Magnetic resonance imaging patterns of children with cerebral palsy: findings from hospital-based surveillance in Vietnam

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Abstract

BACKGROUND: Previous studies on neuroimaging in cerebral palsy (CP) identified inconsistent radiologic findings. The Magnetic Resonance Imaging Classification system (MRICS) was developed by the Surveillance of Cerebral Palsy in Europe to standardize MRI reporting. MRICS aids in predicting future impairments and treatment but it remains largely unexplored in low- and middle-income countries (LMICs) often due to the lack of available MRI data. This study aims to document brain MRI patterns among Vietnamese children with CP.

METHODS: Active prospective ascertainment of children with CP using hospital-based surveillance in the National Children's Hospital, Hanoi, Vietnam between June and November 2017. Data on risk factors and clinical characteristics were collected. Brain MRI reports were obtained from hospital records and classified using the MRICS.

RESULTS: MRI data were available for 264 children with CP (mean age 2.5±2.1 years). MRI showed pathogenic patterns in 76.4%. Nearly half (44.7%) of the children had predominant white matter injury, with predominant grey matter injury in 9.5%, and maldevelopment in 5.3%. MRI findings were associated with the type of CP and timing of causative injury including prematurity, birth asphyxia and infection.

CONCLUSION: MRI findings are consistent with the predominance of white matter injury described in cohorts of children with CP from high income countries. This study furthers understanding of MRI patterns and the related aetiologic factors among children with CP in Vietnam which will inform preventive strategies in similar settings.

INTRODUCTION

Cerebral palsy (CP) is the most common physical disability in childhood. It is a clinically heterogenous condition with complex causal pathways. The most recent and widely used definition describes CP as "a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour; by epilepsy, and by secondary musculoskeletal problems."[1] Although not included in the definition of CP, abnormal brain neuroimaging patterns are reported in over 80% of children with CP.[2] Brain magnetic resonance imaging (MRI) is an important component of evidence-based assessment for diagnosis of CP, and provides clues about the localization, nature, extent and timing of causative brain maldevelopment or injury.[3] These key factors in turn influence capacity for plasticity, and ultimately prognostic outcomes including the topography and severity of motor impairments and associated impairments such as visual, hearing, speech and intellectual impairments, and epilepsy.[3]

Well-characterized causal pathways for CP include preterm birth, congenital anomalies, hypoxia-ischemia, infection, and pre- and perinatal stroke.[4] Growing evidence from CP registers across the world suggest that causal pathways may vary between low-and middle-income countries (LMICs) and high-income countries (HICs).[5–7] For example, hypoxic ischaemic encephalopathy is more commonly reported in LMICs, whereas prematurity predominates in HIC.[6, 8, 9]. Methodological differences may further contribute to the reported variations in risk factors. For example, preliminary findings from an international, multi-centre CP register in LMICs indicate that the proportions of preterm births in children with CP from population-based registers were consistent with the national averages of preterm births in Bangladesh, Indonesia and Nepal.[7] By contrast, findings from the single institution based register included in the same study reported a significantly greater proportion of preterm births compared to the national average in Ghana.[7] Such emerging data from LMICs reaffirm that exploration of MRI patterns is vital to a better understanding of the prevailing aetiologies of CP in LMICs, which will ultimately inform much needed preventive strategies in low resource settings.

A systematic review exploring the value of neuroimaging in CP highlights that a common problem is inconsistent descriptions of radiologic findings.[10] A standardised approach to the classification and nomenclature of MRI patterns in CP is rarely used. Such an approach would enable comparisons of MRI patterns across settings and substantially advance knowledge about CP aetiology. To achieve a common language for reporting neuroimaging findings associated with CP, the Surveillance of Cerebral

Palsy in Europe (SCPE) developed the MRI Classification system (MRICS) which describes patterns of abnormality based on the specific timing of vulnerability in different parts of the brain.[11, 12] This classification system enables investigation of possible structure–function relationships and can therefore aid in prediction of future impairments and inform prevention and treatment of CP.[11] These areas remain unexplored in LMICs, in part due to the lack of available MRI data of children with CP.

