# THE INTERPRETATION OF PROXIMAL CONDUCTION

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The purpose of this presentation is to identify the rationale for the limitations of proximal motor conductions. I will give two examples of commonly performed distal conductions to clarify why proximal motor nerve conduction studies have limited value, and then describe the problems encountered with specific proximal motor nerve conduction studies.

Everyone who performs conduction studies knows a bifid evoked response is recorded over the hypothenar muscles from stimulating the ulnar nerve (Fig 1-A2). This bifid response differs from the response recorded by stimulating the median nerve and recording from the thenar muscles (Fig 1-A1).

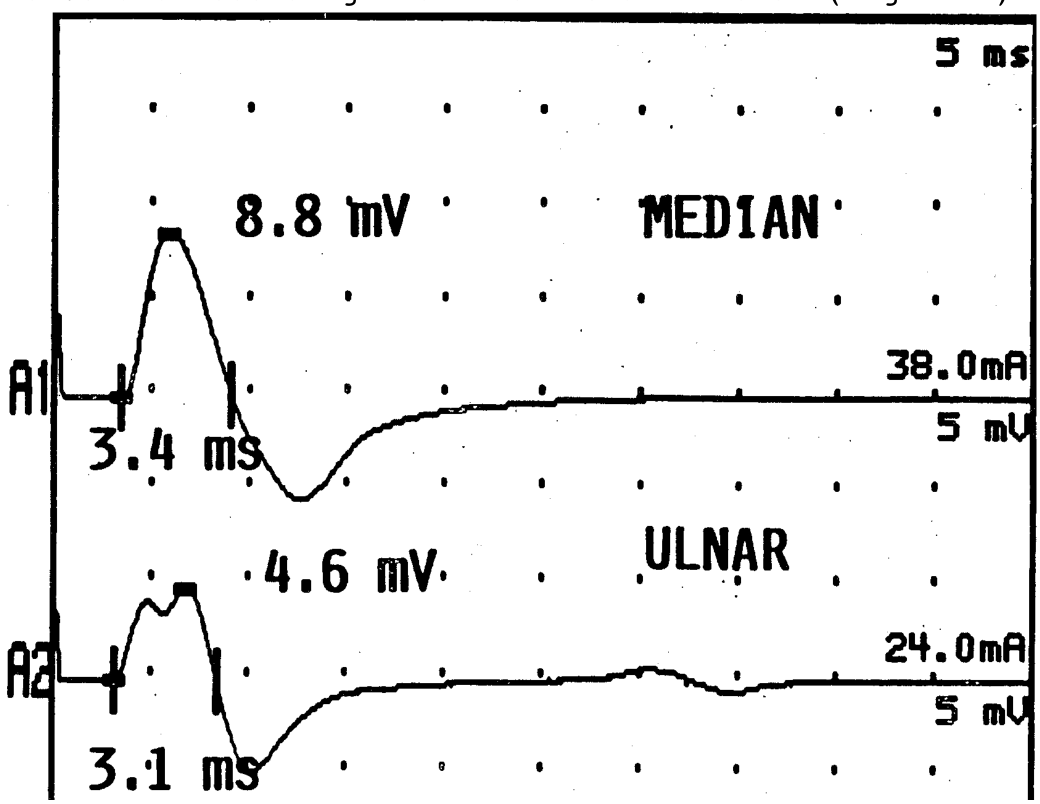


Fig. 1

The reason for the bifid response is evident if the interosseous muscles arestimulated directly over the back of the hand. Electrical responses are observed with decreasing amplitude if the recording electrode is placed over the hypothenar muscles and the dorsum of the hand is sequentially stimulated between the 3rd and the 4th, 2nd and 3rd, and at times between the 1st and 2nd metacarpals on the dorsum of the hand. This indicates that the second hump of the bifid response (Fig 1-A2), with stimulation of the ulnar nerve at the wrist, results from sequential activation of the ulnar innervated muscles from the ulnar to the radial side of the hand.

The second example of a commonly performed distal conduction will further demonstrate the capacity of the recording electrode to "see" electrical activity generated at a considerable distance from the recording electrode. Median and motor nerve conduction studies are performed with the recording electrode over the thenar muscles and the median nerve stimulated between the flexor carpi radialis and the palmaris longus (Fig 2-A1).If the stimulating electrode is placed between the palmaris longus and the flexor carpi ulnaris, the evoked response can be larger than the response obtained with the stimulating electrode placed radial to the palmaris longus. The larger amplitude response is from co-stimulation of the median and ulnar nerve (Fig 2-A3) and recording from the median and ulnar innervated hand muscles. It is frequently thought that the evoked response with stimulation of the ulnar nerve and recording over the thenar muscles (Fig 2-A5) is due to recording from the adductor pollicis. However, if each of the interossei are stimulated over the dorsum of the hand with the recording electrode over the thenar muscles, it can be demonstrated that each of the interossei contribute to the response recorded with the stimulating electrode placed over the thenar muscles. As an example, even if the 4th dorsal and 3rd palmer interossei are stimulated over the dorsum of the hand between the 4th and 5th metacarpals, potentials as great as 1 millivolt can be obtained with the recording electrode on the thenar eminence (Fig 3-A4). Greater amplitudes can be recorded when the stimulating electrode is placed over the 3rd (Fig 3A-3), 2nd (Fig 3-A2) and 1st (Fig 3-A1) dorsal interossei. Thus, the recording electrode placed over the thenar muscles with stimulation of the ulnar nerve at the wrist (Fig 3-A5) "sees" the electrical activity generated from all of the interosseous muscles not those just close to the recording electrode on the thenar eminence.

