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# MAGNETIC RESONANCE IMAGING IN CEREBRAL PALSY: CORRELATION BETWEEN IMAGING PATTERNS AND CLINICAL FINDINGS

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**Abstract**

**Background:** Cerebral palsy (CP) is a neuro-motor disorder that affects various brain functions including movement, muscle tone and posture. Clinical diagnosis of cerebral palsy complemented by magnetic resonance imaging (MRI) can differentiate changes in the various types of cerebral palsy. Present study was aimed to study correlation between Magnetic resonance imaging patterns and clinical findings in children with in cerebral palsy. **Material and Methods:** Present study was cross-sectional observational study, conducted in children with a clinical diagnosis of cerebral palsy undergoing magnetic resonance imaging aged up to 10 years. **Results:** Among 50 children, mean age was 3.89 ± 2.3 years. Males to female ratio was 1.63: 1. The mean weight of the child included in the study was 2.4 ± 0.4 kg. The minimum weight included in the study was 1.6 kg, and the maximum weight was 3.3 kg. Most of the children included in the study were 1.5 to 2.5 kgs (60%). Most common complaints were abnormal movements (54%) followed by seizure episodes (50%). Most common type of cerebral palsy in children was diplegia (32%), followed by quadriplegia and dyskinesia (28%) & hemiplegia (12%). The most common clinical diagnosis among the children included in the present study was spastic diplegia (28%) followed by spastic quadriplegia (24%). Commonest MRI findings was periventricular white matter involvement in 28 children (48%), followed by cerebral cortex involvement (32%). The most common finding among them was ventricular enlargement in 16 children (32%) followed by porencephalic cyst formation (10%). The most common MRI diagnosis among the children included in the present study was periventricular leukomalacia (mild grade) in 34%. Overall correlation between clinical diagnosis and radiological diagnosis with MRI modality is 63.2%. **Conclusion:** MRI findings correlated with Spastic quadriplegic cerebral palsy (100%), spastic diplegic cerebral palsy (100%) and ataxic type of cerebral palsy (100%).

**Keyword:** MRI, Spastic quadriplegic, cerebral palsy, spastic diplegic, ataxic, neuroimaging

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## Introduction

Cerebral palsy (CP) is a neuro-motor disorder that affects various brain functions including movement, muscle tone and posture.[1] The reported incidence of cerebral palsy is approximately 2.5 to 3 per 1000 live births. As compared to females, males have a higher incidence according to the various studies i.e., 1.3: 1. The incidence is associated with gestational age at which the insult occurs, with 1 in 20 surviving pre-terms affected with cerebral palsy. Though prematurity is the commonest risk factor, the majority affected are full term.[2,3]

The CP originates from interference in developing immature brain in the prenatal or perinatal period. Cerebral palsy is a permanent and non-progressive disorder manifesting early in life.[4,5] Cerebral palsy causes various degrees of motor and intellectual impairment and is the commonest physical disability of childhood. Cerebral palsy causes many associated problems such as visual and hearing disability, feeding problems, recurrent episodes of seizures, cognitive disability in children[6]

Clinical diagnosis of cerebral palsy complemented by magnetic resonance imaging (MRI) can differentiate changes in the various types of cerebral palsy. Magnetic resonance imaging plays an important part in the diagnosis, providing details of extent of brain damage. Magnetic resonance imaging defines abnormalities of cortical and white matter structures more clearly than any other imaging method; it is the neuroimaging method of choice. MRI is more sensitive than CT in the detection of both subtle brain malformations, such as Callosal hypogenesis, polymicrogyria and mild degrees of white matter damage.[7] It also determines whether appropriate myelination is present for a given age. Present study was aimed to study correlation between Magnetic resonance imaging patterns and clinical findings in children with in cerebral palsy.

## Material And Methods

Present study was cross-sectional observational study, conducted in department of radiodiagnosis, at XXX medical college & hospital, XXX, India. Study duration was of 18 months (January 2020 to June 2021). Study approval was obtained from institutional ethical committee.

Inclusion criteria

- Children with a clinical diagnosis of cerebral palsy undergoing magnetic resonance imaging aged up to 10 years, parents willing to participate in present study

Exclusion criteria

- Children with the presence of metabolic disorders or neuroimaging suggestive of metabolic disorders.
- Children with inflammatory brain diseases such as meningitis, encephalitis and abscess.
- Patients with claustrophobia, metallic implants (contraindicated for MRI), cardiac pacemakers and cochlear implants.

