

Prognostic value of increased intracranial pressure assessed by ophthalmic artery doppler and optic nerve sheath diameter measurement for mortality in patients with severe traumatic brain injury in the intensive care unit

Abstract

Introduction: Intracranial hypertension is one of the most serious complications of severe traumatic brain injury (TBI). Although intracranial pressure (ICP) monitoring is essential for its management, noninvasive approaches have gained increasing relevance because of their availability and safety. Among these methods, ultrasonographic assessment of the optic nerve sheath diameter (ONSD) and ophthalmic artery Doppler ultrasonography are particularly noteworthy.

Objective: To compare the diagnostic performance of ophthalmic artery Doppler ultrasonography with optic nerve sheath diameter measurement as noninvasive techniques for estimating intracranial pressure and predicting mortality in patients with severe TBI admitted to an intensive care unit.

Methods: This was an observational, comparative, cross-sectional study conducted in patients diagnosed with severe TBI who were admitted to the Intensive Care Unit of Hospital General Villa. The predictive performance of estimated ICP obtained by ONSD measurement and ophthalmic artery Doppler ultrasonography for mortality was assessed using receiver operating characteristic (ROC) curves and the area under the curve (AUC). A binary logistic regression analysis was also performed, considering ICP estimated by both methods, age, and Glasgow Coma Scale score as predictor variables.

Results: A total of 41 patients were included. The mean age was 34.05 ± 16.02 years, with a range of 17 to 79 years. Most patients were male (82.9%, $n = 34$), whereas females accounted for 17.1% ($n = 7$). ICP estimated by ONSD measurement showed an AUC of 0.791 (95% CI, 0.646–0.936; $p = 0.002$), with a sensitivity of 78.6% and specificity of 77.8%. In contrast, ICP estimated by ophthalmic artery Doppler ultrasonography showed an AUC of 0.675 (95% CI, 0.487–0.862; $p = 0.070$), with a sensitivity of 71.4% and specificity of 81.5%. In the multivariable analysis, only ICP estimated by ONSD measurement was independently associated with mortality (OR = 1.339; 95% CI, 1.028–1.746; $p = 0.031$).

Conclusion: Optic nerve sheath diameter measurement demonstrated better predictive performance for mortality than ophthalmic artery Doppler ultrasonography in patients with severe TBI. These findings support its potential utility as a noninvasive technique for assessing neurocritical care patients and highlight the need for prospective multicenter studies with larger sample sizes to confirm these findings.

Keywords: Traumatic Brain Injury; Intracranial Hypertension; Intracranial Pressure; Optic Nerve Sheath Diameter; Doppler Ultrasonography; Neurocritical Care; Mortality

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Introduction

Intracranial hypertension is one of the most feared complications following traumatic brain injury. When it occurs, prompt diagnosis and close clinical monitoring are essential to enable timely and appropriate interventions aimed at improving outcomes in patients with brain injury. The management of intracranial hypertension is based on monitoring intracranial pressure and cerebral perfusion pressure. Cerebral ultrasonography can be used in a variety of settings, including prehospital environments, emergency departments, operating rooms, and intensive care units. The most common neurological conditions evaluated include subarachnoid hemorrhage, traumatic brain injury, and ischemic and hemorrhagic strokes.¹ Traumatic brain injury is one of the leading causes of mortality

and disability worldwide. According to the Centers for Disease Control and Prevention (CDC), approximately 2.5 million people experience a traumatic brain injury annually; among them, 283,000 require hospitalization and 52,000 die, accounting for approximately one-third of all deaths related to traumatic brain injury. In addition, approximately 5.3 million individuals live with a disability resulting from a traumatic brain injury. The World Health Organization (WHO) estimates that approximately 27 million traumatic injuries occur worldwide each year. In the United States, nearly one-third of deaths are attributed to various types of injuries, and approximately 1.7 million people sustain traumatic brain injuries annually.^{2,3}

