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Ultrasonographic Measurement of Optic Nerve Sheath Diameter for Detection of Increased Intracranial Pressure in Patients Scheduled for Elective Tumor Craniotomy

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ABSTRACT

Background: Elevated intracranial pressure (EICP) is a serious neurological condition. The diameter of the optic nerve sheath can be determined by means of ultrasonography as a non-invasive method of detecting EICP.

Objective: The aim of the current work was to evaluate the accuracy of bedside optic nerve sheath diameter (ONSD) by ultrasound (US) as a non-invasive method of detecting increased intracranial pressure (ICP) in patients underwent elective tumor craniotomy in comparison to clinical and radiological computed tomography (CT) findings of EICP.

Patients and Methods: From January 2020 to May 2020, this prospective observational study was conducted on seventy-one patients underwent elective tumor craniotomy at Zagazig University Hospitals. ONSD measurements were done and compared with clinical and radiographic features on CT brain suggesting increase in ICP pre and post-operatively.

Results: There were good relation between ONSD and clinical signs of EICP. it was found that there were increase in preoperative mean ONSD among cases had nausea (4.94±0.57 mm), vomiting (4.97±0.55) mm and headache (4.87±0.6 mm), disturbed conscious level (4.9±0.62 mm) and visual field affection (5±0.46 mm). also, there was increase in postoperative mean ONSD among cases with nausea (4.81±0.67 mm), vomiting (4.81±0.62 mm), headache (4.83±0.63 mm). The cut-off value of ONSD for diagnosing increased ICP was >4.8 mm with sensitivity 78.9%, specificity 63.6% and accuracy 71.8%.

Conclusion: It could be concluded that bedside ultrasonographic measurement of ONSD is a reliable technique for prediction of elevated intracranial pressure.

Keywords: Optic Nerve Sheath Diameter, Elevated Intracranial Pressure, Tumor Craniotomy

INTRODUCTION

An increased intracranial pressure is a serious neurological problem that can result in long-term neurological consequences. Therefore, rapid detection of raised ICP is of great importance to obtain good outcome in such patients. An EICP may be developed by a variety of causes such as head trauma, an intracranial mass lesion, venous sinus obstruction etc. Patients with a mass lesion are at risk for EICP because of the compressive effect of the lesion or obstructive hydrocephalus **(1-2)**.

Although the invasive methods such as intra-parenchymal and intra-ventricular devices are the reference standard for ICP monitoring but they not always used due to many causes such as unavailability of the technique expert in many hospitals, presence of contraindications (coagulopathy) and cost. In addition, they have serious complications such as intra-cranial hemorrhage, seizure and infection **(3-4)**.

With the possible complications of invasive ICP monitoring, non-invasive tools for detection of raised ICP is of potential benefit. Non-invasive tools such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans of the brain are free of these limitations and complications. However, they are time consuming, costly, not always available and have risk of radiation exposure for CT scan. Also, they are not feasible in unstable patient and only give snap shot information. **(3&5)**.

The optic nerve surrounded by a sheath that was in a direct continuation with the meninges so that, Any rise in ICP will cause the optic nerve sheath to dilate with resultant increase in the sheath diameter as a result of increased CSF pressure **(6)**.

This optic nerve sheath diameter can be measured using ultrasonography, which is a non-invasive and rapid method of detecting EICP **(7)**.

Trauma, neurosurgery, and emergency medicine all use this technique. Traumatic brain injury (TBI) has been the subject of numerous research that compare ONSD findings to CT/MRI findings and the effect of brain dehydration measures on its follow-up assessments **(8)**.

We aimed to evaluate the diagnostic accuracy of optic nerve sheath diameter guided by ultrasound in predicating rise in ICP in patients undergoing elective tumour craniotomy and to correlate ONSD measurements to clinical and radiographic features on CT brain suggesting increase in ICP pre and post-operatively in patients scheduled for elective tumour craniotomy.

PATIENTS AND METHODS

From January 2020 to May 2020, this prospective observational study was conducted on seventy-one patients underwent elective tumor craniotomy at Zagazig University hospitals.

***Ethical Consideration*:**

An approval of the study was obtained from Zagazig University Academic and Ethical Committee (ZU-

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IRB#6753). Every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Inclusion Criteria: Patient acceptance, aged between 21 - 60 years, of both sexes, and BMI (kg/m^2) below 30kg/m,^{2} scheduled for elective tumor craniotomy under general anesthesia.

