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Ultrasonographic Measurement of Optic Nerve Sheath Diameter for Detection of Raised Intracranial Pressure in Critically Ill Patients; A Novel, Non-Invasive and Point of Care Test

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ABSTRACT

Objective: To determine the diagnostic accuracy of bedside Ultrasonographic measurement of Optic Nerve Sheath Diameter for detection of raised Intracranial Pressure in critically ill patients in comparison with CT scan brain.

Study Design: Prospective longitudinal study

Place and Duration of Study: Department of Anesthesia and Critical Care Medicine, Pakistan Institute of Medical Sciences, Shaheed Zulfiqar Ali Bhutto Medical University Islamabad, Pakistan from Jun to Nov 2019.

Methodology: Patients with clinical suspicion of raised ICP underwent Ultrasonographic measurement of ONSD by Principal Investigator within one hour prior to shifting of the patients to Radiology suite for CT scan brain to prevent diagnosis bias. The Ultrasonographic measured ONSD value of 5.0 mm was the cutoff limit for detecting raised ICP in our study. The CT scan brain reports were considered positive if findings suggested radiological features of raised ICP like Cerebral edema/effacement of ventricle or cisterns, midline shift or sub arachnoid haemorrhage. The diagnostic accuracy of Ultrasonographic measurement of ONSD for detection of raised ICP was then determined by comparing the results with radiological diagnosis of raised ICP by CT scan brain.

Results: We enrolled total 120 patients in this study. The patients included in our study were suffering from different diseases like Traumatic Brain Injury (TBI), Meningitis, Encephalitis, Space Occupying Lesions (SOLs), Eclampsia, Stroke and Metabolic encephalopathy with different percentages. The ultrasonographic measured ONSD value range was from minimum 4.7 to maximum 6.9 with mean value of 6.1 mm. The sensitivity was 95.5%, specificity 91.3%, positive predictive value 93.2%, negative predictive value 98.5% where ultrasonographic measured ONSD value of 5.0 mm was taken as a cutoff limit. In our study ultrasonographic measured ONSD values showed good diagnostic accuracy for raised ICP detection in comparison with CT scan brain.

Conclusion: We found that ONSD measured through bedside ultrasound is very useful for diagnosis and risk stratification of incipient intracranial hypertension in pregnant patients with pre-eclampsia and eclampsia where invasive monitoring is hazardous due to deranged coagulation profile.

Key words: Intra Cranial Pressure, Optic Nerve sheath diameter, Traumatic Brain Injury.

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INTRODUCTION

Critically ill patients in intensive care units may have raised intracranial pressure due tovarious etiologies including traumatic brain injury, stroke, meningitis, encephalitis, metabolicencephalopathy and eclampsia.[1] Raised intracranial pressure leads to significant morbidity and mortality in critically ill patients. Hence early diagnosis and prompt treatment of raised intracranial pressure plays a pivotal role in the management of such critically ill patients for achieving better outcomes.[2,3] As a matter of fact,invasive ICP monitoring is considered gold standard however it carries several limitations such as invasive nature, need of neurosurgical expertise, risks of infection, hemorrhage and blockage.[4,5] Computed Tomography (CT) scan and Magnetic Resonance Imaging (MRI) brain can also detect raised ICP with reasonable diagnostic accuracy however associated with dangers of inter departmental transport of critically ill patients.[6,7] In this regard, Ultrasonographicmeasurement of optic nerve sheath diameter (ONSD) has gained significant interest inrecent years due to its advantages as noninvasive, inexpensive nature with bed-side availability, reliability and ability to repeat many times.[8-10] The optic nerve sheath is in direct communication with the brain meninges and subarachnoid space. This relationship establishes the physiological basis for using the optic nerve sheath diameter as an important diagnostic tool for intracranial pressure measurement.[11] Ultrasonographic measurement of

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ONSD can detect changes in ICP within seconds which plays a significant role in the management of critically ill ICU patients. We have conducted this prospective observational study to determine the diagnostic accuracy of Ultrasonographic measurement of Optic Nerve Sheath Diameter for detection of raised Intracranial Pressure in critically ill patients at bedside. We have compared Ultrasonographic measurement of Optic Nerve Sheath Diameter with CT Scan Brain as a reference diagnostic tool.[6]

To determine the diagnostic accuracy of bedside Ultrasonographic measurement of Optic Nerve Sheath Diameter for detection of raised Intracranial Pressure in critically ill patients in comparison with CT scan brain.

