The Electrodiagnostic Study and Management of Peripheral Neuralgia and Radiculopathy

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Disclaimer:

- I have no financial disclosures
- The views, information, and conclusions expressed herein are those of the author alone.

Goals:

- Understand the Electrodiagnostic Assessment
- Identify common and uncommon causes of peripheral neuropathy
- Understand the pathophysiology of radiculopathy
- Familiarize with Conservative management strategies

Initial Evaluation

- History
- Neuromuscular examination
- +/- NCS/EMG
- +/- Ultrasound evaluation

The Role of Electrodiagnostics

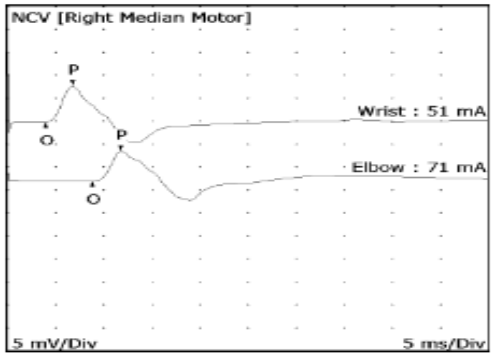
- Localization
- Severity
- Extension of the physical exam

The Role of Electrodiagnostics

- EDX studies establishing or rule out diagnoses, define severity or chronicity of a diagnosis, and assist with prognosis.
- An extension of the examination as a supplement to a thorough evaluation.
- EDX studies are interpreted in real time and often add additional relevant studies or remove irrelevant ones

Electrodiagnostics (EDX) Overview

- Nerve Conduction Study (NCS)
  - Focal examination of a specific nerve
    - Latency
    - Amplitude
    - Conduction Velocity
- Electromyography (EMG)
  - Focal examination of individual muscles
    - Spontaneous Activity
    - Firing Rate (recruitment)



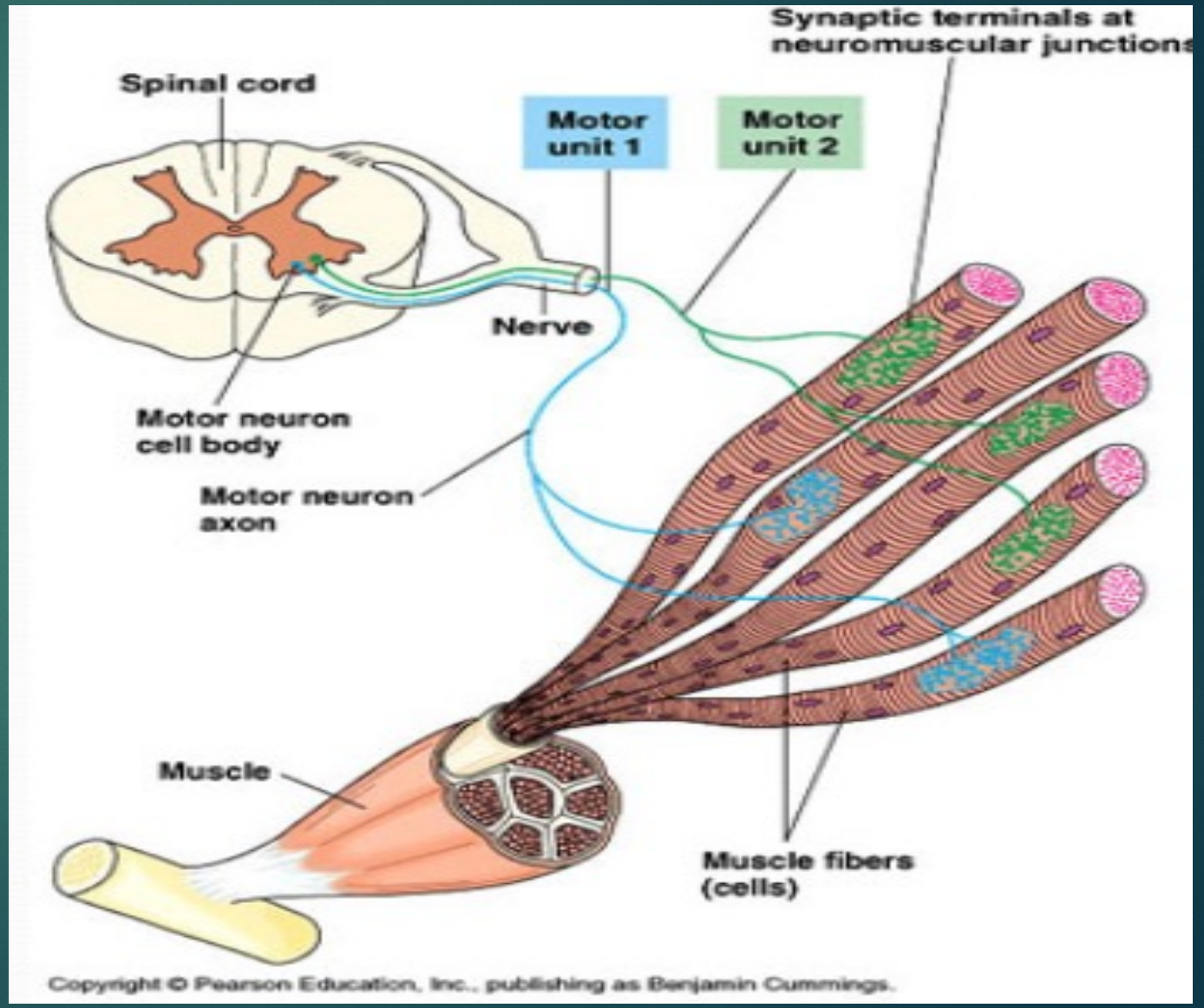
Side	Muscle	Nerve	Root	Ins Act	Fibs	Psw	Amp	Dur	Poly	Recrt	Int Pat
Right	Deltoid	Axillary	C5-6	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Right	Biceps	Musculocut	C5-6	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Right	Triceps	Radial	C6-7-8	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Right	FlexCarRad	Median	C6-7	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Right	Abd Poll Brev	Median	C8-T1	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Right	Cervical Parasp Mid	Rami	C4-6	Nml	Nml	Nml					
Right	Cervical Parasp Low	Rami	C7-8	Nml	Nml	Nml					
Left	Biceps	Musculocut	C5-6	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Left	Triceps	Radial	C6-7-8	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Left	Deltoid	Axillary	C5-6	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Left	FlexCarRad	Median	C6-7	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Left	Abd Poll Brev	Median	C8-T1	Nml	Nml	Nml	Nml	Nml	0	Nml	Nml
Left	Cervical Parasp Mid	Rami	C4-6	Nml	Nml	Nml					
Left	Cervical Parasp Low	Rami	C7-8	Nml	Nml	Nml					

Preparing patients

- A two-part study with the goal of assessing your nerves (from the spinal cord to the peripheral nerves) and how they interact with your muscles
- An uncomfortable study, but far from intolerable.
- Do not use any lotions or moisturizers before your study.
- Wear warm clothing to the appointment

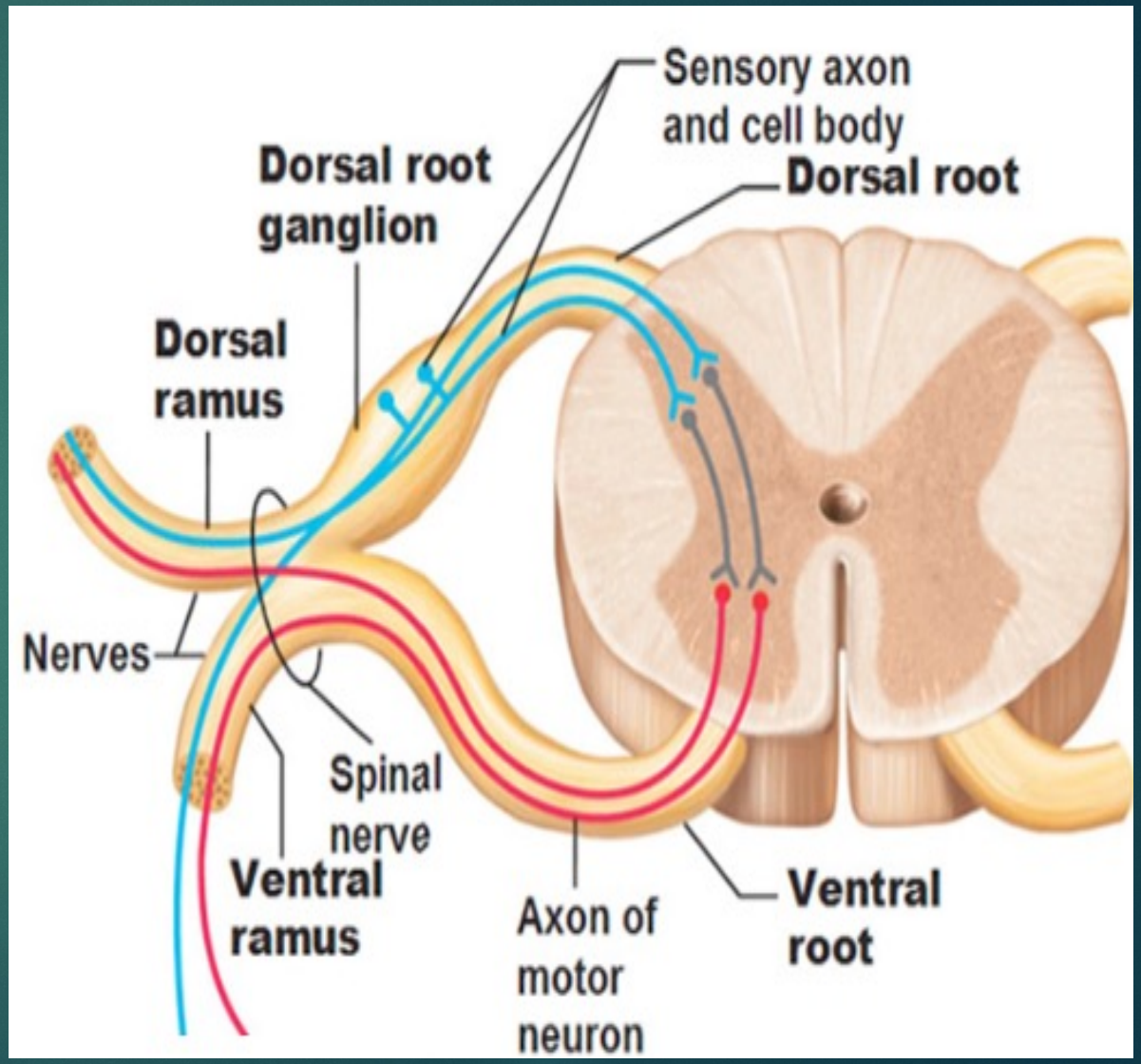
Anatomy & Physiology

- Motor Unit
  - Anterior Horn Cell
  - Axon
  - Terminal Branches
  - NMJ
  - Muscle Fibers



