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Ultrasonographic measurement of optic nerve sheath diameter as a bedside tool in critical care unit to identify raised intra cranial pressures

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Abstract

Aim: Raised intracranial pressure is a common problem in critical care unit and is associated with worse outcome. Several methods have been used to investigate for elevated intracranial pressure (ICP). Here usefulness of optic ultrasound as a bedside tool for assessment of raised ICP in critical care setting was studied.

Material and methods: A prospective study was carried out in Intensive Care Unit (ICU) of tertiary care hospital for a period of 12 months. Patients admitted in ICU during the period of study and who were at the risk of development of raised ICP and needed CT scan for diagnosis were part of the study. 115 patients were included. The optic nerve sheath was identified on ultrasound, and optic nerve sheath diameter (ONSD) was measured 3 mm posterior to the retina. A mean ONSD value of >0.5 cm was taken as positive. CT scan was done immediately afterwards to find any signs of raised ICP.

Results: The mean age of participants was 42.3±10 years with majority of them male (61.7%). The number of cases diagnosed as raised ICP with optic ultrasound was 36 (31.3%) and with CT scan 33 (28.7%) cases. The calculated sensitivity and specificity of optic ultrasound in detection of raised ICP is 100.0% (95% CI: 89.4-100.0) and 96.5% (95% CI: 90.0-99.3) respectively with accuracy of 97.5%.

Conclusion: The present study revealed that ultrasonographic measurement of ONSD as a bedside tool is accurate for screening of patients with probable elevation of ICP. It has advantage of being quick, is without any complication, and patient is not exposed to radiation, besides it does not expose patient to risk of transit during transport to imaging unit as in case of CT scan.

Key words: intracranial pressure, traumatic brain injury, critical care, optic nerve sheath, ultrasound

Introduction

Raised intracranial pressure (ICP) is a common problem in critical care units and in trauma units and is associated with worse outcome. Close ICP monitoring is vital for management of severe traumatic brain injury (TBI) patients to reduce mortality. Indications of intracranial pressure monitoring in TBI has been defined and revised in the 2016 guidelines [1]. Early recognition and management of raised intracranial pressure is essential to maintain cerebral perfusion and to minimize intracerebral damage.

Invasive intracranial monitoring is gold standard method in assessing ICP [2]. As an invasive procedure it has certain limitations, including need of a specialist, risk of infection and bleeding [3,4]. Its availability may also be an issue in resource poor settings.

Lumbar cerebrospinal fluid (CSF) opening pressure or counting CSF drops over time are often used as surrogate markers of ICP. However, it may not correctly depict ICP as pressure is not evenly distributed throughout the subarachnoid spaces [5] and it is an invasive procedure, it also maybe contraindicated.

Numerous methods have been described for non-invasive ICP monitoring, including magnetic resonance imaging (MRI), computed tomography (CT), optic nerve sheath diameter (ONSD) measurement by ultrasonography (USG) and fundoscopy [6,7].

CT scan and MRI is commonly used to diagnose increased ICP. Presence of CT and MR signs suggestive of raised ICP include effacement of basal cisterns, diffuse sulcal effacement and the presence of significant midline shift. These modalities require patient transfer to imaging units, additional manpower and equipment is needed and is time consuming. Critically ill patients requiring high inotropic support or ventilator support present with increased risk during transit and transfer to imaging unit.

Raised ICP can manifest as papilloedema, for which patients can be screened by fundoscopy, a low cost technique, but it has limitations of providing only qualitative assessment and has operator dependence [8]. Also papilloedema does not develop immediately after raised ICP, hence limiting its use in acute settings.

Ultrasonographic measurement of optic nerve sheath diameter (ONSD) is a quick, easy to learn method and can be used at patients bedside for measurement of raised intracranial pressure. It does not have any complication, also patient is not exposed to radiation.

