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Outcomes of surgical versus nonsurgical treatment for multiple rib fractures: A US hospital matched cohort database analysis

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BACKGROUND: Treatment for multiple rib fractures includes surgical stabilization of rib fractures (SSRF) or nonoperative management (NOM). Meta-analyses have demonstrated that SSRF results in faster recovery and lower long-term complication rates versus NOM. Our study evaluated postoperative outcomes for multiple rib fracture patients following SSRF versus NOM in a real-world, all-comer study design.

METHODS: Multiple rib fracture patients with inpatient admissions in the PREMIER hospital database from October 1, 2015, to September 30, 2020, were identified. Outcomes included discharge disposition, and 3- and 12-month lung-related readmissions. Demographics, comorbidities, concurrent injuries at index, Abbreviated Injury Scale and Injury Severity Scores, and provider characteristics were determined for all patients. Patients were excluded from the cohort if they had a thorax Abbreviated Injury Scale score of <2 (low severity patient) or a Glasgow Coma Scale score of ≤8 (extreme high severity patient). Stratum matching between SSRF and NOM patients was performed using fine stratification and weighting so that all patient data were kept in the final analysis. Outcomes were analyzed using generalized linear models with quasinormal distribution and logit links.

RESULTS: A total of 203,450 patients were included, of which 200,580 were treated with NOM and 2,870 with SSRF. Compared to NOM, patients with SSRF had higher rates of home discharge (62% SSRF vs. 58% NOM) and lower rates of lung-related readmissions (3 months, 3.1% SSRF vs. 4.0% NOM; 12 months, 6.2% SSRF vs. 7.6% NOM). The odds ratio (OR) for home or home health discharge in patients with SSRF versus NOM was 1.166 (95% confidence interval [CI], 1.073–1.266; $p = 0.0002$). Similarly, ORs for lung-related readmission at 3- and 12-month were statistically lower in the patients treated with SSRF versus NOM (OR [3 months], 0.764 [95% CI, 0.606–0.963]; $p = 0.0227$ and OR [12 months], 0.799 [95% CI, 0.657–0.971]; $p = 0.0245$).

CONCLUSION: Surgical stabilization of rib fractures results in greater odds of home discharge and lower rates of lung-related readmissions compared with NOM at 12 months of follow-up. (*J Trauma Acute Care Surg.* 2023;94: 538–545. Copyright © 2022 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Therapeutic/Care Management; Level III.

KEY WORDS: Rib fractures; fracture fixation; patient discharge; patient readmission; follow-up studies.

Thoracic injuries with severe rib fractures are one of the leading causes of injury-related deaths, following trauma with a head injury.[1] Usually, multiple displaced rib fractures cause damage to surrounding tissues and generate severe pain that affects inspiration or cough; respiratory functions are therefore impaired, leading to increased risk for further pulmonary or respiratory conditions such as infections, distress, or failure.[2] All of these acute complications further contribute to chronic conditions, such as prolonged pain, loss of productivity and disability.[3] The cutting ends of the fractured ribs may also perforate the lung, producing air, blood or air and blood presence between the chest wall and the lung (hemothorax, pneumothorax, or hemopneumothorax), which is a life-threatening condition.[4]

The mortality rate following traumatic rib fractures varies widely from 5% to 35% and is strongly associated with the number of broken ribs.[5–7] Patients with up to five fractured ribs experience between 5.8% and 10% mortality, whereas patients with eight or more fractured ribs may have a mortality risk of nearly 35%. The higher mortality rates in patients with multiple rib fracture may be, in part, explained by concurrent thorax and nonthoracic organ system injuries but also increased risk of pulmonary diseases such as pneumonia and acute respiratory distress syndrome.[1] Older age, multiple injury, preexisting diseases, and pneumonia, along with

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flail chest, are predictive of mortality in patients suffering from multiple rib fractures.[6,8]

Patients with rib fracture injuries can be treated with nonoperative management (NOM) or surgical stabilization of rib fractures (SSRF). Pain management is the main component of NOM.[9] Patients with severe rib fracture and flail chest injuries can be treated with SSRF, which has been shown to be very effective for relieving pain and is associated with favorable postoperative outcomes. Patients treated with SSRF have been shown to present with lower incidence of posttreatment complications, such as pneumonia, chest wall deformity, respiratory failure, and mortality.[10–12] In addition, SSRF has also been associated with reduced length of intensive care unit stay, length of hospital stay, and duration of mechanical ventilation.[13]

