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Fixation of rib fractures is beneficial for patients with chronic obstructive pulmonary disease, a trauma quality improvement program study

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Abstract

Background Internal fixation for multiple rib fractures is well established. Patients with underlying chronic obstructive pulmonary disease (COPD) have a higher rate of perioperative complications. It is unclear if these patients are suitable candidates for internal fixation and if surgical interventions are harmful to these patients.

Study Design and methods Adult patients with ≥ 3 rib fractures and underlying COPD from the Trauma Quality Improvement Program between 2017 and 2019 were eligible for inclusion. The patients were divided into two treatment groups: operative and non-operative. Furthermore, inverse probability treatment weighting was applied to analyze mortality and adverse hospital events.

Results Patients with COPD in the operative group had higher ventilator use (odds ratio [OR], 3.211; 95% confidence interval [CI], 1.993–5.175; $p < 0.001$). Additionally, they had a longer length of stay (coefficient β, 4.139; standard error, 0.829; $p < 0.001$) and longer ventilator days (coefficient β, 1.937; standard error, 0.655; $p = 0.003$) than in the non-operative group. Furthermore, the mortality rate was lower in the operative group than in the non-operative group (OR, 0.426; 95% CI, 0.228–0.798; $p = 0.008$).

Conclusion Internal fixation of rib fractures plays a crucial role in patients with underlying COPD disease. They presented a better mortality rate without an increased perioperative complication rate.

Keywords Rib fracture, Internal fixation, Chronic obstructive pulmonary disease

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Introduction

Internal fixation is one of the standard treatments for rib fractures [1, 2]. Evidence indicates improved clinical outcomes such as mortality, length of stay (LOS), and the in-hospital pneumonia rates [3, 4]. Hence, better pain control with concomitantly better pulmonary hygiene, resulting from more tolerable rehabilitation exercises, plays a crucial role in treatment practice [5, 6].

However, patients with chronic obstructive pulmonary disease (COPD) are vulnerable to surgery, and perioperative complication rates were significantly higher in these patients than in patients without COPD [7]. Therefore, when clinicians consider elective surgery, careful consideration is necessary because of high postoperative pulmonary complication rates [8]. Moreover, other unwanted events may occur, such as deep vein thrombosis, due to prolonged hospitalization [9].

Hence, the question remains whether elective surgery should be performed in patients with underlying COPD who experience multiple rib fractures. Further, we need to examine whether the perioperative surgical risk or the benefits of internal fixation has a more determined influence on these patients.

In this novel study, we selected patients with ≥3 rib fractures as our target group as they are considered to be a potential group that could benefit from surgical intervention. Additionally, previous studies used≥3 fractures to define major blunt chest wall injuries [3]. Therefore, we used the national database of the American College of Surgeons (ACS) Trauma Quality Improvement Program (TQIP) to answer this question.

Patients and methods

Study population

Figure 1 depicts the patient enrollment protocol. This research applied data from the TQIP for the period 2017–2019. All the diagnosis was under the Abbreviated Injury Scale (AIS) code. All patients with ≥3 ribs fracture (Supplementary Table 1) and COPD were included. We focused on fractures of more than three ribs on one side and did not include the AIS code (45023 in AIS version 2005 and 2015) that may account for three ribs combined bilaterally. AIS codes for severe internal organ injury of the head with AIS severity of ≥4, 6 (untreatable), or 9 (impossible to assign) were excluded (all AIS codes for internal organ injury: Supplementary Table 2). Other exclusion criteria were age<18 years or unknown age, trauma mechanisms other than blunt or unknown mechanisms, arrival at the emergency department (ED) with no signs of life or unknown signs of life, data not from the ACS verification level I or II facilities or unknown facility level [10], patients underwent inter-hospital transferring, or discharge disposition labeled not known/not recorded (NK/NR) from ED, or mortality cases at the ED. The AIS codes of associated thoracic and abdominal injuries (see ***covariate selection***) with an AIS severity of 6 or 9, hospital events of patients, pre-existing conditions, discharge disposition, ventilator days, and labeled NK/NR were excluded. Patients with unavailable LOS were also excluded. Additionally, patients who died within one day of admission and those with missing covariate data were excluded from the study. These covariates, including systolic blood pressure (SBP), pulse rate (PR), respiratory rate (RR), blood oxygen saturation, and Glasgow Coma Scale (GCS), had missing values of <4%. (see ***covariate selection***) Two groups of patients were divided based on the intervention of rib fixation or not: non-operative and operative groups. This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (approval number 20220- 1144B0), and the need for informed consent was waived.

