ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

www.surgicalneurologyint.com

Surgical Neurology International

Editor-in-Chief: Nancy E. Epstein, MD, Clinical Professor of Neurological Surgery, School of Medicine, State U. of NY at Stony Brook.

SNI: Trauma

Editor
Jutty Parthiban, MCh., FNS
Kovai Medical Center and Hospital, Tamil Nadu, India

SNI
Open Access

Original Article

Is optic nerve sheath diameter a promising screening tool to predict neurological outcomes and the need for secondary decompressive craniectomy in moderate to severe head injury patients? A prospective monocentric observational pilot study

Dinesh Verma[1], Ramesh Andi Sadayandi[1], Sathiaprabhu Anbazhagan[1], Krishnan Nagarajan[2], Prasanna Udupi Bidkar[3]

[1]Departments of Neurosurgery, [2]Radiodiagnosis and [3]Anaesthesiology and Critical Care, Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry, India.

E-mail: Dinesh Verma - docsynapse@gmail.com; *Ramesh Andi Sadayandi - asrameshms@gmail.com; Sathiaprabhu Anbazhagan - drasprabhu@gmail.com; Krishnan Nagarajan - lknagarajan1@gmail.com; Prasanna Udupi Bidkar - drprasannabidkar@gmail.com

***Corresponding author:**
Ramesh Andi Sadayandi,
Department of Neurosurgery,
Jawaharlal Institute of
Postgraduate Medical Education
and Research, Puducherry, India.

asrameshms@gmail.com

Received : 10 April 2023
Accepted : 24 July 2023
Published : 04 August 2023

DOI
10.25259/SNI_318_2023

Quick Response Code:

ABSTRACT

Background: Optic nerve sheath diameter (ONSD) has been shown to be a noninvasive and quick method to calculate intracranial pressure (ICP) and subsequent neurologic outcomes, although with variable cutoffs. ICP can be indirectly assessed by noninvasive methods such as transcranial Doppler, ONSD, tympanic membrane displacement, and fundoscopy. Knowledge regarding the diagnostic accuracy of ONSD for predicting unfavorable outcomes within 72 hours (h) of moderate and severe head injury is limited. The objective of this study was to measure ONSD measurements at 24-h intervals in moderate to severe head injury patients and to find its association with clinical outcomes in the target population.

Methods: This prospective observational study was done on moderate to severe head injury patients. ONSD was measured twice at 24-h intervals over 48 h. The clinical outcome was divided into the favorable group (patients who were in conservative treatment with a stable Glasgow Coma Scale [GCS] score and discharged following treatment) and the unfavorable group (patients who had a drop in GCS motor score of one or more, or expired or underwent surgical intervention) within 72 h following traumatic brain injury. The Kruskal–Wallis test, Mann–Whitney test, and receiver operating characteristic curves were used to establish the association between ONSD and clinical outcomes.

Results: ONSD values measured at 24-h intervals >6.1 mm ($P < 0.0146$) and 6.2 mm ($P < 0.0001$) were found to be predictors of unfavorable outcomes (expired or underwent surgery), and hence the need for a secondary decompressive craniectomy (DC).

Conclusion: ONSD is an efficient screening tool to assess neurological outcomes in severe head injury patients. It can reliably predict the need for secondary DC at an earlier stage before secondary brain damage ensues in these patients.

Keywords: Decompressive craniectomy, Neurological outcome, Optic nerve sheath diameter, Traumatic brain injury

INTRODUCTION

Intracranial pressure (ICP) rises in various neurological and nonneurological conditions and requires rapid diagnosis and treatment due to its fulminant nature.[25] Brain trauma foundation (BTF) has enumerated specific indications for ICP monitoring following traumatic brain injury (TBI).[3] ICP can be measured by either invasive or noninvasive methods. Noninvasive methods assess the ICP indirectly without inserting a catheter into the brain parenchyma. They also exclude the adverse effects of invasive techniques.[18] In this context, a noninvasive, safe tool that may be used in the emergency department (ED) to screen patients at risk of developing raised ICP, especially in the early stages, would be beneficial.[21] Most noninvasive methods are based on transcranial Doppler (TCD) and optic nerve sheath diameter (ONSD) measurement by ultrasonography (USG).[7,8,10,24,29] Although ONSD measurement cannot replace invasive ICP monitoring, it can indirectly differentiate between normal and raised ICP. It can also be used to screen the at-risk population when invasive methods are not available or undesirable.[18] However, knowledge regarding the diagnostic accuracy (DA) of ONSD for predicting unfavorable outcomes in TBI within 72 h is limited. Hence, this study was done to measure the ONSD in moderate and severe head injury patients and to find whether ONSD can be used as a reliable indicator of clinical outcomes in these patients.

