

Trends and Outcomes in Patients with Rib Fractures, 2016–2020: A Retrospective Cohort Study from the Nationwide Readmissions Database

Jarva Chow^{1,*}, Elizabeth R Hall^{1,*}, Hua She^{2,*}, Sajid Shahul^{1,*}

¹Department of Anesthesia and Critical Care, University of Chicago, Chicago, IL, USA; ²Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA, USA

*These authors contributed equally to this work

Correspondence: Jarva Chow, University of Chicago, Department of Anesthesia & Critical Care, 5841 S. Maryland Ave. MC4028, Chicago, IL, 60637, USA, Email jchow@bsd.uchicago.edu

Purpose: Readmissions are associated with worse patient outcomes, higher length of stay, and increased costs. Reducing unnecessary readmissions represents a significant opportunity for improving patient outcomes and healthcare delivery.

Patients and methods: This was a retrospective cohort study utilizing the Nationwide Readmissions Database (NRD), part of the United States Healthcare Cost and Utilization Project (HCUP). The NRD was queried to identify all adult (>18 years old) trauma patients with an admission diagnosis of rib fractures. Demographic and hospital data, comorbidities, as well as morbidity and mortality outcomes were collected.

Results: The 2016–2020 NRD identified 553,810 patients admitted with a diagnosis of rib fractures, with 65,244 of those patients readmitted within 30 days of discharge. Patients with rib fractures who were readmitted within 30 days were associated with 9-fold higher mortality over six months than if they were not readmitted. Patients with rib fractures were more likely to be readmitted from small or medium-sized hospitals ($p < 0.001$), had underlying depression (OR 1.42, 95% CI [1.34–1.51]), drug abuse (OR 1.23, 95% CI [1.13, 1.35]), chronic pulmonary disease (OR 1.49, 95% CI [1.41, 1.57]), and obesity (OR 1.22, 95% CI [1.13–1.31]). There was an association with higher readmission rates in patients with a single rib fracture compared with multiple rib fractures.

Conclusion: Patients readmitted within 30 days of discharge with rib fractures are associated with higher six-month mortality. Rib fractures are a common injury in trauma patients. Reducing unnecessary readmissions in this patient population may improve patient outcomes, satisfaction, and decrease healthcare costs.

Keywords: trauma, readmissions, risk factors, retrospective review, rib fractures

Introduction

Rib fractures are common in trauma patients, accounting for approximately 9% of trauma admissions annually and associated with significant morbidity and mortality.^{1,2} Costs associated with rib fracture hospitalizations are high, with an average cost per hospitalization in the United States of \$10,169, and have been increasing, with estimated overall costs at \$209 million in 2007 to \$469 million in 2016.³

Readmissions are associated with worse patient outcomes, higher length of stay, and increasing costs, representing a significant burden to both patients and healthcare systems.⁴ Additionally, the Hospital Readmissions Reduction Program (HRRP), introduced in 2010 under the Affordable Care Act, has further increased interest in readmissions as a quality indicator for hospitals reducing reimbursement for underperforming hospitals.^{5,6} Readmission rates thirty days from initial trauma admission have ranged from 7–30% in trauma patients,^{7,8} with no significant improvement since the

introduction of the HRRP.⁹ Identifying risk factors for readmissions in specific patient populations may represent a more effective method for improving outcomes.

Despite the implementation of the HRRP, significant knowledge gaps remain regarding readmission patterns in specific trauma populations, particularly for rib fractures. Mechanisms underlying readmissions in rib fracture patients are multifactorial and may include inadequate pain management leading to respiratory complications, premature discharge prior to adequate recovery of pulmonary function, insufficiency patient education, and lack of coordinated post-discharge care. Reducing unnecessary readmissions can improve outcomes, patient satisfaction, while improving the use of healthcare resources.^{4,7,9–11} Rib fractures are considered a marker of severe injury, associated with pulmonary insufficiency secondary to a variety of mechanisms including inadequate ventilation, atelectasis, and ineffective clearance of secretions.^{2,12,13} Given the significant morbidity and mortality associated with patients admitted with rib fractures and the associated pathophysiology, we hypothesize that there is an association between readmissions with rib fractures and mortality^{12,13} as well as factors associated with higher likelihood of readmissions. Rib fractures represent an ideal target for readmission reduction initiatives. Identifying modifiable risk factors for readmission in rib fracture patients could inform the development of targeted clinical pathways, enhance resource allocation, and potentially reduce both morbidity and healthcare expenditures. Using the Nationwide Readmissions Database (NRD), we evaluate outcomes and characterize risk factors for all-cause readmissions in patients with an index admission for rib fractures.

Methods

Study Design

We conducted a retrospective cohort study using the NRD for the years 2016 through 2020. The NRD is part of the United States Healthcare Cost and Utilization Project (HCUP) through the US Agency for Healthcare Research and Quality (AHRQ). It includes data from 31 states, 62.2% of the United States total resident population, and accounts for 60.8% of all hospitalizations. The NRD is a publicly available de-identified database, and the need for internal review board approval was waived for this study.

