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Predictors of long-term survival in 5,680 patients admitted to a UK major trauma centre with thoracic injuries*

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ABSTRACT

Introduction The long-term outcomes of chest trauma are largely unknown. We sought to determine the predictors of in-hospital and long-term survival in patients admitted to a major trauma centre (MTC) with chest injuries and to evaluate spatial patterns of injury in our network area.

Methods Retrospective analysis of data collected on the National Trauma Audit Research Network (TARN) database using multivariate analysis and Cox regression analysis. Spatial analysis was performed using ArcGis 10.7.1.

Results Some 5,680 patients were admitted with chest trauma between December 1999 and December 2019. Median patient age was 45 years and the median Injury Severity Score (ISS) was 20. The proportion of patients who had an operation was 39.8%. Age, blood transfusion, head injury, shock, emergency thoracotomy and heart disease were predictors of hospital mortality ($p < 0.05$). However, having an operation on concomitant injuries was protective. ISS and Glasgow Coma Score were discriminators of in-hospital mortality (C-indices 0.76 and 0.80, respectively). The 10-year survival values for patients who survived to discharge from hospital and who were aged <40, 50, 60, 70, 80 and >80 years were 99%, 93%, 95%, 87%, 75% and 43%, respectively. Preadmission lung disease and alcohol/drug misuse were poor predictors of long-term survival ($p < 0.05$). Hotspot analysis revealed the areas with the highest incidents were all close to the MTC.

Conclusions The MTC is geographically central to areas with high numbers of trauma incidents. Although emergency thoracotomy was a predictor of poor in-hospital outcomes, having surgery for concomitant injuries improved outcomes. Patients surviving to discharge have good long-term survivals.

KEYWORDS

Trauma surgery – Survival

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Introduction

Trauma remains the most common cause of mortality in the United Kingdom (UK) in people under the age of 45.[1] Most injuries are due to blunt trauma such as road traffic accidents and falls from a height.[2] Although neurological and abdominal injuries account for most trauma deaths,[3] chest trauma is a significant cause of morbidity and mortality in hospital and of long-term disability on discharge.[4] The management of chest injuries varies across the world, although the Advanced Trauma Life Support protocol formulated by the American College of Surgeons[5] provides a basic framework for the management of chest injuries in the primary and secondary survey.

Specialised major trauma centres (MTCs), however, lead to standardised, highly specialised care that goes beyond the primary and secondary survey aspects of emergency department management and so could help improve outcomes in trauma patients.[6] MTCs have been set up in major cities across the UK.[7] Making sure these centres are appropriately placed geographically is crucial to the delivery of best care, because access to treatment is strongly associated with improved survival.

The Trauma and Audit Research Network (TARN) has been collecting data on patients admitted to peripheral centres and MTCs since 1999, although the data collected became more detailed in 2012.[8] Although long-term disability following chest trauma has been studied,[9] the long-term survival outcomes of those patients having chest trauma (isolated or in conjunction with other body systems) have not been evaluated. Our objective in this paper was to determine the predictors of in-hospital and long-term survival in patients admitted to an MTC with chest injuries and to reveal geographical patterns in incidence of chest trauma outcomes.

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Methods

Patient cohort

This was a retrospective analysis of the TARN database which collects data prospectively on all patients admitted with trauma to MTCs and other trauma units across the UK.[10] These MTCs are supercentres to which all regional trauma is directed and are located in the major cities of the UK.

The TARN database chronicles the patient's admission data (age, gender, comorbidities, geographical location of injury), mechanism of injury, body regions injured, the 2015 version of the Abbreviated Injury Score (AIS), Glasgow Coma Score (GCS), Injury Severity Score (ISS), admission shock (systolic blood pressure < 110mmHg), prehospital intervention (chest drain, airway, blood products and units), emergency department intervention (chest drain, intubation, blood products and units), number of operations, type of operation, outcome at 30 days, total length of hospital stay, length of intensive care unit stay and cause of death.

We analysed whether these characteristics were predictors of in-hospital and long-term survival in 5,680 patients admitted with chest trauma between December 1999 and December 2019.

Survival data

Overall survival was calculated from the date of hospital discharge to date of last follow-up or death from any cause. Follow-up data for patients was obtained from the National Health Service (NHS) central database on 30 April 2020.

Patterns of injury and survival using Geographic Information Systems

Ordinance survey data were applied to develop a base map of the catchment area and were based on incidences as recorded in the TARN database. Data were layered into ArcGIS software version 10.7.1 (ESRI Inc., Redlands, CA, USA). For geographical analysis, Geographic Analysis Machine and Gettis Ord statistics were used to reveal spatial patterning and hotspots at Mid Super Output levels. Distance from referral centre was calculated to determine survival effects.

