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Correlation of optic nerve sheath diameter (ONSD) assessed by computed tomography (CT) with Glasgow coma scale (GCS) in patients with traumatic brain injury in tertiary care hospital of Nepal

Pooja Jaiswal[1], Sudeep KC[2], Shreejana Shrestha[1], Yogita Dwa[3], Sharad Baral[4]

[1]Assoc. Prof., [2]Lecturer, [3]Asst. Prof., [4]Resident, Dept. of Radiology & Imaging, Patan Hospital, Patan Academy of Health Sciences, Lalitpur, Nepal

Abstract

Introduction: The optic nerve sheath, an extension of the dura mater and subarachnoid space filled with cerebrospinal fluid (CSF), connects to the CSF area around the optic nerve. Increased CSF pressure from brain edema can enlarge the sheath. The diameter of the optic nerve sheath (ONSD) remains consistent across different ages, genders, and anatomical locations. Intracranial injuries can worsen clinical conditions, leading to significant morbidity and mortality if not treated. Neurological conditions can be assessed using the Glasgow Coma Scale (GCS) or imaging techniques like CT or MRI, which have their limitations. Evaluating ONSD is a simple, safe, cost-effective, and non-invasive way to track changes in intracranial pressure (ICP).

Method: This cross-sectional, prospective study was done in Department of Radiology, Patan Hospital, Patan Academy of Health Sciences after obtaining ethical clearance. Computed Tomography of patients referred for head injury between 2025 Feb to 2025 Jun were analyzed. Statistical analysis was performed using SPSS v20.

Result: Out of the 55 patients included in data analysis, 37 were males and 18 were females. Majority (65%) belonged to middle age group (20–50 years), with the mean age of 44 years. Significant association was observed between baseline ONSD and GCS.

Conclusion: This study found a significant association between ONSD measured by CT and GCS scores in patients with traumatic brain injury. Higher ONSD values were associated with lower GCS scores, indicating that ONSD can serve as a reliable, non-invasive marker for elevated intracranial pressure and severity of brain injury.

Keywords: Computed Tomography; Glasgow Coma Scale, Optic Nerve Sheath Diameter; Traumatic Brain Injury

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Correspondence: Dr. Pooja Jaiswal, Dept. of Radiology & Imaging, Patan Hospital, Patan Academy of Health Sciences, Lalitpur, Nepal. **Email:** poojajaiswal@pahs.edu.np

Introduction

Traumatic brain injury (TBI) is a serious health problem which can cause mortality and disability. The global burden of TBI has increased in recent years as prevalence rates increased by 8.4% between 1990 and 2016.[1] The Glasgow Coma Scale (GCS) is a widely used clinical tool for initial evaluation of patients with traumatic brain injury (TBI) and predicting patient outcomes.[2] Elevated Intra cranial pressure (ICP) is a critical factor in TBI prognosis and may have devastating effects on patient mortality and neurologic outcomes, yet its initial detection remains difficult.[3]

Different imaging biomarkers such as midline shift, cerebral edema, intracranial hemorrhage and optic nerve sheath diameter are being used for diagnosing, monitoring, and prognosticating neurological conditions, including TBI.[4] Brain Computed Tomography (CT), a rapid and noninvasive tool in head traumas, can be used for the indirect measurement of increased ICP and therefore provides significant information about the prognosis.[5] The optic nerve sheath is anatomically continuous with the subarachnoid space and its diameter can reflect changes in intracranial pressure (ICP).[6] This study aims to evaluate Optic Nerve Sheath Diameter (ONSD) as a reliable surrogate imaging biomarker for GCS scoring and provide a non-invasive method for early detection of elevated ICP in TBI patients which would ultimately enhance the diagnostic and prognostic capabilities of clinicians managing TBI patients.[7,8] This would especially be useful in settings where invasive ICP monitoring is not feasible and GCS scoring has limitations such as in intubated, sedated patients or elderly patients.[7,8]

Method

This observational prospective study was conducted in the Department of Radiology, Patan Hospital from 2025 Feb to 2025 Jun after ethical clearance of the institutional review committee (IRC) of Patan Academy of Health Sciences (PAHS) (Ref: drs2502141984). Total of 55 patients were included in the study based on inclusion and exclusion criteria using a convenient sampling method.

Informed consent was taken from the patients before including them in the study. All patients with TBI over the age of 18 years who visited and were evaluated with a GCS score at the emergency department (ED) and had undergone CT within 6 hours were included in the study. Patients who had no cranial CT within the first 6 hours of trauma, the presence of facial trauma affecting the orbital structure and/or eyeball, and patients with ocular disease affecting the optic nerve and/or orbital cavity, hyperthyroidism accompanying exophthalmos, and age below 18 years were excluded from the study.

