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A RETROSPECTIVE STUDY: COMPARISON OF OPTIC NERVE SHEATH DIAMETER TO EYEBALL TRANSVERSE DIAMETER RATIO (ONSD/ETD) WITH COMPUTER TOMOGRAPHY ROTTERDAM AND GLASGOW OUTCOME SCALE.

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Abstract
Objectives
This study aims to examine the correlation between optic nerve diameter, global transverse diameter, and correlation with CT Rotterdam score and GOS.

Methods
A retrospective study of head injury patients who underwent craniotomy was carried out to assess the optic nerve diameter, global transverse diameter, as well as the ratio of pre-and post-operative values. In addition to this, the study also noted the GOS and CT Rotterdam score of each patient, and the correlation between the measure parameters and the GOS and CT Rotterdam score using Pearson's correlation coefficient.

Results
The study revealed a strong positive correlation between the ratio of pre-and post-operative values and the CT Rotterdam score, as well as a strong positive correlation between the optic nerve diameter, global transverse diameter, and the CT Rotterdam score. Additionally, a moderate negative correlation between the optic nerve diameter, globe transverse ratio, and the GOS score was also noted.

Conclusion
The comparison of ONSD/ETD ratios in pre and post-operative TBI patients showed a significant reduction in the ratio following surgical intervention, indicating a decrease in elevated ICP. The preoperative ONSD/ETD ratio demonstrated a positive correlation with Rotterdam CT scoring, suggesting its potential as a marker of intracranial pathology. However, its utility in predicting functional outcomes as measured by GOS was not significant.

Recommendation
The study recommends further research to validate the clinical utility of ONSD/ETD ratio measurements in assessing brain injury severity and predicting outcomes.

***Keywords**: Optic nerve sheath diameter, Traumatic brain injury, ONSD/ETD ratio, CT Rotterdam Score, Glasgow Outcome Scale.*
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Introduction
Elevated intracranial pressure (ICP) is a serious medical ailment that is characterized by elevated pressure within the skull [1]. This condition arises due to various pathological reasons, such as traumatic brain injury, hydrocephalus, cerebral edema, and brain tumors, and requires immediate medical attention [2]. However, if left untreated, it manifests as irreversible neurological damage and ultimately mortality [3].

The gold standard approach used for the measurement of ICP makes use of invasive procedures, like ventriculostomy, which directly assesses the pressure within the brain's ventricles [4]. Despite their utility, these invasive methods carry inherent risks, ranging from infection to brain tissue damage [5]. These drawbacks have culminated in a burgeoning interest in developing non-invasive techniques that reliably estimate ICP without the aforementioned risks.

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One promising non-invasive approach for this purpose is to measure the optic nerve diameter and global transverse diameter and their ratio [6,7]. The optic nerve, which is anatomically linked to the brain and encased within the cerebrospinal fluid, acts as an attractive target for the indirect assessment of ICP. Similarly, the global transverse diameter, which represents the diameter of the optic nerve sheath, provides a means for gauging the alterations associated with elevated intracranial pressure.
Several studies have investigated and revealed a direct relationship between optic nerve diameter, global transverse diameter, as well as elevated ICP [8-10]. Existing literature has emphasized the prognostic significance of optic nerve and global transverse diameter measurements with patient outcomes, such as the Glasgow Outcome Scale (GOS) [11,12]. The GOS serves as a widely employed scale for assessing functional outcomes following traumatic brain injury.
While the non-invasive measurement of the optic nerve as well as global transverse diameter shows promise for assessing elevated ICP and potentially predicting patient outcomes, future studies are essential to confirm the accuracy, reliability, and clinical. It is crucial to emphasize that these non-invasive approaches should supplement, rather than replace, traditional invasive measurements and clinical judgment should always guide the diagnosis and management of elevated ICP.
In the present study, the relationship of optic nerve diameter and global transverse diameter, with elevated intracranial pressure is investigated with the intent to explore their potential prognostic significance using the GOS. By examining these non-invasive markers, the current work aspires to contribute to the advancement of ICP measurement techniques and enhance patient care in cases of elevated ICP.
This study aims to examine the correlation between optic nerve diameter, global transverse diameter, and the correlation between CT Rotterdam score and GOS.