Covariate selection

Patient demographics, including age, sex, and information on patient conditions in the ED, including ED SBP, PR, RR, blood oxygen saturation, and GCS, were collected. Information about the injuries of the patients was collected, including the AIS of ≥3 rib fractures, Injury Severity Score (ISS), and injury mechanism. Associated injuries, including internal organ injury of the head, thoracic injury (4XXXXX, except superficial injuries [skin/subcutaneous/muscle, pectoral muscle, and breast injury], Supplementary Table 3), and abdominal injury (5XXXXX, except superficial injuries [skin/subcutaneous/muscle, rectus abdominus, and vulva], Supplementary Table 4) were gathered. ACS verification facility level was recorded. The following nine target outcomes were recorded: mortality, unplanned intubation, ventilator days, ventilator-associated pneumonia (VAP), ventilator use, LOS, pulmonary embolism, pressure ulcers, and deep vein thrombosis. Mortality and following clinical course in hospice care were recognized as mortality [10]. Six pre-existing conditions that may influence the target outcomes including current angina pectoris, smoking, diabetes mellitus, chronic renal failure, bleeding disorders and anticoagulant therapy were documented. For patient accepted rib fixation, the time interval from ED to the procedure was recorded.

Statistical analyses

Categorical covariates were presented as absolute numbers (percentages), and continuous covariates presented as medians [first and third quartiles]. Chi-squared test was used for categorical variables were examined using the chi-squared test with continuity correction. Continuous variables were compared using the Mann–Whitney U test. Furthermore, inverse probability treatment weighting (IPTW) was applied for all pretreatment factors for

