



Upper and Lower Extremity Nerve Conduction Studies

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Financial Disclosure

I have received speaking and consulting honoraria from Alexion Pharmaceuticals.

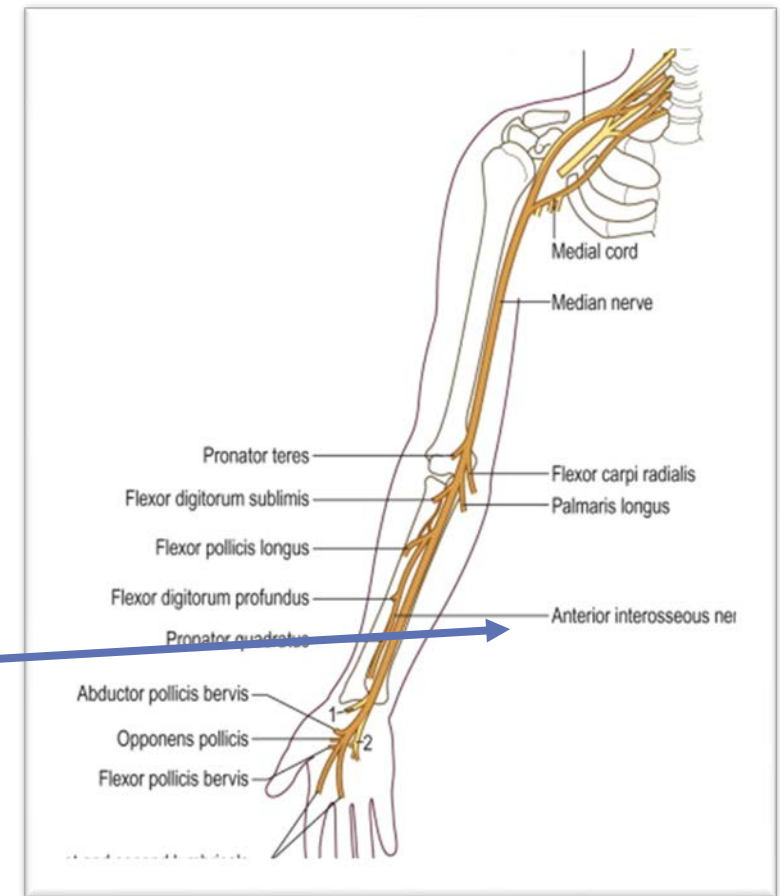
I have received consulting honoraria from UCB and Argenx.

Outline for Today's talk

- **Upper extremity nerve conduction studies**
 - Median nerve
 - Ulnar nerve
 - Radial nerve
 - Median comparison studies
 - Medial antebrachial cutaneous nerve
 - Lateral antebrachial cutaneous nerve
- **Lower extremity nerve conduction studies**
 - Fibular nerve
 - Tibial nerve
 - Sural nerve
 - Femoral nerve
 - Saphenous
- **Phrenic nerve**

Median nerve anatomy

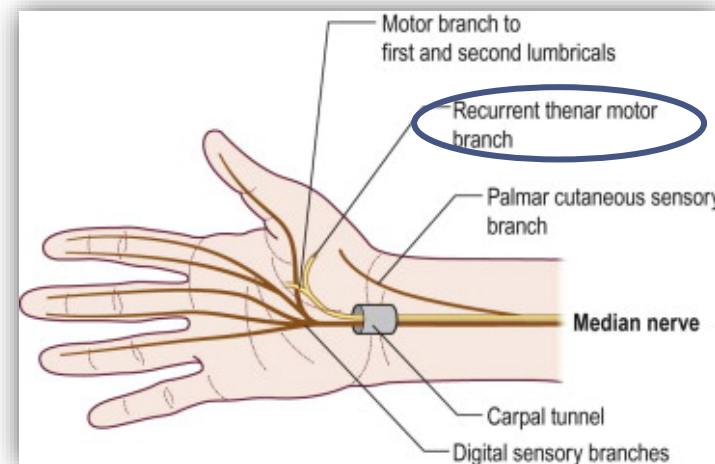
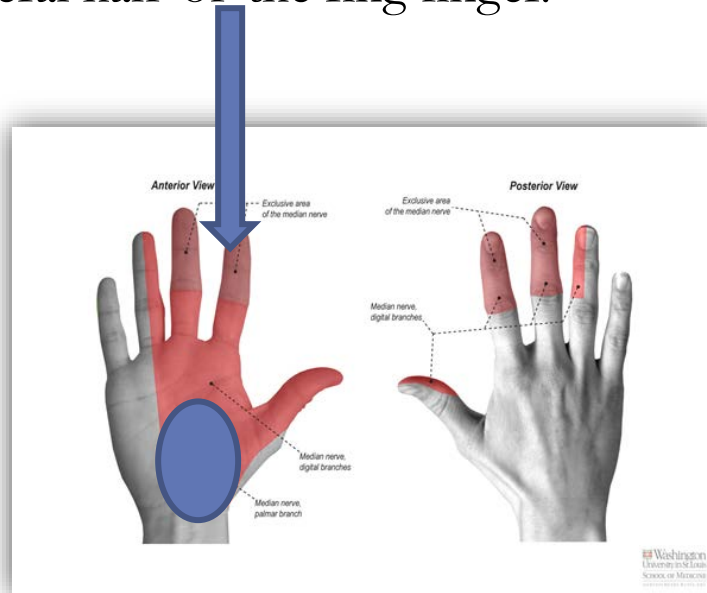
- Median nerve is formed by a combination of:
 - Lateral cord (C6-7) supplies the sensory fibers to the thumb, index, middle finger, proximal median forearm, and thenar eminence.
 - Medial cord (C8-T1) provides motor fibers to the distal forearm and hand.
- The median nerve innervates the pronator teres, then gives branches to the flexor carpi radialis, flexor digitorum superficialis, and palmaris longus.
- **Anterior Interosseus Nerve** (AIN)- innervates the flexor pollicis longus, flexor digitorum profundus (FDP) (digits 2 and 3), and pronator quadratus.



Preston, David C., MD; Shapiro, Barbara E., MD, PhD.
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Median nerve anatomy

- Proximal to the wrist- **the palmar cutaneous sensory branch** (sensation over the thenar eminence)
- Through the carpal tunnel- Motor division goes to first and second lumbricals
 - **Recurrent thenar motor branch** → the thenar eminence (opponens, abductor pollicis brevis, and superficial head of flexor pollicis brevis)
- Sensory branch that goes through the carpal tunnel supplies the medial thumb, index finger, middle finger and lateral half of the ring finger.

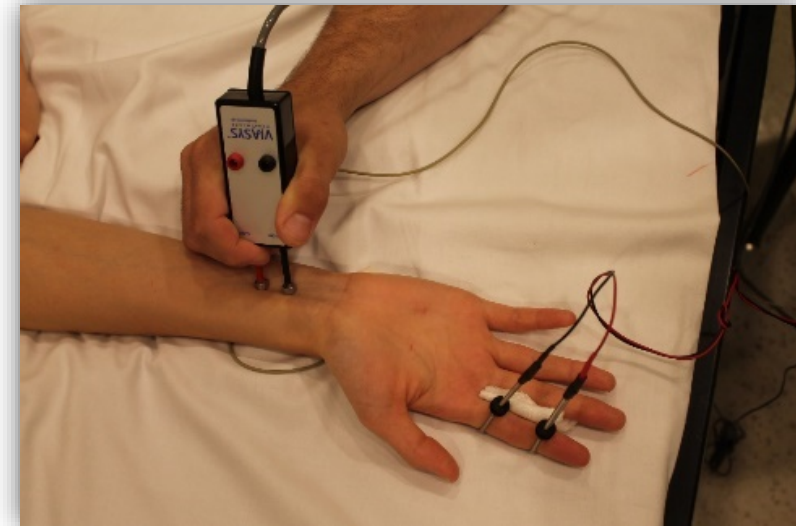


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Median nerve sensory studies

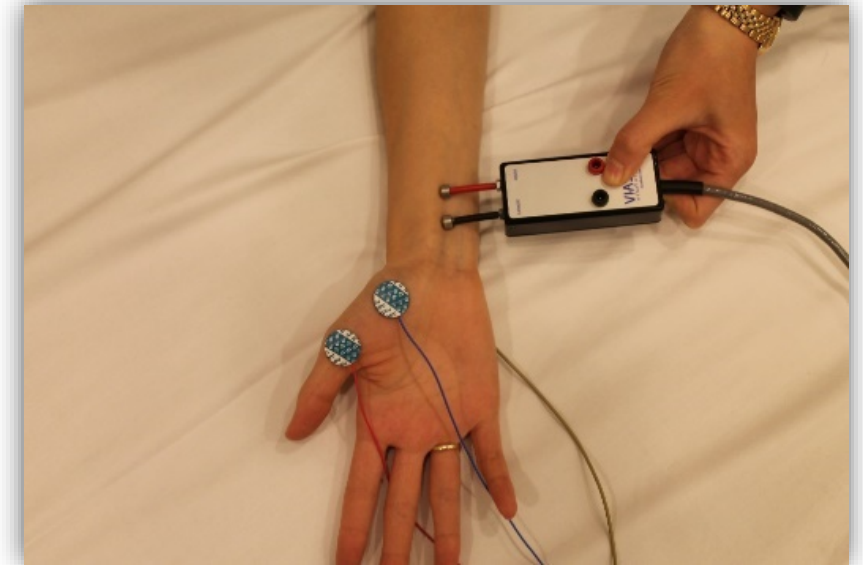
- Recording Site:
 - Index (digit 2)
 - Ring electrodes with G1 placed over the metacarpal-phalangeal joint
 - G2 placed 3-4 cm distally over the distal interphalangeal joint
- Stimulation Site:
 - Wrist: Middle of the wrist between the tendons to the FCR and PL
- Distal Distance:
 - 13 cm
- Reverse for orthodromic study
- Digit 1,3, and 4 can also be recorded