As characteristic MRI patterns are associated with the timing of the brain insult, they are indicative of aetiologic events contributing to CP.[11] Understanding the timing of injury leading to CP is vital to the development of preventive strategies. This is particularly important in LMICs where the rate and severity of CP are considerably higher than in HICs, and there is an overall lack of implementation of known preventive and neuroprotective approaches.[5, 6] Such efforts, including administration of antenatal magnesium sulphate and therapeutic hypothermia, have been substantiated in HICs and contributed to declining rates of CP.[5, 6, 13, 14]

In 2017, we established hospital-based surveillance to identify, and document clinical characteristics of children presenting with CP to the National Children's Hospital (NCH) in Hanoi, Vietnam.[15] In the current study, we aimed to use the MRICS to describe MRI patterns among children with CP in Vietnam.

METHODS

Active prospective case ascertainment, using a method modelled on the Paediatric Active Enhanced Disease Surveillance (PAEDS) system in Australia, was used to identify children newly diagnosed with CP at NCH between June and November 2017. A study protocol and methodological details are published.[15–17]

Participants

Study participants were children aged less than 18 years, who attended the rehabilitation department, were diagnosed with CP, and had an MRI report in their hospital records.

Clinical assessment and data collection

A modified version of the Australian Cerebral Palsy Register case report form, currently used widely for the Global LMIC CP Register Study, was used for clinical data collection (Appendix A).[7] Clinical data were collected at NCH by trained Vietnamese paediatricians through comprehensive history taking, clinical assessment, and review of existing medical records as per the study protocol.[17]. Data were collected on perinatal risk factors, age of CP diagnosis, timing of presumed injury causing CP (pre-perinatal, postnatal, unknown), type, topography and severity of motor and associated impairments of CP. Available brain MRI reports were additionally obtained from the hospital records.

Perinatal asphyxia was diagnosed in any newborn who failed to cry at the time of birth, experienced delayed onset of breathing (> 1min), or required assistance to initiate breathing. Low birth weight was defined as birth weight < 2500 grams. Preterm was defined as children born < 37 weeks gestation. Gross Motor Function Classification System (GMFCS) was used to assess functional severity.[18] The presence and severity of associated impairments were documented based on clinical history, detailed assessment conducted by clinicians, review of available medical records and parent/primary caregiver report. Detailed accounts of the assessment of associated impairments, i.e., epilepsy, intellectual, visual, hearing and speech impairment, are provided in a previous publication.[15]

Classification of MRI findings

Reports of the MRI scans, completed by radiologists at the NCH and stored in the hospital records, were collected and translated from Vietnamese to English. MRI findings from scans completed at any age were included in the study. The MRI findings from translated reports were independently classified using the MRICS by two study investigators (TK and SM, a trained paediatric neurologist).[12] Any disagreements in classification were resolved through discussion between the two investigators and, if necessary, review by a third investigator to achieve consensus. The findings were classified into five groups based on the MRICS: maldevelopment, predominant white matter injury, predominant grey matter injury, miscellaneous

changes and normal. If more than one MRI pattern was found, it was classified according to the predominant pattern most likely to have led to the CP.

Ethical considerations

Ethics approval

was obtained from the University of Sydney Human Research Ethics Committee (HREC) (2016/456), Hanoi Medical University (HMU) (1722/QD-DHYHN) and NCH in Hanoi (812/QD-BVNTU). Informed consent was obtained from parents or caregivers of all study participants. All methods were performed in accordance with the relevant guidelines and regulations.

Statistical analysis

Descriptive analyses (mean, standard deviation (SD), median, inter-quartile-range (IQR) and proportion) was performed. Chi-square testing was used to examine MRI correlates across the MRICS categories. A p-value < 0.05 was considered significant. All analyses were performed using SPSS Statistics software version 24 (IBM Corporation, Chicago, Illinois, USA).

RESULTS

MRI data were available for 264 children and adolescents with CP identified during the study period. The clinical characteristics, including perinatal factors, timing of presumed injury causing CP, type of CP, GMFCS levels and associated impairments, were similar in children with and without MRI data. Mean age at study inclusion (i.e., at the time of presentation to NCH) was 2.5 ± 2.1 (range: 0.3–13.3, median: 1.8) years and 37.5% (n = 99) were female. The majority of children had spastic CP, mainly quadriplegia (75%, n = 198), and 64.9% (n = 171) functioned at GMFCS levels III-V. One or more associated impairments were reported in the majority of children.