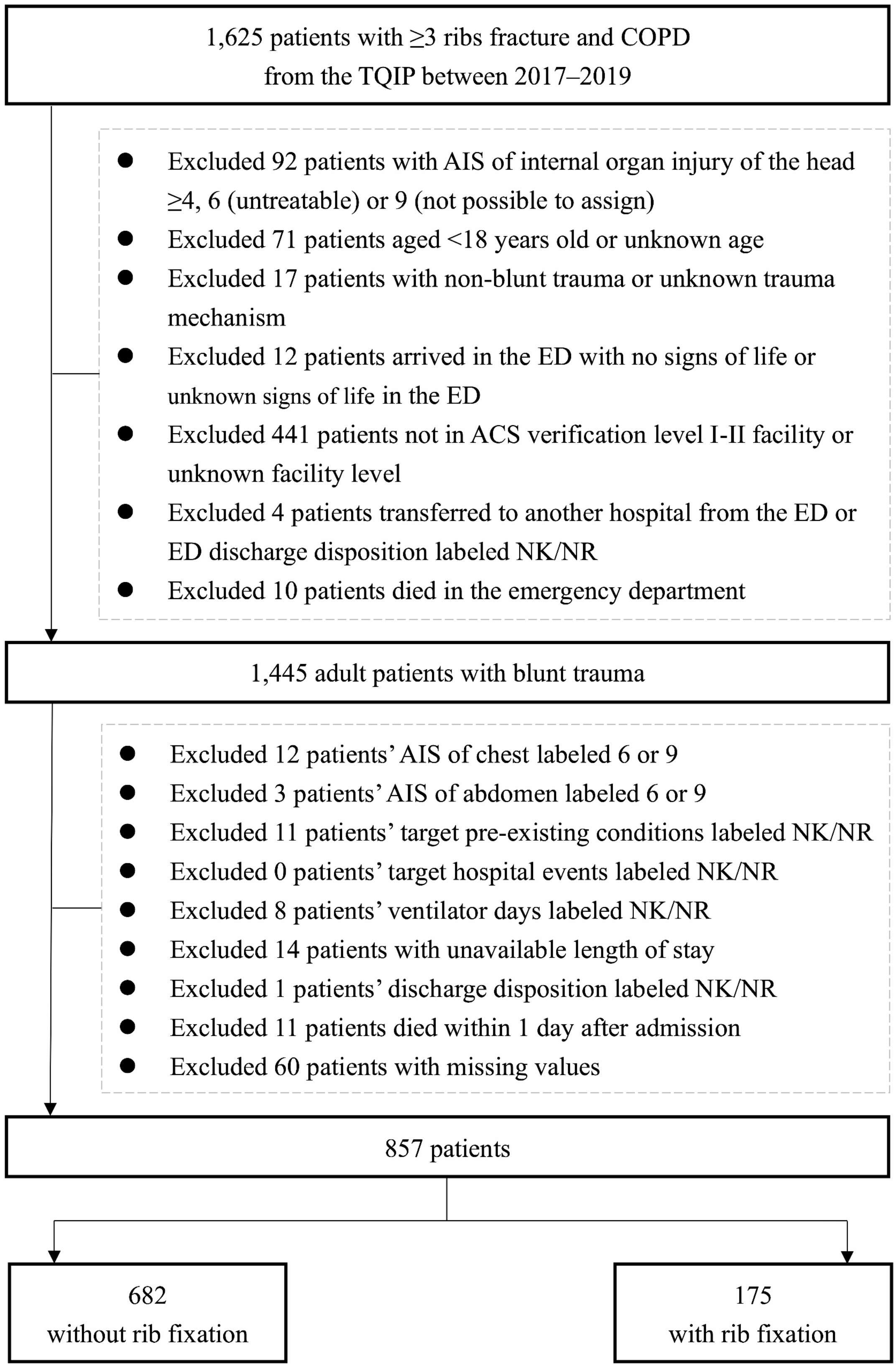

Fig. 1 Patient enrollment procedure. ACS, American College of Surgeons; AIS, Abbreviated Injury Scale; COPD, chronic obstructive pulmonary disease; ED, emergency department; NK/NR, not known/not recorded; TQIP, Trauma Quality Improvement Program

all patients. And IPTW was used to evaluated the main outcomes. Outcomes that are significant (except ventilator days and LOS) after IPTW, and then significant factors predicting these significant outcomes in the univariate analysis were further analyzed using multivariate binomial logistic regression. All pretreatment factors were further analyzed using multivariate linear logistic regression for significant continuous target outcomes (ventilator days or LOS). Statistical significance was set at $p<0.05$. All statistical analyses were performed using the R software (version 2022.12.0+353).

Results

This study included total of 857 patients with ≥3 rib fractures and COPD. And 682 patients (79.6%) were in non-operative group and 175 (20.4%) were in the operative groups. The median age was 68.0 years and the median ISS was 17.0. The overall mortality rate was 13.5%. Table 1 reveals the data of all patients and subgroups of patients with and without surgery. Patients in the operative group had a lower SBP (133.0 vs. 138.0 mm-Hg; $p=0.042$), and higher PR (93.0 vs. 88.0/min; $p=0.023$),and higher RR (20.0 [18.0, 25.0] vs. 20.0 [18.0, 23.8]/min; $p=0.012$), higher ISS (20.0 vs. 17.0; $p=0.005$), and less falling mechanism was found (33.7% vs. 49.9%; $p<0.001$) than the non-operative group. In studying the thoracic injury, the operative group has higher AIS of thoracic injury other than ≥3 rib fractures than the non-operative group (AIS 1–3: 81.7% vs. 71.3%; AIS 4–5: 14.3% vs. 9.4%; $p<0.001$). The concomitant thoracic injury is more severe in the operative group than the non-operative group. There were no statistical differences in the AIS of ≥3 rib fractures between groups.

