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Abstract

This study aimed to determine whether there is early evidence of improved outcomes in Major Trauma Centres following the regionalisation of trauma care in England. An observational study was undertaken using the Trauma & Audit Research Network (TARN), Hospital Episode Statistics (HES), and national death registrations. The outcome measures were trauma care quality indicators (e.g. treatment by a senior doctor) and clinical outcomes (e.g. in-hospital mortality). There were 20,181 major trauma cases reported to TARN during the study period. Following regionalisation of trauma services, all measured care quality indicators improved, fewer patients required secondary transfer between hospitals, and a greater proportion were discharged with a Glasgow Outcome Score of "good recovery". In this early post-implementation analysis, there were no differences in either crude or adjusted mortality. The overall number of traumatic deaths in England did not change following the national reconfiguration of trauma services. Evidence from other countries that have regionalised trauma services suggest that further benefits may become apparent after a period of trauma system maturation.

Key words

Trauma systems; major trauma regionalisation; trauma centres

Introduction

Traumatic injuries annually account for almost six million deaths worldwide[1] and over 10,000 in the United Kingdom.[1,2] There is consistent evidence, particularly from the United States, that inclusive trauma systems with designated trauma centres reduce mortality for severely injured patients.[3-7]

The American College of Surgeons launched an accreditation programme for trauma centres in 1987. Observational studies from the US have shown that quality of care is higher[8-11] and overall mortality is lower for severely injured patients at trauma centres with appropriate resuscitative, imaging, surgical and critical care facilities.[3-7] As a consequence, many countries across the developed world are now at various stages of developing trauma networks.[12-14] Common features of inclusive trauma networks include designation of specialist trauma centres, pre-hospital triage of severely injured patients[15], agreed transfer protocols between network hospitals, and quality assurance programmes.

Although early reports from outside the US support the development of trauma networks[16], this finding has not been universal. For example, a trauma centre pilot in the North of England from the early 1990s did not demonstrate any mortality benefit compared with control regions.[17] Subsequent reports however identified unacceptable regional variation in major trauma outcomes and the need to address this through commissioned trauma networks.[18]

A national system of Regional Trauma Networks (RTNs) was launched across England in April 2012, each with one or more hospitals designated as Major Trauma Centres (MTCs). Although a trauma network has operated in London since 2010, 22 additional MTCs were designated in 2012. There are now 26 MTCs (Figure 1): XXX adult-only, XXX children-only, and XXX receiving both adults and children. Two MTCs (in Manchester and Liverpool) are atypical in that they are each split across three separate hospital sites. The specific model implemented by each RTN varies by region. For example, many MTCs work with satellite hospitals ("Trauma Units") that are capable of providing initial stabilisation or definitive management depending on the spectrum and severity of injuries.[19] Trauma units do not feature in the London RTN, possibly because of the smaller distances between the four MTCs in that region. However, the RTNs throughout England also have a number of common features. For example, within each network, major trauma patients meeting pre-hospital triage criteria are transported directly to an MTC, providing that the journey time does not exceed 45 minutes.[20] All MTCs are required to meet specific criteria, including an all-hours consultant-led trauma team, major trauma CT scanning capability, and dedicated trauma operating theatre.[15]

The reconfiguration of major trauma services has been associated with changes to hospital case mix[21,22], workloads[22,23], clinical processes[21], and surgical training.[24] It has also been suggested that there has been a reduction in mortality following regionalisation of trauma services, based on data from the Trauma Audit & Research Network (TARN).[25-28] However, the clinical impact of trauma service regionalisation has not yet been formally evaluated.

This study used data from TARN, Hospital Episode Statistics (HES), and national administrative mortality records to examine the impact of major trauma service regionalisation in England.

Methods

An observational before-after study was performed using administrative and national trauma registry data submitted by hospitals that were designated as MTCs in 2012.

Data sources

TARN supports the only national trauma registry in England and Wales. MTCs have been financially incentivised to report cases to TARN since the Major Trauma Best Practice Tariff was introduced on 1st April 2012.[29]

Hospital Episode Statistics (HES) record details of all inpatient admissions, outpatient episodes, and Emergency Department (ED) attendances in England.

