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A Retrospective Study Examining the Morbidity and Mortality of Rib Fractures

Amber Ahmed-Issap [1], Marko Raseta [2], Kajan Mahendran [1], Lakshmi Srinivasan [1], Shilajit Ghosh [1], Udo Abah [1]

1. Cardiothoracic Surgery, Royal Stoke Hospital, Stoke-on-Trent, GBR 2. Statistics, Erasmus University Medical Centre, Rotterdam, NLD

Corresponding author: Amber Ahmed-Issap, amberaissap@gmail.com

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Abstract

Introduction

Blunt thoracic trauma (BTT) is the third most common form of traumatic injury, of which rib fractures have been reported to be the most common. Various comorbidities increase the risk of complications following injury. This study aims to explore these risk factors that may contribute to the development of these complications.

Methods

A retrospective study of patients with BTT was conducted at the University Hospitals of North Midlands, a major trauma centre in England. The primary outcome was rib fracture-related complications, defined as the occurrence of ⩾1 of the following: 90-day mortality, pulmonary complications (including infection, pleural effusion and empyema, haemothorax, pneumothorax and pulmonary contusions), ICU admission, or a hospital stay of ⩾7 days.

Results

Of 438 included patients, 199 were admitted to hospital. Recorded complications occurred in 163 patients (37.2%), and 41 patients (9.4%) died within 90 days. In adjusted analyses, age >65 years, lower SpO_2 at presentation and pulmonary contusion were associated with 90-day mortality. Age >65 years and lower SpO_2 were also associated with prolonged hospital LOS. Smoking status was not independently associated with complications or 90-day mortality.

Conclusion

Older age and lower oxygen saturation at presentation may identify patients at greater risk of adverse outcomes following traumatic rib fractures. Pulmonary contusion was also associated with 90-day mortality, although the estimate was imprecise because of the small number of events. These observational associations should not be interpreted as causal.

Categories: Trauma, Emergency Medicine, Cardiac/Thoracic/Vascular Surgery
Keywords: blunt thoracic trauma, long-term prognosis, morbidity and mortality, rib fractures, risk assessment tools

Introduction

Within the United Kingdom (UK), the National Health Service (NHS) faces an ever-worsening imbalance between available resources and demand. This challenge is most acutely evident within the Accident and Emergency (A&E) departments of large NHS Trusts, with patients experiencing prolonged waits for assessment, treatment and admission. This is particularly evident within major trauma centres that process large numbers of patients with varying traumatic injuries.

Thoracic trauma has been reported to comprise 10-15% of all trauma-related hospital admissions globally, with rib fractures accounting for the most common type of clinically significant blunt thoracic trauma [1]. This study aims to examine the clinical outcomes of rib fractures at one of the UK's adult major trauma centres and further determine the risk factors for the composite outcomes of complications.

Epidemiology

The vast majority (70%) of thoracic traumas are due to blunt injuries, such as motor vehicle accidents (MVAs), falls from a height, assaults, or industrial accidents [2]. The remaining cases are due to penetrating injuries [2]. Rib fractures can lead to devastating complications, which can have life-threatening outcomes. Patients who have suffered significant rib fractures commonly deteriorate within the first 2-3 days after the injury [3]. The incidence of pneumonia and other lower respiratory tract infections (LRTIs) is approximately

31% in the elderly with rib fractures [4]. Other complications include pneumothorax (collapsed lung), haemothorax (blood in the thoracic cavity), haemo-pneumothorax (both a pneumothorax and haemothorax), pulmonary contusion (bruising of the lung tissue), flail chest (where several ribs are broken at two or more points allowing for paradoxical movement of a section of the chest wall during respiration) and subcutaneous emphysema (air within the subcutaneous layer of the skin) [3].

Depending on the severity of the injury, rib fractures are a common cause of hospital admissions and may lead to admission to the intensive care unit (ICU) [2]. The length of hospital stay can vary and depends on the patient's age [5], concurrent injuries [1], and/or infections [4]. Baker and colleagues [6] also report a higher readmission rate in patients with moderate to severe rib fractures.

Mortality following rib fractures is challenging to estimate due to possible concomitant injuries and indirect mortality from sequelae. However, it has been estimated that the mortality rate is approximately 10-13% [3,7]. Three main mechanisms have been described in the literature that contribute to this mortality rate: shallow breathing (hypoventilation) due to pain, leading to sputum retention and partial collapse of the lung; damaged lungs causing impaired gas exchange; and finally, altered mechanics due to a disruption in the thoracic ribcage [3].

Aims and objectives

The primary aim of this study was to describe morbidity and 90-day mortality following traumatic rib fractures in adults presenting to a UK major trauma centre. Secondary aims were to identify demographic, clinical and injury-related factors associated with the composite adverse outcome, 90-day mortality, LRTI and prolonged hospital LOS, and to compare outcomes according to admission specialty.

Materials And Methods

Study design

A single-centre retrospective cohort study was conducted in the A&E department at the University Hospitals of North Midlands (UHNM) major trauma centre in Stoke-on-Trent, England. The study was conducted over 27 months, from 01/06/2021 to 12/09/2023.

Population

Patients were identified by the UHNM Information and Performance team from A&E department discharge letters with a discharge diagnosis of 'rib fractures' or its derivatives, including 'fracture of rib', 'fracture of rib closed', 'fracture of rib open', 'multiple fractures of ribs', 'multiple fractures of ribs closed', 'multiple fractures of ribs open', 'flail chest closed' or 'flail chest open'. These were developed from the standardised list of International Classification of Diseases (10th revision ICD-10) principal codes of any blunt thoracic trauma [8]. Only patients with isolated rib fractures and over the age of 18 were included in this study.

Exclusion criteria included age <18 years, patients with polytrauma, lack of scans to confirm the presence of rib fractures, reported rib fractures as 'old' rather than 'acute', and the exact number of rib fractures not stated (such as reported as 'many', not specifying the number of rib fractures).

Outcomes

Data were captured from electronic records and paper notes scanned into the hospital's electronic patient records platform (iPortal). Each patient was searched manually using their unique patient identity number, with recordings of patient demographics, comorbidities at the time of injury, smoking status at the time of injury, mechanism of injury, admission vital signs and imaging type (for example, chest X-ray (CXR) or computed tomography (CT) scan). In this study, chronic lung disease was defined very broadly, encompassing chronic obstructive pulmonary disease (COPD), asthma, interstitial lung disease, emphysema and pulmonary fibrosis. Cardiac disease encompassed all those with valvular abnormalities, written evidence of heart failure, history of myocardial infarction, stent insertion or coronary artery bypass grafts. History of cancer was defined as those with a history of any cancer type, including those in remission. History of kidney disease included those with documented evidence of chronic kidney disease of any stage. Severity of each parameter was not recorded. All data were stored on an Excel (Microsoft Corp, Redmond, WA, USA) spreadsheet for the duration of the study on an encrypted UHNM NHS Trust laptop.

The composite adverse outcome was defined as the occurrence of at least one of the following: 90-day mortality; pulmonary complications, including LRTI, pleural effusion, empyema, haemothorax, pneumothorax and pulmonary contusion; ICU admission; or prolonged hospital LOS of ⩾7 days.

The following outcomes were recorded from medical records or imaging evidence: 90-day mortality (either in-hospital or out-of-hospital); complications including all pulmonary complications (including pneumothorax, haemothorax, pulmonary contusions, pneumonia, and empyema (collection of pus in the pleural space) within two weeks of injury); ICU admission; prolonged hospital stay (defined as ⩾7 days);

hospital admission; total hospital length of stay (LoS); need for surgical management of the rib fractures (rib-fixation surgery), recorded separately as a management intervention rather than a complication; chest infection (both in- or out-of-hospital, recorded from General Practitioner (GP) records by patient note documentation of evidence of infection on respiratory examination, prescription of antibiotics or imaging evidence of infection) within two weeks of injury; presence of pulmonary embolism (PE) within two weeks of injury; need for re-admission if discharged after initial rib fracture diagnosis within two weeks of injury and admission specialty (medicine versus surgical department). The clinical and radiological criteria for respiratory tract infection were not specified and were on the onus of the data extractor.

There was one data extractor for this study. This individual was blinded to the exact outcomes that were being measured and the hypothesis prior to the study.

Further information is found in the Appendix.

Sample size

Our objective was to include a sufficient number of patients to enable the presentation of both unadjusted and adjusted odds ratios, along with 95% confidence intervals, pertaining to the risk factors associated with the development of complications following blunt thoracic trauma. Peduzzi et al. [9] proposed that the sample size necessary to ensure adequate statistical power in a retrospective cohort study is 10 events per variable (EPV) being examined. Consequently, this study required a minimum of 100 events -- patients experiencing complications after blunt thoracic trauma -- given that 10 variables were under investigation.

Statistical analysis

A variety of different statistical methods were used during this study. Categorical data were summarised via numbers and percentages, while continuous data were summarised via means and standard deviations (SD) or medians and interquartile ranges (IQR), subject to the outcome of the Kolmogorov-Smirnov normality test. Equally, group comparisons of categorical data were done by means of the Z-test and F-test, subject to the expected cell counts, while group comparisons in continuous data were done by either t-test or Mann-Whitney U-test, subject to the outcome of the Kolmogorov-Smirnov normality test. All statistical analyses were performed using R statistical software version 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria; packages: pROC and Caret) [10].

Ethical approval

The study was approved as an audit by the UHNM audit team and the Ethics Committee at the University of Edinburgh. Patient and public involvement (PPI) was not undertaken for this study as it was a retrospective observational analysis utilising routinely collected anonymised clinical data. The study underwent review through the appropriate institutional governance and ethics processes at the participating hospital, where it was determined that formal PPI involvement was not required due to the non-interventional nature of the study and the absence of direct patient contact or influence on patient care.