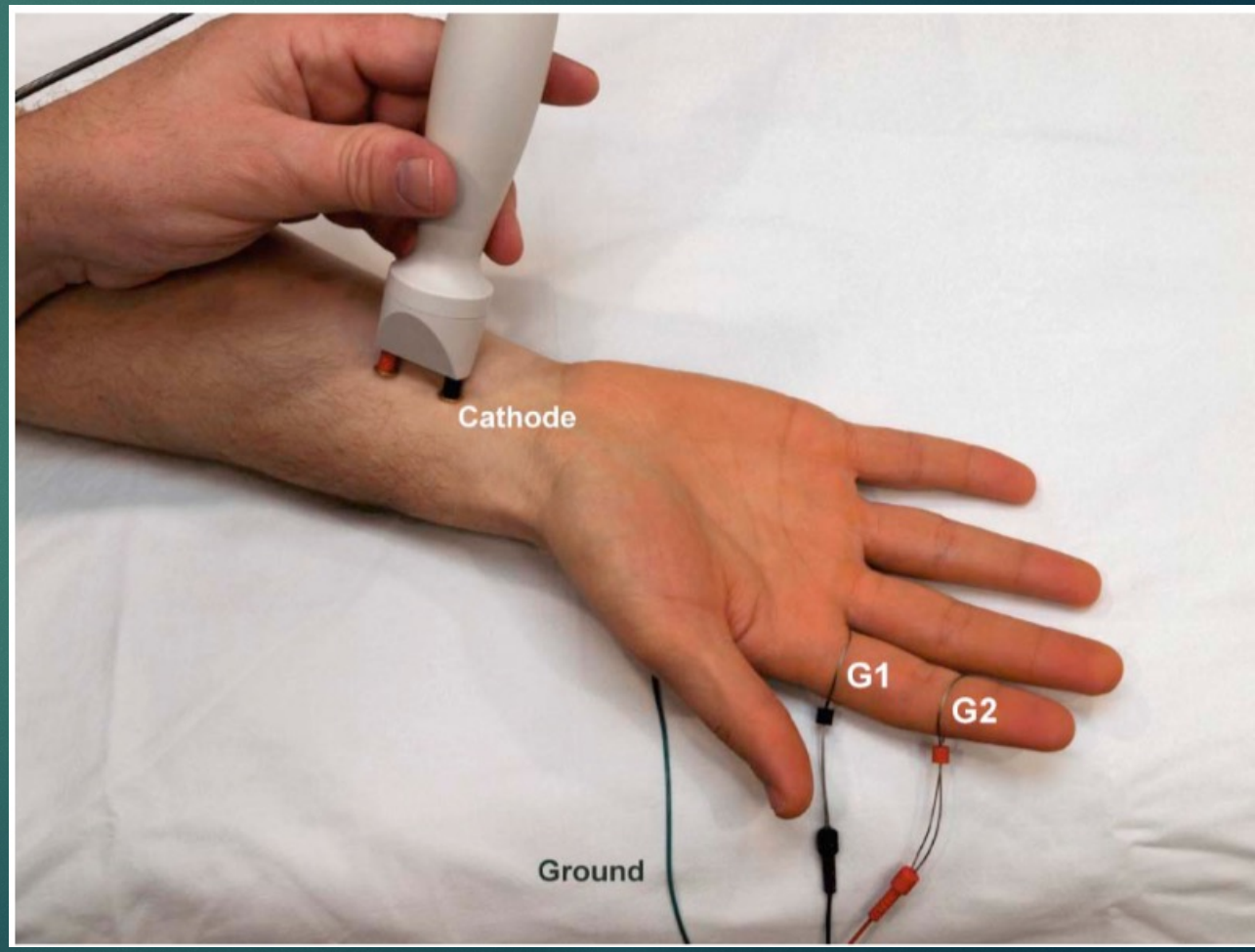
Primary Motor and Sensory Neurons

- Anterior horn cells located in ventral gray matter of the spinal cord
  - Exit ventrally as motor roots
- Dorsal Root Ganglion
  - Near the intervertebral foramen
  - Central and peripheral projections
- Mixed Spinal Nerve
  - Dorsal ramus: innervation to paraspinal muscles and skin
  - Ventral ramus: brachial plexus (C5-T1), intercostal nerves, Lumbosacral plexus



Nerve Conduction Studies (NCS)

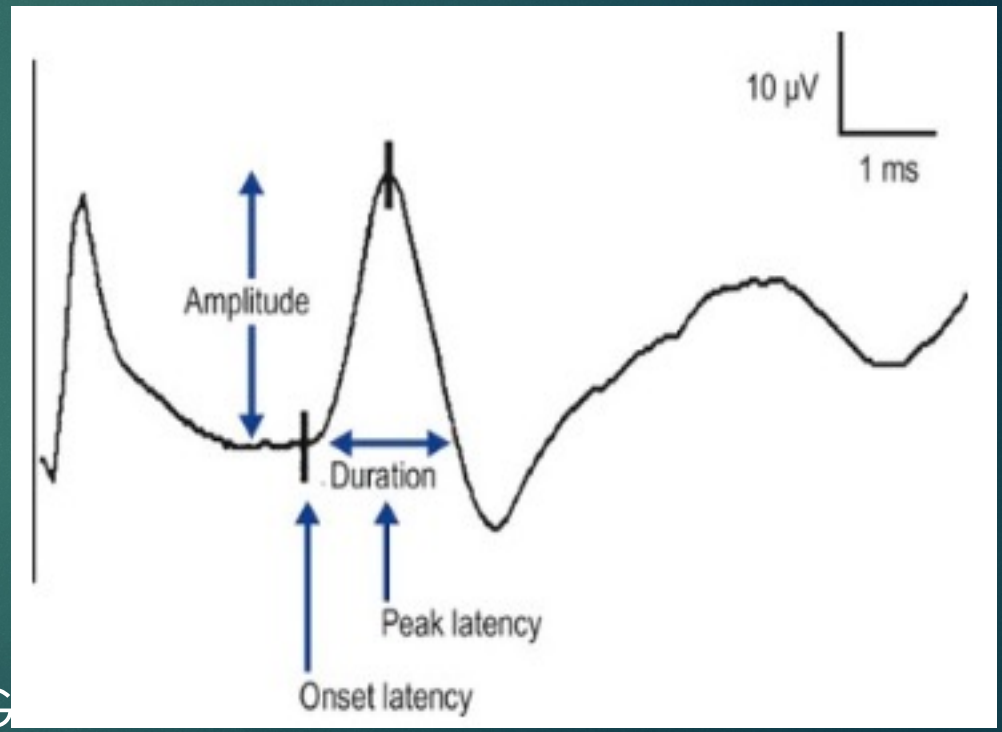
- Motor Conduction Studies
- Sensory Conduction Studies
- Mixed Conduction Studies



NCS: Sensory Conduction Studies

- **Sensory Nerve Action Potential (SNAP)**
  - Summation of all individual sensory fiber action potentials

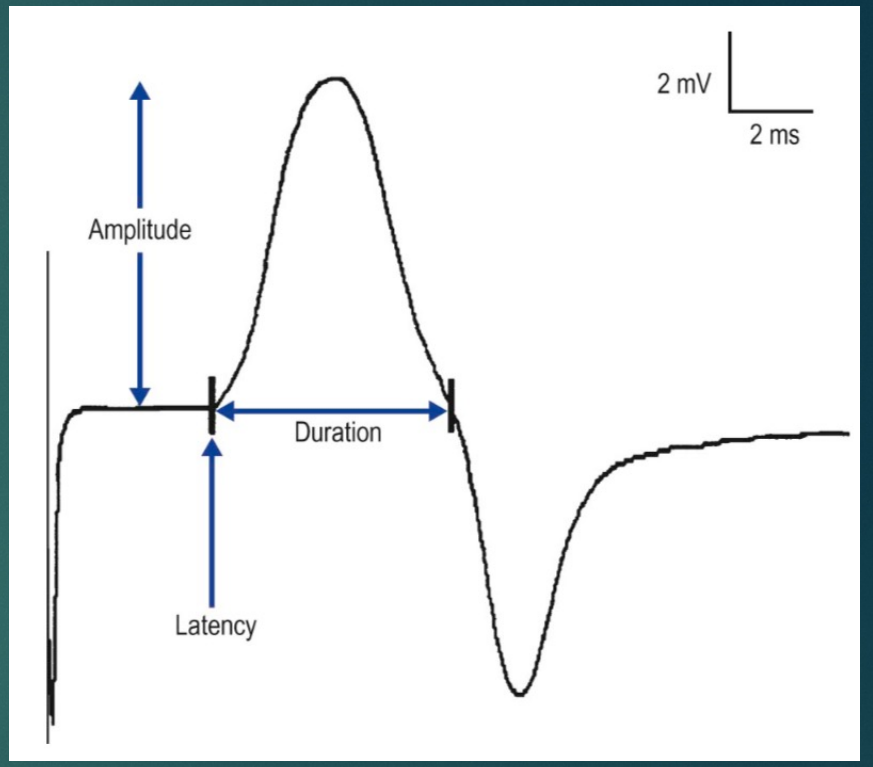
- **Peak latency:** midpoint of first negative peak
- **Amplitude**:
  - low → peripheral nerve involvement
- **Conduction Velocity**: one stimulation
  - Speed of fastest cutaneous sensory fibers



- All SNAPs remain normal in lesions proximal to the DRG

NCS: Motor Conduction Studies

- **<u>Compound Muscle Action Potential (CMAP)</u>**
  - Summation of all underlying individual muscle fiber action potentials



