

Utility of Optic Nerve Sheath Diameter Measurement by Point of Care Ultrasound to Detect Raised Intracranial Pressure: A Prospective Observational Study

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ABSTRACT

Introduction: The main objective of the study was to evaluate the diagnostic utility of Optic Nerve Sheath Diameter (ONSD) measured by Point of Care Ultrasound (POCUS) to detect raised Intracranial Pressure (ICP) among high risk patients in the Emergency Department (ED).

Materials and Methods: Patients above the age of 18 years who presented to the Emergency department with signs and symptoms of raised ICP were included in the study. Patients with cataracts, severe maxillofacial injury, previous history of traumatic brain injury, or ocular surgery were excluded from the study. As per the institutional protocol, the patient was taken for CT head after initial stabilisation. Once the patient had returned back to the ED, investigator performed POCUS to measure ONSD. ONSD value equal to or greater than 5 mm (whether on right eye or left eye) was taken as abnormal. Raised ICP was diagnosed based on the findings of CT brain. Receiver Operating Characteristic curve (ROC) was drawn with ONSD to predict raised ICP and to determine the standard diagnostic test characteristics like Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) and Accuracy.

Results: A total of 69 subjects with high clinical suspicion of raised ICP were included in the study. Of this, 50 subjects (72.5%) had CT findings consistent with raised ICP. 44 (63.8%) patients had the ONSD value of a single eye more than 5 mm. The average ONSD in patients with features of raised ICP in CT brain was 5.4 mm while that in those patients without features of raised ICP on CT brain was 4.4 mm. At the cut-off of 5 mm, ONSD measured by POCUS had a sensitivity of 88%, Specificity of 100%, Positive Predictive Value of 100% and Accuracy of 91.3% to diagnose raised ICP. ROC analysis revealed that the Area under curve (AUC) was 0.983 suggesting excellent discriminative capacity for ONSD to detect patients with raised ICP.

Conclusion: ONSD measurement by POCUS carries excellent accuracy to diagnose raised ICP among high risk patients in acute care settings.

Key words: Optic nerve sheath diameter, Raised intracranial pressure, Point of care ultrasound

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INTRODUCTION

Intracranial Pressure (ICP) is a fundamental parameter for monitoring critically ill neurological patients. Invasive intraventricular monitoring is considered the gold standard for ICP measurement [1]. Apart from being invasive and expensive; this modality is associated with complications such as infection, bleeding, mal positioning, and risk of neurological deficits [2]. CT and MRI are the alternative regular assessment techniques but transporting critically ill patients to the radiology

department also poses danger [3]. Optic Nerve Sheath Diameter (ONSD) measured by Point of Care Ultra Sound (POCUS) has been showing promising results for early diagnosis of raised ICP in acute care settings. ONSD measurement by bedside ultrasound is simple to perform, cost-effective, and can be repeated multiple times without any risk of radiation. This can help in the early detection of raised intracranial pressure in the Emergency Department or any other acute care setting and can be repeated for reevaluation to assess the response to treatment also. Early detection and proper monitoring of ICP help to initiate anti-edema measures promptly, thus improving the patient outcomes.

Systematic review and meta-analysis have confirmed that ocular ultrasound exhibits good diagnostic test accuracy for detecting raised ICP compared to head CT [4,5]. Previous studies have pointed out that ONSD, being an

anatomical measurement made by ocular ultrasound, requires validation in different population subgroups based on age, gender, race, and ethnicity [6-10]. So far, the studies in the Indian population are limited in this regard. A previous study by Sahoo SS and Deepak Agrawal et al have reported a cut-off of 6.3 mm for predicting an ICP >20 mmHg in patients of neuro critical care by using Codman Intra parenchymal probes [11]. Their study was limited by the small sample size. Hence, the goal of our study was to gather further evidence regarding the applicability of ONSD in the Indian population, by determining the accuracy of ONSD measurement taken by POCUS in diagnosing raised ICP among high-risk patients in the Emergency department of a tertiary care hospital in South India.

