Utility of Bedside Ultrasound Measurement of Optic Nerve Sheath Diameter as a Screening Tool for raised Intracranial Pressure in Neurocritical Care Prospective Observational Study

Sushma Gurav1, Kapil Zirpe2, Abhaya Bhoyar3, Prajakta Pote4, Upendra Kapse5, Anand Tiwari7, Prasad Suryawanshi8, Ria Malhotra9, Afroz Khan10, Subhal Dixit11

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ABSTRACT

Intracranial pressure (ICP) needs to be monitored in neurocritical patients. There is a need for portable bedside optic nerve ultrasound (ONUS) for early diagnosis to initiate the measures to reduce ICP.

Objective: To find the utility of bedside ONUS to diagnose raised ICP in neurocritical care.

Materials and methods: After approval from the ethical committee, a prospective observational study was conducted. Optic nerve sheath diameter (ONSD) was measured in two groups: control group patients with neurological symptoms but computed tomography (CT)/magnetic resonance imaging (MRI) not suggestive of raised ICP, and second was study group patients with neurological symptoms and CT/MRI suggestive of raised ICP.

Result: In patients with normal ICP, the mean ONSD in females was 4.47 mm, and in males was 4.66 mm. In patients with raised ICP, the mean ONSD in females was 6.45 ± 0.78 mm, and in males was 6.33 ± 0.70 mm. Regarding the correlation between Glasgow coma scale (GCS) and mean ONSD parameters, the coefficient of correlation (R) is 0.14; thus, there is a weak negative correlation. In our study, no difference was observed in raised mean ONSD in patients with different diagnoses. At a cut-off value of >4.8 mm, the sensitivity and specificity are 100% to diagnose raised ICP.

Conclusion: Optic nerve sheath diameter (ONSD) is a reliable, rapid bedside screening tool in the Emergency Department/Critical Care/Operation Theatre to diagnose raised ICP. In order to keep a record of trends in ICP, we need to measure ONSD frequently. There was no correlation between GCS and ONSD measurement.

INTRODUCTION

Intracranial pressure (ICP) measurement is a well-established monitoring technique. It is a useful modality in prognostication after acute brain injury. Raised ICP is defined as ICP of >20 mm Hg.1 It is an alarming condition in neurocritical care; thus, early diagnosis and prompt measures to reduce the ICP should be initiated. If left untreated intracranial hypertension can affect neurological outcome.1,2

Neuroimaging modalities such as CT scan findings are not accurate in determining the actual ICP.3 Intracranial hypertension can be monitored by two techniques, invasive and noninvasive. Invasive ICP monitoring is the gold standard, usually done by intraparenchymal probes and intraventricular catheters; a manometer connected to a lumbar puncture needle placed in the subarachnoid space.4 Invasive ICP monitoring is not always feasible sometimes due to the nonavailability of specialized equipment and skilled personnel and sometimes due to fear of associated complication like hemorrhage, infection malfunction and finally due to cost of the set-up. In certain situations, such as coagulopathy or thrombocytopenia, invasive ICP monitoring is not possible.4

Bedside noninvasive techniques such as ultrasonography (USG) guided ONSD measurement and transcranial Doppler velocities can be used for rapid assessment of the risk of raised ICP when invasive devices are not available or are contraindicated.5 Neuroimaging may not be possible in hemodynamically unstable patients. ICP is highly labile, hence a need for the device to measure ICP, which is rapid, portable, radiation-free, low-cost, and can be used to get real-time images.5–7

MATERIALS AND METHODS

The aim of the study was to assess the efficacy of bedside ultrasonographic measurement of ONSD for diagnosis of raised ICP in intensive care unit (ICU) patients and to find out the cut-off value of ONSD for raised ICP.

After approval from the Institutional Ethics Committee, a prospective, observational study was conducted from 1st December 2019 to 30th September 2021 in Neurotrauma Unit, Ruby Hall Clinic, Pune, Maharashtra, India. ONSD was measured in two groups (Fig. 1).

• Control group included patients with neurological symptoms such as headache, vomiting, and altered sensorium but CT/MRI reported by the radiologist had no findings suggestive of raised ICP.

• Study group included patients with neurological symptoms like headache, vomiting, altered sensorium, onset weakness, GCS dropping by 2, and CT/MRI reported by radiologist suggestive of elevated ICP such as midline shift, cerebral
edema, effacement of sulci, the collapse of ventricles, and compression of cisterns. These patients underwent ONSD measurement by an observer. A waiver of individual consent was obtained from the institute. Patients with glaucoma, optic nerve tumor, neuritis, orbital fracture, hyperthyroidism, inflammatory eye swelling, or external ophthalmic paresis were excluded.

