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Neonatal Brachial Plexus Palsy: the role of diminished sensibility of the hand on functional recovery

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Chapter 8

The Milestone of Independent Walking is delayed in Infants with a Neonatal Brachial Plexus Palsy

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Submitted

Abstract

Objective

A Neonatal Brachial Plexus Palsy (NBPP) results from traction to the nerves of the arm. Developmental apraxia may occur as the nerve lesion takes place in a critical time window of brain development. The gross motor development has, so far, received little attention. One of the milestones of gross motor skill development is the age at which children can walk independently (AWI). AWI has not been systematically assessed in children with NBPP.

Patients and methods

The parents of 135 children with unilateral NBPP were questioned for the AWI during regular outpatient clinic visit. The results were compared with an international normative WHO study for a normal population (n = 794) in which the mean AWI was 12.1 months (SD 1.8). We analyzed the effects of nerve lesion severity, Apgar-score, and ethnicity.

Results

The mean AWI in NBPP was 14.49 (SD 2.99). This was significantly later than in the normal population ($p < 0.0001$). The mean delay was 2.4 months. Only two-thirds of children with NBPP walked independently, when 95% of the normal population already did. Lesion severity or Apgar did not affect AWI.

Conclusion

AWI is delayed in children with NBPP. The etiology is unclear and may be related to central developmental disability, incomplete function of the affected arm, asphyxia or immobilization during NBPP treatment. Systematic determination of AWI is important and if delayed then it is relevant to look for the cause. Additionally, it can be used to guide physical and occupational therapy.

INTRODUCTION

Neonatal brachial plexus palsy (NBPP) is a nerve traction injury that occurs during birth. The brachial plexus is formed by the spinal nerves C5 through T1; the most common NBPP lesion type involves the two upper spinal nerves (C5 and C6) affecting shoulder function and elbow flexion. The extensor function of elbow, wrist and fingers is diminished when the C7 nerve is also damaged. In more severe lesions, C8 and T1 are involved as well, resulting in partial or total loss of hand function.[1]

A NBPP does not only affect the peripheral nerves, but the development of cortical programs of the affected arm as well. This is likely due to the lack of afferent input during a critical time window resulting in what was coined 'developmental apraxia' or 'dyspraxia'.[2, 3] Central reorganization during movements of the affected arm occurs as shown in functional MRI studies.[4] Other examples of developmental apraxia are, for instance, the absence of an automatic swing of the affected arm during running and walking, the absence of unvoluntary compensatory movements of the arm to keep balance,[5] and a different gait pattern.[6]

The gross motor development of children with a NBPP has, so far, received little attention although there are some indications that it may be disturbed. For instance, increased compensatory movements on the unaffected side were seen in 3- to 5-month-old children with a NBPP, whereas the quality of fidgety movements was not found diminished.[7] In contrast, in an earlier study we found that the quality of fidgety movements was diminished and that a correlation with the severity of the NBPP lesion existed.[8]

Normally, infants begin to move their hands and use visual control to reach for an object at about 4 months of age.[9] The development of eye-hand coordination is hampered if, at that time, the positioning of the hand is impaired by muscle weakness of the shoulder and arm as is the case in NBPP. Additionally, the ability to bring both hands to the mouth may be reduced further affecting the possibility to explore objects. Moreover, leaning on both elbows to obtain a prone position might prove difficult due to disbalance, which affects the ability to explore the surroundings. When babies with a NBPP start sitting, their sitting position is often asymmetric, with their bodyweight towards the healthy side. Sometimes, children even use their knee to support the affected arm.[3] The lack of positioning of the hand in space is often compensated by rotation of the trunk and spine[10], which may be especially caused by a lack of glenohumeral external rotation.[11] Additionally, disturbance of

keeping balance was observed in NBPP.[3] The limitations change the possibilities and way the children with NBPP play which, thereby, affect the normal development of central motor programs.

In patients with a NBPP, it might be helpful to have a simple proxy which can be used to detect the presence of gross motor program disturbances. The age at which children were walking independently (AWI) is one of the gross motor milestones used to assess the overall development in child health. Other milestones are sitting, crawling and standing. The age of achieving the milestones is a signal for screening the overall development of an individual child.[12] Additionally, delay in achieving the milestones is relevant for planning rehabilitation treatment. AWI has not been systematically assessed in NBPP.

In the present paper, we studied whether AWI in children with a NBPP may be delayed.

