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ORIGINAL ARTICLE

Long-term quality of life and functional outcome after rib fracture fixation

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Abstract

Purpose The primary aim of this study was to assess the long-term quality of life and functional outcome after rib fracture fixation for patients with multiple rib fractures or flail chest. Secondarily, this study sought to identify risk factors associated with the quality of life.

Methods A retrospective cohort study with a follow-up by questionnaire was performed at a level-1 trauma center in Switzerland. All adult patients with three or more rib fractures treated with rib fixation between 2010 and 2018 were eligible for inclusion. All outcomes were independently assessed for patients with multiple rib fractures and patients with a flail chest. The outcome measures were quality of life, level of dyspnea, return to work, implant irritation, and implant removal after a minimum of 12 months of follow-up. Quality of life was assessed using the EuroQol five-dimensional five-level questionnaire (EQ-5D-5L) and level of dyspnea was determined with the modified Medical Research Council dyspnea (mMRC) scale.

Results The survey was completed by 74 out of 102 patients (73%) at a median follow-up of 26 months (IQR 15–37). The median EQ-5D utility index score was 0.91 (0.89–1.0), which was equivalent to the reference population (0.902, $p=0.523$). The vast majority of patients experienced 'no problems' or 'slight problems' in any of the EQ-5D-5L dimensions. The complication rate associated with rib fracture fixation was low, implant-related irritation was the most common long-term sequela and occurred in 31% of patients. In multivariable regression analyses, total length of stay on the intensive care unit (ICU-LOS) was independently associated with a worse quality of life.

Conclusions Patients who underwent rib fracture fixation for multiple rib fractures or flail chest after severe chest trauma experienced a good quality of life at least 1 year after surgery. A longer ICU-LOS was independently associated with impaired quality of life. In addition, there were no significant differences in the long-term quality of life and functional outcome between patients with multiple rib fractures and a flail chest. Implant-related irritation was the most important long-term sequela and occurred in one-third of patients.

Keywords Thoracic trauma · Rib fractures · Surgical treatment · Quality of life · Functional outcome

Introduction

Thoracic trauma remains an important cause of morbidity and mortality among the trauma population [1]. Rib fractures are the most frequently encountered injuries after thoracic trauma, accounting for approximately 10–15% of all trauma-related hospital admissions [2, 3]. Fractured ribs are presumed to be a surrogate marker of severe injury, as most patients sustain critical additional injuries [1, 4].

Rib fractures are also associated with a significant morbidity and disability on the long term. These injuries can cause long-lasting physical impairment, dyspnea, and delayed return to work, resulting in a diminished quality of

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life [5–7]. In addition, previous studies have shown that up to a quarter of patients with fractured ribs experience enduring chest pain even 1 year or more after their injury [6, 7].

In the current clinical practice, surgical treatment is increasingly performed in patients with rib fractures, as it is assumed that restoration of the chest wall integrity can improve pain and preserve the normal mechanics of breathing. Although recent evidence suggests that rib fracture fixation can lead to improvement in pulmonary function, a lower incidence of (pulmonary) complications, and a shorter hospital and intensive care unit (ICU) length of stay in selected patients, a definitive consensus on which patients should be operated has not yet been ascertained [8–10]. Contributing to the difficulty in establishing the optimal treatment for patients with rib fractures is that there is limited evidence with respect to the long-term quality of life and functional outcome after rib fracture fixation.

Therefore, the primary aim of this study was to assess the long-term quality of life and functional outcome after rib fracture fixation for patients with multiple rib fractures or flail chest. Secondarily, this study sought to identify risk factors with impaired quality of life.

Methods

The Medical Ethical Review Board granted approval for this study under protocol number EKNZ 2019-00618 and informed consent was obtained from all subjects. This article was written according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [11].

Study design and participants

A retrospective cohort study with a follow-up by questionnaire was performed at a level-1 trauma center in Switzerland. All adult patients with three or more rib fractures or a flail chest treated with rib fixation between January 2010 and December 2018 were eligible for inclusion. Eligible patients were identified using International Classification of Diseases Ninth Revision (ICD-9) diagnosis codes for rib fractures and Swiss Classification of Surgical Intervention (CHOP) procedural codes for rib fixation in an electronic search of the medical files. Inclusion criteria were age 18 years and older and three or more rib fractures as a result of blunt thoracic trauma followed by rib fixation. Patients who were deceased, resided in a foreign country, or unable to fulfill the questionnaire at follow-up were excluded from analysis. In addition, patients were excluded if there was no availability of a CT-scan of the chest or if the patient was transferred to or from another hospital. All eligible patients were invited to participate in this study by a recruitment letter.

