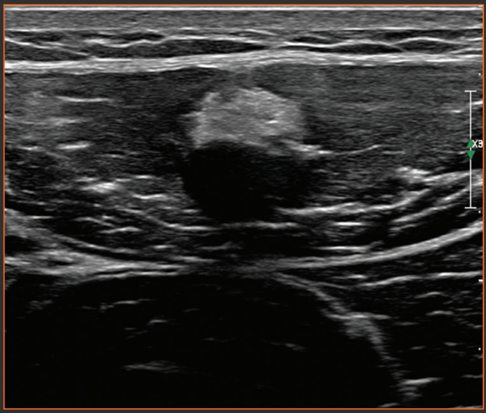
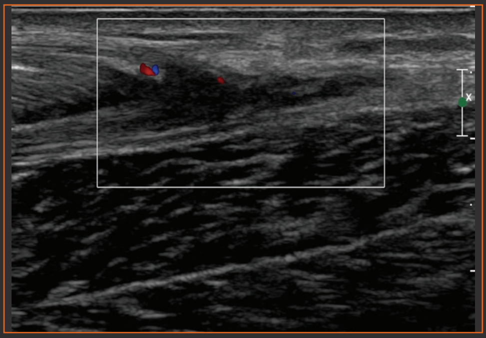
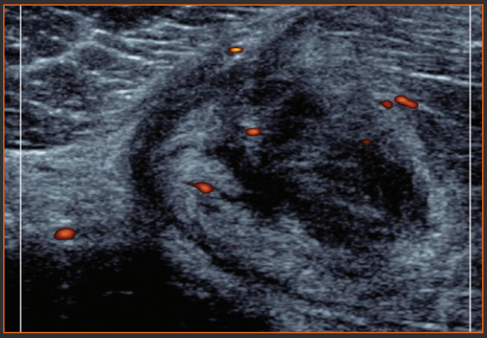
DIAGNOSTIC AND INTERVENTIONAL
MUSCULOSKELETAL ULTRASOUND IMAGING

Journal of the French Musculoskeletal Imaging Society (SIMS)

• Fascias and aponeurosis injuries •



S.I.M.S
SOCIÉTÉ D'IMAGERIE MUSCULO-SQUELETTIQUE

Number 2

June 2020

SOCIÉTÉ D'IMAGERIE MUSCULO-SQUELETTIQUE

Dear colleagues,

The lifting of some lockdown measures from 11 May means that it is possible to gradually resume osteoarticular imaging activities. However, the continued risk of contamination associated with the circulation of the virus means that certain protective measures must be taken when dealing with patients.

Specific information on Covid-19 may be provided to patients, informing them that coming to a radiology clinic puts them at risk of contamination, as for any other time they leave their house, and stating that they will abide by the measures implemented at the imaging facility.

A self-questionnaire may be offered to patients before attending or on arrival at the facility to screen for coronavirus infection and adapt how the patient is managed and how quickly they are seen (JFR questionnaire available at this link).

Musculoskeletal ultrasound can be carried out according to the usual indications. During the pandemic, this requires specific protective measures for both the patient and the radiologist:

- wearing of a mask by the patient and the radiologist;
- specific disinfection between patients of all surfaces in contact with the patient (patient bed, chairs, table, etc.), probes and ultrasound machine (keyboard, trackball, etc.).

In case of a Covid+ patient, other means of imaging must be considered. If the indication for ultrasound is maintained, in addition to a mask (surgical or FFP2), the wearing of a hairnet, gloves, goggles or a visor and a protective gown is recommended.

No scientific studies have determined that cortisone-derivative injections increase or aggravate the risk of coronavirus infection. Radio-guided, CT-guided and ultrasound-guided injections can therefore be carried out according to the usual rules concerning indications, taking into account:

- the risk of contamination for a patient coming to a medical facility;
- precautions for protecting the patient and the medical practitioner from all viral contamination, in addition to the usual sterility measures.

The usual information and specific information on Covid-19 must be provided to the patient before the intervention appropriately and as usual. This can also be done via a virtual consultation.

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Editorial

Dear members and friends,

This latest issue from Diagnostic and Interventional Musculoskeletal Ultrasound Imaging is dedicated to the subject of muscular lesions involving the fascia and aponeurosis. It provides yet another demonstration of how dynamic the French Musculoskeletal Imaging Society (SIMS) is along with how significant a role is played by musculoskeletal imaging in the diagnosis and treatment of these conditions.

I wish first of all to express my gratitude to the editorial committee, whose expert handling of the multitude of ideas for this work successfully ensured its coherence and solid structure. I would also like to thank all our authors, from Belgium, Switzerland, Canada, and France. Diagnostic and Interventional Musculoskeletal Ultrasound Imaging has a clear and defined teaching goal, and its articles are purposefully concise in style, at times using powerful punchlines to get a point across. There are two introductory chapters presenting the symptomatology of intrinsic and extrinsic muscle trauma. Then different teams, each with a wealth of experience, go into detail focussing on the specific anatomical areas of the lower limbs, thoracic wall, and shoulder girdle. It is the care and precision with which these articles have been edited, along with the depth of information provided and high quality of the illustrations, which make this edition such an essential addition to the field of musculoskeletal imaging. Furthermore, once translated it will no doubt become a fundamental tool for communicating on and promoting this technique.

I hope you enjoy reading this work, which aspires to be a compensatory piece to the Covid19 report of our day-to-day in June 2020. I also look forward to us hopefully being reunited in June 2021 with ever more thirst for knowledge and learning.

Last but not least, this Diagnostic and Interventional Musculoskeletal Ultrasound Imaging edition is published alongside a video produced by the Bordeaux sport clinic on the subject of pubalgia

Prof. Alain Blum

President of the S.I.M.S.

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Summary

Fascias and aponeurosis injuries

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01 Intrinsic muscle injuries

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Point 1. Muscle histology

Muscle components are surrounded by connective tissue structures **(Fig. 1)** called the:

- Endomysium, which surrounds the muscle fibers
- Perimysium, which surrounds the muscle fascicles
- Epimysium, which surrounds the muscle

Perimuscular fascias can only be seen on ultrasonography (US), where they appear as hypoechoic bundles bordered by hyperechoic perimysium **(Fig. 2)**.

When a muscle contracts, the purely muscular component shortens and expands **(Fig. 3)** while the pennation angle between the muscle fascicles and their point of attachment increases.

Blood vessels course in the perimysium **(Fig. 4)** and are easy to find on magnetic resonance imaging (MRI) or Doppler US **(Fig. 5)**.

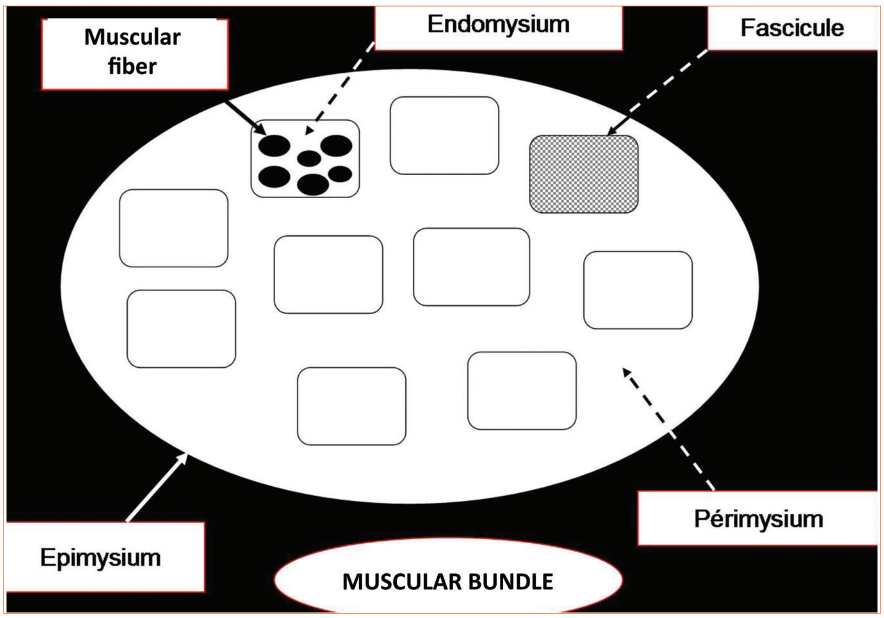

Figure 1: *Components of the muscle.*

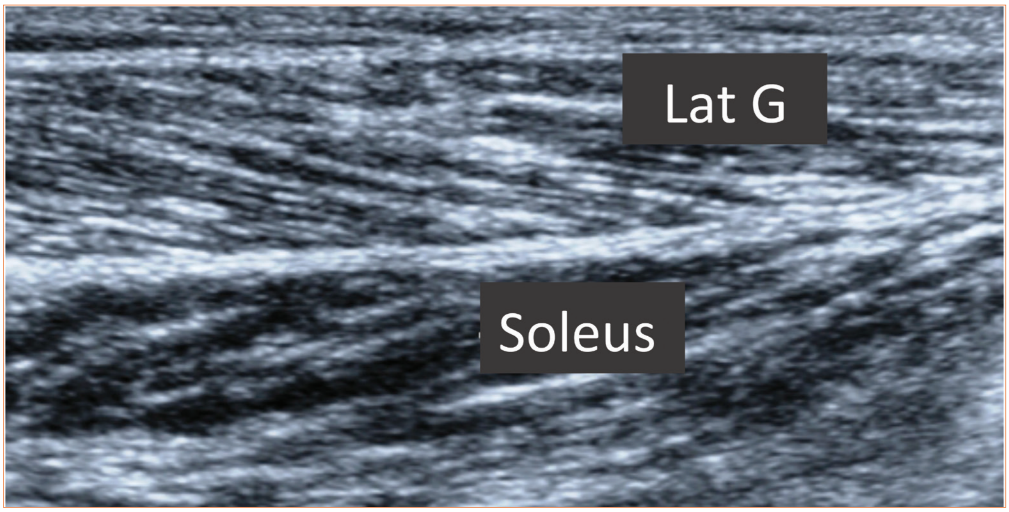

Figure 2: *US appearance. The hypoechoic bundles represent the muscle fascicles and the hyperechoic lines the connective tissue.*

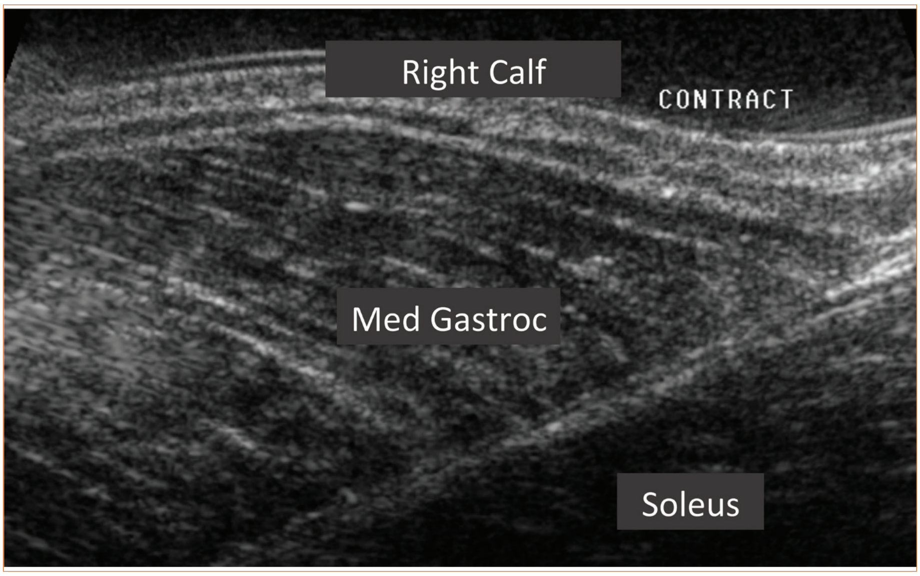

Figure 3: *During contraction, the hypoechoic muscle component shortens and expands, while the pennation angle increases.*

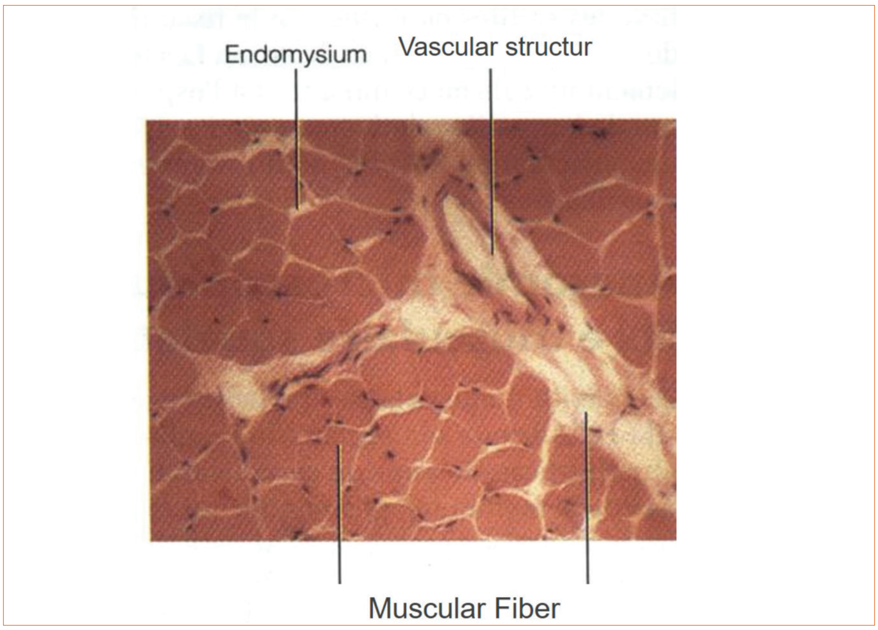

Figure 4: *Vessels coursing within the perimysium.*

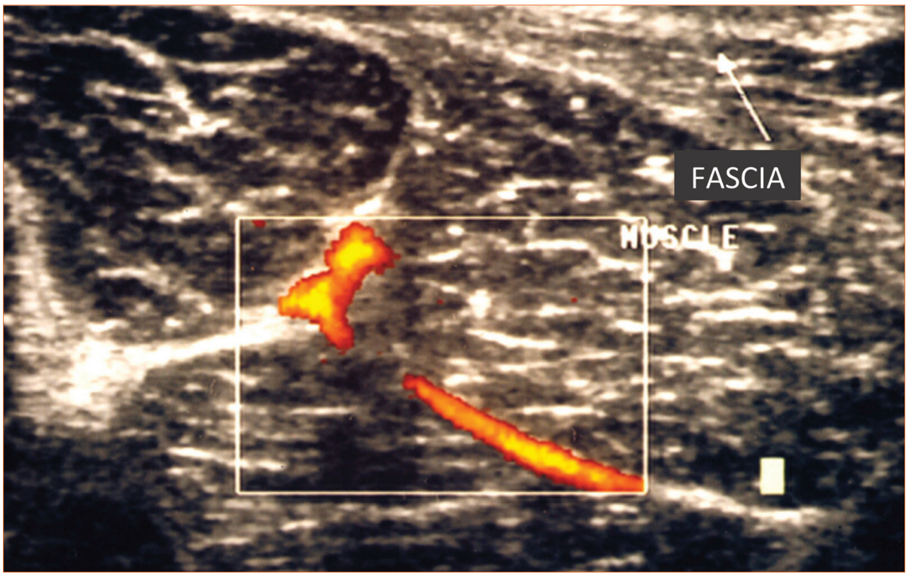

Figure 5: *Doppler image showing perimysium vasculature.*

Point 2. The connective tissue framework of the muscle

Often in certain muscles, one or more connective tissue components arise from the tendon (Fig. 6), while others branch off from the perimuscular fascia (Fig. 7).

Taken together, these form a framework of connective tissue to which the muscle fascicles attach (Fig. 8).

Hence the longitudinal anatomy of a muscle is not bone, then tendon, then body, but bone, then tendon, then intra- and perimuscular connective tissue extensions (Fig. 9). These resemble the stem and veins of a leaf or the branches of a tree (Fig. 10). The muscle fascicles attach to this framework much as the leaves of a tree attach to its branches.

This framework is an important consideration in intrinsic injuries, but only some muscles possess it.

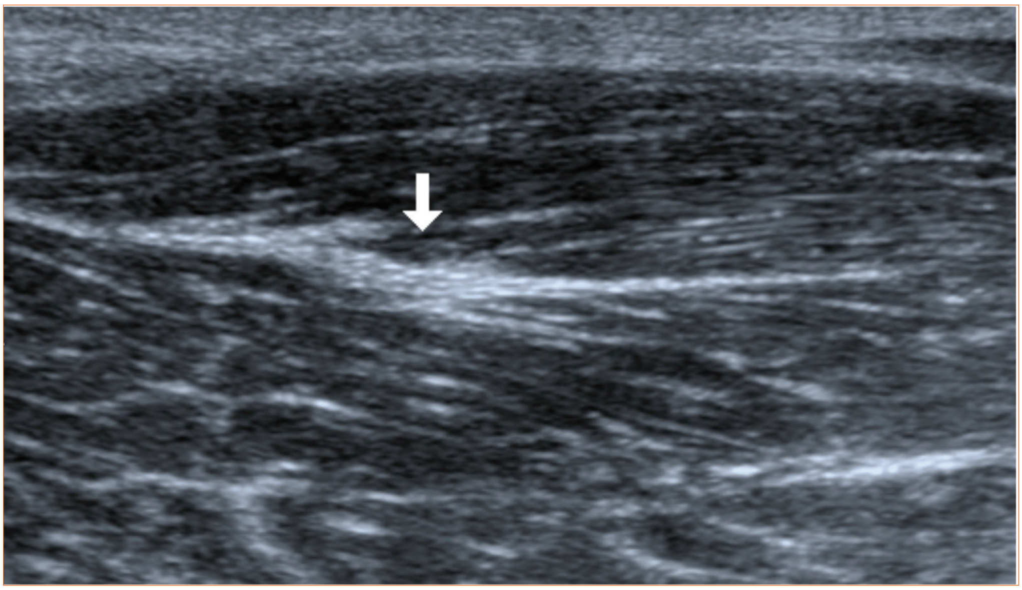

Figure 6: *Intramuscular tendon extension (arrow) in the adductor longus.*

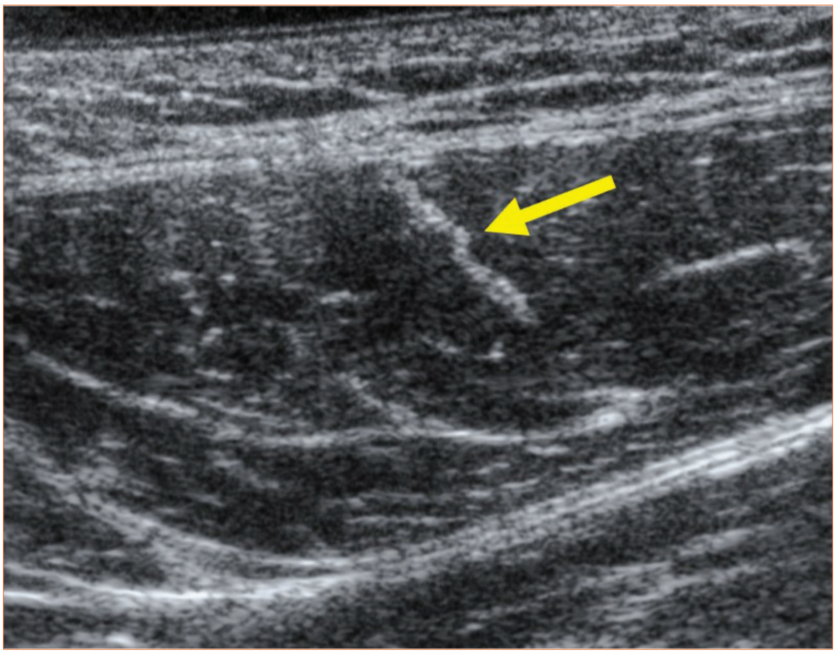

Figure 7: *Intramuscular connective tissue (arrow) branching off from perimuscular fascia.*

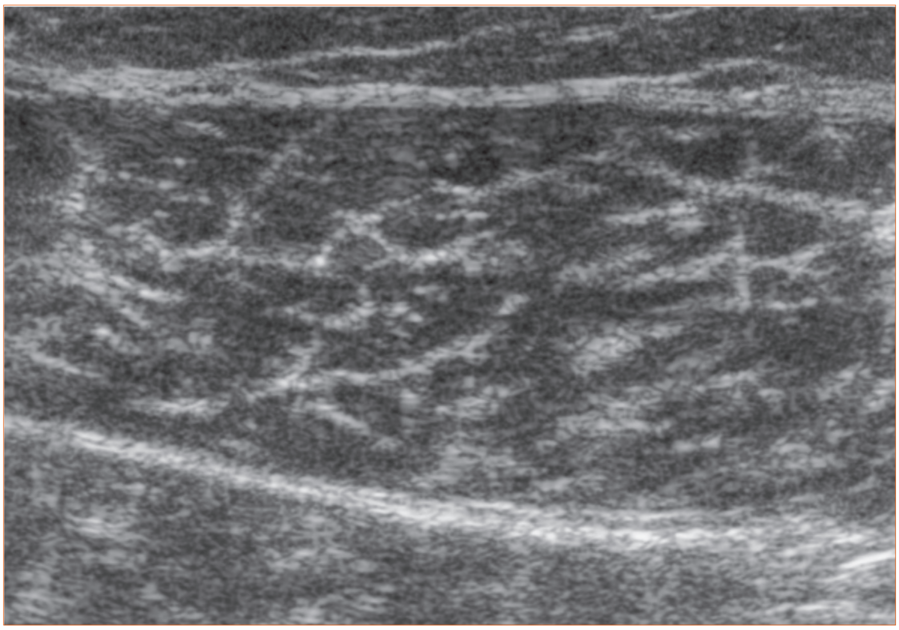

Figure 8 : : *Axial view of the central portion of the muscle showing a hyperechoic connective tissue framework partitioning the hypoechoic muscle components.*

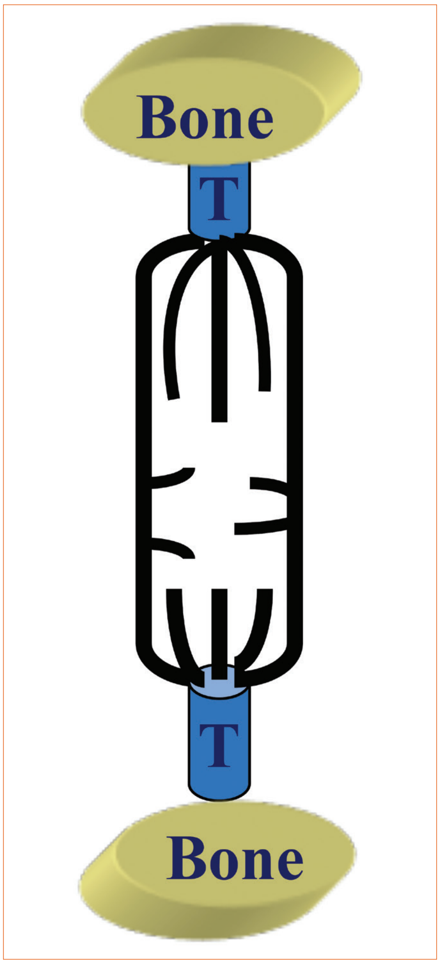

Figure 9: *Longitudinal anatomy of the muscle. Bone, then tendon, then the connective tissue framework, which comprises intramuscular tendinous extensions, perimuscular fascia, and intramuscular connective tissue arising from this fascia.*

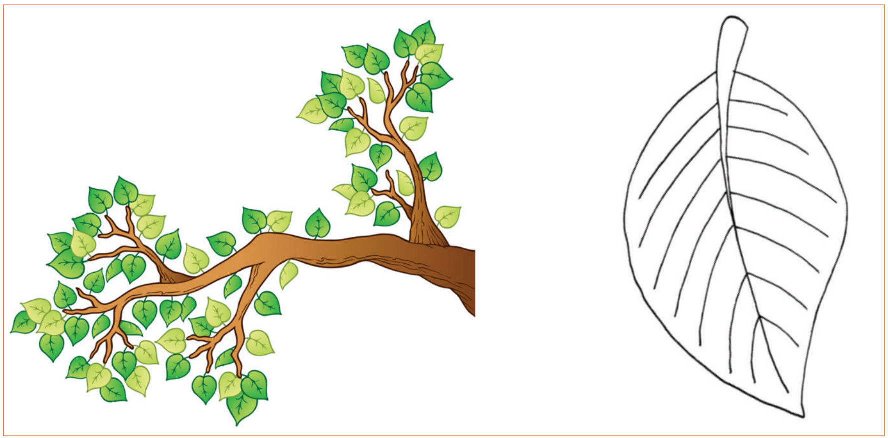

Figure 10: *The connective tissue framework of the muscle can be compared to the trunk and branches of a tree (with the muscle components being the leaves) or to the stem and veins of a leaf.*

Point 3. Types of muscle

Only some muscles possess this connective tissue framework.

Most of those that do are located in the limbs.

The most important connective tissue components are found in the adductors, quadriceps, and calf, particularly the central tendon of the adductor longus, sagittal tendon of the rectus femoris, and soleus **(Fig. 11)**. However, the prime example is the hamstrings, which include several landmarks:

- Intramuscular extension of the conjoined tendon **(Fig. 12)**
- Tendon of the semimembranosus **(Fig. 13)**
- Membranous aponeurosis of the semimembranosus **(Fig. 14)**
- Sigmoid septum of the semitendinosus **(Fig. 15)**
- Central tendon of the semimembranosus **(Fig. 16)**
- Central tendon of the long head of the biceps femoris **(Fig. 17)**

Added to these are the distal tendinous insertions of the medial gastrocnemius and long head of the biceps femoris

Familiarity with these connective tissue components is crucial. They must be checked in all cases, because they are at the root of numerous injuries.

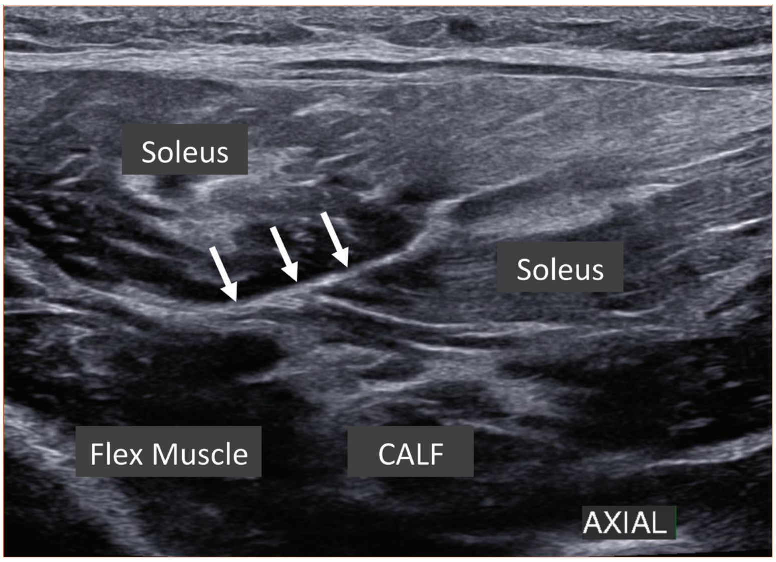

Figure 11 : *Sagittal tendon of the soleus.*

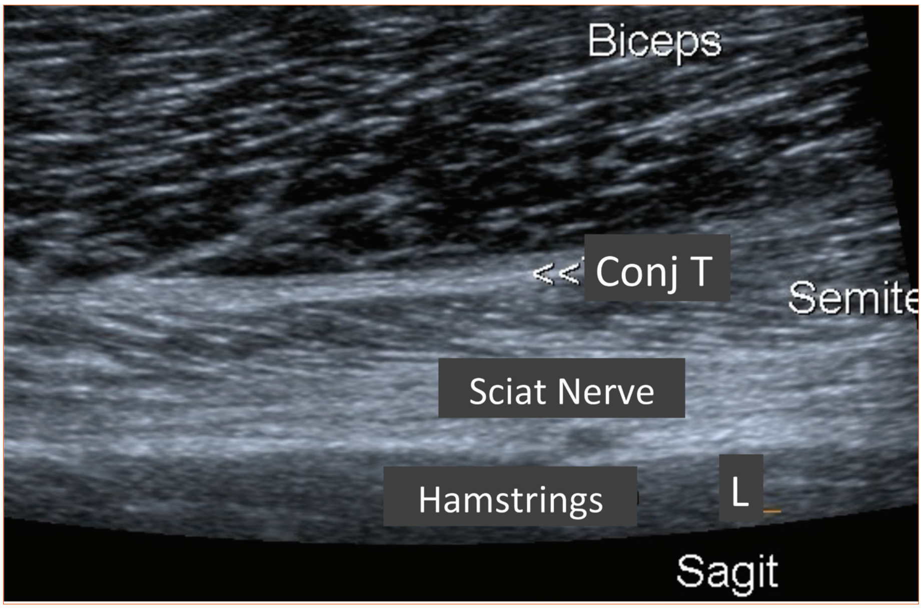

Figure 12 : Intramuscular extension of the conjoined tendon.

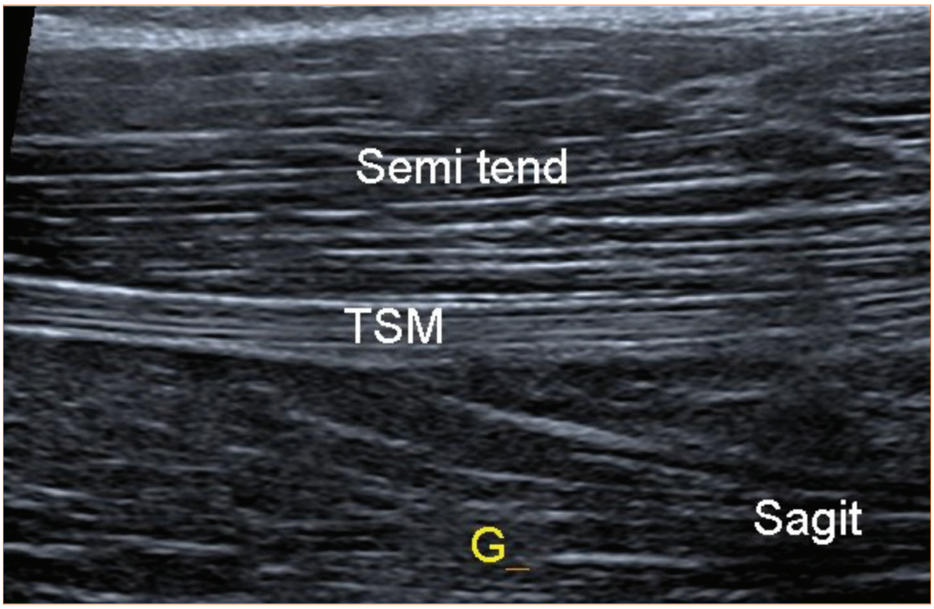

Figure 13 : Tendon of the semimembranosus.

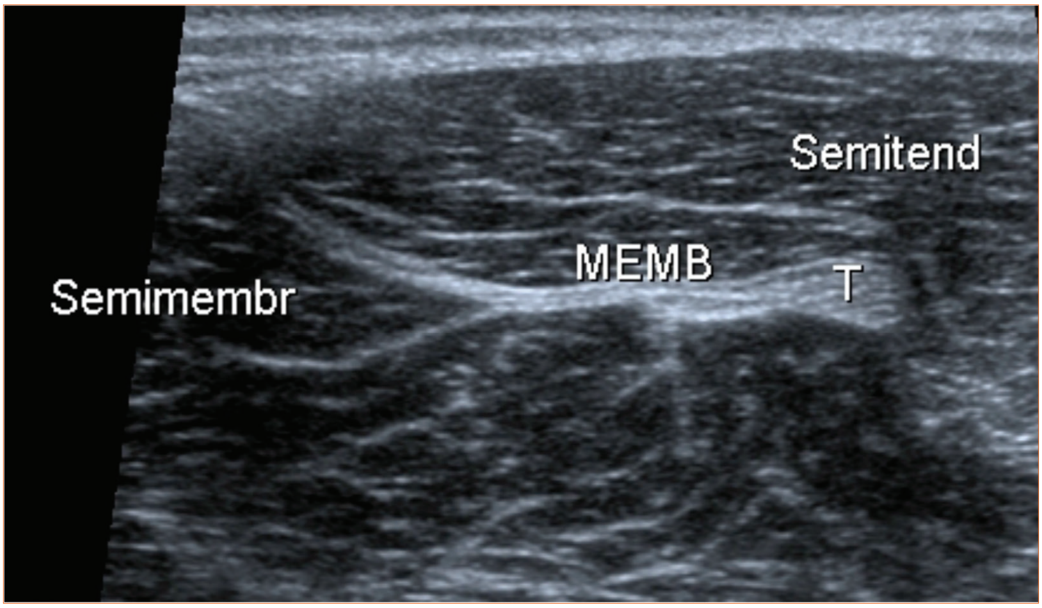

Figure 14 : Membranous tendon of the semimembranosus between the semitendinosus and adductor magnus deeply.

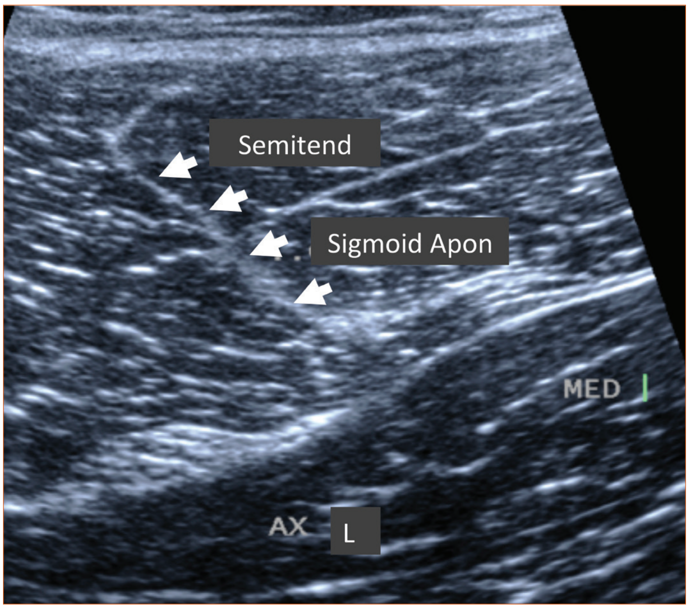

Figure 15 : *Sigmoid septum going through the semitendinosus.*

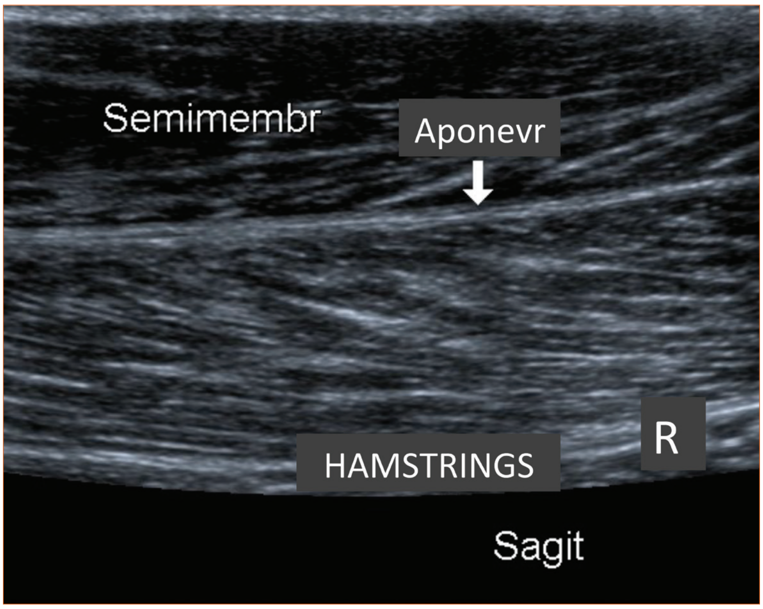

Figure 16 : *Central tendon of the semimembranosus.*

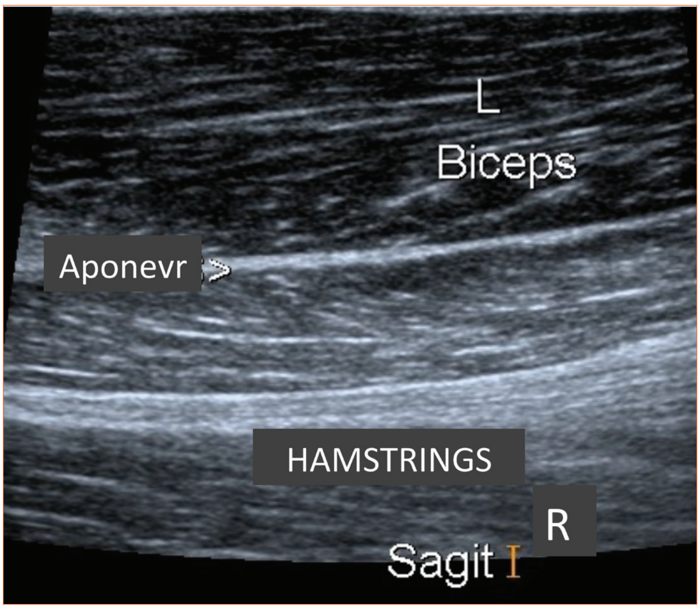

Figure 17 : *Central tendon of the biceps femoris.*

Conversely, other leg muscles like the gastrocnemius, sartorius and gracilis have very few components of this kind.

And there are practically no extensions of connective tissue into the muscles of the walls of the torso.

Therefore, there are muscles that:

- HAVE a connective tissue framework (the limbs)
- DO NOT HAVE an intramuscular connective tissue framework (walls of the torso)

and these muscles present injuries at different sites.

Point 4. Sites of intrinsic injury – muscle and connective tissue injuries

Injuries occur in different locations depending on whether a muscle has or has not an intramuscular connective tissue framework.

In muscles WITHOUT intramuscular connective tissue, injuries originate:

- in the muscle **(Fig. 18)**
- in the muscle attachments **(Fig. 19)**

In muscles WITH intramuscular connective tissue, injuries originate:

- in the connective tissue **(Fig. 20)**
- at the junction between the muscle fascicles and connective tissue **(Fig. 21)**
- little from the muscle **(Fig. 22)**

Injuries that begin in the connective tissue are called: **C injuries**.

Injuries that originate:

- in the muscle
- or at the junction between connective tissue and muscle

are called: **M injuries**.

