Prognostic factors of the independent walking in children with cerebral palsy

Czynniki prognostyczne samodzielnego chodzenia dzieci z mózgowym porażeniem dziecięcym

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ABSTRACT

The purpose of this study was to analyze the clinical picture and neuroimaging findings of cerebral palsy in children who have difficulty walking independently compared to ambulant patients. The study encompassed 345 patients with cerebral palsy aged 6-17. We compared children with cerebral palsy who were not yet walking (n=133) at 6 years of age with children with cerebral palsy who were walking (n=212). Spastic tetraplegia was the most common type of cerebral palsy in the non-walking patients – 74.2%. Diplegia spastica was the dominant type of cerebral palsy, constituting 42.9% of the walking children. Seventy-four (60%) of non-walking patients were unable to sit without support at 2 years of age. The non-ambulant patients were significantly more frequently qualified as level V on the GMFCS scale 105 (79%) than as level IV – 28 (21%). Severe mental retardation and epilepsy 59 (44.3%) were observed more often in the non-ambulant patients. Periventricular leukomalacia and brain atrophy were found most frequently on MRI in the non-ambulant patients. Asphyxia, unable to sit at 2 years of age, epilepsy, mental retardation and MRI changes had a negative impact on the independent walking of children with cerebral palsy.

Key words: cerebral palsy, walking, prognosis

STRESZCZENIE

Celem niniejszej pracy była analiza obrazu klinicznego i wyników badań neuroobrazowych u dzieci z mózgowym porażeniem dziecięcym, które miały trudności z samodzielnym poruszaniem się w porównaniu do pacjentów chodzących. Badaniem objęto 345 pacjentów w wieku 6-17 lat. Porównywano dzieci z porażeniem mózgowym, które jeszcze samodzielnie nie chodziły (n = 133) w wieku 6 lat z dziećmi, które samodzielnie się poruszały (n = 212). Postać tetraplegiczną (74,2%) stwierdzano wśród pacjentów niechodzących. Postać diplegiczną (42,9%) stwierdzono u dzieci samodzielnie poruszających się. Większość pacjentów (60%) niechodzących, również w wieku 2 lat nie siedziało samodzielnie. Dzieci niechodzących częściej kwalifikowano do poziomu V w skali GMFCS 105 (79%) niż do poziomu IV - 28 (21%). Upośledzenie umysłowe w stopniu głębokim oraz padaczkę (44,3%), częściej stwierdzano u dzieci niechodzących. Leukomalacia okołokomorowa i zanik mózgu w MRI najczęściej obserwowano wśród pacjentów, którzy samodzielnie nie poruszali się. Zamartwica, brak zdolności samodzielnego siedzenia w wieku 2 lat, padaczka, upośledzenie umysłowe i zmiany w badaniu MRI miały negatywny wpływ na rozwój samodzielnego chodzenia u dzieci z mózgowym porażeniem dziecięcym.

Słowa kluczowe: mózgowe porażenie dziecięce, chód, rokowanie

INTRODUCTION

Cerebral palsy occurs at different incidence rates, according to statistics, from 1.4 to 3.0 per 1000 live births [1-3]. The clinical picture of the illness is dominated by symptoms indicating damage to the central motor neuron [limb paresis), basal ganglia (involuntary movements), and cerebellum (movement and balance coherence disorders) [1,2]. In approximately 30-40% of children with cerebral palsy, varying degrees of mental retardation are diagnosed. Epilepsy and visual disturbances are observed in 50% of patients with cerebral palsy, and in about 25% - hearing dysfunction. The most common form of cerebral palsy is spastic diplegia - spastic paralysis of the lower limbs, defined as Little's disease [4].

The etiology of cerebral palsy is complex. Besides genetics, there is a number of factors that may cause damage to the central nervous system [1,3]. Of all the causes, thypoxic-ischemic syndrome in term neonates, and intracranial haemorrhage (periventricular and intraventricular) in preterm children [1,3-5] are of the greatest significance in the development of cerebral palsy. Understanding the time of onset of a brain lesion in a child with cerebral palsy and the potential preventability of the neurological injury is important to parents and the children themselves as well as to medical professionals [4-7]. In particular, MRI provides detailed information about brain lesions. Previous studies analyzed MRI findings with the motor impairment of cerebral palsy.

