Neonatal brachial plexus palsy : impact throughout the lifespan

Holst, M. van der

NEONATAL BRACHIAL PLEXUS PALSY

impact throughout the lifespan

MENNO VAN DER HOLST

Neonatal brachial plexus palsy - impact throughout the lifespan

ISBN: 978-94-6295-777-0

Photography: Menno van der Holst
Illustrations: Margo van Os - van der Holst
Design & Lay-out: wenz iD | Wendy Schoneveld
Printed by: Proefschriftmaken | Proefschriftmaken.nl

The printing of this thesis was financially supported by the Scientific College Physical Therapy (WCF) of the Royal Dutch Society for Physical Therapy (KNGF), Boehringer Ingelheim BV, Rijnlands Rehabilitation Center (RRC), Anna Fonds | NOREF Leiden

NEONATAL BRACHIAL PLEXUS PALSY

impact throughout the lifespan

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden
op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker
volgens besluit van het College voor Promoties
te verdedigen op woensdag 20 december 2017
klokke 16.15 uur

door

Menno van der Holst

geboren te Balkbrug, Avereest
in 1980

Promotores prof. dr. T.P.M. Vliet Vlieland
prof. dr. R.G.H.H. Nelissen
Co-promotor dr. D. Steenbeek

Proefschriftcommissie
prof. dr. J.J.G.M. Verschuuren
prof. dr. M.J.A. Malessy
prof. dr. A.C.H. Geurts, Afdeling revalidatiegeneeskunde Radboud Universitair Medisch Centrum, Nijmegen
dr. P. Aarts, Afdeling kinderrevalidatie, Sint Maartenskliniek, Nijmegen
dr. J.A. van der Sluijs, Afdeling Orthopaedie, Vrije Universiteit Medisch Centrum, Amsterdam

Things don't have to change the world to be important

Steve Jobs, Wired 1996

Content of thesis

CHAPTER ONE

General introduction

DEFINITION AND CLASSIFICATION

Neonatal brachial plexus palsy (NBPP) is a traction injury to the brachial plexus sustained during birth. Worldwide reported incidences vary per country and per study and range from 0.1 per 1000 live births to 8.1 per 1000 live births.[1] Risk factors for NBPP have been studied widely and it is well known that especially shoulder dystocia (i.e. the baby's shoulder is obstructed by the maternal pelvis) resulting from higher birth weight (>4000 gram) is related to the occurrence of NBPP; and to a lesser degree, multiparous pregnancies, prolonged labour, breech delivery and/or any otherwise difficult delivery.[2,3] Specific manoeuvres and strategies have been developed to address the management of shoulder dystocia, which have been shown to decrease the occurrence of NBPP.[4] Prevalence of NBPP seems to be higher in some western European countries, including the Netherlands (1-2/1000), compared to other regions, such as Finland (1/1000) and the United Kingdom (0.4/1000).[1,5-8]

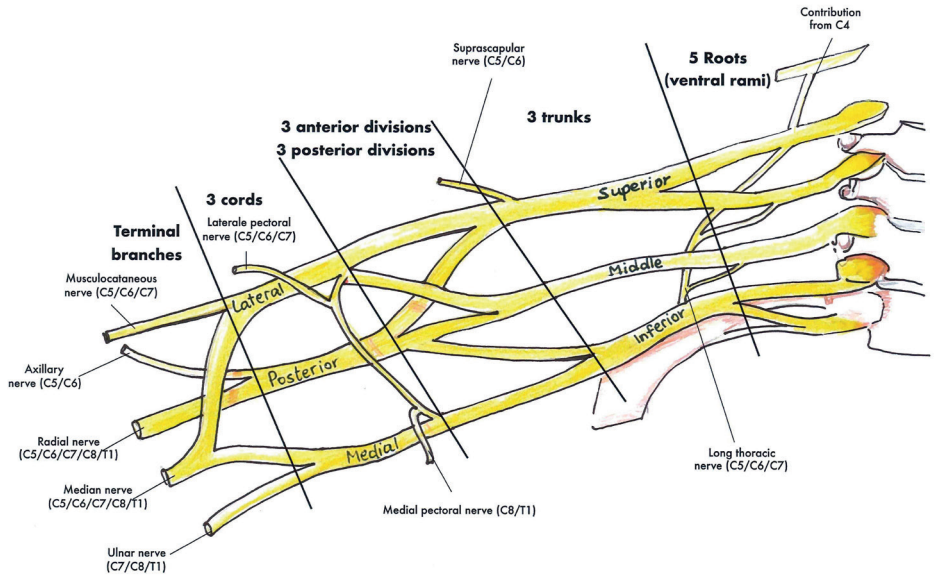

Figure 1 Anatomical representation of the Brachial Plexus

The brachial plexus is formed by the spinal rootlets of the 5th cervical to the 1st thoracic root, which fuse to the superior, the middle and the inferior trunk which in turn branch into 3 anterior divisions and 3 posterior divisions. This results in the formation of the lateral, the posterior and the medial cords which end in the terminal branches: the peripheral nerves of the arm and hand (i.e. Musculocutaneous nerve, Axillary nerve, Radial nerve, Median nerve and Ulnar nerve).

With respect to the extent of the nerve injury in NBPP, Algimantas Narakas proposed a classification based on the level(s) of nerve injury at early presentation, i.e. when infants are 2-3 weeks old.[9,10] This classification distinguishes 4 levels (I-IV): I Upper Erb's palsy (rootlets C5-C6), II Extended Erb's palsy (rootlets C5-C6 and C7), III Total plexus palsy (rootlets C5-T1) and IV Total plexus palsy (rootlets C5-T1) with Horner's syndrome (ipsilateral miosis and ptosis).[9] Erb's palsies (C5-C6) are the most common form of NBPP injuries, total lesions (C5-T1) comprise around 15%, and isolated lower plexus palsies (Klumpke's palsy C8-T1) are very rare.[11-13]

A severity classification of peripheral nerve injuries in general (including NBPP) has been described by Seddon in 1943, which was refined later by Sunderland.[14,15] *Neurapraxia* is the least severe injury: temporary function loss without structural nerve damage. In case of *Axonotmesis* the nerve fibers (axons) are ruptured but the surrounding structures (endoneurial tubes, perineurium) remain intact. Outgrow of axons (estimated at 1 millimetre per day) will lead to spontaneous recovery in the course of months. In *Neurotmesis* the integrity of both the axon and surrounding structures are lost, and spontaneous recovery will not occur. Another type of injury is *Avulsion* of the nerve rootlets from the spinal cord (pre-ganglionic tear); spontaneous recovery will not occur.[16,17]

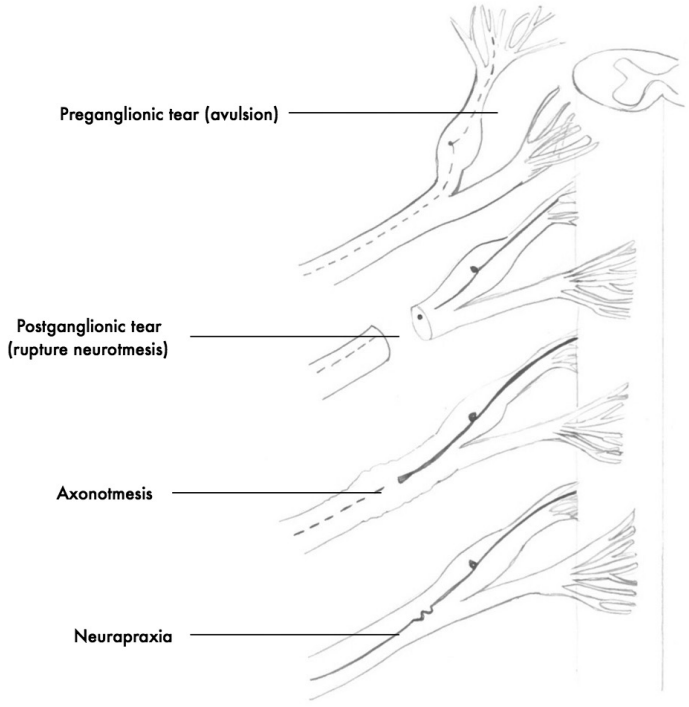

Figure 2 Severity of peripheral nerve injuries
From top to bottom: Avulsion, Neurotmesis, Axonotmesis and Neurapraxia

The natural history of NBPP has been studied by different authors but recovery rates vary greatly due to methodological differences among these papers.[1,2,13,18,19] A systematic review concluded that rates for incomplete spontaneous recovery probably range between 20% and 30%.[13] In infants who do not show spontaneous recovery, the underlying nerve lesion constitutes of neurotmesis or root avulsion, which necessitates early nerve surgery.[13] Usually different forms of injuries within the brachial plexus elements are present in a single patient, which makes comparisons between patients difficult due to heterogeneity.[2,13]

TREATMENT OF NBPP

Early nerve surgery, or 'primary surgery', is indicated in those children with NBPP who show no, or limited, recovery of arm function over time. There is no generally accepted consensus on how to select infants for nerve surgery.[20] Many treating physicians agree that a total brachial plexus lesion is indicative for nerve surgery at an early age.[18,21,22] The oldest 'rule' was provided by Alain Gilbert, who employs absence of biceps recovery at the age of three months as indication for nerve reconstruction.[23] Howard Clarke employs a more stepwise approach with different indicators at different ages.[24]
At the Leiden University Medical Center (LUMC) in The Netherlands, we endeavour early surgery, i.e. complete lesions at three months of age, and incomplete lesions between 3 and 6 months, mainly based on absence of elbow flexion recovery.[25] Ancillary investigations, specifically needle electromyography at the age of 1 month, aid in early identification of severe nerve lesions.[26] Depending on the nature of the nerve lesion, different surgical modalities may be indicated. These include nerve grafting after excision of the neuroma, nerve transfers (e.g. intercostal nerves to musculocutaneous nerves) or a combination of techniques.[22,27-29]
A prospective randomized trial does not exist to answer the question for the indication for early nerve surgery.[30] Meta-analysis of the available literature has been performed with varying outcome.[18,22] These attempts were seriously hampered by different outcome measures used and bias by indication, which makes pooling of data from different studies virtually impossible.[31]

The LUMC is one of the three NBPP expert centers in the Netherlands. Early referral to one of these centers is very important to be able to decide whether nerve surgery treatment as described above is needed.[32] At the LUMC, 1142 patients with NBPP have been evaluated and/or treated until January 2015. Of these 1142 patients, 534 underwent primary (nerve) surgery.

When conservative treatment or primary nerve surgery does not lead to satisfactory function recovery, and limitations in using the affected upper extremity persist, a secondary surgical procedure may be indicated.[2] Persisting functional limitations can be related to the shoulder, the elbow and/or the hand/wrist with close interaction between these joints and whole body

function thus determining functionality for a specific patient as such. In the LUMC, 257 secondary surgical procedures were performed (up to January 2015) consisting of 166 procedures around the shoulder, 29 around the elbow and 62 around the hand/wrist.
Most secondary surgical procedures are performed about the shoulder since decreased active shoulder external rotation range of motion (ROM) (i.e. enabling hand to mouth and hand to head movements) is the most common remaining functional deficit in NBPP. These functional deficits originate from muscle imbalance with subsequent soft tissue and joint contractures resulting in glenohumeral joint deformity.[2,33-35]
To address limited external rotation, various treatments can be performed: botulinum toxin injections in contracted muscles, surgical contracture releases, muscle lengthening, muscle tendon transfers or osteotomies.[34,36-40] Muscle tendon transfers and internal contracture releases around the shoulder are widely used and widely studied.[41] Most studies, however, were mainly focused on ROM and Mallet scores (Mallet scale: instrument measuring general shoulder movements[42]) and did not measure patient or parent satisfaction, functional outcome or quality of life (QoL). Furthermore, most studies were not controlled and could easily be biased by the co-interventions like prior surgical treatment, nerve surgery, and conservative interventions. Also, most studies did not report the clinical course over time.
Regarding the elbow, possible procedures could be pronation osteotomies, possibly in combination with m. biceps tendon rerouting or a release of the membrana interossea to obtain a more functional position of the arm.[43,44] To create some active elbow flexion in case of a complete paralysis of the flexors, a so-called Steindler procedure (flexor pronator group transfer) can be performed, due to which the elbow can be flexed by the normally innervated wrist flexors.[45,46] Surgical options for correction of elbow flexion contractures exist, but give residual flexion contractures of up to 30 degrees. An open release is preferred by our group due to the complications (i.e. additional nerve injuries) seen with arthroscopic releases of the elbow.
To obtain a more functional hand, a variety of muscle tendon transfers remain, usually to improve active wrist extension, thumb extension and /or finger extension.[44,47,48]

Irrespective of treatment choices (e.g. conservative, primary and/or secondary surgery), pediatric physical therapy is important in the management of NBPP.[49] The physical therapist monitors motor performance, joint mobility and muscle strength over time, but more importantly instructs the parents on how to handle (e.g. carry, pick up and clothe) their baby and how to perform exercises to maintain passive ROM. In The Netherlands, physical therapy may start hospital based, always followed by home-based therapy, or starts home based within 7-10 days after birth.[49,50] This home-based therapy is usually guided and monitored by a pediatric physical therapist working in primary care. From the start, passive ROM exercises should be performed for shoulder abduction, forward flexion, internal and external rotation; elbow flexion and extension; wrist extension, pronation and supination; as well as finger flexion, extension and thumb opposition and reposition. These exercises are important in order to maintain passive mobility for future active movement to be unrestrained.[49,51]

Depending on neurological recovery these passive ROM exercises are continued at least until a better prognosis can be predicted. In growing infants glenohumeral joint movement exercises have been described in order to prevent joint and muscle contractures and to normalise shoulder movements.[50,52,53] Contracture prevention can also be supported by applying serial casting, orthoses, dynamic splints or botulinum toxin.[40,54,55] Further treatment should consist of monitoring and improving motor development and motor function. Physical therapy is continued over time depending on treatment history and recovery and a functional, tailored to the individual, therapy program should be applied in combination with home exercises to maintain and/or improve functional abilities. Constraint induced movement therapy, and possibly bimanual intensive training, have also been suggested and described to improve function.[52,56] However, these interventions are not systematically studied and their added value to rehabilitation programs remains to be proven.

CONSEQUENCES OF NBPP IN RELATION TO THE INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY AND HEALTH

NBPP may have functional consequences throughout life.[19,57-71] Depending on initial neurological damage and damage extent, functional recovery and treatment, these consequences may vary from minor to very severe. At different stages of the child's life (from infant to toddler, to preschool age, to grade school age, to adolescence) and even in adulthood NBPP may have its consequences and might influence choices in life (school, education, profession, work etc.). The interaction between the health problem (NBPP) and its consequences in various health related components (body functions and body structures, activities, participation and environmental and personal factors) is represented in the International Classification of Functioning, Disability and Health model (ICF).[72] The ICF was originally accepted in 2001 and a children and youth version, emphasizing the influence of personal factors and environmental factors on the health problem (e.g. the role of parents, family, school, individual background etc.) was derived from the original ICF Model (ICF-CY).[72] As of 2012 the additional components of the ICF-CY (i.e. personal factors and environmental factors) were merged into the ICF creating one model to classify functioning, disability and health throughout the lifespan.[72]
Figure 3 shows an example of the ICF model in relation to a possible problem due to NBPP.

In Table I the most common consequences of NBPP are presented in relation to the ICF model.[66] As can be seen in Table I, NBPP has impact on various components of the ICF. Although the relation between the ICF components and quality of life (QoL) is complex and depends for example on life expectations, it is likely that the condition also affects QoL. In children with NBPP, a decreased QoL and limited upper extremity functioning (UEF) compared to their healthy peers has been reported for children older than 2 years.[73-75]
In addition, NBPP may also have impact on family and parental QoL. Throughout the child's life parents may be worried what the future for their child will bring and what consequences

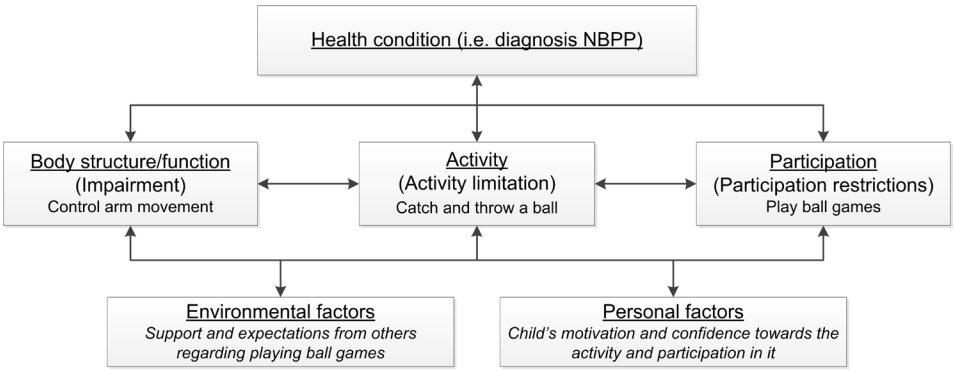

Figure 3 ICF model in relation to possible NBPP problems (impaired control of arm movement)
Model based on the ICF model of the World Health Organisation (WHO).[72]

NBPP will have on the QoL of their child. Age does not seem to have an effect on the family impact but having a younger child with NBPP (age 0-2 years) has greater impact on maternal QoL.[76,77] Parents of children with NBPP, aged 0-18 years, feel that the condition of their child has impact on the family in terms of finances, personal strain, social and mastery problems. Furthermore, parents have an increased risk of psychological problems, distress and a lower QoL. Condition severity is significantly associated with these problems.[58,75-79] How upper extremity functioning (i.e. performing daily activities) and perceived QoL in children under 2.5 years of age are associated to family impact as a whole was not yet known.

THE LONGER-TERM CONSEQUENCES OF NBPP IN ADOLESCENTS AND ADULTS

Only a few studies investigated NBPP in adolescents and (young) adults. Daily functioning (e.g. dressing, washing) in young adults with NBPP has been described as limited, in the majority of patients due to pain.[69,80] Physical problems related to NBPP during normal activities such as cycling and swimming also have been reported. However, only a small proportion of the patients reporting these problems seem to be unable to participate in these activities.[81]

Little was known about the impact of NBPP on patient-perceived participation in society in adult life. There were no studies available focusing on this domain of the ICF and therefore it was unclear to what extent patients experience restrictions in education, work, leisure, sports and/or social activities. Moreover, prior to the current thesis it was unknown whether NBPP has any influence on choice of education and/or work.

Table I Possible consequences of NBPP summarized in relation to the ICF model as derived from focus group research.[66]

Body structures	Body functions	Activities	Participation
• Nerve damage • Muscle atrophy • Muscle stiffness • Joint capsule shortening / stiffening • Connective tissue shortening/ stiffening • Bony deformities • Skin scar tissue	• Decreased muscle force • Decreased muscle endurance • Joint instability • Impaired joint mobility • Gross motor function impairment • Fine motor function impairment • Sensory loss • Pain • Altered body image	Impaired ability to: • Reach • Grasp • Throw • Catch • Push • Pull • Manipulate in hand • Write • Lift objects • Carry objects • Climb • Swim • Perform gross motor activities • Perform fine motor activities • Care for oneself (hair, skin, teeth, nails etc. put on/take off clothes etc, eating/drinking etc.) • Clean • Store daily necessities	Problems in: • Child-parent relationships • Physical activity • Sports • Playing (with Peers) • Hobbies • School • Seeking employment • Work
Environmental factors		**Personal factors**	
• Parents • Siblings • Family • School • External expectations • Assistive devices • Health professionals • Strangers • Domestic animals • Support and relationships • Attitude of 3rd persons • Health services • Education and training services		• Age • Gender • Race • Personal/social experiences • Preferences • Internal expectations	

COMPREHENSIVE ASSESSMENT OF THE CONSEQUENCES OF NBPP

Assessing and monitoring consequences of NBPP on all ICF components is important to understand the progress of NBPP throughout life, to prove efficacy of (new) treatment and to evaluate outcome of (surgical) interventions. In NBPP research, multiple outcome instruments were used, but no consensus exists on which instruments to use.[82] Moreover, only few outcome measures were validated for use in NBPP and a large proportion of the chosen instruments were only used in one or two studies. Often self-developed questionnaires were used without reporting on these instruments' psychometric properties.[82-85] The most common used outcome measures were mainly based on measuring bodily functions (e.g. active ROM, muscle strength) and bodily structures (e.g. passive ROM, muscle length) but seldom on activity and participation levels, which determines functionality as such. Rarely environmental and personal factors were taken into account.[82] Although improving participation throughout life is in the end the main goal of most interventions, it was almost never measured in clinical studies. Furthermore, not many studies assessed patient (or parent) expectations and satisfaction and/or cosmetic consequences of NBPP treatment.[82-85] Table II gives an overview of outcome measures used in NBPP research. It includes the Pediatric Outcome Data Collecting Instrument (PODCI), a well-known instrument regarding QoL measuring aspects across the ICF domains. It assesses different aspects of daily living, overall health and pain in children and adolescents with musculoskeletal disorders.[86] The PODCI is reliable, validated, suitable and tested for children and adolescents (2-18 years old) with Musculoskeletal disorders, including NBPP.[87-90] A Dutch version of this instrument was prior to this thesis not available. As can also be seen in Table II not many instruments were available for arm and hand function, especially not measuring parent reported spontaneous use in daily life.[85] Although the impact of NBPP on family has been described using multiple outcome instruments[75,76,79], these instruments were not mentioned in the systematic reviews regarding outcome measures in NBPP.[82-85]

Despite the comprehensive amount of literature on NBPP and the available outcome measures, not all aspects of NBPP have been researched and there is a lack of well validated outcome measures for NBPP.
For example, healthcare use in children with NBPP and factors which influence this, both in the short and long term, and in regard to whether they are currently in follow-up or not had not been researched. It is important to understand to what extent children with NBPP use care and which patient characteristics, QoL and physical functioning parameters influence this healthcare use. Furthermore, it remains unclear whether patients (or their parents/caregivers) have unmet information needs. This is important to investigate given that clinical, shared, decision making in NBPP is influenced by given or sought information.[91]
To fully understand outcome of NBPP, it is important to take into account all aspects of NBPP including family impact, perceived and/or reported QoL, participation, healthcare use, information need as well as upper extremity functioning (including hand use at home) to be able to understand the consequences of NBPP on life. When the consequences of NBPP on life are better understood, healthcare professionals are more able to support parents and/or patients throughout the NBPP treatment phase and possibly beyond.

Table II Overview of (more) often used outcome measures in NBPP research subdivided in ICF domains. Outcome measures extracted from 4 systematic reviews containing instruments used in NBPP research until 2015.[82-85]

Body structures	**Instrument**	**Type of instrument**	**Region**
ROM (passive/active)	• Goniometer (Degrees)	Device	• Shoulder/Elbow/Wrist/Hand
ROM indexes	• Mallet scale • Gilbert scale • Active movement scale • Toronto test score	Physical examination index	• Shoulder/Elbow • Shoulder/Elbow • Shoulder/Elbow/Wrist/Hand • Elbow/Wrist/hand
Imaging	• MRI • CT • X-ray • Ultrasound	Medical device	• Shoulder/Elbow/Wrist/Hand
Body Functions	**Instrument**	**Type of instrument**	**Region**
Muscle strength indexes	• Medical Research Council • Narakas • Raimondi scale • Gilbert Raimondi scale • Al-Qattan classification • Hand strength (grip)	Physical examination index	• Shoulder/Elbow/Wrist/Hand • Shoulder/Elbow/Wrist/Hand • Wrist/Hand • Elbow • Shoulder/Elbow/Wrist/Hand • Hand
Muscle strength	• Hand Held Dynamometry	Device	• Shoulder/Elbow/Wrist/hand
Functional test	• Towel test • Cookie-test • Nine hole peg test • Pick up test	Physical examination	• Shoulder/Elbow/Wrist/Hand • Elbow • Hand • Shoulder/Elbow/Wrist/Hand
Nerve function	• EMG	Medical device	• Shoulder/Elbow/Wrist/Hand
Nerve function (sensation)	• Semmes Weinstein test • 2 Point Discrimination test • Stereognosis	Physical examination index	• Hand • Shoulder/Elbow/Wrist/Hand • Hand
Activities and Participation	**Instrument**	**Type of instrument**	**Measuring goal/Region**
	• CAPE • ABILHAND (KIDS) • CHEQ • DASH • SF-36	PROM	• Participation/Whole body • Activity/ Shoulder/Elbow/Wrist/Hand • Activity/Hand • Activity/ Shoulder/Elbow/Wrist/Hand • Activity/Participation/Whole body
	• BPOM • AHA	Functional activity assessment	• Activity/ Shoulder/Elbow/Wrist/Hand • Activity/ Shoulder/Elbow/Wrist/Hand

Activities and Participation (incl. Environmental factors)	Instrument	Type of instrument	Measuring goal/Region
	• PODCI	PROM	• Activity/Participation/ Whole body with specific Upper extremity part
	• PEDI	PROM via interview	• Actvity/Participation/ Whole body

ROM: Range of Motion, MRI: Magnetic Resonance Imaging, CT: Computer Tomography, EMG: Electromyography, PROM: Patient Reported Outcome Measure, CAPE: Children's Assessment of Participation and Enjoyment, CHEQ: Children's Hand use Experience Questionnaire, DASH: Disability of the Arm, Shoulder and Hand, SF-36: Short Form 36, BPOM: Brachial Plexus Outcome Measure, AHA: Assisting Hand Assessment, PODCI: Pediatric Outcome Data Collecting Instrument.

OUTLINE OF THIS THESIS

Given the lack of knowledge and available outcome measures the aims of this thesis are:

I. Evaluation of functional outcome of secondary surgery around the shoulder (internal rotation contracture release and external rotation tendon transfers) in the short term and the long term with emphasis on pre-operative nerve surgery.
II. Translation, cross cultural adaptation and evaluation of an outcome measure to evaluate physical functioning and QoL and evaluation of an instrument measuring spontaneous hand use at home.
III. Comprehensive description of the impact of NBPP on the family, on QoL, on Healthcare use and Information need and on participation in adolescents/adults and/or children with NBPP (all part of the ZAP Plexus study: Zorg (Care), Activities and Participation in patients with NBPP).

Chapter 2 describes the short term functional outcomes, including QoL and parental satisfaction, of an internal rotation contracture release and muscle tendon transfers of the mm. Latissimus Dorsi and Teres Major for external shoulder rotation.
Chapter 3 describes the long-term outcomes of internal contracture releases and/or muscle tendon transfers around the shoulder for children with and without a history of nerve surgery.
Chapter 4 exemplifies the cross-cultural translation and adaptation of a well-known musculoskeletal QoL questionnaire, the PODCI, into Dutch. This translated version of the PODCI was used in the ZAP Plexus study as QoL instrument but also as reference instrument for validation of the Hand Use at Home questionnaire (HUH) in children with NBPP.
Chapter 5 illustrates the construct validity and test-retest reliability of the newly developed HUH in children with NBPP or unilateral cerebral palsy (UCP) aged 3-10 years old.

Chapters **6, 7 and 8** are part of the ZAP Plexus study in which age specific outcome measures were used to investigate the impact of NBPP on the family, on QoL, on Healthcare use and Information need and on participation in adolescents/adults and/or children with NBPP. An overview of the used outcome measures is provided in Appendix I.

Chapter 6 reports the parent-perceived family impact, QoL and upper extremity functioning in children with NBPP aged 0-2.5 years old.
Chapter 7 specifies healthcare use and information needs in (parents of) 0-18-year-old children with NBPP.
Chapter 8 describes restrictions in participation, and QoL, but also influence of NBPP on (choice of) education and work in adolescents and adults with NBPP.
Chapter 9 Summary and general discussion
Chapter 10 Summary of this Thesis in the Dutch language.

REFERENCES

1. Chauhan S. P., Blackwell S. B., Ananth C. V. Neonatal brachial plexus palsy: incidence, prevalence, and temporal trends. *Seminars in perinatology.* 2014;38(4):210-218.
2. Hale H.B., Bae D.S., Waters P.M. Current concepts in the management of brachial plexus birth palsy. *J.Hand Surg.Am.* 2010;35(2):322-331.
3. Hoeksma A.F., Wolf H., Oei S.L. Obstetrical brachial plexus injuries: incidence, natural course and shoulder contracture. *Clin.Rehabil.* 2000;14(5):523-526.
4. Crofts J. F., Lenguerrand E., Bentham G. L., et al. Prevention of brachial plexus injury-12 years of shoulder dystocia training: an interrupted time-series study. *BJOG.* 2016;123(1):111-118.
5. Evans-Jones G., Kay S.P., Weindling A.M., et al. Congenital brachial palsy: incidence, causes, and outcome in the United Kingdom and Republic of Ireland. *Arch.Dis.Child Fetal Neonatal Ed.* 2003;88(3):F185-F189.
6. Kallianidis A. F., Smit M., Van Roosmalen J. Shoulder dystocia in primary midwifery care in the Netherlands. *Acta Obstet Gynecol Scand.* 2016;95(2):203-209.
7. Pondaag W., van Dijk J. G., Nelissen R. G., Malessy M. J. [Obstetric brachial plexus injury]. *Nederlands tijdschrift voor geneeskunde.* 2014;158:A7145.
8. Kirjavainen M., Remes V., Peltonen J., et al. Long-term results of surgery for brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2007;89(1):18-26.
9. A. Narakas. *The paralyzed hand.* Edinburgh: Churchill Livingstone; 1987.
10. Taleb C., Nectoux E., Awada T., Liverneaux P. The destiny of an ace: Algimantas Otanas Narakas (1927-1993). *J Brachial Plex Peripher Nerve Inj.* 2013;8(1):6.
11. al-Qattan M. M., Clarke H. M., Curtis C. G. Klumpke's birth palsy. Does it really exist? *Journal of hand surgery.* 1995;20(1):19-23.
12. Kay S. P. Obstetrical brachial palsy. *Br J Plast Surg.* 1998;51(1):43-50.
13. Pondaag W., Malessy M.J., van Dijk J.G., Thomeer R.T. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev.Med.Child Neurol.* 2004;46(2):138-144.
14. Seddon H. J. A Classification of Nerve Injuries. *Br Med J.* 1942;2(4260):237-239.
15. Sunderland S. A classification of peripheral nerve injuries producing loss of function. *Brain.* 1951;74(4):491-516.
16. Sunderland S. Mechanisms of cervical nerve root avulsion in injuries of the neck and shoulder. *J Neurosurg.* 1974;41(6):705-714.
17. Hems T. E., Birch R., Carlstedt T. The role of magnetic resonance imaging in the management of traction injuries to the adult brachial plexus. *Journal of hand surgery.* 1999;24(5):550-555.
18. Bain J. R., Dematteo C., Gjertsen D., Hollenberg R. D. Navigating the gray zone: a guideline for surgical decision making in obstetrical brachial plexus injuries. *J Neurosurg Pediatr.* 2009;3(3):173-180.
19. Foad S.L., Mehlman C.T., Foad M.B., Lippert W.C. Prognosis following neonatal brachial plexus palsy: an evidence-based review. *J.Child Orthop.* 2009;3(6):459-463.
20. Pondaag W., Malessy M.J. The evidence for nerve repair in obstetric brachial plexus palsy revisited. *Biomed.Res.Int.* 2014;2014:434619.
21. Bialocerkowski A., Gelding B. Lack of evidence of the effectiveness of primary brachial plexus surgery for infants (under the age of two years) diagnosed with obstetric brachial plexus palsy. *Int J Evid Based Healthc.* 2006;4(4):264-287.
22. Coroneos C. J., Voineskos S. H., Coroneos M. K., et al. Primary Nerve Repair for Obstetrical Brachial Plexus Injury: A Meta-Analysis. *Plast Reconstr Surg.* 2015;136(4):765-779.
23. Gilbert A., Tassin J. L. [Surgical repair of the brachial plexus in obstetric paralysis]. *Chirurgie.* 1984;110(1):70-75.
24. Bade S. A., Lin J. C., Curtis C. G., Clarke H. M. Extending the indications for primary nerve surgery in obstetrical brachial plexus palsy. *Biomed Res Int.* 2014;2014:627067.
25. Malessy M.J., Pondaag W. Obstetric brachial plexus injuries. *Neurosurg.Clin.N.Am.* 2009;20(1):1-14.
26. Van Dijk J. G., Pondaag W., Buitenhuis S. M., Van Zwet E. W., Malessy M. J. Needle electromyography at 1 month predicts paralysis of elbow flexion at 3 months in obstetric brachial plexus lesions. *Dev Med Child Neurol.* 2012;54(8):753-758.
27. Bialocerkowski A., Kurlowicz K., Vladusic S., Grimmer K. Effectiveness of primary conservative management for infants with obstetric brachial plexus palsy. *Int J Evid Based Healthc.* 2005;3(2):27-44.
28. Tse R., Kozin S. H., Malessy M. J., Clarke H. M. International Federation of Societies for Surgery of the Hand Committee Report: The Role of Nerve Transfers in the Treatment of Neonatal Brachial Plexus Palsy. *The Journal of hand surgery.* 2015;40(6):1246-1259.
29. Malessy M. J., Pondaag W. Neonatal brachial plexus palsy with neurotmesis of C5 and avulsion of C6: supraclavicular reconstruction strategies and outcome. *The Journal of bone and joint surgery. American volume.* 2014;96(20):e174.
30. Bodensteiner J. B., Rich K. M., Landau W. M. Early infantile surgery for birth-related brachial plexus injuries: justification requires a prospective controlled study. *J Child Neurol.* 1994;9(2):109-110.

31. Pondaag W., Malessy M. J. Letters to the Editor: neonatal brachial plexus palsy. *J Neurosurg Pediatr.* 2014;14(5):555-557.
32. Malessy M. J., Pondaag W., Yang L. J., Hofstede-Buitenhuis S. M., le Cessie S., van Dijk J. G. Severe obstetric brachial plexus palsies can be identified at one month of age. *PLoS One.* 2011;6(10):e26193.
33. Hogendoorn S., van Overvest K.L., Watt I., Duijsens A.H., Nelissen R.G. Structural changes in muscle and glenohumeral joint deformity in neonatal brachial plexus palsy. *J.Bone Joint Surg. Am.* 2010;92(4):935-942.
34. Waters P.M. Management of shoulder deformities in brachial plexus birth palsies. *Journal of Pediatric Orthopaedics.* 2010;30(SUPPL. 2):S53-S56.
35. Waters P.M., Smith G.R., Jaramillo D. Glenohumeral deformity secondary to brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 1998;80(5):668-677.
36. Waters P.M. Update on management of pediatric brachial plexus palsy. *J.Pediatr.Orthop.B.* 2005;14(4):233-244.
37. Waters P.M., Bae D.S. Effect of tendon transfers and extra-articular soft-tissue balancing on glenohumeral development in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2005;87(2):320-325.
38. Waters P.M., Bae D.S. The early effects of tendon transfers and open capsulorrhaphy on glenohumeral deformity in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2008;90(10):2171-2179.
39. Waters P.M., Monica J.T., Earp B.E., Zurakowski D., Bae D.S. Correlation of radiographic muscle cross-sectional area with glenohumeral deformity in children with brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2009;91(10):2367-2375.
40. Duijnisveld B. J., Steenbeek D., Nelissen R. G. Serial casting for elbow flexion contractures in neonatal brachial plexus palsy. *J Pediatr Rehabil Med.* 2016;9(3):207-214.
41. Louden E.J., Broering C.A., Mehlman C.T., Lippert W.C., Pratt J., King E.C. Meta-analysis of function after secondary shoulder surgery in neonatal brachial plexus palsy. *J.Pediatr.Orthop.* 2013;33(6):656-663.
42. van der Sluijs J.A., van Doorn-Loogman M.H., Ritt M.J., Wuisman P.I. Interobserver reliability of the Mallet score. *J.Pediatr.Orthop.B.* 2006;15(5):324-327.
43. Metsaars W. P., Nagels J., Pijls B. G., Langenhoff J. M., Nelissen R. G. Treatment of supination deformity for obstetric brachial plexus injury: a systematic review and meta-analysis. *The Journal of hand surgery.* 2014;39(10):1948-1958 e1942.
44. Sebastin S. J., Chung K. C. Pathogenesis and management of deformities of the elbow, wrist, and hand in late neonatal brachial plexus palsy. *J Pediatr Rehabil Med.* 2011;4(2):119-130.
45. Al-Qattan M. M. Elbow flexion reconstruction by Steindler flexorplasty in obstetric brachial plexus palsy. *Journal of hand surgery.* 2005;30(4):424-427.
46. van Egmond C., Tonino A. J., Kortleve J. W. Steindler flexorplasty of the elbow in obstetric brachial plexus injuries. *J Pediatr Orthop.* 2001;21(2):169-173.
47. van Alphen N. A., van Doorn-Loogman M. H., Maas H., van der Sluijs J. A., Ritt M. J. Restoring wrist extension in obstetric palsy of the brachial plexus by transferring wrist flexors to wrist extensors. *J Pediatr Rehabil Med.* 2013;6(1):53-57.
48. Ruchelsman D. E., Ramos L. E., Price A. E., Grossman L. A., Valencia H., Grossman J. A. Outcome after tendon transfers to restore wrist extension in children with brachial plexus birth injuries. *J Pediatr Orthop.* 2011;31(4):455-457.
49. I Bosga-Stork, V Schaaf. Perifeer-neurologische aandoeningen, het obstetrisch plexus brachialis letsel. In: R van Empelen RN-vdS, A Hartman, ed. *Kinderfysiotherapie*. 3 ed. Amsterdam: Reed Business Education; 2103:553-571.
50. Smania N., Berto G., La Marchina E., et al. Rehabilitation of brachial plexus injuries in adults and children. *Eur J Phys Rehabil Med.* 2012;48(3):483-506.
51. Schaaf VAM, Buitenhuis SM. Wetenschapsloket: Acute plexus letsels. *Nederlands tijdschrift voor kinderfysiotherapie.* 2009;21(59):24-27.
52. Ramos L. E., Zell J. P. Rehabilitation program for children with brachial plexus and peripheral nerve injury. *Semin Pediatr Neurol.* 2000;7(1):52-57.
53. Price A., Tidwell M., Grossman J.A. Improving shoulder and elbow function in children with Erb's palsy. *Semin.Pediatr.Neurol.* 2000;7(1):44-51.
54. Michaud L. J., Louden E. J., Lippert W. C., Allgier A. J., Foad S. L., Mehlman C. T. Use of botulinum toxin type A in the management of neonatal brachial plexus palsy. *PM & R : the journal of injury, function, and rehabilitation.* 2014;6(12):1107-1119.
55. Durlacher K. M., Bellows D., Verchere C. Sup-ER orthosis: an innovative treatment for infants with birth related brachial plexus injury. *J Hand Ther.* 2014;27(4):335-339; quiz 340.
56. Berggren J., Baker L. L. Therapeutic application of electrical stimulation and constraint induced movement therapy in perinatal brachial plexus injury: A case report. *J Hand Ther.* 2015;28(2):217-220; quiz 221.
57. Bae D. S., Zurakowski D., Avallone N., Yu R., Waters P. M. Sports participation in selected

children with brachial plexus birth palsy. *J Pediatr Orthop.* 2009;29(5):496-503.
58. Beck C. T. The arm: there is no escaping the reality for mothers of children with obstetric brachial plexus injuries. *Nursing research.* 2009;58(4):237-245.
59. de Heer C., Beckerman H., Groot V. D. Explaining daily functioning in young adults with obstetric brachial plexus lesion. *Disabil Rehabil.* 2014:1-7.
60. Strombeck C., Fernell E. Aspects of activities and participation in daily life related to body structure and function in adolescents with obstetrical brachial plexus palsy: a descriptive follow-up study. *Acta Paediatr.* 2003;92(6):740-746.
61. Strombeck C., Krumlinde-Sundholm L., Forssberg H. Functional outcome at 5 years in children with obstetrical brachial plexus palsy with and without microsurgical reconstruction. *Dev.Med.Child Neurol.* 2000;42(3):148-157.
62. 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.
63. Bellew M., Kay S. P., Webb F., Ward A. Developmental and behavioural outcome in obstetric brachial plexus palsy. *Journal of hand surgery.* 2000;25(1):49-51.
64. Boylan L. S., Fouladvand M. Developmental apraxia arising from neonatal brachial plexus palsy. *Neurology.* 2001;56(4):576-577.
65. Brown T., Cupido C., Scarfone H., Pape K., Galea V., McComas A. Developmental apraxia arising from neonatal brachial plexus palsy. *Neurology.* 2000;55(1):24-30.
66. Sarac C., Bastiaansen E., Van der Holst M., Malessy M.J., Nelissen R.G., Vliet Vlieland T.P. Concepts of functioning and health important to children with an obstetric brachial plexus injury: a qualitative study using focus groups. *Dev.Med. Child Neurol.* 2013;55(12):1136-1142.
67. Ho E. S., Curtis C. G., Clarke H. M. Pain in children following microsurgical reconstruction for obstetrical brachial plexus palsy. *The Journal of hand surgery.* 2015;40(6):1177-1183.
68. Hulleberg G., Elvrum A.K., Brandal M., Vik T. Outcome in adolescence of brachial plexus birth palsy. *Acta Orthop.* 2014:1-8.
69. Partridge C., Edwards S. Obstetric brachial plexus palsy: increasing disability and exacerbation of symptoms with age. *Physiotherapy research international : the journal for researchers and clinicians in physical therapy.* 2004;9(4):157-163.
70. Mancuso C. A., Lee S. K., Dy C. J., Landers Z. A., Model Z., Wolfe S. W. Expectations and limitations due to brachial plexus injury: a qualitative study. *Hand (N Y).* 2015;10(4):741-749.
71. Lagerkvist A. L., Johansson U., Johansson A., Bager B., Uvebrant P. Obstetric brachial plexus palsy: a prospective, population-based study of incidence, recovery, and residual impairment at 18 months of age. *Dev Med Child Neurol.* 2010;52(6):529-534.
72. WHO. ICF. 2016; http://www.who.int/classifications/icf/en/. Accessed 01-07-2016.
73. Akel B.S., Oksuz C., Oskay D., Firat T., Tarakci E., Leblebicioglu G. Health-related quality of life in children with obstetrical brachial plexus palsy. *Qual.Life Res.* 2013.
74. Huffman G.R., Bagley A.M., James M.A., Lerman J.A., Rab G. Assessment of children with brachial plexus birth palsy using the Pediatric Outcomes Data Collection Instrument. *J.Pediatr.Orthop.* 2005;25(3):400-404.
75. Alyanak B., Kilincaslan A., Kutlu L., Bozkurt H., Aydin A. Psychological adjustment, maternal distress, and family functioning in children with obstetrical brachial plexus palsy. *The Journal of hand surgery.* 2013;38(1):137-142.
76. Firat T., Oskay D., Akel B. S., Oksuz C. Impact of obstetrical brachial plexus injury on parents. *Pediatrics international : official journal of the Japan Pediatric Society.* 2012;54(6):881-884.
77. Oskay D., Oksuz C., Akel S., Firat T., Leblebicioglu G. Quality of life in mothers of children with obstetrical brachial plexus palsy. *Pediatrics international : official journal of the Japan Pediatric Society.* 2012;54(1):117-122.
78. McLean L. A., Harvey D., Mutimer K. Risk and resistance factors associated with paternal adjustment to obstetrical brachial plexus injuries. *Journal of clinical psychology in medical settings.* 2014;21(3):244-252.
79. Louden Emily, Allgier Allison, Overton Myra, Welge Jeffrey, Mehlman Charles T. The impact of pediatric brachial plexus injury on families. *The Journal of hand surgery.* 2015;40(6):1190-1195.
80. de Heer C., Beckerman H., Groot Vd. Explaining daily functioning in young adults with obstetric brachial plexus lesion. *Disabil Rehabil.* 2015;37(16):1455-1461.
81. Kirjavainen M. O., Remes V. M., Peltonen J., et al. Permanent brachial plexus birth palsy does not impair the development and function of the spine and lower limbs. *J Pediatr Orthop B.* 2009;18(6):283-288.
82. Sarac C., Duijnisveld B. J., Weide Av, et al. Outcome measures used in clinical studies on neonatal brachial plexus palsy: A systematic literature review using the International Classification of Functioning, Disability and Health. *J Pediatr Rehabil Med.* 2015;8(3):167-186.
83. Dy C. J., Garg R., Lee S. K., Tow P., Mancuso C. A., Wolfe S. W. A systematic review of outcomes reporting for brachial plexus reconstruction. *The Journal of hand surgery.* 2015;40(2):308-313.
84. Bialocerkowski A., O'Shea K., Pin T. W. Psychometric properties of outcome measures

for children and adolescents with brachial plexus birth palsy: a systematic review. *Dev Med Child Neurol.* 2013;55(12):1075-1088.
85. Chang K.W., Justice D., Chung K.C., Yang L.J. A systematic review of evaluation methods for neonatal brachial plexus palsy. *J.Neurosurg. Pediatr.* 2013.
86. Daltroy L.H., Liang M.H., Fossel A.H., Goldberg M.J. The POSNA pediatric musculoskeletal functional health questionnaire: report on reliability, validity, and sensitivity to change. Pediatric Outcomes Instrument Development Group. Pediatric Orthopaedic Society of North America. *J.Pediatr.Orthop.* 1998;18(5):561-571.
87. Bae D.S., Waters P.M., Zurakowski D. Correlation of pediatric outcomes data collection instrument with measures of active movement in children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(5):584-592.
88. Squitieri L., Larson B.P., Chang K.W., Yang L.J., Chung K.C. Understanding quality of life and patient expectations among adolescents with neonatal brachial plexus palsy: a qualitative and quantitative pilot study. *J.Hand Surg.Am.* 2013;38(12):2387-2397.
89. Bae D.S., Waters P.M., Zurakowski D. Reliability of three classification systems measuring active motion in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2003;85-A(9):1733-1738.
90. Dedini R.D., Bagley A.M., Molitor F., James M.A. Comparison of pediatric outcomes data collection instrument scores and range of motion before and after shoulder tendon transfers for children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(2):259-264.
91. Shah A. K., Zurakowski D., Jessel R. H., Kuo A., Waters P. M. Measuring surgeons' treatment preferences and satisfaction with nerve reconstruction techniques for children with unique brachial plexus birth palsies. *Plast Reconstr Surg.* 2006;118(4):967-975.

CHAPTER TWO

Evaluation of shoulder function after secondary surgery in children with neonatal brachial plexus palsy

Menno van der Holst | Thea P.M. Vliet Vlieland | Jorit J.L. Meesters
W. Peter Bekkering | Jochem Nagels | Rob G.H.H. Nelissen

Published:
Journal of Pediatric Rehabilitation Medicine: An Interdisciplinary Approach
8 (2015) 187–196 DOI 10.3233/PRM-150332
Oral abstract presentation VRA congress november 2013, Noordwijk,
The Netherlands

ABSTRACT

Objective

Shoulder function in children with Neonatal Brachial Plexus Palsy (NBPP) can be impaired. Functional gain is possible by an internal contracture release and muscle tendon transfer (ICR+MTT) for external rotation. This study evaluates the functional results of this intervention.

Methods

Assessments were done pre-operatively and 3, 6 and 12 months thereafter and included joint-mobility (ROM), muscle strength, arm function (Assisting Hand Assessment (AHA) and Mallet-score), Quality of Life (QoL) (Pediatric Outcome Data Collecting Instrument (PODCI)) and parental satisfaction. Changes were examined using Wilcoxon's Signed-Rank test and Cohen's effect size.

Results

Ten children (5 boys) aged 3–10 years who underwent a combined ICR+MTT (mm. Latissimus Dorsi/Teres Major) were included. Active and passive external rotation ROM and muscle strength improved ($p < 0.05$). Arm function improved according to the Mallet-score (Hand-to-Head, Hand-to-Mouth, External-Rotation) ($p < 0.05$) and the arm use and pace scales of the AHA ($p < 0.05$). The PODCI Upper Extremity/Physical Functioning and Global Functioning subscales also showed improvements ($p < 0.05$). Parents were highly satisfied concerning daily life activities and sports.

Conclusion

ICR+MTT leads to improvement of ROM, strength, arm function, QoL and high parental satisfaction in this studies' patients and is therefore a good intervention to consider in children with NBPP with limited shoulder function.

INTRODUCTION

Neonatal Brachial Plexus Palsy (NBPP) is the result of an injury to the cervical and/or thoracic nerves (C5-T1), forming the Brachial Plexus, sustained during birth. The incidence of NBPP varies from 0.38 to 5.10 per 1000 live births in various countries.[1-3] Most injuries are mild and spontaneous recovery occurs in about 70% of the children within 4–6 months after birth. The remaining 30% is left with some kind of functional deficit. The clinical manifestations of these injuries depend on the severity of the injury and the roots involved. Children with persisting functional deficits can be either treated conservatively[1,2,4-7] or may undergo micro-neurosurgical intervention.[1,2,4-9] These treatments may not be sufficiently effective in some children[2,4,7,9], resulting in remaining functional deficits and/or anatomical changes which can become permanent or worsen over time.[10]
Limited external rotation of the shoulder is often seen in these children and can be an indication for secondary surgery (contracture-release and/or muscle tendon transfers).[5-7,9,11-23] Observational studies on the outcome of secondary surgical interventions are mainly confined to changes in active or passive range of motion (aROM and pROM) and/or Mallet-scores. Overall, improvements regarding these outcomes were reported in the literature.[11-17,19-23] Two studies described an improvement in quality of life (QoL) using either the Pediatric Data Collecting Instrument (PODCI)[24] or a questionnaire regarding the level of satisfaction with activities of daily living, cosmetics and surgical procedure.[12]
Until now, no study has been conducted which, besides the changes in ROM, Mallet scores and QoL, takes into account other relevant outcomes like muscle strength, bimanual activities and the extent to which parental satisfaction in regard to their treatment expectations are met. Improvements with respect to all of these outcomes are important goals of surgical treatment. The aim of the present study was therefore to comprehensively evaluate the results of a combined internal contracture release and a muscle tendon transfer in the shoulder performed in children with NBPP.

PATIENTS AND METHODS

Study design

This study had an observational design and was conducted between 2008 and 2011 in the Leiden University Medical Center, a tertiary referral center specialized in NBPP in the Netherlands. The institution's medical ethics committee approved the study (Studynr. P08.008). All parents gave written informed consent.

Patients

All children who were seen and physically examined by the orthopedic surgeon (principal investigator), who had an MRI of the affected shoulder and were thereafter, based on the fact that they had limited external shoulder rotation and/or joint deformities, scheduled to undergo a combined internal contracture release and a muscle tendon transfer (mm.

Latissimus Dorsi and Teres Major) were eligible for this study. Additional inclusion criteria were: Age 3–10 years, involvement of C5, C6 and/or C7 rootlets ("shoulder affected") and impairment had to be unilateral.
Fourteen children were eligible to participate. One canceled surgery, two children were excluded because one had bilateral NBPP and the second was cognitively impaired and therefore not able to cooperate. Of the 11 remaining children the parents of one child decided not to further participate after baseline due to non-compliance of the child. This participant is not included in the analyses.

Surgical intervention and postoperative rehabilitation
The following surgical procedures were employed:
Anterior internal contracture release: A deltopectoral incision was performed to expose the coracoid. An incision was then made releasing the coraco-humeral ligament at the anterior capsule of the shoulder at a length of 3 mm.
Tendon transfer: Through a curved incision at the posterior axillary border, the mm. Latissimus Dorsi and Teres Major tendons were detached from the humerus. A second incision was made cranial and posterior at the upper arm, followed by a deltoid split, exposing the humeral head. The detached mm. Latissimus Dorsi and Teres Major were transferred underneath the Deltoid muscle to the mm. Infraspinatus/Supraspinatus footprint area. Both tendons were fixed independently with transosseous sutures at the greater tuberosity of the humerus.
Rehabilitation consisted of 6 weeks baycast-plaster in slight shoulder-abduction and external rotation, followed by physical therapy twice a week for at least 3 months. Treatment consisted of maintaining/improving joint mobility and muscle strength and stimulating bimanual activities. After three months, physical therapy was either stopped or continued until no further functional recovery was seen.

Assessments
All children were seen a day prior to surgery and 3, 6 and 12 months thereafter. All outcome measurements were performed at all follow-up time points except for the bimanual activities test which was not performed at 3 months follow up. All assessments were performed by a pediatric physical therapist (first assessor) with over 5 years of experience with NBPP patients.

Sociodemographic and disease characteristics
The following data were retrieved from the medical record: age, gender, involved nerve roots, affected side and previous treatments.

Shoulder range of motion
Active and passive shoulder range of motion in the directions flexion, extension, abduction, and external rotation (in 0° and 90° abduction) were recorded with a goniometer.[25]

Muscle strength

Isometric muscle strength was measured with the MicroFET II handheld dynamometer, Biometrics, Almere, the Netherlands, using the break method.[26,27] Muscle strength of the shoulder external rotators (0° abduction), shoulder abductors (45° abduction) and shoulder flexors (45° flexion) was measured in Newton.

Shoulder movements

Shoulder movements of the affected arm were measured using the modified Mallet-score. This score measures often used arm movements, including overhead movements, with scores ranging from 1 = no function to 5 = normal function.[28-30] The Active Movement Scale (AMS) with M0 = no contraction to M4 = full motion with gravity eliminated and M5 = less than half the motion to M7 = full motion against gravity was administered for external rotation (0° abduction), abduction and forward flexion.[28,29,31]

Bimanual activities

To assess the use of the affected side during bimanual activities, including overhead movements, the Assisting Hand Assessment (AHA) was used. The AHA is a semi-structured, video-recorded, play-session for children (1.5–12 years) in which toys are used that encourage bimanual handling. Scoring is done by reviewing the video with respect to 22 items, subdivided into 6 categories: 'General Use', 'Arm Use', 'Grasp and Release', 'Fine Motor Adjustment', 'Coordination' and 'Pace', using a 4-point criterion referenced rating scale with 4 = Effective to 1 = Does not do. The minimum total raw score is 22 (0%), the maximum raw score is 88 (100%).[32-34] The total score can also be described in logit-based AHA units (0–100).[35] All play-sessions (baseline, 6 and 12 months post-surgery) were recorded and scored by the first assessor. A second assessor scored 10% of the videos. Discrepancies were discussed and by means of consensus a final score was determined. No more than 4 raw points differences were found and therefore no additional videos were assessed.

Quality of life

QoL was measured with the Pediatric Outcome Data Collecting Instrument (PODCI).[24,29,36-38] The PODCI is a questionnaire designed to assess different aspects of daily living, overall health and pain in children with musculoskeletal disorders. There are 6 scales: 'Upper Extremity and Physical Function', 'Transfer and Basic Mobility', 'Sports and Physical Function', 'Pain and Comfort', 'Happiness' and 'Global Functioning'. The PODCI was translated into Dutch using international guidelines for cross-cultural validation.[39-41] The parent reported version (2– 10 years old) was used.

Parental expectations and post-surgery satisfaction

To identify parental expectations regarding the functional outcome of the surgical intervention a self-developed questionnaire, specifically designed for this study, was used. In this questionnaire parents were asked to list all their expectations at baseline regarding two domains; Activities of daily living (ADL) and sports (including playing activities).

Subsequently they were requested to rank all expectations with respect to their importance, with 1 = the most important expectation and so on (maximum dependant on number of expectations recorded). Twelve months post-surgery, during an interview with the first assessor, parents rated the extent to which their two highest ranked expectations (one in ADL and one in sports) had been met and how satisfied they were overall concerning the functional outcome of the surgical intervention, using a 5-point Likert-scale with 1 = highly unsatisfied to 5 = highly satisfied. A score of 4 indicates an acceptable level of satisfaction.

Statistical analysis

Descriptive statistics were used to describe the clinical characteristics of the patients and the satisfaction regarding treatment expectations. Comparisons of clinical outcomes at the different time points were done by means of Wilcoxon's signed rank tests with statistical significance at $p<0.05$. At 12 months Cohen's effect size compared to baseline was computed (ES: (pre-treatment mean – post-treatment mean)/pre-treatment standard deviation). In general an ES of >0.2 is considered a small effect, >0.5 a moderate effect and >0.8 a large effect.[42] Statistical analyses were executed using SPSS 20.0 software (IBM SPSS Statistics 20.0 for Windows, http://www01.ibm.com/software/ analytics/spss/).

RESULTS

All results of the study are shown in Tables I to IV.

The high number of tests conducted gives an increased chance of a type I error occurring, however correcting for this 'multiple testing' by adjusting the p-levels may lead to an increased chance of a type II error occurring. Therefore, effect sizes, as well as the true observed values (medians and interquartile ranges) are given, whereas correction for multiple testing has not been performed.

