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Investigation of Upper Extremity Resting Position in Children with Brachial Plexus Birth Injury

Kıvanç DELİOĞLU[1*], Ebru ÖZTÜRK[2], Akın ÜZÜMCÜGİL[2], Mintaze Kerem GÜNEL[1]

[1] Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Ankara, Turkey

[2] Hacettepe University, Faculty of Medicine, Ankara, Turkey

*Corresponding author e-mail: kvncdelioglu@gmail.com

ABSTRACT

Purpose: The aim of our study was to investigate the resting position of the upper extremity in different types of nerve injury in brachial plexus birth injury (BPBI).

Method: A total of 193 children aged 4-18 years with BPBI were included in the study. The results of the children's routine physiotherapy assessments were analyzed retrospectively. Resting position of the upper extremity and upper extremity function were assessed using the Modified Mallet Classification. Differences in both global upper extremity resting position and forearm resting position between Narakas types were analyzed, and also the relationship between upper limb resting position and age and function was investigated.

Results: There was a statistical difference in the distribution of the resting position of the upper extremity according to Narakas types ($p<0.001$). In upper trunk injuries, there was a moderate positive correlation between upper extremity resting position and total function of the upper extremity ($p<0.001$, $r=0.605$). Also, there was a moderate negative correlation between age and grade of the upper extremity resting position in children with total plexus injury ($p=0.016$, $r=-0.423$).

Discussion: Increased shoulder internal rotation posture could be seen in all upper trunk injuries and was more common in Narakas type 2b, which also has a negative effect on total upper extremity function. It was found that for both total plexus and upper trunk injuries, the resting forearm posture could be in either supination or pronation. Supination position was more common, particularly in total plexus injuries and Narakas type 2b.

Key Words: Birth Injury, Brachial Plexus, Posture, Upper Extremity, Physiotherapy.

INTRODUCTION

Brachial plexus birth injury (BPBI) occurs as a result of injury to the brachial plexus (BP) during delivery, and the incidence is 0.50 to 3 per 1000 live births (1,2). The extent of the damage can vary from single nerve root to total BP lesions, and this has an impact on the functional capacity of the affected upper extremity. This complex peripheral nerve injury can lead to temporary loss of function or lifelong disability, depending on the severity of the injury (3, 4).

BBPI is frequently classified anatomically according to the injured nerve roots or based on the function of the affected arm. Depending on the injured nerve roots, BPBI is mainly categorized into two main groups which are upper trunk injuries (C5, C6 with or without C7) (accounting for approximately 80% of all BPBI) and total plexus injuries (5,6). In addition, Narakas Classification is an observational classification system based on the active movements of the affected upper extremity after the first two months ages (7). While Type 1 exhibits best level of function and refers to C5-

C6 lesion, Type 3 and Type 4 include total plexus lesion. The Narakas Type 2 represents different severities of C5-C6-C7 root injury and is one of the most frequent BP injuries. To expand this classification method, Al Qattan et al. divided Type 2 into Type 2a and Type 2b. Type 2a is characterized with weakness in shoulder abduction, shoulder external rotation, elbow flexion, and forearm supination (7). The patient is identified as Type 2b if in addition to the symptoms of Type 2a, there is also a persistent insufficient wrist extension during the first 2 months after birth (7).

The nerve damage leads to disorders such as muscle weakness, joint instability or contractures, structural changes in the musculoskeletal system, and sensory deficits (3,8,9). Restrictions in activity and participation also become more evident with growth (8,10). In addition to functional limitations, spinal deformities such as scoliosis and postural or positional changes in the affected upper extremity and other parts of the body may occur (11-14).

In the early period of upper trunk injuries, the posture of the upper extremity was referred to as 'waiter's tip', and with increasing age, this condition appears as internal rotation posture or internal rotation contracture in the affected extremity (15-17). Many scientific publications have published images of the affected arm in internal rotation, the elbow in semi-flexion, the forearm in pronation, or have described the limb position in this way (18-22). In total plexus injuries, the resting position of the forearm is frequently described, and treatments for supination contractures and supination posture are described (23). Although there are many studies on the function of the upper extremity and active/passive joint movements, there are very few studies on upper limb appearance, cosmetic problems, length and circumference inequalities (24,25). Families of children with BPBI report that the appearance of the affected side is very important (24,25), but to our knowledge the posture or resting position of the entire upper extremity has not been investigated before in a large group of cases.