[Insert Table 1 here]

Table 1
Baseline characteristics, CP subtype, motor severity and associated impairments in children with CP with and without MRI data

	With MRI (N = 264) n (%)	**Without MRI (N = 501) n (%)**	***p*-value**
Gender (n = 264)			
Female	99 (37.5)	175 (34.9)	0.48
Mean (± SD) age at study inclusion (years)	2.5 ± 2.1	2.7 ± 2.6	0.65
Mean (± SD) age at diagnosis of CP (years)	1.5 ± 1.6	1.8 ± 1.8	0.14
Timing of presumed injury causing CP (n = 261)			
Pre and perinatal	153 (58.0)	263 (52.5)	0.10
Postnatal	38 (14.4)	60 (12.0)	
Unknown	70 (26.5)	178 (35.5)	
Type of CP (n = 264)			
Spastic			
Quadriplegia	198 (75.0)	334 (66.7)	**0.017**
Monoplegia/hemiplegia	46 (17.4)	111 (22.2)	0.12
Diplegia	10 (3.8)	30 (6.0)	0.19
Dyskinetic	10 (3.8)	25 (5.0)	0.45
Ataxic	-	1 (0.2)	0.47
GMFCS (n = 263)			
Level I	50 (19.0)	129 (25.7)	0.08
Level II	42 (16.0)	79 (15.8)	
Level III	40 (15.2)	63 (12.6)	
Level IV	44 (16.7)	87 (17.4)	
Level V	87 (33.1)	133 (26.6)	
Associated impairments [a]			
Epilepsy (n = 261)	31 (11.9)	51 (10.3)	0.47
Speech impairment (n = 263)	169 (64.3)	281 (56.4)	**0.037**
Intellectual impairment (n = 261)	188 (72.0)	276 (55.3)	0.05
Visual impairment (n = 260)	9 (3.5)	32 (6.6)	0.07
Hearing impairment total (n = 262)	5 (1.9)	8 (1.6)	0.76

aMultiple impairments were reported for several children.

GMFCS, Gross Motor Function Classification System.

Distribution of MRI patterns

MRI findings were abnormal in 76.4% (n = 202) children. Nearly half (44.7%, n = 118) the children had predominant white matter injury. Predominant grey matter injury was reported in 9.5% (n = 25) and maldevelopment in 5.3% (n = 14). The MRI was normal in 23.5% (n = 62) children. Miscellaneous MRI findings were noted in 17.1% (n = 45) children. Of the children with normal MRI findings, 41.9% (n = 26) were under two years of age (Table 2).

Table 2
MRI patterns among the study cohort of children with CP

MRI Classification		n	%
A	***Maldevelopments***	***14***	***5.3***
A1	Disorders of proliferation, migration or organisation	5	1.9
A2	Other maldevelopments (among others: holoprosencephaly, Dandy Walker malformation, corpus callosum agenesis, cerebellar hypoplasia)	9	3.4
B	**Predominant white matter injury**	**118**	**44.7**
B1	Periventricular leukomalacia (PVL) (mild/severe)	19	7.2
B2	Sequelae of intraventricular haemorrhage (IVH) or periventricular haemorrhagic infarction (PVHI)	97	36.7
B3	Combination of PVL and IVH sequelae	2	0.8
C	**Predominant grey matter injury**	**25**	**9.5**
C1	Basal ganglia/thalamus lesions (mild/moderate/severe)	7	2.7
C2	Cortical-subcortical lesions only (watershed lesions in parasagittal distribution/multicystic encephalomalacia) not covered by C3	9	3.4
C3	Arterial infarctions (middle cerebral artery/other)	9	3.4
D	**Miscellaneous** (among others: cerebellar atrophy, cerebral atrophy, delayed myelination, ventriculomegaly not covered by B, haemorrhage not covered by B, brainstem lesions, calcifications)	**45**	**17.0**
E	**Normal**	**62**	**23.5**
	TOTAL	**264**	**100.0**

[Insert Table 2 here]

Pre-perinatal factors and MRI patterns

One in ten (10.2%) of the children were born to mothers who received no or irregular antenatal care, and predominant white matter injury was observed in nearly half (44.4%) of these children. Among those who had complications at the time of birth (such as malpresentation, obstructed or prolonged labour, haemorrhage), 50.0% had predominant white matter injury. Among the children born preterm (< 37 weeks), half (49.6%) had predominant white matter injury and 12.8% had predominant grey matter injury. Of the children with documented birth asphyxia, 38.7% had predominant white matter injury. Of the children with neonatal jaundice, 34.5% had predominant white matter injury and 13.8% had predominant grey matter injury. Pre-perinatal infection was reported in 20.8% of the mothers. Among their children, white matter injury predominated (41.8%) and 27.3% were born preterm. Among the multiple births, 60.0% had predominant white matter injury. Of all children, 22.7% were not fully immunized.

