Brachial Plexopathy, an overview

Learning Objectives:

The brachial plexus is the network of nerves that originate from cervical and upper thoracic nerve roots and eventually terminate as the named nerves that innervate the muscles and skin of the arm. Brachial plexopathies are not common in most practices, but a detailed knowledge of this plexus is important for distinguishing between brachial plexopathies, radiculopathies and mononeuropathies. It is impossible to write a paper on brachial plexopathies without addressing cervical radiculopathies and root avulsions as well.

In this paper will review brachial plexus anatomy, clinical features of brachial plexopathies, differential diagnosis, specific nerve conduction techniques, appropriate protocols and case studies. The reader will gain insight to this uncommon nerve problem as well as the importance of the nerve conduction studies used to confirm the diagnosis of plexopathies.

Anatomy of the Brachial Plexus:

To assess the brachial plexus by localizing the lesion at the correct level, as well as the severity of the injury requires knowledge of the anatomy. An injury involves any condition that impairs the function of the brachial plexus. The plexus is derived of five roots, three trunks, two divisions, three cords, and five branches/nerves.

Spinal roots join to form the spinal nerve. There are dorsal and ventral roots that emerge and carry motor and sensory fibers. Motor (efferent) carries messages from the brain and spinal cord to the peripheral nerves. Sensory (afferent) carries messages from the peripheral to the spinal cord or both. A small ganglion containing cell bodies of sensory fibers lies on each posterior root. They join and form the spinal nerve that exits from the spinal canal through the intervertebral foramina.

This Dorsal Root Ganglion is why sensory NCS's are so important; separating brachial plexus lesions from cervical radiculopathies

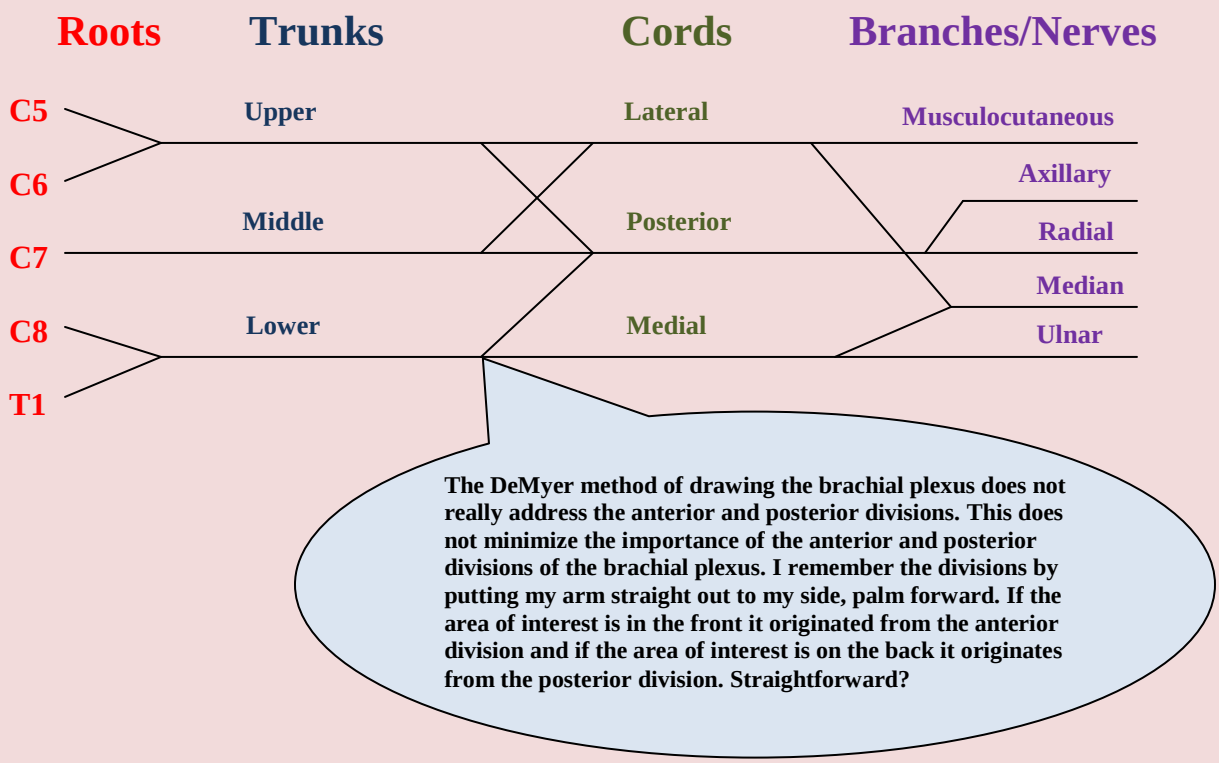
After passing through the foramina the spinal nerve branches into two different divisions called the anterior and posterior rami. The posterior rami supplies the posterior part of the skin and paraspinal muscles. The anterior rami supply the skin of the anterior lateral portion of the trunk and the extremities.

The anterior rami of C5-T1 supply the muscles of the upper limb. Roots combine to form three trunks, the upper, middle and lower trunk. Each trunk has an anterior and posterior division. From there, separation is made into the lateral, medial or posterior cord, and eventually the peripheral nerves.

There are two nerves that come directly from roots proximal to the plexus, the long thoracic and dorsal scapular nerves.
The long thoracic nerve emerges directly from the C5-C7 roots and innervates the serratus anterior muscle. The dorsal scapular nerve emerges from C5 and supplies the rhomboid muscle.

There are 5 distinct regions that include Roots, Trunks, Divisions, Cords and Branches (or nerves). A common mnemonic to remember these fiber interconnections is "Randy Travis Drinks Cold Beer." Of course, some of us have been around longer than Randy Travis has been famous. A mnemonic that spans the course of time is "Read The Damn Cadaver Book."

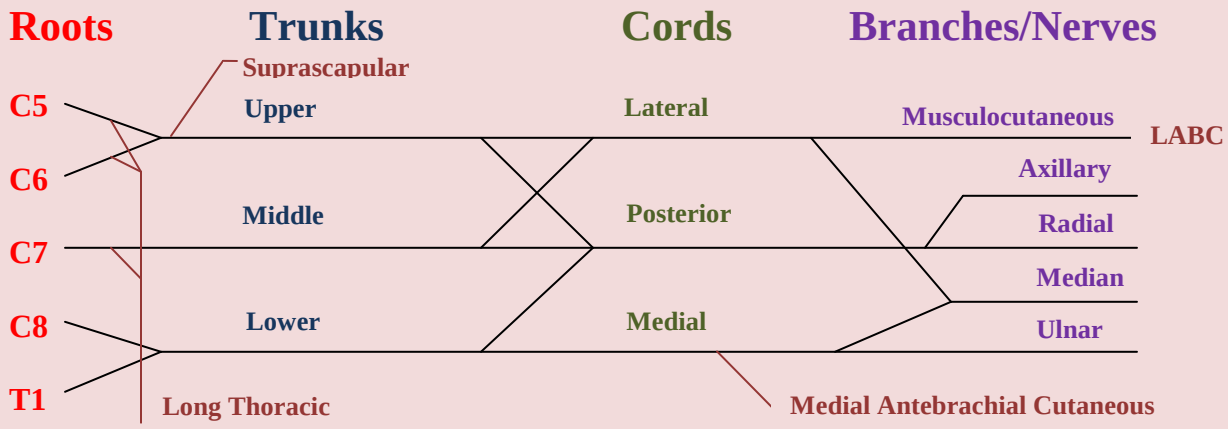
For ease, we use the DeMyer 5-3-3-5 method of drawing the brachial plexus. It is simple, quick and covers 80% of what we need for immediate recall.
Refer to the following drawing often while studying this text.



