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Nonoperative treatment of multiple rib fractures, the results to beat: International multicenter prospective cohort study among 845 patients

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BACKGROUND: Optimal treatment (i.e., nonoperative or operative) for patients with multiple rib fractures remains debated. Studies that compare treatments are rationalized by the alleged poor outcomes of nonoperative treatment.

METHODS: The aim of this prospective international multicenter cohort study (between January 2018 and March 2021) with 1-year follow-up, was to report contemporary outcomes of nonoperatively treated patients with multiple rib fractures. Including 845 patients with three or more rib fractures. Primary outcome was in-hospital mortality. Secondary outcomes included hospital length of stay (HLOS), (pulmonary) complications, and quality of life.

RESULTS: Mean age was 57.7 ± 17.0 years, median Injury Severity Score was 17 (13–22) and the median number of rib fractures was 6 (4–8). In-hospital mortality rate was 1.5% (n = 13), 112 (13.3%) patients had pneumonia and four (0.5%) patients developed a symptomatic nonunion. The median HLOS was 7 days (4–13 days), and median intensive care unit length of stay was 2 days (1–5 days). Mean 5-Level Quality of Life Questionnaire index value was 0.83 ± 0.18 1 year after trauma. Polytrauma patients had a median HLOS of 10 days (6–18 days), a pneumonia rate of 17.6% (n = 77) and mortality rate of 1.7% (n = 7). Elderly patients (≥65 years) had a median HLOS of 9 days (5–15 days), a pneumonia rate of 19.7% (n = 57) and mortality rate of 4.1% (n = 12).

CONCLUSION: Overall, nonoperative treatment of patients with multiple rib fractures shows low mortality and morbidity rate and good quality of life after 1 year. Future studies evaluating the benefit of operative stabilization should use contemporary outcomes to establish the therapeutic margin of rib fixation. (*J Trauma Acute Care Surg.* 2024;96: 769–776.

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

KEY WORDS: Multiple rib fractures; conservative treatment; nonoperative treatment; quality of life; mortality; pneumonia rate.

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Rib fractures are very common thoracic injuries and affect a heterogeneous group.[1,2] Trauma cohorts are frequently stratified on polytrauma status, advanced age, and number of rib fractures suffered.[3,4] Historically, rib fractures were treated nonoperatively, which centralizes around adequate analgesia, (pulmonary) physiotherapy and respiratory support.[5] Over the last decades, however, there has been an increasing interest in the operative treatment of rib fractures in nonflail chest patients.[6] Both treatments are focused on preventing complications such as pneumonia by reducing pain and assuring adequate ventilation.[7] Common reasoning behind studies investigating operative treatment, are the assumed high mortality and morbidity rates associated with nonoperative treatment of rib fractures. Beks et al.[8–10] noted a hospital length of stay (HLOS) of 15 ± 6.3 days in their study protocol, based on two studies. Wijffels et al.[11–13] rationalized the need for rib fixation by stating a pneumonia rate of 35% in patients with multiple rib fractures treated nonoperatively. In another study protocol, Pieracci et al.[14–16] referred to long-term outcomes of two studies reporting prolonged chest wall pain in 64% and prolonged disability in 66% of the patients with nonoperatively treated patients.

To adequately power future interventional studies, it is essential to be aware of the contemporary outcomes of nonoperatively managed rib fractures in the fast-changing field of trauma surgery. Therefore, the primary aim of this study is to report contemporary outcomes of nonoperative treatment of multiple rib fracture patients, which can be used to power future studies. For that reason, patients were stratified by subgroups to create more insight into the heterogeneity of patients with multiple rib fractures.

METHODS

Study Design

This study focuses exclusively on nonoperatively treated patients with multiple (three or more) traumatic rib fractures. All clinical flail chest patients were excluded from this study as these are generally treated operatively in the participating centers. In case flail chest patients were treated nonoperatively, they mostly endured more severe, other injuries (e.g. [severe] traumatic brain injury) and therefore are excluded from this study. All data and written consent were prospectively collected as part of a database, which was an international prospective multicenter cohort study with a follow-up of 1 year conducted in six Level I trauma centers.[17]

The current study is a secondary analysis of the aforementioned database and here we focus on all nonoperatively treated patients. All patients, 18 years or older, with three or more CT-scan confirmed rib fractures after blunt thoracic trauma between January 2018 and March 2021 were included. Patients were excluded in case of cognitive impairment, nontraumatic rib fractures, and rib fractures due to cardiopulmonary resuscitation. This study complied with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Supplemental Digital Content; SDC 2, http://links.lww.com/TA/D375).[18] All data relevant to the study are included in the article or uploaded as supplementary information. IRB approval was obtained (NTR6833).