Ultrasonographic assessment of the optic nerve sheath diameter (ONSD) has emerged as a promising noninvasive method. The optic

nerve sheath is anatomically continuous with the subarachnoid space, allowing it to expand in response to increases in intracranial pressure (ICP).⁴ Clinical studies and meta-analyses have demonstrated its effectiveness in several critical conditions, including traumatic brain injury, subarachnoid hemorrhage, and sepsis.⁵ The most commonly used reference threshold for identifying intracranial hypertension in adults is an optic nerve sheath diameter (ONSD) greater than 5.7 mm. A meta-analysis conducted by Kim and colleagues reported a sensitivity of 91% and a specificity of 77%, with an area under the curve (AUC) of 0.92 for detecting elevated intracranial pressure. This technique is rapid, safe, repeatable, and does not require advanced equipment, making it particularly valuable in critical care settings.^{6,7} The use of transorbital Doppler ultrasonography of the ophthalmic artery, particularly the two-depth Doppler technique, has been proposed as a noninvasive method for assessing intracranial pressure (ICP). This technique evaluates blood flow in the ophthalmic artery at two different locations: intracranial and extracranial. Hemodynamic changes resulting from increased ICP affect the flow pattern, allowing indirect estimation of ICP. The parameters assessed include peak systolic velocity (PSV), end-diastolic velocity (EDV), and mean velocity (MV), as well as Doppler-derived indices such as the pulsatility index (PI) and resistive index (RI). The PI is calculated as $(PSV - EDV) / MV$, whereas the RI is calculated as $(PSV - EDV) / PSV$. Blood flow velocities are dependent on the insonation angle, unlike Doppler-derived indices; therefore, the latter are recommended when velocity measurements are unreliable.⁸

In this study, we aimed to assess the diagnostic performance of ultrasonographic measurement of the optic nerve sheath diameter and ophthalmic artery Doppler ultrasonography as noninvasive approaches for estimating intracranial pressure, as well as to evaluate their prognostic significance for mortality in patients with severe traumatic brain injury admitted to the intensive care unit.

Méthods

An observational, comparative, cross-sectional study was conducted in patients diagnosed with severe traumatic brain injury (TBI) who were admitted to the intensive care unit (ICU) of a hospital in Mexico City. Data were collected from the medical records of 41 patients admitted between December 2024 and February 2026. The main inclusion criteria were patients aged 18 to 79 years of either sex with a diagnosis of severe TBI. Patients younger than 18 years, those with mild-to-moderate TBI, structural ocular injuries, a history of pre-existing neurological diseases that could alter cerebral perfusion or brain anatomy, previous cranial surgery, or craniectomy that could modify intracranial pressure were excluded. For each medical record, sociodemographic data, Glasgow Coma Scale (GCS) scores, and noninvasive neuromonitoring parameters, including optic nerve sheath diameter (ONSD) and ophthalmic artery Doppler measurements, were collected.

Statistical analysis of the data

The statistical analysis was designed to evaluate the predictive ability of intracranial pressure estimated using optic nerve sheath diameter and ophthalmic artery Doppler ultrasonography in relation to mortality among patients with severe traumatic brain injury. A 95% confidence level was established for all analyses, and a p-value ≤ 0.05 was considered statistically significant. The collected data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS), version 21.0 for Windows.

Qualitative variables were expressed as absolute frequencies and percentages and presented in frequency distribution tables. Quantitative variables were analyzed using measures of central tendency and variability. For variables with a normal distribution, the mean and standard deviation were calculated, whereas the median and interquartile range were used for variables with a non-normal distribution. To evaluate the prognostic performance of ultrasonographic optic nerve sheath diameter (ONSD) measurement, estimated intracranial pressure based on ONSD (ICP-ONSD), ophthalmic artery Doppler pulsatility index (ophthalmic artery PI), and intracranial pressure estimated by ophthalmic artery Doppler (ICP-Ophthalmic) as predictors of in-hospital mortality, receiver operating characteristic (ROC) curve analysis was performed. The area under the curve (AUC) and its corresponding 95% confidence interval were calculated for each variable. Optimal cutoff values were also identified based on sensitivity and specificity analyses, selecting those with the best diagnostic balance for predicting mortality.

Results

The study included a sample of 41 patients diagnosed with severe traumatic brain injury who were admitted to the intensive care unit. The mean age was 34.05 ± 16.02 years, with an age range of 17 to 79 years. Most patients were male (82.9%, $n=34$), whereas female patients accounted for 17.1% ($n=7$). The mean Glasgow Coma Scale score at admission was 7.73 ± 3.25 points. Regarding the ultrasonographic variables evaluated, the mean optic nerve sheath diameter was 5.72 ± 0.65 mm, and the estimated intracranial pressure based on optic nerve sheath diameter (ICP-ONSD) was 24.19 ± 3.59 mmHg. In contrast, the ophthalmic artery Doppler index had a mean value of 1.55 ± 0.33 , whereas the intracranial pressure estimated using this method (ICP-Ophthalmic) was 15.53 ± 3.50 mmHg. Overall in-hospital mortality during the study period was 34.1% ($n=14$), while 65.9% of patients survived to hospital discharge ($n=27$) (Table 1).

