# Atlas of Nerve Conduction Studies (NCS)

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Nestor Galvez-Jimenez, John A. Morren, Alexandra Soriano, Karin Armstrong, Melissa Goldberg, Lourdes Gonzalez, and Dana Higginbotham

## Introduction

There may be some acceptable variability in certain aspects of NCS, depending on the laboratory performing the testing. What is described in this chapter follows the methodology utilized in our laboratory, which conforms to what is generally considered standard practice in the field of electrodiagnostic medicine.

N. Galvez-Jimenez (✉) · A. Soriano
Braathen Neurological Center, Cleveland Clinic Florida, Weston, FL, USA

Cleveland Clinic Lerner College of Medicine of Case Western Reserve University, Cleveland, OH, USA
e-mail: galvezn@ccf.org; soriana@ccf.org

J. A. Morren
Neuromuscular Center, Neurological Institute, Cleveland Clinic, and Cleveland Clinic Lerner College of Medicine of Case Western Reserve University, Cleveland, OH, USA
e-mail: morrenj@ccf.org

K. Armstrong · M. Goldberg · L. Gonzalez
Neurophysiology Lab, Cleveland Clinic Florida, Weston, FL, USA
e-mail: armstrk@ccf.org; goldbem2@ccf.org; gonzall5@ccf.org

D. Higginbotham
Neurophysiology Lab, Neuromuscular Center, Neurological Institute, Cleveland Clinic, Cleveland, OH, USA
e-mail: higgind2@ccf.org

## General Concepts

The performance of NCS is deceptively simple but the importance of standardization in key aspects across laboratories cannot be overemphasized. Accordingly, being consistent and attentive to ensure that the studies are always performed in the same fashion is crucial for reliable NCS results.

Most errors during NCS are caused by incorrect or inconsistent technical components. Otherwise, an anatomical variation may produce apparently spurious NCS results as well, so knowledge of these is also essential. Additionally, it is imperative to maintain the tested limb/region at the recommended temperature (above 32 °C for the upper extremities and above 30 °C for the lower extremities, measured at the dorsum of the hands and feet).

Filter settings are also important, though typically preset in modern machines (e.g. 1 Hz–5 kHz for compound muscle action potentials, 10 Hz–5 kHz for sensory nerve action potentials, 2 Hz–10 kHz for needle EMG, and 500 Hz–10 kHz for single fiber EMG).

E1: recording/active electrode. For motor NCS, this is on the motor point of the muscle (the end plate region). Note: E1 used to be referred to


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as G1, but use of this term is now discouraged. The "G" designation referred to "grid" derived from the classic electroencephalography literature, but now obsolete.

E2: reference/inactive electrode. For motor NCS, this is usually on the tendon of the muscle.

Note: Similarly, E2 used to be referred to as G2, but this term is now discouraged.

Recorded responses are those obtained from E1 while E2 is silent. However, in some instances, E2 may be active due to inadvertent volume conduction.

The ground electrode should always be between the stimulation site and recording sites.

As previously discussed in Chap. 1, the expected response is that of a negative (upward) potential. For motor NCS, if there is a positive (downward) deflection preceding the negative deflection, is often because the E1 electrode is not adequately over the motor point/end plate region and its position must be adjusted until a negative first potential response is obtained.

## Upper Extremities

### Sensory NCS

#### Median Sensory Recording at Index Finger (See Fig. 2.1)

Anatomy: brachial plexus (lateral cord ← upper and middle trunk) ← (mostly) C6–7 dorsal root ganglia (DRG).

Position: Patient is supine with the forearm and hand supinated, resting completely on the bed.

Recording electrode location:

E1: Second metacarpo-phalangeal joint.
E2: Second Distal interphalangeal joint, 3–4 cm distally to E1.

Ground: Between stimulation and recording sites, at the dorsum of the hand.

Stimulation: At the wrist between the tendons of the flexor carpi radialis (FCR) and palmaris longus (PL), 13 cm proximal from E1.

Caveats/Notes: make measurements with fingers extended and abducted.

#### Median Sensory Recording at the Thumb (See Fig. 2.2)

Anatomy: brachial plexus (lateral cord ← upper trunk) ← (mostly) C6 dorsal root ganglion (DRG).

Position: Patient is supine with the forearm and hand supinated resting completely on the bed.

Recording electrode location:

E1: first metacarpo-phalangeal joint.
E2: first interphalangeal joint.

Ground: Between stimulation and recording sites, at the dorsum of the hand.

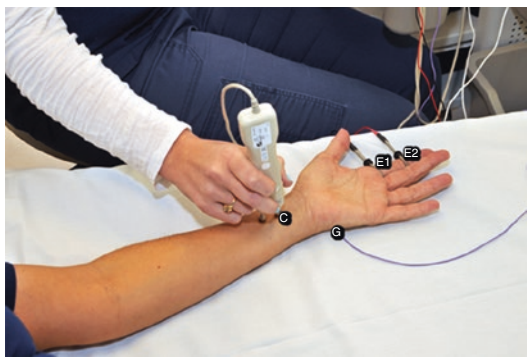


**Fig. 2.1** Median sensory response—stimulating at wrist, recording index. C = Cathode; G = Ground


**Fig. 2.2** Median sensory response—stimulating at wrist, recording thumb. C = Cathode; G = Ground


**Fig. 2.3** Median sensory response—stimulating at wrist, recording middle finger. C = Cathode; G = Ground

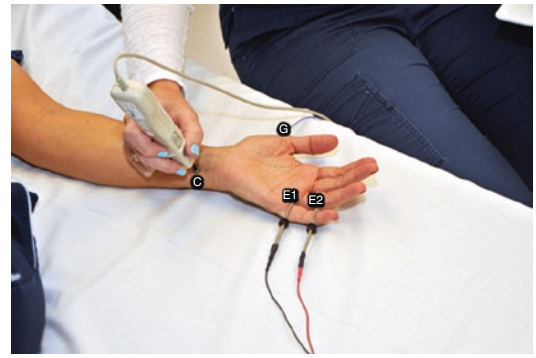


**Fig. 2.4** Ulnar sensory response—stimulating at wrist, recording little finger (D5). C = Cathode; G = Ground

Stimulation: At the wrist between the tendons of the flexor carpi radialis (FCR) and palmaris longus (PL), 13 cm proximal from E1.

Caveats/Notes: make measurements with fingers extended and abducted.

### Median Sensory Recording at Middle Finger (See Fig. 2.3)

Anatomy: brachial plexus (lateral cord ← middle trunk) ← (mostly) C7 dorsal root ganglion (DRG).

Position: Patient is supine with the forearm and hand supinated resting completely on the bed.

Recording electrode location:

E1: Third metacarpo-phalangeal joint.
E2: Third Distal interphalangeal joint, 3–4 cm distally to E1.

Ground: Between stimulation and recording sites, at the dorsum of the hand.

Stimulation: At the wrist between the tendons of the flexor carpi radialis (FCR) and palmaris longus (PL), 13 cm proximal from E1.

Caveats/Notes: make measurements with fingers extended and abducted.

### Ulnar Sensory Recording at Fifth Finger (See Fig. 2.4)

Anatomy: brachial plexus (medial cord ← lower trunk) ← (mostly) C8 dorsal root ganglion (DRG).

Position: Patient is supine with the forearm and hand supinated resting completely on the bed.

Recording electrode location:

E1: Fifth metacarpo-phalangeal joint.
E2: Fifth Distal interphalangeal joint, 3–4 cm distally to E1.

Ground: Between stimulation and recording sites, at the dorsum of the hand.

Stimulation: At the medial wrist between tendons of the flexor carpi ulnaris (FCU) and flexor digitorum profundus (FDP), 11 cm proximal to E1.

Caveats/Notes: make measurements with fingers extended and abducted.

### Dorsal Ulnar Cutaneous Sensory Recording at Dorsum of the Hand (See Fig. 2.5)

Anatomy: brachial plexus (medial cord ← lower trunk) ← (mostly) C8 dorsal root ganglion (DRG).

Position: Patient is supine with the forearm and hand pronated, resting completely on the bed.

Recording electrode location.