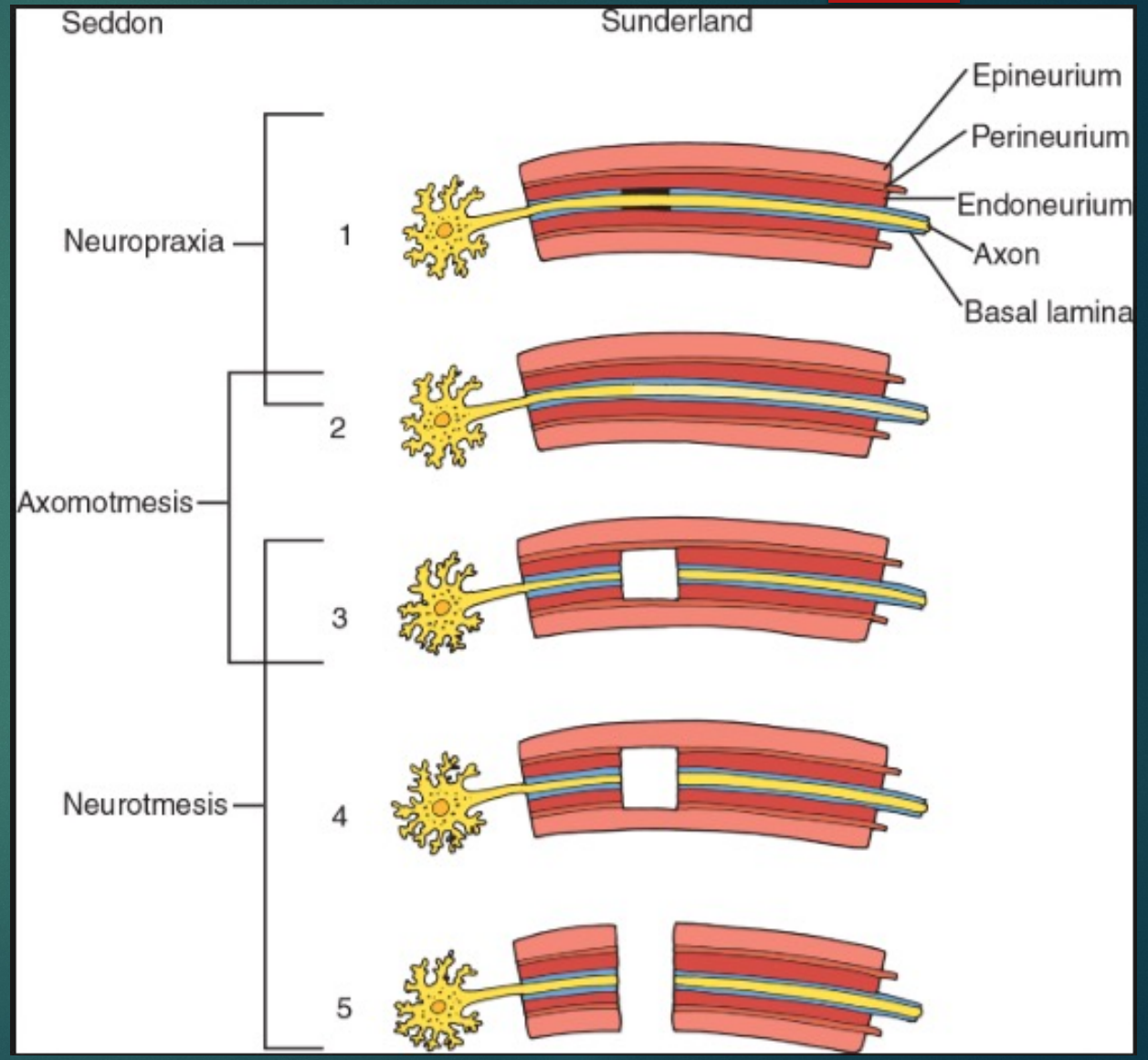
- **Onset Latency**: 3 processes
  1. Time from stim to NMJ
  2. Time across NMJ
  3. Depolarization time across muscle
- **Amplitude**: reflects number of fibers that depolarize
- **Conduction Velocity:** speed of fastest fibers

NCS: Mixed Conduction Studies

- Measure action potentials from both sensory and motor nerve
- Typically only median, ulnar and distal tibial nerves are studied
- Record the Ia fibers (muscle afferents) in addition.
  - Affected earliest in demyelinating lesions
- Clinically important– removal of offending agent should restore complete function

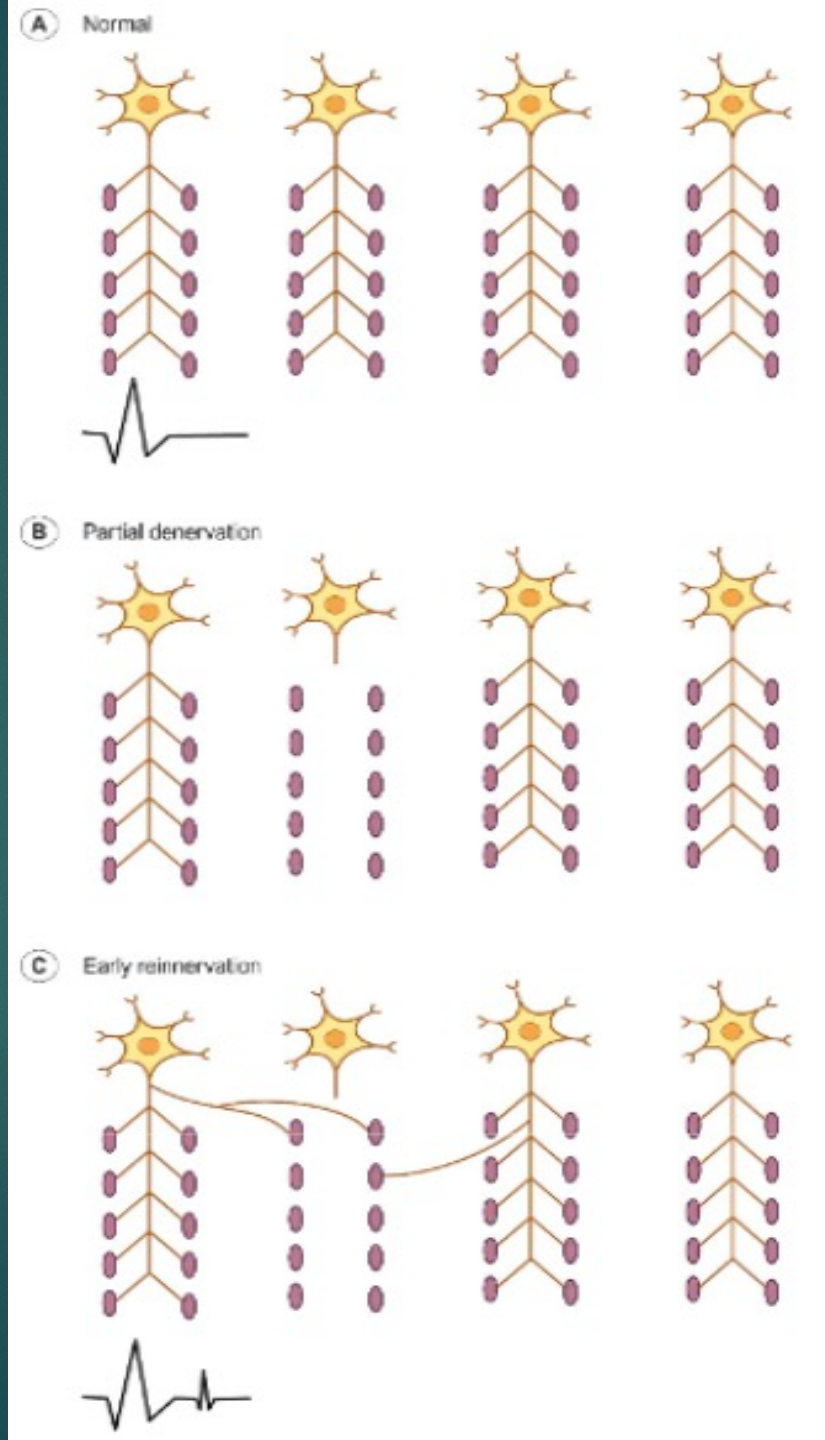
Pathophysiology: Nerve Injury

- **Seddon's Classification**
  - Neurapraxia (conduction block)
  - Axonotmesis (Connective Tissue intact)
  - Neurotmesis (transection)
- **Sunderland's Classification**
  - Type 1: Neurapraxia
  - Type 2: Axonotmesis
  - Type 3: 2 + Endoneurium injury
  - Type 4: 3 + Perineurium injury
  - Type 5: 4 + Epineurium injury (Neurotmesis)

