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Original Research Article

Optic nerve sheath diameter as a non-invasive indicator of intracranial hypertension in traumatic brain injury: correlation with CT head and prognostic implications

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ABSTRACT

Background: Ultrasound guided measurement of optic nerve sheath diameter (ONSD) is an emerging non invasive bedside tool that is being used to detect raised intracranial pressure (ICP) in patients with traumatic brain injury(TBI). Early detection of raised ICP can guide in the timely management of such patients with raised ICP due to TBI.
Methods: A prospective, observational, open labelled study planned with a 30 patients of TBI of both genders, aged between 18 to 70 years. ONSD readings were taken 3 times a day for three days from the time of admission with portable SonoSite ultrasound machine. Data was expressed as mean ±standard deviation. Values were compared using T test and P value was calculated.
Results: Highest reading recorded in patients with GCS <8 was 6.26±0.73 in comparison to 5.38±0.56 (p=0.001) in patients with GCS >8. Highest reading of ONSD correlating with a positive CT finding at admission was 6.22±.81 and was 5.46±.57 (p=0.006) in patients with negative findings on CT. ROC curve with average cut off of 6 mm correlated with positive CT findings with sensitivity of 80%, specificity of 70% and negative predictive value of 87% was found.
Conclusions: Ultrasound-guided ONSD monitoring shows promise for diagnosing intracranial hypertension in traumatic brain injury. Correlations with CT, GCS, and outcomes emphasize its clinical relevance, warranting further validatio.

Keywords: CT head, Functional outcomes, Glasgow coma scale, Intracranial hypertension, Optic nerve sheath diameter, Traumatic brain injury, Ultrasound-guided monitoring

INTRODUCTION

Traumatic brain injuries are the leading cause of illness, mortality, disability, and monetary losses in India and other developing countries. According to estimates, between 1.5 and 2 million people are injured and 1 million people die each year in India.[1] Traumatic brain injury (TBI) is an assault to the brain brought on by an

outside mechanical force that is neither congenital nor degenerative and may produce a reduced level of awareness or a change in consciousness as well as a temporary or permanent impairment of cognitive, physical, and psychosocial functions. Mild, moderate, and severe brain injuries may be classified according to their severity.[1]

Because traumatic brain injuries often result in visits to the emergency department, it is essential to examine these patients for high intracranial pressure (ICP) and localized pathology because, if ignored, they have a significant influence on morbidity and mortality. ICP rise leads in decreased cerebral blood flow and oxygen delivery to the brain, which causes hypoxia and hypoperfusion. Hypoxia and hypoperfusion may be fatal and cause irreversible neurological damage by squeezing the brainstem and other crucial structures and causing herniation. Catheters with transducer tips, fluid-filled devices, and telemetric methods may all be used for invasive ICP monitoring. Invasive intracranial devices are still the industry standard for assessing ICP.[2]

Examples of noninvasive procedures include transcranial doppler, near infrared spectroscopy, impedance mismatch, tympanic membrane displacement, CT scan, MRI, and optic nerve sheath diameter. With CT, localized cerebral illness and ICP rise may be swiftly and painlessly identified. Although there are potentially beneficial approaches for predicting intracranial hypertension, they are expensive, time-consuming to obtain, limited, and necessitate unsafe patient transfers.[3]

Elevated ICP increases the diameter of the optic nerve sheath because it is adjacent to the subarachnoid space and the dura mater. This increase in optic nerve sheath diameter is associated with both the development of ONSD Ultrasonography and its suggested use as a possible indication of intracranial hypertension.[4] It was recently introduced to provide fast bedside measurement of the optic nerve sheath width and non-invasive diagnosis of increased ICP, particularly in patients with traumatic brain injury.[5]

This study aims to investigate the potential of ultrasound-guided optic nerve sheath diameter (ONSD) monitoring as a non-invasive method for detecting intracranial hypertension in traumatic brain injury (TBI) patients. It seeks to establish correlations between ONSD measurements, CT head findings, Glasgow Coma Scale (GCS) scores, and long-term functional outcomes. The study includes a diverse cohort of 30 TBI patients, both genders, aged 18-70. ONSD readings are taken thrice daily for three days and correlated with CT findings. Additionally, it examines the association between ONSD and GCS scores, as well as the Glasgow Outcome Score (GOS) at three months post-admission. The study ultimately aims to validate ONSD as a valuable tool in managing TBI patients, offering non-invasive monitoring and prognostic insights.[6]

METHODS

Study type and setting

This prospective observational open-label study was conducted in the anesthesia department of a tertiary care facility from September 2014 to October 2015. This study was conducted at Dr. Rajendra Prasad Govt. Medical College Kangra at Tanda, Himachal Pradesh. The study was registered with the Clinical Trials Registry of India (CTRI) under registration number CTRI/2018/05/014157.