Table 1 General characteristics of patients with severe traumatic brain injury ($n = 41$)

Variable	Resultad
Age (Years), Mean $\pm$ SD ^a	34.05 $\pm$ 16.02
Glasgow, mean $\pm$ DE ^a	7.73 $\pm$ 3.25
ONSD (mm), mean $\pm$ DE ^a	5.72 $\pm$ 0.65
ICP ONSD (mmHg), mean $\pm$ DE ^a	24.19 $\pm$ 3.59
IP Ophthalmic, mean $\pm$ DE ^a	1.55 $\pm$ 0.33
ICP Ophthalmic (mmHg), mean $\pm$ DE ^a	15.53 $\pm$ 3.50
Male sex, n (%) ^b	34 (82.9%)
Female sex, n (%) ^b	7 (17.1%)
In-hospital mortality, n (%) ^b	14 (34.1%)
In-hospital survival, n (%) ^b	27 (65.9%)

a. Mean and standard deviation. b. Frequency and percentage.

Optimal cutoff points for mortality prediction

ROC curve analysis showed that ICP-ONSD had an area under the curve (AUC) of 0.791 (95% CI: 0.646–0.936; $p=0.002$). The optimal cutoff point was ≥ 24.75 mmHg, with a sensitivity of 78.6% and specificity of 77.8%. ICP-Ophthalmic showed an AUC of 0.675 (95% CI: 0.487–0.862; $p=0.070$). The optimal cutoff point was ≥ 16.75 mmHg, with a sensitivity of 71.4% and specificity of 81.5% (Table 2).

Table 2 Diagnostic utility of increased intracranial pressure assessed by the ophthalmic artery pulsatility index versus optic nerve sheath diameter measurement as prognostic indicators of mortality

Variable	AUC (95% IC)	P	Cutoff point	Sensitivity	Specificity
ICP-ONSD	0.791 (0.646–0.936)	0.002	≥24.75	78.60%	77.80%
ICP-Ophthalmic	0.675 (0.487–0.862)	0.07	≥16.75	71.40%	81.50%

Based on the results obtained from the ROC curve coordinates, the following data were obtained. For ultrasonographic measurement of the optic nerve sheath diameter (ONSD), the optimal cutoff point was ≥5.85 mm, with a sensitivity of 78.6% and specificity of 77.8% for predicting in-hospital mortality. The intracranial pressure estimated using this method (ICP-ONSD) had an optimal cutoff point of ≥24.75 mmHg, with a sensitivity of 78.6% and specificity

of 77.8%. Regarding ophthalmic artery Doppler ultrasonography, the ophthalmic artery pulsatility index (ophthalmic artery PI) showed an optimal cutoff point of ≥1.65, with a sensitivity of 71.4% and specificity of 81.5%. Likewise, intracranial pressure estimated by ophthalmic artery Doppler (ICP-Ophthalmic) had a cutoff point of ≥16.75 mmHg, achieving a sensitivity of 71.4% and specificity of 81.5% (Table 3).

Table 3 Optimal Cutoff Points

Variable	Cutoff	Sensitivity	Specificity
ONSD	≥5.85 mm	78.60%	77.80%
ICP-ONSD	≥24.75 mmHg	78.60%	77.80%
IP-Ophthalmic	≥1.65	71.40%	81.50%
ICP-Ophthalmic	≥16.75 mmHg	71.40%	81.50%

Logistic regression analysis for mortality prediction

The logistic regression model showed a trend toward overall statistical significance ($\chi^2 = 9.404$; $df = 4$; $p = 0.052$), with a Nagelkerke coefficient of determination (R^2) of 0.283, indicating that the variables included in the model explained approximately 28.3% of the observed variability in mortality. In the multivariable analysis, intracranial pressure estimated using optic nerve sheath diameter (ICP-ONSD) was independently associated with mortality, with an odds ratio (OR) of 1.339 (95% CI: 1.028–1.746; $p = 0.031$). Age (OR = 1.042; 95% CI: 0.992–1.094; $p = 0.104$), Glasgow Coma Scale score (OR = 1.074; 95% CI: 0.846–1.363; $p = 0.557$), and intracranial pressure estimated by ophthalmic artery Doppler ultrasonography (OR = 1.109; 95% CI: 0.872–1.410; $p = 0.400$) were not independently associated with mortality (Table 4, Figure 1).

