Diagnosis and management Of neonatal brachial plexus palsy

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1. Introduction

- **Neonatal Brachial Plexus Palsy (NBPP)** is caused by traction of the brachial plexus during birth.

  = birth brachial plexus palsy (BBPP)

  = obstetric brachial plexus palsy (OBPP)

- **Prevalence**
  - approximately 0.4–2.6 per 1000 live births in the US

Pediatr Rev. 2019 Sep; 40(9): 494-496

J Neurosurg Pediatrics 12:395–405, 2013

1. Introduction

- **Etiology:** remains a poorly understood entity
  - NBPP occurs due to over-stretching of the brachial plexus during birth, either by clinician applied (exogenous) or maternal (endogenous) forces
  - Shoulder dystocia: strongly associated with NBPP.
    - A birthing scenario where the fetal shoulder impacts against the mother's pubic symphysis

Neurol Neurobiol (Tallinn). 2020 ; 3(2)

1. Introduction

DEVELOPMENTAL MEDICINE & CHILD NEUROLOGY SYSTEMATIC REVIEW

Editor's Choice

Risk factors for neonatal brachial plexus palsy: a systematic review and meta-analysis

Table 2: Summary of findings for the five most significant risk factors

Outcome[a]	Number of studies[b]	Total population	Number of cases within risk group	Number of cases in total population	OR (95% CI) for NBPP	I^2 (%)	Strength of recommendation[c]
Shoulder dystocia	12	25 825 074	6563	33 984	115.27 (81.35–163.35)	92	Moderate
Macrosomia	13	2 975 874	3896	5892	9.75 (8.29–11.46)	70	Low
(Gestational) diabetes	10	1 651 281	175	3209	5.33 (3.77–7.55)	59	Moderate
Instrumental delivery	7	1 849 398	824	3112	3.8 (2.77–5.23)	77	Low
Breech delivery	11	26 780 930	183	34 960	2.49 (1.67–3.7)	70	Very low

[a]Risk factors implemented in the meta-analysis. [b]Included in the meta-analysis. [c]Based on the Grading of Recommendations Assessment, Development and Evaluation (GRADE) quality of evidence assessment. OR, odds ratio; CI, confidence interval; NBPP, neonatal brachial plexus palsy.

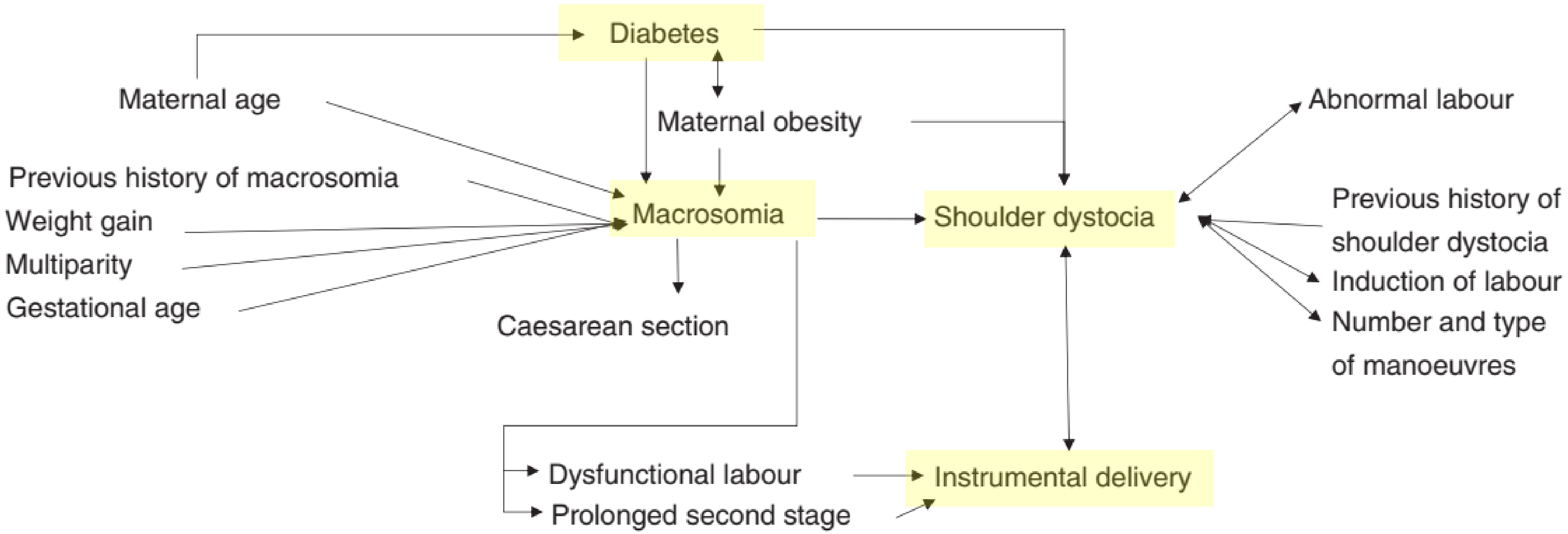
- Prevention remains difficult owing to the unpredictability of these factors and their often labour relatedness.

Developmental Medicine & Child Neurology 2020, 62: 673–683

DEVELOPMENTAL MEDICINE & CHILD NEUROLOGY SYSTEMATIC REVIEW
Editor's Choice

Risk factors for neonatal brachial plexus palsy: a systematic review and meta-analysis

- Moreover, many risk factors are interrelated.



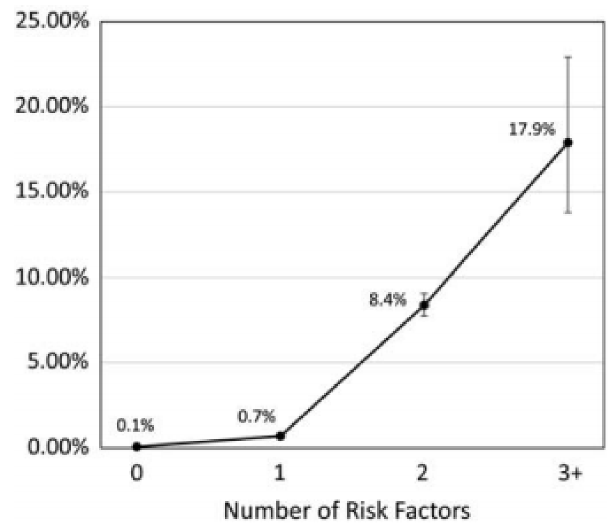
Developmental Medicine & Child Neurology 2020, 62: 673–683

1. Introduction

The Epidemiology of Brachial Plexus Birth Palsy in the United States: Declining Incidence and Evolving Risk Factors

TABLE 5. Multivariate Analysis of Brachial Plexus Birth Palsy Risk by Disease Determinants and Demographic Variables, 1997 to 2012

	Odds Ratio (95% Confidence Interval)
Main variables	
Risk factors	
Shoulder dystocia	113.2 (104.9-122.2)
Heavy-for-dates	8.22 (7.82-8.66)
Macrosomia (> 4.5 kg)	26.8 (24.0-30.0)
Breech delivery	3.56 (2.11-6.03)
Instrumented birth (forceps- or vacuum-assisted)	3.05 (2.56-3.65)
Birth hypoxia	3.08 (2.60-3.64)
Protective factors	
Multiple gestation	0.45 (0.32-0.63)
Cesarean delivery	0.16 (0.15-0.18)
Demographic variables	
Hospital characteristics	
Teaching hospital	1.12 (1.06-1.20)
Patient characteristics	
Female sex	1.27 (1.22-1.31)
Black race	1.88 (1.73-2.04)
Hispanic race	1.35 (1.27-1.44)
Region	
Midwest US (States: OH, MI, IN, IL, WI, MN, IA, MO, KS, NE, SD, ND)	0.88 (0.79-0.97)
West US (States: WA, MT, WY, CO, NM, AZ, UT, NV, CA, OR, HI, AK)	0.77 (0.70-0.84)

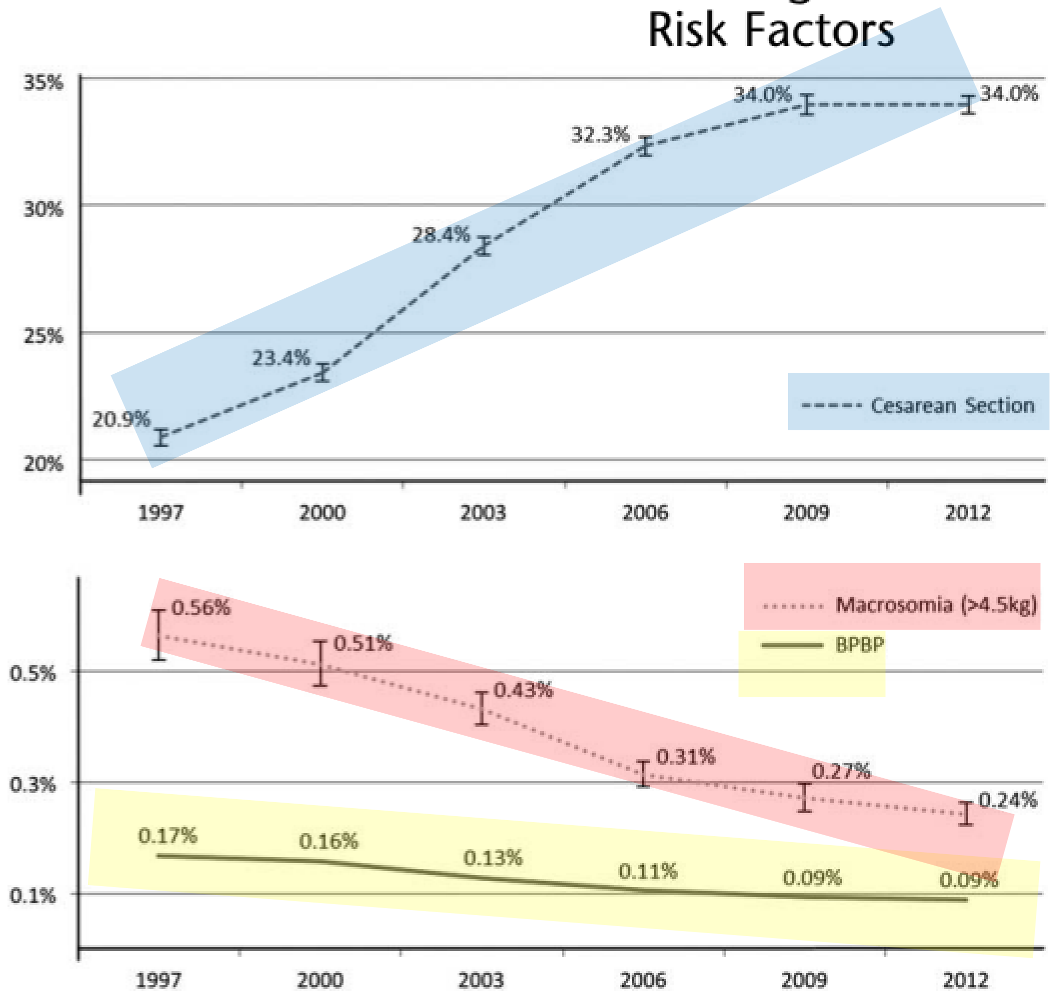


- The risk of NBPP shows a dose-response type relationship with the number of risk factors, rising to over 17% for those with ≥ 3 risk factors.

J Pediatr Orthop Volume 39, Number 2, February 2019

1. Introduction

The Epidemiology of Brachial Plexus Birth Palsy in the United States: Declining Incidence and Evolving Risk Factors



- Estimated incidence of brachial plexus birth palsy as well as the yearly prevalence for 1 major risk factor (macrosomia) and 1 major protective factor (cesarean delivery)

J Pediatr Orthop Volume 39, Number 2, February 2019

1. Introduction

The Epidemiology of Brachial Plexus Birth Palsy in the United States: Declining Incidence and Evolving Risk Factors

TABLE 3. Proportion of Infants With Disease Determinants Among Those Diagnosed With Brachial Plexus Birth Palsy in the US Population, 1997 to 2012

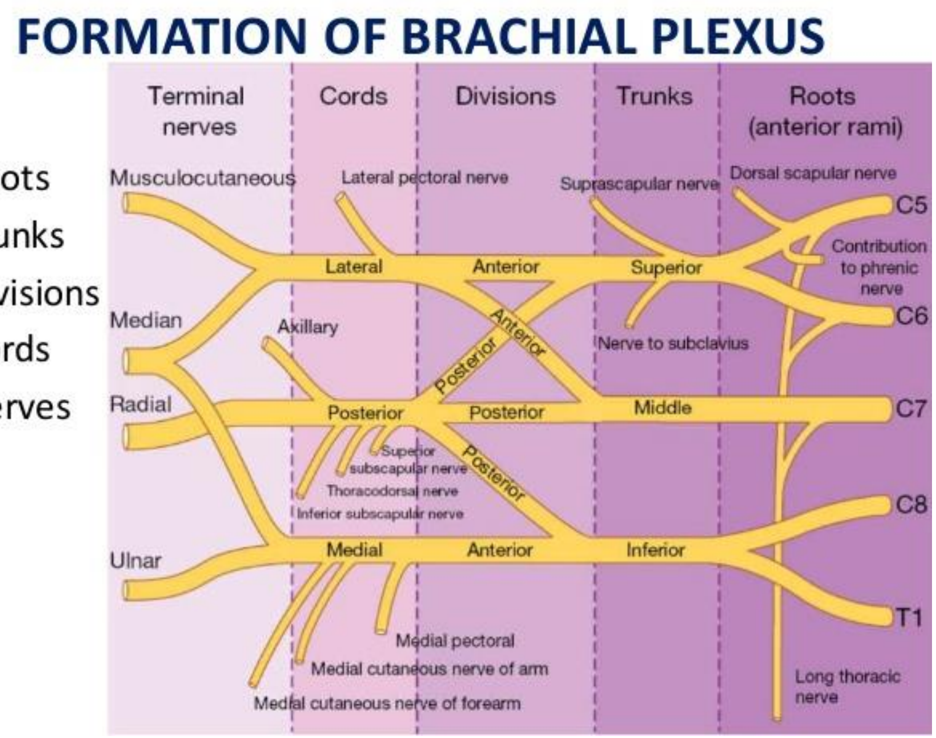
Variables	1997	2000	2003	2006	2009	2012	All Years	*P* (1997 vs. 2012)
Risk factors (%)								
Shoulder dystocia	17.39	15.81	18.50	18.45	21.86	24.35	18.78	< 0.0001
Macrosomia (> 4.5 kg)	7.09	6.36	5.90	3.90	3.81	2.65	5.31	< 0.0001
Heavy-for-dates	23.70	23.51	27.12	26.81	27.87	27.59	25.71	0.0072
Breech delivery	0.25	0.14	0.11	0.10	0.11	0.24	0.16	0.9181
Instrumented birth	3.78	2.94	2.03	1.98	2.52	2.85	2.75	0.1003
Forceps	1.51	0.88	0.83	0.63	0.65	0.55	0.91	0.0022
Vacuum	2.35	2.19	1.20	1.34	1.90	2.30	1.90	0.9020
Birth hypoxia	NA*	2.04	2.38	1.78	1.84	1.89	1.57	0.6949*
No risk factors	55.9	56.8	54.0	56.5	52.7	51.6	55.0	0.0132
Protective factors (%)								
Multiple gestation	0.92	0.82	0.66	0.51	0.76	0.38	0.71	0.0226
Cesarean delivery	2.80	3.78	4.23	5.19	6.13	6.06	4.42	< 0.0001

The corresponding *P*-value compares year 2000 data.
*The variable birth hypoxia was not available in 1997.
NA indicates not available.

