Characteristics of ACS-verified Level I and Level II trauma centers: A study linking trauma center verification review data and the National Trauma Data Bank of the American College of Surgeons Committee on Trauma

Shahid Shafi, MD, MPH, Sunni Barnes, PhD, Chul Ahn, PhD, Mark R. Hemilla, MD, H. Gill Cryer, MD, Avery Nathens, MD, Melanie Neal, MS, *and* **John Fildes, MD***, Dallas, Texas*

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BACKGROUND: The Trauma Quality Improvement Project of the American College of Surgeons (ACS) has demonstrated variations in trauma center outcomes despite similar verification status. The purpose of this study was to identify structural characteristics of trauma centers that affect patient outcomes.

METHODS: Trauma registry data on 361,187 patients treated at 222 ACS-verified Level I and Level II trauma centers were obtained from the National Trauma Data Bank of ACS. These data were used to estimate each center's observed-to-expected (O-E) mortality ratio with 95% confidence intervals using multivariate logistic regression analysis. De-identified data on structural characteristics of these trauma centers were obtained from the ACS Verification Review Committee. Centers in the lowest quartile of mortality based on O-E ratio (n = 56) were compared to the rest (n = 166) using Classification and Regression Tree (CART) analysis to identify institutional characteristics independently associated with high-performing centers.

RESULTS: Of the 72 structural characteristics explored, only 3 were independently associated with high-performing centers: annual patient visits to the emergency department of fewer than 61,000; proportion of patients on Medicare greater than 20%; and continuing medical education for emergency department physician liaison to the trauma program ranging from 55 and 113 hours annually. Each 5% increase in O-E mortality ratio was associated with an increase in total length of stay of one day ($r = 0.25$; $p < 0.001$).

CONCLUSIONS: Very few structural characteristics of ACS-verified trauma centers are associated with risk-adjusted mortality. Thus, variations in patient outcomes across trauma centers are likely related to variations in clinical practices. (*J Trauma Acute Care Surg.* 2016;81: 735–742. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic study, level III.

KEY WORDS: Trauma center; structure; outcomes; variation.

For the past several decades, the American College of Surgeons (ACS) Committee on Trauma has worked diligently to ensure availability of optimal resources for the care of the injured at hospitals throughout the country. State and provincial authorities use ACS verification status to designate hospitals as trauma centers. Multiple studies have shown that injured patients treated at designated trauma centers are more likely to survive than those treated at nondesignated hospitals.[1–4] However, the ACS Trauma Quality Improvement Program (TQIP) has demonstrated that despite availability of optimal resources, risk-adjusted patient outcomes vary among designated trauma centers.[5–7] The Donabedian model of quality management suggests that patient outcomes depend on institutional structures and processes of care.[8] The trauma center verification program is designed to minimize structural variations by ensuring that all trauma centers have similar institutional resources (e.g., staff, equipment). However, it is not known which specific structural features of a trauma center are associated with its patient outcomes. The purpose of this study was to identify specific, measurable institutional characteristics that are associated with improved patient outcomes.

METHODS

This is a retrospective study that linked risk-adjusted patient outcomes at ACS-verified Level I and Level II trauma centers to their structural characteristics. American College of Surgeons staff linked two data sources described below, and provided de-identified data to the investigators to protect identities of the trauma centers and the patients included in this study.

Trauma Center Patient Outcomes

We used data from the National Trauma Data Bank (NTDB, 2008–2010) to measure risk-adjusted outcomes of patients with moderate to severe injuries (defined as Abbreviated Injury Scale [AIS] ≥3) in all ACS-verified Level I and Level II trauma centers with at least 50 complete patients' records. Patient exclusion criteria included age younger than 16 years; time from injury to emergency department (ED) arrival of 1 day or more; deaths in the ED with first recorded systolic blood pressure of less than 90 mm Hg; burns greater than 20%; and primary mechanism of injury of poisoning, drowning, hanging, submersion, asphyxiation, and gunshot wounds to the head. Four trauma centers were excluded as outliers because their observed-to-expected (O-E) mortality ratio exceeded 2.6, skewing the distribution of data. A total of 361,187 patients from 222 trauma centers (Level I, 102; and Level II, 120) constituted the study population. For each center, we calculated O-E mortality ratios with the observed mortality rate at each trauma center as the numerator and its expected mortality rate as the denominator. Expected mortality rate was calculated using ACS-TQIP methodology, i.e., logistic regression analysis, to control for multiple patient characteristics such as age, sex, race/ethnicity, insurance status, mechanism of injury, injury profile, and severity.[5–7] An O-E ratio with a 95% confidence interval (CI) overlapping 1 indicated that observed trauma center mortality was similar to the expected rate after taking into account patient differences. An O-E ratio with 95% CI exceeding 1 indicated that trauma center outcomes were worse than expected, and a ratio with a CI less than 1 indicated that trauma center outcomes were better than expected. Patients with incomplete information were not included in the regression models (n = 79.005).