MATERIALS AND METHODS

This study was conducted as a single-center prospective observational study at a tertiary care referral center for neurological disorders in South India between March 2019 and April 2020. The study was prior reviewed and approved by the Postgraduate Research Monitoring Committee and the Institute Ethics Committee [JIP/IEC/2018/166].

Inclusion criteria

Individuals between 18 and 60 who were admitted to the hospital ED within 24 h following moderate and severe head injuries (Glasgow coma scale [GCS] score 3–12) were included in the study.

Exclusion criteria

Patients with active medical conditions such as diabetes mellitus, hypertension, ophthalmic disorders with optic nerve changes, polytrauma, hemodynamically unstable, penetrating head injury, skull base fracture with cerebrospinal fluid (CSF) leak, and ocular lesions precluding assessment of ONSD were excluded from the study.

Sampling method

Based on a pilot study by Robba *et al*., the area under the curve (AUC) of ICP in predicting surgical intervention was 0.75.[20] By taking this as a reference value, δ as 0.13 and 5% level of significance, the calculated sample size was 29 patients. We evaluated the feasibility of the study in 72 patients. Since the next of kin of 12 patients declined to participate in the study, 60 patients were evaluated for eligibility. After applying exclusion criteria, presence of active medical conditions (n = 18), and failure to find an ocular window (n = 14), 32 patients were further excluded from the study. Hence, 28 patients (21 males and seven females) were enrolled in this study [Figure 1]. A convenient sampling technique was followed for the recruitment of patients, and the study was conducted by the Department of Neurosurgery in Emergency Medical Services (EMS). The study procedures were explained, and written informed consent was obtained from all the study participant's next of kin before enrolling them in the study. The sociodemographic details of the participants were collected and entered into a data sheet.

Measurement of ONSD

Patients who were planned for conservative management on admission based on the clinical examination, computerized tomography (CT) brain findings, and BTF guidelines were taken for ONSD measurements over a period of 48 h. Three readings were taken from each eye by a single investigator (resident neurosurgeon) twice with an interval of 24 h. The mean ONSD value was calculated from the average of six readings each time. The first mean ONSD reading was taken in EMS or trauma intensive care unit (ICU) within 24 h of TBI (ONSD1), and the second was taken after 24 h (ONSD2) from the first reading in the trauma ICU. If the interval between the first CT brain and ONSD1 measurement happened to be more than 6 h, a repeat CT was taken before the ONSD measurement to ensure the patient management (conservative as per initial assessment) remained unaffected. A total of 336 ONSD measurements were taken from 28 moderate to severe head injury patients (3 in each eye 24 h apart). The average ONSD measurement in each eye was utilized in statistical analysis to minimize the effects of the laterality of any lesion. Fifty-six average ONSD measurements were obtained in the study.

Since most TBI patients tend to deteriorate in the first 72 h of TBI, all the participants were observed until 24 h following the second ONSD measurement (ONSD2).[1] The treating team was blinded to the ONSD values so as to avoid unnecessary surgery by the treating team based on the unproven investigation (ONSD).

