A Review of Brachial Plexus Birth Palsy: Injury and Rehabilitation

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ABSTRACT

Brachial plexus injuries during the birthing process can leave infants with upper extremity deficits corresponding to the location of the lesion within the complex plexus anatomy. Manifestations can range from mild injuries with complete resolution to severe and permanent disability. Overall, patients have a high rate of spontaneous recovery (66–92%).[1,2] Initially, all lesions are managed with passive range motion and observation. Prevention and/or correction of contractures with occupational therapy and serial splinting/casting along with encouraging normal development are the main goals of non-operative treatment. Surgical intervention may be warranted, depending on functional recovery.

KEYWORDS: Brachial plexus, Erb's palsy, Klumpke's palsy, serial splinting

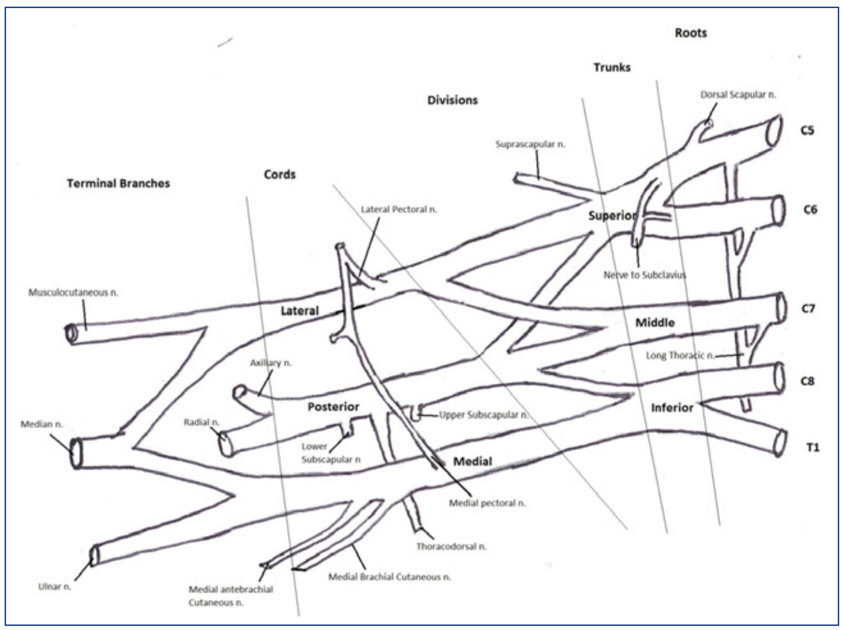
INTRODUCTION

Brachial plexus birth palsy (BPBP) involves injury to any nerve of the brachial plexus during birth. It occurs in 0.42 to 4.6 cases per 1,000 births, which translates to approximately 5 to 50 cases per year in Rhode Island, with varying degrees of severity.[1–3] The most common presentation is Erb's Palsy (50-60%), followed by the more severe upper plexus and pan-plexus variants.[1,4] Klumpke's lower plexus palsy is rare, and occurs in 0.6% of all patients.[5] Maternal risk factors include gestational diabetes, multi-parity and having a previous child with a brachial plexus injury. Maternal factors can cause fetal macrosomia and/or shoulder dystocia, increasing the risk of forceps or suction-assisted deliveries and traction nerve injury.[6] Since the majority of fetuses present in the left occiput anterior position, with the right shoulder under the maternal pelvis, the right upper extremity is most commonly involved.[7] However, only about half of patients have these risk factors, demonstrating our lack of true understanding of the etiology.[8] This article will review the pathology, diagnosis, treatment, rehabilitation and outcomes of BPBP.

ANATOMY

The brachial plexus is derived from the fifth cervical (C5) to the first thoracic (T1) nerve roots. It undergoes a complex pattern of branching and convergence before terminating as peripheral nerves that provide motor and sensory innervation to the upper extremity. (**Figure 1, Table 1**) The plexus can be divided into supraclavicular (roots and trunks) and sub-clavicular (cords and terminal branches) for prognostic purposes, with supraclavicular injuries having worse outcomes.[9]

