The Impact of a Pan-regional Inclusive Trauma System on Quality of Care

Elaine Cole, PhD, Fiona Lecky, MBBS,† Anita West, RN,‡ Neil Smith, PhD,§ Karim Brohi, FRCS,* Ross Davenport; PhD*; on behalf of the ELoTS Study Collaborators*

Objectives: To evaluate the impact of the implementation of an inclusive pan-regional trauma system on quality of care.

Background: Inclusive trauma systems ensure access to quality injury care for a designated population. The 2007 National Confidential Enquiry into Patient Outcome and Death (NCEPOD) found quality deficits for 60% of severely injured patients. In 2010, London implemented an inclusive trauma system. This represented an opportunity to evaluate the impact of a pan-regional trauma system on quality of care.

Methods: Evaluation of the London Trauma System (ELoTS) utilized the NCEPOD study core methodology. Severely injured patients were identified prospectively over a 3-month period. Data were collected from prehospital care to 72 h following admission or death. Quality, processes of care, and outcome were assessed by expert review using NCEPOD criteria.

Results: Three hundred and twenty one severely injured patients were included of which 84% were taken directly to a major trauma center, in contrast to 16% in NCEPOD. Overall quality improved with the proportion of patients receiving ''good overall care'' increasing significantly [NCEPOD: 48% vs ALL-ELoTS: 69%, RR 1.3 (1.2 to 1.4), $P < 0.01$], primarily through improvements in organizational processes rather than clinical care. Improved quality was associated with increased early survival, with the greatest benefit for critically injured patients [NCEPOD: 31% vs All-ELoTS 11%, RR 0.37 (0.33 to 0.99), $P = 0.04$].

Conclusions: Inclusive trauma systems deliver quality and process improvements, primarily through organizational change. Most improvements were seen in major trauma centers; however, systems implementation did not automatically lead to a reduction in clinical deficits in care.

Keywords: outcomes, quality, regionalization, severe injury, trauma systems

(*Ann Surg* 2015;xx:xxx–xxx)

As with many areas of modern medicine, the delivery of high quality trauma care is dependent on timely access to specialist expertise and resources. Quality includes the well-timed delivery of expert, appropriately resourced care. Trauma systems are public health models of care that aim to assure access to, and the quality of injury care for their designated population,[1,2] which are governed by quality assurance and performance improvement frameworks.[3,4] Although regional systems seem to reduce overall mortality through enhanced resources[5–7] and improved access,[1,8] the specific aspects by which they deliver improved quality are unclear. In particular, the differences between organizational change and clinical delivery of care on overall quality are under reported. This has important implications for the future implementation and evolution of trauma systems.

The 2007 National Confidential Enquiry into Patient Outcome and Death (NCEPOD) reviewed the quality of care of all severely injured patients in England and Wales.[9] Cases were identified over a 3-month period and were evaluated by a team of expert advisors. At this time there were no formal regional trauma systems in place in the UK and the report demonstrated inadequacies in the quality of care for 60% of severely injured patients.[9] Three years later in April 2010, the Greater London urban area implemented a contiguous trauma system for a population of 10 million people. The system was designed to be inclusive, with cooperating networks of major trauma centres, trauma units, and prehospital care providers. The NCEPOD study described the base-state before implementation, therefore this represented a unique opportunity to understand the quality, strengths, and weaknesses of organized systems of trauma care. Quality assessment of large scale regionalization in trauma care has yet to be described although has clear global relevance for healthcare system development.

We wished to evaluate the impact of the implementation of an inclusive pan-regional trauma system on quality of care following severe injury. The primary objective of this study was to assess the quality of trauma care and outcomes following regionalization. Second, we wished to examine the effect of trauma networks on access for injured patients and the utilization of secondary transfers across the network. Finally, we wished to evaluate the degree to which the systems goal of inclusiveness had been achieved across the whole network. We conducted a prospective cohort study across the London Trauma System (LTS) and compared the results with those in the original NCEPOD study.

METHODS

Study Setting

The LTS is geographically divided into 4 networks and serves the population Greater London (8.3 million people) and a portion of the wider metropolitan area (10–12 million people approximately). All of the networks are based on the hub and spoke principle of inclusive regionalized care. Services, processes, and resources are subject to designation criteria.[10] Four Major Trauma Centres (MTCs) are responsible for treating the most severely injured patients. MTCs (equivalent to level 1 centers), are specialty hospitals with a full complement of clinical disciplines available on site. Each MTC is associated with a number of designated trauma units (TUs, approximately equivalent to

From the *Centre for Trauma Sciences, Blizard Institute, Queen Mary University of London, London, UK; †Emergency Medicine Research, University of Sheffield, London, UK; ‡Barts Health NHS Trust, Royal London Hospital, London, UK; and §NCEPOD (National Confidential Enquiry into Patient Outcome and Death), London, UK.

Disclosure: No compensation was received in relation to this study. The authors declare no conflicts of interest.

