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Original Article

Magnetic Resonance Imaging Evaluation of the Brain in Children with Developmental Delay

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Abstract

Background: Global developmental delay is an umbrella term used when children are significantly delayed in their cognitive and physical development. There is usually a specific condition that causes this delay. However, it is sometimes difficult to spot this underlying condition. Magnetic resonance imaging (MRI) brain helps to diagnose or to rule out such conditions.

Aim and Objective: The objectives of the study are as follows: (1) To categorize the morphological abnormalities in brain MRI and to determine the prevalence of developmental delay in children. (2) To detect the proportion of normal MRI in children with developmental delay.

Materials and Methods: It is an observational and prospective MRI brain study of 100 pediatric patients done in the radiology department of the tertiary care center for 2 years (October 2020–December 2021).

Results: The majority of the children (36%) were in the age group of 4–6 years. There was male predominance (62%). The prevalence of abnormal MRI findings was 76% in our study. Forty-eight (63.3%) children had findings consistent with neurovascular diseases while 13 (17.1%) and 9 (11.8%) children had congenital and developmental disorders and non-specific imaging findings, respectively. Neoplastic and cystic lesions and multifactorial etiology were noted in 4 (5.2%) and 2 (2.6%) children, respectively. There was a significant association between clinical findings and MRI findings as per the Chi-square test ($P < 0.05$).

Conclusion: The various morphological appearances of developmental delay on MRI and further categorizing them into various subgroups paving way for treating clinicians to plan proper management and parent counseling. The most common cause for the development delay was found to be neurovascular disease.

Key words: Developmental delay, Diffusion weighted imaging, Magnetic resonance imaging, T1W, T2W image

INTRODUCTION

Global developmental delay (GDD) is diagnosed when a child is delayed in one or more milestones, categorized into motor skills, speech, cognitive skills, and social and emotional development.[1] There is usually a specific condition that causes this delay, such as Fragile X syndrome or other chromosomal abnormalities. However, it is sometimes difficult to spot this underlying condition.[2]

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The degree of developmental delay is often further classified as mild (functional age <33% below chronological age), moderate (functional age 34–66% of chronological age), and severe (functional age <66% of chronological age).[3] A significant delay is defined as performance that is two or more standard deviations below the mean on age-appropriate standardized norm-referenced testing (usually conducted in secondary or tertiary care settings).[4] A significant delay in two or more developmental domains affecting children under the age of 5 years is termed GDD.[5]

From a pathophysiological point of view, developmental delay is the result of interference with the normal development of the brain. This interference may occur at a number of different stages in the embryology and/or postnatal development of the brain, affecting the formation of the brain or any of the processes regulating functional

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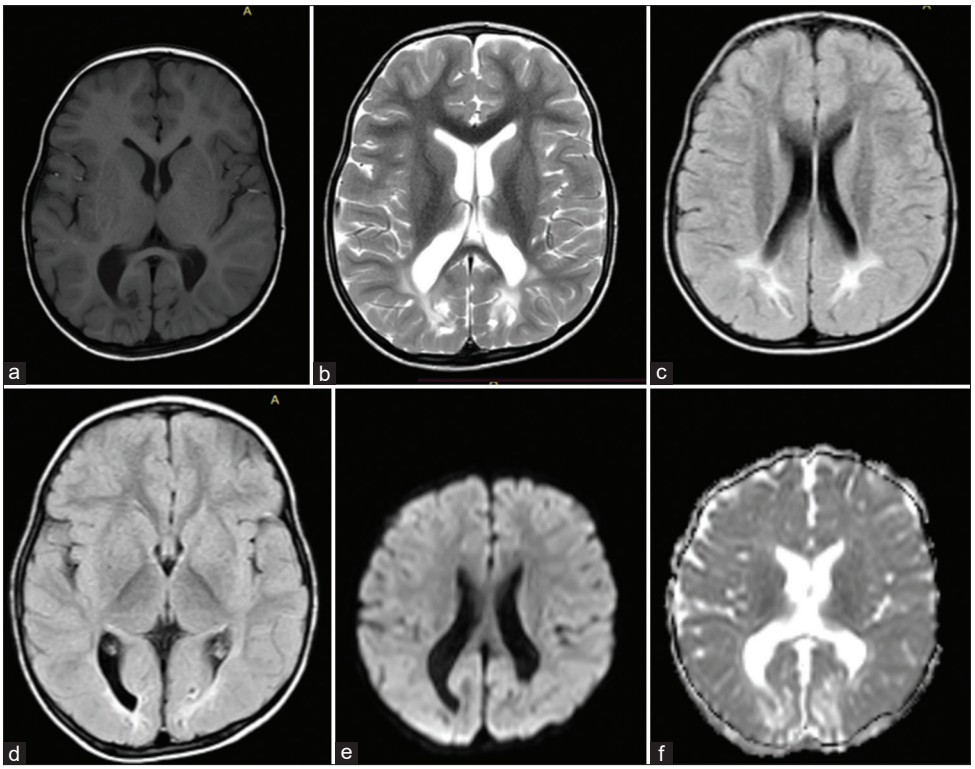