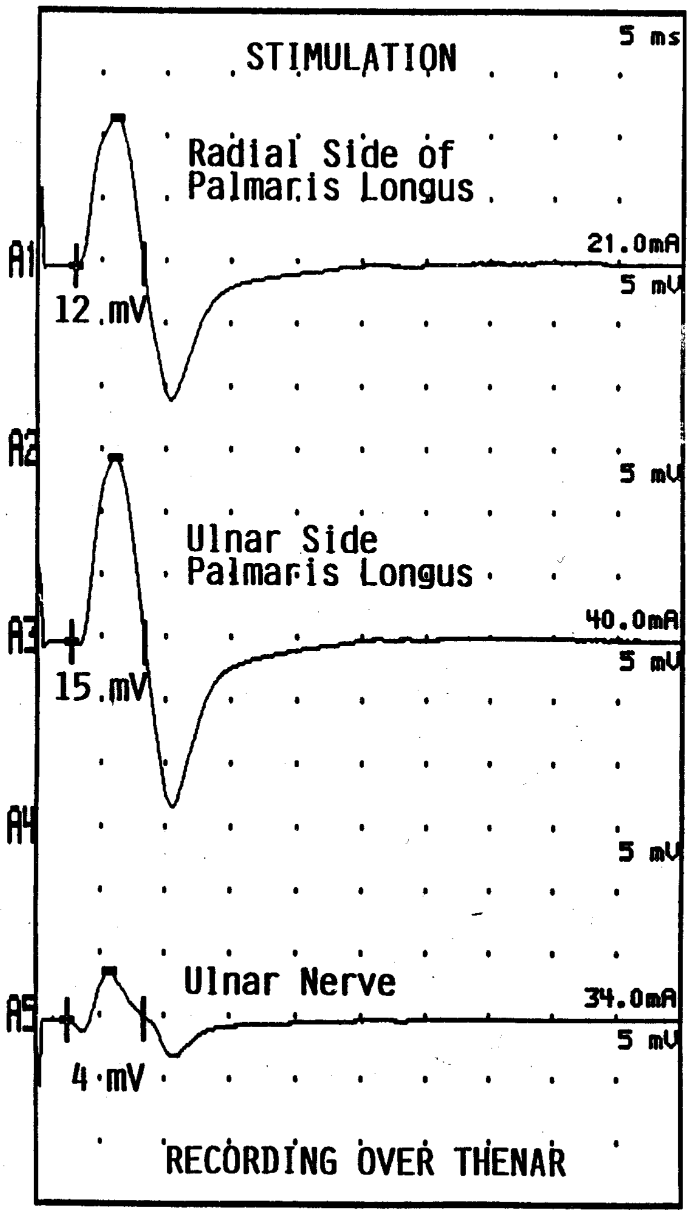


Fig. 2

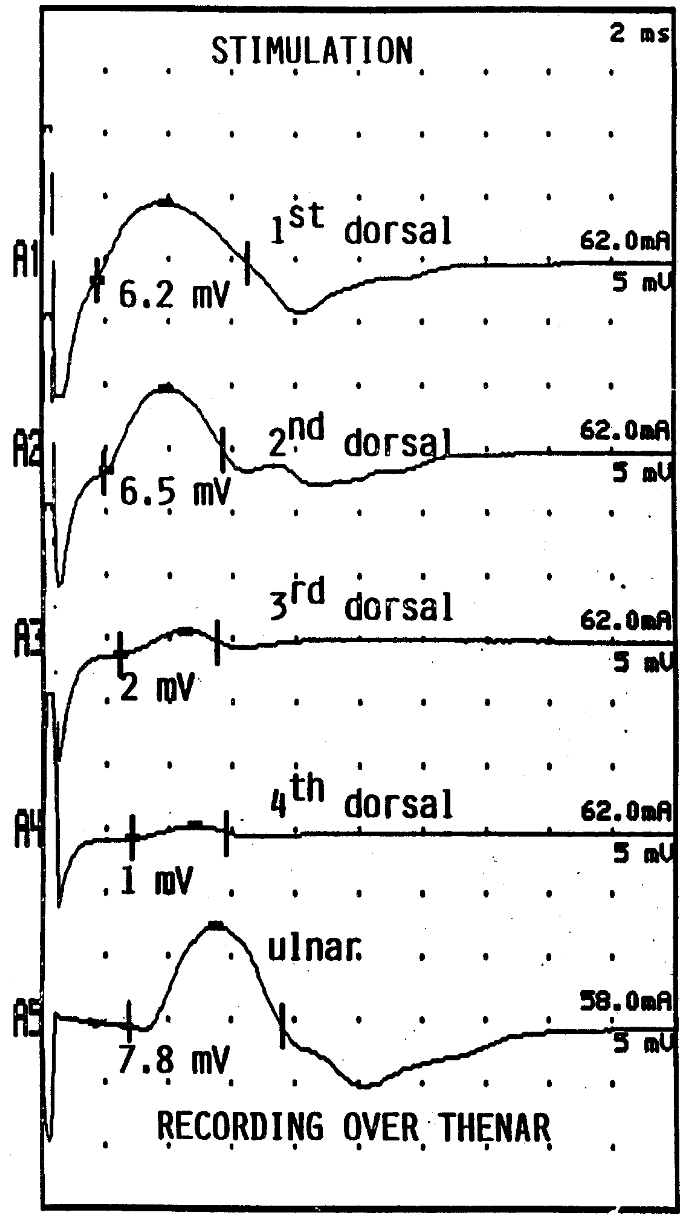


Fig. 3

This concept is important when performing median nerve stimulation proximal and distal to the wrist to demonstrate a conduction block. The median nerve stimulated in the palm of the hand results in a larger amplitude response recorded over the thenar muscles (Fig 4-A2) compared to stimulation of the median nerve proximal to the wrist (Fig 4-A1). However, if the stimulating electrode is pressed very firmly into the palm of the hand the amplitude of the response recorded over the thenar muscles is even greater (Fig 4-A4) than

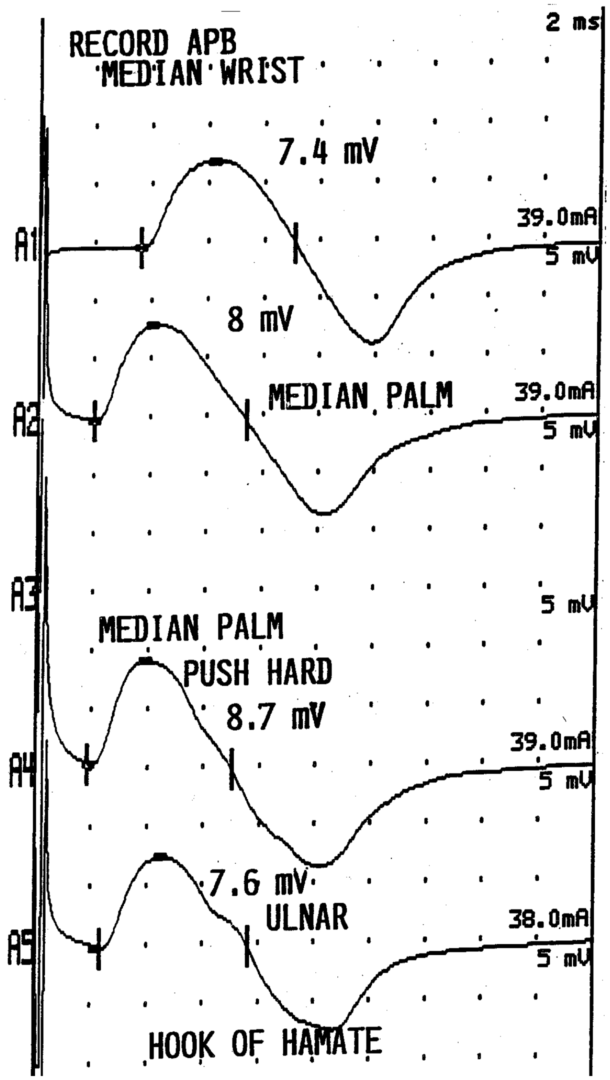


Fig. 4

when the stimulating electrode is pressed gently into the palm of the hand. The configuration of the response can change when the stimulating electrode is firmly pressed into the palm of the hand. This suggests that muscles other than median innervated muscles are being activated and recorded by the electrode placed on the thenar eminence. If the response is similar to that obtained when the palm is stimulated close to the hook of the hamate (Fig 4-A5) this indicates that the evoked response obtained by pressing the stimulating electrode firmly into the palm of the hand also activated the deep branch of the ulnar nerve. The median and ulnar nerves both can be stimulated by either firmly pressing the stimulator into the palm of the hand or by increasing the current. Because both the median and ulnar nerves can be stimulated at the same location in the palm, stimulation of the the median nerve proximal to the wrist and then in the palm of the hand is useless for the purpose identifying a conduction block at the wrist. If the clinician is sure that the ulnar interosseous muscles are not activated by palm stimulation then the above described technique is helpful in identifying a conduction block. This however demands close visual observation of the way the thumb moves when the palm of the hand is stimulated. This is extremely difficult. In summary, the above two examples demonstrate the problems encountered with volume conduction (1). I will build on these examples and describe the problems encountered with specific proximal motor nerve conduction studies.