The Office for National Statistics (ONS) is overseen by the UK Statistics Authority, which is a non-ministerial department responsible for reporting and assessment of official statistics. It collects data on all fatalities from issued death certificates.

Case selection

We included all MTC trauma cases that were reported to TARN. The TARN inclusion criteria are: a significant injury as defined by the TARN procedures manual and admission for ≥72 hours, admission to a high-dependency area, or death following arrival at hospital. Isolated hip fractures in individuals aged ≥65 years are not captured within TARN.

The lead clinician within each hospital was contacted to identify the launch date of their MTC. In the event of phased openings, we sought both the earliest opening date and the date at which all services were active. Cases presenting to each hospital in the nine-month (270 day) periods before and after MTC launch (with a phasing period where appropriate) were extracted from TARN. The choice of 270 days was driven by the available data to ensure that a full before and after dataset was available for each MTC, including those that had a protracted launch.

Patients presenting to the four London MTCs were excluded as a trauma network was established there in April 2010[23] and TARN data was less robust during this period. Patients presenting to all other MTCs in England were included.

HES data were used to characterise differences in case reporting to TARN following trauma service regionalisation. All trauma inpatients at MTC hospitals (primary ICD10 diagnosis S00-T75) were extracted and subjected to an algorithm used by TARN for specific comparisons with HES data. This algorithm produces a measure of case overlap between TARN and HES, and so >100 per cent represents more cases in TARN than would be expected from HES.

ONS mortality data were searched for all traumatic deaths recorded in England between 1st July 2011 and 31st January 2013. Traumatic deaths were identified using ICD-10 codes V01-Y09. Deaths registered as occurring within London were excluded, as were those with hip fracture (ICD10 S72.0-S72.2) recorded in any position on the death certificate. ONS data were used because TARN does not capture patients that die before reaching hospital. The number of deaths was compared for the nine-month periods immediately before and after April 2012.

Definitions

Tachycardia was defined as a heart rate (HR) on arrival at hospital ≥100 beats per minute and hypotension as a systolic blood pressure (SBP) ≤90mmHg. The Revised Trauma Score (RTS) is a physiological severity scale ranging from zero (most injured) to 12 (least injured) which incorporates Glasgow Coma Score (GCS), SBP, and respiratory rate[30].

Outcomes

The clinical outcomes available from TARN were in-hospital mortality and Glasgow Outcome Scale (GOS) at discharge. The GOS is a five-point disability score: “good recovery”, “moderate disability”, “severe disability”, “persistent vegetative state”, and “death”.[31] These categories have detailed definitions but broadly a “good recovery” implies return to normal life, “moderate disability” implies some impairment but living independently, and “severe disability” implies dependent on care for daily support. TARN also includes data on trauma care quality indicators, including seniority of the treating doctor, time to CT scanning (for patients with a head Abbreviated Injury Scale [AIS] score ≥1 and GCS<13), and administration of tranexamic acid to patients with suspected bleeding (defined as requiring blood transfusion in the ED).

Statistical analysis

Continuous variables were compared between the groups using unpaired t-tests for normally distributed data and the Mann-Whitney U test for non-normally distributed data. Categorical variables were compared using the Chi square test with Yate's correction for continuity.

Standardised risk adjusted excess survival rates (*Ws*) were calculated for patients treated before and after MTC designation. *Ws* is a standardised version of the *W* statistic which is calculated as ([observed survivors – expected survivors]/[total patients]) x 100.[32] Expected survival was determined using the sum of survival probability predicted by the risk-adjusted model used in TARN. The covariates used within this model are age, sex, Injury Severity Score (ISS), GCS, and Charlson Comorbidity Index (CCI)[33], which is a weighted comorbidity score that is commonly used in observational studies[34].

Hospital length of stay and critical care length of stay were calculated following exclusion of deceased patients to avoid inappropriate downward bias of these outcome measures. The threshold for statistical significance was set at $p < 0.05$.

Results

The number of cases reported to TARN by MTCs increased from 7 705 to 12 476 following regionalisation. Seventeen hospitals (65.4 per cent) became MTCs within a week either side of 1st April 2012, fourteen MTCs (53.8 per cent) became fully operational on a single day, and twelve (46.2 per cent) utilised a phasing period. The median phasing period was 274 (interquartile range [IQR] 124 – 510) days. Appendix I shows the phasing dates used for each of the new MTCs reported in our analysis.

