Original Article

Magnetic Resonance Imaging (MRI) Evaluation of Neurological Disorders in Pediatric Patients

MRI Evaluation of Neurological Disorders

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ABSTRACT

Objective: To determine the prevalence and pattern of magnetic resonance imaging-detected structural brain abnormalities among children with developmental delay and to assess their association with demographic features, hypoxic insults, and underlying etiological factors.

Study Design: Prospective observational study

Place and Duration of Study: This study was conducted at the Baghdad Medical City and the Children's Central Teaching Hospital, Iraq from 1st October 2024 to 31st January 2025.

Methods: 65 pediatric patients were enrolled, aged between 1 month and 15 years were recruited. Children with previously confirmed genetic syndromes or metabolic disorders were excluded to ensure a more homogeneous population and to focus specifically on structural and neurological causes of developmental delay. This study provides a unique contribution by combining structured MRI data with a clinical correlation matrix of risk factors in a homogeneous pediatric cohort, offering insights into the predictive potential of imaging for early intervention planning.

Results: Fifty (76.9%) had abnormal magnetic resonance imaging findings. The most common abnormalities were periventricular leukomalacia (56%), cerebral atrophy (30%), and schizencephaly (14%), all significantly associated with developmental delays ($p<0.001$). Hypoxic insults were also strongly correlated with delay ($p<0.001$), whereas mode of delivery had no significant association ($p = 0.164$). The leading etiological contributors were traumatic brain injuries (72%), metabolic disorders (70%), and neurovascular diseases (64%).

Conclusion: Magnetic resonance imaging demonstrated high diagnostic yield in detecting structural brain abnormalities among children with developmental delay. The findings emphasize the importance of early neuroimaging and the recognition of clinical risk factors particularly hypoxic injury, trauma, and metabolic imbalanceas key contributors to neurodevelopmental impairment in pediatric populations.

Key Words: Magnetic resonance imaging, Pediatric neurology, Developmental delay, Periventricular leukomalacia, Traumatic brain injury, Neurovascular disorders, Metabolic disorders

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INTRODUCTION

Magnetic Resonance Imaging (MRI) has emerged as a cornerstone in pediatric neurodiagnostics due to its superior soft-tissue contrast, multiplanar capabilities, and the advantage of avoiding ionizing radiation exposure, making it particularly suitable for use in children.[1,2] It plays a pivotal role in diagnosing a wide spectrum of neurological conditions including developmental delay, congenital malformations, metabolic and degenerative disorders, demyelinating diseases, traumatic brain injury, and brain tumors.[3,4]

Technological advancements have further enhanced the diagnostic scope of MRI through specialized modalities such as Diffusion-Weighted Imaging (DWI), Diffusion Tensor Imaging (DTI), Functional MRI (fMRI), and Magnetic Resonance Spectroscopy (MRS).[5-7] These techniques provide critical structural and functional insights. For instance, DWI is instrumental in identifying early hypoxic-ischemic injury by differentiating between acute and chronic lesions[5,6], while DTI reveals microstructural abnormalities in white matter tracts, facilitating diagnosis of myelin-related pathologies and subtle developmental disorders.[6] fMRI has expanded our understanding of pediatric brain function, and MRS offers biochemical profiles useful in detecting metabolic disturbances linked to neurodevelopmental delays.[7,8]

Despite its diagnostic advantages, performing MRI in young children remains challenging due to their inability to stay still during scanning, often

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necessitating sedation or general anesthesia, which introduces additional clinical risks such as respiratory depression.[9-11] Consequently, pediatric MRI requires rigorous sedation protocols, specialized staff, and infrastructure adapted to the pediatric population to ensure safety and image quality.[8,9] Moreover, standardized imaging protocols and continuous professional training are essential for reliable image interpretation and accurate diagnosis.[9]

The prevalence and pattern of MRI-detected structural abnormalities in pediatric patients with developmental delay, emphasizing conditions such as periventricular leukomalacia (PVL), cerebral atrophy, and neuronal migration disorders like schizencephaly.[10,11] MRI's high diagnostic yield, particularly in contrast to modalities such as CT and ultrasonography, positions it as the gold standard in neurodevelopmental imaging.[12,13] In addition to detecting pathology, MRI also provides valuable prognostic information that can guide early intervention strategies, ultimately improving cognitive and motor outcomes and the overall quality of life in affected children.[13] The current study aims to evaluate the prevalence and pattern of structural brain abnormalities detected by MRI in pediatric patients presenting with developmental delays. Furthermore, it investigates the association of MRI findings with various demographic and clinical factors, such as hypoxic insults, traumatic brain injuries, and metabolic disorders. By addressing these associations, the study provides critical insights into the predictive value of MRI findings, contributing to earlier diagnosis and tailored intervention strategies in pediatric neurological disorders.