Spatial statistics were used to reveal patterns, trends and distributions. Spatial autocorrelation was used to determine incident clustering or dispersal. Hotspot analysis uses vectors to identify the locations of statistically significant trends in space and place in the data. The Gettis ord GI* statistic was applied to delineate clusters of trauma incidents, with the Z-score and p-value for each feature (incidence per Mid Super Output Area). A high Z-score and small p-value for a feature indicate a significant hotspot. A low negative Z-score and small p-value indicate a significant cold spot.

Statistical analysis

Continuous variables are expressed as median and interquartile range (IQR) or mean and standard deviation. Categorical variables are expressed as percentages with proportions. Multivariate logistic regression and linear regression were used to discern predictors of in-hospital mortality and length of hospital stay, respectively. Hazard ratios (HRs) are given for mortality with the 95% confidence interval (CI).

Receiver operating characteristic curves were used to compare the discriminatory properties of the GCS and ISS in predicting in-hospital mortality. C-indices were used to quantify the discriminatory properties. Kaplan–Meier plots were used to demonstrate long-term survival. Cox regression multivariate analysis using a forward conditional method was used to determine factors predicting long-term survival (in patients who survived to discharge). Log-rank tests were used to stratify survival based on variable properties. HRs are given with a 95% CI. Analyses were performed using SPSS software version 24 (SPSS Inc., Chicago, IL, USA).

Approval

This was a service evaluation project and was approved by our institution's governance department (Project Approval Number 8475). This project is registered on our institution's audit database. No external (outside our The Leeds Teaching Hospitals NHS Trust) preregistration exists for the reported studies reported in this article. TARN has its own ethical approval (PIAG Section 60) for studies using the data that it holds.

Results

Admission characteristics

Patient admission characteristics are given in Table 1.

In total, some 4,701 of the 5680 patients admitted to the MTC had pre-existing comorbidities as follows: lung disease (chronic obstructive pulmonary disease, lung fibrosis, asthma), 12.2% (n = 575); heart disease (ischaemic heart disease, valvular heart disease, heart failure or arrhythmia), 9.3% (n = 437); peripheral vascular disease (arterial and venous), 0.91% (n = 43); neurological disease (previous stroke or transient ischaemic attack), 5.5% (n = 258); hypertension, 10.3%(n = 482), diabetes mellitus (type 1 or type 2), 5.4%(n = 254); endocrine disease, 2.1% (n = 100); chronic kidney disease, 3.3% (n = 155); alcohol abuse, 7.5%(n = 351); psychiatric disease (depression, anxiety, psychosis), 8.9% (n = 418); and substance (non-alcohol) abuse, 4.6% (n = 218). Ninety-seven patients had multiple admissions with trauma over the study period.

Injury characteristics

In total, 5,680 patients presented with chest trauma: 6.8% (n = 385) with penetrating chest injuries and 93.2% (n = 5,295) with blunt chest injuries. The mechanism of injury is given in Table 2. The median ISS score was 20 (IQR 13–31).

Concomitant injuries were as follows: limb injury, 50.1% (n = 2,878); head injury, 36.2% (n = 2,058); spine injury

Table 1 Admission and discharge characteristics	
Characteristic	***N* = 5,680**
Median age (years)	45 (IQR 26–64)
% Male (*n*)	73.1 (4,150)
Median GCS score	14 (IQR 13–15)
Median ISS score	20 (IQR 13–31.50)
Median time to computer tomography from injury (min)	42 (IQR 23–132)
Median length of stay (days)	9 (IQR 4–19)
Median length of stay in intensive care unit (days)	1 (IQR 0–4)
% Intensive care unit admission (*n*)	59.2 (3,363)
% Shock on admission (*n*)	22.2 (1,263)
% Emergency department chest drain (*n*)	8.3 (470)
% Emergency department intubation (*n*)	11.0 (626)
% Emergency department blood transfusion (*n*)	4.1 (234)
% Hospital mortality (*n*)	10.4 (591)
% Discharged home (*n*)	74.4 (4,225)

GCS = Glasgow Coma Scale; IQR = interquartile range; ISS = Injury Severity Scale

Table 2 Mechanism of injury

	Percentage	**Proportion**
Fall	33.5	1,902 of 5,680
Vehicle collision	52.1	2,961 of 5,680
Pedestrian	22.9	678 of 2,961
Driver	28.0	83 of 2,961
Passenger	18.2	540 of 2,961
Cyclist	9.4	278 of 2,961
Motorcyclist	20.7	612 of 2,961
Stabbing	6.0	343 of 5,680
Shooting	0.46	26 of 5,680

32.9% (*n* = 1,871); abdominal injury 22.2% (*n* = 1,266), facial injury 21.4% (*n* = 1,218) and pelvic injury 20% (*n* = 1,139). The pattern of injury is given in Table 3.