Table I shows the characteristics of the 10 patients; 5 boys/5 girls, affected side: 3 left, 7 right, lesion-topography: 4 C5/C6, 6 C5/C6/C7. Primary treatment consisted of neurolysis (n = 1) nerve reconstruction (n = 5) and conservative treatment (n = 4). The primary surgical treatment had been conducted at the age of 4–8 months. All participants had received physical therapy during the first years of their lives.

Table II shows the changes in shoulder aROM, pROM and muscle strength. Active and passive external rotation ROM and muscle strength increased significantly at one or more time points. The differences for active external rotation in 90° abduction and passive external rotation ROM were statistically significant at 3, 6 and 12 months. Overall, a decrease in both active and passive external rotation ROM was seen between 6 and 12 months. Muscle strength in external rotation increased significantly at 12 months. All ES for external rotation including ROM in degrees, the AMS score and muscle strength in Newtons at 12 months were >0.8, indicating a large improvement. Regarding abduction and flexion, active and

Table I Sociodemographic and disease characteristics of 10 children with Neonatal Brachial Plexus Palsy undergoing a combined internal contracture release and muscle tendon transfer.

	Total group (n=10)
Gender (m/f); no.	5/5
Age, years; median (range)	4.5 (3-10)
Lesion topography; no.	
C5/C6	4
C5/C6/C7	6
Affected side; no.	
Left	3
Right	7
Previous treatment(s); no.	
Neurolysis	1
Nerve reconstruction	5
Conservative	4
Physical therapy; no.	
Yes	10
No	0

passive ROM in degrees, AMS-scores and muscle strength in Newtons, no significant changes were seen. Both active and passive shoulder extension ROM decreased significantly at 3 months, but not at 6 or 12 months.

Table III shows the changes on the Mallet, AHA and PODCI scores. Regarding the Mallet-score, no changes were seen for 'Abduction', whereas significant improvements for 'Hand to Head' and 'Hand to Mouth' were seen at all time points, and for 'External rotation' at 3 months. The 'Hand to Back' item deteriorated at 3 months. At 12 months, large ES were seen for all Mallet sub-scores, except for 'Abduction' and 'Hand to Back'. The AHA 'Arm Use' subscale improved significantly at 6 and 12 months and the 'Pace' subscale at 12 months, with large and moderate ES at 12 months. The AHA total score and all other subscale scores did not change over time. The 'Upper Extremity and Physical Function' and 'Global Functioning' scales of the PODCI also showed significant improvements at 6 months and at both 6 and 12 months respectively. All PODCI scales, except for the 'Happiness scale', showed small ES at 12 months, with the ES for the 'Global Functioning scale' being moderate.

Table IV shows the parental satisfaction regarding pre-operatively highest ranked expectations for the effect on functional improvements, as well as the overall satisfaction with treatment results at 12 months. Eight parents were highly satisfied or satisfied with the results regarding the highest ranked expectations for ADL activities, 6 parents with the results for expectations on sports activities, and 8 parents with the overall treatment outcome.

Table II Shoulder range of motion and muscle strength pre-operatively and at follow up in children with NBPP undergoing a combined internal contracture release and muscle tendon transfer. All results are expressed as median with inter quartile ranges.

Outcome measure	T1 (baseline)	T2 (3 months)	T3 (6 months)	T4 (12 months)	T1-T2 p	T1-T3 p	T1-T4 p	T1-T4 Cohen's d
Active shoulder range of motion; degrees, median (IQR)								
External rotation	-32.5 (-56.3, -18.8)	0 (-12.5, 16.3)	0 (-31.3, 12.5)	-20 (-25, 17.5)	0.018*	0.059	0.052	+1.18
External rotation (90° abduction)	2,5 (-11.3, 22.5)	42.5 (26.3, 62.5)	52.5 (35, 72.5)	45 (30, 61.3)	0.019*	0.008*	0.011*	+1.85
Abduction	150 (110, 161.3)	135 (97.5, 170)	147.5 (118.8, 172.5)	162.5 (140, 172.5)	0.280	0.443	0.103	+0.52
Flexion	147.5 (136.3, 160)	152.5 (107.8, 170)	150 (133.8, 172.5)	152.5 (140, 170)	0.644	0.720	0.592	+0.12
Extension	17,5 (0, 25)	0 (-6.3, 12.5)	10 (0, 12.5)	5 (0, 12.5)	0.049*	0.165	0.178	-0.47
Passive shoulder range of motion; degrees, median (IQR)								
External rotation	-22.5 (-26.3, 0)	30 (22.5, 42.5)	25 (16.3, 45)	20 (20, 37.5)	0.012*	0.008*	0.011*	+1.64
External rotation (90° abduction)	37.5 (15, 62.5)	70 (52.5, 82.5)	77.5 (45, 90)	72.5 (60, 86.3)	0.058	0.032*	0.017*	+1.14
Abduction	160 (128.8, 172.5)	160 (110, 170)	170 (133.8, 180)	170 (154, 180)	0.472	0.483	0.051	+0.52
Flexion	160 (153.8, 167.5)	152.5 (123.8, 166.3)	170 (143.8, 180)	165 (150, 180)	0.075	0.838	0.618	+0.21
Extension	27,5 (17.5, 37.5)	20 (-2.5, 22.5)	25 (20, 26.3)	20 (13.8, 21.3)	0.011*	0.472	0.067	-0.67
Active Movement Scale (M0-M7, worst-best), median (IQR)								
External rotation (0° abduction)	2 (1, 2.8)	5 (2, 5)	5 (4.3, 5)	5 (2, 5)	0.068	0.017*	0.027*	+1.26
Abduction	7 (6, 7)	7 (6,7)	6.5 (5, 7)	7 (6, 7)	1.000	0.317	0.157	+0.28
Flexion	7 (6, 7)	7 (6,7)	6.5 (6, 7)	6.5 (6, 7)	1.000	0.317	0.317	-0.39
Muscle strength ; Newton, median (IQR)								
External rotation (0° abduction)	0 (0, 2.5)	0 (0, 16.4)	0 (0, 23.9)	30.1 (30.1, 46.5)	0.273	0.138	0.017*	+3.81
Abduction	74,9 (23.8, 91.7)	37.5 (18.6, 59.7)	57.2 (45.9, 74.2)	70.7 (50.5, 99.9)	0.116	0.374	0.407	+0.22
Flexion	46,7 (12.8, 75.7)	25.8 (17.3, 54)	53.3 (41.5, 61.9)	56.5 (33.9, 84.4)	0.345	0.678	0.114	+0.50

IQR: inter quartile range
* Significant difference p<0.05
Effect size Cohen's d; >0.2 = small change, >0.5 = moderate change, >0.8 = large change.

Table III Mallet, Assisting Hand Assessment and Pediatric Outcome Data Collecting Instrument scores pre-operatively and at follow up in children with NBPP undergoing a combined internal contracture release and muscle tendon transfer. All results are expressed as median with inter quartile ranges.

Outcome measure	T1 (baseline)	T2 (3 months)	T3 (6 months)	T4 (12 months)	T1-T2 p	T1-T3 p	T1-T4 p	T1-T4 Cohen's d
Malletscore (I-V, worst-best), median (IQR)								
Abduction	4 (4, 4)	4 (3.8, 4)	4 (4, 4)	4 (4, 4)	0.317	0.317	0.317	+0.32
Exorotation	1 (1, 1.3)	2 (1, 3)	2 (1, 3)	1 (1, 3)	0.040*	0.064	0.167	+1.42
Hand to Head	3 (2.8, 3)	4 (3, 4)	4 (4, 4)	4 (3, 4)	0.023*	0.008*	0.008*	+1.23
Hand to Back	4 (2, 4)	2.5 (2, 3.3)	3 (2, 4)	4 (2, 4)	0.038*	0.102	0.317	-0.21
Hand to Mouth	2 (2, 2.3)	4 (3, 4)	4 (3, 4)	4 (3, 4)	0.004*	0.006*	0.006*	+3.55
Assisting Hand Assessment; median (IQR)								
Total score (0-100 logit based AHA units)	82 (76, 83)	x	85 (72.8, 86.3)	86 (73.8, 86.3)	x	0.095	0.095	+0.20
General Use items (%)	100 (83.4, 100)	x	100 (75, 100)	100 (91.7, 100)	x	1.000	0.102	+0.24
Arm Use items (%)	62.5 (56.8, 66.7)	x	75 (56.2, 75)	75 (58.3, 83.3)	x	0.016*	0.007*	+0.95
Grasp-Release items (%)	100 (84.5, 100)	x	100 (75, 100)	100 (67.8, 100)	x	0.854	0.197	-0.16
Fine Motor Adjustment items (%)	100 (69.5, 100)	x	100 (72.3, 100)	100 (75, 100)	x	0.257	0.705	+0.04
Coordination items (%)	100 (95.8, 100)	x	100 (95.8, 100)	100 (95.8, 100)	x	0.317	0.317	+0.15
Pace items (%)	83.4 (66.7, 88.9)	x	88.9 (77.8, 88.9)	88.9 (88.9, 88.9)	x	0.074	0.041*	+0.50
Pediatric Outcome Data Collecting Instrument (PODCI); median (IQR)								
Upper Extremity scale (range 0-100)	71 (50, 84.5)	66.5 (54, 94.3)	73 (57.8, 89)	80 (61.8, 84.8)	0.866	0.043*	0.313	+0.22
Transfer and Basic Mobility scale (0-100)	97 (93.3, 100)	98.5 (94.5, 100)	98.5 (94, 100)	100 (96.3, 100)	0.343	0.197	0.072	+0.42
Sports and Physical Functioning scale (0-100)	88.5 (78.5, 96.3)	88 (80.5, 90.3)	94 (89, 96.5)	95 (87.8, 98)	0.213	1.000	0.068	+0.46
Pain and Comfort scale (0-100)	100 (76.3, 100)	89 (70, 100)	100 (98.3, 100)	100 (93.5, 100)	0.131	0.655	0.109	+0.24
Happiness scale (0-100)	100 (85, 100)	90 (75, 100)	95 (82.3, 100)	100 (93.8, 100)	0.068	0.655	0.109	+0.05
Global Functioning scale (0-100)	88 (75.5, 90.5)	85 (78, 92.3)	90 (86.3, 95.8)	90.5 (80.8, 95.5)	0.735	0.041*	0.024*	+0.57

IQR: inter quartile range
x: The assisting hand assessment was not recorded at T2.
* Significant difference p<0.05
Effect size Cohen's d; >0.2 = small change, >0.5 = moderate change, >0.8 = large change.

Table IV Parental expectations and satisfaction pre-operatively and at follow up in children with Neonatal Brachial Plexus Palsy undergoing a combined internal contracture release and muscle tendon transfer.

Patient no. (age at baseline in years)	No. of expectations at T1 (baseline)	Primary expectation ADL at T1; improvement in:	Satisfaction at T4 (12 months) range 1-5*	Primary expectation Sports at T1; improvement in:	Satisfaction at T4 (12 months) range 1-5*	Overall satisfaction at T4 (12 months) range 1-5*
1 (5)	6	Bringing something to the mouth	3	Swimming	5	5
2 (4)	2	Cycling	5	Swimming	5	5
3 (7)	3	Running	2	Cycling	2	2
4 (3)	4	Eating	4	School gymnastics	5	5
5 (3)	5	Dressing	5	None	3	4
6 (8)	5	Cycling	4	Swimming	4	4
7 (4)	6	Dressing	4	Swimming	4	4
8 (10)	8	Personal hygiene	5	School gymnastics	2	3
9 (3)	2	Placing hand on and above head	5	None	3	5
10 (6)	4	Dressing	5	Swimming	5	5

* Post surgery satisfaction range 1; highly unsatisfied – 5; highly satisfied.

DISCUSSION

In case of persistent external rotation limitations in children with NBPP, secondary surgery consisting of a combined internal contracture release and a muscle tendon transfer (mm. Latissimus Dorsi and Teres Major) can be considered. The current study in 10 children found that shoulder external rotation ROM and strength, bringing the hand to the head and to the mouth, the use of the affected arm in bimanual activities, and overall (arm) function improved significantly in the year following this intervention. A negative effect on shoulder extension ROM and bringing the hand to the back was seen. The majority of parents were satisfied with the result after 12 months.

The results are generally in line with the literature. Concerning shoulder external rotation ROM, positive effects were also reported in 13 other studies.[11-13,15-17,19-24,43] With respect to shoulder abduction, previous studies reported an increase[11-13,15-17,19-24,43], whereas in this

study no significant effect on abduction was seen. This could be due to the relative good shoulder abduction and flexion ROM, AMS scores, strength and Mallet scores before surgery. Improvements of functional movements of the arm, including bringing the hand to the head and mouth have been reported earlier as well.[20,22,23] The same holds for the negative effect on bringing the arm to the back.[15,17]

In general, the effect on shoulder external rotation in ROM and on Mallet scores decreased between 6 and 12 months. This decline might be related to the observation that for most daily activities only a limited range of shoulder external rotation, especially in 0° abduction, is needed. External shoulder rotation in daily activities is usually combined with some shoulder abduction/flexion. It might also be related to the fact that external rotation exercises were only performed during the physical therapy period (first 3 months after baycast-plaster removal). The question remains to what extent external rotation in 0° abduction is of clinical importance regarding the performance of daily activities. Still, loss of external rotation in 0° abduction is one of the parameters indicating the need for secondary surgery.[44,45] Ultimately, active ROM is a composite that will determine overall functionality and thus quality of life of the child.

No previous study included a measurement of muscle strength so far. Although it is difficult to perform muscle strength measures in young children using a handheld dynamometer, it is a well-known and usable assessment instrument for children. Reference values of maximum isometric muscle force obtained with a handheld dynamometer are available for children between the age of 4 and 16.[26] It remains to be established though to what extent the gain in muscle strength seen in the present study contributes to the overall increase in arm function.

Few studies have so far focused on daily activities and quality of life. Regarding bimanual activities, the AHA was never used before in patients undergoing the described intervention. In this study a small, yet positive change in the 'Arm Use' items was seen. The overall AHA score however did not change significantly. This may be due to the relatively good hand function most of our patients had before surgery.

Concerning quality of life, a positive effect for the PODCI scales 'Upper Extremity and Physical Function', 'Sports and Physical Function' and 'Global Functioning' was seen in previous studies[24], where as the present study showed no effect on 'Sports and Physical Function'. In line with the previous studies, no improvements were seen for the other three scales.[24] This lack of effect may be related to the fact that the PODCI is not specifically designed for upper extremity conditions nor for NBPP.[29] For the sake of efficiency in future research in patients with NBPP it could be considered to use only the PODCI 'Upper Extremity and Physical Function' scale.

In concordance with the results of the present study, a relatively large proportion of parents were satisfied with the intervention in previous research as well.[12] Measuring function in children with NBPP is difficult, because most of the time they are fully functional in their own way by employing compensational strategies. Moreover, no consensus exists on how to measure this function in these children.[46] Nevertheless, it is still important to evaluate the effectiveness of surgical interventions in children with NBPP. Children reported functional problems due to NBPP in a recently conducted focus group study[47] and the parents of the children in the current study reported functional problems as well. These findings underline the importance of an evaluation on a functional level.

This study had a number of limitations. First, a relatively small group of patients was used. This is due to the fact that the prevalence of NBPP is fortunately low these days. Therefore, the present study and some previous papers reporting on this surgical procedure included moderate to small groups of patients.[11-13,15-17,20,23] In previous studies, the range of follow-up and age was even wider than in the present study. Moreover, the characteristics of the patients at baseline varied. Although this might be the case, all patients have a limited external shoulder rotation and limited arm function in regard to the Mallet score and the AHA in common. Because of the relatively large number of tests and time points in a small sample so called 'multiple testing' has occurred. Because of this a type I error cannot be ruled out. Correcting for Multiple Testing can be done by adjusting the p-levels, however this method increases the chance of a type II error.[48] To counteract this problem, effect sizes were calculated with predefined cut off points for their interpretation. Overall, the use of effect sizes and the fact that the observed scores and the magnitude of their changes are in line with those reported in the literature, suggest that the changes seen in this group of patients are real and not a result of a type I error.[48] It remains to be established though whether the results are generalizable to other patients with NBPP and external rotation limitations. Another limitation was the observational design, with no control group. However, it is questionable whether using a control group is ethical in this study population. In contrast with most of the previous studies however[11-13,17,20,21], data was gathered prospectively with standardized timing of assessments, using well defined outcome measures allowing an in-depth analysis including multiple components of the ICF-CY (Children and Youth) as well as parental satisfaction.[49]

CONCLUSION

This study showed that a combined internal contracture release and a muscle tendon transfer (mm. Latissimus Dorsi and Teres Major) for external shoulder rotation is a good intervention to restore arm function in children with NBPP. External rotation mobility and muscle strength, hand to head and hand to mouth Mallet-score items, AHA 'Arm Use' items and general functioning increased. Parents were overall highly satisfied with their expectations concerning both daily life activities and sports being met. The results of this

study are important for parents and children as more detailed information on the expected treatment outcomes can contribute to the quality of the decision-making process.

Acknowledgements
We would like to thank H.M. Vermeulen, PhD, J. Verhoef, PhD, K. Boeschoten, OT, S.M. Buitenhuis, PT and the Rijnlands Rehabilitation Center for their contribution.

REFERENCES

1. Malessy MJ, Pondaag W. Obstetric brachial plexus injuries. *Neurosurg.Clin.N.Am.* 2009;20(1):1-14.
2. Pondaag W, Malessy MJ, van Dijk JG, Thomeer RT. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev.Med.Child Neurol.* 2004;46(2):138-144.
3. Hoeksma AF, ter Steeg AM, Nelissen RG, van Ouwerkerk WJ, Lankhorst GJ, de Jong BA. Neurological recovery in obstetric brachial plexus injuries: an historical cohort study. *Dev. Med.Child Neurol.* 2004;46(2):76-83.
4. Waters PM. Comparison of the natural history, the outcome of microsurgical repair, and the outcome of operative reconstruction in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 1999;81(5):649-659.
5. Hale HB, Bae DS, Waters PM. Current concepts in the management of brachial plexus birth palsy. *J.Hand Surg.Am.* 2010;35(2):322-331.
6. Haerle M, Gilbert A. Management of complete obstetric brachial plexus lesions. *J.Pediatr. Orthop.* 2004;24(2):194-200.
7. Waters PM. Update on management of pediatric brachial plexus palsy. *J.Pediatr.Orthop.B.* 2005;14(4):233-244.
8. Kirjavainen M, Remes V, Peltonen J, et al. Long-term results of surgery for brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2007;89(1):18-26.
9. Vekris MD, Lykissas MG, Beris AE, Manoudis G, Vekris AD, Soucacos PN. Management of obstetrical brachial plexus palsy with early plexus microreconstruction and late muscle transfers. *Microsurgery.* 2008;28(4):252-261.
10. Hogendoorn S, van Overvest KL, Watt I, Duijsens AH, Nelissen RG. Structural changes in muscle and glenohumeral joint deformity in neonatal brachial plexus palsy. *J.Bone Joint Surg.Am.* 2010;92(4):935-942.
11. Phipps GJ, Hoffer MM. Latissimus dorsi and teres major transfer to rotator cuff for Erb's palsy. *J.Shoulder.Elbow.Surg.* 1995;4(2):124-129.
12. Edwards TB, Baghian S, Faust DC, Willis RB. Results of latissimus dorsi and teres major transfer to the rotator cuff in the treatment of Erb's palsy. *J.Pediatr.Orthop.* 2000;20(3):375-379.
13. Suenaga N, Minami A, Kaneda K. Long-term results of multiple muscle transfer to reconstruct shoulder function in patients with birth palsy: eleven-year follow-up. *J.Pediatr. Orthop.* 1999;19(5):669-671.
14. van der Sluijs JA, van Ouwerkerk WJ, de GA, Nollet F, Winters H, Wuisman PI. Treatment of internal rotation contracture of the shoulder in obstetric brachial plexus lesions by subscapular tendon lengthening and open reduction: early results and complications. *J.Pediatr.Orthop.B.* 2004;13(3):218-224.
15. Aydin A, Ozkan T, Onel D. Does preoperative abduction value affect functional outcome of combined muscle transfer and release procedures in obstetrical palsy patients with shoulder involvement? *BMC.Musculoskelet. Disord.* 2004;5:25.
16. Vallejo GI, Toh S, Arai H, Arai K, Harata S. Results of the latissimus dorsi and teres major tendon transfer on to the rotator cuff for brachial plexus palsy at birth. *Scand.J.Plast.Reconstr.Surg.Hand Surg.* 2002;36(4):207-211.
17. Terzis JK, Kokkalis ZT. Outcomes of secondary shoulder reconstruction in obstetrical brachial plexus palsy. *Plast.Reconstr.Surg.* 2008;122(6):1812-1822.
18. Julka A, Vander Have KL. Shoulder sequelae of neonatal brachial plexus injuries: orthopedic assessment and management. *J.Pediatr.Rehabil. Med.* 2011;4(2):131-140.
19. Chen L, Gu YD, Hu SN. Applying transfer of trapezius and/or latissimus dorsi with teres major for reconstruction of abduction and external rotation of the shoulder in obstetrical brachial plexus palsy. *J.Reconstr.Microsurg.* 2002;18(4):275-280.
20. Cohen G, Rampal V, Aubart-Cohen F, Seringe R, Wicart P. Brachial plexus birth palsy shoulder deformity treatment using subscapularis release combined to tendons transfer. *Orthop. Traumatol.Surg.Res.* 2010;96(4):334-339.
21. Abdel-Ghani H, Hamdy KA, Basha N, Tarraf YN. Tendon transfer for treatment of internal rotation contracture of the shoulder in brachial plexus birth palsy. *J.Hand Surg.Eur.* 2012;37(8):781-786.
22. Ozben H, Atalar AC, Bilsel K, Demirhan M. Transfer of latissmus dorsi and teres major tendons without subscapularis release for the treatment of obstetrical brachial plexus palsy sequela. *J.Shoulder.Elbow.Surg.* 2011;20(8):1265-1274.
23. Ozturk K, Bulbul M, Demir BB, Buyukkurt CD, Ayanoglu S, Esenyel CZ. Reconstruction of shoulder abduction and external rotation with latissimus dorsi and teres major transfer in obstetric brachial plexus palsy. *Acta Orthop. Traumatol.Turc.* 2010;44(3):186-193.
24. Dedini RD, Bagley AM, Molitor F, James MA. Comparison of pediatric outcomes data collection instrument scores and range of motion before and after shoulder tendon transfers for children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(2):259-264.
25. Ryf C, Weymann A. *Range of motion - AO Neutral-0 Method : measurement and documentation.* Vol v. 1. New York: Thieme; 1999.

26. Beenakker EA, van der Hoeven JH, Fock JM, Maurits NM. Reference values of maximum isometric muscle force obtained in 270 children aged 4-16 years by hand-held dynamometry. *Neuromuscul.Disord.* 2001;11(5):441-446.
27. MicroFET II. 2013.
28. Bae DS, Waters PM, Zurakowski D. Reliability of three classification systems measuring active motion in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2003;85-A(9):1733-1738.
29. Bae DS, Waters PM, Zurakowski D. Correlation of pediatric outcomes data collection instrument with measures of active movement in children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(5):584-592.
30. van der Sluijs JA, van Doorn-Loogman MH, Ritt MJ, Wuisman PI. Interobserver reliability of the Mallet score. *J.Pediatr.Orthop.B.* 2006;15(5):324-327.
31. Curtis C, Stephens D, Clarke HM, Andrews D. The active movement scale: an evaluative tool for infants with obstetrical brachial plexus palsy. *J.Hand Surg.Am.* 2002;27(3):470-478.
32. Holmefur M, Krumlinde-Sundholm L, Eliasson AC. Interrater and intrarater reliability of the Assisting Hand Assessment. *Am.J.Occup.Ther.* 2007;61(1):79-84.
33. Krumlinde-Sundholm L, Holmefur M, Kottorp A, Eliasson AC. The Assisting Hand Assessment: current evidence of validity, reliability, and responsiveness to change. *Dev.Med.Child Neurol.* 2007;49(4):259-264.
34. Krumlinde-sundholm L, Eliasson Ac. Development of the Assisting Hand Assessment: A Rasch-built Measure intended for Children with Unilateral Upper Limb Impairments. SCANDINAVIAN JOURNAL OF OCCUPATIONAL THERAPY; 1/1/2003, 2003.
35. Krumlinde-Sundholm L. Reporting outcomes of the Assisting Hand Assessment: what scale should be used? *Dev.Med.Child Neurol.* 2012;54(9):807-808.
36. Daltroy LH, Liang MH, Fossel AH, Goldberg MJ. The POSNA pediatric musculoskeletal functional health questionnaire: report on reliability, validity, and sensitivity to change. Pediatric Outcomes Instrument Development Group. Pediatric Orthopaedic Society of North America. *J.Pediatr.Orthop.* 1998;18(5):561-571.
37. Huffman GR, Bagley AM, James MA, Lerman JA, Rab G. Assessment of children with brachial plexus birth palsy using the Pediatric Outcomes Data Collection Instrument. *J.Pediatr.Orthop.* 2005;25(3):400-404.
38. Pediatric Data Collecting Instrument (PODCI) http://www.aaos.org/research/outcomes/outcomes_peds.asp. 2013.
39. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976.).* 2000;25(24):3186-3191.
40. Guillemin F, Bombardier C, Beaton D. Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. *J.Clin.Epidemiol.* 1993;46(12):1417-1432.
41. C.G. M, J. L, L.O.P C. The relevance of cross-cultural adaptation and clinimetrics for physical therapy instruments. *Rev Bras Fisioter.* 2007;11(4):245-252.
42. Cohen J. *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Hillsdale, NJ : Lawrence Erlbaum Associates; 1988.
43. Thatte MR, Agashe MV, Rao A, Rathod CM, Mehta R. Clinical outcome of shoulder muscle transfer for shoulder deformities in obstetric brachial plexus palsy: A study of 150 cases. *Indian J.Plast. Surg.* 2011;44(1):21-28.
44. Price A, Tidwell M, Grossman JA. Improving shoulder and elbow function in children with Erb's palsy. *Semin.Pediatr.Neurol.* 2000;7(1):44-51.
45. Hultgren T, Jonsson K, Pettersson H, Hammarberg H. Surgical correction of a rotational deformity of the shoulder in patients with obstetric brachial plexus palsy: Short-term results in 270 patients. *Bone Joint J.* 2013;95-B(10):1432-1438.
46. Chang KW, Justice D, Chung KC, Yang LJ. A systematic review of evaluation methods for neonatal brachial plexus palsy. *J.Neurosurg. Pediatr.* 2013.
47. Sarac C, Bastiaansen E, Van der Holst M, Malessy MJ, Nelissen RG, Vliet Vlieland TP. Concepts of functioning and health important to children with an obstetric brachial plexus injury: a qualitative study using focus groups. *Dev.Med. Child Neurol.* 2013;55(12):1136-1142.
48. Feise RJ. Do multiple outcome measures require p-value adjustment? *BMC.Med.Res.Methodol.* 2002;2:8.
49. WHO. ICF Domains. 2015; http://www.who.int/classifications/icf/en/.

CHAPTER THREE

Outcome of secondary shoulder surgery in children with neonatal brachial plexus palsy with and without nerve surgery treatment history: a longterm follow-up study

Menno van der Holst | C. W. P. Gerco van der Wal | Ron Wolterbeek
Willem Pondaag | Thea P.M. Vliet Vlieland | Rob G.H.H. Nelissen

Published:
Journal of Rehabilitation Medicine 2016 July 18; 48 (7): 609-17
DOI: 10.2340/16501977-2193, ISSN 1650-1977
Poster abstract presentation VRA congress april 2015, Amsterdam, The Netherlands
Oral abstract presentation Narakas Congress february 2016, Barcelona, Spain

ABSTRACT

Objective

Irrespective of treatment history, shoulder dysfunction may occur in children with neonatal brachial plexus palsy. Following internal contracture release and/or muscle tendon transfer (ICR/MTT) shoulder function gain is possible. This study describes the outcomes of ICR/MTT for children with neonatal brachial plexus palsy, with or without prior nerve surgery (a group with prior nerve surgery and a group without prior nerve surgery).

Patients and methods

The study included children who underwent an ICR/MTT with a minimum follow-up of 6 months. Active/passive range of motion (aROM/pROM)/ Mallet scores were recorded (pre-operatively, 6 months, and 1, 3, 5 and 10 years post-surgery). Changes over time within groups were analysed using a linear mixed model.

Results

A total of 115 children (60 boys) were included, 82 with nerve surgery history, mean age 4.7 years (standard deviation (SD) 3.3 years), mean follow-up 6 years (SD 3.2 years). Pre-operatively active external rotation, abduction and forward-flexion were worse in the group with prior nerve surgery. aROM, pROM and Mallet scores, improved at all time-points in both groups. The course and magnitude of these improvements were largely similar in both groups. In the long-term, the effects of ICR/MTT decrease, but remain significant.

Conclusion

In children with neonatal brachial plexus palsy shoulder function improved after ICR/MTT, irrespective of treatment history. Pre-operative shoulder function was worse in the group with prior nerve surgery, resulting in less function in this group after ICR/MTT. Reporting on outcome after secondary shoulder surgery should be stratified into children with and without prior nerve surgery, in order to prevent over- or underestimation of results.

INTRODUCTION

Neonatal brachial plexus palsy (NBPP) is the result of a birth stretch to the brachial plexus with an incidence of 0.38–5.10/1000.[1-3] Most injuries are mild, and spontaneous recovery occurs in 70–80% of cases, leaving the remaining 20–30% with some functional deficit.[4] When sufficient spontaneous recovery is lacking, nerve surgery at a young age (3–9 months) may be indicated.[1,2,5-11] These nerve surgery treatments may not be sufficiently effective in some children, resulting in remaining functional deficits and muscular imbalance.[2,5,7,10] In particular, restoration of external rotation remains incomplete in a large proportion of nerve-surgically treated infants.[12,13] In conservatively treated children, functional deficits and muscular imbalance may develop due to incomplete spontaneous recovery. As a result of muscular imbalance between the internal and external rotators of the shoulder, anatomical changes in the glenohumeral joint may develop, further limiting function.[14,15] Irrespective of treatment history, limited functional recovery of the shoulder and/or anatomical changes to the glenohumeral joint can occur, and this can be an indication for secondary surgery in which an internal contracture-release and/or muscle tendon transfer (ICR/MTT) is performed.[5,6,8,10,16-29] Observational studies on the outcome of such secondary surgical interventions show improvements in active and/or passive range of motion (aROM/pROM) and/or Mallet scores.[16-22,24-28,30] A recent meta-analysis on the outcome of secondary shoulder surgery confirms the effectiveness of these interventions.[31]

Two studies have employed subgroup analysis and reported outcomes separately for patients who have had prior nerve surgery and those who have not.[22,32] One study included 67 patients (mean age 6.4 years, mean follow-up 7.5 years, 37 had prior nerve surgery) who underwent secondary shoulder surgery.[22] The group without prior nerve surgery had better outcomes regarding ROM. The second study reported 91 patients with a tendon transfer to the shoulder, divided into 4 subgroups (upper- and total plexus lesions were analysed separately, and divided with regards to: with/without prior nerve surgery (20 vs 71 patients, respectively)). The group without prior nerve surgery had better pre-operative ROM, but outcome of surgery over time was comparable for the groups.[32] Two studies only included children who have had no prior nerve surgery.[20,33] In 1 study, only one child had prior nerve surgery and the outcomes for this child were described separately.[24] One study reported long-term results of abduction and external rotation.[34] This specific study reported that abduction decreased starting 6 years after surgery, whereas external rotation did not decrease over time.

Thusfar, no study has described the course of clinical outcome both in the long-term and in subgroups based on prior nerve surgery. Since children who have had nerve surgery are different from those who have not, in terms of early spontaneous recovery, these concern different subgroups of children within the NBPP population. Therefore, this long-term followup study aims to describe the course of ROM and function over time, as well as shoulder joint deformities pre-operatively, in 2 subgroups (with and without prior nerve surgery), in patients with NBPP undergoing an ICR and/or MTT.

PATIENTS AND METHODS

Study design

This study concerned a retrospective analysis of clinical data derived from paper or electronic medical records of children seen at the Leiden University Medical Center multidisciplinary brachial plexus clinic (1996–2014). All data were gathered during usual clinical care, according to a standardized (prospectively designed) protocol, and data extraction for the present study was performed between May 2013 and September 2014. The medical ethics committee of the Leiden University Medical Center waived informed consent for this prospective data collection, since it is part of good clinical practice for this tertiary referral clinic.

Patients

All children diagnosed with NBPP were eligible for the present study if they met the following inclusion criteria at the time of data extraction:

- treatment consisted of an internal contracture-release and/or muscle tendon transfer (ICR and/or MTT);
- an electronic or paper medical record was available;
- follow-up period of at least 6 months (first scheduled follow-up after surgery).

Surgical intervention and postoperative rehabilitation

Young children (under 4 years) received an ICR, whereas older children received an ICR and a MTT (mm. latissimus dorsi and teres major). The ICR was performed posteriorly as a subscapular muscle slide until 2002.[35] After 2002 an anterior ICR was performed.

ICR

The anterior ICR was performed through a 1–2-cm deltopectoral incision exposing the coracoid process. The coracohumeral ligament was released at the anterior capsule of the shoulder by an incision of approximately 3 mm (the width of a number 15 surgical knife blade).

MTT

Through a curved incision at the posterior axillary border, the mm. teres major and latissimus dorsi tendons were separately detached from the humerus. The humeral head was then exposed by a second incision cranial and posterior at the deltoid area, followed by a deltoid split. From the first incision, underneath the deltoid muscle the detached mm. teres major and/or latissimus dorsi were transferred to the m. infraspinatus/supraspinatus footprint area at the humeral head. The tendon(s) were independently fixed at the greater tuberosity of the humerus with transosseous sutures.

Rehabilitation consisted of 6 weeks Baycast plaster in slight shoulder abduction and external rotation position, followed by physical therapy twice a week for at least 3 months. Physical therapy consisted of maintaining passive and improving active joint mobility and muscle strength, and stimulating bimanual activities.

Assessments

Sociodemographic and disease characteristics

Age, gender, involved nerve roots, affected side and type of ICR/MMT: release or release and tendon transfer were recorded. History of nerve surgery prior to the ICR/MMT was extracted from the medical record and categorized.

Clinical follow-up

The following data were routinely recorded during the outpatient clinic visit according to a standardized protocol: pROM/aROM of the shoulder and Mallet score. Despite the follow-up protocol, exact timing of time-points differed among patients. Therefore, the following time-frames were defined for statistical analysis: pre-operatively (T0), 6 months (T1, range 0–9 months), 1 year (T2, range 10–18 months), 3 years (T3, range 19–42 months), 5 years (T4, range 43–66 months) and 10 years (T5, range 67–163 months). For analysis, follow-up time-points were defined as time windows about specified follow-up periods. The definition of time windows was based on completeness of data at all follow-up moments in a random selected number of 10 medical records and after consensus among the authors.

Glenohumeral joint deformity

Magnetic resonance imaging (MRI) was used to assess pre-operative glenohumeral joint deformity. From the MRI images the percentage of the humeral head anterior to the midscapular line (%PHHA) and glenoid version were measured.[14]

Shoulder range of motion

aROM of the shoulder in the directions external rotation (in 0º and 90º abduction) abduction, scapulohumeral adduction and forward flexion were recorded with a 5º precision level. In addition, pROM in the directions external rotation (in 0º and 90º abduction), glenohumeral abduction and backward flexion were recorded. All measurements were made using a goniometer.

Mallet score

Shoulder movements of the affected arm were measured using the modified Mallet score. This score measures often used arm movements, including overhead movements, with scores ranging from 1 = no function to 5 = normal function. The aggregated Mallet score was computed as well, with scores ranging from 5 (minimum) to 25 (maximum) points.[36-38]

Statistical analysis

Descriptive statistics were used for the clinical characteristics of the patients and the glenohumeral joint deformity at baseline (means with standard deviations (SD), frequencies with percentages, where appropriate). Difference over time for the clinical outcomes for the total group as well as for the 2 subgroups, were calculated by means of regression analyses using a linear mixed model, thereby taking into account the repeated measurements within-patients. Within the model follow-up time-points were the fixed effects and the patients the

random effect. Outcomes were expressed as estimated means with standard errors and as mean change scores with 95% confidence intervals (95% CI). The level of statistical significance was set at $p < 0.05$ for all analyses. All analyses were carried out using SPSS 20.0 software (IBM SPSS Statistics for Windows, Version 20.0, IBM Corp., Armonk, NY, USA).

RESULTS

A convenience sample of 115 children met the inclusion criteria. The mean follow-up duration was 6 years (SD 3.2 years, range 6 months to 13 years). The mean follow-up within the time windows defined for T1–T5 was as follows: T1; 4.5 months (SD 2.5); T2; 13.1 months (SD 2.6); T3; 29.4 months (SD 7.1); T4; 53.6 months (SD 6.7); and T5; 96.9 months (SD 23.9). The numbers of patients at the follow-up moments are shown in Figure 1.
The baseline patient characteristics are described in Table I. There were 60 boys and 55 girls with a mean age of 4.7 years (SD 3.3), with a total of 47 left sides and 68 right sides affected. Lesion extent was C5 (*n* = 2), C5/C6 (*n* = 66), C5–C7 (*n* = 40), C5–C8 (*n* = 4) and C5–T1 (*n* = 3). Eighty-two children (71.3%) had had prior nerve surgery (group with prior nerve surgery). Primary nerve surgery consisted of nerve reconstruction in 74 and neurolysis in 8 children.

Table I Pre-operative characteristics of all included children with Neonatal Brachial Plexus Palsy undergoing an internal contracture release or a combined internal contracture release and muscle tendon transfer.

	Total Group (n=115)	**Group without prior nerve-surgery (n=33)**	**Group with prior nerve-surgery (n=82)**
Gender			
Male (%)	60 (52.2)	18 (54.5)	42 (51.2)
Mean age at surgery (SD)	4.7 (3.3)	6.8 (4.3)	3.8 (2.3)
Affected side:			
Right (%)	68 (59.1)	16 (48.5)	52 (62.7)
Lesion extent:			
C5 (%)	2 1.7)	2 (6.3)	0 (0)
C5-C6 (%)	66 (57.4)	28 (84.8)	38 (46.3)
C5-C7 (%)	40 (34.8)	3 (9.4)	37 (44.6)
C5-C8 (%)	4 (3.5)	0 (0)	4 (4.8)
C5-T1 (%)	3 (2.6)	0 (0)	3 (3.6)
Surgical intervention			
Release (%)	32 (27.8)	11 (34.4)	21 (25.3)
Release/tendon transfer (%)	83 (72.2)	22 (66.7)	61 (74.4)
Mean %PHHA (SD)	33.6 (13.3)	36.0 (12.1)	32.7 (13.7)
Mean Glenoid version (SD)	-18.1 (9.7)	-19.2 (8.6)	-17.6 (10.1)

%PHHA: Percentage of Humeral Head Anterior to midscapular line. SD: Standard Deviation

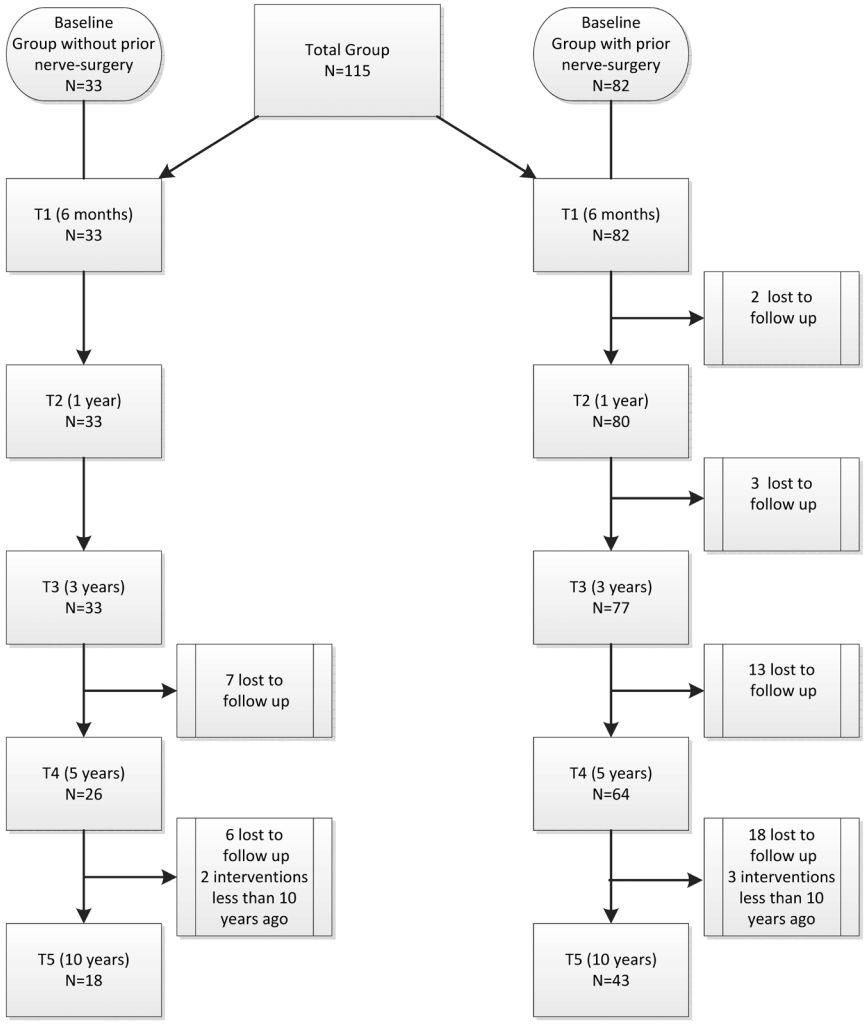

Figure 1 Flowchart showing number of patients in the two subgroups at the different follow up time points.

Depending on the severity of the nerve lesions and the availability of proximal stumps and/or graft material a reconstruction tailored to the individual was performed. The largest group consists of children in whom the superior trunk, or part of the efferents of the superior trunk were reconstructed (*n* = 64). Additional re-innervation was performed on the middle trunk (*n* = 9), the lower trunk (*n* = 1) or both (*n* = 1). The most frequent reconstruction was intraplexal grafting of the complete superior trunk (*n* = 46). The reconstruction of the suprascapular nerve and posterior division of the superior trunk were analysed, as these nerve elements innervate shoulder motion. The suprascapular nerve was reconstructed in

65 infants by means of grafting (*n* = 52) or transfer (*n* = 12). In 6 children reconstruction of the suprascapular nerve was not possible, in 4 children with partial lesions the trajectory to the suprascapular nerve was left intact, while other trajectories were reconstructed. The posterior division of the superior trunk was grafted in 64 children; no reconstruction of the posterior division had been performed in 5 children, and the trajectory to the posterior division was left untouched in 6. The remaining 33 children were conservatively treated (group without prior nerve surgery), usually consisting of contracture prevention and maintaining function by a physical therapist.

Pre-operative values for the group without prior nerve surgery and the group with prior nerve surgery differed in absolute values of ROM in terms of: active external rotation in 0° abduction, abduction, forward flexion and scapulohumeral adduction as well as in the aggregated Mallet score. These measures showed better results in the group without prior nerve surgery compared with the group with nerve surgery (more than 5° in ROM and more than one point in the aggregated Mallet score).

Overall, improvements in aROM, pROM and Mallet scores were seen in all groups. During follow-up, these improvements were largely similar in both groups. The largest changes were found between T0 and T1. Almost all changes within the groups are significant at all time-points, with the exception of active scapulohumeral adduction. In addition, improvement in passive glenohumeral abduction was not significant in the group without prior nerve surgery. Backward flexion and Mallet "Hand to Back" decreased significantly over time, but only for the group with prior nerve surgery. Overall, there was a general tendency to a decrease in function from T1 onwards for both subgroups. Changes over time with 95% CI are shown in Tables II–IV.

Table II and Figures 2–4 show the course of aROM. With the exception of active scapulohumeral adduction in all groups, aROM improved significantly at all time-points compared with baseline. The largest improvement was seen at T1, whereas at later time-points the differences with the pre-operative situation decreased. At all follow-up timepoints, most absolute values of the aROM measures were more favourable in the group without prior nerve surgery than in the group with prior nerve surgery. Only absolute values for external rotation in 0° and 90° abduction were higher for the group with prior nerve surgery.

The course of pROM is shown in Table III. The pre-operative values of pROM were similar in the group without prior nerve surgery and the group with prior nerve surgery. Except for backward flexion and glenohumeral abduction in both groups, all measures of pROM improved significantly at all time-points compared with baseline. Backward flexion decreased significantly at all time-points for the group with prior nerve surgery and for the group without prior nerve surgery only at T1. Like the clinical course of aROM, after an initially large improvement directly following surgery, differences from baseline decreased gradually in both subgroups. This pattern was, however, not seen for backward flexion in the group without prior nerve surgery, which improved after an initial decline at T1.

Table II Active shoulder range of motion pre-operatively and at follow-up in children with Neonatal Brachial Plexus Palsy, with and without prior nerve-surgery, undergoing an internal contracture release or a combined internal contracture release and muscle tendon transfer.

Active range of motion; degrees.	Pre-operative (T0) Estimated mean (S.E.)	T0-T1 Change sc. (95%CI)	T0-T2 Change sc. (95%CI)	T0-T3 Change sc. (95%CI)	T0-T4 Change sc. (95%CI)	T0-T5 Change sc. (95% CI)
Total group						
External rotation (0 degrees of abduction)	-69.0 (3.3)	73.0 (65.3-80.7)	62.4 (54.5-70.2)	65.0 (57.5-72.6)	61.8 (53.7-69.8)	59.0 (50.0-68.1)
External rotation (90 degrees of abduction)	4.3 (3.0)	47.7 (41.2-54.3)	41.8 (35.0-48.5)	47.0 (40.5-53.5)	42.2 (35.4-49.0)	38.6 (31.2-46.0)
Abduction	74.4 (4.4)	46.2 (38.1-54.3)	41.1 (32.7-49.5)	52.8 (44.9-60.7)	50.5 (42.0-58.9)	50.1 (40.8-59.4)
Scapulohumeral adduction	42.5 (1.7)	-0.9 (-5.8-3.8)	-0.8 (-5.2-3.6)	-0.01 (-4.4-4.2)	-6.2 (-11.1- -1.0)	-6.4 (-11.7- -1.0)
Forward flexion	103.2 (4.2)	28.0 (20.9-35.1)	27.5 (20.3-34.7)	33.8 (27.1-40.5)	34.1 (27.0-41.2)	29.0 (21.1-36.9)
Group without prior nerve-surgery						
External rotation (0 degrees of abduction)	-56.5 (5.5)	62.4 (49.8-74.9)	47.8 (34.7-61.0)	48.7 (36.4-60.9)	41.9 (28.3-55.5)	42.8 (27.7-57.8)
External rotation (90 degrees of abduction)	6.7 (5.5)	41.1(29.8-52.5)	37.0 (25.3-48.8)	41.0 (29.7-52.2)	37.7 (25.6-49.8)	25.4 (12.3-38.5)
Abduction	88.1 (8.5)	45.6 (30.9-60.4)	41.0 (25.1-57.0)	46.6 (31.9-61.3)	51.9 (35.7-68.0)	57.7 (40.3-75.1)
Scapulohumeral adduction	37.2 (2.2)	1.8 (-3.2-6.8)	5.4 (0.45-10.4)	1.6 (-3.1-6.4)	1.1 (-4.2-6.5)	-4.7 (-12.2-0.8)
Forward flexion	124.3 (7.7)	20.7 (8.0-33.3)	21.1 (7.3-34.9)	20.6 (8.2-32.9)	24.2 (10.7-37.7)	21.0 (6.3-35.7)
Group with prior nerve-surgery						
External rotation (0 degrees of abduction)	-74.5 (4.0)	77.6 (68.2-87.1)	68.6 (59.1-78.2)	72.1 (62.9-81.4)	69.8 (60.1-79.5)	65.9 (54.9-77.0)
External rotation (90 degrees of abduction)	3.6 (3.5)	50.3 (42.2-58.4)	43.4 (35.2-51.7)	49.2 (41.4-57.1)	43.8 (35.6-51.9)	43.7 (34.7-52.7)
Abduction	68.7 (4.9)	46.4 (36.8-56.1)	41.3 (31.4-51.2)	55.1 (45.8-64.5)	50.1 (40.1-60.1)	46.9 (35.8-58.0)
Scapulohumeral adduction	44.8 (2.2)	-1.4 (-8.1-5.4)	-3.5 (-9.5-2.5)	-0.9 (-6.7-5.0)	-9.5 (-16.2- -2.9)	-7.3 (-14.9-0.2)
Forward flexion	95.2 (4.8)	30.3 (21.7-38.9)	29.6 (21.0-38.1)	38.7 (30.7-46.6)	37.4 (29.0-45.8)	31.6 (22.2-41.0)

Change sc. = Change score; S.E.: Standard Error. T1: 6 months follow up, T2: 1 year follow up, T3: 3 year follow up, T4: 5 year follow up, T5: 10 year follow up.

Table III Passive shoulder range of motion and muscle strength pre-operatively and at follow-up in children with Neonatal Brachial Plexus Palsy, with and without prior nerve-surgery, undergoing an internal contracture release or a combined internal contracture release and muscle tendon transfer.

Passive range of motion; degrees.	Pre-operative (T0) Estimated mean (S.E.)	T0-T1 Change sc. (95% CI)	T0-T2 Change sc. (95% CI)	T0-T3 Change sc. (95% CI)	T0-T4 Change sc. (95% CI)	T0-T5 Change sc. (95% CI)
Total group						
External rotation (0 degrees of abduction)	-7.7 (2.2)	40.3 (35.0-45.5)	38.0 (32.5-43.3)	38.8 (33.5-44.0)	30.6 (25.0-36.2)	25.4 (19.1-31.8)
External rotation (90 degrees of abduction)	47.0 (1.7)	28.1 (23.7-32.4)	25.6 (21.1-30.1)	28.8 (24.5-33.1)	20.3 (15.7-24.9)	17.4 (12.2-22.5)
Glenohumeral abduction	84.4 (1.3)	3.4 (1.4-5.4)	2.2 (0.2-4.2)	4.5 (2.6-6.4)	2.5 (0.5-4.5)	0.2 (-2.0-2.5)
Backward flexion	50.5 (3.3)	-14.5 (-20.7- -8.3)	-13.9 (-20.7- -7.0)	-15.8 (-22.8- -8.9)	-16.3 (-24.8- -7.8)	-13.5 (-24.9- -2.2)
Group without prior nerve-surgery						
External rotation (0 degrees of abduction)	-4.4 (3.9)	36.1 (26.6-45.6)	34.6 (24.7-44.4)	25.2 (15.9-34.5)	15.6 (5.4-25.9)	11.6 (0.4-22.9)
External rotation (90 degrees of abduction)	44.7 (3.1)	31.1 (23.4-38.8)	26.9 (18.2-33.7)	26.0 (18.2-33.9)	20.5 (12.0-29.0)	18.0 (8.9-27.2)
Glenohumeral abduction	84.6 (1.6)	2.8 (-0.3-5.9)	-0.2 (-3.4-3.1)	3.1 (0.1-6.0)	0.6 (-2.7-4.0)	2.4 (-1.3-6.2)
Backward flexion	52.0 (6.4)	-14.0 (-26.6- -1.0)	-9.1 (-23.7-5.4)	-7.9 (-21.8-6.1)	-0.2 (-17.7-17.2)	-3.2 (-22.6-16.3)
Group with prior nerve-surgery						
External rotation (0 degrees of abduction)	-9.1 (2.6)	42.0 (35.8-48.2)	39.5 (33.1-45.9)	44.4 (38.2-50.5)	36.3 (29.8-42.8)	31.3 (23.8-38.8)
External rotation (90 degrees of abduction)	47.9 (2.1)	26.7 (21.4-32.0)	25.1 (19.6-30.6)	29.9 (24.7-35.1)	20.2 (14.6-25.7)	17.1 (10.9-23.3)
Glenohumeral abduction	84.3 (1.6)	3.7 (1.2-6.2)	3.1 (0.6-5.6)	5.1 (2.7-7.4)	3.3 (0.8-5.7)	-0.4 (-3.2-2.4)
Backward flexion	49.2 (3.7)	-14.4 (-21.5- -7.4)	-15.0 (-22.7- -7.4)	-19.4 (-27.4- -11.4)	-22.6 (-32.3- -13.0)	-19.0 (-33.7- -4.2)

Change sc. = Change score; S.E.: Standard Error. T1: 6 months follow up, T2: 1 year follow up, T3: 3 year follow up, T4: 5 year follow up, T5: 10 year follow up.

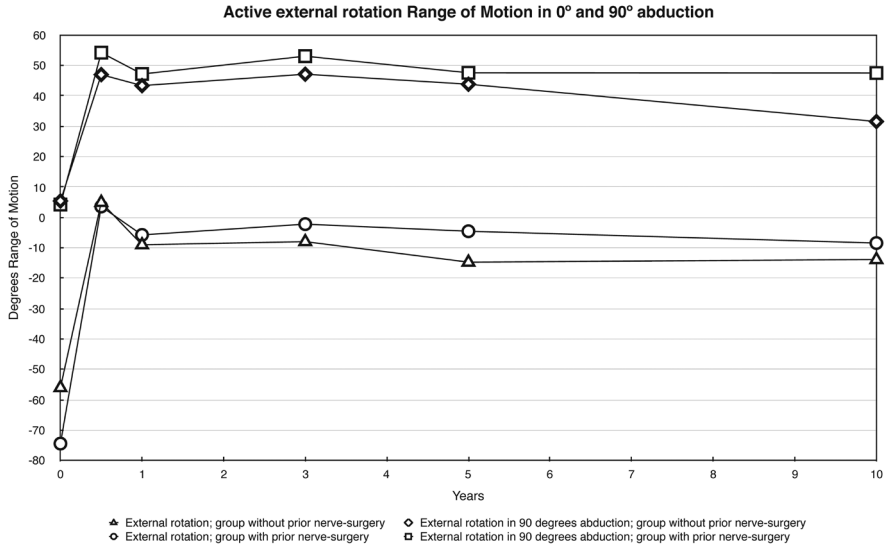

Figure 2 Course of active external Range of Motion in 0° and 90° of abduction over time in two subgroups based on estimated means and mean changes from the mixed linear model; from pre-surgery (T0) to 6 months (i.e. T0+mean change T1), to 10 years post-surgery (i.e. T0+ mean change T5). Differences between T0 and all other time points statistically significant for all groups and variables.

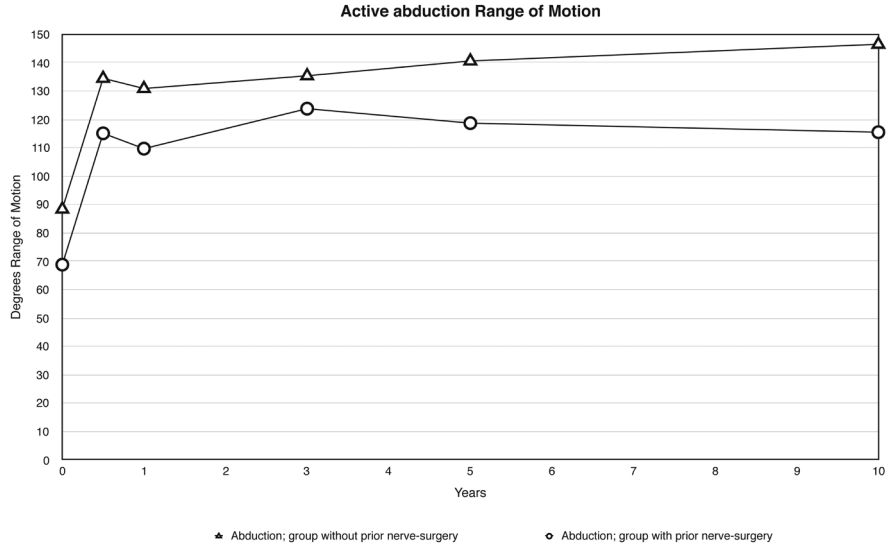

Figure 3 Course of active abduction Range of Motion over time in two subgroups based on estimated means and mean changes from the mixed linear model; from pre-surgery (T0) to 6 months (i.e. T0+mean change T1), to 10 years post-surgery (i.e. T0+ mean change T5). Differences between T0 and all other time points statistically significant for all groups.