PATIENT AND METHODS

The parents of 139 consecutive children with a unilateral NBPP who visited the outpatient clinic in the year 2003, were recruited for the study. The mean age of the children was 3.8 year (range 1-11) at that time. The parents were asked what the AWI of their child was, as most parents can remember this milestone.[13] The age was noted in months. The severity of the NBPP lesion, nerve surgical treatment, the Apgar scores were extracted from the patient files and ethnic background was asked at the parents. The Apgar score at 5 minutes[14] was analyzed (n = 86) as dichotomous variable. We employed a cut-off value of 7 as infants with an Apgar score lower than 7 have greater risk for developmental delay.[15] Four children were diagnosed with cerebral palsy at a later age and were excluded, which left 135 parents for analysis, see Table 1 for patient characteristics.

We compared AWI with an international normative WHO study, which prospectively assessed 794 healthy children in six countries worldwide.[12, 16]

Table 1 Patient characteristics

Number of patients		135
Gender	Male / Female	71 / 64
Age (years)	Mean	3.8
	Range	1 – 11
Nerve surgery	yes / no	115 / 20
Level of lesion	C5-C6	77
	C5-C7	36
	C5-T1	8
	C5-C8	14
Apgar score 5 min (n = 88)	Apgar < 7	n = 24
	Apgar 7 - 10	n = 64
	Mean (SD)	7.35 (2.23)
Ethnicity	Caucasian / non-Caucasian	89 / 46

Legend Table 1
SD: Standard Deviation.

Statistical analysis

Data were analyzed with SPSS Statistics for Windows, version 28 (IBM Corp. Armonk, NY). The error level was set at $p < 0.05$. For continuous outcome variables, t-test were used for comparison of means; linear regression was employed for multivariate analysis, under the assumption of the central limit theorem for the current large sample size.

RESULTS

The mean AWI was 14.5 months (median 14, range 9-24, SD 3.0). For the normal population, the mean AWI was 12.1 months (SD 1.8; n = 794).[16] The difference between the AWI of the NBPP group and normal population was significant ($P< 0.0001$). We analyzed the effect of gender, nerve surgery, Apgar score and ethnicity on AWI using t-tests. The only statistically significant factor was ethnicity ($p = 0.001$, Table 2). We performed linear regression, which showed that ethnicity remained a factor in the multivariate analysis.

Table 2 Univariate analysis of the age (month) of independent walking

Factor		AWI (SD)	p (t-test)
Gender	Male	14.31 (2.98)	0.174
	Female	14.91 (3.07)	
Nerve surgery	Yes	14.59 (3.02)	0.327
	No	13.9 (2.82)	
Ethnicity	Caucasian	15.09 (0.318)	0.001*
	Non-Caucasian	13.33 (0.255)	
Apgar-score	< 7 (n = 24)	15.04 (3.043)	0.722
	7-10 (n = 64)	14.78 (3.026)	
Lesion severity	C5-C6	14.44 (2.53)	#
	C5-C7	14.05 (3.25)	#
	C5-C8	14.83 (3.71)	#
	C5-T1	15.79 (4.15)	#

Legend Table 2

Four different factors were analyzed to assess its effect on the age of walking independently.

AWI: mean age in months; SD: standard deviation;

* statistically significant; # all combinations were tested, p > 0.05 for all.

We additionally analyzed whether lesion severity (number of affected roots) had a relationship with AWI. There were no statistically significant differences when comparing all combinations of severity groups (p > 0.05, Table 2).

We performed linear regression in two ways, a) including all 135 children b) including 88 children for whom the Apgar score was available (Table 3). In both analyses ethnicity was a significant factor, in the second analysis nerve surgery was a significant factor.

The distribution across percentiles and the cumulative percentage of NBPP for age comparing the study group and the normative WHO group is presented in Table 4 and Figure 1. Only 31.1% of children in the NBPP group was walking independently (4th column), when 50% of the normal population already did (1st column). When 95% of the normal population had started walking independently, only two-thirds of children with NBPP had reached this developmental milestone.

Table 3a Linear regression analysis for n = 135, all children

Parameter		B	SE	t	Significance	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept		14.650	1.128	12.989	0.000*	12.418	16.882
Severity	C5-C6	-1.143	0.847	-1.351	0.179	-2.818	0.531
	C5-C7	-1.396	0.914	-1.528	0.129	-3.205	0.412
	C 5-C8	-1.306	1.427	-0.915	0.362	-4.129	1.517
	C5-T1	0[a]	-	-	-	-	-
Ethn	Caucasian	1.604	0.539	2.976	0.003*	0.538	2.670
	Non-Caucasian	0[a]	-	-	-	-	-
Nerve Surgery	Yes	0.259	0.720	0.360	0.720	-1.165	1.684
	No	0[a]	-	-	-	-	-
Gender	male	-0.639	0.508	-1.257	0.211	-1.644	0.366
	female	0[a]	-	-	-	-	-

Table 3b Linear regression analysis for n = 88, for children of whom the 5 minute Apgar score was available.

