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Magnetic Resonance Imaging Patterns and Their Clinical Correlates in Children with Neurodevelopmental Delay: A Cross-Sectional Study

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ABSTRACT

Background: Brain magnetic resonance imaging (MRI) can identify structural patterns that support etiologic assessment in children with neurodevelopmental delay, particularly when neurological examination or perinatal history suggests central nervous system injury.
Methods: This hospital-based cross-sectional study included 78 children aged 6 months to 5 years presenting with neurodevelopmental delay beginning in the first year of life. All underwent detailed neurological examination and 1.5-T brain MRI with T1-weighted, T2-weighted and FLAIR sequences. MRI abnormalities were described by anatomical/pattern category and examined in relation to neonatal complications, birth asphyxia, symptoms and motor findings.
Results: MRI was abnormal in 70/78 children (89.7%). White-matter abnormalities were most frequent (47; 60.3%), followed by corpus-callosal thinning (40; 51.3%) and cortical abnormalities (37; 47.4%); multiple findings could coexist. Abnormal MRI was present in 53/55 (96.4%) children with a history of birth asphyxia and in 10/14 (71.4%) children without recorded neonatal complications. It was found in 33/34 (97.1%) children with quadriparesis, 11/12 (91.7%) with diplegia and all 10 children with hemiparesis. Patient-level reanalysis showed associations of abnormal MRI with neonatal complications (Fisher exact p=0.031), birth asphyxia (p=0.007) and abnormal motor findings (p=0.004).
Conclusion: Structural MRI abnormalities were frequent in this clinically selected cohort. White-matter disease, corpus-callosal thinning and cortical abnormalities predominated, and abnormal scans clustered with adverse neonatal histories and motor deficits. MRI is most informative when integrated with perinatal and neurological assessment rather than interpreted as an isolated severity marker.

Keywords: *developmental delay; magnetic resonance imaging; white matter; birth asphyxia; motor deficit; cerebral palsy.*

INTRODUCTION

Global or multidomain developmental delay is a clinical descriptor rather than a single etiologic diagnosis. A structured history, neurological examination, hearing and vision assessment, and appropriately selected genetic, metabolic and neuroimaging investigations are therefore central to evaluation.[1–3]

MRI provides superior delineation of cortical malformations, white-matter injury, commissural abnormalities and sequelae of perinatal insults. Its yield is higher in clinically selected children with abnormal head circumference, focal neurological signs, seizures or an abnormal neurological examination than in unselected populations.[1,4–6]

The present study evaluated the spectrum of structural brain MRI findings in young children with neurodevelopmental delay and examined whether abnormal MRI was associated with neonatal antecedents and clinically observable neurological features. Developmental-quotient analyses are intentionally reserved for a separate manuscript to prevent duplicate publication of tables and outcomes.

METHODS

Study design and setting: A descriptive cross-sectional study was conducted at Chacha Nehru Bal Chikitsalaya, affiliated with Maulana Azad Medical College, Delhi over one year.

Participants: Seventy-eight children aged 6 months to 5 years were enrolled from the outpatient department, pediatric neurology clinic and child development clinic. Eligible children had developmental delay as the primary complaint with onset in the first year of life. Children with clinically apparent or strongly suspected neurodegenerative disease, and delay secondary to non-cerebral chronic or acquired conditions, were excluded.

Clinical and imaging assessment: Each child underwent structured antenatal, intranatal, neonatal, developmental and family history-taking and detailed physical and neurological examination. All children underwent 1.5-T brain MRI using T1-weighted, T2-weighted and FLAIR sequences. More than one MRI category could be assigned to a child; therefore category percentages are not mutually exclusive and may total more than 100%.

Statistical analysis: Categorical data are presented as frequency and percentage. Patient-level 2×2 tables were constructed from the master data collected. Fisher exact tests were used because several expected cell counts were below five. All tests were two-sided and $p<0.05$ was considered statistically significant.

Ethical considerations: An ethics approval was obtained from IEC of Maulana Azad Medical College, Delhi.

RESULTS

The cohort comprised 58 boys (74.4%) and 20 girls (25.6%); 48 children (61.5%) were aged 13–36 months. Seventy children had at least one abnormal MRI finding, giving an imaging abnormality rate of 89.7%. Specific abnormalities included diffuse cerebral cortical atrophy (n=33), encephalomalacia/gliosis (n=13), periventricular leukomalacia (n=18), prominent white-matter hyperintensity (n=37), and less frequent migrational disorders, leukodystrophy patterns, kernicterus, tuberous sclerosis, Leigh-pattern changes and hydrocephalus.

