10 Routine Upper Extremity, Facial, and Phrenic Nerve Conduction Techniques

MEDIAN MOTOR STUDY *(Figure 10–1)*

Recording Site:

Abductor pollicis brevis (APB) muscle (lateral thenar eminence):
- G1 placed over the muscle belly
- G2 placed over the first metacarpal-phalangeal joint

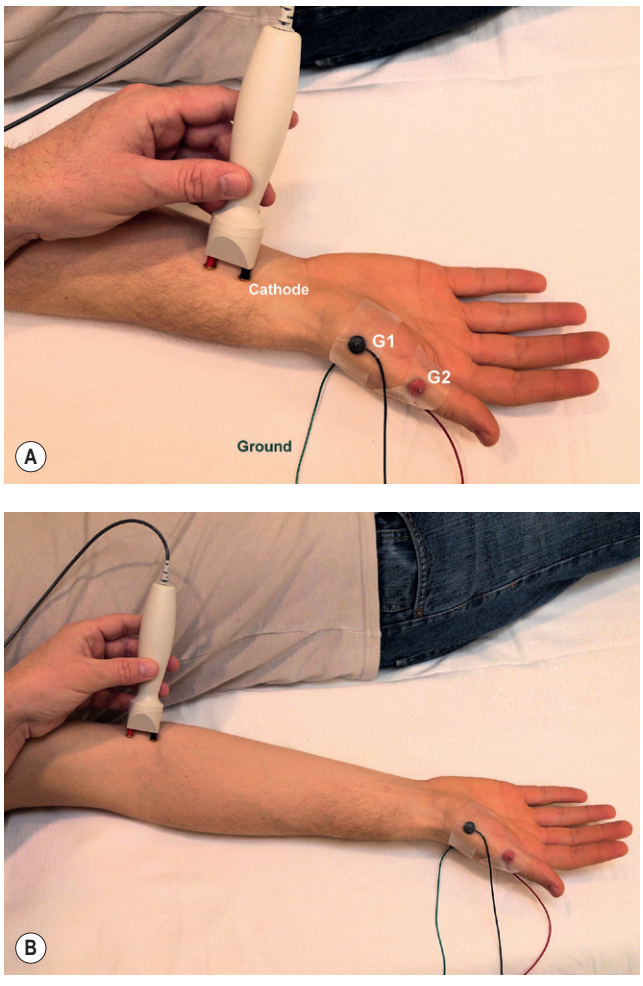

FIGURE 10–1 Median motor study. **A:** Distal stimulation site over the median nerve at the wrist, recording the abductor pollicis brevis muscle. **B:** Proximal stimulation site at the antecubital fossa.

Stimulation Sites:

Wrist: Middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus

Antecubital fossa: Over the brachial artery pulse

Distal Distance:

7 cm

Key Points:

- The study is easy to perform.
- Excessive stimulation at the wrist or antecubital fossa may result in co-stimulation of the ulnar nerve.
- If the amplitude of the compound muscle action potential (CMAP) is larger at the antecubital fossa than at the wrist, consider a Martin–Gruber anastomosis.

MEDIAN MOTOR PALMAR STUDY

(Figure 10–2)

Recording Site:

Abductor pollicis brevis (APB) muscle:
- G1 placed over the muscle belly
- G2 placed over the first metacarpal–phalangeal joint

Stimulation Sites:

Wrist: Middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus at a distance of 7 cm from the recording electrode

Palm: Stimulate in the palm, 7 cm distal to the wrist site on a line drawn from the median wrist to the web space between the index and middle fingers

Distance:

7 cm from the wrist to the APB (wrist stimulation)

Key Points:

- The APB is innervated via the recurrent thenar motor branch of the median nerve, which runs into the palm and then curves back to the thenar muscles.
- A palm/wrist CMAP amplitude ratio >1.2 implies some conduction block across the wrist.

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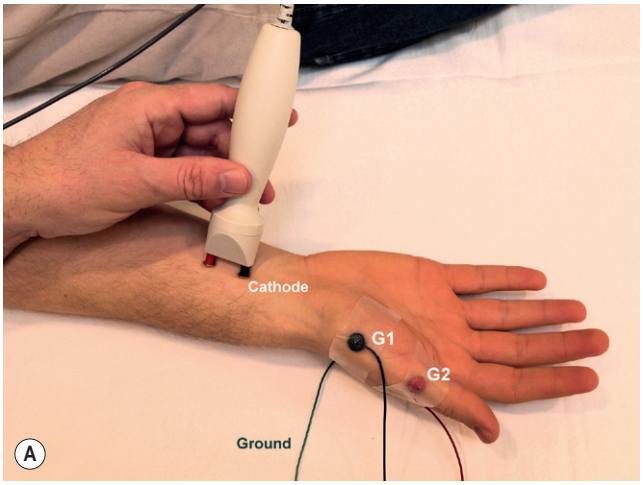


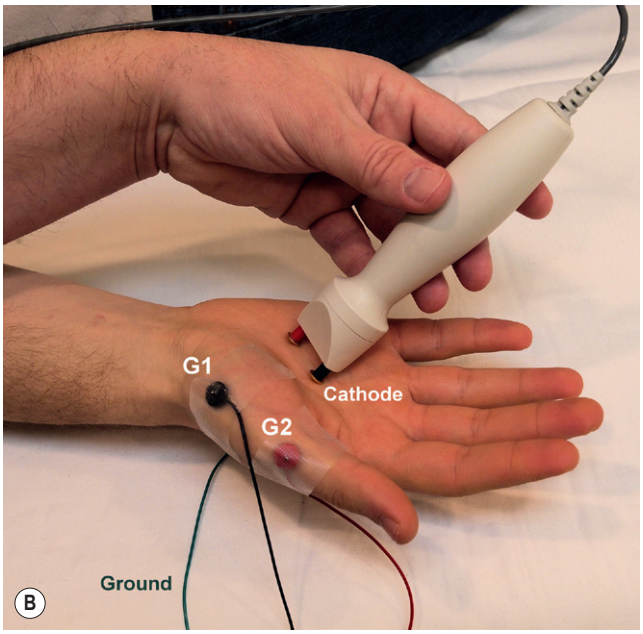


FIGURE 10–2 Median motor palmar study. **A:** Stimulation site over the median nerve at the wrist, recording the abductor pollicis brevis muscle. **B:** Stimulation site over the median nerve in the palm, recording the abductor pollicis brevis muscle.

- Calculation of conduction velocity is not reliable because of the short distances and the course of the recurrent branch of the thenar motor branch.
- If palm stimulation results in baseline distortion due to stimulus artifact, the anode should be rotated until a suitable baseline is obtained.

MEDIAN SENSORY STUDY *(Figure 10–3)*

Recording Site:

Index or middle finger (digit 2 or 3):

Ring electrodes with G1 placed over the metacarpal–phalangeal joint

G2 placed 3–4 cm distally over the distal interphalangeal joint

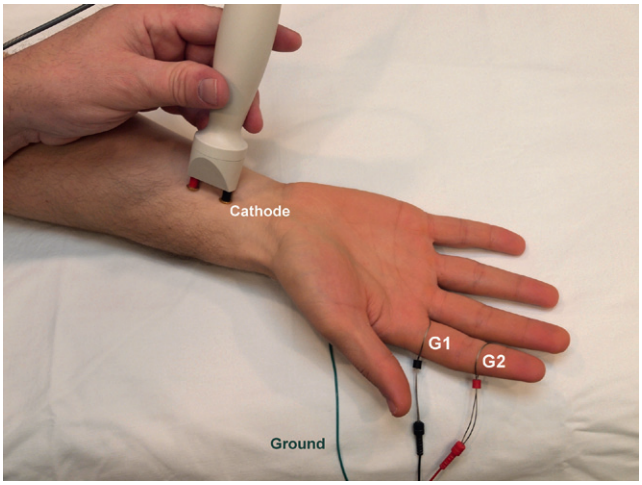


FIGURE 10–3 Median sensory study. Stimulation site over the median nerve at the wrist, recording the index finger.

Stimulation Site:

Wrist: Middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus

Distal Distance:

13 cm

Key Points:

- The study is easy to perform.
- Antidromic study described. For orthodromic study, recording and stimulation sites are reversed.
- A volume-conducted motor potential occasionally may obscure the sensory potential in antidromic studies. If this occurs, have the patient slightly spread their fingers and stimulate again.
- Stimulation also can be performed proximally at the antecubital fossa, similar to the median motor study; however, the proximal sensory response is normally smaller and more difficult to record because of normal temporal dispersion and phase cancellation.
- Digits 1 and 4 both are partially innervated by the median nerve and can also be used for median sensory studies.

