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Comparison of Outcomes in Level I vs Level II Trauma Centers in Patients Undergoing Craniotomy or Craniectomy for Severe Traumatic Brain Injury

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BACKGROUND: Traumatic brain injury (TBI) carries a devastatingly high rate of morbidity and mortality.

OBJECTIVE: To assess whether patients undergoing craniotomy/craniectomy for severe TBI fare better at level I than level II trauma centers in a mature trauma system.

METHODS: The data were extracted from the Pennsylvania Trauma Outcome Study database. Inclusion criteria were patients > 18 yr with severe TBI (Glasgow Coma Scale [GCS] score less than 9) undergoing craniotomy or craniectomy in the state of Pennsylvania from January 1, 2002 through September 30, 2017.

RESULTS: Of 3980 patients, 2568 (64.5%) were treated at level I trauma centers and 1412 (35.5%) at level II centers. Baseline characteristics were similar between the 2 groups except for significantly worse GCS scores at admission in level I centers ($P = .002$). The rate of in-hospital mortality was 37.6% in level I centers vs 40.4% in level II centers ($P = .08$). Mean Functional Independence Measure (FIM) scores at discharge were significantly higher in level I (10.9 ± 5.5) than level II centers (9.8 ± 5.3 ; $P < .005$). In multivariate analysis, treatment at level II trauma centers was significantly associated with in-hospital mortality (odds ratio, 1.2; 95% confidence interval, 1.03-1.37; $P = .01$) and worse FIM scores (odds ratio, 1.4; 95% confidence interval, 1.1-1.7; $P = .001$). Mean hospital and ICU length of stay were significantly longer in level I centers ($P < .005$).

CONCLUSION: This study showed superior functional outcomes and lower mortality rates in patients undergoing a neurosurgical procedure for severe TBI in level I trauma centers.

KEY WORDS: Craniectomy, Craniotomy, Traumatic brain injury, Trauma centers

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Despite advances in neurosurgical and neurocritical care, severe traumatic brain injury (TBI) still carries a high rate of morbidity and mortality.¹⁻³ In an epidemiologic study, the 12-mo mortality rate was as high as 35% in patients with severe TBI, while favorable outcomes at 1 yr were seen in only about 48%.²

In patients with severe TBI, therapy is primarily aimed at preventing increased intracranial pressure and secondary brain insult.⁴⁻⁵ Thus, a significant portion of these

patients undergo neurosurgical interventions. One study found that as many as 35% of patients with severe TBI undergo neurosurgical procedures, which may consist of a craniotomy or a decompressive craniectomy.² These patients therefore require high levels of neurosurgical and neurointensive care capabilities, both of which may be more readily available at tertiary centers.

Level I trauma centers provide multidisciplinary treatment and specialized resources for trauma patients and require trauma research, a surgical residency program and an annual volume of 600 major trauma patients per year. Level II trauma centers provide similar experienced medical services and resources with volume requirements of 350 major trauma patients per year but do not require the research and residency components. As trauma systems mature such as in the state of

ABBREVIATIONS: ACS, American College of Surgeons; AUC, area under the curve; FIM, Functional Independence Measure; GCS, Glasgow Coma Scale; PTOS, Pennsylvania Trauma Outcome Study database; PTSF, Pennsylvania Trauma System Foundation; TBI, traumatic brain injury

Pennsylvania, the distinction between level I and level II trauma centers may no longer be appropriate as patient outcomes could be similar.⁶ However, no study has compared outcomes in level I vs level II trauma centers in patients undergoing a neurosurgical procedure for severe TBI. The purpose of this study was to assess whether patients undergoing a craniotomy or craniectomy for TBI fare better at level I than level II trauma centers in a state with a mature trauma system.

METHODS

The study protocol was reviewed and approved by the University Institutional Review Board. Individual patient consent was not required given the cross-sectional, noninterventional design of the study (query of an existing database). The manuscript conforms to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

The Pennsylvania Trauma System Foundation (PTSF) is the accrediting body for trauma programs throughout the Commonwealth of Pennsylvania.⁶ The study data were extracted from the Pennsylvania Trauma Outcome Study database (PTOS; the PTSF statewide trauma registry), which contains deidentified patient data collected from the medical records of each of the 31 accredited level I and level II trauma centers in the state.

