Clinical Assessment of the Infant and Child Following Perinatal Brachial Plexus Injury

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Abstract

STUDY DESIGN—Literature review

INTRODUCTION—After perinatal brachial plexus injury (PBPI), clinicians play an important role in injury classification as well as the assessment of recovery and secondary conditions. Early assessment guides the initial plan of care and influences follow-up and long-term outcome.

PURPOSE—To review methods used to assess, classify and monitor the extent and influence of PBPI with an emphasis on guidelines for clinicians.

METHODS—We use *The International Classification of Functioning, Disability, and Health (ICF)* model to provide a guide to assessment after PBPI for rehabilitation clinicians.

DISCUSSION—With information gained from targeted assessments, clinicians can design interventions to increase the opportunities infants and children have for optimal recovery and to attain skills that allow participation in areas of interest.

Keywords

brachial plexus injury; infant; child; assessment; muscle; weakness; international classification of functioning; disability; health

Introduction

The purpose of this paper is to review methods to assess and classify perinatal brachial plexus injury (PBPI) in infants and children with an emphasis on guidelines for clinicians. PBPI which occurs primarily during the birth process can be transitory or have long-term consequences.[1] The incidence of PBPI reportedly ranges from 0.38 to 4.6 per 1000 live

births depending on mean birthweight and obstetrical care in the region. [1–4] The most frequent cause of PBPI is a unilateral traction injury due to catching of the anterior or posterior shoulder behind the symphysis pubis or sacrum of the mother. [5–8] This is referred to as shoulder dystocia. Other risk factors for PBPI include maternal gestational diabetes, prolonged labor, labor induction, mechanical assistance (vacuum, forceps) or infant size > 90th percentile (4500 to 5000g).[9–10] Despite the known risk factors, the positive predictive values for identifying PBPI prior to birth are less than 15%.[11] Risk factors continue to be investigated with the goal of prevention.[12–13]

The recovery rate from PBPI is now estimated to be closer to 65%[14–17] versus previous reports of 90%[18]. The difference in rate is influenced by the definition of complete recovery, the scale or method used to measure recovery and the age of the child. Incomplete recovery is more apparent in older children as daily upper limb tasks increase and become more complex.

Clinicians have an important role in injury classification as well as the assessment of recovery and secondary conditions. Early assessment guides the initial plan of care and influences follow-up and long-term outcome.

Models of Rehabilitation

Clinicians use theoretical models to guide the choice of assessment and intervention and to conceptualize outcomes. The traditional medical model concentrates on curing disease with physical impairment as the main focus. The International Classification of Functioning, Disability and Health (ICF) developed by the World Health Organization (WHO, see Fig. 1).[19] is a more contemporary model used by rehabilitation clinicians. This model relies on the dynamic interaction of multiple subsystems in which environmental factors play a key role. Each level of the ICF framework is relevant at all ages yet, the treatment priorities after PBPI typically shift from a strong emphasis on body, structure and function in infancy toward greater emphasis on activity and participation as the child gets older (see Table 1).

The ICF can assist the clinician with decisions on measurement including what, when and which measurement tool to choose. Table 2 and 3 provide a sample list of outcome measures (with abbreviations) classified within the ICF. Table 2a lists assessment tools that are validated for this population (Table 2a). Table 2b includes standardized assessments that are potentially useful but currently are not validated for use after PBPI. These tables are guidelines in the choice of assessment for infants and children with PBPI.

Assessment: Infant

Early infancy is the time to focus on impairment (Table 1). During this period, the team determines the extent of the injury and monitors recovery. Early monitoring informs the decision regarding the need for reconstructive nerve surgery. Select medical tests such as electrodiagnostic measures, MRI, and ultrasound are often used to verify clinical findings.

History

Key information to gather from medical records and parents/caregivers includes a history of maternal gestational diabetes, incidence of sibling PBPI, length of maternal labor and mechanical assistance at delivery. Additional information to document includes the incidence of birth hypoxia, infant APGAR scores, infant birthweight, clavicular fracture and the appearance, posture and movement in the affected limb post-birth. If the history is obtained weeks to months after birth specifics regarding the progression and quality of affected limb movement can be obtained. Details of the actual birth and birthing experience are also important to explore with parents. For many it has been a traumatic experience which they may have not resolved emotionally[85] and can ultimately affect their ability to respond to the needs of their infant.