Figure 1: Birth Hypoxic ischemic insult. Ill-defined axial T2 and FLAIR (b-d) hyperintensity in subcortical and deep white matter of bilateral occipital and posterior parietal lobes, appearing hypointense on axial T1 (a), showing no restriction on DWI (e) and increased ADC (f) value, associated with white matter volume loss causing prominence of occipital horns of bilateral lateral ventricles

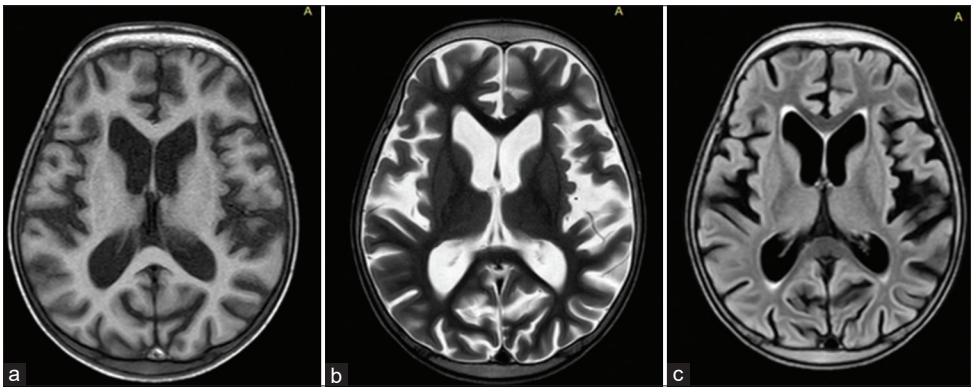


Figure 2: Predominant white matter loss. Axial T1W, T2W, and FLAIR images demonstrate diffuse mild dilatation of supra-tentorial CSF sulcal spaces and ventricular systems associated with mild diffuse white matter volume loss s/o cerebral atrophy-predominantly white matter

development (myelination, neuronal selection, and programmed cell death), which mainly occurs after birth.[6] There are various methods and tests to evaluate development. The best test is the Denver development screening test and its modified form is the Denver development screening test II.[7]

Careful evaluation and investigation can reveal a cause in 50–70% cases[8] with developmental delay this wide variation [Graph 1] could be attributed to patient selection criteria where high proportions are reported; some of the reported abnormalities are in children where diagnosis would be obvious clinically.[9] Brain magnetic resonance imaging (MRI) is one of the major investigations of these patients. Based on the previous studies, about 60% of cases have abnormal brain MRI.[10]

Neurologically, once the child is brought for a developmental delay concern, a delayed developmental status should be assumed unless the evaluation suggests otherwise.[11] If developmental delays are detected late, and opportunities for early intervention are lost, resulting in poor outcomes such as learning difficulties, behavior problems, and functional