Nevertheless, the authors recognise the increasing importance of meaningful PPI engagement in trauma research and acknowledge that incorporation of patient perspectives may strengthen the design and applicability of future prospective studies. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies [11].

Results

Characteristics of study subjects

One thousand eight hundred and sixty-seven patients were identified over a 27-month period, with a total of 438 patients being included in this study. Figure *1* shows the flow of patients through the study.

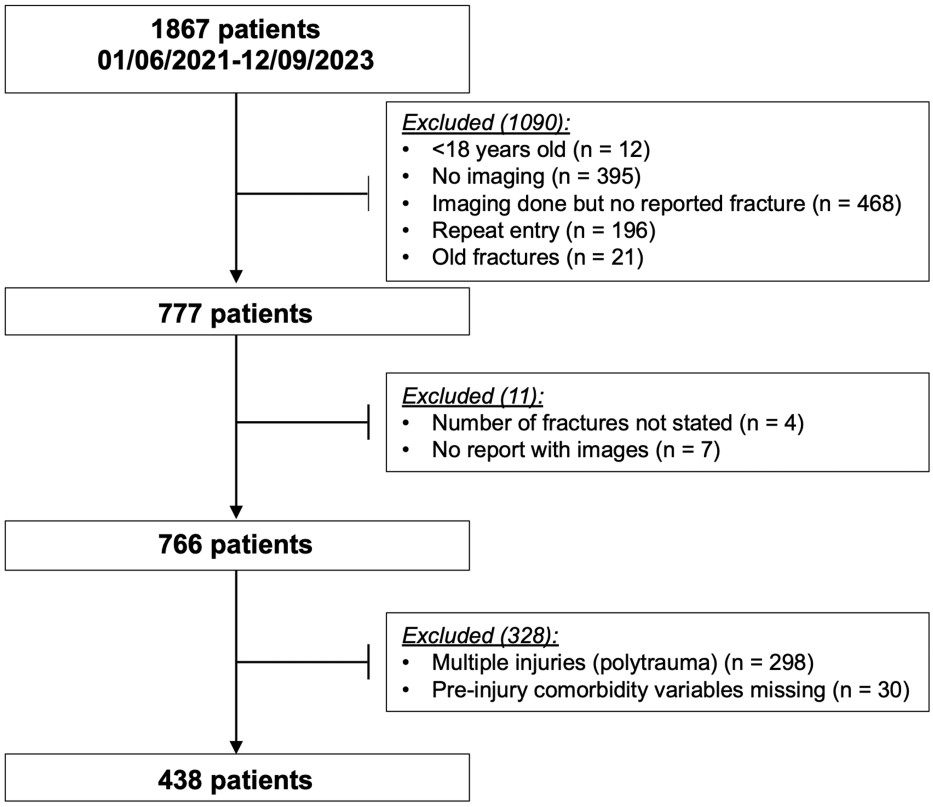


FIGURE 1: Diagram showing flow of patients through the study

All patients with blunt thoracic trauma were identified between 01/06/2021 and 12/09/2023. Patients were excluded if they did not meet the inclusion criteria.

The complete study cohort comprised 438 patients, all of whom contributed to the whole-cohort analyses. Of these, 199 (45.4%) were admitted to hospital and formed the eligible subgroup for inpatient analyses. Baseline characteristics are summarised in Table *1*. The median age was 69 years (IQR 55.0, 80.8), 282 (64.4%) patients were male, and the median number of fractured ribs was 3 (IQR 1, 5). Among admitted patients, the median hospital LOS was 6 days (IQR 2.0, 10.7); 94 (47.2%) were admitted under Medicine and 105 (52.8%) under Surgery. Twelve patients (2.7% of the complete cohort) required ICU admission. Smoking status comprised 202 (46.1%) non-smokers, 152 (34.7%) ex-smokers and 84 (19.2%) current smokers.

Participant demographics (n = 438)	
Age, median (IQR) (years)	69 (55.0, 80.8)
Number of rib fractures, median (IQR)	3 (1.0, 5.0)
BMI, median (IQR) (kg/m^2)	26.4 (23.1, 30.0)
Sex, n (%)	
Female	156 (35.6%)
Male	282 (64.4%)
Mechanism of injury, n (%)	
Fall from height	56 (12.8%)
Fall from standing	192 (43.8%)
Fall from sitting	19 (4.3%)
Fall down the stairs	62 (14.2%)
Direct chest trauma	10 (2.3%)

Kicked by animal	4 (0.9%)
Assault	14 (3.2%)
Sporting accident	5 (1.1%)
RTA - car	29 (6.6%)
RTA - motorbike	17 (3.9%)
RTA - bicycle	10 (2.3%)
RTA - pedestrian	4 (0.9%)
Other - cancer	4 (0.9%)
Other - caused by dystonia	1 (0.2%)
Other - coughing excessively	7 (1.6%)
Other - crushed by animal	1 (0.2%)
Other - not stated	3 (0.7%)
Highest level of imaging in A&E, n (%)	
CT scan	315 (71.9%)
CXR	123 (28.1%)
SpO_2 (%), n (%)	
SpO_2 95-100	340 (77.6%)
SpO_2 90-94	43 (9.8%)
SpO_2 85-89	8 (1.8%)
SpO_2 80-84	1 (0.2%)
SpO_2 75-79	0 (0.0%)
SpO_2 70-74	1 (0.2%)
SpO_2 on supplemental O_2	45 (10.3%)
HR, mean ± SD (beats/minute)	81.8 ± 16.4
RR, median (IQR) (breaths/minute)	18 (16.0, 20.0)
Systolic BP, mean ± SD (mmHg)	143.1 ± 25.8
Smoking status, n (%)	
Non-smoker	202 (46.1%)
Ex-smoker	152 (34.7%)
Current smoker	84 (19.2%)
Comorbidities, n (%)	
Pre-injury anticoagulation	65 (14.8%)
Chronic lung disease	138 (31.5%)
Cardiac disease	123 (28.1%)
Hypercholesterolaemia/hyperlipidaemia	108 (24.7%)
Type 2 diabetes	70 (16.0%)
AF	50 (11.4%)
HTN	187 (42.7%)
History of kidney disease	62 (14.2%)

History of cancer	59 (13.5%)
History of stroke	47 (10.7%)
Current or ex-IVDU	7 (1.6%)
RA	9 (2.1%)
OA	92 (21.0%)
History of alcohol excess	38 (8.7%)
History of VTE	27 (6.2%)
Dementia	33 (7.5%)
Parkinson's disease	12 (2.7%)
Hospital admission, n (%)	199 (45.4%)
Hospital LoS, median (IQR) (days)	6 (2.0, 10.7)
Admission specialty, n (%)	
Medicine	94 (47.2%)
Surgery	105 (52.8%)
ICU admission, n (%)	12 (2.7%)
ICU LoS, mean (SD)	8.5 (10.8)

TABLE 1: Baseline demographics of study participants

IQR = interquartile range; BMI = body mass index; RTA = road traffic accident; A&E = Accident & Emergency; CT = computed tomography; CXR = chest x-ray; SpO_2 = oxygen saturation; O_2 = oxygen; HR = heart rate; SD = standard deviation; RR = respiratory rate; BP = blood pressure; AF = atrial fibrillation; HTN = hypertension; IVDU = intravenous drug user; RA = rheumatoid arthritis; OA = osteoarthritis; VTE = venous thromboembolism; LoS = length of stay; ICU = intensive care unit.

Morbidity and mortality of rib fractures

Figure *2* shows the morbidity and mortality of rib fractures. Complications developed in 37.2% (n = 163) of patients. The most common complications were LRTIs (n = 88, 20.1%) followed by pleural effusions (n = 39, 8.9%). Ninety-eight (22.4%) patients had a prolonged hospital LoS. No patient developed an empyema. Twenty-six (5.9%) patients were re-admitted following initial diagnosis. Nineteen patients were re-admitted following an initial A&E visit without admission, primarily due to shortness of breath secondary to chest pain, with three patients presenting with increased oxygen demand. Seven patients were re-admitted after discharge from a hospital stay due to misdiagnosis on original imaging, LRTI, problems with social situation at home or increased shortness of breath.

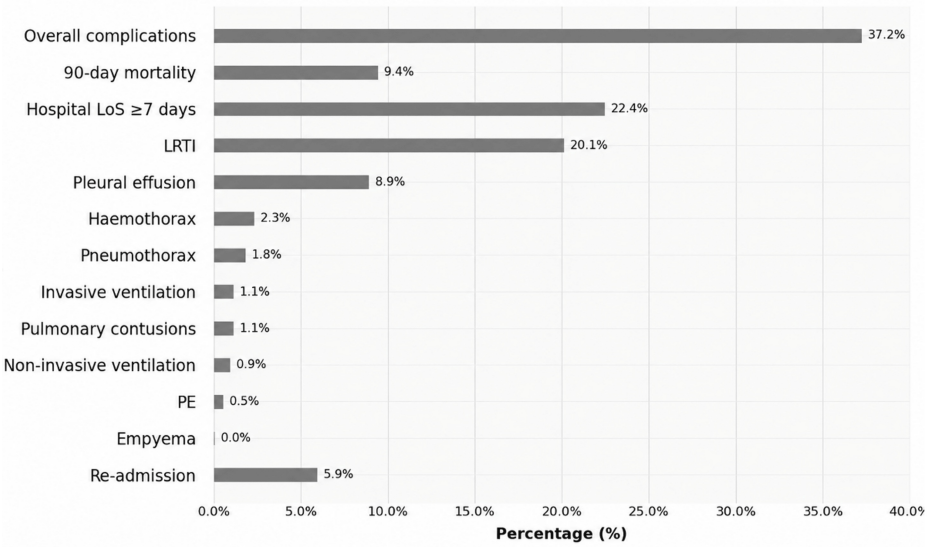


FIGURE 2: Morbidity and mortality of rib fractures

Percentages of patients experiencing overall complications, 90-day mortality, prolonged hospital LOS, individual pulmonary complications, ventilatory support and re-admission following initial discharge.

