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Optic Nerve Sheath Diameter Estimation to Detect Increased Intracranial Pressure in Traumatic Brain Injury patients at a Level I Trauma Center in Eastern India

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ABSTRACT

Objective: To evaluate the diagnostic accuracy of optic nerve sheath diameter (ONSD) measured by ultrasound as a non-invasive marker for detecting elevated intracranial pressure (ICP) in patients with traumatic brain injury (TBI), based on clinical and radiological findings.
Methods: This diagnostic accuracy study included 180 adult patients with isolated TBI admitted to a Level I Trauma Centre in Eastern India. ONSD was measured bilaterally using a 7.5 MHz linear ultrasound probe, 3 mm posterior to the globe. Clinical and radiological parameters were recorded, and increased ICP was determined based on a predefined clinical signs and computed tomography findings. Statistical analysis included logistic regression and receiver operating characteristic (ROC) curve analysis using Jamovi software.
Results: The mean ONSD was significantly higher in patients with increased ICP (5.36±0.56 mm) compared to those without (4.13±0.34 mm, p<0.001). ROC analysis showed excellent diagnostic performance (area under the curve: 0.942), with sensitivity and specificity of 93.2% and 81.8%, respectively, at a cut-off value of 5.0 mm. The positive predictive value was 74.0%, and the negative predictive value was 99.0%. Increased ONSD was associated with TBI severity and poor Glasgow Outcome Scale scores at 3 months.
Conclusion: Ultrasound-measured ONSD is a sensitive, non-invasive bedside tool for detecting increased ICP in TBI patients, particularly useful in resource-limited settings.

Keywords: Traumatic brain injury; Optic nerve; Intracranial pressure; Ultrasonography; Glasgow Coma Scale

INTRODUCTION

Traumatic brain injury (TBI) is a significant global public health concern and a leading cause of morbidity and mortality, particularly among individuals in the productive age group.[15] It is estimated that TBI affects millions of people worldwide, with road traffic accidents, falls,

Funding

No funding was obtained for this study.

Conflict of Interest

The authors have no financial conflicts of interest.

Informed Consent

Written informed consent was obtained from all individual participants or their representatives before enrollment in the study.

Ethics Approval

The study was approved by the Institutional Ethics Committee of All India Institute of Medical Sciences Patna (Approval No: AIIMS/Pat/IEC/PGTh/July22/15). All procedures followed were in accordance with the ethical standards of the responsible committee and with the Helsinki Declaration.

and violent injuries being the predominant causes.[5] In developing countries like India, the burden of TBI is particularly high due to inadequate road safety measures, limited access to specialized trauma care, and a predominantly rural population engaged in high-risk occupations.[1,8] Monitoring of intracranial pressure (ICP) plays an important role in the management of TBI patients, as elevated ICP is strongly associated with poor outcomes, and timely detection can guide interventions to prevent secondary brain injury.[21] Conventionally, invasive monitoring techniques such as external ventricular drains and intraparenchymal catheters are considered the gold standard for ICP measurement. However, these methods carry risks of infection, hemorrhage, and technical complications, limiting their widespread application, especially in resource-limited settings. This has led to increasing interest in non-invasive methods for ICP estimation.[14,19] Among these, optic nerve sheath diameter (ONSD) measurement using bedside ultrasonography has emerged as a promising non-invasive tool for detecting increased ICP. The optic nerve sheath is an extension of the dura mater, and changes in ICP are transmitted directly to the sheath, leading to its distension. Several studies have demonstrated a strong correlation between ONSD and invasive ICP measurements, making it a valuable surrogate marker for intracranial hypertension. In addition, ONSD measurement is rapid, repeatable, and requires minimal technical expertise compared to invasive methods.[12] This study was conducted at a tertiary trauma care center in Eastern India with the objective of evaluating the diagnostic accuracy of ultrasonographic ONSD measurement in detecting raised ICP in patients with TBI, using clinical and radiological findings as reference standards. By validating ONSD as a reliable non-invasive screening tool, this research aims to support timely diagnosis and management of TBI patients, thereby potentially reducing mortality and long-term neurological deficits.

