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Original Research Article

Magnetic resonance imaging evaluation of intracranial abnormalities causing neonatal seizures in the post-COVID era: a cross-sectional study

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ABSTRACT

Background: Neonatal seizures are the most common neurological emergency in the neonatal period, representing the earliest sign of underlying cerebral pathology. Magnetic resonance imaging (MRI) has become the preferred imaging modality due to its superior soft-tissue contrast and ability to detect subtle structural abnormalities. In the post-COVID era, evolving patterns of neonatal neurological injury warrant renewed evaluation of MRI findings in this population. Objectives were to evaluate the spectrum of intracranial abnormalities on MRI in neonates presenting with seizures, and to determine the probable etiology based on MRI findings, in the post-COVID era.
Methods: Hospital-based cross-sectional observational study conducted over 18 months at a tertiary care centre. Forty-five consecutive neonates presenting with seizures underwent MRI brain within one week of onset, using a 1.5 Tesla scanner with T1W, T2W, FLAIR, diffusion-weighted imaging (DWI)/ apparent diffusion coefficient (ADC), and susceptibility-weighted imaging (SWI) sequences. Descriptive statistics were applied.
Results: MRI was abnormal in 77.8% (35/45) of neonates. Hypoxic-ischemic encephalopathy (HIE) was the most common etiology (40.0%), followed by intracranial haemorrhage (31.1%) and infective encephalitis pattern (20.0%). White matter involvement (55.6%) and diffusion restriction (40.0%) were the most frequent MRI findings. Bilateral involvement was present in 64.4%. Normal MRI was seen in 22.2%.
Conclusions: MRI demonstrates high diagnostic yield in neonatal seizures. HIE remains the leading cause; however, the relatively elevated proportions of intracranial haemorrhage and infective encephalitis patterns suggest evolving etiological trends in the post-COVID era. Early MRI with DWI and SWI is essential for timely diagnosis and targeted management.

Keywords: Neonatal seizures, Magnetic resonance imaging, Hypoxic-ischemic encephalopathy

INTRODUCTION

Neonatal seizures are the most common neurological emergency of the newborn period, with an incidence of 1.3-3.5 per 1000 term neonates and up to 130 per 1000 preterm neonates.[1,2] Clinically defined as abnormal, stereotyped, paroxysmal alterations in neurological function within the first 28 days of life (or before 44 weeks gestational age in preterm infants), they frequently represent the earliest manifestation of significant cerebral pathology.[2,3]

The etiological spectrum is broad: HIE accounts for 40-60% of term neonatal seizures, while other major causes include intracranial haemorrhage, metabolic disturbances (hypoglycaemia, hypocalcaemia, hypomagnesaemia), central nervous system infections, structural malformations, inborn errors of metabolism, and genetic epilepsies.[3,4] Accurate identification of the underlying cause is indispensable for treatment decisions and prognostication. MRI has transformed neonatal seizure evaluation, detecting intracranial abnormalities in up to 91% of affected newborns and providing critical

prognostic information.[5,6] DWI with ADC maps is sensitive for early ischaemic injury; SWI detects microhaemorrhages; and MR spectroscopy reveals metabolic signatures that aid diagnosis of HIE and metabolic encephalopathies.[7,8]

The COVID-19 pandemic introduced new complexities into neonatal neurology. Altered prenatal care pathways, increased maternal stress, changes in healthcare-seeking behaviour, and possible vertical SARS-CoV-2 transmission have indirectly affected neonatal neurological outcomes.[9] Direct viral neurotropism, placental vascular impairment, and para-infectious immune-mediated mechanisms have been described in neonates with COVID-associated brain injury, manifesting as white-matter changes, cortical diffusion restriction, microhaemorrhages, and ADEM-like lesions.[10,11] Against this background, this cross-sectional study was conducted to evaluate the spectrum of intracranial MRI abnormalities and to determine the probable aetiology of neonatal seizures at a tertiary care centre in Kerala, India, in the post-COVID era.

