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Comparison of trauma care structures, processes and outcomes between the English National Health Service and Quebec, Canada

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Background: Comparisons across trauma systems are key to identifying opportunities to improve trauma care. We aimed to compare trauma service structures, processes and outcomes between the English National Health Service (NHS) and the province of Quebec, Canada.

Methods: We conducted a multicentre cohort study including admissions of patients aged older than 15 years with major trauma to major trauma centres (MTCs) from 2014/15 to 2016/17. We compared structures descriptively, and time to MTC and time in the emergency department (ED) using Wilcoxon tests. We compared mortality, and hospital and intensive care unit (ICU) length of stay (LOS) using multilevel logistic regression with propensity score adjustment, stratified by body region of the worst injury.

Results: The sample comprised 36 337 patients from the NHS and 6484 patients from Quebec. Structural differences in the NHS included advanced prehospital medical teams (v. "scoop and run" in Quebec), helicopter transport (v. fixed-wing aircraft) and trauma team leaders. The median time to an MTC was shorter in Quebec than in the NHS for direct transports (1 h v. 1.5 h, $p < 0.001$) but longer for transfers (2.5 h v. 6 h, $p < 0.001$). Time in the ED was longer in Quebec than in the NHS (6.5 h v. 4.0 h, $p < 0.001$). The adjusted odds of death were higher in Quebec for head injury (odds ratio [OR] 1.28, 95% confidence interval [CI] 1.09–1.51) but lower for thoracoabdominal injuries (OR 0.69, 95% CI 0.52–0.90). The adjusted median hospital LOS was longer for spine, torso and extremity injuries in the NHS than in Quebec, and the median ICU LOS was longer for spine injuries.

Conclusion: We observed significant differences in the structure of trauma care, delays in access and risk-adjusted outcomes between Quebec and the NHS. Future research should assess associations between structures, processes and outcomes to identify opportunities for quality improvement.

Contexte : Il est indispensable de comparer entre eux les différents systèmes intégrés de traumatologie pour identifier les secteurs où les soins peuvent y être améliorés. Nous avons donc procédé à une comparaison descriptive des structures, du fonctionnement et des résultats entre le National Health Service (NHS) du Royaume-Uni et le Québec, au Canada.

Méthodes : Nous avons réalisé une étude de cohorte multicentrique regroupant des victimes de traumatismes majeurs âgées de 15 ans et plus hospitalisées dans de grands centres intégrés de traumatologie (CIT) de 2014/15 à 2016/17. Nous avons procédé à une comparaison descriptive des structures, de l'intervalle médian avant l'arrivée au CIT et de la durée du séjour aux urgences à l'aide de tests de Wilcoxon. Nous avons comparé la mortalité et la durée des séjours à l'hôpital et à l'unité de soins intensifs (USI) par analyse de régression logistique multiniveau avec redressement des scores de propension stratifiée selon les structures anatomiques les plus gravement touchées.

Résultats : L'échantillon comprenait 36 337 cas du NHS et 6484 cas du Québec. Les différences structurelles du NHS incluaient des équipes médicales de soins préhospitaliers d'urgence avancés (c. transport rapide vers un CIT [« scoop and run »] au Québec), le transport par hélicoptère (c. avion à voilure fixe) et des chefs d'équipes de traumatologie. L'intervalle médian avant l'arrivée au CIT a été plus court au Québec par rapport au NHS pour les transports directs (1 h c. 1,5 h, $p < 0{,}001$), mais plus long pour les transferts (2,5 h c. 6 h, $p < 0{,}001$). La durée du séjour aux urgences a été plus longue au Québec par rapport au NHS (6,5 h c. 4,0 h, $p < 0{,}001$). Le risque de mortalité ajusté a été plus élevé au Québec dans les cas de traumatisme crânien (rapport des cotes [RC] 1,28, intervalle de confiance de 95 % [IC] 1,09–1,51), mais moins élevé dans les cas de traumatisme thoraco-abdominal (RC 0,69, IC de 95 % 0,52–0,90). La durée médiane ajustée des séjours hospitaliers a été plus longue dans les cas de traumatisme à la colonne vertébrale, aux membres et au thorax avec le NHS qu'au Québec, et la durée médiane des séjours à l'USI a été plus longue dans les cas de traumatisme à la colonne vertébrale.

Conclusion : Nous avons observé des différences significatives quant à la structure des soins en traumatologie, quant aux délais pour y accéder et quant aux résultats ajustés en fonction du risque entre le Québec et le NHS. La recherche future devrait se pencher sur les liens entre les structures, le fonctionnement et les résultats afin de mieux cibler les secteurs où il serait possible d'apporter des améliorations.