Nerve	Record	Amplitude (μ V)	Conduction Velocity (m/s)	Distal Peak Latency (ms)	Distal Distance (cm)
Median	Digit 2	≥ 20	≥ 50	≤ 3.5	13

Median motor studies

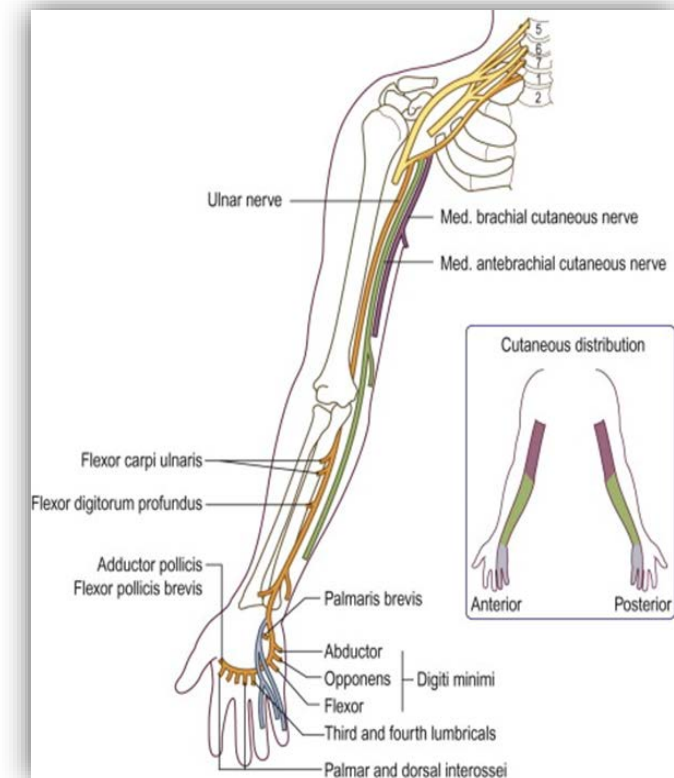
- Recording Site:
 - APB muscle- G1 placed over the muscle belly
 - G2 placed over the first metacarpal-phalangeal joint
- Stimulation Site:
 - Wrist- middle of the wrist between the tendons to the FCR and PL
 - Antecubital fossa- over the brachial artery pulse
 - Distal Distance -6 or 7 cm



Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal Peak Latency (ms)	Distal Distance (cm)
Median	APB	≥4.0	≥49	≤ 4.4	6-7

Ulnar nerve anatomy

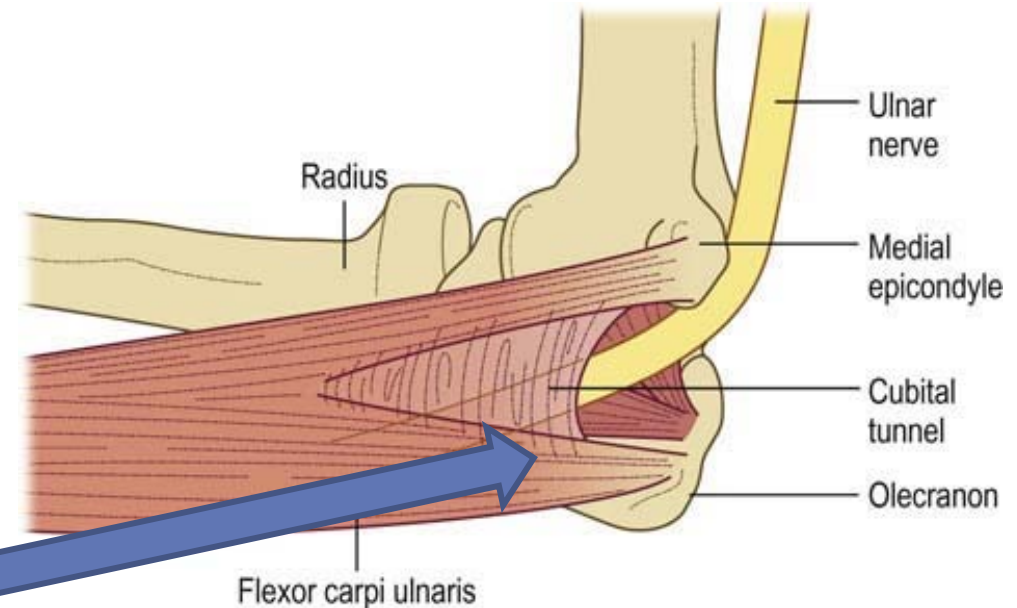
- The ulnar nerve is essentially derived from C8-T1 roots.
- Fibers travel through the **lower trunk** and continue into the **medial cord**.
- The medial brachial and medial antebrachial cutaneous sensory nerves are also from the medial cord.



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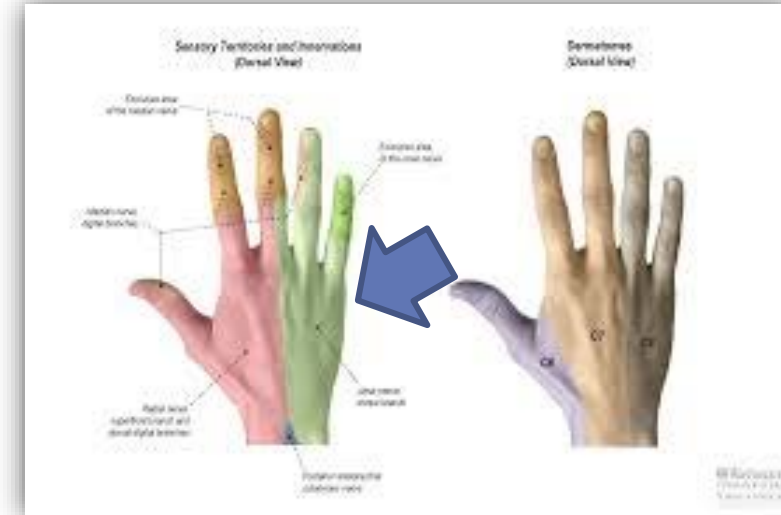
Ulnar nerve anatomy

- The ulnar nerve descends through the upper arm and passes through the *Arcade of Struthers* (deep fascia, muscle fibers from the medial head of the triceps).
- At the elbow the nerve enters the ulnar groove, then the nerve travels under the tendinous arch of the 2 heads of the flexor carpi ulnaris (FCU) (*humeral epicondyle aponeurosis or cubital tunnel*). Branches to FCU and the FDP (to digits 4 and 5) are then given off.



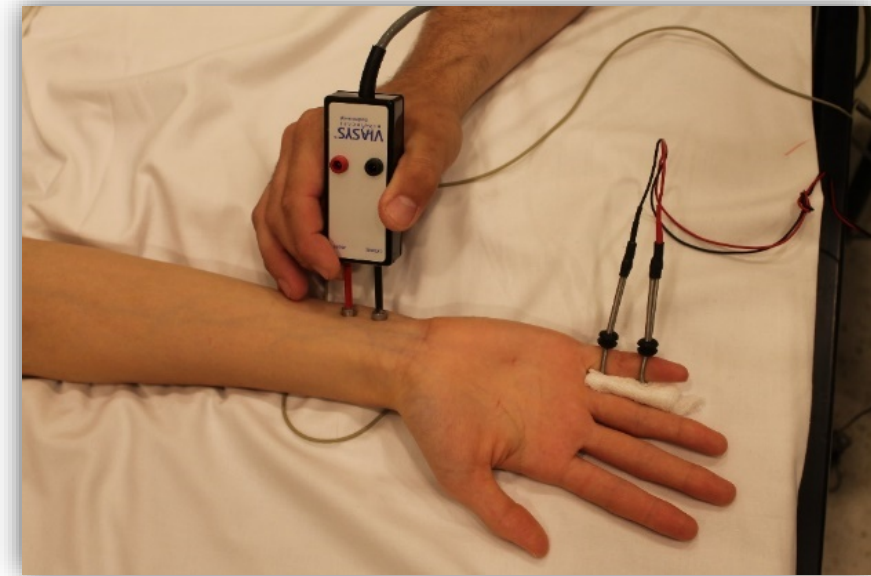
Ulnar nerve anatomy

- Ulnar nerve then gives off the dorsal ulnar cutaneous branch. At the level of the ulnar styloid, the palmar cutaneous sensory branch supplies sensation to the proximal medial palm.
- Then the nerve goes through *Guyon's canal* (medial wrist) to supply sensation to the volar 5th and medial 4th digits and muscular innervation of:
 - hypothenar muscles
 - palmar and dorsal interossei
 - 3 and 4 lumbricals
 - 2 muscles in the thenar eminence, adductor pollicis and deep head of the flexor pollicis brevis.



