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Original Research Article

MAGNETIC RESONANCE IMAGING EVALUATION OF NEUROLOGICAL DISORDERS IN PEDIATRIC PATIENTS: A RETROSPECTIVE HOSPITAL-BASED STUDY FROM SOUTH INDIA

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ABSTRACT

Background: Magnetic resonance imaging (MRI) is an important tool for evaluating pediatric neurological disorders because it enables detailed characterization of structural brain abnormalities without ionizing radiation. The spectrum and diagnostic yield of brain MRI vary according to clinical presentation and underlying neurological risk factors. **Aim:** To evaluate the diagnostic yield and spectrum of brain MRI abnormalities in pediatric patients presenting with neurological disorders.

Materials and Methods: This retrospective hospital-based observational study included 120 pediatric patients aged 0–18 years who underwent brain MRI for neurological indications in South India. Clinical presentation, demographic characteristics, relevant perinatal factors, and MRI findings were analyzed. MRI examinations were classified as normal or abnormal, and abnormal studies were further categorized according to predominant diagnostic and structural patterns. Associations were assessed using Chi-square or Fisher's exact test, with $p<0.05$ considered statistically significant.

Results: Significant MRI abnormalities were identified in 87 patients (72.5%), while 33 (27.5%) had no significant intracranial abnormality. Seizures were the most frequent indication (28.3%), followed by developmental delay (25.0%) and cerebral palsy/motor deficit (20.0%). Hypoxic–ischemic/hypoglycemic-pattern sequelae were the leading predominant diagnostic category (21.8% of abnormal MRI examinations). White-matter abnormalities were the most frequent structural finding (35.0%), followed by ventricular abnormalities (23.3%) and cerebral atrophy (20.0%). Abnormal MRI findings were observed in 95.8% of children with cerebral palsy/motor deficits, 86.7% with developmental delay, and 70.6% with seizures. MRI outcome was significantly associated with major clinical presentation ($p<0.001$), age group ($p=0.010$), and documented hypoxic insult (Fisher's exact $p=0.001$), whereas sex and mode of delivery showed no significant association.

Conclusion: Brain MRI demonstrated a high structural diagnostic yield in clinically selected pediatric patients with neurological disorders. Developmental and motor abnormalities, seizures, and documented hypoxic insult were associated with a greater likelihood of abnormal MRI findings.

Systematic MRI evaluation combined with clinical and perinatal correlation can substantially aid diagnostic assessment in pediatric neurological practice.
Keywords: Pediatric brain MRI; neurological disorders; developmental delay; seizures; cerebral palsy; hypoxic–ischemic injury; white-matter abnormalities; neuroimaging.

INTRODUCTION

Magnetic resonance imaging (MRI) is an important imaging modality in pediatric neurology because of its superior soft-tissue contrast, multiplanar capability, and ability to characterize structural brain abnormalities without exposure to ionizing radiation. Pediatric neuroimaging, however, presents specific challenges related to motion, small anatomical structures, age-dependent changes in brain water content and myelination, and the occasional requirement for sedation. Appropriate age-specific imaging protocols and interpretation in the context of normal brain maturation are therefore essential for reliable diagnosis.[1,2]

Neurological disorders in children encompass a broad clinical spectrum, including seizures, developmental delay, cerebral palsy, focal neurological deficits, congenital malformations, infections, vascular insults, metabolic disorders, traumatic injury, and intracranial neoplasms. Clinical history and neurological examination remain central to diagnosis, while neuroimaging, genetic evaluation, metabolic testing, electrophysiological investigations, and other targeted assessments are selected according to the presenting phenotype.[3,4]

Brain MRI can identify abnormalities related to hypoxic–ischemic injury, white-matter damage, altered myelination, cortical malformations, cerebral or cerebellar atrophy, corpus callosum abnormalities, hydrocephalus, cerebrovascular disease, infection, and focal intracranial lesions. Indian studies evaluating children with developmental and neurological abnormalities have demonstrated a substantial diagnostic contribution from MRI, particularly in patients with associated neurological signs.[5] However, reported MRI yields vary considerably because of differences in patient selection, age distribution, clinical severity, definitions of abnormality, and imaging protocols.[6]

Recent studies continue to demonstrate a high diagnostic yield of MRI in appropriately selected pediatric patients, particularly those with developmental delay, motor abnormalities, seizures, or a history suggestive of perinatal neurological injury.[7,8] Nevertheless, much of the existing literature focuses on selected neurological conditions, especially developmental delay or epilepsy, rather than the overall spectrum of pediatric neurological presentations encountered in routine clinical practice.

The present study was therefore undertaken to evaluate the diagnostic yield and spectrum of brain MRI abnormalities in pediatric patients presenting with neurological disorders in a hospital-based South Indian cohort and to examine their relationship with major clinical and selected perinatal factors.