2. Anatomy of the Brachial Plexus

- **Brachial plexus**
  - an intricate and complex network of nerves responsible for providing motor and sensory innervation to the right and left upper extremities.
  - Originates as an extension from the ventral rami of C5 through T1 spinal nerve roots
  - Organized into five zones: (1) roots, (2) trunks, (3) divisions, (4) cords, and (5) terminal nerve branches

- Roots
- Trunks
- Divisions
- Cords
- Nerves



Neurol Neurobiol (Tallinn). 2020 ; 3(2)

3. Classifications of NBPP

- Clinically, NBPP can be categorized by injury to any one of the spinal nerve roots (i.e., C5, C6, C7, C8, and T1) and associated functional deficit of the affected limb.

- **Spinal nerve roots and related upper extremity function**

Function	Brachial Plexus (BP) Spinal Nerve Root	
Shoulder	Abduction - external rotation	Adduction - internal rotation
	C5, C6	C5-Th1
Elbow	Flexion	Extension
	C5, C6	C6, C7, C8
Wrist	Supination	Extension
	C5, C6	C5, C6, C7
	Radial inclination	Flexion
	C5, C6, C7	C6, C7, C8
	Pronation	Ulnar inclination
	C6, Th1	C7, C8
Hand	Extrinsic muscles	Intrinsic muscles
	C7, C8, Th1	C8

Neurol Neurobiol (Tallinn). 2020 ; 3(2)

3. Classifications of NBPP

TABLE 5: Summary of selected classification instruments for NBPP from the literature

Classification Instrument	Measurement Focus	Age Range (yrs)	ICF Domain	Validated for NBPP
Narakas Classification Scale[1]	severity	0–18	body function & structures	no (but widely accepted)
Terzis Severity Scale[54]	severity	0–18	body function & structures	no
Impairment Rating Scale for Brachial Plexus Palsy[17]	severity	0–18	body function & structures	no
Sunderland Classification[53]	severity	0–18	body function & structures	no
Haerle Shoulder and Elbow Classification[21]	shoulder/elbow	0–18	body function & structures	no

TABLE 4: Articles reporting the most common brachial plexus injury classification instruments stratified by treatment category*

Injury Classification Instrument	Surgical (%)	Medical (%)	Mixed (%)	Total Articles
Narakas Classification Scale	14 (74)	8 (89)	4 (80)	26
Terzis Severity Scale	3 (16)	0	0	3
Impairment Rating Scale for BPP	1 (5)	1 (11)	0	2
Haerle Shoulder and Elbow Classification	1 (5)	0	0	1
Sunderland Classification	0	0	1 (20)	1
total	19 (100)	9 (100)	5 (100)	33

* No significant difference was found among the 5 instruments ($p = 0.81$). BPP = brachial plexus palsy.

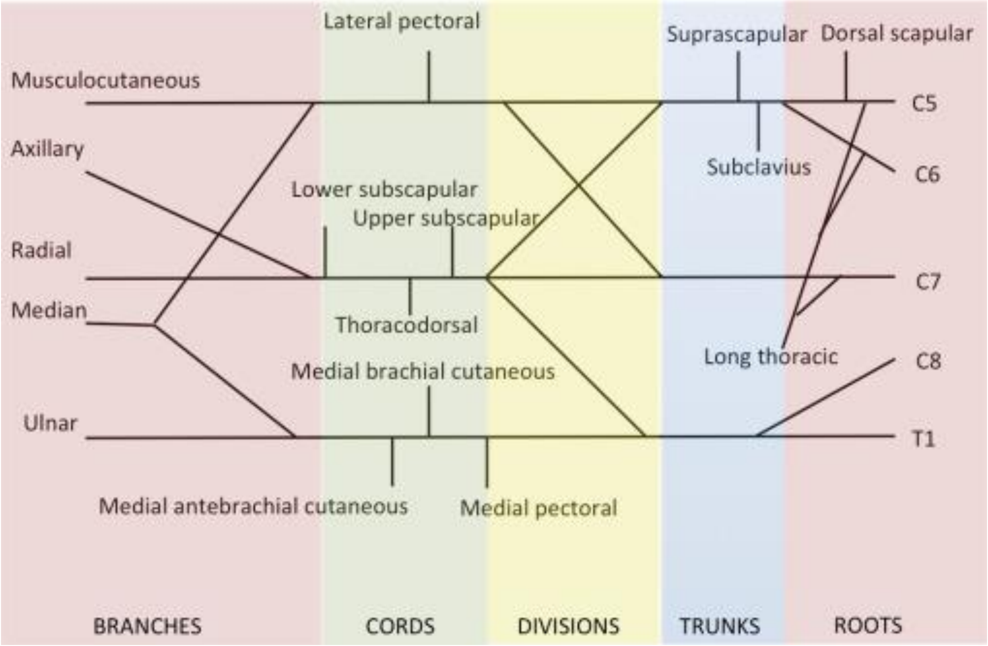
J Neurosurg Pediatrics 12:395–405, 2013

3. Classifications of NBPP

1) Classification according to the levels involved

- **Narakas Classification Scale**

Narakas Classification	Anatomical Location	Functional Deficit
Group I	C5-C6	Shoulder abduction, external rotation, elbow flexion, forearm supination
Group II	C5-C7	As above, plus wrist and digital extension
Group III	C5-T1	Flail extremity
Group IV	C5-T1	Flail extremity with Horner's syndrome



Neurol Neurobiol (Tallinn). 2020 ; 3(2)

3. Classifications of NBPP

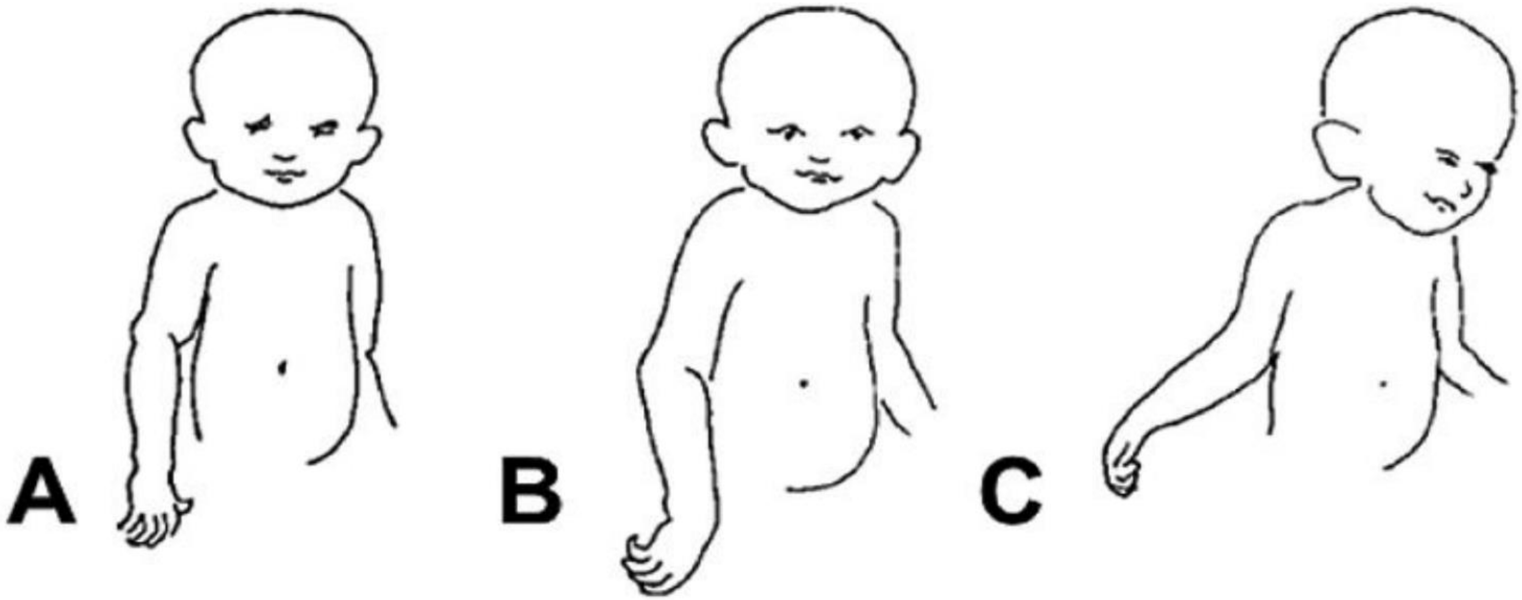
1) Classification according to the levels involved

- **Injury at C5 and C6: Erb's palsy (sometimes Erb-Duchenne palsy)**
  - m/c level of involvement (¾ of NBPP)
- **Injury at C8 and T1: Klumpke's palsy**
  - Debate on whether Klumpke's can occur in a NBPP.
  - The reason for this question is whether is anatomically possible to have a C8, T1 lesion without the involvement of C5-C7.
  - 3 possible cases
    - It appears that an anatomical variation (ex. rib, tendon, bony, or another anomaly) leads to the compromise of C8 and T1.
    - It was initially a complete NBPP, but there was quick recovery of C5 and C7
    - A spinal cord injury has been mistaken for NBPP.

Pediatric Rehabilitation 5th edition, p223-227

3. Classifications of NBPP

- **Representative images of the clinical presentation of NBPP**



C5-C6 spinal nerve roots

C5-C7 spinal nerve roots

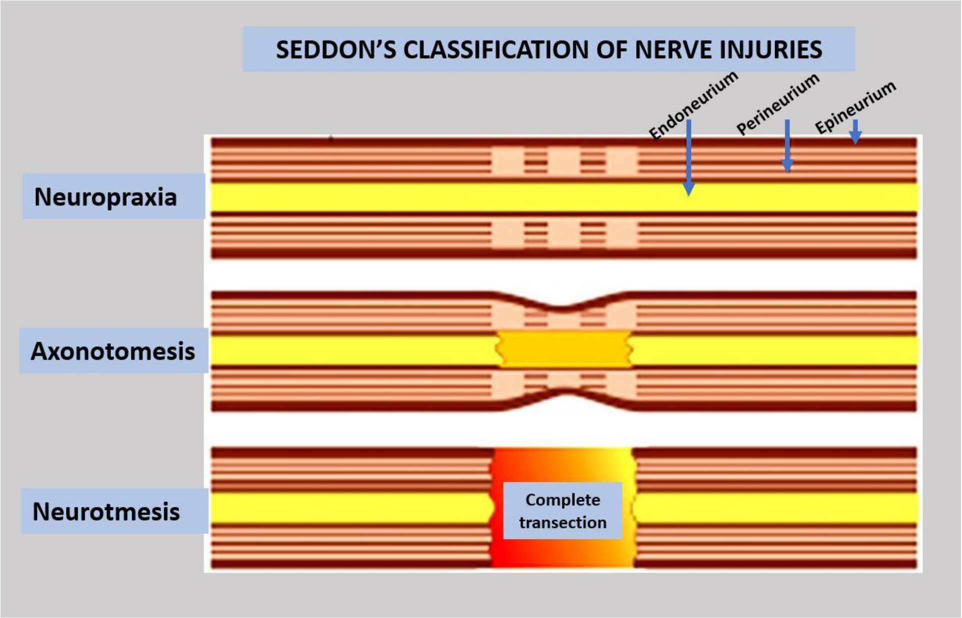
C5-T1 spinal nerve roots

Neurol Neurobiol (Tallinn). 2020 ; 3(2)

3. Classifications of NBPP

2) Classification based on pathological outcome

- **Seddon Classification of Nerve Injury**
  - **Neuropraxia:** Mild degree of insult → impulse conduction failure → conduction block, reversibility (+)
  - **Axonotmesis:** axon disrupted + endoneurial structure and connective tissue intact
  - **Neurotmesis:** axon and connective tissue disrupted

