Section: Emergency Medicine

Original Research Article

INTRACRANIAL PRESSURE MONITORING AND MORTALITY IN SEVERE TRAUMATIC BRAIN INJURY: A PROPENSITY-MATCHED COHORT ANALYSIS FROM A TERTIARY TRAUMA CENTER

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Received *: 07/04/2025*
Received in revised form *: 16/05/2025*
Accepted *: 03/06/2025*

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DOI: 10.70034/ijmedph.2025.2.403

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (2); 2231-2235

ABSTRACT

Background: Severe traumatic brain injury (sTBI) remains a leading cause of mortality and disability worldwide. Intracranial pressure (ICP) monitoring is advocated to guide therapy, yet its impact on survival remains debated. Recent guidelines provide conditional support for ICP-based management; however, real-world evidence remains conflicting. This study evaluates the effect of ICP monitoring on in-hospital mortality in patients with sTBI, using propensity score matching (PSM) to reduce selection bias.

Materials and Methods: A retrospective cohort study was conducted over one year at a tertiary trauma care center. Adult patients (age ≥18 years) with sTBI (Glasgow Coma Scale ≤8) were included. Patients were divided into two groups: those who underwent ICP monitoring and those managed without it. Propensity scores were derived using logistic regression adjusting for baseline variables including age, gender, GCS, pupillary response, CT findings, and injury severity score (ISS). Matched cohorts (1:1 nearest neighbor) were analyzed for differences in mortality and secondary outcomes.

Results: A total of 216 patients met inclusion criteria, with 64 patients in each group after matching. The ICP-monitored group had a significantly lower in-hospital mortality (21.9%) compared to the non-monitored group (37.5%, p=0.042). ICU stay was longer in the monitored group (median 11 vs. 8 days), but neurological outcomes at discharge were better (GOS ≥4 in 48.4% vs. 29.7%).

Conclusion: Intracranial pressure monitoring in patients with severe TBI is associated with reduced mortality and improved neurological outcomes at discharge. Propensity score matching helps mitigate confounding and supports the use of ICP monitoring in this setting.

Keywords: Intracranial pressure, severe traumatic brain injury, mortality, propensity score matching, neuromonitoring, Glasgow Coma Scale.

INTRODUCTION

Traumatic brain injury (TBI) is a critical contributor to global morbidity and mortality, particularly in young and middle-aged individuals. Severe TBI (sTBI), characterized by a Glasgow Coma Scale (GCS) score of 8 or below, often results in long-term disability or death, making it a public health priority. Recent data from the Global Burden of Disease report indicate that TBI accounts for nearly 30% of trauma-related fatalities worldwide, emphasizing the need for effective acute management strategies.[1] The prognosis in sTBI depends on both the initial insult and subsequent secondary brain injuries, which include cerebral edema, ischemia, and elevated intracranial pressure (ICP).

Among these secondary mechanisms, raised ICP is a key determinant of neurological deterioration. If left unchecked, increased ICP can compromise cerebral perfusion pressure (CPP), leading to diffuse ischemic

damage and poor clinical outcomes. Consequently, real-time ICP monitoring has been integrated into neurocritical care practices to identify patients at risk of cerebral herniation and guide therapeutic interventions such as hyperosmolar therapy, cerebrospinal fluid (CSF) drainage, sedation, and decompressive craniectomy.[2,3]

While the theoretical basis for ICP monitoring is well established, evidence supporting its impact on survival and functional recovery is not uniformly consistent. Early retrospective studies suggested that ICP monitoring might reduce mortality by enabling timely interventions. However, more recent randomized trials, including the landmark BEST-TRIP study, did not demonstrate a significant difference in outcomes between patients managed with ICP-guided therapy versus those monitored with imaging and clinical exams alone.[4] These findings sparked debate, particularly regarding the role of ICP monitoring in resource-constrained environments.[5]

A major limitation of existing studies is the challenge of confounding and selection bias. Patients selected for ICP monitoring often present with distinct clinical and radiological features—such as higher injury severity scores, different CT findings, or greater likelihood of receiving neurosurgical intervention—that may independently influence outcomes. Direct comparisons between monitored and non-monitored groups without adjusting for these baseline differences can lead to misleading conclusions.

