

Time to definitive care within major trauma networks in England

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Background: Significant mortality improvements have been reported following the implementation of English trauma networks. Timely transfer of seriously injured patients to definitive care is a key indicator of trauma network performance. This study evaluated timelines from emergency service (EMS) activation to definitive care between 2013 and 2016.

Methods: An observational study was conducted on data collected from the UK national clinical audit of major trauma care of patients with an Injury Severity Score above 15. Outcomes included time from EMS activation to: arrival at a trauma unit (TU) or major trauma centre (MTC); to CT; to urgent surgery; and to death.

Results: Secondary transfer was associated with increased time to urgent surgery (median 7.23 (i.q.r. 5.48–9.28) h *versus* 4.37 (3.00–6.57) h for direct transfer to MTC; $P < 0.001$) and an increased crude mortality rate (19.6 (95 per cent c.i. 16.9 to 22.3) *versus* 15.7 (14.7 to 16.7) per cent respectively). CT and urgent surgery were performed more quickly in MTCs than in TUs (2.00 (i.q.r. 1.55–2.73) *versus* 3.15 (2.17–4.63) h and 4.37 (3.00–6.57) *versus* 5.37 (3.50–7.65) h respectively; $P < 0.001$). Transfer time and time to CT increased between 2013 and 2016 ($P < 0.001$). Transfer time, time to CT, and time to urgent surgery varied significantly between regional networks ($P < 0.001$).

Conclusion: Secondary transfer was associated with significantly delayed imaging, delayed surgery, and increased mortality. Key interventions were performed more quickly in MTCs than in TUs.

Funding information

No funding

Presented as a poster to the London Trauma Conference 2018, London, UK, December 2018; published in abstract form as *Scand J Trauma Resusc Emerg Med* 2019; 27 (Suppl 1): 6

Paper accepted 26 May 2020

Published online 9 July 2020 in Wiley Online Library (www.bjsopen.com). DOI: 10.1002/bjs5.50316

Introduction

Significant improvements in survival have been demonstrated since the implementation of national major trauma networks in England in 2012^{1,2}. Improvements in outcomes have also been reported in other European countries^{3,4}, as well as at state level in Australia⁵ and in the USA⁶. A fundamental operating principle has been the development of systems that allow patients with life-threatening injuries to be transferred in a timely manner to centres that can provide necessary surgical and other interventions^{7–11}. Evaluation of patient pathways and timelines from emergency service (EMS) activation to definitive treatment can provide quality indicators of trauma network performance. Times from injury to

arrival at hospital, and to surgery, are reported to have increased in England between 2008 and 2017¹. A detailed examination of the timelines and outcome of patients with time-critical injury who follow the 'direct to major trauma centre (MTC)' and 'secondary transfer to MTC' pathways in the UK has not been published previously.

The optimal bypass time – the time below which a patient with serious injuries is taken directly to an MTC, even if this involves bypassing a closer trauma unit (TU) – for each trauma network is currently based on clinical consensus¹. After the introduction of major trauma networks in the UK in 2012, most ambulance services bypassed TUs and transferred directly to MTCs only if the estimated transfer time to the nearest MTC was 45 min or less. Following work by the UK major trauma

clinical reference group and National Institute for Health and Care Excellence guideline NG39¹², published in February 2016, many ambulance services increased the bypass time to 60 min. However, limited evidence was available to inform this change, and its impact on overall patient timelines and outcomes is unclear. Evaluation of the regional trauma networks in England has suggested a reduction in the number of patients requiring secondary transfer since regionalization^{13,14}, but whether this has influenced improved trauma outcomes is also unknown.

Significant geographical variation in mortality from major trauma was described consistently before the implementation of regional major trauma networks¹⁵. A challenging aspect in understanding the variation is accounting for differences in geography, population density and service configuration between networks, as well as significantly different transfer times to definitive care. Networks have been encouraged to develop 'bespoke' models in which each major trauma network aims to meet standards by the most appropriate means for their regional circumstances⁷. The impact that this has had on variation in patient timelines and mortality has not been evaluated.

