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Original Article

Determination of optic nerve sheath diameter variability with age in pediatric groups and comparison of increased intracranial pressure and optic nerve sheath diameter in pediatric patients with head trauma

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Abstract

Aim: The aim of this study is to reveal th evariability of the optic nerve sheath diameter (ONSD) with age and to compare the ONSD with increasing intracranial pressure (ICP) findings in computerised cranial tomography (CCT) images of pediatric patients presenting to the emergency department with head trauma.

Material and Methods: The ONSD values of the patients were measured in the transverse sections of the CCT images. The patients who were found to have pathology in CCT images were taken into Group 1 and normal patients were taken in Group 2 as the control group. The data were recorded in the SPSS 21 program. The age, gender, Glasgow Coma Scale, and ONSD values of the groups and the difference between the ONSD values of both eyes were compared.

Results: A total 294 patients were included in the study. Sixty eight patients (23%) were enrolled in Group 1 and 226 (77%) patients were enrolled in Group 2. The mean ONSD value of Group 1 was 5.5±1.08 mm whereas that of Group 2 was measured as 4.1±0.69 mm (p<0.001). One hundred sixty seven patients were discharged after 8-hour monitorization in the emergency room. These patients age were between 0 and 60 months. A statistically significant correlation was found between the ONSD values and ages of these patients (r:0.348, p=001).

Conclusions: Simultaneous measurement of the ONSD and the ONSD difference is an effective method for determining the increase and severity of ICP in children with head trauma.

Keywords: Emergency Department; Pediatric Trauma; Optic Nerve Sheath Diameter.

INTRODUCTION

Traumatic brain injury (TBI) is the leading cause of death and disability in children. TBI in children result in a range of traumatic injuries to the scalp, skull, and brain that are comparable to those in adults but differ in both pathophysiology and management (1,2).

Computerised cranial tomography (CCT) is prefered in first place for detection of intracranial events in the emergency department. However, CCT causes exposure to radiation. For this reason, CCT should be used only in the presence of clinical signs (3).

Intracranial pressure (ICP) is the pressure caused by the total volume of brain, cerebrospinal fluid (CSF) and blood in the skull and it is constant. The ICP will increase as a result of an increase in any of the intracranial structures due to events such as head trauma, ischemic stroke, hemorrhagic stroke, mass lesion and infection. ICP increase is associated with poor clinical outcomes, such as increased mortality rate(3,4).

ICP can be measured by invasive and noninvasive methods. Recently, the measurement of optic nerve sheath diameter (ONSD) has been used to determine increased ICP. The studies demonstrated that ONSD measured in ocular ultrasound, CCT and magnetic resonance imaging was correlated with increased ICP (4-13). However, the brain development and anatomic structure of children are different from adults. In children, the head is bigger

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relative to the body, the cranium is thin, and it transmits energy easily through itself resulting in the tendency to skull fractures. Open sutures in infants can accommodate increases in intracranial pressure and delay the recognition of severe intracranial injuries. Thus, ONSD may vary in children depending on the age and severity of the trauma. The number of studies accounting for this result is not sufficient.

The aim of this study is to reveal the variability of the ONSD with age and to compare the ONSD with increasing ICP findings in CCT images of pediatric patients presenting to the emergency department with head trauma.

MATERIAL and METHODS

This study which was designed as a retrospective study was conducted after obtaining approval from the ethics committee (Institutional Review Board (IRB)) of the hospital. The patients who were admitted to the emergency department with head trauma and who underwent CCT imaging between January 2105 and December 2016 were included in the study. The patients' data were accessed from the automation system of the hospital and admission files. The CCT images were obtained from the PACS system. The CCT images of the patients included in the study were interpreted by a radiologist.

The patients with head trauma, who were aged ≤18 years, who underwent CCT imaging were included. The exclusion criteria were as follows: 1) >18 years of age, 2) Previous history of glaucoma or current medications that might have affected CSF pressure, 3) Ophthalmic diseases, such as tumors or traumas, 4) Electrolyte disorders (such as hypo or hypernatremia, hypo or hypercalcemia), 5) Endocrine disorders (such as hypo or hyperglycemia, hypo or hyperthyroidism).

A standard study form was created for the study. The file numbers, age (month/year), gender, accident type, Glasgow Coma Scale (GCS), ONSD values in CCT images, difference between the ONSD values of both eyes, presence of hemorrhage, site of hemorrhage, amount of hemorrhage, presence of midline shift (MLS), size of MLS (mm), direction of MLS were recorded in this form. The presence of any of the findings including hemorrhage, edema, and MLS in the CCT images was considered pathological.