MEDIAN SENSORY PALMAR STUDY

(Figure 10–4)

Recording Site:

Middle finger:

Ring electrodes with G1 placed over the proximal interphalangeal joint

G2 placed over the distal interphalangeal joint

Stimulation Sites:

Wrist: Middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus at a distance of 14 cm

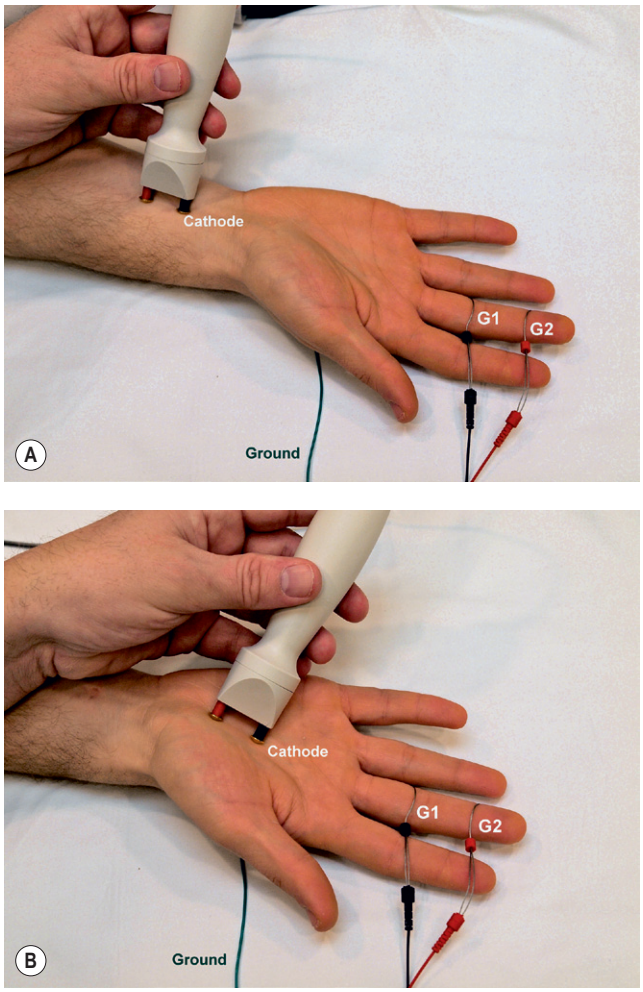


FIGURE 10–4 Median sensory palmar study. **A:** Stimulation site over the median nerve at the wrist, recording the middle finger. **B:** Stimulation site over the median nerve in the palm, recording the middle finger.

Palm: Stimulate in the palm, 7 cm distal to the wrist site on a line drawn from the median wrist to the middle finger

Distal Distance:

7 cm

Proximal Distance:

14 cm

Key Points:

- A palm/wrist sensory nerve action potential (SNAP) amplitude ratio >1.6 implies some conduction block across the wrist.
- It is essential to obtain a clear onset latency at both sites (electronic averaging is often helpful).
- At the palm stimulation, stimulus artifact may contaminate the onset latency. It is essential to obtain a clear onset latency at both the palm and wrist sites. If palm stimulation results in baseline distortion due to stimulus artifact, the anode should be rotated until a suitable baseline is obtained.
- From this study, the conduction velocities for the wrist-to-digit 3 segment and the palm-to-digit 3 segment are displayed on the machine. On some EMG machines, the wrist-to-palm segment conduction velocity is also calculated and displayed on the machine. However, if the EMG machine does not calculate the conduction velocity, it must be mathematically calculated, by subtracting the palm-to-digit 3 onset latency from the wrist-to-digit 3 onset latency. Then a conduction velocity for the wrist–palm segment (i.e., across the carpal tunnel) can be calculated by taking the distance (7 cm) and dividing it by the calculated latency. The wrist-to-palm conduction velocity (i.e., across the carpal tunnel) is normally faster than the palm-to-digit 3 segment. In carpal tunnel syndrome, there is a reversal of this pattern, with relative slowing of the wrist-to-palm segment (see Chapter 17).
- Note that any distance can be used at the wrist and at the palm. However, if the palm-to-digit 3 distance is half the distance of the wrist-to-digit 3, the mathematical calculation is much simpler (see Chapter 17).
- This study is also known as the median segmental sensory study, as two sensory segments of the median nerve (wrist-to-palm and palm-to-digit) are compared.

ULNAR MOTOR STUDY *(Figure 10–5)*

Recording Site:

Abductor digiti minimi (ADM) muscle (medial hypothenar eminence):

G1 placed over the muscle belly

G2 placed over the fifth metacarpal–phalangeal joint

Stimulation Sites:

Wrist: Medial wrist, adjacent to the flexor carpi ulnaris tendon

Below elbow: 3 cm distal to the medial epicondyle

Above elbow: Over the medial humerus, between the biceps and triceps muscles, at a distance of 10–12 cm from the below-elbow site

Axilla (optional): In the proximal axilla, medial to the biceps over the axillary pulse

Distal Distance:

7 cm

Key Points:

- The optimal position is with the elbow flexed between 90° and 135°. If performed in a straight-elbow position, factitious slowing across the elbow will be seen due to underestimation of the true nerve length.
- Higher current intensity usually is needed to achieve supramaximal stimulation at the below-elbow site

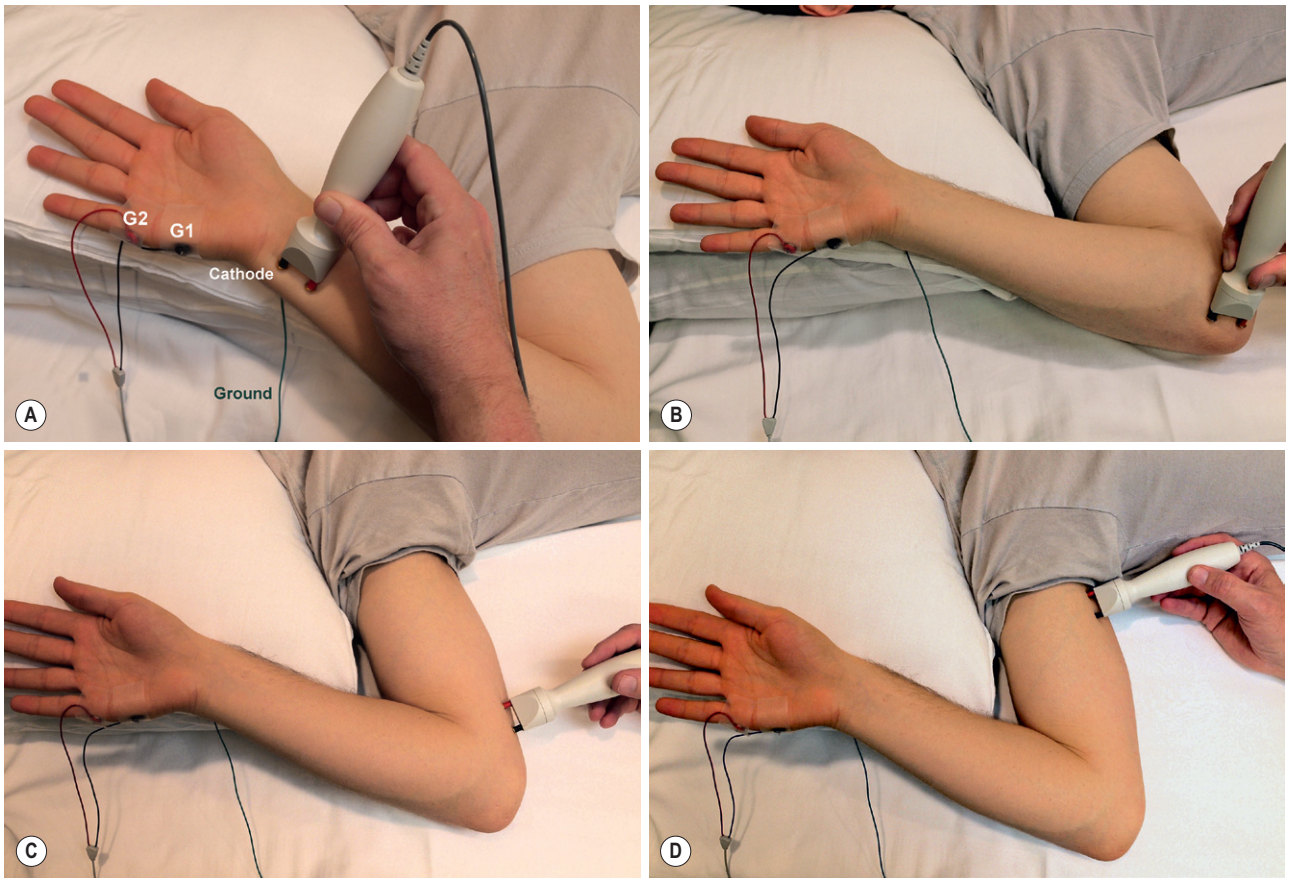


FIGURE 10–5 Ulnar motor study. **A:** Distal stimulation site over the ulnar nerve at the wrist, recording the abductor digiti minimi muscle. **B:** Proximal stimulation site below the elbow. **C:** Proximal stimulation site above the elbow. **D:** Proximal stimulation site in the axilla.

compared with the wrist and above-elbow sites because the nerve lies deep to the flexor carpi ulnaris muscle at this location.

- Stimulation must be at least 3 cm distal to the medial epicondyle at the below-elbow site to ensure that stimulation is distal to the cubital tunnel, a common site of ulnar nerve compression at the elbow. However, if stimulation at the below-elbow site is too distal (>4 cm), the nerve is very deep and very difficult to stimulate, reinforcing that the optimal stimulation site is 3 cm distal to the medial epicondyle.
- Always perform wrist, below-elbow, and above-elbow stimulations. If only the wrist and above-elbow stimulations are performed, one can miss ulnar slowing across the elbow.
- The distance across the elbow must be measured along a curved line, with the elbow flexed, and not as a straight line. This approximates the true anatomic course of the nerve.
- If the CMAP amplitude at the below-elbow site is more than 10% smaller than that at the wrist, consider a Martin–Gruber anastomosis.

ULNAR SENSORY STUDY *(Figure 10–6)*

Recording Site:

Little finger (digit 5):

Ring electrodes with G1 placed over the metacarpal–phalangeal joint

G2 placed 3–4 cm distally over the distal interphalangeal joint

Stimulation Site:

Wrist: Medial wrist, adjacent to the flexor carpi ulnaris tendon

Distal Distance:

11 cm

Key Points:

- Antidromic study described. For orthodromic study, stimulation and recording sites are reversed.
- A volume-conducted motor potential occasionally may obscure the sensory potential in antidromic studies. If this occurs, have the patients slightly spread their fingers and stimulate again.