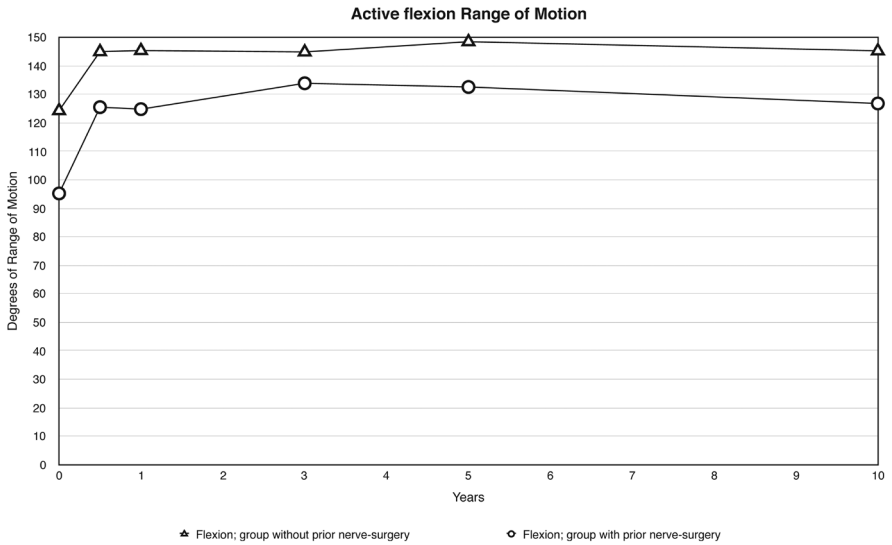

Figure 4 Course of active forward flexion Range of Motion over time in two subgroups based on estimated means and mean changes from the mixed linear model; from pre-surgery (T0) to 6 months (i.e. T0+mean change T1), to 10 years post-surgery (i.e. T0+ mean change T5). Differences between T0 and all other time points statistically significant for all groups.

The course of Mallet scores is shown in Table IV and Figure 5. Pre-operative Mallet scores were similar in the group without prior nerve surgery compared with the group with prior nerve surgery, except for the "Aggregated score", which was 2 points greater in the group without prior nerve surgery. Except for the "Hand to Back" item in all groups, there was a significant improvement compared with baseline for all Mallet items, including the aggregated score. The "Hand to Back" item decreased significantly at all time-points for the group with prior nerve surgery and for the group without prior nerve surgery only at T1. This is in line with the previous pROM findings. The largest improvements in Mallet scores were seen at T1 and T2, whereas at later time-points the differences to the preoperative situation overall decreased. At all follow-up time-points, all absolute Mallet scores, except for the "External Rotation" item at T4 and T5, were more favourable in the group without prior nerve surgery than in the group with prior nerve surgery, leaving the group without prior nerve surgery with better function according to the Mallet score.

Table IV Shoulder function pre-operatively and at follow-up in children with Neonatal Brachial Plexus Palsy, with and without prior nerve-surgery, undergoing an internal contracture release or a combined internal contracture release and muscle tendon transfer.

Mallet score (1-5)	Pre-operative (T0) Estimated mean (S.E.)	T0-T1 Change sc. (95% CI)	T0-T2 Change sc. (95% CI)	T0-T3 Change sc. (95% CI)	T0-T4 Change sc. (95% CI)	T0-T5 Change sc. (95% CI)
Total group						
Abduction	3.2 (0.06)	0.60 (0.46-0.75)	0.47 (0.32-0.62)	0.58 (0.44-0.72)	0.44 (0.30-0.59)	0.41 (0.24-0.57)
External rotation	1.03 (0.11)	1.35 (1.10-1.61)	1.34 (1.07-1.60)	0.99 (0.75-1.24)	0.91 (0.65-1.17)	0.69 (0.41-0.98)
Hand to Head	2.51 (0.08)	1.05 (0.87-1.22)	1.10 (0.91-1.28)	1.06 (0.89-1.23)	0.99 (0.81-1.17)	0.87 (0.67-1.06)
Hand to Back	3.20 (0.10)	-0.50 (-0.70- -0.30)	-0.32 (-0.52- -0.11)	-0.36 (-0.54- -0.17)	-0.44 (-0.64- -0.24)	-0.43 (-0.65- -0.21)
Hand to Mouth	2.61 (0.07)	0.92 (0.75-1.10)	0.76 (0.58-0.94)	0.79 (0.63-0.96)	0.65 (0.48-0.83)	0.43 (0.24-0.63)
Mallet aggregated score	12.49 (0.24)	3.46 (2.91-4.02)	3.32 (2.75-3.88)	3.10 (2.57-3.61)	2.73 (2.18-3.28)	2.02 (1.41-2.63)
Group without prior nerve-surgery						
Abduction	3.35 (0.11)	0.55 (0.33-0.78)	0.38 (0.13-0.64)	0.44 (0.22-0.66)	0.40 (0.16-0.64)	0.56 (0.31-0.81)
External rotation	1.25 (0.20)	1.19 (0.71-1.68)	1.32 (0.80-1.84)	0.89 (0.43-1.34)	0.60 (0.10-1.11)	0.24 (-0.30-0.77)
Hand to Head	2.70 (0.13)	0.87 (0.54-1.19)	1.02 (0.66-1.37)	0.94 (0.63-1.25)	0.86 (0.52-1.20)	0.98 (0.62-1.33)
Hand to Back	3.56 (0.14)	-0.38 (-0.74- -0.03)	-0.14 (-0.52-0.25)	-0.07 (-0.41-0.27)	-0.34 (-0.71-0.03)	-0.21 (-0.60-0.18)
Hand to Mouth	2.57 (0.12)	1.15 (0.85-1.45)	0.89 (0.56-1.21)	1.00 (0.72-1.29)	0.80 (0.48-1.12)	0.60 (0.27-0.93)
Mallet aggregated score	13.29 (0.42)	3.53 (2.62-4.43)	3.78 (2.76-4.80)	3.26 (2.39-4.12)	2.40 (1.42-3.37)	2.23 (1.23-3.23)
Group with prior nerve-surgery						
Abduction	3.10 (0.08)	0.63 (0.45-0.82)	0.51 (0.32-0.69)	0.64 (0.47-0.81)	0.47 (0.29-0.65)	0.34 (0.14-0.54)
External rotation	0.94 (0.14)	1.43 (1.12-1.74)	1.37 (1.06-1.69)	1.05 (0.76-1.33)	1.04 (0.73-1.35)	0.90 (0.56-1.25)
Hand to Head	2.43 (0.09)	1.13 (0.91-1.34)	1.14 (0.92-1.35)	1.12 (0.92-1.32)	1.05 (0.84-1.26)	0.82 (0.58-1.05)
Hand to Back	3.04 (0.11)	-0.55 (-0.80- -0.30)	-0.38 (-0.62- -0.14)	-0.45 (-0.67- -0.22)	-0.46 (-0.70- -0.23)	-0.50 (-0.77- -0.24)
Hand to Mouth	2.63 (0.08)	0.83 (0.61-1.04)	0.71 (0.49-0.92)	0.70 (0.50-0.90)	0.58 (0.37-0.79)	0.35 (0.11-0.59)
Mallet aggregated score	12.19 (0.28)	3.47 (2.80-4.16)	3.21 (2.53-3.89)	3.00 (2.36-3.64)	2.83 (2.16-3.35)	1.88 (1.12-2.63)

Change sc. = Change score; S.E.: Standard Error. T1: 6 months follow up, T2: 1 year follow up, T3: 3 year follow up, T4: 5 year follow up, T5: 10 year follow up.

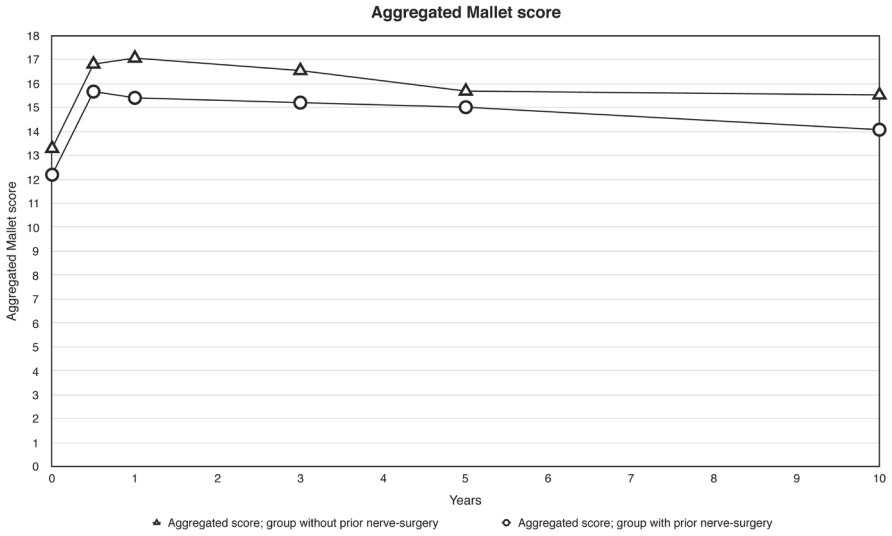

Figure 5 Course of the aggregated Mallet score over time in two subgroups based on estimated means and mean changes from the mixed linear model; from pre-surgery (T0) to 6 months (i.e. T0+mean change T1), to 10 years post-surgery (i.e. T0+ mean change T5). Differences between T0 and all other time points statistically significant for all groups.

DISCUSSION

This long-term follow-up study (over a mean of 6 years) reported the outcomes of secondary shoulder surgery in 115 children with NBPP. In children, both with and without prior nerve surgery, shoulder passive and active external rotation, (glenohumeral) abduction and forward flexion ROM, as well as almost all Mallet score items, improved significantly. Children without prior nerve surgery had overall better pre-operative shoulder function. The positive effects of surgery decreased over time, to some extent, but differences from baseline remained statistically significant. Only backward flexion and the Mallet "Hand to Back" item decreased significantly. The children who were conservatively treated before secondary shoulder surgery had an overall better shoulder function at all follow-up time-points than the children who had undergone nerve surgery prior to shoulder surgery. Only active and passive external rotation, both in 0° and 90° abduction, are slightly better at all follow-up time-points after secondary shoulder surgery for children who had undergone prior nerve surgery.

The favourable effect on ROM and Mallet scores in children with NBPP in the current study is in line with the results of several other studies [16-22,24-30,39,40] and a recent meta-analysis.[31] The same holds for the negative effect on backward flexion and the possibility of bringing the arm to the back.[20,22]

In contrast to the current study, most other studies regarding the outcome of secondary shoulder surgery in children with NBPP did not take prior nerve surgery into account [21,41] or reported the outcomes for both groups as a single series.[16-20,24-30,39,40] Only 2 studies on the outcomes of secondary shoulder surgery described the outcomes for the 2 groups separately.[22,32] One study found, similar to the current study, that those children who have had prior nerve surgery had worse ROM at baseline.[32] The other study only stated that improvement in ROM was greater for the group without prior nerve surgery [22], which is opposed to the findings in the current study, where improvements were similar. However, the absolute values of all endpoint measures, except external rotation, in the current study were more favourable in the group without prior nerve surgery. The number of included patients in the present study who had nerve surgery was relatively high compared with other studies. This is related to the fact that, in the Netherlands, this surgery is performed in 3 centres, of which Leiden is the largest and is also a "last resort" facility for babies with NBPP.[29,30]

Secondary surgery is performed in children with NBPP with limited shoulder function and possible joint deformities, irrespective of prior nerve surgery. The differences in pre-operative characteristics of the group without prior nerve surgery and the group with prior nerve surgery, and the clinical course over time after surgery made it clear that these 2 groups concern different subgroups of patients. Moreover, children in the group with prior nerve surgery were, on average, 3 years younger at the time of surgery. This indicates that these children show shoulder problems earlier in life, possibly because of worse function and/or neurological recovery, and this again shows that both groups differ from each other. Primary nerve surgery is performed only in those children who show no, or insufficient, recovery of function around 3–6 months after birth [11], thus constituting a selected group of children. This phenomenon is usually designated as "confounding by indication", and this makes the outcomes of these subgroups not directly comparable.[42]

Regarding the long-term outcomes of secondary shoulder surgery, most other studies do not show the course of clinical outcome over time at different time-points, but only give pre-operative and post-operative values for the outcomes at a single point in time, which may vary largely among individual patients.[16-22,24-28,39,40] The present study included multiple time-points, which made it clear that the beneficial effect decreases with time, except for backward flexion, which after an initial decline, improved only in the group without prior nerve surgery. The largest decrease was seen for shoulder external rotation ROM, especially in 0° abduction, and for the Mallet "external rotation" item after 6 months' follow-up. Decrease in shoulder function after secondary surgery has been described previously by one study, in particular for abduction 6 years after surgery.[34] In the current study, a gradual decrease was also seen for other outcomes. The decrease in effect might be related to the fact that patients may stop doing exercises at some time after surgery. The question is whether the decrease is clinically relevant, as patients may not always need the full extent of their gained ROM to perform daily activities. Moreover, despite the decrease, more than 5 years after surgery, shoulder function was overall still significantly better than pre-operatively.

This study has a number of limitations. First, there was a variation in follow-up moments between individuals, due to the fact that data was gathered in routine clinical care (e.g. sometimes appointments were rescheduled). Therefore, for analysis, follow-up windows (combining follow-up moments) were defined. The chosen time windows were wide, thus aggregating all available data. Nevertheless, missing data of some patients were present at certain time-points. Between 5 and 10 years after surgery, a number of patients were lost to follow-up; perhaps this group of patients had good clinical function and did not see the necessity of follow-up, or had other reasons not to participate in follow-up. Thus, the group remaining at long term follow-up is prone to selection bias. To a certain extent statistical analyses of the data by means of a linear mixed model deals with missing data. Measurements were made prospectively with a goniometer during regular patient care by 3 dedicated clinicians over time. Thus, intra and inter-observer variability might be present. A long-term prospective outcome study with fixed time-points, to which patients and parents adhere, could solve this limitation. Even so, children may become ill, resulting in rescheduling and thus possible missing data. Secondly, some of the pre-operative patient characteristics, other than the clinical outcomes, varied in terms of type and extent of the lesion within and between both subgroups. The group without prior nerve surgery include only C5/C6±C7 lesions and the group with prior nerve surgery also had 7 children with involvement of C8 and/or T1. Thirdly, 2 types of secondary surgical interventions were used within both groups and a change in operating technique for the ICR was made in 2002. Because all procedures (ICR and ICR/MTT) are designed to improve aROM, pROM and function, no subgroup analyses were done based upon the chosen intervention and/or technique. Fourthly, the size of the 2 subgroups were different, with more patients in the group with prior nerve surgery (82 vs 33). However, these patients differ in lesion severity by definition and clinical outcomes of the secondary surgical intervention may not be directly compared between these groups. Fifthly, no patient reported outcome measure or functional assessment was included, besides the Mallet score. The Mallet score, however, only measures function and not activities. Future studies should include analyses of activities and participation according to ICF standards [43] to further comprehend the outcome of secondary surgery around the shoulder.

In conclusion, the present study shows that, in children with NBPP, shoulder function improves after an ICR/MTT, irrespective of whether they have had prior nerve surgery. Over the course of time the effects of secondary surgery decreased, but differences from baseline remained significant, indicating permanently improved shoulder function. However, this study also showed that pre-operative and postoperative shoulder function with respect to active external rotation in 0° abduction, abduction, forward flexion and scapulohumeral adduction ROM and the aggregated Mallet score, were better at all time-points in children without prior nerve surgery compared with children who had nerve surgery, indicating that both groups are different entities, and should be reported separately. Reporting the outcomes for the 2 groups separately on multiple time-points, will prevent an over- or under-estimation of the results of the orthopaedic intervention and is a good option to

provide more accurate, detailed information. More detailed information on the expected treatment outcome over time, taking into account prior nerve surgery, is important for parents and children and can contribute to the quality of the decision-making process for parents of patients and treating physicians.

REFERENCES

1. Malessy MJ, Pondaag W. Obstetric brachial plexus injuries. *Neurosurg.Clin.N.Am.* 2009;20(1):1-14.
2. Pondaag W, Malessy MJ, van Dijk JG, Thomeer RT. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev.Med.Child Neurol.* 2004;46(2):138-144.
3. Hoeksma AF, ter Steeg AM, Nelissen RG, van Ouwerkerk WJ, Lankhorst GJ, de Jong BA. Neurological recovery in obstetric brachial plexus injuries: an historical cohort study. *Dev. Med.Child Neurol.* 2004;46(2):76-83.
4. Lagerkvist AL, Johansson U, Johansson A, Bager B, Uvebrant P. Obstetric brachial plexus palsy: a prospective, population-based study of incidence, recovery, and residual impairment at 18 months of age. *Developmental medicine and child neurology.* 2010;52(6):529-534.
5. Vekris MD, Lykissas MG, Beris AE, Manoudis G, Vekris AD, Soucacos PN. Management of obstetrical brachial plexus palsy with early plexus microreconstruction and late muscle transfers. *Microsurgery.* 2008;28(4):252-261.
6. Haerle M, Gilbert A. Management of complete obstetric brachial plexus lesions. *J.Pediatr. Orthop.* 2004;24(2):194-200.
7. Waters PM. Comparison of the natural history, the outcome of microsurgical repair, and the outcome of operative reconstruction in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 1999;81(5):649-659.
8. Hale HB, Bae DS, Waters PM. Current concepts in the management of brachial plexus birth palsy. *J.Hand Surg.Am.* 2010;35(2):322-331.
9. Kirjavainen M, Remes V, Peltonen J, et al. Long-term results of surgery for brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2007;89(1):18-26.
10. Waters PM. Update on management of pediatric brachial plexus palsy. *J.Pediatr.Orthop.B.* 2005;14(4):233-244.
11. Pondaag W, Malessy MJ. The evidence for nerve repair in obstetric brachial plexus palsy revisited. *Biomed.Res.Int.* 2014;2014:434619.
12. Pondaag W, de BR, van Wijlen-Hempel MS, Hofstede-Buitenhuis SM, Malessy MJ. External rotation as a result of suprascapular nerve neurotization in obstetric brachial plexus lesions. *Neurosurgery.* 2005;57(3):530-537.
13. Tse R, Marcus JR, Curtis CG, Dupuis A, Clarke HM. Suprascapular nerve reconstruction in obstetrical brachial plexus palsy: spinal accessory nerve transfer versus C5 root grafting. *Plast Reconstr Surg.* 2011;127(6):2391-2396.
14. Hogendoorn S, van Overvest KL, Watt I, Duijsens AH, Nelissen RG. Structural changes in muscle and glenohumeral joint deformity in neonatal brachial plexus palsy. *J.Bone Joint Surg.Am.* 2010;92(4):935-942.
15. Waters PM, Smith GR, Jaramillo D. Glenohumeral deformity secondary to brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 1998;80(5):668-677.
16. Edwards TB, Baghian S, Faust DC, Willis RB. Results of latissimus dorsi and teres major transfer to the rotator cuff in the treatment of Erb's palsy. *J.Pediatr.Orthop.* 2000;20(3):375-379.
17. Phipps GJ, Hoffer MM. Latissimus dorsi and teres major transfer to rotator cuff for Erb's palsy. *J.Shoulder.Elbow.Surg.* 1995;4(2):124-129.
18. Suenaga N, Minami A, Kaneda K. Long-term results of multiple muscle transfer to reconstruct shoulder function in patients with birth palsy: eleven-year follow-up. *J.Pediatr. Orthop.* 1999;19(5):669-671.
19. van der Sluijs JA, van Ouwerkerk WJ, de GA, Nollet F, Winters H, Wuisman PI. Treatment of internal rotation contracture of the shoulder in obstetric brachial plexus lesions by subscapular tendon lengthening and open reduction: early results and complications. *J.Pediatr.Orthop.B.* 2004;13(3):218-224.
20. Aydin A, Ozkan T, Onel D. Does preoperative abduction value affect functional outcome of combined muscle transfer and release procedures in obstetrical palsy patients with shoulder involvement? *BMC.Musculoskelet. Disord.* 2004;5:25.
21. Vallejo GI, Toh S, Arai H, Arai K, Harata S. Results of the latissimus dorsi and teres major tendon transfer on to the rotator cuff for brachial plexus palsy at birth. *Scand.J.Plast.Reconstr.Surg.Hand Surg.* 2002;36(4):207-211.
22. Terzis JK, Kokkalis ZT. Outcomes of secondary shoulder reconstruction in obstetrical brachial plexus palsy. *Plast.Reconstr.Surg.* 2008;122(6):1812-1822.
23. Julka A, Vander Have KL. Shoulder sequelae of neonatal brachial plexus injuries: orthopedic assessment and management. *J.Pediatr.Rehabil. Med.* 2011;4(2):131-140.
24. Chen L, Gu YD, Hu SN. Applying transfer of trapezius and/or latissimus dorsi with teres major for reconstruction of abduction and external rotation of the shoulder in obstetrical brachial plexus palsy. *J.Reconstr.Microsurg.* 2002;18(4):275-280.
25. Cohen G, Rampal V, Aubart-Cohen F, Seringe R, Wicart P. Brachial plexus birth palsy shoulder deformity treatment using subscapularis release combined to tendons transfer. *Orthop. Traumatol.Surg.Res.* 2010;96(4):334-339.
26. Abdel-Ghani H, Hamdy KA, Basha N, Tarraf YN. Tendon transfer for treatment of internal rotation contracture of the shoulder in brachial plexus birth palsy. *J.Hand Surg.Eur.* 2012;37(8):781-786.

27. Ozben H, Atalar AC, Bilsel K, Demirhan M. Transfer of latissmus dorsi and teres major tendons without subscapularis release for the treatment of obstetrical brachial plexus palsy sequela. *J.Shoulder.Elbow.Surg.* 2011;20(8):1265-1274.
28. Ozturk K, Bulbul M, Demir BB, Buyukkurt CD, Ayanoglu S, Esenyel CZ. Reconstruction of shoulder abduction and external rotation with latissimus dorsi and teres major transfer in obstetric brachial plexus palsy. *Acta Orthop. Traumatol.Turc.* 2010;44(3):186-193.
29. Hultgren T, Jonsson K, Pettersson H, Hammarberg H. Surgical correction of a rotational deformity of the shoulder in patients with obstetric brachial plexus palsy: Short-term results in 270 patients. *Bone Joint J.* 2013;95-B(10):1432-1438.
30. Kambhampati SB, Birch R, Cobiella C, Chen L. Posterior subluxation and dislocation of the shoulder in obstetric brachial plexus palsy. *J Bone Joint Surg Br*. 2006;88(2):213-219.
31. Louden EJ, Broering CA, Mehlman CT, Lippert WC, Pratt J, King EC. Meta-analysis of function after secondary shoulder surgery in neonatal brachial plexus palsy. *J.Pediatr.Orthop.* 2013;33(6):656-663.
32. Aydin A, Bicer A, Ozkan T, Mersa B, Ozkan S, Yildirim ZH. Does primary brachial plexus surgery alter palliative tendon transfer surgery outcomes in children with obstetric paralysis? *BMC.Musculoskelet.Disord.* 2011;12:74.
33. Noaman HH. Anterior shoulder release and tendon transfer as 1-stage procedure for treatment of internal rotation contracture deformity in obstetric brachial plexus injuries. *Ann.Plast.Surg.* 2013;71(5):510-518.
34. Pagnotta A, Haerle M, Gilbert A. Long-term results on abduction and external rotation of the shoulder after latissimus dorsi transfer for sequelae of obstetric palsy. *Clin.Orthop.Relat Res.* 2004(426):199-205.
35. Gilbert A, Brockman R, Carlioz H. Surgical treatment of brachial plexus birth palsy. *Clin. Orthop.Relat Res.* 1991(264):39-47.
36. Bae DS, Waters PM, Zurakowski D. Reliability of three classification systems measuring active motion in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2003;85-A(9):1733-1738.
37. Bae DS, Waters PM, Zurakowski D. Correlation of pediatric outcomes data collection instrument with measures of active movement in children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(5):584-592.
38. van der Sluijs JA, van Doorn-Loogman MH, Ritt MJ, Wuisman PI. Interobserver reliability of the Mallet score. *J.Pediatr.Orthop.B.* 2006;15(5):324-327.
39. Thatte MR, Agashe MV, Rao A, Rathod CM, Mehta R. Clinical outcome of shoulder muscle transfer for shoulder deformities in obstetric brachial plexus palsy: A study of 150 cases. *Indian J.Plast. Surg.* 2011;44(1):21-28.
40. Dedini RD, Bagley AM, Molitor F, James MA. Comparison of pediatric outcomes data collection instrument scores and range of motion before and after shoulder tendon transfers for children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(2):259-264.
41. Pearl ML, Edgerton BW, Kazimiroff PA, Burchette RJ, Wong K. Arthroscopic release and latissimus dorsi transfer for shoulder internal rotation contractures and glenohumeral deformity secondary to brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2006;88(3):564-574.
42. Hak E, Verheij TJ, Grobbee DE, Nichol KL, Hoes AW. Confounding by indication in non-experimental evaluation of vaccine effectiveness: the example of prevention of influenza complications. *J.Epidemiol.Community Health.* 2002;56(12):951-955.
43. Forget NJ, Higgins J. Comparison of generic patient-reported outcome measures used with upper extremity musculoskeletal disorders: linking process using the International Classification of Functioning, Disability, and Health (ICF). *J Rehabil Med.* 2014;46(4):327-334.

CHAPTER FOUR

Translation and adaptation of the Pediatric Outcome Data Collecting Instrument (PODCI) into the Dutch language and preliminary validation in children with neonatal brachial plexus palsy

Menno van der Holst | Thea P.M. Vliet Vlieland | Michiel A.J. van de Sande
Janneke C. van Egmond-van Dam | Henricus M. Vermeulen | Rob G.H.H. Nelissen

Published:
Journal of Pediatric Rehabilitation Medicine: An Interdisciplinary Approach
8 (2015) 219–226 DOI 10.3233/PRM-150338
Poster abstract presentation VRA congress november 2014, Rotterdam,
The Netherlands

ABSTRACT

Objective

This study aimed to translate and cross-culturally adapt the Pediatric Outcome Data Collecting Instrument (PODCI) into the Dutch language and evaluate its measurement properties among children (age 3–10) with Neonatal Brachial Plexus Palsy (NBPP).

Patients and methods

The PODCI was translated and adapted according to international guidelines and administered to 10 children with NBPP before and after surgery and thereafter twice again. Subsequently, the Mallet-score, Assisting Hand Assessment and active Range of Motion (aROM) were recorded. Cronbach's-α and correlations between the PODCI and other outcome measures were determined, as well as Intraclass Correlation Coefficients (ICC). In addition, effect sizes (ES), Standard Response Means (SRM) and change scores with the 95% Confidence Interval (95% CI) were calculated.

Results

The final Dutch PODCI 'Upper Extremity and Physical Function' subscale and total score 'Global Functioning' showed good internal consistency (Cronbach's-α 0.695/0.781) and reliability (ICC 0.97/0.80) and were significantly associated with aROM and the Mallet-score. After surgery, a significant change of the total score (ES 0.57, SRM 1.23, change 4.22 points, 95% CI 1.04–7.4) was seen.

Conclusions

The final Dutch PODCI had good measurement properties and appears useful in evaluating quality of life and functioning in children with NBPP.

INTRODUCTION

Neonatal Brachial Plexus Palsy (NBPP) occurs in about 0.38–5.10/1000 live born children[1-3] of which 20–30% remain with some functional deficits.[3] Treatment is directed at improving daily activities and participation and Health-related quality of life (HRQoL) instruments are considered useful in the assessment of these treatment outcomes.[4,5] The number of HRQoL instruments for children with musculoskeletal disorders, taking into account normal neurological maturation, is limited.[4,5] Therefore, the Pediatric Outcome Data Collecting Instrument (PODCI) was developed by the American Academy of Orthopedic Surgeons (AAOS).[4] The PODCI consists of 5 subscales: 'Upper Extremity and Physical Function', 'Transfer and Basic Mobility', 'Sports and Physical Function', 'Pain and Comfort', 'Happiness' and one total score: 'Global Functioning' (summary of all subscales, excluding 'Happiness'). It is available in three versions (2–10 year parent-reported, 11– 18 year parent- and self-reported).

During the development of the PODCI multiple musculoskeletal disorders were tested including Scoliosis, Myelodysplasia, Cerebral Palsy (CP), Juvenile Rheumatoid Arthritis, Legg-Calve-Perthes, Congenital Talipes Equino-varus, Congenital Leg-length Discrepancies, Osteogenesis Imperfecta, Developmental Delay and Abnormal Gait.[4] The PODCI was shown to be reliable, valid and sensitive to change.[4] After its initial development, the PODCI was used in studies evaluating children with NBPP[6-9], CP[10], Unilateral Upper Extremity Deficiencies[11], Scoliosis[12], Arthrogryposis[13], Duchenne Muscular Dystrophy[14,15] and Acute Hand and Wrist Injuries.[16]

So far, the PODCI has been translated into multiple languages (Hebrew/Spanish/Korean/Brazilian) but no Dutch version was available. Only the Korean and Brazilian translations are published.[10,17]

The aim of the present study was to develop a Dutch version of the PODCI, translated and adapted according to international guidelines[18-20], and preliminary examine its reliability, validity and responsiveness in children with NBPP.

PATIENTS AND METHODS

Translation and adaptation

The PODCI consists of 83 to 86 questions depending on the version (11–18 self-reported; 83 questions, 2–10 and 11–18 parent-reported; 86 questions). An Excel (Microsoft, Redmond, Washington/USA) scoring form, downloadable for free from the AAOS website, calculates the standardized and normative sub-scores and total score.[21] Standardized scores range from 0–100, with "0" poor outcome/worse health and "100" best possible outcome/best health. Normative scores are calculated so that a higher score indicates better functioning. All scores are referenced to the American based general/healthy population mean normative score of 50. This normative score does not hold for the Dutch general/healthy population. According to international cross-cultural adaptation guidelines, all PODCI versions were translated and adapted.[18-20]

Stage I: Initial translation
Three bilingual native Dutch-speaking translators, two medically educated and one layperson, translated all PODCI versions from the original language (English) into the target language (Dutch). All items and instructions were translated without discussion among translators. Challenging phrases or uncertainties were highlighted.

Stage II: Synthesis of translations
The three translations were subsequently compared and any discrepancies were resolved by discussion between the translators and the principal investigator (MH). A synthesis of the 3 translations was produced, resulting in one common version in the Dutch language.

Stage III: Back-translation
The common translated versions were back translated into the original language by three bilingual native English-speaking translators, one medically educated and two laypersons, who did not have access to the original versions.

Stage IV: Expert committee
An expert committee comprising a physical therapist (HV), a pediatric physical therapist (JE) and the principal investigator (MH), who is also a pediatric physiotherapist, reviewed all back-translations and the common Dutch translations. During a face-to-face meeting, consensus was reached on final wording, grammatical issues, formatting, cultural relevance and content validity resulting in the final Dutch PODCI versions.

Stage V: Test of the translated and adapted version
The final 2–10 year parent-reported version was field-tested among parents of 10 patients with NBPP who attended the Orthopaedic (outpatient) clinic of the Leiden University Medical Center. These 10 participants were asked to write down any comments on addressed issues, wording or lay out.

Validation
Study design
This study had a prospective cross-sectional design. It was executed between May 2008 and October 2013 in the Leiden University Medical Center, which is a specialized NBPP center in the Netherlands. Ethical approval was obtained from the Institutional Review Board, (addendum) P08.008. All parents gave written informed consent.

Patients
All children with NBPP who were scheduled to undergo shoulder surgery (Internal contracture release and mm. Latissimus Dorsi/Teres Major tendon transfers) were eligible for this study. Additional inclusion criteria were: Age: 3–10 years, Involvement of C5, C6 and/or C7 (“shoulder affected”) and unilateral impairment.

Assessments

Of all children, sociodemographic and disease characteristics (age, gender, involved nerve roots, affected side and previous treatments) were obtained from the medical record pre-operatively.

The translated and adapted Dutch PODCI was self-administered pre-operatively and 12 months thereafter in a clinical setting. Additionally the following assessments were done pre-operatively: Active Range of Motion (aROM): Abduction and External rotation[22], Mallet score measuring often used arm movements, including overhead movements (1: no function – 5: normal function)[7,23,24] and the Assisting Hand Assessment (AHA), a semi-structured, video-recorded, play-session for children (1.5-12 years) in which toys are used that encourage bimanual handling. Scoring is done by reviewing the video with respect to 22 items, subdivided in 6 categories: 'General Use', 'Arm Use', 'Grasp/Release', 'Fine Motor Adjustment', 'Coordination' and 'Pace' using a 4-point criterion referenced rating scale (4: Effective – 1: Does not do).[25-28]

To examine the test-retest reliability the translated and adapted Dutch PODCI was self-administered twice after the initial 12 months follow up, by regular mail, to all parents of the children, with an interval of 2 weeks.

Statistical analysis

Statistical analyses were executed using SPSS 20.0 (IBM, Armonk, New York/USA).[29] All continuous variables were expressed as means and standard deviations (SD), or as medians and Inter Quartile Ranges (IQR), according to their distributions.

Internal consistency

Internal consistency of the final Dutch PODCI (the extent to which the different items are correlated) was determined by calculating Cronbach's alpha. The internal consistency is considered to be good when Cronbach's alpha is between 0.70 and 0.95.[30]

Floor and ceiling effects

Mean final Dutch PODCI scores were determined and floor and ceiling effects were counted. Floor or ceiling effects are present if > 15% of the population scores either the minimum or the maximum.[31]

Construct validity

Spearman's rho was determined between the final Dutch PODCI and all clinical variables (aROM, Mallet score, AHA) to determine the construct validity. Correlations > 0.5 are considered to be moderate to good correlations and correlations > 0.75 are considered to be good to excellent correlations.[32] Significance for all correlations was computed as well with a p value smaller than 0.05 being considered significant.

Responsiveness to change

Cohen's effect size (ES = (pre-treatment mean – post-treatment mean)/pre-treatment SD) and the Standardized Response Mean (SRM = (pre-treatment mean – post-treatment mean)/

change score SD) were computed between pre-operative and 12 months post-operative final Dutch PODCI measurements. An ES/ SRM >0.2 is considered to be a small effect, > 0.5 a moderate effect and > 0.8 a large effect.[33-35] In addition, a paired sample t-test was performed to detect significant changes over time ($p < 0.05$ for statistically significant difference).

Test-retest reliability

Systematic differences between the test and retest were calculated for all final Dutch PODCI scores by means of Wilcoxon's signed rank tests. In addition, intra-class correlation coefficients (ICC) were computed between the test and retest scores, with a value of > 0.70 being considered the minimum acceptable value.[30,36]

RESULTS

Translation and adaptation of the PODCI

During the translation process, a few PODCI items were discussed for adaptation. Question 2 is about pouring milk from a half-gallon container. In The Netherlands, these kind of half-gallon containers are seldom used. One litre and 1.5 litre milk cartons are commonly available. Finally, the 1.5 litre carton was included in question 2 because the weight of this carton is closest to the original half-gallon container. Questions 23 and 24 refer to being able to walk 1 (q24) or 3 blocks (q23). Since there is no definition of the exact length of 1 block, the translation of 'block' into the Dutch word 'straat' (street) was chosen. Question 44 poses a few examples of sport and play activities including touch football. Since touch football is not commonly played in The Netherlands it was removed. The final translated and adapted version (final Dutch PODCI) was used in the field test.

Field test

The final Dutch PODCI was field tested among parents of 10 patients with NBPP. They were asked to state all inconsistencies, wording and lay out problems they found. None were declared and therefore the field-tested version was adopted as the final version.

Validation study

Disease characteristics

Ten patients participated in this study. There were five girls and five boys with a mean age of 5.3 years (SD 2.4). Four had C5/C6 lesions and six had C5/C6/C7 lesions, three were right-side affected and seven left-side. Six were treated neurosurgically (1 neurolysis, 5 Brachial Plexus reconstructions) and four were treated conservatively. The disease characteristics are reported in Table I as well.

All patients completed the pre-operative and post-operative assessments, including the parent reported final Dutch PODCI, whereas nine patients completed the parent reported final Dutch PODCI thereafter twice again to determine the reliability.

Table I Sociodemographic and disease characteristics of 10 children with Neonatal Brachial Plexus Palsy undergoing a combined internal contracture release and muscle tendon transfer participating in the Dutch PODCI validation study.

	Total group (n=10)
Gender (m/f); no.	5/5
Age, years; mean (Standard Deviation)	5.3 (2.4)
Lesion topography; no.	
C5/C6	4
C5/C6/C7	6
Affected side; no.	
Left	3
Right	7
Previous treatment(s); no.	
Neurolysis	1
Nerve reconstruction	5
Conservative	4

Internal consistency, floor and ceiling effects and responsiveness to change

Table II shows the internal consistency of the final Dutch PODCI, the mean pre- and post-operative final Dutch PODCI scores including floor/ceiling and responsiveness to change scores between baseline and 12 months follow-up.

Cronbach's alpha for internal consistency varied between 0.161 and 0.928. It was low for the 'Pain and Comfort' subscale, moderate for the 'Transfer and Basic Mobility' and 'Sports and Physical Function' subscales, and good for the 'Upper Extremity and Physical Function', 'Happiness' subscales and the total score 'Global Functioning'.

No floor scores were seen in the final Dutch PODCI. Ceiling effects, however, were seen for 'Transfer and Basic Mobility', 'Sports and Physical Function' 'Pain and Comfort' and 'Happiness' subscales but not for the 'Upper Extremity and Physical Function' subscale and the total score 'Global Functioning'.

The responsiveness to change (pre-operative - 12 months follow-up) is shown by means of ES, SRM and the paired sample t-test with 95% confidence intervals. ES were small (0.05–0.46) except for the total score 'Global Functioning' it was moderate (0.57). SRM was moderate for the 'Upper Extremity and Physical Function', 'Transfer and Basic Mobility', 'Sports and Physical Function' subscales (0.53–0.67) and small for the 'Happiness' and 'Pain and Comfort' subscales (0.07–0.46). For the total score 'Global Functioning' a large change was found (SRM 1.23). A significant improvement was seen only for the total score 'Global Functioning' (mean change 4.22 points, 95% CI: 1.04–7.41, p = 0.016). The 'Transfer and Basic Mobility' and 'Sports and Physical Function' subscales reached a near significant change over time (p = 0.06).

Table II Measurement properties of the Pediatric Outcome Data Collecting Instrument (PODCI).

PODCI N=10	Mean T1 (min-max)	Mean T2 (min-max)	Mean change (95%CI)	Cronbach's α	Ceiling score T1/T2 No. of patients (%)	Floor score T1/T2 No. of patients (%)	T1-T2 ES Cohen's d	T1-T2 SRM
Upper Extremity scale	67.80 (33-94)	72.20 (38-90)	2.56 (- 3.98 - 9.09)	0.695	0 (0%) / 0 (0%)	0 (0%) / 0 (0%)	+0.22	+0.53
Transfer and Basic Mobility scale	95.10 (78-100)	97.90 (88-100)	2.80 (- 0.27 - 5.87)	0.667	3 (30%) / 7 (70%)	0 (0%) / 0 (0%)	+0.42	+0.65
Sports and Physical Functioning scale	85.80 (57-100)	91.90 (69-100)	6.10 (- 0.42 - 12.62)	0.597	2 (20%) / 1 (10%)	0 (0%) / 0 (0%)	+0.46	+0.67
Pain and Comfort scale	90.90 (67-100)	94.10 (67-100)	3.20 (-1.80 - 8.20)	0.161	6 (60%) / 8 (80%)	0 (0%) / 0 (0%)	+0.24	+0.46
Happiness Scale	93.57 (80-100)	94.00 (60-100)	4.29 (- 1.33 - 9.90)	0.928	4 (40%) / 6 (60%)	0 (0%) / 0 (0%)	+0.05	+0.07
Global Functioning scale	84.00 (69-96)	89.20 (79-98)	4.22 (1.035 - 7.410)*	0.781	0 (0%) / 0 (0%)	0 (0%) / 0 (0%)	+0.57	+1.23

* Significant difference $p<0.05$. Responsiveness to change; Effect size (ES) and Standardized Response Mean (SRM): 0.2 (small effect), 0.5 (moderate effect), 0.8 (large effect). T1 = Baseline. T2 = 12 month follow up. Cronbach's α for internal consistency using raw scores on separate items.

Construct validity

Table III shows the associations between the final Dutch PODCI scores and all other variables. The 'Upper Extremity and Physical Function' subscale correlated moderate to strongly with aROM abduction, Mallet 'External rotation', 'Hand to Head' and 'Hand to Back' items, the total Mallet score and the AHA 'Arm use' items as well as the AHA total score ($r = 0.505–0.915$). All were significant ($p < 0.05$) except for the Mallet 'Hand to Head' item, the AHA 'Arm use' items and the AHA total score. The total score 'Global Functioning' shows high correlations with aROM abduction, Mallet 'External rotation', 'Hand to Head', 'Hand to Back' and 'Hand to Mouth' items as well as the total Mallet score ($r = 0.520–0.901$). All were statistically significant ($p < 0.05$) except for the aROM Abduction and Mallet 'Hand to Back' and 'Hand to Mouth' items. Furthermore the 'Happiness' and 'Pain and Comfort' subscales showed high correlations with Mallet 'External rotation', 'Hand to Head' and 'Hand to Back' items ($r = 0.523–0.667$) of which only the Mallet 'Hand to Head' item correlation to the 'Happiness' subscale is significant ($p < 0.05$).

Test-retest reliability

Table IV shows the mean test and retest scores and ICC for test-retest reliability. None of the differences reached statistical significance. The largest absolute difference was seen in the 'Pain and Comfort' subscale (Test: 90.67, SD 13.98 and Retest: 98.78, SD 3.67). This difference was found to be mainly the result from a large discrepancy between scores provided by one parent (Test: 56 and Retest: 100). The 'Upper Extremity and Physical Function', 'Transfer and Basic Mobility', 'Sports and Physical Function', 'Happiness' subscales and the total score 'Global Functioning' showed a good to moderate test-retest reliability (ICC 0.636–0.972, $p < 0.025$). The 'Pain and Comfort' subscale had a very low ICC (0.022, $p = 0.476$).

Table III Pediatric Outcome Data Collecting Instrument (PODCI) subscales associations with outcome measures.

PODCI N=10	aROM Exo 90°	aROM Abd	Mallet Abd	Mallet Exo	Mallet Hand to Head	Mallet Hand to Back	Mallet Hand to Mouth	Mallet total score	AHA arm use items	AHA total score
Upper Extremity scale	0.202	0.740*	0.411	0.725*	0.538	0.725*	0.414	0.915*	0.505	0.627
Transfer and Basic Mobility scale	0.285	0.145	0.425	-0.227	0.290	0.357	0.000	0.265	0.336	0.450
Sports and Physical Functioning scale	0.479	0.062	-0.291	0.218	0.188	-0.457	0.393	-0.025	0.007	-0.435
Pain and Comfort scale	0.420	0.031	-0.261	0.049	0.667*	-0.128	0.392	0.264	0.111	-0.031
Happiness scale	0.308	-0.10	-0.338	0.523	-0.147	-0.338	0.523	0.245	-0.128	-0.225
Global Functioning scale	0.287	0.591	0.138	0.728*	0.665*	0.520	0.572	0.901*	0.405	0.374

* Significant difference $p<0.05$. Correlations; Spearman's rho (r)
aROM= actiev range of motion
Exo = External rotation
Abd= Abduction
AHA= Assisting Hand Assessment

Table IV Pediatric Outcome Data Collecting Instrument (PODCI) test-retest reliability.

PODCI N=9	T1 Mean (SD)	T2 Mean (SD)	T1-T2 Cronbach's α	T1-T2 ICC
Upper Extremity scale	83.33 (18.13)	83.44 (17.85)*	0.986	0.972**
Transfer and Basic Mobility scale	99.67 (1.00)	99.33 (1.32)*	0.778	0.636**
Sports and Physical Functioning scale	92.56 (5.15)	93.56 (5.59)*	0.973	0.948**
Pain and Comfort scale	90.67 (13.98)	98.78 (3.67)*	0.043	0.022
Happiness scale	88.89 (17.09)	90.56 (13.57)*	0.980	0.96**
Global Functioning scale	91.56 (7.02)	93.56 (6.41)*	0.891	0.803**

* Differences between test and retest did not reach statistical significance (All P>0.05, Wilcoxon Signed Rank test). ** Significance p<0.05. Means with Standard Deviations (SD). Intra Class Correlation (ICC)

DISCUSSION

This study aimed to translate and adapt the PODCI into the Dutch language and validate the 2–10 years parent-reported version for use in children with NBPP. The final Dutch PODCI was found to be a useful tool to evaluate QoL and functioning in children with NBPP. The final Dutch PODCI's internal consistency, responsiveness to change, construct validity and test-retest reliability was overall found to be good.

These findings are generally in line with the literature concerning the development of the PODCI[4] and the usability in children with musculoskeletal disorders including NBPP.[6-13,16] In these reports the validity and reliability was also found to be good. The internal consistency in the present study was lower than reported in the development study of the PODCI[4] and the Brazilian cross cultural adaptation.[17] The 'Pain and Comfort' scale showed a low Cronbach's alpha (0.16, Table II). This could be due to the fact that the study population was rather small. The Korean cross cultural adaptation and validation study however also reported a low internal consistency for this sub-scale.[10]

Floor and ceiling effects were explicitly reported by few other studies.[8,16,37] A ceiling score was observed in all subscales of which the most in the 'Transfer and Basic Mobility', 'Pain and Comfort' and the 'Happiness' subscales (Table II). This corresponds with the findings in the present study, however no ceiling effects were found for the 'Upper Extremity and Physical Function' subscale and the total score 'Global Functioning'. From other publications concerning NBPP patients, floor and ceiling effects can only be concluded from the score ranges observed.[6,7]

The final Dutch PODCI showed to be responsive to change (Table II). Moderate to large ES and SRM were seen especially for the total score 'Global Functioning'. This total score showed a significant difference between baseline and 12 months follow up. This is in line with previous studies in children with musculoskeletal disorders, including NBPP.[9,10,13,16]

The results in regard to the relationships between the final Dutch PODCI scores and Mallet scores (Table III) are in line with previous studies. Bae et al. found significant correlations between the aggregated Mallet scores and the total score 'Global Functioning'.[7] However, Dedini et al. found no significant correlations between ROM and PODCI scores[8] whereas the current study found a significant correlation between the abduction aROM and the 'Upper Extremity and Physical Function' subscale (Table III).

Correlations between the AHA and the final Dutch PODCI have not been investigated before and the present study shows a moderate to good correlation between the 'Upper Extremity and Physical Function' subscale and the AHA 'arm use' items and total score although not significant (Table III).

ICC were found to be good even though the study group was small (Table IV). This is in line with previous studies.[4,10,17,38] The 'Transfer and Basic Mobility' subscale has an ICC value just below the minimal acceptable value of 0.70. This is explained by the fact that one parent reported that putting on a coat was easy at time point 1 and a little hard at time point 2. Due to the relative small study group, the effect of this one different answer is rather large. One could argue though whether the item putting on a coat should be in the 'Transfer and Basic Mobility' scale or in the 'Upper Extremity and Physical Function' scale since putting on a coat is also related to arm function. The 'Pain and Comfort' subscale scores very low because 4 parents reported differently at different time points. The 3 items within this subscale refer to pain in the previous week. Since the test-retest was done in a 2-week period a change in answering is possible. A study within a larger group should be conducted to see whether the test-retest reliability of this subscale is really low.

This study had a number of limitations. First, a relative small, diverse group was used. Secondly, no other questionnaire was used for reference and to measure validity. Thirdly, the patient group used was bound to report problems on the 'Upper Extremity and Physical Function' subscale because of their diagnose. Children with NBPP however mostly don't have problems with other parts of their body and therefor other subscales of the final Dutch PODCI show ceiling effects and no correlations with other measures were seen, as was expected.

To further investigate the psychometric properties of the final Dutch PODCI for general use in children with musculoskeletal disorders, including NBPP, a cross sectional study in a larger group of children should be done.

CONCLUSION

The PODCI is a well-established tool to evaluate QoL and physical functioning in children with musculoskeletal disorders including NBPP as shown in previous studies.[6-13,16] This study showed the final Dutch PODCI version to be reliable and useful to assess QoL and physical functioning in children with NBPP.

Acknowledgements
We thank all translators; the patients who made the effort to participate in this study and the AAOS for their support during the translation and adaptation process. The resulting final versions of the Dutch PODCI are available through the first author.

REFERENCES

1. Hoeksma AF, ter Steeg AM, Nelissen RG, van Ouwerkerk WJ, Lankhorst GJ, de Jong BA. Neurological recovery in obstetric brachial plexus injuries: an historical cohort study. *Dev. Med.Child Neurol.* 2004;46(2):76-83.
2. Malessy MJ, Pondaag W. Obstetric brachial plexus injuries. *Neurosurg.Clin.N.Am.* 2009;20(1):1-14.
3. Pondaag W, Malessy MJ, van Dijk JG, Thomeer RT. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev.Med.Child Neurol.* 2004;46(2):138-144.
4. Daltroy LH, Liang MH, Fossel AH, Goldberg MJ. The POSNA pediatric musculoskeletal functional health questionnaire: report on reliability, validity, and sensitivity to change. Pediatric Outcomes Instrument Development Group. Pediatric Orthopaedic Society of North America. *J.Pediatr.Orthop.* 1998;18(5):561-571.
5. Young NL, Wright JG. Measuring pediatric physical function. *J.Pediatr.Orthop.* 1995;15(2):244-253.
6. Huffman GR, Bagley AM, James MA, Lerman JA, Rab G. Assessment of children with brachial plexus birth palsy using the Pediatric Outcomes Data Collection Instrument. *J.Pediatr.Orthop.* 2005;25(3):400-404.
7. Bae DS, Waters PM, Zurakowski D. Correlation of pediatric outcomes data collection instrument with measures of active movement in children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(5):584-592.
8. Dedini RD, Bagley AM, Molitor F, James MA. Comparison of pediatric outcomes data collection instrument scores and range of motion before and after shoulder tendon transfers for children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(2):259-264.
9. Nath RK, Avila MB, Karicherla P, Somasundaram C. Assessment of triangle tilt surgery in children with obstetric brachial plexus injury using the pediatric outcomes data collection instrument. *Open.Orthop.J.* 2011;5:385-388.
10. Kwon DG, Chung CY, Lee KM, et al. Transcultural adaptation and validation of the Korean version of the Pediatric Outcomes Data Collection Instrument (PODCI) in children and adolescents. *J.Pediatr.Orthop.* 2011;31(1):102-106.
11. Lerman JA, Sullivan E, Barnes DA, Haynes RJ. The Pediatric Outcomes Data Collection Instrument (PODCI) and functional assessment of patients with unilateral upper extremity deficiencies. *J.Pediatr.Orthop.* 2005;25(3):405-407.
12. Lerman JA, Sullivan E, Haynes RJ. The Pediatric Outcomes Data Collection Instrument (PODCI) and functional assessment in patients with adolescent or juvenile idiopathic scoliosis and congenital scoliosis or kyphosis. *Spine (Phila Pa 1976).* 2002;27(18):2052-2057; discussion 2057-2058.
13. Amor CJ, Spaeth MC, Chafey DH, Gogola GR. Use of the Pediatric Outcomes Data Collection Instrument to evaluate functional outcomes in arthrogryposis. *J.Pediatr.Orthop.* 2011;31(3):293-296.
14. McDonald CM, McDonald DA, Bagley A, et al. Relationship between clinical outcome measures and parent proxy reports of health-related quality of life in ambulatory children with Duchenne muscular dystrophy. *J Child Neurol.* 2010;25(9):1130-1144.
15. Henricson E, Abresch R, Han JJ, et al. The 6-Minute Walk Test and Person-Reported Outcomes in Boys with Duchenne Muscular Dystrophy and Typically Developing Controls: Longitudinal Comparisons and Clinically-Meaningful Changes Over One Year. *PLoS Curr.* 2013;5.
16. Kunkel S, Eismann E, Cornwall R. Utility of the pediatric outcomes data collection instrument for assessing acute hand and wrist injuries in children. *J.Pediatr.Orthop.* 2011;31(7):767-772.
17. do Monte FA, Ferreira MN, Petribu KC, et al. Validation of the Brazilian version of the pediatric outcomes data collection instrument: a cross-sectional evaluation in children and adolescents with juvenile idiopathic arthritis. *BMC.Pediatr.* 2013;13(1):177.
18. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976.).* 2000;25(24):3186-3191.
19. Guillemin F, Bombardier C, Beaton D. Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. *J.Clin.Epidemiol.* 1993;46(12):1417-1432.
20. C.G. M, J. L, L.O.P C. The relevance of cross-cultural adaptation and clinimetrics for physical therapy instruments. *Rev Bras Fisioter.* 2007;11(4):245-252.
21. Pediatric Data Collecting Instrument (PODCI) http://www.aaos.org/research/outcomes/outcomes_peds.asp. 2013.
22. Ryf C, Weymann A. *Range of motion - AO Neutral-0 Method : measurement and documentation.* Vol v. 1. New York: Thieme; 1999.
23. Bae DS, Waters PM, Zurakowski D. Reliability of three classification systems measuring active motion in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 2003;85-A(9):1733-1738.
24. van der Sluijs JA, van Doorn-Loogman MH, Ritt MJ, Wuisman PI. Interobserver reliability of the Mallet score. *J.Pediatr.Orthop.B.* 2006;15(5):324-327.
25. Holmefur M, Krumlinde-Sundholm L, Eliasson AC. Interrater and intrarater reliability of the Assisting Hand Assessment. *Am.J.Occup.Ther.* 2007;61(1):79-84.

26. Krumlinde-Sundholm L, Holmefur M, Kottorp A, Eliasson AC. The Assisting Hand Assessment: current evidence of validity, reliability, and responsiveness to change. *Dev.Med.Child Neurol.* 2007;49(4):259-264.
27. Krumlinde-Sundholm L. Reporting outcomes of the Assisting Hand Assessment: what scale should be used? *Dev.Med.Child Neurol.* 2012;54(9):807-808.
28. Krumlinde-sundholm L, Eliasson Ac. Development of the Assisting Hand Assessment: A Rasch-built Measure intended for Children with Unilateral Upper Limb Impairments. SCANDINAVIAN JOURNAL OF OCCUPATIONAL THERAPY; 1/1/2003, 2003.
29. IBM SPSS Statistics 20.0 for Windows. 1912.
30. Terwee CB, Bot SD, de Boer MR, et al. Quality criteria were proposed for measurement properties of health status questionnaires. *J.Clin. Epidemiol.* 2007;60(1):34-42.
31. McHorney CA, Tarlov AR. Individual-patient monitoring in clinical practice: are available health status surveys adequate? *Qual.Life Res.* 1995;4(4):293-307.
32. LG P, MP W. *Foundations of clinical research, applications to practice.* 3rd edition ed: Pearson Education International; 2009.
33. Liang MH, Lew RA, Stucki G, Fortin PR, Daltroy L. Measuring clinically important changes with patient-oriented questionnaires. *Med.Care.* 2002;40(4 Suppl):II45-II51.
34. Guyatt G, Walter S, Norman G. Measuring change over time: assessing the usefulness of evaluative instruments. *J.Chronic.Dis.* 1987;40(2):171-178.
35. Cohen J. *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Hillsdale, NJ : Lawrence Erlbaum Associates; 1988.
36. JC N, IH B. *Psychometric theory.* 3rd ed. New York: McGraw-Hill; 1994.
37. Pencharz J, Young NL, Owen JL, Wright JG. Comparison of three outcomes instruments in children. *J.Pediatr.Orthop.* 2001;21(4):425-432.
38. Christakou A, Laiou A. Comparing the psychometric properties of the pediatric outcomes data collection instrument and the activities scales for kids: a review. *Journal of child health care : for professionals working with children in the hospital and community.* 2014;18(3):207-214.

CHAPTER FIVE

Hand Use at Home questionnaire; validity and reliability in children with neonatal brachial plexus palsy or unilateral cerebral palsy

Menno van der Holst | Yvonne Geerdink | Pauline Aarts | Duco Steenbeek
Willem Pondaag | Rob G.H.H. Nelissen | Alexander C.H. Geurts | Thea P.M. Vliet Vlieland

Submitted
Oral abstract presentation VRA congress November 2016
Maastricht, The Netherlands
Oral abstract presentation EACD congress May 2017
Amsterdam, The Netherlands

ABSTRACT

Objective

To investigate construct validity and test-retest reliability of the parent-rated Hand-Use-at-Home questionnaire (HUH) in children with Neonatal Brachial Plexus Palsy (NBPP) or Unilateral Cerebral Palsy (UCP).

Patients and methods

Children with NBPP or UCP, aged 3-10 years, were eligible. The HUH, Pediatric-Outcome-Data-Collecting-Instrument Upper-Extremity-scale (PODCI-UE, NBPP only), and Children's-Hand-Use-Experience-Questionnaire (CHEQ/mini-CHEQ, UCP only) were administered. The HUH was administered twice in subgroups of both diagnoses. Lesion-extent (NBPP) and Manual-Ability-Classification-System (MACS) levels (UCP) were obtained.

