ORIGINAL ARTICLE

Ultrasonographic Measurement of Optic Nerve Sheath Diameter in Patients with Traumatic Head Injury: A Prospective Observational Study

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ABSTRACT

Introduction: The early detection of elevated intracranial pressure is crucial for guiding interventions and improving patient outcomes in head injury patients. The intracranial pressure assessment with invasive intracranial devices is the gold standard. These devices however has a risk of infection, bleeding and dislodgement. Optic nerve sheath diameter measurement using ultrasonography has emerged as a promising method for indirect intracranial pressure estimation. **Aims:** To observe the changes in optic nerve sheath diameter over period of time, and to correlate the optic nerve sheath diameter with computed tomography findings of raised intracranial pressure in traumatic head injury. **Methods:** A prospective cross-sectional time series study was conducted at Nepalgunj Medical College to assess the utility of ultrasonography measurement of optic nerve sheath diameter in patients with head injuries from August 2023 to January 2024. Forty-nine patients with head injuries were included in the study. The ultrasonographic optic nerve sheath diameter measurements were obtained at admission, 48 hours post-admission, and 1 month post-head injury. The clinical parameters including Glasgow Coma Scale and radiological findings from Computed Tomography head were recorded. **Results:** Forty nine patients were enrolled in the study. Among them, 44.90% (27) were male and 55.10% (22) were female. Age ranged from 5 to 66 years, with a mean of 33.94 ± 15.27 years. The mean optic nerve sheath diameter was 5.24±0.86 mm at admission which decreased to 4.31±0.62 mm at 48 hours and 4.02±0.47 mm at 1 month. Our study showed significant reduction in optic nerve sheath diameter after conservative or surgical treatment in patients with head injury (F = 27.017; P =0.002). **Conclusion:** The ultrasonographic measurement of optic nerve sheath diameter proved to be a valuable tool in monitoring intracranial pressure in patients with head injuries.

Keywords**:** Head injury, Intracranial pressure, Optic nerve sheath diameter

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INTRODUCTION

Increased intracranial pressure (ICP) is a critical emergency with significant risks for morbidity and mortality.[1-3] Detecting elevated ICP early is crucial for guiding treatment in head injury patients and enhancing their prognosis.[4, 5] The ICP assessment with invasive intracranial devices is the gold standard.[6-9] These devices could, however, increase the risk of issues including infection, bleeding, and dislodgement. Furthermore, it cannot be carried out when there are bleeding disorder.[10, 11]

The change in ICP also results in corresponding change in intraorbital subarachnoid space pressure.[7,12] The optic nerve sheath, an extension of the dura, is continuous with the sub-arachnoid space, and a rise in ICP transmits to the optic nerve sheath, causing swelling of the optic sheath, optic disc, and papilledema.[13, 14] The optic nerve sheath diameter (ONSD) can be assessed using Ultrasonography, Computed Tomography (CT) head and MRI Brain. The repeated CT head is an exposure to ionizing radiation and MRI brain is time consuming. The available evidence underscores the significance of ultrasonic measurement as a crucial indicator of ICP as ultrasonography is a non-invasive bedside real time assessment of optic nerve sheath diameter which is free of radiation exposure, less expensive and takes less time. ONSD has recently emerged as a new method correlating with changes in ICP.[15] There are few studies in Nepal correlating ONSD with CT head findings. There are only few research done to monitor optic nerve diameter serially. Our study aimed to do serial monitoring of ONSD using ultrasonography in patients with head injury.

METHODS

This was prospective cross-sectional time series study conducted at Nepalgunj Medical College from August 2023 to January 2024 to do serial monitoring of ONSD using ultrasonography in patients with head injury. The study was conducted in conjunction with the radiology department, had 49 participants of varying ages who were either treated conservatively or surgically. Patients without brain stem reflexes and those with a Glasgow Coma Scale (GCS) score of less than four were excluded from the study. Informed and written consent were obtained from eligible patients. The ONSD measurements were taken with a 6-13 MHz linear transducer probe, applying gel over the closed eye while the patient was in a supine position. ONSD was measured 3 mm posterior to the globe {figure (1a, 1b, 1c)}. The ONSD was calculated as the average measurements of ONSD from both the right and left eyes of each patient. ONSD measurements were done at admission, 48 hours post-admission, 1 month post-head injury, and as required. Additionally, CT head was performed at admission and was repeated when required, analyzing the blood volume, midline shift, third ventricle diameter, compression of basal cistern and brain herniation. Data was entered in Excel sheet and was analyzed using SPSS-PC-26.

