Magnetic resonance imaging of the cerebellum and brain stem in children with cerebral palsy

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Abstract

Purpose: The study aimed to examine the volumes of cerebellum and the brain stem in children with cerebral palsy (CP).

Material and methods: The present study included 21 children with spastic diplegic CP (11 girls and 10 boys). Twenty-one patients with CP were age- and gender-matched with the control patients. All subjects were free from neurological or psychiatric disease, had normal intellectual development, and their brain magnetic resonance imaging (MRI) scans were normal. MRI of forty-two patients were reviewed prospectively.

Results: The CP group had significantly smaller mean of the cerebellar hemispheres and the brain stem than did the control group. The cerebellar volumes were positively correlated with age of children with CP and the control group. No significant correlations between gender and the volumes of cerebellar hemispheres and the brain stem in controls and in the CP group were found. No significant correlations between asphyxia and the volumes of cerebellar hemispheres and the brain stem in the CP group were noted. Positive correlation between the cerebellum volume and IQ scores in children with CP was found. Negative relationship between the cerebellar hemispheres volume and Gross Motor Function Classification System in patients with CP was found. No significant correlation between the brain stem volume and IQ scores in the CP group was detected.

Conclusion: Our data demonstrate that children with CP had smaller volumes of the cerebellum and the brain stem as compared to controls.

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Introduction

The cerebellum integrates these pathways, using the constant feedback on body position to fine-tune motor movements [1]. Moreover, chronic cerebellar stimulation applied to the superio-medial cortex reduces generalized cerebral spasticity, athetoid movements, and seizures [2,3]. The brain stem controls body functions: blood pressure, swallowing, breathing, heartbeat are all managed by this area of the brain. The brain stem also connects the forebrain and the cerebellum with the spinal cord. Cerebellar injury has been implicated in cognitive, social, and behavioral dysfunction among older patients and may contribute from 25% to 50% incidence of long-term cognitive, language, and behavioral dysfunction among formerly preterm infants [4-8]. In previous report Bodensteinen et al. [9] reviewed brain MRI of preterm born children with CP. They examined fifty scans and there were four totally normal scans. Moreover, cerebellar abnormalities were found in 32 children. The cerebellar findings included destruction of major portions of the cerebellum and focal or unilateral loss of cerebellar tissue. Currently, limited information is available regarding the nature and consequences of cerebellar injury in children with spastic diplegia born in term [10-12]. In the prospective study reported here, we now present quantitative MRI measurements of the cerebellar hemispheres and the vermis in children with spastic CP in relation to clinical status.

Material and methods

The present study included 21 children with spastic diplegia CP with a mean age 9.29±4.86 years (11 girls and 10 boys). A group of 21 healthy right-handed children 10.15±4.90 years old, matched for age and sex, were recruited as a comparison

***Table 1*. Relations between the volumes of cerebellum hemispheres and brain stem and gender, age, asphyxia, IQ and GMFCS**

Groups		Variable	r – value	p – value
CP (n=21)				
Girls	vs	Cerebellar hemispheres	-0.31532	NS
Girls	vs	Brain stem	-0.0159	NS
Boys	vs	Cerebellar hemispheres	0.13532	NS
Boys	vs	Brain stem	0.01590	NS
Age	vs	Cerebellar hemispheres	0.48261	0.0026
Age	vs	Brain stem	0.31970	NS
Asphyxia	vs	Cerebellar hemispheres	-0.1490	NS
Asphyxia	vs	Brain stem	-0.3590	NS
IQ	vs	Cerebellar hemispheres	-0.4860	0.0255
IQ	vs	Brain stem	0.44321	0.0441
GMFCS	vs	Cerebellar hemispheres	-0.6293	0.0025
GMFCS	vs	Brain stem	-0.2219	NS
Controls (n=21)				
Girls	vs	Cerebellar hemispheres	0.13413	NS
Girls	vs	Brain stem	-0.2070	NS
Boys	vs	Cerebellar hemispheres	-0.1341	NS
Boys	vs	Brain stem	0.2070	NS
Age	vs	Cerebellar hemispheres	0.65905	0.0011
Age	vs	Brain stem	-0.1627	NS
IQ	vs	Cerebellar hemispheres	0.4860	0.0255
IQ	vs	Brain stem	0.44321	0.0441
GMFCS	vs	Cerebellar hemispheres	-0.6293	0.0025
GMFCS	vs	Brain stem	-0.0236	NS

CP – cerebral palsy; r= Spearman's test; NS – not significant; GMFCS – Gross Motor Function Classification System; IQ – intelligence quotient

group. Asphyxia was confirmed among 6 patients with CP, none of healthy children had asphyxia. Nine children with CP were born as prematures was found in 9 children with CP, while all subjects group were born at term. Spastic diplegia was defined as motor disabilities caused by non-progressive damage of the developing brain with a more pronounced spasticity in lower limbs [14]. The children were each assigned a Gross Motor Function Classification System (GMFCS) according to [15] level by physical terapeutist. All the children in this group had one or more formal psychological assessments (the typical Wechsler Intelligence Scale for Children).