Observation

An initial observation of the infant's state,[66] parent-infant interaction,[86] infant posture[52] and general sensorimotor behavior[23] should be conducted as all of these will greatly affect the formal assessment and intervention. An infant who is highly irritable or a parent who is fearful of the affected limb may influence testing priorities and techniques. Resting posture and spontaneous movements observed in the neonatal period after PBPI provide a general indication of the extent of the injury, muscular involvement and the presence of pain. Global motor asymmetries, not just in the upper limb, affect the development of postural control and long-term function and should be observed and monitored as they may be indicative of central neurological issues.[52,87–88]

After partial or full denervation, the affected upper limb often lies immobile in postures that provide evidence of the lesion. For example, the common "waiter's tip" position of shoulder internal rotation/adduction, elbow extension, supination and wrist flexion suggests injury to the C5-C6 (C7) spinal nerves or roots with partial or full denervation in the associated muscle groups.[2] Some infants maintain the head turned away from the affected side, which may be indicative of injury to neck musculature (i.e., scalenes or sternocleidomastoid), the presence of regional nerve pain or sensory neglect. Sustained asymmetrical head posturing places an infant with PBPI at-risk for torticollis,[89–90] and/or secondary plagiocephally.[89–90]

Specific signs and symptoms are indicative of extensive nerve involvement. The presence of ptosis (drooping eyelid), miosis (pupil constriction) and/or anhidrosis (dry eye) are signs of unilateral Horner's syndrome or injury to the sympathetic trunk; which is linked to injury in the lower roots of the brachial plexus.[91] Difficulty with oxygenation, feeding and asymmetric chest expansion are symptoms of partial denervation to the diaphragm and warrant further screening for phrenic nerve injury (nerves C3, C4, and C5).[92] Concerns raised during observations require further assessment.

Objective Testing

Assumptions made during an observation can be confirmed or refuted through the use of objective measurements. Table 2a provides a list of objective measures within the ICF framework validated for infants and children with PBPI. Table 2b lists measures that are currently not validated with this population but have potential for use.

Pain—If the infant grimaces upon light palpation of the neck and upper shoulder region pain is suspected. If sustained head posturing is noted during observation, a test of visual tracking provides information on the influence pain has on neck movement and visual scanning. The Face, Legs, Activity, Cry, Consolability (FLACC) scale can be used to objectively rate pain on a 0–10 scale based on behavioral cues from 5 categories (Table 4).[53] Many hospitals have adopted the FLACC scale to objectively measure pain in all infants.

Classification of Injury—The original classification of PBPI by Narakas[30] was modified by Al-Qattan[31] to reflect neural recovery over the first few months. This combined scale is useful as an early assessment tool (see Table 5). Once a preliminary diagnosis is made, the infant and family should be referred to a center which specializes in PBPI. A team including a physical or occupational therapist and a surgeon skilled in nerve reconstructive techniques is optimal to guide the plan of care. Ideally, a referral is made within one month of injury to allow for prevention of contractures and deformity, early assessment, monitoring of recovery and initiation of intervention with support and education for families. If distance from care is a factor, it is possible to implement a telemedicine program[93] to support a combined plan of care with the local medical/therapy team and the specialty center.

Neurological and Physical Assessment—Since neurologic disorders can ensue secondary to hypoxia experienced during birth, a neurological screen[23] is essential. This can include an assessment of muscle tone and primitive reflexes and other components such as spontaneous movement[68] and sensation[55] (reviewed below). Findings from an examination of deep tendon reflexes[23] can provide information on muscle innervation and integrity. Physical palpation for clavicular and humeral fractures should be done and confirmed with x-ray.[27] A radial nerve injury is suspected is there is wrist drop into flexion, visible ecchymosis and/or a palpable nodule (suggestive of subcutaneous fat necrosis) along the posterolateral upper arm[94–95] Palpation of the skull can confirm or refute the presence of a cephalo-hematoma[96] or plagiocephally[90].

