Brachial Plexopathies And Proximal Mononeuropathy

Part I

Dumitru, Chapter **19**

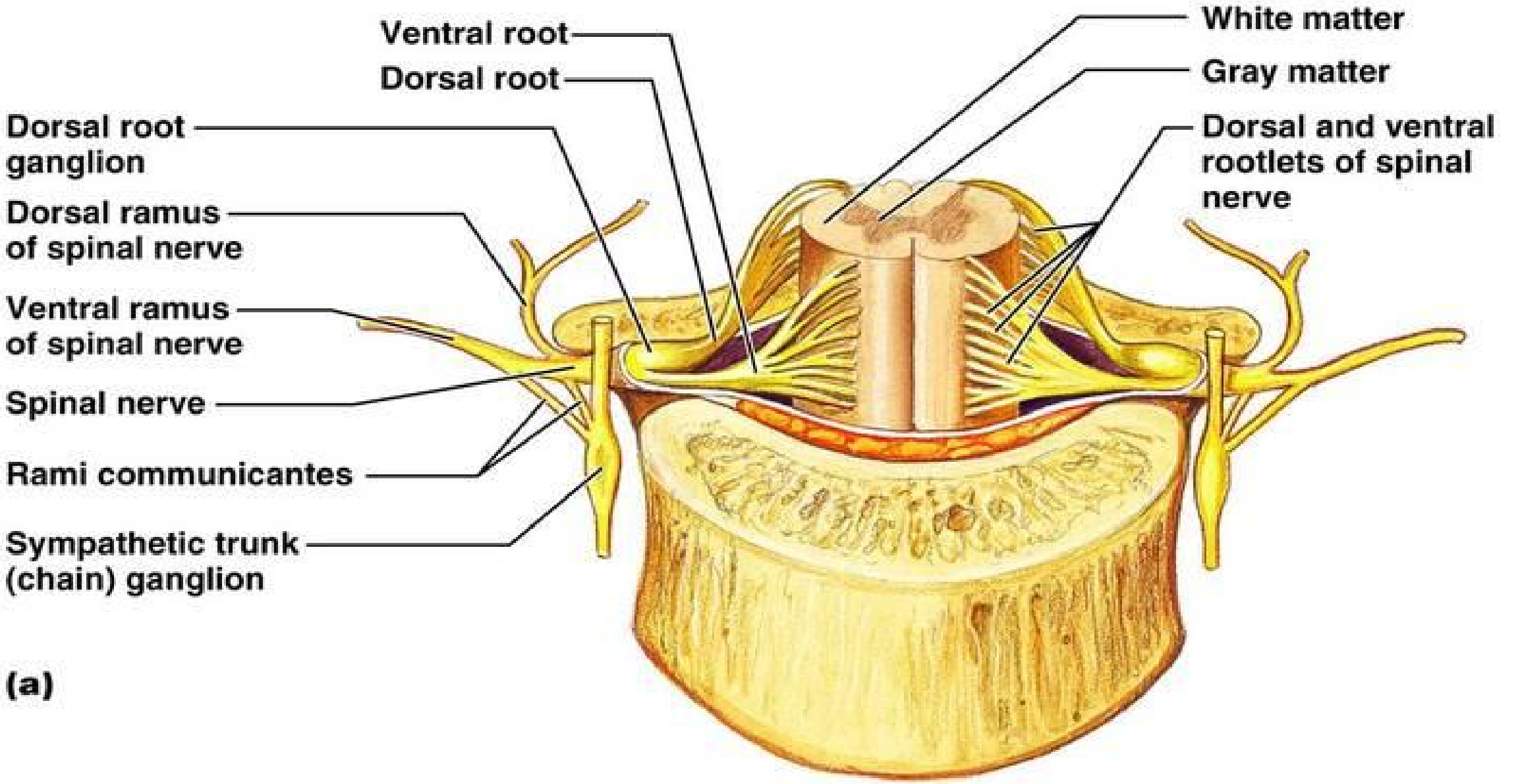
Introduction

- The electrodiagnostic medicine consultation
  - Assessing a nerve's functional status,
  - Locating possible lesion sites,
  - Formulating a prognosis.
- the electrophysiologic evaluation of brachial plexus injuries may even provide more information than that gleaned from the physical examination.
  - conduction block
  - axonal loss
  - Prognosis
- It demands the practitioner be thoroughly familiar with brachial plexus anatomy
- diminution of hand dexterity and proprioception in upper limb Plexopathies result in more substantial functional deficits

ANATOMY/ MORPHOLOGY

Cervical and thoracic roots

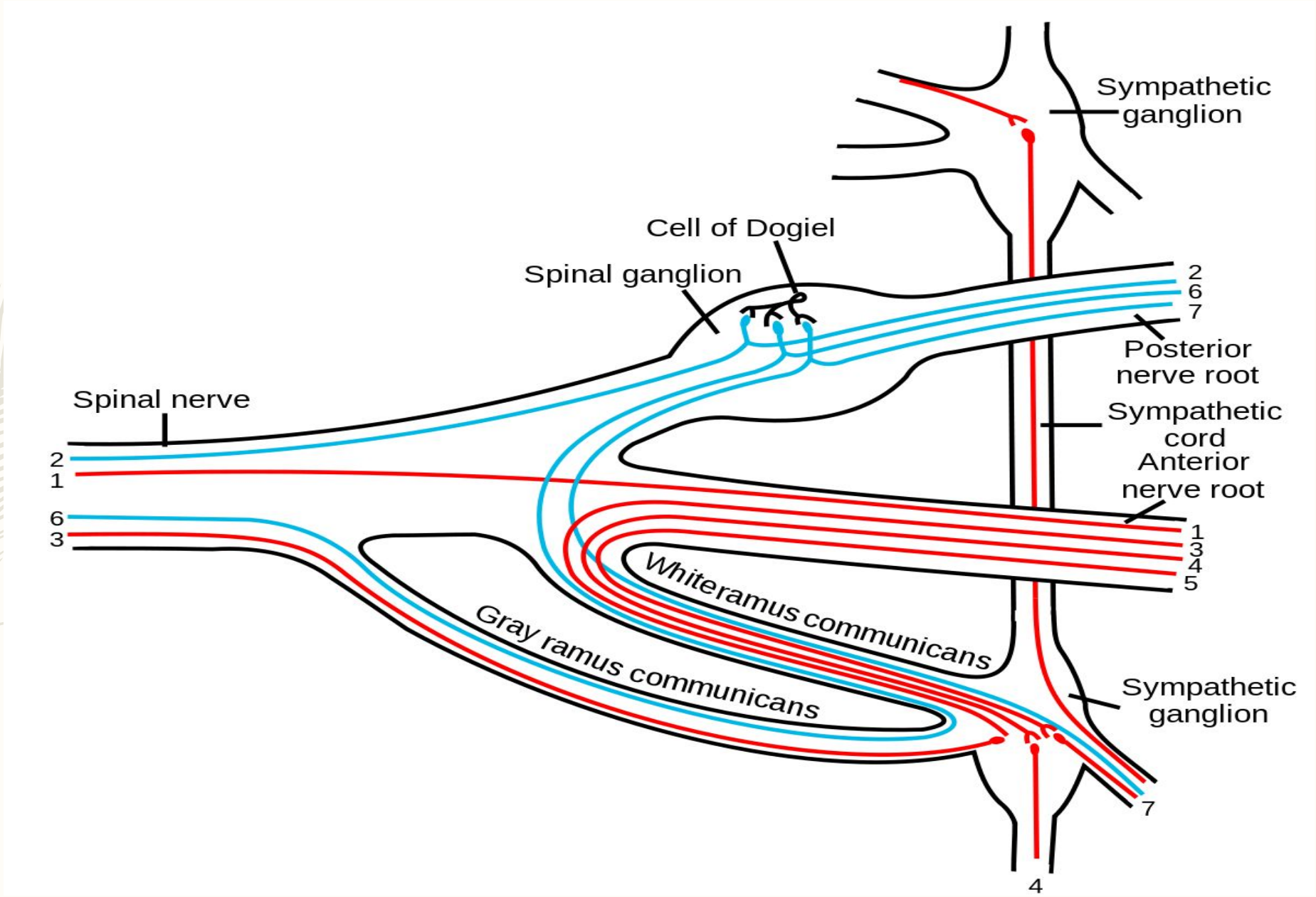
- ventral and dorsal nerve **rootlets** (three times as many dorsal as ventral fibers)
- forms the anterior and posterior spinal **roots**.
- form the short spinal nerve before dividing into anterior and posterior primary rami.
- The **intraspinal portions** of both motor and sensory rootlets/roots are not intimately associated with the supportive meningeal tissues (dura and arachnoid) and thus are afforded little protection from traction forces**.**
- The **posterior** primary ramus proceeds posteriorly to innervate the paraspinal muscles,
- It is the **anterior** primary rami of *CS*-TI cervical spinal nerves that form the brachial plexus



Cervical sympathetic chain

- cervical sympathetic chain ganglia
  - The first four cervical nerves receive rami from the superior cervical ganglion
  - the fifth and sixth cervical spinal nerves receive rami originating from the middle cervical ganglion.
  - The inferior cervical ganglion provides a communicating gray ramus to the seventh and eighth spinal nerves.