Surgery characteristics

The main indications for rib fixation were flail chest with paradoxical chest movement (clinical flail chest), severe chest wall deformity, failure to wean from mechanical ventilation, or intractable pain despite epidural, intravenous, or oral pain treatment. A muscle sparing minimal invasive approach was performed to fix the fractured ribs using the MatrixRIB system (Depuy Synthes). Preferably three bicortical screws were placed on each side of the fracture and if no plate could be inserted due to anatomical boundaries, intramedullary splints were used. The number of fixated ribs depended on the anatomical boundaries and possibility to regain chest wall stability during respiration. If ribs were fractured in more than one place initially only one fracture was fixed, but if needed to augment stability, both fractures were addressed.

Outcome measures and explanatory variables

Data on explanatory variables were retrieved from the German (TraumaRegister DGU®) and the Swiss Trauma Registry (STR) as well as the electronic patient documentation. The following baseline characteristics were obtained: age at trauma, sex, American Society of Anesthesiologists (ASA) classification, smoking status, mechanism of trauma, body mass index (BMI), Abbreviated Injury Scale (AIS) score, Injury Severity Score (ISS), number of rib fractures, presence of bilateral rib fractures, rib fractures in the upper (rib 1–4), middle (rib 5–8), lower (rib 9–12) third or dorsal side of the thorax, displacement (a shaft width displacement in the transversal plane), the presence of a flail segment (three or more consecutive rib fractures in at least two places with or without clinical signs of paradoxical chest wall movement), concomitant injuries including pneumothorax, hemothorax, pulmonary contusion, and sternum fracture, and need for emergency surgery upon time of arrival (e.g. thoracotomy, laparotomy, or craniotomy). The surgery-related characteristics included time from injury until surgery, duration of surgery, surgical approach, number of ribs fixated, the ratio of fixated ribs and fractured ribs (fixated ribs/fractured ribs), and side of rib fixation.

The outcome measures were subdivided into in-hospital and long-term outcomes. The in-hospital outcomes were total hospital length of stay (HLOS) in days, ICU admission (yes or no), ICU length of stay (ICU-LOS) in days, need for mechanical ventilation (yes or no), duration of invasive mechanical ventilation (IMV) in days, incidence of surgery- and implant-related complications (e.g. intra- or postoperative bleeding, infection, and migration or failure of the implant material), reoperations, incidence of disturbed fracture healing (e.g. delayed union, nonunion, and malunion),

incidence of pulmonary complications [e.g. pneumonia and acute respiratory distress syndrome (ARDS)], and mortality. Infections were subdivided into (1) superficial wound infections and (2) fracture-related infections according to the diagnostic criteria established by Metsemakers and colleagues [12]. Pneumonia was defined as having clinical signs (fever, dyspnea, coughing, and desaturation) requiring antibiotic treatment with or without positive sputum cultures. ARDS was defined by severe hypoxemia with a PaO2/FIO2 smaller than 100 mmHg.

The long-term outcome measures were quality of life, level of dyspnea, return to work, implant irritation, and implant removal after a minimum of 12 months of follow-up. Quality of life was assessed using the EuroQol five-dimensional five-level questionnaire (EQ-5D-5L) and the EuroQol Visual Analogue Scale (EQ-VAS) [13, 14]. The EQ-5D-5L is a validated questionnaire designed to measure patient's general health status and scores the severity of problems (ranging from no problems to severe problems) in the following five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. The EQ-5D-5L health states were converted into a single EQ-5D (utility) index score using a scoring algorithm. A higher score reflects a better patient-reported quality of life, with an index value of 1 representing full health [13, 15]. In addition, the outcome scales of all dimensions were dichotomized into the subgroups 'no problems' and 'problems', with this last subgroup ranging from 'mild problems' to 'severe problems and being unable to perform certain activities'. The EQ-VAS is a patient's subjective measurement of generic health ranging from 0–100, where higher scores represent better subjective health experience. The level of dyspnea was measured with the modified Medical Research Council dyspnea (mMRC) scale which is a five-category scale that characterizes the level of dyspnea with physical activity where higher scores corresponds with more dyspnea [16]. In addition to the questionnaires, patients were asked whether they were able to return to their preinjury level of work and were categorized as follows: (1) not able to work, (2) able but not on their preinjury level, and (3) on the same level as before their injury. Implant irritation and implant removal were assessed using a previously described algorithm by Hulsmans and colleagues [17]. Implant irritation was defined as a local pain, tenderness, or discomfort at the implant site. If implant irritation was present, patients were asked whether their complaints required implant removal.

Statistical analysis

All analyses were performed separately for patients with flail chest and patients with multiple rib fractures.