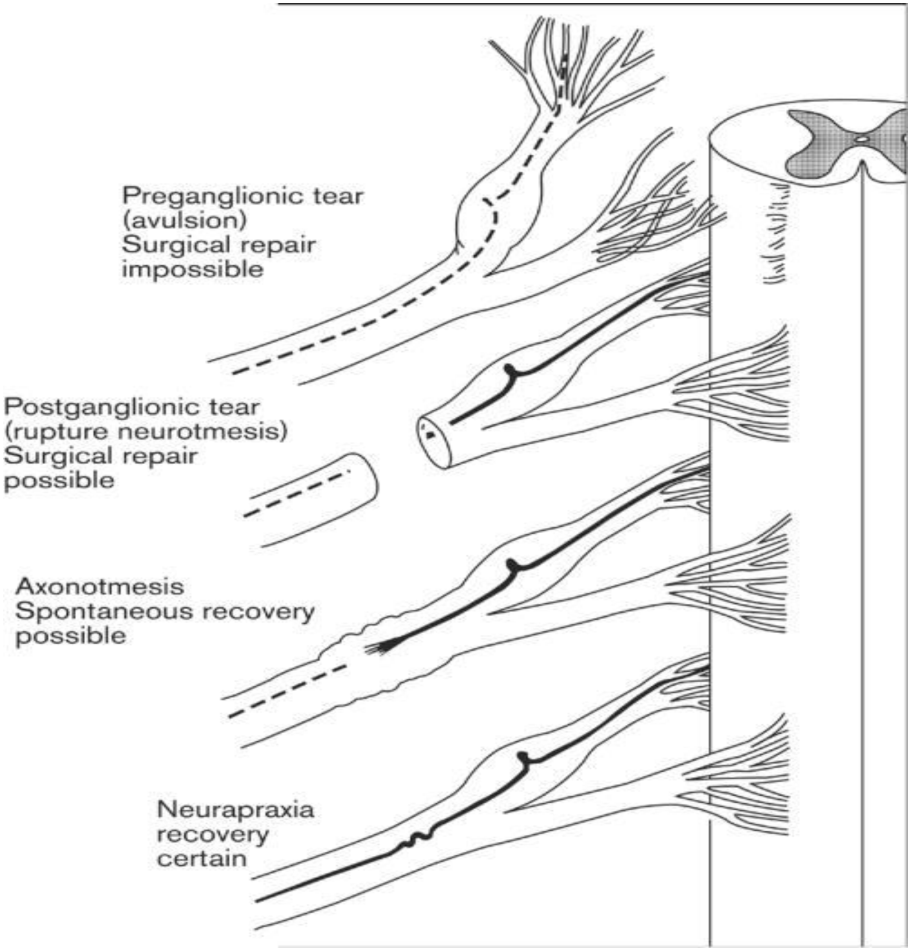


Neurol Neurobiol (Tallinn). 2020 ; 3(2)

3. Classifications of NBPP

3) Classification by their relationship to the dorsal root ganglion

- **Preganglionic**
  - Proximal to dorsal root ganglion
  - <u>Avulsion</u>
- **Postganglionic lesion**
  - Distal to the dorsal root ganglion
  - <u>Rupture</u>



Pediatric Rehabilitation 5th edition, p223-227
Childs Nerv Syst (2016) 32:1393–1397

4. Problems Associated with NBPP

1) Muscle imbalance

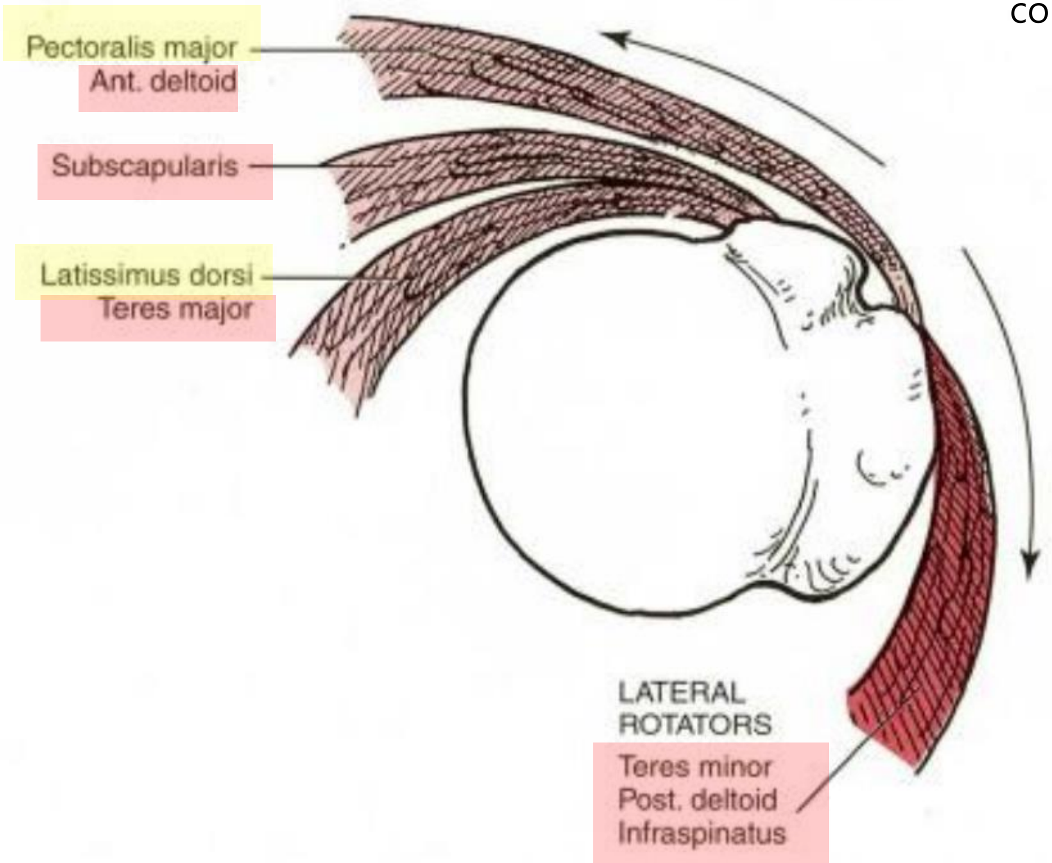
- **Infants with upper trunk NBPP palsies** who demonstrate considerable recovery within the first 2 months → usually recover normal function.

- However, infants with delayed recovery fail to regain full shoulder movement, because rotator cuff and deltoid innervation is incomplete.

J Hand Surg 2011;36A:1360–1369

4. Problems Associated with NBPP

1) Muscle imbalance



A 6-month-old child with left NBPP and internal rotation contracture

- Incomplete recovery

→ <u>muscle imbalance (strong internal rotators and weak external rotators)</u>

→ <u>an internal rotation contracture</u>

J Hand Surg 2011;36A:1360–1369

2) Contractures

- **Contractures:** a decreased range of movements of the joint due to changes in nonskeletal tissues

- **Shoulder contractures**
  - 56% of all NBPP patients (Hoeksma et al.)
  - Once established, shoulder contractures do not resolve spontaneously.

- **Elbow flexion contracture**
  - 48% prevalence (in a retrospective study of 319 patients with various NBPP)

3) Glenohumeral Joint Dysplasia (GHD)

- **GHD** is a set of skeletal alterations in the glenoid cavity and in the humeral head secondary to NBPP, which reversibility has not been clearly defined.

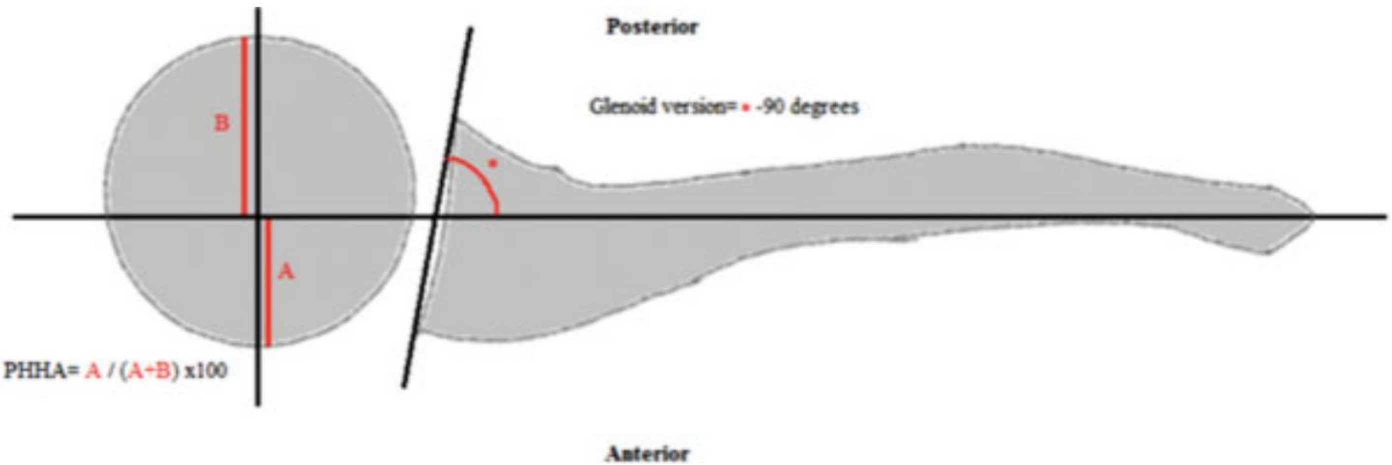
- **Classification**

	Waters' classification[13]
Grade	**Findings**
I	Normal glenoid (< 5 degrees difference in retroversion compared with normal, contralateral, side)
II	Minimum deformity (> 5 degrees difference in retroversion and no posterior subluxation of humeral head)
III	Moderate (posterior subluxation < 35%)
IV	Severe (pseudoglenoid formation)
V	Severe flattening of humeral head and glenoid, with progressive or complete posterior dislocation of humeral head
VI	Glenohumeral joint dislocation in infancy
VII	Growth arrest of proximal humerus

Journal of Brachial Plexus and Peripheral Nerve Injury Vol. 14 No. 1/2019

3) Glenohumeral Joint Dysplasia (GHD)

- **Percentage of humeral head posterior anterior to the middle of the glenoid fossa (PHHA)**
  - The length of the humeral head anterior to the middle of the spine of scapula is divided by the diameter of the humeral head.
- **Glenoid version (according to Friedman et al.)**
  - The angle between the spine of scapula and the glenoid surface is measured and subtracted by 90 degrees.



Journal of Brachial Plexus and Peripheral Nerve Injury Vol. 14 No. 1/2019

3) Glenohumeral Joint Dysplasia (GHD)

- **Correlation of Glenohumeral Joint Deformity to Contractures**
  - **Shoulder internal rotation contracture**

  → Humeral head in an internally rotated position

  → Excessive stress on both the humeral head and glenoid as they grow

  → GHD

  - **Kozin et al. (2004)**
    - 33 patients with residual brachial plexopathy (4.9 years of age, global lesions excluded)
    - <u>All children with internal rotation contracture had some degree of GHD.</u>

3) Glenohumeral Joint Dysplasia (GHD)

- **Correlation between GHD and Extent of NBPP**
  - Erb's paralysis or extended Erb's

  → paralysis of the external rotators but preservation of some internal rotators

  → greater muscle imbalance than total paralysis.

  - If muscle imbalance is the main factor causing contractures and GHD, an inverse correlation between GHD severity and extent of NBPP can be hypothesized.

  - Still on debate: positive result studies vs negative result studies

Journal of Brachial Plexus and Peripheral Nerve Injury Vol. 14 No. 1/2019

3) Glenohumeral Joint Dysplasia (GHD)

- **Anatomic Pathogenesis of GHD**
  - A much less likely etiology would be direct joint trauma during birth
    - The abnormal posture of the upper extremity in BPP patient

    → excessive force on the posterior part of the glenoid

    → erosion and/or inhibition of growth in that part of the glenoid

    → pseudoglenoid formation and posterior dislocation.

  - **The Hueter–Volkmann law**
    - Decreased stress on a growth plate increases bone formation, and excessive stress decreases bone formation

   → proposed as a hypothesis explaining GHD in NBPP.

Journal of Brachial Plexus and Peripheral Nerve Injury Vol. 14 No. 1/2019

3) Glenohumeral Joint Dysplasia (GHD)

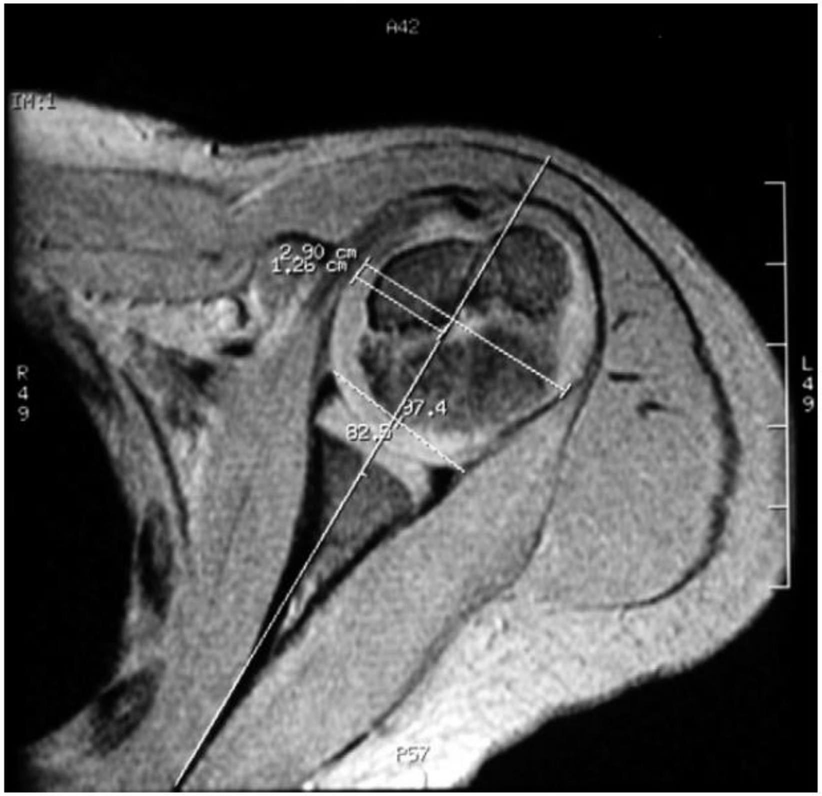


FIGURE 2: An MRI of a normal left shoulder. The cartilage is readily apparent around the humeral head and the glenoid cavity is readily visible. The lines for calculating the glenoscapular version angle (−8°) and PHHA (43%) are drawn. (Courtesy of Shriners Hospital for Children, Philadelphia Unit.)

