Trends in admission timing and mechanism of injury can be used to improve general surgical trauma training

AP Pearce^{1,2}, MER Marsden^{2,5}, N Newell⁴, K Hancorn¹, F Lecky⁵, K Brohi^{1,5}, N Tai^{1,2,5}

¹Department of General Surgery, Royal London Hospital, Barts' Health NHS Trust, London, UK

²Academic Department of Military Surgery and Trauma, Royal Centre for Defence Medicine, Birmingham, UK

³Centre for Trauma Sciences, Queen Mary University of London, UK

⁴Department of Mechanical Engineering, Imperial College, London, UK

⁵Trauma and Audit Research Network, University of Manchester, UK

ABSTRACT

INTRODUCTION The temporal patterns and unit-based distributions of trauma patients requiring surgical intervention are poorly described in the UK. We describe the distribution of trauma patients in the UK and assess whether changes in working patterns could provide greater exposure for operative trauma training.

METHODS We searched the Trauma Audit and Research Network database to identify all patients between 1 January 2014 to 31 December 2016. Operative cases were defined as all patients who underwent laparotomy, thoracotomy or open vascular intervention. We assessed time of arrival, correlations between mechanism of injury and surgery, and the effect of changing shift patterns on exposure to trauma patients by reference to a standard 10-hour shift assuming a dedicated trauma rotation or fellowship.

RESULTS There were 159,719 patients from 194 hospitals submitted to the Network between 2014 and 2016. The busiest 20 centres accounted for 57,568 (36.0%) of cases in total. Of these 2147/57,568 patients (3.7%) required a general surgical operation; 43% of penetrating admissions (925 cases) and 2.2% of blunt admissions (1222 cases). The number of operations correlated more closely with the number of penetrating rather than blunt admissions ($r = 0.89$ vs $r = 0.51$). A diurnal pattern in trauma admissions enabled significant increases in trauma exposure with later start times.

CONCLUSIONS Centres with high volume and high penetrating rates are likely to require more general surgical input and should be identified as locations for operative trauma training. It is possible to improve the number of trauma patients seen in a shift by optimising shift start time.

KEYWORDS

General surgery – Trauma centres – Trauma units

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CORRESPONDENCE TO

Phill Pearce, E: phill.pearce@nhs.net

Introduction

In England and Wales, trauma is the leading cause of death among people aged 15–44 years.¹ Haemorrhage accounts for 75 million years of life lost.² Those who survive the initial injury have poor functional outcomes.^{3–5} NHS England has instituted a series of initiatives that have improved the care of trauma patients since 2000, including the designation of regional trauma networks and development of robust guidelines.⁶ The successful holistic management of a trauma patient requires the combination of expertise across a wide variety of specialties.^{7,8} Surgeons have key roles in the resuscitative and reconstructive phases of trauma care. Recently, a surgical curriculum has

been developed to support the training of surgeons caring for the growing number of trauma patients treated in the UK. However, these advances in training are recent and ‘trauma surgery’ is not recognised as general surgical specialty interest by the General Medical Council.

Training in the operative management of visceral and vascular trauma is essential for surgeons working in major trauma centres. Training requires adequate exposure to trauma patients and is dependent upon a finite volume of admissions and operations. The spatial distribution of this case volume, together with the type and timing of admission, has not been well described in the UK. Case distribution is crucial to inform planning for training

logistics and orientation. Such data are recorded by major trauma centres and trauma units and collated by the Trauma Audit and Research Network. Our primary aim was to describe the distribution and patterns of operative trauma in the UK. Our secondary aim was to examine whether a change in working patterns for trainees could increase exposure to trauma and improve training opportunities.

Materials and methods

All admissions from the England, Wales and Ireland Trauma Audit and Research Network database were examined over the period from 1 January 2014 to 31 December 2016. Details of this dataset are available elsewhere.^{9,10} All hospitals that submitted more than 2000 patient admissions to the Network over the three-year period were included, irrespective of major trauma centre or trauma unit status. The total number, timing and operative case load of trauma patients were recorded at each hospital.

Operative cases were defined as all patients who had one or more laparotomy, thoracotomy or open vascular intervention as recorded by the Network. Prediction of the number of operations a centre would perform was calculated using linear regression, based upon the volume of penetrating or blunt trauma submissions. The identity of the hospitals was blinded to the authors, which prohibited geographical mapping of the data.

