Spectrum of Brain Abnormalities on Computed Tomography in Children with Cerebral Palsy

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ABSTRACT

Introduction: Cerebral palsy (CP) is the most common cause of physical disability in childhood, and neuroimaging plays a crucial role in understanding its etiology. Computed tomography (CT) remains an accessible imaging modality in resource-limited settings. **Objective:** To evaluate the spectrum of brain abnormalities on CT in children with cerebral palsy and correlate findings with clinical subtypes. **Methods & Materials:** This cross-sectional study was conducted in the Department of Pediatric Neurology at Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh, from July 2009 to July 2010. A total of 81 children aged 0-12 years with confirmed cerebral palsy underwent non-contrast CT brain imaging. CT findings were classified and correlated with clinical subtypes. Data were analyzed using SPSS version 12.5, with the chi-square test used for association ($p<0.05$ significant).**Results:** Among 81 children, 52 (64.2%) were male, with a mean age of 4.7 ± 2.8 years. Spastic cerebral palsy was predominant (84.0%), with quadriplegia being the most common subtype (38.3%). Abnormal CT findings were observed in 62 (76.5%) children. Cerebral atrophy was the most frequent abnormality (25.9%), followed by ventricular dilatation (22.2%) and periventricular leukomalacia (18.5%). Significant correlations were found between specific findings and CP subtypes: periventricular leukomalacia with spastic diplegia (54.5%), encephalomalacia with spastic hemiplegia (60.0%), and basal ganglia lesions with dyskinetic CP (71.4%) ($p<0.001$). Normal CT scans were observed in 19 (23.5%) children, predominantly in ataxic and hypotonic subtypes. **Conclusions:** CT brain abnormalities are present in 76.5% of children with CP, with significant correlations between imaging patterns and clinical subtypes. CT remains a valuable diagnostic tool in resource-limited settings, though normal scans in certain subtypes warrant further evaluation with MRI when available.

Keywords: *Cerebral palsy, computed tomography, neuroimaging, brain abnormalities, children, Bangladesh*

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INTRODUCTION

Cerebral palsy (CP) represents the most common cause of physical disability in childhood, encompassing a heterogeneous group of permanent disorders affecting the development of movement and posture[1,2]. These disorders are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. While the clinical diagnosis of CP is based on the characterization of its motor subtypes and topographical distribution, understanding the underlying etiology is crucial for prognostication, management, and family counseling[3]. Neuroimaging plays a pivotal role in this process, offering an in vivo window into the nature, timing, and extent of the brain injury[4,5]. Magnetic Resonance Imaging (MRI) is widely regarded as the gold standard for evaluating brain structure in CP due to its superior soft tissue contrast[6,7]. However, Computed Tomography (CT) remains a relevant and frequently utilized imaging modality, particularly in resource-limited settings where access to MRI is restricted by cost, availability, and the frequent need for sedation in young children[8,9]. CT is highly sensitive for detecting certain pathologies, such as calcifications and acute hemorrhage, offering a rapid and accessible means to identify a broad spectrum of brain abnormalities[8,10].

The abnormalities visualized on CT in children with CP are diverse and reflect the timing of the insult, whether in the prenatal, perinatal, or postnatal period[11]. These can range from the sequelae of hypoxic-ischemic insults, such as periventricular leukomalacia in preterm infants and basal ganglia or watershed injuries in term infants, to congenital structural malformations (e.g., schizencephaly, polymicrogyria), intracranial hemorrhages, and infections[12,13]. Common findings include brain atrophy, encephalomalacia, and ventricular abnormalities[14,15]. The pattern of these findings can often provide valuable retrospective insight into the pathogenic mechanisms leading to the child's clinical presentation[5]. This article aims to review the spectrum of brain abnormalities detected on computed

tomography in children with cerebral palsy. By examining the characteristic CT findings associated with different etiologies and timing of injury, we seek to underscore the ongoing utility of CT in the diagnostic workup of CP, particularly within contexts where it remains the most feasible neuroimaging option[8]. Understanding this spectrum is essential for clinicians to better correlate imaging findings with clinical phenotypes and to guide targeted interventions and support for affected children and their families[3,11].