Forming the plexus:

- The upper trunk is formed by the C5-C6 nerve roots. The upper trunk divides:
    - The anterior division proceeds to the lateral cord and finally, the
        - Outer branch of the median nerve
            - Both motor and sensory fibers. The motor fibers innervate the pronator teres and flexor carpi radialis (with fibers from C7, middle trunk) while the sensory fibers continue to the lateral portion of the hand, and
        - Musculocutaneous nerve
            - Both motor and sensory fibers. Motor fibers innervate the biceps, coracobrachialis, and brachialis muscles. The sensory branch, called the lateral antebrachial cutaneous nerve supplies the skin over the lateral aspect of the forearm.
    - The posterior division proceeds to the posterior cord and branches to the:
        - Axillary nerve
            - Both motor and sensory fibers. Motor fibers innervate the deltoid muscle while sensory fibers innervate sensation over the deltoid region, and
        - Radial nerve
            - Both motor and sensory fibers. Motor fibers innervate the brachioradialis and extensor carpi radialis (longus and brevis) with some contributions to the triceps and supinator. Sensory fibers continue to the lateral dorsum of the hand.
    - Also exiting the upper trunk is the suprascapular nerve
        - A motor nerve innervating the supraspinatus and infraspinatus muscles in the scapular region.
- The middle trunk is formed entirely from the C7 root. Sometimes called the "Axis of Symmetry," because C7 runs directly into its cord while C5-C6 unites and C8-T1 unites.
    - The posterior division goes directly to the posterior cord which,
        - Becomes the axillary nerve (although all fibers supplying the axillary nerve come from the upper trunk),
        - Radial nerve,
            - Motor fibers innervate most of the triceps, and portions of the extensor digitorum communis and extensor indicis proprius among as well as the rest of the extensor muscles in the forearm. The muscles in the forearm are innervated after the radial nerve splits and the motor branch becomes the posterior interosseous nerve.
        - Thoracodorsal nerve, innervating a portion of the latissimus dorsi and
        - Subscapular nerve which innervates a portion of the teres major.

        - The anterior division proceeds to the lateral cord
            - Outer branch of the median nerve
                - Innervating sensory fibers to the middle finger.
- The lower trunk is formed by the C8-T1 nerve roots. The lower trunk divides:
    - The anterior division continues to the medial cord and finally, the
        - Ulnar nerve
            - Both motor and sensory fibers. The motor fibers innervate the flexor carpi ulnaris in the forearm and the abductor digiti minimi, first dorsal interosseous and the deep head of the flexor pollicis brevis muscles in the hand. Sensory fibers innervate the fourth and fifth digit of the hand.
                - The dorsal ulnar cutaneous nerve branches from the ulnar nerve proximal to the wrist and innervated sensation to the medial dorsum of the hand.
        - Inner branch of the median nerve
            - Motor fibers to the abductor pollicis brevis, the superficial head of the flexor pollicis brevis and the opponens pollicis
    - The posterior division of the lower trunk proceeds to the posterior cord
        - Radial nerve
            - Innervates the additional portions of the radial/posterior interosseous muscles not supplied from C7 and middle trunk
    - Additionally, the medial antebrachial cutaneous branches from the medial cord and innervates sensation to the medial forearm.



Injuries and diseases can affect the plexus and cause damage. Upper trunk plexopathies can be caused by a birth trauma, radiation therapy, and neuralgic amyotrophy.

Middle trunk plexopathy is rare and usually caused by injury.

Lower trunk plexopathy is usually caused by trauma, a Pancoast tumor, Dejerine-Klumpke, CABG (associated with a jugular vein), and metastatic disease.

The brachial plexus is a complex structure. The diagnosis of a root lesion depends on abnormalities confined to a single root level without affecting higher or lower limb levels.

Of note, while the above discussion demonstrates the most common appearance of the brachial plexus there are several variants. In fact the "Illustrated Encyclopedia of Human Anatomic Variation: Opus III: Nervous System," notes 29 variations. The most common are the "prefixed plexus" and the "postfixed plexus." When the spinal nerve contributions are shifted up one level (C4 nerve root contributes to the upper trunk) we call it a "prefixed plexus." In cases where the C5 nerve root contributes minimally, the C7 root contributes to the upper trunk while the lower trunk receives fibers from the T2 nerve root is called a "post-fixed plexus."

Clinical features of Brachial Plexopathies:

Brachial plexopathies cause motor and sensory disturbances in the shoulder, arm or both. While both motor and sensory dysfunctions co-exist, it is common for disproportionate degrees of one or the other. Sensory loss is often inconsistent while pain ranges from mild to severe and from transient to persistent. Severe, unrelenting pain is common in avulsion injuries, but is less pronounced in conditions such as neurogenic thoracic outlet syndrome.

Brachial plexus lesions are often classified by etiology (i.e. traumatic or non-traumatic plexopathies)

Traumatic injuries are the most common cause of brachial plexus lesions. They are a result of automobile, motorcycle, bicycle accidents, penetrating knife, or gunshot wounds. Most Traumatic plexopathies are the result of traction and stretch injuries. Severe traction injuries may result in damage to the roots as well as the plexus.

Root avulsions are when the nerve roots are torn and axons are damaged beyond repair. They often occur in combination with brachial plexus injuries. The most common roots affected in root avulsions are C8/T1.

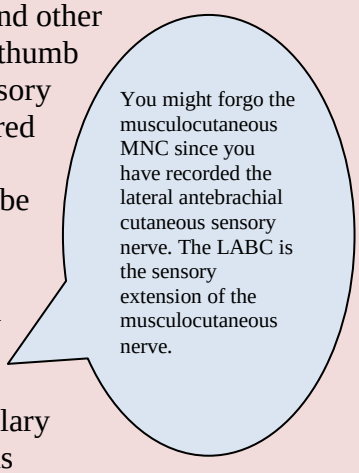
Nontraumatic plexopathies include neuralgic amyotrophy (sometimes called Parsonage-Turner syndrome or idiopathic brachial plexopathy), hereditary brachial plexopathy, neoplastic or radiation induced brachial plexopathy and neurogenic thoracic outlet syndrome to mention a few

Another method of classifying brachial plexopathies is based on clinical and electrodiagnostic findings and our preferred method. Following is a review of what one might see with lesions affecting various trunks and cords of the brachial plexus.

Upper trunk plexopathies

These are the most common brachial plexopathies. Weakness occurs in nearly all muscles with C5-6 innervation including the deltoid and biceps brachii (the patient has difficulty lifting their arms). Sensory loss occurs in the lateral arm, lateral forearm, lateral hand, and thumb.

