Quadriceps

9

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Four muscle bellies form the quadriceps muscle group, occupying the anterior compartment of the thigh: the rectus femoris, the vastus lateralis, the vastus medialis and the vastus intermedius muscles (Fig. 9.1).

The origin of the four bundles varies for each of them, while caudally the tendons of these muscles merge to form the quadriceps tendon, taking a common insertion onto the superior pole of the patella.

The quadriceps acts as a powerful extensor of the leg on the thigh. Moreover, the rectus femoris muscle, with its insertion onto the hip, also contributes to hip flexion; the vastus medialis and lateralis play a secondary role in stabilizing the patella.

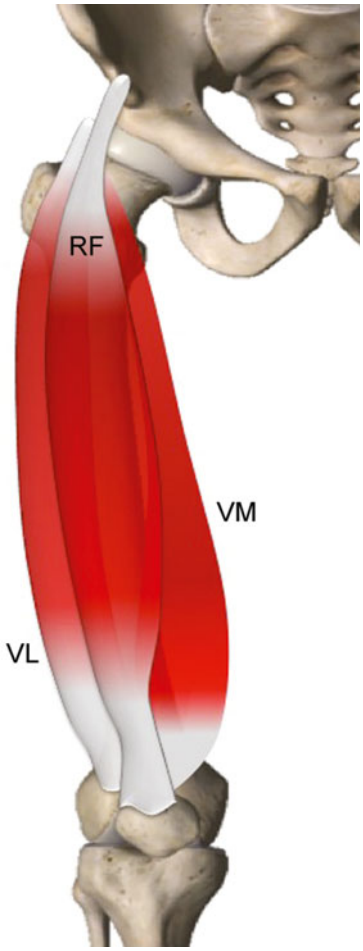

Fig. 9.1 Anatomical scheme of the quadriceps group: *RF* rectus femoris muscle, *VM* vastus medialis muscle, *VL* vastus lateralis muscle. The vastus intermedius muscle lies deep to the RF muscle

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9.1 Rectus Femoris

9.1.1 Anatomy Key Points

The *rectus femoris* is a long fusiform biarticular muscle, forming the anterior superficial portion of the quadriceps muscle group. In respect to the vastus lateralis, vastus medialis and vastus intermedius muscles, the rectus femoris is the most commonly involved in strain injuries and also has the most complex anatomy.

The muscle fibres originate from the hip through a complex proximal insertion, consisting of three separate tendons (Fig. 9.2). The *direct tendon* (or straight head) arises from the anterior inferior iliac spine (AIIS); the *indirect tendon* arises slightly more inferiorly and posteriorly from the supero-lateral aspect of the acetabular rim; the *reflected tendon* (or reflected head) is the smallest and anchors the insertional complex of the rectus femoris, reflecting into the anterior capsule of the hip joint, in the proximity of the greater tuberosity. Each tendon nearly retains a separate identity (with 10–20 % intermingling of fibres) and continues in a specific aponeurosis.

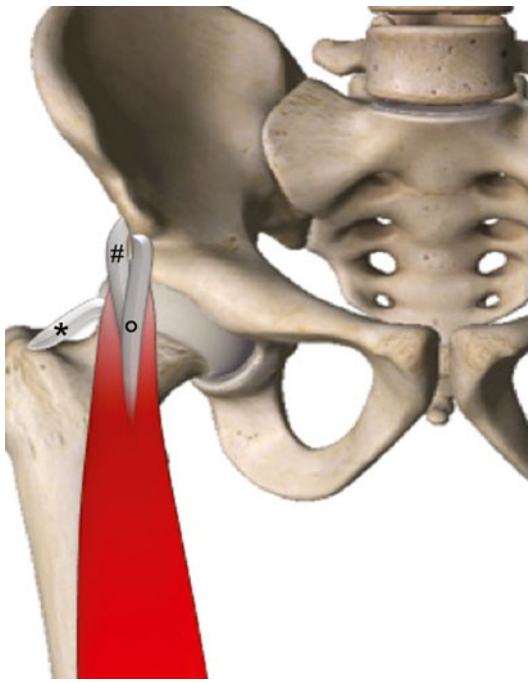

Fig. 9.2 Anatomical scheme of the rectus femoris proximal insertion: (°) direct tendon, (#) indirect tendon, (*) reflected tendon

The strict relationship between the acetabulum and the above-mentioned tendons justifies the frequent association among strain injuries of the rectus femoris muscle, which are common in young athletic patients, and a concomitant tear of the acetabular labrum.

The rectus femoris muscle has a complex internal structure consisting of different muscle fibres and fibrous-aponeurotic components. Proximally, two aponeurosis can be distinguished, the superficial and the central aponeurosis. The *superficial aponeurosis* represents the continuation of the direct tendon within the muscle substance and is oriented on a coronal plane; it extends in the cranial third of the muscle belly and blends with the anterior fascia. The *central aponeurosis* is primarily connected to the indirect tendon and is oriented on a sagittal plane; it is located in the cranial two-thirds of the muscle belly. The inferior surface of the superficial aponeurosis gives origin to the outer muscle fibres, while the inner fibres expand from the lateral and medial side of the central aponeurosis. For this reason, the outer portion of the rectus femoris muscle has a unipennate appearance, while the inner one appears bipennate, so that the rectus femoris muscle is overall composed of a small inner bipennate component surrounded by a large unipennate muscle. Both the outer and inner muscle fibres run caudally to insert into the *deep distal aponeurosis* that

arises from the posterior surface of the distal two-thirds of the muscle and continues distally in the quadriceps tendon. This particular tendinous and "muscle within a muscle" architecture is responsible of unusual patterns of muscle tears that differ from what is typically encountered in other muscles.

The distal myotendinous junction is located between the midline and distal third of the thigh. It continues the distal tendon that blends with the tendons of the vastus lateralis, vastus medialis and vastus intermedius muscles, forming the superficial layer of the quadriceps tendon. The most superficial tendinous fibres of the rectus femoris overcome the patella to reach the tibial tuberosity, contributing to the formation of the patellar tendon.

The descending branch of the lateral femoral circumflex artery furnishes the vascular supply of the rectus femoris muscle; the posterior division of the femoral nerve provides its innervation.

Fig. 9.3 Lower limb position to evaluate the rectus femoris muscle

9.1.2 Ultrasound Examination Technique

The patient lies supine, with the lower limb extended in a neutral position (Fig. 9.3).

Place the probe on the anterior superior iliac spine (ASIS) in an axial position in order to visualize the proximal insertions of the sartorius (medial) and tensor fasciae latae (lateral) muscles as shown in Fig. 7.3.

Then, move the transducer caudally to reach the anterior inferior iliac spine (AIIS), the key bony landmark to identify the rectus femoris proximal insertion (Fig. 9.4). The direct tendon of the rectus femoris can be seen above the AIIS cortex and deep to the iliopsoas muscle.

Pay particular attention when assessing the attachment point of the direct tendon onto the AIIS in young patients. As the growth plate is not completely fixed, this structure is frequently involved in avulsion fracture secondary to strain injuries.

Rotate the transducer by 90° to evaluate the direct tendon on the longitudinal plane (Fig. 9.5). Deep to the hyperechoic band representing the direct tendon, note the shadow determined by the change in orientation of the indirect tendon that descends externally and obliquely toward the upper rim of the acetabulum (Fig. 9.6).