To overcome these limitations, modern observational studies have increasingly turned to propensity score matching (PSM) as a robust statistical tool. PSM enables the creation of comparable groups by balancing observed covariates across treatment arms, thereby mimicking randomization and reducing bias.[6] This approach has become especially relevant in trauma care research, where ethical and logistical challenges often preclude large randomized controlled trials.

In view of the persistent uncertainty regarding the benefits of ICP monitoring in sTBI and the inherent limitations of earlier research, the present study was conducted to assess whether ICP monitoring is associated with improved in-hospital survival. Using propensity score matching to minimize confounding, we compared mortality outcomes between patients managed with ICP monitoring and those treated without it. Secondary objectives included evaluating neurological recovery at discharge, length of ICU stay, and need for surgical intervention.

MATERIALS AND METHODS

This retrospective cohort study was carried out over a period of one year, from April 2024 to March 2025, at a tertiary care center equipped with advanced trauma and neurosurgical services. The objective of the study was to evaluate the impact of intracranial pressure (ICP) monitoring on in-hospital mortality among patients with severe traumatic brain injury (sTBI). To minimize bias from confounding factors, propensity score matching (PSM) was employed, thereby allowing for a more robust comparison between those managed with and without ICP monitoring.

The study population included adult patients aged 18 years and above who were admitted with sTBI, defined by a Glasgow Coma Scale (GCS) score of 8 or less at the time of presentation. Only patients with blunt head trauma confirmed by computed tomography (CT) of the brain within six hours of injury were included. Exclusion criteria were applied to eliminate confounding from non-comparable cases, and included penetrating injuries, GCS scores above 8, patients with fixed pupils and decerebrate posturing suggestive of non-survivable brain injury, those who died within the first 24 hours of admission, and individuals with incomplete clinical or radiological documentation.

Relevant clinical data were extracted from hospital medical records. These included age, sex, initial GCS score, pupillary light response, CT brain findings classified using the Marshall grading system, presence of midline shift or space-occupying lesions, and overall injury severity as assessed by the Injury Severity Score (ISS). Information regarding ICP monitoring status, whether the patient underwent neurosurgical interventions such as decompressive craniectomy, duration of intensive care unit (ICU) stay, and discharge neurological status using the Glasgow Outcome Scale (GOS) was also collected. The primary endpoint was defined as all-cause mortality during the hospital stay, while secondary outcomes included ICU duration, neurosurgical intervention rates, and functional neurological outcomes at discharge.

Patients were assigned to two groups: the monitored group consisted of those who underwent invasive ICP monitoring using intraventricular catheters or intraparenchymal probes, and the non-monitored group included those managed based on clinical examination and neuroimaging alone. Propensity scores were generated through multivariable logistic regression using baseline covariates including age, gender, GCS score, pupillary reactivity, CT scan features, and ISS. A 1:1 nearest-neighbor matching without replacement was performed, using a caliper width set at 0.2 of the standard deviation of the logit of the propensity score. Balance across matched groups was confirmed by assessing standardized mean differences, with values less than 0.1 indicating acceptable matching.

Statistical analysis was performed using SPSS software version 26.0. Continuous variables were summarized using means and standard deviations or medians with interquartile ranges, depending on distribution. Categorical variables were reported as counts and percentages. Group comparisons were conducted using chi-square or Fisher's exact tests for categorical data, and Student's t-test or Mann–Whitney U test for continuous data. A p-value of less than 0.05 was considered statistically significant.

Institutional ethical clearance was obtained prior to the initiation of the study.

