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PREDICTIVE VALUE OF ANTERIOR CEREBRAL ARTERY SPECTRAL DOPPLER IN TERM NEONATES WITH HYPOXIC-ISCHEMIC ENCEPHALOPATHY

Radio-Diagnosis

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ABSTRACT

Hypoxic-ischemic encephalopathy (HIE) is a serious neurological condition with significant long-term neurological impairments and neonatal mortality, as a complication to perinatal hypoxic/ischemic insult. The predictive value of cranial ultrasound with spectral doppler of anterior cerebral artery (ACA), which supplies key areas of the frontal and medial brain regions remains rather underexplored, is hence being evaluated. Materials and significant findings: A prospective study was conducted for a period of 10 months which included 30 term neonates with perinatal hypoxia, low APGAR score at 1 and 5 minutes and/or clinically diagnosed HIE requiring NICU admission. These were compared with 40 healthy term requiring NICU admissions for reasons other than HIE. ACA Doppler indices were calculated and analysed. Correlation analysis revealed significant relationships between HIE severity and ACA parameters: positive correlation with PSV and EDV and negative correlations with PI, and RI. ACA RI was the most promising index in distinguishing between different severities of HIE. EDV and PI mainly distinguish controls from HIE and highlight the difference between mild and severe groups. PSV is the least discriminatory doppler parameter. Conclusion: Cranial Doppler as an adjunct to B-mode imaging allows clinicians to monitor cerebral blood flow velocity and resistance indices, offering valuable information on cerebral perfusion and hemodynamics.

KEYWORDS

Hypoxic ischemic encephalopathy (HIE), cranial ultrasound, Spectral doppler, Anterior cerebral artery (ACA).

INTRODUCTION

Hypoxic-ischemic encephalopathy (HIE) in term neonates remains a critical concern in neonatal care, as it is a leading cause of acute mortality and long-term neurodevelopmental deficits [1,2]. Despite the implementation of therapeutic hypothermia and improvements in neonatal intensive care, accurately predicting outcomes in affected infants during the early postnatal period continues to be a clinical challenge [3].

The assessment of cerebral hemodynamics using Doppler ultrasonography has emerged as a valuable, non-invasive method to monitor changes in cerebral blood flow (CBF) following hypoxic injury. These measurements reflect alterations in cerebrovascular resistance and autoregulatory function, both of which are commonly disrupted in neonates with HIE [4,5]. Although previous studies have primarily focused on Doppler evaluation of the middle cerebral artery (MCA), the predictive value of anterior cerebral artery (ACA) Doppler, which supplies key areas of the frontal and medial brain regions remains rather underexplored [6,7,8].

This study seeks to investigate the significance of ACA Doppler parameters in term neonates diagnosed with HIE. By examining the relationship between ACA flow characteristics and short-term neurological presentation, this research aims to enhance early risk stratification and contribute to more individualized management approaches in affected infants.

The primary cause of HIE, which leads to hypoxemia and hypercapnia, is perinatal asphyxia. A series of harmful processes, such as acidosis, the production of inflammatory agents and excitatory neurotransmitters and the creation of free radicals, are brought on by hypotension and the ensuing reduction in cerebral blood flow. When cerebral hypoperfusion occurs, these metabolic compounds lead to a lack of vascular autoregulation. These events lead to failure of both primary and secondary energy failure, wherein cell metabolism is impaired and ultimately leading to neuronal cell death [9].

HIE can occur secondary to antepartum, intrapartum and post-partum causes. Few antepartum and intrapartum causes include maternal hypotension, gestation induced hypotension, placental abruption, severe maternal anemia, cord prolapse. Pneumonia, meconium aspiration, significant hyaline membrane disease, or congenital cardiac defects that result in hypotension or neonatal respiratory failure can all induce postnatal asphyxia [9].

Clinically, the Sarnat and Sarnat staging system is used to classify the severity of Hypoxic-Ischemic Encephalopathy (HIE) in newborns. It evaluates neonates on clinical signs, EEG changes, duration of symptoms and categorizes neonates into mild, moderate and severe HIE [10].

Various imagining modalities like CT, MRI and cranial ultrasonography can be used to evaluate HIE. CT is associated with risk of radiation exposure to the neonate, and MRI can be time consuming and often requires sedation. Cranial ultrasound hence plays a crucial role in early diagnosis and management of HIE. HIE in terms neonates typical involves the watershed vascular territories in mild-moderate insult, and predominantly affects the thalami, perirolandic cortex, posterior limb of internal capsule, brainstem and hippocampi in profound hypoxia [9]. Spectral doppler as an adjunct to neurosonogram plays an important role in the evaluation, management and prognostication of HIE by providing real-time, non-invasive insights into cerebral hemodynamics.