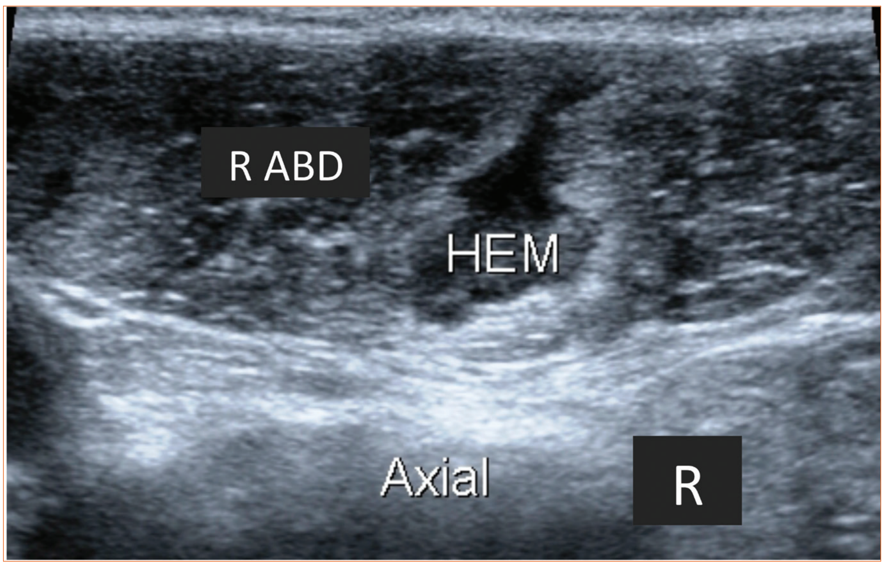

Figure 18: *Muscle without connective tissue framework. Injury in the muscle.*

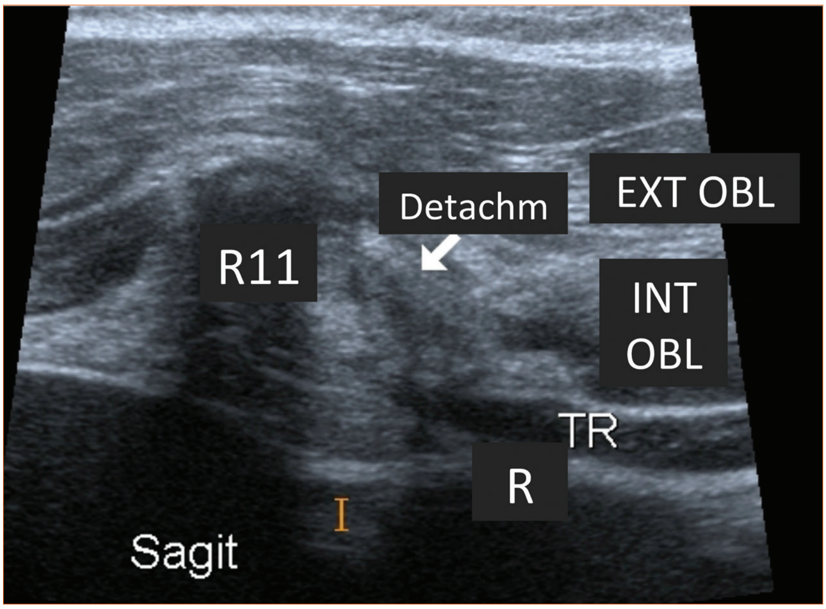

Figure 19: *Muscle without connective tissue framework. Injury at muscle attachment point.*

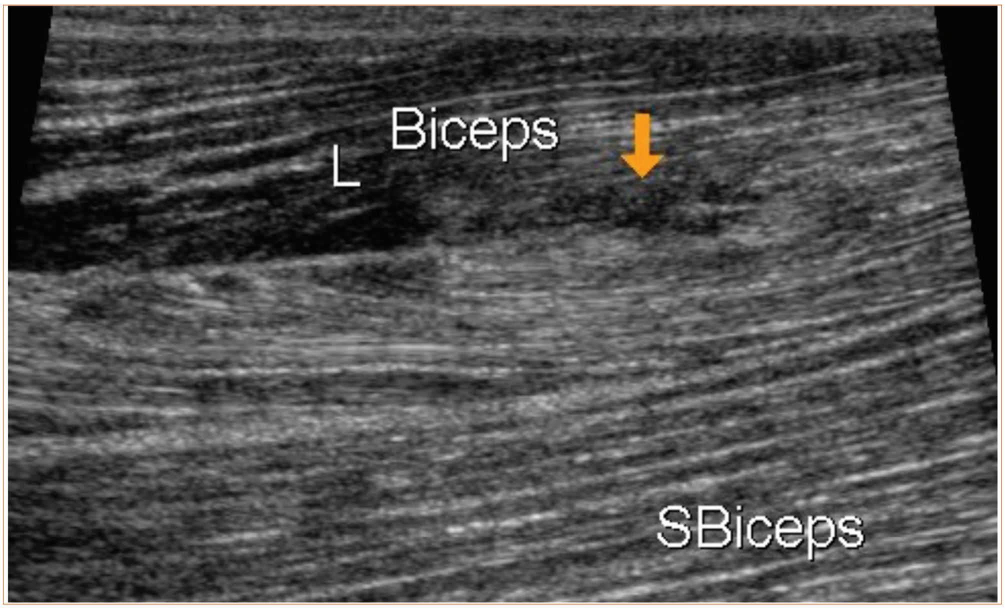

Figure 20: *Muscle with connective tissue framework. Injury in the connective tissue*

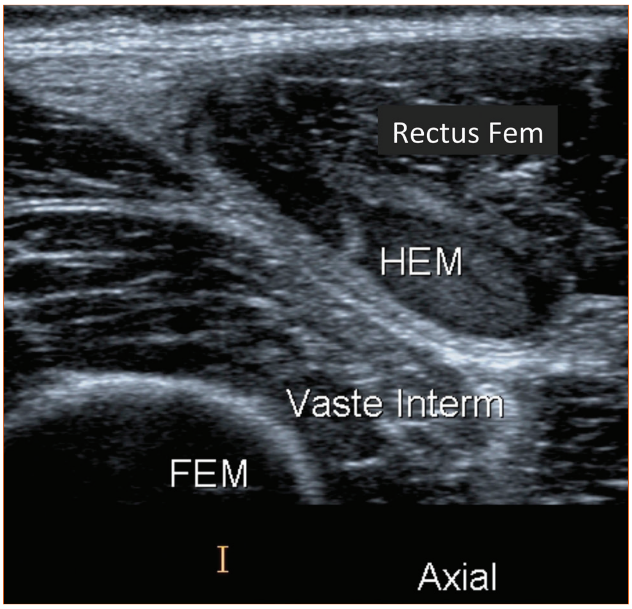

Figure 21: *Muscle with connective tissue framework. Injury at junction between connective tissue (here perimuscular fascia) and muscle.*

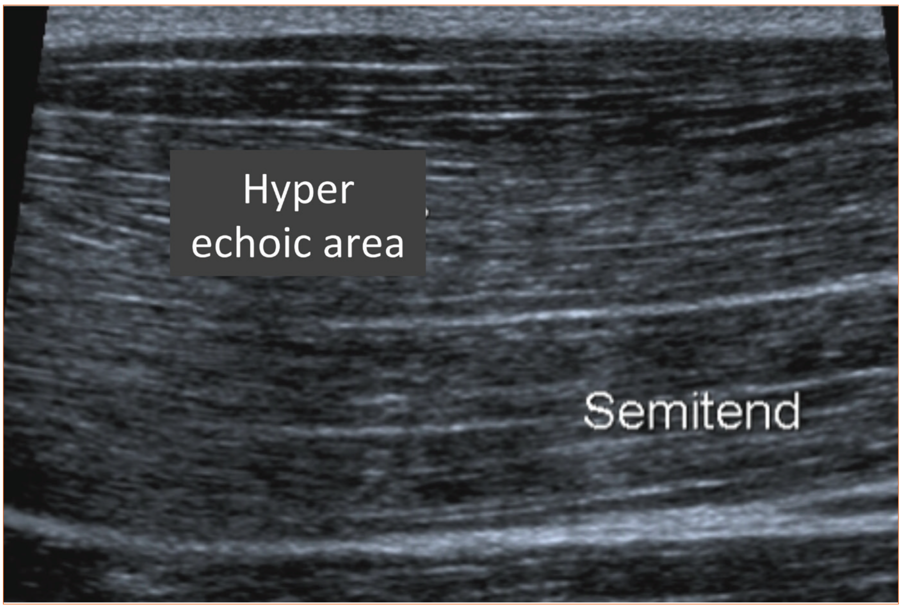

Figure 22: *Muscle with connective tissue framework. Injury in the muscle.*

Point 5. Intrinsic injuries to muscles with intramuscular connective tissue: C injuries

Most intrinsic injuries to the lower limbs have their point of origin within the connective tissue of the muscle, the presumed reason being that this tissue is less elastic.

Less severe injuries may involve the intramuscular connective tissue only, while more severe ones may also disrupt the muscle fascicles attached to it **(Fig. 23)**.

Besides the tendon and its attachment point, the perimuscular fascia **(Fig. 24)** and any of the intramuscular expansions of connective tissue may be the point of origin of an injury **(Fig. 25)**.

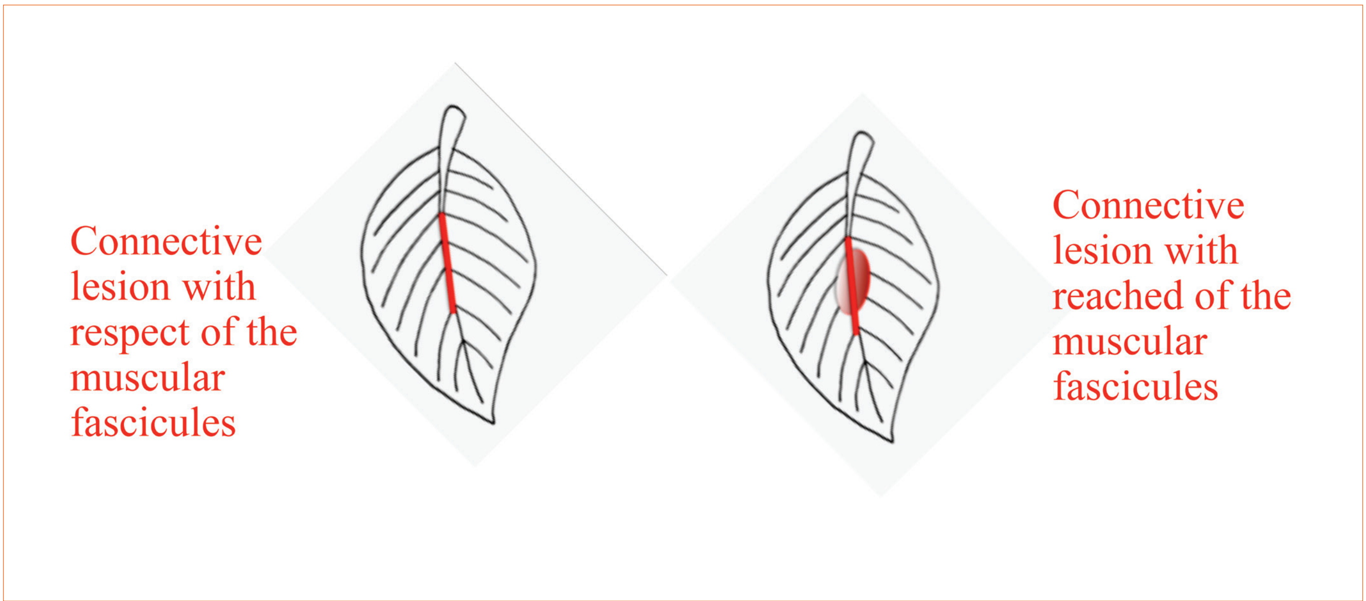

Figure 23: *Injury is limited to connective tissue or extends into neighboring muscle fascicles.*

The site of injury is found by examining such intramuscular expansions longitudinally **(Fig. 26)**. Comparative examination is required to detect certain abnormalities **(Fig. 27)**.

Some muscles like the medial gastrocnemius, long head of the biceps femoris and tensor fasciae latae insert via a distal connective tissue attachment to the peripheral fascia of another muscle **(Fig. 28)**.

Detachment can also occur between two intermuscular septa **(Fig. 29)**.

Sites of intrinsic C injuries
Perimuscular fascia
Intramuscular extension of connective tissue (hence the need for comparative longitudinal examination of the extension)
Distal connective tissue insertion
Intermuscular septal detachment

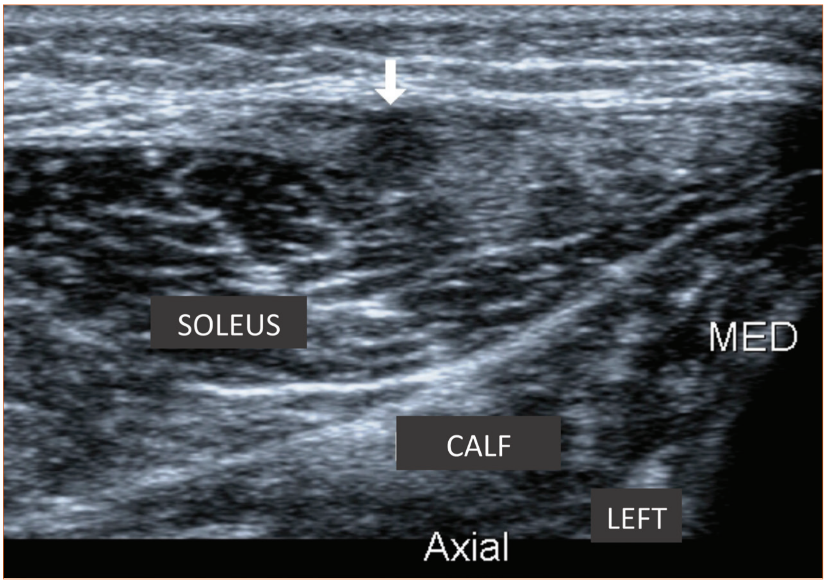

Figure 24: *Focal rupture of perimuscular fascia (arrow).*

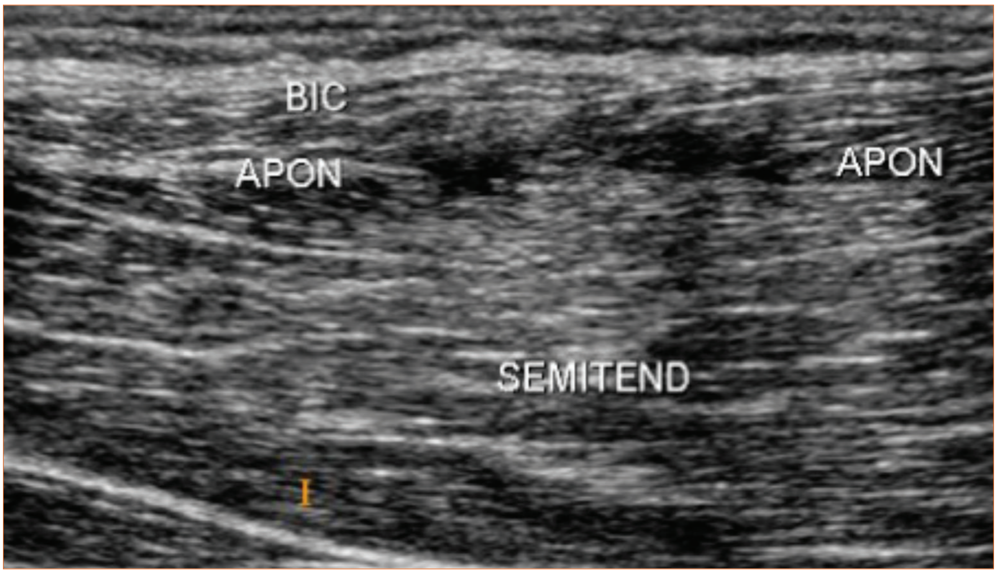

Figure 25: *Rupture that originated in intramuscular connective tissue (here the distal portion of the conjoined tendon). Discreet involvement of neighboring fascicles.*

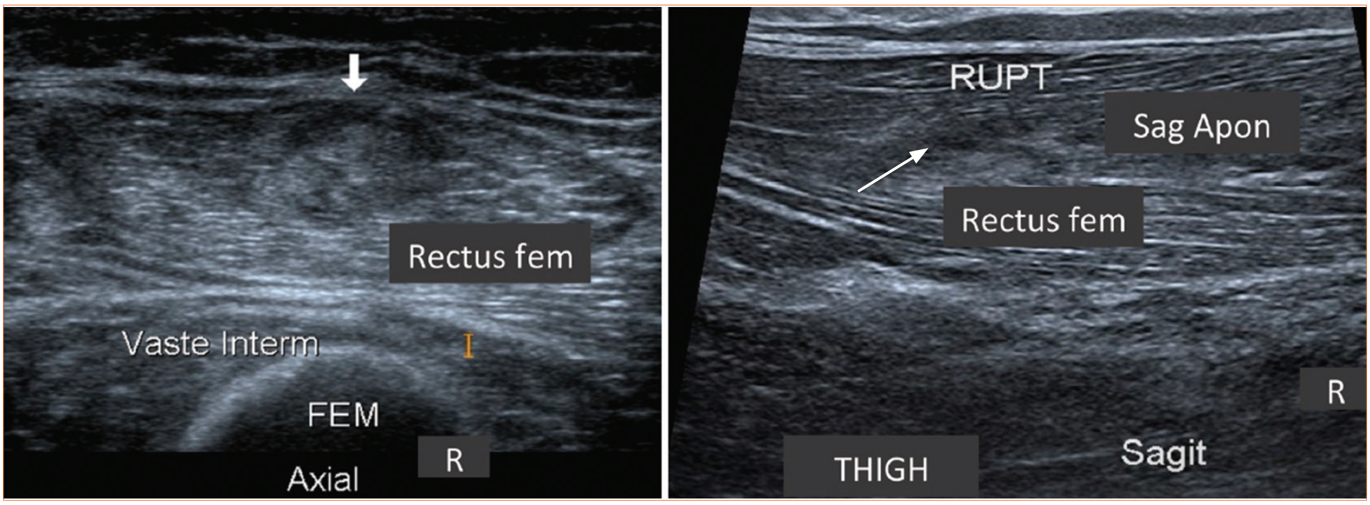

Figure 26: *Rupture that originated in the sagittal intramuscular tendon of the rectus femoris. The axial view shows heterogeneous changes that do not tell us where the injury originated. In contrast, longitudinal examination clearly shows (arrow) the connective tissue origin of the injury.*

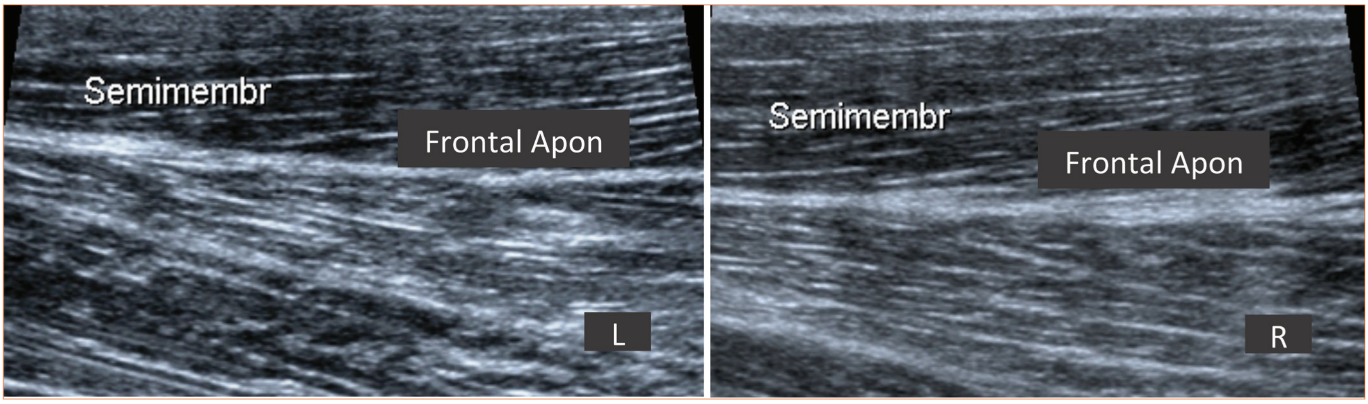

Figure 27: *Comparative images are crucial for identifying the thickening of the central tendon of the right semimembranosus.*

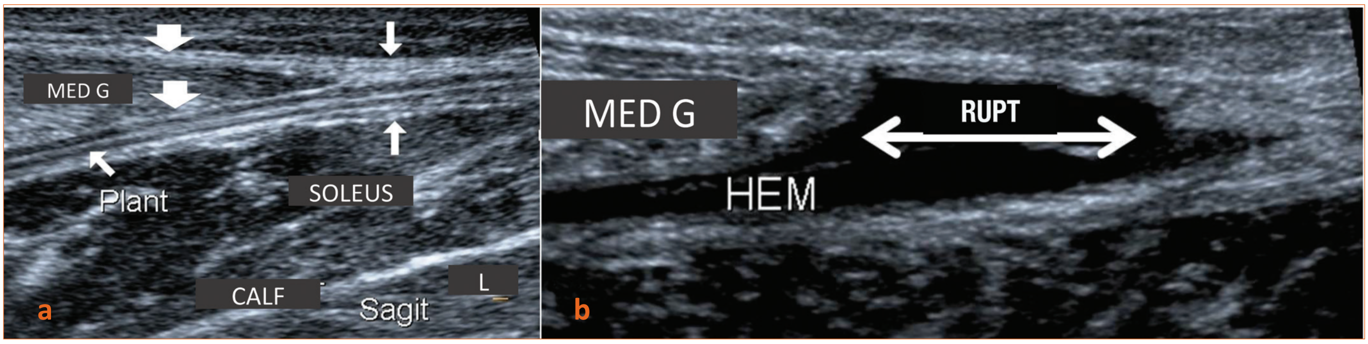

Figure 28: *The perimuscular fasciae of the distal portion of the medial gastrocnemius (large arrows) merge with the posterior fascia of the soleus to form the two components of the Achilles tendon (thin arrows)* **(a)**. *The most common injury at this site is a connective tissue injury: for example, rupture of the distal anterior fascia of the medial gastrocnemius* **(b)**.

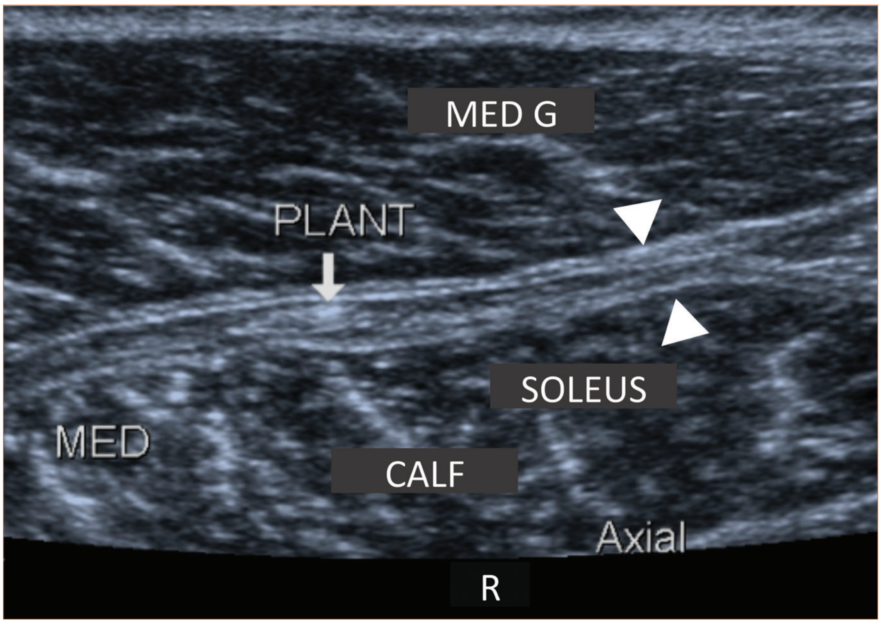

Figure 29: *Intermuscular detachment separating the perimuscular fasciae of the medial gastrocnemius and soleus (arrowheads).*

Point 6. Intrinsic injuries to muscles with intramuscular connective tissue: M injuries

There are three junctions between the muscle fascicles and connective tissue framework:

- the musculotendinous junction **(Fig. 30)**
- between the muscle fascicles and perimuscular fascia **(Fig. 31)**
- between the fascicles and intramuscular connective tissue **(Fig. 32)**

Other intrinsic injuries can occur:

- at a direct attachment point between muscle and bone **(Fig. 33)**
- or in rare cases within the muscle itself, generally in the center of the muscle far from its attachment points **(Fig. 34)**

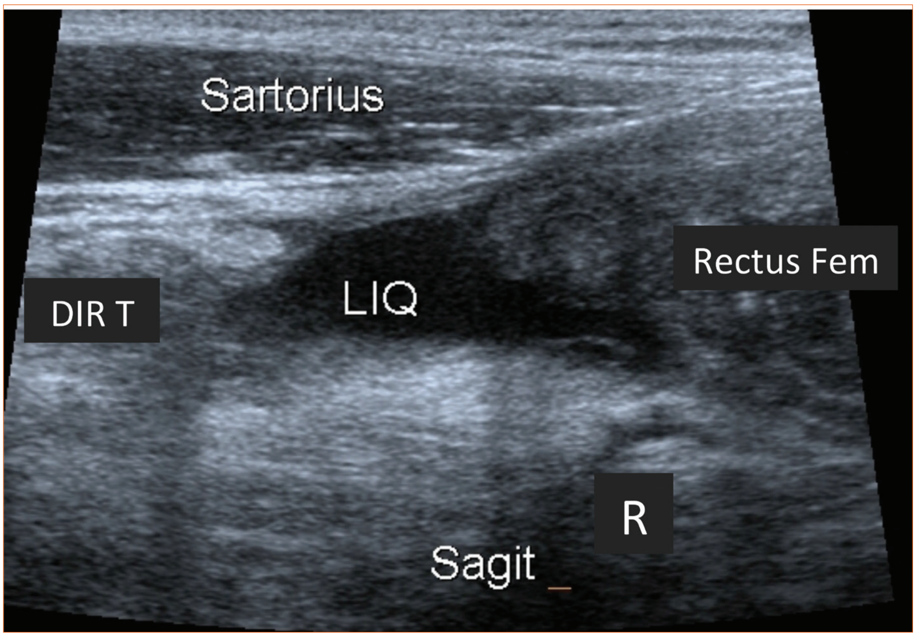

Figure 30 : *Proximal musculotendinous rupture of the rectus femoris.*

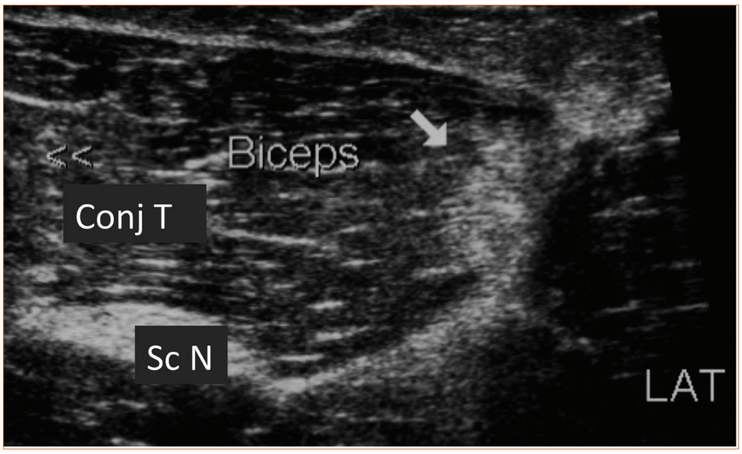

Figure 31 : *Hyperechoic focus representing detachment of the muscle fascicles of the long head of the biceps femoris from the perimuscular fascia.*

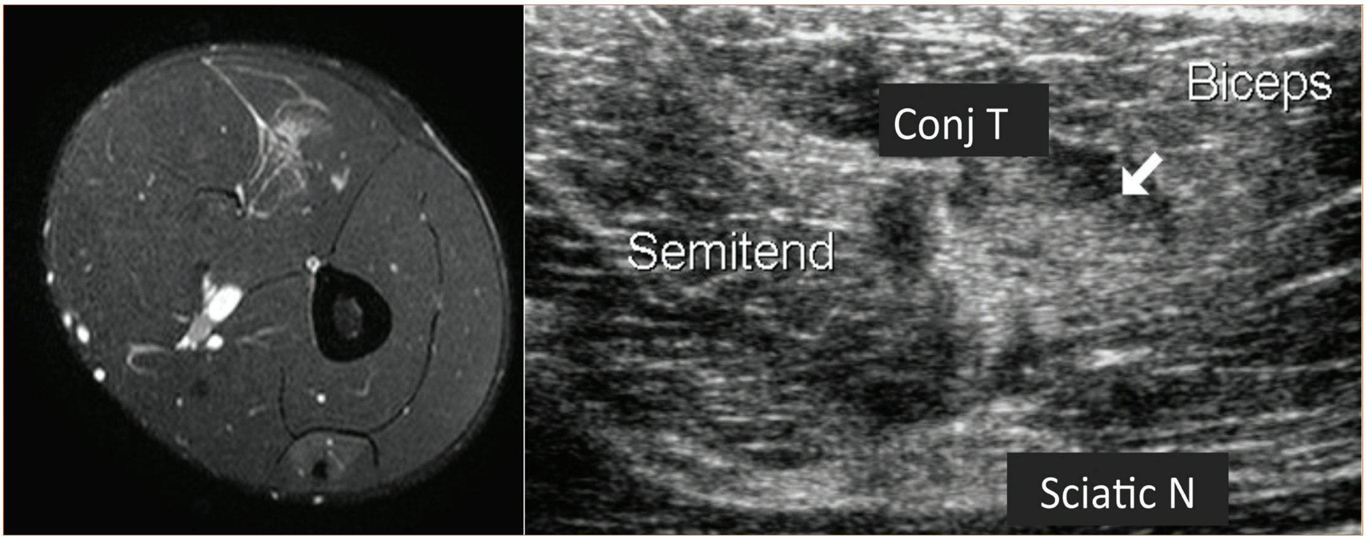

Figure 32 : *Hyperechoic focus and hyper signal T2 representing detachment of the muscle fascicles of the biceps femoris long head from the lateral aspect of the conjoined tendon on MRI and US.*

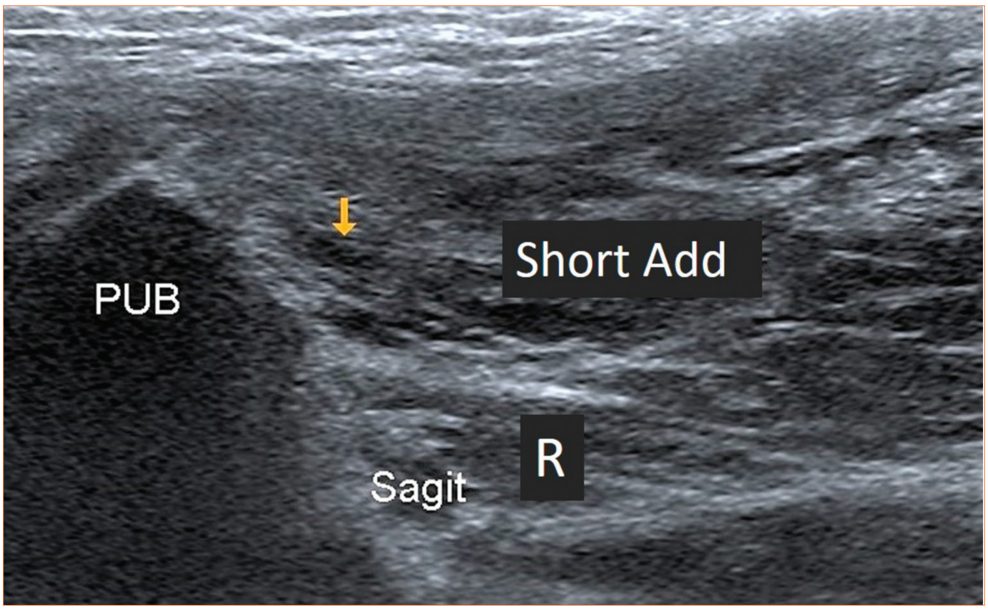

Figure 33 : *Partial rupture of bone/muscle attachment (arrow) at the ischiopubic origin of the adductor brevis*

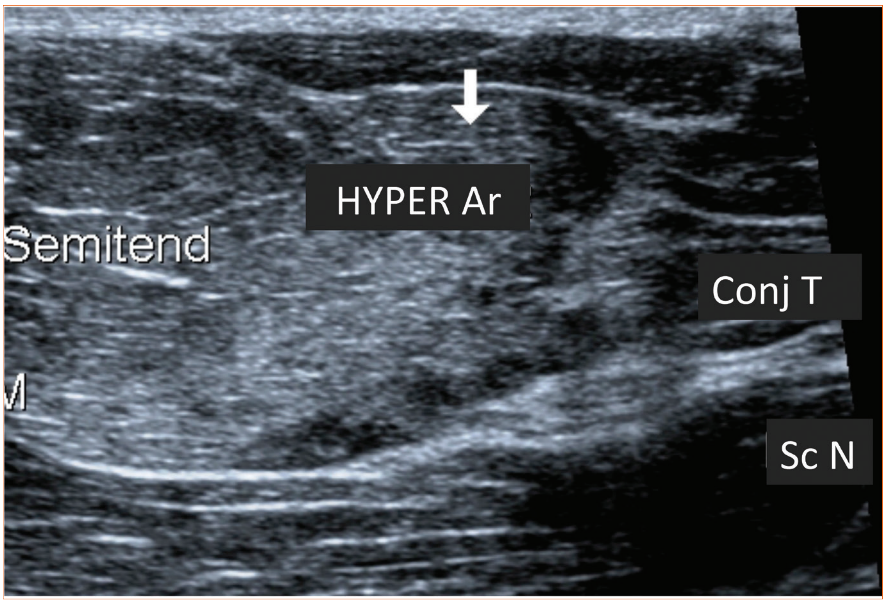

Figure 34 : *Hyperechoic focus representing an injury that originated in the central portion of the belly of the semitendinosus.*

Point 7. Classification of C injuries

Intrinsic C injuries are common, particularly in the lower limbs. The severity of these injuries varies greatly, with this influencing the rest required. These injuries are classed based on the:

- continuity or rupture of the connective tissue component
- partial or complete nature of the rupture (is there a gap?)
- retraction of the distal portion
- location of the injury

With regard to injury location, connective tissue components are subdivided into:

- Major components
  - Primary (proximal) intramuscular component (large branch of the tree – *see* **point 2**)
  - Distal connective tissue junction
- Minor components
  - Secondary (distal) intramuscular component (small branch of the tree – *see* **point 2**)
  - Perimuscular fascia
  - Intermuscular septa

Injuries are classed as:

- *Grade 0* if no injury can be detected on imaging
- *Grade 1C* if there is ill-defined thickening, but not rupture, of a connective tissue component **(Fig. 35)**
- *Grade 2C* if there is:
  - partial rupture of a major component without loss of tension **(Fig. 36)**
  - complete rupture of a minor component **(Fig. 37)**

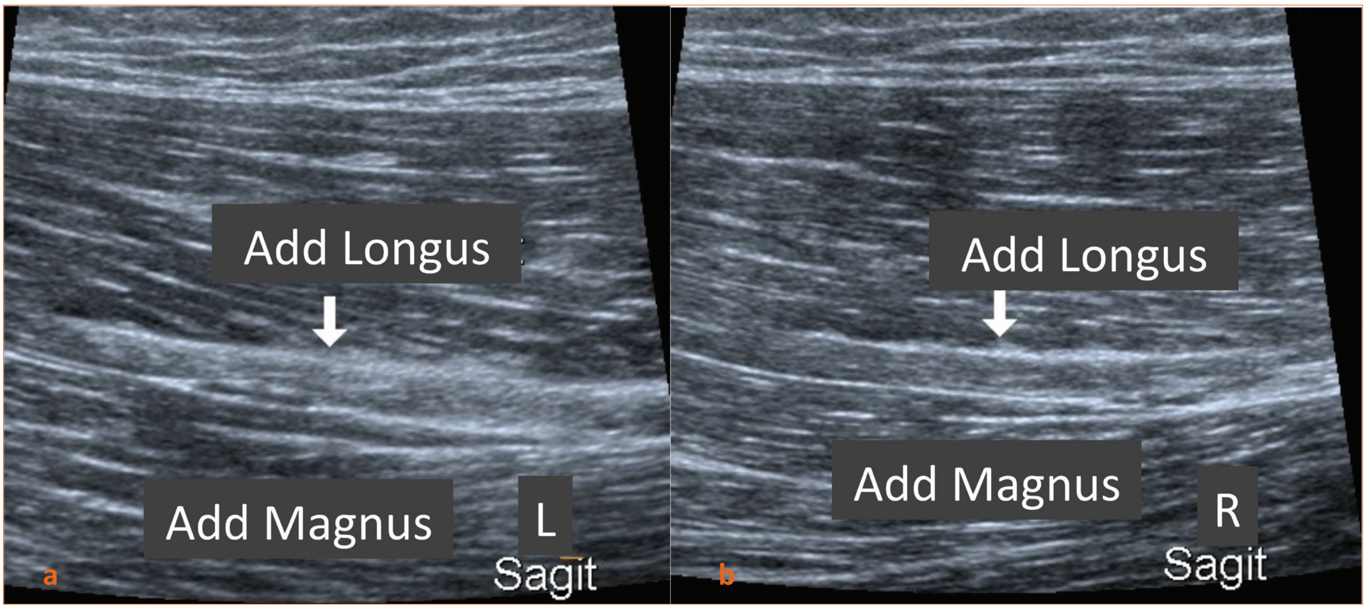

Figure 35 *:Grade 1C: Ill-defined thickening of an intramuscular connective tissue of the left adductor longus* **(a)** *which is clearly visible when compared with the right side* **(b)**.

