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Surgical subspecialization is associated with higher rate of rib fracture stabilization: a retrospective database analysis

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ABSTRACT

Background Surgical stabilization of rib fractures (SSRF) is performed on only a small subset of patients who meet guideline-recommended indications for surgery. Although previous studies show that provider specialization was associated with SSRF procedural competency, little is known about the impact of provider specialization on SSRF performance frequency. We hypothesize that provider specialization would impact performance of SSRF.

Methods The Premier Hospital Database was used to identify adult patients with rib fractures from 2015 and 2019. The outcome of interest was performance of SSRF, defined using International Classification of Diseases—10th Revision Procedure Coding System coding. Patients were categorized as receiving their procedures from a thoracic, general surgeon, or orthopedic surgeon. Patients with missing or other provider types were excluded. Multivariate modeling was performed to evaluate the effect of surgical specialization on outcomes of SSRF. Given a priori assumptions that trauma centers may have different practice patterns, a subgroup analysis was performed excluding patients with 'trauma center' admissions.

Results Among 39 733 patients admitted with rib fractures, 2865 (7.2%) received SSRF. Trauma center admission represented a minority (1034, 36%) of SSRF procedures relative to other admission types (1831, 64%, p=0.15). In a multivariable analysis, thoracic (OR 6.94, 95% CI 5.94–8.11) and orthopedic provider (OR 2.60, 95% CI 2.16–3.14) types were significantly more likely to perform SSRF. In further analyses of trauma center admissions versus non-trauma center admissions, this pattern of SSRF performance was found at non-trauma centers.

Conclusion The majority of SSRF procedures in the USA are being performed by general surgeons and at non-trauma centers. 'Subspecialty' providers in orthopedics and thoracic surgery are performing fewer total SSRF interventions, but are more likely to perform SSRF, especially at non-trauma centers. Provider specialization as a barrier to SSRF may be related to competence in the SSRF procedures and requires further study.

Type Therapeutic/care management.

Level of evidence IV

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Surgical stabilization of rib fractures (SSRF) is inconsistently used despite guidelines. Previous studies show that provider specialty is associated with confidence and competency with the procedure.

WHAT THIS STUDY ADDS

⇒ Only a minority of patients with rib fracture undergoing SSRF are seen at trauma centers. Thoracic and orthopedic providers are more likely to perform SSRF procedures at non-trauma facilities.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Provider specialization has a significant impact on how often SSRF is being performed. This may demonstrate a barrier to utilization of existing guidelines and offer an area of improvement in resources and training.

BACKGROUND

Although most patients with rib fractures are managed without surgery, surgical stabilization of rib fractures (SSRF) is appropriate for a select subset of patients.[1 2] As studies have demonstrated benefit to SSRF, it has been performed more frequently and with broader indications than previously.[3–5] However, SSRF utilization remains far below what is expected given the clinical evidence, even in patients with flail chest.[6–8]

One potential reason for below-expected use of SSRF may be linked to the specialization of providers who perform SSRF. Previous studies have shown that a minority of surveyed academic surgeons have either assisted on or performed an SSRF procedure, including only 33% of trauma surgeons, who considered themselves competent to perform SSRF.[9] Conversely, a majority of thoracic surgeons surveyed responded that they had performed rib fracture repair and an overwhelming majority (91%) stated that they felt competent with SSRF procedures. Provider specialty has not been directly studied with regard to frequency of SSRF performance.

The aim of this study is to elucidate the patient, provider, and hospital-associated factors that affect the frequency of SSRF performance, using a nationally representative database encompassing both trauma centers and non-trauma facilities. We hypothesize that the frequency of SSRF performance is significantly impacted by provider specialization and that this impact may differ based on hospital characteristics.