Study was explained to parents in local language & written consent was taken for participation & study. Demographic data collection (age and sex) and birth and maternal history were noted. Information regarding the clinical type and nature of cerebral palsy was noted from the medical records. These findings were noted in a predesigned proforma. The patient was positioned supine on the scanning table, immobilization of the patient was achieved, and the standard brain coil was applied. Patients were subjected to MRI scanning. When necessary, adequate sedation was given under the supervision of a trained anaesthesiologist.

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Conventional MR imaging was performed on Machine--- 1.5 Tesla GE-Signa HDxt MRI machine. Following sequences were taken, Diffusion-weighted images (b=1000) with corresponding ADC images, Axial T2, Axial T2 FLAIR, Axial GRE, Axial T1, Coronal T2, Sagittal T1 & Axial 3D FS. Whenever needed, post-contrast axial, coronal and sagittal sequences were taken along with axial T1 FLAIR and MR angiography. The correlation between MRI diagnosis and clinical diagnosis was done after obtaining conclusions from clinical diagnosis.

Data was collected and entered in MS Excel. The categorical data were expressed as rate, ratio, proportions and percentage. The continuous data were expressed as mean and standard deviation. The correlation of MRI diagnosis was done with the clinical diagnosis and determined by percentage agreement. Statistical results of this study were analysed and compared with available studies in the literature.

**Results**

A total of 50 children with the clinical diagnosis of cerebral palsy and referred for MRI scan to our department were studied. In our study, commonest age group was newly born to 3 years (46%) followed by the age group 4 to 6 years (42%). The mean age was 3.89 ± 2.3 years. Out of 50 patients with cerebral palsy, 31(62%) patients were males, and 19(38%) patients were females. The males to female ratio were 1.63: 1 in our study.

**Table 1: General characteristics**

| | **No. of patients** | **Percentage** |
|---|---|---|
| Age groups (in years) | | |
| New born to 3 years | 23 | 46 |
| 4 to 6 years | 21 | 42 |
| 7 to 10 years | 7 | 14 |
| Mean age (mean ± SD) | 3.89 ± 2.3 years | |
| Gender | | |
| Male | 31 | 62 |
| Female | 19 | 38 |

The mean weight of the child included in the study was 2.4 +/-0.4 kg. The minimum weight included in the study was 1.6 kg, and the maximum weight was 3.3 kg. Most of the children included in the study were 1.5 to 2.5 kgs (60%)

**Table 2: Birth history distribution of children with cerebral palsy.**

| **Birth history** | **Findings** | **Frequency** | **Percentage** |
|---|---|---|---|
| Birth weight (kgs) | 1.50 to 2.49 | 30 | 60 |
| | 2.50 to 3.49 | 20 | 40 |
| | 3.5 or more | 0 | 0 |
| Birth order | 1 | 28 | 56 |
| | 2 | 17 | 34 |
| | 3 | 5 | 10 |
| | 4 | 0 | 0 |
| Cry at birth | Immediate/ Normal | 17 | 34 |
| | Weak | 6 | 12 |
| | Delayed | 27 | 54 |
| Resuscitation | Yes | 26 | 52 |
| NICU admission | Yes | 40 | 80 |
| Complications | Feeding difficulties | 14 | 28 |

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| | | | |
|---|---|---|---|
| | Seizure episode | 11 | 22 |
| | Jaundice | 11 | 22 |
| | Septicemia | 1 | 2 |

In present study, most common complaints were abnormal movements (54%) followed by seizure episodes (50%).

**Table 3: Various presenting complaints of the children with cerebral palsy**

| Presenting complaints | Frequency | Percentage |
|---|---|---|
| Abnormal movements | 27 | 54 |
| Abnormal posture | 16 | 32 |
| Seizures Yes | 25 | 50 |
| Hyperactivity | 15 | 30 |
| Mental retardation | 8 | 16 |

In the present study most common type of cerebral palsy in children was diplegia (32%), followed by quadriplegia and dyskinesia (28%) & hemiplegia (12%). In our study triplegia was not found.

**Table 4: Type of cerebral palsy.**

| Type of cerebral palsy | Frequency | Percentage |
|---|---|---|
| Diplegia | 16 | 32 |
| Quadriplegia | 14 | 28 |
| Dyskinesia | 14 | 28 |
| Hemiplegia | 6 | 12 |

The most common clinical diagnosis among the children included in the present study was spastic diplegia (28%) followed by spastic quadriplegia (24%).