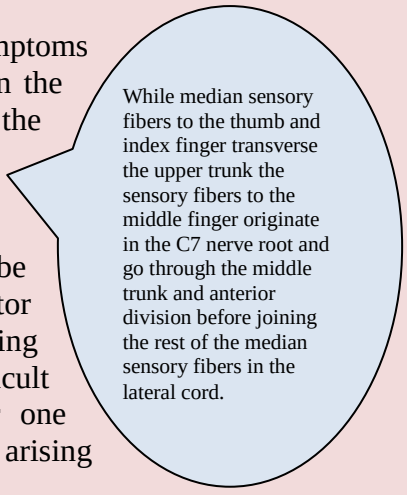
The EMG/NCS will be used to rule out a C5-6 radiculopathy and other mononeuropathies. In the case of the upper trunk, the median (thumb and index finger), radial and lateral antebrachial cutaneous sensory nerves will show reduced amplitudes particularly when compared to the unaffected arm. The median (to the middle and ring finger), ulnar and medial antebrachial cutaneous nerves would be normal in upper trunk plexopathies. Sensory nerve conduction studies would be normal in C5-6 radiculopathies and avulsion injuries. Routine motor nerve conduction studies of the median and ulnar nerves are not particularly useful in distinguishing upper trunk or C5-6 radiculopathies, but MNC's would be absent in avulsion injuries to C5-6. Musculocutaneous and axillary motor nerve studies would show decreased CMAP amplitude as compared to the unaffected side.



An extensive needle EMG should be performed to ensure abnormalities are restricted to muscles innervated by the upper trunk, with sparing of muscles innervated by the middle and lower trunks.

Middle trunk plexopathies

Isolated middle trunk plexopathies are rare. Sign and symptoms resemble those of a C7 radiculopathy. Weakness occurs in the elbow, wrist and finger extensors. Sensory loss occurs in the posterior forearm and the dorsal and palmar aspect of the middle finger.



The median sensory response to the middle finger will be reduced as compared to the unaffected side. Radial motor conduction study will have reduced amplitude. The remaining nerve conduction studies will be unaffected. It can be difficult to distinguish a lesion involving the middle trunk for one involving the posterior cord as there are no nerve branches arising directly from the middle trunk.

Needle EMG abnormalities would include all radial innervated muscles and C7 median forearm innervated muscles.

Lower trunk plexopathies

Lower trunk plexopathies present with symptoms similar to C8-T1 radiculopathies, medial cord plexopathies and even ulnar neuropathies. Weakness is evident in all median and ulnar innervated hand muscles as well as radial innervated distal forearm and wrist muscles. The involvements of radial C8 muscles (lower trunk, posterior cord) help localize the lesion to the lower trunk by excluding the medial cord. Sensory disturbance is seen in the medial aspect of the arm, forearm and hand in a larger distribution than an ulnar neuropathy.

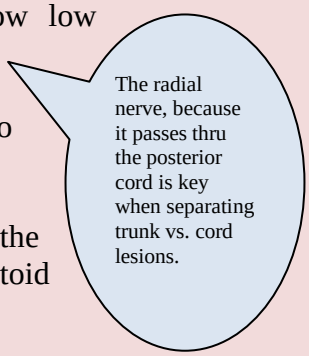
Sensory nerve conduction studies of the ulnar and medial antebrachial cutaneous nerves reveal reduced amplitudes while all median sensory nerves remaining normal. There would be decreased CMAP amplitude in both ulnar and median motor NCS, but this might be true in severe a severe C8-T1 radiculopathy as well.

An extensive needle EMG should be performed to ensure abnormalities are restricted to muscles innervated by the lower trunk. In a lower trunk plexopathy the lower paraspinal muscles will not show denervation, but a C8-T1 radiculopathy would show changes in the paraspinals.

Posterior cord plexopathies

Posterior cord plexopathies, like middle trunk plexopathies, are uncommon. The radial, axillary, upper and lower subscapular and thoracodorsal nerves are derived from the posterior cord. Symptoms of posterior cord lesions include weakness of shoulder abduction and adduction, wrist drop and finger drop, and arm extension weakness. Sensory loss is evident in the lateral arm, posterior arm, forearm, and radial dorsal hand.

The sensory conduction study of the radial nerve would show low amplitude especially compared to the unaffected side. The lateral antebrachial cutaneous nerve would be normal. Motor study to the radial innervated extensor indicis proprius would be expected to show reduced amplitude.



A needle EMG would show denervation in muscles innervated by the posterior cord. Included in the list would be latissimus dorsi, deltoid and radial innervated muscles.

Lateral cord plexopathies

Patients with lateral cord plexopathies experience weakness of shoulder flexion and abduction, elbow, arm pronation and wrist flexion. Sensory loss can be found in lateral forearm, lateral hand, and first three fingers.

Sensory nerve conduction studies to the median innervated first three digits and the lateral antebrachial cutaneous innervated lateral forearm should show reduced amplitude

as compared to the unaffected side. The radial innervated thumb would be preserved in lateral cord lesions (posterior cord), but would be involved if the lesion were in the upper trunk. The motor fibers of the median and ulnar nerves originate from C8-T1, lower trunk and medial cord thus would be unaffected in lateral cord lesions. Motor nerve conduction study of the musculocutaneous nerve to the biceps would show reduced amplitude as compared to the unaffected side.

A needle EMG would show denervation in muscles innervated by the lateral cord, including biceps (C5-C6, upper trunk, lateral cord, and musculocutaneous n.), pronator teres and flexor carpi radialis (C6-C7, upper/middle trunk, lateral cord, and median n.) muscles. Muscles unaffected in lateral cord lesions include deltoid (C5-C6, upper trunk, posterior cord and axillary n.), triceps (C7, middle trunk, posterior cord and radial n.), infra- and supraspinatus (C5-C6, upper trunk, and suprascapular n.).

Medial Cord Plexopathies

Findings of medial cord lesions are the same as lower trunk lesions with one notable exception: the radial MNC. Remember, the C8 motor fibers of the radial nerve go thru the lower trunk then the posterior cord while C8 and T1 motor fibers of the median and ulnar nerves also transverse the lower trunk, but these go thru the medial cord. Therefore only median and ulnar innervated muscles will be affected in medial cord lesions.

Radial sensory is not as useful in medial cord lesions as it is in posterior cord lesions. The sensory fibers come from C5-C6, upper trunk and posterior cord. They would be unaffected in medial cord lesions. Like the median nerve the motor and sensory fibers originate from different nerve roots.

Sensory nerve conduction studies of the ulnar and medial antebrachial cutaneous nerves reveal reduced amplitudes while all median sensory nerve remains normal. There would be decreased CMAP amplitude in both ulnar and median motor NCS, but this would be true in lower trunk lesions as well. Motor nerve conduction study of the radial nerve to the extensor indicis proprius would be symmetrical, side-to-side.

An extensive needle EMG should be performed to ensure abnormalities are restricted to muscles innervated by the medial cord. Again, one would expect the radial innervated muscles in the distal forearm to be preserved in medial cord lesions, but abnormal in lower trunk lesions.