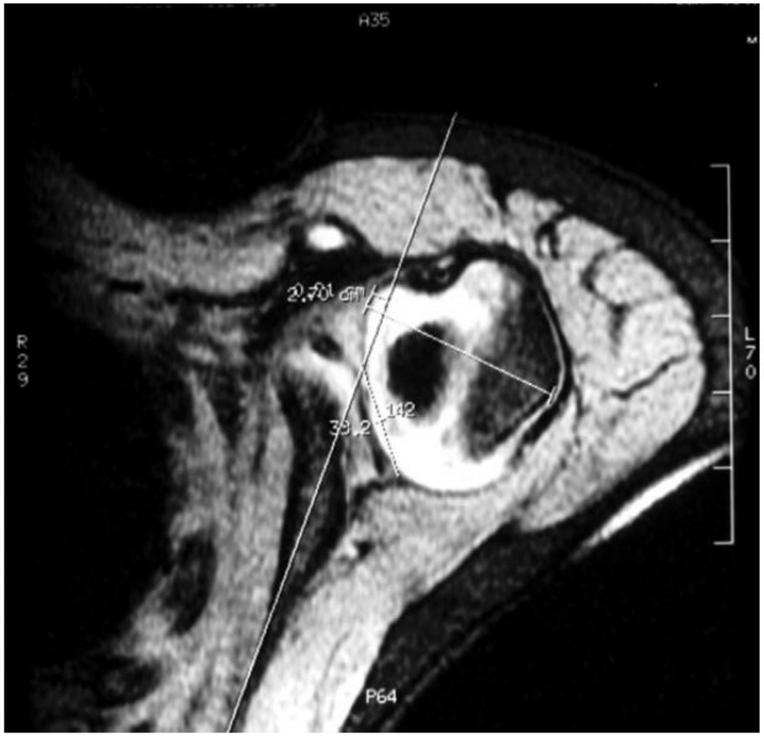


FIGURE 3: Shoulder MRI of a 4-year-old with −10° of passive external rotation. The humeral head articulates with a posterior articular concavity that is markedly retroverted and measures −51°. The humeral head barely crosses the midportion of the glenoid (percentage of humeral head anterior to the middle is 0.21 cm/2.7 cm, or 8%). (Courtesy of Shriners Hospital for Children, Philadelphia Unit.)

J Hand Surg 2011;36A:1360–1369

Original Article
Torticollis Associated With Neonatal Brachial Plexus Palsy

4) Torticollis

- Torticollis can occur concurrently with NBPP.
- Kennedy first recognized the association in 1903.
- A retrospective review of 128 NBPP patients evaluated at the University of Michigan from 2005-2009 → 43% presented concurrently with torticollis.
- Usually face is turned away from the involved arm
- Presence of torticollis was not related to severity and does not affect the probability of recovery from NBPP.
- Recovery from torticollis: 62% of patients by 23 ± 12 weeks with conservative management.

Pediatric Neurology 45 (2011) 305-310

5) Shorter and decreased circumference of the affected arm

- In patients with total palsies: length discrepancies of the humerus, ulna, metacarpals, and phalanges between affected and unaffected side
- In patients with Erb's palsy: discrepancy in the length of the humerus.

Pediatric Traumatology, orthopaedics and reconstructive surgery, 2018, Vol 6, No 2, 22-28

Journal of Brachial Plexus and Peripheral Nerve Injury Vol. 14 No. 1/2019

6) Effect on development

- **Activity limitation**
  - Unable to reach, grasp, and perform bilateral manual task such as catching a large ball, lifting a large object.

- **Self-care limitation**
  - In putting and removing shirts and pants, tying shoes, and buttoning

- **Abnormal development**
  - Movement from prone to sit may be done from one side
  - Asymmetrically strengthening one side of the trunk or delaying balance reactions.

Pediatric Rehabilitation 5th edition, p223-227

7) Clavicle fracture

- **NBPP ← Shoulder dystocia → Fractures of the clavicle**

- **Method:** 1997 to 2012 Kids' Inpatient Database (KID), 23,385,597 population births
- **Results**
  - A BPBP: 1.2/1,000 births
  - Shoulder dystocia: 18.8% of births with a NBPP
  - Clavicle fracture: 7.84% of newborns with a NBPP
  - Shoulder dystocia without clavicle fx: independent risk factor for NBPP (OR 112.1).
  - Shoulder dystocia and clavicle fx: risk for NBPP (OR, 126.7)
  - Multivariable regression showed that, in the setting of shoulder dystocia, the presence of a clavicle fracture (odds ratio, 126.7 vs 112.1; P = .26) was not statistically associated with either decreased or increased risk of NBPP.

J Hand Surg Am. r Vol. 44, June 2019

4. Problems Associated with NBPP

8) Other problems

- **Lack of awareness of the arm**
- **Ulceration from relatively minor trauma**, particularly in insensate areas
- **Pain:** infrequent after NBPP
- **Scoliosis:** sometimes been linked to NBPP
  - But two studies have found no correlation.
- **Self-mutilating behavior** by biting or mouthing the affected arm
  - Age onset: 11-21 months / Duration of behavior: 4-7 months
  - Cause: unclear (severity of the injury? Unusual sensation of the recovering nerve? Surgery?)

Pediatric Rehabilitation 5th edition, p223-227

4. Problems Associated with NBPP

(Case presentation)

- A full term baby (3200g) born by vacuum extraction after a normal pregnancy.

- Directly after birth, no active motion in the left upper limb was seen apart from slight finger flexion. → NBPP diagnosed by physical examination.

- Physiotherapy with full range of motion exercises (once a week) began one week after birth and the parents were taught how to place the baby's arm in a well supported position in order to protect the shoulder joint.

Disabil Rehabil. 2003 Jan 7;25(1):1-8

4. Problems Associated with NBPP

(Case presentation)

Table 1. Passive range of motion (pROM) of the left shoulder in a girl with left-sided OBPI, as documented in the case records at varying ages

pROM	Age 2 mth	4 mth	5 mth	9 mth	1.5 yr	2.5 yr	3.5 yr	4.5 yr
Total abduction	180°	180°	180°	170°	170°	170°	170°	180°
Glenohum. abd.	90°	90°	90°	80°	80°	80°	90°	80°
External rotation	80°	60°	70°	80°	90°	80°	80°	70°
Internal rotation	60°	50°	50°	45°	50°	40°	35°	0°
Horiz. adduction*	normal	↓	↓↓	↓↓	↓↓	↓↓↓	↓↓↓	↓↓↓

* Horizontal adduction was not documented in grades but only in "normal", "slightly diminished" (↓), "diminished" (↓↓), or "strongly diminished" (↓↓↓)

- **2 months:** completely paralyzed elbow flexors and supinator muscle/ improved function of the C7 musculature / normal hand function

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* Horizontal adduction was not documented in grades but only in "normal", "slightly diminished" (↓), "diminished" (↓↓), or "strongly diminished" (↓↓↓)

- **4 months:** she could perform active motions against gravity in all directions with her arm, although not all muscle groups yet showed normal strength.
- **Exercises:** daily by the parents + once a week by the physiotherapist.

Disabil Rehabil. 2003 Jan 7;25(1):1-8

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* Horizontal adduction was not documented in grades but only in "normal", "slightly diminished" (↓), "diminished" (↓↓), or "strongly diminished" (↓↓↓)

- **5 months:** neurological recovery was complete, all muscle groups showed normal strength

Disabil Rehabil. 2003 Jan 7;25(1):1-8

(Case presentation)

Girl at the age of 5 months with a left-sided BPP.
Asymmetrical shoulder contour

A hypoplastic glenoid promontory (arrow) and an inferior subluxation at the left side at 6 months

Disabil Rehabil. 2003 Jan 7;25(1):1-8

4. Problems Associated with NBPP

(Case presentation)

Table 1. Passive range of motion (pROM) of the left shoulder in a girl with left-sided OBPI, as documented in the case records at varying ages

	Age							
pROM	2 mth	4 mth	5 mth	9 mth	1.5 yr	2.5 yr	3.5 yr	4.5 yr
Total abduction	180°	180°	180°	170°	170°	170°	170°	180°
Glenohum. abd.	90°	90°	90°	80°	80°	80°	90°	80°
External rotation	80°	60°	70°	80°	90°	80°	80°	70°
Internal rotation	60°	50°	50°	45°	50°	40°	35°	0°
Horiz. adduction*	normal	↓	↓↓	↓↓	↓↓	↓↓↓	↓↓↓	↓↓↓

* Horizontal adduction was not documented in grades but only in "normal", "slightly diminished" (↓), "diminished" (↓↓), or "strongly diminished" (↓↓↓)

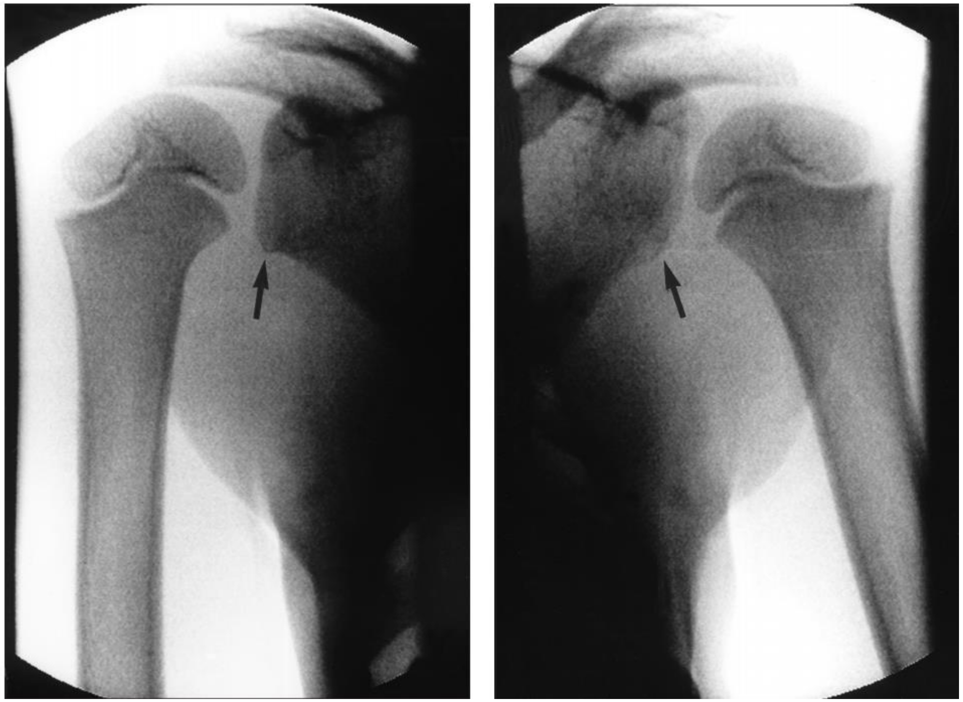
- 4.5 years: normal strength, symmetric arm use
- However, the contours remained asymmetrical.

Disabil Rehabil. 2003 Jan 7;25(1):1-8

4. Problems Associated with NBPP

(Case presentation)

Right Left



4.5 year: left shoulder showing a hypoplastic promontory (arrow). No subluxation

Disabil Rehabil. 2003 Jan 7;25(1):1-8

5. Clinical Examination

- **History taking**
  - Birth number of the child
  - Birth weight
  - Presence of maternal diabetes during the pregnancy
  - Size of previous infants
  - Birth size of the parents
  - Motor and sensory findings at birth
  - The use of vacuum or forceps: may be indicative of any difficulty with delivery
  - Shoulder dystocia
  - Whether there were signs of bruising or other injuries
  - Whether there was involvement of the contralateral arm or the legs at delivery

Pediatric Rehabilitation 5th edition, p223-227

5. Clinical Examination

- **Physical examination**
  - **Visualization of the arm** (including size and bulk)
  - **A cool temperature** may be noted in those with severe involvement
  - **Sensory evaluation:** critical to determine the extent and levels of involvement
  - **Muscle stretch reflexes:** decreased or absent in the distribution of a NBPP.
  - **Primitive reflexes**
    - Moro reflex (shoulder abduction and elbow flexion) → valuable in assessing those active movements
  - **Torticollis**
  - **ROM**
    - <u>Contractures</u> common in shoulder adduction and internal rotation, wrist flexion, forearm pronation, and even at the elbow into flexion commonly in later months and years

Pediatric Rehabilitation 5th edition, p223-227

5. Clinical Examination

- **Evaluation for a bony injury,** as a fracture to the clavicle or humerus

- **Respiratory status and symmetry of chest movements** should also be assessed.
  - Phrenic nerve (composed of nerves C3, C4, and C5) can be involved in more proximal brachial plexus injuries.