Aim

1. To evaluate the diagnostic yield and spectrum of brain MRI abnormalities in pediatric patients presenting with neurological disorders.

Objectives

1. To determine the major clinical indications and characterize the predominant diagnostic and structural abnormalities detected on brain MRI in pediatric patients.
2. To evaluate the association of abnormal brain MRI findings with age, sex, clinical presentation, developmental delay, hypoxic insult, and mode of delivery.

MATERIALS AND METHODS

Study Design and Setting

This was a retrospective hospital-based observational study conducted at viswabharathi medical college, penchikalapadu, kurnool, South India.

Study duration: 1 year (july 1,2025 – June 30, 2026).

Study Population

A total of 120 pediatric patients aged 0–18 years who underwent brain MRI for evaluation of neurological symptoms or suspected neurological disorders during the study period were included.

Patients were identified from available radiology and clinical records, and each eligible patient was included only once in the final analysis.

Inclusion Criteria

Patients were included if they:

- were aged 0–18 years;
- underwent brain MRI for a neurological indication;
- had diagnostic-quality MRI examinations; and
- had sufficient clinical information available for correlation with imaging findings.

Exclusion Criteria

Patients were excluded if they had:

- repeat or follow-up MRI examinations already represented by an initial examination during the study period;
- technically inadequate or incomplete MRI studies;
- insufficient clinical or imaging records for meaningful analysis; or
- MRI performed exclusively for a non-neurological indication.

Clinical Data Collection

Demographic and clinical information was retrieved from MRI requisition forms and available medical records.

The variables recorded included:

- age; sex; presenting neurological symptoms; duration or age of onset of symptoms;
- relevant neurological examination findings; and provisional clinical diagnosis.

Where available, relevant perinatal information including prematurity, mode of delivery, birth asphyxia or other documented hypoxic insult, neonatal intensive care unit admission, and significant neonatal complications was recorded. Relevant biochemical, metabolic, genetic, and other investigations were documented when available.

Classification of Clinical Indications

The primary indication for MRI was classified into the following categories:

- seizures or seizure-like episodes; developmental delay or intellectual disability; cerebral palsy or motor deficit; headache; focal neurological deficit; suspected central nervous system infection; congenital or developmental neurological disorder; altered sensorium; trauma; suspected metabolic or genetic disorder; suspected intracranial mass lesion; and other neurological indications.

Each patient was classified according to the principal clinical indication responsible for MRI referral.

MRI Technique

Brain MRI examinations were performed using a 1.5 Tesla, GE Signa HDxt MRI system according to the institutional pediatric neuroimaging protocol.

The routine imaging protocol included:

- axial T1-weighted imaging; axial and coronal T2-weighted imaging; fluid-attenuated inversion recovery (FLAIR); diffusion-weighted imaging (DWI) with apparent diffusion coefficient maps; gradient-echo or susceptibility-sensitive imaging; and sagittal T1-weighted imaging.

Additional sequences, including three-dimensional T1-weighted imaging, contrast-enhanced imaging, magnetic resonance angiography, magnetic resonance venography, magnetic resonance spectroscopy, and other targeted sequences, were obtained when clinically indicated.

Sedation or anesthesia was administered when required in younger or uncooperative children according to institutional pediatric sedation protocols.

MRI Evaluation

MRI examinations were systematically assessed for abnormalities involving: cerebral and cerebellar volume, cortical and subcortical structures, white matter and periventricular regions; myelination; hypoxic–ischemic changes; acute or chronic infarction; intracranial hemorrhage; focal intracranial lesions; congenital or developmental malformations; corpus callosum and other midline structures; ventricular system and hydrocephalus; thalami and basal ganglia; sellar and pineal regions; brainstem; cerebellum; extra-axial spaces and collections; vascular structures; and other associated intracranial abnormalities.

The final imaging diagnosis was assigned after correlation with the available clinical information.

Classification of MRI Findings

MRI examinations were initially classified as:

1. **Normal/no significant intracranial abnormality**
2. **Abnormal MRI**

Abnormal examinations were subsequently classified according to the predominant diagnostic pattern into: hypoxic–ischemic/hypoglycemic-pattern sequelae; cerebral or cerebellar atrophy; white-matter or myelination disorders; infectious or inflammatory disorders; cerebrovascular abnormalities or chronic gliosis; congenital or developmental malformations; hydrocephalus; epilepsy-associated structural abnormalities; demyelinating disorders; traumatic abnormalities; intracranial tumor or focal mass lesion; metabolic or genetic disorders; and other abnormalities.

For analysis of predominant diagnoses, each abnormal MRI was assigned to one principal diagnostic category.

Individual structural abnormalities were analysed separately, and more than one structural finding could therefore be recorded in the same patient.