The optic nerve is a part of the central nervous system (CNS), sheath surrounding optic nerve is continuation of dura. It is distensible in its retrobulbar segment. When ICP is elevated transmitted pressure results in increased diameter of optic nerve sheath. It eventually results in swelling of the optic disc and papilloedema [9]. Studies have shown that increased ICP results in development of papilloedema which can take hours to days, but distension of the optic nerve sheath occurs within seconds [10,11]. Hence size of optic nerve sheath measured by ultrasound gives an idea about ICP even in acute settings.

Ultrasonographic measurement of the ONSD a fixed distance from the retina has been studied as a non-invasive measure of ICP [12,8].

Aim: The aim of study was to determine usefulness of optic ultrasound as a bedside tool for assessment of raised ICP in critical care setting. Ultrasound was used to measure ONSD in patients who required CT imagining.

Material and methods

Study design

A double-blinded prospective observational study was carried out in Intensive Care Unit (ICU) of Government Medical College Srinagar, a tertiary care hospital, from November 2020 to October 2021. Institutional ethics committee approval was taken before conduct of this study. Informed consent was taken from the patient or his/her attendants/relatives.

Study setting and population

Patients admitted in ICU during the period of study and who were at the risk of development of raised ICP were part of the study. Patients with wide range of pathologies were enrolled, and included those with traumatic brain injury and those with non traumatic causes like tumor, infection, vascular malformation, or obstruction to CSF outflow. This is a single investigator study, patients were enrolled depending on availability of investigator. Patients less than 18 years of age or those having any ocular injury or pathology were excluded from the study.

Patients with clinical suspicion of raised ICP were to undergo CT scan imaging for confirmation as part of their clinical care and diagnosis. Occular ultrasound was done before CT scan imaging for patients included in the study.

Procedure and Measurements

Measurement of ONSD was performed by single investigator experienced in ocular ultrasound; he was blinded to the CT imagining study results.

Scans were conducted in supine position using point of care Ultrasound machine SonositeTM M-Turbo (SonoSite Inc., Bothell, WA, USA) using linear array probe of frequency 13-6 MHz. B-mode was used for sonography as it provides a high-resolution two dimensional evaluation of orbital and intraoccular tissue including optic nerve. A sterile transparent film was placed on closed eye and sterile ultrasound gel was used as a coupling medium. The probe was placed against the eyelids of closed eye (Figure 1) until the optic nerve was visualized as a hypoechoic linear structure with clearly defined margins posterior to the globe (Figure 2).

Figure 1

Figure 2

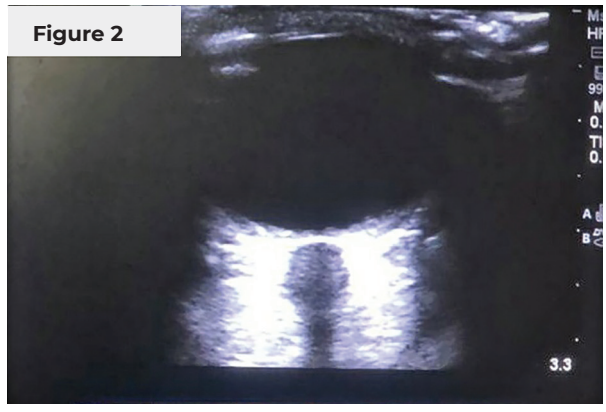
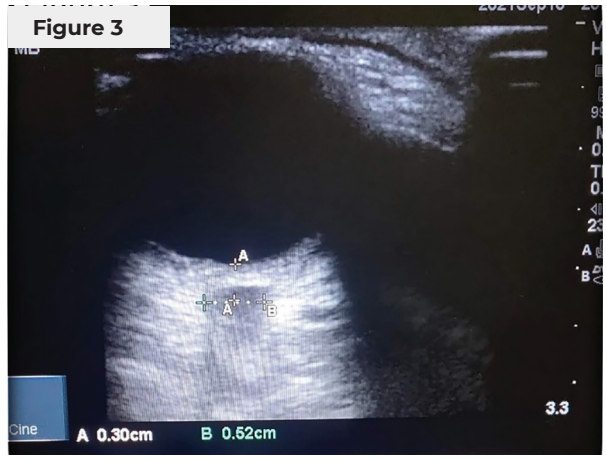


Figure 3



Precautions for use of ocular ultrasound included gentle placement of probe on the closed eye and never in direct contact of cornea or sclera. There has been no reported complication of using ocular ultrasound.

