Management of severe head injury: Institutional variations in care and effect on outcome

Critical Care Medicine - Volume 30, Issue 8 (August 2002) - Copyright © 2002 Lippincott Williams & Wilkins - About This Journal

NEUROLOGIC CRITICAL CARE

Management of severe head injury: Institutional variations in care and effect on outcome

Eileen M. Bulger, MD;
Avery B. Nathens, MD, PhD, MPH;
Frederick P. Rivara, MD, MPH;
Maria Moore, MPH;
Ellen J. MacKenzie, PhD;
Gregory J. Jurkovich, MD

From the Department of Surgery (EMB, ABN, GJJ) and the Department of Pediatrics (FPR), University of Washington, Seattle, WA; University HealthSystem Consortium (MM); and Johns Hopkins School of Public Health (EM), Baltimore, MD.

Presented, in part, at the American College of Surgeons, Surgical Forum, Chicago, IL, 2000.

This study demonstrates that despite the establishment of evidence-based guidelines, there remains considerable institutional variability in the management of severe head injury.

Objective:

The purpose of this study was three-fold: a) to examine variations in care of patients with severe head injury in academic trauma centers across the United States; b) to determine the proportion of patients who received care according to the Brain Trauma Foundation guidelines; and c) to correlate the outcome from severe traumatic brain injury with the care received.

Design:

Retrospective data collection for consecutive patients with closed head injury and long bone fracture admitted over an 8-month period.

Setting:

Thirty-four academic trauma centers in the United States

Patients:

All patients admitted with a presenting Glasgow Coma Scale score ≤8.

Measurements and Main Results:

Variations in care were assessed, including prehospital intubation, intracranial pressure monitoring, use of osmotic agents, hyperventilation, and computed tomography scan utilization. Aggressive centers were defined as those placing intracranial pressure monitors in >50% of patients meeting the Brain Trauma Foundation criteria for intracranial pressure monitoring. The primary outcome variables were mortality, functional status at discharge, and length of stay. Kaplan-Meier survival analysis was performed for aggressive vs. nonaggressive centers. A Cox proportional hazard model was used to evaluate the association between type of center and mortality rate. Length of stay was evaluated by using linear regression.

Results:

There was considerable variation in the rates of prehospital intubation, intracranial pressure monitoring, intracranial pressure-directed therapy, and head computed tomography scan utilization across centers. Management at an aggressive center was associated with a significant reduction in the risk of mortality (hazard ratio, 0.43; 95% confidence interval, 0.27–0.66). There was no statistically significant difference in functional status at the time of discharge for survivors. Adjusted length of stay for survivors at aggressive centers was shorter, compared with the length of stay at nonaggressive centers: −6 days (95% confidence interval, −14 to 2 days).

Conclusion:

Considerable national variation in the care of severely head-injured patients persists. An “aggressive” management strategy is associated with decreased mortality rate for patients with severe head injury, with no significant difference in functional status at discharge among survivors.

Key Words: head injury; intracranial pressure monitoring; neurosurgery; traumatic brain injury; Glasgow Coma Scale

Introduction

Traumatic brain injury is a major public health problem in the United States, affecting nearly 500,000 patients per year ([1]). Approximately 100,000 of these patients will die of their injury, and 90,000 will suffer a long-term neurologic disability. This translates into a societal cost of $75–100 billion per year for medical care and lost productivity ([2]). In 1995, the Brain Trauma Foundation issued evidence-based guidelines for the resuscitation, monitoring, and care of brain-injured patients ([3]). That same year, but before wide dissemination of the guidelines, a national survey of the clinical management of the head-injured patient revealed considerable variations in care ([4]). The current degree of national compliance with these guidelines is unknown. Furthermore, the impact that these guidelines have on trauma outcome has been assessed in only one small series ([5]).