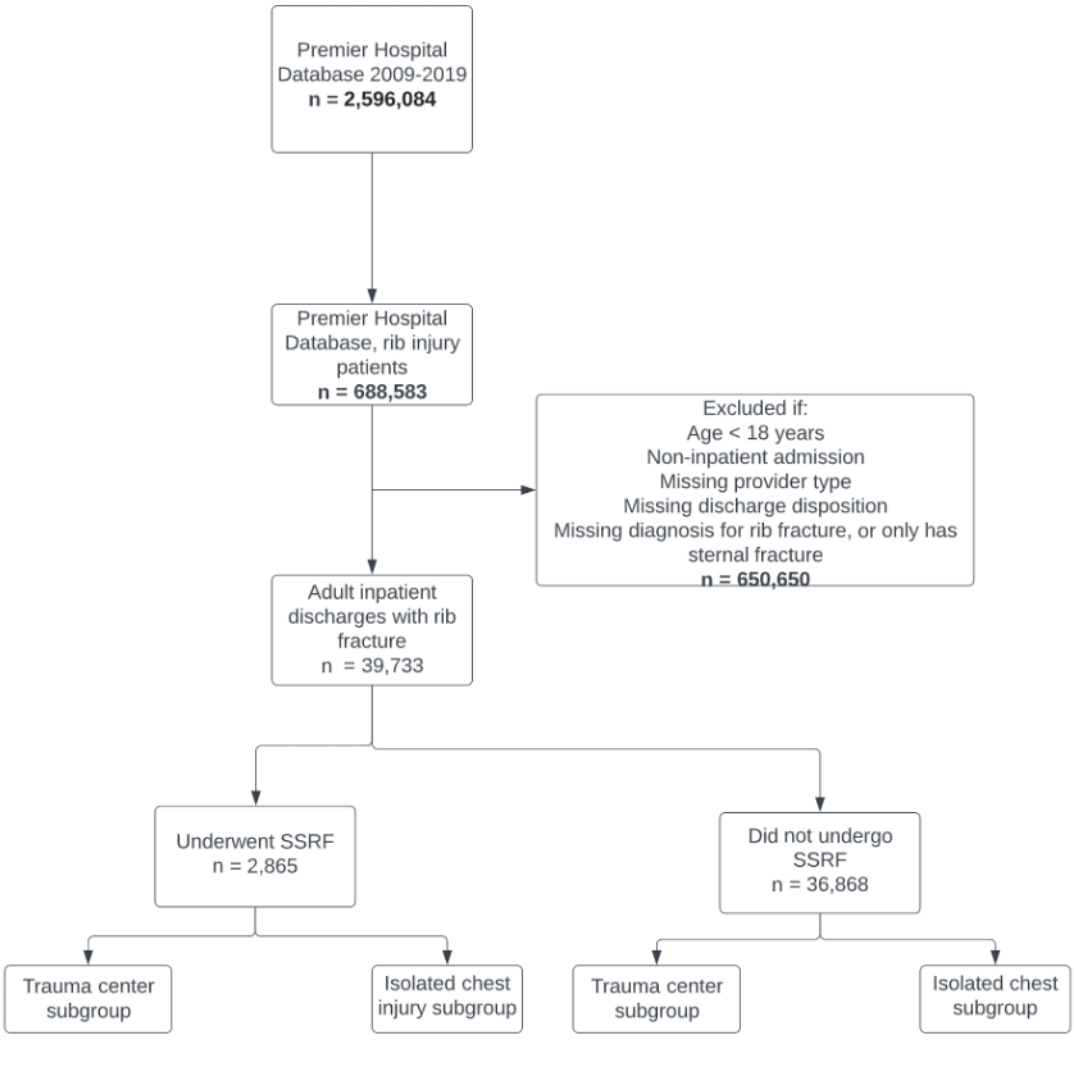

Figure 1 CONSORT flow diagram of study design. CONSORT, Consolidated Standards of Reporting Trials; SSRF, surgical stabilization of rib fractures.

METHODS

This retrospective study used the 2015–2019 iterations of the Premier Hospital Database (PHD), which is a large US-based hospital database containing information on inpatient discharges from geographically diverse, non-profit, non-governmental and community and teaching hospitals as well as health systems from rural and urban areas, encompassing nearly 121 million inpatient admissions.[10] The PHD was queried to identify adult inpatients over the age of 18 years with rib fractures.