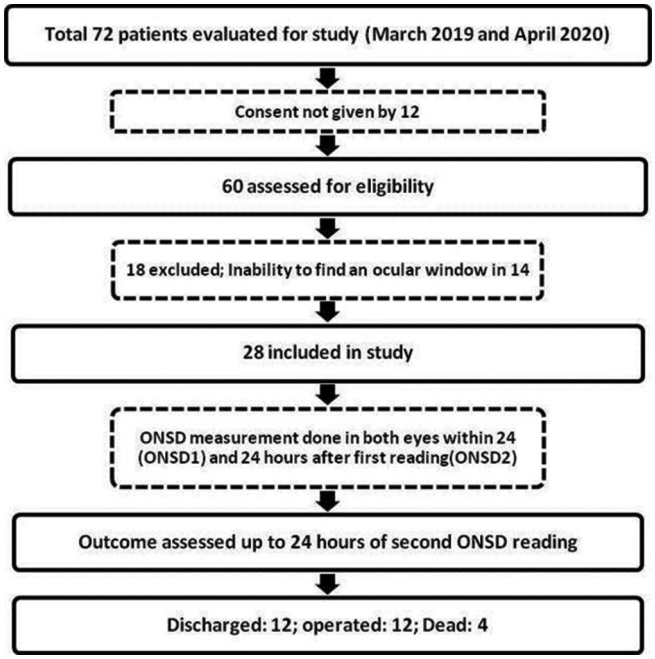

Figure 1: Flow chart of included patients and outcome. ONSD: Optic nerve sheath diameter

The ONSD was measured using a 7.5-MHz linear ultrasound probe (CHISON digital color Doppler system Ebit60) with the lowest possible acoustic power that could measure the ONSD [Figure 2]. Tegaderm (transparent dressing – usually used for central line dressings) was applied over the closed eyelids before the procedure. The probe was placed on the closed eyelids of patients (on both eyes) in the supine position. It was oriented perpendicularly in the vertical plane and around 30° in the horizontal plane. We were able to determine ONSD in the visual axis by placing the probe over the closed eyelids after applying the ultrasound gel. The probe was moved slightly until the optic nerve appeared as a linear hypoechoic object with defined margins behind the globe. After freezing the screen image, we manually determined the ONSD 3 mm behind the globe.[14]

Clinical outcome

The clinical outcome of importance was defined as a drop in GCS by a motor score of one or more, or surgical intervention, or death within 24 h following ONSD2 measurements. The clinical outcomes were compared with ONSD values and divided into the favorable group (patients who were in conservative treatment with a stable GCS score and discharged following treatment) and unfavorable group (patients who had a drop in GCS motor score of one or more, or expired or underwent surgical intervention) within 72 h following TBI.[1] Those who required surgery were subjected to decompressive craniectomy (DC) as per BTF guidelines.[3] In the deceased individuals, extracranial causes of death were ruled out.

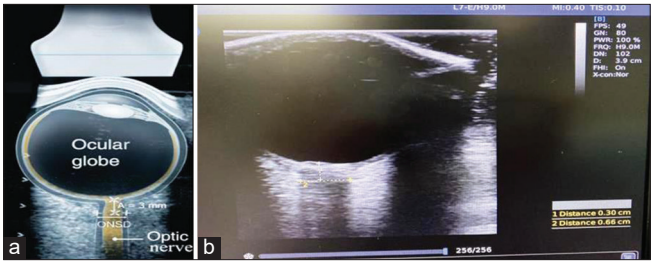

Figure 2: (a and b) Ultrasonographic measurement of optic nerve sheath diameter.

Statistical method

The data were entered in the MS EXCEL spreadsheet, and analysis was done using the Statistical Package for the Social Sciences version 21.0, IBM, USA. Continuous variables were reported as mean ± standard deviation and median, whereas categorical variables were presented as numbers and percentages. The receiver operating characteristic (ROC) curve was used to find out the AUC of ONSD for predicting surgery. Kruskal–Wallis test was applied to find the association between ONSD with the outcome. Mann–Whitney test was applied to establish the relation between ONSD and clinical outcome. The ROC curve of ONSD was plotted to predict an unfavorable outcome. $P < 0.05$ was considered statistically significant. The sensitivity, specificity, and DA of ONSD were assessed.

