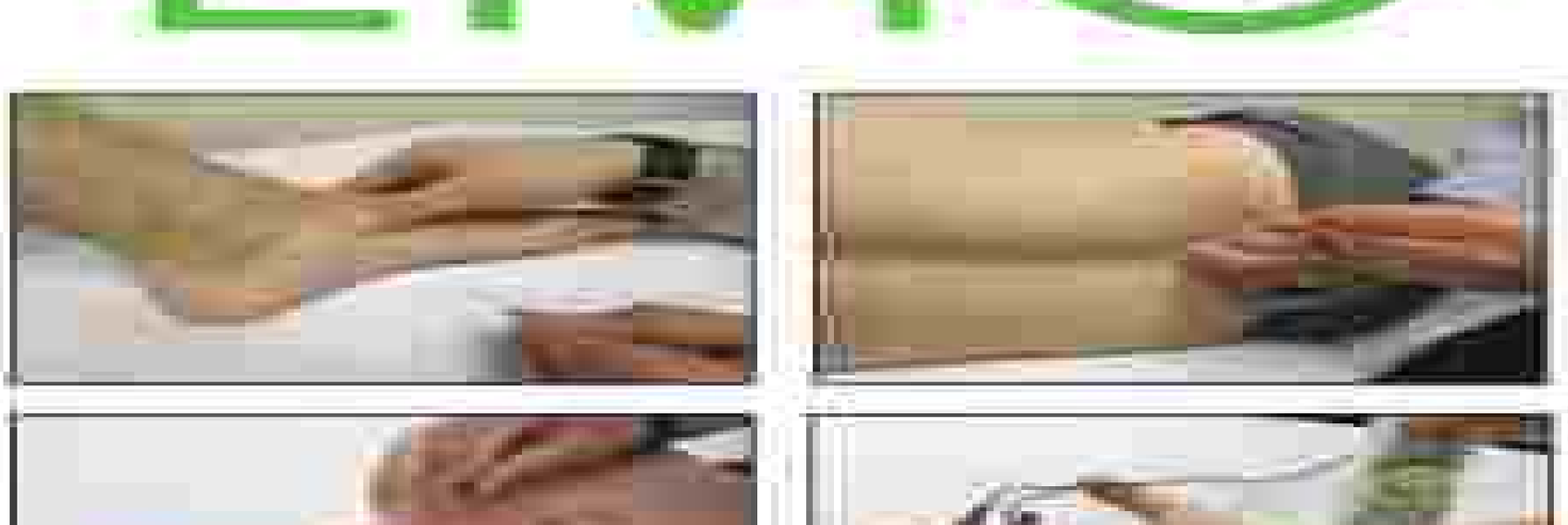
POCKET EMG



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Pocket EMG

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Contents

Preface

When I was a resident preparing for my first independent electrodiagnostic study, I constantly worried about the possibility of freezing up. What if I got stuck or forgot where to put the electrodes? Over time, I learned the essentials and gained confidence, but it wasn't necessarily easy. I wished for a quick text I could refer to while in the "heat of battle."

Now that I'm an experienced electromyographer, I still don't always know everything all the time. I've found that the best approach is to know the reason for the electrodiagnostic study before I enter the room so I can review any tests I may perform that aren't necessarily routine. However there are still times when a study is trickier than usual or outside the norm of what I typically do. This will usually send me out of the room, back to a cumbersome textbook to figure out the next step in my study. But wouldn't it be better to have something small and practical at hand to quickly review in the moment to keep on course? *Pocket EMG* is meant to be that resource.

There are many excellent electrodiagnostic texts available that this book does not try to replace. I have used and still use these books extensively to help me hone my craft and my knowledge base. Instead, *Pocket EMG* is intended to help the novice electromyographer get through the test comfortably and help the more experienced electromyographer remember less commonly used tests and protocols. This is a working text, and I hope it will make your life easier. It is becomes

shipmate and summit in EMG gel, we will have achieved our goal.

The first section of Pocket EMG reviews nerve conduction study set-ups with "pearls of wisdom" for each test. These tests are organized by upper extremity nerve conductions (sensory and motor), lower extremity nerve conductions (sensory and motor), late responses, and other tests (facial nerve conduction, blink reflex, etc). The second section covers needle EMG study set-ups organized into the following groups: upper extremity, lower extremity, paraspinals, and facial muscles. The third section catalogs study protocols for various presenting chief complaints or suspected diagnoses. Please keep in mind that as you go through your study, if your suspected diagnosis changes, you may need to switch protocols. The final section is a collection of high-yield information and tables that should be helpful during electrodiagnostic testing.

This book is designed for every day use at the point of care. We did not attempt to cover every single muscle or nerve you will ever need to check during an electrodiagnostic study. There are some less commonly tested nerves and muscles that were intentionally omitted. Other more extensive texts, including the resources I've listed below, have comprehensive atlases that can be consulted for less commonly performed tests. This book is intended to get the electromyographer through the vast majority of common and not-so-common clinical electrodiagnostic scenarios. I hope you will keep it at your side while you help your patient with this challenging and wonderful test.

One last note: The majority of the normal values used in this book are from Ralph Buschbacher's indispensable *Manual of Nerve Conduction Studies, 2nd Edition* (Demos Medical Publishing 2006), used with his very kind permission. All normal values represent the upper or lower limits of normal. Please keep in mind that normal values can vary from EMG lab to EMG lab.

RESOURCES FOR FURTHER STUDY

Buschbacher RM, Prahlow ND. *Manual of Nerve Conduction Studies*. Second Edition. New York, NY: Demos Medical Publishing; 2006.

Perotto AO. *Anatomical Guide for the Electromyographer: The Limbs and Trunk*. Fourth Edition. Springfield, IL: Charles C. Thomas, Publisher, Ltd; 2005.

Preston DC, Shapiro BE. *Electromyography and Neuromuscular Disorders: Clinical-Electrophysiological Correlations*. Second Edition. Philadelphia, PA: Elsevier; 2005.

Sadoharu KA, ed. *Rehab Clinical Pocket Guide*. Rehabilitation Medicine. New York, NY: Springer; 2013.

Visco CJ, Chimes GP, eds. *McGraw Guide to Electrodiagnostic Medicine*. New York, NY: Demos Medical Publishing; 2007.

Werner RA, Andary MT. Electrodiagnostic Evaluation of Carpal Tunnel Syndrome. *Muscle & Nerve*. 2011; 44: 597–607.

Acknowledgments

The authors of this book would like to especially thank Dr. Cherry Jann for critical contributions to the completion of this text.

Eric would first and foremost like to thank his wife and daughters, Nell and Ava, for their incredible support during this writing process. Second, he would like to thank his parents for instilling the work ethic that helped him get through this book. In addition, he is indebted to his great mentors, too many of which to list here, that helped him become the physician he is today. He is also very grateful to his coauthors, Dave and Victor, who enthusiastically pushed this book to the finish line.

Victor would like to thank his family and especially his wife and best friend, Maria Gloria, who has been a constant supporter of the growth and development of his career. He would also like to thank his mentors through residency and fellowship who have molded him into the physician that he is today. A special thanks to Dr. Eric Wisotzky, who defines what an academic physician should be. Always guiding his residents to become compassionate doctors and scholars in an enjoyable and charismatic way.

Dave would like to thank all of his fellow residents and mentors along the way who have, and continue to provide, an atmosphere filled with mutual respect and motivation. He also wishes to thank his family for providing unconditional support during his journey toward a career in medicine. Both

his mother and sister have offered him strength through the years, and he could not be where he is today without them.

The authors would also like to thank the following individuals for their contributions and acknowledge their help in preparing this book:

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Zachary Carter
Greg Decker
Fatemeh Milani, MD
Louis Torres, MD
Carrie Whitehair, MD

Pocket EMG

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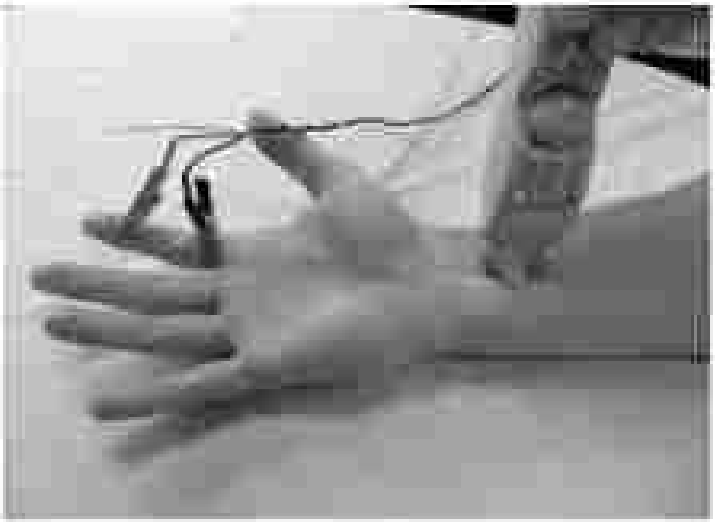
Nerve Conduction Studies

- Upper Extremity Sensory Studies
- Upper Extremity Motor Studies
- Lower Extremity Sensory Studies
- Lower Extremity Motor Studies
- Late Responses
- Other Nerve Conduction Studies

Median Sensory (Antidromic)



ACTIVE: Ring electrode on metacarpophalangeal (MCP) joint of digit 2, 3, or 4

REFERENCE: 3 to 4 cm distal to active electrode

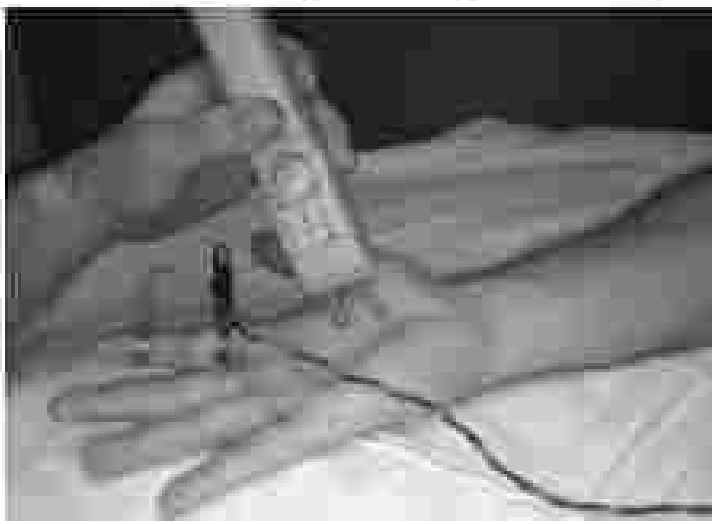
STIMULATION: Proximal to wrist crease between flexor carpi radialis (FCR) and palmaris longus tendons 14 cm from the active electrode

NORMAL VALUES: Amp >30 μV, peak latency <4 msec

Pearls

- Look out for motor artifact, which can obscure the sensory response or be mistaken for an absent sensory response.
- Recording the response at digit 4 may be even more sensitive as these fibers may be the most prone to compression at the wrist.

Median Sensory Palmar (Antidromic)

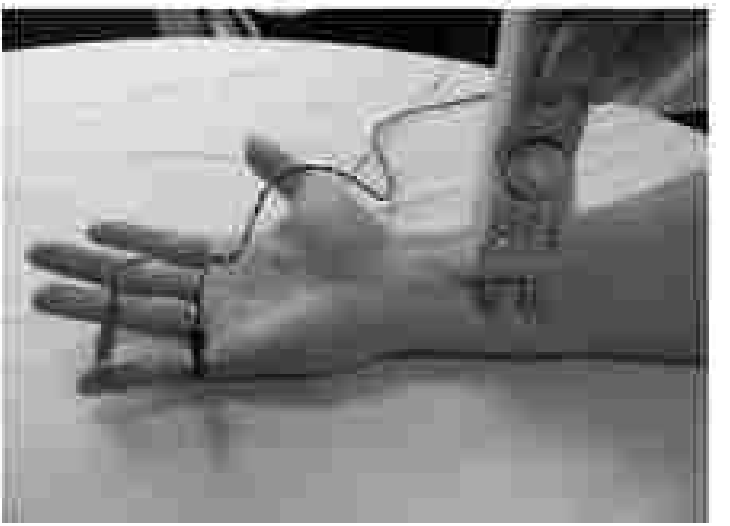


- Setup same as wrist stimulation but instead stimulate in palm, 8.5 cm distal to wrist stimulation site along line drawn from wrist to index finger

Pearls

- A palm/wrist sensory nerve action potential (SNAP) ratio >1.6 suggests median conduction block at the wrist
- This can be useful to diagnose mild carpal tunnel syndrome (CTS) when other tests are normal

Ulnar Sensory (Antidromic)



ACTIVE: Ring electrode on MCP joint of digit 5

REFERENCE: 3 to 4 cm distal to active electrode

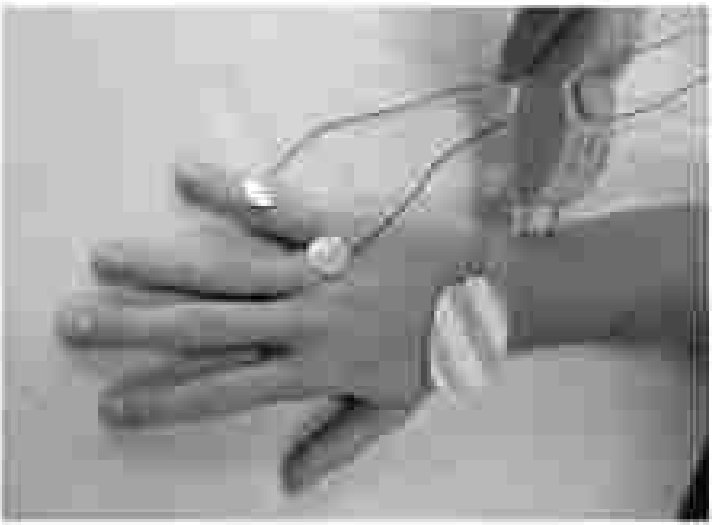
STIMULATION: Medial wrist adjacent to flexor carpi ulnaris tendon 14 cm proximal to active electrode

NORMAL VALUES: Amp >6 μV, peak latency <3.0 msec

Pearls

- Look out for motor artifact, which can obscure the sensory response or be mistaken for an absent sensory response
- May be abnormal in ulnar neuropathy or thoracic outlet syndrome

Dorsal Ulnar Cutaneous (DUC) Sensory Study



ACTIVE: Over the web space between 4th and 5th digit

REFERENCE: Distally 3 to 4 cm over the 5th digit

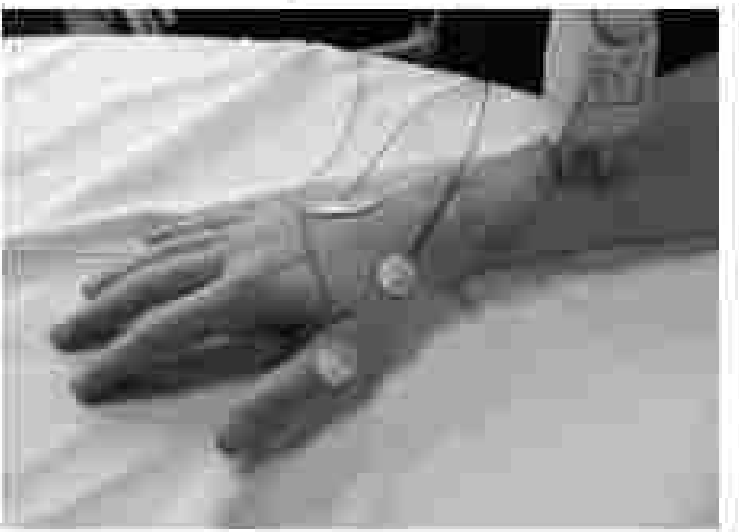
STIMULATION: With hand pronated, proximal to the ulnar styloid process or between the ulna and flexor carpi ulnaris, approximately 8 to 10 cm from active electrode

NORMAL VALUES: Amp >7 μV, peak latency <2.9 msec

Pearls

- May be absent in ulnar neuropathy at the elbow
- Always spared in ulnar nerve lesions at Guyon's canal
- Tests the C8 nerve root, through the lower trunk, and the medial cord

Radial Sensory



ACTIVE: Over superficial radial nerve with EI near extensor tendons of the thumb

REFERENCE: 4 cm distal to active electrode over bony prominence near 1st metacarpophalangeal (MCP) joint

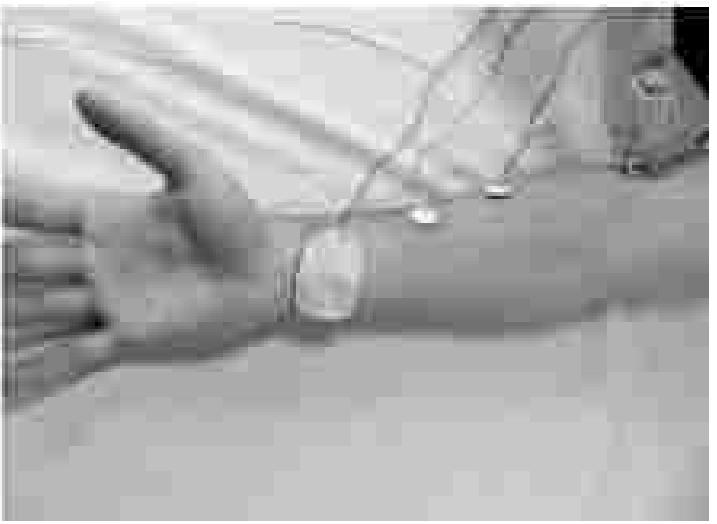
STIMULATION: Dorsal radius 10 cm proximal to active electrode

NORMAL VALUES: Amp >7 μV, peak latency <2.5 msec

Pearls

- Study may be abnormal in radial neuropathy, proximal cord lesions, and upper/middle trunk lesions
- Spared in posterior interosseous neuropathy

Lateral Antebrachial Cutaneous



ACTIVE: 12 cm distal to lateral antecubital fossa in line with radial pulse

REFERENCE: 4 cm distal to active electrode

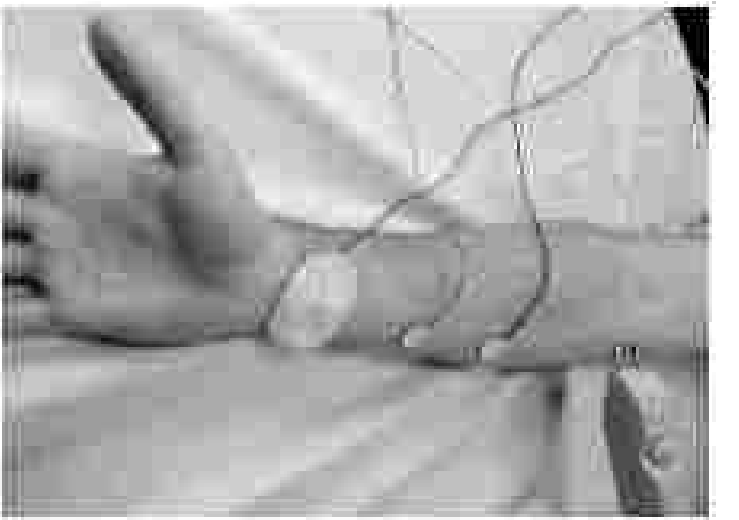
STIMULATION: Antecubital fossa lateral to biceps tendon

NORMAL VALUES: Amp >5 μV, peak latency <2.5 msec

Pearls

- Study may be abnormal in lesions of musculocutaneous nerve, lateral cord, or upper trunk of brachial plexus
- Typically can be stimulated with low intensities
- Side-to-side comparison is essential for this study

Medial Antebrachial Cutaneous



ACTIVE: 12 cm distal to medial antecubital fossa in line with ulnar wrist

REFERENCE: 4 cm distal to active electrode

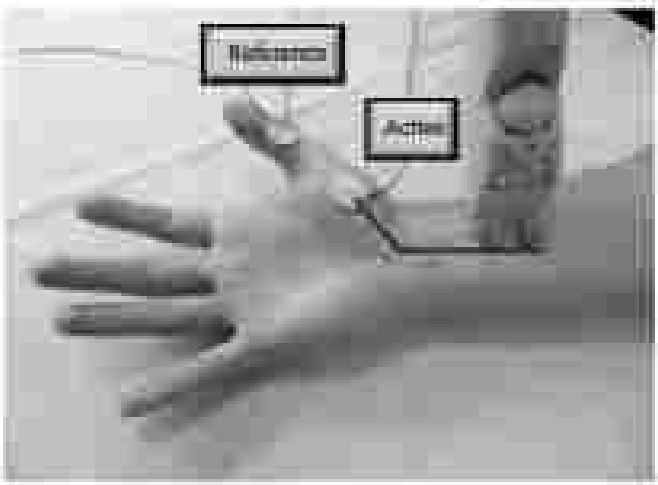
STIMULATION: Medial antecubital fossa between biceps tendon and medial epicondyle