**Table 5: Clinical diagnosis of the children with cerebral palsy.**

| Clinical diagnosis | Frequency | Valid Percentage |
|---|---|---|
| Spastic diplegia | 14 | 28 |
| Spastic quadriplegia | 12 | 24 |
| Dystonic | 8 | 16 |
| Choreoathetoid | 5 | 10 |
| Spastic hemiplegia | 5 | 10 |
| Dyskinetic | 4 | 8 |
| Mixed | 1 | 2 |
| Ataxic | 1 | 2 |

In this study commonest MRI findings was periventricular white matter involvement in 28 children (48%). This was followed with cerebral cortex involvement in 16 children (32%). The most common finding among them was ventricular enlargement in 16 children (32%) followed by porencephalic cyst formation (10%).

**Table 6: Various MRI findings among the children with cerebral palsy.**

| Other MRI findings. | Frequency | Percentage |
|---|---|---|
| Ventricular enlargement | 16 | 32 |
| Porencephalic cysts | 5 | 10 |
| Myelination abnormalities | 5 | 10 |
| Cerebellar atrophy | 3 | 6 |

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| | | |
|---|---|---|
| Malformations | 1 | 2 |

The most common MRI diagnosis among the children included in the present study was periventricular leukomalacia (mild grade) in 34%. This MRI diagnosis was followed by cystic degeneration (moderate to severe) in 20% and basal ganglia involvement in 16%.

**Table 7: MRI diagnosis of the children with cerebral palsy.**

| **MRI diagnosis** | **Frequency** | **Percentage** |
|---|---|---|
| Periventricular leukomalacia (mild grade) | 17 | 34 |
| Cystic degeneration (moderate to severe) | 10 | 20 |
| Basal ganglia lesion | 8 | 16 |
| Atrophy | 3 | 6 |
| Focal gliosis | 3 | 6 |
| Delayed myelination | 2 | 4 |
| Malformation | 1 | 2 |
| Normal | 6 | 12 |

In our study, maximum number of children had findings in occipital region (28.6%) and fronto-parietal region (28.6%). However, cumulative number of children in occipital and parieto-occipital regions are 53.6%.

**Table 8: Predominant areas of white matter involvement in periventricular leukomalacia.**

| **Predominance** | **Frequency (n=28)** | **Percentage** |
|---|---|---|
| Occipital | 8 | 28.6 |
| Parietal and occipital | 7 | 25 |
| Parietal | 3 | 10.6 |
| Frontal, parietal and occipital | 1 | 3.6 |
| Frontal and parietal | 8 | 28.6 |
| Frontal | 1 | 3.6 |

Among the children with clinical diagnosis of spastic diplegia, MRI brain findings revealed 85.8% of the children with periventricular leukomalacia and 14.2% of children revealed cystic degeneration.

Among the children with clinical diagnosis of spastic quadriplegia, MRI brain findings revealed 66 % of the children with cystic degeneration and 34 % of children revealed periventricular leukomalacia.

Among the children with clinical diagnosis of spastic hemiplegic cerebral palsy, MRI brain findings are delayed myelination, malformations, focal gliosis and periventricular leukomalacia among 20% in each of the categories. One of the MRI scans of child with spastic hemiplegic cerebral palsy reveals normal MRI brain study (20%).

Among the children with clinical diagnosis of choreoathetoid cerebral palsy, MRI brain findings revealed 40 % of the

children with basal ganglia and 60 % of children revealed normal findings.

Among the children with clinical diagnosis of dyskinetic cerebral palsy, MRI brain findings revealed 50 % of the children with basal ganglia abnormalities, followed by delayed myelination, focal gliosis in 25% and 25% respectively.

Among the children with clinical diagnosis of dystonic cerebral palsy, MRI brain findings revealed 50 % of the children

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with basal ganglia abnormalities, followed by delayed atrophy, focal gliosis in 25% and 12.5% respectively. One of
the MRI scans of child with dystonic cerebral palsy reveals normal MRI brain study (12.5%). Only 1 child with ataxic type of cerebral palsy was referred for the MRI scan in the study period revealing generalised cerebral atrophy (100%).