LOS = length of stay; LRTI = lower respiratory tract infection; PE = pulmonary embolism.

Table 2 compares patients who experienced the composite adverse outcome with those who did not. Patients experiencing the composite outcome were generally older and had a greater number of fractured ribs. Supplemental oxygen at presentation was more frequent in the composite-outcome group than in the no-outcome group (16.6% versus 6.5%, p = 0.001), as was a fall from standing (52.1% versus 38.9%, p = 0.009). Ex-smokers accounted for 70 (42.9%) patients in the composite-outcome group compared with 82 (29.8%) in the no-outcome group, whereas non-smokers accounted for 62 (38.0%) and 140 (50.9%), respectively. Current smoking prevalence was similar between groups. Sex and chronic lung disease were not significantly associated with the composite outcome in this unadjusted comparison.

Variable	No complications (n = 275)	Complications (n = 163)	Test statistic	p-Value
Age, median (IQR) (years)	66 (53.0, 78.0)	76 (58.5, 83.0)	27711 (MW)	**3.507×10^{-5}**
Number of rib fractures, median (IQR)	2 (1.0, 4.0)	4 (2.0, 5.0)	27439 (MW)	**6.719×10^{-5}**
Sex, n (%)				
Female	96 (34.9%)	60 (36.8%)	0.088999 (Z)	0.77
Male	179 (65.1%)	103 (63.2%)	0.088999 (Z)	0.77
SpO_2 (%), n (%)				
SpO_2 95-100	231 (84.0%)	109 (66.9%)	16.316 (Z)	**5.4×10^{-5}**
SpO_2 90-94	22 (8.0%)	21 (12.9%)	2.2327 (Z)	0.14
SpO_2 on supplemental O_2	18 (6.5%)	27 (16.6%)	10.083 (Z)	**0.001**
Mechanism of injury, n (%)				
Fall from height	46 (16.7%)	10 (6.1%)	9.3693 (Z)	**0.002**
Fall from standing	107 (38.9%)	85 (52.1%)	6.7569 (Z)	**0.009**
RTA - car	17 (6.2%)	12 (7.4%)	0.079169 (Z)	0.78
Smoking status, n (%)				
Non-smoker	140 (50.9%)	62 (38.0%)	6.3159 (Z)	**0.01**

Ex-smoker	82 (29.8%)	70 (42.9%)	7.2135 (Z)	**0.007**
Current smoker	53 (19.3%)	31 (19.0%)	5.0411×10^{-31} (Z)	1.0
Comorbidities, n (%)				
Pre-injury anticoagulation	37 (13.5%)	28 (17.2%)	0.84736 (Z)	0.36
Chronic lung disease	78 (28.4%)	60 (36.8%)	3.003 (Z)	0.08
Cardiac disease	76 (27.6%)	47 (28.8%)	0.025503 (Z)	0.87
Type 2 diabetes	41 (14.9%)	29 (17.8%)	0.43672 (Z)	0.51
AF	28 (10.2%)	22 (13.5%)	0.80855 (Z)	0.37
History of kidney disease	34 (12.4%)	28 (17.2%)	1.5759 (Z)	0.21
History of cancer	33 (12.0%)	26 (16.0%)	1.0526 (Z)	0.30
History of stroke	25 (9.1%)	22 (13.5%)	1.6396 (Z)	0.20
Dementia	14 (5.1%)	19 (11.7%)	**5.425 (Z)**	**0.02**
Hospital admission, n (%)	93 (33.8%)	106 (65.0%)	**38.967 (Z)**	**4.3×10^{-10}**
Hospital LoS, median (IQR) (days)	4.0 (1.0, 7.6)	7.7 (3.6, 14.1)	**9149 (MW)**	**7.083×10^{-13}**
Admission specialty				
Medicine	36 (38.7%)	58 (54.7%)	**29.396 (Z)**	**5.9×10^{-8}**
Surgery	57 (61.3%)	48 (45.3%)	3.8052 (Z)	0.051
ICU LoS, mean (SD)	2.9 (2.2)	15.2 (12.6)	2.0012 (t-test)	0.11

TABLE 2: Comparison of patients who developed the primary outcome of overall complications following rib fractures and those who did not develop the primary outcome

SD = standard deviation; IQR = interquartile range; RTA = road traffic accident; SpO2 = oxygen saturation; O_2 = oxygen; AF = atrial fibrillation; LoS = length of stay; ICU = intensive care unit; NA = not applicable.

Categorical variables are compared by means of either Z test (Z), Fisher's exact test (F), Mann-Whitney U-test (MW) or t-test subject to the expected event counts. Statistically significant associations are indicated in bold text.

Univariable logistic regression analyses of factors associated with the composite adverse outcome are presented in Table *3*. Age >65 years (OR 2.25, 95% CI 1.49, 3.39, $p < 0.001$), each additional fractured rib (OR 1.18, 95% CI 1.08, 1.29, $p < 0.001$), dementia (OR 2.46, 95% CI 1.20, 5.05, $p = 0.01$) and hospital admission (OR 3.64, 95% CI 2.42, 5.47, $p < 0.001$) were associated with higher odds of the composite adverse outcome. Higher SpO_2 at presentation was associated with lower odds of the outcome (OR 0.98 per percentage-point increase, 95% CI 0.96, 0.99, $p < 0.001$). In the separate analysis of admission specialty, compared with admission under Medicine, non-admission (OR 0.19, 95% CI 0.11, 0.32, $p < 0.001$) and admission under Surgery (OR 0.52, 95% CI 0.30, 0.92, $p = 0.02$) were associated with lower odds of the outcome. Sex, mechanism of injury, smoking status, pre-injury anticoagulation, the remaining comorbidities and ICU admission were not statistically significantly associated with the composite adverse outcome.

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	2.25	(1.49, 3.39)	**0.0001**
Number of rib fractures	1.18	(1.08, 1.29)	**0.0002**
Male sex	0.92	(0.62, 1.38)	0.69
SpO_2 (%)	0.98	(0.96, 0.99)	**0.0004**
Mechanism of injury			
Fall from height	0.39	(0.11, 1.42)	0.15
Fall from standing	1.43	(0.46, 4.43)	0.54
RTA - car	1.27	(0.34, 4.76)	0.72
Smoking status			
Non-smoker	0.76	(0.44, 1.29)	0.31
Ex-smoker	1.46	(0.85, 2.52)	0.18
Comorbidities			
Pre-injury anticoagulation	1.33	(0.78, 2.28)	0.29
Chronic lung disease	1.50	(0.99, 2.26)	0.06
Cardiac disease	1.06	(0.69, 1.62)	0.81
Type 2 diabetes	1.24	(0.74, 2.08)	0.43
AF	1.38	(0.76, 2.50)	0.29
HTN	1.40	(0.95, 2.07)	0.09
History of kidney disease	1.47	(0.850, 2.53)	0.16
History of cancer history	1.39	(0.80, 2.42)	0.24
History of stroke	1.56	(0.85, 2.87)	0.15
Dementia	2.46	(1.20, 5.05)	**0.01**
Hospital admission	3.64	(2.42, 5.47)	**5.19×10^{-10}**
Admission specialty			
No admission	0.19	(0.11, 0.32)	**2.43×10^{-10}**
Surgery	0.52	(0.30, 0.92)	**0.02**
ICU admission	1.71	(0.54, 5.40)	0.358

TABLE 3: Univariate analysis of factors affecting the development of overall complications

CI = confidence interval; RTA = road traffic accident; SpO_2 = oxygen saturation; O_2 = oxygen; AF = atrial fibrillation; HTN = hypertension; LoS = length of stay; ICU = intensive care unit.

Statistically significant associations are indicated in bold text.

In the multivariable analysis of the composite adverse outcome (Table 4), patients who were not admitted had lower adjusted odds of experiencing the outcome than patients admitted under Medicine (OR 0.26, 95% CI 0.15, 0.46, $p < 0.001$). Admission under Surgery also showed lower odds relative to Medicine, although this association did not reach statistical significance (OR 0.54, 95% CI 0.28, 1.02, $p = 0.058$). Age >65 years, number of fractured ribs, SpO_2 and dementia were not independently associated with the composite outcome. The differences according to admission pathway probably reflect variation in injury severity, physiological compromise and underlying case mix and should not be interpreted as effects of admission or specialty assignment itself.

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	1.36	(0.86, 2.16)	0.19
Number of rib fractures	1.07	(0.96, 1.18)	0.24
SpO_2 (%)	0.99	(0.97, 1.004)	0.16
Dementia	1.41	(0.63, 3.17)	0.40
Admission specialty			
No admission	0.26	(0.15, 0.46)	**0.000004**
Surgery	0.54	(0.28, 1.02)	0.06

TABLE 4: Multivariable analysis of factors affecting the development of overall complications

CI = confidence interval; SpO_2 = oxygen saturation.

Statistically significant associations are indicated in bold text.

