POCKET EMG

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# Contents

**Preface**  xiii  
**Acknowledgments**  xvii  

Share Pocket EMG

## 1. NERVE CONDUCTION STUDIES  1

### Upper Extremity Sensory Studies  2
- Median Sensory (Antidromic)  2  
- Median Sensory Palmar (Antidromic)  3  
- Ulnar Sensory (Antidromic)  4  
- Dorsal Ulnar Cutaneous (DUC) Sensory Study  5  
- Radial Sensory  6  
- Lateral Antebrachial Cutaneous  7  
- Medial Antebrachial Cutaneous  8  

### Upper Extremity Motor Studies  9
- Median Motor: Distal Stimulation  9  
- Median Motor: Proximal Stimulation  10  
- Ulnar Motor Conduction Study  12  
- Ulnar Motor – Deep Branch  15  
- Radial Motor Conduction Study  16  
- Erb’s Point (Proximal Upper Extremity Motor Studies)  19  

### Lower Extremity Sensory Studies  20
- Superficial Fibular (Peroneal) Sensory  20  
- Sural Sensory  21  
- Saphenous Sensory  23  

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Medial/Lateral Plantar Nerve Sensory Study 24  
Lateral Femoral Cutaneous Nerve Sensory Study 26  
Lower Extremity Motor Studies 27  
Fibular (Peroneal) Motor Study Recording at Extensor Digitorum Brevis 27  
Fibular (Peroneal) Motor Conduction Study Recording at Tibialis Anterior 29  
Tibial Motor or Medial Plantar Motor (Tibial Medial Branch) 30  
Tibial Motor (Tibial Medial Branch) 31  
Lateral Plantar Motor (Tibial Lateral Branch) 32  
Lateral Plantar Motor Motor Normal Values 33  
Femoral Motor 33  
Late Responses 34  
F-Wave 34  
F-Wave Utility 34  
H-Reflex 35  
H-Reflex Stimulation 35  
Other Nerve Conduction Studies 37  
Facial Motor Nerve 37  
Blink Reflex (Trigeminal and Facial Nerves) 38  
Blink Reflex Normal Values 39  
Repetitive Nerve Stimulation (RNS) Protocol 39  
RNS Frequency 40  
Normal RNS Study 40  
Presynaptic NMJ Disorder (Lambert-Eaton Myasthenic Syndrome) 40  
Postsynaptic NMJ Disorder (Myasthenia Gravis) 42  

2. NEEDLE ELECTROMYOGRAPHY 43  

EMG Introduction 44  
Spontaneous Activity 44  
Motor Unit Analysis 44  
Recruitment 45
Upper Extremity Studies 46
  Abductor Pollicis Brevis (APB) 46
  Opponens Pollicis 47
  Flexor Pollicis Longus 48
  Flexor Digitorum Profundus (FDP) 49
  Flexor Digitorum Superficialis (FDS) 50
  Flexor Carpi Radialis (FCR) 51
  Pronator Teres 52
  First Dorsal Interosseous (FDI) 53
  Abductor Digiti Minimi (ADM) 54
  Flexor Carpi Ulnaris (FCU) 55
  Extensor Indicis Proprius (EIP) 56
  Extensor Carpi Ulnaris (ECU) 57
  Extensor Digitorum Communis (EDC) 58
  Extensor Carpi Radialis 59
  Brachioradialis 60
  Anconeus 61
  Triceps 62
  Biceps Brachii 63
  Deltoid 64
  Upper Trapezius 65
  Supraspinatus 66
  Infraspinatus 67
  Rhomboid 68
  Latissimus Dorsi 69
  Serratus Anterior 70

Lower Extremity Studies 71
  Extensor Digitorum Brevis (EDB) 71
  Extensor Hallucis Longus (EHL) 72
  Tibialis Anterior 73
  Fibularis (Peroneus) Longus 74
  Abductor Hallucis 75
  Abductor Digiti Quinti Pedis 76
  Gastrocnemius 77
  Tibialis Posterior 78
  Biceps Femoris (Short Head) 79
  Adductor Magnus 80
  Vastus Lateralis 81
  Iliopsoas 82
Gluteus Medius 83
Tensor Fascia Lata (TFL) 84
Gluteus Maximus 85

Paraspinal Muscles 86
Cervical Paraspinals 86
Lumbar Paraspinals 87

Facial Muscles 88
Tongue 88
Orbicularis Oculi 89
Masseter 90

3. STUDY PROTOCOLS 91

Carpal Tunnel Syndrome (CTS) 92
CTS NCS Protocol 92
Combined Sensory Index 93
Median–Ulnar Sensory to the Ring Finger (Ringdiff) 94
Median–Radial Sensory to the Thumb (Thumbdiff) 95
Median–Ulnar Mixed-Nerve From the Palm (Palmdiff) 96
Median–Ulnar Lumbrical-Interosseous Comparison Study 97
CTS Electromyography (EMG) Protocol 98
CTS Severity: AANEM Monograph 98

Anterior Interosseous Neuropathy (AIN) 99
AIN NCS Protocol 99
AIN EMG Protocol 99

Ulnar Neuropathy at the Elbow (UNE) 100
UNE NCS Protocol 100
UNE EMG Protocol 100