**Table 9: MRI findings in children with spastic diplegia type of cerebral palsy.**

| Birth history | MRI diagnosis | Frequency | Percentage |
|---|---|---|---|
| • Spastic diplegia (n=14) | Cystic degeneration (moderate to severe grade) | 2 | 14.2 |
| | Periventricular leukomalacia (Mild grade) | 12 | 85.8 |
| • Spastic Quadriplegia (n=12) | Cystic degeneration (moderate to severe grade) | 8 | 66 |
| | Periventricular leukomalacia (Mild grade) | 4 | 34 |
| • Spastic hemiplegia (n=5) | Delayed myelination | 1 | 20 |
| | Malformation | 1 | 20 |
| | Focal gliosis | 1 | 20 |
| | Periventricular leukomalacia (Mild grade) | 1 | 20 |
| | Normal | 1 | 20 |
| • Choreoathetoid cerebral palsy (n=5) | Basal ganglia | 2 | 40 |
| | Normal | 3 | 60 |
| • Dyskinetic cerebral palsy (n=4) | Delayed myelination | 1 | 25 |
| | Basal ganglia | 2 | 50 |
| | Focal gliosis | 1 | 25 |
| • Dystonic cerebral palsy (n=8) | Atrophy | 2 | 25 |
| | Basal ganglia | 4 | 50 |
| | Focal gliosis | 1 | 12.5 |
| | Normal | 1 | 12.5 |
| • Ataxic cerebral palsy | Generalised cerebral atrophy | 1 | 100 |

The maximum correlation in our study was noted in Spastic quadriplegic cerebral palsy (100%), spastic diplegic cerebral palsy (100%) and ataxic type of cerebral palsy (100%). Least correlation was noted in mixed cerebral palsy (0%). Overall correlation between clinical diagnosis and radiological diagnosis with MRI modality is 63.2%. Correlation between Spastic triplegic cerebral palsy and hypotonic cerebral palsy with MRI imaging diagnosis could not be made as the children with above clinical diagnosis were not referred to the department in the above-mentioned study period.

**Table 10: Correlation of clinical diagnosis and MRI diagnosis.**

| | MRI | | | | | | | | Total | Number of cas | No. of cases not | Overall correlation (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Atrophy | Basal ganglia | Cystic degenerati | Delayed myelination | Focal gliosis | Malformation | Periventricular leuk | Normal | | | | |

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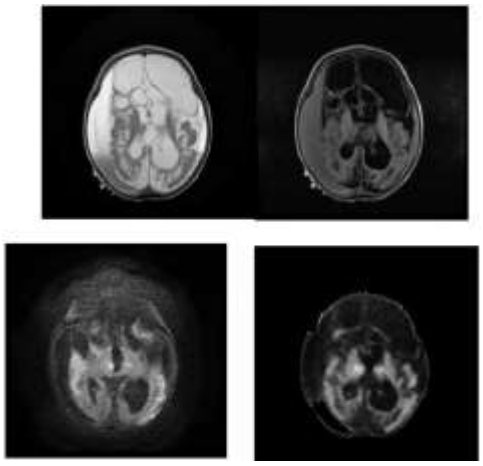
| | | | **on** | | | | **omalacia** | | | **escorrelated** | **correlated** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ataxia | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 100 |
| Choreoathetoid | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 2 | 3 | 40 |
| Dyskinesia | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 4 | 2 | 2 | 50 |
| Dystonic | 2 | 4 | 0 | 0 | 1 | 0 | 0 | 1 | 8 | 6 | 2 | 75 |
| Spastic quadriplegia | 0 | 0 | 8 | 0 | 0 | 0 | 4 | 0 | 12 | 12 | 0 | 100 |
| Spastic diplegia | 0 | 0 | 2 | 0 | 0 | 0 | 12 | 0 | 14 | 14 | 0 | 100 |
| Spastic hemiplegia | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 5 | 2 | 3 | 40 |
| Spastic triplegia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - |
| Hypotonic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - |
| Mixed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| Total | 3 | 8 | 10 | 2 | 3 | 1 | 17 | 6 | 50 | 37 | 13 | 63.2 |

**CASES**

**Case 1:** Clinical history: 2months, male child with history of posturing and not feeding properly.



**Images: (Top) Axial T2 and Axial T2 FLAIR, (bottom) Axial DWI and corresponding ADC map.**

**MRI findings:**

• Few areas of restricted diffusion are seen in bilateral thalami.

• Extensive encephalomalaciac changes are seen in bilateral frontoparietal and temporo-occipital regions.

