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Bedside measurement of the optic nerve sheath diameter with ultrasound in cerebrovascular disorders

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Background/aim: We aimed to show the role of determination of optic nerve sheath diameter (ONSD) by bedside ultrasonography in an emergency department in the diagnosis of cerebrovascular disorders and its correlation with the clinical picture.

Materials and methods: This prospective cross-sectional study included 55 patients with cerebrovascular disorders and 53 controls. Age, sex, ONSD, comorbid disease status, and multidetector computed tomography results of all subjects and application periods and National Institutes of Health Stroke Scale (NIHSS) scores of the patient group were evaluated.

Results: The ONSD of the patient and control groups was determined as a median of 5.7 mm and 3.6 mm, respectively. The ONSD of the patient group was determined to be significantly higher than that of the control group ($P < 0.05$). A positive relationship was determined between NIHSS scores and ONSD values ($P < 0.05$). The specificity and sensitivity values were determined as 98.1% and 81.8%, respectively, for a cutoff value of 5 mm and as 100% and 72.7%, respectively, for a cutoff value of 6 mm.

Conclusion: This study showed that bedside measurement of ONSD is an easy, cheap, and noninvasive method that can be used to support the diagnosis and evaluation of patients with acute stroke.

Key words: Optic nerve, cerebrovascular disorders, ultrasonography

1. Introduction

Cerebrovascular disorders (CVDs) are pathologies with higher mortality in the short term and higher morbidity rates in the long term. These are important pathologies in emergency departments (EDs) due to the higher possibility of reperfusion and the need to be able to decrease the incidences of mortality and morbidity. Timely treatment and supportive care of stroke patients in the ED is crucial for patient outcomes (1). The annual prevalence of stroke has been reported to be 0.15% in developed countries and this rate is gradually increasing. It is the second most frequent cause of death in the European Union and is ranked third globally (2).

CVD results in edema depending on the deterioration of the autoregulation of the brain. Cerebral edema must be diagnosed and treated as it causes an increase in intracranial pressure (ICP) and damages the patient's health (3). There are invasive and noninvasive methods that can be used to determine the increase of ICP (4–6). The gold standard for diagnosing increased ICP is the use of intracranial devices. However, this requires an invasive method that has multiple disadvantages, namely severe complications (infection, hemorrhage, malfunction) and nonfeasibility due to lack of neurosurgical expertise or contraindications (coagulopathy, thrombocythemia) (7). There have been contradictory results in the use of noninvasive methods (6,8,9). Recent studies have shown a correlation between optic nerve sheath (ONS) thickness and ICP (10–13).

Ultrasonography (US) of the intraconal segment of the optic nerve (ON) and its sheath is an easy, cheap, noninvasive method and provides a very promising bedside tool for the detection of increased ICP. The ON and its sheath are tubular structures of about 5 cm in

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length in which the intraconal segment is easily evaluable by US. Histologically, the ONS is surrounded by the same meningeal layers as the brain (14,15). The ON appears as a linear structure located inside the ONS. The ON is surrounded by hypoechoic cerebrospinal fluid in US images. Some US studies have reported that enlargement of ONS diameter (ONSD) is an early sign of increased ICP (13,16–20).

In this study, it was aimed to show the role of determination of the ONSD in the diagnosis of CVDs and its correlation with the clinical picture.

2. Materials and methods

This prospective, cross-sectional study included 55 patients meeting the criteria with CVDs and 53 controls at a referral emergency center of Atatürk Training and Research Hospital, located in Ankara, Turkey. Approval for the study was granted by the ethics committee of this hospital (23 July 2012, no: 45) and informed consent was obtained from all the study participants.

2.1. Patient and control groups

After a complete medical history and family history were obtained, all patients and control subjects underwent a detailed neuroophthalmological examination. The diagnosis of CVD was made according to Emergency Medicine Stroke Guidelines (1,3). After general physical and neuroophthalmological examination, multidetector computed tomography (MDCT) acquisitions were obtained from all subjects. If needed, diffusion-weighted MRI was obtained.

