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ORIGINAL ARTICLE

An increasing trend in geriatric trauma patients undergoing surgical stabilization of rib fractures

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Abstract

Purpose The proportion of geriatric trauma patients (GTPs) (age ≥ 65 years old) with chest wall injury undergoing surgical stabilization of rib fractures (SSRF) nationally is unknown. We hypothesize a growing trend of GTPs undergoing SSRF, and sought to evaluate risk of respiratory complications and mortality for GTPs compared to younger adults (18–64 years old) undergoing SSRF.

Methods The Trauma Quality Improvement Program (2010–2016) was queried for patients with rib fracture(s) who underwent SSRF. GTPs were compared to younger adults. A multivariable logistic regression analysis was performed.

Results From 21,517 patients undergoing SSRF, 3,001 (16.2%) were GTPs. Of all patients undergoing SSRF in 2010, 10.6% occurred on GTPs increasing to 17.9% in 2016 ($p < 0.001$) with a geometric-mean-annual increase of 11.5%. GTPs had a lower median injury severity score (18 vs. 22, $p < 0.001$), but had a higher rate of mortality (4.7% vs. 1.2%, $p < 0.001$). After controlling for covariates, GTPs had an increased associated risk of mortality (OR 4.80, CI 3.62–6.36, $p < 0.001$). On a separate multivariate analysis for all trauma patients with isolated chest Abbreviated Injury Scale 3, GTPs were associated with a similar four-fold risk of mortality (OR 4.21, CI 1.98–6.32, $p < 0.001$).

Conclusion Spanning 7 years of data, the proportion of GTPs undergoing SSRF increased by over 7%. Although GTPs undergoing SSRF had lesser injuries, their risk of mortality was four times higher than other adult trauma patients undergoing SSRF, which was similar to their increased background risk of mortality. Ultimately, SSRF in GTPs should be considered on an individualized basis with careful attention to risk–benefit ratio.

Keywords Surgical stabilization of rib fractures · Geriatric trauma patients · Rib fractures · Flail chest

Introduction

Thoracic trauma is a major contributor to trauma mortality, and accounts for 20–25% of trauma deaths overall [1]. Rib fractures are commonly seen after blunt chest trauma, and are found in up to 10% of all trauma patients, and up to 30% of thoracic trauma patients [2]. Rib fractures are often associated with pulmonary contusion, pneumothorax, hemothorax, and blunt cardiac injury, with increasing numbers of rib fractures associated with worsening morbidity and mortality in a "dose-dependent" manner [3, 4]. Flail chest physiology, significant chest wall instability, or pain refractory to pain management can all lead to pulmonary complications or respiratory failure requiring ventilator support. Surgical stabilization of rib fractures (SSRF) has been shown to improve pulmonary outcomes in select patients with chest wall injury [5–11].

SSRF began in the 1970s, initially to address paradoxical movement of the chest wall in thoracic injury. Paris et al. found that SSRF could avoid or reduce the use of mechanical ventilation [5]. Since that time, randomized prospective studies have demonstrated SSRF for flail chest can minimize ventilation requirements and intensive care unit stay [6–9]. As well, multiple meta-analyses have found improved

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outcomes for patients undergoing SSRF, particularly for flail chest, citing reduced pneumonia, chest deformity, intensive care unit (ICU)/length of stay (LOS) days, decreased need for tracheostomy, and decreased mortality [10, 11]. Thus, the indications for SSRF have expanded to include flail chest requiring mechanical ventilation, symptomatic non-union, severe displacement found during a thoracotomy for another reason, ≥ 3 ribs flail not requiring mechanical ventilation, ≥ 3 ribs with severely displaced fractures defined as bi-cortical displacement, or ≥ 3 rib fractures with mild to moderate displacement and less than 50% of expected forced vital capacity despite adequate pain management [4].

With the expanded criteria for SSRF, use of SSRF has increased. Studies have continued to show an overall mortality benefit. However, rib fractures within GTP have not been well studied on a national level. We wanted to evaluate the trends of GTPs undergoing SSRF, and concomitantly, evaluate the risk of respiratory complications (unplanned intubation, acute respiratory distress syndrome, and pneumonia) and mortality for GTPs compared to younger adults (18–64 years old) undergoing SSRF. We hypothesize a growing trend of GTPs undergoing SSRF, with higher risk of mortality in the GTP group compared to the non-geriatric trauma group (NGTP, younger adults aged 18–64).