Timing of presumed injury causing CP and MRI patterns

White matter injury predominated across all classifications of timing of presumed injury causing CP: 50.3%, 39.5% and 34.3% of pre-perinatal, postnatal, and unknown timing respectively. This was followed by normal MRI findings noted in a 22.9% of pre-perinatally acquired CP, 18.4% of postnatally acquired CP and 28.6% of the children with unknown timing of lesion causing CP. The differences in MRI patterns across the timing of presumed injury causing CP were statistically significant ($p < 0.05$).

[Insert Fig. 1. MRI patterns by timing of the presumed injury causing CP]

Type and severity of CP and MRI patterns

Approximately half of the children with monoplegia/hemiplegia (52.2%), diplegia (50%), quadriplegia (44%) and dyskinetic CP (45.5%) had predominant white matter injury. Significant differences were observed in MRI patterns across different types of CP ($p < 0.05$). Predominant white matter injury was reported among 40%, 38.1%, 45.0%, 54.6%, 45.9% of children with GMFCS levels I, II, III, IV and V respectively. MRI findings were normal among 32.0% and 31.0% of the children with GMFCS levels I and II respectively.

[Insert Table 3 here]

Table 3
Clinical characteristics across MRICS categories among children with CP

	n	*Maldevelopments*	*Predominant white matter injury*	*Predominant grey matter injury*	*Miscellaneous*	*Normal*	*p-value*
Gestational age							
0–27	2	0	1 (50.0%)	1 (50.0%)	0	0	0.52
28–31	25	1 (4.0%)	15 (60.0%)	1 (4.0%)	2 (8.0%)	6 (24.0%)	
32–36	47	1 (2.1%)	23 (48.9%)	6 (12.8%)	8 (17.0%)	9 (19.1%)	
>=37	189	12 (6.3%)	78 (41.3%)	17 (9.0%)	35 (18.5%)	47 (24.9%)	
Pearson test							
Low birth weight	71	3 (4.2%)	40 (56.3%)	4 (5.6%)	9 (12.7%)	15 (21.1%)	0.21
Multiple birth	20	2 (10.0%)	12 (60.0%)	1 (5.0%)	2 (10.0%)	3 (15.0%)	0.45
Birth asphyxia	117	7 (6.0)	58 (49.6%)	15 (12.8%)	13 (11.1%)	24 (20.5%)	0.06
Neonatal jaundice	29	2 (6.8%)	10 (34.5%)	4 (13.8%)	3 (10.3%)	10 (34.5%)	0.39
Mode of delivery							
Caesarean section	93	4 (4.3%)	42 (45.2%)	9 (9.7%)	16 (17.2%)	22 (23.7%)	0.61
Instrumental delivery	5	0	1(20.0%)	2 (40.0%)	1 (20.0%)	1 (20.0%)	
Spontaneous vaginal delivery	163	14 (8.6%)	118 (72.4%)	25 (15.3%)	45 (17.0%)	62 (23.5%)	
Timing of presumed injury causing CP							
Pre and perinatal	153	6 (3.9%)	77 (50.3%)	15 (9.8%)	20 (13.1%)	35 (22.9%)	**0.001**
Post-natal	38	7 (18.4%)	15 (39.5%)	5 (13.2%)	4 (10.5%)	7 (18.4%)	
Unknown	70	1 (1.4%)	24 (34.3%)	5 (7.1%)	20 (28.6%)	20 (28.6%)	
Type of CP							
Spastic							
Quadriplegia	198	10 (5.1%)	87 (43.9%)	15 (7.5%)	41 (20.7%)	45 (22.7%)	**0.047**
Monoplegia/hemiplegia	46	3 (6.5%)	24 (52.2%)	10 (21.7%)	2 (4.3%)	7 (15.2%)	**0.002**
Diplegia	10	0	5 (50.0%)	0	0	5	0.17