RESULTS

Twenty-eight patients (21 males and seven females) with moderate and severe head injuries were enrolled in this study. The median (interquartile range) age, GCS score, ONSD1, and ONSD2 of the study participants were 31 (21–50), 9 (7–11), 6.3 mm (6.075–6.4), and 6 mm (5.5–6.325), respectively [Table 1]. Fifteen study participants had moderate TBI, among which seven underwent surgery, and eight were managed conservatively and discharged. The remaining 13 patients had severe TBI, of which five underwent surgery, four were conservatively managed and discharged, and four died [Table 2].

Among the 28 study subjects, 12 patients (43%) had no deterioration in GCS score during conservative management and were subsequently discharged. Twelve patients (43%) underwent DC, and 4 (14%) expired [Tables 1 and 2].

ONSD and clinical outcomes

Significantly different ONSD1 values were observed between the discharged (6.05 mm), dead (6.25 mm), and operated (6.4 mm) groups ($P = 0.022$). Similarly, significantly different ONSD2 values were observed between the discharged (5.6 mm), dead (6.35 mm), and operated (6.3 mm) groups ($P = 0.006$) [Table 3].

DA of ONSD1 and 2

ONSD1 had a strong discriminating power (AUC 0.747; 95% confidence interval (CI): 0.548–0.891), and an ONSD1 value >6.1 mm was found in 93.75% (sensitivity) of patients with unfavorable outcomes. If the ONSD1 valve was >6.1 mm, there was a 75% positive predictive value (PPV) of predicting an unfavorable outcome. An ONSD1 value was ≤6.1 mm indicated a favorable outcome. The DA of ONSD1 (mm) in predicting unfavorable outcomes was 78.57% [Table 4 and Figure 3].

Similarly, ONSD2 also had a strong discriminating power (AUC 0.844; 95% CI: 0.657–0.952), and ONSD2 value >6.2 mm was found in 62.5% (sensitivity) of patients with unfavorable outcomes. If the ONSD2 valve was >6.2 mm, there was a 90.9% PPV of predicting an unfavorable outcome.

Table 1: Clinical characteristics of subjects.

Subject characteristics	Median (IQR) (*n*=28)
Age	31 (21–50)
GCS	9 (7–11)
ONSD1 (mm)	6.3 (6.075–6.4)
ONSD2 (mm)	6 (5.5–6.325)

GCS: Glasgow coma scale, ONSD1: Optic nerve sheath diameter within 24 h of trauma, ONSD2: Optic nerve sheath diameter 24 h after ONSD1, IQR: Interquartile range, *n*: Number

Table 2: Distributions and management of patients based on severity of TBI.

The severity of TBI (*n*=28)	Management of TBI		
	Surgery	Conservative	Died
Moderate TBI (*n*=15)	7	8	0
Severe TBI (*n*=13)	5	4	4

TBI: Traumatic brain injury, *n*: Number

An ONSD2 value was ≤6.2 mm indicated a favorable outcome. The DA of ONSD2 (mm) in predicting unfavorable outcomes was 75% [Table 4 and Figure 3].

It was observed that four patients, despite high ONSD values, survived, while three patients with low ONSD values deteriorated and underwent surgery [Table 5].

DISCUSSION

The primary aim of this study was to measure the ONSD among 28 patients with moderate to severe head injury and to determine the relationship between ONSD and clinical outcomes in these patients. Significantly different ONSD1 and ONSD2 values were observed between the discharged, dead, and operated groups. The DA of ONSD1 and ONSD2 in predicting unfavorable outcomes was 78.57% and 75%.

The novelty of this study is that it has demonstrated the reliability of ONSD to predict neurological outcomes and the need for secondary DC in the early stages of TBI, where clinical signs and computerized tomography (CT) brain findings are of ambiguous nature. To the best of our knowledge, this is the first study where ONSD values were taken in both eyes at regular intervals in all the study participants, twice within 72 h of TBI, during which most of the patients tend to deteriorate due to intracranial hypertension and loss of autoregulation.[11]

The need for noninvasive methods in TBI patients

Invasive ICP monitoring is presently considered the standard of care in moderate and severe head injury patients despite its lack of level I evidence. Physicians often have to make decisions on a case-by-case basis in the management, particularly in borderline scenarios.[4-6] As a result, it is

Table 3: The relationship between ONSD, and clinical (favorable and unfavorable) outcomes.