OBJECTIVE

The objective of this study is to review the spectrum of brain abnormalities detected on computed tomography (CT) in children with cerebral palsy (CP), and to correlate these findings with clinical subtypes and the probable timing of brain injury, while highlighting the ongoing utility of CT in resource-limited settings.

METHODS & MATERIALS

This cross-sectional study was conducted in the Department of Pediatric Neurology at Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, over one year from July 2009 to July 2010, to evaluate the spectrum of brain abnormalities on computed tomography in children with cerebral palsy. The study population comprised children diagnosed with cerebral palsy attending the Pediatric Neurology Outpatient Department, enrolled using purposive sampling based on predefined inclusion and exclusion criteria. The sample size was calculated using the formula $n = (Z^2 \times p \times (1-p)) / d^2$, where Z=1.96 (95% confidence interval), p=expected proportion of abnormal CT findings (approximately 77% based on previous literature), and d=0.09 (degree of precision), yielding a minimum required sample of 81 children. Parents or legal guardians were interviewed face-to-face using a structured questionnaire emphasizing demographic characteristics, perinatal and postnatal risk factors, antenatal history, developmental milestones, type of motor impairment, and associated comorbidities. All enrolled children underwent non-contrast computed tomography of the brain following standard pediatric protocols, with CT images independently reviewed by a radiologist blinded to clinical findings to minimize bias. CT findings were classified, including cerebral atrophy, ventricular dilatation, periventricular leukomalacia, encephalomalacia, basal ganglia lesions, congenital malformations, hydrocephalus, mixed findings, or normal study, and subsequently correlated with clinical subtypes of cerebral palsy (spastic hemiplegic, spastic diplegic, spastic quadriplegic, dyskinetic, ataxic, hypotonic, and mixed). Data were manually verified and analyzed using SPSS version 12.5, with descriptive statistics calculated for demographic and clinical variables, and the association between type of cerebral palsy and CT abnormalities assessed using the chi-square test, considering a p-value <0.05 as statistically significant. The study protocol received ethical approval from the Institutional Review Board of Bangabandhu Sheikh Mujib Medical University (BSMMU), and written informed consent was obtained from all parents or legal guardians before participation.

Inclusion Criteria:

1) Children aged between 0 and 12 years.
2) Confirmed diagnosis of cerebral palsy established by a pediatric neurologist based on standard clinical criteria.
3) Diagnosis based on the presence of non-progressive motor impairment, abnormal posture and movement, and clinical history consistent with cerebral palsy.

Exclusion Criteria:

1) Progressive neurological disorders.
2) Head trauma or cerebrovascular events.
3) Genetic syndromes affecting the central nervous system.
4) Any contraindications to CT imaging, such as unstable vital signs or inability to tolerate the procedure without sedation.

RESULTS

A total of 81 children with cerebral palsy were enrolled in this study. The table shows a male predominance, with 52 (64.2%) boys and 29 (35.8%) girls, yielding a male-to-female ratio of approximately 1.8:1. Regarding age distribution, the largest cohort comprised children aged 2 to 5 years (38 children, 46.9%), followed by those aged 6 to 12 years (25 children, 30.9%), and children under 2 years (18 children, 22.2%). The mean age of the study population was 4.7 ± 2.8 years (*Table I*).

Table I
Demographic Characteristics of Children with Cerebral Palsy (*n*=81).

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	52	64.20
	Female	29	35.80
Age Group	< 2 years	18	22.22
	2 - 5 years	38	46.91
	6 - 12 years	25	30.86

Table II illustrates the frequency and percentage of various cerebral palsy subtypes among the study participants. Spastic cerebral palsy was the predominant type, accounting for 68 (84.0%) of all cases. Among the spastic subtypes, spastic quadriplegia was the most common, observed in 31 children (38.3%), followed by spastic diplegia in 22 children (27.2%) and spastic hemiplegia in 15 children (18.5%). Dyskinetic cerebral palsy was present in 7 children (8.6%), while ataxic and hypotonic types were less common, comprising 3 (3.7%) and 2 (2.5%) cases, respectively. Mixed-type cerebral palsy was observed in 1 child (1.2%).

