11 Routine Lower Extremity Nerve Conduction Techniques

Tibial Motor Study *(Figure 11–1)*

Recording Site:

Abductor hallucis brevis (AHB) muscle:

- G1 placed 1 cm proximal and 1 cm inferior to the navicular prominence
- G2 placed over the metatarsal–phalangeal joint of the great toe

Stimulation Sites:

Medial ankle: Slightly proximal and posterior to the medial malleolus

Popliteal fossa: Mid-posterior knee over the popliteal pulse

Distal Distance:

9 cm

Key Points:

- The tibial compound muscle action potential (CMAP) often has an initial positive deflection, indicating that G1 is not over the motor endplate. If this occurs, the position of G1 should be changed slightly.
- CMAP amplitude at the popliteal fossa stimulation site often is lower than at the medial ankle stimulation site (normal controls may drop up to 50%). Thus, caution must be used whenever interpreting a drop in amplitude between the ankle and popliteal fossa as a conduction block on tibial motor studies. Side-to-side comparisons often are useful in this situation.
- High stimulation intensities often are required at the popliteal fossa to ensure supramaximal stimulation.
- Recording also can be done to the flexor hallucis brevis (FHB) muscle.

Peroneal Motor Study *(Figure 11–2)*

Recording Site:

Extensor digitorum brevis (EDB) muscle:

- Dorsal lateral foot with G1 placed over the muscle belly
- G2 placed distally over the metatarsal–phalangeal joint of the little toe

Stimulation Sites:

Ankle: Anterior ankle, slightly lateral to tibialis anterior tendon

Below fibular head: Lateral calf, one to two fingerbreadths inferior to fibular head (one can straddle the fibular neck with the stimulator)

Lateral popliteal fossa (above fibular neck): Lateral knee, adjacent to external hamstring tendons, at a distance of 10–12 cm from the below-fibular head site

Distal Distance:

9 cm

Key Points:

- Higher stimulation currents are needed at the below-fibular head site because the nerve lies deep at that location.
- Always perform the ankle, below-fibular neck, and above-fibular neck stimulations. If only the ankle and above-fibular neck stimulations are done, one can miss peroneal slowing across the fibular neck.
- Avoid excessive stimulation at the lateral popliteal fossa site to prevent co-stimulation of the tibial nerve.
- If there is a higher CMAP amplitude at the below-fibular head and popliteal fossa sites than at the ankle, consider an accessory peroneal nerve.

Peroneal Motor Study *(Figure 11–3)*

Recording Site:

Tibialis anterior (TA) muscle:

- Proximal to mid-anterior lateral calf with G1 placed over the muscle belly
- G2 placed distally over the anterior ankle

Stimulation Sites:

Below fibular head: Lateral calf, one to two fingerbreadths inferior to fibular head (one can straddle the fibular neck with the stimulator)

Lateral popliteal fossa (above fibular neck): Lateral knee, adjacent to external hamstring tendons, at a distance of 10–12 cm from the below-fibular head site

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Distal Distance:
Variable (5–10 cm)

Key Points:
- Recording the TA is especially valuable in patients with suspected peroneal neuropathy at the fibular neck. Demonstrating a conduction block, focal slowing across the fibular neck or both may be easier when recording the TA than the EDB.
- Higher stimulation currents are needed at the below-fibular head site because the nerve lies deep at that location.
- Avoid excessive stimulation at the lateral popliteal fossa site to prevent co-stimulation of the tibial nerve.

Femoral Motor Study *(Figure 11–4)*

Recording Site:
Rectus femoris muscle:
G1 placed over the anterior thigh, halfway between the inguinal crease and knee
G2 placed over a bony prominence at the knee

Stimulation Site:
Middle of the inguinal area: Slightly lateral to the femoral pulse, below the inguinal ligament

Distal Distance:
Variable

Key Points:
- Firm pressure is needed when holding the stimulator.
- Difficult study to perform in obese individuals; high currents are typically needed (e.g., >50 mA).
- Limited indications; this study usually is used to compare motor amplitudes from side to side to quantitate the degree of axonal loss in femoral neuropathies, lumbar plexopathies, and severe L4 radiculopathies.
- Normal amplitude is >3 mV; however, side-to-side comparisons are most useful when symptoms are unilateral.

