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Are first rib fractures a marker for other life-threatening injuries in patients with major trauma? A cohort study of patients on the UK Trauma Audit and Research Network database

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ABSTRACT

Background First rib fractures are considered indicators of increased morbidity and mortality in major trauma. However, this has not been definitively proven. With an increased use of CT and the potential increase in detection of first rib fractures, re-evaluation of these injuries as a marker for life-threatening injuries is warranted.

Methods Patients sustaining rib fractures between January 2012 and December 2013 were investigated using data from the UK Trauma Audit and Research Network. The prevalence of life-threatening injuries was compared in patients with first rib fractures and those with other rib fractures. Multivariate logistic regression was performed to determine the association between first rib fractures, injury severity, polytrauma and mortality.

Results There were 1683 patients with first rib fractures and 8369 with fractures of other ribs. Life-threatening intrathoracic and extrathoracic injuries were more likely in patients with first rib fractures. The presence of first rib fractures was a significant predictor of injury severity (Injury Severity Score >15) and polytrauma, independent of mechanism of injury, age and gender with an adjusted OR of 2.64 (95% CI 2.33 to 3.00) and 2.01 (95% CI 1.80 to 2.25), respectively. Risk-adjusted mortality was the same in patients with first rib fractures and those with other rib fractures (adjusted OR 0.97, 95% CI 0.79 to 1.19).

Conclusion First rib fractures are a marker of life-threatening injuries in major trauma, though they do not independently increase mortality. Management of patients with first rib fractures should focus on identification and treatment of associated life-threatening injuries.

INTRODUCTION

First rib fractures have traditionally been considered indicators of increased injury severity and mortality in patients with major trauma.¹⁻³ However, these relationships are not definitively proven. Several reviews mention this association in the context of polytrauma, but the medical literature also includes a number of studies and case reports that describe isolated first rib fractures resulting from relatively minor trauma, without serious complications.⁴⁻⁶

The broad structure of the first rib and its protected position in the body led researchers to postulate that a high amount of energy was needed

Key messages

What is already known on this subject?

- ▶ Previous small single-centre studies have shown an association between first rib fractures and head, cervical spine, brachial plexus and vascular injury. However, all previous studies used CXR as the sole technique for detection of fractures.
- ▶ Until now, there have been no large multicentre studies of the association between first rib fractures and severe or life-threatening injuries.

What this study adds?

- ▶ First rib fractures are a marker of polytrauma and severe injury (Injury Severity Score >15) when compared with patients with other rib fractures.
- ▶ There is an association between significant head, cervical spine, chest, liver and pelvic injuries and first rib fractures.
- ▶ First rib fractures are only associated with increased mortality in patients with polytrauma and have no independent impact on mortality.

to cause a first rib fracture and such high-energy injuries would be associated with greater mortality and morbidity.^{2,3} However, of the five reported injury mechanisms leading to first rib fractures, only three are related to high-energy trauma.^{7,8} These three mechanisms include posteriorly directed trauma to the upper thorax or shoulder girdle, a direct blow to the sternum/anterior chest wall and a direct blow fracturing the clavicle.⁷⁻⁹ The other mechanisms of first rib fracture include a strong sudden contraction of the scalenus anterior muscle (considered a low-energy mechanism) and fractures associated with no identifiable mechanical trauma (thought to be stress fractures).^{4-6,8}

Previous studies of first rib fractures suggest an increased likelihood of serious injuries. Estimates of the incidence of traumatic brain injuries in patients with first rib fractures have ranged from 17.1% to 73%.¹⁻³ Richardson, in his 1975 review of 55 patients with first rib fractures, found that 14.5% had cardiac injuries and 9.1% had brachial plexus injuries.³ Unsurprisingly, these studies quoted



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mortality rates of up to 36.3% among their patients.¹⁻³ However, they were generally small retrospective studies, open to selection bias and their findings are not necessarily generalisable to all patients with trauma. In addition, these studies did not compare patients having first rib fractures with any other control group.

With the increased use of CT as a primary imaging technique in major trauma, it is likely that a higher number of first rib fractures are being diagnosed as incidental findings.¹⁰ As with other intrathoracic injuries, such as isolated rib injuries and small pneumothoraces, the significance of such incidental findings is unclear.¹¹⁻¹³ In light of this, there is a need to re-assess the significance of first rib fractures as indicators of serious injury in patients with major trauma.