Data were presented using absolute numbers with percentages (%) for dichotomous and categorical variables, means with standard deviations (SD) for normally distributed variables, medians with interquartile ranges (IQR) for non-normally distributed data. The Shapiro–Wilk test and Q–Q plots were performed to assess the distribution of continuous variables.

The differences in baseline characteristics were compared between responders and non-responders. All outcome variables were reported separately for patients with multiple rib fractures and flail chest. For analysis of continuous variables, the independent *t* test and the Mann–Whitney *U* test were used for normally and non-normally distributed data, respectively. The Pearson's Chi-square test was used for categorical data and the Fisher's exact test was used in case of a cell count of 5 or less. Since a validated EQ-5D reference value set has not yet been established for the Swiss population, the EQ-5D utility index score was obtained using the EQ-5D German index tariff. The EQ-5D utility index scores of the study population were compared with the reference value of the German population using the independent *t* test.

Bivariate linear regression analyses were performed to assess individual factors affecting the EQ-5D-5L utility index score and the EQ-VAS. Multivariable linear regression analyses were performed to identify factors independently associated with these outcomes. For multivariable analyses, independent variables were substantively selected based on the expected clinical relationship with each of the outcome variables.

All analyses were performed with Stata® 14.0 (StataCorp LP, College Station, TX, USA); a *p* value of less than 0.05 was considered significant.

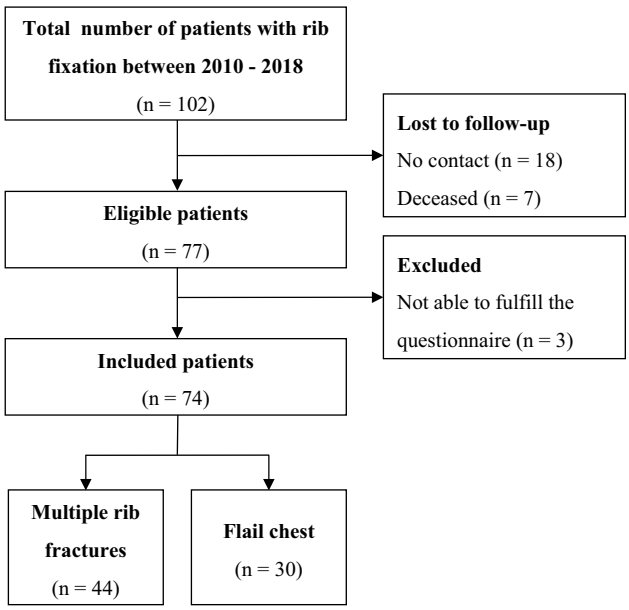

Fig. 1 Flowchart representing the selection of the included patients

Results

Figure 1 shows a flowchart of the inclusion process. A total of 102 patients with multiple rib fractures or flail chest met the inclusion criteria. Of these patients, 18 could not be contacted anymore, 7 were deceased, and 3 were not able to fulfill the questionnaire due to dementia or cognitive impairment. Ultimately, a total of 74 patients (73%) completed the questionnaire and were included for analysis.

The baseline characteristics are shown in Table 1. There were no significant differences observed between responders and non-responders. Of the entire cohort, the median age at trauma was 62 years (IQR 54–75) and 86 patients (84%) were male. The mean ISS was 24 (IQR 20–29) with a median AIS thorax of 4 (IQR 4–4). The median number of rib fractures was 8 (IQR 5–10). Seventy-five percent of patients had rib fractures in the upper level (rib 1–4) of the thorax, 75 patients (74%) had dorsally located fractures, and 39 patients (38%) sustained a flail chest. Emergency surgery was required in 11 patients (11%), of which 5 patients (5%) underwent a laparotomy and 4 patients (4%) underwent a thoracotomy.

The surgery-related characteristics are shown Table 4. The median time from injury to rib fixation was 3 days (IQR 1–6). All patients were treated with plate osteosynthesis, 51

