

Planning Nerve Conduction Studies

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Financial Disclosure

- **Dr. Simmons and Dr. Fullam have no financial disclosures.**

- The view(s) expressed herein are those of the Dr. Fullam and do not reflect the official policy or position of Brooke Army Medical Center, the U.S. Army Medical Department, the U.S. Army Office of the Surgeon General, the Department of the Army, the Department of the Air Force, or the Department of Defense or the U.S. Government.

Intended Audience

- Technologists
- Residents and Fellows
- Physicians starting or returning to EMG practice
- People like us who sincerely enjoy listening to EDX lectures!

Learning Objective

- Learn to apply a rational strategy for planning NCS based on patient symptoms.

Course Outline

- Part 1: Upper Limb Symptoms
- Part 2: Lower Limb and Generalized Symptoms
- Part 3: 10 Principles

Disclaimer: Practices vary across laboratories based on experience, training, and personal preferences!

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Planning NCS: Upper Limb

Daniel B. Simmons, MD

Saint Alphonsus Health System, Boise, ID

Upper Limb Symptoms

- Quality of Symptoms:
  - Tingling
  - Numbness
  - Pain
  - Clumsiness or loss of dexterity
  - Weakness
- Location of Symptoms:
  - Neck/Shoulder
  - Arm
  - Forearm
  - Hand
  - Fingers
  - Well-circumscribed vs poorly localized

Localization:

- Root
  - Cervical radiculopathy, CIDP, GBS
- Plexus
  - Trunk, Cord, etc
- Nerve
  - Median, ulnar, radial, axillary, musculocutaneous
- NMJ
  - Myasthenia Gravis, Lambert-Eaton Myasthenia
- Muscle
  - Myopathy, myositis, dystrophy

Why not this?

- Right median motor
- Right ulnar motor
- Right radial motor
- Right median sensory
- Right ulnar sensory
- Right radial sensory
- Left median motor
- Left ulnar motor
- Left radial motor
- Left median sensory
- Left ulnar sensory
- Left radial sensory

1. Patient discomfort – limit studies to minimum required to answer the clinical question.
2. False positives – the more tests you perform, the higher the probability of false positives.

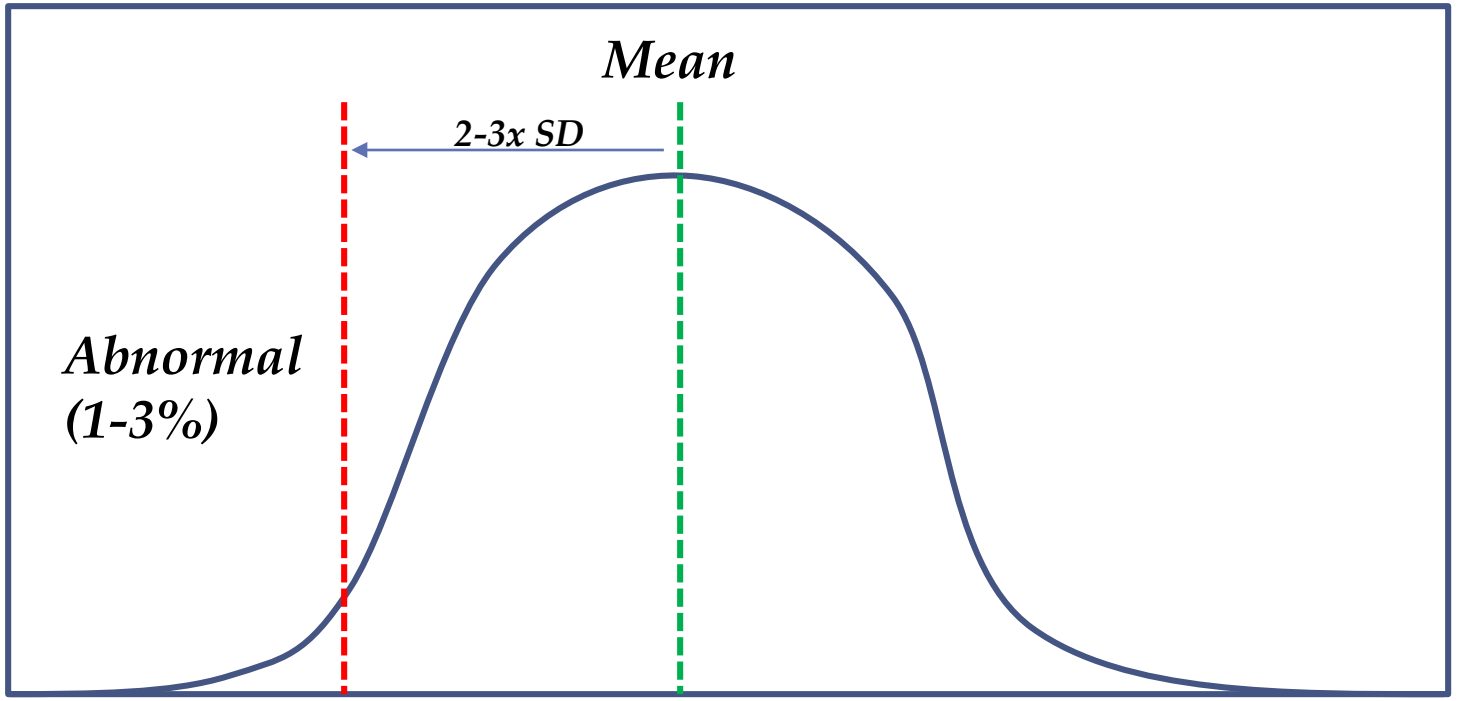
American Association of Neuromuscular & Electrodiagnostic Medicine
2621 Superior Drive NW, Rochester, MN 55901 T: 507.288.0100 F: 507.288.1225 www.aanem.org

Maximum Number Table—Electrodiagnostic Medicine Listing of Sensory, Motor, and Mixed Nerves

Indication	Type of Study/Maximum Number of Studies				
	Needle EMG (95860-95864, 95867-95870, 95885-95887)	Nerve Conduction Studies (95907-95913)			Neuromuscular Junction Testing (Repetitive Stimulation)
		Motor NCS With and/or Without F wave*	Sensory NCS*	H-Reflex*	
Carpal Tunnel (Unilateral)	1	3	4	-	-
Carpal Tunnel (Bilateral)	2	4	6	-	-
Radiculopathy	2	3	2	2	-
Mononeuropathy	1	3	3	2	-
Polyneuropathy/Mononeuropathy Multiplex	3	4	4	2	-
Myopathy	2	2	2	-	2
Motor Neuronopathy (eg, ALS)	4	4	2	-	2
Plexopathy	2	4	6	2	-
Neuromuscular Junction	2	2	2	-	3
Tarsal Tunnel Syndrome (Unilateral)	1	4	4	-	-
Tarsal Tunnel Syndrome (Bilateral)	2	5	6	-	-
Weakness, Fatigue, Cramps, or Twitching (Focal)	2	3	4	-	2
Weakness, Fatigue, Cramps, or Twitching (General)	4	4	4	-	2
Pain, Numbness, or Tingling (Unilateral)	1	3	4	2	-
Pain, Numbness, or Tingling (Bilateral)	2	4	6	2	-

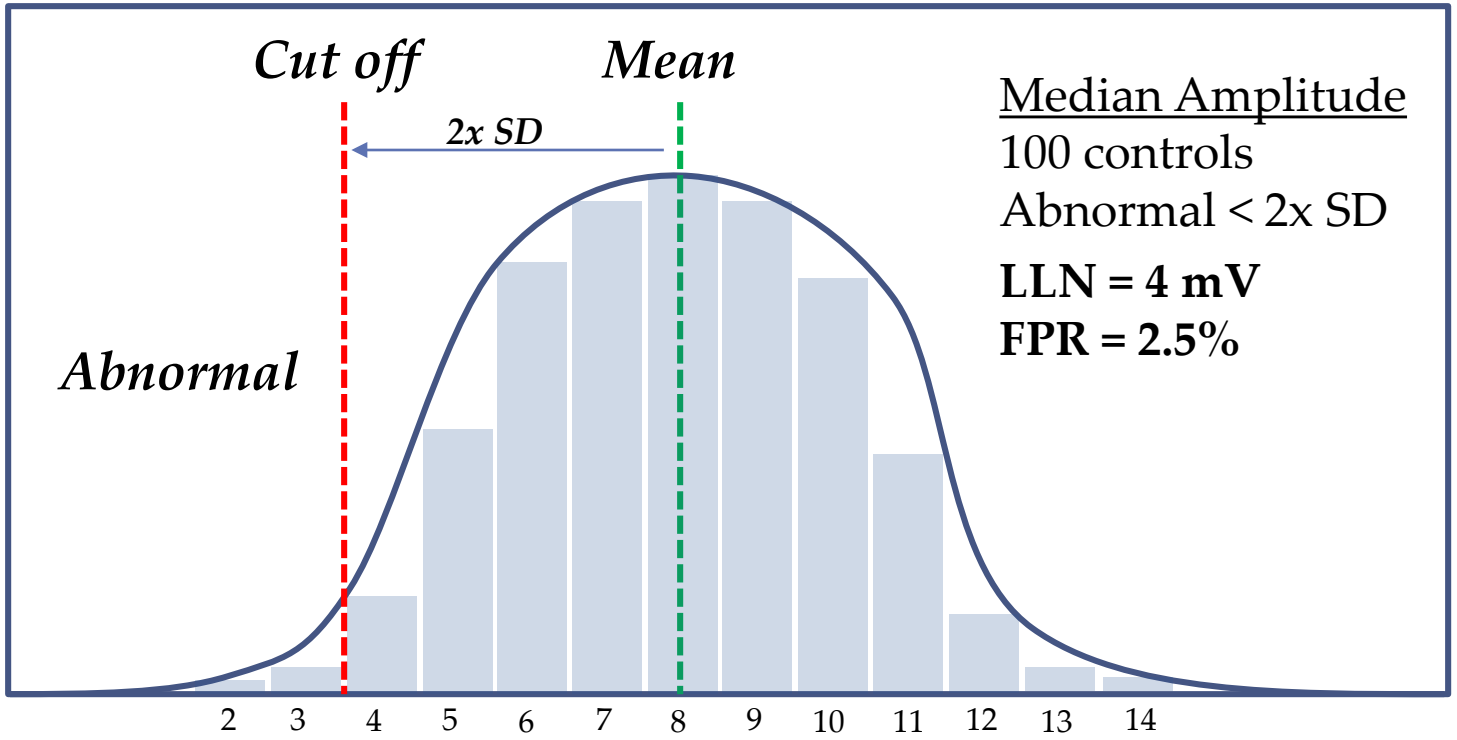
False Positives

- Abnormal (positive) test in an asymptomatic/unaffected person (control)
- Defined by reference ranges in a control population



False Positives

- Abnormal (positive) test in an asymptomatic/unaffected person (control)
- Defined by reference ranges in a control population



False Positives

- If only ONE test abnormality is required for diagnosis, false positive rates are additive.

Study	False Positive Rate
Median Motor	2.5%
Median Sensory	2.5%
Median/Ulnar Palmar Mixed N.	2.5%
Median/Ulnar D4 Comparison	2.5%
Median/Radial D1 Comparison	2.5%
Median/Ulnar Motor Comparison	2.5%
Total	**15%**

- If TWO test abnormalities are required for diagnosis, the overall false positive rate remains low.

False Positives

Recognize the possibility of error.

Always strive for at least two independent data points for diagnosis.

Upper Limb Symptoms

Common Patterns

1. **Intermittent hand paresthesias +/- weakness**
2. Radicular (shooting) pain +/- paresthesias +/- weakness
3. Weakness without paresthesias or pain
4. Everything else

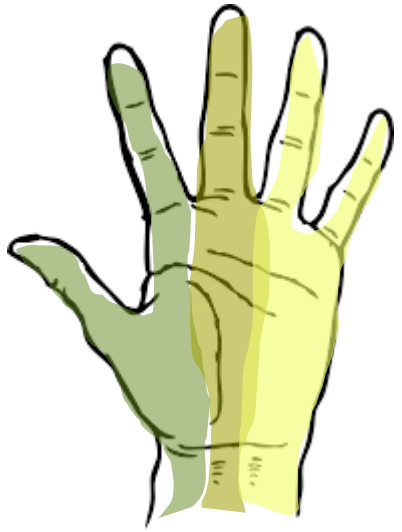
1. Intermittent hand paresthesias



Median



Ulnar



Overlapping or poorly localized

1. Intermittent hand paresthesias



Median

Differential Diagnosis:

- Median neuropathy at the wrist (CTS)
  - Demonstrate slowing across the carpal tunnel
  - Establish presence of conduction block (with great caution)
  - Assess degree of motor and/or sensory axon loss
- Cervical radiculopathy (C6-7)
  - Demonstrate intact sensory response
  - Exclude CTS

1. Intermittent hand paresthesias



Median

Clinical CTS Patterns

- Intermittent → Constant with exacerbations
- Nocturnal → Daytime triggered
- Paresthesias/pain → weakness → atrophy

Electrophysiologic Patterns

- Demyelination → Conduction Block → Axon Loss
- Sensory Fibers → Motor fibers

1. Intermittent hand paresthesias



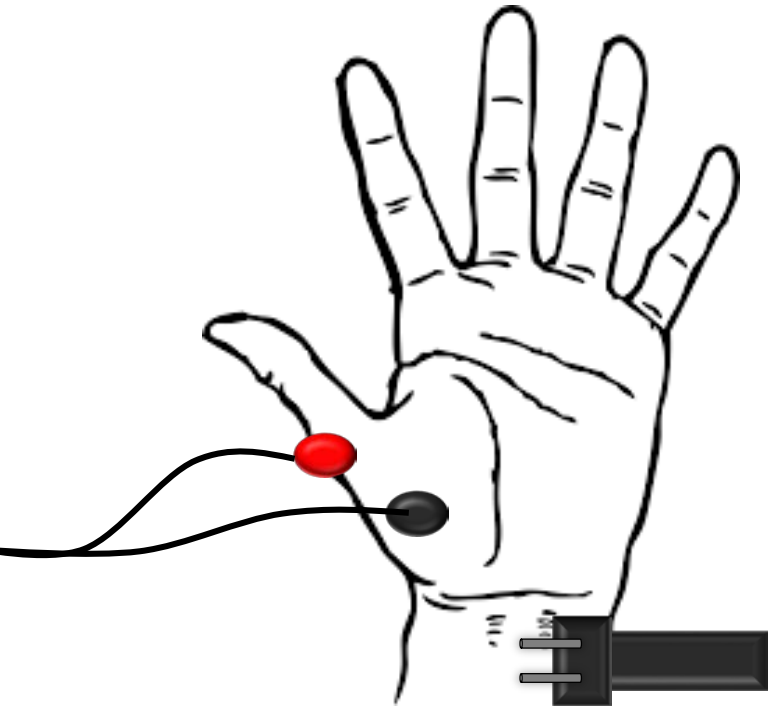
Initial Plan:

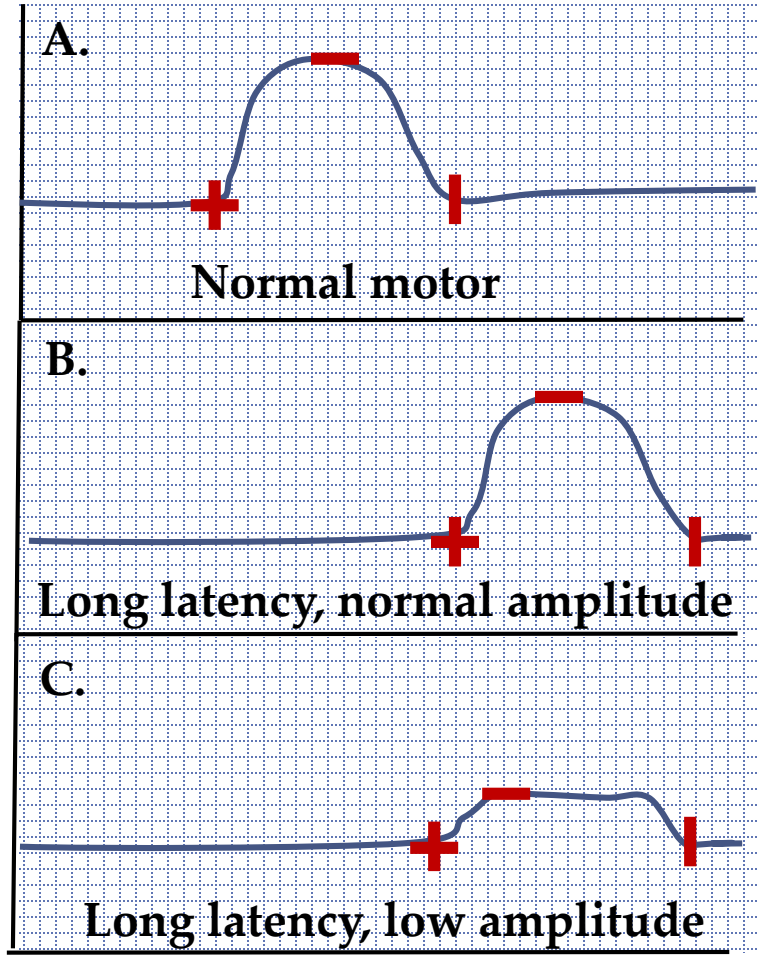
- Median motor
- Median sensory

1. Intermittent hand paresthesias



- Median-APB





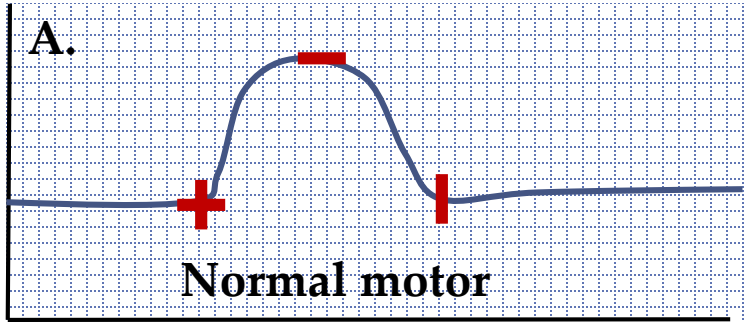
Check sensitive sensory studies to establish diagnosis

Check sensory study to determine physiology

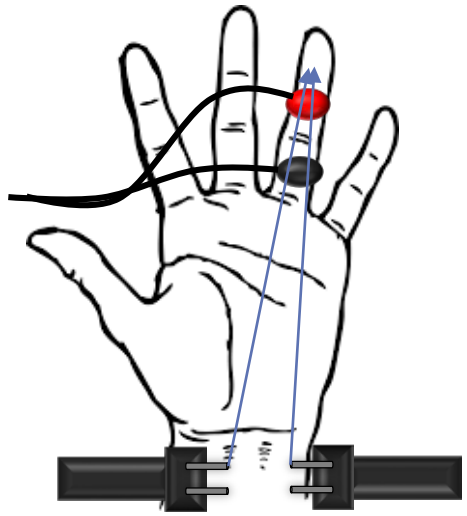
Check for conduction block, sensory axon loss, +/- motor comparison

1. Intermittent hand paresthesias

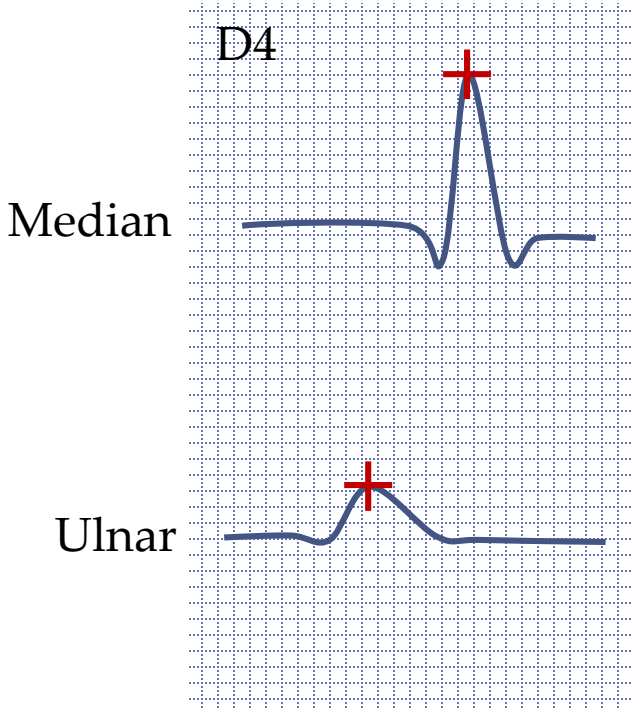




Median-Ulnar Digit IV Comparison Study (ring diff)



Ring diff



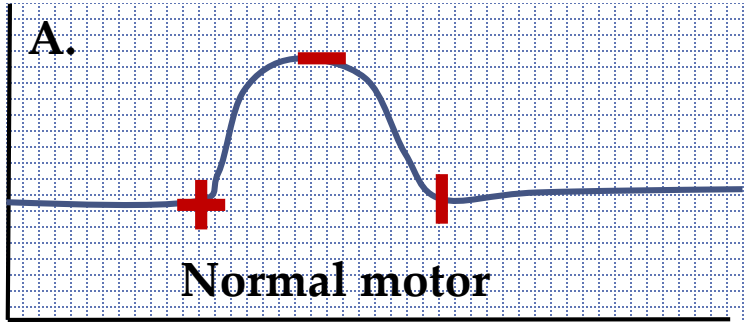
Median	4.0 ms
Ulnar	3.6 ms
Difference	**0.4 ms**

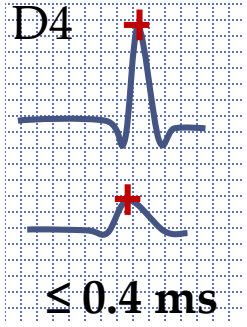
Ring diff ≤ 0.4 ms → CSI

Ring diff > 0.4 ms → Median sensory segmental study

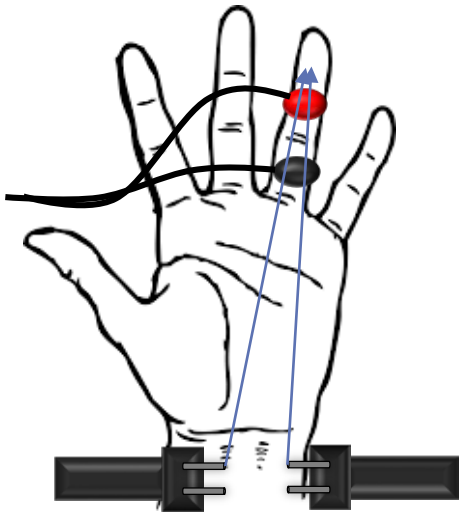
1. Intermittent hand paresthesias



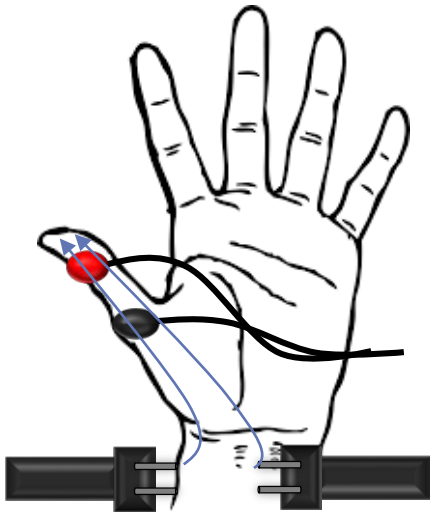




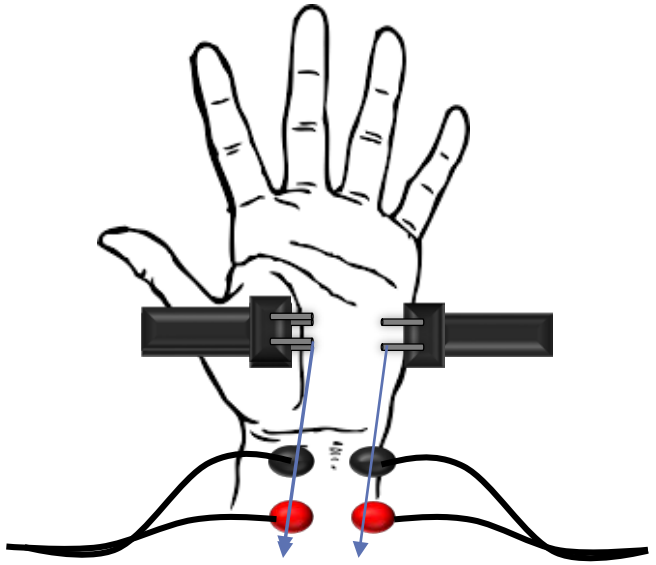
Combined Sensory Index (CSI)
= Ring diff + Thumb diff + Palm diff



Ring diff



Thumb diff



Palm diff

1. Intermittent hand paresthesias



Median	4.0 ms
Ulnar	3.6 ms
Difference	**0.4 ms**

+

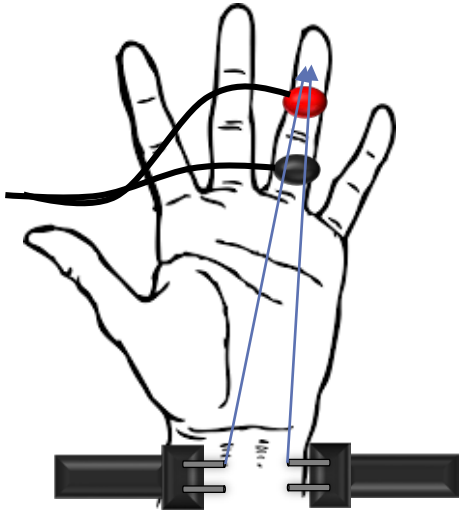
Median	3.6 ms
Radial	3.2 ms
Difference	**0.4 ms**

+

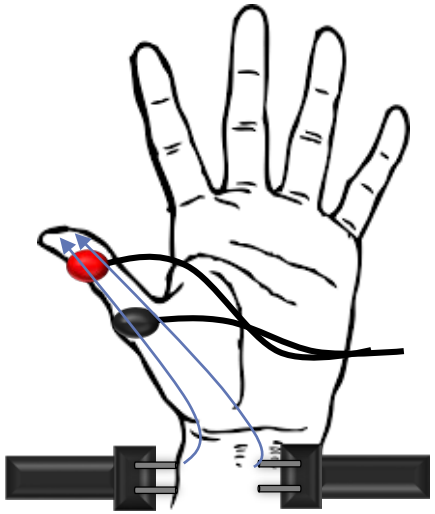
Median	2.5 ms
Ulnar	2.0 ms
Difference	**0.5 ms**

=

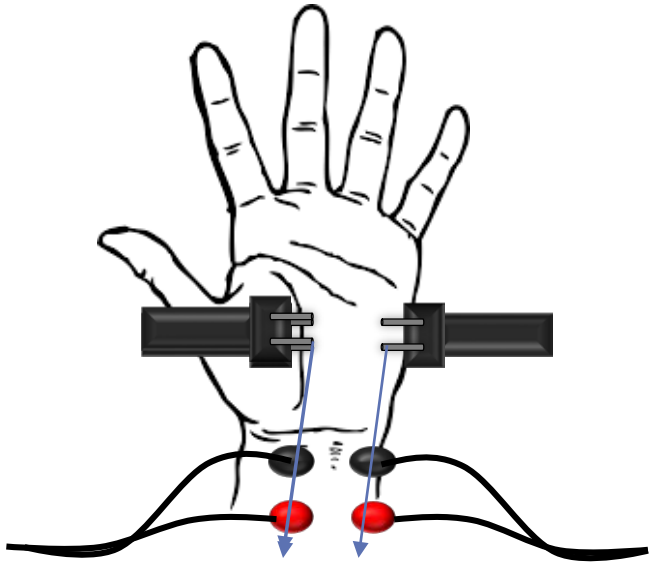
Normal	*<1.0 ms*
CSI	**1.3 ms**



Ring diff



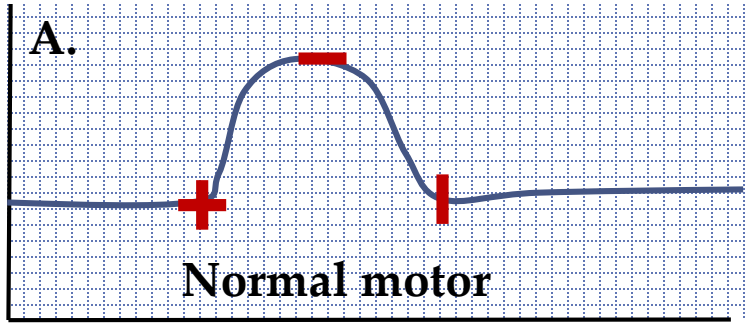
Thumb diff



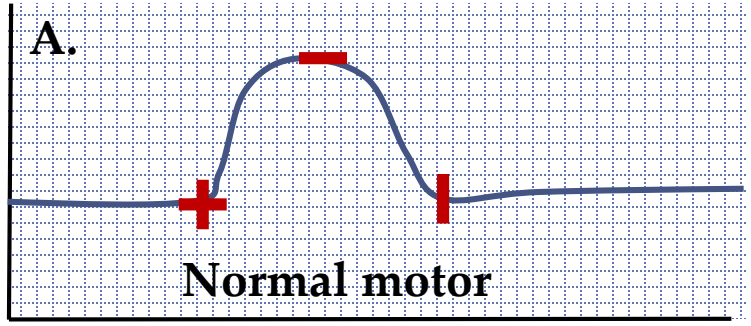
Palm diff

1. Intermittent hand paresthesias





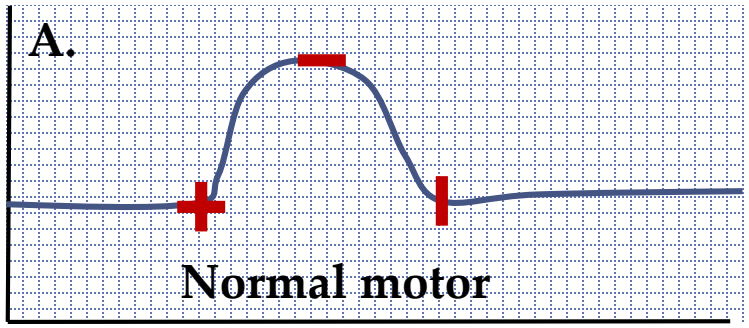
\+ | CSI | <1.0 ms → **Median neuropathy at the wrist excluded**

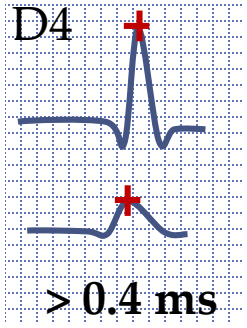


\+ | CSI | ≥1.0 ms → **Median neuropathy at the wrist confirmed**

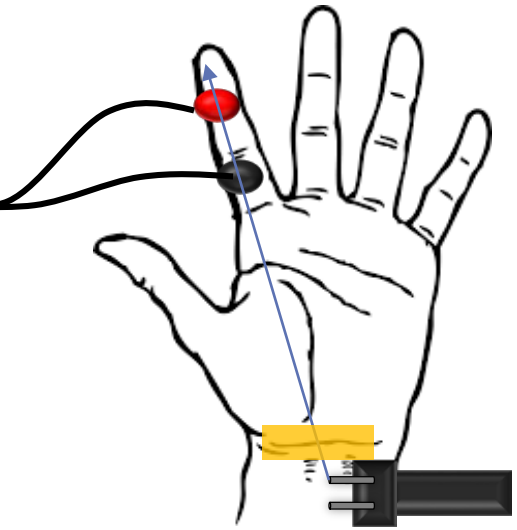
1. Intermittent hand paresthesias

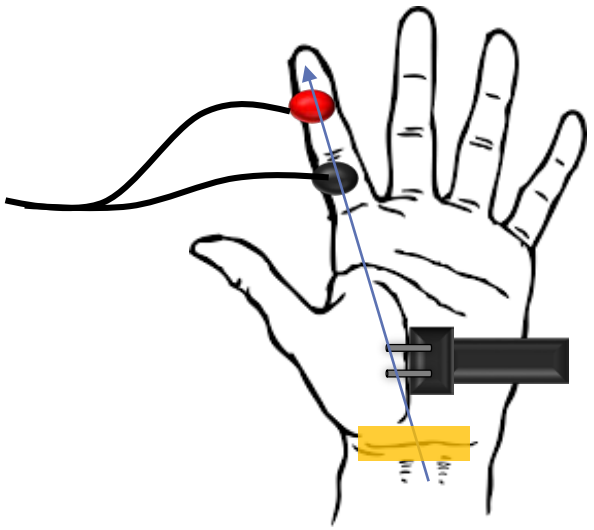


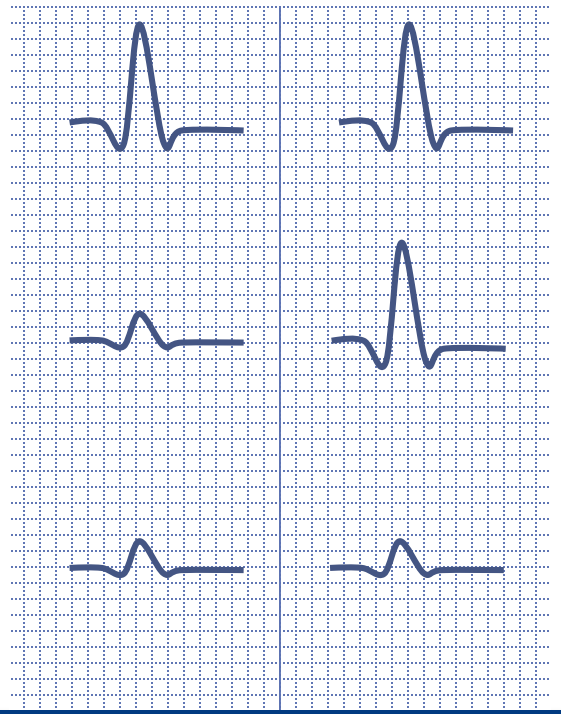




Median D2/3 segmental sensory study
Averaging recommended



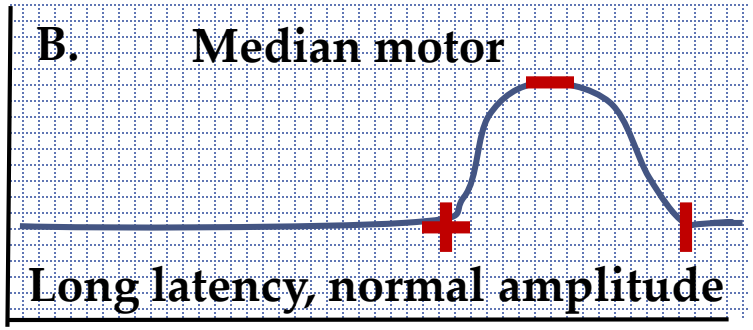




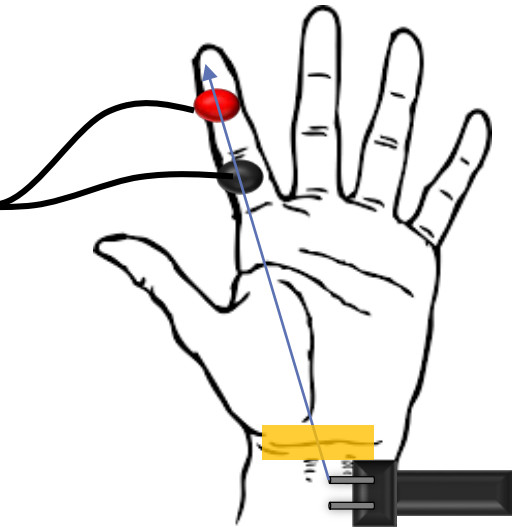
CV	
32 m/s	**Demyelination only**
32 m/s	**Demyelination + Conduction block**
32 m/s	**Demyelination + Axon loss**

