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Original article

Intracranial pressure monitoring in severe traumatic brain injuries: a closer look at level 1 trauma centers in the United States

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A B S T R A C T

Introduction: The Brain Trauma Foundation (BTF) recently updated recommendations for intracranial pressure (ICP) monitoring in severe traumatic brain injury (TBI). The effect of ICP monitoring on outcomes is controversial, and compliance with BTF guidelines is variable. The purpose of this study was to assess both compliance and outcomes at level I trauma centers.
Materials and methods: The American College of Surgeons Trauma Quality Improvement Program database was queried for all patients admitted to level I trauma centers with isolated blunt severe TBI (AIS > 3, GCS < 9) who met criteria for ICP monitoring. Patients who had severe extracranial injuries, craniectomy, or death in the first 24 h were excluded. Comparison between groups with and without ICP monitoring was made, analyzing demographics, comorbidities, mechanism of injury, head Abbreviated Injury Scale (AIS), vital signs on admission, head CT scan findings. Outcomes included in-hospital mortality, mechanical ventilation days, intensive care unit (ICU) length of stay, hospital length of stay, systemic complications, and functional independence at discharge. Multivariable analysis was used to identify independent risk factors for each of the outcomes.
Results: Overall, 4880 patients were included. ICP monitoring was used in 529 patients (10.8%). Stepwise logistic regression analysis identified ICP monitor placement as an independent risk factor for mortality (OR 1.63; 95% CI 1.28–2.07; $p < 0.001$), mechanical ventilation (OR 5.74 95% CI 4.42–7.46; $p < 0.001$), ICU length of stay (OR 4.03; 95% CI 2.94–5.52; $p < 0.001$), systemic complications (OR 2.78; 95% CI 2.29–3.37; $p < 0.001$), and decreased functional independence at discharge (OR 1.71 95% CI 1.29–2.26; $p < 0.001$). Subgroup analysis of patients with head AIS 3, 4, and 5 confirmed that ICP monitors remained an independent risk factor for mortality in both head AIS 4 and 5.
Conclusions: Compliance with BTF guidelines for ICP monitoring is low, even at level I trauma centers. In this study, ICP monitoring was associated with poor outcomes, and was found to be an independent risk factor for mortality. Further studies are needed to determine the optimal role of ICP monitoring in the management of severe TBI.

Introduction

Traumatic brain injury (TBI) is a major burden on US healthcare resources. The Center for Disease Control and Prevention estimates that more than 1.5 million patients sustain traumatic brain injury annually in the United States, and greater than 35% of trauma-related mortality is attributed to TBI [1]. Intracranial pressure (ICP) monitoring is a tool used after TBI to maintain adequate cerebral blood flow and oxygenation, and thereby minimize secondary brain injury. Local complications associated with ICP monitoring include infection, hemorrhage, malfunction, obstruction, or malposition [2]. The systemic complications related to the therapeutic interventions to control intracranial hypertension are not known. The Brain Trauma Foundation (BTF) third edition of international guidelines recommended ICP monitoring in all salvageable patients who sustained severe TBI, with a Glasgow Coma Score (GCS) of 8 or less, and an abnormal head computed tomography (CT). However, these guidelines were based on retrospective and limited prospective observational studies [3] and compliance with these BTF guidelines is variable [4–13].

Our goal was to evaluate current practice patterns regarding the use of ICP monitors in TBI, and to assess the impact of ICP

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monitoring on outcomes at level 1 trauma centers. Level I trauma centers are comprehensive centers that provide total care for every aspect of injury, and are typically University-based teaching hospitals with a lead role in development, education and research [14,15]. We predicted compliance with BTF guidelines would be high at level I trauma centers, due to the emphasis on training and education. We also hypothesized that improved outcomes with ICP monitoring would be demonstrable at level I centers.

Methods

The American College of Surgeons Trauma Quality Improvement Program (TQIP) database was queried for a 2-year time range (2013–2014). TQIP is a detailed trauma database, with strict data quality control entered by participating trauma centers. This study was approved by the Institutional Review Board of the University of Southern California. Patients included were adults (>16 years old) with isolated severe blunt TBI (head AIS greater than or equal to 3), and no other injuries (body part AIS greater than or equal to three), who met the BTF criteria for ICP monitoring. Patients with no signs of life on arrival, transferred from other hospitals, or those receiving a craniectomy within 24 h were excluded. Though patients could benefit from ICP monitoring after craniectomy, the clinical course and outcomes are distinctly different than that of patients who do not undergo surgery. These patients were eliminated from our analysis to achieve a homogenous population of study patients. Also, due to BTF criterion of “salvageability”, patients who died within 24 h were also excluded from this study.