Input variable	Output variable			
Total=28 patients	Favorable outcome	Unfavorable outcome		Statistical analysis
	Discharged (12)	Operated (12)	Dead (4)	*P*-value
ONSD1 (mm)				
Mean±SD	5.85±0.67	6.44±0.26	6.25±0.06	0.022*
Median (IQR)	6.05 (5.375–6.4)	6.4 (6.375–6.5)	6.25 (6.2–6.3)	
Range	4.5–6.6	6.0–7.1	6.2–6.3	
ONSD2 (mm)				
Mean±SD	5.57±0.52	6.1±0.42	6.32±0.17	0.006*
Median (IQR)	5.6 (5.275–5.925)	6.3 (5.675–6.4)	6.35 (6.25–6.425)	
Range	4.6–6.3	5.5–6.6	6.1–6.5	

*Kruskal–Wallis test $P<0.05$. ONSD1: Optic nerve sheath diameter within 24 h of trauma, ONSD2: Optic nerve sheath diameter 24 h after ONSD1, IQR: Interquartile range, SD: Standard deviation

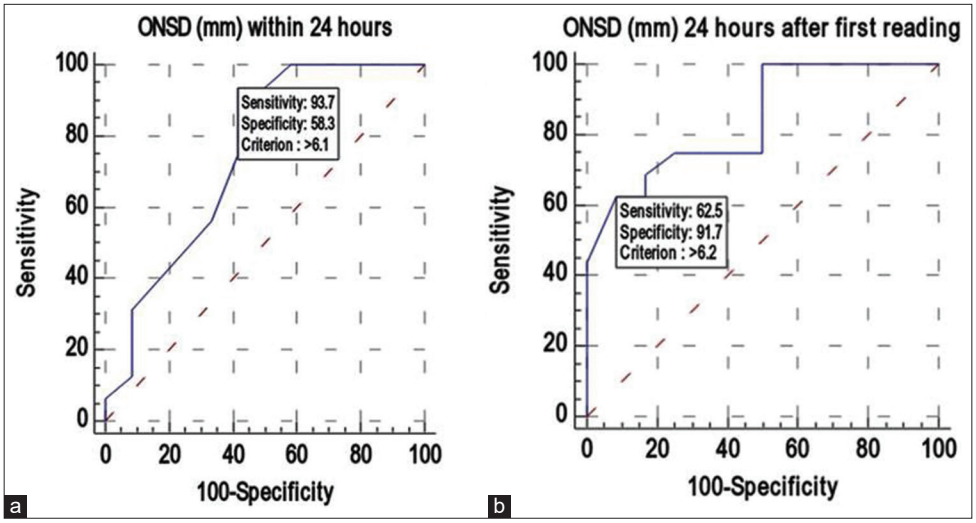

Figure 3: (a and b) Receiver operating characteristics curve of optic nerve sheath diameter (ONSD) 1 and 2 for predicting unfavorable outcome.

Table 4: Prognostic values of measures.

	UO and ONSD1	UO and ONSD2
AUC	0.747	0.8444
SE	0.101	0.0734
95% CI	0.548–0.891	0.657–0.952
P-value	0.0146	<0.0001
Cut off	>6.1	>6.2
Sen	93.75% (69.8–99.8%)	62.5% (35.4–84.8%)
Sp	58.33% (27.7–84.8%)	91.67% (61.5–99.8%)
PPV	75% (50.9–91.3%)	90.9% (58.7–99.8%)
NPV	87.5% (47.3–99.7%)	64.7% (38.3–85.8%)
DA	78.57%	75.00%

AUC: Area under the curve, SE: Standard error, CI: Confidence interval, Sen: Sensitivity, Sp: Specificity, PPV: Positive predictive value, NPV: Negative predictive value, DA: Diagnostic accuracy, UO: Unfavourable outcome, ONSD1: Optic nerve sheath diameter within 24 h of trauma, ONSD2: Optic nerve sheath diameter 24 h after ONSD1

Table 5: Patients survived with high ONSD values and deteriorated in spite of low ONSD values.