Spearman correlations coefficients between the HUH and all clinical variables, Agreement, Standard-Error-of-Measurement (SEM), Smallest-Detectable-Change (SDC), and Intra-Class-Correlation (ICC) were calculated.

Results

260 patients participated (NBPP:181) of whom 56 completed the second HUH (NBPP:16). Median age was 6.9 years for NBPP and 116 had C5-C6 lesions. Median age for UCP was 6.4 years and 33 had MACS II.

The HUH correlated moderately with lesion-extent (r_s=-0.5), PODCI-UE (r_s=0.6) and CHEQ (r_s=0.5), but weakly with MACS-levels (r_s=-0.4). Test-retest reliability was excellent ($ICC_{2,1}$=0.89, SEM=0.599 and SDC=1.66 logits) and agreement was good (mean difference HUH1-HUH2 0.06 logits).

Conclusions

The HUH showed good construct validity and test-retest reliability in children with NBPP or UCP. It is a useful tool to quickly measure spontaneous upper-limb use in the home environment in children with unilateral paresis.

Clinical messages:

- The HUH evaluates spontaneous hand-use in the home environment and shows excellent construct validity and test-retest reliability
- The HUH is able to distinguish between levels of lesion-extent in children with NBPP
- A good ability to use the affected hand not automatically results in a high amount of hand-use
- The HUH fills a gap in the currently available outcome measures

INTRODUCTION

Children with Neonatal Brachial Plexus Palsy (NBPP) or Unilateral Cerebral Palsy (UCP) may have difficulties using their affected upper limb[1-4], and hand use is often less frequent than might be expected based on their functional capacities.[5-9] Upper-limb interventions typically focus on improving functional capacities of the affected upper-limb to optimize daily-life activities and participation (ICF-CY level d). However, a discrepancy is often observed between upper-limb capacity measured in a clinical setting and the actual use in daily life (performance).[7,9] This actual use is important to assess, because one of the most important goals of upper-limb interventions is the transition of newly acquired function and/or capacities to daily use.

Currently available parent-reported questionnaires, validated for children with NBPP and UCP[10,11] or for UCP only[12], assess several aspects of upper-limb performance in daily life, but none of them measure how often the affected upper-limb is spontaneously used in bimanual activities in the home-environment.[13-15]

To capture the amount of daily-life spontaneous use of the affected upper-limb in children with unilateral paresis aged 3-10 years, the parent-reported Hand-Use-at-Home questionnaire (HUH) was recently developed.[16] It was constructed based on the notion that children with unilateral paresis may 'disregard' their affected upper limb, and only use their upper-limb spontaneously when activities require the simultaneous use of both hands (e.g. when closing a zipper). The HUH includes a range of bimanual activities and the scale's internal structure and item-hierarchy was tested in a large sample of children with UCP or NBPP using Rasch analysis.[16] The HUH sum-score was found to be able to discriminate between children with a higher and lower amount of spontaneous use of the affected upper limb.

The HUH is a valuable addition to the current assessment of children with unilateral upper-limb paresis. However, how the HUH is associated with frequently used questionnaires in children with unilateral paresis, disease severity and functional classification has not yet been established to support its construct validity. Furthermore, its test-retest reliability has not yet been examined.

Therefore, the aim of this study was to obtain evidence for construct validity and test-retest reliability of the HUH in children with NBPP or UCP to establish whether the HUH is a useful instrument in daily practice and for future research.

PATIENTS AND METHODS

This study was divided into a construct validity and a test-retest reliability part. It was conducted at the Leiden University Medical Center (LUMC) and the Sint Maartenskliniek rehabilitation center (October 2013-May 2015). Ethical approval was obtained (LUMC P14.071, medical ethical committee Arnhem-Nijmegen 2013/395). All parents gave written informed consent.

The Hand-Use-at-Home Questionnaire

The HUH assesses the amount of spontaneous use of the affected hand in children with unilateral upper-limb paresis aged 3-10 years, performing typical bimanual play and self-care activities.[16] This 18-item, parent-reported questionnaire takes 5-10 minutes to complete. Parents rate items using a 5-point rating scale (never-sometimes-regularly-often-(almost) always). After completion, the ratings are converted into a 3-point rating scale (i.e. never+sometimes=score 0, regularly+often=score 1, always=score 2) and item scores are summed. This sum-score (range 0-36 points) can subsequently be converted into the HUH-score in logits (Appendix 1). The HUH score ranges from -4.69 to 5.17 logits and reflects the extent to which a child spontaneously uses its affected hand in activities at home.

Patients, recruitment, in- and exclusion criteria

Children with unilateral upper-limb paresis (NBPP/UCP) were eligible for the construct validity and the test-retest reliability study if: aged between 3 and 10 years and if their medical record was available. Children with NBPP were recruited from the LUMC NBPP care unit and those with UCP from 11 pediatric rehabilitation centers that are part of the Dutch Collaboration for Implementation of the Pirate Concept (LIPIC, http://www.piratenconcept.nl/).
Parents of eligible patients were invited to participate in this study and could complete the questionnaires online or on paper. Non-responders were reminded once by (e-)mail and/or telephone.

To be included in the construct validity study, the HUH and an additional questionnaire had to be completed (i.e. Pediatric-Outcome-Data-Collecting-Instrument (PODCI) for NBPP and Children's-Hand-Use-Experience-Questionnaire (CHEQ/mini-CHEQ) for UCP)
For inclusion in the test-retest reliability study, parents had to complete a second HUH within a period of 2-4 weeks after the first one and the upper-limb performance of the child had to be stable. Therefore, participants were not invited to complete the second HUH when there had been specific upper-limb interventions (i.e. surgery, botulinum-toxin injections or intensive upper-limb training) less than 3 months prior to completing the first HUH questionnaire or within two weeks thereafter.

Of all participating children, sociodemographic and disease characteristics (age/gender/diagnosis/affected side) were obtained from the medical records. In addition, for NBPP: lesion-extent and treatment history, and for UCP: Manual Ability Classification System (MACS) levels were obtained. Lesion-extent for NBPP was divided into 4 groups based on lesion localization: 1) C5-C6, 2) C5-C7, 3) C5-C8 and 4) C5-T1. Treatment history in children with NBPP can consist of: 1) conservative treatment, 2) primary (nerve) surgery, 3) secondary (orthopaedic: i.e. tendon transfers, osteotomies) surgery or 4) primary and secondary surgery.

PODCI-UE

The PODCI is designed to assess different aspects of daily living, including upper extremity functioning, in children with musculoskeletal disorders (including NBPP) and is available in

Dutch.[17] It is widely accepted to provide information about upper extremity functioning.[13-15] PODCI scale scores range from 0-100, with higher scores indicating better functioning/ Quality of Life (QoL). Only the 'Upper Extremity and Physical Function' scale (PODCI-UE) was used in this study since this scale provides information about difficulties performing activities using the arms/hands (lower score, more difficulties).

MACS

The MACS is a reliable and valid classification for children with Cerebral Palsy and classifies the ability to handle objects in daily activities.[3] It has 5 levels; higher levels representing worse performance.

CHEQ/mini-CHEQ

The CHEQ is a questionnaire validated for children with UCP aged 6 to 18.[10,11] It was also designed for use in children with NBPP[11], but it was only partially validated for this group and has not yet been used in NBPP studies. Therefore, it was not used for this group in this study.

The CHEQ consists of 29 bimanual activities, demanding the use of both hands, assessing a child's experience performing bimanual activities with an impaired hand. The CHEQ measures three aspects of perceived performance, as well as how many activities are executed independently. It also measures whether the affected hand is used as a support or with grip. A trial version of the mini-CHEQ with 21 activities for children aged 4–6 years was used for all UCP children <6 years in this study. We used the percentage of independently performed activities, in which the affected hand was used, as a measure of bimanual performance ($CHEQ_{bim}$).

Statistical analysis

Statistical analyses were executed using SPSS 20.0 (IBM, Armonk, New York/USA). All continuous variables were expressed as means with standard deviations (SD), or as medians with Inter Quartile Ranges (IQR), based on their distributions. Missing values were replaced with predicted values using the Expectation-Maximization technique.

In concordance with the recommended quality criteria to investigate measurement properties of health status questionnaires (COSMIN)[18] we investigated the construct validity by testing the following hypotheses:

- There is a moderate-good negative correlation between HUH-scores and NBPP lesion-extent. NBPP lesion-extent group 1 will have higher HUH-scores than the other groups since a greater lesion-extent will probably affect spontaneous hand use negatively.
- There is a weak negative correlation between HUH-scores and treatment history in NBPP. Conservatively treated children are more mildly affected than surgically treated children and therefore will score higher on the HUH.
- There is a moderate-good positive correlation between HUH-scores and PODCI-UE. Children with less difficulty performing daily-life activities with their affected upper-limb will show more spontaneous use of their affected upper limb.

- There is a weak negative correlation between the HUH and MACS levels in children with UCP because limitations in manual ability will hamper the performance of daily activities but may not necessarily affect the amount of upper-limb use in children with UCP.
- There is a moderate-good positive correlation between the HUH and the $CHEQ_{bim}$ as children who use their affected hand in many of the CHEQ activities are likely to display more spontaneous use of the affected upper-limb.

To test the above hypotheses, Spearman correlation coefficients were calculated. Correlations $0.3<r_s<0.5$ were considered weak, $0.5<r_s<0.75$ moderate to good and $r_s>0.75$ good-excellent ($p<0.05$).[19]
In addition, we used a one-way analysis of variance (ANOVA) with Games-Howell post-hoc testing to further examine our hypotheses regarding the relationships of the HUH with lesion-extent and treatment history in NBPP and with MACS levels in UCP.

Test-retest reliability was investigated by computing the Intra-Class-Correlation coefficient ($ICC_{2,1}$) with the minimum acceptable value being 0.70.[18,20] We used the Bland-Altman method to assess agreement between both HUH-scores. The standard error of measurement ($SEM_{agreement}$) using the within-subject variance (SEM=√error variance) and Smallest Detectable Change (SDC=1.96x√2xSEM) were calculated to determine the minimal change representing a real difference between two scores of an individual above measurement error ($SDC_{individual}$). Additionally, the SDC at group level was computed ($SDC_{group}=SDC_{individual}$ /√n).

RESULTS

In the construct validity study, 260 children and their parents were included (181 NBPP, median age 6.9 years and 79 UCP, median age 6.4 years). Parents of 56 children (16 NBPP, 40 UCP) scored the second HUH within 2-4 weeks after the first HUH and were included in the test-retest reliability study (median age 7.2 years). Table I provides the patient characteristics of the study groups.
There were some missing values in the HUH-questionnaires in the construct validity study (5 questions in 3 individuals). Seven PODCI-UE's could not be calculated, because parents reported that their child was too young to perform several PODCI-UE items. Therefore, 174 PODCI-UE's were used for analysis.

The HUH, PODCI-UE and $CHEQ_{bim}$ scores are presented in Table II. The median HUH-score for the NBPP group was clearly higher than for the UCP group (1.06 and -0.34 logits, respectively). The median PODCI-UE score was 83.0 points (IQR 71.0; 96.0) and 24% obtained the maximum score. The $CHEQ_{bim}$ score was negatively skewed (median 100%). The number of independent activities was normally distributed (mean 16, range 3-28 activities).
In children with NBPP the HUH correlated moderately with lesion-extent ($r_s=-0.5$) and weakly with previous treatment ($r_s=-0.3$). There was a moderate correlation between HUH-scores

Table I Demographic and clinical characteristics of included children with Neonatal Brachial Plexus Palsy (NBPP) and Unilateral Cerebral Palsy (UCP)

	Construct validity study				**Test-retest reliability study**	
	NBPP Group (n=181)		**UCP group (n=79)**		**NBPP=16, UCP=40 (n=56)**	
Gender: n (%)						
Male	87	(48)	40	(51)	30	(54)
Median age in years (Range)	6.9	(3.0-10.5)	6.4	(3.0-10.8)	7.2	(3.3-10.8)
Affected side: n (%)						
Right	86	(48)	40	(51)	18	(32)
Lesion extent: n (%)						
C5-C6	116	(64)			9	(16)
C5-C7	37	(20)	x	x	4	(7)
C5-C8	12	(7)			1	(2)
C5-T1	16	(9)			2	(4)
NBPP treatment history: n (%)						
Conservative treatment	85	(47)				
Primary (nerve) surgery	75	(41)	x	x	x	x
Secondary (orthopaedic) surgery*	4	(2)				
Primary and secondary* surgery	17	(9)				
MACS: n (%)						
I			21	(27)	15	(27)
II	x	x	33	(42)	17	(30)
III			25	(32)	8	(14)

MACS= Manual Ability Classification System,
*i.e. tendon transfers, osteotomies

and the PODCI-UE (r_s=0.6). In children with UCP, the HUH correlated weakly with MACS classification (r_s=-0.4) and moderately with the CHEQbim (r_s=0.5) (all p<0.001).

Table III shows differences in HUH-scores between subgroups of patients with NBPP or UCP. For NBPP we found significant differences between levels of lesion-extent (F=15.65,p<0.001) and treatment history (F=8.41,p<0.001). Greater NBPP lesion-extent was associated with lower HUH-scores. All lesion-extent subgroups differed significantly from the C5-C6 subgroup (p<0.001). A history of primary and/or secondary surgery in children with NBPP was associated with lower HUH-scores (p<0.001). In children with UCP, there were significant differences in HUH-scores between MACS levels (F=7.09, p=0.002). There was no significant difference between MACS I and II, but MACS III was clearly associated with lower HUH-scores (p=0.001).

Table II Group outcomes and correlations with Hand-Use-at-Home Questionnaire (HUH) for NBPP (n=181) and UCP (n=79)

NBPP		
HUH person ability in logits (n=181)		
Median (IQR 25;75)	1.06	(-0.04; 2.78)
PODCI-UE (n=174)		
Median (IQR 25;75)	83.00	(71.0; 96.0)
Correlations:		
NBPP lesion extent (n=181)	-0.5*	p<0.001
NBPP treatment history (n=181)	-0.3*	p<0.001
PODCI-UE (n=174)	0.6*	p<0.001
UCP		
HUH person ability in logits (n=79)		
Mean (SD)	-0.29	(1.27)
Median (IQR 25;75)	-0.34	(-1.22; 0.51)
CHEQbim score (n=79)		
Median (IQR 25;75)	100%	(90.9; 100)
Correlations:		
MACS (n=79)	-0.4*	p<0.001
CHEQbim score (n=79))	0.5*	p<0.001

NBPP= Neonatal Brachial Plexus Palsy, UCP= unilateral cerebral palsy, IQR= Inter Quartile Ranges, SD= Standard Deviation. PODCI-UE = Paediatric Outcome Data Collecting Instrument-Upper Extremity Functioning scale, $CHEQ_{bim}$ = Children's Hand use Experience Questionnaire bimanual score (%)= percentage activities independently executed using both hands, MACS= Manual Ability Classification System. *= Spearman's Rho.

Test-retest reliability (Table IV) was found to be good with an ICC of 0.89 (p<0.001). The absolute agreement is presented in figure 1. The mean difference between the first and the second assessment was 0.06 logits (SD 0.85) The $SEM_{agreement}$ was 0.599 logits, which resulted in a $SDC_{individual}$ of 1.66 logits and a SDC_{group} of 0.22 logits.

DISCUSSION

This study aimed to find evidence for the construct validity and test-retest reliability of the Hand-Use-at-Home questionnaire. Results showed that the HUH is a valid and reliable measure to be used in children with NBPP or UCP aged 3 to 10 years old. The correlation between the HUH and lesion-extent indicated that greater lesion-extent is related to a lower amount of spontaneous hand-use. The weak correlation with MACS levels in children with UCP indicated that a good ability to handle objects is not directly associated with a high amount of spontaneous use of the affected arm/hand. Test-retest reliability was found to be excellent based on a good ICC and good agreement.

Table III Mean Hand-Use-at-Home Questionnaire (HUH) scores and differences within groups for lesion-extent and treatment history in children with NBPP (n=181); and for MACS levels in children with UCP (n=79)

	HUH-score (logits)		**Differences in HUH-score #**	
	Mean	**(SD)**	**Logits**	**(p value)**
Lesion extent (NBPP):			*Compared to C5-C6*	
C5-C6 (n=116)	2.10	(1.98)	-	-
C5-C7 (n=37)	0.72	(1.66)	1.38	**(p<0.001)**
C5-C8 (n=12)	-0.34	(1.24)	2.44	**(p<0.001)**
C5-T1 (n=16)	-0.22	(0.70)	2.32	**(p<0.001)**
Treatment history (NBPP):			*Compared to conservative treatment*	
Conservative treatment (n=85)	2.20	(2.10)	-	-
Primary (nerve) surgery (n=75)	0.88	(1.80)	1.32	**(p<0.001)**
Secondary (orthopaedic) surgery* (n=4)	0.51	(1.53)	1.69	(p=0.301)
Primary and secondary* surgery (n=17)	0.51	(1.40)	1.69	**(p=0.001)**
MACS (UCP):			*Compared to MACS I*	
I (n=21)	0.28	(1.24)	-	-
II (n=33)	-0.14	(1.29)	0.41	(p=0.477)
III (n=25)	-0.99	(0.96)	1.27	**(p=0.001)**

NBPP= Neonatal Brachial Plexus Palsy, UCP= Unilateral Cerebral Palsy, MACS= Manual Ability Classification System
NBPP Lesion extent: Only comparisons of all groups with the C5-C6 group are shown.
NBPP Treatment history: Only comparisons of all groups with the conservatively treated group are shown.
UCP MACS: Only comparisons of all groups with the MACS level I group are shown.
#One way ANOVA with Games-Howell post hoc test
*i.e. tendon transfers, osteotomies

The test-retest reliability results indicate that parents' observations can reliably be used to measure the amount of spontaneous hand use in children with unilateral paresis. In an instrument with high test-retest reliability repeated measurements in an unchanged subject will result in similar outcomes that are not influenced by characteristics of the instrument.[18,20] The absolute agreement between the repeated assessments was good as indicated by the SEMs. When HUH-scores of two groups of children are compared, a group difference of 0.22 logits can be regarded as a real difference, which is not due to natural variation. For individual children, a change in HUH-scores needs to be >1.66 logits to be significantly different.

Little is known about spontaneous use of the affected hand at home in children with unilateral upper-limb paresis. Clinical assessments capture arm/hand use in a test-setting, but do not provide insight into actual daily life performance, nor in the amount of hand use. Spontaneous hand use was investigated in a few studies, but only with regard to children with UCP.[7,21] A qualitative study showed that children with UCP spontaneously use their affected hand mainly in tasks that absolutely require the use of both hands.[7] Another study used an accelerometer in the home environment to objectively measure upper-limb

Table IV Test- retest reliability for the Hand-Use-at-Home Questionnaire (HUH) in children with NBPP or UCP (n=56).

HUH-score Test Median	(IQR 25;75)	0.17 (-0.50; 1.52)
HUH-score Re-Test Median	(IQR 25;75)	0.38 (-0.80; 1.36)
Mean difference	(SD)	0.06 (0.85)
ICC	(95% CI)	0.89 (0.81-0.93)
SEM	(logits)	0.599
$SDC_{individual}$	(logits)	1.66
SDC_{group}	(logits)	0.22

HUH= Hand-Use at Home, IQR= Inter Quartile Ranges, SD= Standard Deviation, ICC=Intra Class Correlation, 95% CI= 95% Confidence Interval, SEM= Standard Error of Measurement, SDC= Smallest Detectable Change

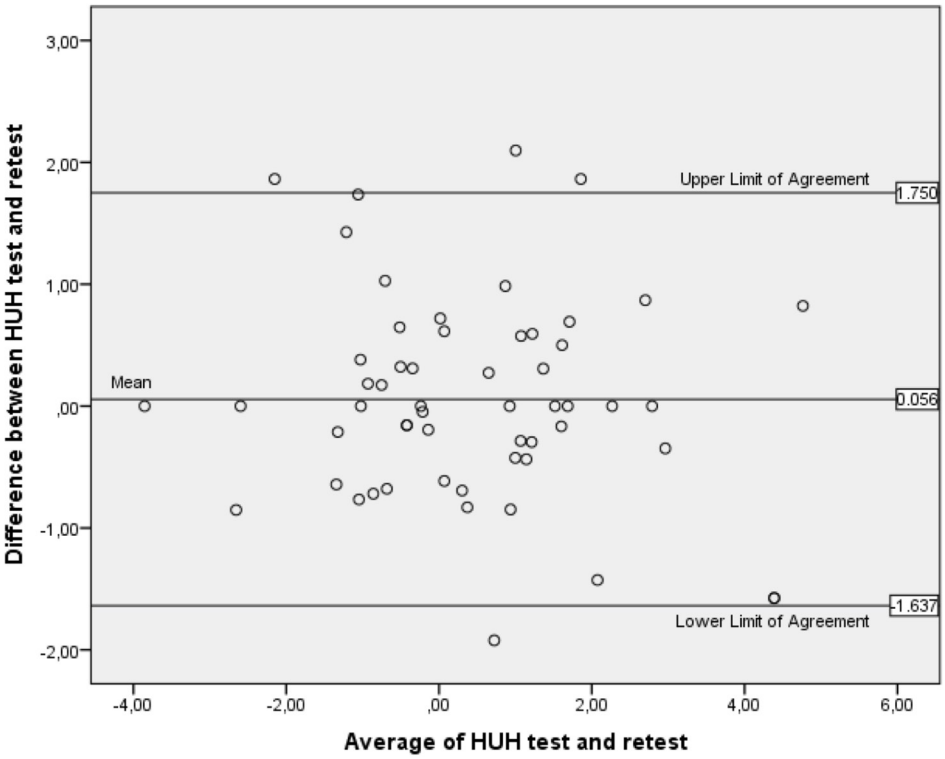

Figure 1 Bland-Altman plot showing agreement between the Hand-Use-at-Home Questionnaire (HUH) test and retest.
(Limits of agreement are located at ± 2 standard deviations from the mean difference)

movements, as was done in adults before.[21] This study found that children with UCP used their affected upper limb, but it was not possible to conclude from the data whether this use was related to bimanual activities.

Several studies reported difficulties in using the affected upper-limb in children with NBPP and found a relationship between lesion-extent and upper-limb capacity.[1,2,4] The actual amount of spontaneous use has, to our knowledge, not been reported for NBPP before. Our study found a moderate relation between (greater) lesion-extent and (lower) amount of spontaneous hand use (Table II/III). In the C5-C6 group the amount of spontaneous hand-use was relatively high but only 22 children (19%, all treated conservatively) had a maximum HUH-score. A possible explanation for this high amount of spontaneous use in the C5-C6 group could be that these children had fully recovered, as occurs in about 70% of the children with NBPP.[2] The association between treatment history and amount of hand use was less strong but conservatively treated children had significantly higher HUH scores than children who were treated surgically. The secondary surgery group (n=4) was too small to explain any relationship with spontaneous hand-use. Our findings indicate that the HUH is able to distinguish between levels of lesion-extent.

The eight daily activities in the PODCI-UE show similarities with items in the HUH, but 3 are unimanual items and some can be performed using only the preferred hand. In contrast, the HUH consists of only bimanual items, hierarchically ordered according to how strong they elicit the use of the affected hand. The moderate relationship between both instruments, measuring different constructs, indicates that children performing well on the PODCI-UE are not automatically inclined to use both their hands simultaneously during daily life activities.

Studies in children with UCP found that higher MACS levels coincided with lower outcomes on unimanual capacity and bimanual performance measures.[22,23] We found that the children with a lower capacity to handle objects independently (MACS III) actually did show significantly less spontaneous use of their affected hand than children with MACS I or II. The weak association between MACS and HUH, however, indicated that a good ability to use the affected hand (MACS I) does not automatically result in a high amount of use of this hand in daily activities.

The association between the HUH and the $CHEQ_{bim}$ in children with UCP was weak. The number of independently performed activities was normally distributed over the sample, but most activities were executed using the affected hand (median 100%). The activities of the CHEQ all specifically require the simultaneous use of both hands and can hardly be performed unimanually, which explains the high $CHEQ_{bim}$ percentages. In contrast, only a few HUH activities explicitly require the use of the affected hand; they elicit the use of the affected hand to an increasing extent in order to assess whether the affected hand is spontaneously used. Our findings indicate that children with UCP do use their affected hand

if the task demands bimanual task execution. The moderate correlation between both instruments indicates that the HUH measures a different construct requiring a specific item-set.

In both diagnosis groups, we found significant relationships between upper-limb capacity reflected by MACS (UCP) and lesion-extent (NBPP) and the amount of spontaneous hand use. This indicates that the amount of hand use is negatively influenced by decreasing abilities to use the upper limb. However, there still is a large portion of unexplained variance in the HUH-score, which might be explained by the presence of developmental disregard.[8,24] Future studies are warranted to establish the possible relationship between developmental disregard and HUH outcomes.

This study had a number of limitations. Firstly, the sample in the NBPP group was relatively heterogeneous in terms of lesion-extent and treatment history, which might have positively influenced HUH outcomes. The UCP sample contained a relative large group of children with MACS III compared to the general UCP population, which might have negatively influenced HUH outcomes. Secondly, there is no golden standard to establish amount of hand-use. Therefore, in our study we used two widely accepted upper-limb outcome measures (PODCI-UE and CHEQ) to examine to what extent the HUH measures a different construct of upper-limb performance. Finally, this study had a cross-sectional design, only measuring arm/hand-use at one point in time. Future studies, for example on analyzing functional outcomes of surgical interventions, are warranted to evaluate the responsiveness of the HUH.

CONCLUSION

In conclusion, our study found that the Hand-Use-at-Home Questionnaire has good clinimetric properties to measure a specific aspect of upper-limb performance: the amount of spontaneous hand use. It can reliably be used by parents of children with unilateral upper-limb paresis, aged 3-10 years, to report spontaneous hand use of their child during daily activities. It provides clinicians and researchers with more insight in daily-life upper-limb performance.

REFERENCES

1. 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.
2. Pondaag W, Malessy MJ, van Dijk JG, Thomeer RT. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev.Med.Child Neurol.* 2004;46(2):138-144.
3. Eliasson AC, Krumlinde-Sundholm L, Rosblad B, et al. The Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and reliability. *Developmental medicine and child neurology.* 2006;48(7):549-554.
4. Strombeck C, Krumlinde-Sundholm L, Forssberg H. Functional outcome at 5 years in children with obstetrical brachial plexus palsy with and without microsurgical reconstruction. *Dev.Med. Child Neurol.* 2000;42(3):148-157.
5. Fedrizzi E, Pagliano E, Andreucci E, Oleari G. Hand function in children with hemiplegic cerebral palsy: prospective follow-up and functional outcome in adolescence. *Developmental medicine and child neurology.* 2003;45(2):85-91.
6. Spaargaren E, Ahmed J, van Ouwerkerk WJ, de G, V, Beckerman H. Aspects of activities and participation of 7-8 year-old children with an obstetric brachial plexus injury. *Eur.J.Paediatr. Neurol.* 2011;15(4):345-352.
7. Brandao M, Ocarino JM, Bueno KM, Mancini MC. Hand use at home and in clinical settings by children with cerebral palsy: a qualitative study. *Occup Ther Int.* 2015;22(1):43-50.
8. Houwink A, Geerdink YA, Steenbergen B, Geurts AC, Aarts PB. Assessment of upper-limb capacity, performance, and developmental disregard in children with cerebral palsy: validity and reliability of the revised Video-Observation Aarts and Aarts module: Determine Developmental Disregard (VOAA-DDD-R). *Developmental medicine and child neurology.* 2013;55(1):76-82.
9. Smits DW, Gorter JW, van Schie PE, Dallmeijer AJ, Ketelaar M, group Ps. How do changes in motor capacity, motor capability, and motor performance relate in children and adolescents with cerebral palsy? *Arch Phys Med Rehabil.* 2014;95(8):1577-1584.
10. Amer A, Eliasson AC, Peny-Dahlstrand M, Hermansson L. Validity and test-retest reliability of Children's Hand-use Experience Questionnaire in children with unilateral cerebral palsy. *Developmental medicine and child neurology.* 2015.
11. Skold A, Hermansson LN, Krumlinde-Sundholm L, Eliasson AC. Development and evidence of validity for the Children's Hand-use Experience Questionnaire (CHEQ). *Dev.Med.Child Neurol.* 2011;53(5):436-442.
12. Arnould C, Penta M, Renders A, Thonnard JL. ABILHAND-Kids: a measure of manual ability in children with cerebral palsy. *Neurology.* 2004;63(6):1045-1052.
13. Sarac C, Duijnisveld BJ, Weide A, et al. Outcome measures used in clinical studies on neonatal brachial plexus palsy: A systematic literature review using the International Classification of Functioning, Disability and Health. *J Pediatr Rehabil Med.* 2015;8(3):167-186.
14. Chang KW, Justice D, Chung KC, Yang LJ. A systematic review of evaluation methods for neonatal brachial plexus palsy. *J.Neurosurg. Pediatr.* 2013.
15. Bialocerkowski A, O'Shea K, Pin TW. Psychometric properties of outcome measures for children and adolescents with brachial plexus birth palsy: a systematic review. *Developmental medicine and child neurology.* 2013;55(12):1075-1088.
16. Yvonne Geerdink PA, Menno van der Holst, Robert Lindeboom, Jan van der Burg, Bert Steenbergen, Alexander C. Geurts. Development and psychometric properties of the Hand-Use-at-Home questionnaire to assess amount of affected hand use in children with unilateral paresis. Submitted september 2016.
17. Holst M, Vlieland TP, van de Sande MA, van Egmond-van Dam JC, Vermeulen HM, Nelissen RG. Translation and adaptation of the Pediatric Outcome Data Collecting Instrument (PODCI) into the Dutch language and preliminary validation in children with Neonatal Brachial Plexus Palsy. *J Pediatr Rehabil Med.* 2015;8(3):219-226.
18. Terwee CB, Bot SD, de Boer MR, et al. Quality criteria were proposed for measurement properties of health status questionnaires. *J.Clin. Epidemiol.* 2007;60(1):34-42.
19. LG P, MP W. *Foundations of clinical research, applications to practice.* 3rd edition ed: Pearson Education International; 2009.
20. JC N, IH B. *Psychometric theory.* 3rd ed. New York: McGraw-Hill; 1994.
21. Sokal B, Uswatte G, Vogtle L, Byrom E, Barman J. Everyday movement and use of the arms: Relationship in children with hemiparesis differs from adults. *J Pediatr Rehabil Med.* 2015;8(3):197-206.
22. Klingels K, Demeyere I, Jaspers E, et al. Upper limb impairments and their impact on activity measures in children with unilateral cerebral palsy. *European journal of paediatric neurology :*

EJPN : official journal of the European Paediatric Neurology Society. 2012;16(5):475-484.
23. Sakzewski L, Ziviani J, Boyd R. The relationship between unimanual capacity and bimanual performance in children with congenital hemiplegia. *Developmental medicine and child neurology.* 2010;52(9):811-816.
24. Brown T, Cupido C, Scarfone H, Pape K, Galea V, McComas A. Developmental apraxia arising from neonatal brachial plexus palsy. *Neurology.* 2000;55(1):24-30.

APPENDIX 1

Conversion table of sum scores to obtain the HUH-person-measure in logit units

Sum score	HUH-score (logits)	SE	Sum score (continued)	HUH-score (logits)	SE
0	-4.695	NA	19	0.513	0.37
1	-3.853	1.04	20	0.649	0.37
2	-3.082	0.76	21	0.786	0.37
3	-2.597	0.64	22	0.925	0.37
4	-2.230	0.57	23	1.066	0.38
5	-1.927	0.53	24	1.211	0.38
6	-1.166	0.50	25	1.361	0,39
7	-1.431	0.47	26	1.518	0.40
8	-1.218	0.45	27	1.684	0.41
9	-1.022	0.44	28	1.861	0.43
10	-0.838	0.42	29	2.053	0.45
11	-0.665	0.41	30	2.265	0.47
12	-0.500	0,40	31	2.506	0.51
13	-0.343	0.39	32	2.788	0.56
14	-0.191	0.39	33	3.134	0.62
15	-0.044	0.38	34	3.599	0.75
16	0.098	0.38	35	4.352	1.03
17	0.238	0.37	36	5.174	NA
18	0.376	0.37			

HUH-score= Hand-Use-at-Home score, SE= standard error, NA= not applicable

CHAPTER SIX

Neonatal brachial plexus palsy in children aged 0 to 2.5 years; parent-perceived family impact, quality of life, and upper extremity functioning

Menno van der Holst | Duco Steenbeek | Willem Pondaag
Rob G.H.H. Nelissen | Thea P.M. Vliet Vlieland

Published:
Pediatric Neurology 2016 September; 62:34-42
DOI: 10.1016/j.pediatrneurol.2016.06.015
Oral abstract presentation Narakas congress february 2016, Barcelona, Spain
Poster abstract presentation VRA congress april 2016, Amsterdam, The Netherlands

ABSTRACT

Objective

To investigate whether parents perceive impact of neonatal brachial plexus palsy on family and quality of life and upper extremity functioning in children less than 2.5 years old.

Methods

This cross-sectional study used the PedsQL Family Impact Module (36 items/one total/four scales/scores 0 to 100), TNO-AZL (Dutch Organisation of Applied Natural Science and Academic Hospital Leiden) Preschool Children's Quality of Life (43 items/12 scales/scores 0 to 100) and 21 upper extremity functioning questions. Associations between neonatal brachial plexus palsy/patient characteristics and family impact, perceived quality of life, and upper extremity functioning were investigated using regression analysis.

Results

Parents of 59 children (median age, 18 months) participated, 49 with C5-C6/C5-C7 lesions. Median Family Impact Module and TNO-AZL Preschool Children's Quality of Life scores were 81.3 to 100.0/100.0 and 78.6 to 100.0/100.0. TNO-AZL Preschool Children Quality of Life scores did not differ significantly to healthy references except for stomach, skin, communication, and motor functioning problems. Parents reported around three upper extremity functioning problems. Greater lesion extent, lower age, still being in follow-up, and right-sided lesions were associated with greater family impact ($P < 0.01$ to $P < 0.1$). No clinically relevant associations were found for perceived quality of life. Greater lesion extent and nerve surgery history were associated with more upper extremity functioning problems ($P < 0.01$). Problems were associated with parental worrying ($P < 0.05$).

Conclusions

Parents perceive having a child with neonatal brachial plexus palsy as impacting on their family depending on the side and severity of the lesion, treatment history, still being in follow-up, and age. They perceive the child's quality of life as relatively normal and not significantly different to healthy peers. However, parents noticed upper extremity functioning problems which increased parental worrying. Healthcare specialists should take these findings into account to better inform or counsel parents in an early stage during treatment.

INTRODUCTION

Neonatal brachial plexus palsy (NBPP) is the result of a stretch injury to the plexus during delivery; its incidence ranges from 1.3 to 2.9/1000.[1,2] Most injuries are mild, but 20% to 30% of the children are left with diminished upper arm function.[2-4] Severe lesions can be treated with nerve surgery at a young age (3 to 9 months). Depending on the clinical course over time, secondary surgery (muscle tendon transfers/osteotomies) may be indicated later on.[5-7] When a child is diagnosed with NBPP, parents face an uncertain future.[8,9] Over time, it will become apparent to which extent recovery can be expected and if nerve surgery will be indicated. Depending on neurological recovery, a better prediction can be made of future arm function. This period is often stressful and worrying for parents and their families. The prognostic uncertainty and consequences for the child's quality of life (QoL) might have impact on families and their QoL.[8-10]

Despite these observations, little research has been done on the impact of NBPP on family and parental QoL in the first years of a child's life. One study found that impact on family was not age dependent.[11] Another study found that having a younger child with NBPP (age 0 to 2 years) had more impact on maternal QoL.[12] Some studies reported impact on the family in terms of finances, personal strain, social and mastery problems, increased risk of psychological problems or distress, and lower maternal QoL.[10-14] Another study found that condition severity was associated with paternal stress and psychological adjustment, both affecting family functioning.[15]

Little is also known about the parent-perceived QoL of young children (less than 2.5 years old) with NBPP. Studies in children with NBPP who are more than two years of age showed that these children have a poorer QoL and limited upper extremity functioning (UEF).[13,16,17]

To fully understand the impact of NBPP in young children on the family, it is important to know how parents perceive their child's functioning. However, this has not been studied before. Insight into family impact, QoL, and UEF and possible influential factors is important to be able to provide adequate care, which may help reduce the impact of having a child with NBPP.

Therefore, the goal of our study was to assess the impact of NBPP on family (including parental QoL), perceived QoL, and UEF of young children (less than 2.5 years old). In addition, we explored possible factors associated with family impact, parent-perceived QoL, and UEF and compared the parent-perceived children's QoL with that in the general Dutch population.

PATIENTS AND METHODS

Study design and patients

This study had a cross-sectional design and was part of a larger study on functioning and QoL of patients of all ages with NBPP. That study was conducted between October 2014 and March 2015 at the multidisciplinary, supraregional NBPP care unit of the Leiden University Medical Center and was approved by its medical ethics committee (P14.071). All patients who visited the NBPP care unit, for whom an electronic medical record was available and who were diagnosed with NBPP, were eligible to participate. Patients with concurrent other medical diagnoses that might influence arm functioning (e.g., cerebral palsy, reduction defects) were excluded.

Recruitment

Eligible patients and/or their parents were sent an invitation (including information) to participate. They were asked whether they wanted to participate online or on paper. All participating patients aged greater than 18 years and parents of patients aged less than 18 years provided written informed consent. Questionnaires were sent via regular mail, or patients were invited by e-mail to the online questionnaire. Patients and/or parents who had not responded to the invitation or did not complete the questionnaires received a reminder.

The present analysis only used data on children aged 0 to 2.5 years.

NBPP and patient characteristics

Age, gender, lesion extent (C5-C6/C5-C7/C5-C8/C5-T1/C8-T1), affected side (right/left), and treatment history (conservative/nerve and/or orthopedic surgery) were extracted from the medical records, and current status regarding discharge from follow-up (yes/no) was noted. Parents were asked whether NBPP was present in their families, what kind of household they had (single-parent/two-parent), and whether the child with NBPP was their firstborn (yes/no). Parents were also asked to state whether they had contact with specific health care professionals (apart from the NBPP care unit) or patient organizations and whether their child had been admitted to hospital for NBPP in the past 12 months.

Parent-reported family impact

The 36-item PedsQL Family Impact Module (FIM) measures the impact of a child's chronic condition on their family and yields a Total Scale score, a parental QoL Summary score (Physical/Emotional/Social/ Cognitive Functioning subscales; 20 items), a Family Functioning Summary score (Daily Activities/Family Relationships; eight items), a Worry score (five items), and a Communication score (three items). It uses a Likert-type response scale (0: never to 4: almost always), and scores are transformed to a 0 to 100 scale (0 = 100/ 1 = 75/ 2 = 50/ 3 = 25/ 4 = 0). Scores are computed as the sum of items divided by the number of items answered. Higher FIM scale scores indicate lower impact. If more than 50% of the items in

a scale were missing, no score was computed. The FIM was found to be reliable and valid and is available in Dutch.[18]

Quality of life

The TNO-AZL (Dutch Organisation of Applied Natural Science and Academic Hospital Leiden) Preschool children's QoL (TAPQOL) was developed to measure QoL in children aged six months to five years. It is a parent-reported, 43-item generic questionnaire, with 12 scales (three to seven items/scale) covering the domains of physical, social, cognitive, and emotional functioning. Questions relate to the past three months and are scored on a three-point scale (complaint/limitation present: never/occasionally/often). In addition, in seven of the 12 scales (stomach/skin/lung/sleeping/appetite/motor functioning/communication), the child's well-being is also measured in relation to these complaints/ limitations, on a four-point scale (fine/ not so good/quite bad/bad). Scale scores are transformed to a 0 to 100 scale, with higher scores indicating better QoL. No missing values are allowed in three-item scales, one in scales with four items, and two in scales with seven items. The social functioning/motor functioning/ communication scales are only relevant for children aged over 1.5 years.[19]

TAPQOL scores were compared with those of healthy, age-matched references, using a sample from the publicly available reference database. The reference data were derrived from 340 Dutch babies visiting youth health care centers (consultatiebureaus, visited by all Dutch children regularly in the first four years).[20] The sample was selected based on age (six to 30 months) and the absence of health problems, resulting in a reference group consisting of 118 children (median age, 21.0 months; range, ten to 30 months), 45 of whom were male.

Upper extremity functioning

To further understand the QoL issues in NBPP, parent-perceived children's UEF was assessed. No NBPP-specific questionnaires on UEF are available for very young children. Therefore, we developed a set of questions regarding activities (15 items), bodily appearance (three items), and development (three items; Table III). The questions were developed by a group of experts from the NBPP care unit bearing in mind the recommendations for measurement properties of health status questionnaires.[21] The measurement aim is discriminative for the upper extremity physical functioning and evaluative for the bodily appearance and developmental aspects. The questions were pilot tested in the present study. Internal consistency was measured by computing Cronbach's α for the different question parts and were 0.92, 0.81, and 0.91 for activities, bodily appearance, and development, respectively. Because there is no gold standard available, criterion validity could not be determined. Because of the design of the present study, reproducibility and responsiveness were not tested.

Regarding UEF activities, parents could state whether they had observed their child perform certain activities using their affected arm/ hand and if so, whether their child had difficulties with them. Scores were (1) "not observed," (2) "has difficulty," (3) "has no difficulty."

The number of problematic activities was counted and divided into three groups: one to three, four to six, and seven or more problems (i.e., mild, moderately, and severely affected UEF). As regards bodily appearance and development, statements were presented which could be rated as (1) "disagree," (2) "agree," (3) "not applicable/no opinion."

Statistical analysis

Descriptive statistics were used for patient characteristics and all outcome measures according to their distribution (Kolmogorov-Smirnov). TAPQOL scores were compared with those of age-matched, healthy references using analysis of covariance (covariates: age/gender; significance level, $P < 0.05$).

To determine which factors are associated with family impact, perceived QoL, and UEF, univariate regression analyses were performed for all FIM and TAPQOL scales and for UEF (activities only; significance level, $P < 0.1$). Factors entered independently, one at a time, were lesion extent (C5-C6/C5-C7 and C5-C8/C5-T1/C8-T1), discharged from follow-up (yes/no), treatment history (nerve surgery/conservative), affected side (right/left), household (single parent/two parent), firstborn (yes/no), responding parent (father/mother), age in years (<1/1 to 2/>2), and UEF activities (1 to 3/ 4 to 6/ >7 problems). Subsequently, a multiple regression analysis was performed with only those factors that were significant in the univariate analyses ($P < 0.1$). All analyses were executed using SPSS 20.0 software (IBM SPSS Sta- tistics for Windows, Armonk, NY: IBM Corp).

RESULTS

From the total cohort of 1142 patients, 104 were eligible for the present study. Parents of 59 patients participated in the present study. Figure 1 shows the flow of these patients, and Table I presents the patient characteristics including healthcare use. Twenty-eight patients (48%) were boys; the median age was 18 months (range, 6 to 30); 26 (44%) had their right side affected and 21 (36%) had been discharged from follow-up. The majority (88%) received physiotherapy.

Table II provides the FIM and TAPQOL outcomes. Median FIM total score was 87.9 (interquartile range [IQR], 74.6 to 96.6), and median FIM scale scores ranged from 81.3 to 100.0 (IQR, 58.3 to 100.0). Figure 2 shows that there is a wide variety in how parents perceive NBPP as impacting on their families. Median TAPQOL scores ranged from 78.6 to 100.0 (IQR, 64.3 to 100.0). About 66% of the TAPQOL scores were not significantly different from the scores of the reference group. However, stomach, skin, motor functioning, and communication scores were lower in the NBPP study population ($P < 0.05$).

Table III provides the outcomes regarding UEF. Parents reported around three problematic activities (IQR, 0.0 to 5.3) and 13 parents report more than seven problems. The most frequently reported problems were "playing with construction materials," "colouring/

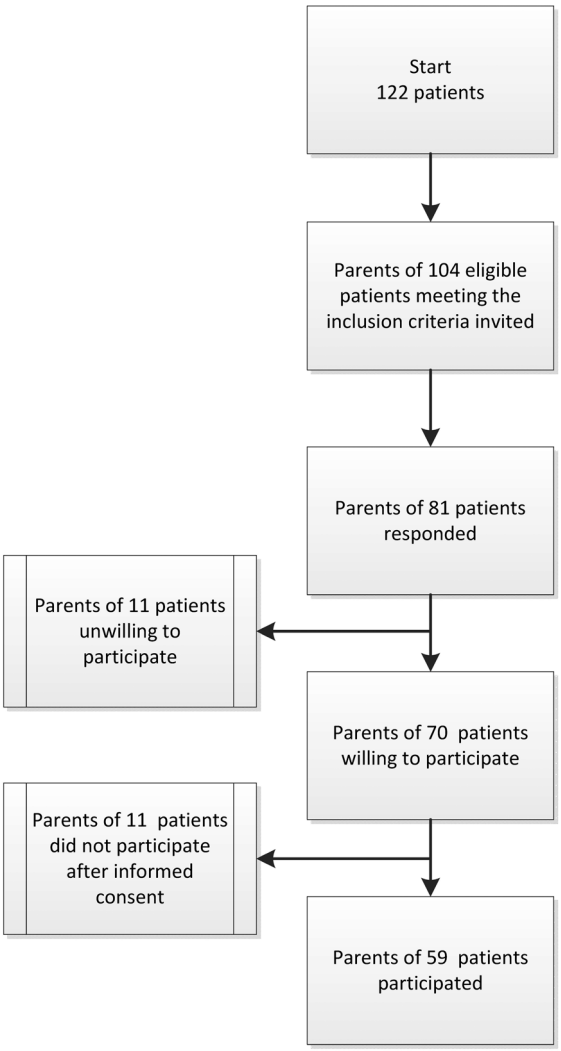

Figure 1 Flowchart of participating parents of patients (0-2.5 years)

painting," "throwing/ rolling a ball," "grasping something located above the head with two hands," "breaking his/her fall," and "drinking from a mug without ears."

With respect to bodily appearance, 16 parents (27%) thought their child's arm looked different; nine (15%) thought the affected arm was shorter; and seven parents (12%), whose child had undergone nerve surgery, felt bad about the visible scars.

Regarding development, 18 parents (31%) felt their child was not able to do what other children were able to, nine (15%) felt their child developed differently, and nine (15%) thought their child more easily became frustrated trying to perform bimanual tasks.

Table I NBPP Patient characteristics and their healthcare use in the past 12 months

Patients (n=59)		
Gender		
Male (%)	28	(47.5)
Age in months Median (IQR) Range	18 (13/24)	6-30
Affected side		
Right (%)	26	(44.1)
Lesion extent		
Group 1: Upper plexus lesions (%)		
C5-C6	40	(67.8)
C5-C7	9	(15.3)
Group2: Total and lower plexus lesions (%)		
C5-C8	7	(11.9)
C5-T1	2	(3.4)
C8-T1	1	(1.7)
Surgical intervention (%)		
Nerve surgery	23	(39.0)
Conservative treatment	36	(61.0)
Discharged from follow-up		
Yes	21	(35.6)
NBPP in family		
Yes (No. of family members with NBPP, range)	4	(1-3)
Questionnaire completed by		
Father (%)	19	(32.2)
Family situation		
Single parent household (%)	4	(6.8)
Firstborn		
Yes (%)	21	(35.6)
Care received from professionals outside NBPP care unit (%)		
Physical therapy	52	(88.1)
Occupational therapy	4	(6.8)
Contact with professionals within NBPP care unit (%)		
Physical therapist	45	(76.3)
Occupational therapist	30	(50.8)
Neurosurgeon	40	(67.8)
Orthopaedic surgeon	12	(20.3)
Rehabilitation specialist	20	(33.9)
Contact with professionals apart from NBPP care unit (%)		
General practitioner	13	(22.0)
Neurosurgeon	17	(28.8)
Orthopaedic surgeon	6	(10.2)
Rehabilitation specialist	8	(13.6)
Paediatrician	30	(50.8)
Plastic surgeon	1	(1.7)
Psychologist	6	(10.2)
Psychiatrist	1	(1.7)
Social Worker	4	(6.8)
NBPP Patient Organisation	8	(13.6)
Hospital admission		
Yes (%)	15	(25.4)

IQR = interquartile ranges (25th percentile -75th percentile)

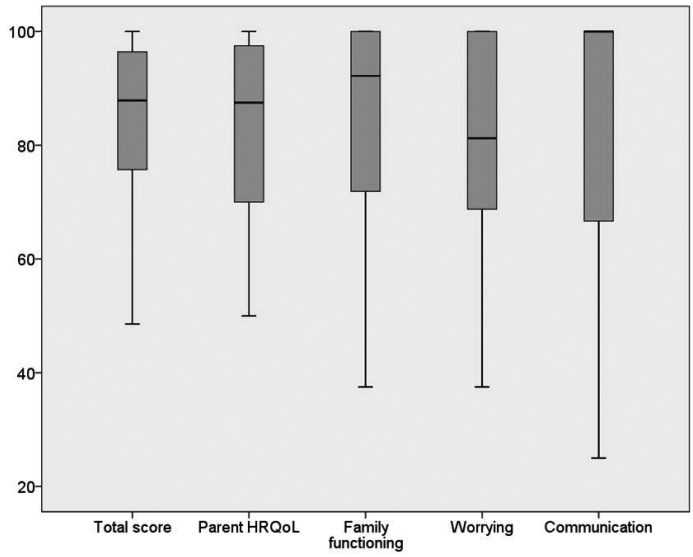

Figure 2 Boxplots showing Family Impact Measure (FIM) scores of 59 children with NBPP

Univariate regression analyses showed that lesion extent, not having been discharged from follow-up, age less than one year, and affected side (right) were independently associated with lower scores on almost all FIM scales (all $P < 0.01$ to $P < 0.1$ [Table IV]). Scores on the Worry and Communication scales showed that nerve surgery treatment was associated with lower scores ($P < 0.01$). Having more UEF problems was associated with more parental worrying ($P < 0.05$).

Multiple regression analysis was done for all FIM scales, with only factors entered which were significantly associated with all FIM scales in the univariate analysis as described previously. This showed that the combination of lesion extent, affected side (right), and lower age (less than one year) was associated with worse outcome on all FIM scales (all $P < 0.01$ to $P < 0.1$ except age in the Worry and Communication scales).

Hardly any significant associations were found for the TAPQOL scales (Table IV). Affected side (right) was associated with a lower score on the "appetite" scale ($P < 0.01$). No multiple regression was performed for the TAPQOL scales because no clinically relevant associations were found in the univariate regression analyses.
Lesion extent (C5-C8/C5-T1/C8-T1), not having been discharged from follow-up, and treatment history (nerve surgery) were independently associated with more reported UEF problems ($P < 0.01$). Multiple regression analysis for UEF showed that lesion extent and nerve surgery history were associated with more reported problems (all $P < 0.01$).

Table II Family Impact Measure (FIM) and TAPQOL scores of 59 children with NBPP; TAPQOL scores compared with healthy, age-matched references

	NBPP group (n=59)			**Healthy reference (HR) group for TAPQOL (n=118)**		
	Median	**IQR**	**(% ceiling score)**			
FIM scores				-	-	-
Total score	87.9	74.6-96.6	(12.1)			
Parent health-related quality of life	87.5	69.7-97.5	(19.0)			
Family functioning	92.2	71.9-100.0	(41.4)			
Worrying subscale	81.3	67.2-95.3	(24.1)			
Communication subscale	100.0	58.3-100.0	(53.4)			
				Median	**IQR**	**(% ceiling score)**
TAPQOL scales,						
Stomach problems scale	**91.7***	81.3-100.0	(48.1)	100.0	95.8-100.0	(75.2)
Skin problems scale	**83.3***	75.0-100.0	(32.7)	100.0	91.7-100.0	(51.7)
Lung problems scale	100.0	97.9-100.0	(75.9)	100.0	100.0-100.0	(86.4)
Sleeping scale	81.3	56.3-93.8	(20.0)	81.3	75.0-100.0	(25.4)
Appetite scale	100.0	83.3-100.0	(52.7)	91.7	75.0-100.0	(39.8)
Liveliness scale	100.0	100.0-100.0	(96.4)	100.0	100.0-100.0	(79.9)
Positive mood scale	100.0	100.0-100.0	(89.1)	100.0	100.0-100.0	(96.6)
Problem behaviour scale	78.6	64.3-92.9	(16.4)	71.4	64.3-80.4	(2.5)
Anxiety scale	83.3	66.7-100.0	(49.1)	83.3	66.7-100.0	(41.5)
Social functioning scale† (NBPP: n=32, HR: n=83)	100.0	83.3-100.0	(68.8)	100.0	83.3-100.0	(61.4)
Motor functioning scale† (NBPP: n=32, HR: n=83)	**87.5***	81.3-100.0	(31.3)	100. 0	93.8-100.0	(74.7)
Communication scale† (NBPP: n=32, HR: n=79)	**81.3***	75.0-93.8	(19.4)	93.8	81.3-100.0	(40.5)

IQR = Interquartile ranges (25th percentile -75th percentile). For all outcomes 0-100, higher scores indicate lower impact/ better functioning. * p<0.05 difference between TAPQOL NBPP group and TAPQOL healthy reference group. † Only for children aged ≥1.5 years.