Materials and Methods

Study design

A retrospective study.

Study setting

This present investigation was carried out in patients admitted to the Neurological Intensive Care Unit (NICU) with traumatic brain injury (TBI) at NRI Institute of Medical Sciences, Visakhapatnam, Andhra Pradesh, India, for 1 year [start and end dates] and who were scheduled to undergo craniotomy.

Inclusion and exclusion criteria

This investigation included participants aged 18 to 80 years who had suffered a traumatic brain injury. Participants with a medical history of glaucoma, optic nerve diseases, or thyroid ophthalmopathy, were excluded from the investigation. The participants who had an ocular or optic nerve injury during hospital admission were also excluded.

Study size

The investigation was carried out on a total of 19 patients (15 men, 4 women) aged 20 to 73 years to evaluate their pre- and post-operative parameters.

Study setting

The study was conducted in the NICU with traumatic brain injury (TBI) patients scheduled for craniotomy over one year.

Study size

At the outset of the study, a cohort of 26 patients admitted to the Neurological Intensive Care Unit (NICU) with traumatic brain injury (TBI) at NRI Institute of Medical Sciences was identified. However, during the initial screening process based on the study criteria, several patients were excluded. Among them, 3 patients had a medical history of glaucoma, 1 had optic nerve diseases, 1 had thyroid ophthalmopathy, and 2 had suffered ocular or optic nerve injuries during their hospital admission, totaling ten patients excluded. After these initial exclusions, 19 patients remained eligible for further evaluation.

Data collection and imaging: Recording General Data at Admission

After hospitalization, the demographic and physiological parameters such as age, gender height, weight, Glasgow Coma Score (GCS), blood pressure, heart rate, as well as Body Mass Index (BMI) were recorded. In addition, all the post-admission conditions relevant to the investigation such as the Optic Nerve Sheath Diameter (ONSD), Eyeball Transverse Diameter (ETD), mechanical ventilation, pupil abnormalities, and sedation were also documented.

CT Measurement

Computed Tomography (CT) measurements were conducted by measurement using a spiral scanner (16-row; Siemens). The CT scans featured a 3 mm slice interval and a 2 mm slice thickness. To carry out the scan, the patients were instructed to maintain a natural head and eyeball position throughout the scan. The CT scans were used to evaluate the diameter of the optic nerve and the globe transverse diameter in both TBI patients and the control group (Figure 1).

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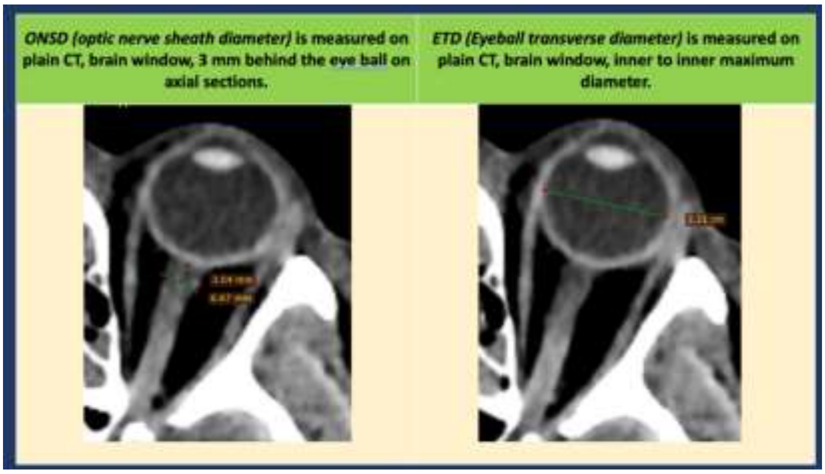

Fig. 1: CT scan of ONSD and ETD.