• Extensive ex-vacuo dilatation of ventricular system and rest of the CSF spaces are noted.

• Bilateral mixed intensity subdural collections are noted in bilateral cerebral convexities.

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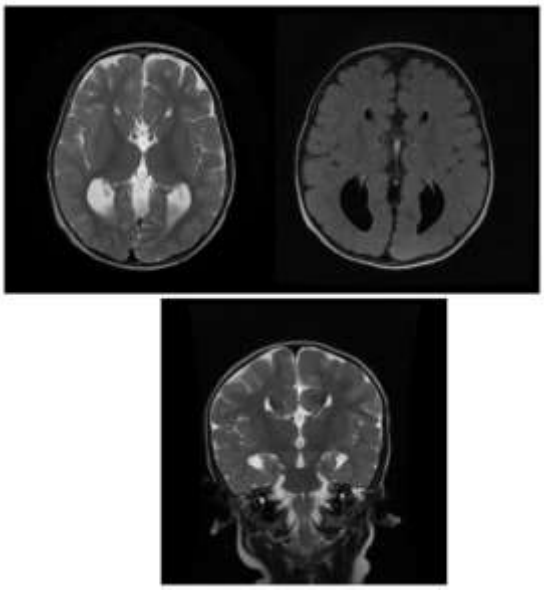
**Case 2:** Clinical history: 3Y male child with history of recurrent episodes of GTCS since 2 years. Developmental delay present. History of abnormal posturing with bilateral extensor plantar reflex.



**Images: (Top) Axial T2 and Axial T2 FLAIR, (bottom) Coronal T2 images.**

**MRI findings:**

• Abnormal ill-defined areas of hyperintensities is noted in periventricular areas of bilateral frontoparietal regions.
• Agenesis of corpus callosum with absent cingulate gyrus is noted.
• High riding 3rd ventricle with Viking helmet sign is noted on coronal images.
• Bilateral lateral ventricles are widely separated with bilateral colpocephaly.

**Discussion**

Categories of cerebral palsy are bilateral (spastic diplegia /quadriplegia), extrapyramidal (dystonic, rigid, choreic, ataxic, and hypotonic subtypes) and unilateral (hemiplegia) spasticity. Grouping helps to understand the disorder in a better way. For example, bilateral spasticity is closely associated with periventricular leukomalacia.[8,9] The most common form of CP in children born at term is hemiplegia while that in children born at preterm is diplegia.[10] Several other classification systems exist based on the pathophysiology, etiology and distribution of motor deficits.

Due to the incidence and multitude of symptoms, cerebral palsy is an important medical and social problem. Clinically, the disease is diagnosed by signs of injury at a particular site: motor cortex (limb paresis), basal ganglia (involuntary movements), cerebellum (disorders of motion and balance).

The modern diagnostics of children with cerebral palsy, apart from the neurological examination, psychological and neurophysiologic evaluation like EEG, also uses neuroimaging such as magnetic resonance imaging (MRI) and computed tomography (CT). Reports of recent years indicate the potential to differentiate changes in the various forms of CP by MRI.

MRI scans help reveal the pathologic basis of the condition, and even the findings have strong correlations with clinical findings. This is beneficial as it helps parents, clinicians, and others involved in the care of children with cerebral palsy to understand the nature of

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children's condition and predict their future needs. Therefore, all children with cerebral palsy should have an MRI scan.[11]

In the present study, slight male preponderance was noted as 62 % of the children were males and 38% were females, and the boy-to-girl ratio was 1.63:1. These findings were consistent with a study by Najjar BA *et al.*,[12] where 65 % of the children were males, 35% were females, and a survey by Kulak W *et al.*,[13] reported 67% of males. In the European cerebral palsy study[11], 63% of the children were males. In contrast to our findings, Yamada K *et al.*,[14] noted female preponderance, with 60% of the female children out of 42 cases.

The present study included children aged up to 10 years. The commonest age group was new-born to three years, which comprised more than one-third of the study population (46%), and the second commonest group was aged between 4 to 6 years (42%), and the mean age was noted as 3.89+-2.3 years. In the European cerebral palsy study[11], the age at the time of examination ranged from 1 year to 8 years, with a mean age of 3.6 years, similar to the present study. In contrast, a recent survey by Dobhal M *et al.*,[15] in Delhi reported the mean age as 62 months. In another study by Najjar BA *et al.*,[12], India, the commonest age group involved was 2-5 years, accounting for 78%. The differences observed in the age distribution of the study pattern and the other Indian studies can be explained by the varying sample size of the study population and the inclusion of different age groups in the latter studies.