Therefore, the aim of our study was to examine the resting position of the upper extremity in different types of nerve injury in BPBI and investigate the relationship between resting position and upper extremity function.

METHODS

Study Design

This cross-sectional study was conducted retrospectively at Hacettepe University between January 2023 and June 2024 and was approved by the Hacettepe University Faculty of Physical Therapy and Rehabilitation Unit Research Ethics Committee (FTREK 24/40). In this study, we retrospectively analyzed the medical information regarding the routine assessments of children with BPBI who applied for medical follow-up and treatment between the years 2019 to 2024.

The medical records of all patients undergoing routine follow-up at our hospital were examined by their therapist, who is the first author of the study. Children's Narakas Classification, which expresses the degree of the nerve injury, was obtained from the medical records. Inclusion criteria were determined as children with BPBI between the ages of 4 and 18 years, as the Modified Mallet Classification is used in children older than 3 years. Exclusion criteria from the study were having any orthopaedic, neurological or systemic disease other than BPBI and having undergone surgery and/or botulinum toxin injection in the last 6 months.

Patients

During the retrospective period, 368 children and their families applied for physiotherapy and rehabilitation follow-up, a home exercise program or physiotherapy and rehabilitation services. 175 of them were excluded as they did not meet the inclusion criteria (two were excluded as they were diagnosed with both cerebral palsy and BPBI, one was diagnosed both spina bifida and BPBI, 83 had surgery or botulinum toxin injection within past 6 months, and 89 were 0-3 years old). Therefore, 193 children between 4-18years old age (7.37±2.85) were included in the study. Two main groups were formed according to nerve injury and these two groups were grouped within themselves according to the Narakas classification: Upper trunk injuries (n=161, 86.40% of all children) were grouped as Narakas Type 1 (n=29, 15.00% of all children), Narakas Type 2a (n=72, 37.30% of all children), Narakas Type 2b (n=60, 31.10% of all children); because the incidence of total plexus injuries is low, Narakas Type 3 and Type 4 injuries were analyzed together as a single group (n=32 , 16.60% of all children).

Assessments

In the study, the Modified Mallet Classification was used to assess the function and resting posture of the affected upper extremity, and all assessments were performed by the first investigator.

The Modified Mallet Classification (MMC) is a valid and reliable assessment tool, recommended by international consensus (26-28). The MMC is widely used to measure both active joint movements and to determine the resting posture of the upper extremity. The results of the MMC were retrospectively used for this investigation. The MMC is performed in children older than 3 years age, which therefore determined the inclusion criterion of the study to include children over the age of 3 years (27). The Mallet classification has been modified by additions made by various researchers over time (29-32). Although the first Mallet classification consisted of five movements, a modified version that assesses six movements is currently preferred (28). The version we used in this study includes the evaluation of six movements and the resting position of the arm (posture of the extremity) (28, 33). The six movement evaluations included in the MMC include the characteristic of ordinal data from grade 1 (no function) to grade 5 (normal function) and were analyzed in this way in our study. Figure 1 shows movement assessments of the MMC (28, 33).

The resting posture of the arm in the MMC consists of six grades, and each grade is divided into two categories depending on the pronation or supination position of the forearm (28, 32). In grade 1, the internal rotation posture in the shoulder joint is the highest, while the internal rotation posture decreases towards grade 5, and grade 5 refers to symmetrical posture. While grade 5 refers to a symmetrical posture, grade 6 which refers to external rotation in the shoulder and supination of the forearm, is a rare condition. Therefore, in the follow-up of shoulder internal rotation posture using the MMC, the change from grade 1 to grade 5 provides ordinal data as a decrease in internal rotation posture (28, 32). In our study, the differences in resting posture of the upper extremity were analyzed according to Narakas type, considering all values between grade 1 and grade 6. In addition, the pronation or supination posture of the forearm was also analyzed according to the Narakas types and the differences were investigated. To investigate the relationship between age and shoulder internal rotation posture in the upper trunk and brachial plexus injuries, the MMC resting posture score was analyzed considering values between grade 1 and grade 5. Figure 2 shows MMC's assessment of the resting position of the upper extremity (28).