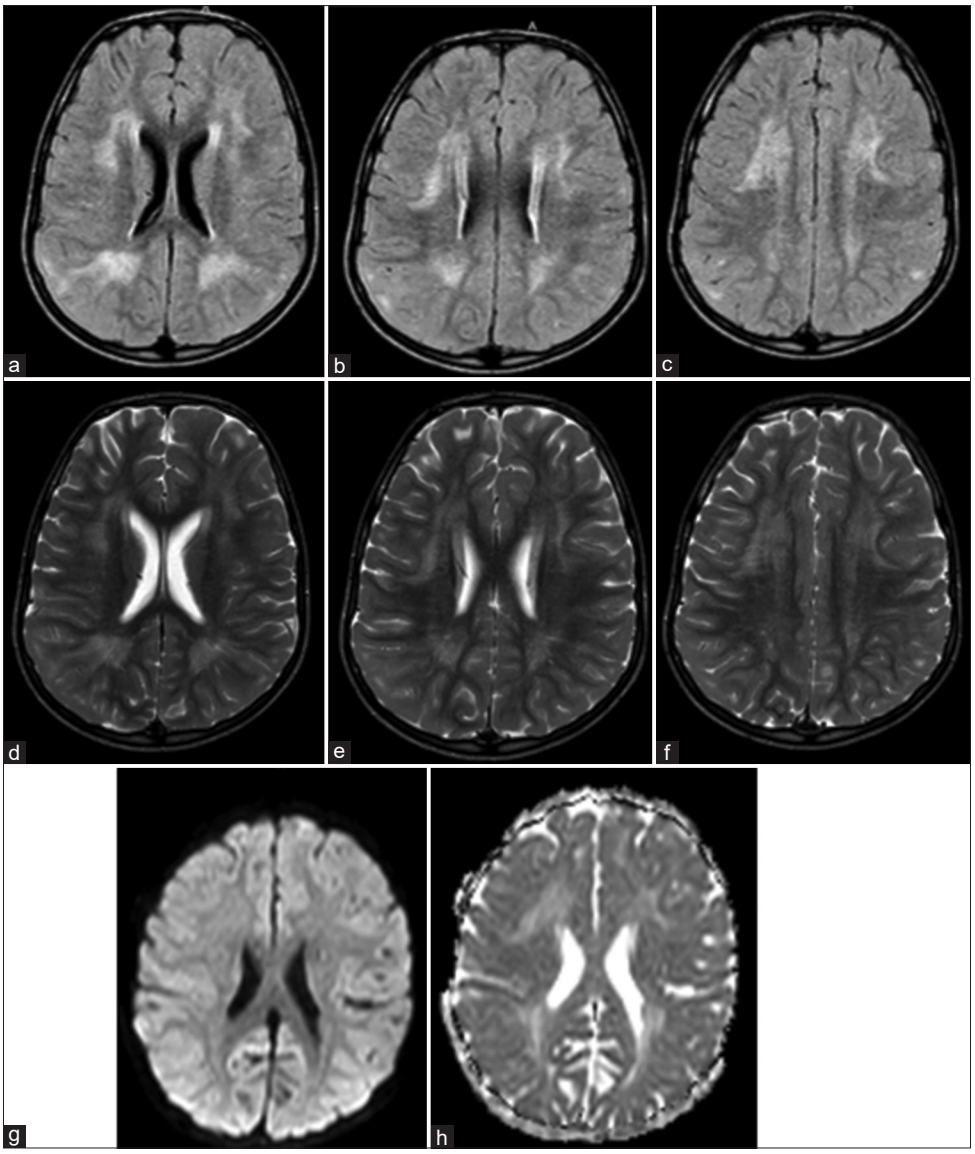


Figure 3: Metachromatic leukodystrophy. Bilaterally symmetrical axial FLAIR and T2W Hyperintensities (a-c, e-g) in bilateral periventricular and subcortical white matter of bilateral frontal and parietal lobes giving butterfly pattern with sparing of subcortical U fibers. On axial T2W images, perivenular sparing is seen giving tigroid like pattern. DWI (g) demonstrates no restricted diffusion associated with increased ADC (h) value

impairments later on in life.[12] There is strong research evidence suggesting that effective early identification of developmental delays and timely early intervention can positively alter a child's long-term trajectory.[13] Hence, the present study was done at our tertiary care center to categorize the morphological abnormalities in brain MRI and to determine the prevalence of the developmental delay in children.