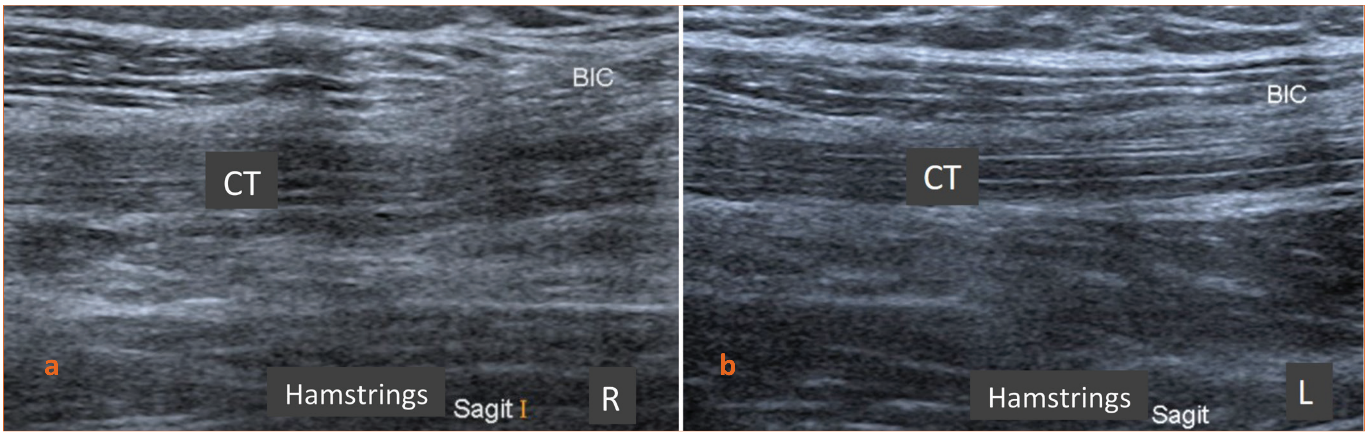

Figure 36 *: Grade 2C: Partial rupture of a major component, here the right conjoined tendon. Heterogeneous thickening, no gap, but disruption of fibrillar structure* **(a)** *clearly visible when compared with the left side* **(b)**.

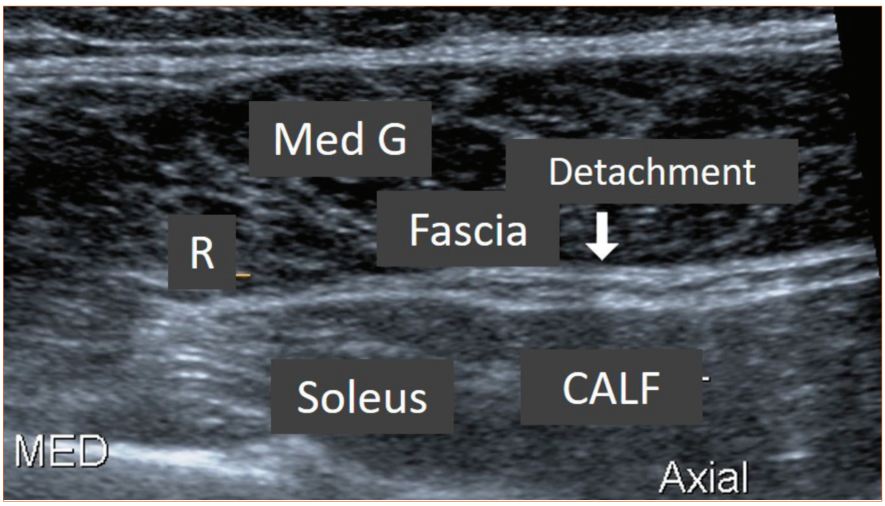

Figure 37 *: Grade 2C: Complete rupture of a minor component, here the intermuscular fascia between the medial gastrocnemius and soleus. Separation of the two muscles without involvement of the perimuscular fasciae or muscle fascicles.*

- *Grade 3C* if there is complete rupture of a major component **(Fig. 38)**
- *Grade 4* if there is complete muscle/connective tissue rupture and retraction **(Fig. 39)**.

Grades 0 and 4 apply to both C and M injuries.

This classification is summarized in Table C **(Fig. 40)**.

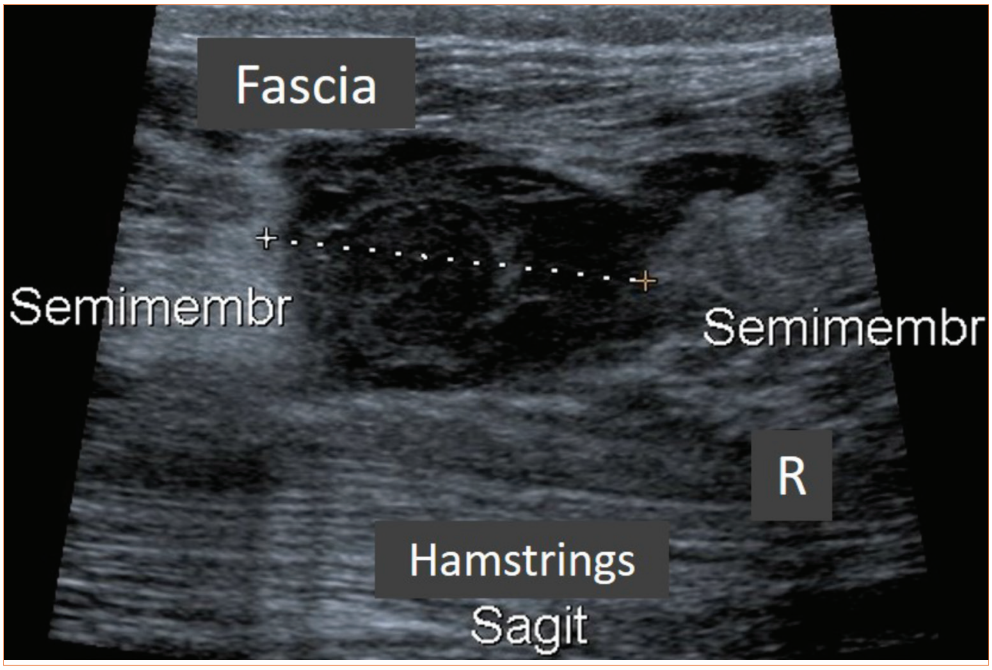

Figure 38 : *Grade 3C: Complete rupture and a gap in a major connective tissue component, here the tendon of the semimembranosus.*

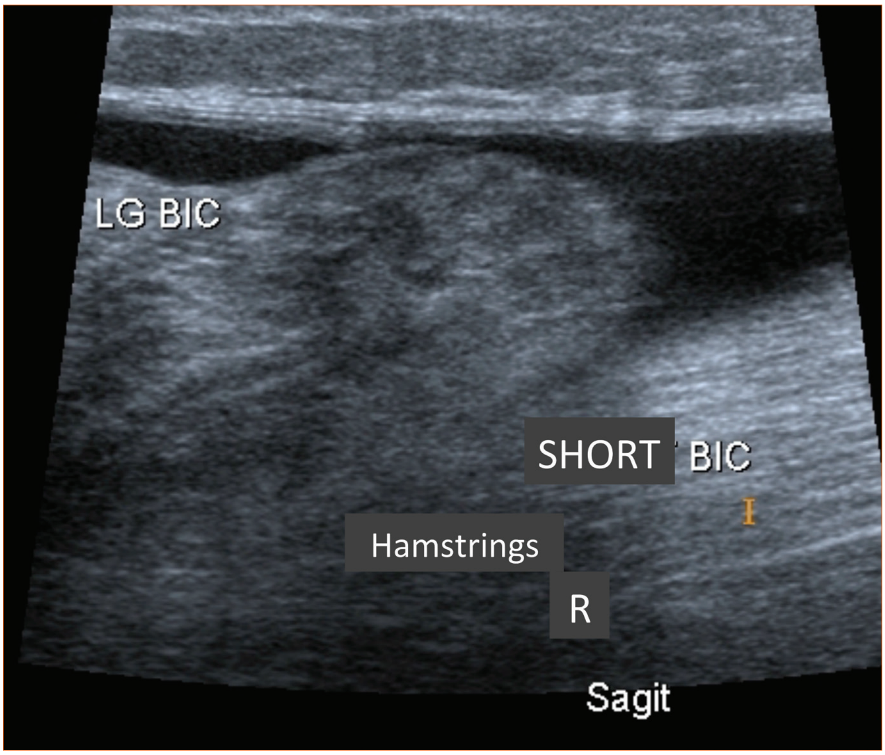

Figure 39 : *Grade 4: Distal connective tissue rupture and retraction of the right biceps long head.*

	Classification of lesions C
GRADE 0	No anomalies detected in imaging
GRADE 1C	Thickening with ill-defined shapes of a connective element without rupture
GRADE 2C	Partial rupture of a major connective element (proximal intramuscular element or distal connective junction) without loss of tension Complete rupture of a minor connective element (secondary intramuscular connective element, perimuscular or intermuscular)
GRADE 3C	Complete rupture of a major connective element with loss of tension
GRADE 4	Complete myo-conjunctive rupture with retraction

Figure 40 : *Table summarizing the severity of C injuries.*

Point 8. Classification of M injuries

M injuries are those that originate:

- at the junction between the muscle fibers and connective tissue framework
  - at the musculotendinous junction
  - at the junction between muscle fibers and perimuscular fascia
  - at the junction between muscle fibers and intramuscular connective tissue extensions
- at the junction between muscle fibers and bone
- within the muscle itself

These injuries are classed as:

- *Grade 0* if no abnormalities are detected on imaging
- *Grade 1M* if there are hyperechoic **(Fig. 41)** or T2-weighted high-signal changes in the muscle fascicles but the muscle architecture is intact. Note that the perimysium is intact so there is no bleeding at this stage. Delayed onset muscle soreness exhibits similar features on imaging **(Fig. 42)** but the mechanisms (and so the case history) are different.
- *Grade 2M* if there is localized **disruption** **(Fig. 43)** of muscle architecture, and thus involvement of the perimysium, but no decrease in muscle expansion during contraction (i.e. no loss of function).
- *Grade 3M* if the muscle no longer expands during contraction and perimysial injury is more significant, leading to either:
  - **Significant disruption**:
    - affecting more than a third of the cross-section of the muscle **(Fig. 44)**
    - involving more than 50% of the length of the muscle/connective tissue junction

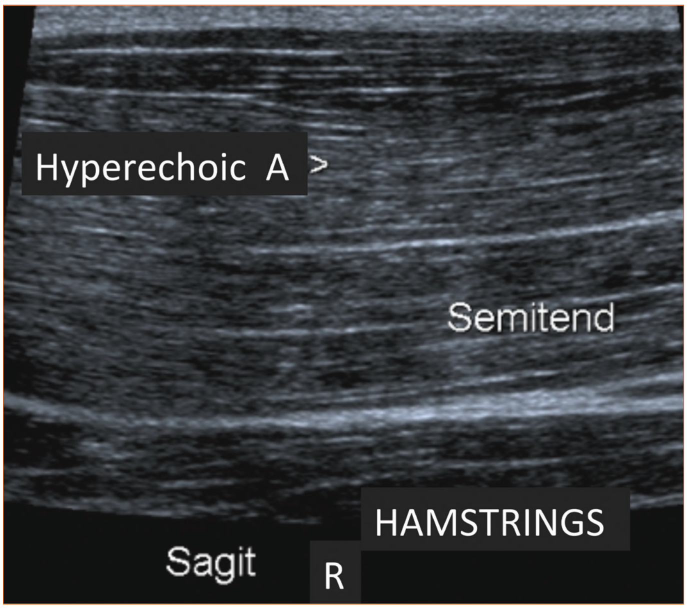

Figure 41 : *Grade 1M. Hyperechoic focus but no disruption of the right semitendinosus.*

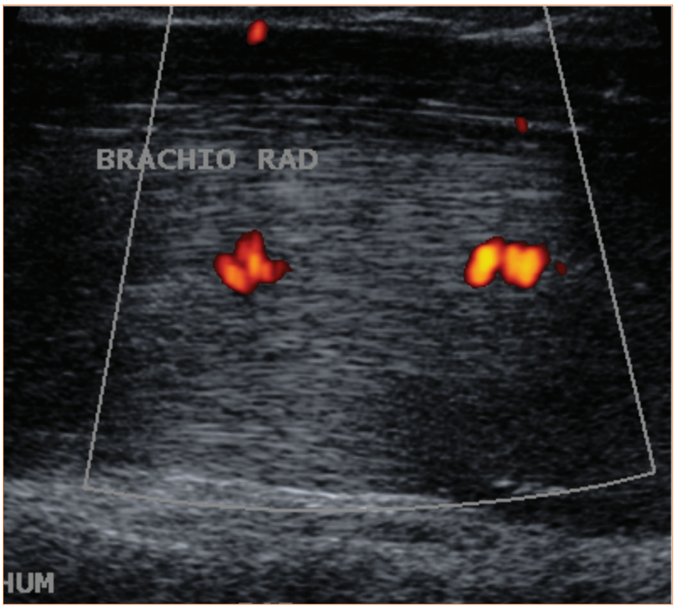

Figure 42 : *Delayed onset muscle soreness. Hyperechoic hypertrophy without disruption of the brachioradialis after a session of eccentric contractions.*

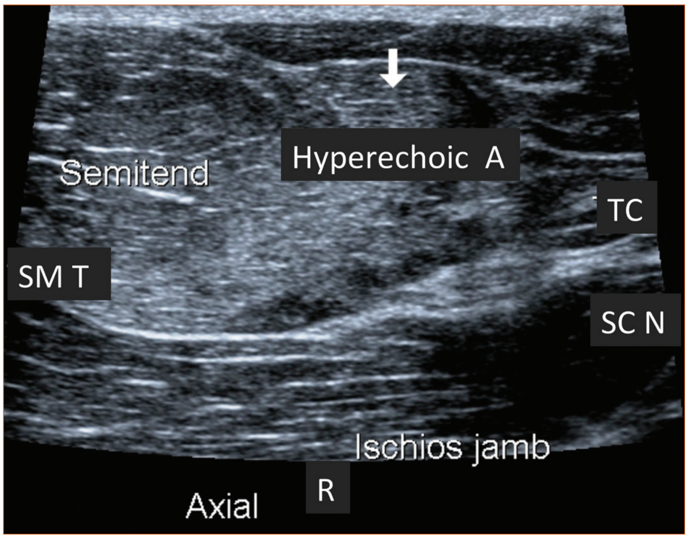

Figure 43 : *Grade 2M. Hyperechoic focus and localized disruption but no well-defined fluid collection in the right semitendinosus.*

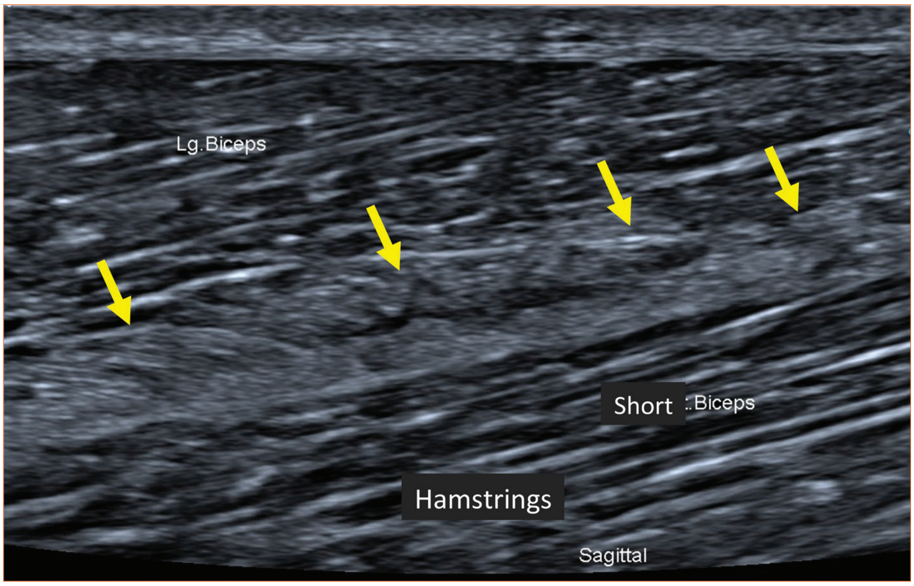

Figure 44 : *Grade 3M. Significant disruption of the peripheral muscle/connective tissue junction in the left biceps long head.*

- ○ Fluid collection more than 3mm thick (Fig. 45)
- *Grade 4* if there is complete muscle/connective tissue rupture (Fig. 46) and retraction.

Grades 0 and 4 are the same in C injuries.

Disruption means the injury moves up to grade 2, a fluid **collection** or **significant disruption** (along with functional impairment during contraction) means grade 3, and **retraction**, grade 4.

These changes are summarized in the M injury table (Fig. 47).

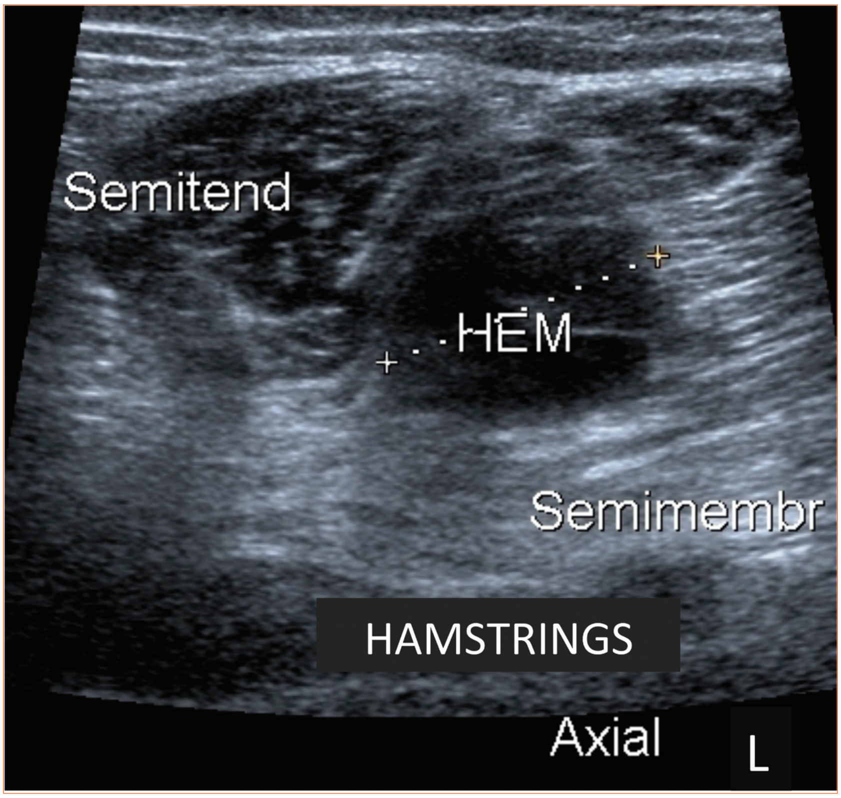

Figure 45 : *Grade 3M. A fluid collection more than 3mm in size at the peripheral muscle/connective tissue junction in the left semimembranosus.*

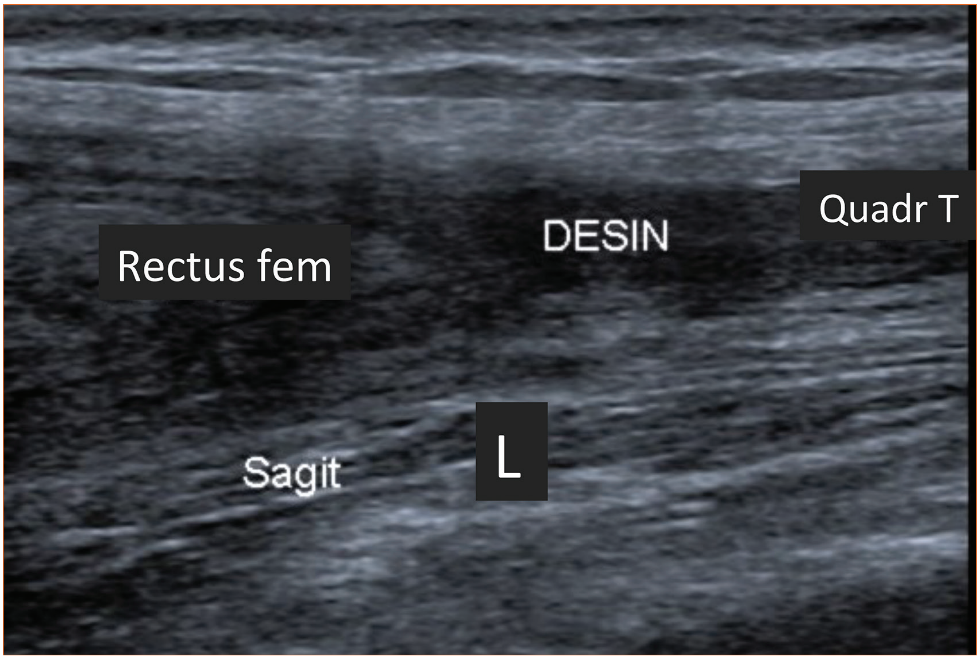

Figure 46 : *Distal musculotendinous rupture with proximal retraction of the left rectus femori.*

	Classification of lesionsM
GRADE 0	No anomalies detected in imaging
GRADE 1M	Hyperechoic range or T2 hyperintense signal, limited, with respect for muscle architecture
GRADE 2M	Hyperechoic range or T2 hyperintense signal with limited disorganization of the muscle architecture
GRADE 3M	Hyperechoic range or T2 hyperintense signal with significant disorganization of the muscle architecture, namely: - a collection of more than 3 mm thick or disorganization reaching more than a third of the axial surface of the muscle or a disorganization reaching more than 50% of the length of the myoconjunctive junction
GRADE 4	Complete myo-conjunctive rupture with retraction

Figure 47 : *Table summarizing the classification of M injuries.*

Point 9. Muscle imaging pitfalls

The difficulties of muscle imaging are well known, particularly those of muscle ultrasonography (US).

Considerable knowledge of anatomy is vital, above all regarding the main intramuscular extensions of connective tissue.

We have already looked at how to conduct the examination (comparative axial slices), but three important pitfalls must be avoided:

- Conducting an emergency examination too early. It is a mistake to believe that the severity of an injury can be diagnosed or that certain injuries can even be detected **(Fig. 48)** before day 2, particularly on US. **Emergency examination = wasted opportunity.**
- It must be remembered that what we see on an image, particularly on T2-weighted magnetic resonance imaging (MRI) sequences, mostly reflects the bleeding caused by the injury and not the injury itself **(Fig. 49)**. Size criteria are specified in the classification, but the extent of bleeding, and hence the appearance of the image, varies with factors like mobilization, compression, coagulation and ill-timed massage. Seeking the origin of the injury, its exact location and the morphological changes that it has caused are the key elements of the examination. An error that is often heard is «I can see a 5cm high signal image on MRI, so the injury measures 5cm». This is wholly untrue! Similarly, as the injury heals, it is not the injury itself that is decreasing, but the bleeding that it has caused. When someone cuts their skin, scar tissue remains that is practically the same size as the initial injury. The same thing happens in muscles. That is why a patient should not be told that their injury is improving because it measures 4cm as against 8cm a fortnight previously.
- The third error is to only use axial views. Examining the connective tissue extension longitudinally is what tells us whether it is or is not the exact site of the injury, whereas the axial changes seen with this

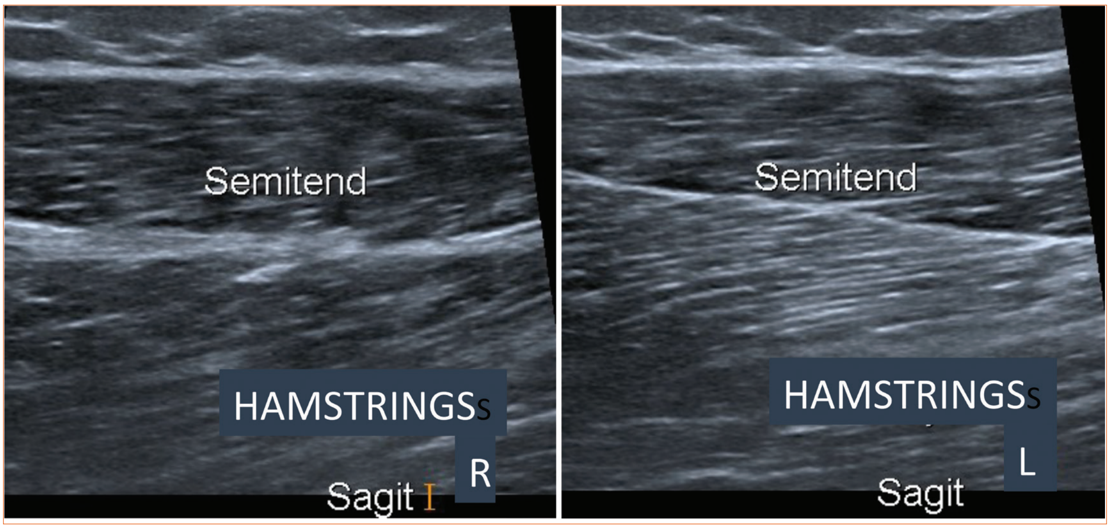

Figure 48 : *Tennis player who felt a sudden pain in the posterior aspect of the right thigh. Examination a few hours after the onset of pain revealed no abnormalities. However, on day 2, ill-defined thickening of the sigmoid septum of the semitendinosus was observed. This finding was incontrovertible in comparison with the left side.*

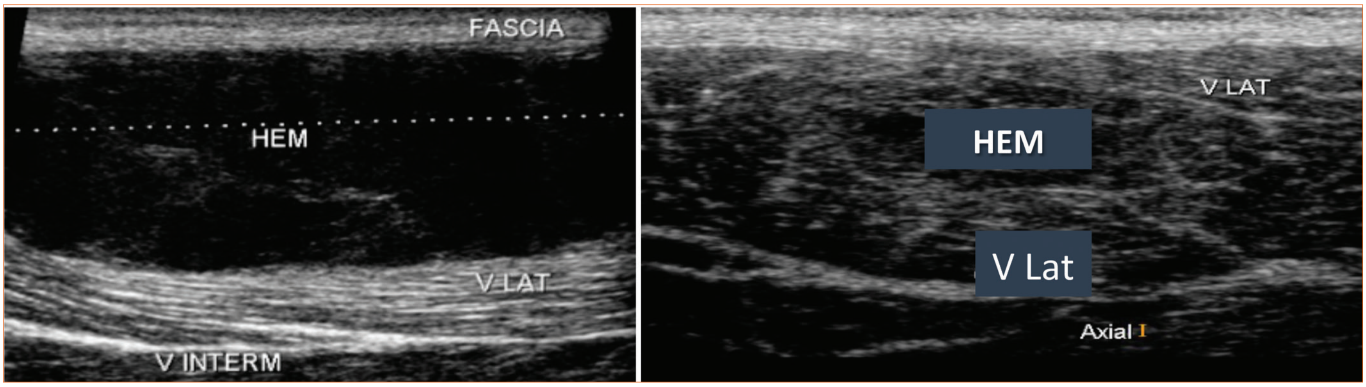

Figure 49 : *The same injury before and after puncture/drainage showing that the bleeding contributed significantly to the appearance of the image.*

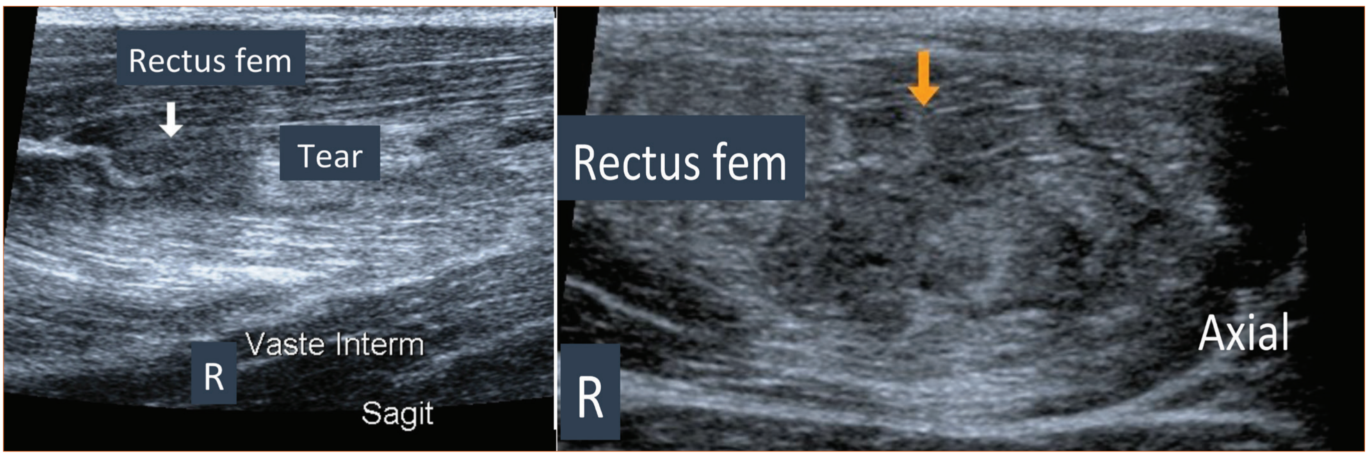

Figure 50 : *Central tendon injury of the right rectus femoris. The connective tissue origin of the injury can clearly be seen on the sagittal view of the long axis of the tendon, whereas it is impossible to identify on the axial view.*

type of injury are insufficient to confirm any such hypothesis. That is why sometimes fanciful descriptions of «onion bulb» injuries and pseudotumors are sometimes encountered **(Fig. 50)**.

Point 10. Healing, sequelae and return to play

Given that areas of high signal persist on T2-weighted MRI long after the injury has healed, US is known to be the best modality during this period.

During the healing phase, the resolution of areas of hyperechogenicity is the determining factor in grade 1 intrinsic injuries.

With grade 2 or higher injuries involving connective tissue components, a scar often persists indefinitely. In this type of injury, reactive vascularization becomes visible on Doppler sequences 2 to 3 days after the injury. The disappearance of this vascularity **(Fig. 51)** is a key element in confirming that US-defined healing has been achieved, although this does not mean that the healed tissue is stable!

Another key point is the resolution of the hazy appearance around the injury, since when this occurs the scar exhibits well-defined contours (Fig. 52).

In severe cases (grades 3 and 4), before we examine the scar tissue, we monitor that gaps are filled, that fluid collections reabsorb, and, above all, that muscle expansion during contraction returns – the last criterion indicating that function has been restored.

During the sequelae phase, calcifications may be observed which can be painful if irregular. Ossifications may also be encountered **(Fig. 53)**. Most importantly, there may be scar tissue. This needs to be carefully described because it can weaken overlying and underlying muscles and cause reinjury. The contraction test is primordial at this stage to detect any retraction that might alter muscle function **(Fig. 54)** or slide **(Fig. 55)**, or attrac the sciatic nerve **(Fig. 56)**.

Return to play depends on the injury grade. However, although imaging can tell us whether the injury has healed, combining imaging with clinical criteria is essential for confirming that the healed tissue is stable.

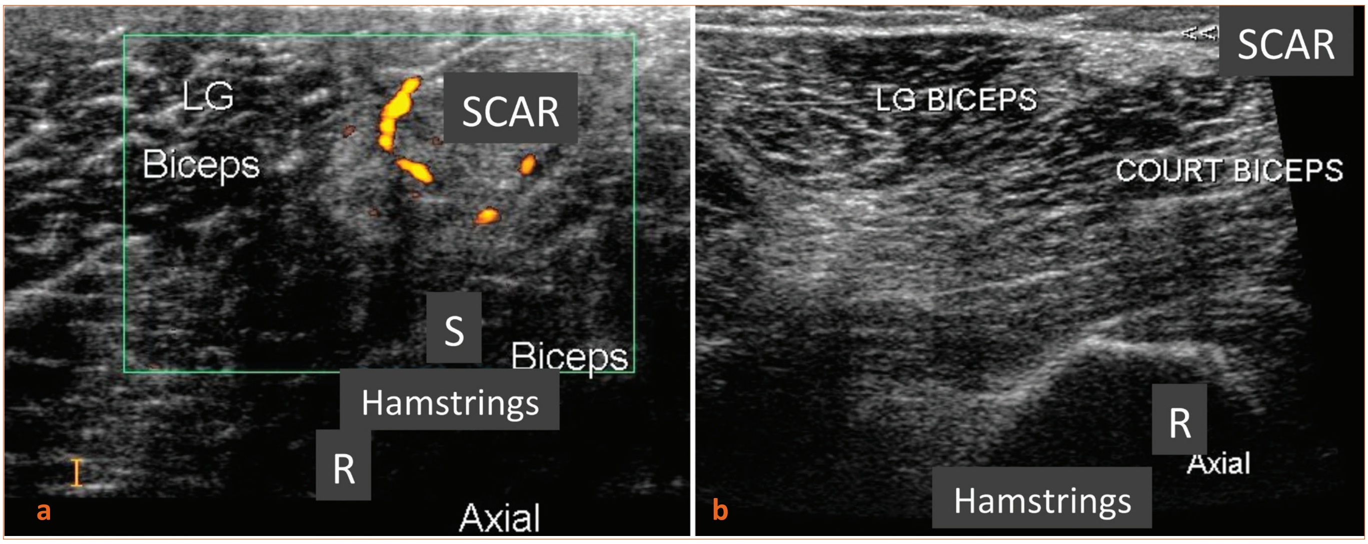

Figure 51 : *Right long head biceps injury in the healing phase with persistent vascularity at 3 weeks* **(a)**. *Decrease in the size of the scar, which has well-defined margins and is avascular at 6 weeks* **(b)**.

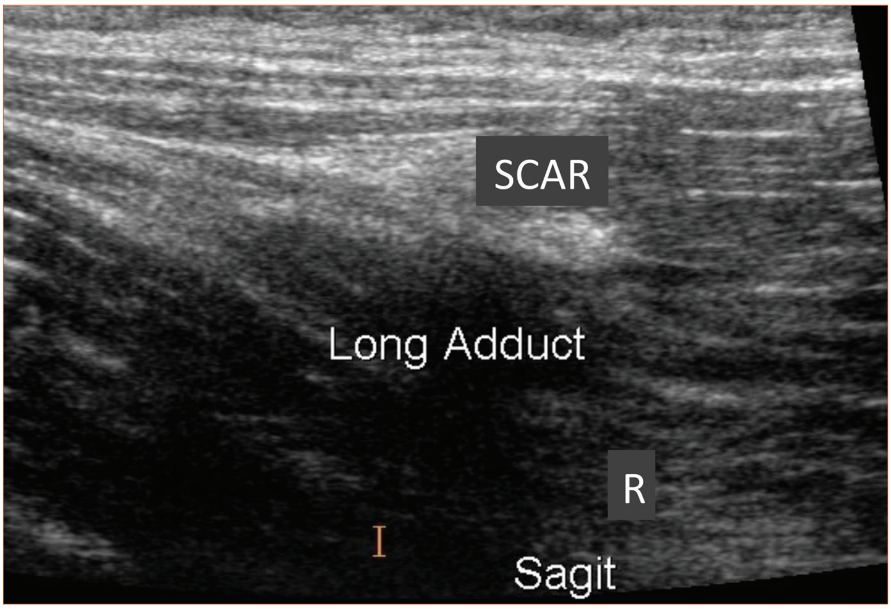

Figure 52 : *Scar with well-defined margins.*

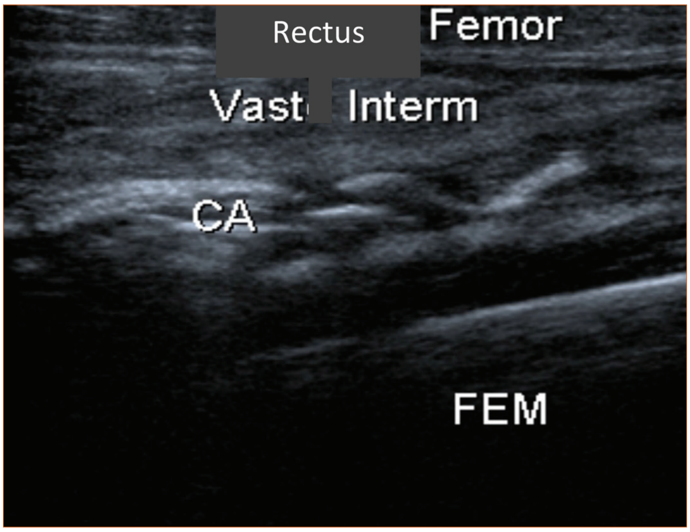

Figure 53: *Irregular calcifications that may cause chronic pain.*

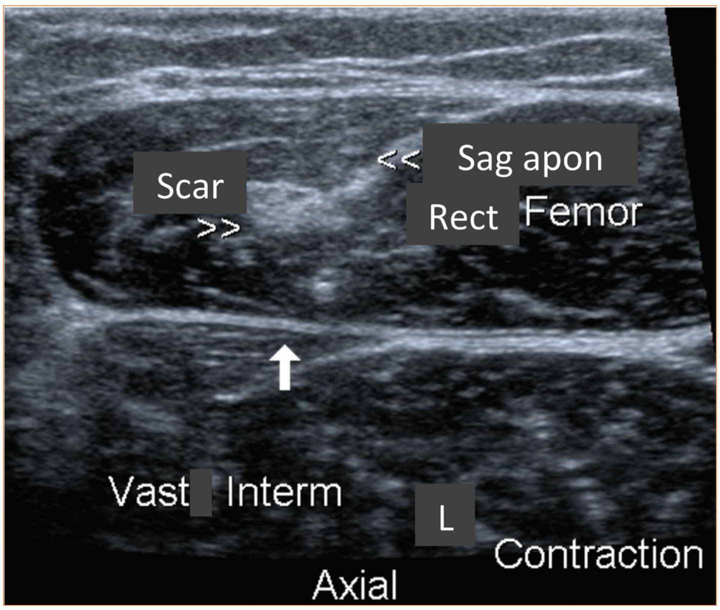

Figure 54 : *Impaired expansion of the rectus femoris during contraction (arrow) around scar tissue in the center of the muscle.*

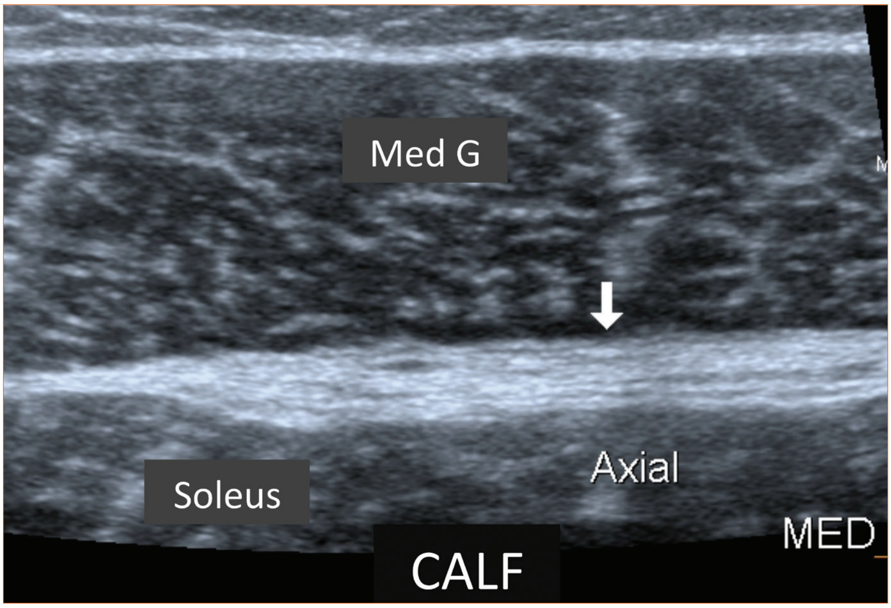

Figure 55 : *Thickening of the space between the aponeuroses of the medial gastrocnemius and soleus impairing normal slide between the two muscles and incarcerating the plantaris tendon.*

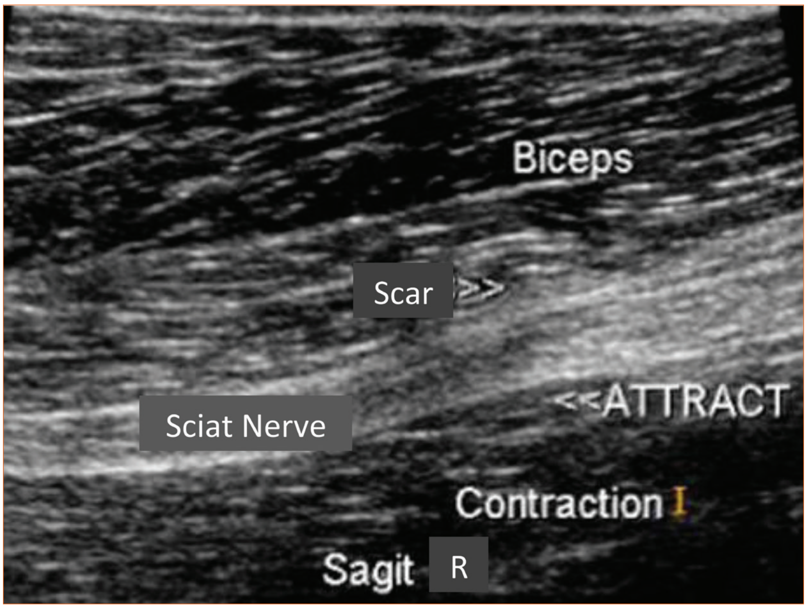

Figure 56: *Scar tissue deep in the biceps attracting the sciatic nerve during contraction.*

	M	C
Gr 1	1 à 2 weeks	
Gr 2	3 weeks	4 weeks
Gr 3	6 weeks	8 weeks
Gr 4	9 to 12 weeks	

Figure 57 : *Table summarizing immobilization types based on injury grade and C or M location.*

In our examinations, we consider connective tissue involvement to be unfavorable because an injury that originates in the connective tissue prolongs the period of incapacity in grade 2 and 3 injuries **(Fig. 57)**.