The objectives of the study were to determine whether patients with first rib fractures were more likely to suffer from other significant injuries, increased injury severity, polytrauma and mortality compared with patients having fractures of other ribs.

PATIENTS AND METHODS

This was a cohort study of prospectively collected data on patients with major trauma, using the Trauma Audit and Research Network (TARN) database. The TARN database is a national database that collects and analyses data on patients with major trauma admitted to the majority of trauma receiving hospitals in England and Wales, as well as participating hospitals in Ireland and other European countries.^{14 15} All patients have each of their individual injuries reliably and reproducibly coded from imaging, operative and autopsy reports at the TARN co-ordination centre at Salford Royal Hospital. The Abbreviated Injury Score (AIS) is used to allocate a numerical severity code to each injury as well as a localiser code which enables precise identification of each rib fracture. The AIS coding system then allows an overall Injury Severity Score (ISS) to be calculated for each patient.¹⁶

The main aims were to compare the prevalence of significant intrathoracic and extrathoracic injuries between patients with first rib fractures and those with other rib fractures and determine the association between first rib fractures and ISS, polytrauma and mortality.

Patients presenting with rib fractures to EDs at TARN participating hospitals between 1 January 2012 and 31 December 2013 were identified from the TARN database. All patients with one or more rib fractures and aged ≥ 16 years were included. Subjects were divided into a study group of patients with first rib fractures and a comparison cohort of patients with other rib fractures, who had not fractured their first ribs. Patients were compared with regard to demographics, mechanisms of injury and the presence of significant intrathoracic and extrathoracic injuries. Multivariate logistic regression was used to determine whether the presence of first rib fractures was significantly associated with increased injury severity (ISS >15) and polytrauma, after adjusting for relevant risk factors (including age, gender and mechanism of injury). Patients with polytrauma were defined as those who had at least one additional injury in a region outside of the chest with an Abbreviated Injury Score (AIS) of ≥ 3 . Risk-adjusted mortality was calculated using the TARN PS14 multivariate model, which adjusts for age, gender, Charlson Comorbidity Score, injury severity and GCS. The standard TARN definition of mortality (in-hospital death or death within 30 days of the initial injury (in patients whose hospital stay exceeded 30 days) was used.

Age, gender, Charlson Comorbidity Index, GCS, the presence of significant intrathoracic and extrathoracic injuries,

ISS and crude mortality were recorded. Intrathoracic injuries included flail chest, ≥ 3 rib fractures, lung injuries with AIS ≥ 3 , intrathoracic vascular injuries with AIS ≥ 3 and injuries to the thoracic aorta and injuries to the heart or pericardium. Extrathoracic injuries included severe injuries (AIS ≥ 3) to the brain, cervical spine, thoracic spine, brachial plexus, liver, spleen and pelvic ring. These injuries were a combination of intrathoracic and extrathoracic injuries traditionally considered as serious and/or life threatening, as well as a smaller number of injuries that had been studied in previous papers on first rib fractures (including brachial plexus injuries, injuries to intrathoracic vascular structures and injuries to the heart and pericardium). The use of a large multicentre database reduced the risk of selection bias.

Data was analysed using SPSS V.21. χ^2 analysis was used to compare categorical variables, including crude mortality rates and injury mechanism. Continuous data were compared using Student's *t*-test. The associations between first rib fractures and polytrauma and ISS (ISS >15) were calculated using multiple logistic regression analysis and reported as adjusted ORs. Risk-adjusted mortality was calculated using multiple logistic regression analysis and reported as adjusted ORs. When calculating risk-adjusted mortality, missing physiological data were imputed, while patients with a missing Charlson Comorbidity Index were included in the model as a separate category (as per the TARN PS14 predictive model). The PS 14 model includes an interaction term for age and gender, and a polynomial transformation of ISS (as this produced the best linear relationship between ISS and mortality). Both these terms were therefore included in our model. In our model, the interaction between age and gender was present but not significant (see online supplementary appendix 1). For all analyses, a *p* value of <0.05 was used as the cut-off for statistical significance.

The study was performed using data from the TARN database. The TARN database holds Section 251 approval to perform research on anonymised patient data. Data for this study came exclusively from the TARN database without author access to patient records, therefore no additional ethical approval was required.