Table 1 Baseline characteristics

Characteristics	Entire cohort $n=102$	Responders $n=74$	Non-responders $n=28$	p value
Age at trauma, median (IQR)	62 (54–75)	63 (54–74)	59 (53–75)	0.845
Male sex, *n* (%)	86 (84)	63 (85)	23 (82)	0.711
ASA class, *n* (%)				0.053
1	19 (19)	15 (20)	4 (14)	
2	43 (42)	36 (49)	7 (25)	
≥3	40 (39)	23 (31)	17 (61)	
Smoker, *n* (%)	21 (21)	15 (20)	6 (21)	0.897
Mechanism of trauma, *n* (%)				0.382
Motor vehicle accident	42 (41)	31 (42)	11 (39)	
Fall from height/stairs	27 (26)	17 (23)	10 (36)	
Other	33 (32)	26 (35)	7 (25)	
AIS score, median (IQR)				
Head	0 (0–2)	0 (0–2)	0 (0–3)	0.566
Face	0 (0–0)	0 (0–0)	0 (0–0)	0.481
Thorax	4 (4–4)	4 (4–4)	4 (4–4)	0.676
Abdomen	0 (0–0)	0 (0–0)	0 (0–2)	0.437
Extremities	0 (0–2)	1 (0–2)	0 (0–2)	0.515
ISS, median (IQR)	24 (20–29)	24 (20–29)	20 (17–29)	0.656
No. of rib fractures, median (IQR)	8 (5–10)	8 (5–10)	7 (5–11)	0.583
Bilateral rib fractures, *n* (%)	20 (20)	15 (20)	5 (18)	0.784
Level rib fractures, *n* (%)				
Upper	77 (75)	57 (77)	20 (71)	0.557
Middle	99 (97)	73 (97)	27 (96)	0.817
Lower	69 (68)	49 (66)	20 (71)	0.616
Displacement, *n* (%)	88 (86)	63 (85)	25 (89)	0.587
Dorsal fractures, *n* (%)	75 (74)	56 (76)	19 (68)	0.424
Flail segment, *n* (%)	39 (38)	30 (41)	9 (32)	0.436
Concomitant injuries, *n* (%)				
Pneumothorax	72 (71)	55 (74)	17 (61)	0.178
Hemothorax	60 (59)	43 (57)	17 (63)	0.610
Pulmonary contusion	48 (47)	34 (46)	14 (50)	0.714
Sternum fracture	15 (15)	12 (16)	3 (11)	0.484
Emergency surgery, *n* (%)	11 (11)	9 (12)	2 (7)	0.466

AIS abbreviated injury scale, *ASA Class*, American society of anesthesiologists classification, *GCS* glasgow coma scale, *n* number, *SD* standard deviation, *ISS* injury severity score, *IQR* interquartile range

patients (50%) were additionally treated with intramedullary splints. The median number of fixated ribs was significantly higher in the group of patients with a flail chest compared to those with multiple rib fractures (5 versus 4, $p = 0.003$). Furthermore, the number of patients who received bilateral rib fixation was also significantly higher among patients with a flail chest (90% versus 0%, $p = 0.019$).

The in-hospital and long-term outcomes of the entire cohort and specified for multiple rib fractures and flail chest are depicted in Table 2. The median HLOS and ICU-LOS were comparable between both groups, with a median of 16 days (IQR 12–21) and 2 days (IQR 1–6), respectively. Significant disadvantage of the flail chest group was observed with respect to ICU admission (90% versus 63%, $p = 0.003$) and need for mechanical ventilation (44% versus 22%, $p = 0.025$). The most common complication was pneumonia (20%), ARDS occurred in one patient (1%). Superficial wound infections occurred in two patients (2%), there were no cases of fracture-related infections. Revision surgery was performed in one patient (1%) due to a persisting thoracic hematoma. There were no implant-related complications and adequate healing of the fractures occurred in all patients. The overall mortality was 0%.

The questionnaires were completed after a median follow-up of 26 months (IQR 15–37) (Table 2). No significant differences were observed with respect to the long-term outcomes between the subgroups of patients with multiple rib fractures and flail chest. The median EQ-5D utility index