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02 Direct muscle injuries: general principles

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1. Definition and epidemiology

- Direct muscle injuries are caused by direct (blunt) trauma.
- These are less frequent compared to indirect muscle injuries.
- All muscles of the body exposed to a blunt trauma may be affected by direct injuries, particularly:
- Muscles having a large surface directly in contact with a bone structure.
- Muscles exposed at the surface of limbs and trunk.

2. Main mechanism of injury

- Following direct trauma, a massive blunt force is directed towards the bone structure with a massive amount of energy dissipated from the deep muscle to the bone. This may potentially lead to injuries involving the following structures of the muscle:
- Peripheral aponeurosis;
- Intramuscular connective tissues;
- Muscle bundles;
- Vascular structures within the main connective tissue structures (responsible for most of hematoma formation in severe direct injuries)

3. Imaging of direct muscle injuries – semiology

- Ultrasound (for superficial muscles) and MRI (for deep muscles or whenever ultrasound is negative) are the imaging methods of choice to explore these injuries. We search for:
- On ultrasound, an ill-defined hyperechoic area within the muscle **(Fig. 1-3)**. On MRI, an ill-defined area of high signal intensity within the muscle on fluid-sensitive sequences (T2, STIR);

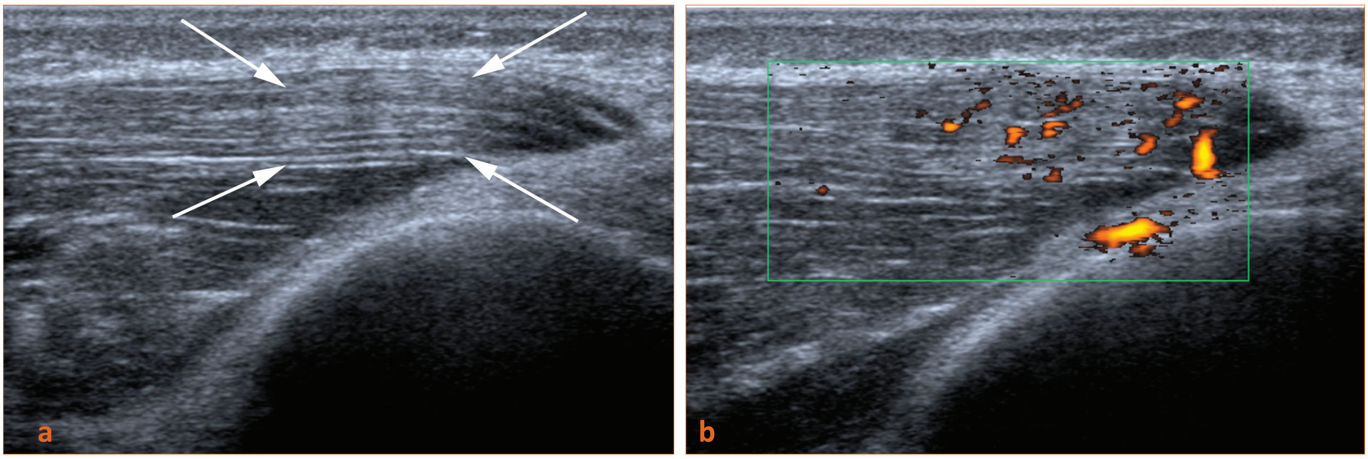

Figure 1: *Low-grade direct injury at the distal aspect of the vastus medialis muscle.* **a**) *Ultrasound (longitudinal view) demonstrates an ill-defined hyperechoic area within the muscle (arrows) with no architectural distortion nor intramuscular hematoma.* **b**) *Power Doppler ultrasound shows intramuscular neovascularization at the site of the injury (repair phase).*

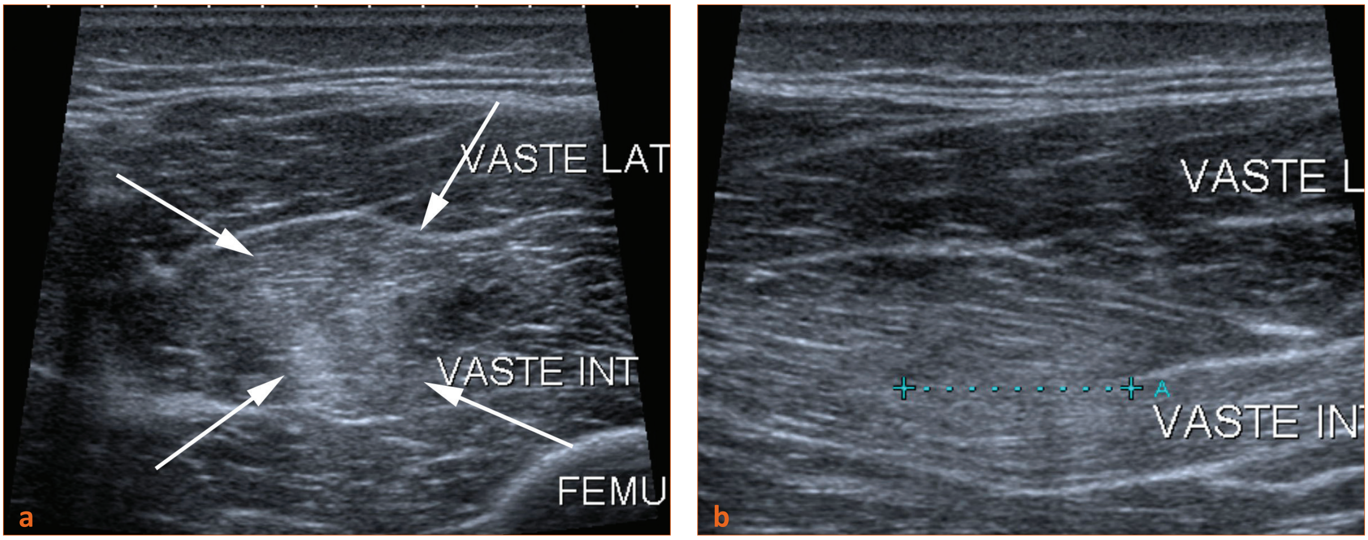

Figure 2: *Low-grade direct injury of the vastus intermedius muscle depicted on ultrasound.* **a**) *The transverse view shows an ill-defined hyperechoic area within the muscle (arrows) with no intramuscular hematoma.* **b**) *The longitudinal view demonstrates no major architectural distortion at the site of the injury.*

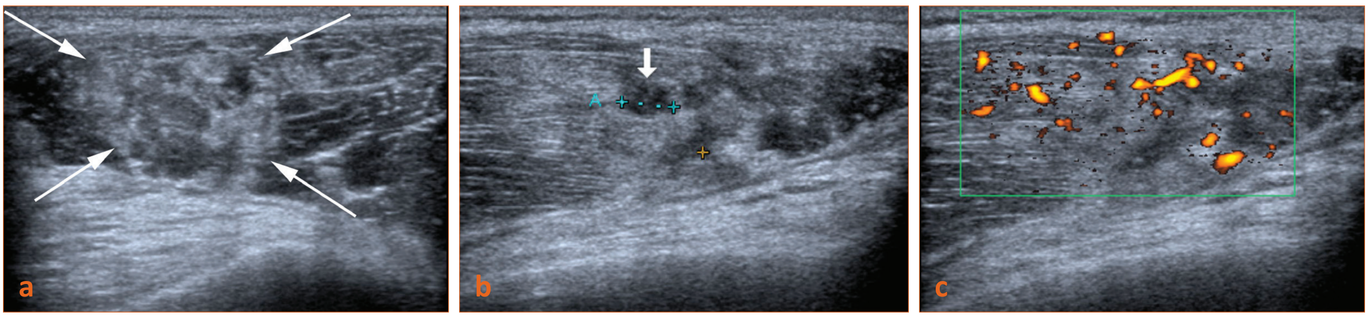

Figure 3: *Intermediate-grade direct injury at the distal aspect of the vastus medialis muscle.* **a**) *Ultrasound (transverse view) demonstrates an ill-defined hyperechoic area within the muscle (arrows) involving less than 50% of the cross-sectional area of the muscle, with some loss of perimysium definition.* **b**) *Ultrasound (longitudinal view) exhibits architectural distortion within the injured area including foci of disrupted perimysium (arrow).* **c**) *Power Doppler ultrasound shows intramuscular neovascularization at the site of the injury (repair phase).*

- An area of architectural distortion within the muscle including distortion of perimysium and changes in bundles' directions **(Fig. 3-4)**;

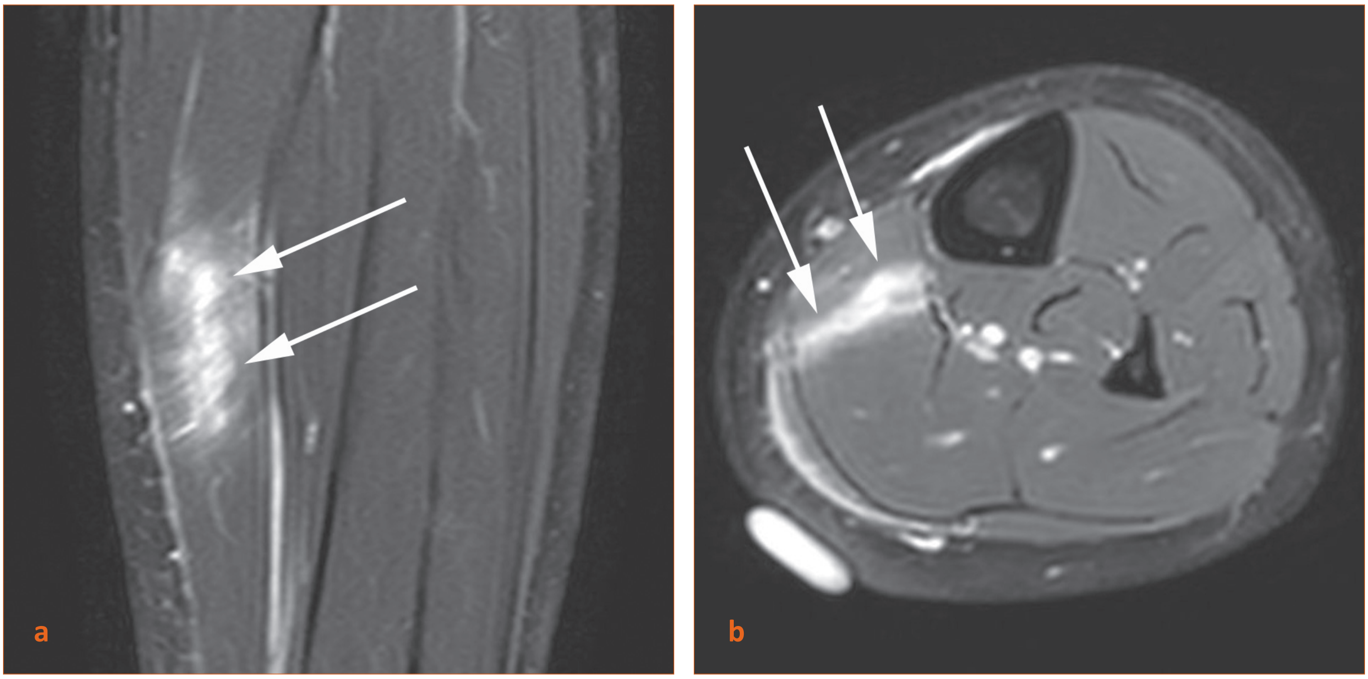

Figure 4: *Intermediate-grade direct injury of the soleus muscle.* **a**) *Coronal MRI T2-weighted image with fat suppression shows an area of architectural distortion as well as a well-defined high-signal intensity within the muscle consistent with a partial rupture (arrows), within an ill-defined area of oedema.* **b**) *Axial MRI T2-weighted image with fat suppression demonstrates that the extension of the partial rupture involves less than 50% of the cross-sectional area of the muscle (arrows).*

- An area of partial or complete rupture within the muscle, including intramuscular hematomas **(Fig. 4-7)**;

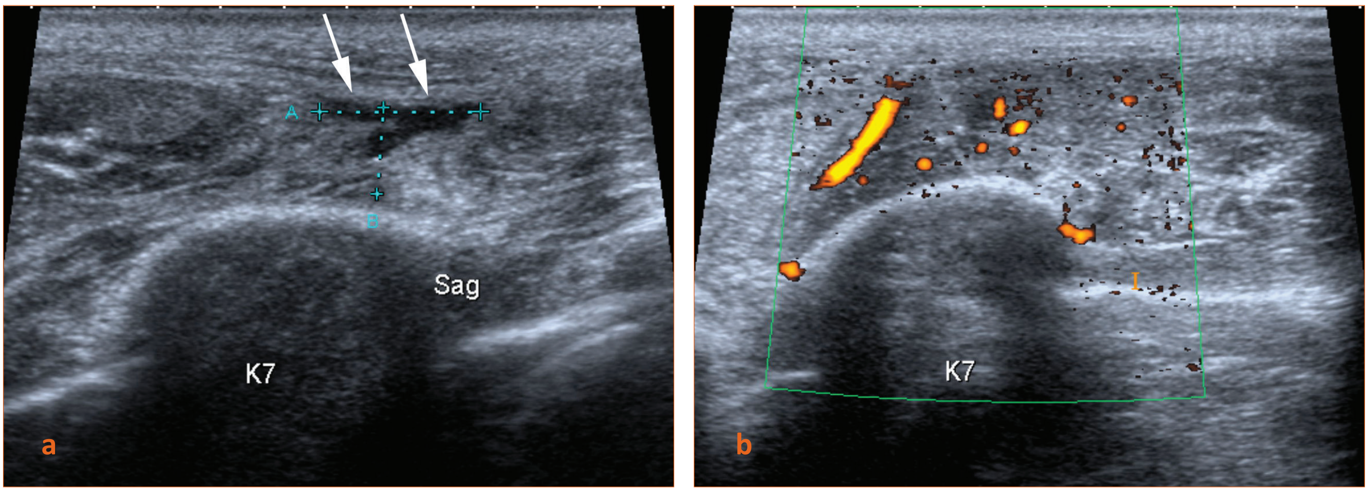

Figure 5: *Intermediate-grade direct injury of the serratus anterior muscle.* **a**) *Ultrasound (transverse view) demonstrates architectural distortion and partial rupture of the muscle (well-defined anechoic area – arrows). Although the injury involves more than 50% of the muscle's thickness, the injury is focal and involves less than 50% of the cross-sectional area of the muscle.* **b**) *Power Doppler ultrasound shows intramuscular neovascularization at the site of the injury (repair phase).*

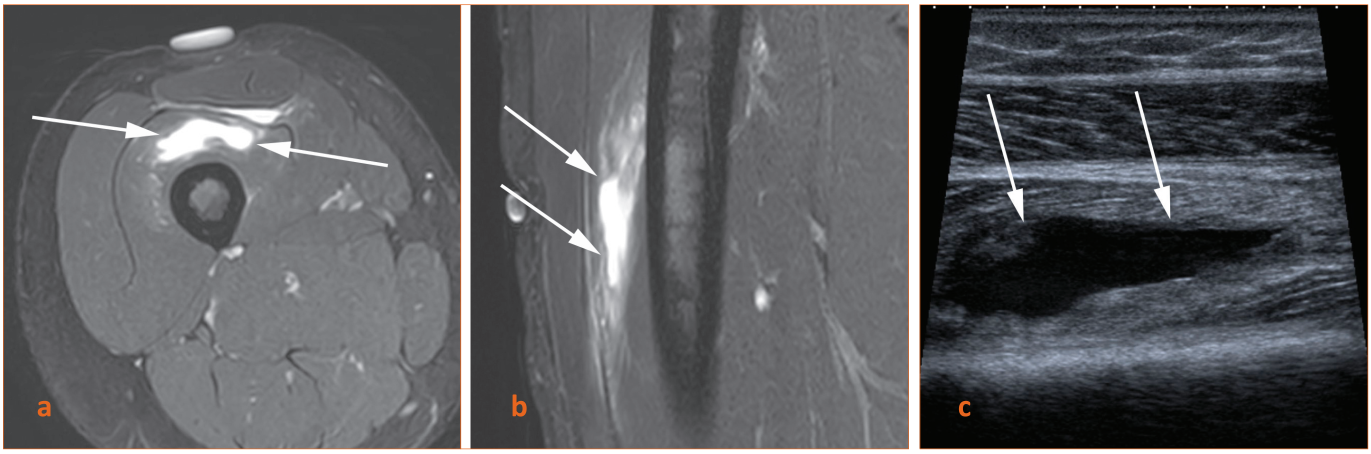

Figure 6: *High-grade direct injury of the vastus intermedius muscle. Axial* (a) *and sagittal* (b) *T2-weighted fat-suppressed MRI images show a well-defined high signal intensity intramuscular hematoma (arrows) involving more than 50% of the cross-sectional area of the muscle in* a. c) *Ultrasound (longitudinal view) was performed after MRI to study the echogenicity and compressibility of the intramuscular hematoma (arrows) before ultrasound-guided aspiration can be performed.*

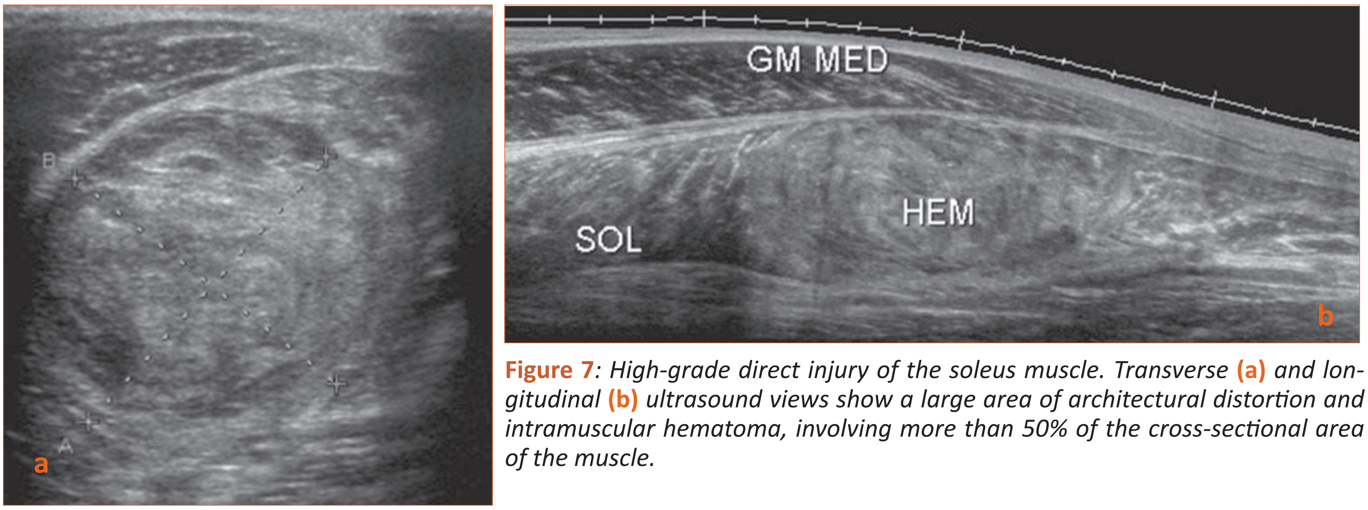

Figure 7: *High-grade direct injury of the soleus muscle. Transverse* (a) *and longitudinal* (b) *ultrasound views show a large area of architectural distortion and intramuscular hematoma, involving more than 50% of the cross-sectional area of the muscle.*

- The appearance of peripheral and intramuscular connective tissue structures: thickening **(Fig. 8)**, partial rupture, or complete rupture.

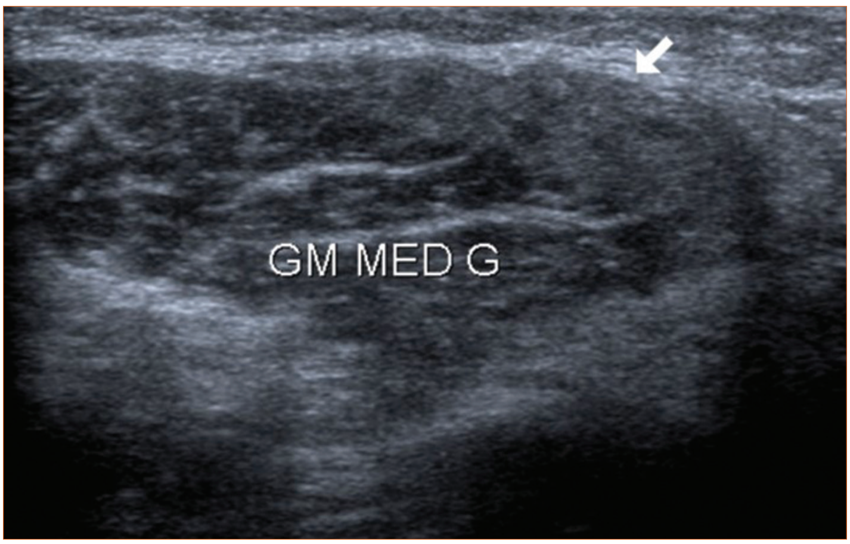

Figure 8: *Transverse ultrasound shows a focal hyperechoic thickening of the peripheral aponeurosis of the medial gastrocnemius muscle (arrow), consistent with post-traumatic aponeurotic ecchymosis. This direct injury was considered as an intermediate grade since it was focal and allowed muscle contraction.*

4. Classification of direct muscle injuries

- Low-grade injuries: intramuscular ill-defined hyperechoic areas or areas exhibiting high signal intensity T2 or STIR within the muscle without any architectural distortion, connective tissue involvement, nor intramuscular hematoma **(Fig. 1-2)**. Muscle function is preserved.
- Intermediate-grade injuries: Intramuscular architectural distortion and/or partial rupture is seen involving less than 50% of the cross-sectional area of the muscle **(Fig. 3-5)**. Connective tissue involvement, intramuscular hematomas or substantial loss of muscle function are not frequent.
- High-grade injuries: Intramuscular architectural distortion and/or rupture is seen involving more than 50% of the cross-sectional area of the muscle **(Fig. 6-7)**. Intramuscular hematomas and involvement of the peripheral aponeurosis are frequent. Substantial loss of muscle function is frequently seen.

5. Involvement of the peripheral aponeurosis

- Such involvement is more frequent in high-grade injuries, mostly representing focal areas of thickening or focal rupture (the last allowing for spontaneous evacuation of intramuscular hematomas after a blunt trauma).
- Focal rupture: might be painful not only in the acute phase but also chronically as muscle hernias may originate and be incarcerated at this site **(Fig. 10)**.
- Diffuse post-traumatic ecchymosis of the peripheral aponeurosis: this rare involvement may be responsible for the increase of intramuscular pressure leading to reduced perfusion and ischemic pain. Such injury might be considered as a high-grade direct injury and some cases must be treated by fasciectomy.

6. Follow-up of direct muscle injuries

- Ideally, these injuries are followed-up using ultrasound (when accessible), mainly those cases presenting with poor clinical outcomes despite adequate therapy.
- Power Doppler ultrasound allows the detection of neovascularization associated with the repair phase, consistent with an active healing process **(Fig. 1,3,5)**.
- Dynamic ultrasound study with contraction allows the evaluation of the degree of distortion associated with the scar tissue, as well as the capacity of muscle contraction.
- Calcifications **(Fig. 9)** and especially ossifications should be searched chronically as these might be associated with iterative injuries.
- Muscle hernias are better depicted when contracting the muscle **(Fig. 10)**.

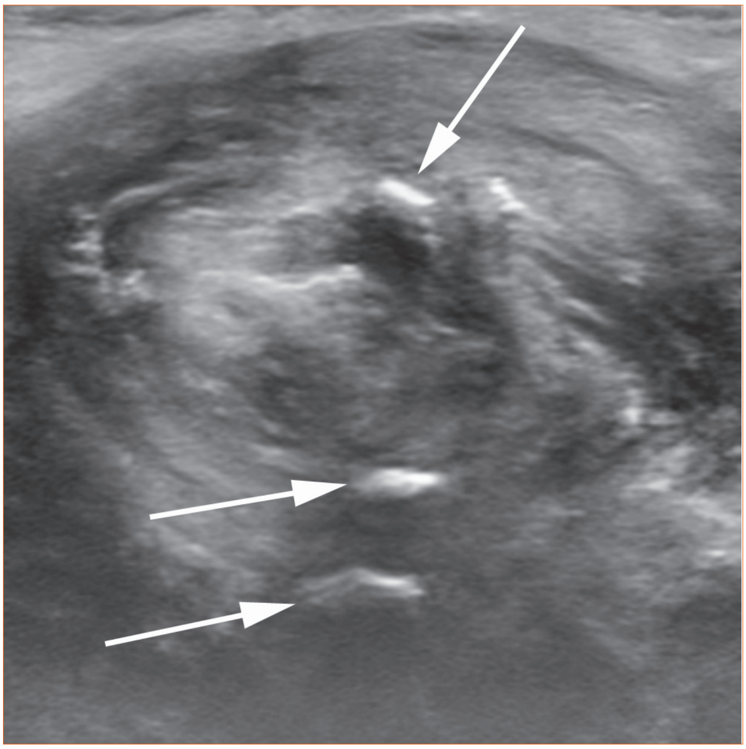

Figure 9: *Follow-up of a high-grade direct injury of the tibialis anterior muscle. Transverse ultrasound shows foci of hyperechoic calcifications exhibiting acoustic shadowing (arrows) within the area of architectural distortion involving more than 50% of the cross-sectional area of the muscle.*

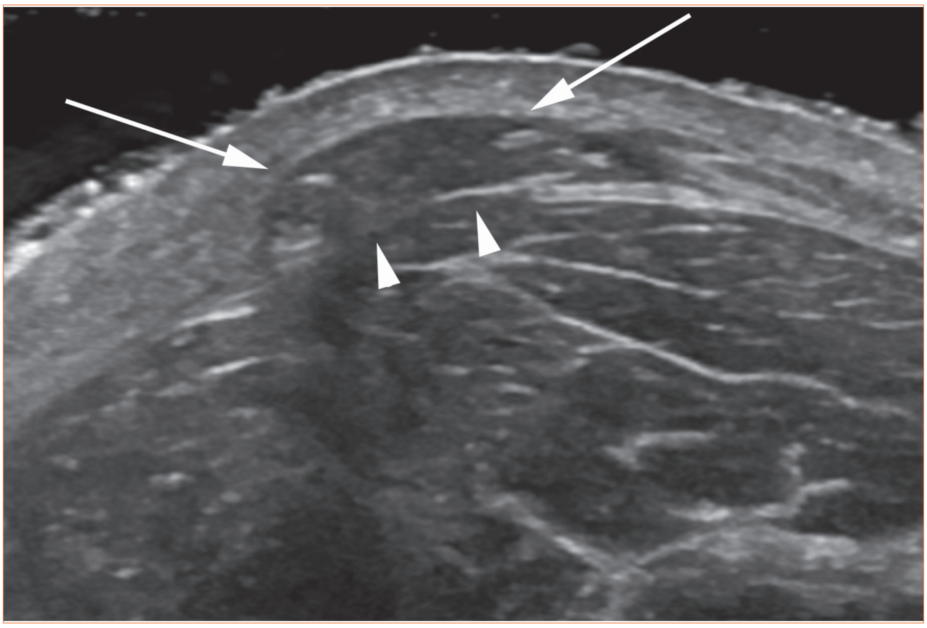

Figure 10: *Transverse ultrasound shows a focal defect of the peripheral aponeurosis of the tibialis anterior muscle following a direct trauma (arrowheads) associated with an adjacent muscle hernia (arrows).*

7. Management of direct muscle injuries

- Acute phase: liquified and organized hematomas must be aspirated using ultrasound guidance (these are anechoic and show some degree of compression when pushing the probe).
- Compression or wrapping the injured area with an elastic bandage is recommended after aspiration to avoid recurrence of the hematoma.
- We must limit the development of hematomas: protocols RICE (Rest, Ice, Compression, Elevation) et POLICE (Protection, Optimal Loading, Ice, Compression, Elevation).
- Refer the patients to rehabilitation (physiotherapy) as soon as possible.

8. Prognostic and final considerations

- Unlike indirect muscle injuries, there is not enough evidence in the literature regarding the prognosis of direct muscle injuries, especially in athletes.
- Imaging plays a major role in the detection and the assessment of the extent of direct muscle injuries. Ultrasound plays a major role in the management of hematomas at the acute phase.
- Ultrasound is better suited in the follow-up of such injuries, allowing for dynamic and vascularization assessments.

03 Quadriceps injuries in 10 points

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Point 1: The quadriceps – general anatomy and function

- The quadriceps femoris is a large muscle which covers almost all the anterior aspect of the thigh as well as a broad portion of its lateral aspect.
- It is composed of three deep muscles, the vastus medialis, vastus intermedius, and vastus lateralis, which are in turn covered by a superficial muscle, the rectus femoris.
- Only the rectus femoris is biarticular. It originates on the anterior inferior iliac spine and acetabular rim and has no femoral attachment, while the vastus muscles have a femoral origin. All four muscles then join in the distal tendon.
- As the primary knee extensor, the quadriceps plays an active role in walking and running. The rectus femoris also plays a moderate role in hip flexion.

Point 2: The vastus muscles

- The vastus muscles attach directly to the femoral shaft via fleshy fibers **(Fig. 1)**
- The vastus intermedius is composed of concentric lamellae which originate in a broad attachment not only around the anterior aspect of the diaphysis, but also in an extensive fashion around its medial and lateral aspects.

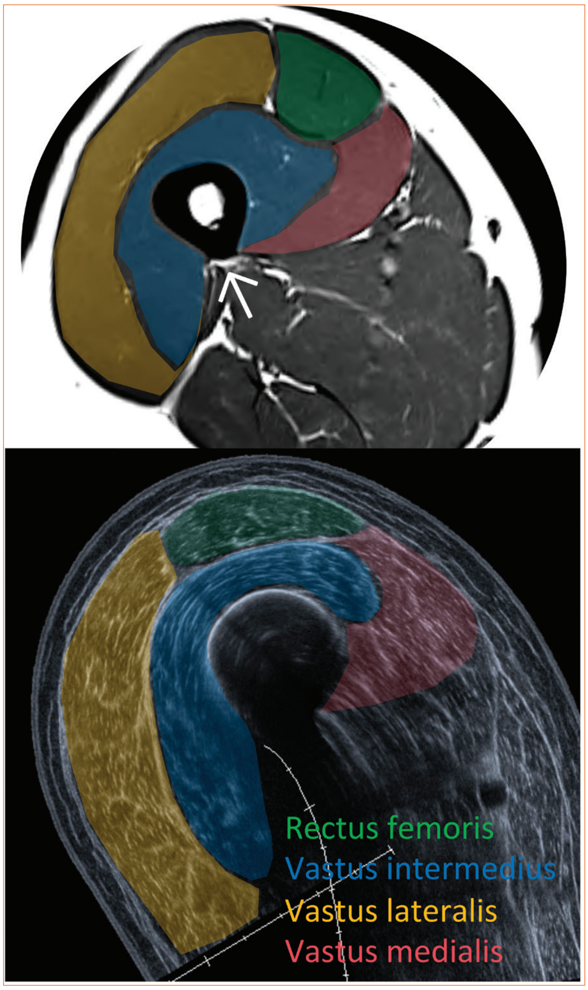

Figure 1: *Transverse T1-weighted MR image and wide-view US image of the middle third of the thigh: Vastus muscles extend all around the femoral shaft, except on the linea aspera. (arrow). Note the posterior expansion of the vastus lateralis.*

- The vastus lateralis has the most proximal origin, just below the greater trochanter **(Fig. 2)**. It is a voluminous muscle which extends in a broad fashion posteriorly beyond the axis of the femur.

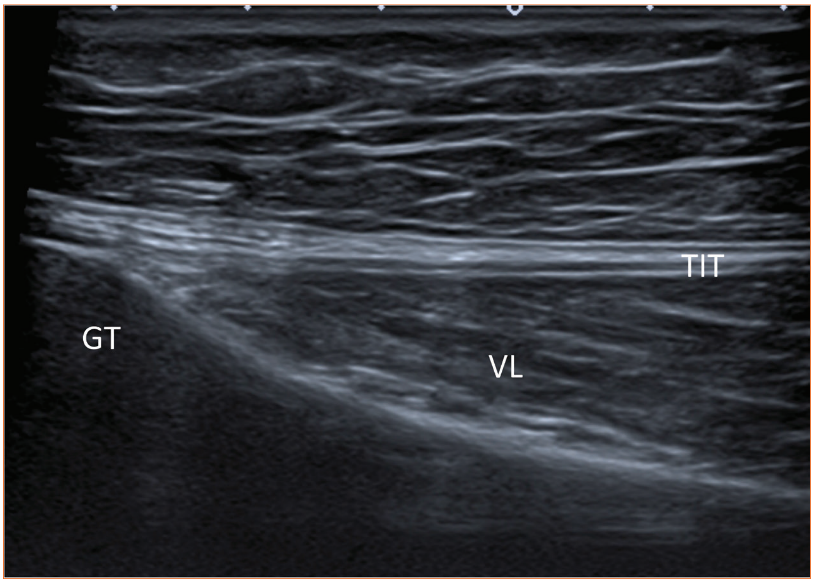

Figure 2: *Long axis US image of the inferior aspect of greater trochanter (GT):proximal insertion of the vastus lateralis (VL), overlayed by the ilio-tibial tract (TIT).*

- The vastus medialis is not as broad as the vastus lateralis but reaches further down toward the knee **(Fig. 3)**.

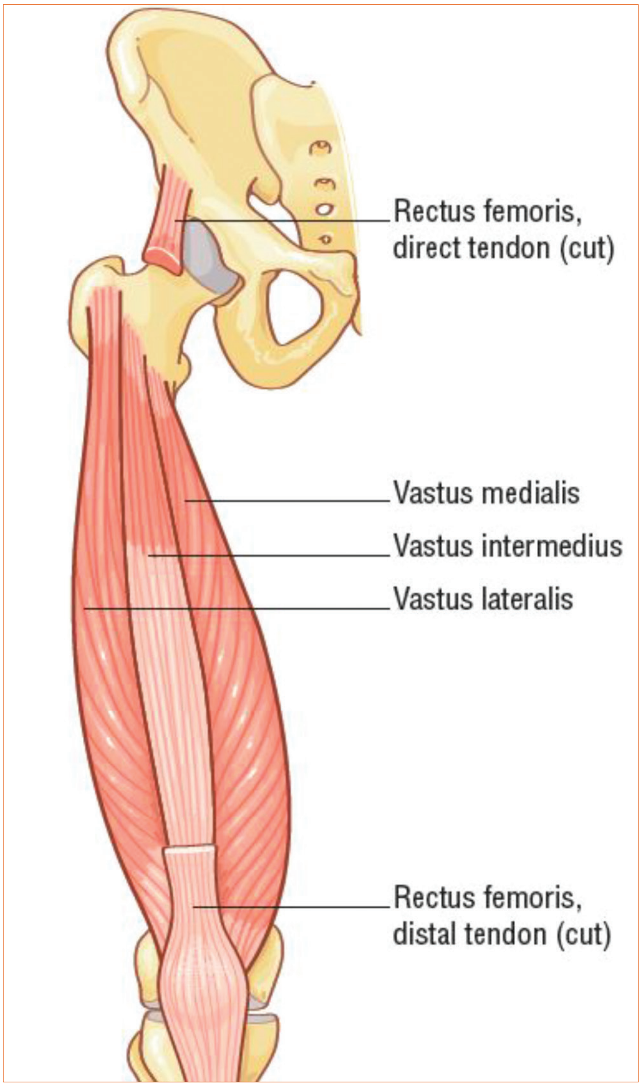

Figure 3: *Quadriceps muscle: 3 vastus bellies.*

- Clearly distinguishing these muscles on ultrasonography (US) is occasionally difficult given that their aponeuroses are often discontinuous **(Fig. 4)**.