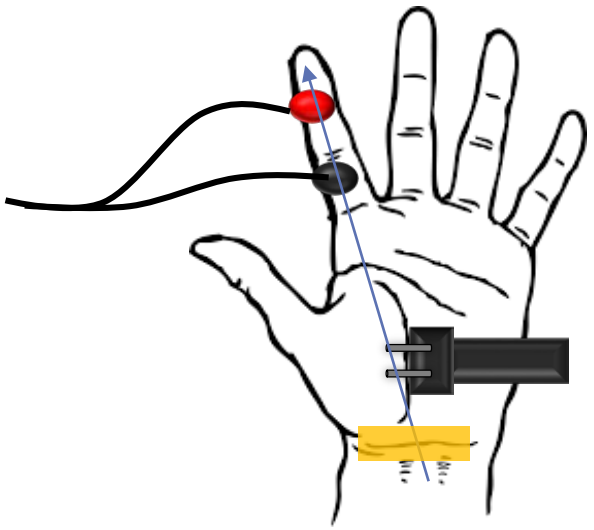
1. Intermittent hand paresthesias

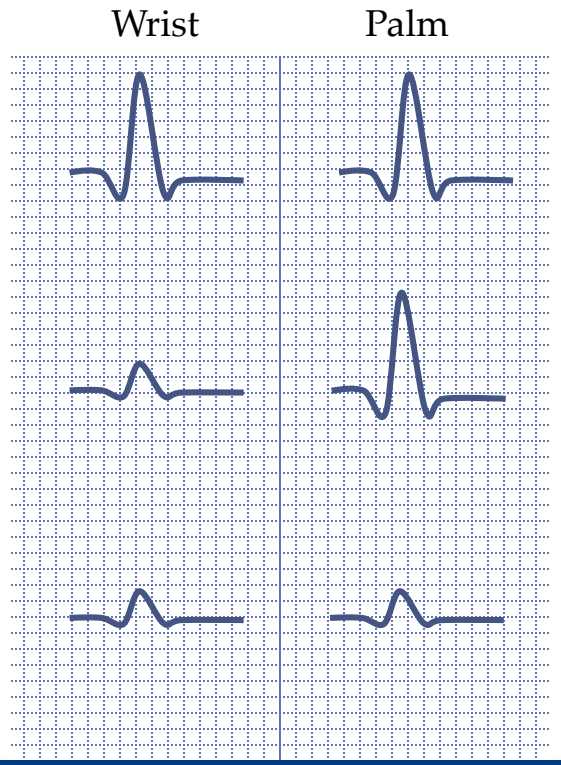




Median D2/3 segmental sensory study







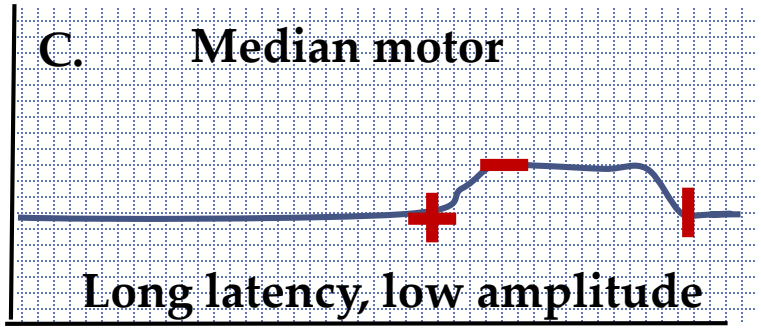
Demyelination only

Demyelination + Conduction block

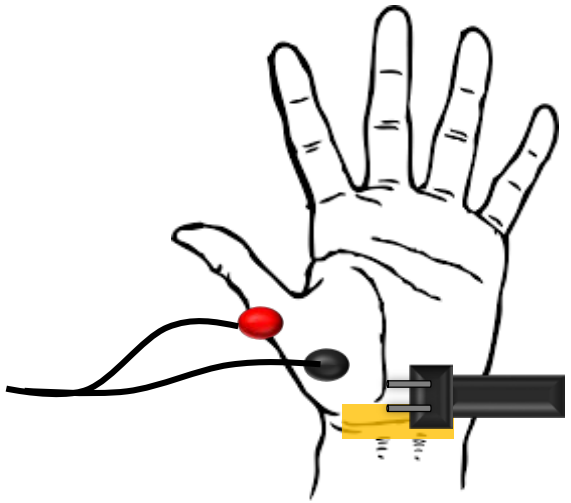
Demyelination + Axon loss

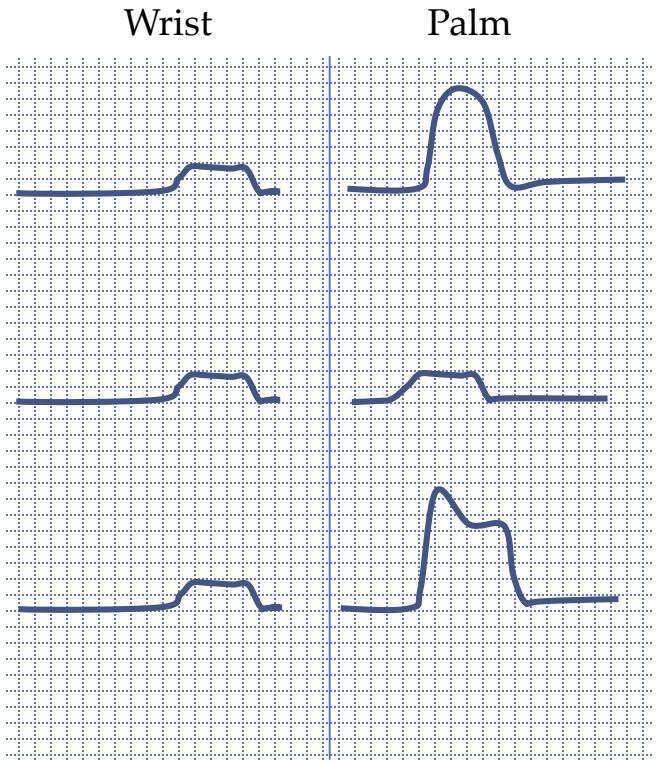
1. Intermittent hand paresthesias





Stimulate palm. **Use great caution** – start with very low current, use very small increments, take note of any change in waveform morphology.





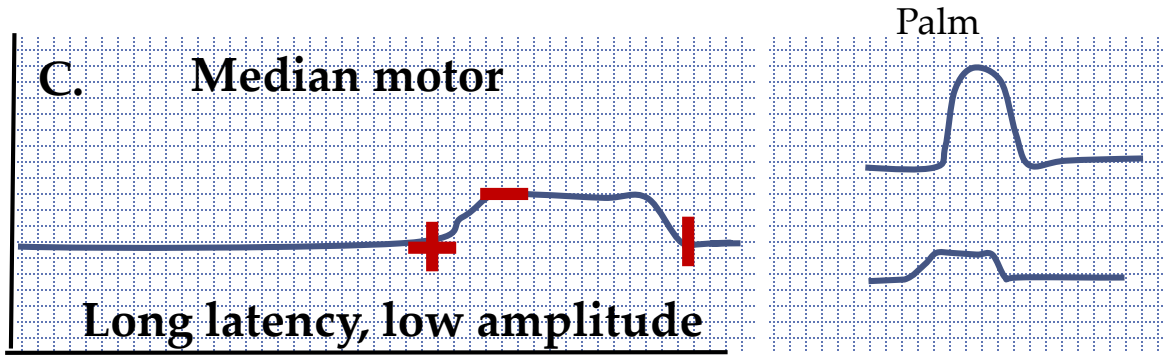
Conduction block
(good prognosis)

Axon loss
(guarded prognosis)

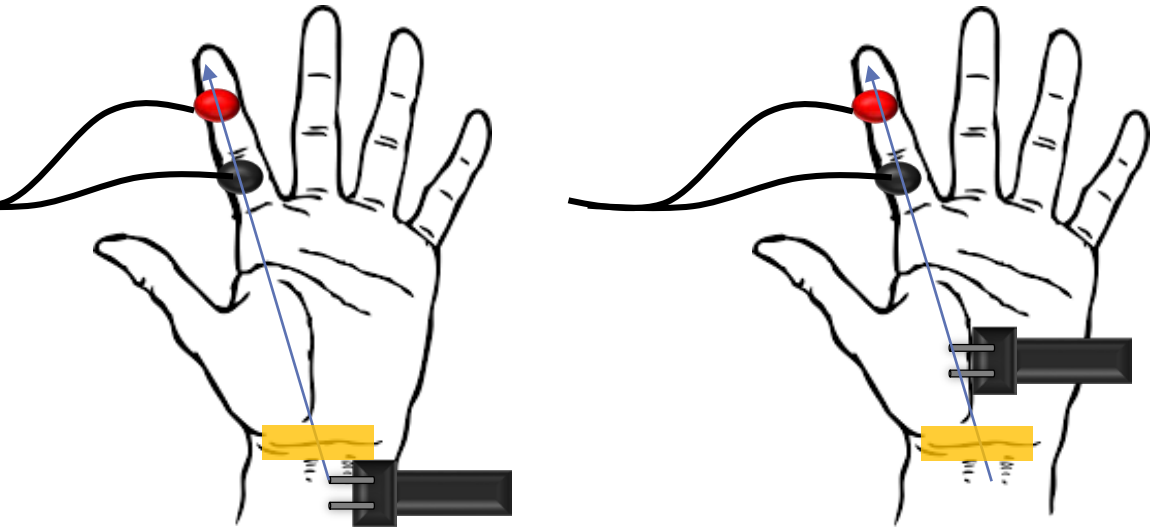
Co-stimulation of ulnar nerve

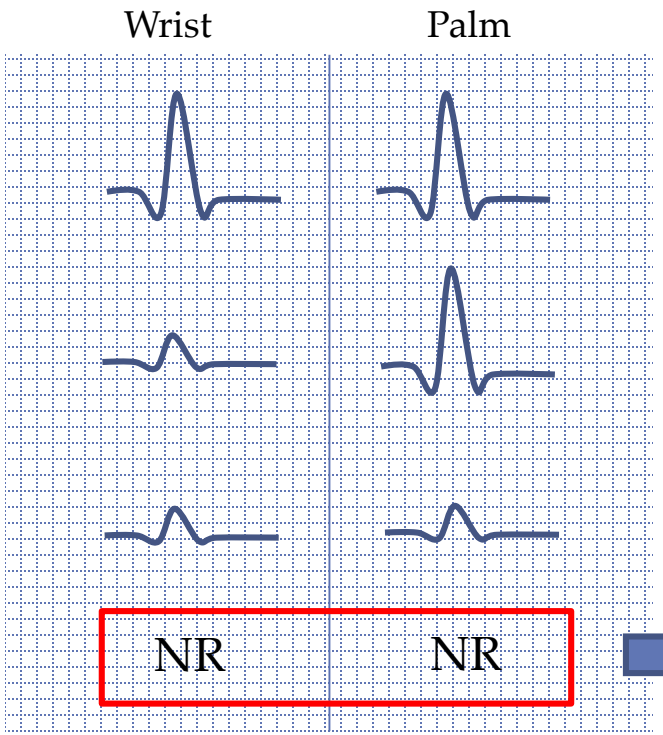
1. Intermittent hand paresthesias





Median D2/3 segmental sensory study to determine presence of sensory axon loss

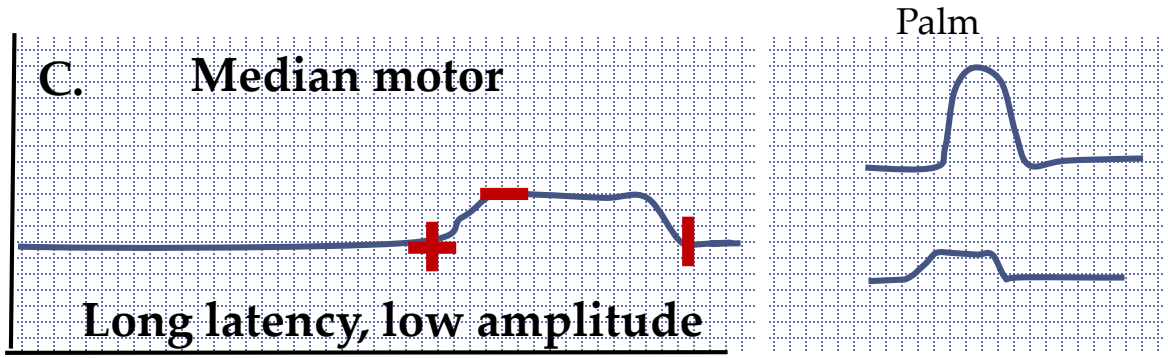


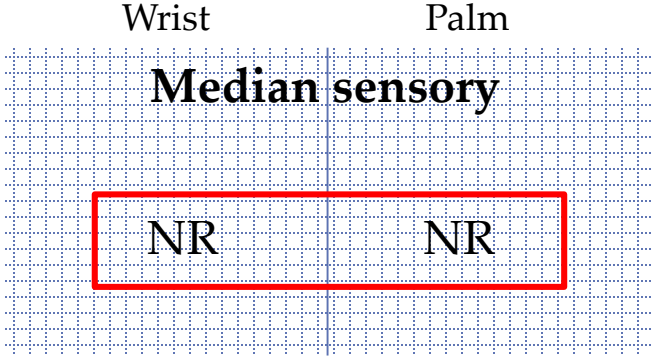


Lumbrical-Interosseous Comparison

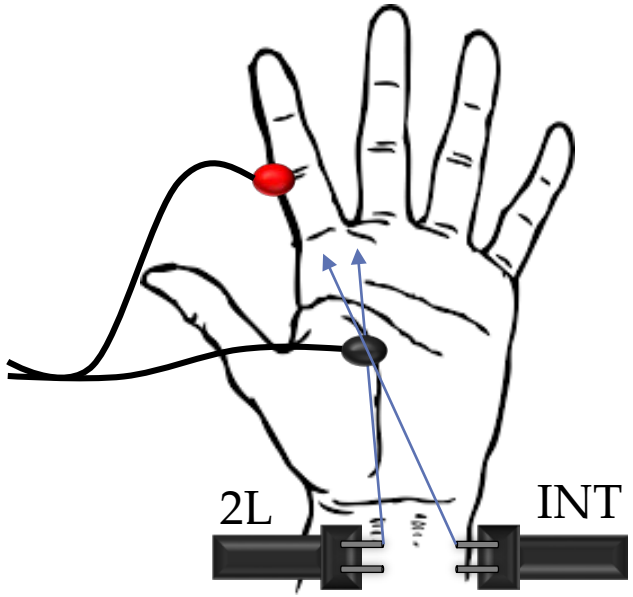
1. Intermittent hand paresthesias

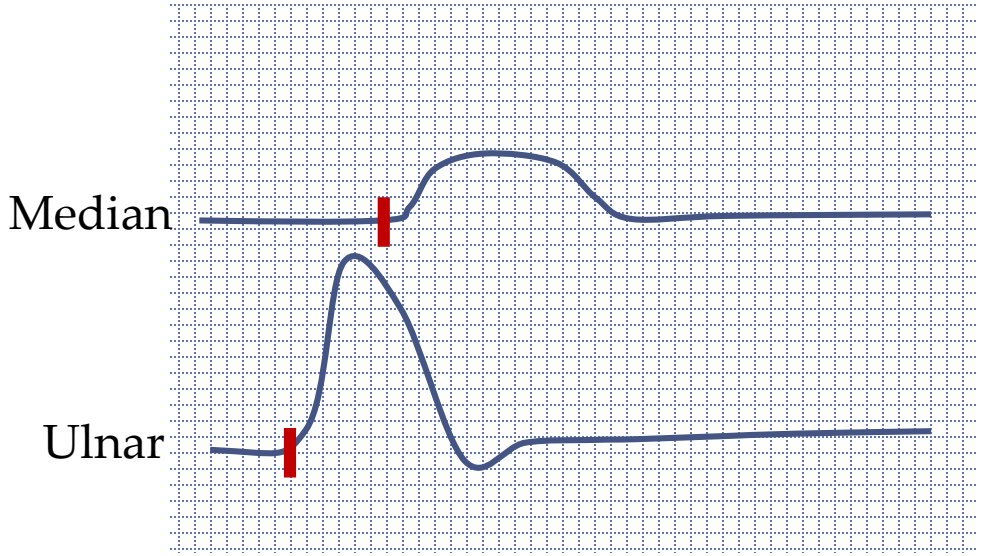






Still need one more study showing slowing across wrist.



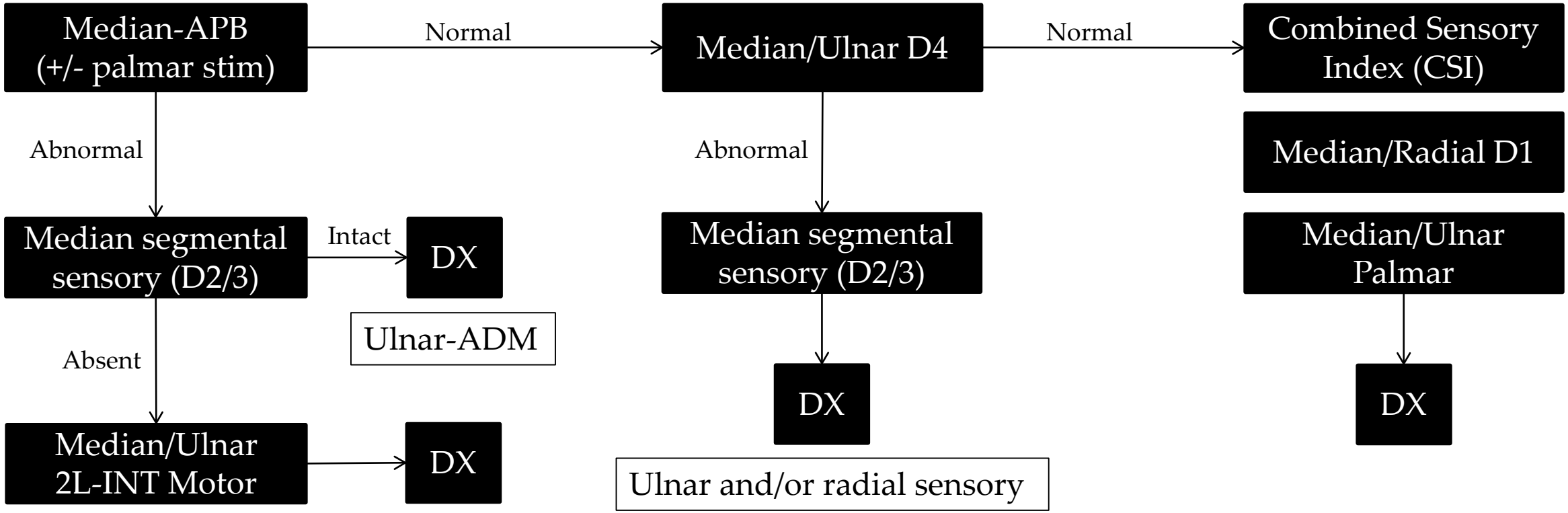


Onset Lat.	
Median	3.7 ms
Ulnar	1.8 ms
Difference	**1.9 ms**

Road Map



Start with most symptomatic hand or dominant hand if equal ➡ Contralateral hand if abnormal



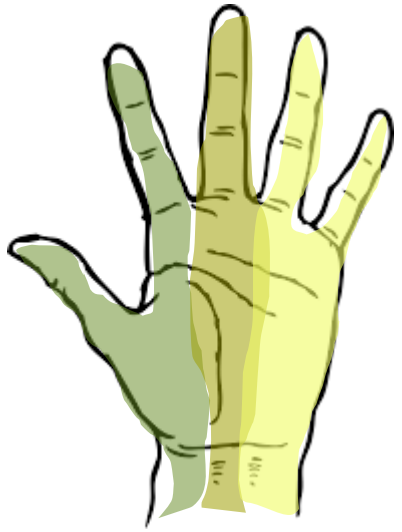
1. Intermittent hand paresthesias



Median

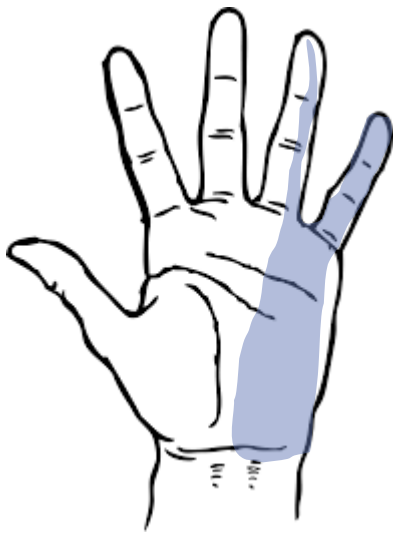


Ulnar



Overlapping or poorly localized

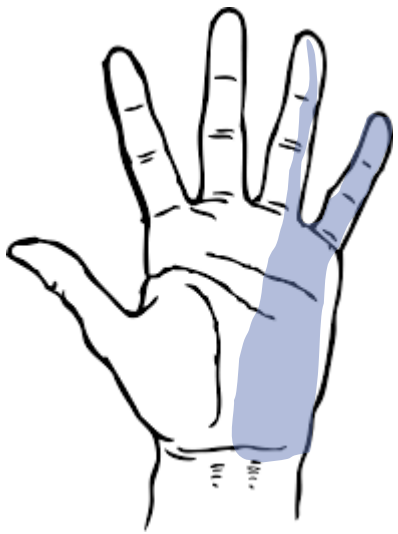
1. Intermittent hand paresthesias



Differential Diagnosis:

- Ulnar neuropathy (elbow or wrist)
  - Demonstrate focal slowing or conduction block
  - Precisely localize region of abnormality
  - Assess degree of motor and/or sensory axon loss
- Cervical radiculopathy (C8)
  - Demonstrate intact sensory response
  - Exclude ulnar neuropathy

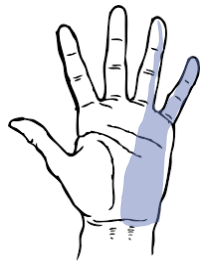
1. Intermittent hand paresthesias



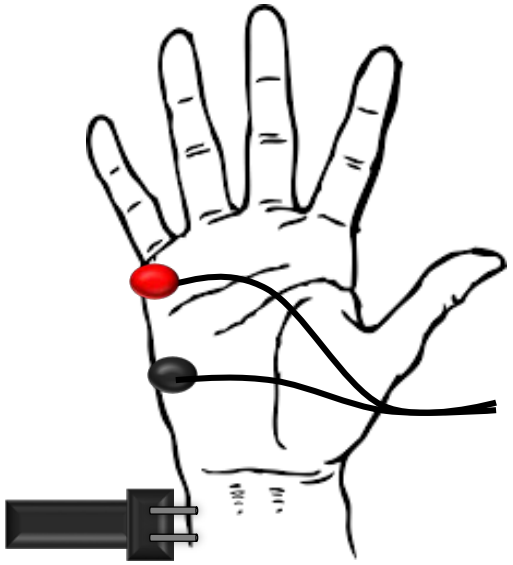
Initial Plan:

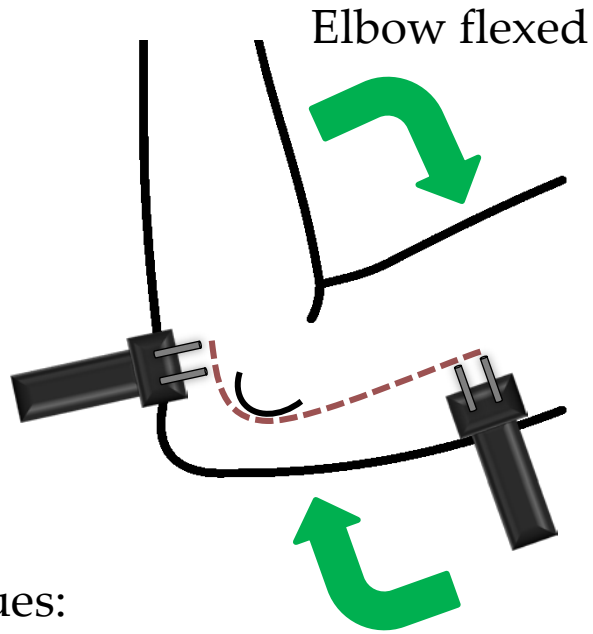
- Ulnar Motor (ADM)
- Ulnar Sensory (D5)

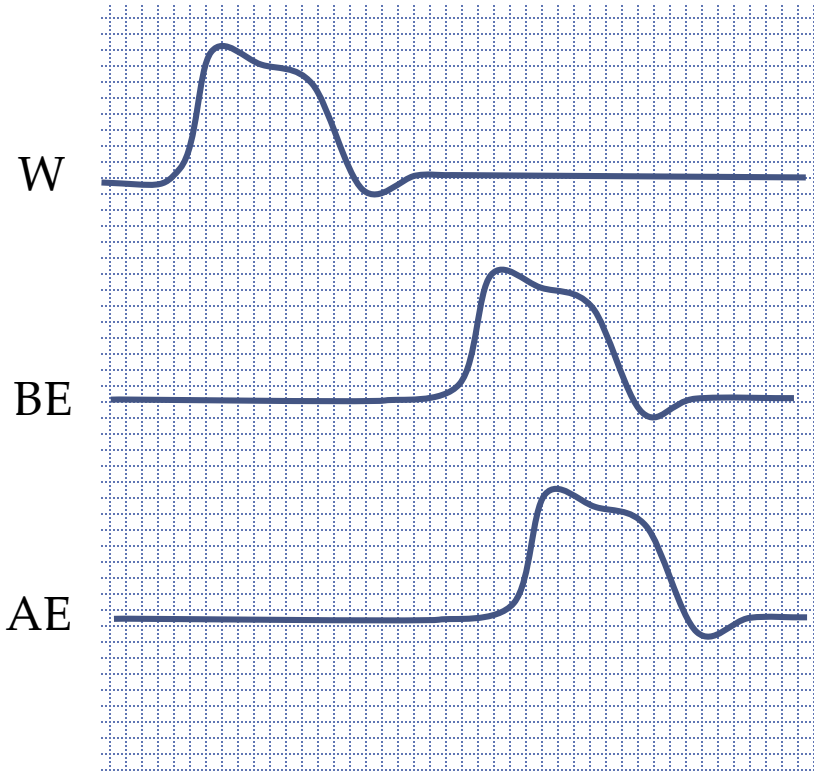
1. Intermittent hand paresthesias



- Ulnar-ADM



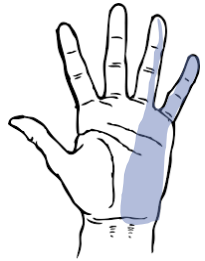




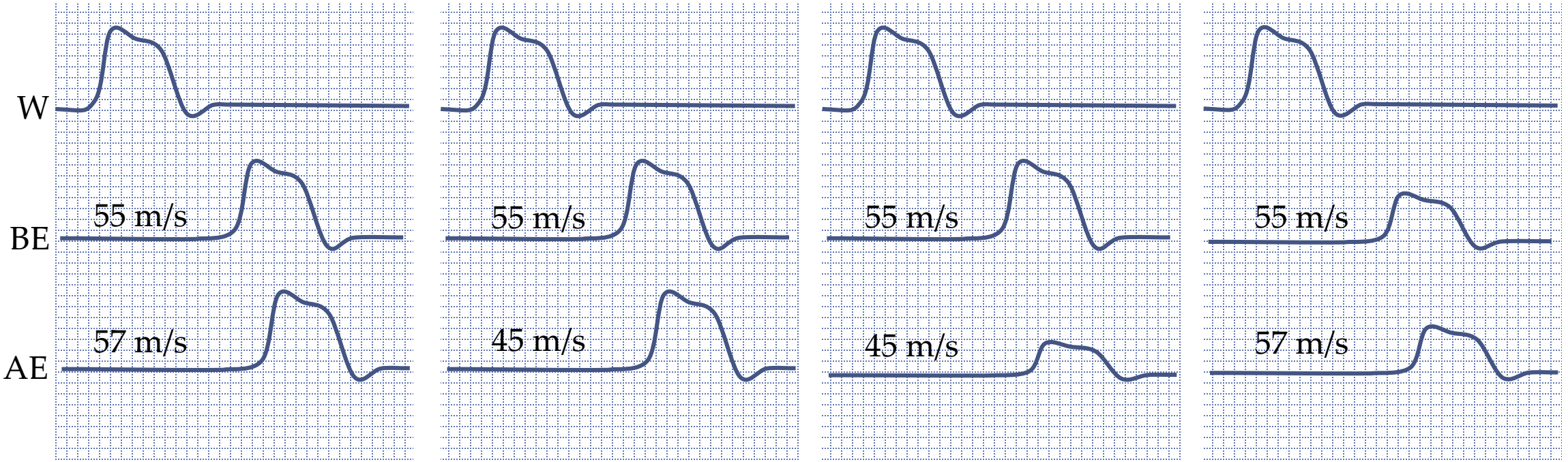
AANEM Reference Values:

1. CV < 43 m/s across elbow
2. CV drop of > 15 m/s

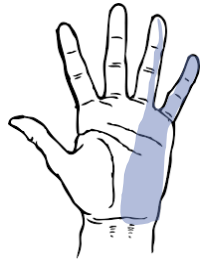
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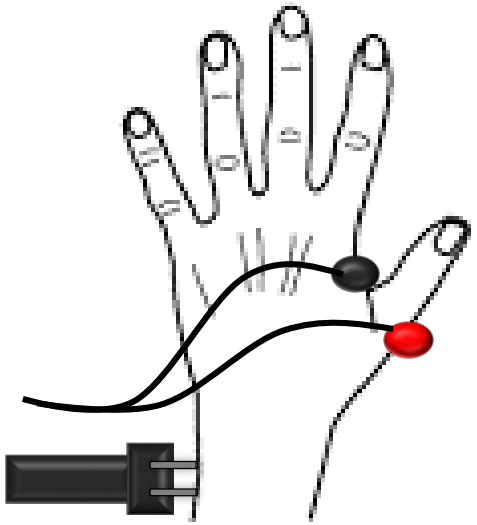
- Ulnar-ADM