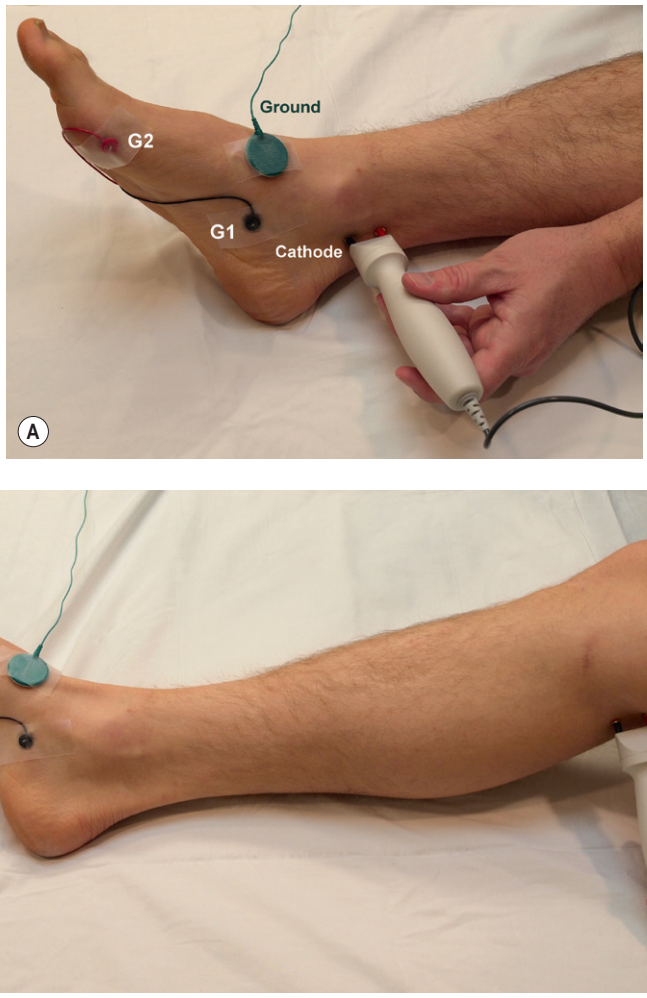

FIGURE 11–1 Tibial motor study. **A:** Distal stimulation site slightly proximal and posterior to the medial malleolus, recording the abductor hallucis brevis muscle. **B:** Proximal stimulation site in the middle of the popliteal fossa.

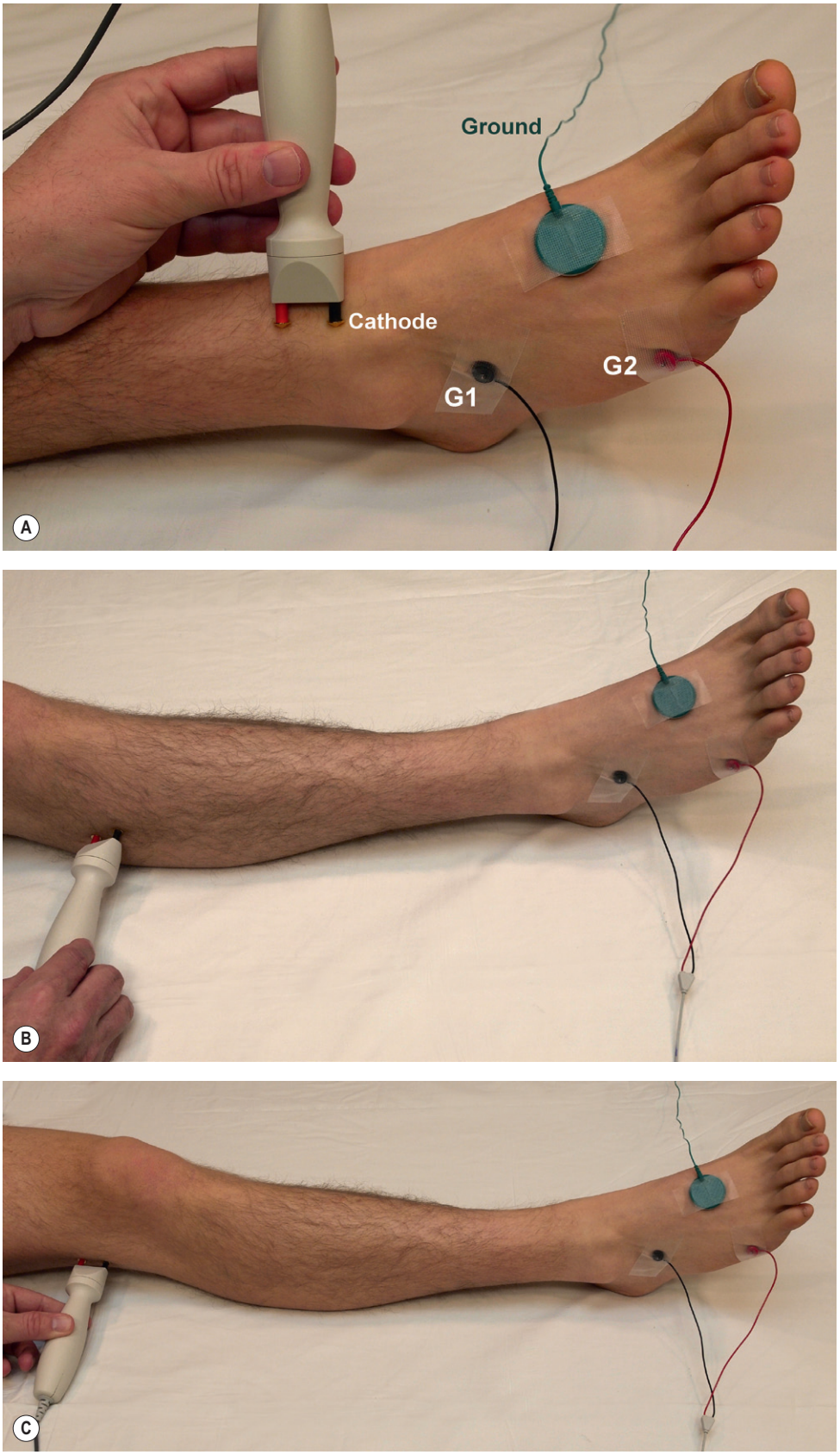

FIGURE 11–2 Peroneal motor study. **A:** Distal stimulation site over the anterior ankle, slightly lateral to the tibialis anterior tendon, recording the extensor digitorum brevis muscle. **B:** Proximal stimulation site below the fibular head. **C:** Proximal stimulation site in the lateral popliteal fossa above the fibular neck.

