Section: Anaesthesiology

Original Research Article

DIAGNOSTIC UTILITY AND ACCURACY OF OPTIC NERVE SHEATH DIAMETER (ONSD) IN DETECTING RAISED INTRACRANIAL PRESSURE IN TRAUMATIC BRAIN INJURY

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ABSTRACT

Background: Raised intracranial pressure (ICP) is a critical determinant of secondary brain injury and outcome in traumatic brain injury (TBI), but invasive ICP monitoring is limited by cost, availability, and procedural risk. Ultrasonographic measurement of optic nerve sheath diameter (ONSD) has emerged as a rapid, bedside, non-invasive surrogate marker of raised ICP. **Objective:** To evaluate the diagnostic utility and accuracy of ONSD in detecting raised intracranial pressure in patients with traumatic brain injury admitted to the intensive care unit. **Materials and Methods:** This prospective observational study was conducted over 18 months in the ICU of a tertiary care teaching hospital. Sixty-nine adult patients with TBI underwent bedside ocular ultrasound with binocular ONSD measurement on Day 0, repeated daily until discharge or death. Raised ICP was defined on the basis of CT and clinical assessment. Diagnostic performance of Day 0 mean ONSD was assessed using receiver operating characteristic (ROC) curve analysis, and its association with CT findings and time since injury was examined. **Results:** The mean age was 38.26 ± 8.79 years, with falls (66.7%) the commonest mode of injury and moderate TBI (60.9%) the commonest severity category. Mean binocular ONSD on Day 0 was 0.54 ± 0.01 cm and declined progressively to 0.50 ± 0.01 cm by Day 4. Raised ICP was identified in 33.3% of patients. ROC analysis of Day 0 mean ONSD yielded an area under the curve of 0.62, with an optimal cut-off of ≥0.55 cm giving a sensitivity of 65%, specificity of 58%, positive predictive value of 46%, negative predictive value of 74%, and overall diagnostic accuracy of 61%. Mean ONSD did not differ significantly by CT finding (p=0.647) or by time since injury (p=0.751). Overall, 87% of patients improved and 13% died by discharge. **Conclusion:** Ultrasonographic ONSD is a simple, non-invasive, bedside tool with moderate diagnostic accuracy and a high negative predictive value for raised ICP in TBI, making it more useful for screening out than for definitively ruling in intracranial hypertension. Serial ONSD measurement tracks improvement in intracranial dynamics and may serve as a valuable adjunct to, rather than a replacement for, invasive ICP monitoring and clinical/radiological assessment.

INTRODUCTION

Traumatic brain injury (TBI) remains a major cause of mortality and long-term disability worldwide, particularly among young adults, and is frequently complicated by raised intracranial pressure (ICP), a critical determinant of neurological outcome.[1] Early identification and timely management of intracranial hypertension are essential, as sustained elevation of ICP is associated with secondary brain injury, cerebral ischaemia, herniation, and increased mortality.

Invasive intracranial pressure monitoring using intraventricular catheters or intraparenchymal probes remains the gold standard for ICP measurement, but is limited by the need for neurosurgical expertise, risk of infection and haemorrhage, high cost, and limited availability, especially in resource-constrained and emergency settings.[2] This has driven interest in

reliable, rapid, non-invasive techniques for assessing raised ICP in TBI.

The optic nerve sheath is a dural extension containing cerebrospinal fluid continuous with the intracranial subarachnoid space, so that a rise in ICP is transmitted along this space and distends the sheath. Ultrasonographic measurement of optic nerve sheath diameter (ONSD) has therefore emerged as a promising non-invasive surrogate marker of raised ICP, being rapid, bedside-friendly, repeatable, and deliverable with portable equipment in emergency departments, intensive care units, and prehospital settings.[3]

Numerous clinical studies and reviews have evaluated the diagnostic performance of ONSD in detecting raised ICP in TBI; while many report high sensitivity and specificity with a strong correlation to invasively measured ICP, others highlight variability related to operator skill, measurement technique, cut-off values, and patient-related factors, and additional parameters such as optic disc elevation and the ONSD-to-eyeball transverse diameter ratio have been explored to improve accuracy.[4] Given this variability and the ongoing debate over its clinical reliability, the present study was undertaken to evaluate the diagnostic utility and accuracy of ONSD, measured serially at the bedside, in detecting raised ICP among adult patients with TBI admitted to the intensive care unit.