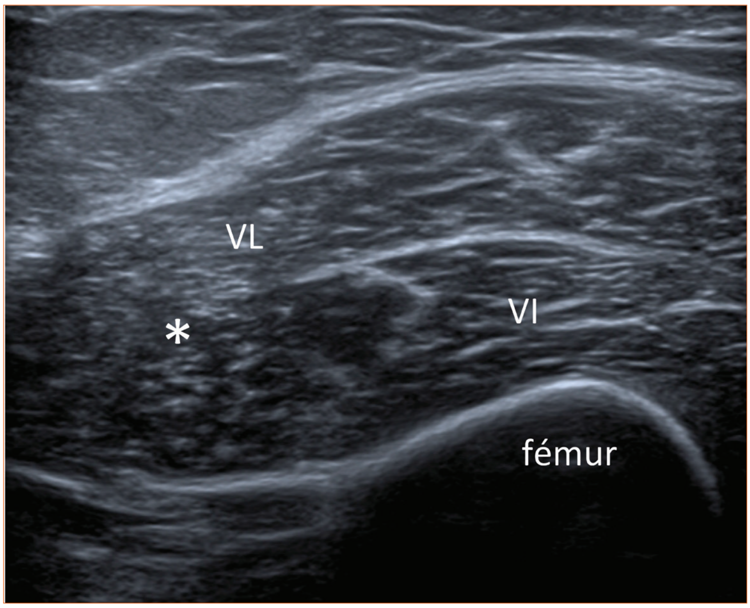

Figure 4: *Short axis lateral US image of the middle third of the right quadriceps muscle: Interruption (*) of the fascia between vastus lateralis (VL) and vastus intermedius (VI).*

Point 3: The rectus femoris – three tendons, three aponeuroses, one double-bellied muscle

- The rectus femoris has an unusual anatomy which must be understood, because the pathological presentations encountered in traumatology result directly from it **(Fig. 5)**.

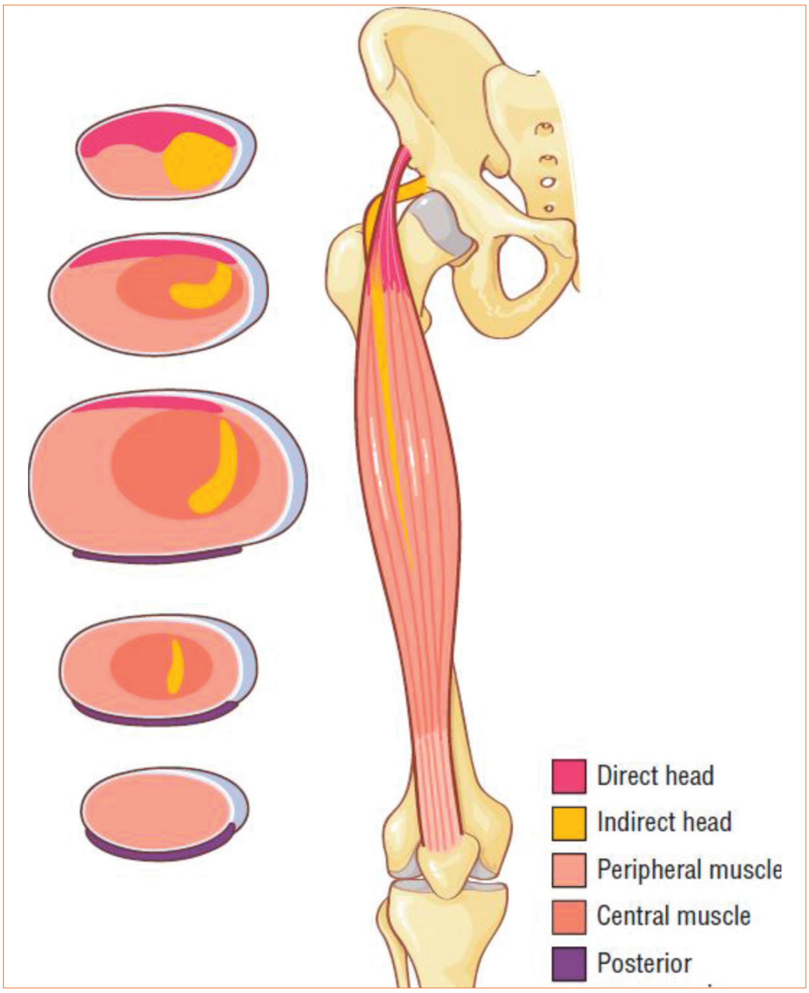

Figure 5: *Quadriceps muscle: Rectus femoris belly.*

- This muscle attaches proximally to the ileum via two main tendons (as well as a more accessory recurrent tendon) which fuse and spread out to form two aponeuroses from which the muscle fibers arise.
- The straight head originates on the anterior inferior iliac spine and gives rise to the superficial aponeurosis, to which the peripheral muscle fibers attach **(Fig. 6)**.

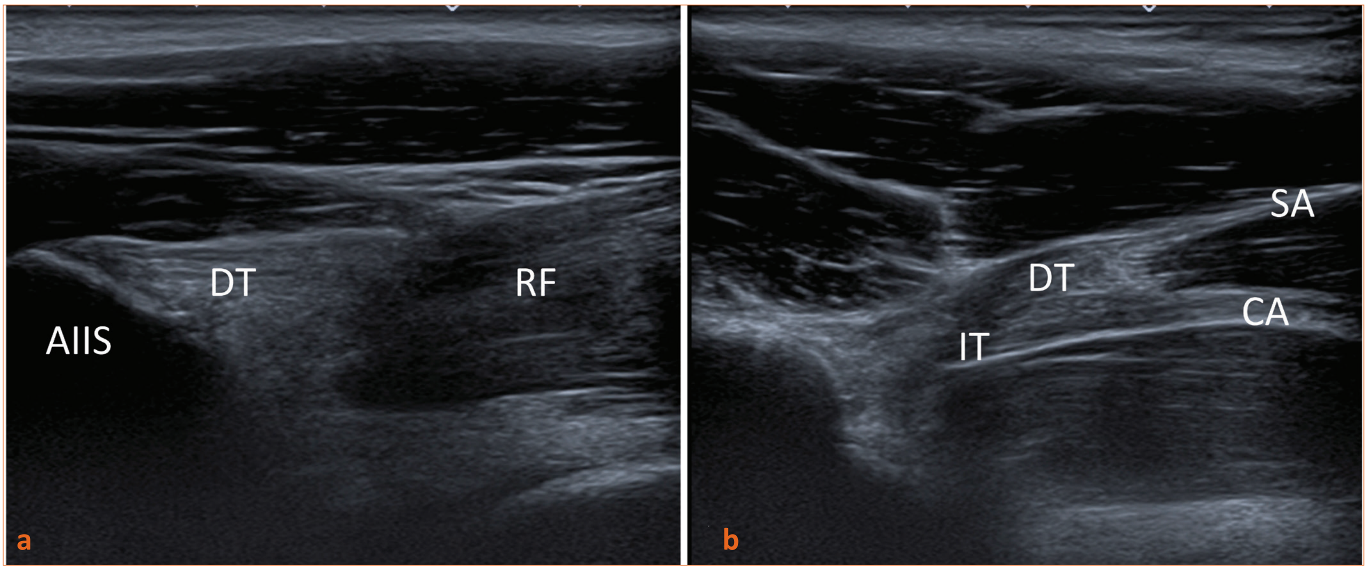

Figure 6: *(a) Sagittal US image along the (AIIS): direct tendon (DT) insertion of the rectus femoris (RF). (b) Oblique sagittal US image: Direct tendon (DT) crosses over indirect tendon (IT), respectively continued by superficial (SA) and central aponeurosis (CA)*

- The reflected tendon which arises from the anterolateral acetabular rim gives rise to the central aponeurosis, a sagittal septum onto which the deep muscle fibers attach, this muscular component being roughly cone-shaped.
- The distal muscle fibers insert onto the distal aponeurosis on the deep posterior aspect of the muscle. This aponeurosis descends in turn to form the distal tendon **(Fig. 7)**.

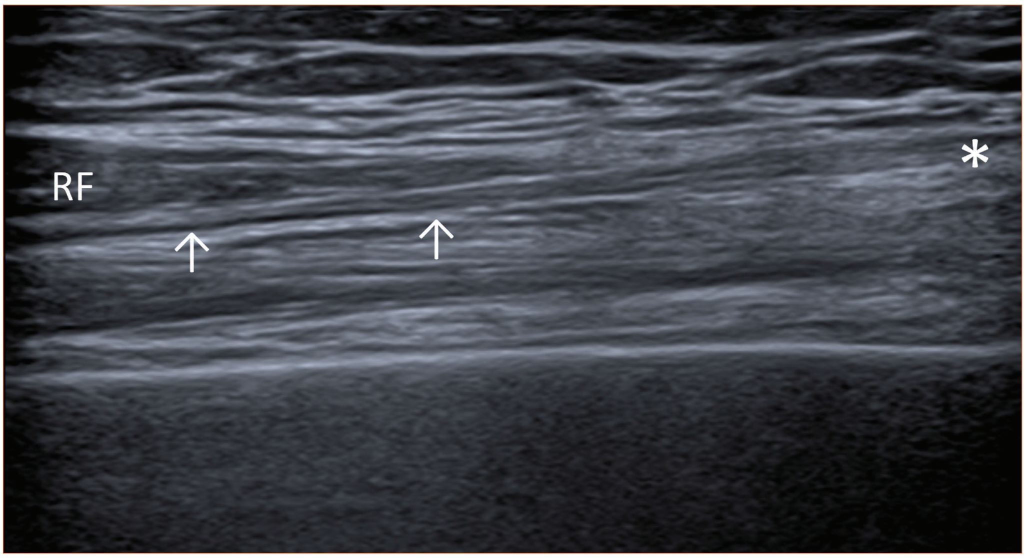

Figure 7: *Long axis US image of the distal junction of rectus femoris (RF) onto the deep aponeurosis (arrows), continued by distal tendon (*).*

Point 4: Proximal lesions of the rectus femoris

- A chapter by Dr. Philippe Meyer in the previous issue of Gel Contact, the annual review of the French musculoskeletal imaging society (SIMS), specifically covers these lesions. To summarize:
- Traumatic proximal rupture is typically caused by a shooting movement and varies with the patient's age. Adolescents mainly present avulsion of the ossification center of the anterior inferior iliac spine which can sometimes cause sequelae involving significant ossification. Less commonly, adults present either wholly tendinous ruptures which mainly involve the straight tendon, or proximal myotendinous junction rupture **(Fig. 8)**.
- Besides traumatic injury, microtrauma- or microcrystalline-related tendinopathy may also occur **(Fig. 9)**.

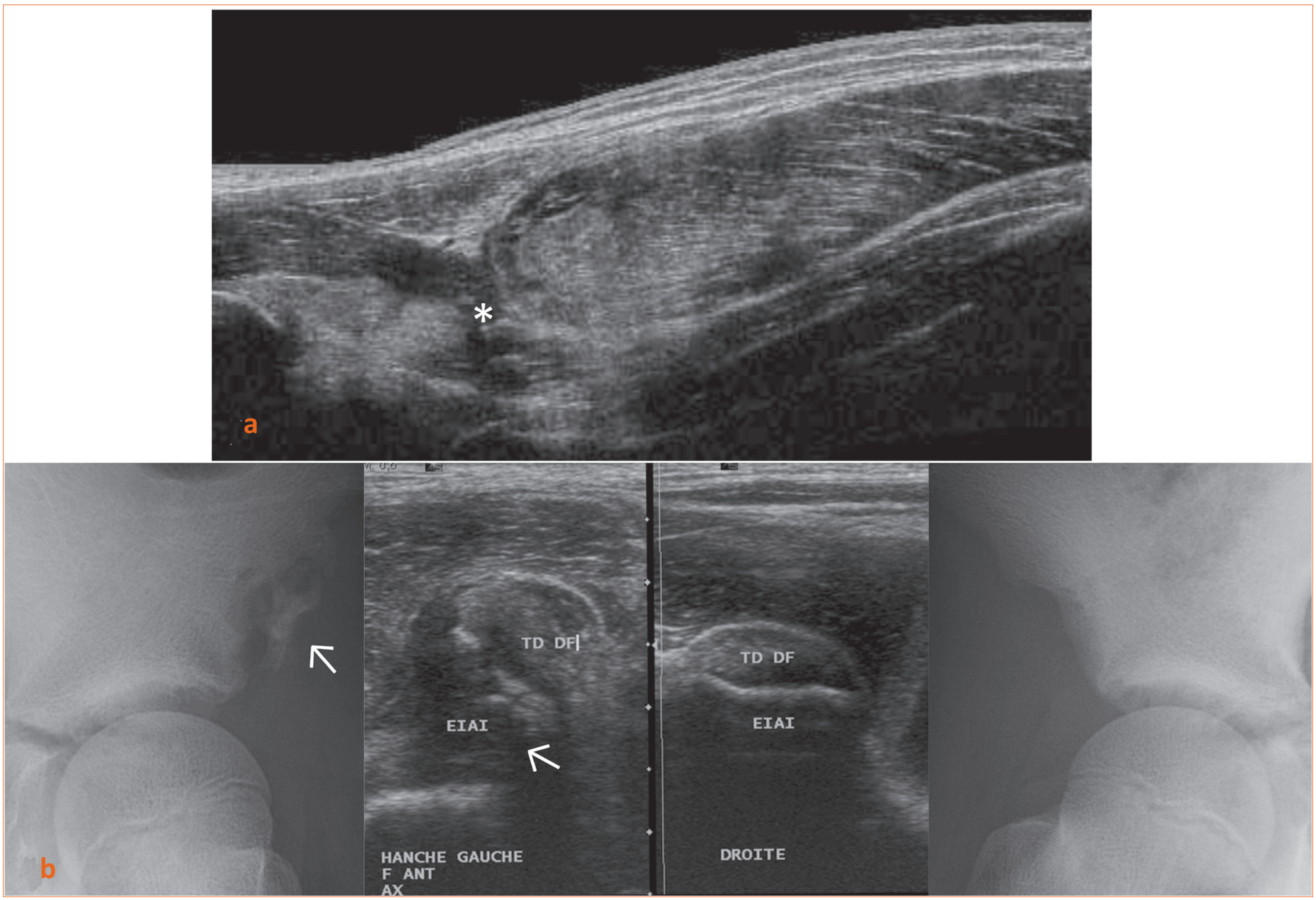

Figure 8: **(a)** *Wide-view sagittal US image of a full thickness tear of rectus femoris proximal myotendinous junction in an adult (*).* **(b)** *11 years old boy with anterior inferior iliac spine apophyseal avulsion. Plain film and axial US with opposite normal images. Fragmentation and separation of bone (arrows) recovered by a mild swollen tendon. (TD DF)*

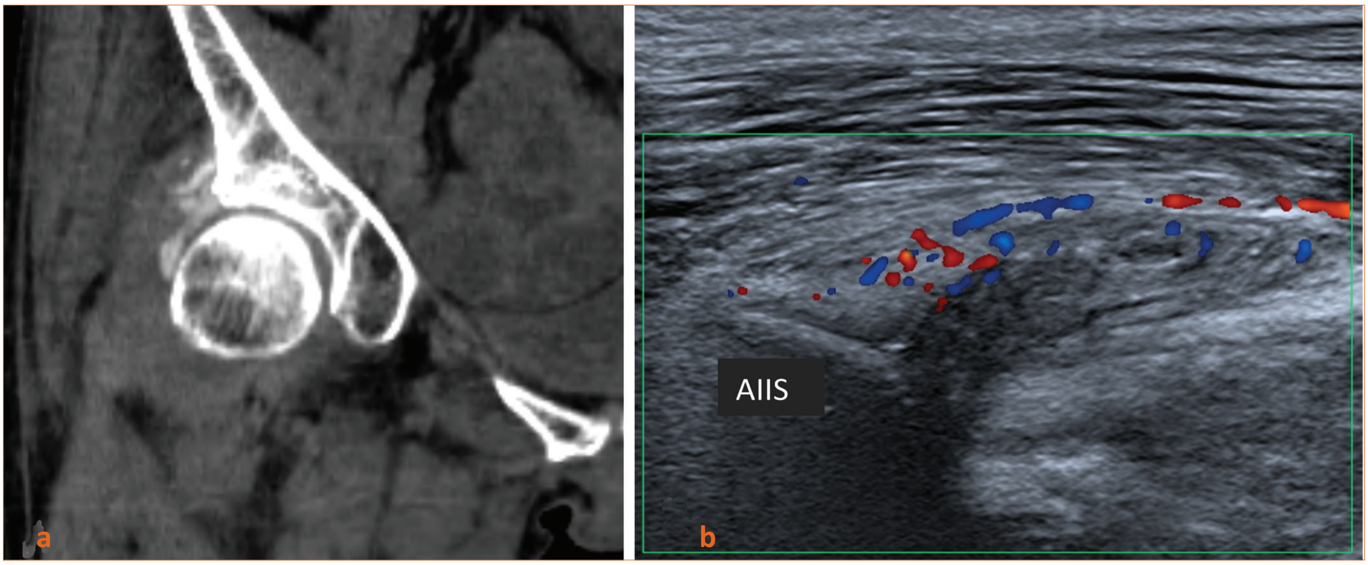

Figure 9: *Gout tophus inside direct and indirect tendons of the rectus femoris, causing hip pain to a 60 years old woman with known hyperuricemia. Coronal plane CT scan image* **(a)**. *Sagittal plane color Doppler image* **(b)**.

Point 5: Intrinsic rectus femoris injuries

- After the hamstring muscles, the rectus femoris is the most common site of intrinsic traumatic injury. This is because of its biarticular nature.
- The specifics of the injury mechanism and a classification of severity are discussed in this issue of Gel Contact by Jean-Louis Brasseur (see above).
- The most noteworthy, and the commonest, injury involves the comma-shaped central sagittal aponeurosis in the upper third of the thigh and the attachment of the fibers of the deep muscle to it. The other peripheral myoaponeurotic and proximal or distal myotendinous junction can also be affected by this type of injury **(Fig. 10)**.

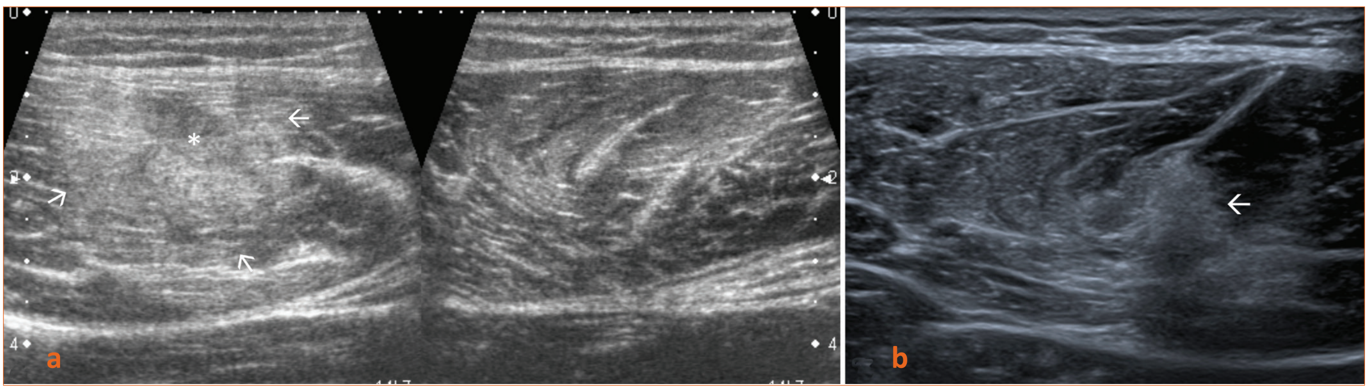

Figure 10: *2 cases of rectus femoris central aponeurosis strains; axial US images.* **(a)** *Intermediate severity tear, with hyperechoic swollen muscle (arrows), and «negative image» of the central aponeurosis itself (*); normal opposite image on the right* **(b)** *well defined, hyperechoic fibrous scar (arrow).*

Point 6: Extrinsic vastus injuries

- The typical extrinsic muscle injury is direct trauma to the quadriceps. This muscle is very vulnerable in sporting contexts (the «dead leg») since it becomes caught between the body causing the trauma at the surface (the hammer) and the femoral diaphysis underneath (the anvil).
- See above in this issue of Gel Contact for a categorization of lesions by Michel Crema. These may involve a contusion only, which appears as an area of increased echogenicity (benign); a localized muscle injury unaccompanied by hematoma (moderate); or an injury to more than 50% of the cross-section of the muscle accompanied by hematoma or even a longitudinal rupture of the muscle (severe).
- The vastus intermedius is the most frequently involved. If there is a lateral blow, damage to the vastus lateralis may also result. Conversely, traumatic medial blows to the vastus medialis are more rare **(Fig. 11)**.

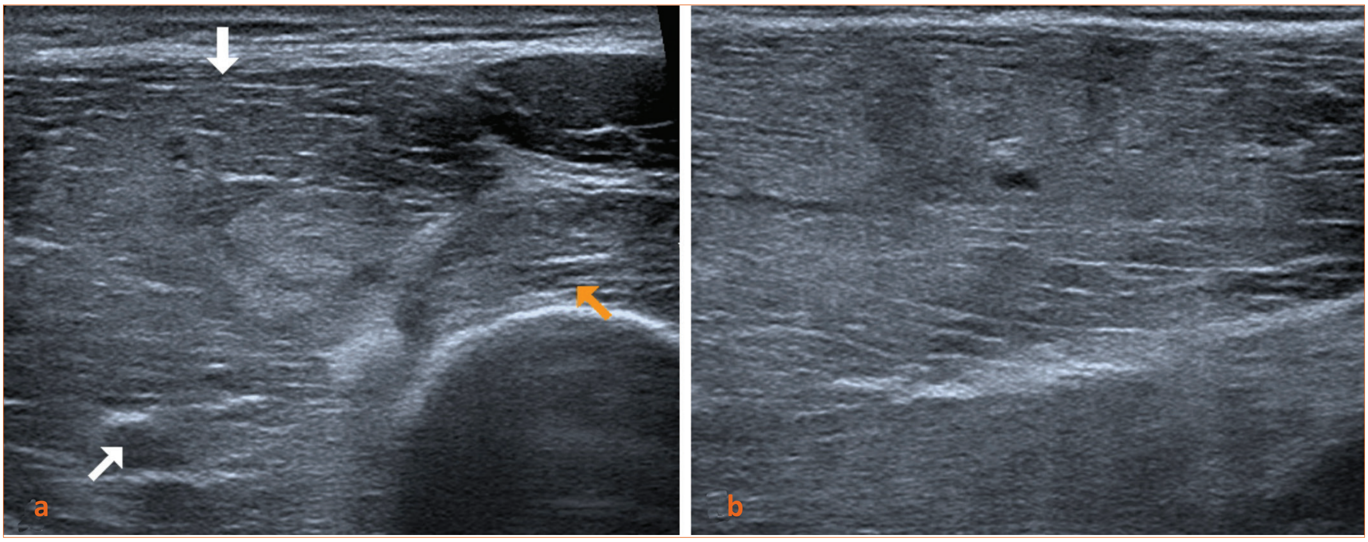

Figure 11: *Short* **(a)** *et long axis* **(b)** *US images, 8 days after a motorbike crash, the patient being stuck beneath it. Homogenous grey muscle swelling with small blood fluid foci in vastus medialis (white arrows), and in vastus intermedius to a lesser degre (yellow arrow): Intermediate severity contusion*

Point 7: Traumatic injury to the distal quadriceps tendon

- The distal tendon is located at the extremity of the deep aponeurosis of the rectus femoris.
- It is composed of three layers which are usually easy to distinguish on US. The superficial layer corresponds to the fibers of the rectus femoris, while the intermediate layer arises from the vastus medialis and vastus lateralis and the deep layer from the vastus intermedius **(Fig. 12)**.
- The prevalence of traumatic tears to the distal tendon is underestimated, because even complete tears can be clinically well tolerated.

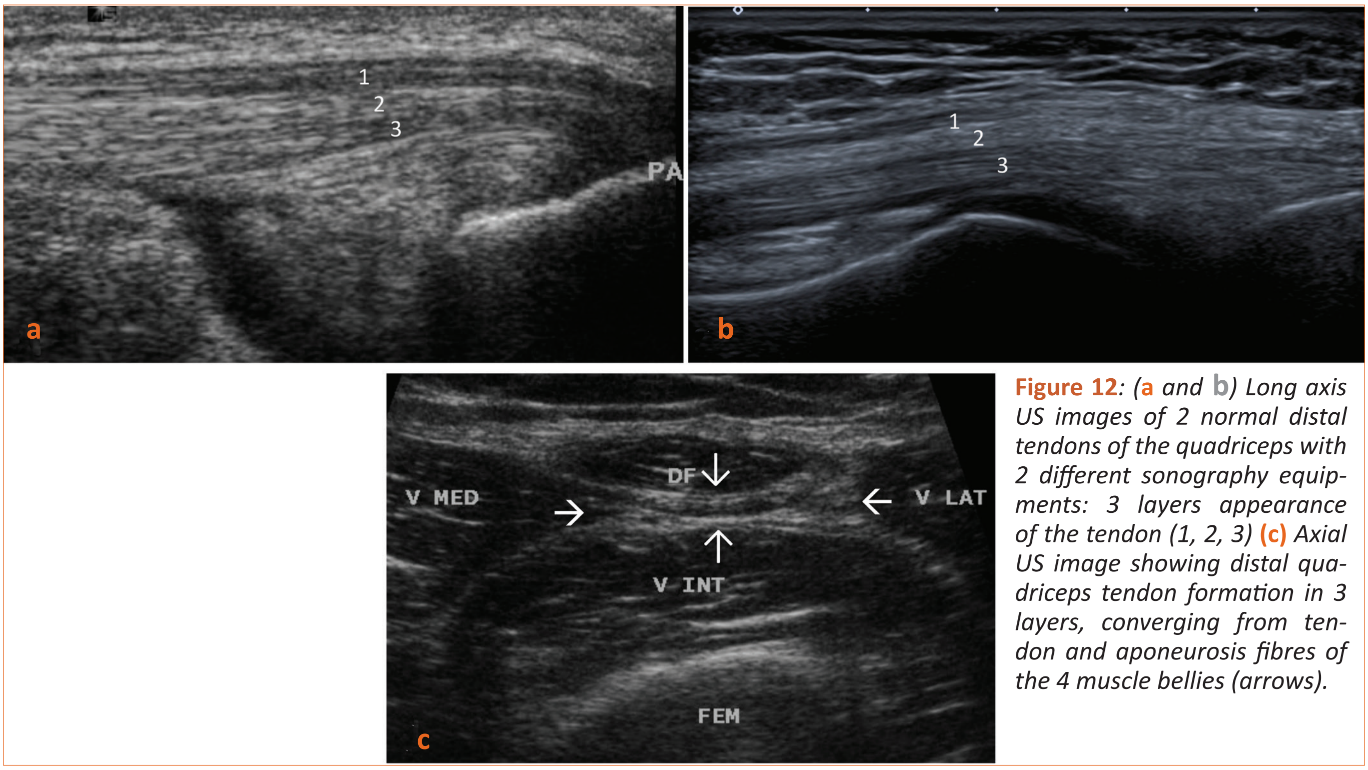

Figure 12: *(a and b) Long axis US images of 2 normal distal tendons of the quadriceps with 2 different sonography equipments: 3 layers appearance of the tendon (1, 2, 3)* **(c)** *Axial US image showing distal quadriceps tendon formation in 3 layers, converging from tendon and aponeurosis fibres of the 4 muscle bellies (arrows).*

- Such tears are easiest to detect on US with the knee moderately flexed, the patient's pain permitting. Gentle pressure with the transducer can also help, as can maneuvers to elicit muscle contraction (as far as such maneuvers are possible) **(Fig. 13)**.

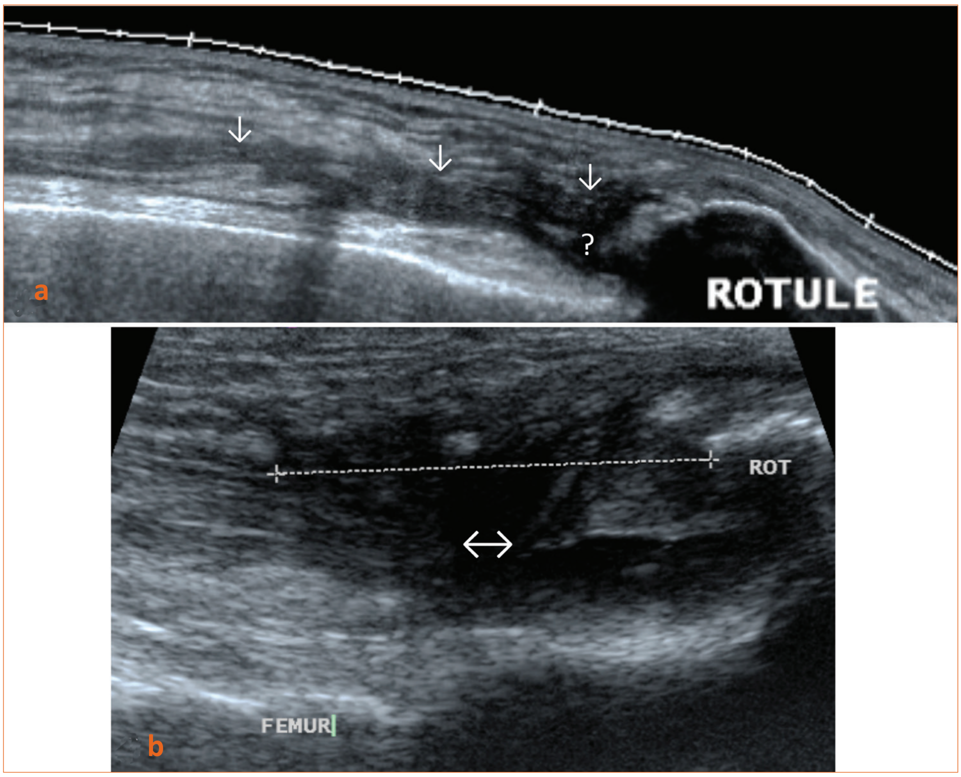

Figure 13: *Sagittal US image with fully extended knee* **(a)** *in a patient with suspicion of acute distal tendon rupture without clinical retraction: clearly abnormal tendon(↓), but it is difficult to assess a full or partial tear (?). Sagittal US image with gentle knee flexion on a cushion in the same patient* **(b)***: clearly full tear with mesurable gap (↔)*

- These tears are easier to detect on magnetic resonance imaging if abundant hematoma is present **(Fig. 14)**.

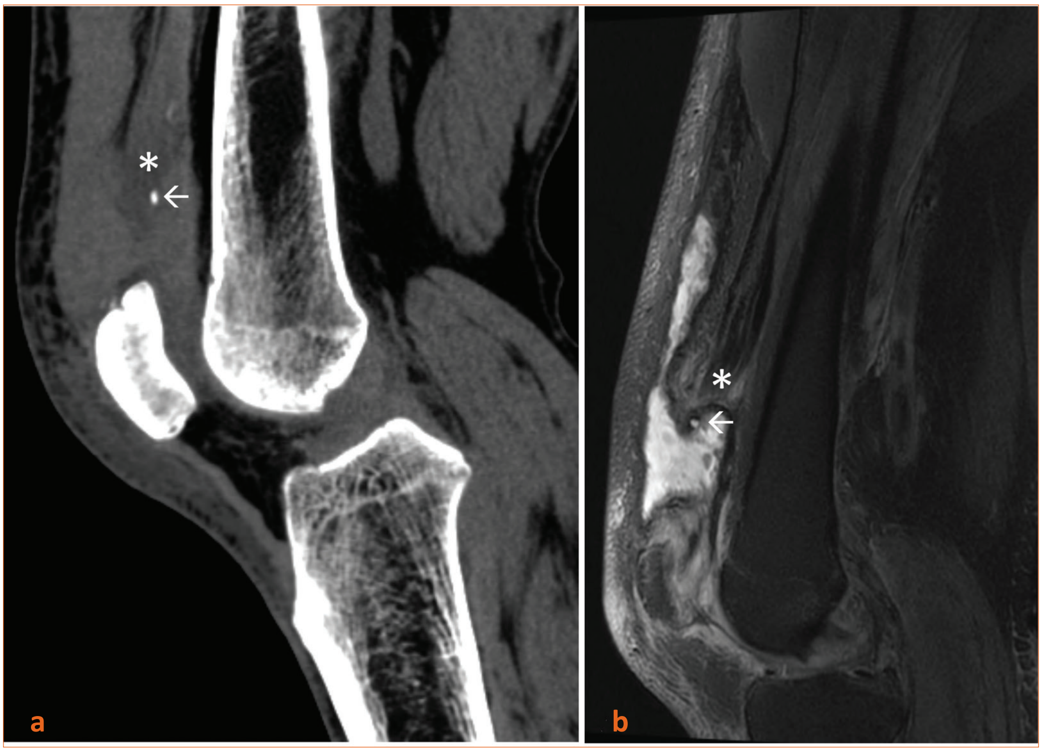

Figure 14: *51 years old patient, 6 weeks after a fall on the knee.CT scan first done for suspected fracture* **(a)**. *Sagittal DP fatsat MR image* **(b)**. *Full thickness tear of the quadricipital tendon at the top of patella, with rétraction (*) and small bony fragment (arrow).*

Point 8: Drain the hematoma, or beware of bony growths and functional sequelae.

- Intrinsic and extrinsic quadriceps injuries cause sometimes large hematomas. **(Fig. 15)**. If the hematoma is larger than around 10cc, or 5cc in certain cases, it should be drained while it is still in the liquid phase to accelerate healing and reduce the risk of cysts or bony growths.
- If an intramuscular hematoma is not drained, its clinical course may be complicated by a bony growth. This is very common in the quadriceps and its outcome is variable. Post-traumatic myositis ossificans near the femoral diaphysis is typical and generally disappears after a few months **(Fig. 16)**. Although less spectacular, peripheral calcification can cause more functional impairment by interfering with muscle contractility **(Fig. 17)**.

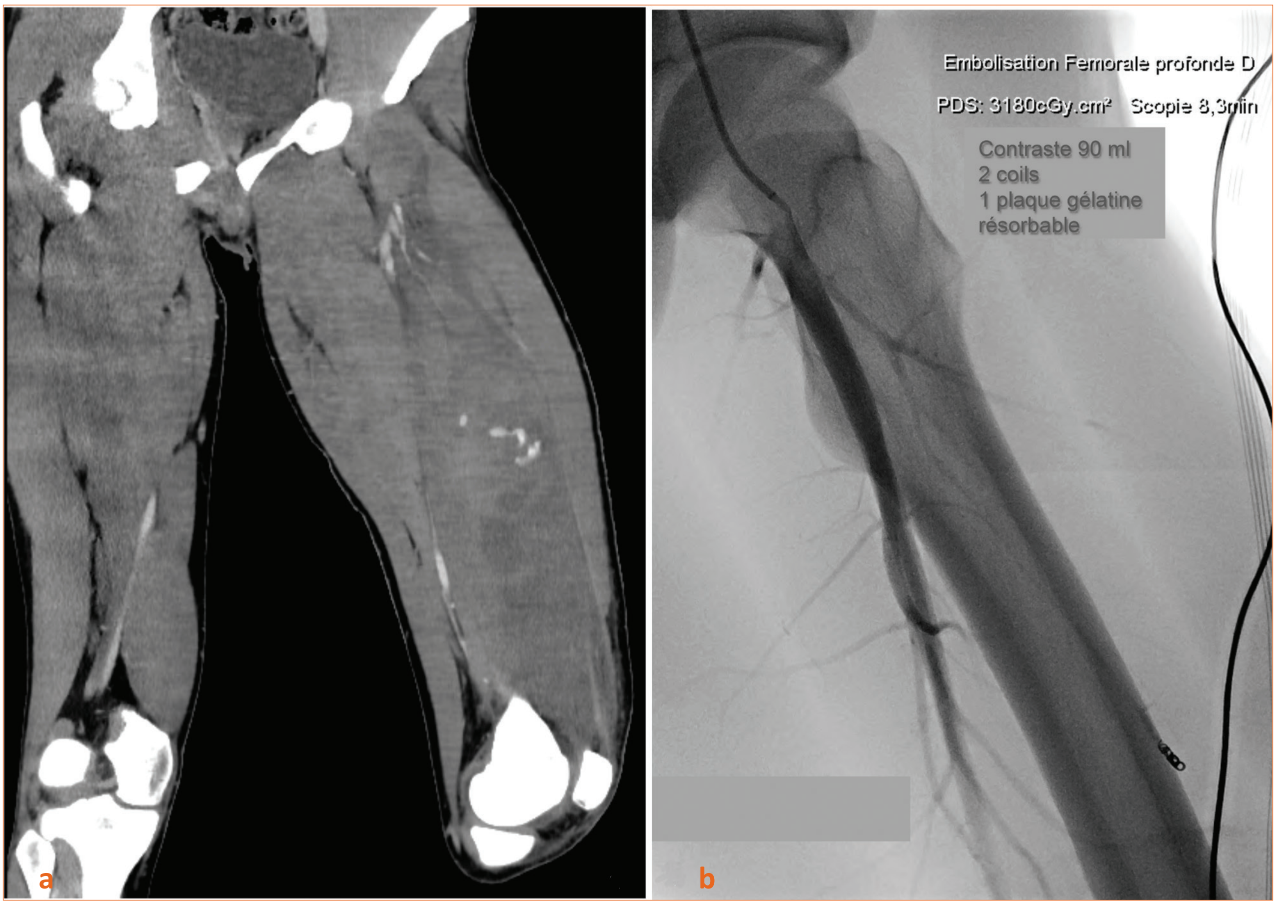

Figure 15: *19 years old patient. Immediate and total impairment after direct trauma during a rugby game: CT scan shows a large hematoma with active bleeding* **(a)** *requiring embolization, fortunately exceptional in this context* **(b)**.