The differences in AIS scores for abdominal injury and pre-existing conditions among the groups weren't statistically significant. However, patients in the surgical group displayed distinct patterns: a higher unplanned intubation rate (20.6% vs. 11.4%; $p=0.002$), increased ventilator use (64.6% vs. 38.0%; $p<0.001$), extended ventilator days (3.0 vs. 0.0 days; $p<0.001$), prolonged LOS (16.0 vs. 9.0 days; $p<0.001$), and a lower mortality rate (8.6% vs. 14.8%; $p=0.043$) compared to the non-operative group. Furthermore, the study highlighted that the mean time interval for rib fixation was 71.5 h.

Additionally, we conducted IPTW comparisons between patients who underwent surgery and those who didn't, finding no significant differences in pretreatment factors (all standardized mean differences>0.1; Supplementary Table). Table 2 presents the outcomes post-IPTW for both groups. Notably, the operative group exhibited a significantly lower mortality rate compared to the non-operative group (6.6% vs. 14.9%; $p=0.002$). However, they also experienced a higher rate of unplanned intubation (19.9% vs. 11.5%; $p=0.012$), increased ventilator usage (59.8% vs. 39.8%; $p<0.001$), longer ventilator dependency (2.0 vs. 0.0 days; $p<0.001$), and an extended LOS (14.8 vs. 10.0 days; $p<0.001$).

Our analysis delved into factors influencing these outcomes. Supplementary Tables 6, 7, and 8 outline the univariate comparison findings for mortality, ventilator usage, and unplanned intubation. Furthermore, Table 3 presents the results of a multivariate analysis post-IPTW in patients who underwent surgery and those who did not.

Factors significantly impacting mortality rates included age, GCS, ISS, presence of ≥3 ribs fractures according to AIS, AIS of thoracic injury (excluding≥3 ribs fractures), angina pectoris, and rib fixation (odds ratio [OR], 0.426; 95% confidence interval [CI], 0.228–0.798; $p=0.008$). Ventilator usage was influenced by SBP, RR, GCS, ISS, injury mechanism (motor vehicle transportation), and rib fixation (OR, 3.211; 95% CI, 1.993–5.175; $p<0.001$). Unplanned intubation was primarily associated with rib fixation (OR, 1.895; 95% CI, 1.139–3.153; $p=0.014$).

Factors contributing to LOS and ventilator duration are outlined in Table 4. Predictors for shorter LOS included female gender, higher GCS, lower ISS, lower thoracic AIS (excluding≥3 ribs fractures), higher AIS for abdominal injury, and angina pectoris. Conversely, chronic renal failure and rib fixation (coefficient β, 4.139; standard error, 0.829; $p<0.001$) correlated with longer hospital stays. In terms of ventilator dependency, shorter durations were associated with female sex, lower RR, higher GCS score, lower ISS, higher AIS for abdominal injury, and angina pectoris. Conversely, rib fixation (coefficient β, 1.937; standard error, 0.655; $p=0.003$) extended ventilator dependency.

Discussion

In a previous study, the perioperative risk for COPD patients was significantly higher than that in the general population, especially for pulmonary complications. In this study, VAP is a major morbidity and mortality event [8]. One study indicated that replacing intubation with non-invasive airway or spinal anesthesia reduces these risks [11]. Although internal fixation is certified for multiple rib fractures, conservative treatment plays a crucial role in various situations. A well-designed pain control protocol for patients with simple multiple rib fractures may provide satisfactory results without requiring intubation for surgical intervention [12–14]. However, in our study, we found improved mortality without increased VAP rate after IPTW. Patients with underlying COPD have poor lung hygiene and require more chest care, and medical treatment during hospitalization when preparing for surgery [15]. Rib fractures further aggravate the respiratory physiology of these patients and are a risk factor for poor clinical outcomes [6]. It is well established that