ELoTS Study Collaborators: Mr Christopher Aylwin, Mr Peter Bates, Mr Duncan Bew, Mr Doug Bowley, Dr Robert Crouch, Ms Michelle Eliot, Dr Andy Eynon, Dr Simon Glasgow, Dr Rebecca Greenhalgh, Dr Gareth Grier, Mr Martin Griffiths, Dr Anthony Hudson, Dr Tom Hurst, Dr Heather Jarman, Mr Jan Jensen, Dr Jeff Keep, Mr Tom Konig, Dr Chris Lacy, Dr Rachel Landau, Ms Gabby Lomas, Mr Tom Loosemoore, Ms Sarah Murphy, Dr Breda O'Neill, Mr Robert Pinate, Professor Keith Porter, Mr Aidan Slowie, Dr Malcolm Tunnicliff, Mr Mark Wilson, Dr Kelvin Wright.

Reprints: Elaine Cole, PhD, Centre for Trauma Sciences, Blizard Institute, Queen Mary University of London, 4 Newark Street, London E1 2AT, UK. E-mail: e.cole@qmul.ac.uk

ISSN: 0003-4932/14/26105-0821
DOI: 10.1097/SLA.0000000000001393

level 3 centers). TUs are capable of treating less severely injured patients and able to initiate treatment and onward transfer of those identified as requiring MTC level care. Prehospital distribution of patients is coordinated via a pan-London triage tool. Prehospital care is provided by the London Ambulance Service in cooperation with regional boundary ambulance services augmented by physician-led emergency medical teams (land and helicopter). Prehospital physicians are tasked to trauma requiring a greater level of care at scene, such as rapid sequence induction of anesthesia.

Data Collection

Evaluation of the London Trauma System (ELoTS) utilized the core methodology described in the NCEPOD report.[9] For the 3 month period from February to April 2013, all trauma patients (adult and paediatric) were identified prospectively within all MTCs and TUs across each network. Patient case notes from prehospital care through to hour 72 of hospital admission (or death) were copied, anonymized and securely stored at each network MTC. Internal review board approval for service evaluation was agreed and data were collected as part of institutional clinical audit. The primary inclusion criterion was severe injury, defined by an injury severity score (ISS) of greater than 15 utilizing Abbreviated Injury Score (AIS 98) coding.[11] This was calculated locally and verified with the Trauma Audit Research Network (TARN: www.tarn.ac.uk). Patients were excluded if they were found to have an ISS less than 16; a nontrauma patient or if there was a delay in presentation of greater than 72 h from injury (primarily due to repatriation from other facilities in the UK or overseas).

To assess improvement to timely resuscitation and early diagnosis, data were collected on demographics, mechanism of injury, prehospital care, trauma team response, time to consultant review, time to diagnostic imaging and operative intervention, and any interhospital transfer arrangements in the first 72 h. Traumatic brain injury (TBI) was the most common severe injury reported by NCEPOD; therefore, we specifically examined time to neurosurgery consultation and emergency neurosurgery. The effects of system care on outcome, namely early mortality was evaluated (defined as per the NCEPOD study criteria as a death 72 hours or less from admission to hospital). Assessment forms from the original NECPOD audit, comprising quantitative and qualitative measures of care were completed for each patient enrolled in the study.

Assessment of Quality of Care

Previous NCEPOD study expert reviewers and representatives from TARN were invited to participate as quality assessors. A multidisciplinary group of 8 independent external experts (from outside the LTS) and 21 peer reviewers was convened. The panel for each network evaluation was comprised of expert and peer reviewers external to that network to mitigate any reporting bias. Anonymized case notes and assessment forms were evaluated using quality performance indicators derived from the NECPOD study. To enhance interassessor reliability, standardized NCEPOD assessment criteria were used for each anonymized case. Panels at each network assessment were encouraged to discuss cases to increase concordance and agree quality grade consensus.

To assess the overall care for each patient a grading system was developed based on the original NCEPOD criteria:

(1) Good care—a standard that you would accept from yourself, your trainees, and your institution.
(2) Clinical deficits—aspects of clinical care could have been improved.
(3) Organizational deficits—aspects of organizational care could have been improved.
(4) Deficits in both—aspects of both clinical and organizational care could have been improved.
(5) Less than satisfactory—several aspects of clinical and/or organizational care were less than satisfactory, well below that you would accept from yourself, your trainees, and your institution.

Data Analysis

ELoTS data were compared with that from the NCEPOD study. Time-based raw data were unavailable from NCEPOD thereby preventing any direct comparative statistical analysis. Where available, summary data from the NCEPOD "Trauma Who Cares" report[9] were used for comparison with ELoTS. Categorical variables were analyzed using Fisher's exact or χ^2 tests and reported as percentage and relative risk (RR) with 95% confidence intervals. Consistent with NCEPOD data, age is expressed as mean, and other numerical nonparametric data are expressed as median with interquartile range. Internal consistency of the quality rating across the MTCs was measured using Cronbach's Alpha.

