



National utilization of rib fracture fixation in the geriatric population in the United States

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Purpose: The use of surgical stabilization of rib fractures (SSRF) has steadily increased over the past decade. Recent literature suggests that a larger population may benefit from SSRF, and that the geriatric population—as the highest-risk population—may receive the greatest improvement from these interventions. We sought to determine the overall utilization of SSRF in the United States.

Methods: The National Trauma Database was analyzed between 2016 and 2017. The inclusion criteria were all patients ≥ 65 years old with rib fractures. We further stratified these patients according to age (65–79 vs. ≥ 80 years old), the presence of coding for flail chest, three or more rib fractures, and intervention (surgical vs. nonoperative management). The main outcomes were surgical interventions, mortality, pneumonia, length of stay, intensive care unit length of stay, ventilator use, and tracheostomy.

Results: Overall, 93,638 patients were identified. SSRF was performed in 992 patients.

Patients who underwent SSRF had improved mortality in the 65 to 79 age group, regardless of the number of ribs fractured. We identified 92,637 patients in the age group of 65 to 79 years old who did not undergo SSRF. This represents an additional 20,000 patients annually who may benefit from SSRF.

Conclusions: By conservative standards and the well-established Eastern Association for the Surgery of Trauma clinical practice guidelines, SSRF is underutilized. Our data suggest that SSRF may be very beneficial for the geriatric population, specifically those aged 65 to 79 years with any rib fractures. We hypothesize that roughly 20,000 additional cases will meet the inclusion criteria for SSRF each year. It is therefore imperative that we train acute care surgeons in this skill set.

Keywords: Geriatric trauma; Rib fractures; Surgical stabilization of rib fractures; Rib fixation; Blunt trauma

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INTRODUCTION

Rib fractures are the most common blunt trauma injury, occurring in 10% of all trauma patients, yet outcomes remain poor [1]. The overall mortality of rib fractures is 10%, and mortality increases with each rib fracture [2]. Previously, the gold standard in rib fracture management was pain control [3]. However, there is now an increasing interest in surgical stabilization of rib fractures (SSRF) to improve outcomes [3].

Flail chest injuries, especially those requiring mechanical ventilation, are the most severe fracture pattern and are universally accepted as an indication for SSRF [1,4–6]. Although widely accepted for flail chest injuries, SSRF is actually only utilized for roughly 5.8% of these patients [7]. Even more recently, chest wall surgeons have demonstrated the efficacy of SSRF for patients with nonflail chest [1,3,8]. These patients tend to have lower injury severity, making it difficult to discern whether SSRF is beneficial [1,3,8]. Nonetheless, SSRF has been shown to result in decreased pain scores and improved quality of life. In addition, trends have been seen towards decreased narcotic usage in non-flail fracture patterns [7].

Rib fractures pose a greater threat to the elderly than to other populations. Patients greater than 65 years old have a higher mortality risk of 20% from rib fractures, with a 10% increase in mortality with each additional rib fracture [2,9–11]. In the elderly population, SSRF has been shown to improve outcomes [9,10,12]. However, large data sets have not been analyzed to evaluate whether SSRF is beneficial, specifically in the geriatric and octogenarian age groups.

Historically, SSRF data were challenging to extract from the National Trauma Data Bank (NTDB), as there were no specific procedure codes for SSRF. After 2016, due to changes in the International Classification of Disease, 10th Revision and the Current Procedural Terminology coding for SSRF, the data quality contained within national datasets has dramatically improved. We sought to determine the overall utilization of SSRF in the elderly population and to identify the potential number of surgical candidates. We hypothesized that by utilizing the NTDB, we would identify many more patients eligible for SSRF.

METHODS

This study was approved by Internal Review Board of the St. Francis Medical Center (No. SFH-21-24). This study protocol was approved by the local Ethics Committee and conducted in accordance with the Declaration of Helsinki and Good Clinical

Practices. Informed consent was waived due to the retrospective nature of this study.