METHODOLOGY

This was a Prospective longitudinal study, completed at the department of Anesthesia and Critical Care Medicine, Pakistan Institute of Medical Sciences, Shaheed Zulfiqar Ali Bhutto Medical University Islamabad, Pakistan. The study period was of six months from June to November 2019 after approval of synopsis from Institutional Ethics Review Board. The study sample size was calculated by WHO (World Health Organization) sample size calculator. **Inlcusion Criteria:** All patients aged 18 years and above of either gender who have been admitted to our ICUs with suspicion of Raised Intra Cranial Pressure were included in the study.

Exclusion Criteria: Patients with diagnosis of Optic Neuritis, Optic Nerve Tumor, Glaucoma, Orbital Fractures or Hyperthyroidism with optic involvement were excluded from the study.

Inclusion and Exclusion Criteria was strictly followed for selection of the patients. After informed written consent for study participation from the legal guardians, detailed clinical history and examination findings were documented in the patient's medical record files. Patients with clinical suspicion of raised ICP underwent Ultrasonographic measurement of ONSD by Principal Investigator within one hour prior to shifting of the patients to Radiology suite for CT scan brain to prevent diagnosis bias. Latest ultrasound machine of GE with 07-13 MHz linear array probe was used with orbital setting of the images. The patients were positioned supine with head end up by 30 0. Opsite® or Tegaderm® was used as a barrier over the eyelid of the patients and coupling gel on the top of it. The eyeball structures were visualized to align the optic nerve directly opposite to the probe with the ONSD width 3 mm behind the globe perpendicular to the vertical axis of the scanning plan. The ultrasound probe was moved gently from temporal to nasal side avoiding pressure on the globe to visualize the optic nerve as a linear hypoechoic structure with clearly defined margins behind the globe. The Ultrasonographic measured ONSD value of 5.0 mm was the cutoff limit for detecting raised ICP in our study. The patients were thoroughly observed for any procedure associated complications. Patients were then shifted to Radiology suite for CT scan brain taking care of all precautionary measures for inter departmental transport of critically ill patients. The CT scans of the patients were reported by Consultant Radiologist having more than 05 years experience. The CT scan brain reports were considered positive if findings suggested radiological features of raised ICP like Cerebral edema/effacement of ventricle or cisterns, midline shift or sub arachnoid haemorrhage. The diagnostic accuracy of Ultrasonographic measurement of ONSD for detection of raised ICP was then determined by comparing the results with radiological diagnosis of raised ICP by CT scan brain.

A total of 120 patients fulfilling inclusion criteria were taken in this study from the Department of Anesthesia &Critical Care Medicine at Pakistan Institute of Medical Sciences, Shaheed Zulfiqar Ali Bhutto Medical University Islamabad after taking informed consent form patients or their legal guardians. All ONSD measurements at bedside were performed by well trained Principal Investigator himself and collected data entered in the specifically designed performa for the study.

All the collected data was analyzed using SPSS version 20. For quantitative variables like age, Mean±SD calculated. Qualitative variables like gender and diagnosis of patients were presented as percentage. The sensitivity, specificity, positive predictive value and negative predictive value along with 95% confidence interval were calculated. *p*-value ≤0.05 was considered as statistically significant.

RESULTS

We enrolled total 120 patients in this study, 65 were males (54.16%), 55 were females (45.83%). In our study, 19 years was the minimum while 73 years was the maximum age reported with mean age 41.3 years and different age group stratifications as shown in Table-I. The patients included in our study were suffering from different diseases like Traumatic Brain Injury (TBI), Meningitis, Encephalitis, Space

Occupying Lesions (SOLs), Eclampsia, Stroke and Metabolic encephalopathy with different percentages as shown in Figure-1. The ultrasonographic measured ONSD value range was from minimum 4.7 to maximum 6.9 with mean value of 6.1 mm. The sensitivity was 95.5%, specificity 91.3%, positive predictive value 93.2%, negative predictive value 98.5% where ultrasonographic measured ONSD value of 5.0 mm was taken as a cutoff limit. In our study ultrasonographic measured ONSD values showed good diagnostic accuracy for raised ICP detection in comparison with CT scan brain.