Figure 1(A)

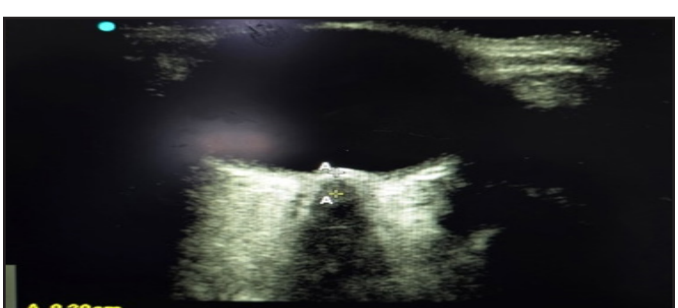

Figure 1(B)

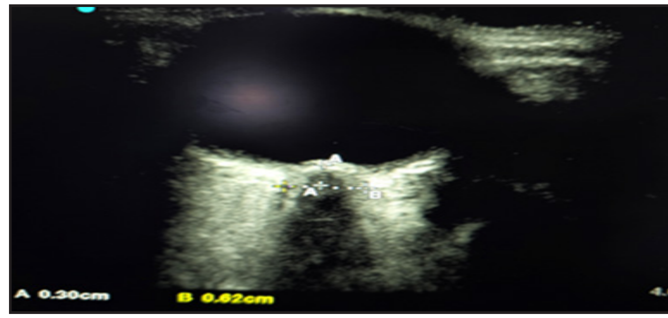

Figure 1(C)

* AA distance is 3mm posterior to the globe. ONSD was measured as B line passing through the point A. ONSD is the transverse distance between two outer hypoechoic zones. The transverse distance of inner hypoechoic region is optic nerve diameter (OND). [Figure 1(a), 1(b), 1(c)]

RESULT

Variable	Mean ± SD
Age	33.94±15.27
Sex	
Male	27 (44.90%)
Female	22 (55.10%)

Table I: General characteristics of patients (N=49)

Among 49 patients, 44.90% (27) were male and 55.10% (22) were female. Age ranged from 5 to 66 years, with a mean of 33.94 ± 15.27 years. [Table I]

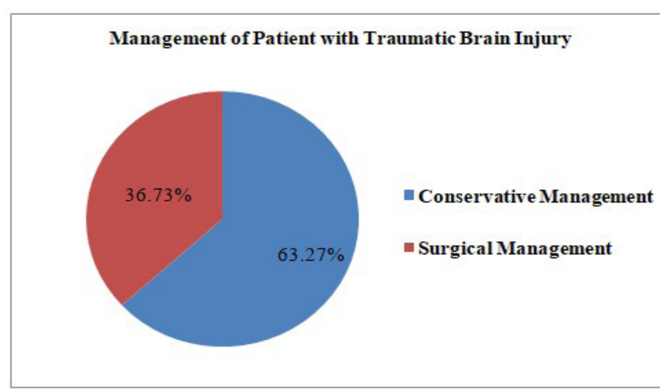

Figure 2: Management of patient with Traumatic Brain Injury (n=49)

Among 49 patients, 36.73% (18) patients with traumatic brain injury underwent surgery, and majority of patients 63.27% (31) were treated conservatively. [Figure 2]

Variables	Frequency (F)	Percentage (%)
Compression of basal cistern		
No	31	63.27
Yes	18	36.73
Herniation		
Absent	31	63.27
Present	18	36.73
Transverse third ventricle diameter		
Not collapsed	26	53.06
Collapsed	23	46.94
	Mean ±SD	
Midline shift in mm (n=49)	5.43 ±3.13	
Blood Volume in ml (n=28)	32.19±11.53	

Table II: Computed Tomography (CT) head findings (n=49)

Among 49 traumatic brain injury patients, 36.73% (18) of patients had compressed basal cistern and brain herniation while 46.94% (23) of patients had collapsed third ventricular diameter. Compressed basal cistern, brain herniation and collapsed third ventricle diameter are the signs of raised intracranial pressure. The mean values of midline shift and blood volume are 5.43 ±3.13 mm and 32.19±11.53 ml respectively. [Table II]