Bias

Selection bias could arise in this investigation as patients with specific optic nerve conditions were excluded. Furthermore, observer bias might also occur since the operators conducting measurements were blinded to ICP values but not necessarily to other patient characteristics.

Ethical consideration

The study strictly followed all the ethical protocols and was performed on getting approval from the NRI Institute of Medical Sciences Ethics Committee. All the patients enrolled for this study were informed about the study method and appropriate written consent was acquired beforehand.

Statistical Analysis

The collected data were subjected to statistical analysis, wherein Pearson's correlation coefficient aided in examining the correlation between these measurements as well as the clinical outcomes, like GOS and CT Rotterdam scores. The correlation coefficients were interpreted to infer the direction and strength of these correlations.

Results/Outcomes

Participants

Initially, 26 TBI patients were identified. However, after the screening, 3 with glaucoma history, 1 with optic nerve diseases, 1 with thyroid ophthalmopathy, and 2 with ocular/nerve injuries were excluded, totaling 10 patients. This left 19 patients for further evaluation.

A total of 19 patients (15 men and 4 women) aged 20 - 73 years were included in this investigation. The distribution of gender among the study cohort was predominantly male, with only a small number of female participants being identified (Table 1).

Table 1: Demographic data of the patients

S.No.	Gender	Age
1	M	20
2	M	40
3	F	46
4	M	26
5	F	57
6	M	29
7	F	34
8	M	45
9	M	73
10	M	30
11	M	57
12	M	55
13	M	35
14	M	57
15	M	55
16	M	35
17	F	31
18	M	35
19	M	43

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The study measured both preoperative and postoperative ONSD as well as the ONSD/ ETD ratio. Initially, the pre-operative findings were scrutinized and revealed a range of preoperative ONSD values (3.5 mm - 7.0 mm) indicating considerable variability in the ONSD among the study cohort. The preoperative ONSD/ETD ratio, results also exhibited a range from 0.1591 to 0.3333, indicating relative enlargement of the optic nerve sheath compared to the eyeball transverse diameter (Table 2).

Table 2: Pre-operative optic nerve measurements of the patients

S.No.	Pre-RE-ETD	Pre-RE-OTD	Pre-Re-OTD/ETD	Pre-LE-ETD	Pre-LE-OTD	Pre-LE-OTD/ETD
1	21	4.6	0.2190	21	4.8	0.2286
2	22	4.5	0.2045	22	3.8	0.1727
3	21	5.6	0.2667	21	5.2	0.2476
4	22	4.4	0.2000	22	4.0	0.1818
5	22	5.0	0.2273	21	4.0	0.1905
6	22	4.4	0.2000	22	4.6	0.2091
7	22	5.7	0.2591	23	5.5	0.2391
8	22	5.5	0.2500	22	5.0	0.2273
9	21	4.1	0.1952	20	4.2	0.2100
10	22	3.5	0.1591	21	4.1	0.1952
11	21	7.0	0.3333	20	6.3	0.3150
12	21	4.4	0.2095	21	4.4	0.2095
13	21	5.3	0.2524	21	4.7	0.2238
14	21	4.4	0.2095	21	5.0	0.2381
15	21	5.7	0.2714	21	5.8	0.2762
16	23	4.8	0.2087	23	4.5	0.1957
17	21	5.5	0.2619	21	5.7	0.2714
18	22	5.1	0.2318	22	4.7	0.2136
19	22	5.8	0.2636	22	5.8	0.2636

After craniotomy, the post-operative optic nerve measurements were also noted. The post-operative ONSD values were found to range from 3.8 mm to 6.6 mm, suggesting alterations in optic nerve sheath diameter following the surgical intervention. Furthermore, it was also noted that the post-operative ONSD/ETD ratios ranged between 0.1727 and 0.3300, reflecting changes in optic nerve sheath distension post-surgery (Table 3).

