ORIGINAL ARTICLE

Effect of Trauma Center Designation on Outcome in Patients With Severe Traumatic Brain Injury

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Objective: To determine the association of the American College of Surgeons (ACS) designation with outcomes in patients, specifically those with severe traumatic brain injuries.

Design: A retrospective review. Logistic regression was performed for mortality, complications, and progression of initial neurologic insult.

Setting: Data from the National Trauma Data Bank.

Patients: A total of 16 037 patients with isolated severe head injury (head acute injury score, ≥3 and other body region abbreviated injury score, <3) classified into 2 groups (level 1 and level 2) according to ACS designation.

Results: Patients admitted to a level 2 center had higher mortality rates (13.9% vs 9.6%; $P < .001$), higher rates of complication (15.5% vs 10.6%; $P < .001$), and higher rates of progression of initial neurologic insult (2.0% vs 1.1%; $P < .001$). After adjustment for the factors that were different between the 2 groups, admission to a level 2 facility remained an independent predictor of mortality (adjusted odds ratio [OR], 1.57; 95% confidence interval [CI], 1.41-1.75; $P < .001$), complications (adjusted OR, 1.55; 95% CI, 1.40-1.71; $P < .001$), and progression of neurologic insult (adjusted OR, 1.78; 95% CI, 1.37-2.31; $P < .001$). Other independent risk factors for mortality were penetrating mechanism, age of 55 years or older, Injury Severity Score of 20 or higher, Glasgow Coma Scale score of 8 or lower, and hypotension (systolic blood pressure, <90 mm Hg).

Conclusion: Patients with severe traumatic brain injury treated in ACS-designated level 1 trauma centers have better survival rates and outcomes than those treated in ACS-designated level 2 centers.

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THE AMERICAN COLLEGE OF Surgeons (ACS) has established standards of care for trauma patients, clearly defining the optimal resources required for designation of trauma centers into 3 levels according to available resources as well as educational and research commitments.[1] Previous National Trauma Data Bank (NTDB) studies of patients with severe trauma[2] and specific critical injuries[3] have demonstrated that level 1 trauma centers had markedly better survival and functional outcomes than their level 2 counterparts. The present study evaluated the effect of ACS trauma center designation on outcomes in patients with isolated severe brain injury (head acute injury score [AIS], ≥3 and no other body region AIS, ≥3).

See Invited Critique at end of article

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METHODS

Data for this study were obtained from the NTDB of the Committee on Trauma of the ACS, which currently houses records for more than 1.3 million trauma patients. The study population consisted of all trauma patients alive on admission with a head AIS of 3 or higher and no other body region with an AIS of 3 or higher. Data elements selected from NTDB for analysis included age, sex, mechanism of injury (blunt or penetrating), ACS trauma level designation (1 or 2), hypotension on admission (systolic blood pressure, <90 mm Hg), Glasgow Coma Score on admission (GCS), functional independence scale scores, hospital length of stay, intensive care unit (ICU) length of stay, days treated with a ventilator, and survival outcomes. Documented complications were also collected regarding occurrence of adult respiratory distress syndrome, aspiration pneumonia, bacteremia, cardiac arrest, coagulopathy, compartment syndrome, dehiscence, disseminated fungal infections, deep venous thrombosis, empyema, esophageal intubation, hypothermia, intraabdominal ab-

Table 1. Comparing the Demographic and Clinical Characteristics of Patients Treated in Level 1 and Level 2 Trauma Centers

	No. (%)			
Characteristic	Total (n=16 035)	Level 1 (n=10 161)	Level 2 (n=5874)	*P* Value[a]
Mean (SD) age, y	40.7 (25.1)	40.5 (24.8)	40.9 (25.6)	.35
Age, ≥55 y	4743 (29.6)	2939 (28.9)	1804 (30.7)	.02
Male	11 169 (69.6)	7069 (69.6)	4100 (69.8)	.79
Mechanism, blunt	15 359 (96.6)	9736 (96.7)	5623 (96.5)	.63
Mean (SD) SBP, mm Hg	137.3 (31.3)	137.1 (30.8)	137.5 (32.1)	.42
Hypotension on admission[b]	1830 (11.4)	1315 (12.9)	515 (8.8)	<.001
Mean (SD) GCS on admission	11.7 (4.5)	11.6 (4.6)	11.8 (4.4)	.47
GCS ≤ 8 on admission	5824 (36.3)	3797 (37.4)	2027 (34.5)	<.001
Mean (SD) ISS	20.7 (9.9)	20.6 (9.9)	20.9 (9.7)	.004
ISS ≥ 20	6537 (40.8)	4038 (39.7)	2499 (42.5)	.001

Abbreviations: GCS, Glasgow Coma Score; ISS, Injury Severity Score; SPB, systolic blood pressure.
[a] The *P* values for categorical variables were derived from a 2-tailed χ^2 test or Fisher exact test; *P* values for continuous variables were derived from a *t* test or Mann-Whitney *U* test.
[b] Defined as SBP of less than 90 mm Hg.