Ulnar sensory study

- Recording Site:
 - Digit 5- ring electrodes
 - G1 placed over the metacarpal-phalangeal joint
 - G2 placed 3-4 cm distally over the distal interphalangeal joint
- Stimulation Site:
 - Wrist: medial wrist, adjacent to the FCU tendon
- Distal distance:
 - 11 cm
- Antidromic study described

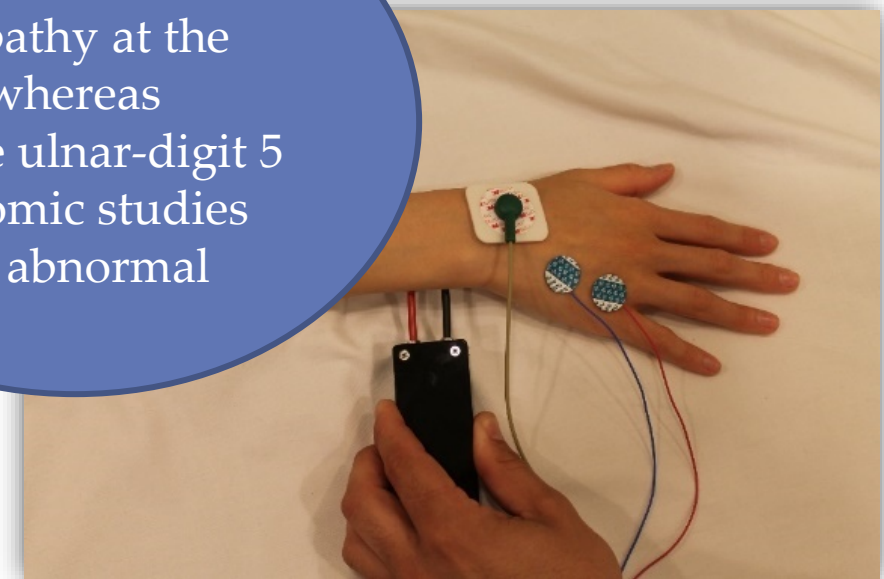


Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Ulnar	Digit 5	≥17	≥50	≤3.1	11

Dorsal ulnar cutaneous study

- Recording Site:
 - Dorsal hand
 - G1 placed over the web space between the little finger and ring finger
 - G2 placed 3-4 cm distally over the little finger
- Stimulation Site:
 - Slightly proximal and inferior to the ulnar styloid with the hand pronated.
- Distal distance:
 - 8-10 cm

Normal in an ulnar neuropathy at the wrist, whereas routine ulnar-digit 5 antidromic studies will be abnormal

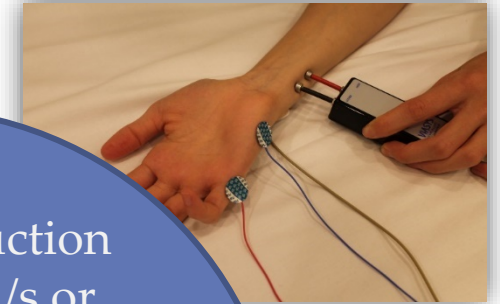


Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Dorsal Ulnar Cutaneous	D4-5 webspace	≥8	≥50	≤2.5	8

Ulnar motor studies

- Recording Site:
 - Abductor Digiti Minimi (ADM)
 - G1 placed over the muscle belly
 - G2 placed over the fifth metacarpal-phalange
- Stimulation Site:
 - Wrist- medial wrist adjacent to the FCU tendon
 - Below elbow- 5 cm distal to the medial epicondyle
 - Above elbow- 5 cm above elbow site
- Distal Distance:
 - 6-7 cm

A drop in conduction velocity by 10 m/s or more across the elbow segment compared to the forearm conduction velocity supports an ulnar neuropathy at the elbow

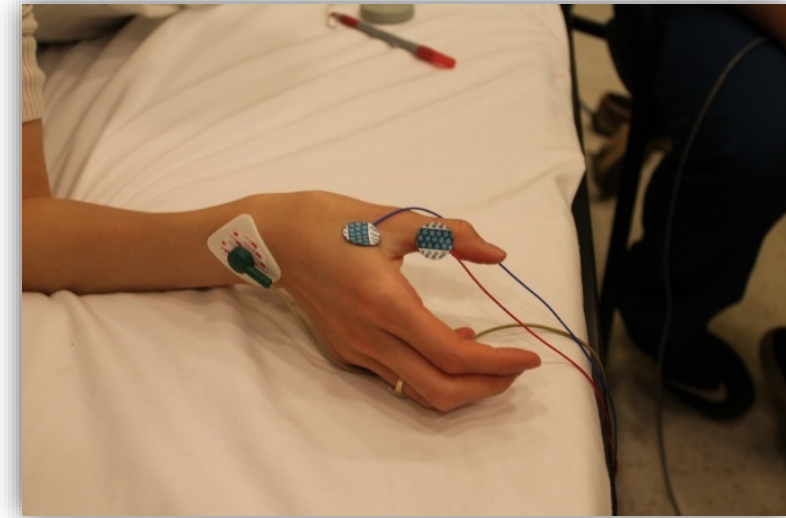


Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal Peak Latency (ms)	Distal Distance (cm)
Ulnar	ADM	≥6	≥49	≤ 3.3	6-7

Ulnar motor studies

Can be helpful if high index of suspicion and ulnar-ADM studies are normal.

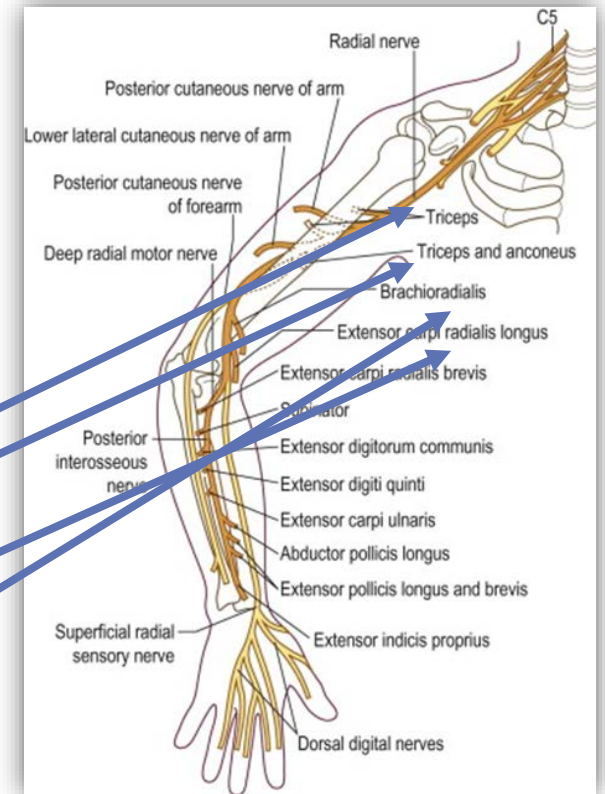
- Recording Site:
 - First Dorsal Interosseus
 - G1 placed over the muscle belly- dorsal web space between the thumb and index finger
 - G2 placed over the metacarpal-phalangeal joint of the thumb
- Stimulation Site:
 - Wrist- medial wrist adjacent to the FCU tendon
 - Below elbow- 5 cm distal to the medial epicondyle
 - Above elbow- 5 cm above elbow site
- Distal Distance:
 - 8-12 cm



Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal Peak Latency (ms)	Distal Distance (cm)
Ulnar	FDI	≥7.0	≥49	≤ 4.5	variable

Radial nerve anatomy

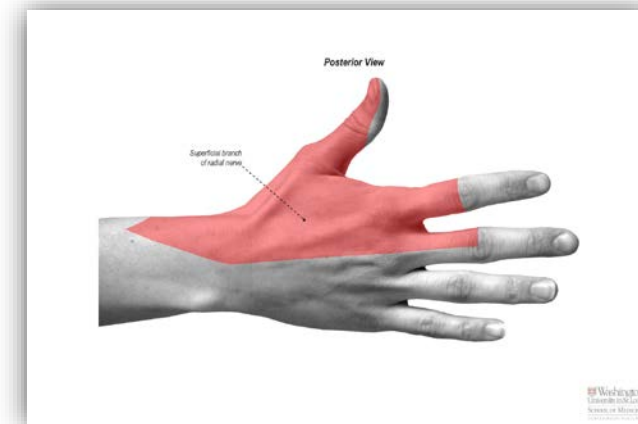
- Radial nerve receives innervation from all 3 trunks of the brachial plexus (C5-T1).
- The posterior divisions of all 3 trunks combine to make the posterior cord.
- The radial nerve comes off the posterior cord.
- 3 sensory branches:
 - posterior cutaneous nerve of the arm
 - lower lateral cutaneous nerve of the arm
 - posterior cutaneous nerve of the forearm
- Muscular branches to the triceps and anconeus.
- Wraps around the posterior humerus in the spiral groove
- In the region of the elbow gives off branch to the brachioradialis and long head of extensor carpi radialis.



Preston, David C., MD; Shapiro, Barbara E., MD, PhD. Published January 1, 2013. Pages 331-345. © 2013.

Radial nerve anatomy

- 3-4 cm distal to the lateral epicondyle- radial nerve bifurcates into 2 nerves
 - Superficial radial sensory nerve
 - supplies the sensation over the lateral dorsum of the hand and the dorsal proximal phalanges of digits 2,3, 4
 - Deep radial motor branch
 - supplies extensor carpi radialis brevis and supinator
 - enters the supinator muscle under the Arcade of Froshe.



