Temporal trends and differences in trauma centre hospital mortality across Ontario from 2005 to 2011

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Abstract

Background: The primary objective of this analysis was to evaluate differences in trauma centre-related mortality over time. Secondarily, we explored trauma centre-specific mortality to determine the extent of variation across centres.

Methods: Data on 26,421 adults (≥18y) admitted to a trauma centre between 2005-2011, were derived from the Ontario Trauma Registry. Generalized estimating equations were used to estimate in-hospital mortality over time. Hierarchical models were used to estimate trauma centre-specific mortality. To quantify variability between centres, median odds ratios were calculated. Adjusted odds of death were calculated for each trauma centre to identify centers with higher, average, and lower than expected mortality.

Results: Mortality decreased from 13.2% in 2005 to 11.2% in 2009. After adjusting for case-mix, the odds of death decreased by approximately 3% (95%CI 0-5%) per year. Trauma centre-specific mortality ranged from 11.4% to 13.1%. After adjusting for case-mix, differences in trauma centre-specific mortality were observed (median odds ratio=1.25), suggesting that the odds of dying were 1.25-fold greater if the same patient was admitted to one randomly selected trauma centre as opposed to another. Differences were most pronounced in isolated head injuries and elderly patients as evidenced by higher median odds ratios and number of outliers.

Interpretation: We observed significant improvement over time in the mortality of severely injured patients cared for at Ontario's trauma centres. However, considerable differences in trauma centre-specific mortality were observed. Differences were most pronounced in the elderly injured and those with isolated traumatic brain injury. System-wide performance improvement initiatives should target these subgroups.

Background

In Canada, injury is a significant public health concern. It is the leading cause of death in those 44 years or younger and the fifth overall leading cause of death.(1) In 2004, there were over 3 million visits to the emergency department due to injuries and over 200,000 of these patients required hospitalization. These injuries resulted in over 13,000 deaths, 5,000 permanent disabilities, and 62,000 partial disabilities.(2) In Ontario, one out of every four emergency department visits and one of every seventeen hospitalizations in 2002-2003 were injury-related.(3) The total annual cost of injury in the province of Ontario in 2004 was approximately 6.8 billion dollars.(2)

In June 1990, Ontario's Ministry of Health and Long Term Care designated nine hospitals as adult trauma centres. Designation was accompanied by funding for infrastructure, 24-hour physician coverage, and incremental funding for each major trauma case.(4) In addition to designation, trauma centres underwent an initial process of voluntary external accreditation in 2006 by the Trauma Association of Canada that evaluated the availability of resources and personnel essential for caring for injured patients.

Large prospective studies have shown that trauma centre care is associated with a 25% lower 1-year mortality as well as improved functional outcomes after severe injury when compared with care at similarly resourced non-trauma centres.(5, 6). However, it is evident that outcomes across similarly accredited trauma centres are not equivalent, even after considering differences in case mix.(7–9)

The primary objective of this analysis was to evaluate differences in trauma centre-related mortality among severely injured adults over time. Secondarily, we explored the extent of variation in mortality across trauma centres with a view to guiding system-wide performance improvement.

Methods

Setting and data source

Nine designated adult trauma centres serve Ontario's 13 million residents. The majority of Ontario's trauma centres (7 of 9) underwent external accreditation by the Trauma Association of Canada in 2006; thus, most have similar human and physical resources required for the care of injured patients.(10)

Data were derived from the Ontario Trauma Registry comprehensive dataset (OTR-CDS). The OTR-CDS contains detailed demographic, diagnostic, and procedural data on patients hospitalized with major trauma across eleven participating adult and pediatric trauma centres in Ontario. Major trauma in the OTR-CDS is defined by the presence of an International Classification of Diseases 10^{th} revision (ICD-10) external cause of injury code in the W78 to Y98 range, and an Injury Severity Score (ISS) of 12 or more.