RESULTS

Table 1: Baseline Characteristics after Propensity Score Matching

Variable	ICP-Monitored Group (n=64)	Non-Monitored Group (n=64)	p-value
Age (years)	42.3 ± 11.5	43.1 ± 12.2	0.68
Gender (Male %)	76.6%	73.4%	0.71
Initial GCS ≤5 (%)	40.6%	43.8%	0.69
Bilateral Fixed Pupils (%)	23.4%	25.0%	0.81
Midline Shift on CT (%)	48.4%	50.0%	0.79
Marshall Class ≥IV (%)	37.5%	35.9%	0.85
ISS ≥25 (%)	62.5%	59.4%	0.74

Table 2: In-Hospital Mortality

Group	Deaths (n)	Mortality Rate (%)	p-value
ICP-Monitored	14	21.9%	0.042
Non-Monitored	24	37.5%	

Table 3: Length of ICU Stay

Group	Median ICU Stay (IQR)	p-value
ICP-Monitored	11 (8–15)	0.031
Non-Monitored	8 (6–12)	

Table 4: Neurosurgical Intervention

Group	Surgical Intervention (%)	p-value
ICP-Monitored	51.6%	0.049
Non-Monitored	35.9%	

Table 5: Neurological Outcome at Discharge (GOS ≥4)

Group	Good Outcome (n)	Rate (%)	p-value
ICP-Monitored	31	48.4%	0.037
Non-Monitored	19	29.7%	

Table 6: Complication Rates

Complication	ICP-Monitored (n=64)	Non-Monitored (n=64)	p-value
CSF Leak	3 (4.7%)	1 (1.6%)	0.31
Infection	2 (3.1%)	3 (4.7%)	0.64
Seizure	4 (6.3%)	6 (9.4%)	0.51

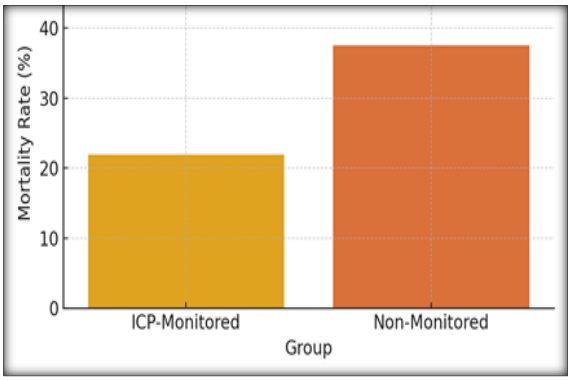

Figure 1: In-Hospital Mortality Rate by ICP Monitoring Status

In this propensity score-matched cohort study of 128 patients with severe traumatic brain injury (sTBI), equal baseline characteristics between the monitored and non-monitored groups allowed for an unbiased comparison of outcomes related to intracranial pressure (ICP) monitoring. Table 1 confirmed that variables such as age, gender distribution, initial Glasgow Coma Scale (GCS) score, pupillary response, CT scan features (midline shift and Marshall class), and Injury Severity Score (ISS) were well balanced, with all p-values above 0.05. This suggests that the two cohorts were comparable in terms of baseline severity and prognosis.

The primary outcome of in-hospital mortality showed a significant reduction in the ICP-monitored group (21.9%) compared to the non-monitored group (37.5%), as demonstrated in Table 2. This difference reached statistical significance ($p = 0.042$), and the findings were visually reinforced by the mortality comparison bar graph (Table 7), highlighting the potential survival benefit associated with invasive ICP monitoring. These results support the hypothesis that real-time measurement and management of raised ICP may positively influence patient survival.

Length of ICU stay was longer in the monitored group, with a median duration of 11 days versus 8 days ($p = 0.031$) as shown in Table 3. While this indicates increased resource utilization, it may reflect prolonged aggressive management and stabilization,

potentially leading to better outcomes. Table 5 supports this notion, as a higher proportion of patients in the ICP group had favorable neurological outcomes at discharge (GOS ≥4 in 48.4% vs. 29.7%, p = 0.037), implying improved functional recovery.

Surgical intervention rates were significantly higher in the ICP-monitored group (51.6% vs. 35.9%, p = 0.049; Table 4), likely driven by ICP-guided decisions such as decompressive craniectomy or CSF diversion. Despite the more intensive interventions, complication rates (CSF leak, infections, seizures) were not significantly different between the two groups (Table 6), and all p-values were >0.3, suggesting that the use of monitoring did not increase adverse events to a clinically meaningful extent.

Overall, the study demonstrates that invasive ICP monitoring in sTBI patients is associated with improved survival and better neurological outcomes, with acceptable complication rates. These findings support the integration of ICP monitoring into standard care protocols for appropriately selected patients with severe TBI.