The study population included all patients older than the age of 18 yr with severe TBI (Glasgow Coma Scale [GCS] score of lower than 9) undergoing craniotomy or craniectomy in the state of Pennsylvania from January 1, 2002 through September 30, 2017. Extracted variables were patient age, sex, systolic blood pressure on admission, GCS on admission, Injury Severity Score (ISS) on admission, trauma center level, intensive care unit (ICU) length of stay, hospital length of stay, discharge status (dead or alive), and Functional Independence Measure (FIM) score at discharge.

Statistical Analysis

Data are presented as mean and standard deviation for continuous variables, and as frequency for categorical variables. Analysis was carried out using Student's *t*-test, Wilcoxon rank sum, χ^2 test or Fisher's exact test as appropriate. Univariate analysis of factors associated with functional status on discharge, mortality, ICU length of stay, and hospital length of stay were carried out using logistic regression analysis. Interaction and confounding were assessed through stratification and relevant expansion covariates. Factors with a *P*-value < .20 in the univariate analysis were entered in a multivariable logistic regression analysis. *P*-values of $\leq .05$ were considered statistically significant. For each final multivariate model, the area under the curve (AUC) was calculated with graphical and standard nonparametric receiver operating characteristic measurements. Statistical analysis was carried out with Stata 14.0 (StataCorp, College Station, Texas).

RESULTS

Baseline Patient Characteristics

Of the 3980 patients who met the inclusion criteria, 2568 (64.5%) were treated at a level I trauma center and 1412 (35.5%) at a level II trauma center. In level I centers, 52.5% (*n* = 1349)

TABLE 1. Patient Characteristics on Admission in Level 1 and Level 2 Trauma Centers

	Level 1 trauma n = 2568 (64.5%)	Level 2 trauma n = 1412 (35.5%)	P-value
Age (yr)	47.5 ± 20.5	47.1 ± 20.5	.5
Gender			
Male	1881 (73.3%)	1045 (74.0%)	.6
Female	687 (26.7%)	367 (26.0%)	
GCS on admission			
3	1838 (71.6%)	905 (64.1%)	
4	80 (3.1%)	69 (4.9%)	
5	103 (4.0%)	77 (5.5%)	<.001
6	221 (8.6%)	138 (9.8%)	
7	208 (8.1%)	124 (8.8%)	
8	118 (4.6%)	99 (7.1%)	
Systolic BP			
Mean SBP, mmHg	141.2 ± 37.7	145.7 ± 38.3	<.005
<120 mmHg, n (%)	645 (25.5%)	324 (23.1%)	.1
>160 mmHg, n (%)	659 (26.1%)	427 (30.5%)	.003
ISS			
Mean ISS	29.5 ± 10.2	29.6 ± 9.5	.8
ISS > 30	823 (32.1%)	473 (33.5%)	.4

were treated prior to 2010 (median year in the study period) vs 50.3% (*n* = 710) in level II centers (*P* = .2). There were more men than women in both level I (73.3%, *n* = 1881) and level II centers (74.0%, *n* = 1045, *P* = .6). A comparison of the patient characteristics of those treated at level I vs level II centers is displayed in Table 1.

Mean age did not differ between level I (47.5 ± 20.5 yr) and level II centers (47.1 ± 20.5 yr, *P* = .5). The proportion of patients below the age of 50 (56.7% in level I vs 56.6% in level II, *P* = .9), 65 (77.5% in level I vs 78.5% in level II, *P* = .5), or 75 yr (87.6% in level I vs 87.7% in level II, *P* = .9) did not differ significantly between the groups (Table 1).

A similar proportion of patients presented with a systolic blood pressure below 120 mm Hg on admission in level I (25.5%, *n* = 645) and level II (23.1%, *n* = 324, *P* = .1) trauma centers (Table 1). However, significantly more patients had a systolic blood pressure above 160 mmHg on admission at level II (30.5%, *n* = 427) than level I centers (26.1%, *n* = 659, *P* = .003). Mean systolic blood pressure was lower in level I (141.2 ± 37.7 mm Hg) than level II centers (145.7 ± 38.3 mmHg, *P* < .005).