Table 4 Logistic Regression Analysis

Variable	OR (Exp(B))	IC 95%	P
ICP-ONSD	1.339	1.028 – 1.746	0.031
Age	1.042	0.992 – 1.094	0.104
Glasgow	1.074	0.846 – 1.363	0.557
ICP-Ophthalmic	1.109	0.872 – 1.410	0.4

Overall Model: $\chi^2 = 9.404$; $gl = 4$; $p = 0.052$.

Discussion

The study population consisted of 41 patients, predominantly male (82.9%), with a mean age of 34.05 ± 16.02 years. These findings are consistent with the known epidemiology of traumatic brain injury (TBI), which predominantly affects young men of working age. The in-hospital mortality rate was 34.1%, reflecting the severity of the study population. In this study, the diagnostic performance of two noninvasive techniques for estimating intracranial pressure (ICP) was evaluated: ultrasonographic measurement of optic nerve sheath diameter (ONSD) and ophthalmic artery Doppler ultrasonography, with particular emphasis on their prognostic value for mortality in patients with severe TBI.

The results showed that variables related to the optic nerve sheath had better discriminative ability for predicting in-hospital mortality. ICP estimated by ONSD (ICP-ONSD) yielded an area under the ROC curve (AUC) of 0.791 (95% CI: 0.646–0.936; $p = 0.002$), whereas ONSD alone showed an AUC of 0.788 (95% CI: 0.643–0.934; $p = 0.003$). Both variables demonstrated acceptable and statistically significant discriminative performance. In contrast, variables derived from ophthalmic artery Doppler ultrasonography (ophthalmic artery PI and ICP-Ophthalmic) yielded an AUC of 0.675 (95% CI: 0.487–0.862; $p = 0.070$), without reaching statistical significance.

When comparing both methods, ICP estimation using ONSD demonstrated greater sensitivity for identifying patients at risk of mortality, whereas ophthalmic artery Doppler showed slightly higher specificity. However, considering the ROC curve analysis and logistic regression results, ONSD measurement demonstrated better overall performance as a prognostic tool for mortality in patients with

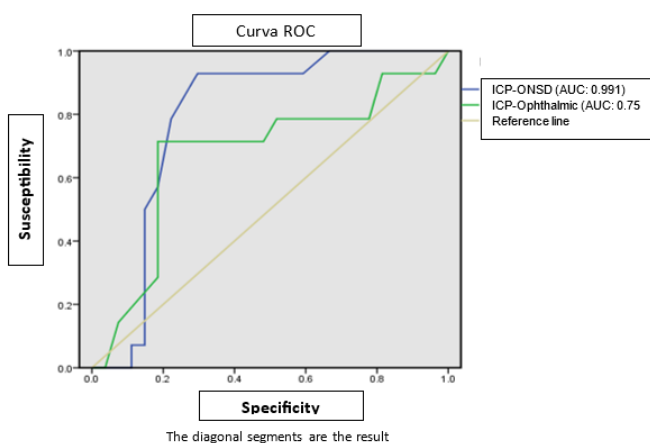


Figure 1 ROC curves of ICP-ONSD and ICP-Ophthalmic for the prediction of mortality in patients with severe traumatic brain injury. Intracranial pressure estimation using optic nerve sheath diameter showed a higher area under the curve (AUC = 0.791) compared with estimation using ophthalmic artery Doppler (AUC = 0.675), indicating better discriminative ability for predicting in-hospital mortality.

severe TBI. These findings are consistent with the pathophysiology of intracranial hypertension described in the literature. The optic nerve sheath maintains anatomical continuity with the intracranial subarachnoid space, allowing changes in cerebrospinal fluid pressure to be transmitted along the optic nerve sheath. Consequently, increases in ICP can result in expansion of the optic nerve sheath, which can be detected by ultrasonography. This anatomical relationship may explain the high sensitivity of ONSD measurement for detecting intracranial hypertension and assessing prognosis in neurocritical care patients.

