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Invited Review

Overview of Thigh and Leg Anatomical and Sonographic Landmarks in Rheumatic Patients

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Abstract

Musculoskeletal ultrasound has become a practical and accessible diagnostic tool for musculoskeletal diseases. It is used to examine joints, tendons, vessels, and nerves due to its wide availability in rheumatology practice. Ultrasound has also been applied for years in other areas such as muscular injuries in sports activities and rheumatic diseases with inflammation such as myositis. The knowledge among rheumatologists about muscle ultrasound is increasingly growing taking into account it is not the main target of their ultrasound activity but mainly based on the evaluation of joint, synovitis, tenosynovitis, vasculitis in giant cell arteritis, and parotid gland evaluation in Sjögren´s syndrome. Thus, the present review describes anatomical and ultrasound findings including all muscles of the thigh (anterior, posterior, medial aspects) and leg (anterior, lateral, posterior superficial, deep posterior compartments) of lower limb structures to ease a comprehensive clinical and sonographic evaluation.

Keywords: Ultrasound, thigh, leg, sonoanatomy

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Introduction

The ultrasound (US) study of the thigh and leg muscles requires long-section probes (4-5cm) with frequencies between 6 MHz and 10 MHz. Frequencies of 6 MHz allow for the viewing of deep structures, while higher frequencies are reserved for superficial structures. Ultrasound provides a global, simple, full, and reproducible view of the thigh and leg, as well as helps beginners to easily identify anatomical structures.

(A) THIGH

We divide the thigh into 3 study areas: (1) the anterior aspect, in which the quadriceps is the main muscle; (2) the posterior aspect, where the hamstrings can be examined, and (3) the medial aspect, where the anatomy of the adductor muscles can be examined.

The main muscle groups in the thigh are shown using basic, easily visible neuro-connective landmarks with hardly any anisotropy and are anatomically constant.[1]

(1) ANTERIOR ASPECT

The study at this level focuses on the quadriceps and sartorius muscles. Some of the structures in this area are shared with the hip region. It includes the tensor fascia lata muscle, which, although lateral, has an intimate relationship with the sartorius and the rectus femoris (RF). The central tendon of the RF is used as the main landmark for the location of most of the structures in this area.[1] (Figure 1)

Anatomy

The quadriceps muscle is made up of the RF and the vast medial, lateral, and intermediate muscles. Each muscle has an individual origin and all of them merge at the quadriceps tendon, which reaches the patella and inserts into the anterior tibial tuberosity through the patellar tendon[2] (Figure 2).

The RF is a thick, fusiform muscle with very sophisticated architecture. Proximally, it is bipennate in form and distally acquires a unipennate fibrillary disposition. It has a double proximal insertion through a direct tendon, which arises in the anterior inferior iliac spine (AIIS) and indirect tendon that arises in the rim of the cotyloid cavity[3-6] (Figure 3). The indirect portion is located posteriorly and laterally to the direct portion. These 2 insertions macroscopically merge in a common tendon. In its proximal third, the sartorius muscle crosses it completely from top to bottom and from lateral to medial (Figure 3).

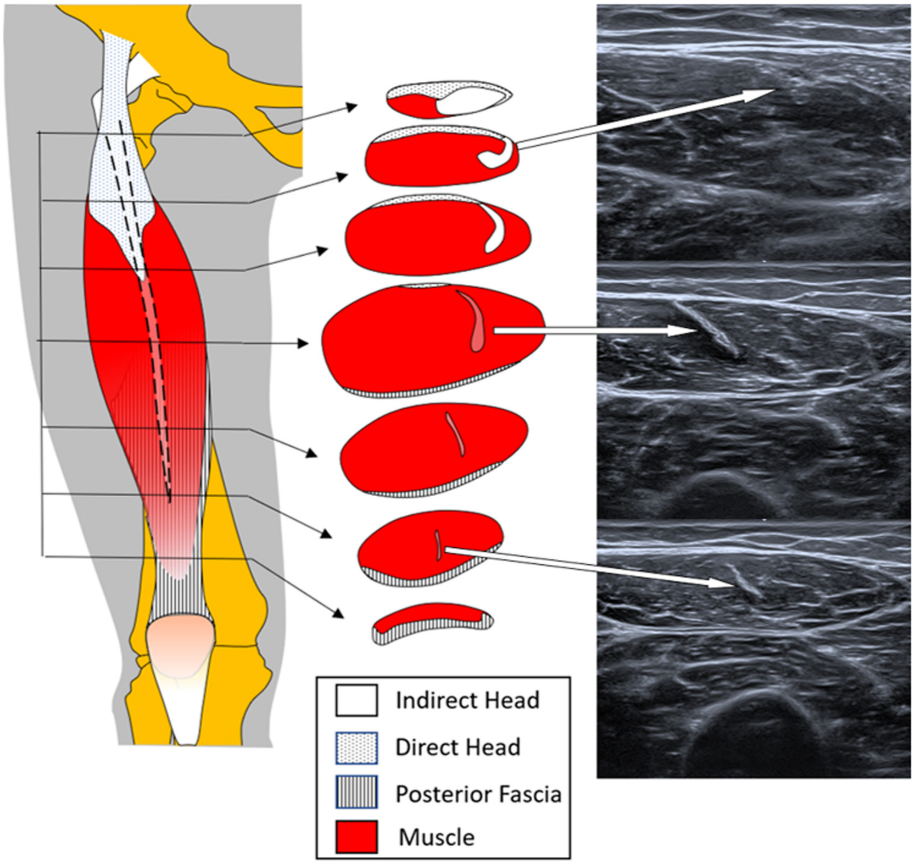

Figure 1. Anatomical drawing and ultrasound assessment of rectus femoris showing its 3 aponeurotic expansions. The indirect tendon (central tendon) is used as the main landmark to identify muscle masses of the quadriceps muscle.

The RF has 3 basic aponeurotic expansions (Figure 1). The indirect tendon develops an intramuscular fascial expansion that progresses through the belly of the muscular body and is known as the fascia or central tendon.[3,7] This expansion is cordonal and lateral in origin, and as it progresses medially and distally, it becomes like a tape until it practically reaches the distal third of the muscle. This central fascia is responsible for the bipennate appearance of the RF. On the other hand, the direct tendon develops a superficial expansion that covers frontally the proximal part of the RF. Finally, in the distal part, all the muscle fibers reach the so-called posterior fascia, an aponeurotic lamina which, with its expansion, is placed on the posterior surface of the muscle and provides the most superficial layer of the quadriceps tendon, thereby producing the unipennate muscular architecture.

The vastus medialis (VM) has its origin in the medial lip of the rough line of the femur and the intertrochanteric line. The vastus lateralis (VL) emerges from the lateral lip of the same rough line. The VL has an oblique fibrillary arrangement from top to bottom and from outside to inside.[8] The VM has a top-down and inside-out arrangement. The muscular mass of the VM is greater in its distal third and its section decreases as it ascends, while the opposite is true of the VL whose proximal section is larger than the distal section. The RF is located between these 2 muscles.

Finally, the vast intermediate (VI) originates from the anterior and lateral surfaces of the femoral shaft and the lateral inter-muscular septum of the thigh. Above it is the RF and next to it, the VM and VL.[8]

The sartorius (Figure 2) originates from the anterior superior iliac spine (ASIS). In the proximal third, the RF jumps from outside to inside and from top to bottom, reaching the medial aspect of the thigh and descending laterally to the large vessels next to the adductor major. At the junction of the proximal third with the mid-third, it becomes medial to these. It is inserted into the tibial metaphysis, forming the first fingering of the pes anserinus insertion.

The tensor fascia lata muscle (TFL) (Figure 2) is a short, thin, flat muscle that covers the anterior aspect of the gluteus medius. It originates from the anterolateral zone of the iliac crest, in the ASIS.[9] Its anterior length is greater than the posterior one.[10]

Ultrasound Examination

Scan position: Patient in a supine position, thigh in slight external rotation, and knee flexion 30º.