Ethics Approval

The Institutional Review Board at the University of Chicago Biological Sciences Division, University of Chicago Medical Center reviewed this project and declared it as exempt because statistical analyses were performed on de-identified information (IRB24-0211, PI: Jarva Chow).

Data Extraction

The NRD was queried to identify all adult (>18 years old) trauma patients with an admission diagnosis of rib fractures. Demographic and hospital data, comorbidities, as well as morbidity and mortality outcomes in the NRD were collected. Variables extracted include age, gender, and presence of operative procedure during index admission, payer, hospital characteristics and bed size, hospital ownership, and patient disposition. Using ICD-10 diagnosis codes with the open access “icdpicr” package, injury severity scores (ISS) were calculated. Diagnoses and procedures were tabulated using the International Classification of Disease, Tenth Revision (ICD-10) codes ([Supplemental Appendix A](#)). Readmissions through 30 days were collected. In the context of NRD, a readmission refers to any hospitalization occurring within 30 days of the index admission, for any cause and regardless of whether it is planned or unplanned. The NRD only includes patients who were admitted. Patients who were discharged from the emergency department or died prior to admission were excluded. Additionally, patients who died during their index admission were excluded. Data extraction was conducted using SAS software (Version 9.4; SAS Institute Inc., Cary, NC) with SAS load codes provided by HCUP Central Distributor (<https://hcup-us.ahrq.gov/db/nation/sasloadprog.jsp>) were slightly modified and used to read the Core, Hospital, Severity, DX_PR_GRPS raw data into SAS data set.

Statistical Analysis

Calculations of 30-day readmissions and 6-month mortality rates were conducted. Elixhauser Comorbidity Software Refined for ICD-10-CM data was not available for the data years 2016–2018; therefore, comorbidity data were only calculated for years 2019–2020. Categorical variables were compared using the chi-square test to examine the associations between demographic factors and 30-day readmission. Continuous variables were compared using the ANOVA test to evaluate the association between demographic factors and 30-day readmissions. Following initial univariate analyses that identified a subset of demographic factors exhibiting statistical significance with 30-day readmissions, these specific predictors were advanced to the next stage of modeling. A multivariable logistic regression model was employed to examine the independent contribution of each significant variable while simultaneously accounting for potential confounding factors. The primary purpose of this multivariable approach was to statistically control for baseline imbalances among the study participants. By adjusting for these covariates, the analysis aims to mitigate bias and provide more robust estimates of the true, isolated associations between the predictors and the outcome. Co-morbidity data was initially included; however, due to serious collinearity problems the data, including injury severity score, were not incorporated in the regression analysis. The decision to utilize 6-month mortality follow-up was due to several reasons. First, rib fractures are associated with prolonged recovery periods, with pain and pulmonary complications potentially extending well beyond the acute phase. Second, the 6-month timeframe allows for the capture of delayed complications and mortality related to the initial injury that may not manifest within 90 days. Third, this timeframe provides a more comprehensive assessment of the association between readmissions and mortality. Also, the NRD structure permits reliable tracking within calendar years up to 6 months, balancing clinical relevance and data availability. All statistical analysis was performed using R software (Version 4.3.1; R Core Team, 2023, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: <https://www.R-project.org>). Given the large sample size, the significance threshold was defined as $p < 0.001$.

Results

In the 2016 to 2020 NRD, there were 553,810 patients admitted with a diagnosis of rib fractures. Of those patients, 65,244 (11.8%) were readmitted within 30 days of discharge, while 488,566 (88.2%) were not readmitted (Table 1). Patients who were readmitted within 30 days were more likely to be older (median age 68 years old vs 64 years old, $p < 0.001$), have lower injury severity scores on index admission (median 10.0 vs 13.0, $p < 0.001$), and have Medicare insurance (59.1% vs

Table 1 Patient Demographics by 30-Day Readmission Status (2016–2020 NRD Data)

	No 30-day Readmission (N=488566)	30-day Readmissions (N=65244)	Total (N=553810)	p-value
Age				
Mean (SD)	62.4 (19.3)	66.3 (17.4)	62.9 (19.2)	<0.001
Median [Min, Max]	64.0 [18.0, 90.0]	68.0 [18.0, 90.0]	65.0 [18.0, 90.0]	
Gender				
Female	190751 (39.0%)	25,807 (39.6%)	216,558 (39.1%)	0.012
Male	297815 (61.0%)	39,437 (60.4%)	337,252 (60.9%)	
Length of stay				
Mean (SD)	7.70 (10.9)	9.09 (12.2)	7.87 (11.1)	<0.001
Median [Min, Max]	4.00 [0, 365]	5.00 [0, 346]	5.00 [0, 365]	
Presence of OR procedure on index admission				
Not present	208868 (42.8%)	25,863 (39.6%)	234,731 (42.4%)	<0.001
Present	279698 (57.2%)	39,381 (60.4%)	319,079 (57.6%)	
Injury severity score (ISS)				
Mean (SD)	16.7 (11.9)	15.4 (12.1)	16.5 (11.9)	<0.001
Median [Min, Max]	13.0 [0, 75.0]	10.0 [0, 75.0]	13.0 [0, 75.0]	

(Continued)

Table I (Continued).