MATERIALS AND METHODS

This prospective observational study was conducted at a Level I Trauma Centre in Eastern India from January 2023 to June 2024. Out of 213 trauma patients assessed during this period, 180 patients aged 18–70 years with isolated traumatic brain injury who presented within 24 hours of injury, were included. Isolated TBI refers to traumatic brain injury without any concomitant injuries to other body regions.[4] Conversely, non-isolated TBI referred to patients with TBI associated with concomitant injuries to any other body regions.[4] Exclusion criteria were non-isolated TBI, polytrauma, pre-existing ocular diseases, penetrating eye injuries, orbital fractures, or patients with facial trauma precluding ocular ultrasound.

After obtaining informed consent, all patients underwent detailed clinical assessment including Glasgow Coma Scale (GCS) scoring. In the absence of invasive intracranial pressure monitoring, increased ICP was diagnosed based on a combination of clinical and radiological criteria. Clinically, patients were considered to have increased ICP if they demonstrated one or more of the following signs: a GCS score ≤8, motor posturing (GCS motor response ≤3), or unilateral/bilateral pupillary dilation. Radiological indicators included either the compression or effacement of basal cisterns, midline shift greater than 10 mm, or both, as observed on non-contrast computed tomography (NCCT) of the head.[6] ONSD measurements were performed within the first hour of patient presentation to trauma emergency department, following the initial diagnosis of isolated TBI and after applying exclusion criteria. ONSD was measured bilaterally using a high-frequency 7.5 MHz linear ultrasound probe. Measurements were taken 3 mm posterior to the globe in the axial plane with the patient in a supine position and head elevated at 30 degrees (**FIGURE 1**). The mean ONSD

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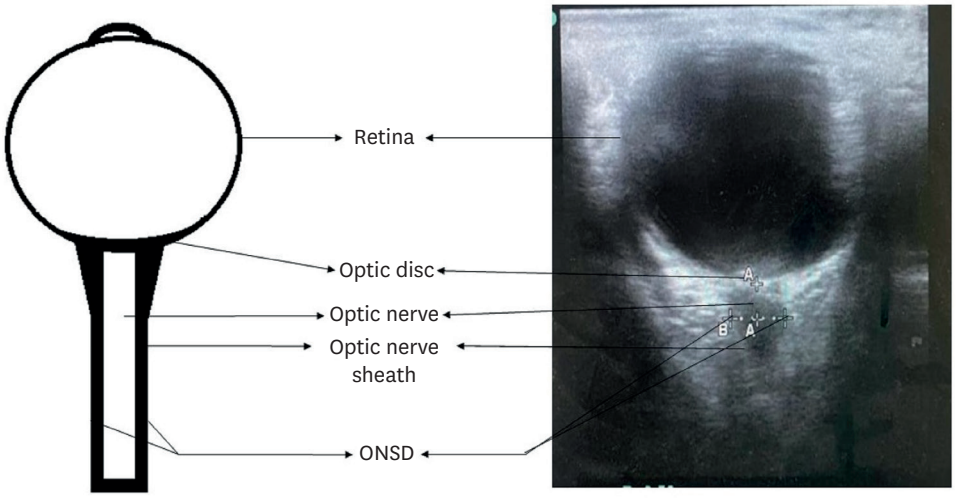

FIGURE 1. Diagram and ultrasound image showing the anatomical landmarks used to measure ONSD, including the retina, optic disc, optic nerve, and sheath.
ONSD: optic nerve sheath diameter.

was calculated by averaging 3 readings from each eye. A threshold of >5 mm was considered increased ONSD. This cut-off is supported by previous literature that identified 5.6 mm as an optimal threshold for predicting increased ICP with good sensitivity and specificity.[16,20] Subsequently, an NCCT head was performed as part of routine TBI evaluation. Based on clinical and radiological findings, increased ICP was identified.