In a study from Srinagar[12], India, the most common type of cerebral palsy observed was spastic diplegia, which contributed to 45% of all cases. In contrast, a European cerebral palsy study[11] reported maximum children with diplegia (35%) followed by hemiplegia (26%), spastic quadriplegia (18%) and dyskinesia (14%).

Recently, Anderson GL *et al.*,[16] noted that among 710 (60%) children with cerebral palsy and available brain MRI, 14% had normal findings, while white matter involvement was the most common lesion (51%), followed by focal cortical (18%) and basal ganglia lesions (14%). Malformations were found in 7% of the children. Among the white matter involvement, 53% were born preterm and spastic bilateral cerebral palsy was the most common subtype (47%). 80% with focal cortical lesions had unilateral cerebral palsy. The spastic bilateral subtype was most common (48%).

The European Cerebral Palsy study[11] showed that white matter damage of immaturity (WMDI, including PVL) was the most common finding (43%), followed by basal ganglia lesions (12.8%), cortical/ subcortical lesions (9.4%), malformations (9.1%), focal infarcts (7.9%) and miscellaneous lesions (7%). A population-based study of brain imaging patterns in cerebral palsy reported white matter injury as the most common imaging pattern for all children with CP, occurring in 19 to 45% of cases across three studies. Krageloh-Mann and horber[17] reported WMI in 56% of scans. However, the results could not be directly comparable since their review only included spastic- dyskinetic CP and preterm children were overrepresented in their review and underrepresented in our review (52 vs. 36%) of the total cohort. On account of increased susceptibility to WMI, it was not expected that 31% to 71% of children born preterm would have this pattern, but perhaps it is more surprising that the imaging of 12% to 32% of children born at term also showed WMI.

A systematic review of studies. Krageloh-Mann and horber[17] using MRI in children with cerebral palsy were performed according to pathogenetic patterns characterizing different timing of occurrence of the lesions. Abnormal MRI was reported in 330 out of 390 cases and gave clues to pathogenesis. Periventricular white matter lesions were most frequent (56%), followed by cortical and deep grey matter lesions (18%), brain maldevelopments were rather rare, described in 9%. A study by Najjar BA *et al.*,[11] reported the commonest MRI abnormality as PVL in 39% of the children, while Gururaj *et al.*,[18] said a very higher rate of PVL that is 58%.

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A review suggested that based on evidence from three population-based cohorts, MRI or a combination of MRI and CT, identifies abnormality consistent with motor impairment in 86% of the children with CP, using current imaging technologies and qualitative assessment methods. However, in the present study, MRI findings were normal in 12% of the children. A similar proportion of normal MRI findings was reported in the European cerebral palsy study[11] (11%). In the present study, MRI findings were correlated with clinical diagnosis. The maximum correlation in our study was noted in Spastic quadriplegic cerebral palsy (100%), spastic diplegic cerebral palsy (100%) and ataxic type of cerebral palsy (100%). The least correlation was noted in mixed cerebral palsy (0%). According to this present study conducted in our institution, the overall correlation between clinical diagnosis and radiological diagnosis with MRI modality is 63.2%.

Correlation between Spastic triplegic cerebral palsy and hypotonic cerebral palsy with MRI imaging diagnosis could not be made as the children with the above clinical diagnosis were not referred to the department in the study mentioned above. These findings suggest that MRI with a higher correlation with clinical diagnosis is a valuable tool and helps determine the etiology and make a better prognosis of cerebral palsy. Kulak W *et al.*,[12] in 2008 also reported that MRI in children with cerebral palsy might help determine the etiology and create a better prediction of cerebral palsy. Overall, the present study showed the usefulness of MRI in diagnosing cerebral palsy. Further studies in the future may focus on etiological aspects and create awareness of possible preventive measures that will help reduce the huge burden of cerebral palsy.

## Conclusion

In present study, MRI findings correlated well with clinical diagnosis. MRI findings correlated with Spastic quadriplegic cerebral palsy (100%), spastic diplegic cerebral palsy (100%) and ataxic type of cerebral palsy (100%). Overall, MRI is a useful diagnostic modality that helps to detect abnormalities in patients with cerebral palsy, which helps in understanding the causal pathways in cerebral palsy, identifying opportunities for future preventive strategies.

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