

The value of optic nerve pod diameter assessment by ultrasonography in comparison with CT scan to predict brain lesions in patients suffering mild brain trauma

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Abstract

Introduction: The use of portable imaging techniques such as ultrasound and the consideration of sensitive and reliable parameters for the evaluation of traumatic brain lesions, such as optic nerve sheath diameter (ONSD) can be considered to detect traumatic brain lesions.

Objectives: The aim of this study was to examine the diagnostic value of ONSD measured by ultrasonography (USG) (in comparison with CT scan) for early detection of pathological brain injuries following mild brain trauma.

Patients and Methods: This cross-sectional study was conducted on patients aged more than 18 years referred with the history of mild brain trauma to emergency departments at one of the three general hospitals in Tehran between April 2016 and September 2017. The patients were evaluated by USG immediately after admission and the ONSD value was measured. The patients were then referred for brain CT scanning.

Results: The right and the left ONSD values were significantly higher in patients with brain hemorrhage as compared to those without this event. Similarly, those patients with brain contusion on CT had significantly higher mean right and left ONSD as compared with those without contusion. The best cutoff value of the right ONSD was 5.0 (yielding a sensitivity of 100% and a specificity of 90.4%) and the value for the left ONSD as 4.7 (with a sensitivity of 100% and a specificity of 87.5%) for predicting cerebral hemorrhage. Similarly, the best cutoff value of the right ONSD was 4.6 (with a sensitivity of 100% and a specificity of 86.5%) and the value for the left ONSD was 5.0 (with a sensitivity of 100% and a specificity of 90.4%) for predicting contusion.

Conclusion: USG can detect traumatic lesions of the brain including hemorrhage and brain contusion with high sensitivity and precision. In this regard, upon the referral of patients with a variety of traumatic brain tumors, even mild traumas, the ONSD assessment by ultrasound can provide very comprehensive and valuable information on the presence and development of traumatic brain injuries.

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Introduction

Intra-ventricular monitoring of intracranial pressure (ICP) is considered as a gold standard for measuring ICP (1). Although the invasive methods of ICP evaluation are precisely and with great benefits, insertion of intra-ventricular drainage may be associated with complications such as difficult insertion, hemorrhage, infections, incorrect placement, as well as sudden decompression (2-4). The idea of using non-invasive methods for assessing ICP has prevented the complications occurring in invasive modalities (5). These non-invasive methods mainly include the measurement of optic nerve sheath diameters (ONSDs), the evaluation of the displacement of the membrane, the trans-

cranial Doppler ultrasonography (USG), the evaluation of dielectric components of the brain, magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), CT computer, and ophthalmodynamometry (5). There are various methods for assessing ONSD that include CT scan, MRI, and USG. The diagnostic accuracy and high capability of CT scanning to assess brain pathologies have turned it into a common tool for assessing ICP increase (6, 7). The ONSD measurement using CT scan has proven it to be a powerful predictor of increased ICP (6). Also, an increase in ONSD based on CT estimating has been a strong prediction of mortality following ICP increase (8). Besides, measuring ONSD based on MRI has been a reliable and effective way of



predicting increased ICP. It has been shown that the ONSD measured by T2-weighted brain MRI has been also associated with an increase in ICP (9), which was 0.49 based on the ROC curve analysis. In this regard, a cutoff of 30.5 mm for ONSD was able to predict increased ICP with a sensitivity of 100% (9). Moreover, ultrasound is a simple, reliable, non-invasive, and diagnostic way to measure ONSD. An ophthalmic ultrasound with frequencies ranging from 5 to 10.5 MHz is used to assess the eye and globe (10, 11). In total, clinical and visual manifestations by CT and ONSD increase assessed using USG has been significantly correlated (12). In meta-analyzing studies, it has also been proven that ultrasound is an accurate test for ruling out an increase in ICP among low-risk patients and its confirmation in high-risk patients (13). Even the measured ONSD values have been correlated with USG with similar values in the MRI.

Objectives

What can improve the assessment and recognition of the brain lesions as well as predicting the resulting outcomes is the use of accurate instruments and reliable indicators in assessing lesions resulting from brain trauma. Today, imaging techniques such as CT and MRI are widely used, although the instrument also has potential limitations, such as the delayed appearance of signs of brain lesions, in particular the contraindications for using these tools. Also, the referral time from admission to referral for imaging is also sometimes long, which will have a significant impact on the consequences of the trauma.

Objectives

The aim of this study was to examine the diagnostic value of ONSD measured by USG (in comparison with CT scan) for early detection of pathological brain injuries following mild brain trauma.