Passive Range-of-Motion—Assessment of PROM available at the neck, glenohumeral (GH) and scapulothoracic (ST) joints is essential.[29,89] Passive ROM into lateral neck flexion and cervical rotation is assessed if postural asymmetries are suggestive of a torticollis.[89] Ideally, the GH joint is evaluated with the scapula stabilized during elevation (flexion/abduction), external rotation (ER) and horizontal adduction. During elevation and horizontal adduction the scapula is stabilized laterally to prevent upward rotation or abduction (Fig. 2a). During shoulder ER, medial glide and elevation of the scapula are prevented (Fig. 2b–c) while the GH joint is externally rotated from an adducted position. Ongoing assessment of PROM throughout infancy and childhood is recommended due to the risk for contracture.[29]

Motor Assessment—An assessment of spontaneous arm movement in supine, prone, sidelying and supported sitting with or without provocation provides information on available motion. According to Bouwstra et al.,[67] "spontaneous movements are endogenously generated by the central nervous system during fetal life and early infancy". An assessment of generalized movements (GMs)[97] predicts infants at-risk for neurological dysfunction.[97–98] Buitenhuis et al.[68] found a diminished quality of fidgety GMs at 3 months

of age in infants who sustained PBPI. While GM's could be valuable to screen for neurological dysfunction and arm asymmetry after PBPI the assessment of GM's must first be validated for use with this population. Another mode to provoke muscle activation is the elicitation of primitive reflexes and postural reactions.[23–25] There are at minimum five reflexes/reactions that are quite useful with this young population since they activate muscles frequently involved post-injury (see Table 6 for details). Additional objective measures confirm or refute suspicions with regard to muscle activation.

The Active Movement Scale (AMS)[20] is used to objectively examine activation of UE muscle groups. The AMS differs from the Toronto Scale (Appendix A)[22] which was designed for use at 3 months of age as a predictor of outcome and use in surgical decision-making. The AMS was designed to be used from the neonatal period to one year of age.[20–21] Yet, an advantage of the AMS is that is can be used until adolescence.[20–21] Scores for fifteen UE joint motions are graded on a 0–7 point scale based on the percent of active motion observed within the available PROM. Active motions performed with gravity minimized are scored from 0–4 and motions performed against gravity are scored from 5–7 (See Appendix B). Each of the 15 joint motions must receive a score of 4 in the gravity minimized range before a higher score against gravity can be given. The scale is proven reliable (overall $K_{quad} = 0.89$).[21] However, since scoring is based on active motion in the available passive range, it is recommended that PROM estimated from visual inspection be verified with goniometry.[99]

Sensation—Behavioral cues such as infant facial grimacing or retractive movements with active motion, PROM or tactile stimulation are used to screen sensation in the upper limb. Behavioral response to a dull pinprick or a light pinch tested along specific UE dermatomes provides objective information on sensation. The scale by Narakas[30] (see Table 7) is one of the few scales to classify sensation in this population.

Electrodiagnostic Studies—Routine evaluations after PBPI do not usually include the electrodiagnostic tests of nerve conduction or invasive electromyography (EMG) due to the high probability for false negative findings in the neonatal period and false positive findings a few months post-term.[27,38] van Dijk et al.[38] outlined potential reasons for a discrepancy between clinical findings and EMG results. One possibility is that the small axonal size in neonates could reduce the time to complete the process of denervation and the start of re-innervation in comparison to adults.[38] Aberrant re-innervation and inadequate motor control[38] are other potential reasons for this discrepancy.

Despite the controversy, clinicians selectively use electrodiagnostic tests after PBPI. Needle EMG is used to examine the integrity of a muscle or muscle groups for surgical decision-making. Others use electrodiagnostic tests, if root avulsions are suspected.[44] For example, the integrity of the roots can be assessed intraoperatively through the elicitation of motor- and sensory-evoked potentials.[43] As discussed above, the interpretation of EMG findings in the few months post-birth is controversial. Yet, van Dijk et al.[40] found that needle EMG conducted at one month of age predicted paralysis of the elbow flexors at 3 months. Non-invasive surface EMG or biofeedback is clinically useful to determine whether muscle activation is present during skills such as reach-to-grasp behavior[41] but is not used routinely.