Examination Technique for the Study of the Quadriceps

The main US landmark is the central tendon of the RF (CT).[1] Its location is simple since it is a constant structure, with practically no anisotropy and it is located along almost all of the anterior aspects of the thigh. The probe is placed in the short axis in the proximal half of the thigh, where the CT is easily located as a more or less tapered and echoic image in the thickness of its muscle mass[11] (Figure 1). Once the CT is located, it is aligned in depth with the bone profile of the femoral shaft.[1] From the CT, the RF is located laterally to the VL, medially the VM, and below the VI, which is in contact with the femoral shaft. Following the CT in the distal direction, it becomes a band that reaches the distal third of the thigh (Figure 1).

Identification of the Origin of the Rectus Femoris

The CT can be followed along its short axis in the proximal direction until the AIIS, which appears as a hyperechoic line with an acoustic shadow with the direct tendon originating superior to it.[1] Once there, the probe can be rotated 90º to assess the direct tendon along its long axis (Figure 3A). By displacing the probe laterally, the indirect tendon is partially visualized, although the image is distorted due to its oblique direction toward the acetabulum, producing a characteristic anisotropy[12-14] (Figure 3B).

For the long axis study of the indirect tendon, the technique proposed by Moraux et al[12] is used. The probe is applied on the short axis over the AIIS and moves slowly until there appears a comet-tailed artifact produced by the indirect tendon, which is lost laterally in the depths. The transducer is then displaced laterally and pivoted 30º, raising the lateral end proximally until viewing the indirect tendon in its long axis with its insertion in the acetabular rim (Figure 3C).

Exam Technique to Study the Sartorius and *Tensor Fascia Lata*

In the assessment of the proximal third by palpation, the AIIS is located and the probe is applied on its short axis, displaying a hyperechoic curved line with an acoustic shadow (Figure 2A).[1,14] The probe is then moved downwards and the muscular section of the sartorius appears, and just behind it is the oval shape of

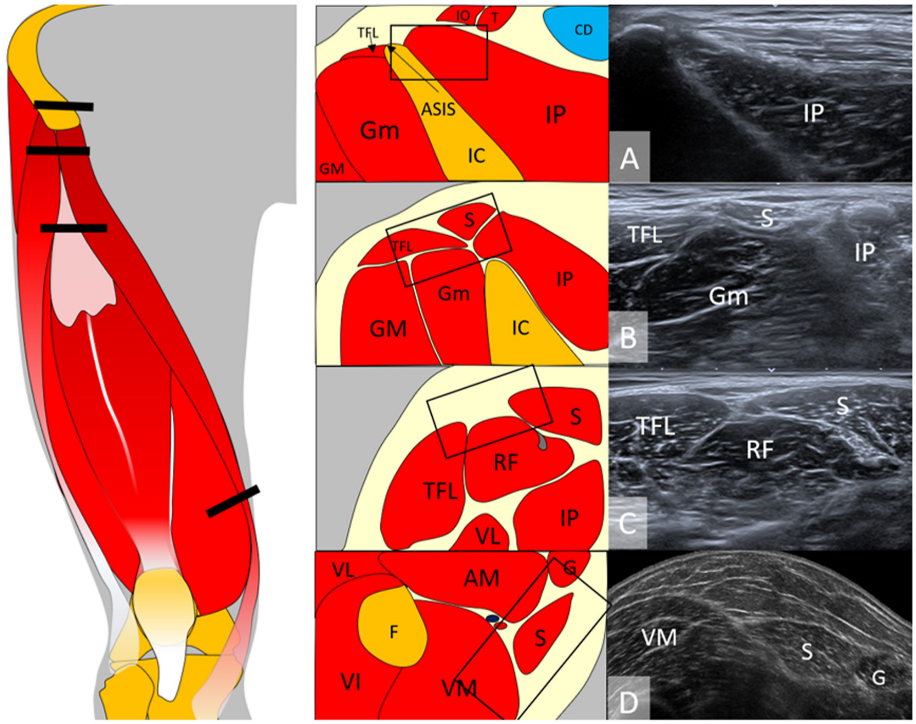

Figure 2. Anatomic drawing and ultrasound assessment of the quadriceps, sartorius, and tensor fascia lata muscles (proximal and distal third). IP, iliopsoas muscle; TFL, tensor fascia lata muscle; S, sartorius muscle; RF, rectus femoris muscle; ASIS, superior anterior iliac spine; IC, iliac crest; CD, colon descendens; IO, internal oblique; T, transversus; GM, gluteus medius; Gm, gluteus minimus; VL, vastus lateralis; VI, vastus intermediate; VM, vastus medialis; G, gracilis; AM, adductor magnus.

the TFL (Figure 2B). Moving the probe distally shows how the RF muscle section emerges from the depth between the TFL (lateral) and sartorial muscle (medial) bellies, giving a characteristic US image.[15] (Figure 2C)

In obese individuals, in whom it is difficult to identify the ASIS, the RF central tendon can be located on its short axis and the probe can be moved proximally until a biconvex lens-shaped structure interposes itself between the skin and the RF, which corresponds to the sartorius muscle. Once the sartorium has been identified, it can be followed proximally until the ASIS is identified.

Assessment of the Middle and Distal Third of the Sartorius. To better expose the distal part of the sartorius, it is recommended to place the thigh in greater external rotation. Once the sartorius is located in the proximal third, it can be followed easily in the distal direction, until reaching the pes anserinus area. The superficial femoral artery and veins run deeply and parallel to the path of the sartorius muscle.[1,15] The saphenous nerve, the distal branch of the femoral nerve,[1,15] is usually lateral and deep to the sartorius (Figure 2D). These vessels reach the posterior aspect of the knee through the Hunter duct (or adductor canal) in the mid-distal third of the thigh.

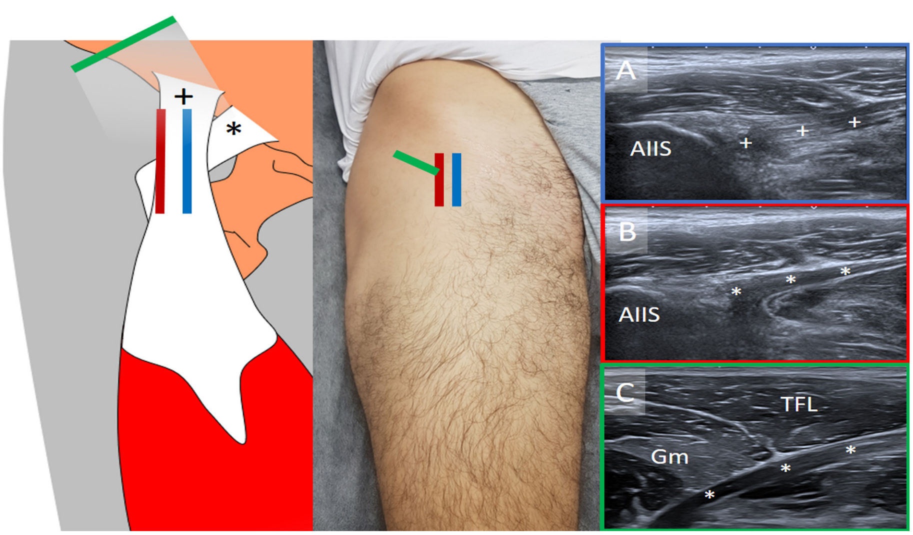

Figure 3. Anatomical drawing and sonographic assessment of the origin of the rectus femoris tendon. (A) Direct tendon, (B): indirect tendon, (C): indirect tendon. AIIS, anteroinferior iliac spine; +, direct tendon; *, indirect tendon; Gm, gluteus minimus; TFL,tensor fascia lata muscle.

(2) POSTERIOR ASPECT

Hamstrings are structurally complex, which makes the US examination more difficult than in other areas. This is due to the volume and the presence of large intramuscular connective expansions, which means that none of their muscles have a uniform architecture.

Anatomy

The hamstrings are formed by the biceps femoris (BF), the semitendinosus (ST), and the semimembranosus (SM) (Figure 4). The body of the hamstring muscle occupies practically the entire relief of the posterior aspect of the thigh. The proximal half is occupied by the long caput of the BF (lateral) and the ST (medial). Deep to the hamstrings is the large muscle mass of the adductor magnum. In the distal and lateral half are the 2 BF caputs. In the distal and medial half of the thigh are the SM and, to a lesser extent, the ST.[1]

The BF has 2 heads: the long head (lhBF) and the short head (shBF). The shBF originates in the distal and lateral half of the thigh, in the *linea aspera* of the femoral shaft, and in the ventral part of the distal tendon of the lhBF.[16] The lhBF is lateral and superficial to the thigh. Distally, the 2 heads develop a single tendon that is inserted into the head of the fibula.