Exclusion Criteria: Glasgow coma score≤ 8, history of ophthalmic problems that render dealing with probe, presence of optic nerve disorders (e.g. optic neuritis, optic nerve neoplasm).

All participants were:

- Asked about the clinical symptoms that could indicate EICP such as nausea, vomiting, headache and blurring of vision
- Asked to obtain a new CT brain 24h pre-operative. EICP-related CT brain abnormalities, such as brain edema, midline shift, effaced brain sulci, and effaced basal cisterns were also documented.
- Assessed by Glasgow Coma Score (GCS) to evaluate the conscious level of the patients pre and post operatively.

Each patient's EICP symptoms and CT brain imaging findings were compared to their ONSD scores in two different settings: 24 hours before surgery **(Figure 2)** and within 24 hours after surgery **(figure 3)**.

Technique of ONSD Ultrasonography measurement:

With the patient in the supine posture, the patient's head and upper torso were lifted 20–30 degrees to avoid any pressure on the eye, and an ultrasound machine was used to measure ONSD With a 13–6 MHz B-mode linear array probe. In order to perform bilateral measurements, a generous amount of ultrasound gel was applied to the closed upper eyelids and the upper eyelids were closed. By closing their eyes and looking ahead, the patient's anatomical landmarks (the optic nerve and lens) may be clearly defined. The optic nerve appeared as a linear hypoechoic structure that expanded out from the globe of the eye with clearly defined boundaries behind the globe after the probe was adjusted slightly. We used mechanical callipers to measure ONSD 3mm behind the globe after freezing the screen image [9] (Figure 1).