Table 2 In-hospital and long-term outcomes after rib fracture fixation

Characteristics	Entire cohort	Multiple rib fractures	Flail chest	*p* value
In-hospital outcomes	*n* = 102	*n* = 63	*n* = 39	
Length of stay, median (IQR)				
Hospital	16 (12–21)	17 (12–21)	16 (13–19)	0.928
Intensive care	2 (1–6)	3 (1–7)	2 (1–6)	0.753
Intensive care unit admission, *n* (%)	75 (74)	40 (63)	35 (90)	**0.003**
Need for mechanical ventilation, *n* (%)	31 (30)	14 (22)	17 (44)	**0.025**
Days on mechanical ventilation, median (IQR)	4 (2–10)	6 (3–14)	3 (2–10)	0.223
Complications, *n* (%)				
ARDS	1 (1)	1 (2)	0 (0)	0.618
Pneumonia	20 (20)	9 (14)	11 (28)	0.085
Tracheostomy	10 (10)	5 (8)	5 (12)	0.500
Infection	2 (2)	1 (2)	1 (3)	0.621
Mortality, *n* (%)	0 (0)	0 (0)	0 (0)	n/a
Long-term outcomes	*n* = 74	*n* = 44	*n* = 30	
EQ-5D utility index score, *n* (%)	0.91 (0.89–1.0)	0.91 (0.89–1.0)	0.91 (0.83–1.0)	0.801
EQ-VAS, *n* (%)	80 (60–95)	78 (60–95)	80 (70–90)	0.630
Problems in dimension, *n* (%)				
Mobility	47 (46)	30 (48)	17 (44)	0.692
Self-care	37 (36)	23 (37)	14 (36)	0.950
Usual activities	45 (44)	28 (44)	17 (44)	0.933
Pain/discomfort	63 (62)	42 (67)	21 (54)	0.195
Anxiety/depression	43 (42)	29 (46)	14 (36)	0.314
mMRC dyspnea scale (*n*, %)				0.788
0	60 (81)	35 (80)	25 (83)	
1	8 (11)	6 (14)	2 (7)	
2	2 (3)	1 (2)	1 (3)	
3	4 (5)	2 (5)	2 (7)	
4	0 (0)	0 (0)	0 (0)	
Implant irritation (*n*, %)	23 (31)	15 (34)	8 (27)	0.498
Implant removal (*n*, %)	0 (0)	0 (0)	0 (0)	n/a
Follow-up in months, median (IQR)	26 (15–37)	27 (17–39)	23 (13–36)	0.351

A two-sided *p* value < 0.05 was considered statistically significant

ARDS acute respiratory distress syndrome, *EQ-5D* euroqol 5-dimensions, *EQ-VAS* euroQol visual analogue scale, *IQR* inter quartile range, *mMRC* modified medical research council, *n* number

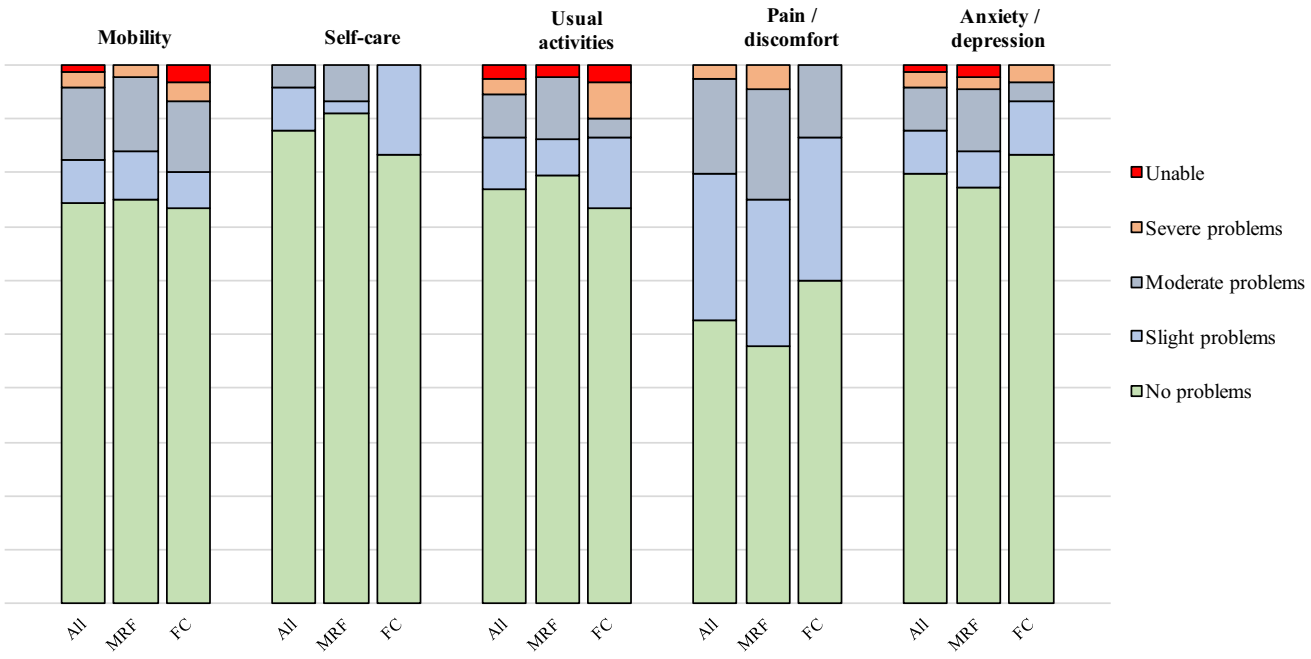

Fig. 2 EQ5D-5L scores of patients with multiple rib fractures (MRF) and flail chest (FC) after rib fracture fixation