In order to better assess the indirect tendon, ask the patient to put the examined leg over the other leg in a cross-legged position (Fig. 9.7a), and then swipe the probe laterally on an axial

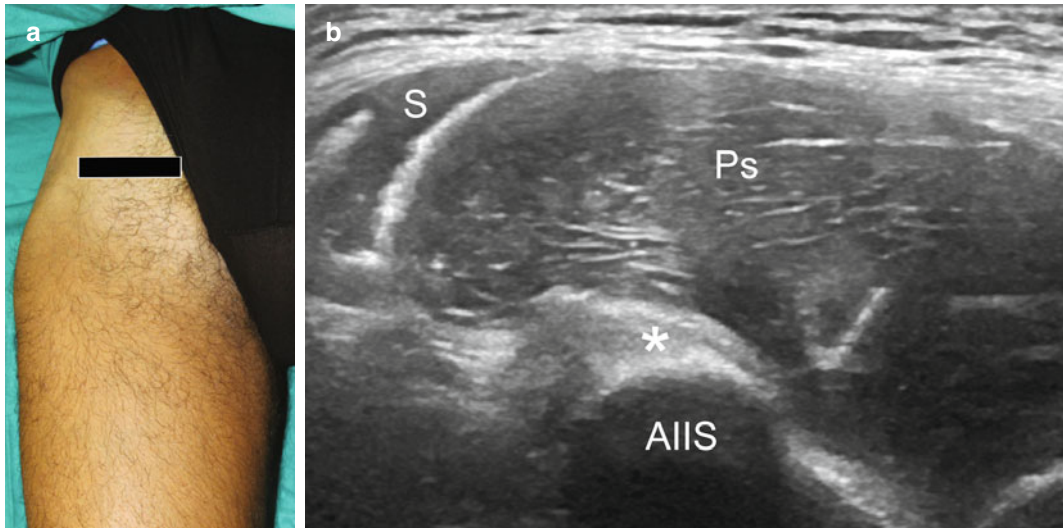

Fig. 9.4 (**a**) Probe position (*axial plane*) to visualize the rectus femoris proximal insertion onto the anterior inferior iliac spine (AIIS). (**b**) US axial scan at AIIS level shows the proximal insertion of the rectus femoris muscle. The direct tendon has an oval hyperechoic shape (*) just above the thin hyperechoic band of the AIIS bony cortex and under the iliopsoas muscle (*Ps*). *S* sartorius muscle

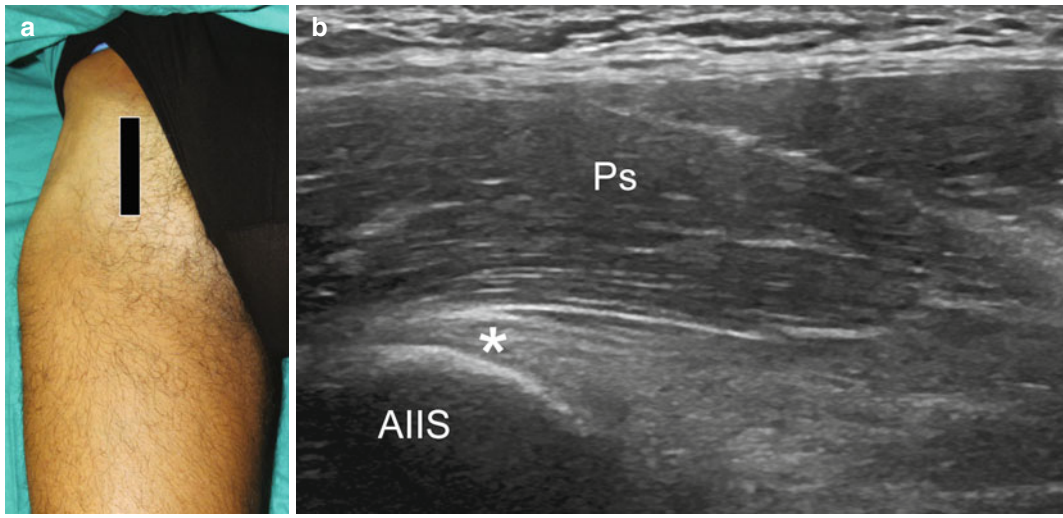

Fig. 9.5 (**a**) Probe position to evaluate the direct tendon of the rectus femoris muscle on the longitudinal plane. (**b**) US longitudinal scan of the direct tendon insertion (*) onto the AIIS. *Ps* iliopsoas muscle

plane, exposing the indirect tendon on its long axis (Fig. 9.7b).

Then, move the transducer medially to reach the anterior inferior iliac spine (AIIS), and then shift the probe caudally to reach the proximal myotendinous junction on its longitudinal plane (Fig. 9.8). Rotating the probe by 90°, complete the evaluation with an axial scan.

Continue the examination exploring the muscle belly and its aponeurotic components on axial scans that provide panoramic views (Fig. 9.9). The exam should be performed from

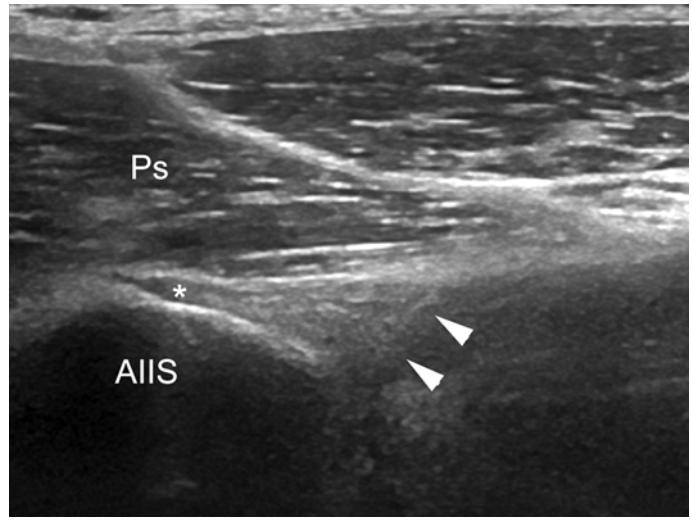

Fig. 9.6 US longitudinal scan shows the direct (*) and indirect (*white arrowheads*) tendon of the rectus femoris muscle. Identify the hypoechoic appearance of the indirect tendon caused by the change in orientation of its fibres (anisotropy), which runs obliquely and externally compared with that of the direct tendon

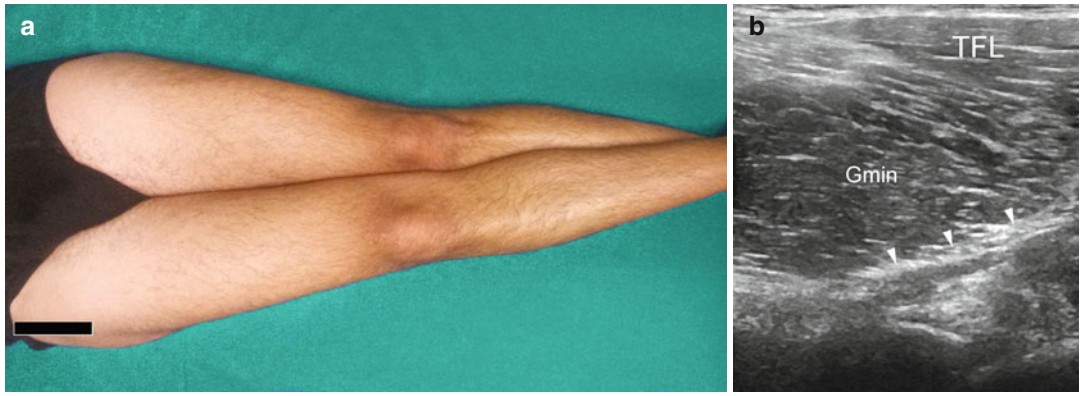

Fig. 9.7 (**a**) Probe position (*axial plane*) to visualize the indirect tendon of the rectus femoris muscle on its long axis. The patient is in a cross-legged position with the examined leg above the other one. (**b**) US axial scan shows the indirect (*white arrowheads*) tendon of the rectus femoris muscle on its long axis. *TFL* tensor fasciae latae, *Gmin* gluteus minimus

