

## Hand function in children with unilateral spastic cerebral palsy

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### ABSTRACT

**Aim** To assess hand function and explore the relationship between hand function and neuroimaging findings in children with unilateral spastic cerebral palsy (US CP).

**Methods** Hand function was assessed using Manual Ability Classification System (MACS, I-V). Brain lesions were divided into five groups: brain maldevelopment (MAL), periventricular white matter lesions (PV WM), cortical/subcortical gray matter lesions (C/SC GM), nonspecific and normal findings.

**Results** Of 114 children with US CP (77 boys and 37 girls), 56 were with right-sided and 58 with left-sided involvement. MACS I was found in 49 (42.9%), MACS II in 19 (16.7%), MACS III in 19 (16.7%), MACS IV in 9 (7.9%) and MACS V in 18 (15.8%) children ( $p=0.002$ ). Computed tomography (CT) as the only neuroimaging has been done in 18 (15.8%), magnetic resonance imaging (MRI) at 94 (82.5%) children, whereas 2 (1.7%) children had neither CT nor MRI. The CT showed PV WM in eight (44.4%), C/SC GM lesions in six (33.3%), and normal findings in four (22.2%) children ( $p=0.709$ ). The MRI showed MAL in eight (8.5%), PV WM in 46 (48.9%), C/SC GM in 28 (29.8%), miscellaneous in two (2.1%), and normal finding in 10 (10.7%) children ( $p=0.0001$ ). Mild hand dysfunction (MACS I and II) was assessed in 68 (59.7%) children, of which 33 had PV WM lesions ( $p=0.001$ ).

**Conclusion** Mild hand dysfunction in children with US CP has been significantly associated with PV WM lesions. The type of brain lesion may help to identify its timing and predict the level of hand dysfunction.

**Key words:** cerebral palsy, child, neuroimaging

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## INTRODUCTION

Unilateral spastic cerebral palsy (US CP) occurs after an insult to the developing brain resulting in motor and sensory impairments mainly lateralized to one body side. The upper limb on the affected side may have different functional limitations that can influence child's every day activities and future professional options (1). The timing, size and location of the lesion influence the clinical presentation of upper limb dysfunction (1). The US CP can be caused by different brain lesions (2). Periventricular white matter lesions, depending on the extent of the lesion, may cause mild to moderate motor impairment (2). Grey matter lesions (cortex, thalamus or basal ganglia) may cause moderate to severe motor impairment of the affected limb (3). In addition, the reorganization of the primary motor cortex after the insult plays an important role in the definite upper limb dysfunction (1,2).

Corticospinal tract projections to the affected limb can be contralateral (the typical pattern), ipsilateral or mixed (the affected limb receives motor projections from both hemispheres) (3).

Neuroplasticity and brain organization in children with US CP result in approximately one third of them having impaired hand controlled by ipsilateral hemisphere (4). During the first 18 months of typical postnatal development inter-hemispheric competition reduces the number of ipsilateral corticomotor connections (4). In children with US CP, who have early brain lesions and atypical development, ipsilateral connections may stay intact (4). Ipsilateral projections are associated with poor function (3,5).

Hand asymmetries, the usual clinical sign of unilateral CP, typically do not appear until 4-6 months of age (6).

Hand dysfunction in children with US CP is a serious problem in their everyday activities. Various studies have been performed to evaluate predictive value of brain lesions for the development of hand dysfunction (3,5). Understanding the association between hand dysfunction and brain lesions may assist in the development of novel upper limb habilitation strategies in children with US CP and promote early intervention to minimize motor dysfunction of an affected limb (2).

Our study was conducted in order to explore relevant data about children with US CP, whose

diagnosis and treatment were made in our hospital. The proper analysis of brain lesions may help setting adequate prognosis and realistic therapeutic goals. It is important for pediatricians, neuropediatricians, physiatrists and physiotherapist, but also other specialists who deal with children suffering from cerebral palsy (orthopedists, psychologists).

The aim of this study was to assess hand function and explore the relationship between hand function and neuroimaging findings in children with unilateral spastic cerebral palsy in the Pediatric Clinic, University Clinical Centre Sarajevo.

## PATIENTS AND METHODS

### Patients and study design

This cross sectional cohort study used data from a prospective longitudinal study on children with unilateral spastic cerebral palsy. The study was performed at the Pediatric Clinic, University Clinical Center Sarajevo (tertiary hospital), during the period 2002-2018.

Inclusion criteria were all children diagnosed with US CP at minimal age of 4 years (born in the period between 1998 and 2013). Exclusion criteria were history of botulinum toxin treatment or hand surgery.