Further research is warranted before electrodiagnostic testing becomes routine with this population.

Radiological Assessment—Diagnostic imaging is useful early post-injury. X-ray verifies whether a clavicular or humeral fracture was sustained during delivery[27] Computerized tomography (CT)/myelography evaluates root avulsions with a sensitivity of 58.3% for post-ganglionic rupture and 72.2% for preganglionic nerve root avulsion.[36] CT myelograms are considered somewhat invasive since they require general anesthesia, lumbar puncture and induce radiation exposure. Magnetic Resonance Imaging (MRI) is being used more frequently as an imaging tool since it is less invasive than a CT myelogram.[44] Somashekar et al.[42] used MRI imaging in a small sample, to detect root avulsions at an overall sensitivity of 75% and specificity of 82%. Finally, non-invasive ultrasound provides information on nerve, GH joint and muscle integrity thus can aide in pre-microsurgical planning.[45–46] An ultrasound of the diaphragm may also be done if damage to the phrenic nerve is suspected.[44] The type of imaging used is controversial and depends on the availability of the specific procedures and the preferences at each specialty center.

Developmental Testing—Muscle imbalance, postural asymmetries and diminished sensation influence sensorimotor development. Currently, there is not a developmental assessment validated for use with infants after PBPI. However, performance on an assessment standardized for use with full-term infants could be used to *estimate* the influence of PBPI on the achievement of motor milestones and to screen for asymmetry. Two tools are recommended. The first is the Test of Infant Motor Performance (TIMP)[69] standardized for use from infants 32 weeks gestational age to 4–5 months post-term. The original normative sample did include term infants. Thus is not intended for just preterm infants. The TIMP has been recommended in the clinical practice guidelines for torticollis.[89] The Alberta Infant Motor Scale (AIMS)[70] is a criterion referenced test standardized for use with infants 2 weeks post-term to 18 months of age. Other valid and reliable developmental assessments may be appropriate but require further validation for use with infants after PBPI (See Table 2b).

Psychological Factors—PBPI places the parents/caregivers and infant at risk for psychological stress. An assessment of psychological adjustment and coping strategies of parents/caregivers by the clinician is essential.[100–101] An older infant or toddler could be at-risk for self-mutilation due to altered sensation in the affected limb, pain or psychological stress.[102–103] Signs of injury or parental report of injury must be monitored on an ongoing basis. Referral to a psychologist or social worker for further support may be indicated.

Assessment: Older Child

As the child becomes a preschooler the focus of clinical care shifts from impairment to age-appropriate activities and participation (see Table 1). Despite the shift in priority, clinicians should continue to provide ongoing assessment of impairment, since it can limit the scope of desired activities and opportunities for social participation.

History

During childhood information obtained on history to date including surgical and rehabilitation intervention received, guides the assessment process.

Objective Testing

Although some assessment tools from infancy are similar, additional tests reviewed below as well as those listed in Table 2, can provide more useful information for the clinician across the ICF framework as the child ages.

Motor Assessment—The AMS can be used until 15 years of age to gather information on muscle activation and joint motion.[20–21] However, as the child gets older and is better able to follow verbal commands the Medical Research Council (MRC) scale[28] may be more suitable to assess muscle strength. Electrodiagnostic studies reviewed above may also be a source of objective information.

The Mallet Scale[26] and the Modified Mallet Scale[27] (See Appendix C) are motor assessments well-suited to children 3 years of age or older. In the Modified Mallet[27], the child imitates six postures that are demonstrated by the clinician for bilateral motion. Scoring ranges from I = no function to V = normal. Russo et al.[48] examined the GH and ST joint contributions to shoulder motion based on the Modified Mallet Scale. The authors found that among children with Erb's Palsy (C5-C6 spinal root involvement) and Extended Erb's Palsy (C5-C7 spinal root involvement) the GH joint contribution was less than the ST joint in the affected shoulder primarily during global ER and elbow flexion/supination (the "hand to mouth" action).[48] This supports previous work documenting atypical GH and ST joint contributions to shoulder motion in children who sustain PBPI,[49] and provides further justification for use of the Modified Mallet scale[27] as a motor assessment tool.