Since its introduction in 1974, the Glasgow Coma Scale (GCS) has been widely adopted as an initial measure of the severity of brain injury ([6]). Previous authors have demonstrated the GCS score to be a predictor of both immediate and long-term outcome after traumatic brain injury ([7] [8] [9] [10] [11] [12]). Traumatic brain injury can be categorized as severe, moderate, or mild based on the presenting GCS. A GCS of ≤8 is considered representative of a severe brain injury, 9–13 moderate brain injury, and 14–15 mild brain injury ([13]). Patients presenting with severe brain injury have the highest mortality rate, typically reported in the range of 39–51% ([8] [14] [15]). These patients are also at highest risk for the development of intracranial hypertension and thus are most likely to benefit from intervention to control intracranial pressure (ICP) ([12] [16]). Thus, this group of patients will most likely benefit from early intervention to minimize secondary brain injury.

The purpose of this study was three-fold: to examine variations in care of patients with severe head injury in academic trauma centers across the United States; to determine the proportion of patients who received care according to the Brain Trauma Foundation guidelines; and to correlate the outcome from severe traumatic brain injury with the care received.

METHODS

This study was conducted as part of the Trauma Benchmarking Project of the University HealthSystem Consortium. University Health Systems Consortium is a consortium of 84 university hospitals in the United States, of which 34 participated in the Trauma Benchmarking Project. Among these participating hospitals, 28 are level I trauma centers and six are level II centers. Approval was obtained from the institutional review board of each study hospital.

Patients

Eligible patients were those 18 yrs or older who were admitted to a study hospital between May 1, 1998, and December 31, 1998, with multiple trauma, consisting of, at a minimum, a head injury (defined as an abbreviated injury score [AIS] score of ≥2) and a fracture of the tibia, fibula, or femur. This population was selected as representative of the blunt trauma population with multiple-system injury. Exclusion criteria included burn injury, pregnancy, spinal cord injury with paralysis, and patients transferred from another institution >24 hrs after injury. For the purpose of this analysis, we focus on those patients with severe brain injury, defined as an initial emergency room GCS score ≤8. For those patients who were intubated, but not paralyzed, the GCS scores were imputed from the motor component by using an approach similar to that described by Meredith et al ([17]).

Data Collection

Medical records were abstracted by trained trauma nurses, who used a standardized abstract form. Information was collected on preexisting conditions, prehospital care, injury severity using the AIS-90 coding system and injury severity score (ISS), operations, number of head computed tomography (CT) scans and results, use of ICP monitors, complications, length of stay, and outcome at hospital discharge.

Data Analysis
Assessment of Variations in Care.

Variations in care were assessed including prehospital intubation, ICP monitoring, use of osmotic agents, hyperventilation, and CT scan utilization. The means, medians, and interquartile ranges of the percentage of patients receiving each therapy were examined. These are displayed as one-way scatterplots with box-and-whisker plots to reflect the distribution. Lines on the scatter plot depict the distribution of the proportion of patients receiving each therapy per center; however, each line may reflect more than one center. Variations in care were stratified further based on injury severity as reflected by an ISS >25 or head AIS ≥4.

Assessment Impact of Variations in Care on Outcome.

Centers were divided into two groups, defined as aggressive vs. nonaggressive based on the frequency of ICP monitor placement in patients meeting the guideline criteria of GCS ≤8 and an abnormal CT scan of the brain. Aggressive centers were defined as those placing ICP monitors in >50% of patients meeting these criteria, whereas nonaggressive centers were defined as those that placed ICP monitors in <50% of these patients. Demographics, injury severity, and treatment strategies were compared between the groups by using the chi-square test for categorical variables and the Student’s *t*-test for continuous variables. Significance was defined as $p < .05$.

Kaplan-Meier survival estimates for patients managed at aggressive vs. nonaggressive centers were performed. The Cox proportional hazards model was used to evaluate the impact of treatment at aggressive vs. nonaggressive centers on mortality rate ([18]). The choice of confounding variables to include in these models was made by using a change in estimates approach ([19]). Briefly, if the addition of a variable to the model changed the estimated hazard ratio for mortality rate at aggressive centers by >5% in either direction, then the variable was considered to be an important confounding variable and was kept in the model. Variables evaluated included age, gender, hypotension on admission, ISS, head AIS, prehospital intubation, intubation at time of admission, and transfer from another institution. Age was included as a categorical value based on age >55 or <55 yrs. By these criteria, the only confounding variables for mortality rate at aggressive vs. nonaggressive centers were head AIS score, ISS score, and age.

