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OPTIC NERVE SHEATH DIAMETER – A MARKER FOR ASSESSING AND PREDICTING INTRACRANIAL PRESSURE IN HEAD INJURY PATIENTS

Neurosurgery

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ABSTRACT

Background: Elevated intracranial pressure (ICP) is a life-threatening complication of head trauma requiring prompt diagnosis. This study evaluates the utility of optic nerve sheath diameter (ONSD) measurement via ultrasonography (ONUS) as a non-invasive bedside method to predict elevated ICP in comparison to cranial CT. **Methods:** In this prospective observational study at a tertiary hospital, 120 adult head injury patients underwent ONUS and cranial CT. ONSD measurements ≥5 mm were considered indicative of raised ICP. Clinical signs, CT findings, and neurosurgical interventions were analysed. Sensitivity, specificity, and predictive values of ONUS for raised ICP and surgical necessity were determined. **Results:** CT identified elevated ICP in 87 patients. Mean ONSD was significantly higher in patients with CT-confirmed raised ICP (5.6 ± 0.54 mm) compared to those without (3.3 ± 0.74 mm, $p < 0.0001$). ONUS demonstrated high sensitivity (97.7%) and specificity (96.8%) for raised ICP, with a positive predictive value (PPV) of 98.8% and a negative predictive value (NPV) of 93.9%. Among 75 patients requiring surgical intervention for intracranial hematomas, ONUS accurately predicted 85.2% of cases, with a PPV of 98.6%. **Conclusion:** ONUS provides a reliable, non-invasive alternative to CT for predicting elevated ICP and guiding surgical decisions in trauma patients. Its portability, rapidity, and cost-effectiveness make it particularly valuable in resource-limited and emergency settings. ONUS holds potential as a critical tool for triaging and monitoring head injury patients.

KEYWORDS

INTRODUCTION

Head injury is one of the most common life-threatening conditions among trauma patients. Elevated intracranial pressure (ICP) is a serious and potentially fatal complication of acute head trauma. Prompt diagnosis and management of elevated ICP can help prevent severe outcomes like herniation and reduce mortality rates.[1] This study investigates the effectiveness of measuring the ONSD through bedside ultrasonography as a non-invasive method to predict elevated ICP in head injury patients. Given the limitations of cranial CT—such as the need for patient transport, feasibility during mass casualty events, and radiation exposure—an alternative investigations like ONSD as a measurement of ICP could offer significant advantages. The research aims to establish the correlation between increased ONSD and elevated ICP, particularly in determining the necessity for surgical intervention and periodic follow up. The established thresholds for normal ONSD—5 mm for adults, 4.5 mm for children aged 1–15 years, and 4.0 mm for infants—will guide the analysis[2,3,4]. This study was approved by the institutional ethical committee.

MATERIALS AND METHODS

The study was designed as a prospective observational study conducted in a tertiary teaching hospital. All adult patients admitted with head injuries are included, while patients with ophthalmic injuries, for whom CT brain could not be performed and critically ill cases are excluded. This approach allows for a comprehensive assessment of the relationship between ONSD and elevated ICP.

All participants received thorough evaluation and resuscitation upon admission, during which clinical features indicative of elevated ICP were systematically documented. Key signs included altered consciousness, with assessments of awareness and responsiveness. Instances of vomiting were recorded, given that this can be a common symptom of increased ICP. Heart rate monitoring was conducted to identify bradycardia, which may occur in such cases, while blood pressure measurements were taken to detect hypertension. Pupillary changes, such as abnormalities in size or reaction to light were observed. By capturing these clinical features, the study aimed to establish a correlation between them and ONSD measurements, enhancing the understanding of how these signs relate to elevated ICP in patients with head injuries.

All participants underwent optic nerve ultrasonography (ONUS) and brain CT. For ONUS, both eyes were scanned in vertical and horizontal planes using a high-resolution 7.5-MHz linear array transducer probe applied gently over the closed eyelids with patient in supine position. The ONSD were measured 3 mm behind the globe in each eye, in both sagittal and transverse planes. The mean ONSD measurements from each eye were averaged to establish a binocular ONSD measurement, with a value of 5 mm or more considered abnormal.