Treatment

Nonoperative treatment consists of adequate pain management (oral, intravenous [IV], and/or epidural analgesia), physiotherapy in breathing exercises, and supportive (mechanical) ventilation when indicated, according to hospital-specific guidelines.

Patient Characteristics

The following demographic data were analyzed: sex, age, mechanism of injury, American Society of Anaesthesiologists score, incidence of chronic obstructive pulmonary disease, smoking status and body mass index (BMI). Prehospital data included trauma mechanism and intubation status. Other injury-related characteristics were the number of rib fractures, the incidence of dislocated, bilateral and dorsal rib fractures, Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), Thorax Trauma Severity Score (TTSS), and concomitant injuries (i.e., pneumothorax, hemothorax, pulmonary contusion, and sternum or clavicle fractures).[19–21] Elderly patients were defined as patients 65 years or older. Multiple trauma was defined as an ISS ≥ 16 and according to the Newcastle definition as an AIS > 2 in at least two body regions.[22,23] Patients with isolated thoracic trauma were defined as patients with a maximum AIS of two in the nonthoracic domains. Dislocation was defined as one or more shaft width displacement.

Outcomes

The primary outcome was the in-hospital mortality rate. Secondary outcome measures included HLOS, intensive care unit length of stay (ILOS), duration of invasive mechanical ventilation (IMV), need for tracheotomy, use of and duration of epidural and IV analgesia, pain at days 3, 5, and 7 (using the numeric rating scale [NRS]), incidence rate of in-hospital complications, such as pneumonia, acute respiratory distress syndrome (ARDS), hemothorax, and pneumothorax was determined. Pneumonia was defined as an infection of the lower respiratory tract with a variety of clinical signs and symptoms (e.g., temperature >38.5°C, auscultation suspected of infiltrate, purulent sputum, leukocytosis, and elevated C-reactive protein) requiring antimicrobial treatment.[24] Acute respiratory distress syndrome was defined based on the Berlin Criteria for ARDS.[25]

Mid- and long-term complications were identified at 6 weeks and 1 year after trauma by physical or telephone check-ups. These outcomes included quality of life (QoL) (measured using the 5-level Quality of Life Questionnaire (EQ-5D-5L), a five-dimensional, five-level questionnaire), burden of dyspnea rate (using the modified Medical Resource Council Dyspnea Scale [mMRC], a five-category scale links the level of dyspnea with physical activity), pain during coughing and breathing (using the NRS), return to work and sport, and nonunion rate (symptomatic nonunion was defined as CT-confirmed nonhealed ribs at least 6 months after trauma, with clinical symptoms).[26,27] All six participating Level I trauma centers completed the one-year follow-up.

Statistical Analysis

All outcomes including HLOS, need and duration of ILOS, need and duration of IMV, tracheotomy, need for analgesia, the incidence of complications, NRS, mMRC and EQ-5D-5L were presented as descriptive data. Patients were stratified by subgroup, which consisted of multiple trauma patients, elderly patients, isolated thoracic injury patients, and stratification of number of rib fractures (3–5, 6–9, and >9 rib fractures). Categorical and dichotomous variables were presented as numbers with percentages (%) and confidence interval (CI). Continuous variables were presented as means and standard deviation (SD) for normally distributed data or as median with interquartile range (IQR) for nonnormally distributed data. Missing data were not imputed. Missing values included AIS head/thorax/abdomen/extremities 5% (39/845), BMI, 3% (25/845), smoking 2% (13/845), 6-week follow up 11% (93/845), one-year follow up 18% (150/845). Statistical analyses were performed using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY).

RESULTS

Patient Characteristics

In total, 845 patients with multiple rib fractures were treated nonoperatively with a complete follow-up rate of 82%. (Fig. 1) The mean age was 57.7 ± 17.0 years and 619 patients (73.3%) were male. Median ISS was 17 (IQR 13–22), median TTSS was 8 (6–10) and the median number of rib fractures was 6 (4–8). All baseline characteristics are displayed in Table 1 and Supplementary 1 (SDC 3, http://links.lww.com/TA/D375).