E1: dorsum of hand between the fourth and fifth finger web space.
E2: 3–4 cm distal to E1, at the base of the fifth finger.

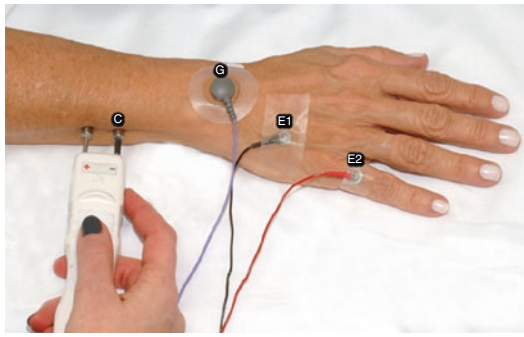


**Fig. 2.5** Ulnar sensory response—stimulating at wrist, recording dorsum of hand (dorsal ulnar cutaneous sensory response). C = Cathode; G = Ground

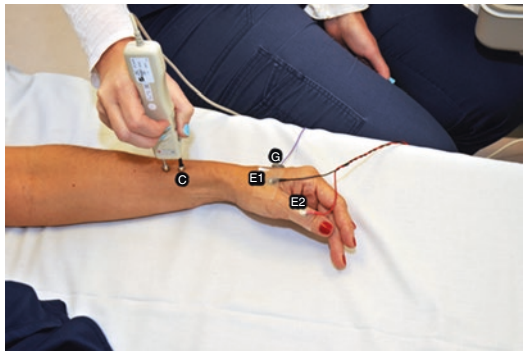


**Fig. 2.6** Radial sensory response—stimulating at distal forearm, recording at first web space. C = Cathode; G = Ground

Ground: Between stimulation and recording sites, at the dorsum of the hand.

Stimulation: At the wrist, 10 cm proximal from E1 recording electrode, stimulating between the ulna and flexor carpi ulnaris (FCU) tendon, proximal to the ulna styloid.

Caveats/Notes: Helpful in determining ulnar neuropathy at the elbow, or most other lesions proximal to the wrist, as it is typically spared in an ulnar lesion at the wrist (Guyon's canal).

### Radial Sensory Recording at Base of the Thumb (See Fig. 2.6)

Anatomy: brachial plexus (posterior cord ← upper and middle trunk) ← (mostly) C6–7 dorsal root ganglia (DRG).

Position: Patient supine with forearm midway between pronation and supination and resting completely on the bed.

Recording electrode location:

E1: At the anatomic "V" or web space formed between the index finger and thumb metacarpals.
E2: First digit interphalangeal joint, 3–4 cm distal to E1.

Ground: Between stimulation and recording sites, at the dorsum of the hand.

Stimulation: over the radius 10 cm proximal to E1.

### Median Palmar Mixed Nerve (See Fig. 2.7)

Anatomy: brachial plexus (lateral cord ← upper and middle trunk) ← (mostly) C6–7 dorsal root ganglia (DRG).

Patient position: Patient supine with arm resting comfortably completely on the bed. Palm facing up and fingers abducted.

Important: This is an orthodromic nerve stimulation study.

Recording electrode location:

E1: at the wrist crease between the flexor carpi radialis and flexor pollicis longus.
E2: 3 cm proximal to E1, in a straight line.

Ground: dorsum of the hand.

Stimulation: in the palm, 8 cm distal to the E1 in the space between the second and third digits (second metacarpal interspace).


**Fig. 2.7** Median palmar mixed nerve study—stimulating the median nerve at the palm, recording at the wrist. C = Cathode; G = Ground

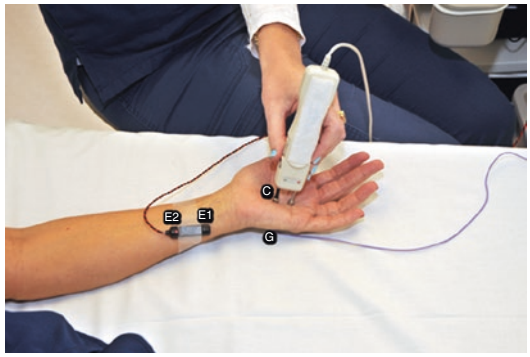


**Fig. 2.8** Ulnar palmar mixed nerve study—stimulating the ulnar nerve at the palm, recording at the wrist. C = Cathode; G = Ground

Caveats/Notes: some laboratories use a standardized bar electrode (shown in picture).

### Ulnar Palmar Mixed Nerve (See Fig. 2.8)

Anatomy: brachial plexus (medial cord ← lower trunk) ← (mostly) C8 dorsal root ganglion (DRG).

Patient position: Patient supine with arm resting comfortably completely on the bed. Palm facing up and fingers abducted.

Important: This is an orthodromic nerve stimulation study.

Recording electrode location:

E1: at the wrist crease between the flexor carpi ulnaris and flexor digitorum profundus.
E2: 3 cm proximal to E1, in a straight line.

Ground: dorsum of the hand.

Stimulation: at the palm, 8 cm distal to the E1 in the space between the fourth and fifth digits (fourth metacarpal interspace).

Caveats/Notes: some laboratories use a standardized bar electrode (shown in picture).

### Medial Antebrachial Cutaneous Sensory Recording Medial Forearm (See Fig. 2.9)

Anatomy: brachial plexus (medial cord ← lower trunk) ← (mostly) T1 dorsal root ganglion (DRG).

Patient position: Patient supine with arm resting comfortably completely on the bed. Palm facing up/forearm supinated and mildly flexed at the elbow.

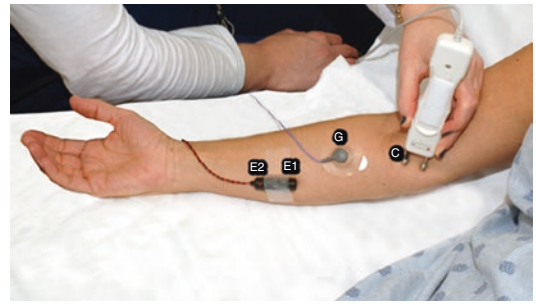


**Fig. 2.9** Medial Antebrachial Cutaneous sensory response—stimulating anteromedial elbow, recording medial forearm. C = Cathode; G = Ground

Recording electrode location:

E1: anteromedial forearm 12 cm distal to the stimulation site/cathode (that is, point between the biceps tendon and the medial epicondyle).
E2: 3 cm distal to E1, in a straight line.

Ground: between the stimulation and recording sites.

Stimulation: find the midpoint between the biceps tendon and medial epicondyle, 12 cm proximal to E1.

Caveats/Notes: some laboratories use a standardized recording bar electrode (shown in picture).

### Lateral Antebrachial Cutaneous Sensory Recording Lateral Forearm (See Fig. 2.10)

Anatomy: musculocutaneous nerve ← brachial plexus (lateral cord ← upper trunk) ← (mostly) C6 dorsal root ganglion (DRG).

Patient position: Patient supine with arm resting comfortably completely on the bed. Palm facing up/forearm supinated and mildly flexed at the elbow.

Recording electrode location:

E1: anterolateral forearm 12 cm distal to the stimulation site, which is a point lateral to the biceps tendon at the antecubital fossa.
E2: 3 cm distal to E1, in a straight line.

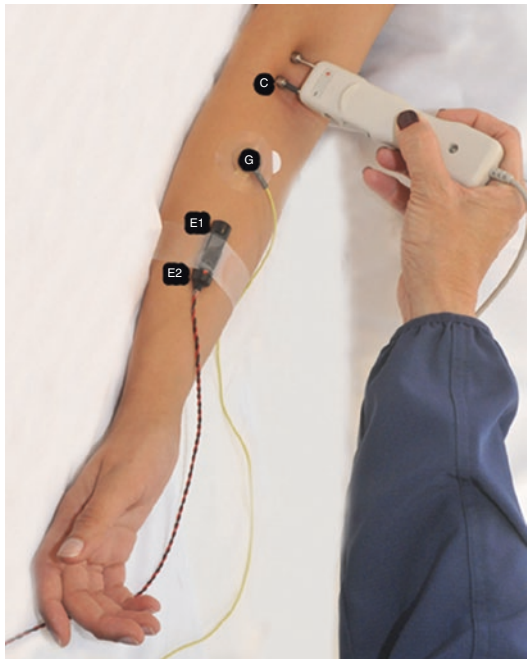


**Fig. 2.10** Lateral Antebrachial Cutaneous sensory response—stimulating anterolateral elbow, recording lateral forearm. C = Cathode; G = Ground

Ground: between the stimulation and recording sites.