MATERIALS AND METHODS

Study design and procedure

The study was conducted as a prospective observational study at the Department of Emergency Medicine, Pushpagiri Institute of Medical Sciences, Thiruvalla, and Kerala, India. The study was approved by the Institutional Research Committee and the Institutional Ethics Committee (PIMS and RC/IRC/413/'19). Assuming the 95% Confidence interval and 5% absolute precision with Sensitivity of 96% and Specificity of 94%, the required minimum sample size calculated was 60. Patients were recruited into the study from June 2019 to November 2020. Patients above the age of 18 years who presented to the Emergency Department (ED) with signs and symptoms of raised intracranial pressure (defined by the presence of 2 or more clinical features which include altered mental status, loss of consciousness, sudden onset severe headache with vomiting, seizures, anisocoria, and 6th cranial nerve palsy) were included in the study. Those patients with cataracts, prior history of ocular surgery, or traumatic brain injury were excluded. Upon the arrival of the patient to the ED, the treating physician did the initial evaluation and stabilization and the investigator were informed about the case. As per institutional protocol, the patient was transported to the Radiology Department for head CT imaging. Soon after the patient returned to the ED after Head CT, the investigator performed POCUS (using Sonority M Turbo TM) to measure Optic Nerve Sheath Diameter (ONSD). The measurement was done in a supine position with the patient directing his gaze anteriorly. The probe was applied horizontally over the closed eyelid after applying a copious amount of gel. ONSD was measured as the distance between the external borders of the hyperechoic area 3 mm posterior to the point where the optic nerve entered the globe, using an electronic calliper along the

axis perpendicular to the retina for both eyes (Figure 1). Three recordings were taken from each eye and the average of these three values was taken. The higher ONSD value (whether Right or Left Eye) was taken for statistical analysis. Raised ICP was diagnosed based on the presence of Midline shift, diffuse cerebral oedema, effacement of sulci and gyri, or dilatation of the ventricles in Head CT.

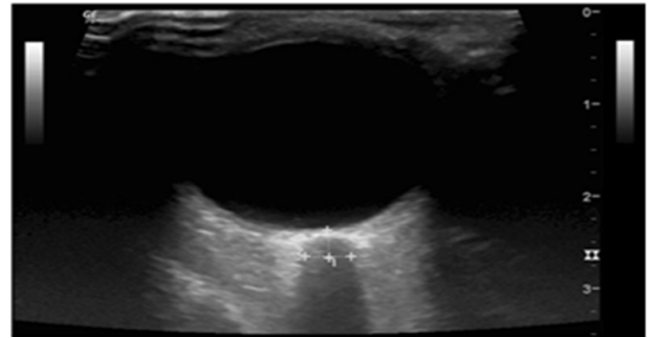


Figure 1: ONSD measurement: Measured 3 mm behind the globe.

Statistical analysis

Categorical and quantitative variables were expressed as frequency (percentage) and mean \pm SD respectively. Descriptive statistics such as mean \pm SD, Median with Inter Quartile Range, minimum and maximum were used to describe ONSD. Receiver Operating Characteristic (ROC) graphs was plotted and the Area under the Curve (AUC) was calculated to assess the diagnostic accuracy of ONSD in detecting raised ICP. Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and accuracy were calculated for ONSD in detecting raised ICP. For all statistical interpretations, $p < 0.05$ was considered the threshold for statistical significance. Statistical analyses were performed by using a statistical software package SPSS, version 20.

RESULTS

Baseline demographics

The study sample included 69 subjects who fulfilled the inclusion criteria. The mean age of the study population was 56 years (SD=19.7). The minimum age included in this study was 19 years and the maximum age was 89 years. Among the study population, 48 (69.6%) were males and 21 (30.4%) were females. These observations are shown in Table 1.

Table 1: Baseline demographics.

Age	
Mean Age	56 years (SD=19.7)
Minimum age	19 years
Highest age	89 years

Gender	Count (%)
Male	48 (69.6%)
Female	21 (30.4%)

Distribution of the study population based on clinical features

Five clinical features of raised ICP were included-Loss of consciousness, altered sensorium, sudden onset severe headache, seizures, and anisocoria. The most common presentation was altered sensorium (87%). The

distribution of other clinical features was Loss of consciousness (69.6%), severe headache (30.4%), Seizures (26.1%), and Anisocoria (27.5%). This is shown in Table 2.

Table 2: Distribution of the study population based on clinical features.