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From the Office of the Chief Quality Officer (S.S., S.B.), Baylor Scott & White Health, Dallas, Texas; Department of Clinical Science (C.A.), UT Southwestern Medical Center, Dallas, Texas; Department of Surgery (M.R.H.), University of Michigan Health System, Ann Arbor, Michigan; Trauma and Emergency Services Department (H.G.C.), University of California, Los Angeles, California; Division of General Surgery (A.N.), Sunnybrook Health Sciences Centre; Department of Surgery, University of Toronto, Toronto, Canada; American College of Surgeons National Trauma Data Bank (M.N.), Chicago, Illinois; and Department of Surgery (J.F.), University of Nevada School of Medicine, Las Vegas, Nevada.
Address for reprints: Shahid Shafi, MD, MPH, Baylor Scott & White Health, 8080N Central Expressway, Suite 900 Dallas, TX 75206; email: shahid.shafi@baylorhealth.edu.

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Trauma Center Institutional Characteristics

Data on 72 structural characteristics of all trauma centers in the study were obtained from the Verification Review Committee (VRC) of ACS Committee on Trauma.[9] The VRC verifies the presence and availability of optimal resources for the care of the injured at hospitals upon their request to be verified as a trauma center. Each hospital completes a Pre-Review Questionnaire (PRQ) that requires self-reporting of detailed information on structural characteristics of the institution and resources available for the care of the injured. A team of trained reviewers from the VRC confirms availability of those resources during a two-day site visit. Data from the prereview questionnaire and site visits are entered into an electronic database at the ACS. We obtained deidentified data on all 222 Level I and Level II trauma centers included in this study from their most recent verification review.

Primary Analysis

To identify structural characteristics that were associated with patient mortality, trauma centers were divided into two groups based on their O-E ratio: those in the lowest quartile of O-E ratio, or the best performers (n = 56; mean O-E ratio, 0.86), were compared to the rest (n = 166). This was done first using univariate analysis with the Wilcoxon rank-sum test for continuous variables and the χ^2 test for categorical variables. Recursive partitioning and regression tree method (RPART, version 3.1-53) was then used to implement a Classification and Regression Tree (CART) analysis to identify independent predictors of best performing trauma centers.[10,11] Recursive partitioning is a fundamental tool in data mining. It helps us explore the structure of a set of data while developing easy-to-visualize decision rules for predicting an outcome. The primary outcome of interest in this analysis was categorical so a classification tree was fit using the R function RPART. The complexity parameter used for our investigation was the procedure's default setting of 0.14. The RPART "class" method was specified.

Secondary Analysis

We also estimated the relationship between O-E mortality ratios and trauma center resource utilization, as measured by hospital length of stay (LOS) as well as volume of trauma patients seen at the centers, using Pearson correlation coefficient and negative binomial regression. Patients who died within the first two days (n = 13,216) were excluded from LOS analyses.

RESULTS

Trauma Center Outcomes

Consistent with prior studies, O-E mortality ratios revealed variations in risk-adjusted patient outcomes across trauma centers. Fourteen trauma centers exhibited lower-than-expected mortality ratios, and 76 centers experienced higher-than-expected mortality ratios, with the remaining 132 centers achieving average mortality ratios based on their patient characteristics (Fig. 1).

Trauma Center Characteristics

Structural characteristics of trauma centers were grouped into 4 categories: facilities, education, staff, and volume (Table 1). A fifth category detailed self-reported processes (Process) in place at trauma centers but did not investigate adherence to these processes. Key findings are summarized below.