### Methods

Manual abilities were assessed according to the Manual Ability Classification System (MACS) (7), which classifies children's ability to handle objects in everyday activities on a 5-level scale: level I- highest ability - the child handles objects easily and successfully; level II – the child handles most objects, but with somewhat reduced quality and/or speed of achievement; level III – the child handles objects with difficulty, needs help to prepare or modify activities; level IV – the child handles a limited selection of easily managed objects in adapted situations, and level V - most limited ability - the child does not handle objects and has severely limited ability to perform even simple actions (7,8).

Neuroimaging data included magnetic resonance images (MRI) and computer tomography (CT) images. Brain MRI scans were acquired with 1.5 and 3T systems (Avanto, Siemens, Erlangen, Germany) and interpreted by a neuroradiologist. The neuroradiological findings were classified

according to a recommendation of the Surveillance of Cerebral Palsy in Europe (SCPE), based on the predominant pattern of brain injury: maldevelopment (MAL), periventricular white matter lesions (PV WM), cortical/subcortical grey matter lesions (C/SC GM), miscellaneous or normal findings (9).

**Statistical analysis**

Standard descriptive methods of statistics and  $\chi^2$  test were used. The significance level of  $p < 0.05$  was used.

**RESULTS**

The study has included 114 children with US CP (77 boys and 37 girls) ( $p = 0.007$ ).

The age of the children at the moment of inclusion into the study was 48 months (4 years) at least. The gestational age of the children was at the range between 28 and 40 gestational weeks (arithmetic mean 38.31 gestational weeks).

Right upper limb was affected in 56 (49%) and left one in 58 (51%) children ( $p = 0.893$ ).

The distribution of the patients according to MACS level was: MACS I was found in 49 (42.9%), MACS II in 19 (16.7%), MACS III in 19 (16.7%), MACS IV in nine (7.9%), and MACS V in 18 (15.8%) children ( $p = 0.002$ ).

The CT as the only neuroimaging was done in 18 children (15.7%), the MRI in 94 (82.4%) children, whereas in two (1.7%) children neither CT nor MRI (due to lack of parents' consent).

**Table 1. Distribution of Manual Ability Classification System (MACS) levels according to neuroimaging (MRI) findings**

MRI finding	No (%) of children according to MACS level					
	Total	I	II	III	IV	V
MAL	8 (7)	2 (4.1)		3 (15.8)	1 (11.1)	2 (11.1)
PV WM	46 (40.3)	23 (46.9)	10 (52.6)	7 (36.8)	2 (22.2)	4 (22.2)
C/SC GM	28 (24.6)	9 (18.4)	5 (26.3)	5 (26.3)	4 (44.5)	5 (27.8)
Non-specific findings	2 (1.7)	1 (2)				1 (5.5)
Normal findings	10 (8.8)	8 (16.4)	1 (5.3)	1 (5.3)		
N/A	20 (17.6)	6 (12.2)	3 (15.8)	3 (15.8)	2 (22.2)	6 (33.4)
<b>Total</b>	114 (100)	49 (100)	19 (100)	19 (100)	9 (100)	18 (100)

MAL, brain maldevelopment; PV WM, periventricular white matter lesions; C/SC GM, cortical/subcortical grey matter lesion; N/A, not available;

The CT showed PV WM in eight (44.4%), C/SC GM lesions in six (33.3%) and normal finding in four (22.2%) children ( $p = 0.709$ ).

The MRI showed MAL in eight (8.5%), PV WM in 46 (48.9%), C/SC GM lesions in 28 (29.8%), miscellaneous in two (2.1%) and normal finding in 10 (10.7%) children ( $p = 0.0001$ ) (Table 1).

The correlation between MACS level and type of brain lesion is presented in Table 2.

The mild hand dysfunction (MACS I and II) was assessed at 68 (59.6%) patients, of which in 33 (48.5%) patients PV WM lesion was found ( $p = 0.001$ ).

**Table 2. Correlation between Manual Ability Classification System (MACS) level and neuroimaging (MRI) findings**

MRI finding	No (%) of children according to MACS level				p
	Total	I+II	III	IV+V	
MAL	8 (7)	2 (2.9)	3 (15.8)	3 (11.1)	0.932
PV WM	46 (40.3)	33 (48.6)	7 (36.8)	6 (22.2)	0.001
C/SC GM	28 (24.6)	14 (20.6)	5 (26.3)	9 (33.3)	0.331
Non-specific findings	2 (1.8)	1 (1.5)	0	1 (3.7)	1.000
Normal findings	10 (8.8)	9 (13.2)	1 (5.3)	0	0.051
N/A	20 (17.5)	9 (13.2)	3 (15.8)	8 (29.7)	0.388
<b>Total</b>	114 (100)	68 (100)	19 (100)	27 (100)	