Patients – survived with high ONSD1 (≥6.1 mm) or ONSD2 values (≥6.2 mm)			
S. No.	**ONSD1 (mm)**	**ONSD2 (mm)**	**OUTCOME**
1	6.6	6.2	Discharged
2	6.1	6.0	Discharged
3	6.3	6.3	Discharged
4	6.4	5.4	Discharged
Patients – deteriorated in spite of low ONSD1 (≤6.1 mm) or ONSD2 (≤6.2 mm)			
S. No.	**ONSD1 (mm)**	**ONSD2 (mm)**	**OUTCOME**
1	6.5	5.6	Operated
2	6.5	5.5	Operated
3	6.4	5.5	Operated

ONSD1: Optic nerve sheath diameter within 24 h of trauma, ONSD2: Optic nerve sheath diameter 24 h after ONSD1

preferable to have a reliable noninvasive method to anticipate the development of intracranial hypertension and secondary brain injury in the early stages.

The role of ONSD in TBI patients monitoring

Techniques such as TCD, ONSD, tympanic membrane (TM) displacement, fundoscopy, and CT/magnetic resonance imaging (MRI) may be helpful in assessing the ICP by noninvasive methods. Among these, ONSD can be used as a potential screening tool for TBI patients because it is quick, efficient, and can differentiate between normal and raised ICP at the bedside. TCD has a high percentage of unsuccessful measurements. Fundoscopy and MRI have a limited role in TBI.[8,18,21]

The advantages of ONSD measurement by USG over CT or MRI

ONSD was measured by USG in previous studies such as Robba *et al.*, Strumwasser *et al.*, Geeraerts *et al.*, Thotakura *et al.*, Rajajee *et al.*, Wang *et al.*, and Soldatos *et al.*[8,10,19-21,23,24,26-28] Kim *et al.*, Legrand *et al.*, and Bekerman *et al.* managed to get the ONSD values by CT.[2,15,17] Geeraerts *et al.*, and Kimberly and Noble, got ONSD values with MRI measurements.[11,16] USG was used in this study to measure ONSD because it is safe, quick, accurate, and can be done at the bedside in TBI patients.

Association between ONSD and clinical outcomes

ONSD1 value >6.1 mm was found in 93.75% of patients with unfavorable outcomes. It was also observed that if the ONSD2 valve was >6.2 mm, then there was a 90.9% probability of predicting unfavorable outcomes. The study could predict that if the ONSD value was <6.1 mm in the study participants, the chance of a favorable outcome was up to 87.5% [Table 4]. A significant association was noted between ONSD and clinical outcomes, thus proving ONSD as a predictor of clinical outcomes, morbidity, and mortality after TBI, as mentioned in previous studies.[2,9,10,11,15-17,19-23,26-28]

Variation in cutoff values of ONSD

The optic nerve sheath is anatomically continuous with the dura mater of the brain, and it has a trabeculated subarachnoid space through which CSF flows. The fibrillary arrangement of arachnoid trabeculations allows the optic nerve sheath to dilate when ICP rises in TBI. The trabeculations in the anterior segment of the optic nerve sheath are sparse with respect to the posterior segment making it more distensible than the posterior segment.[12,13] Studies have confirmed that 3 mm behind the globe is the preferred position to measure ONSD. In line with Helmke and Hansen., the ONSD was measured at 3 mm behind the globe in the study participants.[14]

Studies by Geeraerts *et al*., and Kimberly and Noble, have shown that the cutoff value of ONSD to predict the raised ICP was between 4.5 and 6.3 mm. Variations in ONSD have been attributed to multiple reasons, including the technique used, variations in the machine and probe, the experience of the observer, and the study population from various ethnicities.[11,16]

DA of ONSD in predicting unfavorable outcomes

Studies by Robba *et al*., Rajajee *et al*., and Wang *et al*. have proved the high sensitivity and specificity value of ONSD in their analysis, but only a few studies have discussed its DA.[19,21,27] This study has shown the DA of ONSD1 and ONSD2 (mm) to predict unfavorable outcomes at 78.57% and 75% [Table 4].

