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Original Article

Correlation of optic nerve sheath diameter with intracranial pressure monitoring in patients with severe traumatic brain injury

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ABSTRACT

Aims and objectives: To assess the feasibility and reliability of using optic nerve sheath diameter (ONSD) as an objective measure of intracranial pressure (ICP) in patients of severe head injury.
Methods and materials: This prospective study was carried out in Neurosurgery ICU over a 3-month period (April–June 2012). All patients with severe traumatic brain injury (admission GCS $\leq$8) who had ICP monitoring using Codman® intraparenchymal transducer had serial bedside ONSD measurements taken by a single neurosurgeon using a 7.5 MHz linear probe on the same ultrasound machine (Sonosite Micromaxx®) were enrolled in the study. Patients with significant ocular trauma to either eye were excluded.
Results: A total of 20 patients were enrolled during the study period. The mean age was 27 years (range 2–43 years) with M:F ratio of 3:1 and mean GCS of 6 (range 4–8). The mean ONSD in patients with ICP >20 was 6.6 $\pm$ 0.45 mm as compared to 5.9 $\pm$ 0.57 mm in patients with ICP <20 ($p = 0.028$). The Pearson Correlation Coefficient between ONSD (average of both eyes) and ICP was 0.499 ($p = 0.041$). A cutoff of 6.3 mm detected ICP >20 mmHg with 100% sensitivity and 72.7% specificity.
Conclusion: ONSD is a technically simple, non-invasive method of assessing ICP and correlates well with actual ICP in patients of severe traumatic brain injury. A cutoff of 6.3 mm can be used to plan therapeutic interventions when ICP monitoring is unavailable or contraindicated.

1. Introduction

Severe traumatic brain injury (GCS $\leq$8) in the absence of a clear indication for surgery mandates ICP monitoring for early detection and therapeutic intervention. Intracranial transducer insertion remains the standard procedure.[1] This is not always possible owing to patient contraindications and ICP monitoring availability issues. Fundosopy[2] and transcranial Doppler[3] are non-invasive surrogates, but limited by need of experienced observers in both and suitable sonic windows in the latter. Also, sustained elevation of CSF pressure is required for papilledema to develop, which may take hours to days.[2]

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The optic nerve sheath is a continuation of intracranial dura with a trabeculated subarachnoid space underneath. This space is expansile with respect to raised intracranial pressure, especially in the anterior retrobulbar part.[4] Helmke and Hansen, using a transorbital B scan approach showed that at a distance of 3 mm behind the globe the ONSD changed 60% as compared to only 35% at 10 mm with increasing ICP.[5,6]

Further clinical studies in patients of raised intracranial pressure, suspected by clinical scenario and corroborative imaging, showed positive correlation between ONSD and ICP.[7–11] Direct comparison with invasive ICP monitoring after severe head injury is done in two studies showing significant correlation between ONSD and ICP and a cutoff of 5.7 mm is suggested to predict raised ICP.[12,13]

The present study was done to assess the feasibility and reliability of using optic nerve sheath diameter (ONSD) as an objective measure of intracranial pressure (ICP) in patients of severe head injury and arrive at a cutoff value of ONSD which provided acceptable sensitivity and specificity in detecting raised ICP.

2. Methods and materials

A prospective study conducted at a tertiary care center included consecutively admitted patients of severe traumatic brain injury over a period of three months (April 2012–June 2012), in whom ICP monitoring was done. All patients had GCS $\leq$8 on admission to the neurosurgery ICU and were electively ventilated. A Codman® parenchymal transducer was introduced through a twist drill under aseptic precautions for ICP monitoring. A single neurosurgeon who was blinded toward the ICP of the patient performed the ocular ultrasound using the same ultrasound machine (Sonosite Micromaxx®) within 24 h of ICU admission. A linear 7.5 MHz probe was used for the ocular ultrasound and the transverse diameter of the optic nerve sheath at a distance of 3 mm behind the point of entry into the globe was measured (Fig. 1). The measurements were taken in each eye separately after applying jelly on the eye covered with a thin transparent cover. The mean ONSD of both eyes was calculated. If the mean ICP $\geq$20 over half an hour, it was considered as 'high ICP' and these patients underwent decompressive craniectomy if maximal medical therapy failed.

2.1. *Statistical analysis*

Descriptive statistics of patient variables was calculated. The correlation between ICP and ONSD was studied by Pearson Coefficient of Correlation. The difference of mean ONSD in patients with ICP $\geq$20 and ICP $<$20 was compared by *t*-test. A ROC curve was drawn and the sensitivity and specificity of various cutoff values were plotted to decide an acceptable cutoff.