Measurement of Optic Nerve Sheath Diameter

ONSD was measured on the CCT image displayed on the transverse plane. ONSD measurement was performed 3 mm proximal to the optic disk. Increased ICP considered positive when the (MLS) of ≥ 3 mm, mass effect, severe edema, sulcal effacement, collapsed ventricles and compression of cisterns were present in these images.(1)

According to these results, the patients who were found to have pathology in CCT images were taken into Group 1 and normal patients were taken in Group 2 as the control group.

Statistical Analysis

The data obtained during the study were recorded in the SPSS 21 program and their statistical analyses were carried out. The age, gender, GCS and ONSD values of the groups and the difference between the ONSD values of both eyes were compared. In the statistical analysis, the ONSD value from the right and left eyes were used. The cut-off value, specificity, and sensitivity levels of the ONSD and the ONSD difference of both eyes were identified. GCS, the presence of bleeding, and MLS were compared with ONSD in Group 1.

Whether the distribution of continuous and discrete variables was close to normality or not was investigated with the Kolmogorov Smirnov test. Descriptive statistics were given as mean ± standard deviation or median (minimum-maximum) for continuous and discrete variables while categorical variables were shown as the number of cases and percent (%). Categorical variables were assessed with the Chi-square test; parametric data analysis was performed by the student t-test while non-parametric data were assessed with the Mann Whitney U and Kruskal Wallis test. The appropriate cut-off value, specificity, and sensitivity levels were determined by the ROC analysis. The correlation between MLS and ONSD was measured by the bivariate correlation test. The correlation between the amount of bleeding and ONSD was measured by the bivariate correlation test. Correlation coefficients were determined.

RESULTS

A total 294 patients were included in the study. The mean age was 3.9±4 years. The distribution according to the age groups was given in Table 1.

Table 1. Distribution by age groups

Age Groups	N	%
0-12 month	10	3.4
13-24 month	80	27.2
25 month - 6 age	158	53.7
7-11 age	20	6.4
12 -18 age	26	9.3
Total	294	100

Of the patients, 34 (12%) were admitted to the emergency department with a traffic accident, 258 (87%) with fall and 2 (1%) with assault. Fracture of the cranium was detected in 71 patients (24%).

The detected pathologies in Group I was as follows: MLS in 23 (8%) patients, brain edema in 52 (18%) patients and hemorrhage in 56 (19%) patients. Accordingly, 68 patients (23%) were taken to Group 1 whereas 226 (77%) patients were taken to Group 2. GCS was 15 in all patients in Group II. In Group I, GCS: ≤8 in 21 patients, GCS: 9-14 in 30 patients, and GCS: 15 in 17 patients. The ONSD values of Group I and II were 5.5±1.08 mm and 4.1±0.69 mm, respectively (p<0.001). ONSD value was significantly higher in Group I (p <0.05)(Figure 1).

The cut-off value for detection of a lesion on CCT was determined as 5.0 mm (The area under the curve 0.864, 95% confidence interval: 0.804-0.925). The sensitivity and specificity at this cut-off value were determined as 71% and 91%, respectively (Figure 2).