- Just distal to the gray ramus, the cervical spinal nerves branch to form an anterior and posterior primary ramus.
- sympathetic supply to the head and neck arises from the first thoracic segment.
- A lesion severely affecting the **TI** nerve root can result in **Horner's syndrome** (**miosis, anhidrosis. enophthalmos, and ptosis**).


Sympathetic ganglion
Cell of Dogiel
Spinal ganglion
2
6
7
Posterior nerve root
Spinal nerve
Sympathetic cord
Anterior nerve root
2
1
6
3
1
3
4
5
Whiteramus communicans
Gray ramus communicans
Sympathetic ganglion
7
4

- The brachial plexus is composed of the following

✓ Anterior divisions of five cervical and one thoracic root level (C5-Tl),

✓ three trunks (upper, middle, and lower),

✓ two divisions (anterior and posterior) per trunk,

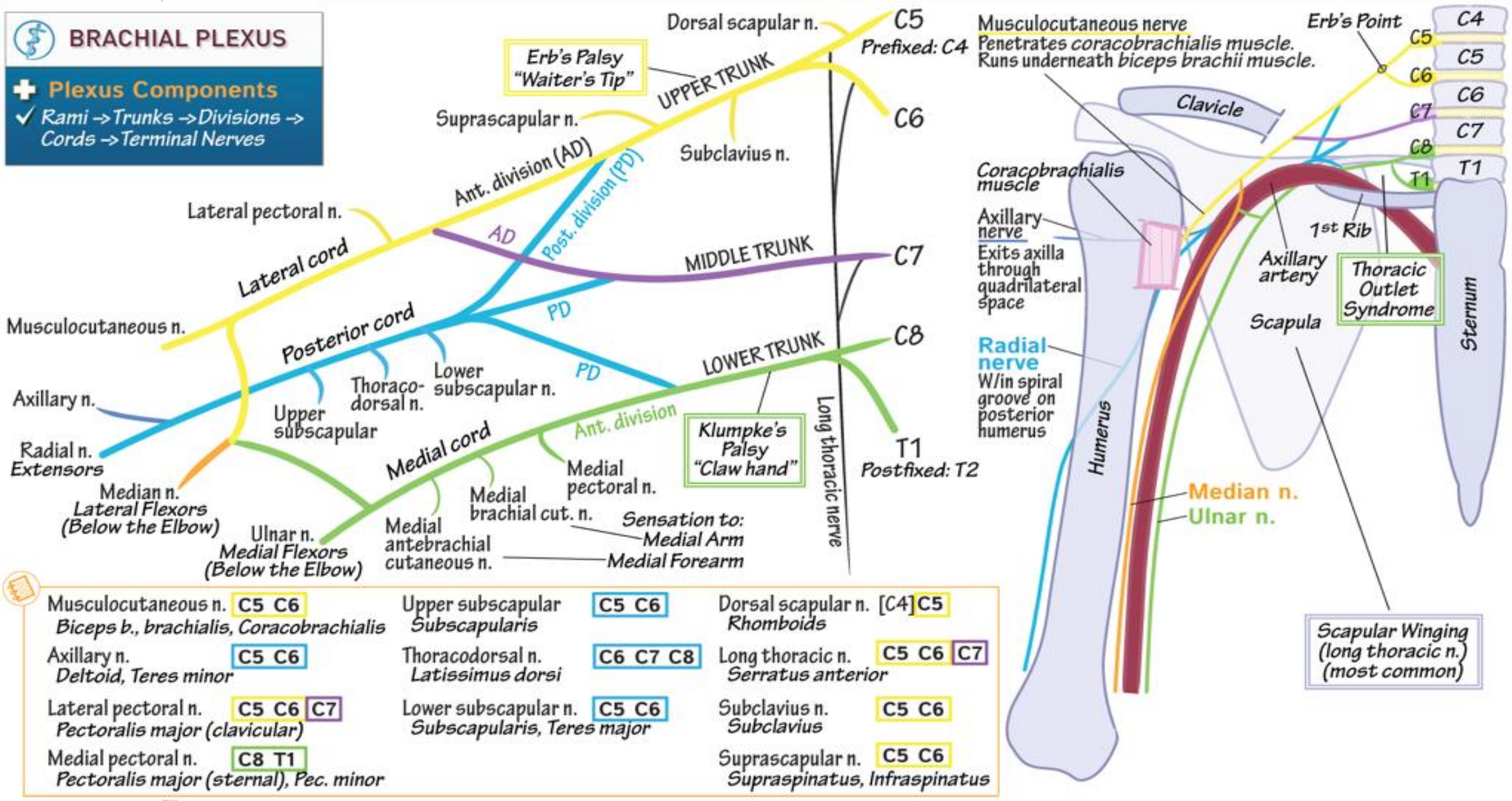
✓ three cords (medial, lateral, and posterior),