Figure 1. Brachial Plexus Anatomy



Pathophysiology

The majority of BPBPs are traction injuries, as with shoulder dystocia when traction on the infant's neck leads to an increased neck shoulder angle.[1] Very rarely, compression injuries from fractured clavicles, hematomas, and pseudo-aneurysm can occur.[7] Lesions can be divided into symptomatic categories using multiple systems. The simplest approach is to classify lesions as pre-ganglionic or post-ganglionic, distal to the dorsal root ganglion. Pre-ganglionic lesions, with the nerve injured proximally, e.g., root avulsions, are more difficult to heal/repair and have worse outcomes than post-ganglionic lesions. It is only possible to determine this

Table 1. Brachial Plexus Functions

Branching Location	Nerve	Root	Innervation	Muscle action
Roots	Dorsal Scapular n.	C5	M: Rhomboid mm. and Levator Scapulae m.	Rhom: scapular retraction, Levator=scapular elevation
	Long Thoracic n.	C5,C6 & C7	M: Serratus anterior m.	Scapular protraction
	First intercostal n.	T1	M: intercostal m.	n/a
Trunks	Suprascapular n.	C5, C6	M: Supraspinatus m, Infraspinatus m. S: Shoulder joint capsule	Supra= Arm abduction. Infra= Arm external rotation
	Nerve to Subclavius	C5, C6	M: Subclavius m.	n/a
Divisions	none			
Cords				
Posterior	Upper Subscapular n	C5-T1	*Motor*: Upper subscapularis m.	Arm internal rotation
	Lower Subscapular n	C5-T1	*Motor*: Lower Subscapularis m., Teres Major m.	LS= Arm internal rotation
	Thoracodorsal n.	C5-T1	*Motor*: Latissimus dorsi m.	Arm adduction
Lateral	Lateral Pectoral n.	C5-C7	*Motor*: Pectoralis Major m.	Arm Adduction
Medial	Medial Pectoral n.	C8-T1	*Motor*: Pectoralis Major m., Pectoralis Minor m.	Arm Addution
	Medial Brachial cutaneous n.	C8-T1	*Sensory*: medial arm	n/a
	Medial Antebrachial cutaneous n.	C8-T1	Sensory: medial forearm	n/a
Terminal Nerves	Radial n.	C5-T1	*Motor*: Triceps mm, brachioradialis m., ECRL, ECRB, ECU, EDC, EIP, EDM, EPL, EPB, APL, Supinator m., Finger extensors *Sensory*: posterior brachial cutaneous, inferior lateral brachial cutaneous, posterior antebrachial cutaneous, superficial radial (post. radial hand)	Elbow extension, Wrist extension, Finger Extension, Thumb extension, thumb abduction, Forearm supination; Brachioradialis=elbow flexion
	Axillary n.	C5-T1	*Motor:* Deltoid m., Teres Minor m., Sensory: Lateral proximal arm	Delt= Arm abduction, Teres= Arm external rotation
	Musculocutaneous n.	C5-C7	*Motor*: Biceps brachii m., Brachialis m, corocobrachialis m. *Sensory:* Lateral cutaneous n. of the forearm	Elbow Flexion, Forearm supination S: lateral forearm
	Median n.	C5-T1	*Motor*: FCR, Palmaris longus m., FDS, radial 1/2 FDP, Pronator teres m. FPL, Pronator quadratus m., FPB (superficial head), Opponens pollicis, APB, 1st-2nd lumbricals *Sensory*: Radial 3 1/2 fingers, palmar cutaneous branch	Wrist flexion, Forearm pronation, thumb flexion/abduction/opposition, finger PIP flexion, IF/MF MCP and DIP flexion
	Ulnar n.	C8-T1	*Motor*: FCU, ulnar 1/2 FDP, Flexor DM, Abductor DM, Opponens DM, Adductor pollicis, FPB (deep head), Palmaris brevis m. Dorsal interossei mm. Palmar interossei mm., 3rd-4th Lumbricals *Sensory*: Dorsal ulnar cutaneous n., Palmar ulnar cutaneous n.	Wrist flexion, Thumb adduction/flexion, SF flexion/abduction/opposition, finger adduction/abduction, 4th and 5th finger DIP/MCP flexion

classification after advanced imaging. The Sunderland classification (**Table 2**) categorizes nerve injuries based on the nerve structures damaged, ranging in severity from neuropraxia to neurotmesis.[10] As expected, patients with less severe damage, e.g., neuropraxia, have a better chance at recovery.