score of the entire cohort was 0.91 (0.89–1.0), which was not significantly different from the mean score of the reference population (0.902; $p = 0.523$). The corresponding EQ-VAS score was 80 (IQR 60–95). The most frequently reported responses for the EQ-5D-5L dimensions were 'no problems' or 'slight problems', an overview of the responses for each EQ-5D-5L dimension is presented in Fig. 2. The severity of dyspnea during exercise reported by the mMRC dyspnea scale was categorized as 0 (only breathless with strenuous exercise) in the vast majority of patients (81%). Six patients (8%) experienced 'mild' to 'severe' complaints of dyspnea. Eighty-three percent of the patients that were employed before their injury reported to be able to work on their preinjury level. However, nine patients (20%) were not able to work on the same level as before their injury and seven patients (16%) were not able to work anymore. The median time between rib fixation and return to work was 12 weeks (IQR 8–20). Implant irritation was found in 23 patients (31%). Two patients (2%) considered implant removal due to the severity of their complaints. However, eventually no patients required implant removal during our follow-up.

In bivariate analysis, AIS thorax ($p = 0.030$), ISS ($p = 0.008$), total number of rib fractures ($p = 0.028$), need for mechanical ventilation ($p < 0.001$), ICU-LOS ($p < 0.001$), and pneumonia ($p = 0.001$) were associated with a reduced long-term quality of life as measured with the EQ-5D-5L (Table 5). For the health-related quality of life according to the EQ-VAS, there was a significant relationship with ASA classification ($p = 0.003$), ISS ($p = 0.015$), need for mechanical ventilation ($p = 0.001$), ICU-LOS ($p = 0.006$), and pneumonia ($p = 0.001$).

In multivariable analysis, a longer ICU-LOS (regression coefficient [β] − 0.010, 95% confidence interval [CI] − 0.017 to − 0.003; $p = 0.008$) was independently associated with a lower EQ-5D utility index (Table 3). Factors independently associated with a lower EQ-VAS were a higher ASA classification (β − 8.245, 95% CI − 14.871 to − 1.619, $p = 0.016$) and a longer ICU-LOS (β − 1.198, 95% CI − 1.917 to − 0.479, $p = 0.002$).

Discussion

With the present study, the long-term quality of life and functional outcome were assessed in patients who sustained severe thoracic injury with multiple rib fractures or a flail chest, requiring rib fracture fixation. The quality of life at a follow-up of at least 1 year postoperatively was considered good compared to the reference population. The vast majority of patients experienced a good recovery and reported 'no problems' or 'slight problems' in any of the five domains tested with the EQ-5D-5L. Furthermore, the complication rate associated with rib fracture fixation was

Table 3 Multivariable analysis

Characteristics	β coefficient	95% CI	p value
EQ-5D-5L			
Age	0.009	− 0.003 to 0.005	0.680
ASA class	0.018	− 0.048 to 0.084	0.591
BMI	− 0.000	− 0.009 to 0.085	0.997
ISS	0.001	− 0.005 to 0.007	0.765
Number of rib fractures	− 0.006	− 0.021 to 0.009	0.417
Flail segment	0.044	− 0.064 to 0.152	0.415
Need for mechanical ventilation	− 0.070	− 0.190 to 0.051	0.247
Intensive care length of stay	− 0.010	− 0.017 to − 0.003	**0.008**
EQ-VAS			
Age	0.132	− 0.303 to 0.568	0.542
ASA class	− 8.245	− 14.871 to − 1.619	**0.016**
BMI	0.243	− 0.613 to 1.101	0.567
ISS	0.112	− 0.488 to 0.711	0.708
Number of rib fractures	0.777	− 0.737 to 2.291	0.304
Flail segment	1.248	− 9.658 to 12.154	0.817
Need for mechanical ventilation	− 5.540	− 17.652 to 6.572	0.359
Intensive care length of stay	− 1.198	− 1.917 to − 0.479	**0.002**

A two-sided p value < 0.05 was considered statistically significant

ASA Class, American Society of Anesthesiologists Classification; BMI, Body Mass Index; EQ-VAS, EuroQol Visual Analogue Scale; ISS, Injury Severity Score

low with implant-related irritation being the most common long-term sequela in 31% of the patients, without the need of any re-intervention.