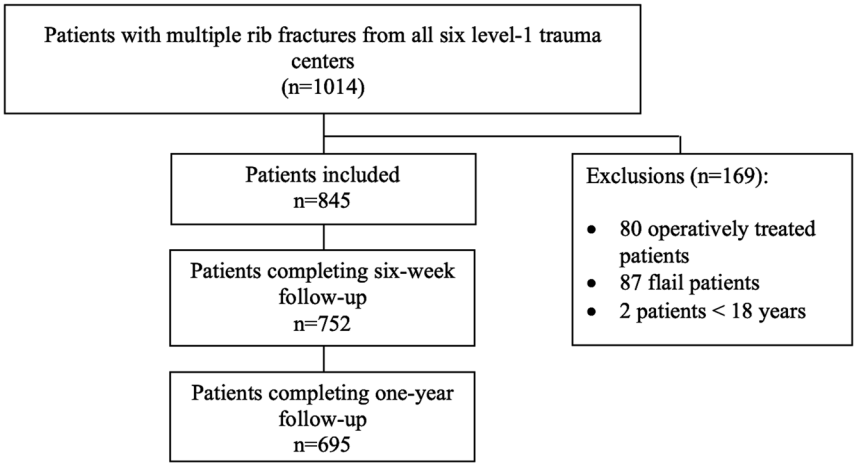

Figure 1. Flowchart of inclusions and follow-up.

In-Hospital Outcomes

The in-hospital mortality rate was 1.5% (95%CI 0.7–2.4% [n = 13]). Mortality rate in the elderly was 4.1% (n = 12) and 1.6% (n = 7) in multiple trauma (ISS ≥ 16) patients and 1.8% (n = 5) in multiple trauma (Newcastle) patients. Three (0.4%) patients died because of pneumonia. In three other patients the decision to withdraw life-sustaining treatment was made due to neurotrauma. One patient died due to pulmonary embolism, one due to infection of total hip prosthesis, one because of gastric perforation, one because of myocardial infarction with preexisting aortic stenosis. In three patients, palliative care was provided because of poor pretrauma condition with no improvements during hospitalization (Table 2 and Supplementary 2 [SDC 4], http://links.lww.com/TA/D375).

Overall median HLOS was 7 days (4–13 days), median ILOS was 2 days (1–5 days) and median IMV was 3 days (1–5 days). Pneumonia was the most common in-hospital complication with 112 cases (13.3%; 95% CI, 11.1–15.8%).

Differences in outcomes were observed between subgroups: in multiple trauma (ISS ≥ 16) patients (n = 438) median HLOS was 10 days (6–18 days) versus 5 days (3–8 days) in non–multiple trauma patients (n = 368). Pneumonia rate was 17.6% (95% CI, 14.0–21.2%; n = 77) compared with 8.2% (95% CI, 5.3–11.0%; n = 30) in non–multiple trauma patients. According to the Newcastle definition, 278 patients with multiple trauma had a median HLOS of 13 days (8–20 days) versus 5 days (3–9 days) in non–multiple trauma patients. The incidence of pneumonia was 19.8% (95% CI, 15.1–24.5%; n = 55) compared to that of non–multiple trauma patients, which was 9.8% (95% CI 7.2–12.4%; n = 50). Elderly patients (n = 290) were admitted median 9 days (5–15 days) versus 6 days (3–13 days) in younger patients (n = 555) and had a pneumonia rate of 19.7% (95% CI, 15.1–24.3%; n = 57) versus 9.9% (95% CI, 7.4–12.4%; n = 55). All in-hospital outcomes are displayed in Table 2 and Supplementary 2 (SDC 4, http://links.lww.com/TA/D375).

Mid- and Long-Term Outcomes

The mean EQ-5D-5L index value was 0.73 ± 0.19 after 6 weeks, which increased to 0.83 ± 0.18 after 1 year. Overall mid- and long-term complication rate was low. Four patients (0.5%; 95% CI, 0.0–0.9%) developed a symptomatic nonunion for which rib fixation was planned and 11 patients (1.3%; 95% CI, 0.5–2.1%) had died to unrelated causes after 1 year (Table 3 and Supplementary 3 [SDC 5], http://links.lww.com/TA/D375).