Inclusion criteria

All patients with traumatic brain injury who were admitted to the neurosurgical unit and the anesthesia ICU were included in the study.

Exclusion criteria

Patients were excluded if they did not meet the specified criteria.

Patient selection

Upon admission, all patients underwent an initial examination and were treated according to the institutional procedure, including resuscitation. To avoid diagnostic suspicion bias, ocular ultrasound was performed before knowledge of the non-contrast computed tomography (NCCT) head results. The ocular ultrasound was performed by an anesthesia department resident trained by a radiologist to assess optic nerve sheath diameter (ONSD). The first Glasgow Coma Scale (GCS) score and ONSD measurements were obtained within two hours of the CT scan, following agreement from the patient's attendants.

Ocular ultrasound procedure

For the ONSD ultrasonography, patients were positioned with their heads elevated at a 300 dorsal angle. The examination was carried out using a Micromaxx Sonosite USG machine (Sonosite, WA, USA) equipped with a high-resolution 7.5 to 10 MHz linear transducer. The ultrasound was performed with the patient's eyes closed. An eye applicap was placed in the patient's eye, and the closed eyelid was covered with a generous quantity of water-soluble ultrasonic gel to facilitate contact with the transducer. The globe was scanned in both sagittal and transverse planes without exerting pressure. The hand used for scanning was supported by the forehead or the bridge of the nose. The examination involved comparing both eyes and carefully inspecting the eyes beneath the closed eyelid, both in the neutral position and during moderate eye movements. The probe was moved side to side in both scanning planes to display the entire breadth of the ocular structures. Gain adjustments were made as needed to spot tiny irregularities and prevent artifacts.

ONSD measurement

The ONSD measurement was taken 3 mm posterior to the globe and perpendicular to the axis of the optic nerve. Two measurements were recorded for each optic nerve, one sagittal and one transverse. ONSD measurements were recorded every 6 hours over a three-day period starting from the patient's admission. A measurement of more than 5mm of ONSD was considered substantial.

Data collection

Following admission, GCS scores, pupil size, and reactivity were noted within 10 minutes of the ONSD measurement and then every 6 hours thereafter. Treatment decisions, whether surgical or conservative, were made at the discretion of the neurosurgeon. Patients were followed up in the neurosurgery outpatient department after discharge, and the Glasgow Outcome Score was recorded at the end of three months for survivors.

Statistical analysis

A structured data collection form was created prior to gathering prospective data. A single abstractor collected and reviewed data quality from selected charts. Data were stored in a Microsoft Excel database and analyzed using suitable statistical software. Unless otherwise specified, data were reported as mean ± standard deviation. The average ONSD between the two eyes was used for analysis.

RESULTS

The table 1 presents a comprehensive overview of patient demographics. It combines age and gender distributions, revealing that the majority of patients are male under the age of 30, constituting 76.7% of the total. Patients aged 30-40 make up 23.3% of the total, with a higher proportion of females in this age group.

Table 1: Demographic distribution of patients.

Age (years)	Frequency (n=30)	Percent (%)	Gender	Frequency (n=30)	Percent (%)
<30	11	36.7	Male	23	76.7
30-40	7	23.3	Female	7	23.3
40-50	5	16.7	Total	30	100.0
50-60	5	16.7			
>60	2	6.7			
Total	30	100.0			

Table 2: CT Head findings of the patients.

CT findings	Operative (%)	Conservative (%)	Total (%)
Contusions	0 (0.0)	11 (68.8)	11 (37.9)
EDH	9 (69.2)	1 (6.3)	10 (34.5)
SAH	0 (0.0)	3 (18.8)	3 (10.3)
SDH	4 (30.8)	1 (6.3)	5 (17.2)

The CT scan findings of the patient were divided into 4 categories that included: contusions, EDH, SAH and SDH. Among the 16 patients who underwent conservative management, 11 patients had contusions on CT, only 1 patient had EDH, patients had subarachnoid hemorrhage and 1 patient had SDH. Out of 13 patients who underwent operative management, 9 patients had EDH and 4 patients had SDH (Table 2).