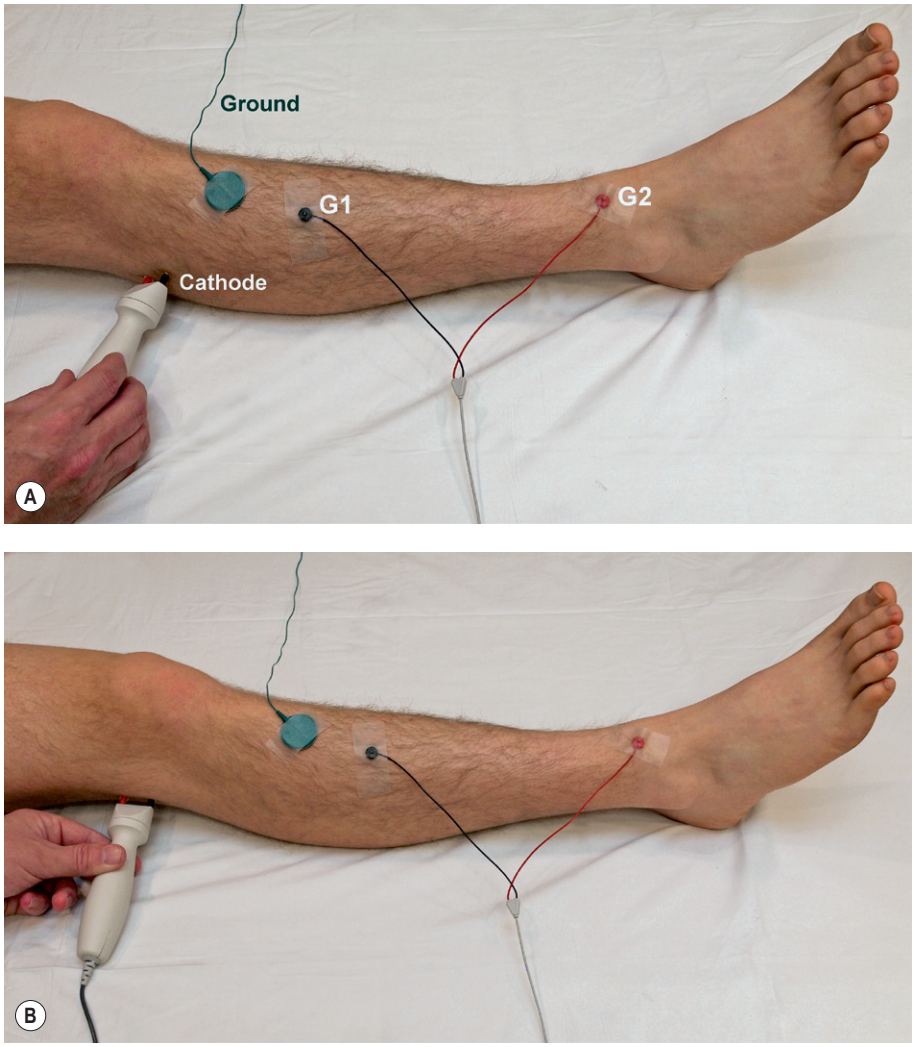

FIGURE 11–3 Peroneal motor study. **A:** Distal stimulation site below the fibular head, recording the tibialis anterior muscle **B:** Proximal stimulation site in the lateral popliteal fossa above the fibular neck.

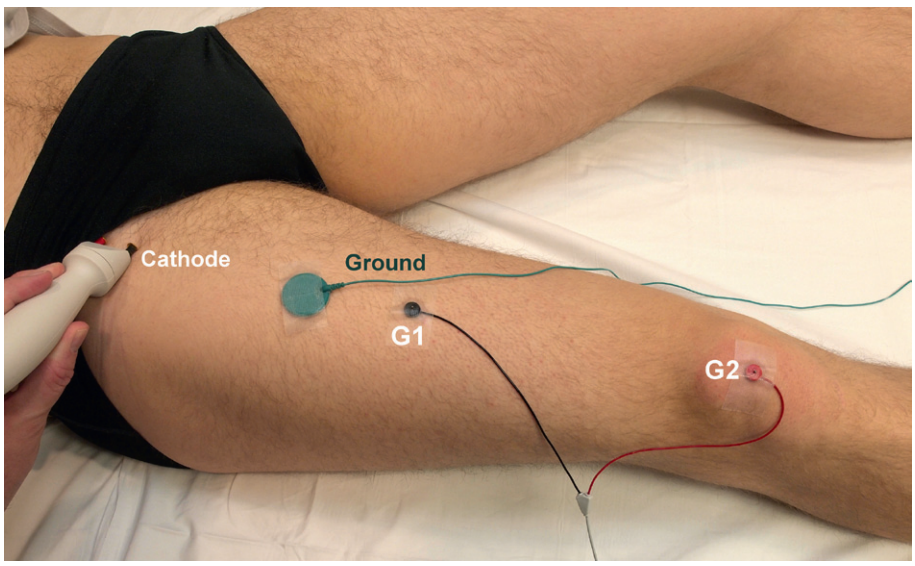

FIGURE 11–4 Femoral motor study. Stimulation site is slightly lateral to the femoral pulse, below the inguinal ligament. The rectus femoris is recorded, with G1 placed over the anterior thigh, halfway between the inguinal crease and knee, and G2 placed over a bony prominence at the knee.