Aims And Objectives

The primary aim of this study is to evaluate the predictive value of anterior cerebral artery spectral doppler in term neonates with hypoxic-ischemic encephalopathy, and to correlate these doppler findings with clinical staging of HIE.

Informed Consent

Informed written consent was obtained from the parents or legal guardians of all participants enrolled in the study. Adequate information about the purpose, procedures, potential risks, and benefits of the study were explained. Participation was entirely voluntary, with the option to withdraw at any point without affecting standard care.

MATERIALS AND METHOD

A prospective study was conducted in department of Radio-diagnosis, JJM medical college and hospital, Davangere for a period of 12 months (January to December 2024), after approval from institutional ethics committee. A total of 90 term neonates were evaluated with B-mode neurosonogram along with ACA spectral doppler. Among these, 50 term neonates with birth weight greater than 2500 grams, with perinatal hypoxia, low APGAR score at 1 and 5 minutes and/or clinically diagnosed HIE requiring NICU admission were considered as cases. Term neonates requiring NICU admission for indications other than HIE were considered as controls. Exclusion criteria included neonates with congenital malformations, chromosomal

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anomalies, intra-uterine infections and sepsis with hemodynamic disturbances.

The cranial sonography was performed using 5 MHz curvilinear transducer in axial, coronal and sagittal planes. Anterior cerebral artery (Right or left) was localized in sagittal plane after placing the transducer on the anterior fontanelle using color doppler (Figure-1). Spectral analysis of the vessel was performed using appropriate sample volume and various doppler parameters like pulsatility index (PI), resistive index (RI), peak systolic velocity (PSV), end diastolic velocity (EDV) were recorded.

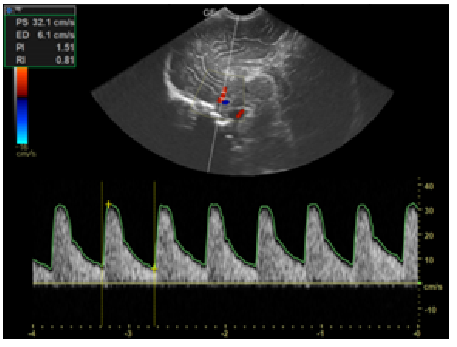

Figure-1: B-mode image with spectral doppler analysis of ACA after localization of the vessel in the sagittal plane of healthy term neonatal brain.

Statistical Analysis

Data analysis was performed using SPSS software, version 17. The Shapiro-Wilk test was used to assess the normality of data distribution. Quantitative variables were presented as mean ± standard deviation, and comparisons between two groups were made using either the Student's t-test or the Mann–Whitney U test, depending on data distribution. Categorical variables were expressed as percentages, and differences in proportions were analyzed using Fisher's exact test. A p-value of less than 0.05 was considered statistically significant.

OBSERVATIONS AND RESULTS

Table-1: Demographic Profiles Of Both Groups.

Variables	Control group	Case group	P-Value
Male : Female	22:18	27:23	
Gestational age (weeks)	38.2 +/- 0.88	37.9 +/- 1.39	0.16
Birth weight (kg)	2.92 +/- 0.41	2.85 +/- 0.47	0.29

The demographic data of both groups are displayed in Table-1. The demographic data in both control and study groups are adequately matched in terms of birth weight, sex and age in gestational weeks. The study included 40 term neonates (controls) admitted in NICU for non-HIE related conditions, and 50 term neonates (cases) with clinically diagnosed HIE. Among 50, 28 (56%) were categorized as HIE grade I, 9 (18%) as HIE grade II, and 13 (26%) as HIE grade III, according to Sarnat and Sarnat classification.

Preliminary B-mode cranial ultrasound showed cerebral oedema in 8 cases of HIE grade III, ill-define periventricular and deep white matter hyper-echogenicity in 3 cases of HIE grade II and 4 cases of HIE grade III. Rest of the neonates had essentially unremarkable B-mode ultrasound findings. Spectral doppler analysis of ACA revealed significant association between doppler indices and cases, controls and different grades of HIE. PI and RI were typically lower in cases, with lowest values in severe cases. A similar but opposite trend was observed in PSV and EDV, which were invariably increased in cases. Figure-2 depicts the spectral doppler analysis of ACA with low PI and RI value in a term neonate with moderate HIE.