Outcome Measures

The primary outcome was the proportion of pediatric patients demonstrating an abnormal brain MRI and the spectrum of predominant MRI diagnoses.

Secondary analyses evaluated: distribution of MRI findings according to major clinical presentation; MRI abnormalities among children presenting with developmental delay; age-wise distribution of MRI diagnostic yield; association between sex and MRI outcome; association between documented hypoxic insult and MRI outcome; and association between mode of delivery and MRI outcome.

Statistical Analysis

Categorical variables were expressed as frequencies and percentages. Continuous variables were summarized as mean ± standard deviation when normally distributed and as median with interquartile range when non-normally distributed.

Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test, as appropriate. Fisher's exact test was used when expected cell frequencies were small. A two-sided p value <0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics

A total of 120 pediatric patients who underwent brain MRI for neurological indications were included in the study. The age ranged from 1 month to 17 years, with a median age of 6.2 years (IQR: 2.9–10.8 years). There were 74 males (61.7%) and 46 females (38.3%).

Eighteen patients (15.0%) were aged <1 year, 38 (31.7%) were aged 1–5 years, 34 (28.3%) were aged 6–10 years, and 30 (25.0%) were aged 11–18 years. A history of prematurity was documented in 10 patients (8.3%), birth asphyxia in 15 (12.5%), significant hypoxic insult in 27 (22.5%), and previous neonatal intensive care unit admission in 19 (15.8%).

Table 1: Demographic and Perinatal Characteristics

Variable	n	%
Total patients	120	100
Male	74	61.7
Female	46	38.3
Age <1 year	18	15.0
Age 1–5 years	38	31.7
Age 6–10 years	34	28.3
Age 11–18 years	30	25.0
Prematurity	10	8.3
Birth asphyxia	15	12.5
Documented hypoxic insult	27	22.5
Previous NICU admission	19	15.8
Vaginal delivery	82	68.3
Caesarean delivery	38	31.7

Clinical Indications for Brain MRI

The most frequent indication for brain MRI was seizures or seizure-like episodes in 34 patients (28.3%), followed by developmental delay/intellectual disability in 30 (25.0%) and cerebral palsy or motor deficit in 24 (20.0%). Other indications included headache, focal neurological deficits, suspected central nervous system infection, congenital/developmental disorders, altered sensorium, trauma, suspected metabolic/genetic disorders, and suspected intracranial mass lesions.

Table 2: Primary Clinical Indications for Brain MRI

Clinical indication	n	%
Seizures/seizure-like episodes	34	28.3
Developmental delay/intellectual disability	30	25.0
Cerebral palsy/motor deficit	24	20.0
Headache	9	7.5
Focal neurological deficit	6	5.0
Suspected CNS infection	5	4.2
Congenital/developmental disorder	3	2.5
Altered sensorium	3	2.5
Trauma	2	1.7
Suspected metabolic/genetic disorder	2	1.7
Suspected intracranial mass lesion	1	0.8
Other indications	1	0.8
Total	**120**	**100**

Overall MRI Diagnostic Yield

Brain MRI demonstrated one or more significant abnormalities in 87 patients (72.5%), whereas 33 patients (27.5%) had normal MRI findings or no significant intracranial abnormality.

Table 3: Overall MRI Findings

MRI outcome	n	%
Abnormal MRI	87	72.5
Normal/no significant abnormality	33	27.5
Total	**120**	**100**

Spectrum of Predominant MRI Diagnoses

Among the 87 abnormal examinations, hypoxic–ischemic/hypoglycemic-pattern sequelae were the most frequent predominant diagnostic category, observed in 19 patients (21.8%), followed by cerebral or cerebellar atrophy in 12 (13.8%). White-matter/myelination disorders and infectious/inflammatory disorders were each identified as the predominant diagnosis in 9 patients (10.3%).

Table 4: Predominant Diagnostic Categories Among Abnormal MRI Examinations

Predominant MRI diagnosis	n	% of abnormal MRI
Hypoxic–ischemic/hypoglycemic-pattern sequelae	19	21.8
Cerebral/cerebellar atrophy	12	13.8
White-matter/myelination disorders	9	10.3
Infectious/inflammatory disorders	9	10.3
Cerebrovascular abnormalities/chronic gliosis	8	9.2
Congenital/developmental malformations	7	8.0
Hydrocephalus	5	5.7
Epilepsy-associated structural abnormalities	5	5.7
Demyelinating disorders	4	4.6
Traumatic abnormalities	3	3.4
Intracranial tumour/focal mass lesion	2	2.3
Metabolic/genetic disorders	2	2.3
Other abnormalities	2	2.3
Total	**87**	**100**

Each abnormal examination was assigned to one predominant diagnostic category.