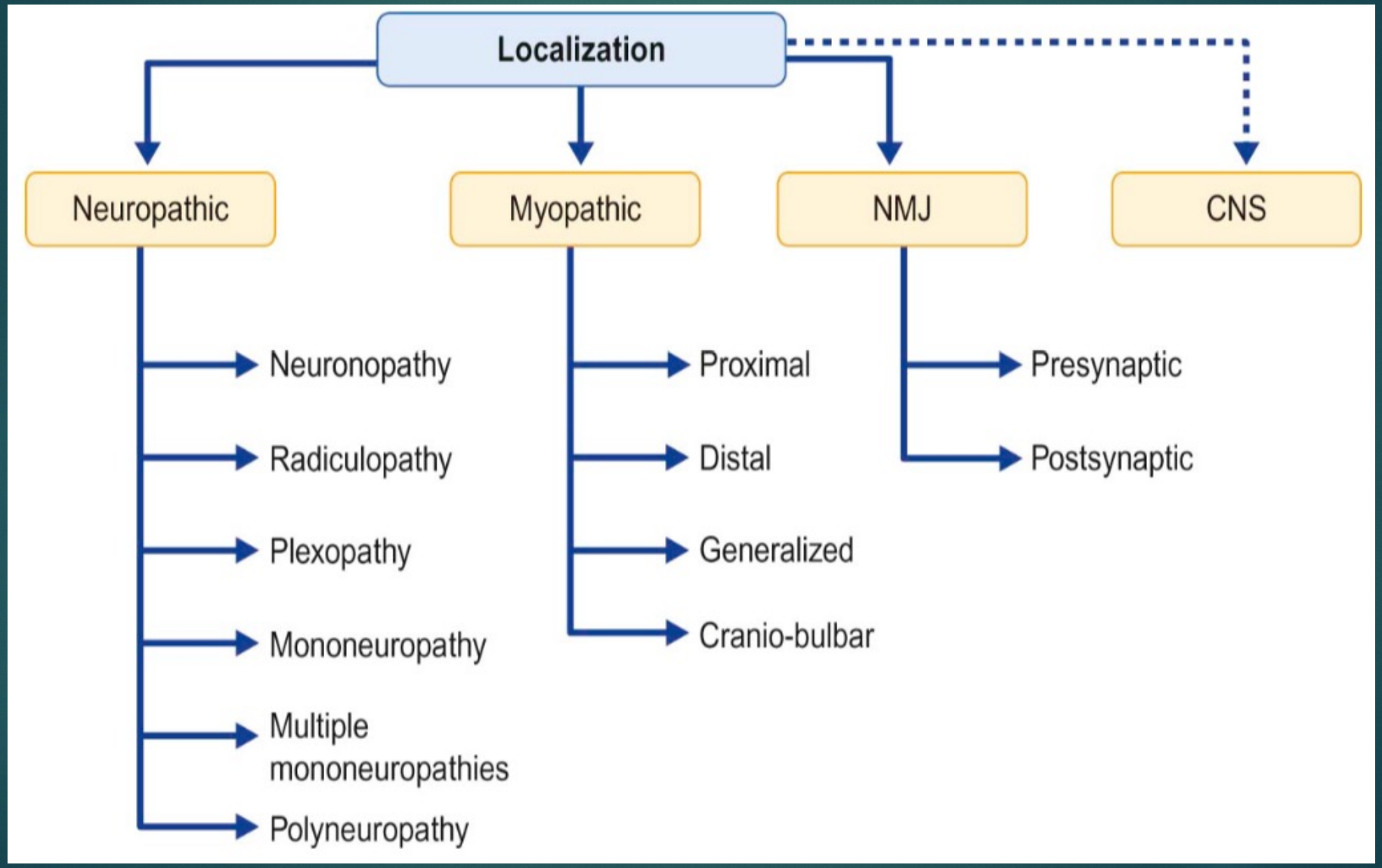


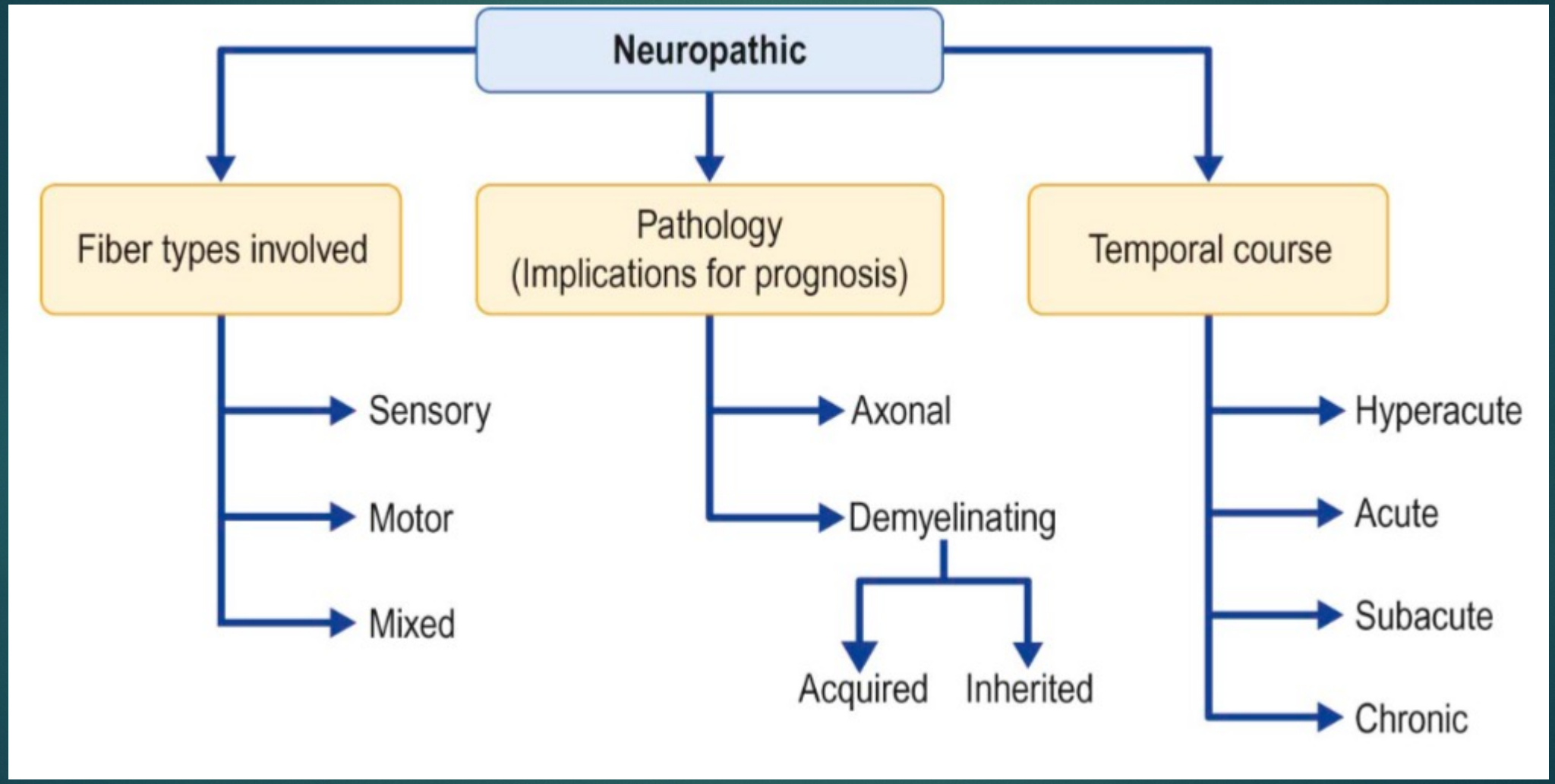
Recovery from Nerve injury

- Remyelination-- **2 to 12 Weeks**
- Collateral Sprouting-- **2 to 6 months**
  - Occurs after degeneration of injured distal axon fragments
  - Severe injury precludes sufficient sprouting
- Regeneration– **up to 18 months**
  - Proximal 6-8mm per day
  - Distal 1-2mm per day



The Role of EMG/NCS:




Neuropathic
Fiber types involved
Pathology
(Implications for prognosis)
Temporal course
Sensory
Motor
Mixed
Axonal
Demyelinating
Acquired
Inherited
Hyperacute
Acute
Subacute
Chronic

Neuropathic Lesions

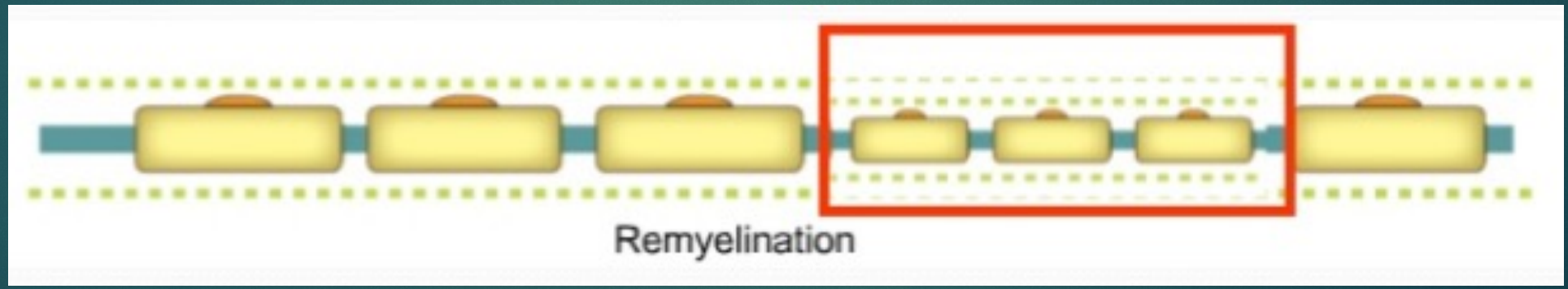
- Axonal Loss:
  - Physical disruption of the nerve
  - Toxic, metabolic, or genetic conditions damaging the axon
- Demyelination
  - Loss or dysfunction of the myelin sheath
  - Entrapment or compression
  - Genetic (CMT); toxic (diphtheria); auto-immune (GBS)
- Conduction block
  - Reduced amplitude proximally, as compared with distal stimulation

Basics: Localization

- Neuropathic: disorder of the peripheral nerve(s)
  - Radiculopathy
  - Plexopathy
  - Mononeuropathy
  - Multiple mononeuropathy
  - Polyneuropathy

Pathophysiology: Demyelination

- Demyelination can follow compression
- Schwann cells proliferate
- Internodal distance shortens
- Conduction velocity prolongs



AXONAL LOSS vs DEMYELINATION

- **REDUCED amplitude**
- **Conduction Velocity normal** or slightly decreased
  - Never below 75% of lower limit of normal
- **Latencies are typically normal** or slightly prolonged
  - Never greater than 130% of upper limit of normal

- **NORMAL** Amplitude
- Marked slowing of CV
- Marked prolongation of distal latency
- Normal myelinated axons do not conduct slower than 35m/s in arms or 30m/s in legs

Hyperacute axonal Loss lesion: (3-4 days)

- Stimulation and recording distal to lesion is normal
- Wallerian Degeneration: 7-11 principle
  - (book answer-- motor 3-5 days; sensory 6-10 days)
- "Pseudo-conduction block"
- Acute trauma, nerve infarction