Patients with rib fractures were identified using International Classification of Diseases—10th Revision (ICD-10) diagnosis codes. Patients were excluded if they were not inpatient admissions, if they did not have a known discharge status, or if they were seen by an unknown provider specialty (figure 1). Rib fractures were stratified into three categories: single rib fractures, multi-rib (non-flail) fractures, and flail chest. Patient demographic and clinical factors, such as age, gender, comorbidity scores, and hospital were also obtained from the database. Elixhauser Comorbidity Indices were calculated using ICD-10 coding. Abbreviated Injury Scale (AIS) scores were also calculated using ICD-10 coding using ICDPIC software refined for R.[11 12] Maximum overall AIS was defined as the maximum AIS found over the six body regions encompassing AIS scoring.[11 12]

The primary outcome was the performance of SSRF procedures. SSRF procedure was categorized by ICD-10 PCS coding. Procedures were categorized by provider type as reported by Premier into general surgery, thoracic surgery, orthopedic surgery, and trauma surgery. For the purpose of analysis, general surgery and trauma surgery categories were combined, given that non-trauma centers were analyzed.

Descriptive analysis was performed to examine the overall demographics of the study population relative to performance of SSRF. Categorical and binary variables were compared using $\chi 2$ testing. Continuous variables were reported as median with IQR and compared using the Wilcoxon rank-sum test. Multivariate modeling was also performed to determine demographic and clinical factors associated with SSRF. Variables for multivariable regression were included if considered clinically salient, such as age or trauma center status. Given a priori assumptions that trauma centers may have different practice patterns, a subgroup analysis was performed on trauma center admissions and non-trauma center admissions separately. In addition, patients with other 'non-chest' injuries, as determined by AIS scoring, may also be impacted by differing practice patterns. As such, a second subgroup analysis was performed for patients with isolated chest injuries, excluding patients with AIS score >1 in any non-chest region.

Table 1 Demographics of all patients with rib fractures based on their receipt of SSRF

Variable	Undergoing SSRF (n=2865)	Not undergoing SSRF (n=36 868)	P value
Age, median (IQR)	57 (46–67)	57 (38–72)	0.426
Male gender, n (%)	2108 (73.58)	22 886 (62.10)	<0.001
White race, non-Hispanic, n (%)	1776 (61.99)	20 652 (56.02)	<0.001
Provider category			
General surgery, n (%)	2372 (82.79)	35 301 (95.75)	<0.001
Orthopedic surgery, n (%)	213 (7.43)	1050 (2.85)	<0.001
Thoracic surgery, n (%)	280 (9.77)	517 (1.40)	<0.001
Teaching			
Teaching	1962 (68.48%)	27 699 (75.13%)	<0.001
Non-teaching	903 (31.52%)	9169 (24.87%)	
Performed at urban centers	2552 (89.08%)	32 408 (87.90%)	0.063
Elixhauser Comorbidity Index, median (IQR)	2 (1–3)	2 (1–3)	<0.001
Fracture type			
Single	228 (7.96%)	22 120 (60.00%)	<0.001
Multi-rib, non-flail	1551 (54.14%)	10 377 (28.15%)	<0.001
Flail	1170 (40.84%)	479 (1.30%)	<0.001
Max AIS overall	4 (2–4)	2 (1–3)	<0.001
Max AIS score, chest region, median (IQR)	4 (2–4)	1 (1–2)	<0.001
Region			
Northeast	526 (18.36%)	7779 (21.10%)	
South	1118 (39.02%)	16 289 (44.18%)	<0.001
Midwest	599 (20.91%)	7511 (20.37%)	
West	622 (21.71%)	5289 (14.35%)	
Presentation to trauma center, n (%)	1034 (36.09)	13 803 (37.43)	0.151

AIS, Abbreviated Injury Scale; SSRF, surgical stabilization of rib fractures.

