Section: Emergency Medicine

Original Research Article

STUDY OF OPTIC NERVE SHEATH DIAMETER BY BEDSIDE ULTRASOUND AS A PREDICTOR OF RAISED INTRACRANIAL PRESSURE IN HEAD TRAUMA

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ABSTRACT

Background: Traumatic Brain Injury (TBI) mostly affects children and young people and is a leading cause of morbidity and mortality globally. The most frequent causes of traumatic brain injury are road traffic accidents, assault, and unintentional falls from heights. The aim was to study the Optic Nerve Sheath Diameter (ONSD) by bedside ultrasonography as a good predictor of raised intracranial pressure in patients presenting with head trauma.

Materials and Methods: This Prospective cross-sectional study was conducted among patients with a history of head trauma in a Tertiary care hospital, Pudukkottai, for a period of 12 months. The study participants who fulfilled the inclusion and exclusion criteria were included throughout the study period. The final attained sample was 248. The demographic data, like name, age of the patient, were analysed. Then, bedside ultrasonographic measurement of Optic Nerve Sheath Diameter and Non Contrast Computed Tomography (NCCT) of brain were done. The data collected were entered in Microsoft Excel and statistical analysis was done through SPSS 23. p-value <0.05 is considered statistically significant.

Results: The most common age group was found in the 21-40 years of age group 102 (41.1%). Male predominance was observed in 211 (85.1%). Road traffic accident 228 (91.9%) was the most common mode of injury. We also observed that the mortality of the patients and decreasing GCS score were significantly increased with increased ONSD values. We also observed that the ONSD values were significantly higher as compared to the CT Brain findings in the present study.

Conclusion: We conclude that the Optic Nerve Sheath Diameter (ONSD) measurement by bedside ocular ultrasound is an effective and non-invasive method for early diagnosis of elevated Intracranial Pressure (ICP) among patients with Traumatic Brain Injury.

Keywords: Head injury, Road traffic accident, Optic nerve sheath diameter.

INTRODUCTION

Traumatic brain injury (TBI) is the term used to describe injuries to the brain brought on by a mechanical impact from the outside that results in symptoms that might be physical, cognitive, emotional, or behavioural. The severity of the injury can vary from full recovery to permanent impairment or death. TBI mostly affects children and young people and is a leading cause of morbidity and mortality globally. The most frequent causes of traumatic brain injury are assault, unintentional falls from heights, and road traffic accidents. TBI most frequently affects people between the ages of 18 and 40, with a greater percentage of men. Intoxication with alcohol contributes significantly to the occurrence of trauma.

Elevated Intracranial Pressure (ICP) in neurological and neurosurgical patients, both traumatic and non-

traumatic, can lead to significant neurological damage due to secondary brain damage. Early detection of a post-traumatic high ICP can facilitate temporary procedures and definitive treatment for patients with neurological compromise. When a post-traumatic increase in intracranial pressure is diagnosed promptly, it is crucial to start anti-oedema and anti-epileptic therapies early on. This improves cerebral perfusion, which in turn leads to favourable prognosis of patients affected by traumatic brain injury.[1,2]

The gold standard for indicating ICP increase is invasive ICP monitoring, which includes lumbar puncture (LP), epidural bolt, micro dialysis catheter, and intra ventricular catheterization. However, these methods can lead to complications such as bleeding, infection, malposition, and device malfunction. Furthermore, not all healthcare facilities have access to these devices. Non-invasive techniques have been developed for the detection of elevated ICP. Non-invasive techniques like computed tomography, fundoscopy, transcranial Doppler pulsatility index, and ultrasonography are used for monitoring intracranial pressure. CT is the most commonly used non-invasive method. The common limitations associated with CT are transportation, increased radiation exposure, time-consuming and expensive. Thus prompted research on newer diagnostic techniques to address these shortcomings.[3,4]

