Pediatrics Tips and Tricks: Essentials of the Brachial Plexus Physical Examination in Newborns

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Introduction

A perceptive physical examination of the newborn is invaluable in guiding the early diagnostic work up for a wide constellation of congenital and traumatic conditions. The pediatric orthopaedic surgeon should be well acquainted with patterns of injury associated with birth trauma, the intricacies of normal and abnormal neurodevelopmental findings, and recognition of deformity in infants. While decreasing in incidence, brachial plexus birth injury (BPBI) still affects approximately 1 in 1,000 newborns.[1-4] Of these children, 20 to 30% will have residual deficits in upper limb function which may require surgical intervention. Serial neuromuscular examination is the gold standard when determining necessary treatment and future functional outcomes.[3-8]

Broadly, BPBI can be categorized based on upper, middle and lower trunk involvement with isolated upper trunk injuries having increased likelihood of spontaneous nerve recovery and better functional outcomes in the long term. Isolated lower nerve trunk is exceedingly rare given the mechanism of injury for BPBI typically involves shoulder dystocia and traction primarily affecting the upper portion of the brachial plexus. Narakas (1987) published a landmark study classifying BPBI into four categories according to nerve roots and corresponding muscle groups affected (Table 1).[6] Ascending group number has been associated with poorer neurologic prognosis and greater likelihood of requiring surgical intervention.[6,7,8,9] Al-Qattan et al. later expanded upon the classification by accounting for the prognostic value associated with the return of elbow flexion and wrist extension.[9] Initial exam of the newborn should aim to differentiate upper versus lower lesions with subsequent follow-up examination monthly through 6 months of age to assess prognosis and need for surgery.[5,7-9]

History

Brachial plexus birth injury is associated with maternal, gestational, and obstetric risk factors which necessitate targeted history and collaboration with obstetric colleagues. Shoulder dystocia remains the strongest risk factor and increases the risk of BPBI by approximately 100-fold. Other well-known risk factors include use of vacuum or forceps during delivery, breech positioning, birth weight $>$ 4.5 kg, and a baby consistently heavier than expected throughout pregnancy. Hypotonia at birth has also been associated with increased risk for BPBI due to increased susceptibility of the brachial plexus to stretch.[2,4,10] Maternal factors including gestational diabetes and protracted active phase of labor are also pertinent.[4,10] Cesarean delivery, twin or multiple birth mates, and lower birth weight are protective.[2,4]

History obtained from the obstetrician should attempt to quantify strength and directionality of force applied during delivery. Widening of the head-shoulder angle is associated with upper root injury and exceedingly more common than lower root injury which is produced by excessive abduction of the arm.11 In multiple studies, less than 20% of BPBI cases have been total/global or lower plexus injuries with a very small minority being isolated lower.[11,12] Cases of BPBI classified as lower root injury are more commonly total plexus injuries with spontaneous recovery of the upper plexus. Greater magnitude of force equates to higher risk of a global brachial plexus injury and nerve root avulsion.[11] Head-to-body interval of greater than 60 seconds, pubic symphysiotomy, intentional clavicle fracture, Zavanelli maneuver with subsequent C-section, and abdominal rescue maneuvers are all key aspects of the obstetric history.[12]

Physical Exam

The physical exam of the newborn can be mystifying for the orthopaedic consult resident due to challenges with examining a patient not yet capable of verbalizing or following commands. A thorough pediatric brachial plexus exam includes assessment of crepitation or deformity, range of motion (ROM), strength, and neurologic function.[13] A quiet, warm room with dim lighting is

Table 1. Narakas (1987) classification, modified and adapted from Al-Qattan et al (2009).[6,9]

Palsy Group	Nerve Roots	Affected Muscles	Clinical Presentation	Outcome (% recover)
I. Erb's	C5-C6	Deltoid, teres minor (axillary n.) Supraspinatus, infraspinatus (suprascapular n.) Biceps, brachialis (musculocutaneous n.) Brachioradialis, supinator (radial n.)	Shoulder adducted and internally rotated, elbow extended, and forearm pronated	80%
II. Extended Erb's	C5-C7	Group I deficits PLUS Wrist extensors (radial n.)	Same as above with wrist drop	60%
III. Total Plexus	C5-T1	Group I – II deficits PLUS Wrist flexors, hand intrinsics (ulnar n., median n.)	Complete flaccid paralysis of the limb	30-50%, functional hand in many cases
IV. Total with Horner's Syndrome	C5-T1	Group I – III deficits PLUS Ptosis, miosis, anhidrosis (sympathetic chain)	Complete flaccid paralysis with Horner's syndrome	Few recover, lifelong deficits

ideal for infants who are sensitive to light and at risk of exposure. The baby should be laid supine with blankets and clothing removed.[10,11] Feeding the newborn beforehand, using distracting objects to divert attention, and involving parents can reduce irritability.[10]