Facilities

Trauma centers were generally large hospitals (median number of hospital beds, 440; intensive care beds, 46; operating rooms, 15). More than 80% provided medical control to local Emergency Medical Services (EMS), with base station located in 60% of the trauma centers. Only 12% were American Burn Association–verified burn centers. More than three quarters relied on a regional blood bank as the source of their blood products, and 60% had an in-patient rehabilitation unit.

Education

Most trauma centers participated in graduate and/or postgraduate training, with a medical school affiliation at 74%, general surgery residency at 60%, orthopedic surgery residency at 43%, neurosurgery residency at 27%, and orthopedics trauma fellowship at 18%. Only a quarter (26%) had an accredited surgical critical care fellowship. More than half (56%) reported active trauma-related research grants.

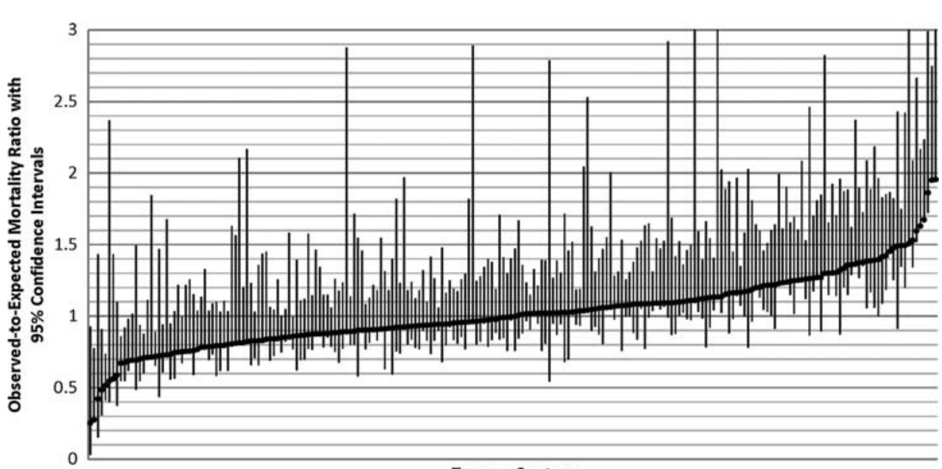

Figure 1. Observed to expected mortality ratios of trauma centers.

TABLE 1. Institutional Characteristics of Trauma Centers (Reported as Medians With Interquartile Ranges for Continuous Variables and Proportions for Categorical Variables)