Differential Diagnosis:

Cervical radiculopathies – while cervical radiculopathy may be the most important piece in differential diagnosis it is really quite easy to make the differential. If the sensory nerve conductions are normal look to cervical radiculopathy (i.e. pre-ganglionic). If the sensory nerve conductions are abnormal consider brachial plexus (or other post-ganglionic) causes.

Mononeuropathy – The most common mononeuropathies in the upper extremities are median neuropathy at the wrist and ulnar neuropathy at the elbow.

There is a relationship of the motor and sensory findings in median neuropathies. The motor and sensory fibers to the hand join at the end of the brachial plexus, so in median neuropathies the sensory and motor abnormalities correspond. If the lesion is in the upper/middle trunk or the lateral cord, median sensory will be affected, but median motor fibers will be spared. Likewise in lower trunk and medial cord lesions the median motor fibers will show changes, but the sensory fibers will be unaffected.

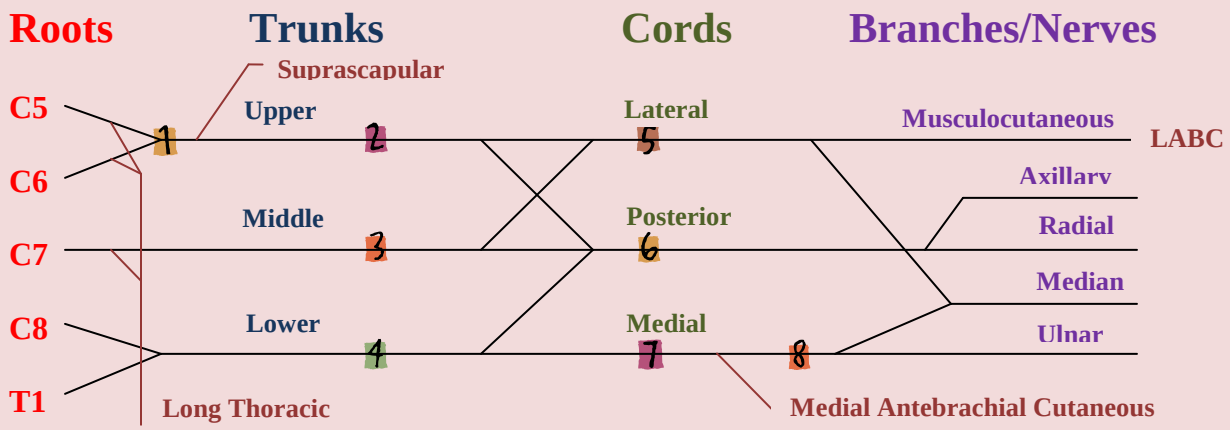
Similarly, in lower trunk and medial cord lesions, sensation to the medial forearm is affected. In ulnar neuropathies the medial antebrachial cutaneous nerve is spared and no such sensory abnormalities are apparent. In addition, lower trunk/medial cord lesions affect the median motor fibers, but an ulnar neuropathy does not.

Radial nerve lesions at the spiral groove affect both motor and sensory fibers distally. Lesions of the posterior cord would also include abnormalities of both the motor and sensory portions since the radial nerve is essentially an extension of the posterior cord. Upper and middle trunk plexopathies would show changes in the sensory NCS, but spare the MNC fibers. Contrasting, lesions in the lower trunk will show MNC abnormalities (distally, i.e. EIP), but the sensory fibers would be spared.

All the NCS findings should be considered in combination. For instance, we wrote the median motor fibers are affected in lower trunk/medial cord lesions while the median sensory fibers would be spared. Certainly, if there was a lower trunk/medial cord lesions ulnar motor and sensory fibers would be abnormal. Look for the combinations.

Nerve Conduction Studies:

The numbers are locations of lesions then look below for the corresponding nerve conduction studies. The normal and abnormal comments are general patterns, not hard and fast rules.



1. Upper trunk before the suprascapular exits –
    a. Patterns of *Abnormal Sensory* NCS
        i. Lateral antebrachial cutaneous
        ii. Radial
            1. may be only mildly abnormal or even normal because some fibers come from the middle trunk
        iii. Median (dig I and dig II)
            1. Dig I most likely abnormal, digit II gets some fibers from the middle trunk.
            2. Dig III would be normal as it receives all sensory fibers from the middle trunk
    b. Patterns of *Normal Sensory* NCS
        i. Ulnar
        ii. Medial antebrachial cutaneous
    c. Patterns of *Abnormal Motor* NCS
        i. Supraspinatus/Infraspinatus
            1. Motor NCS to these muscles can be a challenge. It may be better to have your physician confirm inclusion of these muscles with needle EMG
        ii. Musculocutaneous
            1. You may forgo this MNC exam and perform the LABC, because the LABC is the sensory extension of the musculocutaneous nerve.
        iii. Axillary
    d. Patterns of *Normal Motor* NCS
        i. Median, motor fibers from C8 and T1
        ii. Ulnar, motor fibers from C8 and T1
    e. Patterns of *F-waves* of the median and ulnar nerves would normal
    f. Patterns of *Abnormal Needle EMG*
        i. Muscles affected are deltoid, biceps, brachioradialis, supraspinatus, and infraspinatus
        ii. Muscles partially affected are the pronator teres (C6-7) and triceps (C6-C7-C8)
    g. Patterns of *Normal Needle EMG*
        i. Rhomboids exit the C5 root above this lesion
        ii. Additional muscles from unaffected portions
2. Upper trunk after the suprascapular exits –
    a. Patterns of *Abnormal Sensory* NCS
        i. Lateral antebrachial cutaneous
        ii. Radial
            1. may be only mildly abnormal or even normal because some fibers come from the middle trunk
        iii. Median (dig I and dig II)
            1. Dig I most likely abnormal, digit II gets some fibers from the middle trunk.
            2. Dig III would be normal as it receives all sensory fibers from the middle trunk

b. Patterns of *Normal Sensory* NCS
    i. Ulnar
    ii. Medial antebrachial cutaneous
c. Patterns of *Abnormal Motor* NCS
    i. Musculocutaneous
        1. You may forgo this MNC exam and perform the LABC, because the LABC is the sensory extension of the musculocutaneous nerve.
    ii. Axillary
d. Patterns of *Normal Motor* NCS
    i. Median, motor fibers from C8 and T1
    ii. Ulnar, motor fibers from C8 and T1
    iii. Supraspinatus/Infraspinatus
e. Patterns of *F-waves* of the median and ulnar nerves would normal
f. Patterns of *Abnormal Needle EMG*
    i. Muscles affected are deltoid, biceps and brachioradialis,
    ii. Muscles partially affected are the pronator teres (C6-7) and triceps (C6-C7-C8)
g. Patterns of *Normal Needle EMG*
    i. Supraspinatus and Infraspinatus
    ii. Additional muscles from other segments