✓ multiple terminal nerves innervating the upper limb and shoulder girdle

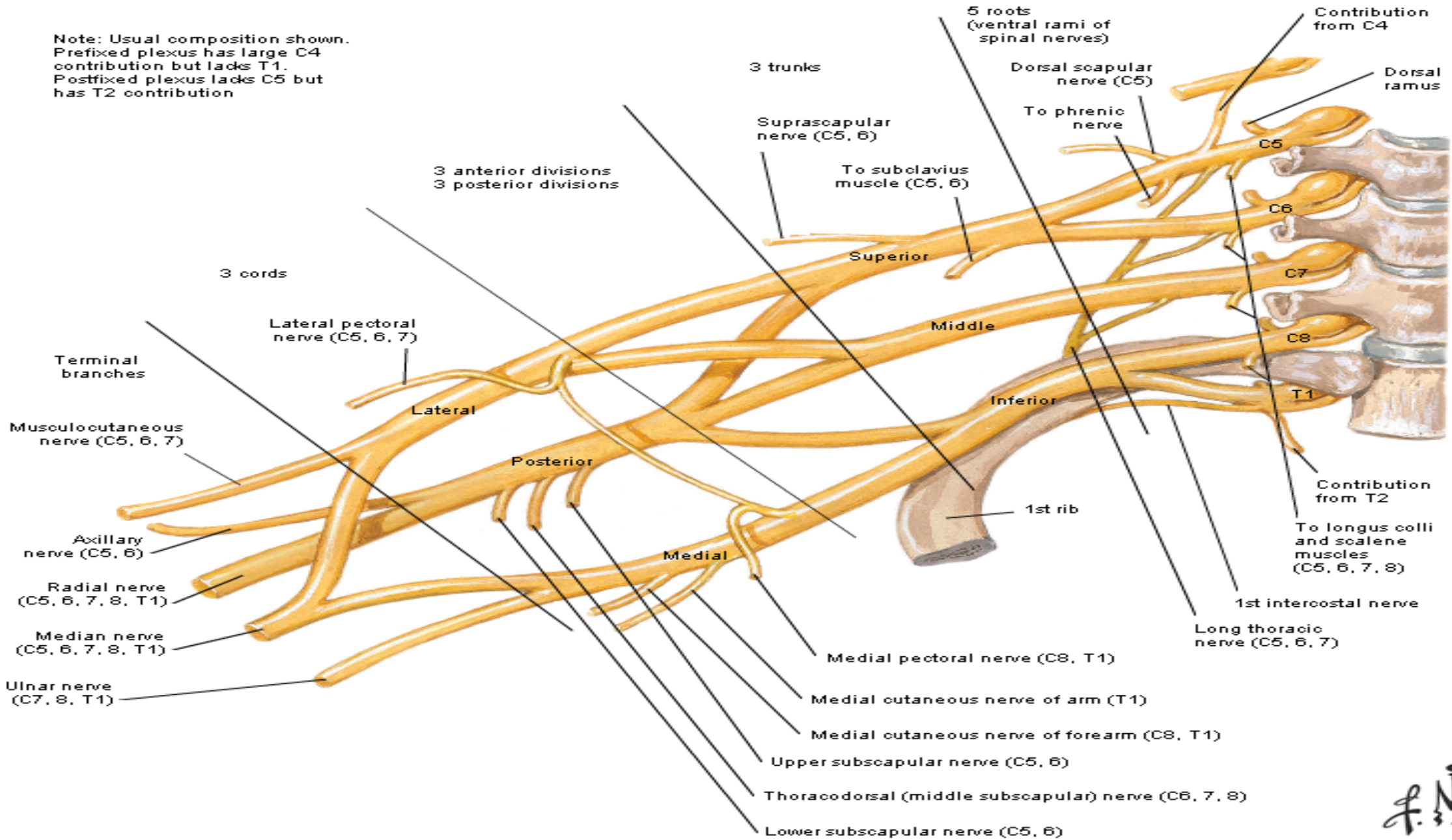
Anatomical variations

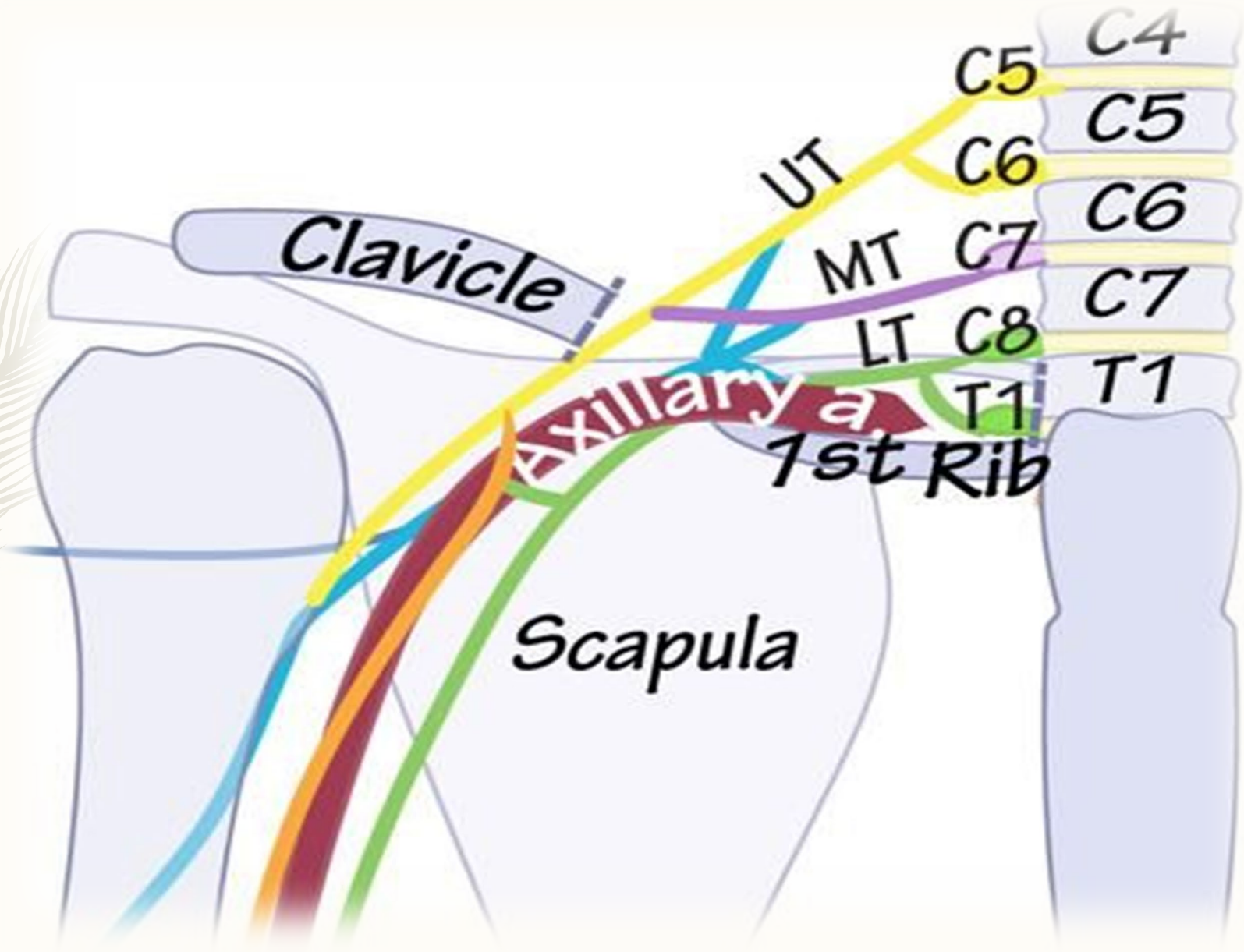
- ***pre- fixed plexus C4-C8:*** ***shifted one level superiorly ,*** a minimal contribution from T1
- ***post-fixed plexus C6-T2:*** ***shifted one level Inferiorly,*** a minimal contribution from *C5, thereby containing neural components from the* ***T2*** *spinal segment.*
- ***C4 and T2 can contribute to the brachial plexus and should be kept in mind when individual lesions are considered.***

Bracial Plexus Formation


BRACHIAL PLEXUS
Plexus Components
Rami -> Trunks -> Divisions -> Cords -> Terminal Nerves
Dorsal scapular n.
C5
Prefixed: C4
Erb's Palsy "Waiter's Tip"
UPPER TRUNK
Suprascapular n.
Subclavius n.
C6
Ant. division (AD)
Post. division (PD)
Lateral pectoral n.
Lateral cord
AD
MIDDLE TRUNK
C7
Musculocutaneous n.
Posterior cord
PD
PD
LOWER TRUNK
C8
Axillary n.
Thoraco-dorsal n.
Lower subscapular n.
Upper subscapular
Radial n.
Extensors
Ant. division
Klumpke's Palsy "Claw hand"
Long thoracic nerve
T1
Postfixed: T2
Medial cord
Median n.
Lateral Flexors
(Below the Elbow)
Medial pectoral n.
Medial brachial cut. n.
Sensation to:
Medial Arm
Medial Forearm
Ulnar n.
Medial Flexors
(Below the Elbow)
Medial antebrachial cutaneous n.
Musculocutaneous n. C5 C6
Biceps b., brachialis, Coracobrachialis
Axillary n. C5 C6
Deltoid, Teres minor
Lateral pectoral n. C5 C6 C7
Pectoralis major (clavicular)
Medial pectoral n. C8 T1
Pectoralis major (sternal), Pec. minor
Upper subscapular C5 C6
Subscapularis
Thoracodorsal n. C6 C7 C8
Latissimus dorsi
Lower subscapular n. C5 C6
Subscapularis, Teres major
Dorsal scapular n. [C4] C5
Rhomboids
Long thoracic n. C5 C6 C7
Serratus anterior
Subclavius n. C5 C6
Subclavius
Suprascapular n. C5 C6
Supraspinatus, Infraspinatus
Musculocutaneous nerve
Penetrates coracobrachialis muscle.
Runs underneath biceps brachii muscle.
Erb's Point
C4
C5
C5
C6
C6
C7
C7
C8
T1
T1
Clavicle
Coracobrachialis muscle
Axillary nerve
Exits axilla through quadrilateral space
1st Rib
Axillary artery
Thoracic Outlet Syndrome
Sternum
Scapula
Radial nerve
W/in spiral groove on posterior humerus
Humerus
Median n.
Ulnar n.
Scapular Winging
(long thoracic n.)
(most common)

Brachial Plexus: Schema




C4
C5
C5
C6
C6
C7
C7
C8
T1
T1
UT
MT
LT
Clavicle
Axillary a.
1st Rib
Scapula

- The clavicle as a landmark

  - Proximal to this bone are the roots, spinal nerves, and trunks.
  - Beneath the clavicle are the divisions,
  - distally are located the cords and terminal nerve branches.
  - The designations medial, lateral, and posterior as applied to the three cords refer to their respective anatomic positions to the axillary artery.