Evaluation was made of the age, sex, presentation time to the ED, ONSD, arterial pressure, pulse rate, comorbid disease frequency, drug use, computed tomography results, and National Institutes of Health Stroke Scale (NIHSS) scores of the 55 patients who presented with CVD to our ED. To minimize the effects of age, sex, and comorbid diseases, the control group was composed of 53 people with similar age and sex characteristics. Comparisons were made for age, sex, and ONSD of the patients and controls. The NIHSS score was compared with the ONSD. Cutoff value and specificity and sensitivity levels were determined for ONSD based on clinical and MDCT findings as a gold standard reference together.

Individuals under the age of 18 years were excluded. Vascular dementia, hypertensive encephalopathy, transient ischemic attack, liver failure, chronic kidney failure, trauma, optic neuritis, cystic lesion around the optic nerves, optic nerve trauma, orbital/cavernous sinus mass, pregnancy, neurofibromatosis, and breast-feeding were also exclusion criteria for the study.

2.2. ONS diameter measurements

ONSD was determined with a 7.5-MHz linear probe and US device (Mindray Biomedical Co., Shenzhen, China). Eye US exams for measurements of ONSD were implemented with the closed-eye method. The linear probe with gel was applied either within the protective cover or directly onto the closed eye. The eyeball was viewed in the sagittal and axial planes. Following the determination of the ONS through US imaging, the ONSD measurements were taken 0.3 cm posterior from the globe. It takes 2 min to apply US to both eyes. Each optic nerve was measured three times and the mean number was recorded. The arithmetic mean values of right and left ONSDs were entered in the analysis.

2.3. Statistical analyses

Analysis of data was performed using SPSS for Windows 15. The conformity of the continuous and discrete numerical variables to normal distribution was analyzed with the Kolmogorov–Smirnov test. Descriptive statistics were shown as mean ± standard deviation or median and interquartile range (IQR) for the continuous and discrete numerical variables, and categorical variables were shown as number of cases (n) and percentages (%). Categorical variables were evaluated with the chi-square test and parametric and nonparametric data were analyzed with the Student t and Mann–Whitney U tests, respectively. The cutoff value and specificity and sensitivity levels were determined through ROC analysis. Unless indicated otherwise, $P < 0.05$ was accepted as statistically significant.

3. Results

The median ages of the patients and control groups in the study were determined as 74 years (IQR: 18) and 72 years (IQR: 13.5), respectively. The rate of males in the patients group was 56.4%, while this rate was 67.9% for the control group. No significant difference was determined between the groups in terms of age or sex ($P > 0.05$). The ONSD of the patient and control group was determined as a median of 5.7 mm (IQR: 0.85) and 3.6 mm (IQR: 0.59), respectively. The ONSD of the patient group was determined to be significantly higher than that of the control group ($P < 0.05$) (Table 1; Figure 1).

While systolic blood pressure and diastolic blood pressure were significantly higher in the patient group ($P < 0.05$), pulse rates were similar to the control group ($P > 0.05$). While comorbid disease frequency (hypertension, diabetes mellitus, presence of atrial fibrillation, and drug use frequency) was significantly higher in the patient group ($P < 0.05$), former stroke history and chronic obstructive pulmonary disease frequencies were similar.

The mean NIHSS score of the patients was 18.1 ± 6.4 and the median value of the presentation time at the ED was 4 h (IQR: 4.7). Patients showed 7.2% hemorrhagic infarct and 54.5% ischemic infarct on cranial tomography (CT), while 38.3% of the patients had no findings on CT (Table 1). When the ONSDs of the patients were evaluated according to the presence or absence of CT findings, the ONSD of

Table 1. Characteristics of the groups.