Data analysis was conducted using Jamovi software. Statistical methods included receiver operating characteristic (ROC) curve analysis, logistic regression and χ^2 tests. The *p*-value of <0.05 was considered statistically significant.

RESULTS

A total of 180 patients with isolated TBI were included in the study. The flowchart of the study is illustrated in **FIGURE 2**. The study had a male predominance of 65% and a mean age was 39.7 years. The majority of patients were in the 18–40 years age group (58.3%), followed by 41–70 years (37.8%), and above 70 years (3.9%). Most injuries were caused by road traffic accidents, followed by falls and assault.

Based on the GCS scores, 43.9% had mild TBI (GCS 13–15), 22.8% had moderate TBI (GCS 9–12), and 33.3% had severe TBI (GCS ≤8). The mean GCS score at presentation was 10.6±4.01. The distribution of intracranial lesions in the study population, showed that contusions were the most common pathology (65.6%), followed by fractures (28.3%), subdural hematoma (23.3%), epidural hematoma (16.1%), subarachnoid hemorrhage (14.4%) and intraventricular hemorrhage (2.2%).

As detailed in **TABLE 1**, patients with increased ICP had higher mean age (41.5 years) compared to those without increased ICP (38.5 years). Males predominated in both groups, with a notably higher percentage (86.2%) among those with increased ICP. The mean GCS score was significantly lower in the increased ICP group (7.48) than in those without (13.0). Mean ONSD was also significantly higher in the increased ICP group (5.36 vs. 4.13 mm), with all 58

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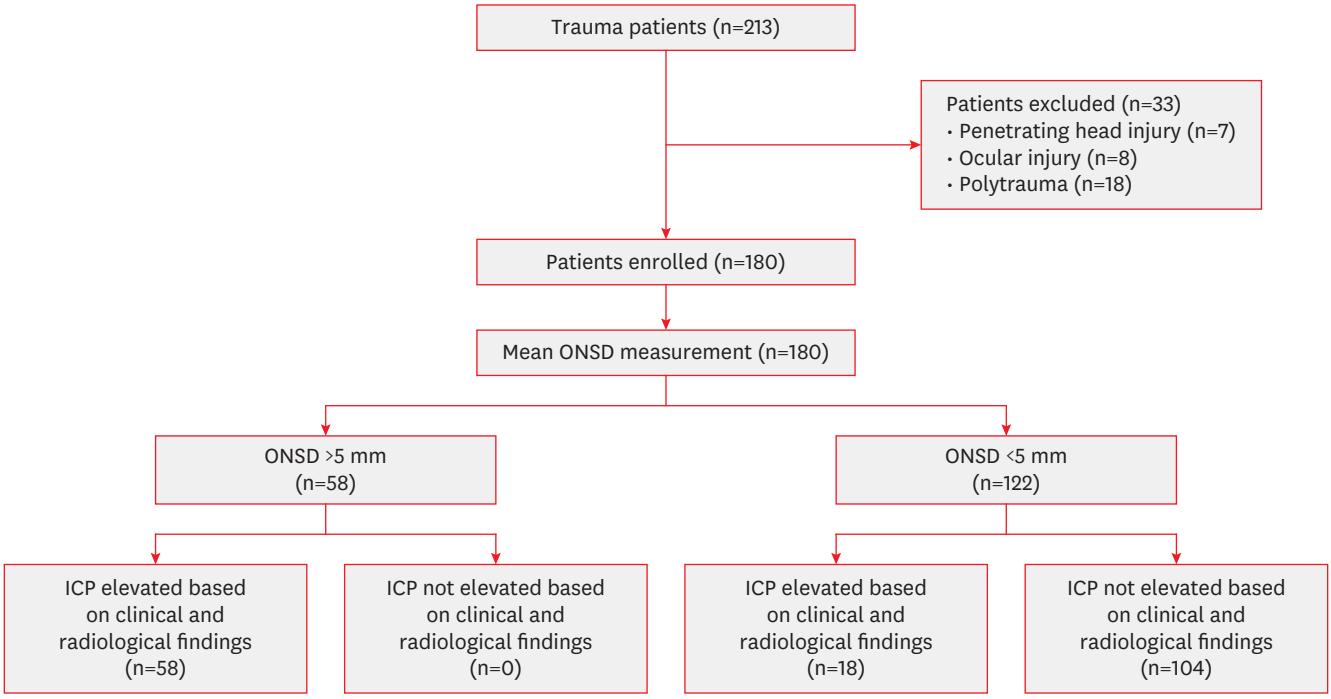