Category	Characteristic	N	Median (IQR) or n (%)
Facility	Patient census (average daily)	220	272 (189–410)
Facility	Number of staffed beds (total)	221	352 (247–488)
Facility	Number of licensed beds (total)	221	440 (329–621)
Facility	Intensive care unit beds (number)	222	46 (30–77)
Facility	Operating rooms (number)	222	15 (11–22)
Facility	Post anesthesia care Unit beds (number)	222	17 (12–24)
Facility	Surgical intensive care unit beds (number)	196	26 (18–37)
Facility	Regional blood bank as the source of blood products	222	173 (78%)
Facility	EMS base station at trauma center	222	133 (60%)
Facility	EMS medical control by trauma center	222	180 (81%)
Facility	Designated burn center	222	26 (12%)
Facility	In-patient rehabilitation unit	222	133 (60%)
Education	Trauma related research grants (current)	208	116 (56%)
Education	Medical school affiliation	222	165 (74%)
Education	Residency program in general surgery	222	128 (60%)
Education	Residency program in orthopedic surgery	222	96 (43%)
Education	Residency program in neurosurgery	222	59 (27%)
Education	Surgical critical care fellowship (accredited)	220	58 (26%)
Education	Fellowship in orthopedic trauma surgery	222	39 (18%)
Process	Use of evidence-based protocols	222	205 (92%)
Process	Performance improvement meetings (yearly)	221	12 (12–12)
Process	Diversion/bypass previous year (number of centers)	222	133 (60%)
Process	Diversion/bypass duration (yearly hours)	221	5 (0–76)
Process	Type specific blood availability (minutes)	220	13 (10–15)
Process	Blood cross match time (minutes)	222	45 minutes (40–45)
Process	Response time for angioembolization after hours	221	30 minutes (30–45)
Process	Cryoprecipitate availability at the center	222	221 (99%)
Process	Immediate access to factor VIIa	222	206 (93%)
Process	Immediate access to factor VIII	222	199 (90%)
Process	Immediate access to factor IX	222	181 (82%)
Staff	Trauma program manager experience (years in position)	222	4 (2–9)
Staff	Trauma program full-time staff (number)	222	6 (4–9)
Staff	Trauma surgeons in the core group (number)	222	6 (4–7)
Staff	Trauma surgeons at the center (number)	222	6 (7–9)
Staff	Trauma surgeons with critical care training (board eligible or certified, number)	221	3 (1–5)
Staff	Surgical director of intensive care unit board eligible or certified	222	141 (64%)
Staff	Trauma surgeons who are ATLS instructors	220	4 (1–6)
Staff	Trauma surgeons cover nontrauma cases	222	179 (81%)
Staff	Trauma medical director experience (years since completing residency)	222	18 (12–23)
Staff	Trauma medical director CME (external, trauma related, hours in previous three years)	218	99 (69–141)
Staff	ED physicians (number)	221	19 (14–27)
Staff	ED physician liaison experience (years since training)	222	15 years (10–22)
Staff	ED physician liaison – CME (hours, last three years)	217	64 (51–88)
Staff	Neurosurgeons (number)	222	4 (3–6)
Staff	Neurosurgeon liaison experience (years since training)	222	15 (9–22)
Staff	Neurosurgical liaison CME (external, trauma related, hours in previous three years)	213	65 (53–91)
Staff	Neurosurgeons dedicated to trauma center when on call	222	168 (76%)
Staff	Orthopedic surgeons (number)	222	9 (6–12)
Staff	Orthopedic liaison experience (years since completing residency)	221	14 (8–21)
Staff	Orthopedic liaison CME (trauma, external, hours in last three years)	219	87 (60–137)
Staff	Orthopedic surgeon dedicated to trauma center when on call	222	199 (90%)
Staff	Anesthesiologist on staff (number)	222	20 (13–35)
Staff	Anesthesia liaison experience (years since completing residency)	222	17 (11–22)
Staff	Anesthesia using certified nurse anesthetists	221	176 (80%)
Staff	Nursing experience in ED (average years)	222	9 years (7–12)
Staff	Nursing experience in ICU (average years)	222	10 (8–12)
Staff	Radiologist attending in-house 24/7	222	84 (38%)
Staff	Social worker dedicated to trauma patients	222	102 (46%)
Staff	Operating room staff in-house 24/7	222	204 (92%)
Volume	ED patients (yearly total, including nontrauma)	221	56.686 (40.076–77,062)
Volume	Trauma related ED visits yearly (yearly)	220	10,186 (6,659–13,637)
Volume	Trauma activations yearly (number)	222	1,178 (674–2024)
Volume	Trauma activations at highest level	222	224 (108–504)
Volume	Patients to emergent operating room from ED	222	111 (56–193)
Volume	Patients with Injury Severity Score 0 to 9 (yearly)	222	791 (453–1,210)
Volume	Patients with Injury Severity Score 10 to 15 (yearly)	222	177 (102–294)
Volume	Patients with Injury Severity Score 16 to 24 (yearly)	222	175 (88–272)

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TABLE 1. *(Continued)*

Category	Characteristic	N	Median (IQR) or n (%)
Volume	Patients with Injury Severity Score 25 or more (yearly)	222	105 (53–184)
Volume	Neurosurgical emergent cases (within 24 hours, yearly)	222	21 (11–35)
Volume	Orthopedics emergent cases (within 24 hours, yearly)	220	257 (136–441)
Volume	Trauma medical director admissions (yearly)	220	124 (69–203)
Volume	Trauma medical director trauma operative cases (yearly)	220	24 (10–50)

ATLS, advanced trauma life support; CME, continuing medical education, ED, emergency department; EMS, emergency medical services; ICU, intensive care unit.

