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Role of Magnetic Resonance Imaging Brain in Children with Developmental Delay: An Observational Study

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1. INTRODUCTION

Developmental delay (DD) is a common pediatric concern characterized by the failure to achieve age-appropriate milestones in one or more domains of development, including gross and fine motor skills, speech and language, cognition, and social/personal interaction. It affects approximately 5–10% of children under five years of age globally, with higher prevalence reported in low- and middle-income countries due to perinatal complications, malnutrition, and limited healthcare access [1,2]. Early identification and evaluation are critical for timely intervention, which can significantly improve functional outcomes and quality of life.

Neuroimaging plays a vital role in the etiological evaluation of developmental delay. Among various imaging modalities, Magnetic Resonance Imaging (MRI) of the brain is considered the gold standard due to its superior soft tissue contrast, multiplanar capabilities, and non-ionizing nature, making it particularly suitable for the pediatric population [3]. MRI can detect a wide range of structural abnormalities, including periventricular leukomalacia, cortical malformations, delayed myelination, and hypoxic-ischemic injuries, which are often implicated in DD [4].

Numerous studies have demonstrated that MRI reveals abnormal findings in 30–80% of children with unexplained developmental delay, especially when associated with neurological signs such as seizures, microcephaly, or abnormal neurological examination [5,6]. The diagnostic yield is significantly increased when MRI is guided by a thorough clinical history and examination.

Hence, this study aims to evaluate the role of brain MRI in identifying structural abnormalities in children presenting with developmental delay and to correlate radiological findings with clinical features, which may aid in establishing a diagnosis and guiding further management.

2. MATERIALS AND METHOD

This was a prospective observational study conducted in the Department of Paediatrics and Radiology, Meenakshi medical college hospital and research institute, Kanchipuram, Tamilnadu at a tertiary care teaching hospital over a period of 12 months.Children aged 6 months to 12 years presenting to the paediatric outpatient or inpatient department with a clinical diagnosis of developmental delay were included in the study. Developmental delay was defined as a significant lag (greater than two standard deviations) in achieving age-appropriate developmental milestones in one or more domains : gross motor, fine motor, speech and language, cognitive, social, or adaptive behaviour. In the study we have included 36 patients who have followed following inclusion and exclusion criteria and after getting informed consent from them..

Inclusion Criteria

Children aged between 6 months and 12 years

Clinically diagnosed with global or specific developmental delay

Referred for MRI brain as part of diagnostic workup

Informed written consent obtained from parents or guardians

Exclusion Criteria

Children with known neurodegenerative or metabolic disorders

- History of head trauma or prior neurosurgical intervention
- Contraindications to MRI (e.g., pacemakers, ferromagnetic implants)
- Refusal of consent by parents or guardians

Method

A detailed clinical history was obtained, including perinatal events (birth asphyxia, prematurity, low birth weight), developmental history, family history of neurological disorders, and any associated comorbidities (e.g., seizures, microcephaly, visual/hearing impairment). A thorough physical and neurological examination was performed.

Imaging Protocol

All patients underwent brain MRI using a 1.5 Tesla scanner. The following sequences were acquired in axial, coronal, and sagittal planes:

T1-weighted

T2-weighted

Fluid Attenuated Inversion Recovery (FLAIR)

Diffusion Weighted Imaging (DWI)

Susceptibility Weighted Imaging (SWI)

T2* gradient sequences when indicated

Contrast-enhanced studies were done in selected cases where intracranial infection or neoplasm was suspected.

Radiological Evaluation

MRI brain scans were reviewed independently by two experienced radiologists blinded to clinical details. Structural abnormalities were categorized as:

White matter abnormalities (e.g., hypoxic-ischemic changes, leukomalacia)

Grey matter abnormalities (e.g., cortical malformations)

Ventricular and midline structural anomalies

Cerebellar and brainstem abnormalities

Delayed myelination or dysmyelination

Miscellaneous findings (e.g., cysts, hemorrhage, infections)

Statistical Analysis

Data were compiled and analyzed using SPSS software version 25 (IBM Corp., USA). Descriptive statistics were used for baseline demographic and clinical variables. Categorical variables were expressed as frequencies and percentages. Association between variables were analyzed using Chi-square or Fisher's exact test, and a p-value of <0.05 was considered statistically significant.

