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Are first rib fractures a marker for other life threatening injuries in major trauma patients? A cohort study of patients on the TARN database.

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Complete List of Authors:	Sammy, Ian; The University of Sheffield, School of Health and Related Reseearch; The University of the West Indies, Department of Clinical Surgical Sciences Chatha, Hridesh ; Salford Royal NHS Foundation Trust, Emergency Department Lecky, Fiona; University of Sheffield, School of Health and Related Research Bouamra, Omar; The Trauma Audit and Research Network, Fragoso-Iñiguez, Marisol; Hope Hospital, Trauma Audit and Research Network Sattout, Abdo; Aintree University Hospitals, Emergency Medicine Hickey, Michael; University Hospital Aintree, Emergency Department Edwards, John; The University of Sheffield, School of Health and Related Reseearch
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Corresponding Author Details

Dr Ian Sammy, FCEM, Director, MSc in Advanced Emergency Care

SCHARR (School of health and related research), The University of Sheffield,

30 Regent Street, Sheffield, South Yorkshire S1 4DA

Phone: +44 114 222 4319 Email Address: ian.sammy@sheffield.ac.uk

Additional Authors

Dr Hridesh Chatha

Emergency Department, Aintree University Hospital, Liverpool, UK

Prof Fiona Lecky

The Trauma Audit and Research Network, University of Manchester, Salford, UK

Dr Omar Bouamra,

The Trauma Audit and Research Network, University of Manchester, Salford, UK

Ms Marisol Fragoso-Iniguez,

The Trauma Audit and Research Network, University of Manchester, Salford, UK

Dr Abdo Sattout,

Emergency Department, Aintree University Hospital, Liverpool, UK

Dr Michael Hickey,

Emergency Department, Aintree University Hospital, Liverpool, UK

Mr John Edwards,

SCHARR (School of health and related research), The University of Sheffield, Sheffield, UK

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Are first rib fractures a marker for other life threatening injuries in major trauma patients?

Abstract

Introduction

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 computed tomography, 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 (TARN). The prevalence of life threatening injuries was compared in patients with first rib fractures to 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 1,683 patients with first rib fractures and 8369 with fractures of other ribs. Life-threatening intra- and extra-thoracic injuries were more likely in patients with first rib fractures. The presence of first rib fractures was a significant predictor of injury severity (ISS>15) and polytrauma, independent of mechanism of injury, age and gender with an adjusted odds ratio of 2.64 (95% CI 2.33 – 3.00) and 2.01 (95% CI 1.80 – 2.25), respectively. Risk adjusted mortality was the same in patients with first rib fractures and those with other rib fractures (AOR 0.97, 95%CI 0.79 - 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.

What does this study add?

What is known about the 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 chest x-ray 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 poly trauma and severe injury (ISS >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.

INTRODUCTION

First rib fractures have traditionally been considered indicators of increased injury severity and mortality in major trauma patients (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 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 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 generalizable to all trauma patients. In addition these studies did not compare patients with 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 intra-thoracic 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 major trauma patients.

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 to patients with fractures of other ribs.

PATIENTS AND METHODS

This was a cohort study of prospectively collected data on major trauma patients, using the Trauma Audit and Research Network (TARN) database. The TARN database is a national database that collects and analyses data on major trauma patients admitted to the majority of trauma receiving hospitals in England and Wales, as well as participating hospitals in the Republic of 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 Scale (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 intra- and extrathoracic injuries between patients with first rib fractures and those with other rib fractures, and determine the association between first rib fractures and injury severity score (ISS), polytrauma and mortality.

