RESEARCH ARTICLE

European Journal of Education and Pedagogy
www.ej-edu.org

Correlation between Optic Nerve Sheath Diameter and Marshall Scale in Acute Traumatic Brain Injury

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ABSTRACT

Background: **Imaging plays integral role in the evaluation of patients with acute traumatic brain injury (TBI), with computerized tomography (CT) being the modality of the choice and the most commonly utilized imaging tool. One of the important determinants of TBI severity is raised intracranial pressure (ICP). Optic nerve sheath diameter (ONSD) was considered as a reliable indirect surrogate for the raised ICP, however, studies assessing role of CT-derived ONSD in evaluation of patients with raised ICP or brain injury are limited.**

Aim of the study: **To assess the correlation between ONSD measured by CT scan and the severity of TBI according to Marshall scale.**

Patients and methods: **A cross-sectional analytic study was conducted on 60 adult patients (52 males, 8 females) presented with acute TBI and referred for brain CT examination. After initial general evaluation of brain CT images, the score of TBI was assessed according to Marshal's scale (I to VI). The transverse ONSD was manually measured on axial CT image at 3 mm distance behind eye globe. The correlation between the grade of TBI and ONSD was subjected to statistical analysis. The study was approved by the Institutional Ethical Review Committee.**

Results: **The means of all, right-sided and left-sided ONSD were 4.695 mm, 4.606 mm and 4.785 mm respectively. There was positive, linear and statistically significant correlation (p value <0.001, r = 0.662) between the mean of ONSD measured by CT scan and Marshall score. When the ONSD measurements of the right and left sides were analyzed separately, the correlation was also significant and positive (r= 0.504 for the right side, r = 0.699 for the left side with p value <0.001 for both). ONSD showed weakly negative and statistically not significant correlation (p value= 0.571, r = - 0.075) with the duration between onset of the trauma and time of CT examination. There was no significant difference between mean ONSD measurements when correlated with the laterality of TBI, age or gender (p values 0.392 0.328 and 0.462 respectively).**

Conclusion: **ONSD measured on brain CT scan is positively correlated with the severity of TBI as assessed by Marshall scale. Because Marshall scale has prognostic implication, ONSD may also have a prognostic value during assessment of patients with TBI.**

Keywords: Computed tomography, intracranial pressure, Marshall scale, optic nerve, traumatic brain injury.

Published Online: May 9, 2023

ISSN: 2736-5476

DOI:10.24018/ejclinicmed.2023.4.3.252

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I. INTRODUCTION

Traumatic brain injury (TBI) is a major worldwide public health problem specially the moderate and severe type, with high morbidity and mortality [1]. Neuroimaging plays an important role in the initial evaluation of patients with acute TBI as well as guidance of management and planning for surgical intervention [2], [3]. Non-enhanced computerized tomography (CT) is the imaging modality of choice during the first 24 hour after the injury because it is readily available, cost effective, rapid and easier to perform on patients who are on ventilator support, in traction, or agitated and it is superior to magnetic resonance imaging (MRI) in evaluating bones and detecting acute intracranial hemorrhage [3]. [4]. Based on initial CT scan findings of TBI, the Marshall score was introduced in 1991 as a classification system for head injury and has been used to predict outcome, guide patient management and design clinical trial [5].

Raised intracranial pressure (ICP), defined as cerebrospinal fluid (CSF) pressure of more or equal to 20 mm HG, can lead to adverse and often irreversible neurological consequence if untreated [6]. Raised ICP is seen frequently after a severe TBI [1], therefore early identification is critical to ensure timely and appropriate management [7]. To avoid complications of the ventriculostomy, the traditional and gold standard method of measuring ICP, non-invasive methods of estimating ICP are preferred whenever possible and optic nerve sheath diameter (ONSD) is increasingly utilized to indirectly assess ICP using ultrasonography [8], CT scan [9] and MRI [10]. On other hand, fewer studies were published studying the significance of brain CT-derived ONSD in the evaluation and grading of TBI. We hypnotized that ONSD measurement using CT scan may give a clue for the severity of the TBI. Therefore, the purpose of this study was to assess the correlation between ONSD measurements using CT scan with the severity of TBI according to Marshall scale.

II. Patients and Method

This cross-sectional study was conducted on 60 adult patients (52 males, 8 females) with acute TBI presented within the first 24 hours of insult and referred for brain CT examination to the CT unit at Middle Euphrates Neuroscience Center, Najaf, Iraq.