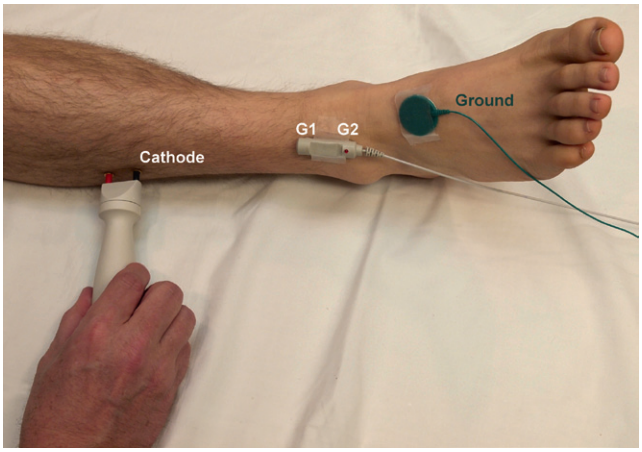

FIGURE 11–5 Superficial peroneal sensory study. Stimulation site is in the lateral calf; recording electrodes are placed between the tibialis anterior tendon and lateral malleolus.

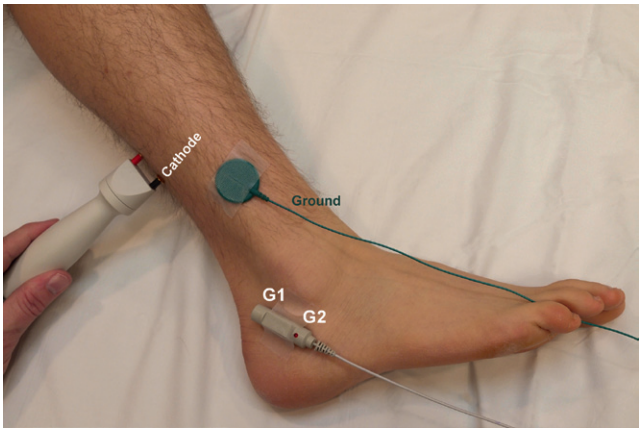

FIGURE 11–6 Sural sensory study. Stimulation site is in the posterior–lateral calf; recording electrodes are placed posterior to the lateral malleolus.

Superficial Peroneal Sensory Study *(Figure 11–5)*

Recording Site:

Lateral ankle:

G1 placed between the tibialis anterior tendon and lateral malleolus

G2 placed 3–4 cm distally

Stimulation Site:

Lateral calf

Distal Distance:

14 cm is the standard, but shorter distances may be helpful (see below)

Key Points:

- Although the normal value for peak latency is based on the standard distance of 14 cm, in many individuals, the nerve is much easier to stimulate at a shorter distance (typically 10–12 cm, and in some individuals as short as 7–9 cm). Supramaximal stimulation usually can be achieved with low stimulation intensities (e.g., 5–25 mA). Thus, if the response is not present stimulating at 14 cm or if high currents are needed, try a shorter distance of 10–12 cm, or 7–9 cm. If a good response is obtained at a shorter distance, do not use the peak latency to determine if the response is normal, but rather the calculated conduction velocity based on the onset latency and the distance used.
- May be abnormal in lesions of the peroneal nerve, sciatic nerve, or lumbosacral plexus.
- 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.
- Antidromic study described; for orthodromic study, recording and stimulation sites are reversed.

Sural Sensory Study *(Figure 11–6)*

Recording Site:

Posterior ankle:

G1 placed posterior to the lateral malleolus

G2 placed 3–4 cm distally

Stimulation Site:

Posterior–lateral calf

Distal Distance:

14 cm is the standard, but shorter distances may be helpful (see below)

Key Points:

- Although the normal value for peak latency is based on the standard distance of 14 cm, in many individuals, the nerve is much easier to stimulate at a shorter distance (typically 10–12 cm). Supramaximal stimulation usually can be achieved with low stimulation intensities (e.g., 5–25 mA). Thus, if the response is not present stimulating at 14 cm or if high currents are needed, try a shorter distance of 10–12 cm. If a good response is obtained, do not use the peak latency to determine if the response is normal, but rather the calculated conduction velocity based on the onset latency and the distance used.
- The study is best performed with the patient lying on his or her side, with the recording leg facing up.
- May be abnormal in lesions of the tibial nerve, sciatic nerve, or lumbosacral plexus.
- To maximize the response, the recording electrodes may have to be repositioned either slightly medially or laterally to the original position.

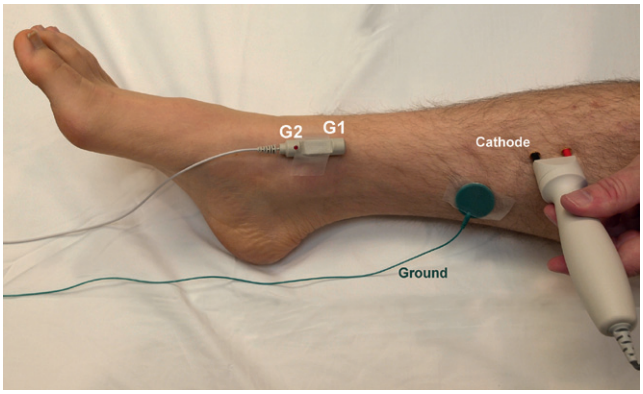

FIGURE 11–7 Saphenous sensory study. Stimulation site in the medial calf between the tibia and medial gastrocnemius; recording electrodes are placed between the medial malleolus and tibialis anterior tendon.