A total of 41 patients (9.4%) had a 90-day mortality (Table 5). Whilst 95.1% of the patients who had a 90-day mortality were aged over 65, only 4.9% ($p < 0.01$) were less than 65. Again, falls from standing were found to be higher in the 90-day mortality group than in the survival group (80.5% and 40.1%, respectively, $p < 0.01$). Like the development of overall complications, more ex-smokers were found in the 90-day mortality group than in the survival group (48.8% and 33.0%, respectively, $p = 0.07$). Pre-injury anticoagulation was more common in the 90-day mortality group (39.0%; $p < 0.01$), as was the requirement for supplemental oxygen on arrival to A&E (24.4%; $p = 0.0002$). All comorbidities were higher in the mortality group than the survival group. More patients in the mortality group developed LRTI than the survival group (39.0% versus 18.1%, respectively; $p < 0.01$).

Variable	90-day mortality (n = 41)	Survived (n = 397)	Test statistic	p-Value
Age >65 (years), n (%)	39 (95.1%)	211 (53.1%)	**25.038 (Z)**	**5.6×10^{-7}**
Number of rib fractures, median (IQR)	3.0 (2.0, 5.0)	3 (1.0, 5.0)	8756 (MW)	0.34
Male sex, n (%)	30 (73.2%)	252 (63.5%)	1.1297 (Z)	0.29
SpO_2 (%), n (%)				
SpO_2 95-100	26 (63.4%)	202 (50.9%)	1.8637 (Z)	0.17
SpO_2 90-94	4 (9.8%)	23 (5.8%)	Fisher	0.30
SpO_2 on supplemental O_2	10 (24.4%)	31 (7.8%)	Fisher	**0.0002**
Mechanism of injury, n (%)				
Fall from height	1 (2.4%)	55 (13.9%)	3.3791 (Z)	0.07
Fall from standing	33 (80.5%)	159 (40.1%)	**23.067 (Z)**	**1.6×10^{-6}**
RTA - car	2 (4.9%)	27 (6.8%)	Fisher	0.70
Smoking status, n (%)				
Non-smoker	17 (41.5%)	185 (46.6%)	0.21489 (Z)	0.64
Ex-smoker	20 (48.8%)	132 (33.2%)	3.3002 (Z)	0.07
Current smoker	4 (9.8%)	80 (20.2%)	1.9635 (Z)	0.16
Comorbidities, n (%)				
Pre-injury anticoagulation	16 (39.0%)	49 (12.3%)	**18.876 (Z)**	**1.4×10^{-5}**

Chronic lung disease	19 (46.3%)	119 (30.0%)	**3.8856 (Z)**	**0.049**
Cardiac disease	20 (48.8%)	103 (25.9%)	**8.4981 (Z)**	**0.004**
Type 2 diabetes	11 (26.8%)	59 (14.9%)	3.1228 (Z)	0.08
AF	12 (29.3%)	38 (9.6%)	Fisher	**0.0008**
History of kidney disease	13 (31.7%)	49 (12.3%)	**9.9299 (Z)**	**0.002**
History of cancer	13 (31.7%)	46 (11.6%)	**11.239 (Z)**	**0.0008**
History of stroke	8 (19.5%)	39 (9.8%)	Fisher	0.07
Dementia	9 (22.0%)	24 (6.0%)	Fisher	**0.002**
Hospital admission, n (%)	26 (63.4%)	173 (43.6%)	**5.126 (Z)**	**0.02**
Admission specialty				
Medicine	20 (76.9%)	74 (42.8%)	**18.281 (Z)**	**1.9×10^{-5}**
Surgery	6 (23.1%)	99 (57.2%)	1.636 (Z)	0.20
Complications, n (%)				
LRTI	16 (39.0%)	72 (18.1%)	**8.8405 (Z)**	**0.003**
Pneumothorax	1 (2.4%)	7 (1.8%)	Fisher	0.55
ICU admission, n (%)	2 (4.9%)	10 (2.5%)	Fisher	0.31
Haemothorax	0 (0.0%)	10 (2.5%)	Fisher	0.61
Pulmonary contusion	3 (7.3%)	2 (0.5%)	Fisher	**0.007**
Re-admission	4 (9.8%)	22 (5.5%)	Fisher	0.29
Prolonged hospital LoS	18 (43.9%)	77 (19.4%)	**11.737 (Z)**	**0.0006**

TABLE 5: Factors influencing 90-day mortality following blunt thoracic trauma

SD = standard deviation; IQR = interquartile range; RTA = road traffic accident; SpO_2 = oxygen saturation; O_2 = oxygen; AF = atrial fibrillation; LoS = length of stay; ICU = intensive care unit; LRTI = lower respiratory tract infection; prolonged hospital LoS = ≥7 days; NA = not applicable.

Categorical variables are compared by means of either Z test (Z), Fisher's exact test (Fisher) or Mann-Whitney U-test (MW). Statistically significant associations are indicated in bold text.

Similarly, 90-day mortality was found to be 15 times more likely in patients aged >65 years (OR 15.53, 95% CI 3.70, 65.25, p = 0.0002), as seen in Table 6. An ex-smoker status was found to increase 90-day mortality almost three-fold (OR 3.03, 95% CI 1.00, 9.18, p = 0.05), and being on anticoagulation therapy before injury raised the chance of mortality within 90 days by 4.6 times (OR 4.55, 95% CI 2.27, 9.11, p < 0.001). Chronic lung disease and cardiac disease doubled the risk of 90-day mortality whilst AF and kidney disease tripled the chances of 90-day mortality. A hospital admission was associated with a two-fold increase in 90-day mortality (OR 2.24, 95% CI 1.15, 4.37, p < 0.05) whilst a prolonged hospital LoS increased it significantly three-fold (OR 3.25, 95% CI 1.67, 6.32, p = 0.0005). Finally, LRTI nearly tripled the likelihood of 90-day mortality (OR 2.89, 95% CI 1.47, 5.69).

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	15.53	(3.70, 65.25)	**0.0002**
Number of rib fractures	1.07	(0.94, 1.22)	0.30
Male sex	1.569	(0.76, 3.23)	0.22
SpO_2 (%)	0.97	(0.96, 0.99)	**0.003**
Mechanism of injury			
Fall from height	6.07×10^4	(1.04×10^4, 3.54×10^5)	0.99

Fall from standing	6.93×10^5	(3.64×10^5, 1.32×10^6)	0.992
RTA - car	2.47×10^5	(6.50×10^4, 9.42×10^5)	0.99
Smoking status			
Non-smoker	1.84	(0.60, 5.63)	0.29
Ex-smoker	3.03	(1.00, 9.18)	**0.05**
Comorbidities			
Pre-injury anticoagulation	4.55	(2.27, 9.11)	**1.96×10^{-5}**
Chronic lung disease	2.04	(1.07, 3.91)	**0.03**
Cardiac disease	2.71	(1.41, 5.20)	**0.0027**
Type 2 diabetes	1.81	(0.84, 3.88)	0.13
AF	3.91	(1.84, 8.29)	**0.0004**
Kidney disease	3.30	(1.60, 6.79)	**0.001**
History of cancer	3.54	(1.71, 7.32)	**0.0006**
History of stroke	2.23	(0.96, 5.16)	0.06
History of VTE	3.88	(1.53, 9.83)	**0.004**
Dementia	4.37	(1.87, 10.19)	**0.0006**
Hospital admission	2.24	(1.15, 4.37)	**0.02**
Admission specialty			
No admission	0.23	(0.11, 0.48)	**8.79×10^{-5}**
Surgery	0.22	(0.09, 0.59)	**0.002**
ICU admission	3.495	(0.91, 13.48)	0.07
Complications			
LRTI	2.89	(1.47, 5.69)	**0.002**
Pneumothorax	1.39	(0.17, 11.61)	0.76
Pulmonary contusion	15.59	(2.53, 96.22)	**0.003**
Re-admission	1.84	(0.60, 5.63)	0.28
Prolonged hospital LoS	3.25	(1.67, 6.32)	**0.0005**

TABLE 6: Univariate analysis of the development of factors related to 90-day mortality

CI = confidence interval; RTA = road traffic accident; SpO_2 = oxygen saturation; AF = atrial fibrillation; VTE = venous thromboembolism; ICU = intensive care unit; LRTI = lower respiratory tract infection; prolonged hospital LoS = ≥7 days.

Statistically significant associations are indicated in bold text.

In the revised multivariable 90-day mortality model (Table 7), age >65 years was associated with increased odds of mortality (OR 6.31, 95% CI 1.35, 29.48, p = 0.019), as was pulmonary contusion (OR 13.51, 95% CI 1.87, 97.46, p = 0.01). The wide confidence interval for pulmonary contusion reflects the small number of events and considerable uncertainty regarding the magnitude of this association. Higher SpO_2 at presentation was associated with lower odds of mortality (OR 0.98 per percentage-point increase, 95% CI 0.95, 1.00, p = 0.027). The remaining evaluated variables were not independently associated with mortality. Given the observational design, these associations should not be interpreted as causal.

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	6.31	(1.35, 29.48)	**0.02**
SpO_2 (%)	0.98	(0.95, 1.00)	**0.03**
Smoking status			
Non-smoker	1.13	(0.31, 4.19)	0.85
Ex-smoker	1.09	(0.30, 3.92)	0.90
Comorbidities			
Pre-injury anticoagulation	2.35	(0.79, 6.99)	0.12
Chronic lung disease	1.33	(0.59, 2.98)	0.49
Cardiac disease	1.33	(0.59, 3.00)	0.49
AF	1.41	(0.45, 4.46)	0.56
Kidney disease	1.44	(0.62, 3.32)	0.39
History of cancer	1.90	(0.81, 4.45)	0.14
History of VTE	1.69	(0.50, 5.67)	0.40
Dementia	2.49	(0.90, 6.88)	0.08
Admission specialty			
No admission	0.79	(0.28, 2.21)	0.66
Surgery	0.53	(0.17, 1.61)	0.26
Complications			
LRTI	1.36	(0.58, 3.17)	0.48
Pulmonary contusion	13.51	(1.87, 97.46)	**0.01**
Prolonged hospital LoS	0.97	(0.37, 2.58)	0.96

TABLE 7: Multivariable analysis of the development of factors related to 90-day mortality

CI = confidence interval; SpO_2 = oxygen saturation; AF = atrial fibrillation; VTE = venous thromboembolism; LRTI = lower respiratory tract infection; LoS = length of stay; prolonged hospital LoS = ≥7 days.