Joint and Skeletal Integrity—Measurement of joint angles via goniometry is essential, yet joint and skeletal integrity is best verified with radiological imaging. Assessment of gleno/scapular angles[47] provides an objective measure of change in the relationship of the GH and ST joints from infancy to adulthood. Specific methods used to assess GH and ST joint angles are outlined in this special issue.[47] Interestingly, Kozin and colleagues[104] demonstrated that tendon transfers improve overall shoulder motion, but do not reduce humeral head subluxation or improve GH joint alignment. Thus, children are still at risk for joint contractures after tendon transfers warranting continued documentation of PROM and emphasis in treatment.

Measures of arm length and girth obtained as the child ages can indicate the presence of significant interlimb asymmetry.[50–51] Differences in arm size and appearance are reportedly "somewhat" to "extremely" important to more than 37% of parents and families of children who sustain PBPI,[50] thus should be documented. Bae et al.[50] found that among children with persistent residual deficits from PBPI "the upper arm, forearm, and hand lengths of the affected limbs were, on average, 95%, 94% and 97% of the unaffected limb respectively". In a longitudinal study, Bain et al.[51] collected measures of arm length and girth at regular time points until 12 months then yearly. The authors found that children with and without

surgical intervention had significant differences between affected and unaffected sides with regard to arm, forearm, and total length as early as the 1-month time point. The 3-month total limb length difference was a statistically significant predictor of 12-month limb length difference. Although measurement of arm length and girth is not essential, since it is important for many parents/families, interlimb differences should be monitored.

Sensorimotor Function and Prehension

Children who sustain PBPI are at risk for temporary or long-lasting postural and developmental disorders[52,87] Bellew et al.[87] found a significant relationship between initial injury severity and level of development in young children who sustained PBPI. A change in hand preference based on capability post-injury could also influence motor learning and subsequent function.[87]

Given the risk of disability, screening of sensorimotor development and prehensile function is recommended for the preschool child with PBPI. Currently, the Assisting Hand Assessment (AHA)[63] is the only known prehensile assessment validated for use with PBPI. Table 2b lists standardized measures that are potentially useful to assess prehension and sensorimotor skills of balance and visual-motor function that require validation for use after PBPI. Further research to validate these assessments for use with this population is warranted.

Activity and Participation

Children who sustain PBPI are at-risk for restrictions in activities and participation.[105–106] Assessment of these aspects of the ICF framework are illustrated in the recently developed tool, The Brachial Plexus Outcome Measure (BPOM).[59] The BPOM[59] has two parts; the Activity Scale and the Self-Evaluation Scales designed to assess activity and participation in children who sustain PBPI (See Appendix D). The activity scale consists of eleven tasks, which contain components of the fifteen movements included in the AMS scale.[20] Activity performance is graded using the Functional Movement Scale; an ordinal scale ranging from '1' cannot complete to '5' completes in a normal movement pattern symmetrical to the unaffected UE. The self-evaluation scale includes 3 visual analog scales (100 mm) to assess the perceived arm and hand function and cosmetic appearance of the limb. This tool has not yet undergone rigorous psychometric testing. Table 2a – b lists other tools useful to assess activity and participation that have been validated, or are recommended for use pending validation, with this population.

A child's self-efficacy and self-esteem may be fragile due to the child's reaction or the reaction of others to their disability. Since these issues have the potential to limit participation in age-appropriate activities and sports they should be monitored. If needed, the child can be referred to a psychologist or social worker for additional support.