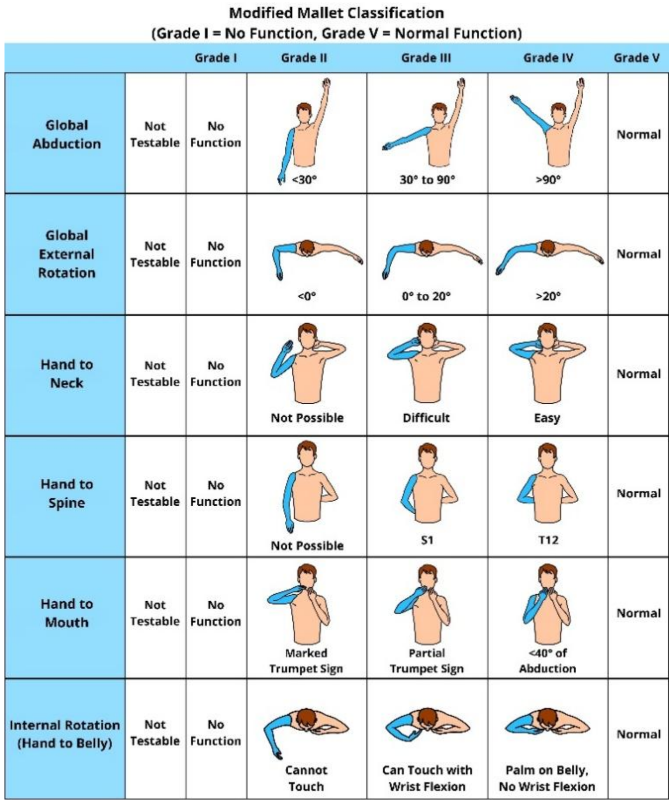

Figure 1. Modified Mallet Classification, movement assessment.

Statistical Analysis

All statistical analyses of the study were done by an experienced biostatistician (2nd researcher). Statistical analyses were performed using IBM SPSS version 23.0 (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). The assumption of the normal distribution of variables was examined using the Shapiro-Wilk test and histograms, boxplots, and Q-Q plot. The descriptive statistics of the continuous data were given as mean and standard deviation for normally distributed variables, median and 25-

75 quartiles for non-normally distributed variables, and frequencies and percentages for categorical data.

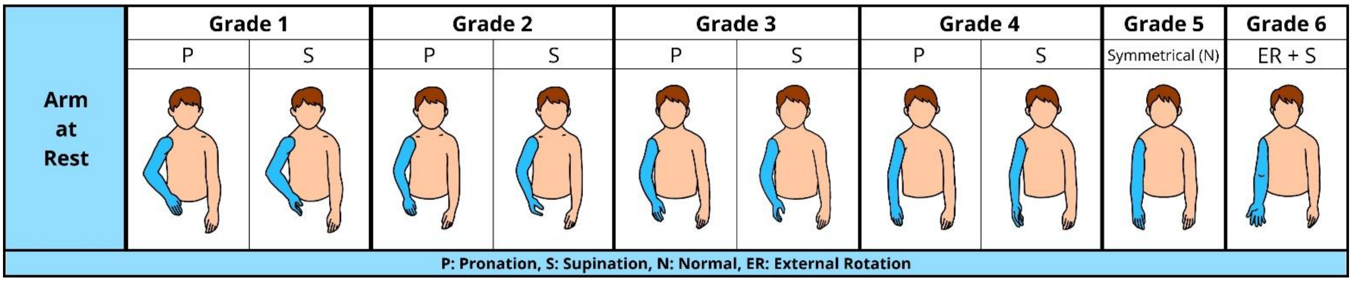

Figure 2. Modified Mallet Classification, upper extremity resting position assessment.

According to the Narakas types, the resting position of the upper limb was analysed using the Chi-square test, Fisher's exact test or its extension Fisher-Freeman Halton test (exact method or Monte Carlo method based on 10000 samples).

