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Predictive value of optical nerve sheath diameter to Eyeball Transverse Diameter ratio on mortality of head trauma

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Abstract. – OBJECTIVE: Optic nerve sheath diameter (ONSD) and Eyeball Transverse Diameter (ETD) can be measured to determine cranial pressure due to intracranial injury. The study aimed to measure the diagnostic potential of ONSD and ETD to predict mortality in head traumas.

PATIENTS AND METHODS: This cross-sectional study included 483 patients who applied to the emergency department with head trauma and analyzed characteristics, Rotterdam Computed Tomography Score (RCTS), Glasgow Coma Score (GCS), ETD, and ONSD. ONSD was calculated from 3 mm proximal to the optic disc in the section by tomography and manually divided to ETD to generate ONSD/ETD (Index).

RESULTS: GCS, RCTS, ONSD (right: R; left: L), and Index (right: R; left: L) indicated a significant difference between mortal and non-mortal trauma (p < 0.001). In ROC analysis of the mortality prediction for the ONSD-R, the sensitivity and the specificity were 83.3% and 57.1% (p = 0.001), while those were 91.7% and 68.2% for ONSD-L (p = 0.0001). In Index-R, the sensitivity and specificity were 74% and 84.5% (p = 0.0001), while those were 75.2% and 85% for Index-L (p = 0.0001).

CONCLUSIONS: The index, which can be measured easily by the proportion of ONSD and ETD at admissions to Emergency Departments by CT, can provide crucial information to physicians in predicting the mortality of patients with head trauma.

Key Words:
Head trauma, Optic nerve sheath, Eyeball transverse diameter, Mortality.

Introduction

Multiple trauma is one of the most important causes of unexpected morbidity and mortality worldwide[1]. Evaluation of increased intracranial pressure is critical in traumatic brain injury (TBI) cases, as it can be potentially fatal if left untreated[1]. Increased intracranial pressure (ICP) has been evaluated as a condition that may result in deadly complications in patients with head trauma in the emergency department[2].

Changes in consciousness in head trauma are evaluated with the Glasgow Coma Score (GCS). However, the unique use of GCS is insufficient to evaluate sedated, intubated, and paralyzed patients. In addition to GCS, Computed Tomography with Rotterdam Scoring (RCTS) is widely used for assessing patients with acute TBI[3]. Non-contrast CT is the first imaging modality of choice because of its rapid image acquisition and availability in most hospitals. It constitutes the earliest objective data available to assess head trauma's severity and prognosis. Recent studies[4] showed a relationship between optic nerve sheath diameter (ONSD), which can be measured in CT, and ICP.

The optic nerve is surrounded by the optic nerve sheath, a subarachnoid membrane layer[5]. As ICP increases, cerebrospinal fluid (CSF) accumulates and causes distension of the optic nerve sheath[6]. The gold standard for estimating ICP increase includes invasive methods such as intraventricular catheterization and intraparenchymal probes[7]. However, such procedures are not routinely performed due to the lack of neurosurgeons or intensive care units and the risk of complications such as bleeding and infection. Optic nerve sheath can be measured to determine the increase in ICP, as its increase is a natural consequence of intracranial injuries[8]. In novel studies, the ratio of the ONSD value to the Eyeball Transverse Diameter (ETD) can provide more sensitive information than the ONSD alone in explaining the ONSD-intracranial pressure relationship[9,10].

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Hence, combining those diameters can give a more potent marker to monitor head trauma.

The present study aimed to evaluate the cases with head trauma who were admitted to the Emergency Department in terms of clinical outcomes, GCS, and RCTS and to investigate the potential diagnostic efficiency of ONSD, ETD, and the combined index (ONSD/ETD ratio) on head traumas.

Patients and Methods

Participants and Ethical Consent

The present cross-sectional research analyzed patients who applied to the emergency department of Afyonkarahisar Health Sciences University Medical Faculty Hospital due to head trauma following a retrospective design. The study group consisted of 483 patients who applied to the emergency department of Afyonkarahisar Health Sciences University Medical Faculty Hospital for five years and were diagnosed with head trauma according to the International Classification of Diseases-10 (ICD-10) coding[11].