- Horner syndrome, hemidiaphragm paralysis from phrenic nerve injury, and winging of the scapula (injury to the long thoracic nerve)

  → suggestive of an avulsion injury

J Neurosurg Pediatrics 12:395–405, 2013

5. Clinical Examination

TABLE 8: Articles reporting the most common physical assessment methods for NBPP stratified by treatment category*

Physical Assessment Method	Surgical (%)	Medical (%)	Mixed (%)	No. of Articles
ROM	122 (32)	33 (25)	16 (18)	171
Mallet Scale	78 (20)	18 (14)	12 (14)	108
MRC Scale	71 (18)	18 (14)	13 (15)	102
Active Movement Scale	18 (5)	8 (6)	12 (14)	38
Narakas Motor Scale	5 (1)	6 (5)	3 (3)	14
Gilbert Shoulder Scale	16 (4)	4 (3)	3 (3)	23
Raimondi Hand Scale	17 (4)	6 (5)	2 (2)	25
sensory	1 (0)	6 (5)	2 (2)	9
other†	58 (15)	32 (24)	26 (29)	116
total	386 (100)	131 (100)	89 (100)	606

* No significant difference was found among the most common assessment methods ($p = 0.22$).
† See *Appendix* for other assessments reported (< 3%).

J Neurosurg Pediatrics 12:395–405, 2013

5. Clinical Examination

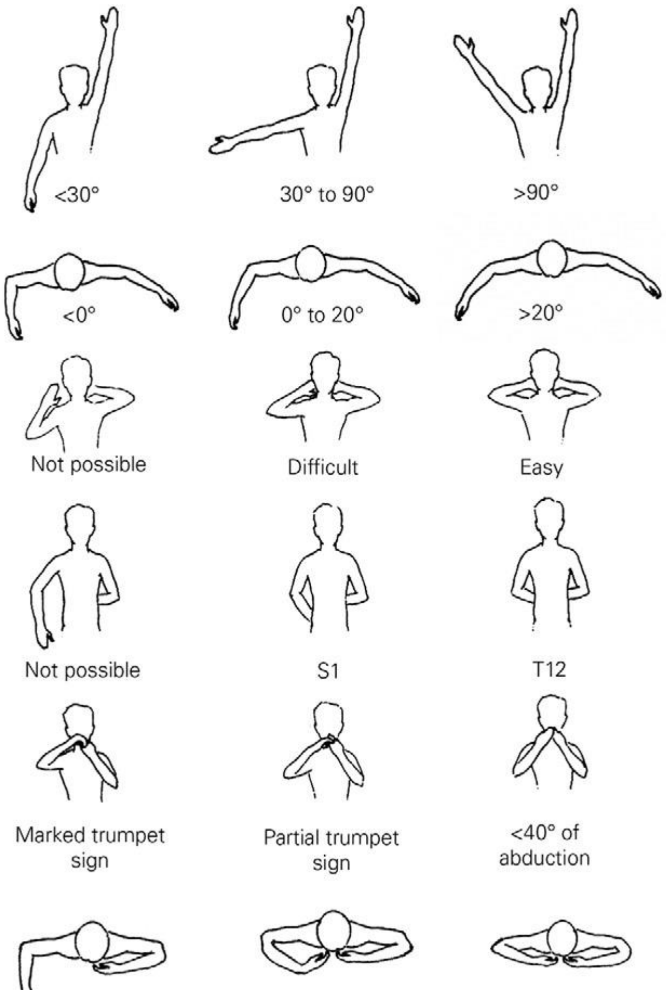
1) Range of Motion

- **ROM of the involved arm and cervical area**

- The child's joints can be unstable and the limbs may have sensory loss, all movements should be performed with great care.

2) Modified Mallet classification

Modified Mallet classification (Grade I = no function, Grade V = normal function)



	Not Testable	Grade I	Grade II	Grade III	Grade IV	Grade V
Global Abduction	Not Testable	No function	<30°	30° to 90°	>90°	Normal
Global External Rotation	Not Testable	No function	<0°	0° to 20°	>20°	Normal
Hand to neck	Not Testable	No function	Not possible	Difficult	Easy	Normal
Hand to spine	Not Testable	No function	Not possible	S1	T12	Normal
Hand to mouth	Not Testable	No function	Marked trumpet sign	Partial trumpet sign	<40° of abduction	Normal
Internal rotation	Not Testable	No function	Cannot Touch	Can touch with wrist flexion	Palm on belly No wrist flexion	Normal

J Hand Surg 2011;36A:1360–1369

3) Medical Research Council (MRC) Scale

Grade 0	No contraction visible or palpable
Grade 1	Flicker of contraction visible or palpable, although no limb movement
Grade 2	Movement with gravity eliminated over almost full range of motion
Grade 3	Movement against gravity over almost full range of motion
Grade 4	Movement against moderate resistance over full range of motion
Grade 5	Normal power

J Hand Surg 2011;36A:1360–1369

4) Gilbert's Rating

Table 3. Gilbert's Rating for Shoulder Paralysis*

Stage	Description
0	Flail shoulder
I	Abduction or flexion to 45°
	No active lateral rotation
II	Abduction <90°
	Lateral rotation to neutral
III	Abduction 90°
	Weak lateral rotation
IV	Abduction <120°
	Incomplete lateral rotation
V	Abduction >120°
	Active lateral rotation

*Assumes full passive range of motion.

Table 4. Gilbert's Elbow Scale

	Score
Flexion:	
Nil or some contraction	1
Incomplete flexion	2
Complete flextion	3
Extension:	
No extension	0
Weak extension	1
Good extension	2
Extension deficit:	
0-30°	0
30-50°	1
>50°	2

5) Raimondi's Hand Evaluation Scale

Table 5. Raimondi's Hand Evaluation Scale for Children With Obstetric Brachial Palsy

Grade	Description
0	Complete paralysis or slight finger flexion of no use; useless thumb—no pinch; some or no sensation
I	Limited active flexion of fingers; no extension of wrist or fingers; possibility of thumb lateral pinch
II	Active flexion of wrist, with passive flexion of fingers (tendosis); passive lateral pinch of thumb
III	Active complete flexion of wrist and fingers; mobile thumb with partial abduction—opposition. Intrinsic balance; no active supination; good possibilities for palliative surgery
IV	Active complete flexion of wrist and fingers; active wrist extension; weak or absent finger extension. Good thumb opposition, with active ulnaris intrinsics; partial pronosupination
V	Hand IV, with finger extension and almost complete pronosupination

6) Toronto Score Grading System

Observation	Muscle grade
Gravity eliminated	
No contraction	0
Contraction, no movement	1
Movement < ½ range	2
Movement > ½ range	3
Full movement	4
Against gravity	
Movement < ½ range	5
Movement > ½ range	6
Full movement	7

6) Towel Test

Fig 1 (a) Nine-month-old girl with Erb's palsy on the left side is assessed with the towel test. Ninety degree of elbow flexion is observed but she is unable to remove the towel. The unaffected side is immobilized by the examiner's hand. A deltoid muscle electromyogram is being recorded with surface electrodes, and is seen in the inset side (b) and (c). The infant completes the test on the normal side.

Journal of Hand Surgery (British and European Volume, 2004) 29B: 2: 155–158

5. Clinical Examination

TABLE 9: Summary of selected physical assessment measures for NBPP from the literature*

Physical Assessment Method	Measurement Focus	Joint	Age Range (yrs)	Validated for NBPP
ROM	movement	whole arm	0–18	no
MRC Scale[31]	movement	whole arm	0–18	no
Active Movement Scale[14]	movement	whole arm	0–18	yes[2,3,14]
Narakas Motor Scale[56]	movement	whole arm	0–18	no (widely accepted)
Toronto Scale[2]	movement	whole arm	3–6 mos	yes[3]
Mallet Scale[3]	movement	shoulder/elbow	>2	yes[3,37]
Gilbert Shoulder Scale[22]	movement	shoulder	0–18	no
Gilbert-Raimondi Elbow Scale[19]	movement	elbow	0–18	no
Raimondi Hand Scale†	movement	hand	0–18	no
Martin Vigorimeter	movement	hand/finger	3–18	no
sensory‡	sensory	whole arm	>2	no
2-PD[8]	sensory	whole arm	≥6	no
Pick-up Test	sensory	whole arm	≥5	no

* Subspecialty tools reported > 3% are included; see *Appendix* for tools reported < 3%. All methods assessed the Body Function and Structures measure of the ICF. 2-PD = two-point discrimination.

† Presented at the International Meeting on Obstetric Brachial Plexus Palsy, 1993.

‡ Normal, abnormal; subjective light touch.

J Neurosurg Pediatrics 12:395–405, 2013

6. Diagnostic evaluations of NBPP

- Electrodiagnostic technique
- CT
- MRI
- Ultrasonography
- Others

TABLE 6: Articles reporting the most common diagnostic methods for NBPP stratified by treatment category*

Diagnostic Method	Surgical (%)	Medical (%)	Mixed (%)	No. of Articles
EMG	19 (23)	10 (38)	5 (45)	34
MRI	23 (27)	5 (19)	3 (27)	31
CT	19 (23)	3 (12)	1 (9)	23
radiography	15 (18)	6 (23)	1 (9)	22
other†	8 (10)	2 (8)	1 (9)	11
total	84 (100)	26 (100)	11 (100)	121

* No significant difference was found among the diagnostic methods ($p = 0.38$).
† Other diagnostic methods reported (in < 1% of the studies) include: histological examination, morphometry, myelography, neurohistopathology, radiographic classification of glenohumeral deformity, winged scapula (scapula alata), CT scanogram with Spearman correlation, ultrasonography.

J Neurosurg Pediatrics 12:395–405, 2013

6. Diagnostic evaluations of NBPP

1) Nerve Conduction Study and Electromyography

- **Electrodiagnostic technique**
  - help provide information regarding the location of nerve injury
  - are also strongly correlated with the severity of injury
  - serve as an invaluable tool for the diagnosis and prognosis of NBPP by offering evidence about the location, severity, and type of nerve injury

- **A high inter-rater reliability assessment of nerve root lesions of NBPP**
  - Two reviewers agreed on injury assessment for C5 (38%), C6 (78%), C7 (92%), C8 (81%), T1 (84%), and all (75%) nerve roots in a study of NBPP by Spires et al. (2017)

Neurol Neurobiol (Tallinn). 2020 ; 3(2)

1) Nerve Conduction Study and Electromyography

(1) Sensory nerve conduction studies

- Helps distinguish if injuries are proximal or distal to the dorsal root ganglion
- **Lesions proximal to the dorsal root ganglion (preganglionic lesion)**
    - Intact SNAPs
- **Lesions distal to the dorsal root ganglion (postganglionic lesion)**
    - Impaired or absent SNAPs
- Sensory nerve action potentials (SNAP) measure the extent of axonal loss through conduction velocity and amplitude.

Neurol Neurobiol (Tallinn). 2020 ; 3(2)

1) Nerve Conduction Study and Electromyography

(2) Motor nerve conduction studies

- **Compound muscle action potentials (CMAP)** represent the summation of motor units and is proportional to the amplitude.
- A reduction or loss of CMAP amplitude indicates fewer or no motor neurons recruited, respectively, which help detect the extent of innervation to the muscle of interest.

(3) Needle EMG

- **EMG** records the electrical activity of motor fibers to detect signs of denervation and reinnervation.

Neurol Neurobiol (Tallinn). 2020 ; 3(2)

1) Nerve Conduction Study and Electromyography

(3) Interpretation of the results

- **Demyelinating nerve lesions**
  - NCS: slow conduction and conduction block across the site of demyelination
- **Axonal loss lesions**
  - NCS: CMAP amplitudes↓, normal conduction velocities (CV)
  - EMG: fibrillation potentials and positive sharp waves
- **Neurotmesis:** absence of CMAPs and motor unit activity

Neurol Neurobiol (Tallinn). 2020 ; 3(2)

6. Diagnostic evaluations of NBPP

INVITED REVIEW

Answer questions and earn CME https://education.aanem.org/URL/JR65.

CME MUSCLE&NERVE WILEY

Early electrodiagnosis in the management of neonatal brachial plexus palsy: A systematic review

- **A systematic literature review to determine the prognostic value of early electrodiagnosis (EDx) in NBPP**

- 16 observational studies, 747 children included

- **Methods of electrodiagnosis**
  - 4 studies: needle EMG
  - 2 studies: included the amplitude of the compound muscle action potential (CMAP) as a single technique
  - 5 studies: combined EMG with complete nerve conductions studies (NCS), including motor and sensory action potentials and conduction velocities
  - 2 studies: only motor NCS and EMG.
  - 1 study: Somatosensory evoked potentials (SEPs): none preoperative, and only one intraoperative
  - 3 studies: intraoperative NCS (1: intraoperative NCS, EMG, and gross motor response to stimulation)

Muscle & Nerve. 2020;61:557–566.

6. Diagnostic evaluations of NBPP

INVITED REVIEW

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CME MUSCLE&NERVE WILEY

Early electrodiagnosis in the management of neonatal brachial plexus palsy: A systematic review

- **The timing of the electrodiagnosis**
  - first (preoperative) EDx intervention: 5 days ~ 14 months after birth
  - Intraoperative EDx: 3 months ~ 19 months after birth.
  - Serial EDx
    - 2 EDx: 1 study
    - 3 EDx: 1 study (over a period of 9 to 87 days after birth)

- **Detailed information about the surface and/or needle electrodes, or set-up parameters:** only in 8 studies

Muscle & Nerve. 2020;61:557–566.