Table II
Distribution of Cerebral Palsy Subtypes (*n*=81).

CP Subtype	Frequency (n)	Percentage (%)
Spastic Quadriplegia	31	38.27
Spastic Diplegia	22	27.16
Spastic Hemiplegia	15	18.52
Dyskinetic	7	8.64
Ataxic	3	3.70
Hypotonic	2	2.47
Mixed	1	1.23
Total	81	100.00

Table III summarizes the computed tomography findings in the study population. Abnormal CT scans were observed in 62 children (76.5%), while 19 children (23.5%) had normal studies. Cerebral atrophy was the most frequent abnormality, detected in 21 children (25.9%). Ventricular dilatation was noted in 18 children (22.2%), and periventricular leukomalacia was identified in 15 children (18.5%). Encephalomalacia was present in 12 children (14.8%), while basal ganglia lesions were observed in 8 children (9.9%). Congenital malformations were found in 5 children (6.2%), and hydrocephalus was present in 4 children (4.9%). Mixed findings, showing a combination of two or more abnormalities, were noted in 10 children (12.3%). Note: Some children had more than one finding; therefore, percentages total more than 100% due to mixed findings.

Table III
Spectrum of CT Brain Abnormalities in Children with CP (*n*=81).

CT Finding	Frequency (n)	Percentage (%)
Cerebral Atrophy	21	25.93
Ventricular Dilatation	18	22.22
Periventricular Leukomalacia (PVL)	15	18.52
Encephalomalacia	12	14.81
Basal Ganglia Lesions	8	9.88
Congenital Malformations	5	6.17
Hydrocephalus	4	4.94
Mixed Findings	10	12.35
Normal Study	19	23.46

Table IV demonstrates the relationship between specific CT abnormalities and the clinical subtypes of cerebral palsy. In spastic quadriplegia (n=31), cerebral atrophy (17 cases, 54.8%) and periventricular leukomalacia (11 cases, 35.5%) were the predominant findings. Among children with spastic diplegia (n=22), periventricular leukomalacia was the most frequent abnormality (12 cases, 54.5%), followed by ventricular dilatation (9 cases, 40.9%). In spastic hemiplegia (n=15), encephalomalacia was characteristic, observed in 9 children (60.0%). For dyskinetic cerebral palsy (n=7), basal ganglia lesions were the most common finding, present in 5 children (71.4%). Congenital malformations were observed in spastic quadriplegia (3 cases) and mixed type (1 case). Normal CT scans were most frequently observed in ataxic (2 of 3, 66.7%) and hypotonic (2 of 2, 100.0%) subtypes. The chi-square test revealed a statistically significant association between CT findings and cerebral palsy subtypes ($p < 0.001$).

Table IV
Correlation of CT Findings with Cerebral Palsy Subtypes.

CT Finding	Spastic Quadriplegia (n=31)	Spastic Diplegia (n=22)	Spastic Hemiplegia (n=15)	Dyskinetic (n=7)	Ataxic (n=3)	Hypotonic (n=2)	Mixed (n=1)	Total (N=81)
Cerebral Atrophy	17(54.8%)	3 (13.6%)	1 (6.7%)	0	0	0	0	21
Ventricular Dilatation	8 (25.8%)	9 (40.9%)	1 (6.7%)	0	0	0	0	18
Periventricular Leukomalacia	11(35.5%)	12(54.5%)	2(13.3%)	0	0	0	0	25
Encephalomalacia	2 (6.5%)	1 (4.5%)	9(60.0%)	0	0	0	0	12
Basal Ganglia Lesions	2 (6.5%)	0	0	5 (71.4%)	0	0	1(100%)	8
Congenital Malformations	3 (9.7%)	0	1 (6.7%)	0	0	0	1(100%)	5
Hydrocephalus	2 (6.5%)	1 (4.5%)	0	0	1(33.3%)	0	0	4
Normal Study	2 (6.5%)	2 (9.1%)	2(13.3%)	2 (28.6%)	2 (66.7%)	2 (100%)	0	12