All data in the OTR-CDS are de-identified at both the patient and facility level. However, unique encrypted patient and facility identifiers are present. This project was reviewed and approved by the Research Ethics Board of Sunnybrook Health Sciences Centre.

Assembly of study cohort

We identified adult patients $\geq$18 years who were admitted between April 1, 2005 to March 30, 2011 to one of Ontario’s trauma centres. For the purpose of this study, we only included those with mechanical mechanisms of injury, and thus excluded patients admitted with poisoning, suffocation, drowning, overexertion, environmental causes and burns. Mechanisms of injury were derived based on the Centers for Disease Control and Prevention’s ICD-10 external cause of injury matrix.(11) Patients without signs of life on arrival [heart rate (HR)=0, systolic blood pressure (SBP)=0, and motor component of the Glasgow Coma Scale (mGCS)=1] were also excluded as they were believed to be unsalvageable, regardless of quality of care received.(12)

Trauma centers were de-identified and were represented by a number (1 to 9). It is plausible that trauma centre volume might identify centres. As such, patient volumes are not presented.

Patient subgroups

Patients were divided into five distinct cohorts that challenge different components of the spectrum of trauma centre care: i) penetrating truncal injury [penetrating mechanism of injury and Abbreviated Injury Scale score (AIS) $\geq$ 3 in the neck, chest or abdomen], ii) patients presenting with shock [SBP in the Emergency Department (ED) $\leq$ 90mmHg], iii) blunt multisystem injury (blunt mechanism of injury and AIS $\geq$ 3 in at least 2 body regions), iv) elderly (aged $\geq$ 65 years), and v) isolated traumatic brain injury (head AIS $\geq$ 4 or head AIS = 3 and mGCS $\leq$ 4, and AIS $\leq$ 2 in any other body region).(13, 14) Patients were not defined as isolated traumatic brain injury if their only qualifying head injury code was a scalp, internal carotid artery, vertebral artery, or bony injury.

Evaluation of differences in trauma centre related mortality over time

We developed a generalized estimating equations model with a binomial distribution to evaluate differences in in-hospital mortality over time after adjusting for changes in patient characteristics over the seven years of study. The following covariates were included in adjusted analyses: study year, patient demographics (sex, age), injury characteristics (mechanism of injury, AIS by body region), vital signs on arrival (HR, SBP, mGCS), and transfer status. Parameters and specifications are displayed in **Table 1**.

Furthermore, survival risk ratios (SRRs) based on AIS scores were calculated for each patient and included in our adjusted analysis as an additional continuous covariate. SRRs were calculated for each patient subgroup separately. An SRR is a database specific point estimate of survival and is defined as the number of patients who survived the AIS coded injury divided by the total number of patients who sustained the same injury.(15) SRRs are bounded by 0 and 1, with a lower score representing lower probability of survival. We applied a traditional worst-injury approach to SRR calculation, in which the smallest (worst) SRR is selected for each patient. Although SRRs are estimates of true survival and are population-specific, they have been shown to further explain variance and offer better discrimination when compared to injury scoring systems such as the ISS.(15)

Evaluation of trauma centre-specific mortality

In addition to evaluating changes in trauma centre mortality over time, we explored trauma centre-specific rates to determine the extent of variation across centres. To adjust for differences in case-mix across centres, several hierarchical logistic regression models were used to estimate the overall trauma centre-specific risk-adjusted mortality, and across each of the five patient subgroups. Patients were considered the lower-level units and trauma centres as the higher level units. Patient-level covariates were age, sex, mechanism of injury, SRR, severe injury by body region, mGCS, SBP, HR, and transfer status. Parameters and specifications are displayed in **Table 1**. Hierarchical models were utilized because they facilitate the exploration of variability across different levels of nested data.(16, 17)

To quantify the variability between trauma centres, we calculated the median odds ratio (MOR). The MOR can be interpreted as the adjusted odds of dying if the same patient was admitted to two different randomly selected hospitals (MOR always has a value of 1 or higher because it compares a higher- versus lower-ranked hospital). It estimates unexplained heterogeneity across different centres after adjusting for patient-level characteristics.(16) Variability across centres was assessed for the overall cohort and for each patient subgroup.