6. Diagnostic evaluations of NBPP

INVITED REVIEW

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CME MUSCLE&NERVE WILEY

Early electrodiagnosis in the management of neonatal brachial plexus palsy: A systematic review

- **Recommendation**
  - **Use of appropriately sized electrodes and stimulation probes.**
  - **Use of a combination of NCS (including CMAP and SNAP) and EMG.**
    - EMG only: useful for topographic diagnosis, but a less quantitative source with regard to prognosis
    - NCS of nontraditional nerves (axillary, musculocutaneous, and radial nerves) sometimes required.
  - **Severity of lesion** should be classified according to the degree of injury of axons and their supporting structures.
  - **Comparing distal and proximal CMAP:** can estimate conduction block
  - **Side-to-side comparison of the amplitudes of CMAP:** <u>can estimate the amount of motor axonal degeneration of the terminal nerves</u> arising from the brachial plexus → **the axonal viability index (AVI)** (ratio of the amplitude of the CMAP of the involved side to that of the unaffected limb) can be used.

Pediatric Rehabilitation 5th edition, p223-227

Muscle & Nerve. 2020;61:557–566.

6. Diagnostic evaluations of NBPP

Motor Nerve-Conduction Studies in Obstetric Brachial Plexopathy for a Selection of Patients with a Poor Outcome

- 44 patients with unilateral NBPP (10-60 days old)
- Bilateral motor NCS → AVI calculation
- Group A, B, C according to the clinical outcome
- ROC curve of each index to define the best cutoff point to detect patients with a poor recovery

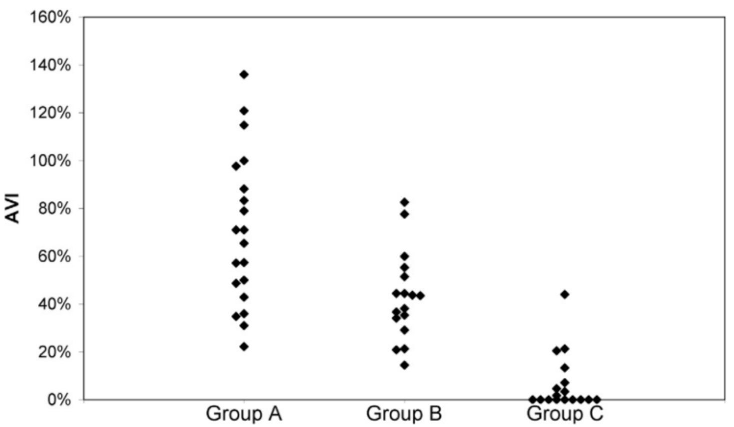

Fig. 1
Distribution of axonal viability indices (AVI) of the proximal radial motor nerve in the three groups. Group C corresponds to the poor outcome group.

E II Cutoff Point, Sensitivity, and Specificity of Each Criterion for Poor Outcome

Criteria	Cutoff Point	Sensitivity (95% Confidence Interval)	Specificity (95% Confidence Interval)
Neurophysiologic criteria *(axonal viability index)*			
Axillary nerve	<10%	88% (64%-98%)	89% (75%-97%)
Musculocutaneous nerve	0%	88% (64%-98%)	73% (56%-86%)
Proximal radial nerve	<20%	82% (57%-96%)	97% (86%-100%)
Distal radial nerve	<50%	82% (57%-96%)	97% (86%-100%)
Ulnar nerve	<50%	59% (33%-82%)	97% (86%-100%)
Clinical criterion			
Biceps score on Medical Research Council motor scale at 3 mo	<2	94% (71%-100%)	81% (65%-92%)

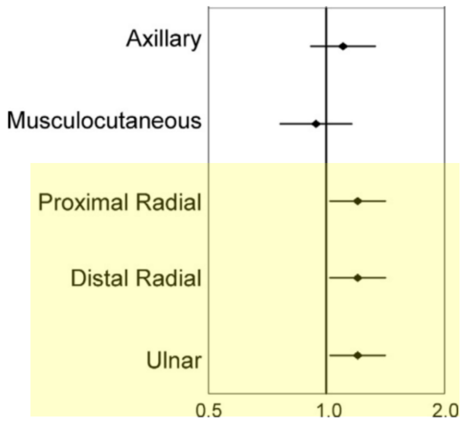

Fig. 9
Specificity of the neurophysiologic criteria in relation to the clinical criterion. The diamonds represent the ratio, and the horizontal bars represent the 95% confidence interval. Horizontal bars crossing the vertical bold line indicate no significant difference in specificity between the methods.

J Bone Joint Surg Am. 2009;91:1729–37

6. Diagnostic evaluations of NBPP

INVITED REVIEW

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CME MUSCLE&NERVE WILEY

Early electrodiagnosis in the management of neonatal brachial plexus palsy: A systematic review

- **Recommendation**
  - **Sensory NCS:** an important prognostic tool for detecting root avulsions
  - **Main criteria for avulsion**
    - presence of normal SNAP or greater than 50% of normal compared with the uninvolved site or laboratory norms
    - EMG abnormalities in the correlated muscle
  - **When both pre- and postganglionic lesions are present**, as this can lead to inaccurate labeling of the injury as an isolated postganglionic lesion.
  - **Serial EDx** at standardized time-frames, the first performed at the nadir of the loss of motor units and the second around the time of decision making for surgery. The nadir time-point is currently unknown, and this warrants further investigation.

Muscle & Nerve. 2020;61:557–566.

  - EMG at 1 month has been shown to have the best prediction for recovery in babies.

Pediatric Rehabilitation 5th edition, p223-227

6. Diagnostic evaluations of NBPP

INVITED REVIEW

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CME MUSCLE&NERVE WILEY

Early electrodiagnosis in the management of neonatal brachial plexus palsy: A systematic review

- **Recommendation**
  - **Inclusion of the following key elements in a final EDx report**
    - Diagnosis
    - Timing of the lesion
    - Location and extent of the injury
    - Recruitment of affected muscles
    - Evolution in time of the lesion
    - Accurate prognosis estimation

Muscle & Nerve. 2020;61:557–566.

6. Diagnostic evaluations of NBPP

2) CT myelography

- **Injury involving the intradural segment** (such as when a nerve root is torn directly from the spinal cord → nerve root avulsion / preganglionic lesion)

- **Limitation**
  - General anesthesia
  - Lumbar puncture to introduce the intrathecal contrast
  - Exposure to ionizing radiation

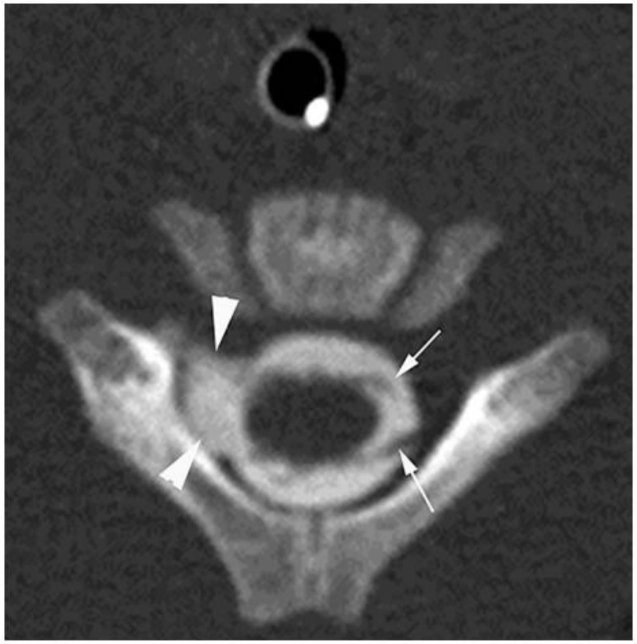


Fig. 2 CT myelogram from a 4-month-old boy with right brachial plexus palsy shows avulsion of both ventral and dorsal nerve roots on the right side at C5 level with a pseudomeningocele (*arrowheads*). Note normal ventral and dorsal nerve roots on the left side (*arrows*)

Childs Nerv Syst (2016) 32:1393–1397

6. Diagnostic evaluations of NBPP

3) Noncontrast high-resolution MRI

- The modality of choice to visualize individual nerve roots
- Sensitivity and specificity for nerve root avulsions: 75 and 82 %

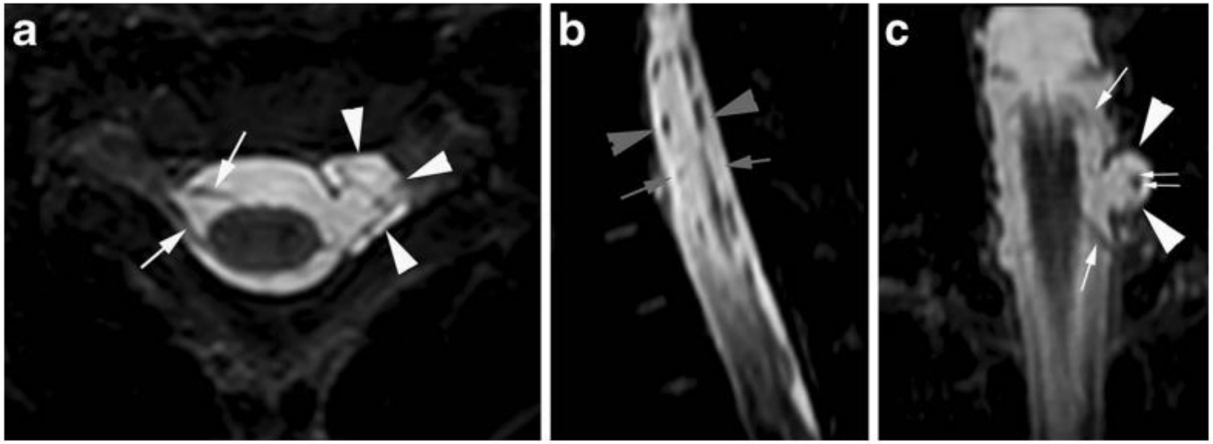


Fig. 3 **a** Axial high-resolution MRI from a 6-month-old girl with clinically suspected left-sided brachial plexus palsy shows intact right C6 ventral and dorsal nerve roots (*arrows*). There is avulsion of the left-sided C6 ventral and dorsal nerve roots and a huge pseudomeningocele (*arrowheads*). **b** Sagittal reformatted image from the left side shows absent ventral and dorsal nerve roots (*arrows* at expected positions) compared to normal nerve roots at C5 level (*arrowheads*). **c** Coronal reformatted image once again shows a huge pseudomeningocele at left C6–7 level (demarcated by *arrowheads*) with absent ventral and dorsal nerve roots. Rounded structure within the pseudomeningocele (*double arrows*) may represent one of the avulsed nerve roots. Normal C5 and C7 nerve roots are also seen (*arrows*)

Childs Nerv Syst (2016) 32:1393–1397

6. Diagnostic evaluations of NBPP

4) Ultrasonography

- Used for the detection and characterization of neuromas, for detection of specific muscle atrophy, and for evaluation of glenohumeral joint stability

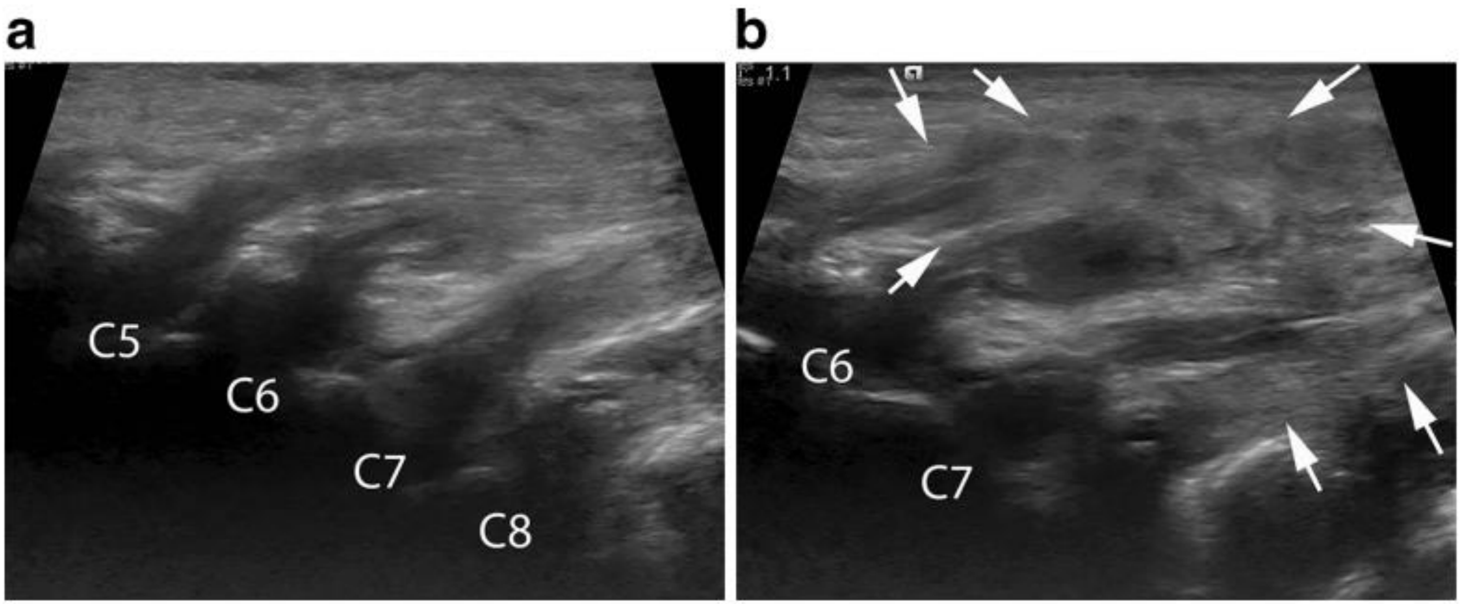


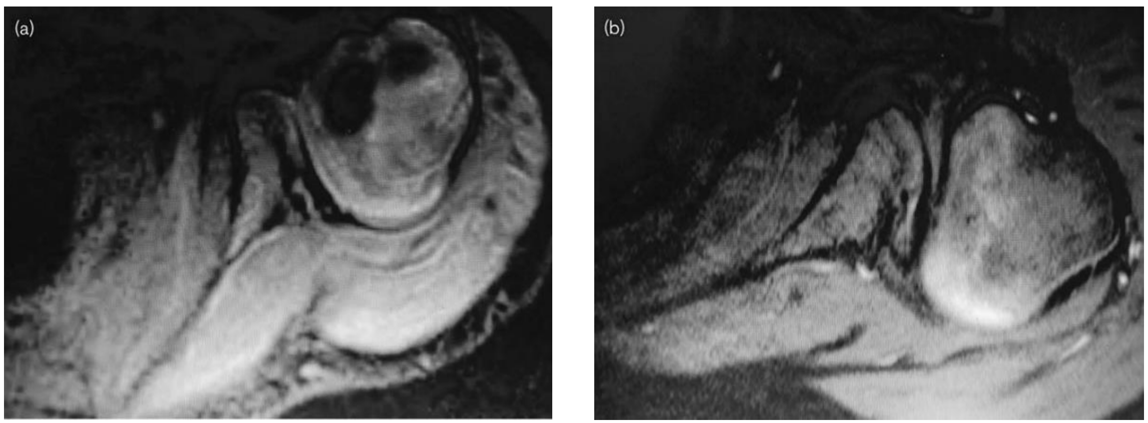
Fig. 4 Ultrasound images from a 3-month-old infant with left-sided brachial plexus palsy. **a** Oblique coronal ultrasound image on the right side shows normal appearance of exiting cervical nerve roots. **b** Oblique coronal ultrasound image on the left side shows echogenic neuroma (*arrows*) with swelling and echogenicity of exiting nerve roots