NORMAL VALUES: Amp >4 μV; peak latency <2.6 msec

Pearls

- Study may be abnormal in lesions of medial cord or lower trunk of brachial plexus
- Typically can be stimulated with low intensities
- Side-to-side comparison is essential for this study

Median Motor: Distal Stimulation



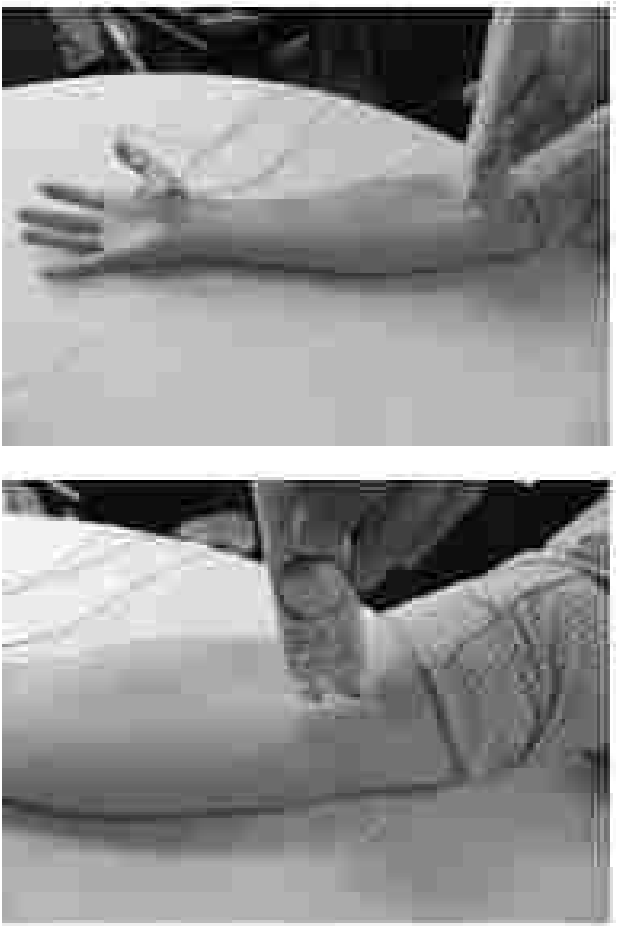
ACTIVE: Over the center of the abductor pollicis brevis (midpoint of first metacarpal just medial to the bone)

REFERENCE: 4 cm distal to active electrode (typically between 1st metacarpophalangeal (MCP) and distal interphalangeal joint (DIP))

STIMULATION: 8 cm proximal to the active electrode along the course of the median nerve. Measure from the active electrode to the middle of the wrist crease, then proximally to a point slightly ulnar to the flexor carpi radialis (FCR) tendon (or between the FCR and palmaris longus)

NORMAL VALUES: Amp >4.1 mV, conduction velocity >49 m/sec, onset latency <4.5 msec, F-wave latency <31.6 msec

Median Motor: Proximal Stimulation



STIMULATION: Place stimulator in antecubital fossa, just medial to biceps tendon. May be easier to palpate biceps tendon with 30-degrees of elbow flexion.

Median Motor: Proximal Stimulation (*continued*)

Pearl: Martin-Gruber Anastomosis

- Be aware of a common anomalous innervation in the forearm, known as Martin-Gruber anastomosis (MGA). This is a cross-over of median motor fibers to the ulnar nerve. This will result in median fibers innervating some ulnar muscles in the hand (first dorsal interosseous [FDI] most common). Can present as:
  - Below elbow stimulation has a lower compound muscle action potential (CMAP) than wrist stimulation when testing the ulnar nerve
  - If MGA fibers innervate ulnar thenar muscles (adductor pollicis), CMAP amplitude is higher at the proximal stimulation than the distal stimulation when testing the median nerve
- Carpal Tunnel Syndrome (CTS) and MGA
  - Median proximal stimulation has an initial positive deflection
  - Unusually fast conduction velocity of the median nerve in the forearm

Ulnar Motor Conduction Study

ACTIVE: Placed over the muscle belly of abductor digiti minimi (ADM); i.e., medial hypothenar eminence

REFERENCE: Placed over bony prominence of 5th metacarpophalangeal (MCP) joint

STIMULATION SITES: 1) wrist, 2) below elbow, 3) above elbow (see photographs on pages 13 and 16)

NORMAL VALUES: Amp >2.0 mV, conduction velocity >50 m/sec, onset latency <3.3 msec, F-wave latency <31.5 msec

Pearls

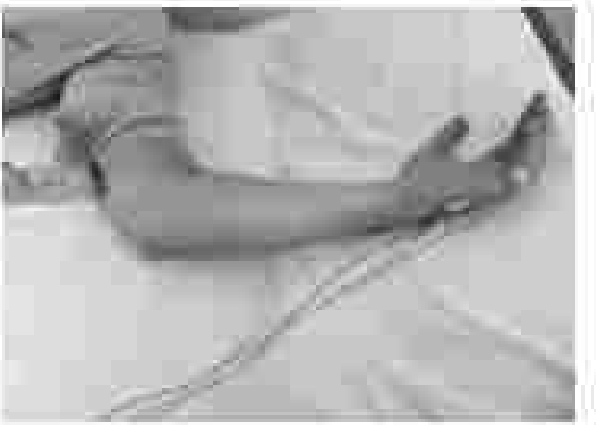
- Optimal position with elbow flexed 90 to 135 degrees
  - If not flexed, slowing may be seen across elbow secondary to underestimation of nerve length
- Distance across elbow should be measured with curved line with the elbow flexed (true course of nerve)
- **"If CMAP amplitude at below elbow site >10% less than that of wrist recording, consider a **MGA (median to ulnar)**."
- With Guyon's canal entrapment neuropathy, the ulnar nerve response may be normal as the abductor digiti minimi (ADM) is usually innervated by the superficial palmar branch of the ulnar nerve
  - **"If suspected, motor responses to the FDI should be studied"**

Ulnar Motor Conduction Study (*continued*)

1. Wrist – Adjacent to flexor carpi ulnaris tendon approximately 7 cm from C1

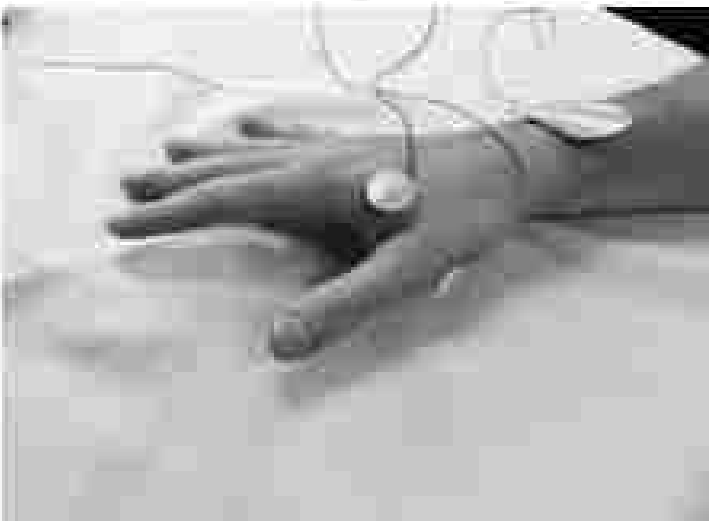
2. Below elbow – 3 to 4 cm distal to medial epicondyle (**at least 3 cm to ensure distal to cubital tunnel**)

Ulnar Motor Conduction Study (*continued*)



3. Above elbow — Stimulation over the medial humerus, between biceps/triceps muscle 10 to 12 cm from below elbow site

Ulnar Motor – Deep Branch



"Example of G1 active being placed over muscle belly of FDI for side-to-side comparison studies in setting of suspected ulnar neuropathy. Reference G2 placed over 1st MCP. Ground over dorsum of wrist, and stimulation sites the same as according to the ADM: 1) wrist, 2) below elbow, 3) above elbow."

NORMAL VALUES: Amp >5.1 mV; distal latency >4.6 msec

Radial Motor Conduction Study

ACTIVE: Placed over the muscle belly of extensor indicis proprius (EIP), with hand pronated two fingerbreadths proximal to ulnar styloid

REFERENCE: Placed over bony prominence of the ulnar styloid

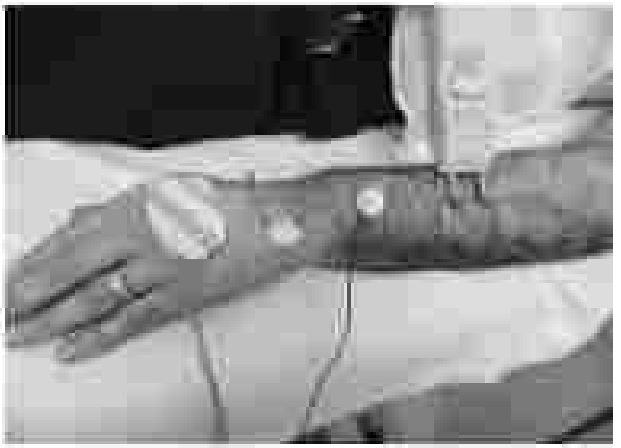
STIMULATION SITES: 1) forearm, 2) elbow, 3) below spiral groove, 4) above spiral groove

NORMAL VALUES: Amp: normal range 1.7 to 11.1 mV, conduction velocity normal range 60.2 to 79.2 m/sec, onset latency <2.1 msec, F-wave latency range 16.2 to 28.1 msec

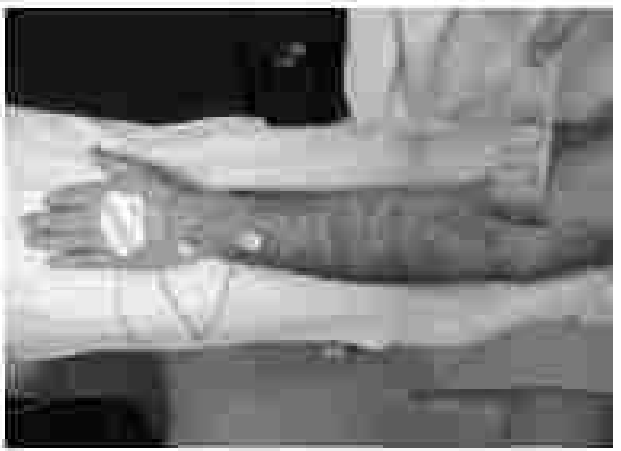
Pearls

- Possible initial positive deflection of CMAP due to other radially innervated muscles in vicinity
- Calipers may assist in approximation of measurements for stimulation sites
- Useful in evaluation of possible **"posterior interosseous neuropathy and radial neuropathy at the spiral groove"**

Radial Motor Conduction Study (*continued*)



1. Forearm — Stimulation over the ulna 4 to 6 cm proximal to G1.

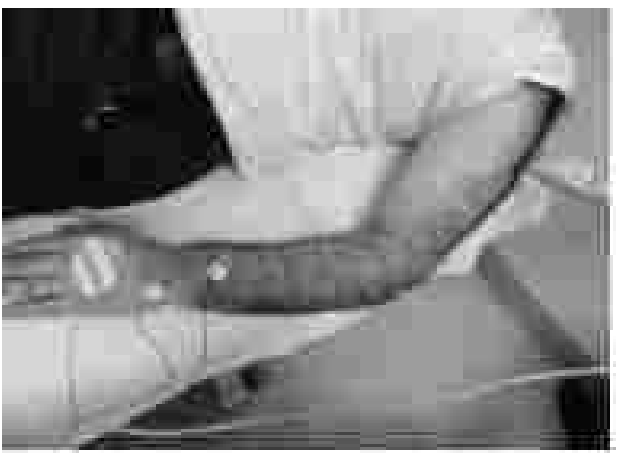


2. Elbow — Stimulation in groove between biceps and brachioradialis muscles.

(*continued*)

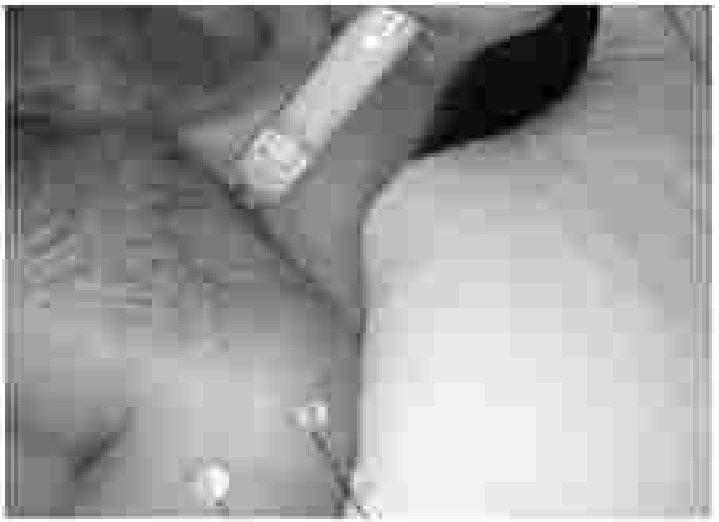
Radial Motor Conduction Study (*continued*)

3. Below spiral groove — Stimulation between biceps brachii and triceps near lateral forearm



4. Above spiral groove — Stimulation over posterior aspect of proximal arm 5 to 7 cm above/below spiral groove site

Erb's Point (Proximal Upper Extremity Motor Studies)



Stimulation site at Erb's point in supraclavicular fossa recording over the deltoid to test the axillary nerve

ACTIVE: G1 placed over proximal upper extremity muscle belly (eg, deltoid, infraspinatus, biceps, triceps)

REFERENCE: G2 reactive point 3 to 4 cm away from muscle tested

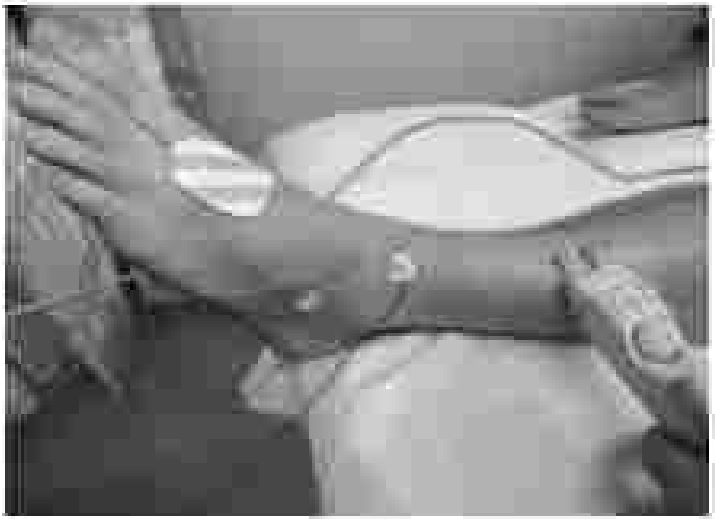
STIMULATION SITE: Erb's point, just posterior to the sternocleidomastoid (SCM) muscle in supraclavicular fossa

NORMAL VALUES: Latency: <5.4 msec (deltoid), <5.6 msec (biceps), <4.3 msec (supraspinatus), <4.8 msec (infraspinatus)

Pearls

- Uncomfortable for patient and difficult to achieve maximum stimulus
- Necessary to do side-to-side comparisons

Superficial Fibular (Peroneal) Sensory



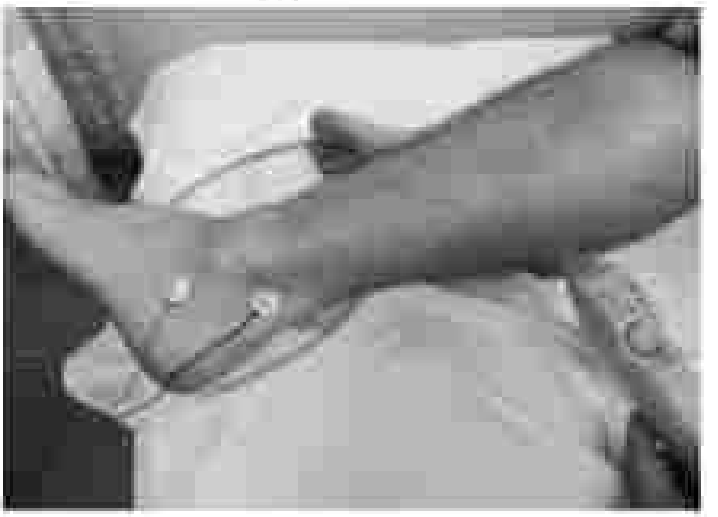
ACTIVE: Over the anterior aspect of the ankle, just lateral to the tendon of the extensor hallucis longus (may need have patient move ankle up and down to locate landmarks)

REFERENCE: 4 cm distal to active electrode

STIMULATION: 10 cm proximal to the active electrode, along the anterior crest of the tibia

NORMAL VALUES: Amp>=17 μV, peak latency<=4.2 msec

Sural Sensory



ACTIVE: Behind the midpoint of the lateral malleolus

REFERENCE: 4 cm distal to active electrode (line electrode may be useful)

STIMULATION: 10 cm proximal to the active electrode in the midline of calf or slightly lateral to the midline

NORMAL VALUES: Amp >4 μV, peak latency <4.5 msec

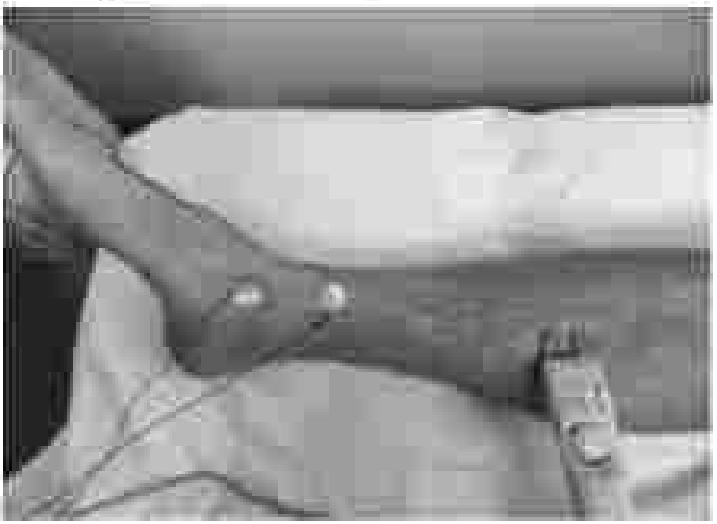
(continued)

Sural Sensory (*continued*)

Pearls

- A hooked/curved electrode probe may be helpful if the patient is supine
- If using a straight electrode probe it may be helpful if the patient is lying on contralateral side
- A "wide sweep" of the trait may be necessary to find the best results
- May want to consider averaging the responses because the amplitudes are typically very small
- If still no responses found, may want to compare to other leg
  - Onset latency greater than 0.4 msec difference from side to side is abnormal
  - Peak latency greater than 0.5 msec difference from side to side is abnormal
  - Onset to peak amplitude decrease more than 77% from side to side is abnormal
  - Peak to peak amplitude decrease more than 67% from side to side is abnormal

Saphenous Sensory



ACTIVE: Between the medial malleolus and tibialis anterior (TA) tendon

REFERENCE: 4 cm distal to active electrode

STIMULATION: Medial calf in the groove between the tibia and medial gastrocnemius

DISTANCE: 14 cm proximal to active electrode

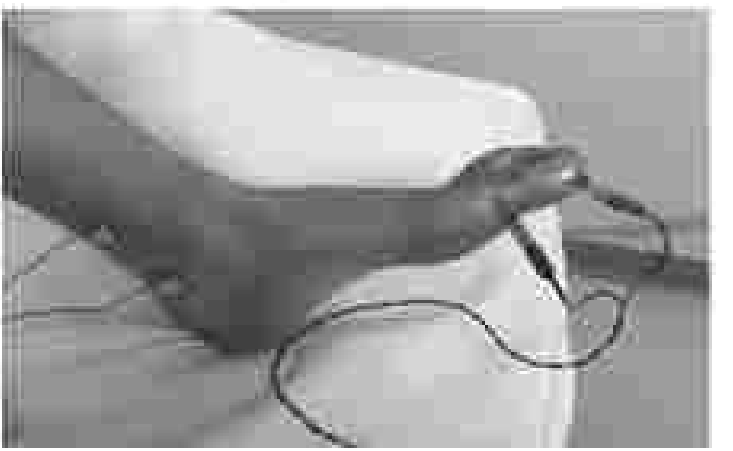
NORMAL VALUES: Amp >2 μV, peak latency <4.4 msec