Fundoscopy allows detection of papilledema, which may take hours to days to develop after sustained elevation of CSF pressure, which stands for increased ICP. The transcranial doppler pulsatility index reflects a decrease in cerebral perfusion pressure due to an increase in ICP, but it is not always easy to perform, even with expert hands. Ultrasonography has become an indispensable component of the emergency department. It is also an easy-to-learn, bedside, non-invasive, and reproducible method. Point-of-care ocular sonography is a quick, cost-effective, bedside and non-invasive method for measurement of Optic Nerve Sheath Diameter (ONSD). It is preferred in instances where a CT scan is unavailable, and invasive monitoring is contraindicated. The optic nerve is a tubular structure surrounded by the same meningeal layers as the brain, with its intraorbital segment evaluable sonographically.[5,6]

Ultrasonographic measurements of the ONSD are reported as a non-invasive and bedside tool to measure elevated intracranial pressure. The optic nerve is encased in a sheath consisting of three meningeal layers, and the subarachnoid space extends with the central nervous system. So, when there is an increase in intracranial pressure, it is transmitted along the optic nerve, dilating the optic nerve sheath. Literature shows a significant association between invasive intracranial pressure measurements and ultrasonographic measurements of the ONSD. Individuals suffering from post-anoxic encephalopathy may experience cerebral edema leading to intracranial hypertension, which is linked to their poor prognosis. Therefore, neurologic outcome prediction may benefit from ultrasonographic studies of the ONSD.[6]

The present study was undertaken to measure the Optic Nerve Sheath Diameter by bedside ultrasonography and to determine the correlation between measured ONSD and CT Brain findings. The aim of the study was to assess the raised intracranial pressure with measured ONSD and to establish its relation with outcomes of the patients with Traumatic Brain Injury.

MATERIALS AND METHODS

Study Setting

The present hospital-based study was carried out by the principal investigator at the Department of Emergency Medicine, Government Medical College and Hospital, Pudukkottai.

Study design

A hospital-based analytical cross-sectional study.

Study participants

The study participants were patients who presented to the Emergency Department of Government Medical College Hospital, Pudukkottai, with a history of head trauma.

Study duration

The study was started after approval from the Institutional Ethical Committee and completed in 12 months (from February 2023).

Sample size

The sample size was calculated using the following formula: 4pq/d2. Prevalence of head trauma according to previous studies was 83 % (P); Q=17% (1-P); absolute precision 5%. Hence, the expected sample size was 248.

Inclusion Criteria

1. Patients >18 years presenting to the Emergency Department with a history of head trauma
2. Patients with a GCS ≤ 12
3. Patients with a history suggestive of increased intracranial pressure (LOC, vomiting, seizures)

Exclusion Criteria

1. Patients <18 years
2. Patients with significant ocular trauma
3. Patients with pre-existing ocular pathology
4. Patients with a history of previous ocular surgery
5. Patients on medications affecting the intracranial pressure

Procedure and Measurements

Ultrasonographic measurement of Optic Nerve Sheath Diameter (ONSD) was done using a 10–13 MHz linear ultrasound probe. All patients were examined in the supine position. Conductive ultrasound gel was placed over a closed upper eyelid without any pressure. The probe was placed on the superior and lateral aspect of the orbit. The optic nerve was visualized as a linear hypoechoic structure with defined margins posterior to the globe. The transverse ONSD was measured 3 mm

behind the retina. Based on prior literature, binocular ONSD ≥ 5.0 mm was considered raised in the studies (ONSD-positive).

Methods of Data Collection

Approval from the institutional ethics committee was obtained before undertaking the study. The study groups were identified by the above criteria (inclusion and exclusion) and informed about the nature of the study. After getting informed and written consent, detailed history taking, clinical examination, laboratory investigations, and bedside ultrasonography of Optic Nerve Sheath Diameter were done according to the study proforma. Patients admitted to TAEI ward with a history of head trauma and a GCS ≤ 12 were taken as study subjects. A complete history, clinical examination, certain relevant biochemical investigations, and bedside ultrasonography of Optic Nerve Sheath Diameter were performed.

After obtaining complete history, a complete clinical examination was performed, with particular importance to the vitals, clinical symptoms, and systemic examination as explained in the proforma. Then bedside ultrasonographic measurement of Optic Nerve Sheath Diameter was done. This evaluation was done at the emergency ward. Then, the patients were subjected to Non-Contrast Computed Tomography (NCCT) of the Brain. Patients were further followed till their stay at the hospital for further prognosis.