ONSD as a screening tool

Thus, the study has clearly demonstrated that ONSD could be used as a potential screening tool to infer ICP indirectly (noninvasive ICP) in moderate and severe head injury patients, the reasons being its measurement by USG, which is less time-consuming, accurate, efficient, low-cost, noninvasive, and can differentiate normal and raised ICP. While USG is readily available in many peripheral centers, the facility to measure the invasive ICP is not available or contraindicated due to various clinical conditions. This study has also proved that ONSD can predict favorable and unfavorable clinical outcomes and the need for DC in the early stages of TBI by a noninvasive method.

The limitations of the techniques, like intra/interobserver variability and nonavailability of the optimal orbital window due to ocular disorders, preclude its use as a definite substitute for invasive methods.

Limitations

The major limitations of this study are its small sample size, and short follow-up period (up to 72 h following head injury). Considering the age group of the study participants, the study results cannot be generalized to the entire population. Hence, studies with a larger sample size involving individuals of different age groups are required to substantiate the results of the study.

CONCLUSION

The ONSD is a potential screening tool for predicting favorable and unfavorable clinical outcomes in moderate and severe head injury patients. It will also provide valuable information about the need for early DC, which will avoid potential loss of time and help the patient to gain a favorable neurological outcome.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Al-Jishi A, Saluja RS, Al-Jehani H, Lamoureux J, Maleki M, Marcoux J. Primary or secondary decompressive craniectomy: Different indication and outcome. Can J Neurol Sci 2011;38:612-20.
2. Bekerman I, Sigal T, Kimiagar I, Ely AB, Vaiman M. The quantitative evaluation of intracranial pressure by optic nerve sheath diameter/eye diameter CT measurement. Am J Emerg Med 2016;34:2336-42.
3. Brain Trauma Foundation, American Association of Neurological Surgeons, Congress of Neurological Surgeons, Joint Section on Neurotrauma and Critical Care, AANS/CNS, Bratton SL, *et al*. Guidelines for the management of severe traumatic brain injury. IX. Cerebral perfusion thresholds. J Neurotrauma 2007;24 Suppl 1:S59-64.
4. Carney N, Totten AM, O'Reilly C, Ullman JS, Hawryluk GWJ,