Table 2. Comparing Neurosurgical Operative Procedures of Patients Treated in Level 1 and Level 2 Trauma Centers

	No. (%)			
Procedure	Total	Level 1	Level 2	*P* Value[a]
Any procedure	2563 (16.0)	1618 (15.9)	945 (16.1)	.79
ICP monitor or ventriculostomy	1388 (8.7)	884 (8.7)	504 (8.6)	.79
Craniotomy or craniectomy	1339 (8.3)	858 (8.4)	481 (8.2)	.57
Incision of brain for drainage of hematoma	229 (1.4)	145 (1.4)	84 (1.4)	.99
Lobectomy or other brain excision	252 (1.6)	120 (1.2)	132 (2.2)	<.001

Abbreviation: ICP, intracranial pressure.
[a] The *P* values were derived from a *t* test or Mann-Whitney *U* test.

scess, jaundice, myocardial infarction, pancreatitis, pneumonia, pneumothorax, progression of initial neurologic insult, pulmonary embolism, renal failure, urinary tract infection, and wound infection. The types of procedures, including intracranial pressure monitor or ventriculostomy placement, craniotomy, craniectomy, incision of brain for drainage of intracerebral hemorrhage and lobectomy, or other brain excision were also collected by procedure code.

The association of the ACS level of trauma center designation with complications and survival outcomes was evaluated using mortality odds ratios (OR) adjusted for age (>55 years), Injury Severity Score (ISS) of 20 or higher, hypotension on admission (systolic blood pressure, <90 mm Hg), blunt vs penetrating mechanism, and GCS on admission (≤8). The SPSS version 13.0 software (SPSS Inc, Chicago, Illinois) was used for statistical analysis. Univariate analysis was performed using the *t* test or analysis of variance for continuous variables and χ^2 tests for categorical variables. All variables with a *P* value less than .2 on univariate analysis were entered into multivariate logistic regression analysis. Adjusted ORs with 95% confidence intervals (CI) were derived from logistic regression analysis and statistical significance was set at *P* values less than .05 after adjustment for risk factors.

RESULTS

During the 5-year study period, 952 242 trauma cases were reported to the NTDB. Facilities varied with respect to the number of years they had reported their cases to the NTDB. A total of 16 035 trauma patients with head AIS of 3 or higher and no other body area AIS of 3 or higher from 126 adult ACS level 1 or 2 facilities who were alive on admission were analyzed. Of the 126 trauma facilities, 71 were ACS-designated level 1 trauma centers and 55 were ACS-designated level 2 trauma centers. **Table 1** shows the number of study patients and the percentage, with each risk factor used in the analysis of mortality by ACS trauma center designation.

The epidemiologic and clinical characteristics of the 2 groups are shown in Table 1 and **Table 2**. Overall crude mortality was 11.1% (1788 deaths). Crude mortality according to ACS designation was 9.6% in level 1–designated and 13.9% in level 2–designated trauma centers (*P*<.001) (**Table 3**). Multivariate analysis adjusting for ACS level, mechanism, age, ISS, hypotension, and GCS showed significantly higher mortality in level 2 centers (adjusted OR, 1.56; 95% CI, 1.40-1.74; *P*<.001). The overall complication rate was 10.6% in level 1centers and 15.5% in level 2 centers (*P*<.001). Importantly, level 2 admission was associated with a higher rate of progression of neurologic insult (2.0% vs 1.1%; adjusted OR, 1.78; 95% CI, 1.37-2.31; *P*<.001). Multivariate analysis adjusting for the described risk factors showed a significantly higher complication rate in the level 2 centers (adjusted OR, 0.65; 95% CI, 0.58-0.71; *P*<.001). Logistic regression analysis adjusting for the described risk factors identified 6 independent risk factors for increased mortality (ISS≥20; GCS≤8; age, ≥55 years), penetrat-

Table 3. Comparing Outcomes of Patients Treated in Level 1 and Level 2 Trauma Centers

Outcome	Mean (SD) Total (n=16 035)	Level 1 (n=10 161)	Level 2 (n=5874)	*P* Value[a]
Deaths, No. (%)	1788 (11.1)	974 (9.6)	814 (13.9)	<.001
Any complication, No. (%)	1980 (12.3)	1072 (10.6)	908 (15.5)	<.001
FIM score	10.4 (2.4)	10.4 (10.3)	10.3 (2.6)	.51
Vent use, d	3.6 (9.3)	3.8 (3.3)	3.3 (7.2)	.54
ICU stay, d	4.9 (7.7)	5.3 (4.3)	4.3 (6.7)	<.001
Hospital stay, d	9.7 (13.9)	10.3 (8.8)	8.8 (12.9)	<.001

Abbreviations: FIM, functional independence measure; ICU, intensive care unit.
[a]The *P* values for categorical variables were derived from a 2-tailed χ^2 test or Fisher exact test; *P* values for continuous variables were derived from a *t* test or Mann-Whitney *U* test.