The population was stratified on the basis of treatment with or without ICP monitoring and comparison was made of demographics, mechanism of injuries, comorbidities, specific pathologic findings (epidural, subdural, subarachnoid, intracranial hemorrhage, and diffuse axonal injury), head AIS, vitals on ED arrival. For the purpose of this analysis, all ICP monitors were considered equivalent. This has been previously established as a reasonable method to limit variables in studying the effect of ICP monitoring [3]. Moreover, there is no evidence in the literature to suggest a difference in mortality rates between intraparenchymal ICP monitors (IPM) or extracranial ventricular drains (EVD). In a recent large study it was shown that there is no difference in outcomes between intraparenchymal and intraventricular catheters [16,17].

Analyzed outcomes included: in-hospital mortality, mechanical ventilation days, ICU length of stay, hospital length of stay, systemic complications, and functional independence at discharge.

Statistical analysis

Univariate analysis was performed comparing the populations treated with or without ICP monitoring. Medians for continuous data were compared with the Mann–Whitney U test. Comparison between percentages of categorical variables was performed with the Fisher Exact or Pearson's chi-squared test, and continuity correction was applied when required.

Logistic regression was then performed with potentially causative variables in which p was less than 0.2 to identify independent predictive variables. Outcomes analyzed included in-hospital mortality, either mechanical ventilation, or length of ICU admission greater than 48 h (identified in the literature as a threshold for increased development of systemic complications), systemic complications, and functional independence. The same outcomes were analyzed in subgroup analyses of patients with head AIS 3, 4, and 5. The population was stratified on the basis of the head AIS and a multivariable logistic regression was performed for each group. Correlation between variables was tested with multicollinearity analysis. The area under the ROC curve with 95% confidence interval was used to assess the accuracy of the test. Statistical significance was set as $p < 0.05$. All statistical analysis was performed using SPSS for windows version 23.0 (SPSS Inc. Chicago, IL) (Fig. 1).

Results

During the two-year study period, there were 4880 patients with isolated severe TBI who met BTF criteria for ICP monitor placement. Only 529 (10.8%) patients were treated with an ICP monitoring device. The patient demographics, clinical condition on admission, comorbidities, and injury severity are displayed in Table 1. Overall, 68.7% of the study patients presented with GCS between 3 and 5. The most common pathological findings were subdural hematoma (65.6%) and subarachnoid hemorrhage (52.2%). Patients treated with ICP monitors were younger and were less likely to have comorbidities (Table 1).

The overall in-hospital mortality was 22.9%. On univariate analysis, patients that had an ICP monitor placed had worse outcomes, including higher in-hospital mortality (27.2% vs 22.4%, $p = 0.012$), more ventilator days (median 8 vs 2 days, $p < 0.001$), longer ICU (median 12 vs 4 days, $p < 0.001$) and hospital length of stay (median 17 vs 6 days, $p < 0.001$), and fewer patients had a good functional outcome at hospital discharge (17.8% vs 28.7%, $p < 0.001$). Patients treated with ICP monitors also had significantly more complications including infections and thromboembolic events (43.5% vs 20.5%, $p < 0.001$, 37.8% vs 15.3%, $p < 0.001$, 12.7% vs 4.7%, $p < 0.001$; Table 2).

Multivariable logistic regression analysis identified age > 65 years (OR 2.58, $p < 0.001$), mechanism of motor vehicle crash (MVC) (OR 0.49 $p < 0.001$), motorcycle crash (MCC) (OR 0.48, $p < 0.001$), automobile versus pedestrian (AVP) (OR = 0.65 $p = 0.020$), assault (OR = 0.49, $p < 0.001$), GCS 3–5 (OR 1.84,

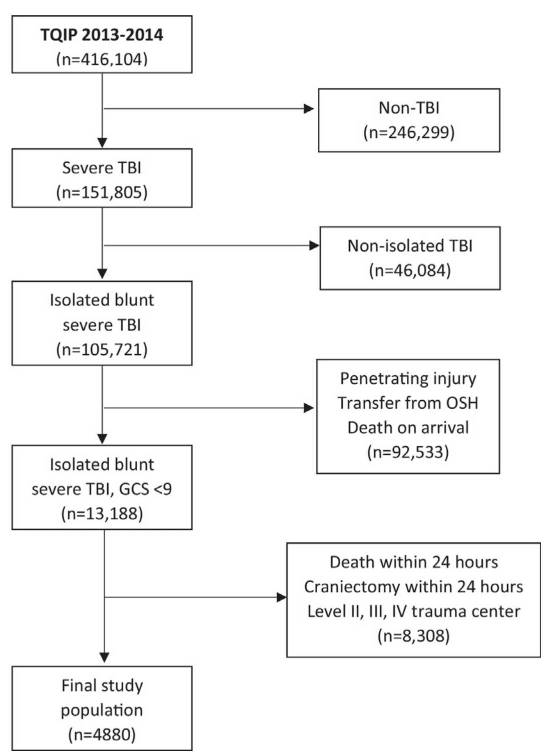

Fig. 1. Study population: selection, inclusion, and exclusion criteria.