Table-I: Analysis Of Ultrasonographic Onsd Sensitivity, Specifity, PPV & NPV With 95% CI

Variable	Percentage
Sensitivity	96.5%
Specificity	91.3%
Positive Predictive Value	93.2%
Negative Predictive Value	98.3%

PPV = Positive Predictive Value
NPV = Negative Predictive Value
CI = Confidence Interval

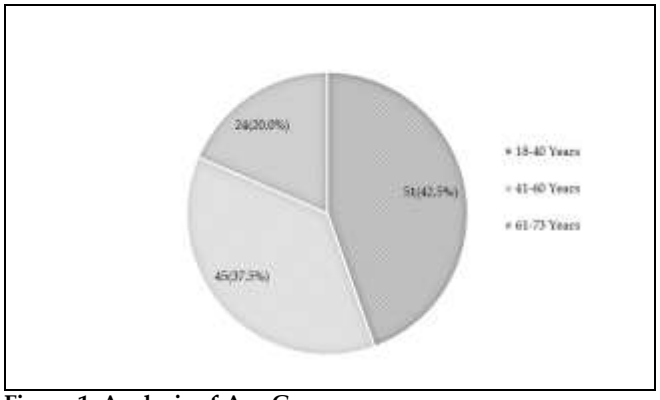

Figure-1: Analysis of Age Groups

DISCUSSION

It is a matter of fact that raised intra cranial pressure in critically ill ICU patients result in significant morbidity & mortality. Early diagnosis and prompt treatment of raised ICP results in better outcomes in such patients.[2,3] Invasive ICP monitoring is considered gold standard however it carries several limitations such as invasive nature, need of neurosurgical expertise, risks of infection, hemorrhage and blockage.[4,5] Computed Tomography scan and Magnetic Resonance Imaging (MRI) are other diagnostic modalities for detection of raised ICP however carries the risk of inter departmental transport related hazards along with ionizing radiations exposures in case of CT scan brain.[6,7,12] Several recent studies concluded that Ultrasonographicmeasurement of optic nerve sheath diameter (ONSD) has emerged as a noninvasive novel diagnostic tool with bed-side availability, reliability and ability to repeat many times.[8,9,10] We have compared our ultrasonographic measured ONSD results for cross validation of diagnostic accuracy with CT scan brain findings of raised ICP.Several researchers documented different values of ultrasonographic measured ONSD for detection of raised ICP which needs detailed studies for developing consensus however 5 mm was the cut off value in our study.[8,9] Major *et al.*, like in our study demonstrated a significant correlation of brain CT scans with ultrasonographic measured ONSD >5 mm with a sensitivity of 86% and specificity of 100% in patients with clinical suspicion of raised ICP.[13] Munawar *et al.*, also compared US ONSD measurements with CT scan brain findings of raised ICP like in our study however they concluded that ONSD of 5.8 mm as a cut-off value provided acceptable specificity, sensitivity, PPV, and NPV for detecting elevated ICP.[14] Therefore best cut-off values for ultrasonographic measured ONSD for detection of raised ICP with reasonable diagnostic accuracy should be established through further detailed studies. Li-juanWang *et al.*, and Chen L, Wang L, Hu Y *et al.*, recently concluded in their respective research studies that Ultrasonic measurement of optic nerve sheath diameter is a useful non-invasive surrogate approach for dynamic monitoring and relative real-time evaluation of the intracranial pressure.[15,16]

One of the strengths of our study is that we have evaluated diverse group of etiologies responsible for raised ICP in significant number of our ICU critically ill patients like TBI, Meningitis, Encephalitis, SOLs, Pre Eclampsia, Eclampsia, Stroke and metabolic encephalopathy. Regarding critically ill hemodynamically unstable TBI patients, our study results coincide with several studies by other researchers which concluded that ultrasonographic measured ONSD is a good screening tool for detecting raised intracranial pressure with significant diagnostic accuracy in comparison with CT scan, MRI or invasive monitoring through intracranial devices.[6,7,17,18] Along with other researchers we also concluded that ultrasonographic measured ONSD is preferred because of its bedside availability, easy technique, repeatable at any time, non-invasive nature and feasibility of dynamic relative real-time ICP monitoring. Jin Pyeong Jeon *et al.*, also demonstrated

significant correlation of bedside ultrasonographic measured ONSD with directly invasively measured ICP in their study in Korean adults with brain lesions.[19]