Structural MRI Abnormalities

White-matter abnormalities represented the most frequent structural finding and were identified in 42 patients (35.0%), followed by ventricular abnormalities in 28 (23.3%), cerebral atrophy in 24 (20.0%), and periventricular leukomalacia/white-matter injury in 18 (15.0%). Corpus callosum abnormalities were observed in 17 patients (14.2%).

Table 5: Distribution of Structural MRI Abnormalities

MRI finding	n	% of total cohort
White-matter abnormalities	42	35.0
Ventricular abnormalities	28	23.3
Cerebral atrophy	24	20.0
Periventricular leukomalacia/white-matter injury	18	15.0
Corpus callosum abnormality	17	14.2
Cerebellar atrophy/abnormality	10	8.3
Chronic infarction/gliosis	9	7.5
Brainstem abnormality	8	6.7
Focal intracranial lesion	8	6.7
Abnormal myelination	7	5.8
Cortical/developmental malformation	7	5.8
Basal ganglia/thalamic abnormality	7	5.8
Intracranial haemorrhage	4	3.3
Acute infarction	3	2.5
Extra-axial collection	3	2.5
Other associated abnormalities	11	9.2

Individual patients could have more than one structural MRI abnormality; therefore, percentages do not total 100%.

Association Between Clinical Presentation and MRI Findings

MRI diagnostic yield differed significantly according to the major clinical presentation. Among 34 patients presenting with seizures, 24 (70.6%) had abnormal MRI findings. Abnormal MRI findings were identified in 26 of 30 patients (86.7%) with developmental delay and 23 of 24 patients (95.8%) with cerebral palsy or motor deficit.

Among the remaining 32 patients with other neurological indications, 14 (43.8%) demonstrated abnormal MRI findings. The association between major clinical presentation and MRI outcome was statistically significant (χ^2=22.90, p<0.001).

Table 6: Association Between Major Clinical Presentation and MRI Findings

Clinical presentation	Total n	Normal MRI n (%)	Abnormal MRI n (%)
Seizures	34	10 (29.4)	24 (70.6)
Developmental delay	30	4 (13.3)	26 (86.7)
Cerebral palsy/motor deficit	24	1 (4.2)	23 (95.8)
Other neurological indications	32	18 (56.3)	14 (43.8)
Total	**120**	**33 (27.5)**	**87 (72.5)**

χ^2=22.90; p<0.001.

MRI Findings in Children with Developmental Delay

Among the 30 children presenting primarily with developmental delay, 26 (86.7%) demonstrated abnormal MRI findings, while 4 (13.3%) had no significant structural abnormality.

Among the 26 abnormal examinations, periventricular/white-matter injury was observed in 14 patients (53.8%), cerebral atrophy and corpus callosum abnormalities in 8 each (30.8%), ventricular abnormalities in 7 (26.9%), and abnormal myelination in 6 (23.1%).

Table 7: MRI Abnormalities Among Children with Developmental Delay

MRI abnormality	n (n=26)	%
Periventricular/white-matter injury	14	53.8
Cerebral atrophy	8	30.8
Corpus callosum abnormality	8	30.8
Ventricular abnormality/hydrocephalus	7	26.9
Abnormal myelination	6	23.1
Cortical/developmental malformation	4	15.4
Basal ganglia/thalamic abnormality	3	11.5
Cerebellar abnormality	3	11.5

Multiple abnormalities could coexist in an individual patient.

Association of Perinatal and Demographic Factors with MRI Findings

A documented history of significant hypoxic insult was present in 27 patients. Abnormal MRI findings were identified in 26 of these 27 patients (96.3%), compared with 61 of 93 patients (65.6%) without a documented hypoxic insult. This association was statistically significant (Fisher's exact test, p=0.001).

Among children delivered vaginally, 58 of 82 (70.7%) had abnormal MRI findings compared with 29 of 38 (76.3%) delivered by caesarean section. The association between mode of delivery and MRI outcome was not statistically significant (p=0.676).

Abnormal MRI findings were detected in 51 of 74 males (68.9%) and 36 of 46 females (78.3%). Sex was not significantly associated with MRI outcome (p=0.366).

Table 8: Association of Selected Clinical and Demographic Factors with MRI Findings

Variable	Normal MRI n (%)	Abnormal MRI n (%)	Total	p value
Hypoxic insult				**0.001***
Present	1 (3.7)	26 (96.3)	27	
Absent	32 (34.4)	61 (65.6)	93	
Mode of delivery				**0.676**
Vaginal	24 (29.3)	58 (70.7)	82	
Caesarean	9 (23.7)	29 (76.3)	38	
Sex				**0.366**
Male	23 (31.1)	51 (68.9)	74	
Female	10 (21.7)	36 (78.3)	46	

Fisher's exact test.