Differences in the hospital length of stay between aggressive and nonaggressive centers were evaluated by linear regression controlling for the confounding variables of ISS, head AIS, age, and hypotension on admission. Patients who died were excluded from the length of stay analysis. In all analyses, sandwich variance estimators were used that allowed for the possibility that observations within each center might be correlated ([20]).

Functional outcome at the time of discharge from the acute care hospital was assessed by the level of supportive care required. Each patient was categorized as independent, partially dependent, or totally dependent. Data regarding discharge disposition also were collected.

All statistical analysis was performed by use of the software program Stata (version 6).

RESULTS

Overview of Subjects

Among the 34 study hospitals, medical records were abstracted on 640 patients of whom 621 had complete data available for analysis. Of this cohort, 182 patients (31%) had a presenting GCS ≤8 and represent the analysis population for this study. These patients were managed at 33 centers. The mean age of this population was 40 yrs (sd, 16) and 75% were male. The primary mechanisms of injury included motor vehicle/motorcycle collisions in 116 patients (64%), bicycle/pedestrian struck injuries in 45 patients (25%), and falls in eight patients (4%). Thirty-nine percent of patients were transferred from an outside institution.

Markers of injury severity for the population included a mean ISS score of 34 (sd, 13) with a mean AIS score for the head of 3.8 (sd, 1). Twenty-four percent of patients were hypotensive on admission, as defined by an initial systolic blood pressure <90 mm Hg. Initial head CT scan results were available for 156 patients, of which 78% had demonstrated intracranial pathology. Data were not available to further characterize CT findings.

The percentage of patients receiving each treatment strategy is illustrated in Table 1. ICP monitors were placed in 105 patients (58%). Some patients received therapy that is often guided by ICP monitoring, such as hyperventilation and osmotic agent use, even although they did not have an ICP monitor placed. For example, there was no ICP monitor placed in 21% of patients receiving osmotic agents and 24% of those undergoing hyperventilation. Of the 105 patients with ICP monitors, only 75 had documentation of their highest ICP value. Of these, 42 (56%) had a highest ICP value ≥25. Osmotic agents were administered to 72% of patients with an ICP ≥25 and to 28% of patients with a highest ICP <25. Hyperventilation was used in 32% of patients with an ICP ≥25 and 18% of patients with a highest ICP <25.

Variable	No. of Patients (%) (*n* = 182)
ICP monitoring	105 (58)
Prehospital intubation	79 (43)

Prehospital or ED intubation	146 (80)
Neurosurgical consultation	140 (77)
Use of osmotic agents	53 (29)
Hyperventilation	25 (14)
Ventriculostomy	23 (13)

ICP, intracranial pressure; ED, emergency department.

Mortality rate for this cohort was 37% (68 patients). Of the surviving 114 patients, eight patients were totally independent at discharge (7%), 65 were partially dependent (57%), and 41 were totally dependent (36%). Discharge disposition included home for 26%, a rehabilitation facility for 46%, a skilled nursing facility for 17%, and transfer to an acute care hospital for 11%. The mean hospital length of stay for survivors was 23 (sd, 14) days.

Variations in Care

Considerable variation in care among the centers was evident. The greatest variability involved the use of ICP monitors and prehospital intubation. As illustrated in figure 1, figure 2, the median rate of use for both was 33% of patients, with a range from 0% to 100% for ICP monitoring and 0% to 90% for prehospital intubation. Seven centers (23%) placed no ICP monitors, whereas two centers (6.5%) placed ICP monitors in all patients with GCS ≤8. As illustrated, stratification by injury severity, including ISS >25 and head AIS ≥4, demonstrated increased rates of ICP monitoring among the more severely injured patients; however, the variability persisted with a median of 50% monitor use (Fig. 1). There were no significant differences in the variability after we stratified on the basis of age. There were 12 centers (39%) in which no patients received prehospital intubation. Stratification by injury severity did not significantly alter the variability in prehospital intubation (Fig. 2).