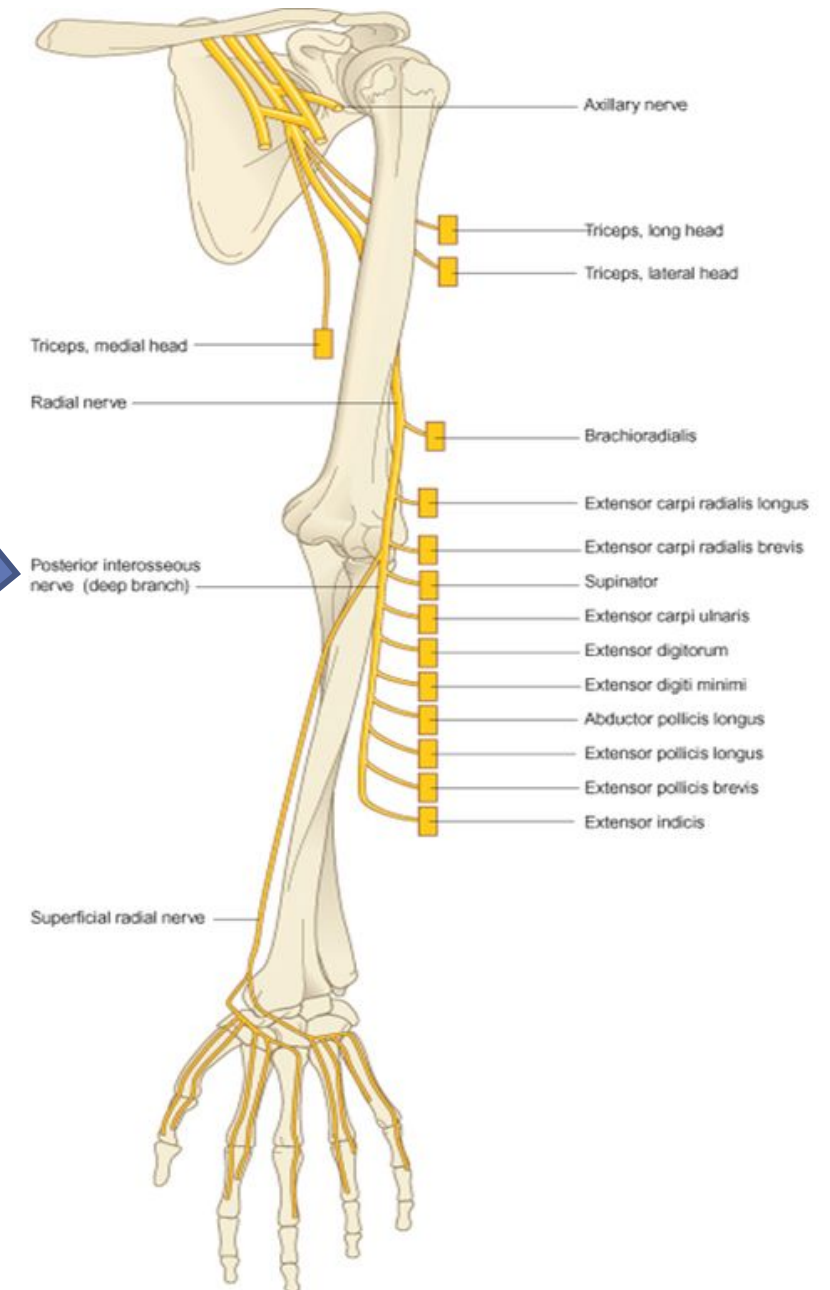
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Radial nerve anatomy

After the supinator it becomes the
Posterior Interosseous Nerve

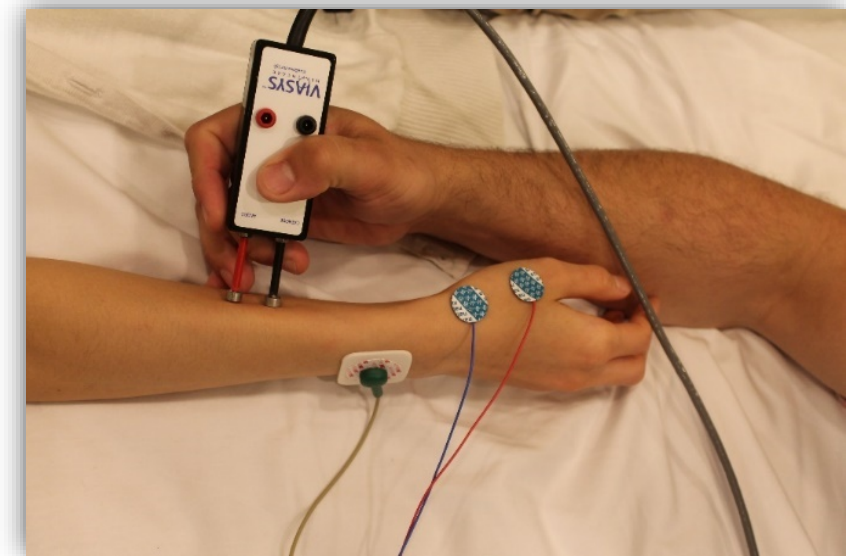
Innervates the:

- extensor digitorum communis
- extensor carpi ulnaris
- abductor pollicis longus
- extensor indicis
- extensor pollicis longus
- extensor pollicis brevis.



Radial sensory study

- Recording Site:
 - G1 placed over the superficial radial nerve as it runs over the extensor tendons to the thumb.
 - G2 placed 3-4 cm distally over the thumb
- Stimulation Site:
 - Over the distal-mid radius
- Distal distance
 - 10 cm

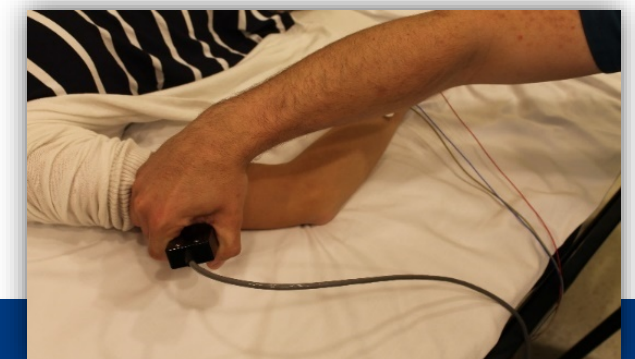
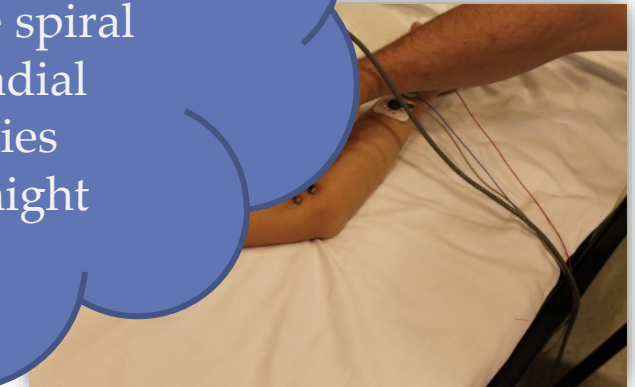
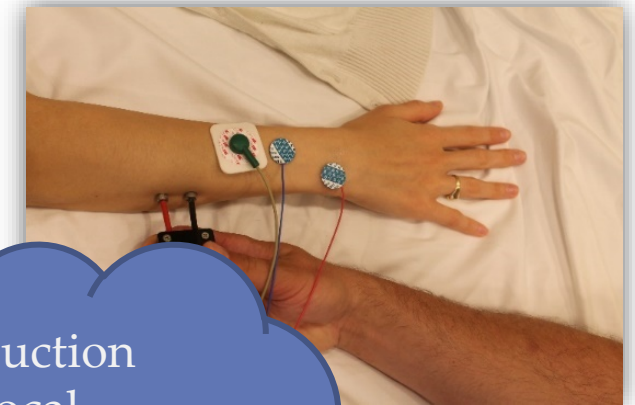


Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Radial sensory	Anatomic snuff box	≥ 15	≥ 50	≤ 2.9	10

Radial motor study

- Recording Site:
 - Extensor indicis – hand pronated
 - G1 placed 2 fingerbreadths proximal to the ulnar styloid
 - G2 placed over ulnar styloid.
- Stimulation Sites:
 - Forearm- over ulna, 4-6 cm proximal to the active recording electrode
 - Elbow- between the biceps and brachioradialis
 - Below spiral groove- lateral mid-arm between biceps and triceps
 - Above spiral groove- posterior proximal arm over the humerus

Look for conduction block and focal slowing at the spiral groove in radial neuropathies
“Saturday night palsies”



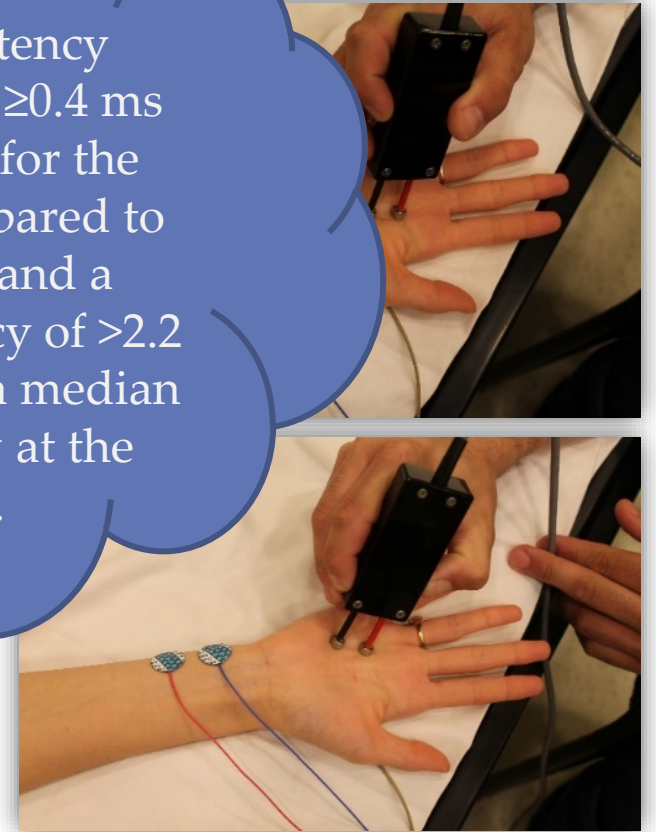
Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Radial	EIP	≥2	≥49	≤2.9	4-6

Studies for median mononeuropathies at the wrist (carpal tunnel syndrome)

