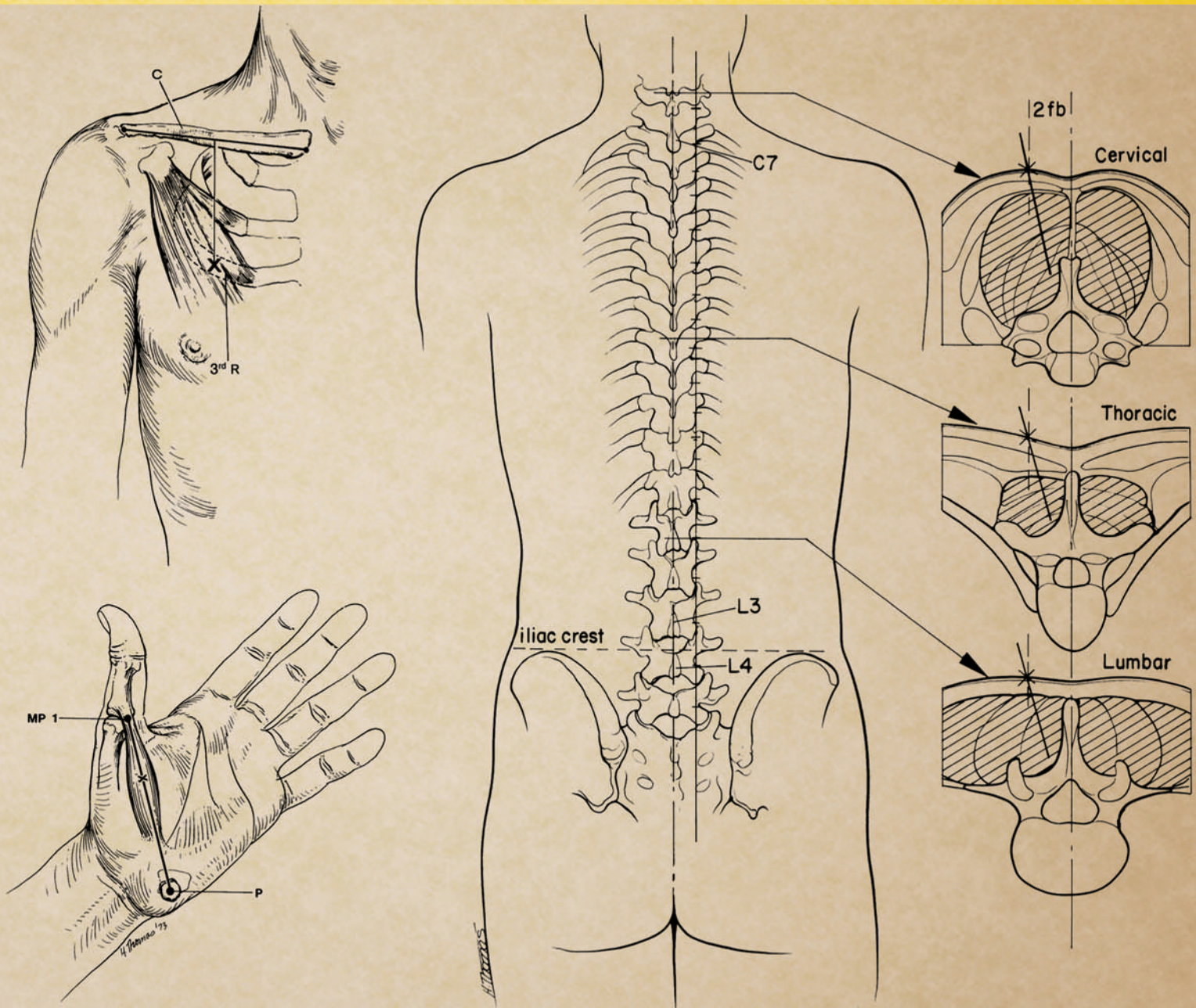


FIFTH EDITION

ANATOMICAL GUIDE *for the* ELECTROMYOGRAPHER

The Limbs and Trunk



ALDO O. PEROTTO M.D.

ANATOMICAL GUIDE FOR THE ELECTROMYOGRAPHER

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The Limbs and Trunk

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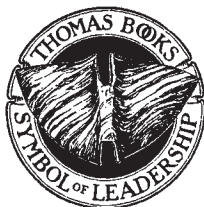
Fifth Edition by

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*To the memory of my Mentor and friend
Dr. Edward Delagi*

And to

*My granddaughter Laura Adriana
and to my grandson Martin Alejandro*

PREFACE

This new edition of the *Anatomical Guide for the Electromyographer* incorporates updated information concerning the basic principles of electromyography. This edition was written at the suggestion of numerous readers who had read the previous edition.

Once again, a vast amount of kinesiological information is included that gives this book a functional angle for the reader. The extensive information also provides the electromyographer with a reminder of the functional anatomy that allows him to understand and analyze the electrical findings.

Great emphasis is placed on describing the insertion of the needle electrode in the intended muscle and to avoid common pitfalls during this phase of the procedure.

The technique described for the study of the diaphragm is not based on my own experience, in contrast to the other muscles in this book. The technique for this muscle was described by Doctor P. Saadeh in 1993. See details of the technique in the footnote of the diaphragm muscle.

In the Appendix, a drawing of the "Nerves Entrapment in the Upper and Lower Extremities Appendix" has been added to facilitate the use and comprehension of anatomic and electromyographic knowledge. It is hoped this new edition will help in the development of future generations of electromyographers.

A.O.P.

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INTRODUCTION

The primary goal of this book is to be able to reach the intended muscle by using simple techniques. Obtaining distances from easily recognizable anatomical landmarks are sufficient to acquire the target muscle and this is essential for the interpretation of the electrical findings.

The fact that the muscles, especially in the upper and lower extremities are in close proximity to each other, and there is more than one nerve supplying the muscles in the limbs, makes this goal extremely important. The proper technique for each muscle was obtained after many anatomical dissections. These dissections were performed at the Anatomy Laboratory of the Albert Einstein College of Medicine (A.E.C.O.M.) and were shared with the residents of the Department of Rehabilitation Medicine and the Electrodiagnostic Laboratory at Jacobi Hospital and at the Albert Einstein Hospital. We arrived at the conclusion that these techniques were very useful.

At the suggestion of many readers of previous editions of this book, we have decided to incorporate information that describes the essentials of electromyographic testing. Only needle electromyography will be described. Nerve conduction techniques will not be described because they are considered to be outside the scope of the book.

ACKNOWLEDGMENTS

Once again, my gratitude to Doctor Edward Delagi for all those years of teaching and friendship in the sixth anniversary of his death. The vacuum left by his passing will never be filled. I dedicate this edition to his memory.

Special thanks to my wife for her support and encouragement. To my son Oscar for the editorial work.

My thanks to Doctor B. Nori, Chief of the Department of Rehabilitation Medicine at Elmhurst Hospital, Bronx, New York for her help in preparing this revision.

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ANATOMICAL GUIDE FOR THE ELECTROMYOGRAPHER

BASIC PRINCIPLES IN ELECTROMYOGRAPHY

This test enables the physician to evaluate the functional activity of the motor unit. It can be a major contributor in the diagnosis of conditions affecting the nerves and the skeletal muscle fibers. The purpose of the test is not to make a diagnosis of a disease, but to assess the functional status of the nerves and the skeletal muscle fibers as mentioned above. The proper localization of the intended muscle with the needle electrode is of paramount importance. The small size of the muscles (as in the hand and facial muscles) and the proximity among them (as in the forearm) makes the use of a clean technique a very important part of the test.

The motor unit (M.U.) is a functional unit which is composed of the following structures:

- (A) The anterior horn cell
- (B) Its axon cylinder
- (C) Terminal branches
- (D) The neuromuscular junction
- (E) The muscle fiber

This test essentially consists of displaying the electrical activity of a living muscle using an intramuscular wire electrode which is placed transcutaneously on the intended muscle. This signal can be converted into a sound and played to a loudspeaker; it can be stored on magnetic tape or printed out using electronic printer or light-sensitive paper.

The muscle under study is evaluated during four different stages:

1. During electrode insertion
2. When the muscle is at rest

3. When the muscle is minimally activated
4. When the muscle is maximally activated

A: DURING ELECTRODE INSERTION

At this moment, a burst of electrical activity occurs which lasts a very short time (approximately 50 msec. or less) (Kimura, 2001). This burst of electrical activity originates in the muscle fiber which is temporarily injured or stimulated by the needle electrode. When the activity ceases, the muscle goes into electrical silence. If the electrical burst becomes prolonged, it could indicate an early sign of neuromuscular dysfunction. If the burst is absent, it indicates that the muscle is no longer viable (severe compartment syndrome, when the entire muscle has been replaced by connective tissue). At this time, an assessment of the amount of fibrotic changes can be made (i.e., resistance to needle insertion).

B: AT REST

A normal muscle is electrically silent at rest. For those muscles in which the innervations become defective, special electrical events develop. The presence of this electrical activity when the muscle is at rest represents one of the most important parts of needle electromyography (Preston & Shapiro, 2005). The presence of abnormal electrical activity can yield such information as: (a) to suggest the neuroanatomic localization of a lesion; (b) the type of spontaneous electrical activity can provide specific diagnostic information (e.g., myotonic discharges are seen only in myopathies); (c) the amount of abnormal activity may determine the severity of the lesion; and (d) this abnormal activity may suggest the time of the lesion, since it takes between 2–3 weeks for them to appear (Preston & Shapiro, 2005).

These spontaneous activities are:

- (a) *Fibrillations*: They represent the spontaneous firing of individual muscle fibers secondary to increased excitability of the muscle membrane following the separation of that muscle fiber from the motor unit (M.U.) (Pease, Lew, & Johnson, 2007). They are usually very small in amplitude (50 to 300 microvolt) and short in duration (~2 msec). It takes approximately 2–3 weeks to appear after the separation has occurred.

Although they may be found in some types of myopathy, they are by far more typical of neuropathies. Fibrillations can be seen in all types of neuropathies affecting the anterior horn cell (Poliomyelitis, ALS) or the axon cylinder (radiculopathies, nerve injuries, systemic diseases). For conditions where the myelin is the primary target (e.g., early stages of diabetes neuropathies; Guillian-Barre syndrome), fibrillations may not be present at the early stages of the conditions. In compression neuropathies, during initial stages where only myelin is affected, fibrillations may not be present. But if the compression continues and the axon cylinder is damaged, fibrillation potentials will appear.

In localized neural insult (entrapment neuropathies), there are three stages of nerve injury:

- (1) Minimal insult, which produces a rapidly reversible nerve block due mainly to edema. No abnormal electrical activity is seen at this stage.
 - (2) Moderate neural injury in which there is failure of an action potential to propagate due to a local demyelization, but the axon cylinder is intact.
 - (3) Severe neural insult: The axon cylinders are damaged, followed by Wallerian degeneration; fibrillation potentials will be present (Dumitru, Amato, & Zwarts, 2002).
- (b) *Positive sharp waves*: These are electrical events whose origin is not well established. It is believed that they originate from a single motor fiber as fibrillation potentials but they last longer than fibrillation (about 10 msec) and the amplitude varies between 50–200 microvolts. The significance of these waves is similar to that of fibrillations; namely, increased membrane excitability secondary to interruption of the connection of the muscle and neural portion of the motor unit. They can also be seen at the last stage of muscular dystrophy (Dumitru et al., 2002; Preston & Shapiro, 2005).
- (c) *Fasciculations*: They represent the firing of the entire motor unit. Two types of fasciculation are recognized: benign (myokynias) and malignant. The former occurs in normal individuals and following stressful, unusual activity. The latter occurs in patients with problems affecting the proximal end of the motor unit, such as anterior horn cell or radiculopathies. According to Buchthal and

Trojaborg, the main difference between the two types is the rate of firing. The benign ones fire approximately every second, while the malignant ones occur approximately every 3 to 5 seconds. They are not seen in primary muscle disease (Preston & Shapiro, 2005).

C: AT MINIMAL VOLUNTARY EFFORT

At this moment, the number of M.U.s recruited is small and the electrical responses from each of them are clearly separated from the others. This allows the electromyographer to study the duration, amplitude and shape of the response from each M.U. In normal muscles, the duration varies from 4 to 11 msec; the amplitude may be greater than 5000 microvolts and they may have four phases. The size of the M.U. determines the difference in these parameters. Large motor units such as the gastrocnemius muscle yield a large response in both duration and amplitude. Small motor units, such as facial muscles or intrinsic hand muscles, yield smaller responses in duration and amplitude. In pathological conditions, these parameters could change significantly:

- (a) In primary muscle disease, as the muscle fibers degenerate and disappear, the amplitude and duration of the M.U. response decreases, producing a short-duration, low-amplitude response.
- (b) In proximal motor unit involvement, such as anterior horn cell disease, or radiculopathies, the entire motor unit is left without innervations. Some of the healthy motor units located in the same area as the affected ones may partially reinnervate those affected fibers. Therefore, the size of this motor unit increases, resulting in abnormally large M.U. response, in amplitude, duration and number of phases (polyphasic).
- (c) In peripheral neuropathies, there is a dual process occurring concomitantly: axonal degeneration and regeneration. This creates a situation in which axons in different stages of involvement may be present; the ability of these axons to conduct impulses will therefore be much different. As a result, a marked "temporal dispersion" will be seen with increased number of phases (Polyphasic) and decreased amplitude of the total response. The reinnervation process usually occurs in a predictable fashion. When the axon reaches the muscle again, it innervates a few

muscle fibers, producing small amplitude, short duration polyphasic potential called “nascent potentials.” These potentials should not be confused with myopathic potentials which may have similar characteristics.

D: AT MAXIMAL VOLUNTARY EFFORT

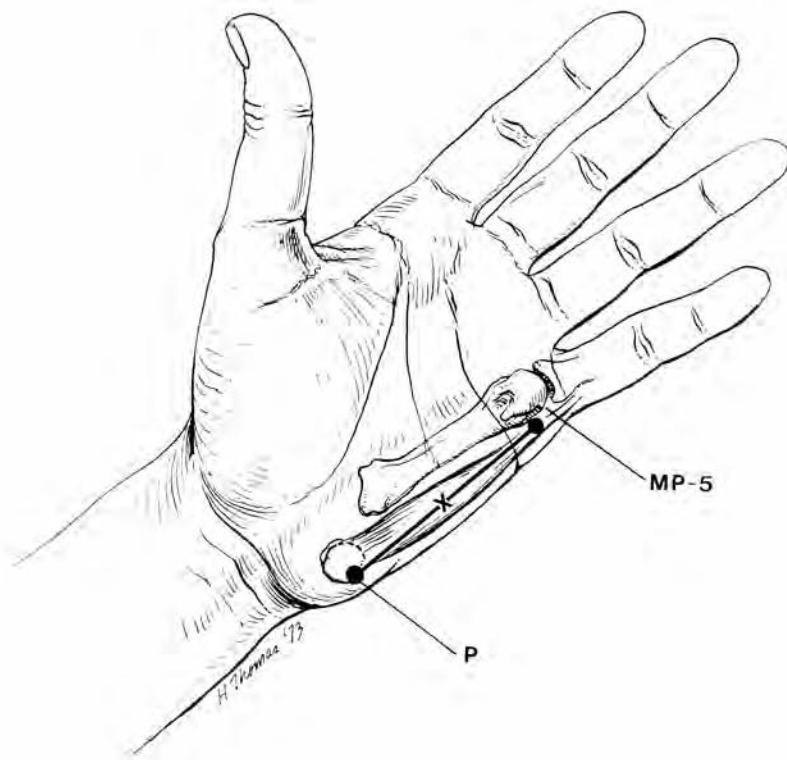
At this moment of the test, the amount of M.U. firing is so large that the details of individual motor units are lost and the base line is totally erased. This is called “complete interference pattern.” In pathological conditions the interference pattern may change. In cases of myopathy, the number of M.U. is unchanged and only the number of muscle fibers is decreased. The patient will have to recruit a large number of M.U.s in order to achieve a given task. This phenomenon is called “early recruitment,” and is one of the key points in establishing the diagnosis of “myopathic pattern.” In neuropathic conditions (Anterior Horn Cell disease; peripheral neuropathies) where there is an actual decrease of M.U., the patient may not be able to recruit enough M.U. so as to erase the base line. This decreased interference pattern is usually an early electrical sign of the neuropathic process.

In entrapment neuropathies, the severity of the nerve damage will depend upon the intensity and the duration of the compression. In early stages of the condition, the nerve will present only a certain amount of edema, resulting in the slowing or absence of nerve conduction in both motor and sensory fiber across the compressed area. Proximal and distal to the area of compression, the nerve will show normal conductivity. As the severity of the compression progresses, the axon cylinder integrity will be affected. The nerve will not conduct across or distal to the area of compression. During the early stages of the compression, the Electromyography (E.M.G.) will not show evidence of denervation potential. The voluntary activity will show an incomplete interference pattern. As soon as the axon cylinder is affected, signs of denervation potential will appear. The interference pattern will decrease and the voluntary electrical activity will stop. When evaluating patients for entrapment neuropathies, special attention should be taken to be sure the denervation activity is only in the entrapment territory and that all other muscles are working normally. In this way, peripheral neuropathies, anterior horn cell disease or radiculopathies can be excluded.

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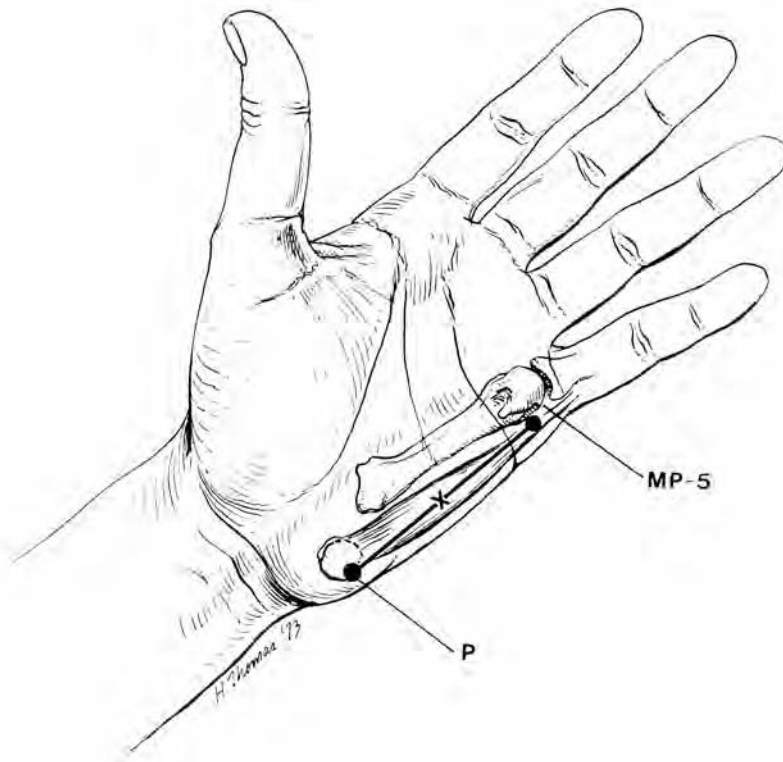
THE LIMBS



SECTION I

HAND

ABDUCTOR DIGITI MINIMI



Innervation

Ulnar Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

From the pisiform.

Insertion

On the medial side of the little finger into the base of the proximal phalanx.

Position

Hand in full supination.

Electrode Insertion (X)

Insert electrode to a depth of one-fourth to one-half inch at the mid-point of a line drawn between the ulnar aspects of the fifth metacarpophalangeal joint (MP-5) and the ulnar aspect of the pisiform (P).

Pitfalls

If the electrode is inserted too deeply it will be in the opponens digiti minimi.

Comments

- (a) Commonly used as recording muscle for ulnar nerve motor conduction study.
- (b) Involved in most ulnar nerve lesions except in Guyon tunnel entrapment when innervated through superficial palmar branch.
- (c) Involved in Klumpke's palsy (avulsion of C8, T1 roots).
- (d) This is the most superficially located muscle in the hypothenar eminence.
- (e) Its function is to abduct the 5th digit to approximately a 45-degree angle.
- (f) This muscle performs a digastrics function with the flexor Carpi ulnaris. As the origin of the abductor digiti minimi is on a sesamoid bone (floating bone), it makes the flexor Carpi ulnaris to contract each time the abductor digiti minimi is used to steady the pisiform bone. Paralysis of the Flexor Carpi ulnaris produces a significant weakness of the Abductor Digiti minimi, because the insertion of the muscle moves.

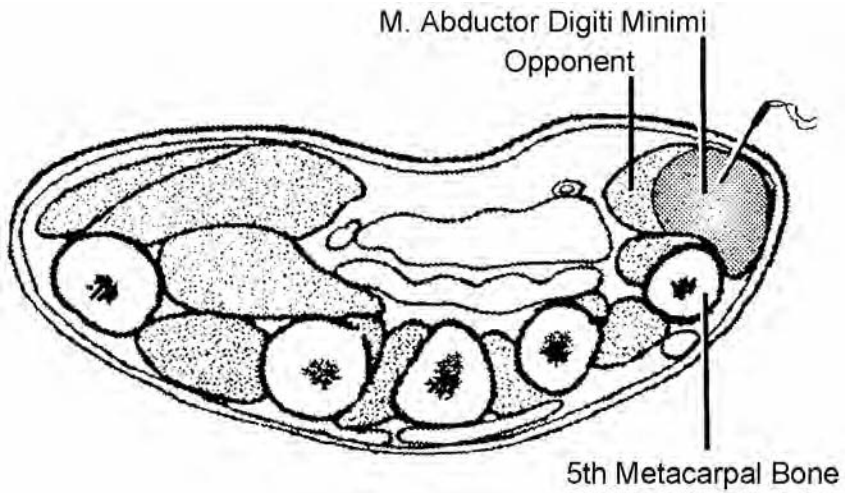
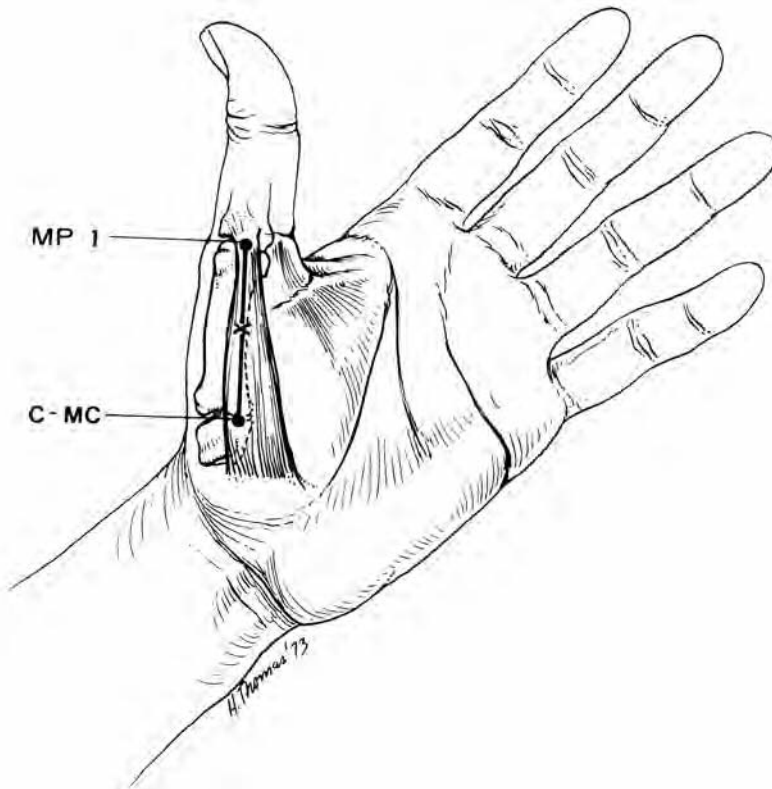


Figure 1. Cross section of the hand through the junction of the proximal and medial third of the metacarpal bones.

ABDUCTOR POLLICIS BREVIS



Innervation

Median Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

From the palmar retinaculum, the tubercle of the scaphoid and that of the trapezium.

Insertion

Lateral side of the base of the proximal phalanx of the thumb.

Position

Hand in full supination.

Electrode Insertion (X)

Midpoint of a line drawn between the volar aspect of the first metacarpophalangeal joint (MP-1) and the carpometacarpal joint (C-MC). Insert to depth of one-fourth to one-half inch.

Test Maneuver

Palmar abduction of the thumb.

Pitfalls

If the electrode is inserted too deeply it will be in the flexor pollicis brevis.

Comments

- (a) Frequently used as recording muscle for median nerve motor conduction study.
- (b) May be involved in all median nerve entrapment syndromes (carpal tunnel; pronator teres, ligament of Struthers) except anterior interosseus syndrome.
- (c) Involved in Klumpke's palsy (avulsion of C8, T1 roots).
- (d) This is the most superficially located muscle in the thenar eminence.
- (e) Its function is to palmarly abduct the thumb to about 90-degree angle.
- (f) In comparative anatomy we found that this muscle is not present in the monkey's hand which cannot make terminal pinch with the other fingers. The monkey hand has 5 fingers, while the human hand has 4 fingers and 1 thumb.

This muscle is one of the biggest acquisitions of the human hand insofar as function is concerned.

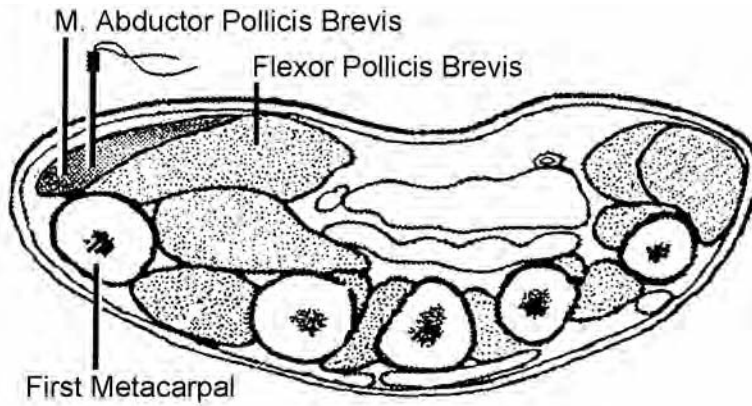


Figure 2. Cross section of the hand through the junction of the proximal and medial third of the metacarpal bones.

ADDUCTOR POLLICIS



Innervation

Ulnar Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, 77.

Origin

Lateral border of the third metacarpal.

Insertion

Medial side of the base of the proximal phalanx.

Position

Hand in full pronation, thumb in radial abduction.

Electrode Insertion (X)

At the free edge of the first web space. The needle is directed toward the proximal end of the first metacarpal bone.

Test Maneuver

Adduct the thumb.

Pitfalls

If the electrode is inserted too dorsally it will be in the first dorsal interosseus; if too volarly it will be in the opponens pollicis.

Comments

- (a) The most distal muscle innervated by the ulnar nerve.
- (b) Paresis or paralysis of this muscle results in Froment's sign (substitution of flexor pollicis longus on attempted adduction of thumb).
- (c) May be involved in ulnar entrapment syndromes (Guyon's Tunnel; cubital tunnel; tardy ulnar palsy; cervical rib) and Klumpke's palsy (avulsion of C8, T1 nerve roots).
- (d) This muscle is a powerful adductor of the thumb and greatly contributes in the strength of the grasp.

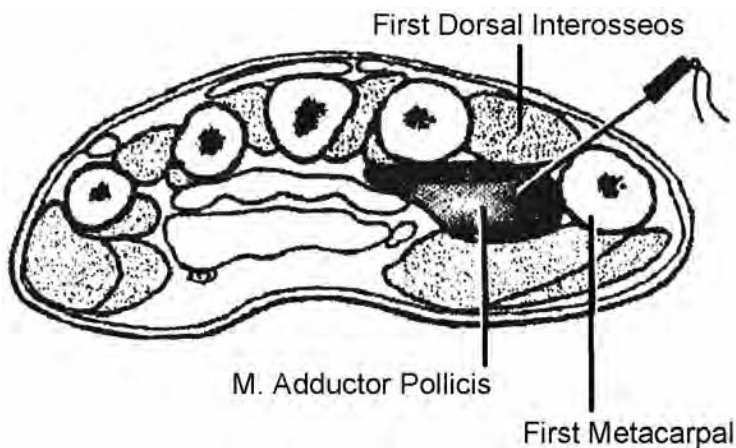
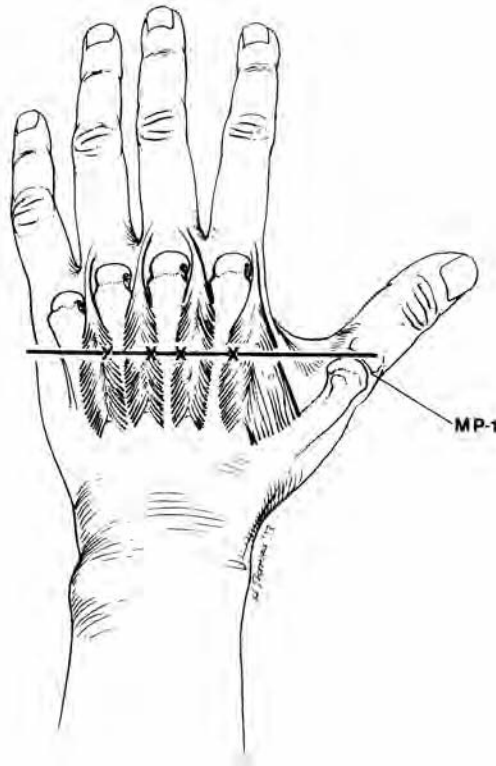


Figure 3. Cross section of the hand through the junction of the proximal and medial third of the metacarpal bones.

DORSAL INTEROSSEI



Innervation

Ulnar Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

The first and second dorsal interossei originate on the radial aspect of the second and third metacarpal. The third and fourth dorsal interossei originate on the ulnar aspect of the third and fourth metacarpal. A small portion of the muscle originates on the opposite metacarpal.

Insertion

Base of the proximal phalanges and the dorsal digital expansions.

Electrode Insertions (X)

The common landmark for both volar and dorsal interossei is a transmetacarpal line perpendicular to the long axis of the hand at the level of the first metacarpal joint (MP-I). Insertions (Xs) are made along this line for specific interosseus muscles as indicated below:

First dorsal: Just radial to second metacarpal

Second dorsal: Just radial to third metacarpal

Third dorsal: Just ulnar to third metacarpal

Fourth dorsal: Just ulnar to fourth metacarpal

Test Maneuver

The first and second dorsal interosseus radially deviate the second and third digit, respectively. The third and fourth dorsal interosseus ulnarly deviate the third and fourth digit, respectively.

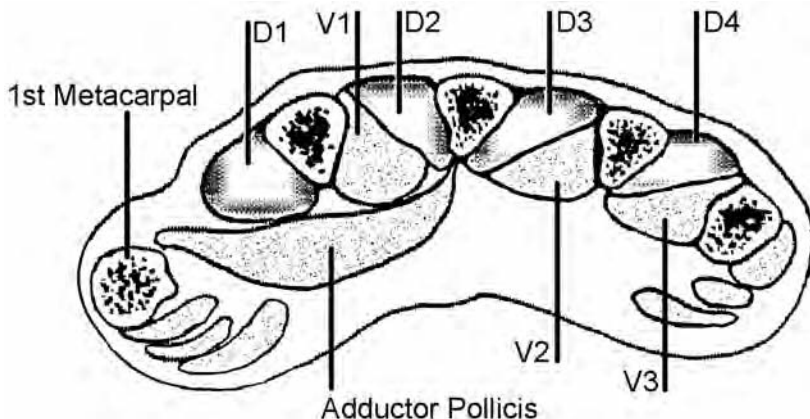


Figure 4. Cross section of the hand through the midsection of the metacarpal bones.

Pitfalls

First dorsal (D1): If the electrode is inserted too deeply it will be in the adductor pollicis.

Second dorsal (D2): If the electrode is inserted too deeply and it is angled in a radial direction it will be in the first volar interosseus; if deeper it will pierce the aponeurosis, and it will be in the adductor pollicis.

Third dorsal (D3): If the electrode is inserted too deeply and angled ulnarly it will be in the second volar interosseus.

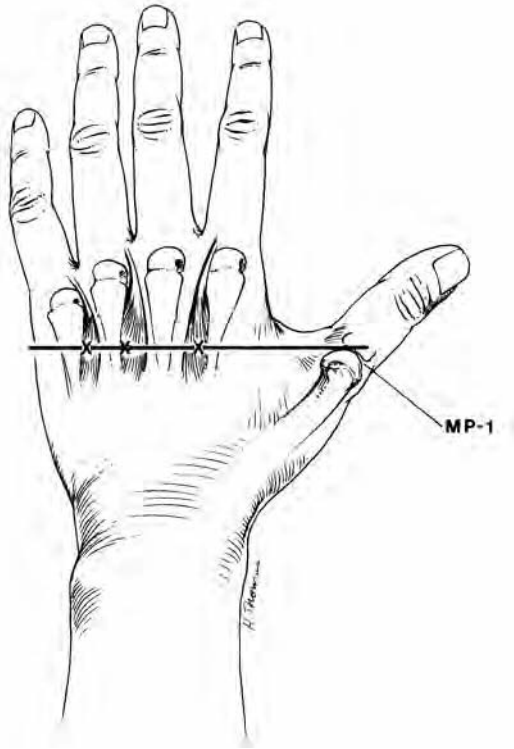
Fourth dorsal (D4): If the electrode is inserted too deeply it will be in the third volar and if deeper, through the palmar aponeurosis in the opponens digiti minimi.

It is a common misconception that the dorsal (D) and volar (V) interosseus muscles lie in parallel planes, one completely over the other in the interosseus space, when in fact the interosseus space is divided obliquely with the greatest portion of the bulk of each muscle lying alongside the metacarpal of the digit upon which it acts; thus, orientation of the electrode along the radial-ulnar line becomes the critical factor rather than the dorsal-volar placement. (See figure page 22).

Comments

- (a) There is a great variability innervation of these muscles so that they are sometimes innervated by either or both of the ulnar or median nerves.
- (b) The first dorsal interosseus occasionally receives innervation from the musculocutaneous nerve (Sunderland).
- (c) The first dorsal interosseus is used as the recording muscle in motor conduction studies of the deep palmar branch of the ulnar nerve. This is frequently involved in Guyon tunnel entrapment and is manifested by an increased latency of more than one ms. over that of the abductor digiti minimi on stimulation at the wrist.
- (d) Frequently involved in Tardy ulnar palsy and Klumpke's palsy (avulsion of C8, T1 nerve roots).
- (e) These muscles help the lumbricals in flexing the M.P. and extending the I.P. joints.
- (f) However, the main function of these muscles is to abduct the fingers. Taking the Long finger as the point of reference, the Index and the Ring fingers moves away from the reference digit. The Long finger present 2 D.I. muscles and presents no V.I.

VOLAR INTEROSSEI



Innervation

Ulnar Nerve, Medial, Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

The first volar arises from the ulnar aspect of the second metacarpal; the second and third volar arise from the radial aspect of the fourth and fifth metacarpal. A small portion of the muscle originates on the opposite metacarpal.

Insertion

Bases of the proximal phalanges and the dorsal digital expansions.

Electrode Insertion (X)

Along the transmetacarpal line, insert electrodes to depth of one-fourth inch.

First volar: Just ulnar to second metacarpal.

Second volar: Just radial to fourth metacarpal.

Third volar: Just radial to the fifth metacarpal.

Test Maneuver

First volar: Ulnarly deviates the second digit.

Second volar: Radially deviates the fourth digit.

Third volar: Radially deviates the fifth digit.

Pitfalls

First volar: If electrode is inserted too superficially it will be in the second dorsal interosseus; if inserted too deeply, it will be in adductor pollicis.

Second volar: If electrode is inserted too superficially it will be in the third dorsal interosseus.

Third volar: If electrode is inserted too superficially it will be in the fourth dorsal interosseus; if inserted too deeply it will be in opponens

Comments

- (a) These muscles show the same variability in innervation as the dorsal interossei.
- (b) Frequently involved in ulnar nerve entrapment (Guyon's tunnel; cubital canal, tardy palsy) and Klumpke's palsy (avulsion of C8, T1 roots).
- (c) These muscles main function is to adduct the 2nd the 4th and the 5th digit.
- (d) These muscles also assist the Lumbrical to flex the M.P. joints and to extend the I.P. joints of the 2nd to the 5th digit.
- (e) The ulnar nerve innervates all the Interossei (Volar and Dorsal) for which this nerve is referred as the nerve "for fine movements." All the muscles it innervates, are concerned with fine movements and dexterity of the digits, such as playing piano or typing.

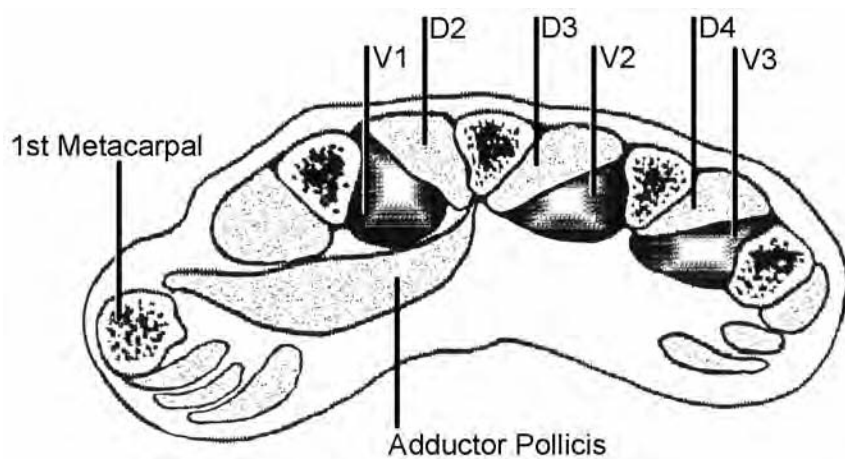
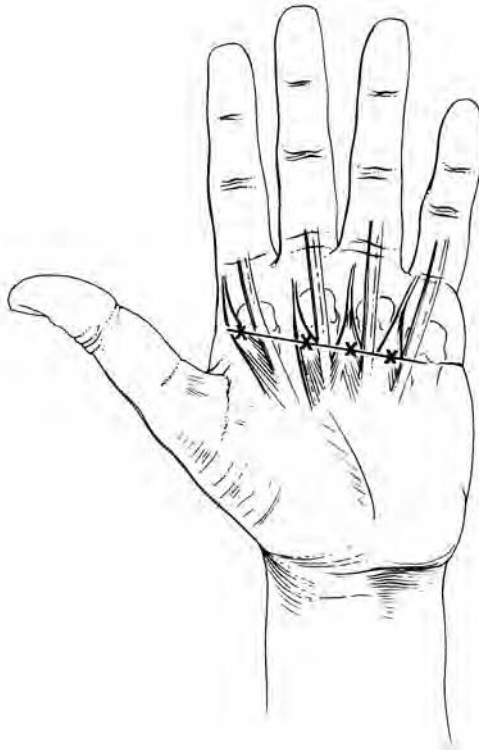


Figure 5. Cross section of the hand through the midsection of the metacarpal bones.

LUMBRICALS



Innervation

First and Second: Median Nerve; Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Third and Fourth: Ulnar Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

From the radial aspect of the tendon sheath of the flexor digitorum profundus.

Insertion

Into the radial lateral band of the dorsal digital expansion.

Position

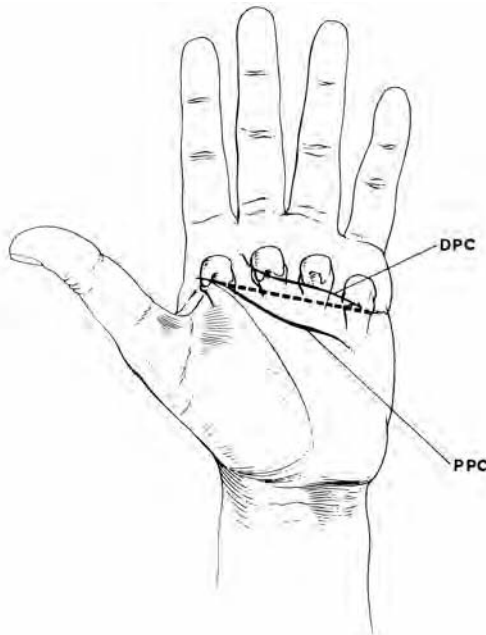
Hand in full supination.

Electrode Insertion (X)

Just proximal to the joint and radial to the flexor tendon.

Test Maneuver

The usual method of testing lumbrical function by extending interphalangeal joints with the metacarpophalangeal joint in flexion is not possible because it physically interferes with the electrode. The preferred method is to maintain the metacarpophalangeal joints in extension and extend the interphalangeal joints against resistance.



The metacarpophalangeal joints have direct relationship with both the proximal (PPC) and the distal (DPC) palmar creases. The distal crease lies over the third, fourth and fifth metacarpophalangeal joints, while the proximal lies over the second metacarpophalangeal joint. The numerical designation of a lumbrical muscle is one less than the number of the metacarpophalangeal joint it crosses, i.e., first lumbrical crosses second metacarpophalangeal joint.

Pitfalls

First Lumbrical: If the electrode is inserted too deeply it will be in the adductor pollicis; if deeper it will be in the first dorsal interosseus.

Second Lumbrical: If the electrode is inserted too deeply it will be in the most ulnar fibers of the adductor pollicis, if deeper the electrode will pierce the aponeurosis, and it will be in the second dorsal interosseus.

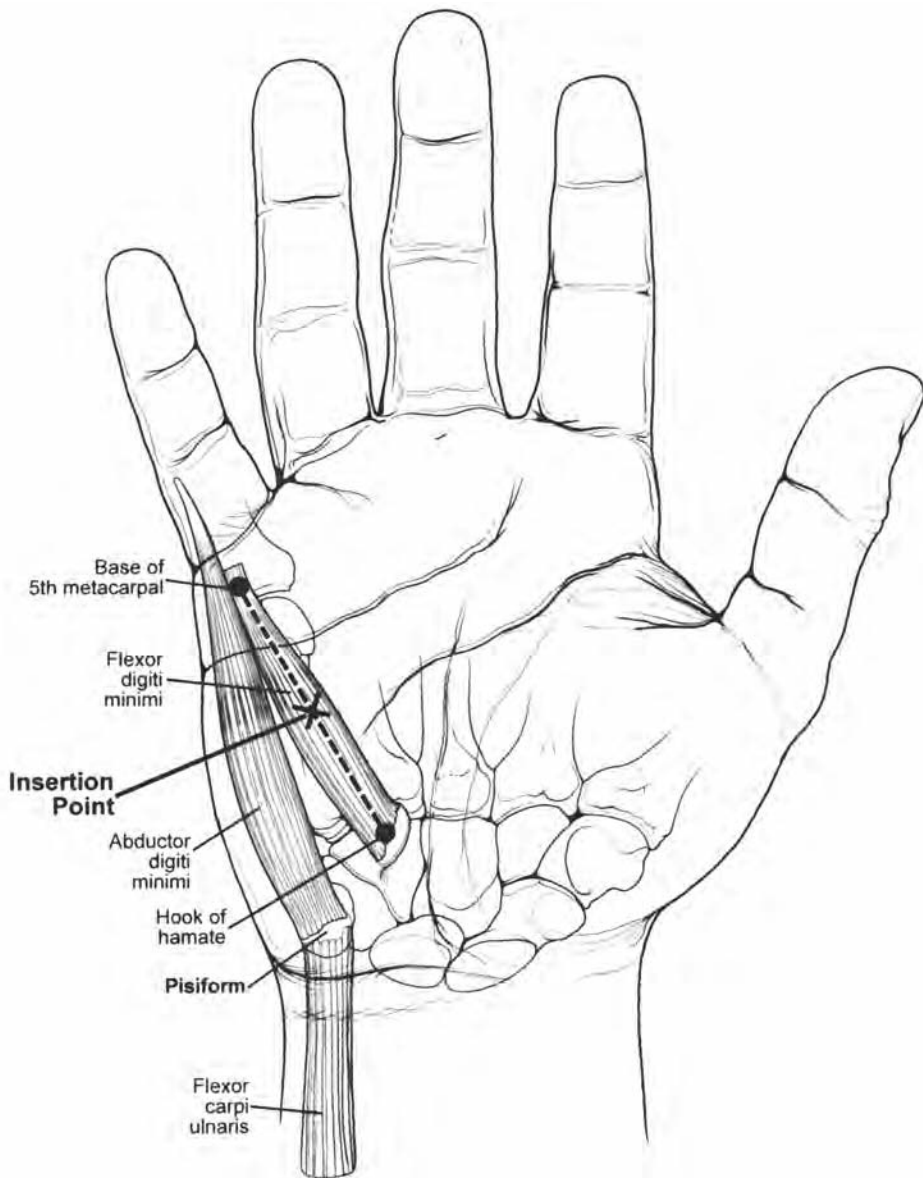
Third Lumbrical: If the electrode is inserted too deeply it will pierce the aponeurosis, and it will be in the second volar interosseus.

Fourth Lumbrical: If the electrode is inserted too deeply it will be in the opponens digiti minimi; if deeper the electrode will pierce the aponeurosis, and it will be in the third volar interosseus.

Comments

- (a) Only 30 to 50 percent of hands have classically described innervation of first and second lumbricals being median innervated and the third and fourth being ulnar innervated.
- (b) When classical innervation is present, median nerve entrapment or injury may result in involvement of the first and second lumbrical while ulnar nerve injury or entrapment may result in third and fourth lumbrical involvement.
- (c) Involved in Klumpke's palsy.
- (d) The main function of these muscles is to flex the M.P. joints and to extend the I.P. joints of all fingers.
- (e) These muscles are unique anatomically speaking since they have their origin and their insertion in soft tissue rather than in bones as all other muscles have.
- (f) Paralysis of this muscle makes fine coordination of the fingers very difficult.
- (g) The name of these muscles comes from the Latin language and means earthworm.

FLEXOR DIGITI MINIMI



Innervation

Ulnar nerve, medial cord, anterior division lower trunk, C8-T1.

Origin

From the hook of the hamate bone and flexor retinaculum.

Insertion

Into the ulnar side of the proximal end of the proximal phalanx of the 5th digit.

Position

Hand in full supination.

Electrode Insertion

Midpoint of a line drawn between the hook of the hamate bone and the palmar aspect of the proximal end of the 5th phalanx, the hook of the hamate bone can be felt pressing over the proximal end of the crease between the thenar and hypothenar eminence.

Test Maneuver

To flex the proximal phalanx of the 5th digit.

Pitfalls

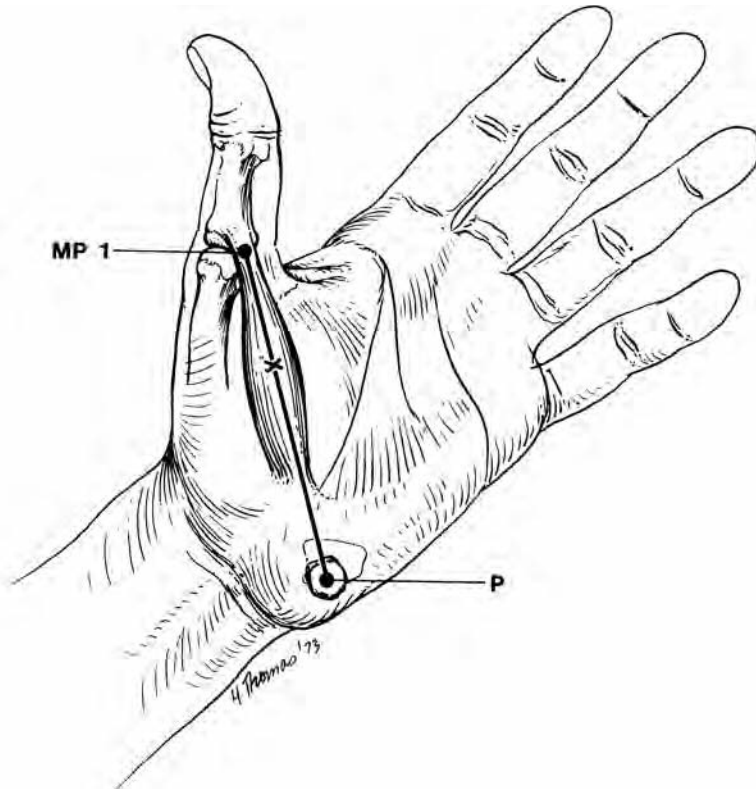
If the electrode is inserted too ulnarly, it will be in the abductor Pollicis Brevis.

If the electrode is inserted too deep it will be in the opponens digiti minimi. If the electrode hit the shaft of the phalanx of the 5th metacarpal bone, will indicate it is too deep and a partial withdrawal will be necessary.

Comments

- (a) Although it's main function is to flex the 5th M.P. joint, it contributes to abduct and oppose the 5th metacarpal bone, therefore helping to the "cupping of the hand."
- (b) This muscle is involved in Guyon's and cubital tunnel entrapment. It also sustains damage in Klumpke's palsy (C8-T1 roots lesions).

FLEXOR POLLICIS BREVIS



Innervation

Superficial Head: Median Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Deep Head: Ulnar Nerve, Medial Cord, Anterior Division, Low Trunk, C8, T1.

Origin

Superficial Head: Ridge of the trapezium and the flexor retinaculum

Deep Head: Ulnar side of first metacarpal.

Insertion

Superficial Head: Radial side of the base of the proximal phalanx thumb.

Deep Head: Ulnar side of base of proximal phalanx of the thumb.

Position

Hand in full supination.

Electrode Insertion (X)

Superficial Head: A line is drawn between the ulnar aspect of the metacarpophalangeal joint (MP-I) and the pisiform (P). The needle is inserted at the junction between the middle and the radial third of this line to a depth of one-fourth to one-half inch.

Deep Head: As above but insert to depth of one-half to three-fourths inch.

Maneuver

Flexes the Metacarpal-phalangeal and carpal metacarpal joints of the thumb and assists in opposition.

Pitfalls

If the electrode is inserted too deeply it will be in the opponens pollicis, and if still deeper it will be in the adductor pollicis brevis.

Comments

- (a) Two sesamoid bones are easily palpable in tendon at metacarpophalangeal joint.
- (b) Due to insertion into extensor mechanism of thumb, it can extend IP joint of thumb when extensor pollicis longus is paralyzed.
- (c) Deep head involved in ulnar nerve injuries. Superficial head involved in median nerve injuries.
- (d) Involved in Klumpke's palsy (avulsion of C8, T1 roots).

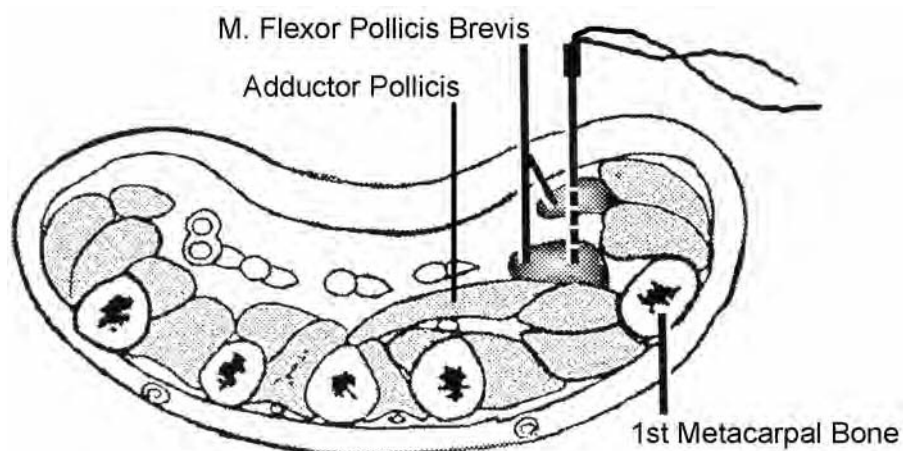
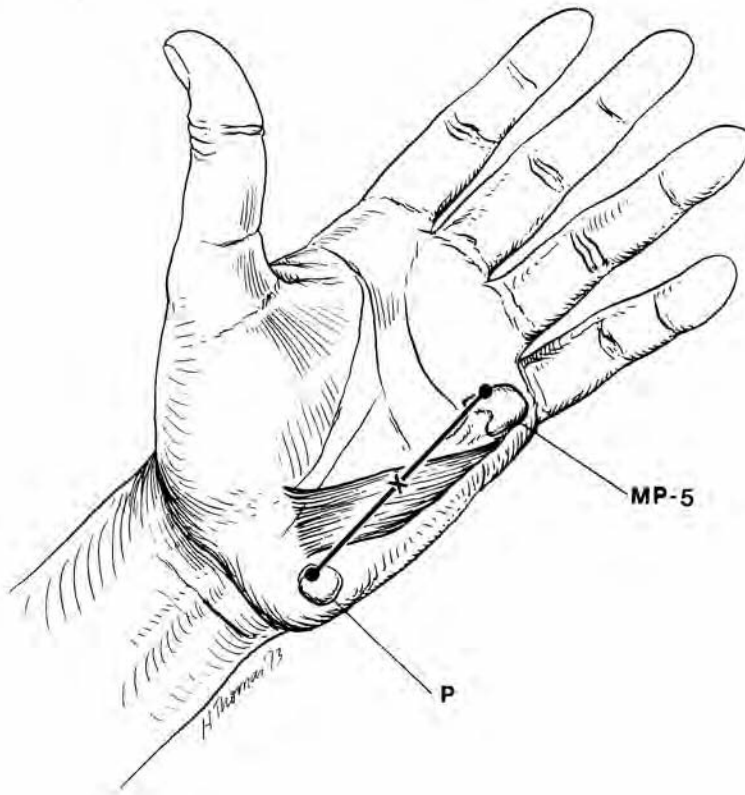


Figure 6. Cross section of the hand through the midsection of the metacarpal bones.

OPPONENS DIGITI MINIMI



Innervation

Ulnar Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

From the flexor retinaculum and the hook of the hamate.

Insertion

Into the medial surface of the fifth metacarpal.

Position

Hand in full supination.

Electrode Insertion (X)

Midpoint of a line drawn between the radial aspect of the fifth metacarpophalangeal joint (MP-5) and the radial aspect of the pisiform (P).

Test Maneuver

Oppose the little finger to the thumb.

Pitfalls

If the electrode is inserted too deeply it will be in fourth lumbrical, if deeper the palmar aponeurosis will be pierced, and the electrode will be in the third volar interosseus.

Comments

- (a) Paralysis prevents full “cupping of hand.”
- (b) Involved in ulnar nerve injuries proximal to Guyon’s Tunnel (cubital tunnel, Tardy palsy, Klumpke’s palsy).
- (c) This muscle’s main function is to make the 5th metacarpal and the 5th digit to partially pivot at the proximal end of the hypothenar eminence and bring the palmar aspect of the tip little finger “face to face” with the thumb, and deepen the cap of the hand (as already mentioned above).
- (d) As it is everybody’s experience, the palm of the hand is very sensitive. Therefore special attention should be paid in holding down the hand of the patient (specially children) to prevent a sudden withdrawal of the hand with the danger of needle rupture.

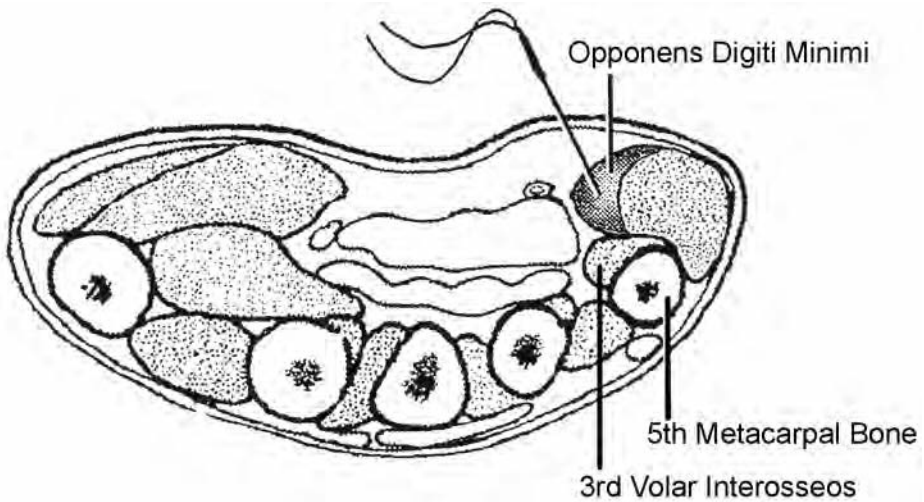
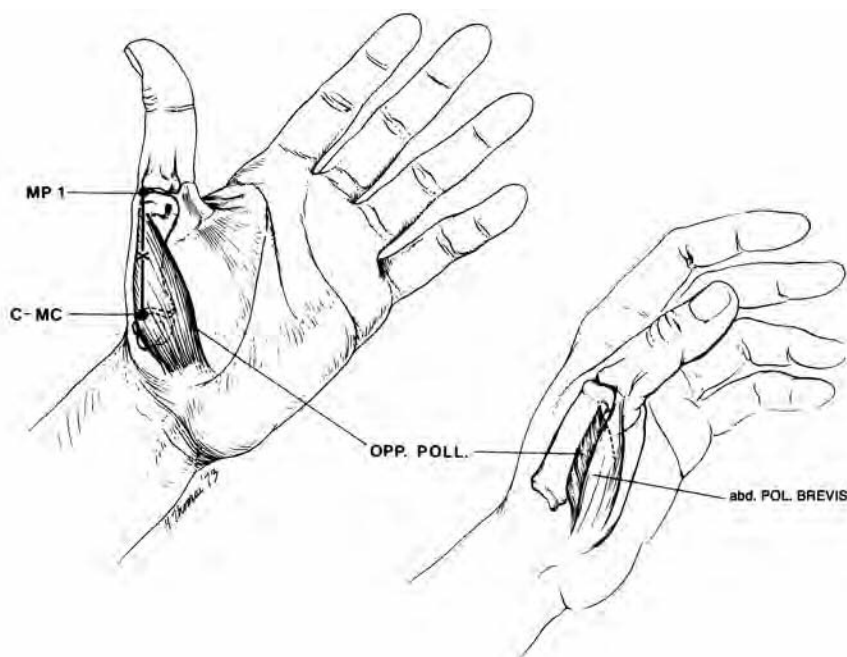


Figure 7. Cross section of the hand through the junction of the proximal and medial third of the metacarpal bones.

OPPONENS POLLICIS



Innervation

Median Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

From the tubercle of the trapezium and the flexor retinaculum.

Insertion

This muscle inserts into the lateral half of the palmar surface of the 1st Metacarpal. It lies deep to the Abductor Pollicis Brevis and lateral to the Flexor Pollicis Brevis.

Position

Hand in full supination.

Electrode Insertion (X)

Midpoint of a line drawn between the radial aspect of the carpometacarpal (C-MC) and the metacarpophalangeal joints (MP-I). The electrode is placed between the abductor pollicis brevis and the first metacarpal to a depth of one-half to three-fourths inch.

Maneuver

Oppose thumb to little finger.

Pitfalls

If the electrode is inserted too deeply it will be in the adductor pollicis. If placed too medially it will be in the abductor pollicis brevis.

Comments

- (a) The contribution to opposition made by this muscle is mainly rotation of the first metacarpal. The abductor pollicis brevis, and the adductor pollicis also contribute to the completion of this motion.
- (b) May be involved in injuries or entrapment of median nerve in pronator muscle and carpal tunnel. Not involved in anterior interosseus entrapment or injury.
- (c) Involved in Klumpke's palsy.
- (d) The opposition of the thumb is much affected in Median nerve injuries. However, the intact Flexor Pollicis Longus and the Adductor Pollicis may mimic opposition, although it is weak and sort of grotesque.
- (e) Opposition is the most complex and important motion of the thumb. It involves extension, then abduction, flexion, medial rotation and finally adduction. It also takes several muscles to produce this motion.

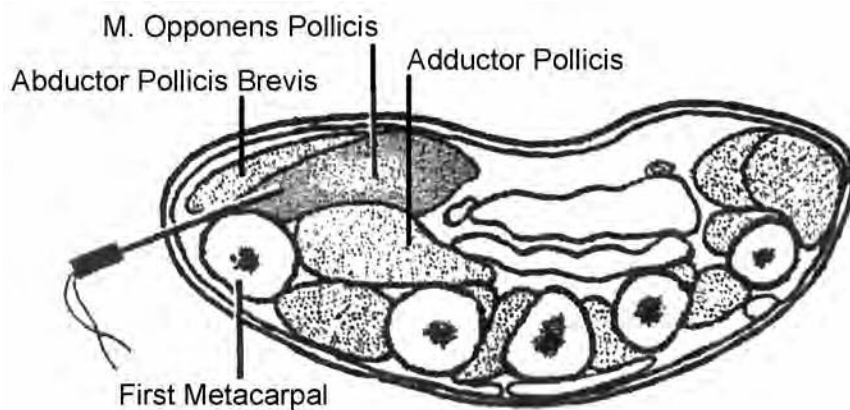
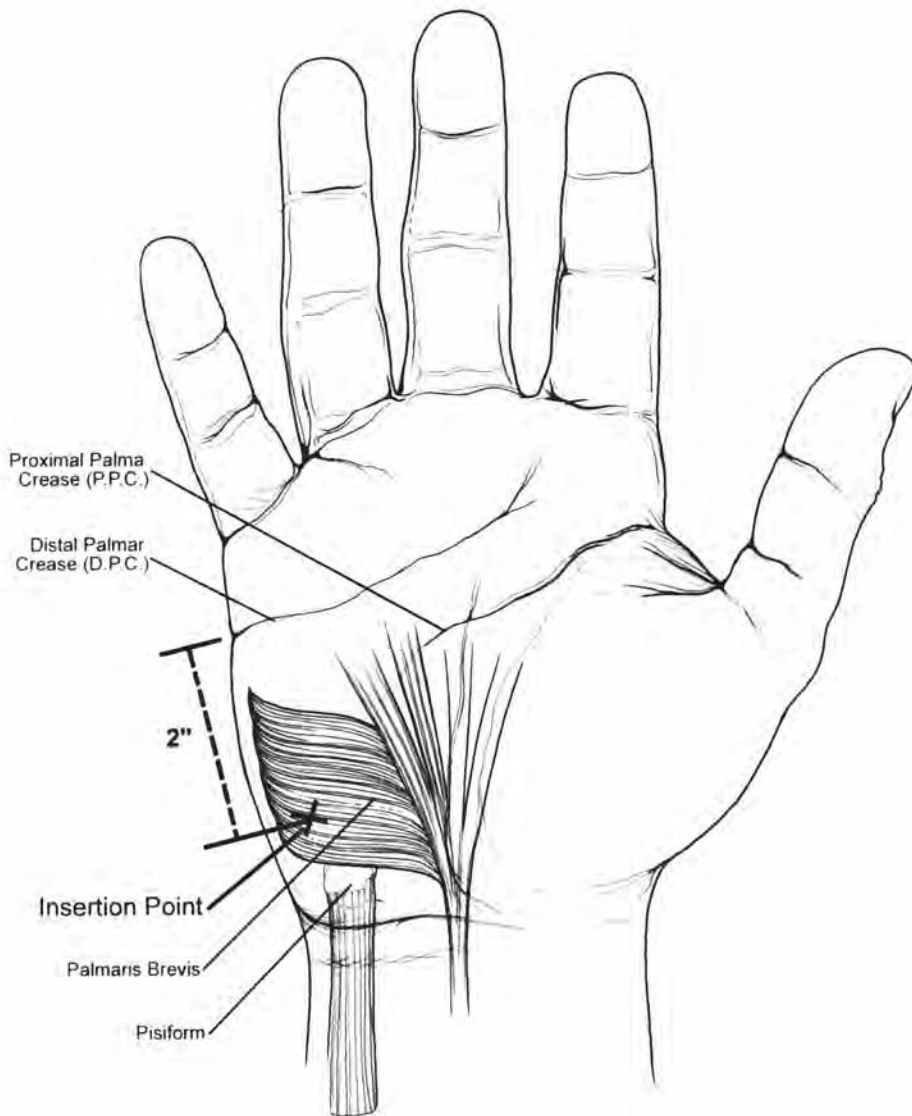


Figure 8. Cross section of the hand through the junction of the proximal and medial third of the metacarpal bones.

PALMARIS BREVIS



Innervation

Ulnar Nerve (Superficial branch); Medial Cord, anterior Division, lower trunk, C8-T1.

Origin

In the hypothenar eminence, this muscle is contained within the fascia, and it is attached to the flexor retinaculum and the border (medial) of the palmar Aponeurosis.

Insertion

Into the skin of the medial border of the hand.

Position

Hand in full supination.

Electrode Insertion

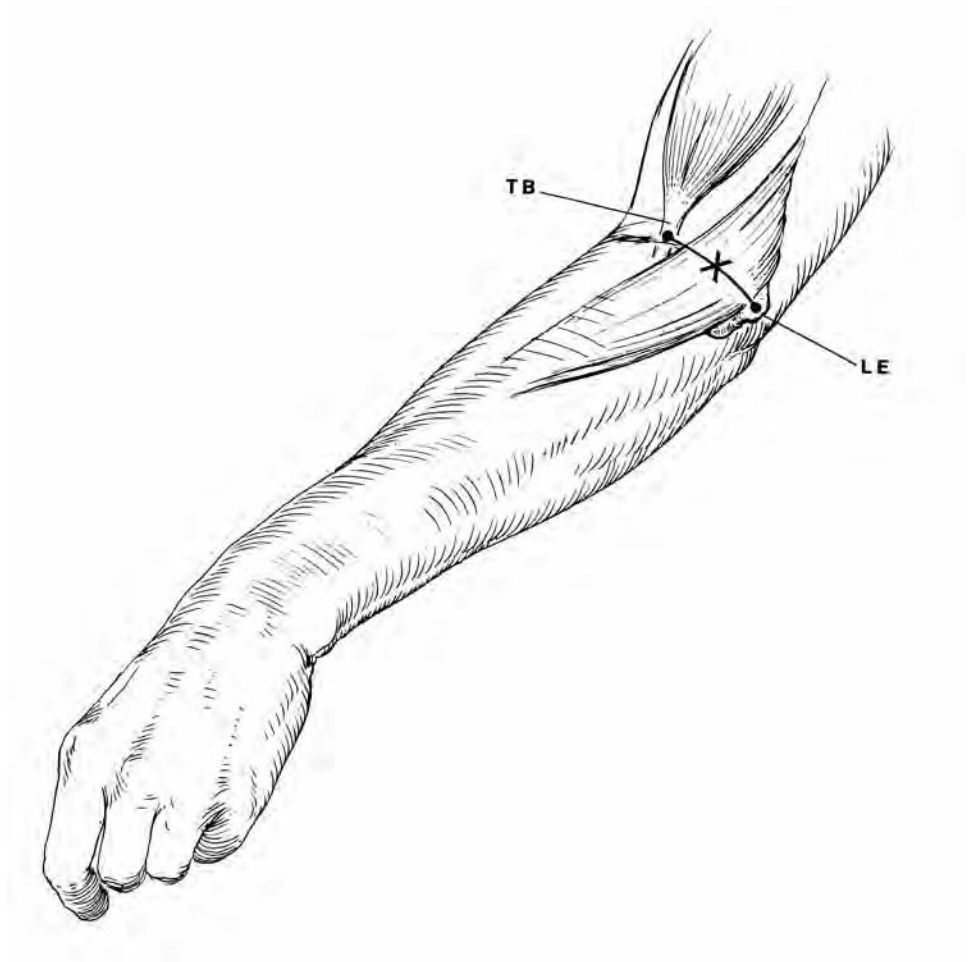
At the medial edge of the hand at the level 2 inches to the proximal palmar crease (P.P.C.). Insert the electrode at an angle of 30° with the skin and advance to about one-fourth of an inch. The electrical activity will appear when the Pisiform bone is pressed upon (reflex activity) or when the 5th digit abduction is restricted.

Pitfalls

If the electrode insertion is too deep, it will enter either abductor digiti minimi or the opponens digiti minimi.

Comments

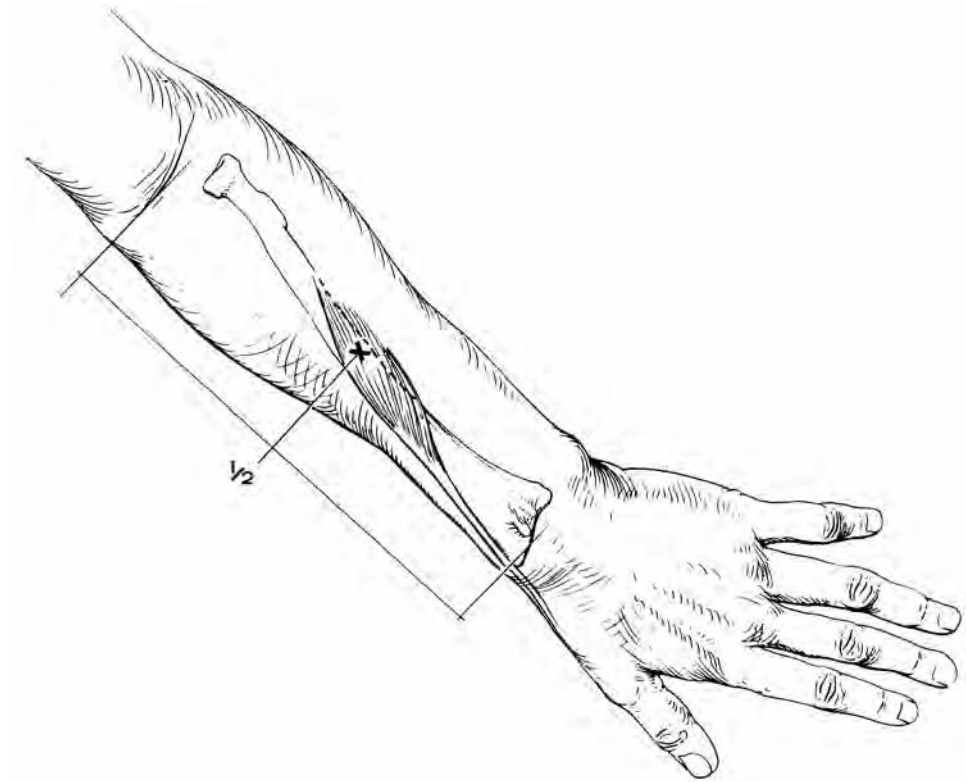
- (a) Its main function is to deepen the cupping of the palm, which adds to the gripping of the hand.
- (b) There are two maneuvers to activate this muscle: (1) to resist the abduction of the 5th digit or (2) to press over the pisiform bone (sesamoid bone). When performing either one of these maneuvers, the medial side of the palm wrinkles, indicating the contraction of the muscle.
- (c) Its Innervation is provided by the superficial branch of the ulnar nerve, while all other ulnar innervated muscles in the hand are supplied by the deep branch of the ulnar nerve.



SECTION II

FOREARM

ABDUCTOR POLLICIS LONGUS



Innervation

Posterior Interosseus Nerve, Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8.

Origin

From the dorsal surface of the body of the ulna, the interosseus membrane, and the middle one-third of the body of the radius.

Insertion

Lateral aspect of the base of the first metacarpal.

Position

Forearm fully pronated.

Electrode Insertion (X)

Over the shaft of the radius at mid-forearm. The electrode will travel through the extensor digitorum communis.

Test Maneuver

Radial abduction of the thumb.

Pitfalls

If the electrode is inserted too proximally it will be in the extensor carpi radialis brevis; if inserted too distally it will be in the extensor pollicis brevis; if it is inserted too ulnarly or too superficial, it will be in the extensor digitorum communis.

Comments

- (a) Tendon involved in DeQuervain's stenosing synovitis.
- (b) Involved in posterior interosseus nerve entrapment and more proximal injuries to the radial nerve.
- (c) Tendon runs through the first compartment of the wrist.
- (d) The main function of this muscle is to abduct the 1st metacarpal, by extending the whole thumb and extending the carpal metacarpal joint.
- (e) Its tendon shares the 1st compartment of the dorsum of the wrist with the Extensor Pollicis Brevis forming the volar boundary of the "Snuff Box." At the bottom of the box, the radial artery can be felt, and a possible fracture of the scaphoid bone can be detected.

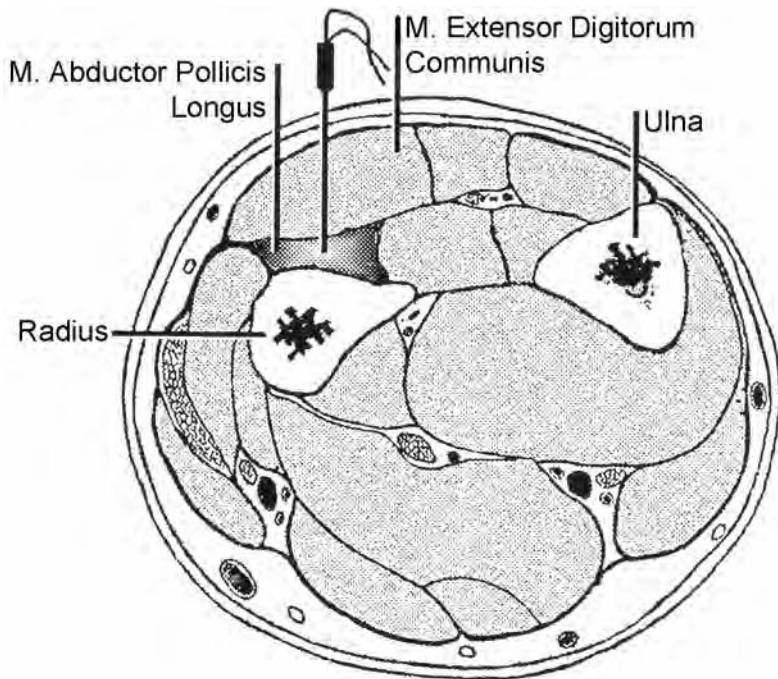


Figure 9. Cross section of the forearm through the mid-third section.