Observation & Palpation

Over 50% of BPBI cases have no known risk factors, so physical exam remains paramount.[2,4] Due to high incidence of humerus and clavicular fractures with BPBI, exam should begin with observation for deformity and asymmetry of shoulders and upper extremities. Skin examination should include careful assessment for open fractures or pinhole wounds about the clavicle and humerus. Palpate both clavicles for step-offs, "bumps", or subcutaneous crepitus.[13,14]

Abnormal posturing of a newborn can distinguish upper from lower brachial plexus lesions (Figure 1). Upper trunk lesions, also known as an Erb's Palsy (C5-C6) is the most common, are characterized by the classic "waiter's tip" appearance of the upper extremity in which: 1) the shoulder is adducted and internally rotated, 2) elbow extended, 3) forearm pronated, and 4) wrist flexed (Figure 2). Extended Erb's (C5-C7) encompasses diminished strength in elbow and finger extensors as well. While less common, total brachial plexus palsy is a more devastating

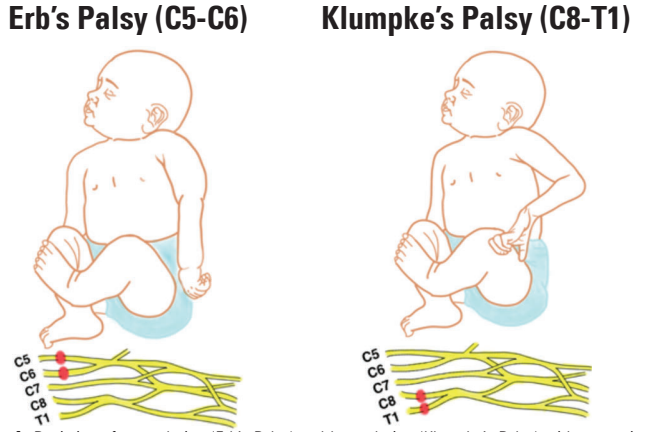

Figure 1. Depiction of upper lesion (Erb's Palsy) and lower lesion (Klumpke's Palsy) with respective nerve roots below.

Figure 2. Picture of infant demonstrating shoulder abduction and internal rotation, elbow extension, and forearm pronation characteristic of an upper trunk injury.

injury in which the affected limb presents as a flaccid, flail extremity. Isolated lower trunk injuries, or Klumpke's Palsy, are rare and produce a "clawed hand deformity" with 1) wrist extension, 2) metacarpalphalangeal hyperextension, and 3) interphalangeal flexion.[6,10] Examiners should also assess for the triad of Horner's Syndrome (ptosis, miosis, and anhidrosis) as injury occurring proximal to white rami communicans hinders the sympathetic output to the head, neck and eye.[6] Respiratory distress may indicate phrenic nerve injury with resultant diaphragm paresis (DP) which occur in up to 2% of brachial plexus injuries. Injury to the phrenic nerve or Horner's syndrome are prognostic indicators as they often as associated with nerve root avulsion.[15]

Range of Motion

Physical exam of the infant involves assessment of range of motion (ROM), active movement, and reflexes. In utero, neonates develop flexion contractures of the elbows, knees, and hips that persist after birth and are a normal finding on

exam.[13] Assessment of neck ROM can lead to identification of torticollis often due to sternocleidomastoid trauma during delivery. Limited upper extremity ROM with fixed adduction and internal rotation of the shoulder and elbow flexion should lead to consideration of arthrogryposis or Sprengel deformity of the scapula. Cerebral palsy should also be included in the differential diagnosis for children with limited ROM or atypical contractures.[10] Gentle ROM exercises may also elicit a painful response if a fracture is present.

Strength Assessment

Motor responses can be elicited in older children by dangling shiny or distracting objects in front of the infant, stimulating a reaching response. Observe shoulder abduction, internal rotation, and external rotation, elbow and wrist flexion and extension, and hand function. The "cookie test" assesses biceps flexion, a critical prognosticator, by requiring the child to bring a treat to their mouth with the affected extremity while the shoulder is restrained in adduction.[9] Strength may be quantified via standard MRC muscle power assessment, or preferentially, using the Active Movement Scale (AMS) which also assigns scores for muscle grade ranging from no contraction to full motion against gravity (Table 2). In comparison to MRC Grades, AMS grades allow for identifying subtle differences in strength in infants and young children with brachial plexus injuries who are not able to cooperate with provider examination or resist force. The AMS is a formal test administered by a trained physician or pediatric physical/occupational therapist with gravity eliminated and against gravity if the infant is capable of the former.[16]

Table 2. Comparison of MRC Grading versus AMS Grading systems.[16]

MRC Grade	Observation	AMS Grade	Observation
Gravity Eliminated			
0	No contraction	0	No contraction
1	Flicker contraction	1	Contraction, no motion
2	Active movement	2	Motion ≤ ½ range
		3	Motion > ½ range
		4	Full motion
Against Gravity			
3	Active movement	5	Motion ≤ ½ range
		6	Motion > ½ range
		7	Full Motion
Against Resistance			
4	Active movement, some resistance		
5	Normal power, full resistance		