Parameters	Discrimination	Patients (n: 55)	Controls	value
Age	Median (IQR)	74 (18)	72 (13.5)	0.601*
Sex	Male: n (%)	31 (56.4)	36 (67.9)	0.216**
	Female: n (%)	24 (43.6)	17 (32.1)	
ONSD	Median (IQR)	5.7 (0.85)	3.6 (0.59)	<0.001*
SBP	Mean ± SD	161.1 ± 20.3	135.1 ± 22.7	<0.001**
DBP	Mean ± SD	91.1 ± 13.6	75.4 ± 14.9	<0.001**
Pulse	Mean ± SD	84.8 ± 24.6	82.6 ± 22.6	0.595**
Comorbid disease	n (%)	50 (90.9)	28 (52.8)	<0.001**
Hypertension	n (%)	37 (67.3)	13 (24.5)	<0.001**
Diabetes mellitus	n (%)	31 (56.4)	11 (20.8)	<0.001**
Atrial fibrillation	n (%)	25 (45.5)	5 (9.4)	<0.001**
Stroke history	n (%)	7 (12.7)	8 (15.1)	0.722**
COPD	n (%)	7 (12.7)	2 (3.8)	0.092**
Drug use	n (%)	48 (87.3)	21 (39.6)	<0.001**
NIHSS	Mean ± SD	18.1 ± 6.4	-	-
Presentation	Median (IQR)	4 (14.7)	-	-
Hemorrhage on CT	n (%)	4 (7.2)	-	-
Ischemia on CT	n (%)	30 (54.5)	-	-
Normal CT findings	n (%)	21 (38.3)	-	-

*: Mann–Whitney U test, **: chi-Square, ***: Student t-test, ONSD: optic nerve sheath diameter, SBP: systolic blood pressure, DBP: diastolic blood pressure, NIHSS: National Institute of Health Stroke Scale, COPD: chronic obstructive pulmonary disease, CT: cranial tomography, SD: standard deviation, IQR: interquartile range.

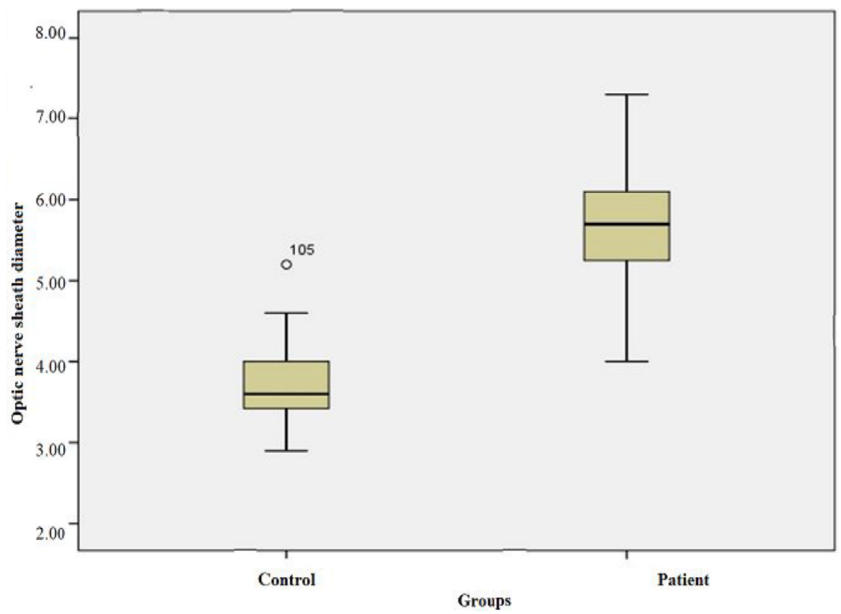

Figure 1. Graphical display of the ONSD of the groups.

the patients with CT findings was 5.24 ± 0.81 and the ONSD diameter of the patients without CT findings was 4.41 ± 1.21 mm. This difference was statistically significant ($P < 0.05$). There was a weak positive correlation between the NIHSS score of the patients and the ONSD ($P < 0.05$, r: 0.363). There was no relationship between the ONSD values of the patients and their age and time of presentation ($P > 0.05$) (Table 2).