Erb's point and the axilla are suggested as stimulation points to identify brachial plexus pathology between the clavicle and elbow (2). If the recording electrode is placed over the thenar eminence and the median nerve is stimulated at the wrist and elbow, the electrodiagnostician is tempted to stimulate either at the axilla or Erb's point to demonstrate a problem between Erb's point and the elbow. However, if the stimulating electrode is placed in the axilla or at Erb's point all the nerves supplying the hand muscles are activated. Therefore the evoked response recorded over the thenar muscles is not isolated to the median innervated muscles. Rather both ulnar and median innervated muscles are both activated. The recorded response reflects the activation of both the median and ulnar innervated muscles. Therefore no interpretation can be made based on the amplitude or conduction velocities measured from stimulation either at the axilla or at Erb's point.

Erb's point stimulation with recording over the biceps (Fig 5-A2) can result in a completely different response compared to that obtained by stimulating the musculocutaneous nerve (Fig 5-A5) as it passes through the coracobrachialis. The musculocutaneous nerve can readily be stimulated at the fold between the anterior deltoid and pectoralis major muscle. Care must be taken not to stimulate all the nerves in the brachial plexus. This is done by observing the hand for no muscle contraction. The reason for the different response obtained with the recording electrode placed over the biceps with stimulation at Erb's point compared to stimulation of the musculocutaneous nerve in the above described location is due to volume conduction.