3. Middle trunk
    a. Patterns of *Abnormal Sensory* NCS
        i. Median nerve to Digit III
        ii. Radial
            1. may or may not be abnormal because some fibers come from the upper trunk
    b. Patterns of *Normal Sensory* NCS
        i. Median to digit I and digit II
        ii. Ulnar
        iii. Lateral antebrachial cutaneous
        iv. Medial antebrachial cutaneous
    c. Patterns of *Abnormal Motor* NCS
        i. All motor NCS should be normal
    d. Patterns of *Normal Motor* NCS
        i. All motor NCS should be normal
    e. Patterns of *F-waves* of the median and ulnar nerves would normal
    f. Patterns of *Abnormal Needle EMG*
        i. Triceps, flexor carpi radialis, and pronator teres muscles.
    g. Patterns of *Normal Needle EMG*
        i. Additional muscles from other segments
4. Lower trunk
    a. Patterns of *Abnormal Sensory* NCS
        i. Ulnar
        ii. Medial antebrachial cutaneous
    b. Patterns of *Normal Sensory* NCS
        i. Median

ii. Radial
iii. Lateral antebrachial cutaneous

c. Patterns of *Abnormal Motor* NCS
i. Median (varying degrees)
ii. Ulnar (varying degrees)

d. Patterns of *Normal Motor* NCS
i. Radial, musculocutaneous and axillary

e. Patterns of *F-waves* of the median and ulnar nerves may have varying degrees of prolonged f-wave latency

f. Patterns of *Abnormal Needle EMG*
i. All ulnar nerve innervated muscles (flexor carpi ulnaris, flexor digitorum profundis, lumbrical muscles, opponens digiti minimi, flexor digiti minimi, abductor digiti minimi,interossei,adductor pollicis), in addition to median C8-T1 muscles (abductor pollicis brevis, flexor pollicis longus, flexor digitorum profundus), and radial C8 innervated muscles (extensor indicis proprius and extensor pollicis brevis).

g. Patterns of *Normal Needle EMG*
i. Pronator teres, triceps, biceps and C8-T1 paraspinals are normal.

5. Lateral cord
a. Patterns of *Abnormal Sensory* NCS
i. Lateral antebrachial cutaneous
ii. Median to digit I and digit II

b. Patterns of *Normal Sensory* NCS
i. Radial
ii. Ulnar
iii. Medial antebrachial cutaneous

c. Patterns of *Abnormal Motor* NCS
i. Musculocutaneous

d. Patterns of *Normal Motor* NCS
i. Median, motor fibers from C8 and T1
ii. Ulnar, motor fibers from C8 and T1
iii. Axillary (posterior cord)
iv. Supraspinatus/Infraspinatus

e. Patterns of *F-waves* of the median and ulnar nerves would normal

f. Patterns of *Abnormal Needle EMG*
i. Pronator teres, flexor carpi radialis, and biceps

g. Patterns of *Normal Needle EMG*
i. Additional muscles from other segments

6. Posterior cord
a. Patterns of *Abnormal Sensory* NCS
i. Radial

b. Patterns of *Normal Sensory* NCS
i. Median
ii. Ulnar
iii. Lateral antebrachial cutaneous
iv. Medial antebrachial cutaneous

c. Patterns of *Abnormal Motor* NCS
    i. Radial
d. Patterns of *Normal Motor* NCS
    i. Median
    ii. Ulnar
e. Patterns of *F-waves* of the median and ulnar nerves would normal
f. Patterns of *Abnormal Needle EMG*
    i. Deltoid, triceps, brachioradialis, extensor carpi radialis longus, extensor indicis proprius, and other radial innervated muscles
g. Patterns of *Normal Needle EMG*
    i. Additional muscles from other segments

7. Medial cord before the medial antebrachial cutaneous nerve exits
    a. Patterns of *Abnormal Sensory* NCS
        i. Ulnar
        ii. Medial antebrachial cutaneous
    b. Patterns of *Normal Sensory* NCS
        i. Median
        ii. Radial
        iii. Lateral antebrachial cutaneous
    c. Patterns of *Abnormal Motor* NCS
        i. Median (varying degrees)
        ii. Ulnar (varying degrees)
    d. Patterns of *Normal Motor* NCS
        i. Radial, musculocutaneous and axillary
    e. Patterns of *F-waves* of the median and ulnar nerves may have varying degrees of prolonged f-wave latency
    f. Patterns of *Abnormal Needle EMG*
        i. Ulnar and median nerve innervated muscles
    g. Patterns of *Normal Needle EMG*
        i. C8 radial innervated muscles are preserved
8. Medial cord after the medial antebrachial cutaneous nerve exits
    a. Patterns of *Abnormal Sensory* NCS
        i. Ulnar
    b. Patterns of *Normal Sensory* NCS
        i. Medial antebrachial cutaneous
        ii. Median
        iii. Radial
        iv. Lateral antebrachial cutaneous
    c. Patterns of *Abnormal Motor* NCS
        i. Median (varying degrees)
        ii. Ulnar (varying degrees)
    d. Patterns of *Normal Motor* NCS
        i. Radial, musculocutaneous and axillary
    e. Patterns of *F-waves* of the median and ulnar nerves may have varying degrees of prolonged f-wave latency

f. Patterns of *Abnormal Needle EMG*
    i. Ulnar and median nerve innervated muscles
g. Patterns of *Normal Needle EMG*
    i. C8 radial innervated muscles are preserved

Case Studies:

Case 1

For your convenience values outside the normal range are **bolded**. Normal values for this age are stated below the tables.

History: 20 year-old-man with a gunshot wound to the anterior neck and right shoulder. There is weakness of the biceps, deltoid and brachioradialis

Temperatures: Right arm: 33.5ºC
Left arm: 34 ºC

Motor Nerve Conduction:

Nerve and Site	Segment	Distance	Latency	Amplitude	Conduction Velocity
Right Median	Rec: APB				
Wrist	Abductor pollicis brevis-Wrist	60 mm	3.2 ms	10.35 mV	
Elbow	Wrist-Elbow	265 mm	7.8 ms	9.57 mV	57.6 m/s
Right Ulnar	Rec: ADM				
Wrist	ADM-Wrist	60 mm	2.4 ms	10.90 mV	
Below elbow	Wrist-Below elbow	240 mm	6.4 ms	9.78 mV	60.0 m/s
Above elbow	Below elbow-Above elbow	125 mm	8.3 ms	9.74 mV	65.7 m/s
Right Musculocutaneous	Rec: Biceps				
Supraclavicular			4.9 ms	**1.29 mV**	
Left Musculocutaneous	Rec: Biceps				
Supraclavicular			4.9 ms	7.79 mV	
Right Axillary	Rec: Deltoid				
Supraclavicular			4.3 ms	**0.78 mV**	
Left Axillary	Rec: Deltoid				
Supraclavicular			3.9 ms	5.44 mV	

Sensory Nerve Conduction:

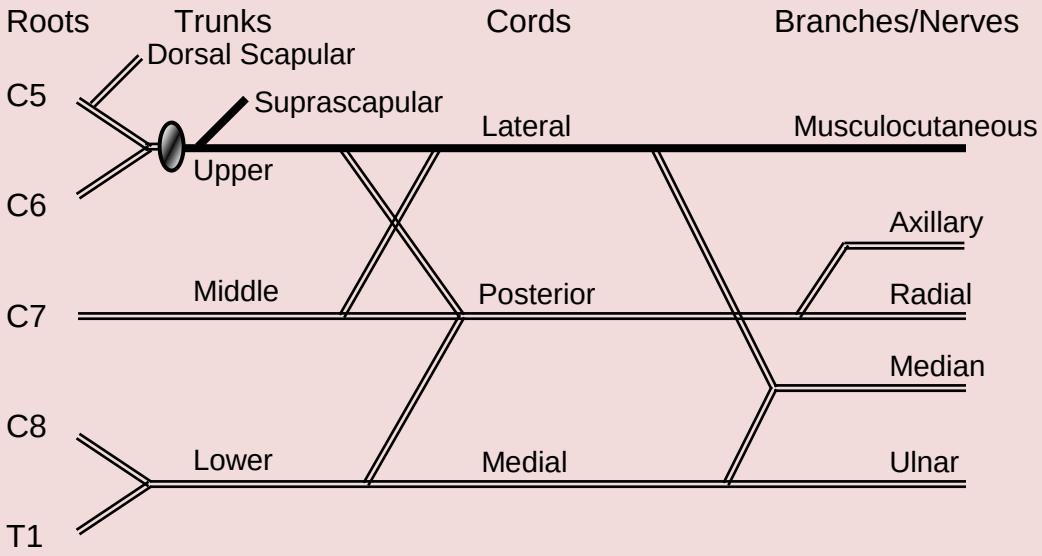
Nerve and Site	Segment	Distance	Amplitude	Peak Latency
Right Median	Rec: Wrist			
Digit II (index finger)	Wrist-Digit II (index finger)	130 mm	39.9 µV	2.7 ms
Right Ulnar	Rec: Wrist			
Digit V (little fing	Wrist-Digit V (little finger)	110 mm	23.9 µV	2.0 ms
Right Radial	Rec: Snuffbox			
Forearm	Anatomical snuff box-Forearm	100 mm	31.8 µV	1.9 ms
Right Lateral antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	**14.2 µV**	2.3 ms
Left Lateral antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	38.9 µV	1.9 ms

Normal values:
Median MNC DML: ≤ 4.2, Amp: ≥ 4, CV ≥ 49
Ulnar MNC DML: ≤ 3.8, Amp: ≥ 6, CV ≥ 49,
CV across elbow may slow ≤ 10
Musculocutaneous: Side-to-side comparison
Axillary: Side-to-side comparison

Median SNC Peak Lat: ≤ 3.2, Amp: ≥ 12
Ulnar SNC Peak Lat: ≤ 2.8, Amp: ≥ 10
LABC SNC Peak Lat: ≤ 2.7, Amp: ≥ 12

Needle highlights: the supraspinatus, deltoid and biceps were abnormal while the rhomboids, serratus anterior and cervical paraspinals were normal.

Discussion: the median to the index finger and the radial sensory nerves conduction studies were normal presumably due to more C7/middle trunk influence. If we had been successful recording a side-to-side MNC difference of the suprascapular over the supraspinatus we may have localized even better, but in this case the needle examination did this for us. The involvement of the supraspinatus on needle examination suggests a proximal lesion before the suprascapular nerve branch is given off. The sparing of the rhomboid and serratus anterior muscles with normal paraspinal exam indicates that there is no involvement of the C5/C6 spinal nerve roots.



Case 2

For your convenience values outside the normal range are **bolded**. Normal values for this age are stated below the tables.

History: This is an 18 year-old man was a victim of a gunshot wound to the left shoulder about 3 weeks ago. There is weakness in median and ulnar innervated muscles, but extensor muscles in the forearm are spared.

Temperatures: Right arm: 33ºC
Left arm: 32.5ºC

Motor Nerve Conduction:

Nerve and Site	Segment	Distance	Latency	Amplitude	Conduction Velocity
Left Median	Rec: APB				
Wrist	Abductor pollicis brevis-Wrist	60 mm	**NR**	**NR**	
Left Ulnar	Rec: ADM				
Wrist	ADM-Wrist	60 mm	**3.9 ms**	**0.10 mV**	
Below elbow	Wrist-Below elbow	240 mm	7.9 ms	0.08 mV	54.4 m/s
Above elbow	Below elbow-Above elbow	125 mm	10.0 ms	0.07 mV	47.6 m/s
Left Radial	Rec: EIP				
Forearm	Extensor indicis proprius-Forearm	100 mm	2.7 ms	7.91 mV	
Lateral brachium	Forearm-Lateral brachium	95 mm	4.4 ms	7.93 mV	55.8 m/s
Spiral groove	Lateral brachium-Spiral groove	120 mm	6.0 ms	7.88 mV	73.1 m/s
Right Median	Rec: APB				
Wrist	Abductor pollicis brevis-Wrist	60 mm	3.6 ms	8.49 mV	
Elbow	Wrist-Elbow	245 mm	8.2 ms	8.37 mV	53.2 m/s
Right Ulnar	Rec: ADM				
Wrist	ADM-Wrist	60 mm	2.8 ms	7.45 mV	
Below elbow	Wrist-Below elbow	213 mm	6.1 ms	7.40 mV	64.5 m/s
Above elbow	Below elbow-Above elbow	100 mm	7.6 ms	7.37 mV	66.6 m/s
Right Radial	Rec: EIP				
Forearm	Extensor indicis proprius-Forearm	100 mm	2.5 ms	8.21 mV	

Sensory Nerve Conduction:

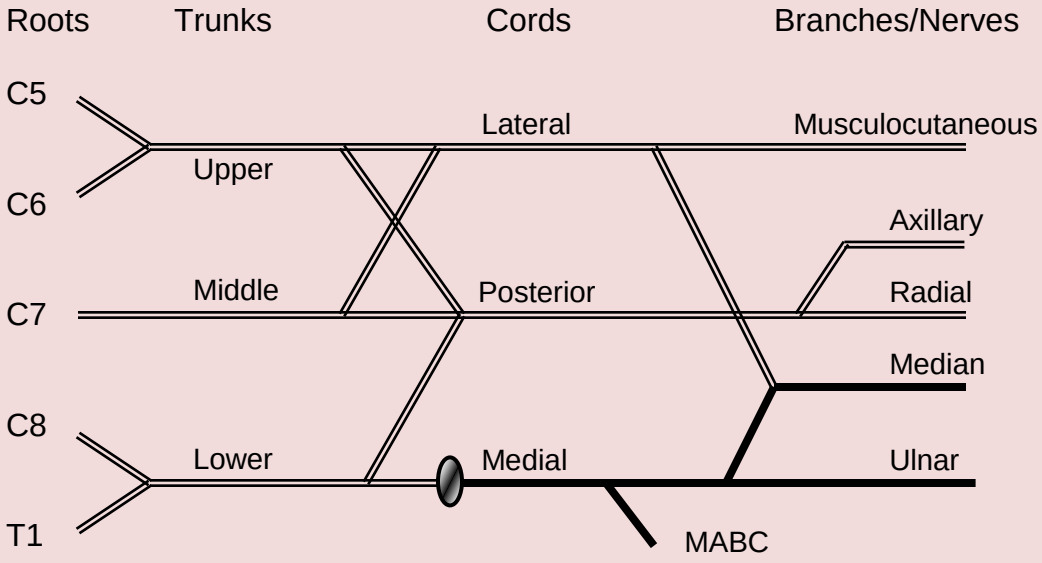
Nerve and Site	Segment	Distance	Amplitude	Peak Latency
Left Median	Rec: Wrist			
Digit II (index finger)	Wrist-Digit II (index finger)	130 mm	13.5 µV	3.2 ms
Left Ulnar	Rec: Wrist			
Digit V (little finger)	Wrist-Digit V (little finger)	110 mm	**NR**	**NR**
Left Radial	Rec: Snuffbox			
Forearm	Anatomical snuff box-Forearm	100 mm	23.5 µV	2.2 ms
Right Radial	Rec: Snuffbox			
Forearm	Anatomical snuff box-Forearm	100 mm	30.8 µV	2.1 ms
Left Lateral antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	12.5 µV	2.2 ms
Right Lateral antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	14.4 µV	2.2 ms
Left Medial antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	**NR**	**NR**
Right Medial antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	20.4 µV	2.1 ms
Right Median	Rec: Wrist			
Digit II (index finger)	Wrist-Digit II (index finger)	130 mm	15.7 µV	3.0 ms
Right Ulnar	Rec: Wrist			
Digit V (little fing	Wrist-Digit V (little finger)	110 mm	10.2 µV	2.5 ms