Table III Upper extremity functioning (UEF) of 59 children with NBPP

UEF activities **My child has difficulty:**	**Not observed**	**Has no difficulty using the affected arm/hand No. (%)**	**Has difficulty using the affected arm/hand No. (%)**
1. Picking up toys (n=59)	0	40 (68%)	19 (32%)
2. Passing toys from one hand to the other (n=59)	0	44 (75%)	15 (25%)
3. Playing with construction materials (Duplo etc.) (n=44)	15	30 (68%)	14 (32%)
4. Colouring/painting (n=29)	30	17 (59%)	12 (41%)
5. Throwing/rolling a ball (n=45)	14	25 (56%)	20 (44%)
6. Carrying big things (big toys etc.) (n=47)	12	35 (74%)	12 (26%)
7. Grasping something above the head with two hands (n=45)	14	29 (64%)	16 (36%)
8. Crawling (n=51)	8	39 (77%)	12 (23%)
9. Raising him/herself to standing position (n=52)	7	39 (75%)	13 (25%)
10. Getting up from the floor (n=47)	12	36 (77%)	11 (23%)
11. Climbing during play (n=46)	13	33 (72%)	13 (28%)
12. Climbing onto a chair or couch (n=42)	17	32 (76%)	10 (24%)
13. Breaking his/her fall (n=47)	12	27 (52%)	20 (38%)
14. Drinking from a mug without ears (n=40)	19	24 (60%)	16 (43%)
15. Putting something to eat in his/her mouth (cake, bread etc) (n=51)	8	37 (73%)	14 (27%)
No. of reported problems of Upper Extremity Functioning activities			
Median (IQR)			3.0 (0.0-5.3)
1-3 problems (no.)			11
4-6 problems (no.)			14
>7 problems (no.)			13

UEF cosmetics and development	**Agree No. (%)**	**Disagree No. (%)**	**Not applicable/ No opinion No. (%)**
Cosmetics:			
My child's arm looks different	16 (27%)	24 (41%)	19 (32%)
My child's arm is shorter than his/her other arm	9 (15%)	22 (37%)	28 (48%)
I feel bad about scars of the operation being visible	7 (12%)	28 (48%)	24 (40%)
Development:			
My child is not able to do what other children are able to	18 (31%)	19 (32%)	22 (37%)
My child does not develop the same as other children	9 (15%)	31 (53%)	19 (32%)
My child is more easily frustrated than other children when trying to perform bimanual tasks	9 (15%)	26 (45%)	24 (40%)

Table IV Regression analyses for all PedsQL™ FIM and TAPQOL scales, and UEF activities for 59 children with NBPP

β -Estimates (95% CI)	Lesion extent C5/C6-C5/C7 († C5-C8/C5-T1/C8-T1)	Discharged from follow-up: Yes († No)	Conservative treatment († nerve surgery)	Affected side Right († Left)	Firstborn: Yes († No)	Age <1 year († age >2)	Age <1 year († age 1-2)	Responding parent: Father († Mother)	Two- parent household († single parent)	UEF activities >7 problems († 1-3 problems)	UEF activities 4-6 problems († 1-3 problems)
FIM:											
Total score	**15.3** (3.1, 27.5)**	**12.8*** (3.3, 22.3)**	**9.1* (-0.6, 18.8)**	**-15.1*** (-24.0, -6.1)**	1.1 (-9.1, 11.2)	**-13.3* (-28.8, 2.2)**	-2.2 (-13.7, 9.3)	2.9 (-7.6, 13.4)	7.8 (-14.0, 29.7)	-9.7 (-25.9, 6.5)	-9.6 (-25.2, 6.1)
Parents' health-related quality of life	**14.1** (0.9, 27.2)**	**12.3** (2.1, 22.6)**	8.2 (-2.1, 18.7)	**-17.3*** (-26.6, -8.0)**	1.4 (-9.3, 12.2)	**-15.5* (-31.9, 0.9)**	-2.6 (-14.8, 9.5)	5.16 (-5.9, 16.2)	9.2 (-14.0, 32.4)	-10.5 (-27.4, 6.5)	-9.4 (-25.7, 7.0)
Family functioning	14.8** (0.8, 28.8)	**11.7** (0.6, 22.7)**	6.1 (-5.1, 17.3)	**-9.0* (-19.8, 1.8)**	-0.7 (-12.2, 10.7)	**-15.9* (-33.4, 1.7)**	-3.4 (-16.4, 9.5)	1.4 (-10.4, 13.4)	4.2 (-20.6, 29.1)	-6.6 (-25.6, 12.5)	-9.7 (-28.1, 8.7)
Worrying	**20.0*** (7.3, 32.8)**	**15.1*** (5.0, 25.2)**	**13.8*** (3.7, 23.9)**	**-14.1*** (-23.9, -4.3)**	3.5 (-7.4, 14.3)	2.1 (-15.0, 19.1)	5.2 (-7.5, 17.8)	-4.0 (-15.2, 7.3)	10.3 (-13.2, 33.7)	**-17.1** (-32.3, -2.0)**	-11.5 (-26.1, 3.1)
Communication	**18.3** (1.1, 35.6)**	**16.2** (2.8, 29.6)**	**16.3** (3.0, 29.5)**	**-17.51*** (-30.3, -4.7)**	-0.2 (14.1, 14.1)	-12.6 (-34.5, 9.4)	-6.0 (-22.2, 10.3)	1.2 (-13.4, 15.9)	5.5 (-25.1, 36.0)	-3.0 (-26.8, 20.9)	-7.6 (-30.6, 15.4)
TAPQOL:											
Stomach problems	3.6 (-8.6, 15.8)	-6.5 (-16.4, 3.5)	-4.3 (-14.0, 5.4)	-6.9 (-16.4, 2.7)	-8.0 (-17.6, 1.7)	**-13.6* (-28.2, 1.1)**	-6.5 (-17.5, 4.5)	4.6 (-5.4, 14.7)	-11.6 (-32.2, 9.0)	-1.1 (-14.0, 11.7)	-2.1 (-14.7, 10.5)
Skin problems	0.3 (-11.3, 11.9)	3.2 (-6.2, 12.7)	-0.1 (-9.2, 9.0)	-4.3 (-13.3, 4.7)	-1.7 (-10.9, 7.6)	3.9 (-10.2, 18.0)	5.8 (-4.8, 16.4)	-2.3 (-11.8, 7.2)	-4.8 (-24.4, 14.9)	-5.2 (-19.4, 8.9)	-5.1 (-18.8, 8.5)
Lung problems	-2.2 (-11.9, 7.5)	-4.4 (-12.3, 3.6)	-4.6 (-12.3, 3.1)	-2.6 (-10.3, 5.1)	4.2 (-3.6, 11.9)	0.4 (-11.6, 12.4)	-1.6 (-10.6, 7.5)	0.5 (-7.6, 8.5)	-7.2 (-23.6, 9.2)	5.0 (-6.3, 16.3)	4.7 (-6.3, 15.8)
Sleeping	-6.4 (-22.6, 9.8)	9.4 (-3.7, 22.5)	9.9 (-2.7, 22.4)	**-14.7* (-26.8, -2.7)**	-7.5 (-20.4, 5.4)	8.6 (-11.3, 28.5)	5.0 (-9.9, 20.0)	7.4 (-5.9, 20.6)	-6.0 (-33.5, 21.6)	-2.9 (-22.9, 17.1)	-5.6 (-24.9, 13.6)
Appetite	6.5 (-3.8, 16.7)	5.5 (-2.9, 13.9)	2.2 (-6.0, 10.3)	**-11.4*** (-18.9, -3.9)**	-2.4 (-10.7, 5.9)	-5.5 (-18.2, 7.2)	-3.9 (-13.4, 5.7)	4.1 (-4.4, 12.6)	-7.3 (-24.9, 10.2)	-9.3 (-23.2, 4.5)	-6.8 (-20.1, 6.6)
Liveliness	-1.1 (-4.6, 2.4)	1.4 (-1.5, 4.2)	-1.5 (-4.3, 1.2)	0.3 (-2.4, 3.1)	1.4 (-1.4, 4.2)	-2.5 (-6.7, 1.7)	1.2 (-2.0, 4.3)	-1.4 (-4.3, 1.5)	-1.0 (-7.0, 5.0)	0.0 (-4.7, 4.7)	-2.4 (-6.9, 2.1)

Positive mood	**6.5** (0.3, 12.7)**	**4.5* (-0.7, 9.7)**	0.0 (-5.1, 5.1)	**-4.8* (-9.6, 0.1)**	3.5 (-1.6, 8.5)	-1.5 (-9.0, 6.0)	**5.4* (-0.2, 11.0)**	0.4 (-4.9, 5.7)	8.6 (-2.2, 19.2)	-5.6 (-13.8, 2.7)	-4.8 (-12.7, 3.2)
Problem behaviour	0.3 (-14.3, 14.9)	3.9 (-8.1, 15.8)	6.5 (-4.9, 17.8)	-7.2 (-18.5, 4.0)	-5.0 (-16.6, 6.7)	13.3 (-4.3, 0.9)	2.3 (-10.9, 15.5)	2.7 (-9.3, 14.7)	-12.8 (-37.4, 11.7)	-10.7 (-27.5, 6.1)	-6.6 (-22.9, 9.6)
Anxiety	-6.5 (-21.2, 8.2)	6.0 (-6.1, 18.0)	3.3 (-8.3, 14.9)	-4.5 (-16.0, 7.0)	1.8 (-10.0, 13.6)	5.3 (-12.6, 23.2)	10.3 (-3.1, 23.7)	3.2 (-8.9, 15.3)	11.4 (-13.5, 36.4)	1.3 (-17.4, 19.9)	-14.6 (-32.6, 3.4)
Social functioning	-7.0 (-19.1, 5.2)	5.7 (-5.5, 17.0)	-3.1 (-13.4, 7.1)	-5.3 (-15.7, 5.2)	-5.3 (-15.7, 5.2)	x	x	6.5 (-4.3, 17.4)	-8.1 (-37.5, 21.4)	-8.3 (-24.7, 8.1)	-9.3 (-25.9, 7.4)
Motor functioning	2.1 (-12.1, 16.4)	8.6 (-3.7, 21.0)	6.8 (-4.8, 18.3)	2.3 (-10.2, 14.6)	**-9.7* (-21.3, 2.0)**	x	x	0.5 (-11.9, 12.9)	-15.8 (-49.2, 17.6)	-13.6 (-33.0, 5.7)	-8.8 (-28.5, 10.8)
Communication	-13.0 (-29.0, 3.1)	8.47 (-5.3, 22.3)	**-13.8** (-26.1, -1.6)**	6.63 (-7.3, 20.6)	-5.6 (-19.3, 8.1)	x	x	2.3 (-11.5, 16.1)	-7.2 (-44.6, 30.2)	4.2 (-16.1, 24.6)	-5.7 (-26.1, 14.6)
UEF:											
Activities	**-4.8*** (-7.2, -2.7)**	**-3.7*** (-5.5, -1.8)**	**-5.1*** (-6.7, -3.5)**	0.5 (-1.6, 2.5)	-0.3 (-2.5, 1.8)	**-3.1** (-6.3, 0.1)**	-1.6 (-3.9, 0.7)	**1.9* (-0.2, 4.0)**	-2.7 (-6.7, 1.2)	xx	xx

* p<0.1, ** p<0.05, *** p<0.01. †= set as β –Estimate = 0 in the univariate regression analysis. FIM=Family Impact Module, TAPQOL= TNO-AZL Preschool children's Quality Of Life, UEF= reported problem of Upper Extremity Functioning. x= no analysis possible due to scale age limitations (no data for children <1 year), xx= no analysis possible.

DISCUSSION

This cross-sectional study on the parent-perceived family impact, QoL, and UEF of 59 children with NBPP aged 0 to 2.5 years showed that lower FIM scores were associated with younger age, lesion extent, affected side, nerve surgery treatment history, and currently being in follow-up. The parents' perception of the children's QoL was not significantly different to that of healthy references for 66% of the TAPQOL scales. Having more UEF problems was associated with lesion extent and nerve surgery treatment history. These problems were associated with more parental worrying.

Our findings regarding the family impact of having a child with NBPP are generally in line with previous studies. Most studies reported a certain degree of family impact, maternal or paternal stress, and an increased risk of psychological problems. The severity of NBPP also influenced family impact.[10-15] Parental QoL scores in the present study indicate that having a child with NBPP influences some parents' lives, which is in line with previous findings.[9,11-13,15] We found that when the right side was affected, FIM scores tended to be lower (Table IV). This might be related to the 90% right-handedness of the general population.[22] Parents may be more worried about their child not being able to fully use their right arm.

A younger age (less than one year) had a significant negative impact on the family in our study (Table IV), unlike what was found in another study.[9] In that study, however, the median age was twice as high. We also found that a lower impact on parental QoL and family functioning was reported for the older children in our study, which might be related to improving prognosis in the still growing child. When parents reported more problems on UEF, they also tended to worry more, indicating that a higher degree of functional impairment has a greater impact on the parents.

Still being in follow-up is likely to imply that the child has not fully recovered and/or is in need of additional treatment in the future which may have impact on family. Six parents (10%) reported that they had sought psychological counselling related to their child having NBPP. In a multidisciplinary NBPP unit, psychological care would probably provide added value.

The FIM has not previously been used in patients with NBPP. Parents with NBPP children scored a median of 81.3 to 100.0 points on all FIM scales, which was also found in studies among parents of children with acquired brain injury and nephrotic syndrome.[23,24] Parents of children with chronic pain had lower scores, they scored 47 to 74 points on all scales.[25] Parents in our study had better FIM scores (up to 20 points higher) compared to U.S. parents of children with a chronic condition.[26] This is most probably related to the easily accessible and well-organized healthcare system in The Netherlands, giving parents confidence that their child with NBPP is taken care of. Furthermore, there is a wide variety in FIM scores as can be seen in Table II and Figure 2. In our study, mildly and severely affected children participated which may be the reason for this variety and relative high median scores.

Nevertheless, QoL and family life scores of most parents of NBBP children are to some extent affected.

To investigate children's parent-perceived QoL, the TAPQOL has not been used before in NBPP studies. QoL outcomes in the present study are in line with the available literature on older children with respect to motor functioning.[13,16,17] TAPQOL scales refer to common problems in young children, and there were few differences in perceived QoL between our NBPP population and the healthy references (Table II). The question remains whether the TAPQOL is suitable for the young NBPP population. QoL in young children is highly dependent on care provided by the parents. Because all parents wish their child to have a good life, the perceived QoL might be biased as parents are the proxy for their own children. However, if this is true in the present study, underestimation of issues reducing QoL is more likely than overestimation.

No NBPP-specific questionnaires were available to evaluate UEF in very young children, prompting us to develop a study-specific set of questions (Table III). There are developmental tools available, but these are performance tests, not available as questionnaires, and thus were not suitable for the present study. Preliminary psychometric property analyses of the UEF-questionnaire were promising. We found that greater lesion extent and a history of nerve surgery were associated with more UEF problems. This could mean that our preliminary set of questions is disease- specific and underlines the need to further develop this NBPP-specific UEF-questionnaire for young children. In this endeavor, however, cross-cultural differences should be addressed to ensure usefulness of the questionnaire across different countries. For example, with construction materials and food, performance can vary across cultures and climbing onto a couch is dependent on its height.

This study had a number of limitations. First, a relatively small sample size was used. However, in the past two years, only 104 newborns with NBPP were seen in the NBPP care unit, 59 (57%) of whom participated. Second, patients seen at our NBPP care unit were referred to us because of a severe lesion, which might lead to confounding by indication. Third, no control group was included to compare outcomes. For family impact, only U.S. population FIM data were available, which are not comparable to our Dutch data because of differences in the health care system and society. For QoL, age-matched reference values were available, partly counteracting this limitation.[19] Fourth, this study had a cross-sectional design with no follow-up, using only self- reported questionnaires. This fact might lead to overestimation or underestimation of results as people might be influenced by unknown factors at the time of completing the questionnaires (e.g., bad mood, work-related stress, etc.). Future studies monitoring parent-perceived family impact, QoL, and UEF over time should enable further optimization of health care for children with NBPP and their parents. Individual and/or group meetings providing detailed information about NBPP, prognosis, treatment strategies, and the possibility to meet fellow parents might provide added value to reduce the impact of having a child with NBPP.

CONCLUSION

When a newborn child is diagnosed with NBPP, this may have effect on the parents and their families. Our findings confirm that parents find to some extent that having a child with NBPP has impact on their family. Although lower age (less than one year) and more severe lesions have been previously reported as being associated with more impact on the family, the present study in infants and very young children showed that right-sided lesions and having more UEF problems were also related to a greater impact on the family. No study in very young children has reported this before, even though this is an important part in the development of young NBPP children. It is essential for healthcare specialists to be aware of these findings, so they can actively provide suitable information and counselling to parents in an early stage to help reduce the possible impact on family.

REFERENCES

1. Pondaag W, Malessy MJ, van Dijk JG, Thomeer RT. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev.Med.Child Neurol.* 2004;46(2):138-144.
2. Chauhan SP, Blackwell SB, Ananth CV. Neonatal brachial plexus palsy: incidence, prevalence, and temporal trends. *Seminars in perinatology.* 2014;38(4):210-218.
3. Evans-Jones G, Kay SP, Weindling AM, et al. Congenital brachial palsy: incidence, causes, and outcome in the United Kingdom and Republic of Ireland. *Arch.Dis.Child Fetal Neonatal Ed.* 2003;88(3):F185-F189.
4. Lagerkvist AL, Johansson U, Johansson A, Bager B, Uvebrant P. Obstetric brachial plexus palsy: a prospective, population-based study of incidence, recovery, and residual impairment at 18 months of age. *Developmental medicine and child neurology.* 2010;52(6):529-534.
5. Hale HB, Bae DS, Waters PM. Current concepts in the management of brachial plexus birth palsy. *J.Hand Surg.Am.* 2010;35(2):322-331.
6. Pondaag W, Malessy MJ. The evidence for nerve repair in obstetric brachial plexus palsy revisited. *Biomed.Res.Int.* 2014;2014:434619.
7. Waters PM. Update on management of pediatric brachial plexus palsy. *J.Pediatr.Orthop.B.* 2005;14(4):233-244.
8. Bellew M, Kay SP. Early parental experiences of obstetric brachial plexus palsy. *Journal of hand surgery.* 2003;28(4):339-346.
9. DeMatteo C, Bain JR, Gjertsen D, Harper JA. 'Wondering and waiting' after obstetrical brachial plexus injury: Are we underestimating the effects of the traumatic experience on the families? *Canadian Journal of Plastic Surgery.* 2014;22(3):183-187.
10. Beck CT. The arm: there is no escaping the reality for mothers of children with obstetric brachial plexus injuries. *Nursing research.* 2009;58(4):237-245.
11. Firat T, Oskay D, Akel BS, Oksuz C. Impact of obstetrical brachial plexus injury on parents. *Pediatrics international : official journal of the Japan Pediatric Society.* 2012;54(6):881-884.
12. Oskay D, Oksuz C, Akel S, Firat T, Leblebicioglu G. Quality of life in mothers of children with obstetrical brachial plexus palsy. *Pediatrics international : official journal of the Japan Pediatric Society.* 2012;54(1):117-122.
13. Alyanak B, Kilincaslan A, Kutlu L, Bozkurt H, Aydin A. Psychological adjustment, maternal distress, and family functioning in children with obstetrical brachial plexus palsy. *The Journal of hand surgery.* 2013;38(1):137-142.
14. Louden E, Allgier A, Overton M, Welge J, Mehlman CT. The impact of pediatric brachial plexus injury on families. *The Journal of hand surgery.* 2015;40(6):1190-1195.
15. McLean LA, Harvey D, Mutimer K. Risk and resistance factors associated with paternal adjustment to obstetrical brachial plexus injuries. *Journal of clinical psychology in medical settings.* 2014;21(3):244-252.
16. Akel BS, Oksuz C, Oskay D, Firat T, Tarakci E, Leblebicioglu G. Health-related quality of life in children with obstetrical brachial plexus palsy. *Qual.Life Res.* 2013.
17. Huffman GR, Bagley AM, James MA, Lerman JA, Rab G. Assessment of children with brachial plexus birth palsy using the Pediatric Outcomes Data Collection Instrument. *J.Pediatr.Orthop.* 2005;25(3):400-404.
18. Varni JW, Sherman SA, Burwinkle TM, Dickinson PE, Dixon P. The PedsQL Family Impact Module: preliminary reliability and validity. *Health Qual. Life Outcomes.* 2004;2:55.
19. Bunge EM, Essink-Bot ML, Kobussen MP, van Suijlekom-Smit LW, Moll HA, Raat H. Reliability and validity of health status measurement by the TAPQOL. *Arch.Dis.Child.* 2005;90(4):351-358.
20. TNO. TAPQOL, TACQOL, TAAQOL. 2013; https://www.tno.nl/media/5004/vragenlijsten_01032012.pdf. Accessed 12/4/2013.
21. Terwee CB, Bot SD, de Boer MR, et al. Quality criteria were proposed for measurement properties of health status questionnaires. *J.Clin. Epidemiol.* 2007;60(1):34-42.
22. Yang LJ, Anand P, Birch R. Limb preference in children with obstetric brachial plexus palsy. *Pediatric neurology.* 2005;33(1):46-49.
23. de Kloet AJ, Lambregts SA, Berger MA, van Markus F, Wolterbeek R, Vliet Vlieland TP. Family Impact of Acquired Brain Injury in Children and Youth. *Journal of developmental and behavioral pediatrics : JDBP.* 2015.
24. Mishra K, Ramachandran S, Firdaus S, Rath B. The impact of pediatric nephrotic syndrome on parents' health-related quality of life and family functioning: an assessment made by the PedsQL 4.0 family impact module. *Saudi journal of kidney diseases and transplantation.* 2015;26(2):285-292.
25. Jastrowski Mano KE, Khan KA, Ladwig RJ, Weisman SJ. The impact of pediatric chronic pain on parents' health-related quality of life and family functioning: reliability and validity of the PedsQL 4.0 Family Impact Module. *Journal of pediatric psychology.* 2011;36(5):517-527.
26. Medrano GR, Berlin KS, Hobart Davies W. Utility of the PedsQL™ family impact module: assessing the psychometric properties in a community sample. *Quality of life research.* 2013;22(10):2899-2907.

CHAPTER SEVEN

Healthcare use and information needs in children with neonatal brachial plexus palsy: a cross-sectional survey among 465 patients

Menno van der Holst | Duco Steenbeek | Willem Pondaag
Rob G.H.H. Nelissen | Thea P.M. Vliet Vlieland

Submitted
Oral abstract presentation VRA congress November 2017
Maastricht, The Netherlands

ABSTRACT

Objective

To investigate healthcare use and information needs of children aged 0-18 years with neonatal brachial plexus palsy (NBPP).

Patients and methods

For this cross-sectional study, all patients and/or their parents seen in our multidisciplinary NBPP clinic over the last 18 years were invited to complete a survey. The survey comprised questions on healthcare use due to NBPP in the past year (contact with the expert team and/or 11 other types of healthcare professionals) and on their current information needs (12 NBPP-related topics). Outcomes were described for 3 age groups (0-1, 2-9 and 10-18 years), and based on follow-up status (early/late/no discharge).

Results

465 parents/patients participated (59, 226 and 180 patients in the 0-1, 2-9 and 10-18 age groups, respectively). 293 (63%) had C5-C6 lesions, 193 (42%) had been discharged from follow-up, 83 of whom were categorized as 'early discharge' (defined as <1 year of age) due to spontaneous lesion recovery (19/59, 50/226 and 14/180).

Over the past year, 198 patients had had contact with the expert team (49/59, 81/226 and 68/180) and 288 with at least 1 other healthcare professional (53/59, 133/226 and 102/180). Of the 83 patients discharged early, 34 reported healthcare use. 228 participants (49%) reported current information needs regarding at least one topic and 23 of these patients were discharged early.

Conclusions

Healthcare use and information needs of children due to NBPP remain considerable even in children who were early and late discharged. Stricter longitudinal follow-up and information provision for all patients with NBPP throughout life is needed.

INTRODUCTION

Neonatal brachial plexus palsy (NBPP) occurs in about 1-3 children per 1000 births in western countries.[1,2] Seventy to ninety percent of these children recover spontaneously, while the remaining 10-30% are left with neurological damage, possibly resulting in functional impairments.[2-5] Children with severe NBPP are usually referred to a tertiary NBPP expert center for further diagnostics and follow-up.[1,6,7] If these children do not show sufficient spontaneous recovery around the age of 3 months, primary, nerve, surgery may be indicated.[8,9] Children with persistent functional limitations can be treated with secondary surgery (e.g. osteotomies, tendon transfers) to improve the functionality of the affected arm/hand and prevent bone and joint deformities.[10-12]

In the Netherlands, most children with NBPP are referred to a specialized NBPP clinic (e.g. the Leiden Nerve Center located at Leiden University Medical Center) by their family doctor, or a pediatrician or pediatric neurologist at a local hospital.[6,13] The Leiden Nerve Center has successfully promoted early referral, i.e. at the age of one month.[13] Infants are assessed and treated by a multidisciplinary expert team involving a variety of medical and allied health care professionals using an interdisciplinary approach.[1,6,8,11,12,14,15] In addition, most children are treated by healthcare professionals in primary care in their place of residence (e.g. allied healthcare or psycho-social) and, if insufficient, interdisciplinary rehabilitation care is provided.[16,17] A considerable proportion of patients are discharged from clinical follow-up at the Leiden Nerve Center, either in their first year of life because of spontaneous recovery without indications for any interventions, or later on in their care trajectory if good functional recovery takes place after conservative or surgical treatment.[8,14,18-22]

Discharge from follow-up necessitates a low threshold for renewed consultation but also satisfactory information for both parents and patients. The need for, and specific content of, this information may change over time and differs for each age group.

At present, there is virtually no literature on the healthcare use of children with NBPP. Furthermore, factors influencing healthcare use by patients with NBPP are largely unknown. No literature is available on the information needs of the NBPP population (whether in clinical follow-up or not), even though decision making regarding NBPP is influenced by the information that is sought or provided.[23] To date, it remains unclear whether patients and/or their parents/caregivers, whether in clinical follow-up or not, have unmet information needs. In order to improve medical decision making, it is important to understand with how many and which healthcare professionals children and their parents have contact throughout their lives due to NBPP. In what way is healthcare use determined by patient characteristics, quality of life (QoL) and physical functioning parameters. Furthermore, what information do patients and/or their parents/caregivers need in order to feel provided with the right information throughout the NBPP treatment phase.

The aim of the present study was therefore to quantify the healthcare use of children with NBPP due to their condition, defined in the present study as the number of professionals involved in their care, and to specify the information needs of patients and/or their parents/caregivers at different ages and in various follow-up categories.

PATIENTS AND METHODS

Study design and patients

This study had a cross-sectional design and was part of a larger study on the functioning and quality of life of patients with NBPP. It was conducted between October 2014 and March 2015 at the Leiden Nerve Center, and was approved by the university's medical ethics committee (P14.071). All patients who visited the Leiden Nerve Center and were diagnosed with NBPP, and for whom an electronic medical record was available, were eligible to participate. Patients with concurrent other medical diagnoses that might influence arm functioning (e.g. cerebral palsy, reduction defects) were excluded.

Recruitment

Eligible patients and/or their parents were sent an invitation (including information) to participate. They were asked whether they wanted to participate online or on paper. All participating patients aged >18 years and parents of patients <18 years of age provided written informed consent. Questionnaires were sent via regular mail, or patients were invited by e-mail to complete the online questionnaire. Patients and/or parents who had not responded to the invitation, or did not complete the questionnaires, received a reminder.
A total of 1142 patients were invited to participate in the overall study of whom 508 patients and/or their parents participated. The present study used the data of 465 patients from this sample who were 18 years or younger. The flow of these patients is presented in Figure 1.

NBPP and Patient characteristics

Medical records were used to extract information on age, gender, lesion-extent (1; upper plexus lesions: C5/C5-C6/C5-C7/C7 and 2; total and lower plexus lesions: C5-C8/C5-T1/C8-T1), affected side (right/left/both) and treatment history (1; conservative, 2; primary, nerve, surgery, 3; secondary, orthopaedic, surgery, 4; primary and secondary surgery).
Three age groups were distinguished, whose outcomes were described separately: 0-1 (0-1 years old), 2-9 (2-9 years old) and 10-18 (10-18 years old).

Follow-up status

The follow-up status of all patients of the Leiden Nerve Center was extracted from the medical records. Based on this, 3 subgroups were defined: (1) Early discharge, i.e. discharged from follow-up within a year after birth; (2) Late discharge, i.e. discharged from follow-up at a later age; and (3) No discharge, i.e. still in follow-up at the Leiden Nerve Center.
For patients in the early discharge subgroup, the reason for discharge had to be full or satisfactory spontaneous recovery, not needing further treatment. This was verified by checking the medical records for the reason for discharge.

Healthcare use (HCU)

The proxy for healthcare use by children with NBPP in this study was defined as the number of healthcare professionals involved in the care for NBPP, within or outside the

Leiden Nerve Center. HCU due to NBPP was measured by asking parents and/or patients whether they had been in contact with specific healthcare professionals, due to the NBPP of their child, since birth (HCU-ever) and whether this contact had taken place in the past 12 months (HCU-12) due to the consequences of NBPP. They were also asked whether they had ever been admitted to hospital for NBPP and whether this had happened in the past 12 months.
One point was allocated when there had been contact with at least 1 of the 5 members of the NBPP expert team (i.e. neurosurgeon, orthopedic surgeon, rehabilitation specialist (physiatrist), physical therapist, occupational therapist). Furthermore, 1 point was allocated for each of the 11 types of healthcare professionals contacted outside the expert team. In addition, 1 point was allocated when the patient had been admitted to hospital. Total HCU scores (range 0-13) since birth (HCU-ever) and with respect to the past 12 months (HCU-12) were calculated.

In addition, the questionnaire asked about any use of complementary medicine (e.g. homeopathy, alternative healers) and contact with the patient organization (Erbse Parese Vereniging Nederland; EPVN, a nationwide patient organization for children and adults with NBPP), since birth and/or in the past 12 months.

Quality of Life (QoL) and physical functioning
Perceived QoL was examined using the TNO-AZL (Netherlands Organization for Applied Scientific Research and Leiden University Hospital) Preschool children's QoL (TAPQOL) and the Pediatric Outcome Data Collecting Instrument (PODCI).

The TAPQOL was developed to measure QoL in children aged 6 months to 5 years. It is a parent-reported, 43-item generic questionnaire, with 12 scales (3-7 items/scale). Questions relate to the past three months and scale scores are transformed to a 0–100 scale, with higher scores indicating better QoL.[24] For the present study, only the TAPQOL scales for Positive mood, Problem behavior, Anxiety, Social functioning and Motor functioning were used for children <2 years of age, since only these scales were found to provide some insight into the QoL of young children with NBPP.[25]

The PODCI was designed to assess different aspects of daily living, including upper extremity functioning, in children with musculoskeletal disorders (including NBPP) and is available in Dutch.[26-28] The instrument consists of 5 subscales and one total score. PODCI scale scores range from 0-100, with higher scores indicating better functioning/QoL. The present study used the 2-10 years and 11-18 years parent-reported versions.

Information need
To determine whether respondents felt a need for information, the first question asked was whether respondents had ever searched for information about NBPP, and if so, whether they had found the information they were looking for. Secondly, we asked if they currently

felt the need for more information (yes/no) regarding: NBPP in general, physical consequences of NBPP, medical treatment of NBPP, assistive devices and government social support, physical activity and sports, pediatric or general physical therapy, occupational therapy, primary surgery, secondary surgery, rehabilitation medicine, social work and patient organizations/peer contact. Thirdly, we asked what the preferred mode of information delivery would be and whether they would use the opportunity to e-mail with a specialized NBPP consultant regarding possible questions and information needs.

We were also interested to find out whether parents or patients had ever received contradictory information from different healthcare professionals (yes/no), to check whether there is a need to further promote uniformity of information provision regarding NBPP.

Statistical analysis

Descriptive statistics (medians with interquartile ranges [IQR] or means with standard deviations [SD]) were used for patient characteristics and all outcome measures. All outcomes are reported separately for all age groups, based on follow-up status.

TAPQOL scores for all follow-up subgroups were compared using an unpaired t-test, and PODCI scores were compared using a one-way analysis of variance with Fischer's Least Significant Difference post-hoc test (significance level, $p<0.05$).

To determine which factors were associated with HCU-12, univariate regression analyses were performed for all age groups (significance level, $p<0.1$). Factors entered independently, one at a time, were: gender (male/female), age, affected side (right/left/both), lesion-extent (1/2), treatment history (1/2/3/4), follow-up status (1/2/3), TAPQOL motor functioning (only for 0-1 year age group) and PODCI Upper Extremity (UE) and Global Functioning (GF) scales (only for 2-9 and 10-18 year age groups). Subsequently, a multiple regression analysis was performed with only those factors that had a significance level of $p<0.2$ in the univariate analyses. Differences in healthcare use based on the factors entered in the univariate and multiple regression analyses are presented as β-estimates with 95% confidence intervals.

RESULTS

Of the 465 included patients, 59 belonged to the 0-1 year age group (median age 1 year), 226 to the 2-9 years group (median age 6 years) and 180 to the 10-18 years group (median age 14 years). The flow of patients is presented in Figure 1. A total of 83 patients belonged to the early discharge subgroup: 19 from the 0-1 age group, 50 from the 2-9 group and 14 from the 10-18 group. All patient characteristics are shown in Table I.

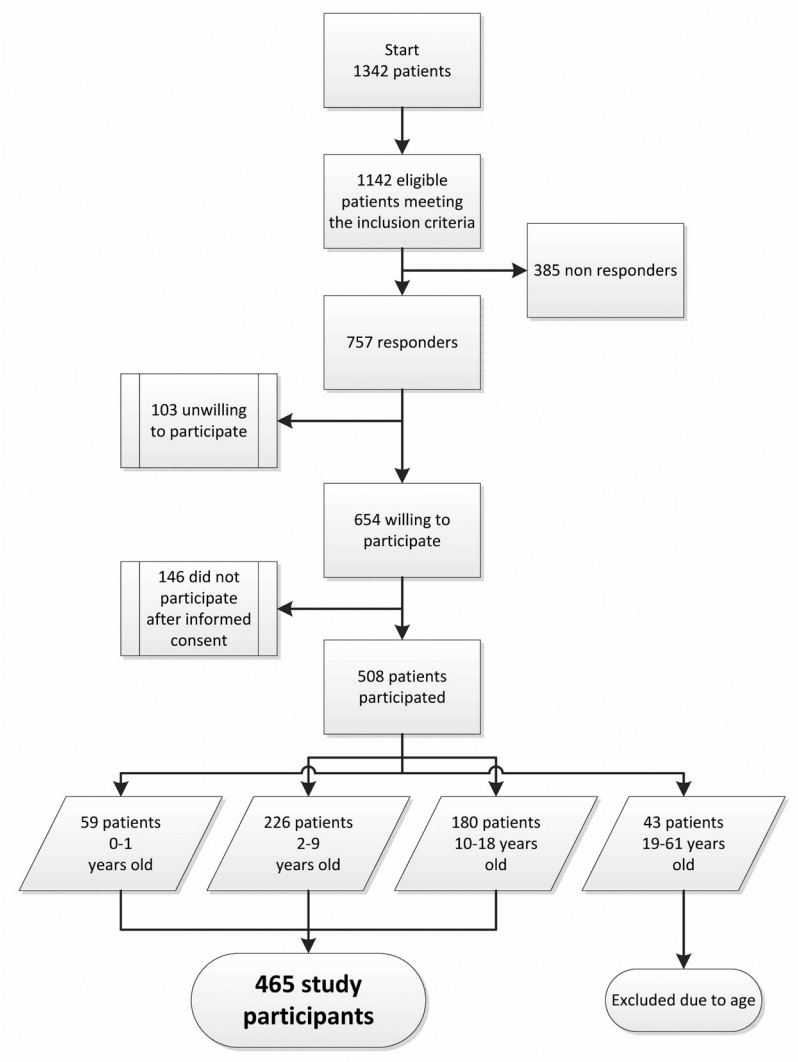

Figure 1. Flowchart showing the formation of the study sample (n=465)

Table I also shows QoL and physical functioning scores (TAPQOL and PODCI). In the 0-1 year age group there was no difference in QoL between the early discharge subgroup and the subgroup still in follow-up. In the 2-9 years age group, however, the subgroup still in follow-up had significantly lower scores on all PODCI scales than the early and late discharge subgroups. Moreover, the subgroup still in follow-up reported significantly lower scores for pain and comfort than the late discharge subgroup. In the 10-18 years age group, statistically significant differences between the subgroup still in follow-up and the two other subgroups were only found for the UE and GF scales. The early discharge subgroup reported problems of upper extremity functioning as well as with sports and physical functioning, resulting in lower QoL scores (GF scale).

Table II presents the healthcare professionals involved in the care of children with NBPP, and these children's median healthcare use (HCU-ever/HCU-12) for all age groups and follow-up subgroups. Since birth, all patients had had contacts with at least 1 (range 1-11) healthcare professional in addition to the NBPP expert team. Hospital admissions due to NBPP were reported by 278 patients (60%) since birth. The most frequently mentioned healthcare professionals contacted since birth were: pediatric or general physical therapist, neurosurgeon, rehabilitation specialist (physiatrist), orthopedic surgeon and pediatrician, but other professionals were mentioned as well, including psychologists (n=39) and psychiatrists (n=21). In the past 12 months 198 patients had had contact with the expert team (divided over the 3 age groups as follows: 49 (83%), 81 (36%) and 68 (38%), respectively). At least 1 (additional) healthcare professional (range 1-7) had been contacted by 288 patients (divided over the 3 age-groups: 53 (90%), 133 (59%) and 102 (57%)). The physical therapist was again the most frequently mentioned healthcare professional contacted.
In the early discharge subgroup, 34 patients (41%) had contacted at least 1 healthcare professional during the past 12 months for their NBPP. In this subgroup, physical therapists were mentioned 23 times.

The outcomes of the regression analyses are presented in Table III. Factors independently associated with healthcare use were lesion-extent, treatment history, follow-up status and QoL and physical functioning (all $p<0.05$). Male gender was associated with higher healthcare use in the 2-9 years age group.
Multiple regression analysis showed that for the 2-9 years age group, greater extent of the lesion, treatment history (primary and secondary surgery), being in follow-up and lower QoL (lower PODCI GF scale-scores) were associated with higher healthcare use. For the 10-18 years age group, only greater extent of the lesion and QoL (lower PODCI GF scale scores) were associated with higher healthcare use (all $p<0.001$-$p<0.05$).

All age groups and all follow-up subgroups reported information needs (Table IV). Sixty-eight percent of the respondents had ever sought information regarding NBPP, but only 49% had found what they were looking for. Furthermore, 18% of the respondents had received/found contradicting information regarding NBPP. A need for information regarding a variety of

NBPP-related topics was reported by 228 patients/parents (49%). In the early and late discharge subgroups, information need was reported by 23/83 patients (28%) and by 42/110 patients (40%), respectively. Information on consequences of NBPP, physical activities/sports and assistive devices and government social support were the most commonly reported topics. The most frequently mentioned preferred modes of information delivery were: internet, the treating physician and the pediatric or general physical therapist.

DISCUSSION

This cross-sectional study in a large sample showed that healthcare use (HCU) since birth by children due to NBPP in the Netherlands is considerable, with up to 11 healthcare professionals involved in care in addition to the expert team, and with possible hospital admissions. However, healthcare use did decrease over time: respondents reported that over the past 12 months, up to 7 healthcare professionals had been involved in addition to the possible involvement of the expert team and hospital admissions. HCU was associated with the children's follow-up status at the tertiary Leiden Nerve Center, as well as with lesion-extent, treatment history, quality of life and physical functioning. A large proportion of patients (42%) discharged from follow-up by the Leiden Nerve Center still had contact with regional healthcare professionals for their NBPP. They included a relatively large proportion of patients (34/83, 41%) discharged at a young age due to supposedly satisfactory spontaneous recovery; this indicates that, against the expectation of the Leiden Nerve Center team, these patients may still perceive functional limitations due to their NBPP. Furthermore, a large proportion (228/465, 49%), including children discharged from follow-up (either early discharge: 23/83, 28%, or late discharge: 42/110, 40%), reported information needs regarding a variety of NBPP-related topics (treatment, sports and physical functioning, assistive devices etc.).

Healthcare use

No study of the healthcare use by patients with NBPP has been performed before, so no comparisons with other countries or centers can be made. Although studies of healthcare use in pediatric populations have been performed, they mainly focused on hospitalization and/or healthcare costs.[29-32] One study among children with various musculoskeletal disorders (e.g. bone, spine, and soft tissue conditions) showed that on average these children had had 1.7 contacts/visits with healthcare professionals in the past 12 months.[33] In contrast, our study found up to a median of 6.0 contacts (range for medians 0-9 depending on age and follow-up status, Table II). However, we only counted the number of healthcare professionals contacted, but not the number of visits. In addition, we took contacts with other healthcare professionals besides the Leiden Nerve Center team into account. Our study showed that allied health professionals, especially (pediatric) physical therapists, were frequently contacted.

Table I Characteristics of 465 patients with neonatal brachial plexus palsy and their quality of life/physical functioning in relation to current follow-up status at the Leiden Nerve Center

	0-1 years (n=59)		2-9 years (n=226)			10-18 years (n=180)		
	Early discharge* (n=19)	No discharge*** (n=40)	Early discharge* (n=50)	Late discharge** (n=44)	No discharge*** (n=132)	Early discharge* (n=14)	Late discharge** (n=66)	No discharge*** (n=100)
Gender								
Male	12 (63%)	16 (40%)	28 (56%)	16 (36%)	70 (53%)	9 (64%)	26 (39%)	43 (43%)
Median age (Range)	1 (0-1)	1 (0-1)	6 (2-9)	6 (2-9)	6 (2-9)	14 (10-18)	15 (10-18)	13 (10-18)
Affected side:								
Right	7 (37%)	19 (48%)	20 (40%)	23 (52%)	61 (46%)	8 (57%)	32 (48%)	53 (53%)
Both	0 (0%)	0 (0%)	1 (2%)	0 (0%)	3 (2%)	1 (7%)	2 (3%)	3 (3%)
Lesion extent:								
Group 1: Upper plexus lesions								
C5	0 (0%)	0 (0%)	1 (2%)	0 (0%)	1 (1%)	1 (7%)	1 (2%)	2 (2%)
C5-C6	16 (84%)	24 (60%)	45 (90%)	39 (89%)	67 (51%)	10 (71%)	34 (51%)	46 (46%)
C5-C7	3 (16%)	6 (15%)	3 (6%)	5 (11%)	33 (24%)	2 (15%)	26 (39%)	30 (30%)
C7	0 (0%)	6 (15%)	0 (0%)	0 (0%)	0 (0%)	1 (7%)	0 (0%)	0 (0%)
Group 2: Total and lower plexus lesions								
C5-C8	0 (0%)	3 (8%)	0 (0%)	0 (0%)	14 (11%)	0 (0%)	0 (0%)	7 (7%)
C5-T1	0 (0%)	1 (2%)	0 (0%)	0 (0%)	17 (13%)	0 (0%)	5 (8%)	15 (15%)
C8-T1	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Surgical intervention								
Primary, nerve, surgery	0 (0%)	23 (58%)	0 (0%)	15 (33%)	92 (70%)	0 (0%)	45 (68%)	79 (79%)
Secondary, orthopedic, surgery	0 (0%)	0 (0%)	0 (0%)	2 (5%)	20 (15%)	0 (0%)	17 (26%)	38 (38%)

Follow-up in years Mean (SD)	0.2 (0.3)	1.0 (0.7)	0.4 (0.3)	3.1 (2.5)	5.1 (2.5)	0.3 (0.3)	9.3 (4.6)	8.9 (4.7)
TAPQOL scales Mean (SD)			x	x	x	x	x	x
Positive Mood scale	100.0 (0.0)	95.7 (10.9)						
Problem Behavior scale	80.4 (23.1)	74.2 (19.4)						
Anxiety scale	86.5 (21.3)	81.6 (20.7)						
Social Functioning scale	95.2 (8.1)	91.1 (15.8)						
Motor Functioning scale	90.6 (7.5)	82.4 (18.0)						
PODCI scales Mean (SD)	x	x						
Upper Extremity			89.9 (12.5)	90.1 (14.1)†	75.3 (18.8) β	92.7 (13.3)	83.2 (15.7)	79.7 (17.6)α
Transfer and Basic Mobility			99.0 (2.4)	99.4 (1.6)†	96.7 (5.4) β	98.9 (2.0)	98.3 (2.8)	98.8 (2.6)
Sports and Physical Functioning			94.4 (7.9)	95.7 (6.9)†	90.9 (9.6) β	94.4 (10.1)	91.3 (10.5)	91.1 (9.4)
Pain and Comfort			94.3 (11.6)	97.9 (7.2)	92.6 (14.7)‡	99.0 (3.3)	87.2 (18.6)α	90.9 (16.3)
Happiness scale			97.5 (7.2)	96.7 (10.0)†	91.6 (13.1) β	90.1 (23.1)	84.6 (17.4)	86.2 (18.6)
Global Functioning scale			94.3 (5.9)	95.9 (5.9)†	88.8 (9.4) β	96.2 (6.6)	89.4 (10.7)	90.1 (8.8) β

*Discharged from follow-up within 1 year after birth, **Discharged from follow-up later in life, ***Still in follow-up.
TAPQOL: TNO-AZL (Netherlands Organization for Applied Scientific Research and Leiden University Hospital) Preschool children's Quality of Life questionnaire
PODCI: Pediatric Outcome Data Collecting Instrument
β significantly different from the early discharge and late discharge groups ($p<0.05$); ‡ significantly different from the late discharge group ($p<0.05$),
α significantly different from the early discharge group($p<0.05$); †not significantly different from the early discharge group.

Table II Healthcare use by 465 patients due to neonatal brachial plexus palsy, since birth and in the past 12 months, in relation to current follow-up status at the Leiden Nerve Center.

	0-1 years (n=59)		**2-9 years (n=226)**			**10-18 years (n=180)**		
	Early discharge* (n=19)	**No discharge*** (n=40)**	**Early discharge* (n=50)**	**Late discharge** (n=44)**	**No discharge*** (n=132)**	**Early discharge* (n=14)**	**Late discharge** (n=66)**	**No discharge*** (n=100)**
	Ever/past 12 months	Ever/past 12 months	Ever/past 12 months	Ever/past 12 months	Ever/past 12 months	Ever/past 12 months	Ever/past 12 months	Ever/past 12 months
Number of patients having had contact with NBPP expert team N	19/12	40/37	50/0	44/5	132/76	14/0	66/17	100/51
Physical therapist	13/11	34/34	33/0	26/4	110/66	3/0	41/12	73/39
Occupational therapist	8/5	25/25	8/0	13/1	57/27	0/0	13/3	31/12
Neurosurgeon	10/7	36/33	24/0	33/3	115/44	4/0	54/12	85/27
Orthopedic surgeon	4/1	13/11	12/0	11/1	64/31	2/0	36/1	68/21
Rehabilitation specialist (physiatrist)	7/4	19/16	14/0	18/1	83/43	2/0	37/9	65/33
Number of patients having had contact with at least 1 professional outside the NBPP expert team N	19/16	40/37	50/14	44/15	132/104	14/4	66/31	100/67
Pediatric/General Physical therapist	15/15	38/37	47/5	37/11	126/86	8/3	65/17	89/53
Occupational therapist	0/0	4/4	1/1	1/0	39/23	1/1	13/3	23/6
Family doctor	7/2	20/11	32/1	15/2	65/14	6/1	39/8	57/8
Neurosurgeon	5/3	20/14	7/0	14/0	78/13	2/1	36/3	54/3
Orthopedic surgeon	4/2	4/4	1/0	2/0	33/14	2/0	14/1	32/4
Rehabilitation specialist (physiatrist)	3/1	10/7	2/0	5/0	51/27	2/1	23/8	52/18
Pediatrician	15/9	32/21	39/2	31/0	94/9	6/0	46/0	70/8
Plastic surgeon	1/0	1/1	1/1	0/0	12/3	0/0	6/0	6/0
Psychologist	0/0	6/6	5/3	2/1	13/6	1/1	4/1	8/1
Psychiatrist	0/0	2/1	2/2	0/0	7/3	0/0	3/0	7/2
Social Worker	1/0	4/4	4/1	0/0	9/2	0/0	5/2	7/3

Hospital admission N								
Yes	3/1	26/14	11/0	15/0	96/5	0/0	45/0	82/1
Contact with Patient Organization N								
Yes	0/0	10/8	4/1	9/4	46/20	0/0	28/5	30/9
Use of complementary medicine N								
Yes	1/0	6/6	10/3	9/0	21/7	0/0	7/3	7/2
Healthcare use[#] Median(IQR)								
Healthcare use ever	4.0 (3.0-4.5)	5.0 (4.0-6.0)	3.0 (4.0-5.0)	3.0 (4.0-5.0)	4.0 (6.0-8.0)	4.0 (1.5-5.0)	6.0 (4.0-7.0)	6.0 (4.8-8.0)
Healthcare use in past 12 months	3.0 (1.5-3.0)	6.0 (5.0-8.0)	0.0 (0.0-1.0)	0.0 (0.0-1.0)	2.0 (1.0-3.0)	0.0 (0.0-1.0)	0.0 (0.0-2.0)	2.0 (0.0-3.0)

*Discharged from follow-up within 1 year after birth. **Discharged from follow-up later in life. ***Still in follow-up.
[#] Healthcare use; number of healthcare professionals/professions involved (range 0-13): NBPP expert team (n=1), additional healthcare professionals (n=11), hospital admission (n=1)

Table III Factors associated with healthcare use in the past 12 months of 465 patients due to neonatal brachial plexus palsy, in relation to age.

	0-1 years (n=59)		2-9 years (n=226)		10-18 years (n=180)	
Factors used in the univariate and/or multiple regression analyses	**Univariate β-estimate (95% CI)**	**Multiple β-estimate (95% CI)**	**Univariate β-estimate (95% CI)**	**Multiple β-estimate (95% CI)**	**Univariate β-estimate (95% CI)**	**Multiple β-estimate (95% CI)**
Gender						
Male	-0.17 (-1.9;1.6)		0.6 (0.14;1.1)*	0.3 (-0.1;0.8)	0.2 (-0.3;0.6)	
Female	reference cat.		reference cat.		reference cat.	
Age	-1.8 (-3.2;-0.5)*	-2.0 (-3.3;-0.8) †	0.04 (-0.08;0.15)		-0.02 (-0.04;-0.01)	
Affected side:						
Right	reference cat.		reference cat.		reference cat.	
Left	-0.7 (-2.4;1.1)		-0.4 (-0.9;0.1)#	-0.4 (-1.1;0.2)	0.2 (-0.2;0.7)	
Both	x		0.8 (-1.0;2.6)	0.9 (-1.3;3.1)	0.4 (-0.6;1.4)	
Lesion extent:						
Upper plexus lesions	reference cat		reference cat.		reference cat.	
Total and lower plexus lesions	3.2 (1.1;5.3) †	1.8 (-0.3;3.8)	2.4 (1.7; 3.0)‡	1.3 (0.7;2.0)‡	1.2 (0.6;1.7)‡	0.9 (0.2;1.6)†
Treatment history:						
Conservative	reference cat.		reference cat.		reference cat.	
Primary,nerve, surgery	2.2 (0.5;3.9)*	1.1 (-0.7;3.0)	1.4 (0.9;1.8)‡	0.2 (-0.4;0.8)	0.4 (-0.2;0.9)	0.3 (-0.4;0.9)
Secondary, orthopedic, surgery	x		0.5 (-1.2;2.1)	-0.2 (-1.8;1.3)	0.2 (-0.5;0.9)	0.4 (-0.8;1.6)
Primary and secondary surgery	x		2.4 (1.5;3.2) ‡	1.0 (0.2;1.9)*	1.0 (0.5;1.6) ‡	0.5 (-0.3;1.2)
Follow-up status:						
Discharged aged < 1 year	-2.9 (-4.6;-1.1) †	-1.9 (-3.7;0.1)*	-1.9 (-2.4;-1.3)‡	-1.1 (-1.8;-0.4)†	-0.7(-1.6;0.2)	-0.1 (-1.0;0.8)
Discharged aged > 1 year	x		-1.7 (-2.3;-1.2)‡	-0.8 (-1.4;-0.2)†	-0.7 (-1.2;-0.3)‡	-0.3 (-0.8;0.2)
Not discharged, still in follow-up	reference cat.		reference cat.		reference cat.	
TAPQOL scales:						
Motor Functioning scale (0-100)	-0.02 (-0.1;0.05)		x		x	
PODCI scales:						
Upper Extremity (UE) scale (0-100)	x		-0.05 (-0.06;-0.04)‡	0.01 (-0.01;0.04)	-0.04 (-0.05;-0.03)‡	-0.01 (-0.02;0.02)
Global Functioning (GF) scale (0-100)	x		-0.11 (-0.13;-0.08)‡	-0.08 (-0.12;-0.03)‡	-0.07 (-0.10;-0.05)‡	-0.06 (-0.1;0.02) †

*p<0.05, †p<0.01, ‡p<0.001, #p<0.2. β-estimate: difference in healthcare use score compared to the reference category (reference cat.). TAPQOL: TNO-AZL (Netherlands Organization for Applied Scientific Research and Leiden University Hospital) Preschool children's Quality of Life questionnaire. PODCI: Pediatric Outcome Data Collecting Instrument. β-estimate for TAPQOL and PODCI scores: each point lower on these scales results in a β-estimate higher or lower healthcare use, e.g. in the 2-9 years age group a score of 20 points less on the PODCI GF scale results in an increase of 1 point on the healthcare use score (20 * the β-estimate of -0.05 =1).

Quality of Life

One of the main goals of interventions in NBPP is to improve all aspects of QoL (i.e. activities, participation) by enhancing bodily functions. The current study showed that patients with a lower QoL score used more healthcare. It is important to acknowledge the current reported QoL of patients, in order to optimize follow-up planning. Our findings regarding QoL and physical functioning are in line with those of previous studies.[25,27,28,34-37] For the more severely affected children (the group still in follow-up), QoL and physical functioning scores were comparable to those reported in other studies.[27,28,36,37] Children in the early and late discharge groups, however, also reported problems of QoL and physical functioning, with older children (the 10-18 years age group) reporting more problems (Table I).

Discharge from follow-up

Children who are discharged from follow-up by the expert team at a young age (<1 year) because of satisfactory clinical functional recovery, i.e. with no need for interventions at the Leiden Nerve Center, were expected to have no specific problems in later life and to have no need for further treatment. But contrary to the expectation of the Leiden Nerve Center team, the parents of these patients were still in need of help from healthcare professionals in their local area. This phenomenon has not been the subject of any study yet, whereas it is an important finding for both healthcare professionals and tertiary expert teams. This issue needs to be addressed, while at the same time preventing overuse of healthcare by less specialized care providers. Our study found that the reported QoL and physical functioning for some of these patients was lower than expected and that some children were still receiving active treatment for their NBPP. The expectation of full recovery at an early age was apparently incorrect, and the question arises whether this appraisal can be adequately made and whether these patients should have been discharged.

Information needs

At the Leiden Nerve Center, not only care requirements but also future information needs are among the factors used to decide whether or not to make routine follow-up appointments. As it turned out, the need for information due to sequelae of NBPP in our population was substantial. About 50% in all age groups reported to have a need for more information than they had been given regarding one or more NBPP-related topics. Since this percentage was found in all age groups, information need appears not to decrease with age.

This study also showed that 18% of the participants had received/found contradicting information regarding NBPP (Table IV). An American study found that decision making is highly influenced by the information found, so uniform, easily accessible information on all reported topics would be valuable to patients with NBPP and/or their parents.[23] Providing the opportunity for e-mail contact with a specialized NBPP consultant would also be useful to our patient population, as 63% of our participants stated that they would use such an option. Only a small proportion of the patients (n=45, 10%) had recently had contact with the patient organization. Communicating the benefits of the patient organization in providing information and peer contacts may further decrease the unmet information needs in the NBPP population.

Table IV Current information needs of 465 patients with neonatal brachial plexus palsy, in relation to age and follow-up status at the Leiden Nerve Center.

		0-1 years (n=59)		2-9 years (n=226)			10-18 years (n=180)		
		Early discharge* (n=19)	No discharge*** (n=40)	Early discharge* (n=50)	Late discharge** (n=44)	No discharge*** (n=132)	Early discharge* (n=14)	Late discharge** (n=66)	No discharge*** (n=100)
Information sought	yes n(%)	12 (63%)	36 (90%)	29 (58%)	30 (68%)	107 (81%)	3 (21%)	32 (49%)	65 (65%)
Information found	yes n(%)	10 (53%)	23 (58%)	23 (46%)	24 (55%)	73 (55%)	2 (14%)	26 (39%)	48 (48%)
Received contradictory information from different healthcare providers	yes n(%)	3 (16%)	9 (23%)	7 (14%)	7 (16%)	36 (27%)	2 (14%)	6 (9%)	14 (14%)
Would like more information on at least 1 of the topics below	yes n(%)	3 (16%)	28 (70%)	17 (34%)	14 (32%)	80 (61%)	3 (21%)	28 (42%)	55 (55%)
Neonatal Brachial Plexus Palsy	yes n(%)	1 (5%)	10 (25%)	9 (18%)	4 (9%)	27 (20%)	1 (7%)	6 (9%)	18 (18%)
NBPP physical consequences	yes n(%)	2 (10%)	18 (45%)	12 (24%)	11 (25%)	56 (42%)	1 (7%)	16 (24%)	36 (36%)
NBPP medical treatment	yes n(%)	1 (5%)	11 (28%)	8 (16%)	4 (9%)	36 (27%)	1 (7%)	4 (6%)	19 (19%)
Assistive devices and government social support	yes n(%)	1 (5%)	17 (43%)	7 (14%)	10 (23%)	47 (36%)	2 (14%)	12 (18%)	34 (34%)
Physical activity and sports	yes n(%)	3 (15%)	16 (40%)	16 (32%)	10 (23%)	55 (42%)	2 (14%)	13 (20%)	26 (26%)
Pediatric or General Physical therapy	yes n(%)	2 (10%)	8 (20%)	7 (14%)	5 (11%)	30 (23%)	2 (14%)	3 (5%)	15 (15%)
Occupational Therapy	yes n(%)	1 (5%)	9 (23%)	3 (6%)	3 (7%)	30 (23%)	2 (14%)	4 (6%)	14 (14%)
Primary surgery	yes n(%)	0 (0%)	3 (8%)	1 (2%)	1 (2%)	16 (12%)	0 (0%)	2 (3%)	12 (12%)
Secondary surgery	yes n(%)	0 (0%)	5 (13%)	1 (2%)	1 (2%)	24 (18%)	1 (7%)	3 (5%)	10 (10%)
Rehabilitation medicine	yes n(%)	1 (5%)	5 (13%)	3 (6%)	3 (7%)	23 (17%)	2 (14%)	4 (6%)	9 (9%)
Social work	yes n(%)	0 (0%)	4 (10%)	2 (4%)	2 (4%)	15 (11%)	0 (0%)	2 (3%)	4 (4%)
Patient organizations/ Peer contact	yes n(%)	1 (5%)	8 (20%)	1 (2%)	1 (2%)	11 (8%)	0 (0%)	4 (6%)	12 (12%)

Preferred mode of information delivery									
Internet	yes n(%)	14 (74%)	32 (80%)	32 (64%)	27 (61%)	104 (79%)	7 (50%)	30 (46%)	74 (74%)
Brochures/Books	yes n(%)	9 (45%)	21 (53%)	20 (40%)	17 (39%)	63 (48%)	4 (28%)	18 (27%)	48 (48%)
Peer contact	yes n(%)	2 (10%)	9 (23%)	6 (12%)	5 (11%)	38 (29%)	2 (14%)	9 (14%)	30 (30%)
Patient organization meetings	yes n(%)	1 (5%)	7 (18%)	3 (6%)	2 (4%)	28 (21%)	3 (21%)	8 (12%)	22 (22%)
Information meeting in the hospital	yes n(%)	5 (26%)	13 (33%)	5 (10%)	9 (20%)	38 (29%)	3 (21%)	17 (26%)	23 (23%)
Treating physician	yes n(%)	14 (74%)	29 (73%)	15 (30%)	17 (39%)	82 (62%)	4 (28%)	22 (33%)	55 (55%)
Family doctor	yes n(%)	6 (30%)	10 (25%)	16 (32%)	6 (13%)	21 (16%)	3 (21%)	10 (15%)	24 (24%)
Pediatric) physical / occupational therapist	yes n(%)	14 (74%)	28 (70%)	27 (54%)	22 (50%)	88 (67%)	5 (35%)	25 (38%)	53 (53%)
Would use possibility to e-mail with specialized NBPP consultant	yes n(%)	9 (45%)	30 (75%)	24 (48%)	20 (46%)	102 (77%)	6 (42%)	28 (42%)	61 (61%)

*Discharged from follow-up within 1 year after birth, **Discharged from follow-up later in life, ***Still in follow-up.