The NTDB is a nationwide database maintained by the American College of Surgeons Committee on Trauma. We retrospectively reviewed the NTDB from January 1, 2016 to December 31, 2017. The inclusion criteria were all patients ≥ 65 years old with any rib fractures. There were no exclusion criteria. We further stratified these patients by age (65–79 years old vs. ≥ 80 years old), the presence of flail chest (code S22.5), the presence of three or more rib fractures (code S22.4), and the presence of SSRF (code 21811–21813). Patient demographics included age, sex, and the Injury Severity Score (ISS). The following outcome variables were analyzed: mortality, pneumonia, length of stay (LOS), intensive care unit (ICU) LOS, ventilator use, tracheostomy rates, and the presence of comorbidities (diabetes, dementia, disability, lung disease, and smoking). The discharge destination for survivors was evaluated (home, inpatient rehabilitation [IPR], or skilled nursing facility).

Continuous data are presented as mean \pm standard error or deviation if normally distributed, and as median and interquartile range (25th–75th) if nonnormally distributed. Continuous variables were assessed with the Student t-test when normally distributed and the Wilcoxon signed rank-sum test when data is skewed. The chi-square test was used to assess categorical variables. We defined statistically significant differences as those with a p-value ≤ 0.05 corresponds to a 95% confidence level. Statistical analysis was performed with Stata ver. 16 (StataCorp., College Station, TX, USA).

RESULTS

SSRF compared to nonoperative treatment in 65- to 79-year-old rib fracture patients

In total, 777 of the 57,129 patients aged 65 to 79 years old underwent SSRF (1.4%). The median age was significantly different between patients who underwent SSRF and those who underwent nonoperative treatment (NOP), with younger patients undergoing SSRF (70.8 years old vs. 71.5 years old, $P < 0.001$). There were no significant differences in the comorbidities reviewed between SSRF and NOP patients ($P > 0.05$), except that patients who had SSRF were less likely to have a preexisting disability (3.5% vs. 6.6%, $P = 0.001$) or dementia (1.4% vs. 4.2%, $P < 0.001$) (Table 1).

SSRF patients had significantly higher ISS (18.8 vs. 14.0), were more likely to be admitted to the ICU (86.9% vs. 44.6%), more likely to have three or more rib fractures (54.7% vs. 46.7%)

Table 1. SSRF compared to NOP in 65- to 79-year-old rib fracture patients from 2016 to 2017

Variable	NOP (n=56,352)	SSRF (n=777)	P-value
Age (yr), mean±SD	71.5±4.3	70.8±4.1	<0.001
Injury Severity Score			
Mean±SD	14.0±9.1	18.8±8.5	<0.001
Median (IQR)	12 (9–17)	17 (13–24)	<0.001
ICU	44.6	86.9	<0.001
Mortality	5.7	3.6	0.011
Flail	5.1	51.1	<0.001
3–5	1.8	16.5	<0.001
6	1.8	24.1	<0.001
Bilateral	0.6	2.6	<0.001
LOS (day), median (IQR)	5 (3–9)	13 (9–20)	<0.001
ICU LOS (day), median (IQR)	0 (0–3)	7 (3–13)	<0.001
Ventilator free (day), median (IQR)	5 (3–8)	9 (7–14)	<0.001
Male sex	61.8	72.7	<0.001
Ventilator	15.6	50.8	<0.001
Anticoagulation	13.5	10.6	0.017
Congestive heart failure	5.6	4.1	0.075
Chronic obstructive pulmonary disease	13.4	13.0	0.770
Cerebrovascular accident	3.9	3.1	0.220
Dementia	4.2	1.4	<0.001
Diabetes	25.7	24.7	0.530
Ethanol use	6.2	6.1	0.860
Disabled	6.6	3.5	0.001
Hypertension	57.6	57.1	0.990
Liver disease	1.5	0.6	0.056
Myocardial infarction history	2.0	1.9	0.950
Psychiatric history	10.6	9.8	0.442
Renal disease	2.6	1.4	0.043
Smoker	12.9	14.3	0.025
Pulmonary embolus	0.5	0.9	0.160
Deep vein thrombosis	1.1	5.2	<0.001
Pneumonia	1.0	5.0	<0.001
Unplanned ICU	3.1	8.2	<0.001
Unplanned intubation	2.8	11.7	<0.001
Rib fracture ≥3	54.7	46.5	<0.001
Destination (survivors)			<0.001
Home	41.3	26.8	
Inpatient rehabilitation	7.2	10.1	
Skilled nursing facility	19.2	23.4	
Other	32.5	39.7	
Tracheostomy	2.6	13.8	<0.001