Table 1. Spectrum of structural brain MRI findings (n=78)

MRI category	No.	%
Normal MRI	8	10.3
Cortical abnormality	37	47.4
Corpus-callosal thinning	40	51.3
Immature myelination	5	6.4
White-matter abnormality	47	60.3
Heterotopia/migrational disorder	3	3.9
Leukodystrophy pattern	2	2.6
Miscellaneous finding	12	15.4

Categories are non-mutually exclusive.

Table 2. Neonatal complications in relation to MRI status

Neonatal history	Total, n	Normal MRI, n (%)	Abnormal MRI, n (%)
Birth asphyxia	55	2 (3.6)	53 (96.4)
Neonatal jaundice	10	2 (20.0)	8 (80.0)
Kernicterus	2	0	2 (100)
Meconium aspiration	3	0	3 (100)
Sepsis	4	0	4 (100)
No recorded neonatal complication	14	4 (28.6)	10 (71.4)

Rows are not mutually exclusive because a child could have more than one neonatal complication.

Table 3. Motor examination pattern in relation to MRI status (n=78)

Motor finding	Total, n (%)	Normal MRI, n (%)	Abnormal MRI, n (%)
No focal motor deficit	21	6 (28.6)	15 (71.4)
Quadriparesis	34	1 (2.9)	33 (97.1)
Diplegia	12	1 (8.3)	11 (91.7)
Hemiparesis	10	0	10 (100)
Paraparesis	1	0	1 (100)

Table 4. Patient-level associations with abnormal MRI

Clinical feature	Normal MRI, n	Abnormal MRI, n	Fisher exact p	Interpretation
Preterm birth: no/yes	6/2	58/12	0.629	Not significant
Developmental quotient <50: no/yes	3/5	12/58	0.177	Not significant
Associated symptoms: no/yes	3/5	21/49	0.696	Not significant
Seizure disorder: no/yes	6/2	32/38	0.149	Not significant
Any neonatal complication: no/yes	4/4	10/60	0.031	Significant
Birth asphyxia: no/yes	6/2	17/53	0.007	Significant
Any intranatal complication: no/yes	4/4	34/36	1.000	Not significant
Abnormal motor finding: no/yes	6/2	15/55	0.004	Significant

Two-sided Fisher exact tests applied.

DISCUSSION

The principal finding was a high prevalence of MRI abnormality (89.7%) in a tertiary, clinically selected cohort. This proportion should not be interpreted as the yield of routine screening in all children with developmental delay: referral enrichment, the requirement for delay beginning in infancy and the high frequency of motor abnormalities increase the pre-test probability of structural disease. Systematic review evidence similarly shows marked heterogeneity in MRI yield according to case selection and imaging technique.[3,6]

White-matter abnormalities, corpus-callosal thinning and cortical abnormalities were the dominant patterns. Such findings are biologically compatible with perinatal white-matter injury, hypoxic–ischemic injury and developmental malformation, but an imaging pattern alone does not establish causation. MRI interpretation should be integrated with timing of exposure, neonatal course, examination and—where indicated—genetic or metabolic testing.[2,5,7]

The concentration of abnormal MRI among children with quadriparesis, diplegia and hemiparesis supports targeted imaging when focal or pyramidal motor signs are present. Practice parameters for cerebral palsy and developmental delay likewise support neuroimaging when an etiology has not been established, with MRI preferred to CT because of its superior anatomical resolution and absence of ionizing radiation.[1,8]

Birth asphyxia and neonatal complications were associated with abnormal MRI. These associations require cautious interpretation: histories may be subject to recall error, exposures overlapped, the cohort had no typically developing comparison group, and the cross-sectional design cannot establish causality. Furthermore, the source terminology "birth asphyxia" was based on recorded history rather than a contemporary composite definition incorporating cord gases, Apgar scores and encephalopathy staging.

LIMITATIONS

This was a single-centre study with a modest, referral-enriched sample. MRI reporting was category based. Several imaging categories overlapped.

CONCLUSION

Structural brain MRI abnormalities were common in young children with neurodevelopmental delay selected from specialist clinics. White-matter abnormalities, corpus-callosal thinning and cortical abnormalities predominated. Adverse neonatal histories and focal motor deficits identified children with particularly high proportions of abnormal imaging. These data support clinically targeted MRI as part of a broader etiologic assessment, while underscoring that imaging patterns must be interpreted alongside the clinical phenotype and verified perinatal history.

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