FIGURE 2. Flowchart showing patient selection and grouping based on ICP.
ICP: intracranial pressure, ONSD: optic nerve sheath diameter.

patients with ONSD >5 mm showing increased ICP. Regarding management, all patients who underwent decompressive craniectomy had increased ICP, while only 1 patient with increased ICP was managed non-operatively. Outcomes were markedly poorer in the increased ICP group, with higher mortality (18.9% vs. 1.6%), more cases of persistent vegetative state and severe disability, and fewer patients achieving good recovery (19% vs. 86.1%).

Subgroup analyses examined the relationship between ONSD and clinical/radiological indicators of raised ICP. As shown in **TABLE 2**, patients with GCS ≤8 (n=60) showed a significantly higher mean ONSD (5.18±0.735 mm, p<0.001). Among those exhibiting motor posturing (GCS motor ≤3, n=27), the mean ONSD was 5.42±0.691 mm, which was also statistically significant (p<0.001). Pupillary dilation was associated with a mean ONSD of 5.23±0.637 mm (p<0.001). Radiologically, compression or effacement of the basal cisterns (n=50) and midline shift >10 mm (n=55) were also significantly associated with increased ONSD (5.31±0.662 mm and 5.35±0.684 mm, respectively; both p <0.001). These findings emphasize a strong correlation between elevated ONSD and clinical as well as imaging signs of increased ICP.

The mean ONSD was across the study was 4.66 mm, with standard deviation of 0.756 and values ranging from 3.40 to 6.35 mm. ROC curve analysis revealed an optimal ONSD cut-off value of 5.0 mm for predicting increased ICP, yielding an area under the curve (AUC) of 0.942 (**FIGURE 3**). At this cut-off, ONSD demonstrated a sensitivity of 93.2% and specificity of 81.8%, with a positive predictive value of 74.0%, and the negative predictive value of 99.0%. Logistic regression analysis demonstrated a significant correlation between ONSD and increased ICP (p<0.001, odds ratio: 0.162). Patients with severe TBI and midline shift had significantly increased ONSD values compared to those with mild or moderate TBI (p<0.001). At 3-month follow-up, mortality was observed in 7.2% of patients, and the Glasgow Outcome Scale (GOS)

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TABLE 1. Baseline characteristics, management, and outcomes in isolated TBI patients with and without increased ICP based on clinical and radiological parameters

Variable	All subjects (n=180)	No increased ICP (n=122)	Increased ICP (n=58)	*p*-value
Age (years)	39.7±17.0	38.5±16.6	41.5±17.5	<0.001
Sex	n=180	n=103	n=77	
Male	117 (65.0)	67 (65.0)	50 (64.9)	0.987
Female	63 (35.0)	36 (35.0)	27 (35.1)	0.987
GCS score	10.6±4.01	13.0±2.88	7.48±3.03	<0.001
ONSD (mm)	4.66±0.76	4.13±0.34	5.36±0.56	<0.001
Management	n=180	n=103	n=77	
Decompressive craniectomy performed	47 (26.1)	0 (0.0)	47 (61.0)	<0.001
Craniotomy performed	31 (17.2)	9 (8.7)	22 (28.6)	<0.001
Non-operative management	95 (52.8)	94 (91.3)	1 (1.3)	<0.001
Surgery deferred due to poor outcome	7 (3.8)	0 (0.0)	7 (9.1)	<0.001
GOS scores at 3 months	n=180	n=121	n=59	
Death	13 (7.2)	2 (1.7)	11 (18.6)	<0.001
Persistent vegetative state	3 (1.7)	0 (0.0)	3 (5.1)	<0.001
Severe disability	18 (10)	8 (6.6)	10 (16.9)	<0.001
Moderate disability	30 (16.7)	6 (5.0)	24 (40.7)	<0.001
Good recovery	116 (64.4)	105 (86.8)	11 (18.6)	<0.001