Stimulation: lateral to the biceps tendon at the antecubital fossa, 12 cm proximal to E1.

Caveats/Notes: some laboratories use a standardized recording bar electrode (shown in picture).

## Motor NCS

### Median Motor Recording at Abductor Pollicis Brevis (APB)

Anatomy/Innervation: Median nerve ← medial cord ← lower trunk ← C8-T1 spinal nerve roots.

Position: Patient supine with forearm supinated, extended at the elbow and resting completely on the bed.

Recording electrode location:

E1: Motor point, belly of the ABP.
E2: first metacarpophalangeal joint.

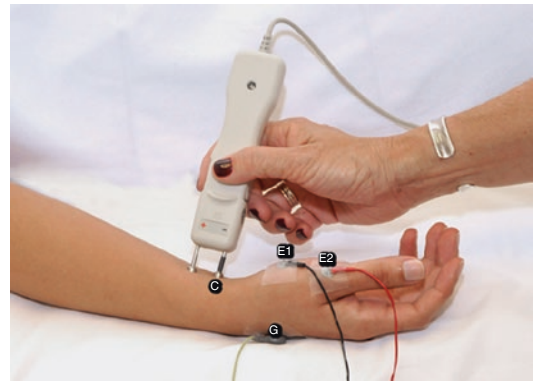


**Fig. 2.11** Median motor response recording the abductor pollicis brevis, distal stimulation at the wrist. C = Cathode; G = Ground

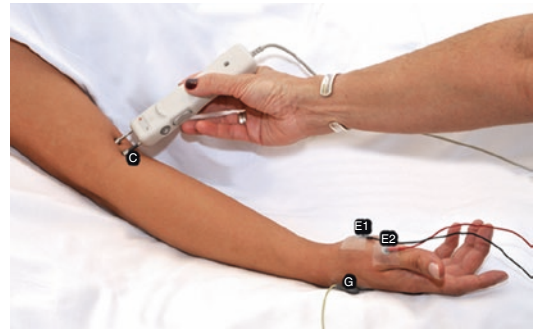


**Fig. 2.12** Median motor response recording the abductor pollicis brevis, proximal stimulation at the elbow. C = Cathode; G = Ground

Ground: Between stimulation and recording sites—usually proximal dorsum of hand. Proximal palm may be used instead.

Stimulation:

Distal site: At the wrist between the tendons of the flexor carpi radialis (FCR) and palmaris longus (PL), 5 cm proximal from E1 (See Fig. 2.11).

Proximal site: Antecubital fossa over pulse of brachial artery, just medial to the biceps tendon (See Fig. 2.12).

Caveats/Notes: If the recorded response when stimulating at the antecubital fossa is larger in amplitude than that recorded when stimulating at the wrist, an anatomical variant/anomalous innervation such as a Martin-Gruber anastomosis

(MGA) must be considered (this type of MGA would involve cross-over median fibers innervating nearby thenar muscles which would typically be ulnar-innervated, like the deep head of flexor pollicis brevis and the adductor pollicis).

### Ulnar Motor Recording at Abductor Digiti Minimi (ADM)

Anatomy/Innervation: ulnar nerve ← medial cord ← lower trunk ← C8–T1 spinal nerve roots.

Position: Patient supine with forearm supinated extended at the elbow and resting completely on the bed.

Recording electrode location:

E1: Motor point, belly of the ADM.
E2: Mid-portion proximal phalanx fifth finger.

Ground: Between stimulation and recording sites—usually proximal dorsum of hand. Proximal palm may be used instead.

Stimulation:

Distal site: At the wrist medial to the tendon of the flexor carpi ulnaris (FCU), 5 cm proximal from E1 (See Fig. 2.13).
Proximal sites:
- Below elbow: 4 cm distal to the ulnar groove/medial epicondyle on the medial forearm (See Fig. 2.14).
- Above elbow: 6 cm proximal to the ulnar groove/medial epicondyle, at the medial arm between biceps and triceps muscles (See Fig. 2.15).

Accordingly, the total distance is 10 cm across the elbow between these two proximal stimulation sites. This measurement must be done following the contour of the medial aspect of the forearm and arm, and the elbow must be in a 90 degrees flexed position. This is done to avoid "bunching up" or redundancy of the ulnar nerve if the arm is extended, which could artifactually produce a decreased distance measurement (since this is done on the surface), resulting in spuriously reduced motor conduction velocity.

Caveats/Notes: If the recorded response when stimulating at the elbow suggest a conduction block between the elbow and the wrist, an anatomical variant/anomalous innervation such as a Martin-Gruber anastomosis must be considered (in this scenario, the crossover median-to-ulnar fibers are stimulated at the wrist, but not at the elbow sites).

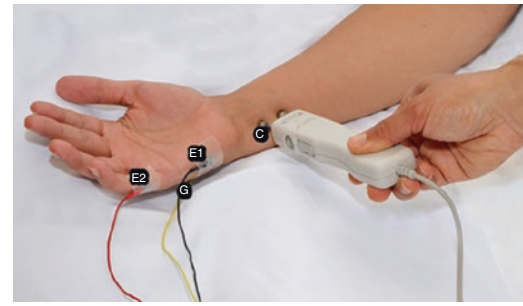


**Fig. 2.13** Ulnar motor recording abductor digiti minimi, with distal stimulation at wrist. C = Cathode; G = Ground

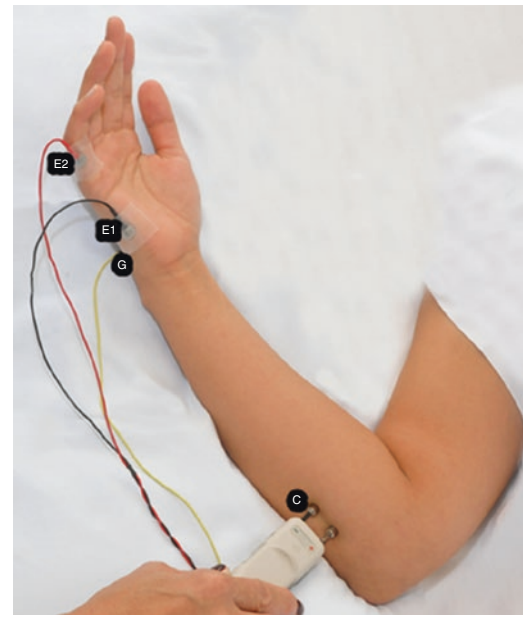


**Fig. 2.14** Ulnar motor recording abductor digiti minimi, with proximal stimulation at below-elbow. C = Cathode; G = Ground

### Ulnar Motor Recording at First Dorsal Interosseous (FDI)

Anatony/Innervation: ulnar nerve ← medial cord ← lower trunk ← C8-T1 spinal nerve roots.

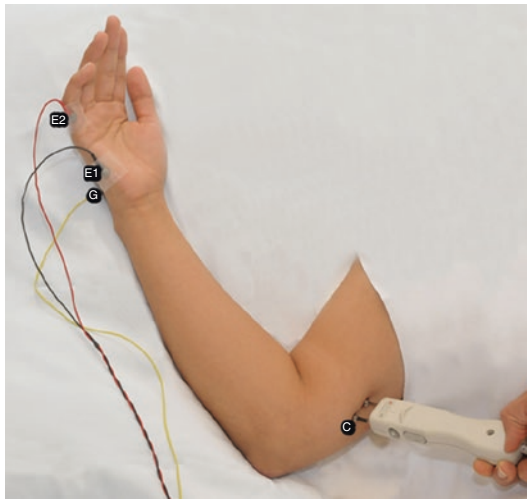


**Fig. 2.15** Ulnar motor recording abductor digiti minimi, with proximal stimulation at above-elbow. C = Cathode; G = Ground

Position: Patient supine with forearm supinated extended at the elbow and resting completely on the bed.