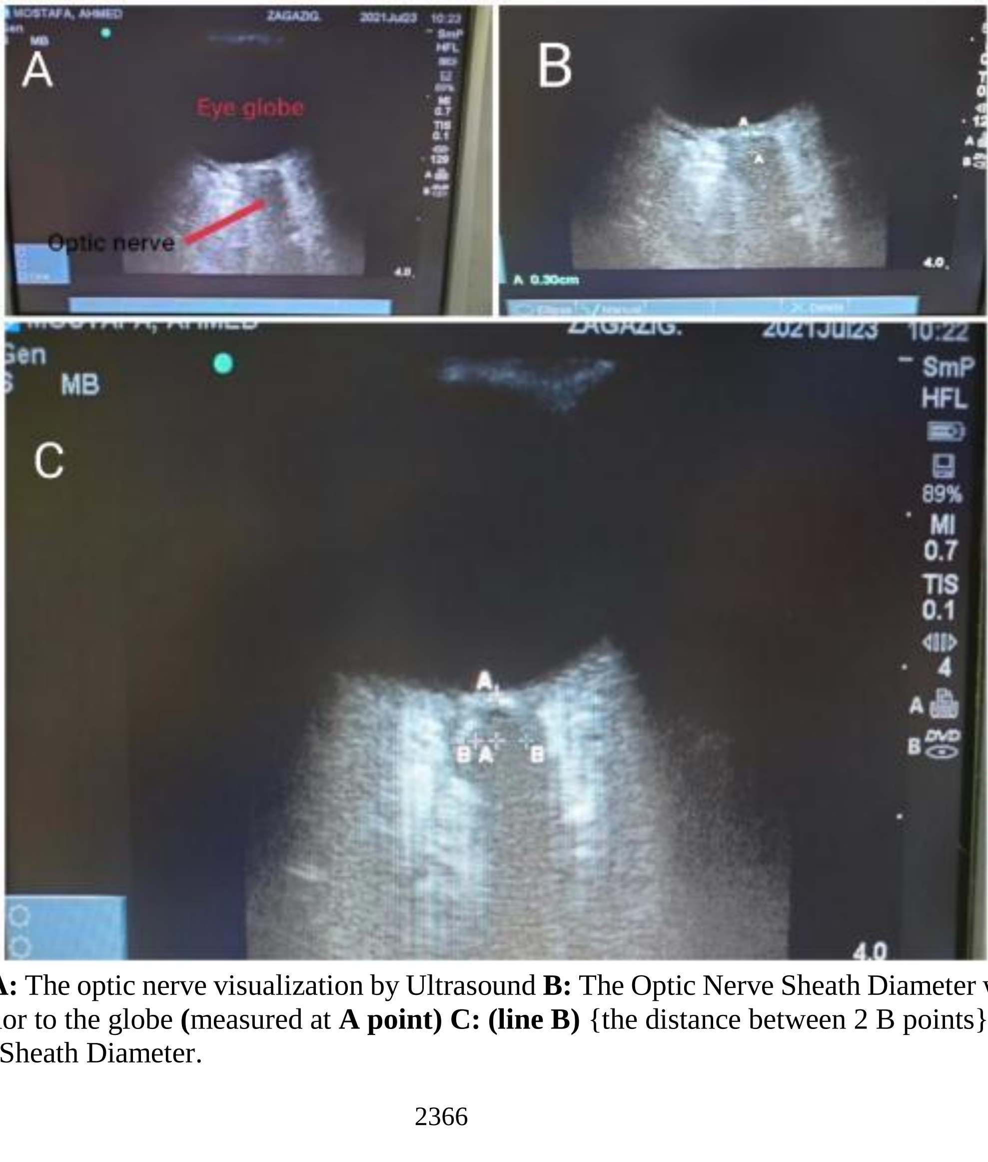

Figure (1): A: The optic nerve visualization by Ultrasound **B:** The Optic Nerve Sheath Diameter was measured 3 mm posterior to the globe **(**measured at **A point) C: (line B)** {the distance between 2 B points} represent the Optic Nerve Sheath Diameter.

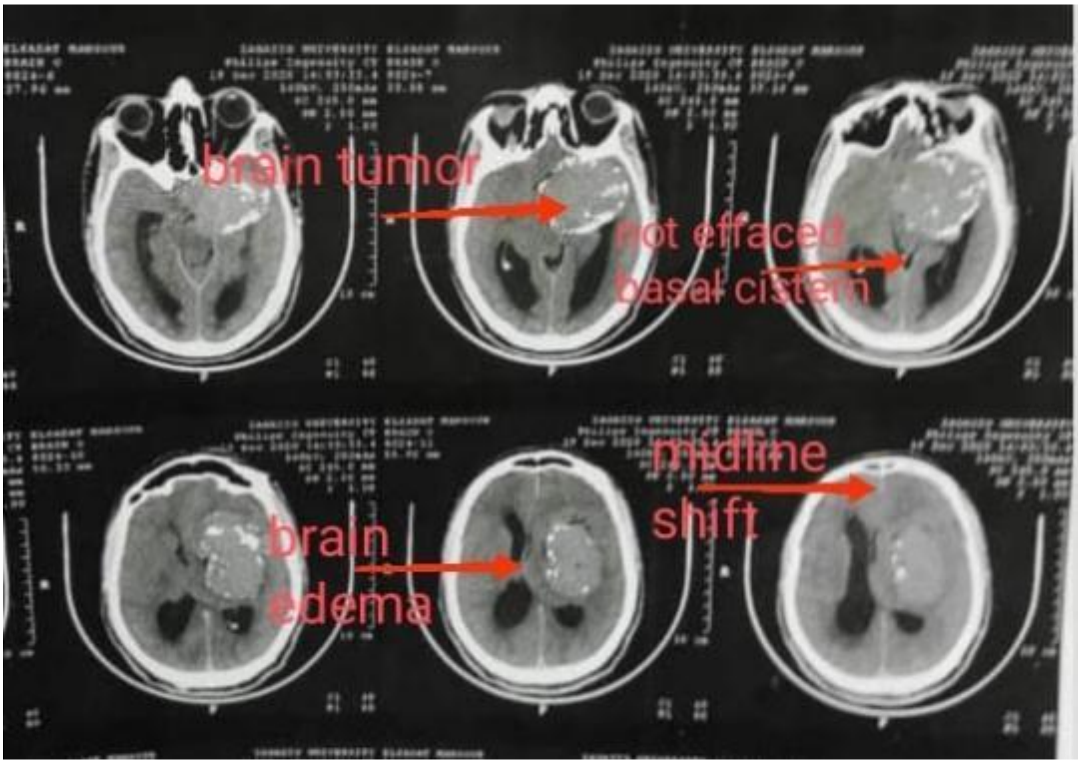

Figure (2): A pre-operative CT brain showing space-occupying lesion with surrounding brain edema with resultant midline shift and preserved basal cistern.