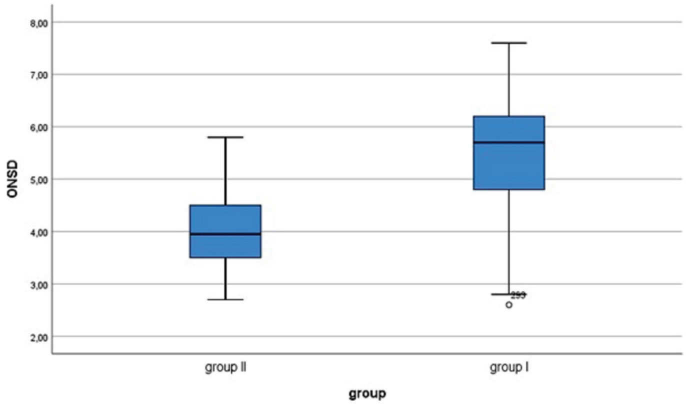

Figure 1. ONSDs according to brain CCT findings

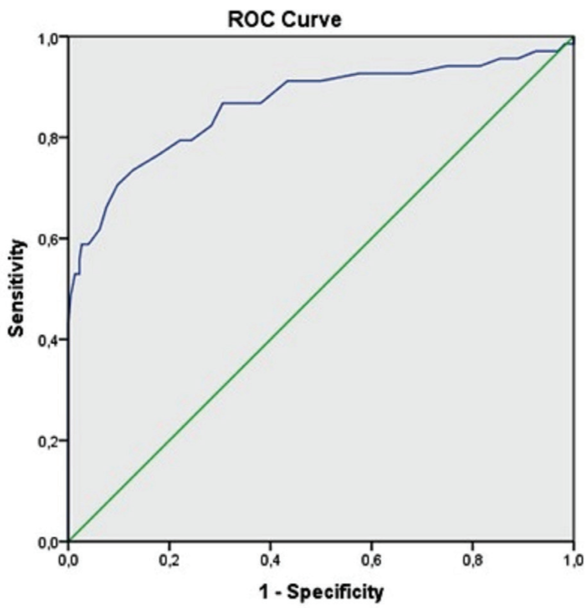

Figure 2. Receiver operating characteristic (ROC) curve of ONSD. The area under the curve is 0.864 (95% CI: 0.804-0.925)

Regarding the difference between right and left ONSD values of both groups, 0.47± 0.42 mm difference was found between both ONSDs in Group I. This difference was 0.27 ± 0.20 mm in Group II. There was a statistically significant difference between the groups (p<0.001).

ONSD value was higher in patients with MLS (p<0.05) (p=0.001)(Table2).The cut-off value of ONSD for MLS detection was found to be 5.5 mm (The area under the curve: 0.888, 95% CI: 0.837-0.939). Sensitivity and specificity at this cut-off value were determined as 65% and 88%, respectively. A statistically significant correlation was determined between the size of MLS and ONSD (r: 0345, p: 0.001). The difference between the ONSD of both eyes of the patients with MLS on their CCTs was found to be significantly higher than other patients (Table 2,3).

Table 2. Comparison of ONSD* with CCT# findings ve GCS of head trauma patients

Pathology	N	ONSD (Mean ±SS)	P
GCS 3-13	51	5.3±1.1	0.001
GCS 14, 15	243	4.2±1.0	
MLSˠ (+)	23	5.4±1.1	0.001
MLS(-)	271	4.2 ±0.9	
Intracranial hemorrhage (+)	56	5.3±1.1	0.001
Intracranial hemorrhage (-)	238	4.1 ±0.8	

*ONSD. Optic nerve sheat diameter, #CCT: computerized cranial tomography, ˠ MLS:midline shift, GCS: Glasgow Coma Scale

Table 3. Comparison of ONSD* difference of both eyes and MLSˠ presence

Pathology	N	ONSD Difference (Mean ±SS)	P
MLS(+)	23	0.57±0.51	0.001
MLS(-)	271	0.29 ±0.24	

ONSD. Optic nerve sheat diameter, ˠ MLS:midline shift,

An intracranial hemorrhage had developed in 56 (19%) of the patients. Of these patients, 21 (38%) had epidural hematoma, 17 (30%) had subdural hematoma, 10 (18%) had subarachnoid hemorrhage (SAH), 7 (12%) had intraparenchymal hemorrhage, 1 (% 2) had SAH along with epidural hemorrhage. The minimum hemorrhage amount was 1 mm, and the maximum was measured as 66 mm. The ONSD measured higher in the patients with intracranial hemorrhage than other patients (p=0.001). A statistically significant correlation was determined between the amount of hemorrhage and ONSD (r: 0334, p: 0.001)(Table 2).

Patients were divided into two groups according to their GCS score: mild TBI with GCS of 14-15 and moderate to severe TBI with GCS of 3-13. The ONSD value of patients with a GCS score ≤13 was found higher than the patients with a GCS score > 13 (p<0.05) (Table 2).

One hundred sixty seven patients were discharged after 8-hour monitorization in the emergency department. These patients' ages were between 0 and 60 months. A statistically significant correlation was found between the ONSD values and ages of these patients(r:0.348, p =.001). The ONSD value was measured as 3.6±0.5 in the 0-12 months group while it was measured as 4.1±0.7 in the 49-60 months group. There was no statistically significant difference in ONSD difference of both eyes of these patients with age (p = 0.197). The mean ONSD difference of these patients was found to be 0.25±0.18 mm. The ONSD values and ONSD differences of the patients according to their ages were given in Table 4.

