

## ORIGINAL RESEARCH

## Sonographic Optic Nerve Sheath Diameter as a Screening Tool for Detection of Elevated Intracranial Pressure

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### Abstract

**Introduction:** Timely diagnosis and treatment of post-traumatic elevated intracranial pressure (EICP) could be reduced morbidity and mortality, and improved patients' outcome. This study is trying to evaluate the diagnostic accuracy of sonographic optic nerve sheath diameter (ONSD) in detection of EICP. **Methods:** Sonographic ONSD of patients with head trauma or cerebrovascular accident suspicious for EICP were evaluated by a trained chief resident of emergency medicine, who was blind to the clinical and brain computed tomography scan (BCT) findings of patients. Immediately after ultrasonography, BCT was performed and reported by an expert radiologist without awareness from other results of the patients. Finally, ultrasonographic and BCT findings regarding EICP were compared. To evaluate the ability of sonographic ONSD in predicting the BCT findings and obtain best cut-off level, receiver operating characteristic (ROC) curve were used. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and negative likelihood ratio (NLR) of sonographic ONSD in determining of EICP was calculated.  $P < 0.05$  was considered as statistically significant. **Results:** There were 222 patients (65.3% male), with mean age of  $42.2 \pm 19.5$  years (range: 16-90 years). BCT showed signs of EICP, in 28 cases (12.6%). The means of the ONSD in the patients with EICP and normal ICP were  $5.5 \pm 0.56$  and  $3.93 \pm 0.53$  mm, respectively ( $P < 0.0001$ ). ROC curve demonstrated that the best cut off was 4.85 mm. Sensitivity, specificity, PPV, NPV, PLR, and NLR of ONSD for prediction of EICP were 96.4%, 95.3%, 72.2%, 98.9%, 20.6, and 0.04, respectively. **Conclusion:** Sonographic diameter of optic nerve sheath could be considered as an available, accurate, and noninvasive screening tool in determining the elevated intracranial pressure in cases with head trauma or cerebrovascular accident.

**Key words:** Intracranial pressure; traumatic brain injury; ultrasonography; optic nerve; tomography

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### Introduction:

Head injury is the most common cause of road-traffic-related morbidity and mortality of all ages (1). Traumatic brain injuries and related increasing intracranial pressure (EICP) might result in the worsening of patient outcomes (2). Timely diagnosis and treatment of post-traumatic EICP could be reduced morbidity and mortality of patients. There are some invasive, expensive or expert needed methods as lumbar puncture, magnetic resonance imaging (MRI), and computed tomography scan (CT-scan) for detection of EICP (3). Physical examination is not always reliable and also, some signs of EICP such as pupil edema are late coming or hardly detected (4). So, reliable, accessi-

ble, easy to learn and noninvasive technique for this purpose, like Sonography, is of interest for clinician. Some studies have assessed the diagnostic accuracy of sonography in animal models, children, and adults in emergent or even in healthy subjects (5-9). These studies were heterogenous from different target population in different settings and their results are not completely applicable for other persons. Our previous study, showed that the sonographic ONSD might be considered as a strong and accurate predicting factor for detection of EICP (10). In this study, we prospectively evaluated the diagnostic accuracy of sonography for detecting EICP in a setting of emergency patients with head trauma or suspicious cerebrovascular accident in a relatively larger sample than previous similar studies. Moreover, we intended to determine the best cut off values of ONSD for detecting EICP in comparison with brain computed tomography scan (BCT) findings.

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## Methods:

### Study design and setting

In this diagnostic trial, we recruited 222 patients suspicious for EICP due to head trauma or cerebrovascular accident referring to emergency department of Imam Hossien Hospital, Tehran, Iran between May and October 2011. The protocol of this study was reviewed and approved by Shahid Beheshti University of Medical Sciences Ethics Committee (code: 6476). The study protocol conformed to the ethical guidelines of the Declaration of Helsinki. After complete explanation about the procedure for the patient, written informed consent was received. Surrogate consent by guardian was obtained in case patients with altered mental status.