Ethical Considerations

The approval to conduct the present study was obtained from the Institutional Ethics Committee. Informed written consent was obtained from the patients/primary caregivers of all the study participants, after explaining the risks and benefits in a language comfortable to them. All procedures were done under the supervision of a trained and experienced guide.

Statistical Analysis

The data were collected using the proforma(enclosed), entered, and analyzed with the SPSS software version 24.0. Descriptive analysis of study variables were expressed as proportion, mean, median, and standard deviation. Chi-square test was used for non-parametric variables. The confidence level was set at 95%. A p-value less than 0.05 ($p < 0.05$) was considered statistically significant.

RESULTS

Table 1: Baseline characteristics of the study participants (n=248)

Variables	Frequency	Percentage
Age group		
≤ 20 years	20	8.1
21- 40 years	102	41.1
41- 60 years	96	38.7
> 60 years	30	12.1
Gender		
Male	211	85.1
Female	37	14.9

Figure 1: Distribution of age group among study participants (n=248)

The most common age group was found to be 21-40 years 102 (41.1%). Male predominance was observed in our study 211 (85.1%)

Table 2: Injury and associated variables details

Variables	Frequency	Percentage
Mode of Injury		
Accidental Fall from Height	15	6.0
Assault	5	2.0
Road traffic accident	228	91.9
Duration of injury		
< 6 Hrs.	237	95.6
> 6 Hrs.	11	4.4
History of alcohol intake		
No	106	42.7
Yes	142	57.3

The majority of the study participants had a road traffic accident 228 (91.9%). The majority of the study participants had a duration of injury of less than 6 hours, 237(95.6%). Alcohol intake history was present in majority of the study participants, 142(57.3%).

Table 3: Neurological symptoms among the study participants

Variables	Frequency	Percentage
Loss of consciousness		
No	**105**	**42.3**
Yes	**143**	**57.7**
Seizures		
No	**216**	**87.1**

Yes	**32**	**12.9**
Vomiting		
No	**102**	**41.1**
Yes	**146**	**58.9**

Our results showed that the majority of the study participants, 143 (57.7%), presented with loss of consciousness. Around 216 (87.1%) of the study participants had no seizures. Vomiting was present in 146 (58.9%) of the study participants.

Table 4: CT Brain findings of the study participants

CT findings	Frequency	Percentage
EDH	21	8.5
SAH	125	50.4
SDH	148	59.7
MLS	92	37.1
DCE	108	43.5
Bony Fracture	63	25.4
Corpus callosum contusion	1	0.40
Hemorrhagic contusion	82	33.1
IHB	86	34.7
ICH	7	2.8
IVH	11	4.43
Pontine contusion	2	0.81
Pneumocephalus	15	6.04
Cerebellar contusion	1	0.40
Midbrain contusion	3	1.21

Our results showed that Subdural hemorrhage (SDH) and Subarachnoid hemorrhage (SAH) were present in the majority of the study participants (59.7% & 50.4% respectively). The other common findings were Diffuse cerebral edema (DCE) (43.5%), Midline shift (MLS) (37.1%), Interhemispheric bleed (IHB) (34.7%), Hemorrhagic contusion (33.1%), and Bony Fracture (25.4%).

Table 5: Distribution of Optic Nerve Sheath Diameter among the study participants

Optic Nerve Sheath Diameter	Frequency	Percentage
≥ 5mm	233	94
< 5mm	15	6

The majority of the study participants 233 (94%), presented with optic nerve sheath diameter more than or equal to 5mm, indicating increased intracranial pressure.