*Row percentages are shown

	n	*Maldevelopments*	*Predominant white matter injury*	*Predominant grey matter injury*	*Miscellaneous*	*Normal*	*p-value*
Gestational age							
						(50.0%)	
Dyskinetic	11	0	5 (45.5%)	0	1 (9.1%)	5 (45.5%)	0.20
Ataxic	0	0	0	0	0	0	
GMFCS							
Level I	50	2 (4.0%)	20 (40.0%)	5 (10.0%)	7 (14.0%)	16 (32.0%)	0.20
Level II	42	0	16 (38.1%)	7 (16.7%)	6 (14.3%)	13 (31.0%)	
Level III	40	3 (7.5%)	17 (42.5%)	6 (15.0%)	4 (10.0%)	9 (22.5%)	
Level IV	44	1 (2.3%)	24 (54.5%)	2 (4.6%)	8 (18.2%)	9 (20.5%)	
Level V	87	8 (9.2%)	39 (44.8%)	5 (5.7%)	20 (23.0%)	14 (16.1%)	
Associated impairments							
Epilepsy	31	4 (12.9%)	12 (38.7%)	3 (9.7%)	5 (16.1%)	7 (22.6%)	0.40
Speech impairment	169	7 (4.1%)	75 (44.4%)	17 (10.1%)	35 (20.7%)	35 (20.7%)	0.11
Intellectual impairment	188	11 (5.9%)	81 (43.1%)	19 (10.1%)	38 (20.2%)	39 (20.7%)	0.47
Visual impairment	9	0	4 (44.4%)	2 (22.2%)	1 (11.1%)	2 (22.2%)	0.70
Hearing impairment	5	0	2 (40.0%)	1 (20.0%)	1 (20.0%)	1 (20.0%)	0.91
*Row percentages are shown							

Associated impairments and MRI patterns

Predominant white matter injury was observed in nearly half the children with epilepsy (38.7%), speech (44.4%), visual (44.4%), intellectual (43.1%) and hearing impairment (40.0%). Normal MRI findings were noted in 22.6% with epilepsy, 20.7% with speech impairment, 22.2% with visual impairment, 20.7% with intellectual impairment and 20.0% with hearing impairment. Figure 2 summarises the types of CP, GMFCS levels and associated impairments across the different MRI patterns. Children with maldevelopment and miscellaneous findings on MRI had more severe motor impairments and more commonly had associated impairments. In contrast, children with predominant grey matter injury more commonly had milder CP.

[Insert Fig. 2 GMFCS, CP type and associated impairments across MRI patterns]

In summary, white matter injury predominated and significant differences were observed in the timing of presumed injury causing CP and type of CP across the different MRI patterns ($p < 0.05$). A range of preventable associated factors, including poor antenatal care, prematurity, birth asphyxia, neonatal jaundice, immunization status and maternal infections, were identified.

DISCUSSION

Our study provides the first standardised description of brain neuroimaging findings among children with CP in an LMIC using the MRICS. It demonstrates the utility of brain MRI in assessing children with CP and the value of the MRICS in generating standardised, thus comparable data. This study contributes significantly to the limited evidence on MRI patterns in children with CP. Our study provides some evidence on the aetiological underpinnings of CP and is an important first step towards the development of preventive strategies in LMICs.

Our findings confirm that white matter injury is the most common injury type seen on MRI among children with CP, and that MRI patterns are associated with the type and timing of the causal of CP. Nearly half the children had predominant white matter injury, which is consistent with findings from a large scale international study demonstrating the application of the MRICS on data from 20 European CP registers.[11] The proportion of children with predominant white matter injury in our study is also congruent with other CP cohorts.[12, 19]

Normal MRI findings were reported among a quarter of children with CP, a higher proportion than in other CP cohorts.[20] This suggests that causal pathways additional to maldevelopment and injury to the developing brain exist and indicates the potential for genetic or metabolic causes. Some studies indicate that genetics may play a role in the causation of CP.[21] Genetic aetiology remains unexplored in LMICs, where it is of particular importance due to the high rates of consanguinity in some countries, which increase the risk of recessively inherited diseases.[22] Studies exploring the genetic basis of CP may ultimately contribute to the establishment of causation among a proportion of children with CP, particularly those without a well-characterized risk factor and brain injury or maldevelopment, thus identifying further opportunities for prenatal screening and prevention. In our study however, the exact age of the children at the time of their MRI scan was not known and nearly half the children with normal MRI findings were under the recommended age (i.e. after 2 years) at which MRI should be performed for classification using MRICS.[12] Patterns such as mild periventricular or basal ganglia or thalamus lesions may have been missed in some of these children due to developing myelination in the first years.[12]

Among children with neonatal jaundice, kernicterus is implicated in brain injury leading to CP and is typically associated with grey matter injury.[23] In our cohort, a proportion of the children with neonatal jaundice had predominant white matter injury, suggesting additional aetiologic mechanisms and the likely interplay between different causal pathways of CP. The MRICS allows description of typical MRI patterns of CP associated with specific timing of vulnerability in different areas of the brain.[12] The predominance of white matter injury in our cohort indicates the timing of the lesions causing CP in the third trimester, which is commonly induced by hypoxic-ischaemic and/or infectious mechanisms.[12] Pre-perinatal maternal infection and suboptimal immunization rates in a proportion of our cohort support this finding.