The long head of the BF, ST, and SM has a common tendon origin in the posterior, superior, and lateral aspect of the ischial tuberosity (IT).[16,17] Semitendinosus is the only one that has muscle fibers that directly reach this IT.[16,18]

The ST occupies the medial and superficial area of the thigh and is inserted into the medial aspect of the tibia, forming the third fingering of the pes anserinus insertion. It is considered to be a digastric muscle[17] since its muscle fibers are interrupted by a connective ring (raphe) located in the proximal quarter of the muscle belly.[18]

The proximal fasciae of the BF and the ST merge on the so-called joint tendon.[17] The part of the

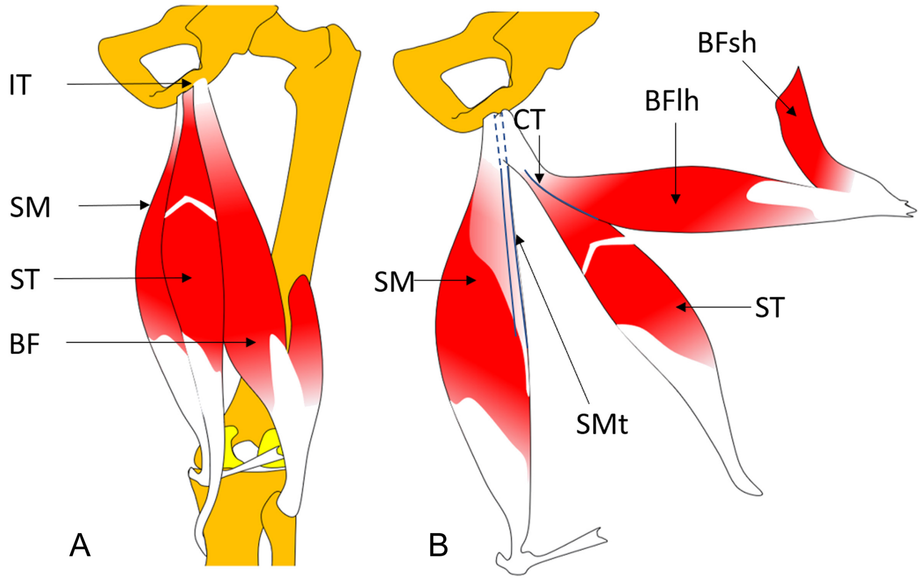

Figure 4. A, B. (A) Drawing of the hamstring muscles. (B) Drawing of expanded hamstring muscles. BF, biceps femoris muscle; ST, semitendinosus muscle; SM, semimembranosus muscle; CT, common tendon; IT, ischial tuberosity; BFlh, biceps femoris long head muscle; BFsh, biceps femoris short head muscle; SMt, semimembranosus tendon; CT, common tendon.

joint tendon that does not have anchored BF muscle fibers is called the "free tendon" and has a variable length (5 ± 3.4 cm).[17,19]

The proximal part of the SM is formed by a tendon lamina attached medially to a powerful 9.4 ± 2.6 cm tendon[17] which descends along the anterior aspect of the ST. The first proximal muscle fibers of the SM start at 30% of the entire length of the muscle.[18] The SM is located in the distal and medial half of the posterior aspect of the thigh and develops a distal tendon with 5 expansions.[20]

The SM and ST head toward the medial aspect of the knee, while the 2 heads of the BF are directed toward the lateral aspect, thus delimiting the upper part of the popliteal rhombus.

The sciatic nerve has an intimate relationship with the BF. Leaving the pelvis, it is placed lateral to the IT, at a very short distance from the origin of the semimembranosus tendon (SMt).[21] In the upper half of the thigh, it is located ventral to the BF and crosses it in the latero-medial direction and from top to the bottom. In the bottom part, it is medial to the shBF and posterior to the lhBF.[17,22]

Ultrasound Examination Scan Position

Patient in a prone position with feet off the table.

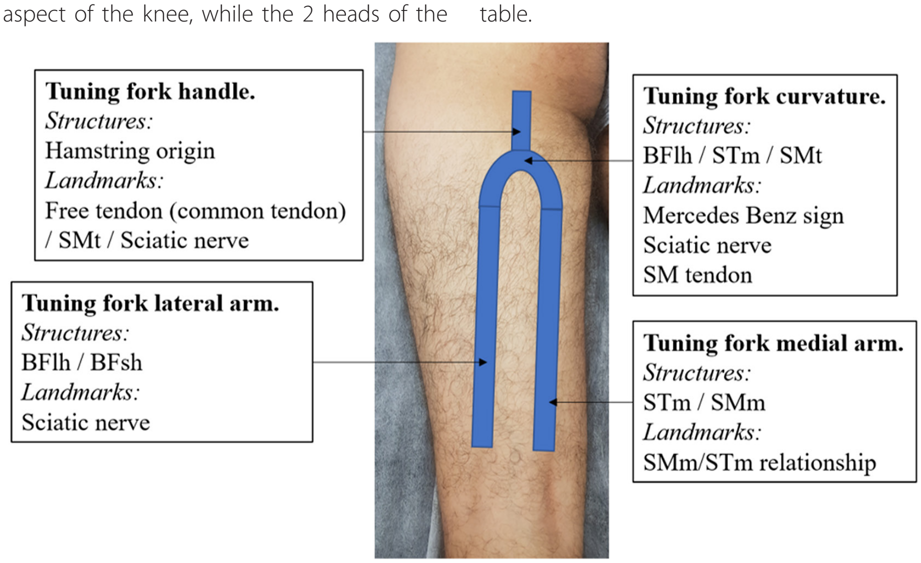

Figure 5. Evaluation technique for the study of hamstrings divides them into 4 areas of interest that, as a mnemonic rule, resemble a tuning fork.

Exploration technique for the study of hamstrings.

Study Areas

The exploration technique recommended is the one proposed by Balius et al[23], in 2019. These authors divide the hamstrings into 4 areas of interest that together are shaped like a tuning fork in an inverted position (Figure 5). Thus, the tuning fork handle corresponds to the origin of the hamstrings and is formed by the common tendon and the SMt. The tuning fork curve corresponds to the upper half of the hamstrings and is formed by the lhBF and ST muscle masses and the SMt. The medial leg of the handle is made up of the SM and ST muscle masses and the lateral leg of the 2 BF heads. Each of these areas has specific landmarks for the US study of their structures.

Assessment of the Proximal Half

The probe is placed in the short axis between the proximal and middle third of the posterior aspect of the thigh, and the oval, fascicular, and hyperechoic section of the sciatic nerve is identified, surrounded by fat.[24] Its image recalls the iconic 3-pointed star of the Mercedes Benz brand. The upper tip corresponds to the joint tendon and on each side of it are the ST (medial) and lhBF (lateral). The lateral tip separates the lhBF section from the adductor magnus. The medial tip separates the ST from the adductor magnus and corresponds to the SM membrane that ends developing the SMt, which is an oval section and smaller than the sciatic nerve. (Figure 6A)

On the other hand, if the probe is placed on the long axis over the sciatic nerve, the muscle mass on top corresponds to the lhBF (Figure 6B). If the long axis probe is placed on the SMt, the muscle body above corresponds to the ST. In this last image, it is possible to observe the characteristic, fine connective ring (raphe) of the ST, which is constant and hyperechoic[23] (Figure 6C).