The correlation between continuous variables was examined using Spearman's correlation coefficient test since the normality assumption did not seem satisfied. The correlation coefficient between 0–0.10, 0.10–0.39, 0.40–0.69, 0.70–0.89, and 0.90–1 was accepted as negligible, weak, moderate, strong, and very strong correlations, respectively (34). A p-value of <0.05 was considered to be statistically significant.

RESULTS

During the study period, the assessment data of 193 children were retrospectively analyzed; 105 of these children were female (54.40%) and 88 (45.60%) were male. Of the children, 125 had right (64.80%) and 68 had left (35.20%) involvement. The mean age of the children between 4 and 18 years was 7.37 years (7.37±2.85). There was no difference in the age of the children according to the Narakas types (p=0.167).

Of the 193 children, 161 (83.40% of all children) had upper trunk injuries and 32 children (16.60% of all children) had total plexus injuries. Children with upper trunk injuries included Narakas type 1, 29 children (15.00% of all children); Narakas type 2a, 72 children (37.30% of all children), Narakas type 2b, 60 children (31.10% of all children). Thirty-two children (16.60% of all children) with total plexus injury were classified as Narakas type and type 4, and these children were analysed as a single group (Narakas type 3/4).

There was a statistical difference in the distribution of the resting position of the upper extremity according to Narakas types (p<0.001): In the resting position classification, there were 11 children in grade 1; there was a difference between Narakas type 3/4 and Narakas type 1, type 2a. There were 25 children in grade 2; there was a difference between Narakas type 2b, type 3/4 and Narakas type 1, type 2a. There were 49 children in grade 3; there was a difference between Narakas type 2b and type 1.

Table 1. The distribution of the resting position of the upper extremity by Narakas type.

Upper Extremity Resting Position	Upper Trunk Injuries			Total Plexus Injuries	p
	Narakas Type 1 n=29	Narakas Type 2a n=72	Narakas Type 2b n=60	Narakas Type 3/4 n=32	
	n(%)	n(%)	n(%)	n(%)	
Grade 1	0(0.00)[a]	1(1.38)[a]	3(5.00)[a,b]	7(21.87)[b]	**<0.001**
Grade 2	0(0.00)[a]	2(2.77)[a]	13(21.58)[b]	10(31.25)[b]	
Grade 3	2(6.89)[a]	19(26.38)[a,b]	29(48.14)[b]	9(28.12)[a,b]	
Grade 4	14(48.27)[a,b]	42(57.96)[b]	14(23.24)[a]	6(18.75)[a]	
Grade 5 (Symmetrical)	13(44.82)[a]	7(9.66)[b]	1(1.66)[b]	0(0.00)[b]	

Grade 6 (Ext Rot + Sup)	0(0.00)[a]	1(1.38)[a]	0(0.00)[a]	0(0.00)[a]	

n: number of children; %: percentage, within the Narakas Type; Ext Rot: External Rotation; Sup: Supination. a and b: The same letter in the grade rows indicates that the columns with Narakas types show similar distribution, while the columns without the same letter are statistically different.

Table 2: The distribution of the forearm resting position by Narakas type.

Forearm Position	Upper Trunk Injuries			Total Plexus Injuries	p
	Narakas Type 1 n=29	Narakas Type 2a n=72	Narakas Type 2b n=60	Narakas Type 3/4 n=32	
	n(%)	n(%)	n(%)	n(%)	
Pronation	27(93.10)[a]	63(87.50)[a]	45(75.00)[a]	14(43.75)[b]	**<0.001**
Supination	2(6.90)[a]	9(12.50)[a]	15(25.00)[a]	18(56.25)[b]	

n: number of children; %: percentage, within the Narakas Type. a and b: The same letter in the grade rows indicates that the columns with Narakas types show similar distribution, while the columns without the same letter are statistically different.

In Grade 6, there was only 1 child and there was no difference in the distribution of children according to Narakas types. Table 1 shows the distribution of the resting position of the upper extremity by Narakas type.