Values are presented as mean ± standard deviation or number of subjects (%).
TBI: traumatic brain injury, ICP: intracranial pressure, GCS: Glasgow Coma Scale, ONSD: optic nerve sheath diameter, GOS: Glasgow Outcome Scale.

TABLE 2. Association between clinical/radiological parameters of increased ICP and mean ONSD

Parameter	Number of patients	Mean ONSD (mm)	Standard deviation	Statistical test	*p*-value
GCS ≤8	60	5.18	0.735	Welch's ANOVA	<0.001
Motor posturing (GCS motor ≤3)	27	5.42	0.691	Independent *t*-test	<0.001
Pupillary dilation	59	5.23	0.637	Welch's ANOVA	<0.001
Compression or effacement of cisterns	50	5.31	0.662	χ^2	<0.001
Midline shift >10 mm	59	5.35	0.684	χ^2	<0.001

ICP: intracranial pressure, ONSD: optic nerve sheath diameter, GCS: Glasgow Coma Scale, ANOVA: analysis of variance.

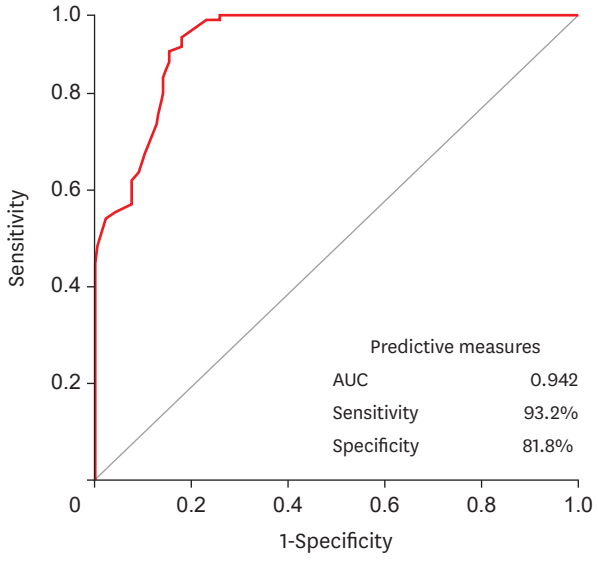

FIGURE 3. ROC curve illustrating the diagnostic accuracy of mean ONSD in predicting elevated ICP.
ROC: receiver operating characteristic, ONSD: optic nerve sheath diameter, ICP: intracranial pressure, AUC: area under the curve.

assessment showed that 64.4% had good functional recovery, while 16.7% had moderate disability, and 10.0% had severe disability. Patients with an ONSD >5 mm were more likely to have unfavorable outcomes (GOS ≤3), highlighting its prognostic value in TBI management.

