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Research Article

The Role of Bedside Optic Nerve Sheath Diameter in Prognosticating Mortality in Head Injury

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Abstract

Objective: To assess the role of optic nerve sheath diameter (ONSD) in predicting mortality, with the goal of reducing overall mortality through early recognition and appropriate interventions.

Design: Prospective study.

Methodology: A study of 180 head injury cases was conducted at a tertiary care hospital over one year to evaluate various ocular manifestations. The Glasgow Coma Scale (GCS) was used to assess head injury severity. Bed side ocular examination and ONSD measurements in primary gaze and in supine position using USG B-scan were obtained. Statistical analysis was done using the chi-square test and descriptive statistics. Ocular neurological signs, ONSD values, and GCS scores were correlated with survival outcomes.

Outcome Measures: In this study of 180 head injury patients, 91.11% had ocular involvement. Most patients were male (88.33%) and between 21-30 years old. Road traffic accidents (81.11%) were the leading cause of injury. Cranial nerve palsies, notably third nerve palsy (2.22%), and pupillary abnormalities (29.44%) were observed. Glasgow Coma Scale (GCS) scores, and optic nerve sheath diameter (ONSD) ≥5mm significantly ($P < 0.0001$ for each) correlated with mortality.

Conclusions: Ocular manifestations were present in 91.11% of head injury cases. An ONSD ≥5 mm was highly associated with mortality. Increased ONSD could serve as a surrogate bedside measure of prognosis and survival in patients of head injuries.

Keywords: Glasgow Coma Scale; Head Injury; Optic Nerve Sheath Diameter; Mortality Prediction

Abbreviations

CLW: Contused Lacerated Wound; CPP: Cerebral Perfusion Pressure; CSF: Cerebro Spinal Fluid; CT: Computed Tomography; GCS: Glasgow Coma Scale; ICP: Intra Cranial Pressure; IH: Intracranial Hypertension; MRI: Magnetic Resonance Imaging; ONSD: Optic Nerve Sheath Diameter; RAPD: Relative Afferent Pupillary Defect; RTA: Road Traffic Accident; RTS: Revised Trauma Score; TBI: Traumatic Brain Injury; USG: Ultra Sonography

Introduction

Traumatic brain injury (TBI) is a significant global health concern, with an estimated incidence of 939 cases per 100,000 people annually, affecting millions worldwide [1]. India bears a particularly heavy burden, with over one million serious head injuries reported annually [2]. Ocular complications in TBI are common, occurring in 25% to 83% of cases, and can be vision-threatening in severe instances [3-6]. The prompt recognition of ocular manifestations is vital, not only for preserving vision but also for assessing neurological damage. Studies show that a higher incidence of ocular findings is observed when ophthalmologists are actively involved in trauma care, highlighting the importance of comprehensive ophthalmic assessments in TBI management [4].

Severe TBI is often associated with elevated morbidity and mortality rates, with nearly 40% of survivors experiencing long-term disabilities. Moreover, fewer than half of the affected individuals achieve favourable neurological outcomes after one year [7,8]. Several prognostic factors, including age, gender, injury severity, Glasgow Coma Scale (GCS) score, motor response, pupillary reactivity, type of brain lesion, and elevated intracranial pressure (ICP), influence the outcome in TBI patients [9,10].

One of the most critical prognostic indicators in severe TBI is elevated ICP, which is closely linked to poor outcomes, including death. Cerebral oedema, a common cause of intracranial hypertension (IH), affects more than 60% of patients with intracranial haemorrhage and can even develop in 15% of patients with initially normal CT scans. Left untreated, increased ICP can lead to a reduction in cerebral perfusion pressure (CPP), resulting in cerebral ischemia, brain herniation, and, ultimately, death [11]. Early recognition and intervention for elevated ICP significantly improve the prognosis in TBI patients.

While invasive ICP monitoring techniques, such as intraventricular catheter placement or craniotomy, are considered the gold standard, they carry substantial risks, including infection and haemorrhage [12]. This has driven the search for reliable, non-invasive alternatives that can provide early indicators of elevated ICP without these complications.

Optic nerve sheath diameter (ONSD) measurement, using ocular sonography or CT imaging, has emerged as a promising, non-invasive method for monitoring ICP. The optic nerve sheath, connected to the subarachnoid space, dilates in response to elevated ICP, allowing for indirect measurement of ICP through ONSD. (13) Studies have demonstrated a strong correlation between increased ONSD and elevated ICP, making it a valuable tool for real-time, non-invasive monitoring [13]. Given its practicality, ONSD measurement could serve as an essential bedside tool in emergency settings.