Table 1 Demographics of all patients with non-operative and operative treatments

Variables	All patients (*n* = 857)		Non-operation (*n* = 682)		Operation (*n* = 175)		*p* value [a]
Age (year)	68.0	[59.0, 75.0]	68.0	[59.0, 76.0]	67.0	[59.0, 74.0]	0.304
Male	591	(69.0)	466	(68.3)	125	(71.4)	0.484
Conditions at the ED							
Systolic blood pressure (mm-Hg)	138.0	[116.0, 157.0]	138.0	[118.0, 159.0]	133.0	[111.0, 150.0]	0.042*
Pulse rate (/min)	90.0	[77.0, 104.0]	88.0	[76.2, 103.0]	93.0	[79.0, 108.0]	0.023*
Respiratory rate (/min)	20.0	[18.0, 24.0]	20.0	[18.0, 23.8]	20.0	[18.0, 25.0]	0.012*
Blood oxygen saturation (%)	95.0	[92.0, 98.0]	96.0	[93.0, 98.0]	95.0	[91.0, 98.0]	0.071
Glasgow Coma Scale	15.0	[15.0, 15.0]	15.0	[15.0, 15.0]	15.0	[15.0, 15.0]	0.800
Injury Severity Score	17.0	[13.0, 24.0]	17.0	[13.0, 24.0]	20.0	[14.0, 29.0]	0.005*
AIS of internal organ injury of head							
Nil	774	(90.3)	616	(90.3)	158	(90.3)	0.068
2	29	(3.4)	19	(2.8)	10	(5.7)	
3	54	(6.3)	47	(6.9)	7	(4.0)	
AIS of ≥ 3 ribs fracture							
3	497	(58.0)	405	(59.4)	92	(52.6)	0.091
4	300	(35.0)	235	(34.5)	65	(37.1)	
5	60	(7.0)	42	(6.2)	18	(10.3)	
AIS of thoracic injury (other than ≥ 3 ribs fracture)							
Nil	139	(16.2)	132	(19.4)	7	(4.0)	< 0.001*
1–3	629	(73.4)	486	(71.3)	143	(81.7)	
4–5	89	(10.4)	64	(9.4)	25	(14.3)	
AIS of abdominal injury							
Nil	700	(81.7)	567	(83.1)	133	(76.0)	0.082
1–3	120	(14.0)	89	(13.0)	31	(17.7)	
4–5	37	(4.3)	26	(3.8)	11	(6.3)	
Injury mechanism							
Fall	399	(46.6)	340	(49.9)	59	(33.7)	< 0.001*
Motor vehicle transportation	354	(41.3)	271	(39.7)	83	(47.4)	
Other	104	(12.1)	71	(10.4)	33	(18.9)	
ACS verification facility level							
I	608	(70.9)	487	(71.4)	121	(69.1)	0.620
II	249	(29.1)	195	(28.6)	54	(30.9)	
Pre-existing conditions							
Bleeding disorder	22	(2.6)	19	(2.8)	3	(1.7)	0.595
Current smoker	331	(38.6)	264	(38.7)	67	(38.3)	0.987
Chronic renal failure	32	(3.7)	27	(4.0)	5	(2.9)	0.644
Diabetes mellitus	208	(24.3)	171	(25.1)	37	(21.1)	0.326
Anticoagulant therapy	139	(16.2)	115	(16.9)	24	(13.7)	0.372
Angina pectoris	1	(0.1)	1	(0.1)	0	(0.0)	> 0.999
Unplanned intubation	114	(13.3)	78	(11.4)	36	(20.6)	0.002*
Ventilator-associated pneumonia	36	(4.2)	29	(4.3)	7	(4.0)	> 0.999
Deep vein thrombosis	19	(2.2)	12	(1.8)	7	(4.0)	0.132
Pulmonary embolism	12	(1.4)	7	(1.0)	5	(2.9)	0.139
Pressure ulcer	20	(2.3)	15	(2.2)	5	(2.9)	0.815
Ventilator use	372	(43.4)	259	(38.0)	113	(64.6)	< 0.001*
Ventilator days	0.0	[0.0, 6.0]	0.0	[0.0, 5.0]	3.0	[0.0, 12.0]	< 0.001*
Length of stay	11.0	[6.0, 18.0]	9.0	[6.0, 16.0]	16.0	[11.0, 23.0]	< 0.001*
Mortality	116	(13.5)	101	(14.8)	15	(8.6)	0.043*