The most common way to describe BPBPs is based on the nerve roots involved, which can be detected by physical examination. Upper trunk (Erb-Duchenne) palsies involve only the disruption of input from the C5 and C6 nerve roots. Upper plexus palsies involve roots C5, C6 and C7, with the addition of more distal deficits. Lower plexus (Klumpke's) palsies involve the C8 and T1 nerve roots and can also affect the sympathetic chain with pre-ganglionic injuries. The most severe is the all-encompassing pan-plexus injury involving nerve roots C5-T1, with disruption to all functions of the upper extremity.

Table 2. Sunderland Classification

	Type of Nerve Injury	Prognosis
Neuropraxia	Stretch injury with intact nerve continuity	Spontaneous recovery likely
Axonotmesis	Axonal injury with intact nerve sheath	Variable recovery
Neurotmesis	Complete nerve rupture; neither axon nor sheath intact	Poor prognosis for spontaneous recovery

Sunderland SS. The anatomy and physiology of nerve injury. *Muscle Nerve*. 1990;13(9):771-784. doi:10.1002/mus.880130903

DIAGNOSIS

Maternal history, physical examination and diagnostic imaging can provide a wealth of information to make the proper diagnosis and injury classification. The patient's mother should be interviewed for the BPBP risk factors mentioned previously. Abnormal primitive reflexes, e.g., Moro reflex and tonic neck reflex, are often the first clues in the newborn examination. It is also important to palpate the infant's clavicle and humerus, as fractures can affect upper extremity movements and be confused with brachial plexus palsy. A septic shoulder and isolated radial nerve palsy should also be in the differential diagnosis, but they are less common and are associated with different physical and laboratory findings.

Depending where the lesion is located, the patient's affected extremity will present in different positions. With Erb's palsy (C5-6), the arm is adducted and internally rotated at the shoulder and extended at the elbow, due to weakness in the deltoid, supero-posterior rotator cuff and biceps. A patient with upper plexus palsy (C5-7) has the above posture as well as wrist and fingers flexion due to radial nerve involvement and wrist/finger extensor weakness. Pan-plexus injuries (C5-T1) typically present with a flaccid extremity. Pre-ganglionic injuries, which carry a worse prognosis,, may lead to head tilting to the opposite side (denervation of paraspinal musculature), medial winging of the scapula, diaphragm dysfunction, and Horner's syndrome.

As children age, their disabilities become more apparent. Scoring systems such as the Toronto Test Score, Active Movement Scale, and Modified Mallet system have been developed to grade and track upper extremity function.[11] The Modified Mallet score is the most commonly used when evaluating older children (≥3 years old). It uses five categories to assess shoulder function, with a 0–5 grading for each category. Higher scores correlate to higher function, but the examination requires patient participation and is heavily weighted toward shoulder external rotation.

Imaging can help clarify the diagnosis and classification. Initially, radiographs of the upper extremity should be obtained to rule out fractures, which could be confused with or occur concomitantly with brachial plexus palsy. MRI and CT myelography can be used to detect root avulsions. Electromyography has been suggested if there is no nerve recovery by 6 months of age, in order to detect a pre-ganglionic injury, which is potentially amenable to operative intervention. Other evidence shows, however, that electromyography can be discordant from clinical bicep function at 3 months of age and the test may not be a reliable indicator for surgery.[1]

TREATMENT AND OUTCOMES

Treatment for a suspected brachial plexus palsy should begin immediately with frequent, passive range of motion of the affected upper extremity. Parents should be instructed to range both arms at every diaper change to make it a daily routine and encourage compliance. Some authors recommend a two-week period of immobilization to promote healing and decrease pain,[9] but others find little evidence that immobilization has any benefit.[1] Contractures can begin as early as 2-3 weeks after birth, with the glenohumeral joint most commonly affected. Without early treatment, the contractures can progress rapidly and cause posterior subluxation/dislocation of the humeral head.[1,9,12]