Observation and Results

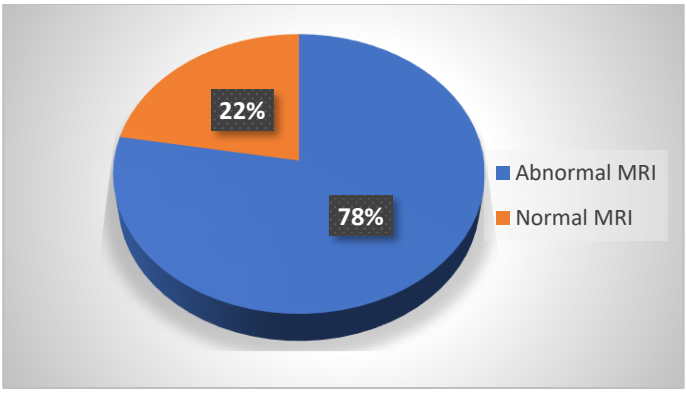
Table 1 : Distribution of demographic profile among study population

Parameters	Frequency	Percentage

Age		
< 2 Years	12	33.3
2 - 5 Years	15	41.7
6 - 10 Years	6	16.7
> 10 Years	3	8.3
Gender		
Male	21	58.3
Female	15	41.7
Residence		
Urban	20	55.6
Rural	16	44.4
Birth Weight		
<2.5 kg (Low birth weight)	11	30.6
≥2.5 kg	25	69.4

The study comprised 36 children with developmental delay, categorized by age, gender, residence, and birth weight. Most children (41.7%) were between 2 to 5 years, followed by 33.3% under 2 years. A smaller proportion included children aged 6–10 years (16.7%) and those above 10 years (8.3%). The study sample had a slight male predominance with 58.3% males and 41.7% females. In terms of residence, the majority were from urban areas (55.6%), while 44.4% resided in rural areas. Notably, 30.6% of the children were born with low birth weight (<2.5 kg), whereas 69.4% had normal birth weight (≥2.5 kg), indicating a substantial number with early neonatal risk factors.

Table 2: Distribution of MRI Findings among study population



MRI scans of the study population revealed that a significant proportion (77.8%) of children with developmental delay had abnormal findings on MRI, while only 22.2% had normal MRI scans. This highlights the utility of neuroimaging in diagnosing underlying structural or developmental brain abnormalities in children with developmental concerns.

Table 3: Distribution of Clinical presentation among study population

Clinical Parameter	Present (n)	Percentage (%)
Birth Asphyxia	10	27.8
Prematurity (<37 weeks)	8	22.2
Low Birth Weight (<2.5 kg)	11	30.6

Seizures	13	36.1
Microcephaly	9	25
Visual Impairment	6	16.7
Hearing Impairment	4	11.1
Positive Family History	5	13.9
Speech delay	27	75
Motor delay	21	58.3
Behavioral abnormalities (e.g., ASD)	3	8.3

The clinical characteristics revealed a spectrum of risk factors and comorbidities. Birth asphyxia was present in 27.8% of children, and 22.2% were born prematurely. Low birth weight was observed in 30.6%, reflecting perinatal complications. Seizures (36.1%) and microcephaly (25%) were also frequent findings. Visual and hearing impairments were reported in 16.7% and 11.1%, respectively. A positive family history of neurological disorders was present in 13.9% of cases. Developmental delay was largely evident in domains like speech (75%) and motor skills (58.3%). Behavioral abnormalities, including autism spectrum disorder (ASD), were noted in 8.3% of the children, further reinforcing the need for thorough developmental assessment.

