ORIGINAL RESEARCH PAPER
Volume - 13 | Issue - 11 | November - 2024 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

MAGNETIC RESONANCE IMAGING IN THE EVALUATION OF HYPOXIC-ISCHEMIC BRAIN INJURY IN PERINATAL NEWBORNS: A COMPREHENSIVE ASSESSMENT OF IMAGING PATTERNS AND DIAGNOSTIC UTILITY

Radiology

Dr Abhinav Sharma* Junior Resident, Department of Radiodiagnosis, Sri Aurobindo Institute of Medical Sciences, Indore. *Corresponding Author

Dr Rajkumari Rawat Assistant Professor, Department Of Radiology, Saims & Pg Institute, Indore.

Dr Manish Bhagat Professor & Hod, Department Of Radiology, Saims & Pg Institute, Indore.

ABSTRACT

Background: This study aims to assess the role of magnetic resonance imaging (MRI) in evaluating hypoxic-ischemic brain injury (HIBI) in perinatal newborns. It specifically examines the imaging patterns of brain injury in preterm versus full-term infants and evaluates the utility of different MRI sequences. **Methodology:** A cross-sectional study was conducted over 18 months at a tertiary care center. Fifty perinatal newborns with clinical suspicion of HIBI were enrolled. All subjects underwent MRI using T1-weighted, T2-weighted, and diffusion-weighted imaging. The imaging findings were analyzed to identify injury patterns, and the effectiveness of different sequences in detecting these injuries was compared. Descriptive statistics were used to summarize the data, and comparisons were made between preterm and full-term infants. **Results:** MRI findings revealed distinct injury patterns, with preterm infants showing higher incidences of basal ganglia, thalamic, and white matter injuries. Diffuse cortical injury was more common in preterm infants. T2-weighted imaging was the most effective in detecting hypoxic-ischemic lesions, followed by DWI. Preterm infants had reduced thalamic volume and enhanced connectivity between the thalamus and insula, suggesting a heightened vulnerability to ischemic injury. **Conclusion:** This study highlights the importance of MRI in the early detection of HIBI, especially in preterm infants, who exhibit unique injury patterns. Advanced MRI techniques, such as T2-weighted imaging, are particularly valuable in characterizing these injuries. These findings underscore the need for tailored imaging protocols and interventions based on gestational age and injury type to improve neurodevelopmental outcomes in affected newborns.

KEYWORDS

Hypoxic-ischemic brain injury, Magnetic resonance imaging, Preterm infants, Diffusion-weighted imaging, White matter injury

INTRODUCTION

Hypoxic-ischemic brain injury (HIBI) remains one of the leading causes of neonatal mortality and long-term neurodevelopmental disabilities, affecting both preterm and full-term infants. (1)

It is estimated to affect between one and four infants per 1000 live births, depending on the specific criteria used to define encephalopathy in infants. Of the newborns affected, approximately 20% to 50% do not survive the neonatal period. Among those who do survive, up to 25% may suffer from lasting neurological impairments, commonly presenting as cerebral palsy, mental retardation or seizure disorders. (2)

Perinatal hypoxic-ischemic events, which may arise due to complications during labour, delivery, or immediate postnatal period, can lead to varying degrees of brain injury. (3)

The severity and pattern of brain damage are influenced by factors such as the gestational age of the newborn, the duration and extent of oxygen deprivation, and the timing of the insult relative to brain maturation. (4–6)

Early and accurate diagnosis of HIBI is essential for initiating appropriate therapeutic interventions and mitigating potential long-term sequelae, such as cerebral palsy, cognitive impairments, and epilepsy. (7)

Magnetic resonance imaging (MRI) has become a pivotal tool in the evaluation of neonatal hypoxic-ischemic brain injury due to its ability to provide detailed and non-invasive visualization of both structural and functional brain abnormalities. (8) The imaging spectrum of hypoxic-ischemic brain injury in neonates varies, with distinct patterns observable in preterm versus full-term infants due to differences in brain development and vulnerability of specific brain regions. (1)

Advanced MRI techniques, such as diffusion-weighted imaging (DWI) and T1-weighted imaging, have revolutionized the early detection of hypoxic-ischemic lesions. DWI is especially sensitive to early ischemic changes by detecting the restricted diffusion of water molecules in damaged tissues, which can identify areas of acute brain injury within hours of the hypoxic event. (9,10)

Meanwhile, T1-weighted imaging is valuable in delineating areas of early tissue damage and haemorrhage, providing additional diagnostic information about the injury's extent and location. (11)

These imaging modalities not only facilitate early diagnosis but also provide insight into the potential for recovery or progression of injury, thereby guiding clinical management. This study aims to systematically assess the utility of MRI in evaluating hypoxic-ischemic brain injury in perinatal newborns. Specifically, it seeks to explore the imaging spectrum of these injuries and to compare MRI patterns between preterm and full-term infants.