Continuous variables: median [first and third quartiles]; Categorical variables: numbers (percentages)

ACS, American College of Surgeons; AIS, Abbreviated Injury Scale; ED, emergent department

[a] Comparison among patients with non-operation and operation

* Statistical significance ($p < 0.05$)

Table 2 Outcomes after the inverse probability of treatment weighting between the non-operative and operative groups

Variables	Non-operation ($n = 858.8$)		Operation ($n = 838.0$)		p value
Unplanned intubation	99.1	(11.5)	167.0	(19.9)	0.012*
Ventilator-associated pneumonia	38.7	(4.5)	38.6	(4.6)	0.963
Deep vein thrombosis	16.9	(2.0)	40.7	(4.9)	0.083
Pulmonary embolism	8.3	(1.0)	15.2	(1.8)	0.284
Pressure ulcer	18.9	(2.2)	19.6	(2.3)	0.903
Ventilator use	341.4	(39.8)	501.0	(59.8)	< 0.001*
Ventilator days	0.0	[0.0, 5.0]	2.0	[0.0, 11.0]	< 0.001*
Length of stay	10.0	[6.0, 16.0]	14.8	[10.0, 22.0]	< 0.001*
Mortality	128.3	(14.9)	55.3	(6.6)	0.002*

Continuous variables: median [first and third quartiles]; Categorical variables: numbers (percentages)

* Statistical significance ($p < 0.05$)

Table 3 Multivariate binomial logistic regression for factors predicting mortality, ventilator use, and unplanned intubation in patients after the inverse probability of treatment weighting for the non-operative and operative groups

Variables	Mortality			Ventilator use			Unplanned intubation		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Age (year)	1.097	1.062–1.133	< 0.001*						
Sex									
Male				-					
Female				0.678	0.387–1.190	0.176			
Systolic blood pressure (mm-Hg)				0.988	0.979–0.996	0.005*			
Pulse rate (/min)				0.996	0.985–1.008	0.544			
Respiratory rate (/min)				1.096	1.050–1.144	< 0.001*	1.033	0.997–1.071	0.074
Glasgow Coma Scale	0.906	0.845–0.97	0.005*	0.550	0.454–0.665	< 0.001*			
Injury Severity Score	1.039	1.003–1.076	0.033*	1.075	1.025–1.128	0.003*			
AIS of internal organ injury of head									
Nil	-			-					
2	0.839	0.231–3.042	0.789	1.793	0.556–5.785	0.329			
3	1.783	0.861–3.696	0.120	0.444	0.112–1.754	0.247			
AIS of ≥ 3 ribs fracture									
3	-								
4	1.877	1.071–3.288	0.028*	1.222	0.702–2.125	0.479			
5	1.241	0.376–4.095	0.723	0.702	0.235–2.097	0.527			
AIS of thoracic injury (other than ≥ 3 ribs fracture)									
Nil	-			-					
1–3	1.492	0.786–2.833	0.222	0.751	0.313–1.806	0.523			
4–5	2.719	1.076–6.872	0.035*	1.472	0.511–4.244	0.474			
AIS of abdominal injury									
Nil				-					
1–3				0.673	0.325–1.394	0.287			
4–5				0.408	0.119–1.392	0.152			
Injury mechanism									
Fall	-			-					
Motor vehicle transportation	1.670	0.946–2.948	0.077	2.025	1.215–3.375	0.007*			
Other	0.756	0.274–2.084	0.589	0.889	0.464–1.704	0.724			
Diabetes mellitus	1.370	0.766–2.451	0.289						
Angina pectoris	625,120	70,461–5,545,937	< 0.001*						
Rib fixation	0.426	0.228–0.798	0.008*	3.211	1.993–5.175	< 0.001*	1.895	1.139–3.153	0.014*

AIS, Abbreviated Injury Scale; CI, confidence interval; OR, odds ratio

* Statistical significance ($p < 0.05$)

Table 4 Multivariate linear logistic regression for factors predicting length of stay and ventilator days in patients after the inverse probability of treatment weighting for the non-operative and operative groups