Walking ability represents one of our most important skills. During the diagnostics of cerebral palsy, parents almost always ask doctors whether their child will walk independently. It is well known that walking ability varies

considerably among different subtypes of cerebral palsy [7-9].

Early identification of ambulatory prognosis and a knowledge of factors that might influence the maintenance of ambulatory capacity would favour the planning of realistic goals when the prognosis of ambulatory capacity is likely to be poor, thus making more effective the use of therapeutic resources and enabling the development of an appropriate treatment plan to prevent the loss of ambulatory capacity in other cases [9].

One of the scales used for functional assessment is the GMFCS (Gross Motor Function Classification System for Cerebral Palsy), which consists of five levels of functioning [10,11]. This scale assesses five locomotor levels: I - walking without functional limitations; II - walking without the aid of orthopedic equipment, restricted movement outside the home; III - walking with the aid of orthopedic equipment, IV - locomotor independence using orthopedic equipment; V - limited locomotion even with orthopedic equipment. The division into locomotor levels of patients with cerebral palsy has played an important prognostic role, informing of the anticipated functional skills within the capability of a child with an injured central nervous system [12,13].

The aim of this study was to evaluate clinical picture and neuroimaging findings of cerebral palsy in children who have difficulty walking independently compared to ambulant patients.

MATERIALS AND METHODS

We evaluated 386 medical data of the patients with cerebral palsy. We included in the retrospective study 345 children with cerebral palsy aged 6-17. They were under the care of the Department of Pediatric Rehabilitation and the Department of Pediatric Neurology and Rehabilitation of the Medical University of Bialystok. We compared children with cerebral palsy who were not yet walking (n=133) at 6 years of age with children with cerebral palsy who were walking (n=212). The patient data had to include the following to be qualified for the study: perinatal history, psychomotor development, laboratory tests, including metabolic, genetic, EEG and MRI of the head. Children with postnatal meningitis, encephalitis, trauma and metabolic or degenerative disorders were excluded from the study. Clinical data such as cerebral palsy risk factors: age, sex, Apgar score, birth weight, labor and delivery, form of cerebral palsy (diplegia, tetraplegia, hemiplegia, dyskinetic and ataxic), epilepsy, mental development and neuroimaging findings were analyzed as factors affecting mobility.

Cerebral atrophy was diagnosed when diffuse sulcal widening of the cerebrum with symmetrical ventricular dilatation without periventricular signal abnormalities was observed. Periventricular leukomalacia was diagnosed in patients who had ventriculomegaly with irregular outlines of the body and trigone of the lateral ventricle, a reduced quantity of periventricular white matter, deep prominent cerebral sulci, and periventricular signal abnormalities of low intensity on T1-weighted images and high intensity on T2-weighted images [22].

Cerebral palsy was defined in accordance with recent consensus statements as a non-progressive motor impairment of early onset, that is presumably cerebral in origin, which may or may not be associated with developmental delays, cognitive disability, language impairment, epilepsy, sensory (auditory or visual) loss, orthopedic abnormalities, or behavioral difficulties [1,2] .

Cerebral palsy was classified as spastic tetraplegia (spasticity of all four limbs and of about equal involvement), and spastic diplegia – spasticity of lower limbs more affected than the upper. Hemiplegia is a form of cerebral palsy that affects one arm and leg on the same side of the body. Dyskinetic cerebral palsy described as causing slow, irregular, writhing involuntary movements that occur at or around the long axis of the limb. Ataxia is used to describe a lack of balance or impairment in the ability to perform smoothly coordinated voluntary movements.

Prematurity was defined by the World Health Organization as an infant with a gestation of less than 37 weeks from the first day of the last menstrual period. Asphyxia is defined as an Apgar score ≤ 4. Diagnosis of mental abnormality was based on clinical assessment, supplemented by standard tests if available at the time of diagnosis, and the need for special education.

Epilepsy was defined as a separate occurrence of two or more apparently unprovoked seizures. The seizure outcome was defined as good if the patient was seizure-free for more than 2 years. Intractable epilepsy was defined as two seizures per month despite appropriate drug therapy [15].

Mental development was divided into the following: mild: 70-84 intelligence quotient (IQ); moderate: 50-69 IQ; severe: <50 IQ. Normal children had IQ > 90.

Statistical analyses were performed using Statistica 8.0 software. The parametric t- test and nonparametric statistical tests: Fisher's Exact test or chi-square test where appropriate were used. The Spearman rank correlation test was used for regression analyses. The critical level for all tests of significance was < 0.05.