AIS characteristics

The following AIS scores were recoded for each body region.

(i) Thorax: AIS 1, 8.0% (*n* = 456); AIS 2, 10.8% (*n* = 616); AIS 3, 48.2% (*n* = 2,735); AIS 4, 27.5% (*n* = 1,564); AIS 5, 5.3% (*n* = 302); AIS 6 <1% (*n* = 7).

(ii) Head: no head injuries (AIS 0) were found in 63.8% of patients (*n* = 3,622) of patients. AIS 1, 6.8% (*n* = 398); AIS 2, 1.1% (*n* = 63); AIS 3, 6.7% (*n* = 5,680); AIS 4, 10.0% (*n* = 567); AIS 5, 11.4% (*n* = 646).

(iii) Face: no facial injuries (AIS 0) were found in 78.6% of patients (*n* = 4,462). AIS 1, 11.0% (*n* = 627); AIS 2, 8.9% (*n* = 505); AIS 3, 1.5% (*n* = 84); AIS 4, <1% (*n* = 2).

(iv) Abdomen: no abdominal injuries (AIS 0) were found in 77.7% of patients (*n* = 4,414). AIS 1, 2.8% (*n* = 159); AIS 2, 9.2% (*n* = 521); AIS 3, 5.5% (*n* = 314); AIS 4, 3.3% (*n* = 188); AIS 5, 1.5% (*n* = 83).

(v) Spine: no spinal injuries (AIS 0) were found in 67.1% of patients (*n* = 3,809). AIS 1, 0.05% (*n* = 3); AIS 2, 24.8% (*n* = 1,406); AIS 3, 6.2% (*n* = 352); AIS 4, 0.77% (*n* = 44); AIS 5, 1.1% (*n* = 60); AIS 6, 0.11% (*n* = 6).

(vi) Pelvis: no pelvic injuries (AIS 0) were found in 79.9% of patients (*n* = 4,541). AIS 1, 0% (*n* = 0); AIS 2, 8.7% (*n* = 494); AIS 3, 2.3% (*n* = 133); AIS 4, 6.6% (*n* = 374); AIS 5, 2.4% (*n* = 138).

(vii) Limb: no limb injuries (AIS 0) were found in 49.3% of patients (*n* = 2,802). AIS 1, 6.0% (*n* = 338); AIS 2, 29.5% (*n* = 1,674); AIS 3, 15.1% (*n* = 856); AIS 4, 0.18% (*n* = 10).

Table 3 Injury pattern

Injury	**Percentage**	***n* (*N* = 5,680)**
Abdominal	22.2	1,266
Pelvic	20.0	1,139
Head	36.2	2,058
Limb	50.1	2,878
Spine	32.9	1,871
Face	21.4	1,218
Multiple	22.1	1,256
Rib fracture	63.2	3,588
Flail	14.6	832
Lung contusion	36.1	2,049
Lung laceration	3.9	223
Pneumothorax	44.3	2,514
Haemothorax	22.7	1,293
Pneumomediastinum	4.4	249
Oesophageal injury	0.19	11
Sternal fracture	10.0	567
Tracheal	0.18	10
Heart	1.6	93
Thoracic aortic	1.1	65
Diaphragm	1.5	87

Operative characteristics

Patients who underwent surgery on a body system were found to comprise 39.8% (n = 2,262) of the cohort. Some 15.5% (n = 880) of the cohort underwent more than one operation (on different days).

Concomitant surgery was as follows: internal fixation, 7.4% (n = 421); external fixation, 1.9% (n = 109); laparotomy, 5.1% (n = 291); bowel surgery, 0.69%(n = 39); liver surgery, 0.90% (n = 51); amputation, 0.53%(n = 30); spinal surgery, 5.4% (n = 308); cranial surgery, 2.8% (n = 161); intracranial pressure monitoring, 2.5%(n = 144); and skin surgery (repair or debridement), 11.7%(n = 663).

With regard to chest surgery performed: thoracotomy accounted for 2.6% of patients (n = 145); bronchoscopy, 0.88% (n = 50); chest wall repair, 0.55% (n = 31); rib fixation, 1.0% (n = 59); lung repair, 0.16% (n = 9); lung resection, 0.14% (n = 8); sternal fixation, 0.11% (n = 6); and heart surgery 0.37% (n = 21).