Recording electrode location:

E1: Motor point, belly of the FDI.
E2: Midportion of the middle phalanx index finger.

Ground: Between stimulation and recording sites—usually proximal dorsum of hand. Proximal palm may be used instead.

Stimulation:

Distal site: At the wrist slightly radial to the tendon of the flexor carpi ulnaris (FCU), otherwise site similar to that used when recording the ADM (See Fig. 2.16).

Proximal sites:

Below elbow: 4 cm distal to the ulnar groove/medial epicondyle on the medial forearm (See Fig. 2.14—i.e. same stimulation site as when recording ADM).

Above elbow: 6 cm proximal to the ulnar groove/medial epicondyle, at the medial arm between biceps and triceps muscles (See Fig. 2.15—i.e. same stimulation site as when recording ADM).

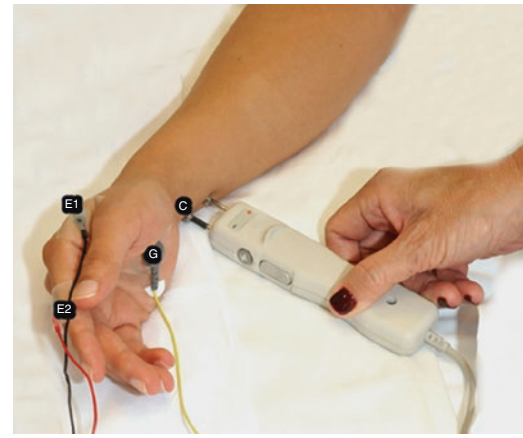


**Fig. 2.16** Ulnar motor recording first dorsal interosseous, with distal stimulation at wrist. C = Cathode; G = Ground

Accordingly, the total distance is 10 cm across the elbow between these two proximal stimulation sites. This measurement must be done following the contour of the medial aspect of the forearm and arm, and the elbow must be in a 90 degrees flexed position. This is done to avoid "bunching up" or redundancy of the ulnar nerve if the arm is extended, which could artifactually produce a decreased distance measurement (since this is done on the surface), resulting in spuriously reduced motor conduction velocity.

Caveats/Notes: If the recorded response when stimulating at the elbow suggest a conduction block between the elbow and the wrist, an anatomical variant/anomalous innervation such as a Martin-Gruber anastomosis must be considered (in this scenario, the crossover median-to-ulnar fibers are stimulated at the wrist, but not at the elbow sites).

## Radial Motor Recording at Extensor Digitorum (Communis) [ED/EDC]

Anatomy/Innervation: posterior interosseous nerve ← radial nerve, posterior cord ← middle and lower trunks ← C7–C8 spinal nerve roots.

Position: Patient supine with forearm pronated and elbow flexed and arm resting completely on the bed.

Recording electrode location:

E1: Motor point, belly of the EDC.
E2: posterior forearm about 5 cm proximal to dorsum of wrist or ulnar styloid.

Ground: on the forearm between the recording and stimulating sites.

Stimulation:

Distal site: At the elbow, at the groove between biceps and brachioradialis muscles (See Fig. 2.17).
Proximal sites:
Below the spiral groove: between the biceps and triceps muscles, usually performed only if there is a significant drop in amplitude when stimulating above the spiral groove recording EDC (See Fig. 2.18).
Above the spiral groove, between the medial and lateral heads of the triceps (See Fig. 2.19).

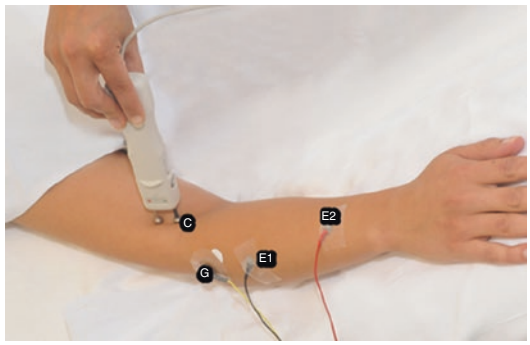


**Fig. 2.17** Radial motor recording extensor digitorum, distal stimulation at elbow. C = Cathode; G = Ground

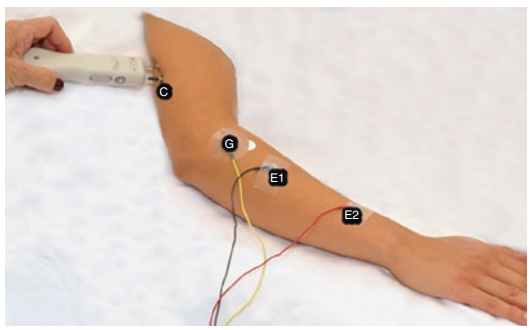


**Fig. 2.18** Radial motor recording extensor digitorum, proximal stimulation at below-spiral groove. C = Cathode; G = Ground

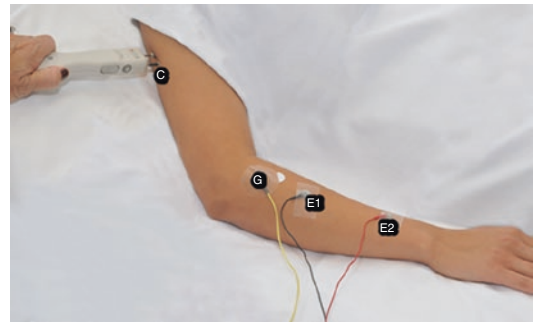


**Fig. 2.19** Radial motor recording extensor digitorum, proximal stimulation at above-spiral groove. C = Cathode; G = Ground

Caveats/Notes: Do above spiral groove stimulation site first, and then do the below spiral groove stimulation site, only if there is a significant drop in amplitude (suggesting conduction block).

## Musculocutaneous Recording at Biceps Brachii

Anatomy/Innervation: musculocutaneous nerve ← lateral cord ← upper trunk ← C5–C6 spinal nerve roots.

Position: Patient supine with forearm supinated and extended at the elbow and resting completely on the bed.

Recording electrode location:

E1: Motor point, belly of the biceps.
E2: distal upper arm over the biceps tendon and antecubital fossa.

Ground: Between stimulation and recording sites.

Stimulation:

Distal: At the axilla beneath the tendon of the short head of the biceps (See Fig. 2.20).
Proximal: At Erbs point, in the supraclavicular fossa posterior to the sternocleidomastoid muscle (See Fig. 2.21).

Caveat: Supramaximal stimulations may be challenging at the Erb's point due to patient discomfort/pain intolerance. Important to compare

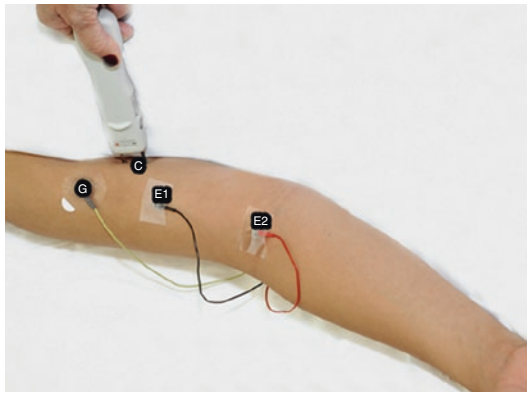


**Fig. 2.20** Musculocutaneous motor recording biceps brachii, distal stimulation at axilla. C = Cathode; G = Ground

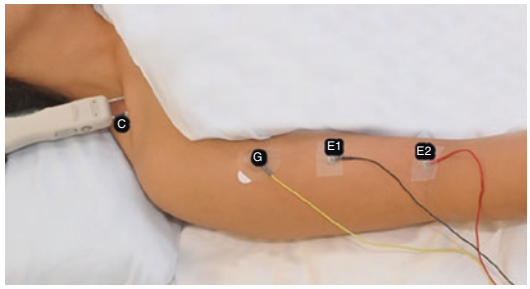


**Fig. 2.21** Musculocutaneous motor recording biceps brachii, proximal stimulation at Erb's point. C = Cathode; G = Ground

amplitude and latency of response to the contralateral side.