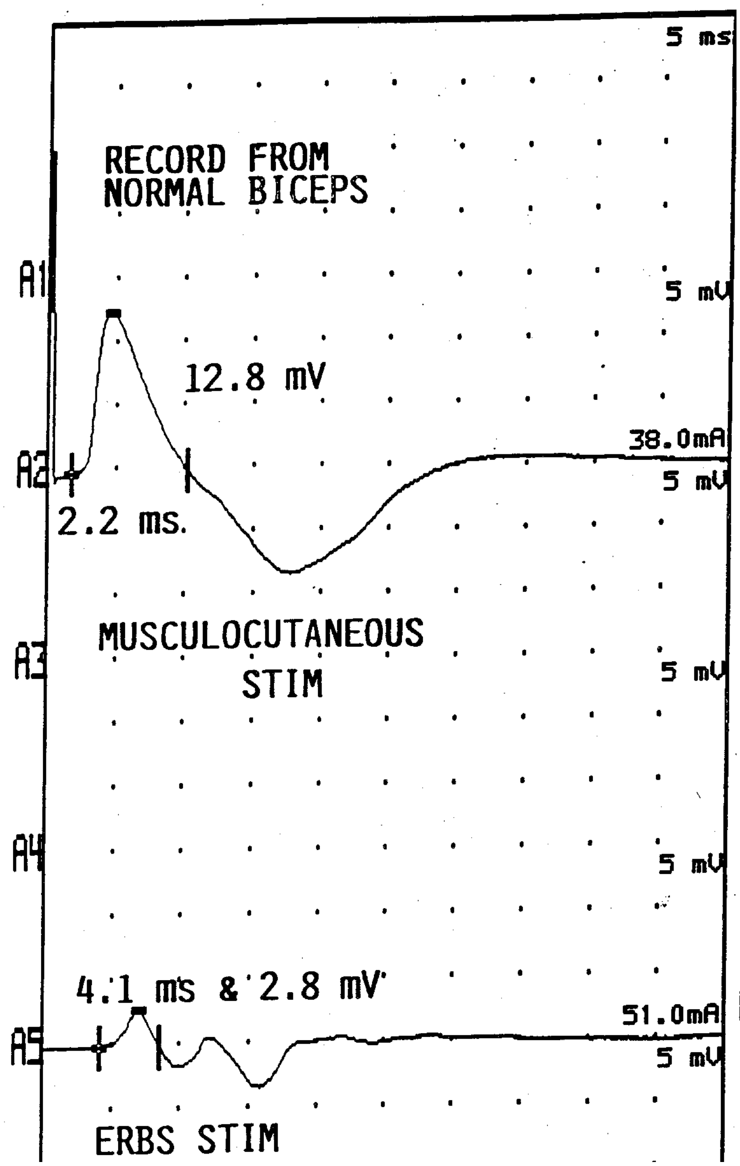


Fig. 5

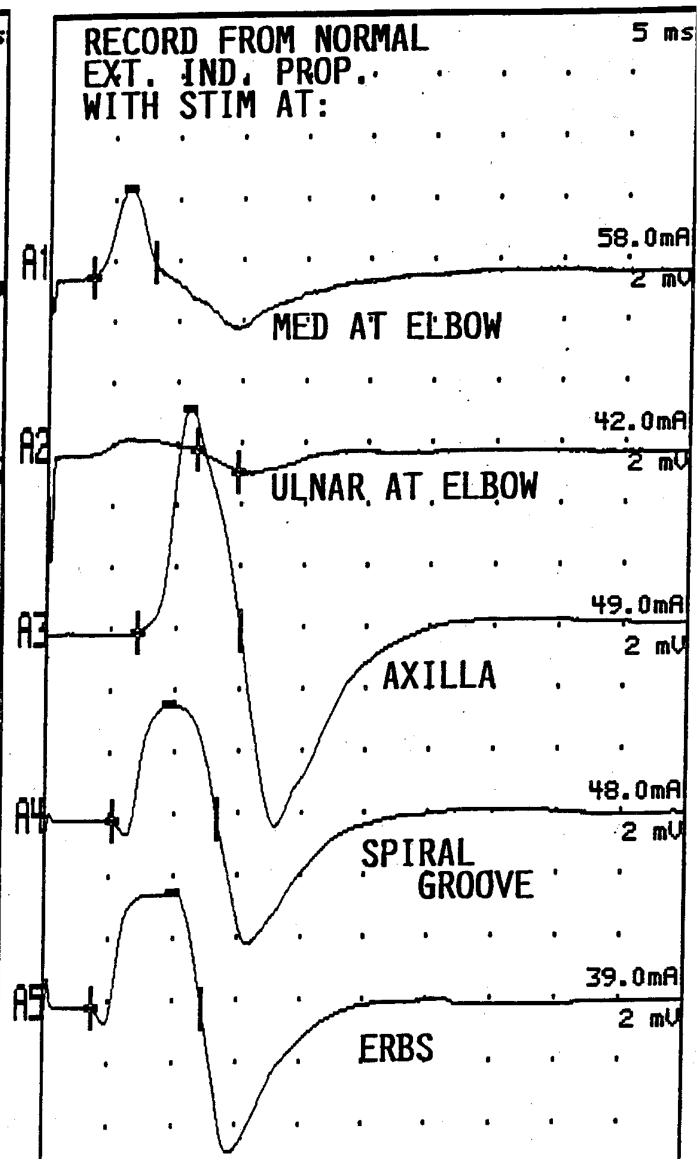


Fig. 6

With Erb's point stimulation all the muscles of the arm are activated. If a recording electrode placed of the thenar eminence can "see" the responsive with stimulation of the interossei between the 4th and 5th metacarpal then it is understandable why the recording electrode placed over the biceps can "see" electrical activity generated in the triceps as well as other muscles activated by Erb's point stimulation. Therefore if the electrodiagnostician is interested in the axons of the musculocutaneous nerve the musculocutaneous nerve is stimulated in isolation.

Radial nerve conductions can be performed to the extensor indicis. Evoked responses are obtained by stimulating the radial nerve (3) at the spiral groove (Fig 6-A4) and between the biceps tendon and the brachioradialis at the elbow. Stimulation proximal to the spiral groove (Fig 6-A3 & A5) is useless because it activates all the muscles supplying the forearm with the recording placed over the extensor indicis. A large evoked response can be obtained by stimulating the median nerve. The recording electrode "sees" the activity generated by all the median innervated muscles in the forearm. It is even possible to record electrical activity from the forearm muscles supplied by the ulnar nerve when stimulated at the elbow (Fig 6-A2). It is understandable, therefore that markedly different responses will be recorded from an electrode placed over the extensor indicis proprius when Erb's point or the axilla are stimulated vs.stimulation of the radial nerve in the spiral groove. The recorded response obtained from the former two points of stimulation reflect volume conduction from many muscles not supplied by the radial nerve whereas stimulation of the radial nerve in the spiral groove evokes a response solely from the radial innervated muscles. In summary, stimulation in the axilla or Erb's point with recording over the dorsum of the forearm are useless for the purpose of evaluating radial nerve lesions proximal to the spiral groove.

Suprascapular neuropathies result in denervation of the supra and/or infraspinatus muscles. This can be demonstrated by needle electromyography of appropriate upper extremity muscles. Conduction studies have been described placing the recording electrode over or in the infraspinatus with stimulation at Erb's point (3). As demonstrated by the first two examples given in this presentation, volume conduction can recorded through muscle and bone. Therefore the recording electrode placed over the infraspinatus with stimulation of Erb's point can "see" electrical activity generated from the muscles on the costal side of the scapula, i.e., the serratus anterior (Fig 7) and the subscapularis. Therefore Erb's point stimulation is useless in evaluating suprascapular neuropathies especially for prognosis where amplitudes of the evoked responses are important.