Several studies report a strong link between maternal infection and white matter injury leading to CP, particularly in preterm births.[24] Intrauterine infections can cause cerebral hypoperfusion of the developing brain resulting in hypoxic-ischaemic injury and/or induce production of pro-inflammatory cytokines which can lead to damage of oligodendrocyte progenitors and thus induce white matter injury.[25] A systematic approach to prevention, identification and treatment of maternal infections is therefore vital to the prevention of CP. Antenatal care can facilitate greater awareness of infection control measures and ensure better understanding of warning signs during pregnancy and childbirth, access to micronutrient supplementation, and immunization, all of which can reduce risk of infections. Perinatal practices, such as interventions to prolong pregnancy, administration of antenatal steroids to mothers expected to deliver prematurely, and optimal delivery care, can also help avert premature birth and obstetric mishaps commonly leading to CP. This is observed in a proportion of our cohort with white matter injury, particularly those with reported birth asphyxia.[26]

Although MRI was not used as a diagnostic tool in this study, it is highly predictive in identification of CP with 86–89% sensitivity at as early as five months corrected age.[27] Diagnosis of CP is typically based on clinical presentation supported by parent reports on attainment of motor milestones. This applies particularly in LMICs where the use of best practice tools, such as the General Movements Assessment and Hammersmith Infant Neurological Examination, is limited and diagnosis is delayed,[26] which often leads to more severe impairment, poor quality of life and high mortality.[28–30] Early diagnosis allows

early intervention, thus providing potential to harness neuroplasticity for enhanced function and participation of children with CP.[31]

International guidelines recommend investigation of all suspected cases of CP by neuroimaging.[27, 32] When safe and feasible, MRI can aid in early diagnosis and support counselling on prognosis, both of which can enhance caregiver wellbeing, an often overlooked consideration in planning interventions for CP.[33] Several studies report correlations between MRI patterns and type, severity, and associated impairments of CP, all of which are vital to guiding clinicians in predicting future functional outcomes of children with CP.[34–36] For example, GMFCS level V predominated in over half the children with brain maldevelopment, an MRI finding predictive of non-ambulant CP.[37] Furthermore, a prospective longitudinal cohort study of children with CP in the Netherlands reports that MRI patterns can support early identification of children at risk for impaired cognition.[38]

The principal contribution of neuroimaging are that it enables better understanding of the aetiopathogenesis of CP.[10] Advanced understanding of the specific MRI patterns of CP and their potential link to specific etiologic events may inform prevention. Our study demonstrating the applicability of the MRICS in a CP cohort is an important step towards the development and implementation of preventive strategies in an LMIC. There is an urgent global need for clinician training to promote evidence-based approach, including the use of the MRICS to ensure better understanding of the various MRI patterns observed in CP, and their implication for prevention and clinical practice. The MRICS and the relevant resources developed by the SCPE group can serve as a valuable training tool to support this.[12]

Study limitations

Our study has some limitations. Firstly, our study cohort, identified prospectively using hospital-based surveillance and strict diagnostic criteria, is not population representative. It includes all children presenting with CP over a six-month period and brain MRI scans were available for 34.5% of the children. These are the children for whom the Vietnamese clinicians requested an MRI. Although similar clinical characteristics are noted in children with and without MRI data in our study, the reason for requesting an MRI was not documented, thus raising the potential for bias in the cohort e.g. severity of impairments, cost of neuroimaging and overall access to MRI. Secondly, MRI reports were obtained from existing hospital records and classified retrospectively by investigators using the MRICS without access to the images or the radiologists who performed, interpreted, and reported the MRI. However, very good interrater reliability is reported with use of MRICS rating both images and reports.[12] Thirdly, data on the timing of the MRI scans were not available, and it is known that interpretation of brain MRI is age dependent.[39] Fourthly, data were not available on whether brain involvement was unilateral or bilateral; this is often crucial for predicting functional outcomes.[11] Finally, we relied on clinical history, assessment conducted by clinicians and existing hospital records for the assessment and documentation of associated impairments.