Aims and Objectives

To assess the diagnostic utility and accuracy of optic nerve sheath diameter in detecting raised intracranial pressure in patients with traumatic brain injury.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Intensive Care Unit (ICU) of PES Institute of Medical Sciences and Research (PESIMSR), Kuppam, a tertiary care teaching hospital, over a period of 18 months, after Institutional Ethics Committee approval. As patients with TBI were frequently unable to provide consent themselves, written informed consent was obtained from their legally authorized representatives at the time of ICU admission.

Study Population and Sampling

Adult patients admitted to the ICU with a diagnosis of traumatic brain injury were enrolled using a purposive sampling method during the study period.

Sample Size

The sample size was calculated based on the study by Agarwal et al,[5] using the appropriate diagnostic-accuracy sample size formula, which yielded a requirement of 69 patients. Accordingly, 69 patients were enrolled in the present study.

Inclusion Criteria

- Patients aged more than 18 years admitted to the ICU with traumatic brain injury
- Patients with no prior drug history or associated systemic illness
- Patients with no ophthalmological disease other than refractive error
- Patients with no history of ocular, orbital, or cranial surgery
- Patients with no history of radiotherapy to the head or orbital region
- Patients with no known liver or renal disorders

Exclusion Criteria

- Patients leaving the hospital against medical advice or referred to higher centres
- Patients unlikely to survive for more than 48 hours from enrolment
- Patients with globe injury or pre-existing ocular disease other than refractive errors

Ocular Ultrasound and ONSD Measurement

Baseline disease severity was assessed using the Glasgow Coma Scale (GCS) at admission, and all patients were managed according to standard ICU protocols, with sedation given as intravenous midazolam at the treating intensivist's discretion. Ocular ultrasound examinations were performed at the bedside by trained physicians, with all measurements for a given patient performed by a single operator to minimise inter-observer variability. A high-frequency linear transducer (7.5–15 MHz) was used with portable, cart-based ultrasound equipment, focused on the retrobulbar area with gain settings optimised for contrast between the optic nerve and periorbital fat.

Patients were positioned supine with the head elevated to approximately 35 degrees. The transducer was placed gently over the closed upper eyelid using sterile coupling gel, avoiding pressure on the cornea or sclera. The optic nerve was visualised as a hypoechoic structure posterior to the globe bordered by hyperechoic dura and periorbital fat, and ONSD was measured 3 mm posterior to the retina — the point of maximum sheath distension in raised ICP — from inner edge to inner edge of the hypoechoic dural margins. Two measurements (sagittal and transverse plane) were taken per eye, and the mean of both eyes was recorded as the final ONSD value for that day. ONSD was measured from Day 1 of ICU admission and repeated daily until discharge or death.

Outcome Measures

The primary outcome was the diagnostic accuracy of Day 0 mean binocular ONSD for detecting raised ICP, defined on the basis of CT and clinical assessment, assessed using sensitivity, specificity, positive and negative predictive values, overall accuracy, and receiver operating characteristic (ROC) curve analysis. Secondary outcomes included the day-wise trend in ONSD, and its association with CT brain findings, time since injury, ICU stay, and outcome at discharge.

Statistical Analysis

Data were entered in Microsoft Excel and analysed using SPSS software version 23.0. Categorical variables were expressed as frequencies and percentages and compared using the Chi-square test;

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continuous variables were expressed as mean ± standard deviation and compared using Student's t-test. ROC curve analysis was used to determine the optimal ONSD cut-off and diagnostic performance. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 69 patients with traumatic brain injury were enrolled and completed the study.