Communicating branches

- The First, a connection between the **medial and lateral pectoral** nerves.

- A second anatomic communication is from the lateral cord to both the medial branch of **the medial cord** that contributes to the median nerve, and a continuation of this connection to the ulnar nerve itself.
- This is a conceivable anatomic pathway for neural fibers from the C7 spinal level to reach the ulnar nerve.
- FCU:C7-T1 (40-90%)

Spinal Nerve Branches

Terminal Nerve Branches

Spinal Nerve Branches

- **Dorsal Scapular Nerve:** C4 -**C5** spinal nerves
- innervates the major and minor **rhomboid muscles**
- **Long Thoracic Nerve**: **C5, C6,C7**
- **innervate** the various digitations of the **serratus anterior muscle**.
- In patients who receive **primarily** a contribution from **the C6 level**, a root lesion affecting the C6 spinal segment can also result in **scapular winging.**
- **Phrenic Nerve**: **C3 ,C4, C5**
  Injuries to the root levels noted above can result **in hemidiaphragmatic dysfunction with elevation**, or poor excursion of the diaphragm.

Trunk

Terminal Nerve Branches

Arises from the **upper trunk**:

- **Suprascapular Nerve**: **C5 and C6** nerve fibers
  - In a brachial plexus injury, preservation of the diaphragm, serratus anterior, and rhomboid muscles, but **weakness of the supraspinatus and infraspinatus muscles** suggests that a lesion affects the proximal portion of the upper trunk, but spares the spinal nerve level.
- **Subclavius Nerve:** C4,C5,C6/ **unimportant clinically and EDX**

Cord

Terminal Nerve Branches

Lateral cord

- The **lateral pectoral nerve :**innervate the **pectoralis major** muscle.
- In occasional anatomic variations,
- originated from spinal nerve levels **C5-C7 (83%)**

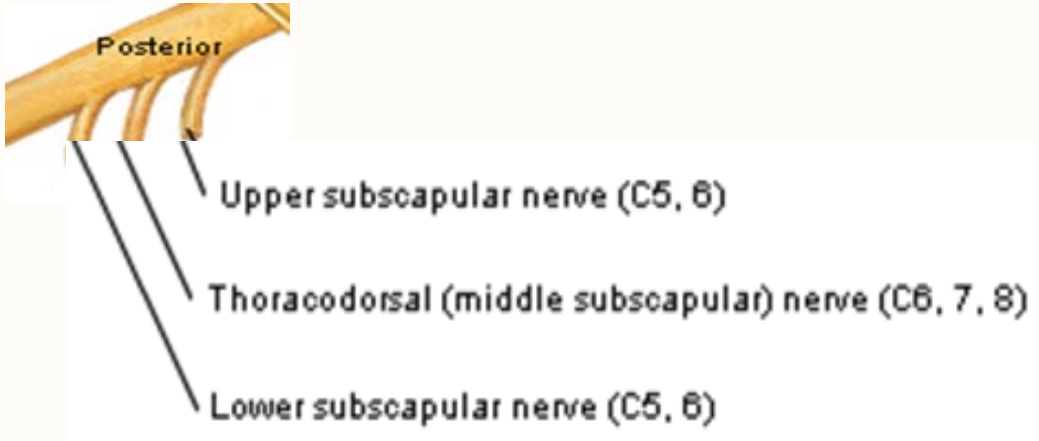
Medial cord

- medial pectoral nerve : **C8 and T1**

❖ **Innervate : pectoralis minor ,inferior portions of the pectoralis major.**

- In occasional anatomic variations, this nerve takes its origin from the upper and middle trunks' anterior divisions just prior to the formation of the lateral cord.'" It is this variant that may explain the preservation of the pectoralis muscle in plexus injuries producing a flail arm but a functional pectoralis muscle.
- ***Medial Cutaneous Nerve of the Arm* : C8 and TI** levels
- ***Medial Cutaneous Nerve of the Forearm***

Posterior cord



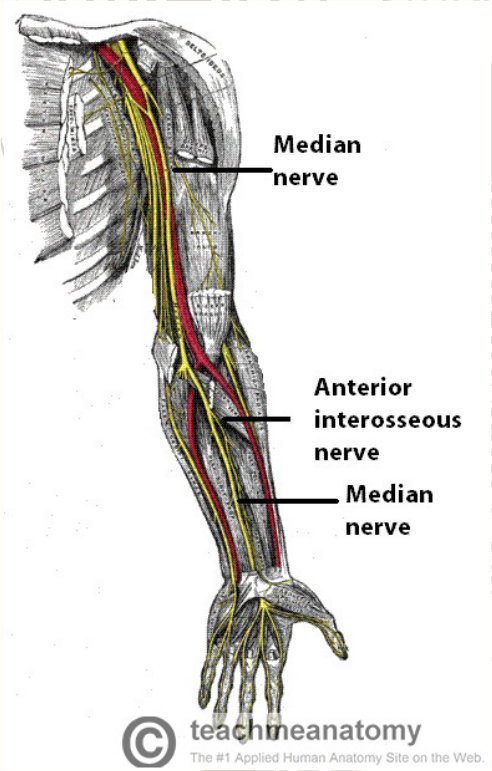
- **The upper subscapular nerve** :C5 and C6 spinal levels.
- Innervate : upper portion of the subscapularis muscle.
- **The *lower subscapular nerve :*** C5 and C6 spinal levels
- Innervate : lower aspects of the subscapularis muscle ,teres major muscle.
- **Thoracodorsal Nerves or middle (long) subscapular nerve :**C5-C7
- Innervate : latissimus dorsi muscle.
- This nerve can also arise in some cases from the radial and axillary nerves.
- with C7 being the sole supply in about 50% of cadavers

- Upper subscapular nerve :
  - ❖ arises more usually from the upper trunk’s posterior divisions
- Lower subscapular nerve takes its origin from :

1. the axillary nerve in just over one-third of cadavers
2. posterior cord in one-third of dissections,
3. the proximal plexus 25% of the time

MAJOR UPPER LIMB PERIPHERAL NERVES

Terminal Nerve Branches



- **Lateral Cord : Musculocutaneous Nerve:**
  - ❖ The major spinal segments :**C5 and C6.**
- **Medial Cord: Ulnar Nerve**
- The spinal levels in the ulnar nerve :**C8 and TI, but C7 is also commonly believed to be present.**
- **Lateral and Medial Cord: Median Nerve :C6-Tl**
- **Motor : C6-TI, while sensory : C6 and C7.**

- **Posterior Cord:**
- **Axillary Nerve:**
- **innervate** : teres minor and deltoid muscle
  - cutaneous branches :lateral aspect of the arm overlying the deltoid
  - The **typical spinal levels** :C5 and C6 +_C7(Rarely)
- **Radial Nerve:**
  - **largest terminal branch of the brachial plexus**
  - **Spinal nerve levels: C5-C8+may contain T1 nerve fibers**

BRACHIAL PLEXOPATHY CHARACTERISTICS

Age, gender, and side

- There are **two large peaks** for age:
- **birth process** secondary to obstetric paralysis :**male/female ratio 1: 1**
- **Obstetric paralysis** tends to affect the **right side more so than the left**.
- **20-30 years**.
  - closed (motor vehicle/motorcycle) or pen (knife/bullet wounds) injury.M>F
  - **unilateral** and tend to involve the **dominant limb**

In a small number of **obstetrically** lesions **(3-6%) both sides** can be affected.

❖ **Less than 3% of adult** lesions result in **bilateral** brachial plexus damage.

Classification:

- **Open/closed**
- **Anatomic location of the lesion:**
  - Supraclavicular
    - *post/pre ganglionic*
  - Infraclavicular
  - panplexopathy
- **complete/incomplete lesion**
  - Complete lesions : poor prognosis compared to incomplete lesions.

Table 19-2. Brachial Plexus Classification: Nature of Injury

Closed	Open
Traction injuries (avulsion/obstetric)	Neurovascular
Radiation-related	Gunshot wound (direct trauma/energy dissipation)
Tumor (primary/secondary)	Laceration
Surgically related (positioning)	Surgically related (direct trauma)
Brachial plexus neuritis/neuropathy	Needles
Rucksack (backpack) paralysis	Miscellaneous
Thoracic outlet syndromes	
Trauma (distraction/stretch)	
Miscellaneous	
Vascular (hematoma)	

Modified from Wilbourn AJ: Brachial Plexus Disorders. In Dyck PJ, Thomas PK, Griffin JW, et al (eds): Peripheral Neuropathy, 3rd ed. Philadelphia, W.B. Saunders, 1992, pp 911–950.