Processes

Performance improvement meetings were held, on average, once every month. More than 90% of the centers reported using evidence-based protocols. More than half (60%) of the centers reported going on diversion/bypass during the previous year, but the median time on divert was only 5 hours annually. Median time to availability of type-specific blood was 13 minutes and cross-matched blood was available at 45 minutes.

Staff

Trauma program managers had worked at the centers for a median of 4 years only, which is a little more than a single VRC review cycle of 3 years. Median number of physicians at each center was 6 trauma surgeons (3 were critical care eligible or certified), 9 orthopedic surgeons, 4 neurosurgeons, 20 anesthesiologists, and 19 ED physicians. Trauma medical directors and specialty liaisons in orthopedics, neurosurgery, ED, and anesthesia were experienced physicians with a median number of years since completion of training ranging from 14 to 18. Trauma surgeons at more than 80% of the centers reported covering nontrauma cases as well. Surgical directors of intensive care units were critical care board eligible or certified in 64% of the centers. Only a third of the centers had an in-house attending radiologist 24 hours a day. Eighty percent of the centers used nurse anesthetists, while 92% of the centers had operating room staff available in-house 24 hours a day.

Volume

Trauma centers generally had busy EDs, with median of 56,686 patients annually. Median number of trauma-related ED visits was 10,186. Median number of annual trauma activations was 1,178, with 224 at the highest level of activation and 111 patients requiring immediate surgery upon presentation to the ED every year. Median annual number of operative interventions related to traumatic injuries undertaken within 24 hours of presentation was 257 by orthopedic surgeons and 21 by neurosurgeons. Median annual number of operative trauma cases on trauma patients for trauma medical directors was 24 cases. These numbers do not include elective operations or nontrauma emergency operations done by trauma surgeons, neurosurgeons, or orthopedic surgeons.

Relationship Between Institutional Characteristics and Patient Outcomes

Univariate analysis comparing the best performing centers to the rest of the trauma centers identified the following structural characteristics that were associated with high-performing centers (Table 2): less busy centers (fewer number of annual patient visits to the ED and fewer trauma activations); higher rate of participation in trauma performance improvement process by neurosurgeons and orthopedic surgeons; higher proportion of patients on Medicare; higher proportion of patients with a blunt mechanism of injury; and centers less likely to use a regional source of blood bank compared to a hospital-based source of blood bank.

Multivariate analysis using CART showed that only 3 structural characteristics were independently associated with high-performing centers:

1. Total number of annual patient visits to the ED of fewer than 61,000
2. Proportion of patients on Medicare exceeding 20%
3. Continuing medical education for ED liaison physician ranging between 55 and 113 hours annually

Association Between O-E Mortality Ratios and Trauma Center Resource Utilization

Regression analysis showed a small but statistically significant association between O-E mortality ratio and hospital LOS (Fig. 2). Each 5% increase in O-E mortality ratio was associated with an increase in hospital LOS of one day ($r = 0.25$; $p < 0.001$).

TABLE 2. Relationship Between Institutional Characteristics and High Performing Centers—Univariate Analysis

Category	Characteristic	Top Quartile Centers (n = 56)	Other Centers (n = 166)	*p* value
Facility	Regional source of blood bank	66%	82%	0.013
Patients	Medicare patient population	22%	16%	0.008
Patients	Blunt mechanism of injury	93%	89%	0.0003
Process	Neurosurgery attendance in performance improvement meetings	81%	73%	0.0197
Process	Orthopedic surgery attendance in performance improvement meetings	78%	73%	0.0292
Volume	Total number of trauma activations in a year (median and IQR)	867 (590–1596)	1,290 (757–2083)	0.0445
Volume	Total number of ED Visits in a year (median and IQR)	51,417 (38,210–60,143)	60,679 (42,066–80,018)	0.015

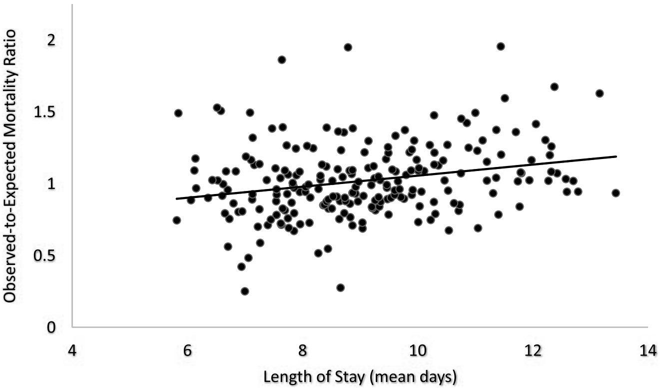

Figure 2. Relationship between trauma centers' observed-to-expected mortality ratios and length of stay.