In addition to overall system performance, we compared quality and performance at major trauma centres (MTC-ELoTS) with similar high volume hospitals in NCEPOD (HV-NCEPOD). High volume centers were previously defined by NCEPOD as those large multispecialty hospitals with on-site neurosurgical facilities who reported greater than 20 cases during the study period. All 4 hospitals which subsequently became MTCs participated in the original NCEPOD research. For this analysis, NCEPOD provided summary data on overall quality assessment, injury severity, mortality, time to assessment, and intervention. Statistical analysis was carried out using SPSSv.21, IBM Corp. A $P < 0.05$ was considered statistically significant.

RESULTS

During the 3 month study period, 344 severely injured patients were identified as suitable for inclusion. Following application of exclusion criteria and removal of cases with missing medical notes there were 321 cases with ISS greater than 15 available for quality assessment. Two hundred and sixty nine (84%) patients were admitted directly to an MTC and 52 (16%) patients were triaged initially to Trauma Units and then secondarily transferred to an MTC. Demographics of enrolled patients are detailed in Table 1. In comparison with NCEPOD, ELoTS patients were older and had increased use of prehospital physician trauma teams, ithat is, Helicopter Emergency Medical Services (HEMS) (Table 1).

Quality Assessment

Overall, patients in the London Trauma System received a significantly higher quality of care than described in NCEPOD. There was a significant increase in the number of patients categorized as receiving "Good overall care" [NCEPOD: 48% vs ALL-ELoTS: 69%, RR 1.3 (1.2 to 1.4), $P < 0.001$]. Improvements were evident in all categories of assessment (Figure 1A), with greatest benefit observed in the reduction of organizational deficits [NCEPOD: 23% vs All-ELoTS: 10%, RR 0.43 (0.30 to 0.61), $P = 0.02$]. Good care was higher in MTCs compared with HV-NCEPOD hospitals [HV-NCEPOD: 58% vs MTC-ELoTS: 74%, RR 1.2 (1.0 to 1.4), $P = 0.02$], with increases in the quality of patient management seen across all categories (Figure 1B). There was good internal consistency between quality ratings across the networks (Cronbach's Alpha 0.76).

Processes of Care

Considerable improvements were observed in the initial assessment of injured patients on arrival at the ED, with a significant increase in trauma team response [NCEPOD: 60% vs All-ELoTS: 92%, RR 1.5 (1.4 to 1.6), $P < 0.001$, Figure 2A]. This was further

TABLE 1. Admission Demographics and Injury Characteristics

	NCEPOD (n = 795)	All-ELoTS (n = 321)	HV-NCEPOD (n = 129)	MTC-ELoTS (n = 269)
Age	40	46	—	44
Male	594 (75)	234 (73)	—	198 (74)
Mode of arrival				
Ambulance service	652 (83)	197 (61)†	76 (59)	147 (55)
Helicopter service	92 (12)	119 (37)†	37 (29)	119 (44)*
Other	51 (5)	5 (2)	16 (12)	3 (1)
PHC activation to ED (min)				
Ambulance service	56	61	—	66
Helicopter service	78	72	—	70
ED arrival time				
08.00–17.59	344 (43)	163 (51)	—	117 (43)
18.00–07.59	419 (53)	158 (49)	—	152 (57)
Injury severity				
ISS 16–24	449 (57)	175 (55)	56 (43)	148 (55)
ISS 25–35	279 (35)	112 (35)	60 (47)	90 (33)
ISS 36–75	67 (8)	34 (10)	13 (10)	31 (12)

Values are expressed as mean or n (%).
Other includes self-presentation and police/other emergency services. Data on patient demographics e and PHC times for HV-NCEPOD patients not available.
*$P = 0.03$.
†$P < 0.001$.
Fishers exact tests between NCEPOD and All-ELoTS, and HV–NCEPOD and MTC-ELoTS.
ED indicates emergency department; HV: high volume, ISS: injury severity score; MTC: major trauma centre, PHC: prehospital care.

enhanced for severely injured patients taken directly to an MTC, with a near universal trauma team response [HV-NCEPOD: 73% vs MTC-ELoTS: 99%, RR 1.3 (1.2 to 1.5), $P < 0.001$, Figure 2A]. Early involvement of senior clinicians was greatly improved with a 3-fold increase in consultant-led trauma teams [NCEPOD: 27% vs All-ELoTS: 88%, RR 3.2 (2.8 to 3.6), $P < 0.001$]. The majority of patients were seen by a consultant in the ED within 30 min of arrival [NCEPOD: 38% vs All-ELoTS: 92%, RR 2.4 (2.2 to 2.6), $P < 0.001$, Figure 2B] with even more marked improvements evident at MTCs [HV-NCEPOD: 57% vs MTC-ELoTS: 97%, RR 1.3 (1.1 to 1.6), $P < 0.001$, Figure 2B].