Methods

We performed a retrospective analysis of the Trauma Quality Improvement Program (TQIP) over a seven-year period from 2010 to 2016 to identify trauma patients with rib fractures who underwent SSRF. Two groups were compared: GTPs (age ≥ 65 years old) and non-GTPs (NGTPs) (age 18–64 years old). All patients meeting the above criteria with complete information were included. The primary outcome was in-hospital mortality. Given that this was a retrospective analysis on a national database without patient identifiers, this study did not require informed or ethics consent and was exempt from Institutional Review Board review.

Patient demographic information was collected as well as pre-hospital comorbidities including congestive heart failure (CHF), cerebrovascular accident (CVA), end-stage renal disease (ESRD), and chronic obstructive pulmonary disease (COPD). Initial trauma injury profile, including Injury Severity Score (ISS) and Abbreviated Injury Scale (AIS) score was also collected. Secondary outcomes evaluated included length of stay (LOS), intensive care unit (ICU) days, as well as in-hospital complications, such as acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), deep vein thrombosis (DVT), myocardial infarction (MI), and pulmonary embolism (PE). A complete list of variables is included in Appendix A. The only variable in the model with missing data was Glasgow

Coma Scale (GCS); this information was missing for 4.9% of patients, and these patients were excluded from our regression analysis.

Descriptive statistics were performed for all variables. A Mann–Whitney U test was used to compare continuous variables and Chi-square test was used to compare categorical variables. Categorical data were reported as percentages, continuous data were reported as medians with interquartile range or means with standard deviation. The magnitude of the association between predictor variables and mortality was measured using a univariable logistic regression model. The variables were chosen based on a review of literature [10–16]. Covariates were then controlled for using a hierarchical multivariable logistic regression model. Two separate multivariable regression models were completed. One multivariable logistic regression analysis was completed for risk of mortality of all adult trauma patients with rib fractures undergoing SSRF. A second multivariable logistic regression analysis was completed for risk of mortality of all adult trauma patients with rib fractures and chest AIS of 3. We chose a chest AIS of 3 with no other injuries as we wanted to compare similarly injured GTPs to NGTPs with rib fracture injury that may benefit from SSRF. These were reported with an odds ratio (OR) and a 95% confidence intervals (CI). All p values were two-sided, with a statistical significance level of < 0.05. All statistical analyses were performed with IBM SPSS Statistics for Windows, Version 24 (Armonk, NY: IBM Corp).

Results

### Patient demographics and national trends

From 21,517 trauma patients with rib fractures undergoing SSRF, 18,516 (86.1%) were NGTPs and 3001 (13.9%) were GTPs. There was a greater percentage of males for NGTPs (72.8% vs. 65.1%, $p < 0.001$). Median ISS was also greater for NGTPs (22 vs. 18, $p < 0.001$). NGTPs were also more likely to be alcohol or drug screen positive (alcohol: 23.3% vs. 6.5%, $p < 0.001$, drug: 27.5% vs. 15.0%, $p < 0.001$). However, NGTPs had a lower medium number of rib fractures (4 vs. 5, $p < 0.001$). On the other hand, GTPs had a greater rate of most comorbidities, including CHF (4.0% vs. 0.6%, $p < 0.001$), CVA (3.0% vs. 0.5%, $p < 0.001$), ESRD (1.2% vs. 0.3%, $p < 0.001$), DM (24.1% vs. 8.1%, $p < 0.001$), hypertension (56.8% vs. 18.9%), and COPD (10.7% vs. 5.4%, $p < 0.001$) (Table 1). From 2010 to 2016, there was an increase in the proportion of SSRF in GTPs, with 10.6% of SSRF completed on GTPs in 2010, increasing to 17.9% of SSRF completed on GTPs in 2016 (Fig. 1).

Table 1 Demographics of adult patients with rib fractures undergoing rib fixation