Volume-Outcome Relationship

Although the CART analysis suggested lower ED volume to be an independent predictor of higher-performing trauma centers, we did not find any association between the number of trauma activations and the O-E mortality ratio (r = 0.114; p 0.09; Fig. 3).

DISCUSSION

This is the first study providing a detailed description of structural characteristics of more than 200 ACS-verified Level I and Level II trauma centers across the country using VRC data. There are 3 major findings of this study. One, of the multiple structural characteristics collected by the ACS on trauma centers, only 3 were independently associated with improved patient outcomes, and none of these are modifiable. Two, high-performing trauma centers with lower mortality ratios were also associated with a reduced hospital LOS. Three, the typical volume-outcome relationship (i.e., high volume associated with improved outcomes) may not apply to trauma centers.

This report provides a systematic description of trauma centers using VRC data that can be followed to determine trends over time. Most of the descriptive data were consistent with anecdotal observations. However, there were a few interesting findings. More than half of the trauma centers reported going on diversion/bypass during the previous year, although it only lasted a few hours during the entire year. This may indicate that these centers were generally working at maximum capacity. A limited surge capacity is concerning, as trauma centers play an important role in regional disaster response systems and may not have the capacity to accommodate mass casualties. Alternatively, isolated events may also contribute to short diversions of 5 hours per year, such as power outage, disruption in water supply, staffing issues, or nonfunctioning CT scanners. The concept of acute care surgery seems to have spread nationwide, with more than 80% centers trauma surgeons now caring for non-trauma patients as well. This is consistent with a recent study using National Surgical Quality Improvement Project data that showed that almost two thirds of emergency general surgical procedures were done at designated trauma centers.[12] Physicians and surgeons caring for trauma patients seem well experienced. However, it was concerning that half of the trauma program managers had only been at their current centers for a little more than a single 3-year VRC review cycle. A quarter of them were at the current job for two years only. This observation suggests a high turnover, which creates challenges for maintaining the quality of trauma programs. Since our data were limited to the time at the current centers, these program managers may have a wealth of experience from prior experiences at other trauma centers. Another interesting observation was that more than 90% of the programs reported using evidence-based protocols. However, we do not have any data on compliance with these protocols. In fact, this is not consistent with our previous survey of 55 trauma centers (a subset of centers that are included in this study) that showed that half of the centers had a written protocol for only 21 of 32 processes studied, and even fewer centers measured compliance with those protocols.[13] While low operative volume for trauma surgeons is well known, our data show similar low operative volume for emergent trauma neurosurgical cases too. This has significant implications for neurosurgical training and maintenance of surgeon skills. On the other hand, it may also indicate an opportunity for trauma surgeons to assume a larger role in the care of traumatic brain injuries, as most of those patients are managed nonoperatively. Prior studies of complex surgical cases have shown that centers with higher volumes of patients achieve better outcomes than those with lower volumes.[14–17] Our findings suggest that this dictum may not be applicable to trauma centers. This is likely related to the fact that the verification process ensures optimal resources along with a minimum volume of patients to achieve trauma center status. Higher volumes of trauma activations do not seem to improve patient outcomes. This may also be related to limited surge capacity at these trauma centers. Differences in activation criteria used by trauma centers may also affect volume-outcome relationship. Hence, the number of trauma activations may not be an appropriate measure of volume-outcome relationship in trauma.