Assessment of the Distal and Medial Half

The sciatic nerve is located in the short axis in the most proximal half of the thigh and the probe is directed toward the internal area to visualize the medial edge of the ST. From that position, the probe is directed distally until the appearance of the first SM fibers, which take on a crescent shape with lateral concavity is. This image should not be confused with the one formed by the connective ring of the ST, which has a medial concavity.[23] As the probe descends and reaches the distal and medial half, the SM grows in the area until it becomes

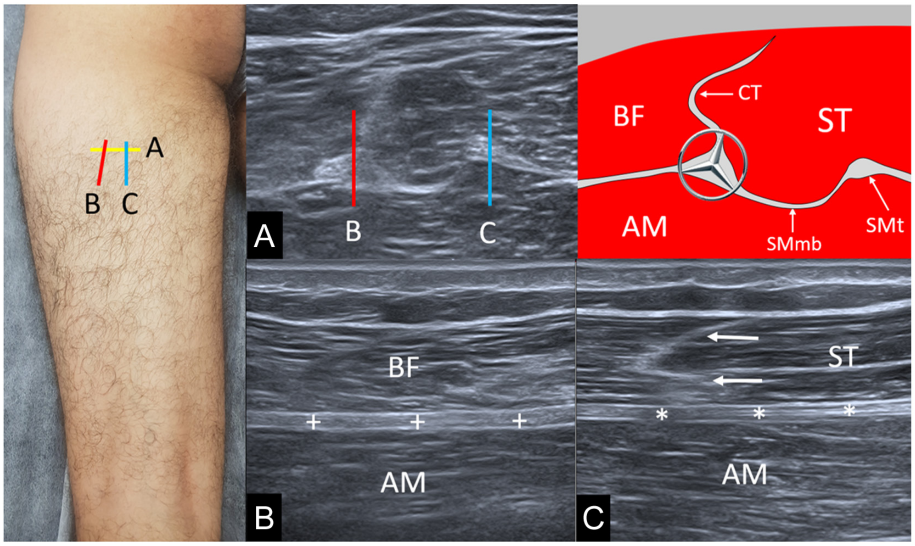

Figure 6. A-C. Sonographic assessment of proximal half of the hamstrings. (A) Short axis exam and diagram showing the location of sciatic nerve (*"Mercedes Benz"* sign) and other structures; (B) Long axis view sciatic nerve; (C) Long axis view semimembranosus tendon. Left side of the figure indicates transducer position. BF, biceps femoris muscle; ST, semitendinosus muscle; CT, common tendon; SMmb, semimembranosus membrane; SMT, semimembranosus tendon; AM, adductor magnus muscle; arrows: rafé; +, sciatic nerve; *, semimembranous tendon.

a large muscle body and the ST decreases in section until it becomes a small circle or ellipse which is located superficial and lateral to the SM (Figure 7).

At this point, if the probe is moved along the short axis toward the inner aspect of the thigh, a small circular section corresponding to the gracilis muscle (G) is found and, in direct contact with it, more anterior and with a fleshy section, there is the sartorius. Thus, the sartorius, G, and ST forms are the "pes anserinus circles."[23] The entire muscular area located between the G and the ST corresponds

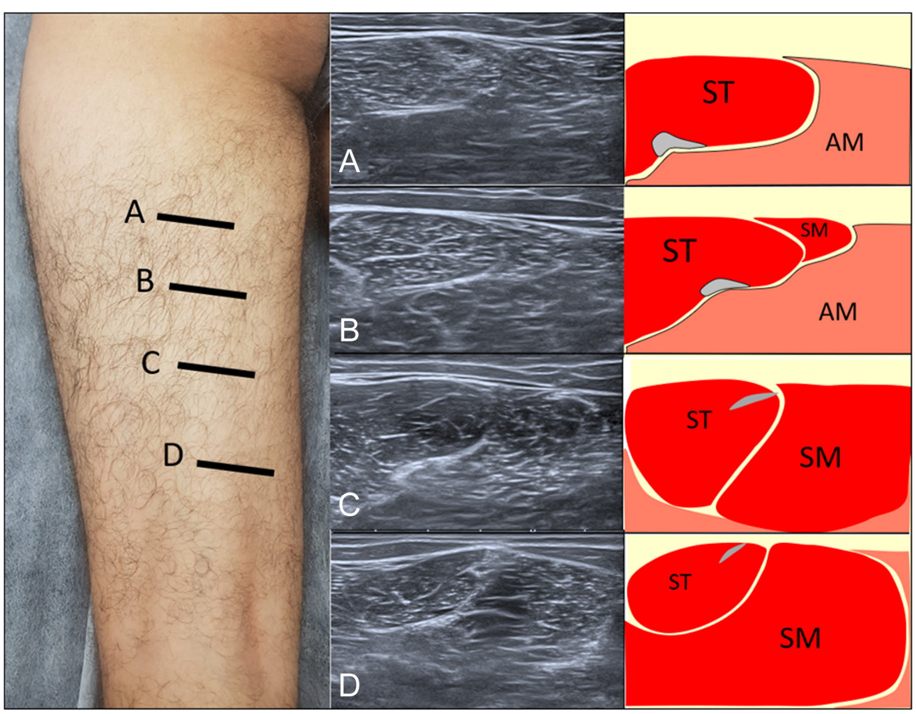

Figure 7. A-D. Sonographic assessment in short axis of the distal and medial half of the hamstring. (A-D) As the probe descends and reaches the distal and medial half, it is observed how the SM enlarges in area and the ST decreases in section locating superficial and lateral to SM muscle. Left side of the figure indicates transducer positioning. ST, semitendinosus muscle; SM, semimembranosus muscle; AM, adductor magnus muscle.

to the large mass of the semi-membrane (Figure 8).

Assessment of the Distal and Lateral Half

The sciatic nerve is located in the short axis in the proximal half of the thigh. The sciatic nerve is followed with the probe along its short axis toward the distal half. In the middle third of the thigh, the shBF appears as a fusiform structure that arises from the *linea aspera* of the femur and grows between the lhBF and the VL. Slightly more distal, the shBF takes a quadrilateral shape. Medial to the shBF is the lhBF with a more triangular appearance. Finally, usually proximal to the popliteal fold, the bifurcation of the sciatic nerve can be observed in the common peroneal nerve and the tibial nerve (Figure 9).

Assessment of the Origin of the Hamstrings

Once again, the sciatic nerve is located in the short axis in the proximal half of the thigh and, lying medial to it, the SMt. Without losing these 2 structures, the probe is displaced proximally and the sciatic nerve and the SMt are observed to progressively approach each other, while the lhBF section acquires a triangular section until it disappears and the ST muscle mass remains present until reaching a hyperechoic line with an acoustic shadow that corresponds to the IT. Superficial to the IT is the common tendon, while the SMt is more lateral and deeper. The sciatic nerve runs lateral to the IT toward the pelvis. By mobilizing the probe, a certain degree of anisotropy can be created, which helps to differentiate the joint tendon from the SMt[23] (Figure 10).

(3) MEDIAL ASPECT

Anatomy

The adductor muscular body is shared by the thigh and the hip. In the medial part of the thigh, there are 2 planes: anterior and posterior. The anterior plane is made up of, from front to back, the pectineus muscle (Pc), the long adductor (AL), and the gracilis (G). The posterior plane is made up of, also from front to back, the adductor brevis (AB) and the adductor magnus (AM)[15] (Figure 11).

The AL originates from the anterior aspect of the pubis. It has a flat and trapezoidal tendon that superficially covers the muscle[25,26] and that becomes intramuscular, descending about 10-15 cm inside.[27] It is anterior to the AM, lateral to the G, and medial to the Pc. It inserts into the mid-third of the *linea aspera* of the femur. The AB originates from the lower branch of the pubis. Its insertion is located in the proximal part of the medial lip of the rough

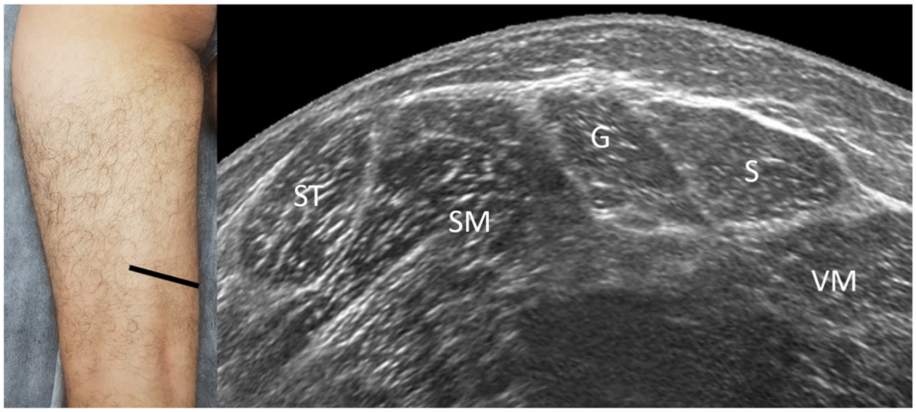

Figure 8. Sonographic panoramic view in the distal and medial half of thigh, showing the pes anserinus and semimembranosus muscles. Left side of the figure indicates transducer positioning. ST, semitendinosus muscle; SM, semimembranosus muscle; G, gracilis muscle; S, sartorius muscle; VM, vastus medialis muscle.

femoral line.[2] The AM is a large muscle. Its origin is located in the lower part of the pubic and ischial branches and in the medial margin of the ischiatic tuberosity.[2] Its complex insertion in the proximal two-thirds of the medial lip of the rough line runs then through a thin and fine connective contribution (fleshy part) and, more distally, through a tendon, in the medial epicondyle of the femur (tendon part).