GCS assessment was done at the time of presentation to the ED by the on-duty doctor and was sent for CT scan of the head. Consent for inclusion of the patient for research was taken at the time of the CT scan. The severity of the patient was graded according to the GCS score. GCS 13–15 as mild Brain Injury, GCS 9–12 as moderate brain Injury and GCS 3–8 as severe Brain Injury: Patients undergoing CT of head were scanned with Philips Ingenuity 128 Slice CT in Department of Radiology in coronal, axial, and sagittal planes by the radiology technician as per the standard protocol. All scans were performed using a 128-Slice Volume CT Scanner, with a multidetector CT using 1.25 mm collimation and 0.8 mm reconstruction interval, 140 kVp, and average 300mA tube current with a pitch of 1.375. Scans were routinely performed in supine position. Multiplanar reformation (MPR) images and axial images were obtained. Acquired raw data were processed in a workstation and images were evaluated in Philips Portal software version 11.

ONSD was measured at a distance of 3 mm behind the eyeball, immediately below the sclera. ONSD was measured from one side of the optic nerve sheath to the other as a section through the centre of the optic nerve. The diameters measured for the patient's left and right eyes were averaged to yield the mean value.

For measuring midline shift, displacement of the septum pellucidum by more than 5 mm from the midline on axial CT images was taken as significant. For assessing cerebral Edema, hypoattenuation in the visible brain parenchyma and loss of differentiation between gray and white matter were considered. Any type of hyperdense acute hematoma (e.g., epidural, subdural, intracerebral) was identified and classified.

Data Entry was done in Microsoft Excel 2016. The collected data were analyzed with IBM SPSS Statistics software version 20. Descriptive analysis was carried out by frequency and proportion for categorical variables. Fisher's exact test was used for the association of GCS with various neuroimaging biomarkers. A 95 % confidence interval was taken and p p-value <0.05 was considered statistically significant.

Result

A total of 55 patients were selected. Among them, there were 37(67.23%) were males and 18(32.73%) were females, Table 1. Among these patients, the mean age was .40 ± 16.10(22.00, 85.00) years, Table 1.

Table 1. Distribution of GCS scores among the patients (N=55)

Characteristics		n(%)
Sex	Female	18(32.73%)
	Male	37(67.23%)
	Total	55(100.0%)
Age (years)	Mean ± SD (min, max)	44.40 ± 16.10 (22, 85)

49 ± 0.87 (2.60, 5.70). Increased ONSD was seen in 19(34.55%) patients whereas midline shift was seen in 10(18.18%), cerebral edema in 24(43.64%) and intracranial hemorrhage in 30(54.55%), Table 2.

Table 2. Proportion of different neuroimaging markers among the patients of traumatic brain injury (N=55)

Neuroimaging markers	n(%)
Increased ONSD	
Yes	19(34.55%)
No	36(65.45%)
ONSD (mm)	Mean ± SD (min, max)
	4.49 ± 0.87 (2.60, 5.70)
Midline shift	
Yes	10(18.18%)
No	45(81.82%)
Cerebral oedema	
Yes	24(43.64%)
No	31(56.36%)
Intracranial hemorrhage (ICH)	
Yes	30(54.55%)
No	25(45.45%)
Total	**55(100.00%)**

The majority of the CT brain scans revealed traumatic subarachnoid hemorrhage, extradural hematoma and intraparenchymal hemorrhage, followed by subdural hematoma, which was seen in five (16.7%). Extradural hematoma, subarachnoid hemorrhage, and intraparenchymal hemorrhage was seen equally in seven (23.33%), Table 3.

Majority of the patients, 26(47.27%) have mild GCS score, followed by moderate 15(27.27%) and severe 14(25.45%), Table 4. Cerebral edema was most prevalent in patients with severe GCS score 11(78.57%), followed by moderate GCS score 12(80%) and mild GCS score one (3.8%)%, p<0.001). Midline shift was observed in 10(18.18%) of patients, six (42.86%) were those having severe GCS, while four (26.67%) with moderate GCS, Table 4.

No midline shift was seen in the mild GCS score. The mean midline shift was significantly greater in the severe group 4.35±5.2 mm, p<0.001, followed by moderate 2.33±4 mm, Table 5.

Optic nerve sheath diameter (ONSD) was not increased in 36(65.45%) patients, entirely among those with mild GCS scores 26(100%). In contrast, increased ONSD was noted in 13(92.86%) patients with severe GCS scores and six (40%) patients with moderate scores. Mean ONSD differed significantly across GCS groups (p<0.001), with the highest mean values in the severe group, 5.29±0.2 mm, followed by moderate, 5.02±0.3 mm, and mild injury, 3.75±0.7 mm, Table 5.