Exclusion criteria included children (less than 18-year-old) and patients with known or obvious orbital pathology or orbital trauma.

All examinations were carried out using 64-multidetector helical CT scan (Brilliance, Philips Medical System 2011). Patients were examined in supine position with the following parameters: KV 120, MAS 300m.As, slice thickness 3 mm and time 12 seconds. All examination were non-enhanced i.e. no intravenous iodinated contrast medium has been administrated.

Demographic data as well as the duration from onset of injury to the time of CT examination were recorded.

Evaluation of CT scan images was done by a board-certified specialist radiologist (with experience of >12-years in neuroradiology). Based on initial brain CT scan findings, TBI was classified according to Marshall scale [5] from I to VI (Fig. 1 and Table I).

The transverse diameter of the optic nerve sheath was measured manually at 3 mm distance behind the eyeball on axial brain image (Fig. 2). The measurements were taken for the left and right eyes and averaged to yield a mean value. All measurements were taken using constant technical settings of brain window (window level and center values of 40 and 80 respectively). ONSD measurements were categorized using 5 mm as a cut-off normal limit [11]

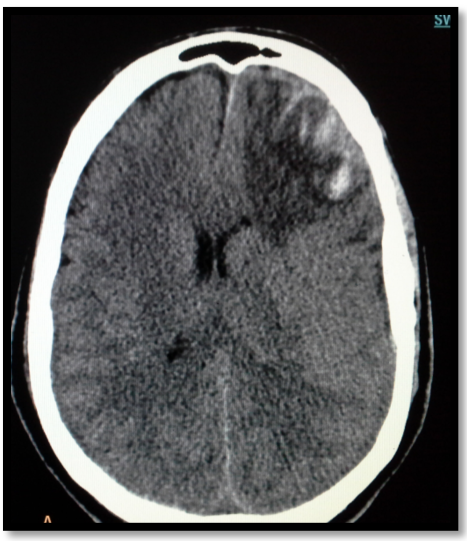

Fig. 1. Axial non-enhanced CT scan of the brain injury in 25-year-old male, showing midline shift=7 mm, effacement of lateral ventricle, left frontal hemorrhagic contusion (grade IV according to Marshal scale).

TABLE I: Marshall Classification of Traumatic Brain Injury using CT Scan [5]

Level	Classification
I	No visible intracranial pathology
II	Diffuse injury with cisterns present and 0- to 5-mm shift
III	Diffuse injury with cisterns compressed or absent and 0- to 5-mm shift
IV	Diffuse injury with midline shift >5 mm but no lesion >25 mm
V	Evacuated mass lesion, any surgically evacuated mass lesion (EML)
VI	Non evacuated mass lesion, any high- or mixed-density mass lesion >25 mm not surgically evacuated (NEML)

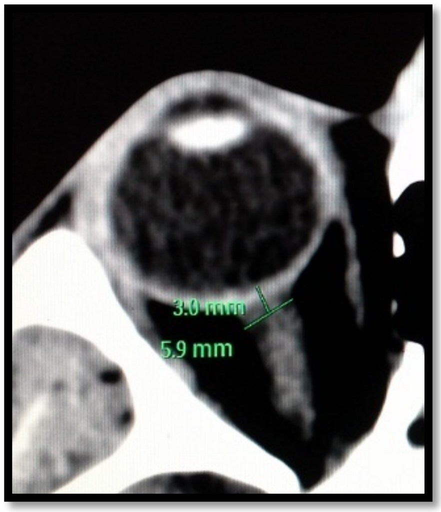

Fig. 2. Zoomed-in axial CT image demonstrating ONSD measurement at 3 mm behind the eye globe.

The study was approved by the Institutional Ethical Review Committee.

Statistical analysis was carried out using SPSS version 23. Categorical variables were presented as frequencies and percentages. Continuous variables were presented as (Means ± SD). Chi-Square test was used for categorical variables and Pearson coefficient for numerical data. P value of ≤ 0.05 was considered significant.

III. Results

Sixty patients with acute TBI were included with mean age of 29.13 (±10.24) years and range of 18-58 years. There was no statistically significant relation between age group and mean ONSD (Table II). Regarding gender, 52 were males and 8 were females, and similarly, there was no statistically significant gender difference between those with ONSD ≤5 mm and those with ONSD >5 mm (Table III).