Pearls

- Study may be abnormal in lesions of the femoral nerve or lumbar plexus
- Side-to-side comparison is essential for this study, especially as low or absent responses may be normal

Medial/Lateral Plantar Nerve Sensory Study

Lateral Plantar Sensory — Orthodromic study stimulating at the little toe and recording at the medial ankle



Medial Plantar Sensory — Orthodromic study stimulating at the great toe and recording at the medial ankle

Medial/Lateral Plantar Nerve Sensory Study (*continued*)

ACTIVE: Above and posterior to medial malleolus

REFERENCE: 3 to 4 cm proximal to active electrode

STIMULATION SITES: Great toe for medial plantar sensory, 5th toe for lateral plantar sensory

GROUND: Medial aspect of foot

NORMAL VALUES: Medial amp >10-20 µV, medial peak latency <3.66 msec, lateral amp >8-20 µV, lateral peak latency <3.65 msec

Pearls

- Study useful for evaluation of possible tarsal tunnel syndrome (distal tibial neuropathy)
- Pure SNAPs difficult to obtain with averaging often required along with side to side comparison
- The foot is also very sensitive to temperature change, which is important to remember when performing the study

Lateral Femoral Cutaneous Nerve: Sensory Study

Lateral Femoral Cutaneous: Stimulation 2 cm medial to anterior superior iliac spine (ASIS) and above the inguinal ligament

ACTIVE: G1 placed 12 cm distally to stimulation site along anterolateral thigh

REFERENCE: G2 placed 3 to 4 cm distally to G1

STIMULATION SITE: Medial to ASIS proximal to inguinal ligament

GROUND: Between G1 and G2

Pearls

- Important to get side to side comparison
- Side to side amplitude difference of >50% is considered abnormal
- May be abnormal if nerve is entrapped or in high lumbar plexopathy

Fibular (Peroneal) Motor Study Recording at Extensor Digitorum Brevis

1. Ankle: Distal stimulation site slightly lateral to tibialis anterior tendon

ACTIVE: Placed over the muscle belly of extensor digitorum brevis (EDB)

REFERENCE: Placed over the MTP of the little toe

STIMULATION SITES: 1) ankle, 2) below fibular head, 3) popliteal fossa

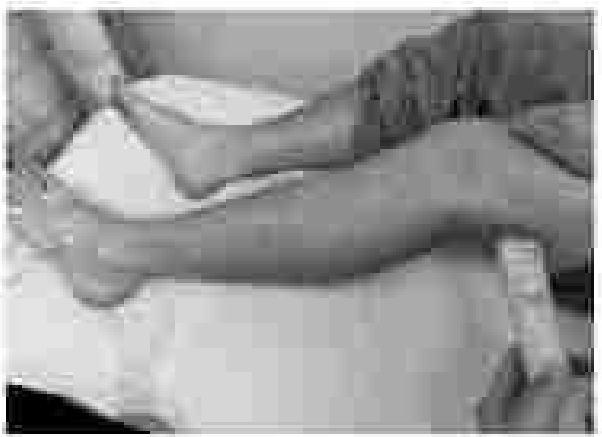
NORMAL VALUES: Amp >1.3 mV, conduction velocity >38 m/sec, onset latency <6.5 msec, F-wave latency <61.2 msec

Pearls

- If a higher CMAP amplitude below the fibular head/popliteal fossa when compared to the ankle, consider **accessory peroneal nerve**
- If overstimulation occurs at the popliteal fossa site, it may co-stimulate the tibial nerve

Fibular (Peroneal) Motor Study Recording at EDB (*continued*)

2. **Below fibular head:** Stimulation of lateral calf just below the fibular head



3. **Popliteal fossa:** Stimulation of lateral popliteal fossa slightly medial to the biceps femoris tendon, approximately 80 cm proximal from the below fibular head site

Fibular (Peroneal) Motor Conduction Study Recording at Tibialis Anterior

1. **Below the fibular head:** Stimulation below fibular head recording at TA
2. **Popliteal fossa:** Stimulation site shown previously and is **"same as when recording at extensor digitorum brevis (EDB)"**

ACTIVE: Placed over the muscle belly of tibialis anterior mid leg lateral to the tibia

REFERENCE: Placed 3 to 4 cm distally over the anterior ankle

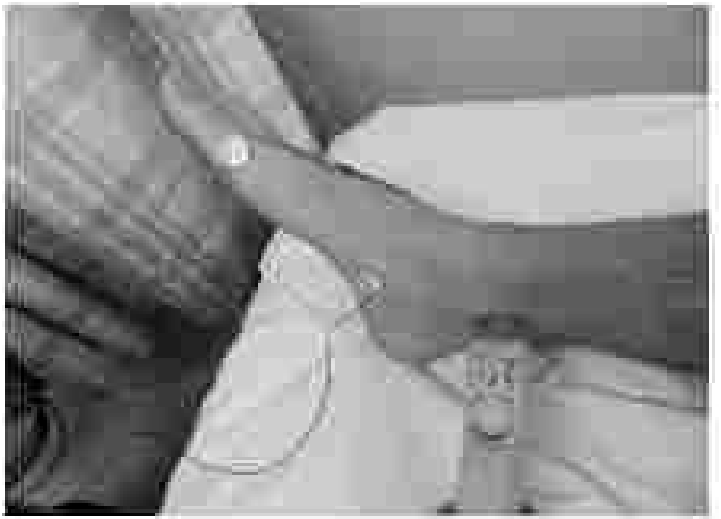
STIMULATION SITES: 1) below the fibular head, 2) popliteal fossa

NORMAL VALUES: Amp: >3.7 mV, conduction velocity >40 m/sec, onset latency <4.9 msec

Pearls:

- Study may be useful in peripheral neuropathy in which no response or small response obtained from recording at the EDB
- Because of the nerve lying deep at this location, may require higher stimulation

Tibial Motor or Medial Plantar Motor (Tibial Medial Branch)



ACTIVE: Slightly anterior and inferior to the navicular tubercle, which is at the superior point of the medial foot arch.

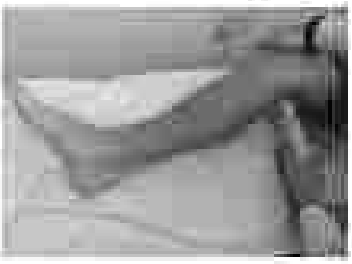
REFERENCE: Slightly distal to the 1st metatarsophalangeal (MTP) joint, on the medial aspect of the toe.

DISTAL STIMULATION: 8 cm proximal to the active electrode. Measure from the active electrode to a point just posterior to the medial malleolus.

NORMAL VALUES: Amp >4.0 mV, conduction velocity >39 m/sec, onset latency <6.1 msec, F-wave latency <61.4 msec.

HELPFUL TIP: It is common to get an initial positive deflection on your recording (meaning you are not at the center of the muscle belly). Try moving the active electrode in different directions to minimize this deflection.

Tibial Motor (Tibial Medial Branch)

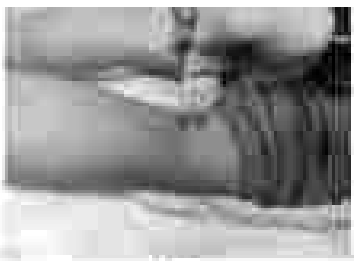


A

B

- **Proximal Stimulation:** Stimulator is placed at the mid-popliteal fossa with the knee flexed 30 to 45 degrees (Image A). If having difficulty getting a good response, try flexing the knee beyond 90 degrees so the stimulator can be placed deeper into the fossa (Image B).

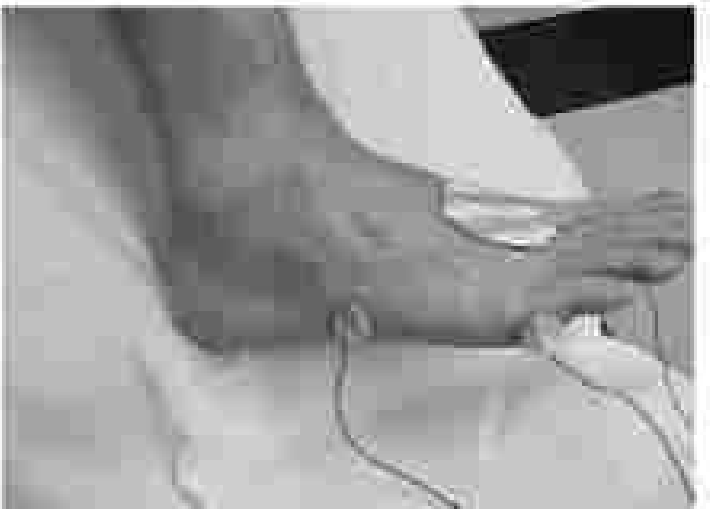
HELPFUL TIP: The tibial nerve can be deep in the popliteal fossa. Typically this stimulation requires a high voltage and possible increased duration of stimulation to elicit optimal recorded amplitude.



C

Proximal Stimulation (Position Variation): Patient lying in prone position (Image C).

Lateral Plantar Motor (Tibial Lateral Branch)



ACTIVE: Approximately half way between the 5th metatarsophalangeal (MTP) joint and the heel, along the lateral arch

REFERENCE: Slightly distal to the 5th MTP joint, on the fat pad aspect of the toe

DISTAL STIMULATION: SAME AS PREVIOUS STIMULATION SITE

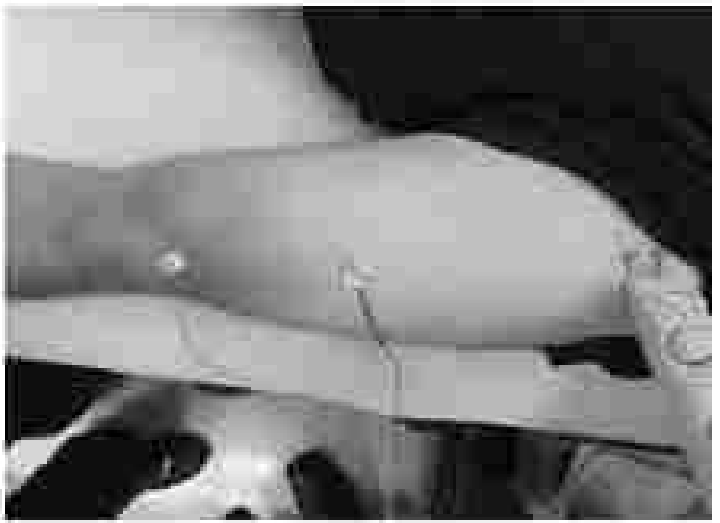
Pearls

- This setup allows comparison of the lateral tibial branch versus the medial branch.
- Typically, the lateral branch latency is greater than the medial branch latency with an upper limit of normal increased latency of 2.5 msec.
- If the medial latency is within 0.5 msec of the lateral latency or exceeds the lateral latency, this is a sign of medial branch slowing.

Lateral Plantar Motor Normal Values

- Amplitude >3.0
- Conduction velocity >41
- Distal latency <6.2

Femoral Motor



ACTIVE: Over anterior thigh halfway between the inguinal crease and the superior patella

REFERENCE: On the patella

STIMULATION: Inferior to the center of the inguinal crease, lateral to the femoral pulse

NORMAL VALUES: Normal amplitude 0.2–11 mV, latency <7.4 msec

Pearls

- Need firm pressure on the stimulator
- May be abnormal in femoral neuropathy, lumbar plexopathy, severe upper lumbar radiculopathy
- Side-to-side comparison of amplitude is essential

F-Wave

PHYSIOLOGY: Antidromic motor response: toward spinal cord, backfiring of small percentage of anterior horn cells, followed by orthodromic motor response back to muscle. This is a pure motor response, but not a true reflex like the H-reflex.

Any routine motor nerve conduction study can be used to check the F-wave. Active and reference electrodes can be kept in the same place.

STIMULATION: Cathodic pointing proximally. Use supramaximal stimulation. Obtain 10 F waves.

NORMAL VALUES: Upper limit of normal in arms is 32 msec. Upper limit of normal in legs is 56 msec.

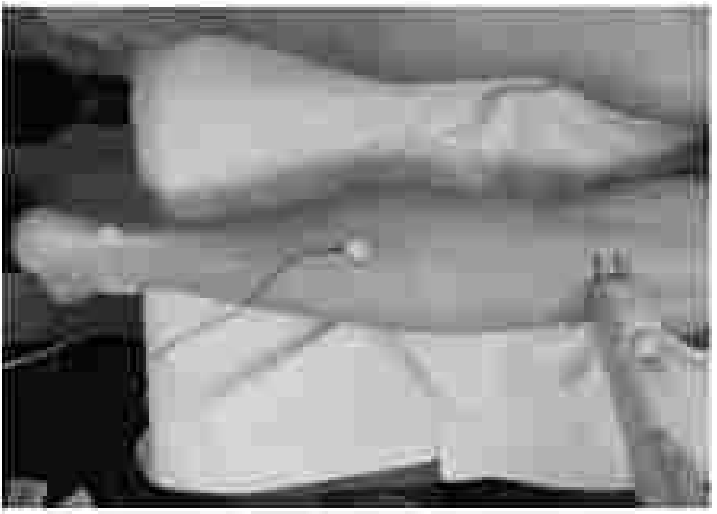
F-Wave Utility

- Most useful for diagnosing early Guillain-Barré, which commonly begins with demyelination of nerve roots
  - May be delayed or absent
- May assist in diagnosing C8-T1 or L5-S1 radiculopathies
- Abnormality may indicate problem with proximal nerve segment, but a lesion anywhere along the nerve may cause F-wave latency increase

Pearls

- Mark earliest F wave latency when it departs baseline
- Jendrassik maneuver can help to elicit the F wave
- Side to side comparison may be helpful
- Tall patients have longer F wave responses

H-Reflex



ACTIVE: On the soleus: measure from popliteal fossa to Achilles tendon at proximal medial malleolus. Divide this line into eight parts. Place active between 5th and 6th markings. This should be two to three fingerbreadths distal to where soleus meets gastrocnemius

REFERENCE: On the Achilles at the ankle

STIMULATION: Cathode-proximally at popliteal fossa

NORMAL VALUES: Mark H-reflex latency at earliest point on rectified trace where it departs from baseline. Normal value for latency depends on patient's height and age (may be absent in older patient). However, side-to-side difference is more helpful — abnormal significant side-to-side difference varies depending on what test you read (anywhere between 1.2 and 2.0 msec)

H-Reflex Stimulation

- Begin stimulating at low intensity
- The H-reflex will be seen with latency of 25 to 30 msec and will continue to increase in amplitude with increased stimulation intensity

(continued)

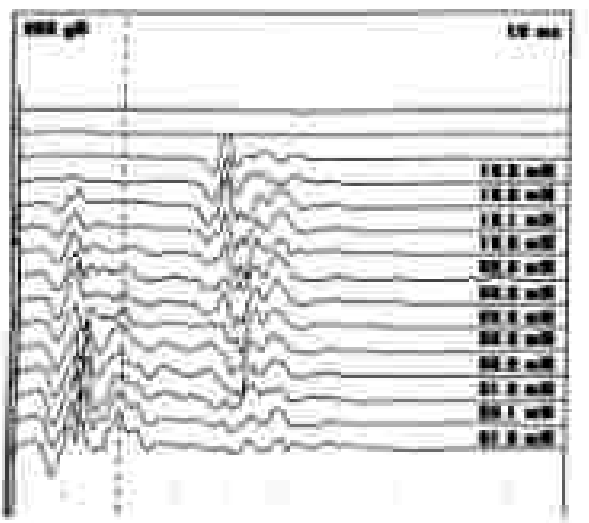
H-Reflex Stimulation (*continued*)

- As stimulation intensity increases, a direct motor M wave will appear
- As stimulation intensity increases further, the M wave will increase in amplitude and the H reflex will decrease in amplitude

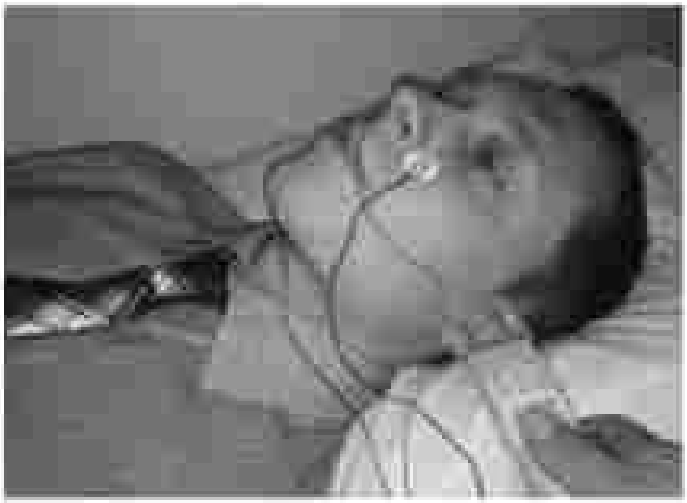
Pearls

- A true reflex (represents S1/Achilles reflex): Ia sensory afferents and alpha motor neuron efferents. Should be present if Achilles reflex present
- At low stimulus with long duration, relatively activate Ia afferents
- Jendrassik maneuver and/or plantarflexion can help to elicit the H reflex
- Can be abnormal with polyneuropathy, tibial nerve or sciatic nerve lesion, S1 radiculopathy

Sample H-reflex tracing



Facial Motor Nerve



Stimulation of facial nerve at angle of jaw (anterior to tragus), recording at nasalis muscle.

ACTIVE: Placed lateral to the middle of nose over nasalis muscle

REFERENCE: Inactive point placed over bridge of nose or contralateral side of side of nose

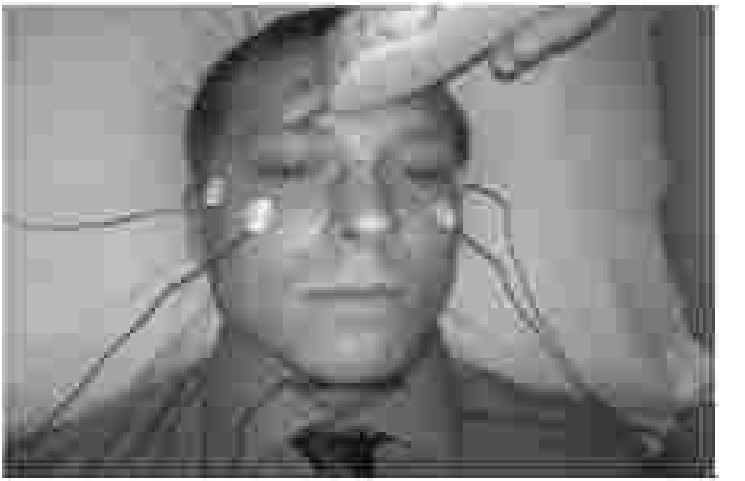
STIMULATION SITES: Over the angle of the jaw at the anterior tragus in front of ear

NORMAL VALUES: Amp >1.0 mV, distal latency <3.1 msec

Pearls

- Possible initial positive deflection of CMAP due to difficulty of getting directly over motor point (co-stimulation of masseter)
- May similarly record other additional facial muscles
- Facial nerve CMAP assessment may assist with condition and prognosis of Bell's palsy

Blink Reflex (Trigeminal and Facial Nerves)



Stimulating supraorbital nerve in evaluating blink reflex. This setup will test cranial nerves 5 and 7 on the right and 7 on the left.