Childs Nerv Syst (2016) 32:1393–1397

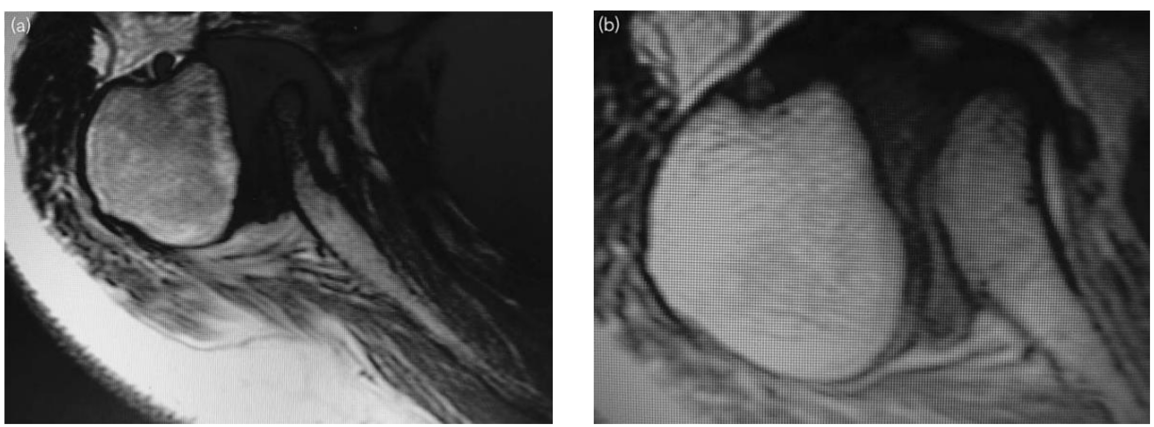
6. Diagnostic evaluations of NBPP

5) Shoulder MRI

- Excellent visualization of the bone contours, hyaline cartilage and muscles.
- The degree of joint congruence and the presence of dysplastic features



Transverse shoulder MRI: humeral head subluxation (Lt: mild; Rt: severe).



Transverse shoulder MRI: glenohumeral dysplasia.

Journal of Pediatric Orthopaedics B 2007, Vol 16 No 4

6. Diagnostic evaluations of NBPP

6) Plain x-rays

- Some abnormalities may mimic a NBPP, including a fracture of the clavicle or humerus.

- Osteomyelitis may also mimic this, and has actually been reported as inciting temporary brachial plexus palsy.

- Neurofibromatosis or other tumors may also damage the brachial plexus.

Childs Nerv Syst (2016) 32:1393–1397

6. Diagnostic evaluations of NBPP

<Comparison of EDx and imaging studies>

- The ideal workup requires the combination of clinical examination, EDx, and imaging techniques, as the strengths of each test often compensate for the other's weaknesses.

- **Limitations of EDx**
  - EDx measures primarily reflect nerve and muscle function and not the internal architecture of the nerve, the quality of damaged nerve, or the anatomical variability.

- **EDx outperformed imaging** with regard to specificity and accuracy of identifying preganglionic injuries.
  - The most marked difference was noted in the lower roots
  - EDx specificity 87.5% C8 and 78.6% at T1
  - Imaging specificity 29.4% at C8 and 57.1% at T1

Muscle & Nerve. 2020;61:557–566.

7. Non-operative Treatments

- **Goals of rehabilitation**
  - Maximizing arm and hand function
  - Maintaining range of motion to prevent the formation of contractures or joint deformity.

- **Education** is initiated when a family is first seen
  - Perform the exercise program <u>several times a day.</u>

Pediatric Rehabilitation 5th edition, p223-227

7. Non-operative Treatments

- **Positioning instruction** begins immediately.
  - Weakness of the arm usually limits it from being moved in front of the face spontaneously → Position the arm so that the baby will have maximal awareness of it.
  - Use of a wrist rattle on the affected arm → baby's attention can be drawn to that arm by sound or vision.
  - Recommend the family to replicate movements with the affected arm that the baby spontaneously does with the unaffected arm, such as bringing the hand to the mouth.

Pediatric Rehabilitation 5th edition, p223-227

7. Non-operative Treatments

- **ROM exercises** are generally initiated after 2 weeks
  - Because there is commonly noted pain with changing position of the shoulder for bathing or dressing in the first 2 weeks, so it appears that there is some early, short-term tenderness after the initial brachial plexus injury.

- When humeral head dislocation → no aggressive ROM in shoulder abduction
- When radial head dislocation → no aggressive ROM in forearm supination

- **Motor training** can help promote normal development and prevent compensatory movements.

- **Sensory stimulation** is as important as motor stimulation and can consist in suckling any finger on the injured limb and stimulating the skin with different textures, temperatures, and vibrations.

Pediatr Rev. 2019 Sep; 40(9): 494-496
Pediatric Rehabilitation 5th edition, p223-227
MediSur 2014, 12, 635–649

7. Non-operative Treatments

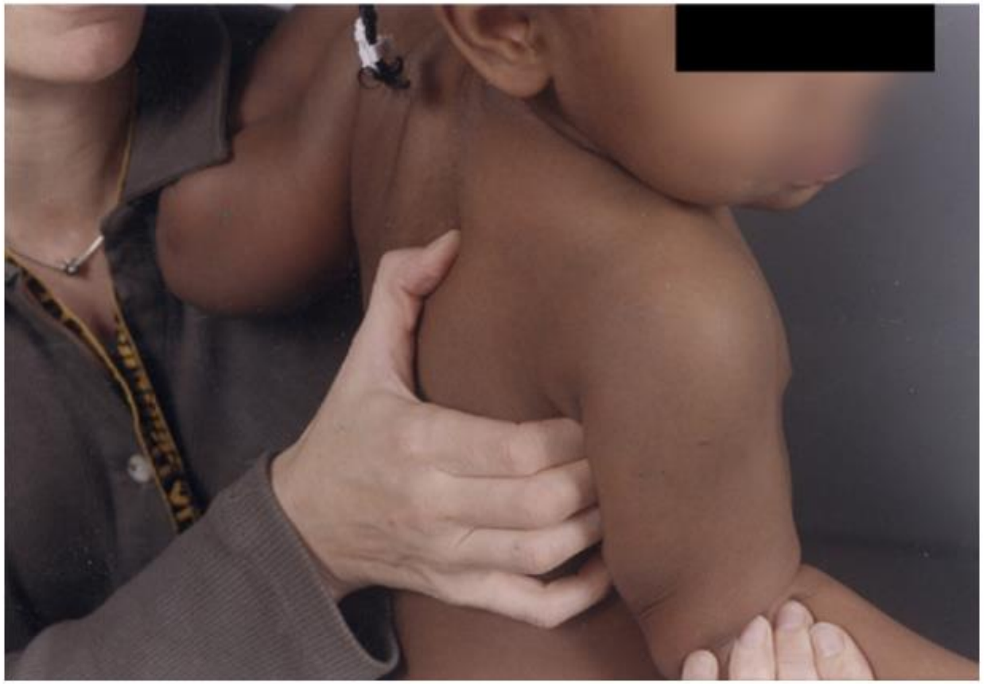


FIGURE 5: Glenohumeral external rotation exercise with scapular stabilization is the mainstay to prevent joint deformity. (Courtesy of Shriners Hospital for Children, Philadelphia Unit.)

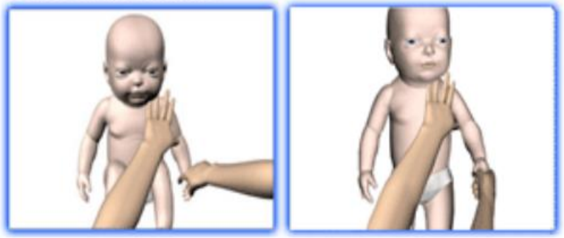
J Hand Surg 2011;36A:1360–1369

7. Non-operative Treatments

Nath Brachial Plexus INSTITUTE

INFANT RANGE OF MOTION EXERCISES

SHOULDER FLEXION



Infant is lying on his/her back. Stabilize shoulder with one hand and wrist with the other. Lift the arm up to the level of the shoulder, thumb leading, elbow straight.

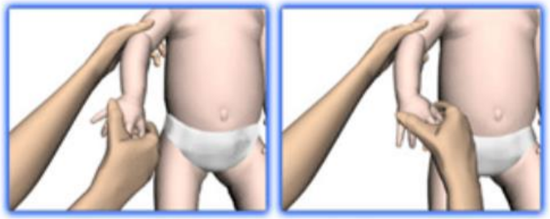
ELBOW FLEXION AND EXTENSION

Infant is lying on his/her back. Stabilize with elbow and hold the wrist with other hand. Bend the elbow then straighten the elbow.

SHOULDER ABDUCTION

Infant is lying on his/her back. Stabilize with one hand at the shoulder so that it doesn't come up and hold forearm with the other hand. Lift the arm sideways away from body, bring the arm straight out to the side.

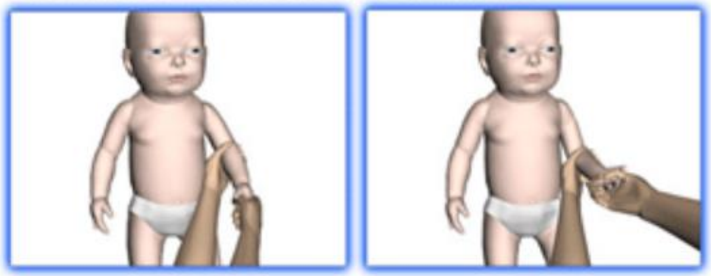
WRIST ABDUCTION AND ADDUCTION



Infant is lying on his/her back. Stabilize the forearm with one hand and hold the child's hand with your other hand. Move the wrist from side to side.

7. Non-operative Treatments

FOREARM SUPINATION AND PRONATION



Infant is lying on his/her back, elbow bent and arm straight out to the side. Hold arm straight out to the side and hold the forearm with the other hand. Roll the forearm up, then roll the forearm down.

SHOULDER ROTATION

Infant is lying on his/her back. Stabilize the upper arm with one hand cupping the elbow and hold the wrist with the other hand. Roll the forearm and hand up, then roll the forearm and hand down.

FINGER FLEXION AND EXTENSION

Infant can be lying or sitting. Stabilize the wrist with one hand and hold the child's fingers with your other hand. Bend the fingers, then straighten the fingers.

FINGER ADDUCTION AND ABDUCTION

Infant can be lying or sitting. Hold the child's wrist straight with palm open and hold the fingers straight. Spread the fingers apart gently, then bring them back together.

7. Non-operative Treatments

- **Splinting** is also commonly done by occupational therapy or physical therapy
  - Initially frequent wrist drop → splint for optimal position of the wrist and fingers
  - Later frequent elbow contracture → splinting is done to minimize that.

Pediatric Rehabilitation 5th edition, p223-227

- Immobilization of the affected limb is not recommended in the absence of a bony fracture.

Pediatr Rev. 2019 Sep; 40(9): 494-496

- Night time splinting is recommended.

Neuropsiquiatr. 2015, 73, 803–808

- **Taping**
  - To help promote optimal positioning of the arm, particularly at the shoulder.