Bell MJ, *et al*. Guidelines for the management of severe traumatic brain injury, fourth edition. Neurosurgery 2017;80:6-15.
5. Chesnut RM, Temkin N, Carney N, Dikmen S, Rondina C, Videtta W, *et al*. A trial of intracranial-pressure monitoring in traumatic brain injury. N Engl J Med 2012;367:2471-81.
6. Cnossen MC, Huijben JA, van der Jagt M, Volovici V, van Essen T, Polinder S, *et al*. Variation in monitoring and treatment policies for intracranial hypertension in traumatic brain injury: A survey in 66 neurotrauma centers participating in the CENTER-TBI study. Crit Care Lond Engl 2017;21:233.
7. De Riva N, Budohoski KP, Smielewski P, Kasprowicz M, Zweifel C, Steiner LA, *et al*. Transcranial Doppler pulsatility index: What it is and what it isn't. Neurocrit Care 2012;17:58-66.
8. Dubourg J, Javouhey E, Geeraerts T, Messerer M, Kassai B. Ultrasonography of optic nerve sheath diameter for detection of raised intracranial pressure: A systematic review and meta-analysis. Intensive Care Med 2011;37:1059-68.
9. Gao Y, Li Q, Wu C, Liu S, Zhang M. Diagnostic and prognostic value of the optic nerve sheath diameter with respect to the intracranial pressure and neurological outcome of patients following hemicraniectomy. BMC Neurol 2018;18:199.
10. 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 2008;34:2062-7.
11. Geeraerts T, Newcombe VF, Coles JP, Abate MG, Perkes IE, Hutchinson PJ, *et al*. Use of T2-weighted magnetic resonance imaging of the optic nerve sheath to detect raised intracranial pressure. Crit Care Lond Engl 2008;12:R114.
12. Hansen HC, Helmke K. The subarachnoid space surrounding the optic nerves. An ultrasound study of the optic nerve sheath. Surg Radiol Anat SRA 1996;18:323-8.
13. Hansen HC, Helmke K. Validation of the optic nerve sheath response to changing cerebrospinal fluid pressure: Ultrasound findings during intrathecal infusion tests. J Neurosurg 1997;87:34-40.
14. Helmke K, Hansen HC. Fundamentals of transorbital sonographic evaluation of optic nerve sheath expansion under intracranial hypertension. I. Experimental study. Pediatr Radiol 1996;26:701-5.
15. Kim YH, Lee JH, Hong CK, Cho KW, Yeo JH, Kang MJ, *et al*. Feasibility of optic nerve sheath diameter measured on initial brain computed tomography as an early neurologic outcome predictor after cardiac arrest. Acad Emerg Med 2014;21:1121-8.
16. Kimberly HH, Noble VE. Using MRI of the optic nerve sheath to detect elevated intracranial pressure. Crit Care 2008;12:181.
17. Legrand A, Jeanjean P, Delanghe F, Peltier J, Lecat B, Dupont H. Estimation of optic nerve sheath diameter on an initial brain computed tomography scan can contribute prognostic information in traumatic brain injury patients. Crit Care Lond Engl 2013;17:R61.
18. Raboel PH, Bartek J, Andresen M, Bellander BM, Romner B. Intracranial pressure monitoring: Invasive versus non-invasive methods-a review. Crit Care Res Pract 2012;2012:950393.
19. Rajajee V, Vanaman M, Fletcher JJ, Jacobs TL. Optic nerve ultrasound for the detection of raised intracranial pressure. Neurocrit Care 2011;15:506-15.
20. 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 2017;14:e1002356.
21. Robba C, Donnelly J, Cardim D, Tajsic T, Cabeleira M, Citerio G, *et al*. Optic nerve sheath diameter ultrasonography at admission as a predictor of intracranial hypertension in traumatic brain injured patients: A prospective observational study. J Neurosurg 2019;132:1279-85.
22. 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 2014;21:245-52.
23. Soldatos T, Karakitsos D, Chatzimichail K, Papathanasiou M, Gouliamos A, Karabinis A. Optic nerve sonography in the diagnostic evaluation of adult brain injury. Crit Care Lond Engl 2008;12:R67.
24. Strumwasser A, Kwan RO, Yeung L, Miraflor E, Ereso A, Castro-Moure F, *et al*. Sonographic optic nerve sheath diameter as an estimate of intracranial pressure in adult trauma. J Surg Res 2011;170:265-71.
25. Tayal VS, Neulander M, Norton HJ, Foster T, Saunders T, Blaivas M. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. Ann Emerg Med 2007;49:508-14.
26. Thotakura AK, Marabathina NR, Danaboyina AR, Mareddy RR. Role of serial ultrasonic optic nerve sheath diameter monitoring in head injury. Neurochirurgie 2017;63:444-8.
27. Wang J, Li K, Li H, Ji C, Wu Z, Chen H, *et al*. Ultrasonographic optic nerve sheath diameter correlation with ICP and accuracy as a tool for noninvasive surrogate ICP measurement in patients with decompressive craniotomy. J Neurosurg 2020;133:514-520.
28. Wang LJ, Chen LM, Chen Y, Bao LY, Zheng NN, Wang YZ, *et al*. Ultrasonography assessments of optic nerve sheath diameter as a noninvasive and dynamic method of detecting changes in intracranial pressure. JAMA Ophthalmol 2018;136:250-6.
29. Zweifel C, Czosnyka M, Carrera E, de Riva N, Pickard JD, Smielewski P. Reliability of the blood flow velocity pulsatility index for assessment of intracranial and cerebral perfusion pressures in head-injured patients. Neurosurgery 2012;71:853-61.

How to cite this article: Verma D, Sadayandi RA, Anbazhagan S, Nagarajan K, Bidkar PU. Is optic nerve sheath diameter a promising screening tool to predict neurological outcomes and the need for secondary decompressive craniectomy in moderate to severe head injury patients? A prospective monocentric observational pilot study. Surg Neurol Int 2023;14:276.