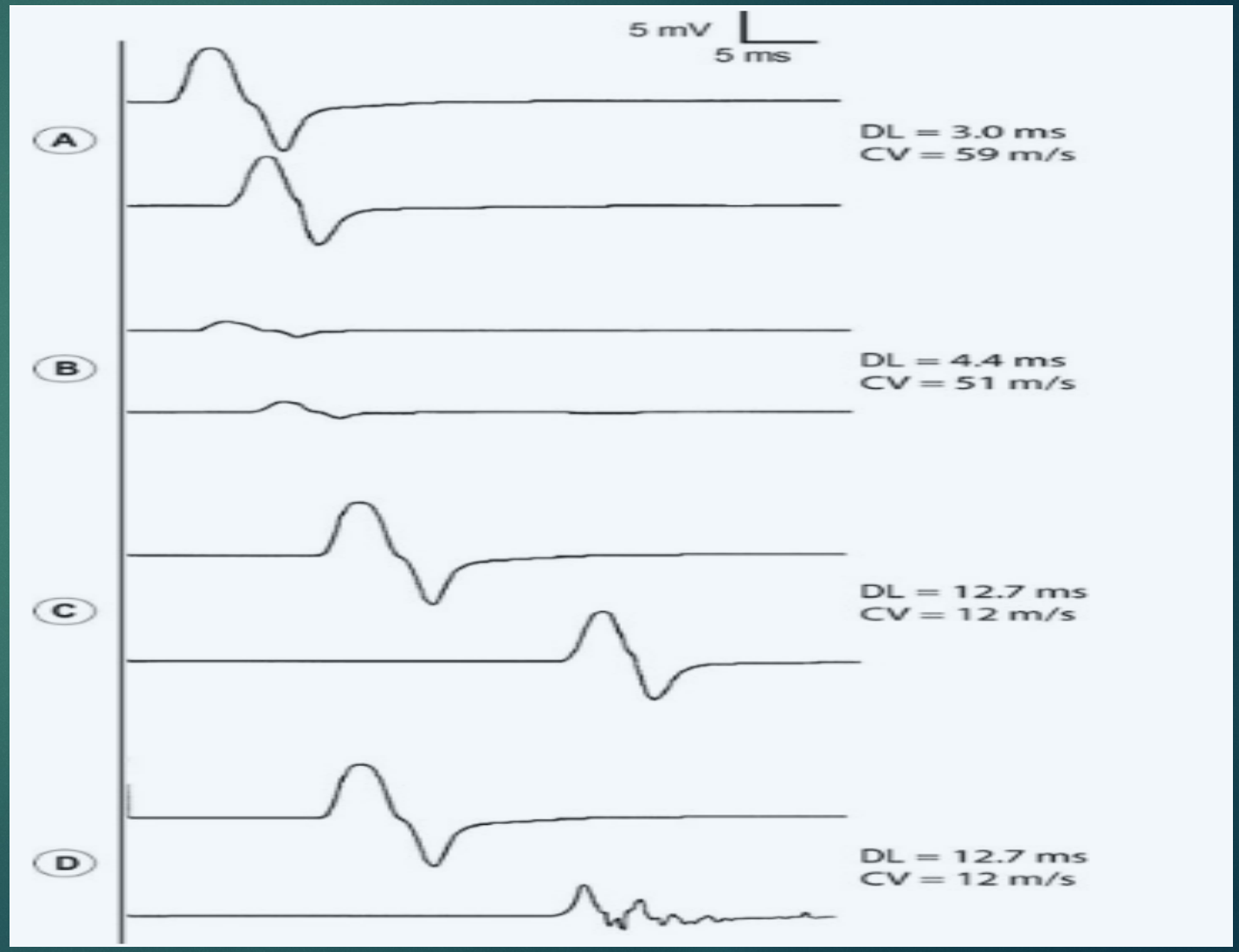
Patterns of Conduction Abnormalities

A. **Normal Study**

B. **Axonal Loss**

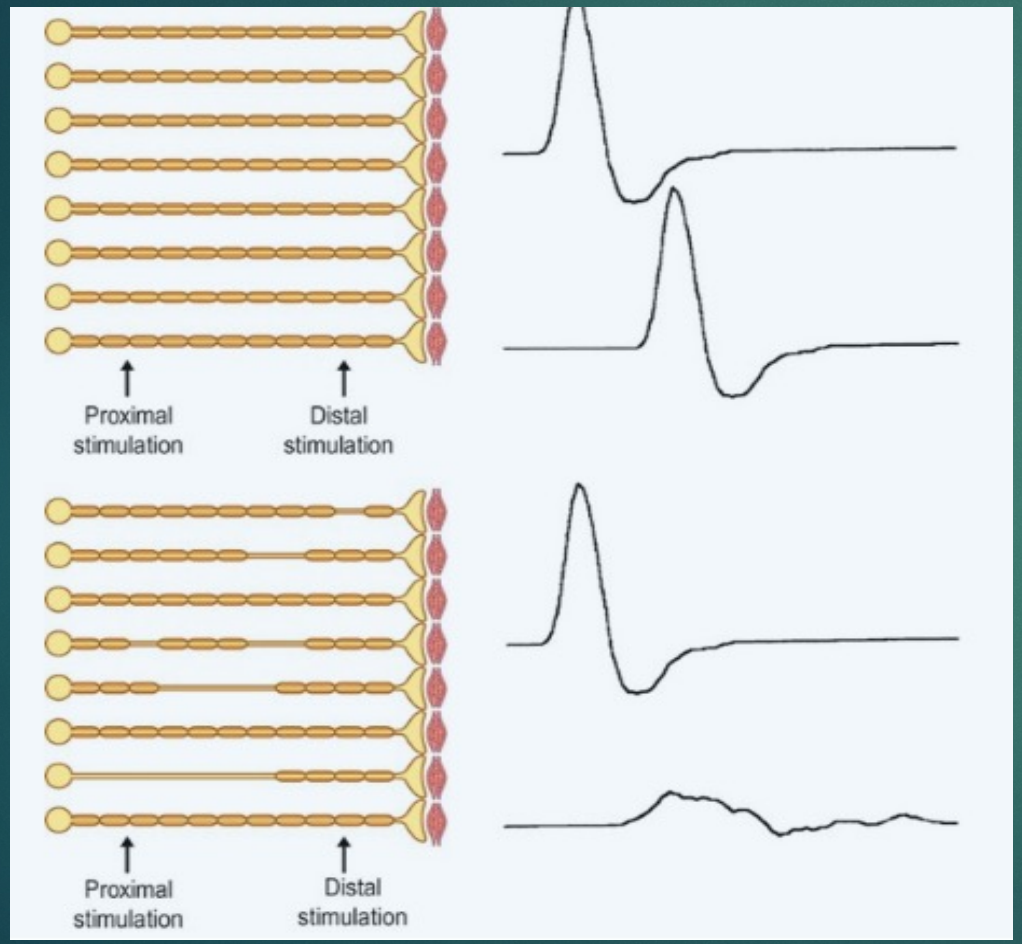
C. **Demyelination**
(uniform slowing)

D. **Demyelination**
(Conduction Block)

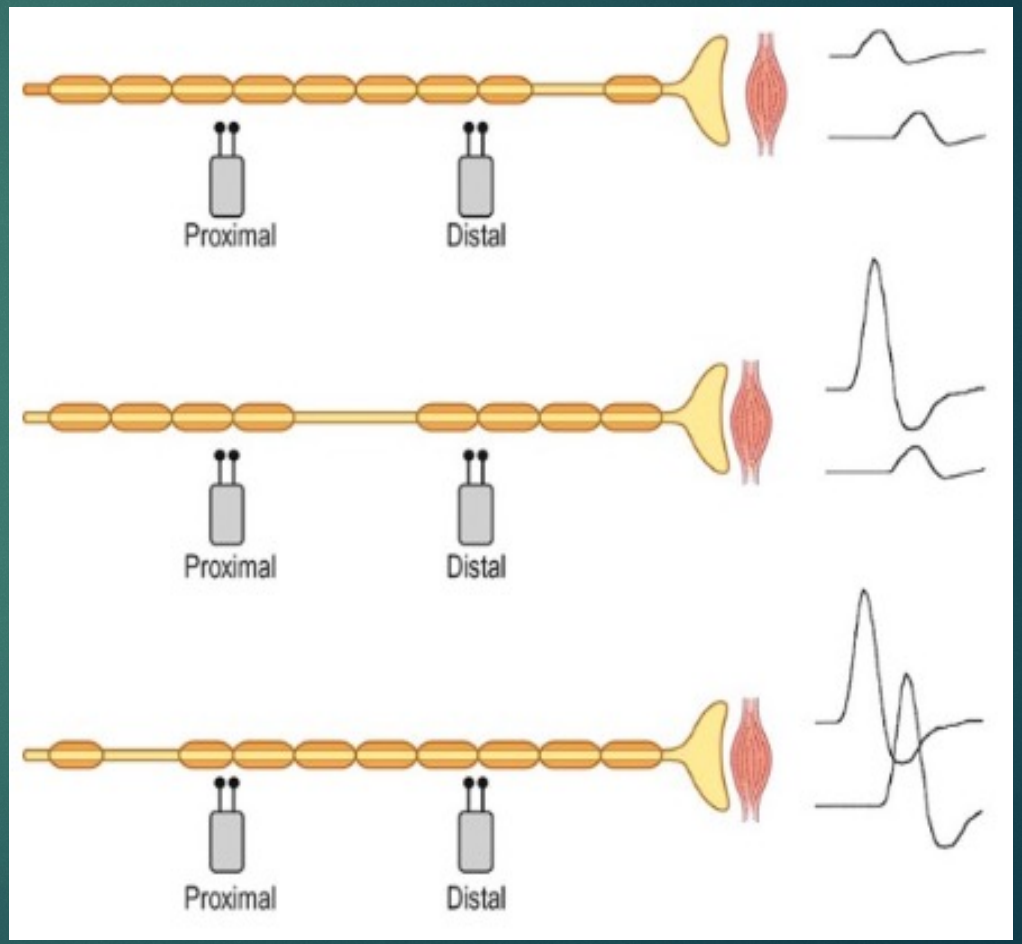


Conduction Block

Acquired Demyelination



Focalized Demyelination

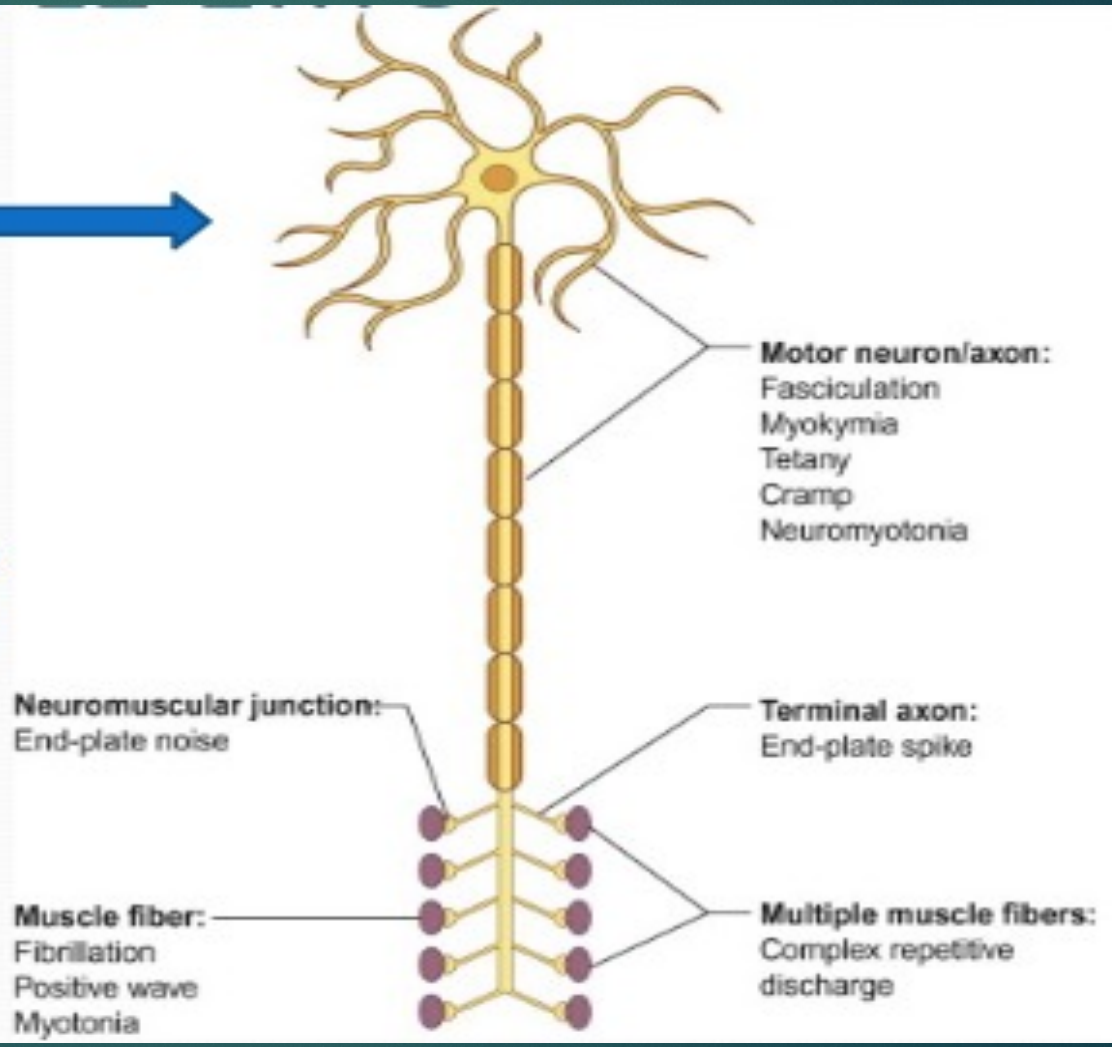


The EMG portion of the study

- Spontaneous activity
  - A normal muscle at rest is quiet
- Motor Unit Action Potential (MUAP) Morphology
  - Duration, amplitude, phases
- Recruitment:
  - Normal ; Decreased ; Increased ; Poor effort
- Interference pattern

Electromyography (EMG)

- **Morphology**
- **Stability**
- **Firing Characteristics**
  - **Fibs/PSWs= Regular**



Importance of Needle EMG testing

- EMG provides evidence of a nerve root lesion
- Classical dermatomes are in the textbook---anatomical variation is present
- Needle EMG has increased correlation to symptoms and PE findings and higher specificity than MRI
- Needle EMG has strong specificity, but only modest sensitivity