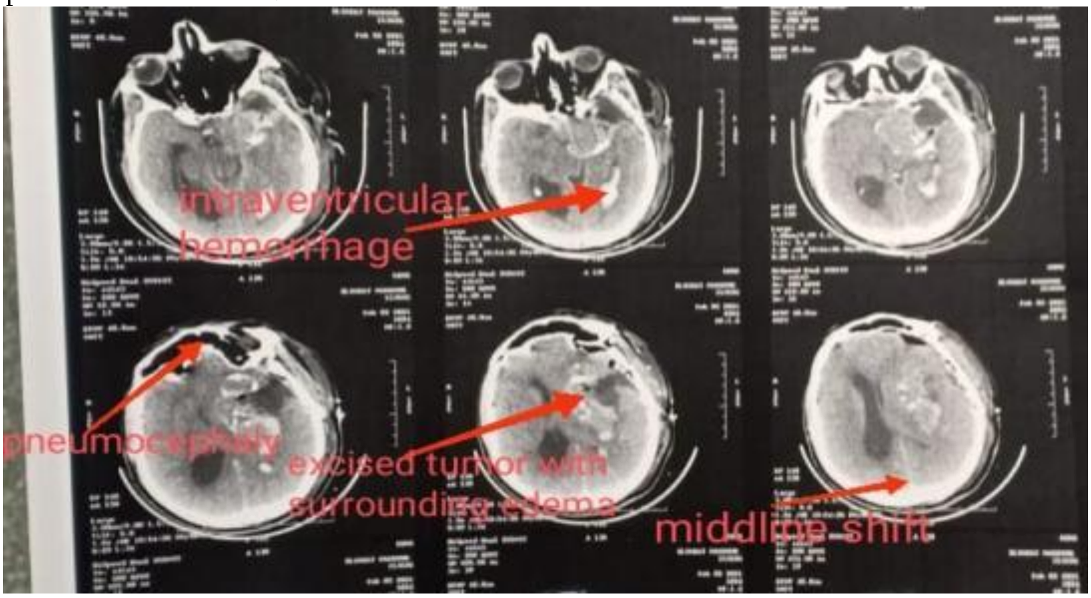

Figure (3): A post-operative CT brain showing total removal of the tumor with surrounding brain edema and midline shift.

Intraoperative:

- Standard monitoring applied for every patient in the operating room (OR) including ECG, non-invasive arterial blood pressure, Pulse Oximetry, and Capnography then vital data are measured before surgery and every 5 minutes throughout the surgery. This include Heart rate (HR), oxygen saturation (SPO2), and mean arterial blood pressure (MAP)**.**
- Induction of the general anesthesia was done by intravenous medications that include Fentanyl (1μg/kg), Propofol (2 mg/kg) and Cis-atracurium (0.15 mg/kg) then intubation was done with endotracheal tube of suitable size.
- Maintenance of anesthesia was done by: Inhalational anesthesia: 1.2% isoflurane, Muscle Relaxation with additional doses of cis-atracurium (0.04 mg/kg) that was given every 20-30 minutes and Opioids was administered in form of Fentanyl 0.5-1μg/kg intravenously for intraoperative increase in heart rate (HR) or mean arterial pressure (MAP) above 20% of baseline. MAP should be maintained above 80 mmHg at least to have a CPP > 50 mmHg.
- Mechanical Ventilation was delivered by using volume-controlled mechanical ventilation. settings was adjusted to tidal volume of 8 ml/kg and respiratory rate of 14-19/min to keep levels of **End-**tidal carbon

dioxide between 30 and 35 mmHg and avoid hypercarbia, which raises CBF and thus ICP.

Postoperative:

If there were no contraindications, the patient was extubated and sent to the critical care unit after intravenous neostigmine (0.05 mg/kg) and atropine (0.02mg/kg) antagonized the patient's remaining neuromuscular blockade and In order to monitor each patient's EICP symptoms and CT brain imaging findings within the first 24 hours after surgery, the ONSD was repeated **(Figure 3).**

Statistical analysis:

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 27 for Windows® (IBM SPSS Inc, Chicago, IL, USA). Numbers and percentages are used to represent data (percent) or mean ± SD. Different qualitative factors were examined using the Chi square (X^2) test. Mc-Nemar test for quantitative factors were compared in the same group at different points in time. If the significant probability was less than 0.05, the threshold for statistical significance, the results were considered statistically significant and highly significant. There was a (P value) of (0.05* and 0.001**).