OBSERVATIONS AND RESULTS

A hospital-based observational and prospective study was conducted among 100 children to categorize the morphological abnormalities in brain MRI and to determine the prevalence of developmental delay in children.

The majority of the children (36%) were in the age group of 4–6 years followed by 31 (31%) children in the age group of 7–9 years, 22 (22%) children in the age group of 2–3 years and 8 (8%) children in the 10–12 years of age. The mean age of the children was 5.79 ± 2.58 years. There was male predominance (62%) whereas female children constituted 38% of the study group. 27 (27%) children were term while 41 (41%) and 32 (32%) children were preterm and late-term, respectively.

Forty-three (43%) children presented with developmental delay had seizures as the main complaint, while 19 (19%) and 7 (7%) children had other neurological deficits and respiratory and cardiac disease, respectively. Four (4%) children had

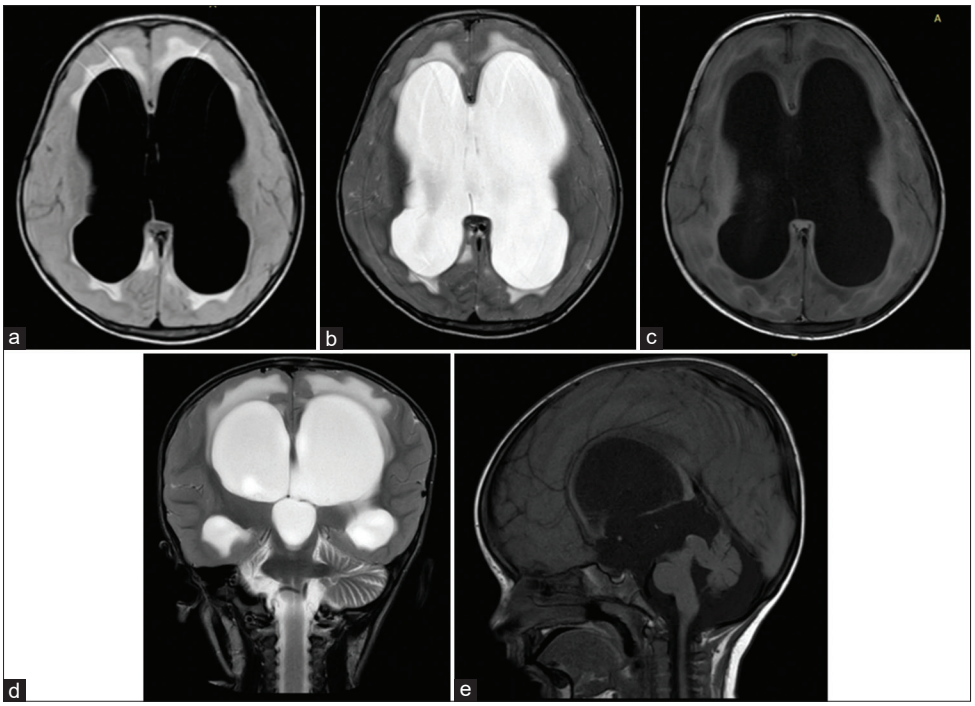


Figure 4: Non-communicating hydrocephalus. Axial FLAIR, T2w and T1w (a-c), coronal T2W, and sagittal T1w images demonstrate grossly dilated bilateral lateral ventricles and third ventricle (Right lateral ventricle measuring 3 cm, left lateral measuring 3.56 cm and third ventricle measuring 2.6 cm) with blunting of gyri and effacement of CSF sulcal spaces of bilateral cerebral hemispheres secondary to aqueductal stenosis at the level of midbrain. Increased T2W and FLAIR signal intensity is seen surrounding bilateral lateral ventricle s/o periventricular CSF ooze. Fourth ventricle appears prominent measuring 8 mm

