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Association of optic nerve sheath diameter with direct intracranial pressure measurement in neurosurgical patients

KC B,[1] Thapa A[2]

[1]Bidur KC, Associate Professor; [2]Amit Thapa, Professor, Department of Neurosurgery, Kathmandu Medical College Teaching Hospital, Sinamangal, Kathmandu, Nepal.

Abstract

Background: Invasive intracranial devices are gold standard for measurement of intracranial pressure (ICP), however optic nerve sheath diameter (ONSD) by using ultrasound is emerging lately as a non-invasive bedside tool.

Objectives: This study aimed to find association between ONSD and invasive ICP and also to find optimum cut off of ONSD to detect raised ICP.

Methods: An analytical observational study using a convenience sample was done at Department of Neurosurgery, Kathmandu Medical College from March 1, 2022 and March 31, 2022. The ONSD of both the eyes were measured using ultrasound in patients with ventriculostomy catheter. Simultaneous ICP was also recorded. The Pearson's correlation coefficient was used to assess an association between the ONSD and direct ICP measurement.

Results: Total of 40 ONSD measurements were done in 12 neurosurgical patients. Age of patients ranged from 17-75 years with mean age of 47.33 ± 17.67 years with male to female ratio of 1:2 respectively. Pearson's correlation coefficient of ONSD and invasive ICP was 0.86 (p-value <0.001) showing significant correlation. Receiver operator characteristic curve generated an area under the curve with value of 0.93 (95% of confidence interval = 0.86 to 1.00). The ONSD cut off value of >5 mm predicted ICP >20 mmHg with a sensitivity of 92.3% and specificity of 85.2%.

Conclusion: There exists a significant correlation between ONSD and invasive ICP with optimal cut off >5 mm to detect raised ICP.

Key words: External ventricular drain; Intracranial pressure; Ocular ultrasound; Optic nerve sheath diameter.

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Address for correspondence

Dr. Bidur KC
Associate Professor, Department of Neurosurgery,
Kathmandu Medical College Teaching Hospital,
Sinamangal, Kathmandu, Nepal.
E-mail: kcbidur@gmail.com

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INTRODUCTION

Gold standard for intracranial pressure (ICP) recording are invasive intracranial devices.[1,2] Lately, non-invasive methods like ocular ultrasound, transcranial doppler, magnetic resonance imaging or computed tomography have been employed to record the ICP.[3-8] By and large, sonographic optic nerve sheath diameter (ONSD) is one of the non-invasive techniques utilised most often.

Invasive intracranial devices may cause complications like dislodgement, infection, and haemorrhage. Moreover, contraindicated in bleeding diathesis.[9-11] There remains the importance of recording ICP non-invasively.[12] As optic nerve sheath (ONS) is continuous with meninges, and subarachnoid space, the pressure within ONS is raised linearly with elevated ICP.[13] This increased ONSD can be recorded and is correlated with direct ICP recordings with various techniques.[14-18]

As there is very scarce data comparing ONSD and invasive ICP in our country, this study aims to find association between ONSD and invasive ICP and also to find optimum cut off of ONSD to detect raised ICP.

METHODOLOGY

An analytical observational study was performed in the Department of Neurosurgery at Kathmandu Medical College Teaching Hospital (KMCTH), Sinamangal, Kathmandu, Nepal between March 1, 2022 and March 31, 2022. This study was approved by Institutional Review Committee (IRC) of KMCTH (Ref. 2502202201). Informed consent was taken from patient's family members. All patients of Neurosurgical intensive care unit (ICU) with ventriculostomy catheter placed as a standard of clinical care for various intracranial pathologies (traumatic and non-traumatic cases), above 16 years of age were enrolled into the study. Those with ocular trauma, ocular pathologies and who were below 16 years of age were excluded.

Sample size was calculated using G*Power ver. 3.1.9.6. Statistical test was correlational bivariate normal model and a priori type of power analysis were selected. With input parameters set as hypothetical effect size of 0.5, alpha error of 0.05, and power of 0.8, the sample size for ONSD measurement was derived. Convenience sampling was done.