A recent systematic review showed that in the current literature, a varying range of outcome measures has been used to report on the health-related quality of life and functional outcome after surgical treatment of rib fractures [18]. Similar to the present study, four previous studies used the EQ-5D-5L to determine the quality of life. Most recently, Beks et al. presented the long-term results of 166 patients with multiple rib fractures (≥ 3 rib fractures) or a flail chest at a follow-up ranging from 1 to 7.5 years after surgery [19]. In accordance to our findings, their patients with multiple rib fractures as well as those treated for a flail chest appeared to have a good recovery, with an EQ-5D utility index comparable to the Dutch reference population. Importantly, although the ISS and the number of fractured ribs were higher among flail chest patients, there was no significant difference in the long-term outcomes compared to patients with multiple rib fractures. In a study of Caragounis et al., patients' quality of life, as measured with the EQ-5D utility index, progressively increased from 0.78 to 0.93 in the first year after surgery [20]. Interestingly, they found that the greatest improvement tended to occur between 6 weeks and 3 months postoperatively. Therefore, we assume that our follow-up duration is appropriate to assess the long-term outcomes after rib fracture fixation. Furthermore, in a retrospective cohort study of Mayberry et al., quality of life was assessed using the Research and Development-36 (RAND-36) survey in patients who required surgical fixation for severe chest wall injuries [21]. They found that patients' health status after surgery was equivalent or even better compared to the general population.

Although the long-term quality of life after rib fracture fixation appeared to be good in our patient population, several studies have not been able to show any quality of life benefit of rib fracture fixation over conservative treatment. In a prospective follow-up study of Walters et al., no significant differences were observed with respect to patient-reported outcome measures including quality of life, pain, and overall satisfaction between patients who received rib fracture fixation an those who were not operated [22]. However, the interpretation of their results was limited due to a low response rate. Additionally, in a retrospective cohort study of Marasco et al., quality of life measured over 24 months after surgery did not differ among the operative and non-operative group [23]. Nevertheless, the authors noted that the rib fracture-related characteristics, such as total number of fractured ribs, thoracic level of rib fractures, and degree of displacement, were not taken into account.

Therefore, as these factors were expected to be of influence on the decision to operate, selection bias could have affected their results. In conclusion, despite strong indications that rib fracture fixation might be beneficial in the long-term with respect to quality of life, high-quality evidence is still needed to determine the difference in outcomes between surgical and non-surgical management.

Knowledge about the course of quality of life, functional outcome, and pain after rib fracture fixation might be of great value to guide patients on what to expect of their recovery. Furthermore, establishing evidence regarding factors predicting the outcome could facilitate identification of patients at risk of an impaired or delayed recovery. Despite the fact that evidence on these factors is scarce in the current literature, a previous study has shown that the total number of fractured ribs and fractures in the lower segment of the thorax might negatively predict patients' quality of life [24]. Nevertheless, the overall injury severity and the severity of the thoracic injuries were not associated with a worse outcome. These results mirror our findings, as the injury-related characteristics such as total ISS, AIS thorax, and presence of a flail chest appeared not to be of influence on the EQ-5D-5L. In addition, only the total ICU-LOS was independently associated with a diminished quality of life in multivariable regression analyses. Taking these results into account, one might suggest that although flail chest patients should be considered as a different entity with more severe intra- and extra-thoracic injuries leading to worse in-hospital outcomes, surgical fixation might restore the chest wall anatomy resulting in a good long-term recovery comparable to patients who sustained rib fractures without a flail chest.

Operative treatment of rib fractures has been associated with complications such as wound- or fracture-related infections, bone-healing complications, implant irritation, and the need for revision surgery. A recent systematic review showed that the overall risk of surgery- and implant-related complications was 10.3% [18]. However, the incidence of the clinically most important complications such as wound- or fracture-related infections was relatively low, indicating that rib fracture fixation is a safe procedure. Nevertheless, it has been shown that implant irritation might be a very important but potentially underestimated problem, as only few studies reported on this outcome. Implant-related irritation varied widely between 0 to 53% among the included studies [18]. In the present study, implant-related irritation was considered the most import long-term sequela after rib fracture fixation, and occurred in about one-third of patients. However, none of the patients required re-intervention or removal of the implant material. A potential explanation for the high rate of patients which experience implant irritation is that ribs are subject to continual movement during respiration, in combination with the narrow anatomical boundaries in which the osteosynthesis material is inserted. As implant-related irritation can result in enduring chest pain, patients should be counseled accordingly.

A number of limitations need to be acknowledged. This study was a retrospective cohort study with a follow-up by questionnaire. Therefore, we were not able to report on the course of patients' recovery during standardized times in the follow-up. Furthermore, although we demonstrated that the quality of life after rib fracture fixation appeared to be good, no comparison was made with a conservatively treated control group, which would have increased the understanding of the impact surgical fixation has on patient-reported quality of life and functional outcomes. In addition, it must be noted that implant-related irritation is a subjective reporting in which patients mostly experience a local discomfort at the site of surgery. Nevertheless, it remains unclear whether this is solely related to the implant material or if other factors such as scar tissue formation, injury pattern, or loss of compliance of the thoracic wall are of influence. However, in our previous study, no restrictive lung function impairment was found after rib fracture fixation [8]. Finally, despite that with 102 patients this study is one of the larger studies reporting on the quality of life after rib fracture fixation, our multiple regression analyses were restricted by the number of predictors that could be incorporated.