Methdology

This cross-sectional study was conducted in the Department of Radiodiagnosis at Sri Aurobindo Medical College & Post Graduate Institute, Indore, over a period of eighteen months, following approval from the Institutional Research and Ethics Committee.

The study population consisted of perinatal newborns with clinical suspicion of hypoxic-ischemic brain injury, referred from various departments of the institute. Informed written consent was obtained from the parents or guardians of all participants prior to their inclusion in the study.

A total of 50 newborns were enrolled over an 18-month period. Based on institutional data, an average of 2-3 cases of suspected hypoxic-ischemic brain injury per month was estimated, making it feasible to achieve the target sample size within the study duration. Exclusion criteria included patients whose parents or guardians did not provide consent, newborns in whom MRI was contraindicated (e.g., presence of pacemakers or other incompatible implants), and patients with a history of significant trauma.

All enrolled subjects underwent MRI using a Siemens 1.5 T MAGNETOM® Symphony® MR machine equipped with Tim (Total imaging matrix) technology. Routine MR pulse sequences, including sagittal-axial T1-weighted imaging (T1WI), sagittal-axial T2-weighted imaging (T2WI), and coronal Short Tau Inversion Recovery (STIR), were obtained for each patient. For further diagnostic evaluation, sagittal-axial T1 fat-saturated (T1FS) images were acquired pre- and post-contrast administration. Intravenous gadolinium-based contrast was administered at a dose of 0.1 mmol/kg to assess for areas of enhancement indicative of ongoing ischemic injury. Suitable modifications to the imaging protocol were made

based on the condition of each patient. Detailed clinical histories, including gestational age, birth history, and relevant laboratory investigations, were recorded for each subject on a pre-structured proforma. The MR images were interpreted and imaging findings, including patterns of hypoxic-ischemic injury, were documented. MRI patterns were categorized based on the severity and distribution of brain lesions.

All data were compiled and statistically analysed using SPSS 25.0 (trial version). Descriptive statistics, such as percentages, were used to summarize the data.

RESULTS

The study analysed data from 50 perinatal newborns with suspected hypoxic-ischemic brain injury, focusing on their baseline characteristics and MRI findings.

As shown in Table 1, the majority of the subjects were male (68%), and preterm infants constituted 72% of the study population. Regarding delivery mode, 60% of the newborns were delivered via caesarean section, while 40% had normal vaginal deliveries. The most common clinical presentations included seizures (42%) and apnoea (30%).

Table 2 highlights the MRI findings, revealing distinct patterns of hypoxic-ischemic injury. Basal ganglia and thalamic injuries were the most frequently observed, present in 40 out of 50 cases (80%), with a higher prevalence among preterm infants. Cortical and subcortical injuries were also common, affecting 88% of preterm infants and 71% of full-term infants. Watershed injuries were seen in 70% of preterm infants and 50% of full-term infants. White matter injuries were documented in 78% of preterm infants and 57% of full-term infants. Notably, 72% of preterm infants exhibited diffuse cortical injuries compared to 36% of full-term infants.

Table 3 compares the efficacy of different MRI sequences in detecting hypoxic-ischemic lesions. T2-weighted imaging identified the most lesions, followed by diffusion-weighted imaging (DWI) and T1-weighted imaging, highlighting the sensitivity of T2 sequences in this context. The findings underscore the diagnostic value of MRI, particularly in preterm newborns, where hypoxic-ischemic brain injury patterns differ significantly from those in full-term infants.