To assess the effect of changing shift pattern on exposure to trauma patients, we performed the following calculations. First we calculated the average number of admissions that occurred during a given shift. Although many hospitals use 12-hour shifts as the basis for on-call cover, we wished to examine theoretical trauma exposure for an individual undertaking a dedicated trauma rotation or fellowship and used the European Working Time Directives as an assumption for the maximum working time.¹¹ For this calculation we therefore assumed a 10-hour shift

and varied the shift's start time. Monday to Friday 8am to 6pm was used as the 'standard shift'. The number of events during the standard shift were compared with events during shifts from 8am to 6pm and 12 noon to 10pm both on Monday to Friday and Wednesday to Sunday. The alternative shifts were selected a priori. We performed the same calculation for operative case exposure. Finally, rather than preselect shifts, we optimised the 10-hour shift to give a shift with the greatest number of exposures both all admissions and to operative cases. This analysis was performed using Python, an open-source general purpose programming language (v2.7; Python Software Foundation).

Statistical analysis

Normally distributed continuous data were reported as mean (with standard deviation); skewed or ordinal data were reported as medians (with interquartile range). Descriptive statistics were used to illustrate demographic information and key patient characteristics. Kolmogorov–Smirnov testing was used to assess normality with chi-square or Fisher's exact tests for categorical data and the unpaired t-test or Mann–Whitney test for normally distributed and nonparametric data, respectively. Correlation of both total and penetrating trauma volume with operative volume was measured using the Pearson cross correlation coefficient. Differences in shift and operative exposure were compared using one-way ANOVA with post-hoc Tukey test. A *P*-value of less than 0.05 was considered statistically significant. Data analysis and visualisation were performed using: SPSS v.25, Microsoft Excel, Python and Tableau (2017).

Results

There were 159,719 entries to the England, Wales, and Ireland Trauma Audit and Research Network database between 2014 and 2016 originating from 194 hospitals (Fig 1). Penetrating injury represented 2.5% of total

submissions but 40.7% of all operations (Table 1). The breakdown of these operations is shown in Table 2.

Within the high-volume centre cohort, 2147 patients (3.7%) required a general surgical operation; 45% of penetrating trauma admissions (925 cases) and 2.2% of blunt trauma admissions (1222 cases). The total admission volume and surgical operative volume at each of the high-volume hospitals is shown in Figure 2. The number of patients at each site undergoing a general surgical operation had a stronger correlation with the number of penetrating admissions than blunt injury (Fig 5).

Similar trends in admission timing are apparent at all high-volume centres. There is a clear diurnal variation in the time of patient arrival with a daily peak between 1600 and 1900 and nadir around 0600 (Fig 4). Additionally, there are daily, weekly and seasonal differences in the admission times of blunt and penetrating trauma. For example, penetrating injuries typically present late at night on the weekends (Supplementary Figure 1).

Differences in exposure to both the total number of trauma admissions and operative cases were observed with changes in shift selection. The baseline Monday to Friday 10-hour shift starting at 8am could be optimised to increase exposure to all trauma admissions by starting the shift at 11am. To maximise exposure to operative cases, a shift should also start at 12 noon (Supplementary Figure 2).

To examine the practical applications of this effect, the cumulative annual number of operations was compared using four example shift patterns across the 20 high-volume centres. The annual operative rate varied significantly with change in start time but not with inclusion of the weekend within the five-day working pattern (Fig 5).

Discussion

This study demonstrates consistent temporal and spatial trends in operative trauma admissions. Trauma training within the UK is evolving and the planning of training

experience to maximise opportunities is essential. Training and fellowship programmes must be planned around high-volume centres and optimal shift patterns. For surgeons in training, operative caseload is a fundamental concern. By using a data-driven approach we have shown that the yield for both operative and non-operative experience can be increased by changes in shift start time. Nationally, the optimal 10-hour shift start time to maximise exposure to trauma admissions is 11am. As we have seen similar temporal patterns across all high-volume centres, the same approach could be used by individual units. Optimising shift start times to maximise exposure to trauma patients may provide a way of improving the allocation of training and resources. As there are several relatively inflexible constraints on training (such as European Working Time Regulations, duration of training and lack of institutional volume), this study provides a potentially viable solution to increase exposure.

Alongside the temporal patterns of trauma care, we also describe a strong correlation between the number of general surgical interventions and the number of penetrating trauma patients seen at each hospital. Our data are consistent with previous work in this regard.¹² Most patients who required surgery had a blunt mechanism of injury but patients with penetrating mechanisms underwent surgery 22 times more frequently. The major trauma Training Interface Group fellowships are being developed to allow senior trainees to develop expertise in both trauma leadership and resuscitative surgery.¹⁵ The resuscitative strand of this fellowship advocates broad procedural skill including 20 trauma laparotomies during the fellowship year. This present study demonstrates that operative trauma exposure of reasonable quantity is only available at a small number of hospitals. The importance of such fellowships and rotations upon an individual's training is apparent, but the exposure to trauma of other trainees in the same centres must also be considered.