METHODS

This prospective observational study was conducted at Baghdad Medical City and the Children's Central Teaching Hospital from 1st October 2024 to 31st January 2025 and approved by the Ethics Committee of the College of Medicine, Al-Iraqia University letter No. 86 dated 6-8-2024. A total of 65 children, aged between 1 month and 15 years were recruited. Children with previously confirmed genetic syndromes or metabolic disorders were excluded to ensure a more homogeneous population and to focus specifically on structural and neurological causes of developmental delay. This study provides a unique contribution by combining structured MRI data with a clinical correlation matrix of risk factors in a homogeneous pediatric cohort, offering insights into the predictive potential of imaging for early intervention planning.

MRI examinations were performed using Siemens MRI scanners, and a selected array of imaging sequences for the highest quality of diagnostic accuracy was employed. The following sequences were used: -

- T1-weighted imaging – anatomical brain structure assessment
- T2-weighted imaging – abnormal white and gray matter detection.
- Fluid-Attenuated Inversion Recovery (FLAIR) – to bring down cerebrospinal fluid signals and bring brain lesions to the forefront.
- Diffusion-Weighted Imaging (DWI) – for finding ischemic and hypoxic changes. T2 Turbo Spin Echo (T2 TSE) – for lesion contrast and tissue characterization.

The first priority was image quality. Therefore, ardent measures needed to be taken, such as sedation (oral or intravenous) or general anesthesia, which was given duly when required, especially in younger children or those who cannot be still for the imaging.

MRI scans were performed using a Siemens 1.5T scanner with the following sequences: axial T1-weighted (TR/TE=500/10 ms), T2-weighted (TR/TE=3000/100 ms), Fluid-Attenuated Inversion Recovery (FLAIR) (TR/TE=9000/114 ms), Diffusion-Weighted Imaging (DWI) with b-values of 0 and 1000 s/mm², and T2 Turbo Spin Echo (T2 TSE). Sedation or general anesthesia was administered as necessary under pediatric sedation protocols to ensure optimal image quality.

Diffusion-Weighted Imaging (DWI) was specifically employed in this study to detect acute ischemic and hypoxic-ischemic brain injuries, enabling the differentiation between cytotoxic and vasogenic edema. This imaging modality provides additional diagnostic insights beyond conventional MRI sequences, particularly in pediatric populations presenting with neurological emergencies.

All MRI images were independently reviewed by two board-certified pediatric neuroradiologists, blinded to the clinical history, to ensure objective interpretation. Structural abnormalities were categorized based on predefined diagnostic criteria and included conditions such as periventricular leukomalacia (PVL), cerebral atrophy, and schizencephaly. The data was entered and analyzed through SPSS-26. Chi-square tests were applied to examine associations between imaging results and clinical variables.

RESULTS

There were 37 (56.9%) males and 28 (43.1%) females. Majority of cases were found under two years of age, 30 (46.2%) cases followed by 2-5 years 22 (33.8%) cases, 6-10 years, 11 (16.9%) cases and more than 10 years, only 2 (3.1%) cases. The evidence of a higher rate of delayed developmental milestones among younger children, particularly children below 2 years old, is the basis for the study's conclusion, which shows the necessity for early diagnosis and targeted therapeutic measures (Tables 1-2).

The majority presented with deviations in MRI, indicating the strong relationship structural brain diseases have with the delayed developmental

milestones. Deviations in 50 patients (76.9%) were found in MRI images, suggesting a link between neuroimaging changes and problems with the child's development. Other than that, 15 patients (23.1%) with standard MRI images that looked typical had delayed early milestones, meaning such people may have diseases that cannot be exactly discovered through a routine MRI scan (Table 3).

The most common aetiology observed was periventricular leukomalacia (PVL), which was detected in 28 patients (56%), thus pointing out the strong association between white matter injury and neurodevelopmental impairment. Cerebral atrophy, which was identified in 15 patients (30%), was the second most common finding, suggesting significant neuronal loss or impaired brain growth as a contributing factor. Schizencephaly, a congenital disorder involving the cortical clefts of the brain, was found in 7 cases (14%), and it is additional evidence of its role in severe developmental delay (Table 4).