This study examined temporal aspects of the patient pathway for patients with major trauma in England from 2013 to 2016. Using the Trauma and Audit Research Network (TARN) data set, geographical and year-by-year variations in patient timelines, including time to hospital arrival, to CT and to urgent surgery in patients with life-threatening injuries, were examined in the hope that reporting patient timelines and related outcomes might be used to guide future trauma system optimization and provide evidence for safe bypass policies.

Methods

The TARN identified patients with major trauma, defined as an Injury Severity Score (ISS) above 15, admitted to hospitals in England between 2013 and 2016. The TARN, established in 1989, supports the only national trauma registry in England, and at 2014 had 100 per cent membership from hospitals receiving trauma cases in England. The TARN inclusion criteria have remained consistent since 1989, and include injured patients of all ages arriving alive at hospital where at least one of the following criteria are met: death during admission, admission to critical care, transfer to specialist care, or admission for more than 72 h. Patients aged over 65 years with isolated neck of femur or pubic ramus fractures are excluded^{16,17}.

Outcomes were time to arrival at hospital, time to first CT, time to a surgical operation (where carried out less than 6 h after arrival), crude mortality and adjusted mortality.

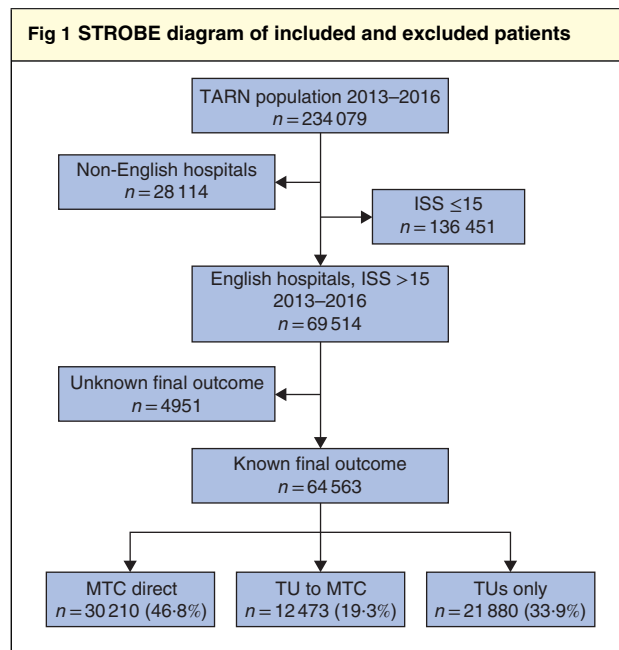
Patients were divided into three groups based on their pathway from call to emergency services: direct to MTC; direct to TU; or from scene to TU and then secondary transfer to an MTC. Data were grouped by year and by (anonymized) major trauma network. Urgent surgical procedures were grouped by specialty.

Statistical analysis

Continuous variables are shown as median (i.q.r.) values, and categorical variables are given as numbers with percentages. Comparison of two-sample medians was carried out using the Bonett–Price test¹⁸. For comparison of the different 'time to' values between network and year of admission, two-way ANOVA was performed after checking for normality of the data using normal plots. The χ^2 test was used for comparison of crude mortality. Adjusted odds of death were obtained from a logistic regression model using age, sex, ISS, Glasgow Coma Scale (GCS) score, Charlson Co-morbidity Index, and the patient pathway as exposure factor¹⁹. All analyses were carried out in Stata[®] release 14.2 (StataCorp, College Station, Texas, USA). The threshold for statistical significance was set at $P < 0.050$.

Results

Some 30 210 patients (46.8 per cent) with an ISS above 15 were transferred directly to an MTC (Fig. 1). A further



TARN, Trauma Audit and Research Network; ISS, Injury Severity Score; MTC, major trauma centre; TU, trauma unit.

Table 1 Patients with major injury requiring urgent intervention, 2013–2016

	2013	2014	2015	2016	Total
ISS > 15	14 666 of 43 741 (33.5)	16 498 of 48 918 (33.7)	18 396 of 54 814 (33.6)	19 954 of 58 682 (34.0)	69 514
Duration of surgery < 6 h	1748 (11.9)	1734 (10.5)	1717 (9.3)	1803 (9.0)	7002
Case ascertainment (%)	66	71	77	86	74

Values in parentheses are percentages. ISS, Injury Severity Score.