On day 1, the mean ONSD value at the time of admission was 5.64±0.69 mm in the operative group. Whereas the mean ONSD value at the time of admission was 6.33±0.80mm in conservative group, with p value =0.021*. The maximum value of ONSD on day 1 was 5.67±0.63 in the operative group and 6.33±0.80 in the conservative group (Table 3).

Table 3: Mean values of ONSD on 1st day.

Time in hours	Operative (n=16) Mean±SD	Conservative (n=14) Mean±SD	P value
Right Trans 0hr	5.64±0.69	6.33±0.80	0.021*
Left Trans 0 hr	5.45±0.62	5.96±0.99	0.118
Right AP 0 hr	5.67±0.63	6.00±0.94	0.288
Left AP 0 hr	5.48±0.57	5.79±0.84	0.268
Right Trans 6 hr	5.54±0.68	6.28±0.85	0.017*
Left Trans 6 hr	5.34±0.63	5.96±1.02	0.066
Right AP 6 hr	5.57±0.66	6.09±0.88	0.086
Left AP 6 hr	5.47±0.59	5.85±0.98	0.229

Continued.

Time in hours	Operative (n=16) Mean±SD	Conservative (n=14) Mean±SD	P value
Right Trans 12 hr	5.46±0.64	6.19±0.89	0.020*
Left Trans 12 hr	5.32±0.56	5.74±0.76	0.113
Right AP 12 hr	5.53±0.62	6.02±0.88	0.103
Left AP 12 hr	5.40±0.57	5.78±0.91	0.198
Right Trans 18 hr	5.37±0.67	6.03±0.96	0.047*
Left Trans18 hr	5.34±0.64	5.83±0.82	0.092
Right AP18hr	5.42±0.60	5.92±0.92	0.101
Left AP18 hr	5.33±0.58	5.77±0.80	0.109
Right Trans 24 hr	5.42±00.62	5.99±0.92	0.068
Left Trans24hr	5.38±.66	5.86±0.79	0.087
Right AP 24 hr	5.33±0.60	5.83±0.89	0.097
Left AP24 hr	5.35±0.53	5.66±0.75	0.213

Table 4: Comparison of GCS with ONSD.

Day	ONSD in patients with GCS>8 Mean±SD (mm)	ONSD in patients with GCS <8 Mean±SD (mm)	P-value
Day-1 Right eye	5.38±0.56	6.26±0.73	0.001**
	(n=15)	(n=15)	
Day-1 Left eye	5.30±0.51	5.97±0.78	0.010**
	(n=15)	(n=15)	
Day-2 Right eye	5.42±00.64	6.15±0.55	0.003**
	(n=15)	(n=14)	
Day-2 Left eye	5.37±.53	5.94±0.55	0.010**
	(n=15)	(n=14)	
Day-3 Right eye	5.33±0.76	6.22±0.76	0.004**
	(n=15)	(n=14)	
Day-3 Left eye	5.19±0.67	5.83±0.63	0.014*
	(n=15)	(n=14)	

Table 5: Comparison of ONSD WITH CT head.

	ONSD in patients with positive CT findings at admission Mean±SD (mm) n=14	ONSD in patients with negative CT findings Mean±SD(mm) n=16	P value
Right eye	6.22±0.81	5.46±0.57	0.006**
Left eye	5.96±0.82	5.36±0.52	0.023*

On day 1 patients with GCS >8 had ONSD values less than the patients with GCS more than 8 in both left eye (5.30±0.51 vs 5.97±0.78) as well as right eye (5.38±0.56 vs 6.26±0.73) which were statistically significant (P value=0.010 and 0.003 respectively). Similarly the ONSD values were significantly higher over the next two days also in both the eyes. Over the period of 3 days it was seen that the ONSD values were comparatively higher in the patients with poor GCS (Table 4).

ONSD values were higher at the time of admission in the patients whose CT head findings were suggestive of raised intracranial pressure in comparison to the patients whose CT head did not had any findings suggestive of raised ICP. The values of transverse and anteroposterior ONSD were averaged and mean ONSD value which corresponded well with positive CT findings of raised ICP on day 1 was found to be 6.22±.81mm (P value=0.006**). Whereas it was seen that mean ONSD of 5.46±.57 didn't had any CT evidence of raised ONSD (Table 5).