Emergency thoracotomies (performed in the emergency room) were performed in 17 patients of whom only 1 survived to discharge. Operative characteristics are summarised in Table 4.

In-hospital outcomes

The in-hospital mortality rate was 10.4% (n = 591). The median length of stay in hospital was 9 days (IQR 4–19) and the median length of stay in intensive care was 1 day (IQR 0–4). Some 74.3% of patients admitted with chest trauma were discharged home (n = 4,225), whereas the remaining hospital survivors were discharged to a rehabilitation unit within our tertiary hospital or to a peripheral hospital.

Predictors of in-hospital outcomes

Table 5 gives the univariate and multivariate values of predictors of hospital mortality. Multivariate analysis revealed that higher age, chest drain insertion, emergency department blood transfusion, heart injury, head injury, lower GCS, admission shock, not being operated on, needing an emergency thoracotomy and preadmission heart disease were significant predictors on hospital mortality.

Table 6 gives the significant predictors of a longer hospital stay from linear regression. As well as a higher age, lower GCS, head injury and having an operation being predictive of hospital mortality, spinal and pelvic injuries were predictors of prolonged hospital stay, as were certain preadmission comorbidities such as psychiatric problems and kidney disease.

Figure 1 gives the receiver operating characteristic curve for the ISS and GCS score. The C-index for ISS was 0.76, whereas the C-index for a lower GCS score was 0.80.

Table 4 Operative characteristics

Operation	Percentage	n (N = 5,680)
Operated (all systems)	39.8	2,262
>1 Operation	15.5	880
Thoracotomy	2.6	145
Bronchoscopy	0.88	50
Chest wall repair	0.55	31
Rib fixation	1.0	59
Lung repair	0.16	9
Lung resection	0.14	8
Sternal fixation	0.11	6
Heart surgery	0.37	21

Long-term survival

Complete survival data were available only for the 14-year period of November 2005 to December 2019, with a total of 3,585 patients being discharged alive from hospital. Mean overall survival was 11.9 years (95% CI 11.737–12.138).

The significant predictors of poor long-term survival from Cox regression were a higher age (p < 0.0001, HR 2.036, 95% CI 1.910–2.210), not having an operation (p = 0.036, HR 0.602, 95% CI 0.374–0.970), pre-existing lung disease (p = 0.024, HR 1.312, 95% CI 1.036–1.663), pre-existing neurological comorbidity (p = 0.042, HR 1.357, 95% CI 1.011–1.822), alcohol misuse (p < 0.0001, HR 2.283, 95% CI 1.698–3.069) and substance misuse (p < 0.0001, HR 2.804, 95% CI 1.622–4.849). The Kaplan–Meier survival curve stratified by age group is shown in Figure 2. The 10-year survival of those patients who survived to discharge from hospital who were aged <40, 50, 60, 70, 80 and >80 years were 99%, 93%, 95%, 87%, 75% and 43%, respectively.

Spatial analysis results

The higher (or lower) the Z-score, the more intense the clustering. Figure 3 offers a hotspot analysis of all trauma events across the region: the larger the circle, the more incidents occurred. The figure shows the hospital (Leeds) as mid position for access to the regional referral trauma centre.

Discussion

Comparison of in-hospital outcomes with previous studies

Although several quality-of-care measures exist for outcomes, mortality remains the most objective and most validated measure.[11] Our mortality rate of 10.4% is higher than some studies which quote 1%–5% mortality; however, in these studies, the ISS is lower than ours[12] or were of a similar value when stratified by ISS.[13] Other studies in high-risk patients with complex injuries from large registries in other countries found a similar, or slightly higher, mortality rate.[14]

In relation to predictors of in-hospital mortality, we found that some factors such as age and pre-existing