Conclusions

PBPI evident immediately after birth requires early assessment and follow-up with a team of PBPI specialists. Early assessment and care provides the infant with the best opportunity to

improve sensory recognition, recover movement, prevent secondary musculoskeletal disorders, and integrate the arm into movement and age-appropriate activities. In addition to physical assessment, clinicians should be mindful of behavioral clues of psychological distress exhibited by the parents/caregivers or the infant/child. Education on the condition and home programs as well as referral to an appropriate professional can help to ease anxiety in these situations. Finally, the ICF model can guide the assessment process from infancy through adolescence. Attention to all facets of development can provide this vulnerable group of infants and children the best chance for recovery and life-long participation in areas of interest.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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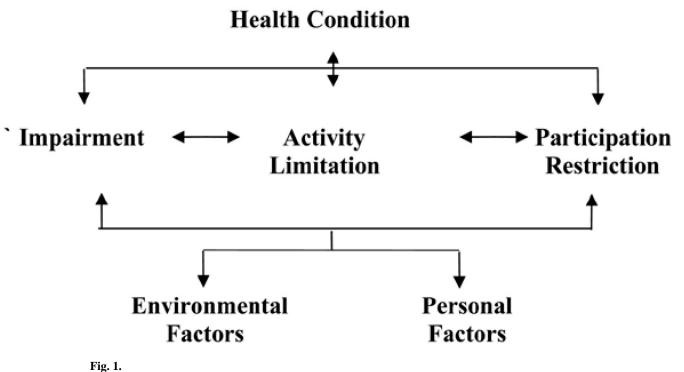
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Highlights

ICF guides assessment after perinatal brachial plexus injury

Use of sensitive measures is essential

Health Condition

`Impairment ⟷ Activity Limitation ⟷ Participation Restriction

Environmental Factors   Personal Factors

Fig. 1.
International Classification of Functioning, Disability, and Health

Fig. 2.
Scapular stabilization: A) lateral during humeral elevation; B) medial and superior during humeral external rotation; C) PROM into external rotation in the sidelying position. (courtesy of SV Duff).

Table 1

ICF Classification from Infancy to Adolescence

	Infant	Toddler	Preschool	School age	Adolescent
Assessment Focus	Impairment & Environment	Impairment & Activity	Impairment & Activity & Participation	Activity & Participation	Participation & Activity
Intervention Focus	• Integration of limb • ROM/strength	• ROM/strength • Integration • Child development	• ROM/strength • Hand function	• Participation in age related school & leisure activities • QOL*	• Participation • QOL
Primary Objective	• Surgery prediction • Sensorimotor recovery and function	• Hand function • Hand preference • Self esteem	• Preschool – prediction of school problems • Hand preference	• ROM/strength: interventions • BTX-A* • Splinting • Secondary surgery	• ROM/strength: interventions • BTX-A • Splinting • Secondary surgery
Other Important Considerations	• Family	• Other interventions • BTX-A • Splinting	• Other interventions • BTX-A • Splinting • Secondary surgery	• Self-Efficacy • Self-Esteem	• Self-Efficacy • Self-Esteem
Personal Factors	• Child development	• Family	• Family	• Future planning	• Future planning

*BTX-A = Botulinum toxin type A; QOL = Quality of life

Table 2

a: Outcome Measures Validated with PBPI - ICF Classification		
BODY FUNCTIONS & STRUCTURES Impairment	**ACTIVITY** Limitation	**PARTICIPATION** Restriction
ACTIVE MOTION/STRENGTH • AMS[20–21] • Toronto Test[22] • Primitive Reflexes / Postural Reactions[23–25] • Mallet[26] & Modified Mallet Shoulder Scale[27] • MRC scale[28] • Pinch/grip dynamometery[29]	***FUNCTIONAL*** • BP Activity and UE CAT[58] • BPOM[59] • PEDI,[60–61] PEDI-CAT[62]	***QUALITY OF LIFE*** • Peds-QL[64]
CLASSIFICATION • Modified Narakas Classification[30–31] • Modified Gilbert Scale for Shoulder Fn[32] • Gilbert-Raimondi Scale for Elbow Fn[33] • Al-Qattan's Scales for Wrist/Hand Fn[34] • Raimondi Scale for Hand Fn[35]	***UNI-BIMANUAL*** • AHA[63]	***PARTICIPATION*** • BPOM[59] • PODCI[65]
DIAGNOSTICS • CT Myelogram,[36] EMG,[37–41] MRI,[42] NCS[43–44] • Ultrasound[45–46]		
NEUROLOGICAL • Deep Tendon Reflexes[23] • Muscle Tone[23] • Primitive Reflexes / Postural Reactions[23–25]		
PHYSICAL • Gleno/scapular angles[47] • Kinematic assessment[48–49] • Limb length/girth[50–51] • Postural assessment[52] • PROM[28]		
PAIN • FLACC scale[53] • FACES pain rating scale[54]		
SENSATION • Sensory Grading System Narakas[29] • Wrinkle test[55] • Two-point discrimination[56]		