Table 3. Types of Intracranial Hemorrhage (N=30)

Types	n(%)
Extradural hematoma (EDH)	7(23.33%)
Subarachnoid hemorrhage (SAH)	7(23.33%)
Intraparenchymal hemorrhage (IPH)	7(23.33%)
Subdural hematoma (SDH)	5(16.67%)
Intraparenchymal hemorrhage (IPH) and subarachnoid hemorrhage (SAH)	3(10.00%)
Subarachnoid hemorrhage (SAH) and intraparenchymal hemorrhage (IPH)	1(3.33%)
Total	**30(100.00%)**

Table 4. Association of GCS with various neuroimaging biomarkers (N=55)

Neuroimaging biomarkers		GCS Grading n(%)			Total	p-value
		Mild (n=26)	Moderate (n=15)	Severe (n=14)		
Increased ONSD	no	26(100.00%)	9(60%)	1(7.14%)	36(65.45)	<0.001*
	yes	-	6(40.00%)	13(92.86%)	19(34.55%)	
Mid line shift	no	26(100.00%)	11(73.33%)	8(57.14%)	45(81.82%)	0.001*
	yes	-	4(26.67%)	6(42.86%)	10(18.18%)	
Cerebral Oedema	no	25(96.15%)	3(20.0%)	3(21.43%)	31(56.36%)	<0.001
	yes	1(3.8%)	12(80.00%)	11(78.57%)	24(43.64%)	
Intra-cranial hemorrhage	no	24(92.31%)	1(6.67%)	-	25(45.45%)	<0.001
	yes	2(7.69%)	14(93.33%)	14(100.00%)	30(54.55%)	
Total		**26(100.0%)**	**15(100.0%)**	**14(100.0%)**	**55 (100.0%)**	

Table 5. Association of GCS score with mean ONSD

GCS score	Mean ONSD	Midline shift
Mild	3.75±0.7 mm	-
Moderate	5.02±0.3 mm	2.33 ± 4 mm
Severe	5.29±0.2 mm	4.35 ± 5.2 mm
	P value	<0.001

A midline shift of >5 mm was considered significant. Patients with a midline shift >5 mm had significantly higher mean ONSD values (6.39 ± 0.41 mm) compared to those with a shift ≤5 mm (5.79 ± 0.43 mm; p<0.001), Table 6.

Table 6. Midline shift and mean ONSD

Midline shift	Mean ONSD
>5mm	6.39 ± 0.41 mm
<5mm	5.79 ± 0.43 mm

An inverse correlation between ONSD and GCS was observed (r=-0.457, p<0.001), indicating that lower GCS scores were associated with increased intracranial pressure, Table 7.

Table 7. Correlation of mean ONSD with GCS grading and mid-line shift

Correlation		GCS Score	Mid-line shift
Mean ONSD	Pearson Correlation	-0.457	0.427
	p-value	<0.001	0.001
	Number of participants	55	55

A strong positive correlation was found between mean ONSD and the degree of midline shift measured on initial CT scans (r=0.427, p<0.001), Table 7.

The incidence of intracranial hemorrhage varied significantly across GCS categories (p<0.001). Among severe TBI patients, all patients exhibited large-volume hemorrhages (e.g., subdural hematoma, intraparenchymal hemorrhage). In contrast, mild GCS patients predominantly showed minor hemorrhagic findings, such as traumatic subarachnoid hemorrhage (SAH) or cerebral contusions.

Discussion

Mean ONSD in this study is 4.49±0.87 mm; this result is in accordance with previous studies measuring ONSD under pathophysiological conditions.[9] ONSD values greater than 7.0 mm have been reported in TBI patients with intracranial hypertension. However, in a retrospective study, ONSD ≥5.0 mm was proposed to detect elevated ICP.[10] The inter-observer and intra-observer variations of ultrasound measurement of ONSD were recently calculated to be 0.5 mm and 0.2 mm, respectively.[11] These results are very similar to those reported in the present study based on CT measurement of ONSD. MRI has also been proposed to measure ONSD with a lower range of values than those reported in this study.[12] However, the limited accuracy of MRI with thicker brain slices may underestimate the real value of ONSD. With MRI measurement, errors have also been reported to be 1.3 to 1.5 mm.[13] The ONSD values measured by CT and MRI are higher than those reported with sonography. In the emergency department, an US evaluation of ONSD ≥ 5.0 mm was associated with CT findings of elevated ICP.[14] A link between MRI-determined ONSD and elevated ICP has also been reported.[11,14] However, to the best of our knowledge, no study has yet focused on brain CT scan that is routinely performed in severe TBI patients. ONSD is much easier to measure on CT scan than with sonography due to the good reproducibility of CT and the lack of a learning curve. Furthermore, with the development of telemedicine, tertiary reference centres now have access to the initial CT scan.[15] ONSD measurement may facilitate transfer decisions.