The proportion of patients who had a GCS score of 3 to 5 (vs GCS of 6-8) was significantly higher in level I (78.7%, *n* = 2021) than level II trauma centers (74.4%, *n* = 1051, *P* = .002). Mean GCS score on admission was significantly lower in level I (3.9 ± 1.6) than level II centers (4.2 ± 1.7, *P* < .005). The breakdown by GCS is detailed in Table 1.

A similar proportion of patients had ISS > 30 in level I (32.1%, *n* = 823) and level II centers (33.5%, *n* = 473, *P* = .4). Mean ISS did not differ between level I (29.5 ± 10.2) and level II centers (29.6 ± 9.5, *P* = .8).

TABLE 2. Comparison of Key Outcomes at Level 1 vs Level 2 Trauma Centers

	Level 1 trauma n = 2568 (64.5%)	Level 2 trauma n = 1412 (35.5%)	P-value
In-patient mortality	37.6% (n = 966)	40.4% (n = 570)	.08
FIM score at discharge	10.9 ± 5.5	9.8 ± 5.3	.0002
Length of hospital stay (days)	17.4 ± 18.8	14.2 ± 14.2	<.0001
Length of ICU stay (d)	11.8 ± 12.6	9.9 ± 8.7	<.0001

Mortality and Functional Outcome

The rate of in-hospital mortality was 37.6% (966/2568) in level I trauma centers vs 40.4% (570/1412) in level II trauma centers ($P = .08$, Table 2). In univariate analysis, the following variables were associated with in-hospital mortality: increasing age ($P < .005$), increasing systolic blood pressure on admission ($P = .02$), decreasing GCS score on admission ($P < .005$), level II trauma centers ($P = .08$), and increasing ISS ($P < .005$). In multivariate analysis, treatment at a level II trauma center was significantly correlated with in-hospital mortality (odds ratio [OR], 1.2; 95% confidence interval [CI], 1.03-1.37; $P = .01$). Other factors associated with in-hospital mortality in multivariate analysis were increasing age (OR, 1.03; 95% CI, 1.031-1.038; $P < .005$), systolic blood pressure > 160 mmHg on admission (OR, 1.2; 95% CI, 1.02-1.4; $P = .02$), decreasing GCS score on admission (OR, 1.19; 95% CI, 1.12-1.23; $P < .005$), and increasing ISS (OR, 1.04; 95% CI, 1.03-1.04; $P < .005$). The AUC for this model was 0.7015 (Table 3).

Mean FIM scores at discharge were significantly higher in level I (10.9 ± 5.5) than level II trauma centers (9.8 ± 5.3; $P = .0002$, Table 2). In univariate analysis, the following variables were significantly correlated with a FIM score < 10: increasing age ($P < .005$), treatment after 2010 ($P = .02$), level II trauma centers ($P = .002$), and increasing ISS ($P < .005$). In multivariate analysis, the factors associated with FIM score < 10 remained level II trauma centers (OR, 1.4; 95% CI, 1.1-1.7; $P = .001$), increasing age (OR, 1.01; 95% CI, 1.001-1.02; $P < .005$), treatment after 2010 (OR, 1.4; 95% CI, 1.1-1.7; $P = .002$), and increasing ISS (OR, 1.04; 95% CI, 1.03-1.06; $P < .005$). The AUC for this multivariate model was 0.6396 (Table 3).

Hospital and ICU Length of Stay

Mean hospital length of stay was significantly longer in level I (17.4 ± 18.8 d) than level II trauma centers (14.2 ± 14.2; $P < .0001$, Table 2). In univariate analysis, the following variables were associated with a longer hospital stay: males ($P < .005$), decreasing age ($P < .005$), level I trauma centers ($P = .002$), and increasing ISS ($P < .005$). In multivariate analysis, the variables associated with longer hospital stay were only level I trauma centers (OR, 0.75; 95% CI, 0.65-0.85; $P < .005$) and decreasing age (OR, 1.02; 95% CI, 1.02-1.03; $P < .005$). The AUC was 0.6376 (Table 3).