Despite favorable outcomes, SSRF is still used infrequently and, when used, usually on the most severely injured patients, such as patients with multiple rib fractures and flail chest.[14,15] The overall effectiveness of SSRF in patients with multiple rib fractures, with or without flail chest, is not well documented. In addition, the main available evidence evaluating the efficacy of SSRF versus NOM comes from meta-analyses of clinical studies, most of which have relatively small sample sizes.[7,11–13] This is due to the inherent complexity of running controlled clinical trials in trauma research, where none of the typical research variables such as patient characteristics and timing of interventions can be scheduled ahead of time. Long et al.[13] published a meta-analysis comparing rib fixation versus conservative care in randomized controlled trial; none of the included studies had more than 75 surgically treated patients.

Our study was therefore designed to evaluate the postsurgical outcomes of patients with multiple rib fractures with SSRF versus NOM in a nationwide database that includes 20% of all inpatient admission and is representative of the entire US population, thus creating a large population for analysis.

PATIENTS AND METHODS

Our retrospective cohort study was conducted in the PREMIER Healthcare Database (PHD). The PHD data are deidentified per 45 Code of Federal Regulations (CFR) 164.506(d)(2)(ii)(B) through the "Expert Determination" method. The research shown here is exempt from institutional review board oversight as dictated by Title 45 CFR, Part 46 of the United States, specifically 45 CFR 46.101(b)(4). The research conducted in this study was predefined in a study protocol, which was approved by all coauthors before the conduct of the analysis.

Database

The PHD contains complete clinical coding, including diagnoses, procedures, and hospital-prescribed medication from more than 20% of all hospital admissions throughout the United States (>1,000 hospitals and hospital systems). Although the database excludes federally funded hospitals (e.g., Veterans Affairs), the hospitals included are nationally representative based on bed size, high-level estimate of geographic region, location (urban/rural), and teaching hospital status. The database contains a date-stamped log of all billed items by cost-accounting departments including medication; laboratory, diagnostic, and therapeutic services; and primary and secondary diagnoses for each patient's hospitalization. Identifier-linked enrollment files provide demographic and payor information. Detailed service level information for each hospital day is recorded; this includes details on medication and devices received.

Cohort

All inpatient encounters with an *International Classification of Diseases, Tenth Revision* (*ICD-10*), diagnosis code indicative of an initial encounter for multiple rib fracture from October 1, 2015, to September 30, 2020, were identified (*ICD-10* diagnosis codes—S22.41: multiple fractures of the ribs, right side; S22.42: multiple fractures of the ribs, left side; S22.43: multiple fractures of the ribs, bilateral; and S22.49: multiple fractures of the ribs, unspecified site, seventh digit for any of the codes: A, initial encounter for closed fracture, or B, initial encounter for open fracture). These initial inpatient admissions were flagged as "index." All patients 18 years or older were included. Exclusion criteria included thorax AIS scores less than 2 or a length of hospital stay less than 2 days (indicative of lower-severity injury). The low-severity injury patients were excluded because they would most likely not qualify for SSRF. Glasgow Coma Scale (GCS) scores were calculated manually from the *ICD-10* codes for "Coma scale, eyes open" (R40.21), "Coma scale, best verbal response" (R40.22), and "Coma scale, best motor response" (R40.23). The "GCS, total score" codes, when provided, were also analyzed (R40.24). When the calculated GCS and the provided "GCS, total score" codes did not concur, the lowest value was used to identify patients with a GCS score of ≤8, as these were excluded because of the extreme severity of their trauma, which might overrule any benefits from any individual surgery. All other index diagnoses of injury and conditions were based on corresponding *ICD-10* codes; for example, flail chest was defined as the presence of *ICD-10* code S22.5.

Outcomes

Our study focused on postsurgical outcomes. Our primary endpoints included discharge disposition. Our secondary endpoints included 3-month and 12-month readmissions with lung-related diagnoses. The following six distinct categories of diagnoses were created: (1) Pneumothorax or Hemothorax (*ICD-10* codes starting with S27.0, S27.1, S72.2, J93, J94.2, and J94.8), (2) Injury or Disease of the Bronchus (*ICD-10* codes starting with J4 and S27.4), (3) Acute Respiratory Distress or Failure (*ICD-10* codes starting with J80 and J96), (4) Lung Diseases and Conditions (*ICD-10* codes J82 and J84–86), (5) Injuries or Disease of the Pleura (*ICD-10* codes starting with J90, J91, J92, J94.0, J94.1, J94.9, and S27.6), and (6) Other Lung Complications, including postprocedural complications (*ICD-10* codes starting with J95, J98, J99, S27.8, and S27.9). For the secondary endpoints, these six diagnosis categories were aggregated, and readmission for any one of these diagnoses was analyzed at 3- and 12-month follow-up. Exploratory endpoints included analyses of inpatient readmissions with each separate diagnosis category.

