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Correlation of optic nerve sheath diameter with Rotterdam CT score in traumatic brain injury

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ABSTRACT

Background: Traumatic brain injury poses a significant challenge for trauma victims. Early identification of such injuries in the emergency department can significantly improve patient outcomes. Apart from clinical examination, the optic nerve sheath diameter (ONSD) has been introduced for early diagnosis in the emergency department.

Methodology: A prospective analysis of all the patients admitted with suspected head injury who underwent Non-contrast computed tomography (NCCT) head was done. All such patients were evaluated with ultrasound-guided Optic nerve sheath diameter (ONSD) assessment, and the same was correlated with Rotterdam CT score (RCTS).

Results: 112 patients were enrolled in the study. The mean age of the study population was 39.02 ± 15.38 years with a male preponderance. ONSD correlated with higher RCTS (>3) with a cut-off value of 5.62 mm as per the receiver operating characteristic curve analysis. The current study identified significant predictors of raised intracranial pressure (ICP), with epidural mass lesions (OR = 1.131, $p = 0.017$), intraventricular hemorrhage (IVH) or subarachnoid hemorrhage (SAH) (OR = 1.071, $p = 0.016$), and episodes of vomiting as key predictors.

Conclusion: The present study demonstrates that ultrasonographic measurement of the ONSD correlates reliably in patients with traumatic brain injury. Moreover, clinical factors such as vomiting, epidural mass lesions, and intraventricular or subarachnoid haemorrhage were significant predictors of elevated ICP, providing valuable adjunctive criteria for risk stratification in emergency care.

Keywords: Intracranial pressure, Optic nerve sheath diameter, Point of care ultrasound, Rotterdam score, Traumatic brain injury

INTRODUCTION

Traumatic brain injury (TBI) is a global public health concern with substantial implications for mortality and long-term disability. A critical determinant of clinical outcome in patients with TBI is the management of increased intracranial pressure (ICP). Persistent elevation of ICP can lead to cerebral ischemia, herniation syndromes, and eventually mortality if not promptly diagnosed and managed.¹

Traditionally, ICP has been monitored using invasive techniques such as intraventricular catheters or intraparenchymal transducers. However, they are invasive in nature and have associated fatal

complications such as haemorrhage, infection, and technical failure.^{1,2} These limitations have accelerated the pursuit of non-invasive, accurate, and bedside-compatible alternatives for ICP estimation. One such method is the measurement of optic nerve sheath diameter (ONSD). The optic nerve is an extension of the central nervous system enveloped by the dura mater, which is surrounded by cerebrospinal fluid (CSF) within the subarachnoid space. When ICP increases, the transmission of pressure through the CSF leads to dilation of the optic nerve sheath, particularly in its anterior segment just posterior to the globe. This phenomenon provides a physiological basis for using ONSD as a surrogate marker for raised ICP.² Given these limitations, the clinical community has expressed a growing interest in identifying reliable, non-invasive alternatives for ICP assessment that are safe, rapid, and suitable for both high-resource and low-resource settings. Further, the prognosis of head injury is guided by various factors, and several scoring systems have been established. In this study, we aim to correlate the findings of ONSD with the Rotterdam Computed Tomography scoring (RCTS) system for the assessment of outcomes in patients with TBI. The current study is driven by the need to evaluate the efficacy of ONSD measurement as a non-invasive, accessible, and practical tool for the early identification of raised ICP in TBI patients.

METHODOLOGY

This prospective observational study was conducted in the trauma unit of a tertiary care teaching hospital in India. The study population included all trauma patients aged 12 years and above who were admitted to the emergency department and underwent neuroimaging (CT head) as per the National Institute for Health and Care Excellence (NICE) guidelines. Patients with severe orbital or facial trauma, known cases of chronic hydrocephalus, patients with pre-existing ocular diseases (including optic nerve pathology), and individuals with thyroid eye disease or a history of glaucoma were excluded from the study.

The study was carried out over a 20-month period, from March 1, 2023, to October 31, 2024. Sampling was done using a purposive method to ensure the inclusion of only those patients who met the specific eligibility criteria. The sample size was calculated using Cochran's formula, with a 95% confidence level ($Z=1.96$), a presumed prevalence (P) of 31.6% based on prior literature, and a 10% margin of error. After accounting for a 10% non-response rate, the final sample size was determined to be 112 patients.