To further characterize variability across centres, adjusted odds ratios (ORs) of death and their 95% confidence intervals (95%CI) were calculated. Trauma centre-specific ORs of death represent the likelihood of death at each hospital relative to the overall average across all centres.(18) A trauma centre has a lower than expected mortality if the upper limit of its 95% CI is <1, representing a significantly lower odds of death. If the lower limit of the 95% CI is >1, the centre has a higher than expected mortality and patients cared for in that centre have a significantly higher odds of death than if cared for in the average centre.

Statistical analysis

Means and standard deviations (SD) were calculated for continuous normally distributed variables and medians and interquartile ranges (IQR) were calculated for continuous variables with a non-normal distribution. Absolute and relative frequencies were measured for discrete variables. Patient and injury characteristics were compared using χ^2 test and non-parametric methods, as appropriate. Multiple imputation was used to address missing values for HR (5%), SBP (5%) and mGCS (13%).(19) For each model in the adjusted analyses, discrimination was estimated using the c-statistic, and calibration was assessed using observed-versus-predicted outcome plots. In all statistical analyses, $p<0.05$ was considered significant. All data were analyzed using SAS (version 9.3, Cary, NC).

Results

We identified 26,421 adult injured patients who received care at one of Ontario's trauma centres between April 1, 2005 and March 30, 2011. The majority of patients were male and the mean age was 52 years +/-22. Most patients were injured as a result of a motor vehicle collision (44%) or a fall (41%). Severe multisystem injuries as measured by the ISS were common; almost half of patients had an ISS $\geq$ 25 (median ISS 24, IQR 16 - 27). Baseline characteristics of the entire cohort and different patients' subgroups are shown in **Table 2.**

Differences in trauma centre-related mortality over time

During the study period, the volume of patients per annum increased by 15%, from 3,449 patients in 2005 to 4,051 patients in 2011. Patient and injury characteristics and the distribution of patient subgroups changed over time. There was an increase in the proportion of elderly injured (age $\geq$ 65 yrs) and patients with isolated traumatic brain injury during the study interval. Injury severity over time was unchanged; as measured by the proportion of patients with an ISS $\geq$ 25 (**Table 3**).

Overall in-hospital mortality was 12% (n=3,174); however, mortality decreased from 13.2% (n=457) in 2005 to 11.2% (n=453) in 2011. After adjusting for changes in patient and injury characteristics over time, the overall adjusted odds of death decreased by approximately 3% per year (OR 0.97 95% CI 0.95 - 1.00). Similarly, the adjusted odds of deaths decreased during the study period for most patient subgroups, ranging from a 5% to a 10% decrease per year (**Figure 1**).

Trauma centre-specific mortality

Trauma centre-specific crude mortality ranged from 11.4% to 13.1% (p=0.21). After case-mix adjustment, the MOR for trauma-related death across various hospitals was 1.25, suggesting that the odds of dying after injury were 1.25-fold greater if the same patient was admitted to one randomly selected trauma centre as opposed to another. Furthermore, differences were evident among centre-specific odds ratios of death compared to the overall average, as one centre was identified as having significantly lower than expected mortality compared to the overall average. Conversely, one centre was identified as having significantly higher than expected mortality. The remaining seven trauma centres had expected rates of mortality given their case-mix.

Similar differences were identified across various patient subgroups, with MORs ranging from as low as 1.21 in the subgroup of patients who were in shock to as high as 1.47 in the isolated traumatic brain injury subgroup. As expected, the highest number of outliers (i.e. centres with higher or lower than expected mortality) was identified amongst the patient subgroups with the highest MORs. Two centres were identified as having significantly lower than expected mortality and two centres were identified as having significantly higher than expected mortality in the elderly subgroup. Furthermore, one centre was identified as having significantly lower than expected mortality and three centres were identified as having significantly higher than expected mortality in the isolated traumatic brain injury subgroup. No centre was characterized as having a higher or lower than expected mortality in the shock and penetrating truncal injury subgroups. Differences in trauma centre-specific mortality are displayed in **Figure 2**.