Variables

Patient variables included chronic comorbidities at the time of index admission, specifically all 31 comorbidities from the Elixhauser index (EI) and 18 comorbidities from the Functional Comorbidity Index. The EI was selected for our analysis and is used here instead of the Charlson Comorbidity Index, as it

includes more chronic conditions (31 vs. 17 in the Charlson Comorbidity Index) and has been shown in prior trauma and general hospital studies to be a stronger predictor for morbidity and mortality, compared with the Charlson Comorbidity Index.[16,17] The complete list of chronic diseases evaluated in this study is shown in Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/C781. For each patient, the Abbreviated Injury Scale (AIS) for all six body regions was calculated, along with the Injury Severity Score (ISS) and the New Injury Severity Score (NISS). Both ISS and NISS were shown to be good predictors of mortality.[18] Concurrent injuries were categorized as follows: injuries were categorized based on the first three digits of *ICD-10* diagnostic codes, resulting in more than 100 distinct injury categories. A complete list of injury categories is shown in Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/C781.

Statistical Analyses

All study variables were analyzed descriptively. Counts and proportions (categorical variables) and means and standard deviations (SDs) (continuous variables) were provided. Patient variables were used to characterize the cohorts and to generate propensity scores (PSs), for fine stratification and weighting (FSW). The PS was defined as the probability of being in the SSRF group (vs. the NOM group) and was calculated using multivariable logistic regression models that included the following covariates indicative of the severity of injury: age, sex, AIS scores for thorax, head and neck, abdominal and extremities, ISS, EI, hemothorax or pneumothorax at time of admission, treatments performed on admission and indicative of severity (drainage, tracheotomy, mechanical ventilation, ICU admission), patient payer, and hospital bed size. These last two variables were included because they could impact health care utilization and discharge status. The PS was used to create 200 strata, based on the distribution of the PSs in the exposed patients (average treatment effect on the treated). Weights were assigned to all NOM patients based on the proportion of treated patients in each stratum. Balance before and after stratification and weighting was analyzed using standardized differences. For the calculations of the primary endpoint, the probability of home discharge was calculated using a quasibinomial generalized linear model with a logit link. Robust standard error estimators were computed to account for the weights. For the 3-month and 12-month long readmission analyses, only patients from hospitals that have provided data continuously for at least 3- or 12-month postindex were included in the analyses. The readmission rates were calculated using a quasibinomial generalized linear model with logit link, with robust standard errors. Results are presented as risk ratios (for home discharge, for 3-month or 12-month readmission) with 95% confidence intervals (CIs).

RESULTS

Fine Stratification and Weighting

Fine stratification and weighting was performed as described previously, as a statistical method to obtain balanced cohorts, while keeping all the patient information in the SSRF and NOM groups. Covariates used for FSW included patient and provider variables, to account for variability due to hospital size. The balance of covariates across stratum before and after FSW is shown in Figure 1. The FSW method successfully balanced all covariates, as shown by the blue dots, with no covariate having a mean difference of >0.1 (indicated in the figure with the dotted line). The use of the 0.1 threshold to demonstrate effective matching was shown in prior research.[19]

Patient Demographics and Injury Severity

As shown in Table 1, 203,450 patients were analyzed, of which 2,870 were treated with SSRF and 200,580 with NOM. Table 1 presents key patient demographic and injury scores in the SSRF cohort, the NOM cohort before FSW, and the NOM cohort after FSW. Before FSW, there were key differences between the SSRF and the NOM cohorts: patients in the SSRF cohort were younger than patients in the NOM cohort (SSRF: mean age, 57.1 years [SD, 16.1 years]; NOM: mean age, 62.2 years [SD, 19.6 years]), had a larger proportion of male patients (SSRF, 72.4% vs. NOM, 60.7%), had a greater proportion of high AIS thorax score patients, and a higher proportion of profoundly severely injured patients (ISS score >25: 8.6% SSRF, 4.6% NOM). As expected, the SSRF cohort, therefore, had significantly higher severity of disease (extreme severity, 40.6% SSRF vs. 18.2% NOM) and risk of mortality (extreme risk, 24.8% SSRF vs. 13.7% NOM). The FSW method was applied to allow for an accurate match, without losing any patient information. The matched NOM cohort therefore also included all 200,580 patients, albeit individual weights given to each patient as a result of the FSW changed the overall patient demographics and clinical presentation. After FSW, the NOM cohort had similar age to the SSRF cohort, a similar proportion of male patients, and similar injury, illness, and mortality scores.