All participants aged over 10 years (100%) had delayed milestones. The prevalence was 80% among the children aged <2 years, 77.3% in the 2-5 year range, and 63.6% in the 6-10 year group. Yet, no statistically significant association was identified between age and the delayed milestones (p=0.603). These results indicate that developmental setbacks can be observed at various ages with no evident pattern. In females, the prevalence of abnormal MRI findings slightly increased (82.1%) compared to males (73%). Nevertheless, the difference was not statistically significant (p=0.385), implying that sex does not substantially impact the occurrence of neurological developmental disorders (Table 5).

Table No. 1: Descriptive statistics

Variable	Mean±SD
Age	1.77±0.84
Hypoxic Insult	0.60±0.49
Traumatic Disease	0.55±0.50
Neurovascular Disease	0.49±0.50
Metabolic Disorder	0.54±0.50
Final Diagnosis Score	2.14±1.21

Table No. 2: Frequency of age (n=65)

Age (years)	No.	%
<2	30	46.2
2-5	22	33.8
6-10	11	16.9
>10	2	3.1

Table No. 3: Classification of patients on MRI findings

MRI Findings	No.	%
Normal	15	23.1
Delay milestone (abnormal MRI)	50	76.9

Table No. 4: **Distribution of diseases leading to delayed milestones**

Disease	No. (%)	p-value
Periventricular leukomalacia	28 (56%)	<0.001
Atrophy	15 (30%)	<0.001
Schizencephaly	7 (14%)	<0.001

Table No. 5: Associate between age and gender with MRI findings

Variable	Normal MRI	Abnormal MRI	p-value
Age (years)			
<2	6 (20%)	24 (80%)	0.603 (NS)
2-5	5 (22.7%)	17 (77.3%)	
6-10	4 (36.6%)	7 (63.6%)	
>10	-	2 (100%)	
Gender			
Male	10 (27%)	27 (73%)	0.385 (NS)
Female	5 (17.9%)	23 (82.1%)	

Table No. 6: Association between mode of delivery and hypoxic insult with MRI findings

Variable	Normal MRI	Abnormal MRI	p-value
Mode of delivery			
Vaginal	12 (23.1%)	40 (76.9%)	0.164 (NS)
Cesarean	2 (16.7%)	10 (83.3%)	
Hypoxic insult perinatal			
Yes	-	35 (100%)	<0.001
No	15 (50%)	15 (50%)	
Natal			
Yes	-	41 (100%)	<0.001
No	15 (62.5%)	9 (37.5%)	
Postnatal			
Yes	-	39 (100%)	<0.001
No	15 (57.7%)	11 (42.3%)	

No statistically significant relationship was found between delivery mode and milestone delays (p = 0.164). The prevalence of abnormal MRI findings was practically the same in the two groups; vaginal delivery: 76.9% of them had abnormal MRI findings. Cesarean section: 83.3% had abnormal MRI findings. Hypoxic events, irrespective of the timing (perinatal, natal, or postnatal), were strongly correlated with the delayed milestones (p < 0.001). Participation in hypoxic events, which led to structural brain abnormalities, was shown by all children (100%), thus confirming the crucial role of oxygen deprivation in neurodevelopmental impairment (Table 6).

White matter abnormalities comprised the dominant observed result, with 49 children (100%) affected, confirming the significant part played by the white matter's viability in the neurodevelopment process. Also, ventricular congenital defects were omnipresent in 32 patients (100%), revealing a strong interrelation with the development delay. Corpus Callosum

abnormalities in 22 patients (100%) were other meaningful structural irregularities. Gray matter abnormalities in 20 (100%) patients, brainstem involvement in 13 (100%) patients, cerebellar abnormalities in 13 (100%) patients were found. All these facts concretely prevail in significant associations with delayed milestones ($p<0.05$). The two most common MRI findings in children experiencing delayed developmental milestones are white matter and ventricular abnormalities, which indicate that periventricular and diffuse white matter damage, are the leading causes of this developmental impairment. The corpus callosum and gray matter anomalies additionally highlight the role of interhemispheric communication and cortical integrity disruption in children suffering from these conditions. Though brainstem and cerebellar involvement are not as frequently observed, they still have a notable association with delayed milestones that could imply possible effects on motor coordination, balance, and autonomic functions. These findings highlight the scope of MRI as a primary tool for diagnosing and as a guide for early intervention in neurodevelopmental disorders [Table 7].

