Original Article

The Value of Bedside Ocular Ultrasound Assessment of Optic Nerve Sheath Diameter in The Detection of Increased Intracranial Pressure in Patients Presenting to the Emergency Room with Headache

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Abstract

Introduction: Headache is one of the most important complaints in emergency room (ER) admissions, and the rate of the increase in intracranial pressure in these cases should not be overlooked. This study was performed to investigate the value of the measurement of optic nerve sheath diameter (ONSD) by ocular ultrasound in ER patients with the complaint of headache and increase in intracranial pressure regarding this. **Materials and Methods:** A total of 100 patients who applied to the ER with the complaint of headache were included in this prospective study. Fifty patients with increased ONSD (≥5 mm) and 50 patients with normal ONSD (<5 mm) were obtained. ONSD measurements were performed with 7.5–10 MHz linear probe and closed-eye technique. In addition to this, all patients underwent cranial computerized tomography (CT) examinations, and CT results were compared with the results of the ocular ultrasound. **Results:** The median right and left ONSD values were detected to be 4.3 mm (3.6–5.5 mm) and 4.4 mm (3.6–5.6 mm) in patients whose cranial CT results were within normal limits. However, the median right and left ONSD values were detected to be 5.5 mm (5.1–6.3 mm) and 5.5 mm (5.1–6.4 mm) in patients whose cranial CT examination results were abnormal. In all cases with abnormal CT findings, the right and the left ONSD measurements were significantly higher (P < 0.001). Furthermore, ONSD value in the ipsilateral side with the lesion was significantly higher than the contralateral side (P < 0.001). **Conclusion:** Bedside ocular ultrasound is a noninvasive and easily applicable method in ER for the detection and evaluation of intracranial hypertension with headache.

Keywords: *Headache, intracranial hypertension, ocular ultrasound, optic nerve sheath diameter*

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Introduction

Headache is one of the most frequent causes of emergency room (ER) admissions.[1-3] Especially, life-threatening causes should be ruled out in the evaluation of these patients.[1] Headache inducing the increase in intracranial pressure is one of these causes. The findings of increased intracranial pressure are very well known, but they are not reliable in every aspect. These findings include generally depressed level of consciousness and hypertension associated with bradycardia. Various invasive methods can be used including measurement with intraventricular catheter, intracranial pressure transducer, subarachnoid bolt, and epidural transducers for the diagnosis and monitorization of intracranial hypertension.[4,5] On the other hand, transcranial Doppler US, b-mode transcranial ultrasound, and measurement of optic nerve sheath diameter (ONSD) have been utilized for noninvasive detection and

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monitorization of intracranial pressure.[6-8] In recent years, ultrasound has begun to be used more frequently in ERs.[9-11] Ultrasound is a noninvasive method which provides crucial information about anatomic structures and functions for emergency medicine physicians (EMPs) with less time. Besides, it provides guidance for EMPs in challenging interventions. In the busy ER, bedside ocular US carries great importance in the evaluation of the eye and surrounding tissues as it is a rapid and noninvasive method.[11] Ocular ultrasound is used to speed up the diagnosis and treatment of various emergencies such as perforation of the globe, retinal detachment, retrobulbar hematoma, lenticular subluxation, vitreous bleeding, and intraocular foreign substance.[11] Complete anamnesis should be obtained while evaluating the patients with suspected intracranial hypertension. Since clinical manifestations may be obscure, attentive physical examination should always be performed. In the detection of a suspected condition during physical examination, imaging modalities should be performed. ONSD measurement by ocular ultrasound which is widely used in the diagnosis of intracranial hypertension is one of these methods.[12-14]

The objective of this study is to demonstrate the usefulness of noninvasive ocular ultrasonographic method which can be easily applied at bedside in the assessment of intracranial hypertension, compare ocular US with cranial computerized tomography (CT), and contribute to the widespread use of ocular ultrasound in ERs.