Variables	Length of stay			Ventilator days		
	Coefficient β (Standard error)		*p* value	Coefficient β (Standard error)		*p* value
Age (year)	0.022	(0.038)	0.559	0.043	(0.027)	0.115
Sex						
Male	Reference					
Female	-1.906	(0.813)	0.019*	-1.785	(0.642)	0.006*
Conditions at the ED						
Systolic blood pressure (mm-Hg)	-0.019	(0.014)	0.171	-0.018	(0.011)	0.094
Pulse rate (/min)	0.003	(0.023)	0.900	0.004	(0.019)	0.852
Respiratory rate (/min)	0.134	(0.072)	0.061	0.138	(0.050)	0.005*
Blood oxygen saturation (%)	-0.010	(0.059)	0.869	-0.073	(0.046)	0.112
Glasgow Coma Scale	-0.325	(0.151)	0.032*	-0.483	(0.109)	< 0.001*
Injury Severity Score	0.357	(0.094)	< 0.001*	0.234	(0.082)	0.004*
AIS of internal organ injury of head						
Nil	Reference					
2	4.059	(2.644)	0.125	1.972	(2.905)	0.497
3	-3.137	(2.145)	0.144	0.149	(1.774)	0.933
AIS of ≥ 3 ribs fracture						
3	Reference					
4	-2.347	(1.057)	0.027*	-0.928	(0.917)	0.311
5	-1.413	(2.890)	0.625	0.543	(2.078)	0.794
AIS of thoracic injury (other than ≥ 3 ribs fracture)						
Nil	Reference					
1–3	3.57	(1.074)	0.001*	0.973	(0.739)	0.188
4–5	3.657	(1.753)	0.037*	3.079	(1.521)	0.043*
AIS of abdominal injury						
Nil	Reference					
1–3	-1.577	(1.245	0.206	-0.702	(1.126)	0.533
4–5	-5.822	(2.331	0.013*	-4.996	(1.711)	0.004*
ACS verification facility level						
I	Reference					
II	-1.158	(0.835)	0.166	0.574	(0.680)	0.399
Injury mechanism						
Fall	Reference					
Motor vehicle transportation	0.876	(1.071)	0.413	0.998	(1.002)	0.319
Other	-1.344	(1.081)	0.214	-1.212	(0.886)	0.172
Pre-existing conditions						
Bleeding disorder	3.503	(4.469)	0.433	2.525	(2.551)	0.323
Current smoker	-0.985	(0.912)	0.281	0.114	(0.695)	0.869
Chronic renal failure	8.045	(3.568)	0.024*	3.172	(2.027)	0.118
Diabetes mellitus	0.465	(1.045)	0.656	0.669	(0.890)	0.452
Anticoagulant therapy	-0.454	(0.969)	0.639	0.400	(0.901)	0.657
Angina pectoris	-16.428	(2.179)	< 0.001*	-6.148	(1.883)	0.001*
Rib fixation	4.139	(0.829)	< 0.001*	1.937	(0.655)	0.003*

AIS, Abbreviated Injury Scale; ED, emergent department

* Statistical significance ($p < 0.05$)

restoring the chest wall anatomy may improve normal respiratory function resulting in better clinical outcomes [16]. However, patients with COPD benefit not only from lung function improvement but also from better pain control and ambulation. One recent study proved that internal fixation of ankle fractures in patients with COPD is safe with improved 30-day mortality [17]. Thus, COPD should not be considered a barrier to the recovery of daily activities post-surgery.

The rate of ventilator use was higher in the surgical group than in the non-surgical group, which seems intuitive because intubation is required for rib fixation. Additionally, the comorbidity of chronic renal failure is associated with a longer LOS in hospital. Another study observed that patients with COPD were more vulnerable to medical conditions other than COPD itself [15]. The risk factors for clinical outcomes and LOS in hospital in patients with COPD have been evaluated in previous studies [18]. The kidney serves as an acid-base-balancing organ in the lungs. Once impaired renal function occurs in patients with COPD, an overall poor outcome is predicted, which is the same outcome observed in our study.