Clinical features	Count	Percent
Loss of consciousness	48	69.6
Altered sensorium	60	87
Severe headache	21	30.4
Seizures	18	26.1
Anisocoria	19	27.5

Distribution according to CT brain findings

Among 69 subjects, 64 patients (92.8%) had abnormal CT findings and 5 (7.2%) had normal CT. The most common CT diagnosis was Intra parenchymal hematoma (37.7%) followed by Subdural haemorrhage (34.8%) and

Subarachnoid haemorrhage (34.8%). Other CT diagnoses were Ischaemic stroke (11.6%), Epidural haemorrhage (7.2%), and Brain tumour (2.9%) (Table 3).

Table 3: Distribution of the study sample based on CT brain diagnosis.

CT report	Count	Percent
EDH	5	7.2
SDH	24	34.8
SAH	24	34.8
Intra parenchymal hematoma	26	37.7
Ischemic stroke	8	11.6
Brain tumour/abscess	2	2.9
Normal	5	7.2

Midline shift, diffuse cerebral oedema, effacement of sulci and gyri, and dilatation of ventricles were taken as the features of raised ICP in CT. Even though 69 subjects with clinical suspicion of raised ICP were included in the study, 50 subjects (72.5%)

had CT findings consistent with raised ICP. Analysing the CT report, 63.8% of subjects had midline shift, 60.9% had effacement of sulci and gyri and 4.3% had dilated ventricle (Table 4).

Table 4: Distribution of the study population based on CT features suggestive of raised Intra cranial pressure.

Individual CT features suggestive of raised ICP*	Count	Percent
Midline shift	44	63.8
Effacement of Sulci and Gyri	42	60.9
Dilatation of Ventricles	3	4.3
Number of patients with CT features of raised ICP*		
YES	50	72.5
NO	19	27.5

*Intracranial pressure

Distribution according to the ONSD value

In this study, 44 (63.8%) of subjects had the ONSD value of a single eye equal to or more than 5 mm, and the rest, 25 (36.2%) had an ONSD value less than 5 mm (Table 5).

Table 5: Distribution of the study population according to the Optic nerve sheath diameter.

ONSD * diameter (mm)	Count (Percent)
<5 mm	25 (36.2%)
> 5 mm	44 (63.8%)

*Optic Nerve Sheath Diameter

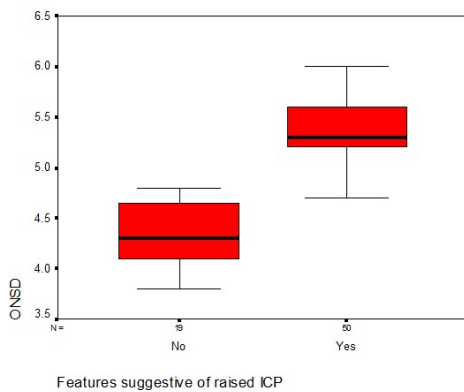
Mean ONSD in subjects with CT finding suggestive of raised ICP was 5.4 mm (standard deviation of 0.4 mm) and ranging between 4.5 mm to 6.2 mm. In patients

without CT findings of raised ICP, mean ONSD was found to be 4.4 mm (standard deviation of 0.3 mm) and ranging between 3.8 mm to 4.8 mm (Table 6 and Figure 2).

Table 6: Descriptive statistics of ONSD according to the CT features of raised ICP.

ONSD*	CT features suggestive of Raised ICP**	
	NO	YES
Mean+SD	4.4 mm+0.3	5.4 mm+0.4
Median (IQR)	4.3 mm (4.1-4.7)	5.3 mm (5.2-5.63)
Minimum	3.8 mm	4.5 mm
Maximum	4.8 mm	6.2 mm

*Optic nerve sheath diameter
**Intracranial pressure



Receiver operating characteristic curve analysis with ONSD for diagnosing raised ICP

This is shown in Figure 3. The AUC was 0.983 ranging between 0.96-1 (p-value <0.01). The Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and Accuracy at the ONSD cut-off value of 5 mm are shown in Table 7.

Figure 2: Box plot for Optic Nerve sheath Diameter and CT features suggestive of raised intracranial pressure.

Table 7: Standard test characteristics of ONSD at the cut off value of 5 mm for predicting raised intracranial pressure.