This study aims to investigate whether ONSD can serve as a predictor of hospital mortality in the absence of ICP monitoring. By identifying early signs of raised ICP through non-invasive ONSD measurements, clinicians can intervene promptly, potentially improving outcomes and reducing mortality in TBI patients.

Materials and Methods

This study comprises 180 cases of head injury treated at the emergency department of a tertiary hospital over 1 year. After receiving approval from the ethics committee and obtaining written consent from patients, including consent for photographs, those with ocular morbidity were evaluated based on age, sex, mode of injury, Glasgow Coma Score (GCS), and associated injuries. Clinical details, including name, age, sex, and address, were documented. The exact mode of injury, type of object involved, and the duration of injury were also recorded.

Ocular examinations included bedside visual acuity assessments, along with a thorough systemic examination to evaluate the severity of head injuries according to the GCS scale, as outlined in the Advanced Trauma Life Support: Course for Physicians (American College of Surgeons, 1993). Pupillary signs were given special importance in determining the level of consciousness and life prognosis. Imaging studies included ultrasonography (USG) of the eye with B-scan to assess optic nerve thickness. In this procedure, a linear probe (7-12 MHz) was applied to the closed upper eyelid of supine patients in primary gaze, using adequate aqueous gel as a coupling agent. In cases where extreme gaze deviations occurred, the lateral axial view was utilized if other views failed. Since the most distensible part of the optic nerve sheath is located approximately 3mm behind the vitreo-retinal interface, optic nerve sheath diameter (ONSD) was measured at this level, perpendicular to the axis of the nerve, using a Philips Affinity series machine. [14] The average of bilateral ONSD measurements was calculated for each patient to assess raised intracranial pressure.

Follow-ups were conducted at the first, second, and third weeks, where any improvement or deterioration in the general condition and ocular findings were noted based on visual acuity, pupillary reactions, and ocular movements. The data, including cause, effect, and outcome, were statistically analyzed for significance using the Chi-Square Test, Frequency, and Percentage methods.

Results and Discussion

Results

This study analyzed 180 head injury patients, of which 159 (88.33%) were males and 21 (11.67%) were females, with a male-to-female ratio of 7.57:1. The most common cause of injury was road traffic accidents (81.11%), followed by assaults (7.78%), falls from heights (5%), and other causes such as falls in bathrooms (6.11%). Statistical analysis revealed that the correlation between male gender and road traffic accidents as the cause of head injury was not significant ($\chi2 = 1.88$, $P = 0.16$) (Table 4).

The severity of head injuries varied, with 76.11% classified as mild (GCS 13-15), 2.78% as moderate (GCS 9-12), and 21.11% as severe (GCS ≤8). Ocular and visual complications were present in 91.11% of cases. The most frequent ocular findings were lid edema (85.56%) and ecchymosis (76.11%), (Table 1). Cranial nerve palsies occurred in 6 patients (3.34%), with third nerve involvement being the most common, found in 4 cases (2.22%), (Table 1) (Figure 2). Pupillary abnormalities were observed in 53 cases (29.43%), with relative afferent pupillary defect (RAPD) present in 17 patients (9.44%), (Table 1). Bilateral dilated fixed pupils were seen in 4.44% of cases (Table 1).

Posterior segment manifestations were found in 12 cases (6.67%), with papilloedema being the most common (3.33%), (Table 1), all of which had optic nerve sheath diameters (ONSD) of ≥5mm. Retinal haemorrhage was present in 4 cases (2.22%), and vitreous haemorrhage and macular oedema were rare, found in 1 case each (0.56%), (Table 1). Optic nerve thickness measurements via USG B-scan revealed that 31 patients had an ONSD ≥5mm (17.2%) while 82.2% had ONSD <5mm (Table 2).

In severe head injuries (GCS ≤ 8) 89.47% were associated with ocular manifestations. All 11 patients with a GCS ≤ 3 exhibited ocular manifestations as well. Among patients with moderate head injuries (GCS 9-12), 80% exhibited ocular manifestations. In patients with mild head injuries (GCS 13-15) 91.97% had ocular manifestations but had a favourable prognosis. Additionally, the relationship between GCS score and pupil abnormality was highly significant ($\chi2 = 25.22$, $P < 0.00001$) (Table 4).

