# Brain Magnetic Resonance Imaging Pattern in Cerebral Palsy

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## Abstract

# Background

Cerebral palsy (CP) leads to a common static motor neurological disease in children that can be demonstrated with varied neuroimaging findings. Magnetic Resonance Imaging (MRI) has a vital role of determining the presence of brain injury and its extent, with any possibility of determining pathogenic pattern and disease severity. The objective of the study is to evaluate the neuroimaging findings in CP and their correlation to disease severity.

# Method

The research was case-control study, consecutive and complete records of all patients who had a clinical diagnosis of CP and performed a head MRI between 2018 and 2019 were enrolled in this study. Cases group were children diagnosed as severe CP with The Gross Motor Function Classification System (GMFCS) IV-V. Control group were children confirmed as CP with GMFCS I-III. Brain imaging was examined by MRI, in which the abnormalities were classified into grey matter or white matter injury, focal vascular disorder and brain malformation. Kruskal-Wallis statistical analysis was applied to identify the correlation.

# Results

Almost 60 cases were reviewed. White matter injury, malformation and focal vascular insult were not correlated significantly to CP severity (OR = 0.73; 95% CI = 0.2-2.2; p = 0.78 and OR = 0.61; 95% CI = 0.2-1.9; p = 0.57 and OR = 2.034; 95% CI = 0.51-0.76; p = 0.63, respectively). Grey matter injury was more frequent discovered in severe CP (50%) and increased the risk of CP severity (OR = 9; 95% CI = 2.2 – 36; p = 0.002).

# Conclusion

Grey matter injury is considered the most frequent abnormalities of Brain MRI in CP and it could increase the risk of severity.

## Introduction

Cerebral palsy (CP) is a persistent disorder that affects neurological function such as mobility and posture, limiting physical exercise, that is caused by non-progressive disorders in the developing fetus or underdeveloped infantile brain.[1–2] Approximately 1.5–3 per 1,000 live births considered as the prevalence

of CP.[3–5] Male sex and preterm infants may be risk factor of developing CP.[6–8] However, factors related to CP severity remain unclear.

CP is specifically limited to brain lesions. It occurs throughout the fetal or neonatal period and lasts until the age of three years. Sensation, cognition, communication, perception, convulsion and/or behaviour disturbances are frequently associated with motor disorders.[1] Various etiological variables might produce clinical presentation variety throughout the prenatal, perinatal, or postnatal period, which can be demonstrated with different neuroimaging findings.[9–10] However, the significant role of the lesion location and type in association with the clinical outcome has not been discussed in depth.

Cerebral magnetic resonance imaging (MRI) is a potential tool for determining the location and degree of the early cerebral damage.[11] Cerebral MRI abnormalities that can be classified as white matter injury, grey matter injury, and localized vascular insult affect 70-90 percent of children with CP.[12] Choi, et al reported that severity of Hypoxic Ischemic Encephalopathy (HIE) model on brain MRI was powerfully related to the disability of in gross motor function, supportable communication, as well as way of thinking.[13] In children with CP, visualizing the brain damage and providing insights into the prognosis prediction is important. Normal MRI does not exclude CP.[14]

## Methods

# Study design

The research design was a case control studies on 60 children diagnosed with CP in January 2018 – December 2019.

# Study subjects

The diagnosis of CP was based on international definition and classification of CP.[1] All CP patients aged 2 – 18 years old who performed brain MRI were included. The gross motor function assessment in CP children was able to be classified into 5 different levels using GMFCS, as follows:

GMFCS I : The patients could walk without limitations.

GMFCS II : The patient could walk with limitations

GMFCS III : The patient could walk using a hand-held mobility device.

GMFCS IV : The patient in limited self-mobility; may use powered mobility.

GMFCS V : The patient could only transport in a manual wheelchair.

The case group was children that confirmed as severe CP with GMFCS level IV to V. The control group was identified as children confirmed as CP with GMFCS level I to III. A child may have one or more

abnormalities.

# Study setting

The site of this study was Paediatric Neurology Outpatient Clinic, Dr. Soetomo Academic Hospital, Surabaya, Indonesia.

# Source of data

Patient information were accumulated from paper-based medical records of neurology outpatient clinic. Brain MRI was performed using GE magnetic resonance spectroscopy and perfusion (MR360 Optima 1.5T GE).

# Procedure

Clinical adjustment of body function and exertion was based on standardized protocol referred to GMFCS for CP. A pediatric neurologist performed the assessments and without knowing the specific type of brain lesion present. A neuroradiology consultant independently reviewed all MRI result and was blind to the result of the clinical assessment.