Lung and Other Organ Injuries at Time of Index

Table 2 shows the proportion of patients in each cohort, with lung complications and other organ injuries, at the time of index. In the SSRF cohort, nearly 30% of patients had pneumothorax, 63% had hemothorax or hemopneumothorax, 37% had lung contusion, and 13% had flail chest. These proportions were far lower in the NOM group, before FSW. After FSW, rates of lung-related injuries and complications were very similar between the SSRF and NOM groups. Key concurrent injuries are also shown in Table 2, with fracture of the shoulder or upper arm being the most prevalent concurrent injury in these cohorts.

Chronic Comorbidities at Time of Index

Chronic comorbidities at the time of index are shown in Table 3. Before FSW, patients in the NOM group had higher EI (SSRF, 2.4 [SD, 1.9] vs. NOM, 2.8 [SD, 2.2]). This is expected based on the fact that, prematching, the NOM group was older than the SSRF group, and many comorbidities (hypertension, cardiac arrhythmia) are associated with increased age. After FSW, a greater balance was achieved between the SSRF and NOM groups.

Provider Types at Time of Index

To ensure comparability in care, the provider size was included in the PS calculation. After FSW, 93.5% of the SSRF and 90.9% of the NOM cohort were treated in an urban hospital (vs. rural), 70.8% of the NOM and 71.2% of the SSRF cohort in teaching hospitals, 0.5% patients in both cohorts in hospitals with less than 100 beds, 3.6% of the SSRF versus 3.7% of the NOM cohort in hospitals with 100 to 199 beds, 9.2% of the SSRF