Figure 1. Variations in the percentage of patients receiving intracranial pressure (ICP) monitors per center. Lines on the scatterplot depict the distribution of the proportion of patients receiving ICP monitors; however, each line may reflect more than one center. The corresponding box-and-whisker plots depict the median, as the line in the middle of the box, and the interquartile range (IQR), as the outer edges of the box. The whiskers extend to the upper and lower adjacent values. The upper adjacent value is defined as the largest data point less than or equal to the 75th percentile + 1.5 × IQR. The lower adjacent value is defined by the smallest data point greater than or equal to the 25th percentile − 1.5 × IQR. The first graph depicts all patients, whereas the remaining bars represent stratification of the population based on injury severity: injury severity score (*ISS*) >25 or Head Abbreviated Injury Score (*HAIS*) ≥4.

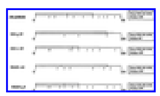

Figure 2. Variations in the percentage of patients receiving prehospital intubation per center. Lines on the scatterplot depict the distribution of the proportion of patients receiving prehospital intubation; however, each line may reflect more than one center. The corresponding box-and-whisker plots depict the median, as the line in the middle of the box, and the interquartile range (IQR), as the outer edges of the box. The whiskers extend to the upper and lower adjacent values. The upper adjacent value is defined as the largest data point less than or equal to the 75th percentile + 1.5 × IQR. The lower adjacent value is defined by the smallest data point greater than or equal to the 25th percentile − 1.5 × IQR. The first graph depicts all patients, whereas the remaining bars represent stratification of the population based on injury severity: injury severity score (*ISS*) >25 or abbreviated injury score for the head (*HAIS*) ≥4.

One potential explanation for the variability observed in ICP monitoring may be variations in the involvement of neurosurgeons in the care of these patients. To address this possibility, the variability of neurosurgical consultation is shown in Figure 3. As illustrated, there were higher rates of neurosurgical consultation than ICP monitoring and less variability. The median for all centers was 90%, with quartiles of 66% and 100%. No neurosurgical consultation was obtained in two centers, contributing only two patients to the cohort. Stratification by injury severity did suggest higher rates of neurosurgical consultation for more severely injured patients, with a median of 100% for both an ISS >25 and head AIS ≥4.

Figure 3. Variations in the percentage of patients receiving neurosurgical consultation per center. Lines on the scatterplot depict the distribution of the proportion of patients receiving neurosurgical consultation; however, each line may reflect more than one center. The corresponding box-and-whisker plots depict the median, as the line in the middle of the box, and the interquartile range (IQR), as the outer edges of the box. The whiskers extend to the upper and lower adjacent values. The upper adjacent value is defined as the largest data point less than or equal to the

75^{th} percentile + 1.5 × IQR. The lower adjacent value is defined by the smallest data point greater than or equal to the 25^{th} percentile − 1.5 × IQR. The first graph depicts all patients, whereas the remaining bars represent stratification of the population based on injury severity: injury severity score (*ISS*) >25 or abbreviated injury score for the head (*HAIS*) ≥4.

Finally, the variation in the use of ICP-directed therapies, including osmotic agents and hyperventilation, is illustrated in Figure 4. Because these are ICP-directed therapies, they likely further reflect the variability in ICP monitoring. Although excessive hyperventilation is discouraged by the Brain Trauma Foundation guidelines, the range in use among centers was 0–75% of patients with a median use of 0%.

Figure 4. Variations in the percentage of patients receiving intracranial pressure-directed therapy per center. Lines on the scatterplot depict the distribution of the proportion of patients receiving either osmotic agents or hyperventilation; however, each line may reflect more than one center. The corresponding box-and-whisker plots depict the median, as the line in the middle of the box, and the interquartile range (IQR), as the outer edges of the box. The whiskers extend to the upper and lower adjacent values. The upper adjacent value is defined as the largest data point less than or equal to the 75^{th} percentile + 1.5 × IQR. The lower adjacent value is defined by the smallest data point greater than or equal to the 25^{th} percentile − 1.5 × IQR.

Impact of Variation in Approach to Care on Outcome

Having identified significant variation in the care of severely head-injured patients among the centers, we postulated that this variability may affect outcome. Because the most significant variability noted involved the use of ICP monitors, we chose this as a marker for an “aggressive” approach to the severely head-injured patient. Therefore, centers were classified as aggressive vs. nonaggressive based on their use of ICP monitoring in accordance with the Brain Trauma Foundation guidelines. Of the 33 centers, two were excluded because they did not report any patients meeting both guideline criteria. Eleven of the remaining 31 were classified as aggressive (36%), with the remainder, 20 (64%), considered nonaggressive. There were 74 patients with a GCS ≤8 managed at aggressive centers and 106 patients with a GCS ≤8 managed at nonaggressive centers.