Clinical evaluation involved a dual-modality approach. All patients underwent a non-contrast CT (NCCT) head scan within 1 hour of admission to identify signs of raised ICP. Radiological criteria considered indicative of raised ICP included massive intracranial haemorrhage (≥ 3 cm in the cerebral hemispheres

or ≥ 1.5 cm in the brainstem), intraventricular extension of subarachnoid haemorrhage (SAH), basal cistern compression, midline shift of ≥ 0.5 cm, and signs of acute hydrocephalus.³ In addition to CT imaging, a bedside ultrasonographic assessment was performed immediately on arrival while doing the primary survey. This involved measuring the ONSD in both internal (distance between the inner dural borders) and external (distance between the outer dural borders) dimensions. All CT interpretations were performed by trained radiologists adhering to standardized procedures to ensure consistency and reliability, while ONSD was measured in the emergency department by a team of emergency physicians and trauma surgeons

To provide prognostic information, the RCTS was calculated for each patient. This score incorporates various radiological parameters, including basal cistern status, midline shift, epidural hematoma, and the presence of SAH or intraventricular haemorrhage. Prior to commencement, ethical approval was secured from our Institutional Ethics Committee (SRMS IMS/ECC/2023/65). All participants provided written informed consent. Patient confidentiality and data protection protocols were strictly followed. A pilot study, representing 10% of the intended sample size (approximately 11 patients), was conducted to test the feasibility and logistics of data collection tools.

Data collection included patient demographics, clinical history, CT and ultrasound findings, and RCTS. Observations were recorded on a structured data collection proforma. Data were analyzed using IBM SPSS version 25. Descriptive statistics such as mean, median, standard deviation, and percentages were used to summarize demographic and clinical variables. Diagnostic performance of ONSD in detecting raised ICP was assessed using receiver operating characteristic (ROC) curve analysis. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were computed. Logistic regression models were employed to explore associations between CT findings, ONSD measurements, and clinical outcomes, with statistical significance set at a p-value of less than 0.05.

RESULTS

The present study included a total of 112 patients with TBI who were evaluated using ONSD measurements and CT imaging. The mean age of the study population was 39.02 ± 15.38 years. The largest age group represented was 41–60 years (39.3%), followed closely by the 21–40 years age group (36.6%). Adolescents and young adults (0–20 years) accounted for 16.1% of the participants, while only 8% of the sample belonged to the elderly population (61–80 years), as shown in table 1.

Table 1: Demographic parameters of patients included in the study	
Variable	All subjects (n=112)
Age (years)	39.02 ± 15.38
Age distribution:	
12-20	18 (16.1%)
21-40	41 (36.6%)
41-60	44 (39.3%)
61-80	9 (8%)
Sex, n (%)	
Male	87 (77.7%)
Female	25 (22.3%)
Mechanism of injury:	
Road traffic injury	86 (76.8%)
Fall	
Others	20 (17.9%)
	6 (5.4%)
Airway patency status at the time of admission:	
Patent	76 (67.9%)
Secured	7 (6.3%)
Threatened	24 (21.4%)
Compromised	5 (4.5%)
Vitals at the time of admission:	
Respiratory rate	20.79 +/- 3.33
SPO2	98.18 +/- 3.4
Heart rate	90.70 +/-18.39
Systolic BP	127.51+/-20.54
Diastolic BP	78.39+/-11.20
GCS	11.9+/-2.9
Pupillary status:	
Both reactive to light	83 (74.10%)
One pupil reactive	15 (13.40%)
Both pupil unreactive	14(12.50%)
Limb disability:	
Yes	92 (82.10%)
No	20 (17.90%)
Signs of skull base fracture:	
Yes	19 (17%)
No	93 (83%)
Post-traumatic seizure:	
Yes	9 (8%)
No	103 (92%)
Focal neurological deficit:	
Yes	35 (31.3%)
No	77 (68.7%)
Episodes of vomiting:	
Yes	33 (29.50%)
No	79 (70.50%)
Admission GCS score	11.92 ± 4.33
Mean ONSD (mm)	5.09 ± 0.60
Final outcome:	
Discharge	95 (84.80%)
Leave against medical advice	6 (5.40%)
Death	11 (9.80%)
BP: Blood pressure; GCS: Glasgow Coma Scale; ONSD: Optic nerve sheath diameter	

A gender-wise analysis revealed a notable male predominance, with 77.7% males and 22.3% females. In terms of mechanism of injury, road traffic injuries (RTIs) were the most common cause, accounting for 76.8% of cases. Falls constituted 17.9% of injuries, and 5.4% were due to other causes such as assault. The airway patency status at admission showed that 67.9% of patients had a patent airway, while 21.4% had a threatened airway, necessitating close monitoring and potential need for a definitive airway. A smaller proportion had secured (6.3%) or compromised (4.5%) airways, often correlating with more severe neurological impairment and lower GCS scores.