Patients and Methods

Study design

This cross-sectional study was conducted on patients aged more than 18 years referred to the history of mild brain trauma to emergency departments at one of the three general hospitals in Tehran between April 2016 and September 2017. The mild brain trauma was considered as the trauma to the skull without neurological associated lesions. In this regard, those suffering head trauma with effect on optics, history of previous eye diseases affecting the optic nerve, hyperthyroidism or any pathologic pathology associated with exophthalmia were all excluded. All patients' basic information including demographic characteristics, history of diseases, history of drug use, mechanism and type of trauma, trauma symptoms at admission, Glasgow coma scale (GCS) and other neurological symptoms on admission were collected through interviews or clinical examinations. The patients were evaluated by USG immediately after admission and

the ONSD value was measured. The patients were then referred for brain CT scanning. In CT scan, all pathologic lesions associated with trauma resulting ICP elevation were evaluated and patients were classified into two groups with and without pathologic brain lesions in the CT scan. In cases where the time interval between sonography and CT was more than 15 minutes, sonography was repeated. The two procedures were performed by the two operators were blind to each other's diagnoses.

Ethical issues

Human rights were respected in accordance with the Helsinki Declaration 1975, as revised in 1983. The informed consent was taken from the patients as well as from parents and first relatives. The study was approved by ethics committee of Iran University of Medical Sciences (Ethical cod# IR.IUMS.FMD.REC1396.9411307008). This study was conducted as the residential thesis of Pedram Kakvan at Iran University of Medical Sciences.

Statistical analysis

For statistical analysis, results were presented as mean \pm standard deviation (SD) for quantitative variables and were summarized by absolute frequencies and percentages for categorical variables. Normality of the data was analyzed using the Kolmogorov-Smirnoff test. Categorical variables were compared using chi-square test or Fisher's exact test when more than 20% of the cells with expected count of less than 5 were observed. The quantitative variables were also compared with *t* test or Mann-Whitney U test. To assess the value of ONSD measured by sonography to determine pathological brain lesions, the area under the ROC was analyzed. For the statistical analysis, the statistical software SPSS version 16.0 for Windows (SPSS Inc., Chicago, IL) was used. *P* values of 0.05 or less were considered statistically significant.

Results

A total of 110 patients (80 men and 30 women) were evaluated. The mean age of patients was 33.14 ± 12.91 years in the range of 18 to 73 years. In terms of the mechanism of trauma to head, 79 cases (71.8%) occurred by a collision with vehicles, 20 cases (18.2%) followed a heavy object on the skull and 11 cases (10%) occurred after falling from height. None of the patients had received an effective medication for increasing ICP. Also, in terms of consciousness score, 88 cases (80%) had GCS of 15 and 22 (20%) had GCS of 14. In terms of the time interval between admission and evaluation by imaging methods. The mean time duration between trauma and patients' admission was 15.68 ± 2.99 minutes. The time between trauma and sonography assessment was 30.41 ± 6.59 minutes. Furthermore, the time between trauma and CT scanning was 46.09 ± 7.26 minutes and finally the mean time duration between sonography and CT performing was also 15.68 ± 2.99 minutes. In terms

of CT findings, basal cistern compression was found in 1 case (1.8%), midline shift more than 0.5 mm in none of the cases, cortical sulcus effacement in 1 case (1.8%). Moreover, intra-ventricular hemorrhage in none of cases was detected. Additionally, hemorrhage in other forms in the brain, such as subarachnoid hemorrhage, were reported in 6 cases (5.5%). Also, 6 cases (5.5%) had cerebral contusion. All patients were discharged without any serious complications.

The ONSD on the right side was 4.24 ± 4.2 mm (range 2.9-2.6 mm) and on the left was 4.24 ± 0.64 mm (in the range of 0.3-3.3 mm). Due to a small number of findings including basal cistern compression, shifts from midline, cortical sulcus effacement, and intra-ventricular hemorrhage, it was not possible to assess the relationship between these findings alone with left and right ONSD values. The right ONSD value in patients with and without any type of hemorrhage was 5.70 ± 0.38 mm and 4.4 ± 0.44 mm, indicating a significant difference between the two groups ($P < 0.001$). Similarly, the left ONSD value in patients with and without any type of hemorrhage was 5.72 ± 0.53 mm and 4.23 ± 0.55 mm, indicating a significant difference between the two groups ($P < 0.001$). Based on the ROC curve analysis, the right ONSD (AUC = 0.957) and the left ONSD (AUC = 0.968) had a high value in predicting the occurrence of cerebral hemorrhage. The best cutoff value of the right ONSD was 5.0 (yielding a sensitivity of 100% and a specificity of 90.4%) and the value for the left ONSD was 4.7 (with a sensitivity of 100% and a specificity of 87.5%) for predicting cerebral hemorrhage. The right ONSD value in patients with and without contusion was 5.40 ± 0.62 mm Hg and 4.19 ± 2.67 mm Hg, indicating a significant difference between the two groups ($P < 0.001$). Also, the value of left ONSD in the patients with and without contusion was 5.42 ± 0.18 mm and 4.24 ± 0.60 mm respectively, indicating a significant difference between the two groups ($P < 0.001$). The best cutoff value of the right ONSD was 4.6 (with a sensitivity of 100% and a specificity of 86.5%) and the value for the left ONSD was 5.0 (with a sensitivity of 100% and a specificity of 90.4%) for predicting contusion. The average of bilateral ONSD in patients with and without hemorrhage was 5.71 ± 0.35 mm and 4.21 ± 0.57 mm respectively ($P < 0.001$). In this regard, mean bilateral ONSD had high value for predicting intracranial hemorrhage (AUC = 0.962). Considering the cutoff point of 5.1 for bilateral ONSD yielding a sensitivity of 100% and a specificity of 89.4%. Similarly, the average of bilateral ONSD in patients with and without contusion was 5.41 ± 0.33 mm and 4.22 ± 0.61 mm respectively ($P < 0.001$). In this regard, mean bilateral ONSD had high value for predicting contusion (AUC = 0.925). Considering the cutoff point of 4.9 for bilateral ONSD yielding a sensitivity of 100% and a specificity of 87.5% (Table 1).