Patients presenting with rib fractures to Emergency Departments at TARN participating hospitals between the 1st January 2012 and the 31st December 2013 were identified from the TARN database. All patients with one or more rib fracture aged 16 and over 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 extra-thoracic 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). Polytrauma patients 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 Glasgow coma score. 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 score, GCS, the presence of significant intra- and extra-thoracic injuries, injury severity score (ISS) and crude mortality were recorded. Intra-thoracic injuries included flail chest, ≥ 3 rib fractures, lung injuries with AIS ≥3, intra-thoracic vascular injuries with AIS ≥3 and injuries to the thoracic aorta and injuries to the heart or pericardium. Extra-thoracic 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 intra- and extra-thoracic 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 intra-thoracic 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 version 21. Chi squared 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 poly trauma and injury severity score (ISS >15) were calculated using multiple logistic regression analysis and reported as adjusted odds ratios. Risk adjusted mortality was calculated using multiple logistic regression analysis and reported as adjusted odds ratios. When calculating risk adjusted mortality, missing physiological data was imputed, while patients with a missing Charlson comorbidity score 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 (Appendix 1). For all analyses, a 'p' value of < .05 was used as the cut-off for statistical significance.

The study was performed using data from the Trauma Audit and Research Network (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 8 covariates included in the risk adjusted mortality model, requiring a minimum sample size of 80 patients.

RESULTS

A total of 10,052 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 8,369 (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 (RTC) was the commonest mechanism of injury for patients with first rib fractures, compared to falls from less than 2m in the control group (Table 1).

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

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).

	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			
16 - 44 years	641 (38.1%)	1981 (23.7%)	
45 - 54 years	289 (17.2%)	1402 (16.8%)	
55 - 64 years	231 (13.7%)	1305 (15.6%)	p<0.001
65 - 75 years	245 (14.5%)	1299 (15.5%)	
>75 years	277 (16.4%)	2382 (28.5%)	
Gender			
Male	1189 (70.7%)	5592 (66.8%)	P=0.002
Female	494 (29.3%)	2777 (33.2%)	
Charlson Comorbidity Index			
Not recorded	269 (16%)	1048 (12.5%)	
0	1070 (63.6%)	4733 (56.6%)	
1 - 5	258 (15.3%)	1900 (22.7%)	p<0.001
6 - 10	53 (3.1%)	474 (5.7%)	
>10	33 (2%)	214 (2.6%)	
Glasgow Coma Score			
3	156 (9.3%)	260 (3.1%)	
4 - 5	49 (2.9%)	65 (0.8%)	
6 - 8	75 (4.5%)	142 (1.7%)	
9 - 12	105 (6.2%)	272 (3.3%)	p<0.001
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			
RTC	1032 (61.3%)	2855 (34.1%)	
Fall < 2m.	163 (9.7%)	3159 (37.7%)	
Fall > 2m	412 (24.5%)	1687 (20.2%)	p<0.001
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

Table 1: Characteristics of patients with first rib fractures compared to those with other rib fractures. RTC = road traffic collision; IQR = interquartile range; ISS = injury severity score. AIS = abbreviated injury score

	First rib fracture (n= 1683)	Other rib fracture (n= 8369)	
Prevalence of Intrathoracic injuries			
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 Extra-thoracic injuries			
Brain AIS ≥ 3	487 (28.9%)	1049 (12.5%)	p<0.001
C- Spine AIS ≥ 3	111 (6.6%)	128 (1.5%)	p<0.001
T- 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

Table 2: Prevalence of significant intra- and extrathoracic injuries in patients with first rib fractures compared to those with other fractures.

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

Co-variates		Unadjusted Odds Ratios				Adjusted Odds Ratios			
		Odds Ratio	95% CI for OR Upper	Lower	'p' value	Odds Ratio	95% CI for OR Upper	Lower	'p' value
Age	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 < 2m	Reference							
	Fall > 2m.	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

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 0.712 (95% CI 0.701 – 0.722)

Co-variates		Unadjusted Odds Ratios				Adjusted Odds Ratios			
		Odds Ratio	95% CI for OR Upper	Lower	'p' value	Odds Ratio	95% CI for OR Upper	Lower	'p' value
Age	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 < 2m		Reference				Reference		
	Fall > 2m.	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

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 – 0.729)

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 polytrauma patients with 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 (AOR 0.97, 95%CI 0.79 to 1.19; p = 0.780) (Table 5).