Correlation with mortality

Severe head injuries (GCS ≤ 8) were significantly associated with increased mortality. All 11 patients with a GCS ≤3 had a 100% mortality rate, indicating a poor prognosis. Among patients with moderate head injuries (GCS 9-12), 20% succumbed. In contrast, patients with mild head injuries (GCS 13-15) had a favourable prognosis, with no deaths reported.

There was a correlation between ONSD ≥5mm and mortality ($\chi2 = 41.67$, $P < 0.0001$), (Table 4). Also pupillary abnormalities were observed in 29.43% cases, with relative afferent pupillary defect (RAPD) present in 9.44% cases, 17.65% of whom died. Bilateral dilated fixed pupils were seen in 4.44% of cases and all these cases were associated with poor prognosis. The relationship between pupil abnormalities and mortality was also highly significant ($\chi2 = 21.26$, $P < 0.0001$), (Table 4).

Ocular Manifestations	No. of Cases (Percentage)	
Lid Edema	154	85.56
Ecchymosis	137	76.11
Ptosis	4	2.22
Lagophthalmos	1	0.56
CLW from Eyebrow to Lower Lid	27	15.00
Sub conjunctival Haemorrhage	122	67.78
Chemosis	112	62.22
Corneal Epithelial Defect	26	14.44
Corneal Perforation	1	0.56

Hyphema	2	1.11
Cranial Nerve Palsies	6	3.34
3rd cranial nerve palsy	4	2.22
6th cranial nerve palsy	1	0.56
7th cranial nerve palsy	1	0.56
Pupillary Involvement	53	29.44
Relative Afferent Pupillary Defect	17	9.44
Bilateral Sluggish Reaction to Light	15	8.33
Unilateral Dilated Fixed	13	7.22
Bilateral Dilated fixed	8	4.44
Posterior Segment Involvement	12	6.67
Papilloedema	6	3.33
Retinal Haemorrhage	4	2.22
Vitreous Haemorrhage	1	0.56
Macular Oedema	1	0.56
Orbital Wall Fractures (isolated and multiple)	73	40.56
Lateral	42	23.33
Superior	30	16.67
Medial	21	11.67
Inferior	18	10.00

Table 1: Ocular manifestations.

Optic Nerve Thickness (mm)	Number of Cases	Percentage
≥ 5mm	31	17.32%
< 5mm	148	82.68%
Total	179	

Table 2: Optic Nerve Thickness Measurements in USG B Scan.

	Correlation of GCS Score and ONSD value		
GCS score group	**Cases with ONSD >/5mm**	**Cases with ONSD<5mm**	**Total**
GCS</8 (Severe)	16	22	38
GCS 9-12 (Moderate)	1	4	5
GCS 13-15 (Mild)	14	122	136
	31	148	179

Table 3: Correlation of GCS and OSND.

One patient had a globe rupture, so a USG B scan could not be performed.

Correlation between Variables	Chi-square value (χ2)	P value	Significance
Correlation Between Male Sex and RTA as Cause of Injury.	1.88	0.16	Not significant
Correlation Between Orbital Wall Fractures and Mortality.	3.85	0.04	Significant
Correlation Between Pupil Reaction Abnormality and Mortality.	21.26	< 0.0001	Highly significant
Correlation Between USG B SCAN (ONSD) Value >/=5 and Mortality.	41.67	< 0.0001	Highly significant
Correlation Between GCS Score and Pupil Abnormality.	25.22	< 0.00001	Highly Significant
Correlation Between different Age group and USG B SCAN (ONSD) Value.	6.087	0.4135	Not significant
Correlation Between Gender and USG B SCAN (ONSD) Value.	1.20	0.273	Not significant
Correlation Between GCS Score </8 and USG B SCAN (ONSD) Value >/5mm.	20.92	<0.001	Highly Significant

Table 4: Correlation between select variables and mortality.

Discussion

In our study on ocular manifestations of head injury, the majority of patients were between the ages of 21-30 (31.11%) and 31-40 (25.00%), aligning with findings by Sahasrabudhe., et al. and Kumari., et al. [15,16]. The most vulnerable group for head injuries was young adults, peaking in the second and third decade of life, likely due to increased exposure to risky environments such as outdoor work, travel, and assault. Elderly patients (>60 years) and young children (<10 years) accounted for significantly fewer cases, which also corresponded with these studies, [15,16].

Ocular involvement was seen in 91.11% of cases, reaffirming its frequent association with head injuries, consistent with Sahasrabudhe's findings (78%), [15]. Overall, our study highlights the significant link between head trauma and ocular manifestations, especially in young adults involved in vehicular accidents.