Study limitations

This study has a number of limitations. Firstly, it has a cross-sectional design with no follow-up, using only self-reported questionnaires. This might lead to overestimation or underestimation of results, as people might be influenced by unknown factors at the time of completing the questionnaires (e.g. mood, stress, etc.). Secondly, outcomes may be influenced by recall bias. Older patients and their parents may have forgotten exactly which healthcare professionals were involved at the time. We therefore only analyzed factors influencing healthcare use in the past 12 months, as recall bias for this period of time was considered minimal.

Thirdly, patients seen at our NBPP clinic were referred to us because of a severe lesion, which might lead to confounding by indication. However, since we had a relatively large group of respondents, this will reflect a good representation of the children seen at NBPP clinics in other academic settings.

The healthcare system and care at university hospitals in the Netherlands differ from those in other countries. The Netherlands has private insurance for all citizens based on a solidarity system (i.e. richer people do not receive financial government support to compensate their insurance rates). It is a small country and travelling distances between cities and to university-based centers are relatively short, which reduces the threshold for visiting a university-based center. Medical specialists in the Netherlands are diagnosis-oriented. In other countries, NBPP specialists combine performing primary and secondary surgery with rehabilitation, whereas staff at the Leiden Nerve Center are accustomed to working in interdisciplinary teams including neurosurgeons, orthopedic surgeons, physiatrists and physical and occupational therapists. This could mean that the present study may have overestimated the number of healthcare professionals involved in the care of these patients. Furthermore, parents may be emotionally attached to specific healthcare professionals, for example their local pediatric physical therapist, which may lead to more healthcare use for their child. Physical therapy for NBPP is considered a chronic indication in the Dutch healthcare system, and is reimbursed by health insurance companies. On the other hand, all patients/parents have to pay up to a maximum of €350 out of their own pocket for all healthcare used per annum, which could form a barrier to healthcare use. The number of visits to healthcare professionals, the costs of NBPP treatment and other aspects of healthcare utilization were not taken into account in the present study, and remain an interesting topic for future research.

Future research and endeavors

Future studies into clinical outcomes of NBPP should take into account the residual healthcare use by children who in the view of the expert teams had good clinical recovery. It is important to find out what patients discharged from follow-up and their parents think about care and information for NBPP, why they still have information needs and if they know how to find/contact the care providers they need.

Finally, there is a need to develop an easy and effective way to deliver information focusing on the different stages of life with NBPP (e.g. when going to school, or when choosing a sport, a subject to study or a profession etc.). Suitable options could include producing a modular informative video providing the information needed by individual patients, or information brochures.

CONCLUSION

Healthcare use and information needs of children with NBPP have not been studied before. Our study of a large NBPP sample has revealed which healthcare professionals are involved in the care for patients with NBPP and what information is needed by this population. Furthermore, it showed that children who showed satisfactory spontaneous clinical recovery at a young age, and were subsequently discharged from follow-up from our tertiary referral center, continued to seek active treatment for their NBPP, reported problems of QoL and physical functioning, and still had need for further information. As parents of children, both early and late discharged from follow-up, report healthcare use and current information needs due to their child's NBPP, stricter longitudinal follow-up on care and information needs by multidisciplinary NBPP expert teams for all patients with NBPP throughout life is needed as NBPP may result in lifelong limitations.

REFERENCES

1. Pondaag W., Malessy M.J., van Dijk J.G., Thomeer R.T. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev.Med.Child Neurol.* 2004;46(2):138-144.
2. Chauhan S. P., Blackwell S. B., Ananth C. V. Neonatal brachial plexus palsy: incidence, prevalence, and temporal trends. *Seminars in perinatology.* 2014;38(4):210-218.
3. Evans-Jones G., Kay S.P., Weindling A.M., et al. Congenital brachial palsy: incidence, causes, and outcome in the United Kingdom and Republic of Ireland. *Arch.Dis.Child Fetal Neonatal Ed.* 2003;88(3):F185-F189.
4. Lagerkvist A. L., Johansson U., Johansson A., Bager B., Uvebrant P. Obstetric brachial plexus palsy: a prospective, population-based study of incidence, recovery, and residual impairment at 18 months of age. *Developmental medicine and child neurology.* 2010;52(6):529-534.
5. Waters P.M. Comparison of the natural history, the outcome of microsurgical repair, and the outcome of operative reconstruction in brachial plexus birth palsy. *J.Bone Joint Surg.Am.* 1999;81(5):649-659.
6. Coroneos C. J., Voineskos S. H., Coroneos M. K., et al. Obstetrical brachial plexus injury: burden in a publicly funded, universal healthcare system. *J Neurosurg Pediatr.* 2015:1-8.
7. Strombeck C., Krumlinde-Sundholm L., Forssberg H. Functional outcome at 5 years in children with obstetrical brachial plexus palsy with and without microsurgical reconstruction. *Dev.Med.Child Neurol.* 2000;42(3):148-157.
8. Pondaag W., Malessy M.J. The evidence for nerve repair in obstetric brachial plexus palsy revisited. *Biomed.Res.Int.* 2014;2014:434619.
9. Tse R., Kozin S. H., Malessy M. J., Clarke H. M. International Federation of Societies for Surgery of the Hand Committee Report: The Role of Nerve Transfers in the Treatment of Neonatal Brachial Plexus Palsy. *The Journal of hand surgery.* 2015;40(6):1246-1259.
10. Louden E.J., Broering C.A., Mehlman C.T., Lippert W.C., Pratt J., King E.C. Meta-analysis of function after secondary shoulder surgery in neonatal brachial plexus palsy. *J.Pediatr.Orthop.* 2013;33(6):656-663.
11. Waters P.M. Update on management of pediatric brachial plexus palsy. *J.Pediatr.Orthop.B.* 2005;14(4):233-244.
12. Hale H.B., Bae D.S., Waters P.M. Current concepts in the management of brachial plexus birth palsy. *J.Hand Surg.Am.* 2010;35(2):322-331.
13. Malessy M. J., Pondaag W., Yang L. J., Hofstede-Buitenhuis S. M., le Cessie S., van Dijk J. G. Severe obstetric brachial plexus palsies can be identified at one month of age. *PLoS One.* 2011;6(10):e26193.
14. Coroneos C. J., Voineskos S. H., Coroneos M. K., et al. Primary Nerve Repair for Obstetrical Brachial Plexus Injury: A Meta-Analysis. *Plast Reconstr Surg.* 2015;136(4):765-779.
15. 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.
16. Ramos L. E., Zell J. P. Rehabilitation program for children with brachial plexus and peripheral nerve injury. *Semin Pediatr Neurol.* 2000;7(1):52-57.
17. Smania N., Berto G., La Marchina E., et al. Rehabilitation of brachial plexus injuries in adults and children. *Eur J Phys Rehabil Med.* 2012;48(3):483-506.
18. Bialocerkowski A., Gelding B. Lack of evidence of the effectiveness of primary brachial plexus surgery for infants (under the age of two years) diagnosed with obstetric brachial plexus palsy. *Int J Evid Based Healthc.* 2006;4(4):264-287.
19. Bialocerkowski A., Kurlowicz K., Vladusic S., Grimmer K. Effectiveness of primary conservative management for infants with obstetric brachial plexus palsy. *Int J Evid Based Healthc.* 2005;3(2):27-44.
20. Duff S. V., DeMatteo C. Clinical assessment of the infant and child following perinatal brachial plexus injury. *Journal of hand therapy : official journal of the American Society of Hand Therapists.* 2015;28(2):126-133; quiz 134.
21. Bain J. R., Dematteo C., Gjertsen D., Hollenberg R. D. Navigating the gray zone: a guideline for surgical decision making in obstetrical brachial plexus injuries. *J Neurosurg Pediatr.* 2009;3(3):173-180.
22. Socolovsky M., Costales J. R., Paez M. D., Nizzo G., Valbuena S., Varone E. Obstetric brachial plexus palsy: reviewing the literature comparing the results of primary versus secondary surgery. *Childs Nerv Syst.* 2015.
23. Shah A. K., Zurakowski D., Jessel R. H., Kuo A., Waters P. M. Measuring surgeons' treatment preferences and satisfaction with nerve reconstruction techniques for children with unique brachial plexus birth palsies. *Plast Reconstr Surg.* 2006;118(4):967-975.
24. Bunge E.M., Essink-Bot M.L., Kobussen M.P., van Suijlekom-Smit L.W., Moll H.A., Raat H. Reliability and validity of health status measurement by the TAPQOL. *Arch.Dis.Child.* 2005;90(4):351-358.
25. van der Holst M., van der Wal C. W., Wolterbeek R., Pondaag W., Vliet Vlieland T. P., Nelissen R. G. Outcome of secondary shoulder surgery in children with neonatal brachial plexus palsy with and without nerve surgery treatment history: A long-term follow-up study. *J Rehabil Med.* 2016;48(7):609-617.

26. Holst Mv, Vlieland T. P., van de Sande M. A., van Egmond-van Dam J. C., Vermeulen H. M., Nelissen R. G. Translation and adaptation of the Pediatric Outcome Data Collecting Instrument (PODCI) into the Dutch language and preliminary validation in children with Neonatal Brachial Plexus Palsy. *J Pediatr Rehabil Med.* 2015;8(3):219-226.
27. Bae D.S., Waters P.M., Zurakowski D. Correlation of pediatric outcomes data collection instrument with measures of active movement in children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(5):584-592.
28. Huffman G.R., Bagley A.M., James M.A., Lerman J.A., Rab G. Assessment of children with brachial plexus birth palsy using the Pediatric Outcomes Data Collection Instrument. *J.Pediatr.Orthop.* 2005;25(3):400-404.
29. Cohen E., Berry J. G., Camacho X., Anderson G., Wodchis W., Guttmann A. Patterns and costs of health care use of children with medical complexity. *Pediatrics.* 2012;130(6):e1463-1470.
30. Lopez M. A., Cruz A. T., Kowalkowski M. A., Raphael J. L. Trends in hospitalizations and resource utilization for pediatric pertussis. *Hosp Pediatr.* 2014;4(5):269-275.
31. Zhong W., Finnie D. M., Shah N. D., et al. Effect of multiple chronic diseases on health care expenditures in childhood. *J Prim Care Community Health.* 2015;6(1):2-9.
32. Ralston S. L., Harrison W., Wasserman J., Goodman D. C. Hospital Variation in Health Care Utilization by Children With Medical Complexity. *Pediatrics.* 2015;136(5):860-867.
33. Gunz A. C., Canizares M., Mackay C., Badley E. M. Magnitude of impact and healthcare use for musculoskeletal disorders in the paediatric: a population-based study. *BMC Musculoskelet Disord.* 2012;13:98.
34. Alyanak B., Kilincaslan A., Kutlu L., Bozkurt H., Aydin A. Psychological adjustment, maternal distress, and family functioning in children with obstetrical brachial plexus palsy. *The Journal of hand surgery.* 2013;38(1):137-142.
35. Akel B.S., Oksuz C., Oskay D., Firat T., Tarakci E., Leblebicioglu G. Health-related quality of life in children with obstetrical brachial plexus palsy. *Qual.Life Res.* 2013.
36. van der Holst M., Vlieland T. P., Meesters J. J., Bekkering W. P., Nagels J., Nelissen R. G. Evaluation of shoulder function after secondary surgery in children with Neonatal Brachial Plexus Palsy. *J Pediatr Rehabil Med.* 2015;8(3):187-196.
37. Dedini R.D., Bagley A.M., Molitor F., James M.A. Comparison of pediatric outcomes data collection instrument scores and range of motion before and after shoulder tendon transfers for children with brachial plexus birth palsy. *J.Pediatr.Orthop.* 2008;28(2):259-264.

CHAPTER EIGHT

Participation restrictions among adolescents and adults with neonatal brachial plexus palsy: the patient perspective

Menno van der Holst* | Jeroen Groot* | Duco Steenbeek | Willem Pondaag
Rob G.H.H. Nelissen | Thea P.M. Vliet Vlieland

** The first two authors contributed equally*

Published:
Disability and Rehabilitation, 2017 september
DOI: 10.1080/09638288.2017.1380717
Oral abstract presentation Narakas congress february 2016, Barcelona, Spain
Poster abstract presentation VRA congress april 2016, Amsterdam, The Netherlands

ABSTRACT

Objective

To examine the impact of neonatal brachial plexus palsy on societal participation of adolescents and adults.

Patients and methods

This cross-sectional study was conducted among patients with neonatal brachial plexus palsy, aged ≥16 years, who had visited our neonatal brachial plexus palsy clinic. Patients completed questions on the influence of neonatal brachial plexus palsy on their choices regarding education/work and their work-performance, the Impact on Participation/ Autonomy questionnaire and the Utrecht Scale for Evaluation of Rehabilitation-Participation. In addition, health-related quality of life was assessed.

Results

Seventy-five patients participated (median age 20, inter quartile range 17-27). Twenty were full-time students, 28 students with a job, 21 employed, 2 unemployed and 4 work-disabled. Sixty-six patients had had a job at some stage. Patients' overall Health-Related Quality of Life was comparable to the general population. 27/75 patients reported that neonatal brachial plexus palsy had affected their choices regarding education and 26/75 those regarding work. 33/66 reported impact on their work performance. On the Impact on Participation/Autonomy questionnaire, 80% (49/61) reported restrictions in the work-and-education domain, 74% in social-relations and 67% in autonomy-outdoors. 37/61 reported participation restrictions on the Utrecht Scale for Evaluation of Rehabilitation-Participation.

Conclusions

Although their overall health-related quality of life was not impaired, a substantial proportion of adolescent/adult patients reported that neonatal brachial plexus palsy had an impact on choices regarding education and profession, as well as on work-performance. Restrictions in participation, especially in work and education were also reported. Guiding patients in making choices on education and work at an early stage and providing tailored physical as well as psychosocial care may prevent or address restrictions, which may improve participation.

IMPLICATIONS FOR REHABILITATION

- Adolescent and adult patients with neonatal brachial plexus palsy perceive restrictions in societal participation, especially regarding the work-and-education domain.
- All patients with neonatal brachial plexus palsy may perceive restrictions in societal participation regardless of lesion severity, treatment history and side of the lesion.
- Adolescents and adults with neonatal brachial plexus palsy report that their choices regarding education and work, as well as their work-performance are influenced by their neonatal brachial plexus palsy.
- Patients with neonatal brachial plexus palsy should be followed throughout their life in order to provide them with appropriate information and treatment when health- or participation-related issues arise.
- Rehabilitation treatment is the best option to address all of the aforementioned issues, as surgical options in adolescents and adults are limited.

INTRODUCTION

Neonatal brachial plexus palsy (NBPP) is caused by traction to the brachial plexus during delivery and can result in severe disabilities of the arm. The incidence varies between 1.6 and 4.6/1000 live births.[1,2] Severity of the injury ranges from mild (neurapraxia/axonotmesis) to severe (neurotmesis/avulsion), but the majority of NBPP is mild and complete, or almost complete, functional recovery will occur in about 70-80%.[1,3] The remaining patients are left with a functional deficit that probably results in problems in one or more domains of the International Classification of Functioning, Disability and Health (ICF).[4] Mild injuries can be treated conservatively, while children with more severe injuries often require primary surgery (nerve reconstruction) at a young age (3-9 months).[5,6] Depending on recovery after conservative treatment or primary surgery, secondary surgery (muscle-tendon transfers/ osseous surgery) may be indicated at a later age.[7-11] Despite these interventions patients with NBPP may still have residual functional limitations that may lead to restrictions or limitations in one or more domains of the ICF.

The above-mentioned surgical and non-surgical interventions are performed in infants and children to improve arm function, activity levels and future societal participation, including education, employment, leisure activities and community living. However, outcome regarding participation among patients with NBBP in later life has rarely been examined[12], and long-term follow-up studies including adults are limited or outdated.[13] The few available studies among adolescents (≥16 years) and adult patients with NBPP mainly evaluated daily functioning (e.g. dressing, washing) and found that patients experienced limitations, mostly due to pain.[14,15] Although daily activities, such as cycling and swimming, were limited, patients could still participate in them.[16] A qualitative study using focus groups included adolescents aged 16 and 17 years and reported perceived problems with activities (e.g. self-care, eating) and sports participation (e.g swimming, gymnastics, football, dancing). This study, however,

also reported that the older participants had adapted to their disabilities over time and therefore perceived less problems.[17] Another study found that participation among patients with NBPP (aged 15-17 years) did not differ from that of age-matched healthy peers.[18] Another study reported that few adult patients experienced limitations of work-performance.[14] The main drawback of these studies is that adult patients were either not included, or included in limited numbers only. Furthermore, no validated instruments specifically designed to measure participation were used.

Currently, no study is available in the literature that reports on the possible influence of NBPP on choices regarding education and work. Studies in other medical conditions that cause limitations to upper extremity function (e.g. cerebral palsy, spinal cord injury [SCI] or hereditary motor and sensory neuropathy [HMSN]) reported restrictions in participation in later life (e.g. education, employment, leisure activities and community living).[19-23] For patients with these conditions, factors influencing restrictions in participation included condition severity, upper extremity functioning, dexterity and level of education.[19-23]

It is unknown to what extent participation by patients with NBPP is influenced by lesion-extent, the affected side, health-related quality of life (HRQoL), upper extremity functioning and pain.

The aim of this study was to investigate if, and to what extent, adolescents (≥16 years) and adults with NBPP face participation restrictions, and if NBPP has any influence on choices regarding education and work as well as on work-performance. A secondary aim was to determine which factors were associated with restrictions in participation in this patient group. We hypothesized that more restrictions in participation among patients with NBPP would be associated with right-sided lesions, greater lesion extent, having had primary and/or secondary surgery, poorer upper extremity function, poorer HRQoL and having bodily pain.

PATIENTS AND METHODS

Study design and patients

A cross-sectional study on the functioning and quality of life of patients with NBPP of all ages (n=1142) was conducted between October 2014 and March 2015.[24] The study was conducted at the Leiden Nerve Center (a specialized multidisciplinary NBPP clinic located at the Leiden University Medical Center). It was approved by the local medical ethics committee (P14.071).

For the larger study, all patients with a diagnosis of NBPP who had visited the Leiden Nerve Center at least once were eligible. Patients were excluded if their medical record was not available or if concurrent or other medical diagnoses that might affect arm function were mentioned in their medical record (e.g. traumatic brachial plexus lesions, cerebral palsy, birth reduction defects: anatomical upper arm anomalies).

Eligible patients and/or their parents were sent an invitation (including information) to participate. The invitation included a statement that all data would be treated confidentially and analyzed anonymously. On a pre-stamped return card, they could indicate whether they were willing to participate, and if so, whether they wanted to participate using paper or electronic questionnaires. Parents of patients under 18 years of age and all patients aged 12 years and older provided written informed consent. After informed consent, patients were sent the set of questionnaires or received an e-mail with a link giving access to the electronic questionnaires. Patients not responding to the invitation received a reminder by mail, phone or e-mail at their last known contact details within 2-4 weeks. Participants who had not completed the questionnaires within 2-4 weeks were reminded by email or phone.

The aims of this cross-sectional study were set in advance and, as the cohort included patients with a large variety of ages, it used age-appropriate questionnaires. The full set of questionnaires used in the study (including those used for the present study) were tested prior to the start. The present study only used data from patients aged ≥16 years. The study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.[25]

NBPP and patient characteristics

Age, gender, lesion-extent (i.e. upper plexus lesions: C5-C6 or C5-C7, and 2: total plexus lesions: C5-C8 or C5-T1), affected side (right/left/both), treatment history (i.e. conservative, primary [nerve] surgery secondary [orthopedic] surgery, both primary and secondary surgery) were extracted from the medical record and current status regarding discharge from follow-up (yes/no) was recorded. All this information was recorded by the two first authors and entered into an existing database, in part comprising the same data, thereby creating a quality check on the data.

Participation

Study and work

To analyze work and education status and the possible influence of NBPP on these aspects, we used a questionnaire constructed for the occasion. Eight questions were formulated, based on the expert opinions of all authors, addressing important issues of education and work for adolescents and adults with NBPP (see Table II).

Impact on Participation and Autonomy (IPA)

The IPA, Dutch Language Version (IPA-DLV) instrument was developed using the ICF components and has proven to be a valid and reliable tool to use in chronic disease populations.[26-28] This tool was, however, not specifically designed for NBPP. IPA measures patient-perceived participation in 5 domains: autonomy indoors (self-care and mobility indoors, 7 items), family role (housekeeping and spending income, 7 items), autonomy outdoors (leisure activities and mobility outdoors, 5 items), social relations (equal communication and intimate relations, 7 items) and work and education (paid work,

volunteer work and education, 6 items). Each item in the domains is scored on a 5-point rating scale (0:very good-4:very poor). Domain scores range from 0 to 4, with higher scores indicating lower participation. A score of 0 means no restrictions are reported. IPA also includes 9 items to determine the extent to which patients perceive their restrictions in participation as problematic, on a 3-point rating scale (0=no problem-2=severe problem).

Utrecht Scale for Evaluation of Rehabilitation-Participation (USER-P)

The USER-P questionnaire is a generic 31-item, self-reported outcome instrument for adults, suitable and reliable for evaluating physical disabilities, including musculoskeletal and neurological conditions.[29]

This tool was designed to rate objective and subjective participation in rehabilitation in 3 domains: frequencies, restrictions and satisfaction. The frequency scale quantifies how much time is spent per week on several participation activities (e.g. work, education, housekeeping, leisure activities, sports, visiting family and friends). The USER-P assesses perceived restrictions and patient satisfaction with regard to performing these activities. Scores range from 0 to 100, with higher scores indicating better functioning (higher frequency, less restrictions and greater satisfaction).

Measures of current HRQoL and functioning (including pain)

Short Form-36 (SF-36)

The current perceived HRQoL and its association with participation were determined using the SF-36, Dutch Language Version (SF-36-DLV).[30] This generic HRQoL instrument has been used before in other NBPP studies.[14] In the SF-36, eight domain scores can be calculated, including the bodily pain score. Scores range from 0-100, with higher scores indicating better functioning/HRQoL. In addition, two summary scores can be calculated: a physical and a mental component score (PCS and MCS, respectively). These scores are based on normative sample data for Dutch adults (n=1062), with mean summary scores (PCS/MCS) of 50 (SD 10).[31-33] This enabled comparison with the outcomes of the present study.

Disabilities of the Arm, Shoulder and Hand (DASH)

The current perceived upper extremity functioning and its association with participation were determined using the DASH, Dutch Language Version (DASH-DLV).[34] This questionnaire has also previously been used in other NBPP studies, allowing comparison of outcomes.[14] The general part (DASH-mean) consists of 30 questions and there is an additional specific module for work (DASH-work, 4 questions) and a module for sports (DASH-sport, 4 questions). Scores range from 0-100, with lower scores indicating better functioning. US reference scores are available to compare DASH outcomes.[35]

Statistical analysis

Descriptive statistics (medians with interquartile ranges [IQR] or means with standard deviations [SD] based on the distribution of the data [Kolmogorov Smirnov's test]) were used for patient and lesion characteristics, and for measures of participation and quality of life.

In order to investigate response-bias, the characteristics of the study participants in terms of age, gender, affected side, treatment history and current state of follow-up were compared with eligible patients who did not participate, using Mann Whitney U and Chi Square tests.

To determine which factors were associated with participation, separate linear regression analyses (with categorical or continuous predictors) were performed for all IPA and USER-P subscales, adjusted for age and gender (significance level $p<0.05$). For each factor a new analysis was performed. In essence a 'univariate' linear regression analysis, adjusted for age and gender was performed for each independent factor.
Factors entered independently were: lesion extent (upper plexus lesions/total plexus lesions), treatment history (conservative, primary [nerve] surgery, secondary [orthopedic] surgery, primary and secondary surgery) affected side (right/left/both) SF-36 PCS, SF-36 MCS, SF-36 bodily pain score and DASH-mean. β-estimates were reported to describe the association between the independent factor and the outcome variable. Due to the explorative nature of this study, we did not correct for multiple testing.[36]

RESULTS

Recruitment and inclusion: There were 242 patients aged ≥16 years of whom 38 were excluded based on the exclusion criteria (medical record not available: n=16, concurrent or other medical diagnoses: n=22). For 54 patients, the last known phone number proved incorrect and these patients did not respond to our invitation by mail either. Eventually, 94 of the remaining 150 patients responded, yielding a response rate of 63%. Of the 94 responding patients, 76 patients were willing to participate. One did not return any of the questionnaires and was therefore additionally excluded. Figure 1 shows the flow of these patients.

Patient characteristics: Table I shows the patient characteristics and the HRQoL, pain and upper extremity functioning scores. The median age of the patients was 20 years (IQR 17-27). Ninety-two percent had upper plexus lesions (C5-C6/C5-C7). Characteristics of participants (n=75) and non-participants (n=129) were comparable, except for gender (more females in the participants group: 65% versus 47%, $p=0.03$) and lesion extent (more C5-C7 lesions in the participants group: 40% versus 12% $p<0.001$). The participants reported good overall HRQoL on the SF-36: the component scale scores (MCS/PCS) were comparable to those of the Dutch general population. Upper extremity functioning as reported on the DASH also appeared to be good and was comparable to that of the US general population.

Education and work status were as follows: 20 participants (27%) were full-time students, 28 (37%) students who also had a job on the side, 21 (28%) had paid employment, 2 (3%) were unemployed and 4 (5%) were work-disabled due to their NBPP. Educational levels were comparable to those in the general Dutch population.[37] The impact of NBPP on choice of education and profession and its impact on performance during these activities are shown in Table II.

Table I Patient characteristics, and DASH and SF-36 scores of 75 adolescents and adult patients with NBPP

Patients (n=75)				
Gender n (%)				
Male		26	(35)	
Age Median (IQR) range		20	(17-27)	16-61
16-18 n (%)		33	(44)	
19-25 n (%)		22	(29)	
26-35 n (%)		11	(15)	
36-61 n (%)		9	(12)	
Affected side n (%)				
right		38	(51)	
left		34	(45)	
both		3	(4)	
Lesion extent				
Group 1: upper plexus lesions n (%)				
C5-C6		39	(52)	
C5-C7		30	(40)	
Group 2: total plexus lesions n (%)				
C5-T1		6	(8)	
Treatment n (%)				
conservative		26	(35)	
primary surgery		16	(21)	
secondary surgery		15	(20)	
primary and secondary surgery		18	(24)	
No longer in follow-up n (%)		38	(51)	
SF-36 (n=66)				
Bodily pain questions:				
Had pain in the past 4 weeks n (%)				
No answer		10	(13)	
No pain		21	(28)	
Mild pain		26	(35)	
Severe pain		18	(24)	
Pain hampered work in the past 4 weeks n (%)				
No answer		10	(13)	
Not at all		38	(51)	
Mildly		20	(27)	
Severely		7	(9)	
Bodily Pain score	Median (IQR)	84	(51.5-100)	
Physical functioning	Median (IQR)	90	(77.5-100)	
Role-physical	Median (IQR)	100	(50-100)	
General health	Median (IQR)	72	(62-91)	
Vitality	Median (IQR)	65	(55-75)	

Table I *Continued*

Patients (n=75)			
Social functioning	Median (IQR)	100	(87.5-100)
Role-emotional	Median (IQR)	100	(100-100)
Mental health	Median (IQR)	72	(64-78)
PCS	Mean (SD)	46.9	(10.5)
MCS	Mean (SD)	50.2	(8.3)
DASH			
DASH general (n=66)	Median (IQR)	16.3	(7.5–32.1)
DASH work (n=44)	Median (IQR)	12.5	(0–18.8)
DASH sport (n=42)	Median (IQR)	18.8	(4.7–31.3)

NBPP = Neonatal brachial plexus palsy. IQR = Interquartile ranges (25th to 75th percentile). SD = Standard deviation. SF-36 = Short Form-36 questionnaire, general population normative scores mean=50, SD=10.[30-33] PCS = Physical component score. MCS = Mental component score. DASH = Disabilities of the Arm, Shoulder and Hand questionnaire, US general population normative score mean=10.1, SD=14.7.[34,35]

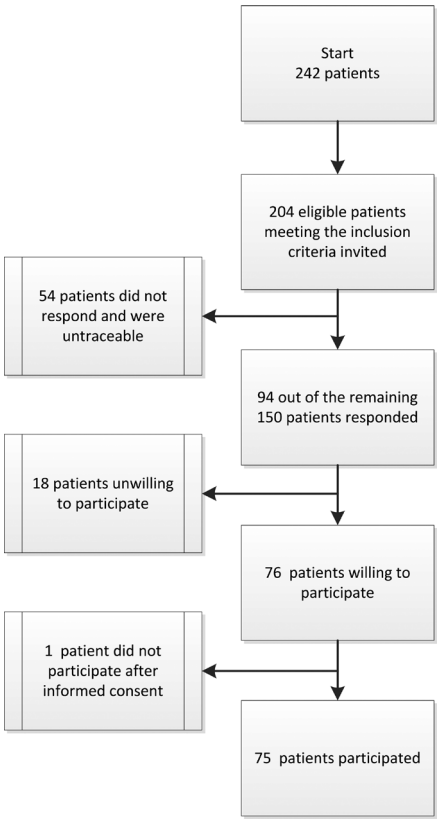

Figure 1 Flowchart of participating patients

Table III shows the participation outcomes (IPA/USER-P). Due to missing values, scores of only 61 participants could be calculated. Overall the IPA median standardized domain sum scores were rather low, indicating that the participants perceived few participation restrictions. This is also reflected in the number of participants who perceived their participation as good or very good. Median scores ranged from 0.14 to 1.00, with the lowest score for autonomy indoors (self-care and mobility indoors) and the highest for work and education. Eighty percent of the participants reported at least 1 restriction in the work and

Table II Education status, work status and the influence of NBPP on education and work among 75 adolescent and adult patients with NBPP

	n	%
What is your work / education status		
Full-time student	20	27
Student having a job on the side	28	37
Having paid employment	21	28
Unemployed	2	3
Work disabled (80-100%) due to NBPP	4	5
What is your highest completed educational level?		
Lower education	28	38
Intermediate education	31	41
Higher education	16	21
Was your choice of education influenced by NBPP?		
Yes	27	36
No	42	56
Haven't made a choice yet	6	8
Was your choice of profession influenced by NBPP?		
Yes	26	35
No	40	53
Never had a job	9	12
Do you currently have a paid job (including part-time jobs, student jobs)	49	65
Did you ever have a paid job (including part-time jobs, student jobs)	66	88
Did NBPP ever hamper you in a job?		
Yes	33	50
No	33	50
Did NBPP play a part in unemployment or work disability?		
Yes	10	15
No	56	85

NBPP= Neonatal brachial plexus palsy. Educational levels: Low: primary education or preparatory secondary vocational education; Intermediate: senior secondary vocational education or senior general secondary and pre-university education; High: higher professional education or university education

education domain. At least 1 restriction in the domains of autonomy outdoors (leisure activities and mobility outdoors) and social relations (equal communication and intimate relations) was reported by 74% and 67% of participants, respectively. The highest percentage of participants rating their restrictions in participation as problematic (minor or severe) was in the work (occupation) and education domain.
According to the USER-P outcomes, 61% of the participants reported perceiving restrictions in participation. Although the number of perceived restrictions was low, the participants did feel dissatisfied with them. In contrast, 82% of the participants reported on the USER-P that they were satisfied with their paid or unpaid work and/or education.

Table IV shows the factors influencing participation. Higher DASH-mean scores and lower SF-36 bodily pain, PCS and MCS scores, were independently associated with higher scores on almost all IPA domains (all $p<0.05$ to $p<0.001$), indicating poorer participation and less autonomy. As regards the scores on the USER-P domains of restriction and satisfaction, the same factors negatively influenced participation (all $p<0.05$ to $p<0.001$), which means that these factors led to more restrictions and less satisfaction. No evidence was found for lesion extent, treatment history or affected side influencing participation outcomes.

DISCUSSION

Participants of this cross-sectional study among adolescents (≥16 years) and adults with NBPP reported good quality of life and upper extremity functioning overall. Although participation was generally also reported to be good, participants did report restrictions in societal participation, mainly related to work (work performance), and influence of NBPP on choice of education and profession. Half of the participants who had had a job at some point, felt professionally hampered by their NBPP. Of the 61 participants who completed the IPA, 49 (80%) reported limitations in the work and education domain. Scores on the USER-P indicated restrictions in participation, and satisfaction with participation possibilities in our participants was somewhat diminished. Restrictions in participation were associated with poorer upper extremity functioning, poorer HRQoL and more pain (DASH/SF-36). No evidence was found for an association with lesion extent, treatment history or affected side. This may indicate that all patients with NBPP, regardless of the initial severity of their lesion may perceive restrictions in participation in later life.

No study previously assessed the impact of NBPP on choice of education and work, and to our knowledge, this is the first study to report on restrictions in participation among adolescents and adults with NBPP, based on validated participation outcome instruments.

Many of our participants reported that NBPP influenced their choice of education and profession. The actual percentages might even be higher, as a large part of our study population was under 20 years of age (n=36) and might not yet have decided on further

Table III Participation scores (IPA and USER-P) of 61 adolescent and adult patients with NBPP

IPA			
standardized sumscores	Median	IQR	Number of participants reporting 1 or more restrictions in:*
autonomy indoors	0.14	0.0 – 0.5	7 possible restrictions; 36 (59%)
family role	0.57	0.0 – 1.0	7 possible restrictions; 36 (59%)
autonomy outdoors	0.40	0.0 – 0.8	5 possible restrictions; 41 (67%)
social relations	0.29	0.0 – 0.8	7 possible restrictions; 44 (74%)
work and education	1.00	0.2 – 1.5	6 possible restrictions; 49 (80%)
Perceived participation n (%)	Very good & good	Fair	Poor & very poor
autonomy indoors	58 (95%)	2 (3%)	1 (2%)
family role	49 (80%)	9 (15%)	3 (5%)
autonomy outdoors	51 (84%)	7 (11%)	3 (5%)
social relations	54 (88%)	5 (8%)	2 (4%)
work and education	39 (64%)	17 (28%)	5 (8%)
Problem experience	No problems	Minor problems	Severe problems
Mobility	43 (70%)	15 (25%)	3 (5%)
Self-care	38 (62%)	16 (26%)	7 (12%)
Family role	43 (70%)	12 (20%)	6 (10%)
Finances	47 (77%)	9 (15%)	5 (8%)
Leisure	38 (62%)	16 (26%)	7 (12%)
Social relations	40 (65%)	14 (23%)	7 (12%)
Helping and supporting	40 (65%)	14 (23%)	7 (12%)
(Voluntary) occupation**	30 (54%)	15 (27%)	11 (19%)
Education***	32 (58%)	14 (25%)	9 (17%)
USER-P			
scores	Median	IQR	Number of participants reporting 1 or more restrictions in:*
frequency	34.6	28.4 – 43.1	x
restrictions	96.9	90.0 – 100.0	11 possible restrictions; 37 (61%)
satisfaction	77.8	69.6 – 91.7	x

NBPP = Neonatal brachial plexus palsy. IQR = Interquartile ranges (25th to 75th percentile). IPA = Impact on Participation and Autonomy questionnaire: autonomy indoors (self-care and mobility indoors), family role (housekeeping and spending income), autonomy outdoors (leisure activities and mobility outdoors), social relations (equal communication and intimate relations) and work and education (paid work, volunteer work and education) IPA standardized sum-scores 0-4; higher scores indicating lower participation and less autonomy. Perceived participation: values are reported as the number of participants who perceived their participation as very good/good, fair, or poor/very poor. Problem experience: values are reported as the number of participants who perceived their restrictions as problematic. [26-28] USER-P = Utrecht Scale for Evaluation of Rehabilitation-Participation questionnaire, USER-P scores 0-100, higher scores indicating higher frequency, less restrictions and higher satisfaction.[29] * number of participants reporting 1 or more restrictions out of the specific number of restrictions mentioned on a domain of the IPA and USER-P ** 5 participants indicated that this IPA item was irrelevant to them. *** 6 participants indicated that this IPA item was irrelevant to them.

education and/or profession. A follow-up study among the same population in a few years could reveal whether the younger participants who currently reported no influence, perceive impact on future choices.

In the current study, we only provided outcomes for the total group and did not differentiate the analyses or results according to lesion-extent or bilateral involvement. Although these patients may perceive more restrictions in participation, the regression analysis provided no evidence for an influence of lesion-extent or bilateral involvement on participation outcomes. Future studies on participation issues should include more patients with total plexus lesions and/or bilateral involvement, to investigate whether lesion-extent or bilateral involvement does indeed not affect participation outcomes.

Participation levels of adolescents (aged 15-17 years) have been investigated previously by Strombeck et al.[18], who reported no differences with age-matched controls. The NBPP group in their study had the same interests, activities and social life as the control group, but had lower self-esteem regarding sports and motor activities and worried more about social life and school factors. We feel that these findings actually support our conclusion that participation is influenced by NBPP. Activities and sports are usually chosen within the patients' capabilities, probably excluding several sports/activity options, which influences participation.

There have been few studies among adolescents (≥16 years) and adult patients with NBPP, that focussed on the presence of pain and limitations in activities of daily living.[14-16] In line with their findings, our study participants also reported pain and limitations in activities. Partridge et al.[15] reported that adult patients with NBPP experience increasing pain over time and this pain was the most impairing factor in their daily life. De Heer et al.[14] recently confirmed this finding in a small group of adult patients with NBPP (n=27), for whom pain, rather than arm-hand function, explained difficulties in performing activities of daily living. We found that both pain and arm-hand functioning (DASH-mean) restricted societal participation. Furthermore, in contrast to the study by De Heer et al., we found substantial restrictions in work-performance. Thirty-three of our participants (33/66 [50%] of the participants who have, or had, work) reported feeling hampered by their NBPP in performing their jobs. The reasons for this difference might be that our population was bigger and more of our patients had a job. Furthermore, our population was more severely affected, as 34/75 (45%) of our participants had undergone primary (nerve) surgery compared to 6/27 (22%) in De Heer's study. However, in our population we found no association between lesion severity and treatment history on the one hand and participation outcomes (IPA and USER-P) on the other. We also found that reported restrictions in participation, including those in the work and education domain, were not influenced by the side of the lesion. Yang et al. reported that only 17% of children with a right-sided lesion were right-handed, compared to 90% in the healthy population.[38] This indicates that these children have developed left-hand preference due to their right-sided lesion in order to

Table IV Factors influencing participation in 61 adolescent and adult patients with NBPP (linear regression analyses adjusted for age and gender)

	IPA				USER-P			
	Autonomy indoors β-estimate (95% CI)	Family role β-estimate (95% CI)	Autonomy outdoors β-estimate (95% CI)	Social relations β-estimate (95% CI)	Work and education β-estimate (95% CI)	Frequencies β-estimate (95% CI)	Restrictions β-estimate (95% CI)	Satisfaction β-estimate (95% CI)
Lesion extent:								
Upper plexus lesions	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat
Total and lower plexus lesions	0.42 (-0.15;0.98)	0.81 (-0.07;1.68)	0.67 (-0.03;1.37)	0.05 (-0.56;0.67)	0.43 (-0.40;1.25)	-4.83 (-19.72;10.07)	-8.30 (-19.20;2.61)	-10.10 (-28.37;8.17)
Affected side:								
Right	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat
Left	0.09 (-0.19;0.37)	0.06 (-0.38;0.50)	0.07 (-0.29;0.42)	0.12 (-0.18;0.42)	-0.15 (-0.55;0.26)	1.79 (-5.48;9.06)	1.03 (-4.51;6.56)	0.44 (-8.67;9.56)
Both	0.19 (-0.42;0.81)	0.22 (-0.74;1.19)	0.03 (-0.75;0.81)	0.03 (-0.63;0.69)	0.19 (-0.70;1.07)	10.51 (-5.34;26.36)	-0.68 (-12.67;11.32)	4.17 (-15.70;24.03)
Treatment history:								
Conservative	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat	reference cat
Primary surgery	0.17 (-0.20;0.54)	0.05 (-0.50;0.60)	0.17 (-0.26;0.59)	0.24 (-0.15;0.63)	0.01 (-0.48;0.50)	-8.22 (-17.70;1.25)	1.20 (-5.57;7.96)	-1.52 (-13.68;10.64)
Secondary surgery	0.09 (-0.25;0.42)	0.05 (-0.45;0.55)	0.15 (-0.23;0.54)	0.34 (-0.01;0.69)	0.26 (-0.19;0.70)	-2.85 (-11.58;5.88)	0.76 (-5.42;6.94)	-0.97 (-12.17;10.23)
Primary and secondary surgery	-0.03 (-0.39;0.33)	-0.24 (-0.78;0.31)	0.10 (-0.32;0.51)	0.06 (-0.32;0.44)	0.32 (-0.16;0.81)	4.66 (-5.18;14.50)	0.97 (-6.04;7.97)	0.58 (-12.05;13.20)
SF-36 Bodily Pain score	-0.01 (-0.01;0.00)*	-0.01 (-0.02;-0.00)*	-0.01 (-0.02;-0.00)*	-0.01 (-0.01;0.01)	-0.01 (-0.02;0.00)*	-0.01 (-0.17;0.16)	0.23 (0.13;0.34)***	0.20 (-0.01;0.40)*
SF-36 physical component score	-0.02 (-0.04;-0.01)***	-0.05 (-0.07;-0.03)***	-0.04 (-0.05;-0.02)***	-0.02 (-0.03;-0.01)**	-0.04 (-0.06;-0.03)***	0.29 (-0.07;0.65)	0.73 (0.54;0.92)***	0.88 (0.49;1.27)***
SF-36 mental component score	-0.04 (-0.05;-0.02)***	-0.05 (-0.07;-0.03)***	-0.05 (-0.06;-0.03)***	-0.04 (-0.05;-0.02)***	-0.04 (-0.06;-0.02)***	0.52 (0.12;0.92)*	0.41 (0.11;0.72)**	1.11 (0.68;1.54)***
DASH general	0.01 (0.01;0.02)***	0.03 (0.02;0.04)***	0.02 (0.01;0.03)***	0.02 (0.01;0.02)***	0.03 (0.01;0.04)***	-0.11 (-0.33;0.12)	-0.33 (-0.46;-0.21)***	-0.47 (-0.72;-2.23)***

NBPP = Neonatal Brachial Plexus Palsy. IPA = Impact on Participation and Autonomy questionnaire autonomy indoors (self-care and mobility indoors), family role (housekeeping and spending income), autonomy outdoors (leisure activities and mobility outdoors), social relations (equal communication and intimate relations) and work and education (paid work, volunteer work and education). [26-28] USER-P = Utrecht Scale for Evaluation of Rehabilitation-Participation questionnaire. [29] DASH = Disabilities of the Arm, Shoulder and Hand questionnaire. SF-36 = Short Form-36 questionnaire. PCS = Physical component score. MCS = Mental component score * p<0.05, ** p<0.01, *** p<0.001, corrected for age and gender. Regression analyses: A new model was made for each factor, containing only that factor, adjusted for age and gender. No model containing all factors was made. β-estimate: difference in IPA/USER-P scores compared to the reference category (reference cat.) The β-estimate for SF-36 and DASH scores indicates the influence of these scores on IPA/User-P domain scores; e.g. a score of 20 points more on the DASH general score results in an increase of 0.60 points on this IPA work and education scale (20 * the β-estimate of 0.03 =0.60).

have one good arm/hand. The fact that the side of the lesion did not correlate with 'work and education participation' in our study may indicate that bimanual functioning may be more important than handedness.

The aforementioned studies regarding problems of daily living may have had biases that influenced the outcome. Kirjavainen et al.[16] included only surgically treated patients, leading to a bias towards more severe lesions, and did not specify the number of participating adolescents and adults.[16] All patients in the study by Partridge et al.[15] were members of the Erb's Palsy Group in the United Kingdom, which could possibly have led to confounding by indication (i.e. patients who are members of patient groups and respond to surveys sent out by these groups, are usually the more affected patients). The present study included patients with lesions ranging from relatively mild, treated conservatively, to severe lesions that warranted nerve reconstruction. We hope to have provided a better representation of the NBPP population, although we acknowledge that including patients from a tertiary referral clinic has probably led to inclusion bias as well.

Our main outcome measures for societal participation, the IPA and USER-P questionnaires, have not been used previously in NBPP studies, nor have they been validated for this patient group. However, they have been used and validated in several other chronic conditions affecting upper limb function, such as stroke, SCI and HMSN.[26,29]

On the IPA, our NBPP patients reported better societal participation than patients after SCI, with 55% of these SCI patients reporting poor social participation and autonomy on several IPA-domains[20]. In our NBPP study we found 3-36% (depending on the IPA domain) of participants reporting fair to poor societal participation. Most restrictions in participation were reported in the work and education domain. Compared to IPA scores of patients with HMSN type 1A[23], our patients reported similar restrictions in autonomy outdoors and work and education.

On the USER-P, patients with SCI had a perceived restrictions score of 72.7 points (IQR 54.5–87.9) and a satisfaction score of 72.5 (IQR 58.3-80.6).[19] Our participants had a higher perceived restrictions score (median=96.9/IQR=90-100), but had comparable satisfaction scores (median=77.8/IQR=69.6-91.7).[19]

Contrary to the conditions in the above studies, our participants had had their deficit(s) since birth. Thus, we had expected that our patients with NBPP would adapt more automatically regarding their participation level, and feel satisfied with choices made within their possibilities. Such adaptation was suggested by the results of the focus group study that was conducted earlier at our center by Sarac et al.[17] In this study children seemed to adapt more fully to their disability with age, and personal and environmental factors played an important role in this.[17] In comparison, the same restricted societal participation, as found in the current study, was found in young adults with cerebral palsy, who also have

their deficits from birth: about 20-30% of young adults with cerebral palsy report restrictions in societal participation.[21] Future participation studies should also address the influence of psychosocial adjustment and family dynamics in adult patients with NBPP.

We used the SF-36 and DASH questionnaires to determine current HRQoL and upper extremity functioning because reference values for the general population were available and because they have previously been used in other NBPP studies on participation.[14,33,35] SF-36 and DASH scores in our population are comparable to those reported by de Heer et al, but DASH-work scores in our population were somewhat higher than reported in that study[14]. As outcomes on the SF-36 and DASH were also comparable to the general population[30,33,35], the question remains whether these instruments are sensitive and specific enough to detect the specific limitations in the NBPP population (e.g. insufficient bimanual activities in the DASH to measure problems in unilateral impairments).

Half of the study population were no longer in clinical follow-up at the Leiden Nerve Center at the time of this study. We discharge patients from follow-up when good neurological recovery has taken place or if residual deficits have reached a plateau. We provide them with information for the future and advise them to make a new appointment for renewed evaluation or treatment if necessary. However, it turns out that many of them reported restrictions in participation, pain and functional limitations, but did not seek to contact us. We do not know who is the primary medical caregiver for these patients and with whom they discuss their participation limitations. These issues should be addressed in future studies to further optimize care and clinical follow-up for adolescents and adults with NBPP.

Possible interventions in adult patients with NBPP are limited and have not been well described. The findings in this study indicate that there is a need for interventions in adulthood. Rehabilitation programs or information provision programs are needed for adolescent and adult patients to enable them to cope better with their disability. These programs could, for example, focus on patient education (especially in the work and education domain), vocational rehabilitation, psychosocial wellbeing, improving ergonomics and pain reduction.

The present study had a number of limitations. It had a cross-sectional design with no follow-up, using only self-reported questionnaires. This might lead to overestimation or underestimation of results, as participants might be influenced by unknown factors at the time of completing the questionnaires (e.g. bad mood, stress, etc.). Only 75 of the 204 eligible patients participated in the present study. This number was limited because not all eligible patients could be traced and reached. The number of participants may also have been influenced by the fact that over half of the eligible patients were no longer in follow-up and their last visit could be years ago. The response rate was further reduced as some of the 75 participating patients did not complete all questionnaires (n=9 for DASH and SF-36, n=14 for IPA and USER-P), even after several reminders, possibly due to questionnaire burnout.

The participating group (n=75) did not differ significantly from the non-responding group (n=129) in terms of patient and disease characteristics. Patients seen at our NBPP clinic were referred to us because of a severe lesion, which might lead to confounding by indication. However, we believe the responders, including conservatively treated patients, are sufficiently representative of adolescents and adults seen at NBPP clinics in an academic setting.

As discussed above, the generic participation outcome measures used in the present study were not validated for use in patients with NBPP. However, as shown in a recent review regarding outcome measures in NBPP, no appropriate NBPP-specific participation outcome measures are available.[12] The outcome measures used in our study seem to provide valuable information, and further studies into the validity and reliability of their use in the NBPP population should be undertaken to fill the gap in available outcome measures in this important ICF domain. In addition, future long-term NBPP studies among children and adults should at least include participation outcome measures.

In conclusion, adolescents and adults with NBPP participating in the current study reported restrictions in societal participation, particularly in terms of work and education, and they perceived NBPP as an influence on their choice of education and profession, and on their work performance. These findings are relatively new and reveal a need for optimization of care, follow-up and information, focusing on the participation components of the ICF for adolescents and adult patients with NBPP.

REFERENCES

1. Pondaag W., Malessy M. J., van Dijk J. G., Thomeer R. T. Natural history of obstetric brachial plexus palsy: a systematic review. *Dev Med Child Neurol.* 2004;46(2):138-144.
2. Hoeksma A. F., Wolf H., Oei S. L. Obstetrical brachial plexus injuries: incidence, natural course and shoulder contracture. *Clin Rehabil.* 2000;14(5):523-526.
3. Chauhan S. P., Blackwell S. B., Ananth C. V. Neonatal brachial plexus palsy: incidence, prevalence, and temporal trends. *Seminars in perinatology.* 2014;38(4):210-218.
4. WHO. ICF. 2016; http://www.who.int/classifications/icf/en/. Accessed 01-07-2016.
5. Gilbert A., Pivato G., Kheiralla T. Long-term results of primary repair of brachial plexus lesions in children. *Microsurgery.* 2006;26(4):334-342.
6. Pondaag W., Malessy M. J. The evidence for nerve repair in obstetric brachial plexus palsy revisited. *Biomed Res Int.* 2014;2014:434619.
7. Hale H. B., Bae D. S., Waters P. M. Current concepts in the management of brachial plexus birth palsy. *The Journal of hand surgery.* 2010;35(2):322-331.
8. Waters P. M. Update on management of pediatric brachial plexus palsy. *J Pediatr Orthop B.* 2005;14(4):233-244.
9. Lagerkvist A. L., Johansson U., Johansson A., Bager B., Uvebrant P. Obstetric brachial plexus palsy: a prospective, population-based study of incidence, recovery, and residual impairment at 18 months of age. *Dev Med Child Neurol.* 2010;52(6):529-534.
10. Arzillo S., Gishen K., Askari M. Brachial plexus injury: treatment options and outcomes. *J Craniofac Surg.* 2014;25(4):1200-1206.
11. Thatte M. R., Mehta R. Obstetric brachial plexus injury. *Indian J Plast Surg.* 2011;44(3):380-389.
12. Sarac C., Duijnisveld B. J., van der Weide A., et al. Outcome measures used in clinical studies on neonatal brachial plexus palsy: A systematic literature review using the International Classification of Functioning, Disability and Health. *J Pediatr Rehabil Med.* 2015;8(3):167-185; quiz 185-166.
13. Gjorup L. Obstetrical lesion of the brachial plexus. *Acta Neurol Scand.* 1966;42:Suppl 18:11-80.
14. de Heer C., Beckerman H., Groot Vd. Explaining daily functioning in young adults with obstetric brachial plexus lesion. *Disabil Rehabil.* 2015;37(16):1455-1461.
15. Partridge C., Edwards S. Obstetric brachial plexus palsy: increasing disability and exacerbation of symptoms with age. *Physiotherapy research international : the journal for researchers and clinicians in physical therapy.* 2004;9(4):157-163.
16. Kirjavainen M. O., Remes V. M., Peltonen J., et al. Permanent brachial plexus birth palsy does not impair the development and function of the spine and lower limbs. *J Pediatr Orthop B.* 2009;18(6):283-288.
17. Sarac C., Bastiaansen E., Van der Holst M., Malessy M.J., Nelissen R.G., Vliet Vlieland T.P. Concepts of functioning and health important to children with an obstetric brachial plexus injury: a qualitative study using focus groups. *Dev.Med. Child Neurol.* 2013;55(12):1136-1142.
18. Strombeck C., Fernell E. Aspects of activities and participation in daily life related to body structure and function in adolescents with obstetrical brachial plexus palsy: a descriptive follow-up study. *Acta Paediatr.* 2003;92(6):740-746.
19. Mader L., Post M. W., Ballert C. S., Michel G., Stucki G., Brinkhof M. W. Metric properties of the Utrecht Scale for Evaluation of Rehabilitation-Participation (USER-Participation) in persons with spinal cord injury living in Switzerland. *J Rehabil Med.* 2016;48(2):165-174.
20. Craig A., Nicholson Perry K., Guest R., Tran Y., Middleton J. Adjustment following chronic spinal cord injury: Determining factors that contribute to social participation. *Br J Health Psychol.* 2015;20(4):807-823.
21. Donkervoort M., Roebroeck M., Wiegerink D., van der Heijden-Maessen H., Stam H., Transition Research Group South West Netherlands. Determinants of functioning of adolescents and young adults with cerebral palsy. *Disabil Rehabil.* 2007;29(6):453-463.
22. van Meeteren J., Roebroeck M. E., Celen E., Donkervoort M., Stam H. J., Transition Research Group South West Netherlands. Functional activities of the upper extremity of young adults with cerebral palsy: a limiting factor for participation? *Disabil Rehabil.* 2008;30(5):387-395.
23. Videler A. J., Beelen A., van Schaik I. N., de Visser M., Nollet F. Limited upper limb functioning has impact on restrictions in participation and autonomy of patients with hereditary motor and sensory neuropathy 1a. *J Rehabil Med.* 2009;41(9):746-750.
24. van der Holst M., van der Wal C. W., Wolterbeek R., Pondaag W., Vliet Vlieland T. P., Nelissen R. G. Outcome of secondary shoulder surgery in children with neonatal brachial plexus palsy with and without nerve surgery treatment history: A long-term follow-up study. *J Rehabil Med.* 2016;48(7):609-617.
25. von Elm E., Altman D. G., Egger M., et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Epidemiology.* 2007;18(6):800-804.