Case mix

Table 1 describes the characteristics of patients received by MTCs between the two periods. Mean age increased from 49.4 years (95 per cent confidence interval (CI) 48.9 – 50.0) to 51.4 (51.0 – 51.8) years ($p < 0.001$) but there was no sex difference between the groups (male sex 65.0 per cent *versus* 63.7 per cent, $p = 0.060$). There were no differences in the proportion of penetrating injuries (3.3 per cent *versus* 3.0 per cent, $p = 0.425$). Similarly, the proportion of patients admitted following falls from > 2m (15.8 per cent *versus* 15.7 per cent, $p = 0.852$) and ≤ 2 m (41.6 per cent *versus* 41.5 per cent, $p = 0.899$) were comparable between the groups. Road traffic collisions increased significantly (27.3 per cent *versus* 30.1 per cent) and the "other" category diminished by a similar proportion (15.3 per cent *versus* 12.7 per cent, $p < 0.001$).

The proportion of patients arriving at hospital by air ambulance increased from 7.2 per cent to 9.7 per cent (p < 0.001). There was a significant fall in the proportion of patients undergoing secondary transfer between hospitals (31.3 per cent *versus* 25.9 per cent, p < 0.001).

Injury Severity Score (ISS) was slightly higher following regionalisation (median 13.0 [IQR 9.0 – 22·0] *versus* 13.0 [IQR 9.0 – 25.0] but neither the proportion with ISS ≥ 15 (45.0 per cent *versus* 46.0 per cent, p = 0.203) nor the median Revised Trauma Score (RTS) changed (median 7.8 [IQR 7.8 – 7.8] *versus* 7.8 [IQR 7.8 – 7.8], p = 0.054). The proportion of patients with tachycardia (HR ≥ 100) on arrival at hospital increased (15.9 per cent *versus* 17.5 per cent, p = 0.003), as did those with GCS ≤ 8 (3.8 per cent *versus* 6.1 per cent, p < 0.001). However, there was no change in the proportion with hypotension (SBP ≤ 90) (5.3 per cent *versus* 5.8 per cent, p = 0.084).

Hospital resource burden

Table 3 shows that, although hospital length of stay did not change (median 9.0 days [IQR 5.0 – 17.0] *versus* 9 [IQR 5.0 – 17.0], p = 0.313), the total bed days for major trauma patients in MTCs increased from 118 150 to 193 339, in keeping with the increased number of patients. Similarly, critical care length of stay was unchanged (median 4.0 days [IQR 2.0 – 10.0] *versus* 4.0 [IQR 2.0-10.0], p = 0.629) but the overall critical care bed days for TARN patients in MTCs increased from 17 296 to 28 834 days. The frequency of surgical operations was unchanged after implementation of MTCs (54.7 per cent requiring any operation pre-implementation *versus* 55.2 per cent post-implementation, p = 0.465). The majority required only one operation (median 1.0 [IQR 1.0 – 1.0] *versus* 1.0 [IQR 1.0 – 2.0], p < 0.001). However, the number of operations per patient appeared to increase following regionalisation (mean 1.4 [95 per cent CI 1.4 – 1.4] *versus* 1.4 [1.4 – 1.5], p < 0.001).

Trauma care quality indicators

All reported quality indicators showed improvement following MTC designation (Table 2). A greater proportion of trauma patients were treated by a consultant-grade doctor (54.3 per cent *versus* 30.4 per cent before; p < 0.001) and patients with suspected bleeding were more likely to receive tranexamic acid in the ED (58.5 per cent *versus* 17.0 per cent before, p = 0.006). Importantly, the seniority of the treating doctor was not recorded in 32.6 per cent of cases before and only 20.2 per cent after the trauma service reconfiguration.

The median time to CT scanning for head injured patients (AIS ≥ 1 and GCS < 13) fell from 49.2 (IQR 31.2 – 76.8) to 31.2 (IQR 19.2 – 55.2) minutes between the two periods (p < 0.001).

