e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2023; 15(12); 327-330

Original Research Article

Optic Nerve Morphometry in Individuals with Elevated Intracranial Pressure: A Prospective Study

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Received: 25-09-2023 / Revised: 28-10-2023 / Accepted: 30-11-2023

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Conflict of interest: Nil

Abstract:

Background and Objectives: Elevated Intracranial Pressure (ICP) is a frequently encountered condition in the pediatric population, arising from both neurological and non-neurological causes. Prompt identification of elevated intracranial pressure is imperative for the proper implementation of therapeutic measures. The non-invasive point-of-care tool of interest in this study is the ultrasonographic measurement of the optic nerve sheath diameter (ONSD). The primary objective of this research was to assess the ONSD in children admitted to the PICU.

Methodology: This hospital-based observational study employed a complete enumeration technique, involving patients aged 2-14 years admitted to the pediatrics department for over 48 hours. Children meeting the clinical criteria for raised ICP (Muir's criteria) and supported by neuroimaging constituted the raised ICP group. ONSD measurements were taken on Day 1 (within 24 hours of admission).

Results: A total of 110 patients were enrolled. The mean ONSD was significantly higher (4.89 ± 0.79) in patients with raised ICP compared to normal children.

Conclusion: Elevated ICP represents a significant neurological condition in the pediatric population, associated with substantial morbidity. Utilizing trans-orbital ultrasound to measure ONSD demonstrated excellent discriminatory performance in detecting elevated ICP.

Keywords: Intracranial Hypertension, Optic Nerve, Child, Intensive Care Unit.

Introduction

Elevated intracranial pressure (ICP), a potentially lethal outcome resulting from acute neurological injury, represents a frequent instigator of secondary brain damage within emergency and intensive care contexts. Recognizing heightened ICP promptly and managing it in a timely manner continue to stand as pivotal factors influencing neurological outcomes.

The conventional techniques for measuring ICP (intraventricular, intraparenchymal, epidural, subdural, and subarachnoidal) involve invasive procedures, carrying inherent risks of iatrogenic complications, including infection, hemorrhage, brain parenchymal injury, inadvertent pain, and discomfort. The routine application of these methods in pediatric cases of nontraumatic coma encounters challenges due to the lack of expertise in precision catheter placement and the associated exorbitant costs. Non-invasive methodologies for ICP measurement, such as ultrasonography-guided optic nerve sheath diameter (ONSD) assessment, transcranial Doppler (TCD) flow index estimation, CT, and MRI, present viable alternatives The appeal of ultrasonography of ONSD lies in its easy availability, portability, and cost-effectiveness, making them attractive substitutes for invasive ICP monitoring [1-5].

Considering its potential to influence clinical practice, ONSD merits investigation as surrogate indicators of ICP in pediatric coma cases. In contrast to adult data, the literature on non-invasive monitoring of elevated ICP in children is notably limited. In this study, we undertook a comparative analysis of the diagnostic accuracy of

ultrasonography-guided ONSD in children admitted to the Pediatric Intensive Care Unit (PICU).

Material and Methods

In this prospective cohort study, conducted in a PICU at a tertiary care teaching institute in India, eligibility criteria included consecutive patients aged 2 to 12 years admitted to the PICU undergoing invasive intracranial pressure (ICP) monitoring with intraparenchymal catheters. Exclusions for ONSD assessment comprised children with optic neuritis, arachnoid cyst of the optic nerve, ocular trauma, and conditions impacting cerebrospinal fluid (CSF) flow. Healthy controls, aged 2 to 12 years, were recruited from children attending routine outpatient checkups and immunization clinics.

After Enrollment, a comprehensive history and clinical examination were conducted. Glasgow Coma Scale (GCS) scores were assessed at PICU admission, and fundoscopy was employed to evaluate papilledema. No sedation was administered to healthy children during the procedures. Optic nerve sheath ultrasonography (ONUS) scans utilized an ultrasound machine equipped with a 6–13 MHz linear-array probe and high-resolution optimization settings. Following gel application, the probe was positioned on the superior and lateral aspect of the orbit against the closed upper eyelid. The probe was slightly angled medially and caudally until the optic nerve appeared as a linear hypoechoic structure with well-defined margins posterior to the globe. After identifying a clear optic nerve, the displayed screen was stored. To ensure uniformity, all images were captured in the vertical and horizontal planes of the eyes. ONSD measurements were taken 3mm behind the retina, and an average of three readings was recorded.