ANCONEUS



Innervation

Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8.

Origin

From the posterior aspect of the lateral epicondyle of the humerus as a continuation of the medial head of the triceps.

Insertion

Lateral aspect of the olecranon process and the proximal portion of the posterior surface of the ulna.

Position

The forearm fully pronated and the elbow at ninety degrees of flexion.

Electrode Insertion (X)

Place the tip of the little finger on the olecranon (O) and ring and middle fingers along with ulna. Insert the electrode just beyond tip of middle finger, radial to the ulna.

Test Maneuver

Extension of the elbow.

Pitfalls

If the needle is inserted too radially it will be in the extensor carpi ulnaris; if inserted too deeply it will be in the supinator.

Comments

This muscle may be considered a continuation of the medial head of the triceps to the lateral epicondyle. It is innervated by a long branch of the radial nerve, which results in its being spared except in very proximal injuries of the radial nerve.

The main function of this muscle is to help the triceps to extend the elbow. It also abducts the ulna during pronation of the forearm and it contracts when the elbow joint needs to be stabilized during flexion.

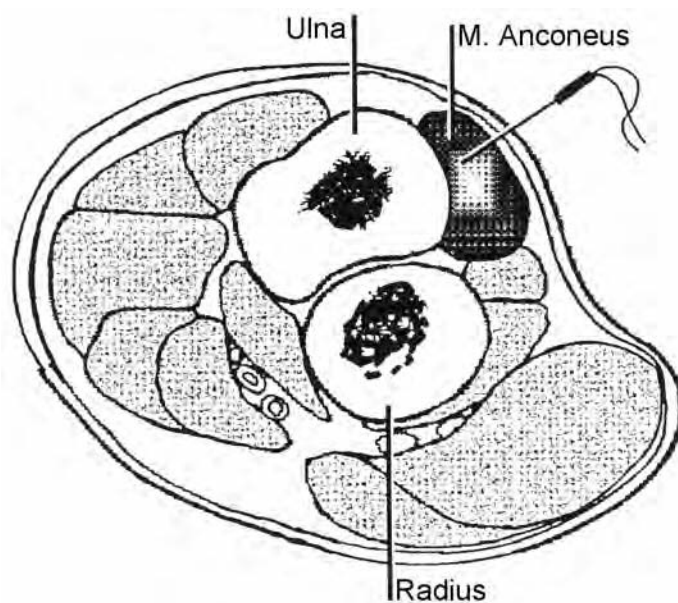
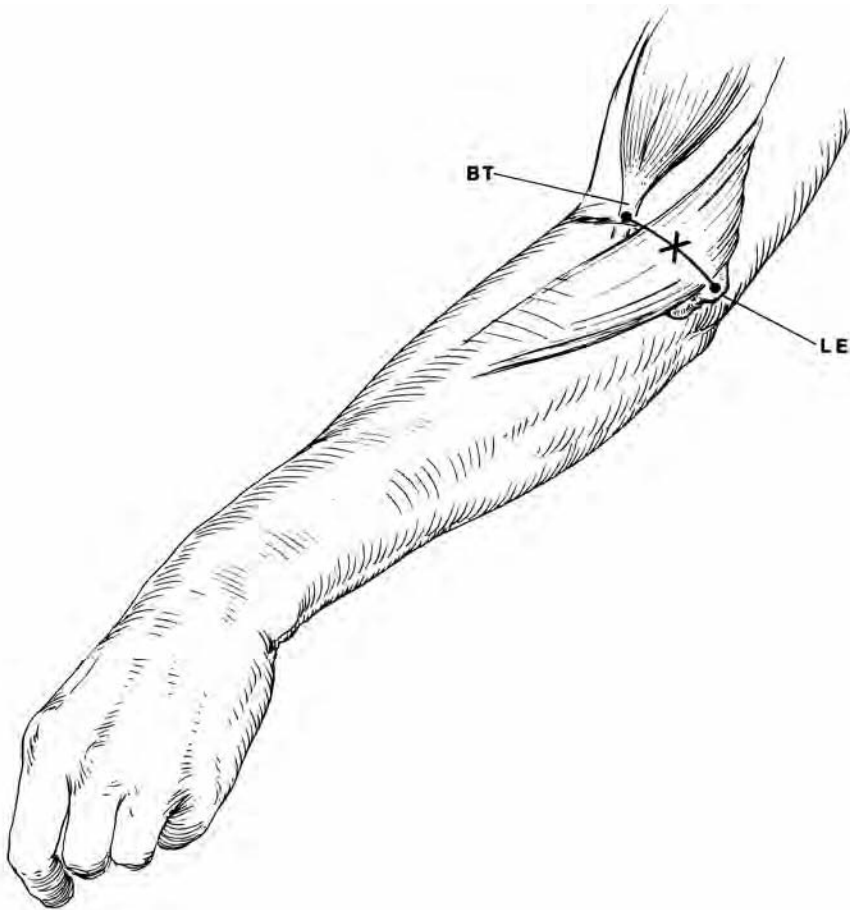


Figure 10. Cross section of the forearm through the distal elbow joint.

BRACHIORADIALIS



Innervation

Radial Nerve, Posterior Cord, Posterior Division, Upper Trunk, C5, C6, C7.

Origin

From the supracondylar area of the lateral aspect of the humerus.

Insertion

Lateral aspect of the radius, just above the styloid process.

Position

Forearm fully pronated.

Electrode Insertion (X)

Midway between biceps tendon (BT) and lateral epicondyle (LE) along flexor crease; insert electrode to a depth of one-half inch.

Test Maneuver

Flexion of the forearm in neutral position.

Pitfalls

If the needle is inserted too laterally it will be in the extensor carpi radialis longus.

Comments

- (a) The only muscle producing flexion of the elbow supplied by radial nerve.
- (b) Can act as supinator or pronator from the extremes of these positions, bringing the forearm into the neutral position.
- (c) The only primary elbow flexor not supplied by the musculocutaneous nerve.
- (d) Paralyzed in radial nerve injuries above or at spiral groove of humerus.
- (e) This muscle forms the lateral boundary of the anticubital fossa.

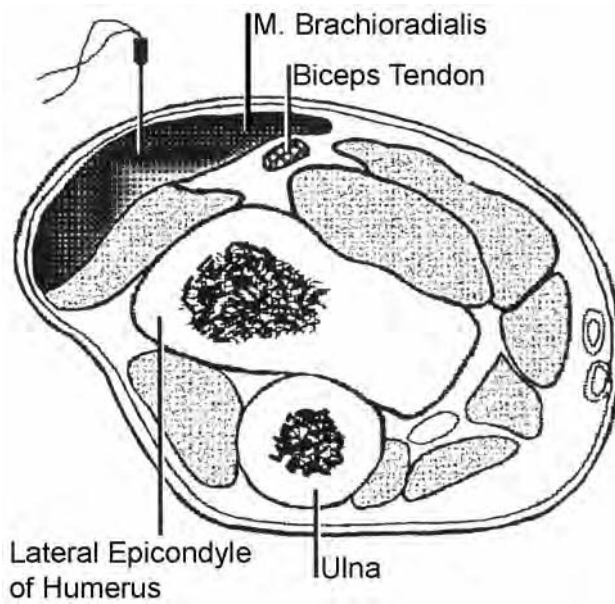
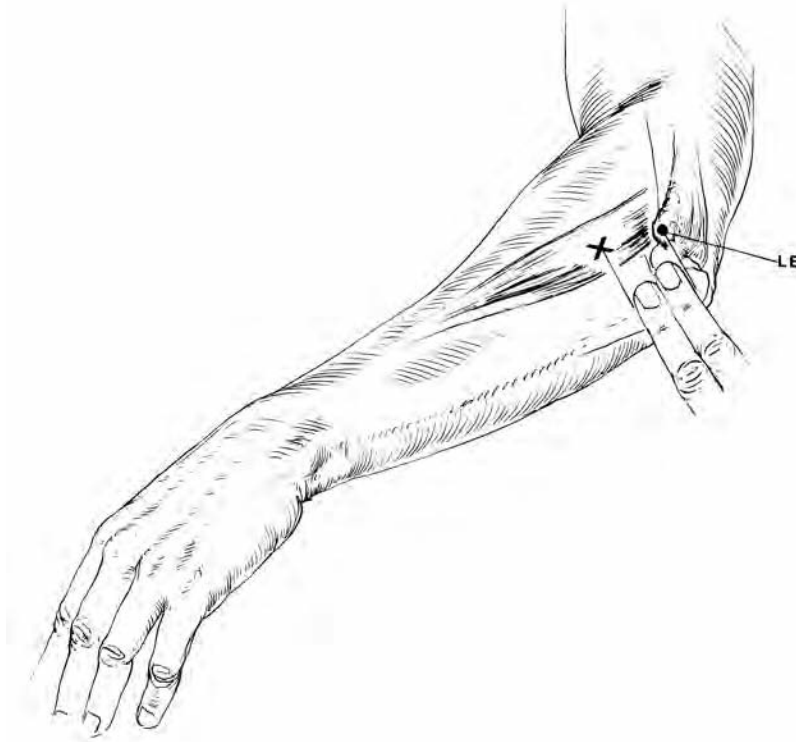


Figure 11. Cross section of the forearm through the midportion of the elbow joint.

EXTENSOR CARPI RADIALIS, LONGUS AND BREVIS*



Innervation

Radial Nerve, Posterior Cord, Posterior Division, Upper and Middle Trunk, C6, C7.

Origin

Longus: The lower third of the supracondylar ridge of humerus.

Brevis: The lateral epicondyle of humerus.

*Because of the close anatomical and functional relationship of these muscles, the authors have found it impossible to develop a technique by which they could place the electrode in one or the other of these muscles with confidence.

Insertion

Longus: Dorsal surface of base of second metacarpal.

Brevis: Dorsal surface of third metacarpal.

Position

Forearm fully pronated.

Electrode Insertion (X)

Insert two fingerbreadths distal to lateral epicondyle (LE).

Test Maneuver

Dorsiflexion of wrist in radial deviation.

Comments

- (a) The tendons of these muscles occupy the second extensor compartment on dorsum of the wrist.
- (b) Usually spared in posterior interosseus syndrome but usually involved in lesions at or, above the spiral groove (of humerus).
- (c) Frequently involved in "Saturday night palsy."
- (d) The main function of this muscle is to extend the wrist in a radial deviation, but in conjunction with the flexor carpi radialis, they radially deviate the hand.
- (e) When these two muscles work in a synergistic way with the extensor carpi ulnaris, they dorsiflex the wrist and allow the fingers to produce a powerful grip.

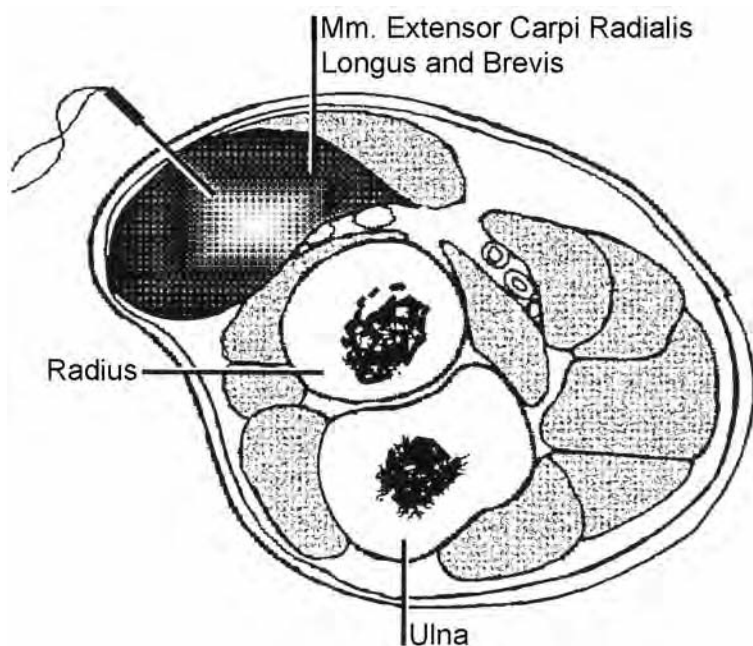
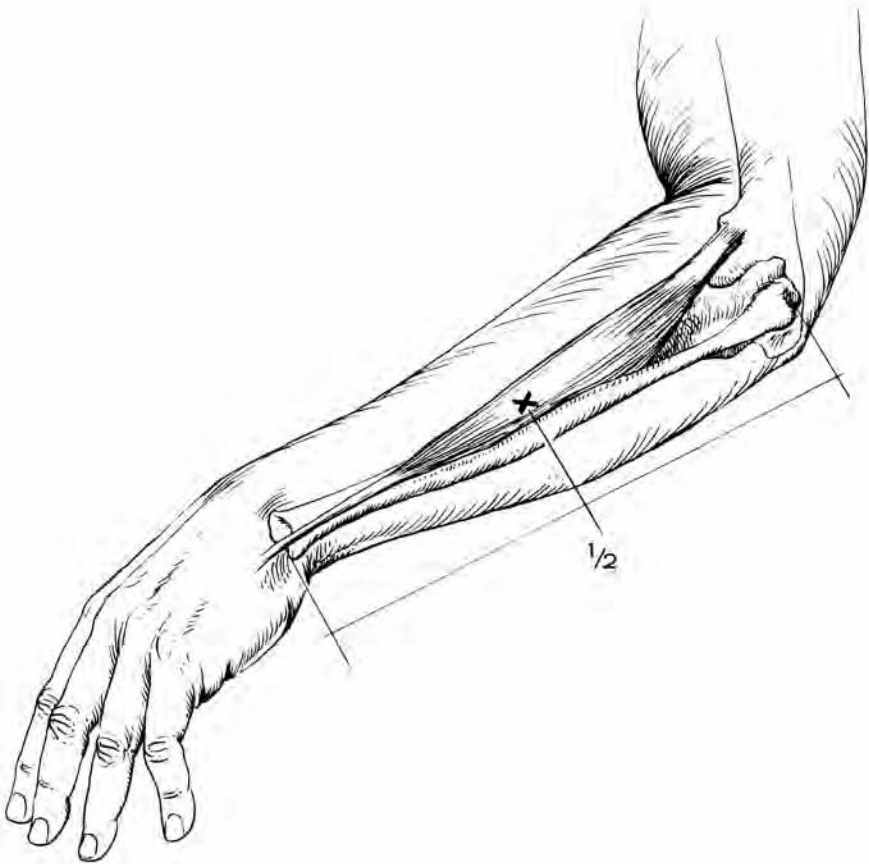


Figure 12. Cross section of the forearm through the distal elbow joint.

EXTENSOR CARPI ULNARIS



Innervation

Posterior Interosseus Nerve, Radial Nerve, Posterior Cord, Posterior Division, Upper, Middle and Lower Trunk, C6, C7, C8.

Origin

Lateral epicondyle of humerus.

Insertion

Dorsal surface of base of fifth metacarpal.

Position

The forearm fully pronated.

Electrode Insertion (X)

Palpate the ulna in middle of forearm and insert needle electrode just above the shaft of ulna.

Test Maneuver

Extend the wrist with ulnar deviation.

Pitfalls

If the needle electrode is inserted too radially it will be in the extensor pollicis longus; and if inserted too proximally it will be in the anconeus.

Comments

- (a) The tendon of this muscle occupies the sixth extensor compartment on dorsum of wrist.
- (b) Involved in posterior interosseus nerve lesions, Saturday night palsy and crutch palsy.
- (c) The main function of this muscle is to dorsiflex the hand in ulnar deviation. When acting together with the extensor carpi radialis (longus and brevis), it dorsiflex the wrist in neutral position. When acting synergistically with the flexor carpi ulnaris, it ulnarly deviates the wrist. In conjunction with the others extensor of the carpo, it supports the wrist for a firm grip.

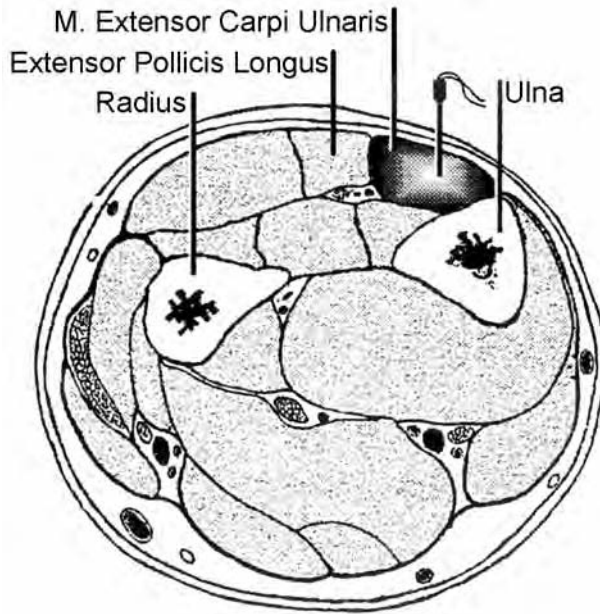
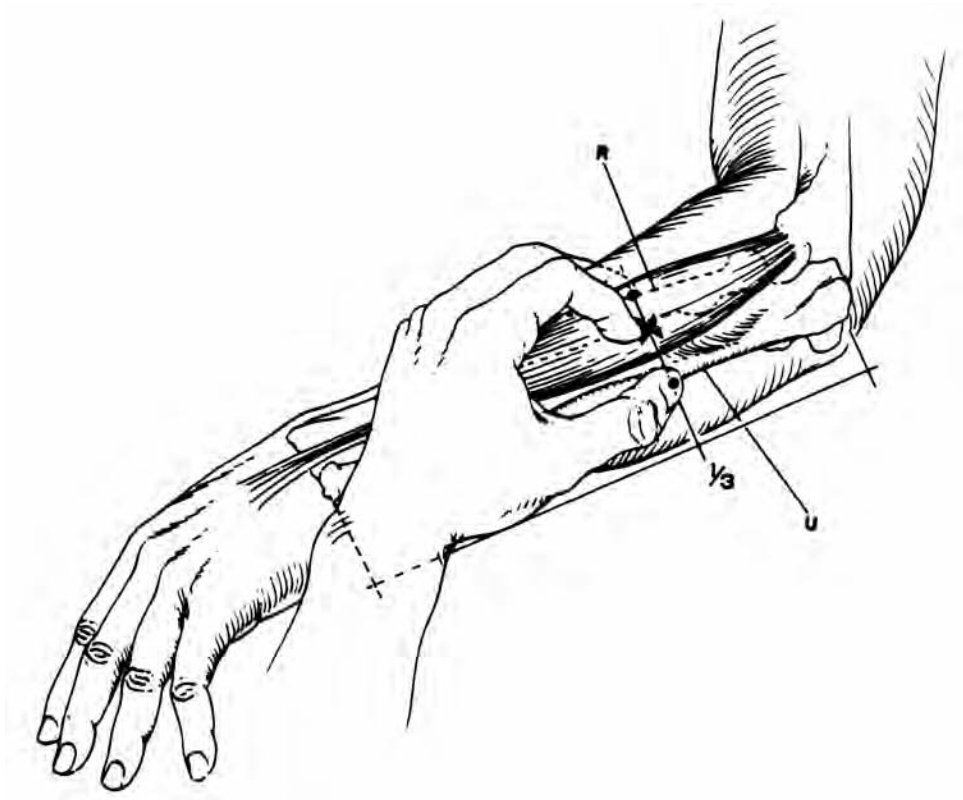


Figure 13. Cross section of the forearm through the mid-third section.

EXTENSOR DIGITORUM COMMUNIS AND EXTENSOR DIGITI MINIMI PROPRIUS*



Innervation

Posterior Interosseus Nerve, Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8.

Origin

Common extensor tendon from the lateral epicondyle of humerus.

*Extensor Digiti Quinti Proprius: Is most frequently a part of the extensor digitorum communis. This muscle lies very close to the extensor digitorum communis but arises from a separate slip and can be found in the mid-forearm on the ulnar border of the extensor digitorum communis.

Insertion

On dorsal surface of base of second to fifth phalanges of fingers.

Position

The forearm fully pronated.

Electrode Insertion (X)

Grasp the forearm at function of upper and middle third with thumb and middle finger on radius (R) and ulna (U). Then with index finger bisect these two points and insert needle electrode at tip of index finger to a depth of one-half inch.

Test Maneuver

Extend metacarpophalangeal joints.

Pitfalls

If the needle electrode is inserted too deeply it will be in the extensor pollicis longus; if inserted too medially it will be in the extensor carpi radialis brevis; if inserted too laterally it will be in the extensor carpi ulnaris.

Comments

- (a) Involved in posterior interosseus and more proximal radial nerve lesion.
- (b) The tendon of the extensor digitorum communis occupies the fourth extensor compartment on the dorsum of the wrist while the tendon of the extensor digiti minimi proprius goes throughout the fifth compartment.
- (c) Involved in lesions of posterior interosseus nerve lesions, "Saturday night" palsy and crutch paralysis.
- (d) The main function of this muscle is to extend the M.P. joints of the medial 4 digits. Through collateral reinforcement originated from the lumbricals and the interosseus muscles, they can also extend the middle and the distal phalanx, although weakly.

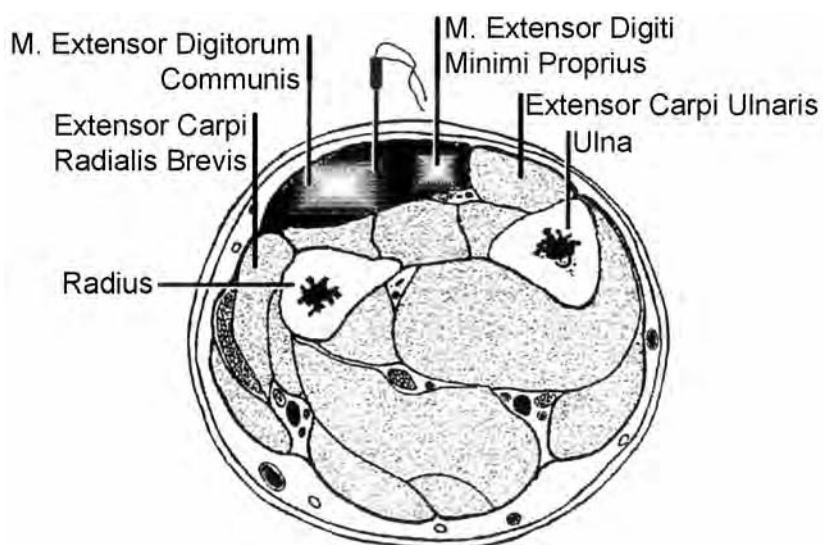
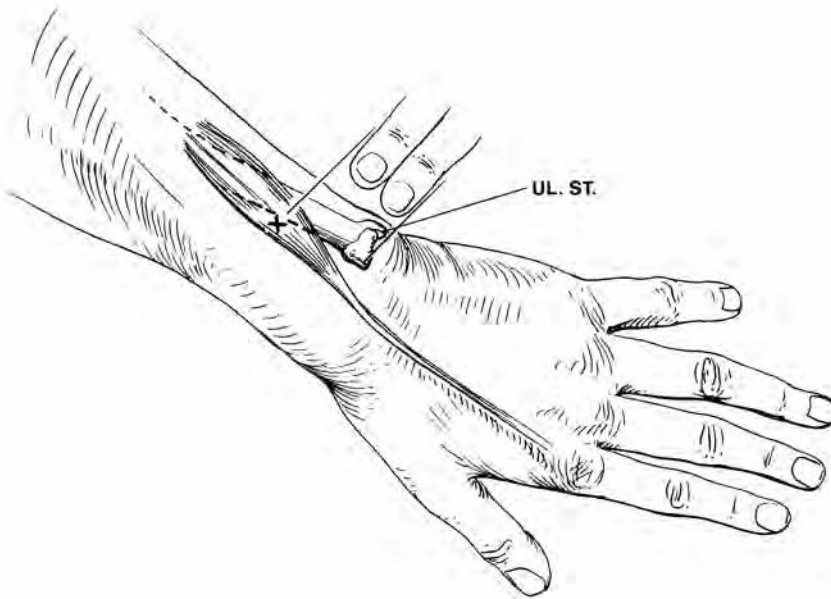


Figure 14. Cross section of the forearm through the mid-third section.

EXTENSOR INDICIS PROPRIUS



Innervation

Posterior Interosseus Nerve, Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8.

Origin

Dorsal surface of lower half of ulnar shaft below the origin of the extensor pollicis longus.

Insertion

Joins ulnar side of tendon of extensor digitorum communis, which goes to index finger; terminates in extensor expansion.

Position

The forearm fully pronated.

Electrode Insertion (X)

Two fingerbreadths proximal to ulnar styloid (UL.ST.) just radial to ulnar at a depth of one-half inch.

Test Maneuver

Extend finger with flexion of other fingers.

Pitfalls

If needle electrode is inserted too radially it will be in the abductor pollicis longus; if inserted too proximally it will be in the extensor digitorum communis.

Comments

- (a) Usually it is the most distal radial nerve innervated muscle (at times the extensor pollicis longus occupies this position).
- (b) Tendon occupies the fourth compartment on dorsum of wrist with extensor digitorum communis.
- (c) Used as recording muscle in radial nerve motor conduction studies.
- (d) Involved in posterior interosseus and more proximal radial nerve injuries ("Saturday night" palsy and crutch palsy).
- (e) This muscle acting in conjunction with the extensor digitorum, extends the index finger at the M.P joint and at the proximal interphalangeal joint. It can work in an isolated fashion, as when the hand is kept in a fist and the index finger is pointing.

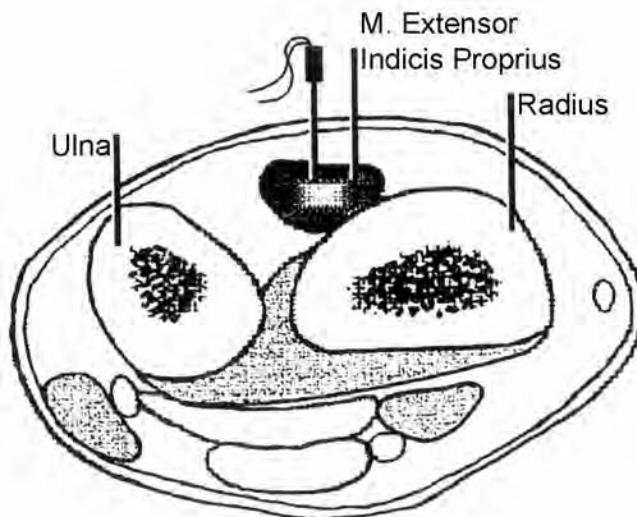
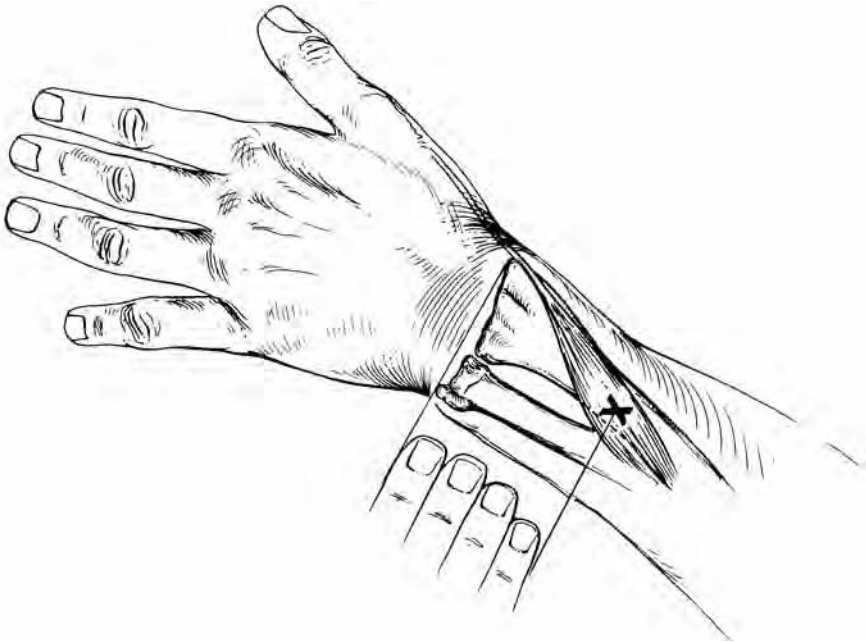


Figure 15. Cross section of the forearm through the distal third.

EXTENSOR POLLICIS BREVIS



Innervation

Posterior Interosseus, Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8.

Origin

Dorsal surface of radial shaft below abductor pollicis longus and in the interosseus membrane.

Insertion

The dorsal aspect of the first phalanx of thumb.

Position

The forearm fully pronated.

Electrode Insertion (X)

Insert needle electrode directly over the ulnar side of radius, four fingerbreadths proximal to wrist. The electrode will travel through the extensor digitorum communis.

Test Maneuver

Extend proximal phalanx of thumb.

Pitfalls

If the needle electrode is inserted too proximally it will be in the abductor pollicis longus.

Comments

- (a) Tendon runs through the first compartment on dorsum of wrist. Distal to this compartment, the tendon forms the radial border of the anatomical "Snuffbox."
- (b) Most distal muscle innervated by radial nerve through posterior interosseus branch.
- (c) Involved in lesions of posterior interosseus and more proximal radial nerve lesions.
- (d) This muscle besides extending the proximal phalanx of the thumb, it may also extend the metacarpal bone of the thumb if its action continues. If its action continues even further, it may help in extending and abducting the hand.

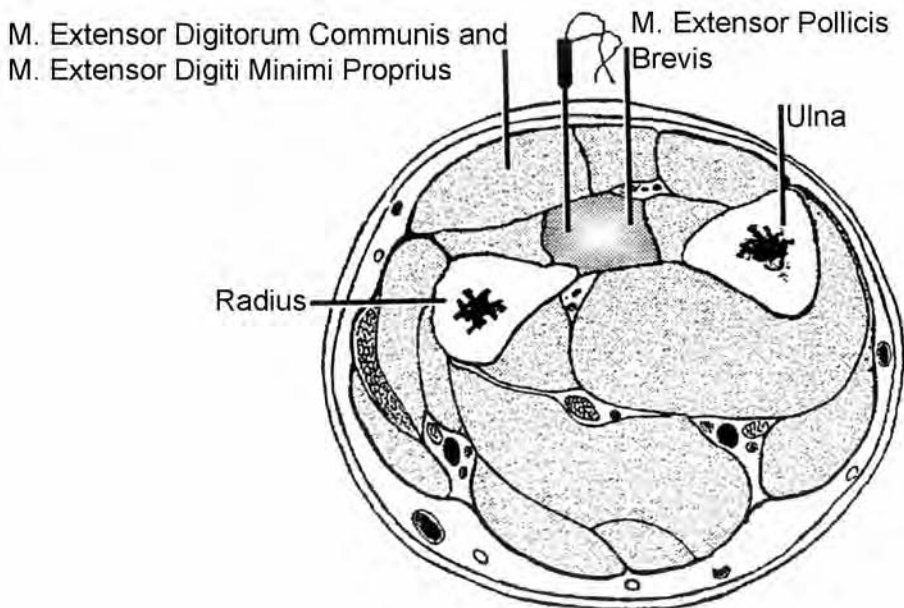
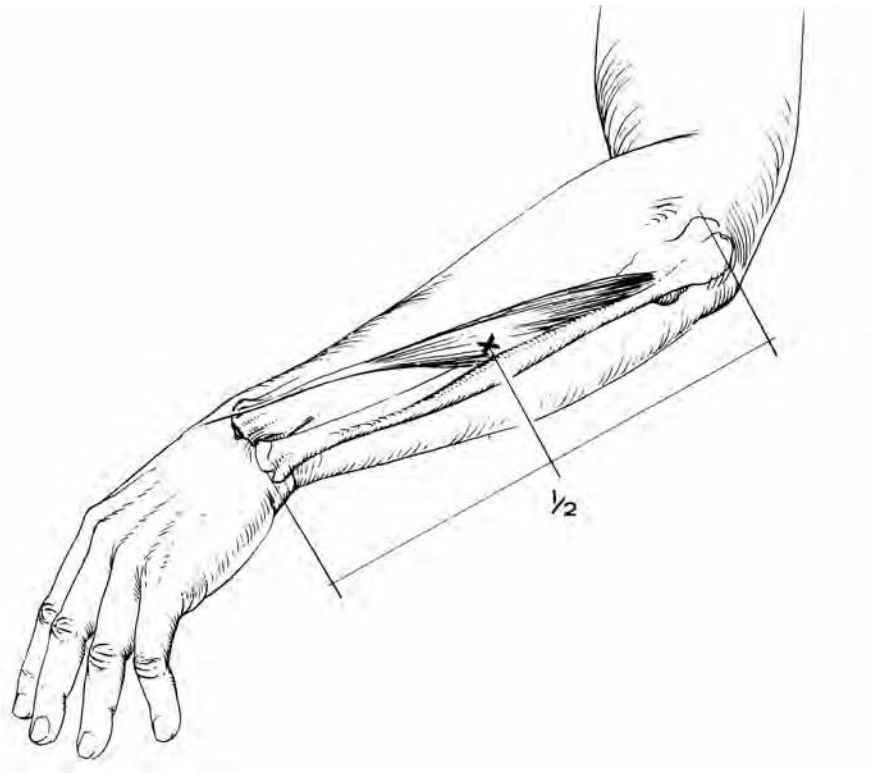


Figure 16. Cross section of the forearm through the proximal end of the distal third.

EXTENSOR POLLICIS LONGUS



Innervation

Posterior Interosseus Nerve, Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8.

Origin

The dorsal surface of the middle third of ulnar shaft below the abductor pollicis longus.

Insertion

The dorsal aspect of base of terminal phalanx of thumb.

Position

The forearm fully pronated.

Electrode Insertion (X)

At mid-forearm insert needle electrode along radial border of ulnar. The electrode will travel through the extensor carpa ulnaris.

Test Maneuver

Extend distal phalanx of thumb.

Pitfalls

If the needle electrode is inserted too ulnarly it will be in the extensor digitorum communis; if inserted too proximally it will be in the abductor pollicis longus.

Comments

- (a) Involved in posterior interosseus and more proximal radial nerve lesions.
- (b) When paralyzed, the flexor pollicis brevis may extend terminal phalanx weakly and give false impression of intact extensor pollicis longus.
- (c) The tendon of this muscle occupies the third extensor compartment on the dorsum of the wrist. Distal to this compartment the tendon forms the ulnar border of the "Snuffbox."
- (d) This muscle, besides extending the distal phalanx of the thumb, it extends also the metacarpal-phalangeal and the carpo-metacarpal joints of the thumb. It helps also in abducting the hand.

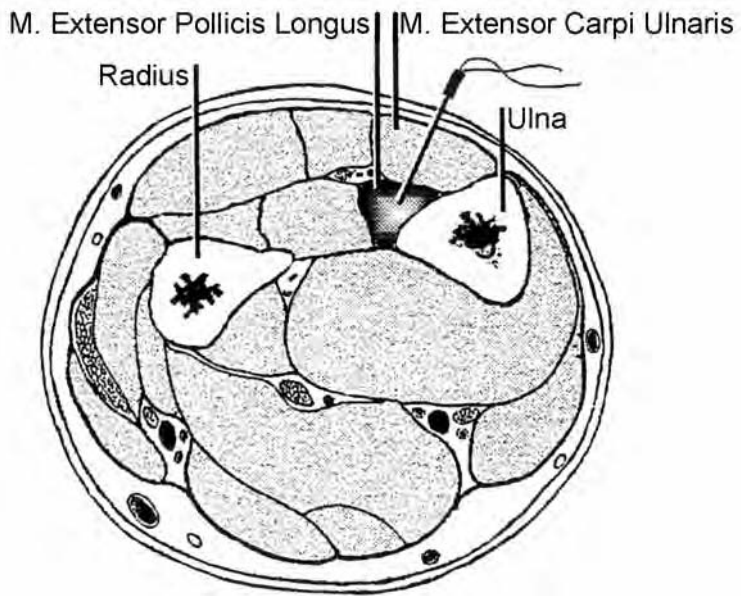
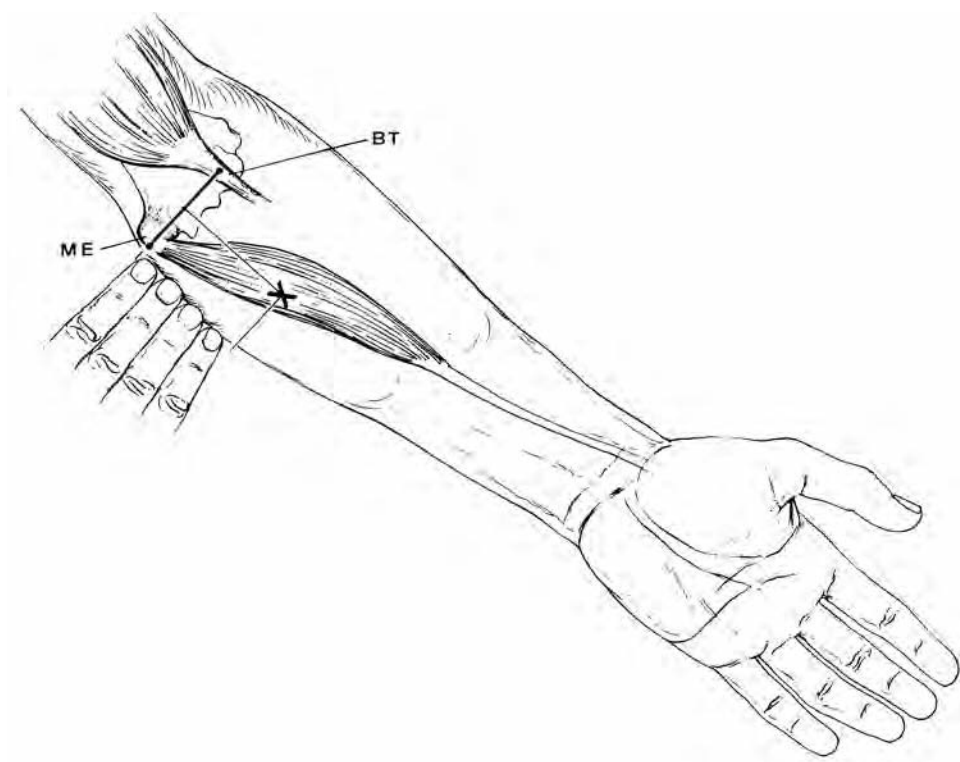


Figure 17. Cross section of the forearm through the distal middle third.

FLEXOR CARPI RADIALIS



Innervation

Median Nerve, Lateral and Medial Cord, Anterior, Divisions, Upper, Middle and Lower Trunk, C6, C7, C8.

Origin

Common tendon from medial epicondyle of humerus.

Insertion

Volar surface of base of second metacarpal.

Position

The forearm fully supinated.

Electrode Insertion (X)

Three to four fingerbreadths distal to the midpoint of a line connecting the medial epicondyle (ME) and biceps tendon (BT).

Test Maneuver

Flexion of wrist with radial deviation.

Pitfalls

If the needle electrode is inserted too deeply it will be in the flexor digitorum sublimus; if deeper it will be in the flexor pollicis longus. If inserted too laterally it will be in the pronator teres, and if inserted too medially it will be in the palmaris longus.

Comments

- (a) The median nerve runs just ulnar to its tendon as it crosses the volar aspect of the wrist.
- (b) Together with the flexor pollicis longus and the radial artery they form the “Radial Trio.”
- (c) The tendinous portion of this muscle at the level of the wrist is a good guide to identify the radial artery pulse, which is located lateral to the tendon.
- (d) This muscle not only flexes the wrist, but also radially deviates it (abduct) when working in conjunction with the extensor carpi radialis.

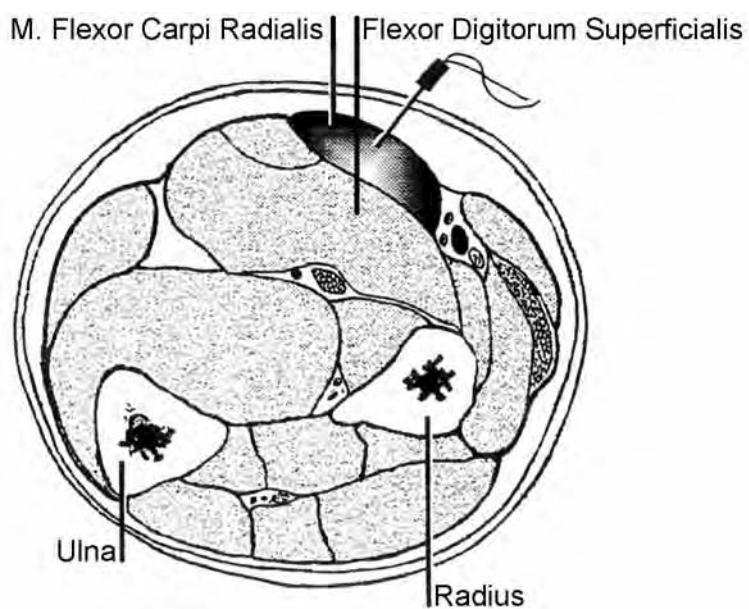
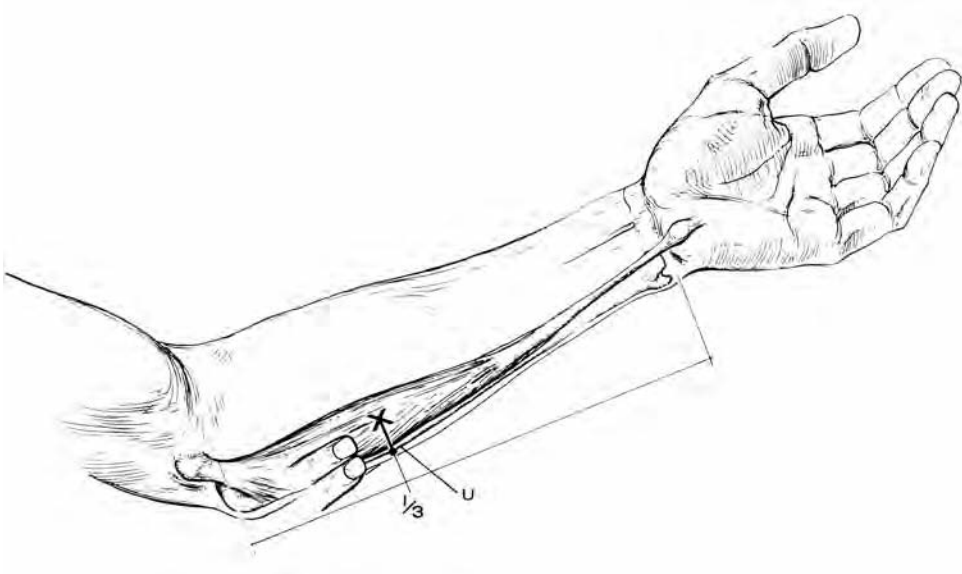


Figure 18. Cross section of the forearm through the middle third.

FLEXOR CARPI ULNARIS



Innervation

Ulnar Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, T1.

Origin

Common tendon from medial epicondyle of humerus, medial margin of olecranon, coronoid process, and upper two-thirds of the dorsal border of ulna.

Insertion

Volar surface of pisiform, hamate and fifth metacarpal.

Position

The forearm fully supinated.

Electrode Insertion (X)

Two fingerbreadths volar to ulna (U) at the junction of the upper and middle thirds of the forearm.

Test Maneuver

Flexion of the wrist with ulnar deviation.

Pitfalls

If the needle electrode is inserted too deeply it will be in the flexor digitorum profundus.

Comments

- (a) The ulnar nerve is located just radial to the flexor carpi ulnaris tendon at the wrist.
- (b) Involved in lesions of ulnar nerve at or above ulnar groove.
- (c) Together with the ulnar nerve and the ulnar artery they form the “ulnar trio.”
- (d) The main function of this muscle is to flex and ulnarly deviate the wrist.
- (e) It also has an important function working together with the abductor digiti minimi in an action call “digastric.” This function is described as the contraction of the flexor carpi ulnaris when the abductor digiti minimi contracts to abduct the 5th digit. This contraction is necessary in order to stabilize the pisiform bone and allow the A.D.M. to produce a strong contraction.
- (f) Paralysis of this muscle produces a significant decrease of the strength of the Abductor Digiti Minimi muscle and therefore the function of the hypothenar group of muscle is altered (the patient can produce a weak “cup” with his hand).

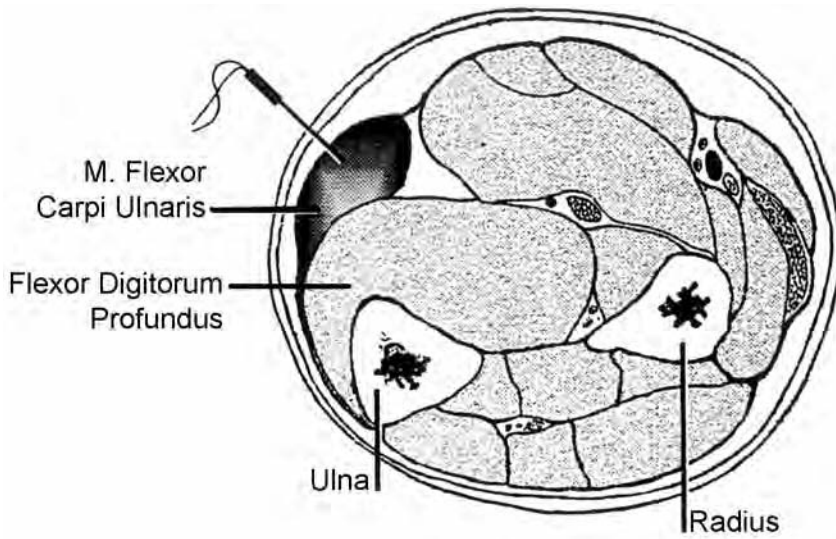


Figure 19. Cross section of the forearm through the middle third.

FLEXOR DIGITORUM PROFUNDUS



Innervation

Digits Two and Three: Anterior Interosseus Nerve, Median Nerve, Medial Cord, Anterior Division, Middle and Lower Trunk, C7, C8.

Digits Four and Five: Ulnar Nerve, Medial Cord, Anterior Division, Lower Trunk, C8, 11.

Origin

Upper three-fourths of volar and medial surfaces of ulna and interosseus membrane.

Insertion

Volar surfaces of bases of distal phalanges of four fingers.

Position

The forearm fully supinated.

Electrode Insertion (X)

Place tip of little finger on olecranon (O) and ring, middle and index fingers along shaft of ulna. Insert needle electrode just beyond tip of index finger just ulnarly to shaft. The ulnar innervated portion is the more superficial (1–2 cm), while the median innervated portion is deeper (3–5 cm).

Test Maneuver

Flexion of distal phalanges of digits.

Pitfalls

If the needle electrode is inserted too volarly it will be in the flexor carpi ulnaris.

Comments

- (a) The four tendons run across the wrist resting on the pronator quadratus. They are deep to the flexor sublimis tendon and the median nerve.
- (b) The two median innervated heads are involved in anterior interosseus nerve lesions, pronator teres muscle and ligament of Struther entrapments manifested by weakness or inability to flex the terminal phalanges of second and third digits.
- (c) The two ulnar innervated heads are involved in cubital tunnel entrapment and higher ulnar, medial cord and C8, T1 lesions. This is manifested by weakness or inability to flex the fourth and fifth terminal phalanges.
- (d) This is the only muscle that can flex the distal interphalangeal joints of all fingers, after the flexor digitorum Superficialis has flexed the proximal interphalangeal joints. This muscle can also flex the metacarpal-phalangeal joints and the wrist joint (rolls-up the fingers and hand).
- (e) The tendon for the index finger separates from the main belly of the muscle early in the distal part of the forearm, and joining the

other flexor tendons they reach their respective digit after traveling the carpal tunnel area.

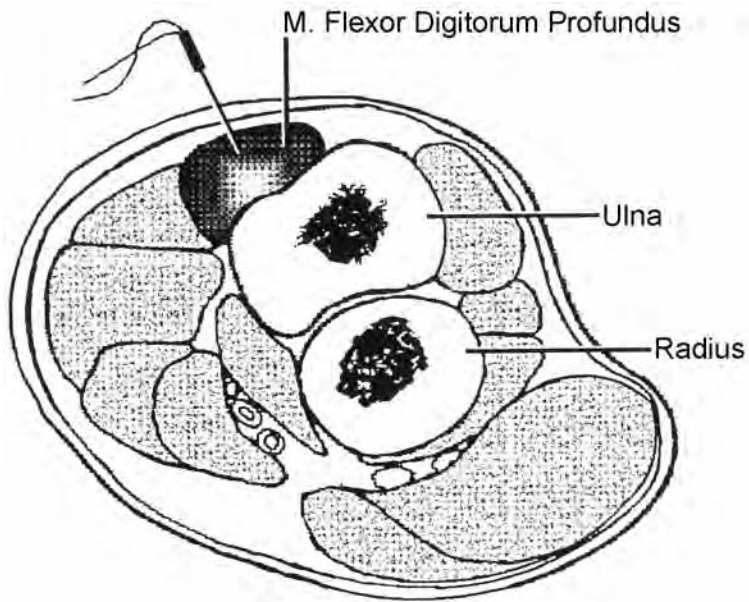
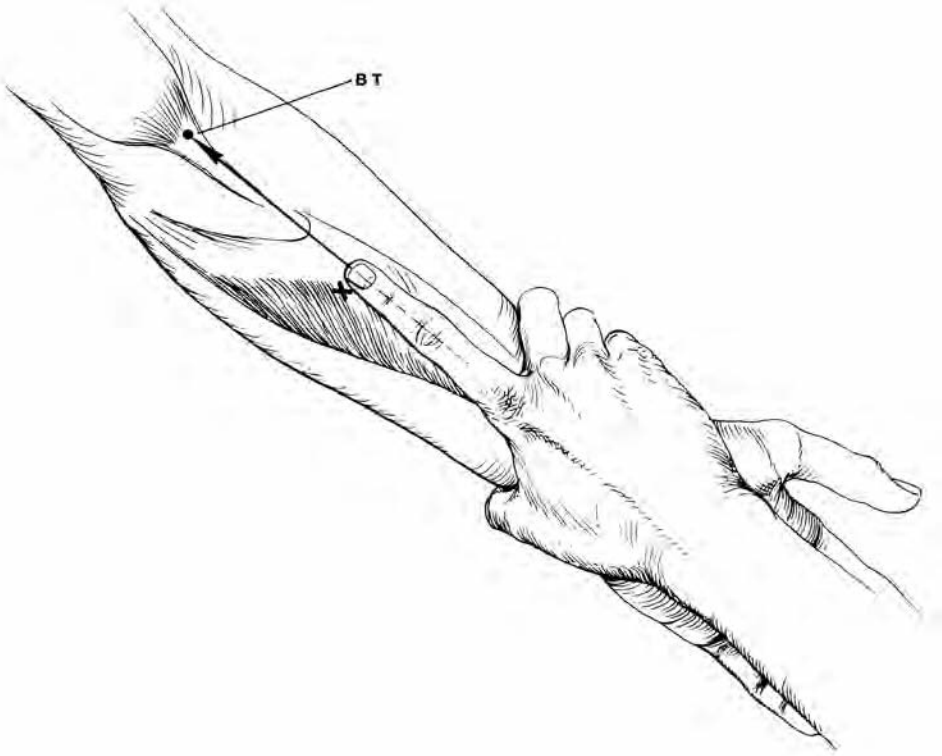


Figure 20. Cross section of the forearm through the middle third.

FLEXOR DIGITORUM SUPERFICIALIS



Innervation

Median Nerve, Lateral and Medial Cord, Anterior Division, Middle and *Lower Trunk*, C7, C8, T1.

Origin

Common tendon from medial epicondyle of humerus, coronoid process of ulna and oblique line of radius.

Insertion

All these tendons insert in the volar surface of the 2nd phalanx. Before inserting in the phalanx, the tendon split in two bands to allow the flexor digitorum profundus tendon to go through and to reach the proximal end of the distal phalanx.

Position

The forearm fully supinated.

Electrode Insertion (X)

Grasp with operator's palm to volar surface of subject's wrist. Point index finger to biceps tendon (BT) and insert needle electrode just ulnarly to tip of index finger. The electrode will travel through the palmaris longus.

Test Maneuver

With the distal interphalangeal joints of three digits maintained in hyper extension, the patient is asked to flex the proximal interphalangeal joint of the free finger.

Pitfalls

If the needle electrode is inserted too radially it will be in the flexor carpi radialis; if inserted too ulnarly it will be in the flexor digitorum profundus; if too distally it will be in the tendon of the flexor carpi radialis longus.

Comments

- (a) The four tendons run across the wrist in pairs: the tendons for the middle and ring fingers are the most superficial, those to the ring and little finger are deeper resting on the flexor digitorum profundus tendons. The medial nerve lies radial to these tendons as it enters the carpal tunnel.
- (b) Involved in median nerve entrapments (pronator teres; ligament of Struther) and higher median nerve lesions.
- (c) The main function of this muscle is to flex the proximal interphalangeal joint. With strong contraction it may also flex the metacarpal-phalangeal joint. As explained in the test maneuver, the 3 fingers which are not tested should be kept in full extension to eliminate the flexor digitorum profundus, which can do the flexing of the proximal interphalangeal joint very easily.

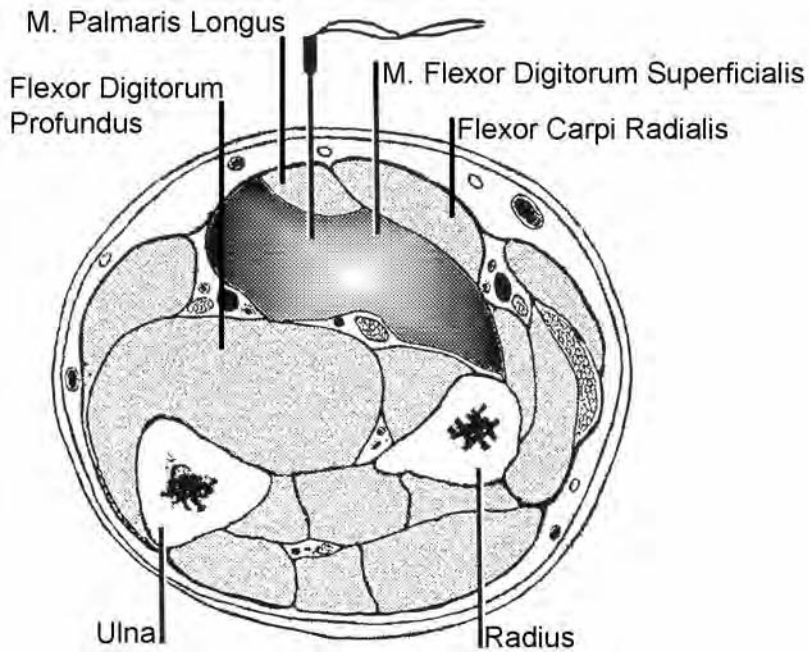
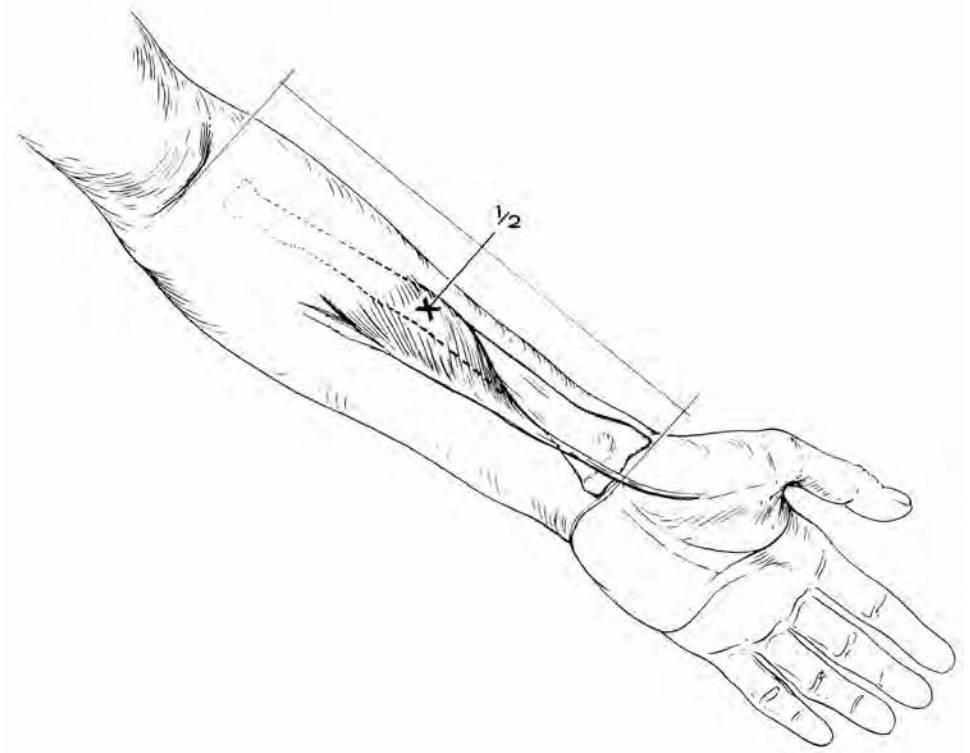


Figure 21. Cross section of the forearm through the middle third.

FLEXOR POLLICIS LONGUS



Innervation

Anterior Interosseus Nerve, Median Nerve, Lateral and Medial Cords, Anterior Divisions, Middle and Lower Trunks, C7, C8, T1.

Origin

The volar surface of the body of the radius from the bicipital tuberosity to the attachment of the pronator quadratus and interosseus membrane.

Insertion

Volar surface of base of distal phalanx of thumb.

Position

The forearm fully supinated.

Electrode Insertion (X)

In the middle of the forearm the needle electrode is inserted from the radial aspect just volar to the radius. The electrode will travel through the flexor carpi radialis and the flexor digitorum superficialis.

Test Maneuver

Flexion of the distal phalanx of thumb.

Pitfalls

If the needle electrode is inserted too superficially it will be in the flexor digitorum sublimis.

Comments

- (a) The tendon of this muscle runs deep across the wrist, radial to the flexor digitorum profundus. With the flexor carpi radialis tendon and the radial artery, it forms the “Radial Trio.”
- (b) In patients with ulnar nerve lesions with paralysis of adductor pollicis, the flexor pollicis longus is brought in, producing flexion of the terminal phalanx of the thumb (Froment’s “signe de journal”).
- (c) Involved in anterior interosseus, pronator teres and ligament of Struther entrapments.
- (d) The main function of this muscle is to flex the distal phalanx of the thumb. No other muscle can do this function. As a secondary function, it flexes the metacarpal phalangeal joint and adducts the metacarpal bone.

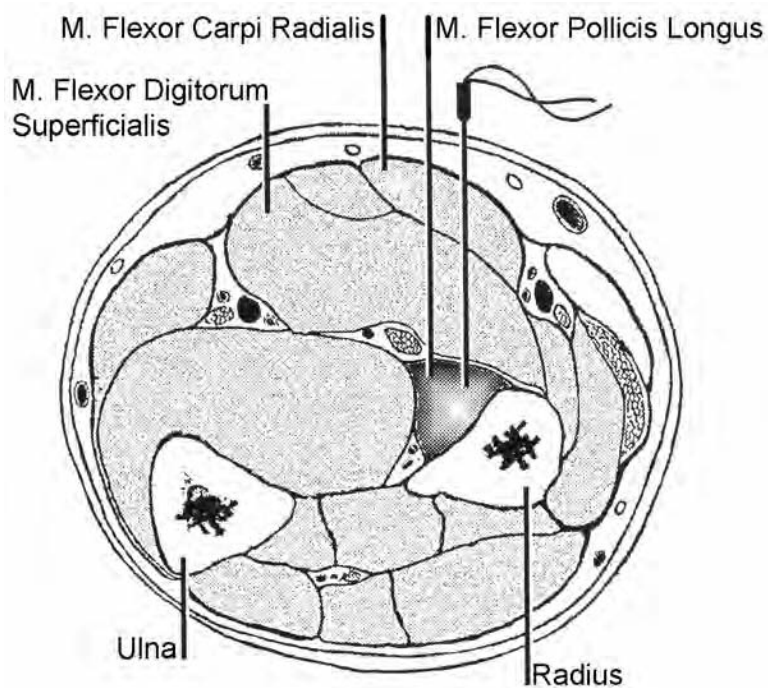
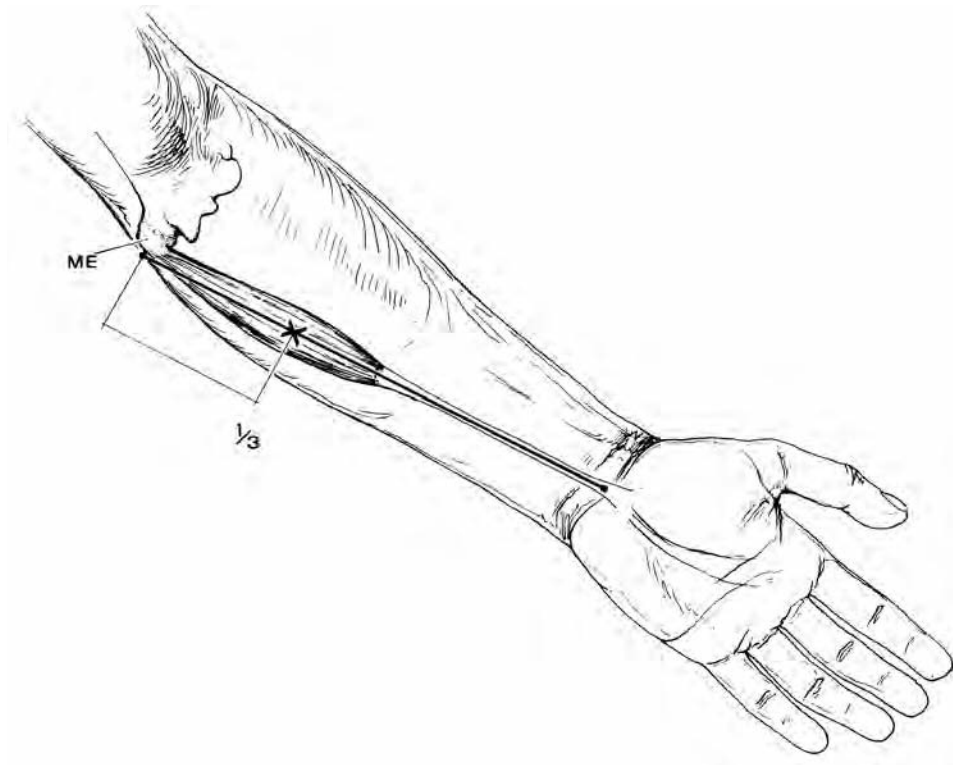


Figure 22. Cross section of the forearm through the middle third.

PALMARIS LONGUS



Innervation

Median Nerve, Lateral and Medial Cord, Anterior Division, Middle and *Lower* Cord, C7, C8, XL.

Origin

The medial epicondyle of humerus.

Insertion

The palmar aponeurosis and flexor retinaculum.

Position

The forearm fully supinated.

Electrode Insertion (X)

At the junction of the upper and middle thirds of a line joining the medial epicondyle (ME) and middle of volar surface of wrist.

Test Maneuver

To cap the palm of the hand.

Pitfalls

If the needle electrode is inserted too medially it will be in the flexor carpi ulnaris; if inserted too radially it will be in the flexor carpi radialis, and if inserted too deeply it will be in the flexor digitorum sublimus.

Comments

- (a) Absent in 10 to 15 percent of individuals.
- (b) Only flexor tendon superficial to the volar carpal ligament.
- (c) Involved in median nerve entrapment syndromes (pronator teres, ligament of Struther).
- (d) In the evolutionary process, this muscle seems to have been relegated to the role of protector of the palmar nerves and vessels through the palmar aponeurosis.
- (e) Its main function is to flex the wrist. When making a fist, it helps to stabilize the wrist and tighten the palmar aponeurosis.
- (f) The tendon of this muscle is a good guide to localize the Median nerve, which is running lateral to it at the wrist level.

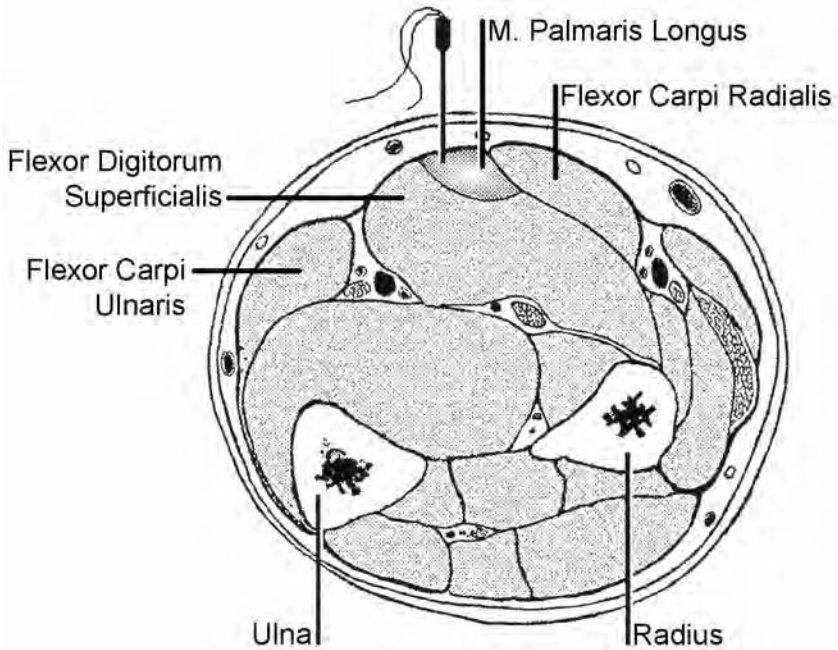
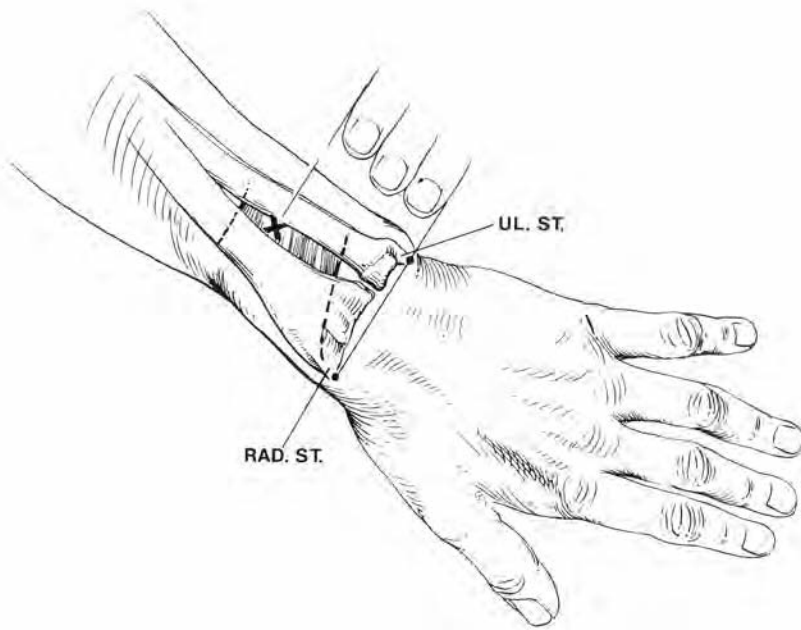


Figure 23. Cross section of the forearm through the middle third.

PRONATOR QUADRATUS



Innervation

Anterior Interosseus Nerve, Median Nerve, Lateral and Medial cords, Anterior Divisions, Middle and Lower Trunks, C7, C8, T1.

Origin

Lower fourth of volar surface of ulna.

Insertion

Lower fourth of lateral border and volar surface of shaft of radius.

Position

The forearm fully pronated.

Electrode Insertion (X)

Three fingerbreadths proximal to midpoint of a line connecting the radial (RAD.ST.) and ulnar styloids (UL.ST.); insert needle electrode

through the interosseus membrane to a depth of approximately three-quarter inches.

Test Maneuver

Pronation of forearm.

Pitfalls

If the needle electrode is inserted too deeply, it will be in the flexor digitorum sublimis.

Comments

- (a) The most distal muscle innervated by the anterior interosseus nerve.
- (b) Involved in median nerve entrapment syndromes (anterior interosseus, pronator teres; ligament of Struther).
- (c) Of the two pronators, this is the weaker of the two. The deep muscle fibers act as a binder between the radius and the ulna.

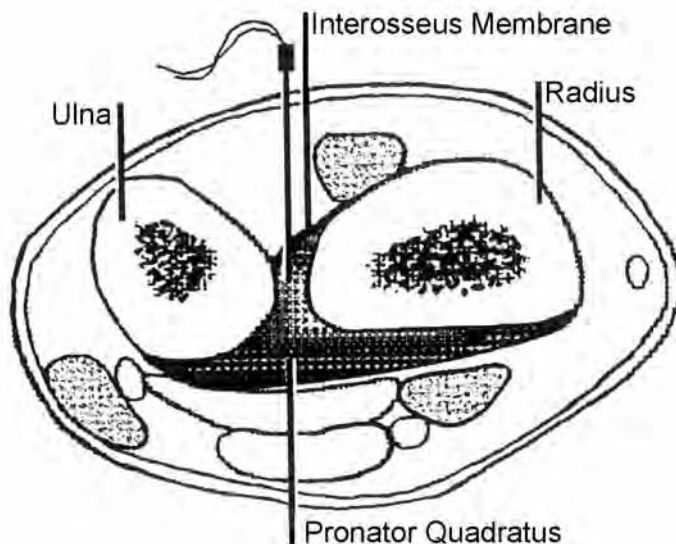
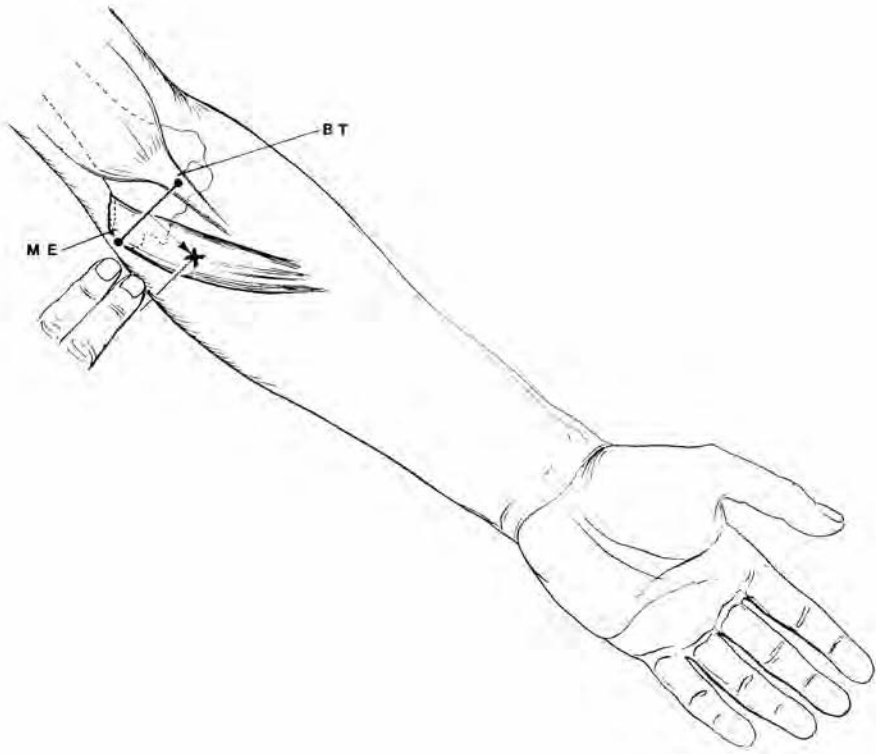


Figure 24. Cross section of the forearm through the distal radio-ulnar joint.

PRONATOR TERES



Innervation

Median Nerve, Lateral Cord, Anterior Division, Upper and *Middle* Trunk, C6, C7.

Origin

This muscle has two heads of origins: (a) from the medial epicondyle of the humerus and (b) the coronoid process of the ulna. The median nerve enters the forearm between these two heads.

Insertion

Lateral surface of radius at mid-shaft.

Position

The forearm fully supinated.

Electrode Insertion (X)

Two fingerbreadths distal to the midpoint of a line connecting the medial epicondyle (ME) and biceps tendon (BT).

Test Maneuver

Pronation of forearm.

Pitfalls

If the needle electrode is inserted too deeply it will be in the flexor pollicis longus; if inserted too ulnarly it will be in the flexor carpi radialis.

Comments

- (a) The most proximal muscle innervated by the median nerve.
- (b) Common site of entrapment as it is pierced by the median nerve.
- (c) May or may not be involved in pronator teres syndrome depending on whether the nerve to the pronator muscle branches proximal to or within the muscle itself.
- (d) Also involved in entrapment at the ligament of Struther.
- (e) Of the two pronators, this is the most powerful.
- (f) Its main function is to flex and pronate the forearm.