The study was approved by the Ethical Committee at the Medical University of Bialystok, Poland

RESULTS

We identified 133 and 212 with cerebral palsy who were, respectively, classified into the non-ambulant and ambulant groups according to their GMFCS level at age 6 (Table I). The mean age of non-ambulant patients was 12.26 ± 3.76 (6-17 years), and ambulant 10.97 ± 4.72 (6-17 years), respectively. Boys accounted for 58% and girls for 42% of the nonwalking group. The walking group consisted of 48% girls and 52% boys (Table I).

Mean gestational age at birth for non-ambulant children with cerebral palsy was 35.21 ± 1.32 weeks versus a mean of 36.37 ± 4.35, ($p<0.001$) for the ambulant patients. Delivery at term was in a slight majority of ambulant patients 59.4%. In contrast preterm labour was observed more frequently in non-ambulant children – 49.6%, but not significantly. A mean Apgar score for the non-walking children with cerebral palsy (4.31 ± 3.60) at 1 minute was sig-

Table I. Clinical data on children with cerebral palsy *Kliniczne dane pacjentów z mózgowym porażeniem dziecięcym*

Variables	Non-walking N=133 %	Walking N=212 %	P value
Gender			
Boys	77 58.0	102 48.0	NS
Girls	56 42.0	110 52.0	NS
Gestational age (week)	35.21 ± 1.32 (26-42)	36.37 ± 4.35 (24 -42)	0.035
Term	67 50.4	126 59.4	NS
Premature	66 49.6	86 40.6	NS
Apgar Score (1-10)	4.31 ± 3.60	6.42 ± 3.43	<0.001
< 4 Asphyxia	75 56.4	71 33.4	NS
> 4 Non Asphyxia	58 43.6	141 66.5	0.034
Birth weight (grams)	2448.3 ± 384.7 (780 - 4000)	2682.6± 902.3 (730 - 4200)	0.04
Type of motor dysfunction			
Spasticity	91 68.9	181 85.4	NS
Extrapyramidal symptoms	13 9.8	11 5.1	NS
Ataxia	4 3.0	3 1.4	NS
Hypotonia	24 18.18	17 8.0	0.028
Type of cerebral palsy			
Tetraplegia	98 74.2	26 12.2	<0.001
Triplegia	21 15.9	0 0	<0.001
Diplegia	14 10.6	91 42.9	<0.001
Spastic hemiplegia sinistra	0 0	43 20.3	<0.001
Spastic hemiplegia dextra	0 0	38 18.0	0.0016
Dyskinetic	0 0	11 5.2	0.022
Ataxia	0 0	3 1.4	NS
Mile stones (years)			
Sitting	1.50 ± 1.74 3.34 ± 1.10	1.15 ± 1.24 1.76 ± 0.56	0.03
Standing	0	2.42 ± 0.86	<0.001
Walking	74 60	8 3.7	<0.001
Sitting without support at 2 yrs			<0.001
GMFCS (levels)			
I	0 0	111 52.3	<0.001
II	0 0	63 29.7	<0.001
III	0 0	38 17.9	<0.001
IV	28 21	0 0	< 0.001
V	105 79	0 0	<0.001
Mental retardation			
Normal	0 0	58 27.4	<0.001
Small delay	10 7.5	95 44.8	<0.001
Mild	45 33.8	53 25	NS
Severe	78 58.6	6 2.8	<0.001
Epilepsy	59 44.3	60 28.3	0.045

p– value from t– test and chi– square test between groups. NS – not significant

nificantly lower than for the walking patients 6.42 ± 3.43, (p<0.001). The birth weight of the non-ambulant patients (2448.3 ± 384.7) was significantly lower than for the ambulant patients 2682.6 ± 902.3, (p=0.04). Birth asphyxia occurred in similar proportion in the studied groups. An Apgar score more than 4 at 1 minute occurred more frequently in the walking children (p=0.034) than in the non-walking patients. Distribution of the documented cerebral palsy subtypes is noted in Table I.

The non-ambulant cerebral palsy group included 98 (74.2%) children with spastic tetraplegia, 14 (10.6%) diplegia, and 21 (15.9%) triplegia. The ambulant cerebral palsy group comprised 91 (42.9%) patients with spastic diplegia, 43 (20.3%) hemiplegia sinistra, 38 (18%), hemiplegia

dextra, 26 (12.2%) tetraplegia, 11 (5.2%) dyskinetic, and 3 (1.4%) ataxia. Spastic tetraplegia was the most common type of cerebral palsy in the non-walking patients – 74.2%. Diplegia spastica was the dominant type of cerebral palsy, constituting 42.9% of the walking children.