The risk of increased intracranial pressure (ICP) in traumatic brain injury is associated with higher mortality rates [17]. Various techniques are available for diagnosing ICP, each with its own challenges. For instance, intracranial catheters can lead to complications such as coagulopathy or thrombocytopenia [18]. While computed tomography (CT) scans provide valuable diagnostic information, they are invasive and involve exposure to ionizing radiation [19]. Additionally, CT scans may not be readily accessible in all settings and can present feasibility challenges for bedridden patients [20].

Studies from various regions have shown a strong correlation between changes in optic nerve sheath diameter (ONSD) and CT scan findings, indicating an increase in ICP [21-24]. Although the ultrasonic method is commonly used for daily measurement of ONSD to assess ICP, there is currently no established threshold for the optic nerve sheath diameter that reliably indicates elevated ICP [25,26]. Previous research has reported that ultrasound measurements typically range from 4.7 to 5 mm [27,28]. A cut-off point of 5 mm has often been considered indicative of increased ICP [27,29,30]. However, other studies suggest that a diameter greater than 5.5 mm may be a more reliable predictor of elevated ICP [31].

We found raised ONSD in 17.32% of patients, (Table 2) with a mean ONSD of 5.25 mm for measurements ≥5.0 mm and 3.83 mm for measurements <5.0 mm. ONSD ≥5.0 mm was considered a surrogate marker for early increased intracranial pressure. In contrast to our observation, Kaur., et al. reported raised ONSD in 46% of their cohort, with mean ONSD values of 5.6 mm and 4.1 mm, respectively, [32]. This difference could be attributed to variations in patient demographics, clinical conditions, or methodologies used between the studies.

Our study revealed a significant increase in ONSD with lower GCS scores (3-8), consistent with Kaur., et al. findings and a highly significant correlation (P-value = 0.000) (Table 3,4). This supports ONSD as an indicator of elevated ICP. However, the lower proportion of raised ONSD in our study may reflect differences in patient ICP levels or selection criteria. We could not assess the 30-degree test, a more reliable ONSD assessment tool, in most of the patients as the patient could not comprehend due to the neurological involvement or restricted movement of the eye.

Both our study and Kaur., et al. found no significant relationship between age or gender and ONSD measurements, (Table 4) This consistency suggests that ONSD is a reliable indicator of ICP irrespective of these demographic factors, making it broadly applicable across diverse patient groups.

Our study recorded a maximum ONSD of 5.80 mm, slightly lower than Kaur., et al. 5.9 mm. These discrepancies might arise from variations in imaging techniques, measurement protocols, or patient characteristics. Standardizing measurement practices could help reconcile these differences.

Conclusion

This study underscores the high prevalence of ocular manifestations in patients with head injuries, emphasizing the critical role of optic nerve sheath diameter (ONSD) measurements in detecting elevated intracranial pressure (ICP) and their significant correlations with ocular signs, Glasgow Coma Scale (GCS) scores, and mortality. The notable relationship between ONSD and GCS in our findings supports the use of ONSD measurements for evaluating ICP in neuro - trauma patients. Given its non-invasive nature, ONSD measurement serves as a valuable tool for quick assessment.

The observed variations in prevalence and maximum ONSD readings compared to existing literature highlight the necessity for further research to standardize methodologies and validate findings across different clinical contexts. This study suggests that ultrasound is a safe and effective method for detecting increased ICP due to trauma, boasting high diagnostic accuracy. The ease of use of this test can facilitate timely diagnoses, potentially reducing the risk of mortality. Furthermore, ultrasound offers a cost-effective alternative to other diagnostic methods, including CT scans, particularly for patients in unstable conditions who cannot be safely transferred from the emergency department.

There is growing interest in non-invasive ICP measurement, with ONSD increasingly recognized as an important metric in this domain. Nonetheless, ONSD measurements are susceptible to various artifacts, and definitive criteria for interpretation remain to be established.

Limitations

The limitations of the study include the fact that no comparison of the ultrasound evaluation of the optic nerve thickness with CT scan/ MRI scan was done as they have the advantage of less operator bias. Also the measurement of the optic nerve on the ultrasound was calculated as the average of the two optic nerves and analysis of individual optic nerve thickness and its correlation with mortality was not done. In spite of these limitations, the strength of this study is the large study population and its prospective nature.

Photographic examples of patients to exhibit various conditions.