Pediatric Rehabilitation 5th edition, p223-227

7. Non-operative Treatments

- **Electrical stimulation:** sometimes done for NBPP
  - Frequently not tolerated at a very young age → over time accepted by many young children.
  - Method: surface electrodes, sufficient stimulation to get a local muscle twitch, 20 minutes twice daily

- **Botulinum Toxin injections**
  - Decrease shoulder subluxation and decrease the need for surgery

Pediatric Rehabilitation 5th edition, p223-227

Use of Neuromuscular Electrical Stimulation in the Treatment of Neonatal Brachial Plexus Palsy: A Literature Review

Author & Year	No. Patients	Female	Country	Lesion	Prior Surgical Treatment	Mean Age at Treatment	Equipment	Settings	Other Treatment
Adedeji & Oyelese, 2009	2*	2*	Nigeria	C5-C7	No	3 weeks	Enraf-Nonius	8.5 mA to 15 mA Pulse duration: 1000 ms Pulse width: 300 ms 15 min per muscle	Yes; exercise, splint, soft tissue massage, two sessions/ week for 4 months
Berggren & Baker, 2015	1	1	United States	C5-T1	No	6 weeks	Not reported	20-25 pps Pulse duration: 0.1-0.15 ms	Yes; exercise, stretching, kinesiotaping, splints, constraint-induced movement therapy, nerve transfer surgery at 3 months
Okafor et al., 2008	8	5	Nigeria	C5-C6	No	22 days	707 model	Three sessions/week for 6 weeks	No
Srilakshmi & Chaganti, 2013	1	1	India	C5-C7	No	4.5 months	Not reported	Faradic and galvanic currents, 5 min per muscle	Yes; ayurvedic treatment, three sessions in 28 days

Note. *For purposes of analysis, one case of bilateral neonatal brachial plexus palsy is shown as two patients.

Table 2

Comparison of Pre and Posttreatment Muscle Strength Scores (MRC) and Active Range of Motion (AROM)

Muscle Group	No. Patients	Pre-treatment MRC Scores	Posttreatment MRC Scores	Pre to Posttreatment Difference	No. Patients	Pretreatment AROM (degrees)*	Posttreatment AROM (degrees)*
Shoulder abduction	12	2	2	0	11	26 ± 28	63 ± 45
Shoulder flexion	2	1	4	3	2	150 ± 0	180 ± 0
Elbow flexion	11	2	2	0	9	10 ± 3.4	51 ± 48
Wrist extension	11	2	2	0	9	8 ± 3	46 ± 50

Note. AROM = active range of motion; MRC = Medical Research Council. *Values presented are mean ± SD.

Table 3

Comparison of Pre and Posttreatment Morphometric Parameters

Morphometric Parameter	No. Patients	Treatment Length	Pretreatment (% of unaffected arm)	Posttreatment (% of unaffected arm)
Arm length, cm	1	28 days	24 (98.7)	28.5 (100)
Arm circumference, cm	1	28 days	13.5 (98.5)	14.8 (100)
Arm circumference, cm*	8	6 weeks	15 ± 1	17 ± 1

Note. *Mean ± SD; unaffected arm circumference not reported.

Use of Botulinum Toxin Type A in the Management of Neonatal Brachial Plexus Palsy

- **Objective:** To evaluate functional outcomes and the impact on surgical interventions after the use of botulinum neurotoxin type A (BoNT-A) for muscle imbalance, cocontractions, or contractures with neonatal brachial plexus palsy.
- **Design:** A retrospective cohort study.
- **Participants:** 59 patients with NBPP (75 injection procedures, 91 muscles and/or muscle groups) received BoNT-A injections (mean age at injection, 36.2 months; range, 6-123 months; 31 boys; 30 right-sided injuries, 28 left-sided injuries, 1 bilateral injury).
- **Methods:** Data collected before BoNT-A use, at ≤6 months follow-up (BoNT-A active [BA]) and at ≥7 months follow-up (BoNT-A not active [BNA])
- **Main Outcome Measurements:** active and passive ROM, Mallet and Toronto scores, parent comments about arm function, preinjection surgical considerations, and postinjection surgical history.

PM&R 2014;6:1107-1119

7. Non-operative Treatments

Use of Botulinum Toxin Type A in the Management of Neonatal Brachial Plexus Palsy

- **Results:** Injection procedures included 51 to shoulder internal rotators, 15 triceps, 15 pronator teres, 9 biceps, and 1 flexor carpi ulnaris.

Table 1. *Pre- and postinjection average total and component Mallet scores and degrees of passive SER of patients with botulinum toxin type A injections to the shoulder*

	No. Patients	Follow-up, mo	Individual Mallet Components					Total Mallet Score	Passive SER
			ABD	SER	Hand to Neck	Hand to Spine	Hand to Mouth		
Before injection	51		3.6	2.5	2.4	2.4	2.5	13.5	50°
Postinjection BA	51	3.0	3.8	2.9	2.7	2.4	2.5	14.4	60°
BA, *P* value			.006	.0003	.002	.563	.652	<.0001	.002
Postinjection BNA	32	14.5	4.1	2.8	3.1	2.8	2.8	15.6	56°
BNA, *P* value			.001	.283	.002	.0002	.087	<.0001	.271

SER = shoulder external rotation; ABD = abduction; BA = botulinum neurotoxin type A active; BNA = botulinum neurotoxin type A not active.

- Surgical intervention was averted, modified, or deferred after BoNT-A in 45% (n = 20) under surgical consideration before BoNT-A.

PM&R 2014;6:1107-1119

Use of Botulinum Toxin Type A in the Management of Neonatal Brachial Plexus Palsy

Table 2. *BoNT-A injections to shoulder internal rotators for patients under consideration for surgery*

ID No.	Age, mo	Surgery Before BoNT-A	Injection Sites	Indication for BoNT-A in Addition to Muscle Imbalance	Post-BoNT-A Interventions
3	14		PM, LD	Defer surgery	S release, LD transfer
7	21	PBPR: SAN-SSN, ulnar fascicles–MCN transfers	PM, LD	Alternative to surgery	S release
8	40	PBPR: graft, SAN-SSN transfer	PM, LD	Alternative to surgery	S release, LD transfer
10	26		PM, LD	Alternative to surgery	Modified surgery: LD and TM transfers only; no release
11	14		PM, LD	Alternative to surgery	S release, LD transfer
14	17		PM, LD	Defer surgery	Deferred S release, repeated BoNT-A injections
	50		PM, LD	Defer surgery	S release, LD transfer
16	14		PM, LD	Defer surgery	Averted S release, LD transfer
23	9		PM, LD	Defer surgery	Deferred LD transfer, repeated BoNT-A injections
	14		PM, LD	Alternative to surgery	S release, LD transfer
24	86		PM, LD	Alternative to surgery	S release, LD transfer
25	15		PM, LD	Defer surgery	Averted S release, LD transfer
34	56	S release, LD transfer	PM	Facilitate function of transferred LD	Averted PM lengthening
36	14		PM, LD	Defer surgery	S release, LD transfer
37	62		PM, LD	Alternative to surgery	S release, LD transfer recommended; lost to follow up
41	22	PBPR: graft	PM, LD, S	Defer surgery	Modified surgery: LD and TM transfers only, no release
50	39		PM, LD, S	Alternative to surgery	Pectoralis minor and S releases, LD transfer
52	7		PM, LD	Alternative to surgery	Averted SAN-SSN
55	115	S release	PM, LD	Alternative to surgery	HO recommended; the family did not pursue
56	17		PM, LD	Alternative to surgery	S release, LD and TM transfer deferred

BoNT-A = botulinum neurotoxin type A; PM = pectoralis major; LD = latissimus dorsi; S = subscapularis; PBPR = primary brachial plexus reconstruction; SAN-SSN = spinal accessory nerve to suprascapular nerve; MCN = musculocutaneous nerve; TM = teres major; HO = humeral osteotomy.

PM&R 2014;6:1107-1119

Use of Botulinum Toxin Type A in the Management of Neonatal Brachial Plexus Palsy

Table 3. *BoNT-A injections to shoulder internal rotators for patients not under consideration for surgery*

ID No.	Age, mo	Pre- and/or Concurrent Surgical History	Injection Site	Indication for BoNT-A	Post-injection Interventions
6	36		PM, LD	Muscle imbalance	
7	17	PBPR: SAN-SSN, ulnar fascicles–MCN transfers	PM, LD	Muscle imbalance	Repeated BoNT-A injections
12	59	S release, LD transfer	PM	Facilitate transfer	Humeral osteotomy
13	86	S and pectoralis minor releases and LD transfer	PM	Facilitate transfer, PM cocontraction	Cocontraction resolved
14	36		PM, LD	Muscle imbalance	Repeated BoNT-A injections
15	44		PM, LD	Muscle imbalance	
19	39		PM, LD	Muscle imbalance	Repeated BoNT-A injections
	55		PM, LD	Muscle imbalance	
20	12		PM, LD	Muscle imbalance	S release, LD transfer
22	30		PM, LD	Muscle imbalance	LD transfer
28	16	PBPR: nerve grafting	PM, LD	Facilitate function after nerve grafting	S release, LD transfer
29	10	PBPR: nerve grafting	PM, LD	Facilitate function after nerve grafting	S release, LD and TM transfers
32	18		PM, LD	Muscle imbalance	
33	14		PM, LD	Muscle imbalance	
34	62		PM	Facilitate function of transferred LD	Repeated BoNT-A injections
35	22	PBPR: nerve grafting	PM, LD	Facilitate function after nerve grafting	Humeral osteotomy
38	11		Left PM, LD	Muscle imbalance	Repeated BoNT-A injections
	27	S release, LD transfer	Left PM	Facilitate function of transferred LD	
	27	PBPR: SAN-SSN, ulnar (FCU br)-MCN, median (FCR br)-brachialis transfers	Right PM, LD	Facilitate function of nerve transfer	
40	9	SAN-SSN transfer concurrent with injections	PM, LD	Facilitate function of nerve transfer	Repeated BoNT-A injections
	19		PM, LD, S	Facilitate function of nerve transfer	
42	12	SAN-SSN transfer concurrent with injections	PM, LD, S	Facilitate function of nerve transfer	
45	52		PM, LD	Muscle imbalance	
46	8	S release, SAN-SSN transfer concurrent with injections	PM, LD	Facilitate function of nerve transfer	
48	23	PBPR: nerve grafting, SAN-SSN transfer (OSH)	PM, LD	Facilitate function of nerve transfer	Repeated BoNT-A injections
49	19	PBPR: nerve grafting	PM, LD, S	Facilitate function of nerve graft	
51	9	SAN-SSN transfer concurrent with injections	PM	Facilitate function of nerve transfer	Repeated BoNT-A injections
	13	—	PM	Facilitate function of nerve transfer	
52	16	—	PM, LD	Muscle imbalance	Repeated BoNT-A injections
57	17	S release, shoulder orthosis concurrent with injections	PM, LD, S	Muscle imbalance	
58	79		PM, LD	Muscle imbalance	

BoNT-A = botulinum neurotoxin type A; PM = pectoralis major; LD = latissimus dorsi; PBPR = primary brachial plexus reconstruction; SAN-SSN = spinal accessory nerve to suprascapular nerve; MCN = musculocutaneous nerve; S = subscapularis; TM = teres major; FCU = flexor carpi ulnaris; br = branch; FCR = flexor carpi radialis; OSH = outside hospital.

PM&R 2014;6:1107-1119

Use of Botulinum Toxin Type A in the Management of Neonatal Brachial Plexus Palsy

- **Active elbow flexion** improved in 67% (P = .005), sustained BNA (P = .004) after triceps injections; 2 of 7 patients averted surgery.

- **Active supination** improved with BA (P = .002), with gains sustained BNA (P = .016).

- **Passive elbow extension** improved after biceps injections by an average 17 (P = .004) BA, although not sustained BNA.

- **Conclusions:** BoNT-A is an effective adjunct to therapy and surgery in managing muscle imbalance, cocontractions, and contractures in neonatal brachial plexus palsy. Use of BoNT-A can result in averting, modifying, or deferring surgical interventions in a number of affected children.

PM&R 2014;6:1107-1119

7. Non-operative Treatments

- As the child grows, rehabilitation remains important for integrating the limb into the body structure through integration activities and postural re-education of the upper limb and the chest.

- It is important to include them in all day-to-day activities, such as with every nappy change, and at each meal (bottle/breast).

- As the child grows, develops, and gains intentional voluntary control and awareness of his/her body, it is important to promote activities that stimulate the affected limb so as to prevent apraxia.

- One possible strategy is to encourage bimanual activities.

Neuropsiquiatr. 2015, 73, 803–808
MediSur 2014, 12, 635–649

8. Prognosis and Follow Up

- **Prognosis**
  - At least 69%: recover spontaneously within several months.
  - However, for patients who do not recover spontaneously, nerve reconstruction and/or secondary musculoskeletal surgery can improve outcomes.
  - Regardless of optimal medical or surgical management, some children with an injured brachial plexus can suffer permanent loss of function and bimanual ability.

→ Such disablements can significantly affect a child's ADLs and involvement in physical activities (such as tying shoelaces, or participation in sports involving the affected arm).

J Neurosurg Pediatrics 12:395–405, 2013

8. Prognosis and Follow Up

- **Close follow-up with serial examinations** is critical in the management of brachial plexus injuries.

- Prognosis depend on the type and severity of the lesion, and the speed of recovery.

- **Biceps muscle strength testing** is one of the simplest and most reliable measures of recovery.
  - BB strength regain within the first month → complete recovery is expected
  - BB strength not recovered by 3 months → surgical repair should be considered (There remains some controversy regarding the ideal timing of surgery.)

Pediatr Rev. 2019 Sep; 40(9): 494-496

Take home message

- **History taking** and **physical examination** of an infant with NBPP is important.

➔ Identify risk factor and predict the extent of injury.

- Look for combined muscle imbalance, limitation of ROM, contracture, torticollis, and respiratory impairment.

- Identify the location and extent of the injury with **electrodiagnostic evaluation** (bilateral NCS + unilateral EMG) at 1 month and at the time of decision making for surgery.

- **Additional imaging study** helps to give additional information about NBPP, to find out combined problems such as GHD, and to rule out some mimics of NBPP, such as a fracture of the clavicle or humerus.

Take home message

- Start **educating parents** about positioning and ROM exercises.

- **Make the child** to be aware of the affected arm and make it to participate in playing and ADL.

- Splinting, taping, electrical stimulation, and botulinum toxin injection can be used.

- **Biceps muscle strength testing** is one of the simplest and most reliable measures of recovery.