Using the hospital automation system and patient file information, CT was taken from patients aged 18 years and older diagnosed with head trauma. Our study was approved by the University Medical Faculty Non-Interventional Studies Ethics Committee on 03.11.2017 with protocol number 2017/11-269. Informed and written consent was obtained from the patients included in the study, and patients who did not meet the study criteria were excluded.

Inclusion and Exclusion Criteria

Patients aged 18 years and older, who applied to our hospital's emergency department with a head trauma diagnosis, who had a CT due to head trauma, and who could access the relevant data from the hospital automation system were included in the study. Exclusion criteria from the study were as follows: head trauma patients under 18 years of age, patients with orbital and sphenoid bone injury demonstrated by CT, presence of intracranial or intraorbital mass, patients whose brain CT could not be reached, presence of hyperthyroidism causing exophthalmos, presence of eye disease affecting the optic nerve and orbit.

Study Design

A standard data collection form was created for the study group. The age and gender of the patients, the causes of head trauma, the features of CT taken at the time of admission, and the localization of bleeding, if any (if fracture, edema, and bleeding in any localization were detected in the CT scan, it was considered pathological), GCS values, hospitalization status, and mortality were determined. The data were processed into the data collection form. Patients who died in the emergency room or intensive care units after hospitalization were recorded as mortal in the data collection form.

Rotterdam Computed Tomography Score

Rotterdam Computed Tomography Score (RCTS), which is determined using the Rotterdam scoring system, is a scoring system that is scored between 1 and 6 based on CT findings and has prognostic value in traumatic brain injuries[12]. It is determined by pathologies such as midline shift, basal cistern compression, epidural space-occupying lesion, and subarachnoid hemorrhage. Adding a +1 point to the total when calculating the Rotterdam CT score is intended to be consistent with the motor response, which is 6 points in full when calculating the GCS. Its results were divided into RCTS: 1-2 and RCTS: 3-6 during statistical analysis. Similarly, neurological examination determined GCS was split into two groups: mild (GCS: 13-15) and severe (GCS: 3-12) traumatic brain injury.

Optic Nerve Sheath Diameter and Eyeball Transverse Diameter Measurement

In all of the included patients, the ONSD and the eyeball transverse diameter (ETD) were measured with the help of CT. In the study group, ONSD was evaluated by a single emergency medicine assistant who had received relevant training. We evaluated axial sections of the patient's CT (Toshiba Aquilon prime 160-slice mobile scanner) accessed through the hospital automation system. ONSD was calculated from 3 mm proximal to the optic disc in the section where the optic nerve was best visualized in the examinations. After the ONSD/ETD measurements were complete in the same cross-section and the widest positioning from the retina to the retina, the ONSD/ETD (index) was calculated manually. The measurement results were recorded in the data collection form.

Statistical Analysis

Frequency analysis was given for the distribution of nominal and ordinal data, and mean, and standard deviation values were given for the definition of measurement data. Before the difference analysis of the measurement data, the Kolmogorov-Smirnov test was performed to test the homogeneity of the data distribution. According to the test results, the Independent Sample *t*-test was used in the double-group difference analysis of the normally distributed data, and the Oneway ANOVA test was used in the study of more than two sample differences. Mann-Whitney U test was used for a different analysis of paired groups in cases where the data distribution did not fit the normal distribution. Spearman's Rho correlation was used in the correlation analysis. Appropriate cut-off value, specificity, and sensitivity levels of ONSD and ONSD/ETD were determined by ROC. All the analyses were performed with SPSS version 23 for Windows (IBM Corp., Armonk, NY, USA) package software. A value of $p < 0.05$ was set as a significant level.

Results

The present research was conducted among patients who applied to the emergency department of the University Medical Faculty Hospital with head trauma for five years. The total number of patient admissions to the emergency department during the study period was 155,961, and 3,844 (2.46%) were patients exposed to trauma. Head trauma was present in 1,242 (0.79%) of these patients. A total of 483 patients (male: 64% and female: 36%) were included in the study. 32.5% of the patients were between 18-29 years old, 53.4% were between 30-64 years old, and 14.1% were 65 and over.