The minimum sample size was calculated as 903 subjects per arm of the study group (a total of 1806 patients), anticipating an incidence of significant injuries of 20% and accepting a margin of error of 5%. For the logistic regression analyses, the sample size was calculated as 10 patients per independent covariate included in the model. There were eight covariates included in the risk-adjusted mortality model, requiring a minimum sample size of 80 patients.

RESULTS

A total of 10052 patients with rib fractures was identified from the TARN database between 2012 and 2013. Of this total, 1683 patients (16.7%) had first rib fractures while the remaining 8369 (83.3%) patients had fractures to other ribs but no first rib fracture (the control group).

The median age of patients with first rib fractures was lower than those with other rib fractures (55.2 (32.9–70.8) years and 64.7 (38.1–80.4) years, respectively; *p* <0.001). Road traffic collision was the most common mechanism of injury for patients with first rib fractures, compared with falls from <2 m height in the control group (table 1).

The median ISS for patients with first rib fractures was significantly higher than the control group (29 vs 26; *p* <0.001). Of

Table 1 Characteristics of patients with first rib fractures compared with those with other rib fractures

| | First rib fracture (n=1683) | Other rib fracture (n=8369) | |
|--|--------------------------------|--------------------------------|---------|
| Median age, years (IQR) | 55.2 (32.9–70.8) | 64.7 (38.1–80.4) | p<0.001 |
| Age groups, n (%) | | | |
| 16–44 years | 641 (38.1) | 1981 (23.7) | p<0.001 |
| 45–54 years | 289 (17.2) | 1402 (16.8) | |
| 55–64 years | 231 (13.7) | 1305 (15.6) | |
| 65–75 years | 245 (14.5) | 1299 (15.5) | |
| >75 years | 277 (16.4) | 2382 (28.5) | |
| Gender, n (%) | | | |
| Male | 1189 (70.7) | 5592 (66.8) | p=0.002 |
| Female | 494 (29.3) | 2777 (33.2) | |
| Charlson Comorbidity Index, n (%) | | | |
| Not recorded | 269 (16) | 1048 (12.5) | p<0.001 |
| 0 | 1070 (63.6) | 4733 (56.6) | |
| 1–5 | 258 (15.3) | 1900 (22.7) | |
| 6–10 | 53 (3.1) | 474 (5.7) | |
| >10 | 33 (2) | 214 (2.6) | |
| GCS, n (%) | | | |
| 3 | 156 (9.3) | 260 (3.1) | p<0.001 |
| 4–5 | 49 (2.9) | 65 (0.8) | |
| 6–8 | 75 (4.5) | 142 (1.7) | |
| 9–12 | 105 (6.2) | 272 (3.3) | |
| 13–14 | 271 (16.1) | 940 (11.2) | |
| 15 | 985 (58.6) | 6407 (76.6) | |
| Intubated | 42 (2.5) | 283 (3.4) | |
| Mechanism of injury, n (%) | | | |
| RTC | 1032 (61.3) | 2855 (34.1) | p<0.001 |
| Fall <2 m | 163 (9.7) | 3159 (37.7) | |
| Fall >2 m | 412 (24.5) | 1687 (20.2) | |
| Shooting/stabbing | 4 (0.2) | 97 (1.2) | |
| Other | 72 (4.3) | 571 (6.8) | |
| Injury severity and pattern | | | |
| Median ISS (IQR) | 29 (13–41) | 26 (9–35) | p<0.001 |
| ISS >15 | 1286 (76.4%) | 3826 (45.7%) | p<0.001 |
| Polytrauma | 809 (48.1%) | 2009 (24.0%) | p<0.001 |

ISS, Injury Severity Score; RTC, road traffic collision.

the patients with first rib fractures, 809 (48.1%) had polytrauma compared with 2009 (24.0%) in the comparator group.

Significant intrathoracic injuries were more common in patients with first rib fractures (table 2). These included flail chest (26.7% vs 16.8%; $p < 0.001$), severe lung injuries with AIS ≥ 3 (44.1% vs 22.1%, $p < 0.001$), heart/pericardial injuries (1.6% vs 0.5% $p < 0.001$) and intrathoracic vascular injuries (2.3% vs 0.8%, $p < 0.001$). The proportion of patients with multiple rib fractures (involving ≥ 3 consecutive ribs) was the same in both groups (44.3% vs 44.2%, $p = 0.952$).