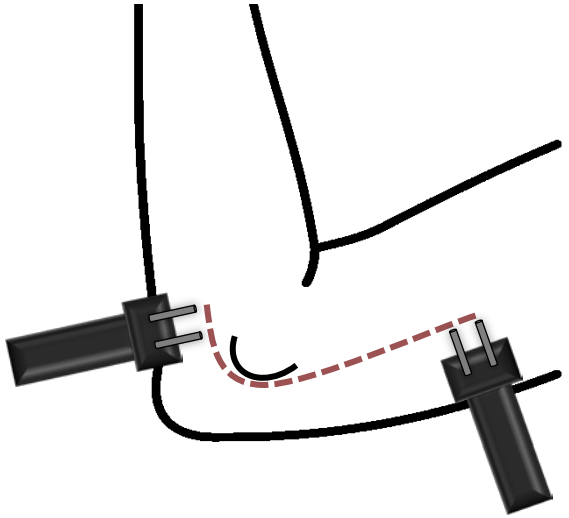


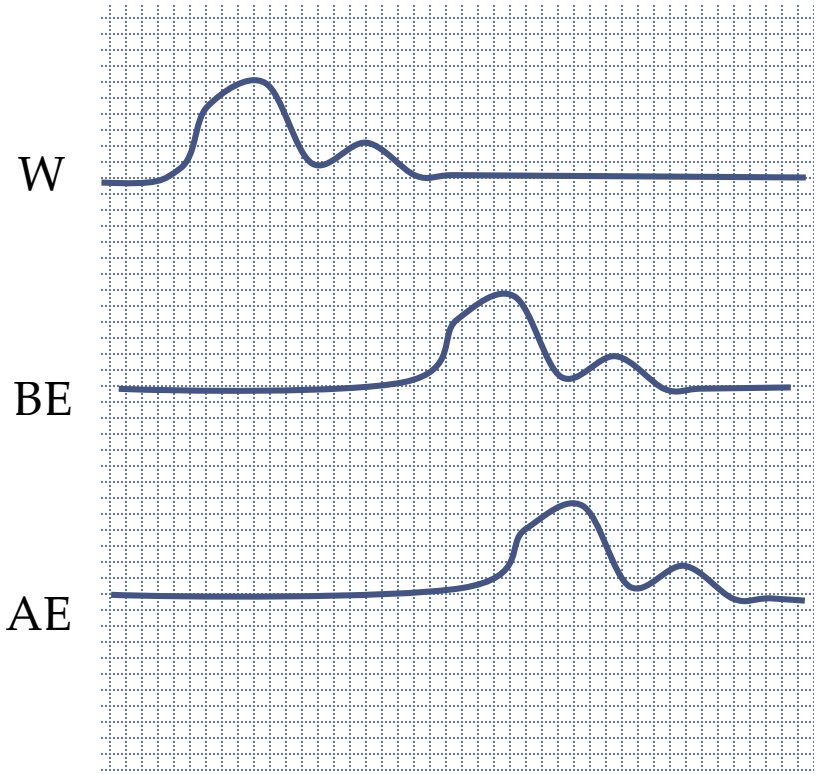
1. Intermittent hand paresthesias



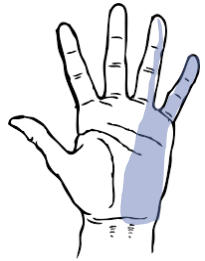
- Ulnar-FDI



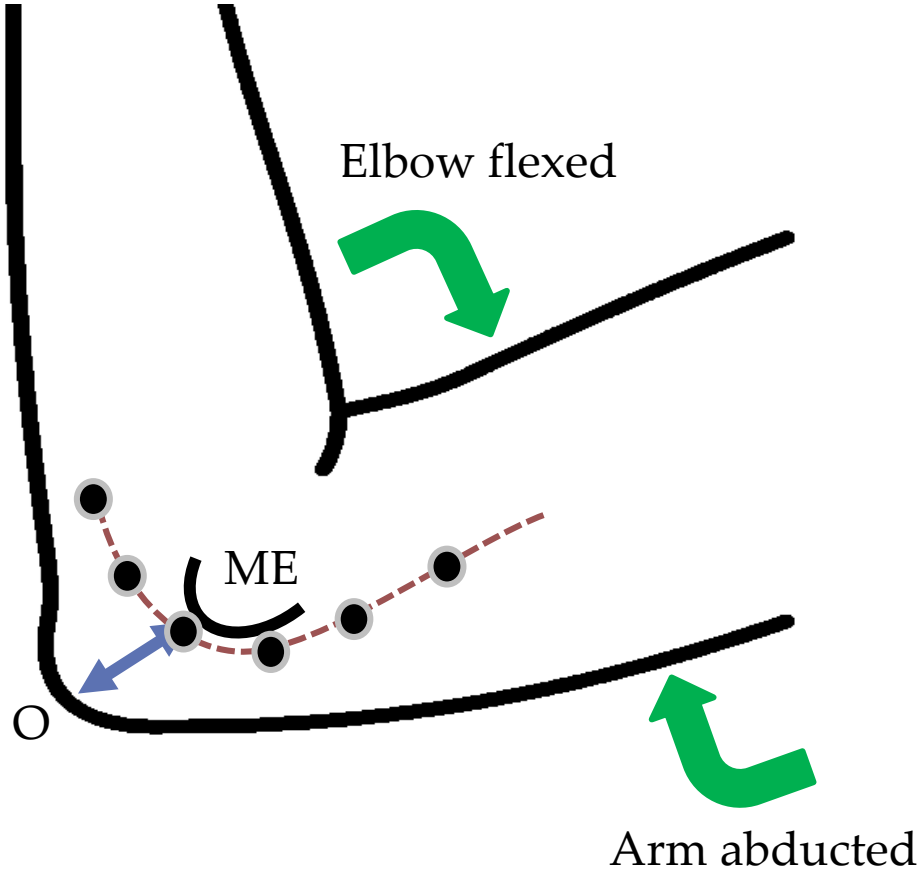


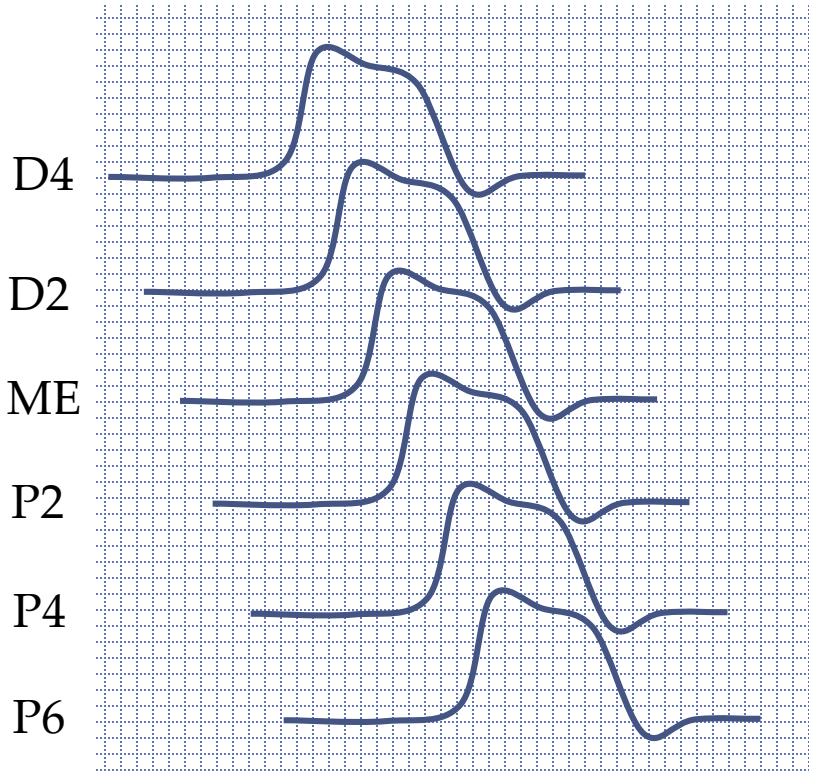


1. Intermittent hand paresthesias

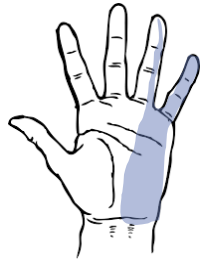


- Inching Studies

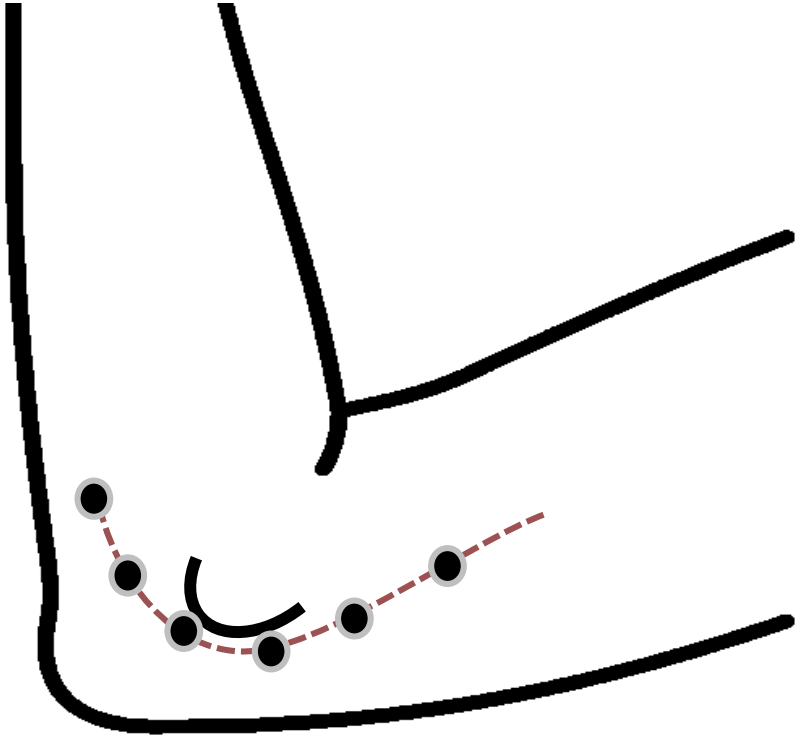


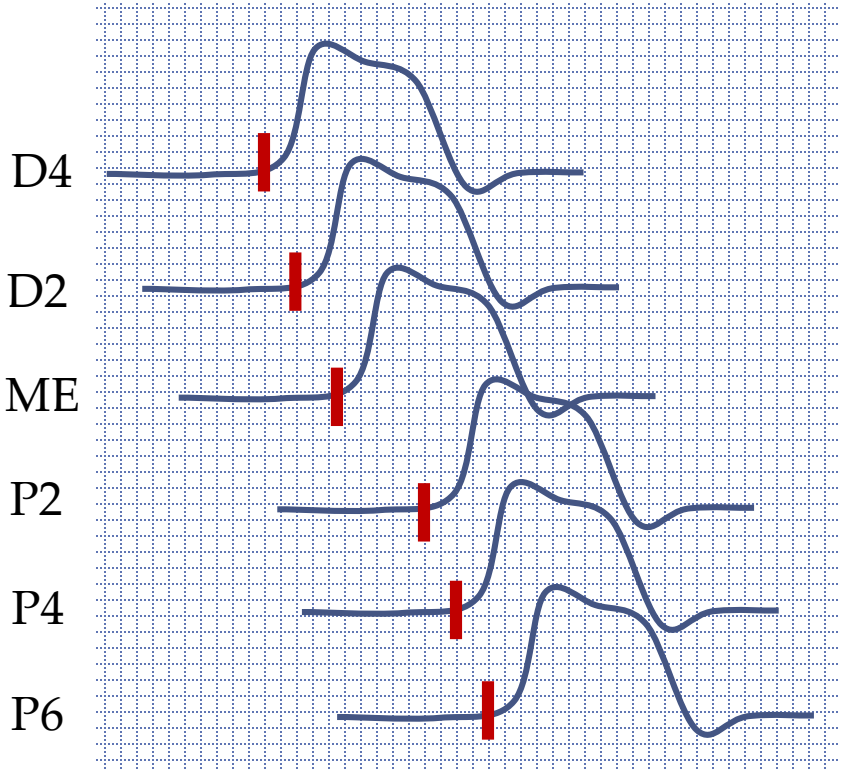


1. Intermittent hand paresthesias



- Inching Studies

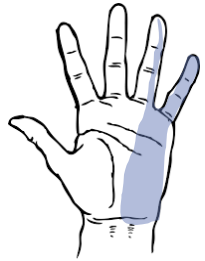




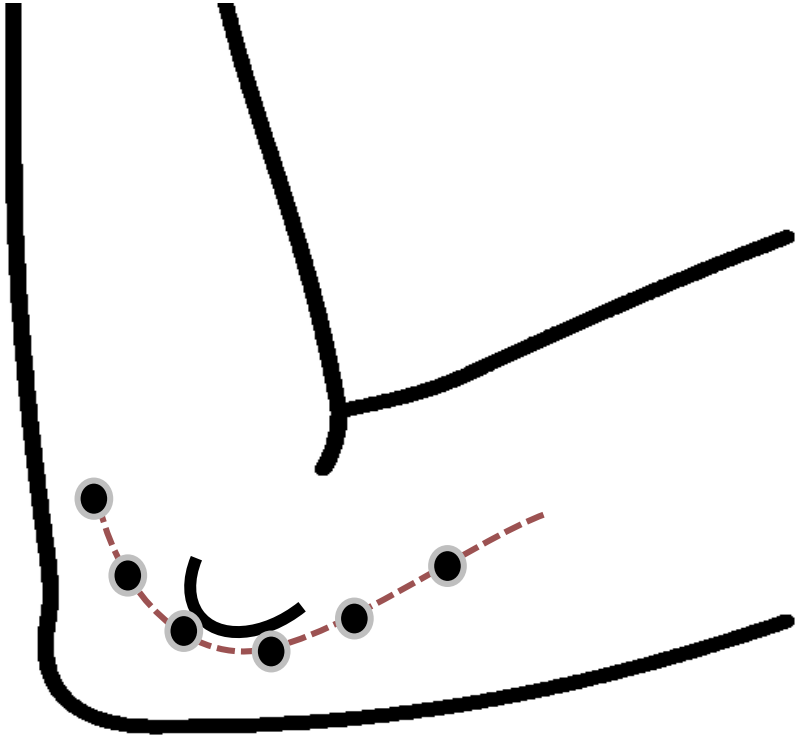
Latency Diff	
D4-D2	0.3 ms
D2-ME	0.4 ms
ME-P2	**1.2 ms**
P2-P4	0.5 ms
P4-P6	0.3 ms

N < 0.7 ms

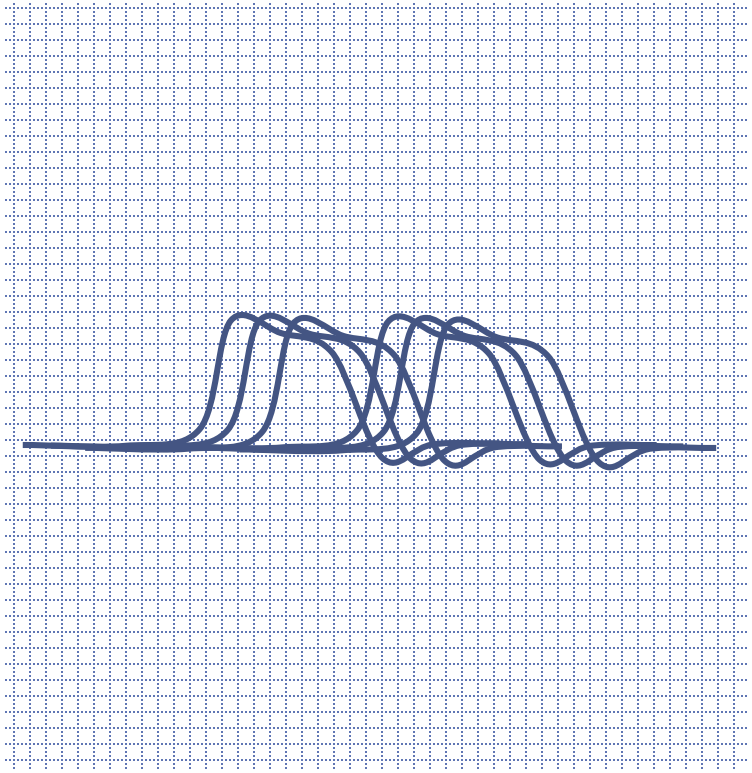
1. Intermittent hand paresthesias



- Inching Studies

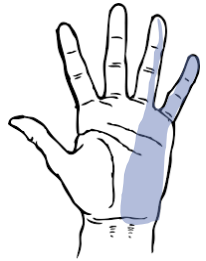


ME

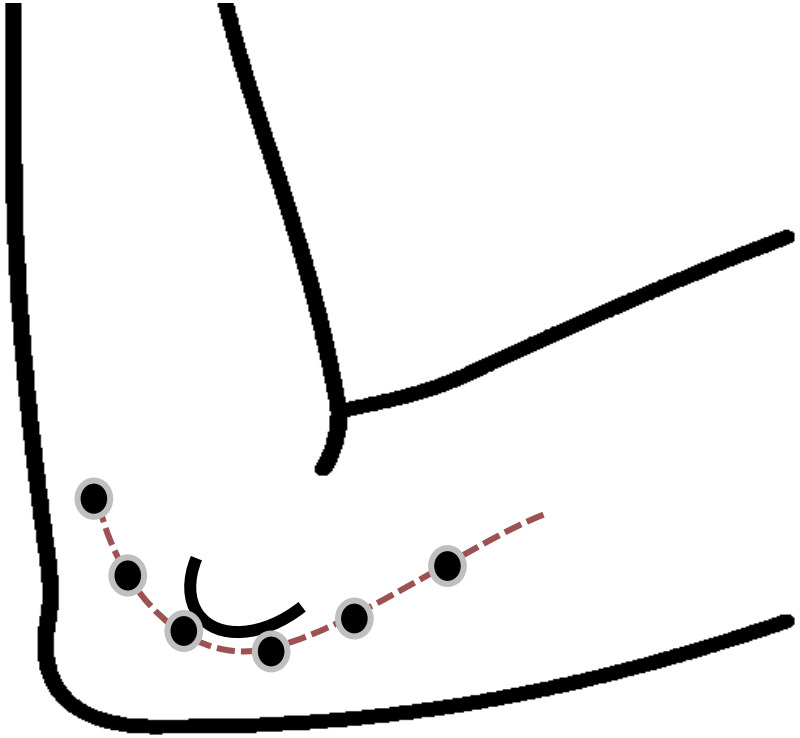


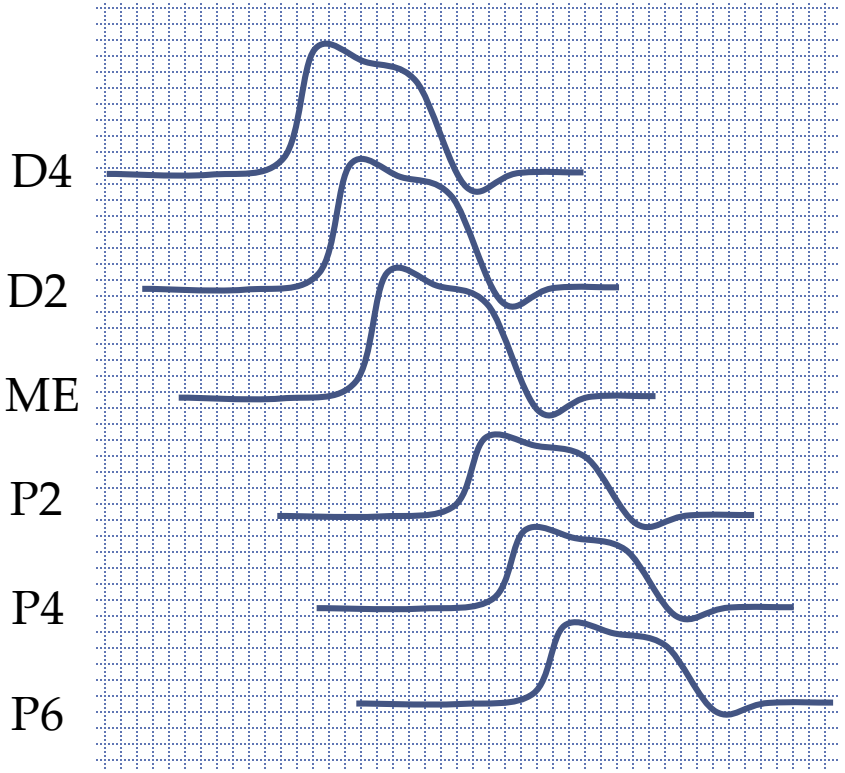
Latency Diff	
D4-D2	0.3 ms
D2-ME	0.4 ms
ME-P2	**1.2 ms**
P2-P4	0.5 ms
P4-P6	0.3 ms

1. Intermittent hand paresthesias



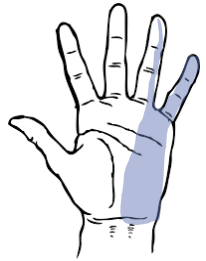
- Inching Studies



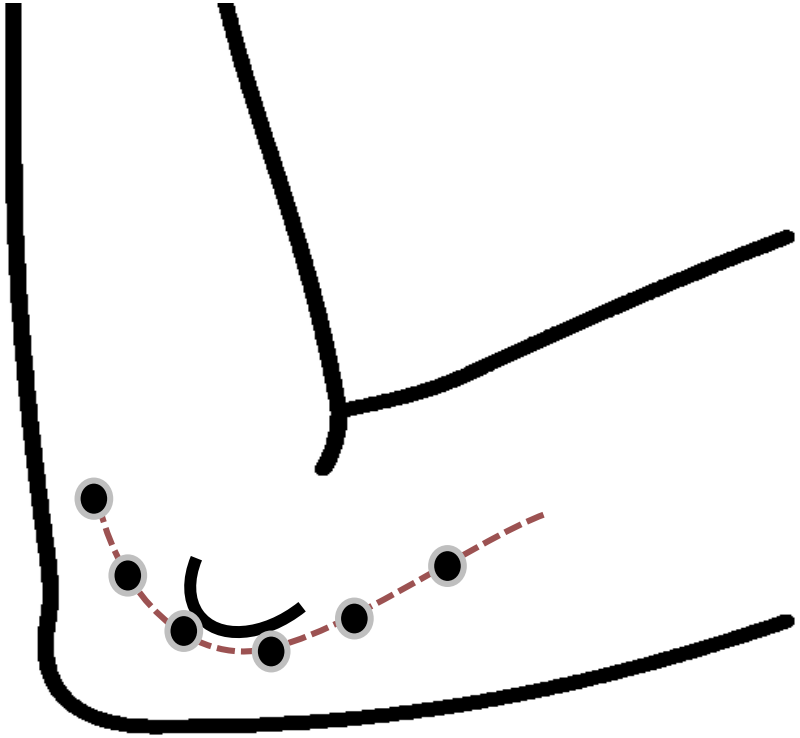


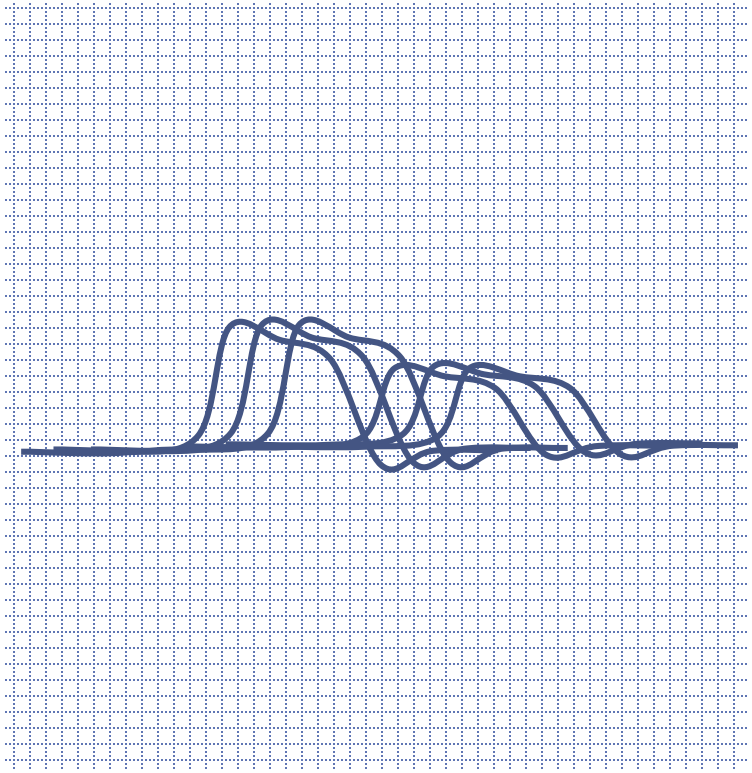
Amplitude	
D4	8.3 mV
D2	8.4 mV
ME	8.4 mV
P2	**5.2 mV**
P4	5.1 mV
P6	5.1 mV

1. Intermittent hand paresthesias



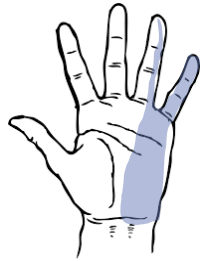
- Inching Studies



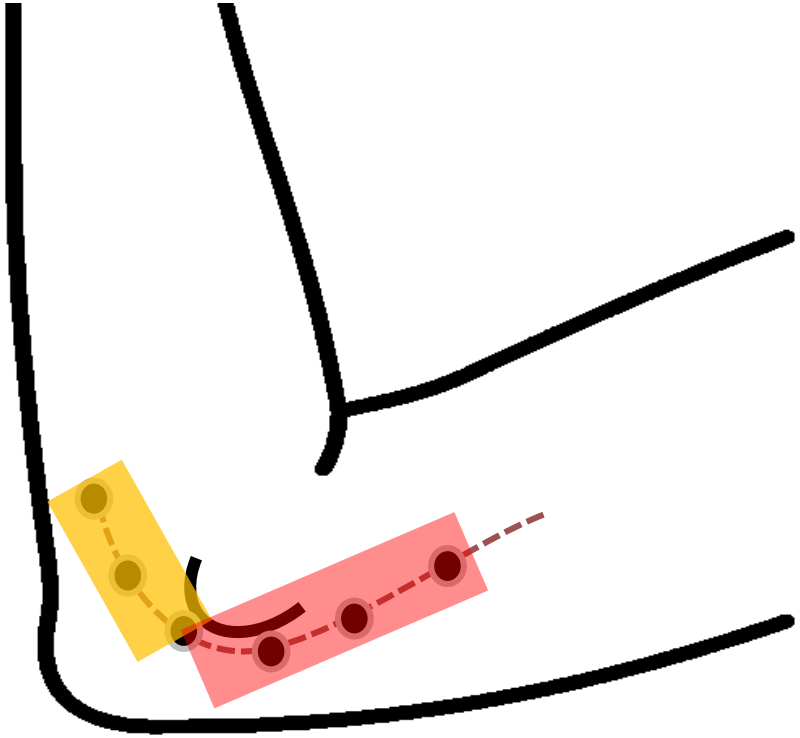


Amplitude	
D4	8.3 mV
D2	8.4 mV
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1. Intermittent hand paresthesias



- Inching Studies



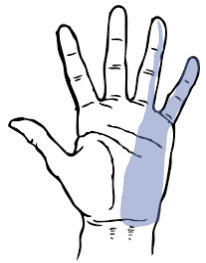
Why do them?

- Detect focal slowing that was otherwise diluted over a longer distance
- Precise localization:
  - Cubital Tunnel Entrapment
  - Retrocondylar Groove Compression

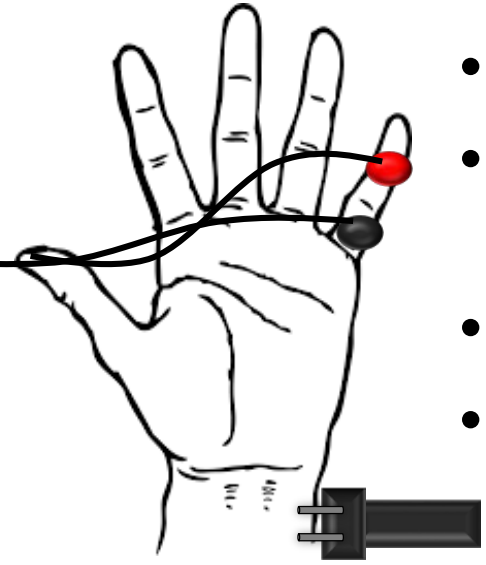
Technical points:

- Start each point with submaximal stimulations to localize nerve
- Increase current by small increments
- Use latency difference, not CV

1. Intermittent hand paresthesias

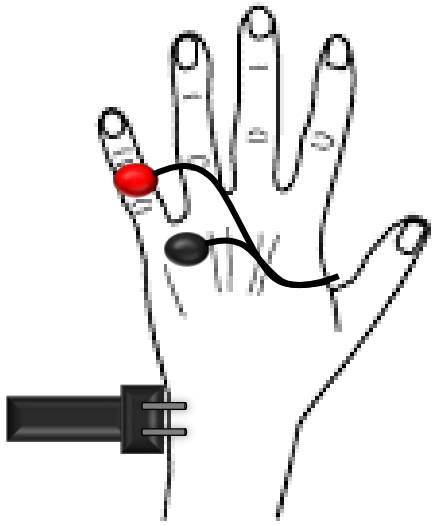


Ulnar Sensory (D5)



- Sensory axon loss
- Contralateral comparison
- Slowing across elbow (with averaging)
- Inching (with caution)
- Spared in deep motor branch lesion in palm
- **Med. Cut. Br. Forearm (MAC) if low/absent**

Dorsal Cutaneous Br.



- Helpful if low/absent
  - Localizes to elbow
- Contralateral comparison
- Not helpful if normal
  - Always spared in lesions at wrist
  - May be spared in lesions at elbow

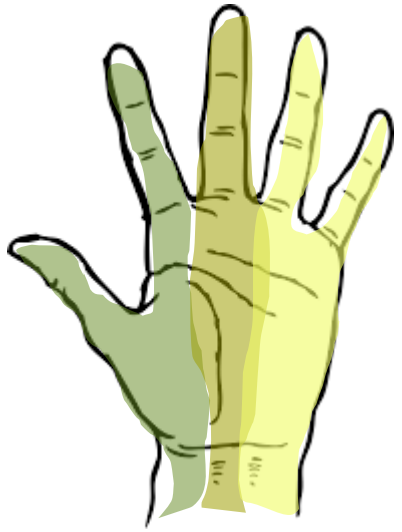
1. Intermittent hand paresthesias



Median



Ulnar



Overlapping or poorly localized

1. Intermittent hand paresthesias



Differential Diagnosis:

- Peripheral entrapment
  - Median > Ulnar
  - CTS symptoms may involve entire hand
- Cervical radiculopathy
  - Paresthesias often poorly localized
  - C6 or C7 > C8

1. Intermittent hand paresthesias



Initial Plan:

- Median Motor
- Ulnar Motor
- Median Sensory
- Ulnar Sensory
- Radial Sensory

Upper Limb Symptoms

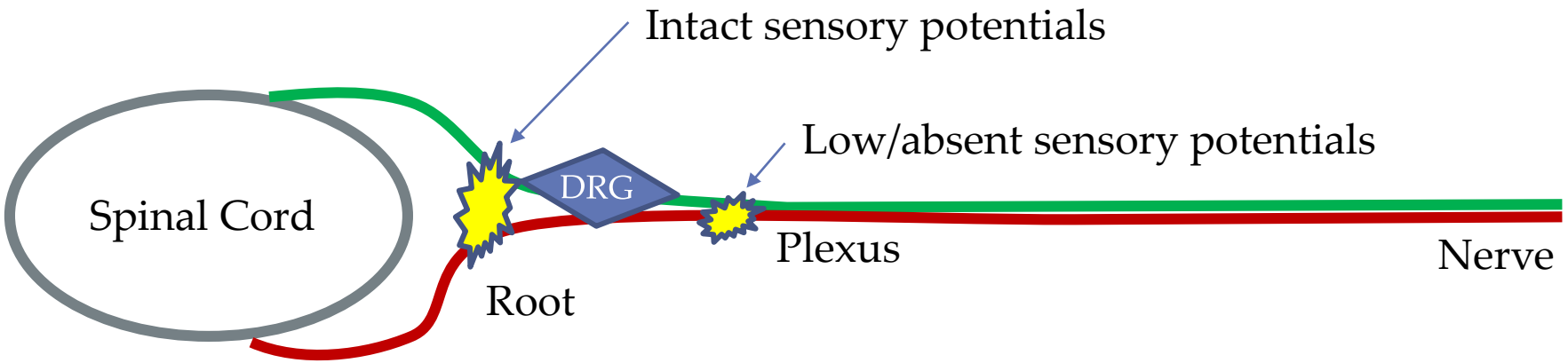
Common Patterns

1. Intermittent hand paresthesias +/- weakness
2. **Radicular (shooting) pain +/- paresthesias +/- weakness**
3. Weakness without paresthesias or pain
4. Everything else

2. Radicular Pain

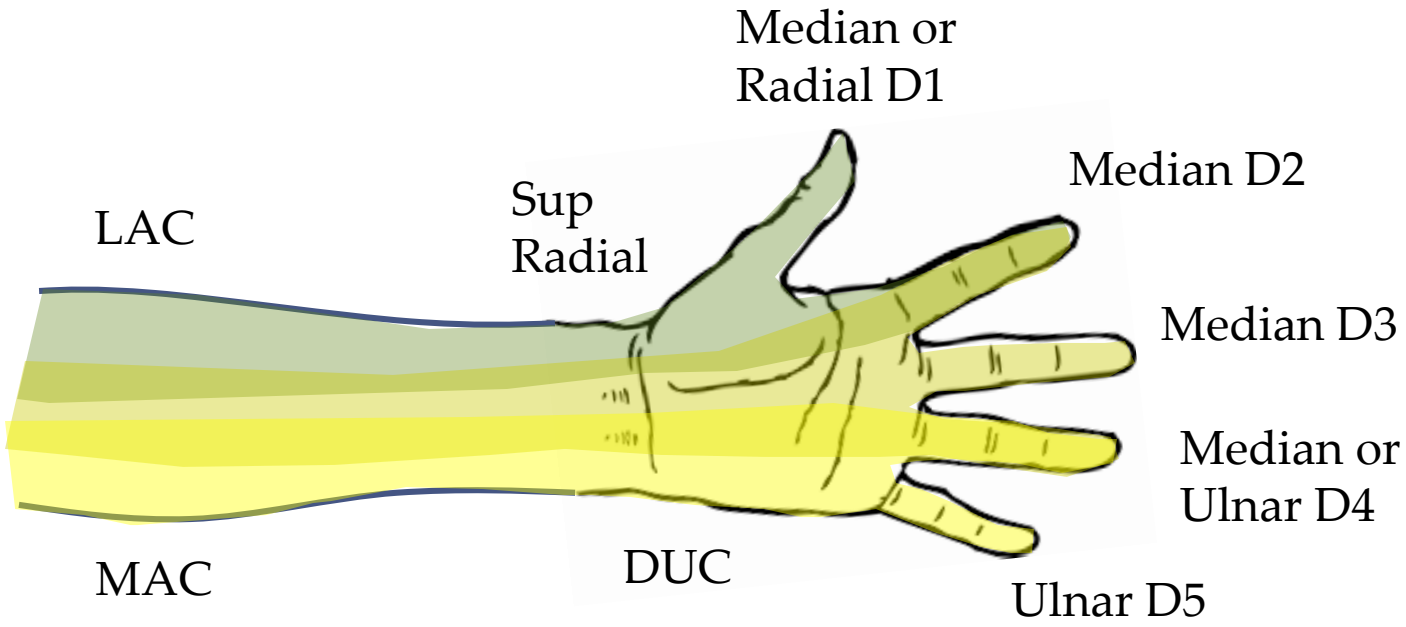


- Shooting pain from neck into shoulder, arm, hand
- Paresthesias often poorly localized
- May be exacerbated by neck positioning or weight bearing
- EDX Goal #1: Exclude entrapment neuropathy
- EDX Goal #2: Establish intact sensory responses in region of paresthesias



2. Radicular Pain





2. Radicular Pain

Initial Plan:

- Median Motor
- Median Sensory
- Ulnar Motor
- Ulnar Sensory

Motor responses often normal in radiculopathy.

