Quality of Care Within a Trauma Center Is not Altered by Injury Type

Shahid Shafi, MD, MPH, Chul Ahn, PhD, Jennifer Parks, MPH, Avery B. Nathens, MD, PhD, Henry M. Cryer, MD, Larry M. Gentilello, MD, Mark Hemmila, MD, and John J. Fildes, MD

Background: Previous studies have demonstrated variations in severity-adjusted mortality between trauma centers. However, it is not clear if outcomes vary by the type of injury being treated.

Methods: National Trauma Data Bank was used to identify patients 16 years or older with moderate to severe injuries (Abbreviated Injury score ≥3) treated at level I or II trauma centers (n = 127,439 patients, 105 centers). Observed-to-Expected mortality ratios (O/E ratios, 95% confidence interval [CI]) were calculated for each trauma center within each of the three injury types: blunt multisystem (two or more body regions; n = 27,980; crude mortality, 15%), penetrating torso (neck, chest, or abdomen; n = 9,486; crude mortality, 9%), and blunt single system (n = 89,973; crude mortality 5%). Multivariate logistic regression was used to adjust for age, gender, mechanism, transfer status, and injury severity (Glasgow Coma Scale, blood pressure). For each injury type, trauma centers' performance was ranked as high (O/E with 95% CI <1), low (O/E with 95% CI >1), or average performers (O/E overlapping 1).

Results: Almost three quarters of the trauma centers achieved the same performance rank in each of the three injury categories. There were 14 low-performing trauma centers in blunt multisystem injuries, six in penetrating torso injuries, and nine in the blunt single system injuries group. None of these centers achieved high performance in any other type of injury.

Conclusions: Risk-adjusted outcomes are consistent within trauma centers across different types of injuries, suggesting that quality improvement efforts should measure, analyze, and focus on hospital-wide systems of care, rather than on isolated quality domains related to specific types of injury.

Key Words: TQIP, Quality of care, Trauma centers, Trauma systems.

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The Committee on Trauma of the American College of Surgeons (ACS) verifies hospitals as trauma centers if they are able to provide specific resources for the care of the injured patient.[1] The primary purpose of the verification process is to improve the quality of care provided to trauma patients by ensuring that the appropriate personnel, equipment, and other resources are available when needed. This approach to improving quality of care has been validated by the findings that injured patients treated at designated trauma centers have a lower mortality rate than those treated at undesignated hospitals.[2,3]

We have recently demonstrated significant variations in patient outcomes across trauma centers despite availability of "optimal" resources.[4–6] Institutional variations leading to differences in patient outcomes are well known in other specialties such as cardiac surgery, vascular surgery (carotid endarterectomy), and oncologic surgery.[7–10] These variations in outcomes suggest that some centers are able to provide high-quality care for a specific disease process by developing local clinical expertise limited to that disease. However, trauma comprises a large variety of injuries to many different organ systems, with varying needs for clinical expertise. For example, a patient with a gunshot wound to the abdomen may require immediate access to an operating room and a trauma surgeon, whereas a patient with a critical traumatic brain injury may require an intensive care unit and a neurosurgeon, and a patient with a complex pelvic fracture may require a trauma surgeon, an angiography suite, an interventional radiologist, an orthopedic surgeon, and an intensivist. It is not known if some trauma centers have more expertise in treating one set of injuries compared with others. Such variation in expertise within a trauma center is possible as the patient mix is variable from center to center. For example, an inner city urban trauma center may see a larger volume of penetrating torso injuries (PEN), whereas a suburban community trauma center may have a large volume prevalence of blunt head injuries.

Our previous study on variations in trauma center outcomes assessed risk-adjusted performance of trauma centers using a single observed-to-expected (O/E) survival ratio for each trauma center encompassing all patients with major injuries (Abbreviated Injury Scale ≥3).[5,6] Differences in patient mix were controlled mathematically using regression techniques. However, a single summary measure of performance may conceal differences in performance of a trauma center for specific types of injuries. We undertook this study to determine whether there are differences in trauma center performance when dealing with different injury patterns.