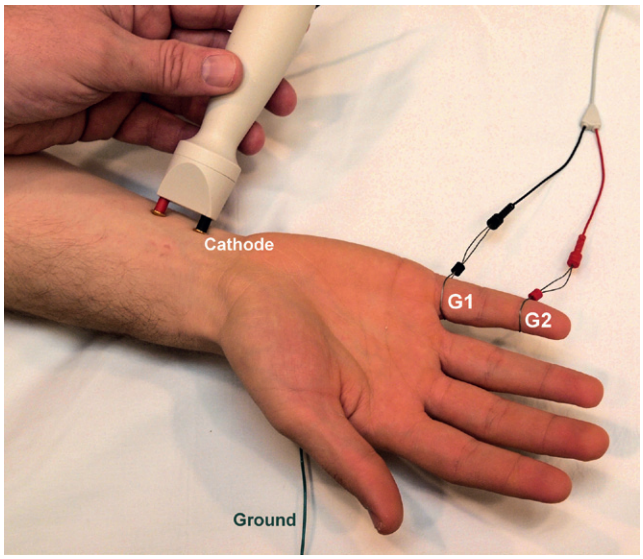


FIGURE 10–6 Ulnar sensory study. Stimulation site over the ulnar nerve at the wrist, recording the little finger.

- May be abnormal in ulnar neuropathy or lower trunk brachial plexopathy (e.g., thoracic outlet syndrome).
- Stimulation also can be performed proximally at the below- and above-elbow sites, similar to the ulnar motor study; however, the proximal sensory responses are normally smaller and more difficult to record because of normal temporal dispersion and phase cancellation.

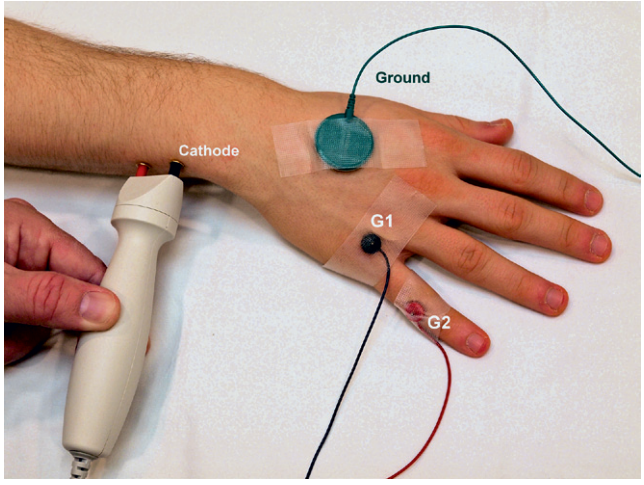


FIGURE 10–7 Dorsal ulnar cutaneous sensory study. Stimulation site slightly proximal to the ulnar styloid, recording in the web space between the fourth and fifth fingers.

DORSAL ULNAR CUTANEOUS SENSORY STUDY *(Figure 10–7)*

Recording Site:

Dorsal hand:

G1 placed over the web space between the little and ring fingers

G2 placed 3–4 cm distally over the little finger

Stimulation Site:

Slightly proximal and inferior to the ulnar styloid with the hand pronated

Distal Distance:

8–10 cm

Key Points:

- Supramaximal stimulation usually can be achieved with low stimulation intensities (e.g., 5–15 mA) because the nerve is quite superficial.
- Often helpful to compare side-to-side amplitudes in cases where one side is symptomatic and the other is not.
- Always spared in lesions of the ulnar nerve at Guyon's canal.
- May be abnormal in some, but not all, cases of ulnar neuropathy at the elbow.

DEEP ULNAR MOTOR BRANCH STUDY *(Figure 10–8)*

Recording Site:

First dorsal interosseous (FDI) muscle (dorsal web space between the thumb and index finger):

G1 placed over the muscle belly

G2 placed over the metacarpal–phalangeal joint of the thumb

Stimulation Sites:

Wrist: Medial wrist, adjacent to the flexor carpi ulnaris tendon

Below elbow: 3 cm distal to the medial epicondyle

Above elbow: Over the medial humerus, between the biceps and triceps muscles, at a distance of 10–12 cm from the below-elbow site

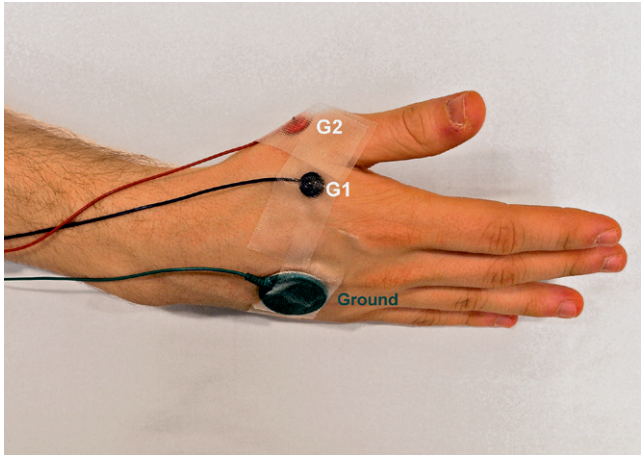


FIGURE 10–8 Deep ulnar motor branch study. Recording the first dorsal interosseous muscle (stimulation sites are the same as the routine ulnar motor studies recording the abductor digiti minimi muscle).

Distal Distance:

8–12 cm (distance measured with obstetrical calipers)

Key Points:

- The deep ulnar motor branch often is preferentially affected in lesions of the ulnar nerve at Guyon's canal.
- Recording the FDI may be more useful than recording the ADM for demonstrating focal slowing of the ulnar nerve across the elbow.
- G2 must be on the metacarpal–phalangeal joint of the *thumb*; if G2 is place on the metacarpal–phalangeal joint of the *index finger*, there will always be an initial positive deflection of the CMAP.
- Always perform the wrist, below-elbow and above-elbow stimulations. If only the wrist and above-elbow stimulations are performed, one can miss ulnar slowing across the elbow.
- Stimulation must be at least 3 cm distal to the medial epicondyle at the below-elbow site to ensure that stimulation is distal to the cubital tunnel, a common site of ulnar nerve compression at the elbow. However, if stimulation at the below-elbow site is too distal (>4 cm), the nerve is very deep and very difficult to stimulate, reinforcing that the optimal stimulation site is 3 cm distal to the medial epicondyle.
- If the CMAP amplitude at the below-elbow site is more than 10% smaller than that at the wrist, consider a Martin–Gruber anastomosis.

MEDIAN VERSUS ULNAR – LUMBRICAL–INTEROSSEI STUDIES

(Figure 10–9)

Recording Site:

Second lumbrical (2L: median innervated) and first palmar interosseous (INT: ulnar innervated); same recording electrodes for both:

G1 placed slightly lateral to the midpoint of the third metacarpal

G2 placed distally over the metacarpal–phalangeal joint of digit 2

Stimulation Sites:

Median nerve at the wrist: Middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus

Ulnar nerve at the wrist: Medial wrist, adjacent to the flexor carpi ulnaris tendon

Distal Distance:

8–10 cm (the same distance must be used for both the median and ulnar studies)

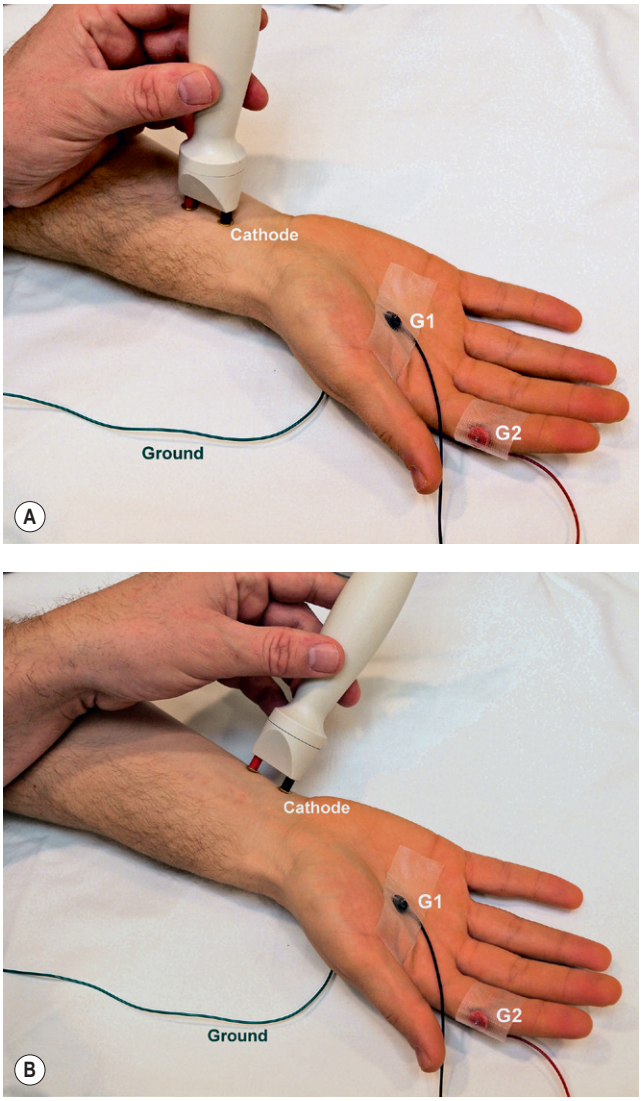


FIGURE 10–9 Lumbrical–interossei studies. **A:** Stimulating the median nerve at the wrist, recording the second lumbrical muscle **B:** Stimulating the ulnar nerve at the wrist, recording the first palmar interosseous muscle.