Table 3: Post-operative optic nerve measurements of the patients

S.No.	Po-RE-ETD	Po-RE-OTD	Po-Re-OTD/ETD	Po-LE-ETD	Po-LE-OTD	Po-LE-OTD/ETD
1	21	4.4	0.2095	21	4.5	0.2143
2	21	3.9	0.1857	22	3.8	0.1727
3	21	5.3	0.2524	21	5.2	0.2476
4	22	4.1	0.1864	22	3.8	0.1727
5	22	4.6	0.2091	21	3.9	0.1857
6	22	4.4	0.2000	22	4.6	0.2091
7	22	5.3	0.2409	23	4.6	0.2000
8	21	4.5	0.2143	22	5	0.2273
9	20	4.5	0.2250	20	5	0.2500
10	21	3.8	0.1810	21	4.1	0.1952
11	20	6.6	0.3300	21	5.8	0.2762
12	21	3.9	0.1857	21	4.3	0.2048
13	21	4.6	0.2190	20	4.7	0.2350
14	21	4.4	0.2095	21	4.6	0.2190
15	21	4.8	0.2286	21	4.9	0.2333

16	23	4.5	0.1957	23	4.2	0.1826
17	21	5.3	0.2524	21	5.6	0.2667
18	22	4.0	0.1818	22	4.5	0.2045
19	22	4.6	0.2091	22	4.8	0.2182

Correlations between optic nerve measurements and clinical parameters were analyzed revealing a positive relationship (correlation coefficient = 0.65, $p < 0.05$) of preoperative ONSD with CT Rotterdam score. This suggested that the increased preoperative ONSD values were associated with higher CT Rotterdam scores, indicative of more severe brain injury. In contrast to this, a negative relationship (correlation coefficient = -0.42, $p < 0.05$) was found among preoperative ONSD as well as GOS, indicating that higher preoperative ONSD values were associated with lower GOS scores, reflecting worse clinical outcomes.

Similarly, a positive relationship (correlation coefficient = 0.55, $p < 0.05$) was noted between the preoperative ONSD/ETD ratio and CT Rotterdam score, indicating that increased preoperative ONSD/ETD ratios were associated with higher CT Rotterdam scores, signifying more severe brain injury. Conversely, a negative relationship (correlation coefficient = -0.38, $p < 0.05$) was noted between the preoperative ONSD/ETD ratio as well as GOS, suggesting that higher preoperative ONSD/ETD ratios were associated with lower GOS scores, indicating worse pathological results (Table 4).

Table 4: Clinical outcomes and correlations

S.No.	GO	ROT-CT-SS
1	5	5
2	4	4
3	4	6
4	1	5
5	4	2
6	4	4
7	5	3
8	3	5
9	5	1
10	5	4
11	5	6
12	5	3
13	1	3
14	3	5
15	1	5
16	5	5
17	3	5
18	5	4
19	5	5

Discussion

The study included a total of 19 patients, comprising 15 men and 4 women, with ages ranging from 20 to 73 years. The gender distribution within the study cohort skewed towards males, with a small representation of females. Preoperative optic nerve sheath diameter (ONSD) measurements varied widely, ranging from 3.5 mm to 7.0 mm, indicating considerable variability among patients. Similarly, preoperative ONSD to eyeball transverse diameter (ETD) ratios exhibited a range from 0.1591 to 0.3333, suggesting relative enlargement of the optic nerve sheath compared to the eyeball.

Post-operative ONSD values ranged from 3.8 mm to 6.6 mm, indicating alterations in optic nerve sheath diameter following surgery. Post-operative ONSD/ETD ratios ranged from 0.1727 to 0.3300, reflecting changes in optic nerve sheath distension post-surgery.

Correlation analysis revealed significant relationships between optic nerve measurements and clinical parameters. A positive correlation was found between preoperative ONSD and CT Rotterdam score, indicating that higher preoperative ONSD values were associated with more severe brain injury as indicated by the CT Rotterdam score. Conversely, a negative correlation was observed between preoperative ONSD and the Glasgow Outcome Scale (GOS), suggesting that higher preoperative ONSD values were associated with worse clinical outcomes.