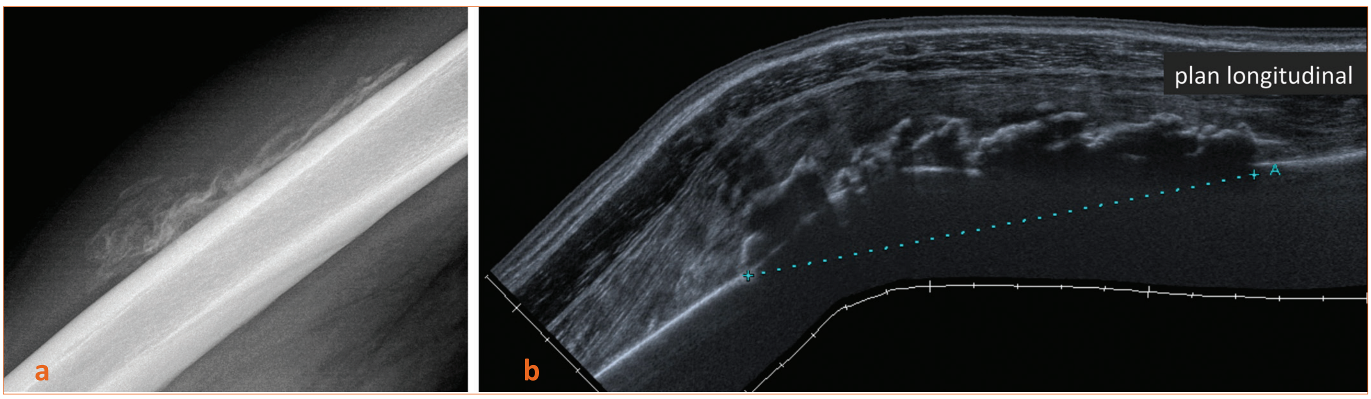

Figure 16: *Patient seen 30 days after a direct trauma with vastus intermedius contusion. Wide muscular ossification along femur on X Ray lateral view* **(a)** *and longitudinal wide-view US image* **(b)**.

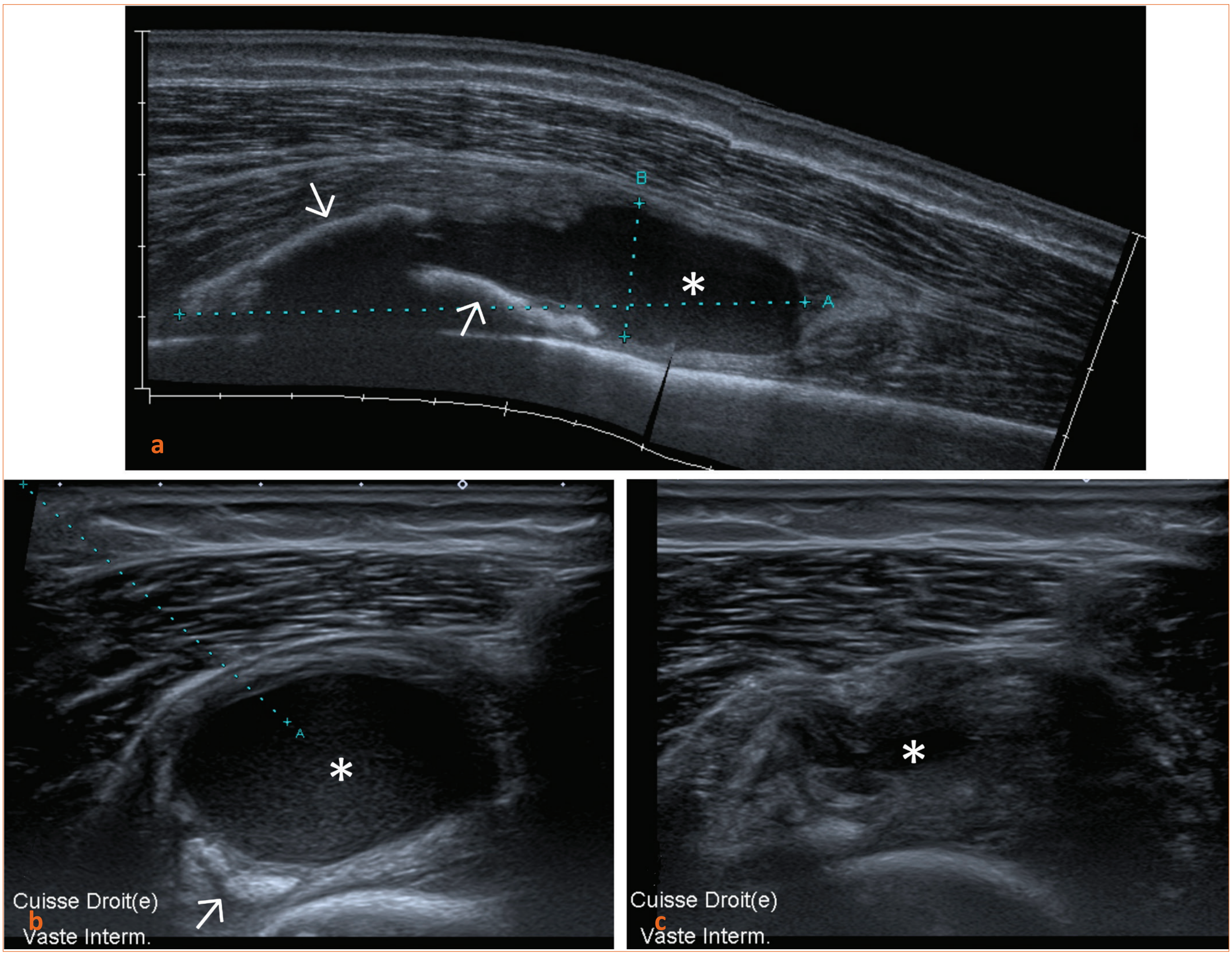

Figure 17: *30 years old patient seen 25 days after direct trauma of the vastus intermedius. Proximal half of the hematoma already shows a calcified rim (arrows) on this longitudinal US image* **(a)** *Distal half of the hematoma (*) is fluid: axial US image before* **(b)** *and after aspiration of 12cc of blood* **(c)**.

Point 9: Consider differential diagnoses

- Obviously, trauma-related pathology predominates in the quadriceps.
- But beware of tumors! It is vital to keep in mind that if a hematoma does not change in size or echogenicity between two assessments roughly 2 weeks apart, then it is something else **(Fig. 18)**.
- Morel-Lavallée lesions frequently occur in the thigh after sliding over hard surfaces, as happens in motorcycle and skiing accidents. Obviously this is a traumatic injury, but it involves a shearing away of subcutaneous fatty tissue and leaves underlying muscles and aponeuroses intact **(Fig. 19)**.

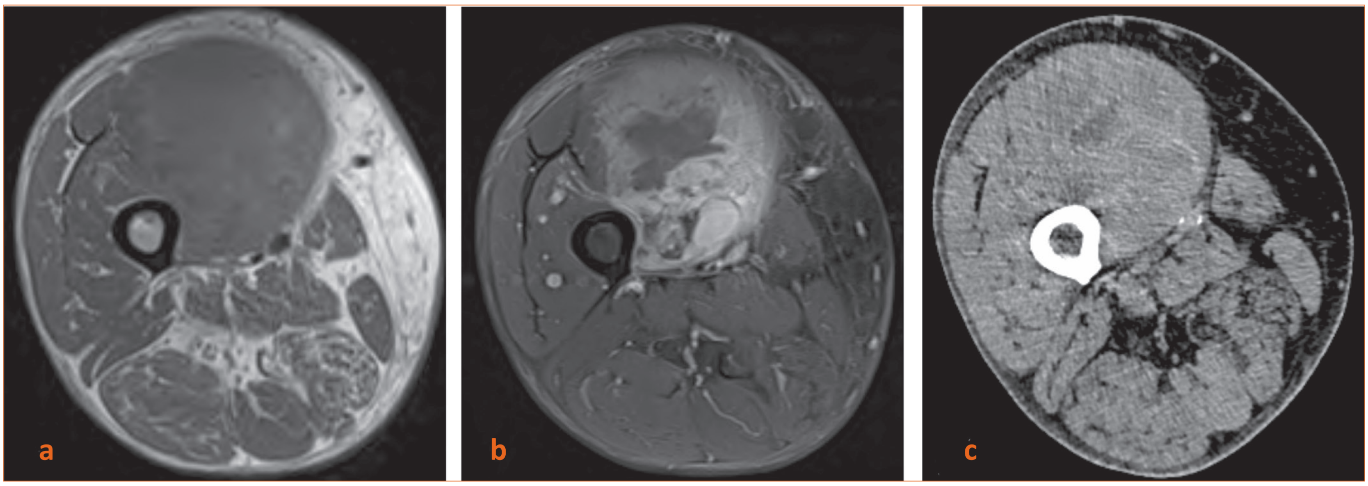

Figure 18: *65 years old patient presenting pain and swelling related to a lifting effort: axial MR T1* **(a)**, *T1 fatsat after injection* **(b)**, *and CT scan images* **(c)**. *Myxoïd sarcoma.*

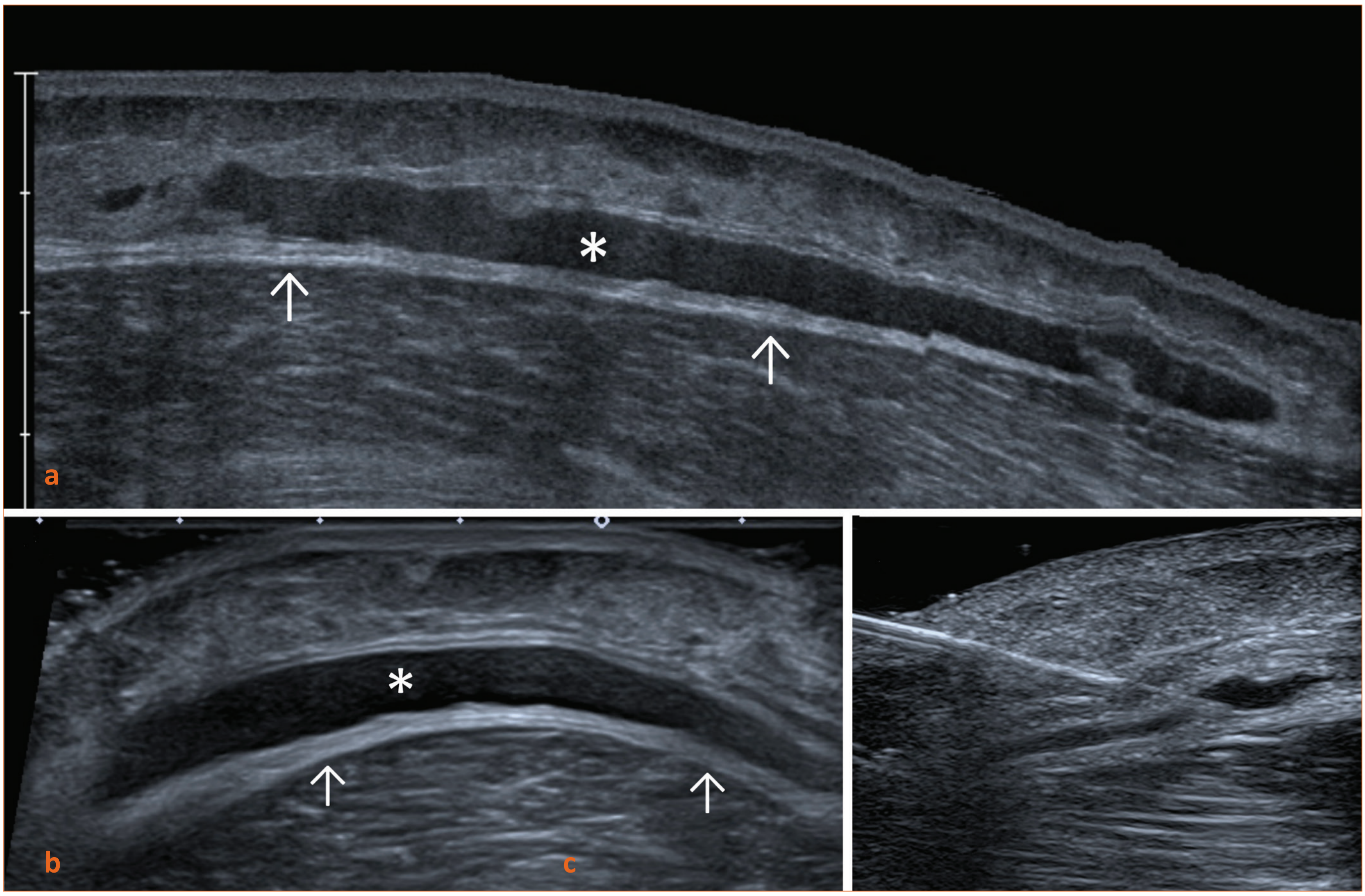

Figure 19: *54 years old woman seen 3 days after a sledge accident. Longitudinal* **(a)**, *axial* **(b)** *and after aspiration* **(c)** *US images Morel-Lavallée lesion. Notice the subcutaneous situation of the seroma (*), and respect of the underneath fascia (arrows) and muscle.*

Point 10: Suggested US protocol for quadriceps injuries

- Axial view along the midline of the anterior thigh. Locate the rectus femoris by its central septum **(Fig. 20)**
- Use the elevator technique – i.e., sweep the transducer up and down the entire rectus femoris.
- At the top, rotate the transducer on the anterior inferior iliac spine for a longitudinal view of the straight tendon of the rectus femoris.
- Tilt the transducer laterally to view the reflected tendon.
- Return to an axial view in the middle of the thigh and scan the length of the vastus muscles while adjusting the focus and, if necessary, frequency of the transducer. If the patient has received a blow to the thigh, let them indicate the site of pain.
- Sagittal view and scan the quadriceps tendon axially with the knee moderately flexed.
- Compare volume, trophism and any suspicious finding contralaterally.

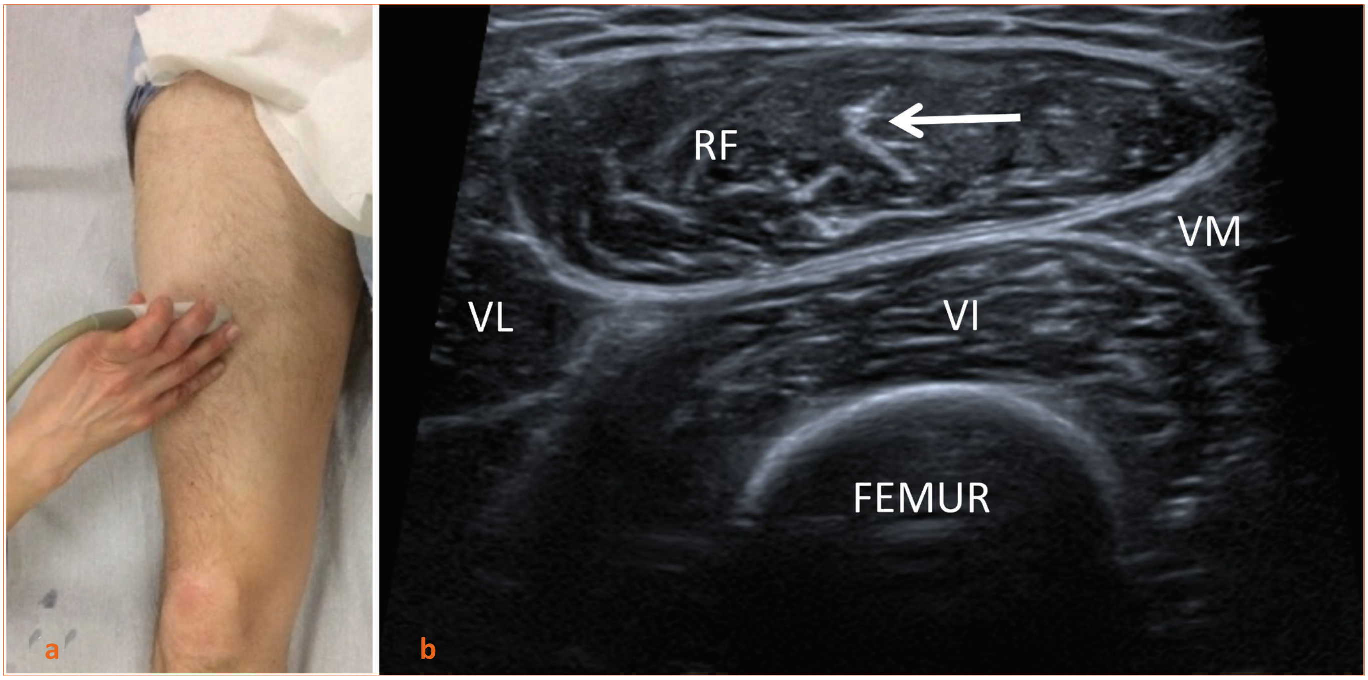

Figure 20: *US axial main scan of the quadriceps muscle. Probe position* **(a)**. *Corresponding US image* **(b)**, *showing rectus femoris central aponeurosis (←) du droit fémoral.*

4 The adductors in 10 points

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1. Origin of the adductors

The adductor muscles comprise the adductor longus, adductor brevis, adductor magnus, pectineus and gracilis. They originate in the infra-pubic region alongside the obturator externus. The pectineus is the most cranial and originates lateral to the tubercle of the pubic crest. The gracilis originates medial to other adductors from the anterior aspect of the pubis and from the medial third of the inferior surface of the ischiopubic ramus. The sartorius originates from the anterosuperior iliac spine and runs anterior to the iliopsoas, rectus femoris, vastus medialis and adductor muscles. The gracilis originates with direct muscle fibers from the deep aspect of the adductor longus and from the articular capsule of the pubic symphysis.

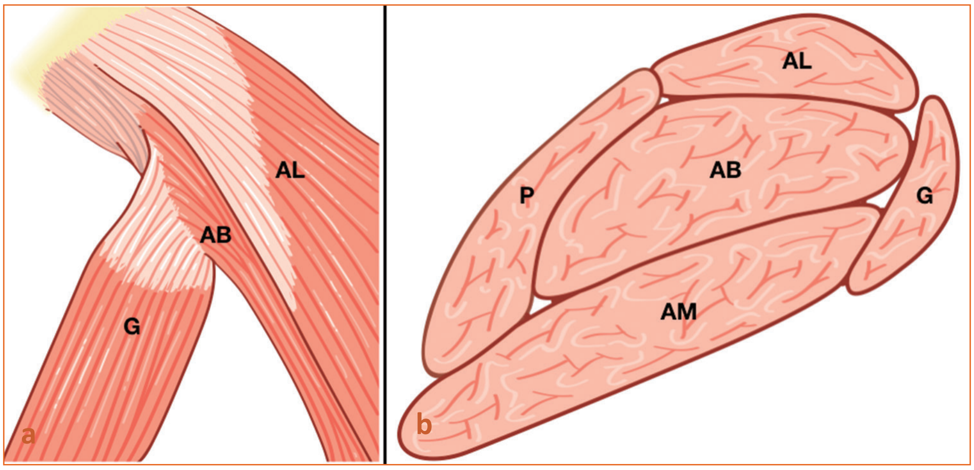

Figure 1*: Anatomical diagram from a frontal view* **(a)** *and an axial view* **(b)** *showing the locations of the adductor muscles AL: adductor longus (reflected in the dissection), AB: adductor brevis, AM: adductor magnus, P: pectineus, G: gracilis.*

2. Adductor longus

The adductor longus originates from the anterior aspect of the pubis near the pubic tubercle and pubic symphysis. The origin includes both tendon (40%) and muscle (60%) fibers. The tendinous fibers are superficial (anterior) and the muscular fibers are deeper (or posterior). The muscular fibers of the adductor brevis and adductor magnus originate directly from the bone. A common aponeurosis connects the superficial fibers of the tendon of the adductor longus to that of the distal tendon of the rectus abdominis. This common aponeurosis share some tendinous fibers with the capsule and fibrocartilage disc of the pubic symphysis. These anatomical connections explain why pain caused by an injury to either of these structures can radiate from the abdomen to the thigh.

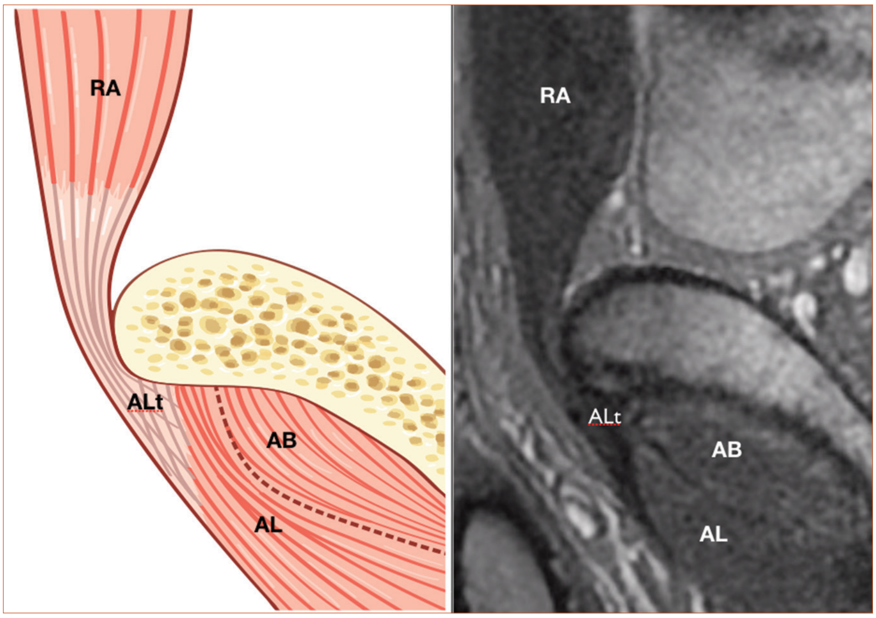

Figure 2: *Anatomical diagram and sagittal T2-weighted fat-saturated (T2FS) magnetic resonance imaging (MRI). RA: rectus abdominis, AB: adductor brevis, AL: adductor longus, ALt: adductor longus tendon.*

Ultrasound (US) shows the adductor longus as the most superficial of the adductors. The muscle forms a clinically palpable cord-like structure. With the transducer orthogonal to this landmark, the intramuscular hyperechoic horizontal band helps to identify the muscle.

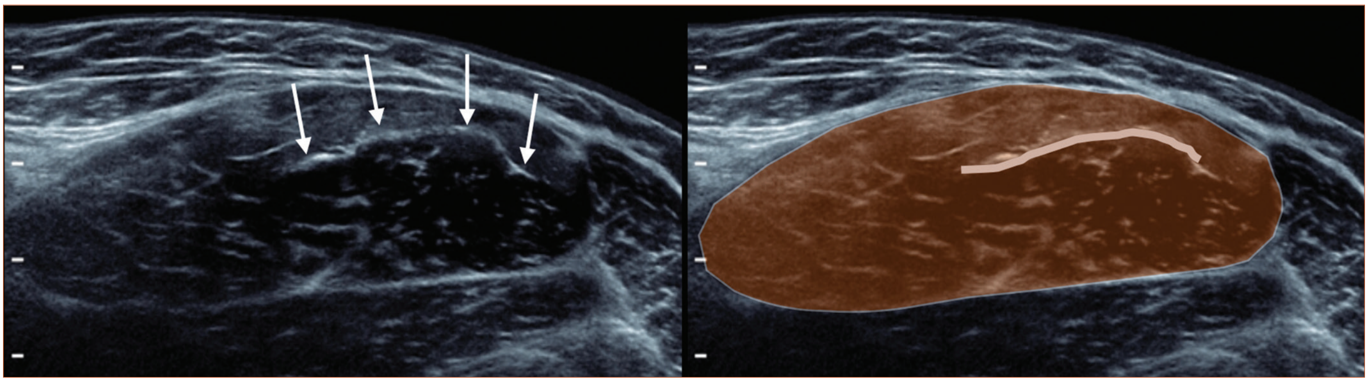

Figure 3: *US identification of the adductor longus and its horizontal longitudinal band.*

3. Gracilis

The gracilis originates with a thin aponeurosis from the body of the adductor brevis (Figure 3). In men, the muscle fibers of the adductor brevis attach to the deep aspect of the gracilis, whereas in women they merge to form a single tendon. The gracilis and adductor longus merge in 10% of cases.

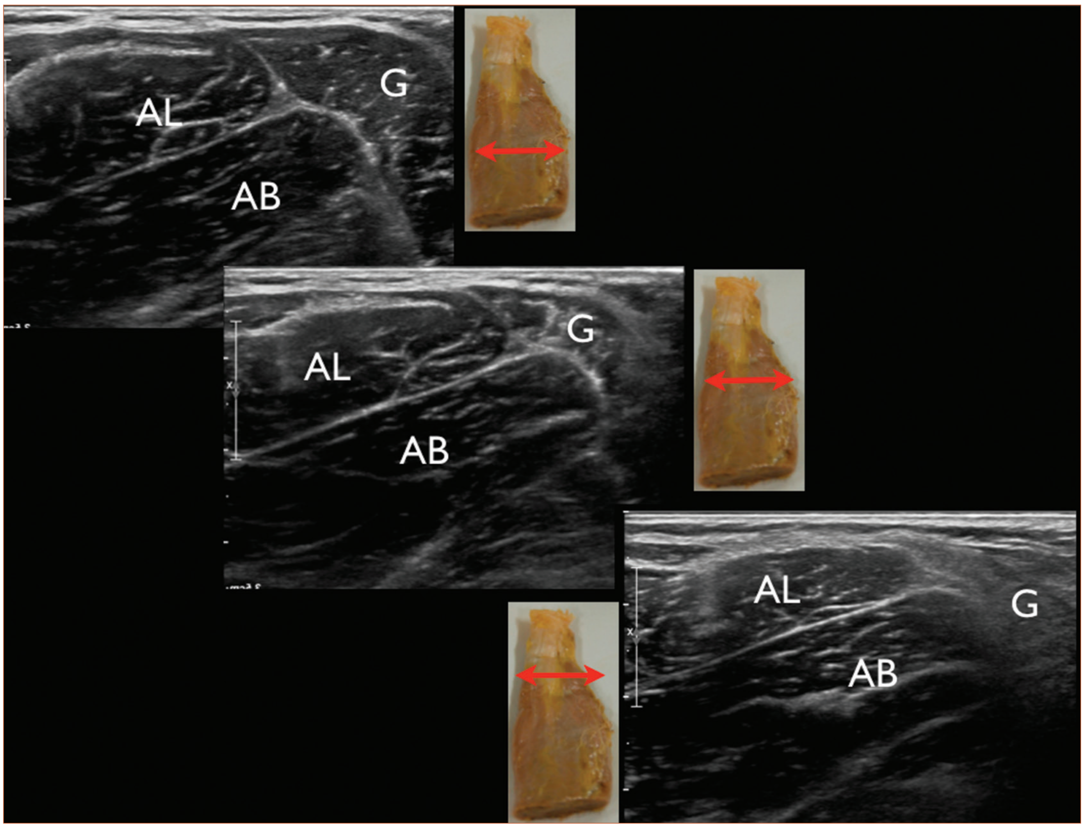

Figure 4: *US identification of the gracilis merging with the adductor brevis. G: gracilis, AB: adductor brevis, AL: adductor longus.*

4. Pectineus

The sartorius aside, the pectineus is the most medial and proximal of the adductors. Its muscular fibers directly originate from the bone near the pubic symphisis. The muscular belly follows the superior pubic ramus then runs in an oblique inferior and lateral direction, medial and deep to the iliopsoas muscle. It inserts onto the upper segment of the linea aspera of the femur, distal to the lesser trochanter.

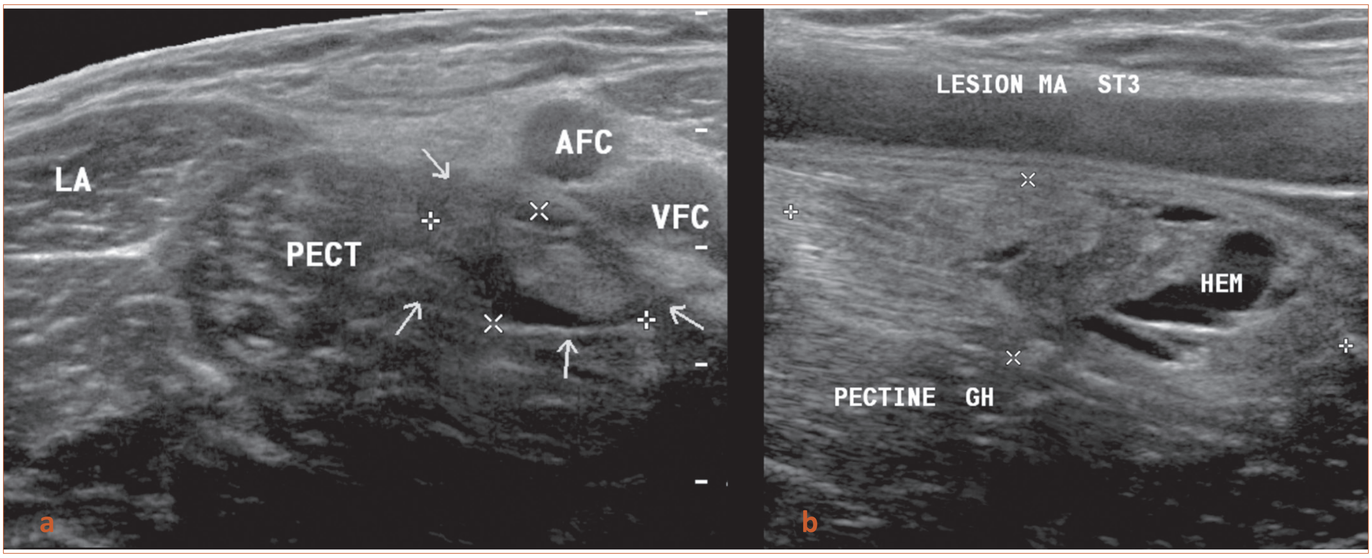

Figure 5: *Soccer player with acute inguinal pain. Axial* **(a)** *and longitudinal* **(b)** *views showing a grade 3 muscle injury (arrows). AL: adductor longus, P: pectineus, HEM: hematoma, CFA: common femoral artery, CFV: common femoral vein.*

5. Adaptive changes in the adductor longus of sportspeople

The tendon of the adductor longus sustains considerable stretching forces during sports with quick directional changes and sudden rotational movements of the pelvis, such as football, soccer, rugby, handball, and hockey. In high level athletes, microtraumatic changes frequently alter the fibrillar structure of the tendon. Common structural changes include nodules of tendinosis and small calcifications. Additionally, the most superficial fibers of the tendon almost always appear hypoechoic due to anistropy in the oblique fibers extending to the aponeurosis of the external oblique muscle.

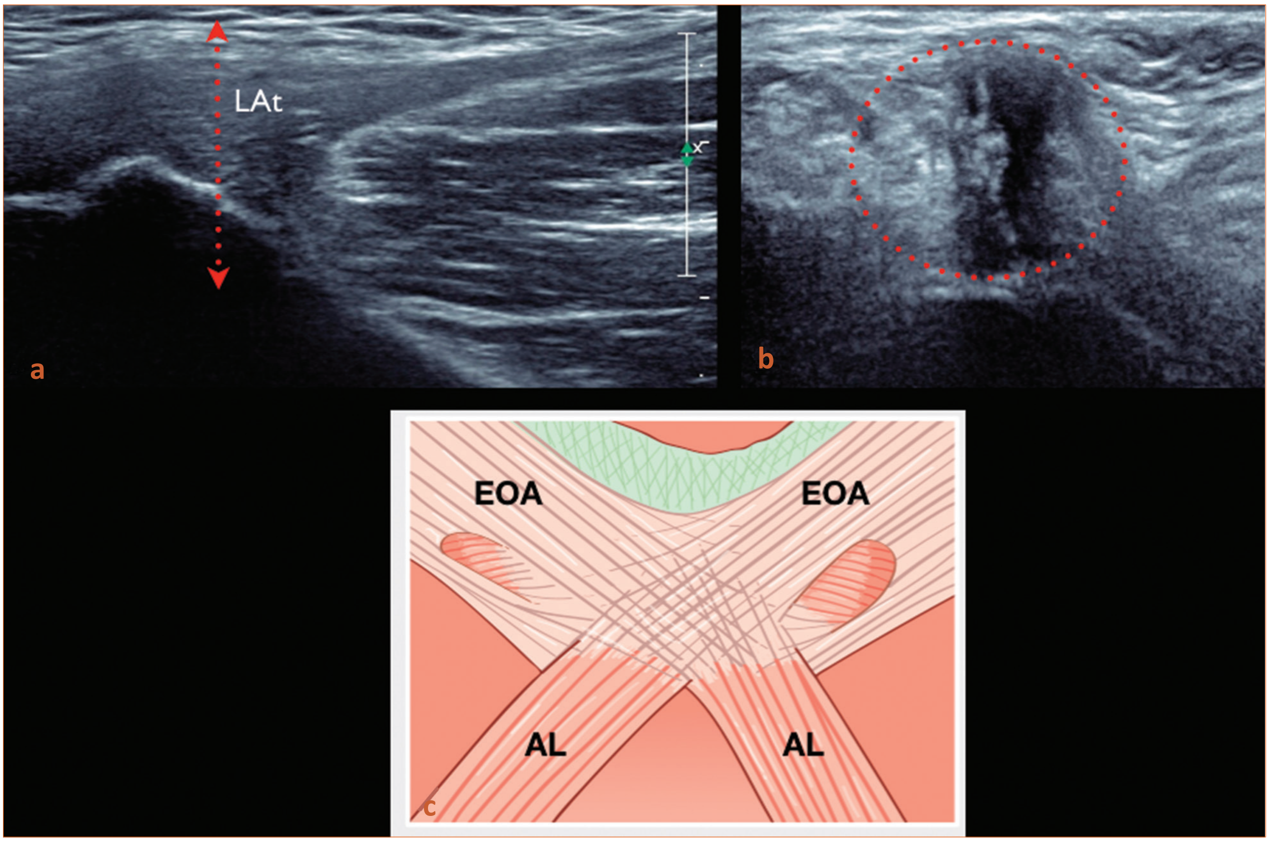

Figure 6: *Ultrasound of a woman from a non-sporting background. Longitudinal* **(a)** *and axial* **(b)** *views show areas of peripheral anisotropy. Diagram* **(c)** *showing extension and overlapping of the most superficial fibers of the adductor longus into those of the aponeurosis of the external oblique muscle. AL : adductor longus ALt : adductor longus tendon. EOA: external obturator aponevrosis.*

Cortical irregularity of the enthesis is common and frequently normal. The secondary ossification center of the anteroinferior corner of the anterior pubic ramus is one of the last to fuse. Up to the age of 26 year old, the irregular appearance of the cortical bone is frequently due to the late fusion of this ossification center. However, the irregularity of the bone may also be a sign of pubic degenerative osteoarthropathy.

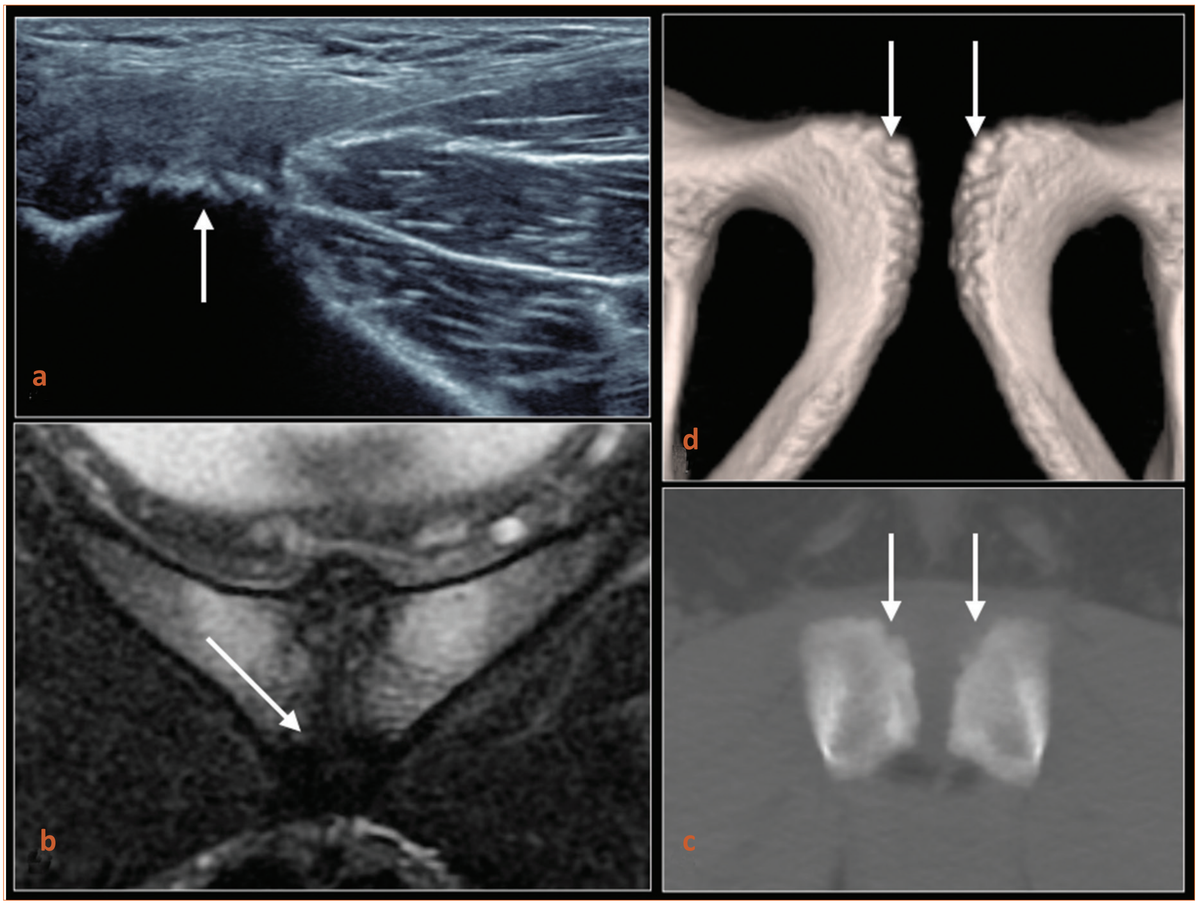

Figure 7: *Cortical irregularity in an asymptomatic patient on US* **(a)** *and volume-rendered computed tomography (CT)* **(c, d)** *as well as in a patient with pubic osteoarthropathy on MRI* **(b)**.

Lastly, grade 1 (< 2cm) or even grade 2 (> 2cm) symphyseal bone marrow edema is a common finding on MRI in asymptomatic soccer and hockey players. Signal changes in the pubic symphysis are also common and fairly nonspecific in sportspeople.

6. Tendinopathy of the adductor longus - « Secondary cleft sign » and pubalgia

One of the aims of imaging in pubalgia is to screen for a partial tears of the tendon of the adductor longus. These tears are usually longitudinal and infracentimetric in the interstitial or deep substance of the tendon. They usually correspond to the secondary clefts described on MRI which result from a rupture of the common enthesis of the tendon and adjacent capsule of the pubic symphysis. Lesions are sometimes bilateral. They appear anechoic on US and show high T2 signal. Initially reported as highly specific and absent in asymptomatic patients, it is now accepted that some entheseal abnormalities are asymptomatic sequelae or adaptive changes, particularly in high level sportspeople.