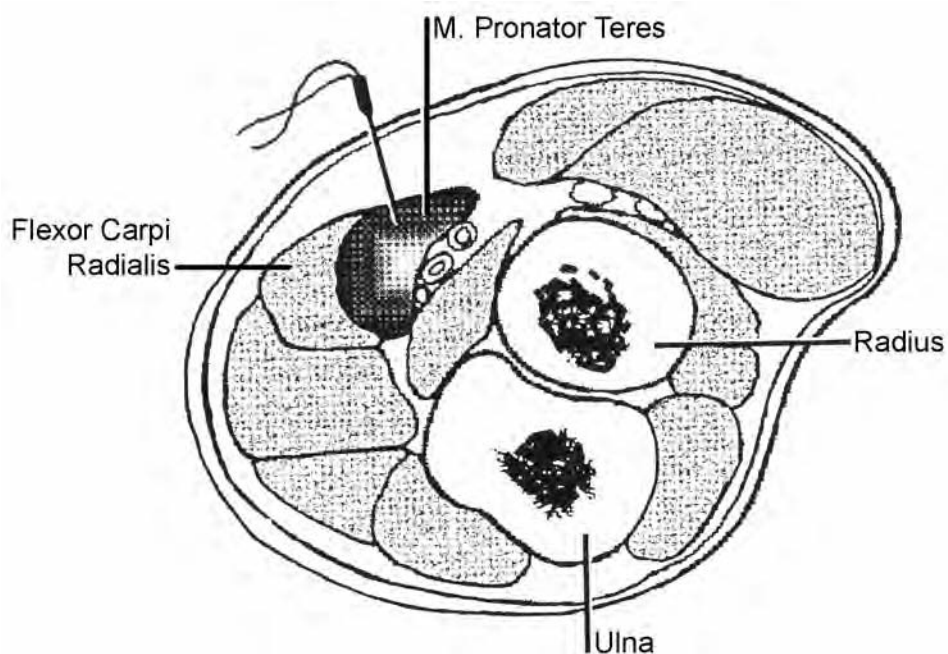
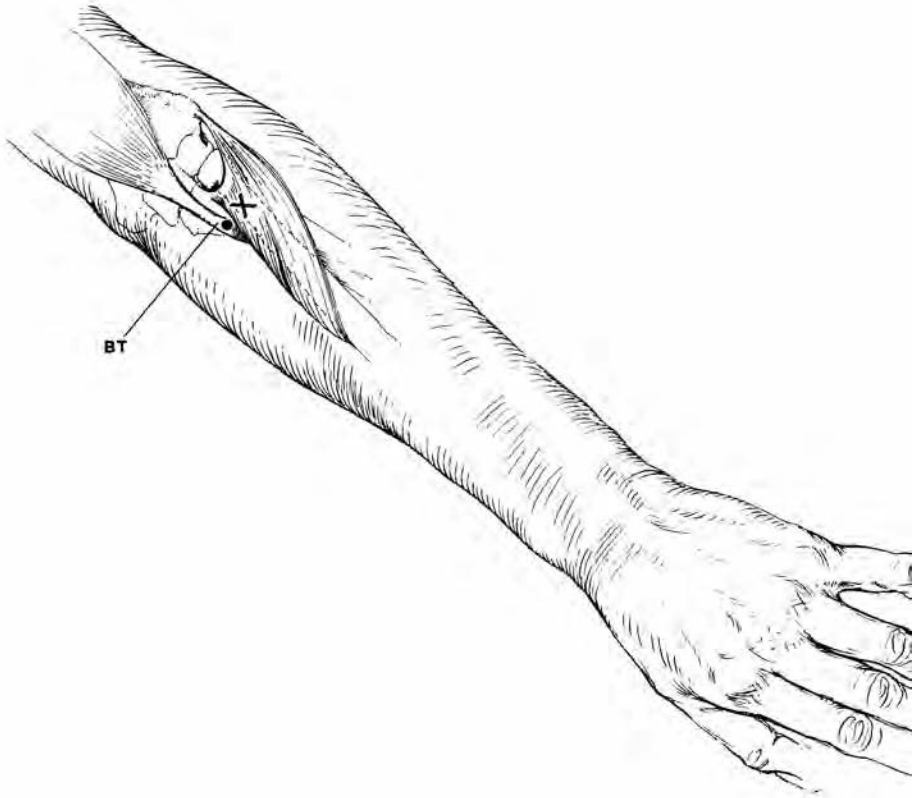


Figure 25. Cross section of the forearm through distal end of the proximal radio-ulnar joint.

SUPINATOR



Innervation

Posterior Interosseus Nerve, Radial Nerve, Posterior Cord, Posterior Division, Upper Trunk, C5, C6.

Origin

Lateral epicondyle of humerus, radial collateral ligament of elbow, supinator crest of ulna.

Insertion

Dorsal and lateral surfaces of upper third of radial shaft.

Position

The forearm fully pronated.

Electrode Insertion (X)

Just radial to the most distal part of insertion of the biceps tendon (BT). The electrode will travel through the extensor digitorum communis.

Test Maneuver

Supination of forearm.

Pitfalls

If needle electrode is inserted too laterally it will be in the brachioradialis. There is danger of puncturing the radial artery.

Comments

- (a) The posterior interosseus nerve passes through an aponeurotic arch (the Arcade of Frohse) between the two heads of this muscle. When this becomes thickened and tight, it might entrap the nerve.
- (b) This muscle supinates the forearm by rotating the radial bone and turning the palm volarly. This muscle is much more powerful than the pronators. Tools, such as screwdrivers, corkscrews, and others, are built for right-handed people that can use their right forearm in all its power through the supinator muscle. For the left-handed person, similar jobs become more difficult.
- (c) This muscle gets involved in radial nerve lesions which occur above the elbow or in elbow traumas involving the posterior interosseus nerve.

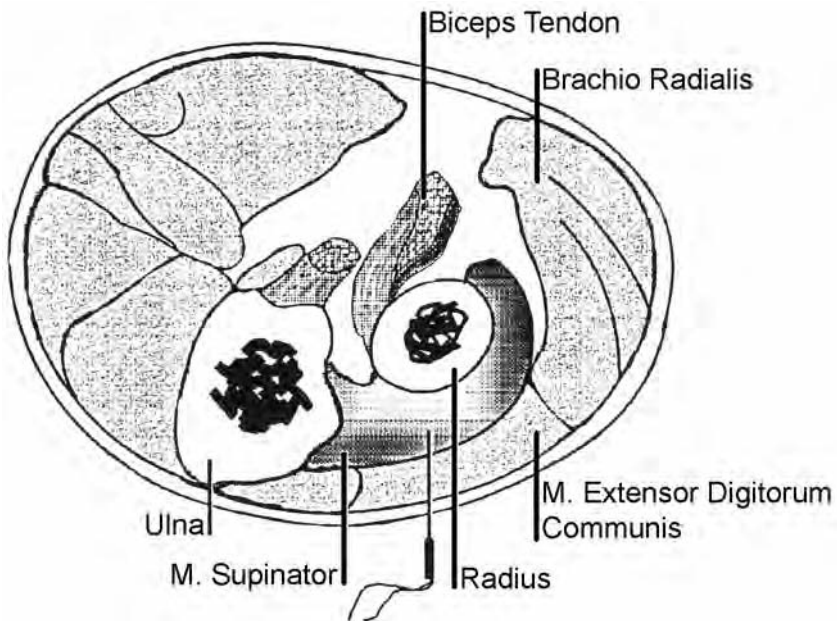
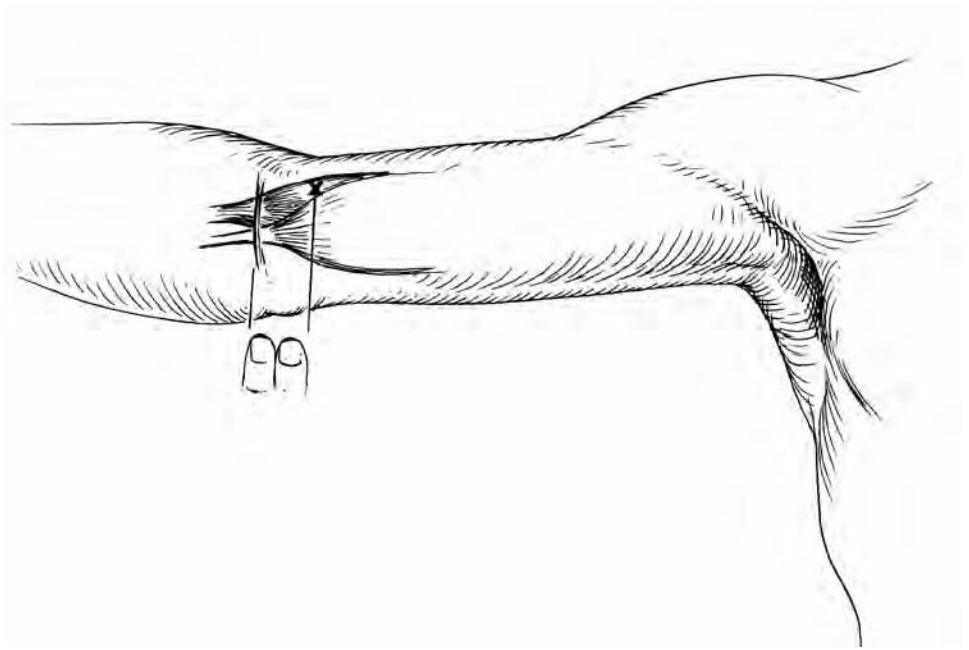


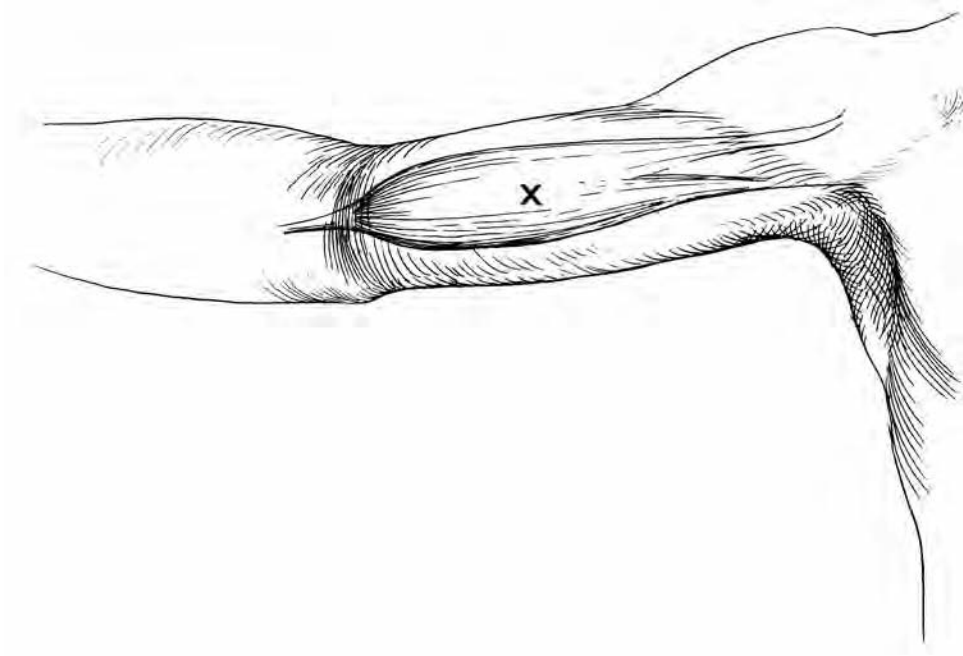
Figure 26. Cross section of the forearm through the proximal third.



SECTION III

ARM

BICEPS BRACHII



Innervation

Musculocutaneous Nerve, Lateral Cord, Anterior Division, Upper Trunk, C5, C6.

Origin

Long Head: From the supraglenoid tuberosity of scapula.

Short Head: From the apex of the coracoid process of the scapula.

Insertion

On the bicipital tuberosity of the radius.

Position

The patient supine with the arm extended.

Electrode Insertion (X)

Into the bulk of the muscle in mid-arm.

Test Maneuver

To flex or to supinate the forearm.

Pitfalls

If the needle electrode is inserted too deeply it will be in the brachialis.

Comments

- (a) Frequently used as recording muscle for musculocutaneous nerve motor conduction study.
- (b) This muscle gets involved in entrapment of the musculocutaneous nerve as it courses through the coracobrachialis muscle. It also gets involved in upper brachial plexus lesions and in high cervical radiculopathies.
- (c) Excessive traction of a baby's head during delivery may produce an elongation of the upper brachial plexus resulting in paralysis of this muscle (obstetrical paralysis or Bell's palsy).
- (d) The biceps shows a dual function: as a strong supinator of the forearm and a powerful elbow flexor. These two functions can be carried out separately.
- (e) The biceps muscle operates at a low grade of strength during flexion of the elbow when the forearm is pronated.

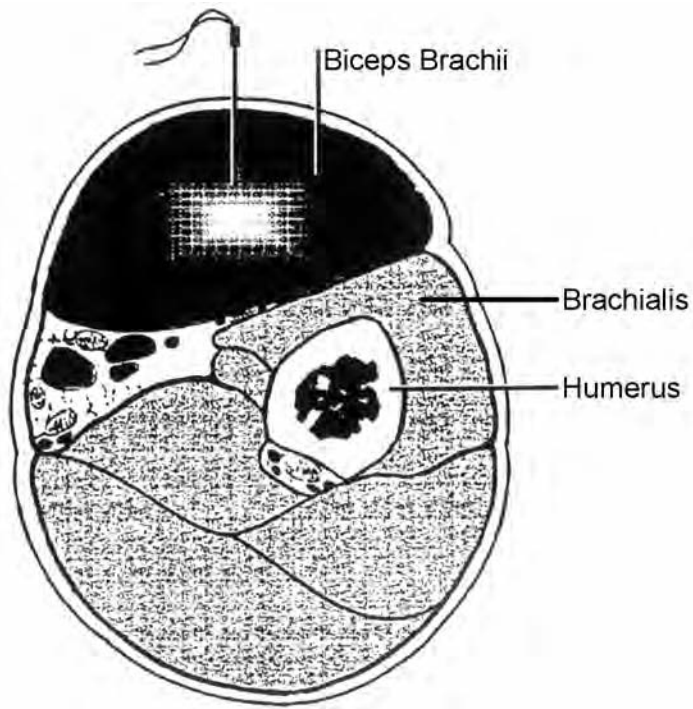
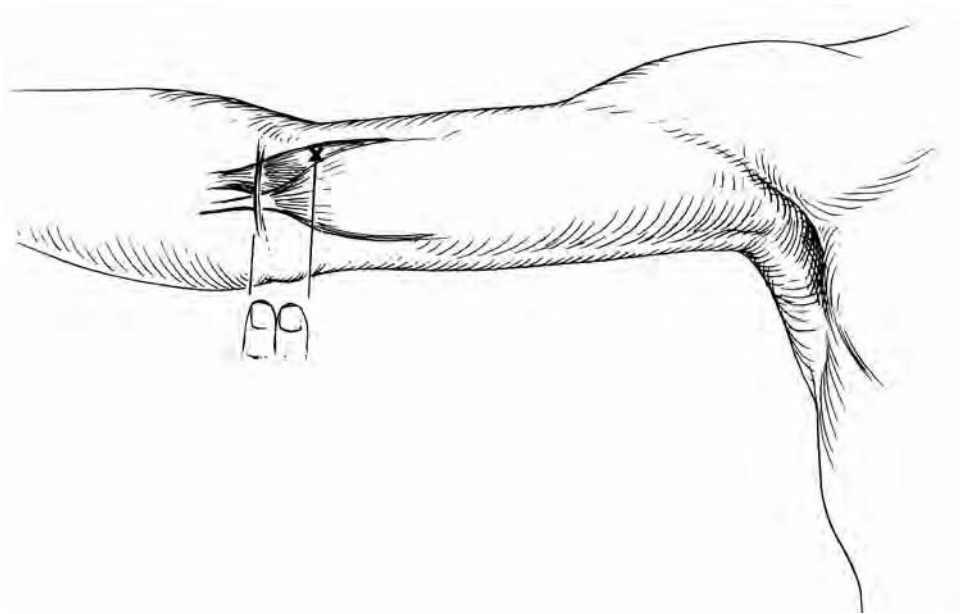


Figure 27. Cross section of the arm through the middle section.

BRACHIALIS



Innervation

Musculocutaneous Nerve, Lateral Cord, Anterior Division, Upper Trunk, C5, C6. (Also innervated by a small branch of the radial nerve.)

Origin

From the volar surface of the distal half of the humerus.

Insertion

On the tuberosity of the ulna and volar surface of the coronoid process.

Position

The patient supine with the forearm extended and pronated.

Electrode Insertion (X)

Two fingerbreadths proximal to elbow crease along and just lateral to the tendon and the bulk of the biceps.

Test Maneuver

Flex forearm with the forearm in pronation. The maneuver should be performed against minimal resistance; otherwise the biceps will be activated.

Pitfalls

If the needle electrode is inserted too medially it will be in the biceps.

Comments

- (a) Most distal muscle innervated by the musculocutaneous nerve.
- (b) Mainly innervated by the musculocutaneous nerve; however, receives a small amount of Innervation from the radial nerve.
- (c) Involved in musculocutaneous entrapment in the coracobrachialis. It also gets involved in upper brachial plexus lesions and upper cervical roots damage (C5–C6).
- (d) Its function is of a pure and strong flexor of the elbow assisted by the biceps, the brachioradialis and the pronator teres.

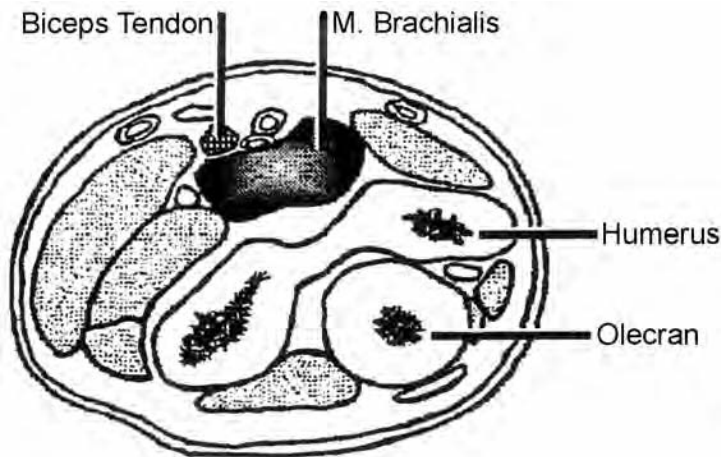


Figure 28. Cross section of the arm through the proximal end of the olecranon fossa.

CORACOBRACHIALIS



Innervation

Musculocutaneus Nerve, Lateral Cord, Anterior Division, Upper and Middle Trunk, C6, C7.

Origin

From the apex of the coracoid process.

Insertion

On the medial border of the humerus opposite the insertion of the deltoid.

Position

Patient supine with arm at side.

Electrode Insertion (X)

Four fingerbreadths distal to the coracoid process (CP) along volar aspect of the arm; insert needle to bone and withdraw.

Test Maneuver

With the elbow flexed to ninety degrees, forward elevation of the arm.

Pitfalls

If the needle electrode is inserted too superficially it will be in the biceps or anterior deltoid; if inserted too laterally it will be in the brachialis.

Comments

- (a) The most proximal muscle innervated by the musculocutaneous nerve.
- (b) The musculocutaneous nerve may be entrapped as it pierces the coracobrachialis muscle. When this occurs, this muscle is usually spared while the biceps and brachialis may be involved.
- (c) This muscle helps to flex and adduct the arm and also stabilizes the gleno-humeral joint.

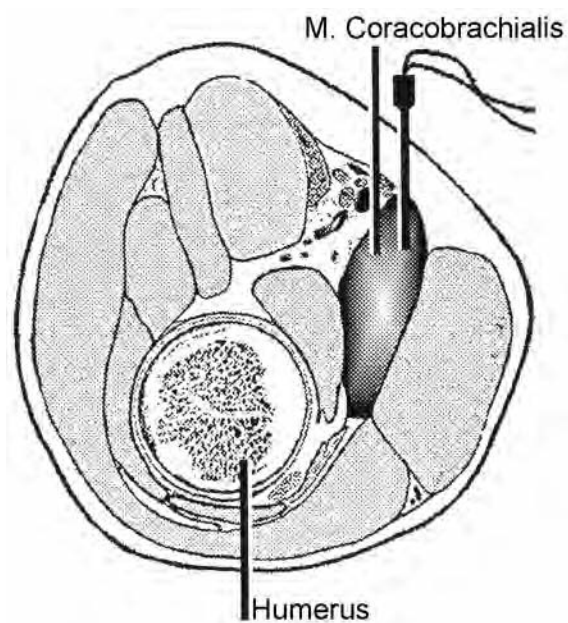
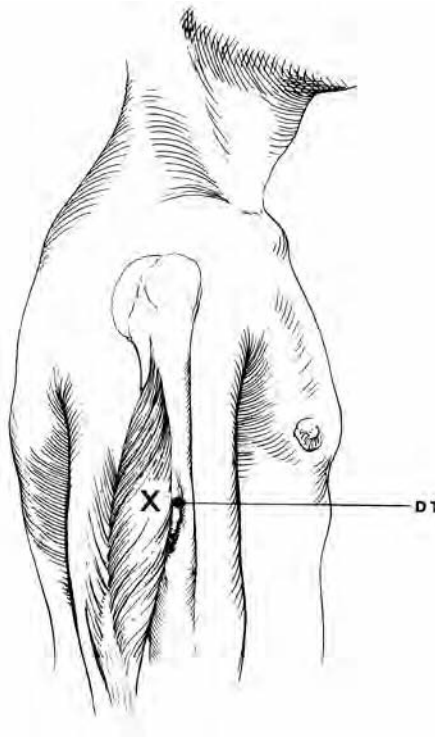


Figure 29. Cross section of the arm through the humeral neck.

TRICEPS



Lateral Head

Innervation

Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8, T1.

Origin

From the dorsal surface of the humerus above the groove for the radial nerve.

Insertion

By common tendon into distal aspect of olecranon process.

Position

Patient prone with arm abducted.

Electrode Insertion (X)

Immediately posterior to the insertion of deltoid or deltoid tubercle (DT).

Test Maneuver

Extension of the elbow joint.

Pitfalls

If the needle electrode is inserted too anteriorly or too proximally it will be in the deltoid.

Comments

- (a) Because of its very proximal Innervation through the radial nerve, it is almost never involved in “crutch paralysis” or “Saturday night palsy.”
- (b) The main function of this portion of the triceps is to extend the elbow joint. A second function is to fix the head of the humerus against the glenoid cavity during abduction of the arm.
- (c) This portion of the triceps is the medial boundary of the “quadri-lateral space,” through which the circumflex (axillary) nerve and the vessels travel. The other borders of this space are: laterally, the surgical neck of the humerus; below: by the teres major muscle and above by the teres minor and suprascapularis muscles.

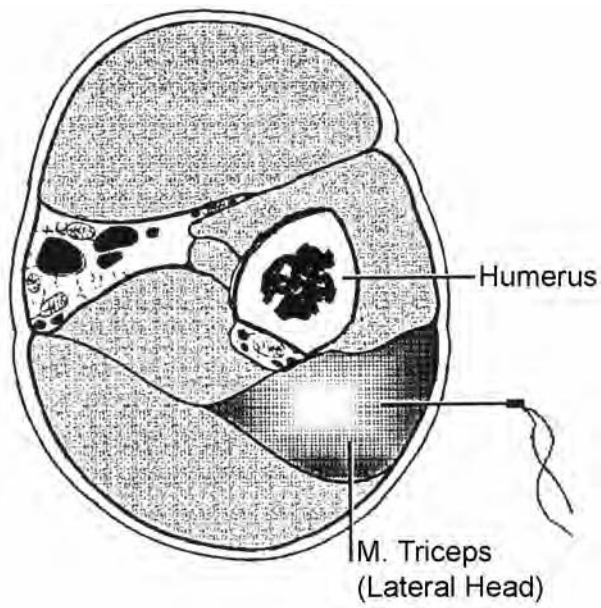
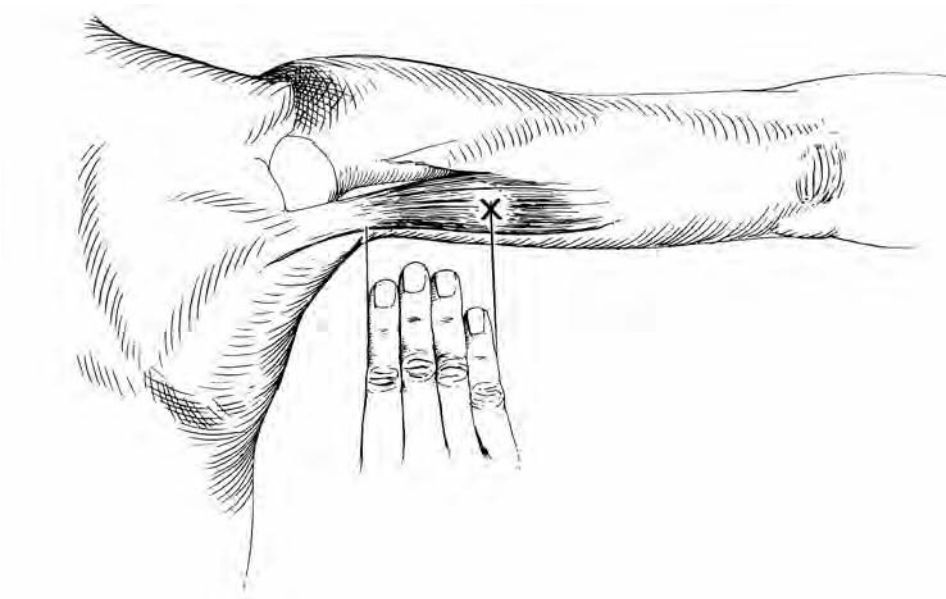


Figure 30. Cross section of the arm through the middle section.

TRICEPS



Long Head

Innervation

Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8, T1.

Origin

Infraglenoid tuberosity of the scapula.

Insertion

Via a common tendon, the three heads of the triceps insert on the dorsal aspect of the olecranon process of the ulna.

Position

Patient prone with arm abducted to ninety degrees and elbow flexed over edge of plinth.

Electrode Insertion

Four fingerbreadths distal to the posterior axillary fold.

Test Maneuver

Extension of the elbow.

Pitfalls

None.

Comments

- (a) Because of its very proximal innervation through the radial nerve, it is almost never involved in “crutch paralysis” or “Saturday night palsy.”
- (b) The main function of this portion of the triceps is to extend the elbow; however, as it crosses the shoulder joint, it helps in extension and adduction of the arm. A 3rd function is to fix the head of the humerus during abduction of the arm.
- (c) This head of the triceps is the medial boundary of the “quadri-lateral space,” through which the circumflex (axillary) nerve and the vessel travel. The other boundaries of this space are: laterally: the surgical neck of the humerus; below: the teres major muscle and above by the teres minor muscle and subscapularis.

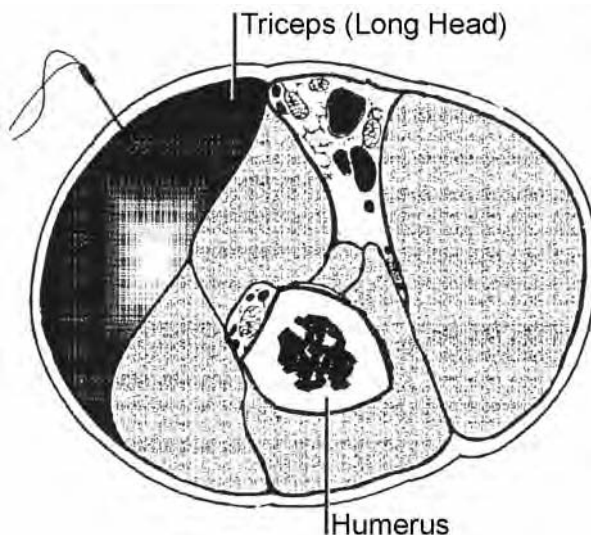
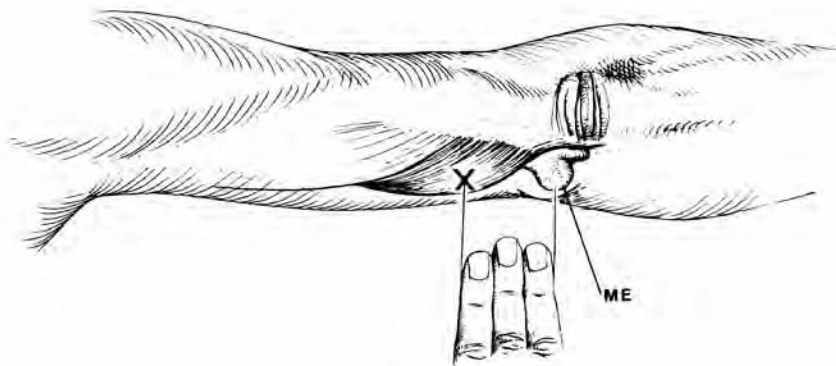


Figure 31. Cross section of the arm through the middle section.

TRICEPS



Medial Head

Innervation

Radial Nerve, Posterior Cord, Posterior Division, Middle and Lower Trunk, C7, C8, T1.

Origin

From the dorsal surface of the shaft of the humerus below the groove for the radial nerve.

Insertion

By common tendon into olecranon processes.

Position

Patient prone with arm abducted.

Electrode Insertion (X)

Three fingerbreadths proximal to the medial epicondyle (ME) of humerus.

Test Maneuver

Extension of elbow.

Pitfalls

If the needle electrode is inserted too anteriorly it will be in the biceps, and there is also the danger of puncturing the brachial artery.

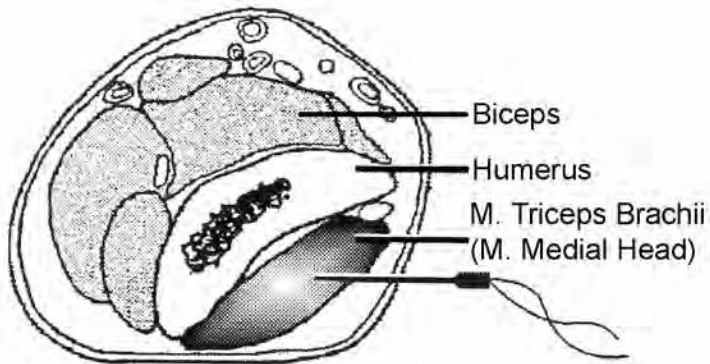


Figure 32. Cross section of the arm just proximal to the elbow joint.



SECTION IV

SHOULDER JOINT

DELTOID, ANTERIOR



Innervation

Axillary Nerve, Posterior Cord, Posterior Division, Upper Trunk, C5, C6.

Origin

Lateral third of the anterior and superior surfaces of the clavicle.

Insertion

Deltoid tubercle of the humerus.

Position

Patient supine with arm at side.

Electrode Insertion (X)

Three fingerbreadths below the anterior margin of the acromion (A).

Test Maneuver

Forward elevation of the arm.

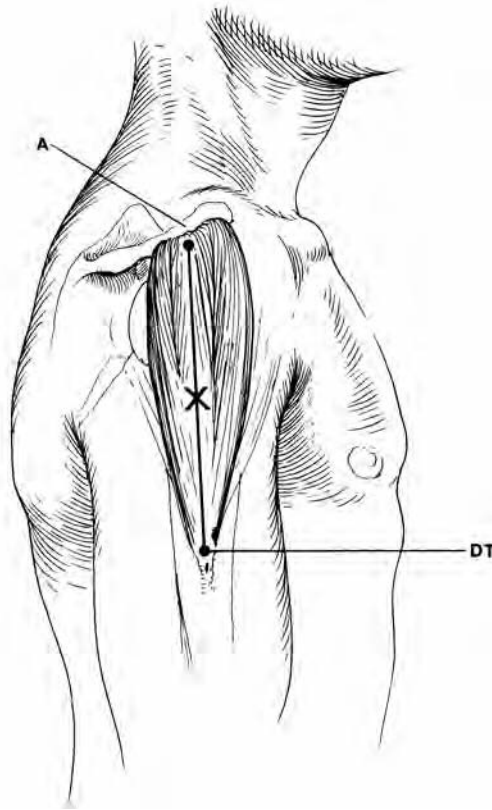
Pitfalls

If the needle electrode is inserted too medially or too deeply it will be in the coracobrachialis.

Comments

- (a) Can be used as recording muscle in axillary nerve motor conduction study.
- (b) If patient has a history of multiple injections into this muscle, electromyographic findings may be misleading.
- (c) This muscle gets involved in axillary nerve injuries secondary to fracture of surgical neck or glenohumeral joint dislocation. Also this muscle is affected in upper brachial plexus injuries (traction) during delivery.
- (d) Its main action is to medially rotate and to flex the arm, in conjunction with the clavicular portion of the pectoralis major.
- (e) This portion of the muscle is used constantly when swinging the arms while walking.
- (f) Together with the other two portions of the muscle, it stabilizes the shoulder joint by holding the head of the humerus against the shallow glenoid cavity of the scapula.

DELTOID, MIDDLE



Innervation

Axillary Nerve, Posterior Cord, Posterior Division, Upper Trunk, C5, C6.

Origin

Acromion.

Insertion

Deltoid tubercle of the humerus.

Position

Patient supine with arm at side.

Electrode Insertion (X)

Halfway between the tip of the acromion (A) and the deltoid tubercle (DT).

Test Maneuver

Abduction of arm.

Pitfalls

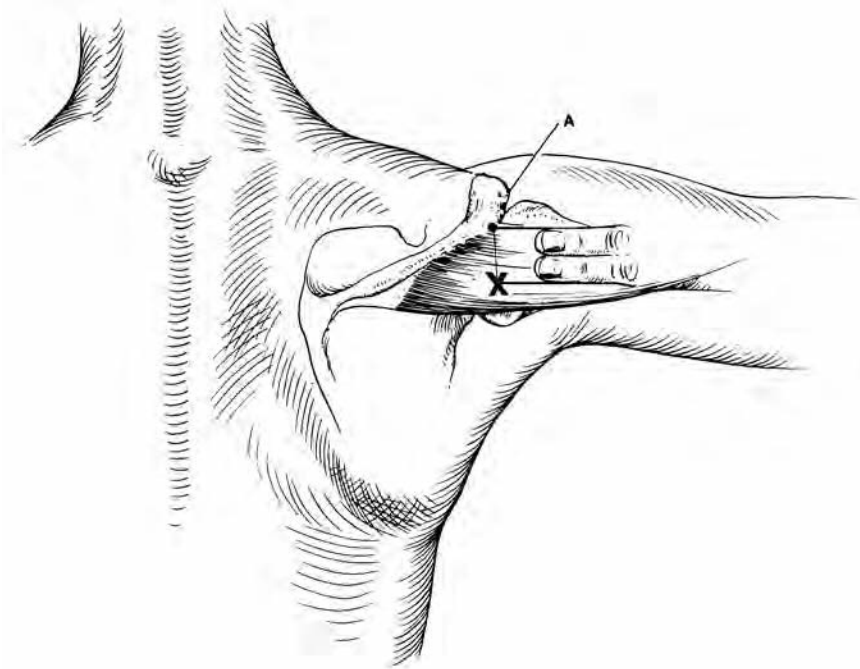
None.

Comments

- (a) Generally used as recording muscle in axillary nerve motor conduction study.
- (b) If patient has a history of multiple injections into this muscle electromyographic findings may be misleading.
- (c) Involved in axillary nerve injuries secondary to fractures, or joint dislocations and in upper brachial plexus injury (traction) during delivery.
- (d) The function of this part of the deltoid is of a powerful abductor of the arm but in order to do this it needs the assistance of the supraspinatus muscle in order to prevent the head of the humerus from raising and hitting the acromion. Therefore, the specific function of the supraspinatus muscle is to fix the head of the humerus against the glenoid cavity of the scapula.
- (e) This portion is also very active in controlling the gravitational descent of the arm, avoiding to drop abruptly against the body.

For cross section, see posterior deltoid on page 123.

DELTOID, POSTERIOR



Innervation

Axillary Nerve, Posterior Cord, Posterior Division, Upper Trunk, C5, C6.

Origin

The spine of the scapula.

Insertion

Deltoid tubercle of the humerus.

Position

Patient prone with arm abducted to ninety degrees and elbow flexed over edge of plinth.

Electrode Insertion (X)

Two fingerbreadths caudal to posterior margin of the acromion (A).

Test Maneuver

To elevate the arm off the plinth.

Pitfalls

If the needle electrode is inserted too medially it will be in the teres minor; if inserted too deeply it will be in the long head of the triceps.

Comments

- (a) Can be used as recording muscle in axillary nerve motor conduction study.
- (b) If patient has a history of multiple injections into this muscle, electromyographic findings may be misleading.
- (c) This muscle is involved in axillary nerve injuries secondary to fracture of surgical neck or glenohumeral joint dislocation. Also in upper brachial plexus injury (traction) during delivery.
- (d) The main function of this portion of the deltoid muscle, is to extend the glenohumeral joint, with the arm parallel to the body, or the arm at 90 degree in abduction.
- (e) When the deltoid muscle becomes paralyzed it loses its bulk and the roundness of the shoulder disappears and the shoulder appears flat and squared.

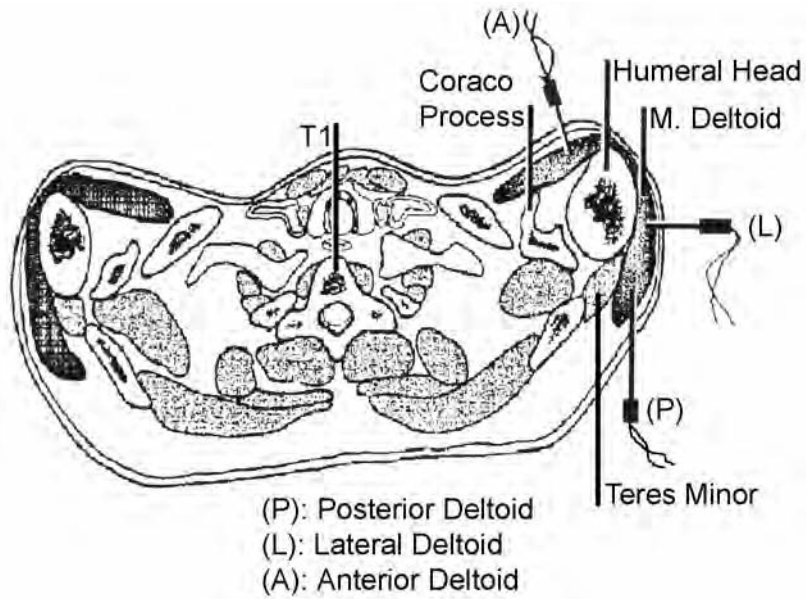
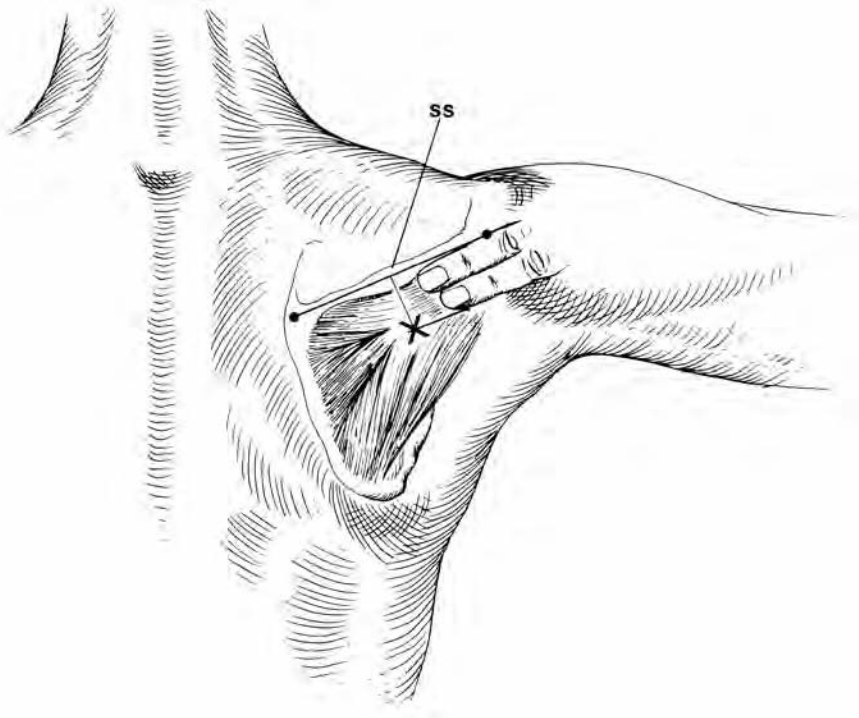


Figure 33. Cross section of the chest at the T1 level.

INFRASPINATUS



Innervation

Suprascapular Nerve, Upper Trunk, C5, C6.

Origin

Infraspinous fossa of scapula.

Insertion.

in the middle facet of the greater tuberosity of the humerus.

Position

Patient prone with arm abducted to ninety degrees and elbow flexed over the edge of plinth.

Electrode Insertion (X)

Insert needle electrode into infraspinous fossa two fingerbreadths below medial portion of spine of scapula (SS) to bone and then withdraw slightly.

Test Maneuver

Externally rotate humerus.

Pitfalls

If needle electrode is inserted too superficially it will be in the trapezius; if too laterally it will be in posterior deltoid.

Comments

- (a) Used as recording muscle in suprascapular nerve conduction study.
- (b) Involved in suprascapular nerve entrapment at the suprascapular notch or at the lateral edge of the spines of the scapular.
- (c) Involved in Erb's type of obstetrical palsy and in proximal brachial plexus injury compromising the upper trunk.
- (d) This muscle's main function is to keep the humeral head against the scapular glenoid cavity, together with the supraspinatus, the subscapularis and the Teres minor. In this way, the middle deltoid can abduct the arm without difficulty. All 4 muscles are generally known as the "rotator cuff muscle."

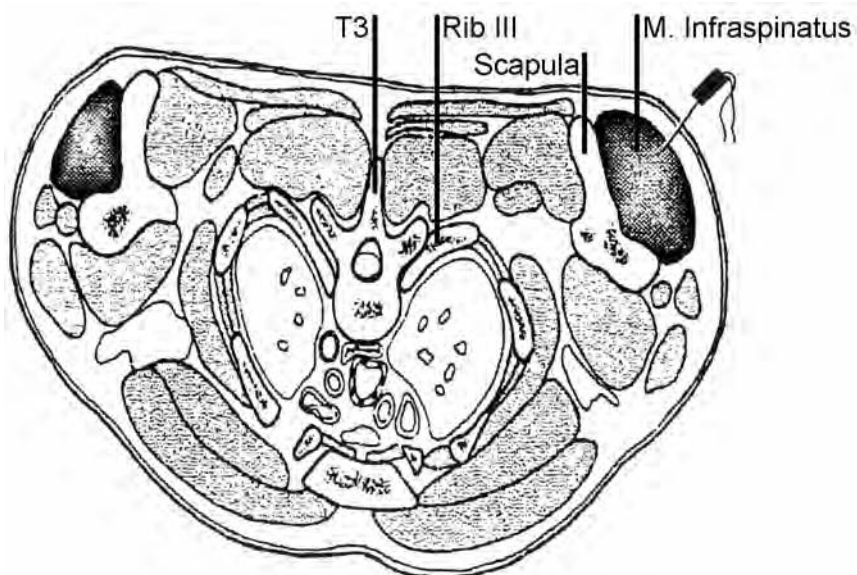
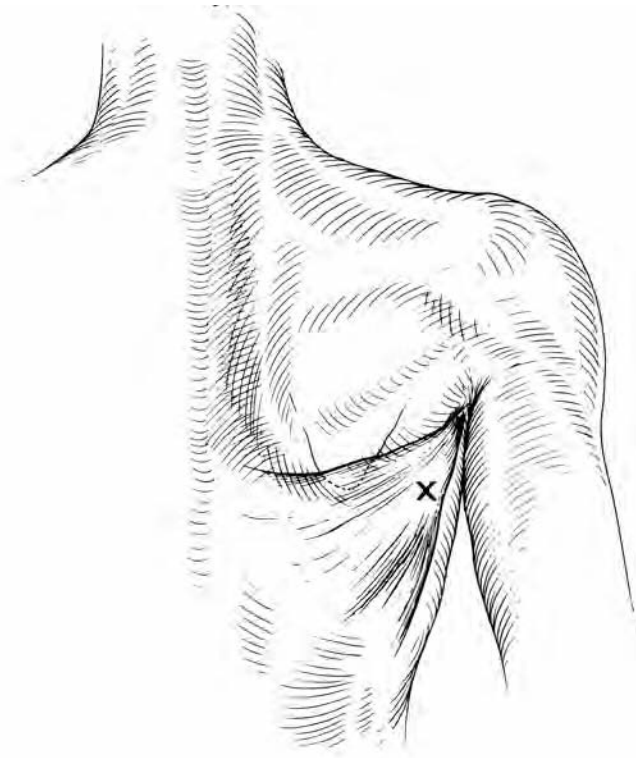


Figure 34. Cross section at the T3 level.

LATISSIMUS DORSI



Innervation

Thoracodorsal Nerve, Posterior Cord, Posterior Division, Upper, Middle and Lower Trunk, C6, C7, C8.

Origin

Spinous processes of lower thoracic vertebrae, lumbodorsal fascia and posterior crest of ilium.

Insertion

Intertubercular groove of the humerus.

Position

Patient prone with arm at side and palm up.

Electrode Insertion (X)

Three fingerbreadths distal to and along posterior axillary fold.

Test Maneuver

Internally rotate, adduct and extend arm.

Pitfalls

If needle electrode is inserted too medially it will be in the teres major.

Comments

- (a) The upper portion of this muscle forms a pocket to accommodate the lower angle of the scapula. The muscle fibers at this point are running almost horizontally. There is usually a small bursa in this place that prevents unusual rubbing.
- (b) The arrangement of the muscle of the upper and lower portion of the muscle is very peculiar. The inferior fibers insert in the upper area of the intertubercular groove and the superior fibers insert in the most distal end of the groove. This arrangement permits the patient's arm to swing around, without exerting any undue traction on the muscles fibers (The tendon unwinds during arm motion).
- (c) The main function of this muscle is to extend, adduct and medially rotate the humerus at the gleno-humeral joint.
- (d) However, when the origins and insertion of this muscle are reversed, it may bring the body to the arm as occurs when performing "chin ups" (in conjunction with the pectoralis major).
- (e) When this muscle is paralyzed, the patient cannot use crutches because the shoulder will move upward.

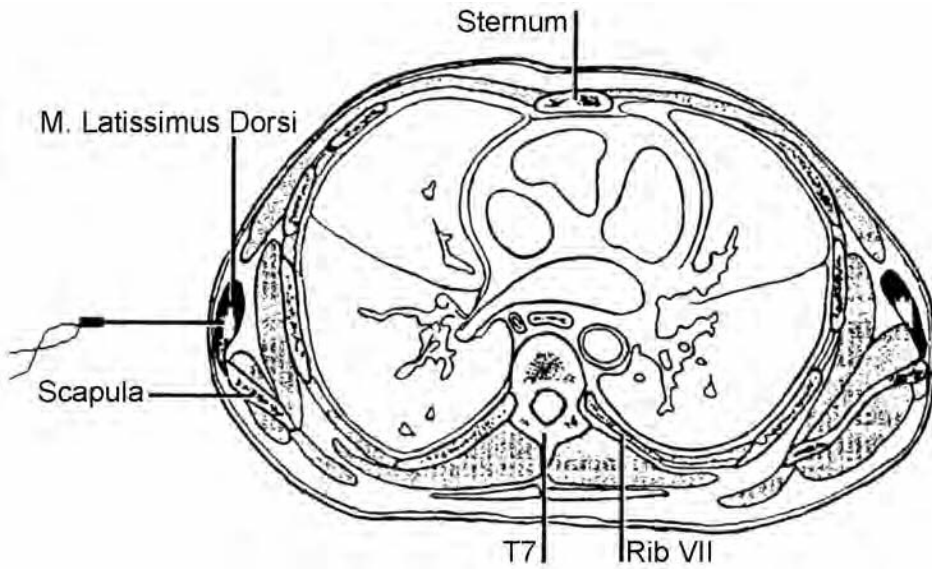
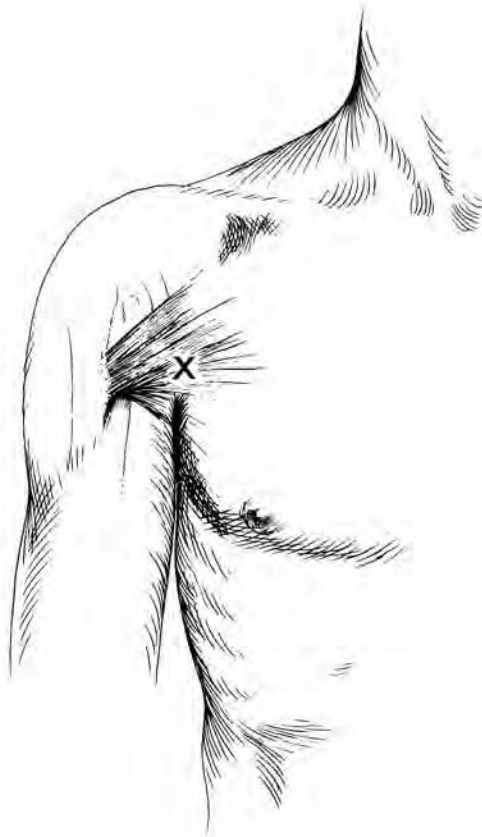


Figure 35. Cross section at T7 level.

PECTORALIS MAJOR



Innervation

Clavicular Portion: Lateral Pectoral Nerve, Lateral Cord, Anterior Division, Upper Trunk, C5, C6.

Sternocostal Portion: Medial Pectoral Nerve, Medial Cord, Anterior Division, Middle and Lower Trunk, C7, C8, T1.

Origin

This muscle originates over the anterior surface of the sternum (except the xiphoid process) and in the cartilage of the first 6 ribs (Sternocostal portion), and the medial half of the anterior surface of the clavicle.

Insertion

This muscle inserts into the lateral lip of the intertubercular groove of the humerus.

Position

Patient supine.

Electrode Insertion (X)

Insert needle electrode into anterior axillary fold.

Test Maneuver

Horizontal adduction of arm.

Pitfalls

If needle electrode is inserted too deeply it will be in the coracobrachialis; if inserted too laterally it will be in the biceps.

Comments

- (a) Innervated by all segments of brachial plexus.
- (b) In lateral cord lesions, the clavicular portion is involved. In medial cord lesions, sternocostal position is involved.
- (c) The muscle fibers of this muscle converge to the humeral groove in special fashion. The sternocostal fibers reach the groove upper portion behind the fibers from the clavicular portion, which insert in the lowest most area of the same groove. When the arm is flexed forward the fibers untwist allowing full motion of the shoulder without restriction.
- (d) The function of this muscle is to internally rotate and adduct the arm. Its clavicular portion in conjunction with the anterior deltoid raises the arm forward and controls its lowering motion. The Sternocostal portion in concert with the Latissimus Dorsi and the Teres Major pull the arm downward against resistance or the trunk upward when the arms are fixed as when climbing.
- (e) This muscle is enclosed in the anterior axillary wall.

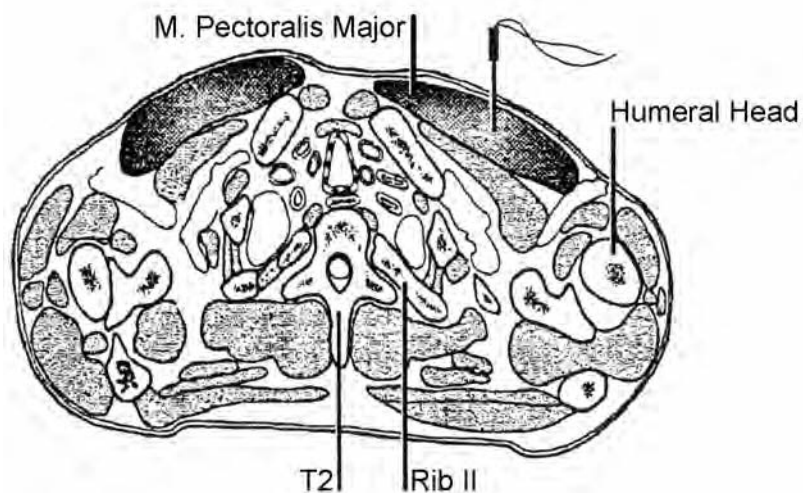
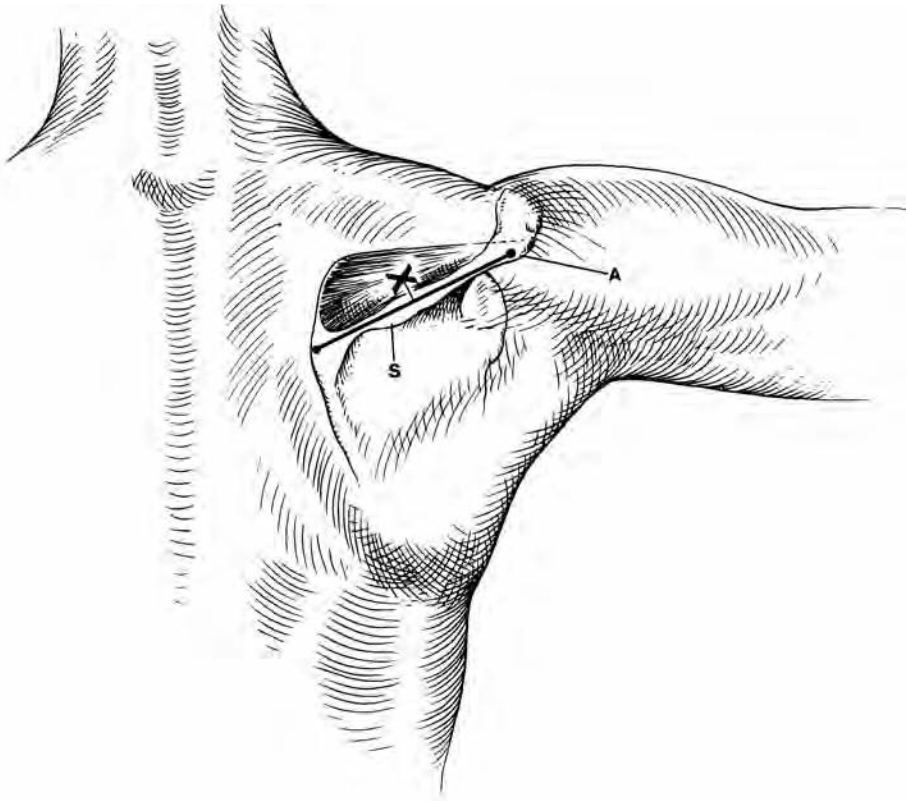


Figure 36. Cross section at T2 level.

SUPRASPINATUS



Innervation

Suprascapular Nerve, Upper Trunk, C5, C6.

Origin

Supraspinatus fossa of scapula.

Insertion

In the superior facet of the greater tuberosity of humerus.

Position

Patient prone with arm abducted to ninety degrees and elbow flexed over edge of plinth.

Electrode Insertion (X)

Insert into supraspinous fossa just above middle of spine of scapula (S). The electrode will travel through the midtrapezius muscle.

Test Maneuver

Externally rotate humerus.

Pitfalls

If needle electrode is inserted too superficially it will be in the trapezius.

Comments

- (a) Involved in Suprascapular nerve entrapment in scapular notch.
- (b) Involved in Erb's palsy.
- (c) The main function of this muscle is to abduct the arm. In conjunction with the Infraspinatus and teres minor, they stabilize the gleno humeral joint during abduction of the arm.
- (d) If the Supraspinatus muscle does not work, the deltoid muscle will mainly pull up the humeral head, which will be hitting the acromiun, which is on top.
- (e) The tendon of this muscle is the most commonly damaged tendon among the rotator cuff group.

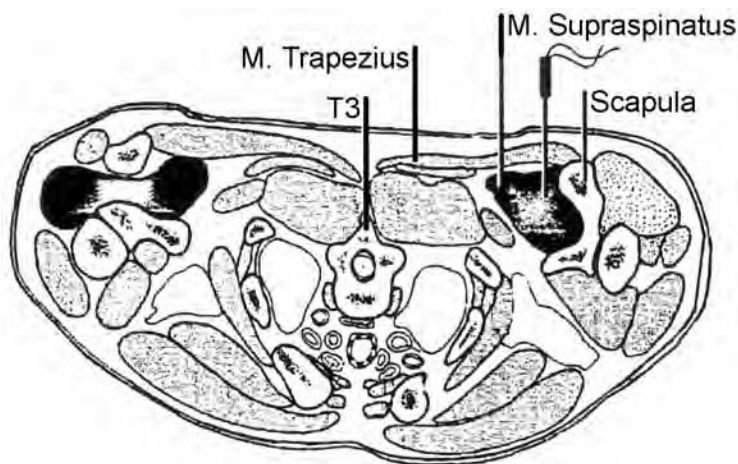
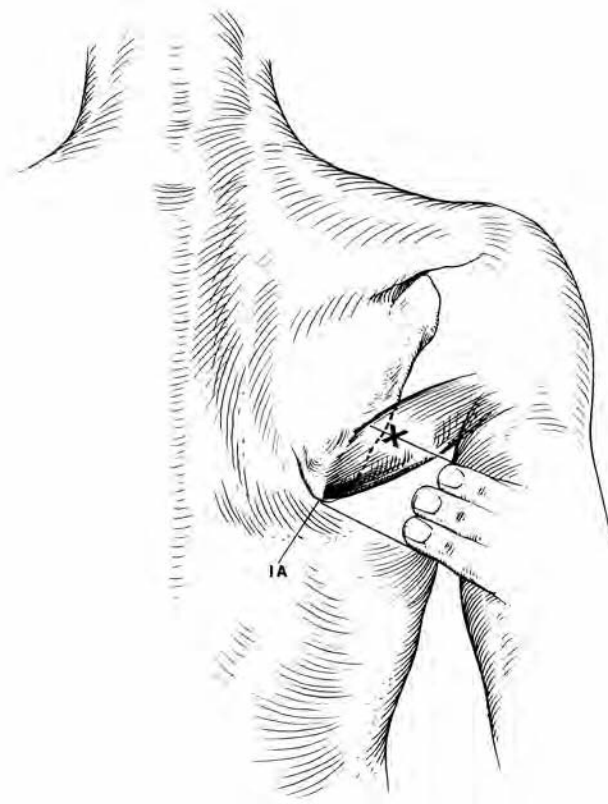


Figure 37. Cross section at T3 level.

TERES MAJOR



Innervation

Lower Subscapular Nerve, Posterior Cord, Posterior Division, Upper Trunk, C5, C6.

Origin

Inferior angle of scapula, over the dorsal aspect.

Insertion

Into the medial lip of the intertubercular groove adjacent to the Latissimus Dorsi.

Position

Patient prone with arm abducted to forty-five degrees and elbow flexed over edge of plinth.

Electrode Insertion (X)

Three fingerbreadths above inferior angle (IA) of scapula along the lateral border.

Test Maneuver

Internally rotate humerus.

Pitfalls

If needle electrode is inserted too caudally it will be in the serratus anterior; if inserted too laterally it will be in the latissimus dorsi.

Comments

- (a) This muscle's main function is to adduct and medially rotate the arm.
- (b) This muscle can be denervated in proximal radial nerve injuries, distal to the clavicle level.

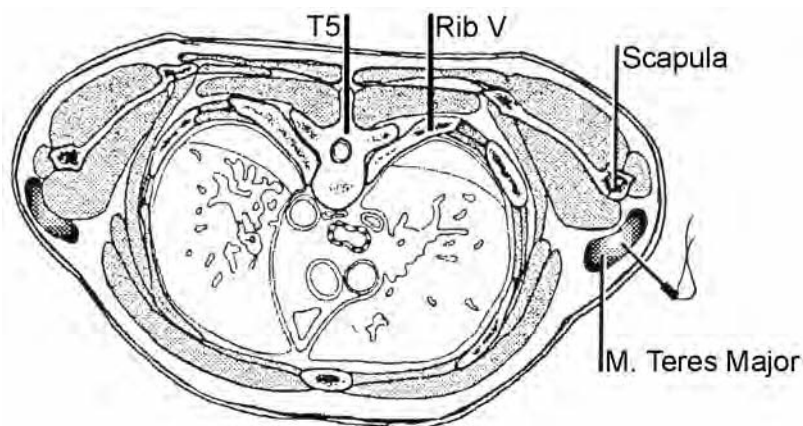
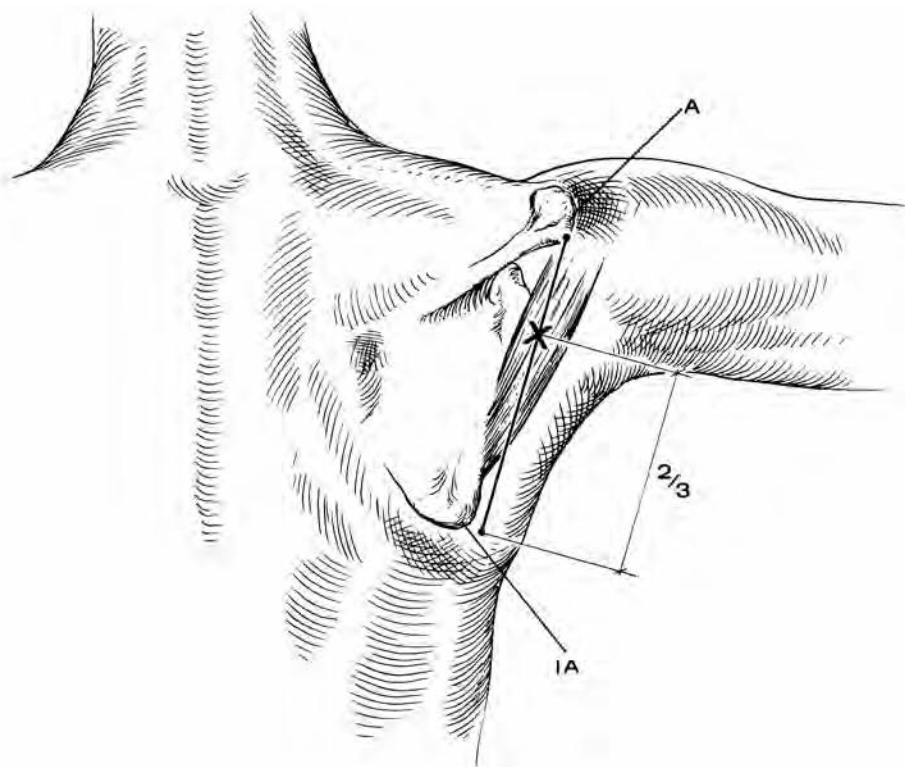


Figure 38. Cross section at T5 level.

TERES MINOR



Innervation

Axillary Nerve, Posterior Cord, Posterior Division, Upper Trunk, C5, C6.

Origin

Upper two-thirds of the axillary border of scapula, over the dorsal aspect.

Insertion

Over the greater tubercle of the humerus, on the inferior facet.

Position

Patient prone with arm abducted to ninety degrees and elbow flexed over edge of plinth.

Electrode Insertion (X)

Insert one-third of the way between acromion (A) and inferior angle (IA) of scapula along lateral border.

Test Maneuver

Externally rotate humerus.

Pitfalls

If needle electrode is inserted too cephalad, it will be in the supraspinatus; if inserted too caudally, it will be in the teres major; if inserted too superficially, it will be in the trapezius. If inserted too medially, it will be in the Infraspinatus.

Comments

- (a) It is usually spared in lesions of the axillary nerve secondary to fracture of the surgical neck of the humerus or dislocation of the glenohumeral joint.
- (b) Involved in lesions of axillary nerve close to posterior cord.
- (c) Involved in Erb's palsy.
- (d) This muscle is one of the "rotator cuff" (the other 2 are the Supraspinatus and the Infraspinatus). All 3 muscles secure the proper alignment of the "large" humeral head, against the "shallow" glenoid cavity of the scapula, and rotate laterally the arm.

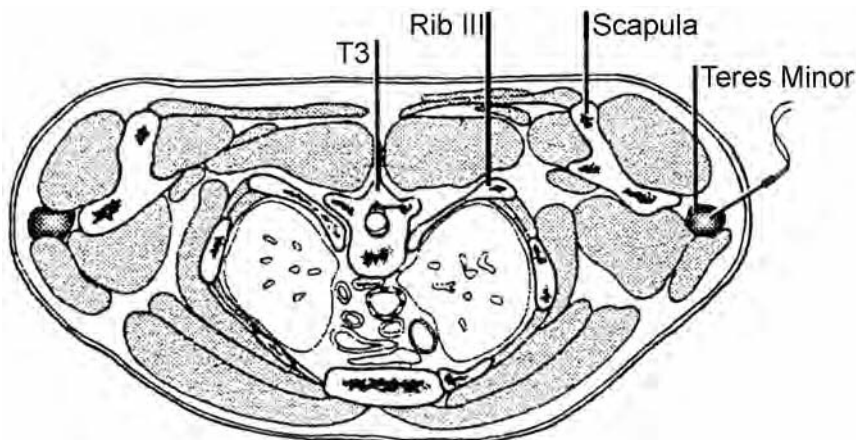
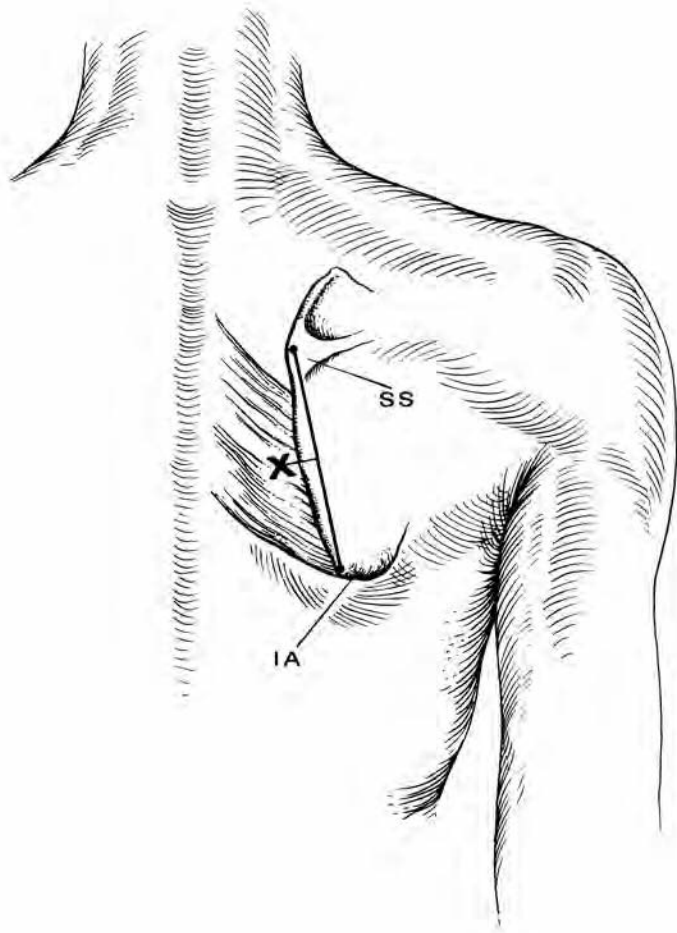


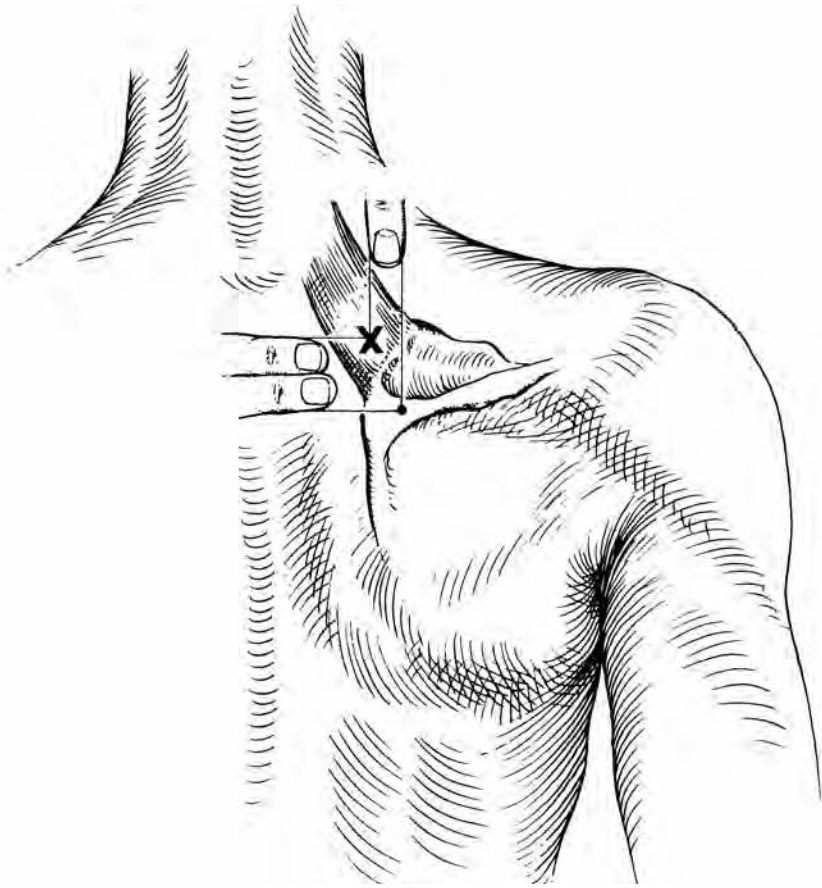
Figure 39. Cross section at T3 level.



SECTION V

SHOULDER GIRDLE

LEVATOR SCAPULAE



Innervation

Dorsal Scapular Nerve (C5) Plus Twigs From C3, C4.

Origin

Transverse processes of upper four cervical vertebrae.

Insertion

Vertebral border of scapular above root of spine.

Position

Patient prone.

Electrode Insertion (X)

Two fingerbreadths cephalad to the medial angle of scapula and one fingerbreadth medial. The electrode will travel through the upper trapezius.

Test Maneuver

Elevate scapulae.

Pitfalls

If needle electrode is inserted too superficially it will be in the trapezius; if inserted too deeply it will be in the paraspinal muscles.

Comments

- (a) This muscle is innervated directly and mainly from C5 root and therefore is an ideal muscle to test integrity of the C5 root.
- (b) Its main function is to elevate the scapula and to tilt the glenoid cavity downward by rotating the scapular counterclockwise on the right side and clockwise on the left side.
- (c) By fixing the scapula against the trunk it may become a mild extensor of the neck (cervical spine).

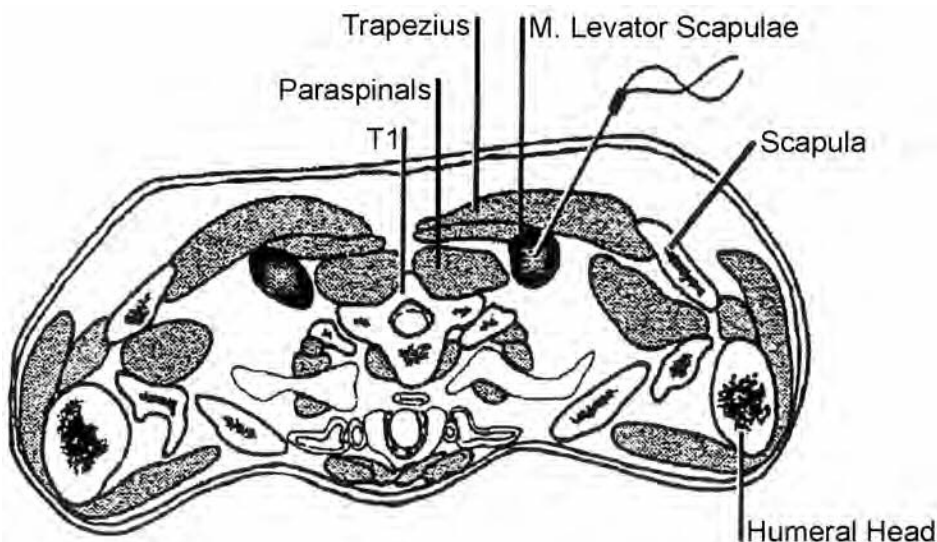
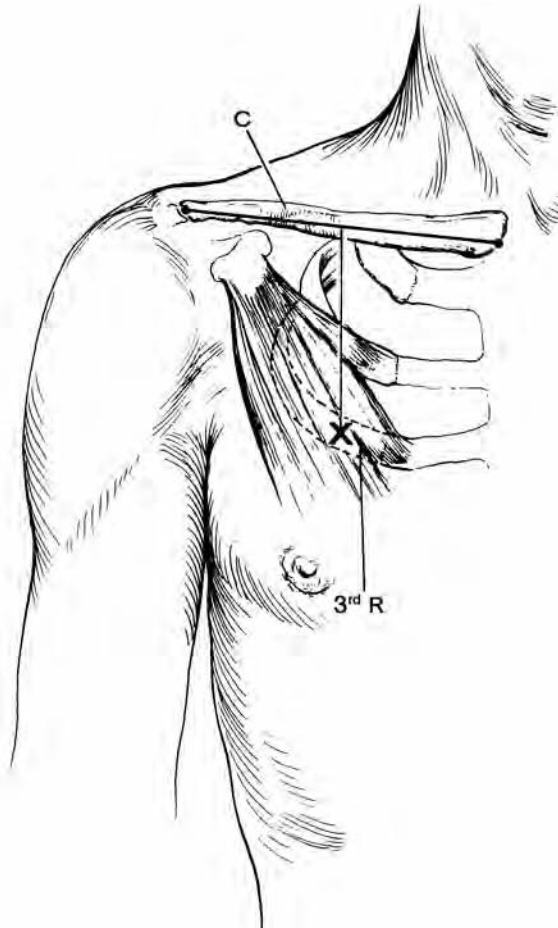


Figure 40. Cross section at T1 level.