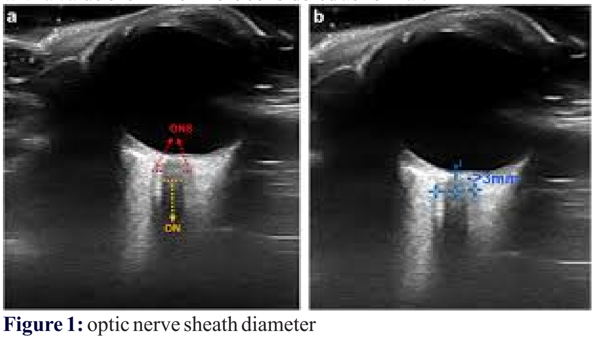

Figure 1: optic nerve sheath diameter

Cranial CT was performed on all participants and the results were reported by a radiologist who was blinded to the ultrasonographic findings. The CT examination was deemed positive for elevated ICP if it revealed significant edema, a midline shift of 3 mm or more, mass effect, effacement of sulci, collapse of ventricles, or compression of cisterns, as per established literature criteria. Decisions regarding surgical intervention were made based on their clinical examination and CT findings.

Data collection included variables such as age, gender, mode of injury, vital parameters, clinical features of elevated ICP, findings from optic nerve ultrasonography (ONUS), CT results, and the neurosurgeon's decision regarding surgical intervention. Statistical analysis was conducted using chi-square testing and Student's t-test to evaluate the relationships between these variables. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Between April 2023 and September 2024, 120 adults participated in the study, consisting of 88 men and 32 women with a median age of 31 years.

The study group had a median Glasgow Coma Scale (GCS) score of 12 (range 6–15). Of the participants, 54 sustained mild head injuries (GCS 13–15), 38 had moderate head injuries (GCS 9–12), and 27 suffered severe head injuries (GCS ≤8).

Clinical signs of raised ICP were observed in 114 participants, with CT scans confirming elevated ICP in 82 of these cases. Among the six individuals who showed no clinical signs of raised ICP, CT revealed intracranial hypertension in five, although this finding was not statistically significant ($p = 0.8131$).

CT imaging identified at least one feature indicative of elevated ICP in 87 participants, while no such features were detected in 33 cases. The average binocular ONSD in the 87 cases with CT-confirmed intracranial hypertension was 5.6 ± 0.54 mm, compared to 3.3 ± 0.74 mm in the remaining 33 cases. This difference of 2.3 mm (95% confidence interval: 1.96–2.64 mm) was statistically significant ($p < 0.0001$), as determined by Student's t-test.

Table 1 Optic nerve ultrasonography (ONUS) was compared with cranial CT to evaluate raised ICP

ONUS	CT POSITIVE	CT NEGATIVE
POSITIVE	86	2
NEGATIVE	1	31

Sensitivity – 97.7%, Specificity – 96.8%, PPV – 98.8%, NPV- 93.9%

A total of 88 participants exhibited evidence of intracranial hypertension on ocular ultrasonography, defined by a mean ONSD of 5 mm or greater. When compared to CT findings as the reference standard, there were two false-positive cases and one false-negative case.

ONUS produced two false-positive results, where the mean ONSD exceeded 5 mm. In both cases, one eye had an ONSD greater than 5 mm, while the other measured below 5 mm. CT scans revealed unilateral optic nerve compression caused by a frontal extradural hematoma, which did not result in hydrocephalus, midline shift, or other signs of raised ICP. Additionally, ONUS was falsely negative in one elderly participants with age-related cerebral atrophy. Despite CT findings showing a subdural hematoma, subarachnoid hemorrhage, and midline shift, the mean ONSD in this case remained below 5 mm.

All participants were assessed by neurosurgeons to determine the need for surgical intervention based on their clinical condition and CT findings. Among the 88 participants diagnosed with raised ICP on ONUS, 75 required surgeries for intracranial hematomas (including two false-positive cases with unilateral frontal extradural hemorrhage). In contrast, only 1 out of 32 participants for whom ONUS did not indicate raised ICP required surgical intervention. This difference was statistically significant (χ^2 test, *p* < 0.0001).

Table 2 Optic nerve ultrasonography (ONUS) in operable lesions

ONUS	SURGERY REQUIRED	SURGERY NOT REQUIRED
POSITIVE	75	13
NEGATIVE	1	31

Sensitivity – 85.2%, Specificity – 96.8%, PPV – 98.6%, NPV- 70.45%

The sensitivity of ONUS in predicting the need for surgical intervention was 85.2%, with a negative predictive value of 70.45%. The specificity was 96.8%, and the positive predictive value was 98.6%. No complications or discomfort were reported during ocular ultrasonographic examinations.

DISCUSSION

The evaluation of individuals with head injuries, especially in the context of multiple trauma, presents significant challenges. Elevated ICP and mass effect are critical factors that influence treatment decisions. While CT scans provide essential information for determining whether surgical evacuation of an intracranial hematoma or the initiation of anti-edema measures is necessary, they require the transfer of unstable patients to the CT suite, which poses risks[5]. In situations involving numerous casualties, surgeons must prioritize patients needing immediate treatment, complicating decision-making further.