Table 1 Demographic information for operative and non-operatively managed trauma across England 2014–2016.

	All hospitals	High-volume centres	All other hospitals	P-value ^a
Hospitals (n)	194	20	174	
Patients, n (%)	159719	57568 (36.0)	102151 (64.0)	
Patient characteristics:				
Gender (% male)	54.3	61.4	52.3	< 0.001
Age, years median (IQR)	64 (44–82)	57 (34–78)	68 (49–84)	< 0.001
ISS, median (IQR)	9 (9–17)	12 (9–22)	9 (9–16)	< 0.001
Penetrating, n (%)	4011 (2.5)	2456 (4.3)	1555 (1.5)	< 0.001
Mortality, n (%)	11450 (7.2)	4790 (8.3)	6660 (6.5)	< 0.001
Operative admissions, n (%)	3254	2147 (66)	1107 (34)	< 0.001
ISS, Injury severity score; IQR, Interquartile range.				
^a P-values correspond to comparison between high-volume hospitals and all other hospitals.				

Table 2 Operative cases across high-volume centres by operative type and mechanism of injury. The total number of operative admissions includes patients undergoing more than one procedure.

	Blunt		Penetrating	
	(n)	(%)	(n)	(%)
Operative cases	1222	56.9	925	43.1
Laparotomy	827	57.8	603	42.2
Vascular repair	266	63.9	150	36.1
Thoracotomy	248	55.7	197	44.3

More than one-third of the trauma patients submitted to the England, Wales, and Ireland Trauma Audit and Research Network came from 20 hospitals. Concentration of major trauma at such hubs is the consequence of establishing regional trauma networks. The intention is to capitalise upon specialist trauma expertise, dedicated resources and benefit from the improved outcomes seen in well-practised systems.^{9,14} The demographics of trauma patients in the UK has changed over recent years, with elderly patients sustaining relatively low-energy injury accounting for the largest patient cohort.¹⁵ Correspondingly, the busiest centres are seeing more severely injured, younger patients, who are more likely to have a penetrating injury.

Figure 2 a) Top 20 hospital sites organised by the number of submissions to the England, Wales and Ireland Trauma Audit and Research Network between 2014 and 2016 by highest to lowest volume. Mean number of submissions = 2878 (standard deviation 511). b) General surgical operative volume at the same centres over the same period. The number of general surgical operative cases varies between 17 and 313.

We have shown a distinct and diurnal pattern of trauma admission that was consistently observed across institutions; a time window of maximal patient presentation that is shifted toward the latter part of the day. Other authors have studied the temporal patterns in trauma admissions.^{7,16–18} Similar diurnal variation has been observed across a variety of trauma systems. One such group has suggested staffing allocation based on these temporal patterns, but limited the discussion to a comparison of only day- and night-time admissions.¹⁶ Use of a continuous data-driven model may allow more nuanced variation in resource allocation.

Our data are limited by the anonymising of the individual hospitals. Previous work has demonstrated the

regional differences in penetrating trauma, with London having the highest concentration.¹⁹ Our data would suggest that operative exposure would follow a similar geographical trend. One particular centre has outlying numbers of both penetrating trauma and operative volume and while the relationship between the two seems valid, this work is not able to explain whether these numbers reflect a difference in the behaviour of the local population or in the clinical approach of the unit.

This study has some inherent limitations. We assume that increased exposure to trauma patients will equate to improved trauma training. This does not account for the quality of education that may occur. We are not able to explore how the quality of training varies by the time of

Figure 4 Diurnal trends in admission times for high-volume centres. Cumulative data from 2014–2016.