DISCUSSION

Main Findings

This prospective cohort study reports present-time outcomes of 845 nonoperatively treated patients with multiple rib fractures. Mortality rate was 1.5% (n = 13), and the pneumonia rate was 13.3% (n = 112). Patients in this study had a median HLOS of 7 days (4–13 days) and a median ILOS of 2 days (1–5 days). Quality of life after 1 year was comparable to general population norms.

The primary aim of this study was to evaluate the current outcomes of patients sustaining multiple rib fractures undergoing nonoperative treatment. A common rationale for studies to investigate rib fixation is the high mortality rate associated with rib fractures due to pulmonary complications resulting in a prolonged HLOS. Although this would have been a valid argument two decades ago when mortality rates were reported of up to 22% in elderly patients and 10% in younger patients, this argument does not seem valid anymore nowadays, as all-cause mortality rate in our study was 1.5% and only three (0.4%) patients died of pulmonary complications.[28,29] This decrease in mortality is most likely attributed to the optimization of the acute trauma and intensive care management, including early resuscitation and optimization of pain management.[30]

Furthermore, multiple recent randomized controlled trials and high-quality comparative prospective observational studies did not find convincing evidence to support rib fixation in patients with multiple rib fractures. It should be mentioned that many of these studies might be underpowered due to the power calculation being based on noncontemporary outcomes of nonoperative chest trauma management as we have shown in our current study. One study by Pieracci et al.[14] reported a significantly lower pain score after 2 weeks, without a reduction in pain medication utilization. However, no significant differences were found in HLOS (6 days), ILOS (2 days), pneumonia rate (2.0% vs. 6.7%), mortality (n = 0), or QoL at any follow-up. Marasco et al.[31] reported no significant difference between nonoperative treatment and rib fixation (HLOS, 9 days vs. 10 days, ILOS 0 vs.

TABLE 1. Demographics, Prehospital and Injury-Related Characteristics of Patients With Rib Fractures Stratified by Subgroups