PECTORALIS MINOR



Innervation

Medial and Lateral Pectoral Nerve, Medial and Lateral Cords, Anterior Division, Upper, Middle and Lower Trunks, C6, C7, C8.

Origin

Anterior bony surface of the third to the fifth ribs, near the cartilage component of the ribs.

Insertion

On the medial border and upper surface of the coracoid process of the scapula.

Position

Patient supine.

Electrode Insertion (X)

In midclavicular line insert needle electrode to anterior surface of the third rib (3rd R) and withdraw slightly. The electrode will travel through the pectoralis major.

Test Maneuver

Scapula depression.

Pitfalls

If needle electrode is inserted too superficially it will be in the pectoralis major.

Comments

- (a) This muscle is located in the anterior wall of the axilla together with the pectoralis major. The neurovascular bundle supplying the upper extremity, travel underneath this muscle at the coracoid process insertion.
- (b) This muscle stabilizes the scapula by pulling it downward and against the thoracic cage. It is also a scapular rotator, tilting the glenoid cavity downward and inferiorly.
- (c) It may become a deep inspirator in forced breathing.

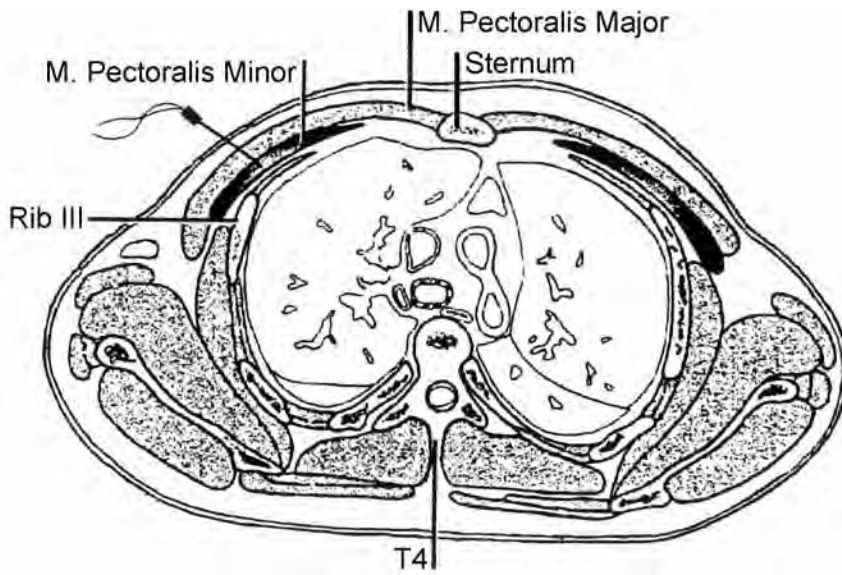
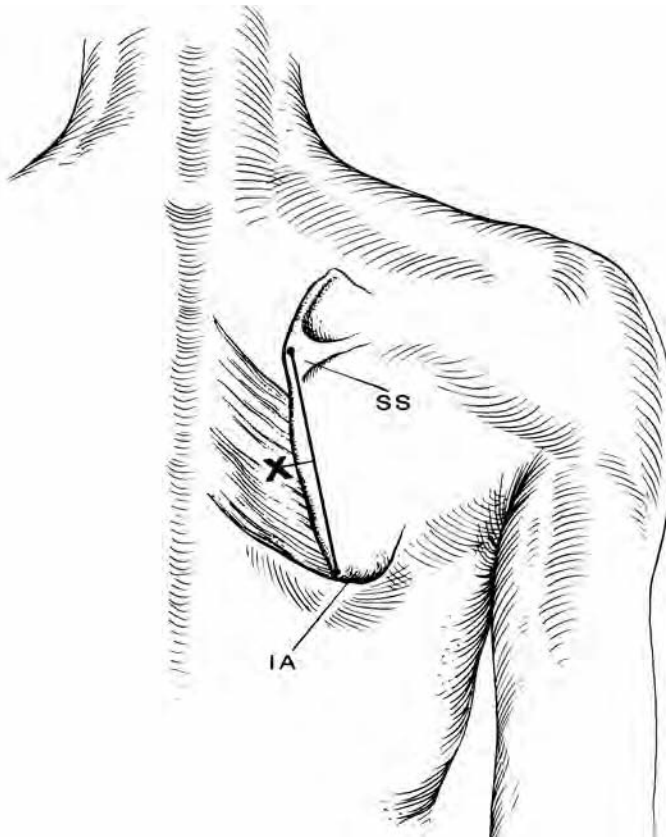


Figure 41. Cross section at T4 level.

RHOMBOIDEUS MAJOR



Innervation

Dorsal Scapular Nerve, C5.

Origin

Spinous processes of the second to fifth thoracic vertebrae.

Insertion

Vertebral border of scapula: from root of spine of scapula to its inferior angle.

Position

Patient prone with arm internally rotated so that dorsum of hand rests on small of back.

Electrode Insertion (X)

Midway between spine (SS) and inferior angle (IA) of scapula just medial to vertebral border. The electrode will travel through the middle trapezius.

Test Maneuver

Raise hand from small of back.

Pitfalls

If needle electrode is inserted too superficially it will be in the trapezius; if inserted too deeply it will be in the erector spinal muscles.

Comments

- (a) This muscle is innervated directly and solely from the C5 nerve root. Therefore it is an ideal muscle to test the integrity of the C5 root.
- (b) The main function of this muscle is to retract the scapula toward the thoracic spine, and to rotate the scapula to depress the glenoid cavity. It fixes the scapula against the chest wall.

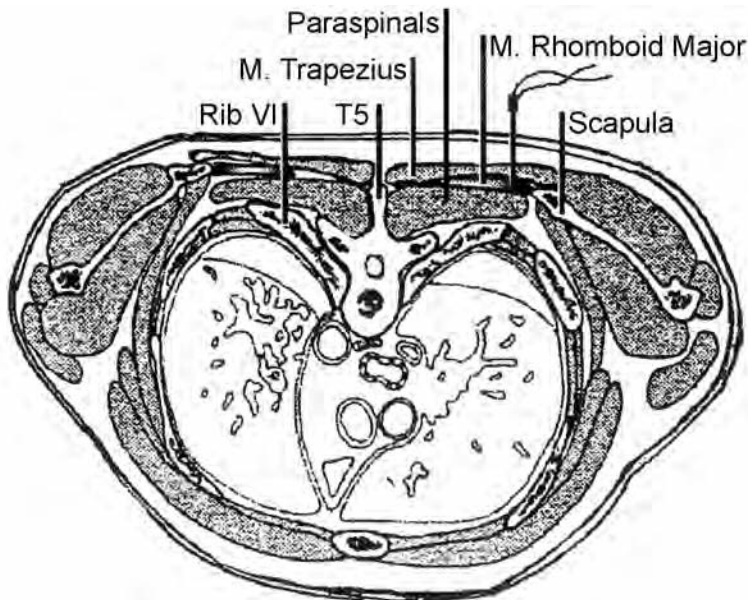
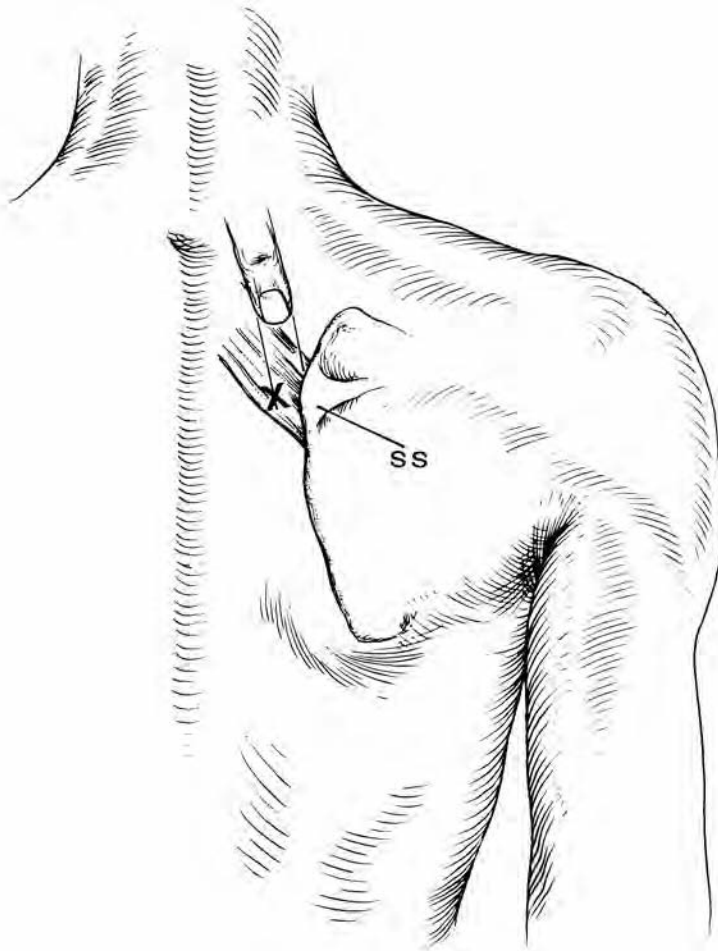


Figure 42. Cross section at T5 level.

RHOMBOIDEUS MINOR



Innervation

Dorsal Scapular Nerve, C5.

Origin

Spinous processes of seventh cervical and first thoracic vertebrae.

Insertion

Vertebral border of scapula at the base of the spine of the scapula.

Position

Patient prone with arm internally rotated so that dorsum of hand rests on small of back.

Electrode Insertion (X)

One fingerbreadth medial to vertebral end of scapular spine (SS).
The electrode will travel through the upper trapezius.

Test Maneuver

Raise hand from small of back.

Pitfalls

If needle electrode is inserted too deeply it will be in the serratus posterior superior.

Comments

See rhomboideus major.

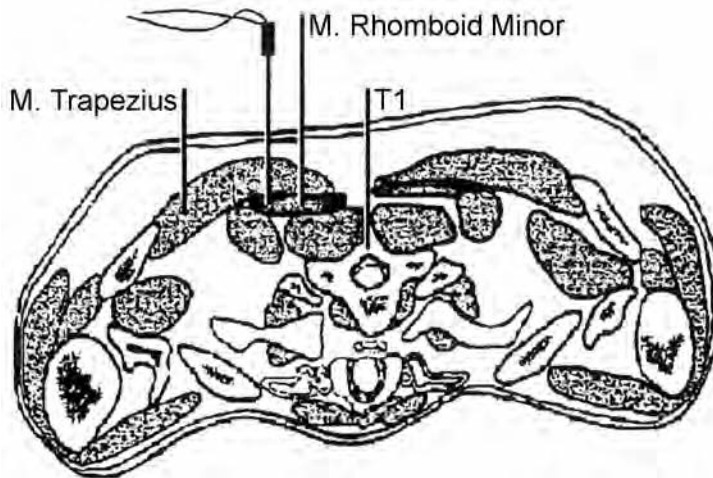
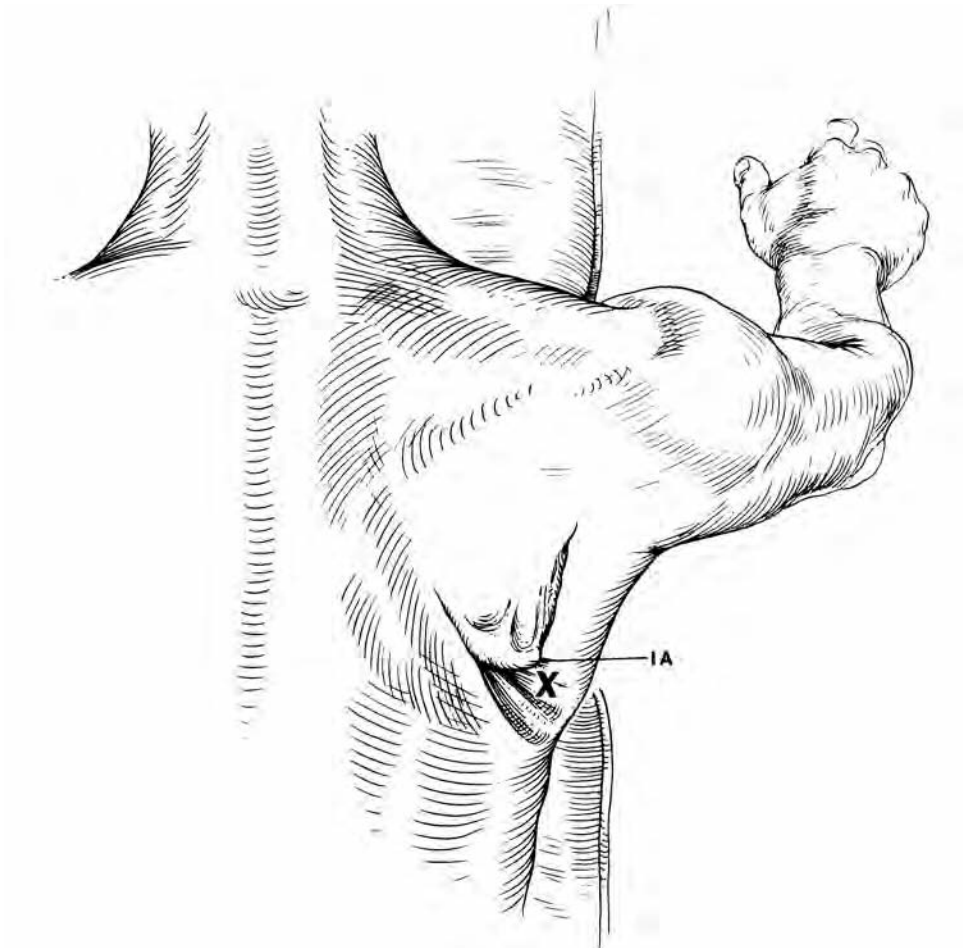


Figure 43. Cross section at T1 level.

SERRATUS ANTERIOR



Innervation

Long Thoracic Nerve, C5, C6, C7.

Origin

Digitations from anterior surfaces and superior borders of upper nine ribs.

Insertion

Ventral surface of vertebral border of scapula, from superior to inferior angles.

Position

Patient prone with arm dangling over edge of plinth.

Electrode Insertion (X)

Just lateral to inferior angle (IA) of scapula.

Test Maneuver

Patient presses hand against resistance.

Pitfalls

If needle electrode is inserted too superficially it will be in the Latissimus dorsi; if inserted too cephalad it will be in the teres major.

Comments

- (a) This muscle is innervated directly from roots C5, C6, C7 through long thoracic nerve. Therefore it is a good muscle to study when trying to distinguish root from more distal lesions.
- (b) The main function of this muscle is to protract the scapula and keep it against the thoracic wall; it also rotates the scapula.
- (c) When this muscle becomes paralyzed secondary to lesions of the long thoracic nerve, the vertebral border of the scapula stands out especially when trying to push (for instance: against the wall). The patient presents what is called “scapula alata” or “winged scapula.”
- (d) A patient with this type of lesion, cannot raise the upper limb or push with that arm.

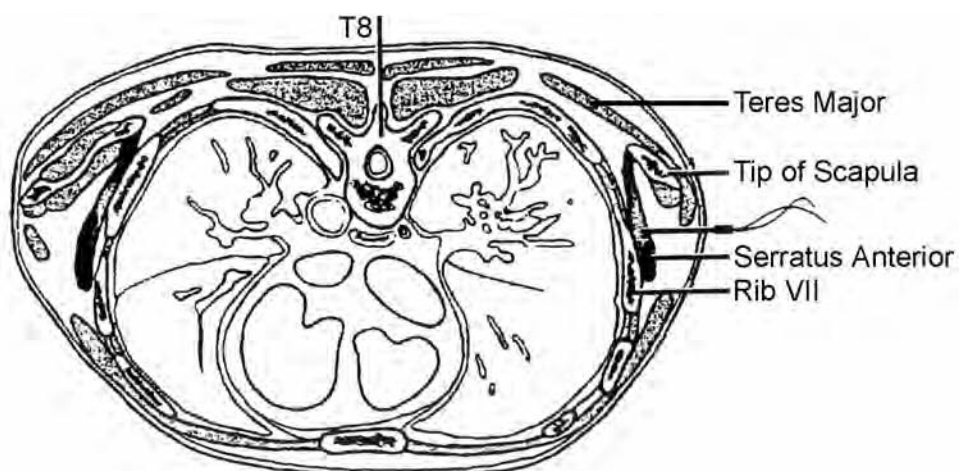
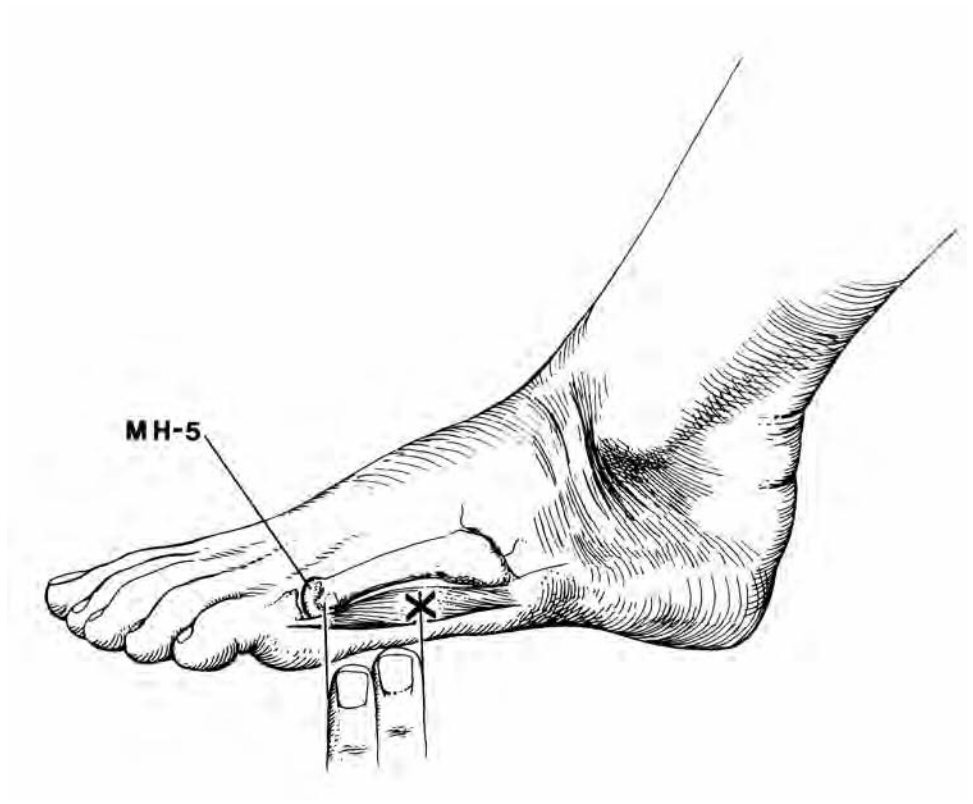


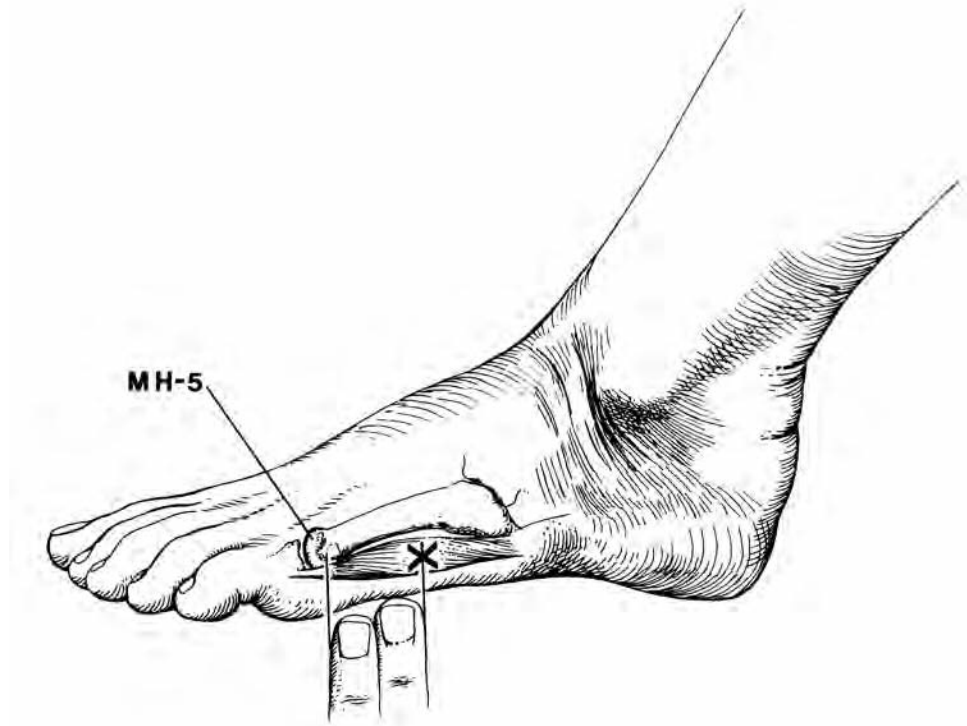
Figure 44. Cross section at T8 level.



SECTION VI

FOOT

ABDUCTOR DIGITI QUINTI



Innervation

Lateral Plantar Nerve, Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

From the lateral process of the tuberosity of the calcaneus.

Insertion

To the lateral side of the base of the proximal phalanx of the fifth toe.

Position

The patient supine.

Electrode Insertion (X)

On the lateral border of the foot, two fingerbreadths proximal to the head of the fifth metatarsal (MH-5).

Test Maneuver

Patient to spread the toes.

Pitfalls

None.

Comments

- (a) Commonly involved in:
 - 1. Peripheral neuropathy secondary to diabetes mellitus
 - 2. Lateral plantar nerve lesion
 - 3. Tarsal-tunnel syndrome idiopathic or following ankle fractures
 - 4. More proximal lesions involving the tibial or sciatic nerve, sacral plexus or S1, S2 roots.
- (b) This muscle can be used as recording muscle for the tibial nerve conduction studies; the distal latency will indicate the functional status of the lateral plantar nerve.
- (c) This muscle is the most lateral in the superficial muscular layer of the foot. The main function of this muscle is to abduct the 5th toe. It can also produce a weak M.P. flexion of the 5th toe.
- (d) This muscle is the main support of the lateral longitudinal arch of the foot.
- (e) A great deal of care should be taken when testing patients with diabetes in order to avoid introducing an infection in the patient's foot. The vascular compromise in this patient may make fighting infections very difficult.

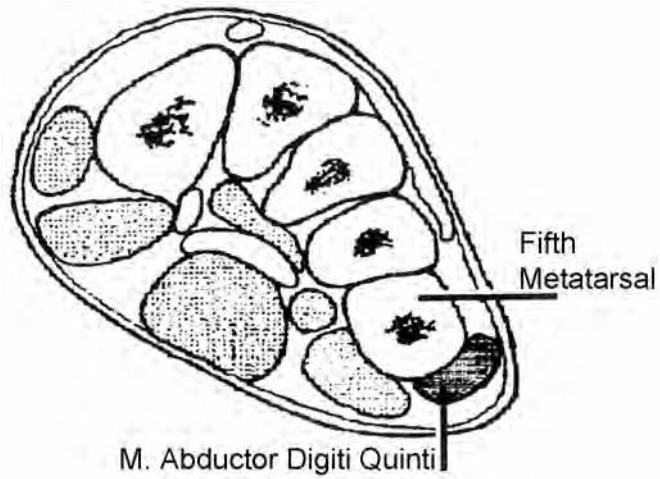
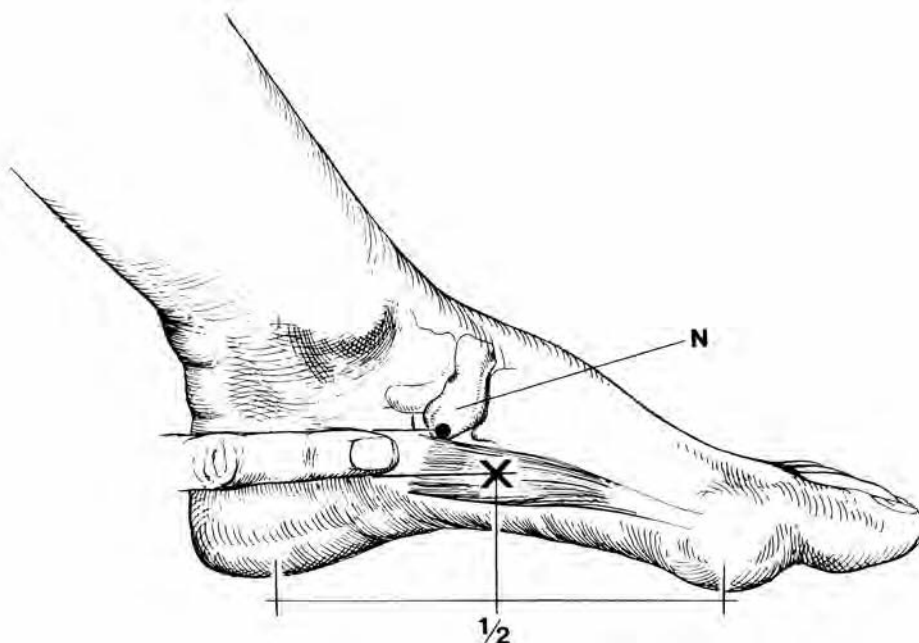


Figure 45. Cross section of the foot at the proximal end of the metatarsal bones.

ABDUCTOR HALLUCIS



Innervation

Medial Plantar Nerve, Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1–S2.

Origin

From the medial tuberosity of the calcaneus.

Insertion

To the medial side of the base of the proximal phalanx of the great toe.

Position

The patient supine.

Electrode Insertion (X)

One fingerbreadth below the navicular (N) bone on midportion of medial aspect of foot.

Test Maneuver

Patient to spread the toes.

Pitfalls

If the electrode is inserted too distally it will be in the flexor Hallucis Brevis; if inserted too deeply it will be in the flexor digitorum Brevis.

Comments

- (a) Commonly involved in:
 - 1. Peripheral neuropathy secondary to diabetes mellitus
 - 2. Medial plantar nerve lesions
 - 3. Tarsal tunnel syndrome, idiopathic or post ankle fracture
 - 4. More proximal lesions involving the tibial or sciatic nerve, sacral plexus or S1, S2 roots.
- (b) This muscle can be used as recording muscle for the tibial nerve conduction studies; the distal latency will indicate the functional status of the medial plantar nerve.
- (c) This muscle is the most medially located muscle of the superficial muscular layer of the foot. Its main function is to abduct the big toe (hallux), and also has a weak flexion action over the M.P. joint of the 1st toe. It supports the medial longitudinal arch of the foot.
- (d) A great deal of care should be taken to avoid introducing an infection in the foot of a patient with diabetes.

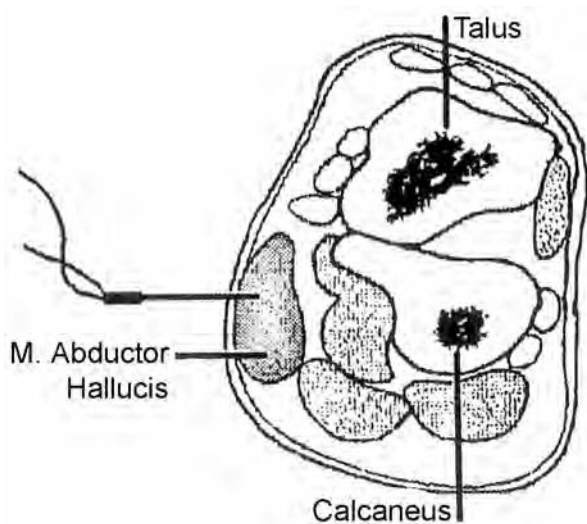
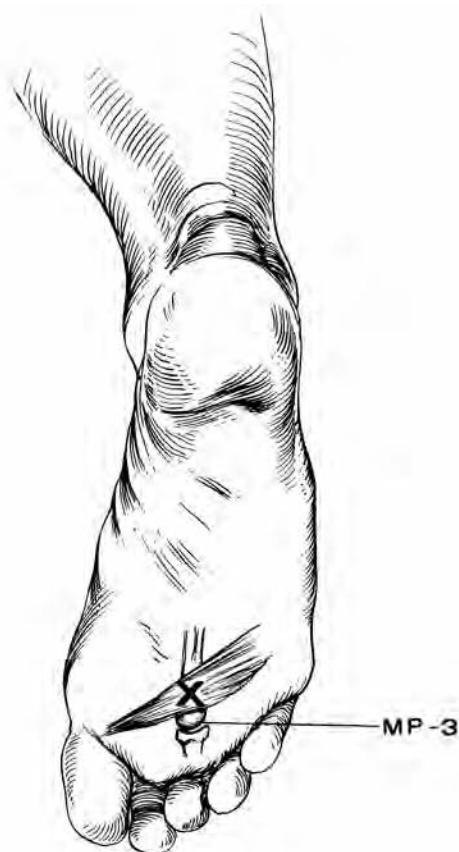


Figure 46. Cross section of the foot through the talocalcaneal joint.

ADDUCTOR HALLUCIS



Innervation

Lateral Plantar Nerve, Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

From the peroneus longus tendon sheath and adjacent parts of the cuboid and second, third and fourth metatarsal bones (oblique head), and from the capsule of the third, fourth and fifth metatarsal-phalangeal joints (transverse head).

Insertion

Into the lateral aspect of the base of the proximal phalanx of the big toe.

Position

The patient supine.

Electrode Insertion (X)

For the transverse head only: Insert the electrode just proximal to the third metatarsalphalangeal (MP-3) joint until the metatarsal bone is felt; withdraw the electrode slightly.

Test Maneuver

Passively abduct big toe and ask patient to adduct.

Pitfalls

If the electrode is inserted too superficially it will be in the lumbrical muscle.

Comments

- (a) This muscle gets involved in peripheral neuropathies, mainly diabetic. It also gets affected in lateral plantar nerve lesions, in tarsal tunnel syndrome, in more proximal lesions of the tibial or sciatic nerves or in sacral plexus or S1–S2 roots compressions.
- (b) The main function of this muscle is to adduct the big toe and also it is a large contributor in holding the transverse arch of the foot. It also has a weak flexion action on the M.P. joint of the big toe. It is located in the 3rd muscular layer of the foot.
- (c) A great deal of care should be taken to avoid introducing an infection in the foot of patients with diabetes.

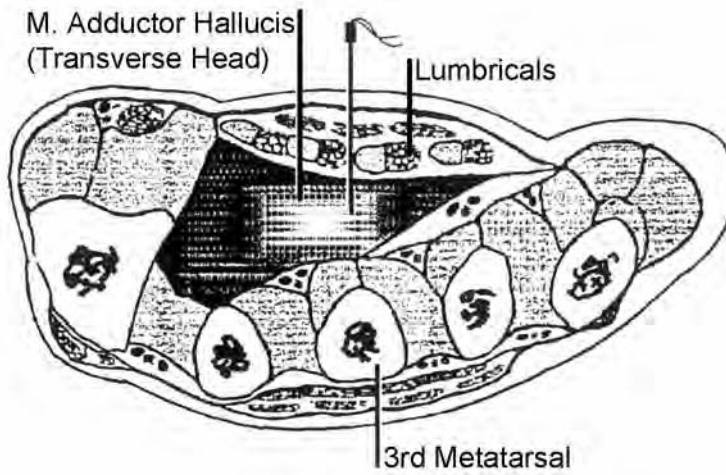
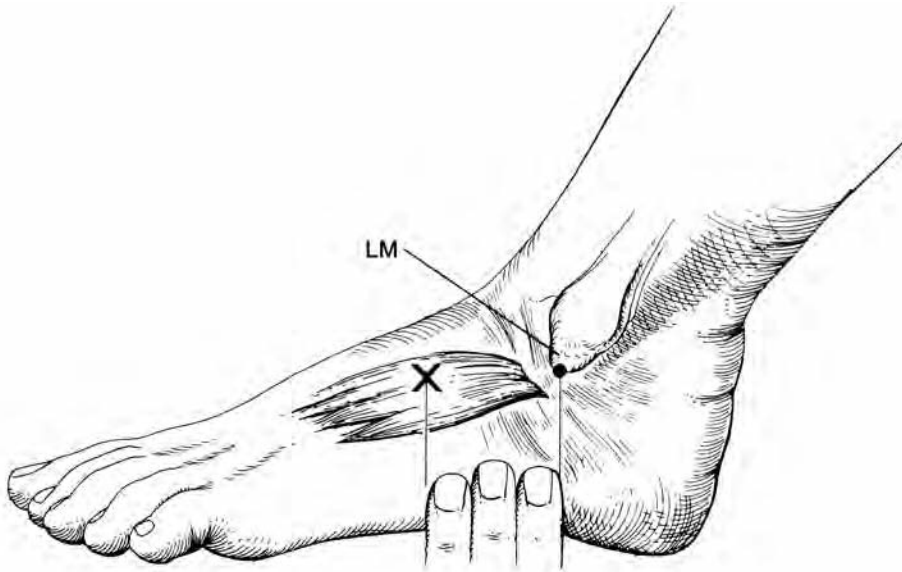


Figure 47. Cross section of the foot through the distal third of the metatarsal bones.

EXTENSOR DIGITORUM BREVIS AND EXTENSOR HALLUCIS BREVIS



Innervation

Deep Peroneal Nerve, Common Peroneal Nerve, Sciatic Nerve, Dorsal Division Sacral Plexus, L5, S1.

Origin

From the upper and lateral surface of the calcaneus.

Insertion

Into the base of the proximal phalanx of the great toe and the tendon of the extensor digitorum longus of the second, third and fourth toes.

Electrode Insertion (X)

Three fingerbreadths distal to the lower border of the lateral malleolus (LM) parallel to the lateral border of the foot.

Test Maneuver

Patient to extend the toes.

Pitfalls

None.

Comments

- (a) Last muscle innervated by deep peroneal nerve.
- (b) This muscle is used as recording muscle for the common peroneal nerve conduction study.
- (c) Involved in:
 - 1. Lesions of peripheral neuropathy secondary to diabetes mellitus
 - 2. Deep peroneal nerve lesions
 - 3. More proximal nerve lesions of common peroneal nerve, sciatic nerve, sacral plexus, or L5, S1 nerve roots.
- (d) This is the only muscle located on the dorsal aspect of the foot. Its main function is to extend the 2nd to 4th M.P. joints (E.D.B.) and the M.P. joint of the big toe (E.H.B.). They contribute with the long extensor to extend the toes. However, from the functional standpoint these muscles are relatively unimportant. Trauma to these muscles may produce bleeding and large edema on top of the foot, but the ankle joint will be spared.
- (e) Attention should be given to avoid introducing an infection in the foot of a patient with diabetes.

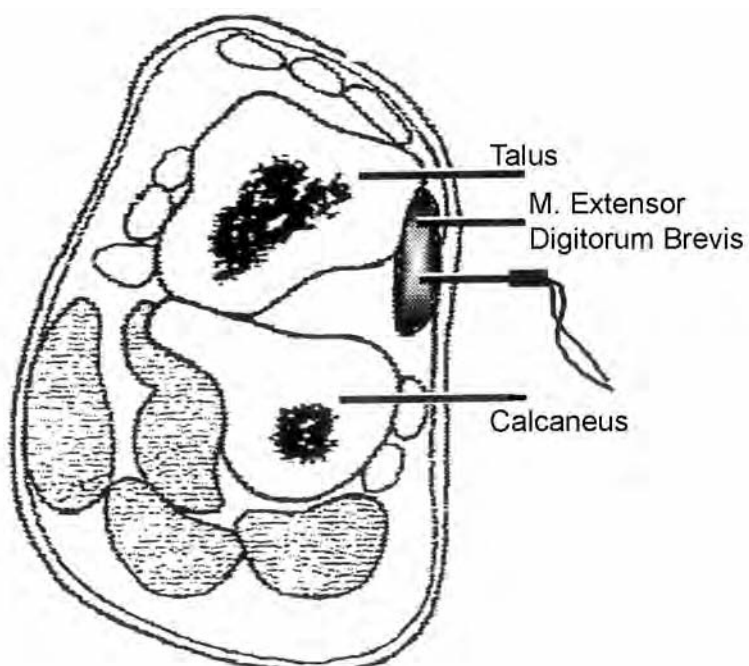
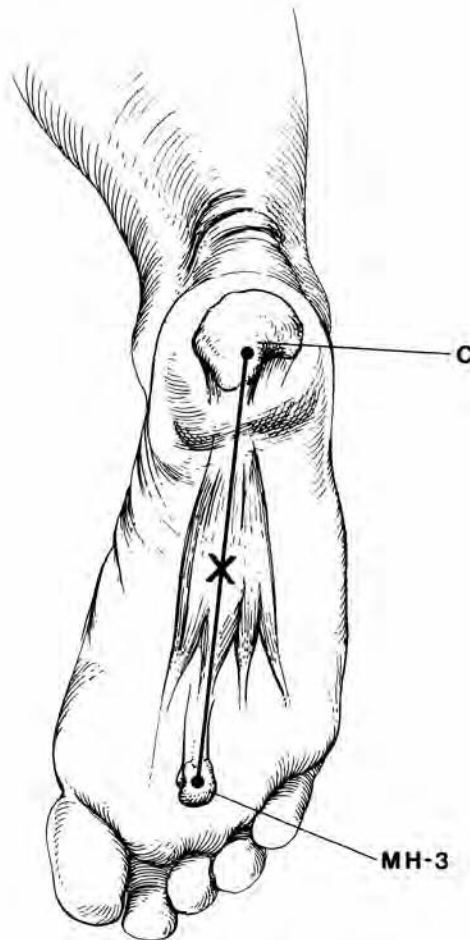


Figure 48. Cross section of the foot through the ankle joint.

FLEXOR DIGITORUM BREVIS



Innervation

Medial Plantar Nerve, Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

From the medial tubercle of the calcaneus and the deep surface of the plantar aponeurosis.

Insertion

Into both sides of the proximal end of the middle phalanx of the 4 lateral toes.

Position

Patient supine.

Electrode Insertion (X)

The electrode is inserted midway between the third metatarsal head (MH-3) and the calcaneus (C) to the plantar aponeurosis and then withdrawn slightly.

Test Maneuver

Patient to flex the toes.

Pitfalls

If the electrode is inserted too laterally it will be in the abductor digiti minimi; if inserted too medially it will be in the abductor hallucis brevis; if inserted too deeply it will be in the quadratus plantae.

Comments

- (a) Commonly involved in:
 - 1. Peripheral neuropathy secondary to diabetes mellitus
 - 2. Medial plantar nerve lesions
 - 3. Tarsal tunnel syndrome
 - 4. More proximal lesions involving the tibial nerve, sciatic nerve, sacral plexus or S1, S2 roots.
 - 5. This muscle is the central muscle of the three muscles located in the most superficial muscular layer of the foot.
 - 6. Its main function is to flex the lateral 4 digits (toes)
 - 7. When the individual is weight bearing this muscle help to support the medial and lateral longitudinal arches of the foot.
- (b) Attention should be given to avoid introducing an infection in the foot of a patient with diabetes.

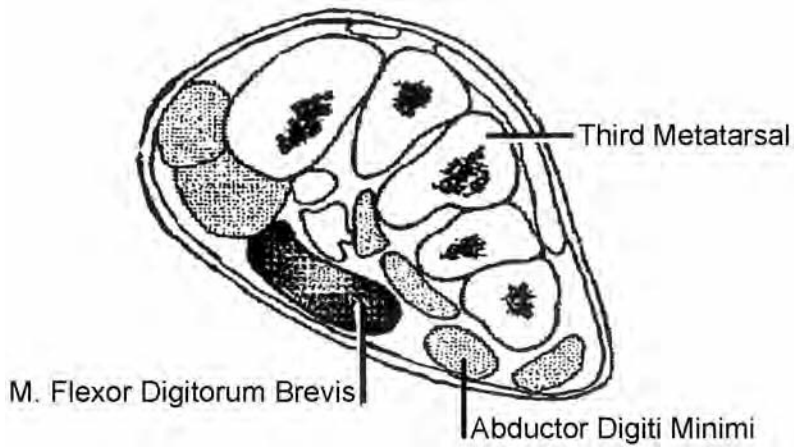
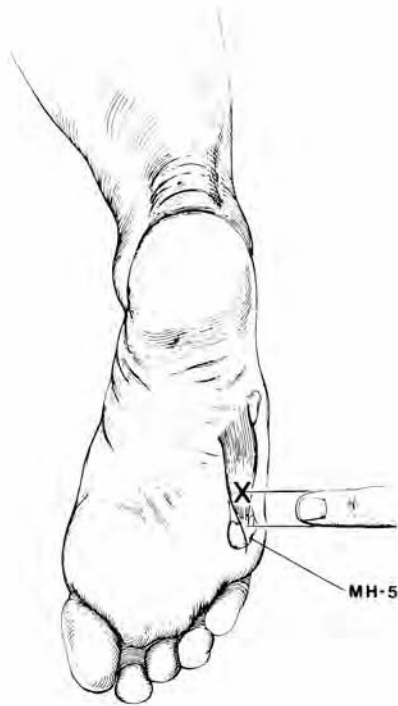


Figure 49. Cross section of the foot through the midportion.

FLEXOR DIGITI QUINTI BREVIS



Innervation

Lateral Plantar Nerve, Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

From the sheath of the peroneus longus tendon and the base of the fifth metatarsal bone.

Insertion

In a common tendon with the abductor digit minimi into the lateral side of the base of the proximal phalanx of the little toe.

Position

The patient supine.

Electrode Insertion (X)

On the plantar surface of the foot, one fingerbreadth proximal to the fifth metatarsal head (MH-5), the electrode is inserted to the bone and then withdrawn slightly.

Test Maneuver

Patient to flex the metatarsalphalangeal joint of the little toe.

Pitfalls

If the electrode is inserted too laterally it will be in the abductor digiti minimi; if inserted too medially it will be in the lumbrical.

Comments

- (a) Commonly involved in:
 - 1. Peripheral neuropathy secondary to diabetes mellitus
 - 2. Lateral plantar nerve damage
 - 3. Tarsal tunnel syndrome
 - 4. More proximal lesions involving the tibial nerve, sciatic nerve, sacral plexus or S1, S2 roots.
- (b) This slender muscle is the most lateral one located in the 3rd layer of muscle of the foot.
- (c) The major function of this muscle is to flex the 5th M.P. joint. Therefore it is a significant helper in stabilizing the foot during push off.
- (d) Attention should be given to avoid introducing an infection in the foot of a patient with diabetes.

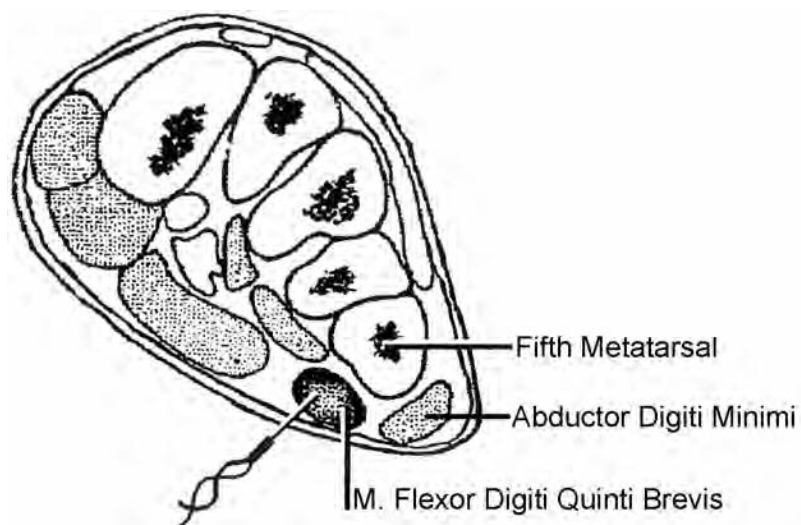
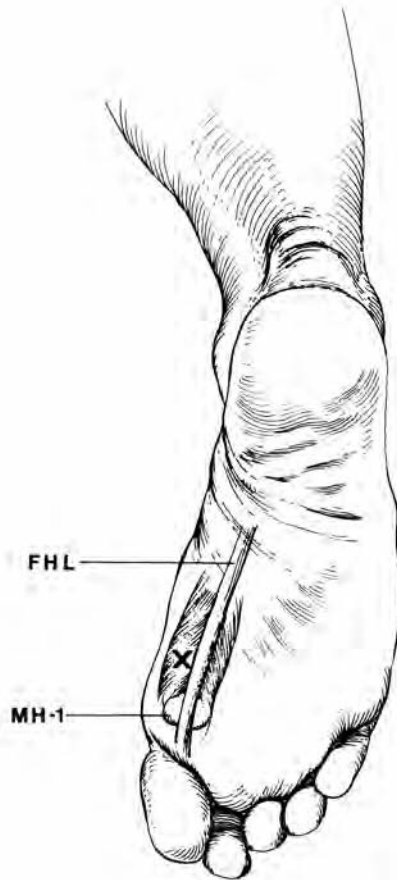


Figure 50. Cross section of the foot through the midportion.

FLEXOR HALLUCIS BREVIS



Innervation

Medial Plantar Nerve, Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

The two muscle bellies originate from a tendinous expansion of the tibialis posterior muscle insertion and from the cuneiform and the cuboid.

Insertion

The two tendons end at each side of the base of the proximal phalanx of the big toe, the medial one in a common tendon with that of the abductor, and the lateral one in a common tendon with that of the adductor hallucis brevis.

Position

The patient supine.

Electrode Insertion (X)

For medial head only: Proximal and medial to the tendon of the flexor hallucis longus.

Test Maneuver

Patient to flex the metatarsalphalangeal joint of the big toe.

Pitfalls

If the electrode is inserted too laterally it will be in the adductor hallucis; if inserted too medially it will be in the abductor hallucis.

Comments

- (a) Commonly involved in:
 - 1. Peripheral neuropathy secondary to diabetes mellitus
 - 2. Medial plantar nerve
 - 3. Tarsal-tunnel syndrome
 - 4. More proximal lesions involving the tibial nerve, sciatic nerve, sacral plexus or S1, S2 roots.
- (b) This is the most medially located muscle in the 3rd (deepest) layer of the foot.
- (c) The main function is to flex the 1st M.P. and to stabilize the big toe at push off.
- (d) There are two sesamoid bones in each of the two tendons. The function of these bones is to avoid high pressure on the head of the metatarsal head during walking or standing.

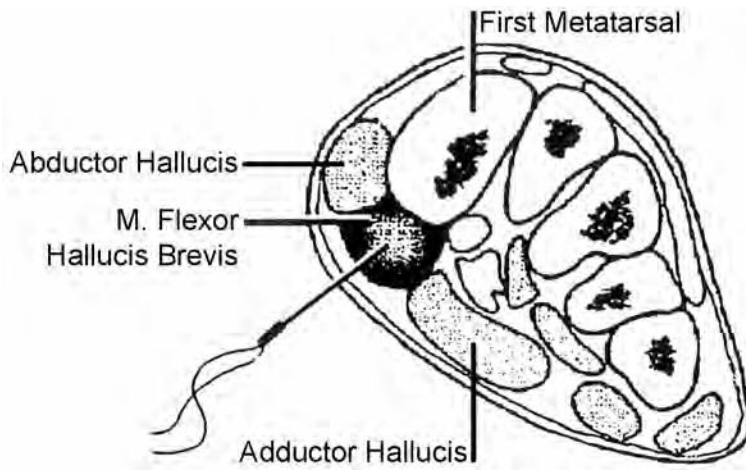


Figure 51. Cross section of the foot through the midportion.

INTEROSSEI*



Innervation

Lateral Plantar Nerve, Tibial Nerve, Sciatic Nerve, Sacral Plexus, S1, S2.

Origin

Dorsal Interossei: From the shaft in the metatarsal bone into the lateral base of the proximal phalanx from the 2nd to the 4th toe. The second toe presents a 2nd Interossei that originates over the medial aspect of the 2nd metatarsal and insert in the proximal phalanx, proximal end, medial aspect of the 2nd toe. This is a similar arrangement to the one in the hand with the exception that in the hands occurs in the 3rd finger.

*It was impossible to differentiate between the dorsal and volar interossei with the needle electrode.

Plantar Interossei: There are only 3 for the 3 lateral toes. They originate from the shaft of the 3rd, 4th, and 5th metatarsal bone and insert into the proximal phalanx, proximal end medial aspect.

Position

The patient is supine.

Electrode Insertion (X)

The needle electrode is inserted one fingerbreadth proximal to the metatarsalphalangeal (MP) joints in the intermetatarsal space. The number of interosseus muscle corresponds to the number of the intermetatarsal space.

Test Maneuver

Spread toes.

Pitfalls

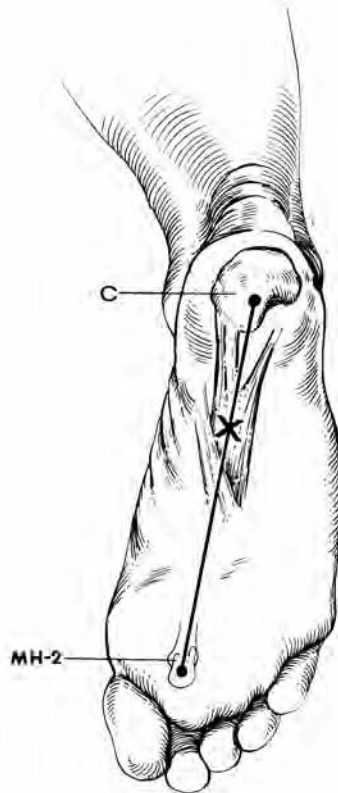
If the needle electrode is inserted too deeply it will be either in the oblique or transverse head of the adductor hallucis.

Comments

- (a) This group of muscles is commonly involved in:
 - 1. Peripheral neuropathy secondary to diabetes mellitus
 - 2. Lateral plantar nerve lesions
 - 3. Tarsal-tunnel syndrome
 - 4. More proximal lesions involving the tibial nerve, sciatic nerve, sacral plexus, or S1, S2 roots.
- (b) These muscles are located in the 4th muscular layer of the foot.
- (c) Its function is to adduct the toes (for the plantar Interossei) and to abduct the digits 2 to 4 (for the dorsal interossei).
- (d) Special attention should be given to avoid introducing an infection in the foot of a diabetic patient.

QUADRATUS PLANTAE

(FLEXOR DIGITORUM ACCESSORIUS)



Innervation

Lateral Plantar Nerve, Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

Medial Head: From medial surface of calcaneus.

Lateral Head: From lateral border of the plantar surface of the calcaneus.

Insertion

Into the tendon of the flexor digitorum longus.

Position

The patient supine.

Electrode Insertion (X)

Insert the electrode at the junction of proximal and middle one-third of a line between the tip of the calcaneus (C) and the second metatarsal head (MH-2). Insert deep to bone and withdraw slightly. The electrode will travel through the flexor digitorum brevis muscle.

Test Maneuver

Patient to flex the toes.

Pitfalls

If the electrode is inserted too superficially it will be in the flexor digitorum brevis; if inserted too laterally it will be in the abductor digiti minimi; if inserted too medially it will be in the abductor hallucis brevis.

Comments

- (a) Involved in lesions of:
 - 1. Peripheral neuropathy secondary to diabetes mellitus
 - 2. Lateral plantar nerve lesions
 - 3. Tarsal-tunnel syndrome
 - 4. More proximal lesions of tibial nerve, sciatic nerve, sacral plexus and S1, S2 nerve roots.
- (b) This muscle is located, together with the lumbricals in the 2nd muscular layer of the foot.
- (c) Its function is to assist the flexor digitorum longus to flex the 4 lateral toes. It also adjusts the pull of the F.D.L. more in line with the longitudinal axis of the foot.
- (d) Special attention should be given to avoid introducing an infection in the foot of diabetic patients.

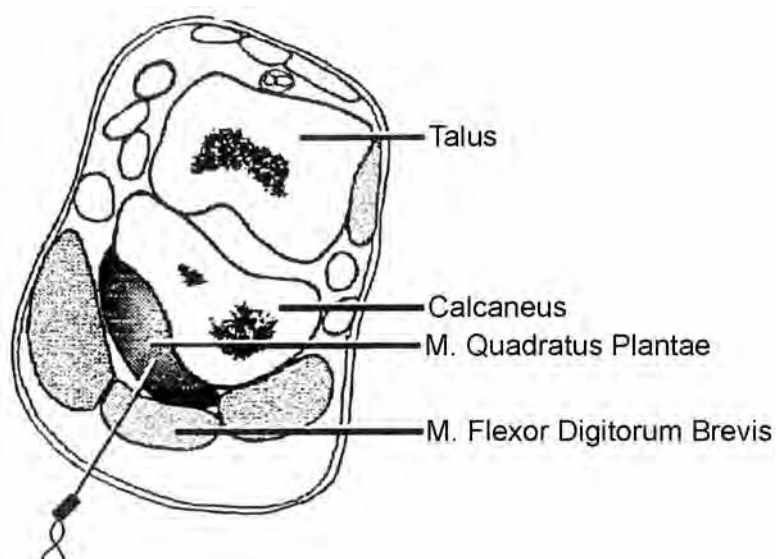
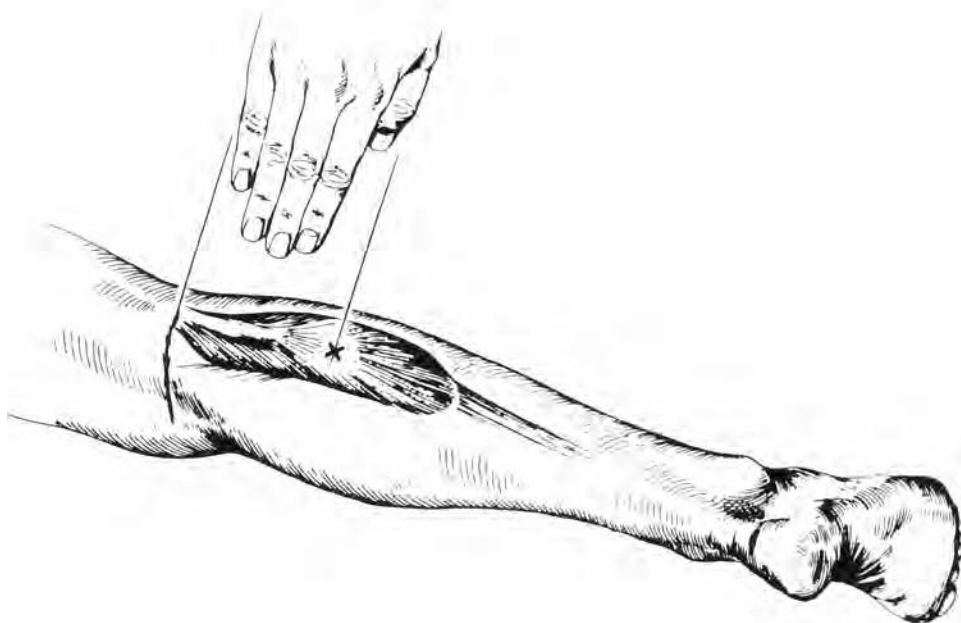


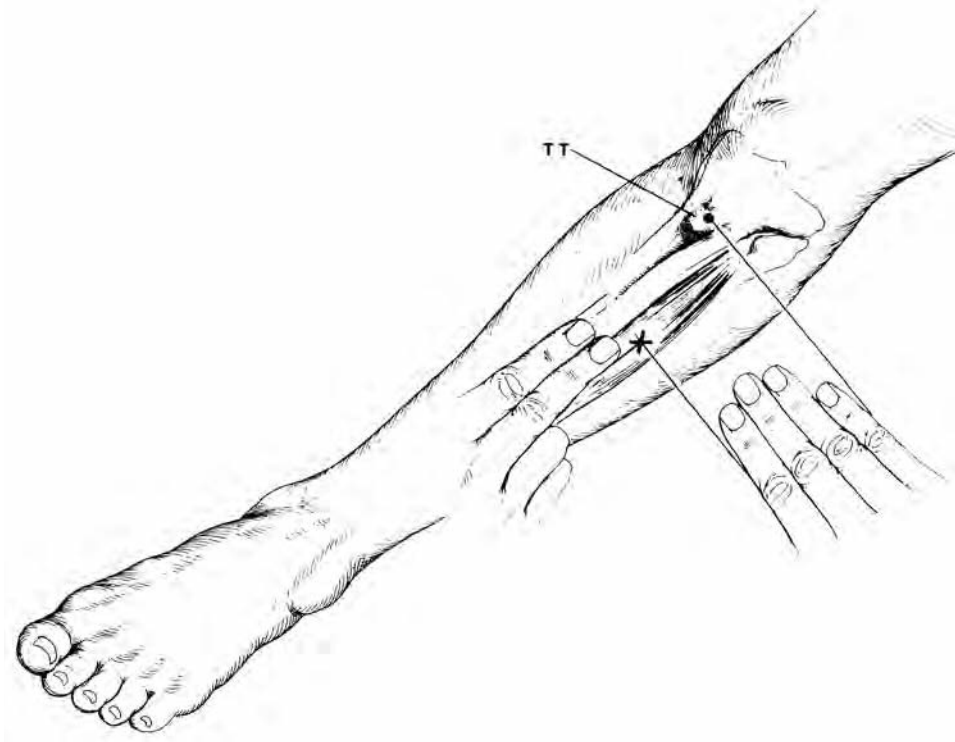
Figure 52. Cross section of the foot through the ankle joint (foot is plantarflexed 45°).



SECTION VII

LEG

EXTENSOR DIGITORUM LONGUS



Innervation

Deep Peroneal Nerve, Common Peroneal Nerve, Sciatic Nerve, Posterior Division Sacral Plexus, L5, S1.

Origin

From the lateral condyle of the tibia, the proximal three-fourths of the fibula and the interosseus membrane.

Insertion

Through a common tendon with the lumbricals and the interossei into the dorsum of the middle and distal phalanx of the four lateral toes.

Position

The patient supine.

Electrode Insertion (X)

Four fingerbreadths distal to the tibial tubercle (TT) and two fingerbreadths lateral to the tibial crest, the electrode is inserted through the tibialis anterior about one inch.

Test Maneuver

Patient to extend the four lateral toes.

Pitfalls

If the electrode is inserted too anteriorly it will be in the tibialis anterior; if inserted too laterally it will be in the peroneus longus.

Comments

- (a) Involved in:
 - 1. Anterior compartment syndrome
 - 2. Lesions of the deep peroneal nerve
 - 3. Common peroneal nerve
 - 4. Sciatic nerve
 - 5. Sacral plexus.
- (b) The main function of this muscle is to extend the lateral four toes and dorsiflex the ankle.

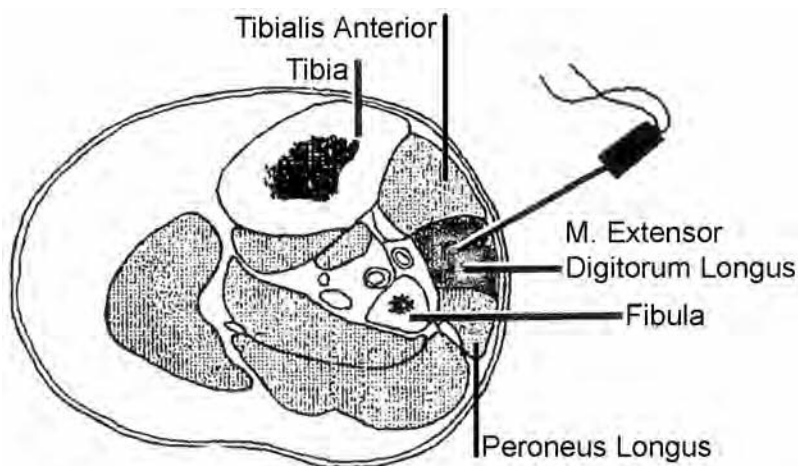
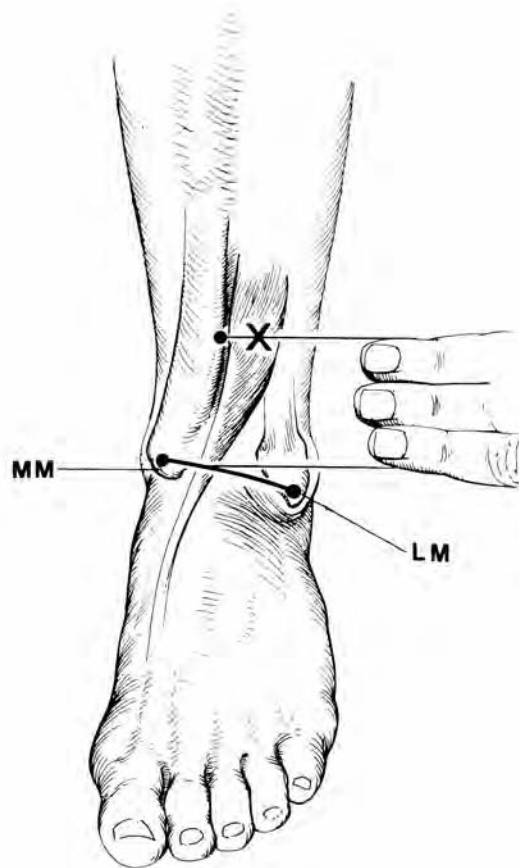


Figure 53. Cross section of the leg through the junction of the upper and middle third.

EXTENSOR HALLUCIS LONGUS



Innervation

Deep Peroneal Nerve, Common Peroneal Nerve, Sciatic Nerve, Posterior Division Sacral Plexus, L5, S1.

Origin

From the midportion of the shaft of the fibula.

Insertion

Into the distal phalanx of the great toe.

Position

The patient supine.

Electrode Insertion (X)

Three fingerbreadths above the bimalleolar line (MM-LM) of the ankle just lateral to the crest of the tibia.

Test Maneuver

Patient to extend the big toe or to dorsi flex the foot.

Pitfalls

If the electrode is inserted too superficially and too proximally it will be in the tibialis anterior; if inserted too laterally it will be in the Peroneus tertius.

Comments

- (a) Involved in:
 - 1. Anterior compartment syndrome
 - 2. Lesion of the deep peroneal nerve
 - 3. Common peroneal nerve
 - 4. Sciatic nerve
 - 5. Sacral plexus
 - 6. L5, S1 root lesions.

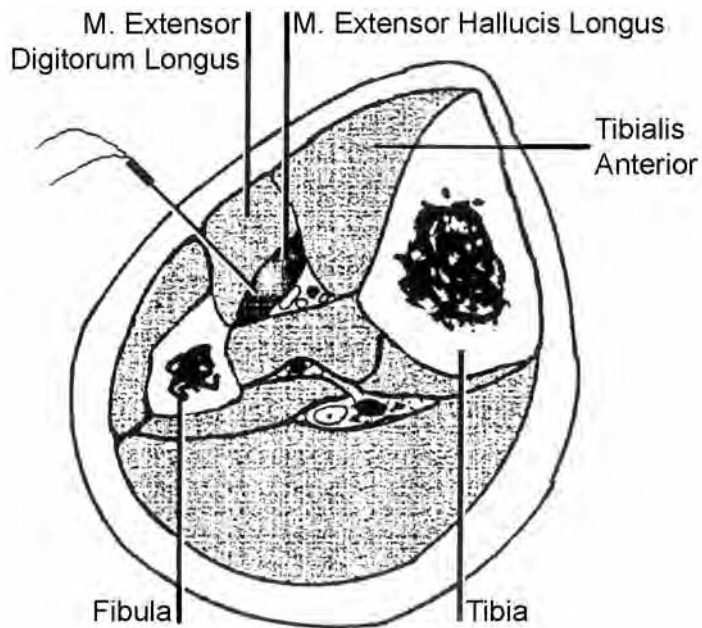
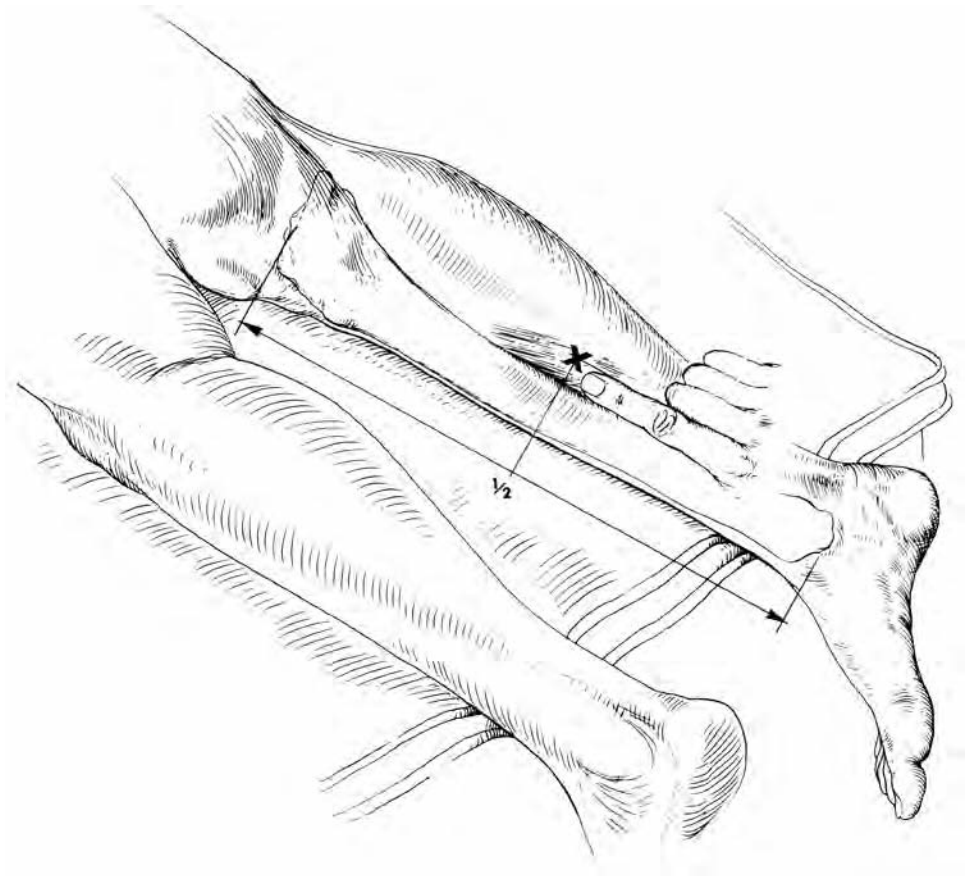


Figure 54. Cross section of the leg through the junction of the middle and lower third.

FLEXOR DIGITORUM LONGUS



Innervation

Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, L5, S1, S2.

Origin

From the body of the tibia below the popliteal line.

Insertion

Into the base of the distal phalanges of the second, third, fourth and fifth toe.

Position

The patient prone.

Electrode Insertion (X)

Palpate the medial edge of tibia at midshaft and insert electrode just posterior to it.

Test Maneuver

Patient to flex the toes, without flexing the ankle.

Pitfalls

If the electrode is inserted too superficially it will be in the soleus; if inserted too deeply it will be in the tibialis posterior.

Comments

- (a) Involved in lesions of:
 - 1. The tibial nerve
 - 2. Sciatic nerve
 - 3. Sacral plexus
 - 4. L5, S1, S2 roots.
- (b) The main function of this muscle is to flex the lateral 4 toes. It is also a good plantar flexor of the foot and a strong supporter of the longitudinal arch of the foot.

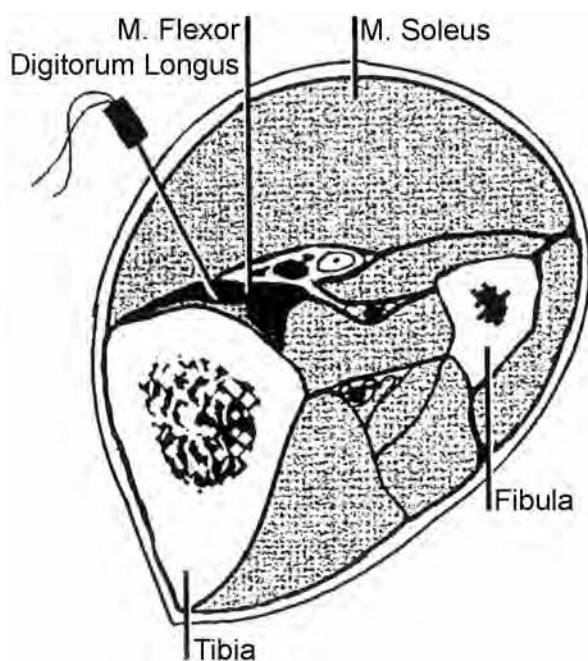
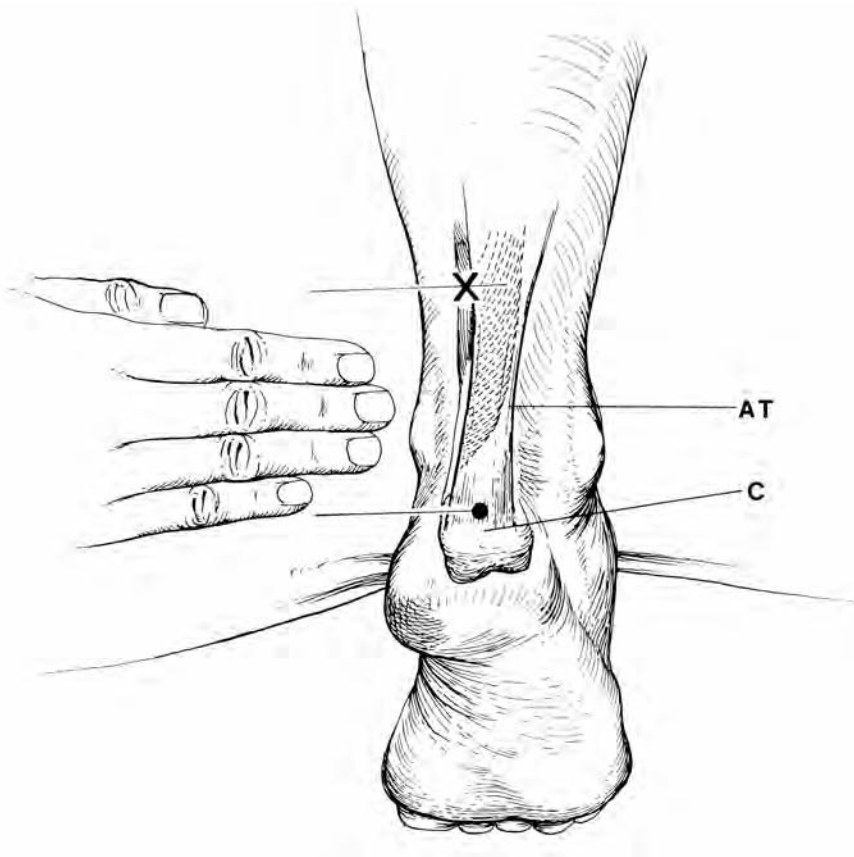


Figure 55. Cross section of the leg through the junction of the middle and lower third.

FLEXOR HALLUCIS LONGUS



Innervation

Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, L5, S1, S2.

Origin

From the inferior two-thirds of the posterior surface of body of the fibula and the interosseus membrane.

Insertion

Into the base of the distal phalanx of the great toe.

Position

The patient prone.

Electrode Insertion (X)

Insert the electrode obliquely five fingerbreadths above the insertion of the Achilles tendon (AT) and anterior to the medial border of this tendon towards the tibia.

Test Maneuver

Patient to flex the big toe, keeping the ankle and the small toes relaxed.

Pitfalls

If the electrode is inserted too deeply it will be in the tibialis posterior; if inserted too anteriorly it will be in the flexor digitorum longus; if inserted too proximal it will be in the lower fibers of the soleus.

Comments

- (a) Involved in lesions of:
 - 1. Tibial nerve
 - 2. Sciatic nerve
 - 3. Sacral plexus
 - 4. L5, S1, S2 roots.
- (b) The main function of this muscle is to flex all joints of the big toe. It is also a plantar flexor of the foot and it is a strong supporter of the longitudinal arch of the foot.

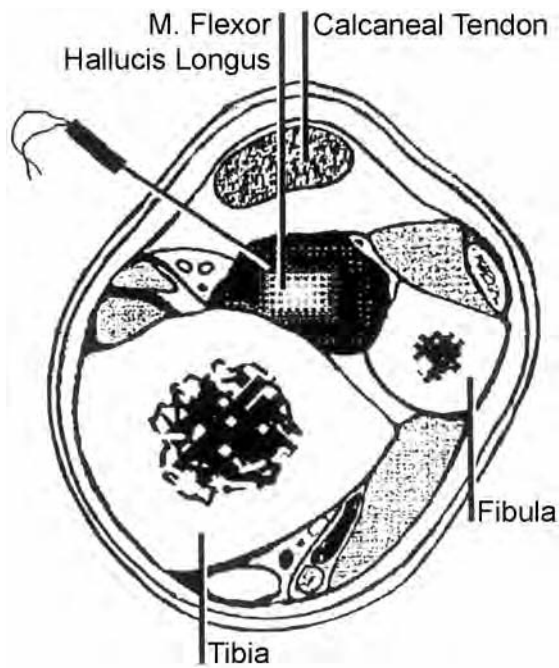
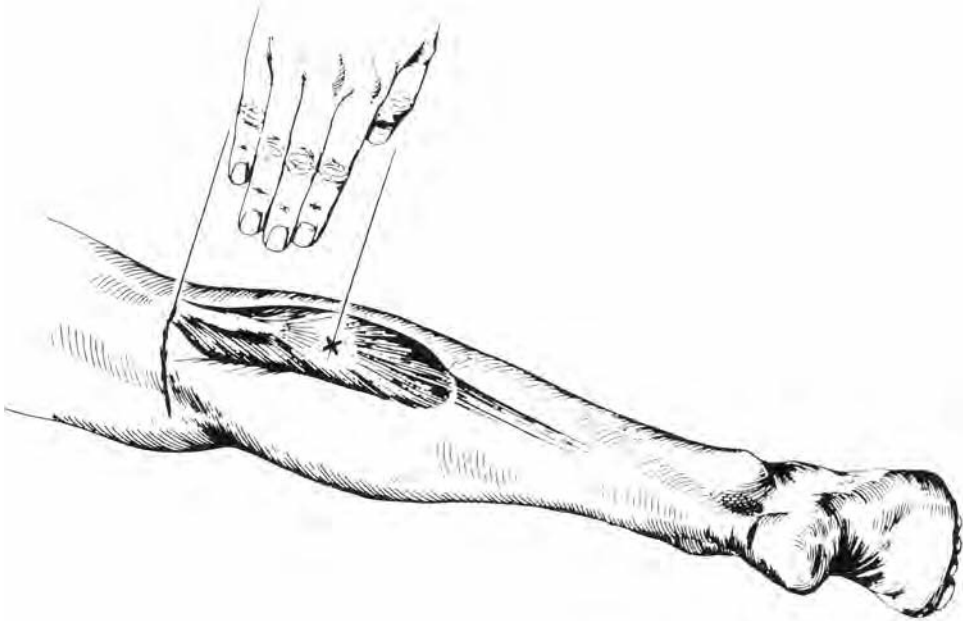


Figure 56. Cross section of the leg through the distal third.