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From the Department of Surgery (S.S., J.P., L.M.G.), Division of Burns, Trauma and Surgical Critical Care, University of Texas Southwestern Medical School, Dallas, Texas; Department of Clinical Sciences (C.A.), University of Texas Southwestern Medical School; Department of Surgery (A.B.N.), University of Toronto, Toronto, Ontario, Canada; Department of Surgery (H.M.C.), The David Geffen School of Medicine, University of California Los Angeles, Los Angeles, California; Department of Surgery (M.H.), University of Michigan, Ann Arbor, Michigan; and Department of Surgery (J.J.F.), University of Nevada School of Medicine, Las Vegas, Nevada.
Address for reprints: Shahid Shafi, MD, MPH, Department of Surgery, Division of Burns, Trauma and Surgical Critical Care, University of Texas Southwestern Medical Center, 5323 Harry Hines Blvd., Mail Code 9158, Dallas, TX 75390-9158; email: shahid.shafi@utsouthwestern.edu.

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METHODS

Data for this study were obtained from the National Trauma Data Bank (NTDB version 6.2 containing 1,466,887 patients from 700 facilities), the largest multicenter repository of trauma patients. Inclusion criteria for this study consisted of adult trauma patients (age 16–99 years) who were treated at ACS verified levels I and II trauma centers. Exclusion criteria consisted of:

1. Delayed presentation to trauma centers (time of admission ≥1 day after injury).
2. Primary mechanism burns, poisoning, drowning, hanging, asphyxiation, submersion.
3. Gunshot wounds to head.
4. Patients deemed dead on arrival and those who died in the emergency department after presenting with a systolic blood pressure of 90 mm Hg or less.
5. Missing information on survival status and Abbreviated Injury score (AIS).
6. Missing information on any inclusion/exclusion criteria.

These criteria identified 348,489 patients from 108 trauma centers. From these, we identified the following three specific cohorts of patients:

Cohort 1—blunt multisystem injuries (BMS), defined as blunt AIS ≥3 injuries to two or more body regions (n = 27,980, crude mortality 15%).
Cohort 2—PEN, defined as penetrating AIS ≥3 injuries to neck, chest, or abdomen (n = 9,486, crude mortality 9%).
Cohort 3—blunt single system injuries (BSS), defined as blunt AIS ≥3 injuries to a single organ system (n = 89,973, crude mortality 5%).

Thus, the final study population consisted of 127, 439 patients from 105 trauma centers. The selection of the BMS trauma patients (cohort 1) allows for the assessment of many processes and outcomes related to interdisciplinary management including critical care, neurosurgery, and orthopedic surgery. By contrast, the penetrating trauma patients (cohort 2) allow for evaluation of processes and outcomes related to judgment, timely operative management, and general surgical technical skills. BSS (cohort 3) comprise most cases enrolled and allow for evaluation of outcomes in patients with a relatively low risk of adverse outcomes. As such, this cohort might identify gaps in the quality of care not evident in the most severely injured patients.

The outcome of interest was mortality during hospitalization. We first calculated observed mortality rates for each trauma center by using the number of patients who died during hospitalization as the numerator and the total number of patients from that center included in the analysis as the denominator. Multivariate logistic regression was then used to determine expected mortality risk for each patient, adjusted for age, gender, mechanism of injury, transfer status, and injury severity (measured using the Injury Severity score, the Glasgow Coma Scale, first systolic blood pressure upon arrival). Interaction terms were explored but were not included in the final model as they were not significantly associated with mortality. The risk-adjustment model was developed in a random half of the data, validated in the other half, and then applied to the entire study population. The model demonstrated excellent discrimination (area under the curve/c-index 0.91). This model was used to determine expected mortality for each patient, which were then used to determine the expected mortality rate of patients at each trauma center. O/E mortality ratios were calculated for each trauma center, along with 95% confidence intervals (CI), by using the observed mortality rate as the numerator and the mean expected mortality rate as the denominator.