Key Points:

- Using the same recording electrodes, the second lumbrical is recorded when the median nerve is stimulated at the wrist, whereas the first palmar interosseous is recorded when the ulnar nerve is stimulated at the wrist.
- In normal subjects, the difference between the two distal latencies is <0.5 ms when the same distance is used for both studies.
- Useful internal comparison study to demonstrate either median neuropathy at the wrist (i.e., carpal tunnel syndrome) or ulnar neuropathy at Guyon's canal.
- This technique is especially useful to demonstrate median neuropathy at the wrist in patients with

coexistent polyneuropathy, in whom sensory and mixed nerve potentials may be absent.

- In healthy individuals, one will often see a small brief spike in front of the lumbrical CMAP (especially if one increases the gain) – this is actually the median palmar mixed nerve potential. If this is seen, mark the onset latency after this mixed potential at the onset of the motor potential.
- If the initial lumbrical CMAP does not have an abrupt deflection from the baseline, the active recording electrode should be repositioned.
- Excessive stimulation must be avoided to prevent co-stimulation of the median and ulnar nerves.
- The interosseous amplitude usually is substantially higher than the lumbrical amplitude.

MEDIAN VERSUS ULNAR – DIGIT 4 SENSORY STUDIES *(Figure 10–10)*

Recording Site:

Ring finger (digit 4):

Ring electrodes with G1 placed over the metacarpal–phalangeal joint

G2 placed 3–4 cm distally over the distal interphalangeal joint

Stimulation Sites:

Median nerve at the wrist: Middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus

Ulnar nerve at the wrist: Medial wrist, adjacent to the flexor carpi ulnaris tendon

Distal Distance:

12–14 cm (same distance must be used for both studies)

Key Points:

- Sensory innervation to the ring finger usually is split, with the lateral half supplied by the median nerve and the medial half supplied by the ulnar nerve. Thus, using the same recording electrodes, median sensory fibers are recorded with median nerve stimulation at the wrist, and ulnar sensory fibers are recorded with ulnar nerve stimulation at the wrist.
- In normal subjects, the difference between the median and ulnar digit 4 latencies is <0.5 ms when the same distance is used for both studies.
- Useful internal comparison study to demonstrate median neuropathy at the wrist (i.e., carpal tunnel syndrome).
- Excessive stimulation must be avoided to prevent co-stimulation of the median and ulnar nerves.
- Antidromic study described. For orthodromic study, recording and stimulation sites are reversed.

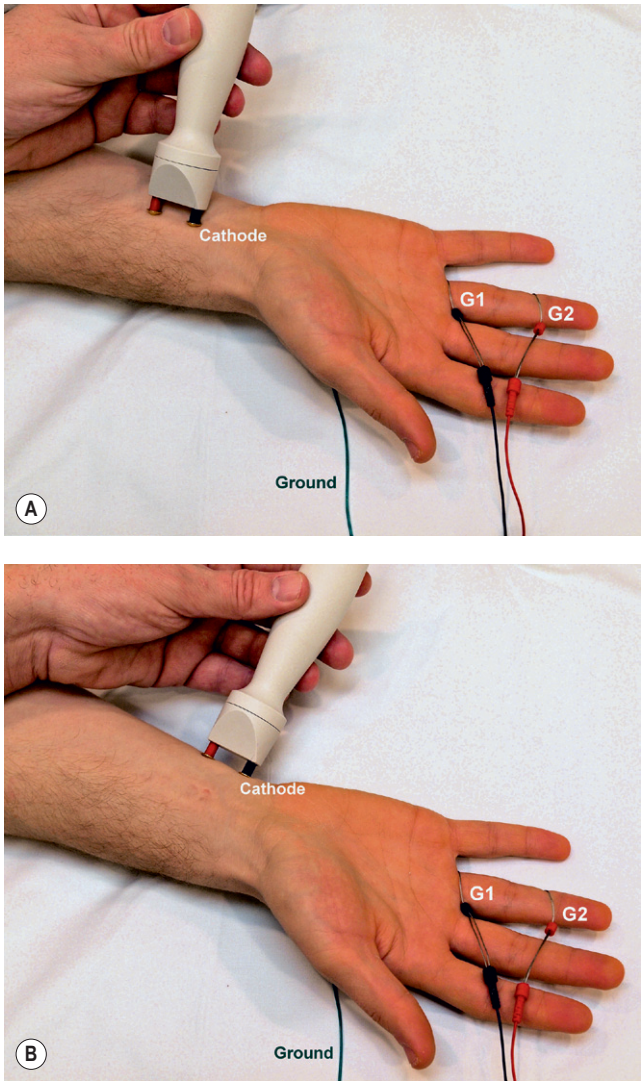


FIGURE 10–10 Digit 4 sensory studies. **A:** Stimulating the median nerve at the wrist, recording the fourth digit. **B:** Stimulating the ulnar nerve at the wrist, recording the fourth digit.

MEDIAN VERSUS RADIAL – DIGIT 1 SENSORY STUDIES

(Figure 10–11)

Recording Site:

Thumb (digit 1):

Ring electrodes with G1 placed over the metacarpal–phalangeal joint

G2 placed distally over the distal interphalangeal joint

Stimulation Sites:

Median nerve at the wrist: Middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus

Radial nerve at the wrist: Medial forearm, over the radial bone

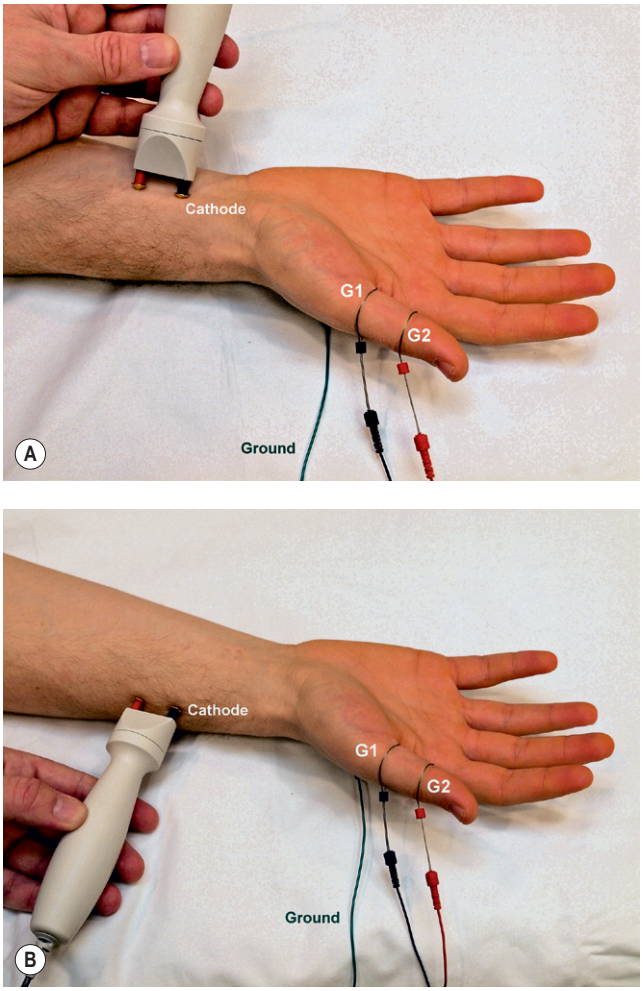


FIGURE 10–11 Digit 1 sensory studies. **A:** Stimulating the median nerve at the wrist, recording the first digit. **B:** Stimulating the radial nerve at the forearm, recording the first digit.

Distal Distance:

10–12 cm (same distance must be used for both studies)

Key Points:

- Sensory innervation to the thumb usually is split, with the lateral half supplied by the radial nerve and the medial half supplied by the median nerve. Thus, using the same recording electrodes, median sensory fibers are recorded with median nerve stimulation at the wrist, and radial sensory fibers are recorded with radial nerve stimulation at the forearm.
- In normal subjects, the difference between the median and radial digit 1 latencies is <0.5 ms when the same distance is used for both studies.
- Useful internal comparison study to demonstrate median neuropathy at the wrist (i.e., carpal tunnel syndrome).
- Excessive stimulation must be avoided to prevent co-stimulation of the median and radial nerves.
- Antidromic study described. For orthodromic study, recording and stimulation sites are reversed.