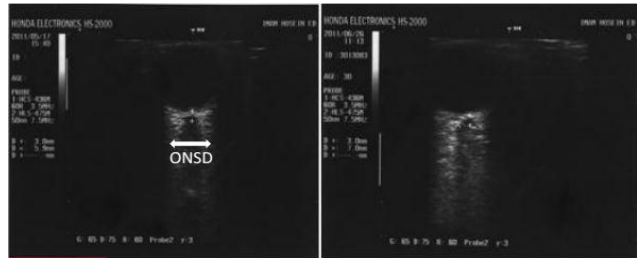
### Participants

The subjects with head trauma or cerebrovascular accident were enrolled. Cases with age < 16, direct trauma to the eye, ophthalmic diseases, and under treatment with medications affecting on intracranial pressure were excluded. Sample size was determined according to sample size calculation for formula of diagnostic tests, considering sensitivity=0.8, specificity=0.8, and  $\alpha=0.05$ . Therefore, sample size was estimated to be 222 cases.

### Intervention

Before doing brain CT-scan for definite diagnosis, ONSD of both eyes was determined by ultrasonography. We did ultrasonography before awareness from the result of BCT to prevent diagnostic suspicious bias. Sonographer was also blind to the patient's clinical condition. Ultrasonographies of the optic nerve was performed by chief resident of emergency medicine who was trained for measurement of ONSD by a radiologist. Trans-orbital ultrasonography of the optic nerve was performed using a 7.5 MHz linear transducer (HS2000, Honda, Korea) sized 5.5×1 cm. The patient was relaxed, calm, in supine position with closed eyes. It was done from the most upper part of the upper eyelid, 3 mm before entrance of the optic nerve to the globe. The ONSD was calculated as the horizontal distance between the 2 cursors (Figure 1). One time measurement was taken for each optic nerve. The mean ONSD registered was the average value obtained from measurements of both right and left eyes, despite the fact that previous studies have shown the presence of intra-ocular symmetry between the OND/ONSDs of fellow eyes (11, 12). Immediately after ultrasonography, BCT was performed and reported by one expert radiologist without awareness from the results of the sonography. Signs of EICP in BCT were effacement of sulci, significant edema, midline shifting, and collapse of ventricle(s). Finally, results of ultrasonography were compared with BCT findings.

Age, gender, level of consciousness according to Glasgow Coma Scale (GCS), type of injury (trauma or cere-



**Figure 1:** Sonographic optic nerve sheath diameter (ONSD).

brovascular accident), ONSD of both eyes by ultrasonography and BCT findings were determined in all patients.

### Statistical analysis

We used mean and standard deviation, for description of quantitative variables. The relation of GCS and ONSD was assessed using person correlation coefficient. To evaluate the ability of ONSD in predicting the BCT results and obtain best cut-off level, receiver operating characteristic (ROC) curve and its area under the curve (AUC) were used. In addition, in specific cut-point we determined operating characteristics consist of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and negative likelihood ratio (NLR). Differences or correlations with  $P < 0.05$  were considered statistically significant. We used STATA version 11.0 statistical software in analysis.