The performance of each trauma center was measured using O/E mortality ratios and the centers ranked as average, low, or high performers. An O/E ratio with 95% CI overlapping 1 indicated that trauma center performance was the same as that expected from its patient mix (average performer). An O/E ratio significantly greater than 1 (i.e. 95% CI not overlapping 1) indicated that the trauma center had more deaths than that expected from its case mix (low performer), and a ratio significantly <1 (i.e. 95% CI not overlapping 1) indicated that the trauma center had fewer deaths than that expected from its case mix (high performer). To assess whether trauma center performance varied by the type of injury to patients, each center was ranked as average, low, or high performer within each of the three patient cohorts. Then, the ranking of each center was compared across the three cohorts to determine consistency of performance ranking across the three cohorts. Fisher's exact tests were also conducted to investigate whether there were significant associations between performance ranking (high, average, and low performers) and characteristics of trauma centers such as teaching status, ownership, and geographic regions.

Data analysis was done using SPSS for Windows (SPSS, Chicago, IL) and SAS (SAS Institute, Cary, NC). For all analyses, $p < 0.05$ was considered significant.

RESULTS

Figure 1 depicts O/E mortality ratios for all centers, again confirming the presence of institutional variations in outcomes of patients across 105 ACS verified levels I and II trauma centers included in this study. Table 1 summarizes the characteristics of these grouped by their overall performance ranking. There were no significant associations between performance ranking (high, average, and low performers) and characteristics of trauma centers such as teaching status ($p = 0.404$), ownership ($p = 0.463$), geographic regions ($p = 0.209$), and verification level of the trauma centers ($p = 0.53$). These centers were predominantly publicly funded, academic centers, which were widely distributed geographically. About a third of the centers performed significantly different from their risk-adjusted expectation. Seventeen were high performers, 16 were low performers, while the rest were average.

Comparison of trauma center performance in BMS versus PEN injuries (Table 2) indicated similar ranking at 73 of 98 centers (74%). Comparison of performance in BMS versus BSS injuries (Table 3) revealed similar performance at 77 of 101 centers (76%). Finally, similar comparison of trauma center performance in PEN versus BSS injuries (Ta-

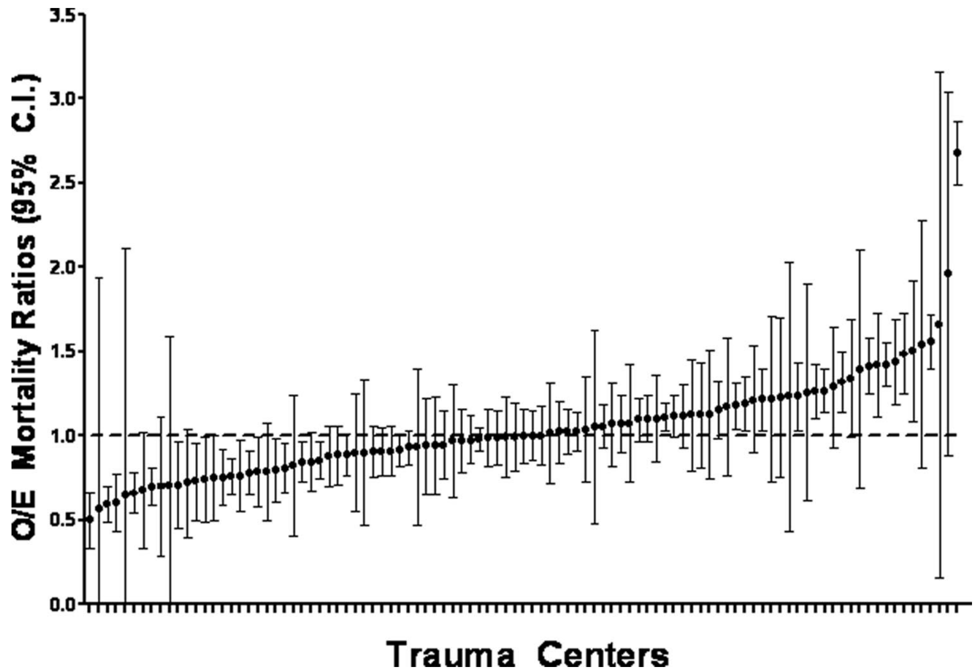

Figure 1. Risk-adjusted mortality at trauma centers.