After adjusting for mechanism of injury, age and gender, the odds of having polytrauma was 2.01 (95% CI 1.80 to 2.25) in patients with first rib fractures, compared with those with other rib fractures (table 3), while the odds of having an ISS >15 was 2.64 (95% CI 2.33 to 3.00) (table 4).

The crude mortality rate in patients with first rib fractures was 14.5% (246 of 1683 patients) versus 8.4% (700 of 8369 patients) in those with other rib fractures ($p < 0.001$). A further analysis of mortality showed that crude mortality in patients with first rib fractures and polytrauma was 21.0% (205 of 978 patients), compared

with 14.9% (400 of 2685 patients) in patients with polytrauma and other rib fractures ($p < 0.001$). However, in patients with isolated chest injuries, crude mortality was similar in those with first rib fracture and those with fractures of other ribs (5.8% (41 of 705 patients) vs 5.3% (300 of 5684) patients, $p = 0.549$). After adjusting for injury severity, age, gender, GCS, comorbidities and the presence of polytrauma, there was no significant difference in risk-adjusted mortality between patients with first rib fractures and those with fractures of other ribs (adjusted odds ratio 0.97, 95% CI 0.79 to 1.19, $p = 0.780$) (table 5).

Serious traumatic brain injuries (28.9% vs 12.5%, $p < 0.001$), cervical spine injuries (6.6% vs 1.5%, $p < 0.001$), thoracic spine injuries (6.7% vs 2.9%, $p < 0.001$), liver injuries (4.0% vs 1.7%, $p < 0.001$) and pelvic ring fractures (8.7% vs 4.2%, $p < 0.001$) were more common in patients with first rib fractures (table 2). However, there was no significant difference in the prevalence of splenic injuries between groups (3.4% vs 2.7%, $p = 0.120$). Patients with first rib fractures were more likely to have sustained brachial plexus injuries, though these injuries were rare in both groups (1.1% vs 0.2%, $p < 0.001$).

Table 2 Prevalence of significant intrathoracic and extrathoracic injuries in patients with first rib fractures compared with those with other fractures

| | First rib fracture (n=1683) | Other rib fracture (n=8369) | |
|--|--------------------------------|--------------------------------|---------|
| Prevalence of intrathoracic injuries, n (%) | | | |
| Flail chest | 449 (26.7) | 1403 (16.8) | p<0.001 |
| Multiple rib fractures (≥3) | 745 (44.3) | 3698 (44.2) | p=0.952 |
| Lung injuries (AIS ≥3) | 743 (44.1) | 1850 (22.1) | p<0.001 |
| Vascular injuries (AIS ≥3) | 39 (2.3) | 67 (0.8) | p<0.001 |
| Thoracic aorta | 23 (1.4) | 53 (0.6) | p<0.001 |
| Heart/pericardium | 27 (1.6) | 41 (0.5) | p<0.001 |
| Prevalence of extrathoracic injuries, n (%) | | | |
| Brain AIS ≥3 | 487 (28.9) | 1049 (12.5) | p<0.001 |
| Cervical spine AIS ≥3 | 111 (6.6) | 128 (1.5) | p<0.001 |
| Thoracic spine AIS ≥3 | 113 (6.7) | 240 (2.9) | p<0.001 |
| Liver AIS ≥3 | 68 (4) | 145 (1.7) | p<0.001 |
| Spleen AIS ≥3 | 57 (3.4) | 226 (2.7) | p=0.120 |
| Pelvic ring AIS ≥3 | 146 (8.7) | 350 (4.2) | p<0.001 |
| Brachial plexus | 18 (1.1) | 16 (0.2) | p<0.001 |

AIS, Abbreviated Injury Score.

DISCUSSION

Our study demonstrated that patients with first rib fractures were more likely to sustain serious intrathoracic and extrathoracic injuries when compared with patients with other rib fractures. In addition, first rib fractures were associated with increased injury severity and polytrauma, while crude mortality rates were higher, supporting the findings of previous research.

The proportion of patients with serious brain injuries in our study was 28.9%, similar to the incidence reported in previous studies, which ranged from 17.1% to 73%.^{1-3 17-20} The proportion of patients with first rib fractures who had cervical spine injuries (6.6%) was also similar to previously reported rates. Poole *et al* reported a prevalence of cervical spine injury of 9.7% with first rib fractures, while Yee *et al* reported cervical spine injuries in 9% of their patients.^{2 18} It should be noted that our study only reported severe injuries to the head and cervical spine (AIS ≥3), while previous studies documented all injuries to these

body areas. The relatively high incidence of serious cervical spine and head injuries in this study reinforces the need to increase our vigilance when dealing with patients with first rib fractures.