Injuries are a major public health issue. They represent the primary cause of death for people younger than 40 years, as well as loss of active life years and temporary or permanent disability for all age groups in North America, Europe and Australia.[1,2] In terms of health care costs, injuries are second only to cardiovascular diseases in Canada and the United States.[1,3]

To reduce the burden of injuries, many regions in North America, Europe and Australia have introduced integrated trauma systems, defined as organized, regional and multidisciplinary structures with the objective of ensuring adequate and optimal management of patients with major trauma.[4,5] Trauma systems have been associated with reductions in mortality, disabilities and costs after injury.[6,7] Quality-improvement programs based on internal benchmarking have been implemented in trauma systems in many high-income countries, including the US (American College of Surgeons Trauma Quality Improvement Program, https://www.facs.org/quality-programs/trauma/quality/trauma-quality-improvement-program/), Australia (Victorian State Trauma Outcomes Registry and Monitoring Group [VSTORM], https://www.monash.edu/medicine/sphpm/vstorm/home) and the United Kingdom (The Trauma Audit & Research Network, https://www.tarn.ac.uk/). These programs allow comparisons of risk-adjusted outcomes across hospitals within a system. Comparisons across trauma systems are key to identifying further opportunities to improve trauma care.[8]

The Trauma and Injury Severity Score made it possible to conduct international comparisons of trauma centres/systems. However, this score is now outdated and is based on a risk-adjustment model with important limits, which may lead to some hospitals' being wrongly labelled as outliers.[9] Furthermore, this method is based solely on mortality, and its validity may be questioned when the patient population or the health care system under evaluation is different from that observed in the US. Other investigators have directly compared trauma systems by looking separately at mortality, adherence to a single clinical process, or the degree of maturity of trauma system structures.[10,11] To our knowledge, studies comparing structures, processes and outcomes across trauma systems are currently lacking. The primary goal of this study was to compare mortality and hospital and intensive care unit (ICU) length of stay (LOS) between Quebec, Canada, and England by means of propensity score analysis. Secondary objectives were to compare system structures and processes related to access to major trauma centres (MTCs).

Methods

This study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[12] The study methods including the statistical analysis plan were established a priori in a protocol approved by all coauthors. However, this protocol was not registered or published.

Study design and setting

We conducted a retrospective multicentre cohort study based on admissions for major trauma to MTCs in the integrated trauma system of Quebec (level I and II centres) and the English National Health Service (NHS) between Apr. 1, 2014, and Mar. 31, 2017.

The population of the UK (56 million) is 7 times that of the province of Quebec, but the country covers only one-tenth of Quebec's territory (0.15 million km^2 v. 1.7 million km^2), with an estimated average population density of 407/km^2, compared to 5.6/km^2 in Quebec.[13,14]

In Quebec, the trauma system was initiated in 1992 by the Quebec Ministry of Health and Social Services and centralized to 59 health care facilities.[15] These hospitals are networked according to geographic and demographic factors into 5 level I centres (3 adult and 2 pediatric hospitals), 5 level II centres, 21 level III centres and 28 level IV centres, which together cover more than 88% of major trauma admissions. All patients treated for an injury in any trauma centre in this system are recorded in the provincial trauma registry (système d'information du Registre des traumatismes du Québec).

In April 2012, the NHS instated regional trauma networks, each comprising 1 or more hospitals assigned as MTCs, in addition to satellite hospitals, designated as trauma units. Depending on the severity of the injury, these units may provide definitive treatment or initial stabilization.[16] There are currently 27 MTCs in the NHS, including 11 for adults, 5 for children, and 11 for both adults and children, and 154 trauma units. The Trauma Research and Audit Network collects data on patients admitted to hospital for major trauma in the NHS. The network is funded by participating hospitals and administrators that submit data to facilitate quality improvement and quality assurance of hospital care for patients with major injury.[16] The registry coverage is complete for major trauma (all MTCs and trauma units submit data on trauma cases).

Both registries contain information on sociodemographic characteristics, injury descriptions, physiologic parameters, diagnostic and therapeutic interventions, and patient outcomes. Trained data coders abstract data from patient charts in each system according to a harmonized data dictionary. The Abbreviated Injury Scale (AIS) 2008 is used to code injuries; AIS coding is conducted locally in Quebec and centrally in the NHS.

Study population and data

We included all adults (> 15 yr of age) with an Injury Severity Score greater than 12 who had a hospital stay of at least 48 hours in an MTC (equivalent to level I or II). We excluded patients identified as dead on arrival; those who had experienced burns, hypothermia or drowning, or were intoxicated without concomitant injury; and admissions secondary to complications (sequelae). For all variables included in the analyses, we compared registry definitions between the système d'information du Registre des traumatismes du Québec and the Trauma Research and Audit Network, harmonized definitions when appropriate, and developed a sensitivity analysis plan according to differences that could not be harmonized.

Ethics committee approval was obtained from the CHU de Quebec – Université Laval. The Trauma Research and Audit Network has UK Health Research Authority Approval (PIAG Section 251) for analysis of the anonymized data it holds.