There was isolated head trauma in 34.6% of the patients and multisystem trauma in 65.4%. The mortality rate in the sample group of our study was 2.48%. According to the GCS groups, 4.3% of the patients had GCS ≤ 12, while 95.7% had GCS ≥ 13. When separated according to RCTS groups, 2.5% of the patients were found to be RCTS (3-6) and 97.5% to be RCTS (1-2). 2.5% of the patients were mortal. Parenchyma bleeding was detected in 4.3%, subarachnoid hemorrhage in 3.3%, subdural bleeding in 1.7%, and epidural bleeding in 0.8% of the patients. The GCS had an average value of 14.64. The mean value of ONSD was 4.74 mm on the right and 4.75 mm on the left. The mean value was 0.21 for the Index-R and 0.21 for the Index-L.

All comparisons of scores are given in Table I. According to trauma type, the GCS score was higher in patients with isolated trauma, and RCTS and ONSD measurements were more elevated in multi-trauma patients ($p < 0.001$). To better understand the effects of GCS on RCTS and ONSD-related parameters, the patients were grouped as GCS < 12 and GCS ≥ 13. The group with a GCS of 12 and below had higher RCTS, ONSD (R/L), and Index (R/L) ($p < 0.0001$). RCTS, ONSD (R/L), and Index (R/L) values were higher in the group with pathological CT. According to the mortality status, RCTS, ONSD-R, ONSD-L, Index-R, and Index-L values were higher in patients with a mortal. GCS measurements were higher in the non-mortal group. GCS, RCTS, ONSD (R/L), and Index (R/L) showed a significant difference between the mortal and non-mortal trauma groups ($p < 0.05$). According to the results of the correlation analysis (Table II), GCS showed a negative correlation with RCTS (r = -0.689; $p < 0.001$), ONSD-R (r = -0.182; $p < 0.001$), ONSD-L (r = -0.244; $p < 0.001$), Index-R (r = -0.223; $p < 0.001$) and Index-L (r = -0.280; $p < 0.001$). According to the bleeding status, RCTS, ONSD (R/L), and Index (R/L) were higher in the patient with bleeding.

As given in Figure 1, in the ROC analysis of the mortality prediction for the ONSD-R, the sensitivity, and the specificity were 83.3% and 57.1% with a cut-off value of 4,785 mm (AUC: 0.786; p = 0.001; 95% CI: 0.677-0.895). The ONSD-L sensitivity was 91.7%, while the specificity was 68.2% at a cut-off value of 5,125 mm (AUC: 0.865; p = 0.0001; 95% CI: 0.787-0.943). In the same analysis for Index-R, sensitivity, and specificity were 74% and 84.5% at a cut-off value of 0.225 mm (AUC: 0.828; p = 0.0001; 95% CI: 0.731 - 0.925). For Index-L, sensitivity, and specificity were 75.2 and 85% at a cut-off of 0.245 mm (AUC: 0.893; p = 0.0001; 95% CI: 0.828 - 0.958).

Discussion

The present study evaluated the relationship between ONSD results and clinical and radiological findings. The index calculated with CT scans in emergency departments can provide important information in assessing intracranial pressure increase. Although ONSD alone has essential value in head trauma, when used in a combined ratio of ONSD and ETD as the Index, their specificity and sensitivity increase; hence, they become more powerful diagnostic weapons for physicians in the emergency against mortality.

Head trauma-related deaths are common, and 50% of trauma-related deaths are accompanied by head trauma, increasing the financial burden

Table I. Comparison of scores between the groups.