Normal values:
Median MNC DML: ≤ 4.2, Amp: ≥ 4, CV ≥ 49
Ulnar MNC DML: ≤ 3.8, Amp: ≥ 6, CV ≥ 49,
CV across elbow may slow ≤ 10
Radial MNC: Side-to-side comparison

Median SNC Peak Lat: ≤ 3.2, Amp: ≥ 12
Ulnar SNC Peak Lat: ≤ 2.8, Amp: ≥ 10
LABC SNC Peak Lat: ≤ 2.7, Amp: ≥ 12
Radial SNC Peak Lat: ≤ 2.7, Amp: ≥ 15
MABC SNC Peak Lat: ≤ 2.7, Amp: ≥ 10

Needle highlights: Median (excluding C7 innervated) and ulnar innervated muscles are abnormal. Radial innervated EIP muscle is normal.

Discussion: Anytime you see an affected median MNC, but spared median SNC consider a lower trunk or medial cord plexopathy (or profound C8/T1 radiculopathy). This is a medial cord injury before the MABC exits. The radial MNC and needle examination exclude the lower trunk and are our keys to localization.



Case 3

For your convenience values outside the normal range are **bolded**. Normal values for this age are stated below the tables.

History: This is a 68 year-old underwent a series of radiation treatments for breast cancer now has spotty right arm weakness.

Temperatures: Right arm: 32ºC
Left arm: 33ºC

Motor Nerve Conduction:

Nerve and Site	Segment	Distance	Latency	Amplitude	Conduction Velocity
Right Median	Rec: APB				
Wrist	Abductor pollicis brevis-Wrist	60 mm	3.7 ms	7.35 mV	
Elbow	Wrist-Elbow	225 mm	8.1 ms	6.57 mV	51.1 m/s
Right Ulnar	Rec: ADM				
Wrist	ADM-Wrist	60 mm	2.9 ms	9.98 mV	
Below elbow	Wrist-Below elbow	210 mm	6.7 ms	8.72 mV	55.3 m/s
Above elbow	Below elbow-Above elbow	100 mm	8.8 ms	8.70 mV	52.6 m/s

Right Radial	Rec: EIP				
Forearm	Extensor indicis proprius-Forearm		2.5 ms	8.91 mV	
Lateral brachium	Forearm-Lateral brachium	110 mm	4.2 ms	8.53 mV	64.7 m/s
Spiral groove	Lateral brachium-Spiral groove	130 mm	6.3 ms	7.94 mV	61.9 m/s
Left Radial	Rec: EIP				
Forearm	Extensor indicis proprius-Forearm		2.3 ms	9.54 mV	

Sensory Nerve Conduction:

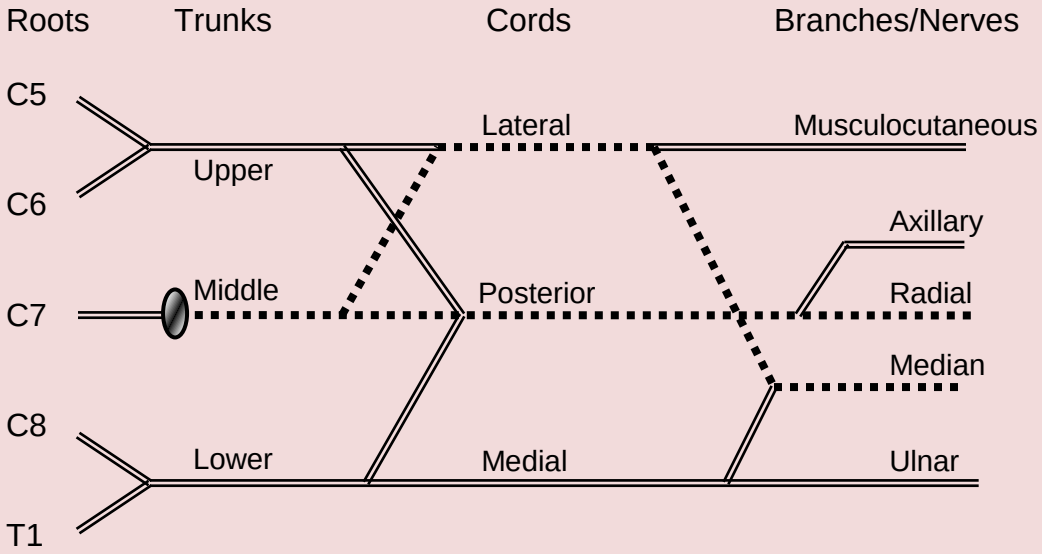
Nerve and Site	Segment	Distance	Amplitude	Peak Latency
Right Median	Rec: Wrist			
Digit I (thumb)	Wrist-Digit I (thumb)	130 mm	18.3 μV	2.9 ms
Digit II (index finger)	Wrist-Digit II (index finger)	130 mm	21.7 μV	2.7 ms
Digit III (long finger)	Wrist-Digit III (long finger)	130 mm	**4.6 μV**	3.1 ms
Right Ulnar	Rec: Wrist			
Digit V (little finger)	Wrist-Digit V (little finger)	110 mm	20.4 μV	2.6 ms
Right Radial	Rec: Snuffbox			
Forearm	Anatomical snuff box-Forearm	100 mm	15.8 μV	2.5 ms
Left Radial	Rec: Snuffbox			
Elbow	Forearm-Elbow	100 mm	17.2 μV	2.3 ms

Normal values:
Median MNC DML: ≤ 4.2, Amp: ≥ 4, CV ≥ 49
Ulnar MNC DML: ≤ 3.8, Amp: ≥ 6, CV ≥ 49,
CV across elbow may slow ≤ 10
Radial MNC: Side-to-side comparison

Median SNC Peak Lat: ≤ 3.2, Amp: ≥ 12
Ulnar SNC Peak Lat: ≤ 2.8, Amp: ≥ 10
Radial SNC Peak Lat: ≤ 2.7, Amp: ≥ 15

Needle highlights: Abnormalities are noted in the triceps, flexor carpi radialis and the pronator teres.