Parameter		B	SE	t	Significance	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept		17.018	1.433	11.875	0.000*	14.166	19.870
Severity	C5-C6	-1.764	0.970	-1.818	0.073	-3.695	0.167
	C5-C7	-2.531	1.052	-2.406	0.018	-4.624	-0.438
	C 5-C8	-2.420	1.656	-1.462	0.148	-5.716	0.875
	C5-T1	0[a]	-	-	-	-	-
Ethn	Caucasian	2.437	0.676	3.606	0.001*	1.092	3.782
	Non-Caucasian	0[a]	-	-	-	-	-
Nerve Surgery	Yes	-2.163	1.021	-2.118	0.037*	-4.196	-0.130
	No	0[a]	-	-	-	-	-
Gender	male	-0.299	0.611	-0.490	0.626	-1.516	0.917
	female	0[a]	-	-	-	-	-
Apgar 5 min	7 - 10	0.249	0.665	0.375	0.709	-1.074	1.572
	< 7	0[a]	-	-	-	-	-

Legend Table 3

Parameter estimates from multiple linear regression; dependent variable: Age (months) of independent walking.

B: regression coefficient; SE: standard error of B; t: coefficient divided by its standard error; [a]: set to zero because it is redundant, * statistically significant

Table 4 Overview of percentiles of walking independently of NBPP and controls

Percentile	Normal (n = 794) Age (months)	NBPP (n = 135) Age (months)	NBPP (n = 135) Cum%
1	8.2	9.4	0
3	9	10	0.7
5	9,4	10	0.7
10	10	11	5.2
25	11	12	14.8
50	12	14	31.1
75	13.1	17	44.4
90	14.4	18	57.0
95	15.3	20	64.4
97	16	21	74.1
99	17.6	23.6	79.3

Legend Table 4

Cum%: Cumulative percentage in NBPP for age of normal children.
Only 31.1% of children in the NBPP group was walking independently (4th column), when 50% of the normal population already did (1st column). When 95% of the normal population (1st column) started walking independently, only 64.4% of children with NBPP (4th column) had reached this developmental milestone.

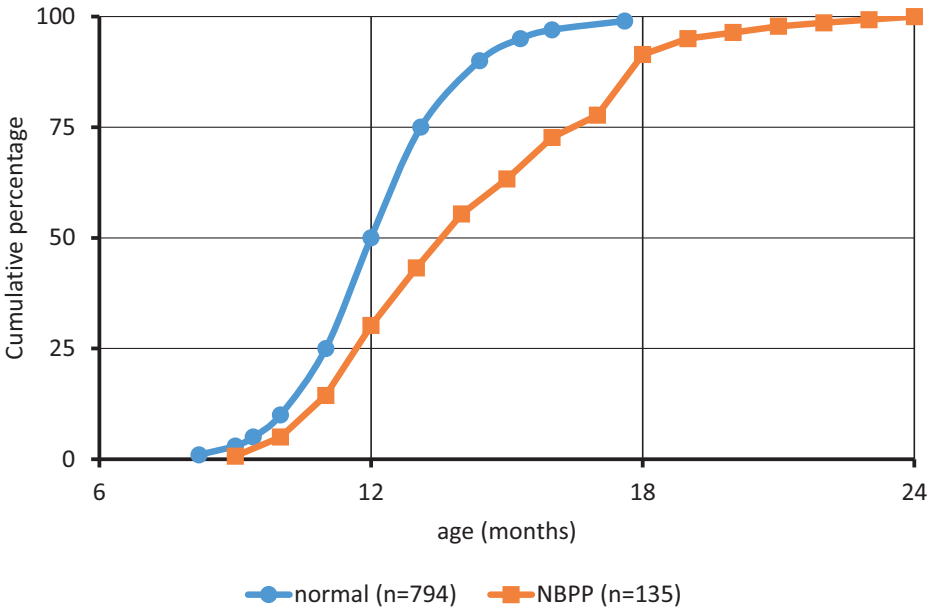

Figure 1 *Cumulative percentage of children (Y-axis) that attained walking independently per age (in months) on the X-axis*

DISCUSSION

In the present study, we found that AWI in children with a NBPP was significantly later than in a normative WHO group.[16] The mean AWI was 14.5 and 12.1 months, respectively. Although this 2.4-month delay may not be relevant for the individual child, this finding is relevant as it may signal delayed gross motor development in patients with NBPP, a possibly underestimated feature in this patient group. It is an important aspect for therapists to include in their evaluation and therapy, and it is important for parents also to know that independent walking may be delayed.