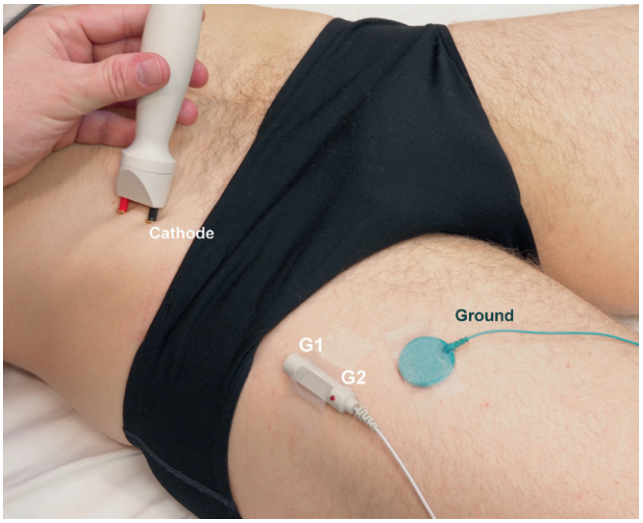

FIGURE 11–8 Lateral femoral cutaneous sensory study. Stimulation site in the inguinal area, above the inguinal ligament, and 1 cm medial to the anterior superior iliac spine (ASIS); recording electrodes are placed over the anterior thigh 12 cm distal to the stimulation site, on a line drawn directly from the ASIS to the lateral patella. Alternate recording site is 2 cm medial to the initial site.

- Side-to-side comparisons of amplitude and latency often are helpful.
- Antidromic study described; for orthodromic study, recording and stimulation sites are reversed.

Saphenous Sensory Study *(Figure 11–7)*

Recording Site:

Medial/Anterior ankle:

G1 placed between the medial malleolus and tibialis anterior tendon

G2 placed 3–4 cm distally

Stimulation Site:

Medial calf: Stimulator placed in the groove between the tibia and the medial gastrocnemius muscle

Distal Distance:

14 cm is the standard, but shorter distances may be helpful (see below)

Key Points:

- Although the normal value for peak latency is based on the standard distance of 14 cm, in many individuals, the nerve is much easier to stimulate at a shorter distance (typically 10–12 cm). Supramaximal stimulation usually can be achieved with low stimulation intensities (e.g., 5–25 mA). Thus, if the response is not present stimulating at 14 cm or if high currents are needed, try a shorter distance of 10–12 cm. If a good response is obtained, do not use the peak latency to determine if the response is normal, but rather the calculated conduction velocity based on the onset latency and the distance used.
- May be abnormal in lesions of the femoral nerve or lumbar plexus.
- 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 are required.
- Response often is small and may be difficult to obtain or absent in normal controls, especially those older than age 40. Side-to-side comparison is necessary before interpreting a low or absent potential as abnormal.
- Antidromic study described; for orthodromic study, recording and stimulation sites are reversed.

Lateral Femoral Cutaneous Sensory Study *(Figure 11–8)*

Recording Site:

Anterior thigh:

Option 1

G1 placed over anterior thigh, 12 cm distal to the stimulation site, on a line drawn directly from the anterior superior iliac spine (ASIS) to the lateral patella

G2 placed 3–4 cm distally

Option 2

Recording electrodes placed 2 cm medial to the Option 1 site

Stimulation Site:

Stimulator placed in the inguinal area above the inguinal ligament, 1 cm medial to the ASIS

Distal Distance:

12 cm is the standard, but shorter distances may be helpful (see below)

Key Points:

- Although the normal values are based on a standard distance of 12 cm, in some individuals, the nerve may be easier to stimulate at a shorter distance (typically 10 cm).
- There are some anatomical variations in terms of where the nerve runs in relationship to the anterior superior iliac spine (see Chapter 32). In more than 80% of individuals, the nerve lies between 0–1.5 cm lateral to the ASIS. However, rarely the nerve runs 5–8.5 cm medial to the ASIS. Thus, if no response is obtained, move the stimulator slightly lateral and then medial to the original stimulation site.
- Firm pressure is needed when holding the stimulator.
- Limited indications; may be abnormal in lesions of the lateral femoral cutaneous nerve (meralgia paresthetica) or lumbar plexus.
- Difficult study to perform in some obese individuals; high currents may be needed. One should always be cautious interpreting a low-amplitude or absent response as abnormal unless comparison studies are made side to side when symptoms are unilateral.
- A motor artifact may be present, which can be recognized by its longer duration than a typical sensory response.

Medial and Lateral Plantar Motor Studies

(Figure 11–9)

Recording Sites:

Abductor hallucis brevis (AHB) muscle:

G1 placed 1 cm proximal and 1 cm inferior to the navicular prominence

G2 placed over the metatarsal–phalangeal joint of the great toe

Abductor digiti quinti pedis (ADQP) muscle:

On lateral foot, G1 placed halfway between the lateral sole of the foot and the lower margin of the lateral malleolus

G2 placed over the metatarsal–phalangeal joint of the little toe

Stimulation Site:

Medial ankle: Slightly proximal and posterior to the medial malleolus

Distal Distance:

9 cm for AHB; variable for ADQP (distance measurement with obstetric calipers required)

Key Points:

- AHB is innervated by the medial plantar nerve and ADQP by the lateral plantar nerve.
- This study is useful in the evaluation of distal tibial neuropathy across the ankle (i.e., tarsal tunnel syndrome).
- Side-to-side comparisons of amplitude and latency are required.