DISCUSSION

The present study employed a prospective, observational, and open-labeled approach to investigate the feasibility of ultrasound-guided serial monitoring of optic nerve sheath diameter (ONSD) as a non-invasive method for diagnosing raised intracranial pressure in patients with traumatic brain injury.[7] This investigation also aimed to assess the functional outcome scoring of patients

admitted to the ICU of the Department of Anesthesia and neurosurgical wards within a tertiary care institution. Through the enrollment of 30 patients presenting with traumatic brain injury who met the inclusion criteria, the study sought to establish correlations between ONSD measurements, CT head findings, Glasgow Coma Scale (GCS) scores, and long-term prognostic implications.[8]

The patient cohort encompassed both male and female individuals aged 18 to 70 years, with a total of 30 patients recruited during the study period. Among these patients, 53.3% underwent operative interventions, while the remaining 46.7% were managed conservatively.[9] The choice of management was often associated with specific CT head findings, where patients undergoing conservative management predominantly exhibited contusions and subarachnoid hemorrhage on CT, while those undergoing operative interventions presented with epidural hematomas (EDH) and subdural hematomas (SDH). The identification of raised intracranial pressure was augmented by CT scan features such as midline shift, effacement of basal cisterns, and ventricular compression.[10]

The study's core focus was the dynamic assessment of ONSD measurements over the course of three days, enabling the evaluation of intracranial pressure trends and potential correlations with patient management strategies. On the first day of admission, the mean ONSD was significantly higher in the conservative management group (6.33±0.80 mm) compared to the operative group (5.64±0.69 mm). This difference persisted across various time intervals on day one, indicating a potential association between ONSD and management strategies. Similarly, on days two and three, ONSD values remained significant in indicating the intracranial pressure dynamics associated with both operative and conservative interventions. These observations suggest that ONSD could serve as an indirect indicator of improvement following operative interventions.[11]

Correlations between ONSD, GCS scores, and CT head findings were explored. Patients with GCS scores ≤8 demonstrated higher ONSD values and a stronger association with positive CT findings suggestive of raised intracranial pressure. Notably, patients with lower GCS scores tended to exhibit higher ONSD values over the study period, underscoring the potential prognostic implications of ONSD measurements.[12]

Further prognostic relevance was indicated by the Glasgow Outcome Score (GOS) assessed at three months post-admission. The association between ONSD values taken at discharge and GOS scores at three months provided valuable insights. The correlation between higher ONSD values and lower GOS scores, as well as the inverse relationship, highlighted the potential utility of ONSD as a predictive tool for functional outcomes.[13]

The study's ability to discriminate between positive and negative CT findings suggestive of raised intracranial pressure was demonstrated by the ROC curve analysis, with an average cut-off value of 6 mm for ONSD. This analysis yielded a sensitivity of 80%, specificity of 70%, and a negative predictive value of 87% when comparing ONSD measurements with CT findings.

In this study, several limitations must be acknowledged. First, the relatively small sample size of 30 patients and the single-center nature of the study may restrict the generalizability of the findings to a broader population. The observational study design prevents the establishment of causal relationships, warranting further interventional research for validation. Additionally, the operator-dependent nature of ONSD measurements raises concerns about potential measurement variability among different practitioners. The short three-month follow-up period limits the assessment of long-term functional outcomes, and the lack of detailed information on exclusion criteria may introduce selection bias. Moreover, the specificity of the ultrasound machine used may limit the study's applicability to settings with different equipment. While correlations between ONSD and clinical parameters were identified, the study falls short of definitively establishing ONSD as a predictive tool for long-term prognosis. Lastly, the possibility of publication bias due to reporting positive correlations should be considered.

CONCLUSION

In conclusion, this study underscores the potential of ultrasound-guided serial monitoring of ONSD as a non-invasive approach for diagnosing raised intracranial pressure in traumatic brain injury patients. The correlations between ONSD measurements, CT findings, GCS scores, and functional outcomes suggest the clinical significance of ONSD as an indicator of intracranial dynamics and potential prognostic implications. Further investigations with larger cohorts and longitudinal follow-up could validate these findings and potentially enhance the clinical utility of ONSD measurements in managing traumatic brain injury patients.

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