In this study, approximately 1 in 4 patients (22%) was in shock (defined as systolic BP 90 mmHg or less) on arrival. When used in early hemorrhage assessment, average time to whole body CT from ED arrival was reduced by two thirds (NCEPOD: 138 mins vs All-ELoTS: 52 mins, Figure 2C). Pre- and postimplementation of the LTS, 14% of patients required emergency hemorrhage control (operative or interventional radiology) but after trauma system implementation substantial reductions in time to laparotomy from ED arrival were observed [NCEPOD: 384 min vs median All-ELoTS: 47 min (IQR 29–88) (no comparative raw NCEPOD data available), Figure 2D].

TBI was suspected in the majority of ELoTS patients (82%), mandating urgent neurological assessment. There were nonsignificant increases in utility of CT head scanning (NCEPOD 68% vs All-ELoTS: 77%, $P = 0.20$) with a median time to CT head scan of 33 min (IQR 21 to 56) for All-ELoTS patients (no comparative time-data availability for NCEPOD). Within the LTS, patients presenting initially to a TU had significantly longer waits for CT Head compared with those taken directly to an MTC (TU: 118 min vs MTC: 38 min, $P < 0.001$, Figure 3A). Additional benefits were seen at MTCs, with a 3-fold increase in CT head within 1 h of arrival [HV-NCEPOD: 28% vs MTC-ELoTS: 82%, RR 2.9 (2.2 to 3.8), $P < 0.001$, Figure 3B]. Compared with NCEPOD, significantly more patients were referred for urgent neurosurgical opinion [NCEPOD: 32% vs All-ELoTS: 55%, RR 1.7 (1.4 to 1.9), $P < 0.01$]. Time to neurosurgical review improved with a 4-fold increase in specialist consultation within 1 hour of referral [NCEPOD: 10% vs All-ELoTS: 45%, RR 4.4 (3.5 to 4.6), $P < 0.001$, Figure 3C], with significant differences observed for those patients admitted directly to an MTC [HV-NCEPOD: 23% vs MTC-ELoTS: 48%, RR 2.2 (1.6 to 3.1), $P < 0.01$]. All MTC patients requiring urgent neurosurgery were operated on within 4 hours from arrival in comparison with 67%

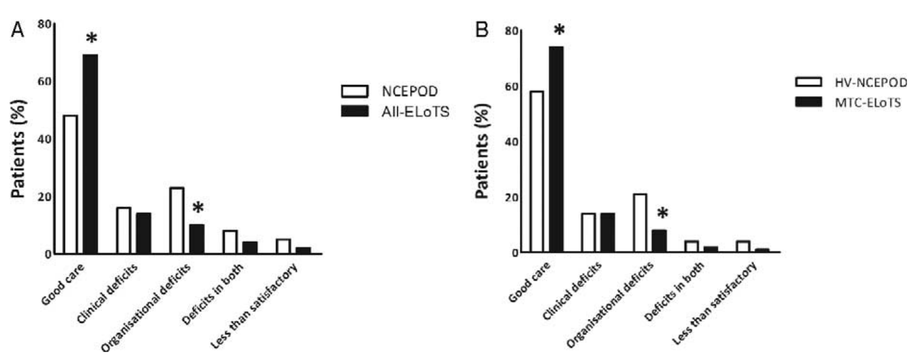

FIGURE 1. (A) Overall quality assessment: NCEPOD versus All-ELoTS. Graphs show percentage of cases per quality grade. Good care: NCEPOD: 48% vs ALL-ELoTS: 69%, RR 1.3 [1.2 to 1.4], $P < 0.01$. Organizationsal deficits: NCEPOD: 23% vs ALL-ELoTS: 10%, RR 0.43 [0.30 to 0.61], $P = 0.02$. (B) Overall quality assessment: HV-NCEPOD vs MTC-ELoTS. Graphs show percentage of cases per quality grade. Good care: HV-NCEPOD: 58% vs MTC-ELoTS: 74%, RR 1.2 [1.0 to 1.4], $P = 0.02$). Organizationsal deficits: HV-NCEPOD: 21% vs MTC-ELoTS: 8%, RR 0.35 [0.39 to 0.71] $P = 0.01$.