Median versus ulnar-palmar mixed nerve studies

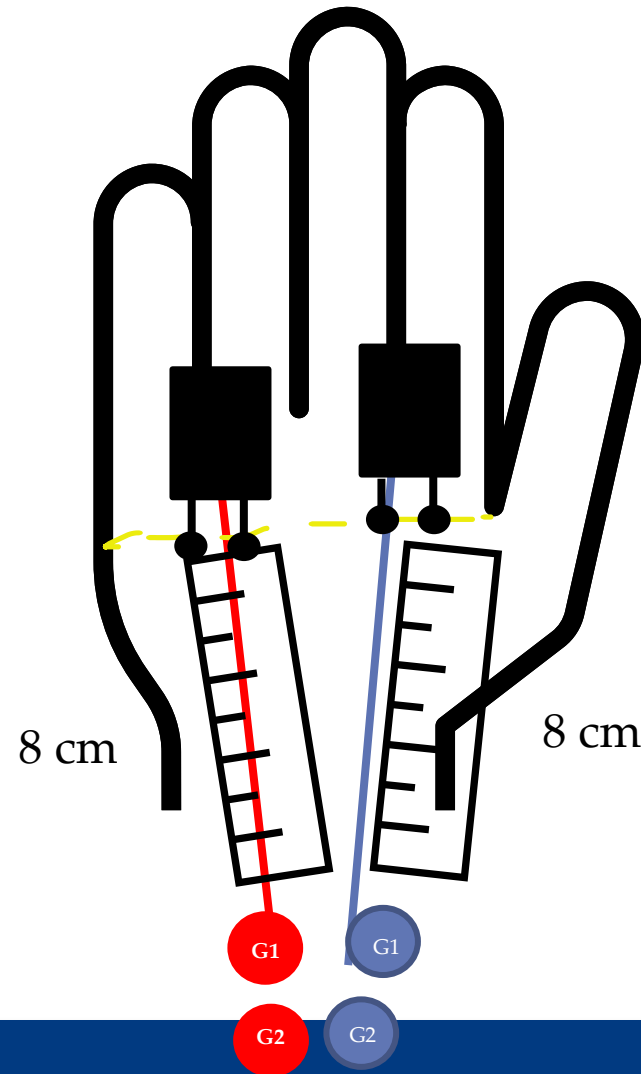
- Median Nerve
 - Recording Site: Median nerve at the wrist.
 - Stimulation Site
 - Median nerve in the palm, 8 cm from the active recording electrode – on a line drawn from the median wrist to the web space between the index and middle fingers.
- Ulnar Nerve
 - Recording Site: Ulnar nerve at the wrist
 - Stimulation Site
 - Ulnar nerve in the palm: 8 cm from the active recording electrode on a line drawn from the ulnar wrist to the web space between the ring and little fingers

An interlatency difference of ≥ 0.4 ms (prolonged for the median compared to the ulnar) and a median latency of >2.2 ms supports a median neuropathy at the wrist.



Nerve	Amplitude (μ V)	Conduction velocity (m/s)	Peak Distal Latency (ms)	Distance (cm)
Median Mixed	≥ 50	≥ 50	≤ 2.2	8
Ulnar Mixed	≥ 12	≥ 50	≤ 2.2	8

Median versus ulnar-palmar mixed nerve studies



Median versus ulnar- lumbrical- interosseous study

○ Recording Site:

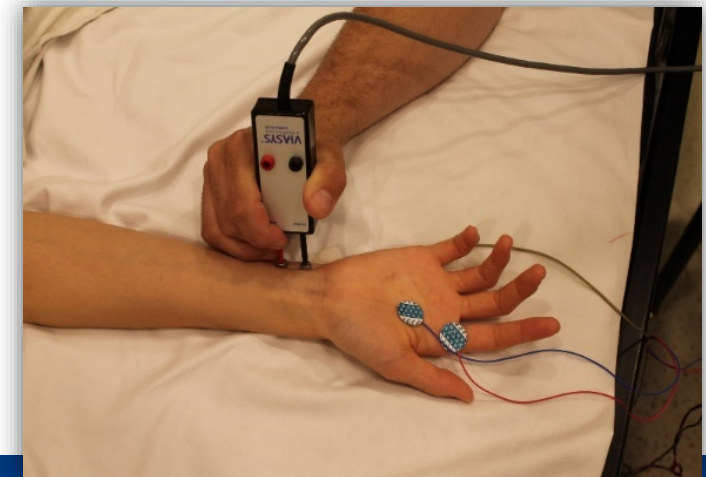
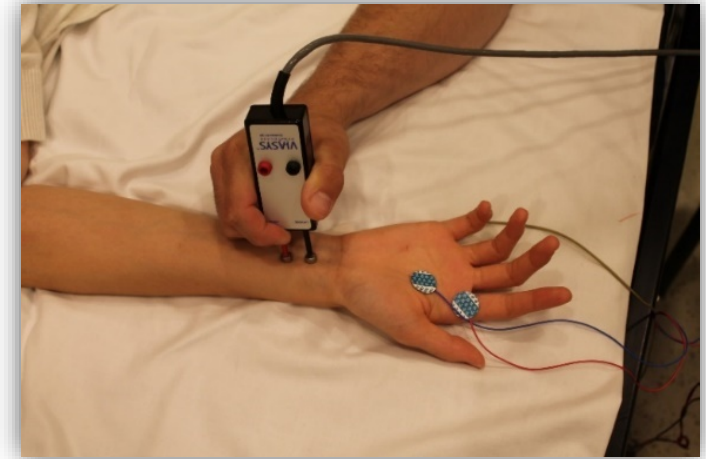
- Second lumbrical and first palmar interosseous are recorded from the same site
- G1 placed slightly lateral to the midpoint of the third metacarpal
- G2 placed distally over the metacarpal-phalangeal joint of digit 2.

○ Stimulation Site

- Median nerve at the wrist
- Ulnar nerve at the wrist

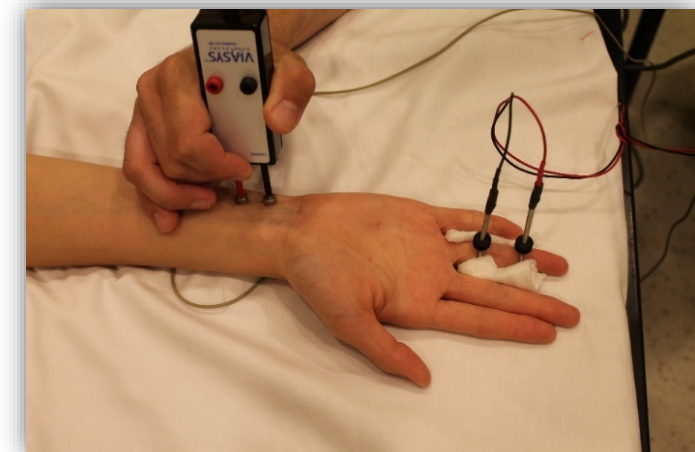
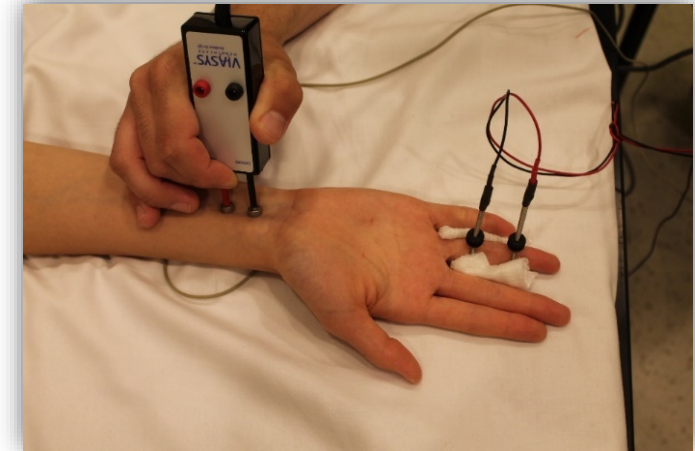
○ Distal distance: 8-10 cm

○ Significant Latency Difference: ≥ 0.5 ms



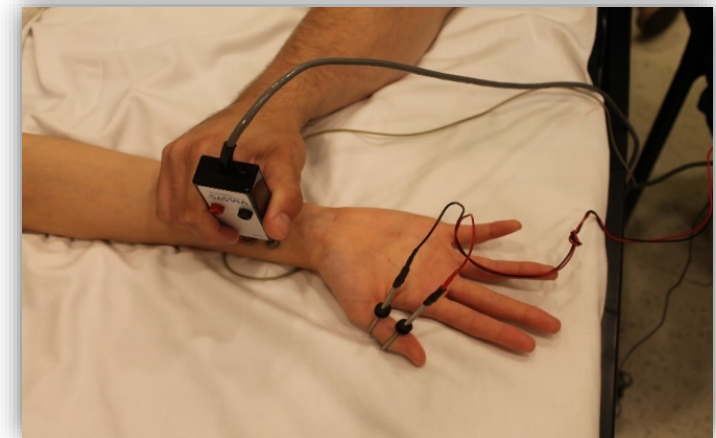
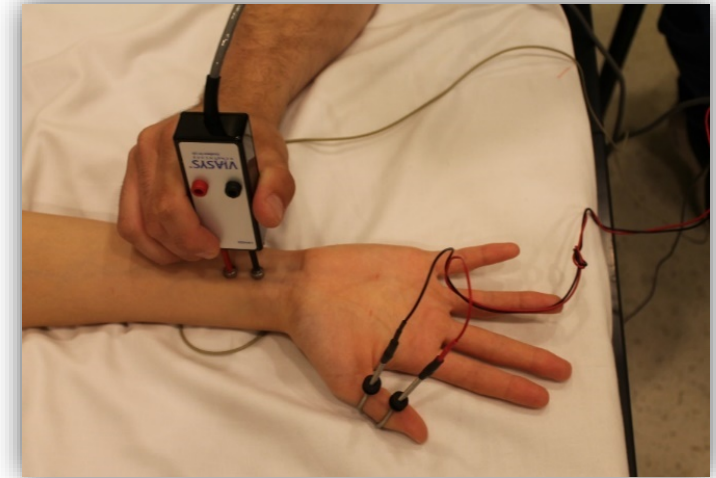
Median versus ulnar-digit 4 sensory studies