26. Cardol M., de Haan R. J., van den Bos G. A., de Jong B. A., de Groot I. J. The development of a handicap assessment questionnaire: the Impact on Participation and Autonomy (IPA). *Clin Rehabil.* 1999;13(5):411-419.
27. Cardol M., de Haan R. J., de Jong B. A., van den Bos G. A., de Groot I. J. Psychometric properties of the Impact on Participation and Autonomy Questionnaire. *Arch Phys Med Rehabil.* 2001;82(2):210-216.
28. Cardol M., Beelen A., van den Bos G. A., de Jong B. A., de Groot I. J., de Haan R. J. Responsiveness of the Impact on Participation and Autonomy questionnaire. *Arch Phys Med Rehabil.* 2002;83(11):1524-1529.
29. Post M. W., van der Zee C. H., Hennink J., Schafrat C. G., Visser-Meily J. M., van Berlekom S. B. Validity of the utrecht scale for evaluation of rehabilitation-participation. *Disabil Rehabil.* 2012;34(6):478-485.
30. Aaronson N. K., Muller M., Cohen P. D., et al. Translation, validation, and norming of the Dutch language version of the SF-36 Health Survey in community and chronic disease populations. *J Clin Epidemiol.* 1998;51(11):1055-1068.
31. Ware JE. *SF-36 Health Survey Manual and Interpretation Guide.* Boston : The Health Institute, New England Medical Center; 1994.
32. VanderZee K. I., Sanderman R., Heyink J. W., de Haes H. Psychometric qualities of the RAND 36-Item Health Survey 1.0: a multidimensional measure of general health status. *Int J Behav Med.* 1996;3(2):104-122.
33. Ware JE Kosinski M, Keller SD. *SF-36 physical and mental summary scales: A users manual.* 2nd ed. Boston MA: The Health Insitute; 1994.
34. Veehof M. M., Sleegers E. J., van Veldhoven N. H., Schuurman A. H., van Meeteren N. L. Psychometric qualities of the Dutch language version of the Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH-DLV). *J Hand Ther.* 2002;15(4):347-354.
35. Hunsaker F. G., Cioffi D. A., Amadio P. C., Wright J. G., Caughlin B. The American academy of orthopaedic surgeons outcomes instruments: normative values from the general population. *The Journal of bone and joint surgery. American volume.* 2002;84-A(2):208-215.
36. Wason J. M., Stecher L., Mander A. P. Correcting for multiple-testing in multi-arm trials: is it necessary and is it done? *Trials.* 2014;15:364.
37. Centraal Bureau voor Statistiek (Netherlands Statistics CBS). Bevolking; hoogst behaald onderwijsniveau; geslacht, leeftijd en herkomst. [Internet]. 2016; http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=82275NED&D1=0&D2=0&D3=0&D4=0-1,4-5&D5=0-1,7,11&D6=60-63,65-67&VW=T. Accessed 29-11-2016.
38. Yang L. J., Anand P., Birch R. Limb preference in children with obstetric brachial plexus palsy. *Pediatr Neurol.* 2005;33(1):46-49.

CHAPTER NINE

Summary and General discussion

SUMMARY

This thesis describes various aspects of the impact of neonatal brachial plexus palsy (NBPP) throughout the patients' lifespan, with a special focus on activities of daily life and participation, Quality of Life (QoL), healthcare usage and information needs. Furthermore, it is concerned with the development and evaluation of measurement instruments for the outcomes of NBPP.

Chapter 1, the general introduction, describes the characteristic features of NBPP with regard to the extent and severity of the lesion and its natural course. Conservative treatment, including pediatric physical therapy, as well as primary and secondary surgical treatment options are described. Important aspects and consequences of NBPP are listed in relation to the International Classification of Functioning, Disability and Health, the ICF.[1] Using this model, common assessment instruments to measure the outcome of NBPP are introduced.

The outcome of secondary shoulder surgery in children with NBPP has been described in several studies, but mainly at the level of the ICF Body Functions and Structure component. An exploration of the outcomes concerning the ICF Body Functions and Structure, Activity and Participation components, including parental expectations and satisfaction was lacking so far. **Chapter 2** describes the comprehensive evaluation of the short-term effects of a combined internal contracture release and a muscle tendon transfer (mm. Latissimus Dorsi and Teres Major) in children with NBPP with respect to arm and hand function, QoL and parental satisfaction. The aim of this procedure is to improve active shoulder external rotation range of motion (ROM) and thus the ability to bring the hand to the head and to the mouth, the use of the affected arm in bimanual activities, and to prevent progression of shoulder deformity. A prospective study on the effect of an external rotationplasty, including 10 children, aged 3-10 years old has been conducted. Children were assessed preoperatively and 3, 6 and 12 months post-operatively. This study showed that all aforementioned functions and activities improved significantly in the year following the intervention. However, a negative effect on shoulder backward flexion ROM and bringing the hand to the back was seen. Parent-reported QoL regarding upper extremity functioning and global functioning improved significantly over a period of 12 months. The majority of parents were satisfied with the results of the surgery and their expectations regarding the improvement of daily activities and sports were mostly met.

Studies describing the long-term outcomes of secondary shoulder surgery for children with NBPP usually combine the data of those children with and without primary (nerve) surgery history. **Chapter 3** describes separately the functional sequelae over time of children with and without primary (nerve) surgery. A retrospective study was conducted using data gathered according to a standardized clinical protocol. This study included 115 children with NBPP, both with (n=82) and without prior primary (nerve) surgery (n=33). Average follow-up time was 6 years (standard deviation 3.3 years). Data on active and passive ROM as well as

Mallet scores gathered before surgery and at 1, 3, 5 and 10 years after surgery, were compared. Overall, shoulder passive and active external rotation, (glenohumeral) abduction and forward flexion ROM as well as almost all Mallet score items improved significantly over time. Over the course of time the positive effects of surgery decreased to some extent, but the differences with the preoperative situation remained statistically significant. Just as in the study described in Chapter 2, backward shoulder flexion and the ability to bring the hand to the back, as measured with the Mallet score, decreased significantly.
Children without prior primary (nerve) surgery had better preoperative shoulder function than children who had undergone primary (nerve) surgery. These conservatively treated children had an overall better shoulder function after secondary shoulder surgery at all follow-up time-points. Only active and passive external rotation, both in 0° and 90° abduction, were slightly better at all follow-up time-points for children who had undergone primary (nerve) surgery.
These outcomes indicate that these subgroups comprise patients with a different phenotype (i.e. severity of brachial plexus lesion) and outcomes for these different cohorts should be reported separately. Thereby, an overestimation or underestimation of the results of the secondary intervention will be prevented. Thus, more tailored and personalized information on the expected treatment outcome can be provided to children and their parents, ensuring the quality of the shared decision-making process.

Patient or parent-reported outcome measures (PROMs) become increasingly more important in the evaluation of treatment outcome. Most validated instruments for outcomes in NBPP are only available in English, which makes them unsuitable for use in Dutch studies. It is therefore necessary to officially translate, cross-culturally adapt and validate instruments for the Dutch language. The Pediatric Outcome Data Collecting Instrument (PODCI) is a PROM for musculoskeletal conditions, validated for use in NBPP, which was previously not available in Dutch. The PODCI is available in a 2-10 and a 10-18 year old parent-reported version, and a 10-18 year old self-reported version. It includes 83-86 questions (depending on the version), yielding 5 subscale scores and a total score.
Chapter 4 concerns the translation and cross-cultural adaptation, according to international guidelines for cross cultural adaptation[2-4], of the aforementioned PODCI versions into the Dutch language. Furthermore, the validation of the 2-10 year parent-reported version for use in children with NBPP was described. The final Dutch PODCI 2-10 year old parent-reported version was first field-tested in 10 children with NBPP, aged 3-10 years old. For validation, the questionnaire was used in 10 children undergoing secondary shoulder surgery and was administered preoperatively and 12 months post-operatively. For test-retest reliability the PODCI was administered twice again with an interval of 2 weeks after the 12 months post-operative follow-up. It was concluded that the Dutch PODCI is a useful and reliable tool to evaluate QoL and functioning in children with NBPP. Overall, it's internal consistency, responsiveness to change, construct validity and test-retest reliability was found to be good.

Because of a lack of available outcome measures concerning hand use in children with unilateral paresis, the Hand Use at Home questionnaire (HUH) was recently developed and tested in children with NBPP and unilateral Cerebral Palsy (UCP). This instrument measures the spontaneous hand use during daily life activities in the home environment, in children with unilateral upper limb paresis. Using Rasch analysis, the HUH was found to be a valid measure which showed good psychometric properties in terms of construct validity, internal consistency and discriminative capacity.[5] **Chapter 5** describes further evidence for the construct validity and test-retest reliability of the HUH questionnaire in the same patient groups. To measure the construct validity, 191 children with NBPP and 79 children with UCP were included. Parents of these children filled out the HUH once and additionally filled out the PODCI (NBPP only) or the Children's Hand use Experience Questionnaire (CHEQ; UCP only). For test-retest reliability 56 parents (16 children with NBPP and 40 with UCP) filled out a second HUH within 2-4 weeks after the first.
Results of this study showed that the HUH is a valid and reliable measure to be used in children with NBPP or UCP aged 3 to 10 years old. A significant correlation was found between the HUH and NBPP lesion-extent, indicating that greater lesion-extent is related to a lower amount of spontaneous hand-use. A relatively weak correlation was found between the HUH and treatment history in children with NBPP. In children with UCP a weak correlation with the Manual Ability Classification System (MACS) levels was found, indicating that a good ability to handle objects is not directly associated with a high amount of spontaneous use of the affected arm/hand. Test-retest reliability of the HUH was found to be excellent, based on a good Intra Class Correlation coefficient (ICC) and good agreement between the first and second HUH scores (Bland-Altman[6]). Based on these results it was concluded that the HUH can be used by parents of children with unilateral upper-limb paresis, aged 3-10 years, to report spontaneous hand-use of their child during daily activities. It provides clinicians and researchers with more insight into daily-life upper-limb performance. Future research into the ability of the HUH to detect changes over time should be conducted to provide the remaining psychometric properties of the HUH.

Most research on the consequences of NBPP has so far been mainly aimed at outcomes on the level of the Body Functions and Structure component of the ICF, in particular in very young children. To investigate activities and participation, QoL, family impact and healthcare use and information needs of patients with NBPP, the so-called ZAP Plexus study (Zorg (Care), Activities and Participation in patients with NBPP) was initiated in 2014. All patients who had ever visited the Leiden Nerve Center, a tertiary referral NBPP expert center within the Leiden University Medical Center (LUMC), were invited to participate in this cross-sectional study using electronic questionnaires. Invitations were sent to 1142 patients and/or parents of whom 508 (45%) participated. Of the participating patients 59 (12%) were between 0 and 1 years old, 226 (45%) between 2-9 years old, 180 (35%) between 10-18 years old and 43 (8%) were between the age of 19 and 61 years. The next three chapters describe the first analyses of the obtained data.

In **Chapter 6** parent-perceived family impact, QoL and upper extremity functioning in 59 children with NBPP in the very young age group (6-30 months old) are described. The parents of these 59 children were asked to fill out the PedsQL™ Family Impact Measure (FIM), the TNO-AZL (Dutch Organisation of Applied Natural Science and Academic Hospital Leiden) Preschool children's QoL (TAPQOL) questionnaire and a set of questions regarding upper extremity functioning of their child.
This study showed that lower FIM scores were associated with younger age, greater lesion-extent, affected side (right), primary (nerve) surgery treatment history and currently being in follow-up. The parents' perception of the children's' QoL was comparable to a healthy reference group for 66% of the TAPQOL scales. Having more upper extremity functioning problems was associated with greater lesion-extent and nerve surgery treatment history. Parents who reported more of these problems tended to worry more than parents who reported less problems.
The findings from this study confirm that parents to some extent find that having a child with NBPP has an impact on their family. No study in very young children has previously reported that right-sided lesions and more upper extremity functioning problems were associated with a greater impact on the family. It is essential for healthcare professionals to take these findings into account at an early stage when counselling parents and their family in order to reduce the impact on the family.

The ZAP plexus study results regarding healthcare use since birth and in the past 12 months, and information needs are reported in **Chapter 7.** Data from 465 patients between the age of 0 and 18 years old who completed questions on contacts with the plexus team and/or 11 other healthcare professionals and current information needs regarding 12 NBPP related topics were analysed. Furthermore, patient and NBPP characteristics and follow-up status at the Leiden Nerve Center (early/late/no discharge) were recorded.
Fifty-nine patients were 0-2 year of age, 226 were 2-9 years old and 180 were 10-18 years of age. There were 193 patients (42%) who had been discharged from follow-up, 83 of whom were categorized as 'early discharged' (defined as <1 year of age, due to spontaneous lesion recovery).
This study showed that healthcare use of children with NBPP in The Netherlands is considerable from the moment of the initial diagnosis. All parents reported to have had contact with at least 1 and up to 11 healthcare professionals (range depending on lesion severity) shortly after birth in addition to the involvement of the plexus team. Healthcare use decreased over time with 288 parents reporting to have had contact with at least 1 and up to 7 healthcare professionals (range depending on lesion severity, treatment history and follow-up status) over the past 12 months besides the possible involvement of the plexus team. Healthcare use in the past 12 months was statistically significantly associated with ongoing treatment in the Leiden Nerve Center, with greater lesion-extent, surgical treatment, lower QoL and diminished physical functioning. A relatively large proportion of discharged patients (81/193, 42%) still had contact with healthcare professionals due to their NBPP. Amongst them were 34 patients who were considered to be (almost) completely recovered

(discharged <1 year of age). Their healthcare use indicates that, contrary to expectations, these patients may experience functional limitations. Furthermore, a relatively large proportion (228/465, 49%) of parents/patients, including 65 discharged children (either early discharged: 23/83, 28% or late discharged: 42/110, 40%), reported information needs regarding a variety of NBPP related topics (treatment, sports and physical functioning, assistive devices etc.). These findings make it clear that after discharge from specialist care, a considerable proportion of patients experience limitations and have information needs, warranting a stricter follow-up protocol and information provision.

In **Chapter 8** restrictions in participation from the patients' perspective in adolescents and adults with NBPP are described. Seventy-five adolescent and adult patients (16-61 years of age) participated of whom 33 were between 16 and 18 years, 22 between 19 and 25, 11 between 26 and 35 and 9 were between 36 and 61 years of age. Patients completed questions on the influence of NBPP on their choices regarding education and work and on their work-performance. Furthermore, the Impact on Participation/Autonomy questionnaire (IPA; 5 domains) and the Utrecht Scale for Evaluation of Rehabilitation-Participation (USER-P; 3 domains) were administered. Additionally, health-related quality of life was assessed using the Short Form 36 (SF-36) and the Disability of the Arm, Shoulder and Hand (DASH) questionnaires and patient and NBPP characteristics were recorded.
Of the 75 participating patients, 20 (27%) were full-time students, 28 (37%) were students who also had a job, 21 (28%) were employed, 2 (3%) were unemployed and 4 (5%) were work-disabled due to their NBPP. The patients' overall HRQoL was comparable to the general population. 27/75 patients reported that neonatal brachial plexus palsy had affected their choices regarding education and 26/75 those regarding work. 33 of the 66 patients who have or had work reported impact on their work performance. On the Impact on Participation/Autonomy questionnaire, 80% (49/61) reported restrictions in the work-and-education domain, 74% in social-relations and 67% in autonomy-outdoors. 37 of the 61 patients who filled out the USER-P reported participation restrictions and they reported to be somewhat less satisfied with the participation possibilities that they had.
More restrictions in participation were associated with worse upper extremity functioning (DASH), lower QoL and more pain (SF-36) but not with lesion extent, treatment history or affected side. This may indicate that all NBPP patients, regardless of the initial severity of their lesion, may perceive restrictions in participation in later life.
The above findings are relatively new and warrant the need for optimization of care. Guiding patients in making choices on education and work at an early stage and providing tailored physical as well as psychosocial care may prevent or address restrictions, which may improve participation.

GENERAL DISCUSSION

Neonatal brachial plexus palsy (NBPP) is a birth injury to the brachial plexus with a large heterogeneity in lesion extent and severity resulting in a wide variety of functional limitations. The prognosis for spontaneous recovery has been reported as good, but a considerable proportion of patients (about 35%) is left with remaining impairments, resulting in problems in daily life activities, participation and overall quality of life (QoL).[7,8] Multiple treatment options are available, including surgery and conservative strategies, all aiming to improve the patient's functioning. As most research has so far mainly been focused on impairments of arm and hand function, more insight into the consequences of NBPP and its treatment including a broader range of aspects of health status is needed. This thesis aimed to comprehensively describe functional outcome of secondary shoulder surgery as well as the overall impact of NBPP throughout the lifespan. The latter was done within the Zorg (Care), Activities and Participation in patients with NBPP study (ZAP Plexus) conducted in the Leiden University Medical Center (LUMC).

FUNCTIONAL OUTCOME OF SECONDARY SHOULDER SURGERY

This thesis showed that, in line with previous research, secondary shoulder surgery improves function at the level of the ICF component Body Functions and Structure.[9-21] By the use of a comprehensive instrument to measure functional outcomes at the level of the ICF component Activities and Participation (i.e. the Pediatric Outcome Data Collecting Instrument; PODCI), and measuring parental satisfaction, it was shown that improvements on these aspects after surgery were also considerable. These latter findings underpin the need to define the outcomes of surgery at the level of activities and participation in future research, further supporting the important role of surgery in creating value for patients. Furthermore, this thesis also showed that both patient characteristics and outcomes of secondary shoulder surgery are different for children who have had primary (nerve) surgery as compared to outcomes for those who have only been treated conservatively. Outcomes should therefore be described separately for these subgroups.

OUTCOME MEASUREMENT IN NBPP

The abovementioned PODCI, covering different components of the ICF, was translated and cross-culturally adapted into a Dutch version according to international guidelines.[2-4] It was validated in a small series of children with NBPP who underwent shoulder surgery. Moreover, its application in a large cohort, including patients with and without nerve and/or secondary surgery, supported its usefulness in the Dutch NBPP population.
The PODCI measures upper extremity functioning in terms of difficulty in performing activities, either or not using the affected arm/hand. However, it does not measure

spontaneous use of the affected arm/hand in daily life. Although there are various instruments available measuring arm/hand use, such as the ABILHAND kids[22] and the Children's Hand Experience Questionnaire (CHEQ)[23,24], these instruments are either not developed for NBPP, they have not been used in NBPP outcome studies or they do not measure parent-rated spontaneous hand use in the home environment. As a result of a national cooperation with the Sint Maartenskliniek rehabilitation centre Nijmegen, a new outcome measure, the Hand Use at Home (HUH) questionnaire was developed and tested to fill this gap.[5] The psychometric properties of this newly developed instrument were proven to be good.[5]
To further study the value of both the PODCI and the HUH in patients with NBPP, including their sensitivity to change, large prospective follow-up studies, irrespective of the treatment provided, are necessary. These studies should include well-chosen follow-up time-points (i.e. six-monthly, as six months is a time period in which rehabilitation goals are usually met or revised) and previous as well as inter current therapy, lesion extent and potential aspects other than age possibly interfering with motor development in children in general (e.g. dyspraxia, learned non-use, concurrent medical diagnoses), should be well documented and accounted for during analyses.

Generic Quality of Life questionnaires

In NBPP research the need for outcome measures, either disease-specific or generic, not only taking into account clinical impact but also the patient's perspective is underlined in a recent systematic review, performed by researchers in the LUMC.[25] This review suggested that generic QoL instruments like the TNO-AZL (Dutch Organisation of Applied Natural Science and Academic Hospital Leiden) preschool children's QoL (TAPQOL), children's QoL (TACQOL), and Adult QoL (TAAQOL) questionnaires might be of added value for this purpose.[25,26] These instruments have been used in the ZAP Plexus study, however the results of the TAPQOL only have yet been analysed in very young children (up to 2 years old). When TAPQOL scores were compared to those of healthy age-matched peers, few differences were found. Therefore, the question remains whether generic standardized questionnaires (in contrast to disease specific or individualized measures) are sensitive enough to detect problems in the NBPP population. Moreover, to date it has not yet been investigated whether the TAPQOL, TACQOL and TAAQOL can be used consecutively over time to provide comparable QoL outcomes throughout the lifespan in individual patients. Future studies should be conducted to investigate whether these instruments can be used in long-term follow-up studies.
Besides the aforementioned generic QoL instruments there are other options available such as the PedsQL™ QoL family of questionnaire.[27,28] These questionnaires have been used in several rehabilitation studies, which makes it possible to compare outcomes in children with NBPP to other patient groups.[29-31] Furthermore, there are different optional modules available for use, such as the PedsQL™ Family Impact Module (FIM) which has indeed been used in one of our studies. Using the PedsQL™ QoL questionnaires could facilitate the monitoring of different kinds of aspects of impact of NBPP throughout the pediatric lifespan using the same family of instruments.[32]

Family impact

This thesis showed that according to the perception of parents, having a 6 to 30-month-old child with NBPP had impact on their family. Younger age, greater lesion-extent, affected side (right), primary (nerve) surgery and currently being in follow-up were found to be associated with a greater family burden. The impact of having a child with NBPP on the family in the early postpartum period was not evaluated. Particularly in that phase the burden to the family may be substantial as the NBPP occurs during birth and can thus not be anticipated by parents. Adding family impact measures, such as the PedsQL™ FIM, to routine assessments and monitoring from birth on might detect family impact in an early stage, so that possible parental counselling can be started if needed.

Long term consequences of NBPP

Another part of this thesis showed that adolescents and adults perceive restrictions in participation, mainly related to work and choice of education due to their NBPP. The extent of restrictions in participation were found to be related to lower QoL and more pain. The presence of pain and functional limitations in adolescent and adult patients have been previously reported[33-35], however, NBPP participation restrictions and impact on study and career choices have only been described in a relatively old study.[36] Even though adolescent and adult patients with NBPP seem to perceive functional limitations, pain and participation restrictions, they are not frequently seen in NBPP expert centers, nor in rehabilitation settings.[34,37] As research in adult NBPP patients is scarce, and most adult patients are lost to clinical follow-up, it is not fully known what the consequences of NBPP are on the long term. In contrast, knowledge on this issue is very important as interventions in childhood are in principle performed to increase the level of functioning at adolescence and beyond.

ICF core set

To be able to determine the impact of NBPP throughout the lifespan it is important to create a common core set , such as an ICF core set, as a universally accepted overall framework to assess the outcome.[38] This framework for NBPP is not yet available. A proposition to create an ICF core set for NBPP has been made by researchers from the LUMC, encompassing 4 steps.[38] The first step concerns the conduct of a systematic review to identify outcome measures, which has already been finished.[25] The second step, a qualitative study using focus groups to identify important concepts of functioning and health in children with NBPP, has been completed as well.[39] The last 2 remaining steps, namely an expert survey and a cross-sectional study, are planned. The cross-sectional study step has been partly described in this thesis (the ZAP Plexus study) but the conduct of a cross-sectional, multicenter study remains for future research.

To be able to evaluate aspects within this future core set it is important to use a solid set of internationally accepted outcome measures. Currently, no consensus exists on which instruments are best and should be used, so that in NBPP studies multiple outcome measures are currently employed.[25,40-42] Most of these instruments concern the Body

Functions and Structure component of the ICF whereas very few address the ICF components Activity and Participation.[25] A new initiative by the Leiden Nerve Center called iPLUTO (international PLexus oUtcome sTudy group) has been launched to create consensus on which outcome measures, covering all components of the ICF, should be used.[43] According to this initiative, a worldwide expert survey was circulated among leading clinicians and researchers aiming to create an international standard on how to evaluate and express results of NBPP treatment and outcome. The preliminary results of this survey showed that about 50% of the 70 respondents agree that Patient/Parent Reported Outcome Measures (PROMs) on the level of the ICF component Activities and Participation should be included in the minimal dataset of outcome measures.[43] However, less than 20% of the respondents reported that they (or their center) have sufficient experience with PROMs to judge which PROMs should be included.[43] Therefore, ongoing efforts to disseminate and discuss the results of our study with practitioners treating the sequelae of NBPP worldwide are needed.

HEALTHCARE IN NEONATAL BRACHIAL PLEXUS PALSY

Early referral

Early referral to a specialized NBPP expert center when a more severe lesion is suspected, is very important.[44] However, also in case of doubtful severity, referral to such a tertiary center is warranted, as this thesis showed that seemingly spontaneously recovered children do report problems in later life. With an incidence rate of 1-2 per 1000 live born children[45] and about 170000-180000 births a year (CBS: statline.cbs.nl 2012-2015), approximately 200-350 children with NBPP are born every year in The Netherlands. However, the exact incidence in the Netherlands is not known. Better registration of all new NBPP patients has been tried through the Dutch Signaling Centre for Child Healthcare (Nederlands Signalerings Centrum Kindergeneeskunde, NSCK; www.nvk.nl/onderzoek/NSCK.aspx) but to date this registration system only showed few new cases each year, not by far reaching the expected number of new infants with NBPP. As data from the 3 NBPP expert centers in The Netherlands are not collectively gathered, it is unfortunately not known how many new born patients with NBPP are seen each year in these centers together. A national, as well as an international collaboration and joint data analysis – both of treated and untreated children – is of utmost importance. With the iPLUTO initiative a uniform gathering of data at fixed time points is aimed for, enabling pooling and comparison of outcome data for different treatment strategies and their outcomes.

Early and later discharge from NBPP expert centers

As stated before, this thesis provides evidence that some children who were discharged from follow-up from the Leiden Nerve Center, either because of good spontaneous recovery soon after birth or through effective surgical treatment, received active treatment for their NBPP later on. Moreover, a number of them reported problems regarding physical, mental

or social functioning. Therefore, the question remains whether the current criteria for discharge are adequate. A long-term natural history clinical follow-up study may provide further answers to this question.

Healthcare use and the role of physical therapy

Healthcare use in children with NBPP, as shown in this thesis, is considerable but decreases over time depending on lesion extent, functional recovery and treatment history. In our research the pediatric physical therapist was the most frequently mentioned healthcare professional with whom patients had had, or still had, contact. The data on healthcare use in adults with NBPP have not yet been fully analysed. However, from the ZAP Plexus study it is known that about 20% of the adult patients reported having contact with a physical therapist. This makes this healthcare professional one of the most contacted healthcare providers for NBPP throughout the lifespan.

Unfortunately, literature on the effectiveness of physical therapy in the treatment of NBPP is scarce. Book chapters on pediatric physical therapy and rehabilitation usually provide general recommendations on the content of the therapy program, e.g. monitoring motor performance, joint mobility and muscle strength over time. Furthermore, they include instructions for parents on how to handle (e.g. pick up, carry, bathe and clothe) their baby and how to perform exercises to maintain passive range of motion (ROM). Multiple sources report to start therapy within 1-3 weeks after birth, but in-hospital treatment may start as soon as the day after birth.[37,46,47] Within the LUMC, pediatric physical therapy for new-born children with NBPP starts directly after birth, according to a protocol of passive ROM exercises to be carried out 7-8 times a day by pediatric physical therapists, in close cooperation with parents and nurses (personal communication S.M. Buitenhuis / J.C. van Egmond-van Dam).

The importance of continuous passive ROM exercises to maintain freedom of movement throughout time in all upper extremity joints has been underlined.[37,47-52] These exercises are performed to prevent possible contractures and joint deformities from occurring, and to keep active movement unrestrained. Combining these exercises with glenohumeral joint movement may further prevent joint and muscle contractures, and may normalise shoulder movements in growing infants.[46,49,50] There is, however, no conclusive evidence base for the effectiveness of passive ROM exercises in general. One recent study suggested that the performance of passive ROM exercises was not associated with the prevalence of shoulder joint deformities in NBPP, but that these deformities were linked to active ROM possibilities of the child.[53] In addition to passive ROM exercises the use of serial casting, orthoses, dynamic splints or botulinum toxin for contracture prevention have been described.[54-57] These studies, however, did not report on the precise content of the additional physical therapy program.

Another role of the physical therapist is monitoring and improving motor development and motor function over time, including stimulation of weight bearing activities (e.g. crawling etc.), postural alignment and muscle strength (with special attention to the rotator cuff muscles). [46,47,50] In children with NBPP, the use of the affected arm might be less than that

of the unaffected arm and children with right-sided lesions have been reported to develop left-handedness.[58,59] By using compensatory strategies during activities, children may learn how to perform activities mostly using their unaffected arm, probably ignoring their affected arm leading to a 'learned non-use', developmental disregard or dyspraxia.[46,60] This phenomenon should be recognised by pediatric physical therapists and/or occupational therapists and addressed during therapy.

Constraint induced movement therapy, and possibly bimanual intensive training, have been suggested and described to possibly improve function (counteracting learned non-use)[46,49,50,61,62] However, in our clinical practice overuse as a possible result of these interventions leading to physical complaints have been frequently reported. Moreover, these interventions have not been systematically studied in NBPP and their added value to rehabilitation programs remains to be proven.

Adherence to complementary home based exercises applied and/or supervised by parents also plays an important role in the physical therapy treatment of NBPP.[47,49-51,53,63] The general notion is that children of whom parents perform or supervise these exercises consistently have better function, however, this is difficult to prove. The use of multimedia for dynamic exercise modelling was found to increase compliance, by improving both the frequency and duration of exercise.[51] The use of virtual reality (gaming) in pediatric rehabilitation is currently being tested in SMART labs in pediatric rehabilitation centers (Rijnlands and Sophia rehabilitation centers) and could possibly add to the child's exercise motivation. However, motivation and effectiveness of the exercises may decrease over time, necessitating periodical evaluation, and if needed alteration of the program.[51,63]

INFORMATION NEEDS AND INFORMATION PROVISION

Half of the patients and their parents/caregivers (49%) in the ZAP Plexus study reported that they needed far more information than given at the outpatient clinic, whereas 18% found that they had received contradicting information from different healthcare professionals. These findings underline the need to provide parents and/or patients with NBPP with adequate and uniform information. In addition, it is also important to optimize communication and the dissemination of knowledge and expertise among care providers. It is strongly recommended to develop and distribute modular information tailored to the individual patients'/parents' information needs, for example through short movies and/or electronic information brochures, provided through an interactive website. The information should be personalized according to aspects such as the lesion extent, treatment and different stages of development (e.g. when going to school, when choosing sports, study or a profession etc.).

IMPLICATIONS AND DIRECTIONS FOR FUTURE CARE AND RESEARCH

The most important findings of this thesis include the observed limitations in activities and participation, the associated healthcare use as well as the healthcare and information needs, even in patients with NBPP who are discharged from follow-up. Furthermore, a possible lack of attention was found for the impact NBPP has on family life as a whole.
Most experts agree upon the need for more and better assessments of all these aspects in NBPP patients and their family, yet there is little consensus on a core set of outcome measures to be used at long-term follow-up. Therefore, the following implications to improve patient care can be made:

- Family impact
  - From birth on more attention should be paid to the family impact of the NBPP and, if indicated by a simple screening test or parents themselves, early counselling of parents and their families should be initiated.
  - Healthcare professionals providing mental support (i.e. psychologists, social workers) should be part of NBPP expert teams and counselled if needed.
- Routine follow-up
  - A stricter monitoring protocol reaching into adulthood should be used taking into account all components of the ICF. Constructing an international database as a result of the iPLUTO initiative is recommend.
  - Implementation of the HUH questionnaire at the Leiden Nerve Center and other NBPP centers around the world.
  - NBPP expert teams should pro-actively reach out to patients and/or their parents, for example via e-mail or phone, to verify whether or not impairments on the level of body functions and structure and/or restrictions in activities or participation exist.
- Information needs
  - Information provision to meet the information needs of patients and/or parents should be optimized and tailored according to individual patients' and parents' needs and preferred modes of delivery.
- Physical therapy
  - A physical therapy consensus management protocol (including recommendations on forms, duration, frequencies, resistance, home exercises and parental involvement etc.) for different ages and development stages throughout the lifespan should be established and systematically evaluated.

All recommendations described above should be discussed, developed and implemented in close collaboration with patients and parents and the patient organisation.

The following directions for future research should be considered:

- New research
  - A follow-up study on family impact of NBPP at birth and at one, three, six and 12 months of age and yearly thereafter to gather additional information on the impact on the family over time.
  - A follow-up study on participation, in particular work-related problems and needs, reaching out to all adolescent and adult patients with NBPP.
  - Comparison of different physical therapy treatment protocols (types of exercises and their intensity, duration and frequency), to provide evidence for best practice in physical therapy.
  - Wearable accelerometers, or other forms of activity monitors, worn for at least a week, should be used to evaluate daily activities in a more objective way. Such instruments could also be used to perform predefined tests at home, prior to the visit at the clinic, or in case of functional deterioration.
- ZAP Plexus based future research
  - A cross-sectional study, and possibly afterwards a follow-up study, on physical activity and sports participation in children with NBPP to be able to provide more adequate information on these topics in clinical care.
  - An analysis of the remaining ZAP plexus data for gaining further insight into the impact of NBPP (i.e. sensibility and sensitisation, upper extremity function, healthcare use and information needs in adult NBPP patients, QoL and participation) and to provide evidence on what instruments are able to detect problems in the NBPP population.
  - Further investigate the value of both the PODCI and the HUH in patients with NBPP, including their sensitivity to change.
  - A follow-up ZAP plexus study, aiming to further describe the course of NBPP and its consequences over time in the now defined and well-described cohort.

All these efforts are necessary to increase insight into all NBPP patients' health status and healthcare needs which will lead to improved patient care in this lifelong condition. With improved care aiming for better participation within society, supporting the patient to adapt to each phase in life if needed, the impact of NBPP throughout the lifespan can be reduced resulting in better quality of life.

REFERENCES

1. WHO. ICF Domains. 2015; http://www.who.int/classifications/icf/en/.
2. Beaton D.E., Bombardier C., Guillemin F., Ferraz M.B. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976.).* 2000;25(24):3186-3191.
3. Guillemin F., Bombardier C., Beaton D. Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. *J.Clin.Epidemiol.* 1993;46(12):1417-1432.
4. C.G. Maher, J. Latimer, L.O.P Costa. The relevance of cross-cultural adaptation and clinimetrics for physical therapy instruments. *Rev Bras Fisioter.* 2007;11(4):245-252.
5. Yvonne Geerdink Pauline Aarts, Menno van der Holst, Robert Lindeboom, Jan van der Burg, Bert Steenbergen, Alexander C. Geurts. Development and psychometric properties of the Hand-Use-at-Home questionnaire to assess amount of affected hand use in children with unilateral paresis. Submitted september 2016.
6. Giavarina D. Understanding Bland Altman analysis. *Biochem Med (Zagreb).* 2015;25(2):141-151.
7. Foad S.L., Mehlman C.T., Foad M.B., Lippert W.C. Prognosis following neonatal brachial plexus palsy: an evidence-based review. *J.Child Orthop.* 2009;3(6):459-463.
8. Duff S. V., DeMatteo C. Clinical assessment of the infant and child following perinatal brachial plexus injury. *Journal of hand therapy : official journal of the American Society of Hand Therapists.* 2015;28(2):126-133; quiz 134.
9. Phipps G.J., Hoffer M.M. Latissimus dorsi and teres major transfer to rotator cuff for Erb's palsy. *J.Shoulder.Elbow.Surg.* 1995;4(2):124-129.
10. Edwards T.B., Baghian S., Faust D.C., Willis R.B. Results of latissimus dorsi and teres major transfer to the rotator cuff in the treatment of Erb's palsy. *J.Pediatr.Orthop.* 2000;20(3):375-379.
11. Suenaga N., Minami A., Kaneda K. Long-term results of multiple muscle transfer to reconstruct shoulder function in patients with birth palsy: eleven-year follow-up. *J.Pediatr.Orthop.* 1999;19(5):669-671.
12. van der Sluijs J.A., van Ouwerkerk W.J., de Gast A., Nollet F., Winters H., Wuisman P.I. Treatment of internal rotation contracture of the shoulder in obstetric brachial plexus lesions by subscapular tendon lengthening and open reduction: early results and complications. *J.Pediatr.Orthop.B.* 2004;13(3):218-224.
13. Aydin A., Ozkan T., Onel D. Does preoperative abduction value affect functional outcome of combined muscle transfer and release procedures in obstetrical palsy patients with shoulder involvement? *BMC.Musculoskelet.Disord.* 2004;5:25.
14. Vallejo G.I., Toh S., Arai H., Arai K., Harata S. Results of the latissimus dorsi and teres major tendon transfer on to the rotator cuff for brachial plexus palsy at birth. *Scand.J.Plast.Reconstr.Surg.Hand Surg.* 2002;36(4):207-211.
15. Terzis J.K., Kokkalis Z.T. Outcomes of secondary shoulder reconstruction in obstetrical brachial plexus palsy. *Plast.Reconstr.Surg.* 2008;122(6):1812-1822.
16. Chen L., Gu Y.D., Hu S.N. Applying transfer of trapezius and/or latissimus dorsi with teres major for reconstruction of abduction and external rotation of the shoulder in obstetrical brachial plexus palsy. *J.Reconstr.Microsurg.* 2002;18(4):275-280.
17. Cohen G., Rampal V., Aubart-Cohen F., Seringe R., Wicart P. Brachial plexus birth palsy shoulder deformity treatment using subscapularis release combined to tendons transfer. *Orthop.Traumatol.Surg.Res.* 2010;96(4):334-339.
18. Abdel-Ghani H., Hamdy K.A., Basha N., Tarraf Y.N. Tendon transfer for treatment of internal rotation contracture of the shoulder in brachial plexus birth palsy. *J.Hand Surg.Eur.* 2012;37(8):781-786.
19. Ozben H., Atalar A.C., Bilsel K., Demirhan M. Transfer of latissmus dorsi and teres major tendons without subscapularis release for the treatment of obstetrical brachial plexus palsy sequela. *J.Shoulder.Elbow.Surg.* 2011;20(8):1265-1274.
20. Kambhampati S. B., Birch R., Cobiella C., Chen L. Posterior subluxation and dislocation of the shoulder in obstetric brachial plexus palsy. *J Bone Joint Surg Br.* 2006;88(2):213-219.
21. Louden E.J., Broering C.A., Mehlman C.T., Lippert W.C., Pratt J., King E.C. Meta-analysis of function after secondary shoulder surgery in neonatal brachial plexus palsy. *J.Pediatr.Orthop.* 2013;33(6):656-663.
22. Arnould C., Penta M., Renders A., Thonnard J.L. ABILHAND-Kids: a measure of manual ability in children with cerebral palsy. *Neurology.* 2004;63(6):1045-1052.
23. Amer A., Eliasson A. C., Peny-Dahlstrand M., Hermansson L. Validity and test-retest reliability of Children's Hand-use Experience Questionnaire in children with unilateral cerebral palsy. *Developmental medicine and child neurology.* 2015.
24. Skold A., Hermansson L.N., Krumlinde-Sundholm L., Eliasson A.C. Development and evidence of validity for the Children's Hand-use Experience Questionnaire (CHEQ). *Dev.Med.Child Neurol.* 2011;53(5):436-442.
25. Sarac C., Duijnisveld B. J., Weide Av, et al. Outcome measures used in clinical studies on

neonatal brachial plexus palsy: A systematic literature review using the International Classification of Functioning, Disability and Health. *J Pediatr Rehabil Med.* 2015;8(3):167-186.
26. TNO. TAPQOL, TACQOL, TAAQOL. 2013; https://www.tno.nl/media/5004/vragenlijsten_01032012.pdf. Accessed 12/4/2013.
27. Varni J. W., Limbers C. A., Burwinkle T. M. Parent proxy-report of their children's health-related quality of life: an analysis of 13,878 parents' reliability and validity across age subgroups using the PedsQL 4.0 Generic Core Scales. *Health and quality of life outcomes.* 2007;5:2.
28. Varni J. W., Limbers C. A., Burwinkle T. M. How young can children reliably and validly self-report their health-related quality of life?: an analysis of 8,591 children across age subgroups with the PedsQL 4.0 Generic Core Scales. *Health and quality of life outcomes.* 2007;5:1.
29. Varni J. W., Burwinkle T. M., Berrin S. J., et al. The PedsQL in pediatric cerebral palsy: reliability, validity, and sensitivity of the Generic Core Scales and Cerebral Palsy Module. *Developmental medicine and child neurology.* 2006;48(6):442-449.
30. Berrin S. J., Malcarne V. L., Varni J. W., et al. Pain, fatigue, and school functioning in children with cerebral palsy: a path-analytic model. *Journal of pediatric psychology.* 2007;32(3):330-337.
31. Maher C. A., Toohey M., Ferguson M. Physical activity predicts quality of life and happiness in children and adolescents with cerebral palsy. *Disability and rehabilitation.* 2016;38(9):865-869.
32. Varni J.W., Sherman S.A., Burwinkle T.M., Dickinson P.E., Dixon P. The PedsQL Family Impact Module: preliminary reliability and validity. *Health Qual.Life Outcomes.* 2004;2:55.
33. Partridge C., Edwards S. Obstetric brachial plexus palsy: increasing disability and exacerbation of symptoms with age. *Physiotherapy research international : the journal for researchers and clinicians in physical therapy.* 2004;9(4):157-163.
34. de Heer C., Beckerman H., Groot V. D. Explaining daily functioning in young adults with obstetric brachial plexus lesion. *Disability and rehabilitation.* 2014:1-7.
35. Kirjavainen M. O., Remes V. M., Peltonen J., et al. Permanent brachial plexus birth palsy does not impair the development and function of the spine and lower limbs. *J Pediatr Orthop B.* 2009;18(6):283-288.
36. Gjorup L. Obstetrical lesion of the brachial plexus. *Acta Neurol Scand.* 1966;42:Suppl 18:11-80.
37. Rietje van Wijlen-Hempel, Sonja Buitenhuis, Willem Pondaag, Martijn Malessy. Obstetrisch plexus-brachialisletsel. In: Mijna Hadders-Algra, Karel Maathuis, Robert F. Pangalila, Jules G. Becher, Jan de Moor ed. *Kinderrevalidatie*. 5 ed. Assen: Koninklijke van Gorcum BV; 2015:525-538.
38. Duijnisveld B. J., Sarac C., Malessy M. J., Brachial Plexus Advisory Board T. I., Vliet Vlieland T. P., Nelissen R. G. Developing core sets for patients with obstetricbrachial plexus injury based on the International Classificationof Functioning, Disability and Health. *Bone Joint Res.* 2013;2(6):116-121.
39. Sarac C., Bastiaansen E., Van der Holst M., Malessy M.J., Nelissen R.G., Vliet Vlieland T.P. Concepts of functioning and health important to children with an obstetric brachial plexus injury: a qualitative study using focus groups. *Dev.Med. Child Neurol.* 2013;55(12):1136-1142.
40. Bialocerkowski A., O'Shea K., Pin T. W. Psychometric properties of outcome measures for children and adolescents with brachial plexus birth palsy: a systematic review. *Developmental medicine and child neurology.* 2013;55(12):1075-1088.
41. Dy C. J., Garg R., Lee S. K., Tow P., Mancuso C. A., Wolfe S. W. A systematic review of outcomes reporting for brachial plexus reconstruction. *The Journal of hand surgery.* 2015;40(2):308-313.
42. Chang K.W., Justice D., Chung K.C., Yang L.J. A systematic review of evaluation methods for neonatal brachial plexus palsy. *J.Neurosurg. Pediatr.* 2013.
43. W.Pondaag M.J.A.Malessy Ipluto - International Plexus Outcome Study Group: First Results. American Society for Peripheral Nerve anual meeting; 2017; Hawaii.
44. Malessy M. J., Pondaag W., Yang L. J., Hofstede-Buitenhuis S. M., le Cessie S., van Dijk J. G. Severe obstetric brachial plexus palsies can be identified at one month of age. *PLoS One.* 2011;6(10):e26193.
45. Pondaag W., van Dijk J. G., Nelissen R. G., Malessy M. J. [Obstetric brachial plexus injury]. *Nederlands tijdschrift voor geneeskunde.* 2014;158:A7145.
46. Smania N., Berto G., La Marchina E., et al. Rehabilitation of brachial plexus injuries in adults and children. *Eur J Phys Rehabil Med.* 2012;48(3):483-506.
47. I Bosga-Stork, V Schaaf. Perifeer-neurologische aandoeningen, het obstetrisch plexus brachialis letsel. In: R van Empelen RN-vdS, A Hartman, ed. *Kinderfysiotherapie*. 3 ed. Amsterdam: Reed Business Education; 2103:553-571.
48. Schaaf VAM, Buitenhuis SM. Wetenschapsloket: Acute plexus letsels. *Nederlands tijdschrift voor kinderfysiotherapie.* 2009;21(59):24-27.
49. Price A., Tidwell M., Grossman J.A. Improving shoulder and elbow function in children with Erb's palsy. *Semin.Pediatr.Neurol.* 2000;7(1):44-51.
50. Ramos L. E., Zell J. P. Rehabilitation program for children with brachial plexus and peripheral nerve injury. *Semin Pediatr Neurol.* 2000;7(1):52-57.

51. Murphy K. M., Rasmussen L., Hervey-Jumper S. L., Justice D., Nelson V. S., Yang L. J. An assessment of the compliance and utility of a home exercise DVD for caregivers of children and adolescents with brachial plexus palsy: a pilot study. *Pm r.* 2012;4(3):190-197.
52. Waters P.M. Update on management of pediatric brachial plexus palsy. *J.Pediatr.Orthop.B.* 2005;14(4):233-244.
53. Justice D., Rasmussen L., Di Pietro M., et al. Prevalence of Posterior Shoulder Subluxation in Children With Neonatal Brachial Plexus Palsy After Early Full Passive Range of Motion Exercises. *Pm r.* 2015;7(12):1235-1242.
54. Duijnisveld B. J., van Wijlen-Hempel M. S., Hogendoorn S., et al. Botulinum Toxin Injection for Internal Rotation Contractures in Brachial Plexus Birth Palsy. A Minimum 5-Year Prospective Observational Study. *J Pediatr Orthop.* 2016.
55. Michaud L. J., Louden E. J., Lippert W. C., Allgier A. J., Foad S. L., Mehlman C. T. Use of botulinum toxin type A in the management of neonatal brachial plexus palsy. *Pm r.* 2014;6(12):1107-1119.
56. Duijnisveld B. J., Steenbeek D., Nelissen R. G. Serial casting for elbow flexion contractures in neonatal brachial plexus palsy. *J Pediatr Rehabil Med.* 2016;9(3):207-214.
57. Durlacher K. M., Bellows D., Verchere C. Sup-ER orthosis: an innovative treatment for infants with birth related brachial plexus injury. *Journal of hand therapy : official journal of the American Society of Hand Therapists.* 2014;27(4):335-339; quiz 340.
58. Yang L. J., Anand P., Birch R. Limb preference in children with obstetric brachial plexus palsy. *Pediatric neurology.* 2005;33(1):46-49.
59. 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.
60. Brown T., Cupido C., Scarfone H., Pape K., Galea V., McComas A. Developmental apraxia arising from neonatal brachial plexus palsy. *Neurology.* 2000;55(1):24-30.
61. Berggren J., Baker L. L. Therapeutic application of electrical stimulation and constraint induced movement therapy in perinatal brachial plexus injury: A case report. *Journal of hand therapy : official journal of the American Society of Hand Therapists.* 2015;28(2):217-220; quiz 221.
62. Buesch F. E., Schlaepfer B., de Bruin E. D., Wohlrab G., Ammann-Reiffer C., Meyer-Heim A. Constraint-induced movement therapy for children with obstetric brachial plexus palsy: two single-case series. *International journal of rehabilitation research. Internationale Zeitschrift fur Rehabilitationsforschung. Revue internationale de recherches de readaptation.* 2010;33(2):187-192.
63. Rasmussen L., Justice D., Chang K. W., Nelson V. S., Yang L. J. Home exercise DVD promotes exercise accuracy by caregivers of children and adolescents with brachial plexus palsy. *PM R.* 2013;5(11):924-930.

CHAPTER TEN

Nederlandse samenvatting en Discussie

SAMENVATTING

In dit proefschrift worden verschillende aspecten van de impact van obstetrisch plexus brachialis letsel (OPBL) gedurende het leven van de patiënt beschreven. Er wordt ingegaan op de impact van OPBL op activiteiten en participatie, maar ook op wat de impact is op de kwaliteit van leven. Verder wordt onderzoek naar het zorggebruik van patiënten met OPBL beschreven, alsook naar de informatiebehoefte van hen en/of die van hun ouders. Daarnaast behelst dit proefschrift de ontwikkeling en de evaluatie van meetinstrumenten die gebruikt kunnen worden om uitkomsten van OPBL te meten.

Hoofdstuk 1, de algemene introductie van dit proefschrift, beschrijft de karakteristieke eigenschappen van OPBL met betrekking tot de uitgebreidheid, de ernst en het natuurlijk beloop van dit traumatische geboorteletsel. In dit hoofdstuk worden zowel de conservatieve behandeling, inclusief (kinder)fysiotherapie, alsook de mogelijke primaire en secundaire chirurgische behandelingen beschreven. Verder worden belangrijke aspecten en consequenties van OPBL weergegeven in relatie tot de 'International Classification of Functioning, Disability and Health' (ICF).[1]
Met behulp van dit ICF-model worden ook veel gebruikte meetinstrumenten om uitkomsten van OPBL te meten, geïntroduceerd.

De uitkomsten van secundaire schouderchirurgie bij kinderen met OPBL is reeds in meerdere wetenschappelijke studies beschreven. Deze studies beschrijven de uitkomsten echter voornamelijk op het gebied van het ICF-component; 'functies en anatomische eigenschappen'. Een uitgebreide analyse van de uitkomsten van deze operatie op meerdere componenten van de ICF (dat wil zeggen zowel 'functies en anatomische eigenschappen' alsook 'activiteiten en participatie'), waarbij ook de verwachtingen van ouders en hun tevredenheid over de behandeling werd meegenomen, was nog niet voorhanden. **Hoofdstuk 2** beschrijft de korte termijn uitkomsten van het opheffen van een schouder endorotatiecontractuur in combinatie met het verplaatsen van spieren en pezen (mm. Latissimus Dorsi en Teres Major) bij kinderen met OPBL in relatie tot de arm en handfunctie, de kwaliteit van leven en de tevredenheid van ouders met betrekking tot de resultaten van deze ingreep. Het doel van de ingreep is het verbeteren van de schouder exorotatie bewegingsmogelijkheden en daardoor de mogelijkheid om de hand naar het hoofd en de mond te brengen, het verbeteren van het gebruik van de aangedane arm tijdens tweehandige taken en om verergering van schoudervergroeiingen te voorkomen. Er is een prospectieve studie uitgevoerd naar het effect van deze exorotatieplastiek bij 10 kinderen tussen de 3 en 10 jaar oud waarbij de kinderen een dag voor de operatie en 3, 6 en 12 maanden na de operatie gemeten werden. Deze studie liet zien dat alle eerder beschreven functies en vaardigheden significant verbeterden in het jaar volgend op de operatie. Er werd echter ook gevonden dat de kinderen na de operatie meer moeite hadden om de arm naar achteren te bewegen (retroflexie) en om de hand op de rug te leggen. De door ouders gerapporteerde kwaliteit van leven met betrekking tot het functioneren van de arm, en het functioneren in het

algemeen, verbeterde ook significant in het jaar volgend op de operatie. De meerderheid van de ouders was erg tevreden met de uitkomsten van de ingreep en zij vonden dat hun verwachtingen met betrekking tot de verbetering op het gebied van activiteiten en sport veelal waren uitgekomen.

Studies die de uitkomsten van secundaire schouder chirurgie bij kinderen met OPBL op de lange termijn beschrijven combineren meestal de data van de kinderen met en zonder primaire (neuro) chirurgie in de voorgeschiedenis. **Hoofdstuk 3** beschrijft de functionele uitkomsten over de loop van de tijd apart voor kinderen met en zonder primaire (neuro) chirurgie in de voorgeschiedenis. Er werd een retrospectieve studie uitgevoerd waarbij er gebruik gemaakt werd van data verzameld volgens een gestandaardiseerd klinisch protocol. Data van in totaal 115 kinderen, waarvan er 82 primaire (neuro) chirurgie hadden ondergaan en 33 niet, werden geanalyseerd. De gemiddelde follow-up duur voor al deze kinderen was 6 jaar (standaarddeviatie 3.3 jaar). Er werd in deze studie gekeken naar de actieve en passieve bewegingsmogelijkheden van de aangedane arm en er werd gekeken naar de Mallet scores van deze kinderen vóór de operatie en 1, 3, 5 en 10 jaar na de operatie. In de totale groep namen de actieve en passieve exorotatie, de (glenohumerale) abductie en de anteflexie, alsmede bijna alle Mallet score items over de tijd significant toe. In de loop der tijd namen de positieve effecten van de chirurgische ingreep wat af, maar de verschillen ten opzichte van voor de operatie bleven statistisch significant. Daarnaast werd er gevonden dat de mogelijkheden om de arm naar achteren te bewegen (retroflexie) en om de hand op de rug te leggen, zoals gemeten met de Mallet score, significant afnamen wat aansluit bij de bevindingen in hoofdstuk 2.
Kinderen die geen primaire (neuro) chirurgie hebben ondergaan, hadden een betere schouderfunctie vóór de ingreep dan de kinderen die wel primaire (neuro) chirurgie hebben ondergaan. De primair conservatief behandelde kinderen hadden ook op alle follow-up momenten een betere schouderfunctie ná de secundaire chirurgische ingreep. Alleen actieve en passieve exorotatie, zowel in 0° als in 90° abductie, waren enigszins beter op alle follow-up momenten voor de kinderen die primaire (neuro) chirurgie hadden ondergaan.
Deze uitkomsten laten zien dat de beschreven groepen bestaan uit kinderen met twee verschillende fenotypen (wat betreft de ernst van het letsel van de plexus brachialis). De uitkomsten van chirurgische ingrepen bij deze kinderen zouden voor de beide groepen apart beschreven moeten worden. Hierdoor kan er voorkomen worden dat er een onder- of overschatting van de resultaten van de orthopedisch chirurgische ingreep gegeven wordt. Tevens kan er hierdoor betere, op maat gesneden informatie aan de patiënt en zijn of haar ouders gegeven worden zodat zij een beter beeld hebben van de te verwachten uitkomsten van de ingreep waardoor de kwaliteit van het beslissingsproces gewaarborgd kan worden.

Door patiënt en/of ouders gerapporteerde uitkomsten (Patient Reported Outcome Measures: PROMs) worden steeds belangrijker bij het evalueren van behandelingen. De meeste uitkomstmaten zijn echter alleen voorhanden in het Engels waardoor ze niet bruikbaar zijn in Nederlandse studies. Het is daarom nodig om goede uitkomstmaten, die

niet voorhanden zijn in het Nederlands, te vertalen en aan te passen aan de Nederlandse situatie. De 'Pediatric Outcome Data Collecting Instrument' (PODCI) is een PROM gericht op patiënten met een musculoskeletale aandoening, die gevalideerd is voor gebruik in de OPBL-populatie. Tot voor kort was deze vragenlijst niet beschikbaar in het Nederlands. Van de PODCI is er een 2-10 jaar en 10-18 jaar ouderversie en een 10-18 jaar jongerenversie beschikbaar. De vragenlijsten bestaan uit 83-86 vragen (afhankelijk van de versie) en er kunnen 5 sub schalen en een totale score berekend worden. In **Hoofdstuk 4** wordt het proces van vertaling en adaptatie van de PODCI naar de Nederlandse taal en situatie volgens internationale richtlijnen voor het vertalen van vragenlijsten beschreven.[2-4] Verder wordt de validatie van het gebruik van de 2-10 jaar Nederlandse ouderversie bij kinderen met OPBL weergegeven. Met de uiteindelijke 2-10 jaar Nederlandse ouderversie is een veldtest uitgevoerd onder 10 kinderen met OPBL tussen de 3 en 10 jaar oud. Voor de validatie is deze vragenlijst vervolgens gebruikt bij 10 kinderen die een secundaire chirurgische ingreep aan de schouder ondergingen, en werd deze ingevuld door ouders vóór de operatie en 12 maanden na de operatie. Om de test-hertest betrouwbaarheid vast te stellen is de PODCI daarna nog 2 maal ingevuld door ouders, met een tussenpose van 2 weken. De conclusie van deze studie was dat de Nederlandse PODCI een bruikbaar en betrouwbaar instrument is om de kwaliteit van leven en het functioneren van kinderen met OPBL te meten. De interne consistentie van de vragenlijst, de responsiviteit om verandering te meten, de construct validiteit en de test-hertest betrouwbaarheid werden over het algemeen goed bevonden.

Omdat er maar weinig vragenlijsten beschikbaar zijn die het gebruik van de aangedane hand meten bij kinderen met een unilaterale parese, is recent de 'Hand Use at Home' (HUH) vragenlijst ontwikkeld en getest voor kinderen met OPBL of met een unilaterale cerebrale parese (UCP). Dit nieuwe instrument meet het spontane gebruik van de aangedane hand in de thuissituatie en is bruikbaar bij kinderen met een unilaterale parese. Middels Rasch analyse is aangetoond dat de HUH een valide instrument is met goede psychometrische eigenschappen op het gebied van construct validiteit, interne consistentie en onderscheidende capaciteiten.[5] In **Hoofdstuk 5** wordt aanvullend bewijs met betrekking tot de goede construct validiteit en test-hertest betrouwbaarheid van de HUH bij kinderen met OPBL of UCP beschreven. Om de construct validiteit te bepalen werden 191 kinderen met OPBL en 79 kinderen met UCP geselecteerd. De ouders van deze kinderen hebben de HUH eenmalig ingevuld en daarnaast hebben de ouders van de kinderen met OPBL de PODCI ingevuld en hebben de ouders van de kinderen met UCP de 'Children's Hand use Experience Questionnaire' (CHEQ) ingevuld. Om de test-hertest betrouwbaarheid te bepalen, hebben de ouders van 56 kinderen (16 kinderen met OPBL en 40 met UCP) de HUH nog een tweede maal ingevuld binnen 2-4 weken nadat ze de eerste HUH hadden ingevuld. De resultaten van deze studie laten zien dat de HUH een valide en betrouwbaar instrument is om te gebruiken bij kinderen met OPBL of UCP tussen de 3 en 10 jaar. Er werd een significante relatie gevonden met de uitgebreidheid van het plexusletsel, wat duidelijk maakte dat uitgebreider letsel verminderd spontaan handgebruik geeft. Er werd een relatief zwakke relatie gevonden met de behandelgeschiedenis van kinderen met OPBL (conservatief

of chirurgisch behandeld). Voor kinderen met UCP werd een zwakke relatie gevonden met de 'Manual Ability Classification System' (MACS), wat aangeeft dat het hebben van een relatief goede mogelijkheid tot het gebruik van de aangedane arm/hand niet altijd automatisch leidt tot het meer spontaan gebruiken van deze arm/hand.
De test-hertest betrouwbaarheid van de HUH werd zeer goed bevonden, gebaseerd op de goede 'Intra Class Correlation coefficient' (ICC) en de goede overeenstemming tussen de eerste en tweede HUH score (Bland-Altman[6]). Op basis van deze resultaten kan geconcludeerd worden dat de HUH goed gebruikt kan worden door ouders van kinderen met een unilaterale parese, in de leeftijd van 3-10 jaar, om het spontane gebruik van de aangedane hand in het dagelijkse leven in kaart te brengen. De uitkomsten van de HUH kunnen gebruikt worden door clinici en onderzoekers om meer inzicht te krijgen in het gebruik van de aangedane arm/hand in het dagelijks leven. Vervolgonderzoek naar de mogelijkheden van de HUH om veranderingen over de tijd te meten moet nog worden uitgevoerd om de resterende psychometrische eigenschappen van de HUH vast te stellen.