Interpretation

Traumatic injury is a major source of death and disability in Canada.(1-3) Significant resources have been allocated towards regionalization of care and investments in designated trauma centres.(4) Care in a designated trauma centre has been associated with a 25% lower 1-year mortality for patients with severe injuries when compared to care in a similarly resourced non-trauma centre in the United States.(5) It is therefore important to evaluate the outcomes of severely injured patients admitted to trauma centres. In addition, exploring variation in outcomes across centres can guide system-wide performance improvement.

This study has three key findings. First, the risk-adjusted odds of death for severely injured patients who received care at trauma centres in Ontario decreased by approximately 3% per year during the study period. Second, we have identified significant differences in mortality across trauma centres. Such differences persisted after adjustment for case-mix and after accounting for correlation of patients' outcomes at different trauma centres. For example, the odds of death would be 1.25-fold greater if the same patient was admitted to one randomly selected trauma centre as opposed to another. Lastly, we found that differences in trauma centre risk-adjusted mortality were most pronounced in elderly patients and those with isolated head injuries.

Despite the observed improvements in trauma centre mortality over the study period, we believe significant opportunities for system-wide performance improvement have been identified. Elderly patients and those with isolated traumatic brain injury were the subgroups with the greatest differences in trauma-centre specific mortality. Factors that may explain such inter-hospital differences in risk-adjusted mortality of these patient subgroups include: differences in structures and processes of care for these patients(20-22), variation in physicians' perceptions of long-term prognosis (23), and variable practice patterns for withdrawal of life sustaining interventions.(24, 25) Further research on these patient subgroups is indicated to highlight the sources of such differences in risk-adjusted mortality between trauma centres. Improved cooperation and sharing of best practices across trauma centres may be the first step towards further reductions in trauma centre mortality.

Limitations

Limited by the retrospective design of our study, we cannot rule out the potential impact of variability in referral patterns, and hence variability in case-mix, across centres on the study results. However, we attempted to adjust for measured differences in case-mix and account for potential correlation of patients' outcomes at different hospitals in our analysis; in addition to adding an extra term to account for the random differences in trauma-related mortality between different hospitals using a random-intercept multilevel model. The observed differences in risk-adjusted mortality across centres might reflect inconsistencies in data coding or data capture and not true differences in quality of care. However, data collection is standardized using a specialized registry across all institutions during the study period. This software was customized with input from Ontario’s trauma centres and its Trauma Registry Advisory Committee and it includes logic checks as well as edit checks to ensure data accuracy, consistency, and completeness.

Underreporting of patients that arrive without signs of life to the emergency department, whether due to local injury patterns or pre-hospital care practices, might positively influence centre-specific mortality; however, we believe that this assumption had no impact on our analysis as patients who arrived without signs of life were excluded. Finally, we acknowledge that the OTR-CDS only captures data on patients hospitalized at trauma centres; thus, our analysis of temporal trends in mortality may not be applicable to all injured patients in Ontario.

Conclusions

We observed significant improvement over time in the mortality of severely injured patients cared for at Ontario’s trauma centres. However, considerable differences in trauma centre-specific mortality were observed. These differences were most pronounced in the elderly injured and those with isolated traumatic brain injury. System-wide performance improvement initiatives should target these patient subgroups.