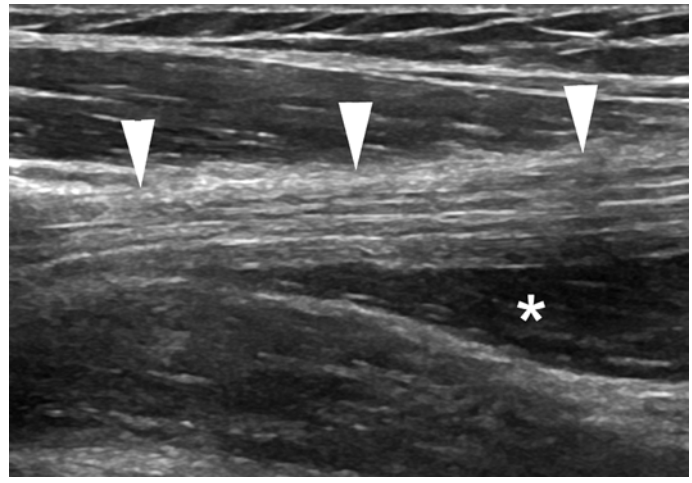

Fig. 9.8 US longitudinal scan shows the proximal myotendinous junction (*white arrowheads*) of the rectus femoris muscle (*)

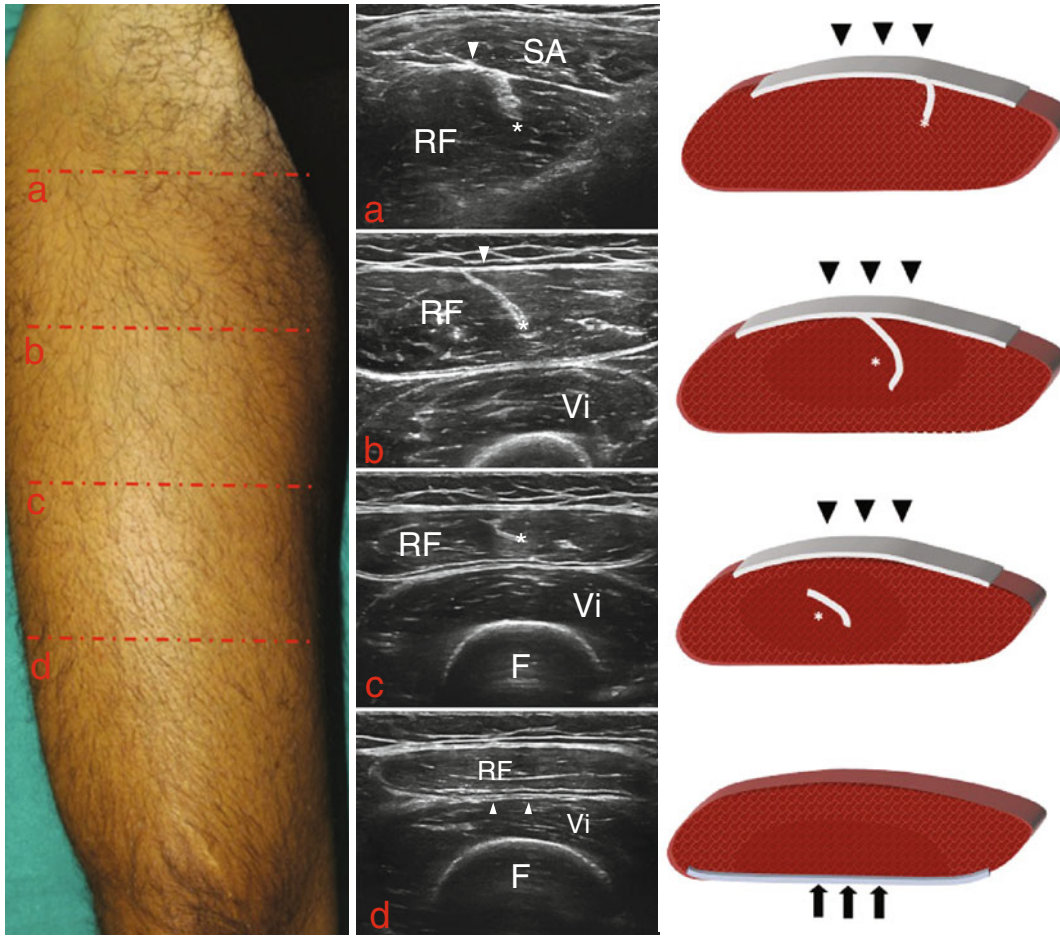

Fig. 9.9 Anatomical schemes correlated to US axial scans at different levels of the rectus femoris muscle and its aponeurotic components. (**a**) Proximal third of the rectus femoris muscle (*RF*). The superficial aponeurosis (*white arrowhead*) is seen as a thin hyperechoic band, just under the sartorius muscle (*SA*); the central aponeurosis (*) appears as a thin hyperechoic structure located within the medial aspect of the muscle. (**b**, **c**) Proximal and distal middle third of the rectus femoris muscle (*RF*). The central aponeurosis (*) becomes flattened, with a typical "comma-shaped" appearance, parallel to the sagittal plane with its long axis and located within the anterior central aspect of the muscle. *Vi* vastus intermedius muscle, *F* femur. (**d**) Distal third of the rectus femoris muscle (*RF*). The deep aponeurosis (*white arrowheads*) is seen as an hyperechoic band, arising from the posterior surface of the muscle belly, located between the rectus femoris and the vastus intermedius (*Vi*) muscles. *F* femur

the proximal myotendinous junction up to the distal myotendinous junction (Fig. 9.10). Look at the superficial aponeurosis at the proximal third and the central aponeurosis at the proximal two-thirds of the muscle belly.

If a strain injury is suspected, perform an accurate examination of the region surrounding the central aponeurosis because it is the most commonly involved in traumatic tears. Indeed, the majority of rectus femoris injuries occur at the deep intramuscular myotendinous junction, while myofascial junction injuries, at the periphery of the muscle, are less frequent.

Rotating the probe by 90°, scan the distal myotendinous junction on its longitudinal plane (Fig. 9.11); then, shift the probe cranially to examine the rectus femoris muscle belly on its major axis (Fig. 9.12).

Complete the examination with the quadriceps tendon analysis (as shown below).