### Results:

There were 222 patients (65.3% male), with mean age of  $42.2 \pm 19.5$  years (range: 16-90 years). A summary of patients' demographic data is presented in table 1. Type of injury was trauma in 204 cases (91.9%) and cerebrovascular accident in 18 (8.1%). Only 27 (12.2%) cases had GCS<15. BCT finding was confirmed 28 (12.6%) cases of EICP. Among cases with decreased GCS, 13 (48.1%) patients had positive BCT findings. The means of sonographic ONSD on the left and right sides were  $4.2 \pm 0.8$  and  $4.1 \pm 0.8$  mm, respectively ( $P = 0.41$ ). The mean of the sonographic diameters of the optic nerve sheath of the two eyes was  $4.1 \pm 0.8$  mm, with no significant relationships with patient age ( $p=0.99$ ) and gender ( $P=0.19$ ). The means of the ONSD in the patients with EICP and normal ICP were  $5.5 \pm 0.56$  and  $3.93 \pm 0.53$  mm, respectively ( $P<0.0001$ ). GCS was inversely associated with right ( $r=-0.37$ ,  $P<0.001$ ), left ( $r=-0.26$ ,  $P<0.001$ ) and mean ONSD ( $r=-0.33$ ,  $P<0.001$ ). Roc analysis demonstrated that the best cut off was 4.85 mm (figure 2). Area under the curve for diagnosis of the EICP was 0.95 (95% CI: 0.89-1.0). Sensitivity and specificity of ONSD for prediction of EICP were 96.4 % (95% CI: 83.9-99.8) and 95.3% (95% CI: 90.4-99.9), respectively. In addition positive and negative predictive value were 72.2% (95% CI: 67.4-79.2) and 98.9% (95% CI: 95.8-99.8), respectively. Positive and negative like-

**Table 1:** Basic characteristics of patients

Characteristics	Total	BCT findings		P value
		Negative	Positive	
Age (year)	42.2±19.5	41.9±19.1	44.6±21.8	0.5
GCS	14.8±0.69	14.9±0.37	13.96±1.45	<0.001
Left ONSD (mm)	4.14±0.77	3.65±0.58	5.5±0.52	<0.001
Right ONSD (mm)	4.12±0.76	3.9±0.52	5.5±0.7	<0.001
Mean ONSD (mm)	4.13±0.75	3.9±0.53	5.5±0.56	<0.001

BCT: Brain computer tomography; GCS: Glasgow coma scale; ONSD: Optic nerve sheath diameter

likelihood ratio of ONSD for detection of EICP was 20.6 (95% CI: 18.2-22.4) and 0.04 (95% CI: 0.02-0.06), respectively.

#### Discussion:

Based on the main result of this study ONSD had acceptable sensitivity, specificity, NPV, and PPV for detection of EICP at cut-off value of 4.85 mm. The probability to have EICP if ONSD is less than 4.85 mm is 0.04, which is sufficiently very low. Previous studies have considered a cut off range of ONSD in predicting of EICP between 5 and 5.9 mm (table 2). Low PPV in this study, despite high sensitivity and specificity, could be due to low number of cases with positive BCT findings.

During last decades, many studies have shown that the ONSD can noninvasively predict the EICP (13-15). One study has been shown that increase of ONSD in cases with EICP occurs faster than other ophthalmoscopic findings (16). However, technique, accuracy, and cut off for detecting EICP are different between these studies. Girisgin et al. have been shown that mean OND in patients suspected to have EICP is significantly higher than the healthy subjects (17). A similar study on 156 Iranian children showed that cases with EICP had significantly larger mean ONDs (7). We have summarized the results of similar studies in emergency setting or

ICU in table 2.

It seems it is time to determine the best cut off point for detection of EICP in different subgroups of children, adults, cases with different underlying diseases (trauma, cerebrovascular accident and so on), gender, age, and any other important factors which affect the normal or pathologic value of OND and ONSD.

As other studies have shown, optic nerve sonography has technical limitations and requires a high level of expertise (18). Sonography may be impossible to perform because of superficial surgical wounds or severe anatomic alterations in patients with head trauma. Moreover, we should consider that BCT signs are not always correspond to real elevation of the intracranial pressure.

#### Conclusion:

Sonographic diameter of optic nerve sheath could be considered as an available, accurate, and noninvasive screening tool in determining the elevated intracranial pressure in cases with head trauma or cerebrovascular accident.

#### Acknowledgment:

We would like to express our special thanks from all cases participated in this study.