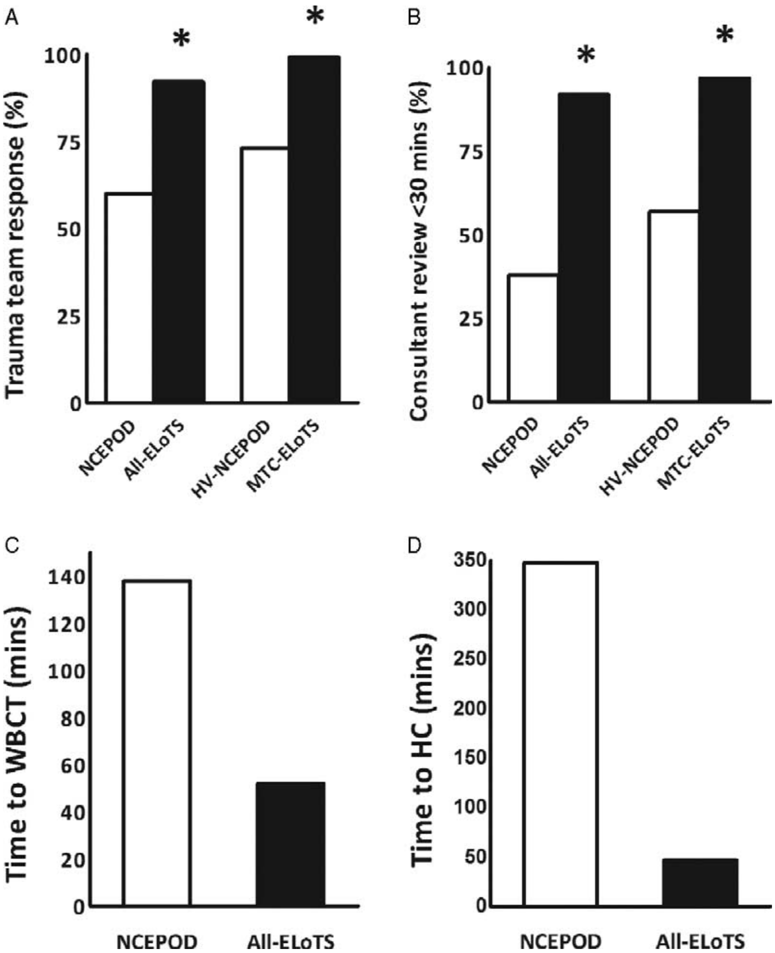

FIGURE 2. (A) Trauma team response. Graph shows percentage of cases per trauma team response, NCEPOD: 60% versus All-ELoTS: 92%, RR 1.5 [1.4 to 1.6], $P < 0.001$; HV-NCEPOD: 73% versus MTC-ELoTS: 99%, RR 1.3 [1.2 to 1.5], $P < 0.001$. (B) Early consultant review. Graph shows percentage of cases reviewed by a consultant or attending grade doctor within 30 min of arrival, NCEPOD: 38% versus All-ELoTS: 92%, RR 2.4 [2.2 to 2.6], $P < 0.001$; HV-NCEPOD: 57% versus MTC-ELoTS: 97%, RR 1.3 [1.1 to 1.6], $P < 0.0001$. (C) Time to whole body CT (WBCT) scan. Graph shows average time to CT scan from arrival, NCEPOD: 138 mins versus All-ELoTS: 52 min. (D) Time to haemorrhage control (HC). Graph shows average time to operative or radiological haemorrhage control from arrival, NCEPOD: 384 mins versus All-ELoTS: 47 min. For Figures 2C and D, raw time-process data not available from NCEPOD precluding statistical comparison with ELoTS.

of those patients NCEPOD hospitals with neurosurgery on-site, [RR 1.5 (1.3 to 1.6), $P < 0.001$, Figure 3D].

Mortality

To substantiate the overall quality improvements, the effect on early mortality (within the first 72 hours) was evaluated. Of the 22 deaths observed, 19 occurred within the first 24 hours postadmission, 2 patients died between 24 and 48 hours, and 1 death occurred just before 72 hours. The primary causes of death were TBI (16), haemorrhage (4), and severe crush injury (2). Overall early unadjusted mortality rates in the LTS were reduced in comparison to NCEPOD (Figure 4). We observed improved early survival for all degrees of injury, with greatest benefits seen in the most critically injured patients (ISS > 35) where crude mortality rates decreased by more than half for ELoTS patients [NCEPOD: 31% vs All-ELoTS 11%, RR 0.37 (0.33 to 0.99), $P = 0.04$]. Similar trends in mortality benefits were seen for patients treated directly at MTCs, where early deaths decreased by nearly half [HV-NCEPOD: 13% vs MTC-ELoTS 7%, RR 0.53 (0.28 to 0.99), $P = 0.06$].

Access to Care and Inclusivity

After system implementation, access to early specialist trauma care increased, with 84% of severely injured patients taken directly to a MTC in contrast to 16% in the NCEPOD study. There was a trend toward fewer patients (n = 52) requiring a secondary transfer from a TU compared with NCEPOD [NCEPOD: 24% vs All-ELoTS: 16%, RR 0.67 (0.51 to 0.89), $P = 0.21$]. Multisystem injury (78%) or patients with TBI requiring neurosurgical consultation (18%) accounted for the majority of secondary transfers. Significant improvements were observed in the receiving institutions with 90% of cases accepted by a consultant grade doctor, compared with 18% in NCEPOD ($P < 0.001$).

Inclusive trauma systems are responsible for the management of all patients, regardless of whether they are taken to an MTC or TU initially. In ELoTS, data derived from TARN demonstrated that 98 patients with ISS greater than 15 remained at TUs. Data capture from this cohort of patients was poor with few case records made available to the study team. We were therefore unable to fully assess the impact of regionalization for patients who remained at a TU without transfer to the regional MTC. From the data available, the median age of patients who remained at a TU postinjury was 82 (IQR: 60–91) and the predominant injury for this cohort was TBI. For patients who were transferred, similar quality improvements seen at MTCs were not observed to the same extent in those patients who were treated at a TU initially (Table 2).