		Multiple Trauma* (ISS ≥ 16)		Elderly (≥65 y)		No. Rib Fractures		
Variables	**Total**	**Yes**	**No**	**Yes**	**No**	**3–5**	**6–9**	**>9**
All, no.	845	438	368	290	555	396	355	94
Age at trauma**	57.7 ± 17.0	56.1 ± 17.6	59.2 ± 16.3	75.7 ± 7.1	48.3 ± 12.4	55.8 ± 17.4	58.7 ± 16.9	61.6 ± 14.5
Sex ratio (F/M)	226:619	121:317	94:274	108:182	118:437	110:286	292:63	24:70
ASA score								
1–2	635 (75.1)	343 (78.3)	263 (71.5)	155 (53.4)	480 (86.5)	303 (76.5)	267 (75.2)	66 (70.2)
3–4	210 (24.9)	95 (21.7)	105 (28.5)	135 (46.6)	75 (13.5)	93 (23.5)	88 (24.8)	28 (29.8)
BMI**	26.1 ± 4.5	26.1 ± 4.8	26.1 ± 4.1	25.9 ± 4.0	26.1 ± 4.7	25.6 ± 4.3	26.4 ± 4.6	26.8 ± 4.4
Smoker*	158 (18.7)	92 (21.0)	56 (15.2)	24 (8.3)	134 (24.1)	69 (17.4)	74 (20.8)	14 (14.9)
COPD	51 (6.0)	23 (5.3)	25 (6.8)	28 (9.7)	23 (4.1)	24 (6.1)	21 (5.9)	5 (5.3)
Trauma mechanism								
Motor vehicle accident	473 (56.0)	244 (55.7)	208 (56.5)	133 (45.9)	340 (61.3)	227 (57.3)	203 (57.2)	44 (46.8)
Fall	309 (36.6)	167 (38.1)	128 (34.8)	143 (49.3)	166 (29.9)	135 (34.1)	129 (36.3)	44 (46.8)
Other	63 (7.5)	27 (6.2)	32 (8.7)	14 (4.8)	49 (8.8)	34 (8.6)	23 (6.5)	6 (6.4)
Intubated at ED	38 (4.5)	36 (8.2)	1 (0.3)	9 (3.1)	29 (5.2)	11 (2.8)	19 (5.4)	8 (8.5)
AIS†								
Head	0 (0–2)	1 (0–3)	0 (0–1)	1 (0–2)	0 (0–2)	0 (0–1)	0 (0–2)	1 (0–3)
Thorax	3 (3–3)	3 (3–4)	3 (3–3)	3 (3–3)	3 (3–3)	3 (3–3)	3 (3–3)	3 (3–4)
Abdomen	0 (0–0)	0 (0–2)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–1)
Extremities	2 (0–2)	2 (1–2)	1 (0–2)	1 (0–2)	2 (0–2)	1 (0–2)	2 (0–2)	2 (1–2)
TTSS†	8 (6–10)	9 (6–11)	7 (6–9)	9 (7–11)	7 (5–10)	7 (5–9)	8 (7–11)	11 (9–13)
ISS†	17 (13–22)	22 (18–29)	13 (10–14)	17 (13–22)	17 (13–22)	14 (11–19)	17 (14–22)	22 (16–29)
Multiple trauma (ISS ≥ 16)*	438 (51.8)	–	–	143 (49.3)	295 (53.2)	165 (41.7)	205 (57.7)	68 (72.3)
No. rib fractures†	6 (4–8)	6 (4–8)	5 (4–7)	6 (4–8)	6 (4–8)	4 (3–5)	7 (6–8)	11 (10–13)
Dislocated rib fractures	243 (28.8)	136 (31.1)	99 (26.9)	88 (30.3)	154 (27.7)	83 (21.0)	114 (32.1)	46 (48.9)
Bilateral rib fractures	185 (21.9)	122 (14.4)	56 (15.2)	65 (22.4)	120 (21.6)	32 (8.1)	85 (23.9)	68 (72.3)
Dorsal rib fractures*	564 (66.7)	315 (71.9)	226 (61.4)	187 (64.5)	377 (67.9)	228 (57.6)	263 (74.1)	72 (76.6)
Concomitant injuries								
Pneumothorax	394 (46.6)	227 (51.8)	156 (42.4)	118 (38.3)	283 (51.0)	165 (41.7)	204 (49.8)	57 (60.6)
Hemothorax	147 (17.4)	86 (19.6)	53 (14.4)	49 (16.9)	98 (17.6)	55 (13.9)	68 (19.2)	27 (28.7)
Pulmonary contusion	316 (37.4)	194 (44.3)	113 (30.7)	85 (29.3)	231 (41.6)	118 (29.8)	142 (40.0)	56 (59.6)
Sternum fracture	82 (9.7)	55 (12.6)	25 (6.8)	30 (10.3)	52 (9.4)	26 (6.6)	35 (9.9)	21 (22.3)
Clavicle fracture	190 (22.5)	111 (25.3)	74 (20.1)	56 (19.3)	134 (24.1)	81 (20.5)	86 (24.2)	23 (24.5)

Values in parentheses are percentages unless indicated otherwise;
*Other indications might not add up due to missing data.
**Mean (standard deviation).
†Median (interquartile range).
ASA, American Society of Anaesthesiologists; COPD, chronic obstructive pulmonary disease; ED, emergency Department; IQR, interquartile range.

TABLE 2. In-Hospital Outcomes of Patients With Rib Fractures Stratified by Subgroups