A brain computer tomography is the gold standard for evaluation of traumatic brain injury. Thus, this study aimed to examine the association between ONSD measured on CT and TBI. The TBI group had a mean ONSD value of 5.5±1.0. In the TBI with midline shift group, the ROC curve analysis showed a correlation between brain herniation and ONSD, with an AUC of 0.912. The results of the present study and the previous studies suggested that the ONSD increases to 5.5 mm as the ICP increases. Based on the results of the ROC analysis in the TBI group, an ONSD of 5.5 mm or more yielded a sensitivity of 46.9%. Therefore, ONSD should be used as one of the parameters in detecting ICP elevation during the initial treatment of patients with severe trauma, it is not useful in ICP monitoring or checking patient's level of consciousness.

Our findings indicate that the ONSD measured via CT increases to 5.5 mm or more with a clear increase in ICP. However, ONSD is not likely to be useful in screening tests. Therefore, ONSD should be used as one of the parameters when the conventional method for ascertaining ICP elevation cannot be used in the initial treatment of patients with severe trauma.

Cranial CT imaging is the most preferred imaging method in patients with head trauma. It provides rapid and accurate diagnosis rates and is noninvasive. The prognostic value of CT results including the condition of the basal cisterns, midline shift, the presence and type of the intracranial lesions, and the presence of intracranial hemorrhage has been well documented.[16] The strongest CT indicators are the association of basal cistern compression and the presence of subarachnoid hemorrhage.[15,16] They are the indicators of poor prognosis with the inclusion of other CT results used in midline shift scoring systems after hemorrhage or contusion.

An association of CT scoring with prognosis in 1,030 patients with head trauma,[17] has been reported. Marshall CT score was a strong indicator of prognosis; however, it caused a wider differentiation between diffuse injuries and mass lesions and had some limitations, such as the inability to specify the type of mass lesions (e.g., epidural hematoma, subdural hematoma.[18]

Our findings demonstrated a statistically significant positive correlation between GCS scores and ONSD, indicating that as GCS scores increase (reflecting better neurological function), the ONSD also increases. Traditionally, elevated ONSD has been associated with raised intracranial pressure (ICP), which is often linked to decreased consciousness levels and hence lower GCS scores.[19,20] However, in other study, the positive correlation between ONSD and GCS has been seen suggesting within a certain physiological range, increased ONSD does not necessarily indicate critical ICP elevation but may reflect a preserved cerebral autoregulation or a compensatory response to mild or moderate injury.[21] Several factors may contribute to this finding. First, our patient cohort may have included a significant proportion of mild to moderate TBI cases, where increased ONSD could be present without corresponding severe neurological impairment. Secondly, differences in CT measurement protocols, inter-observer variability, or local anatomical variations may influence ONSD readings in the population studied. Importantly, this is one of the few studies from Nepal evaluating ONSD using CT rather than ultrasound, providing valuable insights into radiological assessment in resource-limited settings.

Our findings aligns with the majority of existing literature that reports an inverse relationship between ONSD and GCS, where larger ONSD values typically correspond to lower GCS scores due to increased ICP. Other studies have observed an inverse correlation using ultrasound-based ONSD measurements in patients with elevated ICP.[22, 23] The deviation in our study could be attributed to differences in study design, patient selection, severity spectrum, or regional and ethnic variations in anatomical parameters.

This research's main strength is its methodology, featuring a prospective study design, a standardized blinded protocol for ONSD CT measurements, and the simultaneous collection of ONSD diameter and GCS score, highlighting their correlation at the same clinical moment. There were few limitations. Data were collected from our single center. Some patients with less severe forms of TBI may have been hospitalized in primary care hospital ICUs without referral to our hospital after getting CT head. Sever TBI patients rapidly progressing to brain death would not have been considered for transfer to this hospital. The observed statistical significance highlights the potential utility of ONSD as a non-invasive marker for neurological assessment in TBI. Further studies with larger sample sizes, serial ONSD measurements, and correlation with direct ICP monitoring would be beneficial to validate these findings and understand the underlying mechanisms.

Conclusion

Our study found a significant inverse relationship between optic nerve sheath diameter (ONSD) measured by CT and Glasgow Coma Scale (GCS) scores in traumatic brain injury (TBI) patients. Higher ONSD values were associated with lower GCS scores, suggesting ONSD may serve as a reliable, non-invasive marker for increased intracranial pressure and severe neurological impairment. These findings highlight the importance of CT-derived ONSD measurements in TBI assessment, particularly when direct intracranial pressure monitoring is not feasible.

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Conflict of Interest

None

Funding

None

Author Contribution

Concept, design, planning: PJ, SKC, SS, YD, SB; Literature review: PJ; Data collection: PJ; Data analysis: PJ, SKC, SB; Draft manuscript: PJ, SKC; Revision of draft: PJ, SKC, SS, YD, SB; Final manuscript: PJ; Accountability of the work: PJ, SKC, SS, YD, SB.

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