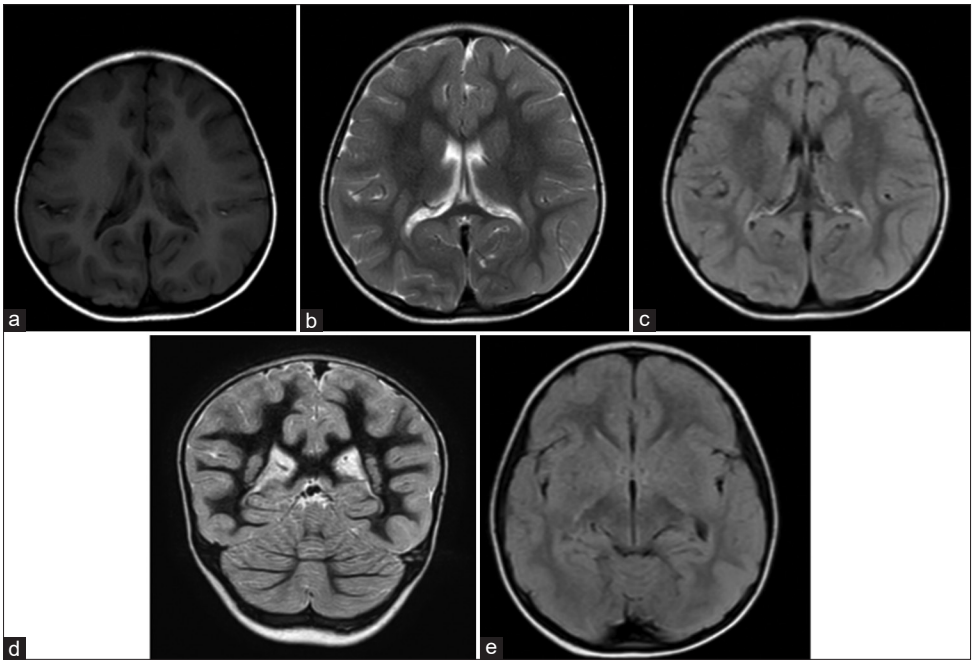


Figure 5: Migrational disorder. There is gray matter like signal intensity area in bilateral parietal periventricular region appearing hypointense on axial T1W (a), isointense on axial T2W (b), FLAIR (c), and coronal T1W-IR images s/o heterotopia (band like). Paucity of sulcations in bilateral cerebral hemispheres.

hypothyroidism. Five (5%) children had associated features such as visual disturbances and reduced head circumference. No significant clinical association was demonstrated in 22 (22%) children.

Among the children with neurological deficits (19%), 9 (47.3%) children had hypotonia while 6 (31.6%) and 3 (15.8%) children had spasticity and gait abnormalities, respectively. One (5.3%) child had hemiplegic cerebral palsy [Table 1].

Table 1: Distribution of children according to prevalence of neurological deficits

Neurological deficits	*N*	%
Hypotonia	9	47.3
Spasticity	6	31.6
Gait abnormality	3	15.8
Hemiplegic cerebral palsy	1	5.3
Total	19	100

Table 2: Distribution of children according to abnormal MRI findings (*n*=76)

Abnormal MRI Findings	*N*	%
Neurovascular	48	63.3
Congenital and Developmental	13	17.1
Non-specific imaging findings	9	11.8
Neoplastic and cystic lesions	4	5.2
Multifactorial	2	2.6
Total	76	100

MRI: Magnetic resonance imaging

Table 3: Distribution of children according to involved brain structures

Involved Brain Structures	MRI findings			
	Normal		Abnormal	
	n	%	*N*	%
White Matter	48	48	52	52
Ventricles	62	62	38	38
Corpus callosum	77	77	23	23
Gray matter	89	89	11	11
Basal ganglia	94	94	6	6
Cranial vault	95	95	5	5
Limbic system	97	97	3	3
Brain stem	97	97	3	3
Others	91	91	9	9

MRI: Magnetic resonance imaging

Table 4: Association of Clinical Findings and MRI findings of children

Clinical findings	MRI findings				Total	*P*-value
	Normal		Abnormal			
	n	%	*n*	%		
Only developmental delay	12	12	10	10	22	<0.05
Developmental delay plus	12	12	66	66	78	
Total	24	24	76	76	100	

MRI: Magnetic resonance imaging

The prevalence of abnormal MRI findings was 76%in our study [Graph 1]. On MRI, 48 (63.3%) children had findings consistent with neurovascular diseases while 13 (17.1%) and 9 (11.8%) children had congenital and developmental disorders and non-specific imaging findings, respectively. Neoplastic and cystic lesions and multifactorial etiology were noted in 4 (5.2%) and 2 (2.6%) children, respectively [Table 2].