# Imaging pattern

Grey matter injury : there was abnormal indicator and / or more dominant capacity reduction in the cortical and/or subcortical grey matter, profound grey matter, or both exist.

White matter injury : there was periventricular and/or profound white matter abnormal signal or volume reduction. There could be dilated ventricles, scalloped ventricles, and cysts.

Focal vascular insult : there was abnormal signal, volume reduction, or porencephaly according to the appropriate vascular territory region. Isolated hemorrhagic lesions and venous sinus thrombosis were considered to be included.

Malformation : there was abnormal formation of the brain, as well as dysplasia of cortical region, gyral abnormal formation including pachygyria, polymicrogyria, or lissencephaly, heterotopia, abnormal cleft of hemispheres referes ro schizencephaly, dysgenesis of cerebellum, agenesis of the corpus callosum, variant hydrocephalus including hydrancephaly or congenital hydrocephalus.

# Statistical analysis

The descriptive and correlation between independent variables and CP severity was examined using the chi-square test. The correlation between MRI finding and CP severity was calculated by Kruskal-Wallis test. Analysis were performed using SPSS software version 25 for Mac with a p-value of $<0.05$ (two sided) intended significant in statistic interpretation.

*Ethical approval*

The study was obtained by the Medical Research Ethics Committee Dr. Soetomo Hospital No 211/Panke.KKE/III/2017.

# Results

In overall CP, females predominated in number over males. There were 31 females and 29 males. Median age of severe CP group was 4.26 year old, while mild-moderate CP was 5.03 years old. The commonest type of CP was spastic quadriplegia in 37 (52.9%) and the less was athetoid in 3 (4.3%). In our study, 47 patients (67.1%) have risk factor of developing CP, in which prenatal risk factor (36.2%) was the commonest (Table 1).

Table 1.Baseline characteristic of the patients.

| | Severe CP | Mild-Moderate CP | *p* value |
|---|---|---|---|
| Mean Age at MRI (year) | 4.26 | 5.03 | 0.67 |
| Sex (n(%)) | | | |
| Male | 14 (46.7) | 15 (50) | 1.00 |
| Female | 16 (53.3) | 15 (50) | |
| Residence (n(%)) | | | |
| Surabaya | 22 (73.3) | 17 (56.7) | 0.92 |
| Outer Surabaya | 8 (26.7) | 13 (43.3) | |
| Patient status (n(%)) | | | |
| Come by self | 21 (70) | 17 (56.7) | 0.87 |
| Referral | 9 (30) | 13 (43.3) | |
| Risk factor (n(%)) | | | |
| None | 11 (36.7) | 12 (40) | |
| Prenatal | 12 (40) | 5 (16.7) | 0.19 |
| Perinatal | 2 (6.7) | 3 (10) | |
| Postnatal | 5 (16.7) | 10 (33.3) | |
| Epilepsy (n(%)) | | | |
| (+) | 19 (63.3) | 12 (40) | 0.52 |
| (-) | 11 (36.7) | 18 (60) | |
| CP type (n(%)) | | | |
| Quadriplegia | 23 (76.7) | 14 (40) | <0.01 |
| Hemiplegia | 5 (16.7) | 1 (3.3) | |
| Diplegia | 2 (6.7) | 14 (46.7) | |
| Athetoid | 0 (0) | 3 (10) | |

MRI was normal in 2 patients, which was one in severe CP, one in mild-moderate CP. MRI was abnormal in 58 patients, and one patient might has more than one abnormalities. White matter, as well as grey matter injury were the commonest abnormality, followed by malformation (table 2)(Figure 1-4).

Table 2.Patterns of abnormal brain MRI abnormalities in CP

| MRI patterns | Severe CP (%) | Mild-Moderate CP (%) | OR | P value |
|---|---|---|---|---|
| Normal | 1(3.3) | 1(3.33) | | |
| Grey matter injury | 15 (50) | 4 (13.3) | 9 (95% CI = 2.2-36) | 0.002* |
| White matter injury | 7 (23.3) | 11 (36.7) | 0.73 (95% CI = 0.2-2.2) | 0.78 |
| Focal vascular insult | 2 (6.7) | 4 (13.3) | 2.034 (95% CI = 0.2-2.2) | 0.63 |
| Malformation | 5 (16,7) | 10 (33.3) | 0.61 (95%CI = 0.2-1.9) | 0.57 |

*Significant for Kruskal Wallis Test

# Discussion

In our research, female majority over males was perceived as 51.7% patients fit in to female sex contradiction of 48.3% males. Yamada et al whose study had 60.25% of 38 cases of CP have also reported female preponderance.[15] However, Kulak et al obtained male majority of the CP study.[16]

