventilation

First Author (Year)	Title	Sample size	Findings
Otaka (2020)	Early Versus Late Rib Fixation in Patients With Traumatic Rib Fractures: A Nationwide Study.	Total: 211pt Early SSRF (<6 days): 113pt Late SSRF (<6 days): 98pt	With Early SSRF: - Decreased ventilation days - Decreased ICU LoS - Decreased hospital LoS
Yeates (2021)	Isolated Thoracic Injury Patients With Rib Fractures Undergoing Rib Fixation Have Improved Mortality.	Total: 60,000pt SSRF: 688pt Medical Management: 59,312pt	- Decrease in mortality
Feyh (2022)	Operative Rib Fixation at a Rural Trauma Center.	Total: 217pt SSRF: 36pt Medical Management: 181pt	- Decrease in mortality
Prins (2022)	Surgical stabilization versus nonoperative treatment for flail and non-flail rib fracture patterns in patients with traumatic brain injury.	Total: 449pt SSRF (Non-flail): 25pt SSRF (Flail): 86pt Medical Management: 338pt	With SSRF in Non-flail: - Decreased rates of pneumonia With SSRF in Flail: - Decreased ICU LOS - Decrease in hospital LOS
Pieracci (2020)	A multicenter, prospective, controlled clinical trial of surgical stabilization of rib fractures in patients with severe, non-flail fracture patterns (Chest Wall Injury Society NONFLAIL).	Total: 110pt SSRF: 51pt Medical Management: 59pt	- Lower 2-week pain score - Pleural space complications Narcotic pain control trended toward less but did not reach significance
Monzou (2021)	Surgical rib fixation as an alternative method of treatment for multiple rib fractures: an audit of results compared with traditional medical management.	Total: 35pt SSRF: 14pt Medical Management: 21pt	- Saw decrease in average pain - Shorter return to work time
Pieracci (2021)	Surgical stabilization of rib fractures in octogenarians and beyond-what are the outcomes?	Total: 360pt SSRF: 113pt Medical Management: 247pt	- Decreased mortality - Decreased narcotics at discharge
Marasco (2022)	Rib fixation in non-ventilator-dependent chest wall injuries: A prospective randomized trial.	Total: 124pt SSRF: 61pt Medical Management: 63pt	- Earlier return to work
Tay-Lasso (2023)	Prospective single-center paradigm shift of surgical stabilization of rib fractures with decreased length of stay and operative time with an intrathoracic approach.	Total: 96 pt Extra thoracic Rib Plating: 59pt Intrathoracic Rib Plating: 37pt	Intrathoracic rib plating: - Had shorter hospital LOS
Zhu (2020)	Rib fixation in geriatric trauma: Mortality benefits for most vulnerable patients	Total: 1,516pt SSRF: 758pt Medical Management: 758 pt	With SSRF: - Decreased in hospital mortality With Early SSRF: - Decreased ICU LOS - Decreased Hospital LOS - Decreased ventilation days - Decreased VAP
Wasfie (2023)	Rib Plating Outcomes in Elderly Trauma Patients with Multiple Rib Fractures: A Community Hospital Experience.	Total: 244pt SSRF: 36pt Medical Management: 208pt	- Increase in Hospital LOS
Christie (2022)	Surgical Stabilization of Rib Fractures Improves Outcomes in the Geriatric Patient Population.	Total: 257pt SSRF: 85pt Medical Management: 172pt	- Decreased mortality - Decreased Readmission - Decreased pleural effusion
Dilday (2022)	Surgical Rib Fixation in Obese Patients with Isolated Flail Chest Improves Outcomes: A Matched Cohort Study.	Total: 1,101pt SSRF: 367pt Medical Management: 734pt	- Decreased ventilation days - Decreased mortality Early SSRF (<72hr): - Decreased ICU LOS - Decreased ventilation days