TABLE 1. Characteristics of Trauma Centers by Performance Rankings

	High Performers	Average Performers	Low Performers
Teaching status (%)			
Academic	6 (35)	32 (44)	9 (56)
Community	11 (65)	35 (49)	6 (38)
Unknown	0	5 (7)	1 (6)
Ownership (%)			
Public	12 (71)	38 (53)	9 (56)
Private	5 (29)	32 (44)	6 (38)
Unknown	0	2 (3)	1 (6)
Geographic region (%)			
Northeast	1 (6)	9 (13)	3 (19)
Midwest	11 (65)	29 (40)	3 (19)
South	2 (12)	19 (26)	7 (44)
West	3 (18)	15 (21)	2 (13)
Unknown	0	0	1 (6)
Level of trauma center (%)			
Level 1	9 (53)	34 (47)	10 (63)
Level 2	8 (47)	38 (53)	6 (38)

ble 4) showed concordant performance at 74 of 99 centers (75%). Interestingly, none of the low-performing centers in one patient cohort achieved a high-performance ranking in any other patient cohort.

DISCUSSION

The findings of this study demonstrate that risk-adjusted patient outcomes at ACS verified levels I and II trauma centers are consistent across the three most common types of injuries. The results also suggest that if a trauma center performs poorly in treating one type of injury, it is not likely to perform well for the rest. Hence, it seems that the quality of care at trauma centers is determined by factors that affect patients with all types of injuries. The most important implication of these findings is that hospital-wide systems of care are more important for improving outcomes of trauma patients rather than expertise in a few specific areas.

TABLE 2. Trauma Center Performance in Blunt Multi System Injuries vs. Penetrating Injuries

	Penetrating Injuries			
Blunt Multisystem Injuries	Low	Average	High	Total
Low	*2*	12	0	14
Average	4	*66*	4	74
High	0	5	*5*	10
Total	6	83	9	98

Italicized indicate concordance in performance ranking at 73 of 98 centers, 74%.

TABLE 3. Trauma Center Performance in Blunt Multi System Injuries vs. Blunt Single System Injuries

	Blunt Single System Injuries			
Blunt Multisystem Injuries	Low	Average	High	Total
Low	*5*	9	0	14
Average	4	*67*	6	77
High	0	5	*5*	10
Total	9	81	11	101

Italicized cells indicate concordance in performance ranking at 77 of 101 centers, 76%.

TABLE 4. Trauma Center Performance in Penetrating Injuries vs. Blunt Single System Injuries

	Blunt Single System Injuries			
Penetrating Injuries	**Low**	**Average**	**High**	**Total**
Low	*1*	5	0	6
Average	8	*69*	7	84
High	0	5	*4*	9
Total	9	79	11	99

Italicized cells indicate concordance in performance ranking at 74 of 99 centers, 75%.

The three cohorts of patients included in this analysis represent a majority of patients with moderate to severe injuries treated at trauma centers. These cohorts were selected as each may present a different set of challenges to the trauma center, as mentioned in the methods above. For example, a patient from a car crash with an intracranial bleed, a hemothorax, blunt splenic injury, and a pelvic fracture may require intubation, tube thoracostomy, an emergent craniotomy, splenectomy, and angioembolization of bleeding in the pelvis, followed by a prolonged period of critical care and rehabilitation. A patient with an open tibial fracture after a fall, on the other hand, may only require operative irrigation and external fixation of his fractures followed by rehabilitation. In contrast, a patient with a gunshot wound to the abdomen with vascular injury and enteric perforation may require an emergency laparotomy, massive resuscitation, and postoperative critical care. Hence, on the surface, it seems that each one of these patients requires a different set of resources. However, our findings show that the outcome of these patients depends on certain common resources. These may include initial evaluation, resuscitation, radiologic imaging, blood bank, anesthesia, critical care, and rehabilitation. In addition, it may be prevention of postoperative or intensive care unit-based complications that may be most important. Hence, it seems that systems of care that are common to all trauma patients are the important determinants of outcomes.