Table 2 Multivariable analysis of factors associated with SSRF performance for all 39 733 identified patients with rib fractures

Variable	OR	95% CI	P value
Provider category (relative to general surgery)			
Orthopedic surgery	2.60	2.16–3.14	<0.001
Thoracic surgery	6.94	5.94–8.11	<0.001
Age	0.98	0.98–0.99	<0.001
Male gender	1.16	1.06–1.27	0.001
Race (relative to relative to non-white designation)	1.21	1.09–1.35	<0.001
Fracture type (relative to single rib)			
Flail chest	25.14	20.74–30.47	<0.001
Multi-rib fractures, non-flail	1.93	1.64–2.28	<0.001
Number of Elixhauser comorbidities*	1.10	1.08–1.13	<0.001
Max AIS overall	0.70	0.64–0.76	<0.001
Max AIS, chest region	1.87	1.72–2.05	<0.001
Region (relative to Midwest)			
Northeast	1.00	0.88–1.14	0.919
South	0.87	0.78–0.97	0.17
West	1.37	1.20–1.56	<0.001
Urban location (relative to rural)	1.36	1.19–1.55	<0.001
Teaching hospital (relative to non-teaching)	0.88	0.80–0.97	0.011
Trauma center facility (relative to non-trauma center)	1.06	0.97–1.16	0.149

*Elixhauser range: 0–13.
AIS, Abbreviated Injury Scale; SSRF, surgical stabilization of rib fractures.

All analyses were performed using STATA SE/V.14 (StataCorp, College Station, Texas, USA). Results are presented as OR with 95% CIs. Findings were considered significant if p≤0.05. P values were not corrected for multiple hypothesis testing.

RESULTS

A total of 39 733 patients were admitted with rib fractures, a minority of whom (14 837, 37.34%) were admitted to trauma centers. Among all patients with rib fractures, 2865 patients (7.21%) received SSRF (table 1). A majority of patients undergoing SSRF had multi-rib, non-flail injuries (54.14%, p<0.001). Patients undergoing SSRF were of similar age (median 57, IQR 46–67) to those who did not undergo SSRF (median 57, IQR 38–72, p=0.426) and had a similar number of Elixhauser comorbidities (2, IQR 1–3 vs. 2, IQR-1–3). SSRF was performed more often in white race, non-Hispanic patients compared with non-white race (61.99% vs. 56.02%, p<0.001). Patients undergoing SSRF had greater maximum AIS score in the chest region (4, IQR 2–4 vs. 1, IQR 1–2, p<0.001) and in their overall maximum AIS score (4 vs. 2, p<0.001). SSRF was more common at teaching centers (68.48% vs. 31.52%, p<0.001), but was not associated with trauma center admission (1034 of 2865, 36.09% vs. 13 803 of 36 868, 37.4%, p=0.151).

Although most patients with rib fractures received care by a general surgeon, there were notable differences in SSRF performance by provider type. In multivariable analysis, SSRF performance was strongly associated with orthopedic (OR 2.60, 95% CI 2.16–3.14, p<0.001) and thoracic surgery provider types (OR 6.94, 95% CI 5.94–8.11, p<0.001) (table 2). Patients with flail chest were also more likely to undergo SSRF (OR 25.14, 95% CI 20.74–30.47, p<0.001). Hospital location in the southern USA (OR 0.87, 95% CI 0.78–97, p<0.001) and western USA (OR 1.37, 95% CI 1.20–1.56, p<0.001) was also associated with differences in SSRF performance. Trauma center designation was not associated with any difference in SSRF performance (OR 1.06, 95% CI 0.97–1.16, p<0.001).

Trauma center subgroups

A total of 14 837 patients (37.3%, 14 837 of 39 733) were admitted to trauma centers. At trauma centers, thoracic surgery (OR 2.46, 95% CI 0.77–7.82, p=0.125) and orthopedic surgery specializations (OR 0.57, 95% CI 0.73–4.59, p=0.605) were not associated with a difference in performance of SSRF in comparison with general surgeons. Fracture pattern and geographic region were also associated with SSRF, with decreased odds of SSRF performance in the southern and northeastern USA at non-trauma centers and at southern US trauma centers (table 3).