3. Results

There were total 20 patients with mean age of 27 years (range 2–43 years) and males (n = 15) were thrice as common as females (n = 5). The mean GCS was 6 (range 4–8) and the mean ICP was 16 (range 3–33). The mean ONSD (average of both eyes) was 6.06 ± 0.64 mm (range 4.75–7.40 mm). There was a positive correlation between the ONSD and ICP; the Pearson Coefficient of Correlation was 0.499 (p = 0.041) (Fig. 2). The mean ONSD in patients with ICP $>$20 was 6.6 ± 0.45 mm as compared to 5.89 ± 0.57 mm in patients with ICP $<$20 and the difference was statistically significant (p = 0.028) (Fig. 3). The higher ONSD values suitably predicted ICP $>$20 (area under

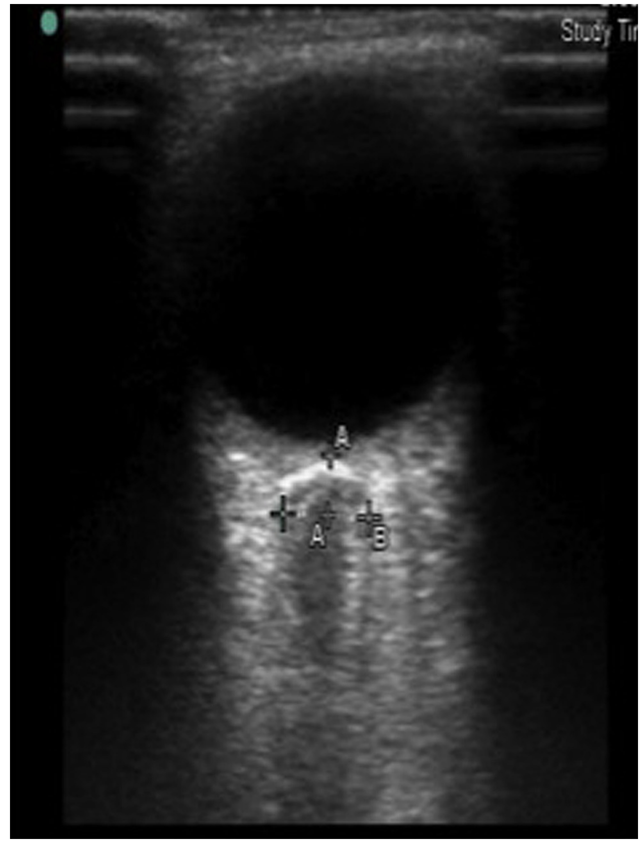


Fig. 1 – Measurement of ONSD as the maximum transverse diameter at 3 mm behind the optic nerve head by a 7.5 MHz probe.

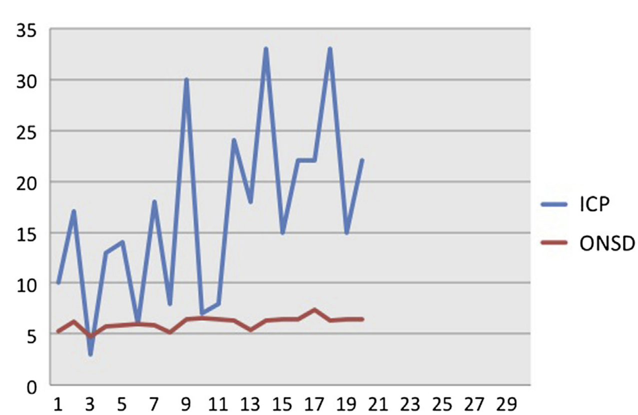


Fig. 2 – Correlation between ONSD and ICP. The Pearson Coefficient of Correlation was 0.499 (p = 0.041).

	ICP ≥ 20	ICP <20	P value
Mean ONSD	6.6 +/- 0.45	5.89 +/-0.57	*0.028*

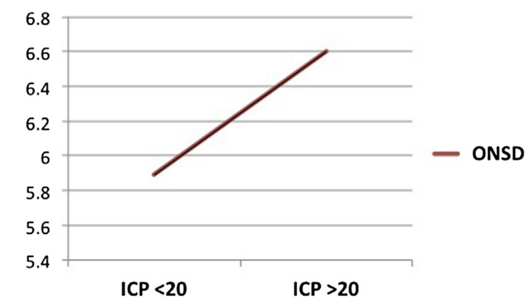


Fig. 3 – ONSD in high and low ICP group of patients.