Age-Wise MRI Diagnostic Yield

MRI diagnostic yield varied significantly across age groups. Abnormal MRI findings were identified in 15 of 18 patients aged <1 year (83.3%), 32 of 38 aged 1–5 years (84.2%), 25 of 34 aged 6–10 years (73.5%), and 15 of 30 aged 11–18 years (50.0%).

The association between age group and MRI outcome was statistically significant (χ^2=11.31, p=0.010).

Table 9: Age-Wise Distribution of MRI Findings

Age group	Total n	Normal MRI n (%)	Abnormal MRI n (%)
<1 year	18	3 (16.7)	15 (83.3)
1–5 years	38	6 (15.8)	32 (84.2)
6–10 years	34	9 (26.5)	25 (73.5)
11–18 years	30	15 (50.0)	15 (50.0)
Total	**120**	**33 (27.5)**	**87 (72.5)**

χ^2=11.31; p=0.010.

Summary of Principal Findings

Overall, **72.5%** of pediatric patients demonstrated significant abnormalities on brain MRI. Seizures, developmental delay, and cerebral palsy/motor deficits were the leading indications for neuroimaging. Hypoxic–ischemic/hypoglycemic-pattern sequelae constituted the most frequent predominant diagnostic category, while white-matter abnormalities were the most frequent structural finding.

MRI abnormalities were particularly frequent among children presenting with cerebral palsy/motor deficits and developmental delay. Major clinical presentation, age group, and documented hypoxic insult were significantly associated with MRI outcome, whereas sex and mode of delivery were not.

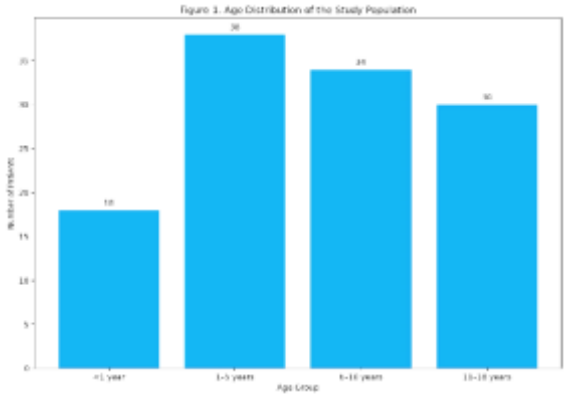

Figure 1: Age Distribution of the Study Population

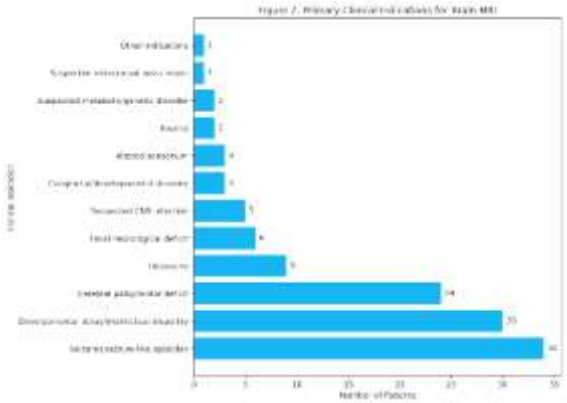

Figure 2. Primary Clinical Indications for Brain MRI

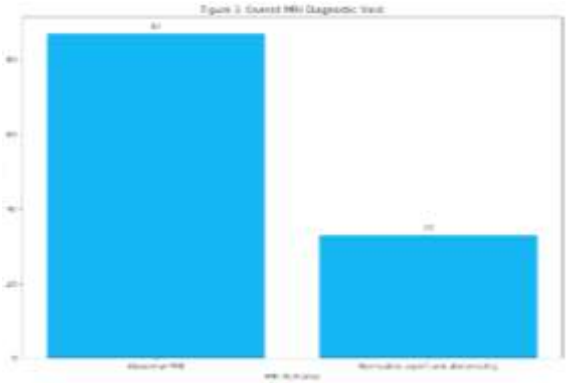

Figure 3. Overall Diagnostic Yield of Brain MRI

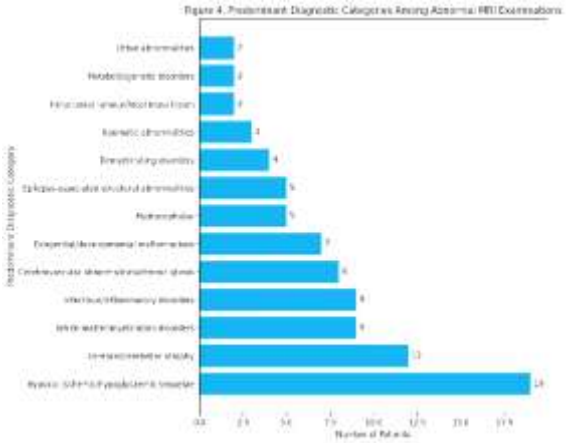

Figure 4. Predominant Diagnostic Categories Among Abnormal Brain MRI Examinations