RESULTS

This study included a total of 90 patients, 19 of them were excluded. The final analysis was done on 71 patients. These patients underwent elective craniotomy and subdivided according to the site of the brain tumor into supra and infra-tentorial.

Regarding patient characteristics and surgical data, the age of the studied cases ranged from 21 to 60 years with mean 44.72 years(±10.65 years) while BMI ranged from 18 to 29 kg/m^2 with mean 27.02 kg/m^2 (± 2.49 kg/m^2). The mean anesthesia duration and operation duration were (7.53 h (±1.2h) & 7.05 h (±1.19h) respectively. The Majority of the studied cases were female which represent 62% of the cases **(Table 1)**.

Table (1): Patients and surgical characteristics of the cases:

Variable		(n=71)	
Age: (year)	Mean ± SD Range	44.72±10.65 21-60	
BMI: (kg/m^2)	Mean ± SD Range	27.02±2.49 18-29	
Anesthesia duration: (hr.)	Mean ± SD Range	7.53±1.2 5.5-15	
Operation duration: (hr.)	Mean ± SD Range	7.05±1.19 5-14.5	
Variable		**n**	**%**
Sex:	Male Female	27 44	38 62
ASA:	I II	55 16	77.5 22.5

SD: Standard deviation BMI: body mass index ASA: American society of anesthesiologists

Regarding the radiological findings on CT of EICP, there was a statistical significance decrease in frequency of midline shift (1.4%), brain edema (22.5%) and effaced brain sulci (0%) in 24h postoperative period compared to 24h preoperative period (14.1%, 53.5%, 14.1%) respectively. Pre- or postoperatively, there were no occurrences of effaced basal cistern (**Table 2**).

Table (2) Pre & post-operative CT findings of elevated intracranial pressure among the studied cases

Variable		Pre-operative (n=71)		Post-operative (n=71)		P
		N	%	n	%	
Mid line shift	No Yes	61 10	85.9 14.1	70 1	98.6 1.4	**0.01***
Brain edema	No Yes	33 38	46.5 53.5	55 16	77.5 22.5	**<0.001 ** **
Effaced Basal Cistern	No	71	100	71	100	1 NS
Effaced brain sulci	No Yes	61 10	85.9 14.1	71 0	100 0	**0.01***

With respect to the tumor site and the ONSD, there was a statistical significance increase in mean ONSD among cases had Infra-tentorial lesion (5.24 ±1.45 mm) compared to cases had supra-tentorial lesions (4.56 ±0.6 mm). **(Table 3)**

Table (3): Relation between tumor site and optic nerve sheath diameter among the studied cases

Variable		N	ONSD...mm		T	P
			Mean	SD		
Tumor site	Infra-tentorial	7	5.24	1.45	2.92	0.005*
	Supra-tentorial	64	4.56	0.6		

About the relation between pre-operative ONSD and clinical signs of EICP, there was a statistically significant increase in mean ONSD among cases with nausea (4.94±0.57 mm), vomiting (4.97±0.55 mm), headache (4.87±0.6 mm), disturbed conscious level (4.9±0.62 mm), and visual field affection (5±0.46 mm) **(Table 4)**.

Table (4): Relation between clinical signs and preoperative-optic nerve sheath diameter among the studied cases

Variable		N	ONSD…mm		T	P
			Mean	SD		
Nausea	No	56	4.38	0.51	**3.72**	**<0.001****
	Yes	15	4.94	0.57		
Vomiting	No	55	4.36	0.50	**4.23**	**<0.001****
	Yes	16	4.97	0.55		
Headache	No	65	4.39	0.55	**2.03**	**0.04***
	Yes	6	4.87	0.60		
Disturbed Conscious Level	No	62	4.44	0.54	**2.37**	**0.02***
	Yes	9	4.9	0.62		
Visual field affection	No	65	4.45	0.55	**2.35**	**0.02***
	Yes	6	5	0.46		

Regarding the relation between the radiological CT findings of EICP and the preoperative ONSD, there was a statistical significance increase in mean ONSD among cases had midline shift, brain edema and effaced brain sulci (5.2±0.72 mm, 4.93 ±0.62 mm, 5.34±0.63 mm) respectively **(Table 5).**