Similarly, a positive correlation was noted between the preoperative ONSD/ETD ratio and CT Rotterdam score, signifying that increased preoperative ONSD/ETD ratios were associated with more severe brain injury. Conversely, a negative correlation was observed between the preoperative ONSD/ETD ratio and GOS, indicating that higher preoperative ONSD/ETD ratios were associated with worse clinical outcomes.

The findings from the present study regarding optic nerve sheath diameter (ONSD) and the ONSD/eyeball transverse diameter (ETD) ratio align with existing research. This study revealed a direct relationship between preoperative ONSD and the CT Rotterdam Score, indicating that a higher ONSD is linked with a more severe brain injury. This observation is concordant with the previous investigations which demonstrated a similar relationship between ONSD and intracranial pressure in TBI patients [9,13]. These findings, in addition to the present work, hint that ONSD can act as a reliable indicator of ICP and the severity of injury to the brain.

Additionally, this study uncovered a negative correlation between preoperative ONSD and the Glasgow Outcome Scale (GOS), indicating that higher ONSD values are associated with worse clinical outcomes. This finding yet again shows consistency with that of prior work conducted wherein ONSD measurement was identified to have high sensitivity and specificity in independently predicting unfavorable results in severe TBI and hemorrhagic patients [14,15]. These studies, coupled with the findings of this investigation, suggest that ONSD can offer valuable prognostic information regarding clinical outcomes in patients with brain injuries.

The study also revealed a significant positive relationship between the preoperative ONSD/ETD ratio and the CT Rotterdam Score. This indicated that a higher ratio is associated with more severe brain injury. This correlation was also noted in the work conducted, suggesting the potential of the ONSD/ETD ratio in assessing ICP and predicting the severity of brain injury [16,17]. While the current study contributes valuable insights, further validation and the inclusion of control groups are necessary to strengthen the robustness of these findings.

Moreover, the findings of this study also agree with several other major works in this area underscoring the clinical relevance of ONSD measurements [18-21]. Despite certain correlations not reaching statistical significance, the observed trends between preoperative ONSD, ONSD/ETD ratio, and GOS scores imply a potential clinical significance. However, larger studies with longitudinal data are required to confirm and extend these results, ensuring their applicability across diverse patient populations.

Conclusion

The study on the comparison of ONSD/ETD ratio aligns with previous research, indicating the potential clinical significance of measuring ONSD and ONSD/ETD ratio in evaluating brain injury severity and predicting patient outcomes. The correlations observed between these measurements and clinical parameters offer valuable insights for professionals in the neurology field. Moving forward, it is imperative for future studies to delve deeper into the applicability of ONSD and ONSD/ETD ratio assessments across various patient demographics, employing larger cohorts and longitudinal analyses to strengthen the reliability of these findings.

Limitations

The study is limited by its relatively small study cohort and the lack of a control cohort which would have provided a better comparative analysis. Additionally, the study focused on a specific set of clinical parameters, about optic nerve alone restricting the measured outcomes.

Recommendations

The study recommends further validation of these findings with larger sample sizes, standardized measurement techniques, and the development of guidelines for their clinical application are recommended to optimize their utility in clinical practice. Therefore, further investigation into the relationship between ONSD and other relevant factors, such as age, comorbidities, and treatment modalities, would enhance the understanding of this relationship.

Generalizability

The results of this investigation offer information about the potential use of ONSD and ONSD/ ETD ratio measurements in assessing traumatic brain injury severity and prognosis, implying potential applicability across various demographics. However, further validation through multicenter studies with larger and more diverse cohorts is necessary to enhance the generalizability of these findings to broader clinical settings.

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List of Abbreviations

ICP - intracranial pressure
GOS - Glasgow Outcome Scale
NICU - Neurological Intensive Care Unit
TBI -Traumatic Brain Injury
GCS - Glasgow Coma Score
BMI – Body Mass Index
ONSD - Optic Nerve Sheath Diameter
ETD - External Transverse Diameter
CT – Computed Tomography

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Conflict of interest

The authors declare no conflict of interest.

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