Table No. 7: Magnetic resonance imaging (MRI) structural abnormalities and their significance

MRI Findings	Yes	No	p-value
Ventricular Abnormalities	32 (100%)	-	<0.001
White Matter Abnormalities	49 (100%)	-	<0.001
Corpus Callosum Abnormalities	22 (100%)	-	0.002
Gray Matter Abnormalities	20 (100%)	-	0.003
Brainstem Abnormalities	13 (100%)	-	0.027
Cerebellum Abnormalities	13 (100%)	-	0.027

DISCUSSION

Magnetic resonance imaging has progressively gained its place in the diagnostic field, making it the most important tool for looking at pediatric neurological disorders associated with delayed developmental milestones. In this piece of research, we aim to find out the correlations between the findings in MRIs, the hypoxic injuries, and the developmental problems, and in the end, we advance the knowledge of their causes. The outcomes show highly significant abnormalities of structural MRI, thus confirming MRI's crucial diagnostic role in pediatric neurodiagnostics. It has been found, being the main ratio, that male children who were primarily affected (56.9%) in this study belong to the same category as many studies before this. This is because, as reported in studies of older, adolescent male patients, they are significantly more susceptible to neurodevelopmental disorders than girls, possibly due to factors of genetics, hormones, and brain structure.[14,15] The findings of previous studies also indicate the existence of this gender difference.[16,17]

Even though the occurrence rates of delayed milestones were high in children below five years (46.2% <2 years; 33.8% in 2–5 years), there was no significant statistical association between age and developmental delays ($p=0.603$) in our analysis. The above statement is a contradiction to what Deng et al[18] stated that the perinatal complications affect younger children, especially neonates, more than other age groups, having a higher risk of severe neurodevelopmental deficits. The result of such discrepancies could be related to different study populations, varying timelines of interventions, or discrepancies in MRI interpretation. In our cohort, MRI was abnormal in 76.9% of cases, so its diagnostic significance was again reinforced. The most revealing changes were white matter changes, ventricular enlargement, corpus callosum dysgenesis, gray matter anomalies, and brainstem/cerebellar defects (these were presented in 100% of cases at variance). The observation aligns with studies published in the literature that stressed the significance of white matter and ventricular anomalies in neonatal hypoxic-ischemic injury.[19,20] The finding that the prevalence of brainstem and cerebellar abnormalities (26%) was much higher than the previously reported 10%[21] might be due to improved imaging techniques, better MRI resolution, or different patient selection criteria.

The main causes uncovered were traumatic, metabolic, and neurovascular conditions, which proved the predominant role of hypoxic-ischemic events in perinatal neurodevelopmental disorders. This is in line with Deng et al[18], who identified perinatal asphyxia as a major contributor to white matter damage and cortical dysfunction. However, our findings contradict Wringer et al[22], who asserted that congenital and genetic disorders are dominant factors. The reasons behind such differences could be dissimilar population characteristics and diverse incidences of perinatal complications. On the other hand, it is contradictory to Chauhan et al[17], who, through a weaker correlation, suggested that certain children with mild hypoxia could still develop normally, even if they had anomalies found on MRI. The range in the severity of hypoxia, the duration of follow-up, and the neuroplasticity mechanisms termed compensatory might give ground to this discrepancy.

Our study has not found any significant relationship between the mode of delivery (vaginal delivery vs. cesarean) and developmental delay ($p=0.164$). Mahmood et al[19] rightly say this, as they concluded emergency cesarean deliveries are perhaps introducing perinatal stress but do not have a long-term effect on the development of a child. On the flip side, however, it was reported by Ali et al[16] where it was found that

cesarean deliveries lead to more white matter being associated with the anomalies. This could have been caused by differences in measures of maternal health, complications of the fetus, or differences in the standards of obstetrics set by the authors of the studies.

Clinically, our findings demonstrate the necessity of early MRI screening in infants going through perinatal hypoxic-ischemic events, thus highlighting the predictive role of white matter and ventricular anomalies for cognitive and motor impairment. A comprehensive strategy, including teams of neurologists, pediatricians, and radiologists, is suggested to bring about an early diagnosis and treatment, giving the children a better opportunity for improvement.

In the end, MRI is still the most powerful tool for assessing pediatric patients who exhibit delayed developmental milestones. It highlights structural and functional damage, such as neurodevelopmental abnormalities, and their linkages. The discrepancies that have been found should stimulate more research through longitudinal and multicenter studies, which will help to better refine the predictive utility of the results of MRI in pediatric neurology. Future long-term research is required to comprehend the predictive power of MRI findings in children with neurodevelopmental disorders.