Table 2: Distribution of patients as per RCTS and CT features

Parameter (RCTS)	Frequency
Basal cisterns:	
Normal	84 (75%)
Compressed	22 (19.60%)
Absent	6 (5.40%)
Midline shift:	
No shift or less than 5mm	99 (88.40%)
Shift more than 5mm	13 (11.60%)
Epidural mass lesion:	
Present	53 (47.30%)
Absent	59 (52.70%)
IVH or SAH:	
Absent	90 (80.40%)
Present	22 (19.60%)
Rotterdam score	
1	27 (24.10%)
2	56 (50%)
3	16 (14.30%)
4	11 (9.80%)
5	2 (1.80%)
RCTS: Rotterdam computed tomography score; CT: Computed tomography; IVH: Intraventricular hemorrhage; SAH: Subarachnoid hemorrhage	

Distribution of different RCTS parameters has been shown in Table 2. The majority of the patients had a RCTS<4 (99/112). For an RCTS >3, diagnostic accuracy was evaluated using a receiver operating characteristic (ROC) curve, which identified a cut-off value of 5.62 mm for ONSD. At this threshold, the sensitivity was 92.3%, the specificity was 89.9%, the PPV was approximately 54.6%, and the NPV was approximately 98.8%. The overall diagnostic accuracy was about 90.2%. Additionally, the positive likelihood ratio (LR+) was approximately 9.13, and the negative likelihood ratio (LR-) was approximately 0.086, as shown in Figure 1. This

suggests that elevated Rotterdam CT scores, which reflect the severity of brain injury, are strongly predicted by mean ONSD.

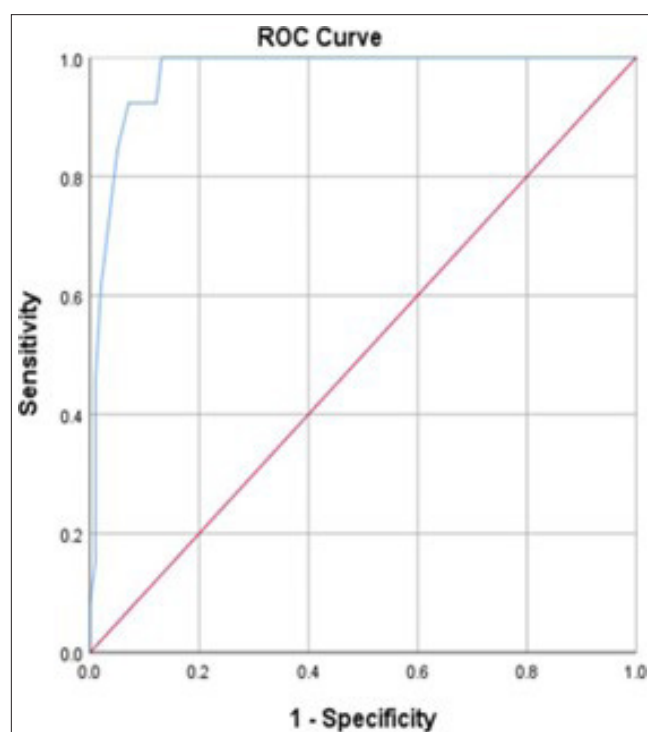


Figure 1: ROC curve analysis showing the correlation between the mean optic nerve sheath diameter (ONSD) and the Rotterdam CT score. With a cutoff value of 5.62 cm, the analysis showed a sensitivity of 92.3% and a specificity of 89.9%. About 54.6% was the positive predictive value (PPV), and about 98.8% was the negative predictive value (NPV). With a positive likelihood ratio (LR+) of roughly 9.13 and a negative likelihood ratio (LR-) of 0.086, the test's diagnostic accuracy was approximately 90.2%. This suggests that elevated Rotterdam CT scores, which reflect the severity of brain injury, are strongly predicted by mean ONSD.

The significant predictors of raised RCTS and poor outcomes are summarized with their corresponding odds ratios (OR) and p-values in Table 3. Episodes of vomiting showed a strong association with higher RCTS with an OR of 0.024 and a p-value of 0.001. The presence of an epidural mass lesion was also significantly associated with an OR of 0.131 and a p-value of 0.017. IVH or SAH demonstrated significance as well, with an OR of 0.071 and a p-value of 0.016. Limb disability had an OR of 15.249 but a p-value of 0.097, indicating a trend without statistical significance. Focal neurological deficit and pupil reactivity (one unreactive pupil) had ORs of 0.537 and 1.621, respectively, but their p-values (0.463 and 0.667) showed no significant association. The overall model strength, as measured by Nagelkerke R^2 , was 0.711.