In 193 children, 149 (77.20%) children had forearm pronation posture and 44 (22.80%) children had supination posture. There was a statistical difference in the distribution of the resting position of the forearm according to Narakas types (p<0.001): 149 children who had pronation posture; there was a difference between Narakas type 3/4 and all other Narakas types. 44 children who had pronation posture; there was a difference between Narakas type 3/4 and all other Narakas types. Table 2 shows the distribution of the forearm resting position by Narakas type.

The relationship between internal rotation posture of the shoulder and function was investigated in both upper trunk injuries and total plexus injuries. The change in internal rotation posture was monitored with the MMC's upper extremity resting position grading system. Grade 1 indicates maximum internal rotation, grade 5 indicates decreased internal rotation posture and the affected side has a symmetrical posture with the healthy side. There was only one child with upper trunk injury classified as grade 6 which reflects shoulder external rotation posture, and this child was not included in the analysis of the relationship between shoulder internal rotation posture and function. In upper trunk injuries, there was a moderate positive correlation between upper extremity resting grade and total function (p<0.001, r=0.605); there was a moderate positive correlation between upper extremity resting grade and active joint movements (p<0.001, 0.422<r<0.625). In total plexus injuries, there was no correlation between upper extremity resting grade and function (p=0.248). Table 3 shows the correlation analysis between motor function and shoulder internal rotation posture.

The relationship between age and upper extremity resting position was also analyzed. There was a moderate negative correlation between age and upper extremity resting position score (grade) in children with total plexus injury (p=0.016, r=-0.423). In children with upper trunk injuries, there was no correlation between age and upper extremity resting position score (p=0.895, r=0.010).

Table 3. The correlation analysis between motor function and shoulder internal rotation posture.

Function (Modified Mallet Classification)	Upper Plexus Injuries (n=160)		Total Plexus Injuries (n=32)	
	Upper Extremity Resting Grade		Upper Extremity Resting Grade	
	p	r	p	r
Global Abduction	**<0.001**	**0.438**	0.181	0.243
External Rotation	**<0.001**	**0.625**	0.441	0.141

Hand to Neck	**<0.001**	**0.565**	0.583	0.101
Hand to Spine	**<0.001**	**0.422**	0.617	-0.092
Hand to Mouth	**<0.001**	**0.515**	0.488	0.127
Hand to Belly	**<0.001**	**0.469**	0.601	0.096
Total Function	**<0.001**	**0.605**	0.248	0.210

r : correlation coefficient

DISCUSSION

The results of a 6-year retrospective study showed that the upper extremity resting postures of children with different Narakas types differed from each other between the ages of 4 and 18 years. The difference in the resting position of the upper extremity may be due to the internal rotation posture of the shoulder, and our study revealed that the resting posture of the forearm also differed between the Narakas types. In upper trunk injuries, global elevation, global external rotation, hand to neck, hand to mouth, hand to belly, hand to spine movements and total function of the upper extremity decreased with increasing shoulder internal rotation posture.

In upper trunk injuries, there was no relationship between increasing age and upper extremity resting position, whereas in total plexus injuries, the resting position gradient decreased with increasing age. This change in upper extremity posture with increasing age in children with total plexus injury may be due to an increase in shoulder internal rotation and elbow flexion contracture, and when the MMC visual scoring system was carefully examined, it was noted that limb length shortening may be a concomitant condition that should be followed up.

Although postural changes or disorders in various body parts such as the spine, pelvis, knee and foot joints have been investigated in BPBI (11, 12), the resting position of the upper extremity and related factors have not been investigated. It is important that the results of our study show both the differences in the resting position of the upper extremity according to nerve damage and the relationship between age and function.

In our study, among the Narakas types with upper trunk injury, the number of children with symmetrical posture (Grade 5) was the highest in Type 1. In Narakas Type 1 and Type 2a group, the resting position of the upper extremity was usually Grade 4 and 5, while Grade 2 and 3 were more common in Narakas Type 2b. This may reflect that delayed spontaneous recovery in upper trunk injuries may lead to increased shoulder internal rotation posture. Several studies have reported that delayed recovery can lead to contractures in the shoulder joint (35), and our study demonstrated this quantitatively in a large number of participants. Furthermore, there was a moderate correlation between upper limb resting posture and function in upper trunk injuries. We think that these two findings should be interpreted together.