Table 4 : Distribution of MRI Abnormalities among study population

MRI Abnormality	Frequency	Percentage
Periventricular leukomalacia (PVL)	8	28.60%
Cerebral atrophy	6	21.40%
Delayed myelination	5	17.90%
Hypoxic-ischemic encephalopathy (HIE) changes	5	17.90%
Cortical malformations (e.g., pachygyria)	4	14.30%
Ventriculomegaly	4	14.30%
Agenesis of corpus callosum	2	7.10%

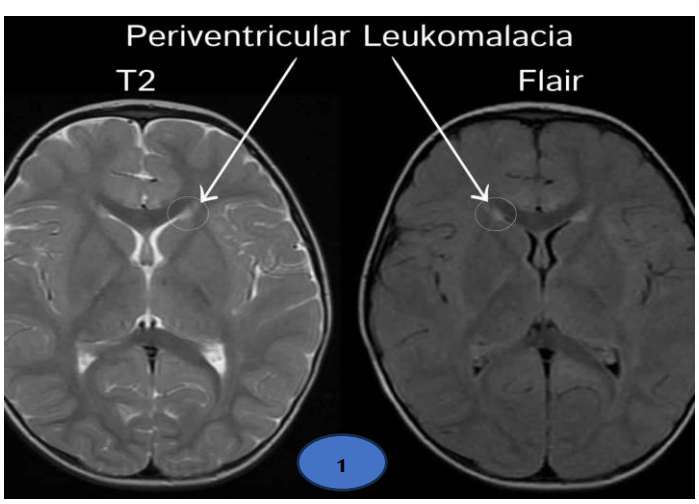
Among children with abnormal MRI findings, periventricular leukomalacia (PVL) was the most common abnormality, accounting for 28.6% of cases. Cerebral atrophy was identified in 21.4% of children. Both delayed myelination and hypoxic-ischemic encephalopathy (HIE) changes were found in 17.9% each. Cortical malformations such as pachygyria and ventriculomegaly were observed in 14.3% of children each, while agenesis of the corpus callosum was noted in 7.1%. These abnormalities indicate a wide range of structural brain pathologies contributing to developmental delays.

Table 5: Association between age, gender and MRI findings

Parameters	MRI Findings		Total	Chi-square	p-value
	Abnormal MRI	Normal MRI			
Age					
< 2 Years	12(33.3%)	0(0%)	12	13.71	<0.001
2 - 5 Years	13(36.1%)	2(5.6%)	15		
6 - 10 Years	2(5.6%)	4(11.1%)	6		
> 10 Years	1(2.8%)	2(5.6%)	3		
Gender					
Male	18(50%)	3(8.3%)	21	1.83	0.175

Female	10(27.8%)	5(13.9%)	15		

Statistical analysis demonstrated a significant association between age and MRI findings. All children under 2 years (33.3%) had abnormal MRIs, while the proportion of abnormal findings decreased with increasing age ($p < 0.001$). This suggests that earlier presentation of developmental delay is more likely to have correlating structural abnormalities. Gender-wise analysis showed that 50% of males and 27.8% of females had abnormal MRI findings, but this difference was not statistically significant ($p = 0.175$), indicating that gender was not strongly associated with MRI abnormalities in this cohort.



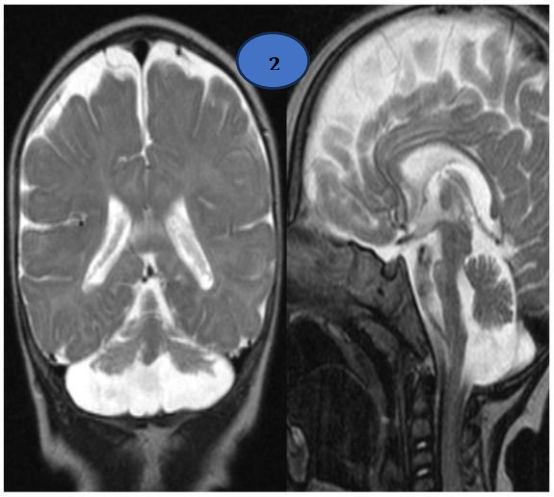


Image 1: Hyperintense (bright) signals around the ventricles indicate white-matter injury; FLAIR distinctly highlights periventricular gliosis.