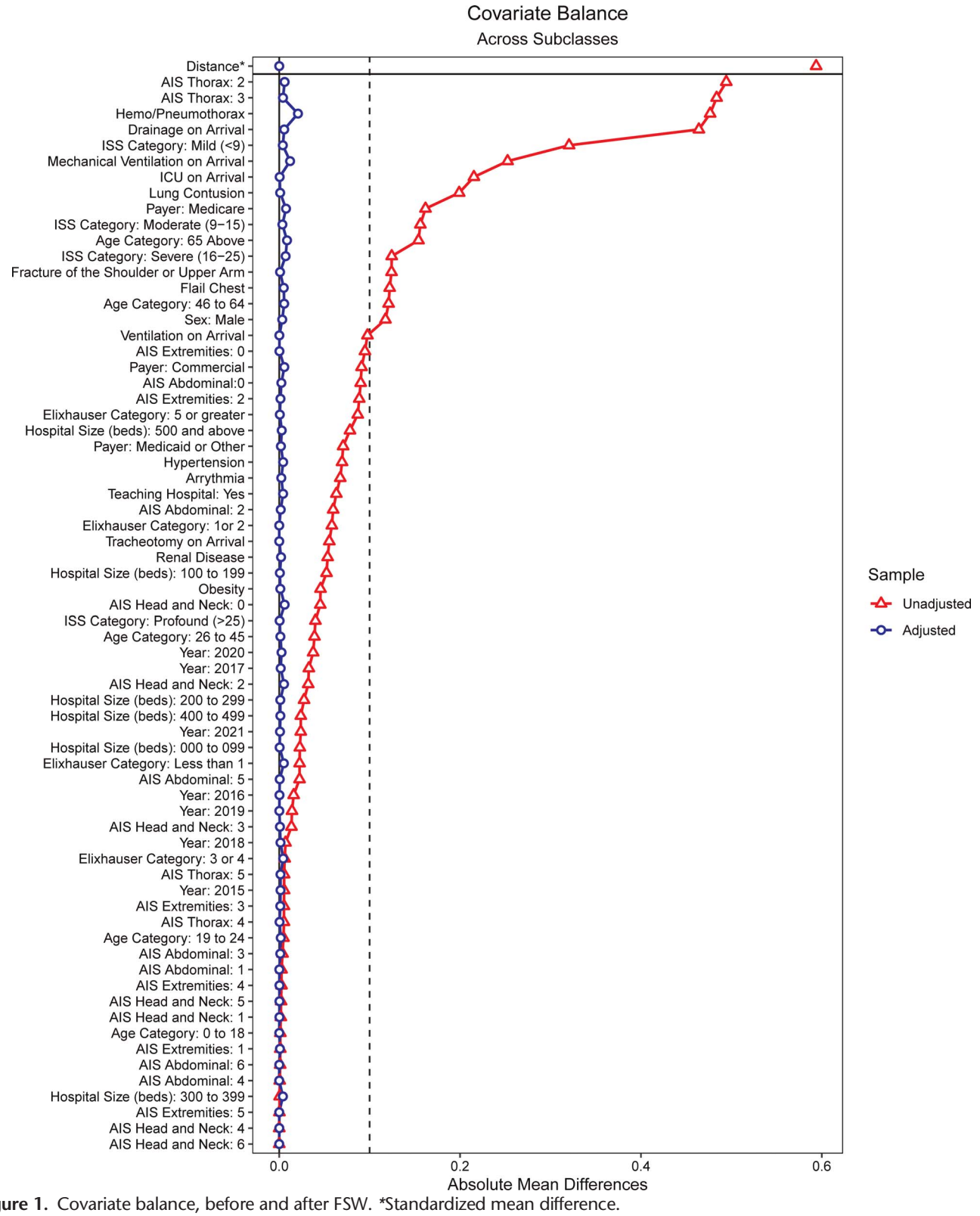

Figure 1. Covariate balance, before and after FSW. *Standardized mean difference.

TABLE 1. Patient Demographics, ISSs, Severity of Illness, and Risk of Mortality, in Patients Treated With SSRF or NOM, Before and After FSW

	SSRF		NOM Before FSW		NOM After FSW	
Patient Clinical Presentation at Index	**n**	**%**	**n**	**%**	**n**	**%**
All	2,870		200,580		200,580	
Average age, mean (SD)	57.2 (16.0)		62.9 (18.9)		57.6 (17.2)	
Age category						
18–64 y	1,868	65.1	99,657	49.7	132,284	66.0
Above 64 y	1,002	34.9	100,923	50.3	68,296	34.0
Sex: male	2,079	72.4	121,729	60.7	145,974	72.8
AIS thorax score						
Score = 2	830	28.9	157,165	78.4	56,804	28.3
Score = 3	1,979	69.0	41,292	20.6	139,150	69.4
Score = 4	26	0.9	763	0.4	1,895	0.9
Score = 5	35	1.2	1,360	0.7	2,731	1.4
ISS Category						
<9: Mild	526	18.3	101,053	50.4	35,958	17.9
9–15: Moderate	1,390	48.4	65,840	32.8	96,432	48.1
16–25: Severe	708	24.7	24,527	12.2	50,903	25.4
>25: Profound	246	8.6	9,160	4.6	17,287	8.6
ISS, mean (SD)	14.1 (8.7)		10.1 (7.5)		14.0 (8.7)	
Severity of illness*						
Unspecified			55	0.0	33	0.0
1: Minor	58	2.0	30,766	15.3	12,498	6.2
2: Moderate	598	20.8	47,490	23.7	36,766	18.3
3: Major	1,049	36.6	85,764	42.8	72,519	36.2
4: Extreme	1,165	40.6	36,505	18.2	78,765	39.3
Risk of mortality**						
Unspecified		0.0	55	0.0	33	0.0
1: Minor	618	21.5	63,295	31.6	45,442	22.7
2: Moderate	696	24.3	61,492	30.7	44,167	22.0
3: Major	844	29.4	48,336	24.1	56,674	28.3
4: Extreme	712	24.8	27,402	13.7	54,264	27.1

*Defined as the extent of physiologic decompensation or organ system loss of function.
**Defined as the likelihood of dying.

versus 9.0% of the NOM cohort in hospitals with 200 to 299 beds, 14.8% SSRF versus 15.2% NOM cohort in hospitals with 300 to 399 beds, 16.3% SSRF versus 16.2% NOM cohort in hospitals with 400 to 499 beds, and the majority (55.6% SSRF vs. 55.4% NOM) in hospitals with 500 and more beds.