The most mutual type of CP in our research was spastic quadriplegia, followed by spastic diplegia. Research of Robinson et al is in assenting with our research, which also had spastic quadriplegia (37.5%) as mutual type of CP.[17] The less mutual types in our research was athetoid( 7.01%) type, alike to remark of Bax et al who had ataxic type in 3.9% CP patients.Number of limbs affected in CP hadsignificant correlation to disease severity in this study. Mean GMFCS scores of quadriplegic CP subjects were considered to be lower compared to other groups.[18] Chen et al found that children with spastic quadriplegia had lower developmental functions compared to spastic diplegia children.[19]

The recent investigation showed that severe CP group had higher prevalence of suffering from epilepsy. However, this resultwas not statistically significant. The possibility to become epilepsy could be determined by the etiology of recurrent seizure. Epilepsy found in 50-94% patients regardless of secondary CPdue to global cortical malformationas well as 50% in stroke children due to perinatal asphyxia.

Magnetic Resonance Imaging was within normal findings in 14.03% of our investigated CP patientsinspection. Approximately, 85.90% CP subjects demonstrated abnormal MRI, this is in agreement with Bax et alresult that showed normal brain MRI in 11.76% CP subjects as well as abnormal brain MRI in 88.24% cases.[1] A matching observationwas constructed by Kulak et alwhich displayed 4.7% normal

brain MRI.[16] Two studies exhibited normal brain imaging of CP subjects in higher percentages 14-16%.[17,20]

Both white matter as well as grey matter lesion were the commonest MRI abnormality discovered in CP. However, only grey matter injury had significant correlation to CP severity. Profound grey matter lesion shows wide range of patterns on brain MRI findings, hence grading techniques vary greatly in some research.[20-22]Profound grey matter caused by abrupt prenatal hypoxic ischemic encephalopathy has been identified as a leading cause of death and CP.[21] Because the basal ganglia and thalamus play such an important role in motor, postural regulator, and movement, the general outcomes of HIE children are poor.[20,23,24] Furthermore, there was a clear link between the severity of profound grey matter injury and cognitive results. A higher likelihood of severe cognitive impairment was linked to more extensive profound grey matter injury affecting additional central sulci or the hippocampus.[13,21,25] The main noteworthy clinical result is that combined involvement of cortical – subcortical and pallidum is related with an extreme gross motor outcome (89 % and 100% respectively), e.g. GMFCS level IV and V.[26]

Cerebral white matter lesion is such as mainpattern of brain injury in premature birth survivors, with thepeak rate is baby in 23–32-week post-conceptional age, during the early several months of a child's existence.[27]White matter damage is demonstrated in about 50% of all CP patients. In preterm survivors, MRI-defined white matter injury (WMI) appears as aberrant movements that are indicative of CP.[28] Furthermore, premature delivery is linked to a higher risk of reduced cerebral grey and white matter volumes, both of which are linked to cognitive development impairment.[29,30] In some populations of full-term newborn, WMI may be more common because in utero insults appear to correlate with a vulnerable time in white matter development prior to the commencement of myelination process.[21,31]Patients with abnormal MRIs were found to have congenital abnormalities in 28.33% of cases. According to Robinson and Kulak, brain MRI revealed a higher number of congenital abnormality cases of 12 percent and 10%, independently.[16,17]

There was no risk factor identified in 36.7% patients of severe CP and 40% in mild moderate. In this study, risk factor had no significant correlation to disease severity.Garfinkle et al reported when compared to children without birth asphyxia, children with CP after neonatal encephalopathy and severe birth asphyxia were experiencing high possibility to have a later more severe neurological subtype (spasticity/paralysis), severe level of GMFCS and nonverbal communication skills impairment, as well as a higher comorbidities consequences.[32]Previous CP registries also showed that overall burden children who got CP as a result of neonatal encephalopathy had a higher-level disability.[32,33] This discrepancy might be caused by giving birth outside the hospital, so the APGAR score was ignored.

# Conclusion

Grey matter injury was the most frequent MRI abnormalities observed in CP patients. It correlated to CP severity.Further studies based on CP etiology and complication with adequate sample size was required

to estimate long term prognosis.

# Abbreviations

CP : Cerebral palsy

GMFCS : Gross motor function classification system

HIE : Hypoxic ischemic encephalopathy

MRI : Magnetic resonance imaging

WMI : White matter injury

# Declarations

**ACCORDANCE** Our research involving human data (MRI imaging and patients data from medical record) and have been approved by the institutional ethics committee.