- Median/Ulnar motor = C8/T1
- Overlapping innervation
- F-waves may be prolonged in C8/T1

Upper Limb Symptoms

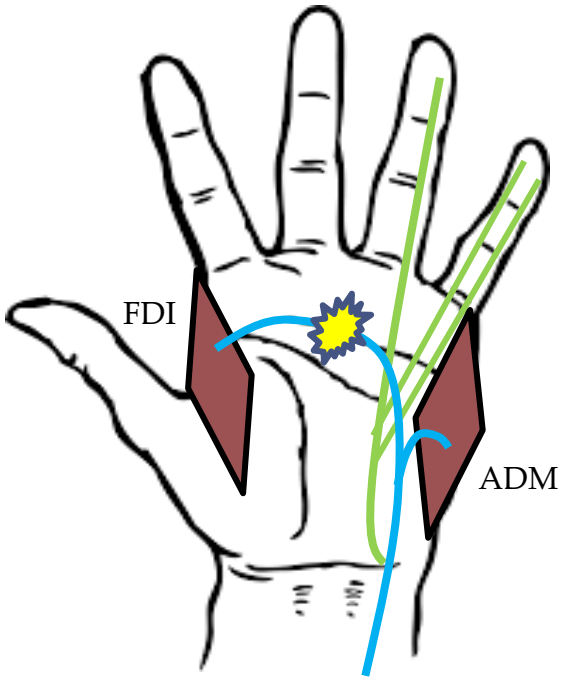
Common Patterns

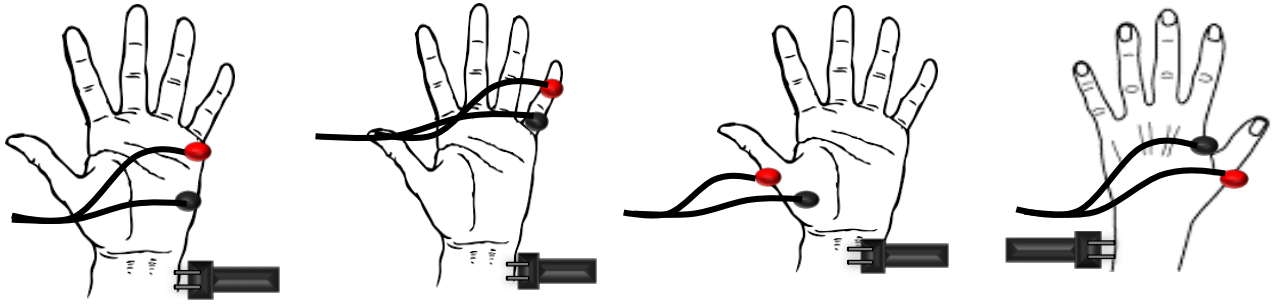
1. Intermittent hand paresthesias +/- weakness
2. Radicular (shooting) pain +/- paresthesias +/- weakness
3. **Weakness without paresthesias or pain**
4. Everything else

3. Weakness only

Focal entrapment (upper limb)

- Intrinsic hand weakness/atrophy
  - Deep ulnar motor branch entrapment in palm
  - Normal ulnar-ADM, ulnar sensory, median-APB
  - Low amplitude ulnar-FDI





Ulnar-ADM: **Normal**

Ulnar-D5: **Normal**

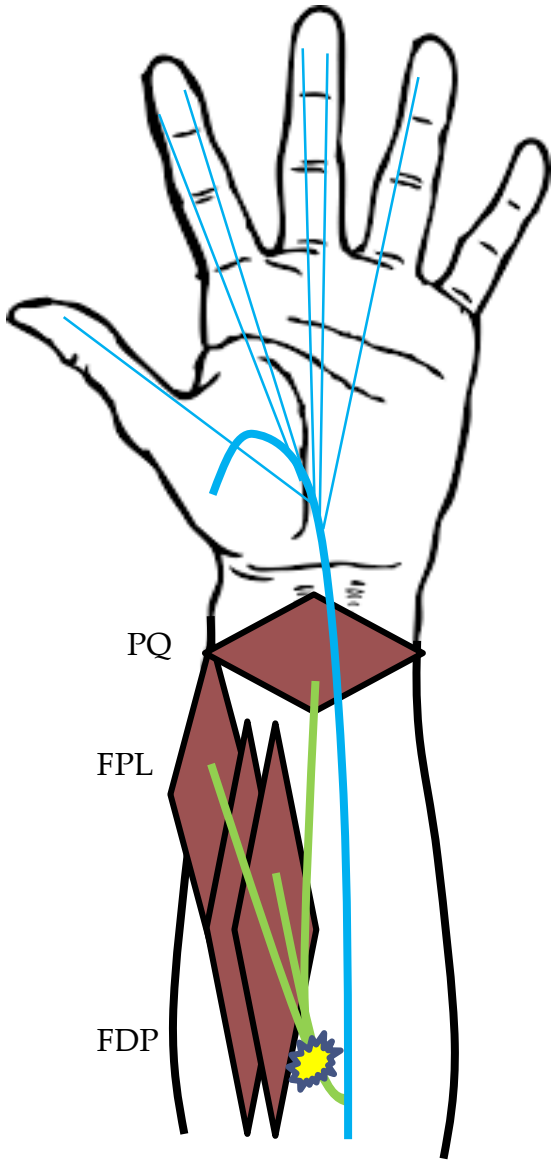
Median-APB: **Normal**

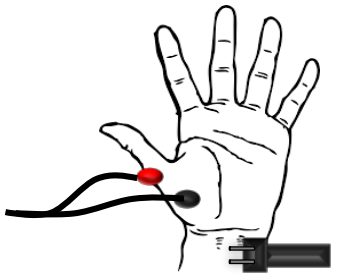
Ulnar-FDI: **Abnormal**

3. Weakness only

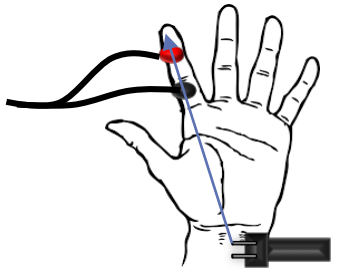
Focal entrapment (upper limb)

- Intrinsic hand weakness/atrophy
  - Deep ulnar motor branch entrapment in palm
  - Normal ulnar-ADM, ulnar sensory, median-APB
  - Low amplitude ulnar-FDI
- Weakness of distal finger flexion (D1-3)
  - Anterior interosseous neuropathy
  - Median motor/sensory studies normal





Median-APB:
Normal

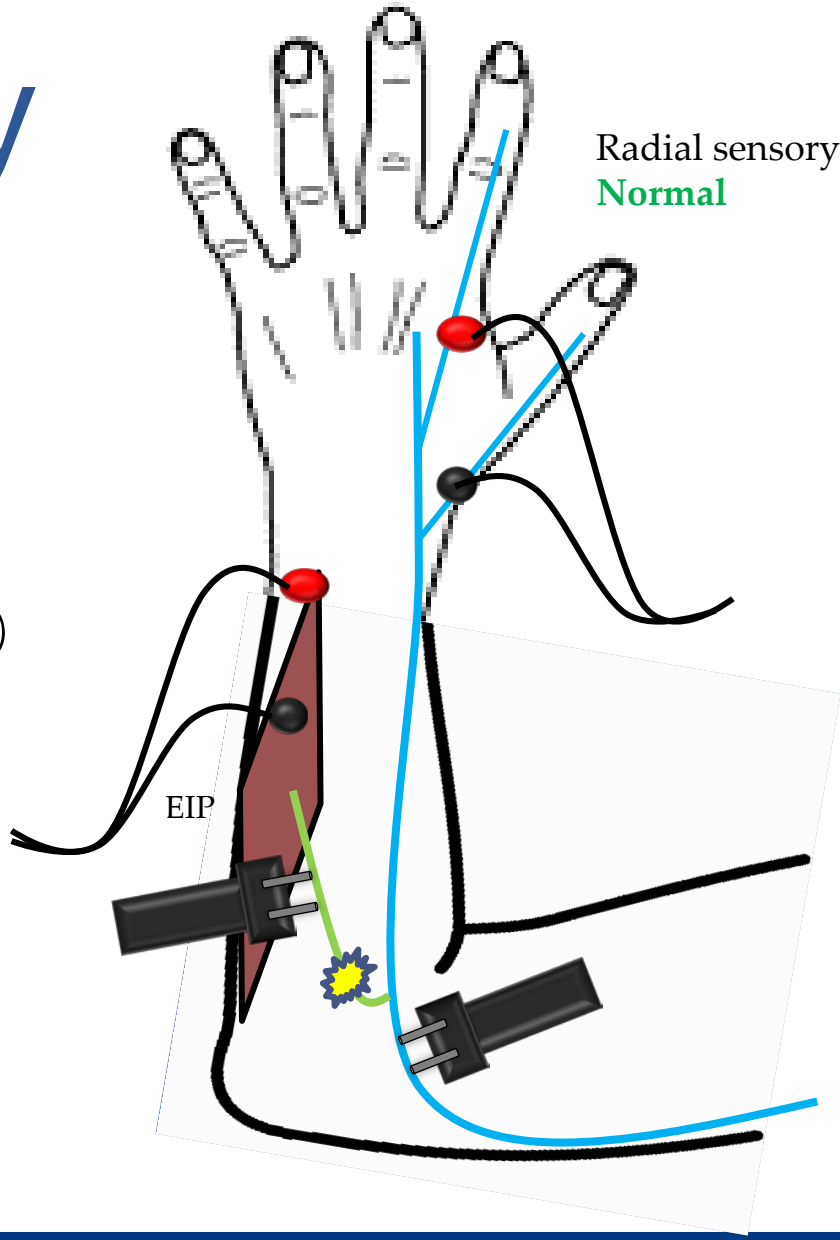


Median-D2:
Normal

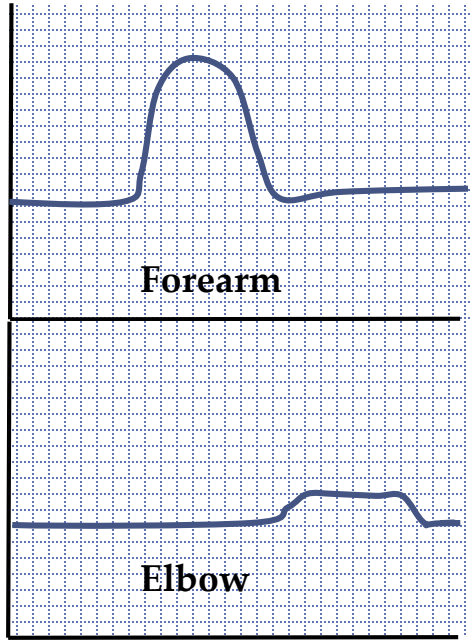
3. Weakness only

Focal entrapment (upper limb)

- Intrinsic hand weakness/atrophy
  - **Deep ulnar motor branch entrapment in palm**
  - Normal ulnar-ADM, ulnar sensory, median-APB
  - Low amplitude ulnar-FDI
- Weakness of distal finger flexion (D1-3)
  - **Anterior interosseous neuropathy**
  - Median motor/sensory studies normal
- Finger drop, wrist extension weakness
  - **Posterior interosseous neuropathy**
  - Radial motor study: conduction block between forearm/elbow or diffusely low amplitude
  - Radial sensory study: normal



Radial sensory:
Normal



Radial-EIP:
Abnormal

3. Weakness only

Generalized Disorder

- Motor nerve
  - Multifocal motor neuropathy
- Motor neuron
  - ALS, Hirayama
- Neuromuscular junction
  - MG, LEMS
- Muscle
  - Myopathy, muscular dystrophy, etc.

Summary

- Avoid the “test everything” strategy
- Select tests based on symptoms and location
- Two abnormal tests are better than one

References

- Preston DC, Shapiro BE. Electromyography and Neuromuscular Disorders: Clinical-Electrophysiologic-Ultrasound Correlations. Fourth Edition, 2021.
- Robinson LR. Electrodiagnosis of Carpal Tunnel Syndrome. Phys Med Rehabil Clin N Am 2007;18:733-746.
- Werner RA, Andary M. AANEM Monograph: Electrodiagnostic evaluation of carpal tunnel syndrome. Muscle Nerve 2011;44:597-607.
- Omejec G, Podnar S. Precise localization of ulnar neuropathy at the elbow. Clin Neurophysiol 2015;126:2390-2396.
- AANEM Practice Parameter for Electrodiagnostic Studies in Ulnar Neuropathy at the Elbow, 2015.

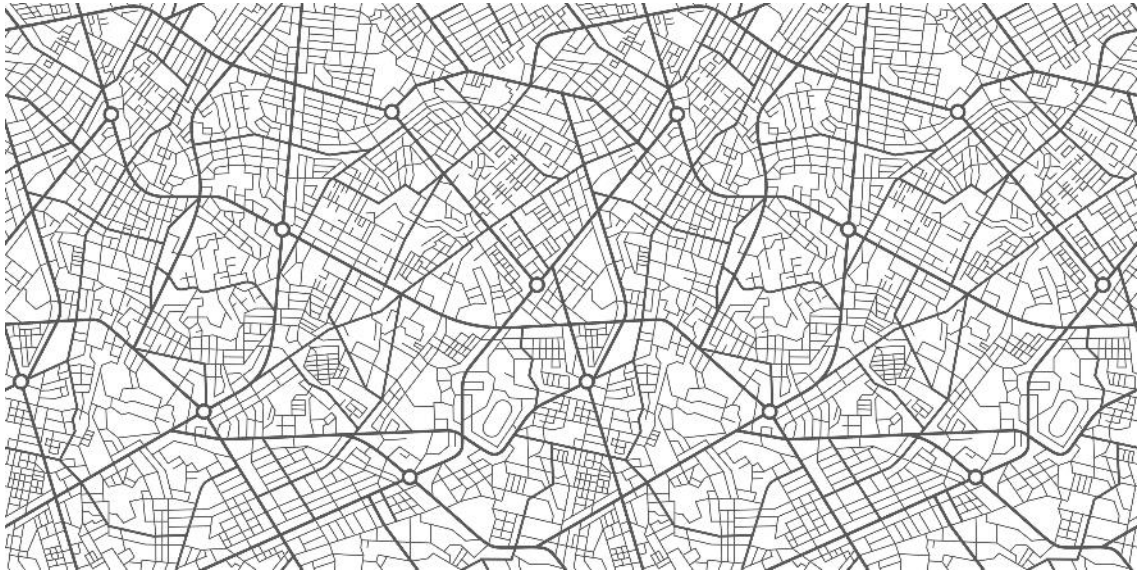


Planning NCS: Lower Limb and Generalized Symptoms

Timothy R. Fullam, MD

Brooke Army Medical Center, San Antonio, TX

Roadmap



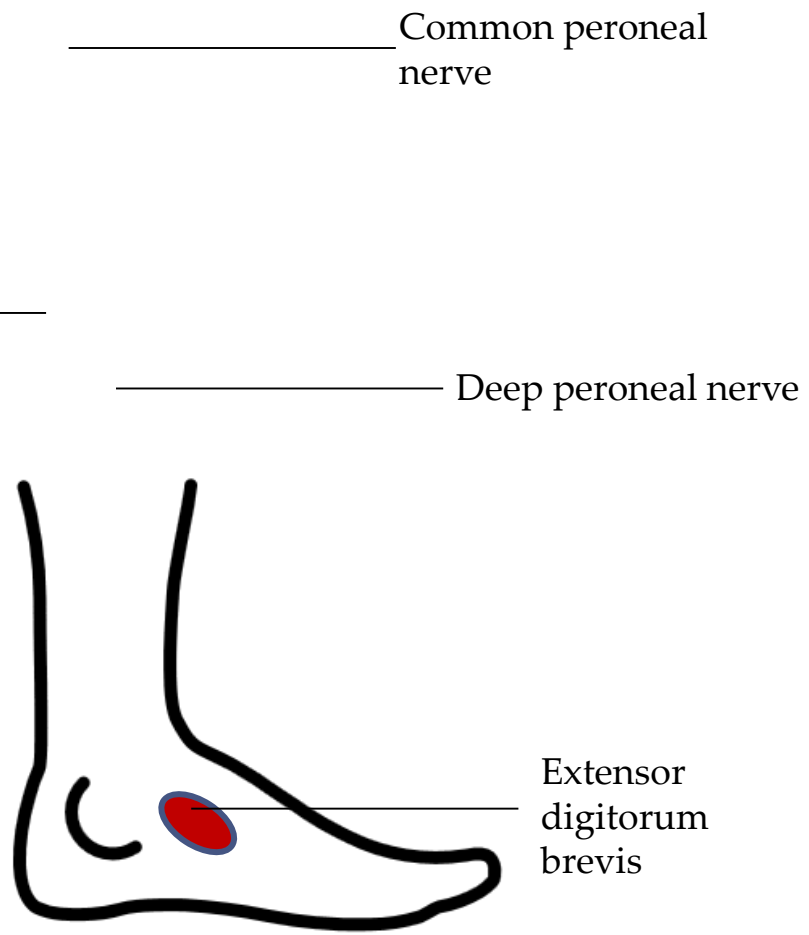
- Lower extremity toolkit
  - Anomalous innervations to be aware of
  - Localization strategies
  - Have more ways to test the same nerve (distal and proximal)
- Case based approach:
  - Foot numbness/pain
  - Foot drop
  - Difficulty walking
  - Generalized weakness

Lower Extremity Toolkit

- Anomalous Innervations to keep in mind:

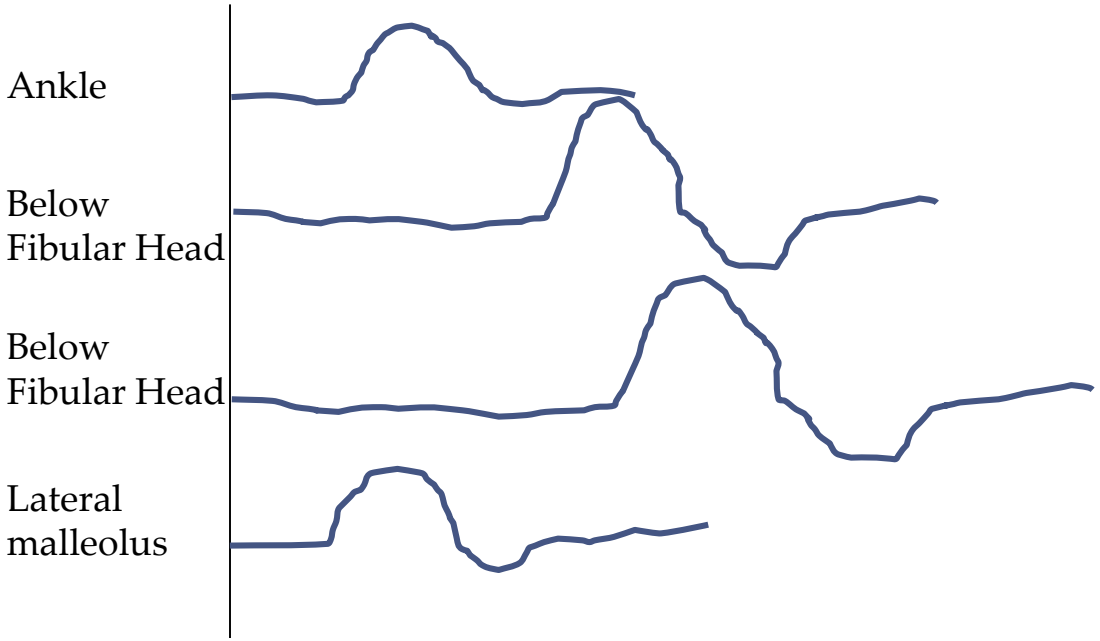
Lower Extremity Toolkit

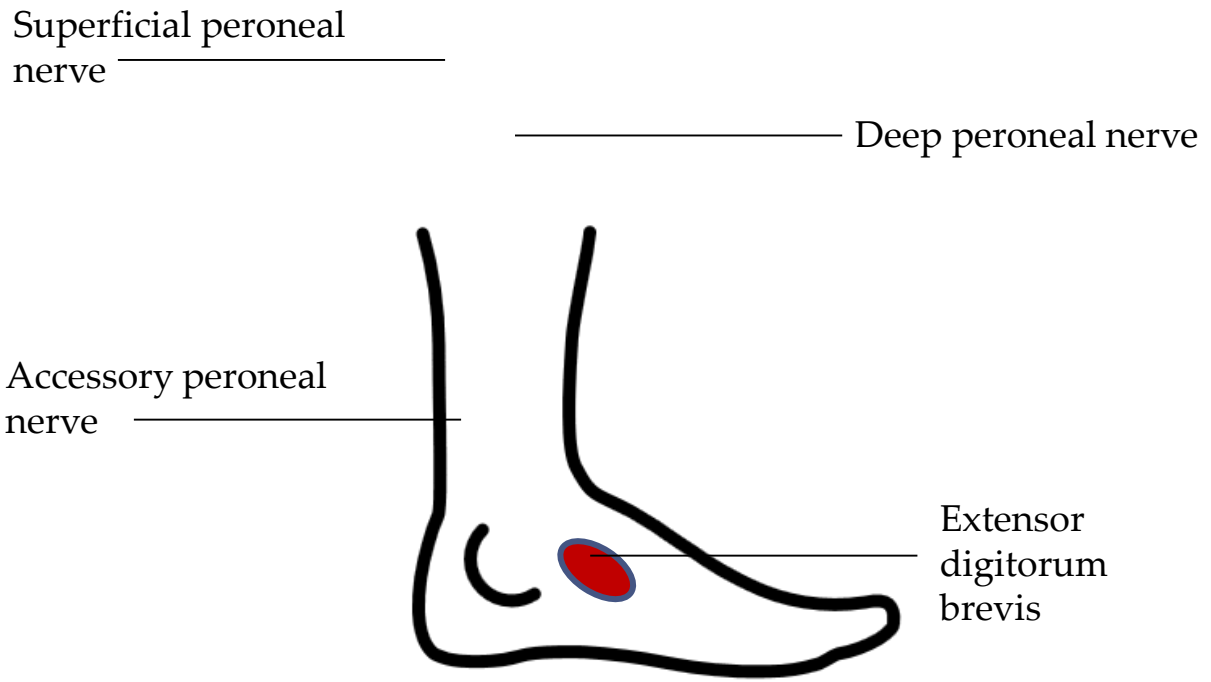
- Anomalous Innervations to keep in mind:
  - Accessory peroneal nerve



Lower Extremity Toolkit

- Anomalous Innervations to keep in mind:
  - Accessory peroneal nerve

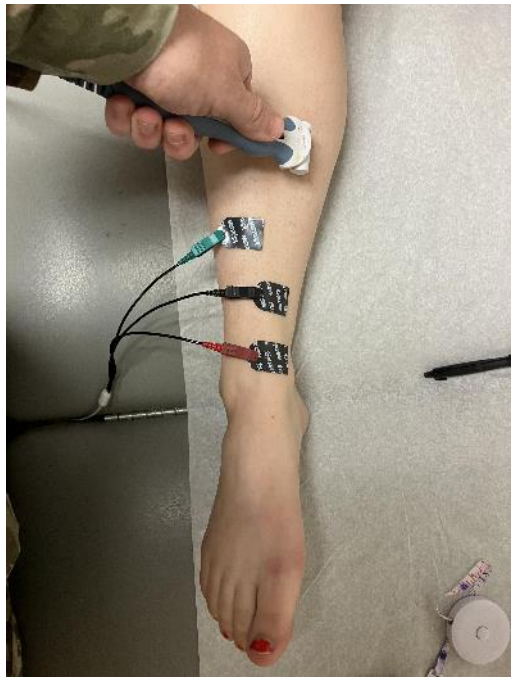




Lower Extremity Toolkit

- Anomalous Innervations to keep in mind:
  - Accessory peroneal nerve
- Sensory studies can be a great localizer
  - pre/post ganglionic
  - Keep in mind proximal studies

Distal Saphenous

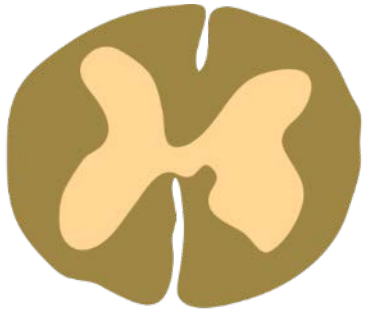


Proximal Saphenous

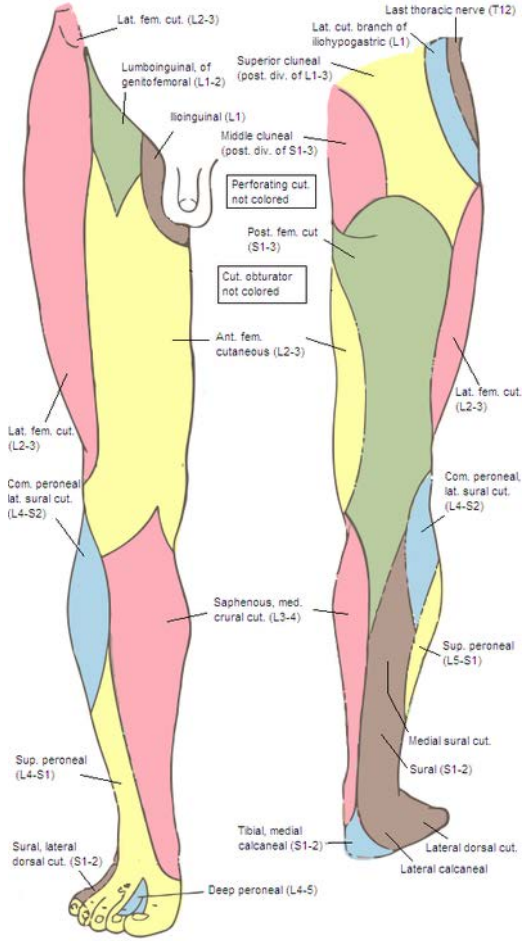


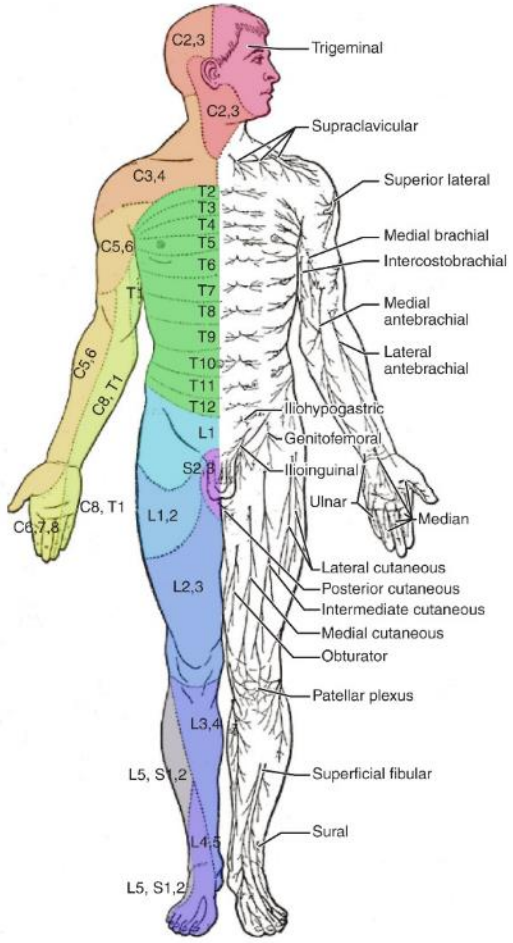
Lower Extremity Toolkit

- Anomalous Innervations to keep in mind:
  - Accessory peroneal nerve
- Sensory studies can be a great localizer
  - pre/post ganglionic
  - Keep in mind proximal studies
  - **STUDY THE SYMPTOMATIC REGION WHEN POSSIBLE**



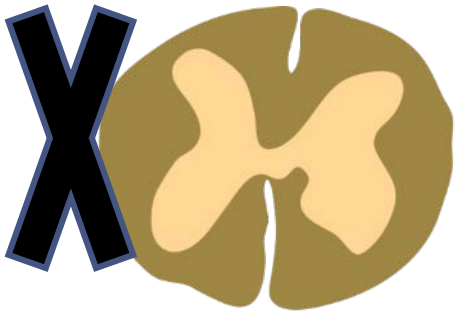
This Photo by Unknown Author is licensed under CC BY-SA



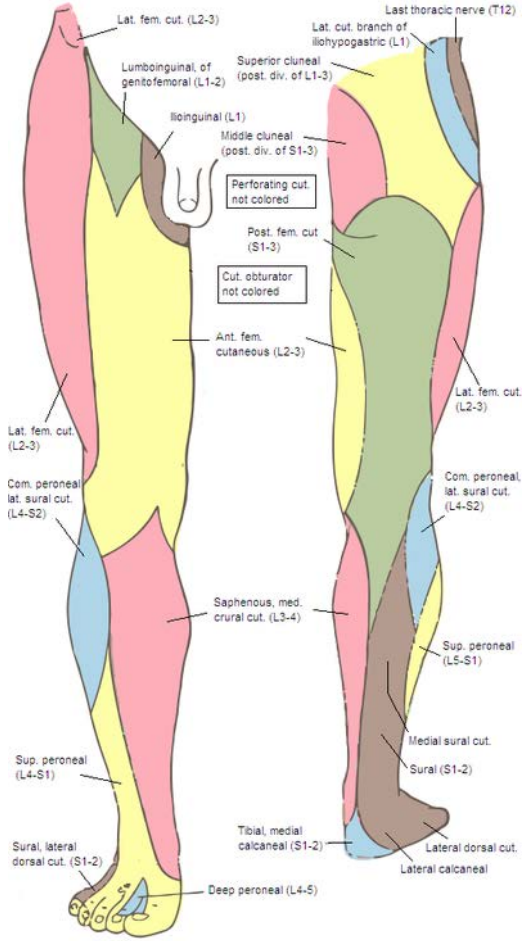


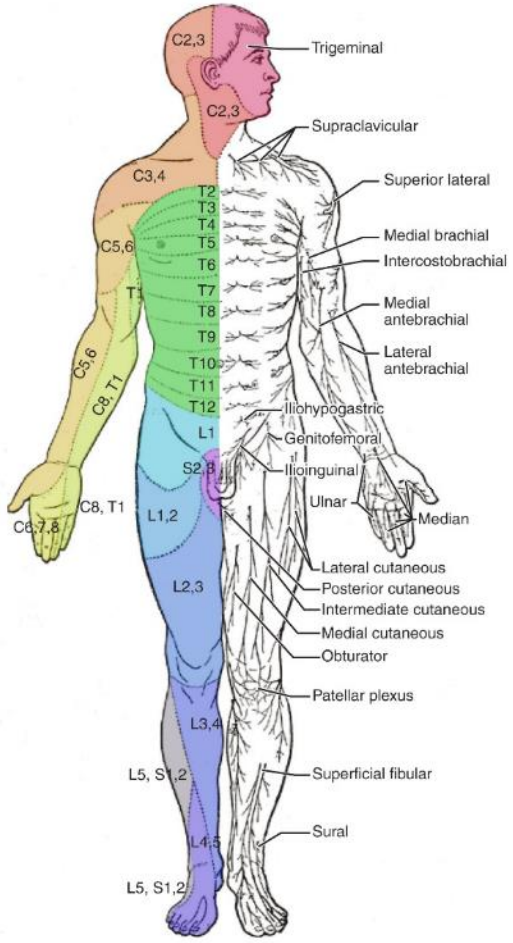
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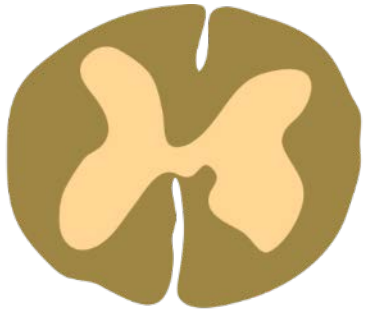
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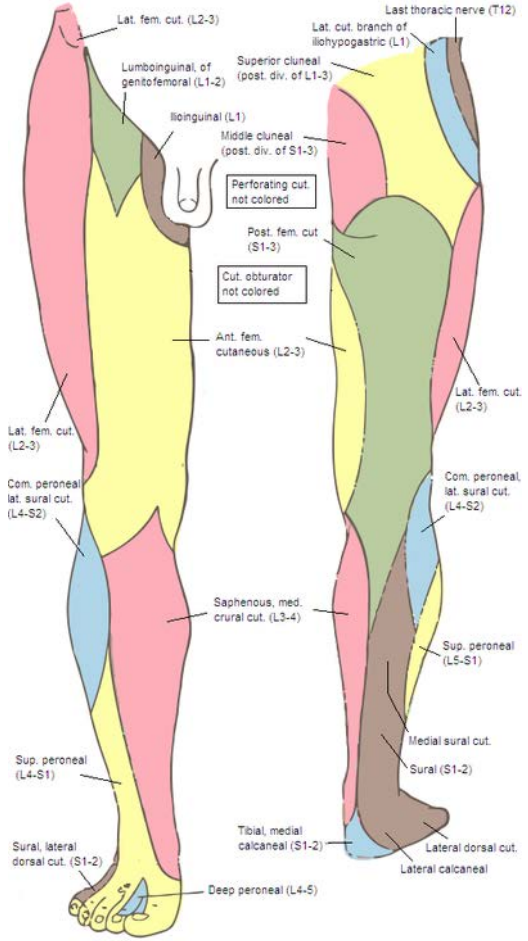


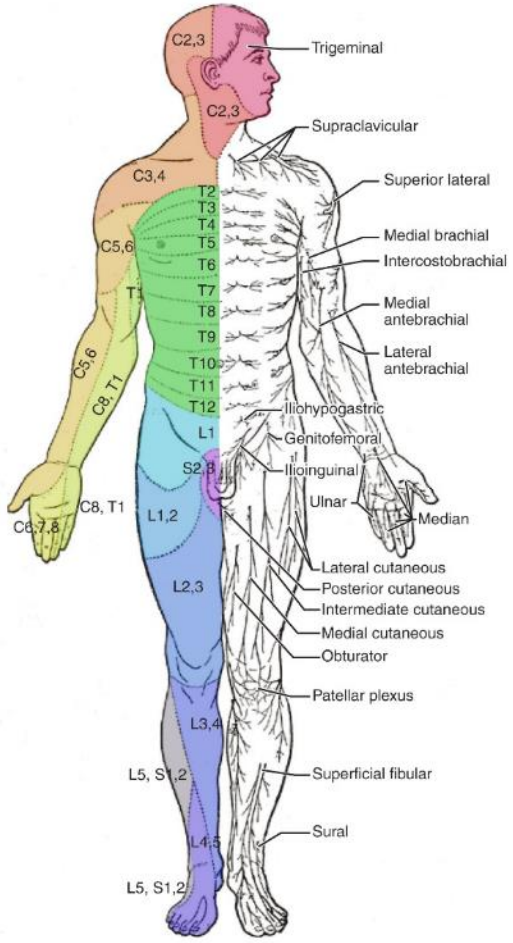
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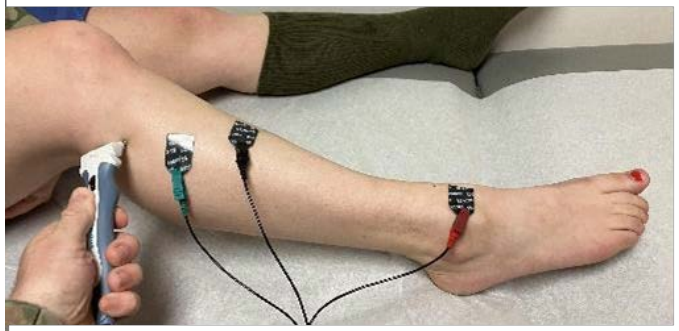


Lower Extremity Toolkit

- Anomalous Innervations to keep in mind:
  - Accessory peroneal nerve
- Sensory studies can be a great localizer
  - pre/post ganglionic
  - Keep in mind proximal studies
- Lower extremities are often affected first by length dependent processes
  - Peroneal and tibial motor studies can also be recorded over proximal muscles
    - Peroneal → Tibialis anterior
    - Tibial → soleus



Tibial motor, recording soleus



Peroneal motor, recording TA

Complaint 1: Foot pain/ numbness

- Patient 1:
  - A 42-year-old male was referred for persistent foot pain after an ankle fracture suffered 5 months prior to presentation
    - Patient needed casting for 6 weeks but continued to have significant pain, worse when weight bearing/walking
- Patient 2:
  - A 50-year-old female was referred for numbness and tingling in the bilateral feet. She first noted symptoms approximately 1 year ago in her bilateral toes and has noted slow/progressive spread to just above her ankles bilaterally. The sensation is described as 'pins and needles' and feels like she 'always has a sock on' her feet, even when barefoot.
    - She denies difficulties/symptoms in her upper extremities
- Patient 3:
  - A 47-year-old was referred for pain in the sole/heel of foot. They recently started road running 3 months prior and has noted progressive dull pain in the sole of the foot. Pain is made better with rubbing but recurs daily, especially when walking or running.
    - Pain has progressed to the point of impaired mobility prompting concern for neurologic etiology



Complaint 1: Foot pain/ numbness

- Pain and numbness of the feet is a common cause for referral to the lab
- Primary Differential:
  - Tarsal tunnel syndrome
    - Likely rarer than number of referrals would suggest
    - Perimalleolar pain, worse with weight bearing, and numbness of sole of feet
    - Helpful if symptoms are asymmetric,
    - Look for intrinsic foot atrophy/sensation loss restricted to sole of foot
  - Local orthopedic problems (tendonitis/fasciitis)
    - Pain often predominates with normal sensory exam
    - History of prior injury? Sudden change in activity?
  - Mild polyneuropathy
    - Often symmetric, slow progression proximally
    - May or may not see atrophy, weakness likely restricted to toe flex/ext
  - S1 radiculopathy (rare cause to be just pain)

Complaint 1: Foot pain/ numbness



Planning the study

- Tibial motor study, include F-waves
  - Most sensitive nerve with prolonged F-wave the most sensitive parameter in peripheral neuropathy

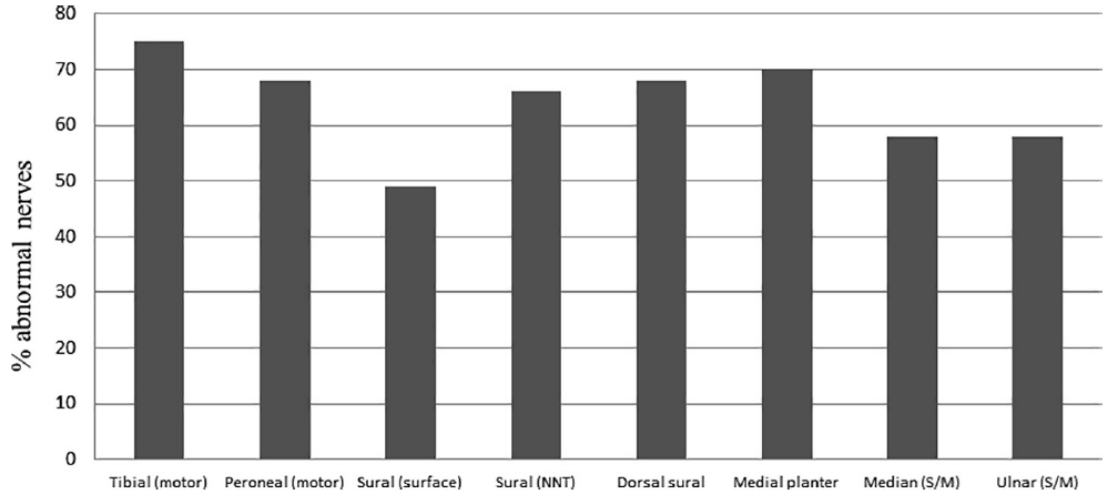
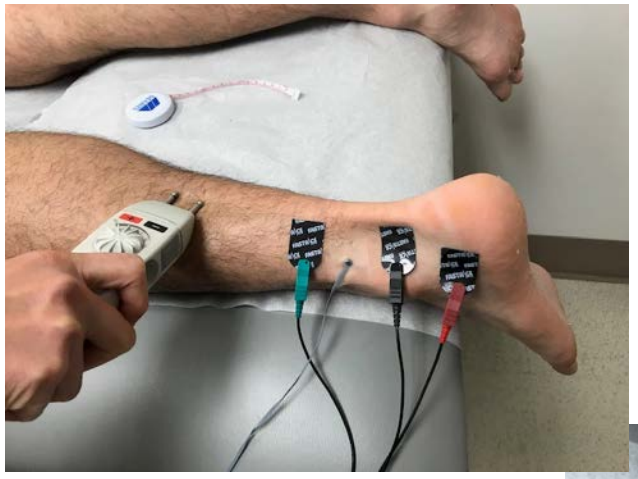


Fig. 3. Percentage of nerves with normal and abnormal nerve conduction studies in 219 patients with clinically confirmed polyneuropathy (PNP+ group). S/M: Sensory/ Motor.