Outcomes Analysis

All outcomes were analyzed using the FSW cohorts, as the nonmatched cohorts were not comparable from a patient demographic, disease presentation, and severity of injury standpoint, as shown in Table 1. The rate of home or home health versus skilled nursing facility discharge, as well as the rates for 3-month and 12-month lung-related readmissions, is shown in Table 4. Patients treated with SSRF had higher rates of home discharge (62% SSRF vs. 58% NOM) and lower rates of lung-related readmissions (3 months, 3.1% SSRF vs. 4.0% NOM; 12 months, 6.2% SSRF vs. 7.6% NOM), across the aggregate and the individual diagnosis categories. As shown in Table 5, the odds ratio (OR) of being discharged home in patients with SSRF versus NOM was 1.166 (95% CI, 1.073–1.267; $p = 0.0002$). Similarly, ORs for lung-related readmission at 3-month or 12-month were statistically lower in the patients treated with SSRF versus NOM (OR [3 months], 0.764 (95% CI, 0.606–0.963), $p = 0.0227$; OR [12 months], 0.799 (95% CI, 0.657–0.971), $p = 0.0245$).

DISCUSSION

This study represents a large real-world analysis of patients admitted with multiple rib fractures and evaluates their discharge and postdischarge outcomes based on SSRF or NOM at time of index admission. Our analysis identified 203,450 patients, of which 2,870 received SSRF treatment and 200,580 patients were treated nonoperatively. The SSRF cohort presented with higher severity of injury and mortality, compared with the NOM group. A fine stratification and matching method was applied to address significant imbalances while keeping all available data, and after FSW, patients with SSRF were shown to have significant higher odds of home discharge and lower odds of 3-month and 12-month lung-related readmissions, compared with patients treated with NOM.

TABLE 2. Lung and Other Organ Injuries Observed in Patients With Multiple Rib Fractures Treated With SSRF or NOM, Before and After FSW

	SSRF		NOM Before FSW		NOM After FSW	
Injuries at Index	**n**	**%**	**n**	**%**	**n**	**%**
Lung trauma						
Pneumothorax	848	29.5	43,652	21.8	69,382	34.6
Hemo- or hemopneumothorax	1,804	62.9	31,334	15.6	114,677	57.2
Lung contusion	1,069	37.2	34,690	17.3	74,811	37.3
Pleural effusion	638	22.2	20,847	10.4	39,015	19.5
Traumatic emphysema	536	18.7	9,794	4.9	30,541	15.2
Flail chest	362	12.6	797	0.4	24,289	12.1
Lung laceration	174	6.1	1,612	0.8	6,392	3.2
Most prevalent concurrent injuries						
Fracture of the shoulder or upper arm	848	29.5	34,352	17.1	59,456	29.6
Fracture of the lumbar spine	623	21.7	37,204	18.5	46,326	23.1
Intracranial injury	535	18.6	36,611	18.3	40,536	20.2
Coma*	495	17.2	28,350	14.1	38,557	19.2
Open head wound	383	13.3	24,942	12.4	29,300	14.6
Fracture of the skull and facial bones	270	9.4	18,109	9.0	22,601	11.3
Fracture of the lower leg, including ankle	257	9.0	15,437	7.7	18,621	9.3
Fracture of the cervical vertebra or other neck region	216	7.5	13,045	6.5	18,017	9.0
Fracture of the forearm	161	5.6	11,200	5.6	13,319	6.6
Injury of pelvic organs	153	5.3	6,993	3.5	12,677	6.3

*Patients with GCS score of ≤8 were excluded. The remaining patients had a GCS score of >8.

Before matching, the SSRF cohort had higher rates of concurrent severe injuries and a higher ISS than patients treated with NOM, suggesting that, in real-world settings, SSRF is mostly provided to the more severe patients. Flail chest affected 12.6% of the SSRF cohort and only 0.4% of the NOM cohort. This difference was most likely due to the fact that surgeons may preferentially perform SSRF on patients with flail chest compared with patients without, as recommended in recent clinical guidelines.[20,21] It is important to note, however, that, of all patients with flail chest (n = 1,159 in our data set), only about a third had SSRF (362 of 1,159 patients) and more than two thirds did not (797 of 1,159 patients). Therefore, while SSRF is more common in flail chest cases, it has not been widely adopted. Our outcomes (home discharge and 3- to 12-month lung-related complications) were ultimately analyzed on two cohorts of patients comprising each approximately 12% to 13% flail chest patients, and in this cohort of mostly nonflail patients, differences were still in favor of SSRF versus NOM.