Values are presented as percentile unless otherwise indicated. SSRF, surgical stabilization of rib fractures; NOP, nonoperative; SD, standard deviation; IQR, interquartile range; ICU, intensive care unit; LOS, length of stay.

and were more likely to have a flail segment (51.1% vs. 5.1%, $P < 0.001$). SSRF patients were significantly more likely to experience hospital-associated complications, including deep vein thrombosis (DVT) (5.2% vs. 1.1%), pneumonia (5.0% vs. 1.0%), unplanned ICU days (8.2% vs. 3.1%), and unplanned intubation (11.7% vs. 2.8%, $P < 0.001$).

Compared to NOP patients, SSRF patients had a longer median LOS (13 days vs. 5 days, $P < 0.001$), and they were admitted to the ICU for a mean of 7 days compared to 0 days ($P < 0.001$). SSRF patients were more likely to be placed on a ventilator (50.8% vs. 15.6%, $P < 0.001$). SSRF patients were more likely to undergo a tracheostomy (1.9% vs. 2.6%, $P < 0.05$). However, mortality was lower in SSRF patients (3.6% vs. 5.6%, $P < 0.05$). Furthermore, SSRF patients were significantly more likely than NOP patients to be discharged to an inpatient rehabilitation center (10.1% vs. 7.2%) or a skilled nursing facility (23.4% vs. 19.2%) than home (26.8% vs. 41.3%) ($P < 0.001$).

SSRF compared to nonoperative treatment in ≥80-year-old rib fracture patients

Of the 36,285 rib fracture patients who were ≥80 years of age, 224 underwent SSRF (0.67%). The median age was statistically similar between the patients who underwent SSRF and those who received NOP. The comorbidities were generally similar between both groups; however, patients who underwent SSRF were less likely to have a defined preexisting disability (10.7% vs. 18.26%, $P = 0.001$) or dementia (7.1% vs. 17.0%, $P < 0.001$) (Table 2).

As was seen in the 65- to 79-year-old age group, SSRF patients had significantly higher ISS (16.7 vs. 12.2, $P < 0.001$), were more likely to be admitted to the ICU (86.6% vs. 41.4%) and were more likely to have a flail segment (52.7% vs. 3.6%) ($P < 0.01$). Among the patients with three or more rib fractures, SSRF patients were more likely to suffer hospital-associated morbidities, including DVT (3.1% vs. 0.7%, $P < 0.001$), pneumonia (1.3% vs. 0.4%, $P < 0.05$), unplanned ICU admission (8.9% vs. 3.1%, $P < 0.001$), and unplanned intubation (9.4% vs. 2.0%, $P < 0.001$).

Octogenarian SSRF patients had a longer median hospital LOS (13 days vs. 5 days) and were admitted to the ICU for a median of 7 days compared to no ICU stays for NOP patients ($P < 0.001$). Furthermore, 40.2% of SSRF patients required ventilator support versus 10.2% of NOP patients ($P < 0.001$). Similar to patients aged 65 to 69 years, SSRF patients in the ≥80-year age group were significantly more likely to require tracheostomy (7.1% vs. 1.1%, $P < 0.001$). However, there was no significant difference in

Table 2. SSRF compared to NOP in ≥80-year-old rib fracture patients from 2016 to 2017