- Recording Site:
 - Ring finger
 - G1 of ring electrodes over the metacarpal-phalangeal joint
 - G2 placed 3-4 cm distally over the distal interphalangeal joint
 - Stimulation Sites:
 - Median nerve at the wrist
 - Ulnar nerve at the wrist
 - Distance 12-14 cm
 - Significant Latency Difference ≥ 0.5 ms



Median versus radial-digit 1 sensory studies

- Recording Site:
 - Thumb (digit 1)
 - Ring electrodes with G1 over the metacarpal-phalangeal joint
 - G2 placed distally over the distal interphalangeal joint
 - Stimulation Sites:
 - Median nerve at the wrist
 - Radial nerve at the wrist: medial forearm, over the radial bone
 - Distal Distance: 10-12 cm
 - Significant Latency Difference ≥ 0.5 ms

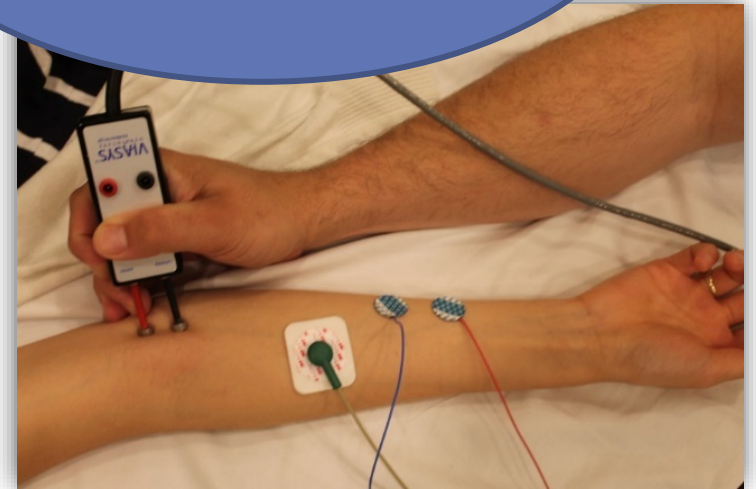


Less commonly used
upper extremity nerve
conduction studies

Medial antebrachial cutaneous sensory study

- Recording Site:
 - Medial Forearm:
 - G1 placed 12 cm distal to the stimulation site, on a line drawn between the stimulation site and the ulnar wrist.
 - G2 placed 3-4 cm distally
- Stimulation Site:
 - Medial Elbow:
 - at the midpoint between the biceps tendon and medial epicondyle.
- Distal distance: 12 cm

Helpful if a lower trunk, medial cord brachial plexopathy is suspected

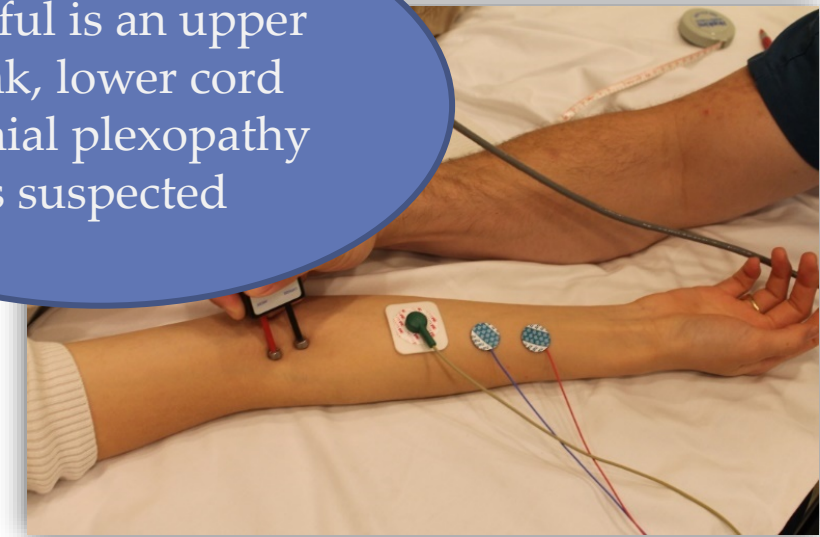


Nerve	Record	Amplitude (μ V)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
MAC	Medial Forearm	≥ 5	≥ 50	≤ 3.2	12

Lateral antebrachial cutaneous sensory study

- Recording Site:
 - Lateral forearm:
 - G1 placed 12 cm distal to the stimulator site on a line drawn between the stimulator site and the radial wrist
 - G2 placed 3-4 cm distally
- Stimulation Site:
 - AC fossa:
 - slightly lateral to the biceps tendon
- Distal distance: 12 cm

Helpful is an upper trunk, lower cord brachial plexopathy is suspected



Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
LAC	Medial Forearm	≥10	≥55	≤3.0	12

Outline for Today's talk

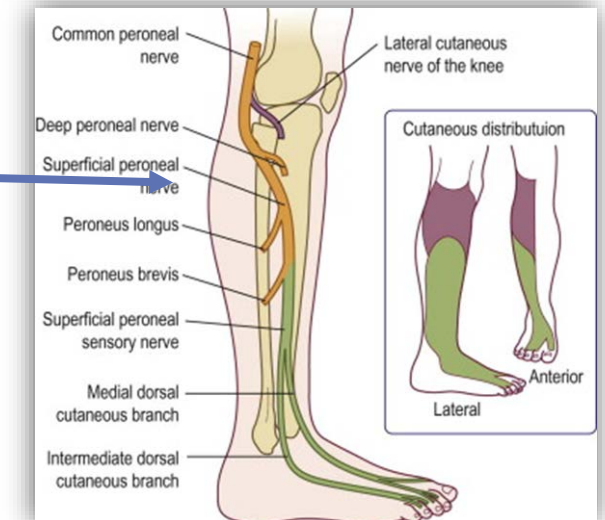
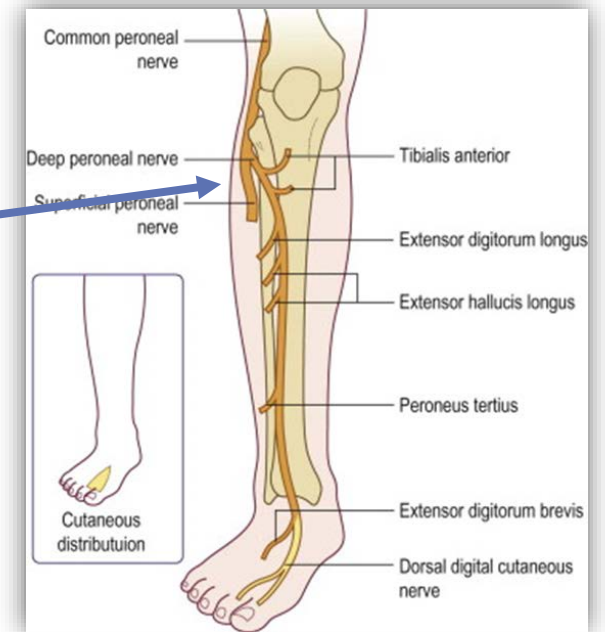
- **Upper extremity nerve conduction studies**
 - Median nerve
 - Ulnar nerve
 - Radial nerve
 - Median comparison studies
 - Medial antebrachial cutaneous nerve
 - Lateral antebrachial cutaneous nerve
- **Lower extremity nerve conduction studies**
 - Fibular nerve
 - Tibial nerve
 - Sural nerve
 - Femoral nerve
 - Saphenous
- **Phrenic nerve**

Fibular nerve anatomy

- The fibular nerve is derived from L4-S1 nerve roots that travel through the lumbosacral plexus and through the sciatic nerve (runs separately from the tibial nerve fibers).
- In the posterior thigh the fibular fibers innervate the short head of the biceps femoris
- The sciatic bifurcates in the popliteal fossa and the common fibular nerve gives off the lateral cutaneous nerve of the knee (supplies lateral knee), then passes through the fibular tunnel.
- Common fibular nerve divides into deep and superficial branches.

Fibular nerve anatomy

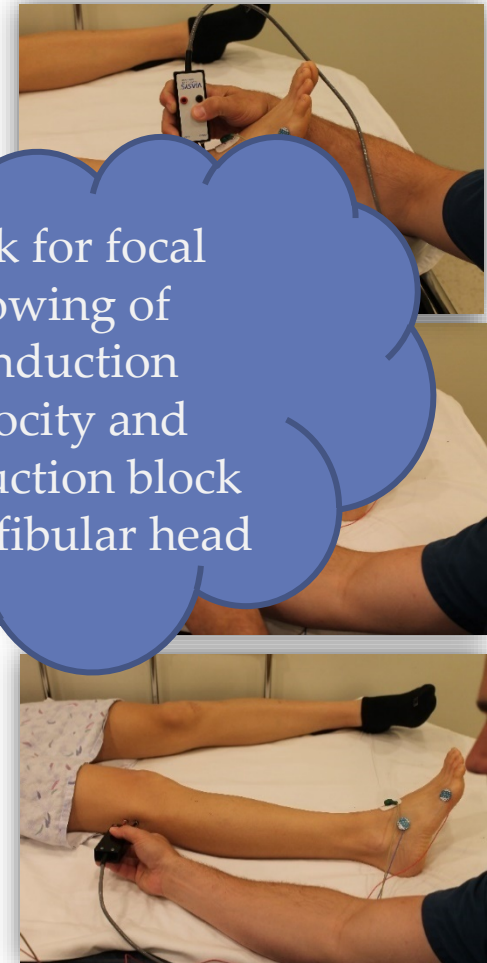
- **Deep fibular nerve** innervates the:
 - Fibularis tertius
 - Tibialis anterior
 - Extensor digitorum longus
 - Extensor hallucis longus
 - Extensor digitorum brevis
 - Skin between the first and second toes
- **Superficial fibular nerve**
 - Fibularis longus
 - Fibularis brevis
 - Mid/lower lateral calf sensation
 - Divides into the medial and intermediate dorsal cutaneous nerves of the foot- supplies sensation to the dorsum of the foot and the dorsal medial 3-4 toes.