After an initial observation period, children can be categorized as having either partial or total paralysis. Patients with total paralysis should be referred to a tertiary center for early surgical evaluation, as they have a very low likelihood of spontaneous recovery. Patients with partial paralysis have a higher chance of recovery, and there is complete recovery by 3 months of age with as many as 92% of these patients.[9,13] Other evidence suggests complete recovery rates may not be as high as originally thought, with as many as 20–30% of patients having a long-term defecit.[1,2] Patients who do not have complete recovery by 1 month of age should be evaluated by a pediatric therapist for continued monitoring and rehabilitation. Many physicians use the lack of antigravity biceps function return by 3 months as an indication for nerve surgery since it is a poor prognostic indicator for complete spontaneous recovery;[1,4] however, this does not preclude good functional recovery. Recovery of wrist extension is also a positive prognostic sign. Other physicians advocate continued rehabilitation until at least 6 months of age before considering surgery. Some evidence has shown that children who recovered antigravity biceps function between the 3rd and 6th months of life always had an incomplete recovery compared to those who regained function prior to 3 months.[9]

If children undergo surgery, it is typically performed between 3 and 8 months of age; earlier surgery (at 3 months) is indicated in children with pan-plexus palsies and Horner's syndrome. The main goals of surgery, in order of importance, are to restore elbow flexion, shoulder abduction, shoulder external rotation, wrist extension and hand function.[7] The options for early surgical intervention include direct nerve repair with resection and grafting, or nerve transfers from surrounding motor nerves. In spite of surgery, many patients still suffer some degree of long-term sequalae.[2] In patients who develop contracture or have persistent weakness, later surgery can be beneficial. Lysis of contractures, osteotomies and local tendon transfers can help return functional motion and correct deformities.[12,14]

Children who recover meaningful biceps function by 6 months of age are typically treated non-operatively with rehabilitation and monitoring. There is little high grade research discussing non-operative management techniques and protocols for brachial plexus birth palsies. All non-operative treatment involves a multidisciplinary team approach, with occupational therapy and splinting to prevent or correct contractures. The goals of treatment prior to muscle function recovery are to prevent contracture, strengthen recovering muscles, stimulate sensory nerves, and encourage the achievement of normal developmental milestones. As the child grows, passive range of motion should be transitioned to participation in age-appropriate activities for rehabilitation with regular follow-up to assess functional scores, arm growth and joint integrity. Elbow flexion contractures are a fairly common occurrence, even with triceps sparing palsies. For children who develop contractures, stretching and serial night splinting can be used for contractures less than 20 degrees. Treating deformities in this range will prevent progression and help cosmetic appearance, as the elbow's functional range of motion is between 30–130 degrees.[15] Serial casting and splinting of elbow flexion contractures can yield good results, but this approach can be complicated by radial head dislocation, bony ingrowth at the joint, and loss of elbow flexion while gaining extension. Much of the research is focused on elbow flexion contractures but contractures preventing forearm supination and shoulder external rotation are also commonly present. A pilot study has shown improvement in Toronto and Active Movement Scales of supination and shoulder external rotation with a Supination-External rotation orthosis worn 22 hours per day with reprieves for therapy twice per day.[16] Botulinum toxin injections with serial casting have also shown promise in patients who failed serial casting alone.[17] The toxin relaxes the antagonist muscle at the contracted joint, particularly in cases of co-contraction, a common long-term complication.

Despite the lack of consensus regarding surgical indications and rehabilitation protocols, patients do have good long-term outcomes. Most studies show the majority of patients are independent in activities of daily living, even with persistent functional deficits.[1,2,7,8,13,19] In a subjective study of adolescents, all patients reported a 'really good' quality of life, but they were also all dissatisfied with their current condition and hoped for continued improvement.[20]

CONCLUSION

Brachial plexus birth palsies can be stressful and challenging for parents and children. Despite a better understanding of the pathology and treatment options, injury incidence has remained unchanged.[1–3] In general, upper plexus palsies recover better than lower plexus and pan-plexus palsies; neuropraxia does better than neurotmesis; and post-ganglionic lesions recover better than pre-ganglionic lesions. Care should continue to focus on early identification and therapy to minimize complications. Early referral to tertiary centers is crucial, as a multi-disciplinary approach can help promote recovery and prevent complication. Fortunately there is a high rate of spontaneous recovery, but for patients who don't recover spontaneously there are non-surgical and surgical options to improve functional outcomes and prevent devastating contractures. With an ever-expanding body of research geared towards improving care and knowledge of the injury, the future should show improved long-term outcomes for these patients.

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