Statistically significant associations are indicated in bold text.

Subgroup analysis

Prolonged Hospital LoS (>7 days)

Further subgroup analysis was conducted to identify factors influencing prolonged hospital LoS (Table *8*). Age >65 years (n = 84, 85.7%, p < 0.01) and male sex (n = 53, 54.1%, p = 0.01) were higher in the prolonged LoS group. Current smoker status protected against prolonged LoS (n = 24, 23.8%, p = 0.13). The number of rib fractures and pre-injury anticoagulation were similar in both the prolonged LoS and normal LoS. Requirement for supplemental oxygen (28.6%; p = 0.01) and chronic lung disease (43.9%; p < 0.05) were more common in the prolonged-LoS group; cardiac disease was also more common, although the difference was not statistically significant (36.7%; p = 0.17). LRTI (44.9% versus 24.8%, p = 0.005) and 90-day mortality (18.4% versus 7.9%, p = 0.048) were more frequent in the prolonged-LoS group than in the group with LOS <7 days.

Variable	Prolonged LoS (n = 98)	LoS <7 days (n = 101)	Test statistic	p-Value
Age >65 (years)	84 (85.7%)	54 (53.5%)	**22.841 (Z)**	**1.76×10^{-6}**

Rib fracture number, median (IQR)	5 (3.0, 6.0)	4.0 (2.2, 5.8)	4245 (MW)	0.11
Male sex, n (%)	53 (54.1%)	73 (72.3%)	**6.3281 (Z)**	**0.01**
SpO_2 (%), n (%)				
SpO_2 95-100	55 (56.1%)	70 (69.3%)	3.1586 (Z)	0.08
SpO_2 90-94	12 (12.2%)	13 (12.9%)	**5.867×10^{-31} (Z)**	**1.00**
SpO_2 on supplemental O_2	28 (28.6%)	13 (12.9%)	**6.5659 (Z)**	**0.01**
Mechanism of injury, n (%)				
Fall from height	7 (7.1%)	12 (11.9%)	0.80262 (Z)	0.37
Fall from standing	54 (55.1%)	37 (36.6%)	**6.1119 (Z)**	**0.01**
RTA - car	9 (9.2%)	6 (5.9%)	0.35739 (Z)	0.55
Smoking status, n (%)				
Non-smoker	40 (40.8%)	46 (45.5%)	0.28093 (Z)	0.60
Ex-smoker	44 (44.9%)	31 (30.7%)	3.6901 (Z)	0.0547
Current smoker	14 (14.3%)	24 (23.8%)	2.3105 (Z)	0.13
Comorbidities, n (%)				
Pre-injury anticoagulation	19 (19.4%)	15 (14.9%)	0.43776 (Z)	0.51
Chronic lung disease	43 (43.9%)	29 (28.7%)	**4.3187 (Z)**	**0.04**
Cardiac disease	36 (36.7%)	27 (26.7%)	1.8608 (Z)	0.17
Type 2 diabetes	18 (18.4%)	15 (14.9%)	0.22664 (Z)	0.63
AF	17 (17.3%)	9 (8.9%)	2.418 (Z)	0.12
HTN	50 (51.0%)	42 (41.6%)	1.4223 (Z)	0.23
History of kidney disease	21 (21.4%)	8 (7.9%)	**6.2452 (Z)**	**0.01**
History of cancer	23 (23.5%)	10 (9.9%)	**5.6751 (Z)**	**0.02**
History of stroke	16 (16.3%)	9 (8.9%)	5.6751 (Z)	0.17
Dementia	18 (18.4%)	5 (5.0%)	**7.4958 (Z)**	**0.006**
Admission specialty				
Medicine	55 (56.1%)	39 (38.6%)	**5.4353 (Z)**	**0.02**
Surgery	43 (43.9%)	62 (61.4%)	**5.4353 (Z)**	**0.02**
Complications, n (%)				
LRTI	44 (44.9%)	25 (24.8%)	**8.0446 (Z)**	**0.005**
ICU admission, n (%)	9 (9.2%)	3 (3.0%)	2.3809	0.12
Re-admission	3 (3.1%)	4 (4.0%)	Fisher	1.00
90-day mortality	18 (18.4%)	8 (7.9%)	**3.9034 (Z)**	**0.048**

TABLE 8: Factors affecting prolonged hospital LoS (≥7 days)

SD = standard deviation; IQR = interquartile range; RTA = road traffic accident; SpO_2 = oxygen saturation; O_2 = oxygen; AF = atrial fibrillation; HTN = hypertension; ICU = intensive care unit; LRTI = lower respiratory tract infection.

Categorical variables are compared by means of either Z test (Z), Fisher's exact test (F) subject to the expected cell counts while continuous variables were compared by Mann-Whitney U-test (MW) due to the outcome of the Kolmogorov-Smirnov test. Statistically significant associations are indicated in bold text.

Factors associated with prolonged hospital LOS were examined using univariable logistic regression (Table 9). Age >65 years was associated with increased odds of prolonged LOS (OR 6.35, 95% CI 2.97, 13.54, p < 0.001), whereas male sex was associated with lower odds (OR 0.48, 95% CI 0.27, 0.86, p = 0.01). Pre-injury anticoagulation was not significantly associated with prolonged LOS (OR 1.72, 95% CI 0.82, 3.62, p = 0.15), while chronic lung disease was associated with increased odds (OR 2.38, 95% CI 1.32, 4.30, p < 0.01). Kidney disease, malignancy and LRTI were also associated with increased odds of prolonged LOS. Higher SpO_2 at presentation was associated with lower odds of prolonged LOS (OR 0.96 per percentage-point increase, 95% CI 0.94, 0.97, p < 0.001). Dementia (OR 4.09, 95% CI 1.54, 10.88, p = 0.005) and 90-day mortality (OR 2.65, 95% CI 1.12, 6.28, p = 0.03) were also associated with increased odds of prolonged LOS in the univariable analyses. Neither non-smoking status (OR 1.43, 95% CI 0.64, 3.16, p = 0.379) nor ex-smoking status (OR 2.23, 95% CI 0.99, 5.03, p = 0.053) was statistically significant compared with current smoking. Admission under Surgery was associated with lower odds of prolonged LOS than admission under Medicine (OR 0.48, 95% CI 0.27, 0.84, p = 0.01).

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	6.35	(2.97, 13.54)	**1.75×10^{-6}**
Number of rib fractures	1.12	(0.996, 1.27)	0.06
Male sex	0.48	(0.27, 0.86)	**0.01**
SpO_2 (%)	0.96	(0.94, 0.97)	**2.46×10^{-10}**
Smoking status			
Non-smoker	1.43	(0.64, 3.16)	0.38
Ex-smoker	2.23	(0.99, 5.03)	**0.053**
Comorbidities			
Pre-injury anticoagulation	1.72	(0.82, 3.62)	0.15
Chronic lung disease	2.38	(1.32, 4.30)	**0.004**
Cardiac disease	1.57	(0.86, 2.87)	0.14
Type 2 diabetes	1.39	(0.66, 2.93)	0.39
History of kidney disease	3.25	(1.40, 7.57)	**0.006**
History of cancer	2.96	(1.34, 6.50)	**0.007**
History of stroke	2.03	(0.86, 4.77)	0.11
Dementia	4.09	(1.54, 10.88)	**0.005**
Admission specialty			
Surgery	0.48	(0.27, 0.84)	**0.01**
ICU admission	1.79	(0.55, 5.86)	0.33
Complications			
LRTI	3.02	(1.65, 5.53)	**0.0003**
Re-admission	0.92	(0.20, 4.24)	0.92
90-day mortality	2.65	(1.12, 6.28)	**0.03**

TABLE 9: Univariate analysis of factors influencing prolonged hospital LoS (≥7 days)

CI = confidence interval; RTA = road traffic accident; SpO_2 = oxygen saturation; O_2 = oxygen; HR = heart rate; SD = standard deviation; ICU = intensive care unit; LRTI = lower respiratory tract infection.

Statistically significant associations are indicated in bold text.

In the revised multivariable analysis of prolonged hospital LOS (Table 10), age >65 years was independently associated with increased odds of a prolonged stay (OR 4.02, 95% CI 1.63, 9.94, p = 0.003). Higher SpO_2 at presentation was associated with lower odds of prolonged LOS (OR 0.98 per percentage-point increase, 95% CI 0.96, 0.99, p = 0.010). Sex, smoking status, chronic lung disease, kidney disease, cancer, dementia, admission specialty, LRTI and 90-day mortality were not independently associated with prolonged LOS. Although male sex, dementia and LRTI showed possible trends, their confidence intervals included the null value. These associations should be interpreted as non-causal because of the observational study design.

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	4.02	(1.63, 9.94)	0.003
Male sex	0.51	(0.25, 1.05)	0.07
SpO_2 (%)	0.98	(0.96, 0.99)	**0.01**
Smoking status			
Non-smoker	0.77	(0.29, 2.08)	0.61
Ex-smoker	1.03	(0.39, 2.76)	0.95
Comorbidities			
Chronic lung disease	1.41	(0.67, 2.99)	0.36
History of kidney disease	1.43	(0.51, 4.01)	0.50
History of cancer	1.84	(0.73, 4.64)	0.20
Dementia	3.19	(0.93, 10.96)	0.07
Admission specialty			
Surgery	1.16	(0.55, 2.45)	0.69
Complications			
LRTI	1.82	(0.91, 3.64)	0.09
90-day mortality	0.97	(0.33, 2.80)	0.95

TABLE 10: Multivariable analysis of factors influencing prolonged hospital LoS (≥7 days)

CI = confidence interval; SpO_2 = oxygen saturation; LRTI = lower respiratory tract infection.