Characteristic	Age < 65 (n = 18,516)	Age ≥ 65 (n = 3001)	p value
Age, year, median (IQR)	44 (31, 53)	71 (67, 76)	< 0.001
Male, n (%)	13,479 (72.8%)	1952 (65.1%)	< 0.001
ISS, median (IQR)	22 (14, 29)	18 (14, 25)	< 0.001
Teaching university, n (%)	11,354 (61.3%)	1736 (57.8%)	< 0.001
Vitals on admission, median (IQR)			
Systolic blood pressure	127 (110, 143)	131 (111, 150)	< 0.001
Respiratory rate	20 (16, 22)	19 (16, 22)	< 0.001
Pulse	97 (83, 114)	87 (75, 101)	< 0.001
Glasgow coma scale score	15 (14, 15)	15 (15, 15)	0.877
Alcohol screen positive, n (%)	4086 (23.3%)	184 (6.5%)	< 0.001
Drug screen positive, n (%)	4572 (27.5%)	412 (15.0%)	< 0.001
Number of rib fractures, median (IQR)	4 (2, 7)	5 (3, 8)	< 0.001
Comorbidities, n (%)			
Congestive heart failure	112 (0.6%)	119 (4.0%)	< 0.001
Cerebrovascular accident	99 (0.5%)	89 (3.0%)	< 0.001
End-stage renal disease	55 (0.3%)	37 (1.2%)	< 0.001
Diabetes	1501 (8.1%)	723 (24.1%)	< 0.001
Hypertension	3495 (18.9%)	1705 (56.8%)	< 0.001
COPD	991 (5.4%)	322 (10.7%)	< 0.001
Smoker	4671 (25.2%)	307 (10.2%)	< 0.001
Blunt mechanism, n (%)	18,350 (99.5%)	2970 (99.6%)	0.418
AIS (grade > 3), n (%)			
Head	2445 (13.2%)	357 (11.9%)	0.048
Abdomen	1510 (8.2%)	97 (3.2%)	< 0.001
Spine	367 (2.0%)	36 (1.2%)	0.003
Upper extremity	12 (0.1%)	3 (0.1%)	0.498
Lower extremity	1442 (7.8%)	172 (5.7%)	< 0.001

ISS injury severity score, *IQR* interquartile range, *COPD* chronic obstructive pulmonary disease

Fig. 1 Surgical stabilization of rib fractures: Age ≥ 65 vs. Age < 65-years-old
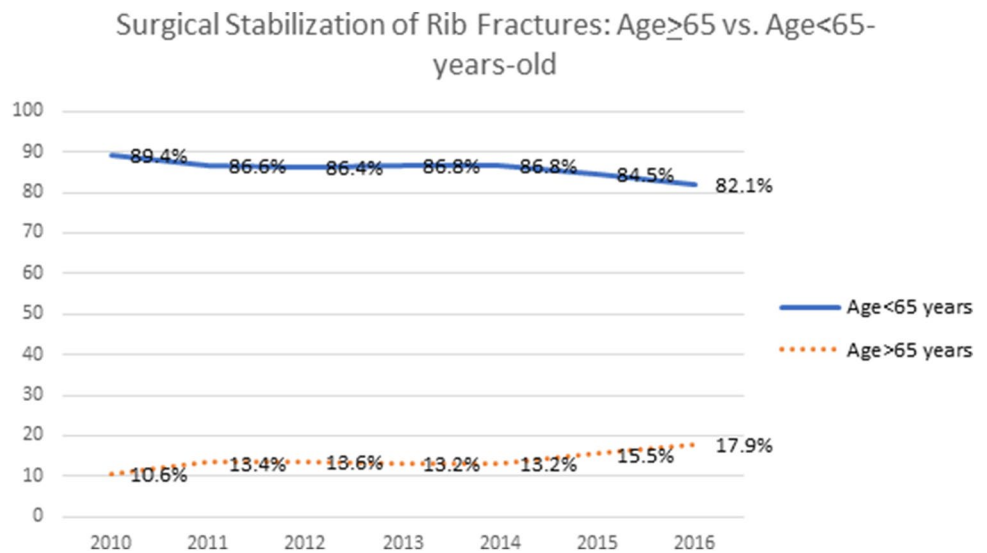
Mortality and other clinical outcomes of trauma patients with rib fractures undergoing SSRF

The rate of mortality was greater in GTPs with rib fractures undergoing SSRF than in NGTPs (4.7% vs. 1.2%, $p < 0.001$). GTPs also had a greater median LOS, ICU days, and ventilator days (LOS: 13 vs. 12 days, $p < 0.001$; ICU: 7 vs. 6 days, $p < 0.001$; ventilator: 8 vs. 7, $p < 0.001$) (Table 2).

Overall, when compared to NGTPs, GTPs had an increased rate of in-hospital complications including AKI (3.6% vs. 2.0%, $p < 0.001$), DVT (7.6% vs. 5.5%, $p < 0.001$), MI (1.6% vs. 0.3%, $p < 0.001$), unplanned intubations (7.6% vs. 3.8%, $p < 0.001$), and unplanned ICU admissions (4.6% vs. 2.7%, $p < 0.001$). There was, however, no difference in the rate of ARDS (4.0% vs. 3.7%, $p = 0.29$) or pneumonia (12.2% vs. 11.2%, $p = 0.086$) between the cohorts.