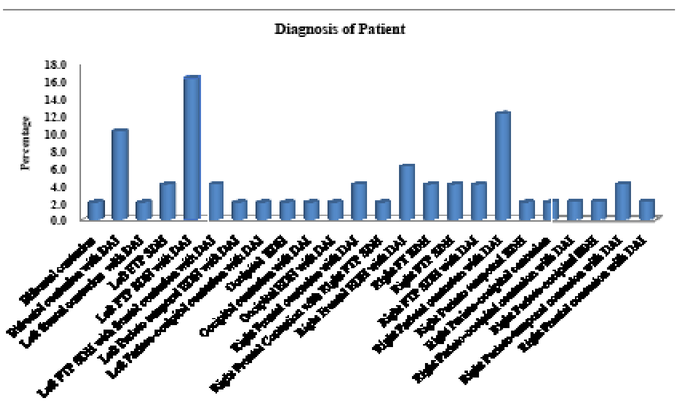

Figure 3: Diagnosis of patient (n=49)

Optical nerve sheath diameter	Mean in mm	F value	p-value
ONSD at admission	5.24±0.86	27.017	P=0.002*
ONSD at 48 hour	4.31±0.62		
ONSD at 1 month	4.02±0.47		

****level of significance at 0.05***

Table III: Comparison of mean and F value of ultrasonographic measurements of optic nerve sheath diameter (n=44)

The mean ONSD value was 5.24±0.86 mm at admission which decreased to 4.31±0.62 mm at 48 hour and 4.02±0.47 mm at 1 month. There was significant reduction in ONSD (F = 27.017; P =0.002) after conservative or surgical treatment in patients with head injury. The result highlights the clinical significance of monitoring ONSD in head injury patients. The change in ONSD could serve as a non-invasive indicator of change in ICP, aiding in the management and prognosis of head injury patients. Five patients (10.2%) died during the course of study. [Table III]

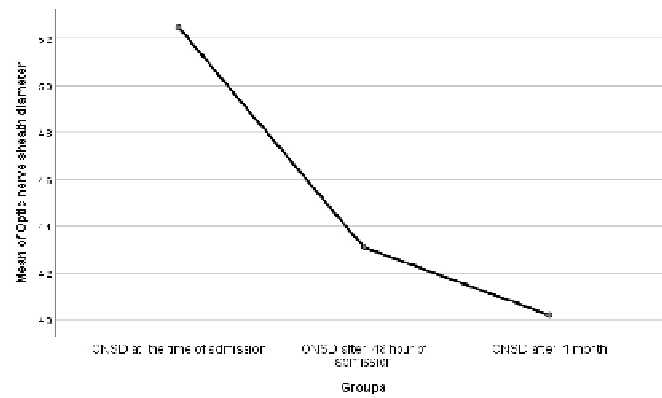

Figure 4: Ultrasonographic measurement of ONSD at differerent time period (n=49) **Bivariate Analysis**

GCS category	Mild (13 to 15)	Moderate (9 to 12)	Severe (3 to 8)	P-Value
	Odds ratio	Odds ratio	Odds ratio	
ONSD	1	4.42 (95%CI, 1.21 to 7.63)	7.96 (95%CI, 3.72 to 12.20)	P=0.001*

****level of significance at 0.05***

Table IV: Multinomial logistic regression analysis for the association of GCS and ONSD at the time of admission (n=49*Fisher's Exact Test

The multinomial logistic regression analysis revealed a significant association (p=0.001) between GCS and ONSD at the time of admission. Compared to patients with mild head injury (GCS 13 to 15), those with moderate head injury (GCS 9 to 12) have 4.42 times higher odds of having an abnormal ONSD (95% CI: 1.21 to 7.63), while patients with severe head injury (GCS 3 to 8) have even higher odds, with an odds ratio of 7.96 (95% CI: 3.72 to 12.20). The findings concluded that, as the severity of head injury increases, there is increase in the ONSD which is statistically significant (p=0.001). [Table IV]

Computed Tomography findings	ONSD at admission
Blood volume (n=28)	r= 0.901 (p=0.003)
Midline shift	r= 0.888 (p=0.01)
Collapsed third ventricular diameter	r= 0.866 (p=0.018)
Brain herniation	r= 0.765 (p=0.03)
Compression of basal cistern	r= 0.855 (p=0.001)

****level of significance at 0.05***

Table V: Association of ONSD with CT head findings in patients with traumatic brain injury at the time of admission (n=49)

The findings revealed that ONSD is positively correlated with midline shift (r=0.888, p=0.01), compression of basal cistern (r=0.855, p=0.001), collapsed third ventricular diameter (r=0.866, p=0.018), brain herniation (r=0.765, p=0.03) and blood volume (r=0.901, p=0.003). These correlations revealed the utility of ONSD as a non-invasive surrogate marker for ICP monitoring in head injury patients. These findings emphasize the importance of integrating ONSD measurements into clinical practice for the comprehensive management of head injury patients, allowing for timely intervention to identify and manage the adverse effects of increased ICP. [Table V]