In contrast to the findings in relation to head and neck injuries, our study recorded a much lower incidence of brachial plexus and vascular injuries in patients with first rib fractures, compared with previous studies. The incidence of vascular injuries in other studies was between 5.5% and 45.3%, compared with 2.3% in our study.^{3 8 17 19} With brachial plexus injuries, the findings are also markedly different: in our study the incidence of brachial plexus injuries with first rib fractures was only 1.1%, compared with an incidence of between 2.7% and 6.7% reported by other researchers.^{1-3 17 19 20} This is likely due to selection bias related to an increase in the incidental detection of first rib fractures with CT. Specifically, brachial plexus and subclavian vessel injuries have traditionally been reported with displaced first rib fractures, whereas undisplaced (occult)

Table 3 Logistic regression analysis of the risk of having polytrauma: patients were defined as having sustained polytrauma if they had at least one additional injury of AIS ≥3 outside of the chest region, AUROC (area under the receiver operating curve) = 0.712 (95% CI 0.701 to 0.722)

| Covariates | | Unadjusted ORs | | | | Adjusted ORs | | | |
|----------------------|-------------------|----------------|-------|-------|---------|---------------|-------|-------|---------|
| | | 95% CI for OR | | | | 95% CI for OR | | | |
| | | OR | Upper | Lower | p Value | OR | Upper | Lower | p Value |
| Age (years) | 16-44 | Reference | | | | | | | |
| | 45-54 | 0.56 | 0.53 | 0.68 | <0.001 | 0.69 | 0.61 | 0.79 | <0.001 |
| | 55-64 | 0.48 | 0.42 | 0.55 | <0.001 | 0.61 | 0.53 | 0.70 | <0.001 |
| | 65-74 | 0.44 | 0.38 | 0.50 | <0.001 | 0.60 | 0.52 | 0.69 | <0.001 |
| | >75 | 0.31 | 0.28 | 0.35 | <0.001 | 0.59 | 0.52 | 0.68 | <0.001 |
| Gender | Male | Reference | | | | | | | |
| | Female | 0.86 | 0.79 | 0.94 | <0.001 | 1.18 | 1.07 | 1.30 | <0.001 |
| MOI | Fall <2 m | Reference | | | | | | | |
| | Fall >2 m | 4.33 | 3.79 | 4.95 | <0.001 | 3.73 | 3.27 | 4.27 | <0.001 |
| | RTC | 5.51 | 4.88 | 6.21 | <0.001 | 4.08 | 3.60 | 4.64 | <0.001 |
| | Shooting/stabbing | 2.59 | 1.69 | 3.97 | <0.001 | 1.95 | 1.26 | 3.02 | p=0.003 |
| | Other | | 2.03 | 2.99 | <0.001 | 1.95 | 1.59 | 2.39 | <0.001 |
| Type of rib fracture | Other ribs | Reference | | | | | | | |
| | First rib | 2.94 | 2.64 | 3.28 | <0.001 | 2.01 | 1.80 | 2.25 | <0.001 |

AIS, Abbreviated Injury Score; MOI, mechanism of injury; RTC, road traffic collision.

Table 4 Logistic regression analysis of the risk of having an ISS of >15 in patients included in the study, AUROC 0.719 (95% CI 0.709 to 0.729)