The non-walking patients exhibited the following types of motor dysfunctions: spasticity was found in 91 (68.9%) of the patients, hypotonia - 24 (18.2%), extrapyramidal symptoms - 13 (9.8%), ataxia in 4 (3.0%) cases. The walking children exhibited the following types of motor dysfunctions: spasticity was found in 181 (85.4%) of the patients, hypotonia - 11 (5.1%), extrapyramidal symptoms - 17 (8.0%), ataxia in 3 (1.4%) cases.

Motor milestones were particularly strong predictors of eventual walking. For instance, a mean age of sitting in the non-walking children was 1.50 ± 1.74 years, standing 3.34 ± 1.10 years. Significantly ($p<0.001$) more 74 (60%) of non-walking patients were unable to sit without support at 2 years of age compared to 8 (3.7%) of walking children.

The walking children were able to sit without support at 1.15 ± 1.24, standing 1.76 ± 0.56 and walking 2.42 ± 0.86 years.

The non-ambulant patients with cerebral palsy were ($p <0.001$) significantly more frequently qualified as level V on the GMFCS scale 105 (79%) than as level IV – 28 (21%). The ambulant children with cerebral palsy were ($p<0.001$) significantly more often classified into levels I –III (Table 1).

Mental development differed significantly between the groups (Table 1). The patients with normal and small delay of mental development were more frequently seen in the ambulant cerebral palsy group. No significant difference was observed in the incidence of mild mental retardation between the studied groups. On the other hand, severe mental retardation was observed more often ($p < 0.001$) in the non-ambulant patients.

In 85% of the non-walking patients, the seizures were resistant to treatment and required the use of at least two antiepileptic drugs. Generalized seizures dominated in about 70%. The rest was partial seizures with secondary generalization. On the other hand, in 32% of the walking children, the seizures were resistant to the antiepileptic drugs. Partial and partial seizures with secondary generalization dominated in 65% of the walking patients (this data is not presented).

MRI was performed on all patients. MRI abnormalities were observed in all of non-ambulant patients (100%) data is not shown. The dominant MRI abnormality in the non-ambulant and ambulant patients was periventricular leukomalacia, in 73 (54.8) and 13 (61.9%), respectively. Brain's atrophy was significantly ($p <0.001$) more frequently observed in non-ambulant children than in ambulant children. Posthemorrhagic porencepahly was observed in similar proportions in the both studied groups. In individual cases in the non-ambulant and ambulant groups, schizencephaly and lizencephaly were observed.

No correlations between walking ability in children with cerebral palsy and gender, preterm birth, and low birth weight were noted (data is not shown). Significant relationships between the walking ability and gestational age, Apgar score >4, normal birth weight, and sitting ability at 2 years of age were observed.

There were no correlations found between the lack of walking ability in children with cerebral palsy and gender, preterm birth, and low birth weight.. On the other hand, significant relationships between the no walking and birth weight, asphyxia, MRI findings, epilepsy and mental retardation were noted ($R= 0.355$; $p <0,001$).

DISCUSSION

In this study we demonstrated that the dominant form of cerebral palsy which prevents independent walking is tetraplegic cerebral palsy. Children who were not able to walk independently were often born prematurely, average birth weight did not exceed 2500g, and the average Apgar score of the patients was 4.31 ± 3.60. Among the motor dysfunctions in the analyzed groups, spasticity dominated - close to 70%. Locomotor independence was affected by mental retardation, no sitting ability at 2 years of age and the occurrence of organic changes (periventricular leukomalacia, brain atrophy) in MRI imaging. Our results are consistent with those of other authors [7-11].

Independent ambulation is a major determinant of participation that prefaces an improved individual quality of life, however defined. For the child with either spastic tetraplegia or dyskinesia, independent ambulation occurs only in a minority 23.7% [16]. These findings are in agreement with our results.

Beckung et al. [8] in a large Europen study including 10 042 children found that the proportion of no walking ability in children with cerebral palsy seems to be rather stable over the years and across the centers, despite the changes that have occurred in neonatal care across Europe. In this study walking ability varied strongly with cerebral palsy type. Additional impairments, as well as the presence of epilepsy, correlated significantly with walking ability and, thus, the walking ability can be an indicator of total disability load. These findings are in agreement with our results.