		Odds Ratio	95% Confidence Interval		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	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
Glasgow Coma Score	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
	Intubated	20.72	10.76	39.88	<0.001
Charlson Score	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
	Not recorded	3.16	2.52	3.97	<0.001
Injury Pattern	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

Table 5: Adjusted odds ratios for mortality (risk adjusted mortality) in patients with rib fractures, adapted from TARN predictive model. Fracpoly = fractional polynomial transformation. AUROC 0.879 (95% CI 0.869 - 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.

DISCUSSION

Our study demonstrated that patients with first rib fractures were more likely to sustain serious intra- and extra-thoracic injuries when compared to 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 to previous studies. The incidence of vascular injuries in other studies was between 5.5% and 45.3%, compared to 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 to 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 computerised tomography. Specifically, brachial plexus and subclavian vessel injuries have traditionally been reported with displaced first rib fractures, whereas undisplaced (occult) 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 to 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 65 years and older (21).

The mortality and injury severity data from this study confirms 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 extra-thoracic (3, 18, 19). Polytrauma patients 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 trauma patients. 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 major trauma patients 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 pre-hospital deaths from the TARN database. There was no ready access to the post-mortem findings of trauma patients suffering pre-hospital demise, and no guarantee that first rib fractures would have been either sought or identified at post-mortem in these patients. However, it would be interesting and important to investigate the incidence of first rib fractures in trauma patients who succumb to their injuries prior to admission to the Emergency Department.

This study confirmed the traditional view that first rib fractures are associated with high energy trauma and more severe injuries in major trauma patients, and has helped to clarify the relationship between first rib fractures and mortality. The increased mortality associated with these injuries was seen only in polytrauma patients, suggesting that first rib fractures are an indicator of life threatening intra- and extra-thoracic 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.

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Author Contribution Statement:

Hridesh Chatha conceived the initial research question, designed the study, collected and analysed and interpreted data and produced the final manuscript. Ian Sammy designed the study, analysed and interpreted the data and produced the final manuscript. Fiona Lecky advised on the study design, supervised the study, contributed to data interpretation and supervised production of the final manuscript. Omar Boumra and Marisol Fragoso-Iniguez collated and analysed data, and contributed to data interpretation and production of the final manuscript. Michael Hickey and Abdo Sattout contributed to the development of the original research question and study design, and advised on data interpretation and production of the final manuscript. John Edwards advised on the study design, data interpretation and production of the final manuscript. Hridesh Chatha and Ian Sammy are responsible for the overall content as guarantors.

Legends for Table and Appendices

Table 1: Characteristics of patients with first rib fractures compared to those with other rib fractures. RTC = road traffic collision; IQR = interquartile range; ISS = injury severity score. AIS = abbreviated injury score

Table 2: Prevalence of significant intra- and extrathoracic injuries in patients with first rib fractures compared to those with other fractures.

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 0.712 (95% CI 0.701 – 0.722)

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 – 0.729)

Table 5: Adjusted odds ratios for mortality (risk adjusted mortality) in patients with rib fractures, adapted from TARN predictive model. Fracpoly = fractional polynomial transformation. AUROC 0.879 (95% CI 0.869 - 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.

Appendix 1: Marginal plot of age and gender in relation to mortality, demonstrating the interaction between age and gender.

Competing Interests

None of the authors have any competing interests to declare. This study received no external funding. TARN is funded by subscription from its member hospitals in England, Wales, Republic of Ireland, Denmark and Switzerland.