Table 19-3. Brachial Plexus Classification: Anatomic Location

Supraclavicular	Infraclavicular	Panplexopathy
Upper Plexus (Roots/Upper Trunk)	**Cords/Branches**	
Incomplete traction injury	Radiation-related	Trauma
Obstetric paralysis	Gunshot wound	Severe traction injury
Brachial plexus neuropathy	Humeral fracture/ dislocation	Postanesthetic paralysis
Thoracic outlet syndrome	Orthopedic procedure	Late metastatic disease
	Axillary arteriogram	Late radiation-induced
Lower Plexus (Roots/Lower Trunk)	Axillary plexus block	
Metastatic tumor	Most neurovascular trauma	
Pancoast syndrome		
Post-sternotomy		
Thoracic outlet syndrome		
Surgery for thoracic outlet syndrome		

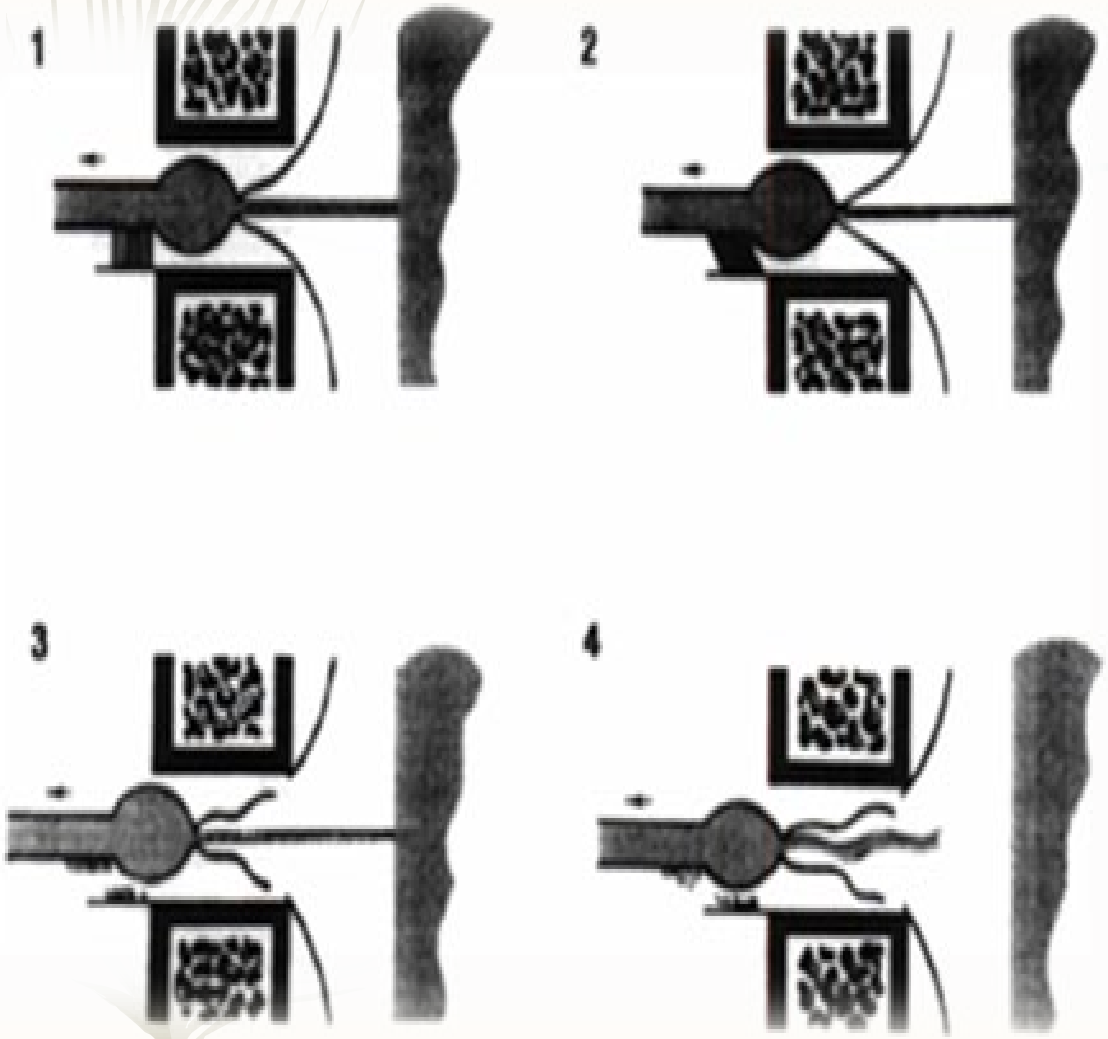
Modified from Wilbourn AJ: Brachial Plexus Disorders. In Dyck PJ, Thomas PK, Griffin JW, et al (eds): Peripheral Neuropathy, 3rd ed. Philadelphia, W.B. Saunders, 1992, pp 911–950.

Types of neural insult:

- ✓ ***stretch or traction:*** most commonly observed
- ✓ ***Contusion***
- ✓ ***Laceration***
- ✓ ***compression***
  1. Internal compression
     - *space-occupying neoplasms, thoracic outlet syndrome, Exuberant callous formation following a clavicular fracture,*
  2. External compression
     - *may arise secondary to the straps of a backpack, crutches, etc.*
- ✓ ***Ischemia***
- ✓ ***Nerve Root Avulsion***

Types of nerve fiber damage:

- **Conduction block (first-degree injury)**
  - **ischemic**
  - **Demyelinating (neurapraxia)**
- Prognosis in pure conduction lesions, is excellent.
- ***Axonal loss :***
- ***without structural damage*** *(*axonotmesis or second-degree injury).
- Restoration of function is usually but not always similar to that prior to the insult.
- **with Structural Damage.** (Neurotmesis third- through fifth-degree injury)



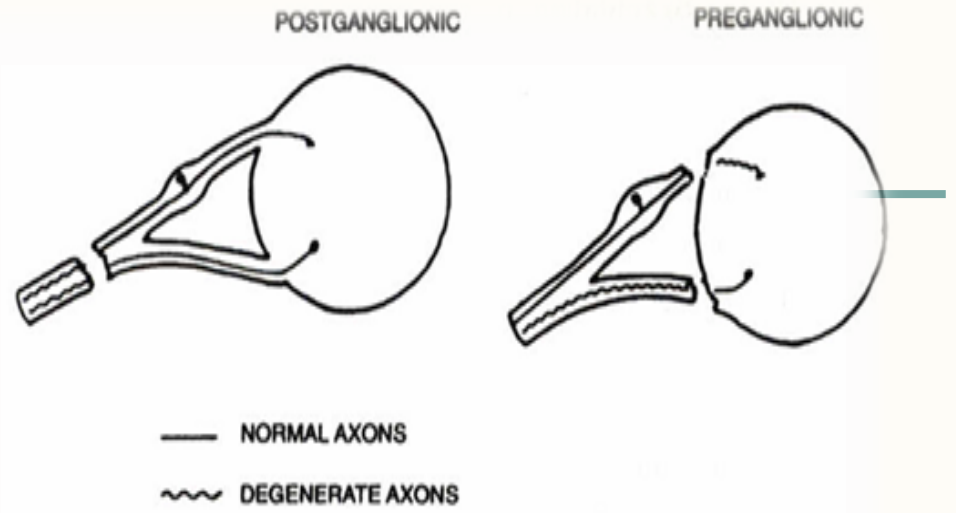


Figure 19-5. **Preganglionic versus postganglionic injury** Postganglionic injury resulting in Wallerian degeneration of both motor and sensory axons. This occurs because the axons have been physically separated from their respective cell bodies in the ventral portion of the spinal cord and dorsal root ganglion. Depending upon the lesion's level of completeness, CMAP and SNAP responses are either diminished or absent. A preganglionic injury produces the same injury to the motor fibers but allows the peripheral sensory fibers to remain in contact with their cell bodies, resulting in a normal SNAP from this segment with similar motor findings to the previously noted lesion. (From Leffert RD: Brachial Plexus Injuries. New York, Churchill Livingstone, 1985, with permission.)