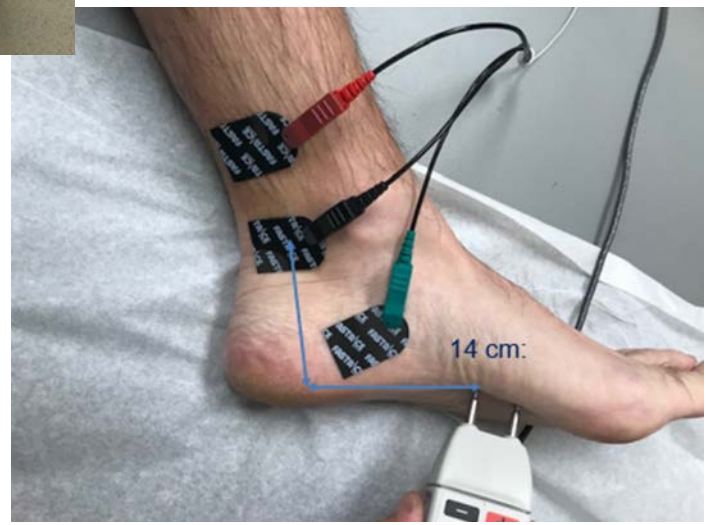
PMID: 31886447; PMCID: PMC6921232.

Complaint 1: Foot pain/ numbness



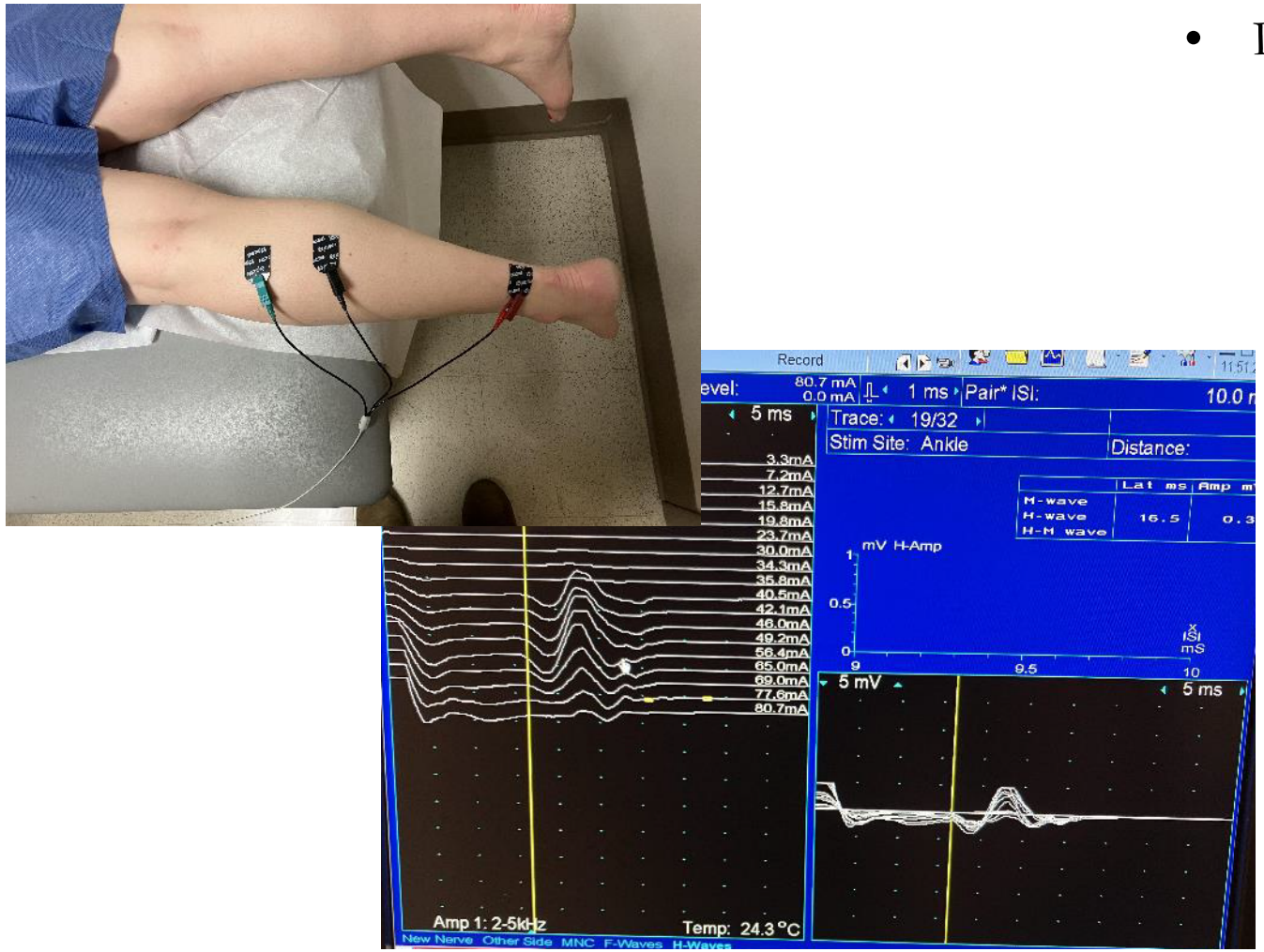
Sural Sensory Study

Medial Plantar Study



- Planning the study
  - Tibial motor study, include F-waves
    - Most sensitive nerve with prolonged F-wave the most sensitive parameter in peripheral neuropathy
  - Sural Sensory study
    - IF: tibial and sural are both normal, add medial plantar OR dorsal sural sensory studies
      - IF normal-polyneuropathy essential ruled out!
    - IF: either tibial or sural abnormal-compare to contralateral side

Complaint 1: Foot pain/ numbness



- Planning the study
  - Tibial motor study, include F-waves
    - Most sensitive nerve with prolonged F-wave the most sensitive parameter in peripheral neuropathy
  - Sural Sensory study
  - H-waves
    - Abnormal in tibial mononeuropathy, sciatic neuropathy, lumbosacral plexopathy, and S1 radiculopathy
    - NOT abnormal in tarsal tunnel syndrome or peroneal neuropathies
    - Normal: H latency ≤ 34 ms (varies based on limb length) OR ≤ 1.5 ms side to side difference

Complaint 1: Foot pain/ numbness

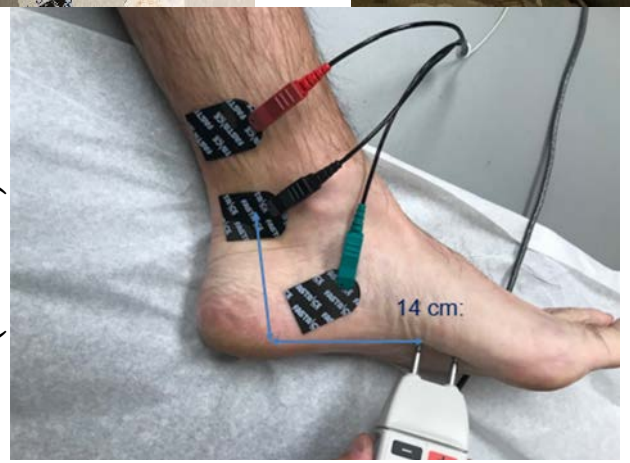
Tibial to ADQP



Tibial to AHB



Medial Plantar (mixed)



- Planning the study
  - Tibial motor study, include F-waves
    - Most sensitive nerve with prolonged F-wave the most sensitive parameter in peripheral neuropathy
  - Sural Sensory study
  - H-waves
  - IF concern/referral for tarsal tunnel:
    - Side to side distal latency/amplitude comparison of tibial motor to AHB and ADQP
    - Side to side medial/lateral plantar mixed nerve studies
      - ONLY HELPFUL IF PRESENT/ASYMMETRIC

Complaint 1: Foot pain/ numbness

- Patient 1: **Tarsal Tunnel Syndrome**
  - A 42-year-old male was referred for persistent foot pain after an ankle fracture suffered 5 months prior to presentation
    - Patient needed casting for 6 weeks but continued to have significant pain, worse when weight bearing/walking
- Patient 2: **Mild Axonal Sensorimotor Polyneuropathy**
  - A 50-year-old female was referred for numbness and tingling in the bilateral feet. She first noted symptoms approximately 1 year ago in her bilateral toes and has noted slow/progressive spread to just above her ankles bilaterally. The sensation is described as 'pins and needles' and feels she 'always has a sock on' her feet, even when barefoot.
    - She denies difficulties/symptoms in her upper extremities
- Patient 3: **Plantar fasciitis**
  - A 47-year-old was referred for pain in the sole/heel of foot. They recently started road running 3 months prior and has noted progressive dull pain in the sole of the foot. Pain is made better with rubbing but recurs daily, especially when walking or running.
    - Pain has progressed to the point of impaired mobility prompting concern for neurologic etiology

- Planning the study
  - Tibial motor study, include F-waves
    - Most sensitive nerve with prolonged F-wave the most sensitive parameter in peripheral neuropathy
  - Sural Sensory study
  - H-waves
  - If concern/referral for tarsal tunnel:
    - Side to side comparisons
  - **Remember to ensure:
    - a sensory study was done in distribution of symptoms
    - consider adding peroneal motor study if sural sensory normal and either tibial study is abnormal
    - If all motor responses are low, remember proximal recording sites

Complaint 2: Foot Drop

- Case 1:
  - 56-year-old referred for persistent right foot drop 3 weeks after a CABG. He cannot dorsiflex his right ankle or toes and notes pins and needles over the dorsum of his foot/lateral calf. He first noted the symptoms upon awakening from surgery.
- Case 2:
  - 36-year-old referred difficulties walking/frequent falls. Symptoms started 2 months ago after severe back pain after he bent over to pick up a heavy box. He noted radiating pins and needles, mostly in his lateral calf.
- Case 3:
  - 35-year-old referred for 2-year history of frequent falls due to 'catching his toes' on the ground. He was otherwise fairly active prior to onset of symptoms. He denies any pain or sensory complaints.



Mukherjee S, Biswas D, Begum S, Bhanja P, Misra AK, Chatterjee P. Granulomatosis with polyangitis with mononeuritis multiplex-immunosuppressives playing a double-edged sword. Lung India. 2014 Oct;31(4):397-400. doi: 10.4103/0970-2113.142143. PMID: 25378852; PMCID: PMC4220326.

Complaint 2: Foot Drop

- Referrals due to concern of radiculopathy or compressive neuropathies are (2) common lower extremity questions
- If foot drop is the primary concern:
  - Differential includes:
    - Peroneal neuropathy at fibular head
    - Sciatic Neuropathy
    - Lumbosacral Plexopathy
    - L5 radiculopathy
    - Severe polyneuropathy
- Primary ankle dorsiflexor is the **tibialis anterior**
  - Innervation: Deep peroneal nerve → common peroneal nerve → sciatic nerve → lumbosacral plexus → L4, **L5**
- Historical clues:
  - back pain/radicular sxs → radiculopathy
  - trauma or stretch injury → sciatic/peroneal neuropathy
  - casting/immobilization → sciatic/peroneal neuropathy
  - occupational exposures (squatting/kneeling) → peroneal neuropathy
  - weight loss, leg crossing → peroneal neuropathy
- Examination clues:
  - Eversion (peroneal) vs Inversion (tibial) → BOTH L5!
  - Appearance of feet

Complaint 2: Foot Drop



Banchs I, Casasnovas C, Albertí A, De Jorge L, Povedano M, Montero J, Martínez-Matos JA, Volpini V. Diagnosis of Charcot-Marie-Tooth disease. J Biomed Biotechnol. 2009;2009:985415. doi: 10.1155/2009/985415. Epub 2009 Oct 8. PMID: 19826499; PMCID: PMC2760395.

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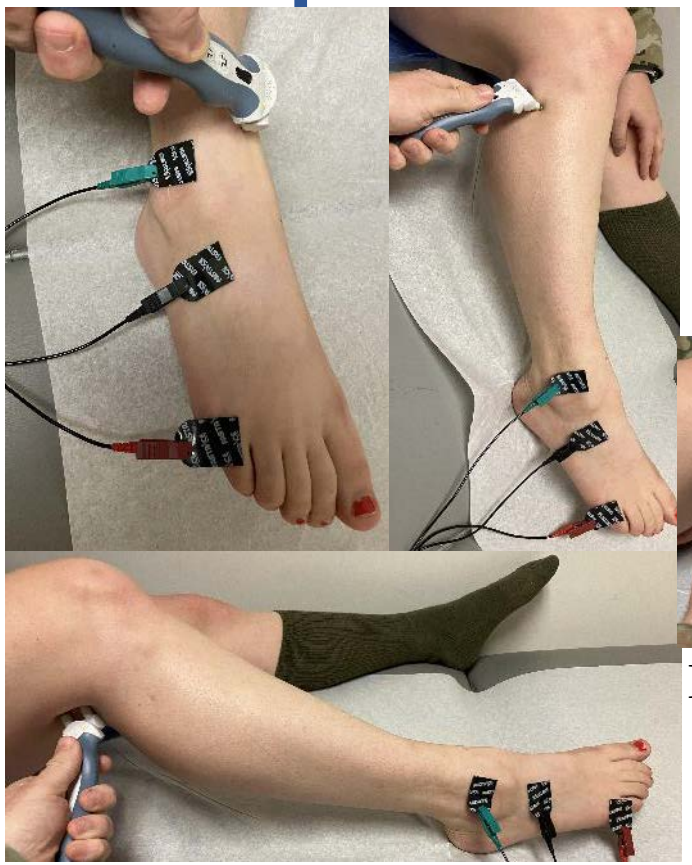
Complaint 2: Foot Drop

Planning the study:

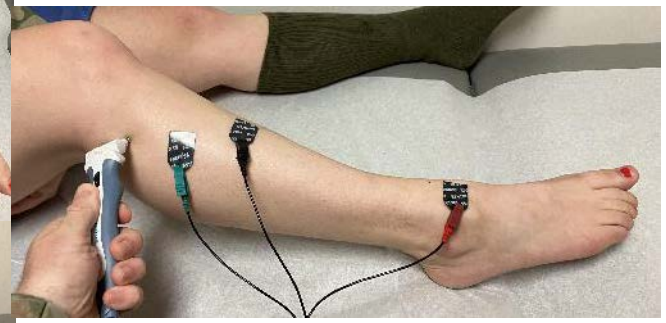
- Go where the money is at!
  - Peroneal motor study (w/ F-waves)
    - Plan to record over both EDB and TA!
  - Superficial peroneal sensory study
  - Side to Side comparisons for both will likely be required!



Superficial Peroneal Sensory



Peroneal motor, recording EDB



Peroneal motor, recording TA

Complaint 2: Foot Drop

Planning the study:

- Go where the money is at!
  - Peroneal motor study (w/ F-waves)
    - Plan to record over both EDB and TA!
  - Superficial peroneal sensory study
  - Side to Side comparisons for both will likely be required!
- Consider tibial and sural sensory study on symptomatic side (to rule out widespread process)

Complaint 2: Foot Drop

Predicting the outcomes:

- Case 1:
  - 56-year-old referred for persistent right foot drop 3 weeks after a CABG. He cannot dorsiflex his right ankle or toes and notes pins and needles over the dorsum of his foot/lateral calf. He first noted the symptoms upon awakening from surgery.
    - Peroneal motor studies on right?
      - **Normal amplitudes/distal latencies/distal CV with reduced CV across the fibular head**
    - Superficial peroneal sensory?
      - **Asymmetric amplitude on right as compared to left (>50% difference)**
    - Tibial/Sural sensory responses?
      - **Normal**
- Case 2:
  - 36-year-old referred difficulties walking/frequent falls. Symptoms started 2 months ago after severe back pain after he bent over to pick up a heavy box. He noted radiating pins and needles, mostly in his lateral calf.
- Case 3:
  - 35-year-old referred for 2-year history of frequent falls due to 'catching his toes' on the ground. He was otherwise fairly active prior to onset of symptoms. He denies any pain or sensory complaints.

Complaint 2: Foot Drop

Predicting the outcomes:

- Case 1:
  - 56-year-old referred for persistent right foot drop 3 weeks after a CABG. He cannot dorsiflex his right ankle or toes and notes pins and needles over the dorsum of his foot/lateral calf. He first noted the symptoms upon awakening from surgery.
    - Diagnosis: **Peroneal neuropathy (demyelinating with secondary axonal features) at the fibular head**
- Case 2:
  - 36-year-old referred difficulties walking/frequent falls. Symptoms started 2 months ago after severe back pain after he bent over to pick up a heavy box. He noted radiating pins and needles, mostly in his lateral calf.
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- Case 2:
  - 36-year-old referred difficulties walking/frequent falls. Symptoms started 2 months ago after severe back pain after he bent over to pick up a heavy box. He noted radiating pins and needles, mostly in his lateral calf.
    - Peroneal motor studies on right?
      - **EDB: Reduced amplitudes in all segments, normal distal latencies and conduction velocities**
      - **TA: reduced amplitude (50%) as compared to left**
    - Superficial peroneal sensory?
      - **Normal**
    - Tibial/Sural sensory responses?
      - **Normal**
- Case 3:
  - 35-year-old referred for 2-year history of frequent falls due to 'catching his toes' on the ground. He was otherwise fairly active prior to onset of symptoms. He denies any pain or sensory complaints.

Complaint 2: Foot Drop

Predicting the outcomes:

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    - Diagnosis: Peroneal neuropathy (demyelinating with secondary axonal features) at the fibular head
- Case 2:
  - 36-year-old referred difficulties walking/frequent falls. Symptoms started 2 months ago after severe back pain after he bent over to pick up a heavy box. He noted radiating pins and needles, mostly in his lateral calf.
  - Diagnosis: **Right L5 radiculopathy**
- Case 3:
  - 35-year-old referred for 2-year history of frequent falls due to 'catching his toes' on the ground. He was otherwise fairly active prior to onset of symptoms. He denies any pain or sensory complaints.

Complaint 2: Foot Drop

Predicting the outcomes:

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- Case 3:
  - 35-year-old referred for 2-year history of frequent falls due to 'catching his toes' on the ground. He was otherwise fairly active prior to onset of symptoms. He denies any pain or sensory complaints.
    - Peroneal motor studies on right?
      - **EDB/TA: No Response**
    - Superficial peroneal sensory?
      - **No Response**
    - Tibial/Sural sensory responses?
      - **No Response**
    - Contralateral Tibial/Sural?
      - **No Response**
    - What should be considered next? Technical?

Complaint 2: Foot Drop

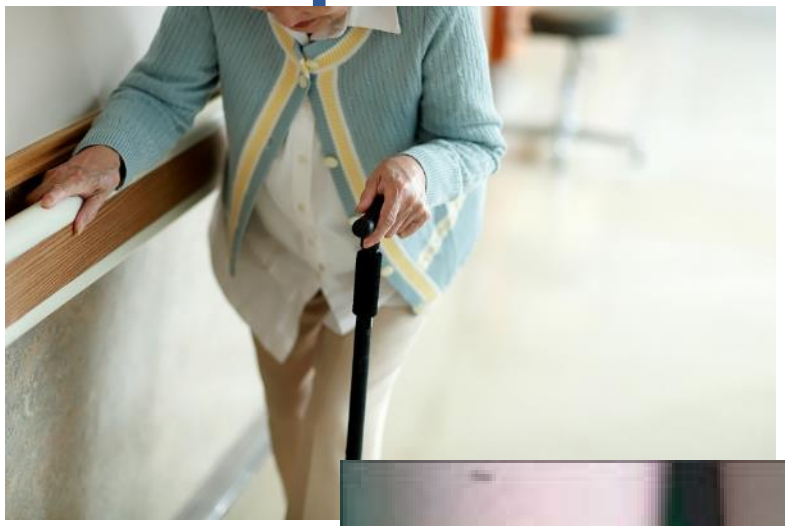
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Banchs I, Casasnovas C, Albertí A, De Jorge L, Povedano M, Montero J, Martínez-Matos JA, Volpini V. Diagnosis of Charcot-Marie-Tooth disease. J Biomed Biotechnol. 2009;2009:985415. doi: 10.1155/2009/985415. Epub 2009 Oct 8. PMID: 19826499; PMCID: PMC2760395.

- Case 3:
  - 35-year-old referred for 2-year history of frequent falls due to 'catching his toes' on the ground. He was otherwise fairly active prior to onset of symptoms. He denies any pain or sensory complaints.
    - Peroneal motor studies on right?
      - **EDB/TA: No Response**
    - Superficial peroneal sensory?
      - **No Response**
    - Tibial/Sural sensory responses?
      - **No Response**
    - Contralateral Tibial/Sural?
      - **No Response**
    - What should be considered next? Technical?
      - Listen to the patient, look at the patient!
    - Upper extremity studies showed normal motor amplitudes but diffusely slow conduction velocities
    - Diagnosis: **Sensorimotor primarily demyelinating polyneuropathy with secondary axonal loss, likely inherited**

Complaint 3: Difficulty walking





Yi TI, Yoon TH, Kim JS, Lee GE, Kim BR. Femoral neuropathy and meralgia paresthetica secondary to an iliacus hematoma. Ann Rehabil Med. 2012 Apr;36(2):273-7. doi: 10.5535/arm.2012.36.2.273. Epub 2012 Apr 30. PMID: 22639754; PMCID: PMC3358686.

- **Case:**
  - 67-year-old referred for evaluation of difficulty walking and going up stairs. They have a history of diabetes mellitus type II. Referral is due to concern for possible radiculopathy.
- Questions:
  - Sensory loss? Which distribution?
    - Lumbosacral polyradiculoneuropathy/plexopathy
    - Radiculopathy (L2-L4)?
  - Weight loss? Muscle wasting?
  - History?
    - Surgery (pelvic/abdominal)→risk factor for femoral neuropathy
    - Diabetes → Diabetic amyotrophy/diabetic lumbosacral polyradiculoneuropathy

Complaint 3: Difficulty walking

- <u>Planning the study:</u>
  - Keep in mind the differential:
    - Femoral neuropathy (not covered by routine LE studies)
    - Lumbar/lumbosacral polyradiculoneuropathy/plexopathy (can we establish asymmetry)
    - Lumbar radiculopathy (L2-L4→where is the sensory loss?)
    - Myopathy (NCS will not establish the diagnosis, get to where the money is at!)
  - While F-waves may be beneficial in this complaint (to evaluate for neuropathy), H-waves are low yield (only assess S1 nerve root, would not add much in terms of localization)
  - Best to start basic and expand as you go….

Complaint 3: Difficulty walking

Tibial/Peroneal Motor studies + Sural Sensory

Complaint 3: Difficulty walking

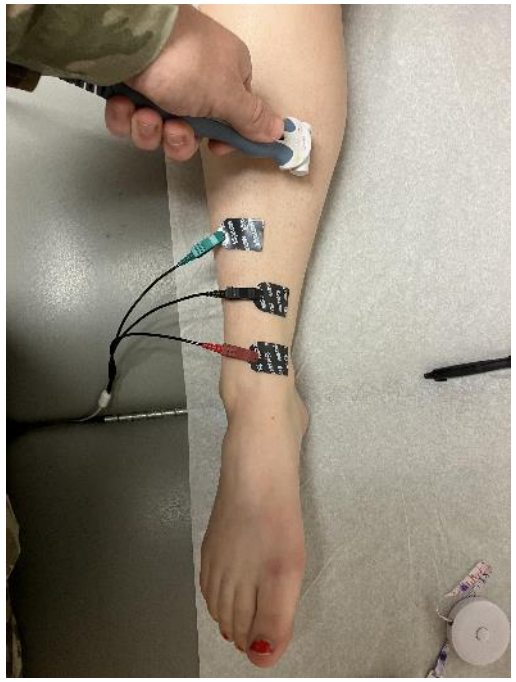
Tibial/Peroneal Motor studies + Sural Sensory

Nml + sensory sxs in saphenous dist.

Perform bilateral saphenous studies

- → Remember proximal sites
- → Start on normal side

Distal Saphenous



Proximal Saphenous



Complaint 3: Difficulty walking

Tibial/Peroneal Motor studies + Sural Sensory

Nml + sensory sxs in saphenous dist.

Perform bilateral saphenous studies

- → Remember proximal sites
- → Start on normal side

Normal OR absent b/l

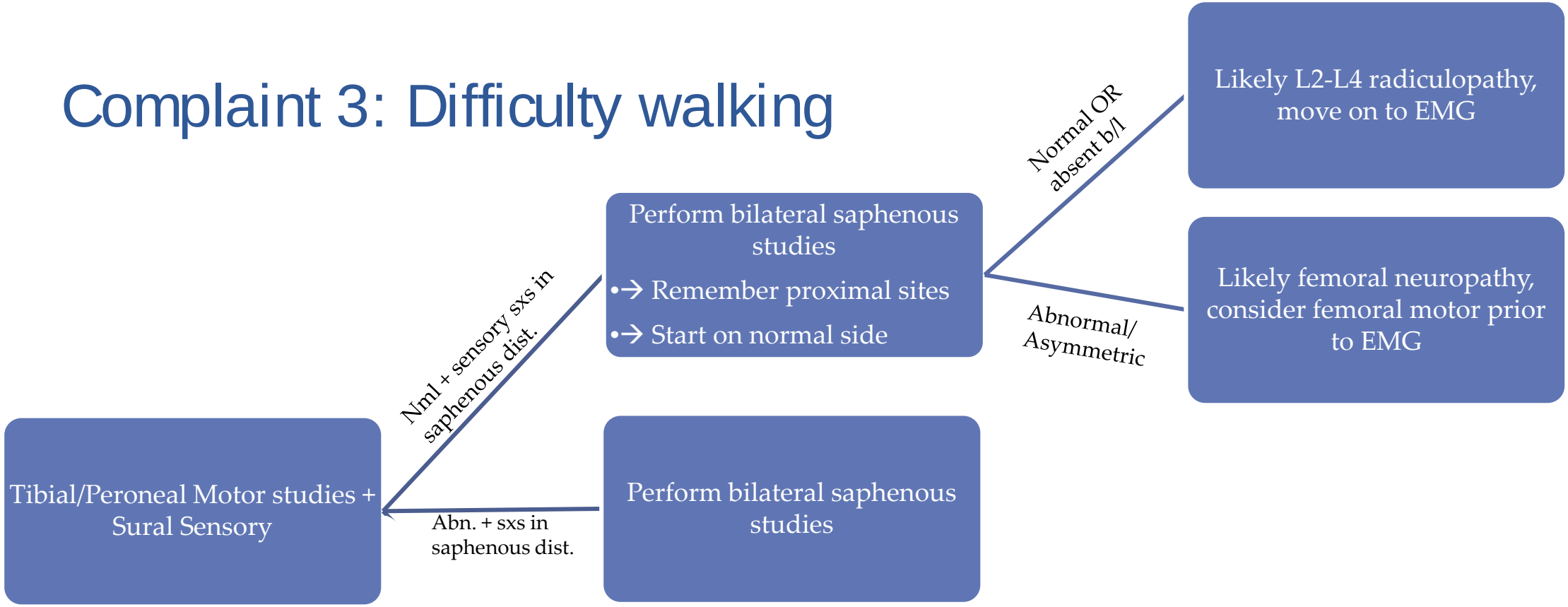
Likely L2-L4 radiculopathy, move on to EMG

Abnormal/ Asymmetric

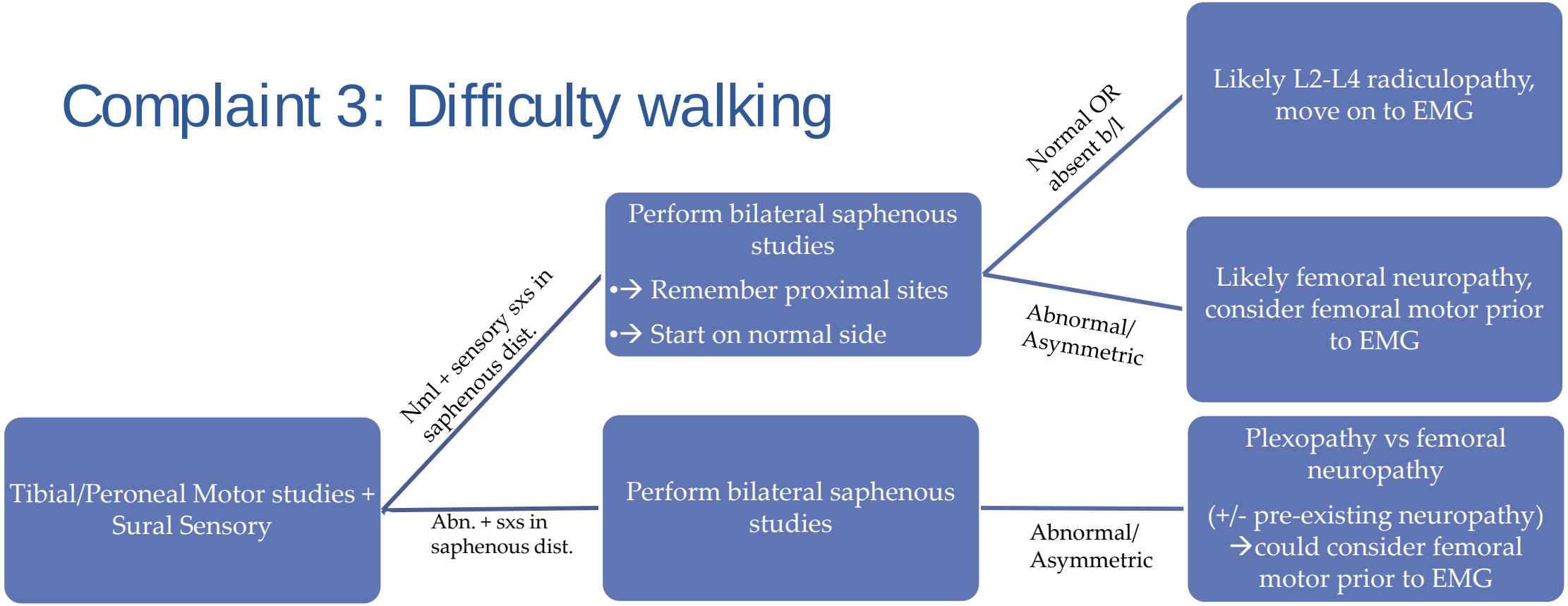
Likely femoral neuropathy, consider femoral motor prior to EMG