		Multiple Trauma* (ISS ≥ 16)		Elderly (≥65 y)		No. Rib Fractures		
Variables	**Total**	**Yes**	**No**	**Yes**	**No**	**3–5**	**6–9**	**>9**
All, no.	845	438	368	290	555	396	355	94
HLOS**	7 (4–13)	10 (6–18)	5 (3–8)	9 (5–15)	6 (3–13)	5 (3–11)	8 (5–14)	12 (7–19)
Need for ICU admission	227 (26.9)	184 (42.0)	36 (9.8)	76 (26.2)	151 (27.2)	66 (16.7)	115 (32.4)	45 (47.9)
ILOS**	2 (1–5)	3 (1–4)	1 (1–3)	3 (2–5)	2 (1–5)	2 (1–5)	2 (1–5)	3 (2–7)
Need for IMV	114 (13.5)	104 (23.7)	7 (1.9)	34 (11.7)	80 (14.4)	37 (9.4)	54 (15.2)	23 (24.5)
Duration of IMV**	3 (1–5)	3 (1–5)	2 (1–5)	3 (2–5)	2 (1–5)	2 (1–5)	2 (1–5)	4 (1–6)
Need for IV analgesia	634 (75.0)	362 (82.6)	272 (73.9)	208 (71.7)	426 (76.8)	251 (63.4)	295 (83.1)	90 (95.7)
Duration of IV analgesia**	2 (1–5)	3 (1–6)	1 (0–3)	2 (0–4)	2 (1–5)	1 (0–3)	3 (1–6)	5 (3–9)
Need for epidural analgesia	141 (16.7)	72 (16.4)	69 (18.8)	45 (15.5)	96 (17.3)	37 (9.3)	65 (18.3)	25 (26.6)
Duration of epidural analgesia**	5 (3–6)	5 (3–6)	4 (3–6)	5 (2–6)	5 (4–6)	5 (3–6)	5 (3–6)	6 (4–7)
Need for tracheotomy	9 (1.1)	7 (1.6)	1(0.3)	2 (0.7)	7 (1.3)	4 (1.0)	3 (0.8)	2 (2.1)
NRS (pain)**								
Day 3	2 (1–3)	2 (1–3)	2 (1–3)	2 (0–3)	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)
Day 5	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)	2 (0–3)	2 (1–4)
Day 7	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)	2 (0–3)	2 (1–3)	2 (2–4)
Complications								
Pneumonia	112 (13.3)	77 (17.6)	30 (8.2)	57 (19.7)	55 (9.9)	37 (9.3)	52 (14.6)	22 (23.4)
ARDS	2 (0.2)	7 (1.6)	0	2 (0.7)	0	0	1 (0.3)	1 (1.1)
Pneumothorax	20 (2.4)	11 (2.5)	7 (1.9)	8 (2.8)	12 (2.2)	7 (1.8)	12 (3.4)	1 (1.1)
Hemothorax	15 (1.8)	11 (2.5)	4 (1.1)	5 (1.7)	10 (1.8)	3 (0.8)	10 (2.8)	2 (2.1)
Empyema	2 (0.2)	2 (0.5)	0	0	2 (0.4)	0	1 (0.3)	1 (1.1)
Pleural effusion	18 (2.1)	12 (2.7)	5 (1.4)	6 (2.1)	12 (2.2)	6 (1.5)	7 (2.0)	5 (5.3)
Other complications	187 (22.1)	129 (29.5)	54 (14.7)	89 (30.7)	98 (17.7)	64 (16.2)	95 (26.8)	27 (28.7)
Mortality	13 (1.5)	7 (1.6)	5 (1.4)	12 (4.1)	1 (0.2)	5 (1.3)	7 (2.0)	1 (1.1)
Place of discharge*								
Home	612 (72.4)	271 (61.9)	310 (84.2)	166 (57.2)	446 (80.4)	300 (75.8)	255 (71.8)	57 (60.6)
Rehabilitation	90 (10.7)	78 (17.8)	12 (3.3)	74 (25.5)	67 (12.1)	41 (10.4)	34 (9.6)	15 (16.0)
Health care facility	93 (11.0)	59 (13.5)	29 (7.9)	23 (7.9)	19 (3.4)	29 (7.3)	47 (13.2)	16 (17.0)
Other	37 (4.4)	23 (5.3)	12 (3.3)	15 (5.2)	22 (4.0)	41 (10.4)	12 (3.4)	5 (5.3)

Values in parentheses are percentages unless indicated otherwise;
*Other indications might not add up due to missing data.
**Median (interquartile range).
ICU, intensive care unit.

1, mortality 3.3% vs. 0% and no differences in QoL at 6 months). Therefore, they did not recommend rib fixation for nonventilated multiple rib fracture patients. Hoepelman et al. solely reported negative results after rib fixation with increased HLOS (12 days vs. 7 days), lower QoL (−0.1 EQ-5D-5L index score) and high implant irritation rate (28%). They found no further significant differences between either group.[17] Lastly, Dehghan et al.[32] report no benefit of operative treatment in nonventilated patients as well as an only modest benefit in patients in need of mechanical ventilation.