Nerve root avulsion

- ✓ **traction forces** and **occasionally penetrating missile or knife** wounds.
- ✓ **severity and poor prognosis.**
- ❖ **avulsion :**The **ventral root** >**posterior** root.
  - they are spread out vertically
  - one-third as thick.
- ❖ **C8 –T1** roots >rostral nerve roots.
  - because they lack the transverse process connective tissue anchoring mechanism

ELECTRODIAGNOSTIC CORRELATS OF PLEXUS INJURIES

Conduction block:

- ✓ A.L and C.B present with significant **weakness and sensory disturbances.**
- ✓ **10 days to 2 weeks** following the acute injury: **EDX**
- – **Conduction block:**
- – **NCS :**Normal
- – **Late responses (H-Reflex and F-Wave) : may ba** delayed or absent
- – **Needle EMG :** reduced recruitment depending upon the severity of the lesion
- – Conduction block arising **secondary to neoplasm and/or radiation :**
- – **dysfunction of the Schwann cells' ability+progressive nature of these lesions+ progress to Wallerian degeneration**.

Demyelination

- compressive and radiation-induced injuries may initially affect the nerves' myelin component.
- action potential slowing across the affected segment.
- The objective is to calculate a conduction velocity or time across the plexus
- most likely is of little clinical significance.
- Slowing of conduction should not be reflected in weakness or an alteration in how cutaneous stimulation is consciously perceived

Axonal loss:

- Clinical and EDX examinations cannot distinguish between the various degrees of injury severity regarding type 2 versus type 5 injuries.
- **SNAP and CMAP: decrease or unobtainabe in** distal to the DRG.
- SNAP :NL in Preganglionic lesions, like radiculopathies
- Needle:PSW/fib,neurogenic MUAP
- **2 weeks after** the plexus injury, NL SNAP with complete absence of cutaneous sensation : **two possible situations**:
- **avulsion** or **a C.B** (**C.B** of the above **2 weeks** is relatively **rare)**.
  - **CMAP** and **needle** is helpful in **distinguishing** between these two possibilities

ELECTRODIAGNOSTIC MEDICINE EVALUATION OF BRACHIAL PLEXOPATHIES

History and physical examination

- is paramount to perform a **directed history and physical examination**.
- In **traumatic** brachial plexopathies the history is usually relatively straightforward
- Possible brachial plexus injuries resulting from metastatic disease, rare compression syndromes (thoracic outlet syndromes), or vascular compromise require a detailed exploration of the patient's complaint,

Table 19-5. Sequence of Electrophysiologic Changes in Axonal Loss Lesions

	Abnormality	Onset	Peak
Nerve Conduction Studies			
Sensory: SNAP amplitude	Decreased amplitude	5–6 days	9–10 days
Motor: CMAP amplitude	Decreased amplitude	2–4 days	6–7 days
Needle Electromyography			
Rest activity	Increased insertional activity	≥ 7–8 days	—
	Fibrillation potentials	10–30 days	21–30 days
Voluntary activity	Decreased recruitment	Immediately	—

Modified from Wilbourn AJ: Electrodiagnosis of plexopathies. Neurol Clin 1985;3:511–529.

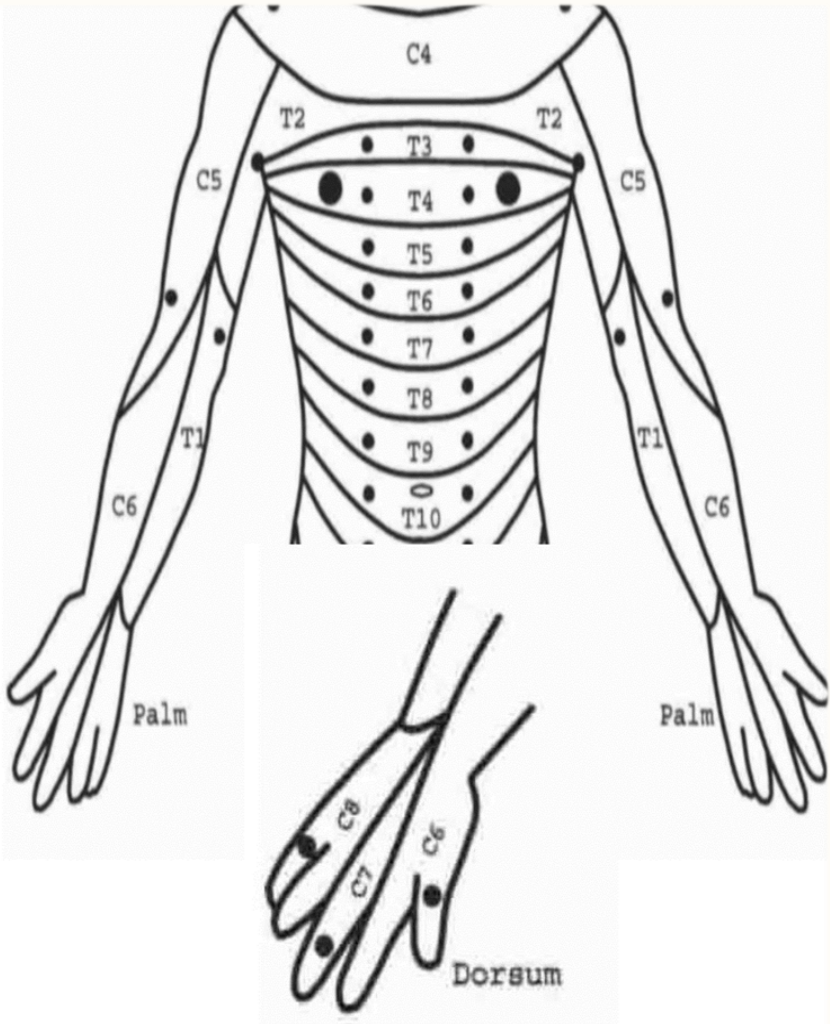
Table 19-6. Electrophysiologic Changes Related to Severity of Lesion

	Very Mild	Mild	Moderate	Moderately Severe	Severe	Very Severe
Nerve Conduction Studies						
SNAP amplitude	Normal	Normal	↓/↓↓	↓↓↓/Absent	Absent	Absent
CMAP amplitude	Normal	Normal	Normal	Normal/↓	↓↓/↓↓↓	Absent
Needle Electromyography						
PSWs/fibrillations	0–1+/1+	1+	1+–2+	2+/3+	3+/4+	3+/4+
Recruitment	Normal	Normal	Normal	Normal/↓	↓↓/↓↓↓	↓↓↓/Absent

The relative sensitivity of the various electrophysiologic parameters can be seen as related to severity of the lesion.
Modified from Wilbourn AJ: Electrodiagnosis of plexopathies. Neurol Clin 1985;3:511–529.

Table 19-4. Nerve Conduction Studies

Brachial Plexus		Peripheral Nerve
Trunk	*Cord*	
		Sensory Studies
Upper	Lateral	Lateral antebrachial cutaneous
Upper	Lateral	Median to first/second digit
Upper	Posterior	Radial to base of first digit
Middle	Posterior	Posterior antebrachial cutaneous
Middle	Lateral	Median to second digit
Middle	Lateral	Median to third digit
Lower	Medial	Ulnar to fifth digit
Lower	Medial	Ulnar: dorsal ulnar cutaneous
Lower	Medial	Medial antebrachial cutaneous



SNAPs of trunks:

- **Upper trunk**:
- Lateral cord: ***LAC,*** **Median** ***digit I,II,***
- Posterior cord: ***SRN***(abnormal in 58% of such cases).
- **Middle trunk:**
- Lateral cord: **Median** ***digit III,II***
- Posterior cord: ***SRN, PAC***
- **Lower trunk:(**about 42% of such lesions).
- Medial cord: **MBC , MAC , DUC,Ulnar digit V**
- Posterior cord: **-**
- Caution is recommended when examining MAC in patients who have undergone a median sternotomy since this nerve is frequently injured.