	No 30-day Readmission (N=488566)	30-day Readmissions (N=65244)	Total (N=553810)	p-value
Payer				
Medicare	227823 (46.6%)	38,545 (59.1%)	266,368 (48.1%)	<0.001
Medicaid	65517 (13.4%)	9416 (14.4%)	74,933 (13.5%)	
Private insurance	137260 (28.1%)	12,245 (18.8%)	149,505 (27.0%)	
Self-pay	25095 (5.1%)	2135 (3.3%)	27,230 (4.9%)	
No charge	2724 (0.6%)	294 (0.5%)	3018 (0.5%)	
Other	28841 (5.9%)	2483 (3.8%)	31,324 (5.7%)	
Missing	1306 (0.3%)	126 (0.2%)	1432 (0.3%)	
Median household income				
0-25th percentile	127949 (26.2%)	17,642 (27.0%)	145,591 (26.3%)	<0.001
26th –50th percentile	128090 (26.2%)	17,093 (26.2%)	145,183 (26.2%)	
51st –75th percentile	121034 (24.8%)	15,832 (24.3%)	136,866 (24.7%)	
76th –100th percentile	103754 (21.2%)	13,758 (21.1%)	117,512 (21.2%)	
Missing	7739 (1.6%)	919 (1.4%)	8658 (1.6%)	
Hospital characteristics				
Large metropolitan areas with at least 1 million residents	259779 (53.2%)	36,370 (55.7%)	296,149 (53.5%)	<0.001
Small metropolitan areas with less than 1 million residents	199641 (40.9%)	24,988 (38.3%)	224,629 (40.6%)	
Micropolitan areas	21911 (4.5%)	2932 (4.5%)	24,843 (4.5%)	
Not metropolitan or micropolitan (non-urban residual)	7235 (1.5%)	954 (1.5%)	8189 (1.5%)	
Hospital bed size				
Small	58051 (11.9%)	8755 (13.4%)	66,806 (12.1%)	<0.001
Medium	120251 (24.6%)	16,978 (26.0%)	137,229 (24.8%)	
Large	310264 (63.5%)	39,511 (60.6%)	349,775 (63.2%)	
Hospital ownership				
Government, nonfederal	81426 (16.7%)	9757 (15.0%)	91,183 (16.5%)	<0.001
Private, not-profit	350657 (71.8%)	47,052 (72.1%)	397,709 (71.8%)	
Private, invest-own	56483 (11.6%)	8435 (12.9%)	64,918 (11.7%)	
Patient disposition				
Routine	245171 (50.2%)	23,673 (36.3%)	268,844 (48.5%)	<0.001
Transfer to short-term hospital	5350 (1.1%)	1813 (2.8%)	7163 (1.3%)	
Transfer other: includes Skilled Nursing Facility (SNF), Intermediate Care Facility (ICF), and another type of facility	146752 (30.0%)	24,987 (38.3%)	171,739 (31.0%)	
Home Health Care (HHC)	84423 (17.3%)	12,808 (19.6%)	97,231 (17.6%)	
Against medical advice (AMA)	6763 (1.4%)	1961 (3.0%)	8724 (1.6%)	
Discharged alive, destination unknown, beginning in 2001	107 (0.0%)	2 (0.0%)	109 (0.0%)	
Risk of Mortality Subclass				
Minor	173637 (35.5%)	13,534 (20.7%)	187,171 (33.8%)	<0.001
Moderate	149905 (30.7%)	19,807 (30.4%)	169,712 (30.6%)	
Major	109219 (22.4%)	20,771 (31.8%)	129,990 (23.5%)	
Extreme	55779 (11.4%)	11,127 (17.1%)	66,906 (12.1%)	
Missing	26 (0.0%)	5 (0.0%)	31 (0.0%)	
Severity of Illness Subclass				
Minor	73539 (15.1%)	6485 (9.9%)	80,024 (14.4%)	<0.001
Moderate	152259 (31.2%)	15,584 (23.9%)	167,843 (30.3%)	
Major	188610 (38.6%)	28,971 (44.4%)	217,581 (39.3%)	
Extreme	74132 (15.2%)	14,199 (21.8%)	88,331 (15.9%)	
Missing	26 (0.0%)	5 (0.0%)	31 (0.0%)	

Notes: p<0.001 considered statistically significant.