GASTROCNEMIUS: LATERAL HEAD



Innervation

Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

From the lateral femoral condyle.

Insertion

Into the calcaneus, through the Achille's tendon.

Position

The patient prone with feet over edge of plinth.

Electrode Insertion (X)

One handbreadth below the popliteal crease on the lateral mass of the calf.

Test Maneuver

Patient to plantar flex the foot with the knee extended.

Pitfalls

If the electrode is inserted too deeply it will be in the soleus.

Comments

(a) Involved in lesions of:

1. Tibial nerve
2. Sciatic nerve
3. Sacral plexus
4. L5, S1, S2 roots.

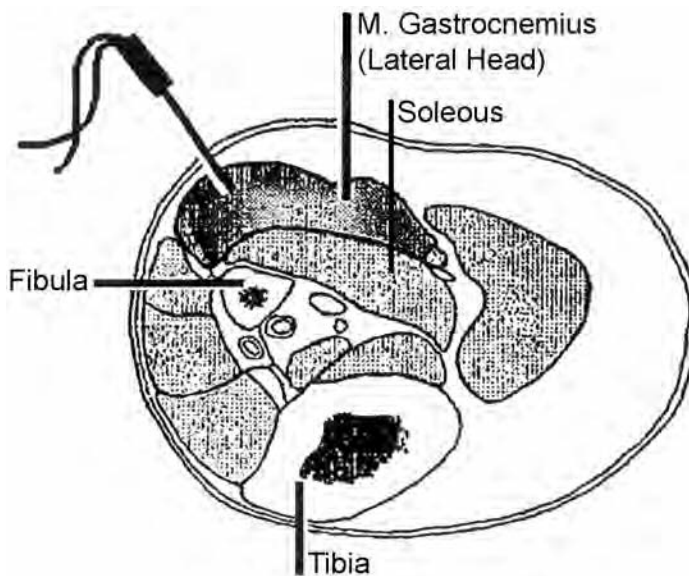


Figure 57. Cross section of the leg through the junction of the upper and middle third.

GASTROCNEMIUS: MEDIAL HEAD



Innervation

Tibial Nerve, Sciatic Nerve, Ventral Division Sacral Plexus, S1, S2.

Origin

From the medial femoral condyle.

Insertion

Into the calcaneus, through the Achille's tendon.

Position

The patient prone with feet over edge of plinth.

Electrode Insertion (X)

One handbreadth below the popliteal crease on the medial mass of the calf.

Test Maneuver

Patient to plantar flex the foot with the knee extended.

Pitfalls

If the electrode is inserted too deeply it will be in the flexor digitorum longus or in the soleus.

Comments

- (a) Involved in lesions of:
 - 1. Tibial nerve
 - 2. Sciatic nerve
 - 3. Sacral plexus
 - 4. L5, S1, S2 roots.
- (b) This muscle injury may produce a very painful condition call "tennis leg," resulting from a partial tear of the medial Gastrocnemius at the muscular-tendon junction.

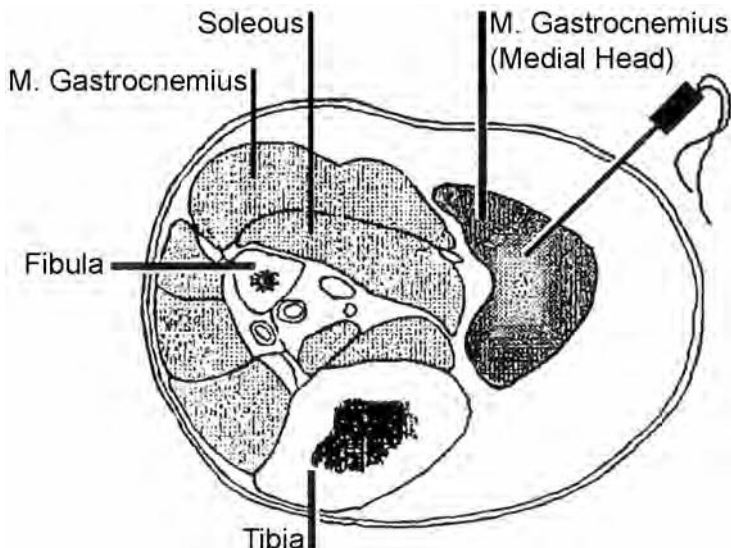
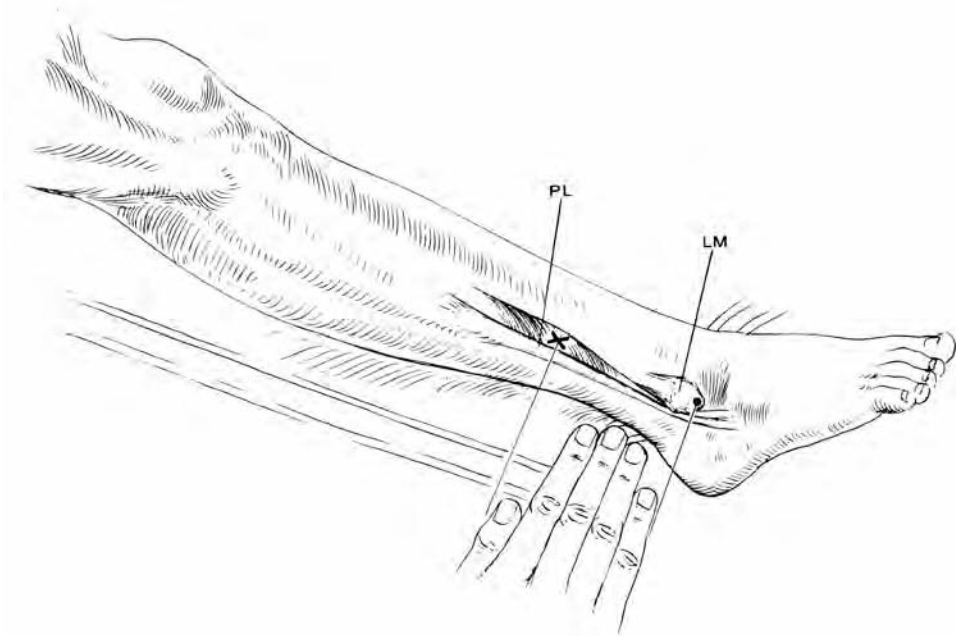


Figure 58. Cross section of the leg through the junction of the upper and middle third.

PERONEUS BREVIS



Innervation

Superficial Peroneal Nerve, Common Peroneal Nerve, Sciatic Nerve, Posterior Division Sacral Plexus, L5, S1, S2.

Origin

From the lower two-thirds of the fibula.

Insertion

Into the base of the fifth metatarsal head.

Position

The patient supine.

Electrode Insertion (X)

One handbreadth proximal to the lateral malleolus (LM) and anterior to the peroneus longus (PL) tendon.

Test Maneuver

Patient to plantar flex and evert the foot.

Pitfalls

If the electrode is inserted too proximally it will be in the peroneus longus; if inserted too anteriorly it will be either in the peroneus tertius or in the extensor digitorum longus.

Comments

- (a) Can be used as recording muscle when the superficial peroneal nerve is to be studied.
- (b) Involved in lesions of:
 - 1. Superficial peroneal nerve
 - 2. Common peroneal nerve
 - 3. Sciatic nerve
 - 4. Sacral plexus
 - 5. L5, S1 roots.
- (c) This muscle main function is to evert the foot and also has a weak action in plantar-flexing the foot.

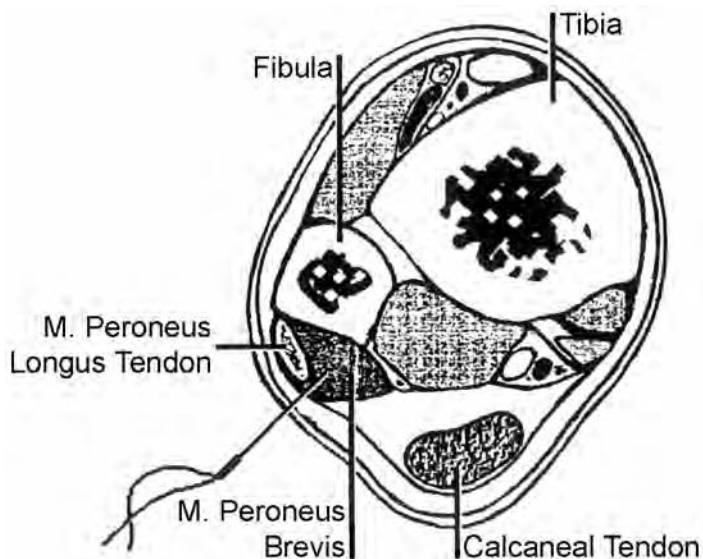
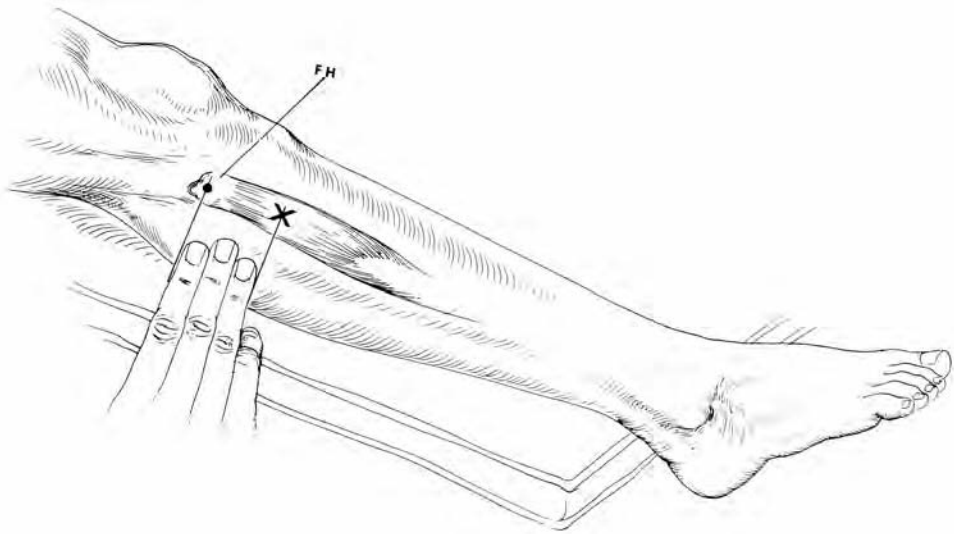


Figure 59. Cross section of the leg through the distal third.

PERONEUS LONGUS



Innervation

Superficial Peroneal Nerve, Common Peroneal Nerve, Sciatic Nerve, Posterior Division Sacral Plexus, L5, S1, S2.

Origin

From the fibular head and from the proximal two-thirds of the fibula.

Insertion

Into the base of the first metatarsal and the first cuneiform.

Position

The patient supine.

Electrode Insertion (X)

Three fingerbreadths below the fibular head (FH) directed toward the lateral aspect of the fibula.

Test Maneuver

Patient to plantar flex and evert the foot.

Pitfalls

If the electrode is inserted too posteriorly it will be in the soleus; if inserted too anteriorly it will be in the extensor digitorum longus.

Comments

- (a) This muscle is involved in lesions of:
 - 1. Superficial peroneal nerve
 - 2. Common peroneal nerve
 - 3. Sciatic nerve
 - 4. Sacral plexus
 - 5. L5, S1 roots.
- (b) The main function of this muscle is to evert the foot. It also has a weak function in plantar-flexing the foot. It is a good support of the transverse arch of the foot.
- (c) Paralysis of this muscle produces a change in the balance of the foot, forcing the patient to walk on the external border of the foot. The transverse arch of the foot flattens down.

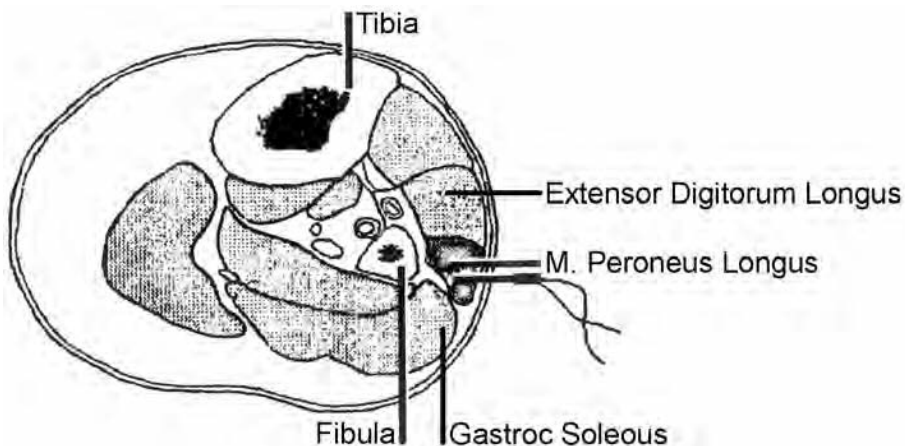
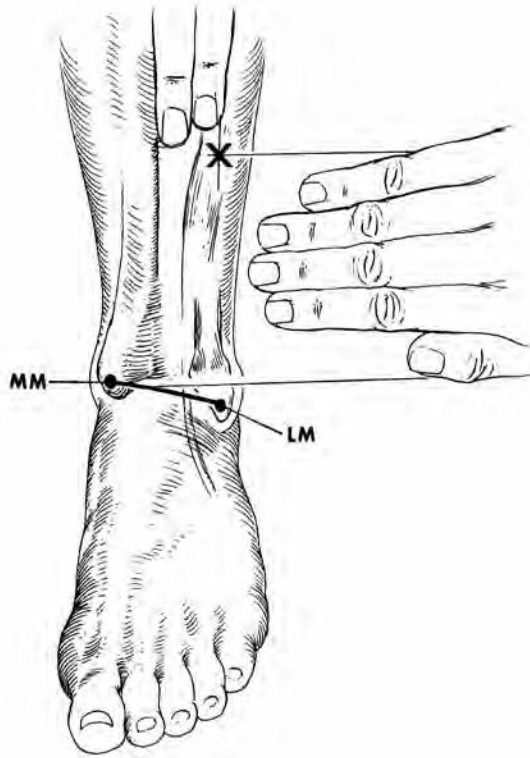


Figure 60. Cross section of the leg through the junction of the upper and middle third.

PERONEUS TERTIUS



Innervation

Deep Peroneal Nerve, Common Peroneal Nerve, Sciatic Nerve, Posterior Division Sacral Plexus, L5, S1.

Origin

From the anterior surface of the lower one-third of the fibula.

Insertion

Into the base of the fifth metatarsal head, anterior surface.

Position

The patient supine.

Electrode Insertion (X)

One handbreadth above bimalleolar line (MM–LM) of the ankle and two fingerbreadths lateral to the tibia.

Test Maneuver

Patient to dorsiflex and evert the foot.

Pitfalls

If the electrode is inserted too medially it will be in the extensor hallucis longus; if inserted too proximally it will be in the tibialis anterior or the extensor digitorum longus.

Comments

- (a) This is the only peroneal muscle located in the anterior compartment of the leg. Therefore, it becomes involved in anterior compartment syndrome.
- (b) This muscle may be considered as part of the extensor digitorum longus (its fifth tendon).
- (c) It is involved in lesions of:
 - 1. Deep peroneal nerve
 - 2. Common peroneal nerve
 - 3. Sciatic nerve
 - 4. Sacral plexus
 - 5. L5, S1.
- (d) This muscle is not present in all individuals. Embryologically it seems to be a muscle which separated from the extensor digitorum longus and found its insertion in the base of the 5th metatarsal head.

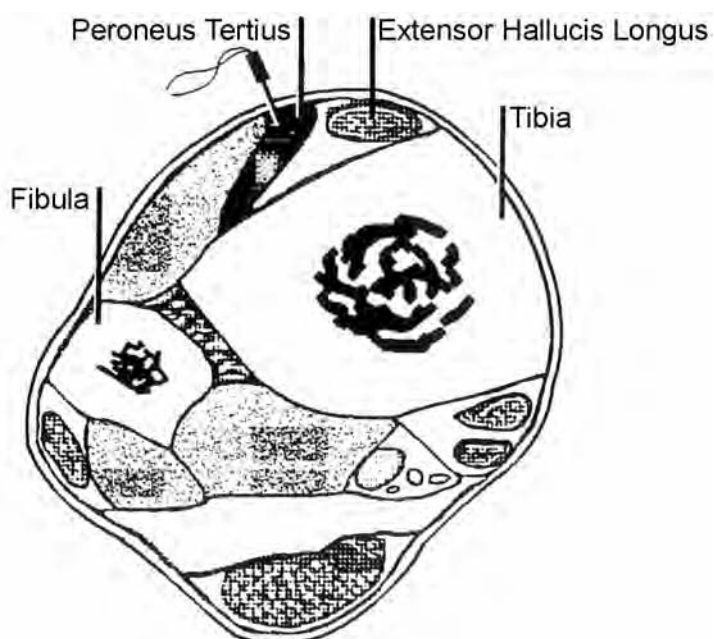
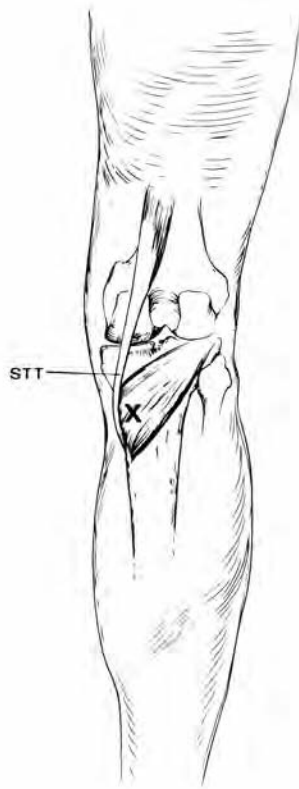


Figure 61. Cross section of the leg through the distal third.

POPLITEUS



Innervation

Tibial Nerve, Sciatic Nerve, Anterior Division Sacral Plexus, L5, S1.

Origin

From the fibrous capsule of the knee joint on the side of the lateral condyle of the femur.

Insertion

Into the triangular area of the tibia above the soleal line.

Position

The patient prone with the knee fully extended.

Electrode Insertion (X)

The needle electrode is inserted laterally to the insertion of the semitendinosus tendon (STT).

Test Maneuver

Flex and internally rotate tibia.

Pitfalls

If the needle electrode is inserted either too distally or too superficially it will be in the gastrocnemius.

Comments

- (a) Involved in lesions of:
 - 1. High tibial nerve
 - 2. Sciatic nerve
 - 3. Sacral plexus
 - 4. L5, S1 roots.
- (b) This muscle is a weak knee flexor. The most important function is to unlock the knee when is in full extension, by moving the lateral condyle of the femur posterior and therefore initiating the knee flexion in a safe way.

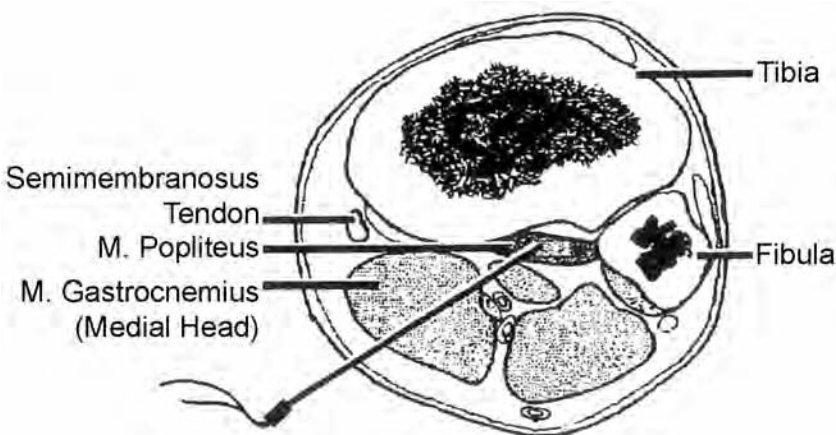
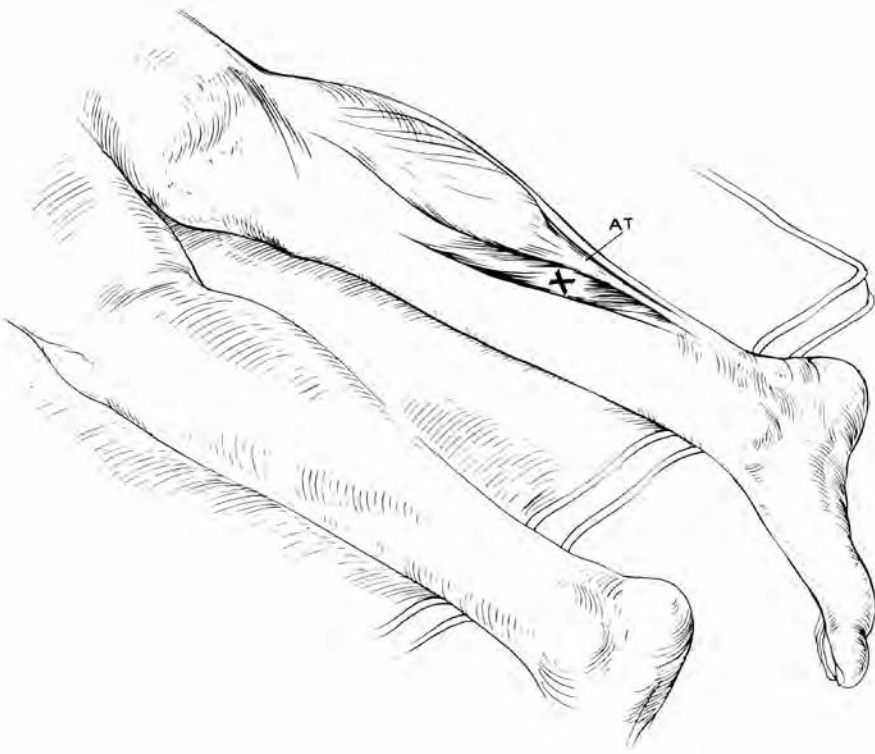


Figure 62. Cross section of the leg through the fibula head.

SOLEUS



Innervation

Tibial Nerve, Sciatic Nerve, Anterior Division Sacral Plexus, L5, S1, S2.

Origin

From the head and the proximal portion of the body of the fibula and the middle one-third of the medial border of the tibia.

Insertion

Through the Achille's tendon, on calcaneus bone.

Electrode Insertion (X)

Insert the electrode distal to the belly of the gastrocnemius muscle, medial and anterior to the Achilles tendon (AT).

Test Maneuver

Patient to plantar flex foot with knee flexed.

Pitfalls

If electrode is inserted too superficially and too proximal it will be in the gastrocnemius.

Comments

- (a) Muscle most commonly used to study the “H” reflex.
- (b) This muscle is involved in lesions of:
 - 1. Tibial nerve
 - 2. Sciatic nerve
 - 3. Sacral plexus
 - 4. S1, S2 roots.
- (c) This muscle and the gastrocnemius (triceps surae), produce a twitch (ankle jerk), when the Achilles tendon is tapped. The center of the reflex is at the S1–S2 spinal cord level.
- (d) The triceps surae is an important muscle to help the venous return of the legs. This is called the “ankle pump.” This pump works only when the triceps surae contracts in a tight quarters provided by the deep fascia enveloping these muscles. When these fascia covertures are damaged (usually due to chronic edema) the pump stops functioning, and the patient develop a chronic edema leading to chronic venous insufficiency.
- (e) This muscle does not cross the knee joint as the gastrocnemius does, therefore it does not help in flexing the knee.

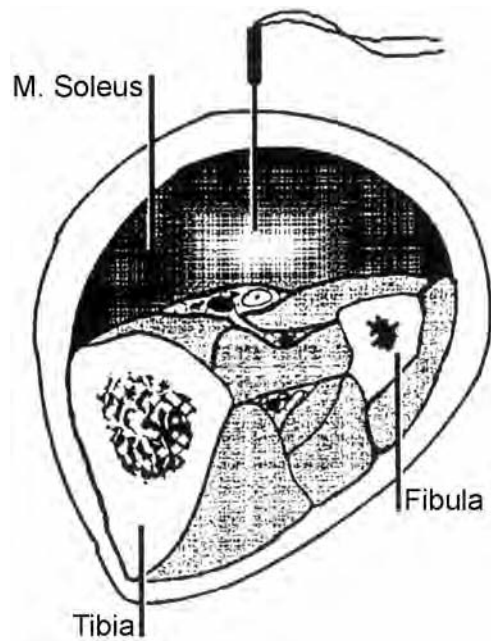
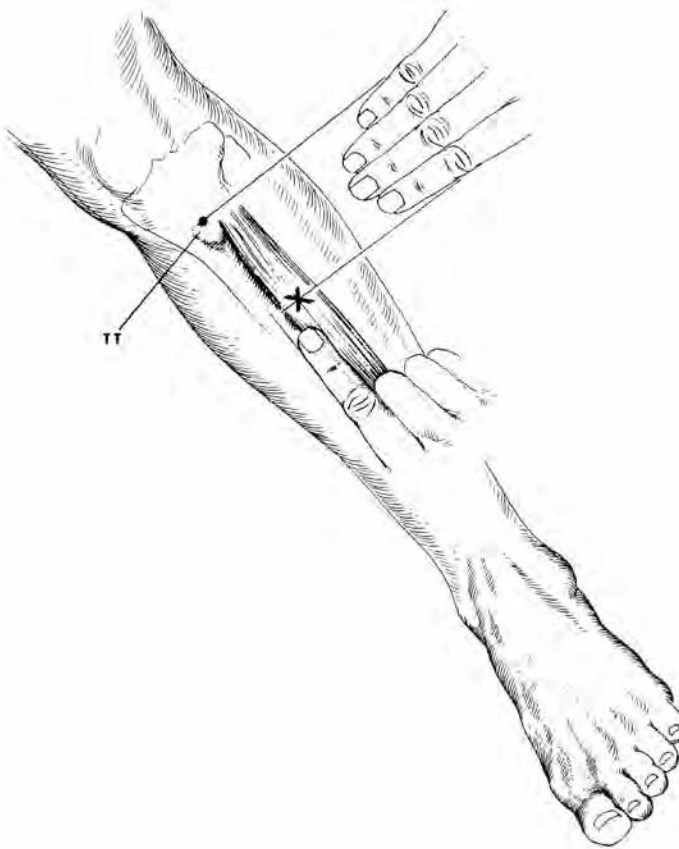


Figure 63. Cross section of the leg through the midportion.

TIBIALIS ANTERIOR



Innervation

Deep Peroneal Nerve, Common Peroneal Nerve, Sciatic Nerve, Posterior Division Sacral Plexus, L4, L5.

Origin

From the lateral condyle and the proximal two-thirds of the shaft of the tibia.

Insertion

On the first cuneiform and the base of the first metatarsal.

Position

The patient supine.

Electrode Insertion (X)

Four fingerbreadths below the tibial tuberosity (TT) and one fingerbreadth lateral to the tibial crest.

Test Maneuver

Patient to dorsiflex the foot.

Pitfalls

If the electrode is inserted too laterally and too deeply it will be in the extensor digitorum communis.

Comments

- (a) First muscle innervated by the deep peroneal nerve.
- (b) Involved in lesions of:
 - 1. Deep peroneal nerve
 - 2. Common peroneal nerve
 - 3. Sciatic nerve
 - 4. Sacral plexus
 - 5. L4, L5 roots.
- (c) When this muscle gets paralyzed, the foot drops into plantar flexion. When the patient tries to walk he has to bring the knee of the affected side high in order to clear the floor. This type of gait is called “high stepping gait” and the condition is usually called “foot drop.”
- (d) This muscle may be severely involved in “anterior compartment syndrome” which is an increased edema in the muscle and a hypertension in the osteoaponeurotic compartment. Under these conditions, the amount of blood flowing into the muscle is much reduced and the muscle may either get totally paralyzed or severely weakened.
- (e) This condition may also occur on trained or professional athletes that do not warm-up adequately.

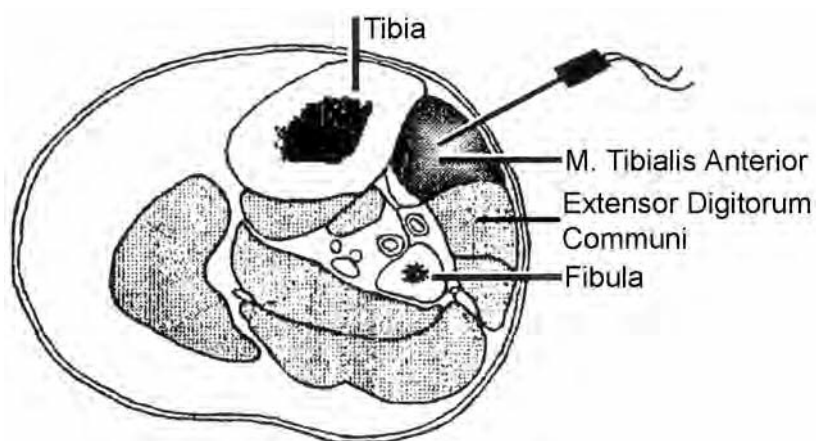
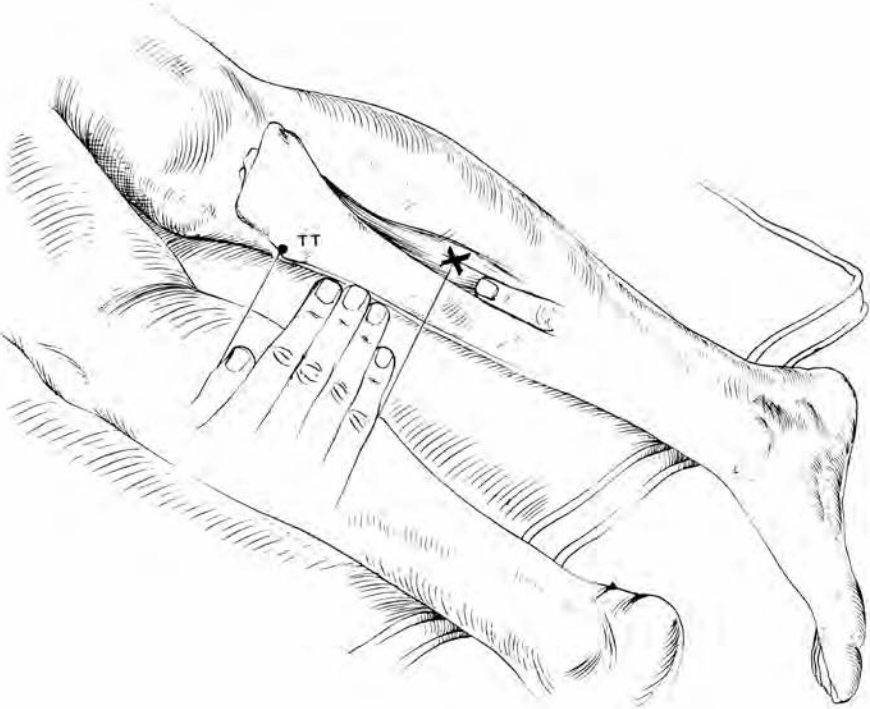


Figure 64. Cross section of the leg through the junction of the upper and middle third.

TIBIALIS POSTERIOR



Innervation

Tibial Nerve, Sciatic Nerve, Anterior Division Sacral Plexus, L5, S1.

Origin

From the interosseus membrane, the posterior surface of the body of the tibia and the upper two-thirds of the medial surface of the fibula.

Insertion

This muscle inserts on the tuberosity of the navicular bone and the medial cuneiform bone, and strong aponeurotic strips are sent across the foot to the bases of the second, third and fourth metatarsal bone.

Position

The patient prone with feet over edge of plinth, thigh internally rotated.

Electrode Insertion (X)

One handbreadth distal to the tibial tuberosity (TT) and one fingerbreadth off the medial edge of the tibia. The electrode is directed obliquely through the soleus and flexor digitorum longus, just posterior to the tibia.

Test Maneuver

Patient is to invert foot in plantar flexion.

Pitfalls

If the electrode is inserted too superficially it will be in the soleus or flexor digitorum longus; if inserted too deeply it will be in the tibialis anterior.

Comments

- (a) Involved in lesions of:
 - 1. Tibial nerve
 - 2. Sciatic nerve
 - 3. Sacral plexus
 - 4. L5, S1 root.
- (b) The main function of this muscle is to plantar flex and invert the foot.
- (c) This is the deepest muscle in the posterior compartment.
- (d) This muscle is the strongest support of the longitudinal arch of the foot.

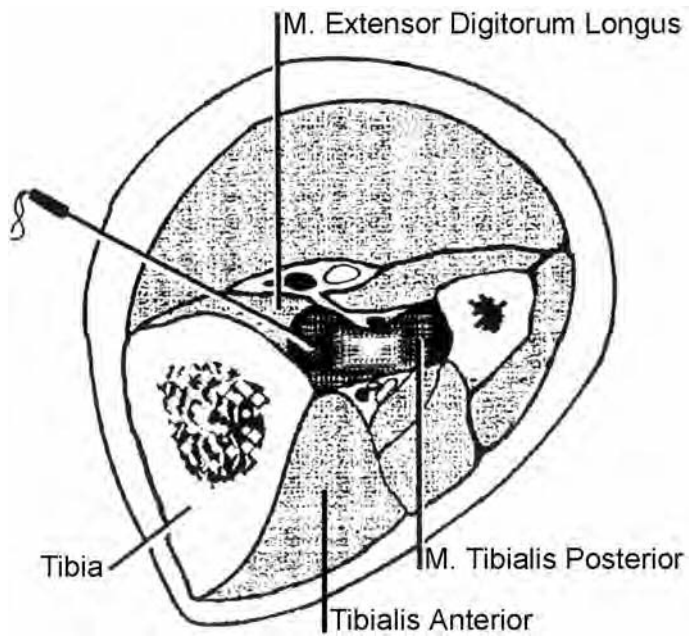
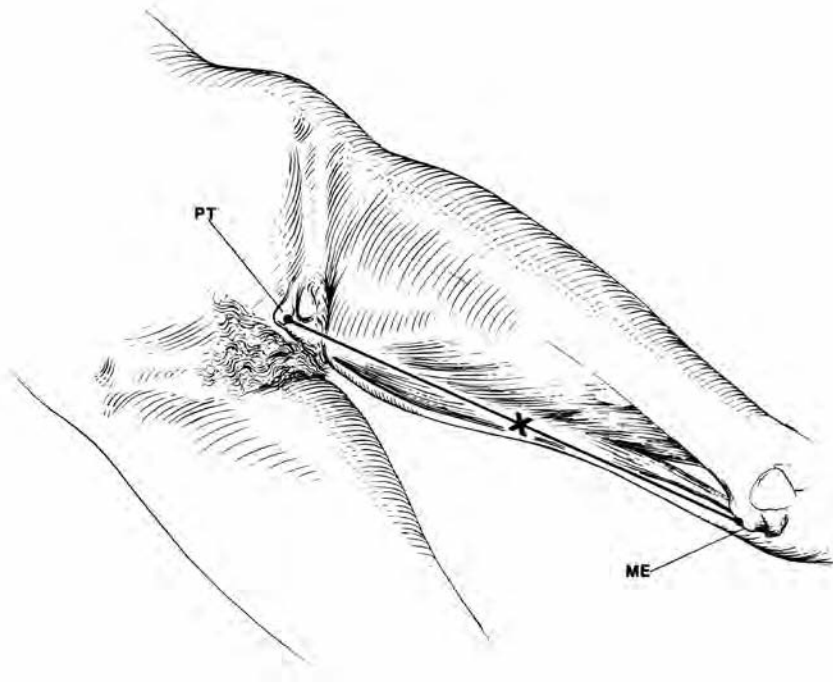


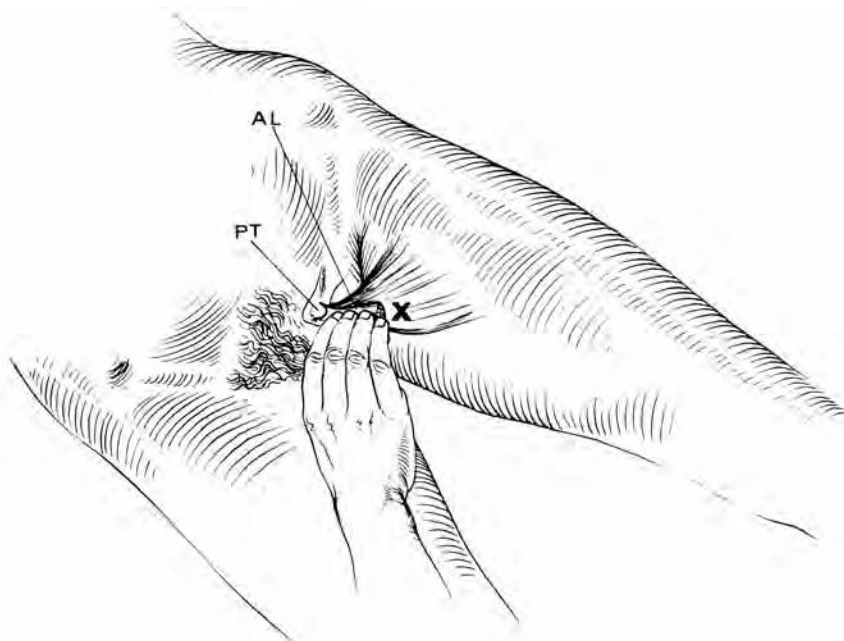
Figure 65. Cross section of the leg through the midportion.



SECTION VIII

THIGH

ADDUCTOR BREVIS



Innervation

Obturator Nerve, Anterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the inferior ramus of the pubis.

Insertion

To a line below the lesser trochanter of the femur.

Position

The patient supine with both lower extremities abducted fifteen degrees.

Electrode Insertion (X)

Palpate the tendon of adductor longus (AL) arising from pubic tubercle (PT) and insert electrode four fingerbreadths distal to tubercle through the adductor longus muscle to about two inches.

Test Maneuver

Patient to adduct the limb.

Pitfalls

If the electrode is inserted too superficially it will be in the adductor longus (laterally) or in the Gracilis (medially); if inserted too medially it will be in the adductor magnus.

Comments

- (a) Involved in:
 - 1. Anterior branch of the obturator nerve lesions
 - 2. Obturator nerve lesions
 - 3. Anterior division of the lumbar plexus lesions
 - 4. L2, L3, L4 roots lesions.
- (b) Landmark for obturator nerve block. Anterior branch lies on ventral surface of muscle, posterior branch lies on the posterior surface.
- (c) The main function of this muscle is to adduct the thigh, and to some extent to flexed over the pelvic bones.
- (d) In patients with upper motor neuron lesions and spasticity in the legs, the thighs are adducted and flexed. Under these circumstances, and if the patient is still able to walk, he does it with a particular gait, showing both knees rubbing each other (kissing knees), and the hip and knees partially flexed.
- (e) This muscle, in conjunction with other adductors are called “protectors of the virginity.”

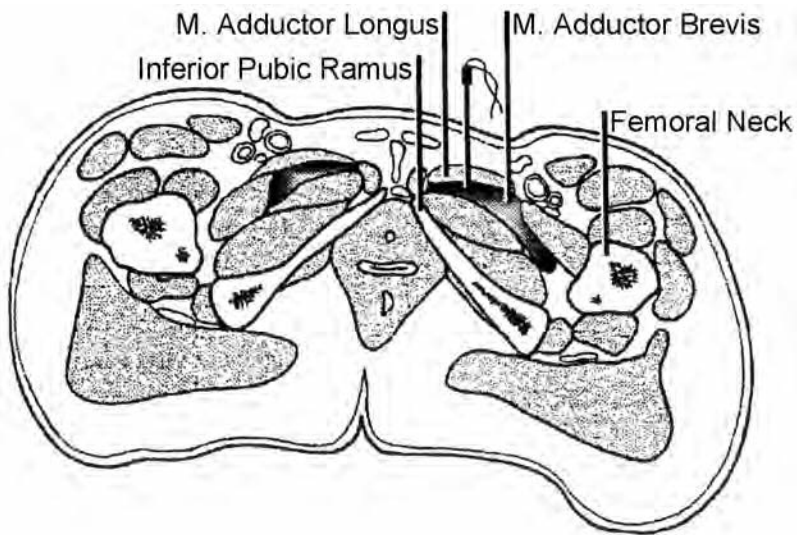
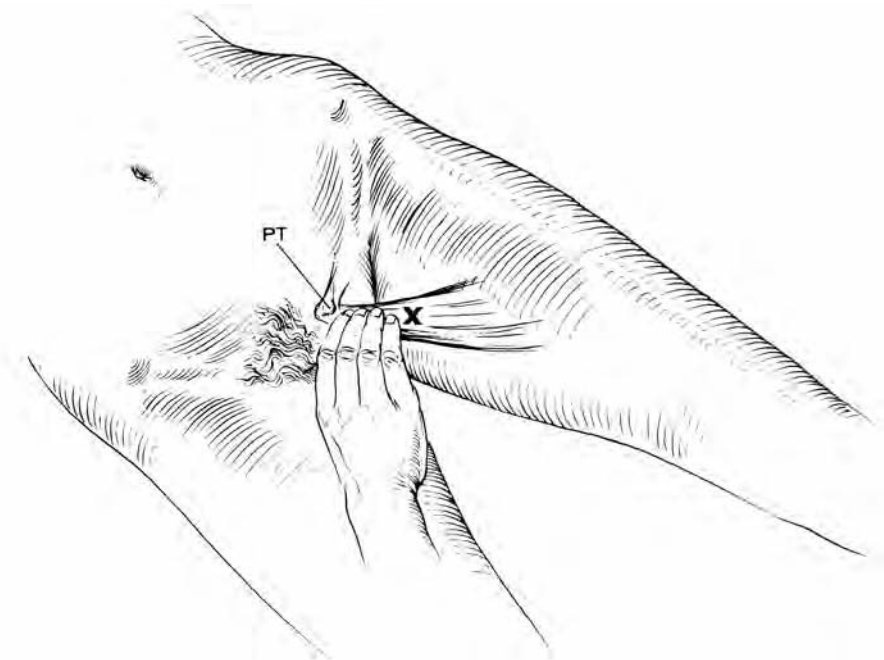


Figure 66. Cross section of the pelvis through the inferior pubic ramus.

ADDUCTOR LONGUS



Innervation

Obturator Nerve, Anterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the pubic tubercle.

Insertion

Into the linea aspera, between the adductor magnus and the vastus medialis.

Position

The patient supine with both lower extremities abducted fifteen degrees.

Electrode Insertion (X)

Palpate the tendon arising from the pubic tubercle (PT) and insert the electrode four fingerbreadths distal to the pubic tubercle into the muscle belly.

Test Maneuver

Patient to adduct limb.

Pitfalls

If the electrode is inserted too medially it will be in the gracilis, if inserted too laterally it will be in the sartorius.

Comments

- (a) Involved in:
 - 1. Anterior branch of the obturator nerve lesions
 - 2. Obturator nerve lesions
 - 3. Anterior division of the lumbar plexus lesions
 - 4. L2, L3, L4 roots lesions.
- (b) The main function of this muscle is to adduct the thigh and in conjunction with the other 2 adductors, helps in flexing and laterally rotating the leg, like when running or walking.
- (c) In spastic conditions (U.M.N.L.), this muscle develops a powerful contraction when minimally stretching it, which interferes with the normal function of this muscle. For gait evaluation, please refer to Adductor Brevis muscle.
- (d) Together with the other adductors are called “protectors of the virginity.”

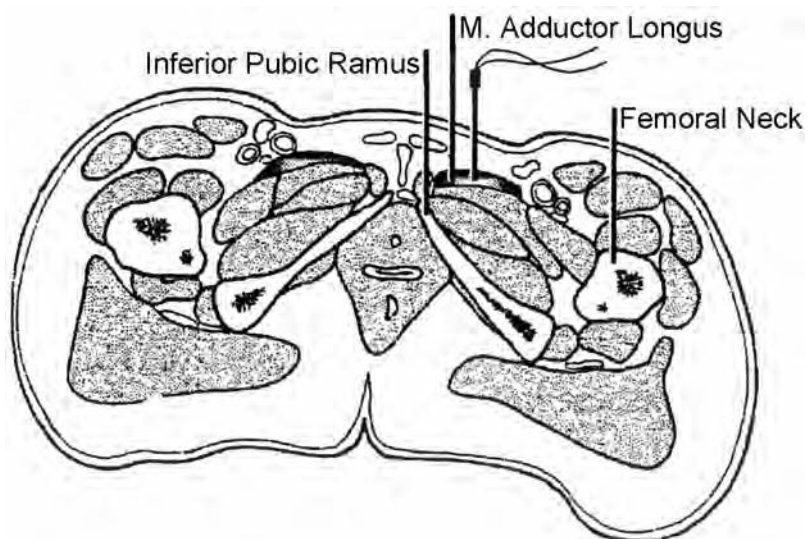
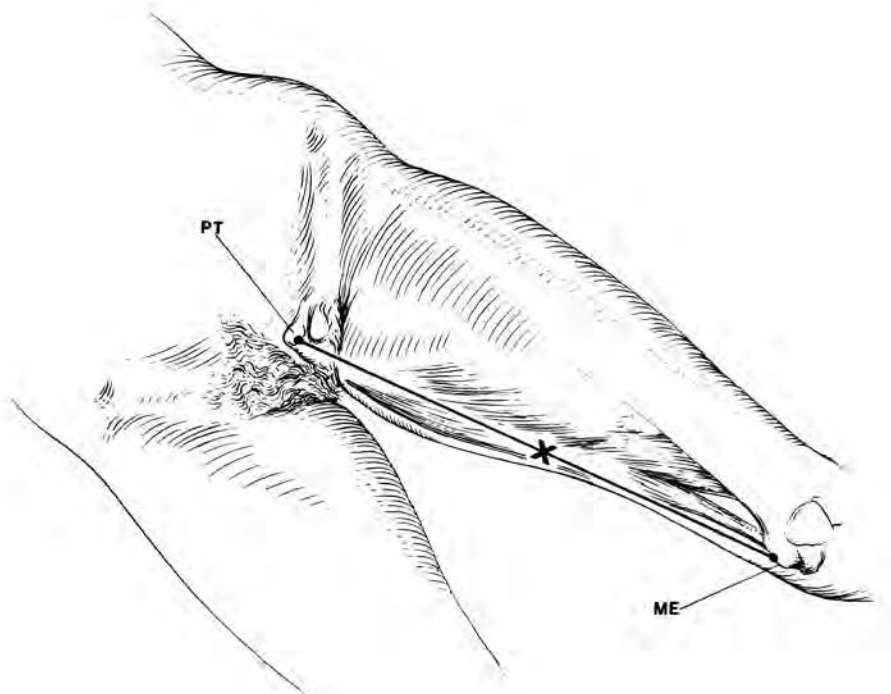


Figure 67. Cross section of the pelvis through the inferior pubic ramus.

ADDUCTOR MAGNUS



Innervation

The adductor portion of this muscle is innervated by the obturator nerve, anterior division of the lumbar plexus, and the L2, L3, L4, L5.

The hamstring portion is innervated by the tibial division of the sciatic nerve, L4, L5.

Origin

From the inferior ramus of the pubis and ischium and the tuberosity of the ischium.

Insertion

Into the linea aspera and the adductor tubercle of the femur.

Position

The patient supine with both lower extremities abducted fifteen degrees and externally rotated.

Electrode Insertion (X)

Midway between the medial femoral epicondyle (ME) and the pubic tubercle (PT).

Test Maneuver

Patient to adduct the thigh.

Pitfalls

If the electrode is too superficial it will be in the gracilis; if inserted too laterally it will be in the sartorius; and if inserted too proximally it will be in the adductor longus.

Comments

- (a) Partially involved in:
 - 1. Posterior branch of the obturator nerve
 - 2. Obturator nerve lesions
 - 3. Anterior division of the lumbar plexus
 - 4. L2, L3, L4 roots lesions.
- (b) Also involved in:
 - 1. High lesions of the sciatic nerve
 - 2. Anterior divisions of the upper portion of the sacral plexus
 - 3. L4, L5 roots lesions.
- (c) This muscle presents two portions: one as an adductor and the other as a hamstring. Morphologically, the latter portion of the muscle is considered to be part of the Hamstrings muscle group. This account for its innervation through the sciatic nerve.
- (d) This is the largest of the adductor group muscles. The two portions present different nerve supply (see above Innervation) and different function. The adductor portion adducts the leg and flexes the thigh. The hamstring portion extends the thigh.
- (e) In its insertion to the femur the two portions leaves a space (adductor hiatus), through which the femoral vessels travel to reach the popliteal fossa.

- (f) Together with the other adductors, this muscle is a “protector of the virginity.”

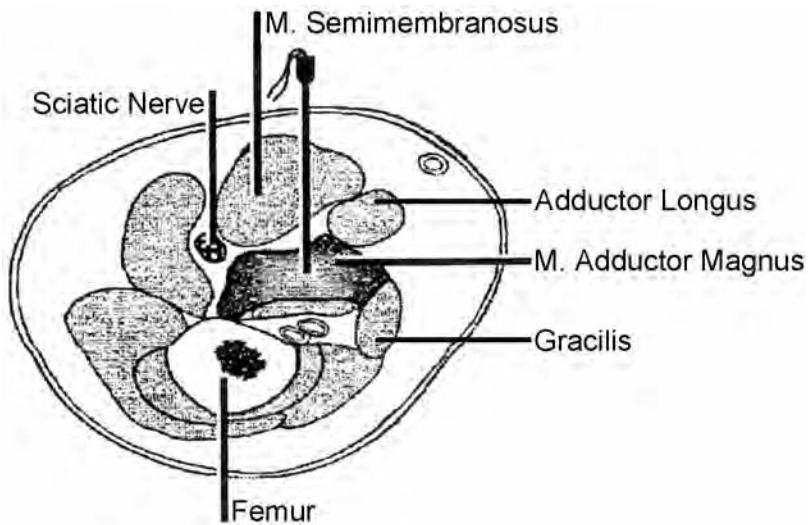
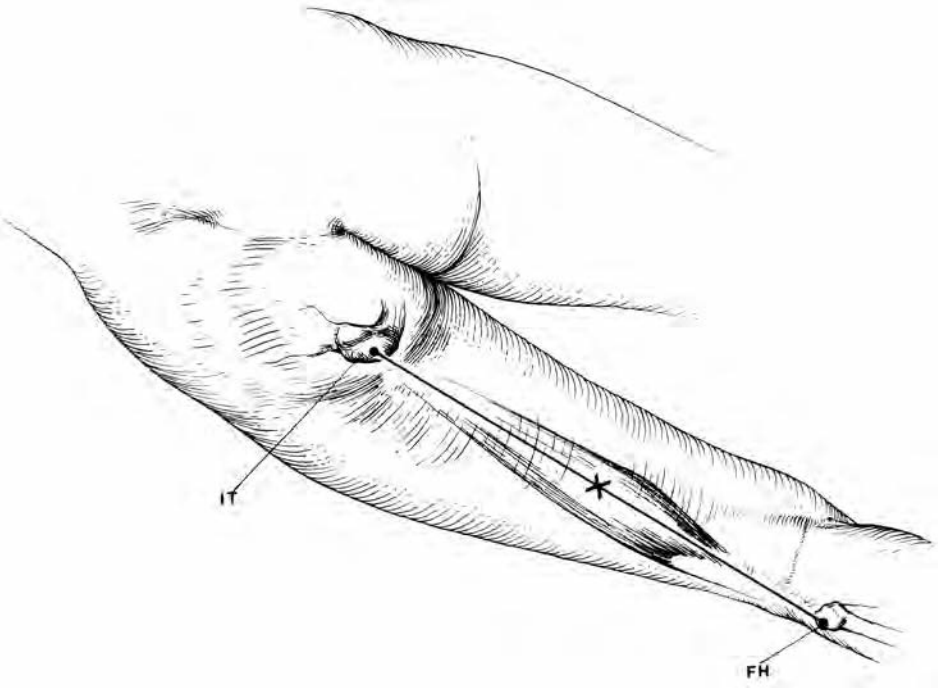


Figure 68. Cross section of the thigh through the middle and distal third.

BICEPS FEMORIS: LONG HEAD



Innervation

Sciatic Nerve (Tibial Portion), Anterior Division, Sacral Plexus, L5, 57.

Origin

From the ischial tuberosity.

Insertion

Into the head of the fibula.

Position

The patient prone.

Electrode Insertion (X)

Insert the electrode at the midpoint of a line between the fibula head (FH) and the ischial tuberosity (IT).

Test Maneuver

Patient to flex the knee.

Pitfalls

None.

Comments

- (a) Involved in lesions of:
 - 1. Sciatic nerve
 - 2. Anterior division of the sacral plexus
 - 3. L5, S1 roots lesion.
- (b) The tendon of this muscle is easy to palpate on the lateral border of the popliteal fossa, especially when the knee is flexed against resistance.
- (c) The main function of this muscle is to extend the thigh and to flex the knee, and externally rotate the leg when the knee is flexed.

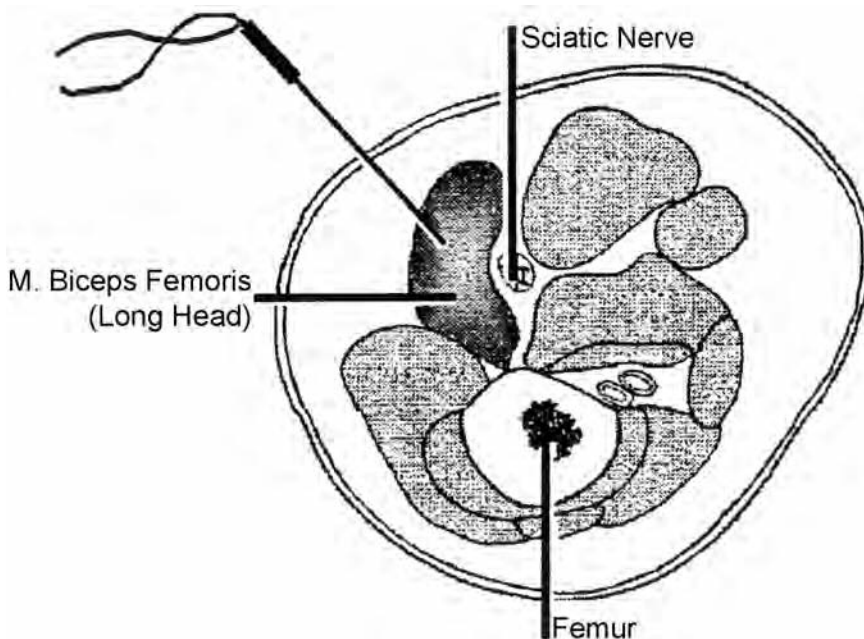
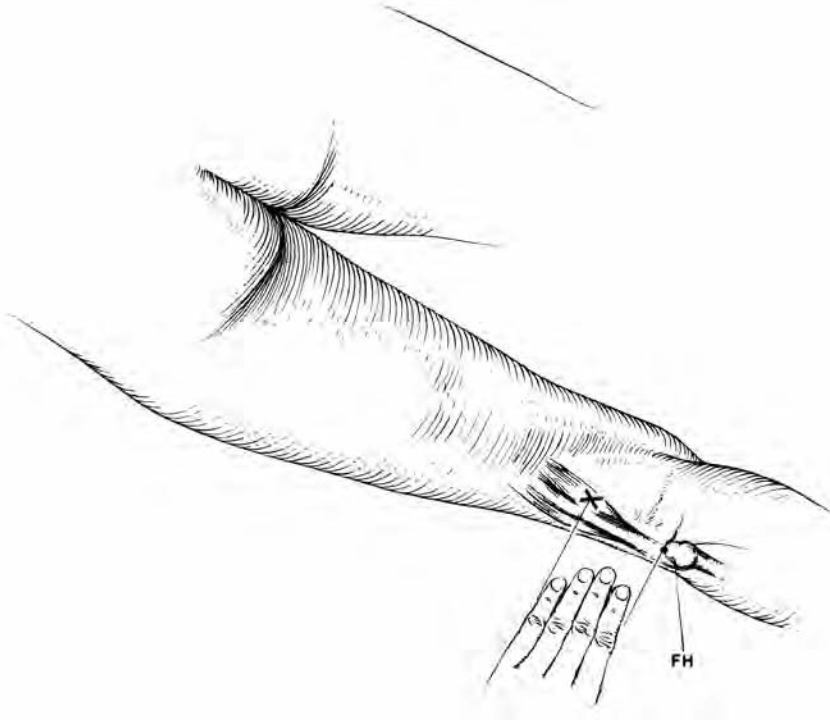


Figure 69. Cross section of the thigh through the middle and distal third.

BICEPS FEMORIS: SHORT HEAD



Innervation

Sciatic Nerve, (Peroneal Division) Posterior Division, Sacral Plexus, L5, S1, S2.

Origin

From the lateral lip of the linea aspera and the upper part of the lateral supracondylar line.

Insertion

Into the head of the fibula and the lateral condyle of the tibia.

Position

The patient prone with the knee flexed to ninety degrees.

Electrode Insertion (X)

Palpate the tendon of the long head of the biceps; grasp it with the fingertips; insert the electrode just medial to it, four fingerbreadths proximal to the fibular head (FH).

Test Maneuver

Patient to flex the knee.

Pitfalls

If the electrode is inserted too medially it will be in the semimembranosus; if inserted too laterally it will be in the long head of the biceps femoris.

Comments

- (a) Involved in lesions of:
 - 1. Sciatic Nerve
 - 2. Anterior division of the sacral plexus
 - 3. L5, S1 roots lesion.
- (b) Only muscle above the knee innervated by the peroneal division of the sciatic nerve.
- (c) This muscle does not qualify as a hamstring muscle, and its main function is to flex the knee and to externally rotate the leg when the knee is flexed.

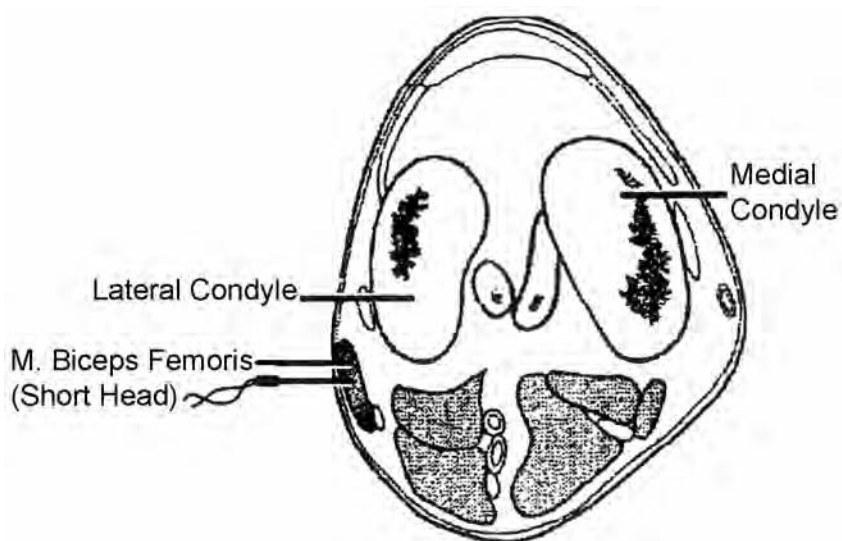
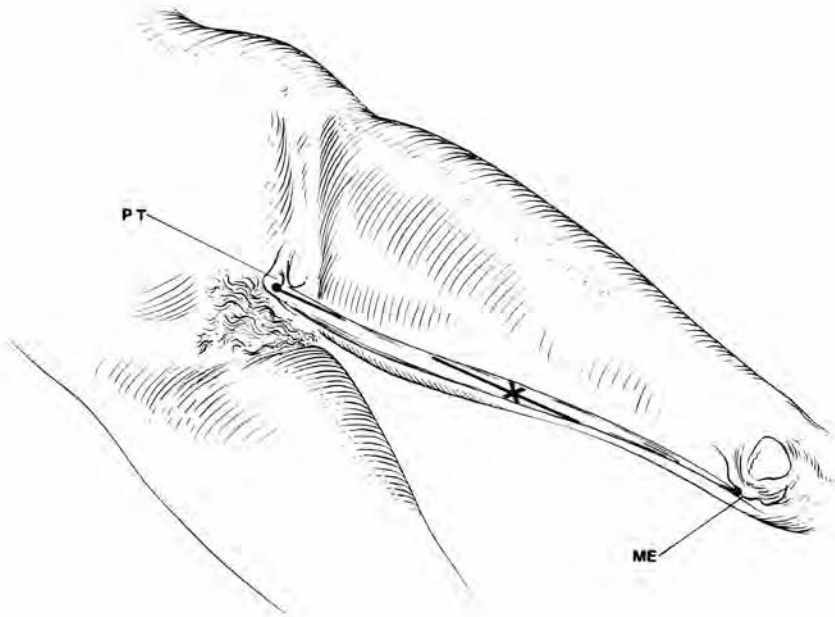


Figure 70. Cross section of the thigh through the upper portion of the knee joint.

GRACILIS



Innervation

Obturator Nerve, Anterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the lower half of the symphysis pubis and the pubic arch.

Insertion

Into the medial surface of the tibia below the condyle.

Electrode Insertion (X)

Insert the electrode to a maximum depth of one-half inch at a point midway between the pubic tubercle (PT) and the medial femoral epicondyle (ME).

Test Maneuver

Patient to adduct the thigh and flex the knee.

Pitfalls

If the electrode is inserted too deeply it will be in the adductor magnus; if inserted too laterally it will be in the adductor longus.

Comments

- (a) Involved in lesions of:
 - 1. Anterior branch of the obturator nerve
 - 2. Obturator for nerve
 - 3. Anterior division of the lumbar plexus
 - 4. L2, L3, L4 roots lesions.
- (b) This muscle has a multifold function: it adducts the thigh; flexes the knee and helps to rotate the leg medially. It is the most superficial of the adductors group. It is the weakest and it is the only one that crosses the knee.
- (c) This muscle is one of the 3 muscles that are part of the “pes anserine” (the other 2 are: Sartorius and Semitendinosus).

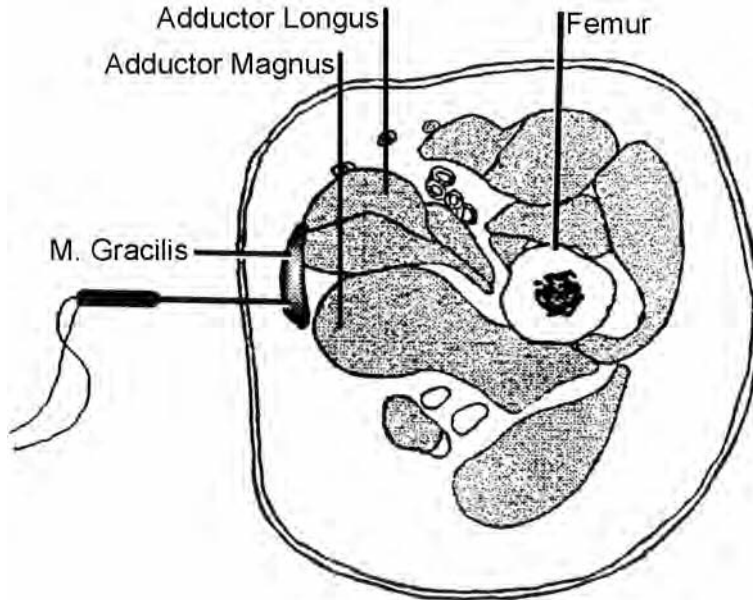
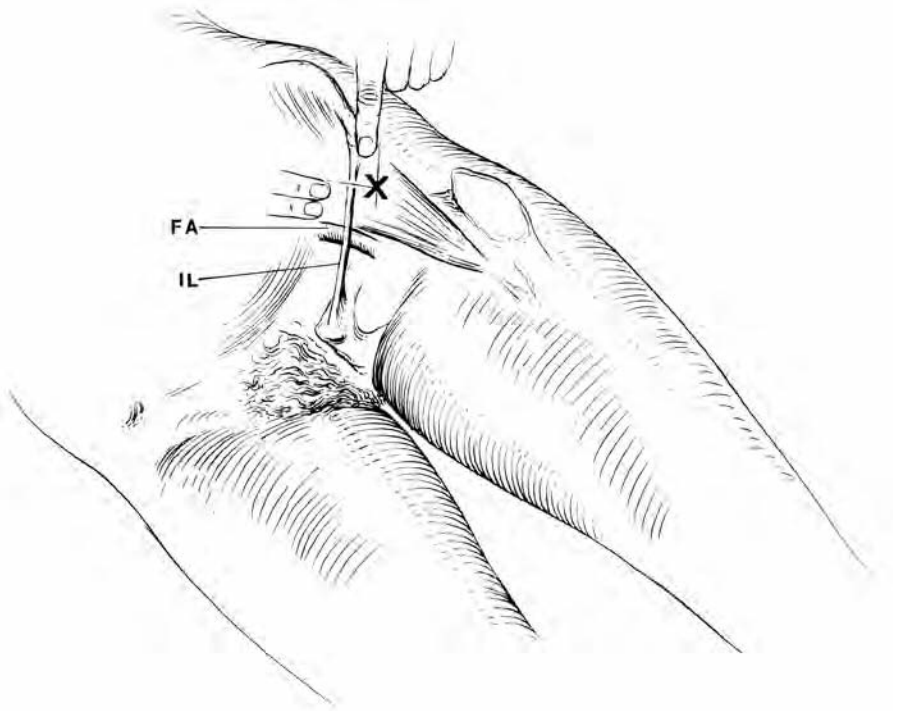


Figure 71. Cross section of the thigh through the junction of the upper and middle third.

ILIOPSOAS



Innervation

Femoral Nerve, Posterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the bodies and the transverse processes of the lumbar vertebrae and the iliac fossa.

Insertion

Into the lesser trochanter of the femur.

Position

The patient supine.

Electrode Insertion (X)

Two fingerbreadths lateral to the femoral artery (FA) and one fingerbreadth below the inguinal ligament (IL).

Test Maneuver

Patient to flex the thigh with the knee flexed beyond ninety degrees.

Pitfalls

If the electrode is inserted too medially it will contact the neurovascular bundle; if inserted too laterally it will be in the sartorius.

Comments

- (a) Involved in lesions of:
 - 1. High femoral nerve
 - 2. Posterior Division of the lumbar plexus
 - 3. L2, L3, L4 roots.
- (b) Forms the external portion of the floor of the Scarpa's triangle.
- (c) The main function of this muscle is to flex the thigh at the hip level and to stabilize this joint. It is the strongest hip flexor. When the thigh is fixed in extension, this muscle can flex the trunk over the thighs, as when sitting from the supine position.
- (d) It is an important antigravitational postural muscle helping to maintain a good erect position.

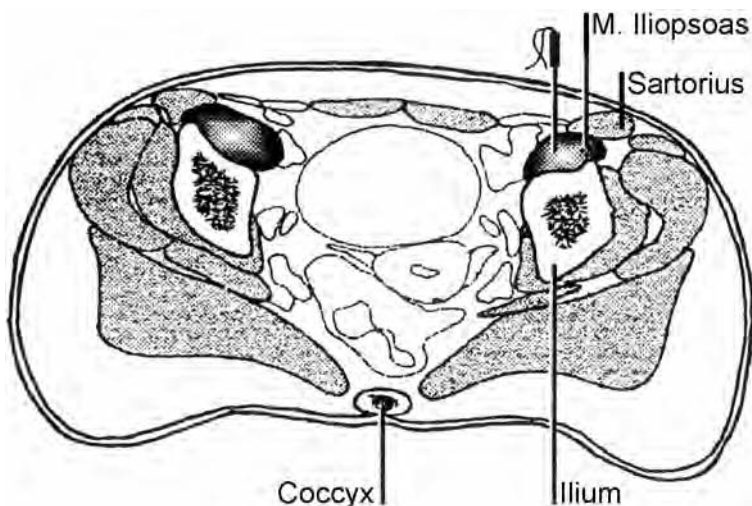
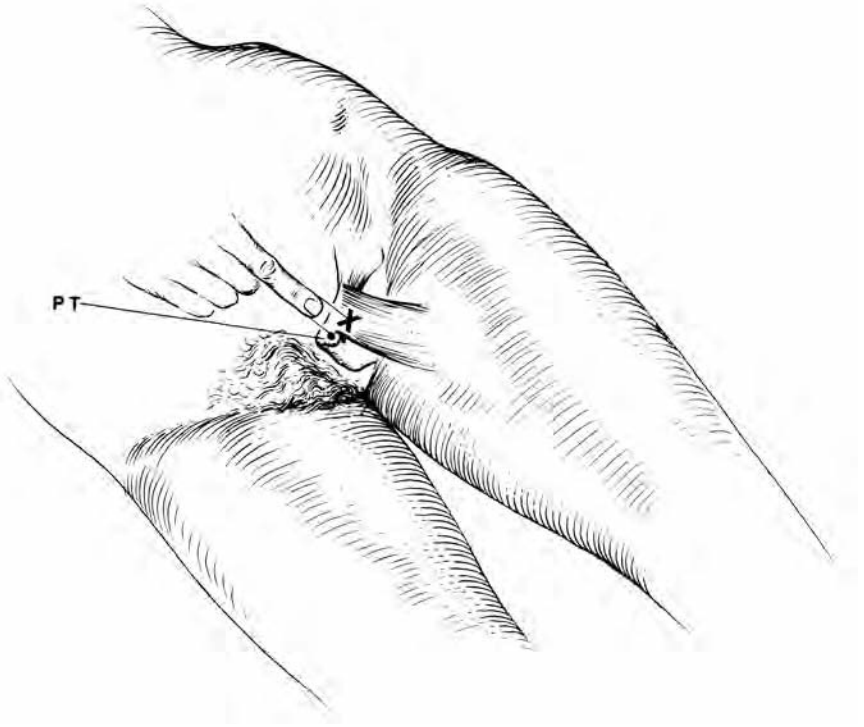


Figure 72. Cross section of the pelvis area just proximal to the hip joint.

PECTINEUS



Innervation

Femoral Nerve, Posterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the superior ramus of the pubis.

Insertion

Into the upper portion of the pectineal line below the lesser trochanter.

Position

The patient supine.

Electrode Insertion (X)

One fingerbreadth lateral to the pubic tubercle (PT).

Maneuver

Patient to adduct the thigh.

Pitfalls

If the electrode is inserted too medially it will be in the adductor longus; if inserted too laterally it will contact the neurovascular bundle.

Comments

- (a) Forms the internal portion of the floor of the Scarpa's triangle.
- (b) Involved in lesions of:
 - 1. Femoral nerve (entrapment) at the inguinal ligament level
 - 2. Femoral nerve proximal to the inguinal ligaments
 - 3. Posterior division of the lumbar plexus
 - 4. L2, L3, L4 roots.
- (c) The main function of this muscle is to adduct the leg and also help in flexing the hip joint.