Table 3: Predictors for poor outcome (RTCS >3)

Predictors	Category	OR	p-value
Pupil reactivity	Both pupil unreactive to light	0.664	0.783
	One pupil unreactive to light	1.621	0.667
	Both pupil reactive to light		Reference
Post-traumatic seizure	Yes	0.681	0.753
	No		Reference
Focal neurological deficit	Yes	0.537	0.463
	No		Reference
Sign of basal skull fracture	Yes	1.613	0.693
	No		Reference
Limb Disability	Yes	15.249	0.097
	No		Reference
Episodes of vomiting	Yes	0.024	0.001
	No		Reference
Basal Cisterns	Absent	0.207	0.264
	Compressed	3.7	Reference
	Normal		2023
Midline Shift	Shift more than 5mm	0.243	0.259
	No shift or less than 5mm		Reference
Epidural mass lesion	Present	0.131	0.017
	Absent		Reference
IVH or SAH	Present	0.071	0.016
	Absent		Reference

IVH: Intraventricular hemorrhage; SAH: Subarachnoid hemorrhage

DISCUSSION

TBI represents a critical global health concern, with outcomes largely dictated by the timely identification and management of secondary brain insults, particularly raised ICP. Elevated ICP is a well-established predictor of poor neurological outcomes and mortality in TBI patients, necessitating prompt diagnosis and intervention.

The current study established a mean ONSD of 5.085 ± 0.604 mm, with a diagnostic cut-off value of 5.62 mm for raised RCTS in patients with TBI. This cut-off demonstrated a sensitivity of 92.3%, specificity of 89.9%, and a diagnostic accuracy of 90.2%, confirming the reliability of ultrasonographic ONSD as a non-invasive marker for severe head injury/RCTS >3. These findings are largely consistent with the recent Indian research. In a study conducted at a Level I trauma centre in Eastern India, reported an ONSD cut-off of 5.0 mm, with high sensitivity and specificity for

predicting raised ICP.³ Though slightly lower than the 5.62 mm cut-off in the current study, the diagnostic trend aligns, particularly in younger, trauma-exposed populations. Similarly, found a cut-off of 5.0 mm, achieving 100% sensitivity and 95% specificity, supporting the clinical use of ONSD as a reliable screening tool in emergency neurotrauma care.⁴ These slightly lower thresholds may reflect differences in patient profiles or measurement timing (e.g., immediate post-trauma vs delayed ICU assessment). Interestingly, observed a higher cut-off value of 5.8 mm, particularly in perioperative TBI patients undergoing decompressive craniectomy.⁵ This reinforces the notion that cut-off values may shift slightly depending on the clinical context, severity of injury, and time elapsed since the insult. Additional validation was provided by who proposed an average ONSD cut-off of 6.0 mm in patients with severe TBI, though this value may reflect a bias toward high ICP thresholds and a sample with advanced cerebral edema or late presentation.⁶ Also, there may be inter-observer variability, and hence, a few studies have taken CT ONSD for evaluation in place of USG. However, it is important to understand that Point-of-Care Ultrasound (POCUS) is a quick bedside tool for screening purposes, and ONSD by POCUS can be utilised effectively to identify raised ICP and head injury in emergency and critical care settings.

We did a comprehensive review of literature over 10 years using Google Scholar for ONSD in head injuries and found that most of the studies had results similar to our study [Table 4]^{2-4,6-14}. Most studies converge on a clinically relevant ONSD range of 5.0–5.8 mm for detecting raised ICP. The slightly

higher threshold of 5.62 mm in the present study may offer greater specificity, as reflected by its PPV of ~54.6% and NPV of ~98.8%, emphasizing its strength in ruling out intracranial hypertension. A positive likelihood ratio (LR+) of ~9.13 and a negative likelihood ratio (LR-) of ~0.086 further reinforce the diagnostic robustness of the chosen cut-off. Thus, this study not only aligns with the diagnostic trends reported in the scientific literature but also underscores the utility of ONSD ultrasonography as an efficient, bedside screening tool for elevated ICP.

The current study identified significant predictors of higher RCTS in patients with TBI, with the presence of vomiting (OR = 0.024, $p = 0.001$), epidural mass lesions (OR = 0.131, $p = 0.017$), and IVH/SAH (OR = 0.071, $p = 0.016$) showing statistically significant associations. These findings are strongly supported by previous studies. For instance, vomiting has long been recognized as a classical clinical marker of raised ICP. It has been postulated that vomiting in TBI patients often results from acute pressure changes affecting the brainstem's vomiting centres. Their review of trauma anaesthesia and ICU care emphasized vomiting as a red flag symptom indicating the need for urgent neuroimaging and ICP monitoring.