Table 5 Univariate and multivariate analysis of in-hospital survival			
	Univariate *p*-value	**Multivariate *p*-value**	**Multivariate odds ratio (95% confidence interval)**
Age	<0.0001	**<0.0001**	1.040 (1.032–1.048)
Male gender	0.01	0.053	0.749 (0.74–1.004)
Penetrating injury	0.045	0.178	0.577 (0.259–1.285)
Intubation	<0.0001	0.117	1.339 (–0.930–1.930)
Chest drain insertion	<0.0001	**0.019**	1.682 (1.089–2.599)
Blood transfusion	<0.0001	**<0.001**	3.348 (1.650–6.795)
Heart injury	<0.0001	**0.001**	4.341 (1.794–10.504)
Flail segment ribs	<0.0001	0.059	1.369 (0.988–1.898)
Haemothorax	<0.0001	0.106	1.315 (0.944–1.831)
Lung laceration	0.06	0.207	1.486 (0.804–2.747)
Head injury	<0.0001	**0.012**	1.504 (1.094–2.068)
Abdomen injury	0.002	0.090	1.345 (0.955–1.894)
Low Glasgow Coma Score	<0.0001	**<0.0001**	0.735 (0.691–0.782)
Intensive care admission	<0.0001	0.562	1.095 (0.806–1.486)
Operated on	0.004	**<0.0001**	0.409 (0.294–0.568)
Thoracotomy	<0.0001	**<0.0001**	5.744 (2.942–11.213)
Preadmission heart disease	<0.0001	**<0.0001**	2.180 (1.517–3.133)
Admission shock	<0.0001	**<0.0001**	1.936 (1.451–2.584)
Neurological disease	<0.0001	0.340	1.245 (0.794–1.952)
Diabetes mellitus	0.001	0.871	1.041 (0.643–1.686)
Before establishment of structured major trauma centre	<0.0001	**0.006**	1.352 (1.112–1.622)

Table 6 Predictors of prolonged hospital stay	
Predictor	***p*-value**
Higher age	**<0.0001**
Tracheal injury	**<0.031**
Pneumomediastinum	**0.011**
Head injury	**<0.0001**
Spine injury	**<0.0001**
Pelvic injury	**0.007**
Lower Glasgow Coma Score	**<0.0001**
Intensive care	**<0.0001**
Operated on	**<0.0001**
Thoracotomy	**<0.0001**
Preinjury neurology	**0.036**
Preinjury hypertension	**0.018**
Preinjury renal impairment	**<0.0001**
Preinjury psychiatric problems	**0.015**

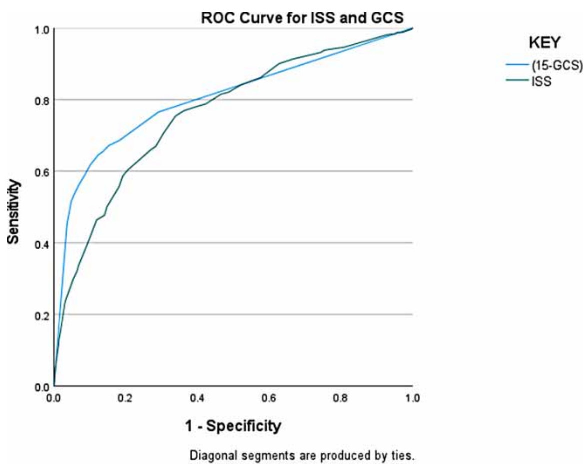

Figure 1 Receiver operating characteristic curves comparing Injury Severity Score and Glasgow Coma Score for in-hospital mortality