46.6%, $p<0.001$). These differences remained significant after controlling for other variables (Table 2). Discharge dispositions other than routine discharge were associated with higher rates of readmission including discharge to skilled nursing facilities (38.3% vs 30.0%), home health care (19.6% vs 17.3%), and leaving against medical advice (3.0% vs 1.4%),

Table 2 Adjusted 30-Day Readmission Rates for Rib Fractures (NRD 2016–2020)^a

Characteristic	OR ^b	95% CI ^b	p-value ^c
<i>Number of rib fractures</i>			
Multiple rib	REF	REF	
One rib	1.149	1.116, 1.184	<0.001
<i>Demographics</i>			
Age	1.005	1.004, 1.006	<0.001
Gender			
Female	REF	REF	
Male	1.101	1.074, 1.127	<0.001
<i>Clinical factors</i>			
Length of stay (LOS)	1.004	1.003, 1.005	<0.001
Risk of Mortality Subclass ^d			
Minor	REF	REF	
Moderate	1.376	1.331, 1.422	<0.001
Major	1.680	1.612, 1.751	<0.001
Extreme	1.692	1.593, 1.796	<0.001
Severity of Illness Subclass			
Minor	REF	REF	
Moderate	1.133	1.090, 1.179	<0.001
Major	1.336	1.281, 1.394	<0.001
Extreme	1.412	1.327, 1.502	<0.001
Maximum AIS severity over all ISS body regions			
Minor	REF	REF	
Moderate	0.840	0.788, 0.896	<0.001
Serious	0.691	0.661, 0.721	<0.001
Severe	0.628	0.595, 0.662	<0.001
Critical	0.642	0.610, 0.676	<0.001
Patient disposition			
Routine	REF	REF	
Transfer to short-term hospital	3.044	2.779, 3.338	<0.001
Transfer other includes Skilled Nursing Facility, intermediate care facility	1.253	1.216, 1.292	<0.001
Intermediate Care Facility (ICF), and another type of facility			
Home Health Care (HHC)	1.205	1.166, 1.246	<0.001
Against medical advice (AMA)	2.644	2.434, 2.874	<0.001
Discharged alive, destination unknown, beginning in 2001	0.240	0.036, 0.942	0.070
<i>Financial factors</i>			
Payer			
Medicare	REF	REF	
Medicaid	1.035	0.993, 1.080	0.110
Private insurance	0.693	0.670, 0.717	<0.001
Self-pay	0.703	0.659, 0.749	<0.001
No charge	0.935	0.793, 1.101	0.400
Other	0.644	0.607, 0.682	<0.001
Median household income			
0–25th percentile	REF	REF	
26th –50th percentile	0.957	0.928, 0.987	0.006
51st –75th percentile	0.914	0.885, 0.944	<0.001
76th –100th percentile	0.890	0.859, 0.922	<0.001

(Continued)

Table 2 (Continued).

Characteristic	OR ^b	95% CI ^b	p-value ^c
<i>Hospital characteristics</i>			
Hospital characteristics			
Large metropolitan areas with at least 1 million residents	REF	REF	
Small metropolitan areas with less than 1 million residents	0.891	0.869, 0.913	<0.001
Micropolitan areas	0.916	0.864, 0.970	0.003
Not metropolitan or micropolitan (non-urban residual)	0.886	0.803, 0.978	0.016
Hospital bed size			
Small	REF	REF	
Medium	0.961	0.923, 0.999	0.046
Large	0.934	0.901, 0.969	<0.001
Hospital ownership			
Government, nonfederal	REF	REF	
Private, not-profit	1.049	1.015, 1.083	0.004
Private, invest-own	1.157	1.107, 1.210	<0.001

Notes: ^aThe table includes all variables in the multivariable analysis. ^bp<0.001 considered statistically significant. ^cp<0.001 considered statistically significant. ^dRisk of mortality subclass is a severity measure using the all patient refined diagnosis related group, severity of illness subclass, and calculates a risk of mortality subclass. https://hcup-us.ahrq.gov/db/vars/aprdrgrisk_mortality/nrdnote.jsp.

Abbreviations: OR, Odds Ratio; CI, Confidence Interval.

Table 1). These differences remained significant after controlling for other variables (Table 2). When the index admission for patients were to small or medium sized hospitals, patients were more likely to be readmitted within 30 days compared with admissions to large hospitals (Table 1). Additionally, patients admitted with rib fractures were more likely to be readmitted when discharged from private non-profit and with private investment-owned hospitals compared with government hospitals (Table 1). These differences remained largely true after multivariate analysis (Table 2).

Patients who also had underlying depression (OR 1.42, 95% [1.34, 1.51]), drug abuse (OR 1.23, 95% CI [1.13, 1.35]), chronic pulmonary disease (OR 1.49, 95% CI [1.41–1.57]), obesity (OR 1.22, 95% CI [1.13–1.31]), peripheral vascular disease (OR 1.20, 95% CI [1.11, 1.31]), and leukemia (OR 1.72, 95% CI [1.32–2.23]) who presented with an initial diagnosis of rib fractures were more likely to be readmitted within 30 days (Table 3).