Table 6: Association between Optic Nerve Sheath Diameter and outcome, Glassgow Coma Scale score and CT findings among the study participants (n=248)

	Optic Nerve Sheath Diameter		Statistical Significance χ^2; df; p-value
	≥ 5 mm	**< 5 mm**	
Outcome			
Death	**120**	**0**	**10.60; 1; 0.001***
Discharged	**113**	**15**	
Glasgow coma scale score			
Severe (≤ 8)	**99**	**0**	**10.60; 1; 0.001***
Moderate (9 - 12)	**134**	**15**	
CT findings			
Positive	**230**	**1**	**187; 1; 0.0001***
Negative	**3**	**14**	

Our results showed that among 120 patients who died during the treatment, all the patients had abnormal ONSD values (≥ 5 mm). Among the discharged patients, 113 had elevated ONSD values. We also observed that the mortality of the patients significantly increased with increased ONSD values. We also observed that the decreasing GCS scores of the patients significantly increased with increased ONSD values. Among the patients with positive CT Brain findings, 230 also had elevated ONSD values. Among the patients with negative CT findings, 14 had normal ONSD values. We also observed that the ONSD values were significantly higher compared to the CT Brain findings in the present study.

Table 7: Diagnostic parameters for optic nerve sheath diameter

Parameters	Value	95% Confidence Interval
Sensitivity	98.7%	96.2 - 99.5
Specificity	93.3%	70.1 - 98.8
Positive Predictive Value	99.5	97.5 - 99.2
Negative Predictive Value	82.3	58.9- 93.8
Diagnostic Accuracy	98.3%	95.9 - 99.7
The Likelihood ratio of a Positive Test	14.8	2.085 - 105.1
The Likelihood ratio of a Negative Test	0.013	0.0071 - 0.02678

Diagnostic Efficacy

The Sensitivity was 98.7% (95% CI: 96.2 - 99.5). The Specificity was 93.3% (95% CI: 70.1 - 98.8). The Positive Predictive Value was 99.5 (95% CI: 97.5 - 99.2). The Negative Predictive Value was 82.3 (95%CI: 58.9- 93.8). The Diagnostic Accuracy 98.3% (95% CI: 95.9 - 99.7). The Likelihood ratio of a Positive Test was 14.8 (95% CI: 2.085 - 105.1). The Likelihood ratio of a Negative Test was 0.013 (95% CI: 0.0071 - 0.02678).

Table 8: Area under the ROC curve (AUC)

The Area under the ROC curve (AUC)	**0.99**
Standard Error [a]	0.01
95% Confidence interval [b]	0.97 to 1.0
Significance level P (Area=0.5)	**<0.0001**

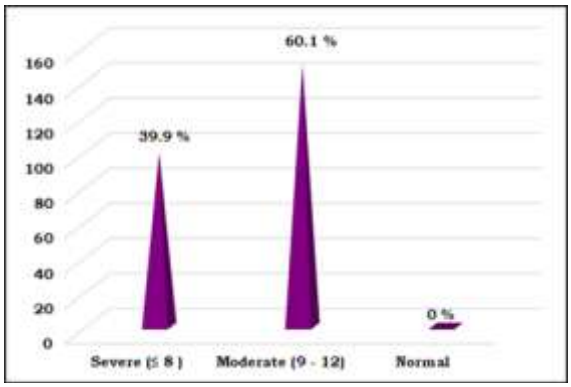

Figure 1: Glasgow coma scale score among the study participants (n=248)

The majority of the study participants had a GCS score of 9-12 149 (60.1%).

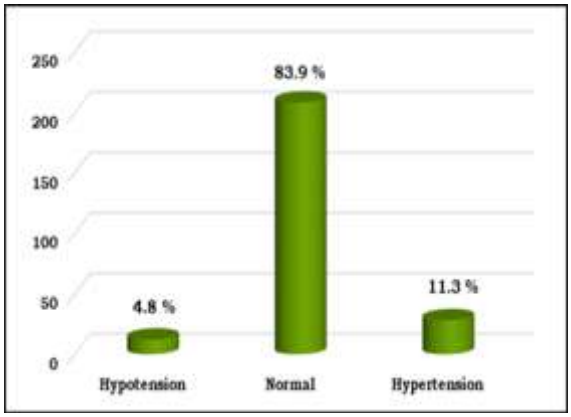

Figure 2: Distribution of blood pressure among the study participants (n=248)

The majority of the study participants, 208 (83.9%) in our study had normal blood pressure.