Statistically significant associations are indicated in bold text.

Development of LRTI

A univariate analysis of factors affecting the development of LRTI was conducted (Table 11). Being >65 years old increased the likelihood of developing LRTI by three-fold (OR 3.02, 95% CI 1.74, 5.24, p < 0.01). Smoking status did not affect the risk of developing LRTI, but a pre-injury diagnosis of chronic lung disease doubles the likelihood of developing this complication (OR 2.05, 95% CI 1.26, 3.31, p < 0.005). Pre-injury anticoagulation did not significantly affect LRTI (OR 1.51, 95% CI 0.82, 2.77, p = 0.19). Higher SpO_2 at presentation was associated with lower odds of LRTI (OR 0.98 per percentage-point increase, 95% CI 0.96, 0.99, p < 0.001). History of kidney disease (OR 1.97, 95% CI 1.08, 3.58, p = 0.03), dementia (OR 3.79, 95% CI 1.83, 7.87, p < 0.001) and hospital admission (OR 6.15, 95% CI 3.54, 10.68, p < 0.001) were associated with higher odds of LRTI. In the separate analysis of admission specialty, compared with admission under Medicine, non-admission (OR 0.11, 95% CI 0.06, 0.20, p < 0.001) and admission under Surgery (OR 0.43, 95% CI 0.24, 0.78, p = 0.005) were associated with lower odds of LRTI. A prolonged hospital LoS (OR 5.86, 95% CI 3.51, 9.79, p < 0.01) and number of fractures (OR 1.19, 95% CI 1.08, 1.32, p = 0.0003) significantly increase the chances of developing LRTI.

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	3.02	(1.74, 5.24)	**7.98×10^{-5}**
Sex (reference category female)	0.85	(0.52, 1.38)	0.51
Number of rib fractures	1.19	(1.08, 1.32)	**0.0003**
SpO_2 (%)	0.98	(0.96, 0.99)	**0.0004**
Smoking status			
Non-smoker	0.74	(0.39, 1.40)	0.36
Ex-smoker	1.14	(0.60, 2.16)	0.69
Comorbidities			
Pre-injury anticoagulation	1.51	(0.82, 2.77)	0.19
Chronic lung disease	2.05	(1.26, 3.31)	**0.00352**
Cardiac disease	1.52	(0.92, 2.50)	0.10
Type 2 diabetes	0.89	(0.46, 1.71)	0.73
AF	1.30	(0.65, 2.60)	0.47
HTN	1.29	(0.81, 2.06)	0.29
History of kidney disease	1.97	(1.08, 3.58)	0.03
History of cancer	1.43	(0.75, 2.71)	0.27
History of stroke	1.61	(0.81, 3.20)	0.17
History of VTE	1.43	(0.58, 3.49)	0.44
Dementia	3.79	(1.83, 7.87)	**0.0004**
Hospital admission	6.15	(3.54, 10.68)	**1.15×10^{-10}**
Admission specialty			
No admission	0.11	(0.06, 0.20)	**1.83×10^{-12}**
Surgery	0.43	(0.24, 0.78)	**0.005**
ICU admission	1.33	(0.35, 5.03)	0.67
Complications, n (%)			
Re-admission	1.51	(0.61, 3.70)	0.37
Prolonged hospital LoS	5.86	(3.51, 9.79)	**1.4×10^{-11}**

TABLE 11: Univariate analysis of the factors related to the development of LRTI

CI = confidence interval; RTA = road traffic accident; SpO_2 = oxygen saturation; AF = atrial fibrillation; HTN = hypertension; VTE = venous thromboembolism; ICU = intensive care unit; LoS = Length of stay; prolonged hospital LoS = ≥7 days.

Statistically significant associations are indicated in bold text.

In the multivariable analysis (Table *12*), patients who were not admitted had lower odds of LRTI than patients admitted under Medicine (OR 0.21, 95% CI 0.10, 0.44, p < 0.001). Admission under Surgery was not significantly associated with LRTI relative to Medicine (OR 0.53, 95% CI 0.25, 1.09, p = 0.088). Prolonged hospital LOS showed a borderline association with LRTI (OR 1.92, 95% CI 0.99, 3.72, p = 0.051), while the remaining included variables were not independently associated with LRTI. These findings may reflect differences in clinical case mix and the temporal relationship between LRTI and hospital LOS and should not be interpreted causally.

Variable	Odds ratio	95% CI for odds ratio	p-Value
Age >65 (years)	1.17	(0.60, 2.28)	0.65
Number of rib fractures	1.07	(0.94, 1.22)	0.31
SpO_2 (%)	0.99	(0.98, 1.01)	0.47
Chronic lung disease	1.54	(0.89, 2.67)	0.15
History of kidney disease	1.42	(0.68, 2.89)	0.34
Dementia	1.62	(0.67, 3.87)	0.28
Admission specialty			
No admission	0.21	(0.10, 0.44)	**0.000037**
Surgery	0.53	(0.25, 1.09)	0.09
Prolonged hospital LoS	1.92	(0.99, 3.72)	0.051

TABLE 12: Multivariable analysis of the factors related to the development of LRTI

CI = confidence interval; SpO_2 = oxygen saturation; LoS = length of stay; prolonged hospital LoS = ≥7 days.

Statistically significant associations are indicated in bold text.

Admission Specialty

Subgroup comparisons were conducted among the 199 admitted patients, comprising 94 patients admitted under Medicine and 105 under Surgery (Table *13*). Patients admitted under Surgery were younger than those admitted under Medicine (median 65.0 (IQR 52.0, 79.0) versus 82.0 (IQR 75.2, 87.8) years; W = 7735, $p < 0.001$). Patients admitted under Surgery had a higher median number of fractured ribs than those admitted under Medicine (5.0 (IQR 4.0, 7.0) versus 3.0 (IQR 2.0, 5.0), respectively; $p < 0.001$) and were more frequently male (70.5% versus 55.3%, $p = 0.04$). Conversely, a fall from standing was more frequent among patients admitted under Medicine (62.8% versus 30.5%, $p < 0.001$). Pre-injury anticoagulation, atrial fibrillation, hypertension, kidney disease, cancer, history of venous thromboembolism and dementia were also significantly more frequent in the Medicine group than in the Surgery group (all $p \leq 0.03$). Chronic lung disease was more frequent in the Medicine group, while smoking-status distributions did not differ significantly between specialties. All 12 ICU admissions occurred among patients admitted under Surgery. Patients admitted under Medicine had a longer median hospital LOS than those admitted under Surgery (8.0 (IQR 4.0, 12.0) versus 5.0 (IQR 2.0, 10.0) days, $p = 0.01$). LRTI (44.7% versus 25.7%, $p = 0.008$) and prolonged hospital LOS (58.5% versus 41.0%, $p = 0.02$) were also more frequent in the Medicine group. The composite adverse outcome (61.7% versus 45.7%, $p = 0.03$) and 90-day mortality (21.3% versus 5.7%, $p = 0.002$) were more frequent among patients admitted under Medicine.

Variable	Medicine (n = 94)	Surgery (n = 105)	Test statistic	p-Value
Age, median (IQR)	82.0 (75.2, 87.8)	65.0 (52.0, 79.0)	**7735 (MW)**	**5.005×10^{-12}**
Number of rib fractures, median (IQR)	3.0 (2.0, 5.0)	5.0 (4.0, 7.0)	**3017 (MW)**	**1.84×10^{-6}**
Male sex, n (%)	52 (55.3%)	74 (70.5%)	**4.2749 (Z)**	**0.04**
SpO_2 (%), n (%)				
SpO_2 90-94	13 (13.8%)	12 (11.4%)	0.08763 (Z)	0.77
SpO_2 on supplemental O_2	15 (16.0%)	26 (24.8%)	1.8429 (Z)	0.17
Mechanism of injury, n (%)				
Fall from height	5 (5.3%)	14 (13.3%)	2.819 (Z)	0.09
Fall from standing	59 (62.8%)	32 (30.5%)	**19.556 (Z)**	**9.768×10^{-6}**

RTA - car	6 (6.4%)	9 (8.6%)	0.099147 (Z)	0.75
Smoking status, n (%)				
Non-smoker	39 (41.5%)	47 (44.8%)	0.10364 (Z)	0.75
Ex-smoker	41 (43.6%)	34 (32.4%)	2.2094 (Z)	0.14
Current smoker	14 (14.9%)	24 (22.9%)	1.5531 (Z)	0.21
Comorbidities, n (%)				
Pre-injury anticoagulation	24 (25.5%)	10 (9.5%)	**7.8775 (Z)**	**0.005**
Chronic lung disease	42 (44.7%)	30 (28.6%)	**4.8985 (Z)**	**0.03**
Cardiac disease	36 (38.3%)	27 (25.7%)	3.0716 (Z)	0.08
Type 2 diabetes	17 (18.1%)	16 (15.2%)	0.12125 (Z)	0.73
AF	18 (19.1%)	8 (7.6%)	**4.8343 (Z)**	**0.03**
HTN	52 (55.3%)	40 (38.1%)	**5.2466 (Z)**	**0.02**
History of kidney disease	21 (22.3%)	8 (7.6%)	**7.4921 (Z)**	**0.006**
History of cancer	24 (25.5%)	9 (8.6%)	**9.1243 (Z)**	**0.003**
History of stroke	15 (16.0%)	10 (9.5%)	1.3291 (Z)	0.25
History of VTE	13 (13.8%)	3 (2.9%)	**6.6606 (Z)**	**0.01**
Dementia	19 (20.2%)	4 (3.8%)	**11.5 (Z)**	**0.0007**
Hospital LoS, median (IQR)	8.0 (4.0-12.0)	5.0 (2.0-10.0)	**5838.5 (MW)**	**0.01**
ICU admission, n (%)	0 (0.0%)	12 (11.4%)	**9.5043 (Z)**	**0.002**
Complications, n (%)				
Overall complications	58 (61.7%)	48 (45.7%)	**4.4708 (Z)**	**0.03**
LRTI	42 (44.7%)	27 (25.7%)	**7.0618 (Z)**	**0.008**
Re-admission	5 (5.3%)	2 (1.9%)	Fisher	0.26
90-day mortality	20 (21.3%)	6 (5.7%)	**9.2497 (Z)**	**0.002**
Prolonged hospital LoS	55 (58.5%)	43 (41.0%)	**5.4353 (Z)**	**0.02**