Radiologically, epidural hematomas and subarachnoid haemorrhage have also been consistently implicated in raised ICP and are associated with poor prognosis. Servadei *et al* concluded that the presence of intracranial bleeding, especially in closed compartments such as the epidural or subarachnoid space, was a reliable predictor of both elevated ICP and worse outcomes.¹⁵

Table 4: Summary of studies conducted over the last 10 years correlating ONSD with TBI

S. No.	Authors	No. of patients	Year	ONSD cut off	ONSD measured by
1	Sitanaya <i>et al.</i> ⁷	69	2022	5.8 mm	POCUS
2	Legrand <i>et al.</i> ⁸	77	2013	7.3 mm	POCUS
3	Shirodkar <i>et al.</i> ⁹	101	2014	4.6-6.2 mm	POCUS
4	Agrawal <i>et al.</i> ¹⁰	120	2020	Different cut-off points with different ICPs.	POCUS
5	Jeon <i>et al.</i> ⁶	62	2017	5.6 mm	POCUS
6	Al-Hassani <i>et al.</i> ¹¹	167	2020	5.6 mm	CT ONSD
7	Hakeem <i>et al.</i> ³	180	2025	5.0 mm	POCUS
8	Gautam M <i>et al.</i> ¹²	60	2020	5.1 +/- 0.66 mm	CT ONSD
9	Amakhian <i>et al.</i> ¹³	40	2023	6.83 mm for RCTS > 4	CT ONSD
10	Das <i>et al.</i> ¹⁴	150	2017	4.88 +/- 0.04 mm for RCTS > 3	CT ONSD vs RCTS
11	Kaur <i>et al.</i> ⁴	100	2020	5.00 mm	POCUS
12	Mehrpour <i>et al.</i> ²	22	2021	4.89 mm	POCUS

POCUS: Point-of-Care Ultrasound; CT ONSD: Computed Tomography Optic Nerve Sheath Diameter; RCTS: Rotterdam computed tomography score

To our surprise, in the current study, pupillary reactivity and focal neurological deficits were not statistically significant predictors, despite their clinical importance. In head injury patients, it has been observed that pupillary changes may sometimes reflect localized cranial nerve damage or delayed herniation rather than early ICP elevation, especially in cases with subtle hematoma expansion. This discrepancy may also be due to the small sample size of our study. The high odds ratio (OR = 15.249) for limb disability suggests a possible association with severe brain injury and increased ICP, though it did not reach statistical significance ($p = 0.097$). This finding warrants further exploration in larger sample sizes or multicentric cohorts. Thus, the predictive value of vomiting, epidural mass lesions, and IVH/SAH in this study corroborates evidence from the clinical literature and supports their inclusion as key criteria in early triage and imaging decisions. Together, they provide a non-invasive clinical framework for identifying patients at high risk for raised ICP, potentially improving response times in resource-limited emergency settings.

LIMITATIONS

The study is limited by its small sample size. Also, a major limitation that appears is that ICP is a dynamic pressure and is affected by various factors. However, we measured ONSD at a single point in time and may have been affected by those factors at that time. Another major limitation is cases of Diffuse Axonal Injuries, where ONSD at presentation may be normal, and RCTS may be low initially, but the patient would have a poorer outcome.

CONCLUSION

The present study demonstrates that ultrasonographic measurement of the ONSD correlates reliably in patients with TBI. These results affirm the utility of ONSD as an effective bedside screening modality for early identification of intracranial hypertension, particularly in settings where invasive monitoring may be impractical or unavailable. Furthermore, clinical factors such as vomiting, epidural mass lesions, and intraventricular or subarachnoid haemorrhage were significant predictors of elevated ICP, providing valuable adjunctive criteria for risk stratification in emergency care. The findings align well with existing literature from global cohorts, supporting the integration of ONSD ultrasonography into neurotrauma assessment protocols to facilitate timely diagnosis and intervention, ultimately aiming to improve patient outcomes.

Authors contribution: NM and HA: Conceptualization; PS, PA, and HA: Methodology; PS, NP, and PA: Data Collection; HA and NP: Formal Analysis; HA and NM: Writing.

Ethical Approval: The research/study approved by the Institutional Review Board at SRMS Institute of Medical Sciences, Bareilly,

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