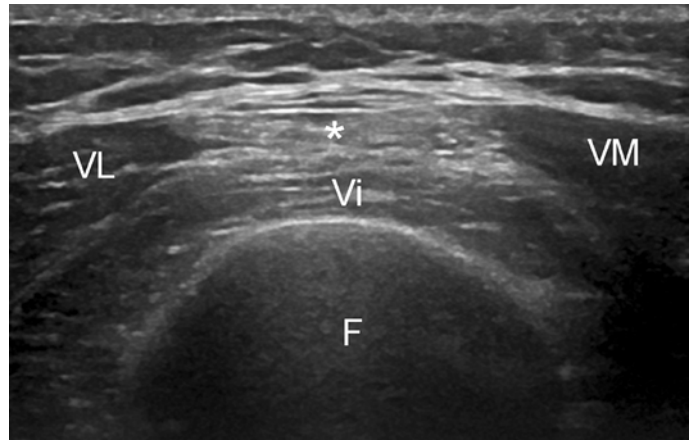

Fig. 9.10 US axial scan of the rectus femoris distal myotendinous junction (*). *VL* vastus lateralis muscle, *VM* vastus medialis muscle, *Vi* vastus intermedius muscle, *F* femur

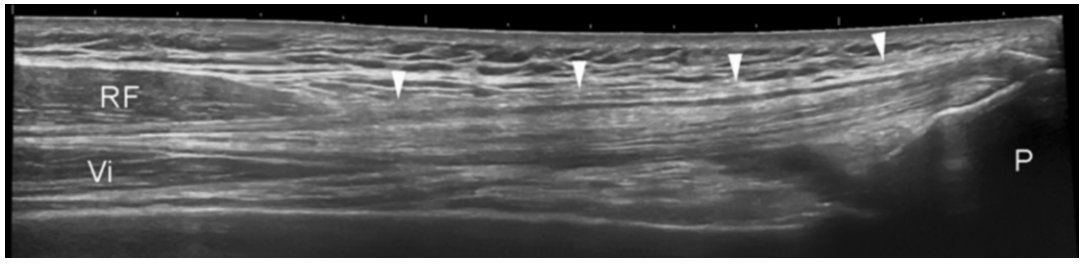

Fig. 9.11 Extended field-of-view of the rectus femoris distal myotendinous junction (*white arrowheads*). *RF* rectus femoris muscle belly, *Vi* vastus intermedius muscle, *P* patella

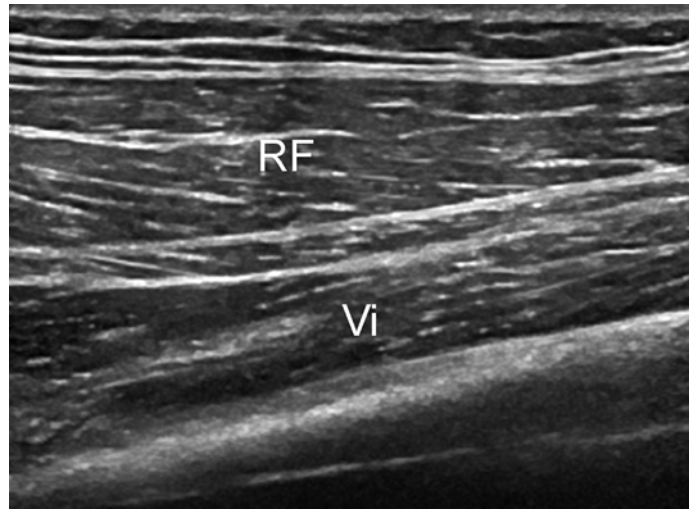

Fig. 9.12 US longitudinal scan of the rectus femoris muscle belly (*RF*). Vi vastus intermedius muscle

9.2 Vastus Muscles

9.2.1 Anatomy Key Points

The *vastus lateralis* (VL) muscle (Fig. 9.13), the largest of the quadriceps femoris bellies, has a multiple origin from the superior intertrochanteric line of the femur, the antero-inferior margin of the greater trochanter, the gluteal tuberosity, the lateral linea aspera and the lateral intermuscular septum. The proximal tendon of the vastus lateralis muscle has a close relationship with the insertional tendon of the gluteus minimum muscle with which it partly bends.

The vastus lateralis muscle belly forms a broad and flattened mass on the femoral shaft lateral to the vastus medialis muscle, deep to rectus femoris muscle and anterior to the biceps femoris muscle. Its lateral surface is covered by the tensor fascia latae muscle (at the proximal third of the thigh) and the ilio-tibial tract (at the distal two-thirds of the thigh).

The distal tendon of the vastus lateralis, together with the vastus medialis tendon, forms the intermediate layer of the quadriceps tendon. In addition, some fibres of the vastus lateralis reach directly the lateral margin of the patella (lateral patellar retinaculum).

The *vastus medialis* (VM) muscle is thicker and less wide than the vastus lateralis. It takes its origin from the entire medial linea aspera, the inferior intertrochanteric line of the femur and the medial intermuscular septum.

The muscle belly covers the medial aspect of the femur, at the same level of the vastus lateralis, placing deep to rectus femoris and anterior to the adductor muscles. At the middle third of the thigh, it is overcome superficially by the sartorius muscle.

The distal tendon of the vastus medialis, together with that of the vastus lateralis, forms the intermediate layer of the quadriceps tendon. Some fibres of the vastus medialis attach directly onto the medial margin of the patella (medial patellar retinaculum).

The *vastus intermedius* (VI) muscle is the deepest of the vastus muscles, lying in direct contact with the femoral diaphysis, largely covered by the vastus lateralis and medialis muscles. It has an extensive proximal insertion onto the inferior and lateral linea aspera (as the vastus lateralis), the anterior and lateral femoral shaft and the lateral intermuscular septum.

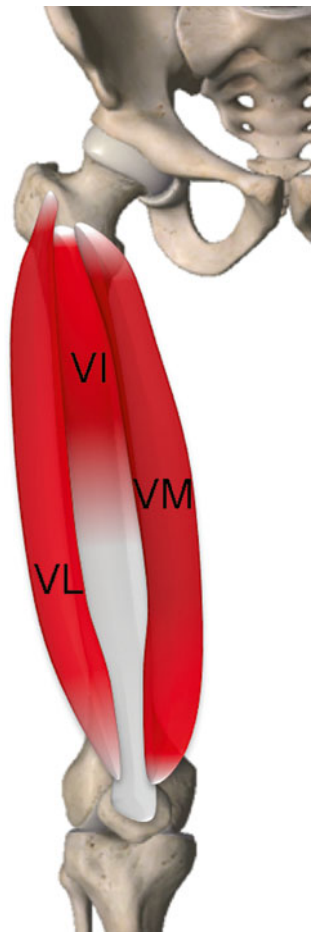

Fig. 9.13 Anatomical scheme of the vastus muscle group: *VM* vastus medialis muscle, *VL* vastus lateralis muscle, *VI* vastus intermedius muscle

The vastus intermedius distal tendon contributes to form the deep layer of the quadriceps tendon.

9.2.2 Ultrasound Examination Technique

The patient lies supine with the lower limb extended on the examination table (Fig. 9.14).

Place the probe in the axial plane on the anterior inferior iliac spine (AIIS), the main bony landmark used to identify the proximal insertion of the rectus femoris muscle, as shown in Fig. 9.4. Then, shifting the probe caudally, visualize its proximal myotendinous junction and muscle belly, as show in Fig. 9.9b.

From this position, shift the probe laterally to image the *vastus lateralis* muscle belly at its proximal third (Fig. 9.15a). The vastus lateralis has a wide proximal insertion on the proximal and lateral femoral shaft not clearly detectable on US examination.

Continue the exam moving the probe caudally along the anterolateral surface of the thigh to examine the vastus lateralis muscle belly in its full extension (Fig. 9.15b), up to the distal myotendinous junction, located at the distal third of the thigh (Fig. 9.16).

Rotate the probe by 90° to visualize the vastus lateralis distal myotendinous junction and tendon on their long axis (section "quadriceps tendon evaluation").

Shifting the probe cranially, complete the US examination imaging the vastus lateralis muscle belly on the longitudinal plane (Fig. 9.17).