Table 3 Elixhauser Comorbidities Odds Ratios (OR) and 95% Confidence Intervals (CI) for Readmission Versus No Readmission (NRD 2019–2020)

Variables	Odds Ratio	95% CI for OR
Acquired immune deficiency syndrome	1.33	[0.96, 1.85]
Alcohol abuse	1.03	[0.97, 1.11]
Autoimmune conditions	1.23	[1.03, 1.47]
Lymphoma	1.33	[1.05, 1.69]
Leukemia	1.72	[1.32, 2.23]
Metastatic cancer	1.08	[0.89, 1.30]
Solid tumor without metastasis, malignant	1.25	[1.07, 1.45]
Dementia	1.10	[1.02, 1.19]
Depression	1.42	[1.34, 1.51]
Diabetes without chronic complications	1.13	[1.04, 1.22]
Diabetes with chronic complications	1.32	[1.24, 1.41]
Drug abuse	1.23	[1.13, 1.35]
Hypertension, complicated	1.40	[1.33, 1.48]
Hypertension, uncomplicated	1.03	[0.98, 1.08]
Chronic pulmonary disease	1.49	[1.41, 1.57]
Obesity	1.22	[1.13, 1.31]
Peripheral vascular disease	1.20	[1.11, 1.31]
Hypothyroidism	1.16	[1.08, 1.24]

Table 4 Readmissions by Rib Fracture Groups

	Multiple rib Fractures	One rib fracture	p-value
30-day readmission for all disease (NRD 2016 Data)			
Yes	8119 (11.3%)	3220 (13.4%)	<0.001
No	63973 (88.7%)	20,860 (86.6%)	
30-day readmission for all disease (NRD 2017 Data)			
Yes	9105 (11.4%)	3455 (13.4%)	<0.001
No	70946 (88.6%)	22,353 (86.6%)	
30-day readmission for all disease (NRD 2018 Data)			
Yes	9516 (11.2%)	3463 (13.4%)	<0.001
No	75152 (88.8%)	22,380 (86.6%)	
30-day readmission for all disease (NRD 2019 Data)			
Yes	10432 (11.2%)	3788 (13.6%)	<0.001
No	82655 (88.8%)	23,999 (86.4%)	
30-day readmission for all disease (NRD 2020 Data)			
Yes	10574 (11.3%)	3572 (13.2%)	<0.001
No	82860 (88.7%)	23,388 (86.8%)	

Notes: $p < 0.001$ considered statistically significant.

Patients who had a single rib fracture on their index admission were more likely to be readmitted compared with patients with multiple rib fractures on their index admission across all years studied (Table 4, Figure 1). This association persisted after controlling for other variables (Table 2). Additionally, patients with rib fractures who were readmitted within 30 days were associated with higher 6-month mortality across all five years studied compared with patients not readmitted (Figure 2). Patients with rib fractures who were readmitted were associated with 9-fold higher 6-month