Common fibular motor study

- Recording Site:
 - Extensor Digitorum Brevis (EDB)
 - Dorsal lateral foot with G1 placed over the muscle belly
 - G2 placed distally over the metatarsal-phalangeal joint of little toe
- Stimulation Sites:
 - Ankle: anterior ankle, lateral to the tibialis anterior tendon
 - Below fibular head: lateral calf, one to two fingerbreadths inferior to the fibular head.
 - Lateral popliteal fossa: Lateral knee adjacent to the external hamstring tendons 10-12 cm from the fibular head site
- Distal distance: 9 cm

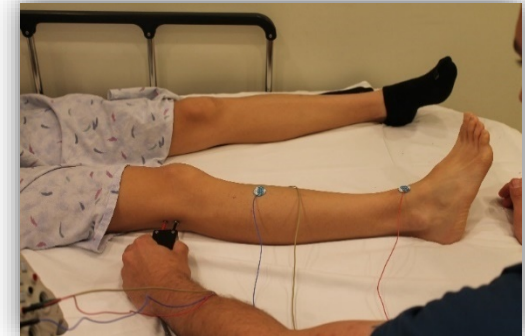
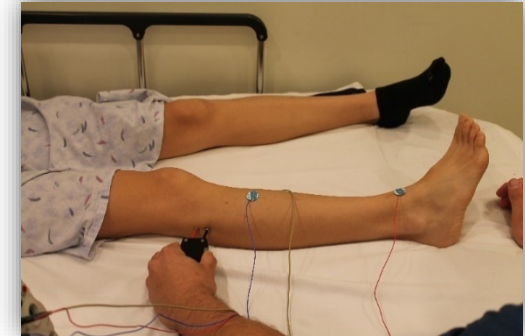
Look for focal slowing of conduction velocity and conduction block at the fibular head



Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Fibular	EDB	≥2.0	≥44	≤6.5	9

Common fibular motor study

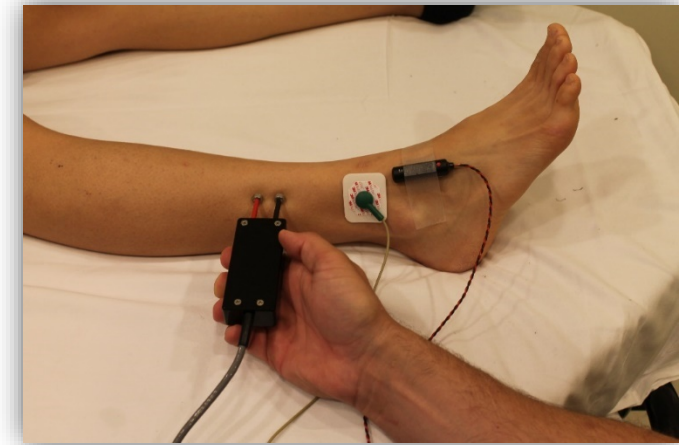
- Recording Site:
 - Tibialis anterior muscle:
 - Proximal to mid-anterior lateral calf with G1 placed over the muscle belly
 - G2 placed distally over the anterior ankle
- Stimulation Site:
 - Below the fibular head
 - Lateral popliteal fossa (10-12 cm from the below fibular head site)
- Distal distance: variable



Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Peroneal	Tibialis Anterior	≥ 3.0	≥ 44	≤ 6.7	5-10

Superficial fibular sensory study

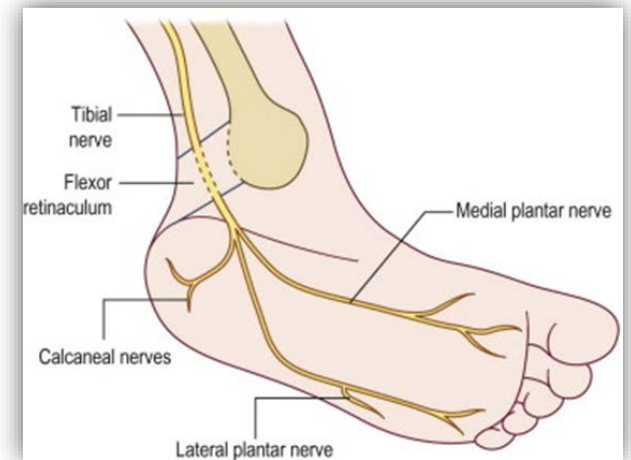
- Recording Site:
 - Lateral ankle
 - G1 placed between the tibialis anterior tendon and lateral malleolus
 - G2 placed 3-4 cm distally
- Stimulation Site:
 - Lateral calf
- Distal distance:
 - 14 cm



Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Superficial Fibular	Lateral Ankle	≥ 6.0	≥ 40	≤ 4.4	14

Distal tibial nerve anatomy

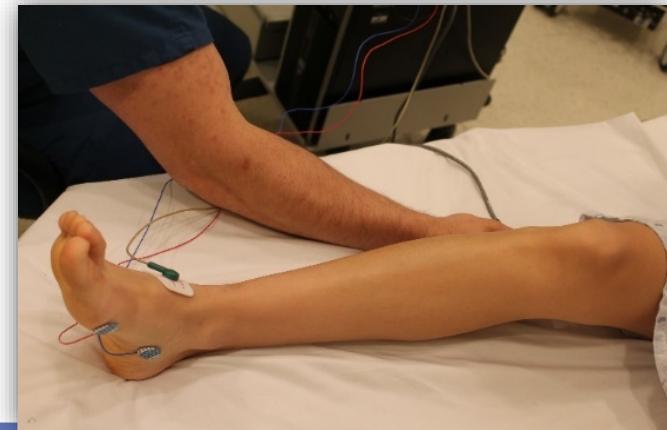
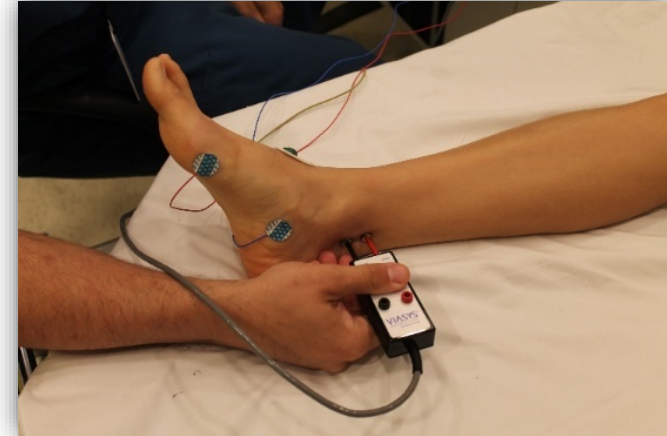
- As the tibial nerve descends distal to the medial malleolus, it runs through the **tarsal tunnel**.
- Tarsal tunnel is a fibro-osseous tunnel made of the medial malleolus and flexor retinaculum.
- Distal tibial nerve divides into the medial and lateral calcaneal sensory nerves (go to the sole, pure sensory) and medial and lateral plantar nerves (motor and sensory fibers)
- Medial plantar innervates abductor hallucis brevis, flexor hallucis brevis, and flexor digitorum brevis.
- Lateral plantar nerve innervates digiti quinti pedis.



Preston, David C., MD; Shapiro, Barbara E., MD, PhD. Published January 1, 2013. Pages 365-371. © 2013.

Tibial motor study

- Recording Site:
 - Abductor Hallucis Brevis (AHB) muscle
 - G1 placed 1 cm proximal and 1 cm inferior to the navicular prominence
 - G2 placed over the metatarsal-phalangeal joint of the great toe
- Stimulation Sites:
 - Medial Ankle- slightly proximal and posterior to the medial malleolus
 - Popliteal fossa: mid-posterior knee over the popliteal pulse
- Distal Distance: 9 cm

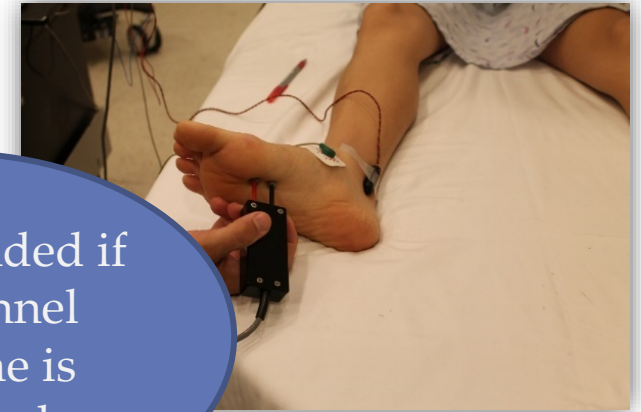


Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Tibial	Abductor Hallucis	≥4.0	≥41	≤5.8	9

Medial and lateral plantar mixed nerve studies

- Recording Site:
 - Medial Ankle:
 - G1 placed slightly proximal and posterior to the medial malleolus
 - G2 placed 3-4 cm proximally
- Stimulation Sites:
 - Medial sole (medial plantar nerve) 14 cm from recording electrodes
 - Lateral sole (lateral plantar nerve) 14 cm from the recording electrodes
- Distal distance- 14 cm