Table 4. ONSDs* according to age				
Number of patients by age		ONSD*		ONSD* difference between two eyes
Age	N (%)	Mean ±SS	Min-max	Mean±SS
1	56 (34)	3.6±0.5	2.7 - 4.8	0.27±0.18
2	44 (26)	3.8±0.5	2.7 - 4.9	0.20±0.14
3	27 (16)	4.1±0.6	2.7 - 5.0	0.29±0.20
4	28 (17)	4.1±0.5	3.0 - 5.6	0.27±0.17
5	12 (7)	4.1±0.7	2.8 - 5.20	0.27±0.17
Total	**167(100)**	**3.8±0.6**	**2.7 - 5.6**	**0.25±0.18**

P = 0.001 for ONSD, p = 0.197 for ONSD difference
*ONSD: Optic Nerve Sheath Diameter

Of the patients included in the study, 32 recovered with sequelae while 262 recovered without sequelae. There was no patient resulted in death. The ONSD values of the patients resulted in sequelae were found to be higher than those recovered without sequelae (Table 5).

Table 5. ONSDs* according to the outcome of patients			
Result	N	ONSD (Mean ±SS)	p
Recovered With Sequelae	32	5.6±0.8	0.001
Recovered Without Sequelae	262	4.2 ±0.9	

*ONSD: optic nerve sheath diameter

DISCUSSION

ICP increase caused by intracranial events can lead to widespread brain ischemia and brain tamponade progressively by lowering cerebral perfusion pressure. Determination and follow-up of ICP increases are very important in terms of prevention of possible brain damage and death. External ventricular device is the gold standard in the measurement of ICP.(4,14)

Optic nerve, subarachnoid space and sheath diameter expand with ICP increase. Measurement of ONSD has been widely used recently for assessment of ICP increase. Measurement of ONSD to detect the increase in ICP may be practically performed by using ultrasonography, CCT and MRI. In a study on pediatric cases with head trauma requiring invasive neurosurgery monitorization, the right ONSD was measured as 5.6±2.5 mm and left ONSD was measured as 5.9±3.2 mm when the mean ICP became 18±10 mmHg. In this study, a correlation was found between ICP and ONSD.(16)

Because ONSD measurement by ultrasound is real-time measurement, it is very useful for the monitorization of increase in ICP. However, having intraobserver and interobserver variability is one of its disadvantages. On the other hand, ONSD measurement in CCT images is objective and simple. However, disadvantages are the radiation content and the cost (14,15). Although there is a 10% difference between the CCT and ultrasonographic measurements of ONSD in healthy adults, a correlation between them has been demonstrated (14).

As brain development is an ongoing process in children, anatomical structure changes with the age. A study conducted with MRI indicated that ONSD varied with age and it was 3.1 mm between 0 and 3 years while it was 3.58 mm between 12 and 18 years, showing a correlation of ONSD with age (17). In this study, the ONSDs of the patients with normal CCT images and clinical findings were observed to increase with age. The ONSD value was 3.6±0.5 in the 0-12 months group while it was measured as 4.1±0.7 in the 49-60 months group. An average increase of 0.1 mm per year can be mentioned for the ONSD value. Therefore, this should be considered while detecting the rise in ICP in cases with intracranial incident due to head trauma.

CCT imaging is the first choice to detect lesions causing an increase in ICP in patients with head trauma. In a study, the ONSD was determined to vary depending on the severity of the intracranial lesion. The ONSD values of the patients with mild TBI (Rotterdam CT Score (RCTS) of 2 and 3) were 3.3 mm (SD 0.39 mm) and 4.1 mm (0.047 mm), respectively whereas the ONSD value in the CCTs of the patients with moderate and severe TBI (RCTS score 4 and above) were measured as 4.83±0.4 in this study (14). However, the minimum and maximum ONSD measurements of the patients vary between 2.7 and 5.6 mm. Therefore, ONSD, which is measured to differentiate the presence of pathology, can sometimes be misleading. We found in our study that the ONSD difference of both eyes did not vary with age when we evaluated the ONSD difference in response to the increase in the ONSD. Therefore in suspected cases, it may be directive to compare the ONSD with the other eye and to measure the difference.

In this study in which patients with head trauma were included, the ONSDs of the patients with intracranial pathology in their CCT images were wider than the other patients. The ONSD was 5.5±1.08 mm in the patients with pathology in CCT while the ONSD was measured as 4.1±0.69 in the patients with normal CCT images. Also, the cut-off value for ONSD was found to be 5.0 mm in order to detect the lesion on CCT in the study. Sensitivity and specificity at this cut-off value were found to be 71% and 91%, respectively.