EMG – Upper Extremity

ADULT EMG: % SENSITIVITY				
LEVEL	**C5**	**C6**	**C7**	**C8**
	Infraspin: 83%	Ancon: 100%	Triceps: 93%	EIP: 100%
	Deltoid: 83%	FCR: 80%	FCR: 93%	FDI: 83%
	BR: 83%	PRT: 78%	Ancon: 78%	ADM: 83%
	Biceps: 71%	BR: 71%	PRT: 61%	FPL: 67%
	PSP: 71%	PSP 63%	PSP: 31%	PSP: 80%

Levin, K.H., 2002. Electrodiagnostic approach to the patient with suspected radiculopathy. Neurol Clin 20, 397–421

EMG – Lower Extremity

ADULT EMG: % SENSITIVITY							
LEVEL	**L3**		**L4**		**L5**		**S1**	
	Rec Fem:	83%	Tib Ant:	92%	EHL:	87%	Gastrc:	90%
	Add Long:	80%	RF:	83%	Per Long:	84%	Abd Hall:	90%
			Add Long:	80%	Tib Post:	81%	EDB:	67%
					Tib Ant:	78%	Tib Post:	64%
					Glut Max:	61%	Glut Max:	61%
					Med Ham:	60%		
					EDB:	33%		

Levin, K.H., 2002. Electrodiagnostic approach to the patient with suspected radiculopathy. Neurol Clin 20, 397–421

Prognosis of Peripheral Nerve Lesions

- **Degree of demyelination**
  - Neurapraxia- substantial recovery in 2-3 months
- **Extent of Axon Loss**
  - Distal axon sprouting may occur, depending on the degree (5 times territory worth of distal sprouting per axon)
- **Distance to muscle**
  - Risk of axonal stenosis, which can prevent reinnervation
  - After 18-24 months, muscle can no longer be reinnervated
  - Root avulsions
  - Lower trunk lesions (brachial plexopathies)
- No definitive treatments to prevent this…

Upper Extremity Neuropathies

More Common

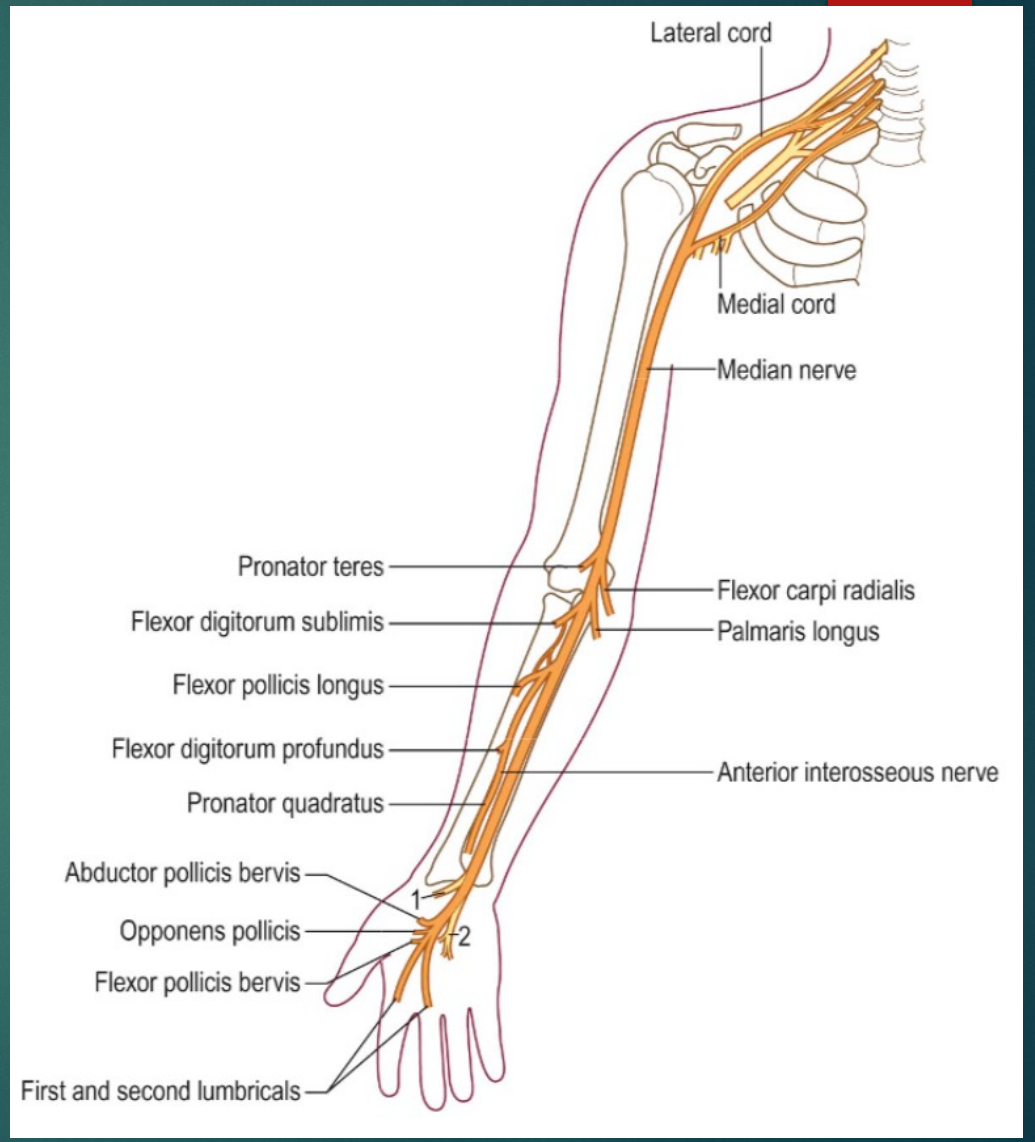
- Median Neuropathy
- Ulnar Neuropathy
- Radial Neuropathy
- Brachial Plexopathy

Less Common

- Axillary Neuropathy
- Suprascapular Neuropathy
- Long Thoracic neuropathy

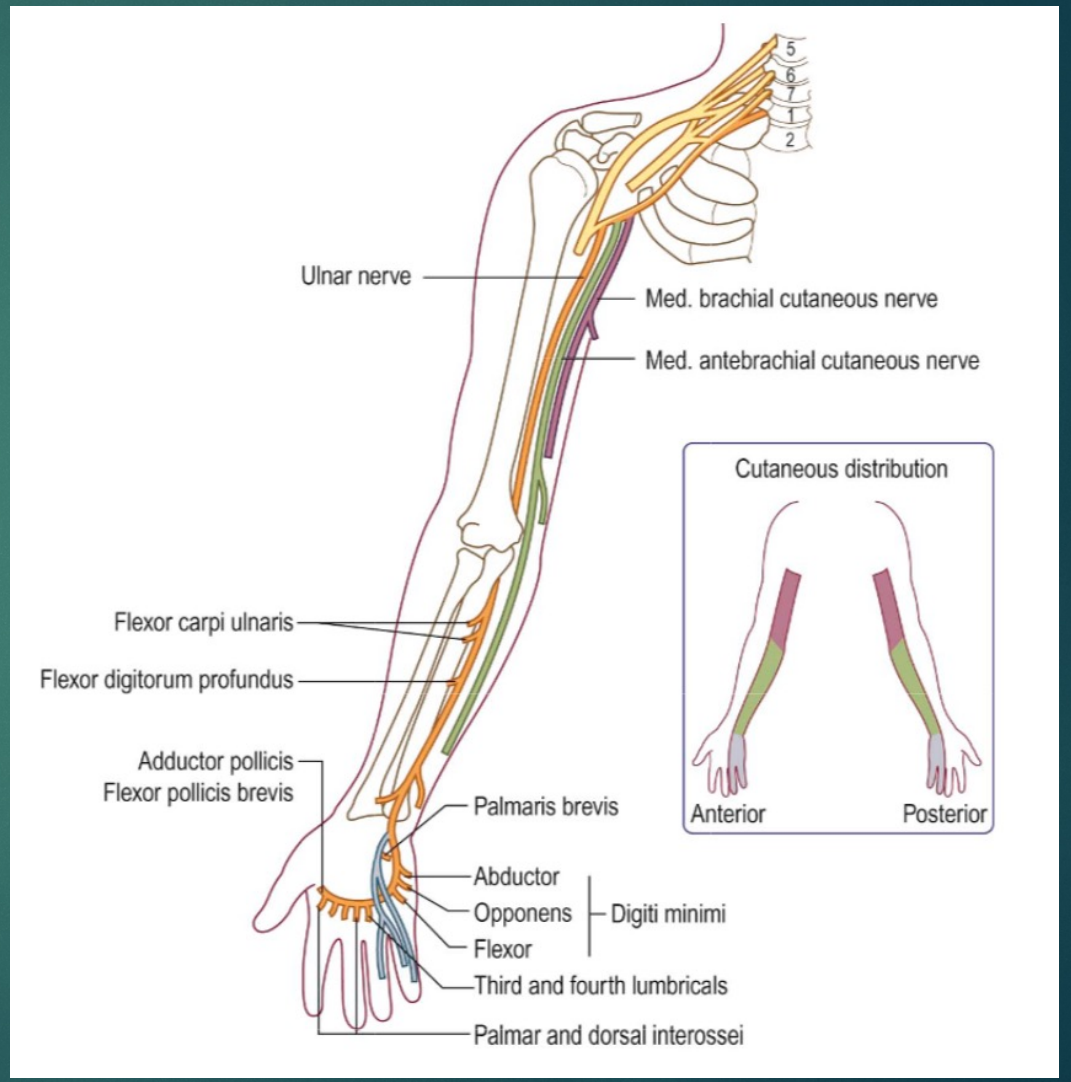
Median Neuropathy

- Etiologies:
  - Entrapment:
    - Elbow- Pronator syndrome
    - Wrist- Carpal Tunnel syndrome
  - Traumatic
- Clinical Exam:
  - Impaired sensation 1-3 digits
  - Finger flexion weakness
  - Wrist flexion weakness
  - APB