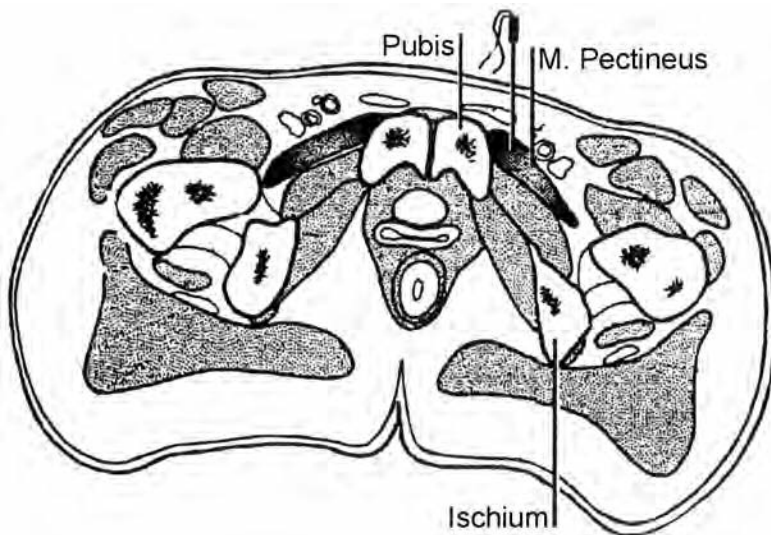
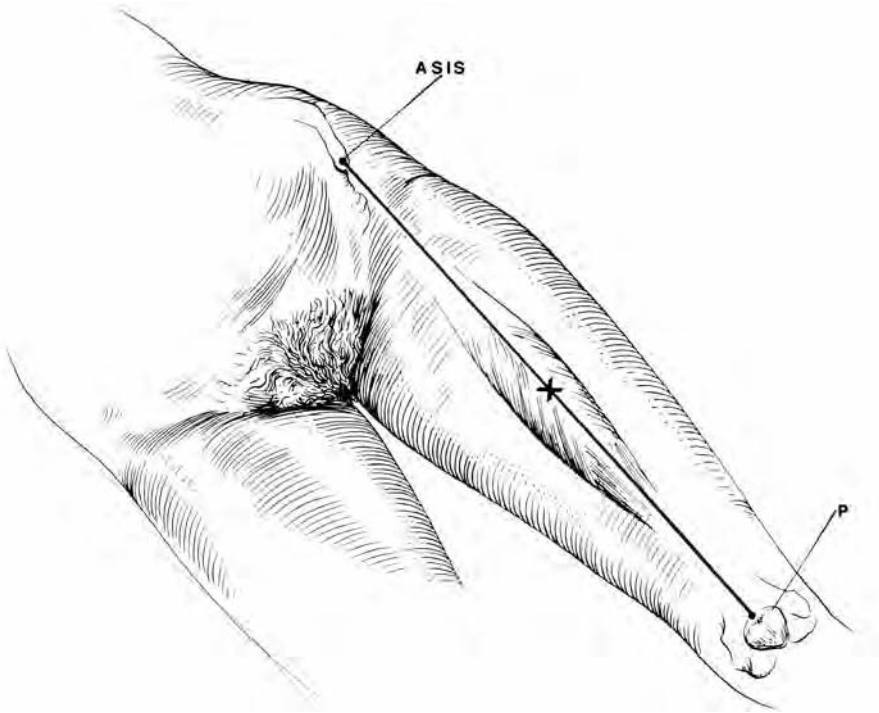


Figure 73. Cross section of the pelvis area through the superior portion of the symphysis pubis.

RECTUS FEMORIS



Innervation

Femoral Nerve, Posterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the anterior inferior iliac spine and the brim of the acetabulum.

Insertion

Through the patella tendon, on the tibial tubercle.

Position

The patient supine.

Electrode Insertion (X)

On the anterior aspect of the thigh, midway between the superior border of the patella (P) and the anterior superior iliac spine (ASIS).

Test Maneuver

Patient to flex the hip with the knee extended.

Pitfalls

If the electrode is inserted too medially and too deeply it will be in the vastus intermedius; if inserted too laterally it will be in the vastus lateralis; if inserted too distally and medially it will be in the vastus medialis.

Comments

- (a) Involved in lesions of:
 - 1. Femoral nerve (entrapment) at the inguinal ligament level
 - 2. Femoral nerve proximal to the inguinal ligament
 - 3. Posterior division of the lumbar plexus
 - 4. L2, L3, L4.
- (b) The main function of this muscle is to flex the hip and to extend the leg and the knee joint. It also stabilizes the hip joint and helps the Iliopsoas muscle to flex the hip.

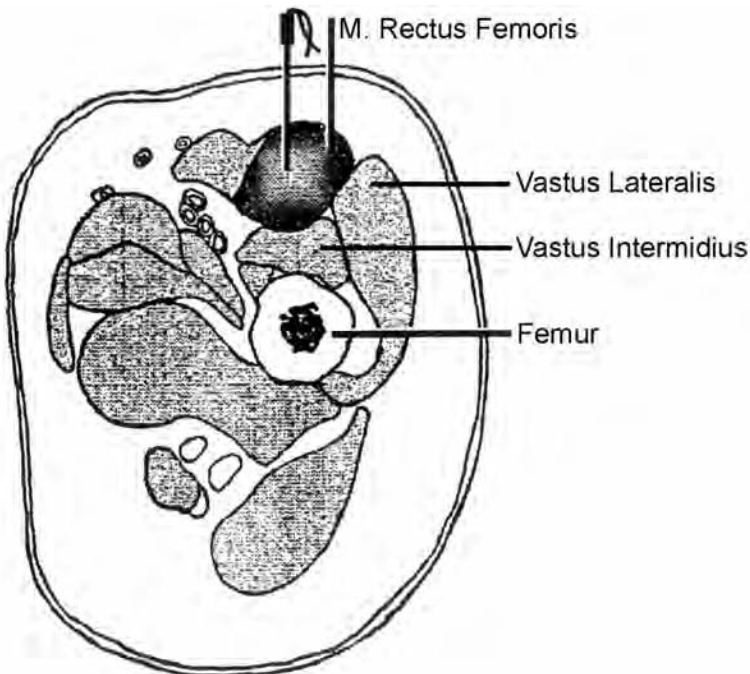
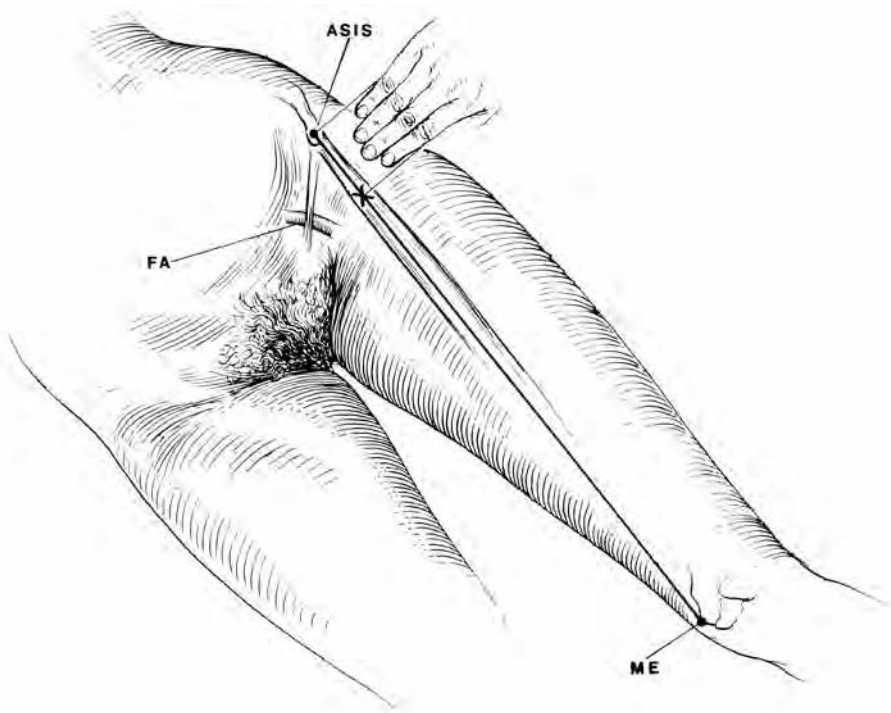


Figure 74. Cross section of the thigh through the junction of the upper and middle third.

SARTORIUS



Innervation

Femoral Nerve, Posterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the anterior superior iliac spine.

Insertion

Below the medial tibial condyle, on the medial border of the body of the tibia.

Position

The patient supine.

Electrode Insertion (X)

Four fingerbreadths distal to the anterior superior iliac spine (ASIS) along the line to the medial epicondyle (ME) of the tibia. Insert the electrode just lateral to the femoral artery (FA) to a depth of about one-half inch.

Test Maneuver

Patient to flex, abduct and externally rotate thigh.

Pitfalls

If the needle electrode is inserted too deeply or too distally it will be in the rectus femoris; if inserted too medially it will be in the iliacus; if inserted too laterally it will be in the tensor fascia lata.

Comments

- (a) Involved in lesions of:
 - 1. Femoral nerve (entrapment) at the inguinal ligament level
 - 2. Femoral nerve proximal to the inguinal ligament
 - 3. Posterior division of the lumbar plexus
 - 4. L2, L3, L4.
- (b) This muscle is the longest muscle in the body and the most superficial muscle on the anterior thigh; its name Sartorius derives from the position of a tailor's leg when sewing by hand.
- (c) Its function consists of a compound motion of flexion, abduction and lateral rotation of the thigh at the hip level and flexing the leg at the knee. If the leg is kept steady, it may help in flexing the trunk over the thigh and rotating the trunk to the opposite side.
- (d) This muscle is one of the 3 muscles forming the "pes Anserine" (the other 2 muscles are: Gracilis and Semitendinosus).

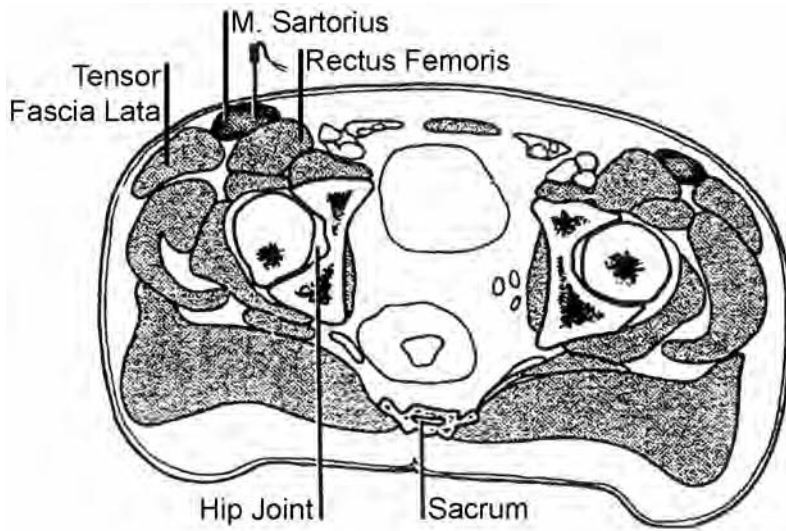
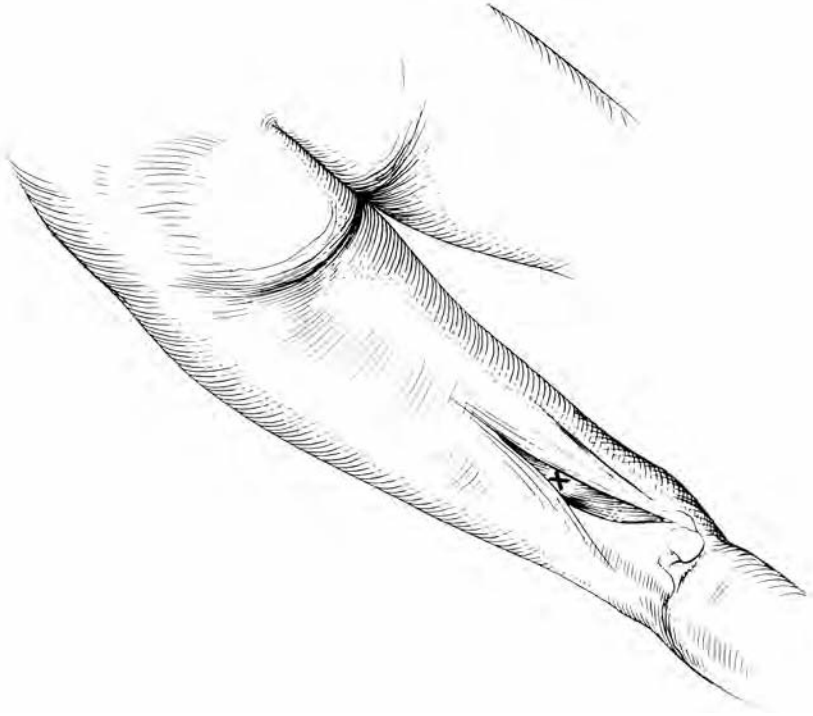


Figure 75. Cross section through the hip joint.

SEMIMEMBRANOSUS



Innervation

Sciatic Nerve (Tibial Portion), Anterior Division Sacral Plexus, L5, S1, S2.

Origin

From the ischial tuberosity.

Insertion

On the medial condyle of the tibia and through a fibrous expansion into the lateral femoral condyle.

Position

The patient prone.

Electrode Insertion (X)

Insert the electrode laterally to the semitendinosus tendon in the apex of the “V” between the semitendinosus tendon and the biceps femoris.

Test Maneuver

Patient to flex the knee and internally rotate the tibia.

Pitfalls

If the electrode is inserted too medially it will be in the semitendinosus; if inserted too laterally it will be the short head of the biceps or into the sciatic nerve; if inserted too deeply it will be in the adductor magnus.

Comments

- (a) Involved in lesions of:
 - 1. Sciatic nerve
 - 2. Anterior division of the sacral plexus
 - 3. L5, S1, S2.
- (b) The main function of this muscle is to extend the hip and to rotate and to flex the leg. If the thigh and the legs are flexed and steady, it can extend the trunk.
- (c) This is one of the muscles affected in the condition called “pull hamstrings” which is a common condition in athletes. It is believed to be the result of insufficient warming-up before the competition.

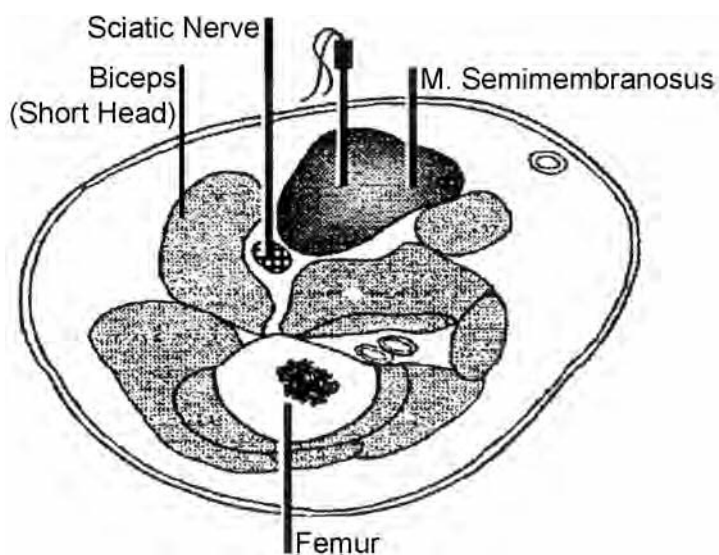
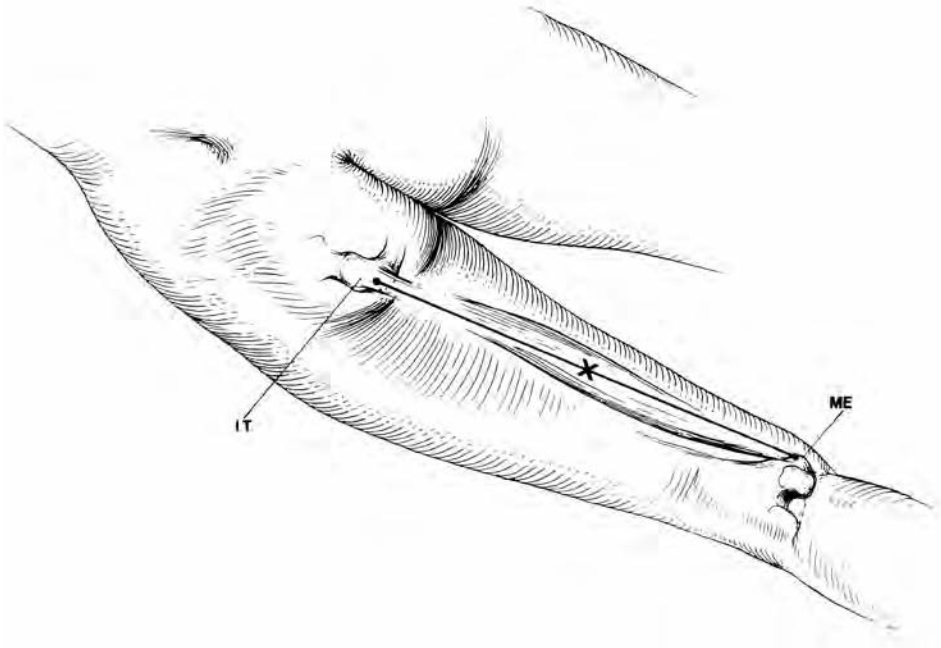


Figure 76. Cross section of the thigh through the lower third.

SEMITENDINOSUS



Innervation

Sciatic Nerve (Tibial Portion), Anterior Division Sacral Plexus, L5, S1, S2.

Origin

From the ischial tuberosity.

Insertion

On the medial condyle of the tibia.

Position

The patient prone.

Electrode Insertion (X)

Midway on a line between the medial epicondyle (ME) of the femur and the ischial tuberosity (IT).

Test Maneuver

Patient to flex the knee and internally rotate the tibia.

Pitfalls

If the electrode is inserted too laterally it will be in the long head of the biceps; if inserted too medially or too deeply it will be in the semimembranosus.

Comments

- (a) Involved in lesions of:
 - 1. Sciatic nerve
 - 2. Anterior division sacral plexus
 - 3. L5, S1, S2 roots.
- (b) The main function of this muscle is to extend the hip and to flex and internally rotate the leg. When the hips and the legs are flexed and they are steady, this muscle can extend the trunk.
- (c) This muscle gets involved in the so-called “pull hamstring” which is very common in athletes.
- (d) Its tendon inserts into the tibia and is part of the so-called “pes anserine” (foot of a goose) where there are several bursas that may become inflamed and very painful. The other 2 muscles of the pes anserine formation are the Gracilis and the Sartorius.

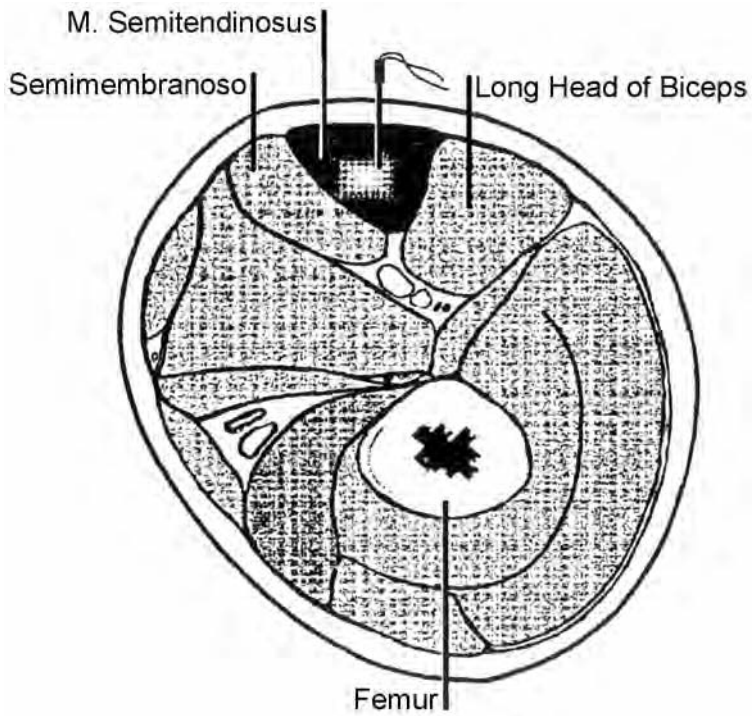


Figure 77. Cross section of the thigh through the midportion.

TENSOR FASCIAE LATAE



Innervation

Superior Gluteal Nerve, Sacral Plexus, L4, L5, S1.

Origin

From outer lip of the anterior portion of iliac crest of the ilium.

Insertion

On the iliotibial tract, just below the greater trochanter.

Position

The patient supine.

Electrode Insertion (X)

Two fingerbreadths anterior to the greater trochanter (GT).

Test Maneuver

Patient to abduct thigh with hip flexed.

Pitfalls

If the electrode is inserted too anteriorly it will be in the sartorius or rectus femoris; if inserted too deeply it will be in the vastus lateralis; if inserted too posterior it will be in the gluteus medius.

Comments

- (a) Involved in lesions of:
 - 1. Superior gluteal nerve
 - 2. Posterior division of the sacral plexus
 - 3. L4, L5, S1 roots.
- (b) The main function of this muscle is to abduct the thigh, rotate it medially and flex the thigh. It is also a mild extensor of the knee.

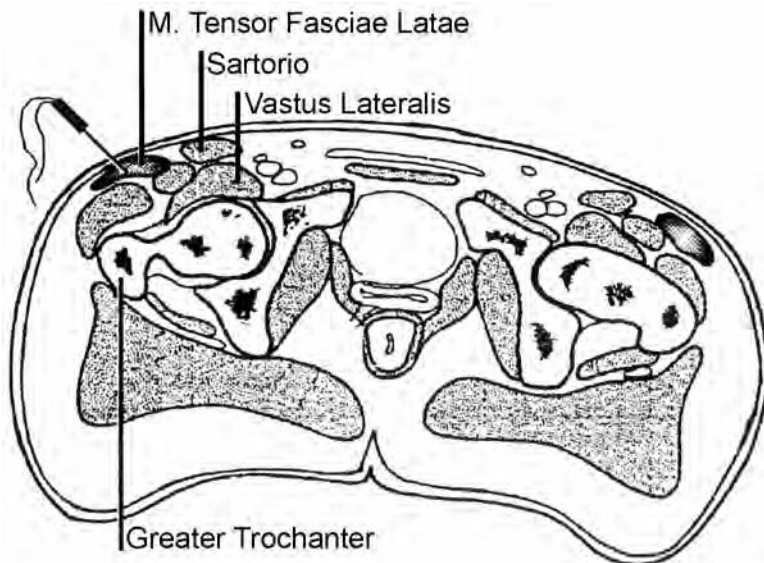
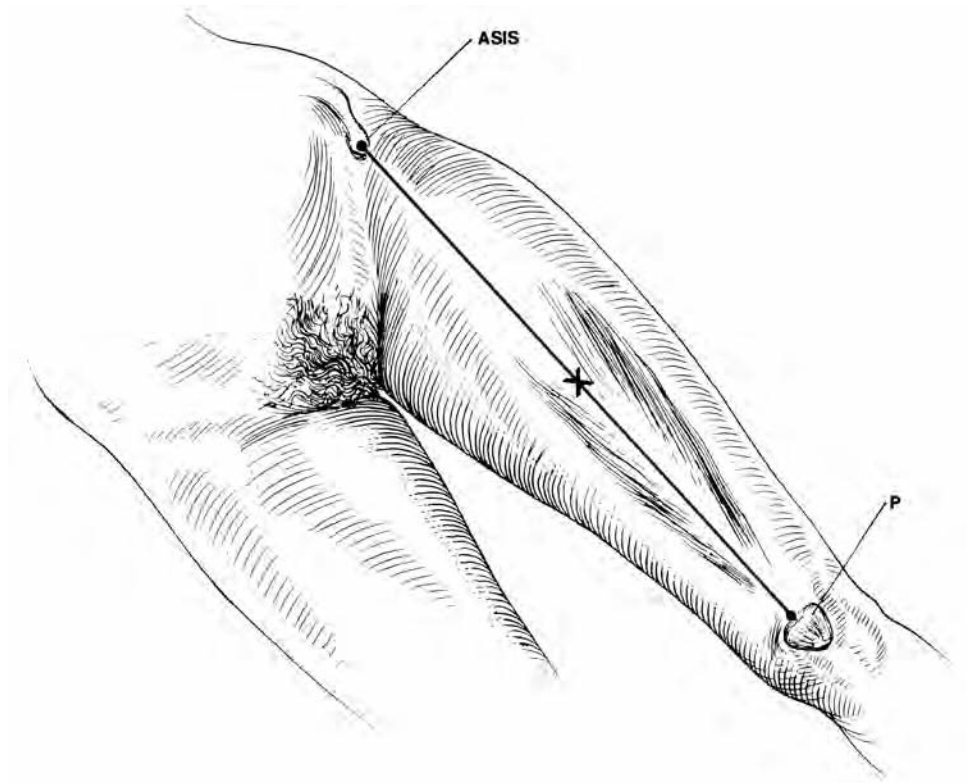


Figure 78. Cross section of the pelvis through the greater trochanter.

VASTUS INTERMEDIUS



Innervation

Femoral Nerve, Posterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the upper three-fourths of the shaft of the femur and from the anterior surface as high as the introchanteric line.

Insertion

Through the quadriceps tendon onto the tibial tubercle.

Position

The patient supine.

Electrode Insertion

Midway between the superior border of the patella (P) and the anterior superior iliac spine (ASIS). The electrode is inserted to the bone and withdrawn slightly.

Test Maneuver

Patient to lift heel from plinth with knee extended.

Pitfalls

If the electrode is inserted too superficially it will be in the rectus femoris; if inserted too laterally it will be in the vastus lateralis; if inserted too medially it will be in the vastus medialis or sartorius.

Comments

- (a) Involved in lesions of:
 - 1. Femoral nerve (entrapment) at the inguinal ligament level
 - 2. Femoral nerve proximal to the inguinal ligament
 - 3. Posterior division of the lumbar plexus
 - 4. L2, L3, L4 roots.
- (b) The main function of this muscle, together with the other 2 vasti and the rectus Femoris is to extend the leg through the quadriceps tendon which contain the patella bone (sesamoid bone) and end up at the tibial tuberosity through the patella tendon. The presence of the patella bone increases greatly the ability of the quadriceps to extend the leg (Mechanical advantage).
- (c) The paralysis of this portion of the quadriceps in conjunction with the paralysis of the other heads of the quadriceps force the patient to change his gait and he does it by placing one hand at the end of the thigh to prevent the knee from buckling, or throwing his knee into a marked recurvatum, which will produce the same effect.

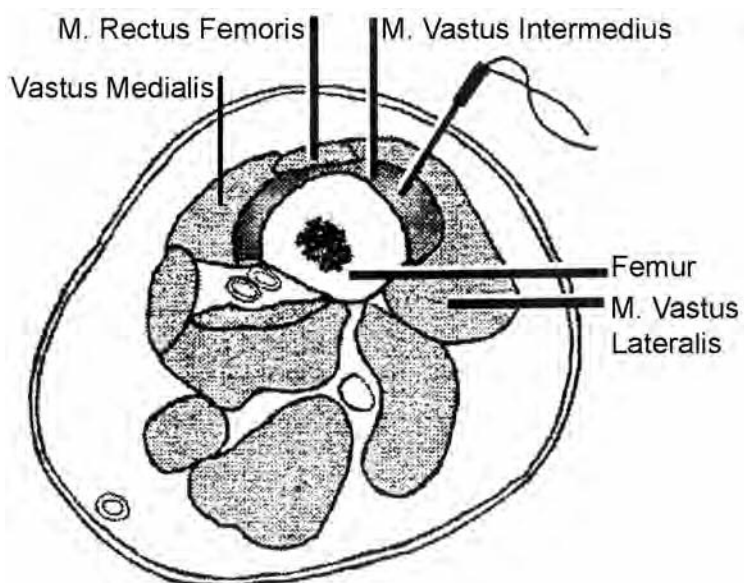
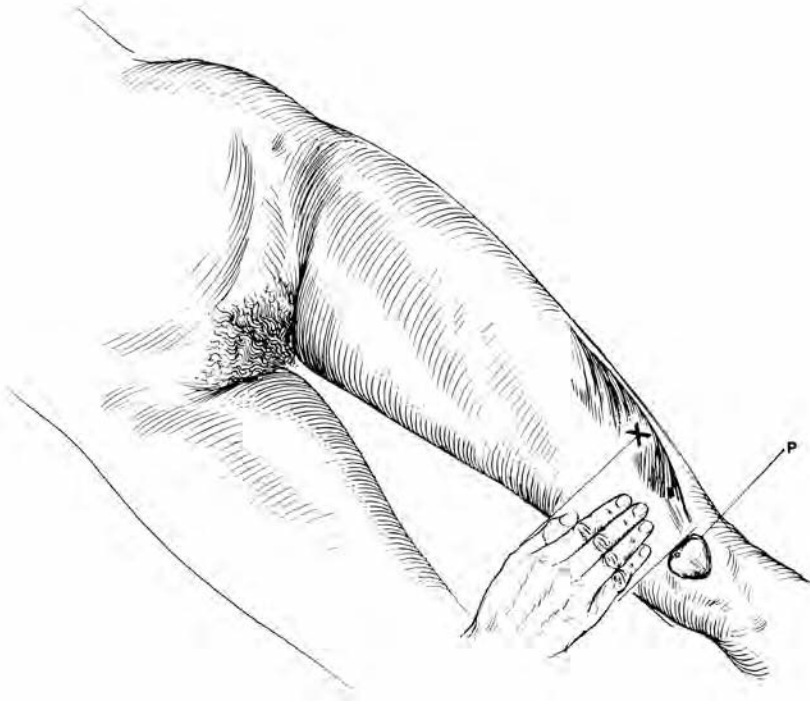


Figure 79. Cross section of the thigh through the middle and distal third.

VASTUS LATERALIS



Innervation

Femoral Nerve, Posterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the intertrochanteric line, the linea aspera and the medial supracondylar line.

Insertion

Through the quadriceps tendon onto the tibial tubercle.

Position

The patient supine.

Electrode Insertion (X)

Over the lateral aspect of the thigh, one handbreadth above the patella.

Test Maneuver

Patient to lift heel from plinth with knee extended.

Pitfalls

If the electrode is inserted too posteriorly it will be in the biceps femoris; if inserted too medially it will be in the rectus femoris.

Comments

- (a) Involved in lesions of:
 - 1. Femoral nerve (entrapment) at the inguinal ligament level
 - 2. Femoral nerve proximal to the inguinal ligament
 - 3. Posterior division of the lumbar plexus
 - 4. L2, L3, L4 roots.
- (b) The main function of this muscle is to extend the knee. When this muscle gets paralyzed, the patient loses the force that keeps the knee in extension. Therefore, the patient develops the feeling that the knee will collapse when loaded during walking for which he tends to support it by placing one hand at the end of the thigh or by forcefully sending his knee into recurvatum which will produce the same effect.

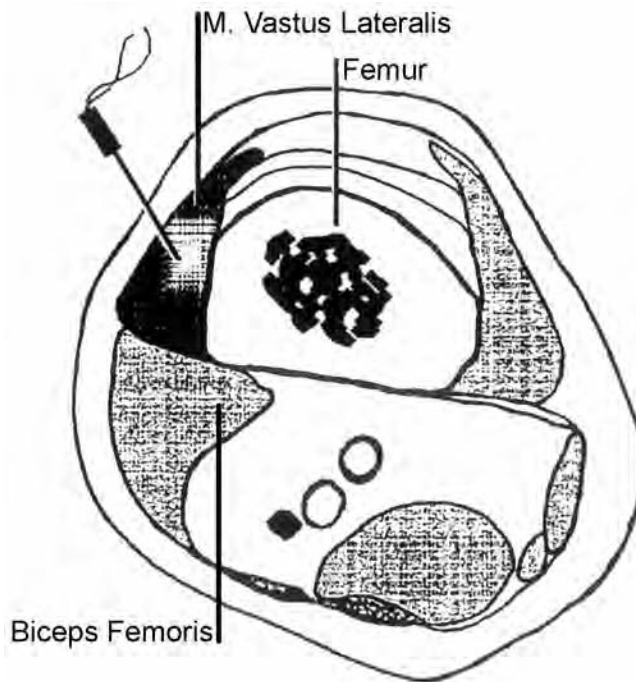
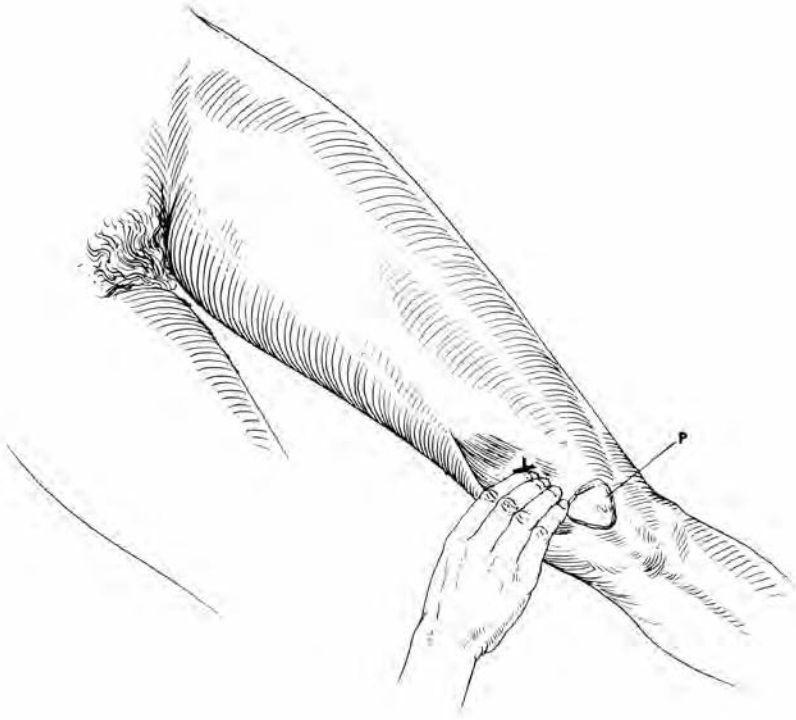


Figure 80. Cross section of the thigh just proximal to the patella.

VASTUS MEDIALIS



Innervation

Femoral Nerve, Posterior Division Lumbar Plexus, L2, L3, L4.

Origin

From the medial lip of the linea aspera and upper part of the supracondylar line.

Insertion

Through the quadriceps tendon onto the tibial tubercle.

Position

The patient supine.

Electrode Insertion (X)

Four fingerbreadths proximal to the superior-medial angle of the patella (P).

Test Maneuver

Patient to lift heel from plinth with knee extended.

Pitfalls

If the electrode is inserted too posterior it will be in the sartorius or gracilis; if inserted too anteriorly it will be in the rectus femoris.

Comments

- (a) Used as recording muscle for femoral nerve motor conduction study.
- (b) Involved in lesions of:
 - 1. Femoral nerve (entrapment) at the inguinal ligaments
 - 2. Intrapelvic femoral nerve
 - 3. Posterior division of lumbar plexus
 - 4. L2, L3, L4 nerve roots.
- (c) The main function of this muscle is to extend the knee through the patella tendon.
- (d) The lower fibers of this muscle run almost perpendicular to the thigh, and therefore they restrain the tendency of the patella to be drawn laterally from the intercondylar groove of the femur.

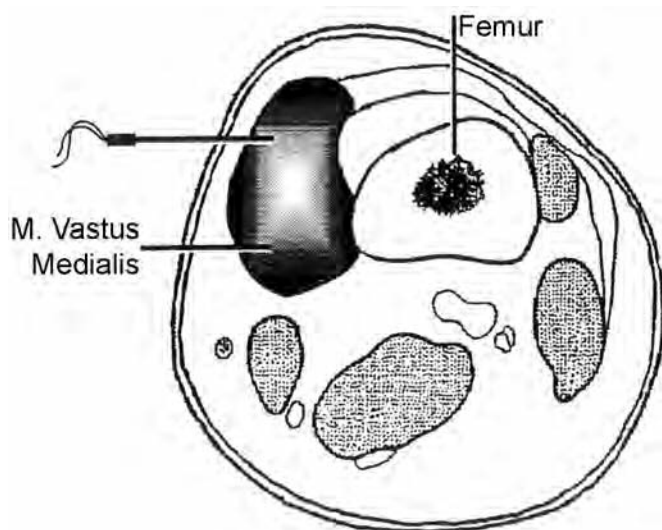
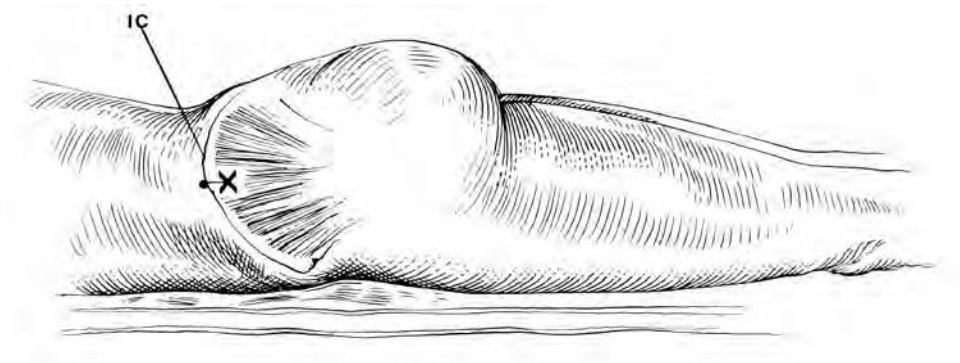


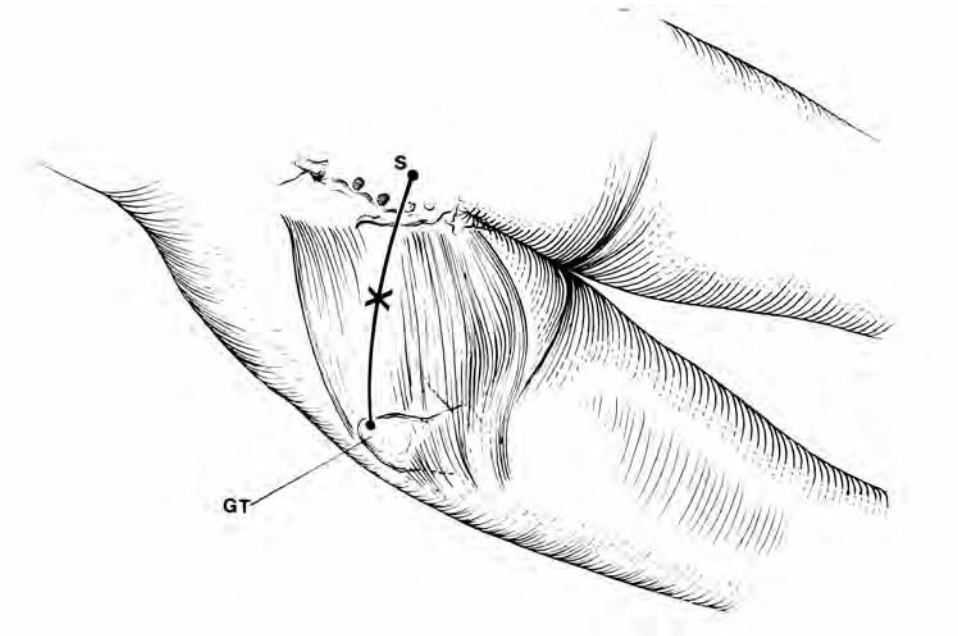
Figure 81. Cross section of the thigh through the distal third.



SECTION IX

**PELVIS AND
HIP JOINT**

GLUTEUS MAXIMUS



Innervation

Inferior Gluteal Nerve, Sacral Plexus, L5, S1, S2.

Origin

From the gluteal line, the posterior surface of the sacrum and coccyx, and the sacrotuberous ligament.

Insertion

Into the iliotibial tract, the gluteal ridge, and the linea aspera of the femur.

Position

The patient prone.

Electrode Insertion (X)

The electrode is inserted to a depth of one to three inches midway between the greater trochanter (GT) and the sacrum (S).

Test Maneuver

Patient to extend the hip with the knee flexed.

Pitfalls

None.

Comments

- (a) Involved in lesions of:
 - 1. Inferior gluteal nerve
 - 2. Posterior division of sacral plexus
 - 3. L5, S1, S2 nerve roots.
- (b) A frequent site of intramuscular injection therefore, pathological findings may be misleading.
- (c) The function of this muscle is to extend the thigh over the pelvic bone. It also assists in lateral rotation of the thigh. By steadying the thigh it assists in righting the trunk from the flex position.
- (d) This muscle is the largest of the gluteal group and one of the largest in the body. It has 3 bursas separating it from underlying structures: (1) the trochanteric bursa, (2) the gluteal femoral bursa, (3) the ischial bursa.
- (e) These bursas are important to evaluate when examining a patient with possible L.S. nerve lesion, because they may mimic nerve lesions when inflamed.
- (f) These bursas are in place to reduce friction. The most commonly affected is the ischial bursa producing an ischial bursitis.

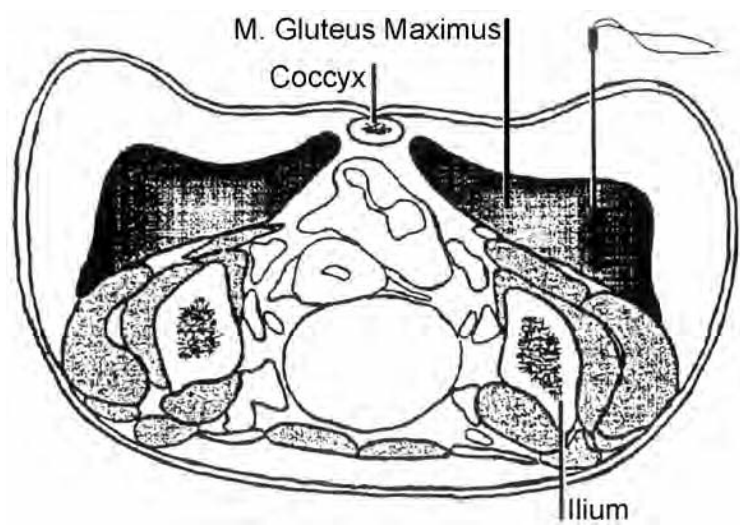
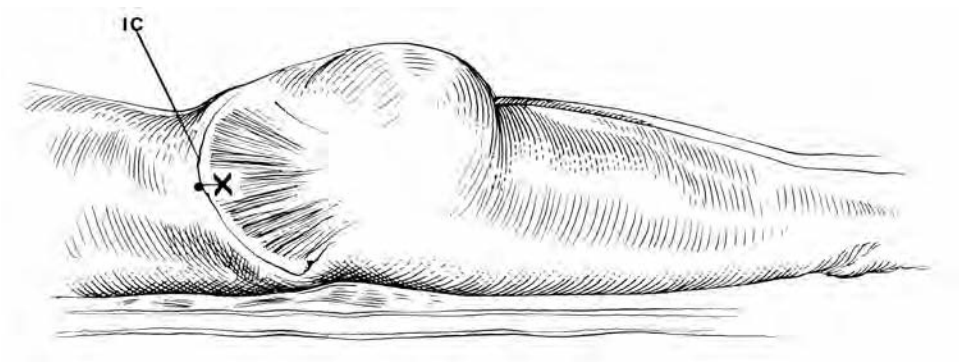


Figure 82. Cross section of the pelvis area just proximal to the hip joint.

GLUTEUS MEDIUS



Innervation

Superior Gluteal Nerve L5, S1.

Origin

From the anterior gluteal line and the crest of the ilium.

Insertion

Into the lateral area of the greater trochanter of the femur.

Position

The patient is prone.

Electrode Insertion (X)

One inch distal to the midpoint of the iliac crest (1C).

Test Maneuver

Patient is asked to abduct the thigh.

Pitfalls

If the electrode is inserted too posterior it will be in the gluteus maximus; if inserted too anteriorly it will be in the tensa fascia lata; if inserted too distally it will be in either the gluteus minimus or maximus.

Comments

- (a) The function of this muscle is to abduct the thigh and it plays an essential part during locomotion. It is responsible for producing a peculiar rhythm in the pelvic area, more evident in females.

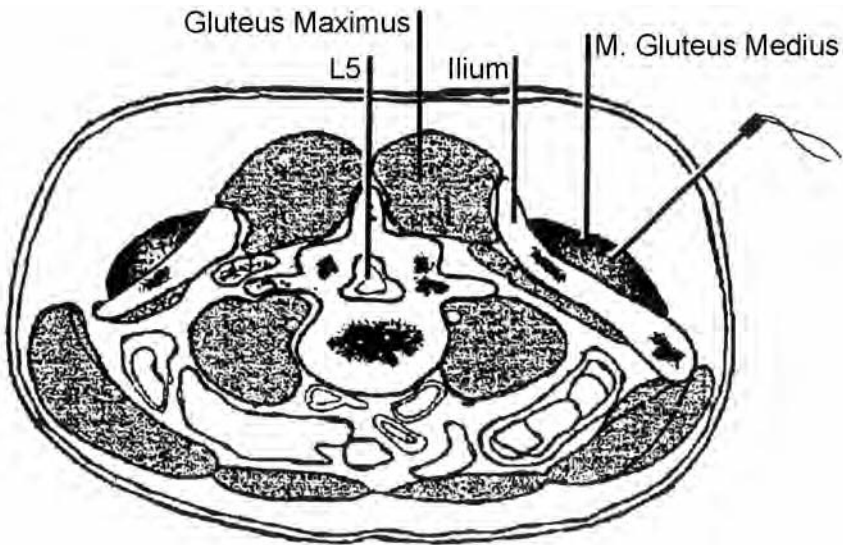
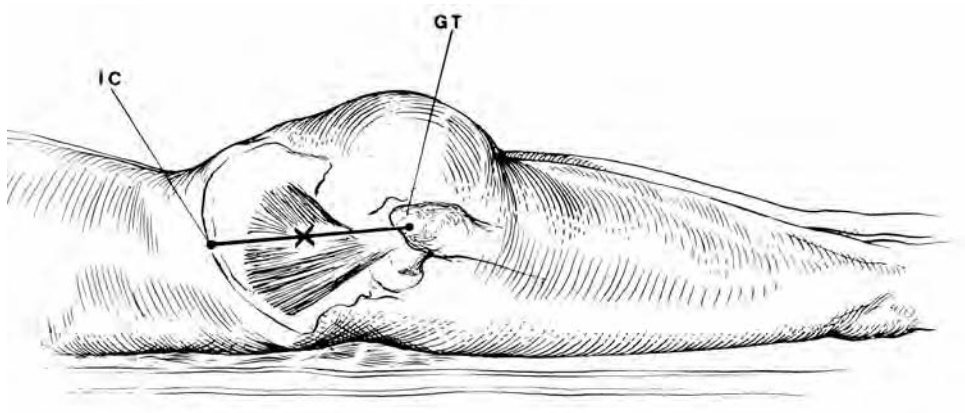


Figure 83. Cross section of the pelvis through the L5 level.

GLUTEUS MINIMUS



Innervation

Superior Gluteal Nerve, Sacral Plexus, L5, S1.

Origin

From the lateral surface of the ilium, between the anterior and inferior gluteal line.

Insertion

Into the anterior surface of the greater trochanter.

Position

The patient prone.

Electrode Insertion (X)

Insert electrode midway between midpoint of the iliac crest (IC) and greater trochanter (GT) deep to bone and withdraw slightly.

Test Maneuver

Patient to abduct the thigh.

Pitfalls

If the electrode is inserted too superficially it will be in the gluteus medius.

Comments

- (a) This muscle gets involved in lesions of the:
 - 1. Superior gluteal nerve
 - 2. Posterior division of the sacral plexus
 - 3. L5-S1 nerve root.
- (b) This muscle is the smallest of the gluteal group and it has a similar function as the gluteus medius. Its anterior fibers help in internally rotating the thigh.
- (c) When this muscle and the gluteus medius become paralyzed or weakened, the effect on the pelvis (supportive and steadying) is lost. Therefore, when the foot is raised on the nonaffected side, the pelvis drops on this side. This produces a waddling gait known as “gluteal gait” (falling of the pelvis on the nonaffected side with each step).

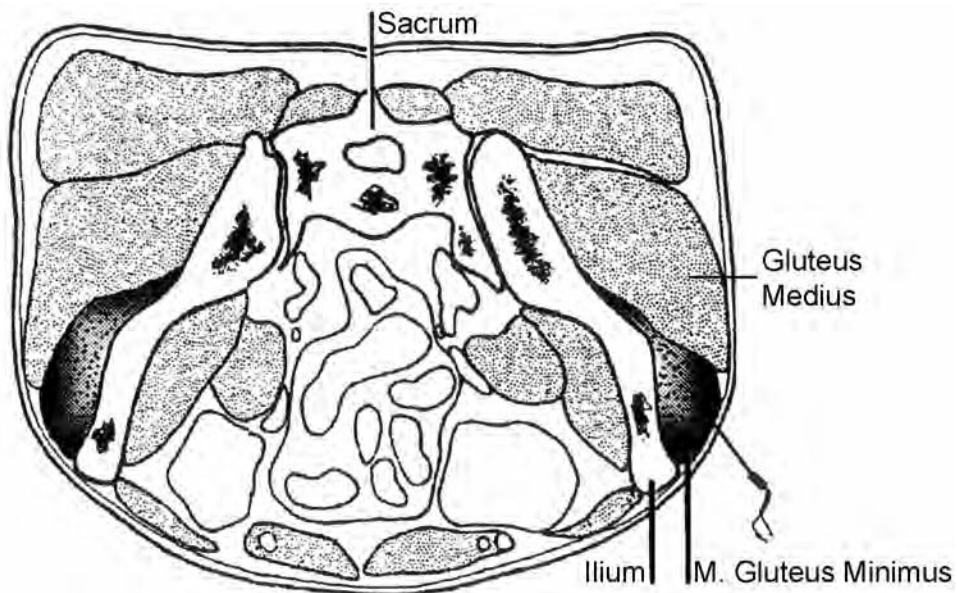
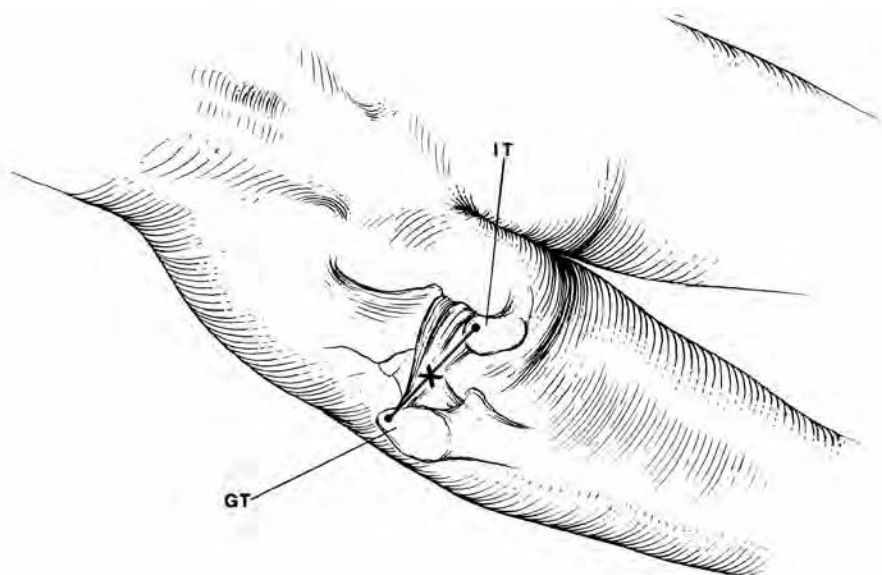


Figure 84. Cross section of the pelvis through the middle of the sacral mass.

OBTURATOR INTERNUS AND GEMELLI*



Innervation

Obturator Internus and Superior Gemellus: Obturator Internus Nerve, Sacral Plexus, L5, S1, S2.

Inferior Gemellus: Quadratus Femoris Nerve, Sacral Plexus L4, L5, S1, S2.

Both Nerves: Arise From the Proximal Segment of the Tibial Portion of the Sciatic Nerve.

Origin

From the ischial spine, the ischial tuberosity, the obturator membrane and the adjacent bone.

Insertion

Into the medial side of the greater trochanter.

*The gemelli are considered the extra pelvic portion of the obturator internus.

Position

The patient prone.

Electrode Insertion

Insert electrode to bone and withdraw slightly at a point midway between the ischial tuberosity (IT) and the posterosuperior aspect of greater trochanter (GT). The electrode will travel through the gluteus maximus muscle.

Test Maneuver

Patient to externally rotate the thigh with the leg extended.

Pitfalls

If the electrode is inserted too medially it will contact the sciatic nerve; if inserted too superficially it will be in the gluteus maximus; if inserted too distally it will be in the quadratus femoris; if inserted too proximally it will be in the piriformis.

Comments

- (a) Involved in lesions of the lumbosacral plexus close to the spine or in L5, S1, S2 radiculopathies.
- (b) The main function of these two muscles is to rotate externally the extended leg and to abduct the thigh when flexed.
- (c) They both hold the head of the femur firmly in the acetabulum.

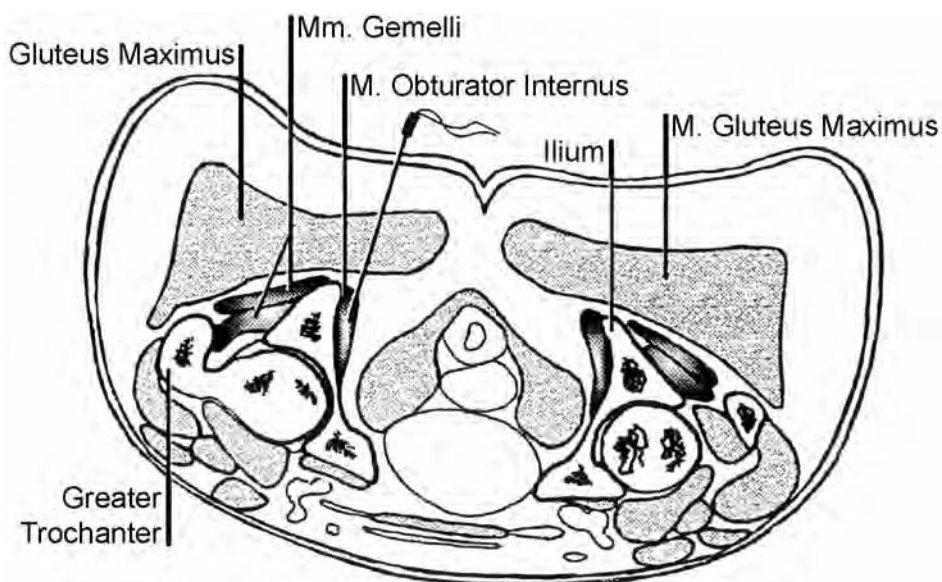
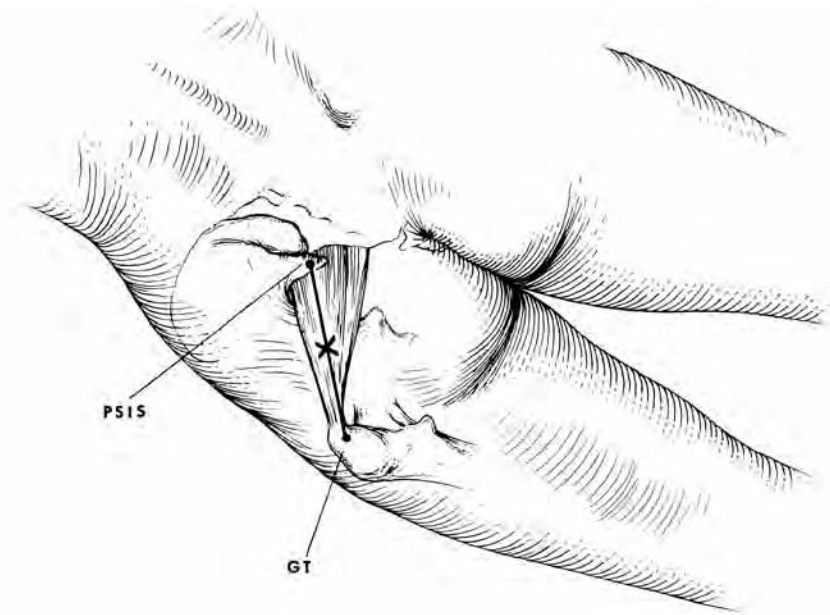


Figure 85. Cross section of the pelvis through the midportion of the hip joint.

PIRIFORMIS



Innervation

Nerve to the Piriformis S1, S2.

Origin

From the front of the sacrum.

Insertion

Into the piriform fossa of the greater trochanter.

Position

The patient prone.

Electrode Insertion (X)

Insert the electrode deep to bone at the midpoint of a line between the posterior inferior iliac spine (SIS) and the posterior-superior margin of the greater trochanter (GT), then withdraw slightly. The electrode will travel through the gluteus maximus muscle.

Test Maneuver

Patient to externally rotate thigh.

Pitfalls

If the electrode is inserted too superficially it will be in the gluteus maximus; if inserted too caudally it will be on the obturator internus or gemelli.

Comments

- (a) The sciatic nerve may be entrapped as it crosses this muscle (piriformis syndrome), but this muscle does not get involved.
- (b) Involved in lesions of S1 and S2. This muscle is innervated directly from these roots.
- (c) Its main function is to rotate the thigh externally with extended thigh, and to abduct the thigh with flexed hip. This muscle is also a good supporter of the femoral head into the acetabulum socket.

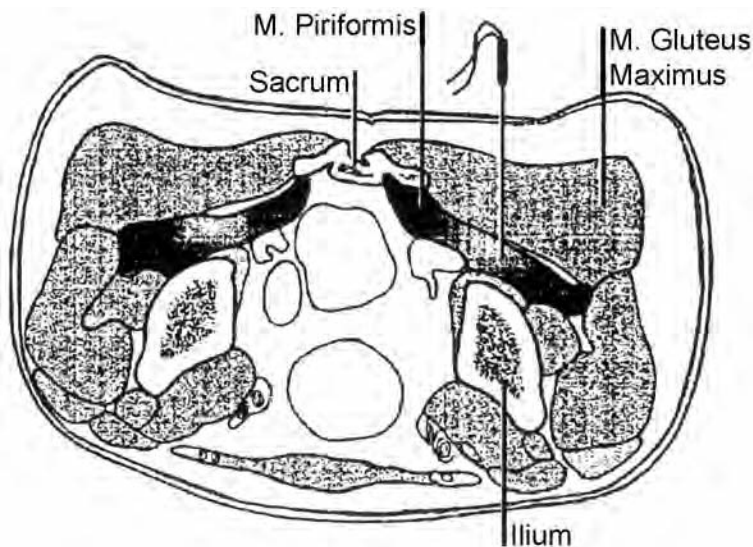
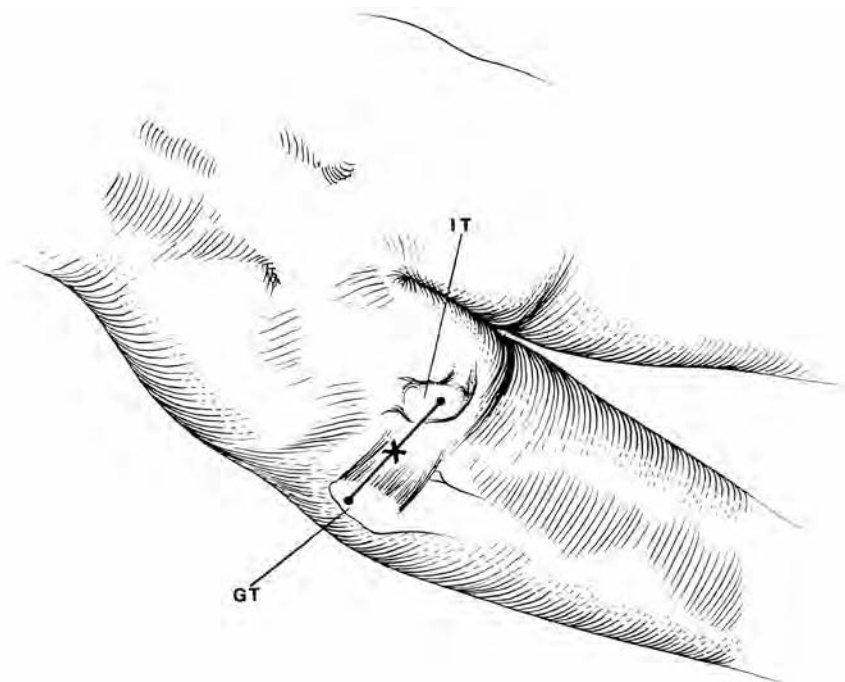


Figure 86. Cross section of the pelvis at the lower sacral mass.

QUADRATUS FEMORIS



Innervation

Nerve to the Quadratus Femoris, Sciatic Nerve (Tibial Portion), L4, L5, S1.

Origin

From the ischial tuberosity deep to the hamstrings.

Insertion

Into the quadrate tubercle of the femur.

Position

The patient prone.

Electrode Insertion (X)

Midway between the greater trochanter (GT) and the ischial tuberosity (IT). The electrode should contact bone and then be

withdrawn slightly. The electrode will travel through the gluteus maximus muscle.

Test Maneuver

Patient to externally rotate thigh.

Pitfalls

If the electrode is inserted too superficially it will be in the gluteus maximus or medius; if inserted too distally it will be in the hamstring group.

Comments

- (a) Involved in lesions of sciatic nerve at its junction with the sacral plexus or L4, L5, S1 roots.
- (b) Its function is to rotate the leg externally with extended leg, and to adduct it with flexed thigh. This muscle is the most important muscle to steady the hip joint (similar to a rotator cuff).

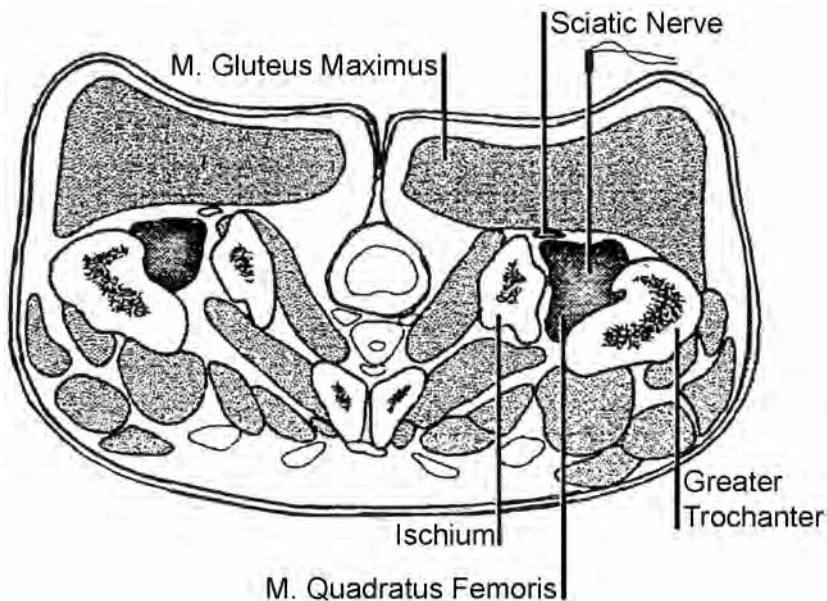
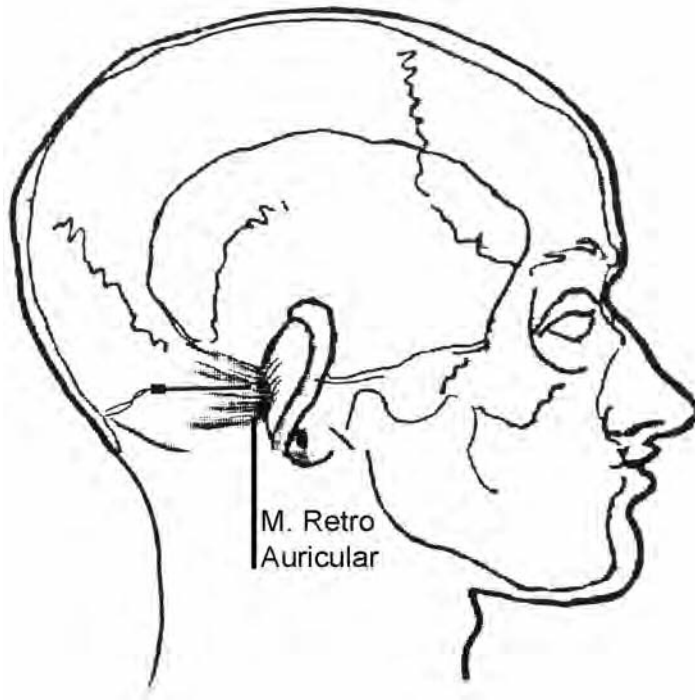


Figure 87. Cross section of the pelvis through the inferior portion of the symphysis pubis.

THE TRUNK



SECTION X

MUSCLES INNERVATED BY CRANIAL NERVES

FACIAL NERVE (NUMBER 7)

FACIAL (VII)

The facial nerve provides the motor innervation of all the muscles in the face (muscles of expression) and it divides into 7 branches after exiting from the stylomastoid foramen. These branches are:

- (a) *Post Auricular Nerve*: Supplies the *retroauricular muscle* and the occipital belly of the occipitofrontalis muscle (This branch leaves the main trunk of the facial nerve before the nerve enters the postero-medial aspect of the parotid gland).

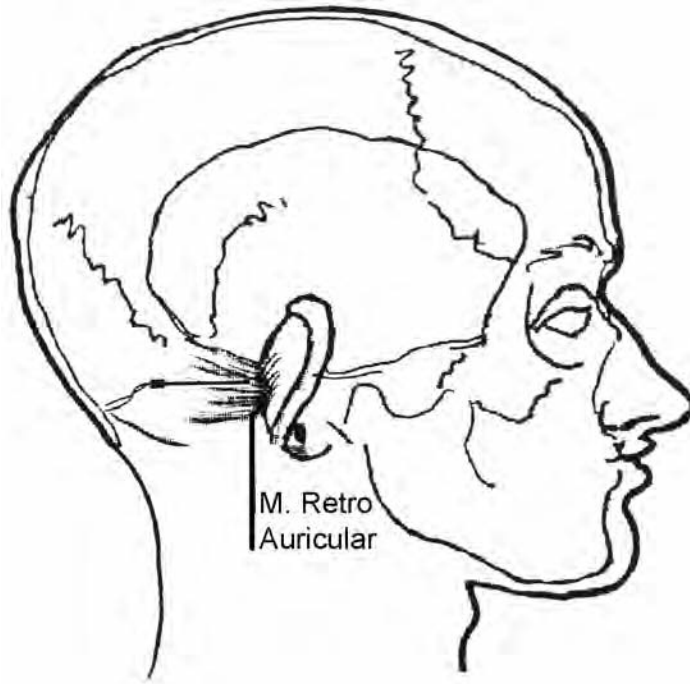
The terminal branches of the facial nerve are subject to great variation, and the following description may occur in a certain percentage of the cases.

- (b) *Temporal Branches*: Supplies the *orbicularis oculi* and the frontal portion of *occipitofrontalis*.
- (c) *Mandibular Branch*: Supplies the depressor anguli oris and muscles of the chin.
- (d) *Cervical Branch*: Supplies the platysma.
- (e) *Zygomatic Branches*: Supplies the zygomatic muscle and *orbicularis oculi*.
- (f) *Superficial Buccal Branches*: Supplies the *orbicularis oris*.
- (g) *Deep Buccal Branch*: Supplies the buccinator and the muscles of the nose.

Only the following muscles will be described as they are the most commonly investigated:

Retroauricular
Frontalis
Orbicularis oculi
Elevator nostril
Orbicularis oris

RETRO AURICULAR OR AURICULARIS POSTERIOR



Origin

From the mastoid part of the temporal bone.

Insertion

To the cranial aspect of the auricle.

Position

Patient in supine position with head rotated to the side not under study.

Electrode Insertion

The auricle is pulled forward and several small creases will appear at the angle formed between the auricle and the scalp. These creases represent the stretching of the muscle underneath. The electrode is placed at that point to one-fourth to one-half inch in depth.

Test Maneuver

The patient is asked to wiggle his ear. Even though the actual motion of the auricle may not be seen, however, electrical activity is generally seen.

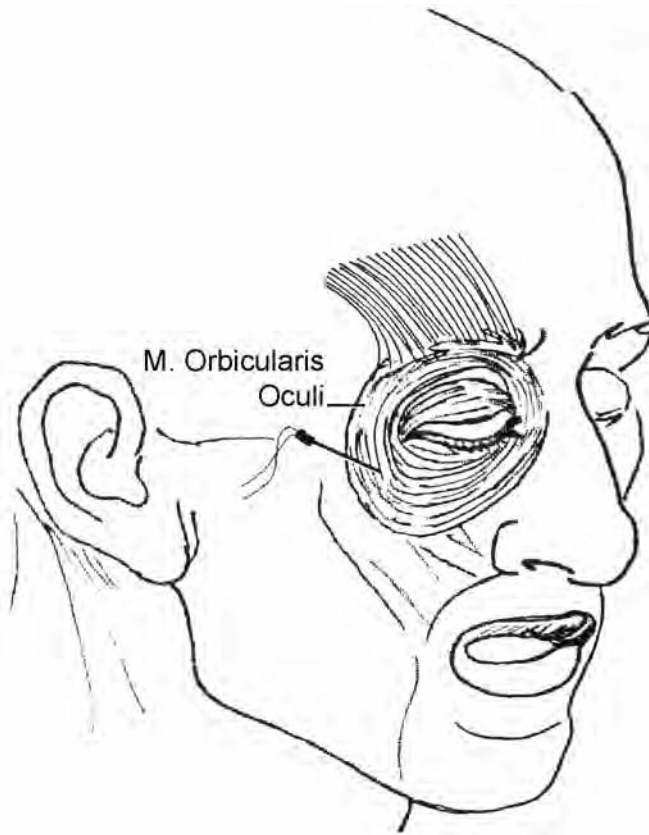
Pitfalls

None.

Comments

- (a) The study of this muscle could help in localizing facial nerve lesion occurring in the parotid gland. In this case, the muscle will show normal electrical activity.
- (b) This muscle is involved in lesions of the facial nerve occurring at the motor nucleus of the 7th C.N., down to the stylomastoid foramen.

ORBICULARIS OCULI



Innervation

This muscle is supplied by the zygomatic portion of the facial nerve.

Origin and Insertion

Two Parts: The central, which travels within the eyelids, and the orbital, which is larger and thicker, encircle the central and insert in the medial palpebral ligament, the bone above and below the ligament, spread around the eyebrows, the temporal region and the cheek.

Position

The patient is supine with the head in neutral position.

Electrode Insertion

Palpate the lateral portion of the eye fossa (bone) and direct the tip of the electrode at a 25–30 degree angle with the skin, in a medial and downward direction. It will penetrate the lower lip portion of the orbicularis oculi.

Test Maneuver

Ask the patient to wink or blink very gently. This maneuver should not be repeated too often because the motion of the electrode can produce some soft tissue damage which may lead to swelling and/or hemorrhage (black eye) due to the extreme looseness of the tissues in the infraorbital area.

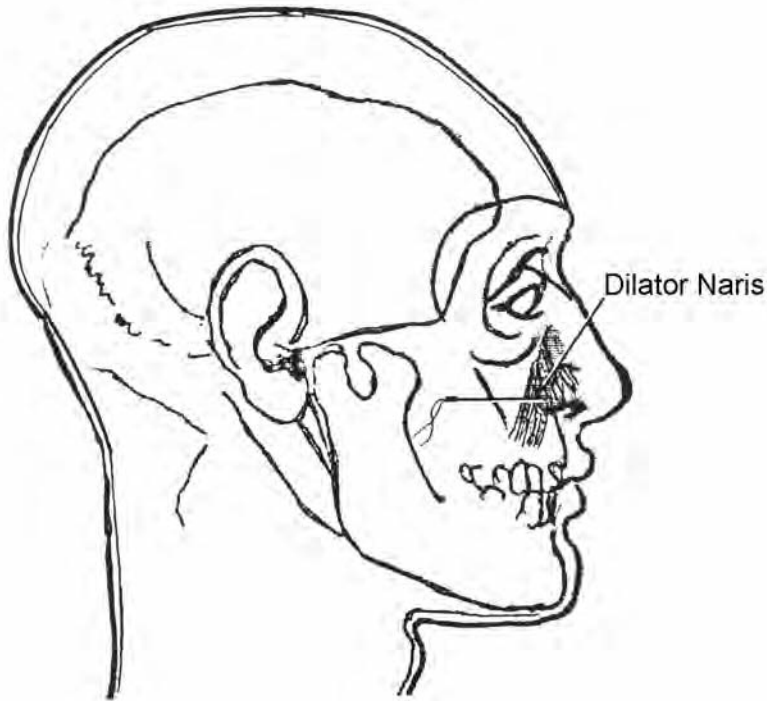
Pitfalls

If the electrode is inserted too perpendicular to the skin, it may enter the orbit which can damage the eyeball.

Comments

- (a) This muscle is used as a pick-up muscle for the blink reflex test.
- (b) This muscle is involved in all nuclear and infranuclear lesions of the facial nerve.
- (c) Its function is multifold:
 - 1. To protect the eye against glare of light and dust in the air.
 - 2. To close the eyelids tight to keep the cornea moist.
 - 3. By closing the eyelids tight, it milked the lacrimal glands producing an increase in tears production.

DILATOR NARIS



Innervation

This muscle is innervated by the bucal branch of the facial nerve.

Origin

From the front of the maxilla above the incisor and canine teeth.

Insertion

Into the ALA of the nostril.

Position

Patient is supine with head in neutral position.

Electrode Insertion

Because of the small size of the muscle, needle electrode is very seldom used. Instead, a surface electrode (8mm DISC) is placed over the skin covering the muscle. This muscle is used as the reference electrode during the blink reflex.

Test Maneuver

Ask patient to take a deep breath through the nose.