ACTIVE: C1 placed below the eye socket over the orbicularis oculi muscle

REFERENCE: C2 placed over inactive lateral canthus of the eyes

STIMULATION SITES: The supraorbital nerve over the mid-eyebrow located at the supraorbital notch

Pearls

- Use two channels with four electrodes to record at both ipsilateral and contralateral sides
- Low current typically required for supraorbital stimulation
- May be helpful in trigeminal neuralgia, facial nerve lesions, demyelinating neuropathies, and brainstem lesions

Blink Reflex Normal Values

- R1 (ipsilateral): Latency <13 msec, side-to-side latency difference <1.2 msec
- R2 (ipsilateral): Latency <41 msec, side-to-side latency difference <5 msec
- R2 (contralateral): Latency <44 msec, side-to-side latency difference <5 msec

Repetitive Nerve Stimulation (RNS) Protocol

1. Perform routine motor nerve conduction studies first to ensure that the nerve is normal.
2. If extremity is cool, warm it to at least 33°C.
3. Immobilize the muscle as best as possible.
4. Stimulate must be supramaximal; perform 3-Hz RNS at rest for 5 to 10 impulses, repeated at least three times, 1 minute apart.
5. If there is greater than 10% decrement, have the patient perform maximal voluntary exercise for 10 seconds. Then immediately repeat 3-Hz RNS consecutive to demonstrate facilitation and repair of the decrement.
6. If there is less than 10% decrement, have the patient perform maximal voluntary exercise for 1 minute; then perform 3-Hz RNS immediately and 1, 2, 3, and 4 minutes after exercise to demonstrate post-exercise exhaustion. If a significant decrement occurs, have the patient perform maximal voluntary exercise again for 10 seconds and immediately repeat 3-Hz RNS to demonstrate repair of the decrement.

(continued)

Pearls

- If the patient reorients for greater than 10 seconds or if the nerve is not stimulated immediately postexercise, a potential increment may be missed.
- Perform RNS on one distal and one proximal motor nerve. Try to study the weaker muscles. If no decrement is found with a proximal muscle, a facial muscle can be tested.
- Any muscle with EMG findings of denervation or myotonia may demonstrate a decrement on RNS. Be aware not to confuse this with decrement from a primary disorder of the neuromuscular junction (NMJ).

RNS Frequency

1. Slow RNS (2–3 Hz) — Used to test stability of the NMJ
2. Rapid RNS (10–50 Hz) — Used to replicate what is seen on voluntary contraction

Normal RNS Study

- In a slow RNS study, there is less than 10% decrement between the first and fourth responses.
- The endplate potentials (EPP) should never fall below threshold, and the CMAP amplitude and area remain stable.
- In slow RNS, decrement in CMAP amplitude and area 2 to 4 minutes after prolonged exercise should remain very similar to the initial stimulation.
- However, in patients with NMJ disorders, the decrement in CMAP amplitude and area becomes more marked with each minute after prolonged exercise.

Presynaptic NMJ Disorder (Lambert-Eaton Myasthenic Syndrome)

- An autoimmune reaction in which antibodies are formed against presynaptic voltage-gated calcium channels, preventing the release of acetylcholine into the NMJ
- In slow RNS, the EPP amplitude will be very low at baseline. Muscle contractions may not be visible because the muscle fiber action potential threshold has not been met
- Have the patient perform 10 seconds of maximal voluntary exercise, then stimulate the nerve supramaximally immediately postexercise, looking for an abnormal increment (greater than 40% above the baseline)
- In rapid RNS, there is a progressive increment in the EPP amplitude to above threshold resulting in a greater than 100% increment in amplitude in a presynaptic NMJ disorder. However, 10 seconds of maximal exercise accomplishes the same thing and is much less painful than rapid RNS.

Pearls

- Fatigue improves with exertion in patients with Lambert-Eaton Myasthenic Syndrome (LEMS)
- Typically does not involve oculobulbar muscle
- Typically proximal weaker than distal muscles, mainly affecting lower limbs

Postsynaptic NMJ Disorder (Myasthenia Gravis)

- An autoimmune reaction in which antibodies are formed against the postsynaptic acetylcholine receptors in the NMJ.
- In slow RNS, the first one or two EPPs will be lower than normal, but still above the muscle fiber action potential threshold. With further acetylcholine depletion in the NMJ, later EPPs will not meet threshold and muscle contractions may not be visible.
- In slow RNS, the decrement is classically described as a "U shape," meaning that after the fourth EPP, the decrement begins to slowly improve. This is due to the depletion of the initial acetylcholine quanta with the first few stimuli, which are gradually replenished from the secondary store after the 5-6th stimulus.

Pearls

- Fatigue worsens with exertion in patients with Myasthenic Syndrome (MG).
- Typically involves oculobulbar muscles.
- Typically proximal weaker than distal muscles.

2

Needle Electromyography

- EMG Introduction
- Upper Extremity Studies
- Lower Extremity Studies
- Paraspinal Muscles
- Facial Muscles

- The Major Components to EMG:
  1. Spontaneous activity
  2. Motor unit analysis
  3. Recruitment

**Can also observe for insertional activity but must consider these findings nonspecific

Spontaneous Activity

- Ensure the muscle is at rest
- Eliminate interference
- Look out for end plate activity
- Sample four quadrants of the muscle
- Observe for abnormal spontaneous activity
  - (see the table in Chapter 8, Characteristics of spontaneous activity)

Motor Unit Analysis

- Generally recommended to observe approximately 20 motor unit action potentials (MUAPs)
- Analyze with slight muscle activation
- MUAPs are typically sensorhythmic
- When the needle is distant from motor unit, MUAP may appear of long duration or polyphasic and may have dull sound
- As the needle gets closer to the motor unit, the MUAPs will look and sound more crisp
- Neurogenic MUAPs: Long duration, high amplitude, polyphasic (5 or more baseline crossings)
  - Typically sound like a low pitched, dull thud
  - Long duration typically >15 large bumps on screen if 10 msec/box (>15 msec duration)
- Myopathic MUAPs: Short duration, low amplitude

Recruitment

- Observe initially at low level of muscle activation
- Normal ratio of firing frequency is 5:1
  - When MUAP reaches 10 Hz, a second MUAP should fire
  - When MUAP reaches 15 Hz, 3 MUAPs should fire
- Neuropathic recruitment: Decreased recruitment of MUAPs
- Myopathic recruitment: Early recruitment of MUAPs
- On rectified screen with 10 msec/box, if 2 of the same MUAPs are on top of each other, the MUAP is firing at 10 Hz
- On long trace with 100 msec/box, if 10 of the same MUAPs are on the screen, that MUAP is firing at 10 Hz and at least one different MUAP should be firing on the screen as well
- A full interference pattern on screen can be utilized to assess recruitment, but it is not as reliable as the above methods

Abductor Pollicis Brevis (APB)

INNERVATION: Median nerve, medial cord, lower trunk, C8–T1

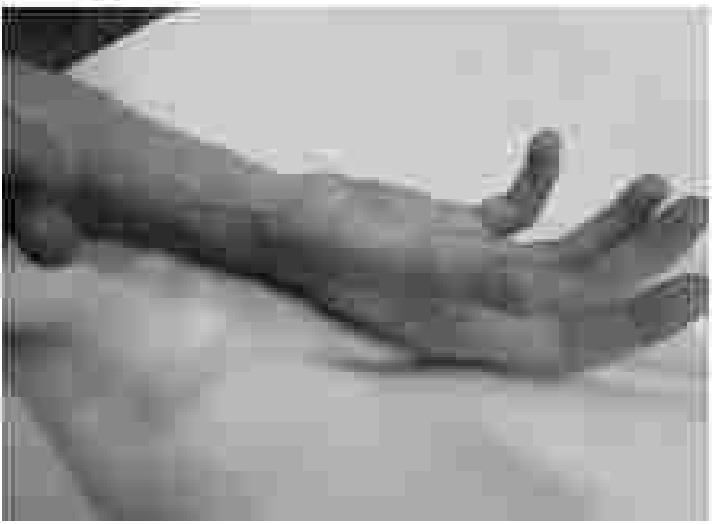
ACTIVATION: Thumb abduction

NEEDLE INSERTION: Midpoint of first metacarpal just medial to the bone

Pearls

- If too deep, may be in the opponens pollicis (also median)
- If too medial, may be in the flexor pollicis brevis, which has median and ulnar innervation (potentially problematic)
- Frequently used for median motor studies, but very painful. Consider avoiding this muscle if more clinically useful information will not be gained
- Spared in anterior interosseous syndrome

Opponens Pollicis



INNERVATION: Median nerve, medial cord, lower trunk, C8-T1

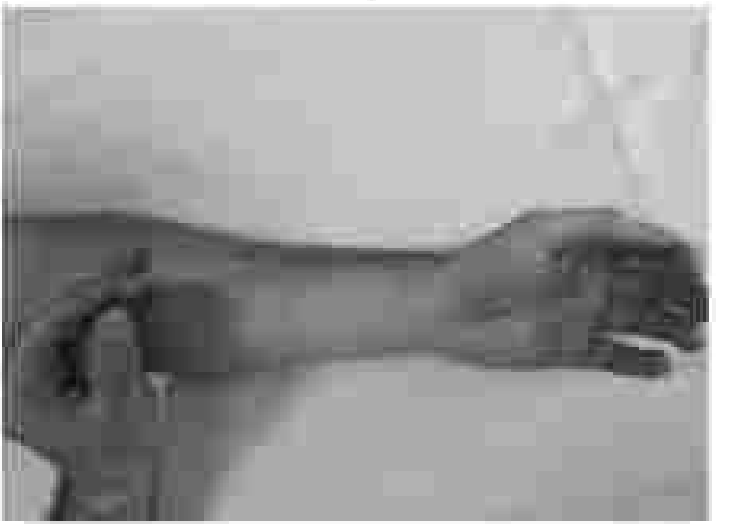
ACTIVATION: Opposition of the thumb to the little finger

NEEDLE INSERTION: With needle parallel to the hand, insert into lateral thenar eminence above first metacarpal bone to a depth of approximately 1/2 inch

Pearl

- May be abnormal in carpal tunnel syndrome, lower trunk/medial cord injury, thoracic outlet syndrome, distal polyneuropathy. Spared in anterior interosseous syndrome. Muscle belly is deep to the APB

Flexor Pollicis Longus



INNERVATION: Anterior interosseous nerve, median nerve, lateral/medial cords, anterior divisions, middle and lower trunks, C7-T1

ACTIVATION: Flexion of distal phalanx of thumb

NEEDLE INSERTION: Mid radial forearm volar to radius

Pearls

- Needle will travel through flexor carpi radialis (FCR) and flexor digitorum superficialis (FDS)
- May be affected in anterior interosseous nerve (AIN) lesions or lesions of the median nerve at the proximal forearm or ligament of Struthers
- Useful as it is a CR median muscle proximal to the carpal tunnel
- **CAUTION:** The radial artery just medial to insertion point

Flexor Digitorum Profundus (FDP)

INNERVATION:

Second and third digit: AIN, median nerve, medial cord, anterior division, middle and lower trunk, C7-C8

Fourth and fifth digit: Ulnar nerve, medial cord, anterior division, lower trunk, C8-T1

ACTIVATION: Distal interphalangeal joint flexion

NEEDLE INSERTION: Three to four fingerbreadths distal to olecranon, superficially fourth and fifth digits and deeper layers second and third digits

Pearls:

- May be abnormal in AIN syndrome or proximal median neuropathies
- Median nerve muscle (deeper layer) is difficult to obtain

Flexor Digitorum Superficialis (FDS)

INNERVATION: Median nerve, lateral and medial cord, anterior division, middle and lower trunk, C7-T1

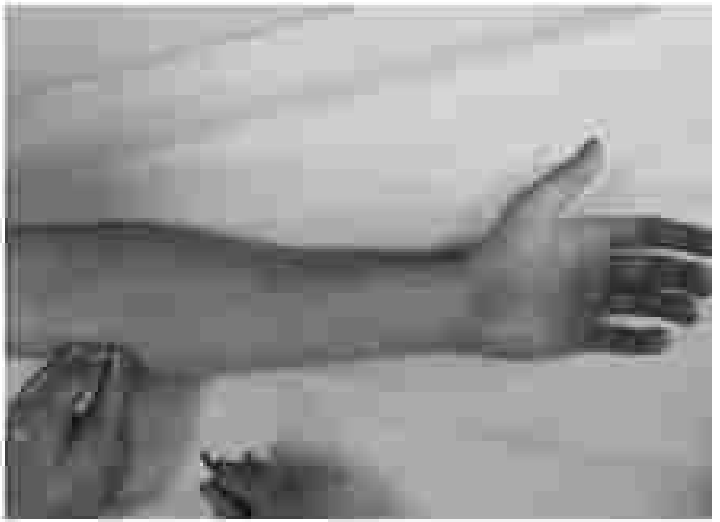
ACTIVATION: Keep DIP hyperextended and only flex the proximal interphalangeal joint

NEEDLE INSERTION: Medial to the midpoint between biceps tendon and midcervix

Pearls

- May be absorbed in proximal median neuropathies
- Spared in AIN syndrome

Flexor Carpi Radialis (FCR)



INNERVATION: Median nerve, lateral and medial cord, upper/middle/lower trunk, C6-C7, C8

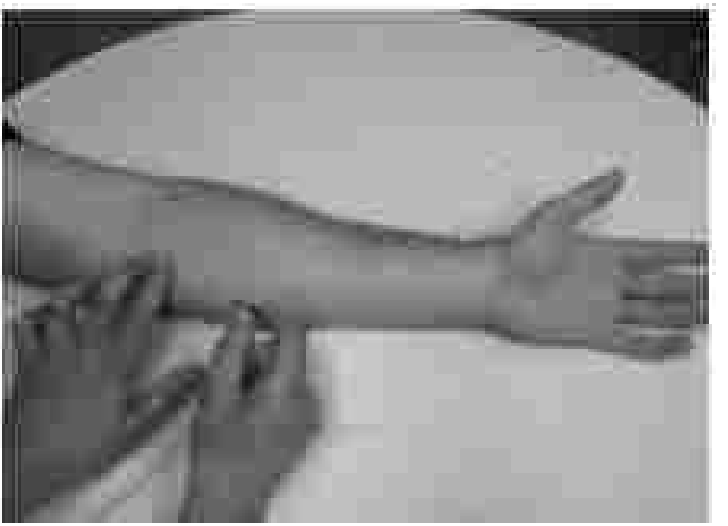
ACTIVATION: Radial deviation and flexion of the wrist

NEEDLE INSERTION: Four fingerbreadths distal to mid-point between biceps tendon and medial epicondyle with arm supinated

Pearl

- Note thumb abnormal in CMC / radiocarpal or proximal median neuropathy. Spared in anterior interosseous syndrome. If needle is too deep, it may be in the flexor digitorum sublimis or pronator teres. If too medial, may be in palmaris longus

Pronator Teres



INNERVATION: Median nerve, lateral cord, upper/middle trunk, C6–C7.

ACTIVATION: Pronation of the hand with elbow extended

NEEDLE INSERTION: With patient in a supinated position, insert needle two fingerbreadths distal to midpoint between the medial epicondyle and the biceps tendon

Pearl

- Often abnormal in C6/C7 radiculopathy or proximal median neuropathy. Is the most proximal muscle innervated by median nerve. If the needle is too deep, may be in flexor digitorum profundis. May be spared in pronator syndrome. Spared in ALS syndrome

First Dorsal Interosseous (FDI)

INNERVATION: Ulnar nerve, medial cord, anterior divisions, lower trunk, C8-T1

ACTIVATION: Abduct the index finger

NEEDLE INSERTION: At the base of the second metacarpophalangeal (MCP)

Pearls

- Abnormal in ulnar neuropathy
- Easiest and least painful of the intrinsic hand muscles
- Innervation can vary. Can be either or both of the ulnar or median nerves
- If inserted too deeply, it will be the adductor pollicis

Abductor Digiti Minimi (ADM)

INNERVATION: Ulnar nerve, medial cord, lower trunk C8-T1

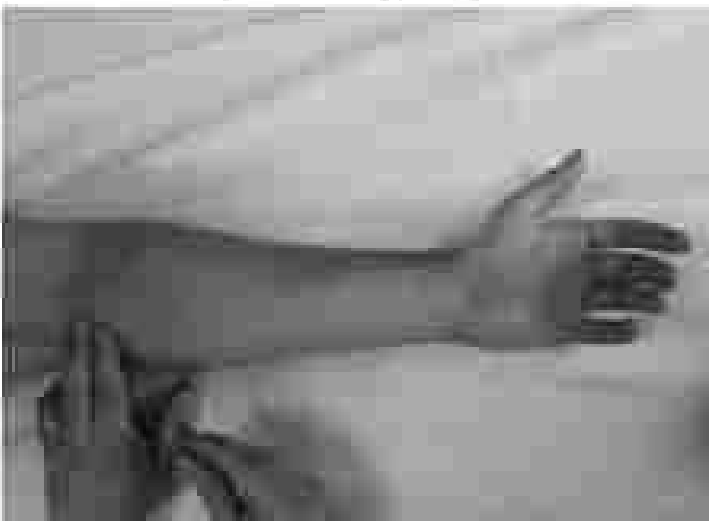
ACTIVATION: Fifth digit abduction

NEEDLE INSERTION: With hand supinated, midpoint of fifth metacarpal

Pearl

- Abnormal in ulnar neuropathy and with lesions to lower brachial/medial cord, and outlet of thoracic outlet syndrome. Also involved in Klumpke's palsy (avulsion of C8/T1 roots)

Flexor Carpi Ulnaris (FCU)



INNERVATION: Ulnar nerve, medial cord, anterior division, lower trunk, C8-T1

ACTIVATION: Ulnar abduction and flexion of the wrist

NEEDLE INSERTION: Medial forearm at midpoint between elbow and wrist with arm supinated

Pearl

- To help localize muscle, may have the patient abduct the fifth digit, which contracts the origin of the FCU from the patient. If needle is too deep, may elicit FDP. Often spared in ulnar neuropathy at the elbow

Extensor Indicis Proprius (EIP)

INNERVATION: Posterior interosseous nerve, radial nerve, posterior cord, middle trunk, C7-C8

ACTIVATION: Extend index finger

NEEDLE INSERTION: Two fingerbreadths proximal to ulnar styloid with depth of approximately 1/2 inch

Pearl

- May be abnormal in C8 radiculopathy, lower trunk/pod cord injury, thoracic outlet syndrome, distal polyneuropathy, and any radial nerve injury including posterior interosseous nerve. EIP is the most distal radially innervated muscle. If too radial, may be in the abductor pollicis longus; if too proximal, then may be in the extensor digitorum communis (EDC).