Discussion

Along with previous studies to evaluate pathological

Table 1. The value of ONSD in predicting hemorrhage and contusion

Parameter	Right ONSD	Left ONSD	Bilateral ONSD
Predicting hemorrhage			
AUC	0.957	0.968	0.962
Lower limit	0.918	0.926	0.923
Upper limit	0.995	1.000	1.000
P value	<0.001	<0.001	<0.001
Cutoff point	5.0	4.7	5.1
Sensitivity	100%	100%	100%
Specificity	90.4%	87.5%	89.4%
Predicting contusion			
AUC	0.925	0.935	0.925
Lower limit	0.868	0.889	0.877
Upper limit	0.981	0.981	0.979
P value	<0.001	<0.001	<0.001
Cutoff point	4.6	5.0	4.9
Sensitivity	100%	100%	100%
Specificity	86.5%	90.4%	87.5%

changes in ICP as well as traumatic changes such as hemorrhage or brain contusion through accurate and reliable non-invasive methods, the present study also used the measurement of the ONSD parameter by USG to evaluate these pathological changes. In this study, ONSD was measured on both sides using USG and was used to predict the incidence of cerebral hemorrhage as well as contusion. Although the primary goal of the study was to evaluate the ability of ONSD to predict other parameters, such as basal cistern compression, midline shift and cortical sulcus effacement, because of the lack of case numbers, it could not be analyzed. In fact, almost all previous studies focused on a variety of traumatic lesions of varying intensity. In summary, we found the value of the ultrasound ONSD measurement of left and right in predicting two major incidents of brain trauma including hemorrhage and contusion. In other words, by non-invasive and non-invasive ONSD measurements, it is possible to predict the occurrence of hemorrhage and contusion with a high sensitivity (about 100%) and a high specificity.

The findings from previous studies have been quite consistent with our study in terms of high ONSD capability in predicting brain lesions and in terms of cutoff points to predict these lesions. In the study by Lee et al, the ONSD value higher than 5.5 mm in USG had high ability to detect an increase in ICP with a sensitivity of 98.7% and a specificity of 85.2% (14). In the study by Komut et al, the ONSD cutting point for differentiating brain lesions in CT was 3.5, with a sensitivity of 70%, a specificity of 74%, and an AUC of 0.728 (15). In the study by Aduayi et al, a cut point of 5.2 with a sensitivity of 81.2%, and a specificity of 100% was able to differentiate brain lesions in CT (16). In the study by Golshani et al, sensitivity and specificity of USG were 100% and 100%, respectively, to determine

the increase in ICP (17). Therefore, an optimal approach for managing patients referred to emergency centers with brain trauma (even in cases with mild traumas) will be primarily an ONSD ultrasonographic evaluation that in the presence of any evidence of pathological lesions such as hemorrhage or cerebral contusion, a subsequent therapeutic approach, including medical or surgical procedures, can be considered. An important advantage of using USG is the possibility of using it in portable form, no need for radiation, and the absence of potential contraindications for other imaging techniques.

Conclusion

As a general conclusion, USG can detect traumatic lesions of the brain including hemorrhage and brain contusion with high sensitivity and precision. In this regard, upon the referral of patients with a variety of traumatic brain tumors, even mild traumas, the ONSD assessment by ultrasound can provide very comprehensive and valuable information on the presence and development of traumatic brain injuries.

Study limitations

During the research, we encountered some problems such as inconsistencies in implementation and time constraints.

Authors' contribution

CHM, MB, ZMA, MHP and KP designed the study, observed accuracy and validity of the study. OB participated in the data collection. KP supervised the project. KP wrote the paper. All authors edited and revised the final manuscript and accepted its publication.

Conflicts of Interest

The authors declared no competing interests.

Ethical considerations

Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the authors.

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