The gender distribution was 52 (86.7%) males and 8 (13.3%) females, but there was no significant relation between ONSD and gender (p=0.462).

TABLE II: Relation between Age Group and Mean Optic Nerve Sheath Diameter

		Mean ONSD		P value
		≤5	>5	
Age group (years)	<25	20(52.6%)	11(50%)	0.328
	25-35	7(18.4%)	8(36.4%)	
	36-45	9(23.7%)	2(9.1%)	
	>45	2(5.3%)	1(4.5%)	
Total		38(100%)	22(100%)	

TABLE III: RELATION BETWEEN GENDER AND OPTIC NERVE SHEATH DIAMETER

Mean ONSD	Gender		P value
	Female	Male	
≤5 mm	6 75.0%	32 61.5%	0.462
>5 mm	2 25.0%	20 38.5%	
Total	8 100.0%	52 100.0%	

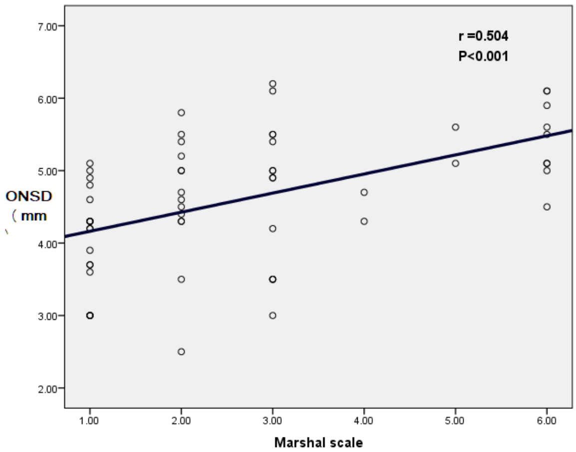

Fig. 3. Correlation between right ONSD and Marshall Scale.

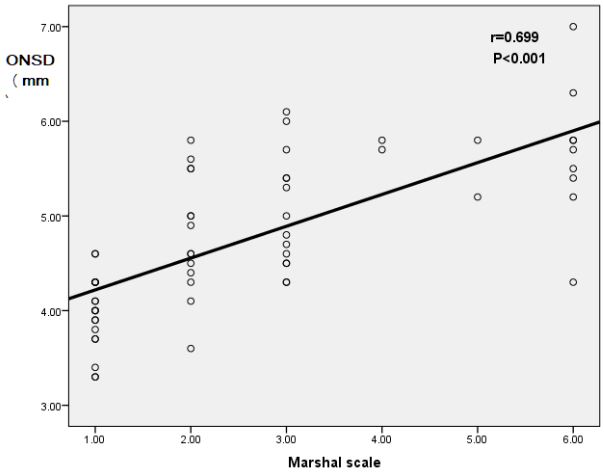

Fig. 4. Correlation between left ONSD and Marshall Scale.

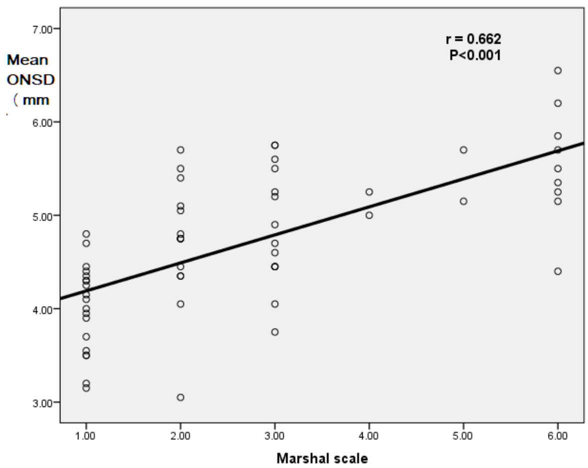

Fig. 5. Correlation between mean ONSD and Marshall Scale.

The means of all, right-sided and left-sided ONSD were 4.695 mm, 4.606 mm and 4.785 mm, respectively. There was no significant difference between mean ONSD measurements when correlated with the laterality of TBI, (p value 0.392). There was highly significant positive correlation between Marshall scale and the right-sided (r=0.504, p value <0.001), left-sided (r=0.699, p value <0.001) and mean ONSD (r=0.662, p value <0.001) (Fig. 3, Fig. 4, and Fig. 5 respectively).