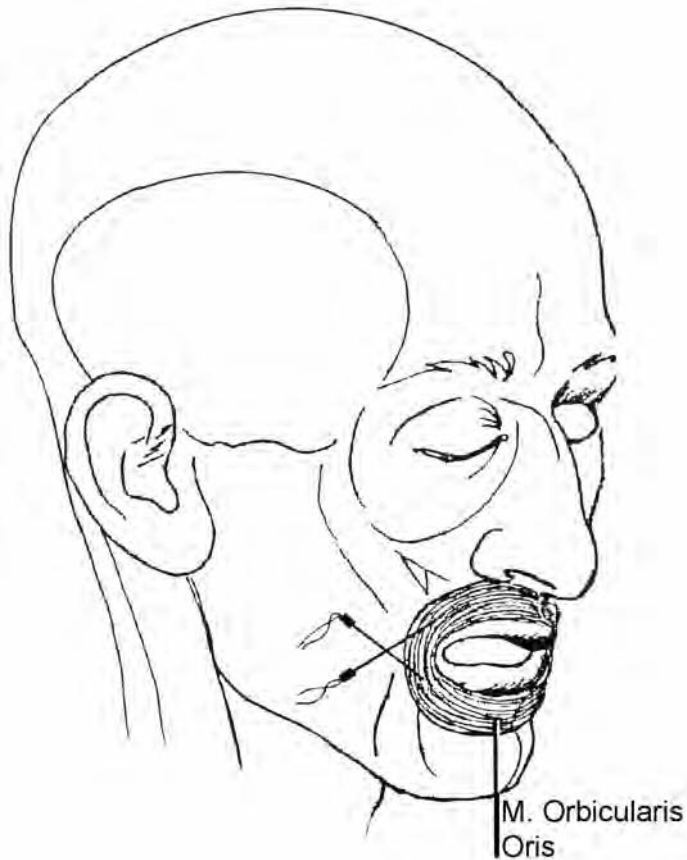
Pitfalls

None.

Comments

- (a) This muscle is involved in all types of facial nerve lesions.
- (b) The action of this muscle becomes evident during laborious breathing. Under normal breathing, its function is insignificant.

ORBICULARIS ORIS



Innervation

This muscle is innervated by the bucal branch of the facial nerve.

Origin and Insertion

As a sphincter muscle around the mouth, this muscle is anchored to the nasal septum and the maxilla above and the mandible below. There is no clear point of origin or insertion. This muscle is in close connection with several small muscles, which give an infinite variety of expressions to the facial activity.

Position

Patient is supine with head in neutral position.

Electrode Insertion

One-finger's breadth lateral to the angle of the mouth the electrode is inserted through the skin at a 20° angle and is advanced toward either the upper or the lower lip. The tip of the electrode should not be closer than 2cm from the midline.

Test Maneuver

The patient is asked to pucker his lips.

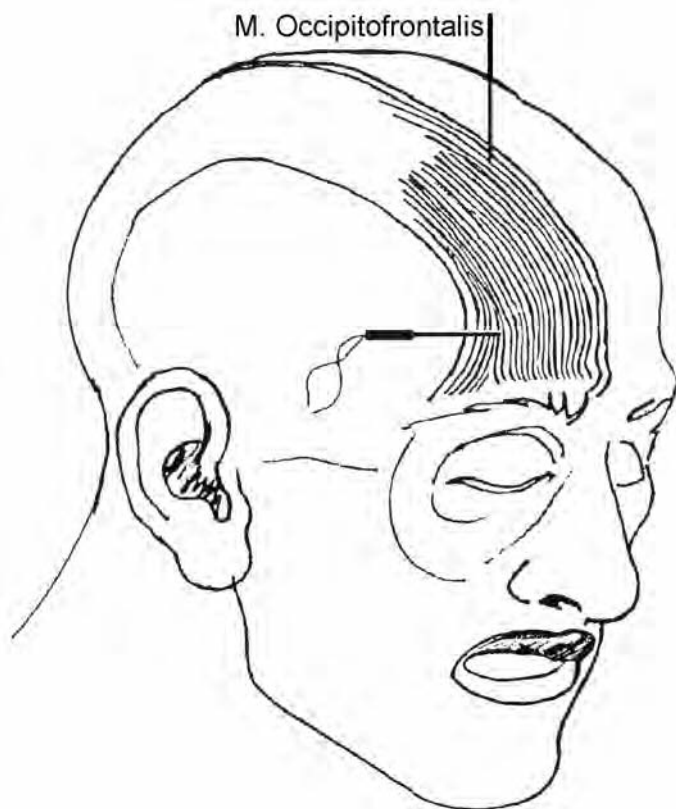
Pitfalls

- (a) If the electrode is inserted too vertically to the skin, the tip may end up in the oral cavity.
- (b) If the tip of the electrode is too close to the midline, it can pick up electrical activity from the opposite half of the muscle due to crossover Innervation.

Comments

One of the important functions of this muscle is to open and close the mouth voluntarily for a variety of reasons. Furthermore, in conjunction with all of the small muscles it is attached to, it becomes an important muscle that conveys a large number of different emotional states associated with mirth or grief; delight or sadness; fear or despair. The paralysis of part of this sphincter produces a marked impact on the ability to express all of these emotional states. This muscle also plays an important role in the proper pronunciation of words and in eating food (chewing). Whistling becomes very difficult and the individual may drool from the corner of his mouth on the affected side.

OCCIPITOFRONTALIS



Innervation

This muscle is innervated by the temporal branch of the facial nerve.

Origin

From the epicranial aponeurosis at the level of the coronal suture in both sides.

Insertion

It descends over the frontal bone to the edge of the orbital margin where it interlaces with the fibers of the orbicularis oculi without having any bone attachment.

Position

The patient is in supine position with the muscle under study closer to the examiner.

Electrode Insertion

One-finger's breadth superior to the orbital margin and two-fingers' breadth from the midline.

Test Maneuver

The patient is asked to raise his eyebrows (frown the forehead transversely).

Pitfalls

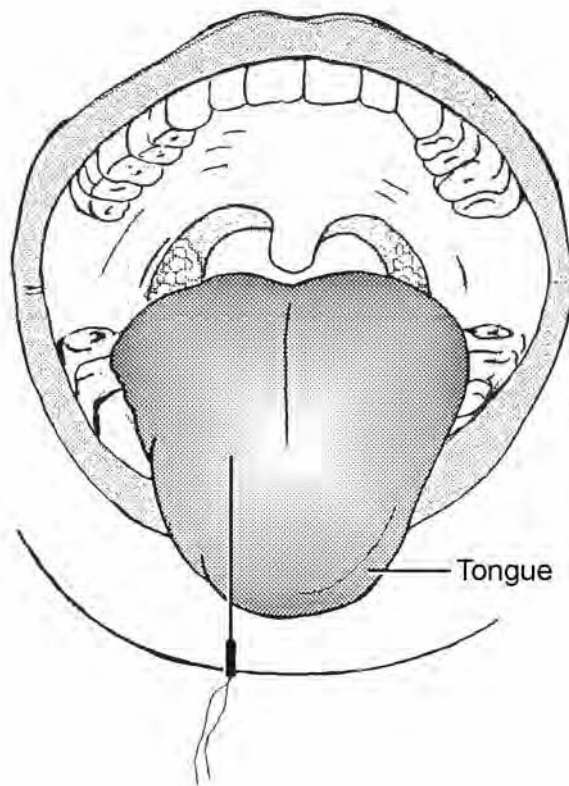
- (a) If the electrode is inserted too low, it may enter the orbicularis oculi.
- (b) If inserted too close to the midline, electrical activity may be found which may be coming from the opposite side due to some crossover innervation of the muscle. It is recommended that the electrode be inserted in a way that the tip will be away from the midline.

Comments

- (a) This muscle is involved in all nuclear and infranuclear lesions of the facial nerve (bell's palsy; cerebellar-pontine angle tumor; fracture of the petrous part of the temporal bone, parotid gland tumors).
- (b) Its main function is to elevate the eyebrows (surprise look) and it is responsible for all the transverse wrinkles in the persons forehead.

HYPOGLOSSAL NERVE (NUMBER 12)

TONGUE



Innervation

Cranial Nerve # 12 Hypoglossal

Origin

- (a) Genioglossus: From the genial tuberosity of the mandible.
- (b) Hypoglossus: From the body and greater horn of the hyoid bone.
- (c) Styloglossus: From the front tip of the styloid process and the stylohyoid ligament.

Insertion

The three paired muscles converge to join in a latticework with the intrinsic tongue muscle.

Position

Patient in sitting position.

Electrode Insertion

The patient is asked to stick out his tongue. The examiner holds the tongue with a gauze and keeps it steady. With the other hand, the electrode (coaxial, disposable, 25mm in length) is inserted on one side of the tongue. The patient is now asked to pull his tongue back into the mouth and is asked to close his mouth and relax. When relaxation is obtained, the background electrical activity of the tongue will cease. If fibrillations and/or fasciculations are present, they can be seen at this time. To assess the muscle activity at maximal effort, the patient is asked to open his mouth and stick out his tongue. It should be remembered that the tongue is a muscle that pushes rather than pulls. Therefore, when the tongue protrudes from the mouth, it is actually producing a contraction.

Test Maneuver

Stick tongue out of the mouth.

Pitfalls

None.

Comments

The tongue electromyography is usually done in patients suspected of suffering from A.L.S. This study requires a great deal of patient's cooperation. The entire procedure should be fully explained to the patient before it starts.

The tongue is a muscle that is very difficult to bring to full relaxation. Therefore the technique should be followed meticulously. When the tongue presents unequal strength on both sides, the tip deviates toward the weak side when protruded. The weak half becomes atrophied and exhibits deep furrows. Complete damage of the hypoglossal nerve on one side, produces a complete paralysis of the hemitongue on the same side. If the condition is long-standing, the atrophy of that side of the tongue is very marked, and when the tongue protrudes out of the mouth, its tip deviates toward the side

of the lesion (it points the side of the lesion).

When both nerves are damaged, the tongue is totally paralyzed. The touch and the taste is not affected, but talking becomes very slow and swallowing very difficult.

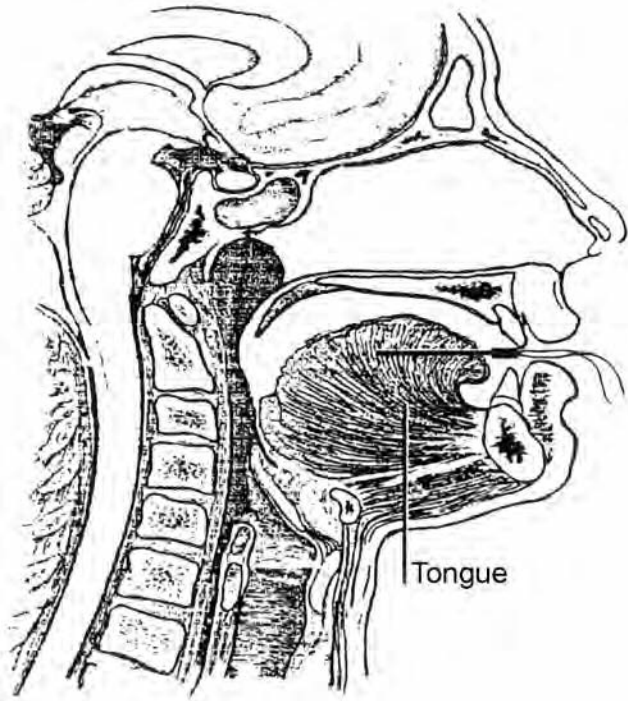
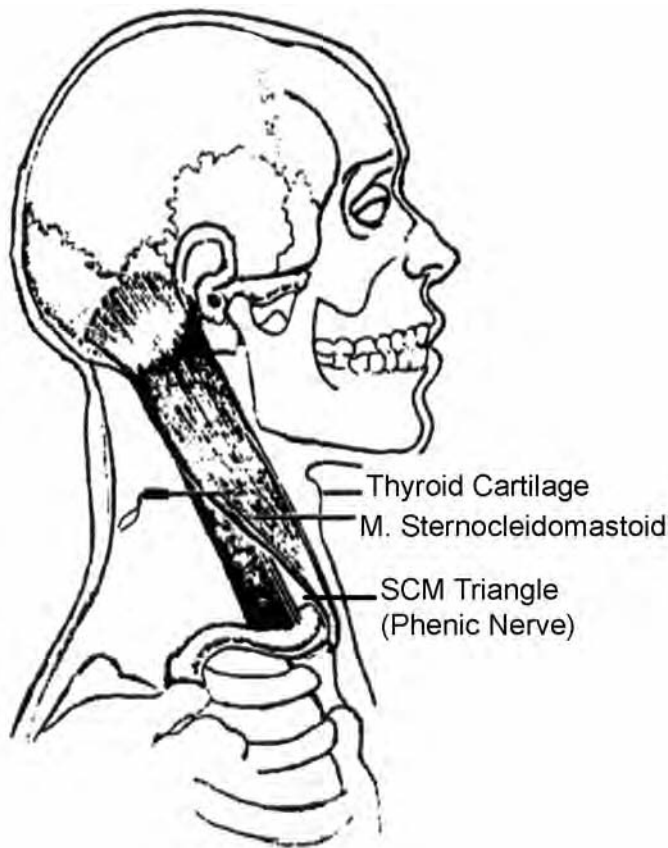


Figure 88. The tongue is resting; no electrical activity should be present.

SPINAL ACCESSORY (NUMBER 11)

STERNO-CLEIDO-MASTOID (S.C.M.)



Innervation

By the spinal accessory nerve which is formed by the spinal roots (upper 5 cervical ventral roots); they ascend through the foremen magnum, to exit through the jugular foremen, after joining the cranial roots.

Origin

Two heads: (a) Sternal or medial from the anterior surface of the manubrium sterni, (b) Clavicular or lateral from the upper surface of the medial third of the clavicle.

Insertion

The two heads merge together and the muscle end over the mastoid process. Before the muscle end, it is pierced by the spinal accessory nerve.

Position

The patient is in supine position with the head in neutral position.

Electrode Insertion

Four-fingers' breadth cephalad to the muscle origin (at the level of the thyroid cartilage) (Adam's apple). Because of the muscle's mobility and the skin looseness, it is practical to pinch the muscle between the index and thumb to anchor it firmly and to allow a safer electrode insertion.

Test Maneuver

The patient is asked to either flex the head or to perform a combined motion of slight head extension and rotation to the opposite side that is being tested (to bring the mastoid process closer to the manubrium sterni).

Pitfalls

- (a) Too deep: The electrode might puncture the carotid artery or the jugular vein.
- (b) Too posterior and too deep: The electrode might damage part of the brachial plexus.
- (c) Too low and too deep: The electrode might puncture the dome of the lung.

Comments

- (a) The S.C.M. constitutes the boundary between the anterior and posterior triangle of the neck.
- (b) Contrary to the trapezius, the S.C.M. is not involved when the spinal accessory nerve is damaged during supraclavicular lymph node biopsy.
- (c) It might become an important accessory breathing muscle.

- (d) This muscle is often involved in torticollis or dystonia musculorum.
- (e) The main function of this muscle is:
 - 1. When acting alone, the contraction of this muscle brings the mastoid process closer to the sternum, rotating the head to the opposite side and extending it.
 - 2. When both muscles are acting together, they flex the head like when raising the head from the pillow.
 - 3. At the triangle form by the clavical and sternal portion of the muscle, the phrenic nerve runs behind it. In cases of persistent or nonresponding hiccups, the phrenic nerve can be blocked at this point bilaterally.

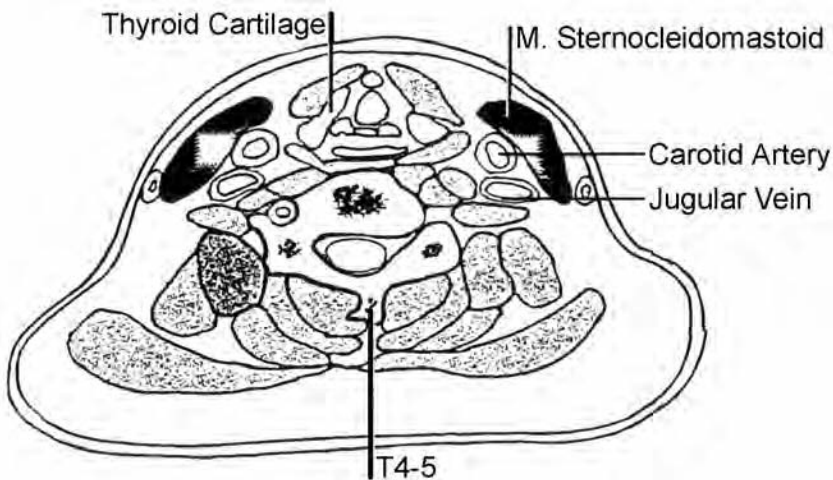
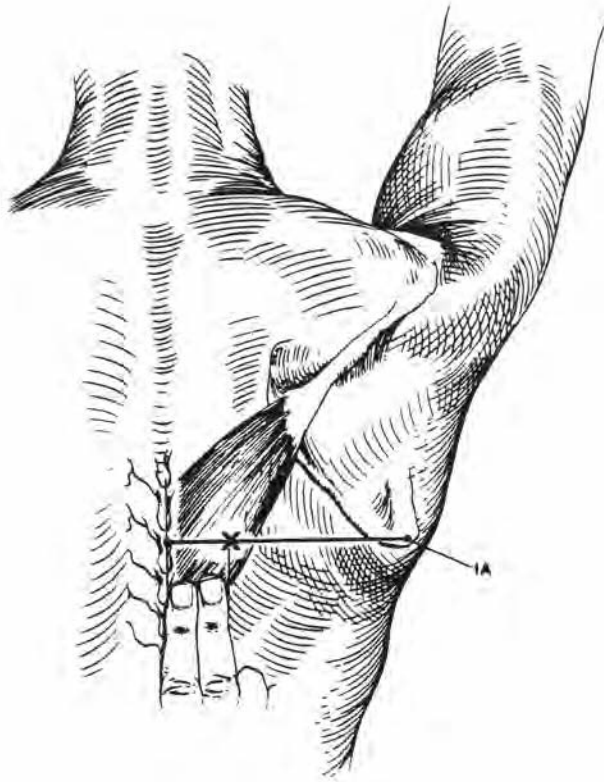


Figure 89. Cross section at the T4-5 vertebral level (thyroid cartilage level).

TRAPEZIUS, LOWER



Innervation

Spinal Portion of Accessory Nerve and Twigs from C3, C4.

Origin

Spinous processes of lower thoracic vertebrae from T7 to T12.

Insertion

The spine of the scapula.

Position

Patient prone with arm extended overhead.

Electrode Insertion (X)

On a line perpendicular to the vertebral column at the level of the inferior angle (IA) of the scapula, two fingerbreadths from the spinous process of that vertebra.

Test Maneuver

Elevate arm from plinth.

Pitfalls

If needle electrode is inserted too deeply or too caudally it will be in the Latissimus dorsi.

Comments

- (a) This muscle may be involved due to injury to the Spinal Accessory nerve during cervical lymph nodes biopsy.
- (b) The main function of this muscle is to depress the scapula and to lower the shoulder. When the superior and lower trapezius acts together, they produce a superior rotation of the scapula.

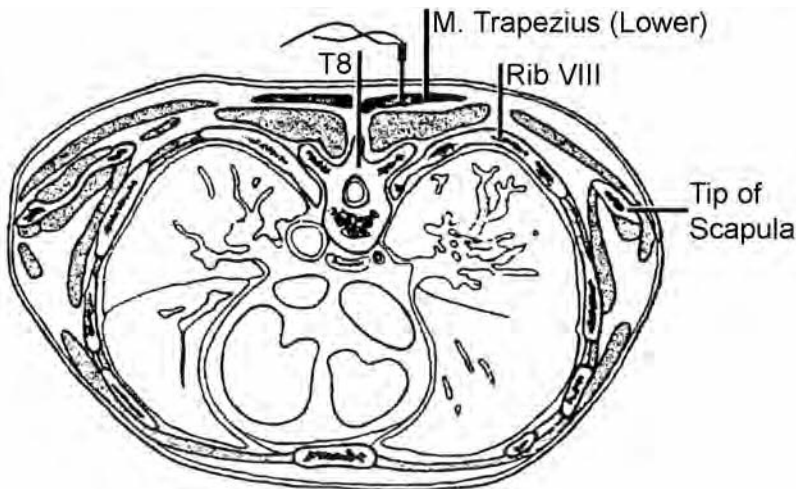
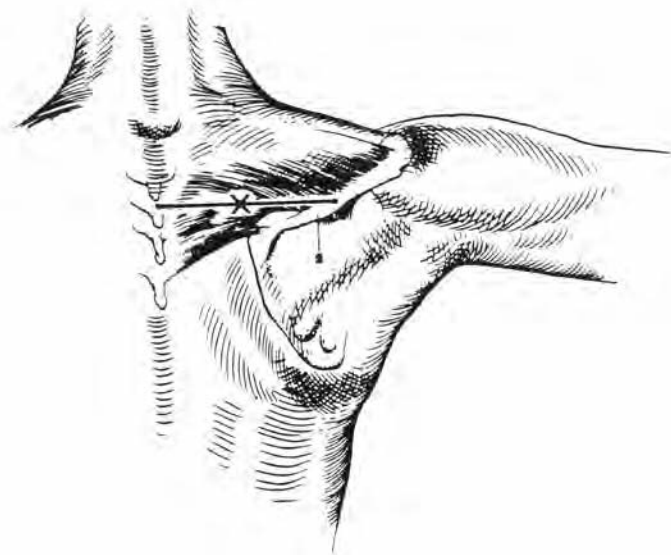


Figure 90. Cross section at the T8 level.

TRAPEZIUS, MIDDLE



Innervation

Spinal Portion of Accessory Nerve and Twigs From C3 and C4.

Origin

The seventh cervical and spinous processes of upper thoracic vertebrae.

Insertion

The acromion process and spine of scapula.

Position

The patient prone with arm abducted to ninety degrees and elbow flexed over the edge of plinth.

Electrode Insertion (X)

Midway between the midpoint of spine (S) of scapula and spinous process of vertebra at the same level.

Test Maneuver

Adduct scapula by elevation of arm from plinth.

Pitfalls

If needle electrode is inserted too deeply it will be in the rhomboideus.

Comments

- (a) This muscle may be involved due to injury to its Innervation in cervical lymph node biopsy.
- (b) The main function of this muscle is to retract the scapula and bring it closer to the midline.
- (c) When this muscle gets paralyzed, the glenoid angle of the scapula drops and the other two angles move upwards due to the unopposed action of the elevator scapula and the rhomboid muscles.

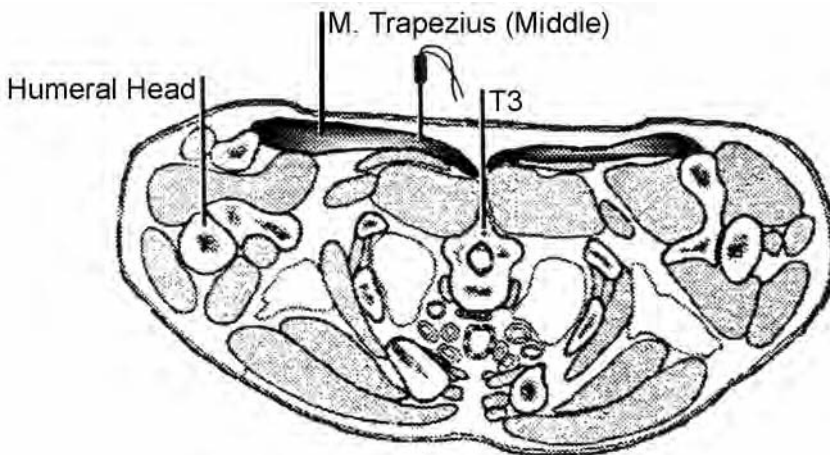
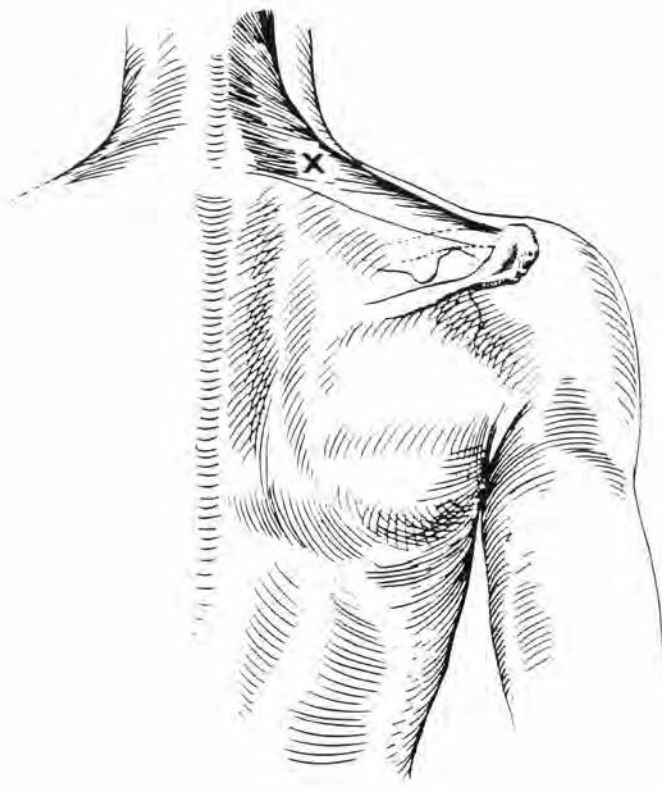


Figure 91. Cross section at the T3 level.

TRAPEZIUS, UPPER



Innervation

Spinal Portion of Accessory Nerve and Twigs from C3 and C4.

Origin

Occipital bone and ligamentum nuchae.

Insertion

The outer third of clavicle.

Position

The patient prone.

Electrode Insertion (X)

At angle of neck and shoulder.

Test Maneuver

Shrug shoulder.

Pitfalls

If needle electrode is inserted too deeply it will be in the levator scapula.

Comments

- (a) This muscle may be involved due to injury to its Innervation in cervical lymph node biopsy.
- (b) The main function of this muscle is to elevate the scapula and in conjunction with the lower portion, produces a superior rotation of the scapula.

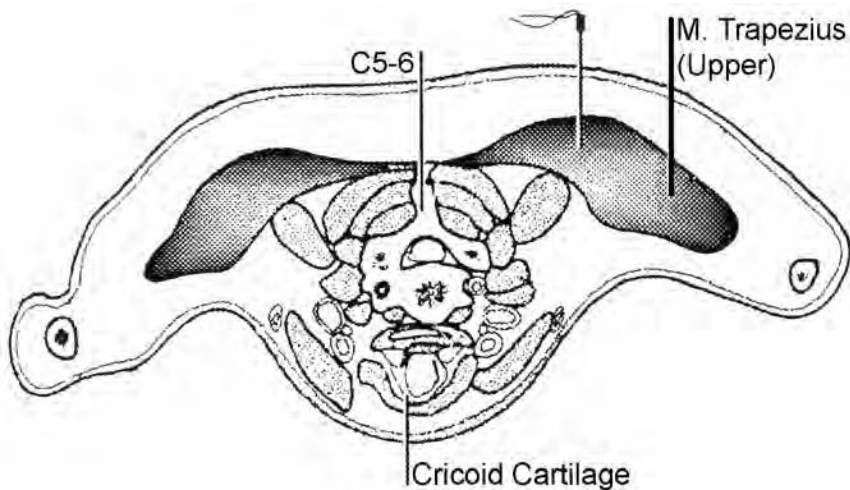
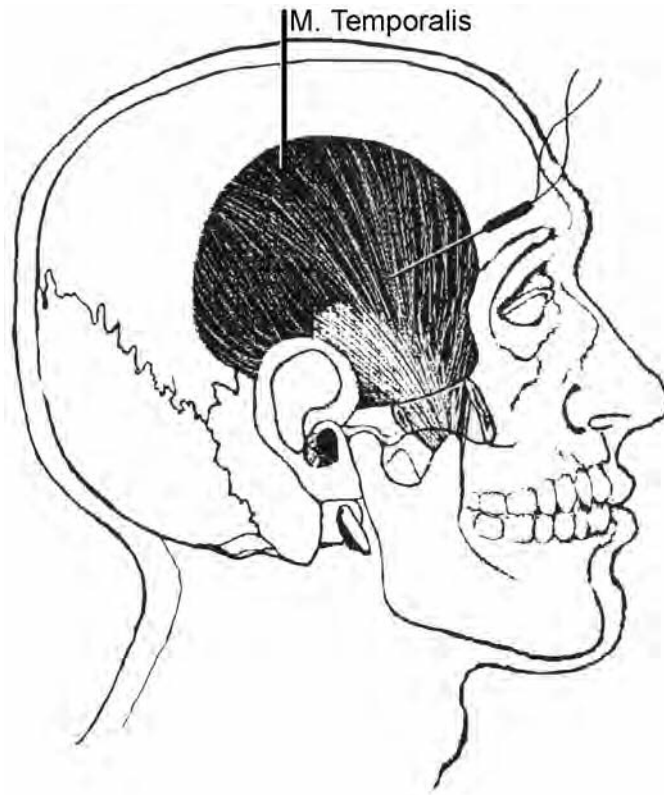


Figure 92. Cross section at the C5-6 level.

TRIGEMINAL NERVE (NUMBER 5)

A. TEMPORAL MUSCLE



Innervation

By the deep temporal nerve, which branches off the anterior trunk of the mandibular nerve (3rd division of the trigeminal nerve).

Origin

From the floor of temporal fossa as well as the fascia covering the muscle.

Insertion

Into the apex and the anterior border of the coronoid process of the mandible.

Position

The patient is either seated with the head resting on a headrest or lying supine with the head in neutral position.

Electrode Insertion

Two-fingers' breadth above the zygomatic arch, and two-fingers' breadth posterior to the eye commissurae.

Test Maneuver

The patient is asked to clench his teeth.

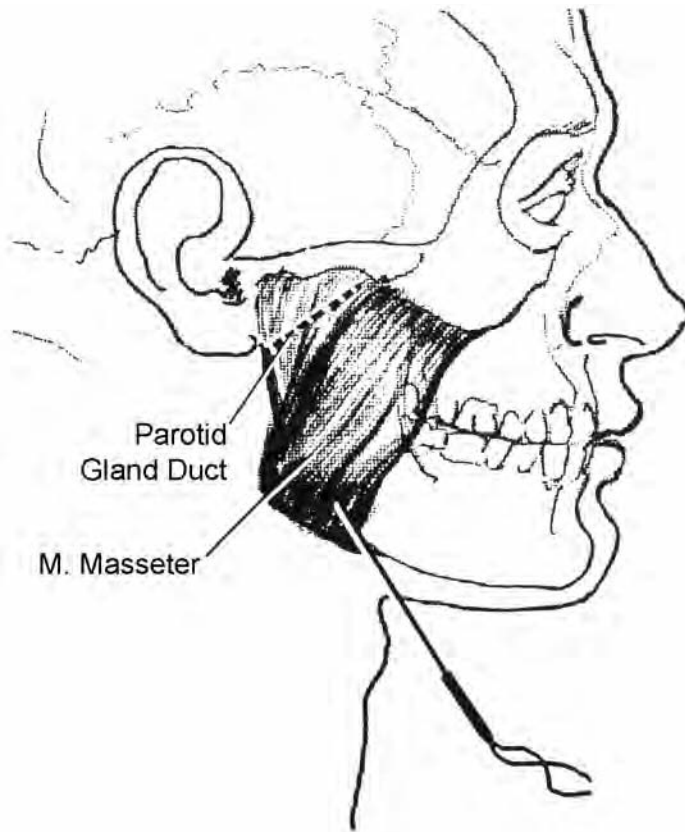
Pitfalls

If inserted too close to the external eye orbit, it could be in the orbicularis oculi. If inserted too close to the zygomatic arch, it could be in the tendinous portion of the temporal muscle.

Comments

- (a) This muscle could be involved in trigeminal neuritis.
- (b) Caution should be exercised to avoid piercing the temporal artery.
- (c) The function of this muscles is to elevate the mandible, closing the jaws. This muscle is a powerful masticator muscle.
- (d) Its posterior fibers move the mandible backwards.

B. MASSETER MUSCLE



Innervation

Nerve to the masseter which branches off the anterior trunk of the mandibular nerve.

Origin

From the zygomatic arch, lower border.

Insertion

The muscular and tendinous part into the lateral aspect of the coronoid process of the mandible.

Position

Patient is either seated with the head resting on a headrest or lying supine with the head in neutral position.

Electrode Insertion

One-finger's breadth posterior to the anterior edge of the muscle (recognizable when patient clenches his teeth or palpating the facial artery which winds around the anterior edge of the muscle) and one-finger's breadth cephalad to the lower edge of the mandible.

Test Maneuver

The patient is asked to clench his teeth.

Pitfalls

If electrode is inserted too close to the zygomatic arch, the duct of the parotid gland can be damaged.

If electrode is inserted close to the posterior edge of the muscle, it will go through the parotid gland.

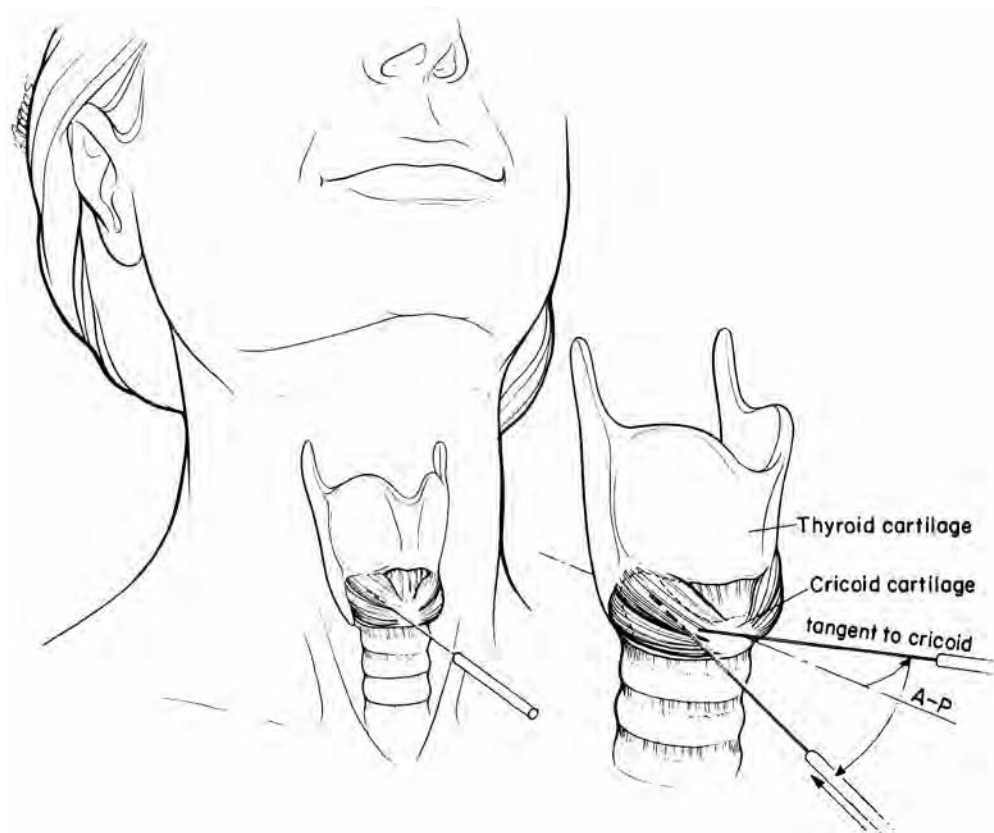
If electrode is inserted too close to the anterior edge of the muscle, the tip may end up in the mouth.

Comments

- (a) This muscle could be involved in trigeminal neuritis.
- (b) The parotid gland and/or the parotid duct can be compromised.
- (c) The muscle's nerve can be damaged during dissection for parotid gland tumors.
- (d) The main function of this muscle is to elevate and protract the mandible. It can produce a powerful bite.

VAGUS NERVE (NUMBER 10)

CRICOTHYROID



Innervation

External branch of the superior laryngeal nerve which branches off the middle of the inferior ganglion of the vagus nerve.

Origin

Antero-lateral surface of the cricoid cartilage (arch).

Insertion

Inferior border of the thyroid lamina and anterior aspect of the inferior thyroid horn.

Position

The patient is supine with the head in neutral position. A pillow is placed across the shoulders to allow the head to be slightly hyper-extended. The skin covering the space between the cricoid and the thyroid cartilage is infiltrated with 1% xylocaine intracutaneously (to produce “orange skin”). This infiltration is done 1cm from the mid-line bilaterally. When introducing the electrode, the larynx should be steady.

Electrode Insertion

A 25mm coaxial disposable EMG electromyography electrode is inserted through the anesthetized skin tangential to the upper border of the cricoid arch in a superior and lateral direction. During the advancement of the electrode the patient vocalizes the vowel “e.” Much higher electrical activity is found when the vocalization of “e” is done at a high pitch rather than at a low pitch.

Test Maneuver

The electrical output of the muscle increases greatly when the high pitched noise is performed. When the patient is asked to elevate his head from the table, only distant electrical activity should be seen (strap muscles distant activity).

Pitfalls

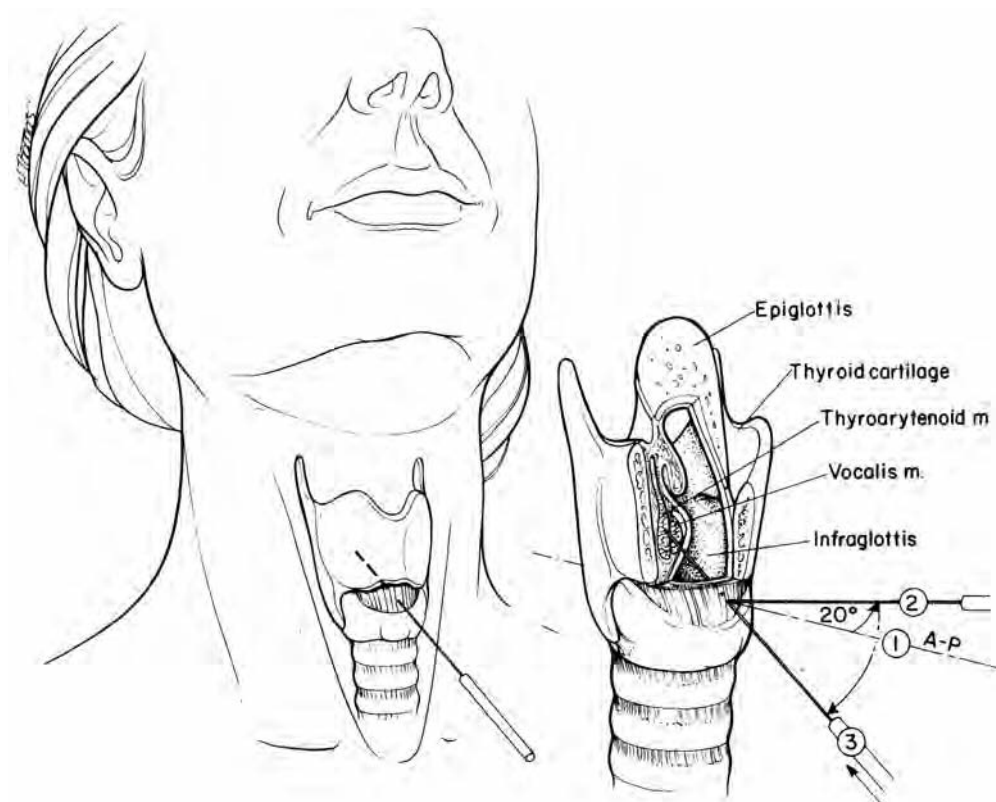
If the electrode is too superficial, it will be in the sternohyoid muscle. If it is too deep it will be in the lateral cricoarytenoid muscle.*

Comments

- (a) The main function of this muscle is to stretch and tense the vocal fold.
- (b) If this nerve is affected at the same time as the recurrent laryngeal, the problem is affecting the vagus nerve or vagus nucleus. There will be alteration of the vocal cord function and position.
- (c) In isolated lesions of this nerve, the patient will have difficulty attaining high voice tones.

*Minoru Hirand et al: Use of hookwire electrodes for electromyography of the intrinsic laryngeal muscles. *Journal of Speech and Hearing Research* 12: 362–373, 1969.

VOCALIS OR THYROARYTENOID MUSCLE



Innervation

Recurrent laryngeal nerve from the vagus nerve.

Origin

From the posterior aspect of the thyroid cartilage.

Insertion

To the postero-lateral border and muscular process of the arytenoid cartilage.

Position

The patient is supine with the head in neutral position. A pillow is placed across the shoulders to allow the head to be slightly hyper-extended. This facilitates the recognition of the thyroid and the cricoid cartilages. The skin covering the space between the thyroid and the cricoid cartilage is anesthetized with 1% xylocaine. This permits the patient to feel less pain which in turn decreases the tension in the patient and the tendency to evoke the swallowing reflex. For purposes of introducing the electrode, the patient's larynx should be steady.

Electrode Insertion

A 50mm coaxial disposable EMG electrode is inserted through the skin and the cricothyroid membrane. As soon as the electrode pierces the membrane, its direction is oriented to about 20° laterally and 45° superiorly or proximally. The intention is to advance the electrode submucosally, avoiding entering the subglottic cavity.¹ Other investigators using the same entrance, prefer to enter the subglottic cavity and then angle the electrode cephalad and to the side of the muscle that is to be studied.² With either technique, it is advisable to advance the electrode while the patient is phonating. The electrical activity increases as the electrode approaches the muscle.

Test Maneuver

The electrical activity increases during glottal stop (Valsalva); waxes and wanes with breathing activity (inspiration = increase; expiration = decrease); vocalizing ('e').

Pitfalls

If the electrode's tip is in the subglottic cavity, the electromyographic machine produces a large amount of interference noise. If the electrode is too deep, it may reach the lateral cricoarytenoid muscle.

¹ Blair R et al.: Laryngeal electromyography: Technique and application. *Otolaryngology Clin. North Amer.* 1978: 11:225.

² Minoru Hirano et al.: Use of hook-wire electrodes for electromyography of the intrinsic laryngeal muscles. *Journal of Speech and Hearing Research* 12: 362-373, 1969.

Comments

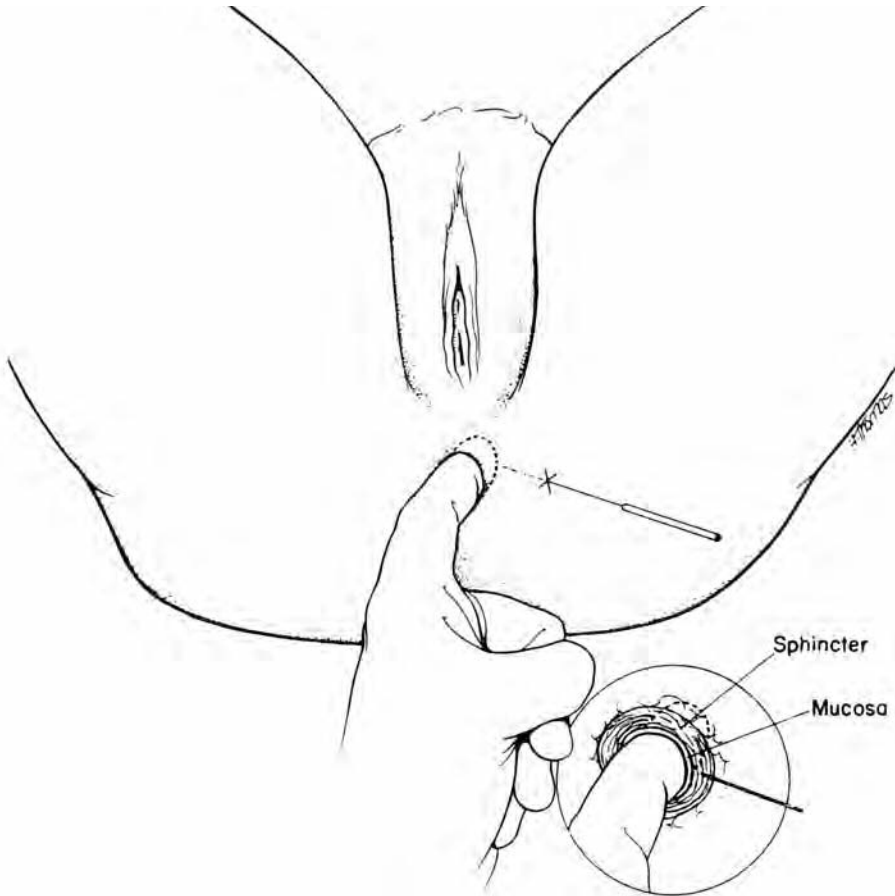
- (a) The thyroid and cricoid cartilages are much more developed in males than in females. Therefore, the identification of the anatomic landmarks is much easier and the procedure simpler in males than in females.
- (b) The recurrent laryngeal nerve on the right side can be affected in patients with aneurism of the aortic arch; both nerves can be damaged in tumors invading the mediastinum; in vagal neuritis; in lesions of the nucleus of the vagal nerve (A.L.S.).
- (c) The recurrent laryngeal nerve innervates all the intrinsic laryngeal muscles except the cricothyroid (superior laryngeal nerve).
- (d) This muscle is the principal relaxer of the vocal folds. This muscle pulls the arytenoids cartilage anteriorly and therefore slackening the volar ligaments.

SECTION XI

**MUSCLES OF THE
PERINEAL REGION**

PELVIC DIAPHRAGM

A. SPHINCTER ANI EXTERNUS (RECTAL SPHINCTER)



Innervation

By the pudendal nerve (from S2–3–4 roots and anterior division of the sacral plexus).

Origin and Insertion

This is a funnel-shaped sphincter which is formed by the lowest most part of the levator ani muscle. Its fibers attach firmly to the coccyx in the back and the perineal body in the front.

Position

The patient is in supine position with both legs in stirrups (GYN position) in order to expose widely the perineal region.

Electrode Insertion

Bimanual maneuver is recommended. With the free hand gloved, the index finger is placed inside the anus with the pulp side of the finger “looking” to the hemisphincter under study. A 50mm electrode is inserted about two-fingerbreadths from the edge of the rectum. The finger placed inside the anus will guide the electrode to reach the proper placement and to prevent the tip from piercing the rectal mucosa. During this maneuver great care should be taken to avoid puncturing the examiner’s finger with the electrode.

Test Maneuver

The patient is asked to contract the sphincter as if trying to avoid having a bowel movement.

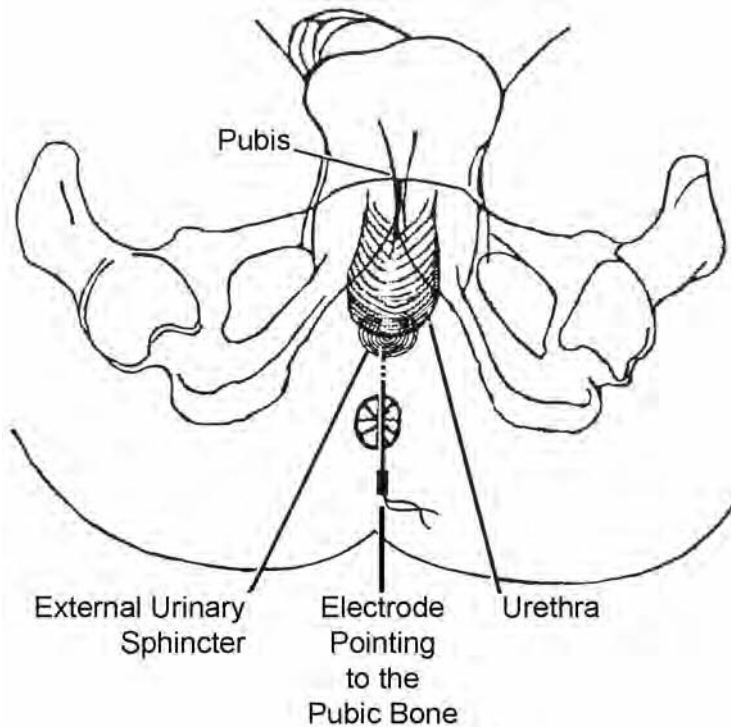
Pitfalls

- (a) If too deep, it may penetrate the rectum space.
- (b) If too superficial, it will be in the gluteus maximus.

Comments

- (a) The muscle is involved in unilateral or bilateral lesions of the pudendal nerve, at the pelvic level or at the sacral plexus, cauda equine or conus medullaris level.
- (b) This muscle is used as pick-up for the electrical evaluation of the pudendal reflex (both hemisphincters should be tested for comparison reasons).
- (c) The natural tone of the sphincter keeps the canal and the anus closed; this closure can be tightened voluntarily by the patient.
- (d) Internal hemorrhoids can be present and therefore special attention should be paid to avoid puncturing them which will result in a prolonged, oozing bleeding.
- (e) Large varicose (piles) in the rectal canal should also be avoided and they can be seen in patients with portal hypertension or in hepatic cirrhosis.

B. SPHINCTER URETHRAE (URINARY SPHINCTER)



Innervation

By the pudendal nerve, from S2–3–4 roots and anterior division of the sacral plexus.

Origin and Insertion

This muscle lies deep to the perineal membrane, forming a complete cuff of the urethra, just distal to the prostate. Peripheral fibers anchor to the perineal membrane, the inferior pubic rami and the perineal body.

Position

The patient is in supine position with both legs in stirrups (GYN position) in order to expose the perineal region.

Electrode Insertion

Bimanual maneuver is recommended. With the free hand gloved, the index finger is placed inside the rectum with the pulp side of the finger facing up. A 50mm or 75mm electrode is inserted two fingerbreadths volar to the anus and through the perineal body. The electrode is directed upward and cephalad at an angle of about 45° toward the pubic bone. The finger placed within the rectum has to identify the lower pole of the prostate, and guide the electrode to enter the sphincter muscle which is located just distal to the prostate. During this maneuver great care should be taken in order to avoid puncturing the examiner's finger with the electrode.

Test Maneuver

The patient is asked to contract the sphincter as if trying to avoid passing urine.

Pitfalls

- (a) If the electrode is directed
 1. Too volarly, it may enter the corpus spongiosum or the bulbospongiosus muscle.
 2. Too dorsally, it will be in the rectal sphincter or enter the rectum.
 3. Too deep, it will enter the prostate.

Comments

- (a) In females, the muscle is poorly developed and therefore it is very difficult to identify. On the other hand, the approach to this muscle is intravaginally which carries a significant risk of infection.
- (b) This muscle is affected in unilateral or bilateral lesions of the pudendal nerve, sacral plexus, cauda equine, or conus medullaris. Paralysis of this muscle may result in urinary incontinence.
- (c) In males this muscle is well developed and it forms a true voluntary sphincter that compresses the urethra and cuts off the flow of urine.
- (d) In females, this muscle is not as well developed as in males. The

inferior portion of this muscle blends with the wall of the vagina forming an urithrovaginal sphincter that constrict both the urethra and the vagina.

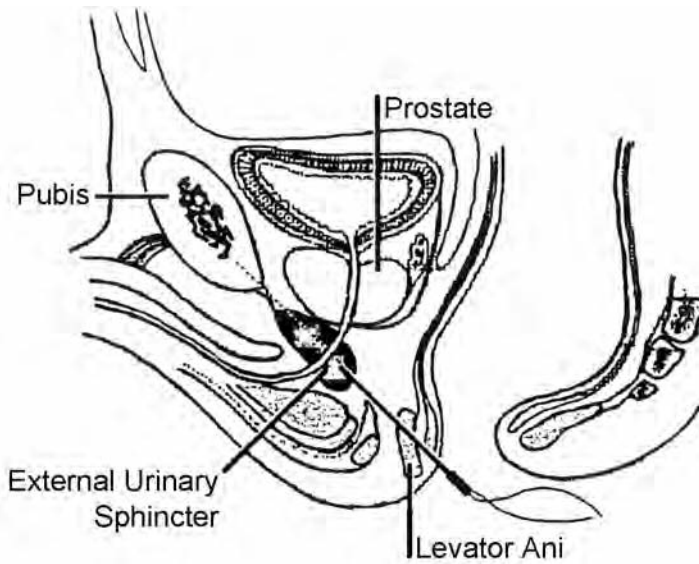
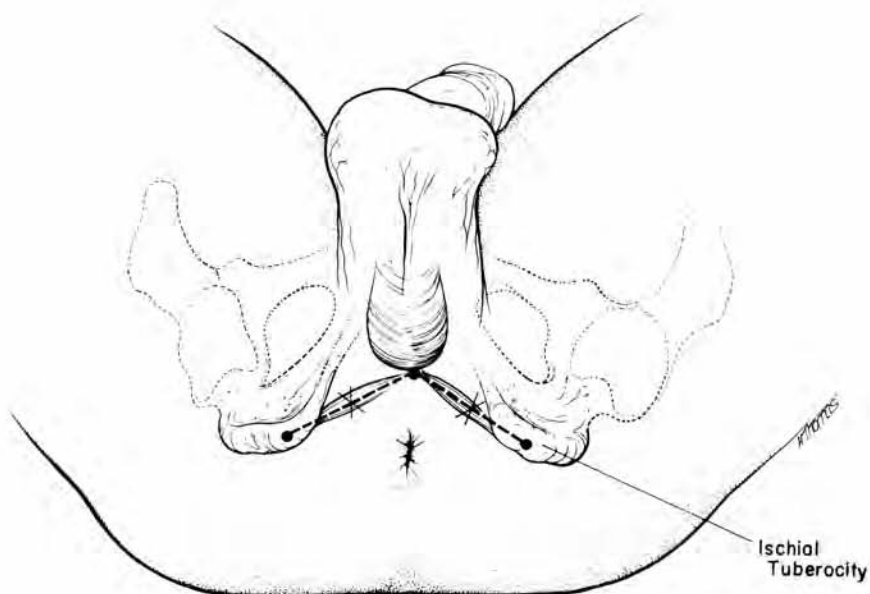
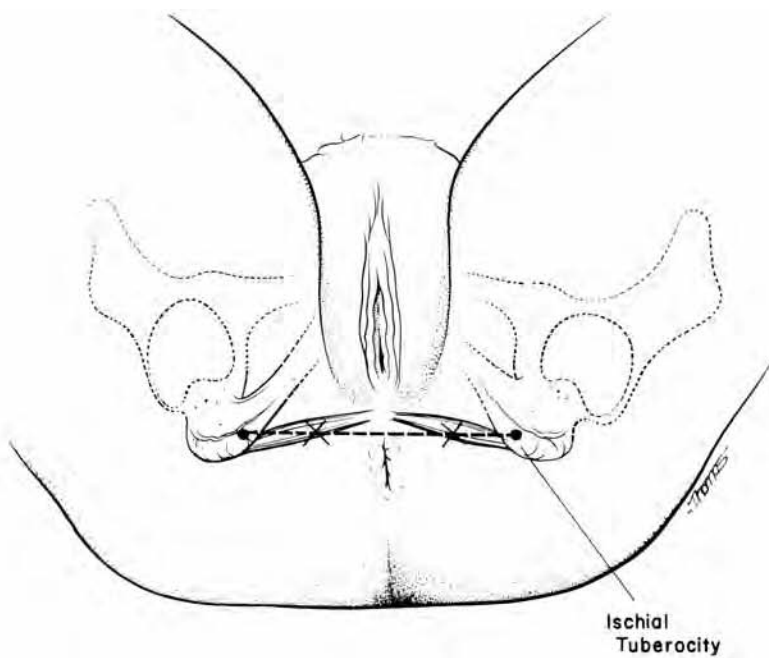


Figure 93. Cross section of the pelvic area showing the proper electrode insertion.

TRANSVERSUS PERINEAL SUPERFICIALIS



Innervation

By perineal branch of pudendal nerve from S3–4 roots and anterior division of sacral plexus.

Origin

From the ischial tuberosity following the posterior border of the perineal membrane.

Insertion

Into the perineal body.

Position

The patient is in supine position with both legs in stirrups (GYN position) in order to fully expose the perineal region.

Electrode Insertion

In Females: The two ischial tuberosities are identified. An imaginary line joining them will pass between the posterior commissure of the vagina and the anus. The electrode is inserted on this line midway between the ischium and the perineal body. The length of the electrode will depend upon the thickness of the cellular layer. Usually a 50mm electrode is sufficient.

In Males. The urethra is palpated in the ventral aspect of the shaft of the penis and followed posteriorly until it turns deep behind the pubis. At this point, an imaginary line is drawn to each ischial tuberosity. The electrode is inserted at the midpoint of this line.

Test Maneuver

Its function is to fix the perineal body, therefore the patient is asked to contract the pelvic floor as if to prevent a bowel movement.

Pitfalls

If the electrode is inserted too posteriorly, it will be in either the rectal sphincter or in the levator ani; too lateral, it will be in the ischio-cavernosus; too anterior, it will be in the urethra (in males) or in the bulbo cavernosus (in females).

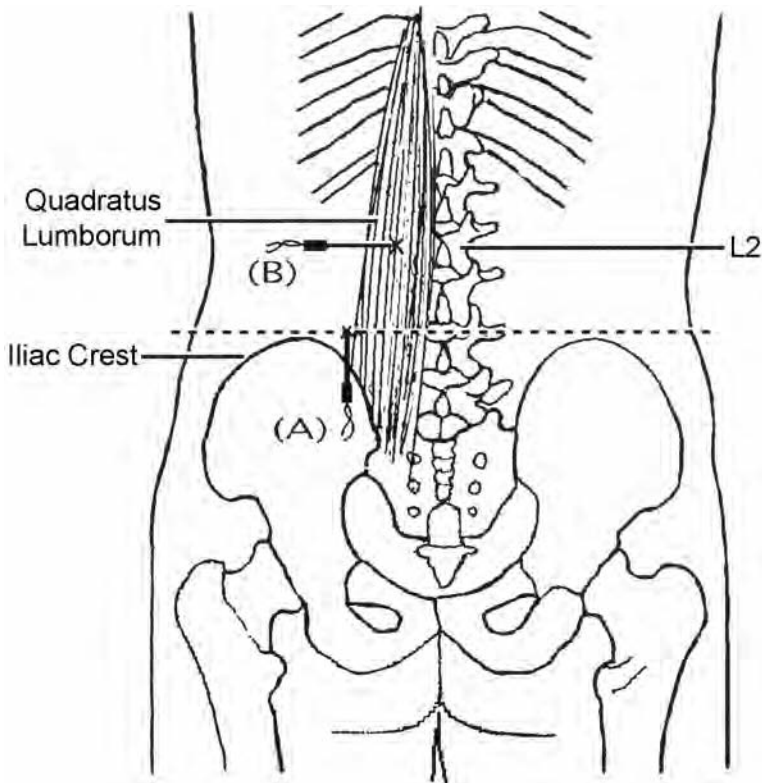
Comments

- (a) This muscle, as all the other muscles in the perineal region that runs in a transverse direction helps support the prostate in males. In females it forms the limit between the urogenital diaphragm (anteriorly) and the anal triangle (posterior) and gives major support to these two structures.
- (b) This muscle is affected in lesions of the pudendal nerve, sacral plexus, cauda equine or conus medullaris. In females, it can also be damaged as a result of delivering large babies (over stretching or rupture of the muscle). In multiparas, it may no longer have the strength or sufficient tone to be a significant support for the pelvic viscera.
- (c) In females, during delivery, if episiotomy is performed at 4 or 8 hours, the muscle can be severed. When the episiotomy is repaired at the end of the delivery, it may or may not bring the two ends of the muscle together. In the latter situation, a weakness in the perineal floor will develop. This situation may lead to sexual problems and prolapse of the pelvic viscera in the future.

SECTION XII

**MUSCLES OF THE
PARASPINAL REGION**

QUADRATUS LUMBORUM



Innervation

Ventral rami (from T12–L1–2–3).

Origin

From the posterior two inches of the iliac crest and the iliolumbar ligament.

Insertion

To lower border of last rib and transverse processes of upper 4 lumbar vertebrae.

Position

The patient is in prone position.

Electrode Insertion

The patient is asked to elevate the chest off the table to increase the lumbar lordosis, thus allowing the precise identification of the lateral border of the erector spinae muscle. Two areas can be chosen: (a) One finger's breadth lateral to the erector spine mass and just proximal to the iliac crest: the electrode will travel through the latissimus dorsi aponeurosis before entering the quadratus lumborum. (b) The 2nd lumbar vertebra level is identified and the electrode is inserted three-fingers' breadth lateral to the spinous process. The electrode will travel through the latissimus dorsi aponeurosis and the erector spinae before entering the muscle. Because of the thickness and toughness of the lumbar aponeurosis, piercing it is easy to feel, which helps in appreciating where the tip of the electrode may be at any given time.

Test Maneuver

The patient is asked to laterally bend the body, or to hike the hemipelvis on the ipsilateral side.

Pitfalls

Approach (a): if the electrode is too superficial, it will be in the latissimus dorsi; if too medial, it will be in the erector spinae; if too lateral, it will be in the internal oblique. If too deep, it may enter the abdominal cavity.

Approach (b): if electrode is too superficial, it will be in the erector spinae; if too deep, it will be either in the psoas muscle (medially) or in the retroperitoneal renal space. If too medial, it will be in the multifidus; if too lateral, it will be in the renal space.

Comments

This muscle is involved in lesions of the T12–L1 root, in A.H.C. diseases or degenerative conditions such as A.L.S. By attaching to the last rib, it extends the anchorage of the diaphragm to the iliac crest, therefore making it an important accessory respiratory muscle.

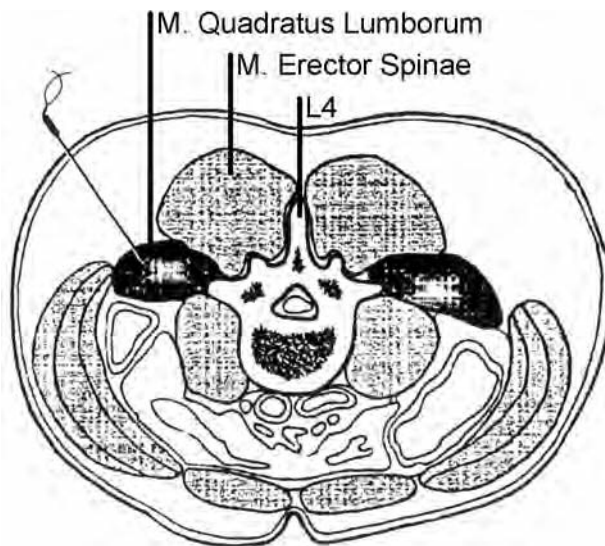
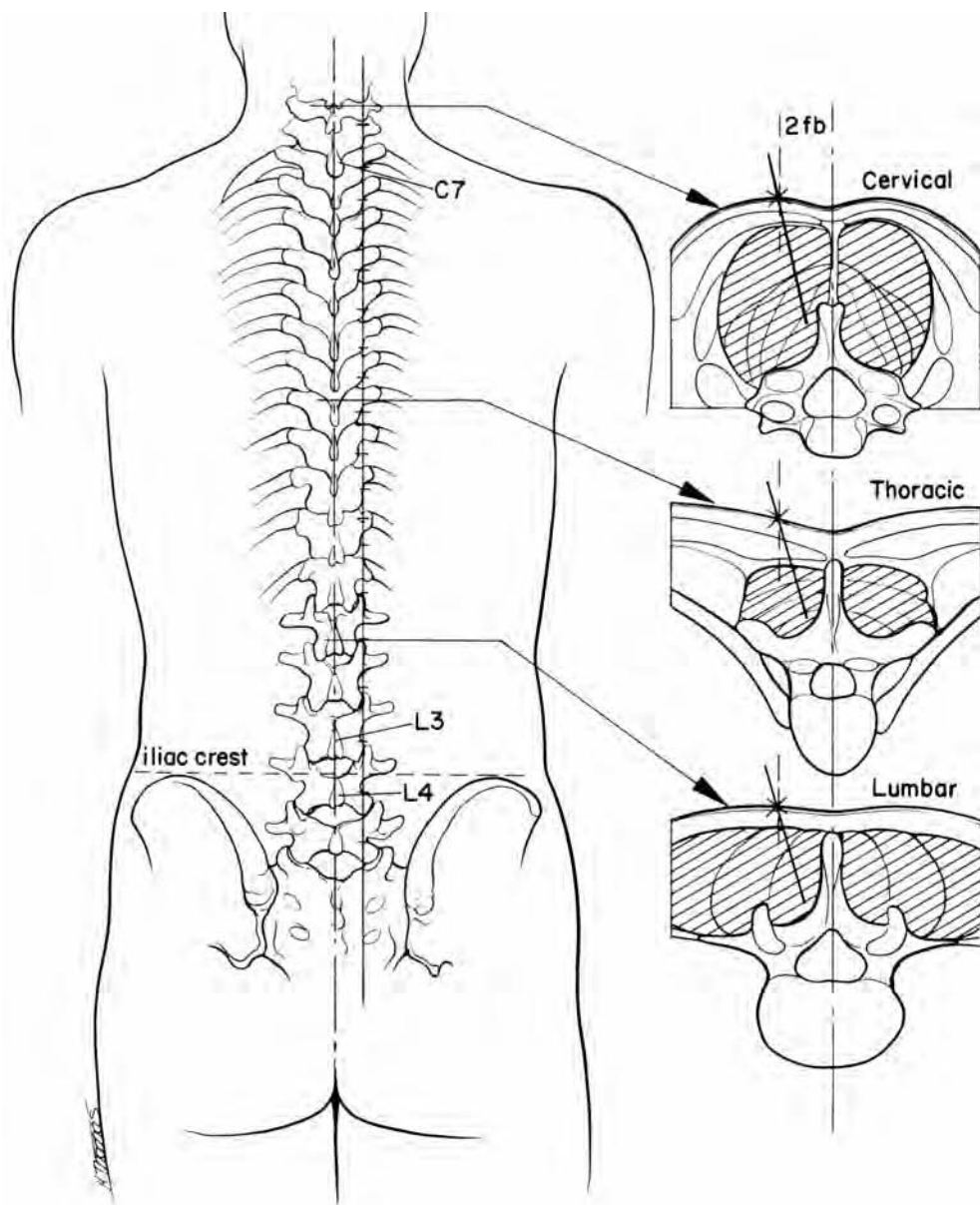


Figure 94. Cross section at the L4 level.

PARASPINALS



Paraspinal muscles are a generic anatomical term used to identify all those muscles located at each side of the spinous process of the spinal column. They are divided in 3 regions: the Cervical, the Thoracic, and

the Lumbo-Sacral. All of these muscles are positioned in several layers and they are so close together that it is impossible to isolate them individually for electrodiagnostic purposes. However, if the electrode is placed in the angle between the lamina of the vertebra and the spinous process, it will be in the multifidus.

Innervation

All of these muscles are supplied by branches of the posterior division of the spinal nerve at their respective level. The innervation usually extends to one or two segments above and below a particular level. This creates a significant amount of overlapping innervation in the entire paraspinal groups. This anatomical characteristic makes it very difficult to assess the precise localization in cases of radicular compromise.

Origin and Insertion

It is impossible to describe the origin and insertion of all paraspinals; this would be beyond the scope of this book. Suffice to say that the deeper the muscles, the shorter they are; the more superficial, the longer distance they travel.

Position

The patient is in prone position. If the cervical area is to be studied, a pillow is placed across the chest of the patient, thus allowing the patient's head to flex and to rest on its forehead.

If the lumbo-sacral area is to be investigated, the pillow is placed across the abdomen, producing a mild "arching" of the lower spine. For the thoracic area, the patient is flat.

Electrode Insertion

Prior to inserting the electrode, the level of the spine must be identified. Two landmarks are used: for the cervical and thoracic area, the spinous process of C7 (prominent) is identified and the count is done up or down accordingly. For the lumbo-sacral area, an imaginary line is drawn between the upper most part of the iliac crests. This line intersects the spinal column at the L3-L4 intervertebral level. The count proceeds up or down accordingly.

The electrode is inserted about one to two-fingers' breadth from the spinous process of the identified level, down to the lamina of the vertebra.

Test Maneuver

For the cervical area: The patient is asked to elevate or extend the head.

If full relaxation cannot be obtained, the patient is asked to push the head onto the examining table.

For the lumbo-sacral area: The patient is asked to elevate the whole leg (from the hip) on the side under study.

If full relaxation cannot be obtained, the patient is asked to either push with the knee on the side under study onto the examining table, or slightly elevate the pelvis off the table.

Pitfalls

If the electrode is too superficial, it may be in the superficial muscular layer of the back (trapezius; latissimus dorsi; rhomboids or splenius).

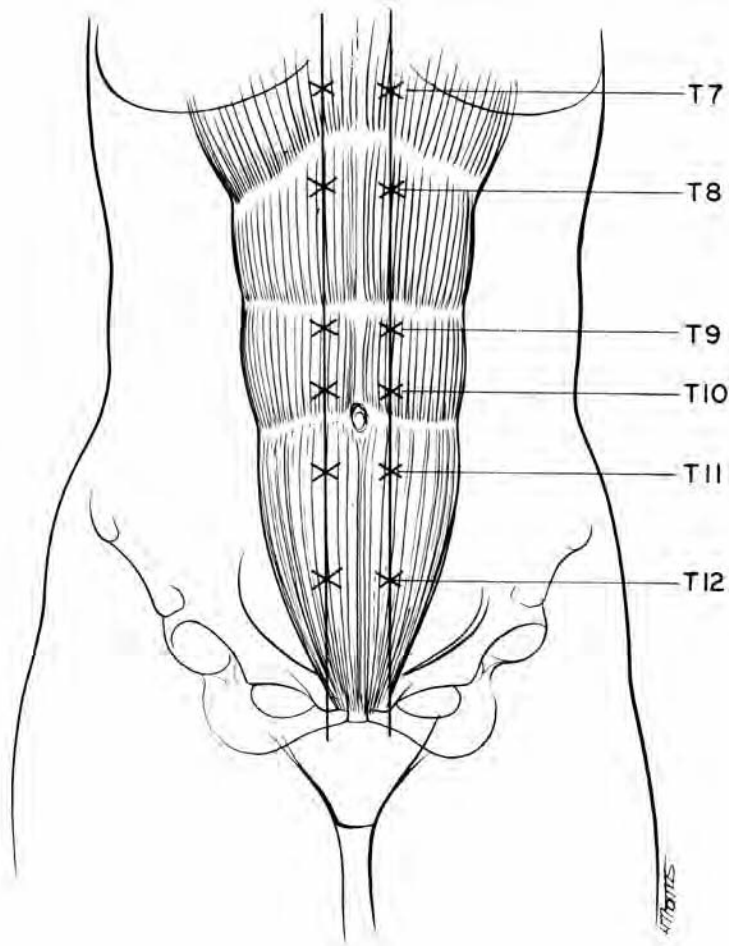
Comments

The paraspinal muscles can be affected segmentally in processes involving the roots, the cauda equine, the conus medularis, vascular accidents involving the anterior spinal artery or in degenerative or inflammatory conditions involving the A.H.C. (polio, A.L.S.). When studying the C7–T1 segment, care should be taken to avoid going too deep and accidentally causing damage to the sympathetic outflow, which results in unilateral Horner's syndrome (author experience).

SECTION XIII

**MUSCLES OF THE
ABDOMINAL WALL**

RECTUS ABDOMINAL



Innervation

By intercostal T7–T12.

Origin

From the pubic crest and the ligament in front of the pubic symphysis. This muscle broadens as it travels upward at each side of the linea alba.

Insertion

To the xiphoid process and over the costar margin to the 7th, 6th and 5th cartilages. In the supraumbilical portion this muscle is crossed by three horizontal tendinous intersections firmly attached to the anterior layer of the muscle aponeurotic sheath.

Position

The patient is in supine position.

Electrode Insertion

The electrode is inserted two-fingers' breadth lateral to the abdominal midline. The exact point of insertion will depend upon the intercostal nerve to be evaluated. The supraumbilical portion is supplied by T7–8–9; the umbilical portion by T10 and the infraumbilical portion by T11–T12.

Test Maneuver

The patient is asked to lift the body off the table keeping both legs on the table. If the patient cannot perform this maneuver, then is asked to elevate both legs keeping the body flat on the plinth. These 2 maneuvers will give a sustained contraction of the muscles. If burst of muscle contraction are intended, the patient is asked either to cough or to perform the Valsalva's maneuver.

Pitfalls

If the electrode is placed too lateral, it will be in the flat abdominal wall muscles. If it is too deep, it may enter the abdominal cavity.

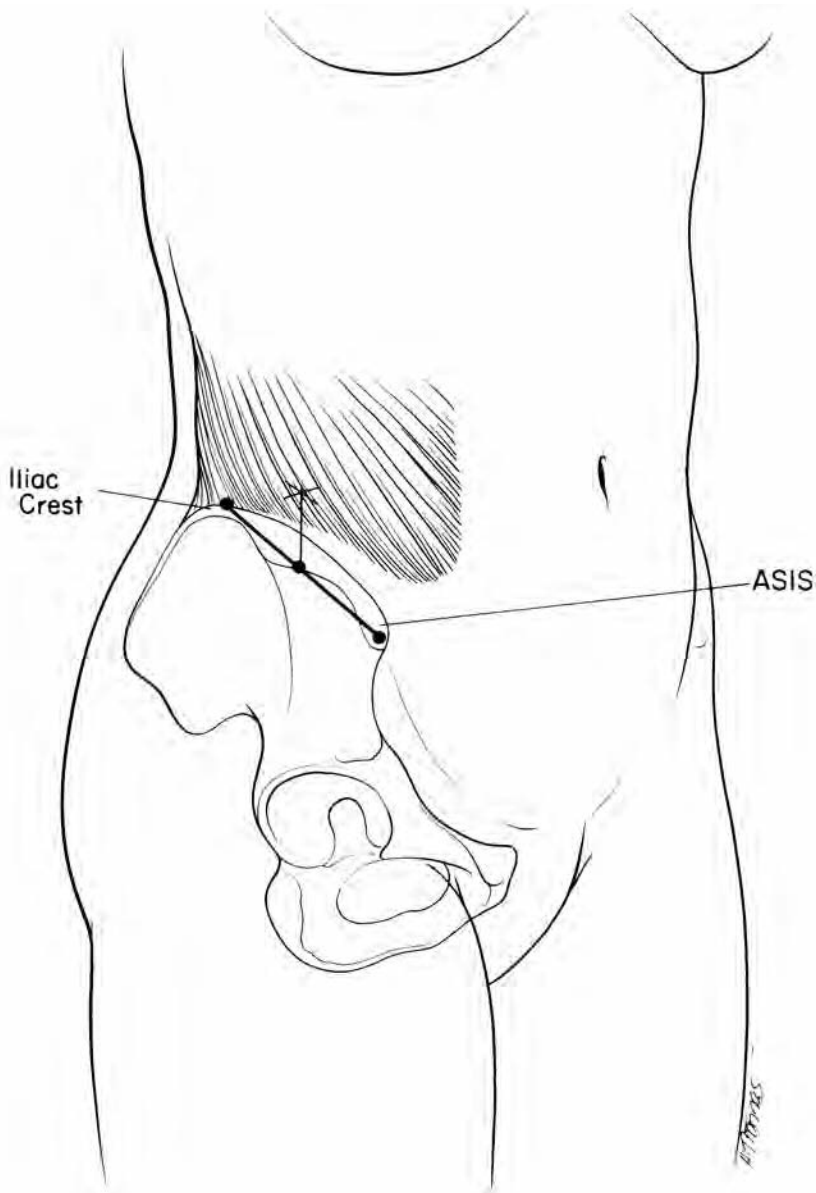
Comments

To prevent the above from happening, one must pay attention to the piercing of the anterior aponeurosis. Once this is felt, the electrode is advanced very cautiously until a resistance is felt again. This represents the posterior aponeurosis and it *must not* be pierced. In the uppermost portion of the muscle, which rests over the rib cage, the insertion must be performed through the skin lying on top of a rib which will prevent further penetration. This muscle is affected in thoracic radiculopathies (very rare), in intercostals neuritis (herpet-

ic); in anterior horn cell (A.H.C.) diseases (polio; amyotrophic lateral sclerosis (A.L.S.).