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DISCUSSION

TBI remains a major public health concern worldwide, being one of the leading causes of mortality, disability, and socioeconomic burden, particularly in the 18–44-year age group—the most productive phase of life.[3,9,10] In India, the burden is more pronounced due to a combination of poor road infrastructure, limited enforcement of traffic safety regulations, and widespread reliance on two-wheeled transport.[11]

The demographic profile in our study aligns with existing literature, showing a male predominance (3:1), which reflects the societal structure and higher occupational exposure of males. Studies by Andelic et al.[3] and Kamal et al.[11] also documented a significantly higher prevalence of TBI among males. The mean age of our cohort was 39.7 years, with most patients in the 18–40-year range. This trend has been reported by various studies indicating that younger adults are particularly vulnerable due to increased exposure to risk factors such as road traffic accidents, industrial injuries, and interpersonal violence.[2,11,17,20]

In our study, mild head injuries (GCS 13–15) comprised 43.9% of cases, moderate head injuries accounted for 22.8%, and severe head injuries represented 33.8%. This highlights the significant burden of mild TBIs on trauma centers. The median GCS was 10.6. In contrast, Robba et al.[18] reported a mean GCS of 7, which may reflect a higher proportion of severe cases in their study. Among the observed computed tomography findings, contusions were the most prevalent (65.6%), followed by subdural hematoma (23.3%), epidural hematoma (16.1%), subarachnoid hemorrhage (14.4%), and intraventricular hemorrhage (2.2%). These findings are consistent with those of Altayar et al.[2] and Geeraerts et al.[7] who noted that contusions and subdural hematomas often contribute to increased ICP.

Ultrasonographic ONSD offers a rapid, bedside method for assessing increased ICP, especially when invasive monitoring is either unavailable or contraindicated. In our study, the mean ONSD was 4.66 mm (±0.793), with a median of 4.45 mm. These values are comparable to Robba et al.[18] (median ONSD: 4.9 mm), and slightly lower than those reported by Lee et al.[13] who recorded a higher ONSD (5.68±0.78 mm) likely due to a predominance of severe TBI cases in their cohort. We adopted a cut-off value of ≥5 mm to define increased ONSD, based on ROC analysis, supported by previous studies.[16,22] Using this threshold, 32.2% of patients were categorized as having increased ICP, among whom 65% had severe TBIs.

In the absence of invasive ICP monitoring—considered the gold standard but often unavailable in resource-limited settings—our study relied on a combination of validated clinical and radiological indicators to identify increased ICP. This approach was informed by previous high-quality meta-analyses that evaluated the diagnostic accuracy of clinical and radiological findings. Clinical signs such as a GCS score ≤8 demonstrated a sensitivity of 75.8% and specificity of 39.9%, while motor posturing (GCS motor response ≤3) had a sensitivity of 54.3% and specificity of 63.6%. Pupillary dilation, although less sensitive (28.2%), showed a high specificity of 85.9% for increased ICP. Radiological markers including effacement or compression of the basal cisterns on NCCT showed a sensitivity of 85.9% and specificity of 61.0%, while a midline shift greater than 10 mm was highly specific (89.2%) albeit less sensitive (20.7%).[6] These criteria were chosen for their practical applicability and moderate-to-high diagnostic accuracy, making them appropriate surrogate markers for raised ICP in our observational study, particularly in settings where invasive methods are not feasible.

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The ROC curve analysis in our study demonstrated an AUC of 0.942, which signifies excellent discriminatory power of ONSD in identifying increased ICP. This is in close agreement with findings from Sharawat et al.[20] (AUC: 0.976) and Mathews et al.[16] (AUC: 0.90). At the 5 mm cut-off, ONSD demonstrated a sensitivity was 93.2%, specificity 81.8%, and overall accuracy 88.3%. The positive predictive value was 74.0%, indicating that most patients with ONSD ≥5 mm had raised ICP; the negative predictive value was 99.0%, affirming the reliability of ONSD in ruling out raised ICP.