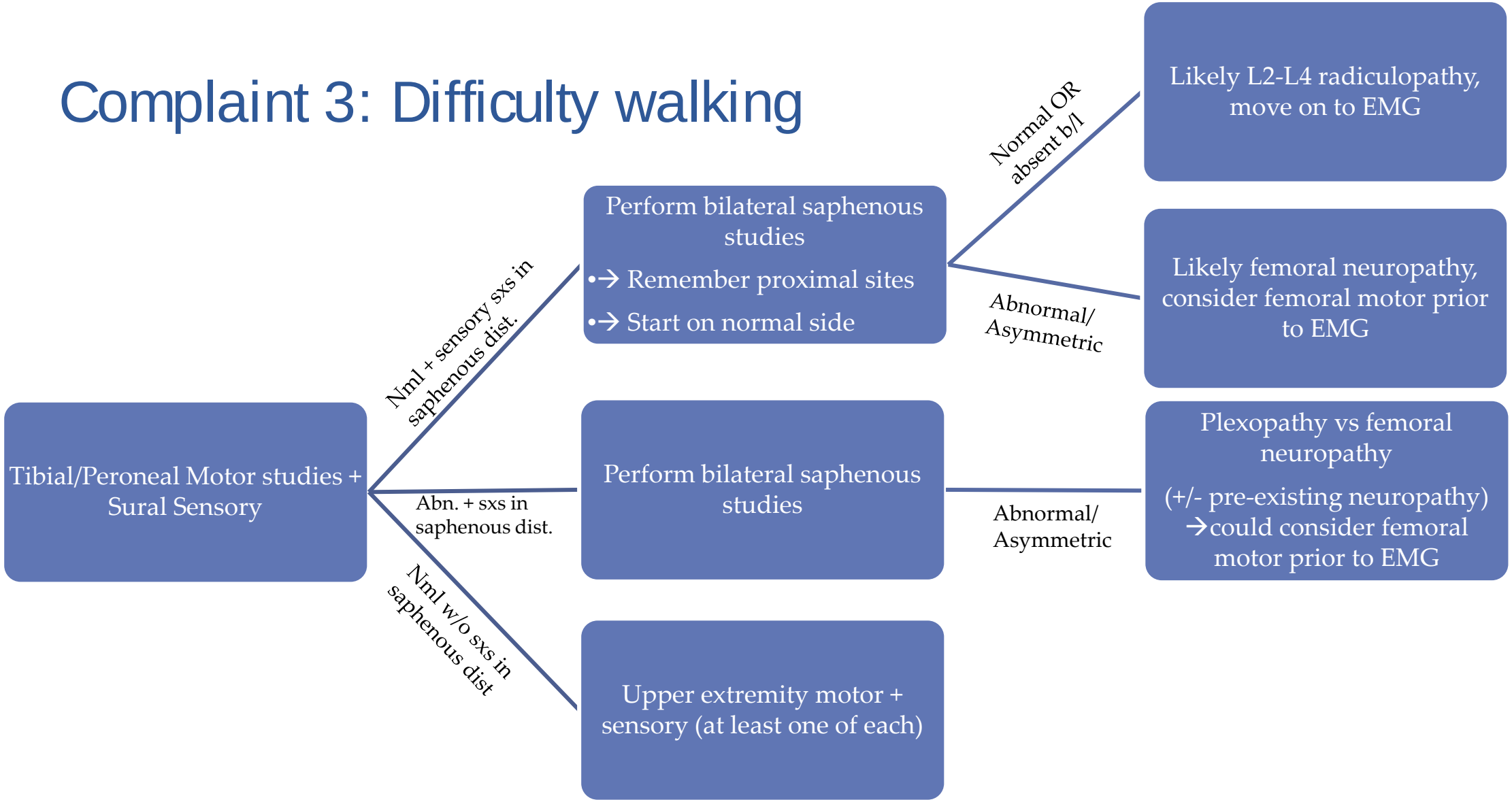
Complaint 3: Difficulty walking



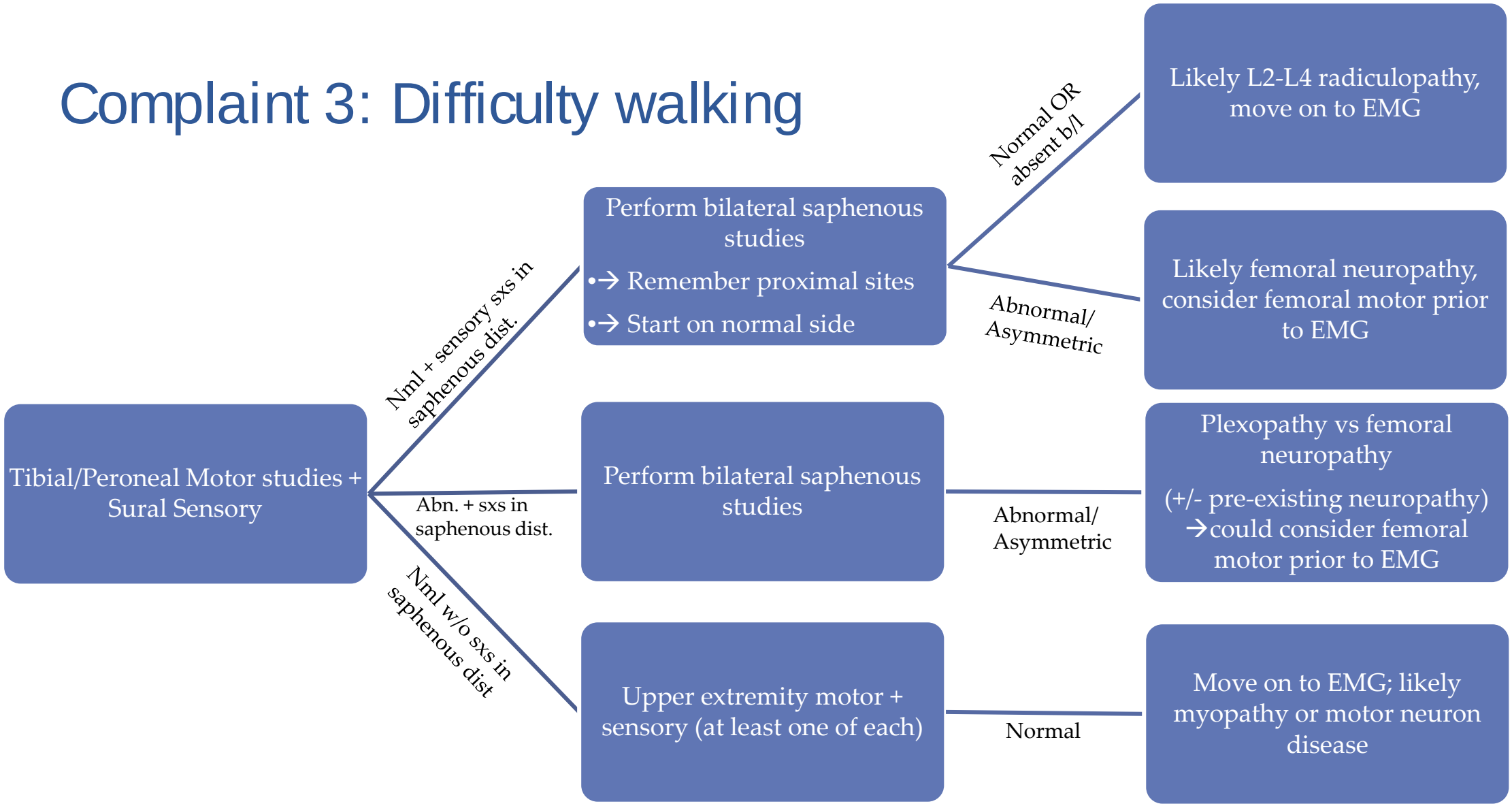
Complaint 3: Difficulty walking



Complaint 3: Difficulty walking



Complaint 3: Difficulty walking



Complaint 4: Generalized Weakness



- 59-year-old referred due to an 8-month history of weakness. Symptoms came on abruptly and have gradually worsening since onset, noting difficulty going up and down stairs and getting out of chairs. She constantly feels fatigued. No numbness or difficulty swallowing/speaking.

Complaint 4: Generalized weakness

- Differential of generalized weakness is broad, ranging from seemingly more benign causes to autoimmune muscle/NMJ disorders
  - LEMS
  - Myasthenia Gravis
  - Inflammatory Myopathy
  - Fibromyalgia/Chronic Fatigue Syndrome
- Important historical clues:
  - Time course
  - Oculobulbar involvement
  - Medication exposures
  - Symmetry?

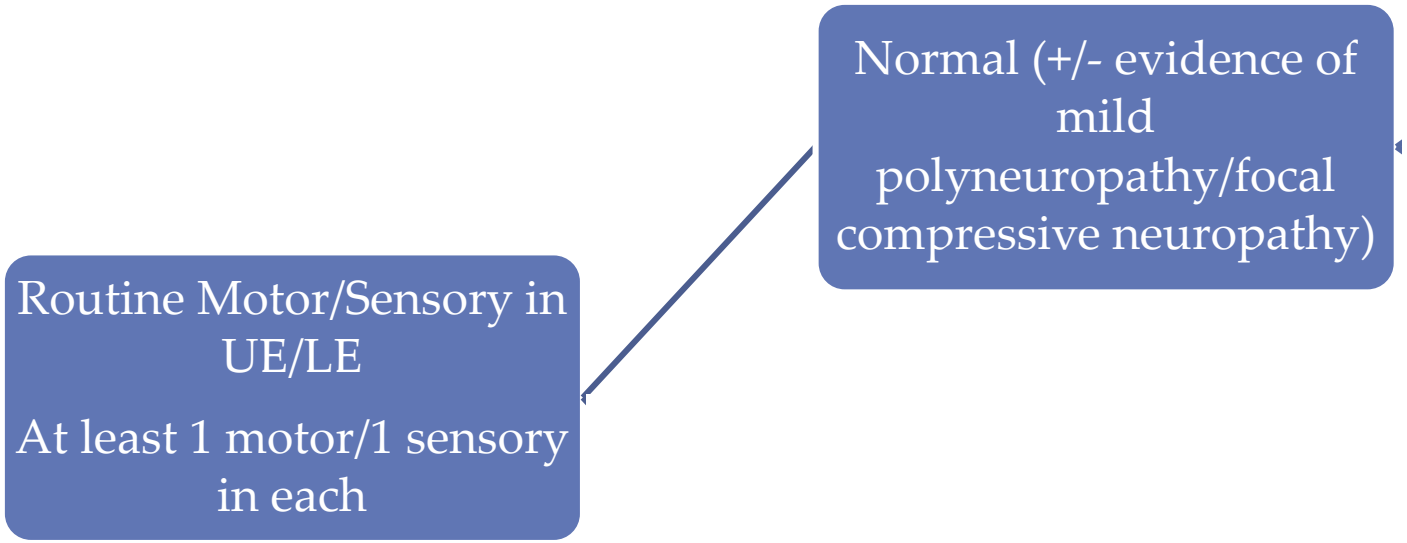


Complaint 4: Generalized weakness

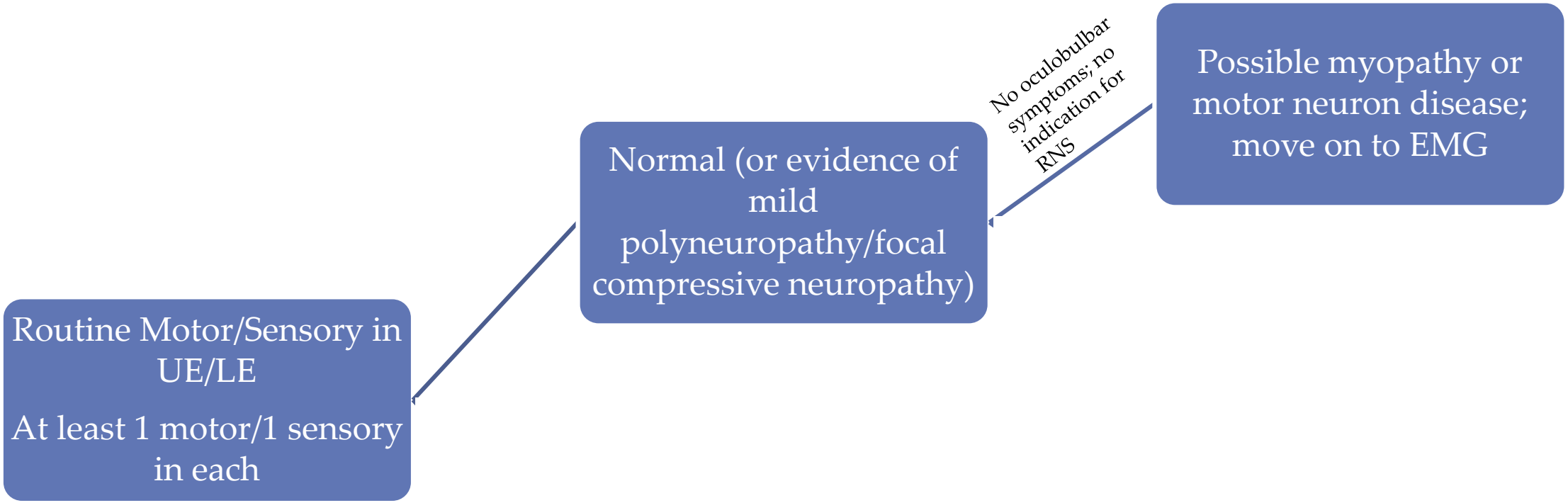
Routine Motor/Sensory in UE/LE

At least 1 motor/1 sensory in each

Complaint 4: Generalized weakness



Complaint 4: Generalized weakness



Complaint 4: Generalized weakness

Routine Motor/Sensory in UE/LE

At least 1 motor/1 sensory in each

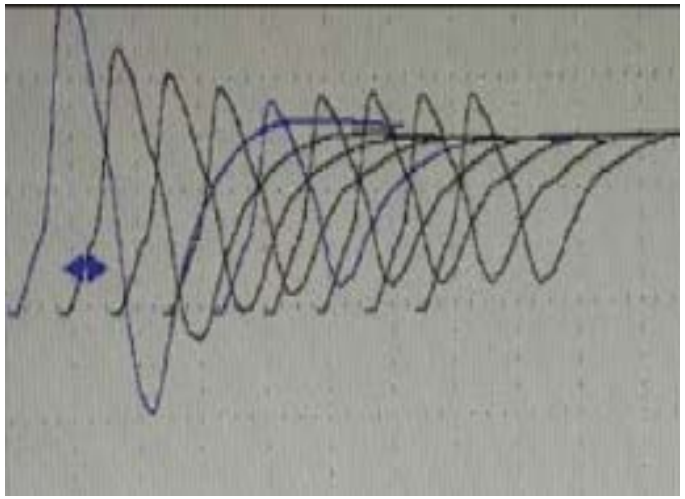
Normal (or evidence of mild polyneuropathy/focal compressive neuropathy)

No oculobulbar symptoms; no indication for RNS

Possible myopathy or motor neuron disease; move on to EMG

+ oculobulbar sxs/indication for RNS

RNS to evaluate for NMJ defect/MG



Shah PA, Wadia PM. Reversible man-in-the-barrel syndrome in myasthenia gravis. Ann Indian Acad Neurol. 2016 Jan-Mar;19(1):99-101. doi: 10.4103/0972-2327.168639. PMID: 27011638; PMCID: PMC4782563.

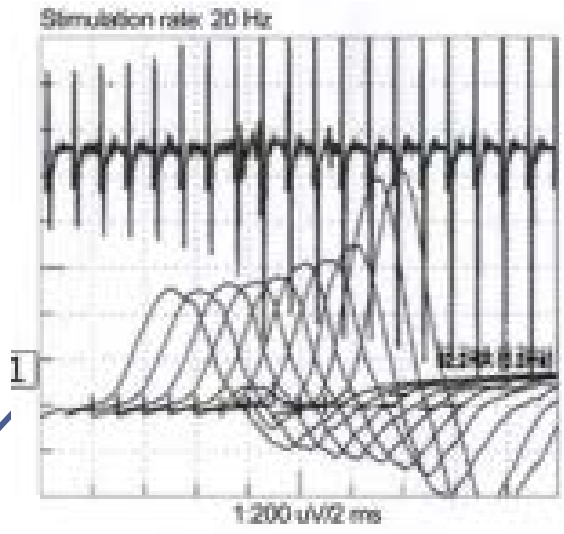
Standard sites:

1) Ulnar recording ADM
2) Spinal accessory recording trapezius
3) Facial recording nasalis

Complaint 4: Generalized weakness

Post exercise facilitation:

1) 10 seconds exercise preferable to high frequency (20-50 Hz) stimulation
2) Typically will see CMAP increments over 100%!!



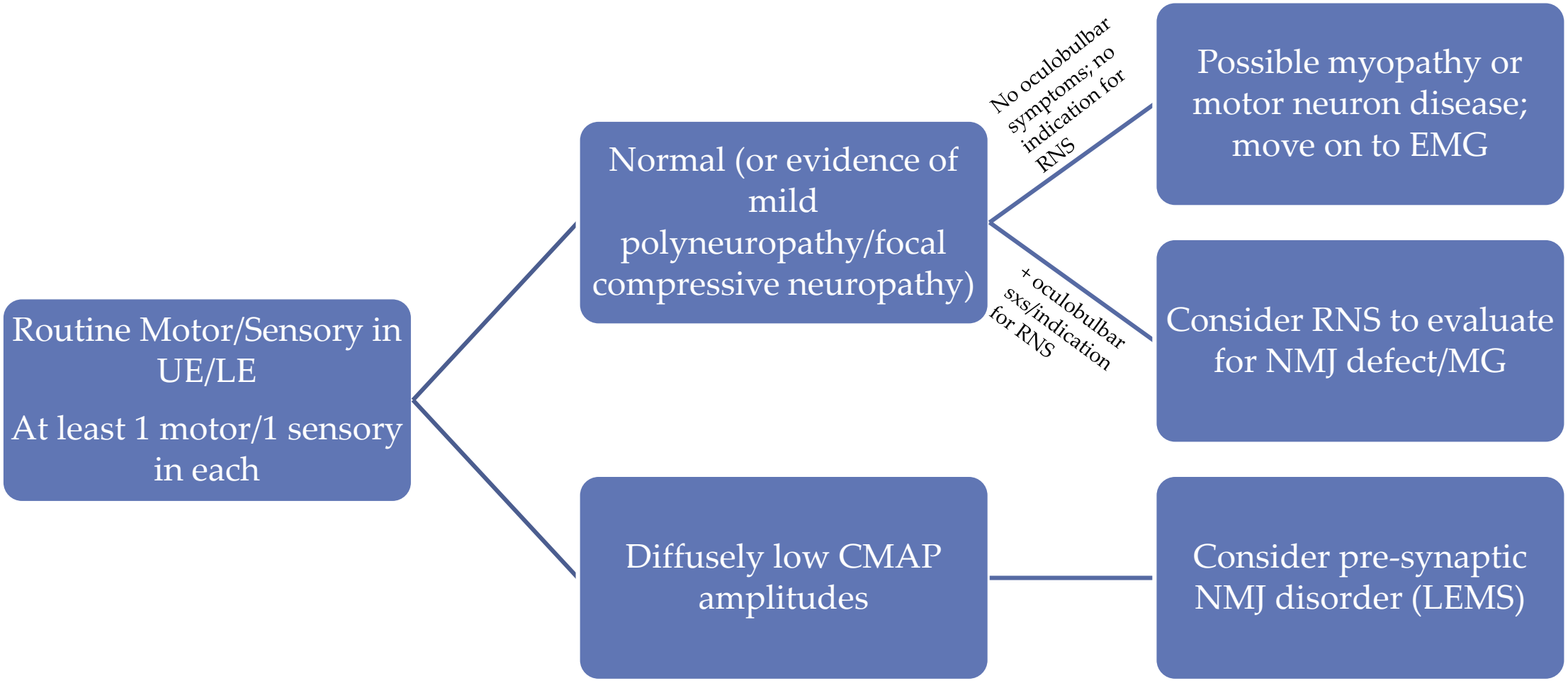
Asano F, Watanabe K, Shinkai M, Tei Y, Mishina K, Tanabe M, Ishii H, Shinoda M, Shimokawaji T, Kudo M, Kaneko T. Relapse of both small cell lung cancer and Lambert-Eaton myasthenic syndrome after a 13-year disease-free survival period. Chin J Cancer. 2016 Jul 2;35(1):63. doi: 10.1186/s40880-016-0127-x. PMID: 27370896; PMCID: PMC4930592.

Routine Motor/Sensory in UE/LE

At least 1 motor/1 sensory in each

Diffusely low CMAP amplitudes

Complaint 4: Generalized weakness



Summary/ Key points

- The legs are often affected first by length-dependent processes (i.e. neuropathy)
  - Utilize proximal recording sites for peroneal (tibialis anterior), tibial (soleus), and saphenous (stimulating at knee) to garner more information
- Always include a sensory study in the distribution of the patient's most bothersome numbness/tingling when possible (esp. if below the knee)
  - Maximize the localization (i.e. pre versus post ganglionic)
- Utilize the non-symptomatic side to establish a norm in difficult to study nerves
- Don't get lost in the weeds:
  - Patients may have more than one problem—does it explain their symptoms/is it associated with the chief complaint?
  - If no answers are being found, move on to EMG!
- If diffusely low CMAP amplitudes, consider testing for post-exercise facilitation

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- Asano F, Watanabe K, Shinkai M, Tei Y, Mishina K, Tanabe M, Ishii H, Shinoda M, Shimokawaji T, Kudo M, Kaneko T. Relapse of both small cell lung cancer and Lambert-Eaton myasthenic syndrome after a 13-year disease-free survival period. Chin J Cancer. 2016 Jul 2;35(1):63. doi: 10.1186/s40880-016-0127-x. PMID: 27370896; PMCID: PMC4930592. (http://creativecommons.org/licenses/by/4.0/; http://creativecommons.org/publicdomain/zero/1.0/)
- Shah PA, Wadia PM. Reversible man-in-the-barrel syndrome in myasthenia gravis. Ann Indian Acad Neurol. 2016 Jan-Mar;19(1):99-101. doi: 10.4103/0972-2327.168639. PMID: 27011638; PMCID: PMC4782563. (http://creativecommons.org/licenses/by-nc-sa/3.0)



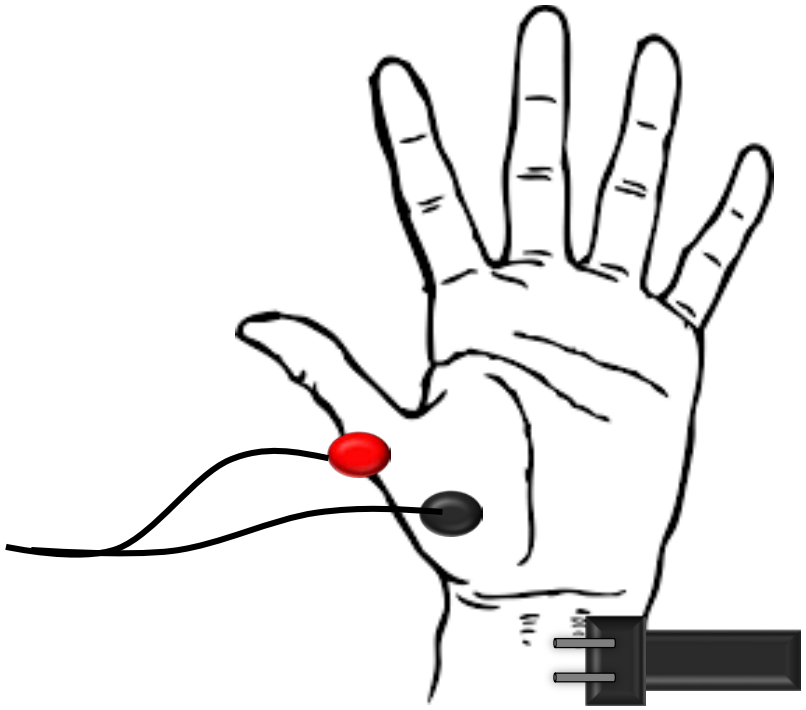
Planning NCS: 10 Principles

Daniel B. Simmons, MD
Saint Alphonsus Health System, Boise, ID

Timothy R. Fullam, MD
Brooke Army Medical Center, San Antonio, TX

Principle #1

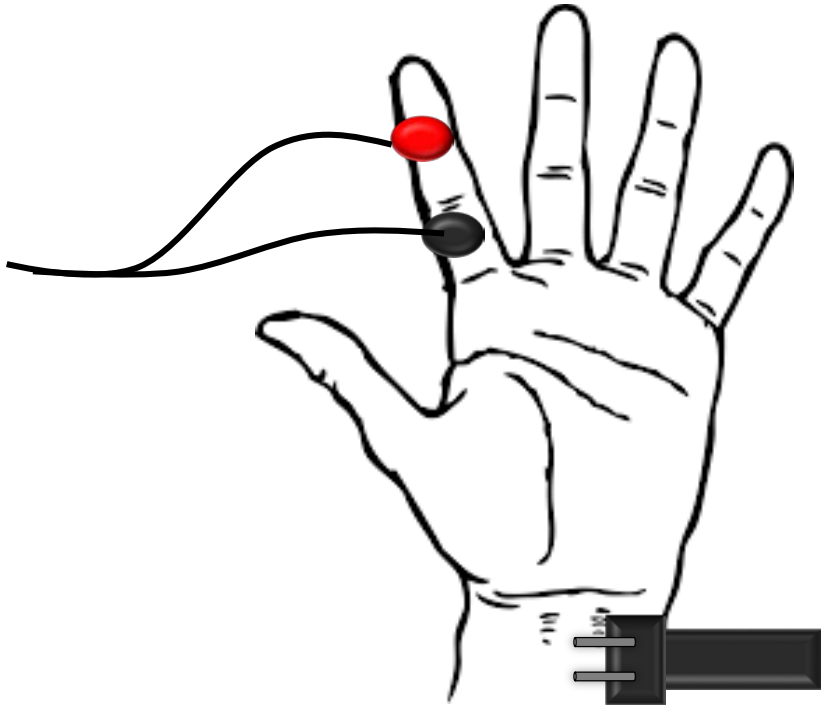
- 45-year-old male complains of bilateral hand paresthesias.
- Median MNC Rec: APB



Median-APB	Latency	Amplitude	CV
Stim: Wrist	**6.5 msec**	5.4 mV	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Principle #1

- 45-year-old male complains of bilateral hand paresthesias.
- Median MNC Rec: APB
- Median SNC Rec: Index Finger (D2)



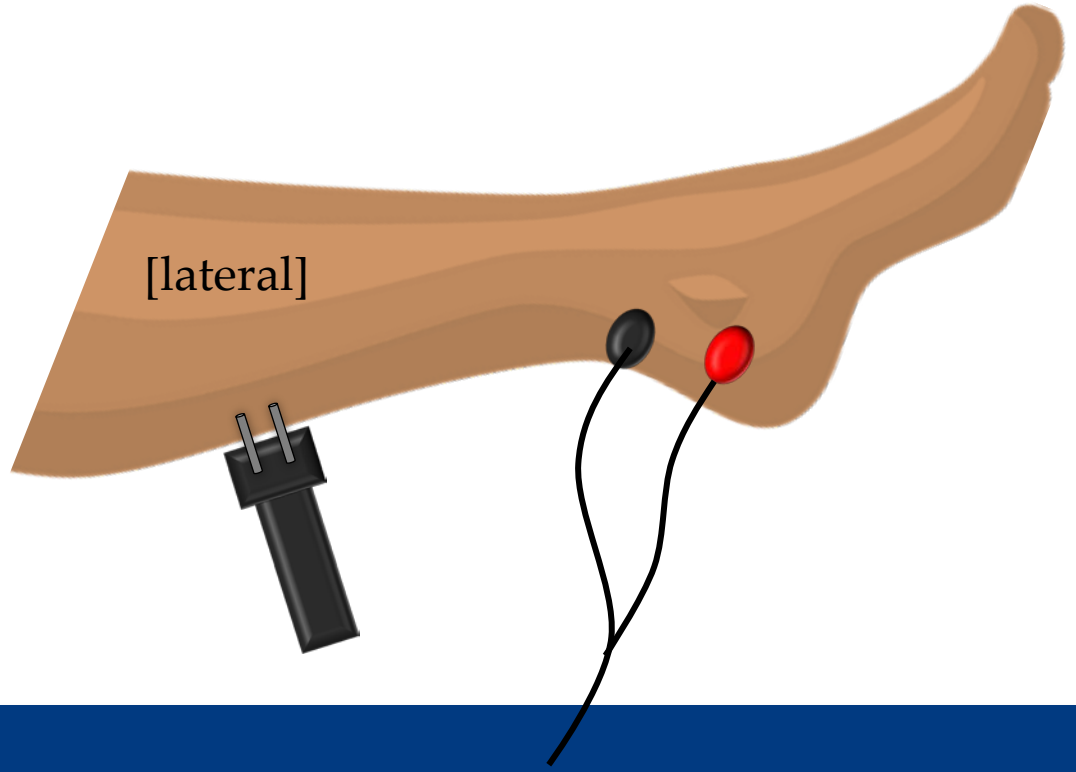
Median-APB	Latency	Amplitude	CV
Stim: Wrist	**6.5 msec**	5.4 mV	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Median-D2	Latency	Amplitude	CV
Stim: Wrist	3.1 msec	55 uV	53 m/s
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*

Principle #1

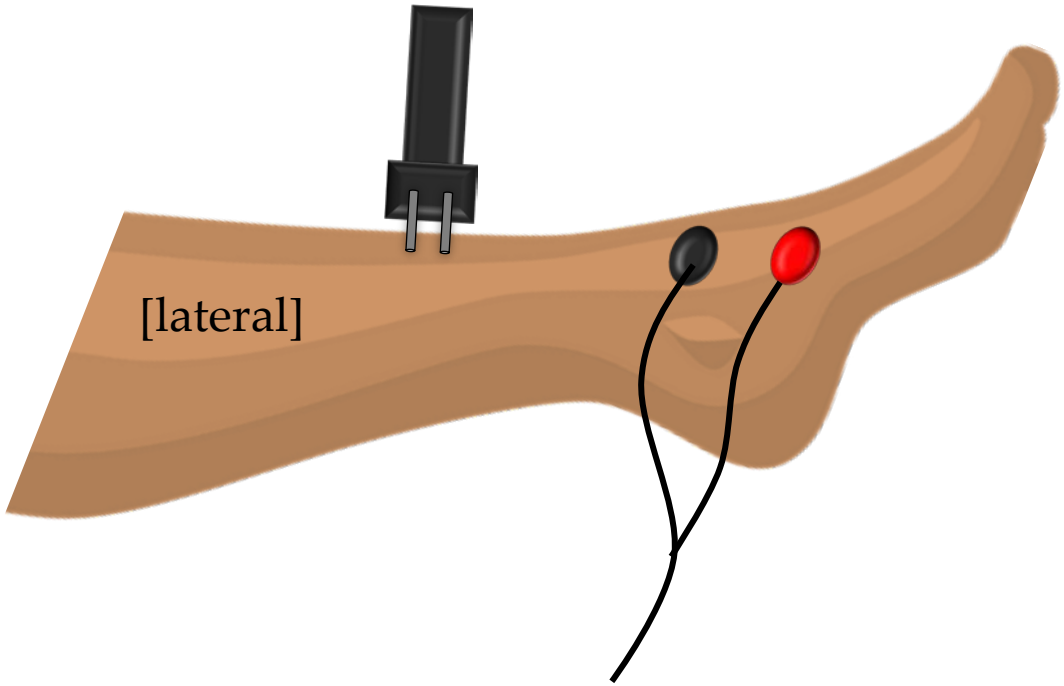
- 58-year-old female diabetic presenting with 5 years of paresthesias of the toes.
- Sural SNC

Sural	Latency	Amplitude	CV
Stim: Calf	**NR**	NR	NR
Reference:	*< 4.5 msec*	*> 4.0 uV*	*> 40 m/s*



Principle #1

- 58-year-old female diabetic presenting with 5 years of paresthesias of the toes.
- Sural SNC
- Superficial Fibular (Peroneal) SNC

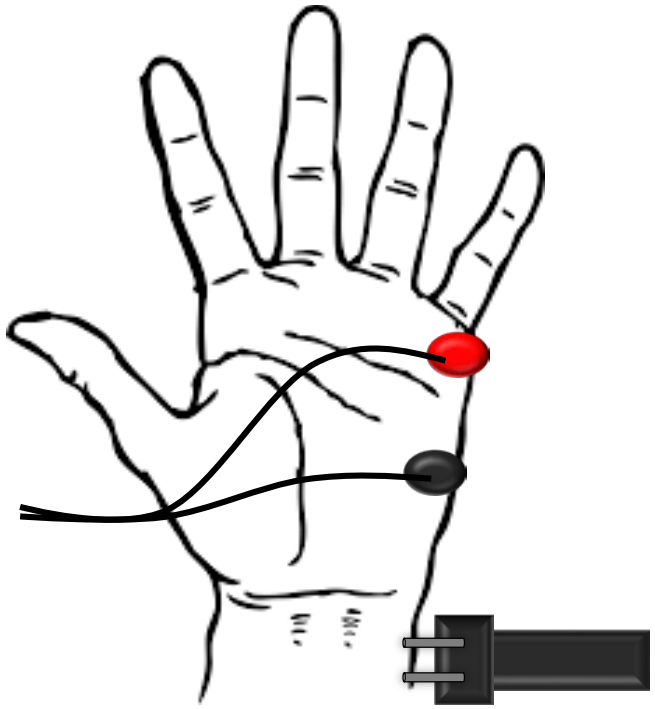


Sural	Latency	Amplitude	CV
Stim: Calf	**NR**	**NR**	**NR**
Reference:	*< 4.5 msec*	*> 4 uV*	*> 40 m/s*

Fibular	Latency	Amplitude	CV
Stim: Ant Leg	3.1 msec	17 uV	49 m/s
Reference:	*< 4.5 msec*	*> 6 uV*	*> 40 m/s*

Principle #1

- 35-year-old male complains of wrist pain without weakness or paresthesias.
- Ulnar MNC Rec: ADM



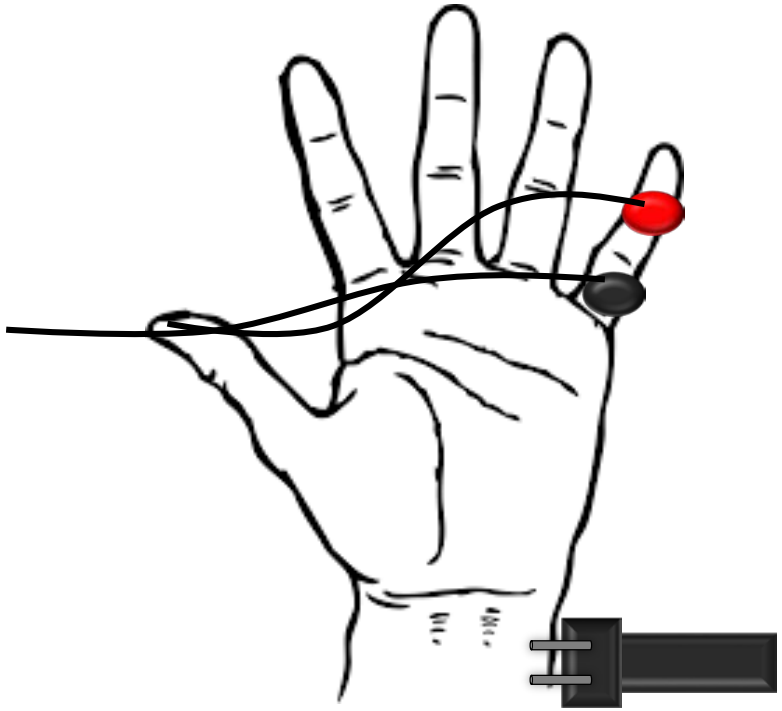
Ulnar-ADM	Latency	Amplitude	CV
Stim: Wrist	2.9 msec	12.5 mV	--
Stim: Below Elbow		**3.1 mV**	**42 m/s**
Stim: Above Elbow		12.3 mV	56 m/s
Reference:	*< 3.8 msec*	*> 7.8 mV*	*> 49 m/s*

Principle #1

Repeat the study if the results don't make sense. Check everything!