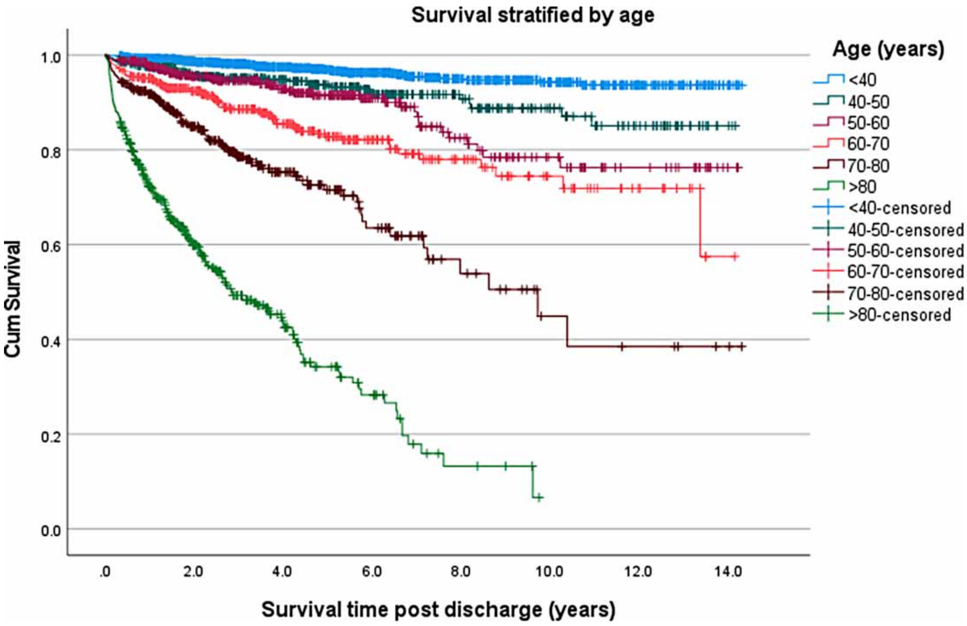

Figure 2 Kaplan–Meir curve of all patients stratified by age at discharge

conditions correlate with a systematic review of predictors for thoracic injury mortality.[15] The authors found that the number of rib fractures correlated with mortality outcomes, although we did not find this to be the case. Cardiovascular shock and blood transfusions have been shown to be predictors of higher in-hospital mortality and these were evident in our population also.[16]

Our median length of stay is similar to that in other studies of high-volume trauma centres.[17,18] Studies using tailored scoring systems incorporating age, pulmonary contusions and number of rib fractures found that these factors correlated with length of hospital stay.[19,20]

TARN publishes data from MTC centres in the UK periodically. We looked at chest trauma results from other such centres nationally available through the TARN website, as well as their clinical reports. We found that some of our management was in keeping with the national TARN data, such as the time from admission to computed tomography scanning for chest trauma with median (IQR) times of 31 (20–60) min for non-isolated chest injuries and 98 (36–219) min for isolated chest injuries between April 2017 and March 2018.[21] This finding is expected because the initial management of trauma in emergency departments in MTC centres has become fairly standardised nationally.

By contrast, we found that our rib fixation rate of 1%was much lower than the national average of 3.4%during the same period.[21] Part of this variation concerns the vigorous debate in the literature about whether or not to fix rib fractures.[22,23] Some surgeons fix rib fractures in inpatients only if there is a clinical flail causing significant respiratory compromise,[24,25] whereas others have more liberal indications for rib fixation such as persistent pain and non-flail rib displacement. Our unit tends to fix ribs in the former case and found that rib fixation did not impact in-hospital mortality although it was associated with an increase in length of hospital stay. This correlates with data from other MTCs in the UK.[26]

We found that undergoing an emergency thoracotomy was a strong predictor of in-hospital mortality (16 of 17 patients died following an emergency thoracotomy). There is evidence that for emergency thoracotomies, survival improves for certain factors such as penetrating injuries and signs of life on admission.[2,27] There remains considerable variation in when to perform a thoracotomy.[28,29]

We found that operating on concomitant injuries was associated with improved in-hospital survival, and this is reflected in other studies looking at non-thoracic trauma.[30,31]

Comparison of long-term outcomes with previous studies

There are very few studies in the literature looking at long-term survival following trauma.[32] Our long-term results indicate that if patients survive their initial trauma inpatient episode, then their long-term survival is good.