CMAPs of trunks :

- **Upper trunk**:
- Lateral cord: *Biceps brachii*
- Posterior cord: *Deltoid*
- **Middle trunk:**
- Lateral cord: -
- Posterior cord: *Triceps or EI*
- **Lower trunk**:
- Medial cord: **Tenar, Hypotenar**
- Posterior cord: *EI*

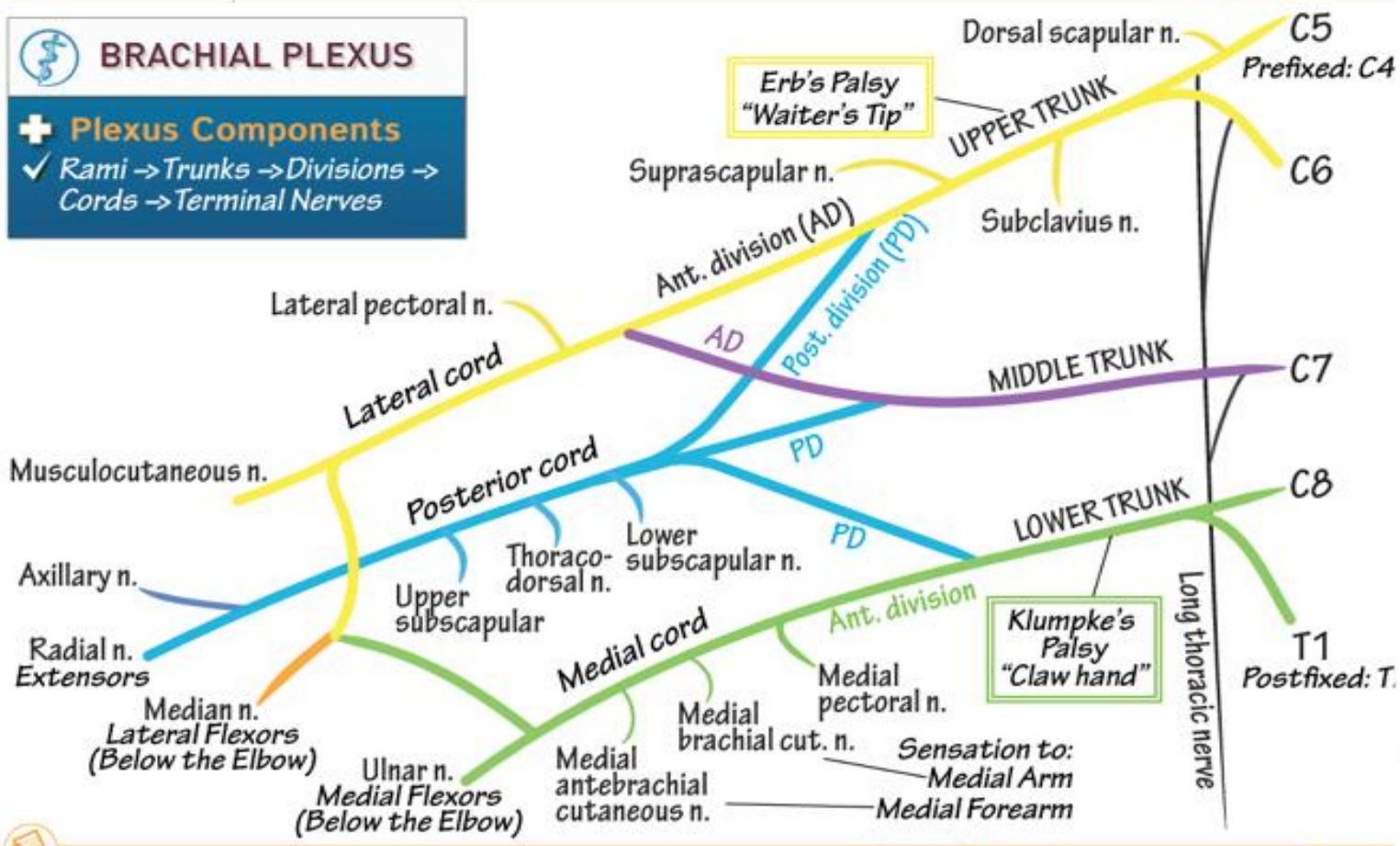
SNAPs and CMAPs of cords:

- Lateral cord SNAP: **Median *digit III,II ,I, LAC***
- Lateral cord CMAP: Biceps brachii
- Posterior cord SNAP: ***SRN, PAC***
- Posterior cord CMAP:EDC, deltoid
- Medial cord SNAP: **MBC , MAC , DUC,Ulnar digit V**
- Medial cord CMAP:Tenar,hypotenar

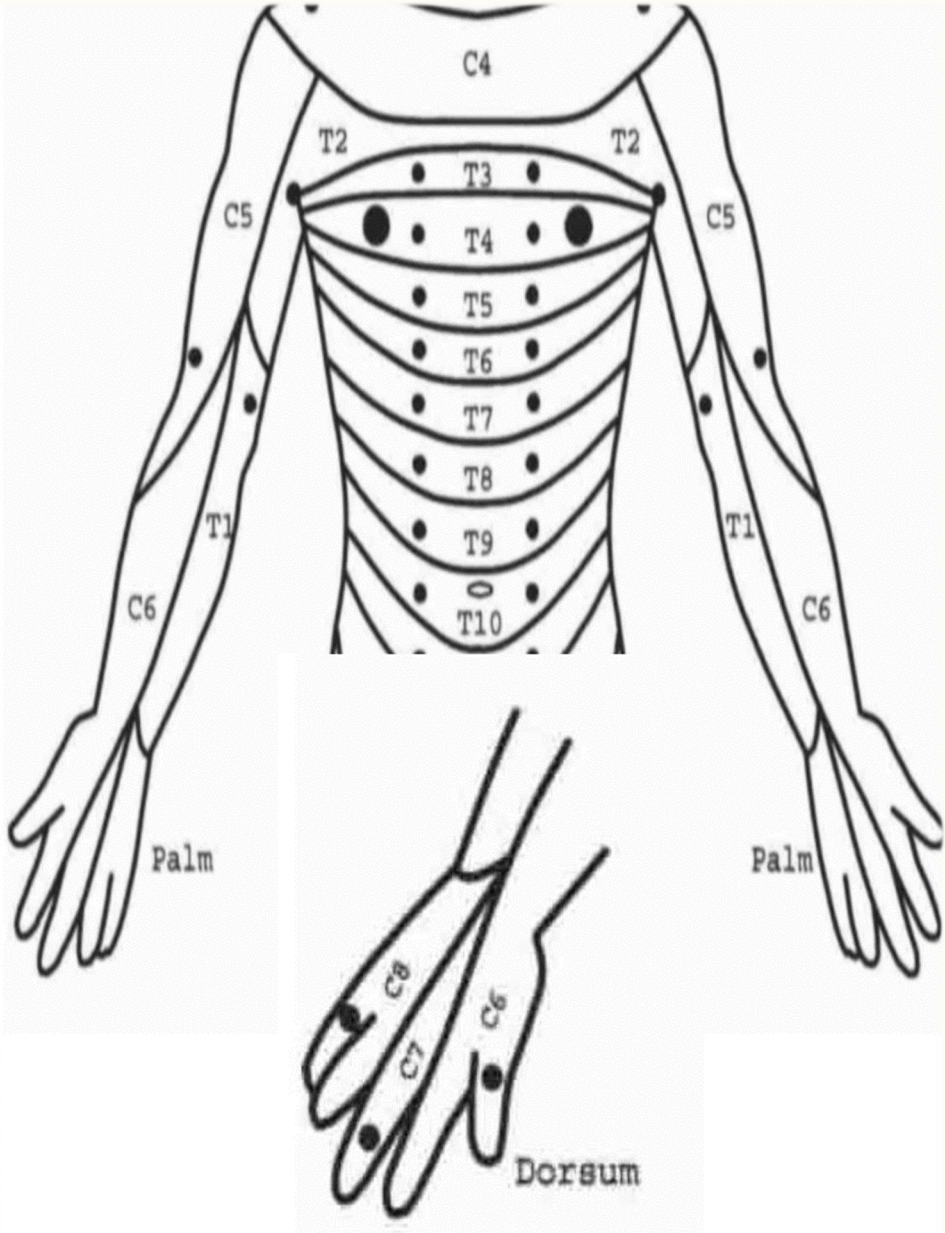
BRACHIAL PLEXUS

Plexus Components

✓ Rami → Trunks → Divisions → Cords → Terminal Nerves



Musculocutaneous n. C5 C6 *Biceps b., brachialis, Coracobrachialis*	Upper subscapular C5 C6 *Subscapularis*	Dorsal scapular n. [C4] C5 *Rhomboids*
Axillary n. C5 C6 *Deltoid, Teres minor*	Thoracodorsal n. C6 C7 C8 *Latissimus dorsi*	Long thoracic n. C5 C6 C *Serratus anterior*
Lateral pectoral n. C5 C6 C7 *Pectoralis major (clavicular)*	Lower subscapular n. C5 C6 *Subscapularis, Teres major*	Subclavius n. C5 C6 *Subclavius*
Medial pectoral n. C8 T1 *Pectoralis major (sternal), Pec. minor*		Suprascapular n. C5 C6 *Supraspinatus, Infraspinat*