Recommended if
tarsal tunnel
syndrome is
suspected

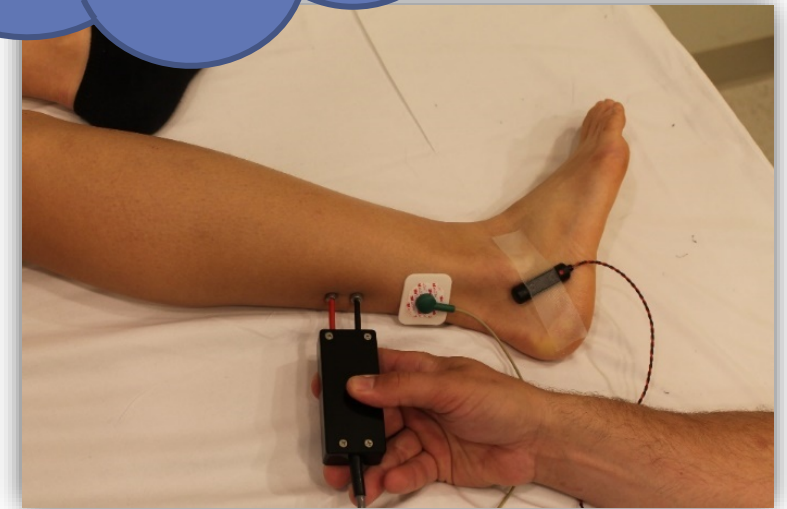


Nerve	Amplitude (μ V)	Conduction velocity (m/s)	Peak Distal Latency (ms)	Distance (cm)
Medial Plantar	≥ 3	≥ 45	≤ 3.7	14
Lateral Plantar	≥ 3	≥ 45	≤ 3.7	14

Sural nerve study

- Recording Site:
 - Posterior ankle- G1 placed posterior to lateral malleolus
 - G2 placed 3-4 cm distally
- Stimulation Site:
 - Posterior-lateral calf
- Distal distance: 14 cm

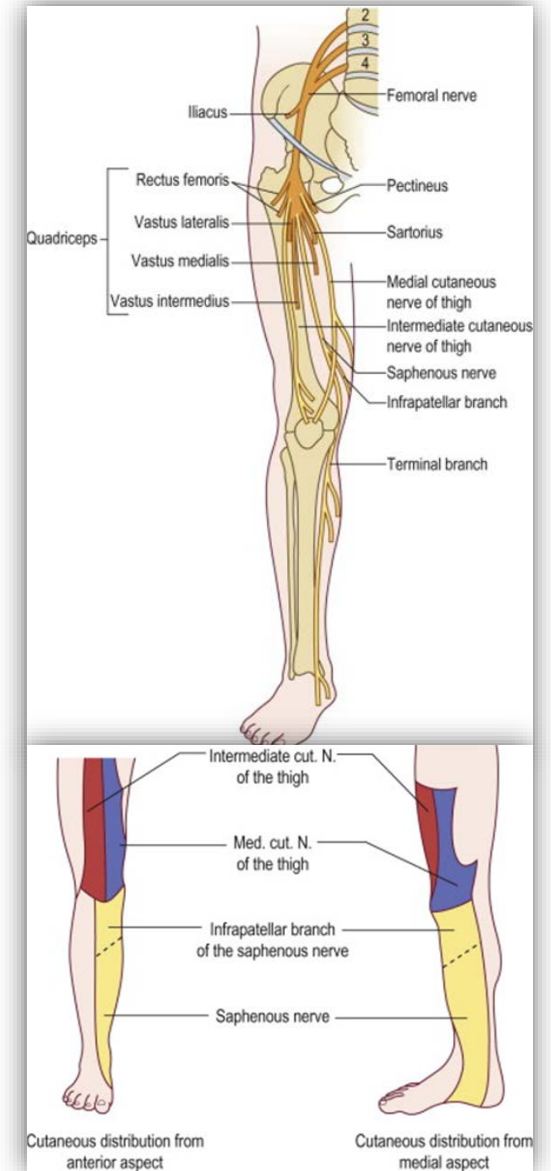
The sural nerve is routinely studied in polyneuropathies and can be helpful if a sciatic neuropathy is suspected



Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Sural	Posterior ankle	≥ 6.0	≥ 40	≤ 4.4	14

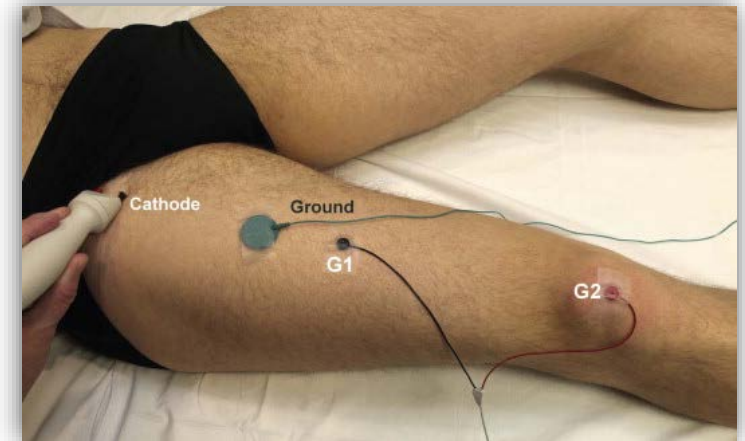
Femoral nerve anatomy

- The femoral nerve is derived from the lumbar plexus (L2-4 nerve roots).
- The muscular branches are given off to the psoas and then iliacus and then it runs beneath the inguinal ligament. It divides into the medial and intermediate cutaneous nerves of the thigh and the muscular branches to the sartorius and pectineus.
- Posterior division supplies the quadriceps femoris muscles and then continues as the saphenous nerve to supply sensation to the medial border of the calf.
- The lateral femoral cutaneous nerve, derived from the lumbar plexus, receives innervation from L2-3 nerve roots.



Femoral motor study

- Recording Site:
 - Rectus Femoris muscle
 - G1 placed over the anterior thigh, halfway between the inguinal crease and the knee
 - G2 placed over the knee
- Stimulation Site:
 - Middle of the inguinal area, lateral to the femoral pulse, below the inguinal ligament
- Distal distance: variable



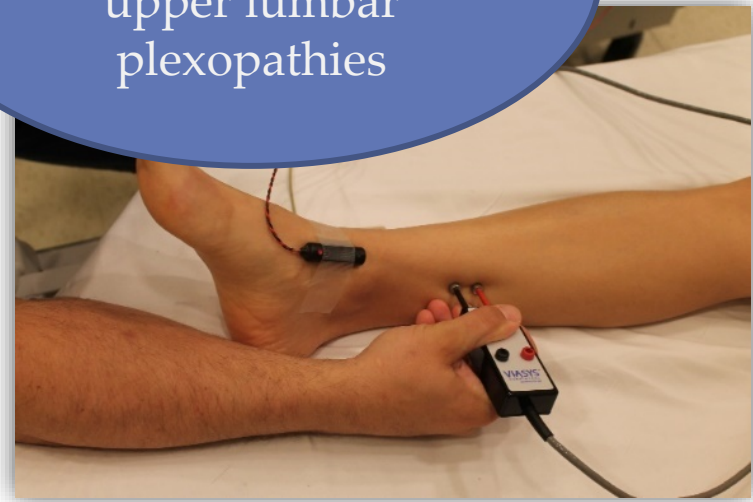
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Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Femoral	Rectus Femoris	≥3.0	≥40		variable

Saphenous nerve study

- Recording Site:
 - Medial/anterior ankle
 - G1 placed between the medial malleolus and tibialis anterior tendon
 - G2 placed 3-4 cm distally
- Stimulation Site:
 - Medial calf- stimulator placed in the groove between the tibia and the medial gastrocnemius
- Distal distance: 14 cm standard

Helpful in femoral neuropathies and upper lumbar plexopathies



Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Saphenous	Medial/ Anterior ankle	≥ 4.0	≥ 40	≤ 4.4	14

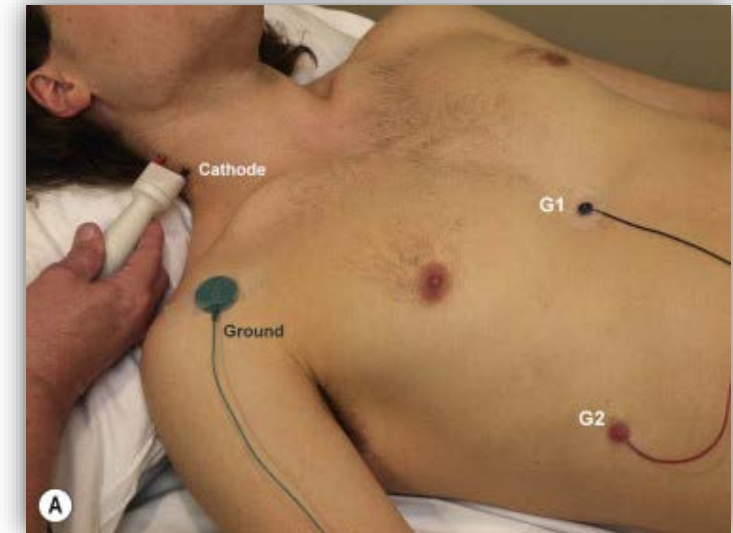
Outline for Today's talk

- **Upper extremity nerve conduction studies**
 - Median nerve
 - Ulnar nerve
 - Radial nerve
 - Median comparison studies
 - Medial antebrachial cutaneous nerve
 - Lateral antebrachial cutaneous nerve
- **Lower extremity nerve conduction studies**
 - Fibular nerve
 - Tibial nerve
 - Sural nerve
 - Femoral nerve
 - Saphenous
- **Phrenic nerve**

Phrenic motor nerve conduction study

- Recording Site:
 - Diaphragm muscle
 - G1 placed 5 cm above xiphoid process
 - G2 placed over the anterior costal margin 16 cm from G1
- Stimulation Site:
 - Lateral neck, posterior to sternocleidomastoid, 3 cm above the clavicle.
- Key Points:
 - Firm pressure needed.
 - Watch out for stimulation of the brachial plexus or spinal accessory nerve.

Nerve	Record	Amplitude (μ V)	Conduction Velocity (m/s)	Distal peak latency (ms)	Distal Distance (cm)
Phrenic	Diaphragm	≥ 320		≤ 8.0	Varies



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Thank you so much for your attention!

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