Risk of mortality in trauma patients with rib fractures undergoing SSRF

After adjusting for covariates, the most significant risk factor for mortality was age ≥ 65 years old (OR = 4.80, CI 3.62–6.36, $p < 0.001$). This was followed by ESRD (OR 3.97, CI 1.80–8.74, $p = 0.001$), diabetes (OR 1.79, CI 1.23–2.32, $p = 0.001$), and COPD (OR 1.64, CI 1.11–2.43, $p = 0.013$). For each additional point of ISS, there was an increased risk of mortality (OR 1.04, CI 1.02–1.05, $p < 0.001$) (Table 3).

When evaluating the risk of mortality in adult trauma patients with a chest AIS of 3, age ≥ 65 years old was

Table 3 Multivariable logistic regression analysis for risk of mortality in adult patients with rib fractures undergoing rib fixation

Risk factor	OR	CI	p value
Age ≥ 65 vs. Age < 65 years-old	4.80	3.62–6.36	< 0.001
Systolic blood pressure	0.99	0.98–0.99	< 0.001
Injury severity score	1.04	1.02–1.05	< 0.001
Respiratory rate	1.01	0.99–1.02	0.371
Pulse	1.01	1.00–1.01	0.063
Glasgow coma scale	0.92	0.89–0.95	< 0.001
AIS (grade > 3)			
Head	1.22	0.88–1.67	0.226
Abdomen	1.19	0.80–1.75	0.394
Spine	1.17	0.60–2.28	0.646
Upper extremity	0.98	0.78–1.23	0.878
Lower extremity	1.28	0.88–1.86	0.198
Comorbidities			
Congestive heart failure	1.11	0.52–2.36	0.790
Cerebrovascular accident	0.87	0.34–2.20	0.760
End-stage renal disease	3.97	1.80–8.74	0.001
Diabetes	1.79	1.23–2.32	0.001
Hypertension	1.28	0.86–1.70	0.093
COPD	1.64	1.11–2.43	0.013
Smoker	0.76	0.54–1.06	0.108

AIS abbreviated injury scale, *COPD* Chronic Obstructive Pulmonary Disease

Table 2 Clinical outcomes in adult patients with rib fractures undergoing rib fixation

Outcome	Age < 65 (n = 18,516)	Age ≥ 65 (n = 3001)	p value
LOS, days, median (IQR)	12 (7, 20)	13 (9, 20)	< 0.001
ICU, days, median (IQR)	6 (3, 13)	7 (4, 15)	< 0.001
Ventilator, days, median (IQR)	7 (3, 13)	8 (3, 15)	< 0.001
Complications, n (%)			
Acute kidney injury	373 (2.0%)	109 (3.6%)	< 0.001
Acute respiratory distress syndrome	662 (3.7%)	119 (4.0%)	0.289
Deep vein thrombosis	1027 (5.5%)	227 (7.6%)	< 0.001
Myocardial infarction	49 (0.3%)	49 (1.6%)	< 0.001
Pulmonary embolism	417 (2.3%)	61 (2.0%)	0.449
Unplanned intubation	699 (3.8%)	229 (7.6%)	< 0.001
Unplanned ICU admission	491 (2.7%)	139 (4.6%)	< 0.001
Pneumonia	2066 (11.2%)	367 (12.2%)	0.086
Disposition, n (%)			< 0.001
Home	9633 (53.0%)	652 (22.9%)	
Long term acute care	6477 (35.6%)	1293 (45.3%)	
Skilled nursing facility	2052 (11.3%)	892 (31.3%)	
Mortality, n (%)	213 (1.2%)	140 (4.7%)	< 0.001

LOS length of stay, *IQR* interquartile range, *ICU* intensive care unit

Table 4 Multivariable logistic regression analysis for risk of mortality in adult patients with isolated chest AIS = 3

Risk factor	OR	CI	*p* value
Age ≥ 65 vs. Age < 65 years-old	4.21	1.98–6.32	< 0.001

associated with an increased risk of mortality (OR 4.21, CI 1.98–6.32, *p* < 0.001) (Table 4).

Discussion

Our large national analysis, spanning 7 years of TQIP data, found an increase in the number of GTPs undergoing SSRF over time. When comparing GTPs to NGTPs, despite a lower ISS, there were more in-hospital complications, and ultimately an increased rate of mortality for GTPs. After adjusting for age, vitals, ISS, and comorbidities, GTPs undergoing SSRF were found to have an over four-fold increased associated risk of mortality, when compared to NGTPs undergoing SSRF. However, when comparing mortality risk between GTPs and NGTPs with a chest AIS of 3, GTPs were found to also have a four-fold increased associated risk of mortality. Given that the risk of mortality is the same between the two models, we would offer that SSRF does not add any additional risk of mortality.