Outcomes

Table 3 describes the outcomes for all patients within TARN and Table 4 for those within the ISS ≥ 15 subgroup. There was no difference in mortality between the two periods for either of these groups (whole dataset 6.0 before *versus* 6.5 per cent after, p = 0.233; ISS ≥ 15 subgroup 10.8 per cent *versus* 11.7 per cent, p = 0.218). Figure 2 shows that there were no significant differences in standardised risk adjusted excess survival rates (*Ws*) in the nine months before and after the MTCs were fully operational (pre- *Ws* -0.17 [95 per cent CI -0.68 – 0.34] *versus* post-implementation 0.03 [-0.36 – 0.43]). Figure 3 shows that the same finding was observed for the ISS ≥ 15 subgroup (pre- *Ws* -0.06 [95 per cent CI -1.11 – 0.99] versus post-implementation 0.14 [-0.67 – 0.95]). Figure 4 is a funnel plot that shows variation in Ws between MTCs but that this was not in excess of what would have been expected by chance alone.

There was an increase in the proportion of patients discharged with a GOS of "good recovery" (52.4 per cent before *versus* 64.5 per cent [p < 0.001]), which was also apparent in the ISS ≥ 15 subgroup (46.4 per cent *versus* 54.3 per cent, p < 0.001). However, the proportion of cases without a recorded GOS also fell between the two periods (24.2 per cent *versus* 14.7 per cent, p < 0.001).

There was no change in the overall number of traumatic deaths registered in England before and after the national reconfiguration of trauma services (11 665 *versus* 11 377, p = 0.566).

Reporting comprehensiveness

Estimated reporting to TARN increased from 78.1 per cent (standard deviation 31.5) of potentially eligible HES cases to 105.1 per cent (20.1) following regionalisation.

Discussion

This study represents the first national assessment of trauma service regionalisation in England.

There were few differences in case mix between the two periods. The injury severity (as measured by the ISS and RTS) did not change, although the post-regionalisation group was older and included a greater proportion of patients with evidence of physiological compromise (tachycardia and GCS ≤ 8). This finding is contrary to previous reports that overall injury severity falls in new trauma centres due to expanded pre-hospital triage criteria and increased patient volumes.[22,36] The increase in mean age may however reflect the increasing number of elderly patients recognized as suffering major trauma by expanded pre-hospital triage protocols.

It has been reported that the national re-configuration of trauma services in England and Wales has resulted in quantifiable improvements to trauma mortality.[25-28] However, these reports are based on an analysis that used a much earlier (2008) baseline and included data from a wider range of hospitals submitting data to TARN. Our analysis of national TARN submissions by MTCs did not find evidence of reduced length of stay, critical care length of stay, or mortality (crude and risk adjusted). These data are supported by analysis of all nationally registered traumatic deaths, which showed no change in trauma mortality in the nine months following regionalisation in 2012.

These findings are consistent with studies that suggest the benefits of trauma service regionalisation become apparent over a number of years.[37-39] Trauma system "maturation" includes development of pre-hospital triage protocols, refinement of hospital systems, and accumulation of staff experience.[40,41] Although early mortality benefits have been claimed following the launch of new trauma systems[41,42], most studies have suggested that improvements in clinical outcomes are only realised after a period ranging from 2-10 years.[37-39] It is therefore likely that further improvements resulting from the April 2012 reconfiguration will become apparent in future evaluations.

Our study did however identify some early improvements that are associated with the trauma system reconfiguration. First, there is evidence that some process measures might have improved between the two periods. These include the seniority of the treating doctor, use of tranexamic acid, and early access to CT scanning for head injured patients. Second, fewer patients required secondary transfer between hospitals, most likely because they were transported directly to a MTC. This shift may reduce the administrative burden associated with transferring patients between hospitals and delays to specialist intervention.[22] A number of studies have shown that patients transferred directly to an appropriate facility have better outcomes than those undergoing secondary transfer[43-46]. Finally, the data could be consistent with a morbidity improvement as more patients were discharged with a GOS of "good recovery" following regionalisation. As death is still a relatively rare event (<6.5 per cent) in trauma patients that reach hospital alive, it is likely that a morbidity benefit will become apparent before improvements in mortality. However, there is a strong likelihood that this difference can be explained by changes in reporting practice. Although GOS was not recorded in 24.2 per cent of cases before regionalisation, this proportion improved to 14.7 per cent afterwards. It is possible that many of the cases with missing data were discharged with a "good recovery" (this being the predominant outcome in both groups) and so the apparent improvement may simply reflect better coding.