a: Outcome Measures Validated with PBPI - ICF Classification		
BODY FUNCTIONS & STRUCTURES Impairment	**ACTIVITY** Limitation	**PARTICIPATION** Restriction
• Semmes Weinstein Monofilaments[57]		

b: Potential Outcome Measures for use with PBPI (Not Validated) – ICF Classification		
BODY FUNCTIONS & STRUCTURES	**ACTIVITY**	**PARTICIPATION**
BEHAVIOR • NBAS[66]	*DEVELOPMENTAL*SM • TIMP,[69] AIMS,[70] PDMS-2[71] • BSID-III[72]	*QUALITY OF LIFE* • KIDSCREEN-52[80]
*ll**NEUROLOGICAL* • Generalized Movements[67–68]	*DEXTERITY* • FDT,[73] NHPT[74]	*GOAL-BASED* • COPM,[81] GAS[82]
	UNI-BIMANUAL • BOT-2,[75] MAP,[76] MA-2[77] • Movement ABC-2,[78] QUEST[79]	*PARTICIPATION* COSA,[83] MfunPS[84]

*
Fn = Function

*
SM = Sensorimotor

**
See Table 3 for list of abbreviations and associated outcome measure

Table 3

Outcome Measure Abbreviations

ABBREVIATION	OUTCOME MEASURE
AIMS	Alberta Infant Motor Scale
AHA	Assisting Hand Assessment
AMS	Active Movement Scale
BPOM	Brachial Plexus Outcome Measure
BOT-2	Bruininks-Oseretsky Test of Motor Proficiency, 2nd Ed
BSID III	Bayley Scales of Infant Development, 3rd Ed
BP Activity and UE CAT	Brachial Plexus Activity and Upper Extremity Computerized Adaptive Testing
COPM	Canadian Occupational Performance Measure
COSA	Child Occupational Self-Assessment
CT	Computed Tomography
EMG	Electromyography
FLACC	Face, Legs, Activity, Cry, Consolability Scale
FDT	Functional Dexterity Test
GAS	Goal Attainment Scaling
GMs	Generalized Movements
MA-2	Melbourne Assessment 2
MAP	Miler Assessment of Preschoolers
MfunPS	Miller Function and Participation Scales
Movement ABC-2	Movement Assessment Battery for Children-2nd Ed
MRC	Medical Research Council
MRI	Magnetic Resonance Imaging
NBAS	Neonatal Behavioral Assessment Scale
NCS	Nerve Conduction Studies
NHPT	Nine Hole Peg Test
QUEST	Quality of Upper Extremity Skills Test
PDMS-2	Peabody Developmental Motor Scales, 2nd Ed
PEDI-CAT	Pediatric Evaluation of Disability Inventory – Computer Adapted Testing
Peds QL	Pediatric Quality of Life
PODCI	Pediatric Outcomes Data Collection Instrument
QUEST	Quality of Upper Extremity Skills Test
PROM	Passive Range-of-Motion
TIMP	Test of Infant Motor Performance

Table 4

The FLACC Scale to Assess Non-Verbal Signs of Pain

CRITERIA	Score 0	Score 1	Score 2
Face	No particular expression or smile	Occasional grimace or frown, withdrawn, uninterested	Frequent to constant quivering chin, clenched jaw
Legs	Normal position or relaxed	Uneasy, restless, tense	Kicking, or legs drawn up
Activity	Lying quietly, normal position moves easily	Squirming, shifting, back and forth, tense	Arched, rigid or jerking
Cry	No cry (awake or asleep)	Moans or whimpers; occasional complaint	Crying steadily, screams or sobs, frequent complaints
Consolability	Content, relaxed	Reassured by occasional touching, hugging or being talked to, distractible	Difficult to console or comfort

Merkel S, Voepel-Lewis T, Malviya S. Pain assessment in infants and young children: the FLACC scale. *Am J Nurse*. 2002;102(10)55-8.