Our study noted the white matter and ventricular [Figures 1, 2 and 3] abnormalities in 52 (52%) and 38 (38%) children [Figure 4] with developmental delay, respectively. The corpus callosum was abnormal in 23 (23%) children while the gray matter [Figure 5] showed abnormalities in 11 (11%) children. Abnormalities of the basal ganglia and cranial vault were seen in 6 (6%) and 5 (5%) children, respectively. The limbic system and brain stem abnormalities were seen in 3 (3%) children each. Around 9 (9%) of children had involvement of other brain structures such as vermis, cerebellar tonsils, subarachnoid spaces and cisterns, and choroid plexus [Figure 6, Graph 2 and Table 3].

Out of 43 (43%) developmentally delayed children associated with seizures, 40 (40%) children had abnormal MRI. Further, it was noted that among 24 (24%) children with normal MRI only 3 (3%) children were associated with seizures [Graph 3].

Among 22 (22%) children presenting with "only" developmental delay, 12 (12%) children had normal MRI findings. Out of 78 (78%), children presented with additional clinical features along with developmental delay, 66 (66%) children had abnormal MRI. There was a significant association between clinical findings and MRI findings as per the Chi-square test ($P < 0.05$).

METHODOLOGY

The study was conducted among 100 children to categorize the morphological abnormalities in brain MRI and to determine the prevalence of developmental delay in children.

Study Design Duration

A hospital-based observational and prospective study was done in 2 years.

Study Area

The study was done at a tertiary care center in the department of radiodiagnosis on attending outpatient department/inpatient department.

Study Population

All children between 2 years and 12 years of age with a history of developmental delay were referred from the pediatric department at our tertiary care enter who fulfilled the inclusion criteria.

Sample Size

The sample size was 100 patients.

Inclusion and Exclusion Criteria

2–12 years of children with a history of development delay referred from the pediatric department are included in the