12 473 (19.3 per cent) were transferred initially to a TU and then had a secondary transfer to an MTC for definitive treatment. The remaining 21 880 patients (33.9 per cent) were transferred directly to a TU and received definitive treatment at that hospital.

Proportion of patients requiring urgent intervention

Case ascertainment (a measure of data completeness) increased year-on-year from 66 per cent in 2013 to 86 per cent in 2016 (Table 1). The total number of recorded patients with an ISS above 15 increased year-on-year from 14 666 in 2013 to 19 954 in 2016, although the proportion of patients with ISS above 15 remained the same (33.5 per cent in 2013, 34.0 per cent in 2016). Absolute numbers of patients who underwent urgent surgery within 6 h were similar in 2013 (1748) and 2016 (1803). As a proportion, patients undergoing surgery within 6 h decreased year-on-year, from 11.9 per cent in 2013 to 9.0 per cent in 2016. Most procedures were performed by either orthopaedic surgery, neurosurgery or general surgery (Table 2). The most common procedures are shown in Fig. 2.

Transfer time

Median transfer time from emergency call to hospital arrival in the 4-year period was 1.43 (i.q.r. 1.03–1.88) h direct to MTCs, 1.52 (1.12–2.08) h direct to TUs, and 6.58 (5.03–8.42) h to MTCs indirectly (Table 3). Compared with direct transfer to an MTC, secondary (indirect) transfer time to an MTC was significantly increased ($P < 0.001$). Direct transfer to a TU was also significantly longer than direct transfer to an MTC ($P < 0.001$). There was a significant year-on-year increase in transfer time to MTCs (median 1.32 (i.q.r. 0.98–1.78) h in 2013 versus 1.52 (1.15–1.98) h in 2016; $P < 0.001$), to TUs (1.35 (0.98–1.87) versus 1.67 (1.23–2.28) h respectively; $P < 0.001$), and to MTCs indirectly (6.47 (4.97–8.30) versus 6.77 (5.22–8.72) h; $P < 0.001$) (Table 3).

There was significant variation between networks for transfer time averaged over the 4-year period for direct

Table 2 Urgent surgery, grouped by surgical specialty and initial hospital admission site

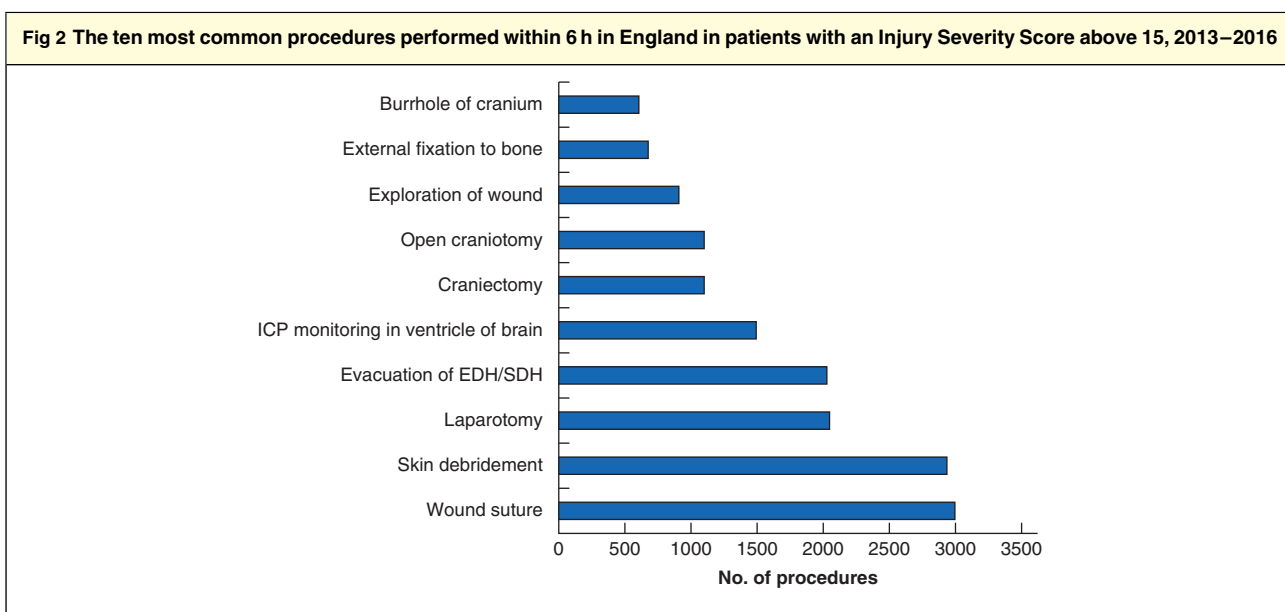
Surgical specialty	No. of procedures
Trauma unit	<i>n</i> = 5180
Orthopaedics	2034 (39.3)
Neurosurgery	1626 (31.4)
General surgery	743 (14.3)
ENT/maxillofacial surgery/ophthalmology	139 (2.7)
Prehospital/emergency department	133 (2.6)
Major trauma procedure unspecified	126 (2.4)
Vascular	100 (1.9)
Plastic surgery	91 (1.8)
Other	81 (1.6)
Cardiothoracic surgery	73 (1.4)
Interventional radiology	59 (1.1)
Obstetrics and gynaecology	3 (0.1)
Major trauma centre	<i>n</i> = 7833
Orthopaedics	2557 (32.6)
Neurosurgery	1890 (24.1)
General surgery	1235 (15.8)
Major trauma procedure unspecified	728 (9.3)
Vascular	323 (4.1)
Plastic surgery	261 (3.3)
ENT/maxillofacial surgery/ophthalmology	257 (3.3)
Interventional radiology	256 (3.3)
Cardiothoracic surgery	204 (2.6)
Other	99 (1.3)
Prehospital/emergency department	93 (1.2)
Obstetrics and gynaecology	5 (0.1)