Further analysis of trauma care quality assessment revealed broad differences in the categories of observed deficit between patients seen initially at TUs and those presenting directly to MTCs (Table 3). Poor or incomplete documentation was noted for 1 in 10 cases at MTCs and 8% of patients had room for improvement in 1

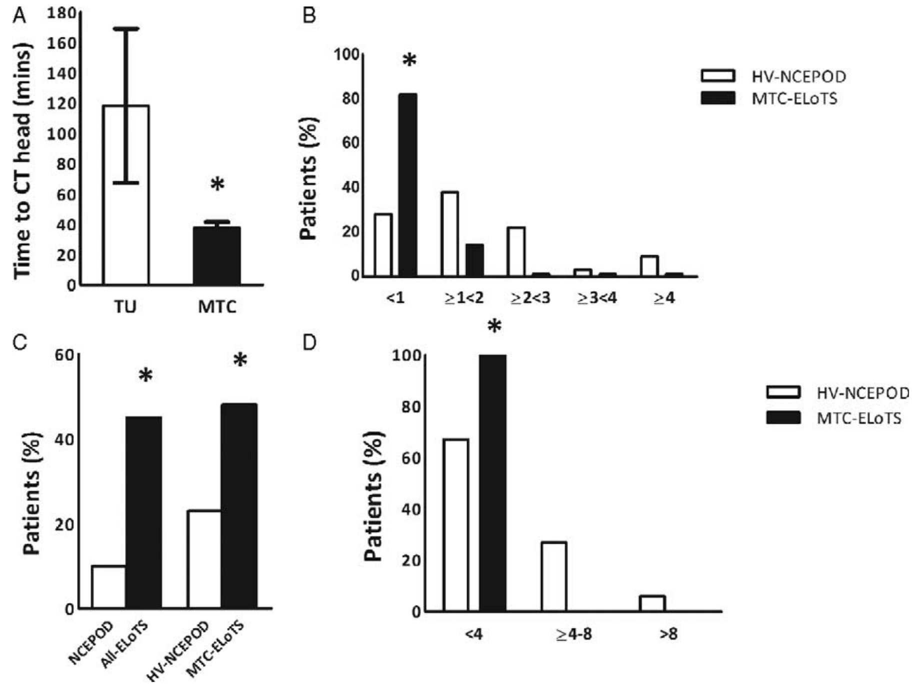

FIGURE 3. (A) Time to CT head. Graph shows average time to CT scan from arrival (95% CI) at ELoTS TU and MTC, TU: 118 min (67 to 169) versus MTC: 38 min (34 to 42), $P < 0.001$. (B) Time to CT head—high volume versus MTC. Graph shows time to CT head per percentage of patients. Patients scanned within 1 h from arrival, HV-NCEPOD: 28% versus MTC-ELoTS: 82%, RR 2.9 [2.2 to 3.8], $P < 0.001$. (C) Time to early neurosurgical review. Graph shows percentage of patients receiving neurosurgical review within 1 h from arrival, NCEPOD: 10% versus All-ELoTS: 45%, RR 4.4 [3.5 to 4.6], $P < 0.001$; HV-NCEPOD: 23% versus MTC-ELoTS: 48%, RR 2.2 [1.6 to 3.1], $P < 0.001$. (D) Time to urgent neurosurgery. Graph shows time to urgent neurosurgical intervention from arrival. Emergency operation within 1 h: HV-NCEPOD: 67% versus MTC-ELoTS: 100%, (RR 1.5 [1.3 to 1.6], $P < 0.001$.

aspect of clinical management. In the available TU case notes, one-third of patients were reported to have had deficits in care resulting from either a lack of senior decision making or clinical care (Table 3).

DISCUSSION

The effects of public health systems on the quality and delivery of care are difficult to evaluate as baseline assessments are rarely available. We have shown that institution of a regional trauma is associated with significant improvements in the overall quality of care for patients treated at MTCs, and that this is almost exclusively due to organizational change. Improvements in the timely delivery of specialist multidisciplinary care were associated with increased survival. However, decreased time-to-process measures such as hemorrhage control may be related to improvements in access rather than specific clinical decision making. The system model did not seem to directly reduce deficits in the clinical aspects of care, and there was a suggestion of increased inequality of access across the region with improvements in quality and data availability in MTCs not observed in TUs. Nevertheless, the implementation of a large inclusive regional trauma system has resulted in demonstrable care quality and outcome benefits for the majority of severely injured trauma patients.

Previous retrospective pre- and postanalyses of an inclusive trauma system reported significantly reduced in-hospital mortality, specifically for those with minor injuries and for patients over the age of 70 years.[12] Three years after implementation, system improvements were associated with improved early mortality for severely and critically injured patients; however, further benefits of the network are as yet unknown. It is important to go beyond mortality and look at other sensitive measures of outcome and system successes. To do this, expert and peer assessment may be more valuable than measuring processes of care and key performance indicators, as it allows a closer, broader evaluation of patient pathways and care. There were expectations that the London Trauma System would lead to improved clinical quality; however, this was not automatically seen at the 3 year time point after implementation.