Figure 1: Right Eye: Lagophthalmos on closure of eyes in patients with 7th nerve palsy.

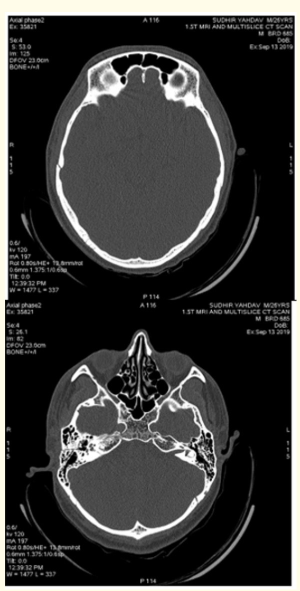

Figure 1(a): CT head and MRI of the same patient showing fracture of squamous part of right temporal bone extending to the petrous part of the right temporal bone.

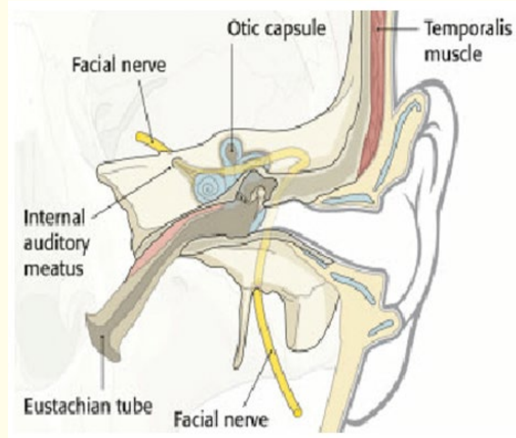

Figure 1(b): Mechanism of 7th nerve palsy resulting from fracture of petrous part of the temporal bone causing injury to tympanic part of the 7th nerve.

Figure 2: Right third nerve palsy with ptosis due to right temporal lobe contusion with pneuomocephalus.

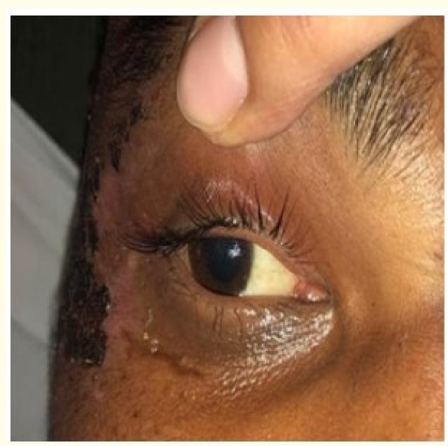

Figure 2(a): Same patient with right lid elevated showing exodeviation with traumatic mydriasis of right eye due to third nerve palsy.

Figure 3: Showing right eye traumatic mydriasis with right lower lid tear on lateral aspect.

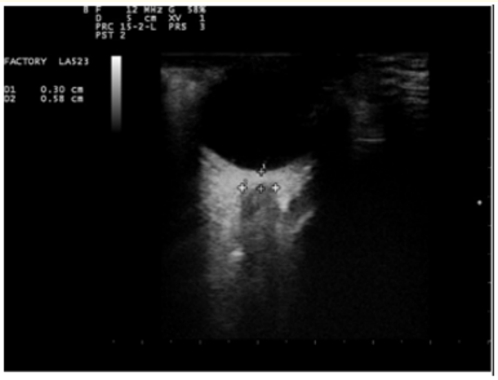

Figure 4: USG B scan of this patient showing optic nerve sheath diameter 5.8mm.

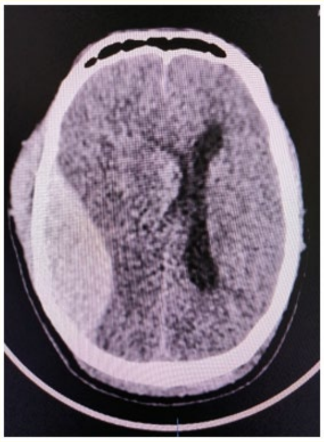

Figure 4(a): CT scan of the same patient showing a large lenticular-shaped hyperdensity in the right parietal region in the extradural location, causing a significant midline shift towards the left side, suggestive of an extradural haemorrhage. A hypodensity is noted in the right parietal lobe adjacent to the above-mentioned hyperdensity, suggestive of brain edema.

Conflict of Interest

No authors have any proprietary interest.

The authors declare that they have no competing interests.

None of the authors has any conflicts of interest to disclose.

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