Ocular ultrasound was performed using an ultrasound machine with a 13-6 MHz linear probe with orbital imaging settings. The measurements were performed by an ICU doctor trained in ONSD measurements. The patients were positioned supine with a 30° head up. Tegaderm was applied to the closed eyelid, and copious jelly was put on the probe, which was then placed on the superior and lateral aspects of the orbit. The two-dimensional mode was used, and ONSD was measured 3 mm behind the globe using an electronic caliper along an axis perpendicular to the optic nerve. An average of three readings were taken for each eye (Fig. 2 and Flowchart 1). ONSD by ultrasound was correlated with the CT/MRI findings of raised ICP reported by the radiologist.

**Statistical Analysis**

Qualitative data parameters were analyzed by using frequency and percentage. Quantitative data variables are expressed by using mean, standard deviation (SD), etc. For statistical analysis t-test, Chi-squared test, and analysis of variance (ANOVA) test using Statistical Package for the Social Sciences and Microsoft Excel were used. A p-value of <0.05 was termed as significant.

**Results**

A total of 157 patients were screened, four patients were excluded, 21 patients were included in the control group, and 132 in the study group (Flowchart 2).

In control patients with normal ICP, the mean ONSD in females was 4.47 ± 0.13 mm, and in males was 4.66 ± 0.13 mm.

In the study group, 104 were males, and 28 were females. The mean age of the patients was 53.2 ± 16.4 years. Distribution of patients according to GCS: 88 patients had GCS < 8, 24 patients had GCS between 9 and 12, and the remaining 20 were between 13 and 15. In the study group, 59 (44.69%) patients had intracranial bleeding, 44 (33.33%) were traumatic brain injury, 18 (13.63%) were cerebral infarct, two (1.51%) were post craniotomy, four (3.03%) had a space-occupying lesion, and five (3.78%) cases were included of others (two of encephalitis, two of venous sinus thrombosis, and one of subarachnoid hemorrhage with accelerated hypertension). Table 1 shows the demographic characteristics of the study group.

The mean, minimum, and maximum of ONSD in relation to gender in patients with raised ICP were:

- In females, the mean ONSD was 6.45 ± 0.78, with a range from 5.3 to 7.7 mm.
- In males, the mean ONSD was 6.33 ± 0.70 with a range from 5.1 to 8.4 mm.

In patients with GCS < 8, the mean ONSD was 6.44 ± 0.69 mm; in patients with GCS 9–12 was 6.45 ± 0.78 mm.

**Flowchart 1:** Flowchart of study performa in our ICU

**Flowchart 2:** Case distribution from screening to the exclusion of cases
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6.16 ± 0.80 mm; and in patients with GCS, 13–15 was 6.23 ± 0.73 mm. Regarding the correlation between GCS and Mean ONSD parameters, the coefficient of correlation (R) is 0.14; thus, there is a weak negative correlation between GCS and ONSD.

The comparison of mean ONSD in relation to the diagnosis of the patients was statistically not significant (p = 0.842) after applying a one-way ANOVA test (Table 2).

In patients with normal ICP, the mean ONSD was 4.57 ± 0.14 mm, and in patients with raised ICP, the mean ONSD was 6.36 ± 0.72 mm. The difference was found to be statistically significant (p = 0.000). Table 3 shows the comparison of mean ONSD in relation to CT/MRI findings of raised ICP.

The receiver’s operating characteristics of ONSD in relation to CT/MRI findings suggestive of raised ICP are depicted in Figure 3. Table 4 shows the receiver’s operating characteristics of ONSD in relation to CT/MRI findings suggestive of raised ICP. The positive group (area under the ROC curve (AUC)) is >4.8 mm, which means that if the ONSD is >4.8 mm, then the patient will have raised ICP, and if the ONSD is ≤4.8 mm, then the patient will have normal ICP. At a cut-off of >4.8 mm, the sensitivity and specificity are 100%.

**DISCUSSION**

Point of care optic nerve sheath ultrasound is a bedside tool used to evaluate for increased ICP. ONSD reflects changes in ICP, especially in the early stages, and these changes are real-time. The optic nerve sheath is anatomically continued with the dura mater of the brain. It has trabeculated arachnoid space, and it is through this that cerebrospinal fluid slowly percolates, and fluctuations in size occur based on changes in ICP. Hansen et al. described the relationship between intraorbital subarachnoid space around the optic nerve and intracranial subarachnoid space in 1996. The bulbous portion of the optic nerve, roughly around 3 mm posterior to the globe, is most distensible and sensitive to changes in ICP. In 1989, Galetta et al. described the relationship between ONSD and raised ICP. The mean ONSD was 4.4–4.8 mm. The mean ONSD in males, 4.4–4.8 mm. The mean ONSD in males was significantly higher than in females (p = 0.005). In 2015, Cardim et al. conducted a prospective study on healthy volunteers. He found that ONSD in males and females was significantly higher than in females (p = 0.005). In 2015, Cardim et al. conducted a prospective study on healthy volunteers. He found significant differences between ONSD in males and females 4.2 (interquartile interval 3.9–4.6) vs 4.1 (3.6–4.2) mm.