**Name of the ethic committee** (KomiteEtikPenelitianKesehatan RSUD Dr. Soetomo Surabaya / *Medical Research Ethical Committee Dr. Soetomo General Academic Hospital, Surabaya*

**Ethical clearance no:** 211/Panke.KKE/III/2017

**Ethics approval**: Ethical clearance no 211/Panke.KKE/III/2017granted from Medical Research Ethical Committee Dr. Soetomo General Academic Hospital Surabaya.

**Consent for publication:** Not applicable

**Availability of data and material:** The datasets generated and/or analysed during the current study are not publicly available due to institution policy, but are available from the corresponding author on reasonable request.

**Competing interests:** The authors declare that they have no competing interests.

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**Author's contributions:** Gunawan design conceptual framework, data collection, analysis and interpretation, discussion and summary. Noviandi contribute to data analysis, statistics, literature review and discussion. Samosir revised the manuscript, figures and tables editing and literature review. All authors discussed the results and to the final version of the manuscript.

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# Figures

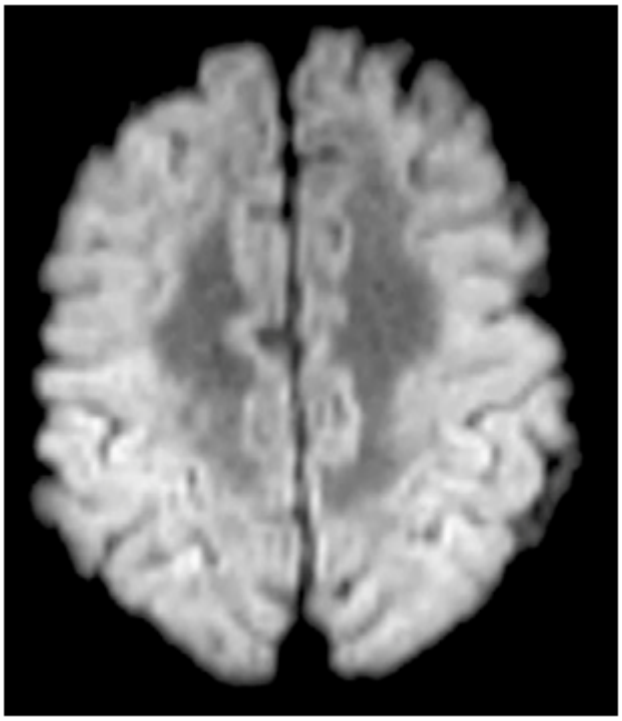


**Figure 1**

Brain MRI pattern exhibited grey matter injury

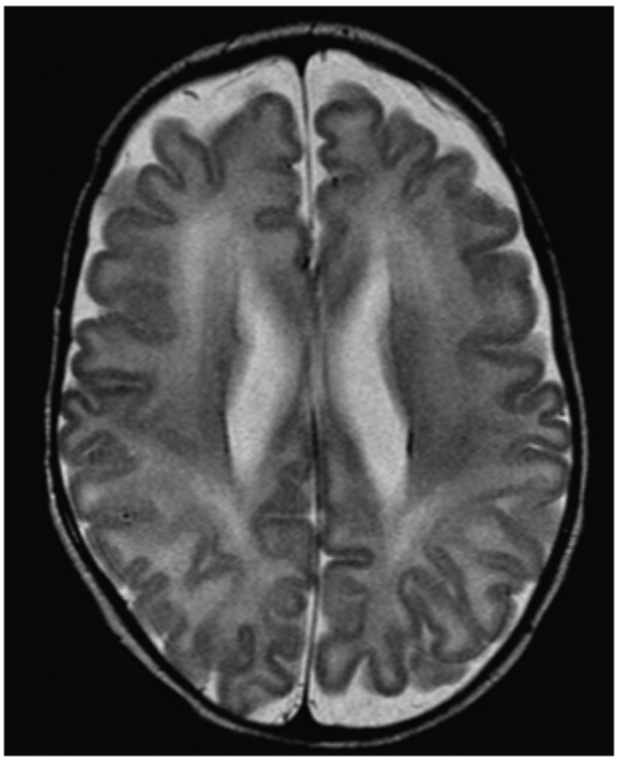
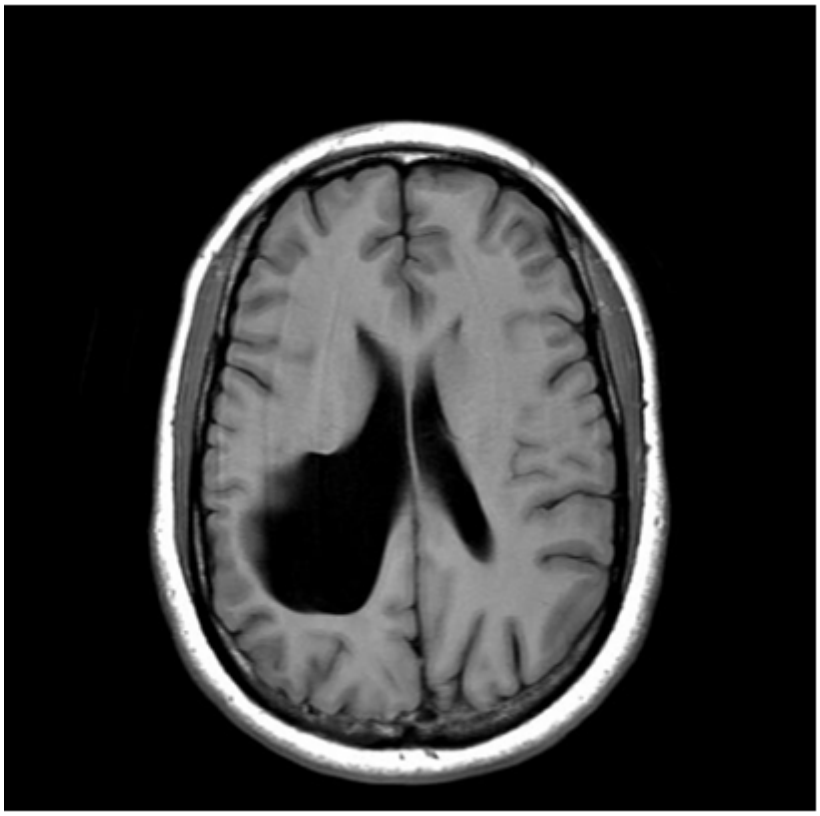


