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Intracranial pressure versus cerebral perfusion pressure as a marker of outcomes in severe head injury: a prospective evaluation

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Abstract

BACKGROUND: Intracranial pressure (ICP) monitoring is a standard of care in severe traumatic brain injury when clinical features are unreliable. It remains unclear, however, whether elevated ICP or decreased cerebral perfusion pressure (CPP) predicts outcome.

METHODS: This is a prospective observational study of patients sustaining severe blunt head injury, admitted to the surgical intensive care unit at the Los Angeles County and University of Southern California Medical Center between January 2010 and December 2011. The study population was stratified according to the findings of ICP and CPP. Primary outcomes were overall in-hospital mortality and mortality because of cerebral herniation. Secondary outcomes were development of complications during the hospitalization.

RESULTS: A total of 216 patients met Brain Trauma Foundation guidelines for ICP monitoring. Of those, 46.8% (n = 101) were subjected to the intervention. Sustained elevated ICP significantly increased all in-hospital mortality (adjusted odds ratio [95% confidence interval]: 3.15 [1.11, 8.91], $P = .031$) and death because of cerebral herniation (adjusted odds ratio [95% confidence interval]: 9.25 [1.19, 10.48], $P = .035$). Decreased CPP had no impact on mortality.

CONCLUSIONS: A single episode of sustained increased ICP is an accurate predictor of poor outcomes. Decreased CPP did not affect survival.

Traumatic brain injury (TBI) is the leading cause of death in the young adult population. Each year, 1.6 million people across the United States sustain severe traumatic brain injury (sTBI) that results in 52,000 deaths, and 80,000 people had a permanent neurologic disability.[1] Management of these patients is targeted toward prevention of secondary brain injury that is shown to further deteriorate outcomes.[2–7] The cornerstone of management in preventing secondary lesions has traditionally included monitoring of intracranial pressure (ICP) and cerebral perfusion pressure (CPP = mean arterial pressure – ICP) via utilization of ICP monitoring devices.

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Nevertheless, the scientific foundation of preferential end point, ICP vs CPP, to predict outcomes and to trigger interventions remains controversial. Thus, we set out to study survival and in-hospital morbidity measures in patients having severe blunt head injury by stratifying patients according to ICP vs CPP values recorded in the intensive care unit setting. We hypothesized that elevated ICP would be a more reliable predictor of adverse outcomes in patients with blunt sTBI.

Methods

After approval by the Institutional Review Board, a prospective observational study was conducted of trauma patients with blunt severe TBI (Glasgow Coma Scale score $\leq$ 8 and/or head Abbreviated Injury Scale [AIS] score $\geq$3) meeting the Brain Trauma Foundation inclusion criteria for ICP monitoring (Glasgow Coma Scale score $\leq$ 8 after resuscitation and abnormal computed tomography scan of the head) admitted to the surgical intensive care unit at Los Angeles County and University of Southern California Medical Center (LAC + USC) from January 01, 2010, to December 30, 2011. The LAC + USC is an American College of Surgeons–verified Level 1 Trauma Center that manages an average of 5,000 trauma admissions annually.

Demographic and clinical variables collected included age, gender, blood pressure on admission, Glasgow Coma Scale (GCS) score on admission, Injury Severity Score (ISS), AIS for each body region (head, chest, abdomen, and extremity), type of intracranial injury, and interventions performed. The Marshall Score for patients with TBI was calculated for each patient. The opening pressure was recorded. The study population was stratified into 2 study arms according to their ICP monitoring findings: elevated sustained ICP, defined as a single episode of ICP greater than 20 mm Hg for more than 15 minutes, and decreased CPP, defined as a single episode of CPP less than 50 mm Hg. An opening pressure greater than 20 mm Hg that lasted for more than 15 minutes was considered as an episode of elevated sustained ICP. All subsequent analyses were performed comparing these groups. Neurosurgical recommendations were reviewed for each enrolled case. The treatment of elevated ICP was collected. The number of episodes of sustained elevated ICP was also documented. Currently, LAC + USC Medical Center uses continuous ICP monitoring, and thus, the study captured all episodes of sustained (>15 minutes) and elevated (>20 mm Hg) ICP.

Primary outcomes were overall in-hospital mortality and mortality caused by cerebral herniation. Secondary outcome was the development of complications (acute kidney injury [AKI], pneumonia, and deep vein thrombosis [DVT]).

Statistical analysis

Continuous variables were dichotomized using clinically relevant cutpoints: age ($\leq$55 vs >55 years), systolic blood pressure on admission (hypotension; <90 vs $\geq$90 mm Hg), international normalized ratio (<1.3 vs $\geq$1.3), ISS ($\leq$15, 16 to 24, $\geq$25), AIS score ($\geq$3 vs <3), Marshall score (>3 vs $\leq$ 3), and heart rate on admission (tachycardia; >120 vs $\leq$120 bpm). The groups were compared for differences in the underlying characteristics using Fisher exact or Pearson chi-square tests as appropriate for categorical variables and Student *t* test for continuous variables.

To identify if ICP or CPP were independent predictors of mortality, a univariate analysis was performed dividing the study groups into alive and deceased. Differences at *P* less than .2 were inserted into a logistic regression for mortality along with decreased CPP and sustained elevated ICP. The same process was replicated for mortality because of cerebral herniation.

Overall in-hospital mortality and mortality because of cerebral herniation were assessed for each study group using logistic regression to adjust for factors that were significant at *P* less than .05. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were derived from the logistic regression.

A Forest plot was displayed to examine the impact of each variable in the outcomes. The study population was divided into 4 groups according to their ICP and CPP findings (ICP normal/CPP normal, ICP normal/CPP decreased, ICP elevated/CPP normal, and ICP elevated/CPP decreased). Differences in mortality between those groups were assessed using the Pearson chi square.

Values are reported as mean $\pm$ standard error of the mean for continuous variables and as percentages for categorical variables. All analyses were performed using the Statistical Package for Social Sciences (SPSS Windows), version 12.0 (SPSS, Inc., Chicago, IL).

Results

Overall, 216 trauma patients met the inclusion criteria. A total of 53.2% (115 patients) did not receive an ICP monitoring based on physician's discretion and were, thus, excluded. A total of 101 patients were available for further analysis. The study population was predominantly men (79.2%) with a mean age of 40.1 years. Hypotension was present in 2.0% of the patients, whereas 25.7% were tachycardic on admission; 43.6% of the patients had a Marshall score greater than 3%, and 38.6% had a GCS of 3 on admission. Patients who experienced an episode of increased sustained ICP had a significantly higher incidence of subarachnoid hemorrhage (Table 1)

Table 2 shows the characteristics of the study population stratified by the presence of 1 episode of decreased CPP. The patients who experienced decreased CPP were significantly more injured (ISS $\geq$ 25: 67% vs 41%, $P = .015$) and had a higher incidence of subarachnoid hemorrhage (68% vs 46%).

Elevated ICP is treated according to the implemented treatment protocol at LAC + USC Medical Center (Table 3).