More than half of the children with a NBPP were later than the 75th percentile of the normative group. In our multivariate analysis, ethnicity and nerve surgery were predictive factors. As ethnicity was also a factor in the normative control group, this finding was expected. Nerve surgery was a significant factor in one of the linear regression models, while it was not in the univariate analysis. Children with a more severe NBPP (as they were indicated for nerve surgery) had a 2 months shorter AWI in the regression analysis. This

seemingly contradictory finding may be due to the small number of conservatively treated children (n = 9) in the second linear regression model. Nerve lesion severity as expressed as the number of roots affected, did not correlate with AWI. No significant difference was found in AWI between four levels of neurological lesion severity. Therefore, motor performance of the arm may not be the sole or most important determining factor. Central nervous system development may be of key influence on AWI. The exact mechanism why AWI is delayed in children with a NBPP remains unclear.

The delay of AWI in children with a NBPP can be explained in four ways. Firstly, gross motor development is delayed and the milestone AWI is a representative feature of this delay. The risk of having central developmental disability in children with a NBPP is increased. In as much as 13% of 35 children with a NBPP had a central developmental disability at the age of 5.[8] In addition, functional MRI analysis of patients with a NBPP suggested that brain functional disturbances are present and extend beyond the sensorimotor network, and cascades serial remodeling in the brain.[17] NBPP occurs at a critical period of development of the sensorimotor cortex and premotor cortical areas. As both proprioceptive and sensory afferent nerves and efferent nerves are damaged in this timeframe, this may have a profound effect on cortical development of motor programming. If gross motor development is indeed delayed, other milestones such as sitting, crawling and standing, should than also be delayed, which should be the subject of further study.

Secondly, the delay in AWI might be explained by the incomplete function of the affected arm. After all, movements that precede walking or aid in walking, are hampered. The children can't pull themselves up properly which is necessary to stand and later walk, or they missed the crawling stage which is preliminary to walking. Parents frequently mention that their child shoves on the buttocks to move around for a prolonged period of time, instead of crawling or walking. A previous study showed significant difficulties with keeping balance at the age of 5-15 years.[3] Children with a NBPP may, therefore, be hampered to walk in the absence of balance control. In the current study, the severity of the nerve lesion, either expressed as the necessity of nerve surgery, or expressed as the number of roots involved in the lesion, did not correlate with AWI. This finding makes it less likely that the nerve lesion itself is the main limiting factor for independent walking.

Thirdly, most children with a NBPP have suffered a traumatic birth which may in itself lead to developmental delay as a result of asphyxia. As such, this factor would probably be reflected

in a relationship with the Apgar score. The risk of developmental vulnerability at 5 years of age was found to be inversely associated with the 5 min Apgar score across its entire range.[14] In the present study, however, the Apgar score at 5 minutes was not independently related to AWI, so it seems unlikely that this factor is explanatory in this patient cohort. Fourthly, in children who have undergone nerve surgery at an early age, the surgery itself and the postoperative immobilization may play a role. We believe that this factor is of minor importance.

The mean weakness of our study was that the age of AWI was retrieved from the memory of the parents. They were questioned retrospectively after about four years. Correct parental recall of developmental milestones like AWI has been shown to be accurate frequently, although there was a greater discrepancy associated with an increased lapse of time from the event.[13] In our cohort, the distribution of walking independently showed two peaks, at 12 and 18 months. This is most likely caused by the way parents answered AWI as 'one year' or 'one-and-a-half year', as they could not exactly remember the age in months. Additionally, the definition of AWI was broadly defined in the present study. Parents may have remembered when their child made their first few wobbly steps, or when they could make several steps in a row. We feel, however, that these uncertainties do not disregard the findings of our paper due to the large cohort we studied and the big difference we found compared with the normative group. A second weakness was that the NBPP study population was from a tertiary referral center for nerve lesions, which most likely is skewed towards the more severely affected children. This is reflected in the high percentage of children who were treated with nerve surgery at a young age. An additional weakness, is that the AWI in our cohort was compared with a cohort from the literature instead of a control group from our own region, which may have reduced straight statistical comparison. A recent meta-analysis showed that most physical therapy interventions focus only on the affected arm.[18] The main significance of our paper is to draw attention to the relevance of monitoring the general development of children with an NBPP. Physical and occupational therapy should not only focus on the affected arm, but a broader view is necessary. Therapy needs to start as early as possible to signal any delay of the general senso-motor development, and to attempt supportive therapy. Special attention is needed for the development of proper balance.

CONCLUSION

Children with a NBPP have a delay of 2 months in AWI. More than half of the children with an NBPP are later than the 75th percentile of a WHO normative group. The underlying cause for the delay in AWI is unclear, but could be related to a delay in gross general motor development. Other factors, such as a diminished balance, may play an additional role. Since AWI is delayed, physical and occupational therapy should not only focus on the affected arm, but on general motor development as well.

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