Variables	*Head trauma (n: 167)*	*Multi-trauma (n: 316)*	*p-value*
GCS	14.96 ± 0.46	14.47 ± 2.12	0.0001[a]
RCTS	1.01 ± 0.15	1.16 ± 0.54	0.0001[a]
ONSD - *Right*	4.24 ± 0.47	5.01 ± 0.77	0.0001[b]
ONSD - *Left*	4.24 ± 0.47	5.02 ± 0.74	0.0001[b]
ETD - *Right*	22.45 ± 0.95	22.57 ± 0.99	0.2013[b]
ETD - *Left*	22.45 ± 0.94	22.48 ± 1.10	0.785[b]
Index - *Right*	0.18 ± 0.02	0.22 ± 0.03	0.0001[a]
Index - *Left*	0.19 ± 0.02	0.22 ± 0.03	0.0001[a]
	Pathological CT (n: 51)	**Normal CT (n: 432)**	
GCS	12.22 ± 4.42	14.93 ± 0.63	0.0001[a]
RCTS	1.86 ± 1.08	1.02 ± 0.14	0.0001[a]
ONSD - *Right*	5.33 ± 0.95	4.67 ± 0.72	0.0001[b]
ONSD - *Left*	5.37 ± 0.89	4.68 ± 0.71	0.0001[b]
ETD - *Right*	22.29 ± 1.04	22.56 ± 0.97	0.0677[b]
ETD - *Left*	22.26 ± 0.94	22.50 ± 0.99	0.1052[b]
Index - *Right*	0.24 ± 0.04	0.20 ± 0.03	0.0001[a]
Index - *Left*	0.24 ± 0.04	0.20 ± 0.03	0.0001[a]
	Mortal (n: 12)	**Not Mortal (n: 471)**	
GCS	6.75 ± 4.83	14.84 ± 0.99	0.0001[a]
RCTS	2.42 ± 1.00	1.07 ± 0.38	0.0001[a]
ONSD - *Right*	5.60 ± 0.83	4.72 ± 0.76	0.0001[b]
ONSD - *Left*	5.77 ± 0.67	4.73 ± 0.74	0.0001[b]
ETD - *Right*	22.11 ± 0.96	22.54 ± 0.98	0.134[b]
ETD - *Left*	22.14 ± 0.81	22.48 ± 0.99	0.239[b]
Index - *Right*	0.25 ± 0.03	0.21 ± 0.3	0.0001[a]
Index - *Left*	0.26 ± 0.03	0.21 ± 0.03	0.0001[a]
	Bleeding (n: 25)	**No Bleeding (n: 458)**	
GCS	10.16 ± 5.05	14.88 ± 0.87	0.0001[a]
RCTS	2.68 ± 0.94	1.02 ± 0.17	0.0001[a]
ONSD - *Right*	5.72 ± 0.90	4.69 ± 0.73	0.0001[b]
ONSD - *Left*	5.78 ± 0.83	4.70 ± 0.71	0.0001[b]
ETD - *Right*	22.01 ± 0.93	22.56 ± 0.98	0.0068[b]
ETD - *Left*	21.98 ± 0.85	22.50 ± 0.99	0.0102[b]
Index - *Right*	0.26 ± 0.04	0.20 ± 0.03	0.0001[a]
Index - *Left*	0.26 ± 0.03	0.21 ± 0.03	0.0001[a]
	RBS 3-6 (n: 12)	**RBS 1-2 (n: 471)**	
GCS	8.92 ± 4.78	14.79 ± 1.33	0.0001[a]
ONSD - *Right*	5.86 ± 0.83	4.71 ± 0.75	0.0001[b]
ONSD - *Left*	5.75 ± 0.68	4.73 ± 0.74	0.0001[b]
ETD - *Right*	22.39 ± 0.89	22.53 ± 0.98	0.6162[b]
ETD - *Left*	22.24 ± 0.96	22.48 ± 0.99	0.412[b]
Index - *Right*	0.26 ± 0.03	0.21 ± 0.03	0.0001[a]
Index - *Left*	0.26 ± 0.03	0.21 ± 0.03	0.0001[a]

[a]Mann-Whitney U, [b]Independent *t*-test. GCS: Glasgow Coma Score, CT: Computed Brain Tomography, RCTS: Rotterdam Computed Tomography Score, ONSD: Optic Nerve Sheath Diameter, ETD: Eyeball Transverse Diameter. ONSD values are in mm. The index was calculated with the ONSD/ETD ratio.

on society[13]. During our study, trauma patients constituted 2.46% of the patients who applied to the emergency department of our hospital. 0.79% of all patients were diagnosed with head trauma at hospital admissions, and the ratio of head trauma patients younger than 18 years of age after

Table II. Relationship and correlation analysis of GCS scores between RCTS and optic nerve.