A systems approach to performance improvement in health care has been advocated by the Institute of Medicine in a series of landmark reports, titled “To Err is Human—sBuilding a Safer Health System” and “Crossing the Quality Chasm: A New Health System for the 21st Century.”[11,12] This approach is generally based on classical principles of quality improvement described by Donabedian[13]in terms of structures, processes of care, and outcomes. This shifts the focus of quality improvement from individual practitioners to institution-wide systems of care which determine patient outcomes. These principles have been embraced to some extent in the trauma performance improvement process. However, the current process of trauma center verification by the ACS is focused primarily on ensuring presence of institutional structures and specific resources, with little emphasis on delivery of care. Unfortunately, at the present time, there is very little information on which specific components of systems of care are the primary determinant of outcomes. Hence, there is a need to explore the relationship between various structures and processes of care at trauma centers and their patient outcomes, and to determine “best practices.”

The National Surgical Quality Improvement Program is the best known effort to improve the quality of surgical care using a systems approach.[14–19] For each hospital, a ratio of O/E mortality is calculated (with its 90% CI) and plotted on a chart, which demonstrates the performance of each hospital compared with all others. The results are shared with each hospital regularly in the form of comparative, site-specific, and outcome-based annual reports, periodic assessment of performance, self-assessment tools, and structured site visits.[20] In addition, best practices are identified by comparing better performers with worse performers, and these practices are disseminated. Since the inception of National Surgical Quality Improvement Program, 30-day postoperative mortality and morbidity in the Veteran’s Affairs system have declined by 27% and 45%, respectively.[21] We advocate a similar approach to improving quality of care in trauma, called the Trauma Quality Improvement Program (TQIP), which we have described earlier.[5,22]

An important task for TQIP is to develop and validate specific trauma center structures and, more importantly, processes of care that determine patient outcomes.[23,24] Thus, if a trauma center is not performing well, it should be provided with the information and tools so that specific deficiencies in relevant structures and processes of care may be identified and corrected. On the basis of the findings of this study, it is clear that useful measures of quality of care will cut across all aspects of trauma care. Thus, we may find that presence of in-house trauma surgeons may not be as important as having a system in place to monitor compliance with evidence-based protocols for common clinical conditions in trauma patients, such as prevention of ventilator-associated pneumonia, use of massive transfusion protocol for significant hemorrhage, and intracranial pressure monitoring for severe traumatic brain injury. It is also likely that certain widely used measures of processes of care, such as prophylactic antibiotics use in elective surgery, are not applicable to trauma patients. Hence, there is an urgent need for research in defining processes of care relevant to trauma patients and objective means of measuring them.

This study has a few limitations. NTDB is simply an aggregate of trauma registry data from participating trauma centers with no external validation of data, its quality, or consistency. The version used in this study (version 6.2) also suffered from a lack of standardized definitions or criteria to identify patients who should be included in the registries. Another important limitation of this study is exclusion of patients due to incomplete information. We did not have enough information on these patients to impute missing values in a statistically valid fashion. Also, the risk-adjustment model used did not account for different number of patients from each trauma center. Hence, the results may be disproportionately weighted by the experience of trauma centers with larger patient populations. The predictors used in the risk-adjustment model used were limited to those available in NTDB. However, a high c-index suggests good model fit with the predictors included in the model. The outcome used in this study was in-hospital mortality. A 30-day mortality may be a better outcome but trauma registries do not capture these data at the present time. Other measures of quality of care such as complications, costs, and functional outcomes are also not captured well in NTDB. Finally, the study population was limited to three specific cohorts of patients with moderate to severe injuries. However, we believe these the three cohorts represent patients most likely to benefit from the resources of a trauma center.

In conclusion, this study demonstrates that risk-adjusted patient outcomes are consistent within trauma centers across different types of injuries, suggesting that trauma quality improvement efforts should measure, analyze, and focus on hospital-wide systems of care, rather than on isolated quality domains or specific injuries. Objective measures of processes of care need to be developed and validated and incorporated into TQIP, the new paradigm in trauma quality improvement.

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