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Ultrasound Assessment of Optic Nerve Sheath Diameter and its Correlation with Clinical parameters, Fundus Examination and Brain Computed Tomographic Findings in Diagnosis of Cerebral Edema in ICU Patients

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Abstract

Introduction: Recently, the measurement of optic nerve sheath diameter by ultrasonography (USG) has gained more attention. Optic nerve sheath diameter (ONSD) assessment with ocular ultrasound is a non-invasive, reliable approach for detecting increased intracranial pressure (ICP).

Aim of the study: To evaluate the value of ultrasound assessment of optic nerve sheath diameter and its correlation with clinical parameters, fundus examination, and brain Computed Tomographic findings in ICU patients with Cerebral edema.

Subjects and Methods: 70 participants were enrolled in our study, which was divided into 80 control and 90 patients with disturbed consciousness levels. All patients were subjected to optic nerve US and laboratory investigations, such as liver function tests, kidney function tests, random blood sugar, serum sodium (Na), and potassium (K).

Results: Our study found that the cut-off point of mean ONSD for detecting elevated ICP was 5.28 mm with 97% sensitivity and 99% specificity.

Conclusion: Ocular ultrasonography might be used at the bedside to diagnose elevated intracranial pressure.

Keywords: Intracranial pressure; optic nerve sheath diameter; cerebral edema.

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1. Introduction

One of the primary causes of morbidity and mortality is intracranial hypertension (IH). In this context, many techniques were used to identify and evaluate patients with elevated intracranial pressure (ICP). IH, often referred to as an increase in ICP (IICP) or increased intracranial pressure (RICP), is a clinical

condition in which the pressures inside the skull are noticeably elevated. Pressures below 20 mmHg are regarded as pathological. When seriously ill patients are admitted to the intensive care unit, IH is crucial. It's critical to choose a correct diagnosis and course of treatment for raised ICP because it can cause poor neurological outcomes [1].

Raised ICP, brain edema, and brain herniation syndromes are three distinct but related disorders seen in neuro-critical care units. In managing elevated ICP and cerebral edema, the precise mechanism and clinical context are very important. Cerebral edema is a pathological buildup of excess water in the parenchyma of the brain and is brought on by either cytotoxic or vasogenic mechanisms [2,3].

There are two types of ICP monitoring techniques: invasive and non-invasive. The primary method for assessing intracranial pressure still involves invasive intracranial devices (ICP). Invasive techniques include the use of implantable micro-transducers, the subarachnoid screw, and epidural and external ventricular devices (EVD) [4-6]. There are non-invasive techniques, like as bedside instruments and neuroimaging, that have been developed for fast measurement and assessment because there are some difficulties with invasive ICP monitoring that are expected [5]. ICP can be indirectly measured using non-invasive methods. Non-invasive techniques include Trans Cranial Doppler (TCD), Imaging-Based Techniques (CT and MRI), Fundus examination, and Optic Nerve Sheath Diameter (ONSD) [7-9].

The assessment of ONSD by bedside ultrasonography has been regarded as a non-invasive and trustworthy way to identify critically ill patients with increased ICP. It has been demonstrated in numerous investigations to have a significant correlate with ICP measurements made directly. Because the optic nerve sheath is distensible and connected to the dura mater and the subarachnoid space of the brain, changes in CSF pressure have an impact on the volume of the ONS.

Changes in CSF pressure have an effect on the volume of the optic nerve sheath, particularly in the anterior segment of the retro-bulbar compartment, which is located about 3 mm posterior to the globe, due to the distensibility of the optic nerve sheath and its continuity with the dura mater and the subarachnoid space of the brain, which contains CSF. The ONSD, like any other physiological change, varies with changes in ICP [10].

The current study aimed to assess the significance of brain computed tomography findings, fundus examination, clinical data, and ultrasound measurements of the optic nerve sheath diameter in ICU patients with cerebral edema.

2. Subjects and methods

2.1. Subjects

170 participants were enrolled in our study, which was divided into 80 control and 90 patients with disturbed consciousness levels.

Inclusion criteria

Any patients older than 18 years old presented with clinically suspected increased ICP because of trauma, intracranial hemorrhage, hepatic encephalopathy, uremic encephalopathy, intracranial tumors, and electrolyte disturbance.

Exclusion criteria

Any patients <18 years old, glaucoma, orbit fracture, corneal opacity, and lens opacity.

