

COMPARISON OF CT SCAN BRAIN AND ULTRASOUND-GUIDED OPTIC NERVE SHEATH DIAMETER (US-ONSD) FOR NON-INVASIVE DETECTION OF CEREBRAL EDEMA IN STROKE PATIENTS

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Abstract

Objective: To determine the accuracy of ultrasound-based optic nerve sheath diameter (US-ONSD) for determining raised intracranial pressure (ICP) in stroke patients.'

Methods: In this validation study, we included 100 patients who were admitted with stroke in the ICU of CMH, Quetta, with suspicion of raised ICP. Initially, all patients underwent a CT scan to determine the presence, size, and location of the stroke and measure intracranial pressure (ICP). After CT scan evaluation bedside ultrasound was performed by single operator in all patients for measuring ONSD.

Results: The patients had an average age of 48.7 ± 11.9 years. The APACHE IV score averaged 55.8 ± 14.5 . The sensitivity of US-ONSD in relation to CT scan was 92.1%, while specificity was 90.9%. The positive predictive value (PPV) was notably high at 98.8%, suggesting that a positive test result is highly indicative of actual elevated ICP, while the negative predictive value (NPV) was 58.8%.

Conclusion: The diagnostic accuracy of US-ONSD measurement in predicting raised ICP, when compared to CT findings, was good, yielding an optimal cutoff of 5.5 mm.

INTRODUCTION

Stroke, encompassing both ischemic and hemorrhagic types, continues to be a significant public health challenge, ranking as the second leading cause of death worldwide and the third leading contributor to overall mortality and disability.¹ According to statistics from 2019, the global prevalence of stroke was estimated at approximately 101 million individuals, around 56.4 million were women and 45 million were

men.¹ In stroke patients who arrive at the emergency department or intensive care unit, elevated intracranial pressure (ICP) poses a significant threat. Timely diagnosis and treatment are crucial, as increased ICP can result in detrimental neurological consequences. A reading above 20 mmHg is classified as a critical medical emergency.²

The conventional approach to assessing intracranial pressure (ICP) involves direct

measurements via intraparenchymal or intraventricular devices. However, these methods carry risks, including infection and hemorrhage.^{3, 4} Alternatively, computed tomography (CT) scans are recognized as effective non-invasive tools for evaluating ICP. Specific CT indicators, such as a midline shift greater than 5 mm, sulcal effacement, and the compression of basal cisterns, are key signs that may indicate elevated ICP levels.⁵

The optic nerve and its contents connect seamlessly to the subarachnoid space inside the skull. When intracranial pressure (ICP) rises, it is conveyed to the optic nerve, causing it to enlarge. The diameter of the optic nerve sheath can increase within seconds in response to this pressure change.⁶ Measuring the optic nerve sheath diameter (ONSD) through ocular ultrasound has been thoroughly researched as an effective bedside technique to identify elevated ICP. Additionally, ultrasound is devoid of radiation exposure and is more cost-effective compared to brain imaging methods.^{7, 8}

Given its advantages, we have begun utilizing ultrasound (US) to measure optic nerve sheath diameter (ONSD) for assessing the intracranial pressure (ICP) conditions of our patients. This study aims to evaluate the accuracy of ultrasound-based ONSD measurements in identifying elevated ICP, using CT scans as the gold standard.

METHODS:

In this validation study, we included 100 patients who were admitted with stroke in the ICU of CMH, Quetta, with suspicion of raised ICP. We did not include patients with significantly elevated ICP on CT evaluation requiring urgent surgery, those with a history of optic neuritis, or individuals contraindicated for CT scans.

Initially, all patients underwent a CT scan to determine the presence, size, and location of the stroke and measure intracranial pressure (ICP). Any of the following indicators were recorded as signs of elevated ICP: significant intracranial hemorrhage, the presence of intraventricular extension of subarachnoid hemorrhage (SAH), compression of the basal cisterns, a midline shift of 0.5 cm or greater, or the occurrence of acute hydrocephalus.

After CT scan evaluation bedside ultrasound was performed by single operator in all patients for measuring ONSD. The measurements were obtained by placing the patient in the supine position. The US probe was placed perpendicular to the optic nerve axis (B-mode), the ONSD measurements were obtained 3 mm behind the globe from both eyes. Two measurements were obtained in each eye and average was calculated for each side, after that average from both eyes was calculated and noted as final ONSD. ONSD of 5.5 mm was taken as cut off value of increased ICP.

Data was analyzed using SPSS v23. Diagnostic accuracy of US was determined in terms of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

RESULTS:

The baseline characteristics of the patients included an average age of 48.7 ± 11.9 years. The APACHE IV score averaged 55.8 ± 14.5 . In terms of gender, there were 41 females (41%) and 59 males (59%). The type of stroke was classified as ischemic in 46 participants (46%) and hemorrhagic in 54 participants (54%). The average respiratory rate was 21 breaths per minute (mean $\pm$ SD: 21 ± 1.6), and the pulse rate averaged 88.1 ± 7.4 beats per minute. Blood pressure readings showed a systolic blood pressure (SBP) of 149 ± 11.5 mmHg and a diastolic blood pressure (DBP) of 87 ± 6.4 mmHg (Table 1).