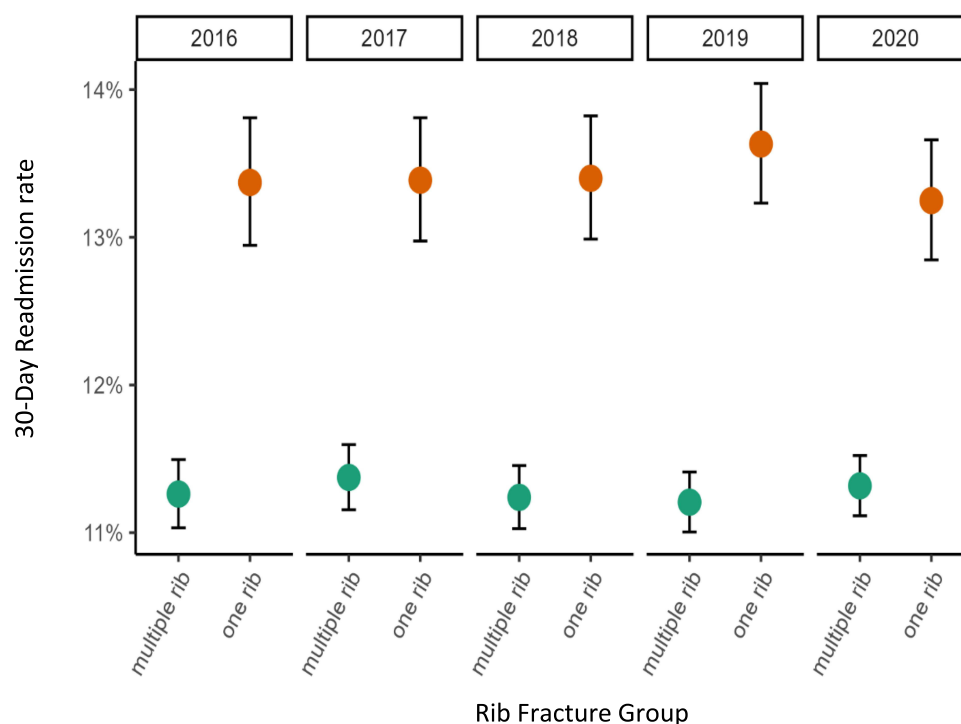


Figure 1 30-Day Readmission Rate by Rib Fracture Group. Visualization of data in Table 4; 2016: $n=96172$, $p < 0.001$; 2017: $n=105859$, $p < 0.001$; 2018: $n=110511$, $p < 0.001$; 2019: $n=120874$, $p < 0.001$; 2020: $n=120394$, $p < 0.001$.

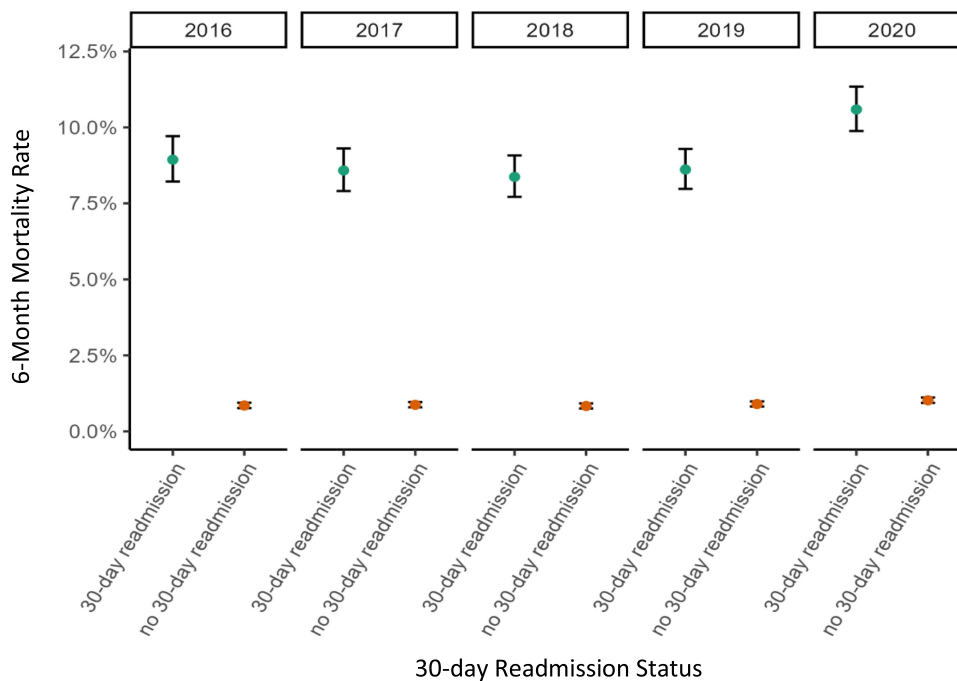


Figure 2 6-Month Mortality by Readmission Status. 2016: n=48234, $p < 0.001$; 2017: n=53344, $p < 0.001$; 2018: n=55593, $p < 0.001$; 2019: n=60870, $p < 0.001$; 2020: n=58573, $p < 0.001$.

mortality from their initial discharge than if they were not readmitted (Figure 2, Table 5). This was observed in each of the years studied, with higher mortality observed in 2020 compared with other years. These differences remained significant after performing regression analysis for 6-month and 60-day mortality (Supplemental Appendices B and C).

Table 5 6-Month Mortality Rate by Readmission Status

Rib Fracture Patient Mortality Rate Between Different Readmission Groups (NRD 2020 Data)				
	30-day readmission (N=6979)	No 30-day readmission (N=51594)	Total (N=58573)	p-value
DIED				
Yes	739 (10.6%)	527 (1.0%)	1266 (2.2%)	<0.001
No	6240 (89.4%)	51,067 (99.0%)	57,307 (97.8%)	
Rib Fracture Patient Mortality Rate Between Different Readmission Groups (NRD 2019 Data)				
	30-day readmission (N=7129)	No 30-day readmission (N=53741)	Total (N=60870)	p-value
DIED				
Yes	614 (8.6%)	483 (0.9%)	1097 (1.8%)	<0.001
No	6515 (91.4%)	53,258 (99.1%)	59,773 (98.2%)	
Rib Fracture Patient Mortality Rate Between Different Readmission Groups (NRD 2018 Data)				
	30-day readmission (N=6523)	No 30-day readmission (N=49070)	Total (N=55593)	p-value
DIED				
Yes	546 (8.4%)	409 (0.8%)	955 (1.7%)	<0.001
No	5977 (91.6%)	48,661 (99.2%)	54,638 (98.3%)	

(Continued)

Table 5 (Continued).