Variable	NOP (n=36,285)	SSRF (n=224)	P-value
Age (yr), mean±SD	84.3±2.8	83.8±2.9	0.012
Injure Severity Score			
Mean±SD	12.2±8.2	16.7±9.0	<0.001
Median (IQR)	10 (9–14)	14 (10–21)	<0.001
ICU	41.4	86.6	<0.001
Mortality	7.5	7.1	0.820
Flail	3.6	52.7	<0.001
3–5	1.4	18.8	<0.001
6	1.1	21.4	<0.001
Bilateral	0.34	3.57	<0.001
LOS (day), median (IQR)	5 (3–8)	13 (9–18)	<0.001
ICU LOS (day), median (IQR)	0 (0–3)	7 (3–11)	<0.001
Ventilator free (day), median (IQR)	5 (3–7)	11 (8–15)	<0.001
Male sex	44.5	52.7	<0.001
Ventilator	10.2	40.2	<0.001
Anticoagulation	21.2	19.6	0.560
Congestive heart failure	10.6	6.7	0.058
Chronic obstructive pulmonary disease	12.0	17.0	0.022
Cerebrovascular accident	5.5	4.5	0.500
Dementia	17.0	7.1	<0.001
Diabetes	20.5	21.0	0.860
Ethanol use	1.5	1.8	0.600
Disabled	18.2	10.7	0.004
Hypertension	65.4	67.0	0.620
Liver disease	0.4	0.0	0.320
Myocardial infarction history	2.0	0.5	0.091
Psychiatric history	8.4	8.5	0.960
Renal disease	3.0	1.3	0.160
Smoker	3.3	4.9	0.180
Pulmonary embolus	0.3	0.5	0.650
Deep vein thrombosis	0.7	3.1	<0.001
Pneumonia	0.4	1.3	0.029
Unplanned ICU	3.1	8.9	<0.001
Unplanned intubation	2.0	9.4	<0.001
Rib fracture ≥3	52.1	50.5	0.620
Destination (survivors)			<0.001
Home	23.5	8.8	
Inpatient rehabilitation	6.0	9.3	
Skilled nursing facility	35.3	46.1	
Other	35.2	35.8	
Tracheostomy	1.1	7.1	<0.001

Values are presented as percentile unless otherwise indicated. SSRF, surgical stabilization of rib fractures; NOP, nonoperative; SD, standard deviation; IQR, interquartile range; ICU, intensive care unit; LOS, length of stay.

mortality between the SSRF and NOP groups (7.5% vs. 7.1%, P=0.82).

SSRF compared to nonoperative treatment in 65- to 79-year-old patients with three or more rib fractures and LOS of 3 or more days

In total, 357 of 25,152 65- to 79-year-old patients with three or more rib fractures and LOS of 3 or more days underwent SSRF (1.4%). The median age was significantly different between patients who underwent SSRF and those who underwent NOP, with younger patients undergoing SSRF (70.6 years old vs. 71.5 years old, P<0.001). There were no significant differences in the comorbidities reviewed between SSRF and NOP patients (P>0.05), except that patients who underwent SSRF were less likely to have preexisting dementia (0.6% vs. 4.3%, P=0.001) (Table 3).

In comparison to NOP patients, SSRF patients had significantly higher ISS (17.2 vs. 15.9, P=0.002) and were more likely to be admitted to the ICU (86.3% vs. 55.7%, P<0.001). SSRF patients were significantly more likely to experience hospital-associated complications, including DVT (4.8% vs. 1.5%), pneumonia (3.9% vs. 1.3%), unplanned ICU days (10.6% vs. 3.9%), and unplanned intubation (10.6% vs. 3.9%) (P<0.001).

Furthermore, SSRF patients had a longer median LOS (12 days vs. 6 days, P<0.001). SSRF patients were more likely to be placed on a ventilator (44.0% vs. 17.5%, P<0.001) and to undergo a tracheostomy (12.3% vs. 3.5%, P<0.001). However, there was no statistically significant difference in mortality (8.3% vs. 11.0%, P=0.32).

SSRF compared to nonoperative treatment in ≥80-year-old patients with three or more rib fractures and LOS of 3 or more days

A total of 110 of 16,005 ≥80-year-old patients with three or more rib fractures and LOS of 3 or more days underwent SSRF (0.68%). The median age was not significantly different between patients who underwent SSRF and those who underwent NOP (83.6 years old vs. 84.3 years old, P=0.03). There were no significant differences in the comorbidities reviewed between the SSRF and NOP patients (P>0.05), except that patients who had SSRF were less likely to have preexisting dementia (6.4% vs. 17.9%, P=0.002) (Table 4).