MEDIAN VERSUS ULNAR – PALMAR MIXED NERVE STUDIES

Median Nerve *(Figure 10–12A)*

Recording Site:

Median nerve at the wrist:

G1 placed over the middle of the wrist between the tendons to the flexor carpi radialis and palmaris longus

G2 placed 3–4 cm proximally

Stimulation Site:

Median nerve in the palm: In the palm, 8 cm from the active recording electrode on a line drawn from the median wrist to the web space between the index and middle fingers

Distal Distance:

8 cm

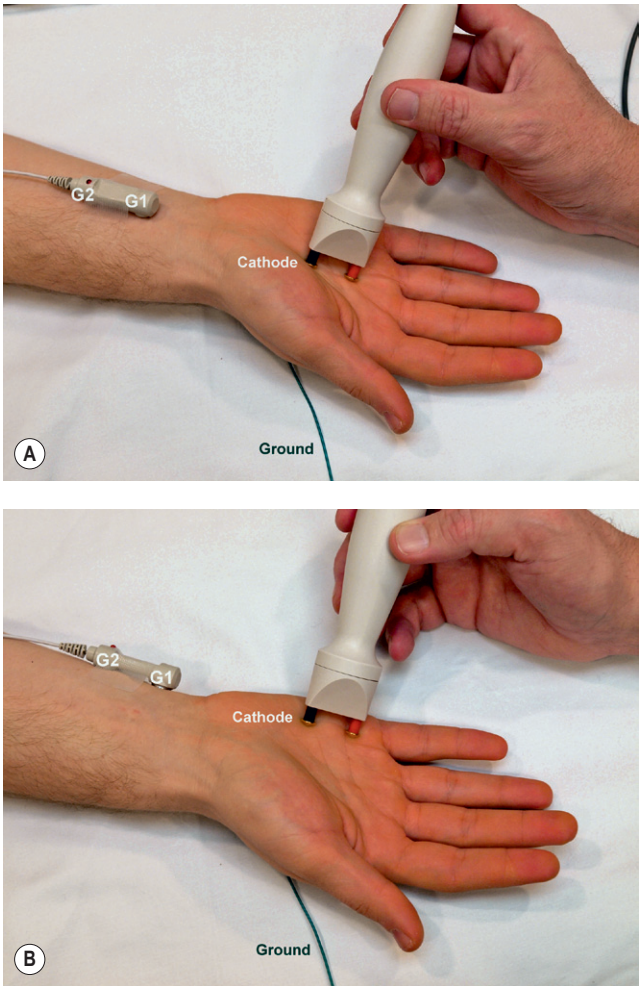


FIGURE 10–12 Palmar mixed nerve studies. **A:** Median mixed nerve palmar studies. Stimulating the median nerve in the palm, recording the median nerve at the wrist. **B:** Ulnar mixed nerve palmar studies. Stimulating the ulnar nerve in the palm, recording the ulnar nerve at the wrist.

Ulnar Nerve *(Figure 10–12B)*

Recording Site:

Ulnar nerve at the wrist:

G1 placed over the medial wrist, adjacent to the flexor carpi ulnaris tendon

G2 placed 3–4 cm proximally

Stimulation Site:

Ulnar nerve in the palm: In the palm, 8 cm from the active recording electrode on a line drawn from the ulnar wrist to the web space between the ring and little fingers

Distal Distance:

8 cm

Key Points:

- In normal subjects, the difference between the median and ulnar palmar latencies is <0.4 ms when the same distance is used for both studies.
- Useful internal comparison study to demonstrate subtle median slowing across the wrist (i.e., carpal tunnel syndrome).
- Caution: as the distance used is short, be very careful in measuring the distance of 8 cm correctly.
- Excessive stimulation must be avoided to prevent co-stimulation of the median and ulnar nerves.

RADIAL MOTOR STUDY *(Figure 10–13)*

Recording Site:

Extensor indicis proprius (EIP) muscle:

With hand pronated, G1 placed two fingerbreadths proximal to the ulnar styloid

G2 placed over the ulnar styloid

Stimulation Sites:

Forearm: Over the ulna, 4–6 cm proximal to the active recording electrode

Elbow: In the groove between the biceps and brachioradialis muscles

Below spiral groove: Lateral midarm, between the biceps and triceps muscles

Above spiral groove: Posterior proximal arm over the humerus

Distal Distance:

5–7 cm

Key Points:

- The radial CMAP usually has an initial positive deflection due to other nearby radial-innervated muscles; thus, no need to change the active recording electrode site to try to get on the motor point.
- Surface-measured distances often are inaccurate in radial motor studies, especially at proximal stimulation sites. Distances to the sites below and above the spiral groove are best measured with obstetric calipers.
- Useful in the diagnosis and assessment of posterior interosseous neuropathy and especially radial neuropathy at the spiral groove.

RADIAL SENSORY STUDY

(Figure 10–14)

Recording Site:

Superficial radial nerve:

G1 placed over the superficial radial nerve as it runs over the extensor tendons to the thumb

G2 placed 3–4 cm distally over the thumb

Stimulation Site:

Over the distal-mid radius

Distal Distance:

10 cm

Key Points:

- The study is easy to perform.
- In most patients, you can actually feel the nerve as it runs over the extensor tendon to the thumb (have the patient extend their thumb and palpate over the tendon feeling for the nerve). Thus, it is easy to place the recording electrode directly over the nerve.
- May be abnormal in radial neuropathy or lesions of the posterior cord and upper or middle trunks of the brachial plexus.
- Spared in posterior interosseous neuropathy.

MEDIAL ANTEBRACHIAL CUTANEOUS SENSORY STUDY

(Figure 10–15)

Recording Site:

Medial forearm:

G1 placed 12 cm distal to the stimulation site, on a line drawn between the stimulation site and the ulnar wrist

G2 placed 3–4 cm distally

Stimulation Site:

Medial elbow: At the midpoint between the biceps tendon and medial epicondyle

Distal Distance:

12 cm

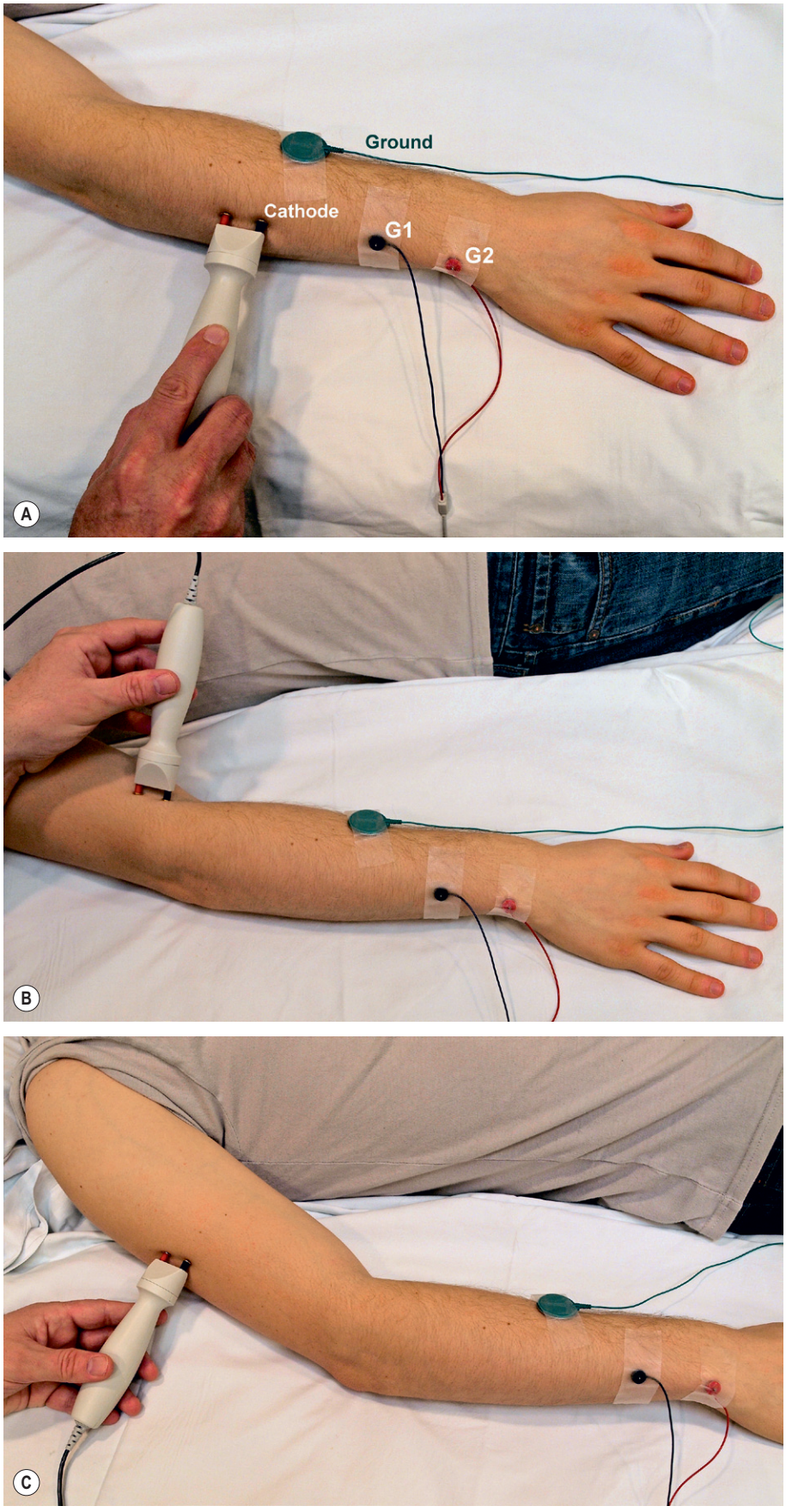


FIGURE 10–13 Radial motor study. **A:** Distal stimulation site in the forearm, recording the extensor indicis proprius muscle. **B:** Proximal stimulation site at the elbow, between the brachioradialis muscle and biceps tendon. **C:** Proximal stimulation site in the arm, below the spiral groove.

FIGURE 10–13, cont'd D: Proximal stimulation site in the arm, above the spiral groove.