Values in parentheses are percentages. The total number of procedures (*n*) is less than the aggregate because some procedures are recorded under more than one specialty. ENT, ear, nose and throat.

transport to MTCs ($P < 0.001$), direct transfer to TUs ($P < 0.001$) and indirect transfer to MTCs ($P < 0.001$).

Time to first CT

Patients transferred directly to an MTC had significantly shorter median time from emergency call to CT than those transferred to a TU (2.00 (i.q.r. 1.55–2.73) versus 3.15 (2.16–4.63) h respectively; $P < 0.001$). A significant year-on-year trend of increasing time from emergency call to first CT was observed at MTCs (1.97 (1.48–2.68) h in



ICP, intracranial pressure; EDH, extradural haematoma; SDH, subdural haematoma.

Table 3 Time to hospital arrival, CT and urgent surgery

	Time (h)				
	2013	2014	2015	2016	All years
Hospital arrival					
MTC direct	1.32 (0.98–1.78)	1.40 (1.05–1.82)	1.45 (1.08–1.90)	1.52 (1.15–1.98)	1.43 (1.03–1.88)
MTC indirect	6.47 (4.97–8.30)	6.57 (5.08–8.27)	6.57 (5.05–8.33)	6.77 (5.22–8.72)	6.58 (5.03–8.42)
TU direct	1.35 (0.98–1.87)	1.42 (1.07–1.93)	1.53 (1.15–2.08)	1.67 (1.23–2.28)	1.52 (1.12–2.08)
First CT scan					
MTC direct	1.97 (1.48–2.68)	1.97 (1.53–2.68)	2.00 (1.55–2.70)	2.07 (1.62–2.83)	2.00 (1.55–2.73)
MTC indirect	n.a.	n.a.	n.a.	n.a.	n.a.
TU direct	2.87 (2.03–4.22)	2.98 (2.08–4.40)	3.13 (2.18–4.55)	3.43 (2.35–5.02)	3.15 (2.17–4.63)
Urgent surgery					
MTC direct	4.45 (2.92–6.60)	4.27 (2.90–6.53)	4.37 (3.02–6.75)	4.40 (1.45–6.48)	4.37 (3.00–6.57)
MTC indirect	7.00 (5.13–8.98)	7.13 (5.50–9.10)	7.50 (5.50–9.48)	7.33 (5.77–9.47)	7.23 (5.48–9.28)
TU direct	5.00 (3.12–6.85)	5.37 (3.75–7.42)	6.03 (3.80–8.30)	5.03 (3.47–7.68)	5.37 (3.50–7.65)

Values are median (i.q.r.). MTC, major trauma centre; TU, trauma unit; n.a., not applicable.