Compared to patients who underwent NOP, SSRF patients had no significant difference in the ISS (15.0 vs. 14.1, P=0.15) but were more likely to be admitted to the ICU (83.6% vs. 51.8%, P<0.001). SSRF patients were significantly more likely to

Table 3. SSRF compared to NOP in 65- to 79-year-old patients with three or more rib fractures and length of stay of 3 or more days from 2016 to 2017

Variable	NOP (n=25,152)	SSRF (n=357)	P-value
Age (yr)	71.5±4.3	70.6±4.1	<0.001
Congestive heart failure	5.9	3.1	0.030
Dementia	4.3	0.6	0.001
Liver disease	1.6	0.3	0.050
Deep vein thrombosis	1.5	4.8	<0.001
Pneumonia	1.3	3.9	<0.001
Unplanned ICU	4.2	8.1	<0.001
Unplanned intubation	3.9	10.6	<0.001
Tracheostomy	3.5	12.3	<0.001
Male sex	61.6	70.9	<0.001
Mortality	11.0	8.3	0.320
Injury Severity Score	15.9±7.7	17.2±7.8	0.002
ICU admission	55.7	86.3	<0.001
Ventilator	17.5	44.0	<0.001
Length of stay (day)	6 (4–10)	12 (9–18)	<0.001

Values are presented as mean±standard deviation, percentile, or median (interquartile range).

SSRF, surgical stabilization of rib fractures; NOP, nonoperative; ICU, intensive care unit.

Table 4. SSRF compared to NOP in ≥80-year-old patients with three or more rib fractures and length of stay of 3 or more days from 2016 to 2017

Variable	NOP (n=16,005)	SSRF (n=110)	P-value
Age (yr)	84.3±2.8	83.6±2.8	0.030
Dementia	17.9	6.4	0.002
Deep vein thrombosis	1.0	2.7	0.060
Pneumonia	0.6	1.8	0.080
Unplanned ICU	4.0	9.1	0.010
Unplanned intubation	2.6	9.1	<0.001
Tracheostomy	1.5	3.6	0.060
Male sex	44.1	50.9	0.150
Mortality	17.2	16.0	0.820
Injury Severity Score	14.1±6.7	15.0±6.6	0.150
ICU admission	51.8	83.6	<0.001
Ventilator	10.4	36.4	<0.001
Length of stay (day)	6 (4–9)	13 (9–17)	<0.001

Values are presented as mean±standard deviation, percentile, or median (interquartile range).

SSRF, surgical stabilization of rib fractures; NOP, nonoperative; ICU, intensive care unit.

experience hospital-associated complications, including unplanned ICU days (9.1% vs. 4.0%, $P=0.01$) and unplanned intubation (9.1% vs. 2.6%, $P<0.001$). They were significantly more likely to experience DVT (2.7% vs. 1.0%, $P=0.06$) and nonsig-

nificantly more likely to have pneumonia (1.8% vs. 0.6%, $P=0.08$).

SSRF patients had a longer median LOS (13 days vs. 6 days, $P<0.001$) and were more likely to be placed on a ventilator (36.4% vs. 10.4%, $P<0.001$). SSRF patients were not more likely to undergo tracheostomy (16.0% vs. 17.2%, $P=0.06$). There was no significant difference in mortality (16.0% vs. 17.2%, $P=0.82$).

SSRF compared to nonoperative treatment in ≥65-year-old patients with three or more rib fractures, LOS of 3 or more days, and flail chest

Sixty-six of 413 ≥65-year-old patients with three or more rib fractures, LOS of 3 or more days, and flail chest underwent SSRF (15.9%). The median age was not significantly different according to whether patients underwent SSRF or NOP (72.9 years old vs. 74.3 years old, $P=0.15$). Diabetes was more prevalent in the SSRF patients (33.3% vs. 22.3%, $P=0.05$) (Table 5).