Author contributions

- Conception and design: Gomez, Nathens
- Acquisition of data: Gomez, AlAli, Xiong
- Analysis and interpretation of data: Gomez, Alali, Haas, Xiong, Tien, Nathens
- Drafting of manuscript: Gomez, Alali, Haas, Nathens
- Critical revision of manuscript: Gomez, Alali, Haas, Xiong, Tien, Nathens
- Final approval of manuscript: Gomez, Alali, Haas, Xiong, Tien, Nathens

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Table 1. Covariates

Parameter	Specification
Gender	Male
	Female
Age†	Continuous
Injury mechanism*	MVC – occupant
	MVC - pedestrian
	MVC - motorcyclist
	Fall
	Other blunt
	Firearm
	Cut/pierce
	Other
Glasgow Coma Scale - motor	Continuous
Systolic blood pressure†	Continuous
Heart rate†	Continuous
Survival risk ratio	Continuous
Injury severity by body region‡	Head AIS $\geq$ 4
	Chest AIS $\geq$ 3
	Abdomen AIS $\geq$ 3
Transfer	Yes
	No

*Motor vehicle collision. †Data was fitted differently for each model. ‡Abbreviated Injury Scale.

Table 2. Baseline patient and injury characteristics

	Overall n=26,421	Penetrating truncal injury n=1,032	Shock in ED n=1,230	Blunt multisystem injury n=9,942	Elderly (≥ 65) n=8,715	Isolated traumatic brain injury n=9,167
Male	18,751 (71)	937 (91)	848 (69)	8,852 (69)	5,259 (60)	6,401 (70)
Age in years						
Mean (SD)	52 (22)	32 (14)	49 (21)	47 (20)	78 (8)	62 (21)
≥ 65	8,715 (33)	38 (4)	322 (26)	2,262 (23)	8,715 (100)	4,923 (54)
Injury mechanism*						
MVC - occupant	9,886 (37)	0 (0)	616 (50)	6,008 (60)	1,827 (21)	1,085 (12)
MVC - pedestrian	585 (2)	0 (0)	18 (1)	198 (2)	116 (1)	190 (2)
MVC - motorcyclist	1,323 (5)	0 (0)	50 (4)	561 (6)	129 (1)	215 (2)
Fall	10,874 (41)	0 (0)	298 (24)	2,489 (25)	6,259 (72)	6,320 (69)
Other blunt	1,854 (7)	0 (0)	60 (5)	474 (5)	203 (2)	962 (10)
Firearm	518 (2)	362 (35)	64 (5)	0 (0)	20 (<1)	78 (1)
Cut/pierce	761 (3)	670 (65)	92 (7)	0 (0)	37 (<1)	37 (<1)
Other	620 (2)	0 (0)	32 (3)	212 (2)	124 (1)	280 (3)
Injury Severity Score						
Median (IQR)	24 (16 - 27)	19 (17 - 26)	29 (21 - 41)	29 (22 - 38)	25 (16 - 25)	25 (16 - 25)
≥ 25	12,608 (47)	398 (39)	849 (69)	7,019 (71)	4,504 (52)	4,618 (50)
GCS motor						
5 - 6	21,666 (82)	860 (83)	770 (63)	7,665 (77)	7,366 (85)	7,265 (79)
3 - 4	2,306 (9)	53 (5)	144 (12)	961 (10)	784 (9)	1,027 (11)
1 - 2	2,449 (9)	119 (12)	316 (26)	1,316 (13)	565 (6)	875 (10)
Shock in ED (SBP ≤90mmHg) †	1,230 (5)	131 (13)	1,230 (100)	725 (7)	322 (3)	156 (2)
Severe injury (AIS≥3) ‡						
Head	15,198 (58)	58 (6)	684 (56)	5,473 (55)	5,454 (63)	9,167 (100)
Chest	10,088 (38)	769 (75)	547 (45)	6,794 (68)	2,841 (33)	0 (0)
Abdomen	2,646 (10)	454 (44)	206 (17)	1,834 (18)	650 (7)	0 (0)
Lower extremity	5,510 (21)	67 (6)	305 (25)	4,073 (41)	1,531 (18)	0 (0)
Transfers from outside institutions	12,406 (47)	245 (24)	444 (36)	4,726 (48)	4,188 (48)	4,435 (48)
In-hospital mortality	3,174 (12)	116 (11)	410 (33)	1,303 (13)	1,754 (20)	1,475 (16)
Died in ER	368 (1)	45 (4)	106 (9)	150 (2)	141 (2)	118 (1)