TABLE 3. Multivariate Logistic Regression Models

Outcome	Predictors	OR	P-value	AUC
Inpatient mortality	Level 2 center	1.19	.01	
	Older age	1.04	<.005	0.7015
	SBP > 160mmHg	1.2	.02	
	Higher ISS	1.04	<.0001	
	Lower GCS	1.19	<.005	
FIM < 10 at discharge	Level 2 center	1.4	.001	
	Older age	1.01	<.005	0.6396
	Treatment after 2010	1.4	.002	
	Higher ISS	1.04	<.005	
	Level 1 center	0.75	<.001	
Length of hospital stay (> 15 d)	Younger age	1.02	<.001	0.6376
	Level 1 center	0.83	<.001	
Length of ICU stay (> 10 d)	Younger age	1.02	<.001	0.6202
	Higher ISS	1.01	.033	

Mean ICU length of stay was significantly longer in level I (11.8 ± 12.6 d) than level II trauma centers (9.9 ± 8.7; $P < .005$, Table 2). In univariate analysis, the following variables were associated with a longer ICU stay: decreasing age ($P < .0001$), level I trauma centers ($P = .002$), and increasing ISS ($P < .005$). In multivariate analysis, the variables associated with longer ICU stay were only level I trauma centers (OR, 0.83; 95% CI, 0.72-0.95; $P = .009$) decreasing age (OR, 1.02; 95% CI, 1.02-1.03; $P < .005$), and increasing ISS (OR, 1.01; 95% CI, 1.03-1.06; $P = .03$) with an AUC of 0.6202 (Table 3).

DISCUSSION

Trauma Level Certification Process

In an effort to optimize trauma care, the American College of Surgeons (ACS) has developed a comprehensive process of verification for trauma centers with several clinical, educational, administrative, and other requirements. ACS reviews the state-designated trauma centers and verifies the adequacy of their resources. However, this differs from the state of Pennsylvania where trauma centers are verified by the PTSF through a distinct process that is based on the accreditation requirements established by the Foundation's Standards Committee and approved by the Foundation's board of directors. In the Pennsylvania trauma system, even though level I and II trauma centers may be thought to provide the same level of care, there are actually several differences between the two. Level I trauma centers tend to have higher patient volumes and more specialized personnel with better access to technological resources.⁷ This comes, however, at a

significantly higher cost in level I centers, which may be problematic in the current healthcare environment with the ever increasing economic pressures.⁷ It is therefore of utmost importance for level I centers to demonstrate that they provide better patient outcomes than their level II counterparts.

Studies have shown that following level I designation, trauma centers have seen a positive impact on survival and patient care.⁸ DiRusso et al⁹ analyzed outcomes in a regional trauma center before and after level I certification and found a decrease in mortality and length of stay with significant cost savings following the verification process. Along similar lines, Demetriades et al¹⁰ analyzed data on 130 154 patients with severe trauma (ISS > 15) from the National Trauma Data Bank and concluded that those treated in level I trauma centers have considerably better survival outcomes than those treated in level II centers. This distinction between level I and level II trauma centers appears to apply for TBI as well. As such, Cornwell et al¹¹ demonstrated a 42% decrease in odds of death among patients with severe TBI following level I trauma center designation. Likewise, DuBose et al⁸ reviewed 16 037 patients with isolated severe TBI from the National Trauma Data Bank and found level I centers to have lower mortality and complication rates along with lower rates of progression of initial neurologic insult than level II centers. The authors, however, did not control for neurosurgical procedures nor did they stratify their analysis per state. As discussed above, more mature trauma systems tend to have similar outcomes between level I and II trauma centers.⁶

Comparison of Outcomes by Trauma Level

This study is the first to compare the outcomes of patients undergoing craniotomy/craniectomy for severe TBI in PTOS-verified level I vs II trauma centers. The results show a clear, significant benefit in terms of mortality and functional outcomes favoring level I trauma centers. It is noteworthy that level I centers still managed to achieve better surgical outcomes than their level II counterparts despite treating patients who generally have more complex traumas and are more severely brain-injured.