The principal limitation of this study is that the reconfiguration of major trauma services included changes to the way in which cases were reported to TARN. In particular, MTCs were financially incentivised to report cases in the post-regionalisation period under the Best Practice Tariff.[29]

Unsurprisingly, our analysis of HES data suggested that reporting to TARN increased following regionalisation. This is a further potential benefit of the trauma service reconfiguration, as comprehensive reporting will improve TARN as a resource both for observational trauma research and benchmarking quality between MTCs. However, it is difficult to know for certain what impact changes in reporting might have had on outcome differences between the time periods. In particular, the absolute number of patients, hospital bed days, and critical care bed days may reflect both a shift of trauma workload into MTCs and increased reporting. A second limitation is that trauma network processes might not have aligned perfectly with the national launch date of April 2012. We attempted to reduce the effect of staggered launches by contacting major trauma leads at each hospital and incorporating a phasing period into our analyses. However, it is also possible that hospitals began modifying processes earlier, perhaps in anticipation of being designated as MTCs. This might explain why a previous analysis of TARN data that used a 2008 baseline found evidence of improved mortality in the later period[25-28]. However, choosing an earlier baseline would have exposed this study to greater risk of incorporating factors that may be not be attributable to regionalisation, such as changes in pre-hospital administration of tranexamic acid.[47]

This study describes the first formal evaluation of regionalised trauma care in England. Although our early post-implementation analysis did not show evidence of reduced trauma mortality, this finding is consistent with other studies that found mortality benefits only follow a prolonged period of trauma system maturation.[37-39] However, our data were consistent with improvements across all measured care quality indicators, case reporting to TARN, and reduced need for secondary transfer of trauma patients. Further work over longer time periods is necessary to evaluate the newly regionalised service in England to ensure that it ultimately achieves the best possible outcomes for major trauma patients.

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Table 1

	Before	After	P-value
Patients	7 705	12 476	
Age*	49.4 (48.9 – 50.0)	51.4 (51.0 – 51.8)	< 0.001‡
Sex			
Male	5 010 (65.0 per cent)	7 947 (63.7 per cent)	0.059†
Female	2 695 (35.0 per cent)	4 529 (36.3 per cent)	0.059†
Mechanism of injury			
Vehicle incident	2 106 (27.3 per cent)	3 758 (30.1 per cent)	< 0.001†
Fall from >2m	1 217 (15.8 per cent)	1 957 (15.7 per cent)	0.852†
Fall from ≤2m	3 205 (41.6 per cent)	5 177 (41.5 per cent)	0.899†
Other	1 177 (15.3 per cent)	1 584 (12.7 per cent)	< 0.001†
Vital signs			
Systolic blood pressure (mmHg)**	134 (118 – 151)	134 (119 – 151)	0.482¥
SBP ≤90mmHg (per cent)	405 (5.3 per cent)	729 (5.8 per cent)	0.084†
HR ≥100bpm (per cent)	1 222 (15.9 per cent)	2 182 (17.5 per cent)	0.003†
Glasgow Coma Score**	15 (15 – 15)	15 (15 – 15)	< 0.001¥
GCS ≤8 (per cent)	294 (3.8 per cent)	762 (6.1 per cent)	< 0.001†
Injury Severity Score**	13 (9 – 22)	13 (9 – 25)	< 0.001¥
ISS ≥15 (per cent)	3 469 (45.0 per cent)	5 733 (46.0 per cent)	0.203†
Revised Trauma Score**	7.8 (7.8 – 7.8)	7.8 (7.8 – 7.8)	0.054¥
Injury type			
Penetrating	251 (3.3 per cent)	380 (3.0 per cent)	0.425†
Blunt	7 454 (96·7 per cent)	12 096 (97.0 per cent)	0.425†
Transfer by air ambulance	551 (7.2 per cent)	1 210 (9.7 per cent)	< 0.001†
Transfer from another hospital	2 408 (31.3 per cent)	3 228 (25.9 per cent)	< 0.001†