The ONSD was measured using 5-13 MHz linear array transducer of GE healthcare ultrasound system (model: LOGIQ e, GE Healthcare Shanghai, Co., Ltd., Shanghai-201203, P.R. China) by single investigator who had already done more than 100 ONSD previously. The patient was placed in supine position at 30 degrees head up position. After applying coupling gel at the temporal side of the closed eyelid, linear transducer was kept horizontally along the long axis of the eye facing transducer toward the opposite eye. Transducer was adjusted till appearance of hypoechoic shadow of optic nerve behind the globe. The ONSD of both eyes were measured separately taking transverse diameter of hypoechoic shadow right angle to long axis of hypoechoic shadow of optic nerve from outer wall to outer wall at 3 mm behind the globe by using machine inbuilt electronic caliper. Two measurements were taken for each eye immediately and data obtained were averaged to yield mean ONSD. Simultaneously throughout the ONSD measurement of both eyes of single patient, direct ICP measurement obtained through the ventriculostomy catheter were recorded from the ICP monitor by separate investigator and different data obtained were averaged to yield the mean ICP for the same patient. The ONSD along with simultaneous direct ICP recording was measured once every day for three days and whenever the ICP is above 20 mmHg for more than five minutes to evaluate for dynamic changes in ONSD according to changes in ICP.

Even though, ultrasound is thought to be operator dependent technique, ONSD by transorbital sonography is of low cost, easy to teach novice operators and has low intra and inter-operator variability.[19,20]

Statistical analysis was performed using IBM SPSS Statistics for Macintosh, version 25 (IBM Corp., Armonk, N.Y., USA). The Pearson's correlation coefficient was used to assess an association between the ONSD and direct ICP measurement. A receiver operator characteristic (ROC) curve was constructed to determine the optimal ONSD cut off to detect ICP >20 mmHg.

RESULTS

Total of 40 ONSD measurements along with simultaneous 40 ICP recordings were recorded on 12 patients. Male to female ratio was 1:2 respectively. The age of patients ranged from 17 years to 75 years with mean age of 47.33 $\pm$ 17.67 years. Mean ONSD for both eyes were 5.01 $\pm$ 0.06 mm. Pearson's correlation coefficient was applied to test the association between the ONSD and invasive ICP which was found to be 0.86 (p-value <0.001) (Figure 1).
As ONSD measurements were compared with invasive ICP, a receiver operator characteristic (ROC) curve for ICP >20 mmHg was plotted to find the optimal cut off value to maximise sensitivity and specificity (Figure 2).

The ROC curve demonstrated an area under curve (AUC) of 0.93 (95% CI =0.86 to 1.00). By looking at AUC, the ONSD cut off value of >5 mm yielded the best suitable test characteristics and precisely predicted ICP >20 mmHg with a sensitivity of 92.3% and specificity of 85.2%.