Table 3. Primitive reflexes relevant to brachial plexus examination of newborn, modified and adapted from Payares-Lizano and Pino (2019).[12]

Reflex	Age present (mo)	Description	Upper Trunk BPI (C5, C6)	Lower Trunk BPI (C8, T1)
Moro "startle"	< 6	Startle: Loud noise or abrupt change in head position produces abduction of shoulder, extension of elbow and digits. Embrace: Immediately followed by adduction and flexion.	Startle: Weak shoulder abduction, external rotation Embrace: Weak elbow flexion	Startle: Unable to extend IP joints Embrace: Unable to flex wrist or MCP joints
Grasp	< 3	Grasps examiner's finger in palm	N/A	Characteristic claw hand deformity, unable to activate intrinsic hand muscles
Neck righting	< 10	When head is turned to one side, trunk and limbs spontaneously follow to ipsilateral side	Asymmetry may not be apparent, subtle difficulty flexing elbow when reaching across body	N/A
Symmetric tonic neck	< 6*	When neck is flexed, upper limbs flex and lower limbs extend	Weak elbow flexion	N/A
Asymmetric tonic neck	< 6*	When head is turned to one side, ipsilateral "face side" limbs extend and contralateral "skull side" limbs flex	Ipsilateral: Weak shoulder abduction Contralateral:Weak elbow flexion	Asymmetry may not be apparent, subtle contralateral sided weakness with wrist flexion

* May require 1-2 months to develop, disappear up to 10 months later.

Serial examination with reference to previous scores is an objective method of tracking the natural history of an infant's injury.

Neurologic Function

Primitive reflexes are a useful tool when identifying brachial plexus injury (Table 2). Simply observing infants and ranging joints does not result in a consistent, reproducible muscle activation as demonstrated by primitive reflexes. Subtle asymmetries in the Moro, grasp, tonic neck, and neck righting reflexes can help localize injury as upper lesion, lower lesion, or flaccid paralysis (flail limb).[12] For example, a child with unilaterally absent grasp reflex but symmetric Moro reflex may have a lower brachial plexus lesion. When testing primitive reflexes, the Moro reflex may lead to agitation and should be performed last. Note, primitive reflexes may be abnormal in children with concurrent neuromuscular conditions including cerebral palsy.

Differential Diagnosis

Shoulder dystocia, the leading risk factor for BPBI, occurs when maternal pelvic inlet obstructs the fetal shoulder,

which can lead to a traction injury most commonly affecting the upper trunk of the brachial plexus. Clavicle and humerus fractures are associated with shoulder dystocia. The literature is variable on whether clavicular fractures are protective against BPBI. Some studies suggest that timing of the clavicle fracture is pertinent, e.g., whether the fracture occurs prior to extensive traction on upper extremity.[17] Additionally, spiral morphology of clavicular fracture correlates with BPBI. Plain films are sufficient to diagnose the fracture and may also lead to identification of hemidiaphragm position, if visible.[18] Infants with clavicular or humerus fractures often present with pseudoparalysis, or a reluctance to move the affected limb due to fracture-related pain. To distinguish pseudoparalysis from BPBI, repeat exam in two to four weeks is recommended to allow for fracture healing and mitigate the confounding effects of fracture pain.[18]

Radial nerve palsy due to prolonged compression of the upper arm against the maternal pelvic brim or due to humeral shaft fracture should also be on the differential diagnosis list when evaluating a new patient with suspected BPBI. Infants with isolated radial nerve palsy present with inability to extend the wrist, thumb, and metacarpophalangeal joints (Figure 3). Importantly, preserved external rotation of the shoulder and elbow flexion differentiates radial nerve palsy from upper trunk injuries. Bruising along the posterolateral aspect of the affected arm or presence of a subcutaneous nodule representing fat necrosis are skin lesions that imply prolonged radial nerve compression (Figure 3).[19] Radial nerve palsy often resolves spontaneously within months of initial injury and may be treated conservatively with passive stretching and extension splinting to prevent wrist and digital flexion contractures.

Figure 3. Typical presentation of isolated radial nerve palsy. **(A)** Wrist and finger drop with preserved elbow flexion. **(B)** Subcutaneous nodule with posterolateral bruising.

Conclusion

Workup for suspected brachial plexus birth injury (BPBI) begins during infancy with a thorough orthopedic evaluation. Assess for risk factors and obtain maternal and birth history including birth weight, presence of shoulder dystocia, and any heroic maneuvers employed during delivery. A physical exam incorporating observation of deformity, primitive reflexes, and strength grading systems will help determine extent of BPBI (Erb's, Extended Erb's, Global) and differentiate from birth fracture or neonatal radial nerve palsy. Evaluate for Horner's syndrome and phrenic nerve injury as these may be indicators of nerve root avulsion. Patients with associated upper extremity fractures require repeat examination after fracture healing to rule out pseudoparalysis.

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