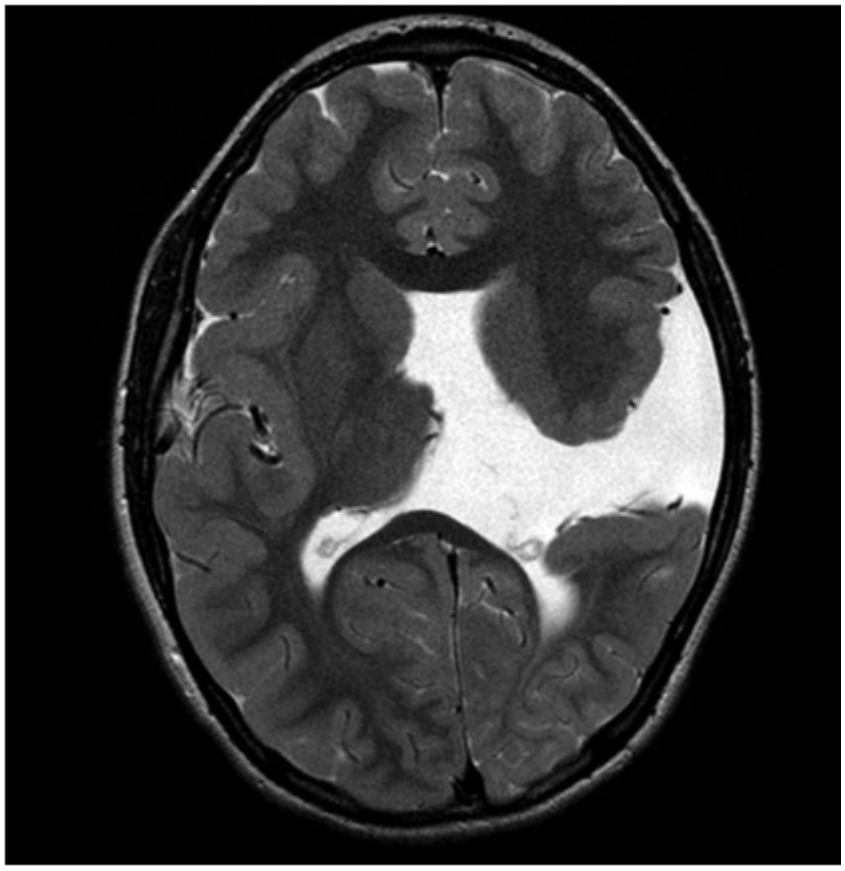
**Figure 2**

Brain MRI pattern exhibited white matter injury



## Figure 3

Head MRI of the patientexhibitedfocal vascular insult (poreencephaly)



## Figure 4

Head MRI pattern exhibited brain malformation (schizencephaly)