Principle #2

- 40-year-old female presents with paresthesias of the left ring and small fingers during sleep and while resting her elbow on a desk while using a computer.
- Ulnar SNC Rec: Small Finger (D5)

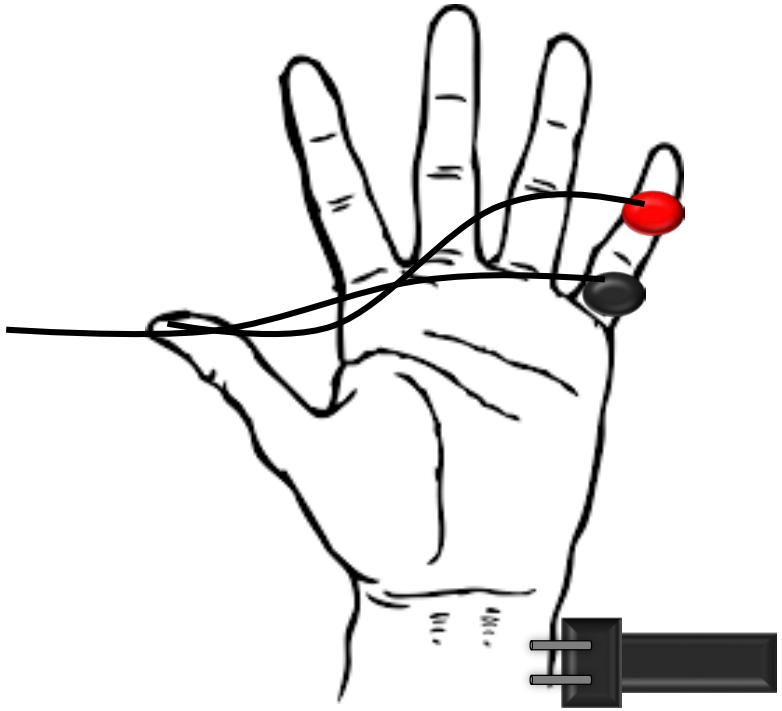


Ulnar-D5	Latency	Amplitude	CV
L. Wrist	3.8 msec	11 uV	**47 m/s**
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

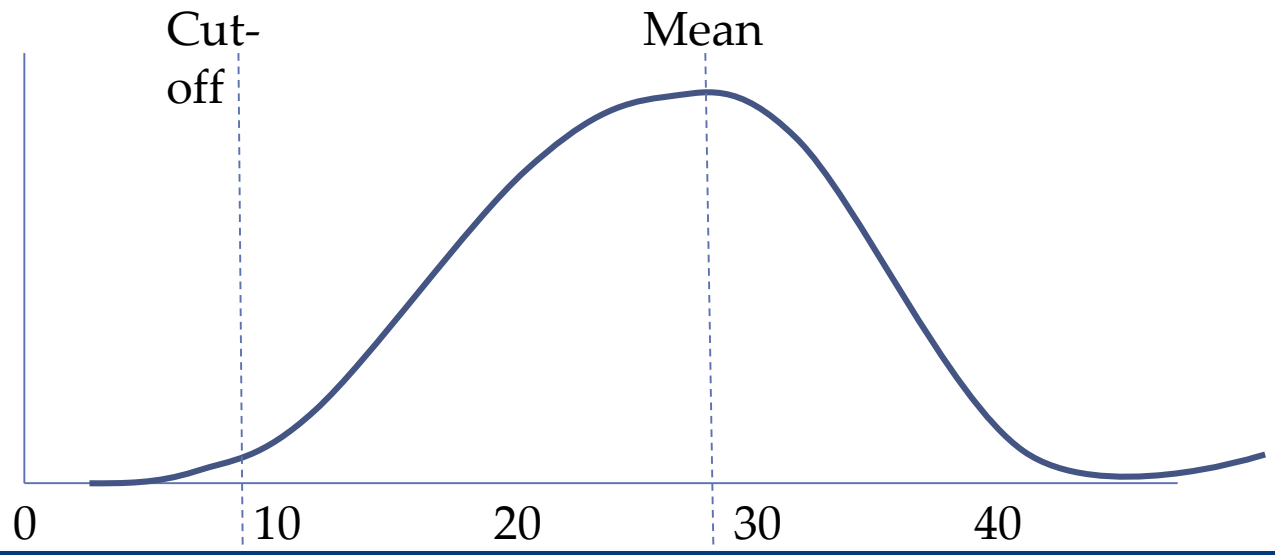
Is there evidence of sensory axon loss?

Principle #2

- 40-year-old female presents with paresthesias of the left ring and small fingers during sleep and while resting her elbow on a desk while using a computer.
- Ulnar SNC Rec: Small Finger (D5)

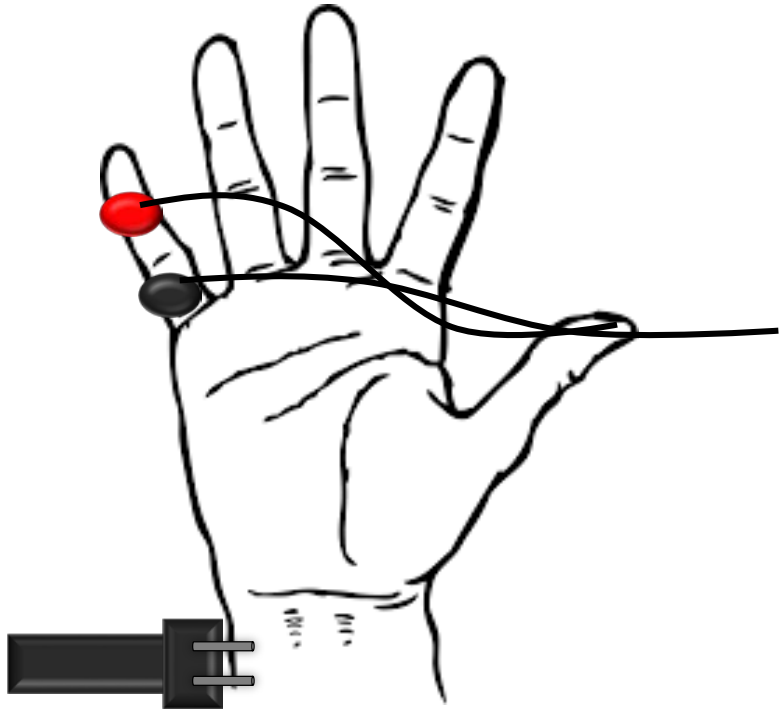


Ulnar-D5	Latency	Amplitude	CV
L. Wrist	3.8 msec	11 uV	**47 m/s**
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*



Principle #2

- 40-year-old female presents with paresthesias of the left ring and small fingers during sleep and while resting her elbow on a desk while using a computer.
- Ulnar SNC Rec: Small Finger (D5)



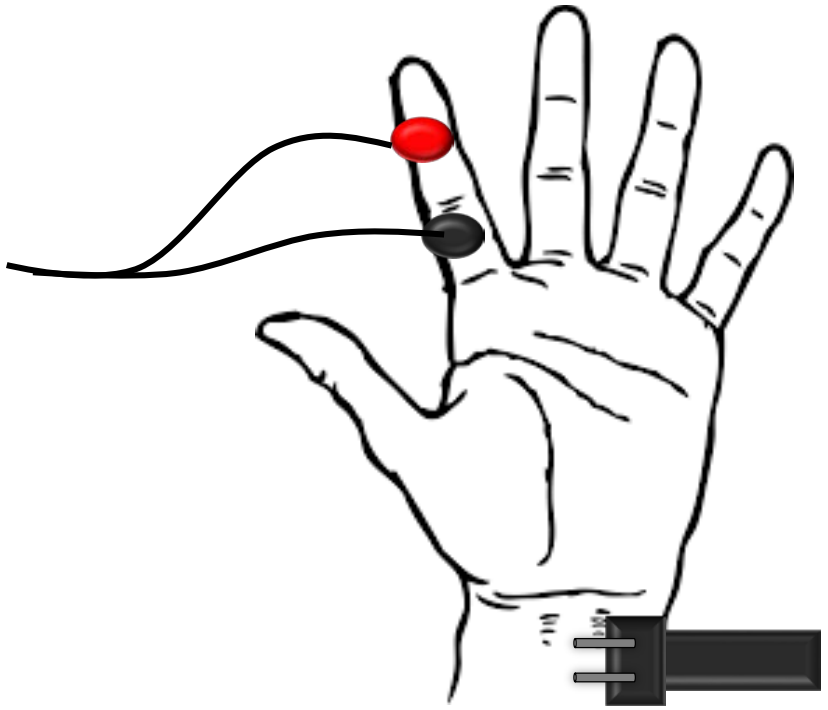
Ulnar-D5	Latency	Amplitude	CV
L. Wrist	3.8 msec	11 uV	**47 m/s**
R. Wrist	3.2 msec	28 uV	54 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

Principle #2

Contralateral studies can help establish the patient's own normal values.

Principle #3

- 46-year-old male housekeeper presents with 3 months of intermittent numbness in bilateral thumb and index fingers, especially when using a vacuum.
- Median SNC Rec: Index finger (D2)

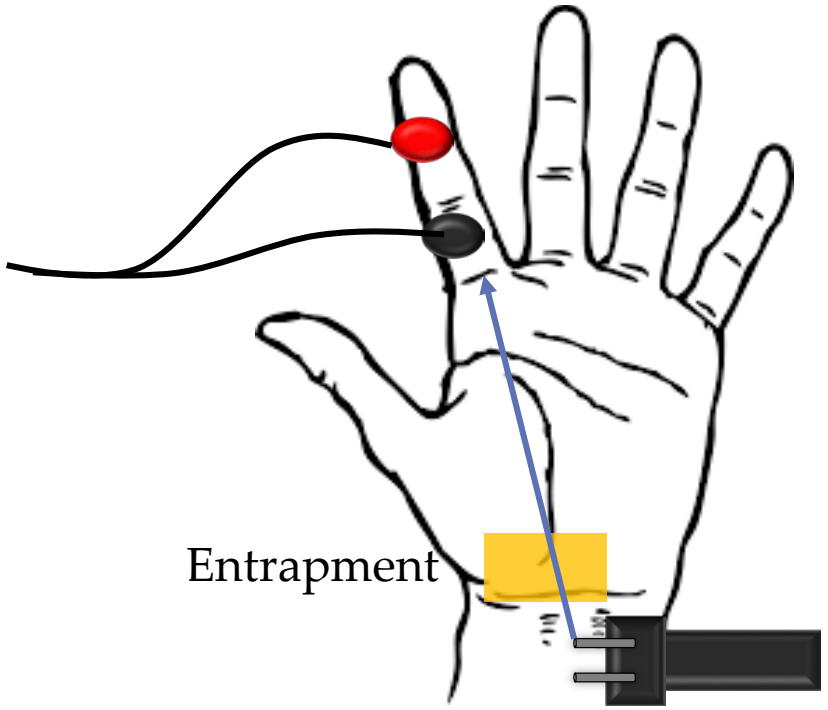


Median-D2	Latency	Amplitude	CV
R. Wrist	**NR**	**NR**	**NR**
L. Wrist	**5.2 msec**	**10 uV**	**33 m/s**
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*

Is there evidence of sensory axon loss?

Principle #3

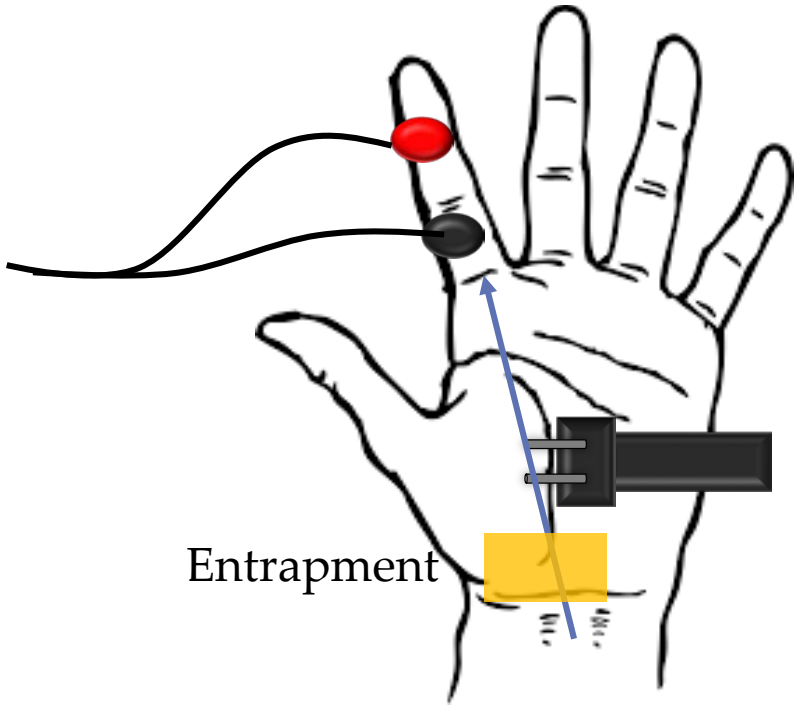
- 46-year-old male housekeeper presents with 3 months of intermittent numbness in bilateral thumb and index fingers, especially when using a vacuum.
- Median SNC Rec: Index finger (D2)



Median-D2	Latency	Amplitude	CV
R. Wrist	**NR**	**NR**	**NR**
L. Wrist	**5.2 msec**	**10 uV**	**33 m/s**
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*

Principle #3

- 46-year-old male housekeeper presents with 3 months of intermittent numbness in bilateral thumb and index fingers, especially when using a vacuum.
- Median SNC Rec: Index finger (D2)



Median-D2	Latency	Amplitude	CV
R. Wrist	**NR**	**NR**	**NR**
R. Mid-palm		**6 uV**	51 m/s
L. Wrist	**5.2 msec**	**10 uV**	**33 m/s**
L. Mid-palm		23 uV	59 m/s
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*

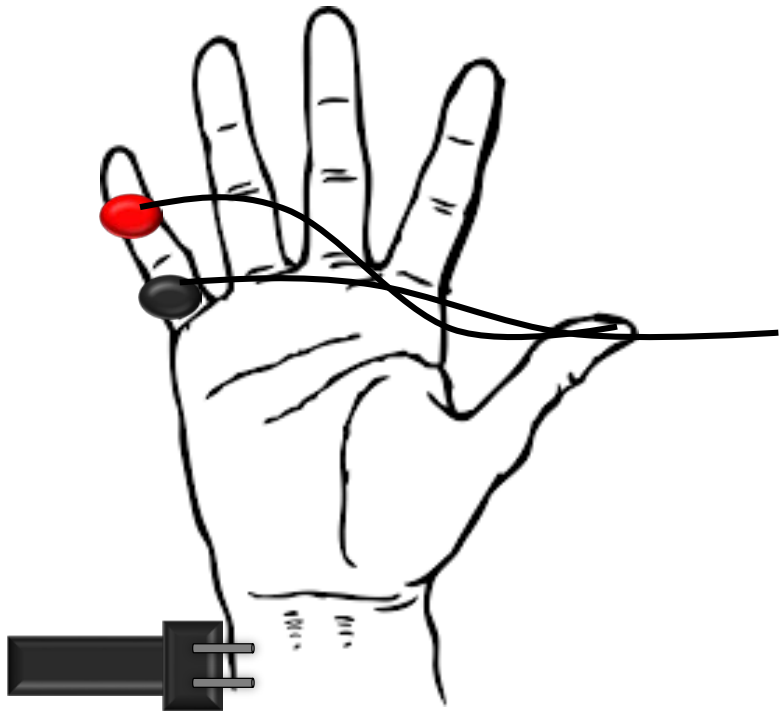
Evidence of bilateral conduction block and right-sided axon loss.

Principle #3

Low amplitude usually means axon loss UNLESS there is conduction block distal to the stimulation site.

Principle #4

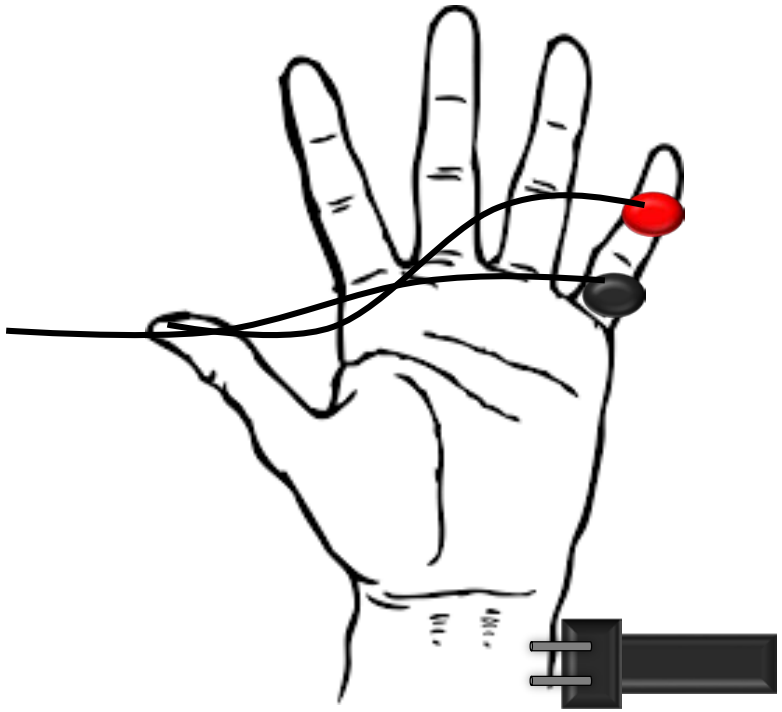
- 60-year-old male complains of numbness of the ring and small fingers (D4-5) and medial hand after 4-vessel cardiac bypass graft surgery.
- Ulnar SNC Rec: Small finger (D5)



Ulnar-D5	Latency	Amplitude	CV
R. Wrist	3.8 msec	**4 uV**	**47 m/s**
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

Principle #4

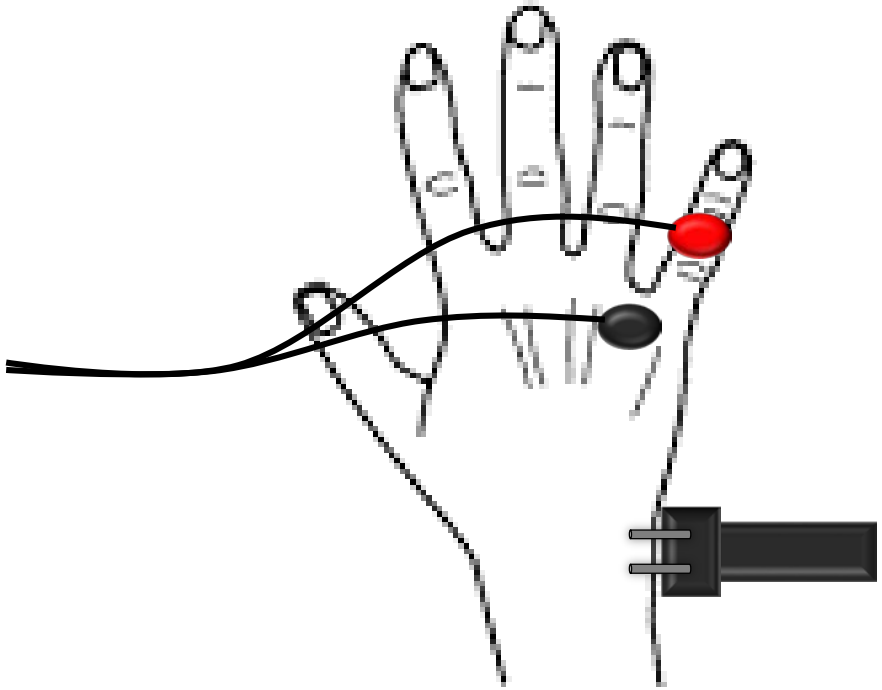
- 60-year-old male complains of numbness of the ring and small fingers (D4-5) and medial hand after 4-vessel cardiac bypass graft surgery.
- Ulnar SNC Rec: Small finger (D5)



Ulnar-D5	Latency	Amplitude	CV
R. Wrist	3.8 msec	**4 uV**	**47 m/s**
L. Wrist	3.1 msec	12 uV	50 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

Principle #4

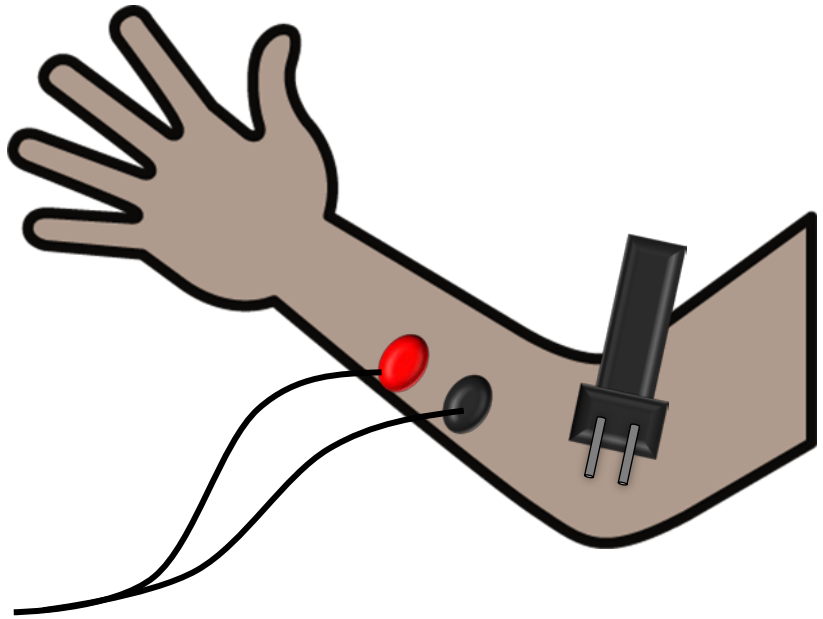
- 60-year-old male complains of numbness of the ring and small fingers (D4-5) and medial hand after 4-vessel cardiac bypass graft surgery.
- Dorsal Cutaneous Branch Ulnar N.



Ulnar-D5	Latency	Amplitude	CV
R. Wrist	3.8 msec	**4 uV**	**47 m/s**
L. Wrist	3.1 msec	12 uV	50 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*
DCBUN	**NR**	**NR**	**NR**

Principle #4

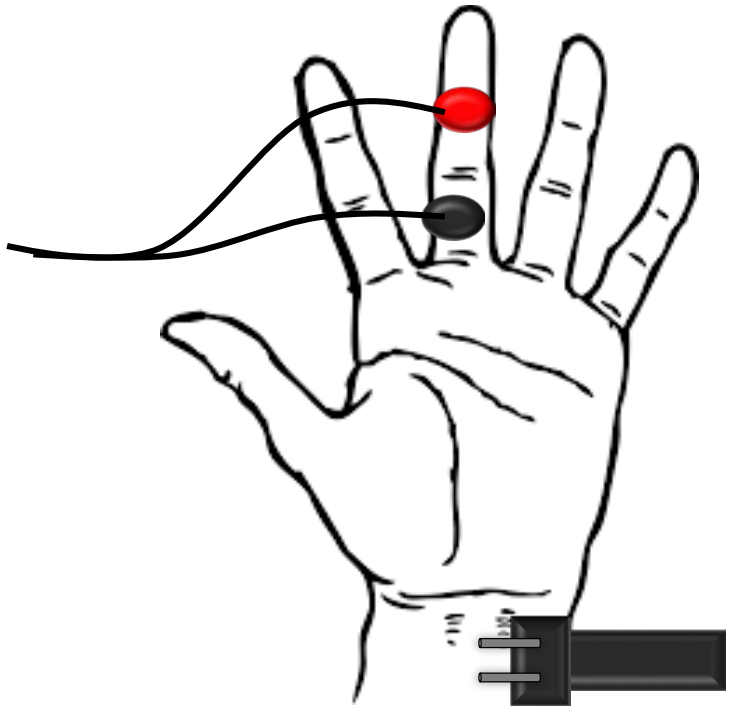
- 60-year-old male complains of numbness of the ring and small fingers (D4-5) and medial hand after 4-vessel cardiac bypass graft surgery.
- Medial Cutaneous N. Forearm



Ulnar-D5	Latency	Amplitude	CV
R. Wrist	3.8 msec	**4 uV**	**47 m/s**
L. Wrist	3.1 msec	12 uV	50 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*
DCBUN	**NR**	**NR**	**NR**
MCNF	NR	NR	NR

Principle #4

- 60-year-old male complains of numbness of the ring and small fingers (D4-5) and medial hand after 4-vessel cardiac bypass graft surgery.
- Median SNC Rec: Long Finger (D3)

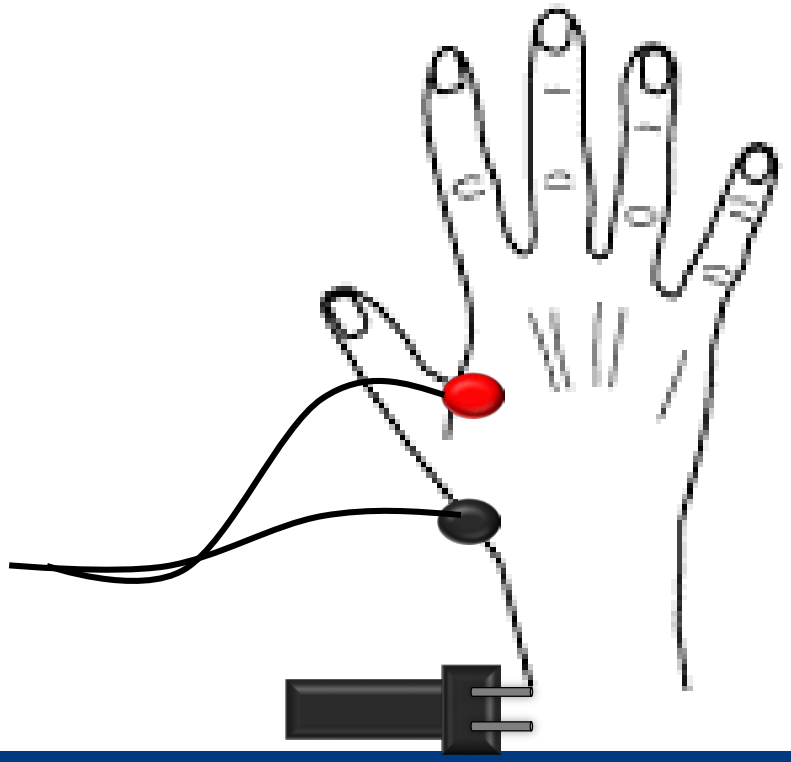


Ulnar-D5	Latency	Amplitude	CV
R. Wrist	3.8 msec	**4 uV**	**47 m/s**
L. Wrist	3.1 msec	12 uV	50 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

DCBUN	**NR**	**NR**	**NR**
MCNF	NR	NR	NR
Median-D3	Normal	Normal	Normal

Principle #4

- 60-year-old male complains of numbness of the ring and small fingers (D4-5) and medial hand after 4-vessel cardiac bypass graft surgery.
- Superficial Radial SNC



Ulnar-D5	Latency	Amplitude	CV
R. Wrist	3.8 msec	**4 uV**	**47 m/s**
L. Wrist	3.1 msec	12 uV	50 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

DCBUN	**NR**	**NR**	**NR**
MCNF	NR	NR	NR
Median-D3	Normal	Normal	Normal
Radial	Normal	Normal	Normal

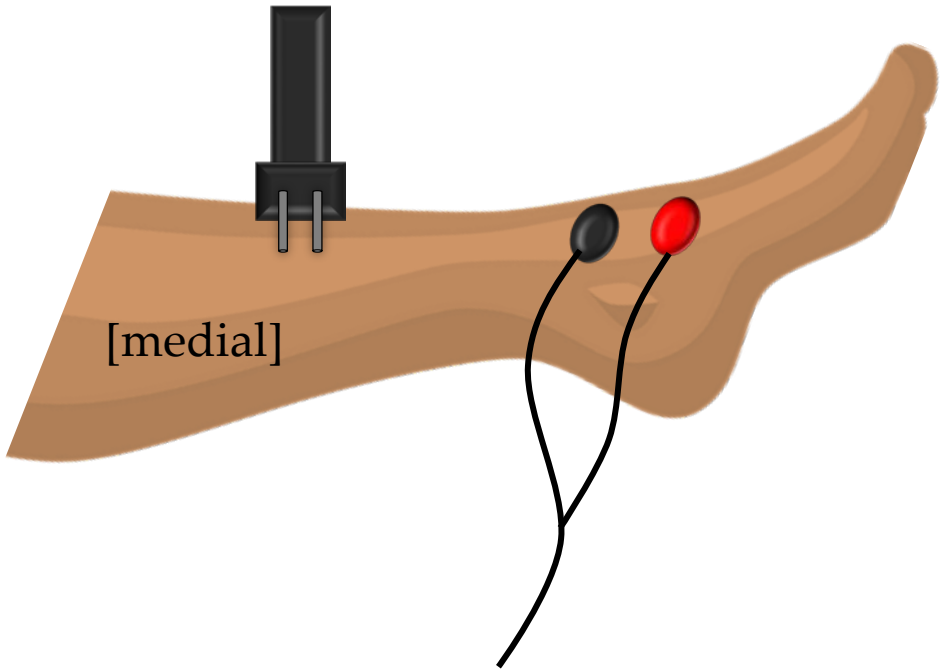
Diagnosis: Brachial Plexopathy

Principle #4

Keep looking until you find a normal nerve (within reason).

Principle #5

- 57-year-old female presents with back pain, left knee "giving out," and numbness of the left medial lower leg.
- Left saphenous SNC



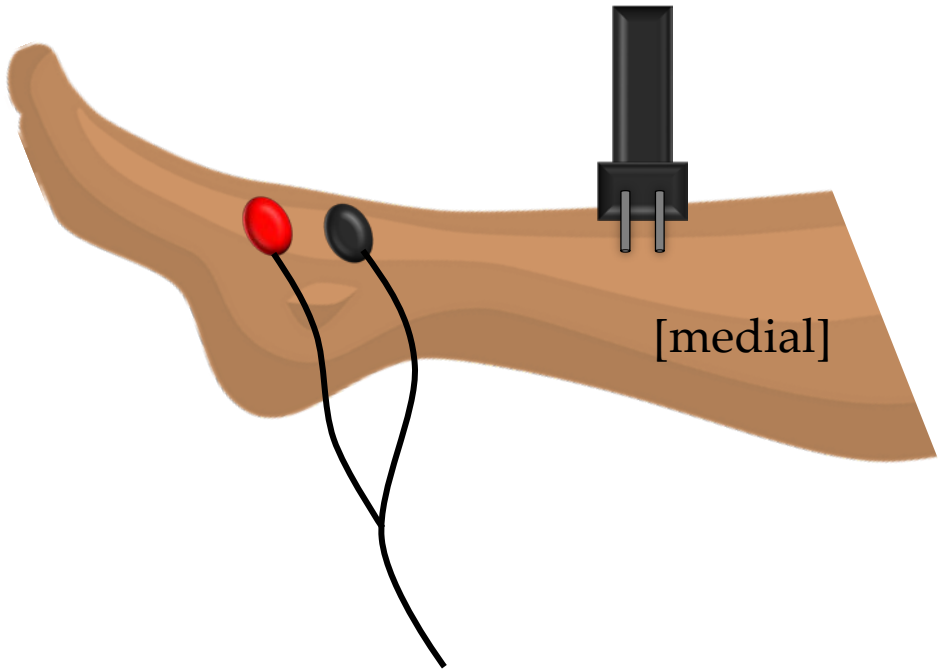
Tibial MNC	Normal	Normal	Normal
Fibular MNC	Normal	Normal	Normal
Sural SNC	Normal	Normal	Normal
Fibular SNC	Normal	Normal	Normal

Saphenous	Latency	Amplitude	CV
Left	NR	NR	NR
Reference:	*< 4.4 msec*	*> 4 uV*	*> 40 m/s*

Diagnosis?