The findings of the present study are consistent with recent scientific evidence. A meta-analysis published in 2025, including 516 patients with brain injuries, reported that increased optic nerve sheath diameter was significantly associated with higher mortality, with an area under the curve of 0.87, a sensitivity of 86%, and a specificity of 78%.⁹ Although the AUC observed in our study was slightly lower (0.788–0.791), the results showed a similar trend and support the prognostic utility of this tool. The observed differences may be explained by the smaller sample size of our study, as well as differences in the clinical characteristics of the study populations. Similarly, a study conducted at a Level I trauma center in India reported an AUC of 0.942 for identifying elevated intracranial pressure using ultrasonographic measurement of the optic nerve sheath diameter, with a sensitivity of 93.2% and specificity of 81.8%, using a cutoff value of 5.0 mm¹⁰. Although our results were lower, a consistent pattern was observed, with an ONSD cutoff value of 5.85 mm, yielding a sensitivity of 78.6% and specificity of 77.8%. This cutoff value is clinically relevant, as it is close to the 5.7-mm threshold reported in several studies and meta-analyses as an indicator of intracranial hypertension in adults. Regarding ophthalmic artery Doppler ultrasonography, the findings demonstrated moderate discriminative ability, which was lower than that observed with optic nerve sheath diameter measurement.

Although transorbital Doppler ultrasonography has been proposed as a noninvasive option for assessing intracranial pressure through hemodynamic changes in the ophthalmic artery, its diagnostic accuracy remains inconsistent. Therefore, understanding the mechanisms underlying cerebrovascular autoregulatory disturbances is essential for establishing appropriate neuromonitoring strategies and facilitating timely treatment in patients with severe traumatic brain injury.^{11,12,13} Our findings support this observation, as neither the ophthalmic artery pulsatility index (ophthalmic artery PI) nor ICP estimated by ophthalmic artery Doppler (ICP-Ophthalmic) reached statistical significance for predicting mortality. One possible explanation is that Doppler-derived parameters may be influenced by multiple physiological and hemodynamic factors, including systemic blood pressure, intravascular volume status, vasopressor use, and alterations in cerebral autoregulation, which may reduce their discriminative ability when used in isolation.

Additionally, binary logistic regression analysis allowed the identification of factors independently associated with in-hospital mortality. The only variable that demonstrated an independent and statistically significant association with mortality was ICP-ONSD (OR = 1.339; 95% CI: 1.028–1.746; $p = 0.031$), indicating that for each 1-mmHg increase in ICP estimated using this method, the odds of death increased by approximately 33.9%. This finding suggests that increased intracranial pressure, as estimated by optic nerve sheath diameter measurement, is associated with a higher risk of mortality. In contrast, variables derived from ophthalmic artery Doppler ultrasonography did not reach statistical significance in the multivariable analysis. These findings reinforce the results obtained from the ROC analysis and suggest that optic nerve sheath diameter

assessment may have greater prognostic relevance than ophthalmic artery Doppler ultrasonography for predicting mortality in patients with severe traumatic brain injury.

Furthermore, the utility of ultrasonographic techniques has also been explored as part of a multimodal neuromonitoring approach. Measurement of the optic nerve sheath diameter (ONSD) allows the identification of changes associated with increased intracranial pressure, while other Doppler modalities may provide information on cerebral hemodynamic alterations associated with intracranial hypertension.^{14,15} Taken together, these tools may contribute to a more comprehensive assessment of neurocritical care patients; however, they should not be considered substitutes for invasive ICP monitoring when the latter is indicated. Their main advantage is that they are relatively rapid, repeatable, and noninvasive techniques, allowing them to be used as complementary tools for serial monitoring and the early identification of patients at risk of neurological deterioration.

Conclusion

The results of the present study suggest that ultrasonographic measurement of the optic nerve sheath diameter (ONSD) has better prognostic performance for mortality than ophthalmic artery Doppler ultrasonography in patients with severe traumatic brain injury. These findings support its utility as a noninvasive method for the assessment of neurocritical care patients and justify the need for larger, prospective, multicenter studies to validate these findings and more precisely establish its role in intracranial pressure monitoring.

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