Materials and Methods

This prospective study was conducted in a university hospital with 100 patients aged >18 years who applied to adult ER in 3 months with complaints of headache without a history of trauma and in whom cranial CT was indicated. The approval from ethics committee was taken (ethic committee decree # 2016-3/3). The exclusion criteria were as follows: patients with a history of trauma, who are younger than 18 years of age, who are pregnant, with a history of glaucoma or ophthalmic diseases, and individuals with ocular prosthesis. The patients' data such as age, sex, cranial CT findings, and ONSD measurements were recorded. During the study period, ONSD measurements of each patient were performed and recorded by the same emergency physician. Patients were examined in the supine position with a closed eyelid. Both eyes were scanned in vertical and horizontal planes through the eyelid. Then, optic disc of the eye was viewed, and ONSD measurements were performed in transverse and sagittal planes by using hypoechoic lines, 3 mm proximal to the optic disc. The patients were divided into two groups based on their ONSD measurements (normal ONSD: <5 mm and increased ONSD: ≥5 mm), and the results were compared with those of the cranial CT. Cranial CT images were obtained after ONSD measurements and evaluated by the radiologist.

Statistical analysis

Shapiro–Wilk test was used to determine whether data obtained fitted to normal distribution pattern. For the comparison of data with normal and nonnormal distribution between two independent groups, independent samples *t*-test and Mann–Whitney U-test were used, respectively. For the comparison of categorical data, Pearson Chi-square and Fisher's exact test were used. Categorical variables were expressed as n (%). For all statistical analyses, SPSS Statistics Version 21.0 (IBM Corp., USA) was used. Level of significance was accepted as $P = 0.05$ with a confidence interval.

Results

A total of 100 patients were included in the study (males 51% and females 49%). Cranial CT findings were within normal limits in 39.2% and pathologic in 60.8% of the male patients, respectively. Cranial CT findings were within normal limits in 67.3% and pathologic in 32.7% of the female patients, respectively. Based on these results, pathologic cranial CT findings were significantly more frequent in male patients ($P < 0.05$). Totally, 47% patients had abnormal CT findings and these findings were, respectively, metastatic tumor ($n = 27$), intracranial hemorrhage ($n = 12$), primary intracranial tumor ($n = 4$), aneurysm ($n = 2$), and hydrocephalus ($n = 2$).

In patients whose cranial CT examination results were within normal limits, the median right and left ONSD values were detected as 4.3 mm (3.6–5.5 mm) and 4.4 mm (3.6–5.6 mm), respectively. However, in patients whose cranial CT examination results were abnormal, the median right and left ONSD values were detected to be 5.5 mm (5.1–6.3 mm) and 5.5 mm (5.1–6.4 mm), respectively. In all cases with abnormal cranial CT findings, the right and left ONSD measurements were significantly higher ($P < 0.001$).

The right- and left-sided ONSD measurements were found to be significantly increased in all cases with pathologic cranial CT findings ($P < 0.001$). In only three cases, higher ONSD values were obtained despite normal cranial CT findings. These patients were later diagnosed as meningitis during the follow-up period. On cranial CT, median right ONSD values of the patients with right-sided lesions were calculated as 5.7 mm (5.3–6.3 mm) and median left ONSD as 5.4 mm (5.1–5.8 mm). On cranial CT, median right ONSD value of the patients with left-sided lesions was calculated as 5.3 mm (5.1–6.1 mm) and median left ONSD value as 5.6 mm (5.2–5.8 mm). Based on these results, ONSD measurements ipsilateral

Table 1: Comparison of cranial CT findings, and ONSD measurements

Cranial CT finding	Median (min-max) right ONSD measurement	Median (min-max) left ONSD measurement	*P*
Normal	4.3 mm (3.6-5.5 mm)	4.4 mm (3.6-5.6 mm)	*P*<0.001
Pathologic	5.5 mm (5.1-6.3 mm)	5.5 mm (5.1-6.4 mm)	*P*<0.001
Right-sided lesion	−5.7 mm (5.3-6.3 mm)	−5.4 mm (5.1-5.8 mm)	*P*<0.001
Left-sided lesion	−5.3 mm (5.1-6.1 mm)	−5.6 mm (5.2-5.8.mm)	*P*<0.001

ONSD=Optic nerve sheath diameter; CT=Computed tomography

Table 2: Evaluation of ONSD measurements based on comorbid diseases of the patients