As described before, also for the *vastus medialis* muscle examination, the rectus femoris muscle must be considered the main anatomic landmark, so start the examination placing the probe in the axial plane to visualize the rectus femoris muscle belly, as shown in Fig. 9.9a.

Shifting the probe medially on the axial plane, the vastus medialis muscle appears anterior to the adductors, medial to the rectus femoris and superficial to the vastus intermedius muscles (Fig. 9.18). Similar to the vastus lateralis muscle, the tendinous origin of the vastus medialis is not clearly identifiable on US examination.

Fig. 9.14 Lower limb position for vastus muscles evaluation

Move the probe caudally, along the anteromedial thigh, to examine the vastus medialis muscle belly on the axial plane, at different levels (Fig. 9.19).

Note the close relationship of the vastus medialis muscle with the superficial femoral neurovascular bundle for almost its entire course. The course of the femoral bundle, located medially to the vastus medialis, can be used as a helpful anatomical landmark (Fig. 9.20).

The vastus medialis muscle belly extends more distally than the vastus lateralis and the vastus intermedius muscles, descending in proximity of the superior pole of the patella (Fig. 9.21).

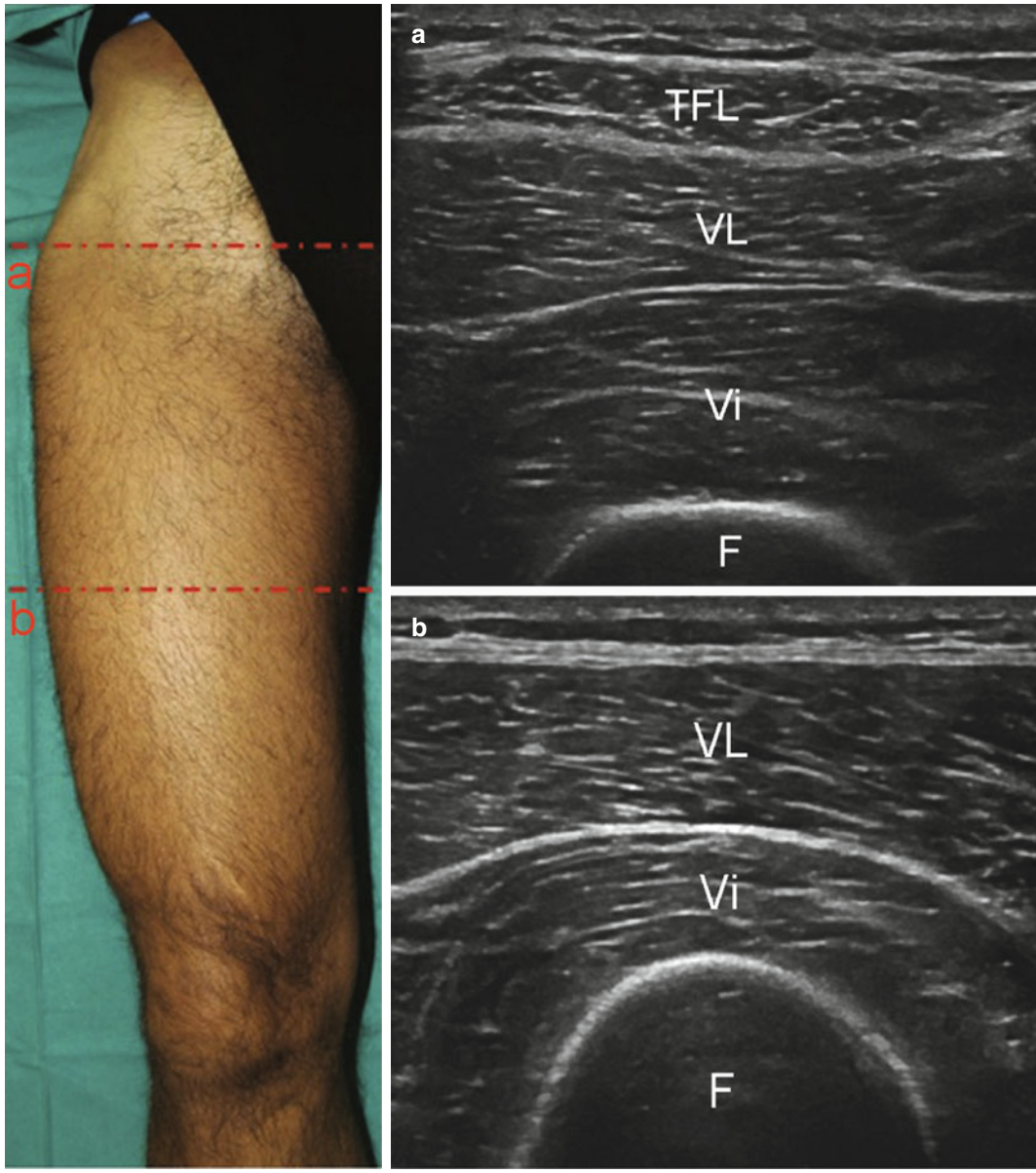

Fig. 9.15 Probe position to evaluate the vastus lateralis muscle on the axial plane. (**a**) US axial scan at the proximal third of the anterolateral thigh: the vastus lateralis (*VL*) muscle belly is identifiable deep to the tensor fasciae latae (*TFL*) and superficial to the vastus intermedius (*Vi*) muscles. (**b**) US axial scan at the middle and distal third of the thigh: the vastus lateralis (*VL*) lies in a superficial position, just under the subcutaneous tissue. *Vi* vastus intermedius muscle. *F* femur

At the distal third of the thigh, visualize its distal myotendinous junction and tendon on the axial plane (Fig. 9.22).

Rotate the probe by 90° to evaluate the distal myotendinous junction and tendon also in the longitudinal plane (Fig. 9.23).

Starting from the position shown in Fig. 9.9a, the *vastus intermedius* muscle belly is seen deep to rectus femoris muscle in direct contact with the anterior surface of the femoral shaft (Fig. 9.24). The identification of the femoral cortex on the deep portion of the image helps to find the exact scan.

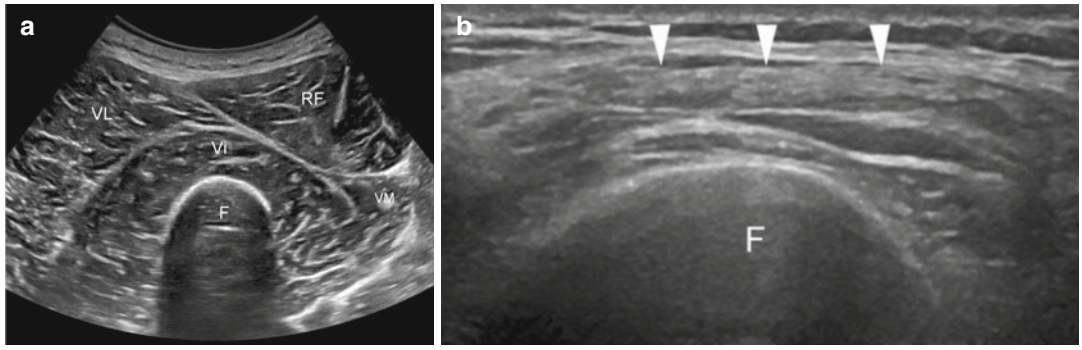

Fig. 9.16 (**a**) US axial scan at the middle third of the anterolateral thigh, using a convex-array probe that allows a more panoramic view. The vastus lateralis muscle (*VL*) is imaged lateral to the rectus femoris (*RF*) and superficial to the vastus intermedius muscles (*Vi*). *VM* vastus medialis muscle, *F* femur. (**b**) US axial scan of the distal myotendinous junction of the vastus lateralis muscle (*white arrowheads*). *F* femur

