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Optic Nerve Sheath Diameter Assessment In Traumatic Head Injury And Its Correlation With Serial CT Evaluation As A Measure To Assess ICP

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ABSTRACT

Background: Raised intracranial pressure (ICP) is a critical determinant of morbidity and mortality in traumatic brain injury (TBI). Non-invasive measurement of optic nerve sheath diameter (ONSD) offers a potential surrogate for ICP monitoring.

Objectives: To assess the correlation between ONSD measurements on ultrasound and serial computed tomography (CT) with ICP in TBI patients and evaluate their role in guiding clinical decisions.

Methods: A prospective observational study was conducted on 50 adult TBI patients with CT features of raised ICP at a tertiary care hospital. ONSD was measured bilaterally 3 mm posterior to the globe on ultrasound at admission (T1) and before follow-up CT (T2). ICP values, Glasgow Coma Scale (GCS) scores, and CT findings were recorded. Statistical tests included paired t-tests, independent t-tests, and Pearson's correlation.

Results: The mean age was 36.2 ± 12.8 years; 75.5% were male. Mean ONSD decreased from 5.50 mm (right) and 5.32 mm (left) at T1 to 4.90 mm and 4.91 mm at T2. Mean ICP fell from 13.8 ± 4.31 mmHg to 10.7 ± 3.50 mmHg ($p < 0.001$). ONSD strongly correlated with ICP at T1 ($r = 0.895$ right; $r = 0.856$ left) and T2 ($r > 0.95$ for both; $p < 0.001$). No significant differences in ONSD or ICP reduction were observed between surgical and conservative groups.

Conclusion: ONSD is a reliable, non-invasive marker of raised ICP and may serve as a valuable monitoring tool in TBI, particularly in settings where invasive monitoring is unavailable.

KEYWORDS: Traumatic brain injury, intracranial pressure, optic nerve sheath diameter, computed tomography, ultrasonography.

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INTRODUCTION

Traumatic brain injury (TBI) is a major public health challenge worldwide, accounting for substantial morbidity, mortality, and long-term disability. Global estimates suggest that nearly 69 million individuals sustain TBI annually, with the highest incidence in low- and middle-income countries due to road traffic collisions, falls, and violence (1,2). In India alone, approximately 1.5–2 million new cases occur annually, with mortality approaching 1 million deaths per year (3). Road traffic accidents constitute nearly 60% of TBI cases in the country, followed by falls (20–25%) and interpersonal violence (~10%) (4).

The pathophysiology of TBI involves both **primary injury**, occurring at the moment of trauma, and **secondary injury**, which develops in the minutes to days following trauma. Secondary injury is mediated by a cascade of neurochemical, vascular, and inflammatory processes, with **elevated intracranial pressure (ICP)** being one of the most critical contributors to worsening neurological status and poor prognosis (5,6). Raised ICP compromises cerebral perfusion pressure, leading to ischemia, herniation, and death if uncorrected (7).

The **gold standard** for ICP measurement is via invasive monitoring, most commonly using an external ventricular drain (EVD) or intraparenchymal catheter (8). While accurate, these procedures are associated with complications such as haemorrhage, infection, and technical difficulties, and may be contraindicated in patients with coagulopathy or distorted intracranial anatomy (9). Furthermore, invasive ICP monitoring is often unavailable in resource-limited settings.

Non-invasive modalities for ICP assessment, including transcranial Doppler, MRI, CT, and optic nerve sheath diameter (ONSD) measurement, have emerged as valuable adjuncts (10–12). The optic nerve sheath is contiguous with the subarachnoid space, and increases in ICP are transmitted to the sheath, causing measurable distension (13,14). Ultrasonographic measurement of ONSD 3 mm posterior to the globe is simple, rapid, and correlates strongly with invasive ICP values, with cut-offs between 5.0 and 5.4

mm reported to predict raised ICP with high sensitivity and specificity (15–18). CT-based ONSD measurement offers similar diagnostic accuracy and is feasible in patients undergoing imaging for other clinical indications (19).
This study aimed to evaluate the correlation between ONSD measured on ultrasound and serial CT with ICP in TBI patients, and to assess whether ONSD can serve as a reliable non-invasive surrogate for ICP monitoring in guiding clinical decisions.

MATERIALS AND METHODS

This **prospective observational study** was conducted in the Department of General Surgery at Subharti Medical College, Meerut, over an 18-month period from July 2023 to December 2024. Ethical approval was obtained from the Institutional Ethics Committee (IEC/SURG/2023/07), and written informed consent was obtained from all participants or their legal guardians in accordance with the Declaration of Helsinki.

Inclusion criteria were adult patients (>18 years) with TBI, CT features suggestive of raised ICP (graded using the Modified Marshall CT classification), and planned for serial CT evaluation.