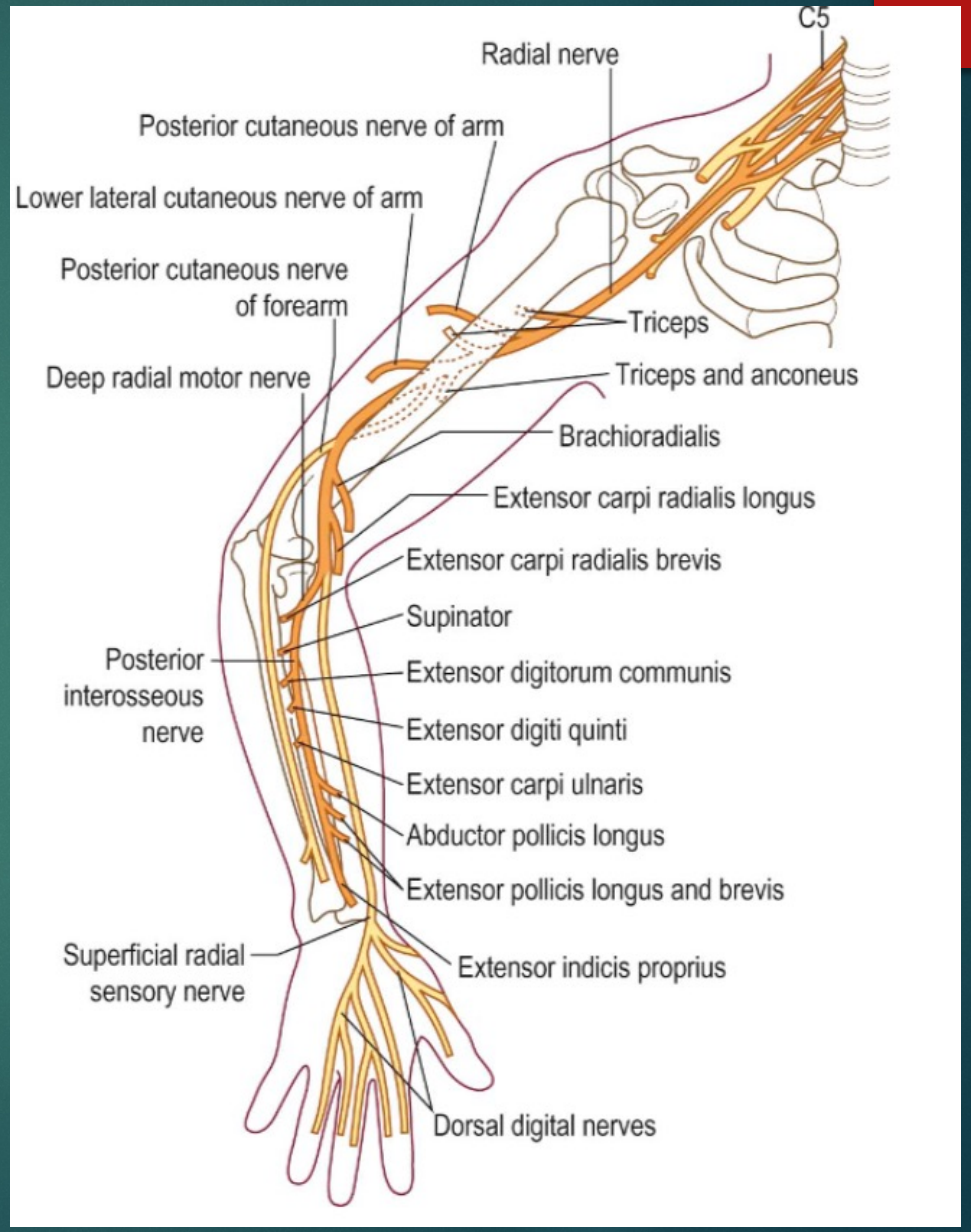
Ulnar Neuropathy

- Etiologies:
  - Entrapment:
    - Cubital Tunnel
    - Guyon's Canal
  - Traumatic
- Clinical Exam:
  - Impaired sensation 4th and 5th digit
  - Atrophy/ Weakness of ADM, FDI, intrinsics



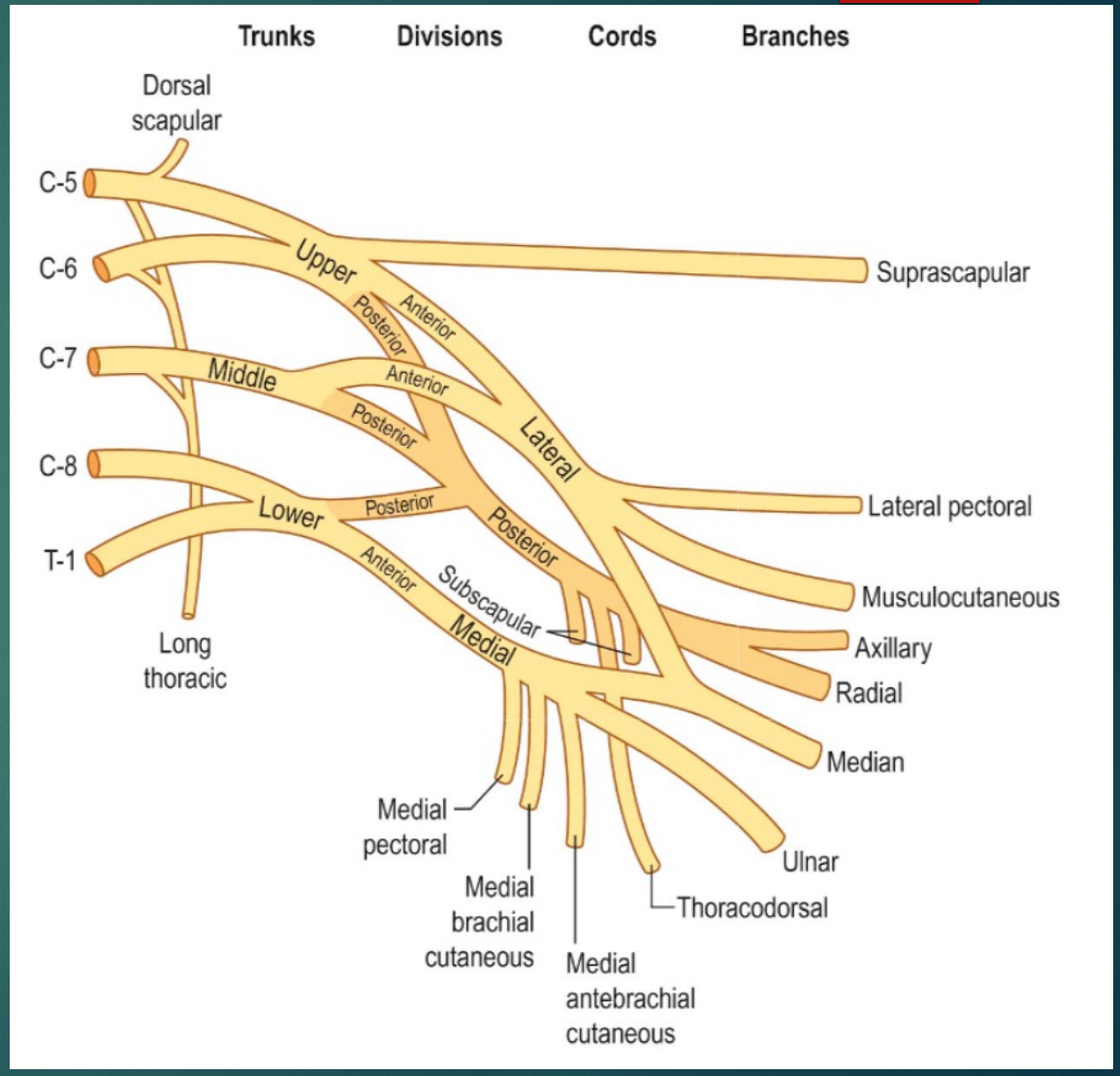
Radial Neuropathy

- Etiologies
  - Compressive:
    - Crutch use (axilla)
    - Radial Tunnel
    - Watches / wrist bands / casts
  - Traumatic
- Clinical Exam
  - Wrist drop
  - +/- Sensation changes