Inching Across the Elbow 101

Ulnar Neuropathy at the Wrist (UNW) 102
UNW NCS Protocol 102
UNW EMG Protocol 103
UNW Severity 103
UNW Different Entrapment Sites 103
Radial Neuropathy 104
Radial Neuropathy NCS Protocol 104
Radial Neuropathy NCS Patterns 104
Radial Neuropathy EMG Protocol 105
Radial Neuropathy EMG Patterns 105
Fibular (Peroneal) Neuropathy 106
Fibular (Peroneal) Neuropathy NCS Protocol 106
Fibular Neuropathy NCS Patterns 106
Fibular (Peroneal) Neuropathy EMG Protocol 107
Fibular Neuropathy EMG Patterns 107
Cervical Radiculopathy 108
Lumbar Radiculopathy 109
Polyneuropathy 110
Polyneuropathy Motor Nerve Conductions 110
Polyneuropathy Sensory Nerve Conductions 110
Polyneuropathy Late Responses 110
Polyneuropathy EMG Protocol 110
Interpretation 111
Demyelination 111
Conduction Block 111
Criteria for Acute Demyelinating Polyneuropathy 112
Criteria for Chronic Demyelinating Polyneuropathy 112
Femoral Neuropathy 113
Femoral Neuropathy NCS Protocol 113
Femoral Neuropathy EMG Protocol 113
Brachial Plexopathy 114
Brachial Plexopathy NCS Protocol 114
Mapping of Sensory Potentials 115
Brachial Plexopathy EMG Protocol 115
Brachial Plexopathy Lesions and Associated Findings 115

Lumbosacral Plexopathy 117
Lumbosacral Plexopathy NCS Protocol 117
Lumbosacral Plexopathy EMG Protocol 118
Diabetic Amyotrophy 118

Sciatic Neuropathy 119
Sciatic Neuropathy NCS Protocol 119
Sciatic Neuropathy EMG Protocol 120

Tarsal Tunnel Syndrome (TTS) 121
TTS NCS Protocol 121
Medial (Left) and Lateral (Right) Plantar Mixed Nerve 122
TTS EMG Protocol 123

Myopathy 124
Myopathy NCS Protocol 124
Myopathy EMG Protocol 124
Myopathic MUAPs 125

Amyotrophic Lateral Sclerosis (ALS) 126
ALS NCS Protocol 126
ALS EMG Protocol 127

Postpolio Syndrome (PPS) 128
PPS NCS Protocol 128
PPS EMG Protocol 128
PPS EMG findings 128

Foot Drop 130
Foot Drop NCS Protocol 130
Foot Drop EMG Protocol 130
Foot Drop Differential Diagnosis 130

4. HIGH-YIELD INFORMATION 131

Contraindications/Safety in EMG 132
Characteristics of Spontaneous Activity 135
Troubleshooting Checklist 139
Time Course After Axonal Injury 140
Troubleshooting in the ICU 140
Report Writing Template 141
Billing/Coding: NCS 142
Billing/Coding: EMG 142
Normal Values 144

Index 147
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. If it becomes
dog-eared and covered 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 everyday 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


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Share
Pocket EMG
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 $>10 \mu V$, 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, 6.5 cm distal to wrist stimulation site along line drawn from wrist to index finger

**Pearls**

- A palmar/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 <4.0 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 >5 µV, peak latency <2.9 msec

Pearls

- May be abnormal in ulnar neuropathy of 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 E1 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 <2.8 msec

**Pearls**

- Study may be abnormal in radial neuropathy, posterior 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 (mid-point 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.
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
ACTIVE: Placed over the muscle belly of abductor digit 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 14)

NORMAL VALUES: Amp >7.9 mV, conduction velocity >50 m/sec, onset latency <3.7 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 digit minimi (ADM) is usually innervated by the superficial palmar branch of the ulnar nerve
  - **If suspected, motor responses to the FDI should be studied**
1. Wrist—Adjacent to flexor carpi ulnaris tendon approximately 7 cm from G1

2. Below elbow — 3 to 4 cm distal to medial epicondyle (**at least 3 cm to ensure distal to cubital tunnel**)
3. Above elbow — Stimulation over the medical humerus, between biceps/triceps muscle 10 to 12 cm from below elbow site
**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 recording 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 24.1 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 brachil 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
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 inactive 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
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: 14 cm proximal to the active electrode, along the anterior crest of the tibia

NORMAL VALUES: Amp >7.7 µV, peak latency <4.2 msec
Sural Sensory

ACTIVE: Behind the midpoint of the lateral malleolus

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

STIMULATION: 14 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 calf 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 72% 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 response 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
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 >10–30 µV, medial peak latency <3.68 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

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LOWER EXTREMITY MOTOR STUDIES

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

(continued)
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 10 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 >1.7 mV, conduction velocity >43 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 >4.4 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)

- **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.

**Proximal Stimulation (Position Variation):** Patient lying in prone position (Image C).
Lateral Plantar Motor (Tibial Lateral Branch)

ACTIVE: Approximately halfway between the 5th metatarso-phalangeal (MTP) joint and the heel, along the lateral arch.

REFERENCE: Slightly distal to the 5th MTP joint, on the lateral 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 3.5 msec.
• If the medial latency is within 0.3 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 ≤6.3

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:** Cathode pointing proximally. Use supra-maximal 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 where it departs baseline
- Jendrassik maneuver can help to elicit the F-wave
- Side-to-side comparison may be helpful
- Taller 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 pointing proximally at popliteal fossa

**NORMAL VALUES:** Mark H-reflex latency at earliest point on rastered 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 text 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 34 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 over additional facial muscles
- Facial nerve CMAP assessment may assist with confirmation and prognosis of Bell’s palsy
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:** G1 placed below the eye socket over the orbicularis oculi muscle

**REFERENCE:** G2 placed over inactive lateral canthus of the eyes

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

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**Pearls**

- Use two channels with four electrodes to record at both ipsilateral and contralateral sides
- Low current typically required for supramaximal 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 <7 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. Stimulus 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 postexercise 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 postexercise 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 exercises for greater than 10 seconds or 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