Compared to patients who underwent NOP, SSRF patients had no significant difference in the ISS (22.6 vs. 22.0, $P=0.64$) but were more likely to be admitted to the ICU (97.0% vs. 84.0%, $P=0.002$). SSRF patients were not significantly more likely to experience hospital-associated complications, including unplanned ICU days (7.6% vs. 6.8%, $P=0.01$), unplanned intubation (10.6% vs. 8.5%, $P>0.05$), DVT (4.6% vs. 3.2%, $P=0.56$), and pneumonia (7.6% vs. 5.1%, $P=0.41$).

SSRF patients had a longer median LOS (15 days vs. 10 days, $P<0.01$). SSRF patients were more likely to be placed on a ventilator (66.7% vs. 46.3%, $P=0.002$) and were more likely to undergo tracheostomy (21.2% vs. 10.4%, $P=0.012$). There was a significant difference in mortality (5.9% vs. 31.1%, $P=0.002$).

DISCUSSION

SSRF, which is principally used in patients with flail chest, appears to be underutilized [13]. The recent Eastern Association for the Surgery of Trauma guidelines make a conditional recommendation for its use in flail chest and do not address the use of SSRF in nonflail patients, based on the available evidence at the time these recommendations were issued [6]. New literature, specifically the results from Pieracci et al. [7], suggest that a multitude of patients could potentially benefit from SSRF.

We identified over 93,638 patients older than 65 years of age who presented to a trauma center with rib fractures in 2016 to 2017. SSRF was performed at an overall rate of only 1.1%. Approximately 50% of the patients who underwent SSRF had flail

Table 5. SSRF compared to NOP in ≥65-year-old patients with three or more rib fractures, length of stay of 3 or more days, and flail chest from 2016 to 2017

Variable	NOP (n=413)	SSRF (n=66)	P-value
Age (yr)	74.3±7.0	72.9±6.1	0.150
Diabetes	22.3	33.3	0.050
Deep vein thrombosis	3.2	4.6	0.560
Pneumonia	5.1	7.6	0.410
Unplanned ICU	6.8	7.6	0.810
Unplanned intubation	8.5	10.6	0.570
Tracheostomy	10.4	21.2	0.012
Male sex	62.7	69.7	0.270
Mortality	31.1	5.9	0.002
Injury Severity Score	22.0±10.4	22.6±7.7	0.640
ICU admission	84.0	97.0	0.005
Ventilator	46.3	66.7	0.002
Length of stay (day)	10 (7–18)	15 (10–22)	<0.010

Values are presented as mean±standard deviation, percentile, or median (interquartile range).

SSRF, surgical stabilization of rib fractures; NOP, nonoperative; ICU, intensive care unit.

chest (a widely accepted indication). Although mortality was lower in patients who underwent SSRF, all other metrics do not appear to suggest improved outcomes.

Patients who underwent SSRF in the 65- to 79-year-old age range had no significant differences in any preoperative comorbidities; however, they appeared to have a higher preinjury functional status, as they had fewer disability and dementia diagnoses. The SSRF cohorts for both age categories clearly had higher ISS, a higher likelihood of flail segments, more admissions to the ICU, longer median hospital LOS, and a higher likelihood of requiring ventilator assistance. Additionally, more of these patients progressed to tracheostomy. As would be expected due to longer hospital stays, patients in both age groups who underwent SSRF had a higher rate of hospital complications including DVT and pneumonia.

More importantly, the discharge destination for both age cohorts in patients who underwent SSRF was IPR. The lower rate of home discharges in SSRF patients was most likely due to the higher rate of IPR admissions.