As the literature continues to underscore the mortality benefit for SSRF, the use of SSRF has increased over time, particularly for GTPs [12]. In support of this, we found a greater than 7% increase from 2010 to 2016 in the use of SSRF for GTPs. Although we are the first study to show this national trend of SSRF in GTPs, other studies have provided data to support a growing interest in SSRF over time as the number of publications on SSRF has nearly increased tenfold over the past decade [4]. Likewise, SSRF has gained a significant boost from the introduction of dedicated new equipment and materials, with more surgeons becoming comfortable with the operative technique [17]. However, in Mullens et al.'s retrospective study using the Pennsylvania Trauma System Foundation database, only 57 patients underwent rib fixation out of 12,910 patients with multiple rib fractures in 2016–2017 [18], showing that regional trends still persist. Future research is needed to clarify whether this increase is related to a nation-wide increase in rate of SSRF in GTPs or simply increased volume at high-volume centers.

Multiple studies have shown that elderly patients in general have worse surgical or trauma outcomes, with higher rates of in-hospital complications and mortality. In Bulger et al.'s retrospective study comparing 277 GTPs to NGTPs, they found GTPs to have increased ventilator days, LOS, pneumonia, and a higher rate of mortality [13]. In support of this, we found that GTPs in general had a lower ISS, but had an increased rate of in-hospital complications, including nearly double the rate of AKI, nearly a five-fold rate of MI, and an almost 50% increase in rate of DVT. Furthermore, there was also a nearly four-fold increased rate of mortality. Although the GTP group had increased comorbidities, another likely cause is due to frailty, a decreased ability of the elderly patient to deal with stressors [19]. This decreased physiologic reserve, from less efficient adaptive and homeostatic mechanisms, likely contributes to an increased background rate of morbidity and mortality [20]. This is seen in Hashmi et al. systematic review and meta-analysis on GTPs, GTPs had a higher overall mortality rate than adult trauma patients; furthermore, patients older than 74 had a higher risk for mortality than the younger geriatric group [21].

Thus, even after controlling for multiple covariates, GTPs still have an increased risk of mortality. In a single-center retrospective study on rib fracture patients, Bergeron et al. found that GTPs had a lower ISS, however, a five-fold increased risk of mortality [22]. Furthermore, in our study, after controlling for age, ISS, vitals, and comorbidity, we found that GTPs undergoing SSRF still had an increased (greater than four-fold) associated risk of mortality when compared to NGTPs.

However, we wanted to clarify whether this increased risk of mortality was associated with SSRF rather than simply an increased risk of mortality from rib fracture alone. As we found that GTPs undergoing SSRF had a greater than four-fold risk of mortality in comparison to NGTPs, we ran a separate multivariate analysis comparing GTPs and NGTPs with chest AIS of 3 and no other injuries, and found that GTPs had a background four-fold risk of mortality than NGTPs. Given that there was a similar risk of mortality, we would offer than SSRF does not add significant risk of mortality to the GTP group. This is in line with an institutional experience by Fitzgerald et al. who first reported 23 GTPs who underwent SSRF, without any pneumonia or deaths within the operative group [14]. They went on to study 34 more GTPs who underwent SSRF, and also had no infections or deaths over a three-year span [20]. Although these were not compared to nonoperative controls, the rate of infection or death was significantly lower than expected from historic controls, and in the right patient, SSRF at least does not confer additional risk of mortality.

There are limitations to this study, including those inherent to a retrospective database study, such as missing data, input error, misclassification, and reporting bias. In addition, pertinent missing variables from this database include details of the SSRF operation, such as what prompted the decision to operate (flail chest or bi-cortical deformity), operative time, surgical service (trauma vs. orthopedic surgery vs. thoracic surgery) performing the operation, as well as timing to surgery. We are also missing data regarding withdrawal of care, time to death, and cause of death. Blood

product transfusion data, chest tube insertion rate, empyema, and retained hemothorax were not available. As well, data regarding thoracic epidural catheter use, used stabilization systems, and incidence of flail chest were absent. Need for other surgery and incidence of video-assisted thoracoscopic surgery were also unavailable. Finally, as a retrospective study, we are unable to make conclusions regarding cause and effect.

Conclusion

From 2010 to 2016, the proportion of GTPs undergoing SSRF increased by over 7%. Although GTPs undergoing SSRF had lesser injuries, their risk of mortality was four times higher than other adult trauma patients undergoing SSRF, which was similar to their increased background risk of mortality found with a chest AIS of 3. Ultimately, SSRF in GTPs should be considered on an individualized basis with careful attention to risk–benefit ratio.

Compliance with ethical standards

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