2013 *versus* 2.07 (1.62–2.83) h in 2016; $P < 0.001$) and at TUs (2.87 (2.03–4.22) *versus* 3.43 (2.35–5.02) h respectively; $P < 0.001$) (Table 3).

There was significant variation between networks for time from emergency call to first CT at MTCs ($P < 0.001$) and at TUs ($P < 0.001$).

Time to surgery

Median time from emergency call to urgent surgery averaged over the 4-year period was 4.37 (i.q.r. 3.00–6.57) h

for direct transfers to MTCs, 5.37 (3.50–7.65) h for direct transfers to TUs, and 7.23 (5.48–9.28) h for indirect transfers to MTCs (Table 3). Patients transferred directly to an MTC had a significantly shorter median time from emergency call to urgent surgery compared with patients transferred to a TU ($P < 0.001$) or those having secondary transfer to an MTC ($P < 0.001$) (Table 4).

There was significant variation between networks for time from emergency call to surgery averaged over the 4-year period for direct transfer to MTCs ($P < 0.001$) and direct transfer to TUs ($P < 0.001$).

Table 4 Average timelines

	MTC	TU	Secondary transfer to MTC
Time to arrival (h)	1.43 (1.06–1.88)	1.51 (1.12–2.08)*	6.58 (5.03–8.41)†
Time to first CT (h)	2.00 (1.55–2.73)	3.15 (2.17–4.63)*	n.a.
Time to surgery (h)	4.37 (3.00–6.57)	5.37 (3.50–7.65)*	7.23 (5.48–9.28)†

Values are median (i.q.r.). MTC, major trauma centre; TU, trauma unit; n.a., not applicable. * $P < 0.001$, MTC versus TU; † $P < 0.001$, MTC versus secondary transfer to MTC (Bonnett–Price test).

Secondary transfer and mortality

Crude mortality averaged over the 4-year period in patients with an ISS above 15 who had surgery within 6 h was significantly higher in patients who underwent secondary transfer to an MTC than in patients transferred directly from emergency call to an MTC (19.6 (95 per cent c.i. 16.9 to 22.3) versus 15.7 (14.7 to 16.7) per cent respectively; $P = 0.004$, χ^2 test). This was associated with an increased time from emergency call to CT (3.15 (i.q.r. 2.17–4.63) versus 2.00 (1.55–2.73) h respectively; $P < 0.001$) and increased time from emergency call to surgery (7.23 (5.48–9.28) versus 4.37 (3.00–6.57) h; $P < 0.001$) (Table 4). The crude and adjusted odds of death for patients admitted directly to MTCs were lower than in those admitted to MTCs via a secondary transfer (MTC: crude odds ratio (OR) 0.76 (95 per cent c.i. 0.63 to 0.92), adjusted OR 0.88 (0.70 to 1.11)). The crude and adjusted odds of death for patients directly admitted to MTCs were lower than those treated in TUs (MTC: crude OR 0.87 (0.83 to 0.91), adjusted OR 0.77 (0.72 to 0.82)).

Discussion

This study reports timelines for severely injured patients in England since the launch of regional trauma networks. The analysis demonstrated that direct transfer to an MTC significantly reduced time to CT and to urgent surgery compared with transfer to a TU or transfer to an MTC via a TU. Patients going directly to an MTC for urgent surgery also had a lower crude mortality rate than those transferred via a TU. The data suggest that, on average, severely injured patients requiring urgent surgery undergoing secondary transfer wait about 3 h longer before surgery than patients transferred directly to an MTC. A reduction in the number of secondary transfers of trauma patients in England has been considered a positive outcome despite any direct evidence to suggest an association with reduced mortality or morbidity¹³.