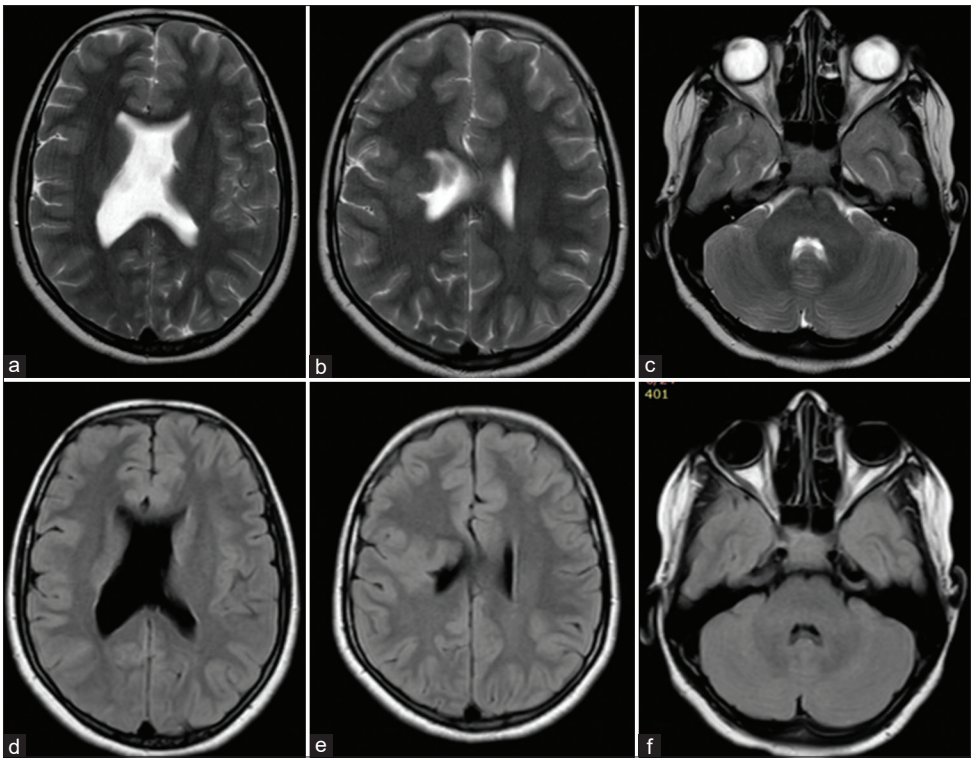
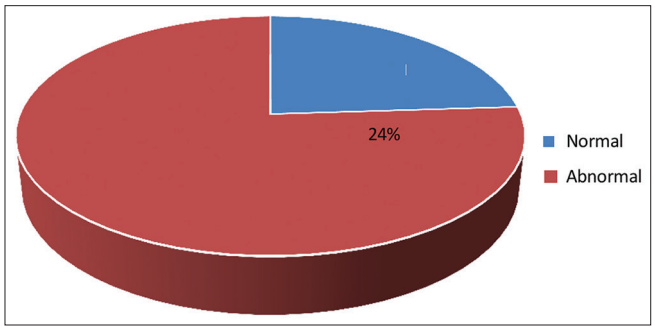
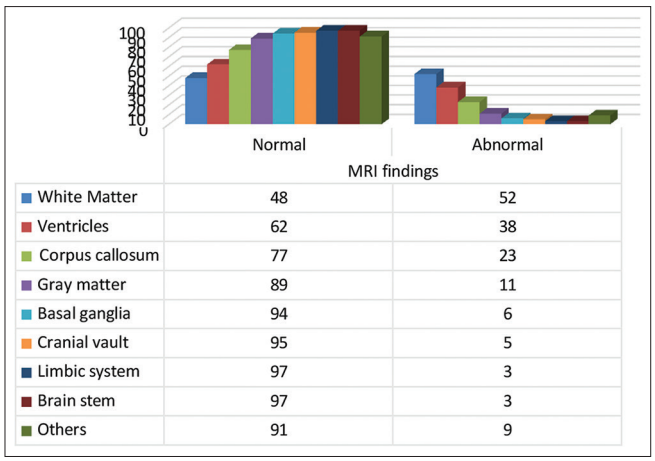


Figure 6: Septo-optic dysplasia. Axial T2 (a-c) and FLAIR (c-e) demonstrates absent septum pellucidum. Nodular grey matter heterotopia in subependymal and subcortical region of right frontoparietal lobes. Polymicrogyria noted in right frontoparietal region. Grey matter lined CSF cleft is noted in right frontoparietal region with dimpling on lateral wall of the right lateral ventricle s/o closed lip schizencephaly. Hypoplastic right optic nerve is noted

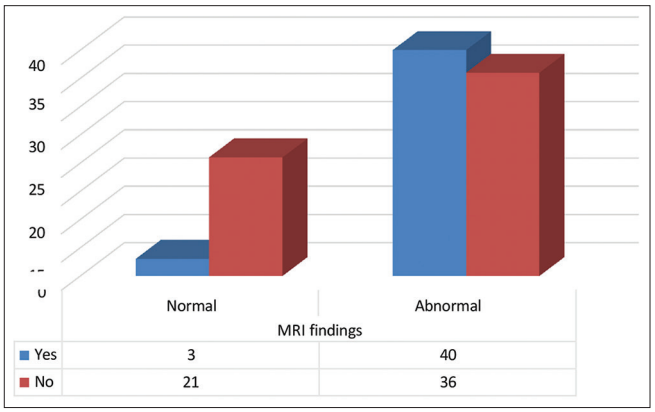


Graph 1: Distribution of children according to Magnetic resonance imaging Findings



	Normal	Abnormal
White Matter	48	52
Ventricles	62	38
Corpus callosum	77	23
Gray matter	89	11
Basal ganglia	94	6
Cranial vault	95	5
Limbic system	97	3
Brain stem	97	3
Others	91	9

Graph 2: Distribution of children according to involved brain structures



	Normal	Abnormal
Yes	3	40
No	21	36

Graph 3: Association of seizures and magnetic resonance imaging findings of children

study. Patients with contraindications to MRI such as metallic body implants and artificial heart valves, patients with acute infections such as tonsillitis and pneumonia, andchildren with a known genetic disorder such as Downs and Turner syndromes are excluded from the study.