Our findings are consistent with the literature. A recent large study of 864,485 patients from the National Readmission Database reported that patients with SSRF were younger (compared with patients with nonoperative care), had higher rate of severe injuries, and were more likely to be discharged to home. Their OR for readmission was also lower than that of patients treated nonoperatively

TABLE 3. Chronic Comorbidities at Time of Index, in the SSRF and NOM Cohorts, Before and After FSW

	SSRF		NOM Before FSW		NOM After FSW	
Key Comorbidities	**n**	**%**	**n**	**%**	**n**	**%**
EI, mean (SD)	2.4 (1.9)		2.8 (2.2)		2.4 (1.9)	
Hypertension	1,454	50.7	112,286	56.0	94,416	47.1
Fluid and electrolyte disorders	660	23.0	50,485	25.2	50,771	25.3
Diabetes	510	17.8	42,679	21.3	33,729	16.8
Chronic pulmonary disorders	500	17.4	40,598	20.2	32,361	16.1
Alcohol use disorder	430	15.0	27,909	13.9	29,680	14.8
Obesity	418	14.6	20,050	10.0	28,964	14.4
Cardiac arrhythmia	406	14.1	41,913	20.9	27,906	13.9
Depression	367	12.8	27,480	13.7	21,583	10.8
Drug use disorder	276	9.6	16,561	8.3	20,566	10.3
Hypothyroidism	271	9.4	24,953	12.4	15,764	7.9

TABLE 4. Outcomes Following SSRF and NOM, in FSW Matched Cohorts

	SSRF		NOM	
Outcomes	**n**	**%**	**n**	**%**
Discharge disposition				
Home or home health	1,775	61.8	116,642	58.2
Skilled nursing facility or other inpatient care	1,095	38.2	83,938	41.8
3-mo Readmissions*				
Lung-related inpatient readmission**	89	3.1	8,059	4.0
Pneumohemothorax	13	0.5	1,870	0.9
Injury or disease of the bronchus	41	1.4	3,611	1.8
Acute respiratory distress or failure	39	1.4	3,409	1.7
Pneumonia and related conditions	10	0.3	765	0.4
Injuries or disease of the pleura	26	0.9	2,624	1.3
Other lung complications	19	0.7	1,692	0.8
12-mo Readmissions				
Patients with 12 mo medical history	2,192		157,333	
Lung-related inpatient readmission**	135	6.2	11,893	7.6
Pneumohemothorax	16	0.7	2,067	1.3
Injury or disease of the bronchus	70	3.2	6,467	4.1
Acute respiratory distress or failure	60	2.7	5,314	3.4
Pneumonia and related conditions	12	0.5	992	0.6
Injuries or disease of the pleura	35	1.6	2,904	1.8
Other lung complications	26	1.2	2,267	1.4

*All patients in the study had 3 months medical history.
**Lung-related readmissions may have more than one lung-related diagnosis.

(OR, 0.55 [95% CI, 0.33–0.92]; $p = 0.022$).[22] This study however only included 90-day follow-up periods, whereas we identified continued benefits to 12 months postindex.

Several studies have demonstrated lower rates of pulmonary complications in SSRF versus NOM groups, consistent with our findings. Specifically, odds of pneumonia (OR, 0.41; 95% CI, 0.27–0.64; $p < 0.001$) and dyspnea (OR, 0.23; 95% CI, 0.09–0.54; $p < 0.001$) were shown to be favorable to SSRF versus NOM.[23] The rate of delayed hemopneumothorax has also been shown to be two times higher in NOM versus SSRF group.[24] Findings from individual studies have also been aggregated in a number of recent meta-analyses, which confirmed the clinical benefits of SSRF versus NOM for lung-related complications in the postoperative period.[13,25]

The imbalance of the severity of patients at index reinforced the need for a rigorous matching method, which would allow comparison of similarly injured patients in the NOM and SSRF cohorts. Many different matching methodologies exist and have merits. We used an FSW approach based on PSs, for the following reason: bias reduction is often achieved with PS matching or stratification, where five strata may be created based on the PS. When PSs are used to match a comparison group directly to a control group, it may result in better bias reduction than stratification but also leads to significant loss of information, as unmatched data are not used in the analysis.[26]This loss of information is particularly important when exposures are rare, as is the case in our study (SSRF only accounted for approximately 1% of all cases). The goal of the FSW methods is therefore to achieve bias reduction but without information loss. This method was recently developed by Desai et al.[27] who showed in a 2017 paper that, in observational studies with exposures less than 5%, FSW resulted in greater bias reduction and better overall results than matching or (nonfine) stratification. Following Desai's publication, this method has been used in multiple research papers.[28–30]