There was no difference in mean age or gender distribution between the patients managed at aggressive vs. nonaggressive centers (Table 2). There was also no significant difference in the annual volume of trauma patients treated in these two groups of centers. The mean number of patients admitted with an ISS >9 per hospital per year was 1121 (sd, 558) for the aggressive centers and 892 (sd, 237) for the nonaggressive group (p = .126). There was no statistically significant difference in injury severity between the groups as reflected by ISS, head AIS, or hypotension on admission (Table 2).

Variable	Aggressive Center (*n* = 74)	Nonaggressive Center (*n* = 106)	*p*
Mean age, yrs	36.7 ± 12.8	41.6 ± 17.4	.13
Percent male, %	76	75	.86
ISS ≥ 25 (%)	55 (74)	78 (74)	.91
HAIS ≥ 4 (%)	47 (63)	67 (63)	.97
Hypotension (%)	17 (23)	27 (25)	.70

ISS, injury severity score; HAIS, Abbreviated injury score for the head.

There were significant differences in the treatment strategies between the aggressive and nonaggressive centers (Table 3). There were significantly higher rates of neurosurgical consultation, intubation on admission, use of osmotic agents, hyperventilation, and ventriculostomy in aggressive centers. There were also significantly more head CT scans per patient in aggressive centers (mean, 3.5; sd, 3.0 CT scans/patient) vs. nonaggressive centers (mean, 1.9; sd, 1.5 scans/patient). There was no statistical difference in pulmonary arterial catheter use or prehospital intubation between the groups.

Variable	Aggressive Center (*n* = 74; %)	Nonaggressive Center (*n* = 106; %)	*p*
ICP monitoring	51 (69)	26 (24)	<.001
Neurosurgical consultation	67 (91)	73 (69)	.001
Prehospital intubation	35 (47)	44 (42)	.44
Intubation in the field or ED	55 (74)	91 (85)	.05
Hyperventilation	15 (20)	10 (9.4)	.04
Use of osmotic agents	36 (49)	17 (16)	<.001

Ventriculostomy	14 (19)	9 (8.5)	.04
Pulmonary arterial catheter	25 (34)	33 (31)	.71
Mean no. of head CT scans per patient	3.5 ± 3.0	1.9 ± 1.5	<.001

ICP, intracranial pressure; ED, emergency department; CT, computed tomography.

Overall mortality rate was 27% (20 of 74) at the aggressive centers vs. 45% (48 of 106) at nonaggressive centers (p = .01). Kaplan-Meier survival analysis indicated a significant difference in mortality rate for patients managed at aggressive vs. nonaggressive centers (p = .01 by log rank test; Fig. 5). Cox proportional hazards regression revealed an adjusted hazard ratio for death of 0.43 (95% CI 0.27–0.66) for management at an aggressive center compared with a nonaggressive center.

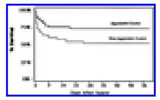

Figure 5. Kaplan-Meier survival estimates for patients managed at aggressive vs. nonaggressive centers (p = .01, log rank test). Aggressive centers were defined as those placing intracranial pressure monitors in >50% of patients with an initial Glasgow Coma Scale score ≤8 and an abnormal computed tomography scan of the head. Cox proportional hazard analysis revealed a significant reduction in mortality rate for patients managed at aggressive centers with a hazard ratio of 0.43 (95% confidence interval, 0.27–0.66).

When we compared hospital length of stay by using linear regression to control for ISS, head AIS, hypotension on admission, and age, management at an aggressive center was associated with a decrease in length of stay by 6 days (95% confidence interval, −14 to 2 days, p = .143). There was no significant difference in the functional status of survivors at the time of discharge (p = .45; Table 4). There was a trend toward higher rates of discharge to rehabilitation facilities by nonaggressive hospitals as opposed to skilled nursing facilities or acute care transfers (p = .07; Table 4).