Onderzoek naar de consequenties van OPBL heeft zich tot dusver, zoals reeds eerder vermeld, voornamelijk gericht op het ICF-component; 'functies en anatomische eigenschappen'. Dit is zeker het geval in onderzoek bij jonge kinderen met OPBL. Om meer te weten te komen over de mogelijkheden op het gebied van activiteiten en participatie van kinderen en volwassenen met OPBL en om te onderzoeken wat de kwaliteit van leven, de eventuele impact op de familie, en wat het zorggebruik en de informatiebehoefte is in deze patiëntenpopulatie, is de zogenaamde ZAP-Plexus (Zorg, Activiteiten en Participatie) studie gestart in 2014. Alle patiënten die ooit in het Zenuwcentrum, een specialistische OPBL-poli in het Leids Universitair Medisch Centrum, zijn gezien werden uitgenodigd om deel te nemen aan deze cross-sectionele studie waarbij gebruik werd gemaakt van elektronische vragenlijsten. In totaal zijn er 1142 patiënten uitgenodigd van wie er uiteindelijk 508 hebben deelgenomen aan de studie. Negenvijftig van deze patiënten (12%) waren tussen de 0 en 1 jaar oud, 226 (45%) tussen de 2 en 9 jaar oud, 180 (35%) tussen de 10 en 18 jaar en 43 (8%) tussen de 19 en 61 jaar oud. De volgende 3 hoofdstukken beschrijven de analyse van een gedeelte van de verzamelde data binnen de ZAP-studie.

In **Hoofdstuk 6** wordt de door ouders ervaren impact van het hebben van een kind met OPBL op de familie, de kwaliteit van leven van het kind en de armfunctie van 59 kinderen (6-30 maanden oud) beschreven. De ouders van deze 59 kinderen hebben de 'PedsQL™ Family Impact Measure (FIM)' en de 'TNO-AZL (Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek en Academisch Ziekenhuis Leiden) Preschool children's QoL (TAPQOL)' kwaliteit van leven vragenlijst ingevuld. Daarnaast hebben zij ook een aantal vragen met betrekking tot het functioneren van de aangedane arm/hand van hun kind beantwoord.
Deze studie toonde aan dat lagere FIM-scores (dat wil zeggen grotere impact) geassocieerd waren met lagere leeftijd, uitgebreider letsel, aangedane zijde (rechts), eerder ondergane neurochirurgische behandeling en of het kind nog in behandeling is bij het zenuwcentrum.

De ouders van de kinderen met OPBL beoordeelden de kwaliteit van leven van hun kind op 8 van de 12 TAPQOL schalen (66%) vergelijkbaar met hoe ouders van gezonde kinderen de kwaliteit van leven van hun kind beoordelen. Ouders die meer problemen in het functioneren van de arm van hun kind rapporteerden, hadden kinderen met een ernstiger letsel en deze ouders maakten zich meer zorgen dan ouders waarvan het kind een minder ernstig letsel had.
De bevindingen in deze studie bevestigen dat ouders tot op zekere hoogte impact op hun familie ervaren wanneer zij een kind met OPBL hebben. Tot op heden is er niet eerder een studie gepubliceerd die rapporteerde dat wanneer hele jonge kinderen met OPBL een rechtszijdig letsel hebben en wanneer er meer problemen zijn met het functioneren van de arm, dit meer impact heeft op de familie. Het is van belang dat zorgverleners die werken met kinderen met OPBL en hun ouders deze bevindingen ter harte nemen zodat zij ouders goed kunnen begeleiden. Op deze manier zou de impact op de familie mogelijk beperkt kunnen worden.

De resultaten met betrekking tot het zorggebruik en de informatiebehoefte van kinderen met OPBL (en hun ouders) tussen de 0 en 18 jaar worden besproken in **Hoofdstuk 7**. Voor deze studie zijn de data geanalyseerd van 465 deelnemende patiënten die vragenlijsten met betrekking tot zorggebruik sinds de geboorte en in de afgelopen 12 maanden hebben ingevuld. In deze vragenlijsten werd gevraagd of men contact had gehad met het plexusteam en/of met 11 andere zorgverleners. Tevens werd er gevraagd of men behoefte had aan informatie aangaande 12 OPBL gerelateerde onderwerpen. Uit de medische status van de patiënten werd informatie gehaald met betrekking tot patiënt en OPBL-karakteristieken en of men wel of niet ontslagen was uit follow-up (vroeg/laat/niet ontslagen).
Negenenvijftig deelnemende patiënten (12%) waren tussen de 0 en 1 jaar oud, 226 (45%) tussen de 2 en 9 jaar oud en 180 (35%) tussen de 10 en 18 jaar. Van deze patiënten waren er inmiddels 193 ontslagen uit follow-up (42%) waarvan er 83 werden gecategoriseerd als zijnde vroeg ontslagen. Vroeg ontslagen houdt in dat deze patiënten uit zorg ontslagen werden voordat zij 1 jaar oud waren omdat ze goed spontaan herstel lieten zien.
Deze studie toonde aan dat het zorggebruik van kinderen met OPBL in Nederland aanzienlijk is vanaf het moment dat de diagnose gesteld is. Ouders rapporteerden dat ze, naast het contact met het plexusteam, met tenminste 1 en met maximaal 11 (afhankelijk van de ernst van het letsel) zorgverleners contact hebben gehad wegens het OPBL van hun kind, sinds de geboorte. Over de tijd nam dit zorggebruik weer af, waarbij 288 ouders rapporteerden de afgelopen 12 maanden contact te hebben gehad met tenminste 1 en met maximaal 7 zorgverleners naast het eventuele contact met het plexusteam. Het zorggebruik in de afgelopen 12 maanden was significant geassocieerd met het nog in behandeling zijn bij het plexusteam, met ernstiger letsel, chirurgische behandelingen, verminderde kwaliteit van leven en verminderd fysiek functioneren.
Een relatief groot gedeelte van de patiënten die ontslagen waren uit follow-up (81/193, 42%) had nog steeds contact met zorgverleners vanwege hun OPBL. Onder hen waren 34 patiënten waarvan gedacht werd dat volledig spontaan herstel was opgetreden, waardoor

ze ontslagen werden uit follow-up voordat ze 1 jaar oud waren. Dit betekent dat deze patiënten, tegen alle verwachtingen in, toch nog functionele beperkingen kunnen ervaren. Met betrekking tot de informatiebehoefte rapporteerde een relatief grote groep patiënten (49%) dat zij behoefte hadden aan meer informatie over verschillende aspecten van OPBL (onder andere over behandeling, sport en fysiek functioneren en hulpmiddelen). Onder hen waren 65 ontslagen patiënten, van wie er 23 ontslagen waren voor het eerste levensjaar. Deze bevindingen maken duidelijk dat een aanzienlijke hoeveelheid patiënten beperkingen ervaart en informatiebehoefte heeft nadat ze ontslagen zijn door het plexusteam. Daarom is een strikter protocol voor langere follow-up en informatievoorziening nodig.

In **Hoofdstuk 8** worden beperkingen in participatie beschreven, zoals deze ervaren worden door adolescente en volwassen patiënten met OPBL. Aan deze studie deden 75 adolescente en volwassen patiënten tussen de 16 en 61 jaar oud mee. Van hen waren 33 tussen de 16 en 18 jaar oud, 22 tussen de 19 en 25 jaar, 11 tussen de 26 en 35 en 9 tussen de 36 en 61 jaar oud.
De deelnemende patiënten vulden vragen in met betrekking tot de invloed van OPBL op hun studie en werkkeuze, en met betrekking tot de invloed op het uitvoeren van hun werk. Verder werden de 'Impact on Participation and Autonomy' (IPA, 5 domeinen) en de 'Utrecht Scale for Evaluation of Rehabilitation-Participation' (USER-P; 3 domeinen) ingevuld. Om de gezondheid gerelateerde kwaliteit van leven in kaart te brengen werd de 'Short Form 36' (SF-36) en de 'Disability of the Arm, Shoulder and Hand' (DASH) vragenlijsten ingevuld. In aanvulling op de verkregen data werd uit de status van de deelnemende patiënten de patiënt en OPBL-karakteristieken gehaald.
Van de 75 deelnemende patiënten waren 20 voltijd student (27%), 28 student met een bijbaantje (37%), 21 werkten (28%), 2 waren werkloos (3%) en 4 arbeidsongeschikt vanwege hun plexus letsel (5%). Over het algemeen was de gezondheid gerelateerde kwaliteit van leven van de patiënten goed. Een groot gedeelte van de deelnemende adolescenten en volwassenen (54/75, 72%) gaf aan dat zij enige vorm van beperking in participatie ervaarden, voornamelijk op het gebied van werk en studiekeuze. 27 van de 75 patiënten geven aan dat OPBL invloed heeft gehad op de keuzes die zij gemaakt hebben op het gebied van studie en 26 van de 75 gaven aan dat het geval was voor keuze van werk. 33 van de 66 patiënten die ooit gewerkt heeft gaf aan dat OPBL ook invloed heeft gehad op het uitvoeren van hun werk. Op de IPA geeft 80% (49/61) restricties in het 'werk en opleiding' domein aan, 74% in het 'sociale relaties' domein en 67% in het 'autonomie buitenshuis' domein. 37 van de 61 patiënten geeft participatie restricties aan op de USER-P en geeft aan enigszins verminderd tevreden te zijn met de participatiemogelijkheden die zij hebben.
Participatiebeperkingen waren geassocieerd met een verminderde mogelijkheid van het gebruiken van de arm (DASH-score), verminderde kwaliteit van leven en meer pijn (SF-36-scores), maar niet met de uitgebreidheid van het letsel, de behandelingen in het verleden of de zijde van het letsel (links of rechts). Dit zou kunnen inhouden dat alle patiënten met OPBL, ongeacht de ernst van het initiële letsel, op latere leeftijd participatierestricties kunnen ervaren.

Deze bevindingen zijn relatief nieuw en geven aan dat het nodig is om de zorg te optimaliseren. Het is hierbij belangrijk dat patiënten in een vroeg stadium ondersteund worden bij het maken van keuzes op het gebied van studie en werk en dat zij op maat gemaakte fysieke en psychosociale zorg ontvangen om beperkingen te minimaliseren wat participatie ten goede kan komen.

ALGEMENE DISCUSSIE

Obstetrisch plexus brachialis letsel (OPBL) is een geboorte letsel van de plexus brachialis, die kan resulteren in diverse functionele problemen. Ongeveer 35% van de patiënten blijft in meer of mindere mate beperkingen houden op het gebied van dagelijkse activiteiten en participatie.[7,8] Veel onderzoek naar OPBL is gericht op functie- en structuurniveau van het ICF.[9-21] Het is echter belangrijk ook te focussen op het activiteiten- en participatieniveau en daarom richt dit proefschrift zich op alle aspecten van de ICF en wordt de impact van OPBL in brede zin en door het leven heen beschreven. Een deel van de uitkomsten beschreven in dit proefschrift komt voort uit de 'Zorg, Activiteiten en Participatie bij patiënten met OPBL' studie (ZAP-Plexus studie).

FUNCTIONELE UITKOMSTEN VAN SECUNDAIRE SCHOUDER CHIRURGIE

Dit proefschrift toont aan dat secundaire schouderchirurgie effectief is bij kinderen met OPBL en de uitkomsten sluiten daarbij aan bij de huidige literatuur.[9-21] In dit proefschrift wordt echter duidelijk dat de ingreep ook een positief effect heeft op activiteiten- en participatieniveau en dat ouders over het algemeen heel tevreden zijn over de resultaten van de ingreep. Voor patiënten die in het verleden een neurochirurgische ingreep hebben ondergaan zijn de uitkomsten van de chirurgie wel anders dan voor patiënten die deze ingreep niet hebben ondergaan omdat deze patiënten een andere uitgangssituatie hebben wat invloed heeft op de uitkomsten. Concluderend is het van belang om uitkomsten van secundaire schouderchirurgie niet alleen te beschrijven op het gebied van functie en structuur maar ook op het gebied van activiteiten en participatie, en dit voor beide subgroepen patiënten apart te doen.

UITKOMSTMATEN VOOR OPBL

Er zijn vele uitkomstmaten beschikbaar voor OPBL en de voor dit proefschrift volgens internationale richtlijnen[2-4] vertaalde PODCI (Pediatric Outcome Data Collecting Instrument) blijkt een goede aanvulling voor de bestaande Nederlandse uitkomstmaten voor OPBL. De PODCI meet onder andere de armfunctie van kinderen, er wordt daarbij echter niet gekeken naar spontaan gebruik in de thuissituatie. Ondanks dat er uitkomstmaten bestaan die

armgebruik meten, zoals de ABILHAND-kids[22] en de Children's Hand Experience Questionnaire (CHEQ)[23,24], was er geen instrument voorhanden die het door ouders gerapporteerde spontane gebruik in de thuissituatie kon meten. In samenwerking met de Sint Maartenskliniek in Nijmegen is daarom de HUH (Hand Use at Home) vragenlijst ontwikkeld die dit wel meet.[5] Om de waarde van zowel de PODCI als de HUH binnen de OPBL populatie verder te bepalen zijn extra studies nodig die ook kijken naar de mogelijkheden van deze instrumenten om verandering over de tijd te meten in grote groepen patiënten.

Generieke kwaliteit van leven vragenlijsten

Het belang van het meten van de door de patiënt of ouders gerapporteerde kwaliteit van leven (KvL) van patiënten met OPBL wordt onderschreven in de literatuur.[25] Er wordt onder andere aangegeven dat generieke vragenlijsten hiervoor wellicht geschikt zouden zijn. In dit proefschrift wordt de generieke TAPQOL (TNO-AZL; Nederlandse organisatie voor toegepast natuurwetenschappelijk onderzoek en het academisch ziekenhuis Leiden, preschool childrens quality of life[26]) vragenlijst gebruikt en het blijkt dat deze vragenlijst in de plexuspopulatie geen problemen op het gebied van kwaliteit van leven laat zien. De vraag rijst dan ook of generieke vragenlijsten wel in staat zijn om verminderde kwaliteit van leven op te pikken in deze populatie. Vervolgonderzoek moet uitwijzen wat de rol voor generieke KvL vragenlijsten is in OPBL-onderzoek. Binnen dit onderzoek zouden ook andere lijsten, zoals de PedsQL™ KvL vragenlijsten[27,28], gebruikt kunnen worden omdat deze ook reeds eerder in ander revalidatie onderzoek zijn gebruikt.[29-31] Uitkomsten van kinderen met OPBL zouden dan vergeleken kunnen worden met uitkomsten van andere patiëntengroepen.

Impact op de familie

In dit proefschrift werd met de PedsQL™ Family Impact Module (FIM)[32] aangetoond dat ouders tot op zekere hoogte impact op hun gezin ervaren wanneer zij een kind met OPBL hebben. De mate van impact bleek afhankelijk te zijn van verschillende factoren zoals rechtszijdig letsel, ernst van het letsel en jongere leeftijd. In de dagelijkse praktijk zou er meer aandacht moeten zijn voor impact op de familie. De FIM zou hierbij een goede aanvulling zijn op de reeds gebruikte batterij meetinstrumenten binnen de zorg vanuit de plexusteams.

Lange termijn consequenties van OPBL

Plexus brachialis letsel heeft niet alleen consequenties op de kinderleeftijd maar ook volwassenen rapporteren problemen zoals blijkt in dit proefschrift. De ervaren problemen die gerapporteerd worden, liggen met name op het gebied van werk en studie. Zowel de uitvoering als de keuze op deze gebieden blijkt beïnvloed te worden door OPBL. Factoren die hierbij een rol spelen zijn de mate van ervaren pijn en functionele beperkingen op het gebied van armfunctie[33-35]. Ondanks dat deze problemen gerapporteerd worden zijn er maar weinig volwassen patiënten onder controle bij het plexus team en/of onder behandeling in revalidatiecentra.[34,36] De resultaten geven aan dat meer onderzoek naar de consequenties van OPBL op de volwassen leeftijd gewenst is, en in aanvulling op interventies, uitgevoerd op

de kinderleeftijd, wellicht ook op latere leeftijd voor sommige patiënten extra begeleiding nodig is om het functioneren op de langere termijn te verbeteren.

ICF core set

Om de impact van OPBL goed te kunnen bepalen is het belangrijk om een universeel raamwerk voor een set van uitkomstmaten te hebben. Binnen het LUMC is er een voorstel, bestaande uit vier stappen, gedaan om zo'n raamwerk volgens het ICF model op te zetten.[37] Een aantal stappen, zoals het uitvoeren van een systematische review voor het identificeren van geschikte uitkomstmaten[25] en een kwalitatieve studie naar wat patiënten met OPBL belangrijk vinden in hun functioneren[38], zijn reeds uitgevoerd. De ZAP-Plexus cross-sectionele studie is een vervolgstap op de hiervoor genoemde stappen en de uitkomsten van dit onderzoek zijn gedeeltelijk in dit proefschrift beschreven. Uit onderzoek blijkt dat er geen consensus bestaat hoe uitkomsten bij OPBL precies gemeten moeten worden en welke meetinstrumenten hiervoor gebruikt zouden moeten worden.[25,39-41] Om internationaal tot consensus te komen over wat er belangrijk is om te meten en met welke meetinstrumenten dit moet gebeuren, is het iPLUTO (international PLexus oUtcome sTudy group) initiatief in het leven geroepen door het Leidse zenuwcentrum. Middels dit initiatief is een van de resterende stappen ondernomen waarbij door middel van het uitzetten van een enquête onder OPBL-experts getracht wordt voorgenoemde consensus te bereiken in het kader van het te ontwikkelen raamwerk.

GEZONDHEIDSZORG BIJ OBSTETRISCH PLEXUS BRACHIALIS LETSEL

Vroege verwijzing

Het is van belang kinderen met een ernstig OPBL vroeg door te verwijzen naar een OPBL-expert centrum. Dit geldt ook voor kinderen waarbij over de ernst van het letsel getwijfeld wordt. Dit proefschrift laat namelijk zien dat ook kinderen waarvan gedacht wordt dat ze spontaan hersteld zijn, toch op latere leeftijd problemen rapporteren. Op jaarbasis worden er naar schatting ongeveer 200-350 kinderen met OPBL geboren (incidentie 1-2/1000[42], geboortecijfers 170000-180000/jaar: CBS, statline.cbs.nl 2012-2015) maar de exacte incidentie is niet bekend. Het is ook niet bekend hoeveel van deze kinderen er gezien worden in de 3 expert centra die er in Nederland zijn. Een nationale en internationale samenwerking (onder de vlag van iPLUTO) om inzichtelijk te krijgen wat de incidentie is, hoeveel nieuwe kinderen er jaarlijks gezien worden en wat de uitkomsten van alle kinderen met OPBL (conservatief en chirurgisch behandeld) zijn, is van belang om beter inzicht te krijgen in de populatie en de verschillende behandelstrategieën.

Vroeg en laat ontslag uit OPBL-expert centra

Zoals reeds aangegeven wordt in dit proefschrift bewijs geleverd dat sommige kinderen die ontslagen zijn uit follow-up van het multidisciplinaire plexusteam toch nog problemen ervaren en elders nog actieve therapie voor hun OPBL krijgen. Het is daarom de vraag of

de criteria voor ontslag adequaat zijn. Een lange termijn prospectieve studie zou een antwoord op deze vraag kunnen geven.

Zorggebruik en de rol van de fysiotherapie

Zorggebruik door kinderen met OPBL is afhankelijk van het letsel, het functioneel herstel en de behandelstrategie. Uit ons onderzoek blijkt dat de meest gebruikte zorgverlener voor OPBL, de (kinder)fysiotherapeut is. Onder volwassen patiënten blijkt ook 20% contact te hebben met de fysiotherapeut. Er is echter op het gebied van de effectiviteit van fysiotherapie bij OPBL bijna geen literatuur voorhanden. Er zijn wel aanbevelingen voor de inhoud van het fysiotherapie programma en zo wordt het monitoren van de motoriek, de gewrichtsmobiliteit en de spierkracht aangeraden. Binnen de vroege interventie wordt ook het geven van instructies aan ouders op het gebied van houding en hantering, verzorgen en oefenen aangeraden. Er wordt over het algemeen aangeraden om fysiotherapie binnen 1-3 weken na de geboorte te starten, maar het kan al gestart worden zodra het kind geboren is.[36,43,44] In het LUMC wordt de fysiotherapie gestart direct na de geboorte en wordt er gewerkt volgens een vast protocol van passieve oefeningen (persoonlijke communicatie S.M. Buitenhuis / J.C. van Egmond-van Dam).

Het onderhouden van de passieve mobiliteit wordt sterk aangeraden in de literatuur om contracturen te voorkomen.[36,44-49] Het combineren van deze passieve oefeningen met actieve oefentherapie zou contracturen, spierdysbalans en gewrichtsvervorming in opgroeiende kinderen tegen kunnen gaan.[43,46,47] Er is echter tot op heden nog geen overtuigende evidentie voor deze oefenvormen.

Voor de fysiotherapie is het verder van belang de ontwikkeling van de motoriek te monitoren en te stimuleren.[43,44,47] Kinderen met OPBL gebruiken soms hun aangedane arm minder vaak dan de niet aangedane arm en kunnen daarom bij rechtszijdig letsel, linkshandig worden.[50,51] Het komt ook voor dat ze vergeten de aangedane arm te gebruiken doordat ze erg goed zijn in compenseren.[43,52] Deze fenomenen moeten herkend en behandeld worden door (kinder)fysiotherapeuten en/of ergotherapeuten.

Het inzetten van het geforceerd laten gebruiken van de aangedane arm tijdens therapie (CiMT: constraint induced movement therapy), en eventueel tweehandig trainen (BIT: bimanual intensive training), wordt in de literatuur ook voorgesteld om functie te verbeteren.[43,46,47,53,54] In de dagelijkse praktijk zien wij echter kinderen met klachten van overbelasting, mogelijk als gevolg van deze vormen van therapie. De toegevoegde waarde van deze therapieën zou verder onderzocht moeten worden.

Naast (kinder)fysiotherapie zijn het uitvoeren van huiswerk oefenprogramma's minstens zo belangrijk.[44,46-48,55,56] In de praktijk lijkt het erop dat kinderen van ouders die zich goed houden aan deze programma's beter presteren, echter dit is lastig aan te tonen. Het is in elk geval van belang om de oefenprogramma's aan te bieden en ervoor zorg te dragen dat deze ook uitgevoerd blijven worden.[48,56] Allerhande middelen, zoals multimedia en gaming, zouden voor dit doeleinde kunnen worden ingezet en onderzocht.

INFORMATIEBEHOEFTE EN INFORMATIEVOORZIENING

Aangezien dit proefschrift laat zien dat de informatiebehoefte in de ZAP Plexus onderzoekspopulatie groot is, en er aangegeven wordt dat er af en toe tegenstrijdige informatie gegeven is, is het van belang de informatievoorziening te optimaliseren en uniformeren. Tevens is het hierbij van belang dat er kennisuitwisseling plaats vindt tussen de verschillende zorgverleners. Hiervoor wordt aangeraden om een modulaire informatiefilm te maken welke informatie geeft die toegespitst is op de individuele patiënt en zijn/haar huidige levensfase (e.g. als het naar school gaat, als het een sport gaat kiezen, als er studie of werkkeuzes gemaakt moeten worden).

IMPLICATIES EN RICHTING VOOR ZORG EN TOEKOMSTIG ONDERZOEK

De belangrijkste bevindingen van dit proefschrift zijn onder andere de aangeven beperkingen in activiteiten en participatie, het bijkomende zorggebruik, alsmede de informatiebehoefte, die zelfs door OPBL-patiënten die reeds ontslagen zijn uit follow-up worden aangegeven. Verder werd er gevonden dat er mogelijk te weinig aandacht is voor de impact die OPBL op het gezin kan hebben.
De meeste experts zijn het eens over het feit dat de hierboven genoemde aspecten meer aandacht verdienen en beter onderzocht moeten worden. Er is echter nog geen consensus over hoe dit op de lange termijn vorm gegeven moet worden. Daarom kunnen de volgende aanbevelingen gedaan worden om de patiëntenzorg te verbeteren:

- Impact op de familie
  - Vanaf de geboorte zou er meer aandacht besteed moeten worden aan impact van OPBL op de familie. Indien nodig kan dan in een vroeg stadium hulp geboden worden.
  - Psychosociale hulpverlening (i.e. psychologie, maatschappelijk werk) zouden standaard deel uit moeten maken van het OPBL-expert team.
- Routine follow-up
  - Er zou een strikter follow-up protocol gedurende het leven van de patiënt gehanteerd moeten worden, waarbij alle componenten van de ICF gemonitord worden.
  - De HUH moet standaard afgenomen worden binnen het Leidse Zenuwcentrum en in andere OPBL-centra in de wereld.
  - OPBL-expert teams zouden proactief patiënten/ouders moeten benaderen om te verifiëren of er wel of geen problemen bestaan op de componenten van de ICF.
- Informatiebehoefte
  - Informatievoorziening dient geoptimaliseerd te worden en aangepast aan de individuele patiënt om zo aan de behoefte van patiënten/ouders te voldoen.
- (Kinder)fysiotherapie
  - Er dient een fysiotherapie consensus behandel/zorgprotocol opgesteld te worden voor de verschillende leeftijds- en ontwikkelingsfases gedurende het leven. Dit protocol dient te voorzien in aanbevelingen op het gebied van oefenvormen, oefenduur, oefenfrequentie, oefenweerstand, huiswerkprogramma's, ondersteuning van ouders en leerkrachten, etc. en dient systematisch geëvalueerd te worden.

Alle hiervoor beschreven aanbevelingen moeten besproken en ontwikkeld worden in nauwe samenwerking tussen behandelaars, ouders en de patiëntenorganisatie.

De volgende richtingen voor toekomstig onderzoek kunnen overwogen worden:

- Nieuw onderzoek
  - Een follow-up studie naar de impact op de familie direct na de geboorte en 1, 3, 6 en 12 maanden na de geboorte en ieder opvolgend jaar zou meer informatie kunnen geven over het beloop in de tijd van de impact op de familie.
  - Een follow-up studie naar participatie, in het bijzonder op het gebied van werk gerelateerde problemen en behoeftes, zou uitgevoerd moeten worden onder alle adolescente en volwassen patiënten met OPBL.
  - Een studie waarbij verschillende fysiotherapeutische behandelprotocollen (typen oefeningen en hun duur, frequentie en intensiteit) vergeleken worden, moet worden uitgevoerd om te bepalen wat het beste behandelprotocol is.
  - Draagbare accelerometers of andere vormen van bewegingsmonitoring, die tenminste een week gedragen worden, zouden gebruikt moeten worden om op een meer objectieve manier dagelijkse activiteiten te evalueren. Dergelijke metingen kunnen thuis uitgevoerd worden voordat het bezoek aan de polikliniek plaats vindt of indien er achteruitgang van functie is.
- Toekomstig onderzoek gebaseerd op de ZAP-Plexus studie
  - Een cross-sectionele studie, mogelijk met opvolgend een follow-up studie, gericht op fysiek functioneren en sportparticipatie bij kinderen zou uitgevoerd moeten worden om betere informatie op deze gebieden te kunnen geven aan patiënten.
  - De resterende data van de ZAP-plexus studie moet geanalyseerd worden om nog verder inzicht te krijgen in de impact van OPBL (i.e. sensibiliteit en sensitisatie, armfunctie in de gehele populatie en zorggebruik en informatiebehoefte van volwassen patiënten). Tevens kan er daarbij bekeken worden welke meetinstrumenten in staat zijn om problemen in de OPBL-patiëntenpopulatie te registreren.
  - De toegevoegde waarde van het gebruik van de PODCI en de HUH in de OPBL-patiëntenpopulatie, inclusief de sensitiviteit om veranderingen over de tijd te meten, dient verder bepaald te worden
  - Een follow-up van de huidige ZAP-plexus studie waarmee inzicht verkregen kan worden in het beloop van OPBL over de tijd in het nu goed gedefinieerde en beschreven cohort, dient uitgevoerd te worden.

Al deze inspanningen zijn nodig om een beter inzicht te krijgen in de gezondheidsstatus en gezondheidszorgbehoeftes van alle patiënten met OPBL wat tot verbeterde zorg kan leiden voor deze levenslange aandoening. Middels verbeterde zorg, die zich richt op betere participatie in de maatschappij, waarbij de patiënt ondersteund wordt bij het zich aanpassen aan iedere nieuwe fase van het leven indien nodig, kan de impact van OPBL door het leven heen gereduceerd worden, hetgeen tot een betere kwaliteit van leven van patiënten en hun ouders en naasten leidt.

REFERENTIES

1. WHO. ICF Domains. 2015; http://www.who.int/classifications/icf/en/.
2. Beaton D.E., Bombardier C., Guillemin F., Ferraz M.B. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976.).* 2000;25(24):3186-3191.
3. Guillemin F., Bombardier C., Beaton D. Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. *J.Clin.Epidemiol.* 1993;46(12):1417-1432.
4. Maher C.G., Latimer J., Costa L.O.P. The relevance of cross-cultural adaptation and clinimetrics for physical therapy instruments. *Rev Bras Fisioter.* 2007;11(4):245-252.
5. Yvonne Geerdink Pauline Aarts, Menno van der Holst, Robert Lindeboom, Jan van der Burg, Bert Steenbergen, Alexander C. Geurts. Development and psychometric properties of the Hand-Use-at-Home questionnaire to assess amount of affected hand use in children with unilateral paresis. Submitted september 2016.
6. Giavarina D. Understanding Bland Altman analysis. *Biochem Med (Zagreb).* 2015;25(2):141-151.
7. Foad S.L., Mehlman C.T., Foad M.B., Lippert W.C. Prognosis following neonatal brachial plexus palsy: an evidence-based review. *J.Child Orthop.* 2009;3(6):459-463.
8. Duff S. V., DeMatteo C. Clinical assessment of the infant and child following perinatal brachial plexus injury. *J Hand Ther.* 2015;28(2):126-133; quiz 134.
9. Phipps G.J., Hoffer M.M. Latissimus dorsi and teres major transfer to rotator cuff for Erb's palsy. *J.Shoulder.Elbow.Surg.* 1995;4(2):124-129.
10. Edwards T.B., Baghian S., Faust D.C., Willis R.B. Results of latissimus dorsi and teres major transfer to the rotator cuff in the treatment of Erb's palsy. *J.Pediatr.Orthop.* 2000;20(3):375-379.
11. Suenaga N., Minami A., Kaneda K. Long-term results of multiple muscle transfer to reconstruct shoulder function in patients with birth palsy: eleven-year follow-up. *J.Pediatr.Orthop.* 1999;19(5):669-671.
12. van der Sluijs J.A., van Ouwerkerk W.J., de Gast A., Nollet F., Winters H., Wuisman P.I. Treatment of internal rotation contracture of the shoulder in obstetric brachial plexus lesions by subscapular tendon lengthening and open reduction: early results and complications. *J.Pediatr.Orthop.B.* 2004;13(3):218-224.
13. Aydin A., Ozkan T., Onel D. Does preoperative abduction value affect functional outcome of combined muscle transfer and release procedures in obstetrical palsy patients with shoulder involvement? *BMC.Musculoskelet.Disord.* 2004;5:25.
14. Vallejo G.I., Toh S., Arai H., Arai K., Harata S. Results of the latissimus dorsi and teres major tendon transfer on to the rotator cuff for brachial plexus palsy at birth. *Scand.J.Plast.Reconstr.Surg.Hand Surg.* 2002;36(4):207-211.
15. Terzis J.K., Kokkalis Z.T. Outcomes of secondary shoulder reconstruction in obstetrical brachial plexus palsy. *Plast.Reconstr.Surg.* 2008;122(6):1812-1822.
16. Chen L., Gu Y.D., Hu S.N. Applying transfer of trapezius and/or latissimus dorsi with teres major for reconstruction of abduction and external rotation of the shoulder in obstetrical brachial plexus palsy. *J.Reconstr.Microsurg.* 2002;18(4):275-280.
17. Cohen G., Rampal V., Aubart-Cohen F., Seringe R., Wicart P. Brachial plexus birth palsy shoulder deformity treatment using subscapularis release combined to tendons transfer. *Orthop.Traumatol.Surg.Res.* 2010;96(4):334-339.
18. Abdel-Ghani H., Hamdy K.A., Basha N., Tarraf Y.N. Tendon transfer for treatment of internal rotation contracture of the shoulder in brachial plexus birth palsy. *J.Hand Surg.Eur.* 2012;37(8):781-786.
19. Ozben H., Atalar A.C., Bilsel K., Demirhan M. Transfer of latissmus dorsi and teres major tendons without subscapularis release for the treatment of obstetrical brachial plexus palsy sequela. *J.Shoulder.Elbow.Surg.* 2011;20(8):1265-1274.
20. Kambhampati S. B., Birch R., Cobiella C., Chen L. Posterior subluxation and dislocation of the shoulder in obstetric brachial plexus palsy. *J Bone Joint Surg Br.* 2006;88(2):213-219.
21. Louden E.J., Broering C.A., Mehlman C.T., Lippert W.C., Pratt J., King E.C. Meta-analysis of function after secondary shoulder surgery in neonatal brachial plexus palsy. *J.Pediatr.Orthop.* 2013;33(6):656-663.
22. Arnould C., Penta M., Renders A., Thonnard J.L. ABILHAND-Kids: a measure of manual ability in children with cerebral palsy. *Neurology.* 2004;63(6):1045-1052.
23. Amer A., Eliasson A. C., Peny-Dahlstrand M., Hermansson L. Validity and test-retest reliability of Children's Hand-use Experience Questionnaire in children with unilateral cerebral palsy. *Dev Med Child Neurol.* 2015.
24. Skold A., Hermansson L.N., Krumlinde-Sundholm L., Eliasson A.C. Development and evidence of validity for the Children's Hand-use Experience Questionnaire (CHEQ). *Dev.Med.Child Neurol.* 2011;53(5):436-442.
25. Sarac C., Duijnisveld B. J., Weide Av, et al. Outcome measures used in clinical studies on neonatal brachial plexus palsy: A systematic

literature review using the International Classification of Functioning, Disability and Health. *J Pediatr Rehabil Med.* 2015;8(3):167-186.
26. TNO. TAPQOL, TACQOL, TAAQOL. 2013; https://www.tno.nl/media/5004/vragenlijsten_01032012.pdf. Accessed 12/4/2013.
27. Varni J. W., Limbers C. A., Burwinkle T. M. Parent proxy-report of their children's health-related quality of life: an analysis of 13,878 parents' reliability and validity across age subgroups using the PedsQL 4.0 Generic Core Scales. *Health Qual Life Outcomes.* 2007;5:2.
28. Varni J. W., Limbers C. A., Burwinkle T. M. How young can children reliably and validly self-report their health-related quality of life?: an analysis of 8,591 children across age subgroups with the PedsQL 4.0 Generic Core Scales. *Health Qual Life Outcomes.* 2007;5:1.
29. Varni J. W., Burwinkle T. M., Berrin S. J., et al. The PedsQL in pediatric cerebral palsy: reliability, validity, and sensitivity of the Generic Core Scales and Cerebral Palsy Module. *Dev Med Child Neurol.* 2006;48(6):442-449.
30. Berrin S. J., Malcarne V. L., Varni J. W., et al. Pain, fatigue, and school functioning in children with cerebral palsy: a path-analytic model. *J Pediatr Psychol.* 2007;32(3):330-337.
31. Maher C. A., Toohey M., Ferguson M. Physical activity predicts quality of life and happiness in children and adolescents with cerebral palsy. *Disabil Rehabil.* 2016;38(9):865-869.
32. Varni J.W., Sherman S.A., Burwinkle T.M., Dickinson P.E., Dixon P. The PedsQL Family Impact Module: preliminary reliability and validity. *Health Qual.Life Outcomes.* 2004;2:55.
33. Partridge C., Edwards S. Obstetric brachial plexus palsy: increasing disability and exacerbation of symptoms with age. *Physiotherapy research international : the journal for researchers and clinicians in physical therapy.* 2004;9(4):157-163.
34. de Heer C., Beckerman H., Groot V. D. Explaining daily functioning in young adults with obstetric brachial plexus lesion. *Disabil Rehabil.* 2014:1-7.
35. Kirjavainen M. O., Remes V. M., Peltonen J., et al. Permanent brachial plexus birth palsy does not impair the development and function of the spine and lower limbs. *J Pediatr Orthop B.* 2009;18(6):283-288.
36. Wijlen-Hempel R, Buitenhuis S.M., Pondaag W., Malessy M. Obstetrisch plexus-brachialisletsel. In: Mijna Hadders-Algra, Karel Maathuis, Robert F. Pangalila, Jules G. Becher, Jan de Moor ed. *Kinderrevalidatie*. 5 ed. Assen: Koninklijke van Gorcum BV; 2015:525-538.
37. Duijnisveld B. J., Sarac C., Malessy M. J., Brachial Plexus Advisory Board T. I., Vliet Vlieland T. P., Nelissen R. G. Developing core sets for patients with obstetricbrachial plexus injury based on the International Classificationof Functioning, Disability and Health. *Bone Joint Res.* 2013;2(6):116-121.
38. Sarac C., Bastiaansen E., Van der Holst M., Malessy M.J., Nelissen R.G., Vliet Vlieland T.P. Concepts of functioning and health important to children with an obstetric brachial plexus injury: a qualitative study using focus groups. *Dev.Med. Child Neurol.* 2013;55(12):1136-1142.
39. Bialocerkowski A., O'Shea K., Pin T. W. Psychometric properties of outcome measures for children and adolescents with brachial plexus birth palsy: a systematic review. *Dev Med Child Neurol.* 2013;55(12):1075-1088.
40. Dy C. J., Garg R., Lee S. K., Tow P., Mancuso C. A., Wolfe S. W. A systematic review of outcomes reporting for brachial plexus reconstruction. *The Journal of hand surgery.* 2015;40(2):308-313.
41. Chang K.W., Justice D., Chung K.C., Yang L.J. A systematic review of evaluation methods for neonatal brachial plexus palsy. *J.Neurosurg. Pediatr.* 2013.
42. Pondaag W., van Dijk J. G., Nelissen R. G., Malessy M. J. [Obstetric brachial plexus injury]. *Nederlands tijdschrift voor geneeskunde.* 2014;158:A7145.
43. Smania N., Berto G., La Marchina E., et al. Rehabilitation of brachial plexus injuries in adults and children. *Eur J Phys Rehabil Med.* 2012;48(3):483-506.
44. Bosga-Stork I, Schaaf V. Perifeer-neurologische aandoeningen, het obstetrisch plexus brachialis letsel. In: R van Empelen RN-vdS, A Hartman, ed. *Kinderfysiotherapie*. 3 ed. Amsterdam: Reed Business Education; 2103:553-571.
45. Schaaf VAM, Buitenhuis SM. Wetenschapsloket: Acute plexus letsels. *Nederlands tijdschrift voor kinderfysiotherapie.* 2009;21(59):24-27.
46. Price A., Tidwell M., Grossman J.A. Improving shoulder and elbow function in children with Erb's palsy. *Semin.Pediatr.Neurol.* 2000;7(1):44-51.
47. Ramos L. E., Zell J. P. Rehabilitation program for children with brachial plexus and peripheral nerve injury. *Semin Pediatr Neurol.* 2000;7(1):52-57.
48. Murphy K. M., Rasmussen L., Hervey-Jumper S. L., Justice D., Nelson V. S., Yang L. J. An assessment of the compliance and utility of a home exercise DVD for caregivers of children and adolescents with brachial plexus palsy: a pilot study. *PM & R : the journal of injury, function, and rehabilitation.* 2012;4(3):190-197.
49. Waters P.M. Update on management of pediatric brachial plexus palsy. *J.Pediatr.Orthop.B.* 2005;14(4):233-244.

50. Yang L. J., Anand P., Birch R. Limb preference in children with obstetric brachial plexus palsy. *Pediatr Neurol.* 2005;33(1):46-49.
51. 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.
52. Brown T., Cupido C., Scarfone H., Pape K., Galea V., McComas A. Developmental apraxia arising from neonatal brachial plexus palsy. *Neurology.* 2000;55(1):24-30.
53. Berggren J., Baker L. L. Therapeutic application of electrical stimulation and constraint induced movement therapy in perinatal brachial plexus injury: A case report. *J Hand Ther.* 2015;28(2):217-220; quiz 221.
54. Buesch F. E., Schlaepfer B., de Bruin E. D., Wohlrab G., Ammann-Reiffer C., Meyer-Heim A. Constraint-induced movement therapy for children with obstetric brachial plexus palsy: two single-case series. *International journal of rehabilitation research. Internationale Zeitschrift fur Rehabilitationsforschung. Revue internationale de recherches de readaptation.* 2010;33(2):187-192.
55. Justice D., Rasmussen L., Di Pietro M., et al. Prevalence of Posterior Shoulder Subluxation in Children With Neonatal Brachial Plexus Palsy After Early Full Passive Range of Motion Exercises. *PM & R : the journal of injury, function, and rehabilitation.* 2015;7(12):1235-1242.
56. Rasmussen L., Justice D., Chang K. W., Nelson V. S., Yang L. J. Home exercise DVD promotes exercise accuracy by caregivers of children and adolescents with brachial plexus palsy. *PM & R : the journal of injury, function, and rehabilitation.* 2013;5(11):924-930.

CHAPTER ELEVEN

List of publications
Curriculum vitae
Dankwoord
Appendix

LIST OF PUBLICATIONS

PEER-REVIEWED ARTICLES

Van der Holst M, Steenbeek D, Pondaag W, Nelissen RGHH, Vliet Vlieland TPM. Participation restrictions among adolescents and adults with Neonatal Brachial Plexus Palsy: the patient perspective.
Disability and Rehabilitation 2017, online September 24.

Geerdink Y, Aarts P, van der Holst M, Lindeboom R, Van Der Burg J, Steenbergen B, Geurts AC. Development and psychometric properties of the Hand-Use-at-Home questionnaire to assess amount of affected hand-use in children with unilateral paresis.
Dev Med Child Neurol 2017; 59: 919-925.

Van der Holst M, Steenbeek D, Pondaag W, Nelissen RGHH, Vliet Vlieland TPM. Neonatal brachial plexus palsy in children aged 0 to 2.5 years; parent-perceived family impact, quality of life, and upper extremity functioning.
Pediatr Neurol 2016; 62: 34-42.

Van der Holst M, van der Wal CWPG, Wolterbeek R, Pondaag W, Vliet Vlieland TPM, Nelissen RGHH. Outcome of secondary shoulder surgery in children with neonatal brachial plexus palsy with and without nerve surgery treatment history: A long-term follow-up study.
J Rehabil Med 2016; 48: 609-17.

Van der Holst M, Vliet Vlieland TPM, van de Sande MA, van Egmond-van Dam JC, Vermeulen HM, Nelissen RGHH. Translation and adaptation of the Pediatric Outcome Data Collecting Instrument (PODCI) into the Dutch language and preliminary validation in children with neonatal brachial plexus palsy.
J Pediatr Rehabil Med 2015; 8: 219-26.

Van der Holst M, Vliet Vlieland TPM, Meesters JJL, Bekkering WP, Nagels J, Nelissen RGHH. Evaluation of shoulder function after secondary surgery in children with neonatal brachial plexus palsy.
J Pediatr Rehabil Med 2015; 8: 187-96.

Sarac C, Bastiaansen E, Van der Holst M, Malessy MJ, Nelissen RG, Vliet Vlieland TP. Concepts of functioning and health important to children with an obstetric brachial plexus injury: a qualitative study using focus groups.
Dev Med.Child Neurol. 2013; 55: 1136-42.

ABSTRACTS

Geerdink Y, Van Der Holst M, Aarts P, Lindeboom R, Van Der Burg JJW, Steenbergen B, Steenbeek D, Pondaag W, Nelissen RGHH, Vliet Vlieland TPM, Geurts ACH. The Hand-Use-at-Home Questionnaire to assess spontaneous hand-use in children with unilateral paresis: evidence for validity and reliability
Oral Presentations. Dev Med Child Neurol 2017; 59 S2: 45.

Geerdink Y, Van Der Holst M, Aarts P, Lindeboom R, Van Der Burg JJW, Steenbergen B, Steenbeek D, Pondaag W, Nelissen RGHH, Vliet Vlieland TPM, Geurts ACH. The Hand-Use-at-Home Questionnaire to assess spontaneous hand-use in children with unilateral paresis: evidence for validity and reliability
Abstracts of meeting DCRM November 2016. Clinical Rehabilitation. 2017; 31 issue 6: 835-841.

Domingos, J. Eagle, M. Moraux, A. Butler, J. Decostre, V. Ridout, D. Mayhew, A. Selby, V. Guglieri, M. Van der Holst, M. Jansen, M. Verschuuren, J. de Groot, I. Niks, E. Servais, L. Hogrel, J. Straub, V. Voit, T. Ricotti, V. Muntoni, F. Outcome measures for Duchenne muscular dystrophy from ambulant to non-ambulant: Implications for clinical trials
Neuromuscular Disorders, S12, volume 27, Elsevier 2017

Domingos, J. Eagle, M. Moraux, A. Butler, J. Decostre, V. Ridout, D. Mayhew, A. Selby, V. Guglieri, M. Van der Holst, M. Jansen, M. Verschuuren, J. de Groot, I. Niks, E. Servais, L. Hogrel, J. Straub, V. Voit, T. Ricotti, V. Muntoni, F. Outcome measures for Duchenne muscular dystrophy from ambulant to non-ambulant: Implications for clinical trials
Neuromuscular Disorders, S185, volume 26, Elsevier 2016

Ricotti, V. Eagle, M. Butler, J. Decostre, V. Deborah, R. Moraux, A. Anthony, K Sleby, V. Guglieri, M. van der Holst, M. Jansen, M. Morgan, J. de Groot, I. Niks, E. Verschuuren, J. Servais, L. Hogrel, J.Y. Voit, T. Straub, V. Muntoni, F. Outcome measures for Duchenne muscular dystrophy from ambulant to non-ambulant: Implications for clinical trials
Neuromuscular Disorders, S229, volume 25, Elsevier 2015

CURRICULUM VITAE

Menno van der Holst werd geboren op 29 april 1980 te Balkbrug. In 1998 sloot hij het Hoger Algemeen Voortgezet Onderwijs af aan het Thomas a Kempis college in Zwolle. In 2000 startte hij de Opleiding Fysiotherapie aan de Hogeschool Leiden. In 2004 studeerde hij af als fysiotherapeut om vervolgens in 2005 te starten met de Post-HBO Opleiding Kinderfysiotherapie bij de Transfergroep in Rotterdam. In juni 2008 rondde hij de Opleiding tot Kinderfysiotherapeut af.

Kinderfysiotherapie
In oktober 2004 begon Menno zijn loopbaan als fysiotherapeut op de Afdeling Kinderrevalidatie van het Rijnlands Revalidatie Centrum (RRC) in Leiden. Vanaf 2007 combineerde hij deze functie met een baan bij het Willem Alexander Kinder- en Jeugdcentrum in het Leids Universitair Medisch Centrum (LUMC), binnen de Dienst Fysiotherapie. Aandachtsgebieden binnen zijn werkzaamheden als kinderfysiotherapeut zijn kinderoncologie en neuromusculaire aandoeningen met speciale aandacht voor Duchenne Musculaire Dystrofie (DMD).

Onderzoek
In 2007, bij de start van de werkzaamheden in het LUMC, zette Menno zijn eerste wetenschappelijk project op bij prof. dr. Rob Nelissen binnen de plexusletsels polikliniek. In 2013 werden de onderzoekwerkzaamheden binnen deze polikliniek onder leiding van prof. dr. Thea Vliet Vlieland, prof. dr. Rob Nelissen, dr. Duco Steenbeek en dr. Willem Pondaag uitgebreid tot een promotietraject. In de afrondende fase van zijn promotie is hij in september 2016 gestart met onderzoek bij het Duchenne Centrum Nederland onder leiding van prof. dr. Jan Verschuuren en dr. Erik Niks van de afdeling neurologie in het LUMC. Tevens is hij vanaf oktober 2016 verbonden aan het Kenniscentrum van het RRC waar hij een onderzoeksproject op het gebied van kinderen met cerebrale parese uitvoert.

Onderwijs
Vanaf 2009 is Menno verbonden als docent en coach aan de Opleiding Kinderfysiotherapie in Rotterdam en binnen het LUMC als docent aan de minor Translational Neuroscience (fysiotherapie bij kinderen met DMD).

Nevenactiviteiten
Van 2007 tot en met 2016 organiseerde Menno samen met andere vrijwilligers een jaarlijks buitensport kamp (Herfstherrie) in de Belgische Ardennen vanuit de stichting kinderoncologische vakantiekampen (SKOV).

DANKWOORD

Een proefschrift schrijven doe je niet alleen en via deze weg wil ik iedereen die mij op wat voor manier dan ook heeft gesteund, hartelijk danken.

Speciale dank gaat uit naar alle patiënten en/of hun ouders, en de Erbse Parese Patiënten Vereniging Nederland voor hun bijdrage aan één of meerdere van de studies in dit proefschrift.

Mijn begeleidingsteam: Thea Vliet Vlieland en Rob Nelissen, promotores, Duco Steenbeek, co-promotor, en Willem Pondaag; veel dank voor het getoonde vertrouwen voorafgaand aan en tijdens mijn promotietraject. Thea, heel veel dank voor al jouw begeleiding, de inhoudelijke gesprekken, je geduld, kritische blik en tomeloze inzet. Zonder jou had ik het niet gekund! Rob, Duco en Willem dank ook voor jullie tijd, inzet en waardevolle bijdragen. Rob, veel dank voor het mede mogelijk maken van dit traject. Duco, veel dank voor je enthousiasme en bevlogenheid. Willem, veel dank voor je inhoudelijk input en schrijftips. Ik had mij geen beter begeleidingsteam kunnen wensen.

Zonder collega's kun je niet promoveren. Dank aan alle collega's van de Fysiotherapieafdeling, het Plexusteam en het Neuromusculaire Team in het LUMC, Team Herfstherrie van de SKOV en aan alle collega's van de Kinderrevalidatie en het Kenniscentrum in het RRC. Extra dank gaat uit naar het ZAP-Plexus bel-team en mijn collega's Kinderfysiotherapie in het LUMC. Janneke, Peter, Charlotte en Danielle, jullie hebben mij vaak genoeg uit de wind gehouden als het nodig was.

Eric Vermeulen, hoofd Dienst Fysiotherapie, dank voor je vertrouwen, enthousiasme en de mogelijkheden die je me hebt geboden. Leidinggevenden en management van het RRC: Japhet van Abswoude, Margreet Kooij, Felicie van Vree, Paulien Goossens en Frans van den Broek d'Obrenan, dank voor alle mogelijkheden en (financiële) ondersteuning. Flexibiliteit was het sleutelwoord in deze!

Yvonne Geerdink, door toeval kwamen we met elkaar in contact en onze samenwerking heeft tot mooie dingen geleid. Dank voor de samenwerking, discussies, gezamenlijke praatjes, gezelligheid en natuurlijk voor de Hand-Use-at-Home vragenlijst.

Jorit Meesters, kamergenoot, collega en paranimf. Ik kon altijd bij je terecht voor onderzoeksvragen, het inkorten van abstracts en allerhande wetenschapstips. Mijn dank daarvoor is heel groot. Verder veel dank voor je humor, gezelligheid en uiteraard het aanleveren van het standaardwerk!

Job Pantjes, getuige bij mijn huwelijk en nu ook paranimf, ik wil jou en Lot (en natuurlijk Maud en Fedde) danken voor alle gezelligheid en afleiding de afgelopen jaren.

Veel dank aan vrienden en familie; Maarten en Wilma, Lodewijk en Marlinde, Rutger en Cyntha, Marije en Rik, Lodewijk en Marjolein en Alexander en Margreet, jullie hebben altijd geïnteresseerd meegeleefd.

Speciale dank aan mijn schoonouders, Bart en Anna Lou van Os, voor hun interesse, aanmoedigingen en hulp met taalkundige zaken rondom mijn proefschrift.

Uiteraard gaat er ook speciale dank uit naar mijn ouders die me altijd hebben gesteund in alle keuzes die ik door het leven heen heb gemaakt. Pa, de fysiotherapie zit toch in het bloed!

En natuurlijk gaat de meeste dank uit naar mijn vrouw Margo en mijn twee prachtige kinderen Anne en Juliet. Jullie hebben mij de ruimte gegeven wanneer nodig, steunden mij in alles en zorgden altijd voor gezelligheid en afleiding. Ik zou dit niet zonder jullie hebben gekund. Ik hou van jullie.

APPENDIX

Outcome measures used in the ZAP Plexus study

Patients / Questionnaire	Dimension	0-2 years	2-10 years	10-16 years	³16 years	Described in chapter
Socio-demographic status	**Socio-demographic**	p	p	p	s	6, 7, 8
Disease specific questions	**NBPP specific**	p	p	p	s	6, 8
Health care usage	**Health care usage and satisfaction**	p	p	p	s	7
PedsQL™ FIM	**Family Impact**	p	p	p		6
ABILHAND-Kids	**Upper extremity functioning**		p >6 yrs	p <15 yrs		x
HUH*	**Upper extremity functioning**		p			5
PODCI-NL	**Upper extremity functioning**		p	p, s	s <19 yrs	7
DASH-DLV	**Upper extremity functioning**				s	8
MHOQ-DLV	**Upper extremity functioning**				s	x
TAPQOL	**Overall quality of life**	p	p <5 yrs			6
TACQOL	**Overall quality of life**		p >5 yrs s >8 yrs	p >5 yrs s <15 yrs		x x
TAAQOL	**Overall quality of life**				s	x
DISABKIDS	**Overall quality of life**		p, s 4-7 yrs p, s >8 yrs	p, s		x x
SF-36	**Overall quality of life**				s	8
SQUASH	**Physical activity**		p >8 yrs	p <12 yrs	s >19 yrs	x
AQUA	**Physical activity**			s >12 yrs	s <19 yrs	x
IPA	**Participation**				s	8
USER-P	**Participation**				s	8
Rotterdam Transition Profile	**Transition into adulthood**				s	x

*Added to the ZAP-Plexus study to investigate the newly developed Hand Use at Home questionnaire in NBPP. (p)= parent-reported, (s)= self-reported. > or <...yrs= questionnaire only used over or under a specific age. x= not yet analyzed. PedsQL™ FIM: PedsQL™ Family Impact Module, HUH: Hand Use at Home questionnaire, PODCI-NL: Peadiatric Outcome Data Collecting Instrument Dutch version, DASH-DLV: Disabilities of the Arm, Shoulder and Hand Dutch Language Version, MHOQ-DLV: Michigan Hand Outcome Assessment Dutch Language Version, TAPQOL: TNO-AZL for Preschool childrens' Health Related Quality of Life questionnaire, TACQOL: TNO-AZL for Childrens' Health Related Quality of Life questionnaire, TAAQOL: TNO-AZL for Adolescent's and Adult's Health Related Quality of Life questionnaire, SF-36: Short Form 36, SQUASH: Short Questionnaire to Asses Health Enhancing physical activity, AQUA: Activity Questionnaire Amsterdam, IPA: Impact on Participation and Autonomy, USER-P: Utrecht Scale for Evaluation of Rehabilitation-Participation.