In upper trunk injuries, an internal rotation posture develops in the first year after birth due to a strength imbalance between the internal and external rotators of the shoulder, with the internal rotator muscles being stronger and less affected by denervation (4,15,17,18). Over time, this problem leads to glenoid hypoplasia, posterior subluxation or dislocation of the humeral head, various levels of disorders in the glenohumeral joint, and related functional limitations (4,17,36). Although the internal rotation posture of the upper extremity and the deficiency of external rotation are often referred to as internal rotation contracture (4,16,17), recent studies have shown that there may be limitations in activities that involve internal rotation of the joint (33, 37, 38). Internal rotation posture of the shoulder, flexion posture or contracture in the elbow joint causes the arm to be displaced towards the front of the body (13,17,33). This position is not only disadvantageous for external rotation, but also for hand to spine, hand to belly, hand to mouth movements (17,33,38). Therefore, monitoring the resting posture of the upper extremity is important not only for cosmetic or appearance reasons, which are often important to families, but also for functional reasons. The fact that this multidirectional insufficiency in the shoulder joint has been shown to be common in Narakas type 2b supports the results of our study. Therefore, we believe that the resting position of the extremities should be monitored in all classes of Narakas type

2, especially Narakas type 2b, and the treatment plans should consider resting position.

There was also a difference in the resting position of the forearm between the Narakas types. Supination posture was found to be more common in total plexus injuries than in other injury types. In total plexus injuries, surgery is often performed to restore pronation function (23). As a supinated hand cannot perform functional grasping and releasing (8), we believe that positioning the forearm in pronation or neutral rotation from early postnatal life may be both functionally and cosmetically beneficial in children with total plexus injuries. Supination posture was also found to be possible in upper trunk injuries, particularly in the Narakas type 2b. This supports the findings that although supination is difficult to perform in the early stages of upper trunk injury, supination is gained with age and even pronation of the forearm becomes more difficult after 2-3 years of age (8, 39). When we interpret the results of our study together with these studies (8, 39), we think that it is necessary to be very careful when choosing treatments and orthotic applications (4, 17) to reduce the pronation position in the early period of upper trunk injuries.

There was a moderate relationship between upper extremity posture and motor function only for upper trunk injuries, but not for total plexus injuries. Bae et al investigated the relationship between upper limb size difference and motor function and the results of this study show that there is no relationship between function and size difference (24). However, the small number of participants in this study and the fact that children were not grouped according to nerve damage may be the underlying reasons for the lack of a relationship in this study. In our study, the lack of correlation between function and upper extremity position in total plexus injuries may be due to the fact that these children may have different functional deficits due to the diversity in nerve damage, especially the hand, finger and forearm functions continue to develop over a longer period of time such as 7-8 years of age (8), and extremity posture is similarly distributed in each grade.

The results revealed that resting position grades of upper extremity decreased with increasing age in children with total plexus injury. It has been reported that arm shortness becomes apparent with increasing shoulder internal rotation and elbow flexion posture (40). The relationship showed in our study may mean that the shortness or length difference of the affected arm increases with increasing age. It has been reported that the affected upper limb is approximately 95% of the length and diameter of the unaffected side (24), but this difference may be greater in children with total plexus injuries or delayed spontaneous recovery. Therefore, we believe that the treatment of these children should be enriched with play and activity-based interventions that increase the use of the limb.

Limitations

The fact that our study is not a longitudinal follow-up study is a limitation, and being a single-center study is also a limitation. There is a need to examine the results of longitudinal studies in which the same patients are followed up in the future.

CONCLUSION

In BPBI, the resting position of the upper extremity differs between Narakas types in the late period, such as pre-school, school-aged and adolescence. Increased internal rotation posture in upper trunk injuries is more common in Narakas type 2b but may be seen in all type 2 groups, and this has a negative effect on total upper extremity function. Resting forearm posture showed that children can be in both supination and pronation. Supination may be more common, particularly in total plexus injuries and Narakas type 2b. The change in upper extremity resting posture with increasing age may be a predisposing factor for upper extremity length discrepancy in total plexus injuries.

