

BRACHIAL PLEXUS

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Primary Disciplinary Field(s): Anatomy, Neurology, Orthopedic Surgery.

1. Core Definition and Function

The **brachial plexus** is an intricate and vital network of peripheral nerves originating primarily from the spinal nerve roots of the lower cervical and upper thoracic regions, specifically C5 through T1. This complex anatomical structure is singularly responsible for providing nearly all motor and sensory innervation to the entire upper limb, encompassing the shoulder girdle, arm, forearm, and hand. Its existence allows for the tremendous dexterity, strength, and sensory perception characteristic of human hand function and manipulation. The plexus acts as a crucial electrical switchboard, collecting individual nerve fibers as they exit the vertebral column and systematically reorganizing them into specific peripheral nerves destined for distinct muscle groups and skin territories.

Functionally, the brachial plexus serves as the primary conduit for electrochemical impulses. Motor signals originating in the central nervous system traverse the plexus to command muscle contractions, facilitating complex movements such as lifting, gripping, and fine motor tasks. Simultaneously, sensory information—including pain, temperature, touch, and proprioception (awareness of position)—is gathered from the periphery and relayed back through the plexus to the spinal cord and brain. Because of its critical role, damage to even a small segment of the plexus can result in profound and often devastating functional impairment, ranging from sensory loss to complete paralysis of the affected limb.

The location of the brachial plexus, situated deep within the neck and shoulder region, renders it somewhat protected, yet its passage through narrow osteofascial canals makes it vulnerable to mechanical stresses. It begins deep to the sternocleidomastoid muscle, passes between the anterior and middle scalene muscles, runs beneath the clavicle, and enters the axilla (armpit). This complex course exposes it to high-risk scenarios, including sudden violent traction injuries, compressive forces, and penetrating trauma. Understanding the architecture of this network is paramount for neurologists and surgeons when localizing and treating neurological deficits of the upper extremity.

2. Anatomical Structure and Organization

The organization of the **brachial plexus** is conventionally described by the mnemonic "Roots, Trunks, Divisions, Cords, Branches," reflecting the five major stages of rearrangement that the nerve fibers undergo as they proceed distally toward the limb. The process begins with the Roots, which are the ventral rami of the C5, C6, C7, C8, and T1 spinal nerves. These roots emerge between the anterior and middle scalene muscles, forming the most proximal segment of the

plexus. It is at this level that the dorsal scapular nerve (supplying the rhomboids and levator scapulae) and the long thoracic nerve (supplying the serratus anterior) typically arise, underscoring the early distribution of nerves to the shoulder girdle musculature.

Next, the five roots merge to form three Trunks: the superior trunk (C5 and C6), the middle trunk (C7), and the inferior trunk (C8 and T1). These trunks pass through the posterior triangle of the neck and are located superior to the clavicle. At this juncture, the suprascapular nerve and the nerve to the subclavius branch off the superior trunk, initiating the innervation of the rotator cuff muscles. The trunks then travel toward the clavicle, a bone that plays a significant role in protecting them but also contributes to potential compression injuries, particularly in the event of a fracture.

As the trunks pass deep to the clavicle, each divides into an anterior and a posterior Division, resulting in six divisions in total. The anterior divisions primarily carry fibers that will supply the flexor compartments of the upper limb (muscles responsible for bending the elbow and wrist), while the posterior divisions carry fibers destined for the extensor compartments (muscles responsible for straightening). This division into flexor and extensor components represents a crucial functional segregation that determines the motor outcome of the eventual peripheral nerves. It is a transitional phase that occurs rapidly and is often overlooked clinically but is essential to the plexus's structural logic.

The six divisions then regroup medial to the pectoralis minor muscle to form the three Cords, named according to their relationship to the axillary artery: the lateral cord (formed by the anterior divisions of the superior and middle trunks), the posterior cord (formed by all three posterior divisions), and the medial cord (formed by the anterior division of the inferior trunk). These cords are the immediate precursors to the major peripheral nerves of the arm. The cords begin to give off their own set of branches, such as the lateral and medial pectoral nerves and the thoracodorsal nerve, providing specific innervation to chest and back muscles before terminal branching occurs.

3. Functional Significance and Innervation

The immense functional significance of the **brachial plexus** stems from its efficient restructuring of neural input into five major terminal branches that provide dedicated motor and sensory functions to the entire upper limb. These five terminal nerves--the Musculocutaneous, Axillary, Radial, Median, and Ulnar nerves (commonly remembered by the mnemonic MARMU)--are responsible for executing every movement and sensing every sensation below the shoulder. The Musculocutaneous nerve, a branch of the lateral cord, innervates the primary forearm flexors (biceps brachii, brachialis) and provides sensation to the lateral forearm, thus governing essential elbow flexion.