### Axillary Recording at Deltoid Muscle

Anatomy/Innervation: Axillary nerve ← posterior cord ← upper trunk ← C5-C6 spinal nerve roots.

Position: Patient is supine with forearm supinated, resting completely on the bed.

Recording electrode location:

E1: Motor point, belly of the deltoid (lateral head).
E2: distal upper arm, above elbow.

Ground: Between stimulation and recording sites, usually at the shoulder joint.

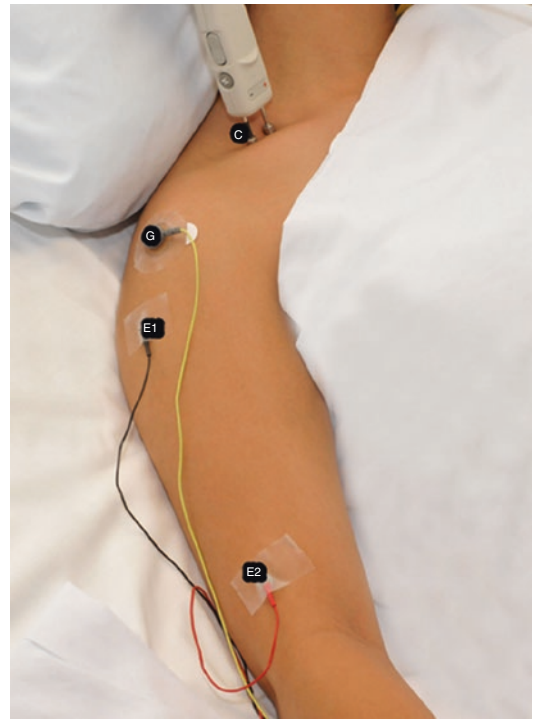


**Fig. 2.22** Axillary motor recording deltoid, stimulation at Erb's point. C = Cathode; G = Ground

Stimulation: At Erbs point, in the supraclavicular fossa posterior to the sternocleidomastoid muscle (See Fig. 2.22).

Caveat: Supramaximal stimulations may be challenging at the Erb's point due to patient discomfort/pain intolerance. Important to compare amplitude and latency of response to the contralateral side.

## Lower Extremity

### Sensory NCS

#### Sural (Sensory) Recording Posterior Distal Leg/Lateral Ankle (See Fig. 2.23)

Anatomy: the medial cutaneous branch from the tibial nerve, and the lateral cutaneous branch from the common fibular nerve ← sciatic nerve ← lumbosacral plexus ← S1–2 dorsal root ganglia (DRG).

Patient position: Patient in a lateral decubitus position (contralateral limb down), with the knee

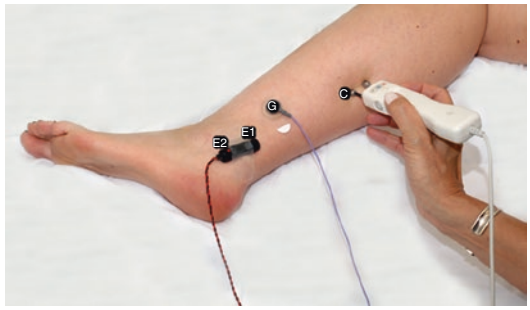


**Fig. 2.23** Sural (sensory) recording at ankle/lateral malleolus, stimulating at distal calf. C = Cathode; G = Ground

slightly flexed and leg resting comfortably, completely on the bed.

Recording electrode location:

E1: postero-inferior to the lateral malleolus.
E2: placed on the side of the foot 3 cm distal to E1.

Ground: Lateral lower leg, between stimulation and recording sites.

Stimulation: Posterior aspect of distal leg, with stimulation electrode 14 cm proximal to the E1.

Caveats/Notes: some laboratories use a standardized recording bar electrode (shown in picture).

### Superficial Peroneal (Fibular) Sensory Recording Dorsolateral Aspect of Ankle/Proximal Foot (See Fig. 2.24)

Anatomy: peroneal (fibular) nerve ← sciatic nerve ← lumbosacral plexus, L5 (>S1) dorsal root ganglion (DRG).

Patient position: Patient in supine with the leg resting comfortably, completely on the bed.

Recording electrode location:

E1: lower lateral leg, dorsum of ankle with E1 located halfway between lateral malleolus and extensor digitorum longus tendon.
E2: placed 3 cm distal to E1.

Ground: Distal lower leg, between stimulation and recording sites.

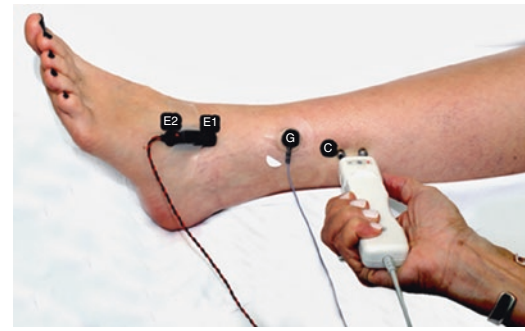


**Fig. 2.24** Superficial peroneal (fibular) sensory recording dorsolateral aspect of ankle/proximal foot, stimulating lateral distal leg. C = Cathode; G = Ground

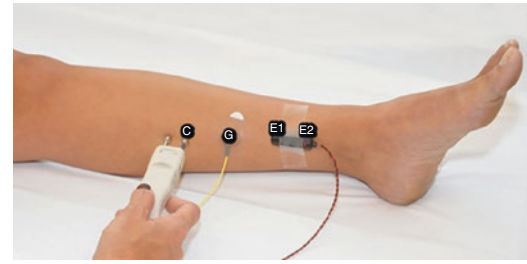


**Fig. 2.25** Saphenous (sensory) nerve recording medial distal leg, stimulation at medial calf. C = Cathode; G = Ground

Stimulation: Placing stimulating electrode (cathode) in a straight line 10 cm (but may be up to 14 cm) proximal to E1.

Caveats/Notes: Some laboratories use a standardized recording bar electrode (shown in picture).

### Saphenous Nerve Recording Medial Distal Leg (See Fig. 2.25)

Anatomy: femoral nerve ← lumbar plexus ← L3–L4 dorsal root ganglia (DRG).

Patient position: patient supine with the leg resting comfortably, completely on the bed.

Recording electrode location.

E1: medial leg/lower calf at ankle medial to the tibialis anterior tendon.
E2: 3 cm distal to E1, in the space between the medial malleolus and the tibialis anterior muscle tendon.

Ground: medial lower leg/lower calf, between stimulation and recording sites.

Stimulation: cathode 10 cm (but may be up to 14 cm) proximal to E1 between the medial gastrocnemius and the tibia.

Caveats/Notes: Some laboratories use a standardized recording bar electrode (shown in picture). The saphenous response is often difficult to obtain with consistency. Therefore, one should be careful to interpret an unelicitable response as a pathological finding, unless the contralateral response (in an unaffected limb) is obtained.

### Lateral Femoral Cutaneous Nerve Recording Lateral Thigh (See Fig. 2.26)

Anatomy: lumbar plexus, L2–3 dorsal root ganglia (DRG).

Patient position: patient supine with the leg resting comfortably, completely on the bed.

Recording electrode location:

E1: recording electrode is placed on the anterolateral aspect of the thigh 12 cm distal to the stimulation site.
E2: 3 cm distal to E1.

Ground: lateral thigh, between stimulation and recording sites.

Stimulation: cathode is placed superior to the inguinal ligament about 1 cm medial to the anterior superior iliac spine (ASIS).

Caveats/Notes: Some laboratories use a standardized recording bar electrode (shown in picture). The lateral femoral cutaneous nerve response is also often difficult to obtain with consistency (especially in overweight/obese individuals). Therefore, one should be careful to interpret an unelicitable response as a pathological finding, unless the contralateral response (in an unaffected limb) is obtained.

### Medial and Lateral Plantar Mixed Nerve Response Recording the Medial Ankle (See Figs. 2.27 and 2.28)

Anatomy: tibial nerve ← sciatic nerve ← lumbosacral plexus, S1 (>S2, L4–5) dorsal root ganglia (DRG).