Trauma system structures and processes of care

We compared trauma system structures descriptively using elements previously used in the literature for comparisons of trauma systems (population coverage of trauma centres, designation/accreditation, prehospital triage, prehospital interventions, trauma team leaders and benchmarking activities).[17]

For processes of care, we focused on delays (access to care) using data that were comparable across the 2 systems. We thus compared time to an MTC, determined in hours from the incident to arrival in the emergency department (ED) of the MTC, stratified by transfer status (transferred from another acute care hospital v. direct transport) and time in the ED, calculated as hours from arrival in the ED to transfer to a ward.

Outcome measures

Our primary outcome was mortality, defined as any death after arrival in the ED and before hospital discharge (30-d in-hospital death was used in sensitivity analyses). Secondary outcomes were hospital and ICU LOS, both determined as days from admission to discharge.

Statistical analysis

We compared time to the MTC and time in the ED using the Wilcoxon test. To compare outcomes, we conducted risk adjustment using propensity scores based on the propensity to be treated in one system over the other, conditional on risk factors specific to each outcome (established by literature review and consultation with experts). These risk factors included age, sex, modified Charlson Comorbidity Index score, body region of the worst injury, maximum AIS score, Glasgow Coma Scale (GCS) score and systolic blood pressure measured on arrival at the MTC, mechanism of injury and transfer. All variables were treated in categories according to cut points frequently used in the literature.[9]

For mortality, we generated risk-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) using a multilevel logistic regression model in which the propensity score and the trauma system (Quebec v. NHS) were entered as fixed effects, and the hospital was modelled as a random intercept to take into account the clustering of patients within hospitals. To account for survival bias in the analysis of hospital and ICU LOS, we used the Fine–Gray competing risks model to generate risk-adjusted hazard ratios (HRs) and 95% CIs.[18] This is a proportional hazards model that includes deaths but censors them at the maximum observed LOS. We censored patient outliers at the 95th percentile (90 d and 60 d for hospital LOS and ICU LOS, respectively).

We adjusted the propensity score in both models by entering the propensity score as a categoric variable (quantiles) in addition to any covariable that was unbalanced between groups, following published recommendations on propensity score analyses.[19] We assessed balance by standardized difference for continuous and dichotomous covariates with a threshold fixed at greater than 0.10. Analyses were performed for the whole sample and then stratified by body region of the most serious injury (head, thoracoabdominal, spine or extremities). For each region, we also stratified by age (< 65 yr, ≥ 65 yr).

To handle missing data, we used multiple imputation. Imputation models included all independent and dependent variables in respective analytical models. We used the Markov chain Monte Carlo method to generate 20 data sets based on the highest proportion of missing data.[20]

Sensitivity analyses

To assess the robustness of the results, we conducted sensitivity analyses planned a priori. First, for mortality, we repeated analyses after excluding observations with missing data (may have different mechanisms of missing data across systems) and patients aged 85 or older (differences in level of care directives). We then excluded the variable comorbidities from the model (may have been recorded differently across systems) and level II centres in Quebec. Finally, we repeated analyses on mortality by restricting observations by time to death (24 h, 72 h, 7 d, 30 d). Second, for hospital and ICU LOS, we repeated analyses after excluding patients transferred to another acute care facility. All analyses were conducted using SAS System for Windows, Version 9.4 (SAS Institute).

Results

Trauma system structures

During the study period (2014/15 to 2016/17), Quebec presented a higher number of centres per 100 000 population than the NHS (Table 1). For prehospital care, both systems bypassed smaller hospitals for patients within 60 minutes of an MTC. However, triage criteria were uniform in Quebec and variable across NHS regions, and advanced emergency interventions (e.g., tracheal intubation) were provided on scene in the NHS but not in Quebec. For the organization of intrahospital care, the on-site presence of a trauma team leader was ensured at all MTCs in the NHS, whereas it was available in only 1 level I centre in Quebec. In other hospitals, care coordination was at the discretion of the ED physician.[21] Both Quebec and the NHS used process and outcome quality indicators, but more indicators were used in Quebec than in the NHS, and feedback and accountability differed across the 2 systems.

Study populations

The final study sample included 6484 cases from Quebec and 36 337 cases from the NHS (Figure 1). The GCS score and systolic blood pressure were missing in 8.7% and 0.6% of observations, respectively, in Quebec, and 20.6% and 19.1%, respectively, in the NHS. Patients were slightly older in Quebec (2820 [44.3%] v. 13 660 [37.6%] aged ≥ 65 yr) but a greater proportion had no comorbidities recorded (4026 [62.1%] v. 19 835 [54.6%]) (Table 2).