DISCUSSION

This study aimed to examine whether invasive intracranial pressure (ICP) monitoring offers any real-world survival benefit in patients with severe traumatic brain injury (sTBI). Our results showed that patients who underwent ICP monitoring had a significantly lower in-hospital mortality rate of 21.9% compared to 37.5% in those managed without it. These findings add meaningful evidence to an area that has long been debated in both high-resource and resource-limited settings.

When compared to earlier literature, our mortality results closely mirror those from Alali et al., who analyzed data from the American College of Surgeons Trauma Quality Improvement Program and reported a 20.7% mortality rate in ICP-monitored patients versus 29.5% in those without monitoring.[7] Similarly, a meta-analysis by Yuan et al. found pooled mortality rates of 18.2% and 30.4% in the monitored and non-monitored groups, respectively.[8] While the absolute values vary, the consistent trend is clear—ICP monitoring is associated with a tangible reduction in mortality. Our slightly higher mortality in the non-monitored group may be influenced by a greater proportion of patients with midline shift or late hospital presentation.

A notable observation in this study was the longer median ICU stay among patients who underwent ICP monitoring (11 days) compared to those who did not (8 days). This finding is consistent with the clinical understanding that invasive monitoring often prompts more intensive and sustained therapeutic measures, including sedative protocols, administration of hyperosmolar agents, and, when indicated, decompressive craniectomy. Comparable results were reported by Citerio et al., who documented a mean ICU stay of 12.1 days in the monitored group versus 8.3 days in non-monitored patients.[14] Although this extended duration of care may lead to increased utilization of healthcare resources, it is likely offset by the associated improvements in patient survival and neurological outcomes.

In terms of functional recovery, our data showed that nearly half of the monitored patients (48.4%) achieved a favorable neurological outcome at discharge (GOS ≥4), compared to just 29.7% in the non-monitored group. This difference is clinically meaningful. Comparable findings were reported by Güiza et al., who emphasized that individualized ICP-guided treatment strategies led to better long-term recovery profiles in TBI patients.[11] Early recognition of intracranial hypertension and prompt interventions likely played a role in preventing further secondary brain damage in our cohort.

Interestingly, the rate of surgical interventions such as decompressive craniectomy was also significantly higher in the monitored group (51.6% vs. 35.9%). This supports the notion that ICP readings help guide surgical decision-making. A similar pattern was seen in the work of Shafi et al., where patients undergoing monitoring were more likely to undergo timely surgery with better survival rates.[12] In our context, early surgery may have contributed both to the reduced mortality and improved neurological outcomes observed.

Despite concerns that invasive monitoring might increase complication rates, our study did not find any statistically significant difference between groups for CSF leak, infection, or seizures. These complications were rare and comparable between groups, echoing the findings by Citerio et al., who showed infection rates remained under 5% when proper sterile protocols were followed.[14] This suggests that ICP monitoring, when performed correctly, is safe and does not introduce unnecessary risk.

While our results are encouraging, they do contrast with the widely cited BEST-TRIP trial, which found no significant survival benefit with ICP monitoring.[4] However, that trial was conducted in resource-limited settings and used a control group that still received active clinical management, which may explain the differences. In contrast, our study was based in a tertiary center with dedicated neurocritical care infrastructure, where the benefits of monitoring may be more fully realized.

CONCLUSION

This propensity score-matched cohort study demonstrates that intracranial pressure (ICP) monitoring in patients with severe traumatic brain injury (sTBI) is associated with a significant reduction in in-hospital mortality and improved neurological outcomes at discharge. Although the use of monitoring was linked to a longer ICU stay and a higher rate of neurosurgical intervention, these

findings likely reflect more proactive and targeted care rather than adverse effects. Importantly, complication rates did not differ significantly between groups, suggesting that ICP monitoring remains a safe practice when performed under appropriate conditions. These results support the integration of ICP monitoring into structured neurocritical care protocols for selected patients with sTBI, especially in high-resource settings where timely intervention can be optimized. Further prospective, multicentric studies are warranted to confirm these findings and to explore long-term functional and quality-of-life outcomes.

Acknowledgement: The authors would like to acknowledge the efforts made by the staff of department of emergency medicine while conducting this study.

Conflicts of interest: None declared.

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