The specificity and sensitivity values were determined as 98.1% and 81.8%, respectively, for a cutoff value of 5 mm and as 100% and 72.7%, respectively, for a cutoff value of 6 mm. The area under the curve was determined as 0.99 (95% confidence interval: 0.978–1.0) (Figure 2).

4. Discussion

In this study, we showed that the ONSD measured by bedside US was increased in patients with stroke. However, we found a weak positive correlation between ONSD enlargement and stroke severity, although it was statistically significant.

The World Health Organization has described CVD as a clinical condition that develops suddenly due to vascular reasons, continues for more than 24 h, and results in focal or global cerebral dysfunction (21).

Brain tissue uses 20% of the entire cardiac output and 25% of all oxygen flow. Cerebral blood flow is the most important factor that affects brain function. Ischemia

Table 2. Relationships between ONSD and NIHSS, presentation time, and age.

	Correlation coefficient	P-value	Number of patients (n)
NIHSS	0.363	0.006	55
Age	0.010	0.919	108*
Presentation time	0.005	0.969	55

*: Pearson correlation, ONSD: optic nerve sheath diameter, NIHSS: National Institute of Health Stroke Scale.

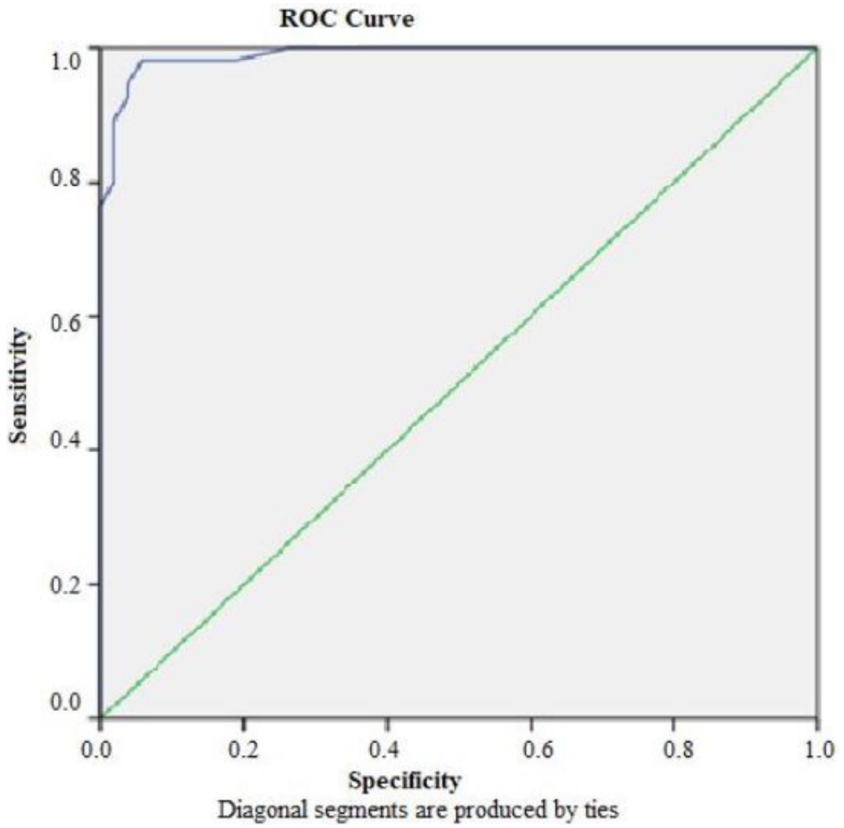

Figure 2. ROC curve for ONSD in CVD cases.

develops at the tissue level as a result of a thromboembolic event or hemorrhage in the clinical picture of CVD (22).

As sufficient energy will not be able to be provided for the Na,K-ATPase pump as a result of this ischemia, there will be Na and accompanying water input into the cells. Consequently, cytotoxic edema and, in subsequent periods, cell necrosis develop. Enzymes and free radicals in the cells fragmented as a result of necrosis are released and enter a vicious cycle that causes more neuron destruction. Changes in the cerebral blood flow developing as a result of CVD, the breakdown of cerebral perfusion pressure due to edema that develops at the tissue level, and ineffective CSF circulation cause an increase in ICP (17,22,23).