CONCLUSION

Our large study provides the first description of the range of MRI patterns in children with CP in Vietnam using the MRICS and supports use of MRIs for assessment of children with CP. Our findings from an LMICs concur with the predominance of white matter injury noted in children with CP in cohorts from HICs. We also demonstrated associations between MRI findings and known risk factors, clinical characteristics and associated impairments, which will assist clinicians in predicting outcomes, planning interventions for children with CP, and counselling families. Effective use of MRIs for the assessment of children with CP in LMICs will further the understanding of the aetiologic pathways of CP and thus inform interventions and support development of preventive strategies in these settings.

Declarations

Ethics approval and consent to participate

Ethics approval was obtained from the University of Sydney Human Research Ethics Committee (HREC) (2016/456), Hanoi Medical University (1722/QD-DHYHN) and NCH (812/QD-BVNTU) in Hanoi, Vietnam. Informed consent was obtained from parents or caregivers of all the study participants.

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors report there are no competing interests to declare.

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Authors' contributions

Conceptualization: TK, GK, EJE. Methodology: TK, THHK, NTHG, TQD, NVB, NB, GK, EJE. Literature review: TK. Quality assessment: TK, RD, NTVA. Investigation: NTHG, TQD. Data cleaning: TK, RD, NTVA. Data analysis: TK, SSM. Data interpretation: TK, , NTVA, NVB, NB, SSM, GK, EJE. Writing—original draft preparation: TK. Manuscript revision: TK, NB, SSM, GK, EJE. All authors have approved the submitted and final version.