Discussion: This is a middle trunk plexopathy. The median sensory fibers to digit I and digit II originate primarily in C6 and upper trunk, but median sensory fibers to the long finger originate in C7 and the middle trunk. Radial sensory fibers arise from C5/C6 and some from C7 (demonstrated by the normal, but not overwhelmingly so, radial SNC, in this case) while radial motor fibers originate in C7 and C8 (EIP is C8 while triceps is C7).



Case 4

For your convenience values outside the normal range are **bolded**. Normal values for this age are stated below the tables.

History: 27 year-old man was unloading a scissor-lift (heavy equipment) from a flatbed truck when it shifted abruptly and fell on to his left head, neck and body, pinning him between lift and a nearby semi-truck. Evaluate left upper extremity weakness.

Temperatures Left arm: 33ºC

Motor Nerve Conduction:

Nerve and Site	Segment	Distance	Latency	Amplitude	Conduction Velocity
Left Median	Rec: APB				
Wrist	Abductor pollicis brevis-Wrist	60 mm	**NR**	**NR**	
Left Ulnar	Rec: ADM				
Wrist	ADM-Wrist	60 mm	**NR**	**NR**	
Left Radial	Rec: EIP				
Forearm	EIP-Forearm		**NR**	**NR**	
Left Axillary	Rec: Deltoid				
Supraclavicular fossa	Deltoid- Supraclavicular fossa		**NR**	**NR**	

Sensory Nerve Conduction:

Nerve and Site	Segment	Distance	Amplitude	Peak Latency
Left Median	Rec: Wrist			
Digit II (index finger)	Wrist-Digit II (index finger)	130 mm	13.48 μV	2.9 ms
Left Ulnar	Rec: Wrist			
Digit V (little finger)	Wrist-Digit V (little finger)	110 mm	11.22 μV	2.8 ms
Left Radial	Rec: Snuffbox			
Forearm	Anatomical snuff box-Forearm	100 mm	23.73 μV	2.4 ms
Left Lateral antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	14.80 μV	2.4 ms
Left Medial antebrachial cutaneous	Rec: Forearm			
Elbow	Forearm-Elbow	100 mm	10.77 μV	3.1 ms

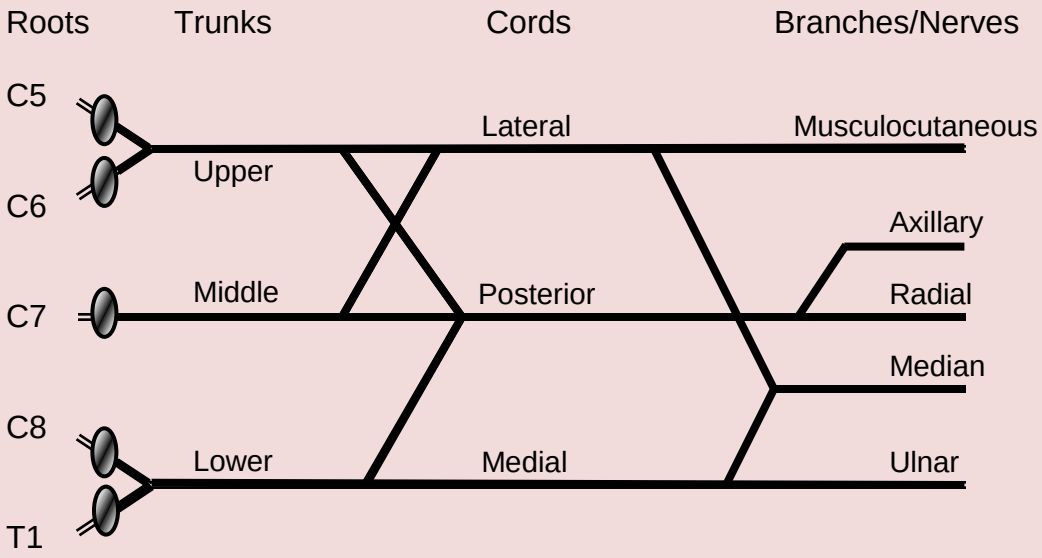
Normal values:
Median MNC DML: ≤ 4.2, Amp: ≥ 4, CV ≥ 49
Ulnar MNC DML: ≤ 3.8, Amp: ≥ 6, CV ≥ 49,
CV across elbow may slow ≤ 10
Radial MNC: Side-to-side comparison

Median SNC Peak Lat: ≤ 3.2, Amp: ≥ 12
Ulnar SNC Peak Lat: ≤ 2.8, Amp: ≥ 10
LABC SNC Peak Lat: ≤ 2.7, Amp: ≥ 12
Radial SNC Peak Lat: ≤ 2.7, Amp: ≥ 15
MABC SNC Peak Lat: ≤ 2.7, Amp: ≥ 10

Needle highlights: Increased insertional activity and abnormal spontaneous activity was seen in all muscles. No volitional activity could be generated in any muscle tested.

Discussion: This is the worst of the worst. Although it is not really a brachial plexus injury, root avulsions show preganglonic findings (normal SNC, abnormal MNC) in a patient that is unable to use his arm at all. This study represents the electrical findings of an acute left C5-8 nerve root avulsions. The

electrical activity indicates no motor sparing in any of the myotomes tested indicating a poor prognosis for spontaneous recovery.



Bibliography

Amato, Michael A. and James A. Russell. Neuromuscular Disorders. McGraw-Hill, New York. 2009.

Blum Andrew S. and Seward B. Rutkove, eds. The Clinical Neurophysiology Primer. Humana Press Inc. Totowa, New Jersey. 2007.

Bromberg, Mark B. Brachial Plexus Syndromes. Up-to-Date Online, 18.2. April 23, 2010.
http://www.utdol.com/online/content/topic.do?topicKey=Brachial Plexus Syndromes.

Daube, Jasper, ed. Clinical Neurophysiology. F.A. Davis Company, Philadelphia. 1996.

DeMyer, William. Neuroanatomy. Williams & Wilkins, Baltimore. 1998.

Dumitru, Daniel, Anthony Amato and Machiel Zwarts. Electrodiagnostic Medicine, 2nd Ed. Hanley and Belfus, Philadalephia. 2002.

Kimura, Jun. Electrodiagnosis in Diseases of the Nerve and Muscle, Principles and Practice. 3rd Ed. Oxford, New York, Philadelphia. 2001.

Oh, Shin. Clinical Electromyography: Nerve Conduction Studies. 2nd Ed. Williams and Wilkins, Baltimore. 1993.

Preston, David and Barbara Shapiro. Electromyography and Neuromuscular Disorders; Clinical-Electrophysiologic Correlations. 2nd Ed. Elsevier, Philadelphia. 2005.

Wilbourn, Asa J. "Brachial Plexus Lesions." Peripheral Neuropathy. Ed. Dyck, Peter J. and P. K. Thomas. 4th Ed. Elsevier Saunders. Philadelphia. 2005.