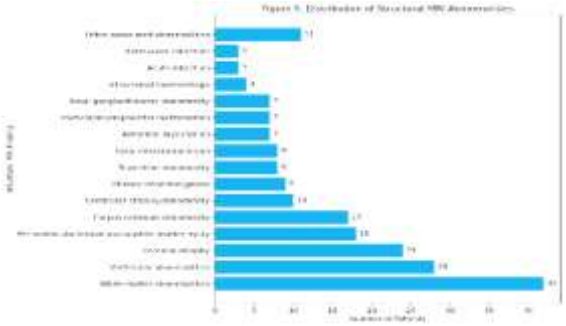

Figure 5. Distribution of Structural Abnormalities Detected on Brain MRI

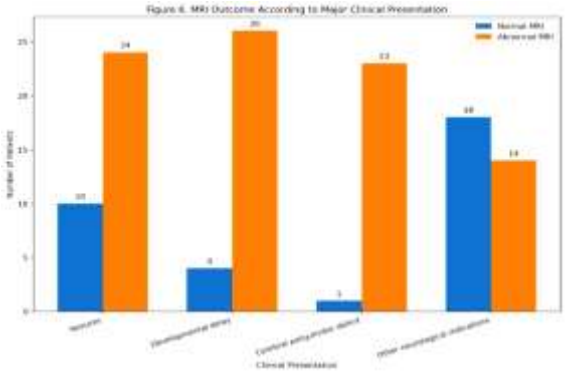

Figure 6: Brain MRI Outcome According to Major Clinical Presentation

DISCUSSION

The present study evaluated brain MRI findings in 120 pediatric patients presenting with a broad spectrum of neurological indications. Significant MRI abnormalities were identified in 87 patients (72.5%), while 33 (27.5%) had normal or no significant intracranial abnormality. Seizures or seizure-like episodes were the most frequent indication for MRI (28.3%), followed by developmental delay/intellectual disability (25.0%) and cerebral palsy or motor deficit (20.0%). Hypoxic–ischemic/hypoglycemic-pattern sequelae constituted the leading predominant diagnostic category, whereas white-matter abnormalities were the most frequent individual structural finding.

A close comparison is provided by Maheshwari et al., who retrospectively evaluated 112 pediatric brain MRI referrals across a broad range of neurological indications in India. Seizures or seizure-like episodes were their most frequent indication, followed by developmental delay and hemiparesis/cerebral palsy.[9] The distribution is similar to the present study, in which the corresponding proportions were 28.3%, 25.0%, and 20.0%, respectively. Maheshwari et al. also identified hypoxic/hypoglycemic-related sequelae as the leading imaging pattern, followed by brain atrophy.[9] These similarities suggest that seizures, developmental abnormalities, motor deficits, and sequelae of previous cerebral injury constitute an important component of pediatric neuroimaging workload in tertiary-care practice.

The overall MRI abnormality rate of 72.5% in the present study is within the broad range reported in clinically selected pediatric neurological populations. Momen et al., in a large series of 580 children with developmental delay, identified abnormal MRI findings in 340 patients (58.6%), with neurovascular/traumatic abnormalities forming the largest etiological group.[11] Kalaiarasan et al. reported an abnormal MRI yield of 64% among 100 children with developmental delay.[12] Randhawa et al. found abnormalities in 80% of their developmental-delay cohort, with evidence of perinatal hypoxic insult being the commonest pattern.[13] Alamri et al. reported abnormal MRI findings in 153 of 218 children (70%) undergoing complete assessment for global developmental delay or intellectual disability.[14]

These differences in diagnostic yield should not be interpreted as differences in MRI sensitivity. Published studies vary considerably in patient selection, age, severity of neurological impairment, inclusion of associated abnormalities, and definitions of a significant MRI finding. The present study included a broader neurological referral population rather than only children with developmental delay, making direct percentage-to-percentage comparisons inappropriate.

Within the developmental-delay subgroup of the present study, 26 of 30 children (86.7%) demonstrated abnormal MRI findings. This is notably higher than the overall study yield and supports the observation that MRI abnormalities are enriched in children with clinically evident neurodevelopmental impairment. Dittakavi et al. reported abnormal morphological MRI findings in 87.5% of 40 children with developmental delay, closely approximating the present subgroup result.[16] Their most frequently involved anatomical structure was the white matter (52.5%).[16] Similarly, Usmani et al. reported structural abnormalities in 81% of children with developmental delay, with white-matter abnormalities occurring in 63%.[18]

The developmental-delay findings are also comparable with the second reference study by Salem et al., in which 50 of 65 children (76.9%) demonstrated abnormal MRI findings. Periventricular leukomalacia was reported in 56% of abnormal examinations and cerebral atrophy in 30%.[10] In the present developmental-delay subgroup, periventricular/white-matter injury was observed in 53.8% and cerebral atrophy in 30.8%, showing a close numerical correspondence.