Although the SSRF patients demonstrated higher morbidity and complication rates, it should be kept in mind that these patients were not truly a matched cohort to the NOP patients. More specifically, patients undergoing SSRF had significant chest wall injuries and were more severely injured, with mean and median ISS greater than 16. These patients most likely had longer hospital stays due to both the SSRF procedure and overall injury sever-

ity along with more in-hospital complications even in the presence of lower in-hospital mortality. The presence of higher ISS scores in this patient population clearly means that other organ systems were damaged, which in itself can lead to longer hospital and ICU stays, a longer period of ventilator use, and a higher risk of complications. Therefore, these variables seem to be related to a higher degree of patient complexity, rather than whether patients underwent SSRF. As seen in prior studies, there was a mortality benefit of SSRF, even though these patients had higher ISS scores, longer hospital LOS, and longer ICU LOS [8,9]. These data suggest that in patients selected for SSRF, the operation was performed as a last-ditch salvage effort. While survival improved, the overall outcomes were not of profound benefit, perhaps reflecting selection bias. Our data suggest that these geriatric patients are clearly severely injured.

However, in our subgroup analysis of patients with three or more rib fractures and flail chest, there were few significant differences in these parameters. Only ICU admission, need for ventilator support, and LOS remained significantly different between NOP and SSRF patients. Importantly, however, mortality was much more favorable in SSRF patients, despite their higher ISS scores, meaning they were more complex trauma patients. Nonetheless, they showed better mortality outcomes, even though there were more complications and longer hospital stays when SSRF was performed.

Upon further review of the NTDB from 2016 to 2017, we identified 36,065 patients in the 65- to 79-year-old age range, with rib fractures, who did not undergo SSRF. These patients had both flail chest (5,240 patients) and three or more rib fractures (30,824 patients). Additionally, our data showed that SSRF was only performed at a rate of 1.4% in patients with three or more rib fractures and a rate of 15.9% in patients with three or more rib fractures and flail chest, although both are widely accepted indications for SSRF. These data suggest that SSRF is underutilized, and that performing SSRF in better surgical candidates might lead to improved outcomes. Multiple studies have demonstrated benefits from a larger range of indications, and further demonstrated that age should not be a deterrent in patient selection. In fact, there is mounting evidence that patients with more comorbid conditions and less physiologic reserve stand to benefit most from surgical intervention [8,10,14]. As well, Pieracci et al. [7] demonstrated the benefit of SSRF in nonflail chest patients. They found that SSRF was beneficial for patients with lower ISS and even in patients with isolated rib fractures [7].

Large retrospective datasets have significant limitations. We in-

cluded all patients with three or more rib fractures, regardless of whether these rib fractures were displaced. We did this because it is difficult to tease out whether ribs were displaced using this large dataset. More precise data can be collected in the future if a prospective study is performed. Additionally, geriatric polytrauma patients with complex injury patterns, comorbid conditions, and frailty are challenging to analyze. We did not exclude traumatic brain injury patients nor early deaths (less than 24 hours), although early deaths were excluded from our subdata analysis. These factors could have drastically altered the mortality numbers, which warrants future study. More large multicenter prospective trials on SSRF in this patient population are needed.

In conclusion, we believe that SSRF should be considered in elderly polytrauma patients. Although this population has comorbid conditions and frailty, which make them poorer operative candidates and put them at high risk for mortality, these are specifically the patients who benefit most from SSRF. Although this analysis did not demonstrate mortality benefits in the over 80-year-old population, there is still a large cohort of individuals 65 to 79 years who had a mortality benefit from SSRF. More surgeons need to be trained in this procedure and more centers need to be developed with the resources to perform these operations. The wider application of SSRF deserves further study in a prospective multicenter study.

NOTES

Ethical statements

This study was approved by Internal Review Board of the St. Francis Medical Center (No. SFH-21-24). This study protocol was approved by the local Ethics Committee and conducted in accordance with the Declaration of Helsinki and Good Clinical Practices. Informed consent was waived due to the retrospective nature of this study.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Author contributions

Conceptualization: VJ, MM, EJ, ARD; Data curation: EJ, ARD; Formal analysis: EJ; Methodology: EJ, ARD; Project administration: JMB, VJ, MM, ARD; Visualization: JMB, LA, VJ, ARD;

Writing—original draft: JMB, LA, KS; Writing—review & editing: JMB, LA, VJ, MM, ARD.

All authors read and approved the final manuscript.

Additional information

The data of this study was presented at the 2021 Chest Wall Injury Submit in Denver, CO, USA.

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