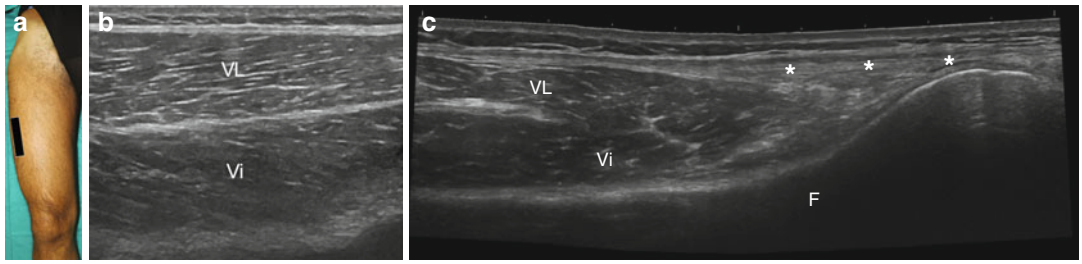

Fig. 9.17 (**a**) Probe position to evaluate the vastus lateralis muscle on the longitudinal plane. (**b**) US longitudinal scan of the vastus lateralis muscle belly (*VL*). (**c**) Extended field-of-view of the vastus lateralis and vastus intermedius muscles along the lateral thigh; *Vi* vastus intermedius muscle; (*), ilio-tibial band

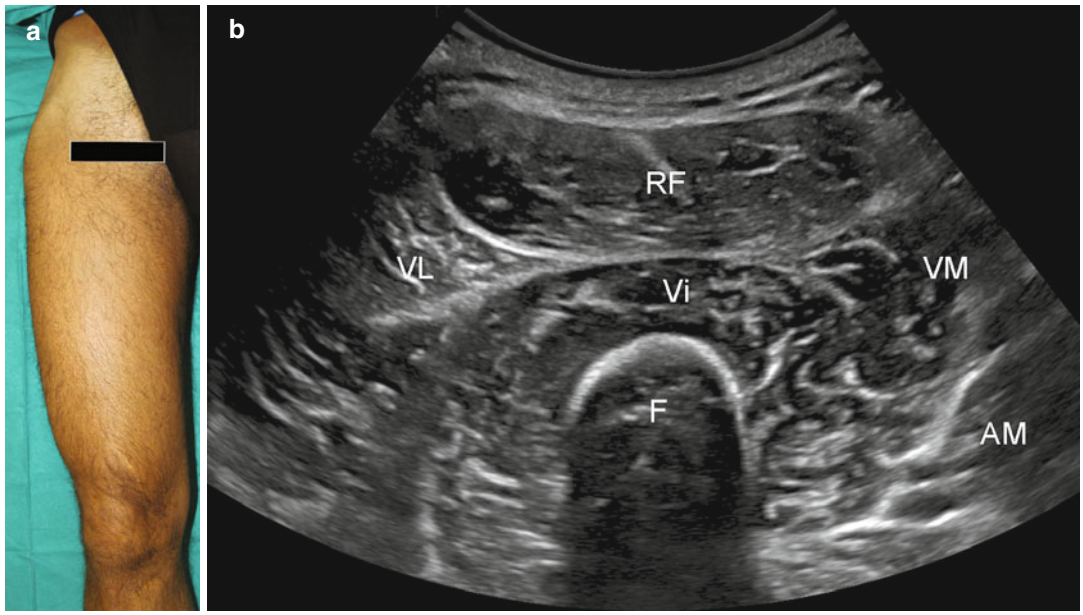

Fig. 9.18 (**a**) Probe position to evaluate the vastus medialis muscle on the axial plane. (**b**) Panoramic axial scan of the anteromedial muscles of the thigh. *RF* rectus femoris muscle, *VL* vastus lateralis muscle, *VM* vastus medialis muscle, *Vi* vastus intermedius muscle, *AM* adductor magnus muscle, *F* femur

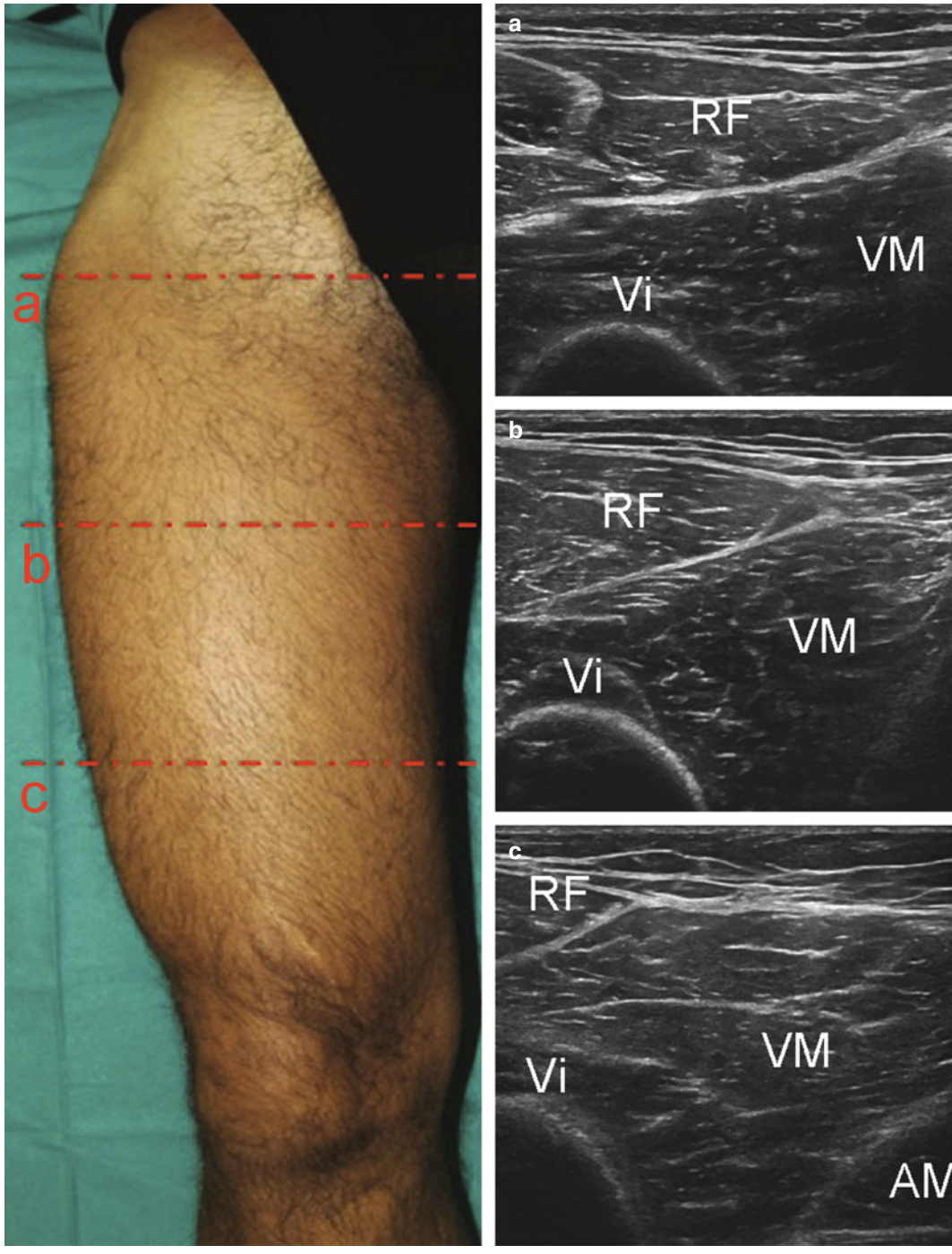

Fig. 9.19 Probe position to evaluate the vastus medialis muscle belly at different levels on the axial plane. US axial scan of the vastus medialis (*VM*) muscle belly at the proximal (**a**), middle (**b**) and distal (**c**) third of the anteromedial thigh. *RF* rectus femoris muscle, *Vi* vastus intermedius muscle, *AM* adductor magnus muscle