The accuracy of US-Based Optic Nerve Sheath Diameter (ONSD) in relation to elevated intracranial pressure (ICP) is demonstrated in the findings. Among the 100 patients assessed, 83 were identified with elevated ICP on CT scans, of which 82 were also indicated by the US-Based ONSD to have elevated pressure. Conversely, 7 patients with elevated ICP were not detected by the US-Based ONSD. In the group without elevated ICP, 10 were accurately recognized by the US-Based ONSD, while 1 was misclassified. This data results in a sensitivity of 92.1%, indicating the test's effectiveness in identifying those with elevated ICP. The specificity stands at 90.9%, reflecting its accuracy in determining those without elevated ICP. The positive predictive value (PPV) was notably high at 98.8%, suggesting that a positive test result is highly indicative of actual

elevated ICP, while the negative predictive value (NPV) was 58.8%, indicating a lower

reliability in ruling out the condition when the test result is negative (Table 2).

Table 1. Baseline Characteristics.

Age (Years)	48.7±11.9
APACHE IV score	55.8±14.5
Gender (%)	
Female	41 (41.0%)
Male	59 (59.0%)
Type of Stroke (%)	
Ischemic	46 (46.0%)
Hemorrhagic	54 (54.0%)
Respiratory rate/min	21±1.6
Pulse rate/min	88.1±7.4
SBP (mmHg)	149±11.5
DBP (mmHg)	87±6.4

Table 2. Accuracy of US-Based ONSD.

ICP according to US-Based ONSD	Elevated ICP on CT		Total
	Yes	No	
Yes	82	01	83
No	07	10	17
Total	89	11	100
Sensitivity= 92.1%			
Specificity=90.9%			
PPV= 98.8%			
NPV=58.8%			

DISCUSSION:

The present study found excellent sensitivity and specificity of US-ONSD for measuring raised ICP.

In their research, Jeon and colleagues identified that a cut-off measurement of 5.6 mm for US-ONSD can effectively indicate the presence of ICP. This threshold demonstrated a high sensitivity of 93.8% and a specificity of 86.7%, specifically in populations from Korea.⁹

In their study, Altayar and colleagues found that a USG-ONSD measurement exceeding 5.5 mm could be an effective predictor of ICP. This threshold demonstrated a notable sensitivity of 92.9%. However, the specificity was recorded at only 50%, indicating that about half of those who did not have elevated ICP were incorrectly classified as having raised ICP.¹⁰

In a different study, Jenjitrant and colleagues established a lower threshold of 3.15 mm for their method of measurement. This finding is noteworthy as it demonstrates a high sensitivity rate of 97.4%. However, the specificity was

markedly lower at 13.8%, suggesting that many false positives may occur.¹¹

A recent investigation established a threshold of 4.8 mm for identifying elevated ICP using CT-ONSD. This study reported a sensitivity of 60.5% and a specificity of 61.2% for this diagnostic criterion. These findings suggest that while the 4.8 mm cutoff may be useful for detecting increased ICP, the relatively modest sensitivity and specificity indicate that further research may be needed to enhance its reliability in clinical practice.¹²

Schuchardt and colleagues presented essential findings regarding the assessment of ONSD in their study. They observed that when the ONSD exceeded 5.8 mm, the test exhibited a sensitivity of 88.9%. Additionally, the specificity was reported at 61.5%, suggesting that there was a moderate level of correctly identifying those without the condition. Furthermore, the NPV was quite high at 96%, highlighting the test's effectiveness in ruling out the disease when the ONSD measurement was below the threshold.¹³

Kerscher and colleagues found that using a cut-off measurement for the optic nerve sheath diameter (ONSD) of 5.73 mm or greater resulted in a notable negative predictive value (NPV) of 82.6%. Additionally, their research indicated a sensitivity of 92% and a specificity of 86.4%.¹⁴

Mitchell and colleagues [20] observed that the detection of confirmed papilledema during ophthalmoscopic examinations exhibited a sensitivity of merely 48%. In contrast, its specificity was found to be perfect at 100%, accompanied by a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 64% in relation to diagnosing ICP.¹⁵

In our research, we utilized B-mode ultrasound to assess the optic nerve sheath diameter (ONSD). It is important to note that measurements taken using B-mode can be influenced by the blooming artifact, a phenomenon that arises due to inconsistent sensitivity levels.¹⁶ This artifact tends to be more pronounced when sensitivity settings are lower, potentially leading to inaccuracies. Although the impact of this effect is generally less than 0.5 mm, it is not significant for larger lesions; however, it can have implications when precisely measuring ONSD.

Enlargement of the ONSD can occur in conditions that lead to ICP, including optic neuritis, meningioma, and leukemic infiltration.¹⁷ The 30-degree head position test is regarded as the most effective method for distinguishing between these conditions. A reduction of more than 5% in ONSD when comparing the initial measurement to the measurement taken at a 30-degree angle signifies the presence of fluid within the sheath, indicating elevated ICP.

CONCLUSION:

The diagnostic accuracy of ONSD measurement in predicting raised ICP, when compared to CT findings, is good, yielding an optimal cutoff of 5.5 mm.

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