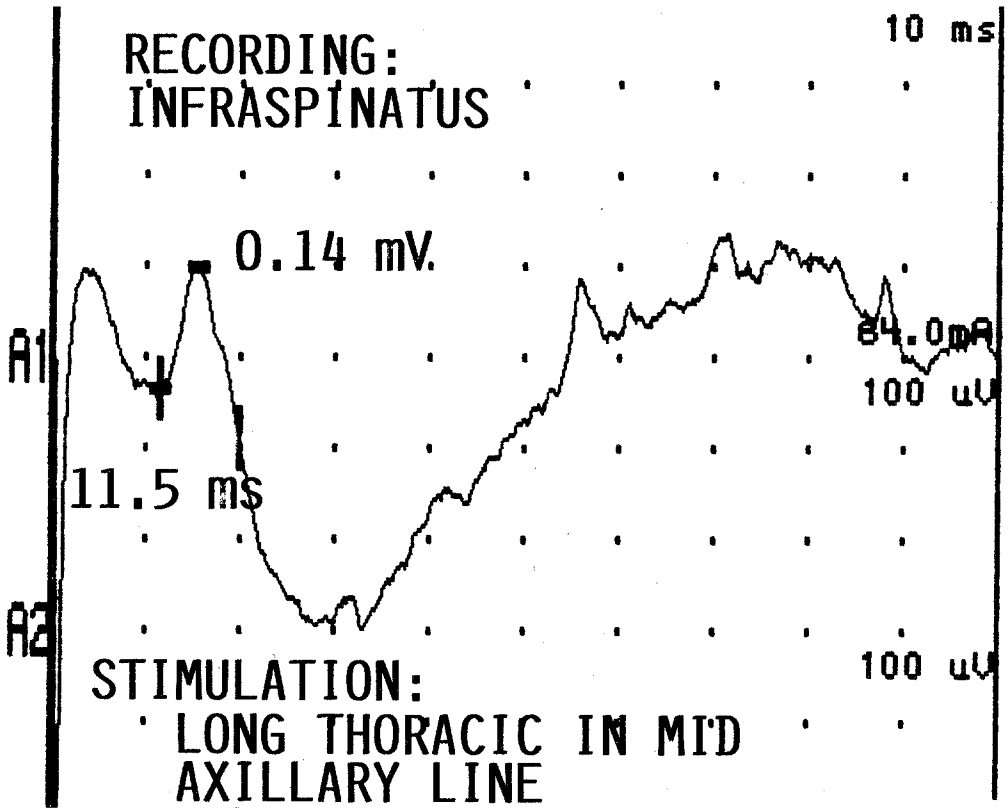


Fig. 7

Peroneal motor conductions are frequently performed to identify a conduction block at the fibular head (3). If the recording electrode is placed over the extensor digitorum brevis and the tibial nerve is stimulated behind the medial mallelous (Fig 8-A3) the evoked responses with an initial negative deflection can be recorded (Fig 8-A3). Care must be taken when stimulating proximal to the fibular head, to avoid stimulating the tibial nerve (Fig 8-A5). It is also possible to obtain amplitudes of significant magnitude by stimulating either the abductor hallucis or abductor digit minimi directly. Because all the small muscles of the feet can be recorded with an electrode placed over the extensor digitorum brevis with stimulation