Sensitivity	88%
Specificity	100%
False negative rate	12%
False positive rate	0
Positive predictive value	100%
Negative predictive value	76%
Accuracy	91.3%

In this study, the accuracy of ONSD measured using POCUS to detect raised ICP was 91.3% with a Sensitivity of 88% and Specificity of 100%. Result also showed a 100% Positive Predictive Value and 76% Negative predictive value for diagnosing raised ICP with ONSD.

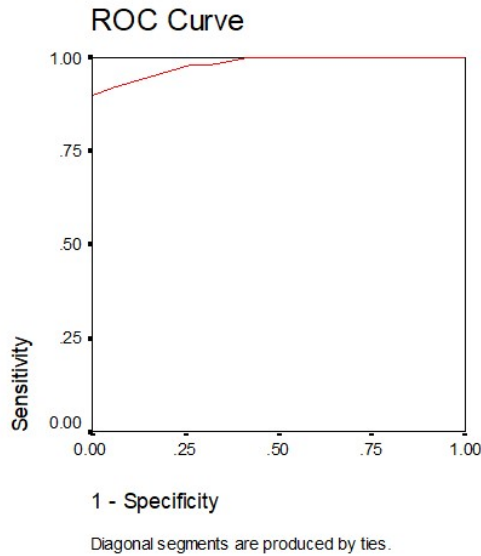


Figure 3: ROC curve for predicting raised ICP with ONSD.

DISCUSSION

ONSD measurement by POCUS has recently emerged as a

Table 8: Comparison of previous studies with our study.

Study	Sample Size	ONSD cut off	Specificity	Sensitivity
Rajajee V	65	4.8 mm	94%	96%
Blaivas	35	5 mm	95%	100%
Tayal	59	5 mm	65%	100%
Kimberly	15	5 mm	93%	88%
Moretti	94	5.2 mm	73.8%	93.1%
Major	26	5 mm	100%	86%
Our study	69	5 mm	100%	88%

As evident in the table, the standard diagnostic test characteristics of ONSD measurement by USG as a non-invasive parameter to detect raised ICP are almost similar to that of other international studies [12-17]. But we can see that the threshold value of the ONSD is different in each study. It may be due to the fact that ONSD varies according to age, region, and ethnicity. The strength of this study was its relatively high sample size compared to other similar studies (and includes all age group of adult population). So our study shows a strong relationship between signs of raised ICP on Head CT and optic nerve sheath diameter on ocular ultrasound.

Limitations of the study: This study has many limitations. First of all, this is a single centre study that has included 69 cases only. It needs to be validated in

promising modality to identify raised ICP at bedside. ONSD measurement technique by POCUS can be learned easily by the acute care physician as the learning curve is short.

This study is mainly intended to identify the standard diagnostic test characteristics of ONSD measurement by POCUS for predicting raised ICP among high-risk patient population.

The study has included 69 subjects who have possessed high clinical suspicion of having raised ICP. This sample is representative of a high risk population. The sample size of our study is comparable to that of other international studies [12-17].

In this study, due to practical considerations; we have taken CT brain as the reference standard to diagnose raised ICP.

The ROC and AUC analysis has revealed that, the curve being located in the left upper corner; ONSD by POCUS carries excellent discriminative capacity to detect raised ICP. At the ONSD cut of value of 5 mm, the test has carried a sensitivity of 88%, Specificity of 100%, PPV of 100%, and NPV of 76% and an overall accuracy of 91% to diagnose Raised ICP.

These results are in accordance with the findings of the previous studies. The comparison between our study and other international studies is shown in Table 8.

other settings and in a bigger population before extrapolating the results. The cut-off value of ONSD was more than or equal to 5 mm in this study. But it may vary depending on ethnicity, region, and age. Also, due to practical reasons, we used CT as our reference standard for the detection of raised ICP in this study even though invasive ICP monitoring is the gold standard. Additionally, a single investigator who is trained in ocular ultrasound has performed all the measurements hence inter observer variation is not assessed. Hence future studies are required to address all these issues and to gather further evidence in this regard.

CONCLUSION

Optic nerve sheath diameter measurement obtained by Point of care ultrasound carries excellent diagnostic accuracy to predict raised ICP among high-risk patients in acute care settings.

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