At non-trauma facilities, orthopedic (OR 5.92, 95% CI 4.62–7.59, p<0.001) and thoracic surgeons (OR 20.98, 95% CI 16.15–27.05, p<0.001) were more likely to perform SSRF (table 3). Similar to trauma centers, fracture pattern and geographic region were also associated with SSRF.

Isolated chest injuries

A total of 20 949 (52.7%) patients were admitted with isolated chest injuries (defined as AIS score ≤1 for non-chest regions). Of these, a minority (6533 of 20 949, 31.18%) were admitted to trauma centers. Similar to the full cohort, orthopedic (OR 5.67, 95% CI 4.38–7.35) and thoracic providers (OR 19.67, 95% CI 15.04–25.73, p<0.001) were more likely to perform SSRF in

Table 3 Multivariable analysis of SSRF performance among 14 837 patients with rib fractures at trauma center locations vs. 24 896 patients at non-trauma centers

	Trauma center		Non-trauma center	
Variable	OR (95% CI)	P value	OR (95% CI)	P value
Provider category (relative to general surgery)				
Orthopedic surgery	0.57 (0.73–4.59)	0.605	5.92 (4.62–7.59)	<0.001
Thoracic surgery	2.46 (0.77–7.82)	0.125	20.98 (16.15–27.05)	<0.001
Age	0.98 (0.98–0.99)	<0.001	0.98 (0.98–0.99)	<0.001
Male gender	1.41 (1.18–1.69)	<0.001	1.43 (1.24–1.63)	<0.001
Race (relative to non-white designation)	1.15 (0.93–1.43)	0.176	1.13 (0.96–1.33)	0.116
Fracture type (relative to single rib)				
Flail chest	830.89 (443.55–1556.49)	<0.001	407.65 (302.66–549.06)	<0.001
Multi-rib fractures, non-flail	59.23 (33.12–105.94)	<0.001	19.36 (15.80–23.73)	<0.001
Number of Elixhauser comorbidities	1.00 (0.95–1.05)	0.780	0.99 (0.96–1.03)	0.941
Region (relative to Midwest)				
Northeast	0.85 (0.64–1.11)	0.249	0.78 (0.64–0.95)	0.017
South	0.75 (0.59–0.94)	0.016	0.75 (0.63–0.88)	0.001
West	1.62 (1.24–2.11)	<0.001	1.16 (0.93–1.45)	0.163
Urban location (relative to rural)	1.39 (1.05–1.85)	0.02	1.49 (1.22–1.81)	<0.001
Teaching hospital (relative to non-teaching)	0.89 (0.71–1.11)	0.308	0.74 (0.64–0.85)	<0.001
Max AIS overall	0.75 (0.65–0.87)	<0.001	0.62 (0.55–0.71)	<0.001
Max AIS score in chest region	1.59 (1.37–1.85)	<0.001	1.43 (1.26–1.64)	<0.001

AIS, Abbreviated Injury Scale; SSRF, surgical stabilization of rib fractures.

patients who were not admitted to trauma centers. At trauma centers, there was no significant association between provider type and SSRF performance (table 4).

DISCUSSION

This study used a large nationally representative database to identify factors associated with performance of SSRF among patients admitted with rib fractures. In our analysis, we found that provider specialization, facility characteristics, and fracture type were all strongly associated with performance of SSRF. The majority of SSRF admissions were at non-trauma center locations. At these locations, thoracic surgery provider type was strikingly associated with SSRF. In non-trauma center locations, there were also notable regional differences in care, with SSRF less likely to be performed in the south and northeast. We think that this is the first study of provider type associations with SSRF performance in such a large population, encompassing both trauma and non-trauma centers.