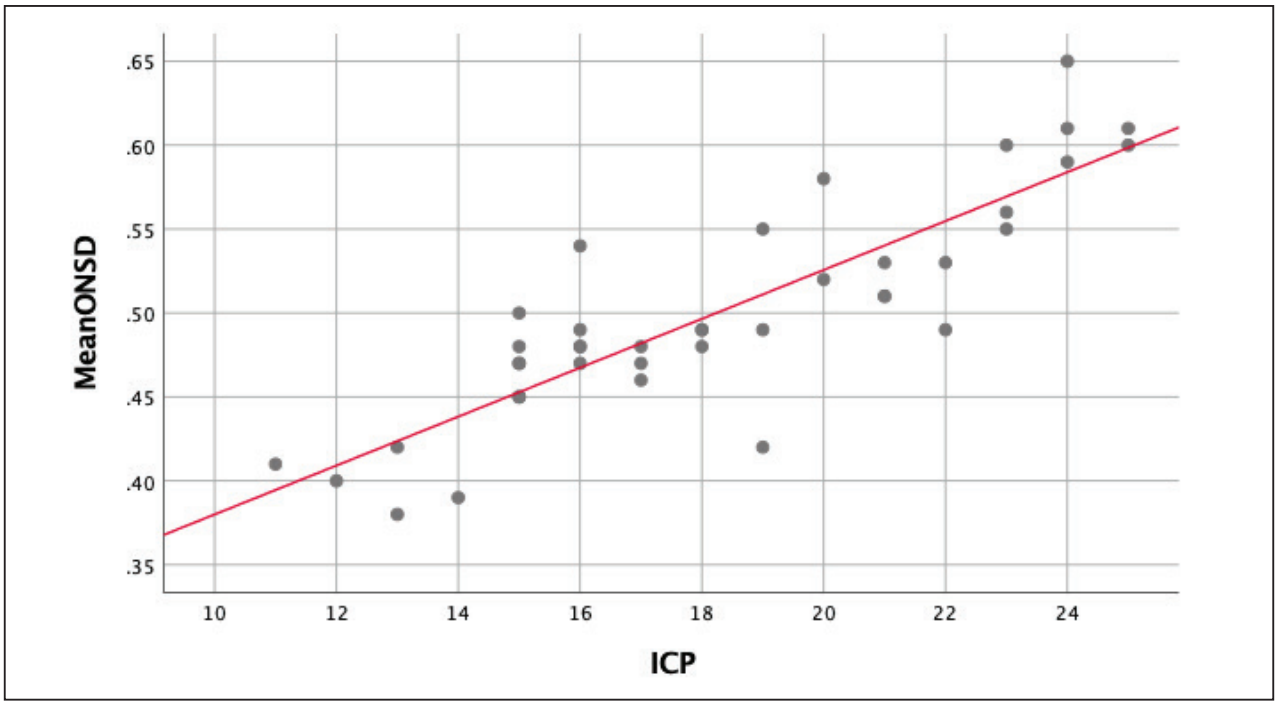

Figure 1: **Scatter plot analysis demonstrating correlation between intracranial pressure and mean optic nerve sheath diameter**