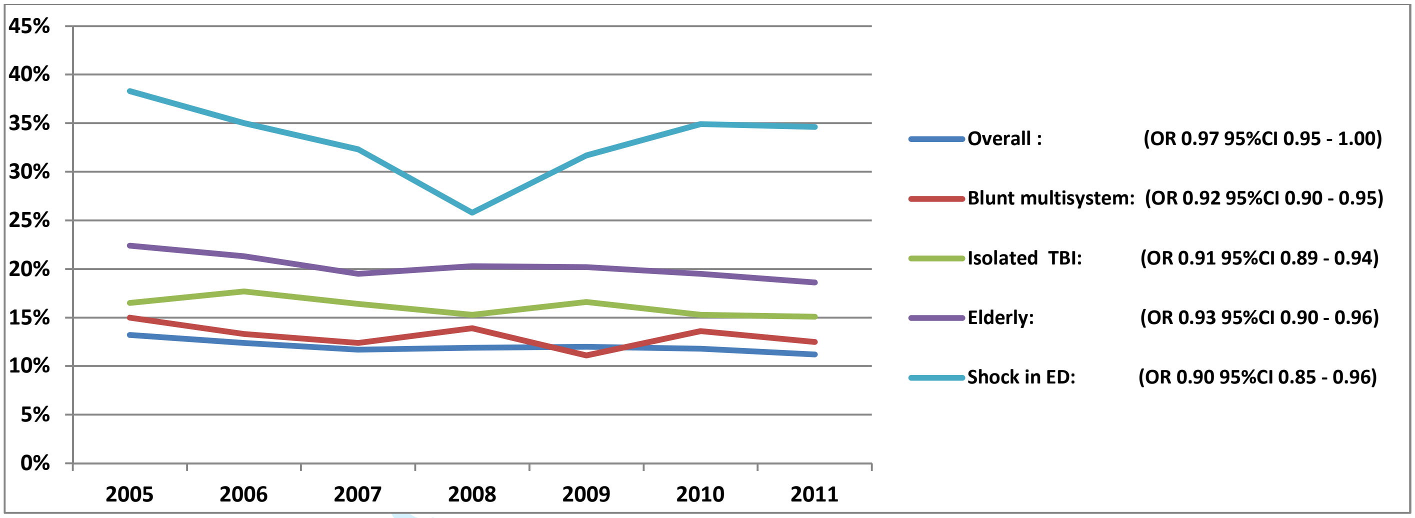
All data is presented as n (%) unless otherwise specified. *Motor vehicle collision. †Systolic blood pressure. ‡Abbreviated Injury Scale.

Table 3. Baseline patient, injury characteristics, and distribution of patient subgroups over time

	Study year, no. (%)*							
	2005 n=3,449	**2006** n=3,677	**2007** n=3,848	**2008** n=3,691	**2009** n=3,797	**2010** n=3,908	**2011** n=4,051	***p***
Male	2,643 (71)	2,646 (72)	2,686 (70)	2,631 (71)	2,694 (71)	2,757 (71)	2,874 (71)	0.52
Mean age (SD)	50 (21)	50 (21)	51 (22)	53 (22)	53 (22)	54 (22)	54 (22)	<0.01
ISS ≥ 25†	1,619 (47)	1,707 (46)	1,830 (48)	1,816 (49)	1,815 (48)	1,858 (48)	1,963 (48)	0.27
Penetrating truncal injury	159 (5)	146 (4)	148 (4)	157 (4)	153 (4)	133 (3)	136 (3)	0.06
Shock in ED	175 (5)	177 (5)	170 (4)	167 (5)	161 (4)	189 (5)	191 (5)	0.67
Blunt multisystem injury	1,373 (40)	1,479 (40)	1,491 (39)	1,326 (36)	1,347 (35)	1,410 (36)	1,516 (37)	<0.01
Elderly	997 (29)	1,069 (29)	1,254 (33)	1,249 (34)	1,298 (34)	1,361 (35)	1,487 (37)	<0.01
Isolated TBI‡	1,137 (33)	1,181 (32)	1,319 (34)	1,298 (35)	1,417 (37)	1,396 (36)	1,420 (35)	<0.01