METHODS

This hospital-based cross-sectional observational study was conducted in the Department of Radiodiagnosis at a tertiary care referral centre with a dedicated Neonatal Intensive Care Unit (NICU). The study was carried out over a period of 18 months, from February 29th 2024, to August 29th 2025, following approval from the Institutional Ethics Committee. The study population comprised neonates presenting with seizures who were admitted to the NICU and underwent MRI of the brain within one week of seizure onset.

The sample size was calculated based on a previously published study by Shaik et al reporting a proportion of MRI-detected abnormalities of 79%.[12] Using a 95% confidence level and 15% relative allowable error, the minimum sample size was estimated to be 45. A convenience sampling technique was employed, and all eligible neonates were consecutively enrolled until the required sample size was achieved. Ethical approval was obtained before the commencement of the study, and written informed consent was secured from the parents or legal guardians of all participating neonates. Strict confidentiality and anonymity of patient data were maintained throughout the study.

Neonates presenting with seizures and undergoing MRI brain evaluation within one week of seizure onset were included in the study, while those with an already established diagnosis prior to MRI or those who underwent imaging after one week of the seizure episode were excluded. After obtaining ethical clearance, eligible cases were identified, and MRI studies were retrieved from the hospital Picture Archiving and Communication System (PACS).

Clinical data including demographic details, gestational age, birth weight, perinatal history, age at seizure onset, type of seizures, and associated clinical findings were collected using a pre-designed structured proforma. MRI of the brain was performed using a 1.5 Tesla Siemens scanner following a standardized protocol that included axial T1-weighted, axial T2-weighted, fluid-attenuated inversion recovery (FLAIR), DWI with ADC maps, SWI, sagittal T2-weighted, and coronal T2-weighted sequences. Contrast-enhanced MRI was performed only when clinically indicated, such as in suspected cases of infection, vascular malformation, or neoplasm.

The primary outcome measures included the spectrum of intracranial abnormalities detected on MRI and the probable etiology of neonatal seizures based on imaging findings. Data were entered into Microsoft excel and analyzed using IBM SPSS Statistics version 26. Categorical variables were expressed as frequencies and percentages, while numerical variables were summarized as mean and standard deviation.

RESULTS

A total of 45 neonates with seizures were included in the study. The majority of neonates presented within the first week of life, with 26 (57.8%) presenting at ≤7 days, while 19 (42.2%) presented after 7 days. Female neonates constituted 26 (57.8%) of the study population, and males accounted for 19 (42.2%). Most of the neonates were born at term, 33 (73.3%), whereas 12 (26.7%) were preterm. Regarding birth weight, 31 (68.9%) neonates had a birth weight ≥2.5 kg, while 14 (31.1%) weighed <2.5 kg. Normal vaginal delivery was the most common mode of delivery, observed in 33 (73.3%) cases, followed by lower segment caesarean section in 10 (22.2%) and instrumental delivery in 2 (4.4%) cases. Birth asphyxia was present in 11 (24.4%) neonates and absent in 34 (75.6%) (Table 1).

Table 1: Demographic and perinatal characteristics of study participants, (n=45).

Characteristics	Category	N (%)
Age at presentation (in days)	≤7	26 (57.8)
	>7	19 (42.2)
Gender	Female	26 (57.8)
	Male	19 (42.2)
Gestational age (in weeks)	Term	33 (73.3)
	Preterm	12 (26.7)
Birth weight	≥2.5 kg	31 (68.9)
	<2.5 kg	14 (31.1)
Mode of delivery	NVD	33 (73.3)
	LSCS	10 (22.2)
	Instrumental	2 (4.4)
Birth asphyxia	Present	11 (24.4)
	Absent	34 (75.6)

With respect to clinical profile, seizures most commonly occurred within the first 3 days of life in 25 (55.6%) neonates, whereas 20 (44.4%) developed seizures after 3 days. Clonic seizures were the most frequent type, seen in 16 (35.6%) neonates, followed by tonic seizures in 11 (24.4%), subtle seizures in 10 (22.2%), and mixed seizure types in 8 (17.8%). Associated clinical findings were present in 33 (73.3%) neonates, while 12 (26.7%) had no associated findings (Table 2).