Overall QoL after one year was comparable to Dutch (0.86 ± 0.18 vs. 0.83 ± 0.18 in our study) and Swiss general population norms (0.81 ± 0.14 in Swiss women and 0.83 ± 0.15 in Swiss men).[33,34] This is interesting as previous literature found that trauma patients generally have worse QoL scores than the general population.[35] Marasco et al.[16] reported a significant decrease in QoL after 24 months among nonoperatively treated patients compared with Australian norms at all time points. However, in a follow-up study comparing QoL in patients treated nonoperatively versus operatively at the same study site, they found no difference.[31] Therefore it is less likely that the results they found are due to treatment choice, but rather a result of the injuries sustained. Although we cannot state that nonoperative treatment is noninferior to rib fixation based on our study alone, we do recommend strict patient selection when considering rib fixation in patients with multiple rib fractures, taking our results and the results of the aforementioned comparative studies into account.

For future studies, it is paramount that contemporary data is used for power analysis, it is also important to note that focusing on the reduction of HLOS of operatively treated patients may not provide significantly more benefits in the future. Although a decrease in HLOS could be statistically significant in a large trial, it would be irrelevant for patients who have already spent a considerable amount of time in-hospital, especially if long-term outcomes are favorable anyway. All things considered, improving care for patients with rib fractures should not mainly focus on mortality and HLOS, but on improving functional outcomes, avoidance of complications and selecting the right patients in which it might have benefit.

TABLE 3. Mid- and Long-Term Outcomes of Patients With Rib Fractures Stratified by Subgroups

		Multiple Trauma* (ISS ≥ 16)		Elderly (≥65 y)		No. Rib Fractures		
Variables	**Total**	**Yes**	**No**	**Yes**	**No**	**3–5**	**6–9**	**>9**
All, no.	845	438	368	290	555	396	355	94
6 wk follow-up								
EQ-5D-5L index value**	0.73 ± 0.19	0.71 ± 0.21	0.77 ± 0.17	0.73 ± 0.20	0.74 ± 0.19	0.72 ± 0.19	0.72 ± 0.20	0.72 ± 0.15
EQ-5D-5L VAS**	68.2 ± 18.4	66.1 ± 18.2	71.2 ± 18.2	67.8 ± 18.9	68.4 ± 18.2	66.7 ± 18.2	67.4 ± 18.0	63.9 ± 18.7
mMRC†	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)
NRS (pain)†								
General	2 (1–3)	2 (1–3)	2 (1–3)	2 (0–3)	2 (1–3)	2 (1–3)	2 (1–3)	2 (2–3)
Breathing	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	1 (0–2)
Couching	2 (0–4)	2 (0–3)	2 (0–4)	1 (0–3)	2 (0–4)	1 (0–3)	2 (0–4)	2 (0–3)
Complications								
Pneumonia	3 (0.4)	0	3 (0.8)	1 (0.3)	2 (0.4)	0	3 (0.8)	0
Pneumothorax	3 (0.4)	3 (0.7)	0	0	3 (0.5)	2 (0.5)	1 (0.3)	0
Hemothorax	6 (0.7)	5 (1.1)	0	2 (0.7)	4 (0.7)	4 (1.0)	2 (0.6)	0
Empyema	0	0	0	0	0	0	0	0
Pleural effusion	7 (0.8)	2 (0.5)	5 (1.4)	3 (1.0)	4 (0.7)	1 (0.3)	2 (0.6)	4 (4.3)
Other complications	67 (7.9)	46 (10.5)	16 (4.3)	27 (9.3)	40 (7.2)	28 (7.1)	26 (7.3)	13 (13.8)
Mortality	3 (0.4)	2 (0.5)	0	2 (0.7)	1 (0.2)	1 (0.3)	1 (0.3)	1 (1.1)
1 year follow-up								
EQ-5D-5L index value**	0.83 ± 0.18	0.71 ± 0.21	0.77 ± 0.17	0.81 ± 0.18	0.84 ± 0.18	0.82 ± 0.18	0.83 ± 0.19	0.81 ± 0.16
EQ-5D-5L VAS**	76.1 ± 18.8	75.5 ± 18.8	77.0 ± 18.4	75.2 ± 17.7	76.5 ± 19.3	76.1 ± 18.6	76.3 ± 18.4	75.4 ± 20.0
mMRC†	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–3)	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)
NRS (pain)†								
General	0 (0–2)	0 (0–3)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–3)
Breathing	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Couching	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Return to work without limitations	348 (4.1)	169 (38.6)	167 (45.4)	24 (8.3)	324 (58.4)	172 (43.4)	149 (42.0)	27 (28.7)
Return to sport	296 (35.0)	141 (32.2)	143 (38.9)	67 (23.1)	229 (41.3)	150 (37.9)	122 (34.4)	24 (25.5)
Complications								
Recurrent hemothorax	2 (0.2)	1 (0.2)	0	0	2 (0.4)	2 (0.5)	0	0
Symptomatic nonunion	4 (0.5)	3 (0.7)	1 (0.3)	1 (0.3)	3 (0.5)	1 (0.3)	2 (0.6)	1 (1.1)
Mortality	11 (1.3)	6 (1.4)	4 (1.1)	10 (3.4)	1 (0.2)	6 (1.5)	4 (1.1)	1 (1.1)