Table 1. Trauma system components and benchmarking activities in Quebec and the English National Health Service*

Component/activity	Quebec	NHS
Trauma system component		
Trauma centres	10 MTCs (5 level I [3 adult centres and 2 pediatric centres], 5 level II, 21 level III, 28 level IV)	27 MTCs, 154 trauma units
No. of MTCs per 100 000 population	0.125	0.05
No. of MTCs per 1000 km^2	0.006	0.111
Designation/accreditation	Institut national d’excellence en santé et services sociaux; mandatory	Strategic Health Authorities; mandatory
Prehospital triage	Uniform, validated tool (adapted from American College of Surgeons Committee on Trauma)	Varies across regions
Bypass to MTC	60 min	60 min
Highest level of prehospital care	Level II. Basic Life Support	Level IV. Advanced Life Support On-Scene, Physician Field Care
Prehospital intubation	None	Tracheal intubation Surgical airway Nontracheal intubation intervention: pharyngeal tube, supraglottic airway device, airway positioning
Prehospital transportation	Ground; fixed-wing aircraft	Ground; fixed-wing aircraft; helicopter
Trauma team leader	In 1 level I hospital	All MTCs
Benchmarking activities		
Process indicators	13	Tranexamic acid, rapid sequence intubation, rehabilitation prescription
Risk-adjusted outcomes	Death, readmission, complications, hospital length of stay	Death
Feedback	Confidential audit and feedback reports	Publicly available reports, dashboards, best practice tariffs, alerts (2 SDs), alarms (3 SDs)
Accountability	Mandatory quality-improvement report; linked to accreditation	Pay-for-performance indicators
Frequency	Accreditation cycles (about 3 yr)	4 mo (reports), 3 mo (dashboard)

MTC = major trauma centre; NHS = English National Health Service; SD = standard deviation.
*Sources: The Trauma Audit & Research Network (https://www.tarn.ac.uk/) and the Trauma Care Continuum, Institut national d’excellence en santé et services sociaux (https://www.inesss.qc.ca/thematiques/sante/traumatologie/continuum-de-services-en-traumatologie-cst.html).

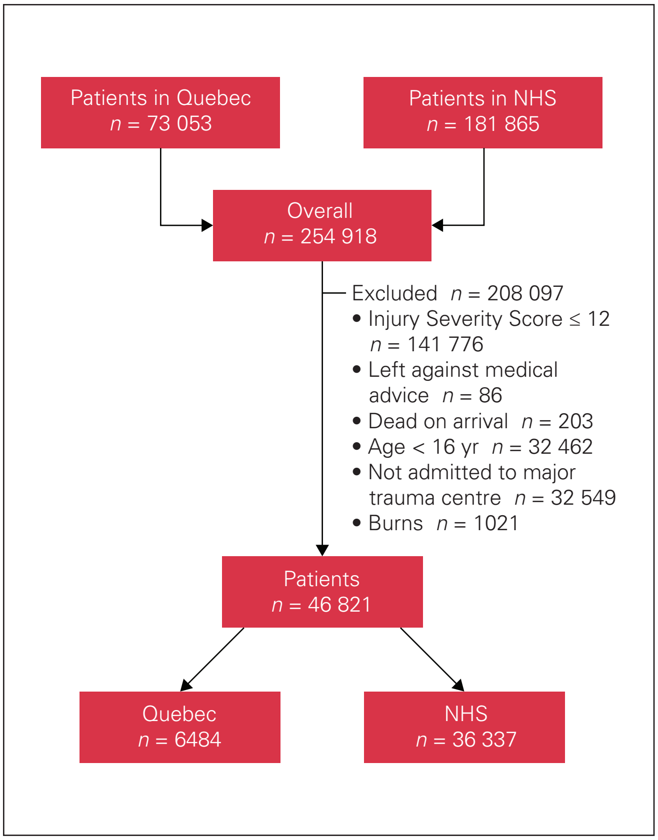

Fig. 1. Flow diagram showing selection of patients from Quebec and the English National Health Service (NHS).

The 2 systems had similar proportions of males and head injuries and similar GCS scores, but injuries were less severe in Quebec than in the NHS (2484 patients [38.3%] v. 7976 patients [22.0%] with maximum AIS score of 3). In Quebec, more than half of patients (3363 [51.9%]) were transferred in from another hospital, compared to 14 166 patients (39.0%) in the NHS.

Processes of care

Globally, the median time to the MTC was 1 hour longer in Quebec than in the NHS (2.7 h [interquartile range 1.0–6.2 h] v. 1.6 h [interquartile range 1.2–2.2 h], $p < 0.001$). When we stratified by transport status, the median time to an MTC was 30 minutes shorter for patients transported directly in Quebec than in the NHS, whereas it was 210 minutes longer for patients transferred in from another acute care hospital (Table 3). This difference was observed for all patient subgroups. The median time in the ED was shorter in the NHS than in Quebec, both globally and in all subgroups ($p < 0.001$).