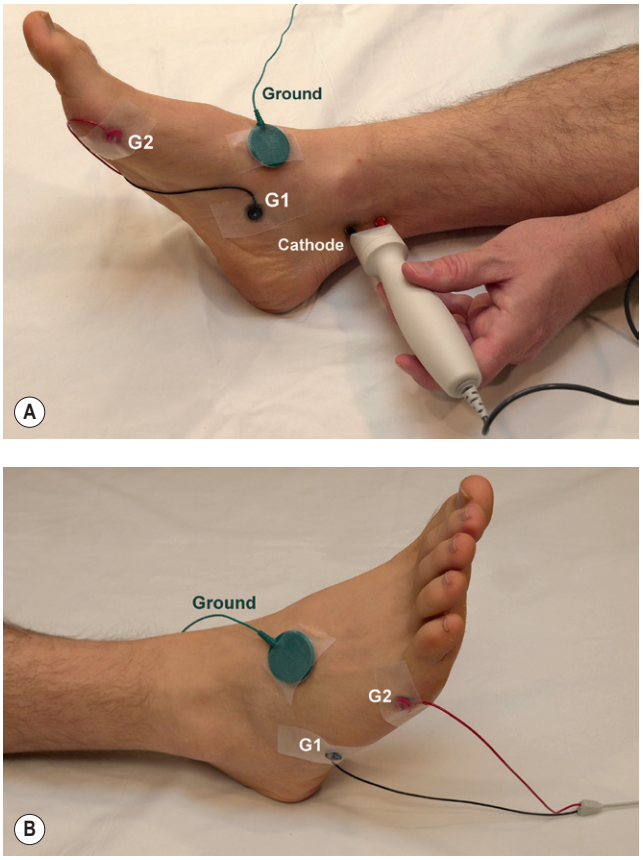

FIGURE 11–9 A: Medial plantar motor study. Stimulation site is slightly proximal and posterior to the medial malleolus, and the abductor hallucis brevis muscle is recorded. **B:** Lateral plantar motor study. Stimulation site is slightly proximal and posterior to the medial malleolus, and the abductor digiti quinti pedis muscle is recorded.

- CMAP of the AHB or ADQP often has an initial positive deflection, indicating that G1 is not over the motor endplate. If this occurs, the position of G1 should be changed slightly.

Medial and Lateral Plantar Sensory Studies

(Figure 11–10)

Recording Site:

Medial ankle:

G1 placed slightly proximal and posterior to the medial malleolus

G2 placed 3–4 cm proximally

Stimulation Sites:

Great toe (medial plantar sensory): Ring electrodes, with cathode placed proximally near the metatarsal–phalangeal joint of the great toe; anode placed 3–4 cm distally

Little toe (lateral plantar sensory): Ring electrodes, with cathode placed proximally near the metatarsal–phalangeal joint of the little toe; anode placed as distally as possible

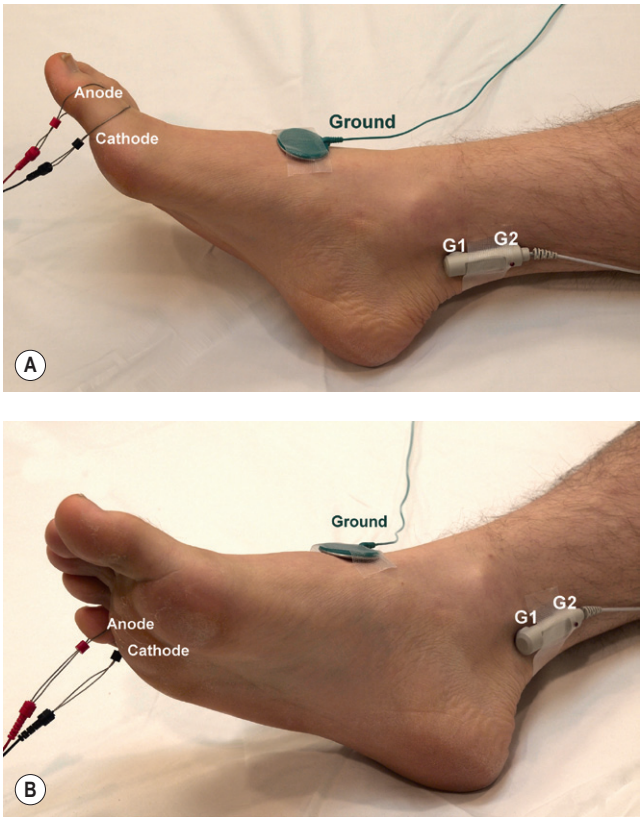

FIGURE 11–10 A: Medial plantar sensory study. The great toe is stimulated, and the tibial nerve is recorded slightly proximal and posterior to the medial malleolus. **B:** Lateral plantar sensory study. The little toe is stimulated, and the tibial nerve is recorded slightly proximal and posterior to the medial malleolus.

Distal Distance:

Variable

Key Points:

- Orthodromic study described; for antidromic study, recording and stimulation sites are reversed.
- This study is useful in the evaluation of distal tibial neuropathy across the ankle (i.e., tarsal tunnel syndrome).
- Potentials are very small and difficult to obtain, even in normal controls.
- Averaging often is required.
- Side-to-side comparisons of amplitude and latency are required.
- Side-to-side comparison is necessary before interpreting a low or absent potential as abnormal.