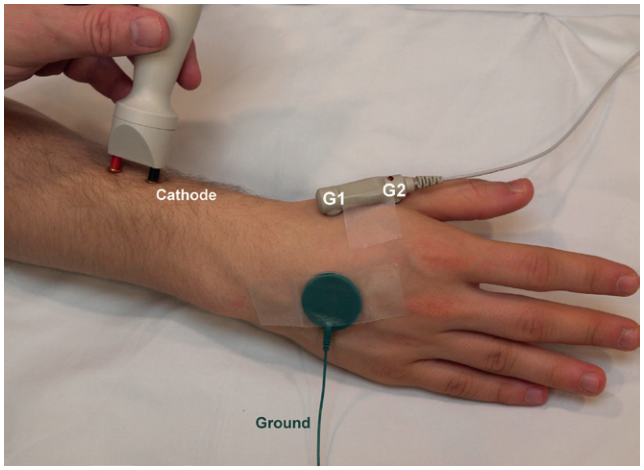


FIGURE 10–14 Radial sensory study. Stimulation site over the radius, recording electrodes placed over the radial sensory nerve as it runs over the extensor tendons to the thumb.

Key Points:

- May be abnormal in lesions of the medial cord or lower trunk of the brachial plexus.
- Typically absent or very low in true neurogenic thoracic outlet syndrome.
- Because the nerve is quite superficial, supramaximal stimulation usually can be achieved with low stimulator intensities (e.g., 5–15 mA).
- To maximize the response, the recording electrodes may have to be repositioned either slightly medially or laterally to the original position.
- Side-to-side comparisons of amplitude and latency often are helpful.

LATERAL ANTEBRACHIAL CUTANEOUS SENSORY STUDY

(Figure 10–16)

Recording Site:

Lateral forearm:

G1 placed 12 cm distal to the stimulator site, on a line drawn between the stimulator site and the radial wrist

G2 placed 3–4 cm distally

Stimulation Site:

Antecubital fossa: Slightly lateral to the biceps tendon

Distal Distance:

12 cm

Key Points:

- The study is easy to perform.
- May be abnormal in lesions of the musculocutaneous nerve, lateral cord, or upper trunk of the brachial plexus.
- Because the nerve is quite superficial, supramaximal stimulation usually can be achieved with low stimulation intensities (e.g., 5–15 mA).
- Excessive stimulation may result in direct stimulation of the biceps.
- To maximize the response, the recording electrodes may have to be repositioned either slightly medially or laterally to the original position.
- Side-to-side comparisons of amplitude and latency often are helpful.

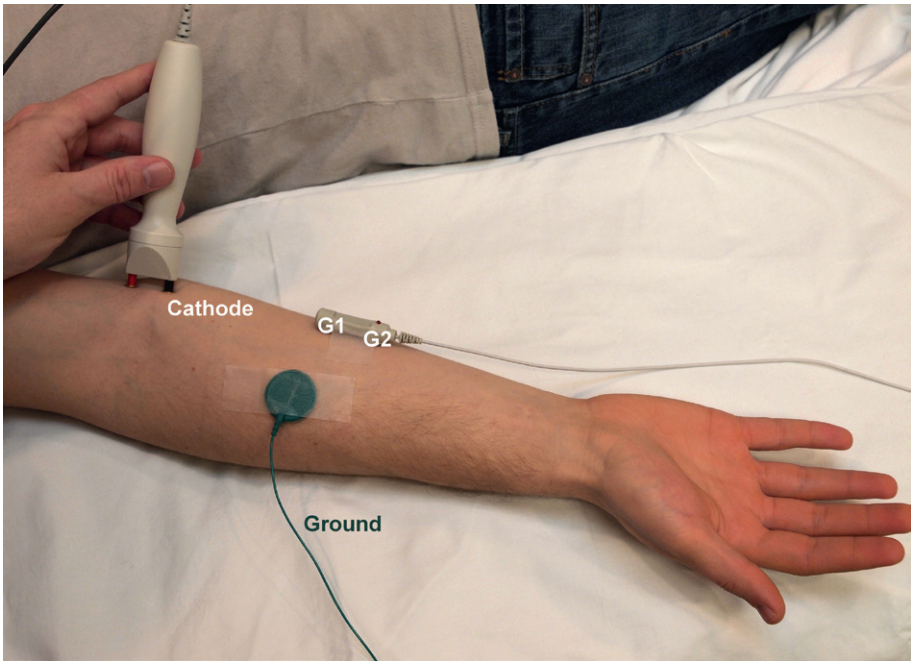


FIGURE 10–15 Medial antebrachial cutaneous sensory study. Stimulation site in the medial elbow, recording over the medial forearm.

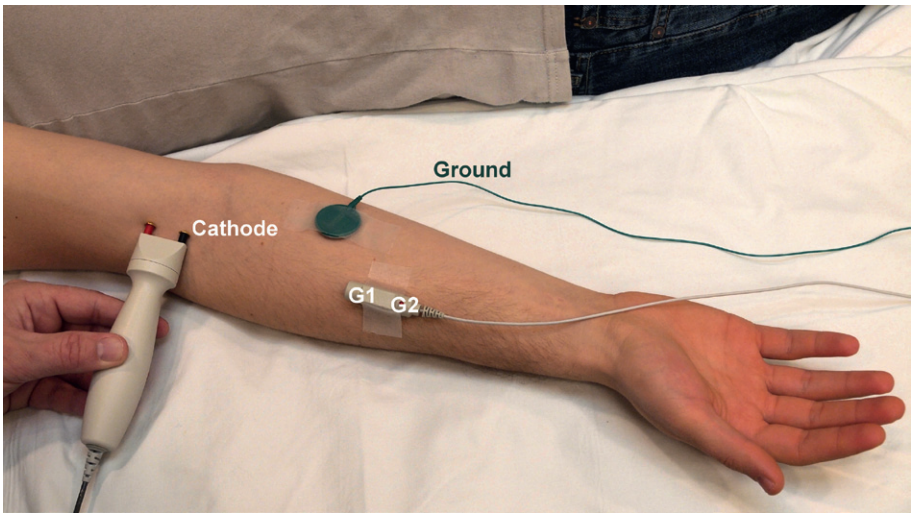


FIGURE 10–16 Lateral antebrachial cutaneous sensory study. Stimulation site just lateral to the biceps tendon in the antecubital fossa, recording over the lateral forearm.

UPPER EXTREMITY PROXIMAL STIMULATION STUDIES

(Figure 10–17)

Recording Sites:

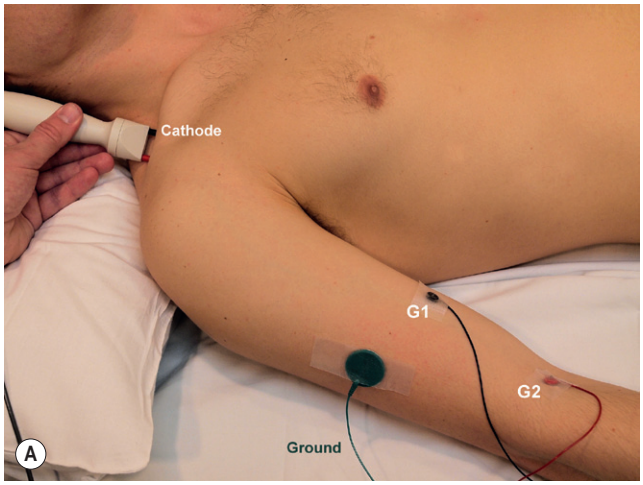
Any upper extremity muscle:
Belly-tendon method:
- G1 placed over muscle belly
- G2 placed over the tendon

Common muscles recorded:
- Deltoid
- Infraspinatus
- Biceps
- Triceps

Stimulation Sites:

Erb's point: Supraclavicular fossa, just posterior to the sternocleidomastoid muscle

Cervical nerve roots: Monopolar needle used as the stimulator cathode, inserted into the paraspinal muscles, 1–2 cm lateral to the spinous process, down to the lamina (surface disc electrode over the spinous process serves as the stimulator anode). The cervical level selected for study depends on the root innervation of the muscle being studied.



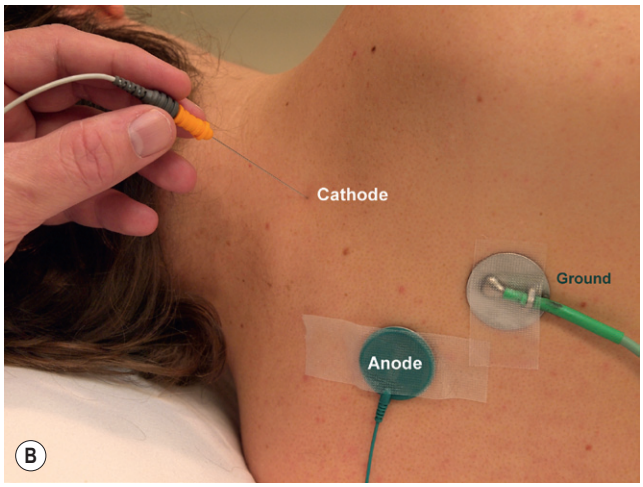
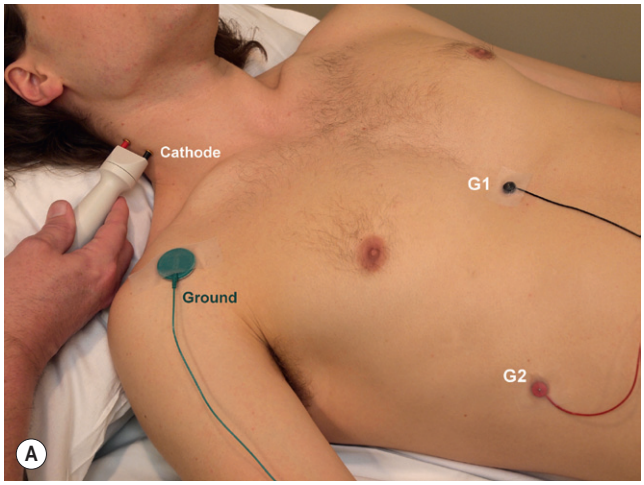


FIGURE 10–17 Upper extremity proximal stimulation studies. **A:** Stimulation site at Erb's point, just posterior to the sternocleidomastoid muscle in the supraclavicular fossa. In this example, the biceps brachii is recorded with surface recording electrodes. **B:** Stimulation site at the cervical roots. A monopolar needle is inserted at the desired level as the cathode, with an additional surface electrode serving as the anode.