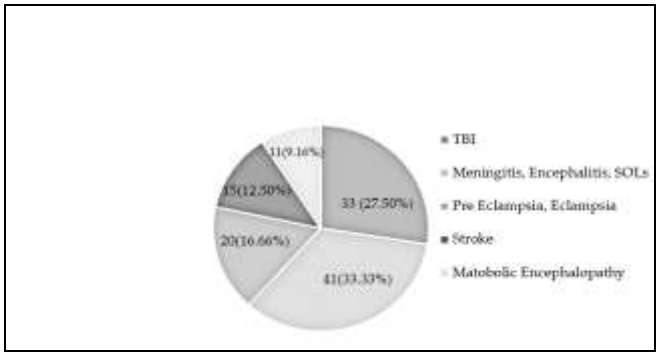

Figure-2: Etiologies Of Raised ICP In Our Study

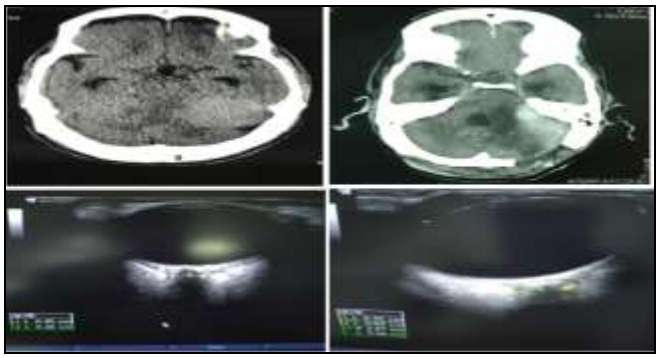

Fig. 1 A, B, C, D, USG ONSD and CT scan for Detection of raised ICP in 57 years old male with Meningioma who Developed post Neurosurgery Meningitis Associated with Secondary Hydrocephalus

Interestingly, we also received significant number of Pre eclampsia & Eclampsia patients in our ICU from Obstetrics and Gynaecology department who benefited a lot from bedside USG measured ONSD for monitoring of ICP. These young reproductive age group eclamptic patients are prone to develop neurological complications like cerebral edema, ischemic infarct and subarachnoid hemorrhage, which may lead to raised ICP resulting in significant morbidity & mortality.[20] Therefore we can save precious human lives of young female patients suffering from preventable, reversible and treatable causes by intensive monitoring in ICUs especially for raised ICP.[20] However, invasive ICP monitoring which is gold standard is either not feasible or contraindicated due to coagulation abnormalities while on other hand bedside USG measured ICP monitoring can play a significant role as demonstrated in several studies.[22] Singh SK, Bhatia K *et al*., Bala R, Banerjee A *et al*., and Sima Fallah Arzpeyma1 *et al*., concluded in these studies that ultrasonographic measured OSND is a bedside, easily available, non invasive surrogate marker for raised ICP monitoring and could be part of a holistic approach for managing such critically ill patients.[23,24]

Finally, it is worth mentioning here that Robba C et al compared different ultrasound guided non-invasive techniques with invasive ICP measurement of intracranial pressure in neurointensive care.[25] They concluded that ultrasonographic measured ONSD and venous transcranial Doppler have shown strong correlation with invasive ICP monitoring in critically ill patients with brain injury. In our study, we also used ultrasonographic measured ONSD measurements for detection of raised ICP with reasonable diagnostic accuracy however future prospective large cross sectional studies are needed to further validate these results. We are hopeful that in the near future, ultrasonographic ONSD measurements for detection of raised ICP, would be part of useful everywhere available diagnostic tools.

CONCLUSION

ONSD measured through bedside ultrasound with good negative predictive value is a highly sensitive, specific, devoid of ionizing radiations, non-invasive novel diagnostic tool for detection of raised Intra Cranial Pressure. Bedside ultrasonographic measured ONSD detection of raised ICP is especially suitable for critically ill ICU patients where inter departmental transport is hazardous because of higher vasopressors as well as ventilatory support requirements. We found that ONSD measured through bedside ultrasound is very useful for diagnosis and risk stratification of incipient intracranial hypertension in pregnant patients with pre-eclampsia and eclampsia where invasive monitoring is hazardous due to deranged coagulation profile.

LIMITATIONS OF STUDY

In this present study, we restricted ourselves for determining the diagnostic accuracy of bedside ultrasonographic measured ONSD for detection of raised ICP and did not measure the effect of treatment on the ONSD. However, it could be addressed by detailed future studies because we can monitor the treatment response as well as disease prognosis ultrasonographic ONSD measurement of raised ICP due to its advantages as noninvasive nature with bed-side availability, reliability and ability to repeat many times.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

RUK & RIS: Study design, drafting the manuscript, data interpretation, critical review, approval of the final version to be published.

NK & SS: Data acquisition, data analysis, approval of the final version to be published.

AB & MIM: Critical review, concept, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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