LTS was designed as an inclusive system, which theoretically should reduce inequalities caused by access issues and variations in standards of care. Trauma system quality guidance primarily focuses on resources at MTCs,[13] yet clearly TUs have an important role to play. Access to data at TUs was very limited but where available did suggest the beneficial effects on care quality seen at MTCs were not observed for patients seen initially in TUs. This observation requires further detailed study to evaluate the effect of volume on care postsystem implementation[14] and potential for unfamiliarity with clinical protocols, reduced engagement or an unintended exclusive approach to trauma care within the network. In an exclusive trauma system only those acute care hospitals with the most resources are designated as trauma centres.[15,16] Evaluation of

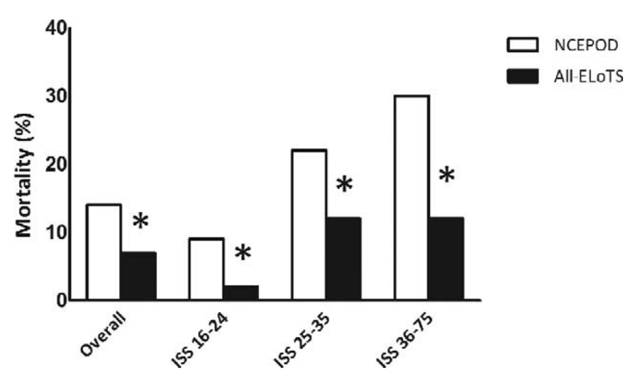

FIGURE 4. Outcome at 72 h NCEPOD versus All-ELoTS patients. Graph shows mortality within 72 h from arrival. Overall: NCEPOD: 15% versus All-ELOTS: 7%, RR 0.46 [0.29 to 0.71], $P < 0.01$; ISS 16–24: NCEPOD: 8% versus All-ELOTS:2%, RR 0.27 [0.09 to 0.79], $P < 0.01$; ISS 25–35: NCEPOD: 22% versus All-ELOTS:13%, RR 0.56 [0.33 to 0.97], $P = 0.03$; ISS 36–75: NCEPOD: 31% versus All-ELOTS 11%, RR 0.37 [0.33 to 0.99], $P = 0.04$.

TABLE 2. Overall Quality Assessment: NCEPOD Versus ELoTS TU Patients

	Good	Clinical Deficits	Organizational Deficits	Deficits in Both	Less Than Satisfactory
All-NCEPOD (795)	380 (48)	129 (16)	180 (23)	65 (8)	41 (5)
LV-NCEPOD (668)	306 (46)	112 (17)	154 (23)	60 (9)	36 (5)
TU-ELoTS (52)	20 (39)	11 (21)	9 (17)	9 (17)	3 (6)

Values are expressed as n (%). $\chi 2$ analysis between low volume and trauma units not significant for any quality category.
LV indicates NCEPOD hospitals not included in the high volume cohort; TU, trauma unit.

TABLE 3. Clinical and Organizational Deficits

Identified Deficits	TU (52)	MTC (269)
Senior review/decision making	15 (29)	13 (5)*
Diagnostic imaging delays	7 (13)	13 (5)*
Poor documentation	6 (12)	27 (10)
Transfer/admission delays	7 (13)	3 (1)*
Clinical issues	17 (33)	22 (8)*
Initial assessment delays	6 (12)	2 (1)*
Airway and respiratory management	3 (6)	6 (2)
Hemorrhage control delays	4 (8)	4 (1)*
C-spine clearance and MSK management	0	6 (2)
TBI assessment delays	4 (8)	0*
Other	0	4 (1)

Values are expressed as n (%).
*$P < 0.01$.
TU indicates trauma unit; MTC, major trauma center; MSK, musculoskeletal; TBI, trauma brain injury.

exclusive systems suggests that although they are cheaper, quality and outcomes are reported to be worse than inclusive systems.[15,17–19] Data available from TUs when compared with lower volume (LV)-NCEPOD suggest that within LTS there exists a degree of system exclusivity with the potential to impact on quality of care. Further work is required across the system as a whole to explore this effect and how it may be mitigated.

There are several limitations to this study which principally relate to availability of data. First, we acknowledge that we were unable to compare the LTS with data from London-only hospitals within the NCEPOD study. The primary objective was not to directly compare specific hospitals but rather evaluate the quality of an organized system of trauma care against the pre-existing standard demonstrated in the 2007 report; however, we recognize the potential differences in populations. Implementation of regional trauma systems across England and Wales since 2010 has largely been based on the London model and therefore we hope that findings from the LTS will have direct relevance for other network evaluation. Second, we could not access all of the records for patients who remained at TUs during the study period. A complete evaluation of quality was therefore only possible for TU patients transferred to an MTC or admitted directly to an MTC and the impact for those remaining at TUs is uncertain. According to TARN, 49% of injured patients in the UK were managed entirely outside of MTCs in 2013, and this figure may be under-reported given data incompleteness nationally (F Lecky, TARN, personal communication). The missing ELoTS TU data does impact on the interpretation of the study findings and requires further evaluation a national level. Third, there was the potential for inter-assessor variability although we aimed to reduce this risk through utilization of the same core NCEPOD assessment criteria during the quality review with emphasis on discussion between grading assessors to improve concordance. Finally, cause and effect cannot be attributed from this observational study. Quality and outcome benefits associated with regionalization may have arisen from other changes in clinical practice, for example, use of tranexamic acid or introduction of hemorrhage protocols, although therapeutic advances in trauma care are more likely to be available initially within MTCs.