The Axillary nerve, arising from the posterior cord, is crucial for shoulder stability and abduction, supplying the deltoid and teres minor muscles. Damage here significantly compromises the ability

to lift the arm. Arguably the largest and most functionally diverse of the terminal branches is the Radial nerve, also originating from the posterior cord. This nerve is responsible for innervating all muscles of the posterior compartment of the arm and forearm, making it the primary controller of elbow, wrist, and finger extension. Injury to the radial nerve characteristically results in "wrist drop," illustrating its essential role in antigravity support for the hand.

The Median and Ulnar nerves collaborate to control the complex, fine motor movements of the forearm and hand. The Median nerve, derived from contributions from both the lateral and medial cords, supplies most of the flexors of the forearm and is indispensable for pronation and thumb opposition--the critical movement that facilitates gripping. Sensory innervation from the Median nerve covers the majority of the palm and digits, highlighting its importance in tactile sensation. In contrast, the Ulnar nerve, a direct continuation of the medial cord, is often referred to as the "nerve of fine hand movements." It supplies the intrinsic hand muscles (excluding the thenar eminence and lateral two lumbricals), enabling precision tasks and providing sensation to the medial side of the hand and the ring and little fingers.

The integrated function of these five nerves ensures a continuum of force, movement, and sensation. For instance, lifting a heavy object requires the Axillary nerve to stabilize the shoulder, the Musculocutaneous nerve to flex the elbow, and the Radial nerve to counteract the weight by extending the wrist slightly, all while the Median and Ulnar nerves ensure a secure grip. A loss of function in any one of these major nerves due to plexus damage fundamentally disrupts this delicate synchrony, leading to significant disability and loss of functional independence.

4. Etiology of Brachial Plexus Injuries (BPI)

Brachial Plexus Injuries (BPI) represent a significant clinical challenge, often resulting from high-energy mechanisms that cause sudden, violent displacement or compression of the upper limb relative to the trunk. The most common mechanism in adults is the application of severe traction or stretching forces, usually when the head and neck are forced away from the shoulder, such as during motorcycle accidents or high-speed vehicular trauma. These forces can lead to avulsion injuries, where the nerve roots are torn completely from the spinal cord--the most severe and often irreversible type of injury--or rupture, where the nerve is torn outside the spine.

As noted in clinical observations, the incidence of BPI is disproportionately high among individuals participating in intense activities, particularly competitive sports and recreational motorcycling, due to the high risk of sudden, impactful trauma to the shoulder region. Furthermore, substantial evidence indicates that a considerable number of BPI cases also result from injury sustained in the **workplace**. These occupational injuries often involve heavy machinery, falls from heights, or repetitive strain leading to compression syndromes. The resulting nerve damage can be disabling, requiring prolonged rehabilitation or surgical intervention to restore function.

Beyond traction injuries, BPI can also result from penetrating trauma, such as gunshot wounds or stab wounds, which directly sever or damage the nerves, or from compressive forces. Compression can occur acutely, as seen with fracture dislocations of the shoulder or clavicle, or chronically, such as in cases of thoracic outlet syndrome, where the nerves, subclavian artery, and vein are compressed as they pass through the narrow passageway between the collarbone and the first rib. The specific mechanism of injury dictates the location, severity, and prognosis of the resultant neurological deficit, necessitating detailed diagnostic imaging and neurological assessment.

5. Clinical Manifestations and Diagnosis of BPI

The clinical presentation of a Brachial Plexus Injury is highly variable, depending on which parts of the plexus (roots, trunks, divisions, or cords) are affected, and whether the injury is supraclavicular (above the clavicle, typically affecting roots/trunks) or infraclavicular (below the clavicle, typically affecting cords/terminal branches). A patient with a complete brachial plexus injury (known as a flail arm) presents with total paralysis and anesthesia of the entire upper limb. More commonly, the injury is partial, leading to specific patterns of weakness and sensory loss. For example, an upper plexus injury (C5, C6) often results in an inability to abduct the shoulder or flex the elbow, while a lower plexus injury (C8, T1) primarily compromises hand function and grip strength.