Patient position: Patient supine with the leg resting comfortably, completely on the bed.

Orthodromic stimulation.

Recording electrode location:

E1: recording electrode is placed on the posteromedial aspect of the distal leg/medial malleolus in the hollow between the Achilles tendon and medial malleolus.
E2: 3 cm proximal to E1.

Ground: dorsum of foot, between stimulation and recording sites.

Stimulation:

Medial Plantar: cathode is placed 11–14 cm distal to E1 on the medial aspect of the sole of the foot.

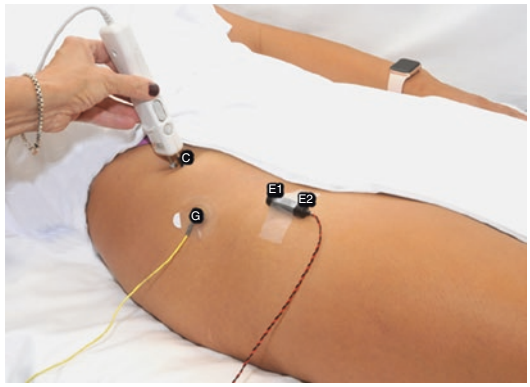


**Fig. 2.26** Lateral femoral cutaneous nerve recording lateral thigh, with stimulation above inguinal ligament. C = Cathode; G = Ground

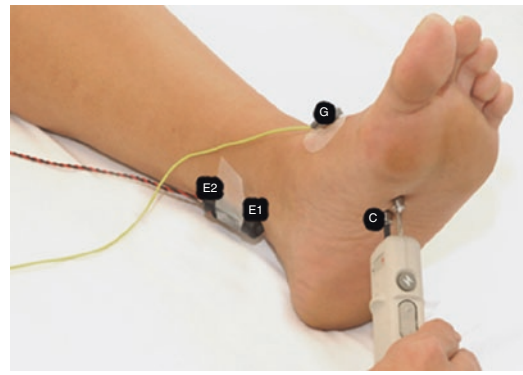


**Fig. 2.27** Medial plantar mixed nerve response recording the medial ankle, stimulation at the medial sole. C = Cathode; G = Ground

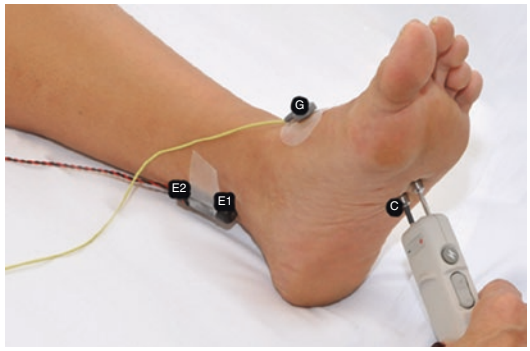


**Fig. 2.28** Lateral plantar mixed nerve response recording the medial ankle, stimulation at the lateral sole. C = Cathode; G = Ground

Lateral Plantar: cathode is placed 13–14 cm distal to E1 on the lateral aspect of the sole of the foot.

Caveats/Notes: Some laboratories use a standardized recording bar electrode (shown in picture). Commonly, the plantar mixed nerve responses (especially the lateral response) may be unobtainable secondary to technical factors, especially if the patient is older than 50 years and/or has evidence of thickened skin of the sole of the foot. Therefore, one should be careful to interpret an unelicitable response as a pathological finding, unless the contralateral response (in an unaffected limb) is obtained. When these technical factors are less likely (especially in those less than 50 years old), absent plantar mixed nerve responses may be the earliest electrodiagnostic manifestation of a length-dependent large fiber polyneuropathy. However, the complete set of routine lower extremity studies should be performed and plantar mixed nerve responses interpreted in the context of other electrodiagnostic findings obtained and the clinical presentation.

## Motor NCS

### Peroneal (Fibular) Motor Recording at Extensor Digitorum Brevis (EDB)

Anatomy/Innervation: Deep Peroneal (fibular) nerve ← Common Peroneal (fibular) nerve ← Sciatic nerve ← Lumbosacral trunk and Posterior division of the Sacral Plexus ← L5-S1 spinal nerve roots.

Patient position: Patient supine with the leg resting comfortably, completely on the bed.

Recording electrode location:

E1: recording electrode is placed on the motor point, belly of the extensor digitorum brevis.
E2: distal to E1, at the fifth metatarsophalangeal joint.

Ground: dorsum of foot, between stimulation and recording sites.

Stimulation:

Distal Site: cathode is place on a straight line up 6–8 cm (usually 7 cm) proximal to E1, stimulating at the distal ankle crease over the peroneal (fibular) nerve (See Fig. 2.29).
Proximal stimulation is performed at two sites:
Below the fibular head: 2–4 cm below the fibular head in the lateral calf (See Fig. 2.30).
Above the fibular head: in the lateral popliteal fossa adjacent to the biceps femoris tendon, about 10–12 cm proximal to the below-fibular head stimulation site (See Fig. 2.31).

Caveats/Notes: Some laboratories only perform a below-fibular head site stimulation when there is evidence of a conduction block between the ankle and above-fibular head stimulation sites.

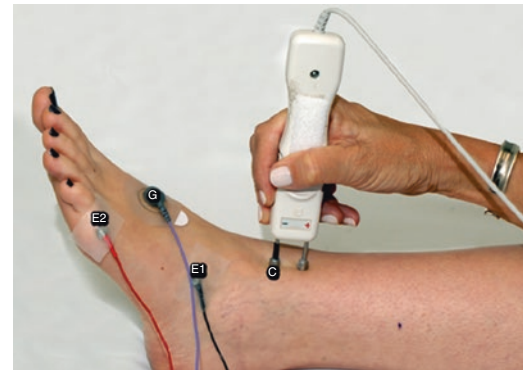


**Fig. 2.29** Fibular motor recording at extensor digitorum brevis, distal stimulation at ankle. C = Cathode; G = Ground

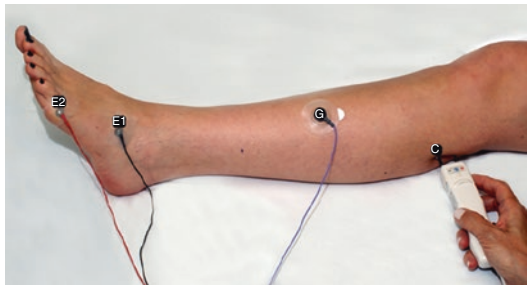


**Fig. 2.30** Fibular motor recording at extensor digitorum brevis, proximal stimulation at below-fibular head. C = Cathode; G = Ground

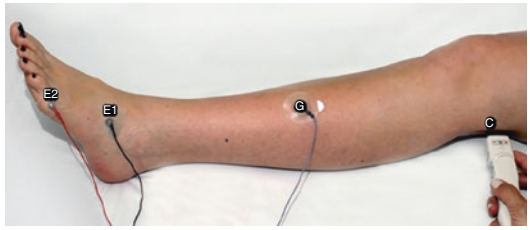


**Fig. 2.31** Fibular motor recording at extensor digitorum brevis, proximal stimulation at above-fibular head. C = Cathode; G = Ground

If the amplitude of the CMAP is reproducibly higher at the below and above-fibular head stimulation sites (compared to that at the distal ankle stimulation site), then an accessory peroneal (fibular) nerve variant must be considered. This is typically confirmed by eliciting a significant response with stimulation at the posterior aspect of the lateral malleolus, while recording the EDB.

## Peroneal (Fibular) Motor Recording at Tibialis Anterior (TA)

Anatomy/Innervation: Deep Peroneal (fibular) nerve ← Common Peroneal (fibular) nerve ← Sciatic nerve ← Lumbosacral trunk and Posterior division of the Sacral Plexus ← L4, L5 spinal nerve roots.

Patient position: Patient supine with the leg resting comfortably, completely on the bed.

Recording electrode location:

E1: recording electrode is placed on the muscle belly of the tibialis anterior muscle.
E2: placed anterior/top of ankle.