An earlier study suggested that patients with cerebral palsy reach 90% of motor capacity by 5 years of age (12), which is consistent with our results. Harris et al. [17], who studied 106 children with cerebral palsy aged from 3 to 8 , defined the age limits of the emergence of new motor skills at 6 to 7 years of age. For this reason, only children over 6 years old - the period of the most rapid development of functional skills - were qualified to the study group. The determination of conditions for functional development of a child with cerebral palsy is difficult and ambiguous. Damage to the brain releases primary reflex patterns of movement and postures from the stimulating and inhibitory effect of cortical and subcortical generators of movement as an expression of maturity of the central nervous system. Numerous studies point to a variety of factors determining functional skills. The authors [9,10,16,18,19] agree that the decisive influence on the performance of motor skills has the following: the topography of the palsy, the nature of paralysis, the presence of persistent primitive reflexes, age of achievement/non achievement of the fundamental motor

Table II. Magnetic resonance imaging (MRI) abnormalities in non ambulant children with cerebral palsy compared with ambulant children. *Wyniki badań rezonansu magnetycznego u dzieci z mózgowym porażeniem niechodzących w porównaniu dziećmi samodzielnie poruszającymi się.*

MRI abnormalities	Non-walking (n=133) n %	Walking (n=212) n %	P-value
Normal	0 0	12* 6.6	0.016 vs nonambulant
Periventricular leukomalacia	73 54.8	145 68.4	NS
Cerebral atrophy	37 ** 27.8	15 7.0	<0.001 vs ambulant
Posthemorrhagic porencephaly	13 9.7	25 11.8	NS
Multicystic encephalomalacia	5 3.7	6 2.8	NS
Schizencephaly	3 2.2	6 2.8	NS
Lisencephaly	2 1.5	1 0.5	

p– value from chi– square test between groups. NS – not significant

skills, associated problems such as an epilepsy, vision and hearing defect, or dislocation of joints. The child's level of intelligence is not without significance. A key factor, however, is the anatomical location and the area of brain damage, which due to incomplete knowledge of the physiology and pathology of movement control is often difficult to determine precisely [12,17,18]. Our results are similar to these reports.

Wu et al. [7] found that, among children who were not yet walking at 2 years of age, 10% could walk independently by age 6 to 7 and an additional 17% could walk with support. The clinical factors most useful in predicting future ambulation were motor milestones at 2 years (ability to roll, sit, or stand), and the type of cerebral palsy.

Fedrizzi et al. [20] evaluated the relationship between the degree of mental retardation and the results of MRI in 30 cases of the diplegic form. They found the relationship between the degree of intelligence and periventricular leukomalacia on the MRI. We have shown a similar relationship in our report.

About 10% of cerebral palsy is attributable to congenital brain malformations. Kwong et al. [21] observed congenital brain anomalies in 42% of children with tetraplegia. In the present study we also found congenital brain malformations (schizencephaly, lisencephaly)

In a prospective study, Wood and Rosenbaum [11] assessed the motor functions of 657 children with cerebral palsy. In particular, children who were functioning at higher levels of GMFCS (I and II) in the majority moved by themselves, while fewer than half of the children who moved independently were classified in the GMFCS level III [11]. Our results are consistent with this data. In the current paper, the dominant motor dysfunction preventing independent movement was spasticity; on the other hand, spasticity allows achieving certain motor functions, such as facilitating the stabilization of body segments, and thus the anti-gravity action will facilitate keeping the torso in an upright position and creates conditions for limited locomotion.

Several reports mention a significant relationship between mental retardation, motor impairment, and epilepsy [3,19,22-25]. Carlsson et al. [25] found that children with cognitive impairment had a higher frequency of epilepsy than those without cognitive impairment. These findings are in agreement with our data. In the present study, a higher proportion of magnetic resonance imaging abnormalities were observed in children with tetraplegic cerebral palsy and epilepsy compared with cerebral palsy. Our findings are comparable with previous studies [19,23,24].

In conclusion: asphyxia, lack of independent sitting ability at the age of 2, epilepsy, mental retardation, changes observed in MRI were factors that had a negative impact on the ability of independent walking of children with cerebral palsy.

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