Pectineus is a muscle located in front of the AL, with a wide laminar aspect. It originates from the so-called pectineal crest of the pubis and inserts into the proximal and medial extension of the linea aspera (pectineal line).[2] Gracilis is a long muscle with an ovoid section that runs through the medial aspect of the thigh, between the adductor muscles and the hamstring.[28] Thus, in front of it, we can then locate the AL (proximal) and the AB (distal) and, behind it, the ST (proximal) and the SM (distally).

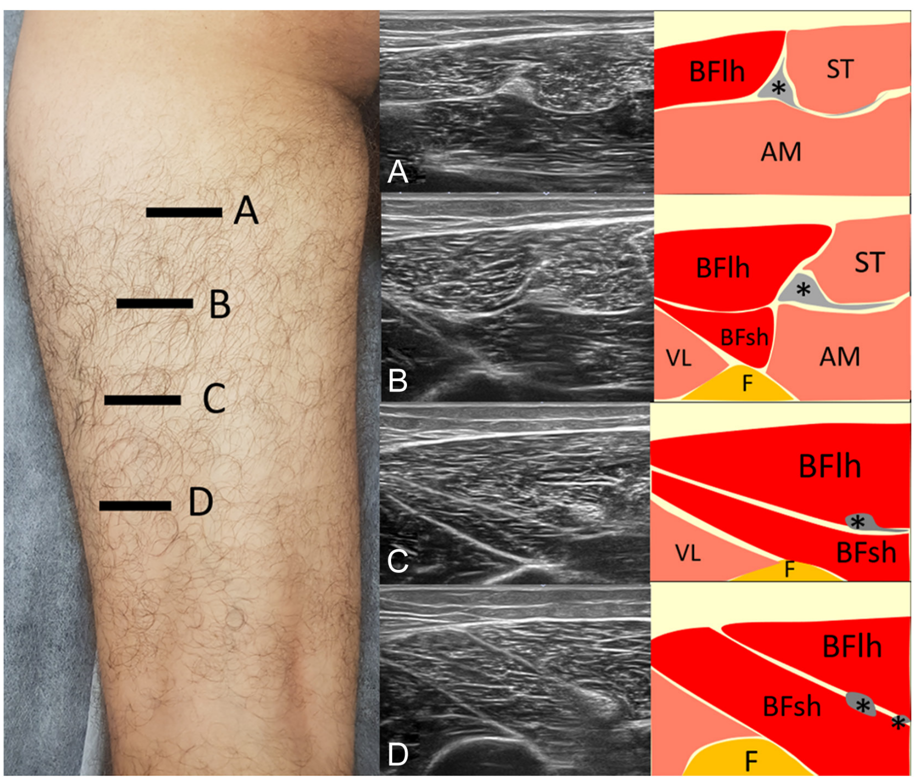

Figure 9. A-D. Sonographic assessment in the short axis of distal and lateral half of hamstring. (A-D) When the probe descends and reaches the distal and lateral half, emerges the short head deeper to the long head of the biceps femoris. In (D), the sciatic nerve has been divided into its tibial and femoral components. Left side of the figure indicates transducer positioning. BFlh, biceps femoris, long head muscle; BFsh, biceps femoris, short head muscle; ST, semitendinosus muscle; VL, vastus lateralis muscle; AM, major adductor; F, femur; *, sciatic nerve.

Ultrasound Examination

Scan position: Patient in supine position with discreet hip flexion and external rotation of the thigh. The AL tendon is palpated, which is in tension in this position, while the rest of the adductor structures are relaxed (Figure 11).

Exploration Technique for the Study of Adductors

The probe is placed on the short axis to the AL tendon and the intramuscular part of the echoic and taped tendon is observed with its muscular belly around (Figure 11A). Rotating the probe 90º, an image of the longitudinal tendon is obtained, which is followed proximally until its insertion into the pubic symphysis, which consistently offers a conical image (Figure 11B).

Returning to the initial position on the short axis of the AL, the transducer is then displaced along the axis in the posterior direction until reaching the gracilis, which appears as an elliptical shape in the lateral margin of the image.[29] Next to it, 3 muscular structures with a triangular appearance are observed: the AL and, below it, the AB, and below that, the AM. This US shape is characteristic and reminds one of a sun—the gracilis muscle—emitting rays, thus dividing the adductors. In the myofascial space, which is delimited by the AL and the AB, the superficial obturator nerve can be seen, and between the AB and the AM, the deep obturator nerve. (Figure 12)

(B) LEG

The leg is divided into 4 anatomical compartments: the anterior, lateral and posterior, superficial, and deep compartments,[30] each with its characteristic landmarks (Figure 13). A dynamic study is essential for the US evaluation of the leg muscles.

(1) ANTERIOR ASPECT

Anatomy

The anterior compartment involves 3 muscles: The tibialis anterior (TA), the extensor hallucis longus (EHL), and the extensor digitorum longus (EDL).

Tibialis anterior muscle originates from the upper half of the lateral surface of the tibia and the interosseous membrane. In the thickness of the proximal area of the muscle, a powerful connective band is created that develops into the TA tendon and acquires a cordonal shape

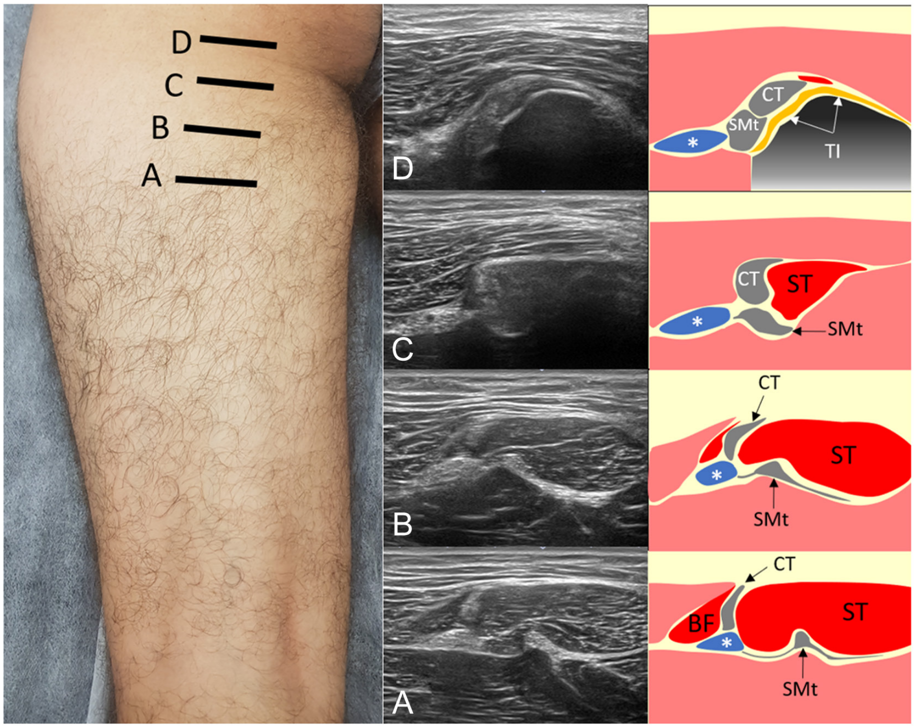

Figure 10. A-D. Sonographic assessment in short axis of the hamstring origin. (A-D) shows how does the sciatic nerve approaches to semitendinosus tendon from one to other until reaching the ischial tuberosity. Left side of the figure indicates transducer positioning. BF, biceps femoris muscle; ST, semitendinosus muscle; SMt, semimembranosus tendon;, CT, common tendon; IT, ischial tuberosity; *, sciaticus nerve.