Regarding patient outcomes, our study revealed a mortality rate of 7.2%, which is significantly lower than Kamal et al.[11] reported rate of 34.58%. This could be due to differences in inclusion criteria and severity grading. Additionally, 64.4% of our patients achieved a favorable outcome on the GOS at 3 months, compared to 15.72% at 6 months in Kamal et al.'s cohort.[11] The disparity may also be attributed to the higher number of severe TBIs and complications in their study. Surgical intervention was required in 43.3% of cases: decompressive craniectomy (26.1%) and craniotomy (17.2%). These rates are slightly lower than those reported by Kamal et al.[11] (55%), likely due to variations in case severity and institutional protocols. The remaining 52.8% were managed conservatively, which aligns with the growing recognition of individualized, evidence-based approaches in neurotrauma care.

Overall, our findings support the incorporation of ONSD measurement into routine neurotrauma assessment. It offers a valuable, repeatable, non-invasive bed-side technique for identifying patients at risk of increased ICP and facilitates early intervention. In resource-limited settings where invasive neuromonitoring are not feasible, ONSD can serve as an effective triage tool to guide decision-making.

Limitations

This single-center study lacked invasive ICP monitoring and instead relied on clinical and radiological findings, which may have introduced classification bias. The study did not assess the temporal relationship between increased ONSD and the onset of increased ICP. Additionally, the study was not designed to identify specific clinical triggers for performing ONSD in the setting of an increased ICP. Inter- and intra-observer reliability of ONSD measurements was not assessed. Long-term outcomes beyond 3 months were not evaluated. Future multicenter studies incorporating serial ONSD measurements and invasive ICP monitoring are needed to confirm the temporal association and larger sample population to validate ONSD as a reliable real-time early screening tool.

CONCLUSION

This study demonstrates the utility of ONSD measurement as a non-invasive, reliable predictor of increased intracranial pressure in traumatic brain injury patients. The findings highlight a strong correlation between increased ONSD and poor neurological outcomes, reinforcing its clinical significance in early diagnosis and decision-making for TBI management. Given the challenges associated with invasive ICP monitoring, ONSD ultrasound emerges as a practical alternative in settings where invasive monitoring is contraindicated or unavailable. It provides a rapid, bedside tool to aid in early risk stratification, guiding timely interventions and improving patient outcomes. However, despite its high diagnostic accuracy, ONSD should complement, not replace, clinical and radiological assessments for ICP monitoring. Further multi-center studies with larger cohorts

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are recommended to establish standardized protocols and refine cutoff values for different patient populations.