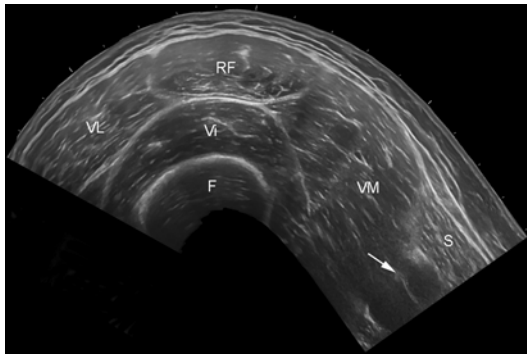

Fig. 9.20 Extended field-of-view of the vastus medialis (*VM*) muscle belly at the middle third of the anteromedial thigh. Look at the superficial neurovascular bundle (*white arrow*). *RF* rectus femoris muscle, *VL* vastus lateralis muscle, *VM* vastus medialis muscle, *Vi* vastus intermedius muscle, *S* sartorius muscle, *F* femur

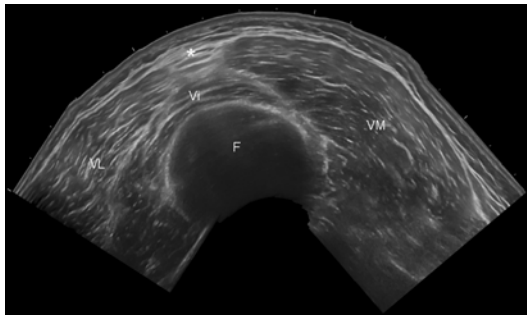

Fig. 9.21 Extended field-of-view of the vastus medialis (*VM*) muscle belly at the distal third of the thigh. The vastus medialis shows a large muscle belly while the vastus lateralis (*VL*) and the vastus intermedius (*Vi*) muscles start to decrease in size to become tendinous. *Asterisk*, rectus femoris distal tendon fibres

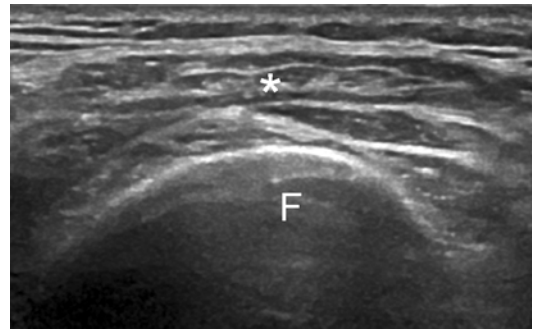

Fig. 9.22 US axial scan of the vastus medialis distal myotendinous junction (*). *F* femur

Move the probe caudally, along the central anterior thigh, to visualize the entire muscular mass.

In patients with significant muscle mass, such as obese patients or athletes, the use of low-frequency-convex array probes may help to obtain an appropriate depiction of the deeper aspect of the muscle.

At the distal third of the thigh, identify the distal myotendinous junction on an axial plane, up to the distal tendon where the vastus intermedius muscle fibres fit into the deep lamina of the quadriceps tendon (Fig. 9.25).

Rotate the probe clockwise by 90 ° and get a longitudinal scan of the distal tendon and the myotendinous junction (Fig. 9.26).

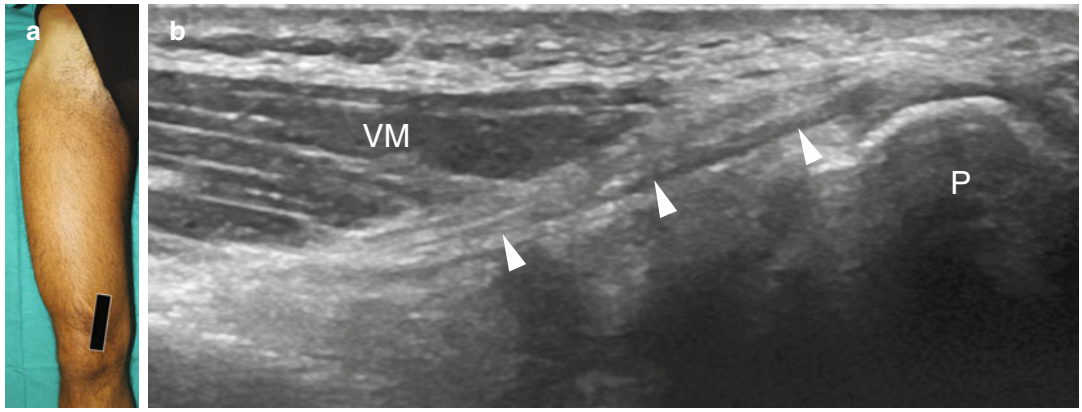

Fig. 9.23 (**a**) Probe position to evaluate the vastus medialis distal myotendinous junction on the longitudinal plane. (**b**) US longitudinal scan of the vastus medialis (*VM*) distal myotendinous junction. *White arrowheads*, vastus medialis distal tendon; *P* patella

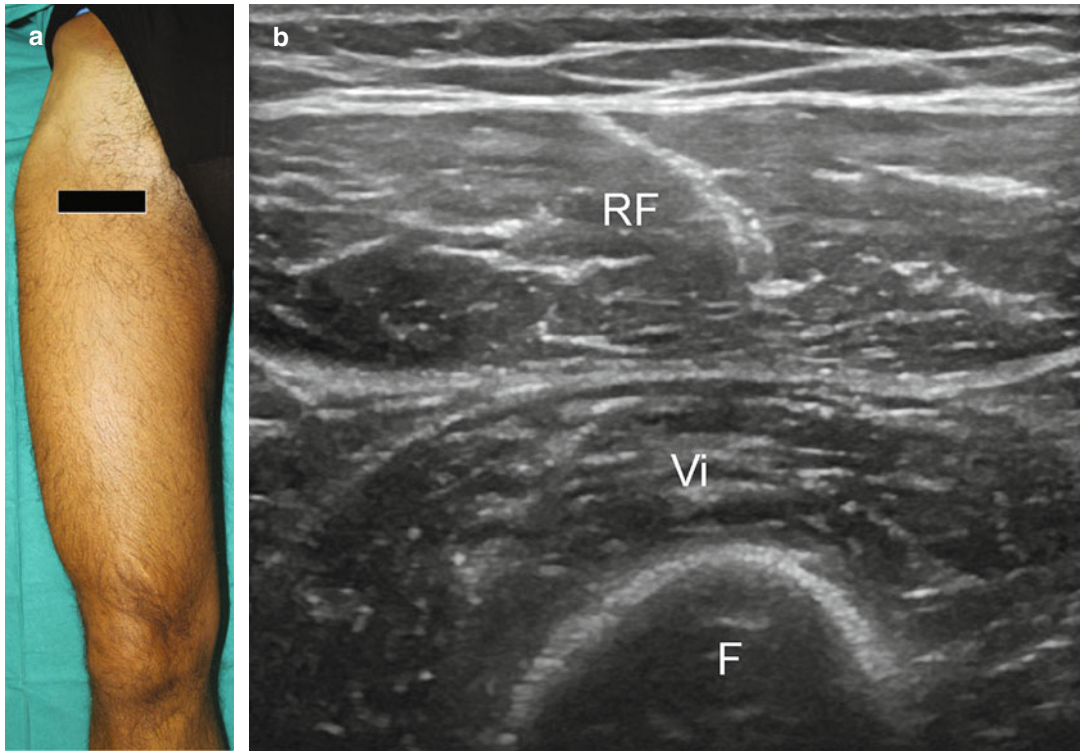

Fig. 9.24 (**a**) Probe position to evaluate the vastus intermedius muscle on the axial plane. (**b**) US axial scan of the vastus intermedius muscle belly. *Vi* vastus intermedius muscle, *RF* rectus femoris muscle, *F* femur