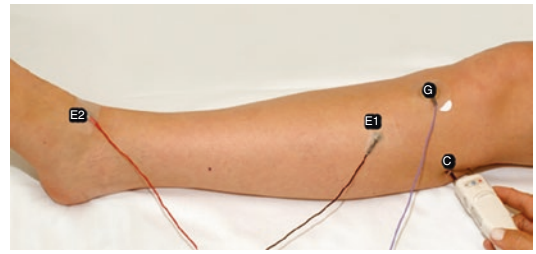


**Fig. 2.32** Fibular motor recording at tibialis anterior, distal stimulation at below-fibular head. C = Cathode; G = Ground

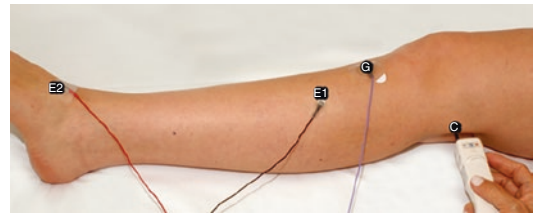


**Fig. 2.33** Fibular motor recording at tibialis anterior, proximal stimulation at popliteal fossa/above-fibular head. C = Cathode; G = Ground

Ground: between stimulation and recording sites.

Stimulation:

Stimulation is performed at two sites:

Distal stimulation: 2–4 cm below the fibular head in the lateral calf (See Fig. 2.32).
Proximal stimulation: in the lateral popliteal fossa adjacent to the biceps femoris tendon, about 10–12 cm proximal to the below-fibular head stimulation site (See Fig. 2.33).

Caveats/Notes: Amplitude and configuration of the motor response may vary considerably depending on location of E1. Unless there is evidence of conduction block between the standard distal and proximal stimulation sites outlined, there is usually no need to stimulate further between these sites in the popliteal fossa.

## Tibial Motor Recording at Abductor Hallucis (AH)

Anatomy/Innervation: Medial Plantar nerve ← Tibial nerve ← Sciatic nerve ← Anterior division of the Sacral Plexus, S1 > S2 spinal nerve roots.

Patient position: patient supine with the leg resting comfortably, completely on the bed.

Recording electrode location:

E1: recording electrode is placed on AH muscle belly on the medial aspect of the plantar arch, 1 cm distal to the prominence of the navicular bone.

E2: base of great toe, at the first metatarsophalangeal joint.

Ground: dorsum of foot, between stimulation and recording sites.

Stimulation:

Distal site: 8 cm proximal to E1 at the hollow space between the medial malleolus and Achilles tendon (See Fig. 2.34).

Proximal site: lateral aspect of the popliteal fossa, at the level that corresponds to the lower border of the kneecap (See Fig. 2.35).

Caveats/Notes: Proximal stimulation may be difficult to perform in some individuals with an abundant popliteal fat pad, hence firm pressure and higher stimulation intensity may be needed (sometimes associated with marked discomfort). Commonly, a significant drop in amplitude from the proximal stimulation site (compared to that obtained at the distal/ankle stimulation site) is noted. Accordingly, caution must be applied to not overcall a partial/incomplete conduction block in this scenario (typically, an amplitude drop of up to 50% may be dismissed).

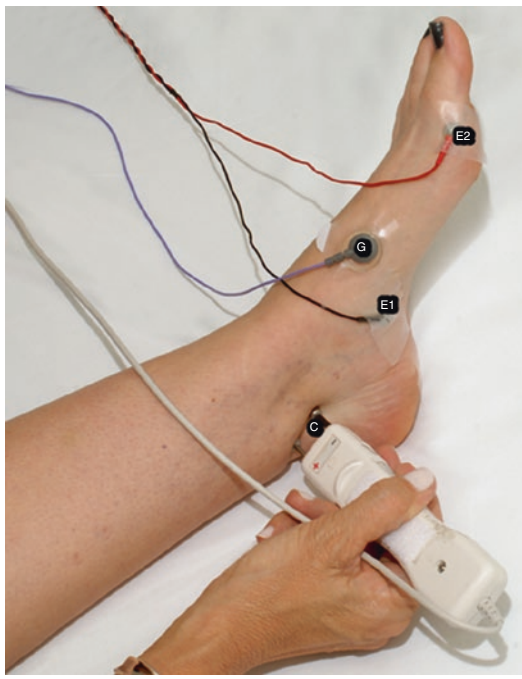


**Fig. 2.34** Tibial motor recording abductor hallucis, distal stimulation at medial ankle. C = Cathode; G = Ground

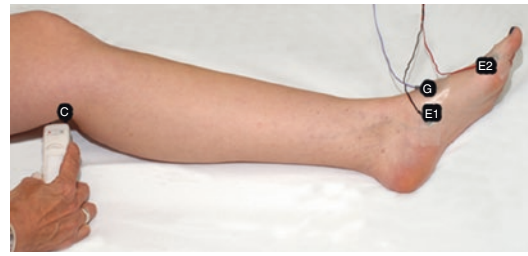


**Fig. 2.35** Tibial motor recording abductor hallucis, proximal stimulation at popliteal fossa. C = Cathode; G = Ground

## Tibial Motor Recording at Abductor Digiti Quinti Pedis (ADQP)

Anatomy/Innervation: Lateral Plantar nerve ← Tibial nerve ← Sciatic nerve ← Anterior division of the Sacral Plexus, S1 > S2 spinal nerve roots.

Patient position: Patient supine with the leg resting comfortably, completely on the bed.

Recording electrode location:

E1: recording electrode is placed on ADQP muscle belly—about mid-distance between the lower edge of the lateral malleolus and the lateral border of the foot.

E2: little toe, at the fifth metatarsophalangeal joint.

Ground: dorsum of foot, between stimulation and recording sites.

Stimulation:

Distal site: 8 cm proximal to E1 at the hollow space between the medial malleolus and Achilles tendon (See Fig. 2.36).

Proximal site: lateral aspect of the popliteal fossa, at the level that corresponds to the lower bor-

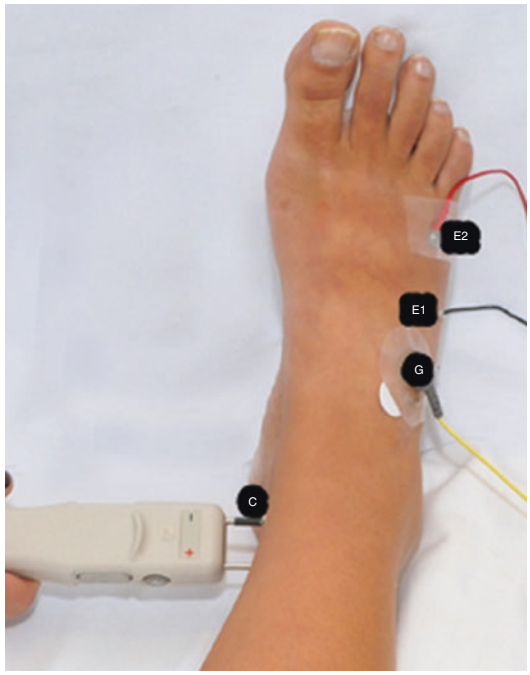


**Fig. 2.36** Tibial motor recording abductor digiti quinti pedis, distal stimulation at medial ankle (proximal stimulation at popliteal fossa is identical to that for abductor hallucis). C = Cathode; G = Ground

der of the kneecap (See Fig. 2.35—i.e. same proximal stimulation site when recording AH).

Caveats/Notes: Proximal stimulation may be difficult to perform in some individuals with an abundant popliteal fat pad, hence firm pressure and higher stimulation intensity may be needed (sometimes associated with marked discomfort).

## Femoral Motor Recording at Rectus Femoris

Anatomy/Innervation: Femoral nerve ← Posterior division of the Lumbar Plexus ← (L2)L3-L4 spinal nerve roots.

Patient position: Patient supine with the leg resting comfortably, completely on the bed.

Recording electrode location:

E1: recording electrode is placed over the belly of the rectus femoris in the anterior thigh, approximately at mid-point between the hip and knee joints.

E2: tendinous portion just above the knee.