In summary, we have assessed the effect of a regional inclusive system on the quality of trauma care and demonstrated clear improvements which translate to tangible patient outcomes. Inclusive trauma systems seem to deliver quality through organizational change, but may not automatically lead to a reduction in preventable errors or improvements in clinical care. Robust system wide performance improvement programmes with quality assurance, multidisciplinary education, and on-going trauma training for MTCs and TUs are required to avoid clinical variance and provide optimal care for all injured patients. Three years after implementation of the LTS, we have shown substantial improvements in the quality and processes of trauma care which are associated in reduced mortality after severe injury in patients treated at MTCs.

ACKNOWLEDGMENTS

Dr Amy Coates, Ms Ilona Dickson, Mrs Aysha Khalid, Mr Simon Luck, Ms Carole Olding, Ms Leila Razavi, Mr Conrad Shaw, and Ms Lisa Waddingham contributed with case identification and TARN verification.

REFERENCES

1. Celso B, Tepas J, Langland-Orban B, et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. *J Trauma*. 2006;60:371–378; discussion 378.
2. Lansink KW, Leenen LP. Do designated trauma systems improve outcome? *Curr Opin Crit Care*. 2007;13:686–690.
3. Gruen RL, Gabbe BJ, Stelfox HT, et al. Indicators of the quality of trauma care and the performance of trauma systems. *Br J Surg*. 2012;99(Suppl 1):97–104.
4. Nathens AB, Cryer HG, Fildes J. The American College of Surgeons Trauma Quality Improvement Program. *Surg Clin North Am*. 2012;92:441–454.
5. Demetriades D, Berne TV, Belzberg H, et al. The impact of a dedicated trauma program on outcome in severely injured patients. *Arch Surg*. 1995;130:216–220.
6. Mullins RJ, Mann NC. Population-based research assessing the effectiveness of trauma systems. *J Trauma*. 1999;47:S59–S66.
7. Sampalis JS, Denis R, Lavoie A, et al. Trauma care regionalization: a process-outcome evaluation. *J Trauma*. 1999;46:565–579; discussion 579-581.
8. Lansink KW, Gunning AC, Spijkers AT, et al. Evaluation of trauma care in a mature level I trauma center in the Netherlands: outcomes in a Dutch mature level I trauma center. *World J Surg*. 2013;37:2353–2359.
9. Findlay GMI, Carter S, Smith N, et al. *Trauma: Who Cares?: A Report of the National Confidential Enquiry into Patient Outcome and Death*. London: NCEPOD; 2007.
10. Healthcare for London. Designation criteria for trauma networks. Available at: http://www.londonhp.nhs.uk/wp-content/uploads/2011/03/Major-trauma-designation-criteria.pdf. 2008. Accessed 18 April 2015.
11. Baker SP, O'Neill B, Haddon Jr W, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14:187–196.
12. Twijnstra MJ, Moons KG, Simmermacher RK, et al. Regional trauma system reduces mortality and changes admission rates: a before and after study. *Ann Surg*. 2010;251:339–343.

13. Rotondo MF, Cribari C, Smith RS. *American College of Surgeons Committee on Trauma: Resources for the Optimal Care of the Injured Patient.*. Chicago: American College of Surgeons; 2014.
14. Karthikesalingam A, Hinchliffe RJ, Loftus IM, et al. Volume-outcome relationships in vascular surgery: the current status. *J Endovasc Ther.* 2010;17: 356–365.
15. Utter GH, Maier RV, Rivara FP, et al. Inclusive trauma systems: do they improve triage or outcomes of the severely injured? *J Trauma*. 2006;60:529–535; discussion 535–537.
16. Evans CC, Tallon JM, Bridge J, et al. An inventory of Canadian trauma systems: opportunities for improving access to trauma care. *CJEM*. 2014;16:207–213.
17. Demetriades D, Martin M, Salim A, et al. The effect of trauma center designation and trauma volume on outcome in specific severe injuries. *Ann Surg*. 2005;242:512–517; discussion 517–519.
18. Nathens AB, Jurkovich GJ, Maier RV, et al. Relationship between trauma center volume and outcomes. *JAMA*. 2001;285:1164–1171.
19. Cudnik MT, Newgard CD, Sayre MR, et al. Level I versus Level II trauma centers: an outcomes-based assessment. *J Trauma*. 2009;66:1321–1326.