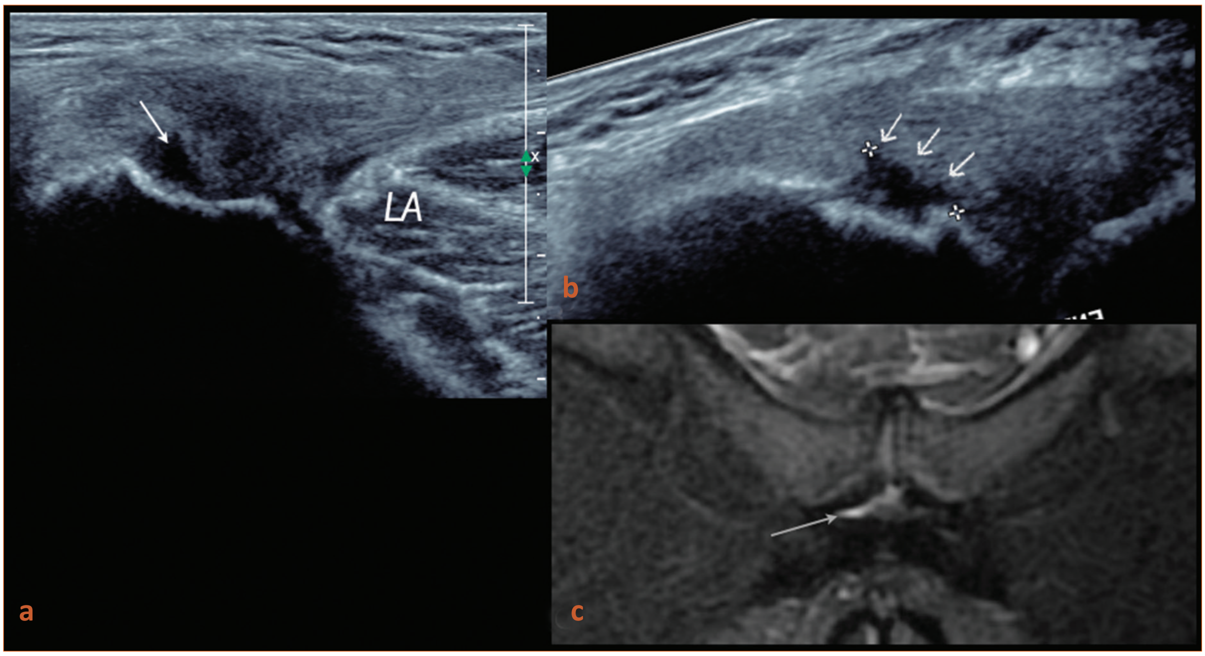

Figure 8: *Assessment of pubalgia in an amateur soccer player. Axial* **(a)** *and longitudinal* **(b)** *US and coronal T2FS MRI showing a proximal tear of the adductor longus (white arrow) matching a secondary cleft sign.*

7. Rupture of adductor longus tendon

Ruptures of the tendon are less common than muscle strains. Large ossifications may ultimately develop and cause chronic pain.

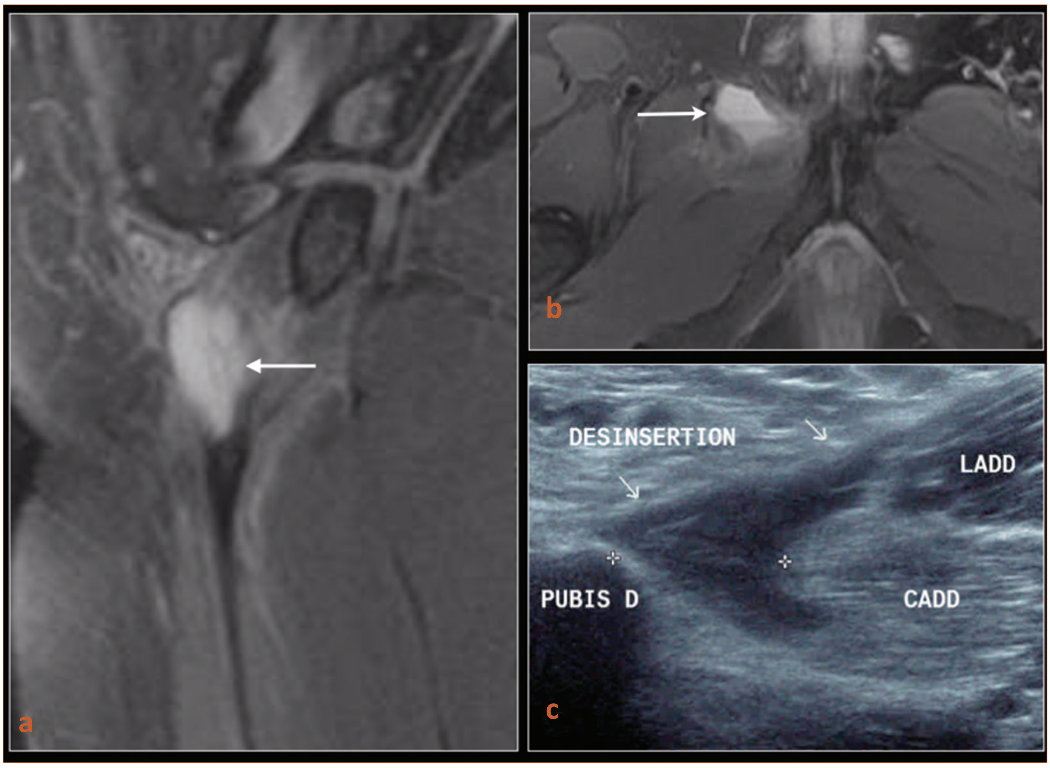

Figure 9: *28-year-old rugby player with acute inguinal pain. Sagittal* **(a)** *and axial* **(b)** *T2FS MRI and longitudinal US* **(c)** *showing a hematoma and retraction of the tendon. LADD : adductor longu. CADD : adductor brevis.*

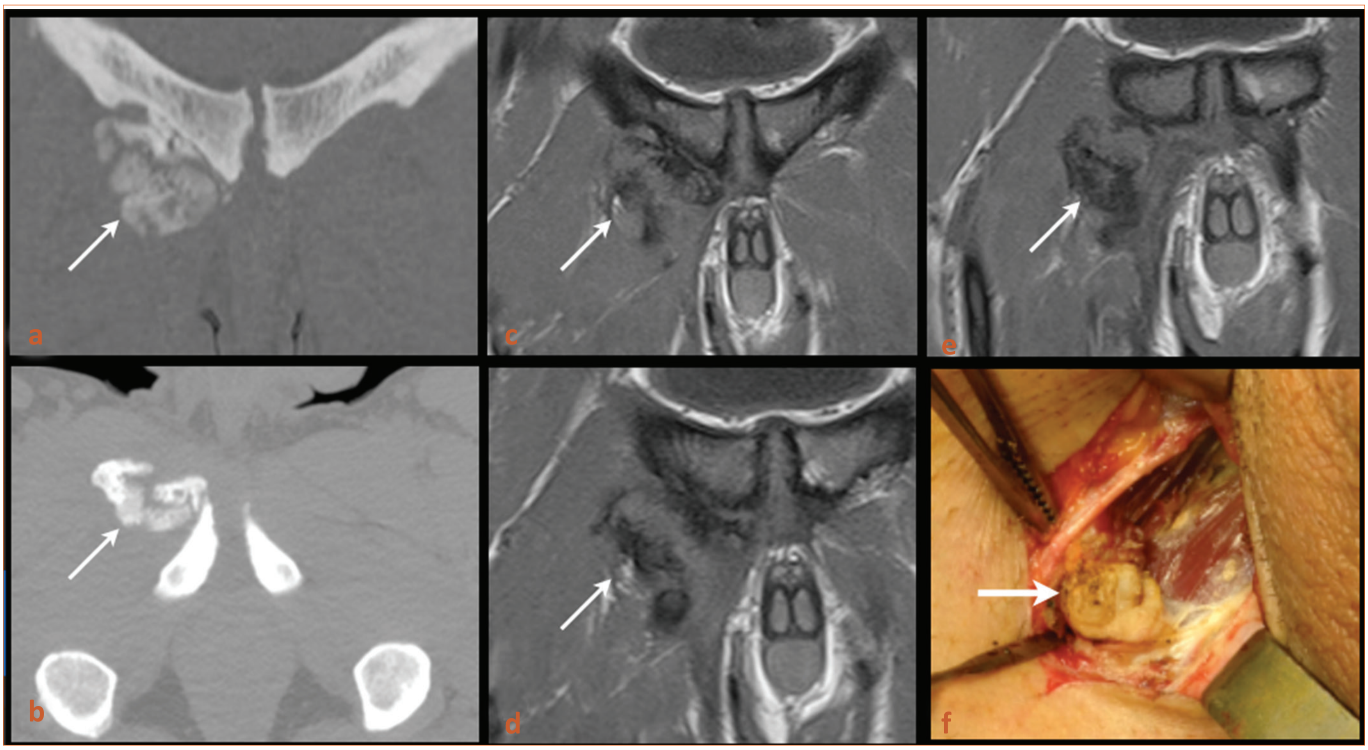

Figure 10: *Another patient (soccer player) 8 months after an acute episode of pain. CT* **(a,b)** *and coronal MRI* **(c,d,e)** *showing an ossification requiring surgical removal* **(f)**.

8. Strain of the adductor longus

These strains manifest as acute inguinal pain. Soccer is most commonly involved with preferential occurence at shooting. Adductor muscles are more commonly involved than iliopsoas and rectus femoris. According to Serner, MRI performs slightly better than US.

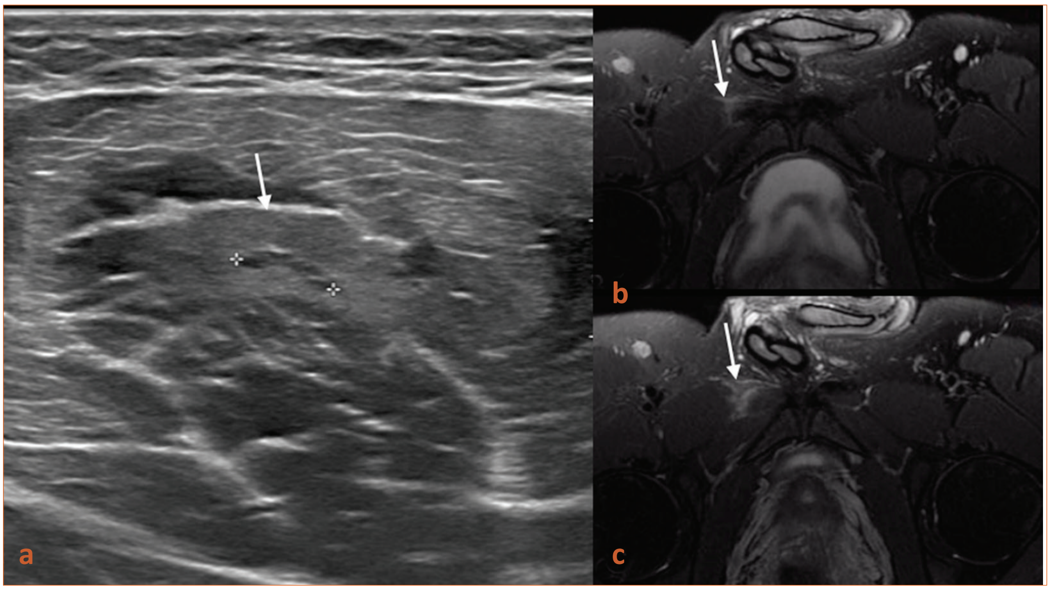

Figure 11: *Acute inguinal pain in a soccer player. US* **(a)** *showing a grade 2/3 heterogeneous tear with a discreet hematoma adjacent and posterior to the horizontal aponeurotic band. Similar finding on axial T2FS MRI* **(b,c)**.

9. The obturator nerve – an interesting and little known neighbor

The obturator is a terminal branch of the lumbar plexus. It arises from roots L2 to L4, travels through the obturator canal at the superior margin of the obturator foramen, then turns anterior and divides into two terminal branches:

- The anterior branch innervates the pectineus, adductor longus, adductor brevis and gracilis plus the skin of the lower third of the medial thigh.
- The posterior branch innervates the adductor magnus and adductor brevis as well as the posterior aspect of the knee.

These two branches respectively run anterior and posterior to the adductor brevis where US can detect these.

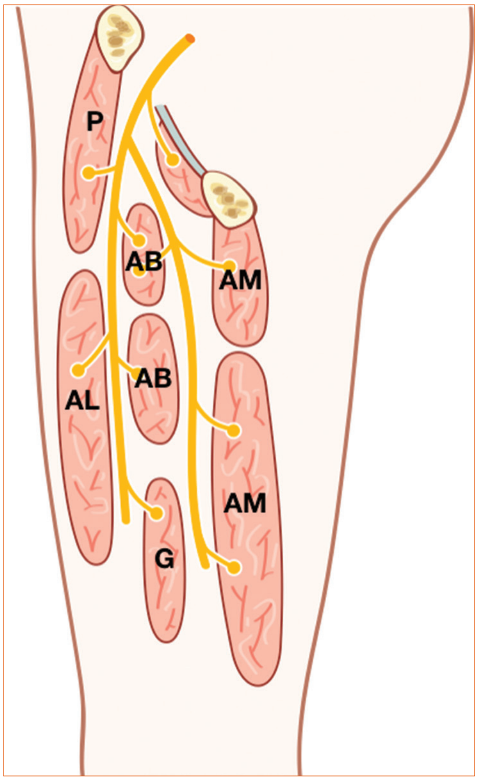

Figure 12: *Diagram from a sagittal view of the obturator nerve. AL: adductor longus, AB: adductor brevis, AM: adductor magnus, G: gracilis, P: pectineus.*

10. Conclusion: US assessment of pubalgia in 5 views!

- Two axial views of the deep inguinal ring between the rectus abdominis medially and the ostium of the epigastric arteries laterally. A Valsalva maneuver is performed to screen for a protrusion of preperitoneal fat and rule out an hernia of the abdominal wall.
- Two longitudinal views of the tendon of the adductor longus.
- One axial view of the pubic symphysis. Osteophytes and erosions are common and frequently incidental findings.

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05 Hamstring injury

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1. Background

Hamstring injuries are among the most common muscle injuries in sportspeople. They can occur at any point along the musculotendinous chain. Myoaponeurotic tears are the most frequent injury, mostly occurring in the proximal semimembranosus and distal long head of the biceps femoris. Wholly aponeurotic tears may also occur, particularly in the central tendon of the semitendinosus. Injuries may also be encountered in the proximal enthesis and distal tendon insertion.

2. Proximal entheseal pathology: early-stage injuries

Such injuries can be difficult to detect on ultrasonography (US) because these structures lie deep to, and so are covered by, the gluteus maximus. In patients complaining of pain, a hyperintense signal on magnetic resonance imaging (MRI) does not usually give rise to any correlated finding on US **(Fig. 1)**.

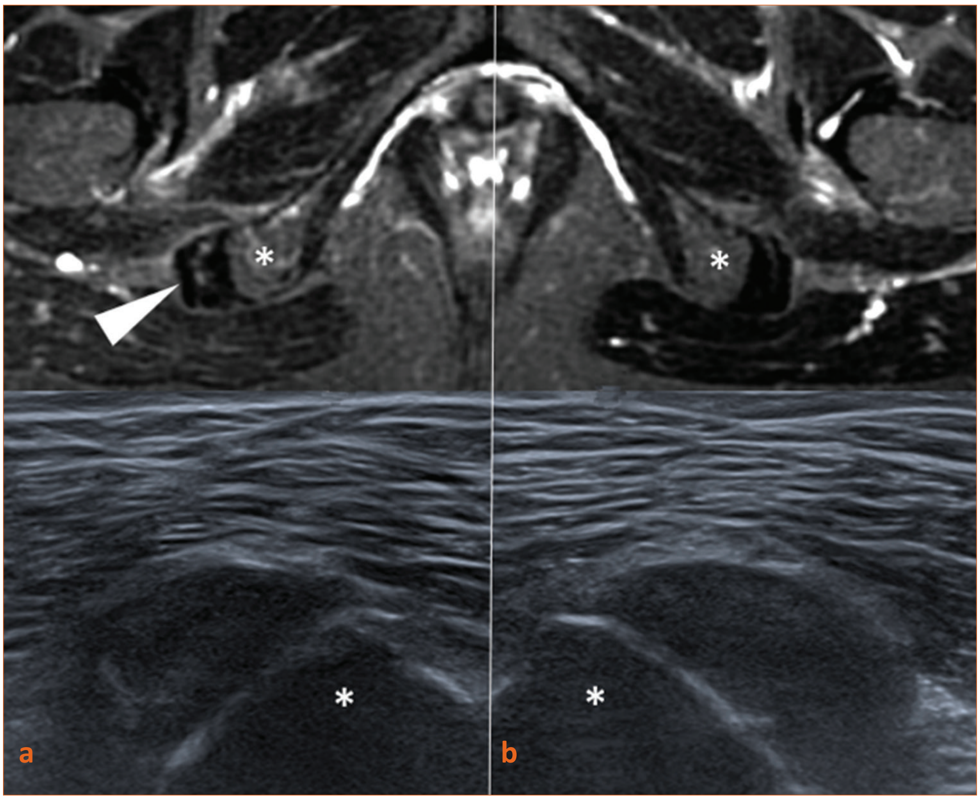

Figure 1 : *Early-stage hamstring injury. T2-weighted fat-saturated (T2FS) axial MRI and axial US of a painful right ischium (a). Comparative T2FS axial MRI and axial US of normal left ischium (b).On MRI, the injury manifested as a punctiform hypersignal in the tendons (arrowhead) on the ischium (asterisk). US images were normal (a) and identical on the contralateral side (b).*

3. Proximal entheseal pathology: partial tears

These usually begin on the deep aspect of the tendons **(Fig. 2)** near the ischial cortex. The presence of the sacrotuberous ligament [1], which is confused with the superficial fibers of the conjoined tendon, creates an illusion that the tendon's morphology is intact. Hence US is often misleading, since all that can be seen is an area of hypoechogenicity, even though the deep aspect of the tendon is indeed torn.

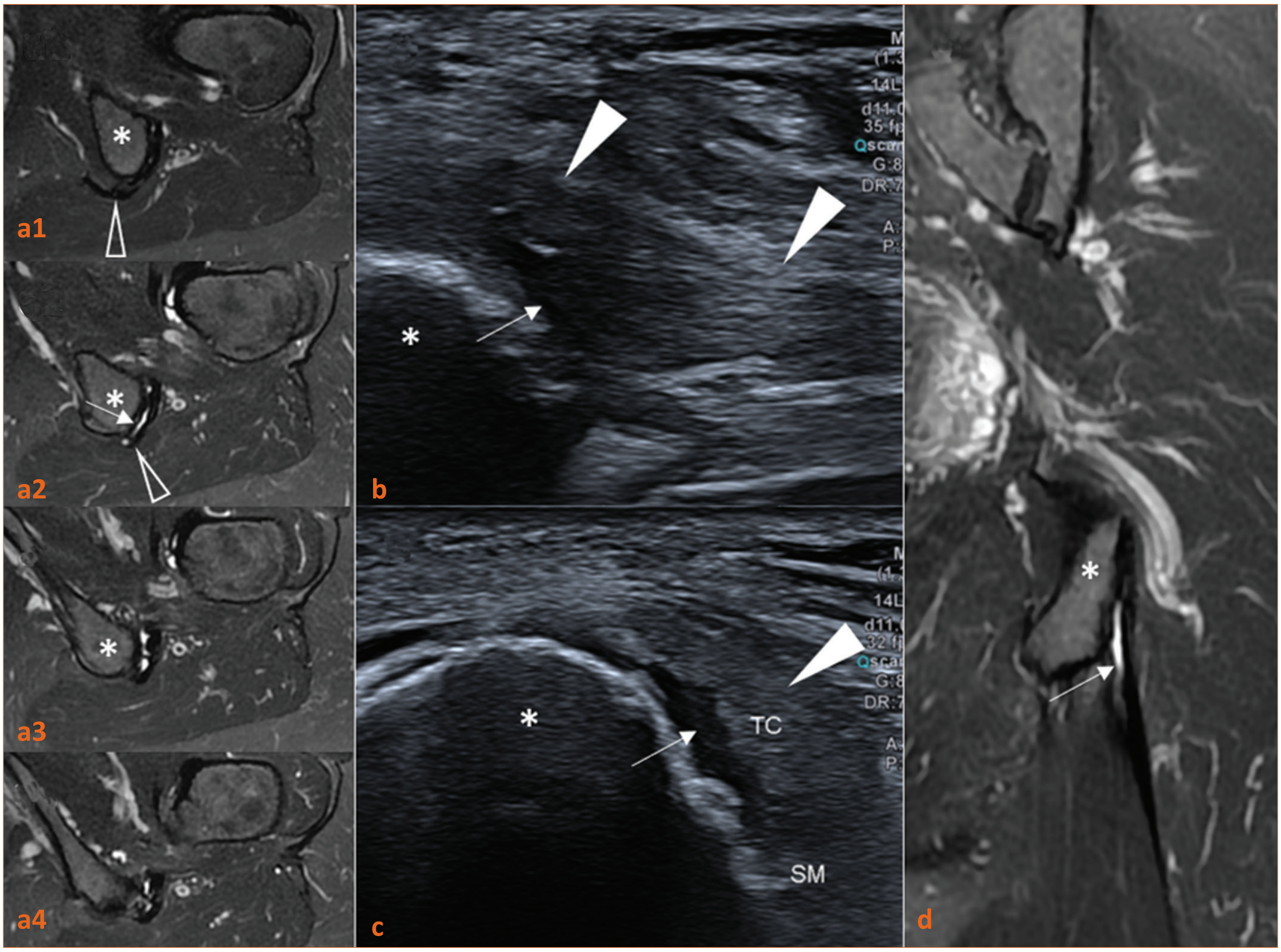

Figure 2 : *Tear to the deep aspect of the hamstrings. T2FS axial MRI (a) from proximal (1) to distal (4) and T2FS frontal MRI of the ischium (d). Sagittal (b) and axial (c) US of the ischium. The injury manifested as a partial tear to the deep aspect of the conjoined tendon (arrow) near the ischial cortex (asterisk). US diagnosis was difficult because of the mostly intact morphology of the tendon (white arrowheads) which was held in place by, and confused with, the sacrotuberous ligament (hollow arrowhead).*

4. Proximal entheseal pathology: proximal tendinous avulsion

Such injuries may be rare, but they are important and must be identified because treatment may in some cases involve transosseous fixation. Tendinous avulsion usually occurs in the conjoined tendon with or without semimembranosus involvement **(Fig. 3)**. The biceps tendon is sometimes separate from that of the semitendinosus, in which case isolated avulsion of the biceps is possible. Isolated avulsion of the semimembranosus is rarer [2].

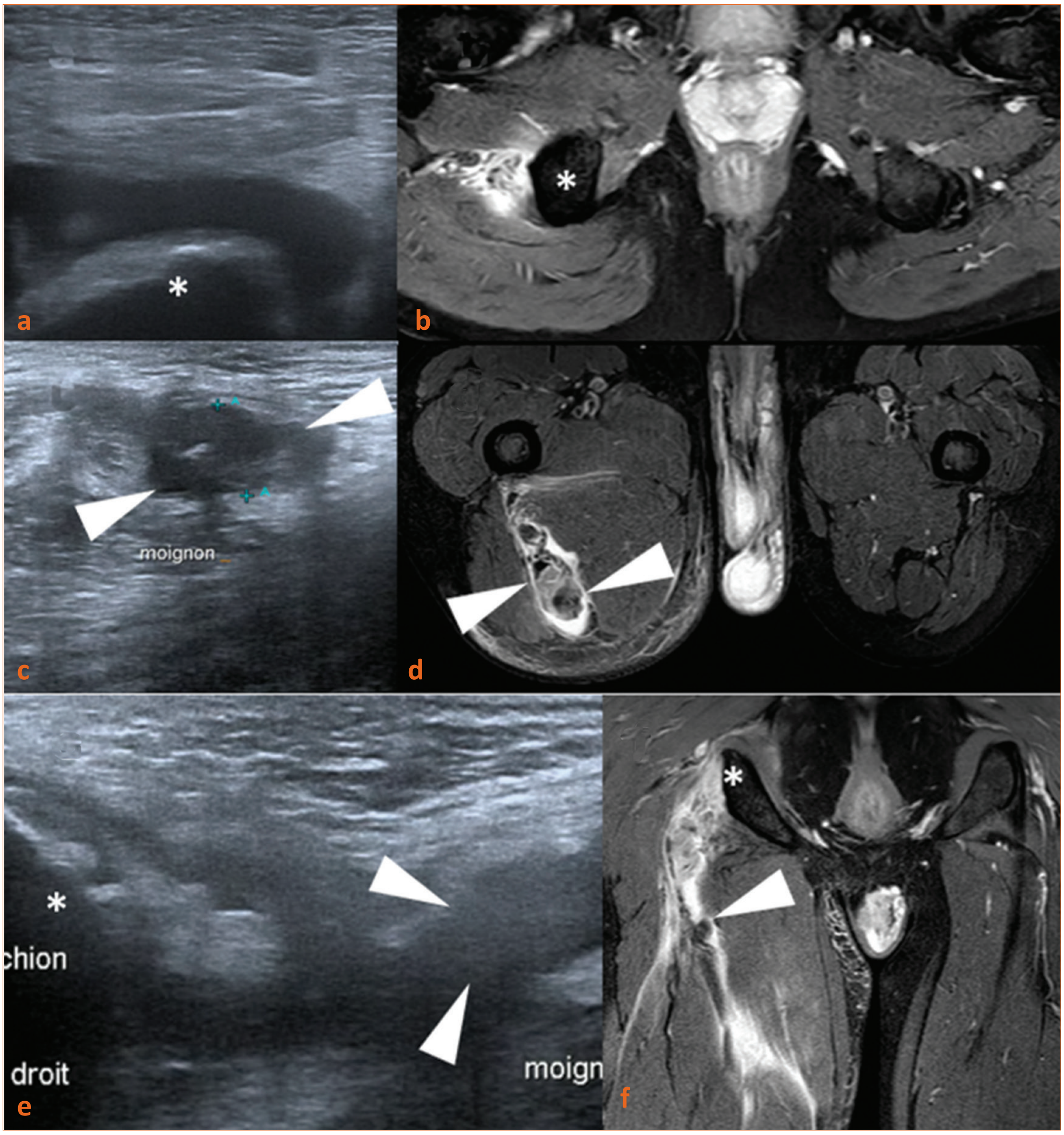

Figure 3 : *Complete rupture of proximal hamstring tendons. Axial US (a) and T2FS MRI (b) of the ischium. More distally, axial US (c) and T2FS MRI (d) of the proximal portion of the thigh. Sagittal US of the ischium (e) and frontal T2FS MRI (f). The surface of the ischial bone (asterisk) was bare and devoid of attached tendons, and exhibited a superficial collection of fluid (a and b). The tendon stumps were found distally as a broadly curved structure lying between the gluteus maximus laterally and adductor magnus medially (c and d). The stumps (arrowheads) had lost their anisotropy on US (c). They exhibited a higher signal than tendons normally would on MRI (d). They were also wider, having retracted and folded back on themselves (c and d). Sagittal US (e) and frontal MRI (f) were used to measure the distance between the ischium (asterisk) and tendon stumps (arrowheads).*

5. Proximal entheseal pathology: special case of children and adolescents

An unfused apophysis is the weak point in the musculotendinous complex [3]. An avulsion of the bone **(Fig. 4)** is therefore more common than rupture of the tendon.

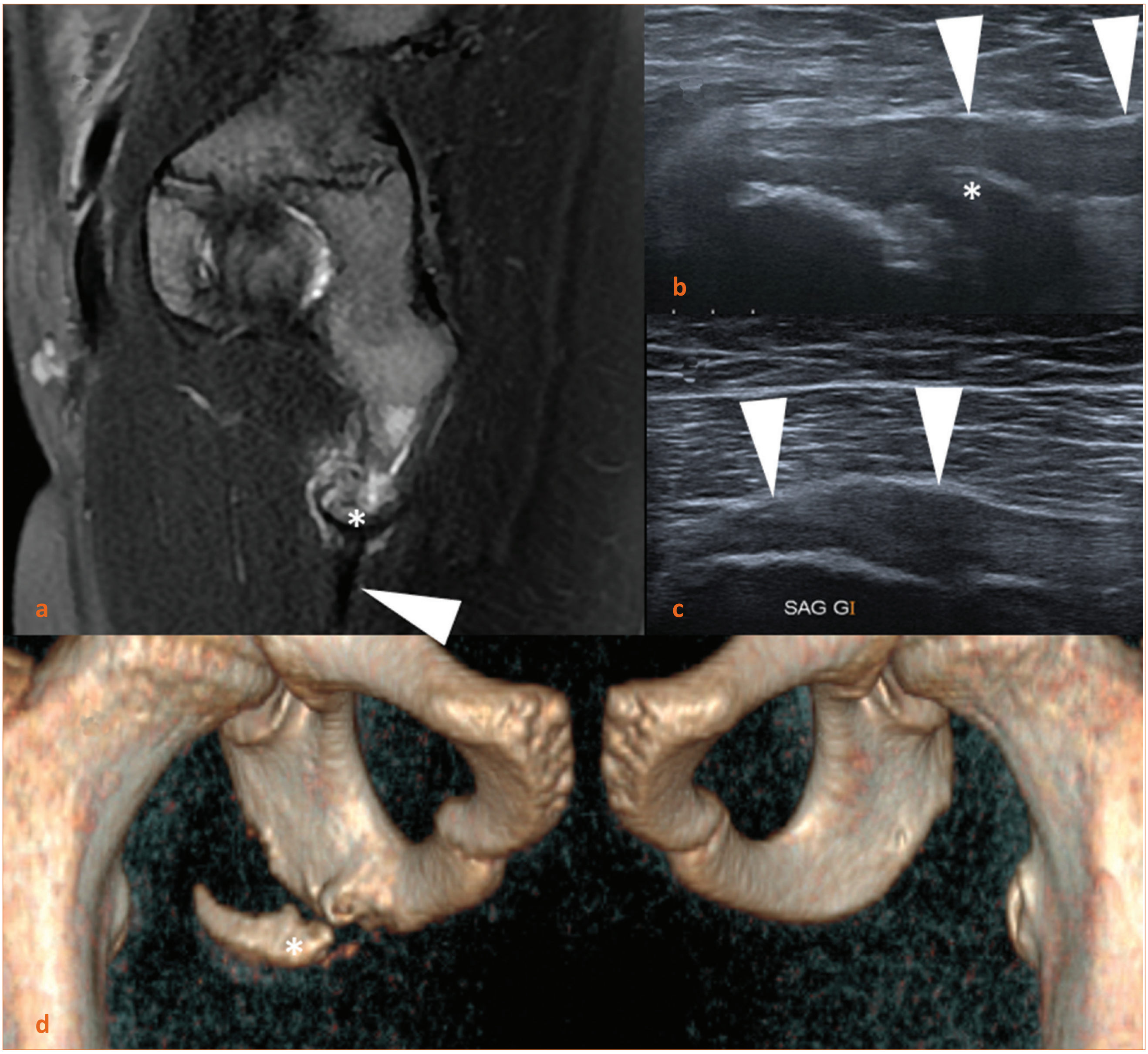

Figure 4 : *Avulsion of the ischial apophysis in a 14-year-old. T2FS sagittal MRI (a), volume-rendered computed tomograpy (b), and sagittal US of injured (c) and normal (d) sides. Unfused apophysis (asterisk) detached and retracted distally. The tendon remained intact (white arrowheads) despite being stretched, but was still attached to the apophyseal center.*

6. Injury to the broad tendon of the semimembranosus

This is a peripheral myoaponeurotic injury to the proximal muscle fibers of the semimembranosus. These muscle fibers attach to the perimuscular aponeurosis which arises from the broad tendon **(Fig. 5)**.

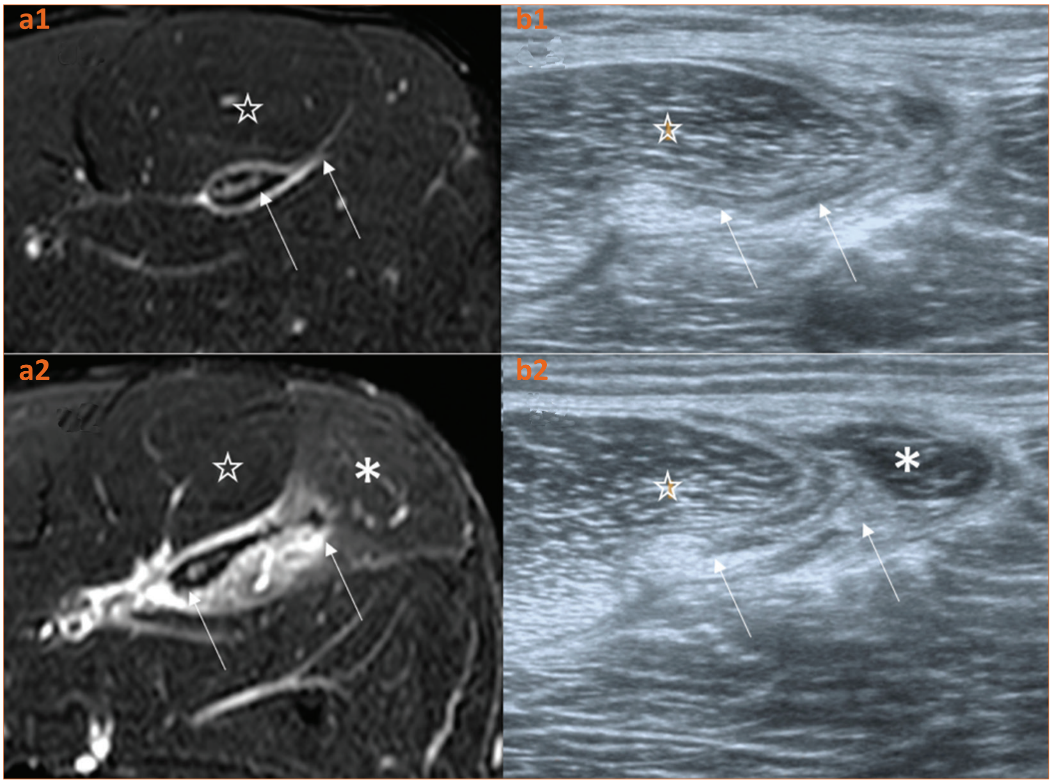

Figure 5 : *Injury of the semimembranosus proximal tendon. T2FS axial MRI (a) and axial US (b) from proximal (1) to distal (2). The injury (arrows) was located in the proximal tendon which courses under the semitendinosus (star) and extended as far as the proximal and lateral muscle fibers of the semimembranosus (asterisk).*

7. Biceps injuries

These are common. They can occur at the proximal musculotendinous junction in the conjoined tendon **(Fig. 6)**. They can also occur more distally, between the long and short heads of the biceps. In such cases they usually involve a distal connective tissue injury to the aponeurosis of the long head **(Fig. 7)** accompanied by detachment of neighboring muscle fascicles.