Values are presented in numbers with percentages unless indicated otherwise.
* Other indications might not add up due to missing data.
**Mean (standard deviation).
†Median (interquartile range)

Therefore, we stratified our cohort in subgroups. Naturally, some outcomes differed between subgroups. Literature is inconclusive whether number of rib fractures is a predictor for morbidity and mortality, as contradicting results have been reported. Shulzhenko et al.[36] concluded that sustaining five or more rib fractures is a predictor of worse outcome independent of trauma burden and patient characteristics, and Peek et al.[3] found that an increased number of rib fractures was a marker of injury severity with a modest increased risk on mortality (OR, 1.05 per rib; 95% CI, 1.04–1.06; $p < 0.001$). On the contrary, Whitson et al.[37] implied that the number of rib fractures is not an independent predictor of outcome after multivariable logistic regression. In our study, HLOS was longer and pneumonia rate was higher in patients with more rib fractures. It is likely that they were more severely injured which is reflected by higher ISS, higher rate of multiple trauma, and more concomitant injuries in the thoracic region. Interestingly, increased ILOS and mortality rate were not associated with the number of rib fractures in our study. Elderly patients still had higher mortality rates compared with younger patients (4.1% vs. 0.2%), but this difference was to be expected as in any type of injury. As these studies solely investigate nonoperatively treated patients, this decrease is likely attributable to improvements to the trauma and intensive patient care in the past decades rather than improvements in the operation procedure of rib fixation.[37] The indications for rib fixation remain elusive as these articles failed to show superiority from rib fixation. However, a small subgroup might benefit from operative treatment.

The strengths of this study are its prospective design, large sample size, and limited missing data. However, this study has several limitations. First, this is not a comparative study, so comparing results to operatively treated patients should be done cautiously.[17] However, this was not the goal of this study as it was to report contemporary results of nonoperative treatment.

Second, it could be argued that centers with nonoperative treatment as the standard of care are likely to have better outcomes in nonoperative management than centers who previously performed rib fixation in select cases. Thus, their superior nonoperative outcomes may not be generalizable, while rib fixation cases were excluded from this study, which was the preferred treatment for a selected group of patients in three hospitals previously.[8]

Third, information on specific analgesia and the value of this information is limited as there is no consensus on optimal analgesic strategy. Hospitals treated patients according to local protocol and at the discretion of the treating physician. Although this makes results generalizable, use of this information is limited to general analgesic use and not specific analgesic treatment.

Fourth, baseline QoL measures of included patients were not measured (which is near impossible in trauma patients). So, QoL after 1 year might be comparable to general population, but it is uncertain whether the preinjury QoL measures were superior or inferior to those of the general population.

In conclusion, nonoperative treatment in a cohort of 845 patients with multiple rib fractures shows a low mortality rate and similar long-term outcomes compared with national norms of noninjured population. These are the results to beat for rib fixation to become the standard of care for all multiple rib fracture patients and instead of defining the lowest possible threshold for surgery, the surgical community should explore the narrow margins of indications in which rib fixation is truly beneficial.

AUTHORSHIP

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DISCLOSURE

I, Felix Peuker, attest on behalf of all authors, that we had full access to the data of the study, conducted all data analyses independently from the funding entity, and take complete responsibility for the integrity and accuracy of the data reported in the manuscript. Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D375).

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