The optic nerve sheath was identified on ultrasound, and ONSD was measured using electronic calipers on a static image of the optic nerve from edge to edge of the nerve at 3 mm posterior to the retina (Figure 3). ONSD was measured in both the eyes, both transverse and sagittal plane, and mean of the measurements was recorded. A mean ONSD value of >0.55 cm was taken as positive. Time taken for the measurement was recorded.

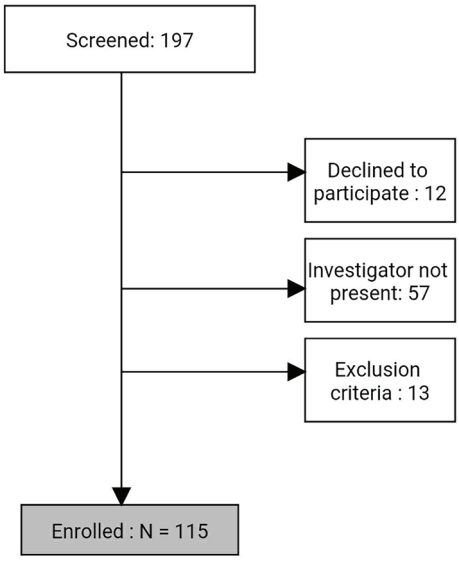
CT scans were done immediately after ONSD measurements and were reviewed by independent investigator for signs of raised ICP, the investigator was blinded to ONSD measurements.

Signs of raised ICP on CT imaging included: Effacement of sulci with evidence of significant oedema; Collapse of mesencephalic cisterns; Midline shift of 3 mm or greater; Collapse of third ventricle; Hydrocephalus or Evidence of herniation. Presence of raised ICP was based on presence of any of above findings on CT and absence determined by absence of all the findings noted.

Statistical analysis

Data were analyzed using STATA version 11.2 statistical software. Brain CT was defined as a gold standard. Using data obtained from the study, sensitivity, specificity, positive and negative predictive value, positive and negative likelihood ratio and accuracy of ultrasonographic measurement of ONSD in prediction of raised ICP was calculated.

Figure 4 - Patient enrollment flowchart



Results

A total of 115 patients were enrolled in the study (Figure 4). There were 71 (61.7%) male and 44 (38.3%) female patients with mean age of study population being 44.6 years.

Traumatic brain injury was the most common (54.8%) diagnosis followed by CNS Infection (15.7%) and Seizures (14.8%) (Table 1).

Out of total study population, 36 patients had raised ONSD measurements (>0.55 cm). Mean ONSD measurement in this group was 0.61cm. Average time taken for optic ultrasound for ONSD measurement in a patient was 3.2 minutes.

Table 1 Patient characteristics

Gender	
Male	71 (61.7%)
Female	44 (38.3%)
Diagnosis	
Traumatic Brain Injury	63 (54.8%)
CNS Infection	18 (15.7%)
Seizures	17 (14.8%)
Hydrocephalus	8 (7%)
Vascular Malformations	5 (4.3%)
Tumors	4 (3.5%)

CT scan imaging was positive for sign of raised intracranial pressure in 39 patients. It included all patients who had raised ONSD measurements (>0.55 cm).

Three patients had signs of raised intracranial pressures on CT scan but ONSD measurements on optic ultrasound were normal (<0.55 cm) (Table 2).