Variables	GKS ≤ 12 (n: 21)	GKS ≥ 13 (n: 462)	*p* (*t*-test)	r	*p* (Corr.)
RCTS	2.57 ± 1.12	1.04 ± 0.24	0.0001[a]	-0.689	0.0001
ONSD - *Right*	5.47 ± 0.89	4.71 ± 0.75	0.0001[b]	-0.182	0.0001
ONSD - *Left*	5.56 ± 0.64	4.71 ± 0.74	0.0001[b]	-0.244	0.0001
ETD - *Right*	22.03 ± 1.04	22.55 ± 0.97	0.0176[b]	-0.131	0.0043
ETD - *Left*	21.91 ± 0.85	22.50 ± 0.99	0.0073[b]	-0.121	0.0087
Index - *Right*	0.25 ± 0.04	0.21 ± 0.03	0.0001[a]	-0.223	0.0001
Index - *Left*	0.25 ± 0.03	0.21 ± 0.03	0.0001[a]	-0.280	0.0001

[a]Mann-Whitney U, [b]Independent *t*-test. RCTS: Rotterdam Computed Tomography Score, ONSD: Optic Nerve Sheath Diameter, ETD: Eyeball Transverse Diameter. ONSD values are in mm. The index was calculated with ONSD/ETD ratio.

removing other exclusion criteria was 0.3%[14]. The high rate of real non-emergency patient admissions in the emergency departments in our country can explain this. In our study, 64% of the patients were male and primarily middle-aged. Men are exposed to head trauma more than women, maybe because the male gender has a more active life than the female gender in our society.

Although CT is predictive in severe head traumas with increased intracranial pressure, such as hematoma, its predictive effect is limited in other non-severe head traumas. However, CT helps make early surgical intervention decisions[15]. Invasive and non-invasive methods that can evaluate intracranial pressure changes in patients undergoing CT evaluation with head trauma can guide patient management. Today, largely invasive procedures are used to detect intracranial pressure changes. The availability of invasive methods, on the other hand, causes difficulties due to the need for neurosurgery expertise and contraindications[16]. Measurement of ONSD is helpful in this sense and can provide information about the increase in intracranial pressure. Lee et al[17] investigated changes in ONSD with the help of CT in patients with subarachnoid hemorrhage. In the present study, ONSD was significantly increased in patients with a clinically poor course compared to patients with a good prognosis. However, ONSD values are correlated with changes in intracranial pressure[18].

Few studies in the literature evaluate the usability of ONSD measurements in CT in head traumas. In the study of Legrand et al[19], the increase in ONSD performed with CT measurements in severe head traumas increased significantly in mortal patients. In our study, the values in mortal patients increased compared to patients who were not mortal. This result suggested that necessary treatment approaches should be applied without delay due to the mortality risk in patients with increased ONSD. In the same study, the sensitivity of ONSD values was above 7.30 mm, indicating mortality was 86.4%, and the specificity was 74.6%[19]. A different study by Sekhon et al[20] investigated the relationship between ONSD results and intracranial pressure changes in patients with severe traumatic brain injury. In this study, a strong correlation was found between intracranial pressure changes and ONSD, the sensitivity was 97%, and the specificity was 42%. Although intracranial pressure was not measured in our study, the increase in ONSD values in the patient group with high RCTS, whose intracranial pressure increase was expected, can be evaluated following the literature. In our study, in the patient group with pathological CT, the ONSD was 5.33 ± 0.95 mm in the right eye and 5.37 ± 0.89 mm in the left eye. In the patient group without pathology in CT, the ONSD was 4.67 ± 0.72 mm