Image 2: Coronal MRI showing cortical thinning and sulcal widening

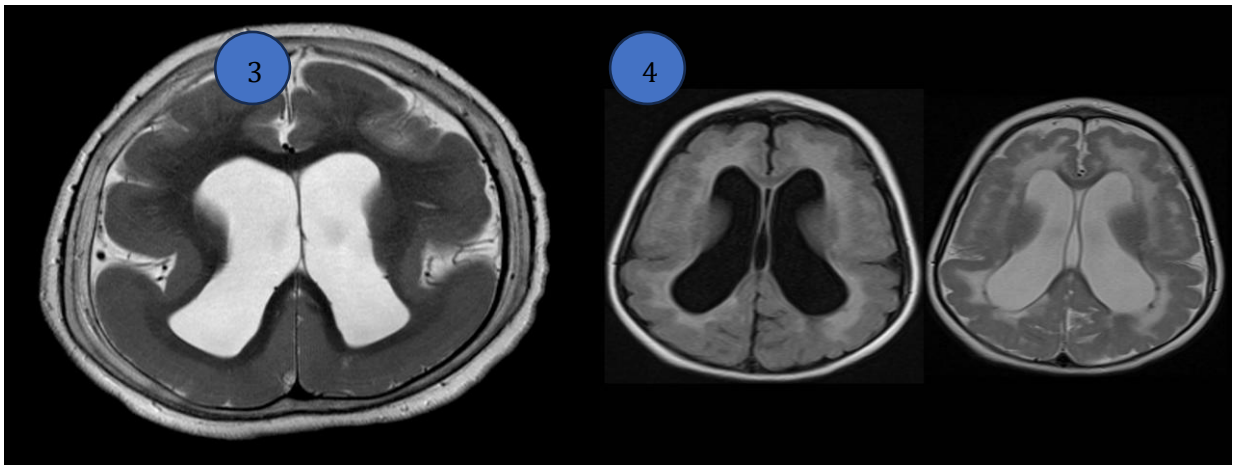


Image 3: Shows broad, flattened gyri and shallow sulci—hallmarks of pachygyria.

Image 4: Highlights the smoothened cortical surface with incomplete sulcation and thickened cortex—two defining features of pachygyria.

3. DISCUSSION

Developmental delay (DD) is a common pediatric concern that encompasses impairments across motor, speech-language, cognitive, and social domains. Timely identification of underlying etiologies is essential for appropriate management and prognosis. Neuroimaging, particularly Magnetic Resonance Imaging (MRI), has emerged as a crucial tool in evaluating structural brain abnormalities in children presenting with developmental delay.

In the present study involving 36 children with developmental delay, a high proportion (77.8%) demonstrated abnormal MRI findings. Anand Mathew et al. (2020) conducted a cross-sectional study involving 60 Indian children (6 months–12 years)

with developmental delay. They found that 75% of the children had abnormal MRI findings, highlighting MRI's significant diagnostic utility in such cases[7]. Similarly, Sharma V, et al. In a cross-sectional study of 50 Indian children aged 6 months to 6 years with developmental delay, brain MRI revealed abnormalities in 72 % of cases—highlighting its substantial diagnostic value in neurodevelopmental disorders[8]. Dittakavi et al., who reported an even higher abnormality rate of 87.5% among 40 children aged 6 months to 12 years.[9] our results confirm MRI's pivotal role while suggesting slightly lower yet substantial yield in similar settings. Vaghela et al. also found a high prevalence of MRI abnormalities in pediatric developmental delay—a rate of approximately 81.4% (110/135 cases) [10]