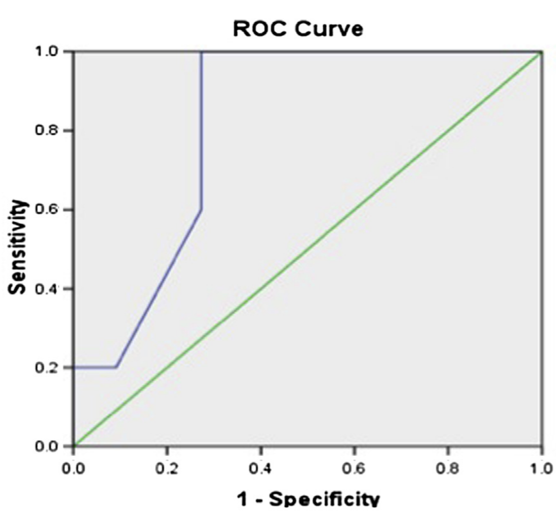
Table 1 – Cutoff values of ONSD with sensitivity and 1-specificity. A cutoff of 6.27 mm has a sensitivity of 100% and specificity of 72.7%.

Positive if greater than or equal to	Sensitivity	1-Specificity
4.65	1.000	1.000
5.02	1.000	0.909
5.35	1.000	0.818
5.60	1.000	0.727
5.85	1.000	0.636
5.92	1.000	0.455
6.1	1.000	0.364
6.27	1.000	0.273
6.32	0.800	0.273
6.42	0.600	0.273
6.55	0.200	0.091
7.00	0.200	0.000
7.50	0.000	0.000

ROC 0.818 ($p = 0.047$) and the 95% confidence intervals were 0.608 and 1.028) (Fig. 4). A cutoff of 6.3 mm predicted ICP >20 with a sensitivity of 100% and specificity of 72.7% (Table 1).

4. Discussion

Intracranial pressure monitoring is a standard tool to make therapeutic decisions in neurointensive care units.[1] Non-invasive methods that reflect intracranial pressure changes can supplement but not replace ICP monitoring as the standard of care. When ICP monitoring is not available or contraindicated, these tools may provide critical inputs for decision-making.



Area Under the Curve

Test Result Variable(s):VAR00001

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.818	.107	.047	.608	1.028

Fig. 4 – ROC curve showing area under the curve between sensitivity and 1-specificity plotting.

Papilledema is a reliable indicator of raised intracranial pressure. However to perform a fundoscopy in a comatose patient on ventilator is cumbersome and especially difficult in patients with extensive lid edema. Furthermore the onset of papilledema is delayed and requires experienced observers.[2] Transcranial Doppler (TCD) can also detect alteration of blood flow due to increased intracranial pressure, however trained observers are required and lack of suitable sonic window may impair its utility in about 5% cases.[3] Assessing ONSD is relatively easy and requires minimal training. For this study, the neurosurgeon underwent a half day 'point of care' ultrasound course and did ocular ultrasound on 5 patients & volunteers before being accredited for doing ultrasound.

Optic nerve is a continuation of central nervous system with its sheath formed by a trabeculated subarachnoid space and surrounded by the intracranial dura. Cadaveric studies had shown that the retrobulbar part dilates maximally with increasing ICP as compared to rest of the nerve owing to the fact that subarachnoid trabeculations are denser posteriorly and the sheath was thinnest at the anterior retrobulbar part.[4] Ossoinig performed the first ultrasound measurement of the optic nerve using an A-scan technique.[14] A linear relation between ICP and ONSD measured by 'A' scan was shown by a number of studies.[15–18] However, the measurement at a specified distance along the optic nerve to add uniformity was difficult with A scan. Helmke and Hansen, using a transorbital B scan approach showed that at a distance of 3 mm behind the globe the ONSD changed 60% as compared to only 35% at 10 mm with increasing ICP.[5,6]

The linear relation between raised intracranial pressure and ONSD measured by 'B' scan is proven by a number of studies.[7–11] Most of these studies were based upon raised ICP on clinical and imaging grounds. Geeraerts et al found a strong correlation between largest ultrasonic ONSD among either eye and invasively monitored ICP in severe head injury.[12] Soldatos et al found a statistically significant correlation between ONSD and ICP in patients of severe head injury, which also correlated with imaging findings and TCD observations.[13] Others still consider invasive monitoring as the gold standard and have found the utility of ONSD more in ICU's which lack access to neurosurgeons.[13]

In the present series, statistically significant correlation was seen between the ONSD and ICP; the Pearson Coefficient of Correlation was 0.499 ($p = 0.041$). The probability of a higher ONSD being associated with higher ICP than a lower ONSD was 82% (area under ROC 0.818, 95% Confidence intervals 0.608 and 1.028) and a cutoff value of 6.3 mm for ONSD predicted raised ICP with 100% sensitivity and 72.7% specificity. A higher sensitivity and specificity is desirable so as not to miss any patient with raised ICP and simultaneously not to over diagnose it. Geeraerts et al suggested a cutoff of 5.7 mm for detecting raised ICP with sensitivity and negative predictive value of 100%.[12] They used the largest ONSD of either right or left eye for comparison whereas we measured the average ONSD of both eyes. The cutoff value of 5.7 mm was also suggested by Soldatos et al with a sensitivity and specificity of 74% and 100% respectively.[13] Here patients with significant ocular trauma were included with measurement of single eye ONSD whereas we excluded such patients from the study group. A cutoff of 5.7 mm in the present study group was associated with 100% sensitivity and 38% specificity and a higher cutoff at 6.3 mm increased specificity at no loss of sensitivity.