Table (5) Relation between CT findings of elevated intracranial pressure and Preoperative-optic nerve sheath diameter among the studied cases

Variable		N	ONSD…mm		t	P
			Mean	SD		
Mid line shift	No	61	4.53	0.55	**3.40**	**0.001***
	Yes	10	5.20	0.72		
Brain edema	No	33	4.27	0.40	**5.21**	**<0.001****
	Yes	38	4.93	0.62		
Effaced brain sulci	No	61	4.51	0.54	**4.43**	**<0.001****
	Yes	10	5.34	0.63		

In terms of postoperative ONSD and clinical EICP signs, it was found that there was a statistical significance increase in mean ONSD among cases had nausea (4.81±0.67 mm), vomiting (4.81±0.62) mm and headache (4.83±0.63 mm). No statistical significant difference found in disturbed consciousness level or visual field affection **(Table 6)**.

Table (6): Relation between clinical signs of elevated intracranial pressure and postoperative-optic nerve sheath diameter among the studied cases

Variable		n	ONSD…mm		T	P
			Mean	SD		
Nausea	No	24	4.25	0.25	**3.90**	**<0.001****
	Yes	47	4.81	0.67		
Vomiting	No	36	4.45	0.58	**2.53**	**0.01***
	Yes	35	4.81	0.62		
Headache	No	9	4.36	0.52	**2.13**	**0.03***
	Yes	62	4.83	0.63		
Disturbed Conscious Level	No	63	4.57	0.61	1.88	0.06
	Yes	8	5.01	0.64		NS
Visual field affection	No	65	4.61	0.63	0.66	0.51
	Yes	6	4.78	0.47		NS

As regards to the radiological postoperative ONSD measurements, it was found that the cases with brain edema had a statistically significant increase in mean ONSD (4.92±0.46 mm) when compared to cases without (4.37±0.54 mm) **(Figure 4).**

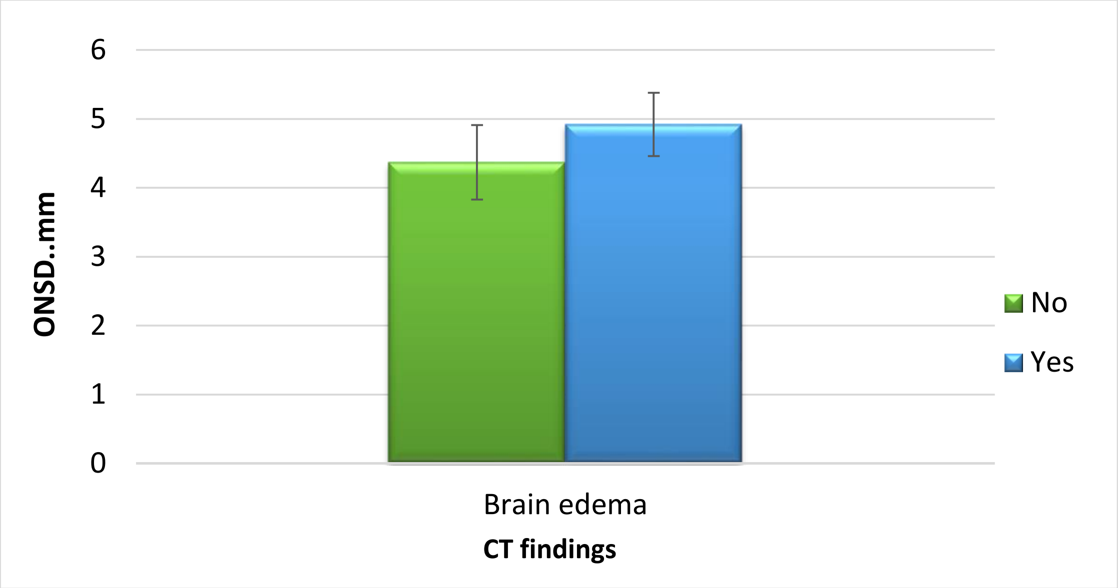

Figure (4): Relation between brain edema and postoperative-optic nerve sheath diameter among the studied cases.