Demographic and Clinical Profile at Admission

The mean age of the study population was 38.26 ± 8.79 years, with the largest proportion of patients in the 31–40 year age group (39.1%). Gender distribution was near-equal (49.3% male, 50.7% female). Falls were the commonest mode of injury (66.7%), and 49.3% of patients were admitted to the ICU within 6 hours of injury. The mean GCS at admission was 11.04 ± 1.99, with moderate TBI (GCS 9–12) in 60.9% of patients; a normal pupillary reaction was noted in 65.5%. [Table 1]

Table 1: Demographic and Clinical Profile at Admission

Characteristic	Number (n)	Percentage (%)
Age Group (years)		
< 30	14	20.3
31–40	27	39.1
41–50	20	29.0
> 50	8	11.6
Mean age ± SD: 38.26 ± 8.79 years		
Gender		
Male	34	49.3
Female	35	50.7
Mode of Injury		
Road traffic accident	23	33.3
Fall	46	66.7
Time Interval Between Injury and ICU Admission		
≤ 6 hours	34	49.3
> 6 hours	35	50.7
Glasgow Coma Scale at Admission		
Mild TBI (13–15)	19	27.5
Moderate TBI (9–12)	42	60.9
Severe TBI (≤8)	8	11.6
Mean GCS ± SD: 11.04 ± 1.99		
Pupillary Reaction at Admission		
Normal	45	65.5
Abnormal	24	34.5

CT Brain Findings at Admission

Cerebral contusion was the commonest CT finding (71.0%), followed by diffuse cerebral edema (18.8%); subdural haematoma, epidural haematoma, and subarachnoid haemorrhage were each seen in a small proportion of patients. [Table 2]

Table 2: CT Brain Findings at Admission

CT Brain Finding	Number (n)	Percentage (%)
Contusion	49	71.0
Diffuse cerebral edema	13	18.8
Subdural haematoma (SDH)	3	4.4
Epidural haematoma (EDH)	2	2.9
Subarachnoid haemorrhage (SAH)	2	2.9

Sedation, Ventilatory, and Neurosurgical Support

Sedation with midazolam was required in 76.8% of patients, mechanical ventilation in 24.6%, and neurosurgical intervention in 18.8%, with the remainder managed conservatively. [Table 3]

Table 3: Sedation, Ventilation, and Neurosurgical Intervention

Support Required	Number (n)	Percentage (%)
Sedation with Midazolam		
Yes	53	76.8
No	16	23.2
Mechanical Ventilation		
Required	17	24.6
Not required	52	75.4
Neurosurgical Intervention		
Required	13	18.8
Not required	56	81.2

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Optic Nerve Sheath Diameter Measurements

On Day 0, mean ONSD was 0.54 ± 0.01 cm in the right eye and 0.55 ± 0.01 cm in the left eye, giving a mean binocular ONSD of 0.54 ± 0.01 cm. Serial measurement showed a progressive decline in mean binocular ONSD from 0.54 ± 0.01 cm on Day 0 to 0.50 ± 0.01 cm by Day 4. [Table 4]

Table 4: Day 0 ONSD Measurements and Day-wise Trend

Parameter	Mean ONSD (cm)	Standard Deviation
Day 0 ONSD by Eye		
Right eye	0.54	0.01
Left eye	0.55	0.01
Mean binocular ONSD	0.54	0.01
Day-wise Mean Binocular ONSD		
Day 0	0.54	0.01
Day 1	0.53	0.01
Day 2	0.52	0.01
Day 3	0.51	0.01
Day 4	0.50	0.01

Distribution of Raised Intracranial Pressure

Raised ICP was identified in 33.3% of patients, while 66.7% showed no evidence of raised ICP. [Table 5]

Table 5: Distribution of Raised Intracranial Pressure

ICP Status	Number (n)	Percentage (%)
Raised ICP present	23	33.3
Raised ICP absent	46	66.7