Table 4. Independent Risk Factors for Mortality

Step	Variable	Cumulative R^2	R^2	Adjusted OR (95% CI)	*P* Value
1	ISS ≥ 20	0.134	0.134	4.84 (4.29-5.47)	<.001
2	GCS	0.196	0.061	3.77 (3.36-4.24)	<.001
3	Age, y	0.220	0.025	2.53 (2.26-2.84)	<.001
4	Mechanism, penetrating	0.235	0.015	3.85 (3.08-4.81)	<.001
5	ACS level 2 admission	0.242	0.007	1.56 (1.40-1.74)	<.001
6	Hypotension[a]	0.243	0.001	1.32 (1.14-1.53)	<.001

Abbreviations: ACS, American College of Surgeons; CI, confidence interval; GCS, Glasgow Coma Score; ISS, Injury Severity Score; OR, odds ratio.
[a]Defined as systolic blood pressure of less than 90 mm Hg.

ing mechanism, hypotension on admission, and admission to a level 2 trauma center (**Table 4**).

COMMENT

Trauma systems, centers, and programs have demonstrated appreciable benefit to survival in severely injured patients.[2-20] Since 1987, ACS oversight has regulated a verification and consultation system designed to assist hospitals in improving trauma care and establish acceptable levels of performance in the care of trauma patients.[1] The ACS *Resources for Optimal Care of the Injured Patient 1999*, published by the ACS, identifies 108 essential criteria for level 1 trauma center designation. The accomplishment of these criteria is an expensive and resource-consuming process. It is essential to establish the investment value of these major commitments of money and resources in terms of lives saved and improved functional outcomes.

The association between ACS level designation and outcomes of injured patients has previously been examined using NTDB records. In a recent study[3] it was reported that patients with major cardiovascular or liver injuries treated at ACS-designated level 1 centers had considerably better survival rates than patients treated in level 2 or other trauma centers. In another study it was demonstrated that the adjusted mortality of severely injured patients (ISS>15) in ACS-designated level 2 centers and undesignated centers was notably higher than in level 1 centers.[2]

Others have examined the relationship between level of trauma center designation and outcomes.[4,9,20,21] Using a Severity Characterization of Trauma, Pasquale and colleagues[20] found no difference in survival outcomes between level 1 and level 2 centers for patients with 9 types of injuries (head, brain, neck, chest, lung, liver, spleen, aorta, and vena cava). Their use of a predictive model for comparison between different facilities, however, may be misleading owing to the fact that, by design, these models favor small centers that admit fewer patients with severe injuries. The major limitations of using the various predictive models for comparison of outcomes between trauma centers are well known.[22] In another small study, Helling et al[21] also suggested that designation level might not significantly affect mortality. In their examination of outcomes following severe liver injuries, however, they were only able to identify 43 and 14 patients treated at level 1 and level 2 facilities, respectively. Owing to their small number, little conclusion can be drawn from the statistically insignificant trend toward improved survival associated with level 1 admission in this study (51% vs 71%; $P=.18$).

Several groups have attempted to more clearly demonstrate the role trauma level designation and type of verification may play in outcomes following trauma. Observed benefits of regionalized care systems in the United States and other countries have included reduction of delays, inadequate care, and preventable deaths due to trauma.[18] The survival benefit of trauma systems has also been demonstrated. Sampalis and colleagues[12] noted that the development of a regionalized non-ACS trauma center designation in Canada significantly improved the survival rates of patients treated at these facilities. Results from other non-ACS systems vary, however, with at least 1 study of trauma registry data on patients with major injuries admitted to North Carolina state-designated level 1 and level 2 trauma centers failing to demonstrate any difference in adjusted case fatality rate.[13] While data on state-level designations may be too limited to provide a significant conclusion, state-specific criteria for trauma center designation can vary considerably and lack the international oversight and organization facilitated by verification and periodic review of a wider-reaching organization such as the ACS.