The primary outcome of interest in this study was performance of SSRF based on provider type. A minority of patients in this study (7.2%) underwent SSRF procedures, which was similar to the results of previous studies.[1 2] Although general

Table 4 Multivariable analysis of SSRF performance of 20 949 patients with isolated chest injury, defined as AIS score ≤1 for non-chest areas

	Trauma center		Non-trauma center	
Variable	OR (95% CI)	P value	OR (95% CI)	P value
Provider category (relative to general surgery)				
Orthopedic surgery	1.02 (0.11–8.87)	0.985	5.67 (4.38–7.35)	<0.001
Thoracic surgery	1.63 (0.32–8.06)	0.549	19.67 (15.04–25.73)	<0.001
Age	0.98 (0.97–0.98)	<0.001	0.98 (0.98–0.99)	<0.001
Male gender	1.90 (1.42–2.54)	<0.001	1.48 (1.26–1.75)	<0.001
Race (relative to non-white designation)	1.11 (0.79–1.55)	0.530	1.21 (0.98–1.49)	0.073
Fracture type (relative to single rib)				
Flail chest	900.22 (398.45–2033.88)	<0.001	563.07 (383.63–826.44)	<0.001
Multi-rib fractures, non-flail	48.52 (23.62–99.64)	<0.001	18.95 (15.12–23.75)	<0.001
Number of Elixhauser comorbidities	1.05 (0.98–1.14)	0.138	0.97 (0.93–1.02)	0.339
Region (relative to Midwest)				
Northeast	0.79 (0.53–1.17)	0.249	0.63 (0.50–0.80)	<0.001
South	0.59 (0.41–0.86)	0.006	0.69 (0.56–0.84)	<0.001
West	1.33 (0.89–1.98)	0.151	1.14 (0.88–1.48)	0.297
Urban location vs. rural	1.29 (0.86–1.92)	0.204	1.48 (1.16–1.88)	0.001
Teaching hospital vs. non-teaching	0.89 (0.64–1.24)	0.509	0.71 (0.60–0.85)	<0.001
Max AIS chest	1.20 (1.04–1.39)	0.009	0.86 (0.80–0.94)	0.001

AIS, Abbreviated Injury Scale; SSRF, surgical stabilization of rib fractures.

surgeons and trauma surgeons were the most common provider type, other surgical specialties were more likely to perform SSRF. This was especially notable at non-trauma facilities, where specialty providers were significantly more likely to perform SSRF. Mayberry *et al* demonstrated that trauma surgeons self-reported decreased confidence and competence in performing SSRF procedures.[9] Our finding may corroborate that trauma providers may not be performing SSRF due to unfamiliarity with the procedure, especially at community hospitals.[8] In comparison, Mayberry *et al* demonstrated that thoracic surgeons were the only provider specialization in which a majority reported having assisted or performed rib fracture repair, which may be why they were found to be more likely to perform SSRF.[9]

The results of this study also highlight the association of hospital location characteristics with the performance of SSRF. Previous studies of hospital characteristics indicated that nearly half of patients with rib fracture present to non-trauma center facilities.[13–15] In comparison, approximately two-thirds of patients in this study presented to non-trauma center facility, with only 36.1% of patients undergoing SSRF being admitted to a trauma center. Though Tignanelli *et al* demonstrated an increased likelihood of SSRF at level I trauma centers using the National Trauma Databank (NTDB), our results demonstrate that this may only be a minority of patients undergoing SSRF.[6] This finding may suggest that a majority of SSRF patients are not captured in studies of the ACS-TQIP Database or NTDB, which only encompass US trauma centers. In addition, the geographical location of hospitals was also demonstrated to play a role in the frequency of SSRF intervention. Both trauma centers and non-trauma centers in the southern region of the USA were found to be less likely to perform SSRF. This result reflects findings of previous studies which show that the southern USA had the slowest rate of increase in SSRF usage during the study period.[1] Conversely, trauma centers in the western USA were more likely to perform SSRF. A potential reason for these differences is in the regionalization of providers, with providers trained in one region remaining in that region for practice, leading to a lack of exposure to SSRF from providers in other regions who may be more familiar with the procedure. Similar geographical differences in practice pattern have been demonstrated in other aspects of surgery.[16 17] Further studies regarding geographical differences in SSRF acceptance may help further delineate the cause of these regional differences.