Figure 5 Potential trainee exposure to general operations in four a priori selected shift patterns per year in high-volume hospitals. * denotes significant ($P < 0.05$) differences with analysis of variants testing ($P < 0.05$).

the day or the trainer's workload. Equally, changes in shift times must be balanced against the other learning opportunities including ward rounds and trauma meetings. We compared only a small number of shift patterns and have assumed a 10-hour dedicated trauma shift. The patterns compared are examples but are representative of desirable working scenarios. Shift patterns have to account for work–life balance and we purposefully avoided constructing unrealistic scenarios which maximised case exposure through consistent working of every weekend, evening and night. Indeed, we must acknowledge that a consistent 11am to 9pm shift is likely to be unfeasible for some. Nonetheless, the importance of working overnight

for trauma exposure has previously been demonstrated and appropriate work schedules should recognise this.¹⁶ This study was enabled by the Network dataset, which allows consistent analysis of national level data, but is limited by institutional variation in data completeness and structural difference in the financial incentive for submission between major trauma centres and trauma units. Similarly, strict eligibility criteria for inclusion in the Network dataset means that a proportion of patients attending as a trauma call are not included in the analysis. This missing cohort will include those with very minor injuries who do not require admission but also those admitted for less than 72 hours (assuming no specialist transfer). These patients

will still require hospital and staffing resource which has not been included in this analysis.

Conclusion

Operative trauma volume is closely related to penetrating trauma volume. The proportion of penetrating to blunt trauma varies greatly across high-volume centres. The centres with the high volume and high penetrating rates are likely to require more general surgical input and should be the focus of operative trauma training. Exposure to operative trauma cases could be optimised at these centres by modification of shift times which accounts for the diurnal variation in trauma admission. Of course, although this work represents idealised theoretical exposure using retrospective data, future job planning at individual units could use the trends (combined with realistic domestic, social, and educational commitments) to better facilitate training.

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References

- Public Health England. *Health Profile for England. Chapter 2: Trends in mortality*. 2018. <https://www.gov.uk/government/publications/health-profile-for-england-2018/chapter-2-trends-in-mortality> (cited August 2019).
- World Health Organization. Disease burden and mortality estimates, child causes of death 2000–2017. http://www.who.int/healthinfo/global_burden_disease/estimates/en/index2.html (cited August 2019).
- Cannon JW. Hemorrhagic shock. *N Engl J Med* 2018; **378**: 370–379.
- Halmin M, Chiesa F, Vasan SK *et al*. Epidemiology of massive transfusion: a binational study from Sweden and Denmark. *Crit Care Med* 2016; **44**: 468–477.
- Mitra B, Gabbe BJ, Kaukonen KM *et al*. Long-term outcomes of patients receiving a massive transfusion after trauma. *Shock* 2014; **42**: 307–312.
- 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.
- Davenport RA, Tai N, West A *et al*. A major trauma centre is a specialty hospital not a hospital of specialties. *Br J Surg* 2009; **97**: 109–117.
- Brohi K, Cole E, Hoffman K. Improving outcomes in the early phases after major trauma. *Curr Opin Crit Care* 2011; **17**: 515–519.
- Kehoe A, Smith JE, Edwards A *et al*. The changing face of major trauma in the UK. *Emerg Med J* 2015; **32**: 911–915.
- Lecky F, Woodford M, Yates DW. Trends in trauma care in England and Wales 1989–97. UK Trauma Audit and Research Network. *Lancet* 2000; **355**: 1,771–1,775.
- NHS Employers. Working Time Directive. <http://www.nhsemployers.org/about-us/nhs-european-office/nhs-workforce-and-the-eu/working-time-directive> (cited August 2019).
- Trauma and Audit Research Network. Resources. <https://www.tarn.ac.uk/Content.aspx?ca=4> (cited August 2019).
- NHS Health Education. England. Advanced training in major trauma. <http://severndeanery.nhs.uk/recruitment/vacancies/show/mt-2019> (cited August 2019).
- Cole E, Lecky F, West A *et al*. The impact of a pan-regional inclusive trauma system on quality of care. *Ann Surg* 2016; **264**: 188–194.
- Christensen MC, Nielsen TG, Ridley S *et al*. Outcomes and costs of penetrating trauma injury in England and Wales. *Injury* 2008; **39**: 1,013–1,025.
- Laupland KB, Ball CG, Kirkpatrick AW. Hospital mortality among major trauma victims admitted on weekends and evenings: a cohort study. *J Trauma Manag Outcomes* 2008; **3**: 8.
- Car BG, Jenkins P, Branas CC *et al*. Does the trauma system protect against the weekend effect? *J Trauma* 2010; **69**: 1,042–1,048.
- Guly HR, Leighton G, Woodford M *et al*. The effect of working hours on outcome from major trauma. *Emerg Med J* 2006; **23**: 276–280.
- Vaziri K, Roland JC, Robinson L, Fakhry SM. Optimizing physician staffing and resource allocation: sine-wave variation in hourly trauma admission volume. *J Trauma* 2007; **62**: 610–614.