The primary purpose of this study was to identify specific, measurable structural characteristics that are associated with improved patient outcomes. We found 3 such characteristics, but

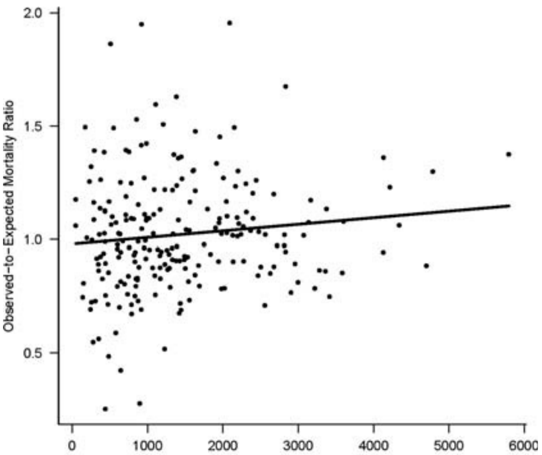

Figure 3. Relationship between trauma centers' observed-to-expected mortality ratio and total number of trauma activations in a year.

two of them were not modifiable (volume and insurance status) while the third one (continuing medical education for ED liaison) had a wide range and, probably, a marginal impact on patient outcomes. We believe these findings are a testament to the success of the ACS verification program, as it ensures uniform availability of optimal resources at all verified trauma centers. Differences in patient outcomes at ACS-verified centers shown by ACS-TQIP are likely not related to their structural characteristics. Hence, the most likely source of variation in patient mortality is related to variations in clinical practices, i.e., how the care is actually delivered at the bedside.

The current study did not measure clinical practices. However, our previous work has shown that compliance with several commonly recommended practice guidelines at trauma centers remains suboptimal with only two thirds of the patients getting the optimal care indicated by their injuries.[18] Reasons for low adoption of evidence-based practices at trauma centers remain unclear.[19] In another study using NTDB data, Haas et al.[20] have shown that compared to trauma centers with higher mortality rates, those with lower mortality have fewer complications and a higher rate of rescue from those complications. Another interesting finding in the current study was the small but statistically significant association between higher O-E mortality ratios and increased hospital LOS. In a previous study, we found that injury severity and complications, but not O-E ratios, were the most important predictors of LOS.[21] This area needs further exploration.

This study has limitations that should be recognized. First, this is a retrospective analysis of existing data with all its inherent limitations. Specifically, 79,005 were excluded from calculations of O-E ratios owing to missing information on at least one of the predictors. However, none of the centers were excluded from this analysis owing to missing data. Second, analysis of structural characteristics of trauma centers was based on self-reported data in PRQ. Third, trauma programs were generally located in full-service hospitals, and not freestanding trauma centers. Hence, their structure and function might be affected by nontrauma services. Fourth, we only included ACS-verified centers in this analysis. In a few states, verification is done regionally, and our findings may not be applicable to those centers. Additionally, since only ACS-verified centers were included in the study, it is not possible to study the relationship between VRC requirements and patient outcomes. Fifth, the only outcome used to measure trauma center performance was in-hospital mortality. For several injuries, such as orthopedic and brain injuries, functional outcomes may be more important. Sixth, like all other data in PRQ, the definition and criteria for operative cases done within 24 hours may vary from center to center. Seventh, exclusion of early deaths in the LOS analysis may introduce survivors bias, especially if early mortality rates differed between centers. Lastly, patient data were obtained from 2008 to 2010, but trauma center data were obtained from most recent verification visit within the preceding 3-year period. Since every center undergoes a site review every 3 years, a large change in institutional structure and practices is unlikely within that timeframe. Although unlikely, a significant change can occur at a trauma center with a change in medical, nursing, or administrative leadership.

In conclusion, our study describes multiple structural characteristics of all ACS-verified Level I and Level II trauma centers, and the differences among them. However, the analysis used in this study suggests that these structural differences are not associated with patient outcomes at those centers. Hence, variations in patient outcomes noted in TQIP are likely related to differences in clinical practices at those centers or unmeasured differences in patient populations.

AUTHORSHIP

S.S., S.B., C.A., M.H. H.G.C., A.N., M.N., and J.F. were involved in study conception and design. S.S., A.N., M.N., and J.F. were involved in acquisition of data. S.S., S.B., and C.A. were involved in analysis and interpretation of data. S.S. drafted the manuscript. S.S., S.B., C.A., M.H., H.G.C., A.N., M.N., and J.F. critically revised the manuscript.

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DISCLOSURE

The authors declare no conflicts of interest.

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