Anisocoria refers to unequal pupil diameters of the eyes. A difference of 1 mm between the pupil diameters of both eyes is physiological. If this difference is over 1 mm, it is considered pathological. When the intracranial events produce third cranial nerve palsy, ipsilateral pupil dilatation results in anisocoria. Based on this information, ONSD difference between two eyes was measured in a study in which ONSD measurement was performed by ultrasonography for detecting an increase in ICP due to non-traumatic events. The difference between the ONSDs of two eyes was found to be 0.45 mm in patients without pathology in CT images and this difference was detected to be increased (0.97 mm) in patients with unilateral structural lesions.

In our study, the difference in the ONSD values of two eyes in Group 2 patients with normal CCT images was found to be 0.27 ± 0.20 mm. This difference was found to be 0.47 ± 0.42 mm in the patients of Group 1 with lesions in CCT images and the difference was detected to increase. With this result, ONSD measurement was made in the CCT of the suspected cases and increased in ICP can be demonstrated by calculating the ONSD difference of both eyes.

MLS is a life-threatening condition, requiring immediate diagnosis and treatment. The increase in MLS grade was found to be associated with the severity of head injury, low GCS score and poor outcomes in many studies. A positive correlation was found between ONSD and MLS in a study on patients with head trauma (18). In another study on patients with intracranial incidents due to nontraumatic causes, a positive correlation was found between ONSD and the extent of MLS. In this study, the cut-off value of ONSD for MLS detection was set at 5.3 mm (4).

In our study, 23 patients with intracranial pathology developed MLS due to head trauma. The ONSD of the patients in whom MLS developed was measured higher than other patients. A statistically significant correlation was detected between the amount of MLS and ONSD. The cut-off value of ONSD for detecting the MLS was set at 5.5 mm. The sensitivity and specificity at this cut-off value were found to be 88% and 65%, respectively. At the same time, the ONSD difference between two eyes of the patients with MLS (0.57 ± 0.51) in the CCT was found to be significantly higher than that of the other patients without MLS (0.29 ± 0.24). These findings indicate that MLS can be detected in the cases with suspicion by measuring ONSD in CCT images and the difference of ONSD between both eyes.

Intracranial injury due to head trauma can be in the form of primary and secondary injuries. Therefore, increase in ICP will vary in a child having head trauma as a result of a primary and secondary injury. The close monitorization of increase in ICP of the children with severe TBI was found to be related to the decline in the in-hospital pediatric mortality (19,20). Performing ONSD measurements on the first CBT images in emergency department may be useful in terms of determining the severity of trauma. Hence, the ONSD of the patients with intracranial hemorrhage was measured significantly higher than other patients in our study. At the same time, there was a correlation between the amount of bleeding and ONSD. Considering the amount of bleeding and likelihood of MLS together, ONSD can be used to make the decision of operation.

TBI has been classified based on injury severity as assessed by the GCS. GCS is assessed as follows: 15-13 mild, 12-9 moderate, 8-3 severe (21). In our study, ONSD was found to be more dilated in patients with moderate and severe TBI (5.3±1.1mm) compared to patients with mild TBI (4.1±1.1 mm).

Death and disability that occur secondary to TBI in pediatric patients make the parents worry (19). A study on the prognostic value of ONSD reported that there was no difference between good and poor outcomes in cardiac arrest patients in terms of neurologic outcome (poor outcome: 6.66 mm SD 0.78 v. Good outcome: 6.60 mm) (22). Again, in another study on cardiac arrest patients, ONSD was found to be 5.6±0.3 mm in patients with good neurological outcome whereas it was 6.3±0.5 mm in patients with poor outcomes (23). In our study, ONSD was found to be 4.2±0.9 mm in patients with good neurological outcome whereas it was 6.3±0.5 mm in patients resulted in sequelae. In terms of prognosis; the ONSD measured in the images of the first CCT obtained in the emergency department can be used.

CONCLUSION

In conclusion, the ONSD increases with age in children. However, the ONSD difference between the two eyes does not change with age. In the case of ICP increase due to head trauma, the ONSD and the ONSD difference of both eyes increase related to the severity of the lesion. Therefore, simultaneous measurement of the ONSD and the ONSD difference is an effective method for determining the increase and severity of ICP in children with head trauma.Therefore, the ONSD which is measured in the first CCT images of TBI-developing patients can be used in the diagnosis and follow-up of the ICP increase. However, more extensive studies are necessary.

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