Outcomes

The overall crude mortality rate was 13.2% (n = 855) in Quebec and 11.8% (n = 4299) in the NHS. The adjusted odds of death for all major trauma were higher in Quebec than in the NHS (OR 1.16, 95% CI 1.02–1.33) (Table 4). Similarly, analyses of injury subgroups suggested that the adjusted odds of death were higher in Quebec than in the NHS for head injury (OR 1.28, 95% CI 1.09–1.51) and extremity injury (OR 1.77, 95% CI 1.00–3.12 globally and OR 2.03, 95% CI 1.06–3.88 for patients ≥ 65 yr of age). However, the odds of death for thoracoabdominal injury

Table 2. Characteristics of patients with major trauma in Quebec and the English National Health Service, 2014/15 to 2016/17

Characteristic	No. (%) of patients Quebec n = 6484	No. (%) of patients NHS n = 36 337
Age, yr		
16–44	1778 (27.4)	12 993 (35.7)
45–54	761 (11.7)	5006 (13.8)
55–64	1075 (16.6)	4678 (12.9)
65–75	1152 (17.8)	5157 (14.2)
≥ 76	1718 (26.5)	8503 (23.4)
Male sex	4542 (70.0)	25 266 (69.5)
Modified Charlson Comorbidity Index score		
0	4026 (62.1)	19 835 (54.6)
1–5	1216 (18.7)	12 376 (34.0)
6–10	447 (6.9)	3213 (8.8)
≥ 11	795 (12.3)	913 (2.5)
Mechanism of injury		
Motor vehicle	2200 (33.9)	12 942 (35.6)
Low fall	1404 (21.6)	12 406 (34.1)
High fall	1854 (28.6)	7188 (19.8)
Stabbing, shooting	227 (3.5)	1099 (3.0)
Other	799 (12.3)	2702 (7.4)
Body region of most severe injury		
Head	3549 (54.7)	20 301 (55.9)
Thorax	1564 (24.1)	8655 (23.8)
Abdomen	232 (3.6)	1097 (3.0)
Spine	718 (11.1)	2627 (7.2)
Extremity	390 (6.0)	3494 (9.6)
Other	31 (0.5)	163 (0.4)
Injury Severity Scale score		
12–16	1612 (24.9)	9821 (27.0)
17–24	2082 (32.1)	9773 (26.9)
25–39	2552 (39.4)	14 885 (41.0)
≥ 40	238 (3.7)	1858 (5.11)
Maximum Abbreviated Injury Scale score		
3	2484 (38.3)	7976 (21.9)
4	1758 (27.1)	13 567 (37.3)
5–6	2242 (34.6)	14 794 (40.7)
Glasgow Coma Scale score		
3–8	1140 (17.6)	5561 (15.3)
9–12	462 (7.1)	2879 (7.9)
13–15	4882 (75.3)	27 897 (76.8)
Systolic blood pressure, mm Hg		
≥ 90	6263 (96.6)	34 609 (95.2)
< 90	221 (3.4)	1728 (4.8)
Transfer	3363 (51.9)	14 166 (39.0)

NHS = English National Health Service.

Table 3. Comparison of median time to major trauma centre and median time in the emergency department			
	Median (IQR)		
Variable	Quebec	NHS	*p* value
Overall			
Time to MTC, h	2.7 (1.0–6.2)	1.6 (1.2–2.2)	< 0.001
Transfer	6.0 (4.0–9.3)	2.5 (1.5–4.9)	< 0.001
No transfer	1.0 (0.7–1.5)	1.5 (1.1–1.9)	< 0.001
Time in ED	6.4 (3.1–16.1)	4.0 (2.8–6.1)	< 0.001
Head injury			
Time to MTC	2.9 (1.0–5.9)	1.5 (1.1–1.2)	< 0.001
Transfer	5.3 (3.6–8.3)	2.9 (1.5–5.0)	< 0.001
No transfer	0.9 (0.7–1.4)	1.4 (1.1–1.8)	< 0.001
Time in ED	5.8 (2.8–15.8)	4.0 (2.6–5.9)	< 0.001
Thoracoabdominal injury			
Time to MTC	1.9 (0.9–6.2)	1.6 (1.2–2.2)	< 0.001
Transfer	6.6 (4.6–10.7)	2.6 (1.7–5.1)	< 0.001
No transfer	1.0 (0.7–1.5)	1.6 (1.2–2.0)	< 0.001
Time in ED	6.7 (3.1–16.1)	4.1 (3.0–6.1)	< 0.001
Spine injury			
Time to MTC	4.4 (1.4–8.4)	1.7 (1.3–2.3)	< 0.001
Transfer	7.0 (4.9–11.9)	2.0 (1.4–4.1)	< 0.001
No transfer	1.2 (0.9–1.9)	1.7 (1.3–2.2)	< 0.001
Time in ED	9.0 (4.7–18.7)	4.7 (3.4–6.9)	< 0.001
Extremity injury			
Time to MTC	1.9 (0.9–5.9)	1.7 (1.3–2.3)	0.009
Transfer	5.9 (4.1–7.7)	2.0 (1.5–4.4)	< 0.001
No transfer	1.0 (0.7–1.7)	1.6 (1.2–2.1)	< 0.001
Time in ED	5.5 (3.2–12.4)	4.1 (3.1–6.1)	< 0.001

ED = emergency department; IQR = interquartile range; MTC = major trauma centre; NHS = English National Health Service.

were lower in Quebec than in the NHS (OR 0.69, 95% CI 0.52–0.90). The odds of death for spine injuries were not statistically different between the 2 trauma systems.