TABLE 13: Patient demographics and complication rates depending on the admission specialty

SD = standard deviation; RTA = road traffic accident; SpO_2 = oxygen saturation; O_2 = oxygen; AF = atrial fibrillation; HTN = hypertension; VTE = venous thromboembolism; LoS = length of stay; ICU = intensive care unit; LRTI = lower respiratory tract infections; prolonged hospital LoS = ≥7 days.

Categorical variables are compared by means of either a Z test (Z) or Fisher's exact test (Fisher), subject to the expected cell counts, while continuous variables were compared via the Mann-Whitney U test (MW) or t-test, subject to the outcome of the Kolmogorov-Smirnov test. Statistically significant associations are indicated in bold text.

These unadjusted differences may reflect variation in age, case mix and clinical admission pathways.

Discussion

This study explored several outcomes following isolated blunt thoracic trauma: first, examining the morbidity and mortality associated with rib fractures and second, risk factors that increased the risk of complications and mortality after trauma.

Morbidity and mortality of blunt thoracic trauma

The 90-day mortality rate among patients with rib fractures in this study was 9.4%. This value is similar to that seen in previous studies, ranging from 0.5% to 23% [1,2,12,13]. Overall complications were reported to be 37.2%, in keeping with the findings of 38% by Battle and colleagues [14].

The most common pulmonary complication in this study was LRTI, occurring in 20.1% of patients, an almost two-fold increase from those reported in Battle and colleagues' study on complications in the recovery phase of blunt thoracic trauma [14]. This may be due to a lower threshold in this study in identifying LRTI based on imaging findings, GP records, and documentation of infection, whilst Battle and colleagues [14] only included those patients with documentation of infection.

Battle and colleagues identified nearly double the number of patients with a prolonged LoS at 40% compared to this study's 22.4% [14]. The literature indicates that increased age, multiple rib fractures, infection, pain, and concomitant injuries such as lung injury or pneumothorax requiring a chest drain will greatly increase this period of stay in the hospital as well as mortality rates [15]. In this study, an increased age of >65 years, chronic lung disease and a history of malignancy were higher in those who had a prolonged LoS. Additionally, overall complication rates were higher in the prolonged LoS cohort, with LRTI being the most common pulmonary complication (Table *8*).

Readmission rates were 5.9%, primarily due to pain or increased shortness of breath, which were also noted in Callisto and colleagues' study [16]. Additionally, some patients were initially misdiagnosed after a CXR was misinterpreted, with the true diagnosis of rib fractures only identified after a CT scan. This highlights the importance of high-resolution imaging when rib fractures are suspected.

Factors that are associated with an increased likelihood of complications after rib fractures

Age

Several factors contributed to a higher likelihood of complications and mortality within 90 days. Notably, older age emerged as a statistically significant risk factor for both overall complications and 90-day mortality (Tables *3*, *5*, *6*, *7*). This aligns with the findings of Marini and colleagues [5], which indicate that being over 65 years old elevates mortality risk in a study involving 1,199 adult trauma patients. Furthermore, Bankhead-Kendall and colleagues' study [12] in 4413 blunt trauma patients found that patients aged >65 years have a four-fold increase in developing morbidity and mortality compared to their younger counterparts. Battle and colleagues [14] report similar results, with 66% of patients over 65 years old developing complications (68.1% in this study). This study found that an age >65 years is associated with an increased risk of mortality by 15-fold in a univariate analysis (Table *6*) and approximately six-fold higher adjusted odds in the multivariable analysis (Table *7*). Interestingly, Cull and colleagues [17] found that when concomitant injuries were excluded in patients who were ⩾65 years old, morbidity and mortality were not as high as expected, at only 3.9% of 129 patients with rib fractures. Research into the effects of additional injuries at the time of the trauma is needed to explore this finding in depth, which could form the basis of further research.

Male Sex

More male than female patients presented with rib fractures. Although the estimated odds of 90-day mortality were higher among male patients, the association was not statistically significant in either the initial group comparison or the univariable analysis (Tables *5*, *6*). Marini and colleagues [5] found that the male sex was a significant predictor of mortality following rib fractures.

Pre-injury Anticoagulation

Pre-injury anticoagulation was not significantly associated with the composite adverse outcome in either the initial comparison or the univariable analysis (Tables *2*, *3*). It was associated with 90-day mortality in the initial comparison and univariable analysis (Tables *5*, *6*), but this association was no longer statistically significant after multivariable adjustment (Table *7*). However, Battle and colleagues' study [14] showed pre-injury anticoagulation was statistically significant in increasing the risk of overall complications (OR 2.9, 95% CI 1.1, 4.8), and Giamello and colleagues' study [18] on 745 patients, where 14.4% of patients on pre-injury anticoagulation suffered complications compared to only 5.5% on pre-injury anticoagulation in the no-complications group. Stolarski and colleagues [19] found contrasting results: patients on anticoagulants or antiplatelets developed fewer pulmonary complications and did not increase overall morbidity and mortality following rib fractures.

Number of Rib Fractures

A greater number of fractured ribs was associated with the primary adverse outcome in the univariable analysis (Tables *2*, *3*) but was not independently associated with this outcome after adjustment (Table *4*). The number of fractured ribs was not significantly associated with 90-day mortality (Tables *5*-*7*). This aligns with Marini and colleagues' study [5], which shows that the number of rib fractures was not predictive of mortality in a large cohort study. In fact, Leichtle and colleagues [20] revised guidelines for ICU admission following rib fractures to de-emphasise the number of rib fractures and age. They found that this successful change reduced the number of ICU admissions without significantly reducing pulmonary complications and

overall mortality in these injured patients. However, Liman and colleagues [13] report an increased mortality risk in patients with more than two rib fractures at 4.7% in a study involving approximately 1500 patients, while Sirmali and colleagues [2] report that more than three rib fractures lead to an increase in both complications and mortality.

Patient Co-morbidities

Several comorbidities were associated with adverse outcomes in the univariable analyses, although the pattern differed by outcome. Chronic lung disease and kidney disease were each associated with 90-day mortality, prolonged hospital LOS and LRTI. A history of cancer was associated with 90-day mortality and prolonged LOS, while cardiac disease, atrial fibrillation and a history of venous thromboembolism were associated with 90-day mortality. Dementia was associated with the composite adverse outcome, 90-day mortality, prolonged LOS and LRTI. However, these associations were not retained in the corresponding multivariable models (Tables *7*, *10*, *12*). Type 2 diabetes and history of stroke were not significantly associated with 90-day mortality. These comorbidities may therefore represent markers of age, frailty and underlying clinical vulnerability rather than independent determinants of outcome.

Previous studies have similarly identified associations between pre-existing disease and outcomes following rib fractures. Battle and colleagues [14] reported a high prevalence of chronic lung disease among patients who developed complications, while Al-Embideen and colleagues [21] found that COPD was associated with pneumonia, longer hospital and ICU stays and an increased requirement for oxygen at discharge. Cardiac and other comorbidities have also been associated with complications following conservatively managed rib fractures [22]. Poor nutritional status, altered bone health and reduced mobility may contribute to adverse outcomes among patients with renal disease, cerebrovascular disease or malignancy [23-25], although the present findings do not establish causal relationships.

Smoking Status

In unadjusted analyses, ex-smokers were more frequent and non-smokers less frequent among patients experiencing the composite adverse outcome (Table *2*). Smoking status was not significantly associated with the composite adverse outcome in the univariable regression analysis (Table *3*). For 90-day mortality, ex-smoking status showed a borderline univariable association (OR 3.03, 95% CI 1.00, 9.18, p = 0.05; Table *6*), but neither ex-smoking nor non-smoking status was independently associated with mortality after multivariable adjustment (Table *7*).

Battle and colleagues [14], who combined non-smokers and ex-smokers into a single category, similarly found no significant association between non-smoking status and complications.

Grigorian and colleagues [26] reported lower in-hospital mortality among current smokers in both univariable and multivariable analyses, describing a possible “smoker’s paradox,” which has also been reported in cardiovascular disease [27]. Such findings should be interpreted cautiously because they may reflect residual confounding, younger age and fewer comorbidities among smokers, healthy-survivor effects, or selection and collider bias rather than a protective effect of smoking. Although biological mechanisms involving inflammatory and endothelial responses have been proposed [28], no established causal mechanism explains this association.

Supplemental Oxygen

Requirement for supplemental oxygen at presentation was associated with complications (Table *2*) and 90-day mortality (Table *5*). This finding is likely to reflect confounding by indication: patients with greater respiratory compromise or more severe injuries are more likely to receive supplemental oxygen and are also more likely to experience adverse outcomes [14]. The association should therefore not be interpreted as evidence that oxygen therapy causes harm. Rather, oxygen requirement may represent a marker of physiological compromise warranting careful clinical assessment and monitoring.