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REFERENCES

1. Koshinski JL, Russo SA, Zlotolow DA. Brachial plexus birth injury: a review of neurology literature assessing variability and current recommendations. Pediatr Neurol. 2022;136:35-42.
2. Louden E, Marcotte M, Mehlman C, Lippert W, Huang B, Paulson A. Risk factors for brachial plexus birth injury. Children. 2018;5(4):46.
3. Leblebicioğlu G, Pondaag W. Brachial plexus birth injury: advances and controversies. J Hand Surg Eur Vol. 2024:17531934241231173.
4. Zuo KJ, Ho ES, Hopyan S, Clarke HM, Davidge KM. Recent advances in the treatment of brachial plexus birth injury. Plast Reconstr Surg. 2023;151(5):857e-74e.
5. Strombeck C, Krumlinde-Sundholm L, Remahl S, Sejersen T. Long-term follow-up of children with obstetric brachial plexus palsy I: functional aspects. Dev Med Child Neurol. 2007;49(3):198-203.
6. Al-Qattan M. Assessment of the motor power in older children with obstetric brachial plexus palsy. J Hand Surg Br. 2003;28(1):46-9.
7. Al-Qattan MM, El-Sayed AA, Al-Zahrani AY, Al-Mutairi SA, Al-Harbi MS, Al-Mutairi AM, et al. Narakas classification of obstetric brachial plexus palsy revisited. J Hand Surg Eur Vol. 2009;34(6):788-91.
8. Delioğlu K, Uzumcugil A, Gunel MK. Activity-based hand-function profile in preschool children with obstetric brachial plexus palsy. Hand Surg Rehabil. 2022;41(4):487-93.
9. Brown SH, Wernimont CW, Phillips L, Kern KL, Nelson VS, Yang LJ-S. Hand sensorimotor function in older children with neonatal brachial plexus palsy. Pediatr Neurol. 2016;56:42-7.
10. Partridge C, Edwards S. Obstetric brachial plexus palsy: increasing disability and exacerbation of symptoms with age. Physiother Res Intern. 2004;9(4):157-63.
11. Candan SA, Fırat T, Livanelioğlu A. Assessment of spinal curvatures in children with upper trunk obstetrical brachial plexus palsy. Pediat Phys Ther. 2019;31(2):149-54.
12. Słonka K, Sobolska A, Klekot LH, Proszkowiec M. The importance of physiotherapy in the process of posture formation in children with obstetric brachial plexus injury. Neurologia Dziecięca. 2011;20(40):35-9.
13. Wickstrom J. Birth Injuries of the Brachial Plexus Treatment of Defects in the Shoulder. Clin Orthop. 1962;23:187-96.
14. Russo SA, Kozin SH, Zlotolow DA, Nicholson KF, Richards JG. Motion Necessary to Achieve Mallet Internal Rotation Positions in Children With Brachial Plexus Birth Palsy. J Pediatr Orthop. 2019;39(1):14-21.
15. Gilbert A. Brachial Plexus Injuries: Published in Association with the Federation Societies for Surgery of the Hand: CRC Press; 2001.
16. Bahm J. Brachial plexus injuries in children. Nerves and Nerve Injuries: Elsevier; 2015. p. 315-29.
17. Verchere C, Durlacher K, Bellows D, Pike J, Bucevska M. An early shoulder repositioning program in birth-related brachial plexus injury: a pilot study of the Sup-ER protocol. Hand. 2014;9(2):187-95.
18. Bahm J. The surgical strategy to correct the rotational imbalance of the glenohumeral joint after brachial plexus birth injury. J Brachial Plex a Peripher Nerve Inj. 2016;11(01):e10-e7.
19. Schmitt C, Mehlman CT, Meiss AL. Hyphenated history: Erb-Duchenne brachial plexus palsy. Am J Orthop (Belle Mead NJ). 2008;37(7):356-8.
20. Katzenstein M. A child with Erb palsy depicted in art. Clin Pediatr (Philia). 1996;35(7):381-.
21. Yang LJ. Neonatal brachial plexus palsy--management and prognostic factors. Semin Perinatol. 2014;38(4):222-34.
22. van Dijk JG, Pondaag W, Malessy MJ. Obstetric lesions of the brachial plexus. Muscle Nerve. 2001;24(11):1451-61.
23. Metsaars W, Nagels J, Pijls B, Langenhoff J, Nelissen R. Treatment of supination deformity for obstetric brachial plexus injury: a systematic review and meta-analysis. J Hand Surg Am. 2014;39(10):1948-58. e2.
24. Bae DS, Ferretti M, Waters PM. Upper extremity size differences in brachial plexus birth palsy. Hand. 2008;3(4):297-303.
25. Hulleberg G, Elvrum A-KG, Brandal M, Vik T. Outcome in adolescence of brachial plexus birth palsy: 69 individuals re-examined after 10–20 years. Acta Orthop. 2014;85(6):633-40.
26. Pondaag W, Malessy MJA. Outcome assessment for Brachial Plexus birth injury. Results from the iPluto world-wide consensus survey. J Orthopaedic Res. 2018;36(9):2533-41.
27. Duff SV, DeMatteo C. Clinical assessment of the infant and child following perinatal brachial plexus injury. J Hand Ther. 2015;28(2):126-34.
28. Delioğlu K, Unes S, Tuncdemir M, Ozal C, Bıyık KS, Uzumcugil A. Interrater reliability of face-to-face, tele-and video-based assessments with the modified Mallet classification in brachial plexus birth injuries. J Hand Surg Eur Vol. 2023:17531934231196118.
29. Bae DS, Waters PM, Zurakowski D. Reliability of three classification systems measuring active motion in brachial plexus birth palsy. JBJS. 2003;85(9):1733-8.
30. Abzug JM, Chafetz RS, Gaughan JP, Ashworth S, Kozin SH. Shoulder function after medial approach and derotational humeral osteotomy in patients with brachial plexus birth palsy. J Pediatric Orthop. 2010;30(5):469-74.
31. Nath RK, Somasundaram C, Mahmooduddin F. Triangle tilt and steel osteotomy: similar approaches to common problems. Open Orthop J. 2011;5:124.
32. Nath RK, Karicherla P, Mahmooduddin F. Shoulder function and anatomy in complete obstetric brachial plexus palsy: long-term improvement after triangle tilt surgery. Childs Nerv Syst. 2010;26:1009-19.
33. Uzumcugil A, Delioğlu K, Yilmaz A, Serin A. The Pericoracoid Tissue Release in Children With Brachial Plexus Birth Injury. J Hand Surg. 11:S0363-5023(24)00488-X. 2024.
34. Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. Anesth Analg. 2018;126(5):1763-8.