The median hospital LOS was 14.6 days (standard deviation [SD] 16.4 d) in Quebec and 18.2 days (SD 25.4 d) in the NHS. After risk adjustment, the HR suggested a slightly shorter hospital LOS in Quebec in the overall sample that did not reach statistical significance (HR 1.09, 95% CI 0.98–1.21) (Table 4) (note that an HR greater than 1 indicates a higher hazard of discharge and therefore shorter LOS). Analyses of injury subgroups showed shorter hospital LOS in Quebec than in the NHS for patients with thoracoabdominal injuries (HR 1.17, 95% CI 1.06–1.29) and for patients less than 65 years of age with spinal injuries and extremity injuries (HR 1.64, 95% CI 1.04–2.58, and HR 1.35, 95% CI 1.06–1.71, respectively). Proportional hazards assumptions were respected in all models.

During their hospital stay, 16 367 patients (45.0%) in the NHS and 3767 patients (58.1%) in Quebec were admitted to the ICU. The crude median ICU LOS was 8.7 (SD 12.4) days in the NHS and 7.7 (SD 8.7) days in Quebec. The proportion of patients with head injury admitted to the ICU was similar in the NHS and Quebec (20 639 [56.8%] and 3741 [57.7%]), whereas a higher proportion of patients with thoracoabdominal injury were admitted to the ICU in the NHS than in Quebec (9629 [26.5%] v. 1400 [21.6%]). In the overall sample and in subgroups with head and thoracoabdominal injuries, risk-adjusted ICU stays were similar between the 2 trauma systems (Table 4). For patients with spine injuries, the ICU LOS was shorter in Quebec than in the NHS for patients younger than 65 years of age (HR 1.45, 95% CI 1.07–1.96).

Sensitivity analysis

In each sensitivity analysis, the adjusted odds of death were very similar to the results of the main analyses (Table 5). However, no difference in the odds of death within 24 hours of arrival was observed. In Quebec, there was a trend toward lower hospital LOS when deaths or patients transferred to another acute care hospital were excluded.

Discussion

In this retrospective, international cohort study, we observed differences in trauma system structure, processes and risk-adjusted outcomes between Quebec and the NHS. Notably, in Quebec, time to an MTC was shorter for patients transported directly and longer for those who were transferred in, and time in the ED was longer than in the NHS. Patients managed at MTCs in Quebec had a greater risk-adjusted odds of death than those in the NHS, specifically patients with a head injury, and those aged 65 years or older with extremity injuries. Conversely, patients with thoracoabdominal injuries had greater odds of death in the NHS than in Quebec. Hospital LOS was shorter in Quebec than in the NHS for patients with thoracoabdominal injuries, and those younger than 65 years of age with spine or extremity injuries. Intensive care unit LOS was shorter in Quebec than in the NHS for patients with spinal injuries.

Previous studies have shown differences in outcomes before and after implementation of trauma systems, and between inclusive and exclusive systems.[6,22] However, few investigators have compared countries with an integrated (inclusive) trauma system.[23,24] A Canadian study showed that the odds of death among patients admitted in inclusive systems was 32% lower than the odds among patients admitted in noninclusive systems.[25] This result persisted in patient subgroups, especially those with head or thoracoabdominal injuries. The authors suggested that these differences might be explained by the presence of a greater number of recommended trauma system components. Other studies have shown a decrease in hospital and ICU LOS after the introduction of trauma systems, and shorter LOS in countries with an inclusive rather than an exclusive trauma system.[26–28] Matsumoto and colleagues[24] observed a

Table 4. Odds of death and hazard ratios for hospital and intensive care unit length of stay*