In addition, this study demonstrated the striking differences in SSRF performance based on fracture type. Mayberry *et al* demonstrated that a minority of surgeons (44%) accepted flail chest as an indication for intervention, suggesting low utilization, even with the publication of randomized trials supporting the use.[9 18 19] We found that patients with flail chest were overwhelmingly likely to undergo SSRF (OR 900.22, 95% CI 398.45–2033.88, p<0.001) at both trauma and non-trauma centers, suggesting a possible increased adherence to current guidelines for this injury pattern by providers. Furthermore, multi-rib, non-flail injuries demonstrated decreased likelihood of SSRF performance compared with flail chest, suggesting some possible adherence to NONFLAIL guidance.[1] A subgroup analysis was performed of patients with isolated chest injury as defined by AIS scoring to exclude possible confounding factors that may influence surgical candidacy. Results from this analysis were consistent with the analysis of the full cohort, with increased performance of SSRF by more specialized providers at non-trauma center facilities. Chest region AIS did not show any significant association in either the trauma center group or the non-trauma center group, suggesting that other factors played a role when SSRF was performed in these patients. However, patients with flail chest were overwhelmingly likely to undergo SSRF, regardless of presenting center.

There are several limitations to this retrospective study. The study relies on an administrative database and the fracture patterns and the indications for surgery are not adjudicated. The accuracy of individual entries cannot be verified by the study team. As such, race and ethnicity data cannot be verified and may be misclassified or misidentified. This study cannot therefore assess whether surgery was 'appropriate' among the patients in the study as this is a complex clinical decision. We think that the impact of potential inaccuracies on the findings should be limited by the large cohort of patients analyzed in this study. Additionally, rib fractures in this study were characterized using ICD-10 diagnosis codes. Inaccuracies in ICD-10 coding could potentially lead to mischaracterization of a patient's injuries, leading to incorrect inclusion or exclusion from the study population. The impact of this potential source of error should, however, be minimized by the large patient cohort. Lastly, the designation of provider specialization is provided by the database, and may be inaccurate. The differentiation of general versus trauma surgeon may, for example, be arbitrary, especially at non-trauma centers. Nonetheless, we think it is unlikely that thoracic surgeon specialty and general/trauma surgeons could be miscategorized given the requirement for board certification of thoracic surgeons.

SSRF is underused, despite the presence of multiple evidence-based practice guidelines supporting its usage. Provider specialization is significantly associated with the frequency of SSRF procedures performed. Though thoracic and orthopedic surgeons make up a small fraction of providers performing SSRF, they are significantly more likely to perform them than their general surgery and trauma surgery counterparts. This difference in frequency may indicate barriers to utilization of SSRF among certain provider types, including sufficient training and institutional resources.

Contributors All authors were involved in the conception or design of this work. AB, ALS and CWT collected data and performed statistical analysis. AB and CWT created figures and tables. All authors drafted and revised the abstract; drafted the article; and edited and critically reviewed the final article. CWT acts as guarantor for the work and controlled the decision to publish.

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Competing interests CWT is a consultant for Atricure, Zimmer Biomet, Sig Medical and Medtronic, but these relationships have not influenced this work in any way.

Patient consent for publication Not required.

Ethics approval This study was considered exempt by the local institutional review board (IRB# EM-17-06).

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. This retrospective study used the 2015–2019 iterations of the Premier Hospital Database (PHD; Premier, Charlotte, North Carolina, USA), which is a large US-based hospital database containing information on inpatient discharges from geographically diverse, non-profit, non-governmental and community and teaching hospitals as well as health systems from rural and urban areas, encompassing nearly 121 million inpatient admissions. These data may be obtained from Premier.

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