Several factors may explain the findings of this study. Patients undergoing a neurosurgical procedure for severe TBI are often very ill, suffer from increased intracranial ventricular pressure, and are at high risk of secondary brain injury thus requiring a high level of neurosurgical and neurocritical care, both of which may be more readily available at level I trauma centers. Additionally, neurosurgeons at high-volume level I trauma centers may be more experienced in the operative and postoperative management of TBI and its complications (intracranial hypertension, cerebral ischemia) than their level II counterparts. Indeed, Nathens et al¹² showed a strong association between trauma center volume and outcomes in trauma patients at high risk of mortality. Similarly, in a nicely executed study, Alali et al¹³ found that high-volume hospitals are associated with lower in-hospital mortality rates following severe TBI. Rapid imaging, shorter delays to surgery with more aggressive early treatment of severe TBI, greater general

and neurointerventional capabilities, and better nursing support at level I trauma centers are other factors that may explain the difference in outcomes. Additionally, level I centers are more likely to comply with TBI guidelines as demonstrated in a study that surveyed 385 level I and level II trauma centers.¹⁴ Several studies have suggested that stricter adherence to the TBI guidelines improve functional outcomes and decrease mortality.¹⁵⁻¹⁷ Lastly, the higher FIM scores achieved in level I centers may reflect better access to physical and occupational therapy and early intensive neurorehabilitation programs.

Higher Complexity in Level 1 Trauma Centers

The findings of our study stand in stark contrast to those of Rogers et al⁶ who also extracted data from the Pennsylvania Trauma Outcome Study but found no difference in survival of trauma patients (all categories included) between level I and level II trauma centers in Pennsylvania. The authors concluded that in mature trauma systems such as in Pennsylvania, the distinction between level I and level II trauma centers blurs. However, while there was no difference in survival, the trauma complexity was higher in Level 1 centers. More specifically, the rate of sustained penetrating injuries in Level 1 was twice as high as that of Level 2 (10.1% vs 5.5%, $P < .001$). As shown in this study, the distinction should remain for patients with severe TBI requiring neurosurgical procedures as these patients have complex injuries; are critically ill; and require the highest level of neurosurgical, neurocritical, and multidisciplinary care. The fact that the same database was queried in both studies lends further credence to our conclusion.

One would expect level I trauma centers to be more efficient than level II centers in caring for patients with severe TBI, with potentially shorter hospital and ICU stays. The results of this study, however, showed longer hospital and ICU length of stay in level I trauma centers. This could be the result of a higher proportion of patients with lower GCS scores and more complex brain/systemic injuries in level I centers. It is also possible that level I centers utilize more monitoring modalities than level II centers, which could prolong the length of stay especially in the ICU. Lastly, patients with severe TBI could be more frequently transitioned to comfort measures in level II trauma centers. Our findings concur with recent literature on the topic. Mabry et al¹⁸ found that of all trauma centers, level I centers have the highest mean ICU and hospital length of stay.

Limitations

Our study has several limitations that need to be taken into consideration. The PTOS database does not include the patients' exact neurosurgical diagnosis on presentation. Therefore, we were unable to determine the breakdown of pathologies (eg diffuse axonal injury, acute subdural hematoma, or traumatic subarachnoid hemorrhage) treated at level 1 vs level 2 trauma centers. Furthermore, we considered outcomes at discharge only as no follow-up outcomes are available in the dataset. We also did not evaluate secondary outcomes such as procedural

complications for lack of availability in the dataset as well. Lastly, we did not control for patient volume in our analysis, but analyzed trauma centers based on their state designation.

CONCLUSION

This study showed superior functional outcomes and lower mortality rates in patients undergoing craniotomy/craniectomy for severe TBI in level I compared with level II trauma centers. A randomized controlled trial is thereby necessary to clarify whether patients with complex neurosurgical needs are better cared for in Level I trauma centers.

Disclosures

The data were provided by the Pennsylvania Trauma Systems Foundation. The Foundation specifically disclaims responsibility for any analyses, interpretations, or conclusion. The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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