| Covariates | | Unadjusted ORs | | | | Adjusted ORs | | | |
|----------------------|-------------------|----------------|-------|-------|---------|--------------|---------------|-------|---------|
| | | 95% CI for OR | | | p Value | OR | 95% CI for OR | | |
| | | OR | Upper | Lower | | | Upper | Lower | p Value |
| Age (years) | 16–44 | Reference | | | | | | | |
| | 45–54 | 0.69 | 0.61 | 0.78 | p<0.001 | 0.83 | 0.73 | 0.95 | p=0.006 |
| | 55–64 | 0.56 | 0.50 | 0.64 | p<0.001 | 0.75 | 0.65 | 0.86 | p<0.001 |
| | 65–74 | 0.51 | 0.44 | 0.58 | p<0.001 | 0.75 | 0.65 | 0.86 | p<0.001 |
| | >75 | 0.30 | 0.27 | 0.34 | p<0.001 | 0.61 | 0.53 | 0.69 | p<0.001 |
| Gender | Male | Reference | | | | | | | |
| | Female | 0.73 | 0.67 | 0.79 | p<0.001 | 0.97 | 0.89 | 1.07 | p=0.585 |
| MOI | Fall <2 m | Reference | | | | Reference | | | |
| | Fall >2 m | 3.71 | 3.29 | 4.19 | p<0.001 | 2.97 | 2.64 | 3.36 | p<0.001 |
| | RTC | 5.37 | 4.81 | 5.99 | p<0.001 | 3.74 | 3.36 | 4.20 | p<0.001 |
| | Shooting/stabbing | 2.08 | 1.39 | 3.10 | p<0.001 | 1.26 | 1.03 | 2.34 | p=0.035 |
| | Other | 2.17 | 1.83 | 2.59 | p<0.001 | 1.63 | 1.36 | 1.97 | p<0.001 |
| Type of rib fracture | Other ribs | Reference | | | | | | | |
| | First rib | 3.85 | 3.40 | 4.36 | p<0.001 | 2.64 | 2.33 | 3.00 | p<0.001 |

ISS, Injury Severity Score; MOI, mechanism of injury; RTC, road traffic collision.

Table 5 Adjusted ORs for mortality (risk-adjusted mortality) in patients with rib fractures (adapted from TARN predictive model)

| | | OR | 95% CI | | p Value |
|------------------------|-----------------------|-------|--------|-------|---------|
| | | | Upper | Lower | |
| ISS(FracPoly) | ISS_1 | 1.14 | 1.09 | 1.21 | 0.000 |
| | ISS_2 | 0.99 | 0.98 | 1.00 | 0.003 |
| Age (years) | 16–44 | Ref | | | |
| | 45–54 | 1.73 | 1.20 | 2.49 | 0.003 |
| | 55–64 | 1.92 | 1.31 | 2.82 | 0.001 |
| | 65–75 | 4.43 | 3.10 | 6.31 | <0.001 |
| | >75 | 18.09 | 13.12 | 24.94 | <0.001 |
| Gender | Male | Ref | | | |
| | Female | 1.01 | 0.65 | 1.58 | 0.958 |
| Age/gender interaction | 16–44#Female | Ref | | | |
| | 45–54#Female | 0.97 | 0.46 | 2.03 | 0.931 |
| | 55–64#Female | 1.06 | 0.50 | 2.23 | 0.888 |
| | 65–75#Female | 1.25 | 0.67 | 2.34 | 0.477 |
| | >75#Female | 0.83 | 0.50 | 1.37 | 0.455 |
| GCS | GCS 15 | Ref | | | |
| | GCS 13–14 | 1.89 | 1.49 | 2.38 | <0.001 |
| | GCS 9–12 | 3.85 | 2.77 | 5.35 | <0.001 |
| | GCS 6–8 | 4.49 | 2.91 | 6.92 | <0.001 |
| | GCS 4–5 | 12.66 | 7.84 | 20.44 | <0.001 |
| | GCS=3 | 32.66 | 24.61 | 43.35 | <0.001 |
| Charlson Score | Intubated | 20.72 | 10.76 | 39.88 | <0.001 |
| | 0 | Ref | | | |
| | 1–5 | 1.81 | 1.47 | 2.22 | <0.001 |
| | 6–10 | 2.47 | 1.83 | 3.32 | <0.001 |
| | >10 | 4.51 | 3.11 | 6.54 | <0.001 |
| Injury pattern | Not recorded | 3.16 | 2.52 | 3.97 | <0.001 |
| | Isolated chest injury | Ref | | | |
| | Polytrauma | 1.01 | 0.78 | 1.31 | 0.925 |
| Type of rib fracture | Other ribs | Ref | | | |
| | First rib | 0.97 | 0.79 | 1.19 | 0.780 |

AUROC 0.879 (95% CI 0.869 to 0.890).