Table 2: Clinical profile of neonatal seizures among study participants, (n=45).

Characteristics	Category	N (%)
Age at seizure onset (in days)	≤3	25 (55.6)
	>3	20 (44.4)
Type of seizure	Clonic	16 (35.6)
	Tonic	11 (24.4)
	Subtle	10 (22.2)
	Mixed	8 (17.8)
Associated clinical findings	Present	33 (73.3)
	Absent	12 (26.7)

MRI findings showed that white matter involvement was the most common abnormality, present in 25 (55.6%) neonates, followed by diffusion restriction in 18 (40.0%) and haemorrhage in 17 (37.8%). Grey matter involvement was noted in 15 (33.3%) cases, while basal ganglia/thalamic involvement was seen in 10 (22.2%) neonates. Corpus callosum involvement was observed in 9 (20.0%) cases, and posterior fossa abnormalities were identified in 3 (6.7%) neonates. No cases of calcification were detected (0%) (Table 3).

Table 3: MRI tissue and structural Involvement, (n=45).

MRI feature	Present, N (%)	Absent, N (%)
White matter involvement	25 (55.6)	20 (44.4)
Diffusion restriction	18 (40.0)	27 (60.0)
Haemorrhage	17 (37.8)	28 (62.2)
Grey matter involvement	15 (33.3)	30 (66.7)
Basal ganglia / thalamic involvement	10 (22.2)	35 (77.8)
Corpus callosum involvement	9 (20.0)	36 (80.0)
Posterior fossa abnormality	3 (6.7)	42 (93.3)
Calcification	0 (0.0)	45 (100.0)

Based on MRI etiology, HIE was the most common cause, identified in 18 (40.0%) neonates, followed by intracranial haemorrhage in 14 (31.1%) and infective encephalitis pattern in 9 (20.0%). Vascular infarcts/thrombosis, metabolic encephalopathy, and structural malformations were each observed in 3 (6.7%) cases. A normal MRI was reported in 10 (22.2%) neonates. Regarding laterality, bilateral involvement was most common, seen in 26 (57.7%) cases, followed by left-sided involvement in 7 (15.5%) and right-sided involvement in 2 (4.4%). Overall, MRI abnormalities were detected in 35 (77.8%) neonates, while 10 (22.2%) had normal MRI findings (Table 4).

Table 4: MRI-based etiology and laterality, (n=45).

Variables	Subcategory	N (%)
Etiology	HIE	18 (40.0)
	Intracranial haemorrhage	14 (31.1)
	Infective encephalitis pattern	9 (20.0)
	Vascular infarcts/ thrombosis	3 (6.7)
	Metabolic encephalopathy	3 (6.7)
	Structural malformations	3 (6.7)
	Normal MRI	10 (22.2)
Laterality	Left-sided	7 (15.5)
	Right-sided	2 (4.4)
	Bilateral	26 (57.7)
	Normal	10 (22.2)
Overall MRI result	Abnormal	35 (77.8)
	Normal	10 (22.2)

DISCUSSION

This study demonstrated that MRI identified intracranial abnormalities in 77.8% of neonates presenting with seizures, consistent with the 70-85% reported in previous studies,12,13 affirming MRI as the cornerstone of etiological evaluation in this population.

HIE was the leading etiology at 40.0%, in line with reported prevalence of 35-50% across Indian and international cohorts.[3,4,14] The classic imaging signatures-diffusion restriction in the basal ganglia, thalamus after acute-profound injury, and parasagittal cortical watershed changes after partial-prolonged hypoxia were well represented in this cohort, as described by Barkovich et al and de Vries et al.[6,8] Early-onset seizures (≤3 days) in 55.6% reinforce the central role of perinatal insults.