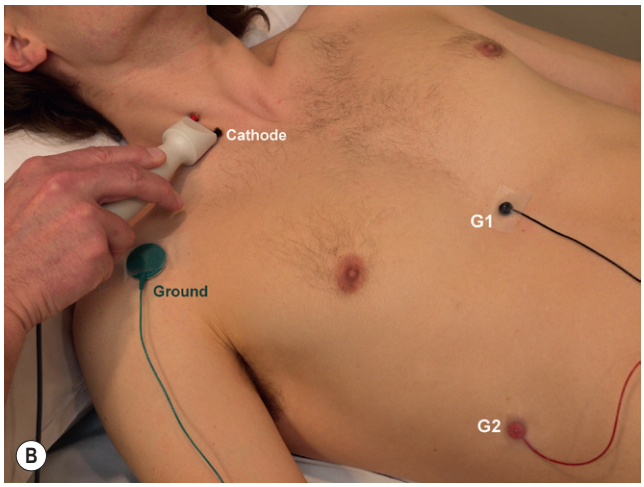


FIGURE 10–18 Phrenic motor study. Recording the diaphragm with G1 placed two fingerbreadths above the xiphoid process and G2 placed over the anterior costal margin 16 cm from G1. **Stimulation Option A:** Posterior to the sternocleidomastoid (SCM) muscle, approximately 3 cm above the clavicle. **Stimulation Option B:** Stimulating between sternal and clavicular heads of the SCM, just above the clavicle.

Key Points:

- Supramaximal stimulation may be difficult to achieve at Erb's point and at the root level.
- Recording of proximal muscles also can be done with a monopolar needle inserted into the muscle as G1 and a surface disc electrode as G2.
- Side-to-side comparisons of amplitude and latency are necessary when performing motor studies to proximal muscles.
- Surface measured distances often are inaccurate at proximal stimulation sites. Proximal distances are best measured with obstetric calipers.
- *Caution*: Rare cases of pneumothorax have been reported with root stimulation with improper needle placement too laterally.

PHRENIC MOTOR STUDY

(Figure 10–18A,B)

Recording Site:

Diaphragm muscle:

G1 placed two fingerbreadths (5 cm) above the xiphoid process

G2 placed over the anterior costal margin 16 cm from G1

Stimulation Site:

Option 1: Lateral neck: Posterior to the sternocleidomastoid muscle (SCM), approximately 3 cm above the clavicle (Figure 10–18A)

Option 2: Anterior-lateral neck: Between sternal and clavicular heads of the SCM, just above the clavicle.

Both heads of the SCM can be easily seen by having the patient flex their neck for a few seconds (Figure 10–18B)

Distal Distance:
Variable

Key Points:
- Firm pressure is needed when holding the stimulator.
- If the stimulator is not in the correct location, the spinal accessory nerve can be stimulated (causing contraction of the trapezius).
- If the stimulator is not in the correct location, the brachial plexus can be stimulated (causing movement of the shoulder).
- In thin individuals, the diaphragm contraction often can be visualized and appears similar to a hiccup.
- Difficult study to perform in obese individuals.
- Amplitudes are slightly larger during inspiration (see detailed phrenic nerve normal values at the end of this chapter).
- Do not perform this study in the intensive care unit in patients who have an external pacemaker (risk of current spread to the heart); caution if an internal jugular catheter, implanted cardiac pacemaker, or cardioverter-defibrillator is nearby (see Chapter 40).

FACIAL MOTOR STUDY *(Figure 10–19)*

Recording Site:
Nasalis muscle:
G1 placed lateral to mid-nose
G2 placed on the contralateral side of the nose at the same location

Stimulation Site:
Anterior tragus: directly in front of the lower ear

Distal Distance:
Variable

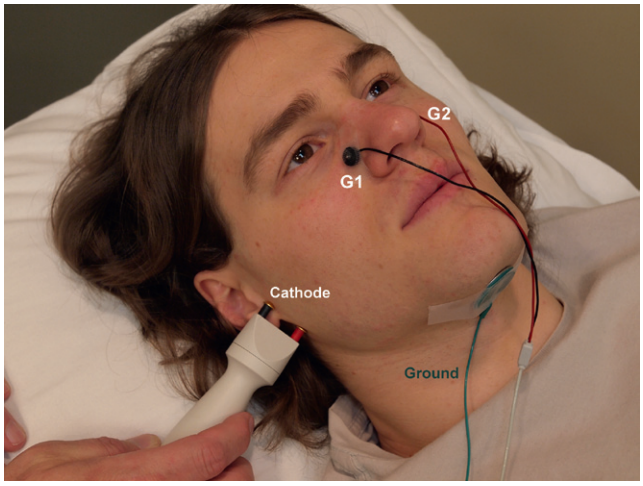


FIGURE 10–19 Facial motor study. Stimulating the facial nerve anterior to the tragus, recording the nasalis muscle.

Key Points:
- Excessive stimulus may result in direct stimulation of the masseter muscle.
- Other facial muscles may be used as recording sites, including the frontalis, mentalis, and orbicularis oculi, using similar montages. G1 is placed over the center of the muscle; the contralateral muscle is used as the site for G2.
- This technique stimulates the entire facial nerve where it exits the skull at the stylomastoid foramen. Often higher currents are needed, and the study can be uncomfortable. Individual facial branch stimulation is often much easier and more comfortable for the patient (see Facial Motor Branch Study below).

FACIAL MOTOR BRANCH STUDY
(Figure 10–20)

Frontal Branch *(Figure 10–20A)*

Recording Site:
Frontalis muscle:
G1 placed over the frontalis, above the eyebrow, slightly medial to the center of the brow
G2 placed on the contralateral frontalis muscle

Stimulation Site:
Three to four fingerbreadths lateral to the eye

Distal Distance:
Variable

Zygomatic Branch *(Figure 10–20B)*

Recording Site:
Nasalis muscle:
G1 placed lateral to mid-nose
G2 placed on the contralateral side of the nose at the same location

Stimulation Site:
Over the zygomatic bone just anterior to the ear

Distal Distance:
Variable

Mandibular Branch *(Figure 10–20C)*

Recording Site:
Mentalis muscle:
G1 placed over the mentalis muscle in the chin
G2 placed over the contralateral mentalis muscle

Stimulation Site:
Over the angle of the jaw

Distal Distance:
Variable

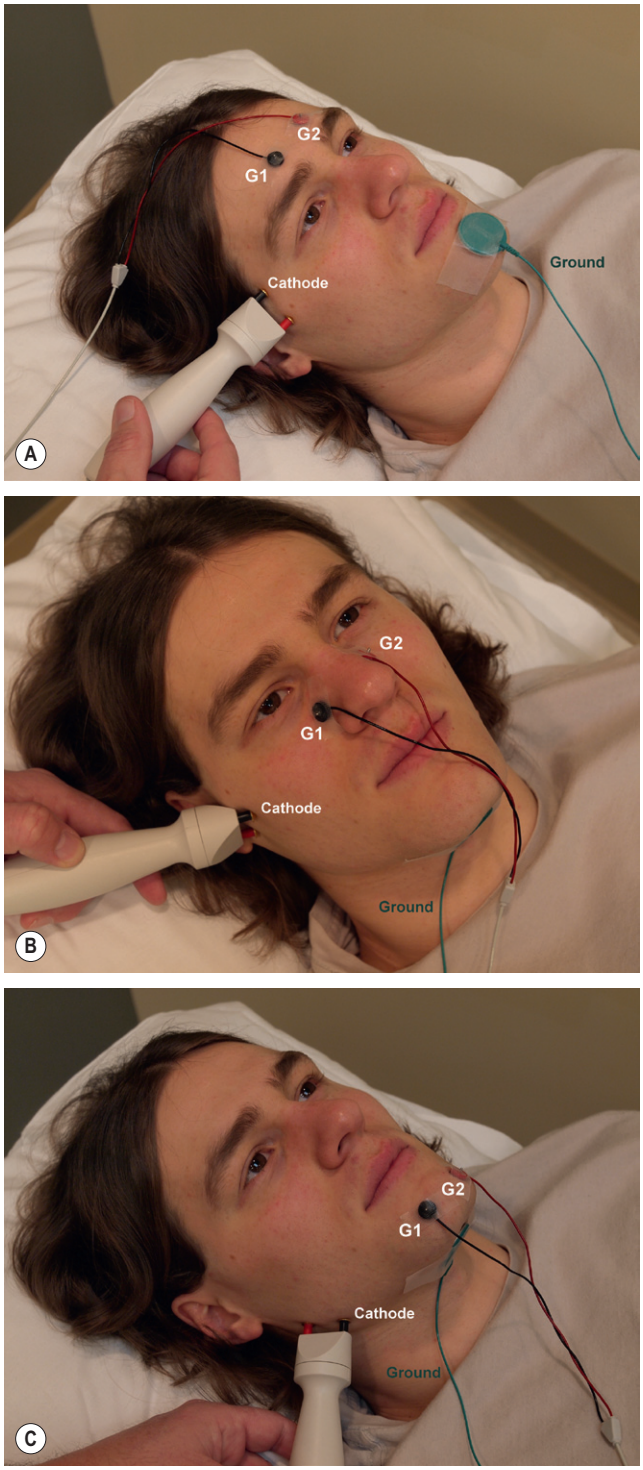


FIGURE 10–20 Facial motor branch studies. **A:** Frontal branch study, recording the frontalis. **B:** Zygomatic branch study, recording the nasalis muscle. **C:** Mandibular branch study, recording the mentalis muscle.