There was very weak negative and statistically not significant correlation (r = 0.075, p=0.571) between mean ONSD and duration after trauma (Fig. 6).

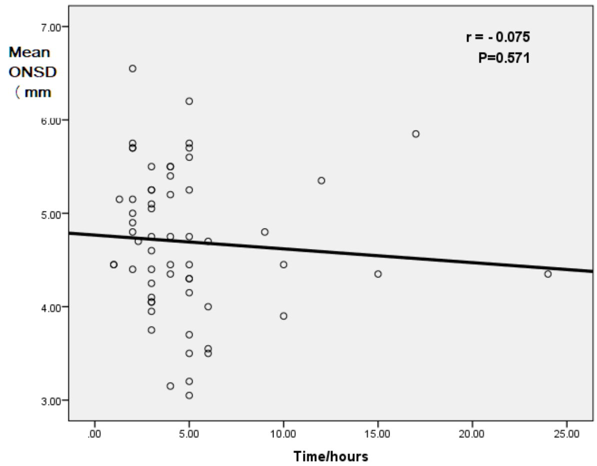

Fig. 6. Correlation between mean ONSD and duration after trauma.

IV. DISCUSSION

Raised ICP is considered one of the important clinical factors that determines the next step in management of acute TBI and can be measured directly or inferred indirectly from ONSD measurement [12].

Many studies have found significant correlation between direct ICP measurements (using ventriculostomy) and indirect assessment of ICP by measuring the ONSD (using optic nerve ultrasound or MRI) in patients with TBI [13], [14]. The underlying pathogenesis behind the enlargement of ONSD in case of increased ICP is believed to be due to the equilibration of CSF pressure between orbital and cranial cavities and the CSF flow and pressure toward the peri-neural sub-arachnoids space around the optic nerve is increased causing expansion of the optic nerve sheath [15]. It has been known for a long time that ICP may be raised after the initial head injury due to mass lesions, an increase in brain-water content (edema), and an increase in blood volume [16]. This raised ICP is reflected on CT imaging by the effacement of mesencephalic cisterns and midline shift, both of which are utilized in the Marshall score [17].

Reference [12] found that simultaneous measurement of ONSD on CT scan and ICP were strongly correlated and ONSD was much more predictive of ICP than other CT features. Furthermore, studies have also found high degree of agreement between MRI and CT measurements of ONSD in different intracranial pathologies [17], [18]. Therefore, findings of the current study could be another supportive evidence of using CT scan as an additional indirect method for assessing ICP. Prognosis is an essential element in evaluation of patients with acute head injury. Glasgow Coma Scale (GCS), one of the most commonly used clinical method for evaluating head injury patients, can reliably predict mortality at 24 hours after injury, but has only limited ability to predict longer-term outcome [19], [20]. Because Marshall categories are related to the mortality rate [21], the positive correlation between CT-derived ONSD and Marshall scale in our study can have prognostic impact. This finding supports [14] and [22] studies, and the former concluded that TBI patients with thicker ONSD on initial CT scan tend to have poor prognosis regarding survival and long term disability.

Although a gradual decrease in the initially abnormal ONSD has been observed over 10 hours in patients with severe TBI, until reached the normal values [23], our study showed no significant impact of the duration between onset of the trauma and CT examination on ONSD values up to the first 24 hours. This inconsistency may be attributed to the predominance of mild to moderate degrees of TBI cases in our study. Nevertheless, further evaluation of temporal evolution of ONSD by serial follow-up measurements after trauma would be interesting.

This study has some limitation, including relatively small sample size, no correlation with the actual ICP values using direct invasive measures and lack of follow-up of the patient's outcomes. However, we think that results of our study can be considered as preliminary and future researches entitling these issues seem worthy.

In conclusion, there was a positive direct correlation between ONSD measured on CT scan and the severity of TBI. ONSD was not significantly affected neither by laterality of TBI nor the duration after trauma. ONSD may have a prognostic value during assessment of patients with TBI. Measurement of ONSD by CT scan could alert clinicians to the presence of elevated ICP, whenever invasive methods of measuring ICP is contraindicated or is not available. Considering the feasibility and rapidity of ONSD measurement on CT scan, it might be useful to include ONSD measurement in the initial routine CT evaluation of head injury. The study raises a question about the possible added value of incorporating ONSD measurement into Marshal's scale and studies evaluating this modified scale are encouraged.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

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