White-matter abnormalities were the most frequent structural finding in the entire present cohort, occurring in 42 patients (35.0%). Periventricular leukomalacia/white-matter injury was identified separately in 18 patients (15.0%). White-matter abnormalities are repeatedly reported in children with developmental and neurological impairment. Alamri et al. identified white-matter abnormalities in 104 of 153 abnormal MRI examinations (68%), making them the most frequently affected structure in their cohort.[14] Widjaja et al., in 90 children with idiopathic developmental delay, reported abnormal MRI findings in 84%, including white-matter abnormalities in 26%, ventricular abnormalities in 48%, and corpus callosum abnormalities in 44%.[20]

The present study also demonstrated ventricular abnormalities in 23.3%, cerebral atrophy in 20.0%, and corpus callosum abnormalities in 14.2% of the total cohort. These percentages were higher within the developmental-delay subgroup, in which corpus callosum abnormalities occurred in 30.8% and ventricular abnormalities in 26.9%. Differences from the higher frequencies described by Widjaja et al. are expected because their cohort was specifically enriched for developmental delay with additional clinical abnormalities, whereas the present study included heterogeneous neurological indications.[20]

The predominance of hypoxic-related imaging abnormalities is another important finding. Hypoxic–ischemic/hypoglycemic-pattern sequelae constituted the predominant diagnostic category in 19 of 87 abnormal MRI examinations (21.8%), corresponding to 15.8% of the overall study population. Maheshwari et al. similarly reported hypoxic/hypoglycemic-related injury as their leading diagnostic pattern.[9] Kalaiarasan et al. found traumatic/neurovascular abnormalities in 30% of their cohort, including hypoxic–ischemic encephalopathy in 12 patients and periventricular leukomalacia in 10.[12]

Das et al. reported hypoxic–ischemic insult as the most frequent etiological category, accounting for 32.7% of 110 children younger than 5 years with developmental delay. Their study also demonstrated a significant association between a history of perinatal hypoxic insult and hypoxic–ischemic MRI changes ($p<0.01$).[17] The present study similarly demonstrated a strong association: 26 of 27 children (96.3%) with a documented significant hypoxic insult had abnormal MRI findings, compared with 65.6% of those without such a history (Fisher's exact test, $p=0.001$).

This association should nevertheless be interpreted carefully. A history of hypoxic insult increases the likelihood of structural MRI abnormalities but does not establish hypoxia as the cause of every detected lesion. MRI morphology, timing, clinical history, laboratory data, and perinatal records must be considered together before assigning a specific etiology. Koul et al. similarly found that perinatal history was significantly associated with the ability to identify an underlying etiology in children with global developmental delay, while abnormal MRI itself was strongly associated with etiological detection.[19]

Seizures were the commonest indication for MRI in the present study, and 24 of 34 children (70.6%) presenting primarily with seizures demonstrated an abnormal MRI. Mathur et al. studied 50 pediatric patients presenting with seizures and reported structural abnormalities in approximately one-third

of examinations; inflammatory granulomas and hypoxic–ischemic injury were among the leading abnormalities.[15] The higher yield observed in the present seizure subgroup may reflect differences in referral criteria, underlying neurological comorbidity, disease spectrum, and selection of patients for MRI rather than a difference in imaging performance.

The strongest MRI yield in the present study occurred among children presenting with cerebral palsy or motor deficit (95.8%), followed by developmental delay (86.7%) and seizures (70.6%), compared with 43.8% among other neurological indications. The relationship between major clinical presentation and MRI outcome was statistically significant (χ^2=22.90, p<0.001). Alamri et al. similarly found a high prevalence of MRI abnormalities among children with predominant motor delay and reported significant associations between selected neurological examination abnormalities and abnormal MRI findings.[14] These observations emphasize that clinical phenotype substantially influences MRI diagnostic yield.

Age group was also significantly associated with MRI outcome in the present study (p=0.010). Abnormal findings occurred in 83.3% of patients younger than 1 year, 84.2% of those aged 1–5 years, 73.5% of those aged 6–10 years, and 50.0% of those aged 11–18 years. The greater yield in younger children may reflect referral enrichment for congenital, perinatal, developmental, and early neurological disorders. Age itself, however, should not be interpreted as a causal determinant of structural brain abnormalities.

In contrast, Salem et al. found no significant association between age and abnormal MRI/developmental findings (p=0.603).[10] Their cohort was smaller and restricted to children with developmental delay, whereas the present study included a broader spectrum of neurological disorders. This difference illustrates the influence of study design and case selection on age-related associations.