Intracranial haemorrhage was identified in 31.1%, notably higher than the 10-20% reported in most pre-pandemic series.[13] This elevation may partly reflect the routine incorporation of SWI, which markedly improves sensitivity for microhaemorrhages.[15] Importantly, many haemorrhagic cases exhibited co-existing features-multifocal distribution, parenchymal signal abnormalities, and diffusion restriction-suggestive of an underlying infectious aetiology. Hong et al demonstrated that

neonatal sepsis and viral encephalitis produce haemorrhagic parenchymal injury through endothelial damage, inflammatory vasculopathy, and coagulopathy.[16] Clinicians should therefore not ascribe haemorrhage solely to prematurity or birth trauma when the imaging pattern implies an infectious process.

An infective encephalitis pattern was observed in 20.0%, marginally higher than the 10-15% reported in earlier Indian studies.[17] DWI facilitates early detection of encephalitic changes even before CSF abnormalities become manifest.[18] The exact contribution of SARS-CoV-2-via direct neurotropism, placental vascular impairment, or para-infectious immune mechanisms-could not be definitively established owing to variable serological testing across the cohort.[10,11]

White matter involvement was the dominant structural finding (55.6%), reflecting the inherent vulnerability of the immature brain's white matter to hypoxia, ischaemia, and systemic inflammation.[6,19] Diffuse white matter injury is consistently associated with adverse neurodevelopmental outcomes, underscoring its prognostic importance. Bilateral distribution (57.7%) is consistent with the global, non-focal injury mechanisms that predominate in neonatal seizures (HIE, infectious, metabolic).

Basal ganglia/thalamic involvement (22.2%) represents the classic acute-profound HIE pattern linked to motor impairment and epilepsy risk.[6] Vascular infarcts, metabolic encephalopathy, and structural malformations were each seen in 6.7%, consistent with prior reports.[13] Despite their relatively low prevalence, each category necessitates targeted evaluation-prothrombotic workup for infarcts, metabolic/genetic investigations for encephalopathy, and chromosomal/gene-panel testing for malformations.

Normal MRI in 22.2% indicates that a meaningful subset of neonatal seizures arises from functional, biochemical, or channelopathic causes not detectable on structural imaging.[20] This underscores the necessity of integrating MRI interpretation with EEG, metabolic investigations, and genetic testing in every neonate with seizures. Collectively, the elevated proportions of haemorrhagic and infective etiologies in this post-COVID cohort suggest a potentially evolving etiological landscape that warrants prospective multicentre evaluation.

This single-centre study with a modest sample may limit generalisability and subgroup analysis. The cross-sectional design precludes causal inference and long-term outcome assessment. EEG correlation was not uniform. Advanced MRI sequences (spectroscopy, perfusion imaging) and definitive microbiological confirmation were unavailable in all cases. Inconsistent SARS-CoV-2 testing limited attribution of findings to COVID-related mechanisms.

CONCLUSION

MRI identified intracranial abnormalities in 77.8% of neonates presenting with seizures, confirming its indispensable role in etiological evaluation. HIE remains the leading cause (40.0%), while elevated proportions of intracranial haemorrhage (31.1%) and infective encephalitis patterns (20.0%) highlight evolving etiological trends in the post-COVID era. White matter involvement and diffusion restriction were the most frequent MRI findings, with predominantly bilateral distribution reflecting diffuse cerebral injury. Normal MRI in 22.2% emphasises the continued necessity of electroclinical and biochemical correlation. Routine early MRI with DWI and SWI, interpreted alongside clinical, laboratory, and EEG findings, is essential for timely diagnosis, targeted management, and improved neonatal outcomes. Larger multicentre prospective studies are warranted to characterise evolving etiological patterns and long-term neurodevelopmental sequelae.

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