Late response and others:

- F-wave is **rarely important** in assessing possible plexus lesion location.
- ✓ ***H-Reflex*** may also be **abnormal due to a previous** radiculopathy or peripheral nerve lesion.
- transplexus latency is **rarely important**
- Nerve Root Stimulation: initial positive deflection and **volume conducted**
- SEP is delusive as first line.
- Only sensory fibers are examined with the SEP,

Needle:

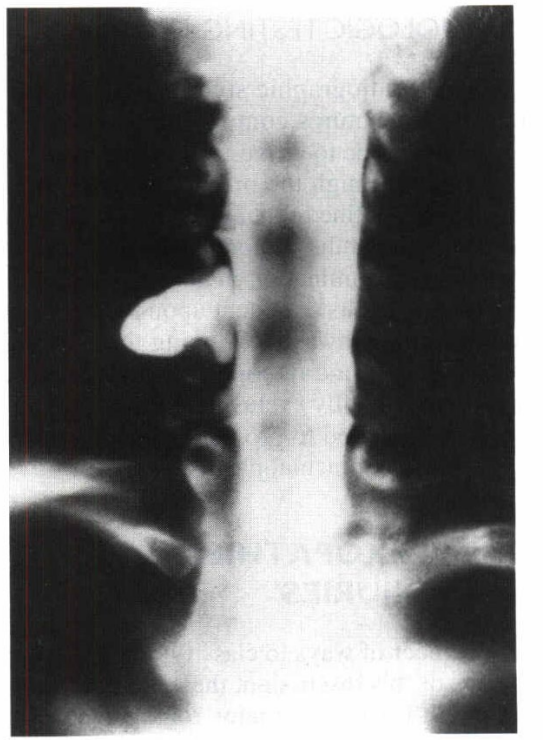
- **Avulsion: paraspinal, serratus anterior, rhomboid, phrenic**
- **Upper trunk**: supraspinatus, infraspinatus,(deltoid,biceps:distal to origin of suprascapular nerve)
- **Middle trunk: pectoral, LAD,TM**
- **Lower trunk:** *Pectoral(m,M)* **,EDC,EI**
- Medial cord: *Pectoral(m,M):abn, radial innervate:NL*
- Lateral cord: *Pectoral(M):abn, radial innervate:NL*
- Posterior cord: LAD, *radial innervate*

Needle EMG.

- **After history and P/E**, the single **most important** aspect of the electrodiagnostic medicine consultation is **needle EMG**.
- *PSW/Fib:* **1-6 weeks**, depending upon the distance(**paraspinal :7-14 days)**
- **most appropriate time of consultation** : **about 3-4 weeks after the injury.**
- **Reinnervation** :**same pattern** as denervation, i.e., proximal to distal
- ***CRD, Myokymia, and Fascicularion Potentials:*** ***chronic phases of plexopathies***
- myokymia :likely due to the radiation as opposed to the neoplasm
- **MUAP:** ***Recruitment/***

ANATOMIC AND Physiologic CORRELATIONS

Imaging:



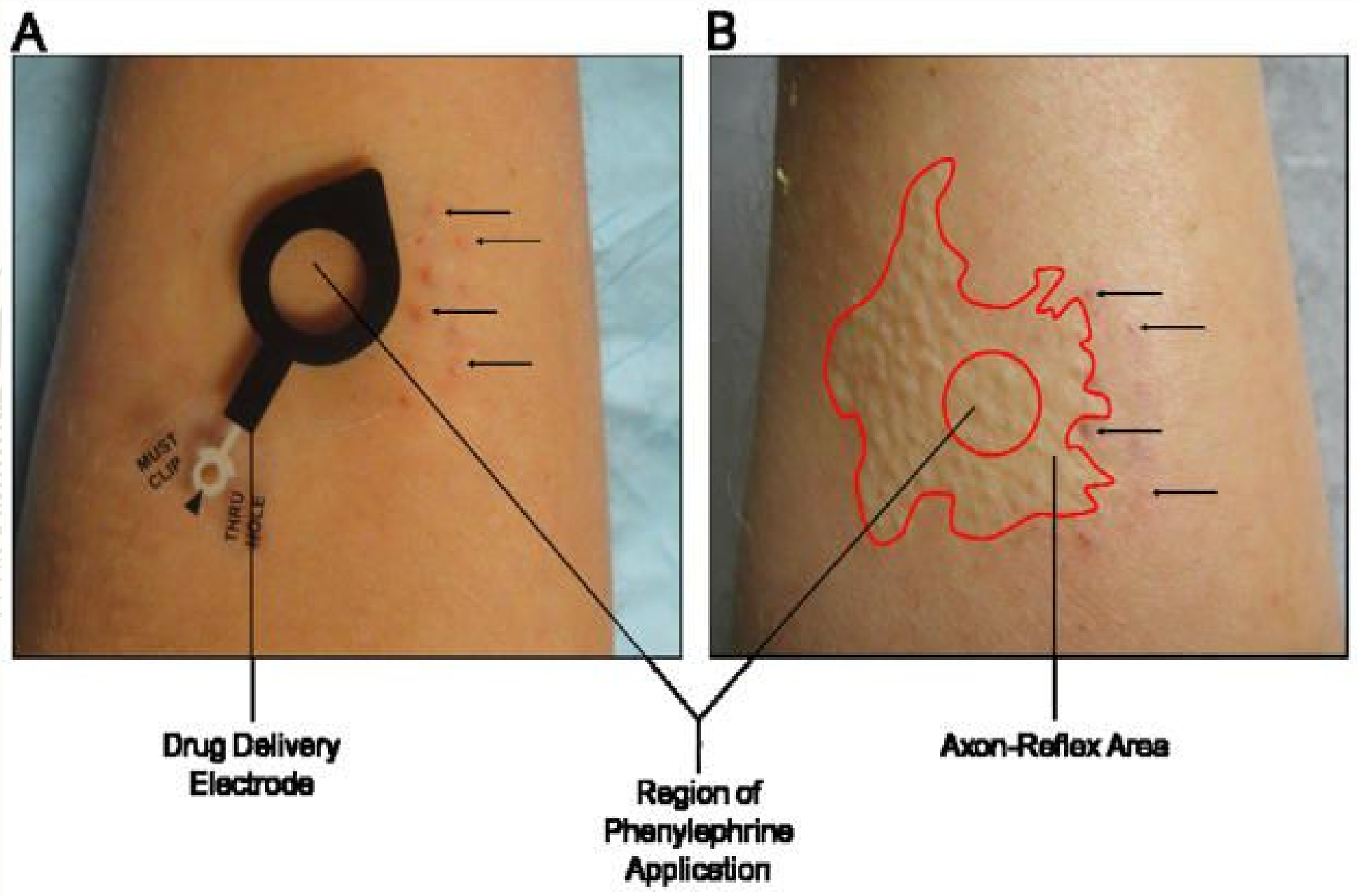
1. **Plain radiographs** of the neck and shoulder girdle:

- Lateral cervical spine tilting :**with an associated severe plexus traction injury**
- transverse process: fractured.
- first rib fracture :poor prognostic sign for the C8/T I nerve roots or lower trunk.
- C5 root avulsion +_ respiratory compromise:chest radiographs or fluoroscopy.

2. **Myelography** :I month after an injury (formation of meningeal diverticula)

- A period of 1 month :possibility **of arachnoiditis because of fresh hemorrhage** into the subarachnoid space.

3. **CT studies:** difficulty visualizing nerve roots and rootlets
4. **MRI** :choice for most peripheral nerve disorders
5. **Axon Reflex Testing** :**neural integrity distal to DRG**.(**postganglionic lesion**, results in an **absent flare response)**


A
B
RUST CUP
THRU HOLE
Drug Delivery Electrode
Region of Phenylephrine Application
Axon-Reflex Area