Methods

The study was done at our tertiary care center in the department of radiodiagnosis. Informed consent was taken in writing from the patient's attendant. Infants were examined and sedated with IV drugs under the consent and

presence of the pediatrician using anesthetic drugs by the anesthetist in their presence. MRI brain was done by MRI machine of power 1.5 Tesla of Philips which was available at our tertiary care center. The sequences used were: Axial T1, T2, and FLAIR images, Coronal T2W, Sagittal T1W, GRE, and inversion recovery images, DW1, and ADC maps.

DISCUSSION

A hospital-based observational and prospective study was conducted among 100 children to categorize the morphological [Table 4] abnormalities in brain MRI and to determine the prevalence of developmental delay in children. In India, sources have found the prevalence of 1.5–2.5% of developmental delay in children under 2 years of age.[14] These impairments impact not only the child and the family, but also society, in terms of the cost of providing health care, educational support, and treatment services.[15] Evidence supports that early treatment of developmental disorders leads to improved outcomes for children and reduced costs to society.[16]

In the present study, the majority of the children (36%) were in the age group of 4– 6 years followed by 31 (31%) children in the age group of 7–9 years, 22 (22%) children in the age group of 2–3 years, and 8 (8%) children in the 10–12 years of age. The mean age of the children was 5.79 ± 2.58 years. There was male predominance (62%) whereas female children constituted 38% of the study group. There was no significant difference in the mean age of male and female children as per the Student's *t*-test ($P > 0.05$). This is similar to the studies of Elanchezhian and Kalaivani.[17] and Ali *et al*.[18]

It was observed in the present study that among the children with neurological deficits (19%), 9 (47.3%) children had hypotonia while 6 (31.6%) and 3 (15.8%) children had spasticity and gait abnormalities, respectively. One (5.3%) child had hemiplegic cerebral palsy. The prevalence of abnormal MRI findings was 76%in our study. This is concordant to the studies of Elanchezhian and Kalaivani[17] Bouhadiba *et al*.,[19] Moon *et al*.,[20] Momen *et al*.,[21] Habibullah *et al*.,[22] and Kalaiarasan *et al*.[23]

It was observed in our study that 48 (63.3%) children had findings consistent with neurovascular diseases while 13 (17.1%) and 9 (11.8%) children had congenital and developmental disorders and nonspecific imaging findings, respectively. Neoplastic and cystic lesions and multifactorial etiology were noted in 4 (5.2%) and 2 (2.6%) children, respectively. This is consistent with the studies of Elanchezhian and Kalaivani[17] Ali *et al*.[18]

In the present study, 15 (15%) and 35 (35%) children in the age group of 2–3 years and 4–6 years, respectively, had abnormal brain MRI findings while 21 (21%) and 5 (5%) children in the age group of 7–9 years and 10–12 years, respectively, had abnormal brain MRI findings. There was a significant association between age and MRI findings of children as per the Chi-square test ($P < 0.05$). Habibullah *et al*.[22] noted similar observations in their study.

It was observed in our study that among 22 (22%) children presenting with "only" developmental delay, 12 (12%) children had normal MRI findings. Out of 78 (78%), children presented with additional clinical features along with developmental delay, 66 (66%) children had abnormal MRI. There was a significant association between clinical findings and MRI findings as the per Chi-square test ($P < 0.05$). Similar observations were noted in the studies of Habibullah *et al*.[22] and Ali *et al*.[18]

CONCLUSION

The most common cause of developmental delay is neurovascular pathologies predominantly affecting white matter and the ventricular system. MRI is the only modality for diagnosis. MRI is safe for children as it has no ionizing radiation. MRI helps in the early identification of causes for developmental delay and, therefore, early intervention will be possible, which is going to prevent long-term insults and detrimental consequences.

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