Table 2 Diagnostic accuracy of raised ONSD measurement in prediction of elevated ICP

STATISTIC	VALUE	95% CI
Sensitivity	100%	89.42-100.00
Specificity	96.47%	90.03-99.27
Positive predictive value	91.67%	78.35-97.10
Negative predictive value	100%	-
Positive likelihood value	28.33	9.32-86.1
Negative likelihood ratio	0.00	-
Accuracy	97.46%	92.75-99.47

On analysis of the data, ONSD has sensitivity of 100.0% (95% CI: 89.42-100.0) and specificity of 96.47% (95% CI: 90.03-99.27).

Discussion

Raised ICP is frequently encountered in critical care units in patients with different pathologies and it is life threatening. It is essential to identify patients with high ICP and intervene to maintain adequate cerebral perfusion. Hence, a rapid and reliable bedside tool for detection of raised ICP is much needed.

Use of ultrasound in critical care has increased in recent years. A portable ultrasound machine is ubiquitous in critical care units nowadays. Ultrasonographic ONSD measurement for raised ICP is based on anatomical fact that optic nerve is in communication with CNS with the intraorbital part of subarachnoid space being distensible.

In our study ultrasonographic ONSD measurement for raised ICP has sensitivity of 100% and specificity of 96.47%, with accuracy of 97.46%

Our results support use of ultrasonographic ONSD measurement for detection of raised ICP in critical care setting. It is quick, noninvasive, safe and inexpensive. Portable ultrasonography equipment is commonly available in critical care units and hence can be used as a bedside tool. It provides quantitative assessment of ICP and is repeatable. Also no complications were observed during the procedure.

These results are in conformation with other studies in which ONSD was studied in different clinical settings and showed good correlation with ICP measured with methods including invasive methods and CT imaging [13,8].

Recent studies suggest that daily monitoring of ONSD measurement by ultrasonography can be useful for determination of increased ICP, it also can be used for evaluating

the neurological prognosis of the patients [14,15,16]. With the development of technology the USG devices are getting more portable. Smaller handheld or pocket-sized USG devices are already being used. These devices can be used to screen high risk patients at their bedside.

Our study was aimed at detecting usefulness of OSND measurement for detection of raised intracranial pressures in a group of patients with different pathologies. CT scan imaging was used for comparison as it is the most common diagnostic tool being used in our set up.

CT scanning requires equipment to which access is variable in resource limited settings. It exposes patient to increased risk of transit as it needs transport of patient to specific imaging unit. There is also risk of radiation exposure.

We support use of invasive method to measure and continuously monitor absolute ICP values for high risk patients in accordance with guidelines for TBI management. However as shown in our study ultrasonographic measurement seems to be of value as it is accurate, reliable non invasive tool and can be used in situations where there is clinical suspicion for intracranial hypertension but invasive monitoring is unavailable, contraindicated or risky to perform. It does not interrupt treatment as can other modalities like CT scan, can be done on bedside of patient and is repeatable. It can also be used for screening and to select patients for invasive monitoring in resource limited settings.

Limitations

Sonographic experience is one of the limitations to use of ocular sonography. Many patients could not be included in the study as only one investigator was available. However due to single investigator, inter-observer variability was excluded. Continuous measurement is not possible with ocular ultrasound and it needs to be repeated in patients at higher risk of raised ICP.

The criterion standard used to compare ultrasound examination is not ideal because CT imaging is not a true measurement of ICP. Though CT scan has good reliability in acute settings

ONSD measurement may be raised without elevated intracranial pressure as seen in few rare conditions like optic neuronitis, optic nerve trauma or cavernous sinus mass leading to false positive finding, though we did not encounter these in our study.

Conclusion

ONSD measurement for detection of raised ICP is an effective diagnostic tool and has a strong correlation with CT scan imaging for raised ICP detection. It is quick, easy, inexpensive and without any complications.

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