Conclusion

In conclusion, the results of this study showed that patients who underwent rib fracture fixation for multiple rib fractures or flail chest after severe chest trauma experienced a good quality of life at least 1 year after surgery. A longer ICU-LOS was independently associated with an impaired quality of life. In addition, there were no significant differences in the long-term quality of life and functional outcome between patients with multiple rib fractures and a flail chest. Implant-related irritation was the most important long-term sequela and occurred in one-third of patients.

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Compliance with ethical standards

Conflict of interest The authors declared no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Appendix

See Tables 4, 5.

Table 4 Surgery-related characteristics

Characteristics	Entire cohort $n=102$	Multiple rib fractures $n=63$	Flail chest $n=39$	p value
Time injury to ORIF, d, median (IQR)	3 (1–6)	3 (1–7)	2 (1–5)	0.624
Duration of surgery, min, median (IQR)	139 (123–180)	135 (120–147)	151 (134–195)	**< 0.001**
Surgical approach, *n* (%)				0.269
Anterior	8 (8)	5 (8)	3 (8)	
Anterolateral	21 (21)	15 (24)	6 (15)	
Posterior	8 (8)	5 (8)	3 (8)	
Posterolateral	55 (54)	35 (56)	20 (51)	
Number of ribs fixated, median (IQR)	5 (3–6)	4 (3–4)	5 (4–7)	**0.003**
Ratio fixated ribs/fractured ribs	0.6 (0.5–0.9)	0.6 (0.5–0.9)	0.6 (0.5–0.9)	0.986
Side of rib fixation, *n* (%)				**0.019**
Unilateral	98 (96)	100 (100)	35 (90)	
Bilateral	4 (4)	0 (0)	4 (10)	

A two-sided p value < 0.05 was considered statistically significant

d days, *IQR* interquartile range, *min* minutes, *N* number, *ORIF* open reposition internal fixation

Table 5 Bivariate analysis

Characteristics	EQ-5D utility index			EQ-VAS		
	β coefficient	95% CI	p value	β coefficient	95% CI	p value
Age	0.000	− 0.000 to − 0.000	0.080	0.055	− 0.306 to 0.416	0.762
Female	− 0.045	− 0.146 to 0.059	0.391	− 0.307	− 14.123 to 13.509	0.965
ASA	0.005	− 0.039 to 0.049	0.811	− 8.580	− 14.044 to − 3.117	**0.003**
BMI	0.001	− 0.005 to 0.006	0.818	0.383	− 0.346 to 1.112	0.298
Smoker	0.047	− 0.045 to 0.839	0.311	− 5.497	− 17.655 to 6.660	0.370
Diabetes	− 0.014	− 0.114 to 0.086	0.784	− 6.325	− 19.577 to 6.926	0.345
AIS thorax	− 0.067	− 0.128 to 0.007	**0.030**	− 7.423	− 15.521 to 0.674	0.072
Injury Severity Score	− 0.005	− 0.008 to − 0.001	**0.008**	− 0.576	− 1.038 to − 0.114	**0.015**
Total number of fractures	− 0.011	− 0.021 to − 0.001	**0.028**	− 0.720	− 2.046 to 0.605	0.282
Flail segment	0.003	− 0.072 to 0.079	0.928	1.655	− 8.349 to 11.658	0.743
Sternum fracture	0.006	− 0.093 to 0.107	0.896	− 0.358	− 13.692 to 12.977	0.958
Need for mechanical ventilation	− 0.137	− 0.212 to − 0.063	**< 0.001**	− 17.126	− 27.096 to − 7.153	**0.001**
Intensive care length of stay	− 0.010	− 0.017 to − 0.005	**< 0.001**	− 1.019	− 1.738 to − 0.299	**0.006**
Pneumonia	− 0.152	− 0.240 to − 0.065	**0.001**	− 0.153	− 0.240 to 0.065	**0.001**
Infection	− 0.155	− 0.381 to 0.070	0.174	− 3.305	− 33.606 to 26.994	0.828
Follow-up time	− 0.000	− 0.003 to 0.001	0.405	0.171	− 0.077 to 0.418	0.174

A two-sided p value < 0.05 was considered statistically significant

AIS abbreviated injury scale, *ASA Class* American society of anesthesiologists classification, *BMI* body mass index, *EQ-5D* euroqol 5-dimensions, *EQ-VAS* euroqol visual analogue scale

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