Although an association between secondary transfer and increased mortality has been described in other countries^{20–22}, a more recent study²³ was inconclusive

and systematic reviews^{24–26} suggest that the relationship is complex and context-dependent. Trauma networks have a number of variables, both within and between countries, that could significantly affect the influence of secondary transfer on outcomes. Prehospital care can be basic or delivered to critical care standards by high-level practitioners. Transport can be by different methods (for instance, air or ground) and can (combined with local geography) be rapid or relatively slow. TUs (or their equivalent) can be small with limited facilities and staff, or may deliver care close to that of MTC standards, lacking only some trauma specialties. There may be systems in place to deliver key interventions effectively and transfer quickly, or a struggle to refer and commence transfer. Interhospital transfer may be highly organized or delivered in an *ad hoc* manner by the transferring hospital.

The results reported in this study support the acceptance of increased bypass times to MTCs in the UK where this can be achieved safely because, even when transfer times are moderately increased, patients still have a reduced time to definitive intervention than with the alternative routes. Caution is required when interpreting the decreased unadjusted crude mortality of patients transferred directly to an MTC, as it is impossible to adjust for the many potential possible confounders that may influence this finding.

In terms of the safety of longer transfers, most networks recommend transfer to the nearest TU where airway compromise or significant haemorrhage is detected that cannot be managed effectively. Increasingly in the UK, physician–paramedic prehospital critical care teams delivered by helicopter or fast response vehicles are available. They all have advanced airway capability and many now carry blood and/or blood products, which may make direct transfer to MTCs more frequent and safer.

The present study also identified significant variations in patient timelines between regional networks and a trend to increased patient timelines between 2013 and 2016 for seriously injured patients. The evidence for a direct correlation between a reduced time to hospital and outcome is mixed, but, overall, shorter times are associated with better outcomes⁹. Increased transfer times direct to MTCs may be explained partially by increased bypass time, resulting

in an increase in the number of primary transfers bypassing TUs and a reduction in the rate of secondary inter-hospital transfers²⁷. It is unclear why the increase would persist over the whole period. Furthermore, transfer times to TUs and to MTCs indirectly have also increased steadily since 2013. This trend was reported previously¹ in patients with ISS above 9. This suggests that longer primary transfer distances are not the only explanation for increasing transfer times. Increased response times and/or increasing scene times could be relevant factors. Variation in road networks and hospital distribution in different networks means that some variation should be expected¹, and this is not unique to injured patients²⁸. Observed variation may, therefore, not be due to regional trauma network processes and systems alone.

The heterogeneity of international trauma systems and study methods makes direct comparison and pooling of results from UK trauma networks and systems and those from other countries challenging. This may, in part, explain why an association between secondary transfer and increased mortality has not been reported uniformly. A recent analysis²⁹ of a French regional trauma system found no increased mortality associated with secondary transfer. This might be expected to be comparable to the UK system, but the authors suggested that results may reflect the very specific system of physician-led prehospital care within their trauma system. The study also included only injured patients involved in road traffic accidents, limiting further comparison with the present results. Results reported on the same subject from countries with significantly different healthcare systems are probably valid only within similar healthcare environments³⁰.

The present results are likely to be most generalizable to other regions with inclusive trauma systems⁸, 'average' European regional geography and well established prehospital care, ambulance dispatch and responses.

The findings reported are based on analysis of the TARN national database. During the study period, estimated overall case ascertainment increased from 66 to 86 per cent, and comprehensive data from TUs were limited. The confounding effect of increased data submission to the TARN and the variability in data submission are limitations of this study. Another limitation is the time 'cut-off' for urgent surgery. Some patients may have required urgent surgery and not received it within 6 h, and others may have had surgery within 6 h without time-critical pathology. To establish the accuracy of this cut-off time for identifying time-critical surgical patients, it would be necessary to identify patients prospectively or attempt to identify other

indicators of time-critical pathology, such as altered physiology or resuscitation interventions.

Acknowledgements

No preregistration exists for the reported studies in this article. Because of the sensitive nature of the data collected for this study, requests to access the data set from qualified researchers trained in human subject confidentiality protocols may be sent to TARN (www.tarn.ac.uk).

Disclosure: C.G.M. is employed by NHS England and is responsible for the implementation of trauma networks in England and Wales. D.J.L. is Clinical Director of a trauma network in England and sits on the board of the Trauma Audit and Research Network. The authors declare no other conflict of interest.

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