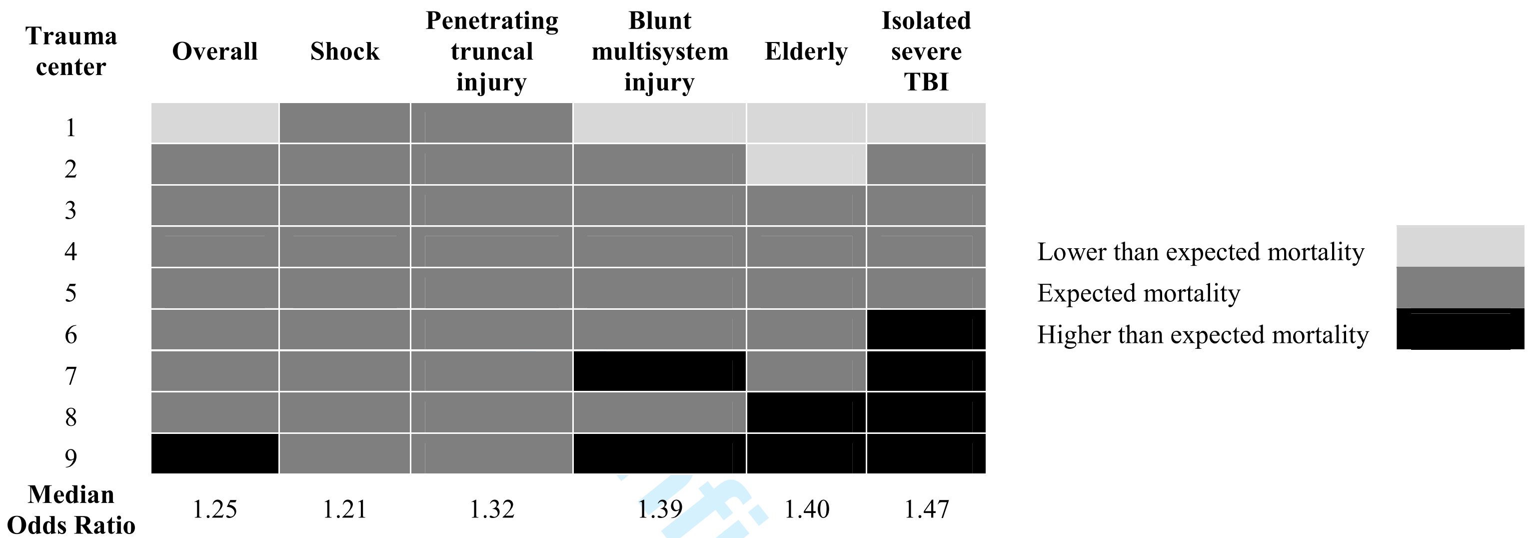
*All data is presented as n (%) unless otherwise specified. †Injury Severity Score. ‡Traumatic brain injury.

Figure 1. Differences in trauma centre mortality over time across patient subgroups



Odds ratios represent the adjusted likelihood of death by 1-year increments in the study period.

Figure 2. Differences in trauma centre-specific adjusted mortality overall and across patient subgroups



Trauma centres where the upper limit of the 95% confidence interval for in-hospital mortality is below 1 (displayed in light grey) are characterized as having lower than expected mortality (lower adjusted likelihood of death compared to the rest). Conversely, trauma centres where the lower limit of the confidence interval is above 1 (displayed in black) are characterized as having significantly higher than expected mortality.