	Aggressive Center (*n* = 54; %)	**Nonaggressive Center (*n* = 58; %)**
Functional status		
Independent	3 (6)	4 (7)
Partially dependent	28 (52)	36 (62)
Totally dependent	23 (42)	18 (31)
Disposition		
Home	12 (22)	16 (28)
Rehabilitation	20 (37)	32 (55)
Skilled nursing facility	12 (22)	7 (12)
Acute care hospital	9 (17)	3 (5)

DISCUSSION

Despite the availability of evidence-based guidelines for the management of head-injured patients, considerable variations in care remain. This issue was first explored in 1995 by a national survey of trauma centers ([4]). These authors demonstrated considerable variations in care among centers and concluded that “the establishment of guidelines for the management of head injury based on available scientific data may lead to improvement in the standard of care.” These guidelines subsequently were developed by the Brain Trauma Foundation and, by the end of 1996, had been widely distributed to practitioners caring for these patients. Our data reveal that although some practice patterns have been modified, variability remains, particularly in prehospital intubation, ICP monitoring, ICP management strategies, and use of head CT scan.

An update to the 1995 guidelines was published in 2000. There was no change in the recommended indications for ICP monitoring ([21]). The new guidelines did recommend prehospital intubation for patients with severe head injury because of an association with improved outcome ([22]). This is supported by a recent study of 671 patients with severe head injury for whom prehospital intubation was associated with a significant reduction in mortality rate from 57% to 36% ([23]). There was considerable variability in the proportion of severely head-injured patients receiving prehospital intubation in our series. Furthermore, this variation remained even when stratified by injury severity. This likely reflects the wide variations in prehospital systems, training, and protocols across this country resulting in fixed prehospital resources for a given center. The median rate for prehospital intubation among centers was only 33%, and 39% of centers had no patients receiving prehospital intubation. Oral endotracheal intubation in these patients may be limited by the presence of an intact gag reflex, and thus restrictions on the prehospital use of paralytic agents may contribute to this low rate. Clearly, further prospective trials of prehospital intubation for head-injured patients are needed and should be conducted in emergency medical systems with extensive experience and training for these techniques.

One of the most controversial topics in the management of head-injured patients is the indication for ICP monitoring. Although it has not been shown that lowering

ICP in head-injured patients directly affects outcome, several studies have correlated improved outcome with aggressive ICP management ([16] [24] [25] [26]). A recent review of data from 12 Canadian trauma centers revealed a significant association between ICP monitoring and improved survival ([27]).

The use of cerebral perfusion pressure-directed therapy for the management of head-injured patients is also controversial. Preservation of cerebral perfusion pressure has been shown to reduce long-term neurologic disability ([7] [28] [29]). However, two recent studies have challenged this approach, suggesting that elevations in ICP are more closely associated with outcome than maintenance of cerebral perfusion pressure ([30] [31]). Furthermore, Robertson et al. ([31]) reported that cerebral perfusion pressure-directed therapy was associated with a higher rate of ARDS, presumably attributable to increased fluid resuscitation and use of inotropes to improve systolic blood pressure. Although this controversy persists, ICP or cerebral perfusion pressure-directed therapy cannot be conducted effectively without the use of ICP monitors.

The guideline indications for ICP monitoring include all patients with a GCS ≤8 and an abnormal CT scan of the head, or patients with a GCS ≤8 with a normal CT scan but two or more of the following risk factors: age >40 yrs, unilateral or bilateral motor posturing, or systolic blood pressure <90 mm Hg ([32]). For simplicity, we have focused on only those patients meeting the first criteria, that is, those having both a GCS ≤8 and an abnormal finding on head CT. The 1995 national survey, which relied on the report of neurosurgical intensive care unit managers, revealed that for patients meeting these criteria, 30% of centers would place monitors in 75–100% of these patients, 17% in 50–75% of patients, 24% in 25–50% of patients, and 18% in < 25% of patients. Our data, which reveal actual practice patterns, demonstrate that only 11 of 31 centers (35%) placed ICP monitors in >50% of patients meeting these criteria. The 1995 survey also found that increased ICP monitoring was associated with centers receiving a higher volume of patients. In our series, there was a trend toward higher trauma volume in the aggressive centers, but this did not reach statistical significance.