as it progresses distally until it is inserted at the first metatarsal base and on the plantar surface of the medial cuneiform.[31] Lateral to the TA is the EDL. It originates from the tibia plateau, 3-quarters of the way down the fibula and the interosseous membrane. It is inserted through tendons into the second and third phalanx of the triphalangeal fingers. Below, and somewhat distal to the EDL, is the EHL, which originates in the middle third of the fibula and in the interosseous membrane and is inserted at the base of the distal phalanx of the first finger.[31]

The TA lines the lateral aspect of the tibia and in a more external cutaneous plane is the EDL. In the axial section, both muscles have a triangular section with an anterior base and a posterior vertex. Between them, and somewhat more distal, the EHL appears with a smaller triangular section, anterior vertex, and posterior base. In the distal part of the leg, the EHL is located below the EDL.

Ultrasound Examination

Scan Position

Patient in a supine position, limb in extension, and slight internal rotation with the anterior compartment exposed.

Exploration Technique for the Study of the Anterior Compartment

Place the probe in the upper-middle third of the anterior aspect of the leg. The lateral surface of the tibia is seen as a marked hyperechoic oblique line with an acoustic shadow. This structure continues medially with the echoic band and deep to the interosseous membrane. On the tibia is the TA, with a triangular section with anterior base, which contains a hyperechoic band inside it corresponding to the tendon, which is used as a US landmark.[31]

Identifying the other muscles requires a dynamic study consisting of repeated flexions and extensions of the toes. In this way, the mobilization of an anterior base triangle corresponding to the common flexor digitorum (CFD) is observed, medial to the TA. While the toes are being moved, the transducer is displaced distally and the EDL section is detected as a mobile triangle with an anterior vertex and a posterior base[31] (Figure 14).

In the depth of this compartment, first between the TA and the EDL and then between the TA and the EHL, the anterior tibial artery and veins are located, accompanying the deep peroneal nerve.

(2) LATERAL ASPECT

Anatomy

The lateral compartment is formed by the peroneus brevis (PB) and the peroneus longus (PL), which run parallel to each other along the leg. The PL descends above the PB and its muscle section is proximal, while the PB muscle section is more distal. Thus, in the upper part of the compartment, there is only the PL muscle mass, and as one progresses downwards, the PB muscle mass appears.[31]

Peroneus longus muscle originates from the head and the upper two-thirds of the lateral aspect of the fibula. The cuboid is bent and inserts at the base of the first metatarsal through a long tendon. The PB originates from

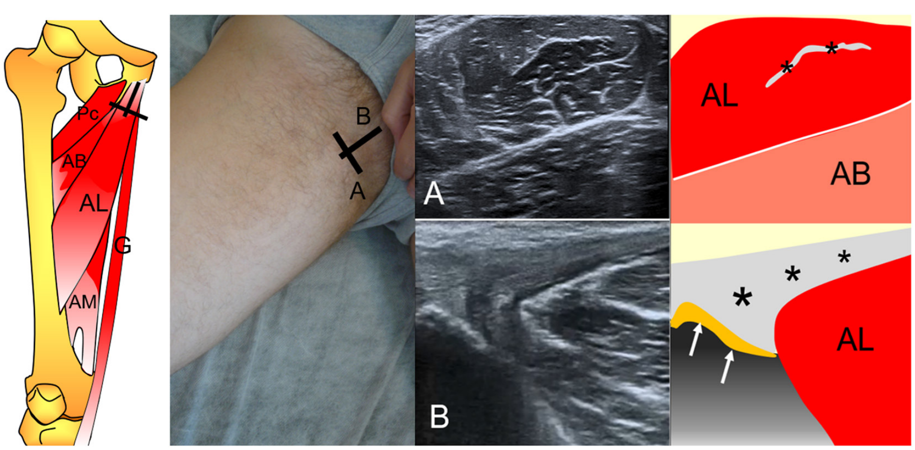

Figure 11. A, B. Sonographic assessment of adductor longus. (A) Short axis view identifying the intramuscular tendon of the adductor longus. (B) Long axis cut along adductor longus tendon reaching the pubic symphysis. Left side of the figure indicates transducer positioning. AL, adductor longus muscle; AB, adductor brevis muscle; *, adductor longus tendon; Arrows: pubic symphysis.

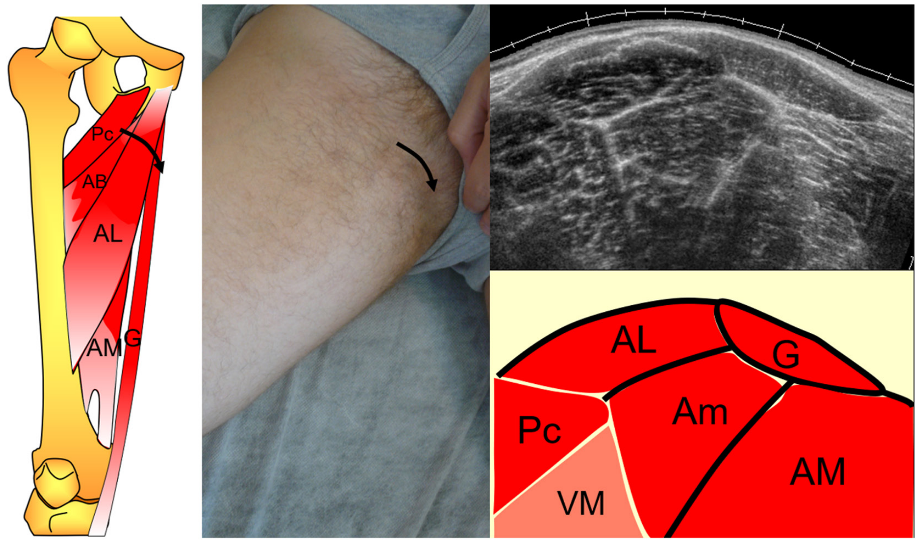

Figure 12. Sonographic panoramic view in the proximal and medial third of thigh. Starting with the probe in the same position as Figure 11A and moving backward until the gracilis muscle section appears. In this position, the different adductor muscles are observed. Left side of the figure shows diagram of adductor muscles and beside it, the displacement of the probe. AL, adductor longus muscle; AB, adductor brevis muscle; AM, adductor magnus muscle; G, gracilis muscle; Pc, pectineus muscle; VM, vastus medialis muscle.

the lower half of the lateral aspect of the fibula and has a tendon that inserts at the base of the V metatarsal.[31]

Ultrasound Examination Scan Position

Patient in a supine position, limb in extension, and internal rotation, so that the lateral compartment is exposed.

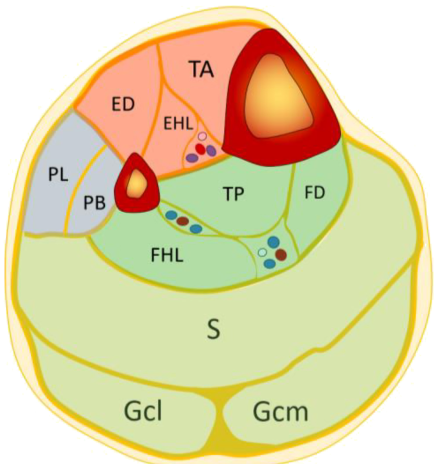

Figure 13. Diagram of section in the middle third of the leg. Four anatomical compartments are defined. Anterior compartment: (TA) tibialis anterior, (ED) extensor digitorum, (EHL) extensor hallucis longus. Lateral compartment: (PL) peroneus longus, (PB) peroneus brevis. Deep posterior compartment: (TP) posterior tibialis, (FD) flexor digitorum, (FHL) flexor hallucis longus. Superficial posterior compartment: (S) soleus, (Gcl) caput longus gastrocnemius muscle, (Gcm) caput medialis gastrocnemius muscle.