The ON is unique because it represents an extension of the central nervous system and has a cover (dura, arachnoid, and pia) (24). The positive relationships between raised ICP and the dilatation of the ONS and papillae edema have been known for several years (25–27).

Watanabe et al. (28) and Moretti et al. (29) stated that the ONSD decreased with CSF drainage in patients with intracerebral hemorrhage. In the current study, ONSD was seen to increase significantly as the clinical condition of the patient worsened. The main reason for this may be the development of altered ONSD caused by the increasing ICP in stroke patients creating a rising pressure on the optic nerve and perineuronal CSF circulation. Another mechanism that may cause an increase in the ONSD could be that the ON, which is accepted as an extension of the brain, affects the ONSD with the effect of raised cranial perfusion pressure. In addition, it must be remembered that papillary edema, which is caused by ICP, may lead to increased ONSD (26,27).

In some studies, ONSD has been reported as 4.9–5.9 mm in cases of ICP (17,20,30,31). Soldatos et al. (17) determined ONSD as 6.1 mm in patients with severe brain injuries, 4.2 mm in moderate-severe injuries, and 3.6 mm in the control group. Kimberly et al. (13) reported that the mean ONSD in patients with ICP of <20 cmH_2O was 4.4 mm, and it was 5.4 mm in patients with ICP >20 cmH_2O. Skoloudík et al. (32) emphasized that ONSD enlargement was not detected in any acute ischemic stroke patients or healthy volunteers, but it was detected in 86% of patients with acute intracerebral hemorrhage.

In the current study, ONSD was determined as 5.7 mm in the patient group. These data are consistent with the literature. In this study, it was thought that ICP had increased as a result of the mass effect of the cerebral edema. In these patients, hemorrhagic infarcts develop, and consequently an increase occurs in the ONSD. It can be considered that the ONSD varied with the ICP changes in such patients and therefore the values determined were significant.

NIHSS scores have been reported to be effective in showing the general status of patients and mortality rates (33,34). In one study, however (34), no relationship was determined between NIHSS score and ONSD. In the current study, a significant relationship was found between NIHSS score and ONSD. It can be considered that the magnitude of the involvement area in ischemic infarcts and the status of hematoma (magnitude, extension to ventricle or peripheral tissues) in hemorrhagic infarcts are changing the clinical picture and ICP of the patients.

Sahoo et al. (18) stated that the sensitivity and specificity values were 100% and 91%, respectively, for a cutoff value of 5 mm and 100% and 73.6%, respectively, for a cutoff value of 6 mm for severe traumatic brain injury patients. Amini et al. (20) reported that ONSD of greater than 5.5 mm predicted an ICP of ≥20 cmH_2O with sensitivity and specificity of 100%. Soldatos et al. (17) reported the sensitivity and specificity values as 71% and 100%, respectively, when the cutoff value was 5.7 mm for adult brain injury patients. In the current study, the specificity and sensitivity values were determined as 98% and 82%, respectively, for a cutoff value of 5 mm and as 100% and 72.7%, respectively, for a cutoff value of 6 mm for patients with cerebrovascular disorders. These results show similarity with other studies in literature.

There are some limitations of our study. First, the ONSD measurements were not taken by a single expert. Second, ICP measurements were not made for the study patients because appropriate recording is not possible for stroke patients. The US application time could not be standardized due to the differences in the application period of the patients included in the study. Differences between groups in terms of comorbid diseases is another limitation. In the future, larger, randomized, controlled multicenter trials are needed to support our findings.

In conclusion, the bedside measurement of ONSD is a quick, easy, cheap, and noninvasive method that can be a useful tool in evaluation of patients with acute stroke. It can be used to support the diagnosis and for quick evaluation for treatment.

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