In remote locations lacking accessible CT facilities, clinicians face difficult decisions regarding the urgency of transferring patients. Until now, there has been no rapid, non-invasive bedside method for detecting elevated ICP beyond physical examination, which is often inadequate[2,5]. The difficulty of accurately detecting raised ICP increases significantly in cases where patients are unconscious, sedated, paralyzed, or intubated. This study reinforces the unreliability of clinical signs of intracranial hypertension, highlighting the need for more effective diagnostic tools in acute trauma settings.

It is important to note that with elevated ICP, the optic nerve diameter increases earlier, followed by papilledema; thus, ocular USG can detect increased ICP earlier than ophthalmoscopy. [3,6] Performing a lumbar puncture during trauma resuscitation is typically not feasible and can be dangerous.[7]

Ultrasonography has become a vital tool in emergency services, with many centres now equipped with ultrasound facilities. Over the past two decades, extended focused abdominal sonography for trauma (eFAST) has established itself as a fundamental screening method for both abdominal and chest trauma. Optic nerve ultrasonography (ONUS) expands the application of ultrasonography to head trauma, utilizing a 7.5-MHz linear probe.

Research by Hayreh in 1968 demonstrated a consistent communication between the subarachnoid space of the optic nerve sheath and the intracranial cavity, establishing a link between cerebrospinal fluid pressures and ONSD. [8] Although ONSD does not vary with patient positioning,[9] studies have shown that widened optic nerve sheaths are indicative of intracranial hypertension, further supporting the use of ONUS in emergency settings.

Hansen et al. established a direct relationship between increasing ICP and the dilation of the optic nerve sheath by monitoring ICP during fluid infusion or removal via lumbar puncture.[4] Previous studies have indicated that normal ONSD measured by ultrasound ranges from 4.7 to 5.0 mm. The sonographic measurement of ONSD is a technique that is easily learned, reproducible, and exhibits low intra- (±0.1 mm) and inter-observer (±0.2 mm) variation.[10]

In this study, cranial CT was utilized as the reference standard for comparison, as initial head CT characteristics show a linear relationship with baseline ICP.[11] While direct intracranial pressure monitoring might offer greater sensitivity in detecting raised ICP, it is much more invasive and is not recommended for mild or moderate head injuries, where CT is typically performed after initial resuscitation. There is substantial literature supporting the notion that specific CT findings correlate well with elevated ICP in acute trauma scenarios.[5]

Data from the National Institutes of Health Traumatic Coma Databank, published in 1990, indicated that in a cohort of 753 severe head injury cases, CT findings such as mass effect with a midline shift of 3 mm or more and abnormal mesencephalic cisterns were highly correlated with elevated ICP based on invasive pressure monitoring.[12]

This study demonstrated a strong relationship between signs of raised ICP observed on head CT and dilated optic nerve sheaths as seen in ocular ultrasonography. It suggests that a bedside sonographic assessment could effectively rule out elevated ICP. Similar findings have been reported in other studies. Our findings indicate that optic nerve ultrasonography (ONUS) has high sensitivity (85.2%) and a negative predictive value (70.45%) for predicting the need for surgical intervention, making it an effective bedside screening tool for identifying intracranial hematomas requiring evacuation.

Other non-invasive methods, such as Near infrared spectroscopy, fontanometry, Doppler sonography of the brain, and evoked potential studies, require specialized equipment and trained personnel.[14] They also tend to indicate raised ICP only in later stages, potentially increasing the risk of severe complications and poor outcomes.

Overall, bedside assessment of ONSD using ONUS shows promise as a sensitive screening test for elevated ICP in adults with head injuries. Additionally, ONUS can aid in detecting traumatic optic nerve injury, retinal detachment, and vitreous injury.

The optic nerve-sheath diameter measurement has emerged as a valuable bedside procedure for assessing ICP changes following decompressive craniectomy, ONSD monitoring has been shown to reliably reflect reductions in ICP, providing clinicians with a non-invasive, real-time indication of the procedure's effectiveness. Its ease of use and repeatability make it an ideal tool for continuous monitoring, particularly in resource-limited settings, where advanced neuroimaging modalities may not be available. A limitation of this study is that CT does not directly measure ICP.

CONCLUSION

This study highlights a strong correlation between ONSD measured via ocular ultrasound and CT evidence of elevated intracranial pressure (ICP), requiring surgical intervention. ONUS can serve as a valuable alternative to CT for certain unstable patients, aiding in the triage of mass casualties and informing decisions about transferring patients from remote areas to hospitals equipped with CT facilities. Additionally, it can be used for ICP monitoring in post operative patients. Overall, ONUS has significant potential as an effective tool in the assessment and follow up of trauma victims with head injuries who underwent surgical intervention.

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