Extensor Carpi Ulnaris (ECU)

INNERVATION: Posterior interosseous nerve, radial nerve, posterior cord, middle/lower trunk, C7-8

ACTIVATION: Ulnar wrist extension

NEEDLE INSERTION: Just proximal to midpoint of ulna on dorsal forearm

Pearls:

- Affected by lesions of posterior interosseous nerve, crutch palsy, or Saturday night palsy
- May be abnormal in thoracic outlet syndrome, CII radic ulopathy, or distal polyneuropathy
- If needle is inserted too radially, will be in extensor pollicis longus
- If needle is inserted too proximally, will be in anconeus

Extensor Digitorum Communis (EDC)

INNERVATION: Posterior interosseous nerve, radial nerve, posterior cord, middle/lower trunk, C7-8

ACTIVATION: Middle finger extension

NEEDLE INSERTION: With forearm pronated, insert needle three to four fingerbreadths distal to olecranon and three fingerbreadths above (radial) to ulna

Pearls

- Affected by lesions of posterior interosseous nerve, crutch palsy, or Saturday night palsy
- If needle is inserted too laterally, will be in extensor carpi ulnaris
- If needle is inserted too deeply, will be in extensor pollicis longus
- If needle is inserted too medially, will be in extensor carpi radialis brevis

Extensor Carpi Radialis

INNERVATION: Radial nerve, posterior cord, upper/middle trunk, C6-7

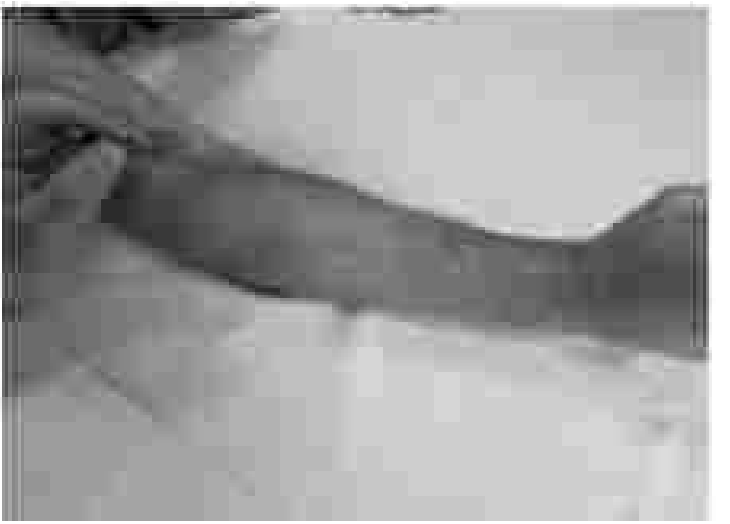
ACTIVATION: Radially extending wrist

NEEDLE INSERTION: With forearm pronated, insert needle two fingerbreadths distal to lateral epicondyle on the dorsal forearm

Pearls:

- Affected by radial nerve lesions above or at spiral groove
- If needle is inserted too distally, may be in posterior interosseous nerve innervating muscles

Brachioradialis



INNERVATION: Radial nerve, posterior cord, upper trunk, C5–6

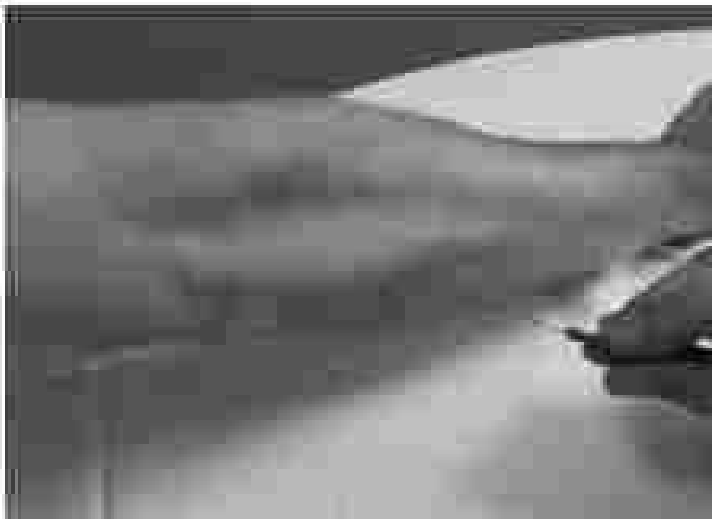
ACTIVATION: Elbow flexion with wrist midway between pronation and supination

NEEDLE INSERTION: Slightly distal to midpoint between biceps tendon and lateral epicondyle

Pearls

- Affected by radial nerve lesions above or at spiral groove
- Spared in posterior interosseous nerve lesions
- If needle is inserted too laterally, may be in extensor carpi radialis longus

Anconeus



INNERVATION: Radial nerve, posterior cord, posterior divisions, middle/lower trunk, C6-C7-C8

ACTIVATION: Extension of the elbow

NEEDLE INSERTION: Two fingerbreadths distal to olecranon with forearm pronated and elbow extended

Pearl

- Only radial muscle in the forearm innervated from above the spiral groove, thus spared except in very proximal injuries of radial nerve

Triceps

INNERVATION: Radial nerve, posterior cord, upper/middle/lower trunk, C5–C8

ACTIVATION: Extend the elbow

NEEDLE INSERTION: Below the midpoint between the lateral epicondyle and shoulder

Pearls

- Lateral head is usually the easiest to study
- Abnormal in C7 radiculopathy
- Spared in radial neuropathy at the spiral groove because it is very proximally innervated
- Almost never involved in isolated ulnar palsy

Biceps Brachii

INNERVATION: Musculocutaneous nerve, lateral cord, anterior division, upper trunk, C5–C6

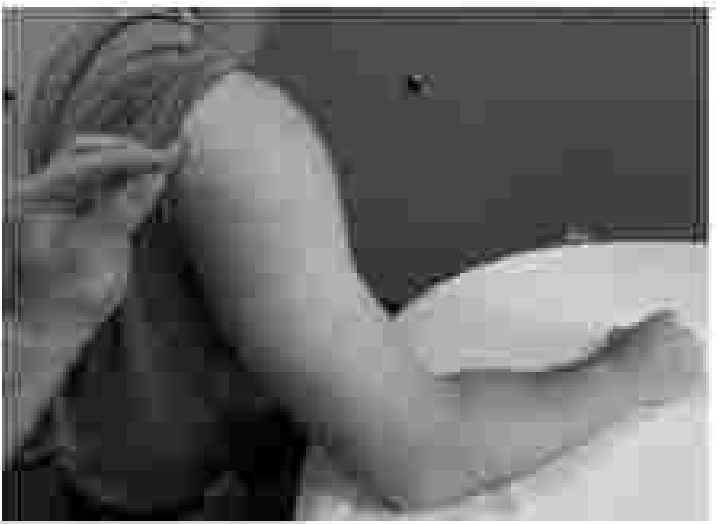
ACTIVATION: Flexion or supination of the arm

NEEDLE INSERTION: Middle of muscle belly between elbow and anterior shoulder. If too deep, may be in brachioradialis

Pearl

- Note abnormalities in C5/C6 radiculopathies or upper trunk/lateral cord pathology

Deltoid



INNERVATION: Axillary nerve; posterior cord, upper trunk, C5–6

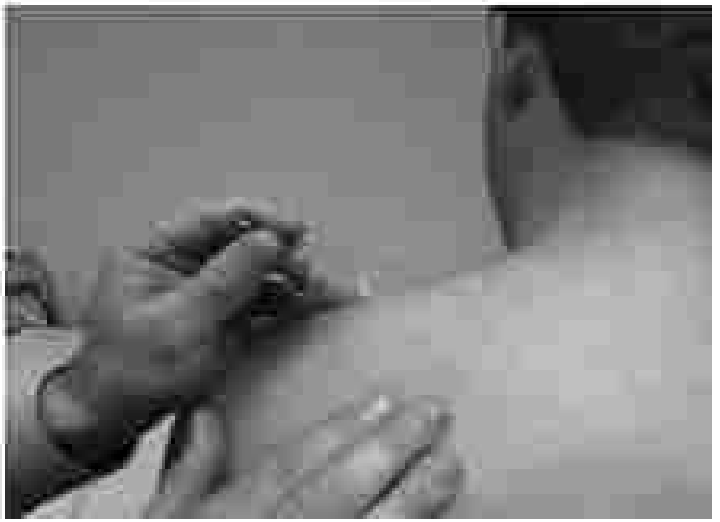
ACTIVATION: Arm abduction

NEEDLE INSERTION: Halfway between tip of acromion and deltoid tubercle

Pearls

- May be abnormal in fractures of surgical neck, glenohumeral joint dislocation, or upper plexus injuries during delivery
- Some polyphasia is normal in this muscle

Upper Trapezius



INNERVATION: Spinal accessory nerve, C3–4

ACTIVATION: Shoulder shrugging

NEEDLE INSERTION: Angle of neck and shoulder

Pearls:

- If needle is too deep, may hit levator scapulae
- May be abnormal in spinal accessory nerve lesions caused by surgery (neck dissection) or radiation in head and neck cancer patients

Supraspinatus

INNERVATION: Suprascapular nerve, upper trunk, C5–C6

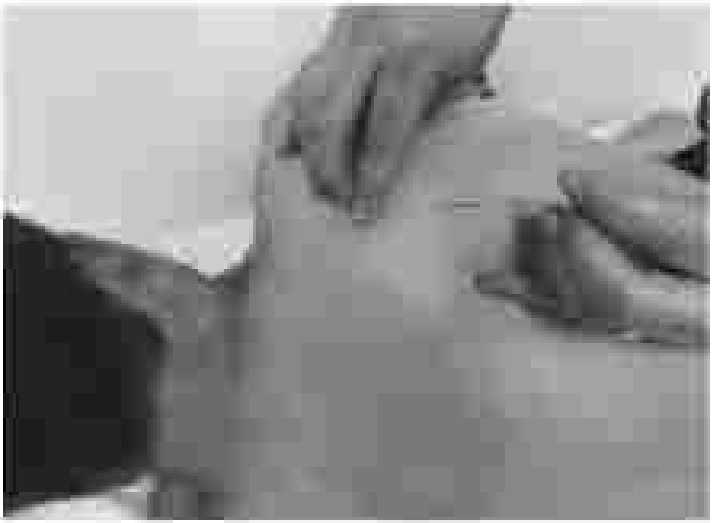
ACTIVATION: Abduct the shoulder (scaption)

NEEDLE INSERTION: Superior and medial to the midpoint of spine of scapula

Pearls

- If the needle is inserted too superficially, it will be in the trapezius
- Involved in suprascapular nerve entrapment in scapular notch but may be spared in suprascapular neuropathy at the spinoglenoid notch
- Also can be involved in rotator cuff injury
- Harder to study than the infraspinatus

Infraspinatus



INNERVATION: Suprascapular nerve, upper trunk, C5–6

ACTIVATION: Shoulder external rotation

NEEDLE INSERTION: Infraspinatus fossa just below midpoint of spine of scapula

POSITION: Side lying with tested shoulder up.

Pearls

- If too superficial, will be in trapezius
- If too lateral, may be in posterior deltoid
- May be only abnormality in suprascapular nerve lesions at spinoglenoid notch (may be caused by paralabral cysts seen in throwing athletes)
- Can be used as recording muscle for suprascapular nerve conduction

Rhomboid

INNERVATION: Dorsal scapular nerve, C5

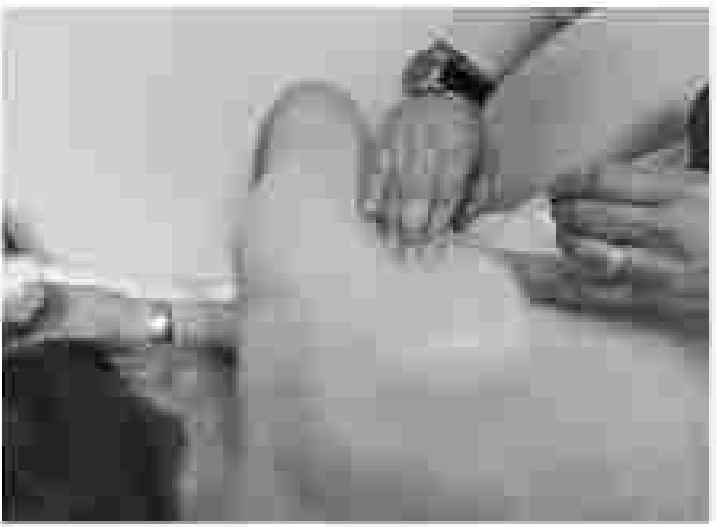
ACTIVATION: Push off of back with internally rotated arm

NEEDLE INSERTION: With patient side-lying and arm internally rotated with dorsal aspect of hand on the back, insert needle between medial border of scapula and midback

Pearl

- If too superficial, may be in trapezius. If too deep, may be in paraspinals. Distal muscle to check for **C5 radiculopathy**. Spared in upper trunk plexopathy because the dorsal scapular nerve branches proximal to plexus

Latissimus Dorsi



INNERVATION: Thoracodorsal nerve; posterior cord; upper/middle/lower trunk; C6–8

ACTIVATION: Shoulder internal rotation, adduction, and extension

NEEDLE INSERTION: Lateral to tip of scapula at posterior axillary line

POSITION: Side lying, with tested shoulder up

Pearl

- If too medial, may be in lower rhomboid

Serratus Anterior

INNERVATION: Long thoracic nerve, C5–C7

ACTIVATION: flex shoulder and push arms forward straight against resistance

NEEDLE INSERTION: Over the sixth rib at the mid-axillary line or just lateral to inferior angle of scapula

Pearls

- There is a risk of neurovascular bundle injury or pneumothorax if the needle is inserted between the ribs
- Place fingers on rib and keep needle in between the fingers to avoid inserting into the intercostal space
- Helpful in distinguishing root from more distal lesions
- Typically spared in brachial plexopathy

Extensor Digitorum Brevis (EDB)

INNERVATION: Deep peroneal nerve, common peroneal nerve, sciatic nerve, lumbosacral plexus, L4-L5-S1

ACTIVATION: Extension of the toes

NEEDLE INSERTION: Distant of first two fingerbreadths distal to lateral malleolus, parallel to lateral border of the foot

Pearls

- May be involved in tarsal tunnel syndrome
- Some denervation and atrophy may represent a normal variant in subjects
- Recording muscle for the common peroneal nerve conduction study

Extensor Hallucis Longus (EHL)

INNERVATION: Deep peroneal nerve, common peroneal nerve, sciatic nerve, lumbosacral plexus, L4-L5-S1

ACTIVATION: Extension of the great toe

NEEDLE INSERTION: Three to four fingerbreadths above the ankle lateral to crest of the tibia

Pearls

- Often abnormal in polyradiculopathy
- If too proximal, may be in tibialis anterior
- If too lateral, may be in peroneus tertius

Tibialis Anterior

INNERVATION: Deep fibular nerve, common fibular nerve, sciatic nerve, posterior division of sacral plexus, L4-L5

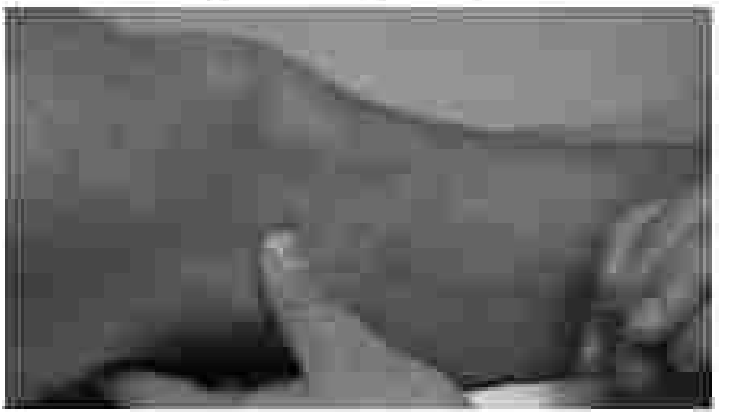
ACTIVATION: Dorsiflexion of the ankle

NEEDLE INSERTION: Four fingerbreadths below the tibial tuberosity and one fingerbreadth lateral to the tibial crest

Pearls

- Often abnormal in L4-5 radiculopathy and lesions of the deep or common fibular nerves
- Of the deep fibular nerve innervated muscles, simplest to localize and activate
- When this muscle is paralyzed, foot drop develops
- May be involved in anterior compartment syndrome

Fibularis (Peroneus) Longus



INNERVATION: Superficial fibular nerve, common fibular nerve, sciatic nerve, posterior division of sacral plexus, L5–S1

ACTIVATION: Evert the ankle

NEEDLE INSERTION: Three to four fingerbreadths distal to the fibular head in the lateral calf toward the lateral aspect of the fibula

Pearls

- Most accessible muscle innervated by superficial fibular nerve
- Often abnormal in lesions of the superficial or common fibular nerves. Also involved in sciatic nerve, sacral plexus, and L5, S1 injuries

Abductor Hallucis

INNERVATION: Medial plantar nerve, tibial nerve, sciatic nerve, lumbosacral plexus, S1-S2

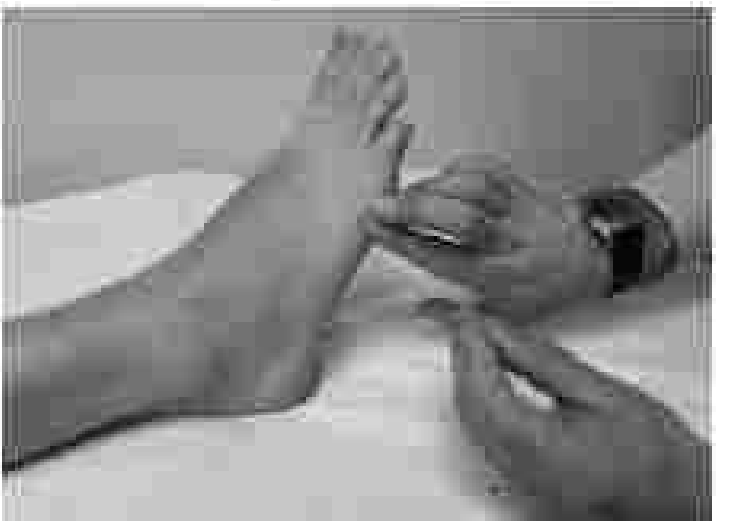
ACTIVATION: Spread the toes

NEEDLE INSERTION: Medial foot at midpoint between ball and heel, one fingerbreadth below the navicular bone

Pearls

- If needle is too distal, will be in flexor hallucis brevis
- If too deep, will be in flexor digitorum brevis
- Difficult to activate
- Painful
- May be abnormal in neuropathy, tarsal tunnel syndrome, sciatic neuropathy, or L5/S1 radiculopathy
- If too proximal, will be in abductor
- Side to side comparison may be helpful, as abnormal findings may be present in asymptomatic patients

Abductor Digiti Quinti Pedis



INNERVATION: Lateral plantar nerve, tibial nerve, sciatic nerve, lumbosacral plexus, S1-2

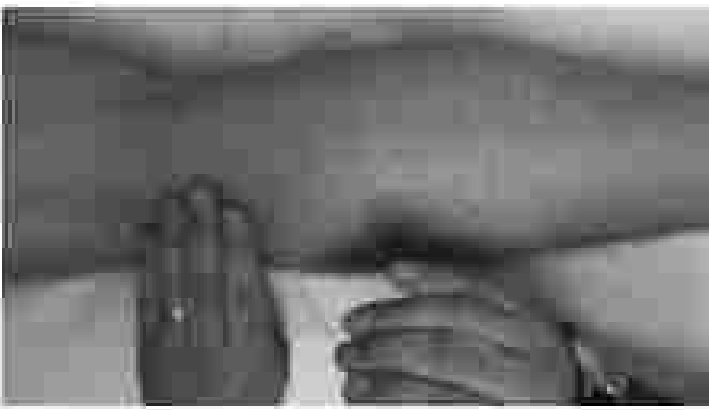
ACTIVATION: Spread the toes

NEEDLE INSERTION: Lateral foot (two to three fingerbreadths proximal to fifth metatarsal phalangeal joint

Pearls

- Difficult to activate
- Painful!
- May be abnormal in neuropathy, tarsal tunnel syndrome, sciatic neuropathy, S1-2 radiculopathy
- Side to side comparison may be helpful, as abnormal findings may be present in asymptomatic patients

Gastrocnemius



INNERVATION: Tibial nerve, ventral division of sacral plexus, sciatic nerve, S1-S2

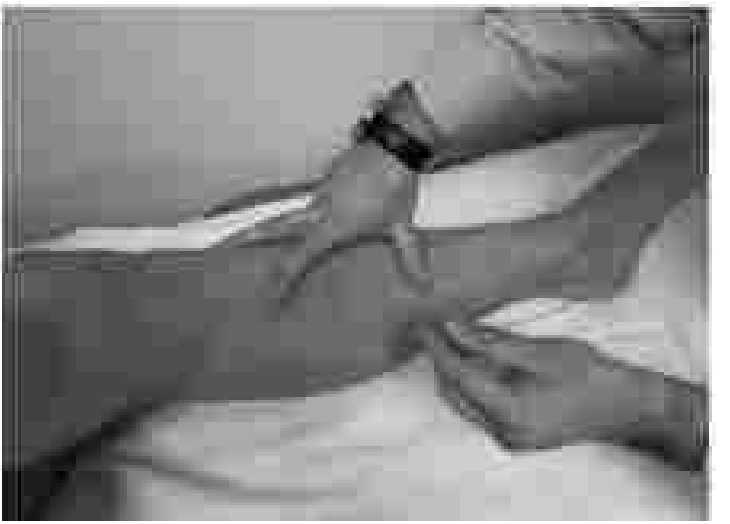
ACTIVATION: Plantar flex the ankle with the knee extended

NEEDLE INSERTION: For lateral head, one handbreadth below the popliteal crease on the lateral mass of the calf. For medial head, one handbreadth below the popliteal crease on the medial mass of the calf

Pearls:

- If the electrode is inserted too deeply, it will be in the soleus
- Involved in the lesions of tibial nerve, sciatic nerve, sacral plexus, and L5-S2 roots
- Medial head of the gastrocnemius is often difficult to activate

Tibialis Posterior



INNERVATION: Tibial nerve, sciatic nerve, lumbosacral plexus, L5–S1

ACTIVATION: Ankle inversion

NEEDLE INSERTION: Medial to the tibia, slightly distal to the midpoint between the ankle and knee

Pearls

- If too superficial, will be in soleus or flexor digitorum longus (unsure that inversion activates motor units)
- If too deep, will be in tibialis anterior
- Very useful in evaluating etiology of foot drop to differentiate between peroneal neuropathy vs. sciatic nerve, lumbosacral plexopathy, or L5 radiculopathy

Biceps Femoris (Short Head)