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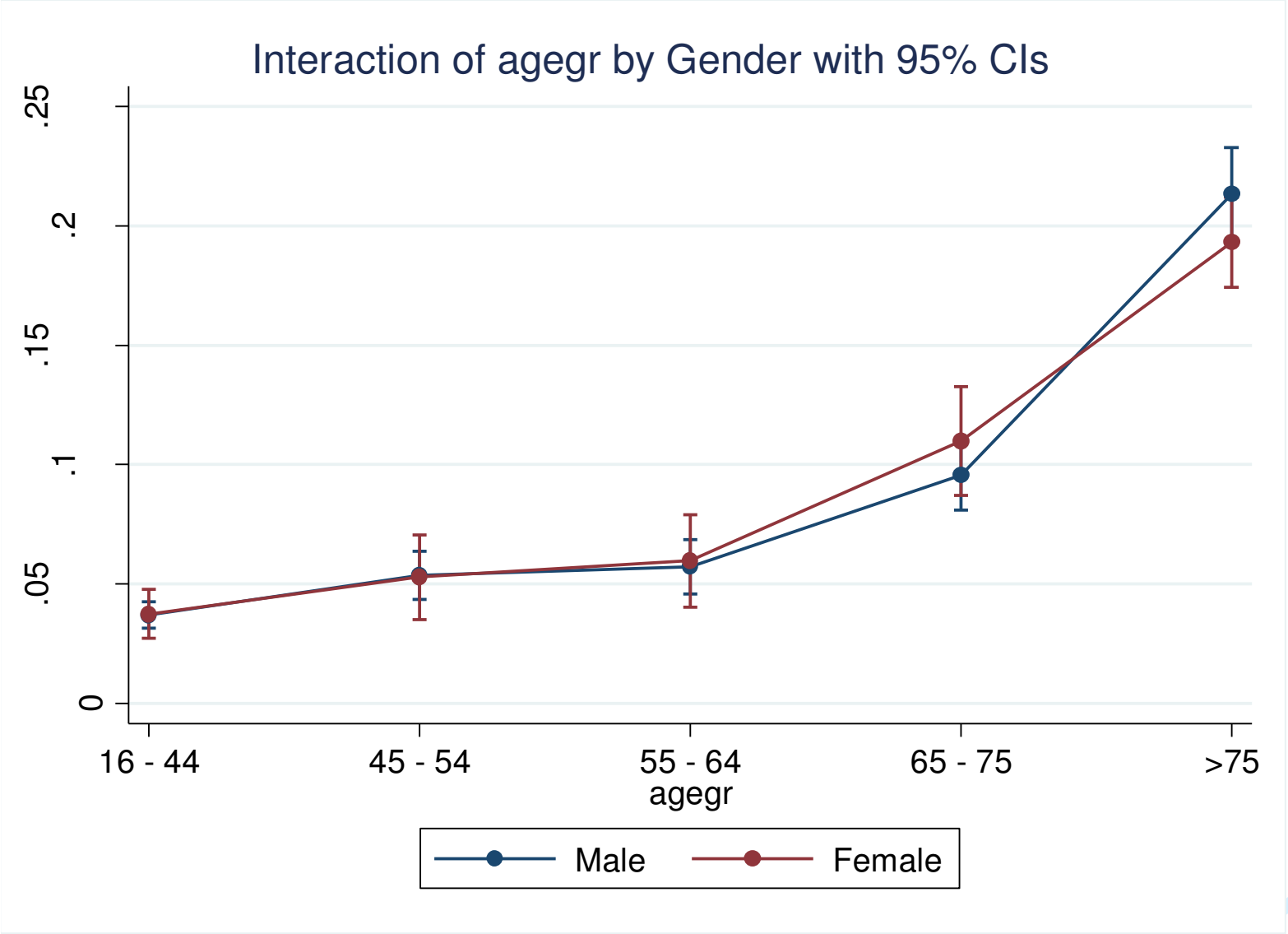

Appendix 1: Marginal plot of age and gender in relation to mortality, demonstrating the interaction between age and gender.