Diagnosis relies on a meticulous physical examination combined with sophisticated neurophysiological and imaging studies. The clinical examination focuses on identifying the specific muscle groups affected, grading muscle strength, and mapping the areas of sensory deficit to localize the level of injury within the plexus. Electrodiagnostic studies, including electromyography (EMG) and nerve conduction velocity (NCV) tests, are critical for determining the severity of the damage (axonotmesis, neurotmesis, or neuropraxia) and distinguishing between preganglionic (avulsion) and postganglionic injuries. The presence of functioning muscles innervated by the injured nerve roots suggests a postganglionic injury, which has a better spontaneous recovery potential.

Imaging plays an essential complementary role. Magnetic Resonance Imaging (MRI) of the cervical spine and brachial plexus is used to directly visualize the nerve roots and surrounding soft tissues, helping to identify root avulsions, pseudomeningoceles (cysts formed by the torn meningeal coverings), and hematomas. High-resolution ultrasonography has also emerged as a non-invasive tool for visualizing the peripheral nerve bundles themselves, assessing continuity, and detecting neuromas (tangled masses of regenerating nerve fibers). Accurate and timely diagnosis is paramount, as surgical intervention for severe injuries often carries a time-sensitive window of opportunity, typically within 3 to 6 months post-injury, before irreversible muscle atrophy occurs.

6. Management and Prognosis

The management strategy for a **brachial plexus injury** is dictated by the severity and type of nerve damage. Mild injuries (neuropraxia), characterized by temporary conduction block without structural damage to the axon, are usually managed conservatively with immobilization, pain control, and physical therapy, often resulting in full recovery within weeks to months. However, more severe injuries (axonotmesis or neurotmesis) require aggressive intervention. Physical and occupational therapy are foundational to all treatment plans, aimed at preventing joint stiffness (contractures) and maintaining muscle bulk while awaiting potential nerve regeneration.

For injuries involving nerve rupture or avulsion, surgical reconstruction is typically necessary. Surgical options include nerve grafting, where a segment of a sensory nerve (often the sural nerve from the leg) is harvested and used to bridge a gap in the damaged brachial plexus segment. When the nerve root is avulsed from the spinal cord, preventing traditional repair, surgeons often perform nerve transfers. This technique involves redirecting a less critical, functioning nearby nerve (e.g., intercostal nerves, accessory nerve) to supply the target muscle group, sacrificing the donor nerve's function to restore more essential functions like elbow flexion or shoulder abduction.

The prognosis for BPI varies widely. Spontaneous recovery is common in mild injuries and in certain types of traction injuries where the neural sheath remains intact. However, avulsion injuries carry the poorest prognosis, often requiring complex reconstructive surgery and resulting in significant residual functional deficits. The outcome is highly dependent on factors such as patient age, the specific level of injury, the length of the nerve gap requiring repair, and the time elapsed between injury and surgical treatment. Rehabilitation is lengthy and intensive, often lasting for years, and frequently includes secondary procedures such as tendon transfers or joint fusion to improve function after maximal nerve recovery has been achieved.

7. Pediatric Considerations: Obstetric Brachial Plexus Palsy

While often associated with adult trauma, the **brachial plexus** is also frequently injured during childbirth, resulting in a condition known as Obstetric Brachial Plexus Palsy (OBPP). This injury typically occurs during a difficult delivery, often involving shoulder dystocia, where excessive lateral traction is placed on the infant's head and neck to deliver the shoulder. This stretching mechanism damages the nerves, usually affecting the C5 and C6 roots (Erb-Duchenne palsy), leading to weakness in the shoulder and elbow muscles, classically presenting with the "waiter's tip" posture (arm adducted, internally rotated, elbow extended, and wrist flexed).

Conversely, a less common form, Klumpke's palsy, results from injury to the lower roots (C8, T1), which can occur if the arm is pulled excessively overhead during delivery. This causes weakness primarily in the intrinsic hand muscles and may be associated with Horner's Syndrome if the T1 root is involved preganglionically. The initial management for OBPP is conservative, focusing on

non-operative treatment with range-of-motion exercises and splinting to prevent contractures, given the high rate of spontaneous recovery, particularly in mild stretching injuries.

If significant functional improvement is not observed within the first 3 to 6 months of life, surgical exploration and repair are typically indicated. Microsurgical nerve procedures, including grafting and nerve transfers, are performed to maximize the potential for function before the crucial period of motor development ends. The long-term impact of OBPP can range from full recovery to permanent loss of shoulder or hand function, requiring careful monitoring by a multidisciplinary team including pediatric neurologists, orthopedic surgeons, and rehabilitation specialists.

Further Reading

[Wikipedia: Brachial Plexus](#)

[National Institute of Neurological Disorders and Stroke \(NINDS\): Brachial Plexus Injuries](#)

[American Association of Neurological Surgeons \(AANS\): Brachial Plexus Injury](#)