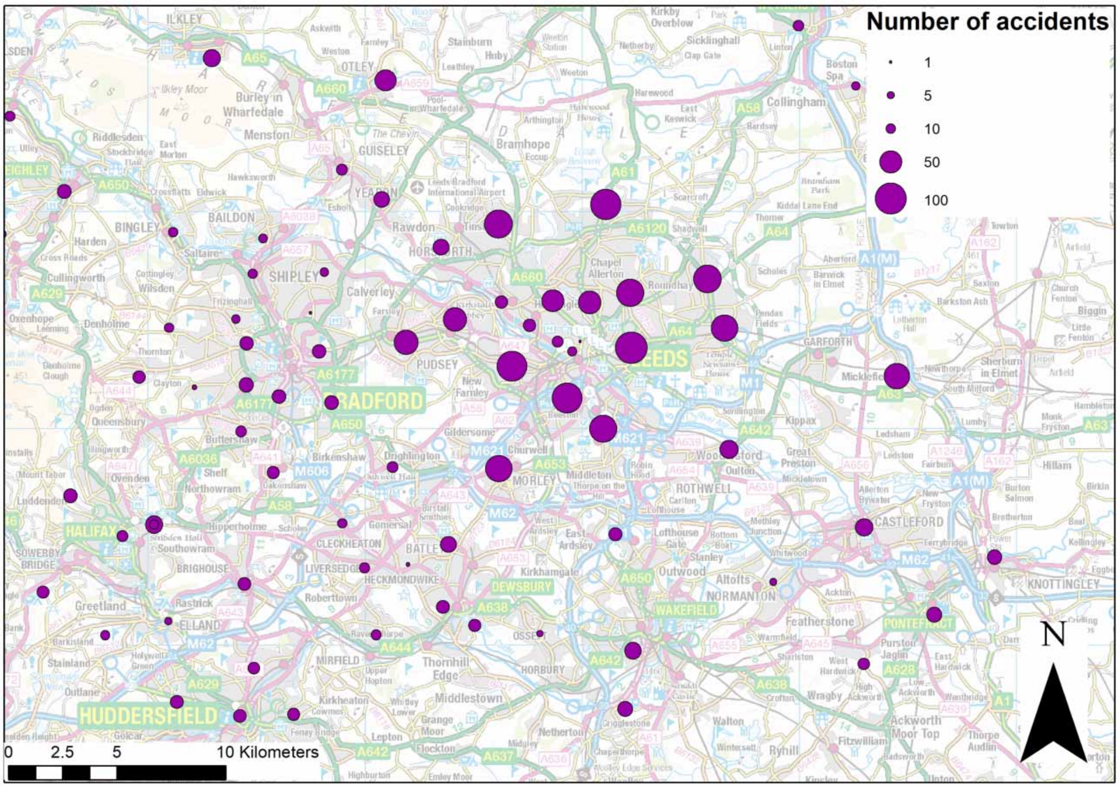

Figure 3 Hotspot maps of incidence (graduated scale – the larger the dot the higher the number of accidents)

MTC impact on outcomes

Although we did not look specifically at the impact of establishing an MTC on hospital outcomes in chest trauma, our multivariate analysis did show that in-hospital survival improved following the establishment of an MTC in our hospital. However, this may be related to other factors such as improvement in tertiary hospital care in general within our hospital as well other local hospital policies introduced across the trust during this period. However, this interesting finding does warrant further investigation in future studies.

Study limitations

As this was a retrospective analysis, there exist the problems associated with this, including the accuracy of data input within the database. The TARN database has evolved over the years to include more fields and more detailed input of data. For example, comorbidities were added in more detail during each admission following the formal introduction of MTCs in the UK from 2014 onwards. Furthermore, because this study is a single MTC experience, it may be difficult to extrapolate to MTCs in general, and larger multicentre studies may be needed.

Conclusion

This is the largest study looking at the long-term outcomes of patients admitted to a MTC with chest injuries. We found that inpatient mortality is related to concomitant injuries such as head injury, and patterns of thoracic injury such as cardiac trauma rather than isolated rib fractures. Successful management of these patients in a MTC demonstrates a good long-term outcome after adjusting for age and comorbidities.

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References

1. Moran CG, Lecky F, Bouamra O *et al*. Changing the system – major trauma patients and their outcomes in the NHS (England) 2008–17. *EClinicalMedicine* 2018; **2-3**: 13–21.
2. Whittaker G, Norton J, Densley J, Bew D. Epidemiology of penetrating injuries in the United Kingdom: A systematic review. *Int J Surg* 2017; **41**: 65–69.
3. Lecky FE, Bouamra O, Woodford M *et al*. Epidemiology of polytrauma. In: Pape H-C, Peitzman AB, William SC, Giannoudis PV. *Damage Control Management in the Polytrauma Patient*. New York: Springer; 2010. pp13–24.