Region of injury; subgroup	Death, adjusted OR† (95% CI)†	Adjusted HR† (95% CI)‡	
		Hospital LOS	ICU LOS
Overall	1.16 (1.02–1.33)	1.09 (0.98–1.21)	1.00 (0.90–1.11)
Head			
Overall	1.28 (1.09–1.51)	0.99 (0.85–1.16)	1.01 (0.89–1.16)
Age < 65 yr	1.35 (1.06–1.73)	0.90 (0.70–1.16)	0.96 (0.83–1.11)
Age ≥ 65 yr	1.27 (1.04–1.57)	0.91 (0.80–1.04)	1.02 (0.86–1.22)
Thoracoabdominal			
Overall	0.69 (0.52–0.90)	1.17 (1.06–1.29)	1.01 (0.87–1.18)
Age < 65 yr	0.67 (0.44–1.00)	1.23 (1.09–1.40)	1.03 (0.87–1.22)
Age ≥ 65 yr	0.69 (0.48–0.99)	1.17 (1.00–1.37)	0.99 (0.78–1.25)
Spine			
Overall	1.30 (0.71–2.35)	1.23 (0.97–1.56)	1.36 (1.07–1.71)
Age < 65 yr	1.27 (0.36–4.50)	1.64 (1.04–2.58)	1.45 (1.07–1.96)
Age ≥ 65 yr	1.31 (0.66–2.60)	1.16 (0.90–1.49)	1.26 (0.83–1.92)
Extremities			
Overall	1.77 (1.00–3.12)	1.07 (0.90–1.28)	0.80 (0.64–0.99)
Age < 65 yr	1.37 (0.39–4.83)	1.35 (1.06–1.71)	0.80 (0.62–1.04)
Age ≥ 65 yr	2.03 (1.06–3.88)	0.93 (0.69–1.27)	0.67 (0.43–1.05)

CI = confidence interval; HR = hazard ratio; ICU = intensive care unit; LOS = length of stay; OR = odds ratio; NHS = English National Health Service.
*Reference is NHS.
†Adjusted for the following variables in a propensity score: age, sex, modified Charlson Comorbidity Index score, body region of worst injury, maximum Abbreviated Injury Scale score, Glasgow Coma Scale score, systolic blood pressure, mechanism of injury and transfer.
‡Where the hazard of discharge is modelled so that HRs greater than 1 indicate shorter LOS in Quebec than in the NHS (reference).

Table 5. Odds of death and hazard ratios for hospital and intensive care unit length of stay in sensitivity analysis*

Variable	Death, adjusted OR† (95% CI)	Adjusted HR† (95% CI)‡	
		Hospital LOS	ICU LOS
All patients	1.16 (1.02–1.33)	1.09 (0.98–1.21)	1.00 (0.90–1.11)
Complete data observations	1.18 (0.99–1.40)	1.06 (0.94–1.19)	0.96 (0.85–1.08)
Only level I hospitals in Quebec	1.16 (0.97–1.39)	1.01 (0.86–1.19)	0.91 (0.78–1.06)
Without adjustment for comorbidities	1.21 (0.98–1.38)	1.10 (0.99–1.23)	1.01 (0.90–1.13)
Patients aged < 85 yr	1.18 (1.00–1.36)	1.11 (0.99–1.25)	0.98 (0.88–1.10)
30-d in-hospital mortality	1.10 (0.96–1.27)	—	—
7-d mortality	1.10 (0.94–1.29)	—	—
72-h mortality	1.15 (0.95–1.38)	—	—
24-h mortality	1.04 (0.83–1.30)	—	—
Deaths excluded	—	1.29 (1.11–1.50)	1.12 (0.96–1.32)
Transfer to another acute care hospital excluded	—	1.35 (1.19–1.55)	—

CI = confidence interval; ICU = intensive care unit; HR = hazard ratio; LOS = length of stay; OR = odds ratio; NHS = English National Health Service.
*Reference is NHS.
†Adjusted for the following variables in a propensity score: age, sex, modified Charlson Comorbidity Index score, body region of worst injury, maximum Abbreviated Injury Scale score, Glasgow Coma Scale score, systolic blood pressure, mechanism of injury and transfer.
‡Where the hazard of discharge is modelled so that HRs greater than 1 indicate shorter LOS in Quebec than in the NHS (reference).

significant difference in mean hospital LOS between Japan (18 d) and the US (5 d). They hypothesized that this difference may have been due to wishes of patients and families to stay in the hospital as long as possible in Japan.

The median prehospital time in the present study was on average 30 minutes shorter in Quebec than in the NHS for direct transports, probably owing to the "scoop and run" strategy associated with basic life support at the scene in the province, compared to the "stay and play" strategy associated with advanced life support in the NHS. This may explain the lower odds of death among patients with thoracoabdominal injuries. Because hemorrhagic shock is a time-sensitive condition — more than 21% of patients die within 6 hours of injury[29] — this group of patients will benefit most from rapid evacuation to an MTC. In contrast, patients with head injury have been shown to benefit from prehospital advanced life support techniques such as tracheal intubation and drug administration, which are not performed in Quebec.[30,31] The median ED time was 2 hours shorter in the NHS than in Quebec (4 h v. 6 h), despite the fact that both systems work on 4-hour targets for ED stays. This might be explained by the advanced resuscitation techniques used in the prehospital setting in the NHS coupled with the presence of a trauma team leader on site in all MTCs. Multidisciplinary trauma team leader paradigms have been shown to improve patient outcomes.[21] Longer ED time may also reflect problems in access to ward beds, ICU beds or surgical care, which have been shown to be the most important determinants of time in the ED.[32,33]