Medial and Lateral Plantar Mixed Nerve Studies *(Figure 11–11)*

Recording Site:

Medial ankle:

G1 placed slightly proximal and posterior to the medial malleolus

G2 placed 3–4 cm proximally

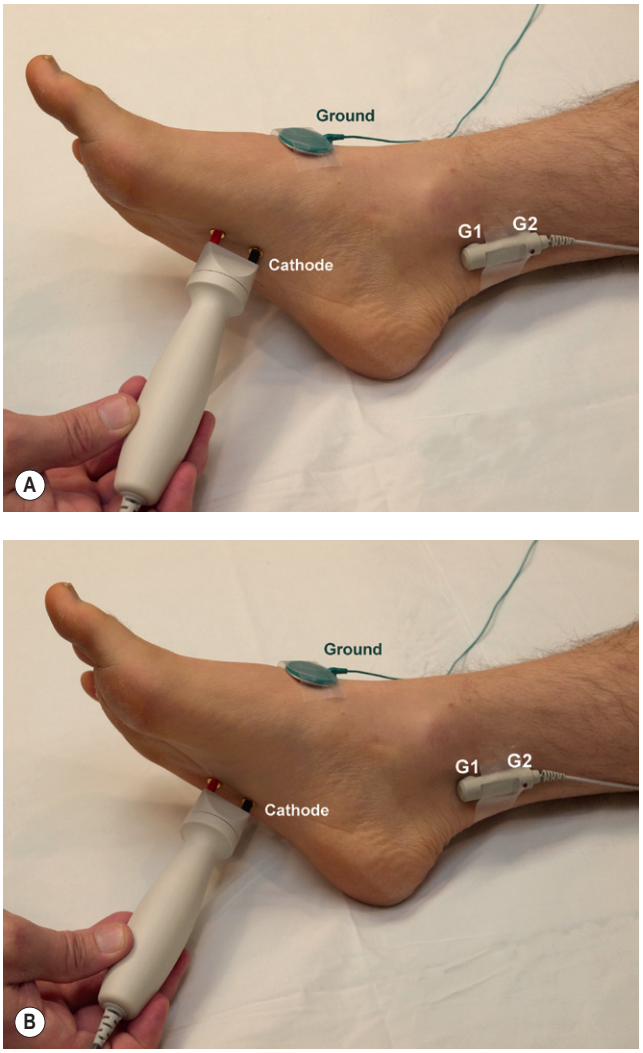

FIGURE 11–11 A: Medial plantar mixed study. The medial sole is stimulated, and the tibial nerve is recorded slightly proximal and posterior to the medial malleolus. **B:** Lateral plantar mixed study. The lateral sole is stimulated, and the tibial nerve is recorded slightly proximal and posterior to the medial malleolus.

Stimulation Sites:

Medial sole (medial plantar nerve): At a distance of 14 cm from the recording electrodes (measure 7 cm from the recording site into the sole of the foot, then an additional 7 cm on a line drawn parallel to the web space between the first and second toes)

Lateral sole (lateral plantar nerve): At a distance of 14 cm from the recording electrodes (measure 7 cm from the recording site into the sole of the foot, then an additional 7 cm on a line drawn parallel to the web space between the fourth and fifth toes)

Distal Distance:

14 cm

Key Points:

- Mixed nerve study, technically easier than orthodromic sensory studies.

- This study is useful in the evaluation of distal tibial neuropathy across the ankle (i.e., tarsal tunnel syndrome).
- Potentials may be small and difficult to obtain in normal controls, especially the lateral plantar response.
- Averaging often is required.
- Side-to-side comparisons of amplitude and latency are required.
- Side-to-side comparison is necessary before interpreting a low or absent potential as abnormal.

Soleus H Reflex Study *(Figure 11–12)*

Recording Site:

Soleus muscle:

Posterior calf with G1 placed one to two fingerbreadths distal to where the soleus meets the two bellies of the gastrocnemius

G2 placed over the Achilles tendon

Stimulation Site:

Popliteal fossa: Mid-posterior knee over the popliteal pulse

Distal Distance:

Variable (usually in the range of 20–25 cm)

Key Points:

- Stimulator pulse duration must be set at 1000 µs (i.e., 1 ms) to more selectively activate the Ia sensory fibers.
- H reflex occurs with low stimulation intensities.
- As stimulator current is slowly increased, the H reflex appears first, without a direct muscle response; as the current is increased further, the H reflex increases and a direct muscle response also occurs; as the direct muscle response grows the H reflex decreases.
- H reflex is a late reflex, usually with a triphasic morphology (positive–negative–positive) occurring at 25–34 ms.
- Comparison to the contralateral side is often helpful in determining if a latency is abnormal (latency difference >1.5 ms).
- The distal distance must be the same from side to side to ensure a valid side-to-side comparison
- H reflex is delayed or absent in polyneuropathy, tibial neuropathy, sciatic neuropathy, lumbosacral plexopathy, or S1 radiculopathy.