2.2. Methods

The following procedures were performed on all patients:

- Full medical history, Clinical examination, Glasgow coma scale (GCS), Laboratory investigations: including CBC (complete blood count), coagulation profile (PT, PC, INR, and PTT), liver function tests [ALT (alanine aminotransferase), AST (aspartate aminotransferase), bilirubin and albumin], kidney function tests (urea, creatinine), blood sugar and serum electrolytes including Na, K, and calcium (Ca), computed tomography brain and fundus examination.
- All patients had an optic nerve US performed at the time of admission, and the results were reviewed 48 hours later after they had received the best possible care.

2.3. Statistical Procedures

Using the SPSS statistical computer tool version 22 to scientifically arrange, tabulate, and analyze the acquired data (SPSS Inc, USA). The standard deviation (SD), mean, and range of the data were calculated. For numerical data, the standard deviation (SD), mean, and range were calculated. The independent and dependent tests were used to determine significance. For qualitative data presented as numbers, Chi-square (2) was used as a significance test, and a P value of 0.05 was used to determine statistical significance.

3. Results

The current study didn't reveal any statistically significant difference between the patients and control groups regarding age (*P=0.198*) and sex (*P=0.427*).

Our results proved a statistically significant difference in the GCS of patients with higher ICP due to metabolic reasons at the admission and 48 hours later (*P= 0.0001*). There was also a significant increase in the mean GCS of patients with increased ICP due to metabolic causes after 48h (Table 1). CT brain was done for all cases and revealed 46 (51.1%) patients with signs of increased ICP.

Table 1: GCS of higher ICP patients as regarded to metabolic causes.

Parameters	Metabolic causes (N=37)	*P-value*	Other causes (N=53)	*P-value*
On admission	10.7±2.4	<0.001*	10.9±2.9	<0.001*

After 48 hours	13.7±2.0	12.2±3.2

* Significant.

There was a statistically significant relation between Fundus examination and CT brain *(P< 0.001*). There were 22 (47.8%) patients with papilledema and CT findings of elevated ICP in our study (Table 2, Figure 1).

Table 2: Relation between Fundus examination and CT brain.

Parameters		Elevated ICP	Not-elevated ICP	*P-value*
Papilledema	Yes	22 (47.8%)	4 (9.1%)	<0.001*
	No	24 (52.2%)	40 (90.9%)	

* Significant.

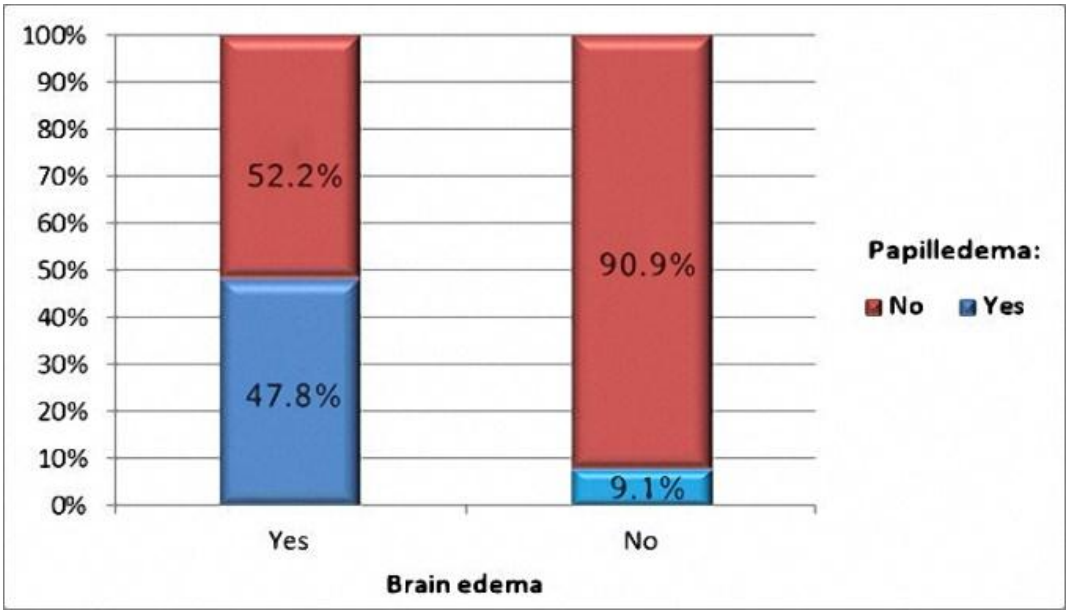

Figure 1: Relation between Fundus examination and CT brain.