Comorbid diseases	Normal ONSD, *n* (%)	Increased ONSD *n* (%)	Total *n* (%)	*P*
Hypertension	15 (55.6)	12 (44.4)	27 (100)	*P*<0.05
Malignancy	3 (11.1)	24 (88.9)	27 (100)	
Other	8 (50.0)	8 (50.0)	16 (100)	
None	24 (80.0)	6 (20.0)	30 (100)	*P*<0.05

ONSD=Optic nerve sheath diameter

Table 3: Correlation between outcomes of the patients, and ONSD measurements

Outcomes	Normal ONSD *n* (%)	Increased ONSD *n* (%)	Total *n* (%)	*P*
Discharge	48 (77.4)	14 (22.6)	62 (100)	*P*<0.001
Clinical hospitalization	2 (10.0)	18 (90.0)	20 (100)	*P*<0.001
Clinical referral	0 (0.00)	2 (100)	2 (100)	*P*<0.001
ICU stay	0 (0.00)	6 (100)	6 (100)	*P*<0.001
Referral to ICU	0 (0.00)	9 (100)	9 (100)	*P*<0.001
Emergency surgery	0 (0.00)	1 (100)	1 (100)	*P*<0.001

ONSD=Optic nerve sheath diameter

with the lesion were higher when compared with the contralateral side [Table 1] ($P < 0.001$).

The median Glasgow Coma Scale (GCS) value in patients with increased ONSD was 12 (6–15), while in patients with normal ONSD, it was calculated as 15 (15–15). A significant drop in GCS was seen in patients with increased intracranial pressure ($P < 0.05$).

Sixty-two percent of the study participants were discharged on the day of their hospital admissions while 20% of them were admitted to hospital. Two percent of the patients were referred to an external clinic due to the lack of vacant hospital beds, and 1% of the patients were followed up in the ICU. While 6% of these patients were hospitalized in ICU of our hospital, 9% of the patients were referred to an ICU of another center. Only one patient (1%) got an indication for surgery. This patient who admitted to the ER with headache and projectile vomiting was diagnosed as hydrocephalus and had a ventriculoperitoneal shunt operation. Cranial CT demonstrated an increase in ventricular dilatation. The patient was operated urgently with the diagnosis of shunt dysfunction.

Comorbid diseases of the study participants included hypertension (27%), malignancies (27%), and other chronic diseases as chronic obstructive pulmonary disease, diabetes, and heart failure (16%). While in 30% of the patients, no history of any chronic disease was obtained. Higher ONSD values were detected in 62.8% of the patients with comorbid diseases. ONSD values were within normal limits in 37.2% of the patients. In cases with comorbid diseases, a significant increase in ONSD values was detected [Table 2] ($P < 0.05$).

ONSD values were within normal limits in 77.4% and increased in 22.6% of the patients who were discharged whereas ONSD values were within normal limits in 10% and increased in 90% of the hospitalized patients. In all patients hospitalized in ICUs of our hospital or those referred to a clinic of an external center and ICU, higher ONSD values were detected. The only patient who underwent emergency surgery had also an increased ONSD value [Table 3]. According to these results, hospitalized or referred patients had significantly higher ONSD values ($P < 0.001$).

Discussion

Headache complaint takes an important part in ER admissions. In these patients, prompt action should be taken in order to diagnose the underlying pathology. Establishment of the diagnosis of intracranial hypertension requires a detailed anamnesis, complete physical examination, and advanced imaging modalities. If the diagnosis of intracranial hypertension is overlooked or delayed, morbidity and mortality rates increase.

Diagnostic methods can be invasive or noninvasive. Noninvasive and advanced imaging modalities such as CT and magnetic resonance imaging are very expensive and also require transportation to another place. In recent years, especially in the detection of intracranial hypertension, noninvasive bedside measurements of ultrasound-guided ONSD have been used frequently for the diagnostic process and lowering healthcare costs.

In healthy individuals, ONSD values range between 3.7 and 5.0 mm.[15,16] Furthermore, in our study, ONSD values over 5 mm were considered to be pathologic. The patients were divided into two groups as those with normal (<5 mm) and elevated ONSD (≥5 mm) values, and these values were compared with the results of cranial CT.

According to a study performed by Skoloudík *et al.*, control CT results obtained for male patients with intracranial hypertension and increased ONSD values at 6 h demonstrated intracranial bleeding in 52%, acute ischemic stroke in 60%, and other etiologic factors in 56% of the cases.[17] Similarly, in our study, pathological cranial CT results were obtained in 32% of female patients and 60.8% of male patients.