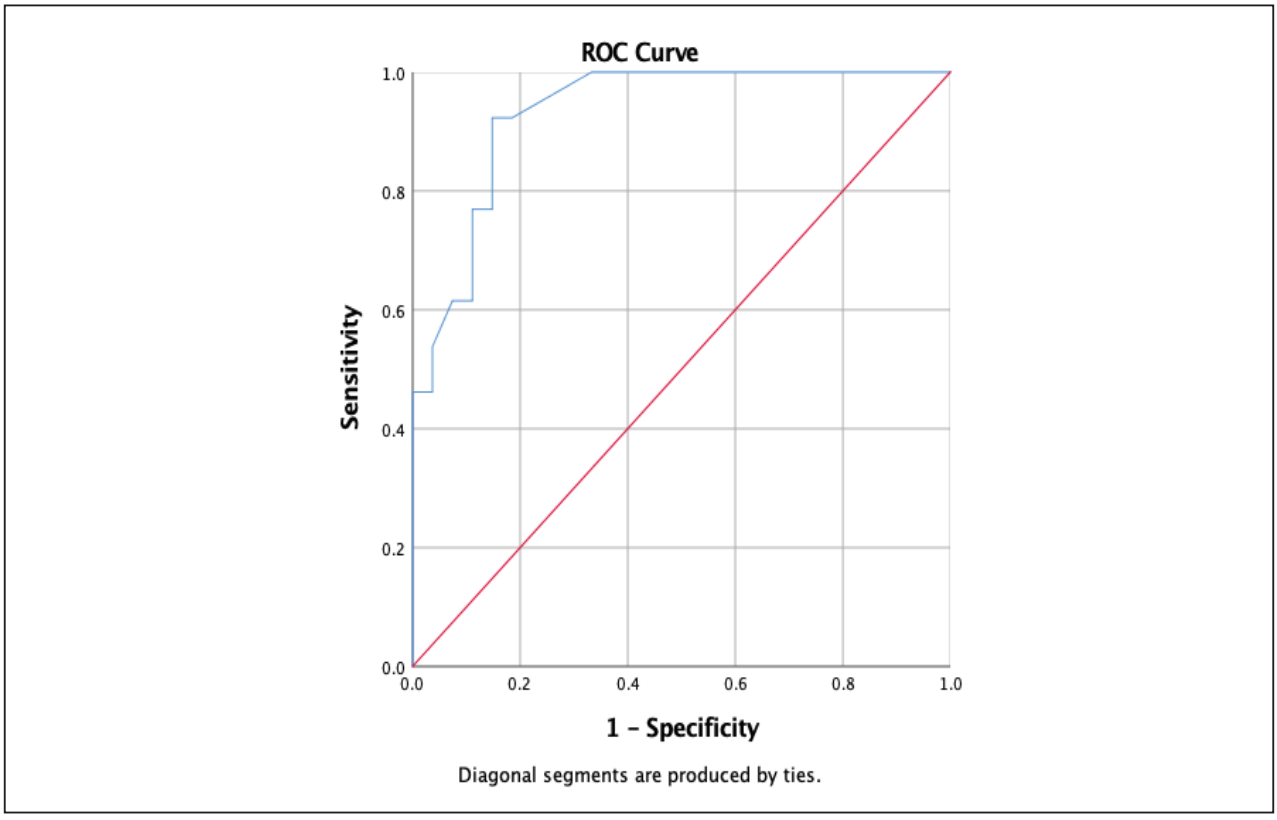

Figure 2: **Receiver operator characteristic curve plotted between optic nerve sheath diameter and intracranial pressure**

DISCUSSION

Non-invasive methods of ICP recordings can be employed as an adjunct but not to substitute the invasive ICP monitoring as a standard of clinical care. When invasive ICP monitoring is contraindicated or unavailable, ONSD by transorbital sonography could provide useful information regarding the status of ICP.

Conventionally, ventricular ICP signifies a more universal, illustrative recordings of pressure all over the intracranial space, if any pressure created by a focal lesion like haemorrhage or tumor will be imparted to the lateral ventricle until equilibrium is attained. Conversely, because ICP is often compartmentalised in cases of focal injury induced intraparenchymal pressure, intraparenchymal ICP recording is used as a local recording of a regional phenomenon.[21,22] The ONSD, which is theoretically linked to the subarachnoid space and familiar as a manifestation of global ICP is thought to have a more substantial association with ventricular pressure as opposed to focal intraparenchymal pressure. Hence, this study has also chosen ventricular pressure as criterion standard for more accurate ICP recordings, to compare with ONSD by transorbital sonography.

In this study, there was a significant association between ONSD and invasive ICP with Pearson's correlation coefficient of 0.86 (p-value <0.001). Similar to this study, Geeraerts et al. showed a significant association between largest ultrasonic ONSD among either eye and invasively monitored ICP in severe head injury.[23] Soldatos et al. detected a statistically significant association between ONSD and ICP in patients of severe head injury, which also corresponded with TCD observations and imaging findings.[24] Study from Nepal by Shrestha et al. also found significant positive correlation comparing ONSD and invasive ICP in patients with severe traumatic brain injury.[25]

Data were used to plot a ROC curve which allowed to alter the threshold value to optimise either sensitivity or specificity according to priority. This study showed ONSD cut off value of >5 mm yielded the best suitable test characteristics to detect ICP >20 mmHg with a sensitivity of 92.3% and specificity of 85.2%. Similar to this study, Maissan et al. showed optimal cut off value of 5.0 mm for ONSD with sensitivity of 94% and specificity of 98% to detect ICP >20 mmHg in mechanically ventilated patients with traumatic brain injury at the ICU.[26] Kimberly et al. also found ONSD value of >5 mm to detect the ICP >20 cm H_2O with sensitivity of 88% and specificity of 93%.[27] But in contrast, Geeraerts et al. suggested a cut off of 5.7 mm for detecting raised ICP with sensitivity and negative predictive value of 100%.[23] The cut off value of 5.7 mm was also suggested by Soldatos et al. with a sensitivity and specificity of 74% and 100% respectively.[24] Higher cut off value in these studies could be because study was done in different ethnic groups and moreover, Geeraerts et al. have used largest ONSD of either right or left eye as compared with average ONSD of the both eyes in this study. Limitation of this study is that it was a single centre study with very small sample size.

CONCLUSION

There exists a significant correlation between ONSD by using transorbital sonography and directly measured ICP via ventriculostomy catheter with optimal cut off ONSD value of >5 mm to detect raised ICP. The ONSD can be used as a portable, non-invasive tool to detect increased ICP as an adjunct to invasive ICP measurement.

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