Because of the marked variability in the use of ICP monitors, this variable was selected as a marker for an aggressive vs. nonaggressive approach to the severely head-injured patient. That this was a reliable marker is supported by the many significant differences in care noted between the two groups. These included higher rates of neurosurgical consultation, greater use of ICP-directed therapy, and higher rates of ventriculostomy in the aggressive centers. There was also increased head CT scan utilization in the aggressive centers, which may have affected therapy. There were no significant differences in prehospital intubation rates or the use of pulmonary arterial catheters between these centers. This suggests that the differences in outcome between the aggressive and nonaggressive centers are not related to variation in prehospital care or intensive care resources.

Survival analysis in this study reveals a significantly lower risk of death for patients managed at aggressive centers. The greatest limitation of this study is the use of mortality as the primary end point. One could argue that salvaging a greater number of patients with significant neurologic disability is not beneficial. Thus, long-term outcome after discharge would be ideal. We did attempt to contact patients for 6-month follow-up; however, of the 112 survivors, follow-up was obtained for only 34 (ten from nonaggressive centers, 24 from aggressive centers). These numbers were too small for meaningful analysis, and the potential for selection bias was high. We report no significant difference in functional neurologic status at the time of discharge but recognize the limitations regarding variable discharge timing among the centers. The length of stay analysis suggests that when we controlled for confounding variables, hospital stay was significantly shorter at aggressive centers. However, there were a higher number of transfers to other acute care facilities from the aggressive centers, and length of stay is likely also significantly affected by the financial options for rehabilitation.

This study demonstrates that despite the establishment of evidence-based guidelines, there remains considerable institutional variability in the management of severe head injury. In many instances, system changes may be necessary to improve the availability of ICP monitoring, increase neurosurgeon involvement in the care of these patients, and improve prehospital resources. The development of protocol-based management algorithms, based on the guideline recommendations, also may help to reduce the variability in care. We conclude that the striking differences in mortality rates between the aggressive and nonaggressive centers call for the prospective evaluation of aggressive management strategies for head-injured patients.

REFERENCES

1. Valadka AB : Injury to the cranium . In: Trauma . Mattox KL , Feliciano DV , Moore EE (Eds). New York , McGraw-Hill , 2000 , pp 377–399

2. Injury in America: A Continuing Public Health Problem . Washington, DC , National Academy Press , 1985

3. Guidelines for the management of severe head injury. Brain Trauma Foundation, American Association of Neurological Surgeons, Joint Section on Neurotrauma and Critical Care . J Neurotrauma 1996 ; 13 : 641–734 Citation

4. Ghajar J , Hariri RJ , Narayan RK , et al: Survey of critical care management of comatose, head-injured patients in the United States . Crit Care Med 1995 ; 23 : 560–567 Full Text

5. Vukic M , Negovetic L , Kovac D , et al: The effect of implementation of guidelines for the management of severe head injury on patient treatment and outcome . Acta Neurochir 1999 ; 141 : 1203–1208 Abstract

6. Teasdale G , Jennett B : Assessment of coma and impaired consciousness. A practical scale . Lancet 1974 ; 2 : 81–84 Citation

7. Changaris DG , McGraw CP , Richardson JD , et al: Correlation of cerebral perfusion pressure and Glasgow Coma Scale to outcome . J Trauma 1987 ; 27 : 1007–1013 Abstract

8. Levati A , Farina ML , Vecchi G , et al: Prognosis of severe head injuries . J Neurosurg 1982 ; 57 : 779–783 Abstract

9. Narayan RK , Greenberg RP , Miller JD , et al: Improved confidence of outcome prediction in severe head injury. A comparative analysis of the clinical examination, multimodality evoked potentials, CT scanning, and intracranial pressure . J Neurosurg 1981 ; 54 : 751–762 Abstract

10. Choi SC , Narayan RK , Anderson RL , et al: Enhanced specificity of prognosis in severe head injury . J Neurosurg 1988 ; 69 : 381–385 Abstract

11. Levin HS , Gary HE Jr, Eisenberg HM , et al: Neurobehavioral outcome 1 year after severe head injury. Experience of the Traumatic Coma Data Bank . J Neurosurg 1990 ; 73 : 699–709