Table 5

Combined Classification of Perinatal Brachial Plexus Injury

Group	Name	Roots or spinal nerves injured	Weakness/ Paralysis at 2–3 weeks of age	Condition at 2 months of age	Likely Outcome
I	Upper Erb's Palsy	C5, C6	Shoulder abduction/external rotation, elbow flexion	Variable recovery of shoulder/ elbow motion	Good spontaneous recovery in > 80% of cases
IIa	Extended Erb's Palsy with early recovery of wrist extension	C5, C6, C7	As above with wrist drop	As above with active wrist extension	Good spontaneous recovery in > 60% of cases
IIb	Extended Erb's Palsy with no early recovery of wrist extension	C5, C6, C7	As above with wrist drop	As above. No active wrist extension	Good spontaneous recovery in > 60% of cases
III	Global palsy with no Horner's Syndrome	C5 to C8, T1	Complete flaccid paralysis	Variable recovery of arm motion. No Horner's Syndrome.	Good spontaneous recovery of shoulder/ elbow in > 30–50% of cases. Functional hand frequently noted.
IV	Global palsy with Horner's Syndrome	C5 to C8, T1	Complete flaccid paralysis with Horner Syndrome	Variable recovery of arm motion. Horner's syndrome may be present.	Without surgery severe arm deficits are expected.

1) Narakas AO. Obstetrical brachial plexus injuries. In Lamb DW (Ed), The Paralyzed Hand. New York: Churchill Livingstone, 1987, 116–135. 2) Al-Qattan MM, El-Sayed AAF, Al-Zahrani AY, et al. Narakas classification of obstetric brachial plexus palsy revisited. *J Hand Surg [Eur]*. 2009;34:788–91.

Table 6

Key Primitive Reflexes Elicited to Assess Muscle Activation after PBPI

NAME	AGE	STIMULUS	RESPONSE
Moro Reflex	0–4 months	Sudden neck extension into gravity	Shoulder abduction/external rotation and elbow flexion
Placing Reaction	0–6 months	Tactile stimulation along dorsum of hand at the edge of a table	Shoulder flexion with wrist extension
Grasp Reflex	0–4 months	Pressure in palm of hand	Flexion of the fingers
Asymmetrical Tonic Neck Reflex (ATNR)	6 weeks to 6 months	Head turning toward one side	Elbow extension on face side; elbow flexion on skull side
Forward Protective Response	Onset 6–7 months	Hold infant securely at chest, move infant forward toward surface in head-first positions	Arm extension and abduction bilaterally
Sideward Protective Response	Onset 6–11 months	With infant in sitting gently move laterally to elicit protective response	Arm extension or abduction to the side to prevent falling

1) Fiorentino MR. *Normal and Abnormal Development: the influence of Primitive Reflexes on Motor Development*. Springfield, IL: Charles C. Thomas Pub. 1972. 2) Gabbard CP. Early motor development. In Gabbard CP (Ed) *Lifelong Motor Development*. San Francisco: Pearson Benjamin Cummings, 2012, pp. 240–280.

Table 7

Sensory Grading System

S0	**No reaction to painful stimuli or any other stimuli**
S1	Reaction to painful stimuli, none to touch
S2	Reaction to touch, but not light touch
S3	Apparently normal sensation

1) Narakas AO. Obstetrical brachial plexus injuries. In Lamb DW (Ed), The Paralyzed Hand. New York: Churchill Livingstone, 1987, 116–135. 2) Al-Qattan MM, El-Sayed AAF, Al-Zahrani AY, Al-Mutairi AS, Al-Harbi MS, Al-Mutairi AM, Al-Kahtani FS. Narakas classification of obstetric brachial plexus palsy revisited. *J Hand Surg [Eur]*. 2009;34:788-91.