Key Points:

- Stimulating the separate facial branches is technically easier than stimulating the entire facial nerve at the stylomastoid foramen.
- Always do both sides. In most cases, the contralateral normal side will serve as the control and the presumed baseline value.

BLINK REFLEX (TRIGEMINAL AND FACIAL NERVES) *(Figure 10–21)*

Recording Site:

Bilateral orbicularis oculi muscles:

For each side, G1 placed on the face over inferior eye socket, just lateral and inferior to the pupil at mid-position

G2 placed over the lateral canthus of the eye

Stimulation Site:

Supraorbital notch: Medial superior eye socket over the supraorbital notch

Distal Distance:

Variable

Key Points:

- The study is easy to perform.
- The patient should be in a relaxed state, lying supine on the examining table, with the eyes either open or gently closed
- Supramaximal stimulation can be achieved with low currents, typically 10–15 mA.
- For each side, both the ipsilateral and contralateral sides are recorded. Usually 2–5 traces are superimposed to determine the minimal R1 and R2 latencies.
- This study is useful in assessing facial nerve palsies, demyelinating neuropathies, and brainstem lesions.

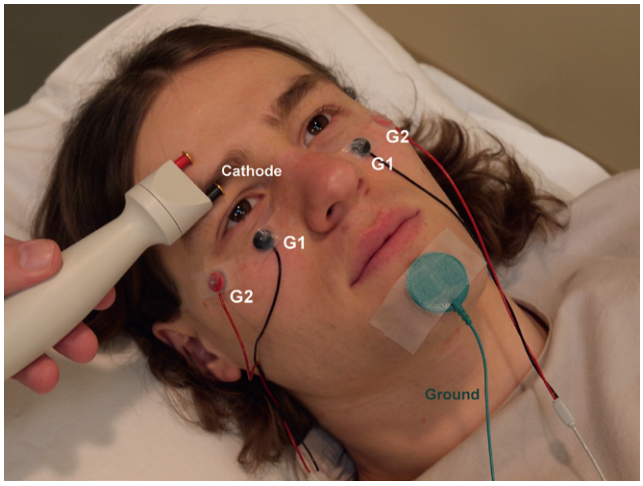


FIGURE 10–21 Blink reflex. Stimulating the supraorbital nerve over the medial eyebrow, recording both orbicularis oculi muscles.

NERVE CONDUCTION STUDIES: NORMAL ADULT VALUES

Upper Extremity

Motor

Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal Latency (ms)	Distal Distance (cm)
Median	Abductor pollicis brevis (APB)	≥4.0	≥49	≤4.4	7
Ulnar	Abductor digiti minimi (ADM)	≥6.0	≥49	≤3.3	7
Ulnar	First dorsal interosseous (FDI)	≥7.0	≥49	≤4.5	Variable (8–12*)
Radial	Extensor indicis proprius (EIP)	≥2.0	≥49	≤2.9	4–6

*Distance measured with calipers.

Antidromic Sensory

Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Distal Peak Latency (ms)	Distal Distance (cm)
Median	Digit 2	≥20	≥50	≤3.5	13
Ulnar	Digit 5	≥17*	≥50	≤3.1	11
Radial	Snuffbox	≥15	≥50	≤2.9	10
Dorsal ulnar cutaneous†	Dorsal D4–5 web space	≥8	≥50	≤2.5	8
Lateral antebrachial cutaneous†	Lateral forearm	≥10	≥55	≤3.0	12
Medial antebrachial cutaneous†	Medial forearm	≥5	≥50	≤3.2	12

*Many consider ulnar antidromic sensory amplitudes that are higher than 10 μV to be normal in adults older than 60.

†In these less commonly performed studies, side-to-side comparisons, especially of amplitude, often are more useful than normal value tables, when symptoms and signs are limited to one side.

Palmar mixed Nerve Studies

Nerve	Amplitude (μV)	Conduction Velocity (m/s)	Peak Distal Latency (ms)	Distance (cm)
Median mixed	≥50	≥50	≤2.2	8
Ulnar mixed	≥12	≥50	≤2.2	8

F Responses*

Nerve	Minimal F Latency (ms)
Median	≤31
Ulnar	≤32

*For tall or short patients, F responses must be normalized for height (see Chapter 4).

Median–Ulnar Internal Comparison Studies

Study*	Significant Latency Difference (ms)†
Median mixed: Palm-to-wrist Ulnar mixed: Palm-to-wrist	≥0.4
Median motor: Wrist to second lumbrical Ulnar motor: Wrist to interossei	≥0.5
Median sensory: Wrist to digit 4 Ulnar sensory: Wrist to digit 4	≥0.5
Median sensory: Wrist to digit 1 Radial sensory: Wrist to digit 1	≥0.5

*For each paired study, identical distances are used for both the median and the ulnar study.

†Values that exceed these cutoffs imply focal slowing and are useful in the electrodiagnosis of both median neuropathy across the carpal tunnel and ulnar neuropathy across Guyon's canal.

Median Palmar Stimulation Studies

Study	Significant Palm/Wrist Amplitude Ratio*
Median motor: Wrist to abductor pollicis brevis Median motor: Palm to abductor pollicis brevis	>1.2
Median sensory: Wrist to digit 2 Median sensory: Palm to digit 2	>1.6

*Values that exceed these cutoffs imply some element of conduction block of the median nerve across the carpal tunnel.

Major Upper Extremity Motor Latencies from Erb's Point Stimulation

Nerve	Muscle	Latency (ms)	Distances (cm)†
Axillary*	Deltoid	≤4.9	15–21
Musculocutaneous*	Biceps	≤5.7	23–29
Suprascapular	Supraspinatus	≤3.7	7–12
Suprascapular	Infraspinatus	≤4.3	10–15

*The axillary and musculocutaneous nerves also can be stimulated in the axilla, with typical distal motor latencies of up to 3.3 ms. Both axillary and Erb's point stimulations often are technically difficult. In patients with symptoms limited to one side, comparing both latencies and amplitudes side to side always is preferable to using normal value tables.

†Distances measured with calipers (need the call out sign here) – then skips aline between this and the source.

Source: Data from Kraft, G.H., 1972; Axillary, musculocutaneous, and suprascapular nerve latency studies. Arch Phys Med Rehab 53, 382; and Currier, D.P., 1971; Motor conduction velocity of axillary nerve. Phys Ther 51, 503.

Phrenic Motor Study*

Nerve	Record	Amplitude (μV)	Distal latency (ms)
Phrenic	Diaphragm	597 ± 139 >320	6.3 ± 0.8 <8.0

*From Markand ON, Kincaid, J.C., Pourmand, R.A., 1984; et al. Electrophysiologic evaluation of diaphragm by transcutaneous phrenic nerve stimulation. Neurology 34, 606–614.

Phrenic Motor Study: Detailed Normal Studies[†]

		Absolute Values			Interside Differences		
Parameter	Phase	Mean ± SD	L/U Limits	5th/95th	Mean ± SD	Mean + 2SD	95th
Onset latency (ms)	Inspiration	6.55 ± 0.69	5.18/7.92	5.53/7.72	0.23 ± 0.19	0.61	0.53
	Expiration	6.59 ± 0.67	5.25/7.92	5.58/7.72	0.40 ± 0.36	1.9	1.11
Amplitude (mV)	Inspiration	1.00 ± 0.27	0.46/1.54	0.66/1.46	0.25 ± 0.18	0.61	0.6
	Expiration	0.71 ± 0.19	0.33/1.10	0.50/1.06	0.14 ± 0.10	0.35	0.33
Duration (ms)	Inspiration	14.99 ± 3.14	8.70/21.28	11.18/20.25	2.14 ± 1.72	5.57	4.71
	Expiration	20.98 ± 3.30	16.13/28.32	11.18/20.25	2.44 ± 1.65	5.74	5.54

[†]From Resman-Gaspersc, A., Podnar, S., 2008; Phrenic nerve conduction studies: technical aspects and normative data. Muscle Nerve 37, 36–41.
L/U, lower/upper limits; 5th/95th, 5th/95th percentile limits.

Craniobulbar

Motor

Nerve	Record	Amplitude (mV)	Distal Latency (ms)
Facial	Nasalis	≥1.0	≤4.2
Facial	Orbicularis oculi	≥1.0	≤3.1

Blink Reflex

Response	Latency (ms)	Side-to-Side Latency Difference (ms)
R1 (ipsilateral)	≤13	≤1.2
R2 (ipsilateral)	≤41	≤5
R2 (contralateral)	≤44	≤7

Notes:

1. All normal value tables assume normal controlled temperature and standard distances.
2. All motor and sensory amplitudes are measured from baseline to negative peak.
3. All sensory and mixed nerve distal latencies are peak latencies; however, all sensory and mixed nerve conduction velocities are calculated based on the onset latency.
4. Some values may need to be adjusted for extremes of height or age (see Chapter 8).
5. Comparison between the affected and unaffected limb often is very useful and may be more useful than normal value tables.
6. This is one set of normal values; others exist. Ideally, each laboratory should develop its own set of normal values.