#### Conflict of interest:

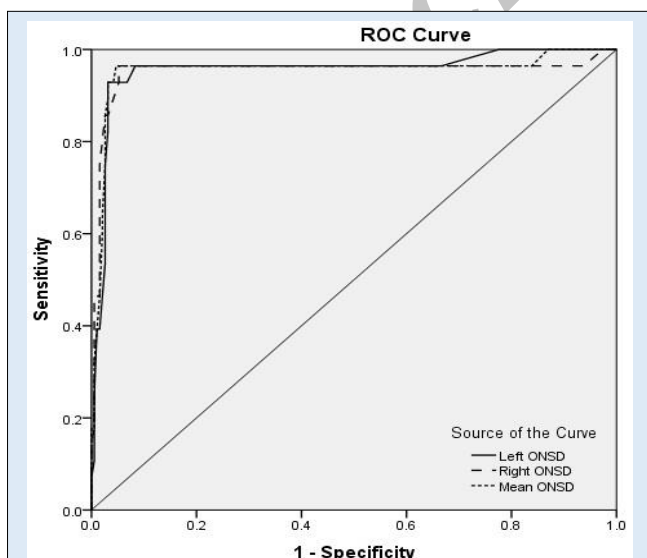
There was no conflict of interest.

#### Author's contribution:

All authors contribute in drafting/revising the manuscript, study concept or design, analysis or interpretation of data.

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**Figure 2:** Receiver operator characteristic (ROC) curve at various cut offs of optic nerve sheath diameter.

**Table 2:** Summary of similar studies

Study	Sample (n)	Study population	Cut off, gold standard	Sensitivity	Specificity
Le et al. USA 2009 (6)	68	Cases with suspected or confirmed increased ICP, presenting to the ED or ICU of an urban, academic, freestanding, tertiary-level children's hospital, age range: 0-18 years	ONSD > 4 mm in infants under 1 year ONSD > 4.5 mm in children > 1 year CT-scan / ventriculostomy / lumbar puncture	96%	48%
Kimberly et al. USA 2008 (19)	15	Adult patients in both the ED and the neurologic ICU who had invasive intracranial monitors placed as part of their clinical care, age > 18 years old	ONSD > 5 mm Invasive intracranial monitors	88%	93%
Karakitsos et al. Greece 2006 (8)	54	Patients with brain injury (GCS < 8), mean age $\pm$ SD = 40 $\pm$ 18.6	OND > 5.9 mm CT-scan	74%	65%
Blaivas et al. USA 2003 (20)	14	ED patients with a suspicion of EICP due to possible focal intracranial pathology, age > 18 years old	ONSD > 5 mm CT-scan	100%	95%
Bäuerle et al. Germany 2011 (21)	10	Patients with idiopathic intracranial hypertension, age $\geq$ 18 years old	ONSD > 5.8 mm Measuring the CSF opening pressure by lumbar puncture	90%	84%
Geeraerts et al. France 2008 (22)	37	Adult patients requiring sedation and ICP monitoring after severe traumatic brain injury, subarachnoid hemorrhage, intracranial hematoma, or stroke, age range: 18-76 years	ONSD > 5.86 mm Invasive measurement ICP via a parenchymal device	95%	79%
Geeraerts et al. UK 2008 (23)	38	Patients requiring ICP monitoring after severe traumatic brain injury, mean age $\pm$ SD = 35 $\pm$ 14	ONSD > 5.82 mm CT-scan	90%	92%
Tayal et al. USA 2007 (24)	59	Adult ED patients with suspected intracranial injury with possible elevated intracranial pressure without obvious ocular trauma, > 18 years old	OND > 5 mm CT-scan	100%	63%
Soldatos et al. Greece 2008 (18)	76	Critical care patients, age > 18 years old	ONSD > 5.7 mm Invasive ICP measurement using an intraparenchymal catheter	74%	100%
Major et al. UK 2011 (25)	26	Adult patients who required CT from the ED, age > 18 years old	ONSD > 5 mm CT-scan	86%	100%

ED: Emergency department, CT: Computed tomography, GCS: Glasgow coma scale, ICP: Intracranial pressure, ICU: Intensive care unit, OND: Optic nerve diameter, ONSD: Optic nerve sheath diameter, mm: Millimeter; SD: Standard deviation



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