Sex was not significantly associated with MRI outcome in the present study (p=0.366). Although abnormal findings were somewhat more frequent among females (78.3%) than males (68.9%), this difference was not statistically significant. Salem et al. similarly reported no significant sex association (p=0.385).[10] Therefore, the present findings do not support sex as an independent clinical discriminator for predicting an abnormal pediatric brain MRI.

Mode of delivery also showed no significant relationship with MRI outcome (p=0.676). Abnormal MRI findings occurred in 70.7% of children delivered vaginally and 76.3% of those delivered by caesarean section. Salem et al. likewise reported no significant association between mode of delivery and MRI findings (p=0.164).[10] These observations suggest that documentation of a specific hypoxic or neurological perinatal event is clinically more informative than mode of delivery alone.

An important finding is that 27.5% of children had normal or no significant structural MRI abnormality despite neurological symptoms. Das et al. reported an almost identical normal MRI proportion of 27.2% in children with developmental delay.[17] A normal conventional MRI does not exclude epilepsy, metabolic or genetic disease, subtle neurodevelopmental abnormalities, or functional disturbances. Usmani et al. further demonstrated the potential value of advanced techniques by identifying abnormal proton MR spectroscopy metabolite ratios in a proportion of developmentally delayed children whose conventional MRI was structurally normal.[18]

Overall, the present findings are consistent with the broader pediatric neuroimaging literature. The relatively high diagnostic yield, predominance of white-matter and hypoxic-related abnormalities, and higher rate of abnormal MRI among children with developmental or motor deficits support the importance of clinically directed neuroimaging. At the same time, MRI findings should be interpreted as one component of a multidisciplinary diagnostic process and not as a substitute for detailed neurological, developmental, metabolic, electrophysiological, and genetic evaluation where indicated.

Strengths

The study included a broad spectrum of pediatric neurological presentations rather than restricting analysis to a single disease group. Clinical indications, predominant diagnostic categories, individual structural abnormalities, developmental-delay findings, and selected demographic and perinatal factors were analysed separately.

An important methodological strength was the distinction between predominant diagnostic category and individual structural abnormalities. Each abnormal MRI was assigned to one predominant diagnostic category, whereas multiple anatomical abnormalities could be recorded in the same patient. This approach avoids inappropriate summation or double counting of diagnostic categories.

The study also incorporated clinical–radiological correlation by examining MRI outcomes according to age, sex, major clinical presentation, developmental delay, hypoxic insult, and mode of delivery.

Limitations

This was a single-center retrospective hospital-based study, and the study population consisted of children referred for MRI because of neurological indications. The findings therefore represent the diagnostic spectrum of a clinically selected cohort and should not be interpreted as population prevalence.

Clinical presentations were heterogeneous, and some diagnostic subgroups contained relatively small numbers of patients. Information regarding

perinatal events and previous clinical history depended on the completeness of available medical records.

Additional MRI sequences, contrast-enhanced imaging, angiography, spectroscopy, and other advanced techniques were performed according to clinical indication rather than uniformly in all patients. Consequently, subtle abnormalities detectable only by specialized imaging techniques may have been under-recognized.

Genetic, metabolic, electrophysiological, and other confirmatory investigations were not uniformly available for all patients. MRI appearances classified as hypoxic–ischemic, metabolic, genetic, or other etiological patterns therefore require appropriate clinical correlation and should not be considered definitive etiological diagnoses based on imaging alone.

Future Directions

- Prospective multicenter studies using standardized pediatric neuroimaging protocols and uniform definitions of structural abnormalities are needed to validate these findings in larger populations.
- Future research should integrate conventional MRI with developmental assessment, electroencephalography, metabolic testing, genomic investigations, and advanced imaging modalities such as diffusion tensor imaging, susceptibility-weighted imaging, MR spectroscopy, and quantitative volumetric analysis when clinically appropriate.
- Longitudinal studies correlating baseline MRI patterns with subsequent motor, cognitive, developmental, seizure, and functional outcomes would further clarify the prognostic relevance of individual imaging abnormalities.

CONCLUSION

Brain MRI demonstrated significant structural abnormalities in 72.5% of pediatric patients evaluated for neurological indications. Seizures were the most frequent clinical indication, followed by developmental delay and cerebral palsy or motor deficits.

Hypoxic–ischemic/hypoglycemic-pattern sequelae constituted the leading predominant diagnostic category, while white-matter abnormalities represented the most frequent individual structural finding. MRI abnormalities were particularly frequent among children presenting with motor deficits, developmental delay, and a documented history of hypoxic insult.

Major clinical presentation, age group, and documented hypoxic insult were significantly associated with MRI outcome, whereas sex and mode of delivery were not. These findings emphasize the value of integrating detailed clinical and perinatal information with systematic MRI assessment in the evaluation of pediatric neurological disorders.

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