The cut-off value of ONSD for diagnosing increased ICP was >4.8mm with sensitivity 78.9%, specificity 63.6% and accuracy 71.8%. **(Table 7, Figure 5)**

Table (7): Validity of preoperative-optic nerve sheath diameter in diagnosis of elevated ICP among studied cases:

Cut off	AUC (95% CI)	P	Sensitivity	Specificity	PPV	NPV	Accuracy
>4.8 Mm	**0.82 (0.73-0.92)**	**<0.001 ****	**78.9%**	**63.6%**	**73.2%**	**72.4%**	**71.8%**

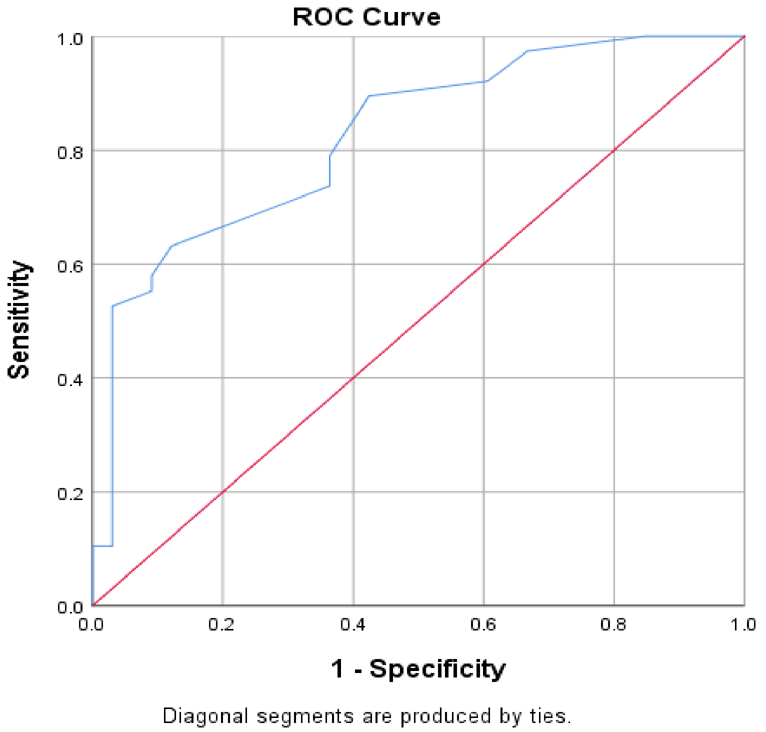

Figure (5): Roc curve of Validity of preoperative-optic nerve sheath diameter in diagnosis of elevated ICP among the studied cases.

DISCUSSION

One of the most serious neurological issues that might have long-term consequences is elevated intracranial pressure (EICP) [(1)].

This study was carried out to evaluate the diagnostic accuracy of optic nerve sheath diameter guided by ultrasound in detecting the rise in ICP in patients scheduled for elective tumor craniotomy and to compare ONSD measurements to clinical and radiographic features on CT brain suggesting increase in ICP pre and post-operatively.

This study showed a good relation between an increased ONSD measured by US and the presence of clinical and radiological feature (on brain CT scan) of raised ICP pre and post-operatively in patients scheduled for elective tumor craniotomy.

With respect to the tumor site and the ONSD, there was a statistically significant increase in mean ONSD among cases had Infra-tentorial lesion, compared to cases had supra-tentorial lesions (P = 0.005).

One of the results of **Mehrotra *et al.*** [(10)] our findings corroborate this conclusion. When they studied brain tumors in the first year of life, they discovered that elevated intracranial pressure was more than twice as common with lesions in the posterior fossa. ($P < 0.01$).

On the contralateral the study of **Zhang *et al.*** [(11)]**,** they found the ICP in supratentorial lesions considerably elevated compared to the ICP in the infra-tentorial lesions evaluated by trans-cranial Doppler**.**

About the relation between pre-operative ONSD and clinical signs of EICP there was a statistical significance increase in mean ONSD among cases had nausea, vomiting and headache. No statistical significant difference found in disturbed consciousness level or visual field affection.

Shafiq *et al.* [(12)] found that seventy percent of patients based on clinical variables, who underwent tumor craniotomies showed a rise in intracranial pressure (ICP), while 65 percent had an increased ICP based on radiographic evidence. This elevation in ICP was predicted by the increased ONSD measured by US in 61% of cases. ONSD had a diagnostic accuracy of 87.5% in diagnosing elevated ICP.