Soldatos *et al*. observed an inverse correlation between ONSD measurements and GCS scores.[18] In the study, the patients were divided into three separate groups based on ONSD measurements as cases with serious, the moderately severe cases with head traumas, and the control group. The median GCS scores of the cases with serious or moderately severe head traumas and the control group were calculated as 14, 11.1, and 4.9 points. Similarly, in our study including nontraumatic patients, median GCS scores of the groups with higher and lower ONSD values were calculated as 12 and 15 points. This condition can be explained by impaired consciousness of the patients related with the increased intracranial pressures of the patients. However, the study was performed with patients having head traumas which is different from our study and included only nontraumatic patients.

In our study, in all 47 cases with pathologic cranial CT, ONSD measurements were above normal values. However, in 3 (5.6%) of 53 cases with normal cranial CT findings, increased ONSD measurements were obtained, and these patients were later diagnosed as meningitis during follow-up period. In many other studies where ONSDs were measured using transorbital ultrasound, similar results were obtained.[19-23]

In a study performed by Komut *et al.*, the significance of ONSD measurements in nontraumatic cases using ocular ultrasound with respect to increased intracranial pressure was investigated, and similar to our study, higher ONSD values were detected in the group with pathologic cranial CT findings.[20] However, in the same study, a significant correlation could not be detected between ONSD values and age. In our study, median age in the group with higher ONSD values was estimated as 61 (19–87) years, and in the group with normal ONSD values, it was 47 (20–91) years.

Admissions to our hospital consist mainly (27%) of patient group with malignancies. However, in a study performed by Komut *et al.*, only 10% of the hospital admissions comprised of patients with malignancies. Since the incidence of malignancies increase with age, higher ONSD values might be more frequently detected in the elder patient group.

In a study by Golshani *et al.*, the value of optic nerve ultrasound and ophthalmoscopy in the detection of intracranial pressure was evaluated.[21] In their study, fundoscopic examination and ocular ultrasound were used to estimate ONSD first; then, cranial CT images were obtained using spiral CT. Similar to our study, ONSD measurements were above normal in all patients in whom findings of newly developed intracranial hypertension were detected on cranial CT. However, in other patients, ONSD values were within normal limits. Similar to the outcomes of our study, these results support the assertion that ocular ultrasound can detect the increase in intracranial pressure.

In our study, right and left ONSDs were compared with the laterality of the lesion as detected on CT. On cranial CT, median right-sided ONSD value of the patients with right-sided lesions was calculated as 5.7 mm (5.3–6.3 mm) and median left-sided ONSD as 5.4 mm (5.1–5.8 mm). On cranial CT, median right ONSD value of the patients with left-sided lesions was calculated as 5.3 mm (5.1–6.1 mm) and median left-sided ONSD as 5.6 mm (5.2–5.8 mm). Based on these result measurements, the diameters of optic nerve sheaths ipsilateral with the lesion were higher when compared with the contralateral side. Previous studies also revealed similar results.[7,18,19,21,23,24]

Most of the studies investigating the relationship between increase in intracranial pressure and ONSD have included patients who are hospitalized in clinics or ICUs.[22,24-26] Therefore, subheading of " the outcomes of the patients" in our study was not present in these studies. In our study, 28% of 50 patients with ONSD were discharged, 36% of them were hospitalized in our hospital, 12% of them were hospitalized in ICUs of our hospital, 18% of them were transported to external ICUs, and only one (2%) patient underwent emergency surgery. As is understood from these results, our university hospital provides healthcare services to great number of patients with various disorders.

Conclusion

Ocular ultrasound which can be easily applied at bedside appears to be useful to make the diagnosis of intracranial hypertension in nontraumatic cases as a noninvasive method. Regarding this, treatment costs may decrease, the need to transfer patients to another center is eliminated, and a considerable amount of time is spared. Ultrasound has become a widely used diagnostic tool with more frequent use by emergency physicians.

Obviously, the use of ocular ultrasound in cases with intracranial hypertension should be investigated in large series of studies.

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Conflicts of interest

There are no conflicts of interest.

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