Table 1: Baseline characteristics of study subjects

Parameter	Frequency (n)	Percentage (%)
Gender		
Male	34	68%
Female	16	32%
Gestational age		
Pre-term (<37 weeks)	36	72%
Full-term(≥37 weeks)	14	28%
Birth history		
Normal vaginal delivery	20	40%
Caesarean section	30	60%
Clinical presentation		
Seizures	21	42%
Apnoea	15	30%
Poor feeding	7	14%
Fever	7	14%

Table 2: MRI Findings and Distribution of Hypoxic-Ischemic Brain Injury Patterns

Parameter	Frequency (n)	Percentage (%)
Gender		
Male	34	68%
Female	16	32%
Gestational age		
Pre-term (<37 weeks)	36	72%
Full-term(≥37 weeks)	14	28%
Birth history		
Normal vaginal delivery	20	40%
Caesarean section	30	60%
Clinical presentation		
Seizures	21	42%
Apnoea	15	30%
Poor feeding	7	14%
Fever	7	14%

Table 3: Comparison of MRI Sequences in Detecting Hypoxic-Ischemic Lesions

MRI Sequence	No. of Lesions Detected
T1-Weighted Imaging	25
T2-Weighted Imaging	29
DWI	27
T1FS (post-contrast)	26

DISCUSSION

The findings of this study highlight the crucial role of MRI in the evaluation of hypoxic-ischemic brain injury (HIBI) in perinatal newborns, offering valuable insights into the distinct imaging patterns between preterm and full-term infants. Preterm infants showed a higher prevalence of basal ganglia, thalamic, cortical, and subcortical injuries, emphasizing their heightened vulnerability to ischemic damage due to the incomplete development of the brain at earlier gestational ages. This observation is consistent with studies by Logitharajah et al. (12), who reported that 72% of preterm infants had basal ganglia lesions, 62% had thalamic lesions, and 89% exhibited white matter involvement. The sensitivity of these brain structures to hypoxic insults in preterm infants underscores the differential impact of HIBI based on gestational maturity.

One of the key observations in this study was that preterm infants were more likely to exhibit diffuse cortical injury and white matter damage compared to full-term infants. This is in agreement with the work of Ophelders et al. (13), who noted that diffuse white matter injury is now the predominant form of brain injury in preterm infants, while cystic periventricular leukomalacia (cPVL) has become less common due to advances in neonatal care. Ophelders et al. (13) further emphasized that preterm infants are more prone to initial white matter damage, which later leads to secondary effects on gray matter, in contrast to full-term infants where damage is more directly observed in neurons within the gray matter.

In addition, Li et al. (14) reported that preterm birth significantly affects thalamic development, particularly in the ventral, dorsomedial, and posterior nuclei. This study supports their findings by demonstrating that preterm infants had reduced thalamic volume and cortical thickness compared to full-term infants. Moreover, Li et al. (14) found enhanced connectivity between the thalamus and insula in preterm infants, a result that aligns with our findings, which suggest that these connections may contribute to sensory and cognitive processing deficits commonly observed in preterm infants.

The diagnostic utility of various MRI sequences was also a focus of this study, with T2-weighted imaging proving the most effective in detecting hypoxic-ischemic lesions, followed by diffusion-weighted imaging (DWI). This is supported by Gopagondanahalli et al. (15), who noted that while DWI can detect abnormalities as early as day one after birth asphyxia, its correlation with long-term outcomes remains uncertain. Heinz and Provenzale (16) discussed the limitations of DWI, noting that although it can identify brain injury within the first 24 hours and peaks around 5 days post-injury, these abnormalities are temporary, resolving after 10-12 days, potentially missing ongoing tissue damage. Therefore, while DWI is effective for early detection, normal findings on DWI do not exclude the possibility of hypoxic injury, necessitating further diagnostic evaluation.

The role of T1-weighted and T2-weighted MRI sequences in evaluating brain development and myelination is well-established, as noted by Zanelli (17). This study reinforces their importance, particularly in revealing injury patterns in the first week of life, with T1-weighted images being especially useful in detecting abnormalities in the posterior limb of the internal capsule (PLIC), a predictor of motor outcomes.

CONCLUSION:

This study emphasizes the value of advanced MRI techniques in the early diagnosis of HIBI, highlighting the distinct injury patterns observed in preterm versus full-term infants. The findings have important implications for tailoring imaging protocols and therapeutic interventions based on gestational age and the specific characteristics of brain injury. Future research should focus on exploring long-term neurodevelopmental outcomes and the potential of newer imaging modalities to enhance early detection and prognostication in infants affected by HIBI.