Regarding the relation between the radiological CT findings of EICP and the preoperative ONSD, there was a statistical significance increase in mean ONSD among cases had midline shift, brain edema and effaced brain sulci.

Qayyum *et al.* [(13)] did a study on 24 adult patients to determine the accuracy of ocular ultrasonography in predicting intracranial hypertension. Ocular ultrasonography was matched to CT findings of a midline shift, sulcal effacement with substantial edema, the collapse of the third ventricle, and hydrocephalus. They concluded that ultrasound guided optic nerve sheath diameter is a sensitive and specific test for predicting elevated ICP.

Regarding postoperative ONSD and clinical EICP signs, there was a statistically significant increase in mean ONSD among cases with nausea, vomiting, headache, disturbed conscious level and visual field affection.

Thotakura *et al.* [(14)] found that ultrasonography ONSD measurement can be used as an alternative technique when invasive ICP monitoring is not accessible, and serial recording of ONSD can be useful and provide valuable information for decision making.

As regards to the radiological postoperative ONSD measurements, it was found that the cases with brain edema had a statistically significant increase in mean ONSD, when compared to cases without brain oedema.

More than one study backs up our findings about the link between ONSD and CT characteristics of elevated ICP. **Aduayi *et al.*** [(15)] did an investigation on 160 adults referred to the radiology department for CT and ONSD scans, which involved blinded observation. They found that optic nerve sheath ultrasonography has a high degree of accuracy in predicting elevated ICP (86.3 percent) Did cranial CT confirm symptoms of elevated ICP with intracranial space-occupying lesions (SOL), mean binocular ONSD of 5.7 ± 0.59 mm while (13.7%) had intracranial SOL without any cranial CT evidence of increased ICP, mean binocular ONSD of 4.8 ± 0.39 mm. Their two groups had a statistically significant difference in the mean ONSD. Mean binocular ONSD is excellent for predicting elevated ICP if there is at least one indication on cranial CT.

Regarding to validity of preoperative-optic nerve sheath diameter in the current study for diagnosis of elevated ICP among studied cases, the cut-off value of ONSD for diagnosing increased ICP was >4.8mm with sensitivity 78.9%, specificity 63.6% and accuracy 71.8% . There has been a substantial variability around the ideal ONSD cut-off value that best predicts elevated ICP. Could be due to a variety of reasons such as changes in the technique utilized as well as differences between machines as well as populations from a variety of ethnic backgrounds [(16)]**.**

A cutoff $\geq$ 4.8 mm has been validated for detecting increased ICP by several authors in their studies e.g. the study of **Goel *et al.*** [(17)] that included 100 patients with traumatic brain injury. They assessed the utility of optic nerve ultrasonography in head injury. A mean binocular ONSD less than 5.00 mm was considered normal. Mean binocular ONSD greater than 5.00 mm had a sensitivity of 98.6% and specificity 92.8% for detection of raised ICP. Binocular ONSD larger than five millimeters (5.00 millimeters) was found to be very sensitive and specific for the detection of elevated ICP.

Also the study done by **Rajajee *et al.*** [(18)] used either intra-parenchymal ICP or external ventricular drains in patients at risk of increased intracranial pressure in the intensive care unit. The ONSD tests were carried out on 65 people. An ONSD greater than 0.48

cm was found to be ideal for the detection of high ICP (more than 20 mmHg) and to be sensitive to 96% (95%) and specific to 94% (92–96%), respectively.

Shirodkar ***et al.*** **[19]** perform a study for Correlation of measurement of ONSD using ultrasound with magnetic resonance imaging. A 4.8 mm ONSD cutoff was reported to be 75 percent sensitive and 100 percent specific for the detection of MRI indications of increased ICP, such as midline shift, edema, and effacement.

In disagreement with our results **Zoerle** ***et al.*** **[20]** study. They found that In patients with subarachnoid hemorrhage, ONSD was not linked to intracranial pressure (SAH). Unlike our group of patients, their study included individuals who had SAH in addition to intraventricular and/or cerebral hemorrhage. After SAH, the flexibility of the ONS was reduced, and this was the cause of the patient's symptoms.

CONCLUSION

It could be concluded that bedside US guided ONSD measurement provides a non-invasive real time valuable technique for detecting increased ICP in patients undergoing elective brain tumor craniotomy compared with clinical and radiographic CT brain finding pre and postoperatively.

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