Diagnostic Accuracy of ONSD

ROC curve analysis of Day 0 mean ONSD yielded an area under the curve of 0.62, with an optimal cut-off of ≥0.55 cm. At this cut-off, ONSD showed a sensitivity of 65%, specificity of 58%, positive predictive value of 46%, negative predictive value of 74%, and overall diagnostic accuracy of 61% for detecting raised ICP, indicating fair discriminatory performance with a relatively high negative predictive value. [Table 6]

Table 6: ROC Curve Analysis and Diagnostic Accuracy of Mean ONSD (Day 0)

Parameter	Result
ROC Curve Analysis	
Area under ROC curve (AUC)	0.62
Optimal cut-off value	≥ 0.55 cm
Diagnostic Accuracy at Optimal Cut-off	
Sensitivity	65%
Specificity	58%
Positive predictive value	46%
Negative predictive value	74%
Overall accuracy	61%

Duration of ICU Stay and Outcome

The mean ICU stay was 7.8 ± 3.1 days, with 50.7% of patients staying ≤7 days. At discharge, 87% of patients showed clinical improvement and 13% died. [Table 7]

Table 7. Duration of ICU Stay and Outcome at Discharge

Parameter	Number (n)	Percentage (%)
Duration of ICU Stay		
≤ 7 days	35	50.7
> 7 days	34	49.3
Mean ICU stay ± SD: 7.8 ± 3.1 days		
Outcome at Discharge		
Improved	60	87
Expired	9	13

Association of Mean Day-0 ONSD with CT Findings and Time Since Injury

There was no statistically significant association between the type of intracranial lesion on CT and mean Day-0 ONSD (p=0.647), although slightly higher values were noted with epidural haematoma and diffuse cerebral edema (Table 8). Similarly, mean Day-0 ONSD did not differ significantly between patients presenting within 6 hours and those presenting after 6 hours of injury (p=0.751). [Table 8]

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Table 8: Association Between CT Brain Findings and Mean Day-0 ONSD

CT Brain Finding	n	Mean ONSD (cm)	SD	P value
Contusion	49	0.549	0.017	
Diffuse cerebral edema	13	0.552	0.018	
Subdural haematoma	3	0.538	0.015	0.647
Epidural haematoma	2	0.560	0.007	
Subarachnoid haemorrhage	2	0.545	0.028	

Table 9: Association Between Time Since Injury and Mean Day-0 ONSD

Time Since Injury	n	Mean ONSD (cm)	SD	P value
≤ 6 hours	34	0.549	0.017	0.751
> 6 hours	35	0.550	0.017	

DISCUSSION

Traumatic brain injury remains a major cause of morbidity and mortality worldwide, particularly in settings where early diagnosis and continuous monitoring of intracranial pressure pose significant challenges. The present study evaluated the diagnostic utility and accuracy of ultrasonographic ONSD in detecting raised ICP among ICU patients with TBI.

The mean age of 38.26 ± 8.79 years, with the majority of patients in the 31–40 year age group, is consistent with Geeraerts et al., who observed that TBI patients admitted to intensive care commonly belonged to the third and fourth decades of life,[6] and with Rajajee et al. and Kimberly et al., who reported comparable mean ages in cohorts undergoing ONSD assessment for suspected raised ICP.[7,8] The near-equal gender distribution observed in the present study contrasts with the male predominance reported by Soldatos et al. and Geeraerts et al,[9,6] though more recent series by Legrand et al. have shown a narrowing gender gap, particularly where falls rather than road traffic accidents predominate,10 consistent with falls being the commonest mechanism of injury (66.7%) in the present cohort.

The mean GCS at admission (11.04 ± 1.99) and predominance of moderate TBI in this study mirror the findings of Kimberly et al. and Rajajee et al,[8,7] and the predominance of cerebral contusions on CT is consistent with the fall-related injury pattern reported by Legrand et al. and Geeraerts et al.[10,6]

Mean binocular ONSD on Day 0 (0.54 ± 0.01 cm) in this study was slightly lower than the 0.55–0.57 cm reported by Kimberly et al. in patients with raised ICP,[8] which may reflect the predominance of moderate rather than severe TBI in the present cohort. The progressive decline in serial ONSD from Day 0 to Day 4 parallels the reductions in ONSD following effective ICP-lowering therapy reported by Geeraerts et al. and Robba et al,[6,11] supporting the role of serial ONSD monitoring as a dynamic marker of intracranial status rather than a single static measurement.