Exploration Technique to Study the Lateral Compartment

The probe is placed on the short axis in the middle and lateral third of the leg. Two muscle structures separated by the hyperechoic band of the PB are observed. In the upper part, the muscle mass corresponds to the PL. As the probe is distal, the PB replaces the PL. The PB hyperechoic band divides the PB section from that of the PL and approaches the cutaneous plane, the more distal the transducer is located[31] (Figure 15).

(3) POSTERIOR SUPERFICIAL COMPARTMENT

Anatomy

The superficial posterior compartment is made up of the 2 heads of the gastrocnemius, the soleus and the plantaris. The gastrocnemius and soleus have aponeuroses that distally develop the Achilles tendon, which inserts into the calcaneus.

The gastrocnemius is a digastric muscle originating from the medial (medial condyle) and lateral (lateral condyle). From its origin, the fibers of both heads are directed obliquely toward the midline of the leg until they insert into the anterior fascia of the gastrocnemius, which covers the posterior soleus fascia, to form together with the Achilles tendon. The fibers of the medial caput reach a more distal level than those of the lateral caput.[2,32]

The soleus originates in the posterior and proximal third of the fibula and in the proximal third of the tibia through the so-called arcus tendineus.[2] From it, the powerful anterior aponeurosis emerges, from which 3 aponeurotic expansions originate: 1 medial (tibial), 1 central, and 1 lateral (peroneal). The medial and lateral expansions progress intramuscularly until disappearing inside the muscle, while the central tendon is directed posteriorly until its connective tissue is incorporated into the Achilles tendon. This intricate connective structure conditions a complex arrangement of muscle fibers.[33]

The plantaris arises in the lateral supracondylar line of the femur, above the origin of

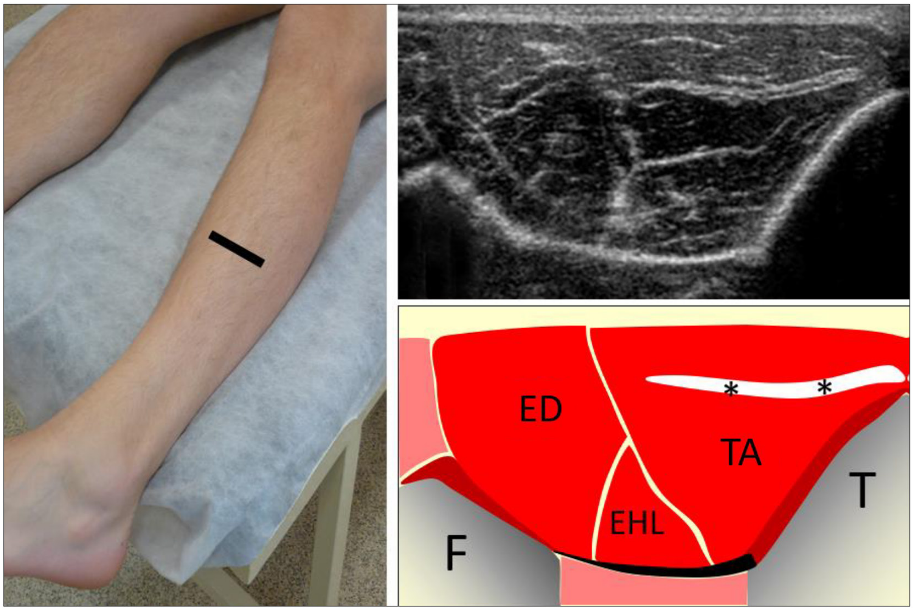

Figure 14. Sonographic assessment in short axis of anterior compartment of the leg. Left side of the figure indicates transducer positioning. TA, tibialis anterior; ED, extensor digitorum; EHL, extensor hallucis longus. T, tTibia; F, fibula; *, tibialis anterior tendon.

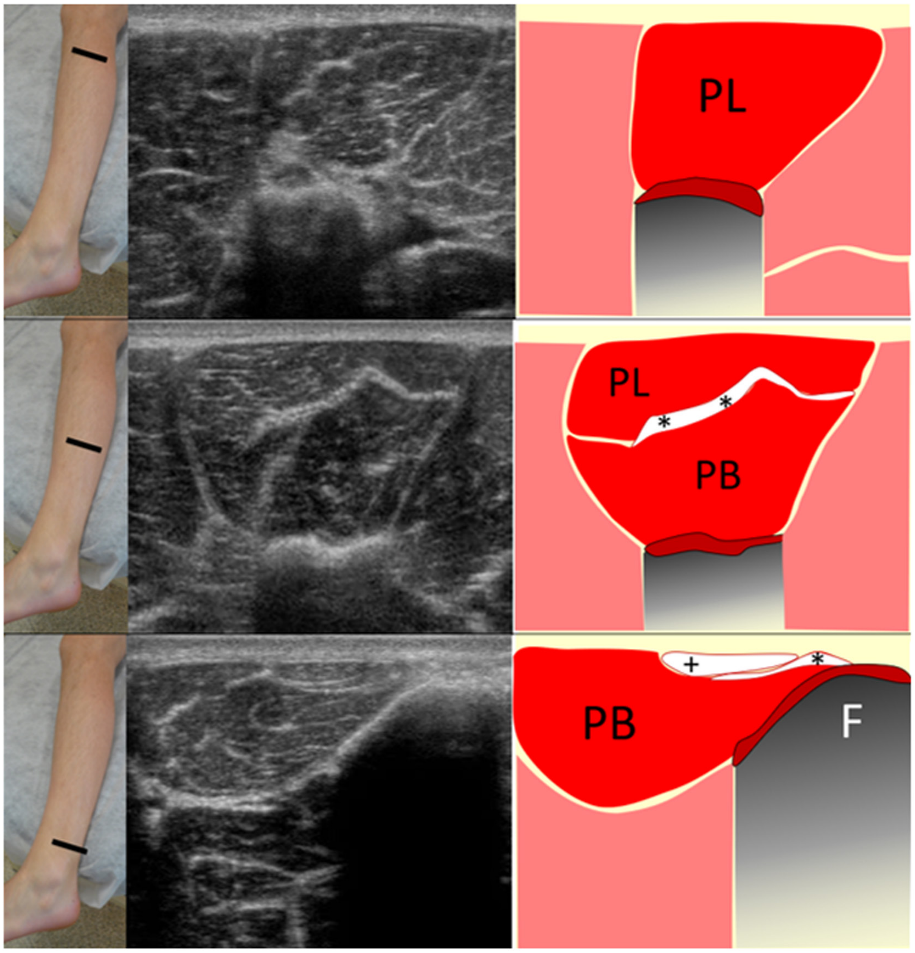

Figure 15. Sonographic assessment in short axis of the lateral compartment of the leg. Left side of the figure indicates transducer positioning. PL, peroneus longus; PB, peroneus brevis.

the lateral head of the gastrocnemius. It has a small muscular belly that develops a long tendon that descends between the ventral fascia of the medial head of the gastrocnemius and the dorsal fascia of the soleus until reaching the medial margin of the Achilles tendon. It is inserted next to the Achilles tendon in the calcaneus, though this is highly variable.[34,35]

Ultrasound Examination

Scan Position

Patient in a prone position, with the calf exposed. Ankle and foot hanging off the table.

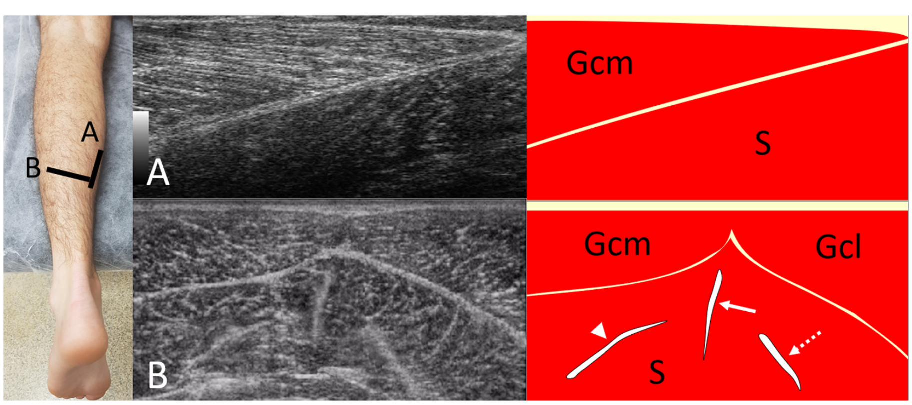

Figure 16. A, B. Sonographic assessment of posterior and superficial compartment of the leg. (A): Long axis cut. (B): Short axis cut showing the 3 intramuscular fascia of the soleus (Arrowhead: peroneal fascia; Continuous arrow: central tendon; Dashed arrow: tibial fascia). Left side of the figure indicates transducer positioning. S, soleus muscle; Gcl, caput longus gastrocnemius muscle; Gcm, caput medialis gastrocnemius muscle.