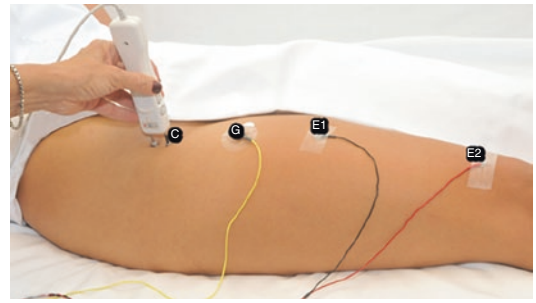


**Fig. 2.37** Femoral motor recording at rectus femoris, stimulation at just below inguinal ligament. C = Cathode; G = Ground

Ground: proximal thigh, between stimulation and recording sites.

Stimulation: cathode is place below the inguinal ligament at the inguinal crease, just lateral to the femoral pulse point (See Fig. 2.37).

Caveat: Effective stimulation may be difficult to perform in some larger individuals due to tissue impediment (including difficulty palpating the femoral pulse). Hence firm pressure may be required. Observing the contraction of the rectus femoris is more important in this scenario. If no observable rectus femoris contraction is noted, or other muscles (e.g. vastus medialis) respond to stimulation instead, the cathode must be repositioned.

## Tibial H-Reflex Recording at Soleus

Anatomy/Innervation: Tibial nerve ← Sciatic nerve ← Anterior division of the Sacral Plexus, S1 > S2 spinal nerve roots.

Patient position: The patient should be prone on the bed, using a pillow or similar item to help keep the limb comfortable during the study.

Recording electrode location:

Recording: E1 is placed at soleus muscle, just over the point in between the medial and lateral heads of the gastrocnemius muscle. It is helpful to have the patient plantar flex the foot to help with delineating space just below the separation of the two heads of the gastrocne-

mius muscle. The E1 electrode must be placed over this space.

Reference: E2 is placed in distal leg, typically above or at the Achilles tendon (usually 10–15 cm distal to E1).

Ground: Proximal to E1 on the leg below the knee, between stimulation and recording sites.

Stimulating: mid-popliteal fossa (over the popliteal pulse), with the cathode positioning reversed/polarity of the stimulator reversed, so that the cathode is effectively proximal to the anode in the popliteal fossa (See Fig. 2.38).

Caveats/Notes: The tibial H-reflex response usually has a latency between 25 and 35 ms.

The H-response/reflex begins to be observed before the "M" or muscle response.

As the intensity of the H-reflex stimulation increases, the M response increases and the H-response decreases until the H-response is no longer obtainable.

The tibial H-reflex is commonly absent after age 60, after lumbosacral spine surgeries, proximal (e.g. root-level) demyelination injury, axon-loss radiculopathies, and large fiber polyneuropathies [loss of the sensory (afferent) and/or motor (efferent) volley]. Therefore, this response provides a very sensitive evaluation of those S1 > S2/tibial sensory fibers that pass through the popliteal fossa.

The tibial H-reflex is affected by both axon loss and demyelination processes along the S1 > S2/tibial nerve fiber pathway from the popliteal fossa to the spinal cord, including the preganglionic sensory root segment.

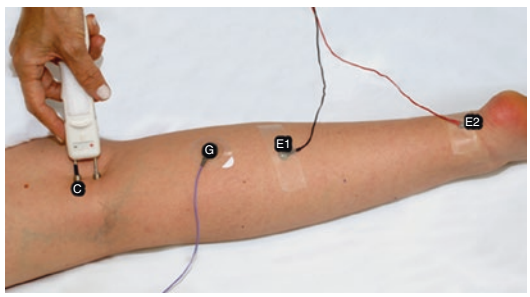


**Fig. 2.38** Tibial H-Reflex recording at Soleus. C = Cathode; G = Ground

Although a bilaterally absent tibial H-reflex response may confer less diagnostic yield in the work-up of a focal lesion/process, reduction or absence of the response with preservation on the contralateral/unaffected side is diagnostically valuable.

The lack of proper positioning and patient relaxation commonly results in an absent/suboptimal response.

## Spinal Accessory Motor Recording at Trapezius

Anatomy/Innervation: spinal accessory nerve ← C3&C4 spinal nerves.

Patient position: Patient supine with arm resting comfortably, completely on the bed.

Recording electrode location:

E1: Belly of the (upper) trapezius muscle.

E2: placed on top of the shoulder (over glenohumeral joint).

Ground: upper back, between stimulation and recording sites.

Stimulation: lateral to the sternocleidomastoid muscle.

This setup can be used during the repetitive nerve stimulation protocol, in the work-up of a neuromuscular junction transmission disorder (See Fig. 2.39).

Caveats/Notes: Some laboratories may use a standardized bar electrode connected to the hand-held stimulator prongs via an adapter (shown in picture).

## Facial Motor Recording at Nasalis

Anatomy/Innervation: Facial nerve (cranial nerve VII) originates from the union of the axons coming from the facial motor nucleus (primarily motor fibers for facial expression muscles) and the nervus intermedius (giving parasympathetic, taste, and non-taste sensory fibers). The zygomatic branch innervates the nasalis muscle.

Patient position: Patient supine, semi-recumbent.

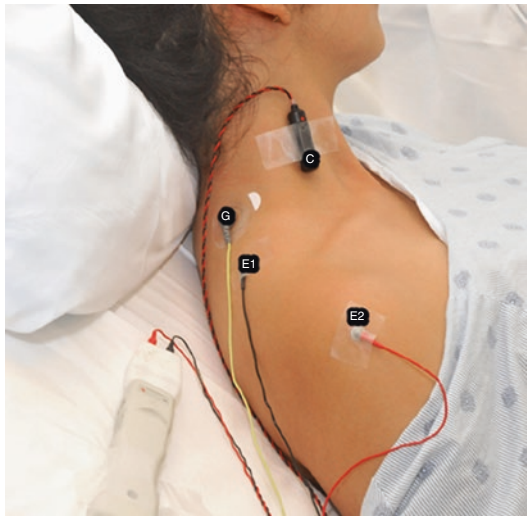


**Fig. 2.39** Spinal accessory motor recording at trapezius, stimulation lateral to the sternocleidomastoid muscle. C = Cathode; G = Ground

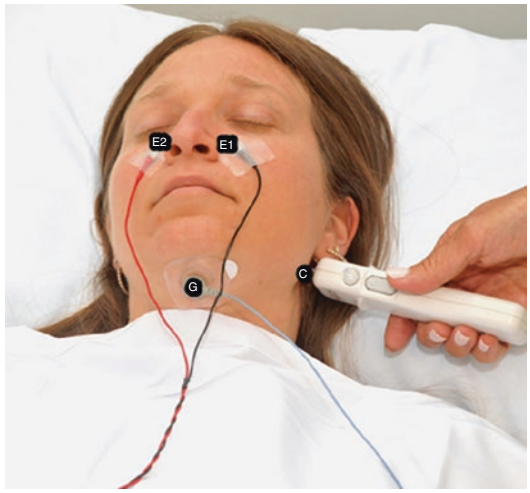


**Fig. 2.40** Facial motor recording at nasalis, stimulation at anterior mastoid process. C = Cathode; G = Ground

Recording electrode location:

E1: recording electrode is placed on the nasalis muscle (immediately lateral to mid-nose) bilaterally.

E2: placed at the same location contralaterally.

Ground: under the chin (shown in picture), or forehead.

Stimulation: cathode is place just below the ear and anterior to the mastoid process (See Fig. 2.40).

Caveat: Disposable electrodes may be used for facial nerve conduction studies. In a similar manner, other facial muscles may be used for recording purposes. However, each laboratory must ensure technique consistency for results reliability, reproducibility, and comparison purposes.

The nasalis (shown), frontalis, zygomaticus, orbicularis oris, orbicularis oculi, buccinators or quadratus labii superioris (levator labii superioris), and mentalis muscles may all be target muscles from which the facial CMAP response may be recorded.

The chosen muscle will depend on the clinical context and indication, determined on a case-by-case basis.

Suboptimal placement of the stimulating electrode may result in an initial positive deflection in the motor response. The appropriate motor response consists of an initial negative deflection.

## Suggested Reading

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