The area under the ROC curve for Day 0 mean ONSD in the present study was 0.62, with a sensitivity of 65%, specificity of 58%, and overall accuracy of 61% — considerably more modest than the diagnostic performance reported in several other series. Rajajee et al. and Kimberly et al. reported higher AUC values,[7,8] and Dubourg et al., in a systematic review and meta-analysis, reported higher pooled diagnostic accuracy,[12] while Hemanth et al. reported a sensitivity of 88%, specificity of 100%, and an AUC of 0.983 for ONSD in detecting CT-confirmed raised ICP in an emergency department population,[13] and Berhanu et al., in a meta-analysis of 38 studies, similarly reported high pooled sensitivity and specificity.[14] This discrepancy is most plausibly explained by differences in reference standard: many of the higher-accuracy studies validated ONSD against simultaneously measured invasive ICP, whereas the present study defined raised ICP using CT and clinical assessment, a less direct and potentially less consistent reference standard. This is consistent with Agarwal et al., who similarly found only a modest correlation between ONSD and ICP severity when validated against therapeutic intensity level rather than a single invasive ICP threshold,[5] and with Tanna et al., who noted that variability in measurement technique, operator expertise, and reference standard across studies contributes to the wide range of reported sensitivity (88–95%) and specificity (80–90%) for ONSD in TBI.15 The consistently high negative predictive value seen across studies, including the present one, reinforces that ONSD is best applied as a screening tool to help rule out raised ICP rather than as a stand-alone diagnostic test, an interpretation supported by the earliest correlational work of Maissan et al. and by the more recent sonographic-index work of Martínez-Palacios et al., both of which emphasised standardised technique as key to reproducible diagnostic performance.[16,17]

No significant association was found between CT lesion type or time since injury and mean Day-0 ONSD in this study, suggesting that ONSD elevation in TBI is a relatively generalised response to raised ICP rather than being specific to any one radiological lesion type, and that it can be reliably measured from early presentation onward without a strong timing-related confounder. The mean ICU stay (7.8 ± 3.1 days) and outcome distribution (87% improved, 13% mortality) in this study were broadly comparable to those reported by Geeraerts et al. and Legrand et al,[6,10] with mortality concentrated among patients with severe TBI and sustained intracranial

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hypertension, consistent with the established literature.

Limitations

- The study was conducted at a single centre with a relatively small sample size, which may limit generalisability of the findings to broader and more diverse populations.
- Raised intracranial pressure was not confirmed using invasive ICP monitoring in all patients, which may have affected the accuracy of correlation between ONSD measurements and true ICP values.
- ONSD measurements are operator-dependent, and inter-observer variability could not be completely eliminated despite standardised measurement technique.

CONCLUSION

Ultrasonographic measurement of optic nerve sheath diameter is a simple, non-invasive, bedside tool with moderate diagnostic accuracy for detecting raised intracranial pressure in patients with traumatic brain injury. A mean binocular ONSD cut-off of ≥0.55 cm showed fair sensitivity and specificity with a high negative predictive value, making it particularly useful as a screening modality to rule out raised ICP. Serial ONSD measurement reflected dynamic changes in intracranial status, with a progressive reduction corresponding to clinical improvement, and ONSD correlated reasonably with clinical severity. Although it cannot replace invasive ICP monitoring, ONSD ultrasonography serves as a valuable adjunct for early detection, risk stratification, and ongoing monitoring of patients with traumatic brain injury, particularly in resource-limited and critical care settings. Multicentre studies validating ONSD against simultaneous invasive ICP monitoring are recommended to refine optimal cut-off values and strengthen its clinical applicability.

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