Rib Fracture Patient Mortality Rate Between Different Readmission Groups (NRD 2017 Data)				
	30-day readmission (N=6269)	No 30-day readmission (N=47075)	Total (N=53344)	p-value
DIED				
Yes	538 (8.6%)	411 (0.9%)	949 (1.8%)	<0.001
No	5731 (91.4%)	46,664 (99.1%)	52,395 (98.2%)	
Rib Fracture Patient Mortality Rate Between Different Readmission Groups (NRD 2016 Data)				
	30-day readmission (N=5741)	No 30-day readmission (N=42493)	Total (N=48234)	p-value
DIED				
Yes	513 (8.9%)	361 (0.8%)	874 (1.8%)	<0.001
No	5228 (91.1%)	42,132 (99.2%)	47,360 (98.2%)	

Notes: p<0.001 considered statistically significant.

Discussion

In a large national cohort of patients hospitalized with rib fractures, 11.8% were readmitted within 30 days. Independent predictors of presentation associated with 30-day readmission included drug abuse, chronic pulmonary disease, depression, leukemia, and peripheral vascular disease. We also found that patients who had a single rib fracture on their index admission were more likely to be readmitted compared with patients with multiple rib fractures. Patients who were readmitted within 30 days with rib fractures were associated with a 9-fold increase in mortality compared with patients who were not readmitted. In 2020, patients readmitted within 30 days with rib fractures had a higher mortality rate than in other years. COVID-19 may have contributed to this increase, a possibility that warrants detailed investigation on its own.

The results of this study identified factors associated with higher rates of readmission related to patients' comorbidities. Factors associated with higher likelihood of readmission in this study included underlying depression, dementia, drug use, obesity, chronic pulmonary disease, and leukemia. Surprisingly, alcohol abuse was not associated with increased likelihood of readmissions. Neiman and colleagues found underlying comorbidities to be more strongly associated with higher readmissions than the severity of the admission injury.⁹ Further evaluation of comorbidities and readmissions may require prospective studies to more fully elucidate any relationship.

It is noteworthy that there was an association with higher readmission rates in patients with a single rib fracture compared with multiple rib fractures, and lower injury severity scores (ISS) compared with higher ISS (Table 1, Table 4, Figure 1). The counterintuitive finding that patients with single rib fractures had higher readmission rates than those with multiple rib fractures warrants particular attention. This may reflect systematic under-triage of patients with isolated injuries, leading to shorter lengths of stay, less intensive pain management, and premature discharge before adequate recovery of respiratory function. Patients with single rib fractures may require the same vigilant attention to pain control, pulmonary hygiene, and discharge planning as those with more extensive injuries. Of note, we did not exclude polytrauma cases from the analysis. We reported the association of one rib fracture with higher rates of readmissions, which is not necessarily indicative of a causal relationship. Additional trauma or other underlying conditions may have contributed to the higher readmission rates observed in patients with one rib fracture. While Harcombe and colleagues found a longer LOS less associated with readmission, Baker et al found a longer LOS more likely to be associated with readmission.^{1,8} We similarly found a longer LOS (mean 9.09 days, median 5.0 days) to be more likely to be associated with higher 30-day readmissions compared with a shorter LOS (mean 7.70 days, median 4.0 days, Table 1). In the multivariable analysis, after adjustment of relevant confounders, increased length of stay remained associated with increased odds of readmission (OR 1.004, Table 2). These findings could be for a variety of reasons. Patients with multiple rib fractures may require higher intensity care for more extensive injuries that require closer follow-up. These patients may have additional injuries that require more aggressive management of the respiratory insufficiency that is

associated with rib fractures. Our findings suggest patients with lower injury severity scores and rib fractures may also require high-intensity discharge planning with close follow-up to minimize unnecessary readmissions. Additionally, patients with more severe injuries may be more likely to die rather than presenting for readmission. Finally, injury severity may simply not be associated with readmissions.

Our findings have several important implications for clinical practice and discharge planning in patients with rib fractures. The identification of specific risk factors including depression and chronic obstructive pulmonary disease, drug abuse, and obesity can provide an evidence-based framework for pre-discharge risk stratification. The association between specific comorbidities and readmission risk suggests opportunities for early intervention. Patients with chronic pulmonary disease should be evaluated by pulmonology specialists prior to discharge, patients with depression may benefit from psychiatric consultation, medication optimization, and enhanced social support services prior to discharge. Pain management represents a critical target for readmission prevention. Inadequate analgesia in rib fracture patients leads to splinting, hypoventilation, atelectasis, and pneumonia, all of which have potential to increase readmissions. Our findings suggest that discharge protocols should be comprehensive and individualized, potentially including multimodal analgesia, regional techniques, and clear plans for outpatient pain management. For patients with substance use disorders, addiction medicine specialists or pain management teams experienced in treating patients with complex pain and substance use histories should be involved. Trauma centers should consider implementing a standardized risk assessment tool that incorporates these factors to identify patients at highest risk for readmission, enabling targeted allocation of resources and more intensive post-discharge follow-up.