Exclusion criteria included polytrauma, immediate surgical intervention, associated spinal cord injury, orbital trauma, optic nerve pathology, meningitis, hypercapnia, post-cardiac arrest, orbital deformities precluding ultrasound, and hypotension (SBP < 90 mmHg) at admission.

Clinical assessment: All patients underwent detailed history-taking and neurological examination, including Glasgow Coma Scale (GCS) scoring on admission and prior to follow-up CT. Physiological parameters such as blood pressure, oxygen saturation, and respiratory status were monitored.

ONSD measurement: ONSD was measured using a 7.5 MHz linear ultrasound probe (Sonosite Plus 180). Patients were positioned supine, with closed eyelids and a coupling gel applied to the upper lid. The probe was gently placed to avoid ocular compression. ONSD was measured in both sagittal and transverse planes, 3 mm posterior to the globe, for each eye. The average of right and left values was used for analysis.

ICP measurement: Invasive ICP monitoring was performed where clinically indicated. Otherwise, ICP was estimated indirectly from radiological findings and neurological status.

CT evaluation: Non-contrast CT scans of the brain were performed on admission (T1) and at follow-up (T2), with ONSD measured on axial images at 3 mm behind the globe. CT scores were assigned using the Modified Marshall classification.

Statistical analysis: Data were analysed using SPSS v26. Continuous variables were expressed as mean ± standard deviation (SD). Paired t-tests assessed within-patient changes between T1 and T2. Independent t-tests compared surgical and conservative management groups. Pearson's correlation coefficient evaluated relationships between ONSD and ICP at both time points. A p-value < 0.05 was considered statistically significant.

RESULTS

The study included 50 patients with traumatic brain injury, with a mean age of 36.2 ± 12.8 years (range 12–71 years). The largest proportion of cases (30.6%) were in the 21–29-year age group. Males predominated, accounting for 75.5% of cases, while females represented 24.5%. The majority of injuries were sustained due to road traffic accidents, with the frontal, temporal, and parietal lobes being the most frequently involved regions on imaging.

On clinical assessment, the mean Glasgow Coma Scale (GCS) score improved from 10.5 ± 3.53 at admission to 11.6 ± 3.83 prior to follow-up imaging, a change that was statistically significant (p = 0.001). Mean intracranial pressure (ICP) decreased significantly from 13.8 ± 4.31 mmHg at admission to 10.7 ± 3.50 mmHg at follow-up (p < 0.001). Similarly, mean optic nerve sheath diameter (ONSD) measurements showed significant reductions: the right eye decreased from 5.50 mm to 4.90 mm and the left from 5.32 mm to 4.91 mm (p < 0.001 for both).

Correlation analysis revealed a strong positive relationship between ONSD and ICP at both time points. At admission, the right ONSD correlated with ICP at r = 0.895 and the left at r = 0.856 (p < 0.001 for both). At follow-up, correlations remained high, with r = 0.954 for the right eye and r = 0.956 for the left (p < 0.001 for both).Table 1

Table 1: Correlation Between ONSD and ICP at Admission (T1) and Follow-Up (T2)

Time Point	ONSD Right (mm)	ONSD Left (mm)	ICP (mmHg)	r-value (Right)	p-value	r-value (Left)	p-value
T1	5.50 ± 1.06	5.32 ± 0.91	13.8 ± 4.31	0.895	<0.001	0.856	<0.001
T2	4.90 ± 0.73	4.91 ± 0.73	10.7 ± 3.50	0.954	<0.001	0.956	<0.001

ONSD values decreased significantly between T1 and T2 for both eyes (p < 0.001). ICP also showed a significant reduction (p < 0.001). Correlations between ONSD and ICP remained strong at both time points.

Regarding management, 64% of patients were treated conservatively and 36% underwent surgical intervention. No statistically significant difference was observed in the degree of ONSD or ICP reduction between the two groups. Overall mortality was low, and while follow-up CT scores showed a trend toward higher values in non-survivors, this difference was not statistically

significant.

DISCUSSION

This study was therefore designed to investigate the correlation between ONSD and serial ICP values, and to evaluate the relationship of ONSD with GCS scores, CT severity grading, and motor responses. Furthermore, the study aimed to assess changes in these parameters over time and explore how management strategies (surgical vs. conservative) impact physiological and radiological outcomes. By establishing statistically significant associations, this research intends to validate the use of CT-measured ONSD as a reliable, non-invasive tool for early detection, ongoing monitoring, and prognosis of raised ICP in TBI patients. The findings have the potential to enhance patient triage and decision-making in critical care, especially in settings where invasive monitoring is impractical or unavailable.