Though it is difficult to give a cutoff value that represents the standard to apply to the general population with one time measurement, it gives acceptable correlation with ICP at the time of measurement, especially when the latter is not available or contraindicated. The main limitation of this study is the small number of subjects. We however believe that the results would be reproducible across larger number of patients. Nevertheless, the differences of ONSD across age groups, gender and temporal relation of increase in ONSD to rising intracranial pressure will need to be evaluated by further studies.

5. Conclusions

Ultrasonic optic nerve sheath diameter (ONSD) is a reliable indicator of intracranial pressure that can be easily done by a neurosurgeon at the bedside and help therapeutic decisions and repeated measurements can be done to keep a watch on trends of ICP. A cutoff of 6.3 mm precisely indicates raised intracranial pressure and can be used to plan further intervention when ICP monitoring is unavailable or contraindicated.

Conflicts of interest

All authors have none to declare.

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Nil.

REFERENCES

1. Czosnyka M, Pickard JD. Monitoring and interpretation of intracranial pressure. *J Neurol Neurosurg Psychiatry*. 2004;75:813–821.
2. Stiffen H, Eifert B, Aschoff A, Kolling GH, Volcker HE. The diagnostic value of optic disc elevation in acute elevated intracranial pressure. *Ophthalmology*. 1996;103:1229–1232.
3. Hassler W, Steinmetz H, Gawlowski J. Transcranial Doppler ultrasonography in raised intracranial pressure and in intracranial circulatory arrest. *J Neurosurg*. 1988;68:745–751.
4. Hayreh SS. Pathogenesis of oedema of the optic disk (papilloedema), a preliminary report. *Br J Ophthalmol*. 1964;48:522–543.
5. Helmke H, Hansen HC. Fundamentals of transorbital sonographic evaluation of optic nerve sheath expansion under intracranial hypertension. I Experimental study. *Paediatr Radiol*. 1996;26:701–705.
6. Helmke H, Hansen HC. Fundamentals of transorbital sonographic evaluation of optic nerve sheath expansion under intracranial hypertension. II Patient study. *Paediatr Radiol*. 1996;26:706–710.
7. 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;49:508–514.
8. Tsung JW, Blaivas M, Cooper A, Levick NR. A rapid noninvasive method of detecting elevated intracranial pressure using bedside ocular ultrasound: application to 3 cases of head trauma in the pediatric emergency department. *Pediatr Emerg Care*. 2005;21:94–98.
9. Malayeri AA, Bavarian S, Mehdizadeh M. Sonographic evaluation of optic nerve diameter in children with raised intracranial pressure. *J Ultrasound Med*. 2005;24:143–147.
10. Blaivas M, Theodoro D, Sierzenski PR. Elevated intracranial pressure detected by bedside emergency ultrasonography of optic nerve sheath. *Acad Emerg Med*. 2005;45:336–337.
11. Girisgin AS, Kalkan E, Kocak S, Cander B, Gul M, Seniz M. The role of optic nerve ultrasonography in the diagnosis of elevated intracranial pressure. *Emerg Med J*. 2007;24:251–254.
12. Geeraerts T, Launey Y, Martin L, et al. Ultrasonography of the optic nerve sheath may be useful for detecting raised intracranial pressure after severe brain injury. *Intensive Care Med*. 2007;33:1704–1711.
13. Soldatos T, Karakitsos D, Chatzimichail K, Papathanasiou M, Gouliamos A, Karabanis A. Optic nerve sonography in the diagnosis evaluation of adult brain injury. *Crit Care*. 2008;12:R67.
14. Ossoinig KC. Standardised echography: basic principles, clinical applications and results. *Int Ophthalmol Clin*. 1979;19:127–210.
15. Cennamo G, Gangemi M, Stella L. The correlation between endocranial pressure and optic nerve diameter: an ultrasonographic study. *Ophthalmic Echography*. 1987;7:603–606.
16. Gangemi M, Cennamo G, Maiuri F, et al. Echographic measurement of the optic nerve in patients with intracranial hypertension. *Neurochirurgia*. 1987;30:53–55.
17. Tamburelli C, Aricle C, Mangiola A, et al. CSF dynamic parameters and changes of optic nerve diameters measured by standardised echography. *Ophthalmic Echography*. 1993;13:101–109.
18. Raboel PH, Bartek Jr J, Andresen M, Bellander BM, Romner B. Intracranial pressure monitoring: invasive versus non-invasive methods – a review. *Crit Care Res Pract*. 2012;2012:950393.