Table 2

	Before	**After**	**P-value**
Assessed by consultant in the ED (n = 11 997)	2 343 (30.4 per cent)	6 776 (54.3 per cent)	< 0.001†
Time to CT for head-injured patients (n = 1 250)	49.2 (31.2 – 76.8) minutes	31.2 (19.2 – 55.2) minutes	< 0.001‡
Administration of tranexamic acid to bleeding patients (n = 342)	58 (17.0 per cent)	200 (58.5 per cent)	0.006†

Table 3

	Before	**After**	**P-value**
Patients	7 705	12 476	
Number of operations*	1.4 (1.4 – 1.4)	1.4 (1.4 – 1.5)	< 0·001¥
Required any operation (per cent)	4 215 (54.7 per cent)	6 892 (55.2 per cent)	0·465†
Length of stay**	9 (5 – 18)	10 (5 – 18)	0.135¥
Total bed days	118 150	193 339	
Critical care length of stay**	4 (2 – 11)	4 (2 – 11)	0.370¥
Total critical care bed days	17 296	28 834	
Glasgow Outcome Score			
Good recovery	4 035 (52.4 per cent)	8 044 (64.5 per cent)	< 0.001†
Moderate disability	818 (10.6 per cent)	1 223 (9.8 per cent)	
Persistent vegetative state	6 (0.1 per cent)	13 (0.1 per cent)	
Severe disability	203 (2.6 per cent)	626 (5.0 per cent)	
Unavailable	2 144 (27.8 per cent)	1 714 (13.7 per cent)	
Mortality	464 (6.0 per cent)	805 (6.5 per cent)	0.233†

Table 4

	Before	**After**	**P-value**
Patients	3 469	5 733	
Length of stay **	10 (5 – 19)	10 (5 – 21)	0.910¥
Critical care length of stay **	5 (2 – 12)	5 (2 – 12)	0.688¥
Glasgow Outcome Score			
Good recovery	1 609 (46.4 per cent)	3 115 (54.3 per cent)	
Moderate disability	446 (12.9 per cent)	614 (10.7 per cent)	
Persistent vegetative state	6 (0.2 per cent)	12 (0.2 per cent)	
Severe disability	167 (4.8 per cent)	448 (7.8 per cent)	
Unavailable	838 (24.2 per cent)	841 (14.7 per cent)	< 0.001†
Mortality	376 (10.8 per cent)	671 (11.7 per cent)	0.218†

Captions

Table 1 – Characteristics of patients received by hospitals that became Major Trauma Centres. *mean (95 per cent confidence intervals); **median (interquartile ranges); † Chi square test (Yate's correction); ‡ t-test; ¥ Mann-Whitney test.

Table 2 – Quality indicators for patients reported to TARN. *median (interquartile ranges); † Chi square test (Yate's correction); ‡ t-test.

Table 3 – Outcomes for patients reported to TARN. *mean (95 per cent confidence intervals); **median (interquartile ranges); † Chi square test (Yate's correction); ‡ t-test; ¥ Mann-Whitney test.

Table 4 – Outcomes for the patients with ISS ≥ 15. *mean (95 per cent confidence intervals); **median (interquartile ranges); † Chi square test (Yate's correction); ‡ t-test; ¥ Mann-Whitney test.

Figure 1 – Map of England showing location of all 26 Major Trauma Centres (MTCs).

Figure 2 – Graph showing the standardised rate of survival (*Ws* with 95 per cent confidence intervals) between the three time periods for all TARN patients. These are the before and after categories together with a "phasing" period that includes patients treated between the dates of MTC "launch" and having all major trauma services in place.

Figure 3 – Graph showing the standardised rate of survival (*Ws* with 95 per cent confidence intervals) between the three time periods for patients with ISS ≥ 15.

Figure 4 – Funnel plot showing standardized rate of survival (Ws) versus precision (number of cases) for hospitals before and after MTC designation. The "target" represents the overall average of the indicator (i.e. no variation between MTCs) and the control limits at 2 and 3 standard deviations from the target line.