Results

In the study, 110 patients were included, with a mean age of 7.6 years. Most presented with non-traumatic coma, primarily due to neurological disorders, with meningoencephalitis being the most common, followed by stroke. Among GCS ≤12 patients, 85.94% showed ONSD measurements suggestive of raised ICP. CT scan and MRI brain were commonly performed, with the main imaging indication being clinical signs of raised ICP with progressive neurological deterioration, as shown in Table-1.

The mean values of ultrasound-guided ONSD measurement for three age groups were displayed in Table-2. We established the threshold for ultrasonographic ONSD measurement as >4.0 mm in infants, >4.71 mm in children aged 1–10 years, and >5.43 mm in adolescents >10 years for detecting raised ICP. The sensitivity and specificity of these thresholds were 100% and 60–66.7%, respectively, as outlined in Table-3.

Table 1: Clinico-demographic parameters of study participants

Characteristics	n	%
Age (in years); mean ± SD	7.6 ± 4.8	
< 1 yrs	9	8.33
1-10 yrs	55	50.00
>10 yrs	46	41.67
Male	73	66.67
Female	37	33.33
History		
Blast injury	2	2.08
Diabetic Ketoacidosis	5	4.17
Hemolytic uremic syndrome	2	2.08
Meningeoencephalitis	62	56.25
Non-Traumatic Coma	94	85.42
Primary Neurological injury	85	77.08
Road traffic accidents	14	12.50
Secondary neurological injury	9	8.33
Space occupying lesion	2	2.08
Status Epilepticus	5	4.17
Stroke	16	14.58
Traumatic brain injury	16	14.58
Wilson Disease	2	2.08
GCS		
≤12	96	87.50
>12	14	12.50
Clinical signs suggestive of raised ICP	60	54.17

CT Scan/MRI brain suggestive of raised ICP	32	29.17
US Guided ONSD suggestive of raised ICP	92	83.33
GCS with US Guided ONSD suggestive of raised ICP		
≤ 12	83	85.94

Table 2: Ultrasound guided ONSD measurements

Age Group	ONSD in mm; Mean ± SD	
	Patients with signs of raised ICP	Patients with no signs of raised ICP
< 1 yrs	4.54 ± 0.38	4.43 ±0.81
1-10 yrs	6.64 ± 0.75	5.13 ± 0.81
>10 yrs	6.48 ± 0.71	5.65 ± 0.96

Table 3: Sensitivity and specificity of Ultrasound guided ONSD based on ROC curves

Age Group	ONSD in mm	Sensitivity (%)	Specificity (%)
< 1 yrs	4.02	100.00	61.50
1-10 yrs	4.75	99.80	64.20
>10 yrs	5.06	98.50	67.71

Discussion

The ONSD range in normal pediatric populations has been studied in different regions. In the US, using a threshold of >4 mm in infants and >4.5 mm in children >1 year, ultrasonographic ONSD was considered a sign of elevated ICP. In the UK, with 102 children, ONSD ranged from 2.1 to 4.3 mm, and >4 mm in infants and >4.5 mm in children >1 year were deemed abnormal.

A German study with 483 children found that Ultrasonographic ONSD >4.5 mm was definitely pathological and required further investigation [6-8]. In our study, the mean age was 7.6 years, aligning closely with the German cohort [7]. However, our mean age was lower compared to the African cohort [9] and the Iranian cohort [10], and slightly higher than that reported for US children [8]. We present mean values of ultrasound-guided ONSD measurement for three age groups. Thresholds for ultrasonographic ONSD are >4.0 mm in infants, >4.71 mm in children (1–10 years), and >5.43 mm in adolescents (>10 years) for detecting raised ICP. Sensitivity and specificity are 100% and 60–66.7%, respectively, consistent with prior studies [11,12,13-17] It's worth noting that our cohort had a small sample size, particularly in infants. Therefore, larger prospective studies among children of varying age groups are necessary to establish the accuracy of Ultrasonographic ONSD measurement. This method has the potential to serve as an acceptable, non-invasive, safe, and easily repeatable screening and diagnostic tool for the diagnosis of raised intracranial pressure. The use of different operators for Ultrasonographic ONSD measurement introduces the potential for operator bias, given the operator-dependent nature of ultrasonography. Despite extensive efforts in training operators (intensive care physicians and fellows) to standardize image capture—with the optic nerve at the center of the screen and measurements taken 3 mm behind the papilla—operator variability may still exist.

Conclusion

In summary, a measured ONSD value of 4.0 mm demonstrates favorable sensitivity and specificity in identifying elevated ICP. The non-invasive bedside ultrasound assessment of ONSD serves as a valuable supplement to existing invasive intracranial catheter monitoring methods. The combo of ONSD measurement and GCS can be seen as a superior screening tool for detecting increased ICP, especially in resource-limited developing nations.

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