The paralysis or weakness of this muscle produces an obvious bulging of the anterior abdominal wall. This muscle has several functions, besides helping the other abdominal muscles to compress the abdominal viscera. It also pulls and compresses the lower edge of the ribs and stabilizes the pelvis during walking. By doing this, it enables the thigh muscles to act efficiently.

EXTERNAL OBLIQUE



Innervation

By the intercostal from T7–T12.

Origin

In the rib cage, from the 5th to the 12th ribs (interdigitate with the serratus anterior and latissimus dorsi). The posterior edge remains free and blends with the posterior lumbar fascia.

Insertion

Into the outer lip of the anterior half of the iliac crest. The anterior edge of the muscle ends in a broad aponeurosis which runs anterior to the rectus abdominal muscle and joins the one from the opposite side at the midline (linea alba).

Position

The patient is in supine position.

Electrode Insertion

The highest point in the iliac crest is identified as well as the anterior superior iliac spine (A.S.I.S.). Midway along this line, the electrode is inserted just cephalad to the iliac crest, until the aponeurosis is pierced.

Test Maneuver

The patient is asked to lift the shoulder of the ipsilateral side off the table.

Pitfalls

If the electrode is too deep (2nd aponeurosis is pierced), it will be in the internal oblique; if deeper yet (3rd aponeurosis is pierced), it will be in the transversus abdominal; if deeper yet, it will enter the abdominal cavity.

Comments

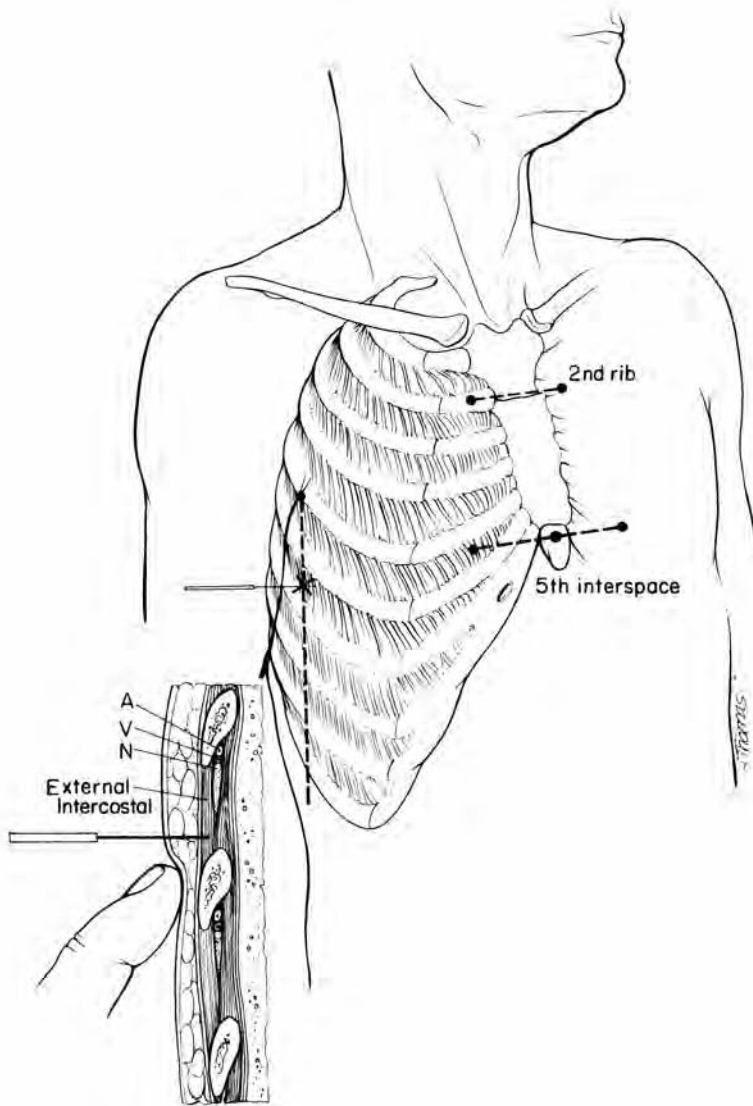
This muscle is affected in thoracic radiculopathies (very rare) or intercostal neuritis (herpetic); in A.H.C. diseases (polio, A.L.S.). The paralysis or weakness of this muscle produces a flabby and protuberant lateral abdominal wall. The muscular fibers do not extend below the level of the A.S.I.C. nor medial to a vertical line drawn from the tip of the 9th costal cartilage.

The aponeurotic portion of the muscle blends medially with the anterior aponeurosis of the rectus abdominal muscle. In the lowest most part of this blending, a triangular cleft is formed between its attachment to the pubic symphysis and the pubic tubercle. This opening is the superficial ring of the spermatic canal, allowing the exit of the spermatic cord.

SECTION XIV

**INTERCOSTAL
AND DIAPHRAGM
MUSCLES**

INTERCOSTALS



Innervation

Both, the internal and external intercostals by the anterior division of the spinal nerves from T1 to T11. There is a 3rd intercostals muscle which is deepest located (next to the pleura) but for all practical purposes will not be mention in this chapter.

Origin

- (a) External: From the inferior border of the rib above.
- (b) Internal: From the floor of the costal groove above.

Insertion

Both muscles to the upper border of the rib below. The muscle fibers of the external intercostal are directed obliquely downwards and externally, while the fibers of the internal intercostal are directed also obliquely but 90° angle to the external intercostal (downward and vertebrally).

Position

The patient is in supine position.

Electrode Insertion

The most accessible area is the anterior axillary line. To count the ribs, two methods can be used: (1) identifying the angle of Lewis (junction between the manubrium and the body of the sternum). At each side of this angle the rib #2 inserts: counting downward, the intercostal space can be identified. (2) Identifying the xiphoid process, the 5th intercostal space can be identified at each side of it (between the 5th and 6th ribs). This space can be followed laterally toward the anterior axillary line, and the counting of the ribs can be done in an upward or downward direction. When the intended intercostal space is well identified, the free hand's index finger is positioned on the rib below and the electrode is then inserted just proximal to the finger and tangential to the upper edge of the rib. The progression of the electrode is stopped as soon as piercing the aponeurosis is felt. At this moment, electrical activity should be present with each inspiration.

Test Maneuver

The patient is asked to inspire.

Pitfalls

- (a) If too deep, it may enter the pleural cavity with possible puncture of the lung underneath. If there is any doubt during the procedure, a chest X ray should be taken. I do not believe X ray should be a routine test in all patients.
- (b) If the electrode is too superficial, it may be in any of the muscles that attach to the chest wall (latissimus dorsi, serratus anterior, pectoralis major, pectoralis minor) depending upon the intercostal muscle under investigation.
- (c) If the electrode is placed too close to the lower edge of the proximal rib, the neurovascular bundle can be injured.

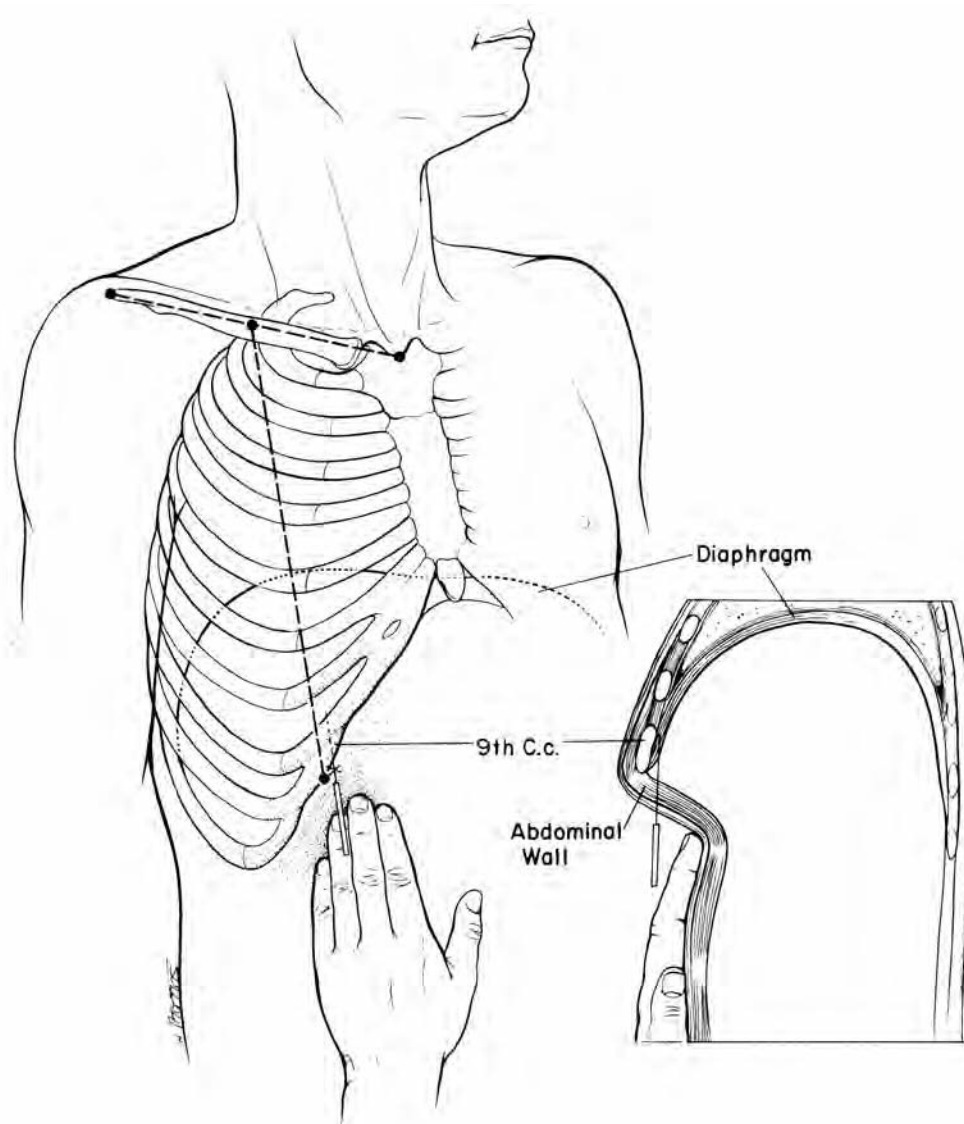
Comments

This muscle can be involved in thoracic radiculopathies (very rare); in intercostal neuritis (herpetic); in A.H.C. diseases (polio, A.L.S.). The intercostal muscles are inspiratory muscles. They contract only in forced expiration. The paralysis of these muscles produces a significant decrease in amplitude of the rib cage as we see in normal breathing. In obese individuals or in females with large breasts, it could be difficult to identify the appropriate intercostal space.

During inspiration this muscle elevates the ribs producing an increase in the diameters of the thoracic cavity (transverse and antero-posterior). This muscle also maintains a certain rigidity of the intercostals space, which prevent the spaces bulging out during expiration or to moving in during inspiration.

When studying this muscle, it must be remembered that the neurovascular elements are running along the lower border of the rib above. Placing the needle electrode tangential to the rib above creates danger of injuring the neurovascular bundle.

DIAPHRAGM



Innervation

By phrenic nerves (C3–4–5) and peripherally by lower intercostal nerves (T6–11).

Origin

From the thoracic outlet (last 6 ribs): it is divided into several portions: sternal, costar, vertebrocostal and lumbar or vertebral part.

Insertion

To a strong central tendon that is pierced by the inferior vena cava.

Position

Patient in supine position.

Electrode Insertion

The 9th rib cartilage is localized at the point where the paramedial-clavicular line intersects the rib cage. This line is identified by drawing a line from a point midway between the sternal notch and the lateral end of the clavicle (medial to the midclavicular line). The intersection of this line with the margin of the rib cage corresponds approximately to the angle formed by the rib cage and the rectus abdominus muscle. A 50mm monopolar electrode is used. With his free hand, the electromyographer firmly and continuously depresses the abdominal wall just distal to the rib cage. In this way the costar margin is sharply delineated. The electrode is inserted in a direction parallel to the posterior aspect of the chest wall. The electrode will travel through the skin, subcutaneous tissue, and abdominal wall muscles (these muscles will show electrical activity if the patient is not relaxed). By continuing to advance the electrode, it will enter the costar insertion of the diaphragm.*

Test Maneuver

The regular patient's breathing will produce bursts of electrical activity during inspiration which will alternate with electrical silence during expiration. A deep inspiration will produce a sustained activity which will last the whole length of the inspiration effort.

Pitfalls

- (a) If electrode is introduced perpendicular to the skin without a

* P. B. Saadeh, C. F. Crisafulli, J. Sosner, and E. Wolf, Needle electromyography of the diaphragm: A new technique, *Muscle and Nerve*, 16: 15-20, 1993.

- sharp delineation of the costar margin, it may penetrate the abdominal cavity.
- (b) If electrode remains too superficial, it will be in the abdominal wall muscles.
 - (c) If the electrode is inserted more than 4–5 cm in depth, it may reach the pleural cavity.

Comments

- (a) The diaphragm presents three large openings: (a) vena cave (tendon portion) at the lower 8th thoracic vertebra level, (b) esophageal opening (through the right crus at the 10th thoracic vertebra level, (c) Aortic opening in front of the 12th thoracic vertebra.
- (b) This muscle is the chief inspiratory muscle. During its contraction both domes flatten down increasing the vertical diameter of the thoracic cavity. This increases the volume of the thoracic cavity and decreases the intrathoracic pressure, producing the air to flow into the lungs. The changes in the thoracic and abdominal pressure are also important in blood circulation, forcing the vena cava blood to move upward toward the heart. Other important functions of the diaphragm are in helping urination, defecation and delivering (parturition).
- (c) The lesion of the phrenic nerve can occur at the neck and at the mediastinum (commonly by tumors or adenopathies) or in high spinal cord injuries. In the former conditions the respiration of the patient may not be affected (especially if it is unilateral). In the latter, the respiration is severely affected and the patient may die if proper respiratory support is not administered rapidly.
- (d) In cervical spinal cord lesions at or distal to C5, the function of this muscle will be enough to keep the patient alive.
- (e) Although the phrenic nerve is mainly a motor nerve, one-third of its fibers are sensory and they supply the pleura and pericardium.
- (f) Irritation of this nerve is common and causes an attack of hiccups.
- (g) In obese people, it may be very difficult to identify the proper landmarks; trying in these people may become dangerous. If in doubt, the investigation should be cancelled.

APPENDIX

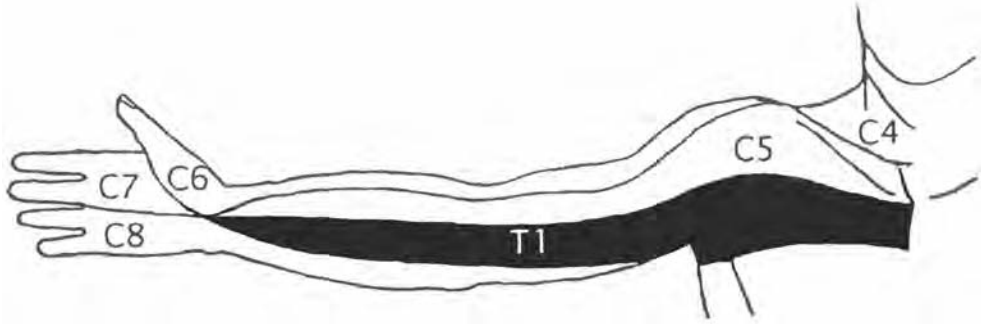


Figure 95. Dermatomal distribution of the anterior aspect of the upper extremity.

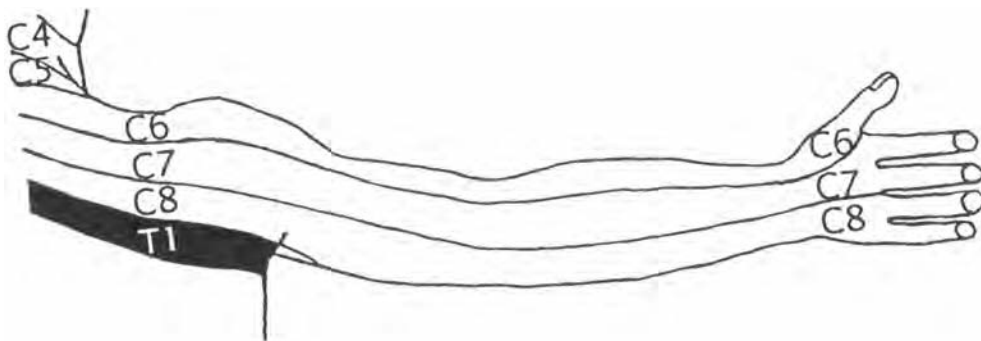


Figure 96. Dermatomal distribution of the posterior aspect of the upper extremity.

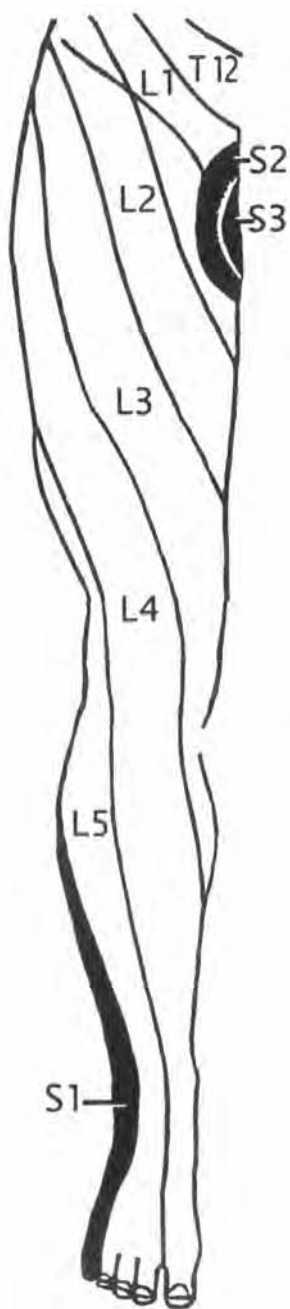


Figure 97. Dermatomal distribution of the anterior aspect of the lower extremity.

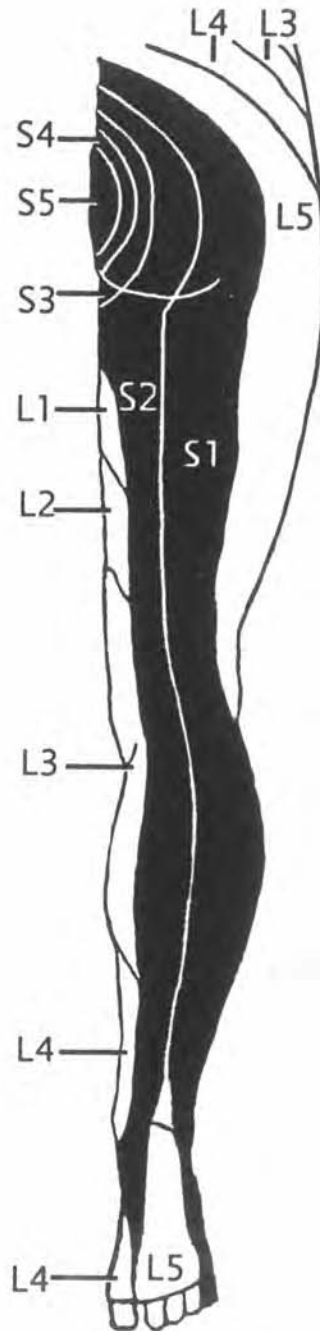


Figure 98. Dermatomal distribution of the posterior aspect of the leg and gluteal region.

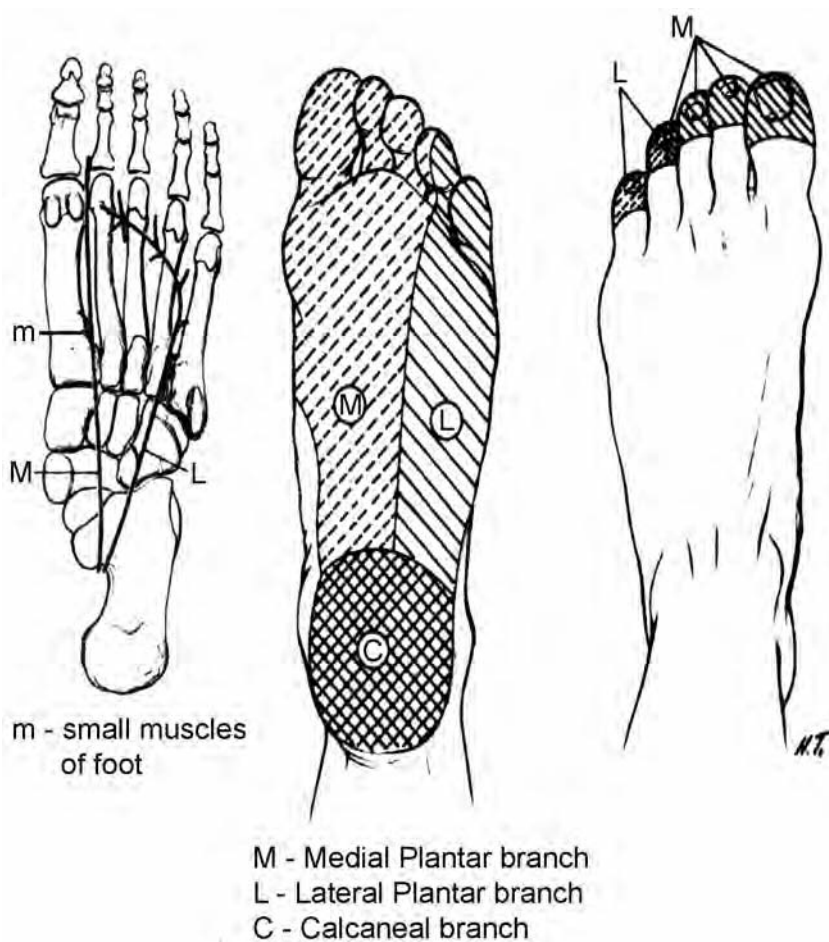


Figure 99. Cutaneous distribution of the posterior tibial nerve. (From Omer, G. E. and Spinner, M.: *Management of Peripheral Nerve Problems*. Philadelphia, W. B. Saunders Co., 1980.)

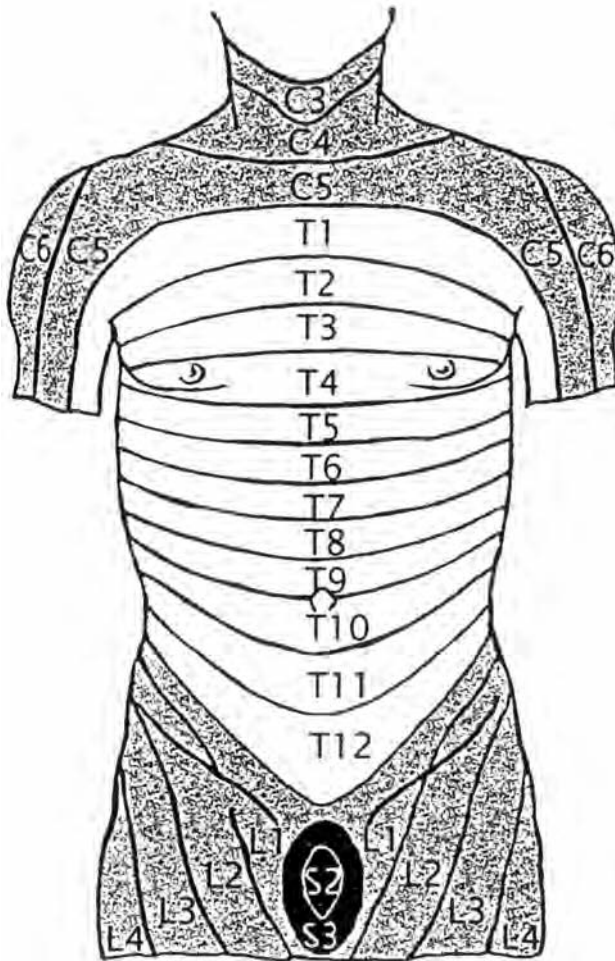


Figure 100. Dermatomal distribution of the anterior aspect of the trunk.

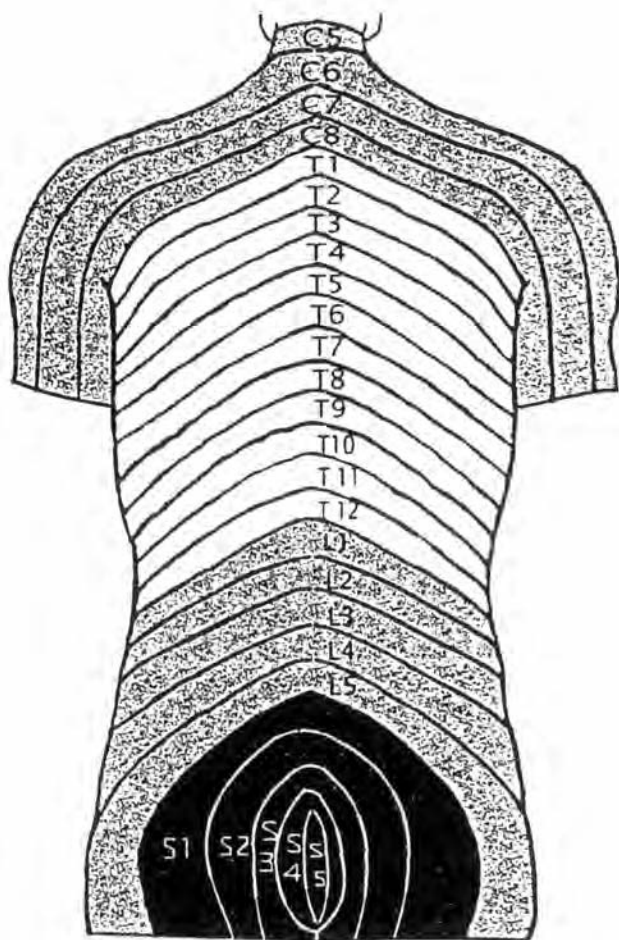


Figure 101. Dermatomal distribution of the posterior aspect of the trunk.

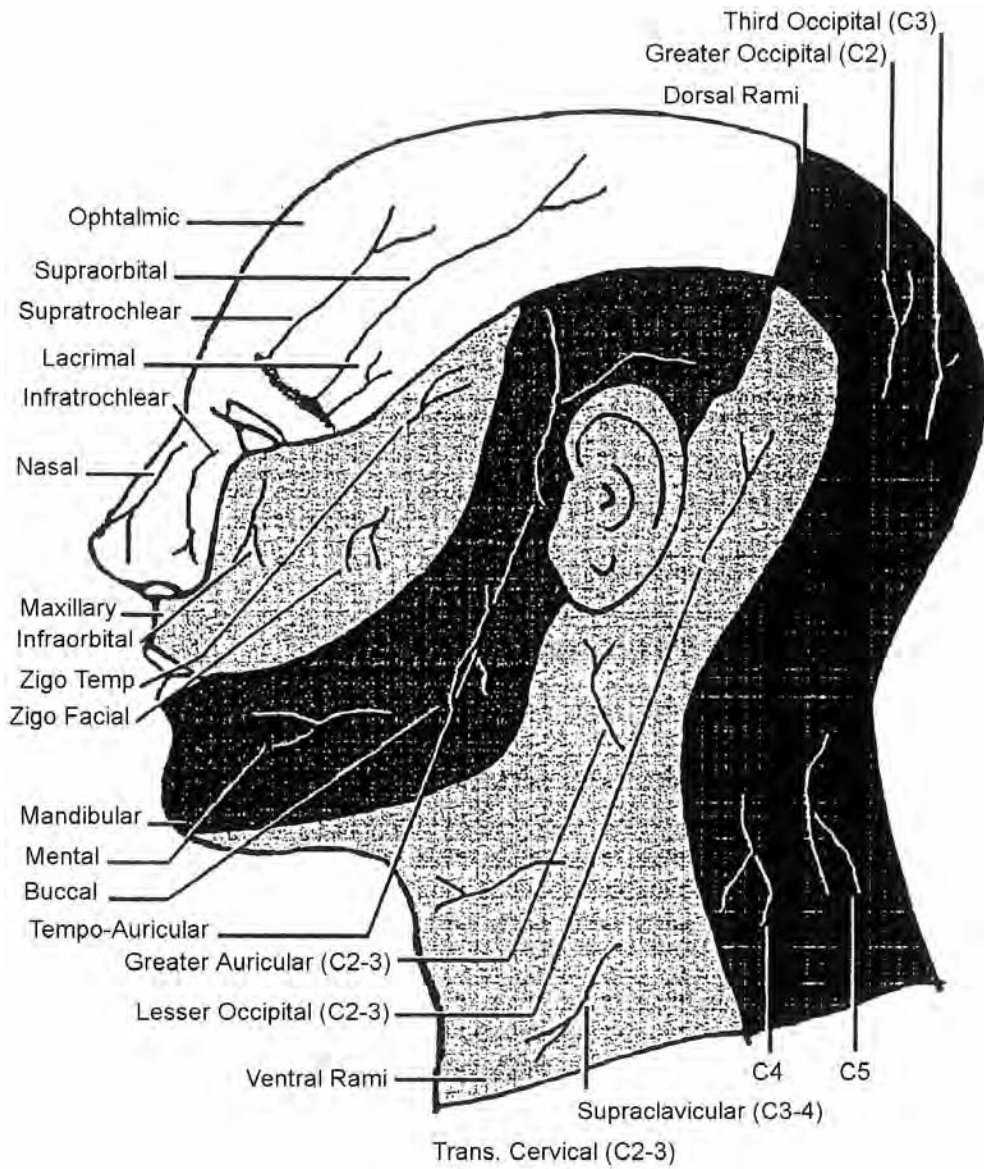


Figure 102. Dermatomal distribution of the face and neck. Trigeminal and cervical spinal nerves coverage.

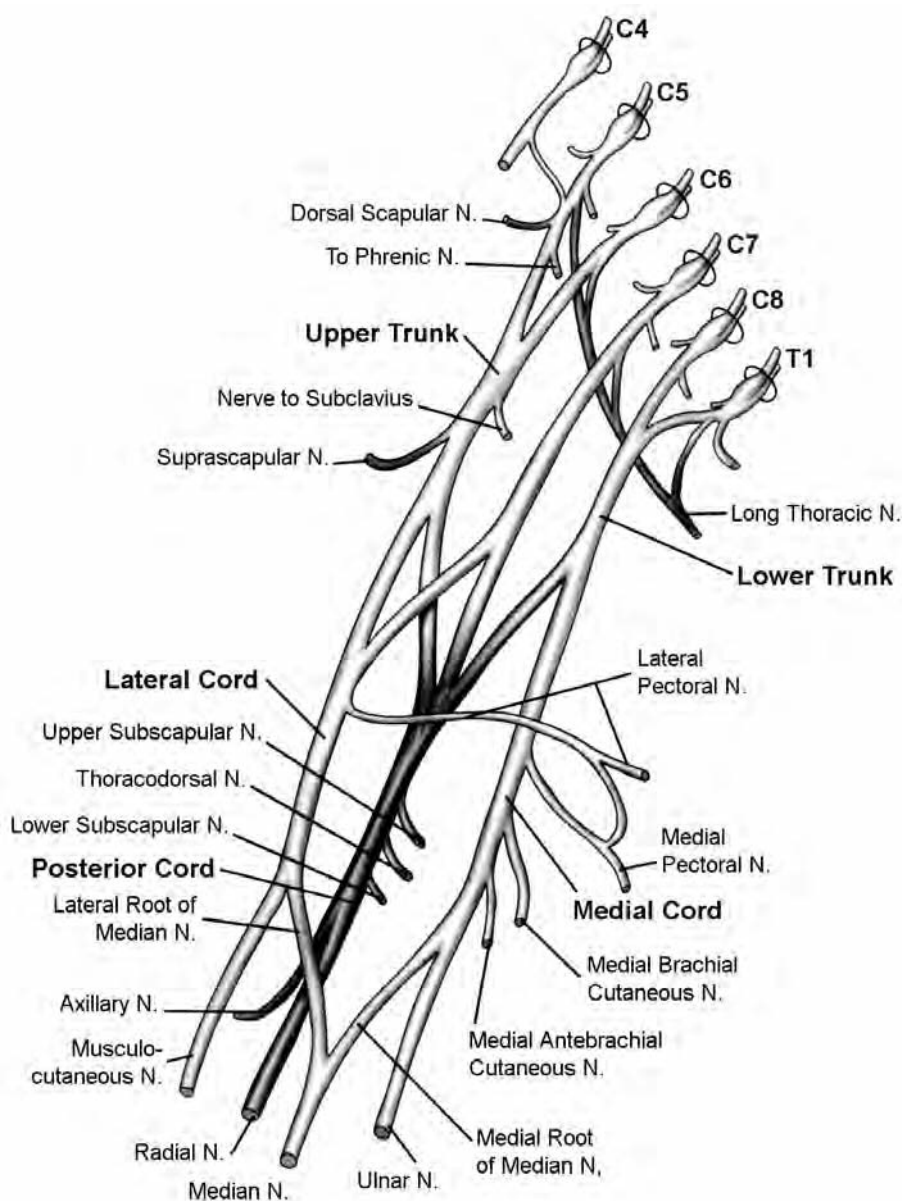


Figure 103. The Brachial Plexus.

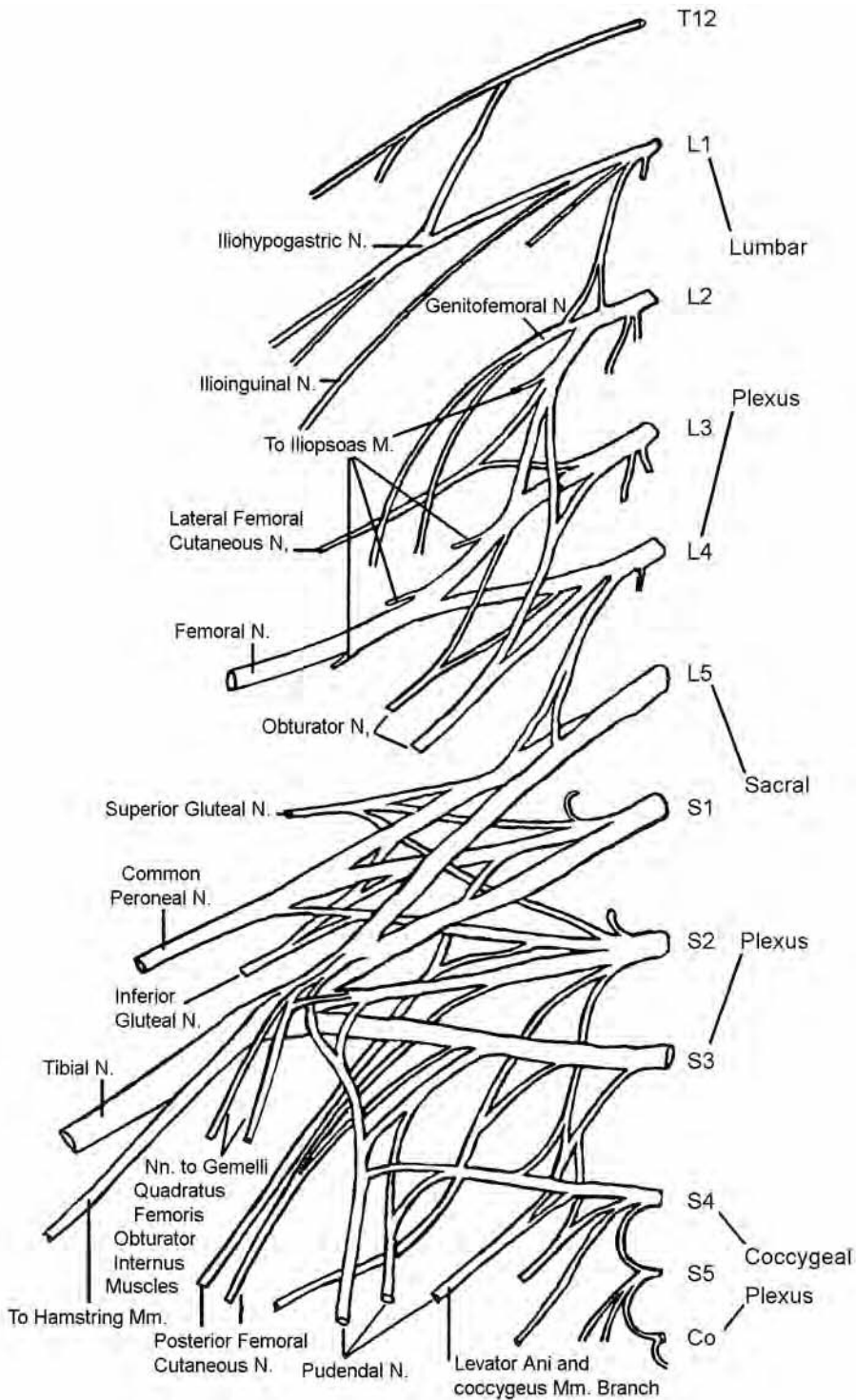


Figure 104. The lumbo-sacral-coccygeal plexus.

NERVE ENTRAPMENTS

**UPPER EXTREMITIES
LOWER EXTREMITIES**

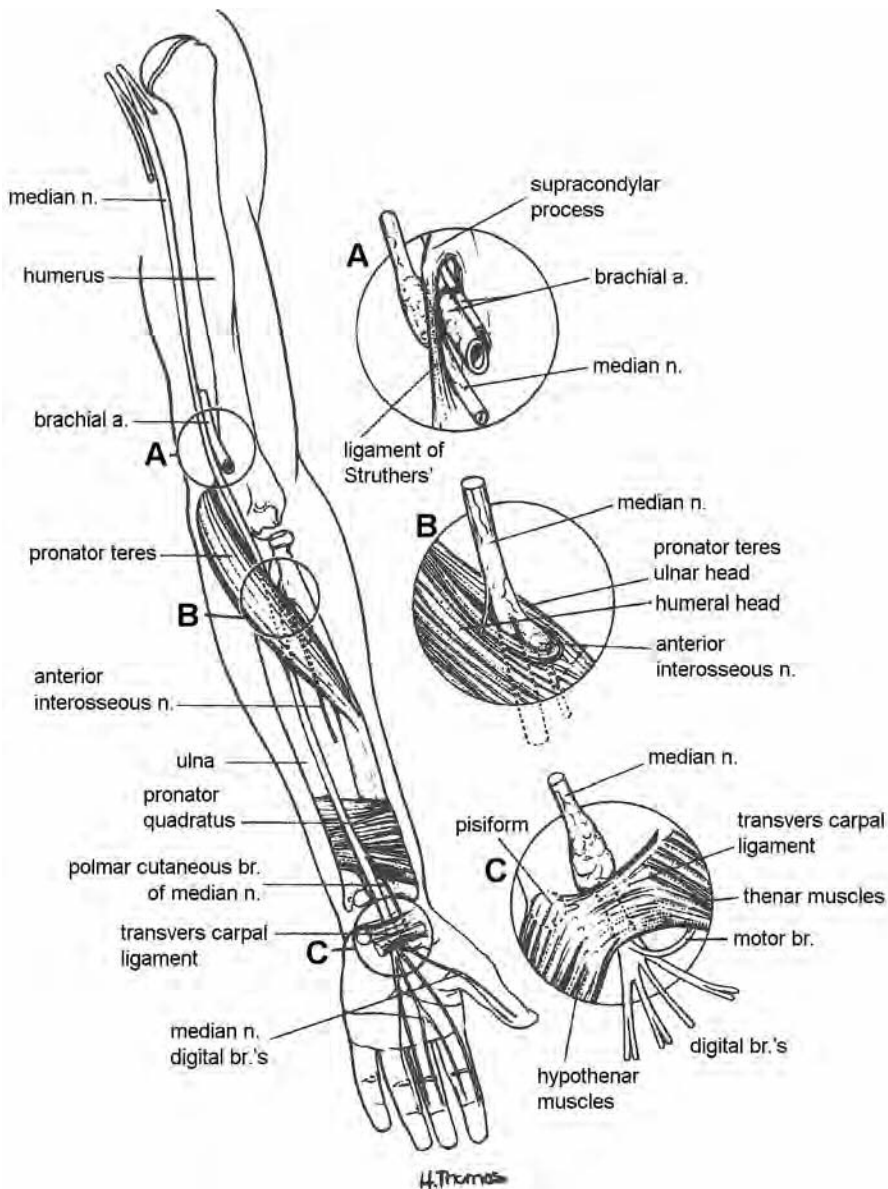


Figure 105. Common sites of median nerve entrapment. A, supracondylar; B, pronator teres; C, carpal tunnel.

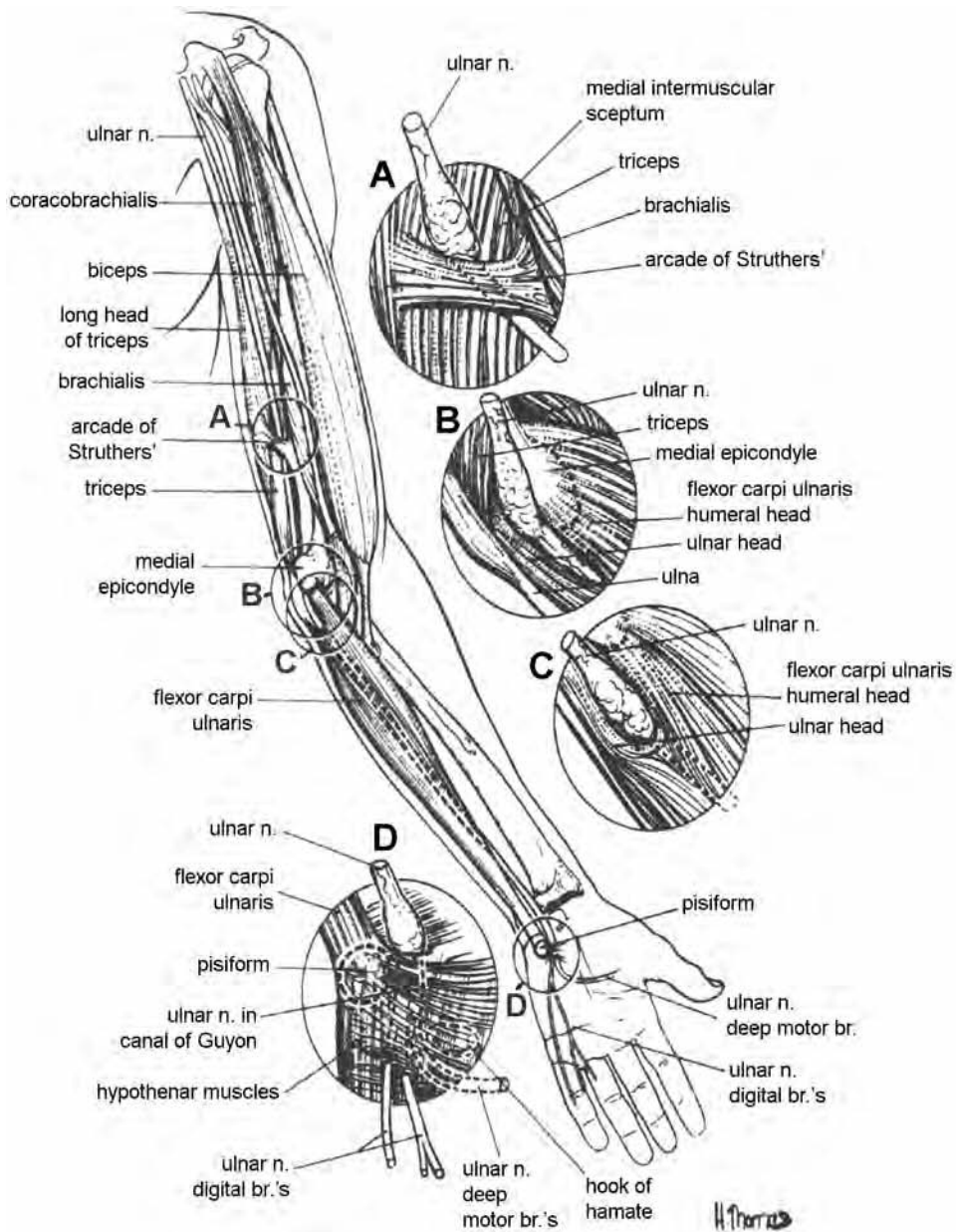


Figure 106. Common sites of ulnar nerve entrapment. A, arcade of Struthers; B, cubital tunnel; C, flexor carpi ulnaris; D, Guyon's tunnel.

ASA P. Ruskin MD.: *Current therapy in physiatry*. W. B. Saunders Co., 1984. Chapter on: "Peripheral nerve entrapment syndromes," by Aldo Perotto MD. and Edward F. Delagi MD., pp. 308-323.

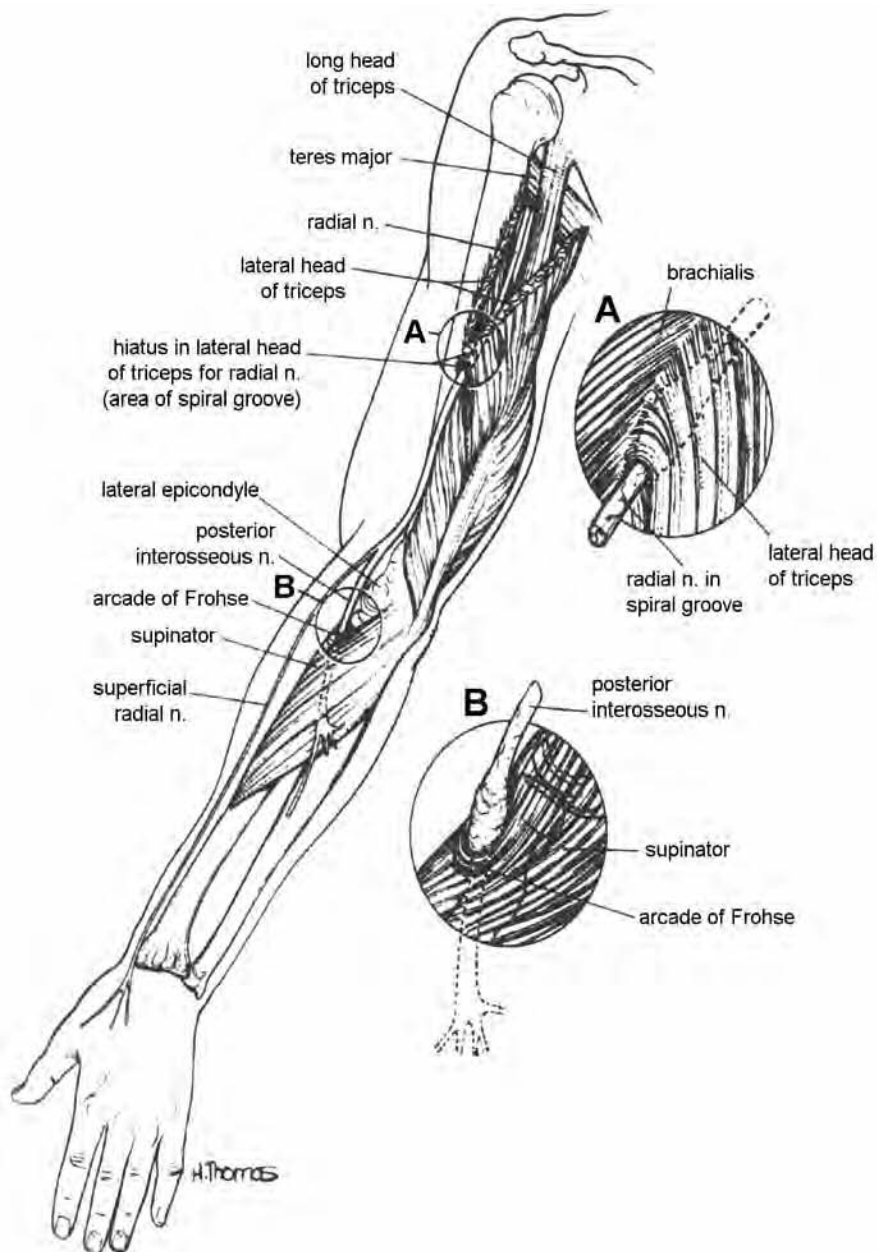


Figure 107. Common sites of radial nerve entrapment. A, spiral groove; B, arcade of Frohse.

ASA P. Ruskin MD.: *Current therapy in physiatry*. W. B. Saunders Co., 1984. Chapter on: "Peripheral nerve entrapment syndromes," by Aldo Perotto MD. and Edward F. Delagi MD., pp. 308–323.

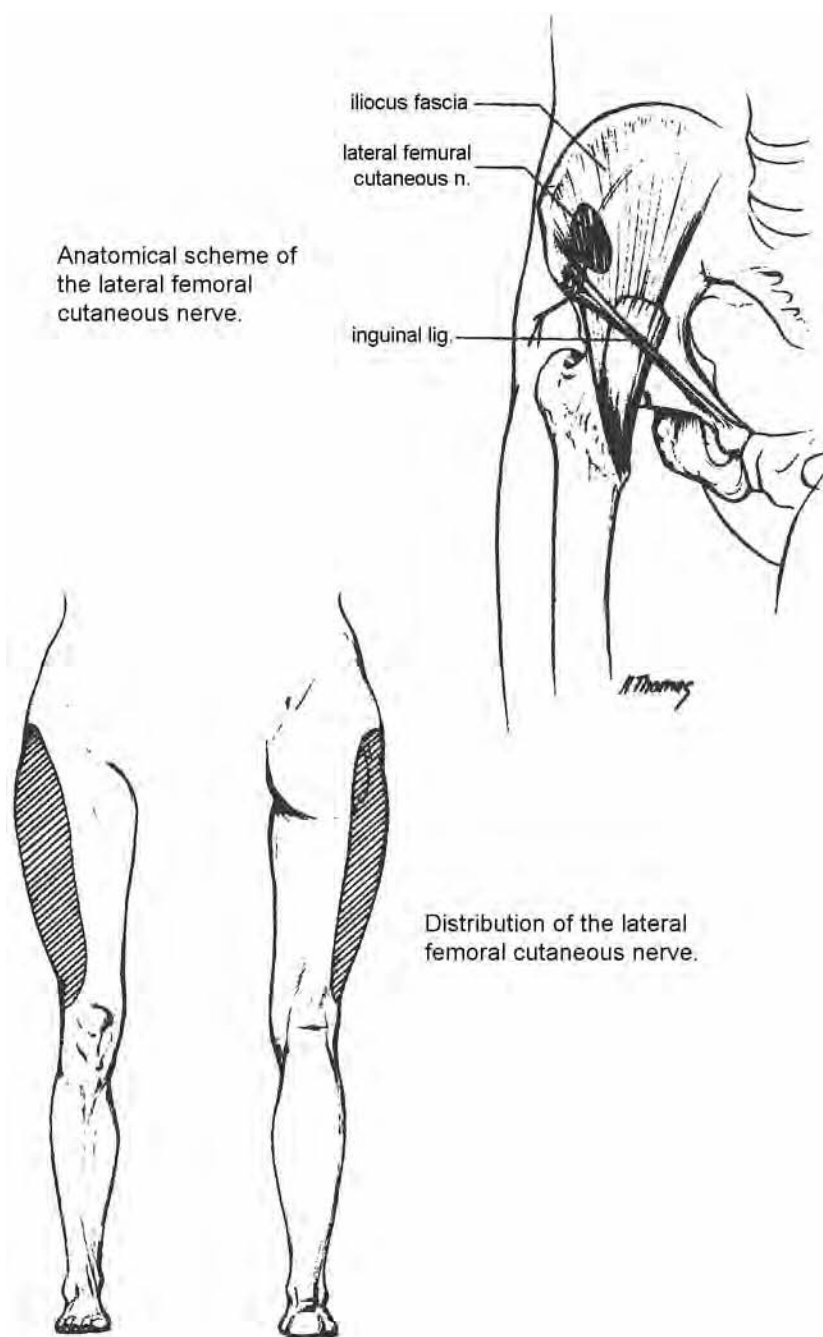


Figure 108. Distribution of lateral femoral cutaneous nerve. (From Omer, G. E. and Spinner, M.: *Management of Peripheral Nerve Problems*. Philadelphia, W. B. Saunders Co., 1980.)

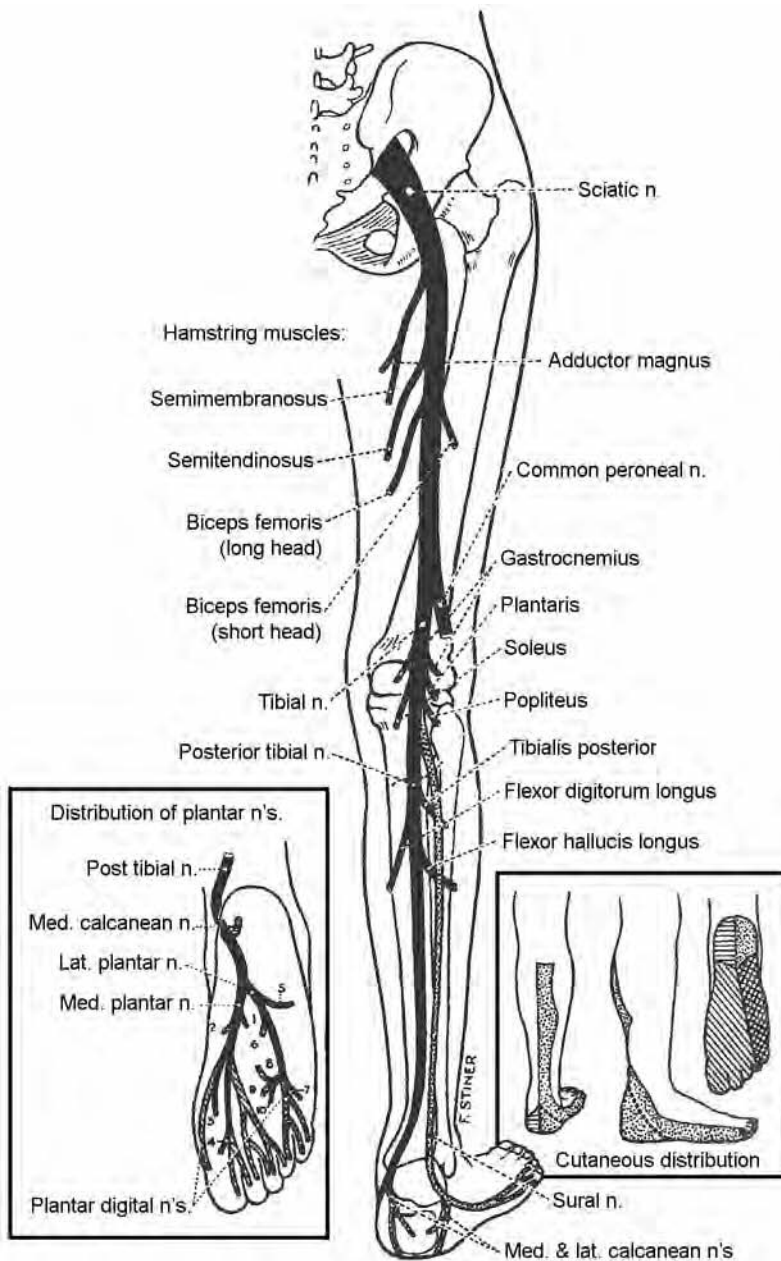


Figure 109. Course and distribution of the sciatic, tibial, posterior tibial, and plantar nerves. (From Haymaker, W., and Woodhall, B.: *Peripheral Nerve Injuries*, 2nd ed. W. B. Saunders Co., 1953.)

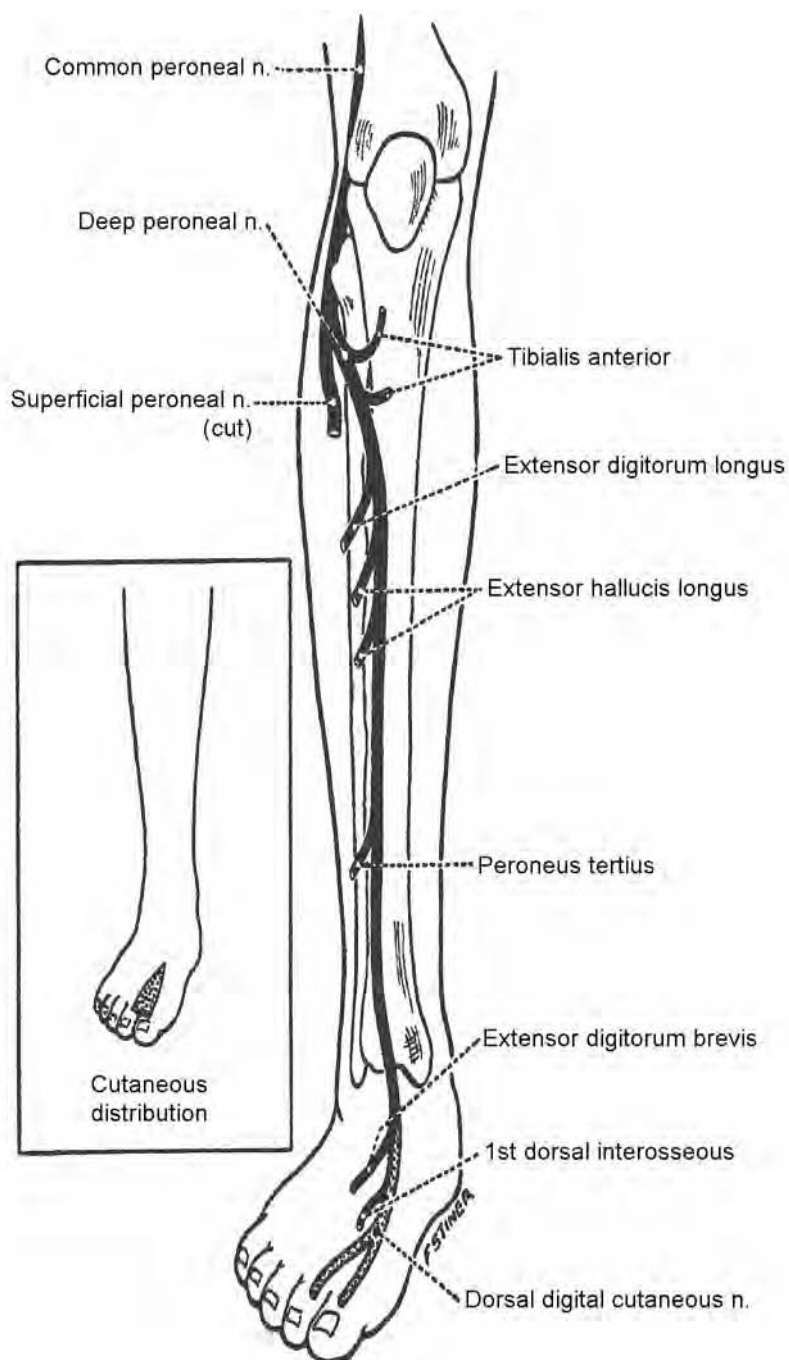


Figure 110. Course and distribution of the deep peroneal nerve. (From Haymaker, W., and Woodhall, B.: *Peripheral Nerve Injuries*, 2nd ed. W. B. Saunders Co., 1953.)

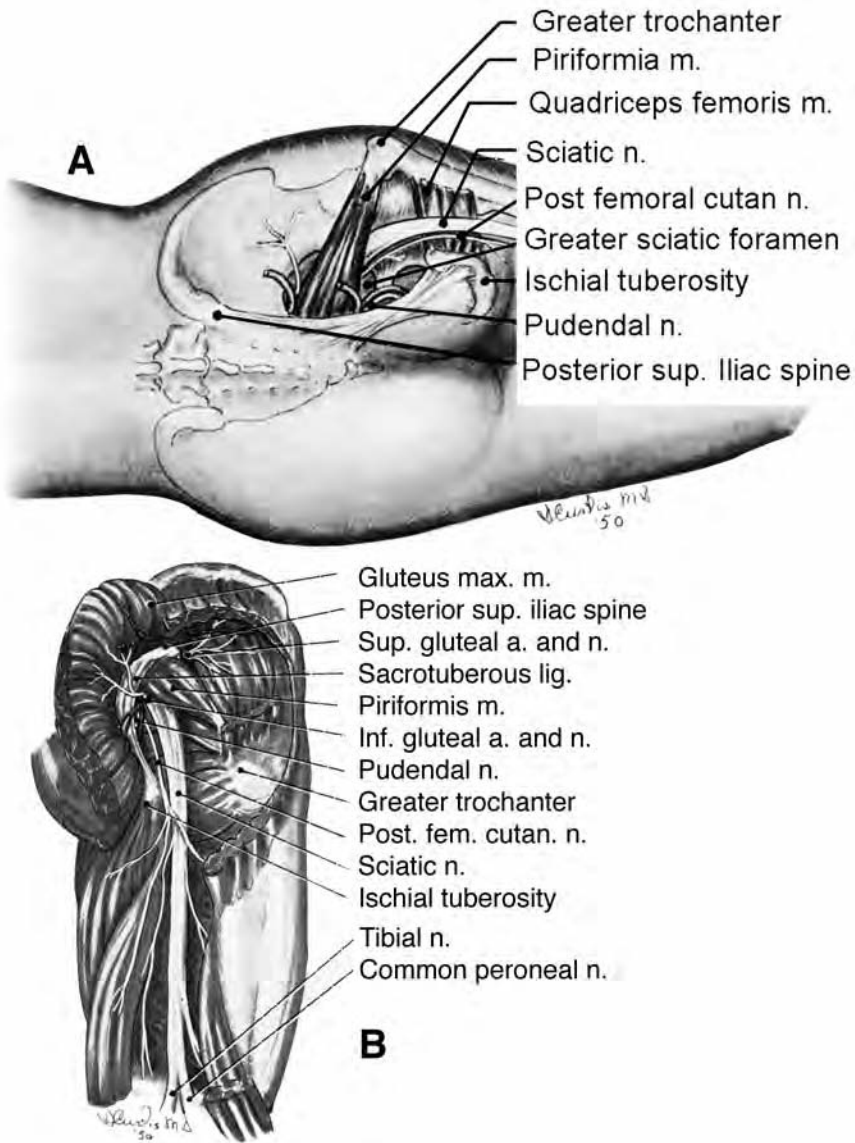


Figure 111. Site of piriformis syndrome. (From Moore, D. C.: *Regional Block: A Handbook for Use in the Clinical Practice of Medicine and Surgery*, 4th ed. Springfield, Charles C Thomas, 1971.)

MUSCLE INNERVATION FOR ALL MUSCLES SHOWN IN THIS BOOK

	<i>peripheral nerve</i>	<i>brachial plexus</i>			
		<i>cord</i>	<i>division</i>	<i>trunk</i>	<i>root</i>
abductor digiti minimi	ulnar	medial	anterior	lower	C8–T1
abductor pollicis brevis	median	medial	anterior	lower	C8–T1
adductor pollicis	ulnar	medial	anterior	lower	C8–T1
dorsal interosseous	ulnar	medial	anterior	lower	C8–T1
volar interosseous	ulnar	medial	anterior	lower	C8–T1
lumbricals (1–2)	median	medial	anterior	lower	C8–T1
lumbricals (3–4)	ulnar	medial	anterior	lower	C8–T1
flexor digiti minimi	ulnar	medial	anterior	lower	C8–T1
flexor pollicis brevis (sup head)	median	medial	anterior	lower	C8–T1
flexor pollicis brevis (deep head)	ulnar	medial	anterior	lower	C8–T1
opponens digiti minimi	ulnar	medial	anterior	lower	C8–T1
opponens pollicis	median	medial	anterior	lower	C8–T1
palmaris brevis	ulnar	medial	anterior	lower	C8–T1
abductor pollicis longus	post interos. (radial)	posterior	posterior	middle & lower	C7–C8
anconeus	radial	posterior	posterior	middle & lower	C7–C8
brachioradialis	radial	posterior	posterior	upper	C5–C6
extensor carpi radialis (longus & brevis)	radial	posterior	posterior	upper & middle	C6–C7
extensor carpi ulnaris	post interos. (radial)	posterior	posterior	upper, middle & lower	C6–C7–C8
extensor digitorum communis extensor digiti minimi proprius	post interos. (radial)	posterior	posterior	middle & lower	C7–C8
extensor indicis proprius	post interos. (radial)	posterior	posterior	middle & lower	C7–C8
extensor pollicis brevis	post interos. (radial)	posterior	posterior	middle & lower	C7–C8
extensor pollicis longus	post interos. (radial)	posterior	posterior	middle & lower	C7–C8
flexor carpi radialis	median	lateral & medial	anterior	upper, middle & lower	C6–C7–C8
flexor carpi ulnaris	ulnar	medial	anterior	lower	C8–T1
flexor digitorum profundus (#2–3)	ant. interos. (median)	medial	anterior	middle & lower	C7–C8

	<i>peripheral nerve</i>	<i>cord</i>	<i>brachial plexus</i>			
			<i>division</i>	<i>trunk</i>	<i>root</i>	
Flexor digitorum profundus (#4–5)	ulnar	medial	anterior	lower		C8–T1
flexor digitorum sublimis	median	lateral medial	anterior	middle lower		C7–C8–T1
flexor pollicis longus	ant. interos. (median)	lateral medial	anterior	middle lower		C7–C8–T1
palmaris longus	median	lateral medial	anterior	middle lower		C7–C8–T1
pronator quadratus	ant. interos. (median)	lateral medial	anterior	middle lower		C7–C8–T1
pronator teres	median	lateral	anterior	upper & middle		C6–C7
supinator	post interos. (radial)	posterior	posterior	upper		C5–C6
biceps brachii	musculo- cutaneous	lateral	anterior	upper		C5–C6
brachialis	musculo- cutaneous	lateral	anterior	upper		C5–C6
coraco-brachialis	musculo- cutaneous	lateral	anterior	upper & middle		C6–C7
triceps	radial	posterior	posterior	middle & lower		C7–C8–T1
deltoid	axillary	posterior	posterior	upper		C5–C6
infraspinatus	suprascapular	—	—	upper		C5–C6
latissimus dorsi	thoraco dorsal	posterior	posterior	upper, middle lower		C6–C7–C8
pectoralis major (clavicular)	lateral pectoral	lateral	anterior	upper		C5–C6
pectoralis major (sterno-costal)	medial pectoral	medial	anterior	middle & lower		C7–C8–T1
supraspinatus	suprascapular			upper		C5–C6
teres major	lower scapular	posterior	posterior	upper		C5–C6
teres minor	axillary	posterior	posterior	upper		C5–C6
levator scapulae	dorsal scapular twigs from					C5 C3–C4
pectoralis minor	medial & lateral pectoral	medial & lateral	anterior	upper, middle & lower		C6–C7–C8

	<i>peripheral nerve</i>	<i>brachial plexus</i>			
		<i>cord</i>	<i>division</i>	<i>trunk</i>	<i>root</i>
rhomboideus major	dorsal scapular				C5
rhomboideus minor	dorsal scapular				C5
serratus anterior	long thoracic				C5–C6–C7
trepezius	accessory (c.n. #11) (spinal portion) nerve twigs from				C3–C4

	<i>peripheral nerve</i>			<i>L–S plexor division</i>	<i>root</i>
abductor digiti quinti	lateral plantar	tibial	sciatic	ventral	S1–S2
abductor hallucis	medial plantar	tibial	sciatic	ventral	S1–S2
adductor hallucis	lateral plantar	tibial	sciatic	ventral	S1–S2
extensor digitorum brevis	deep peroneal	common peroneal	sciatic	dorsal	L5–S1
flexor digitorum brevis	medial plantar	tibial	sciatic	ventral	S1–S2
flexor digiti quinti	lateral plantar	tibial	sciatic	ventral	S1–S2
flexor hallucis brevis	medial plantar	tibial	sciatic	ventral	S1–S2
interossei	lateral plantar	tibial	sciatic	ventral	S1–S2
quadratus plantae	lateral plantar	tibial	sciatic	ventral	S1–S2
extensor digitorum longus	deep peroneal	common peroneal	sciatic	posterior	L5–S1
extensor hallucis longus	deep peroneal	common peroneal	sciatic	posterior	L5–S1
flexor digitorum longus		tibial	sciatic	ventral	L5–S1–S2
flexor hallicis longus		tibial	sciatic	ventral	L5–S1–S2
gastrocnemius (lat. & median heads)		tibial	sciatic	ventral	S1–S2
peroneus brevis	Superficial peroneal	common peroneal	sciatic	posterior	L5–S1–S2
peroneus longus	Superficial peroneal	common peroneal	sciatic	posterior	L5–S1–S2
peroneus tertius	deep peroneal	common peroneal	sciatic	posterior	L5–S1

		<i>peripheral nerve</i>		<i>L-S plexor division</i>	<i>root</i>
popliteus		tibial	sciatic	anterior	L5-S1
soleus		tibial	sciatic	anterior	L5-S1-S2
tibialis anterior	deep peroneal	common peroneal	sciatic	posterior	L4-L5
tibialis posterior		tibial	sciatic	anterior	L5-S1
adductor brevis	obturator nerve			anterior	L2-L3-L4
adductor longus	obturator nerve			anterior	L2-L3-L4
adductor magnus	obturator nerve			anterior	L2-L3- L4-L5
biceps femoris (long head)			sciatic (tibial portion)	anterior	L5-S1
biceps femoris (short head)			sciatic peroneal port.)	posterior	L5-S1-S2
gracilis	obturator			anterior	L2-L3-L4
iliopsoas	femoral			posterior	L2-L3-L4
pectineus	femoral			posterior	L2-L3-L4
rectus femoris	femoral			posterior	L2-L3-L4
sartorius	femoral			posterior	L2-L3-L4
semimembranosus			sciatic (tibial port.)	anterior	L5-S1-S2
semitenoinosus			sciatic (tibial port.)	anterior	L5-S1-S2
tenso fascie latae	superior gluteal			posterior	L5-S1-S2
vastus intermedius	femoral			posterior	L2-L3-L4
vastus lateralis	femoral			posterior	L2-L3-L4
vastus medialis	femoral			posterior	L2-L3-L4
gluteus maximus	inferior gluteal nerve			posterior division	L5-S1-S2

<i>peripheral nerve</i>		<i>L-S plexor division</i>	<i>root</i>
gluteus medius	superior gluteal nerve	posterior division	L4–L5–S1
gluteus minimum	superior gluteal nerve	posterior division	L4–L5–S1
obturator internus and gemelci	obturator internus nerve	anterior division	L5–S1–S2
piriformis	piriformis nerve		S1–S2
quadratus femoris	quadratus femoris nerve	sciatic (tibial portion)	L4–S1–S2
<i>peripheral nerve</i>		<i>division</i>	<i>root</i>
retro auricular	facial (C.N. #7)	postauricular	
orbicularis oculi	facial (C.N. #7)	temporal	
dilator naris	facial (C.N. #7)	deep buccal	
orbicularis oris	facial (C.N. #7)	superficial buccal	
occipital frontalis	facial (C.N. #7)	temporal	
tongue	hypoglossal (C.N. #12)		
sterno-cleido-mastoid	spinal accessory (C.N. #11)	spinal portion	
		twigs from C3–C4	
trapezius	spinal accessory (C.N. #11)	spinal portion	
		twigs from C3–C4	
temporal	trigeminal (C.N. #5)	deep temporal	} from the mandibular nerve
masseter	trigeminal (C.N. #5)	masseter	
cricothyroid	vagus (C.N. #10)	superior laryngeal	
thyroarytenoid	vagus (C.N. #10)	recurrent laryngeal	
rectal sphincter	pudendal	anterior division sacral plexus	
urinary sphincter	pudendal	anterior division sacral plexus	
transverse perineal	pudendal	anterior division sacral plexus	
superficialis			
quadratus lumborum	spinal	ventral division T12–L3	
paraspinals	spinal	dorsal division	
rectus abdominal	intercostals	T7–T12	
external oblique	intercostals	T7–T12	
intercostals	spinal	ventral division T1–T11	
diaphragm	phenic	(C3–4–5)	
	lower intercostals	(T6–11)	