4. Yeo TP. Long-term sequelae following blunt thoracic trauma. *Orthop Nurs* 2001; **20**: 35–47.
5. Galvagno SM Jr, Nahmias JT, Young DA. Advanced trauma life support® update 2019: management and applications for adults and special populations. *Anesthesiol Clin* 2019; **37**: 13–32.
6. Dalton MK, Uribe-Leitz T, Hashmi ZG *et al.* A national assessment of trauma systems using the American College of Surgeons NBATS tool: geographic distribution of trauma center need. *Ann Surg* 2022; **276**: e584–e590.
7. McCullough AL, Haycock JC, Forward DP, Moran CG II. Major trauma networks in England. *BJA: Br J Anaesth* 2014; **113**: 202–206.
8. Roberts Z, Collins JA, James D *et al.* Epidemiology of adolescent trauma in England: a review of TARN data 2008–2017. *Emerg Med J* 2020; **37**: 25–30.
9. Carrie C, Guemmar Y, Cottenceau V *et al.* Long-term disability after blunt chest trauma: don't miss chronic neuropathic pain! *Injury* 2019; **50**: 113–118.
10. The Trauma Audit & Research Network (TARN). *Data Monitoring*. https:// www.tarn.ac .uk/Content.aspx?ca=4&c=3573 (cited January 2023).
11. Gruen RL, Gabbe BJ, Stelfox HT, Cameron PA. Indicators of the quality of trauma care and the performance of trauma systems. *Br J Surg* 2012; **99**: 97–104.
12. Zhang S, Tang M, Ma J *et al.* Thoracic trauma: a descriptive review of 4168 consecutive cases in east China. *Medicine (Baltimore)* 2019; **98**: e14993.
13. Chrysou K, Halat G, Hoksch B *et al.* Lessons from a large trauma center: impact of blunt chest trauma in polytrauma patients–still a relevant problem? *Scand J Trauma Resusc Emerg Med* 2017; **25**: 42.
14. Huber S, Biberthaler P, Delhey P *et al.* Predictors of poor outcomes after significant chest trauma in multiply injured patients: a retrospective analysis from the German trauma registry (Trauma Register DGU®). *Scand J Trauma Resusc Emerg Med* 2014; **22**: 52.
15. Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: a systematic review and meta-analysis. *Injury* 2012; **43**: 8–17.
16. Croce MA, Tolley EA, Claridge JA, Fabian TC. Transfusions result in pulmonary morbidity and death after a moderate degree of injury. *J Trauma* 2005; **59**: 19–23.
17. Van Vledder MG, Kwakernaak V, Hagenaars T *et al.* Patterns of injury and outcomes in the elderly patient with rib fractures: a multicenter observational study. *Eur J Trauma Emerg Surg* 2019; **45**: 575–583.
18. Sirmali M, Türüt H, Topçu S *et al.* A comprehensive analysis of traumatic rib fractures: morbidity, mortality and management. *Eur J Cardiothorac Surg* 2003; **24**: 133–138.
19. Chen J, Jeremitsky E, Philp F *et al.* A chest trauma scoring system to predict outcomes. *Surgery* 2014; **156**: 988–993.
20. Pressley CM, Fry WR, Philp AS *et al.* Predicting outcome of patients with chest wall injury. *Am J Surg* 2012; **204**: 910–913.
21. The Trauma Audit & Research Network (TARN). *Clinical report Issue 1 - MARCH 2019; I: Core measures for all patients; II: Thoracic & abdominal injuries 3+ rib fractures; Patients in shock.* https://www.bsuh.nhs.uk/stn/wp-content/uploads/ sites/18 /2019/07/Sussex-Trauma-Network-TARN-report-032019.pdf (cited January 2023).
22. Beks RB, Peek J, de Jong MB *et al.* Fixation of flail chest or multiple rib fractures: current evidence and how to proceed. A systematic review and meta-analysis. *Eur J Trauma Emerg Surg* 2019; **45**: 631–644.
23. Ingoe HM, Coleman E, Eardley W *et al.* Systematic review of systematic reviews for effectiveness of internal fixation for flail chest and rib fractures in adults. *BMJ Open* 2019; **9**: e023444.
24. Wada T, Yasunaga H, Inokuchi R *et al.* Effectiveness of surgical rib fixation on prolonged mechanical ventilation in patients with traumatic rib fractures: A propensity score-matched analysis. *J Crit Care* 2015; **30**: 1227–1231.
25. The Operative Rib Fixation (ORiF) study. ISRCTN Registry. ISRCTN10777575. https:/ /doi.org/10.1186/ISRCTN10777575 (cited January 2023).
26. Walters ST, Craxford S, Russell R *et al.* Surgical stabilization improves 30-day mortality in patients with traumatic flail chest: a comparative case series at a major trauma center. *J Orthop Trauma* 2019; **33**: 15–22.
27. Nevins EJ, Bird NTE, Malik HZ *et al.* A systematic review of 3251 emergency department thoracotomies: is it time for a national database? *Eur J Trauma Emerg Surg* 2019; **45**: 231–243.
28. Dennis BM, Medvecz AJ, Gunter OL, Guillamondegui OD. Survey of trauma surgeon practice of emergency department thoracotomy. *Am J Surg* 2016; **212**: 440–445.
29. Mollberg NM, Glenn C, John J *et al.* Appropriate use of emergency department thoracotomy: implications for the thoracic surgeon. *Ann Thorac Surg* 2011; **92**: 455–461.
30. Wieck MM, Cunningham AJ, Behrens B *et al.* Direct to operating room trauma resuscitation decreases mortality among severely injured children. *J Trauma Acute Care Surg* 2018; **85**: 659–664.
31. Uzoigwe CE, Burnand HG, Cheesman CL *et al.* Early and ultra-early surgery in hip fracture patients improves survival. *Injury* 2013; **44**: 726–729.
32. Peetz AB, Brat GA, Rydingsward J *et al.* Functional status, age, and long-term survival after trauma. *Surgery* 2016; **160**: 762–770.