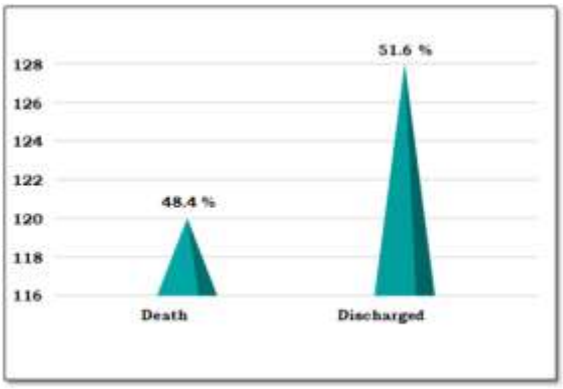

Figure 3: Outcome of the study participants (n=248)

In our study, 138 (51.6%) patients were discharged after treatment, while 120 (48.4%) died during the treatment. (Table 6 & Fig 3).

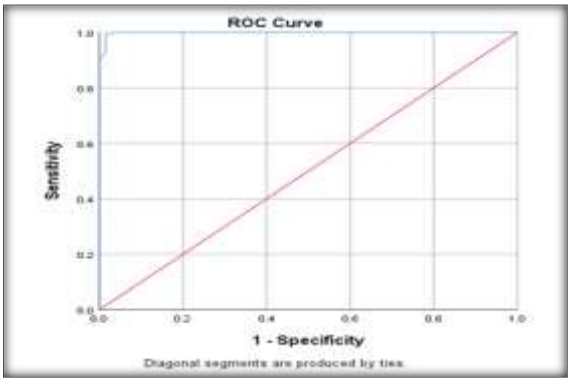

Figure 4: Receiver Operating Curve

DISCUSSION

In the intensive care units all over the world, Traumatic Brain Injuries contribute significantly to the patient load. Increased intracranial pressure management plays a vital role in the management of Traumatic Brain Injury, hence it requires monitoring

of the same. The optic nerve is contained within the fluid-filled Optic Nerve Sheath (ONS) that is connected to the fluid-filled spaces inside and around the brain. Whenever there is an increase in the intracranial pressure, more fluid enters the sheath, thereby increasing its diameter. This Optic Nerve Sheath Diameter (ONSD) can be measured with an ultrasound exam of the eye.

Socio-demographic characteristics

In the present study, we observed an increased male predominance (85.1%). Mahmoud et al[7] in their study in Egypt, reported that 78% of their study subjects were males. Kshirsagar et al[9] in their study observed that the male-to-female ratio was 2:1 among patients with traumatic brain injury in India. In our study, the most common age group affected was 21-40 years (41.1%). Jagoda et al[8] have also reported that Traumatic Brain Injury occurs predominantly among males in the 2nd to 4th decade. Males in their middle years are the most often involved in trauma cases because they tend to engage in high-risk behaviours like speeding and driving without using any safety gear, which increases the likelihood of motorbike accidents and the resulting financial burden on the community.

Injury

The majority of the study participants had a road traffic accident 228 (91.9%) followed by accidental fall from a height 15 (6 %). Mahmoud et al [7] reported that the most common mode of trauma was road traffic accident, followed by fall from height. Agrawal et al [10] had also reported that the most common mode of trauma was motor vehicle collision (81%), followed by fall from height (19%). The increased incidence of road traffic accidents can be attributed to rapid modernization, better roads, and high-speed vehicles in the market.

Glasgow Coma Scale (GCS)

The majority of the study participants, 149 (60%) had a Glasgow coma scale between 9 and 12, indicating moderate traumatic brain injury, and 99 participants (39.9%) had a GCS score of ≤ 8, indicating severe traumatic brain injury. Canakci et al [11] stated that a significant drop in GCS was seen in patients with increased ICP. Altayar et al [12] reported that GCS values were lower in patients with positive CT criteria for high ICP, but no statistical significance was observed. Mabrouk et al [13] observed significantly lower GCS in patients (65% with severe traumatic brain injury) with increased ONSD. Mahmoud et al [7] had also observed a significant inverse correlation between the mean ONSD and the GCS of patients. In concurrence, we also observed that the decreasing GCS scores of the patients significantly increased with increased ONSD values.