The age/gender interaction term (Age#Female) refers to the ratio of odds of death between males and females for each age group. Both age/gender interaction and fractional polynomial transformation of ISS were included in the model as these are part of the PS14 model, which was used to calculate adjusted mortality in our sample. Fracpoly, fractional polynomial transformation; ISS, Injury Severity Score; TARN, UK Trauma Audit and Research Network.

fractures are more likely to be detected on CT, but less likely to lead to these complications. On balance, it would appear that the relationship between first rib fractures and brachial plexus and vascular injuries may have been somewhat overstated in the past. While these complications are clearly of theoretical concern, our study suggests that they are less commonly seen with first rib fractures than previously reported. However, given the inclusion criteria for TARN, it is possible that patients with brachial plexus injuries may not have met these criteria and therefore would not have been included on the database, or in this study.

This study demonstrated a significant difference in the mechanism of injury causing first rib fractures, compared with fractures to other ribs. Road traffic accidents were the most common cause of first rib fractures, reinforcing the hypothesis that these injuries are associated with high-energy impact mechanisms. In contrast, the association between low-level falls and other rib fractures reflects the older age of the control group, as low-level falls are the most common injury mechanism in patients aged ≥ 65 years.²¹

The mortality and injury severity data from this study confirm the widely held view that first rib fractures are associated with increased mortality, higher injury severity and polytrauma.^{3 17 18} This is the first study to show that this increased risk is independent of other variables, such as mechanism of injury, age and gender.

In our study, there was no difference in risk-adjusted mortality between patients with first rib fractures and those with fractures of other ribs, after adjusting for other factors such as injury severity and age. This suggests that rather than being a primary cause of death, first rib fractures are a marker for increased injury severity which in turn leads to increased mortality. Other studies have also noted a wide variety of causes of death in patients with first rib fractures, many of which are extrathoracic.^{3 18 19} Patients with polytrauma found to have first rib fractures should therefore be monitored more intensively and managed more aggressively to ensure that we do not miss other serious injuries, inside and outside of the chest. However, in patients with first rib fractures with isolated chest injuries, the crude mortality rates were similar to those with other rib fractures. This suggests that these patients may not require such escalation of care.

This is the first study to have undertaken a systematic comparison of patients with and without first rib fractures using a large, multicentre database of patients with trauma. While this approach would have minimised the risk of under-reporting and selection bias, there are a few limitations of this study that should be acknowledged. The use of the TARN database effectively excluded patients with less severe injuries, given the inclusion criteria for TARN (patients included in the TARN dataset must fulfil at least one of the following criteria: length of stay ≥ 72 or admitted to a high-dependency area or death in hospital or trauma transferred to another hospital for specialist/critical care).¹⁶ However, we were primarily interested in the outcome of patients with first rib fracture who had suffered significant trauma and the inclusion of patients with major trauma achieved this aim. In addition, the number of patients suffering first rib fractures from isolated low-energy trauma is minimal, with only a handful of reports in the medical literature.⁴⁻⁶ A more significant omission is the exclusion of prehospital deaths from the TARN database. There was no ready access to the postmortem findings of patients with trauma suffering prehospital demise and no guarantee that first rib fractures would have been either sought or identified at postmortem in these patients. However, it would be interesting and important to investigate the incidence of first rib fractures

in patients with trauma who succumb to their injuries prior to admission to the ED.

This study confirmed the traditional view that first rib fractures are associated with high-energy trauma and more severe injuries in patients with major trauma and has helped to clarify the relationship between first rib fractures and mortality. The increased mortality associated with these injuries was seen only in patients with polytrauma, suggesting that first rib fractures are an indicator of life-threatening intrathoracic and extrathoracic injury. The incidence of associated injuries in patients with first rib injuries differed significantly from that reported in the medical literature. It is likely that this study provides a more accurate estimate of these associations in the wider trauma population due to its large size and the comprehensive nature of the TARN database. These findings could be useful in developing evidence-based protocols for the investigation and management of patients presenting with first rib fractures following major trauma.

Contributors HC conceived the initial research question, designed the study, collected, analysed and interpreted the data and produced the final manuscript. IAS designed the study, analysed and interpreted the data and produced the final manuscript. FL advised on the study design, supervised the study, contributed to data interpretation and supervised production of the final manuscript. OB and MF-I collated and analysed the data and contributed to data interpretation and production of the final manuscript. MH and AS contributed to the development of the original research question and study design and advised on data interpretation and production of the final manuscript. JE advised on the study design, data interpretation and production of the final manuscript. HC and IAS are responsible for the overall content as guarantors.

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