A major finding of the current study was the statistically significant correlation between optic nerve sheath diameter (ONSD) and intracranial pressure (ICP). The mean ONSD measured during the first CT (T1) was 5.50 mm (right) and 5.32 mm (left), and these values were positively correlated with elevated ICP (mean 13.8 mmHg at T1). The correlation coefficients were remarkably strong ($r = 0.895$ for ONSD right and $r = 0.856$ for ONSD left, $p < 0.001$), confirming ONSD as a reliable non-invasive surrogate marker of raised ICP. These results align with **Lim TK et al. (2017)[20],** who reported a mean ONSD of 5.5 ± 1.0 mm in TBI patients with elevated ICP, establishing that an ONSD threshold above 5.5 mm is indicative of intracranial hypertension on CT imaging. Similarly, **McLaughlin et al. (2021)[21]** demonstrated that patients with elevated ICP consistently had higher ONSD values (range 5.7–6.4 mm) throughout hospitalization, with the strongest correlations occurring at the initial CT assessment ($r = 0.54$). These findings further validate ONSD as a practical and non-invasive marker for ICP monitoring, particularly in settings where invasive monitoring is not feasible.

In this study, the relationship between ONSD and CT severity scores (e.g., Rotterdam score and lesion burden) was investigated, showing a clear pattern of elevated ONSD correlating with more severe CT findings. This is strongly supported by the findings of **Gautam et al. (2020)[22],** who reported a mean ONSD of 5.1 ± 0.66 mm in patients with severe Rotterdam CT scores (4–6), compared to 3.8 ± 0.64 mm in those with lower scores (1–3). Their ROC curve analysis yielded an AUC of 0.915, suggesting excellent predictive accuracy of ONSD for identifying severe TBI. **Das et al. (2017)** [23]found a similar linear relationship, where ONSD values progressively increased with higher Rotterdam CT scores, establishing a significant correlation ($p < 0.001$). **Al-Tameemi et al. (2023)[24]** also reported significant positive correlations between ONSD and Marshall scale grading ($r = 0.662$, $p < 0.001$), further substantiating the diagnostic and prognostic value of CT-derived ONSD in assessing TBI severity.

The study observed a notable, albeit statistically non-significant, decrease in ONSD values from T1 to T2 (right: 5.50 mm to 4.90 mm; left: 5.32 mm to 4.91 mm), which was paralleled by a reduction in ICP (from 13.8 mmHg to 10.7 mmHg). This trend mirrors the longitudinal findings of **McLaughlin et al. (2021)[21],** who observed that ONSD values declined with effective ICP management over time, though the strength of correlation between ONSD and ICP diminished at later stages (e.g., T3, T4). Such serial monitoring is valuable in resource-limited or emergency settings where invasive monitoring may not be immediately available. These data suggest that changes in ONSD can reflect dynamic shifts in intracranial physiology and offer a window into therapeutic response.

Although the Kruskal-Wallis test in the present study did not find a statistically significant difference in ICP among GCS severity groups ($\chi^2 = 4.05$, $p = 0.132$), the trend indicated higher ICP levels among mild (14.8 mmHg) and severe (14.0 mmHg) groups compared to moderate cases (11.7 mmHg). This pattern suggests a potential non-linear or context-specific interaction between clinical and physiological measures of brain injury. **Lim TK et al. (2017) [20]** similarly reported that patients with lower GCS scores had higher ONSD and ICP, reinforcing the inverse relationship between neurological function and pressure burden. While statistical significance was not achieved, the observed trends warrant further exploration in larger samples.

Comparisons between surgical and conservative management groups revealed higher baseline ONSD and ICP values in surgically treated patients, though none of the differences reached statistical significance. This is consistent with **McLaughlin et al. (2021)[21],** who found that higher ONSD readings were associated with poorer functional outcomes and greater likelihood of requiring surgical intervention, although predictive values for mortality varied depending on the measurement time point. **Gautam et al. (2020)**[22] also indicated that elevated ONSD correlated with worse CT scores and need for aggressive treatment, supporting its utility in guiding clinical decision-making.

The strengths of this study include its prospective design, standardized ONSD measurement protocol, and integration of ultrasound and CT findings. Limitations include a relatively small sample size, reliance on estimated ICP in some patients, and single-centre design. Future studies should validate these findings in larger, multi-centre cohorts and explore whether ONSD-guided interventions improve outcomes.

CONCLUSION

ONSD measurement by ultrasound and CT is a reliable, non-invasive method for assessing and monitoring ICP in TBI patients. Its strong correlation with ICP at both admission and follow-up supports its use as an adjunct to clinical and radiological evaluation, particularly in settings where invasive monitoring is unavailable.

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