Previous studies have excluded trauma patients with a single rib fracture from their analysis of readmission rates.¹ This may represent an assumption that less severe injury is associated with less morbidity, whereas we found higher 30-day readmission rates in patients with single rib fractures compared with multiple rib fractures. Efforts to reduce hospital readmissions for less severe injuries often involve improving communication between healthcare providers, enhancing patient education, implementing effective discharge planning, and addressing social determinants of health.^{7,9–11} Establishing strong connections between hospitals and community-based healthcare services can also contribute to improving post-discharge care and reduce the likelihood of readmissions.^{7,10}

From a healthcare policy perspective, our findings support several recommendations. First, expansion of HRRP metrics to include trauma-specific diagnosis such as rib fractures. Current HRRP measures focus primarily on medical conditions and may not adequately capture the unique challenges of trauma patients. Second, reimbursement models that support comprehensive discharge planning and post-discharge surveillance. Current models may not adequately compensate hospitals for the time-intensive care coordination required for high-risk trauma patients. Bundled payment models that post-discharge time periods may incentivize hospitals to invest in readmission prevention programs. Quality metrics specific to rib fracture care, including adequate pain management, pulmonary complication rates, and functional recovery would allow for more meaningful comparisons across institutions and identify opportunities for improvement. Finally, research funding for prospective trials of readmission prevention interventions in trauma populations. While our retrospective study identifies risk factors, rigorous testing of specific interventions is necessary to guide evidence-based practice.

This study has several limitations. The NRD is an administrative database subject to errors in data reporting and coding. We were unable to differentiate between planned and unplanned readmissions, or whether the readmission was related to the initial injury. Additionally, patients are not followed across different years in the NRD, therefore data for patients readmitted across calendar years were not captured. The NRD is able to follow patients readmitted to different hospitals but does not track readmissions across state lines and may miss readmissions to different states from the index admission. The retrospective nature of this study can only identify associations with readmissions but cannot establish causality. Notably, comorbidity data are not available prior to 2019. Therefore, we examined their association with readmissions only in the combined 2019–2020 dataset (Table 3). In addition, we used the `vif()` function from the *car* package to calculate the Variance Inflation Factor (VIF) for each predictor in the model. The VIF quantifies the extent to which the variance of a regression coefficient is inflated due to collinearity with other predictors. The VIF for ISS score reached as high as 149 in some models, well above the commonly used cutoff of 5, indicating severe multicollinearity. For this reason, ISS score was not included in the multivariate analysis. Our study period also

includes 2020, coinciding with the COVID-19 pandemic, which substantially altered healthcare delivery and patterns. The pandemic may have affected our findings in several ways. Hospital admission thresholds may have increased, with more patients managed as outpatients to preserve hospital capacity, potentially increasing our cohort for 2020 with more severely injured patients. Patients may have been more hesitant to seek care for post-discharge complications, leading to underestimation of readmission rates or delayed readmissions. Also, competing mortality risks from COVID-19 infection may have influenced six-month mortality rates, particularly in older patients and those with multiple comorbidities. While we cannot fully quantify these effects with the available data, 2020 trends should be interpreted with these contextual factors in mind. Future studies examining post-pandemic readmission patterns would be valuable to determine whether trends have normalized or whether practice changes implemented during the pandemic have had lasting effects on care delivery.

However, the NRD remains the largest database for tracking readmissions in the United States created to help analyze national readmissions. Our results may help identify risk factors in patients admitted with rib fractures to facilitate hypothesis generation in reducing preventable readmissions in this patient population.

Conclusion

Rib fractures are a common injury in trauma patients and are associated with significant morbidity and mortality, healthcare costs, and readmission following index hospital stay. There are many factors associated with increased risk of readmission after rib fracture injury, including comorbidities such as obesity, underlying pulmonary disease, drug use, and depression. Our study also demonstrated an unexpected association with increased readmission rates in patients with a single rib fracture compared with patients with multiple rib fractures. This somewhat unanticipated finding challenges current theories and has potential implications for future research regarding discharge resources and follow-up planning for trauma patients. This large-scale national study demonstrates that 30-day readmission following rib fracture hospitalization is associated with a nine-fold increase in six-month mortality, underscoring readmission prevention as a critical patient safety priority rather than merely a cost-containment measure. With over 553,000 patients admitted annually for rib fractures in the United States, and an 11.8% readmission rate, even modest improvements in readmission prevention could substantially impact patient outcomes, healthcare costs, and quality of life.

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Disclosure

The authors report no conflicts of interest in this work.

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