MAL, brain maldevelopment; PV WM, periventricular white matter lesions; C/SC GM, cortical/subcortical grey matter lesion; N/A not available

**DISCUSSION**

In our US CP-child study, entire birth years, from 1998 born children onwards, were prospectively followed to determine the relationship between the fine motor function as related to the nature of the brain lesion. In this study, which has included 114 children, statistically significant presentation of boys was noticed. The same results have been published by other authors (10-12). The incidence of cerebral palsy is significantly higher in males due to greater vulnerability to hypoxia in males and higher incidence of preterm births in males (11).

Distribution of our patients according to the affected limb is almost equal between right and left side. The same result was published by Arnold and associates (12).

According to the gestational age of children involved in our study, there was a statistically significant presentation of patients with 40 weeks gestational age (arithmetic mean 38.31). The similar results were published by Himpens et al. (13); investigating the relationship between gestational age and type of cerebral palsy, extremely

preterm infants (gestational age 23-27 weeks), predominance of developed bilateral spastic cerebral palsy with no cases of US CP was found. No extremely preterm born children in our study were noticed.

The MACS evaluate child's typical use of hands and upper limbs, not the best use (14). According to the distribution of MACS level, the results of our study have shown statistically significant presentation of MACS I and MACS II patients. Nordstrand, Eliasson and Holmefur published the data for 96 children with US CP and found that mild hand dysfunction (levels I and II) was dominant, similarly to our results, but no levels IV and V were found (15). Klevberg et al. published the data of 64 patients with US CP and found no children with MACS level IV and MACS level V. Our results are similar for mild hand dysfunction (16).

The brain damage is also predictive of outcome. In larger lesions the motor function can be managed via existing ipsilateral tract of contralesional hemisphere (3,8). This possibility for reorganization is unique to the young brain (4).

Cortical malformations which originate in the first two trimesters of pregnancy result in less severe hand impairments than periventricular lesions, which originate early in the third semester of pregnancy. In the cases of unilateral brain damage occurring during the intrauterine period, the functional compensation of the affected hemisphere by the unaffected hemisphere is possible, but it is limited and inferior to normal motor function (8). Neuroplasticity during early brain development decreases with gestational age at which the lesion is acquired (17). This suggests that C/SC lesions, which originate in the late third semester of pregnancy and perinatally, result in more severe hand dysfunction than PV WM lesions (17).

Brain lesion leading to ipsilateral motor control, which occurs during early second trimester of pregnancy (maldevelopment), or a lesion which occurs during early third semester of pregnancy (white matter lesion), conveys better hand function than lesions acquired toward the end of gestation, such as infarct (17).

Neuroimaging is an important part of the diagnostic workup for cerebral palsy. MRI is superior to CT for several reasons (MRI does not involve

exposure to ionizing radiation, it gives extremely clear, detailed images of the brain that CT cannot achieve). In 15.7% children from our study only CT was done, without statistically significant difference between the types of lesions. MRI was done in 82.4% children. The most frequent lesions were PV WM (48.9%) and C/SC GM lesions (29.8%).

The study of Klevberg et al., which included 42 children with US CP, has shown that two most predominant patterns of brain lesions were white matter lesions and gray matter lesions (16). In our study, with larger population involved, white matter lesions were the predominant pattern of brain lesions.

The study of Maileux Lisa et al. including 73 children with US CP, 42 were with periventricular white matter lesions and 29 with cortical/subcortical lesions (2). These results are similar to the results of our study.

The correlation between MACS levels and types of brain lesions may help for further investigations on predictive value of some types of brain lesions for certain levels of upper limb dysfunction. The mild hand dysfunction (MACS I and II) was assessed in 59.6%, of which 48.5% patients had PV WM lesions. Children with PV WM lesions have higher chances of developing better upper limb function than children with C/SC GM lesions (2). The similar results have been published by Holmstrom et al. although the group was small, which included 17 participants with US CP (3).

Neuroradiological findings can be used to make crude prediction of future hand dysfunction in young children with unilateral CP. Impaired function in one hand is a major limitation in children with US CP (18).

The development of affected hand function might be quite different in the parts of the world with limited access to habilitation services, as it is the case in our country (15).

In conclusion, mild hand dysfunction in children with US CP has been significantly associated with periventricular white matter lesions in the brain, with no significant association between severe hand dysfunction and type of brain lesions. Neuroradiological findings may help to predict the development of hand dysfunction in children with US CP.

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## TRANSPARENCY DECLARATION

Competing interests: None to declare.

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