The higher unplanned intubation rate in the surgical intervention group was attributed to a more aggressive treatment strategy for patients who experience such events. Fortunately, the overall complication rate is not higher in the surgical intervention group. The other two clinical outcomes related to rib fixation were longer ventilator days and LOS. In previous studies on the internal fixation of rib fractures, shorter ventilator days and LOS were recorded [19, 20]. The main reason for this difference was attributed to different patient enrollment criteria. In our study, we selected patients with three or more rib fractures and underlying COPD compared to the general population. A more careful extubation plan will be applied to these patients, causing a prolonged hospital course. The purpose of our original design was to evaluate the risk of additional surgical intervention in patients with COPD. Although the severity is higher in our study and internal fixation prolongs the treatment course. The overall mortality was still better in the operative group than in the non-operative group.

Another result was that the AIS of the thoracic injury other than ≥3 rib fractures only affected the mortality rate, but not the unplanned intubation and ventilator use rates. This may be because the underlying disease of COPD renders the baseline lung function of these patients equally poor, which overtakes the influence of anatomical severity. This conclusion is similar to that of a previous study in which a score to assess respiratory function could predict the outcome better than AIS alone [21].

This study has several limitations. First, we could not assess the effect of rib fractures on pulmonary function in patients with COPD, since pulmonary function may change after trauma. An intuitive way to resolve this issue is to arrange a pulmonary function test immediately after hospitalization. However, currently, performing a pulmonary function test in the early clinical phase is challenging because the pulmonary function test is not initially considered the core treatment for patients with trauma. A well-designed study protocol is required to conduct pulmonary function tests during early hospitalization to clarify the relationship between rib fractures and underlying COPD. Second, individual medical treatments for COPD in these patients could not be determined in the TQIP database. Although the treatment of COPD is standardized, variations still occur, which may affect the outcome for each patient.

In conclusion, for COPD patients with ≥3 rib fractures, internal fixation may offer a better mortality outcome without an increased complication rate. Restoring normal respiratory function is a priority in the treatment of these patients and internal fixation of the ribs may help achieve this goal.

Abbreviations

ACS	American College of Surgeons
AIS	Abbreviated Injury Scale
CI	Confidence interval
COPD	Chronic obstructive pulmonary disease
ED	Emergency department
GCS	Glasgow Coma Scale
IPTW	Inverse probability treatment weighting
ISS	Injury Severity Score
LOS	Length of stay
NK/NR	Not known/not recorded
OR	Odds ratio
PR	Pulse rate
RR	Respiratory rate
SBP	Systolic blood pressure
TQIP	Trauma Quality Improvement Program
VAP	Ventilator-associated pneumonia

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Supplementary Material 6

Supplementary Material 7

Supplementary Material 8

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Author contributions

Chien-An, Liao: conceptualization, investigation, writing(equal); Jen-Fu, Huang: methodology; Chih-Po, Hsu: data analysis; Chih-Yuan, Fu: data collection(equal); Szu-An Chen: data curation(equal); Yu-San Tee: resources, formal analysis; Chien-Hung, Liao: software; Chi-Hsun, Hsieh: validation; Chi-Tung, Cheng: writing-review and editing; and Ling-Wei, Kuo: supervision.

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Data availability

The data belongs to the trauma quality improvement programYou can require the data from them.

Declarations

Informed patient consent/consent to publication
This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (approval number 20220- 1144B0), and the need for informed consent was waived.

Informed consent
This is a de-identified data base study, no consent is needed.

Competing interests
The authors declare no competing interests.

Generative AI and AI-assisted technologies in the writing process
No AI- or AI-assisted technologies were used in this article.

COI Statement
None.

Meeting presentation
None.

Data sharing statement
Trauma Quality Improvement Program is a publicly accessible database that can be obtained from the American College of Surgeons website(https://www.facs.org/quality-programs/trauma/quality/trauma-quality-improvement-program/).

Research involving human participants and/or animals
This is a data base study, no human nor animal participants involved.

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