Clinical features

The clinical features we evaluated in the present studies were loss of consciousness, seizures, and vomiting. Mahmoud et al [7] in their study observed that altered mental status, abnormal posturing, unequal dilated and fixed pupils, and Cushing's triad were commonly presenting clinical features. Studies by Mabrouk et al [13] and Tarzamni et al [14] revealed that clinical features had poor diagnostic parameters (low and specificity) for diagnosis of increased ICP. Amini et al [15] also concluded that physical examination alone was not an acceptable indicator to identify elevated ICP because of low sensitivity, specificity, and diagnostic accuracy.

Computerized Tomography findings

We used CT brain as the gold standard for the diagnosis of elevated ICP. We observed that Subdural Hemorrhage 148 (59.7%), Subarachnoid Hemorrhage 125 (50.4%) and Midline Shift 92 (37.1%) were the common findings in CT brain. In our study, we also observed that 108 participants (43.5%) had Diffuse Cerebral Edema, 63 participants (25.4%) had Hemorrhagic contusion, and 82 participants (33.1%) had bony fractures. Qayyum et al [16] reported the commonest CT Brain findings were extradural hemorrhage, subdural hemorrhage, subarachnoid hemorrhage, hemorrhagic contusion, and/or skull bone fractures. Qayyum et al [16] observed sulci effacement (87%), and Midline Shift (29%). Mahmoud et al [7] and Mabrouk et al [13] documented that the common findings were ventricles compression, sulci effacement (77.5%), cisterns compression, loss of grey/white matter differentiation (80%) and midline shift (65%).

Optic Nerve Sheath Diameter (ONSD)

In our study, we observed that the majority of the study participants 93.9% who presented to the Emergency Department with head trauma had Optic Nerve Sheath Diameters more than or equal to 5mm. Among them, 51.5% participants died during their course in the hospital. Kshirsagar et al [9] reported that increased ONSD was observed among 79% of the study participants. Mabrouk et al [13] observed that the cutoff value of ONSD for diagnosing increased ICP as more than or equal to 4.95 mm. Mabrouk et al [13] also reported that the ONSD was significantly higher among patients with increased ICP as compared to patients with normal ICP.

Computerized Tomography or Optic Nerve Sheath Diameter – Diagnostic Parameters

Mahmoud et al [7] reported that ONSD was an effective tool in diagnosing elevated ICP (> 5 mm). They documented that the sensitivity was 100 %, specificity was 96%, PPV was 100%, NPV was 98.04%, AUC of 0.99, and diagnostic accuracy of 99%. We also observed that the ONSD values were significantly higher compared to the CT findings in the present study. The participants, other than ONSD positives had a lower mean binocular ONSD (4.5 ± 0.22 mm). In our study, we have reported that the Sensitivity was 98.7% (95% CI: 96.2 - 99.5). The Specificity was 93.3% (95% CI: 70.1 - 98.8). The Positive Predictive Value was 99.5 (95% CI: 97.5 - 99.2). The Negative Predictive Value was 82.3 (95%CI: 58.9- 93.8). The Diagnostic Accuracy was 98.3% (95% CI: 95.9 - 99.7) for ONSD when

used as a diagnostic tool to detect raised intracranial pressure.

CONCLUSION

We conclude that the Optic Nerve Sheath Diameter (ONSD) measurement by bedside ocular ultrasound is an effective and non-invasive method for early diagnosis of elevated intracranial pressure among patients with Traumatic Brain Injury. Though inter-observer variability in assessments may be considered as a potential setback, it can be reduced by practice and training. Larger studies with a longer follow-up period would provide detailed information to establish consistent techniques and a range of normal ONSD values.

Limitations of the study: The limitations of the study were the study design - a cross–sectional study, a smaller sample size, and a single-centre study. So the results cannot be generalised.

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Conflict of Interest: Nil

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