REFERENCES

1. Agrawal D, Raghavendran K, Zhao L, Rajajee V. A prospective study of optic nerve ultrasound for the detection of elevated intracranial pressure in severe traumatic brain injury. **Crit Care Med 48:**e1278-e1285, 2020 PUBMED | CROSSREF
2. Altayar AS, Abouelela AZ, Abdelshafey EE, Mohammed KSS, Hassan AA, Khattab MA, et al. Optic nerve sheath diameter by ultrasound is a good screening tool for high intracranial pressure in traumatic brain injury. **Ir J Med Sci 190:**387-393, 2021 PUBMED | CROSSREF
3. Andelic N. The epidemiology of traumatic brain injury. **Lancet Neurol 12:**28-29, 2013 PUBMED | CROSSREF
4. Bez M, Bez D, Tsur AM, Nadler R, Benov A, Chen J. Isolated versus non-isolated traumatic brain injuries identification and decision making: a comparative study. **Isr Med Assoc J 24:**574-578, 2022 PUBMED
5. Cole TB. Global road safety crisis remedy sought: 1.2 million killed, 50 million injured annually. **JAMA 291:**2531-2532, 2004 PUBMED | CROSSREF
6. Fernando SM, Tran A, Cheng W, Rochwerg B, Taljaard M, Kyeremanteng K, et al. Diagnosis of elevated intracranial pressure in critically ill adults: systematic review and meta-analysis. **BMJ 366:**l4225, 2019 PUBMED | CROSSREF
7. Geeraerts T, Merceron S, Benhamou D, Vigué B, Duranteau J. Non-invasive assessment of intracranial pressure using ocular sonography in neurocritical care patients. **Intensive Care Med 34:**2062-2067, 2008 PUBMED | CROSSREF
8. Government of India, Ministry of Road Transport and Highways Transport Research Wing. Road accidents in India 2019 [Internet]. New Delhi: Government of India, Ministry of Road Transport and Highways Transport Research Wing, 2019. https://morth.nic.in/sites/default/files/RA_Uploading.pdf [Accessed April 9, 2025]
9. Gururaj G. Epidemiology of traumatic brain injuries: Indian scenario. **Neurol Res 24:**24-28, 2002 PUBMED | CROSSREF
10. Iaccarino C, Carretta A, Nicolosi F, Morselli C. Epidemiology of severe traumatic brain injury. **J Neurosurg Sci 62:**535-541, 2018 PUBMED | CROSSREF
11. Kamal VK, Agrawal D, Pandey RM. Epidemiology, clinical characteristics and outcomes of traumatic brain injury: evidences from integrated level 1 trauma center in India. **J Neurosci Rural Pract 7:**515-525, 2016 PUBMED | CROSSREF
12. Khan MN, Shallwani H, Khan MU, Shamim MS. Noninvasive monitoring intracranial pressure - a review of available modalities. **Surg Neurol Int 8:**51, 2017 PUBMED | CROSSREF
13. Lee SH, Kim HS, Yun SJ. Optic nerve sheath diameter measurement for predicting raised intracranial pressure in adult patients with severe traumatic brain injury: a meta-analysis. **J Crit Care 56:**182-187, 2020 PUBMED | CROSSREF
14. Luerssen TG. Intracranial pressure: current status in monitoring and management. **Semin Pediatr Neurol 4:**146-155, 1997 PUBMED | CROSSREF
15. Maas AI, Stocchetti N, Bullock R. Moderate and severe traumatic brain injury in adults. **Lancet Neurol 7:**728-741, 2008 PUBMED | CROSSREF
16. Mathews A, Cattamanchi S, Panneerselvam T, Trichur RV. Evaluation of bedside sonographic measurement of optic nerve sheath diameter for assessment of raised intracranial pressure in adult head trauma patients. **J Emerg Trauma Shock 13:**190-195, 2020 PUBMED | CROSSREF
17. Montorfano L, Yu Q, Bordes SJ, Sivanushanthan S, Rosenthal RJ, Montorfano M. Mean value of B-mode optic nerve sheath diameter as an indicator of increased intracranial pressure: a systematic review and meta-analysis. **Ultrasound J 13:**35, 2021 PUBMED | CROSSREF
18. Robba C, Cardim D, Tajsic T, Pietersen J, Bulman M, Donnelly J, et al. Ultrasound non-invasive measurement of intracranial pressure in neurointensive care: a prospective observational study. **PLoS Med 14:**e1002356, 2017 PUBMED | CROSSREF
19. Sekhon MS, McBeth P, Zou J, Qiao L, Kolmodin L, Henderson WR, et al. Association between optic nerve sheath diameter and mortality in patients with severe traumatic brain injury. **Neurocrit Care 21:**245-252, 2014 PUBMED | CROSSREF

20. Sharawat IK, Kasinathan A, Bansal A, Sahu JK, Sodhi KS, Dogra MR, et al. Evaluation of optic nerve sheath diameter and transcranial doppler as noninvasive tools to detect raised intracranial pressure in children. **Pediatr Crit Care Med 21:**959-965, 2020 PUBMED | CROSSREF

21. Shim Y, Kim J, Kim HS, Oh J, Lee S, Ha EJ. Intracranial pressure monitoring for acute brain injured patients: when, how, what should we monitor. **Korean J Neurotrauma 19:**149-161, 2023 PUBMED | CROSSREF

22. Zhang T, Liu CF. Clinical value of bedside transcranial doppler ultrasound in assessing intracranial pressure in critically ill pediatric patients with nervous system disease. **Zhongguo Dang Dai Er Ke Za Zhi 24:**973-978, 2022 PUBMED | CROSSREF