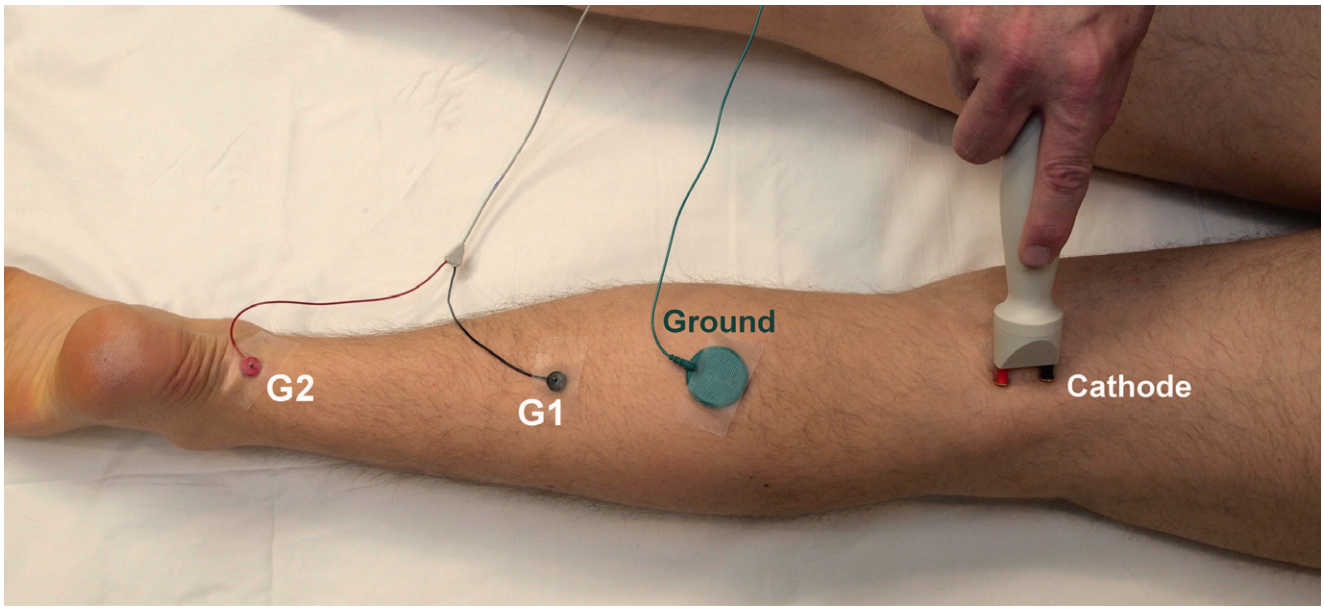

FIGURE 11–12 Soleus H reflex. The tibial nerve is stimulated in the middle of the popliteal fossa; the cathode is pointing rostral, and the soleus muscle is recorded.

NERVE CONDUCTION STUDIES OF THE LOWER EXTREMITY: NORMAL ADULT VALUES

Motor

Nerve	Record	Amplitude (mV)	Conduction Velocity (m/s)	Distal Latency (ms)	Distal Distance (cm)
Peroneal	Extensor digitorum brevis (EDB)	≥2.0	≥44	≤6.5	9
Peroneal†	Tibialis anterior (TA)	≥3.0	≥44	≤6.7	5–10
Tibial	Abductor hallucis brevis (AHB)	≥4.0	≥41	≤5.8	9
Tibial†	Abductor digiti quinti pedis (ADQP)	≥3.0	≥41	≤6.3	Variable*

*Difficult to measure unless calipers are used.

† In cases where one side is symptomatic and the other is not, it is often helpful to compare the amplitudes side to side, rather than use normal value tables.

Antidromic Sensory

Nerve	Record	Amplitude (μV)	Conduction Velocity (m/s)	Peak Latency (ms)	Distal Distance (cm)
Sural	Posterior ankle	≥6	≥40	≤4.4	14†
Superficial peroneal	Lateral ankle	≥6	≥40	≤4.4	14†
Saphenous*	Medial/anterior ankle	≥4	≥40	≤4.4	14†
Medial plantar*	Medial ankle	≥2	≥35	–	Variable
Lateral plantar*	Medial ankle	≥1	≥35	–	Variable
Lateral femoral cutaneous‡	Anterior thigh	≥4		≤2.6	12

*In some normal individuals without symptoms, especially those older than age 40, these responses may be very small, requiring electronic averaging, or may be absent. Thus, a low-amplitude or absent potential should not necessarily be interpreted as abnormal. Side-to-side comparisons often are very useful in this regard if one side is symptomatic and the other is not.

†Although the normal values for peak latency are based on the standard distance of 14 cm, in many individuals, it is much easier to stimulate at a shorter distance (typically 10–12 cm). Supramaximal stimulation usually can be achieved with low stimulation intensities (e.g., 5–25 mA). Thus, if the response is not present stimulating at 14 cm or if high currents are needed, try a shorter distance of 10–12 cm. If a good response is obtained, do not use the peak latency to determine if the response is normal, but rather the calculated conduction velocity based on the onset latency and the distance used.

‡Although the normal value for peak latency is based on the standard distance of 12 cm, in some individuals, the nerve may be easier to stimulate at a shorter distance (typically 10 cm). Difficult study to perform in obese individuals. Thus, a low-amplitude or absent potential should not necessarily be interpreted as abnormal unless side-to-side comparisons are done in patients with symptoms limited to one side.

Source: from Shin, Y.B., Park, J.H., Kwon, D.R., Park, B.K., 2006. Variability in conduction of the lateral femoral cutaneous nerve. Muscle Nerve 33 (5), 645–649. Values based on reported mean minus 2 SD for amplitude, and mean plus 2 SD for peak latency.

Plantar Mixed Nerve Studies

Nerve	Amplitude (μV)	Conduction Velocity (m/s)	Distal Peak Latency (ms)	Distance (cm)
Medial plantar*	≥3	≥45	≤3.7	14
Lateral plantar*	≥3	≥45	≤3.7	14

*In some normal individuals without symptoms, especially those older than age 40, these responses may be very small, requiring electronic averaging, or may be absent. Thus, a low-amplitude or absent potential should not necessarily be interpreted as abnormal. Side-to-side comparisons often are very useful in this regard.

Late Responses*

Nerve	Minimal F Latency (ms)	Minimal H Latency (ms)
Peroneal	≤56	N/A
Tibial	≤56	≤34†

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

†Compare side to side. Any difference in latency >1.5 msec between sides is considered abnormal.

Notes:

1. All normal value tables assume 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 have 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.