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Figures

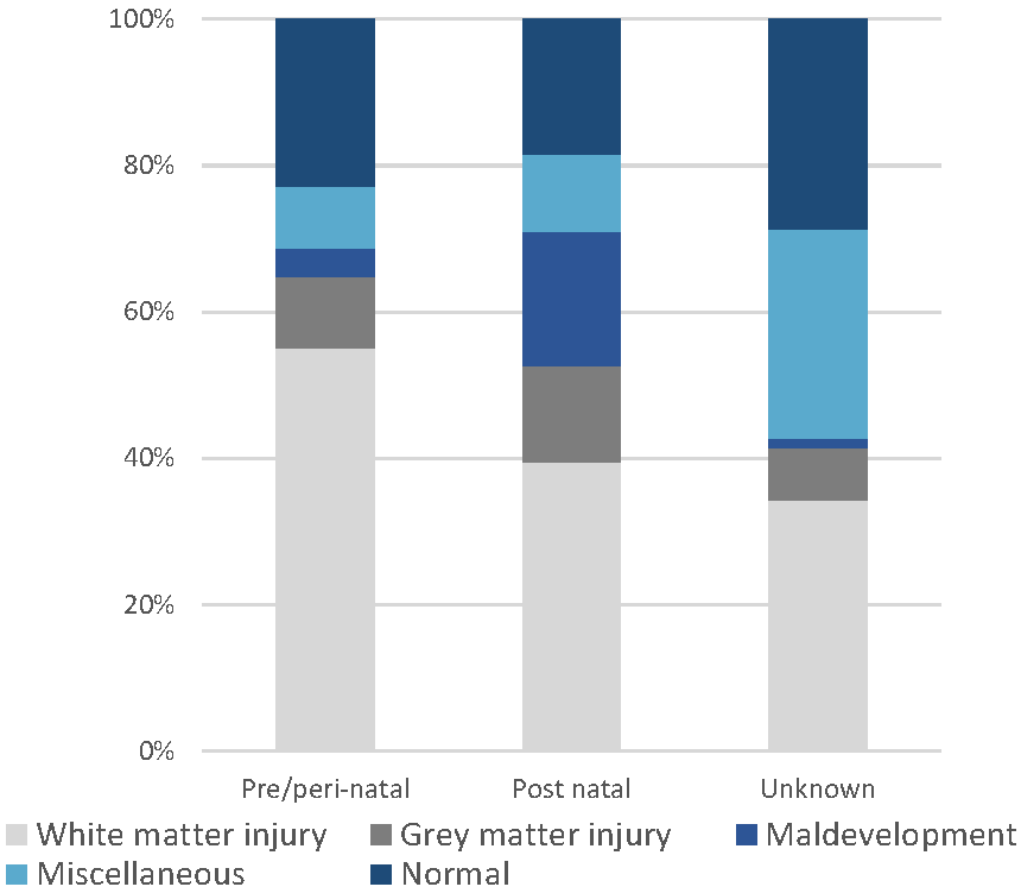

Figure 1

MRI patterns by timing of the presumed injury causing CP

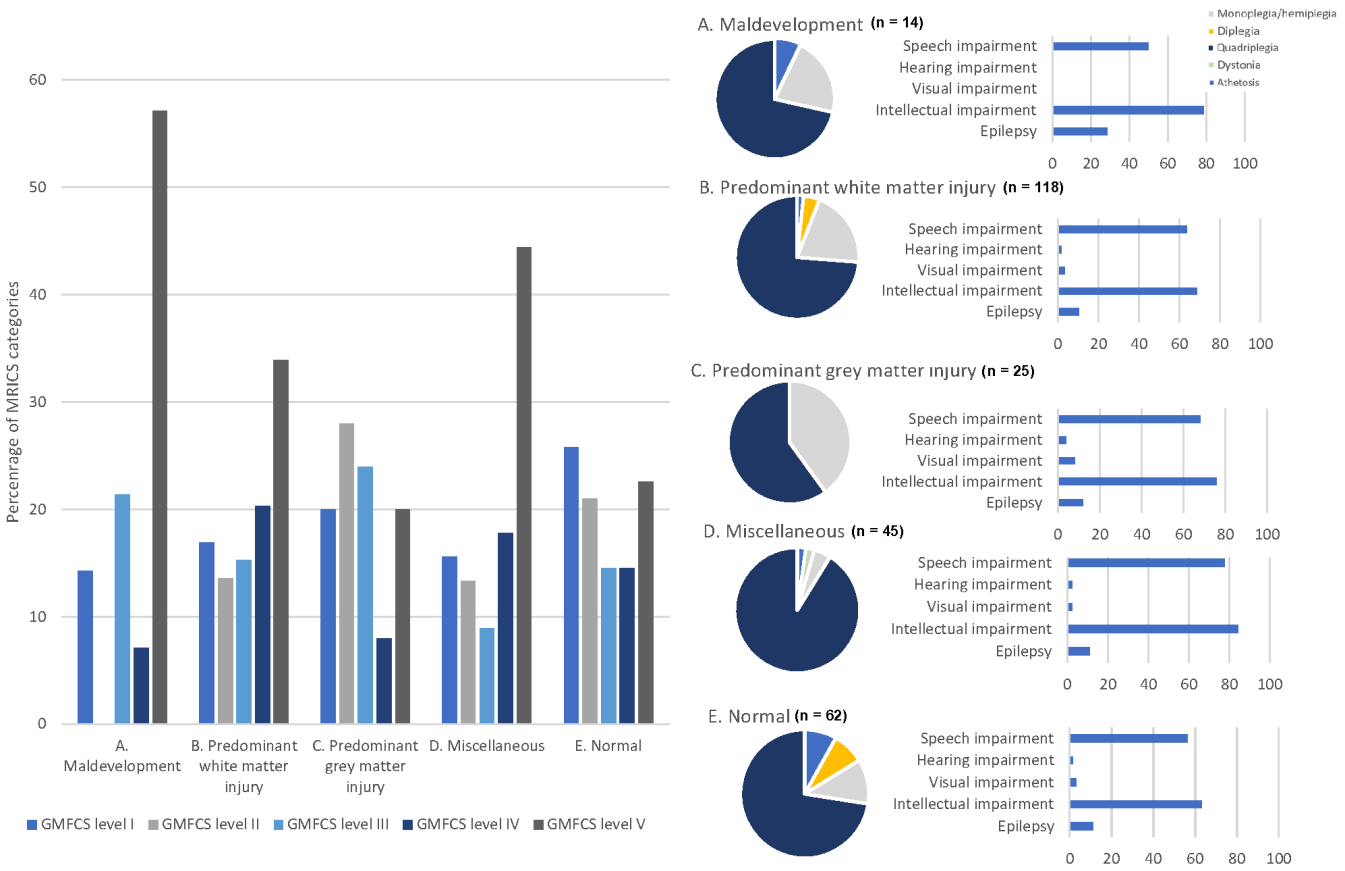

Figure 2

GMFCS, CP type and associated impairments across MRI patterns