The most frequent MRI abnormality in our study was periventricular leukomalacia (PVL) (28.6%), a white matter injury commonly associated with prematurity and birth asphyxia. This correlates with other study, they studied 153 children aged 6 months to 12 years with developmental delay and found 32% had periventricular white matter changes—many consistent with periventricular leukomalacia—making PVL the most common MRI lesion subtype in their cohort [11], paralleling Vaghela et al.'s findings, who identified white matter anomalies—in particular, periventricular and diffuse types—as the predominant abnormality (around 30–35%). Cerebral atrophy (21.4%) and delayed myelination (17.9%) were also prevalent, similar to the findings of Singh et al. conducted a prospective observational study involving 75 children aged between 6 months and 12 years presenting with developmental delay, to evaluate the diagnostic yield of magnetic resonance imaging (MRI). Their findings demonstrated that cerebral atrophy was present in 22.7% of the cases, while delayed or hypomyelination was observed in 18.7% of the children. These results highlight the important role of MRI in identifying underlying structural abnormalities in the developing brain, contributing significantly to the diagnostic workup of neurodevelopmental disorders[12]. Delayed myelination and cerebral atrophy in our group also mirror their results, with cerebral atrophy reported in roughly 20% of Vaghela's cohort [10].

Cortical malformations, including ventriculomegaly, pachygyria, and agenesis of the corpus callosum (totaling ~21.4%), were noted at slightly lower rates than in Vaghela's cohort, where congenital malformations accounted for 25–30% . Variations may stem from referral patterns or inclusion criteria differences[10].

In our study, a notable 27.8% of children had a history of birth asphyxia, and 22.2% were premature both well-established risk factors for adverse neurodevelopmental outcomes. This finding is in agreement with those reported by Panigrahy et al., who emphasized the role of hypoxic-ischemic events in structural brain injury detectable on MRI [13]. The presence of hypoxic-ischemic encephalopathy (HIE) changes in 17.9% of our children further corroborates this. Vaghela et al. similarly linked perinatal insults to MRI abnormalities, reporting asphyxia/prematurity in about one-third of cases[10] . The presence of HIE changes (17.9%) in our sample also reflects this clinical profile.

Speech delay was the most frequent clinical presentation (75%), followed by motor delay (58.3%), aligning with results from Ravichandran G et al., in this Karnataka-based cohort, comprehensive milestone assessments revealed that delays in both motor and language domains often co-occurred, reflecting global developmental delay in many cases [14]. Seizures were also common (36.1%) in our cohort, which is comparable to observations made in similar Indian studies [8, 12].

Our study and study by Dittakavi et al underscore birth asphyxia, prematurity, and low birth weight as common antecedents. These risk factors are known to contribute to PVL, cerebral atrophy, and hypoxic changes—patterns recognized in both cohorts. This convergence reinforces the etiological link between perinatal insult and structural brain abnormalities detectable on MRI[9].

Statistical analysis showed a significant correlation between younger age groups (<2 years) and abnormal MRI findings ($p < 0.001$), implying that early-onset developmental delays are more likely to have structural correlates. This is similar to observations by Majumdar et al., who reported higher detection rates in infants compared to older children [7]. However, no significant association was found between gender and MRI abnormalities in our study ($p = 0.175$), which concurs with previous research by Sreenivas et al. [12]. Our study and study by Vaghela's observed, that younger children (<2 years) had a higher frequency of structural abnormalities. Although Vaghela et al. did not provide age-stratified statistics, their inclusion of infants and early childhood populations showed a similar trend toward increased detection in younger ages[10].

In the U.S., major guidelines (Shevell et al.) report that brain MRI abnormalities are observed in 60–80% of children with developmental delay, underscoring MRI's global clinical value. [15].

The heterogeneity of MRI abnormalities including PVL, HIE, cerebral atrophy, delayed myelination, and cortical malformations indicates that developmental delay is often multifactorial in etiology. The integration of detailed clinical history, developmental assessment, and MRI findings is essential for holistic evaluation and early intervention.

4. CONCLUSION

Our study highlights the significant role of MRI in evaluating children with developmental delay, with a high proportion of cases showing abnormal neuroimaging findings. The most commonly observed abnormalities included periventricular leukomalacia, cerebral atrophy, and delayed myelination. A strong association was noted between early age at presentation and the presence of MRI abnormalities. These findings emphasize the importance of early neuroimaging in the diagnostic

workup of developmental delay, as it aids in identifying underlying structural brain abnormalities and guiding appropriate intervention and management strategies.

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