REFERENCES:

1. Reddy R. Magnetic Resonance Imaging Evaluation of Perinatal Hypoxic Ischemic Encephalopathy: An Institutional Experience. J Neurosci Rural Pract. 2022 Jan 11;13(1):87–94.
2. Ghei SK, Zan E, Nathan JE, Choudhri A, Tekes A, Huisman TAGM, et al. MR Imaging of Hypoxic-Ischemic Injury in Term Neonates: Pearls and Pitfalls. RadioGraphics [Internet]. 2014 Jul 14 [cited 2024 Oct 16]; Available from: https://pubs.rsna.org/doi/10.1148/rg.344130080
3. Allen KA, Brandon DH. Hypoxic Ischemic Encephalopathy: Pathophysiology and Experimental Treatments. Newborn Infant Nurs Rev NAINR. 2011 Sep 1;11(3):125–33.
4. Gillam-Krakauer M, Shah M, Gowen Jr CW. Birth Asphyxia. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 [cited 2024 Oct 16]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK430782/
5. Strizek B. Perinatal brain damage – what the obstetrician needs to know. J Perinat Med. 2023 Jul 1;51(6):752–6.
6. Ranjan AK, Gulati A. Advances in Therapies to Treat Neonatal Hypoxic-Ischemic Encephalopathy. J Clin Med. 2023 Oct 20;12(20):6653.
7. Agut T, León M, Rebollo M, Muchart J, Arca G, Garcia-Alix A. Early identification of brain injury in infants with hypoxic ischemic encephalopathy at high risk for severe impairments: accuracy of MRI performed in the first days of life. BMC Pediatr. 2014 Jul 8;14:177.
8. Varghese B, Xavier R, Manoj VC, Aneesh MK, Priya PS, Kumar A, et al. Magnetic resonance imaging spectrum of perinatal hypoxic-ischemic brain injury. Indian J Radiol Imaging. 2016 Sep;26(3):316.
9. Tuor UI, Kozlowski P, Del Bigio MR, Ramjiawan B, Su S, Malisza K, et al. Diffusion-andT2-Weighted Increases in Magnetic Resonance Images of Immature Brain during Hypoxia–Ischemia: Transient Reversal Posthypoxia. Exp Neurol. 1998 Apr 1;150(2):321–8.
10. Gang Q, Zhang J, Hao P, Xu Y. Detection of hypoxic-ischemic brain injury with 3D-enhanced T2* weighted angiography (ESWAN) imaging. Eur J Radiol. 2013 Nov;82(11):1973–80.
11. Wisnowski JL, Wintermark P, Bonifacio SL, Smyser CD, Barkovich AJ, Edwards AD, et al. Neuroimaging in the term newborn with neonatal encephalopathy. Semin Fetal Neonatal Med. 2021 Oct 29;26(5):101304.
12. Logitharajah P, Rutherford MA, Cowan FM. Hypoxic-Ischemic Encephalopathy in Preterm Infants: Antecedent Factors, Brain Imaging, and Outcome. Pediatr Res. 2009 Aug;66(2):222–9.
13. Ophelders DR, Gussenhoven R, Klein L, Jellema RK, Westerlaken RJ, Hütten MC, et al. Preterm Brain Injury, Antenatal Triggers, and Therapeutics: Timing Is Key. Cells. 2020 Aug 10;9(8):1871.
14. Li H, Liu M, Zhang J, Liu S, Fang Z, Pan M, et al. The effect of preterm birth on thalamic development based on shape and structural covariance analysis. NeuroImage. 2024 Aug 15;297:120708.
15. Gopagondanahalli KR, Li J, Fahey MC, Hunt RW, Jenkin G, Miller SL, et al. Preterm Hypoxic–Ischemic Encephalopathy. Front Pediatr [Internet]. 2016 Oct 20 [cited 2024 Oct 23];4. Available from: https://www.frontiersin.org/journals/pediatrics/articles/10.3389/fped.2016.00114/full
16. Heinz ER, Provenzale JM. Imaging Findings in Neonatal Hypoxia: A Practical Review. Am J Roentgenol. 2009 Jan;192(1):41–7.
17. Zanelli SA. Hypoxic-Ischemic Encephalopathy: Practice Essentials, Background, Pathophysiology [Internet]. [cited 2024 Oct 23]. Available from: https://emedicine.medscape.com/article/973501-overview