The ultrasonographic measurement of the ONSD of the study population revealed that the range of average ONSD for the cases was 5.20-7.61 mm and 3.73-5.10 mm for controls. The Receiver-operating characteristic (ROC) curves analysis revealed that ultrasonographic ONSD had an excellent prediction in the determination of elevated ICP at the cut-off point of average ONSD 5.28 mm with 97 % sensitivity and 99% specificity (Table 3).

Table 3: Validity of ONSD.

	AUC	P-value	Cut-off point	Sensitivity %	Specificity %
Cases vs controls					
ONSD (RT)	0.989	<0.0001*	5.33	98.5	98.7
ONSD (RT)	0.990	<0.0001*	5.35	98.5	98.7
Average ONSD	0.996	<0.0001*	5.28	97	99

* Significant.

4. Discussion

Elevated intracranial pressure (EIP) is a potentially fatal condition caused by a variety of neurological and non-neurological disorders [11]. ONSD ultrasonography has become a common bedside method for detecting increased ICP [12].

Our study was designed to use a simple, accurate, and rapid bedside method to aid in the rapid diagnosis of patients with clinically suspected increased intracranial pressure who presented to us in the emergency department with DCL and to aid in the diagnosis of IH caused by various causes in patients for whom transportation for radiological assessment by CT or MRI would be risky and life-threatening.

Our study included 170 participants, 80 of whom were controls and 90 of whom had disturbed consciousness levels. Patients and controls were statistically matched in terms of age and gender. Our research found that measuring ONSD with ocular ultrasonography is useful in predicting elevated ICP. These findings are consistent with those of Chen *et al.*, 2019, who discovered that ONSD decreases immediately after CSF pressure decreases, indicating that ONSD responds to ICP in real time [13].

The average ONSD measured with ocular ultrasound in the control group was 4.64 0.37 mm, and the mean ONSD in males and females was 4.60.38 mm and 4.70.36 mm, respectively. Patterson *et al.*, 2018, found in their study that the value of ONSD by ocular ultrasound in healthy adults was 4.8 mm [14]. These findings were consistent with Shirodkar *et al.*, 2014, who discovered that the mean ONSD in the control group was 4.8 mm in males and 4.6 mm in females [15]. Moretti and Pizzi, 2009, reported a similar study in which they discovered that the mean ONSD using ocular ultrasound in the control group was 4.9 0.4 mm [16].

Anakçi *et al.*, 2018, discovered a significant decrease in GCS in patients with high ICP [17]. Nash *et al.*, 2015, found that an ONSD of > 5 mm ensures no increase in ICP [18], which is consistent with our findings. Aduayi *et al.*, 2015, also agreed with the current study, stating that the mean ONSD was higher in patients with brain injury who had cranial CT confirmed findings of raised ICP than in patients with brain injury who did not have any cranial

CT evidence of raised ICP than in controls (5.7 0.59 mm vs 4.8 ± 0.39 mm vs 4.5 ± 0.22 mm), respectively (*P< 0.01*) [19].

The best cut-off value for predicting increased ICP was >5.2 mm (81.2% sensitivity, 100% specificity, and 0.9 AUC). This was consistent with the findings of Maissan *et al.,* 2015, who conducted a study on patients with traumatic brain injury whose ICPs were monitored and who were admitted to the ICU [20]. They discovered that ICP and ONSD returned to baseline almost immediately. At a cut-off of 5.0 mm, the correlation between ICP and ONSD was strong, with a sensitivity of 94%, specificity of 98%, and area under the curve of 0.99 for detecting elevated ICP. Rajajee *et al.,* 2011, on the other hand, reported that bedside measurement of ONSD is an accurate non-invasive method to identify ICP > 20 mmHg in a heterogeneous group of patients with acute brain injury with ONSD > 4.8 mm has the greatest accuracy [21].

Conclusion

ONSD ultrasound measurement is a useful marker for detecting elevated ICP. It is non-invasive, safe, and outperformed Fundus examination and CT signs of increased intracranial pressure in both diagnosis and patient follow-up.

Ethical considerations

The study was approved by the ethical committee of the faculty of medicine at Fayoum University.

Availability of data and materials

The data sets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Patient consent

Informed written consents for participation were taken and signed by the eligible relatives before recruitment and randomization.

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Conflicts of Interest: All authors declare no conflict of interest.

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