DISCUSSION

The raised intracranial pressure is a dire emergency which need to be dealt either conservatively, and if necessary surgically.[1,4,5] There are few direct and indirect methods in existing literature to assess the raised ICP. The gold standard method of ICP monitoring is invasive which has the risk of complications.[6,7,8,9,10,11] The raised intracranial pressure is reflected in the subarachnoid space of intraorbital cavity which can be measured as optic nerve sheath diameter.[7,12,13,14] The ultrasonography is bedside real time examination of optic nerve sheath diameter, less expensive and less time consuming.[6]

Though few research has been done in the past to assess the optic nerve sheath diameter using ultrasonography, there are only few research done to monitor optic nerve diameter serially. We conducted the research to fill the lacunae on the same.

In the current study, 36.73% (18) of patients had compressed basal cistern and brain herniation while 46.94% (23) of patients had collapsed transverse diameter of third ventricle which are the signs of raised intracranial pressure on the basis of CT head. We did not perform the invasive ICP monitoring to confirm the raised ICP. The study done by sekhon et al showed that when ONSD cutoff is 6mm, it has the sensitivity of 97%, specificity of 42%, positive predictive value of 67% and a negative predictive value of 92 % in predicting ICP to be more than 20 mmHg.[16] Soldatos et al investigated ocular sonography in severe head injury patients with GCS<8.[17] Their findings indicated a 96% probability of elevated ICP when ONSD exceeded 5 mm, contrasting with a 9% probability for diameters below 5 mm. A 5.8 mm ONSD is identified as the threshold for ICP surpassing 20 mmHg, with a 90% likelihood of accurate diagnosis.[17] A prospective observational study conducted by Raffiz and Abdullah revealed that intracranial pressure exceeding 20 mm Hg had an ONSD cut off value of 5.205 mm with a sensitivity of 95.8% and a specificity of 80.4%.[18]

Our study revealed that ONSD is positively correlated with midline shift (r=0.888, p=0.01), compression of basal cistern (r=0.855, p=0.001), collapsed third ventricular diameter (r=0.866, p=0.018), brain herniation (r=0.765, p=0.03) and blood volume (r=0.901, p=0.003). These correlations revealed the utility of ONSD as a non-invasive surrogate marker for ICP monitoring in head injury patients. These findings emphasize the importance of integrating ONSD measurements into clinical practice for the comprehensive management of head injury patients, allowing for timely intervention to identify and manage the adverse effects of raised ICP. The findings showed that moderate head injury (GCS 9 to 12) have 4.42 times higher odds of having an abnormal ONSD (95% CI: 1.21 to 7.63), while patients with severe head injury (GCS 3 to 8) have even higher odds, with an odds ratio of 7.96 (95% CI: 3.72 to 12.20). The findings concluded that, as the severity of head injury increases, there is a significant increase in the ONSD measurements at the time of admission. Das et al stated that higher the ONSD, greater is the severity of traumatic brain injury. The ONSD >5.8mm indicated critical Traumatic brain Injury (TBI).[19]

In this study, ONSD was 5.24±0.86mm at admission which decreased to 4.31±0.62mm at 48 hour and 4.02±0.47mm at 1 month follow up. There was significant reduction in ONSD after conservative or surgical treatment in head injury patients (F=27.017; P =0.002). This highlights the clinical significance of monitoring ONSD in head injury patients.

The change in ONSD could serve as a non-invasive indicator of change in ICP, aiding in the management and prognosis of head injury patients. The changes in ONSD could serve as a non-invasive indicator of changes in ICP, aiding in the management and prognosis of head injury patients. The ultrasonographic measurement of optic nerve sheath diameter in critical care units serves to estimate intracranial pressure (ICP) fluctuations, validated in multiple studies, including a meta-analysis.[20]

Our findings support ONSD as a reliable, cost-effective, non-invasive, and expeditious method for ICP monitoring in patients with traumatic brain injury. Our study has advanced the existing literature by highlighting the utility of ONSD monitoring and showcasing its diagnostic value in traumatic brain injury patients. Moving forward, there is a need for further research endeavour's utilizing larger datasets and extended follow-up periods to strengthen the evidence base surrounding the use of ONSD measurement in the clinical management of traumatic brain injury patients.

LIMIITATION

This is a single centre study and sample size is also small.

CONCLUSION

Serial ultrasonography measurement of ONSD proved to be a valuable tool in monitoring intracranial pressure in patients with head injury. The study highlights the association between ONSD and CT findings suggestive of raised ICP, emphasizing the potential utility of ONSD as a non-invasive method for evaluating elevated ICP.

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