Exploration Technique to Study the Superficial Posterior Compartment

The probe is placed on the long axis in the middle third of the posterior aspect of the leg, in its most medial part. Immediately below the skin, a muscular structure with an oblique ordered, and parallel fibrillar tracing is identified, which is the medial head of the gastrocnemius. Moving the probe distally shows how this muscle ends up forming a bevel shape.[29,36] If the probe is placed at the same level, but in the lateral area, the lateral head is observed, which has a somewhat more proximal bevel shape[29] (Figure 16A).

If the probe is placed on the short axis, in the mid-third of the leg, in the midline, the heads of the gastrocnemius appear as 2 crescents, with their vertices converging in the midline, are observed. Beneath, there is a half-crown of coarse tissue that corresponds to the soleus. Depending on the placement of the probe, the presence of the 3 fasciae can be observed[37] (Figure 16B).

(4) DEEP POSTERIOR COMPARTMENT

Anatomy

The deep posterior compartment is made up of 4 muscles. Three of them are located in the middle and distal third of the leg: the tibialis posterior (TP), the flexor hallucis longus (FHL), and the flexor digitorum longus (FDL). The fourth and most proximal are the popliteus.

The FDL originates from the lower two-thirds of the fibula and defines an important triangular section based on this bone. Its tendon is directed medially toward the posterior aspect of the talus until it reaches the calcaneus and becomes inserted at the base of the distal phalanx of the first finger.[2] The FHL originates from the central area of the posterior aspect of the tibia and defines a triangular section based on this bone. It has a long tendon at the medial edge of the muscle that reaches the medial retromaleolar space, and from there, it goes to the sole of the foot to become inserted, through 4 tendons, at the bases of the distal phalanx of the triphalangeal toes.[2] The TP originates from the interosseous membrane, in the distal and posterior part of the tibia and in the upper two-thirds of the medial aspect of the fibula. A powerful tendon emerges from the middle of the leg and progresses from the medial side of the muscle to the medial malleolus to insert into the tuberous bone of the scaphoid. The TP is located deep in the compartment, located between the FDL and the FHL.[2]

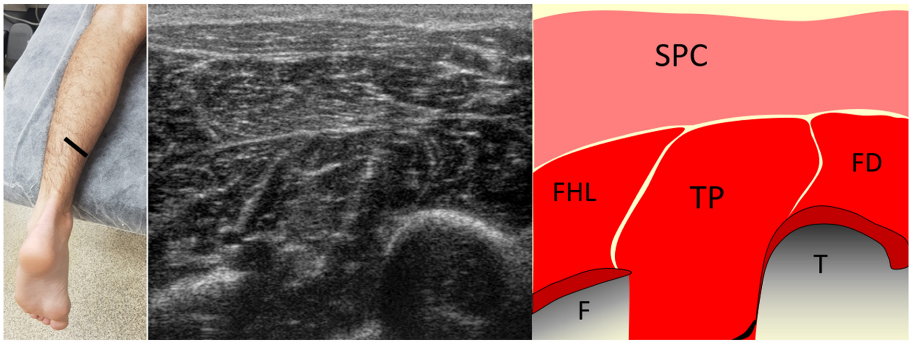

Figure 17. Sonographic assessment in short axis of the posterior and deep compartment of the leg. Left side of the figure indicates transducer positioning. TP, posterior tibialis; FD, flexor digitorum; FHL, flexor hallucis longus; SPC, superficial posterior compartment; T, tibia; F, fibula.

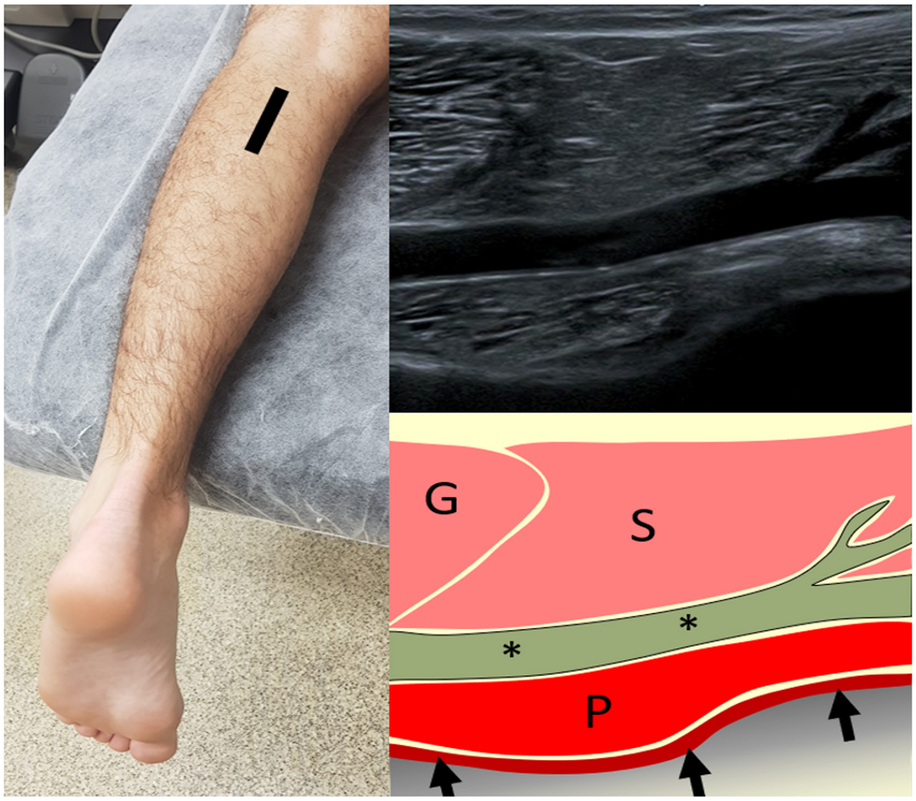

Figure 18. Sonographic assessment of posterior and superficial compartment of the leg (popliteal muscle). On the left, the image shows the position of the probe. G, gastrocnemius muscle; S, soleus muscle; P, popliteus muscle; *, popliteal vessel; Arrows, tibia.

The popliteal muscle is thin and flat and is located in the proximal third of the leg, below the vasculo-nervous bundle on the posterior aspect of the knee. It has a triangular appearance with a medial base and a vertex pointing to the external interline of the knee. It emerges from the posterior surface of the tibia, proximal to the soleus. By means of a tendon, it inserts into the lateral condyle of the femur, below the lateral head of the gastrocnemius.[38]

Ultrasound Examination Scan Position

Patient in a prone position, with the calf exposed. Ankle and foot hanging off the table.

Exploration Technique for the Study of the Deep Posterior Compartment

The probe is placed on the short axis of the posterior aspect of the leg, distal to the lower edge of the gastrocnemius. The bony profiles of the tibial and fibula are then identified. The probe is moved medially until the 2 bone edges are situated on the same horizontal plane. Once this is achieved, the individual actively mobilizes their toes. In this way, the muscle masses of the FDL anchored in the fibula and the FHL anchored in the tibia are delimited. The rest of the musculature located basically on the interosseous membrane, which is not mobilized, corresponds to the TP[31] (Figure 17).

In the proximal part, the popliteal muscle is located, it is sufficient to follow the popliteal vascular-nervous package and the muscle is located between it and the profile of the tibia. Once located, the probe should be moved obliquely[31] (Figure 18).

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