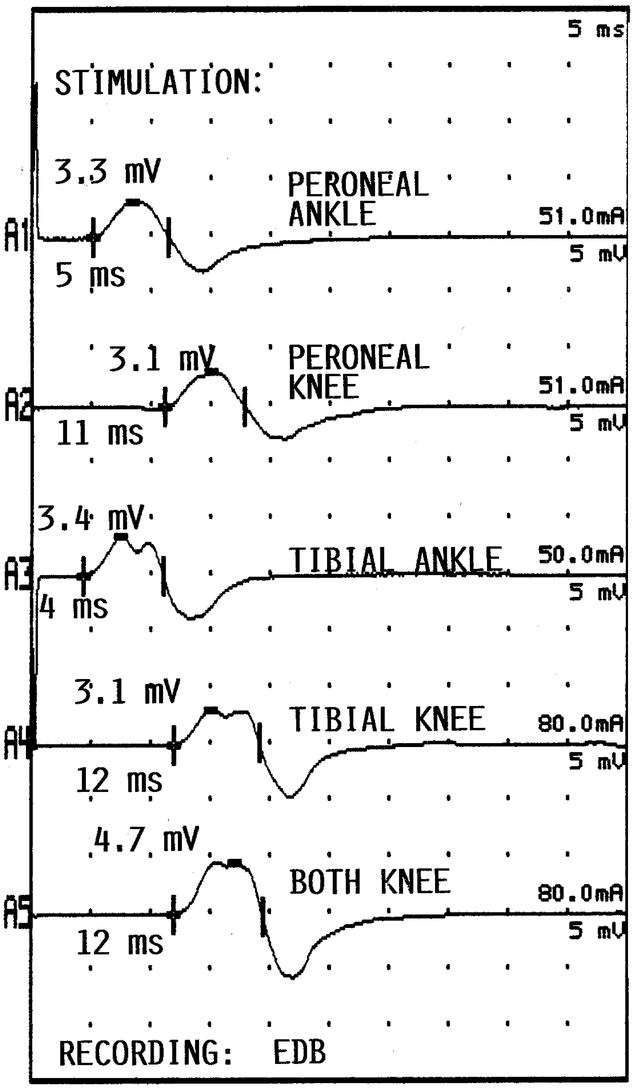


Fig. 8

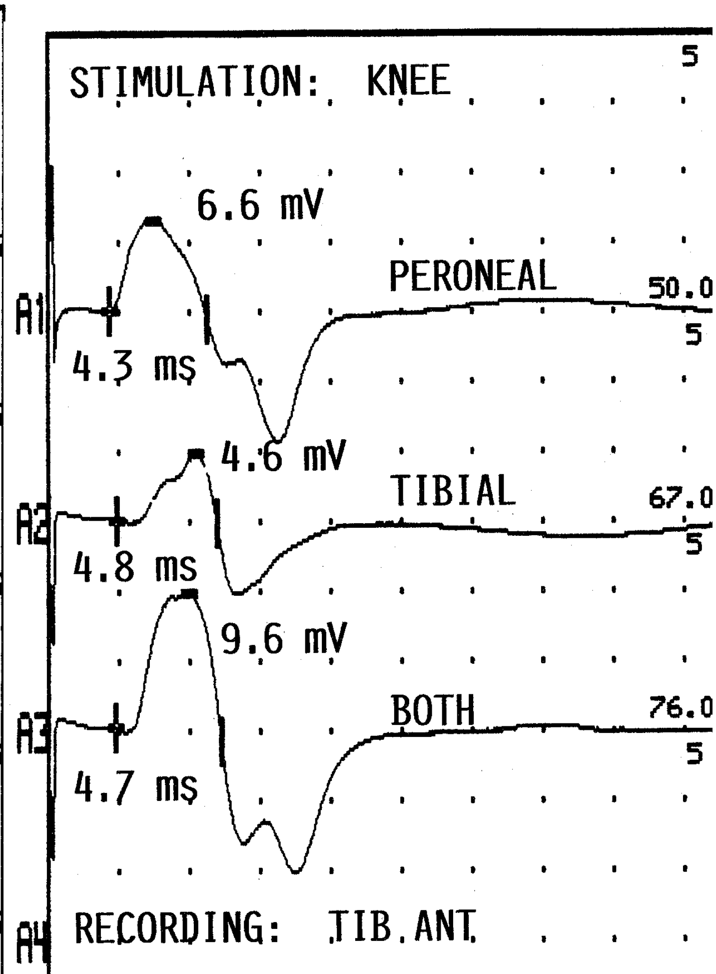


Fig. 9

of either the peroneal nerve at the ankle (Fig 8-A1) and knee (Fig 8-A2) or tibial nerve at the ankle (Fig 8-A3) and knee (Fig 8A4, it is not possible to identify lesions in the peroneal division of the tibial nerve between the hip and the knee. Similarly with the recording electrode placed over the tibialis anterior (Fig 9), stimulation of either the peroneal (Fig 9-A1) or tibial (Fig 9-A2) nerve at the knee will result in recording an evoked response. It is relatively easy to stimulate both the peroneal and tibial nerves at the knee (Fig 9-A3). The evoked response is larger than that obtained by stimulating either the peroneal or tibial nerve alone at the knee (Fig 9-A1,2). Axons supplying the dorsiflexors and plantarflexors are in close proximity from the spinal root to the thigh level. Because of this it is not possible to evaluate the peroneal division of the sciatic nerve between the spinal roots and the thigh. The response would be similar to that obtained by stimulating both the peroneal and tibial nerves at the level of the knee (Figs 8-A5 & 9-A3).

Tibial nerve stimulation recording over the abductor hallucis is also a common motor conduction study (Fig 10-A1,2). It is easy to obtain at an evoked response, with the recording electrode over the abductor hallucis, by stimulating the peroneal nerve at the ankle (Fig 10-A3,4). Because the initial reflection is frequently negative, it might be interpreted that a person has an anomalous innervation of the abductor hallucis.This conception can be refuted by stimulating directly over the extensor digitorum brevis muscle and recording over the abductor hallucis. Because the electrical activity generated in the extensor digitorum brevis muscle can be recorded from an electrode placed over the abductor hallucis muscle, an attempt to stimulate the axons in the tibial nerve either at the level of the root or within the sciatic nerve high in the thigh without stimulating the axons contributing the peroneal nerve is not helpful in identifying lesions of tibial nerve axons from the root level to the thigh. The evoked response would be similar to that obtained by stimulating both the tibial and peroneal nerves at the knee (Fig 10-A5) It is similarly useless to evaluate tibial nerve axons innervating the plantarflexors by placing the recording electrode over the gastrocnemius muscle with stimulation at the root level or high in the thigh. The response would be similar to that obtained by stimulating both the tibial and peroneal nerves at the knee (Fig 11-A3), which has wave form characteristics similar to those obtained by stimulating the tibial (Fig 11-A1) and peroneal (Fig 11-A2) separately.