The positive effect of ACS trauma center designation has been more clearly demonstrated. In addition to the aforementioned studies,[2,3] DiRusso et al[9] have shown that preparation and achievement of ACS level 1 verification is associated with a significant decrease in overall mortality (7.38% vs 5.37%; $P<.05$) and a marked decrease in mortality for those most severely injured (ISS>30). They also noted that average length of stay was notably shorter after verification. Biffl et al[4] found that, despite increased age and acuity of the trauma patient population in the decade following the achievement of ACS level 1 status, ICU lengths of stay were shorter and mortality due to late sepsis and multiple organ failure was lower. Finally, in a study of 43 New York state trauma centers by Cooper et al,[7] the authors noted that treatment at a center meeting ACS criteria was associated with a lower observed and risk-adjusted mortality rate compared with one not meeting ACS criteria. It is interesting to note, however, that these investigators were unable to document an inverse relationship between hospital volume and inpatient mortality. Other authors have debated the role that volume may specifically play in trauma outcomes.[11,17] While volume is most likely an important factor, the increased staffing, nursing support, and higher technology requirements demanded by higher ACS designation level is almost certainly paramount[12] to outcomes following injury.

The effect of an organized trauma system on traumatic brain injury treatment has been examined by several investigators.[4,5,8,10,14,16] Biffl et al[4] found that following the development of a level 1 trauma facility, nonsurvivors had increased mortality attributable to blunt central nervous system injury.[4] In their study of the influence of a statewide trauma system on outcomes of these types of patients, Mullins et al[10] noted that patients with head injuries appeared to benefit from trauma system development more than patients with other index injuries, with a clearly demonstrated reduction in the risk of death in patients with head injuries (adjusted OR, 0.70; 95% CI, 0.59-0.82).[16] In patients with severe head injuries (head AIS≥3), Cornwell et al[14] also found that changes in care associated with achieving state designation of level 1 status resulted in decreased mortality (23.8% vs 17.2%; $P=.07$) and a resulting 42% decrease in the odds of death for these patients ($P=.03$).

We found that after multiregression analysis, admission to a level 1 facility was an independent predictor of survival compared with level 2 admission in isolated severe brain injury. The reasons for this finding are likely multifactorial. As Ehlrich et al[8] have suggested, ACS verification and consultation is associated with improvement in important clinical care parameters paramount to the care of patients with traumatic brain injuries. Following ACS consultation and verification, they noted a significant improvement in the early acquisition of head-computed axial tomographic scans and other care parameters in patients with neurologic injuries at their facility. Other important factors that might provide rationale for our findings include better neurosurgical care in the operating room and improved intensive care capabilities in tertiary hospitals. Early and effective application of advanced trauma life support principles in better developed trauma systems may also aid by limiting the occurrence of secondary brain injury and the propagation of the initial neurologic insult. Perhaps the construct of level 1 trauma centers with in-house neurosurgical capabilities and rapid imaging and interventional availability may provide an opportunity for more aggressive early treatment of patients with severe brain injuries compared with their level 2 counterparts. The construct of the NTDB alone does not provide adequate information to definitively identify the role of these possible explanations in our findings.

This study has shown that patients sustaining severe traumatic brain injury treated at ACS-designated level 1 trauma centers have a considerably better overall survival rates than patients treated at level 2 centers after adjusting for patient-level risk factors. This finding might be important in planning trauma systems and triage of patients with traumatic brain injury.

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INVITED CRITIQUE

This article examines the outcomes of patients with head injuries using the NTDB and compares the outcomes of patients with head injuries between level 1 and level 2 centers. The results demonstrate higher rates of both mortality and complication in level 2 facilities. The implications of this kind of study suggest the need for further regionalization of these devastating injuries that constitute as much as 50% of trauma-related mortality in trauma centers. This relationship between level of resource commitment and outcome for head injuries has been suggested by others and has been one of the most dramatic outcomes of regionalization and development of trauma centers overall. The use of the NTDB to do this study is also useful. It avoids specific problems found in smaller geographically based studies. The fact that outcomes will improve as resources increase is not surprising.

One problem does arise in understanding the implications of these data. In general, a level 1 hospital has the highest level of neurosurgical and neurointensive care. The ability to keep these patients alive and get them into long-term care or rehabilitation environments is routine today. Few patients die if the care team decides to sustain their life. One interpretation may be that in a level 2 facility there is a greater tendency to let patients with severe brain injuries follow their natural course and to withdraw care. This would lead to more in-hospital deaths. These deaths would not be due to less resources or quality of care. It would likely be accompanied by fewer long-term survivors and poor outcome in rehabilitation centers. One limitation of the NTDB is that it does not allow for this comparison, because long-term follow-up of rehabilitation and neurologic outcome is not currently available.

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