Principle #5

- 57-year-old female presents with back pain, left knee "giving out," and numbness of the left medial lower leg.
- Right saphenous SNC



Tibial MNC	Normal	Normal	Normal
Fibular MNC	Normal	Normal	Normal
Sural SNC	Normal	Normal	Normal
Fibular SNC	Normal	Normal	Normal

Saphenous	Latency	Amplitude	CV
Left	NR	NR	NR
Right	NR	NR	NR
Reference:	*< 4.4 msec*	*> 4 uV*	*> 40 m/s*

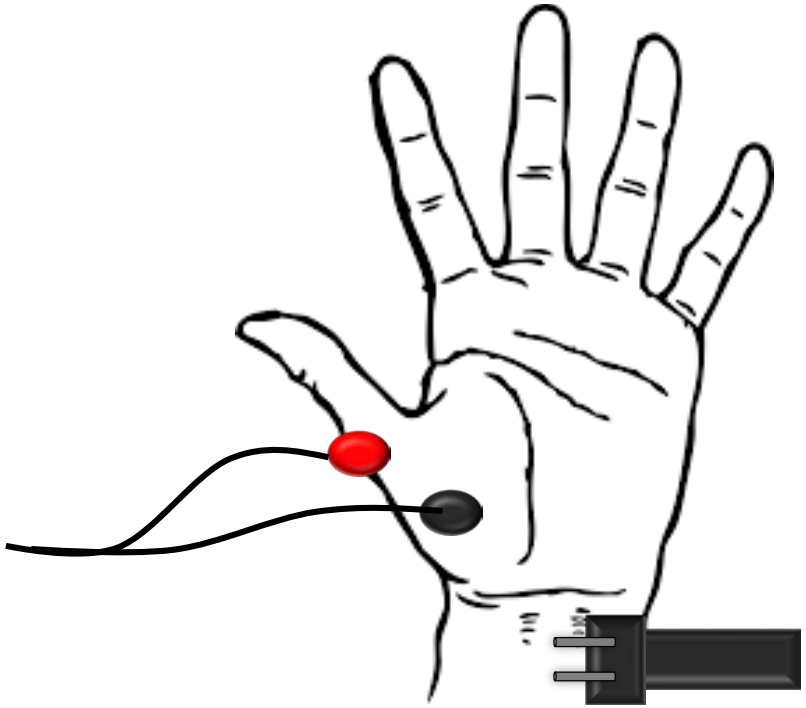
Diagnosis: pending EMG

Principle #5

For difficult nerves, study the asymptomatic side first to ensure you can get a response.

Principle #6

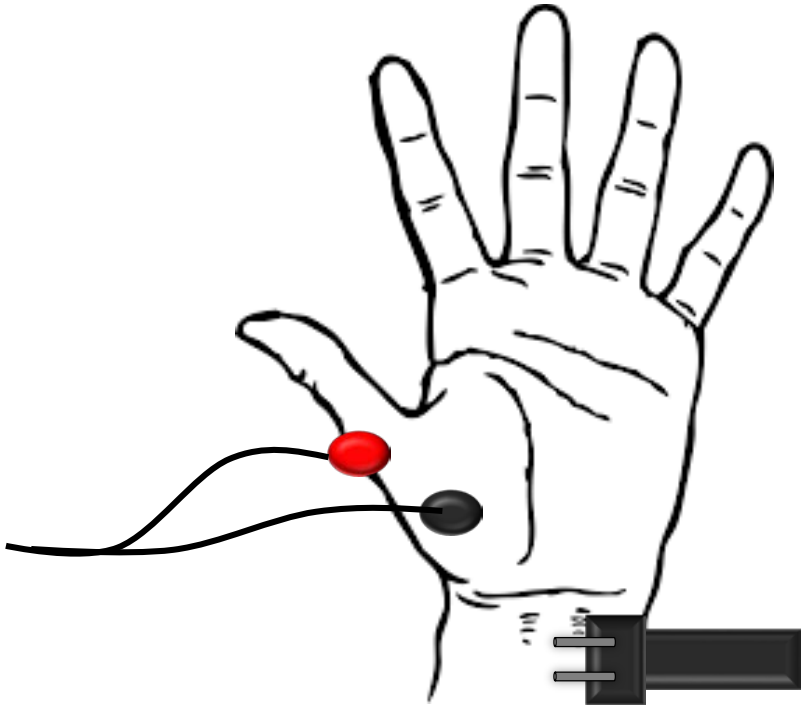
- 37-year-old male presents with >10 years of double vision, eyelid drooping, difficulty swallowing, weakness of the legs, and abnormal gait.
- Median MNC Rec: APB



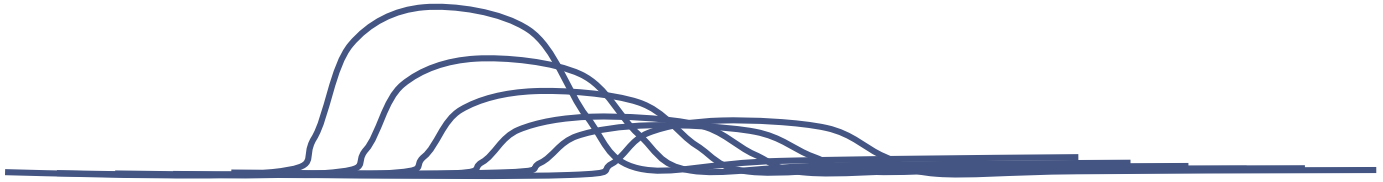
Median-APB	Latency	Amplitude	CV
Stim: Wrist	3.4 msec	4.3 mV	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Principle #6

- 37-year-old male presents with >10 years of double vision, eyelid drooping, difficulty swallowing, weakness of the legs, and abnormal gait.
- Median MNC Rep. Stim.



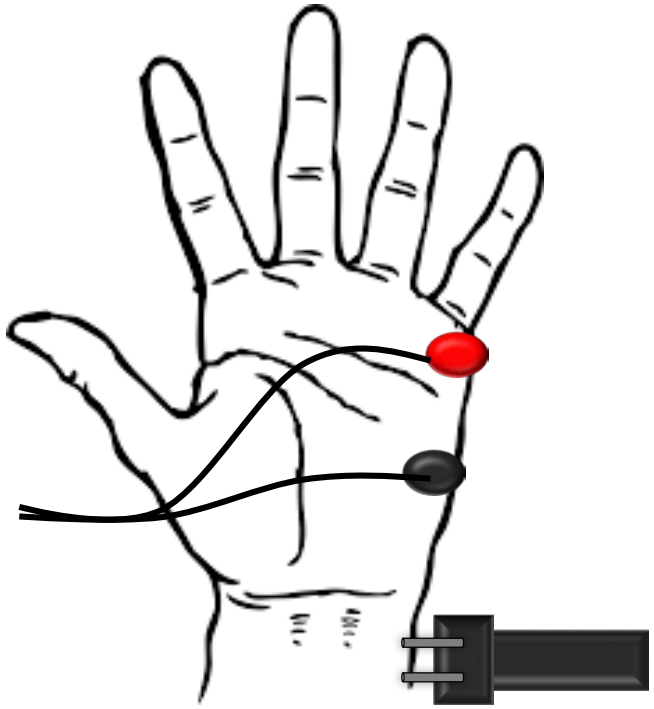
Median-APB	Latency	Amplitude	CV
Stim: Wrist	3.4 msec	4.3 mV	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--



Diagnosis?

Principle #6

- 37-year-old male presents with >10 years of double vision, eyelid drooping, difficulty swallowing, weakness of the legs, and abnormal gait.
- Ulnar MNC Rec: ADM

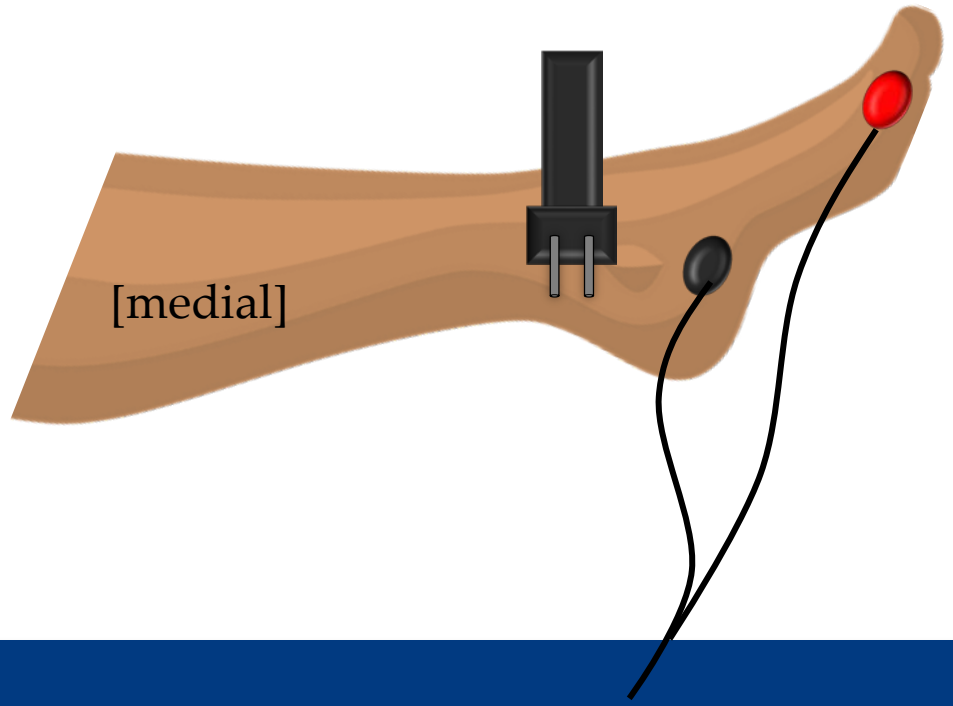


Median-APB	Latency	Amplitude	CV
Stim: Wrist	3.4 msec	4.3 mV	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Ulnar-ADM	Latency	Amplitude	CV
Stim: Wrist	2.9 msec	**1.4 mV**	--
Stim: Below Elbow		**1.2 mV**	50 m/s
Stim: Above Elbow		**1.1 mV**	51 m/s
Reference:	*< 3.8 msec*	*> 7.8 mV*	*>49 m/s*

Principle #6

- 37-year-old male presents with >10 years of double vision, eyelid drooping, difficulty swallowing, weakness of the legs, and abnormal gait.
- Tibial MNC Rec: AH

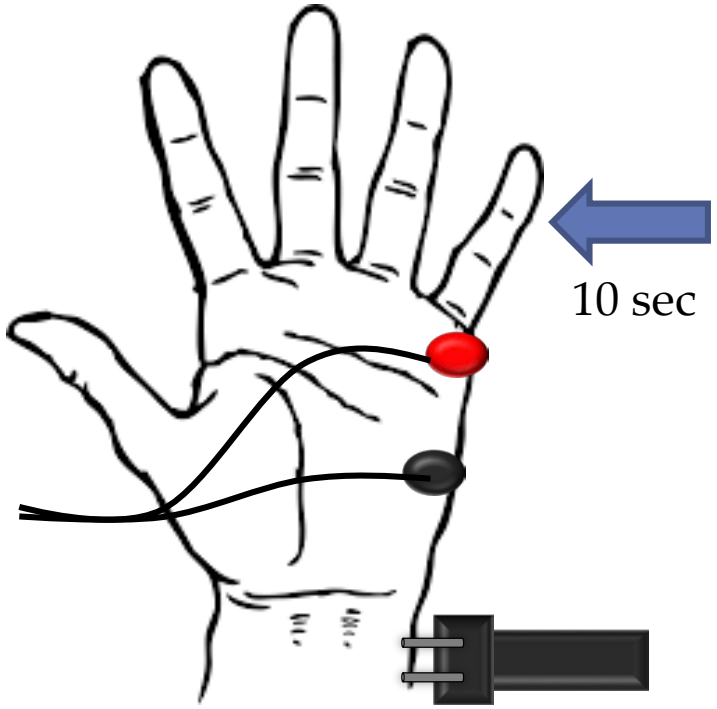


Tibial-AH	Latency	Amplitude	CV
Stim: Ankle	4.9 msec	**0.8 mV**	--
Reference:	*< 6.1 msec*	*> 4.4 mV*	

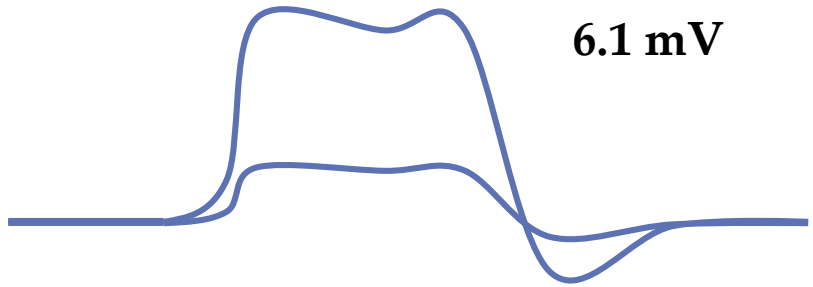
Median SNC	Normal
Ulnar SNC	Normal
Sural SNC	Normal

Principle #6

- 37-year-old male presents with >10 years of double vision, eyelid drooping, difficulty swallowing, weakness of the legs, and abnormal gait.



Ulnar-ADM	Latency	Amplitude	CV
Stim: Wrist	2.9 msec	**1.4 mV**	--
Reference:	*< 3.8 msec*	*> 7.8 mV*	



Diagnosis?

Principle #6

If motor amplitudes are diffusely low, check for post-exercise facilitation.

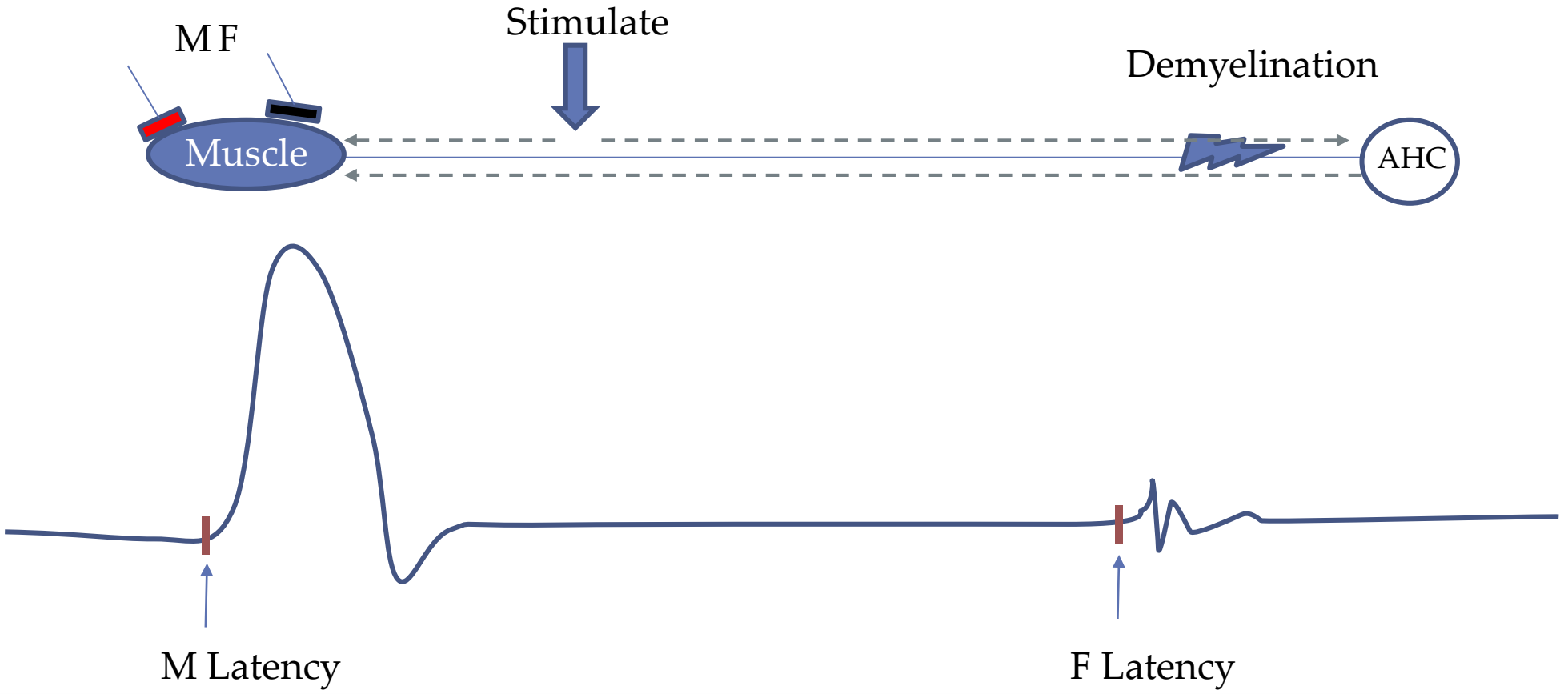
Principle #7

- 23-year-old female admitted for rapidly progressive weakness.
- Median, Ulnar, Tibial MNC: Normal
- Median, Ulnar, Sural SNC: Normal

What else should be done?

Principle #7

F waves:



Principle #7

- 23-year-old female admitted for rapidly progressive weakness.
- Median, Ulnar, Tibial MNC: Normal
- Median, Ulnar, Sural SNC: Normal

F-waves	Latency	Reference
Median	NR	< 31 msec
Ulnar	NR	< 32 msec
Tibial	86 msec	< 56 msec

Diagnosis?

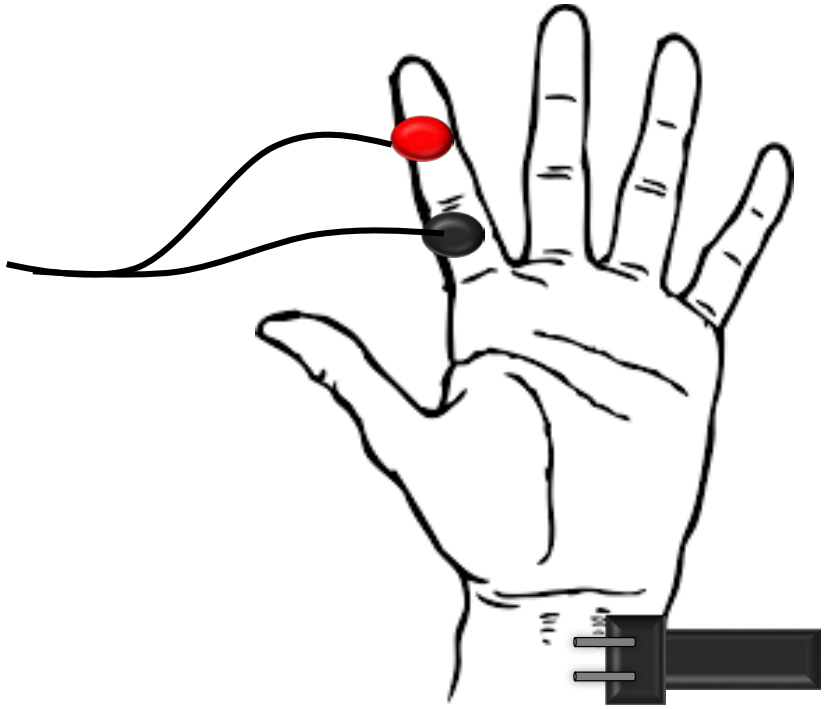


Principle #7

Think about F-waves and H-waves for polyneuropathy evaluations.

Principle #8

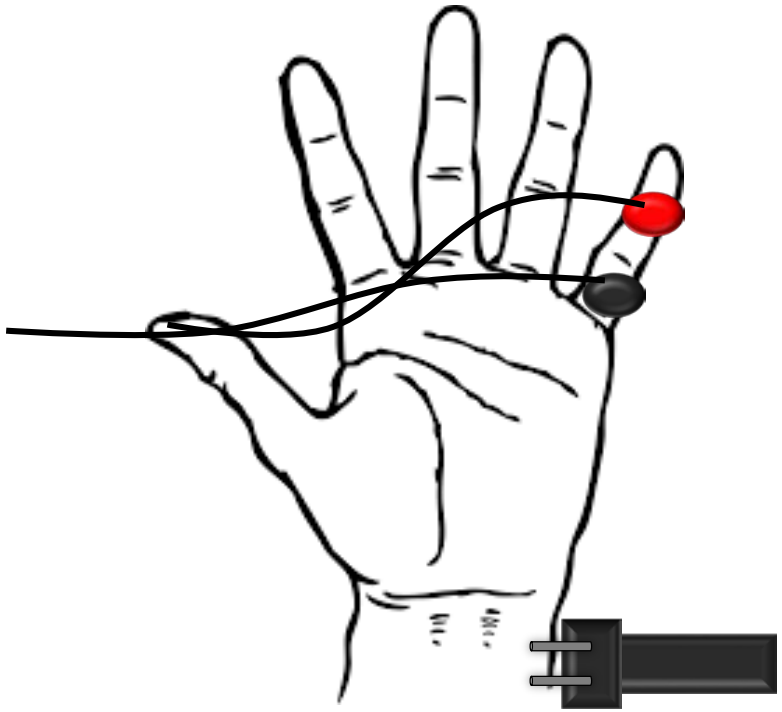
- 45-year-old male with known carpal tunnel syndrome presents with constant numbness of the dorsal lateral palm, thumb, index, and middle fingers.
- Median SNC Rec: Index Finger (D2)



Median-D2	Latency	Amplitude	CV
L. Wrist	4.5 msec	10 uV	37 m/s
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*

Principle #8

- 45-year-old male with known carpal tunnel syndrome presents with constant numbness of the dorsal lateral palm, thumb, index, and middle fingers.
- Ulnar SNC Rec: Small Finger (D5)



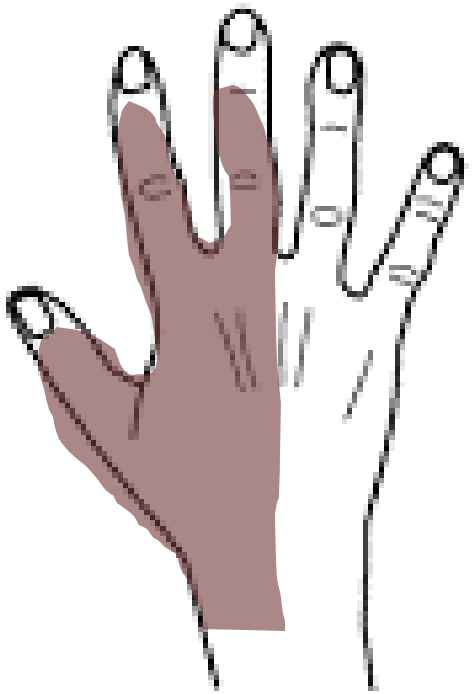
Median-D2	Latency	Amplitude	CV
L. Wrist	**4.5 msec**	**10 uV**	**37 m/s**
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*

Ulnar-D5	Latency	Amplitude	CV
L. Wrist	3.3 msec	17 uV	52 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

Diagnosis?

Principle #8

- 45-year-old male with known carpal tunnel syndrome presents with constant numbness of the dorsal lateral palm, thumb, index, and middle fingers.

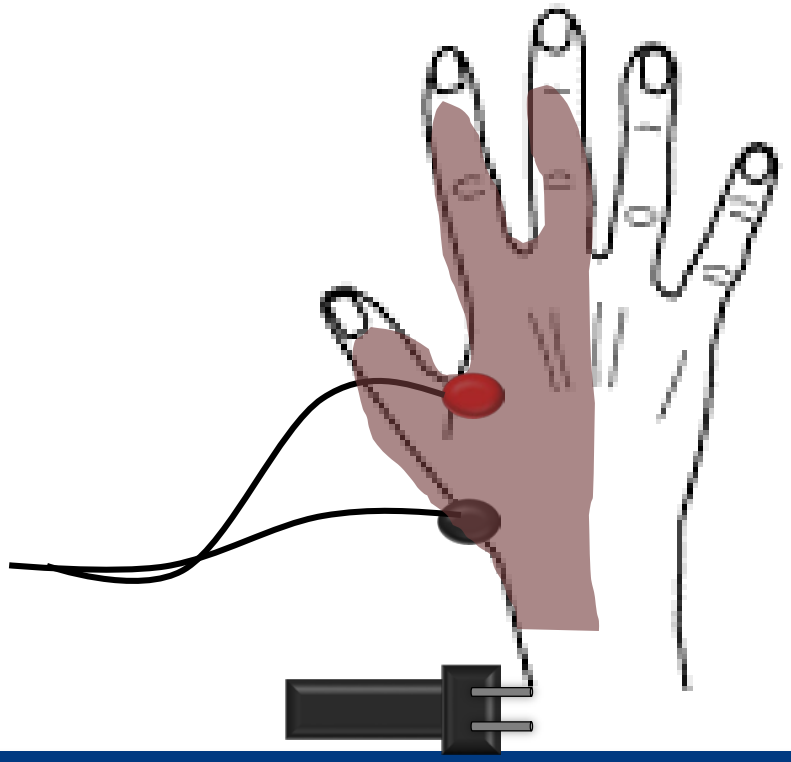


Median-D2	Latency	Amplitude	CV
L. Wrist	**4.5 msec**	**10 uV**	**37 m/s**
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*

Ulnar-D5	Latency	Amplitude	CV
L. Wrist	3.3 msec	17 uV	52 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*

Principle #8

- 45-year-old male with known carpal tunnel syndrome presents with constant numbness of the dorsal lateral palm, thumb, index, and middle fingers.
- Radial SNC Rec: Snuffbox



Median-D2	Latency	Amplitude	CV
L. Wrist	**4.5 msec**	**10 uV**	**37 m/s**
Reference:	*< 4.0 msec*	*> 19 uV*	*> 49 m/s*
Ulnar-D5	**Latency**	**Amplitude**	**CV**
L. Wrist	3.3 msec	17 uV	52 m/s
Reference:	*< 4.0 msec*	*> 10 uV*	*> 49 m/s*
Radial	**Latency**	**Amplitude**	**CV**
L. Wrist	**3.1 msec**	**6 uV**	**46 m/s**
Reference:	*< 2.8 msec*	*> 10 uV*	*> 49 m/s*

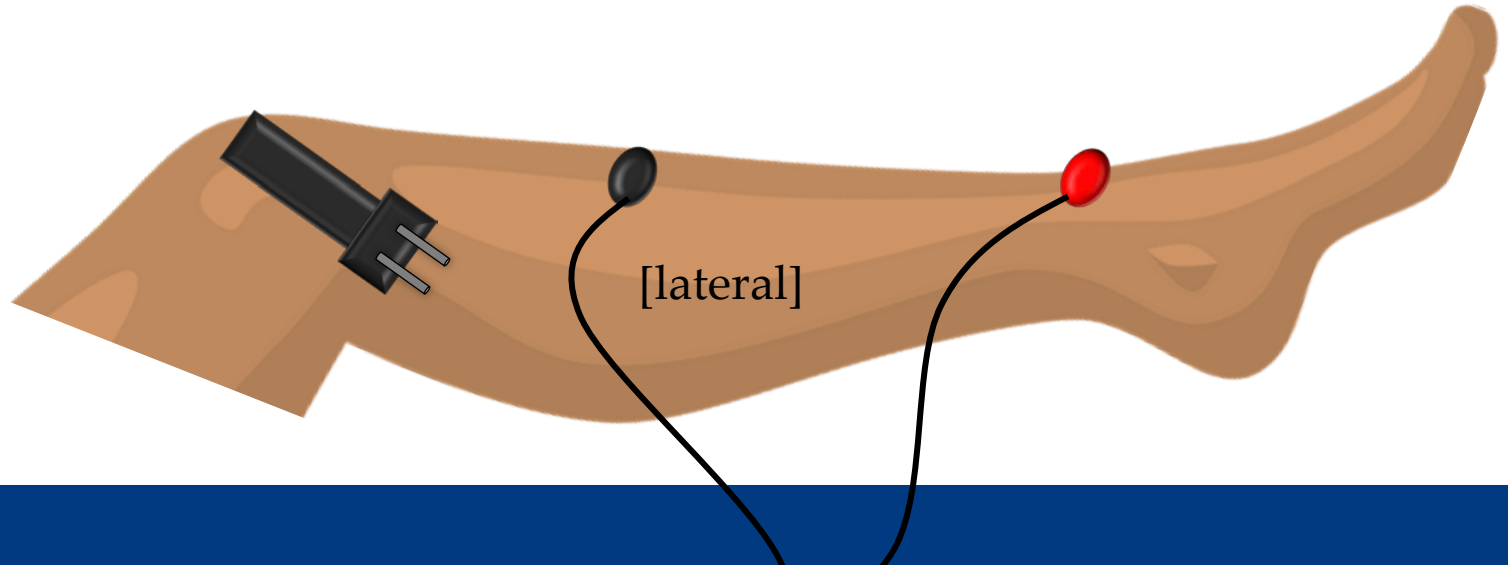
Principle #8

Study the symptomatic region whenever possible.

Principle #9

- 25-year-old male with weakness of ankle dorsiflexion (foot drop).
- Fibular (peroneal) MNC Rec: Tibialis Anterior

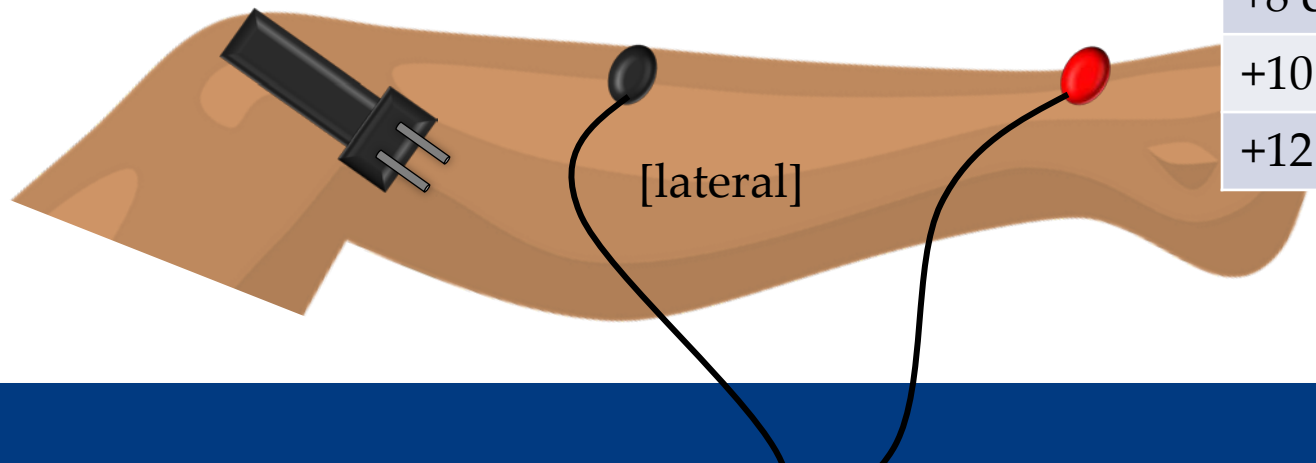
Fibular-TA	Latency	Amplitude	CV
Fibular head	5.2 msec	6.4 mV	--
Knee		5.8 mV	**42 m/s**
Reference:	*< 6.7 msec*	*> 3.0 mV*	*> 44 m/s*



Principle #9

- 25-year-old male with weakness of ankle dorsiflexion (foot drop).
- Fibular (peroneal) MNC Rec: Tibialis Anterior
- Inching Studies

Fibular-TA	Latency	Amplitude	Latency Diff
Fibular head	5.2 msec	6.4 mV	--
+2 cm	5.5 msec	6.4 mV	0.3 msec
+4 cm	5.8 msec	6.4 mV	0.3 msec
+6 cm	6.1 msec	6.3 mV	0.3 msec
+8 cm	**7.3 msec**	**5.8 mV**	**1.2 msec**
+10 cm	7.5 msec	5.8 mV	0.2 msec
+12 cm	7.8 msec	5.7 mV	0.2 msec

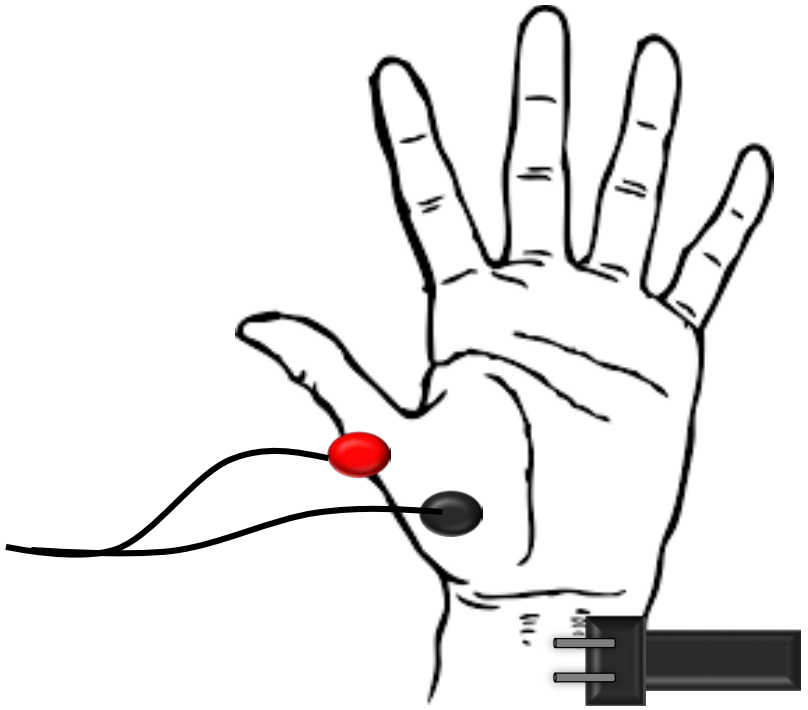


Principle #9

Segmental or inching studies can detect focal slowing or conduction block that may be missed on routine NCS.

Principle #10

- 60-year-old male presents with…
- Median MNC Rec: APB



Median-APB	Latency	Amplitude	CV
Stim: Wrist	**4.8 msec**	**1.1 mV**	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Carpal tunnel syndrome?
Motor neuron disease?
NMJ Disorder?
Technical error?
What did you expect to find?

Principle #10

- 60-year-old male presents with…
- Median MNC Rec: APB
- **Listen to the patient.**

Median-APB	Latency	Amplitude	CV
Stim: Wrist	**4.8 msec**	**1.1 mV**	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Carpal tunnel syndrome – Hand paresthesias?
Motor neuron disease – Painless weakness?
NMJ Disorder – Generalized weakness, smoker?
Technical error – Vague/nonspecific symptoms?

Principle #10

- 60-year-old male presents with…
- Median MNC Rec: APB
- **Look at the patient.**

Median-APB	Latency	Amplitude	CV
Stim: Wrist	**4.8 msec**	**1.1 mV**	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Carpal tunnel syndrome – Normal bulk of thenar eminence?
Motor neuron disease – Atrophy of hand muscles?
NMJ Disorder – Abnormal gait, eyelid drooping?
Technical error – Extremity edema, obesity, cold?

Principle #10

- 60-year-old male presents with…
- Median MNC Rec: APB

Median-APB	Latency	Amplitude	CV
Stim: Wrist	**4.8 msec**	**1.1 mV**	--
Reference:	*< 4.6 msec*	*> 4.2 mV*	--

Carpal tunnel syndrome – Stimulate palm.
Motor neuron disease – Check other motor studies.
NMJ Disorder – Post-exercise facilitation, rep stim.
Technical error – Check study parameters/setup.

Principle #10

Listen to the patient.

Look at the patient.

Remember Principle #1

Repeat the study if the results don't make sense. Check everything!

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Questions?

Thanks for your attention!