Because of the significant heterogeneity in patient presentation, we focused our analysis on postdischarge outcomes, as the nature of the treatments and length of hospital stay during the index may be related to a multitude of other nonchest injuries. We focused on home discharge and lung-related readmissions, as these are indicators for treatment success and possibly associated with SSRF. We observed that patients with SSRF had lower readmissions at both 3 and 12 months, compared with patients with NOM. Long-term outcomes following SSRF are poorly documented. A 2019 study by Beks et al.[10] with 3.9 years follow-up included 103 patients. The recent meta-analyses do not control postoperative follow-up time, as these vary considerably from study to study, are usually short, and are often not reported.[7,13,31] Our 12-month follow-up data point thus represents an important finding that suggests sustained effectiveness of the procedure after discharge.

Our study has the following limitations: we used a large, hospital billing database for this analysis. Errors in data entry or inaccurate diagnoses or procedures would lead to errors in our final analysis. Patients selecting to get care outside of the PREMIER hospital system would also be lost to follow-up in our analysis. In addition and as outlined previously, there was significant heterogeneity in patient presentation. We used established scores and indices (ISS, NISS, and EI) to evaluate and quantify severity, for matching purposes, but exact severity was not available beyond that provided by diagnoses and procedures. To create a cohort of patients with comparable severity of injury, we excluded patients with extreme severity, such as GCS score of ≤8. This cutoff was based on the presence of a GCS score of ≤8 any time during the index admission and may have resulted in patients being excluded, even if their GCS score improved during index. An additional limitation includes the lack of characterization of NOM care in terms of the exact types of treatment or medication received. Finally, video-assisted thoracic surgery evacuation treatments received during the index admission were also not characterized.

Despite these limitations, we provided a real-world assessment of SSRF versus NOM in patients with multiple rib fractures and high ISS scores. We used a methodology to include all patient data, from both the NOM and SSRF cohorts, and showed that SSRF results in greater odds of home discharge and lower rates of lung-related complications compared with NOM. Importantly, the study included all adult patients in the US PREMIER hospital

TABLE 5. Odds Ratios for Home Discharge, 3-Month and 12-Month Lung-Related Readmissions, in Patients With SSRF vs NOM

Outcomes	**OR**	***p***
Home discharge	1.166 (95% CI, 1.073–1.267)	0.0002
Lung-related readmission at 3 mo	0.764 (95% CI, 0.606–0.963)	0.0227
Lung-related readmission at 12 mo	0.799 (95% CI, 0.657–0.971)	0.0245

settings and may not be generalizable to pediatric patients or patients treated in other settings.

CONCLUSION

The study findings provide important evidence regarding demographic characteristics and clinical outcomes of patients with multiple rib fractures for SSRF versus NOM cohorts. Compared with patients treated with NOM, patients in SSRF cohort were younger, with higher rates of concurrent and severe injuries, indicating that surgical intervention is selectively being provided to the more severe patients. However, patients with SSRF demonstrated better recovery and were more likely to be discharged home versus to a skilled nursing facility or other inpatient care than NOM patients. At 3 and 12 months postadmission, the lung-related readmission rates were lower in SSRF than NOM cohort.

AUTHORSHIP

A.M.S., C.E.H., S.W., T.G., A.W., and M.V. designed the study and wrote the first draft of the protocol. J.W.R. reviewed the protocol. All authors signed off on the protocol. M.A., J.W.R., and C.E.H. conducted and finalized the data analysis. J.W.R. conducted all quality controls on the analyses. A.M.S. and A.W. led the clinical data interpretation. All authors were involved in the drafting, review, and finalization of the manuscript.

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DISCLOSURE

S.W., T.G., A.W., J.W.R., C.E.H., and M.V. were employees of JnJ at the time of the study. M.A. was working with Mu Sigma as a contractor to JnJ at the time of the study. A.M.S. is a consultant for DePuy Synthes, a J&J company, and a consultant for Globus Medical.

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