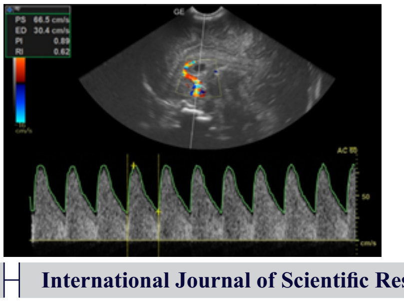

Figure-2: Spectral doppler analysis of ACA in a term neonate at 37weeks with low APGAR score and moderate HIE.

DISCUSSION

On spectral Doppler analysis of right anterior cerebral artery, PSV, EDV, PI and RI showed significant association ($p<0.05$) in cases and control groups (Table-2). PSV and EDV was higher, whereas PI and RI was lower in cases when compared to control group. The change in neonatal doppler indices occurs in response to hypoxia similar to a brain-sparing effect.

Table-2: Comparison Of Doppler Parameters Between Study Group And Control Group.

Doppler Parameter	Control group	Case group	P-Value
PSV (cm/s)	36.0 +/- 12.9	47.4 +/- 22.5	**<0.001**
EDV (cm/s)	8.46 +/- 3.09	16.4 +/- 9.50	**<0.001**
PI	1.38 +/- 0.21	1.20 +/- 0.17	**<0.001**
RI	0.75 +/- 0.05	0.67 +/- 0.06	**<0.001**

This centralization of blood flow to critical organs like the brain is necessary to maintain oxygenation which occurs via vasodilatation and an increase in blood flow in the cerebrovascular circulation. As a result, when resistance declines, cerebral blood velocity and EDV rise while RI and PI fall.

Table-3: Association of doppler parameter with severity of HIE.

	Mild HIE	Moderate HIE	Severe HIE	P Value
PSV	42.5 +/- 16.0	55.7 +/- 29.1	53.4 +/- 24.0	0.146
EDV	12.1 +/- 5.38	20.1 +/- 12.9	21.6 +/- 10.4	**0.002**
PI	1.28 +/- 0.15	1.14 +/- 0.18	1.15 +/- 0.15	**0.015**
RI	0.72 +/- 0.03	0.64 +/- 0.06	0.59 +/- 0.03	**<0.001**

(First column indicates the doppler parameters with PSV & EDV measured in cm/s)

Among PI, RI and EDV, which shows significant association with severity of HIE (Table-3), RI shows the clearest, step-wise separation among varying grade of HIE. There is progressive decline in RI of ACA, being 0.75 +/- 0.05 in controls, 0.72 +/- 0.03 in grade I HIE, 0.64 +/- 0.06 in grade II HIE and 0.59 +/- 0.03 in grade III HIE. The decrease in RI correlates well with the increasing severity of HIE. Similar findings were also noted in study conducted by Rao et al [11] and Jain et al [12].

While PI, RI, and EDV all exhibit strong correlations with varying HIE severity, only the RI value is statistically significant ($p \approx 0.042$) in distinguishing between the moderate and severe HIE groups. EDV and PI mainly distinguish controls from HIE and highlight the difference between mild and severe groups. PSV is the least discriminatory doppler parameter, showing only modest increase from grade I to grade III HIE, and hence significant only for control vs severe grades.

Parallel to RI, EDV parameter in ACA doppler shows strong relationship with the severity of HIE. EDV shows a gradual increasing trend, 12.1 +/- 5.38 cm/s in mild HIE to about 21.6 +/- 10.4 cm/s in severe cases. This increase in EDV is as a result of vasodilatory effect and also majorly responsible for the decrease in RI values.

CONCLUSION

Based on the finding of present study it can be concluded that grey scale cranial sonography along with spectral doppler imaging and with various doppler indices like RI, PI, EDV of anterior cerebral arteries in HIE neonates has very high sensitivity and specificity in grading and prognostication of HIE. It would be safe to recommended that in all neonates with clinical suspicion of HIE, neurosonogram along with spectral doppler of cranial arteries should be done for evaluation of HIE.

Summary

The study found that spectral Doppler assessment of the anterior cerebral artery can help differentiate between normal neonates and those with hypoxic-ischemic encephalopathy (HIE), as well as between different grades of HIE severity. Doppler indices like RI, PI, and EDV showed consistent changes with increasing severity—particularly a fall in resistance and rise in blood flow. Among these, RI showed the clearest pattern in grading HIE. These findings suggest that Doppler ultrasound is a useful, non-invasive tool in evaluating and monitoring HIE in newborns.

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Limitations

The findings are based on data from a single institution, which is a tertiary care centre, and may limit the generalizability to broader populations. The study also did not assess long-term neurodevelopmental outcomes, which would be valuable in validating the prognostic significance of Doppler findings.

Conflict Of Interest

The authors declare that they have no conflict of interest.

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