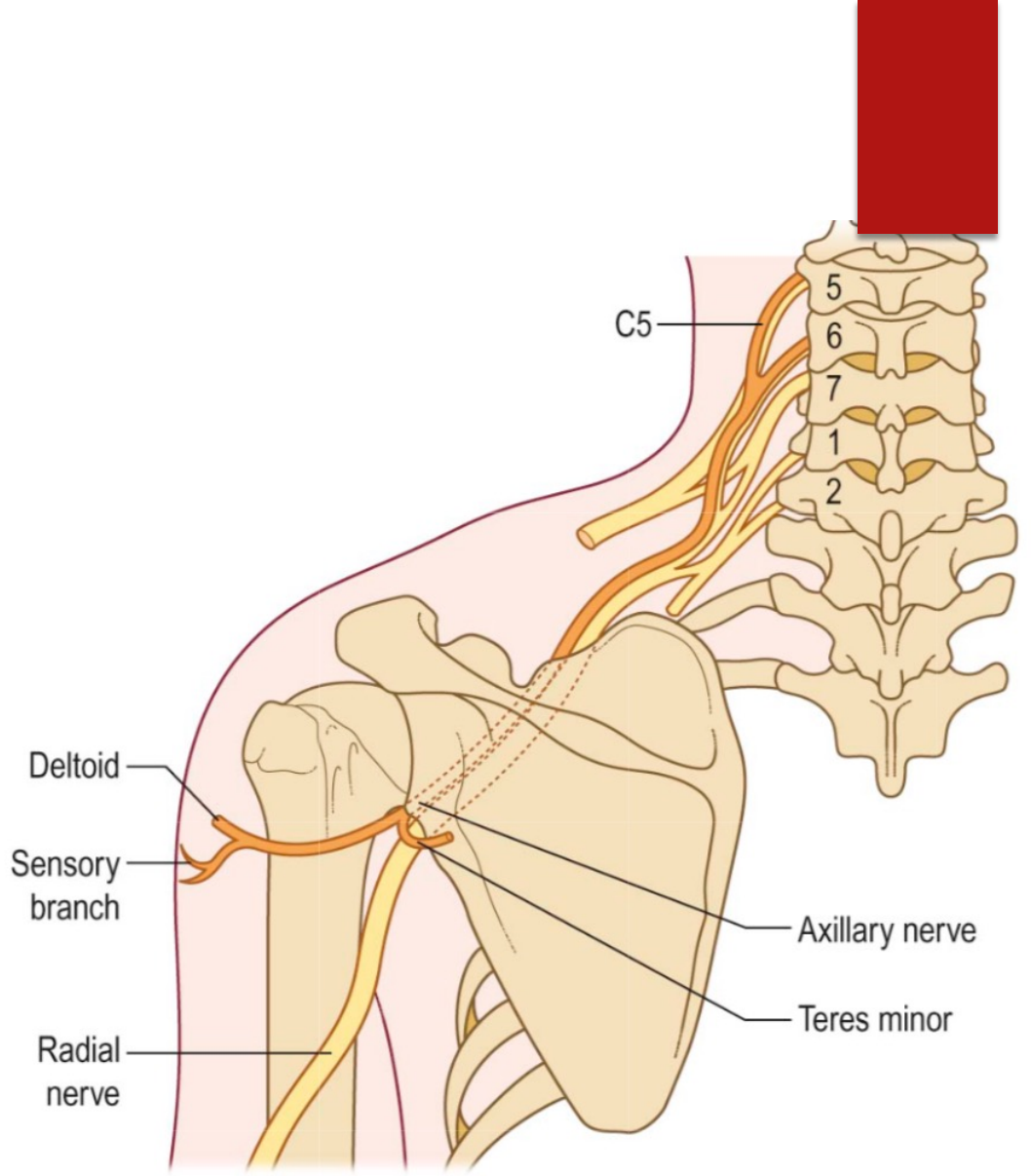
Brachial Plexopathy

- Traumatic
- Hematoma
- Inflammatory
- Mass



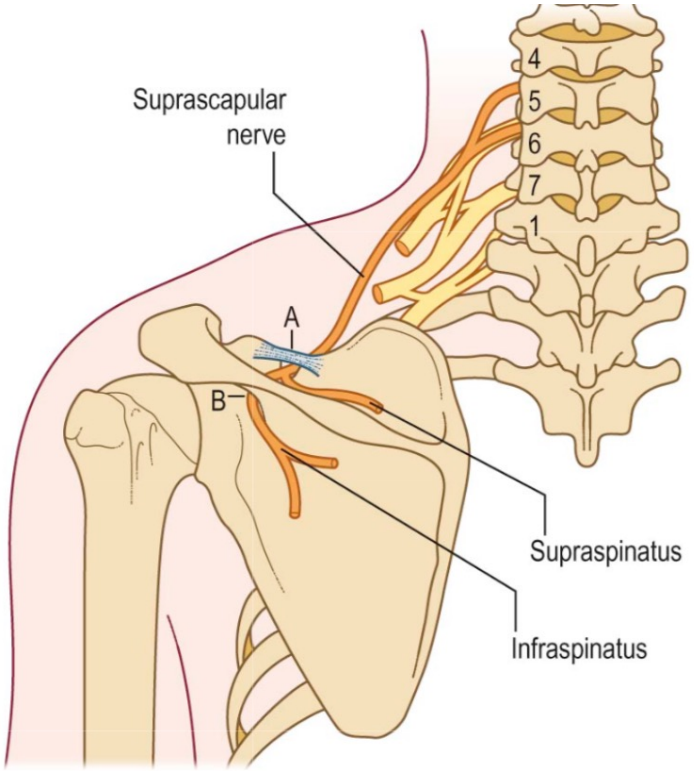
Axillary Neuropathy

- Etiologies
  - Compressive:
    - Quadrilateral space syndrome (rare)
  - Traumatic:
    - Shoulder dislocation
    - Humerus fx
- Clinical Exam
  - Numb patch
  - Shoulder abduction weakness



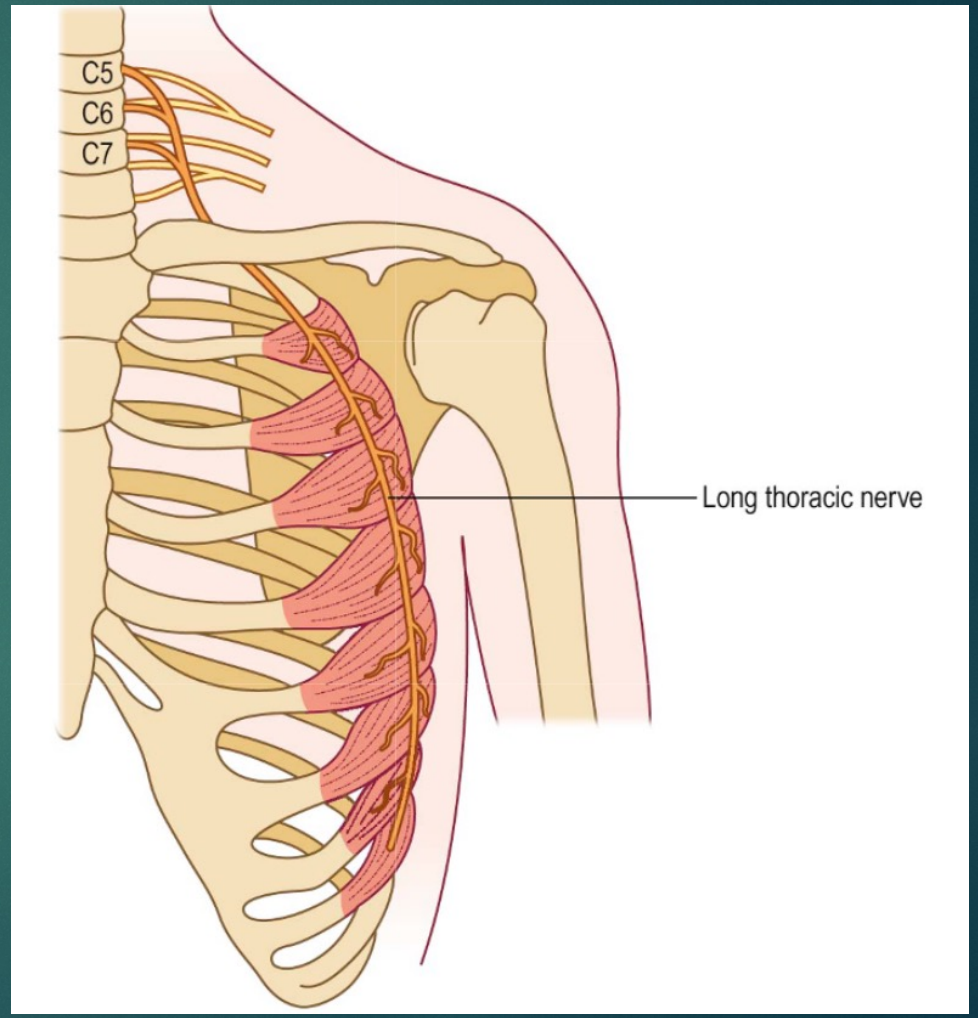
Suprascapular Neuropathy

- Etiologies
  - Compressive:
    - Ganglion Cyst
    - Rotator cuff tear
  - Traumatic:
    - Repetitive overstretch in athletes
    - Surgical positioning
- Clinical Exam
  - Pain with shoulder movements
  - IS/SS weakness



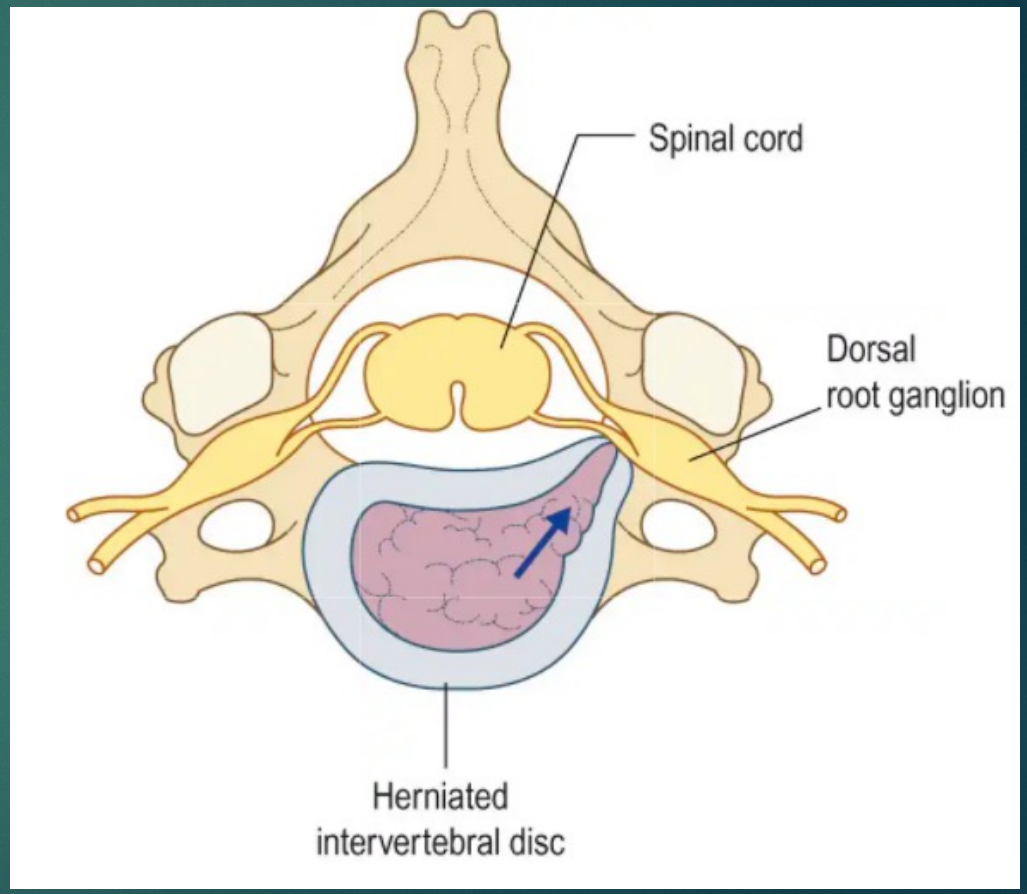
Long Thoracic Neuropathy

- Etiology:
  - Most from inflammation
  - Ruck sack palsy
  - Other stretch/compression
- Clinical exam:
  - Medial winging



Radiculopathy

- Herniation of nucleus pulposus
- Spinal Stenosis:
  - Degenerative Spondylosis
  - Ligament hypertrophy
  - Spondylolisthesis



Radiculopathy

EDX Diagnosis: neuropathic abnormalities in muscles that share the same nerve root innervation

Patients typically undergo a screening examination when no true deficits are found on physical examination, but any weak muscles should certainly be tested.

Radiculitis (sensory radiculopathy) vs Radiculopathy

Affected peripheral muscles are variable based on the fascicular structure of nerves

The Physical Exam

- L3/L4: squat test
- L5/L4: Heel-walking
- L5: Trendelenburg test S1: Toe-walking

- SLR/Slump test

- C5/6: Infraspinatus comparison testing
- C8/T1: ABP and FDI

Muscle Stretch Reflex Testing:

C5/6: Brachioradialis
C7: Triceps

L4: Patella
L5: Medial Hamstring
S1: Achilles

Spinal Imaging Interpretation

- Interpret the symptoms, correlate the imaging. The degree of pathology does not always correlate with symptom severity.

- Age-related changes are prevalent
  - Degenerative changes are present at least 30% of the time, even in asymptomatic individuals by age 40.
  - “disc bulge” is present in >70% of people after age 30

- Lumbar MRI is not as useful for interpretation when stenosis is mild.

Radiculopathy Management

- Conservative approach to managing a radiculopathy has been shown to result in good to excellent outcomes.
- Neurological weakness--- to operate or not?
- >75% of disc herniations resolve spontaneously by around 1 year
  - This was shown in conjunction with ESI treatment

Treatments

- NSAIDs remain the mainstay of treatment for acute and chronic conditions
- Consider oral steroids acutely – 5 day treatment with 5 day taper or Medrol dose pack---provider choice (hold NSAIDs during tx)
- Opiates:
  - Short course in acute injury with radicular symptoms
  - Use in chronic cases makes pain worse!
- Neuropathic Agents
- Epidural Steroid Injection
  - Interlaminar
  - Transforaminal
  - Traditionally given in a series of three; provider dependent

Surgical Consultation

- Myelopathy
- Cervical stenosis with abnormal EMG findings
- Unstable spine
- Severe dynamic spondylolisthesis
- Fracture
- Infection
- Tumor

References:

- Preston, D. C., & Shapiro, B. E. (2013). *Electromyography and neuromuscular disorders: Clinical-electrophysiologic correlations*. Elsevier Saunders.
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