The observed differences in outcomes in our study may be explained by geographic differences. The NHS covers a smaller geographic area than Quebec, with high population density, multiple MTCs and relatively stable weather conditions. All these factors can improve timely access to care, as shown by the overall shorter time to the MTC in the NHS than in Quebec. Differences in prehospital trauma system structure and patient management, including prehospital interventions, triage criteria and transport, may also explain the observed differences in outcomes. The observed differences in mortality may also have been due to different approaches to withholding or withdrawing active measures of care. In a pan-Canadian multicentre prospective cohort study, 70% of deaths among patients with traumatic brain injuries occurred after withdrawal of active measures of care, and significant variation in the proportion of deaths after withdrawal of active measures of care was observed across providers.[34] The withholding or withdrawal of life-sustaining treatment can be partly driven by cultural, religious or spiritual beliefs of patients, their families and medical teams,[35] which are likely to differ across countries. Likewise, this difference might be due to hospital-specific treatment protocols or differences in prognosis determination.[36] We did not have information on decisions to withhold or withdraw care in either of the trauma systems.

Since discharge destination is the most important determinant of hospital LOS,[37] the finding that hospital and ICU LOS were shorter in Quebec than in the NHS, particularly among patients aged younger than 65 years with spine, thoracoabdominal or extremity injuries, suggests that challenges in transfer to long-term care and rehabilitation differ between the 2 systems. Unlike the NHS, Quebec has a “zero delay to rehabilitation” policy, which may explain the shorter hospital LOS, particularly for younger patients and those with spine injuries.[38]

The observed differences in the structure of trauma care, access to care and risk-adjusted outcomes between 2 integrated trauma systems allow us to generate hypotheses for future research. First, differences in geographic distribution (higher population density in the NHS) and prehospital care (stay and play in the NHS) may explain shorter times to the MTC for transfers and longer times for direct transports, respectively, in the NHS. Second, longer overall time to the MTC in Quebec may partly explain the lower mortality rate among patients with head injuries in the NHS (all patients with major head injuries must be transferred to an MTC), whereas shorter times for direct transports in Quebec may explain the lower mortality rate among patient with thoracoabdominal injuries, despite longer ED times in Quebec (major thoracoabdominal injuries can be treated at the nearest hospital with general surgery). Third, longer LOS in the NHS, particularly for younger patients, may reflect challenges in access to rehabilitation. Future research should strive to develop models using observed data or simulations that incorporate system, processes and outcomes to explore hypotheses regarding the role of structures and processes in outcome variations.

Limitations

This study has several strengths, including harmonized inclusion criteria and standardized data collection procedures with rigorous quality control of data collected over the same period. Unlike studies based solely on hospital administrative data,[22] our study used data that allowed adjustment for several physiologic parameters and injury severity. In addition, we had access to large samples with good population coverage for both trauma systems. The similarity of the 2 populations (a high proportion of older patients, a low proportion of penetrating trauma and a single-payer health care system) represents a major advantage for the validity of the comparisons. The propensity score method, which significantly improved the case-mix balance between populations, was also a strength of our study.

Regarding limitations, residual confounding may have been present owing to confounding factors subject to measurement errors (e.g., GCS score measured once, on arrival) or factors that were not measured (e.g., pupillary activity, episodes of intracranial hypertension in patients with traumatic brain injuries). Second, intersystem differences in coding may have led to biased comparisons. For example, comorbidities are notoriously underreported in clinical registries.[39] However, in the sensitivity analyses, the results were similar with and without adjustment for comorbidities. Third, the GCS score was missing in varying proportions in the 2 systems. We used multiple imputation to handle missing data. However, the validity of this approach depends on the assumption that data are missing at random. Even though this could not be verified, our knowledge of the mechanisms of missing data in either system suggests that available data explained the missing data mechanism well. When imputation models are specified correctly, multiple imputation of missing physiologic data in trauma registries has been shown to lead to valid effect estimates.[40] Fourth, we had no information on prehospital death or on patients with major trauma discharged before 48 hours. This may have led to selection bias, which may have affected comparisons between systems. Finally, owing to the lack of aggregated national trauma data in Canada, our comparison was limited to 1 Canadian province.

Conclusion

In this international cohort study, we observed differences in patient mortality, hospital LOS and ICU LOS between 2 inclusive trauma systems, which may be explained by differences in the structure of the systems and timely access to specialized care. The results highlight the potential value of international comparisons for quality improvement and underline the need for an international core data set with harmonized data elements (e.g., the Utstein template[41]). To be optimal, this data set would need to incorporate data on prehospital death, level-of-care decisions and patient-reported outcomes, including function in daily activities and quality of life.

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