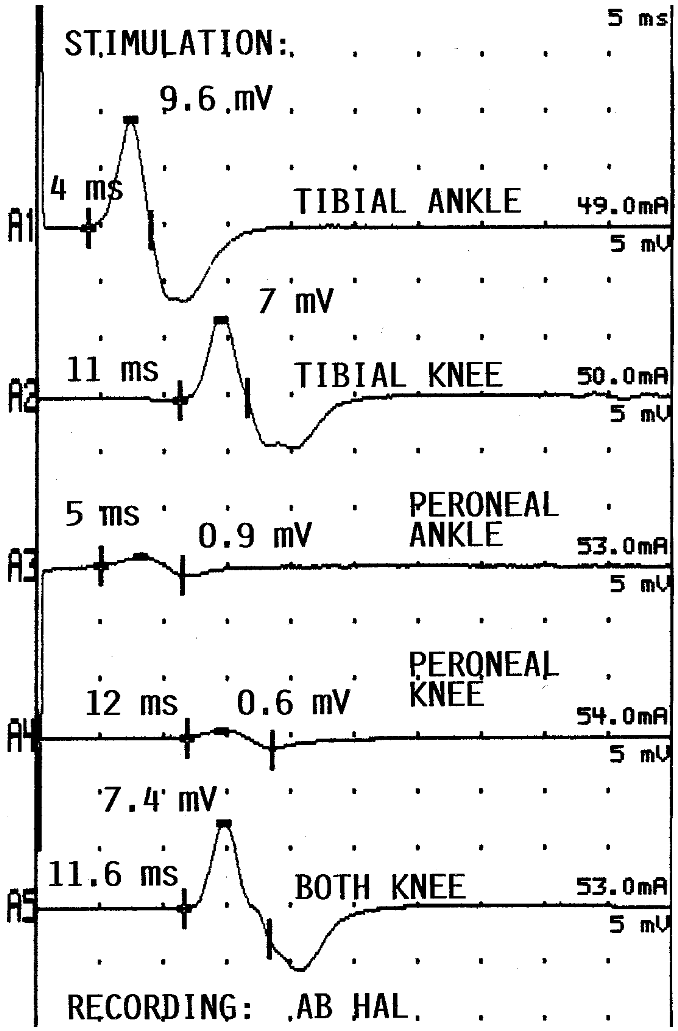


Fig.10

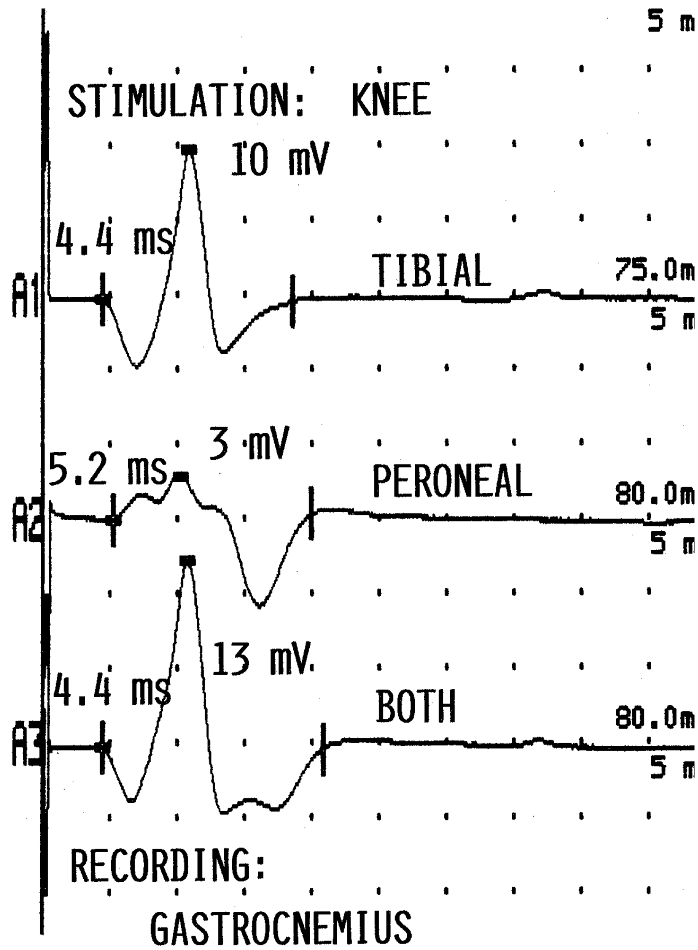


Fig. 11

In conclusion, proximal motor conduction studies present the electrodiagnostician with technical problems related to volume conduction. For this reason I believe that most proximal motor nerve conduction studies are useless.

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