Maude et al. conducted a prospective observational study where 136 normal healthy volunteers were enrolled. In this study, the median ONSD found was 4.41 mm,

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**Table 1:** Demographic characteristics of patients in control and study groups

<table>
<thead>
<tr>
<th>Gender</th>
<th>Study group (N = 132)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>104</td>
</tr>
<tr>
<td>Female</td>
<td>28</td>
</tr>
</tbody>
</table>

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**Table 2:** Mean ONSD in relation to diagnosis in the study groups

<table>
<thead>
<tr>
<th>Diagnosis of patients</th>
<th>Number</th>
<th>Mean ONSD (mm)</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infarct</td>
<td>18 (14%)</td>
<td>6.37 ± 0.70</td>
<td>0.276</td>
<td>0.842 NS</td>
</tr>
<tr>
<td>Traumatic brain injury</td>
<td>44 (26%)</td>
<td>6.27 ± 0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intracranial bleed</td>
<td>59 (45%)</td>
<td>6.39 ± 0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>7 (04%)</td>
<td>6.18 ± 0.58</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One-way ANOVA test applied; p-value = 0.842, nonsignificant (NS)

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**Table 3:** Comparison of mean ONSD in the control group and study group with CT/MRI findings

<table>
<thead>
<tr>
<th>CT/MRI findings suggestive of raised ICP</th>
<th>No</th>
<th>ONSD (mean ± SD)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>132</td>
<td>6.36 ± 0.72</td>
<td>−25.99, df = 147</td>
<td>0.000*</td>
</tr>
<tr>
<td>No</td>
<td>21</td>
<td>4.56 ± 0.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unpaired t-test applied; p-value = 0.000, significant
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with 95% of ONSD readings in the range of 4.25–4.75 mm.13

In our study group, we observed mean ONSD in females was 6.45 ± 0.78 mm and in males was 6.33 ± 0.70 mm. In our study, the mean difference in ONSD of both eyes (right–left) eye was not significant in both males and females (p = 0.4418). Yanamandra et al. conducted a prospective observational study. This study found that the mean difference in the ONSD of both eyes (right–left) was not statistically significant (p = 0.533).14

Kaur et al. found that ONSD was increased in patients with low GCS 3–8, and they reported that there is a noticeable relationship between low GCS and ONSD.15 In our study, there is a weak negative correlation between GCS and mean ONSD parameters. That means when GCS falls, ONSD increases, but in a weak or unreliable manner.

The mean ONSD was 4.57 ± 0.16 mm in patients with normal ICP, and the mean ONSD was 6.31 ± 0.71 mm in patients with raised ICP. In our study, we observed that mean ONSD was found to be significantly higher in patients with CT/MRI findings suggestive of raised ICP compared to patients with radiological findings not suggestive of raised ICP. Our study findings are consistent with the previous study done by Bala et al. in 2017.16

The cut-off obtained using ROC was >4.8 mm. At a cut-off of >4.8 mm, the sensitivity and specificity found were 100%. The positive predictive value of the ONSD measurement to detect raised ICP was 100%, and the negative predictive value was 100% with an accuracy of 100%. Our findings were similar to the study conducted by Blavias et al. on 35 patients with raised ICP from either head trauma or intracranial bleeding. He reported a cut-off value of 5 mm for normal ONSD with a sensitivity of 100% and specificity of 95%.17 In another study conducted by Rajajee et al. for the detection of raised ICP, the cut-off ONSD was >4.8 mm with a sensitivity of 96% and specificity of 94%.18

The current noninvasive technique will not replace the traditional invasive techniques, as they lack accuracy compared to their invasive counterparts. This implies that this technique can reliably be used as a screening tool for detecting raised ICP and thereby initiate measures to decrease raised ICP.5,6,19 ONSUS is a rapid bedside procedure that can be completed within 5 minutes and was completed within 4 minutes in our study.10 This technique showed a good correlation with imaging findings with specificity and sensitivity at a cut-off value >4.8.

Limitations
This study was a single-center study. Raised ICP wasn’t compared with the invasive method; rather, CT images were being used as surrogates. Our observer was not blinded for CT/MRI reports, so there is a possibility of observer bias to some extent. Although our observer was trained in USG, interobserver variation was a concern, but an attempt to overcome this limitation was done by taking three readings in each eye. We haven’t noted ONSD correlation with anti-edema treatment since the noninterventional study.

Conclusion
Optic nerve ultrasound (ONUS) is a reliable bedside screening tool for the measurement of ONSD for the diagnosis of raised ICP in neurointensive care patients. A weak negative correlation was observed between GCS and mean ONSD parameters.

Acknowledgment
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References