Abstract

12. Marmarou A , Anderson RL , Ward JD , et al: Impact of ICP instability and hypotension on outcome in patients with severe head trauma . J Neurosurg 1991 ; 75 : S59–S66

13. Advanced Trauma Life Support for Doctors . Chicago, IL , American College of Surgeons , 1997

14. Celli P , Fruin A , Cervoni L : Severe head trauma. Review of the factors influencing the prognosis . Minerva Chir 1997 ; 52 : 1467–1480 Abstract

15. Lannoo E , Van Rietvelde F , Colardyn F , et al: Early predictors of mortality and morbidity after severe closed head injury . J Neurotrauma 2000 ; 17 : 403–414 Abstract

16. Narayan RK , Kishore PR , Becker DP , et al: Intracranial pressure: To monitor or not to monitor? A review of our experience with severe head injury . J Neurosurg 1982 ; 56 : 650–659 Citation

17. Meredith W , Rutledge R , Fakhry SM , et al: The conundrum of the Glasgow Coma Scale in intubated patients : A linear regression prediction of the Glasgow verbal score from the Glasgow eye and motor scores . J Trauma 1998 ; 44 : 839–844 Abstract

18. Kaplan E , Meier P : Nonparametric estimation from incomplete observations . J Am Stat Assoc 1958 ; 53 : 457–481

19. Mickey R , Greenland S : The impact of confounder selection criteria on effect estimation . Am J Epidemiol 1989 ; 129 : 125–137 Abstract

20. Hardin J , Hilbe J : Generalized Linear Models and Extensions . College Station, TX : Stata Press , 2001

21. The Brain Trauma Foundation: The American Association of Neurological Surgeons. The Joint Section on Neurotrauma and Critical Care . Indications for intracranial pressure monitoring . J Neurotrauma 2000 ; 17 : 479–491 Abstract

22. The Brain Trauma Foundation: The American Association of Neurological Surgeons. The Joint Section on Neurotrauma and Critical Care . Resuscitation of blood pressure and oxygenation . J Neurotrauma 2000 ; 17 : 471–478 Abstract

23. Winchell RJ , Hoyt DB : Endotracheal intubation in the field improves survival in patients with severe head injury. Trauma Research and Education Foundation of San Diego . Arch Surg 1997 ; 132 : 592–597 Abstract

24. Eddy VA , Vitsky JL , Rutherford EJ , et al: Aggressive use of ICP monitoring is safe and alters patient care . Am Surg 1995 ; 61 : 24–29 Abstract

25. Saul TG , Ducker TB : Effect of intracranial pressure monitoring and aggressive treatment on mortality in severe head injury . J Neurosurg 1982 ; 56 : 498–503 Abstract

26. Becker DP , Miller JD , Ward JD , et al: The outcome from severe head injury with early diagnosis and intensive management . J Neurosurg 1977 ; 47 : 491–502 Abstract

27. Lane PL , Skoretz TG , Doig G , et al: Intracranial pressure monitoring and outcomes after traumatic brain injury . Can J Surg 2000 ; 43 : 442–448 Abstract

28. Rosner MJ , Rosner SD , Johnson AH : Cerebral perfusion pressure : Management protocol and clinical results . J Neurosurg 1995 ; 83 : 949–962 Abstract

29. Robertson CS , Contant CF , Narayan RK , et al: Cerebral blood flow, AVDO2, and neurologic outcome in head-injured patients . J Neurotrauma 1992 ; 9 (Suppl 1): S349–S358 Abstract

30. Juul N , Morris GF , Marshall SB , et al: Intracranial hypertension and cerebral perfusion pressure: Influence on neurological deterioration and outcome in severe head injury. The Executive Committee of the International Selfotel Trial . J Neurosurg 2000 ; 92 : 1–6 Abstract

31. Robertson CS , Valadka AB , Hannay HJ , et al: Prevention of secondary ischemic insults after severe head injury . Crit Care Med 1999 ; 27 : 2086–2095 Full Text

32. Indications for intracranial pressure monitoring. Brain Trauma Foundation . J Neurotrauma 1996 ; 13 : 667–679 Citation