INNERVATION: Sciatic nerve (peroneal division), lumbosacral plexus, L5-S1

ACTIVATION: Flexion of the knee

NEEDLE INSERTION: Three to four fingerbreadths proximal to lateral femoral condyle and medial to tendon of long head of biceps femoris

Pearls

- Only muscle innervated by fibular division of sciatic above the fibular neck
- If muscle abnormal, rules out fibular neuropathy at fibular head
- Can be abnormal in sciatic neuropathy, lumbosacral plexopathy, or L5/S1 radiculopathy

Adductor Magnus

INNERVATION: Obturator nerve, anterior lumbar plexus, L2–4

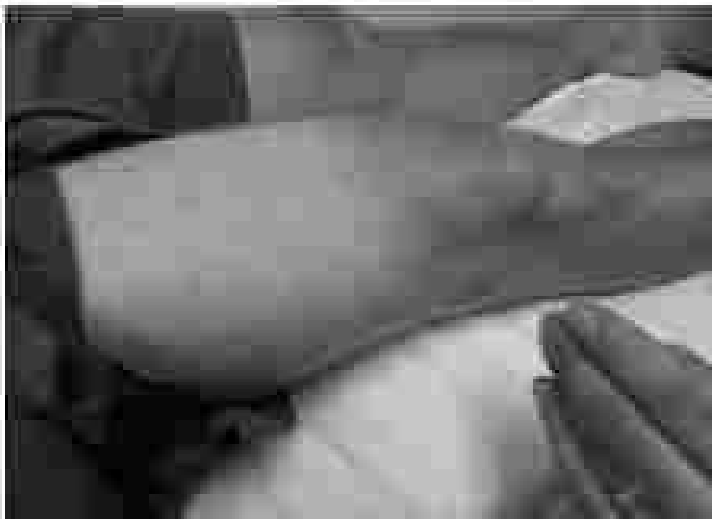
ACTIVATION: Hip adduction

NEEDLE INSERTION: Midway between medial femoral condyle and pubic tubercle

Pearls

- If too superficial, will hit m gracilis
- If too lateral, will hit m sartorius
- If too proximal, will hit m adductor longus

Vastus Lateralis



INNERVATION: Femoral nerve, lumbar plexus, L2-L3-L4

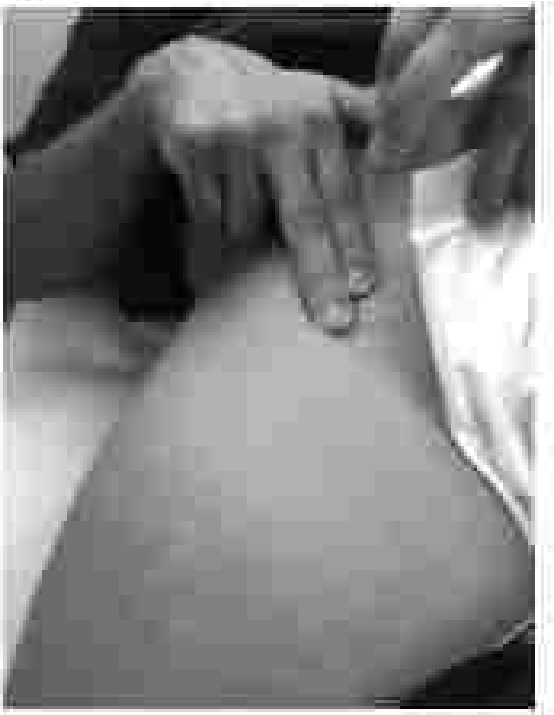
ACTIVATION: Extension of the knee

NEEDLE INSERTION: Lateral thigh four to five fingerbreadths proximal to lateral knee

Pearl

- Often abnormal in injuries to femoral nerve, lumbar plexus, or L2-L3-L4 roots

Iliopsoas



INNERVATION: Femoral nerve, posterior division lumbar plexus, L2-4

ACTIVATION: Hip flexion with a flexed knee

NEEDLE INSERTION: Two fingerbreadths lateral to the femoral artery and 1 fingerbreadth inferior to the inguinal ligament

Pearls

- Spared in femoral nerve lesions at the inguinal ligament
- If needle is inserted too laterally, will be in sartorius

Gluteus Medius

INNERVATION: Superior gluteal nerve, lumbosacral plexus, L4–S1 (strongly L5)

ACTIVATION: Hip abduction

NEEDLE INSERTION: With patient side-lying with tested muscle up, insert needle into lateral thigh two to three fingerbreadths distal to iliac crest

Pearls

- If too posterior, will be in gluteus maximus
- If too anterior, will be in tensor fascia lata (TFL)
- Can (help) differentiate lumbosacral plexopathy (abnormal) from sciatic neuropathy (normal)

Tensor Fascia Lata (TFL)

INNERVATION: Superior gluteal nerve, lumbosacral plexus, L4-S1 (strongly L5)

ACTIVATION: Hip internal rotation

NEEDLE INSERTION: With patient side-lying with tested muscle up, insert needle two fingerbreadths anterior to greater trochanter below ASIS

Pearls

- If too deep, will be in vastus lateralis
- If too posterior, will be in gluteus medius
- If too anterior, will be in sartorius or rectus femoris
- Can help differentiate lumbosacral plexopathy (absent) from sciatic neuropathy (normal)

Gluteus Maximus

INNERVATION: Inferior gluteal nerve, lumbosacral plexus, L5–S2 (mostly S1)

ACTIVATION: Hip extension

NEEDLE INSERTION: Insert needle one to three inches deep halfway between greater trochanter and sacrum.

Pearl

- Can help differentiate lumbosacral plexopathy (abnormal) from sciatic neuropathy (normal)

Cervical Paraspinals

INNERVATION: Dorsal rami, spinal nerves, nerve roots

POSITIONING: With the patient in the lateral decubitus (or prone) position, neck flexed, and pillows under head to make level

ACTIVATION: Extension of the neck

NEEDLE INSERTION: Two fingerbreadths lateral to spinous process in approximate 45 degree angle directed medially

Pearl

- Of note there is marked overlap in the innervation of paraspinal muscles, thus abnormalities have more relevance in the diagnosis of radiculopathy rather than with exact localization of radiculopathy

Lumbar Paraspinals

INNERVATION: Dorsal rami, spinal nerves, nerve roots

POSITIONING: With the patient in the lateral decubitus (or prone) position, neck flexed, and pillows under head to make level

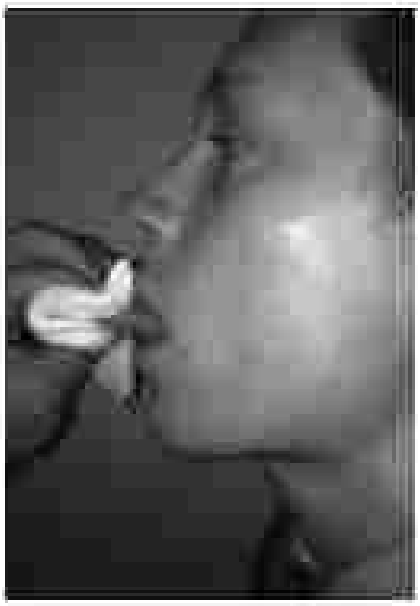
ACTIVATION: Extension of the hip with leg straight

NEEDLE INSERTION: Two fingerbreadths lateral to spinous process in approximate 45 degree angle directed medially

Pearl

- Of note there is marked overlap in the innervation of paraspinal muscles, thus denervation have more role value in the diagnosis of radiculopathy rather than with exact localization of radiculopathy.

Tongue



INNERVATION: CN XII, hypoglossal

ACTIVATION: Stick tongue out of mouth

NEEDLE INSERTION: Patient will stick tongue out of mouth. Examiner will hold end of tongue with gauze and insert needle laterally into one side of tongue. Patient is then asked to relax tongue into mouth

Pearls

- Difficult to treat
- Tested for cases of suspected motor neuron disease (i.e., amyotrophic lateral sclerosis [ALS])

Orbicularis Oculi

INNERVATION: Temporal/zygomatic branches of the facial nerve (CN VII)

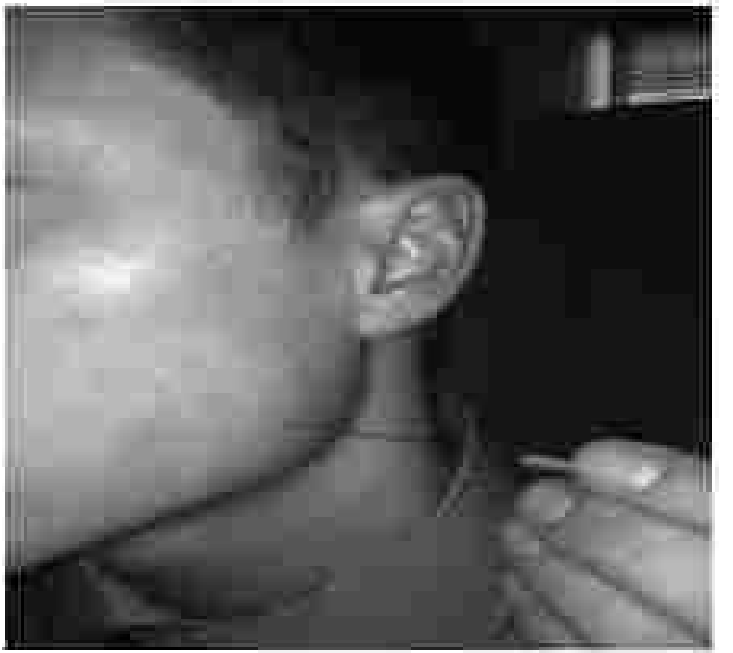
ACTIVATION: Close eyes

NEEDLE INSERTION: Lateral to inferior ridge of eye socket with needle facing away from eye

Pearls

- Insert needle tangentially as muscle is very thin
- Use a study to accustom to the patient
- Avoid too many needle passes or blinking maneuvers as this may cause a "black eye"

Masseter



INNERVATION: Trigeminal nerve (V3)

ACTIVATION: Clench jaw

NEEDLE INSERTION: Two fingerbreadths anterior to the angle of the jaw and one to two fingerbreadths cephalad

Pearls

- Insert anteriorly to avoid parotid gland
- However, if inserted too anteriorly, the needle can end up in the mouth
- May be useful for cases of suspected motor neuron disease or trigeminal neuritis

3

Study Protocols

- Carpal Tunnel Syndrome (CTS)
- Anterior Interosseous Neuropathy (AIN)
- Ulnar Neuropathy at the Elbow (UNE)
- Ancting Across the Elbow
- Ulnar Neuropathy at the Wrist (UNW)
- Radial Neuropathy
- Fibular (Peroneal) Neuropathy
- Cervical Radiculopathy
- Lumbar Radiculopathy
- Polyneuropathy
- Femoral Neuropathy
- Brachial Plexopathy
- Lumbosacral Plexopathy
- Sciatic Neuropathy
- Tarsal Tunnel Syndrome (TTS)
- Myopathy
- Amyotrophic Lateral Sclerosis (ALS)
- Footpolio Syndrome (FPS)
- Foot Drop

CTS NCS Protocol

1. Median and ulnar sensory studies
2. Median and ulnar motor studies

Suggestive of CTS if:

1. Prolonged median sensory latency
2. Prolonged median distal motor latency
3. Normal ulnar studies (polyneuropathy less likely)
4. Indicative of more severe CTS if diminished median compound muscle action potential (CMAP) or sensory nerve action potential (SNAP) amplitudes

If studies are normal but clinical suspicion of CTS is high:

1. Compare median sensory distal latency to ipsilateral ulnar sensory distal latency
   - If >0.4 msec latency difference, likely to be CTS
2. Can also proceed to combined sensory index (CSI)—described below
3. Can also check median to ulnar lumbrical/interosseous comparison study—described below
4. Can also check the median nerve proximal and distal to the wrist
   - Indicative of CTS with conduction block if:
     - Distal/proximal SNAP ratio >1.6
     - Distal/proximal CMAP ratio >1.2

Combined Sensory Index

1. This is done when the median NCS are normal or borderline, but clinical suspicion of CTS is high.
2. This involves six different NCS, comparing the latency differences among the median, ulnar, and radial sensory nerves in the hand.
3. Essentially the individual nerve latencies are being compared to each other rather than a set standard range.

CSI Calculation

1. CSI is calculated by adding the three latencies.
   - CSI equals ringdiff + thumbdiff + palmdiff.
   - CSI equal to or greater than 0.9 ms is considered abnormal, giving a diagnosis of CTS.
2. The order to perform the study is:
   ringdiff → thumbdiff → palmdiff.
3. There are certain threshold latency differences after each step to determine whether to stop (normal) or continue (abnormal) the study.

Median–Ulnar Sensory to the Ring Finger (Ringdiff)

Median

Ulnar

ACTIVE: Ring or clamp electrode on the ring finger just distal to metacarpophalangeal (MCP) joint

REFERENCE: 4 cm distal to active electrode near distal interphalangeal (DIP) joint

STIMULATION (TWO SITES): 14 cm proximal to active electrode along the median and ulnar nerves

- This is comparing antidromic latencies to the ring finger
- If the ringdiff is less than 0.2 msec, this designates "unlikely to be CTS" and further testing is unnecessary
- If the ringdiff is greater than 0.4 msec, this designates "probable CTS" and further testing is unnecessary

Median–Radial Sensory to the Thumb (Thumbdiff)

Median

Radial

ACTIVE: Ring or clamp electrode on the thumb just distal to MCP joint

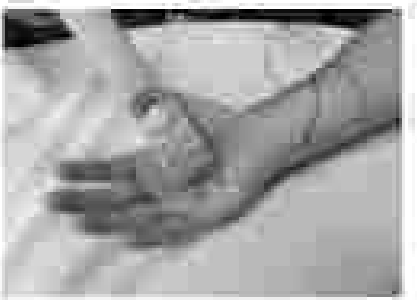
REFERENCE: 4 cm distal to active electrode just distal to interphalangeal (IP) joint

STIMULATION (TWO SITES): 10 cm proximal to active electrode along the median and radial nerves

- This is comparing antidromic latencies to the thumb
- If the thumbdiff is less than 0.3 msec, this designates "unlikely to be CTS" and further testing is unnecessary
- If the thumbdiff is greater than 0.5 msec, this designates "probable CTS" and further testing is unnecessary

Median–Ulnar Mixed-Nerve From the Palm (Palmdiff)

Median



Ulnar

ACTIVE (TWO SITES):

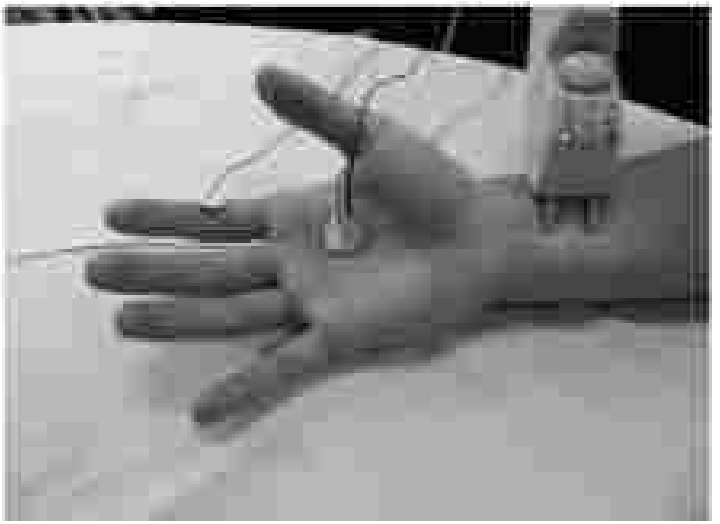
- Median—Electrode just proximal to the wrist crease along median nerve course
- Ulnar—Electrode just proximal to the wrist crease along ulnar nerve course

REFERENCE (TWO SITES): Median and ulnar—4 cm proximal to active electrode

STIMULATION (TWO SITES):

- Median—8 cm distal to active electrode, between the second and third metacarpals
- Ulnar—8 cm distal to active electrode, between fourth and fifth metacarpals
  - This is comparing orthodromic latencies across the wrist
- If palmdiff greater than or equal to 0.5 msec, this designates "CTS" and further testing is unnecessary

Median–Ulnar Lumbrical-Interosseous Comparison Study



- Not part of CSS, but can also be used as a sensitive test to diagnose CTS affecting motor fibers

ACTIVE: Just lateral to the midpoint of the third metacarpal, over both the second lumbrical (median innervated) and the first palmar interosseous (ulnar innervated)
REFERENCE: Over second PIP joint
STIMULATION:
1. Median nerve at wrist (8–10 cm from active electrode)
2. Ulnar nerve at wrist (8–10 cm from active electrode)

- Same distance should be used for median and ulnar studies
- Significant for CTS if difference in latency of median nerve is 0.5 msec or greater than distal latency of ulnar nerve
- Remember that this is testing motor fibers so will only be abnormal if median motor fibers have been affected
- Can be useful in diagnosing CTS in presence of neuropathy if sensory responses are absent

CTS Electromyography (EMG) Protocol

EMG may be low yield in suspected CTS if NCS is normal unless other diagnosis is suspected.

1. Abductor pollicis brevis (APB) or opponens pollicis
2. At least two C6-7 muscles to exclude cervical radiculopathy
3. If APB is abnormal, must check at least one proximal median muscle (pronator teres, flexor carpi radialis) to exclude proximal median neuropathy
4. At least two lower trunk/C8-T1 muscles

CTS Severity: American Association of Neuromuscular and Electrodiagnostic Medicine (AANEM) Monograph

1. Mild: Prolonged median sensory latency
2. Moderate: Prolonged median sensory latency and prolonged motor distal latency
3. Severe CTS: Prolonged motor and sensory latencies with axon loss defined by any of the following:
   - Absent or low amplitude median SNAP
   - Low-amplitude or absent thenar CMAP
   - Evidence of abnormal spontaneous activity, reduced recruitment, or motor unit potential changes on needle EMG

AIN NCS Protocol

1. Standard CTS study

AIN EMG Protocol

1. At least one of the following AIN-innervated muscles: Pronator quadratus, flexor pollicis longus, flexor digitorum profundus
2. Also test distal median muscle as well as nonmedian C8/T1 muscle

UNE NCS Protocol

1. Ulnar sensory studies with elbow in flexed position at digit 5 and stimulation at the wrist
2. Median sensory response at wrist recording at digit 2
3. Ulnar motor studies with elbow in flexed position at abductor digiti minimi (ADM). Stimulation at wrist, below elbow, and above elbow
4. Median motor study to APB at wrist and antecubital fossa

UNE EMG Protocol

1. First dorsal interosseous (FDI) or ADM, FDI 5 and flexor carpi ulnaris
2. At least two cervical/lower trunk/C8-T1 muscles to exclude cervical radiculopathy or plexopathy
3. C8 and T1 paraspinals

Suggestion of UNE if:

1. Low amplitude ulnar SNAP at digit 5
2. Prolonged ulnar CMAP latency and drop in amplitude greater than 10% with stimulation above the elbow. FDI may be more sensitive compared to ADM
3. Decrease conduction velocity >10 m/sec across the elbow compared to the forearm segment
4. Decreased amplitude of the dorsal ulnar cutaneous SNAP. Can be spared in some UNE so normal value does not rule out UNE
5. Short segment incremental study can be performed to localize the lesion
6. Abnormal spontaneous activity in ulnar innervated muscles

- Short incremental studies (inching) to localize lesion of the ulnar nerve across the elbow
  - A. First map out the nerve by using submaximal stimulation (recording at ADM) at various medial/lateral locations from below to above elbow. At each site, make a mark at the highest CMAP amplitude
  - B. Mark off 1 cm segments from 4 cm below to 4 to 6 cm above the elbow (zero point can be a line from medial epicondyle to olecranon)
  - C. Supramaximally stimulate at each 1 cm increment
- Evaluation
  - Any abrupt increase in latency/drop in amplitude between segments would imply focal demyelination
    - Normal latency difference between sides should be 0.1 to 0.4 msec
    - May be beneficial to record at both the ADM and FDI as the FDI may be more sensitive to injury

ULNAR NEUROPATHY AT THE WRIST (UNW)

UNW NCS Protocol

1. Ulnar and median sensory studies
2. Ulnar and median motor studies
3. In addition to ulnar motor recording at ADM, must also check recording at FDI
4. Dorsal ulnar cutaneous sensory studies (bilateral for comparison)

Suggestive of UNW if:

1. Prolonged ulnar sensory latency
2. Prolonged ulnar distal motor latency >4.5 msec to FDI
3. Indicative of more severe UNW if diminished CMAP or SNAP amplitudes
4. Normal median studies

If studies are normal but clinical suspicion of UNW is high:

1. Can also check median to ulnar (unilateral/intramuscular comparison study (>0.4 msec latency difference is significant))
2. Can perform an inching motor study across the wrist in 1 cm increments, recording at the FDI (>0.5 msec latency increase over 1 cm increment considered abnormal)
3. Can compare motor latency difference between FDI to ADM (>2.0 msec difference is abnormal)
4. Can compare symptomatic FDI to contralateral FDI (>1.3 msec latency difference is significant)

UNW EMG Protocol

1. FDI (distal deep palmar motor branch) and ADM (proximal deep palmar motor branch)
2. If FDI or ADM is abnormal, must check a proximal ulnar muscle (flexor carpi ulnaris, flexor digitorum profundus) to exclude an ulnar neuropathy at the elbow
3. At least two normal C8/lower trunk muscles to rule out radiculopathy

UNW Severity

1. Mild: Prolonged sensory latency +/- decreased SNAP amplitude
2. Moderate: Abnormal sensory latency and prolonged motor distal latency
3. Severe UNW: Prolonged motor and sensory latencies with any of the following:
   - Absent ulnar SNAP
   - Low-amplitude or absent CMAP
   - Evidence of abnormal spontaneous activity, reduced recruitment, or motor unit potential changes on needle EMG

UNW Different Entrapment Sites

1. Pure motor, distal deep palmar branch (only FDI latency affected)
2. Pure motor, proximal deep palmar branch (both FDI and ADM latencies affected)
3. Motor and sensory (proximal canal lesion)
4. Pure sensory, involving only the fibers to the volar fourth and fifth digits

Radial Neuropathy NCS Protocol

1. Radial motor study bilaterally
2. Median and ulnar motor studies on symptomatic side
3. Radial sensory study bilaterally
4. Median and ulnar sensory studies on symptomatic side

Radial Neuropathy NCS Patterns

Lesion	Radial SNAP	Radial CMAP	Conduction Block
Posterior interosseous neuropathy (distal)	Normal	Low amplitude	None
Posterior interosseous neuropathy (compressive)	Normal	Normal	Between forearm and elbow
At spiral groove (distal)	Low amplitude	Low amplitude	None
At spiral groove (compressive)	Normal	Normal	Across spiral groove
At axilla (distal)	Low amplitude	Low amplitude	None
At axilla (compressive)	Normal	Normal	None
Superficial radial	Low amplitude	Normal	None

Radial Neuropathy EMG Protocol

1. Two muscles innervated by posterior interosseous nerve (extensor indicis proprius [EIP], extensor digitorum communis [EDC])
2. Two radial muscles between posterior interosseous nerve and spiral groove (brachioradialis, extensor carpi radialis)
3. One radial muscle above spiral groove (triceps)
4. One nonradial posterior cord muscle (deltoid)
5. Two nonradial C7 muscles (flexor carpi radialis [FCR], pronator teres, FDS)

Radial Neuropathy EMG Patterns

Lesion	Abnormal
Posterior interosseous neuropathy	PIN muscles (EIP, EDC, extensor carpi ulnaris [ECU])
Spiral groove	PIN muscles, extensor carpi radialis [ECR], brachioradialis
Axilla	PIN muscles, ECR, brachioradialis, triceps

Fibular (Peroneal) Neuropathy NCS Protocol

1. Fibular motor study (check recording at tibialis anterior if recording at extensor digitorum brevis (EDB) does not localize the lesion)
2. Tibial motor study
3. Superficial fibular and sural sensory studies

Consider testing bilaterally to confirm abnormal or borderline results.

Fibular Neuropathy NCS Patterns

Lesion	Superficial fibular SNAP	Sural SNAP	Fibular CMAP	Tibial CMAP	Conduction Block at fibular head
Deep fibular	Normal	Normal	Low amplitude	Normal	None
Common fibular	Low amplitude	Normal	Low amplitude	Normal	Present
Sciatic	Low amplitude	Low amplitude	Low amplitude	Low amplitude	None
Lumbosacral plexus	Low amplitude	Low amplitude	Low amplitude	Low amplitude	None
L5	Normal	Normal	Low amplitude	Low amplitude	None

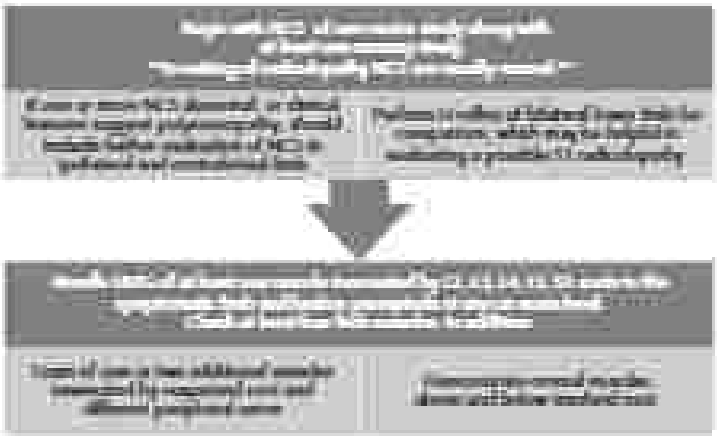
Fibular (Peroneal) Neuropathy EMG Protocol

1. Two muscles innervated by deep fibular nerve (tibialis anterior, extensor hallucis longus (EHL))
2. One muscle innervated by superficial fibular nerve (peroneus longus)
3. Tibialis posterior and another tibial innervated muscle
4. Short head of biceps femoris

Checking bilaterally may be helpful with any borderline abnormal findings.

Fibular Neuropathy EMG Patterns

Lesion	Abnormal Muscles
Deep fibular nerve	Tibialis anterior, extensor hallucis longus
Common fibular nerve	Above plus peroneus longus
Sciatic neuropathy	Above plus tibialis posterior, flexor digitorum longus, and short head of biceps femoris



Polyneuropathy Motor Nerve Conductions

1. Fibular and tibial in one leg.
2. One motor nerve conduction in the contralateral leg.
3. One motor nerve conduction in one arm.
   - If asymmetry is noted, recommend to test other nerves on contralateral limb.

Polyneuropathy Sensory Nerve Conductions

1. Sural and superficial fibular in one leg.
2. One sensory nerve conduction in the contralateral leg.
   - If asymmetry is noted, recommend to test other nerves on contralateral limb.

Polyneuropathy Late Responses

1. F-waves may be helpful.
2. Bilateral H reflexes may be helpful.

Polyneuropathy EMG Protocol

1. Tibialis anterior.
2. Gastrocnemius.
3. Quadriceps.
4. PSM.
5. Biceps brachii, triceps, or deltoid.
   - These should all be checked on one side. In addition, check at least one muscle on the other limb. If asymmetry, check other muscles.
   - If abnormal proximal muscles or if radiculopathy on differential, check paraspinals as well.

Interpretation

1. Axonal vs. demyelinating vs. both
2. Motor vs. sensory vs. both
3. Diffuse vs. multifocal

Demyelination

1. Defined as one or more of the following:
   - Conduction velocity slower than 75% of the lower limit of normal (LLN) OR
   - Prolonged distal latency longer than 130% of upper limit of normal OR
   - Any motor, sensory, or mixed nerve conduction velocity slower than:
     - 38 m/sec in arms
     - 30 m/sec in legs
2. If borderline conduction velocity with normal amplitudes, most likely a demyelinating lesion
3. If borderline conduction velocity with low amplitudes, most likely an axonal lesion

Conduction Block

1. Typically defined as >20% drop in **AREA** between proximal and distal stimulation sites
   - Using area as the primary criterion (rather than just amplitude) takes temporal dispersion into account
2. This is important for prognostic purposes as quantifying amount of conduction block helps indicate how much weakness and sensory loss are due to demyelination rather than axonal loss
   - Conduction block has better prognosis than axonal loss

Criteria for Acute Demyelinating Polyneuropathy

1. Need three of the following four:
   - Prolonged distal latency in two or more nerves not at entrapment sites (DL >115% upper limit of normal (ULN) for normal CMAP amplitudes or >125% ULN for low CMAPs)
   - CV slowing in two or more nerves not at entrapment sites (CV <85% the LLN for CMAP amplitudes >50% LLN or CV <90% LLN for CMAP amplitudes <50% LLN)
   - Prolonged late response (>125% ULN)
   - Conduction block or temporal dispersion in one or more nerves (definite conduction block if distal CMAP is <50% area of proximal CMAP)

Criteria for Chronic Demyelinating Polyneuropathy

1. Need three of the following four:
   - Prolonged distal latency in two or more nerves not at entrapment sites (DL >130% ULN)
   - CV slowing in two or more nerves not at entrapment sites (CV <75% LLN)
   - Prolonged late response (>130% ULN)
   - Conduction block or temporal dispersion in one or more nerves (definite conduction block if distal CMAP is <50% area of proximal CMAP)

Inherited demyelinating polyneuropathies: two of first three criteria need to be met. CV slowing is seen, but no conduction block

Femoral Neuropathy NCS Protocol

1. Femoral, tibial, and fibular motor studies (bilateral for comparison)
2. Saphenous sensory study (bilateral for comparison)

Suggestive of femoral neuropathy if:

1. Decreased femoral motor amplitude (ascend)
2. Decreased saphenous sensory amplitude (ascend)
3. Normal tibial and fibular studies

If studies are normal but clinical suspicion of femoral neuropathy is high:

1. Isolated femoral neuropathy is an uncommon finding; more common is a lesion in the lumbar plexus or L2–4 radiculopathy
2. Must have a clear side-to-side difference, especially with the saphenous sensory
3. If the lesion is purely demyelinating, NCS may be normal and EMG may only show reduced recruitment

Femoral Neuropathy EMG Protocol

1. At least two quadriceps muscles (vastus lateralis, vastus medialis, or rectus femoris)
2. If the quadriceps are abnormal, must check iliopsoas to evaluate for femoral neuropathy at the inguinal ligament
3. At least one hip adductor (adductor brevis, longus, or magnus) to evaluate obturator nerve (L2, L3, L4)
4. Tibialis anterior to evaluate deep fibular nerve (L4, L5, S1)
5. At least two non-femoral muscles not innervated by L2–L4 to exclude a more generalized process
6. L2, L3, and L4 paraspinal muscles

Brachial Plexopathy NCS Protocol

1. Brachial plexus lesions often result in abnormal SNAPs (and thus are very useful pieces of information)
2. Perform sensory studies that correlate with symptoms such as lateral antebrachial cutaneous (LAC), radial, median, ulnar, medial antebrachial cutaneous (MAC) SNAPs (may need side-to-side comparison studies to illustrate clear asymmetry)
3. Routine motor studies recording at wrist and stimulating at elbow should be performed but less useful overall as that radial/median/ulnar motor studies record from the distal C8-T1 muscles
   - May help in assessing medial cord/lower trunk lesions (median and ulnar CMAPs) or posterior cord/lower trunk lesions (radial CMAP)
   - Most brachial plexopathies are axonal loss lesions so no focal slowing or conduction block will be seen in most lesions
4. Motor conduction studies across the plexus require stimulation at the axilla or Erb's point, which may be difficult to achieve supramaximal stimulation (may give misleading impression of conduction block)
   - Additionally costimulation of adjacent nerves always an issue at Erb's point
5. Median and ulnar F-waves may be prolonged as well when compared to asymptomatic side

Mapping of Sensory Potentials

SNAP	Cord	Trunk
LAC	Lateral	Upper
Radial to thumb	Posterior	Upper
Median to thumb	Lateral	Upper
Radial to snuffbox	Posterior	Upper/middle
Median to index finger	Lateral	Upper/middle
Median to middle finger	Lateral	Middle
Median to ring finger	Medial	Middle/lower
Ulnar to ring finger	Medial	Lower
Ulnar to little finger	Medial	Lower
Dorsal ulnar cutaneous	Medial	Lower
MAC	Medial	Lower

Brachial Plexopathy EMG Protocol

1. Examination/EMG study should be performed including muscles representing trunks, cords, and peripheral nerves corresponding with areas of clinical weakness.
   - May need to include at least one muscle associated with each peripheral nerve (median, ulnar, radial, AIN, PIN, axillary, musculocutaneous, suprascapular)
   - Sample muscles innervated by same peripheral nerve but with different roots

Brachial Plexopathy Lesions and Associated Findings

1. Upper trunk (Erb's palsy—Turner syndrome, stinger, Erb's palsy, radiation)—Findings may include:
   Abnormal LAC and radial/median (recording at the thumb) SNAPs. EMG abnormalities may be found in deltoid, biceps, brachialis/brachioradialis, supraspinatus, and infraspinatus. Partial involvement in triceps, pronator teres, and FCR. Note sparing of rhomboids, serratus anterior, and cervical paraspinals.

(continued)

2. Middle trunk – Findings include:
   Abnormal median SNAP (middle finger) and radial SNAP; EMG abnormalities found in C7 innervated muscles (triceps, pronator teres, FCR). Sparing of paraspinals
3. Lower trunk (thoracic outlet syndrome, Klumpke's palsy) – Findings include:
   Abnormal MAC, dorsal ulnar cutaneous (DUC), and ulnar SNAPs; EMG abnormalities in all ulnar innervated muscles as well as median/radial innervated muscles containing C8-T1 fibers (e.g., FPL, APB, and EDI).
4. Lateral cord – Findings include:
   Abnormal LAC and median SNAP; EMG abnormalities in biceps and proximal median innervated forearm muscles, including pronator teres and FCR. Distal forearm muscles should be normal
5. Posterior cord – Findings include:
   Abnormal radial SNAPs; EMG abnormalities in radially innervated muscles including EDP, ECR, brachioradialis, and triceps. Additional abnormalities possible in deltoid, teres minor, and latissimus dorsi
6. Medial cord – Findings include:
   Similar abnormalities to lesions in lower trunk except normal findings are associated with C8 innervated muscles. Abnormalities in ulnar, DUC, and MAC SNAPs; EMG abnormalities in distal ulnar/medial innervated muscles containing C8-T1 fibers.

Lumbosacral Plexopathy NCS Protocol

1. Fibular motor study:
   - Record at EDB, stimulate at ankle, below fibular neck and lateral popliteal fossa. Bilateral studies for comparison
2. Tibial motor study:
   - Record at abductor hallucis brevis (AHB), stimulate at medial ankle and popliteal fossa. Bilateral studies
3. Sural sensory study:
   - Record at posterior ankle, stimulate at posterior calf. Bilateral studies
4. Superficial fibular study:
   - Record at lateral ankle, stimulate at lateral calf. Bilateral studies
5. Additional studies for suspected lumbar plexopathy or lateral femoral cutaneous neuropathy:
   - Saphenous sensory study: Record medial ankle, stimulate medial calf. Bilateral studies
   - Femoral motor study: Record rectus femoris, stimulate femoral nerve at the inguinal ligament. Bilateral studies.
   - Lateral femoral cutaneous study: Record over anterior thigh, stimulate the anterior superior iliac spine. Bilateral studies.
6. Conduct upper extremity study if findings are bilateral to rule out polyneuropathy

Lumbosacral Plexopathy EMG Protocol

1. Minimum two fibular-innervated muscles
2. Minimum two tibial-innervated muscles
3. Minimum one sciatic-innervated muscle in the thigh
4. Minimum one superior and inferior gluteal-innervated muscle
5. Minimum two femoral-innervated muscles
6. Minimum one obturator-innervated muscle
7. Paraspinal muscles: L2, L3, L4, L5, S1

Suggestive of lumbosacral plexopathy if:

1. Normal distal latency and conduction velocity with decreased SNAP amplitudes for lesions affecting the plexus. In severe cases, SNAP may be absent
2. Decreased amplitude with fibular or tibial CMAP can be seen with lower lumbosacral plexopathy with axonal loss
3. Normal UMC of paraspinal muscles
4. Abnormal spontaneous activity in muscles distal to injury, including gluteal muscles and thigh adductors

Diabetic Amyotrophy

1. Typically more axonal than demyelinating
2. Often affects:
   - Upper lumbar nerve roots
   - Lower extremity peripheral nerves:
     - Femoral
     - Obturator
     - Fibular motor and sensory
     - Saphenous
3. EMG often shows denervation in proximal muscles and paraspinals

Sciatic Neuropathy NCS Protocol

1. Routine tibial and fibular motor studies (bilateral)
2. Sural sensory studies (bilateral)
3. Superficial fibular sensory studies (bilateral)
4. Tibial and fibular F-wave responses (bilateral)
5. H-reflexes (bilateral)
   - If there is an isolated foot drop, may consider fibular motor recording at the tibialis anterior and stimulating above and below the fibular neck to increase the yield of finding conduction block or focal slowing across the fibular neck
   - If suspecting piriformis syndrome, consider comparing the H-reflex latency between the hip in neutral position and in FAIR (flexion, adduction, internal rotation) position

Suggestive of sciatic neuropathy if:

1. Decreased fibular motor amplitude (axonal)
2. Decreased tibial motor amplitude (axonal)
3. Decreased sural sensory amplitude (axonal)
4. Prolonged or absent tibial and fibular F-waves and/or H-reflexes
   - Must have clear side-to-side difference in amplitude or latency to be considered sciatic neuropathy
   - Sural sensory studies are often difficult to obtain and can be absent even in normal subjects, especially in the elderly
   - The fibular division of the sciatic nerve is typically damaged more easily than the tibial division; therefore, the fibular fibers are often affected out of proportion to the tibial fibers

Sciatic Neuropathy EMG Protocol

1. At least two fibular-innervated muscles (tibialis anterior, extensor hallucis longus, peroneus longus)
2. At least two tibial-innervated muscles (gastrocnemius, tibialis posterior, flexor digitorum longus)
3. Short head of biceps femoris
4. At least one superior gluteal-innervated muscle (gluteus medius, tensor fascia latae)
5. At least one inferior gluteal-innervated muscle (gluteus maximus)
6. At least two nonsciatic, non-L5-S1-innervated muscles (vastus lateralis, iliopsoas, adductor longus)
7. L5, S1 paraspinal muscles

1. Routine tibial and fibular motor studies
2. Sural and superficial fibular sensory studies
3. Tibial F-wave responses (bilateral)
4. H-reflex responses (bilateral)
5. Medial/lateral plantar motor
6. Medial/lateral plantar mixed studies or sensory studies

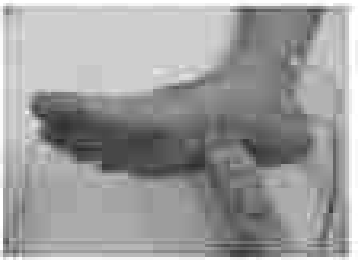
TTS NCS Protocol

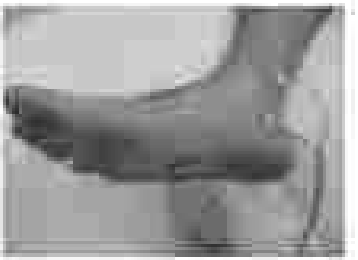
Medial and lateral plantar motor (described in NCS section of this book): Stimulating tibial nerve at medial malleolus and recording at abductor hallucis brevis (medial plantar) and at abductor digiti quinti pedis (lateral plantar) (must compare to contralateral side)

Medial and lateral plantar mixed studies (see figures below): Recording at medial malleolus and stimulating from medial side (medial plantar) and from lateral side (lateral plantar) (must compare to contralateral side)

1. Because this study is performed on the most distal limb, warming of the foot may be necessary to obtain accurate conduction velocities.
2. Averaging of several stimulations may be necessary because the recorded amplitudes are very small.