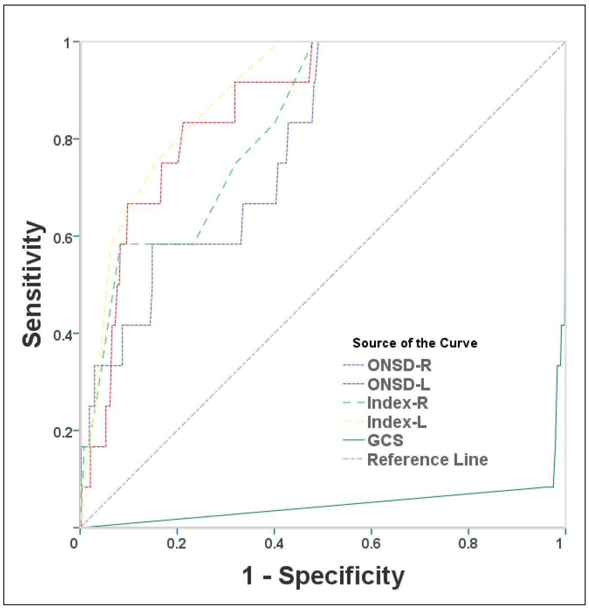

Figure 1. The ROC curve of ONSD and ONSD/ETD index for mortality of head trauma.

in the right eye and 4.68 ± 0.71 mm in the left eye. The higher ONSD that can be detected in patients with pathological CT may be a guide in the follow-up and treatment.

The ratio of the ONSD measurement to the ETD can provide more sensitive information than the ONSD alone in explaining the ONSD-intracranial pressure relationship[21]. In the study of Zhu et al[22], the ONSD and Index were elevated in comatose patients. The Index could be more valuable than ONSD in predicting supratentorial-lesion prognosis. According to Kim et al[23], the ONSD had a strong correlation with ETD, and their ratio might provide a more substantial value than ONSD itself as a marker of ICP. Legros et al10 reported that periodic sheath and optic nerve diameter in the first MRI could predict the risk of developing cerebral artery infarcts. Zhao et al[24] said that ONSD and ONSD/ETD were strongly correlated with the prognosis of stroke. The mortality rate in the sample group of our study was 2.48%, and its value increased in patients with an ONSD greater than 5 mm and ONSD/ETD greater than 0.25. They may be promising diagnostic markers for early stroke assessment. In the present study, the ONSD/ETD ratio was above 0.22 in the patients with low GCS, those with pathological CT, and mortal patients, supporting the presence of increased intracranial pressure in the mentioned patient groups. The most important output of the research is that the index may help with mortality for head traumas with high specificity and sensitivity.

Limitations

The study has some limitations. Due to the exclusion of patients with ophthalmic and sphenoid injuries, the number of patients with severe head trauma was lower in the patient group. For this reason, Rotterdam CT scores did not show a homogeneous distribution in the patient group. The most important limitation is the measurement evaluation in a single sequence. The alternative measurement methods described in the literature were not used to evaluate the patient group, and the possible changes in intracranial pressure were not assessed with different techniques.

Conclusions

In the presence of pathological CT, such as intracranial bleeding and fracture, ONSD and ONSD/ETD increased together. Similar to these results, patients with a high mortality risk had higher ONSD and Index values. However, ONSD and ETD parameters alone have essential values in head trauma; their specificity and sensitivity increase when used in a combined ratio as a novel index. Hence, they become more powerful diagnostic weapons for physicians in the emergency against the mortality of head traumas.

Conflict of Interest

The Authors declare that they have no conflict of interest.

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Informed Consent

Informed consent was obtained from all individual participants included in the study.

Ethics Approval

Our study was approved by the University Medical Faculty Non-Interventional Studies Ethics Committee on 03.11.2017 with protocol number 2017/11-269.

Availability of Data and Materials

The present study is based on a scientific research thesis. The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' Contributions

GK and OKO participated in the study's design, data analysis, and manuscript drafting. They contributed to the guidance of the research and review. The authors have read and approved the final version of the manuscript.

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