LRTI

LRTI was more frequent among patients who died within 90 days than among survivors (39.0% versus 18.1%; Table *5*) and was associated with mortality in the univariable analysis (OR 2.89, 95% CI 1.47, 5.69, p = 0.002; Table *6*). However, this association was not retained after adjustment (OR 1.36, 95% CI 0.58, 3.17, p = 0.478; Table *7*), suggesting that the unadjusted relationship may reflect injury severity, physiological compromise or differences in case mix. LRTI was the most common pulmonary complication in the present cohort, occurring in 20.1% of patients, compared with 11% in the study by Battle and colleagues [14]. Bulger and colleagues [29] reported that the risk of pneumonia increased by 27% with each additional rib fracture.

Admission Specialty

To our knowledge, this is the first study to examine outcomes according to admission specialty following rib fractures. Patients admitted under Medicine experienced higher rates of the composite adverse outcome and 90-day mortality than those admitted under Surgery (Table *13*). However, the medical group was older and had a greater burden of comorbidity, whereas supplemental oxygen use and ICU admission were more common in the surgical group. These unadjusted differences are therefore likely to reflect differences in patient characteristics, physiological compromise, injury severity and clinical triage rather than an effect of admission specialty itself.

Limitations

This study has several limitations. First, it was a retrospective, single-centre study conducted at a UK major trauma centre. Differences in case mix, referral pathways and access to specialist trauma services may therefore limit the generalisability of the findings to other hospitals and healthcare systems.

Data were extracted retrospectively by a single researcher, and inter-rater reliability could not be assessed. The study was dependent on the completeness and accuracy of routinely recorded clinical information and ICD-10 coding; consequently, eligible patients may have been missed, or some variables misclassified. The clinical and radiological diagnosis of LRTI was not based on a prospectively standardised definition, which may also have introduced measurement variability.

Information on analgesic strategies, regional anaesthesia and chest physiotherapy was not recorded consistently and could not be incorporated into the analyses. Established measures of injury severity, such as the Injury Severity Score or RibScore, could not be calculated reliably because of missing information. Residual confounding by injury severity, physiological compromise, frailty and clinical triage is therefore likely. This is particularly important when interpreting associations involving admission specialty and supplemental oxygen, because these factors may act as markers of underlying clinical severity rather than causes of adverse outcomes.

Finally, the relatively small number of deaths and some other outcomes reduced statistical precision, as reflected by the wide confidence intervals around several estimates. The regression analyses should therefore be regarded as exploratory, and the reported associations should not be interpreted as causal. Larger multi-centre prospective studies using standardised outcome definitions, detailed treatment information and validated injury-severity measures are required to confirm these findings.

Conclusions

In this single-centre cohort of 438 patients with traumatic rib fractures, the composite adverse outcome occurred in 37.2% of patients, and 90-day mortality was 9.4%. In adjusted analyses, age >65 years, lower oxygen saturation at presentation and pulmonary contusion were associated with 90-day mortality, while age >65 years and lower oxygen saturation were associated with prolonged hospital LOS. Outcomes also differed according to admission specialty, although these differences are likely to reflect variation in age, comorbidity, injury severity, physiological compromise and clinical triage. These findings may help identify patients requiring closer assessment and monitoring, but should be interpreted as exploratory associations rather than causal effects and require confirmation in larger multi-centre prospective studies.

Appendices

Reproducibility materials: Data dictionary, operational definitions, statistical analysis plan, and STROBE compliance

Study Overview

This supplementary appendix provides full methodological transparency for a single-centre retrospective cohort study conducted at a UK major trauma centre (University Hospitals of North Midlands NHS Trust). The study evaluates morbidity and mortality following blunt chest wall trauma (rib fractures) and associated risk factors, including pre-injury comorbidities.

Data Sources and Management

Data source: iPortal electronic patient records, A&E documentation, radiology reports, discharge summaries

Data extraction: Single trained investigator

Blinding: Extractor blinded to study hypothesis

Storage: Secure encrypted NHS Trust device

Software: Microsoft Excel (data capture), R v4.5.1 (analysis)

Identifier: Unique anonymised study ID assigned to all patients

Data dictionary

Demographics

Variable	Definition	Type	Coding
Age	Age at the time of injury	Continuous	Years
Sex	Biological sex	Categorical	Male/Female
Smoking status	Smoking at the time of injury	Categorical	Current/Former/Never
Mechanism of injury	Cause of trauma	Categorical	RTC/Fall/Assault/Other

TABLE 14: Demographics

Comorbidities (Binary Variables)

All comorbidities were coded as 0 = absent, 1 = present.

Variable	Operational definition
Chronic lung disease	COPD, asthma, ILD, emphysema, pulmonary fibrosis
Cardiac disease	IHD, MI, HF, valvular disease, CABG, PCI/stents
Diabetes mellitus	Type 1 or Type 2 diabetes
Chronic kidney disease	Any documented CKD (stage 1–5)
Hypertension	Documented diagnosis or treatment
Malignancy	Any current or previous cancer (including remission)

TABLE 15: Comorbidities (binary variables)

Injury Characteristics

Variable	Definition
Rib fractures	Radiologically confirmed acute fractures
Number of rib fractures	Total count on imaging
Flail chest	Clinical or radiological diagnosis
Laterality	Left/Right/Bilateral
Imaging modality	CXR/CT/Both

TABLE 16: Injury characteristics

Physiological Variables (A&E presentation)

Variable	Unit
Heart rate	bpm
Systolic BP	mmHg
Respiratory rate	breaths/min
Oxygen saturation	%
GCS	3-15

TABLE 17: Physiological variables (A&E presentation)

Outcomes

Primary Composite Outcome (binary)

Occurrence of any of the following:

90-day mortality

Pneumonia

Respiratory failure

Pneumothorax requiring intervention

Haemothorax requiring intervention

Empyema

ICU admission

Prolonged LOS (⩾7 days)

Secondary Outcomes

Outcome	Definition
90-day mortality	Death within 90 days of injury
In-hospital mortality	Death during index admission
ICU admission	Level 2/3 care admission
Pneumonia	Clinical/radiological infection ≤14 days
Chest infection	Antibiotic-treated LRTI ≤14 days
Pulmonary embolism	CT-confirmed PE ≤14 days
Rib fixation	Surgical stabilisation
Readmission	Within 14 days
Length of stay	Total inpatient days
Prolonged LOS	≥7 days

TABLE 18: Secondary outcomes

Derived Variables

Variable	Definition
Comorbidity count	Total number of comorbidities per patient
Age group	<65 vs ≥65 years (if used)
Injury burden	Number of rib fractures

TABLE 19: Derived variables

Operational definitions

Exposure Definitions

Comorbidities defined as documented pre-existing diagnoses prior to injury in medical records.

Outcome Definitions

Respiratory complications: pneumonia, pneumothorax, haemothorax, empyema, respiratory failure

ICU admission: any level 2 or 3 care admission

Prolonged LOS: hospital stay ⩾7 days (resource utilisation threshold)

Statistical analysis plan

General Approach

Software: R v4.5.1

Significance: $p < 0.05$ (two-sided)

Normality: Kolmogorov-Smirnov test + graphical assessment

Descriptive Statistics

Continuous: mean ± SD or median (IQR)

Categorical: n (%)

Comparative Analysis

Categorical variables: Chi-square or Fisher's exact test

Continuous variables: t-test or Mann-Whitney U test

Regression Modelling

Multivariable logistic regression used for:

Primary composite outcome

Mortality outcomes

Covariates

Age

Sex

Smoking status

Number of rib fractures

Key comorbidities

Outputs

Adjusted odds ratios (OR)

95% confidence intervals

Missing Data Handling

<5% missing: complete-case analysis

5% missing: sensitivity analysis performed

No imputation performed (avoid model-dependent bias)

Missingness reported per variable

Cut-point Rationale

Length of stay ⩾7 days: reflects clinically significant morbidity and resource utilisation; consistent with prior rib fracture literature and upper distribution threshold

Age ⩾65 years (if applied): standard geriatric threshold used in UK trauma epidemiology

Bias and Confounding

Adjusted for known confounders (age, sex, comorbidities, injury burden)

Residual confounding acknowledged (frailty, socioeconomic status not captured)

Multicollinearity assessed using VIF

Model fit assessed using Hosmer-Lemeshow test

Ethics and governance

Classified as audit under institutional review.

Approved by UHNM audit department and University ethics committee.

No patient consent required due to anonymised retrospective data.

PPI not undertaken due to non-interventional design.

STROBE compliance

This study adheres to the guidelines of the STROBE Initiative for observational cohort studies.

Key domains addressed

Study design clearly defined

Setting and population described

Variables and outcomes fully operationalised

Bias and limitations acknowledged

Statistical methods fully reported

Missing data strategy specified

Ethics and data governance reported

A completed STROBE checklist is available upon request as supplementary material.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Amber Ahmed-Issap, Kajan Mahendran, Lakshmi Srinivasan, Shilajit Ghosh, Udo Abah

Acquisition, analysis, or interpretation of data: Amber Ahmed-Issap, Marko Raseta, Udo Abah

Drafting of the manuscript: Amber Ahmed-Issap, Marko Raseta, Udo Abah

Critical review of the manuscript for important intellectual content: Amber Ahmed-Issap, Kajan Mahendran, Lakshmi Srinivasan, Shilajit Ghosh, Udo Abah

Supervision: Udo Abah

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. University of Edinburgh Ethics Committee issued approval 49. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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