Medial (Left) and Lateral (Right) Plantar Mixed Nerve





ACTIVE: Above and posterior to medial malleolus

REFERENCE: 3 to 4 cm proximal to active

STIMULATION SITE

- Medial side (medial plantar) 14 cm from active electrode
- Lateral side (lateral plantar) 14 cm from active electrode (along line drawn to web space between fourth and fifth toes)

Must do side-to-side comparison

NORMAL VALUES: Amps >3.0 μV, conduction velocity >45 m/sec, distal peak latency <3.7 msec

Pearls

- Use firm pressure on the stimulator, because the plantar skin can be thick
- If failing a response may be difficult, even in normal subjects, so make small adjustments to the stimulator or recording electrodes when looking for response
- Stimulus artifact may interfere with the recording, so consider averaging responses
- Questionable waveform responses must be interpreted with caution

Suggestive of TTS if:

1. Decreased bilateral plantar motor, sensory, or mixed amplitude (axonal)
2. Prolonged latency of bilateral plantar motor, sensory, or mixed (demyelinating)
   - Must have clear side-to-side difference in amplitude or latency to consider TTS
   - Often mixed plantar studies are obtainable even in normal subjects
   - Mixed plantar studies are more difficult to obtain but more sensitive for TTS

TTS EMG Protocol

1. Abductor hallucis brevis and abductor digiti quinti pedis (must be compared with the contralateral side)
2. At least two distal tibial-innervated muscles proximal to the tarsal tunnel (gastrocnemius, soleus, tibialis posterior, flexor digitorum longus)
3. At least one distal fibular-innervated muscle in the calf (tibialis anterior, extensor hallucis longus)

Myopathy NCS Protocol

1. At least one upper extremity motor and sensory conduction study with corresponding F-wave response, for example, median motor, median sensory, and median F-wave
2. At least one lower extremity motor and sensory conduction study and corresponding F-wave response, for example, tibial motor, sural sensory, and tibial F-wave
   - If there is a clinical history of fatigability and CMAP amplitudes are decreased or borderline, may want to consider evaluating for neuromuscular junction (NMJ) disorder. Exercise the muscle maximally for 10 seconds, then repeat a single supramaximal distal stimulation, looking for CMAP increment >100% of baseline, suggestive of Lambert–Eaton myasthenic syndrome
   - May also perform repetitive nerve stimulation (3 Hz) if considering NMJ disorder. If a significant decrement (>10%) is found with repetitive nerve stimulation, then further testing for NMJ disorder is warranted

Myopathy EMG Protocol

1. At least two upper extremity distal and two proximal muscles. Recommend testing muscles with different peripheral nerve innervations
2. At least two lower extremity distal and two proximal muscles. Recommend testing muscles with different peripheral nerve innervations
3. At least one paraspinal muscle
   - Always try to study the weaker muscles and choose muscles that can easily be biopsied
   - Fibrillations and positive sharp waves are usually seen with neurogenic disorders; however, abnormal spontaneous activity can occur in many myopathic disorders if there is segmental inflammation or necrosis of muscle fibers

Myopathic MUAPs

1. Short duration
2. Small amplitude
3. Polyphasic
4. Early recruitment
5. With little movement, the screen will fill with short-duration small, polyphasic motor unit action potentials (MUAPs) that cannot be differentiated from each other.
   - If the MUAP parameters are indeterminate, consider performing quantitative MUAP analysis. Compile 20 MUAPs from different locations within each muscle, then calculate the mean amplitude and duration and compare with age-matched controls.

1. Electrodiagnostic testing plays an important role in evaluation of patients with suspected motoneuronal disease, most commonly ALS.
2. Degenerative and progressive affecting upper motor neurons (UMNs) and lower motor neurons (LMNs)
3. Signs and symptoms include muscle atrophy, weakness, fasciculations (LMN), along with bulbar findings, spasticity, hyperreflexia, Babinski signs, Hoffman signs (UMN)
4. Spares sensory and autonomic function
5. Diagnosis based on El Escorial criteria set 1998 at neurology meeting
   - Evaluation of four body regions: Craniobulbar, cervical, thoracic, and lumbosacral
   - Definite ALS: UMN and LMN findings in three regions
   - Probable ALS: UMN and LMN findings in two regions
   - Must rule out other pathology as the cause such as cervical/lumbar stenosis, autoimmune conditions, lymphoma

ALS NCS Protocol

1. Median motor studies to APB at wrist and elbow (most affected side)
2. Ulnar motor study to ADM at wrist, below and above elbow (most affected side)
3. Fibular motor study to EDB at ankle, below fibular head, above fibular head, and popliteal fossa
4. Tibial motor study to abductor hallucis at ankle and popliteal fossa
5. Median SNAP at wrist to second digit
6. Ulnar SNAP at wrist to fifth digit

7. Sural SNAP at calf to ankle
8. F-waves: Median, ulnar, and tibial
9. H-reflexes

ALS EMG Protocol

1. Cover at least three limbs including both proximal and distal muscles of different myotomes and dermatomes
2. Thoracic paraspinalis
3. Bulbar muscles (e.g., tongue, masseter, sternocleidomastoid (SCM))
4. Would expect pattern of denervation, reinnervation, decreased activation, decreased recruitment

PPS NCS Protocol

1. Perform routine motor and sensory nerve conduction studies to at least three extremities, starting with the weakest limb. Sensory studies can be skipped for the noninvolved extremity.
2. Both motor and sensory conduction velocities, latencies, and amplitudes should be normal in PPS.
3. CMAP amplitude may be decreased or absent over muscles with significant atrophy.

PPS EMG Protocol

1. At least two muscles innervated by different peripheral nerves that share the same root levels (similar to radiculopathy screen). This is done for each root level to exclude a superimposed process, such as radiculopathy or entrapment neuropathy.
2. EMG is performed on the same limbs as the NCS. Check the weakest muscles first.
3. Paraspinal muscles are not required.
4. Bulbar muscles may be considered if there is facial weakness.

PPS EMG Findings

1. MUAPs have very large amplitude, long duration, and are polyphasic. This represents a chronic nerve reinnervation pattern. MUAP amplitudes can be as large as 20 to 30 mV.
2. Recruitment pattern is decreased, representing a neuropathic process.
3. Nearly all muscles tested should show similar results, even in the unaffected extremity, but to a lesser degree.

4. Some muscles may show increased insertional activity and/or spontaneous activity, representing ongoing denervation. This is to a much less degree compared to the chronic reinnervation pattern.

EMG is used to evaluate patients with a history of polio to help exclude other superimposed processes such as radiculopathy, entrapment neuropathy, myopathy, or motor neuron disease. Most PPS patients will have diffuse, chronic, underlying abnormalities on EMG, which makes it very challenging to find evidence of a new superimposed neurogenic process

Foot Drop NCS Protocol

1. fibular nerve recording at EDB or tibialis anterior (looks at deep fibular nerve)
2. Superficial fibular nerve (if abnormal, may be indicative of common fibular neuropathy or more proximal neuropathy)
3. Test tibial CMAP and sural SNAP (abnormalities would point to sciatic neuropathy or lumbosacral plexopathy)

Foot Drop EMG Protocol

1. One deep fibular innervated muscle (tibialis anterior)
2. One superficial fibular innervated muscle (peroneus longus)
3. One tibial innervated muscle
4. One sciatic innervated muscle (short head biceps femoris)
5. One lumbosacral plexus innervated muscle (gluteus medius)

Foot Drop Differential Diagnosis

- Tibialis anterior injury
- Polyneuropathy
- Deep fibular neuropathy
- Common fibular neuropathy
- Sciatic neuropathy
- Lumbosacral plexopathy
- Lumbar radiculopathy
- Spinal cord pathology
- Brain pathology

4

High-Yield Information

- Contraindications/Safety in EMG
- Characteristics of Spontaneous Activity
- Troubleshooting Checklist
- Time Course After Axonal Injury
- Troubleshooting in the ICU
- Report Writing Template
- Billing/Coding: NCS
- Billing/Coding: EMG
- Normal Values

1. **Risk of electrical injury**
   - Always use a three-hole, properly grounded outlet
   - Keep unnecessary electrical equipment outside of the exam room
   - Be aware of equipment that is damaged, wet, giving off an unusual smell, or unusually hot
   - Never perform electrodiagnostic (EDX) on patients with external guide wires (e.g., pacing) in place
   - If a central line is in place, it is preferable to use the contralateral side for exam

2. **Pacemakers (implanted) and cardioverter/defibrillators**
   - Much lower risk than individuals with external devices in place
   - Theoretically possible nerve conduction studies (NCS) to be mistaken for arrhythmia
   - Recommend consultation with patient's cardiologist prior to EDX
   - If performed, maintain distance between stimulators and implanted device, and use contralateral side to device if possible

3. **Pneumothorax**
   - Must suspect after EMG; exam if the patient is experiencing chest pain/shortness of breath
   - If suspect, obtain a chest x-ray and consult a specialist for possible chest tube placement
   - Sampling of certain muscles at higher risk: Diaphragm, serratus anterior, supraspinatus, rhomboids, and cervical/thoracic paraspinals

4. **Infection**
   - Proper hand hygiene should always be used as in any patient encounter
   - Gloves should be worn during EMG portion of exam
   - After every NCS, the surface electrodes should be cleaned

(continued)

CONTRAINDICATIONS/SAFETY IN EMG (Continued)

- Caution should be taken for inadvertent needle sticks and when recapping needles
- Antibiotic prophylaxis is not recommended by the American Heart Association for patients at high risk for endocarditis
  - Risk considered similar to phlebotomy

5. Bleeding
   - Minimal risk for bleeding with EMG without coexistent medical conditions or anticoagulant medications
   - Caution in patients with: Thrombocytopenia, chronic renal failure, and history of coagulopathies
   - In regard to anticoagulants, heparin/low-molecular-weight heparin (LMWH) and warfarin provide greatest risk
   - No evidence-based medicine to guide course; however, general consensus is to use caution when performing EMG in anticoagulated patients
   - If required, use smallest gauge needle possible. Avoid non-compressible muscles where potential for compression of neurologic structures exists. Avoid muscles with large arteries or veins nearby and limit number of passes through such muscles
   - Can consider use of ultrasound along with needle EMG to help accurately locate muscle, avoid blood vessels, and scan for hematomas
   - Incidence of hematoma formation in anticoagulated patients is low
   - 1.25% risk of paraspinal hematoma on anticoagulation (warfarin/heparin/LMWH) and 0.61% risk of paraspinal hematoma on antiplatelet medications (Gerkens, 2013)
   - No compelling evidence to support routinely deferring an EMG because of antiplatelet or thrombolytic anticoagulant use, and medications should not be discontinued before needle examination (Gerkens, 2013)

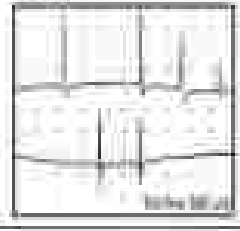
(continued)

CONTRAINDICATIONS/SAFETY IN EMG (Continued)

- Proposed guidelines (Genthon, 2013):
  - Perform testing in patients with INR values <3.0
  - If INR >3.0, perform EMG at discretion of electromyographer using common sense
  - No need to hesitate in performing testing on patients taking antiplatelet agents
  - Anticoagulants and antiplatelet medications should not be routinely discontinued for needle EMG

Genthon JT, Paul AT, Boon AJ. Electromyography and Anticoagulation. PM&R. 2013; Suppl. 1: S3–S7.

CHARACTERISTICS OF SPONTANEOUS ACTIVITY

Spontaneous Activity	Source	Morphology	Significance	Appearance	Sound
Miniature endplate potentials (MEPP) or endplate spikes	Motor endplate	Small amplitude, negative spike, monophasic	Normal. May be painful region to sample		Seashell
Fibrillation potentials	Muscle fiber	Initial positive deflection	Ongoing denervation		Rain on the roof, rhythmic

(Continued)

CHARACTERISTICS OF SPONTANEOUS ACTIVITY (Continued)

Spontaneous Activity	Source	Morphology	Significance	Appearance	Sound
Positive sharp wave	Muscle fiber	Initial positive deflection with prolonged negative phase	Ongoing denervation		Dull pop; rhythmic
Complex repetitive discharge (CRD)	Multiple muscle fibers	Multimuscle repetitive discharges with abrupt onset and termination	Chronic denervation		Machine gun

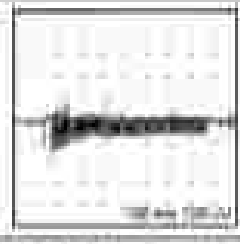
(Continued)

CHARACTERISTICS OF SPONTANEOUS ACTIVITY (Continued)

Spontaneous Activity	Source	Morphology	Significance	Appearance	Sound
Myotonic discharges	Muscle fiber	Waxing/waning amplitude and frequency	Associated with myotonia		Dive bomber
Fasciculations	Motor unit	Look like motor units with irregular firing pattern	May or may not be normal depending on other findings	Looks like a motor unit	Popcorn popping
Myokymia	Motor unit	Rhythmic, repetitive discharges of same motor unit	Classic for radiation plexopathy		Marching soldiers

(Continued)

CHARACTERISTICS OF SPONTANEOUS ACTIVITY (Continued)

Spontaneous Activity	Source	Morphology	Significance	Appearance	Sound
Cramp	Motor unit	Interference pattern	May be normal or representative of neurologic disorder	Looks like interference pattern	Loud discharge of several motor units
Neuromyotonia	Motor unit	High frequency decrementing amplitude discharge of single motor unit	Neuromyotonia (Isaac's syndrome)		Ping
Tremor	Motor unit	Synchronous burst of many different motor units	May be benign vs. neurologic disorder (i.e., Parkinson's)	Looks like many motor units	Marching soldier

Waveforms reprinted with permission from Gao P, Cros D, Visser C. A Practical Approach to Electrodiagnostic Medicine: An Illustrated Guide for Clinicians. New York: NY Demos Medical Publishing; 2011.

TROUBLESHOOTING CHECKLIST

- ☐ Temperature: ideally 33 degrees or above
- ☐ Amplifier on
- ☐ Not enough or too much gel
- ☐ Skin impedance (remove lotion, clean skin, abbride thick skin)
- ☐ Electrodes plugged into correct channels
- ☐ Electrode placement (incorrect or not adequately inferred)
- ☐ Ground on
- ☐ Cathode/anode switched
- ☐ Stimulator placement
- ☐ Distance between active and reference
- ☐ Active electrode off motor point (if initial positive deflection)
- ☐ Check if correct study chosen on screen and correct side of the body
- ☐ Stimulation intensity hasn't been turned up at all or not high enough (can go up on duration/pulse width as well)
- ☐ Interference
  - Turn off lights
  - Remove cell phone (from doctor and patient)
  - Unplug electric bed
  - Uncross stimulator and recording electrodes
  - Cross active and reference electrodes
  - Use 60 Hz notch filter if needed

TIME COURSE AFTER AXONAL INJURY

- Decreased recruitment may be seen immediately if complete conduction block or axonal injury
- CMAPs absent by day 7 to 9
- SNAPs absent by day 10 to 11
- Maximal abnormal spontaneous activity typically seen 3 weeks after axonal injury
- Neuropathic motor units typically depending on distance from nerve injury to muscle seen 3 months after axonal injury

TROUBLESHOOTING IN THE ICU

- Bring a second person for study to help with positioning
- If sedation limits motor unit recruitment, ask primary team if sedation can be reduced for the study
- If poor cooperation limits motor unit recruitment, assess muscles that can be activated by painful stimulus
- If positioning limits ability to test certain muscles, strategize testing of other less commonly tested muscles innervated by same nerve roots or peripheral nerves (bring EMG book with you to help)
- Consider omitting muscles not absolutely necessary to test
- Do not perform electrodiagnostic study when patient has external pacemaker → high risk of electrical injury!!!
- If central access, avoid left's stimulation on that side
- Minimizing interference is a challenge: clean skin thoroughly, ensure enough gel, turn off any unnecessary electrical devices in room (don't accidentally turn off or unplug patient's ventilator!), operator and patient should not touch metal part of hospital bed

REPORT WRITING TEMPLATE

- Patient name and date of birth
- Date of exam
- Referral source
- Chief complaint
- History of present illness
- Physical examination
- **Motor nerve conduction studies:**
  - The _____ nerve(s) demonstrated normal/prolonged distal motor latencies, normal/decreased amplitude, and normal/slowed conduction velocities
- **Sensory nerve conduction studies:**
  - The _____ nerve(s) demonstrated normal/prolonged peak latencies and normal/low amplitudes
- **Late responses:**
  - The _____ F-waves showed normal/prolonged latencies with no significant side-to-side difference
  - H-reflexes were present and symmetric bilaterally
- **Needle EMG:**
  - Needle EMG examination of the _____ reveals no abnormal spontaneous activity. Motor unit potential morphology is normal with full recruitment on maximal effort or reduced recruitment on submaximal effort
- **Impression:**
  - This is a normal study. There is no electrophysiologic evidence of a large fiber neuromuscular pathology, plexopathy, radiculopathy, or myopathy

Pearl

- Coming to a conclusion
  - Always correlate clinical findings with electrodiagnostic findings
  - If an electrodiagnostic interpretation does not fit with clinical findings, think twice before stating your conclusion

BILLING/CODING: NCS

1. 95905: 1–2 nerve conduction studies
2. 95906: 3–4 nerve conduction studies
3. 95907: 5–6 nerve conduction studies
4. 95908: 7–8 nerve conduction studies
5. 95911: 9–10 nerve conduction studies
6. 95912: 11–12 nerve conduction studies
7. 95913: 13 or more nerve conduction studies
8. 95900: Blink reflex (bilateral)
9. 95937: Neuromuscular junction testing (repetitive stimulation), each nerve

Important points:

- If testing same nerve at different recording sites (i.e., fibular nerve recording at extensor digitorum brevis [EDB] and tibialis anterior), cannot bill for separate NCS
- F-wave does not count as separate NCS
- Each H-reflex counts as separate NCS (i.e., bilateral H-reflexes count as 2 NCSs)

BILLING/CODING: EMG

1. If done on same day as NCS
   - 95885: Limited extremity EMG
     - When testing less than 5 muscles in a limb
     - May bill up to 4 units (one unit for each limited limb tested)
   - 95886: Complete extremity EMG
     - Minimum 5 muscles
     - Can be 5 limb muscles or 4 corresponding paraspinal
     - Must cover 3+ peripheral nerve or 4+ spinal levels
   - 95887: Nonextremity EMG

(continued)

2. If done without NCS:
   - 95860: 1 extremity with or without paraspinals
   - 95861: 2 extremities with or without paraspinals
   - 95863: 3 extremities with or without paraspinals
   - 95864: 4 extremities with or without paraspinals
   - 95870: Limited study of muscles in 1 extremity or scattered muscles
3. 95867: Cranial nerve muscle, unilateral
4. 95868: Cranial nerve muscle, bilateral
5. 95869: Thoracic paraspinal muscles (excluding T1 or T12)

NORMAL VALUES

Upper Extremity Motor Studies					
Nerve	Recording Site	Amp (mV)	Conduction Velocity (m/sec)	Onset Latency (ms)	F-wave latency (ms)
Median	APB	6.1	49	4.5	31.6
Ulnar	ADM	7.9	50	3.7	31.5
Ulnar	FDI	5.1	–	4.6	–
Axillary	DP	1.7–11.1	40.2–79.2	2.1	16.2–24.1

Upper Extremity Sensory Studies (Antidromic)			
Nerve	Recording Site	Onset to Peak Amp (μV)	Peak Latency (ms)
Median	2nd digit	19	3.0
Ulnar	5th digit	6	3.0
Radial	Snuffbox	7	2.8
DLFC	Dorsal webspace between 4th and 5th digit	5	2.9
LABC	Lat forearm	5	2.5
MABC	Med forearm	8	2.6

(Continued)

Lower Extremity Motor Studies					
Nerve	Recording Site	Amp (mV)	Conduction Velocity (m/sec)	Onset Latency (ms)	F-wave Latency (ms)
Fibular	EDB	1.0	38	6.5	61.2
Fibular	Fibular anterior	1.7	40	4.9	–
Tibial	Abductor hallucis	4.4	39	6.1	61.4
Femoral	Rectus femoris	0.2–11	–	7.4	–

Lower Extremity Sensory Studies (Antidromic)			
Nerve	Recording Site	Onset to Peak Amp (μV)	Peak Latency (ms)
Sural	Posterior lateral ankle	6	4.5
Superficial fibular	Lateral ankle	7.7	4.2
Saphenous	Medial ankle	3	4.8
Medial plantar	Medial ankle	10–30	5.68
Lateral plantar	Medial ankle	6–29	5.63
Lateral femoral cutaneous	Anterior lateral thigh		4.5

(Continued)

Proximal Upper Extremity Motor Studies (Erb' Point Stimulation)		
Nerve	Recording Site	Latency
Axillary	Deltoid	5.8
Musculocutaneous	Biceps	5.6
Suprascapular	Supraspinatus	4.3
Suprascapular	Infraspinatus	4.8

Please note that normal values represent the following:
Amplitude: lower limit of normal.
Conduction velocity: upper limit of normal.
Latency: upper limit of normal.
These normal values are from Buchthal's, Manual of Nerve Conduction Studies.

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