CONCLUSION

Detection of structural brain MRI is best for patients with developmental delays. Targeted MRI screening for affected children is essential for early intervention and individualized treatment.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Fatimah A. Salem, Nada A. Muneam
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REFERENCES

1. Parmentier CEJ, Kropman T, Groenendaal F, et al. Cranial MRI beyond the neonatal period and neurodevelopmental outcomes in neonatal encephalopathy due to perinatal asphyxia: A systematic review. J Clin Med 2023;12:7526.
2. Kumar P, Zelena D, Gautam A. Theranostic Applications of Nanotechnology in Neurological Disorders. Singapore: Springer Nature;2024;1-29.
3. Muneam SA, Muneam NA. Exploring the biophysical mechanisms of taurine's effect on myeloperoxidase enzymatic kinetics in pre-diabetic and type 2 diabetic patients. J Biosci Appl Res 2023;9(4):331-41.
4. Ali AS, Naziya PS, Murthy GSN, et al. Magnetic resonance imaging (MRI) evaluation of developmental delay in pediatric patients. J Clin Diagn Res 2015;9(1):TC21-4.
5. Mahmood AT, Said TT, Nuaman BN. The value of myelination milestone on MRI in the assessment of developmental delay in pediatric patients. Iraqi J Med Sci 2022;20(3):220-6.
6. Sungura RE, Spitsbergen JM, Mpolya EA, Sauli E, Vianney JM. Neuroimaging magnitude of pediatric brain atrophy in northern Tanzania. East Afr Health Res J 2020;4(2):134-41.
7. Pavlova MA, Krägeloh-Mann I. Limitations on the developing preterm brain: Impact of periventricular white matter lesions on brain connectivity and cognition. Brain 2013; 136(4):998-1011.
8. Deng W, Pleasure J, Pleasure D. Progress in periventricular leukomalacia. Arch Neurol 2008;65(10):1291-5.
9. Muneam SA, Muneam NA, Muayed A. Biofactors' impact on diabetes prognosis. J Biosci Appl Res 2024;10(4):816-25.
10. Oberklaid F, Efron D. Developmental delay: Identification and management. Aust Fam Physician 2005;34(9):739-42.
11. Kammer B, Pfluger T, Schubert MI, Keser CM, Schneider K. Magnetic resonance imaging of pediatric patients. Pediatr Radiol 2006;36(2): 113-20.
12. Nguefack S, Kamga KK, Moifo B, et al. Causes of developmental delay in children aged 5 to 72 months at the child neurology unit of Yaounde Gynaeco-Obstetric and Paediatric Hospital (Cameroon). Open J Pediatr 2013;3(3):279-85.
13. Musullulu H. Evaluating attention deficit and hyperactivity disorder (ADHD): A review of current methods and issues. Front Psychol 2025;16:1466088.
14. Kamphof HD, et al. Fetal growth restriction: Mechanisms, epidemiology, and management. Matern Fetal Med 2022;4(3):186-96.
15. Yuzkan S, et al. Use of thalamus L-sign to differentiate periventricular leukomalacia from neurometabolic disorders. J Child Neurol 2023; 38(6-7):446-53.
16. Abdi SS, De Haan M, Kirkham FJ. Neuroimaging and cognitive function in sickle cell disease: A systematic review. Children 2023;10(3):532.

17. de Bruijn CAM, et al. Neurodevelopmental consequences of preterm punctate white matter lesions: A systematic review. Pediatr Res 2023; 93(6):1480-90.
18. Mequanint MB, et al. Open lip schizencephaly: An unusual cause of hemiparesis: A case report. Radiol Case Rep 2024;19(11):5354-8.
19. Wortinger LA, et al. Association of birth asphyxia with regional white matter abnormalities among patients with schizophrenia and bipolar disorders. JAMA Netw Open 2021;4(12):e2139759.
20. Sutovska H, et al. Prenatal hypoxia affects foetal cardiovascular regulatory mechanisms in a sex- and circadian-dependent manner: A review. Int J Mol Sci 2022;23(5):2885.
21. Mequanint s, Birara M, et al. Open lip schizencephaly: An unusual cause of hemiparesis: a case report. Radiol Case Reports 19.11 (2024): 5354-8.
22. Wortinger, Laura A., et al. Association of birth asphyxia with regional white matter abnormalities among patients with schizophrenia and bipolar disorders. JAMA 4.12 (2021): e2139759-9.