DISCUSSION

This study demonstrated that abnormal neuroimaging findings were present in 76.5% of children with cerebral palsy, which closely aligns with the global prevalence of 77-85% reported in recent literature and underscores the high diagnostic yield of computed tomography in this population[3,8]. The predominance of spastic cerebral palsy (84.0%) in our cohort, with quadriplegia being the most common subtype (38.3%), reflects patterns observed in contemporary studies from South Asian and resource-limited settings, where perinatal asphyxia and neonatal infections remain prevalent[9,16]. Cerebral atrophy emerged as the most frequent abnormality (25.9%), consistent with recent findings from India, where atrophy was reported in 28.4% of children with CP, representing the chronic sequelae of global hypoxic-ischemic insults[4,17].

The strong association between periventricular leukomalacia and spastic diplegia (54.5%) observed in our study corroborates the established pathophysiological mechanism whereby premature infants sustain injury to periventricular white matter, affecting corticospinal tracts to the lower extremities[11,12]. Recent systematic reviews have confirmed that PVL remains the predominant imaging finding in children with spastic diplegia, particularly those with a history of prematurity and low birth weight[5,18]. Similarly, the characteristic finding of encephalomalacia in 60.0% of children with spastic hemiplegia reflects focal vascular insults, most commonly in the middle cerebral artery territory, as documented in contemporary neuroimaging studies[19,20]. These focal lesions typically result from perinatal arterial ischemic stroke, which accounts for approximately 30% of hemiplegic CP cases[21].

The significant correlation between basal ganglia lesions and dyskinetic cerebral

palsy (71.4%) observed in our study reinforces the established link between deep gray matter injury and extrapyramidal motor involvement[22,23]. Recent advances in neuroimaging have further characterized these lesions as sequelae of acute perinatal asphyxia in term infants, where the basal ganglia and thalamus are particularly vulnerable due to their high metabolic activity and glutamate receptor density[24,25]. Furthermore, kernicterus resulting from severe neonatal hyperbilirubinemia remains an important cause of basal ganglia injury, particularly in settings with limited access to neonatal intensive care[26,27].

The finding that 23.5% of children had normal CT scans, predominantly among those with ataxic and hypotonic subtypes, highlights the limitations of CT in detecting subtle abnormalities such as migrational disorders, cerebellar hypoplasia, or metabolic insults[28,29]. Contemporary guidelines increasingly recommend magnetic resonance imaging as the modality of choice for CP evaluation, with studies demonstrating abnormal findings in up to 89% of children undergoing MRI compared to 77% with CT[30,31]. However, in resource-limited settings where MRI access remains constrained by cost, availability, and the need for sedation, CT continues to serve as a valuable first-line neuroimaging tool[8,32].

LIMITATIONS

This single-center study with a relatively small sample size (n=81) and data collected from 2009-2010 limits the generalizability and contemporaneous relevance of our findings. The use of CT rather than MRI reduced sensitivity for detecting subtle white matter abnormalities and structural malformations, while retrospective data collection was subject to parental recall bias. Additionally, the lack of long-term follow-up data prevented correlation of imaging findings with functional outcomes.

CONCLUSION

This study found that CT brain abnormalities are present in 76.5% of children with cerebral palsy, with significant correlations between specific imaging findings and clinical subtypes: periventricular leukomalacia with spastic diplegia, encephalomalacia with spastic hemiplegia, and basal ganglia lesions with dyskinetic CP. CT remains a useful diagnostic tool in resource-limited settings, though 23.5% normal scans, especially in ataxic and hypotonic subtypes, highlight the need for MRI when available. These findings support the role of neuroimaging in guiding the diagnosis and management of children with CP.

RECOMMENDATIONS

It is recommended that CT brain imaging be routinely incorporated into the diagnostic evaluation of children with cerebral palsy in resource-limited settings, given its high yield of abnormal findings. MRI should be prioritized for children with normal CT scans, particularly those with ataxic and hypotonic subtypes. Future multicenter studies using advanced MRI techniques are needed to further characterize brain abnormalities, and a national CP registry should be established in Bangladesh to facilitate research and improve clinical outcomes. Additionally, public health initiatives should focus on preventing preventable risk factors such as birth asphyxia and neonatal jaundice.

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