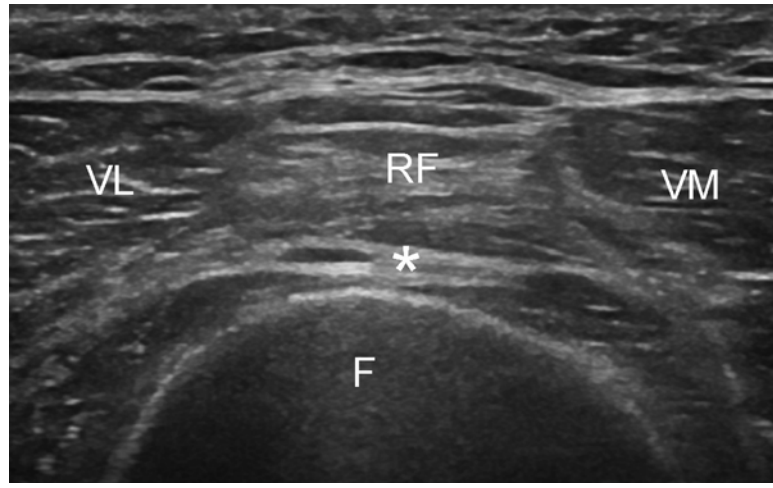

Fig. 9.25 US axial scan of the vastus intermedius distal myotendinous junction (*). *RF* rectus femoris muscle, *VL* vastus lateralis muscle, *VM* vastus medialis muscle, *F* femur

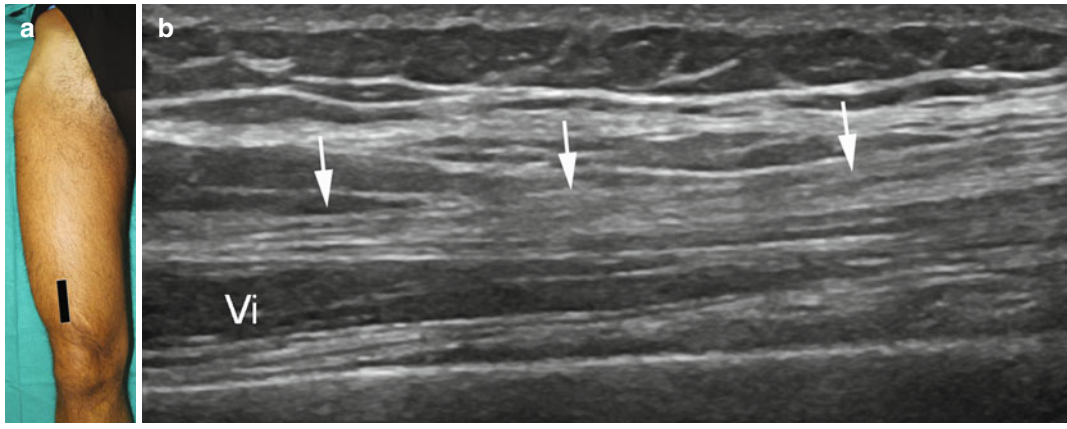

Fig. 9.26 (**a**) Probe position to evaluate the vastus intermedius distal myotendinous junction on the longitudinal plane. (**b**) US longitudinal scan of the vastus intermedius distal myotendinous junction (*white arrows*). *Vi* vastus intermedius muscle

9.2.3 Summary Table

Muscle	Origin	Insertion	Nerve supply	Action
Rectus femoris	AIIS (direct tendon), supero-lateral aspect of the acetabular rim (indirect tendon), anterior capsule of the hip joint (reflected)	Superior pole of the patella (superficial lamina of the quadriceps tendon), tibial tuberosity (patellar tendon)	Femoral nerve	Extension of the knee Flexion of the hip
Vastus lateralis	Superior intertrochanteric line of the femur, antero-inferior margin of the greater trochanter, gluteal tuberosity, lateral linea aspera, the lateral intermuscular septum	Superior pole of the patella (intermediate lamina of the quadriceps tendon)	Femoral nerve	Extension of the knee
Vastus medialis	Medial linea aspera, inferior intertrochanteric line of the femur, medial intermuscular septum	Superior pole of the patella (intermediate lamina of the quadriceps tendon)	Femoral nerve	Extension of the knee
Vastus intermedius	Inferior and lateral linea aspera, anterior and lateral femoral shaft, lateral intermuscular septum	Superior pole of the patella (deep lamina of the quadriceps tendon)	Femoral nerve	Extension of the knee

9.3 Quadriceps Tendon

9.3.1 Anatomy Key Points

The distal insertions of the vastus muscles converge with the rectus femoris muscle to form an apparently unique tendinous structure, the quadriceps tendon.

The *quadriceps tendon* is a multilayered fibrous band that attaches onto the superior pole of the patella. It has a trilaminar appearance because three different layers constitute it: the superficial one contains the fibres from the rectus femoris muscle; the intermediate lamina is formed by the vastus medialis and lateralis fibres melted together; the deep layer contains the vastus intermedius distal tendinous fibres. These distinct layers are separated by fibroadipose bands of tissue that allow gliding movements during quadriceps muscle activation.

9.3.2 Ultrasound Examination Technique

The patient lies supine with the knee flexed at about 30°–45° to straighten the tendon.

Place the probe on a longitudinal plane with the distal edge on the superior pole of the patella and evaluate the quadriceps tendon on its major axis (Fig. 9.27a–c).

Then complete the examination with axial scans (Fig. 9.27c). Pay attention to the quadriceps tendon features: usually, it appears quite irregular because of the orientation of the converging fibres coming from the three different layers (rectus femoris, vastus medialis and lateralis, vastus intermedius muscles).

Extended field-of-view systems are particularly well suited to illustrate the distal myotendinous junctions and the tendon in a panoramic image.

Fig. 9.27 (**a**) Probe position to evaluate the quadriceps tendon on the longitudinal plane. (**b**) US longitudinal scan shows the typical hyperechoic multilayered appearance of the quadriceps tendon. The superficial lamina of the quadriceps tendon is formed by the rectus femoris fibres (*white arrowheads*); the intermediate layer is constituted by the fibres of the vastus lateralis and medialis; the vastus intermedius contribute to the formation of the deep lamina (*void arrowheads*). (*) suprapatellar recess; *P* patella. (**c**) US axial scan shows the oval hyperechoic appearance of the quadriceps tendon (*). (°), articular cartilage; *T* femoral trochlea

Suggested Reading

Hart JM, Pietrosimone B, Hertel J, Ingersoll CD (2010) Quadriceps activation following knee injuries: a systematic review. J Athl Train 45(1):87–97

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