35. Hoeksma AF, Wolf H, Oei SL. Obstetrical brachial plexus injuries: incidence, natural course and shoulder contracture. Clin Rehabil. 2000;14(5):523-6.

36. Waters PM, Smith GR, Jaramillo D. Glenohumeral deformity secondary to brachial plexus birth palsy. J Bone Joint Surg Am. 1998;80(5):668-77.

37. Delioğlu K, Uzumcugil A, Öztürk E, Bıyık KS, Ozal C, Gunel MK. Cut-off values of internal rotation in the glenohumeral joint for functional tasks in children with brachial plexus birth injury. J Hand Surg Eur Vol. 2023:17531934231154362.

38. Delioğlu K, Uzumcugil A, Öztürk E, Kerem Gunel M. Relative importance of factors affecting activity and upper extremity function in children with Narakas Group 2 brachial plexus birth palsy. J Hand Surg Eur Vol. 2021;46(3):239-46.

39. Sibinski M, Sherlock DA, Hems TE, Sharma H. Forearm rotational profile in obstetric brachial plexus injury. J Shoulder Elbow Surg. 2007;16(6):784-7.

40. Ho ES, Kim D, Klar K, Anthony A, Davidge K, Borschel GH, et al. Prevalence and etiology of elbow flexion contractures in brachial plexus birth injury: a scoping review. J Pediatr Rehabil Med. 2019;12(1):75-86.