All MRI scans were obtained using a 1.5 T MR scanner (Picker Edge Eclipse) with the use of a standard circularly polarized head coil. The cerebellar hemispheres were aligned in the axial plane along the line drawn perpendicular to the vertical that ran tangential to the dorsal brain stem on the mid-sagittal slice [13] Total volumes of the cerebellar hemispheres (mm^3) and brain stem volumes (mm^3) were obtained by outlining these structures on all coronal slices in which they were visible. Descriptive analysis, matched *t* tests were used, as appropriate. Non-parametric statistics were used to assess the significance between CP and healthy patients. The critical level for all tests of significance was <0.05.

The study was approved by the Ethical Committee at the Medical University of Białystok.

Results

Sixteen spastic diplegia children had hypoxic-ischaemic lesions with patterns of periventricular leukomalacia, subcortical lesions or cortical infarction in MRI. Five patients had normal MRI scans. All healthy subjects had normal MRI. The CP group had a significantly smaller mean volume of cerebellum hemispheres than did the control group (107,009.2 mm^3 ±18,022.59 vs 128,755.2 mm^3 ±34,535.01; p=0.03255). The mean difference was approximately 17%. The CP group also had a significantly smaller mean volume of brain stem than did the control group (12,311.76 mm^3 ±4,463.21 vs 16,959.14 ±2,426.71; p=0.00236). The volume of cerebellum was positively (R=0.6590; p=0.00116) correlated with age of controls (*Tab. 1*). Similarly, we found the significant (R=0.4826; P=0.0266) relationship between the cerebellum volume and age of children with CP. No significant correlation between the brain stem volume and age of controls and CP patients were found. No relationships between gender and the volumes of cerebellar hemispheres and the brain stem in CP patients and in controls were found. Similarly, we did not find relations between gender and the volumes of cerebellar hemispheres and the brain stem in the CP group. We did not observe significant correlations between asphyxia and the volumes of cerebellar hemispheres and the brain stem in the CP group were found. No asphyxia was noted in controls. Small delay – 70-84 IQ had 10 children with CP, moderate – 50-69 IQ (1 patient with CP), and severe <50 IQ (none). Normal children had IQ> 90. Normal intelligence had 10 children with CP and all healthy subjects. Positive correlation between the cerebellar volume and IQ scores in children with CP was noted (R=0.482; p=0.023). Similarly, we did find significant correlation (R=0.44324, p=0.0441) between the brain stem volume and IQ scores in CP patients. Negative correlation (R=-0.6239, p=0.0025) between the cerebellar hemispheres volume and GMFCS in patients with CP was found. Most of children with spastic CP were classified into the I and II levels of GMFCS compared to the control. On the other hand, the healthy subjects were classified only into a I level of GMFCS. No significant relationship between the brain stem volume and GMFCS in the CP group was found.

Discussion

In this study, we demonstrated that smaller volumes of the cerebellar hemispheres and the brain stem were common findings in the children with spastic diplegia. We also demonstrated no correlations between asphyxia and the volumes of cerebellar hemispheres and the brain stem in the CP group. Positive relationship between the cerebellar volume and IQ scores in children with CP. We found negative correlation between the cerebellar hemispheres volume and GMFCS in patients with CP. Our findings are in partially consistent with Bodensteiner et al. study [9]. They found common cerebral abnormalities such as decreased white-matter volume without gliosis, periventricular leukomalacia, and a thin corpus callosum. Similar findings described Srinivasan et al. [15] determining the absolute cerebellar volumes in term and preterm infants in correlation with risk factors. The median cerebellar volume of preterm was significantly smaller as comparing to term-born infants. Moreover, in the multiple regression analysis of perinatal variables showed that only infants with supratentorial lesions were significantly associated with the reduction in cerebellar volumes. These data are in accordance with results of the present study. The cerebellar abnormalities have been also described in three children with unilateral cerebellar aplasia by Swiss authors [16]. Neuroradiological investigations revealed complete aplasia in one child and subtotal aplasia in two patients. There was contralateral underdevelopment of the brain stem. The infant with hemiplegic CP had an additional supratentorial periventricular parenchymal defect, contralateral to the cerebellar hypoplasia. The authors concluded that unilateral cerebellar aplasia has presumably resulted from a prenatal destructive lesion, possibly an infarct, but the timing and exact nature was unknown [16]. Recently Booth et al., [1] in functional MRI showed that the cerebellum has reciprocal connections with both left inferior frontal gyrus and left lateral temporal cortex, whereas the putamen has unidirectional connections into these two brain regions. Our data demonstrate that children with CP had smaller volumes of the cerebellar hemispheres and the brain stem compared to controls.

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