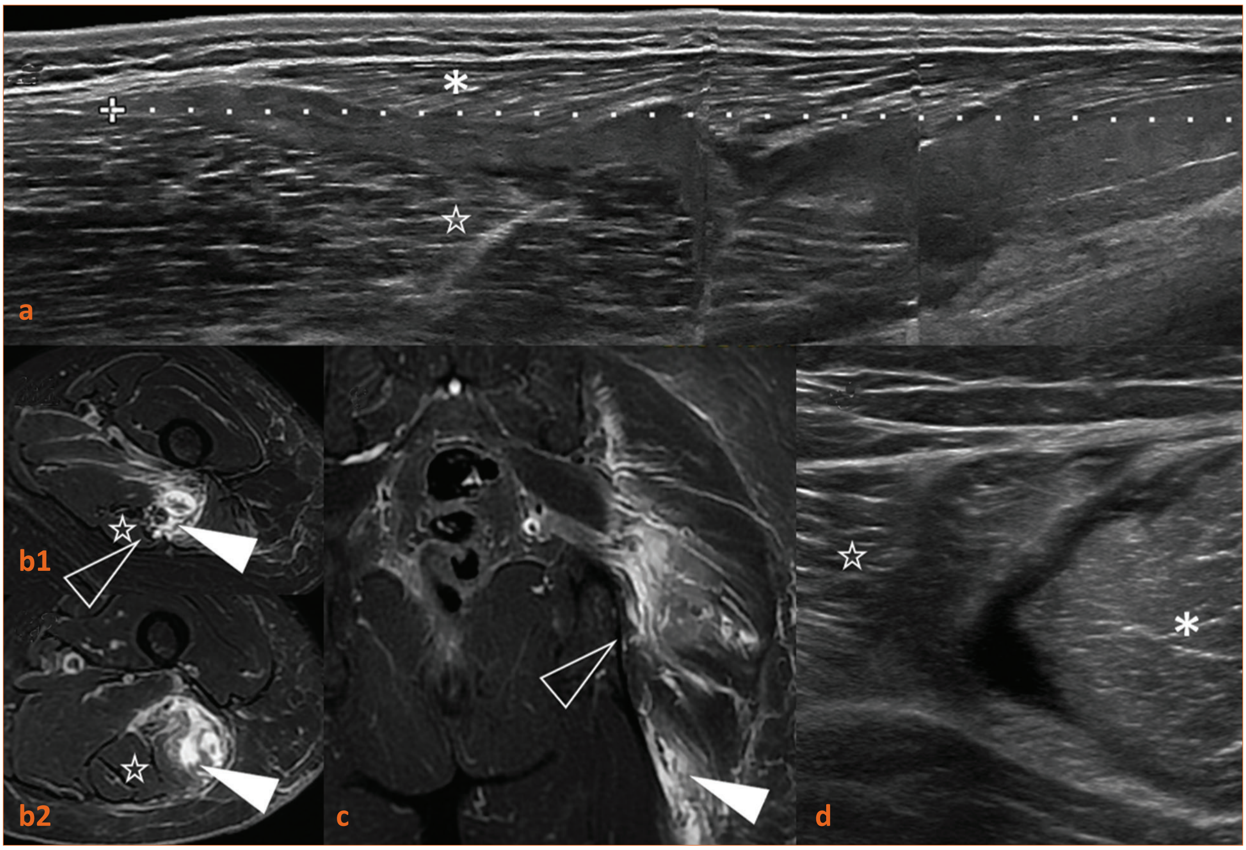

Figure 6 : *Rupture of the proximal musculotendinous junction of the biceps. Sagittal US (a), T2FS axial MRI (b) from proximal (1) to distal (2), frontal short tau inversion recovery (c), and axial US (d).This injury lay in the proximal musculotendinous junction. The long head of the biceps (white arrowheads) detached from the conjoined tendon (hollow arrowheads). There was a large hematoma between the biceps (asterisk) and semitendinosus (star).*

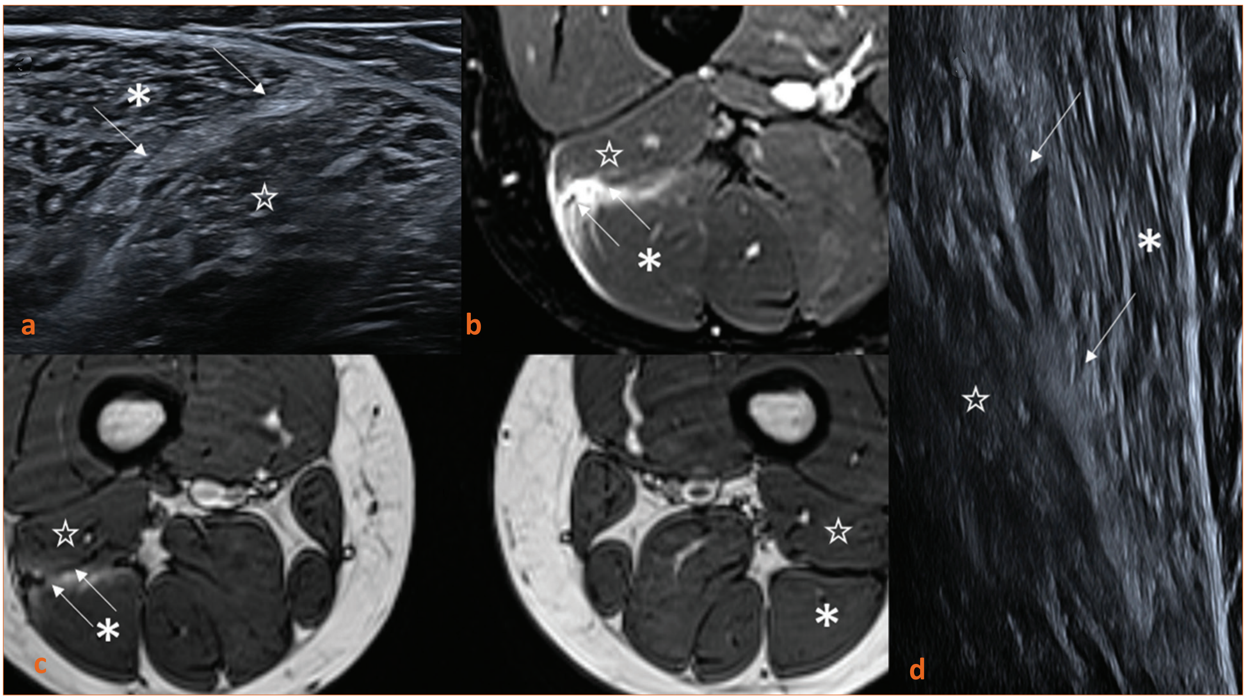

Figure 7 : *Peripheral aponeurotic injury of the long head of the biceps femoris. Axial US (a), axial T2 water (b) and in-phase (c) Dixon MRI, and sagittal US (d). This was a distal connective tissue injury to the aponeurosis of the long head of the biceps (asterisk), which had ruptured (arrows). Nearby muscle fascicles had detached, exhibiting high signal on MRI and disruption on US. The aponeurosis and muscle fibers of the short head (star) appeared intact.*

8. Pure aponeurotic injuries

These usually involve the central tendon of the semitendinosus **(Fig. 8)** or more rarely the posterior tendon of the long head of the biceps **(Fig. 9)**.

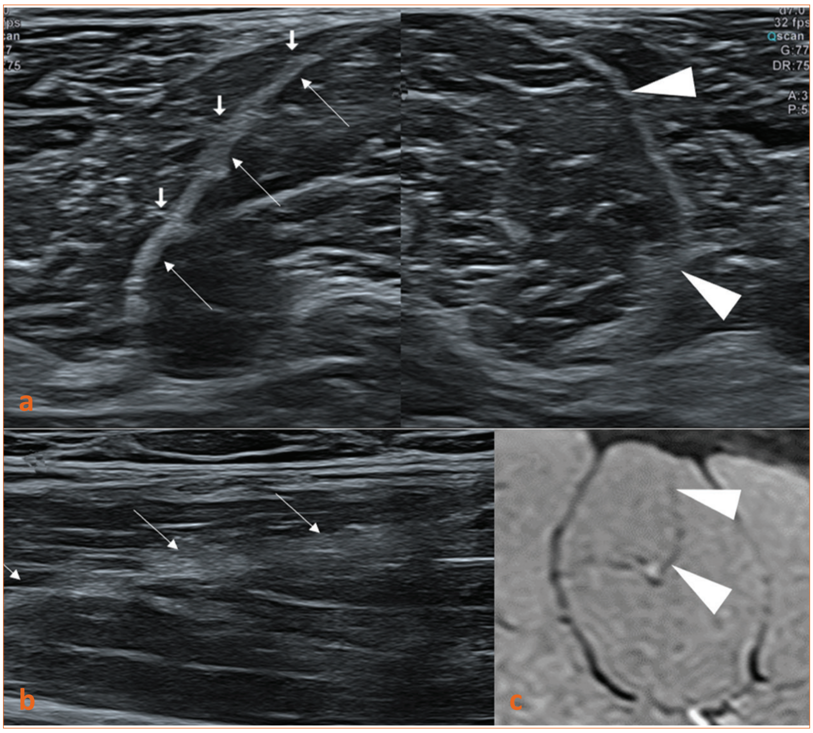

Figure 8 : *Central tendon injury of the semitendinosus. Axial US of both thighs (a), sagittal US of injured muscle (b), and axial proton-density fat-saturated MRI of a normal central tendon (c). The injury was located in the central tendon of the semitendinosus, which had a hyperechoic, thickened appearance (arrows). This central tendon usually appears as a thin, continuous structure (arrowheads), as in the contralateral healthy thigh (a) and on MRI (c).*

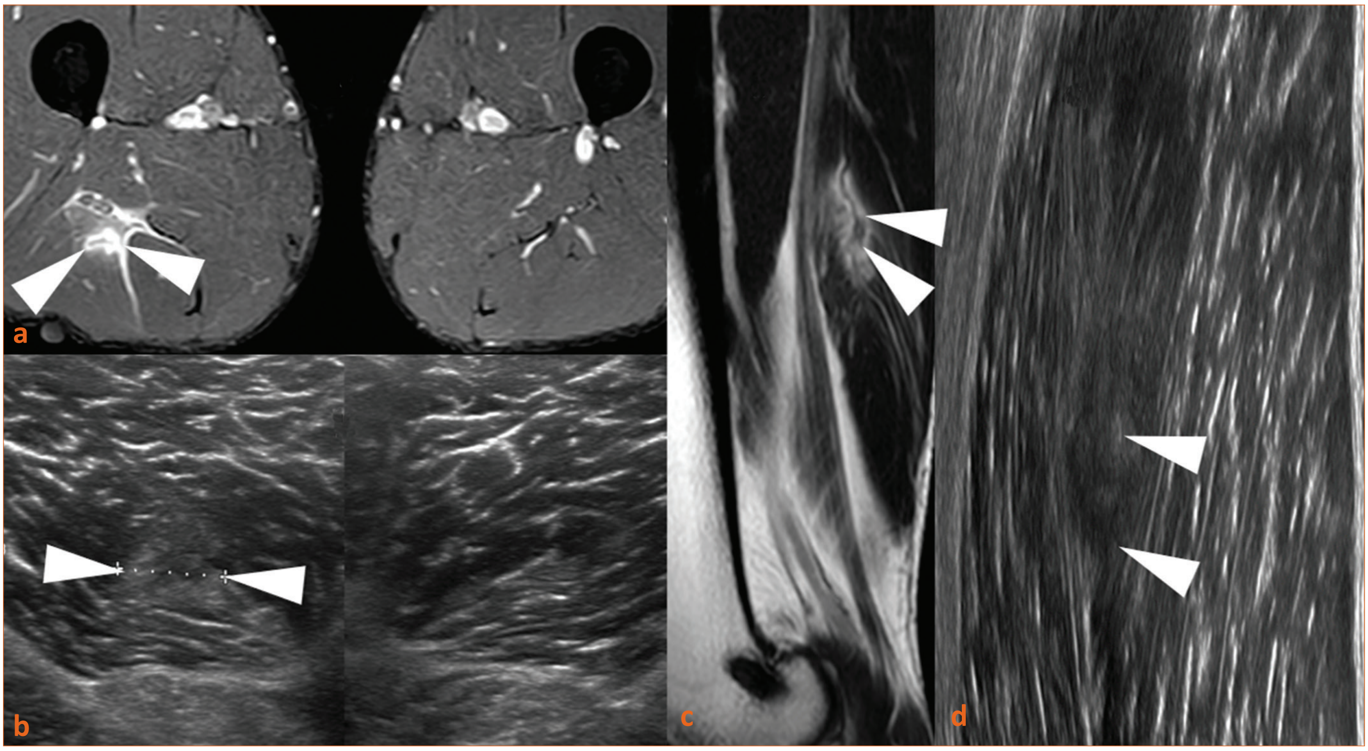

Figure 9 : *Central tendon injury of the biceps. T2FS axial MRI (a), axial US (b), sagittal T2 (c), and sagittal US (d). This purely aponeurotic injury occurred in the central tendon of the posterior portion of the long head of the biceps (arrowheads).*

9. Distal entheseal rupture

Distal avulsion of the hamstrings rarely occurs as an isolated injury (2). It can involve the biceps tendon on the fibula **(Fig. 10 and 11),** the semitendinosus **(Fig. 12)**, or the semimembranosus.

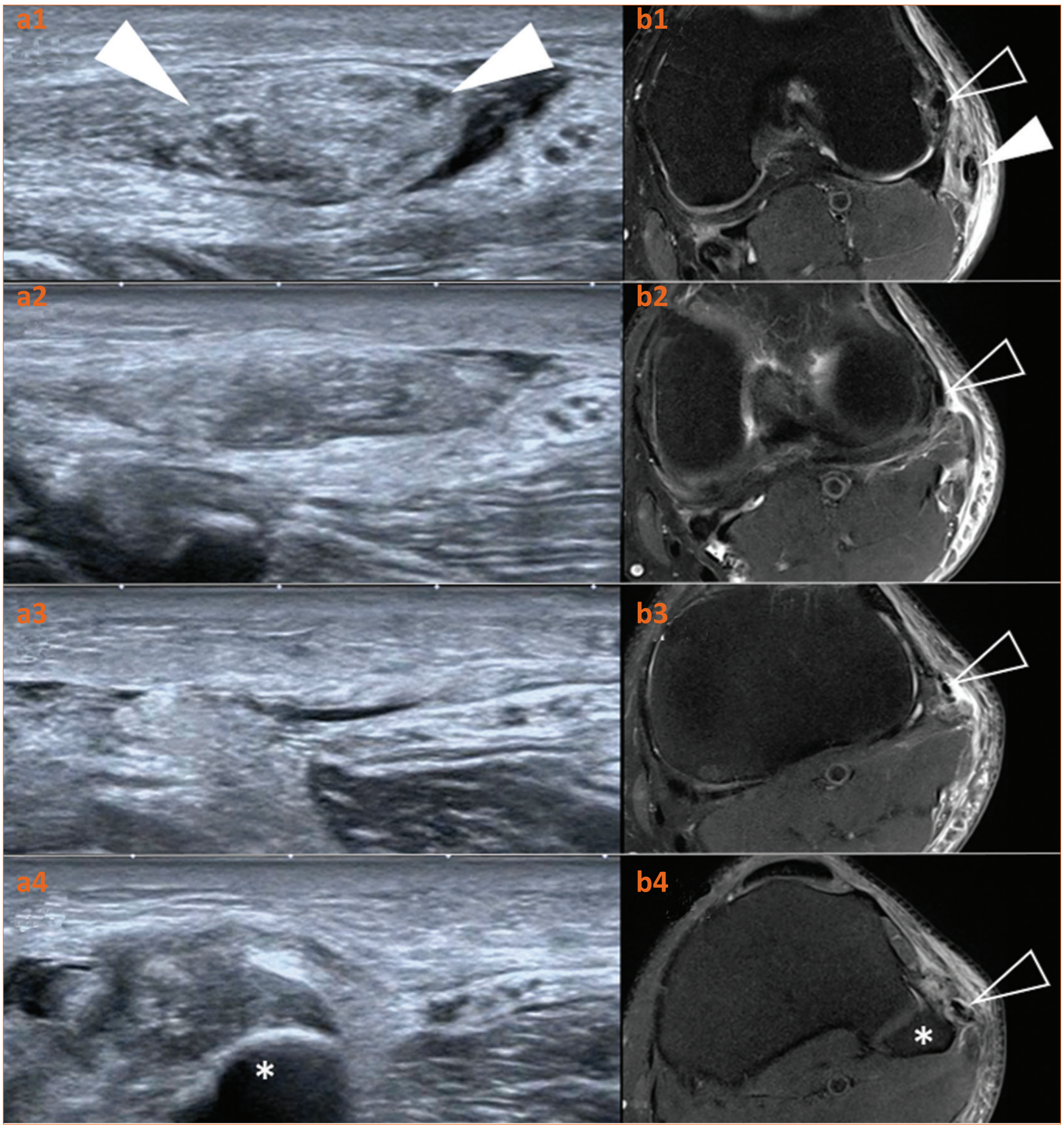

Figure 10 : *Distal rupture of biceps tendon. Axial US views (a) and T2FS MRI (b) from proximal (1) to distal (4). The tendon stump (white arrowheads) was found beside the common fibular nerve as a thick, oval-shaped structure owing to its folding back on itself. It was surrounded by a hematoma. It was then no longer visible on more distal views, nor was it attached to the head of the fibula (asterisk). Note the intact lateral collateral ligament (hollow arrowheads).*

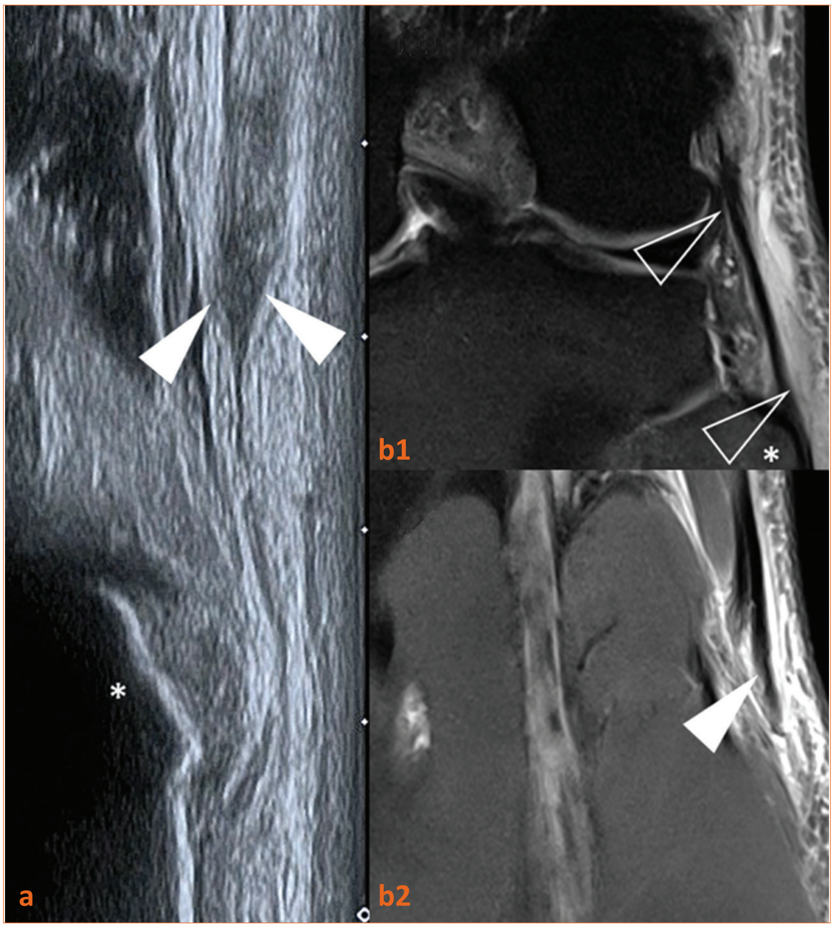

Figure 11 : *Distal rupture of the biceps tendon (same case as Figure 10). Sagittal US (a) and frontal T2FS MRI views (b) from front (1) to back (2). The tendon stump (white arrowheads) had retracted from the head of the fibula (asterisk). Note the intact lateral collateral ligament (hollow arrowheads).*

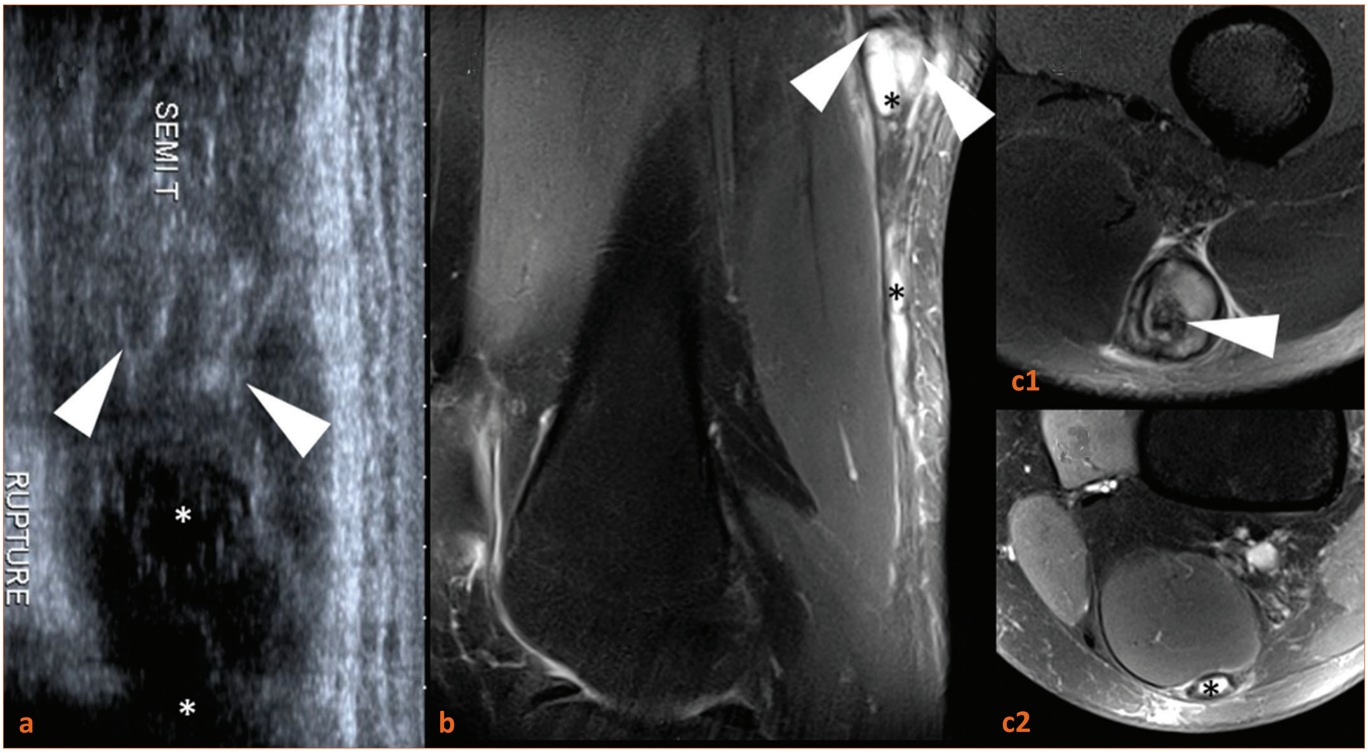

Figure 12 : *Distal rupture of the semitendinosus tendon. Sagittal US (a) as well as sagittal (b) and axial proton-density fat-saturated MRI (c) from proximal (1) to distal (2). The tendon stump (white arrowheads) had retracted far from its enthesis, leaving a long tube-like area of distal fluid (asterisks).*

10. Conclusion

US provides a simple means of detecting and monitoring hamstring injuries but it may not perform as well as MRI, particularly if an injury has a proximal, ischial location or is in its early stages.

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6 Iliopsoas anatomy and pathology

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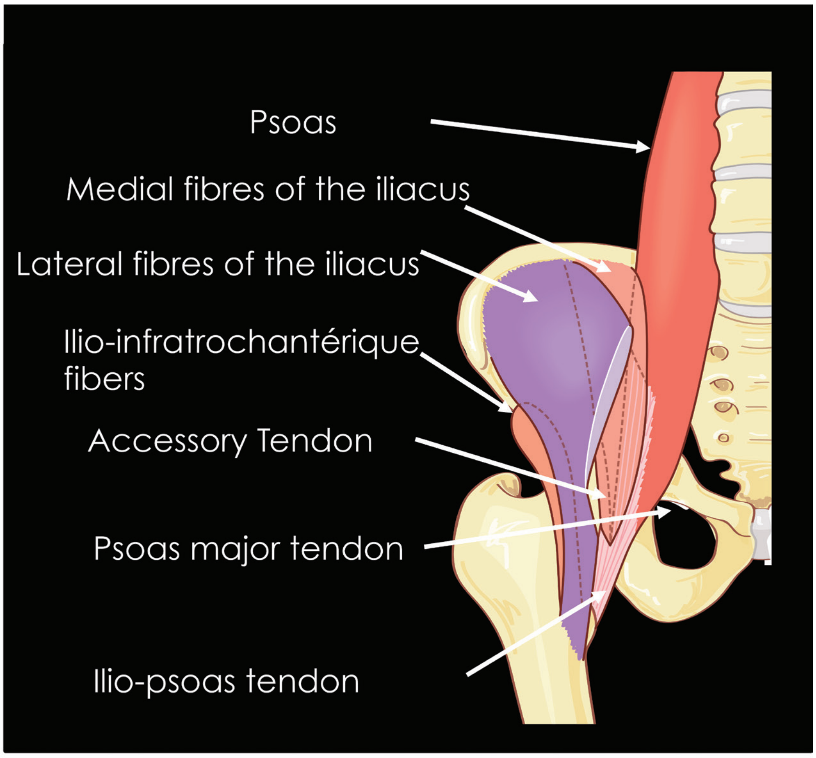
Point 1 : Anatomy

From medial to lateral : Psoas (3) (+tendon -4) - Medial iliac muscle (5) - Lateral iliac muscle (6) - ilio-infratrochanteric tractus (7)

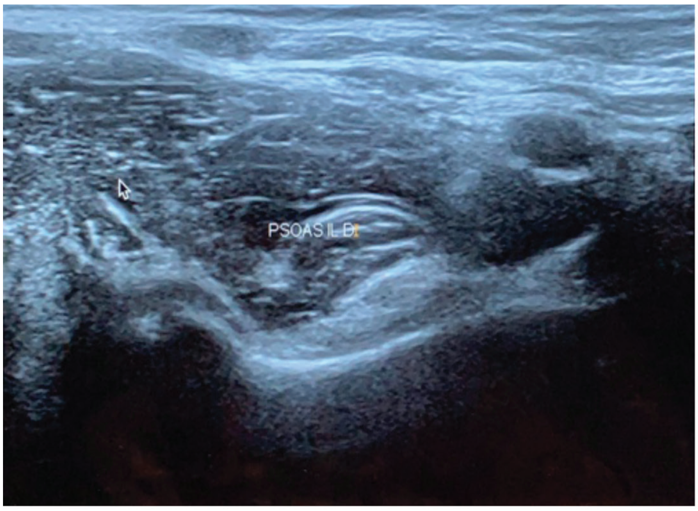
Tatu, 2002



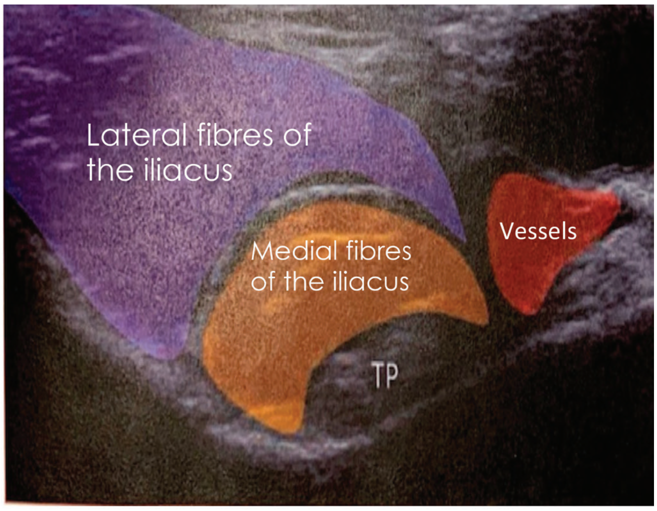
R.Guillin, SIMS

Point 2 : US Anatomiy

- **Axial US image showing an axial iliopsoas view, proximal to the inguinal canal**

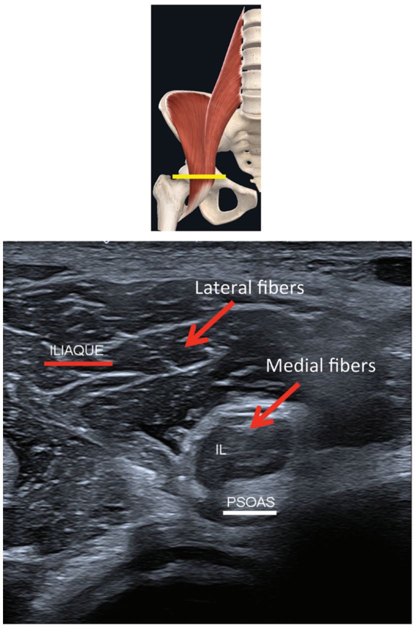


P.Peetrons



R.Guillin, SIMS

- **Axial US images iliopsoas axial views from proximal to distal**



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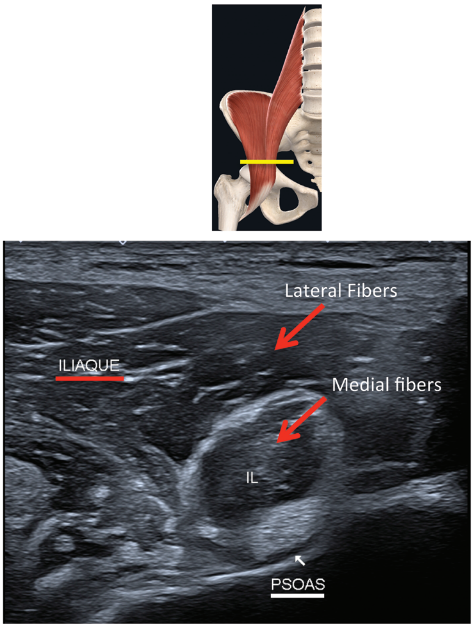
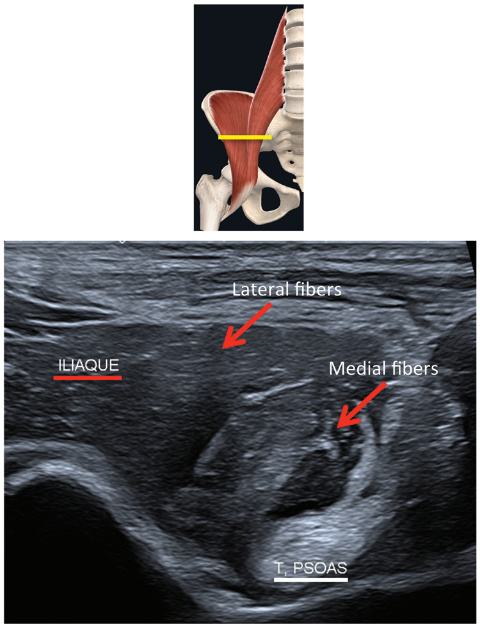


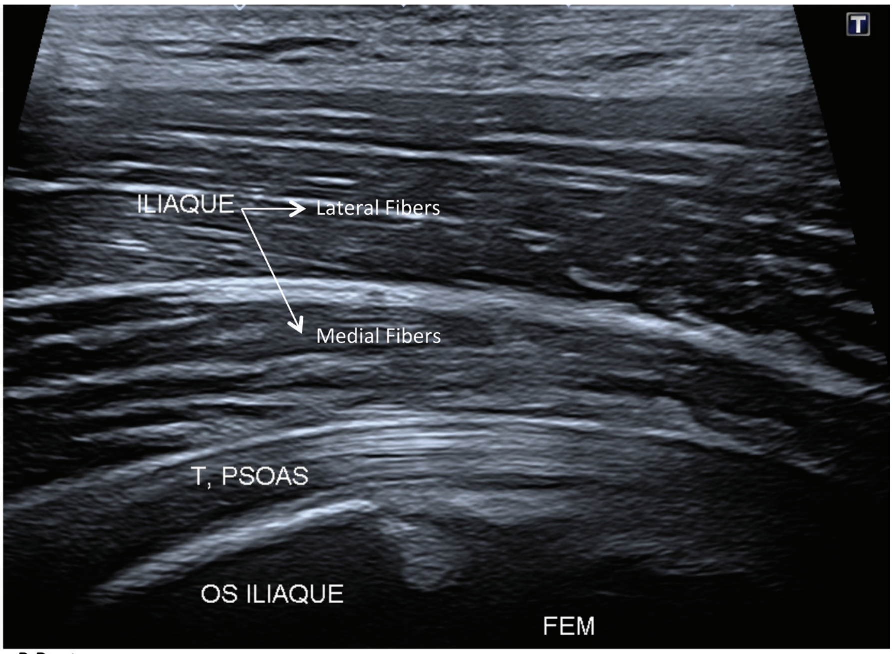
Transverse



Transverse high

P.Peetrons

- **Sagittal US images of the iliopsoas**



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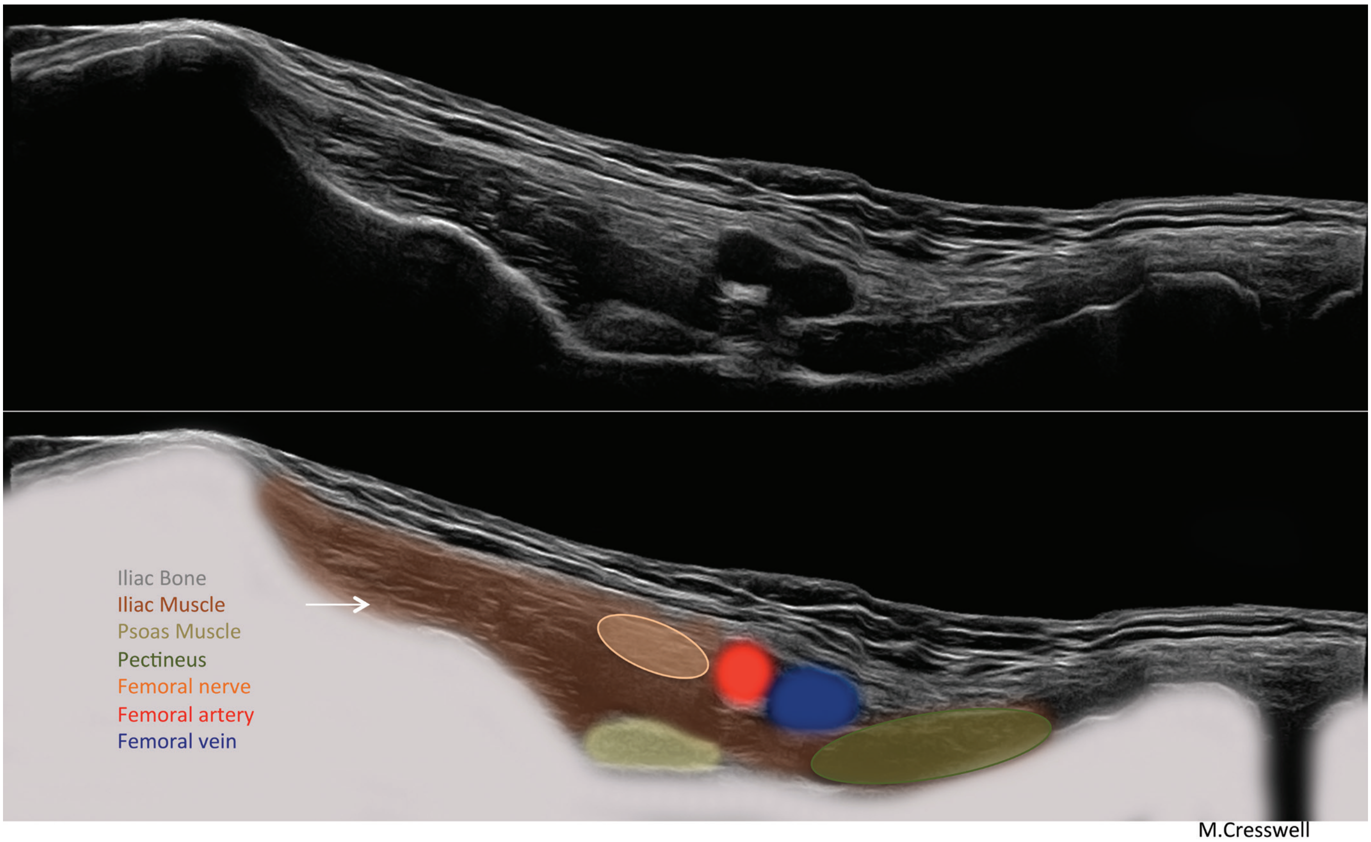
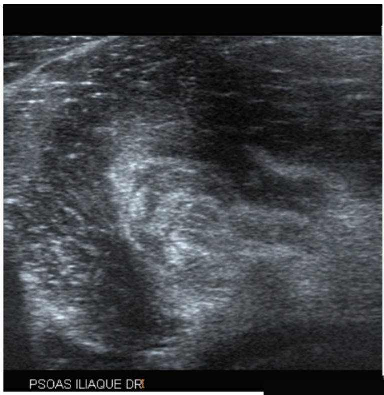
- **US anatomy of the inguinal canal**



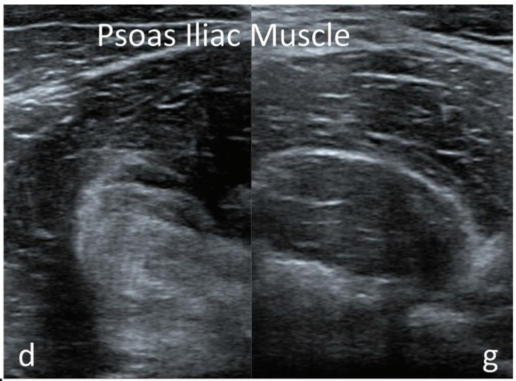
M.Cresswell

Point 2 : Iliopsoas intrinsic pathologies

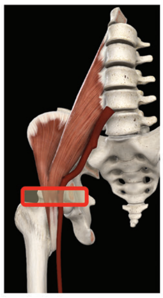
- **Myotendinous junction rupture of the medial iliac muscle** (most frequently involved)



26 years old man, field hockey player. Hyperechogenicity and architectural distortion of the right medial iliac muscle. MRI : Hyperintense lesion.



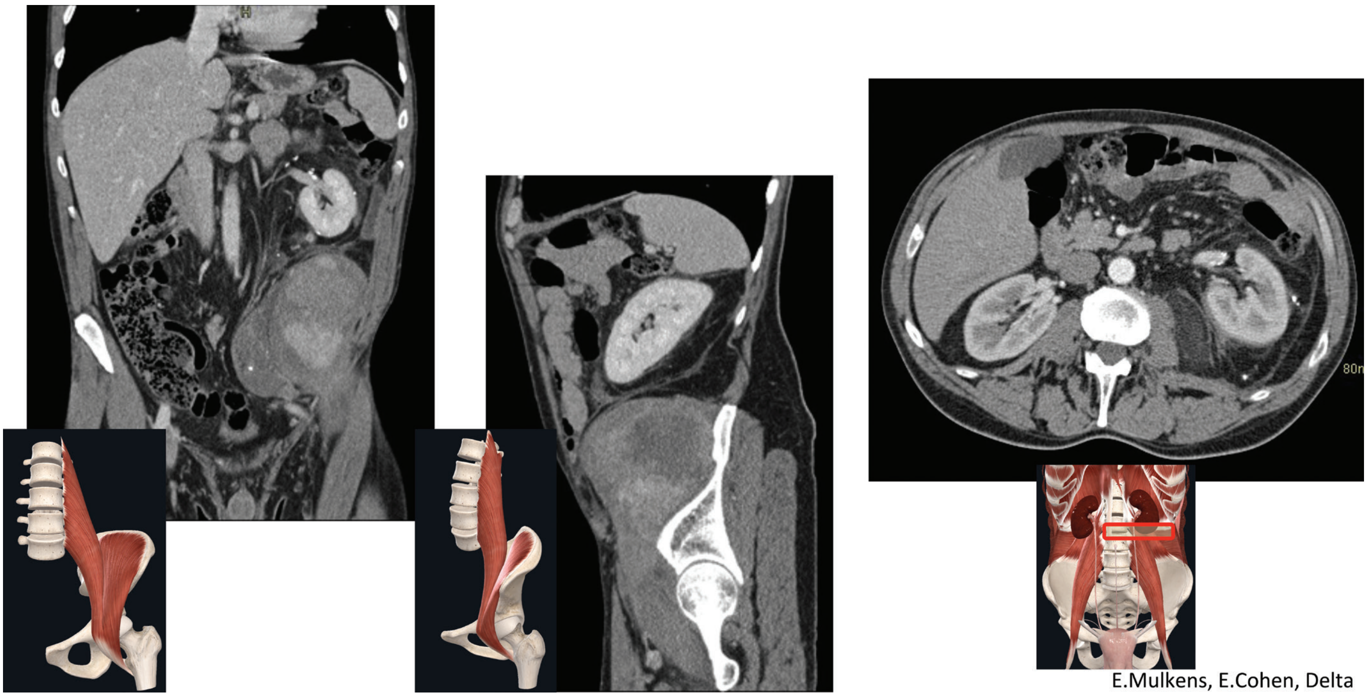
pathological normal



P.Peetrons

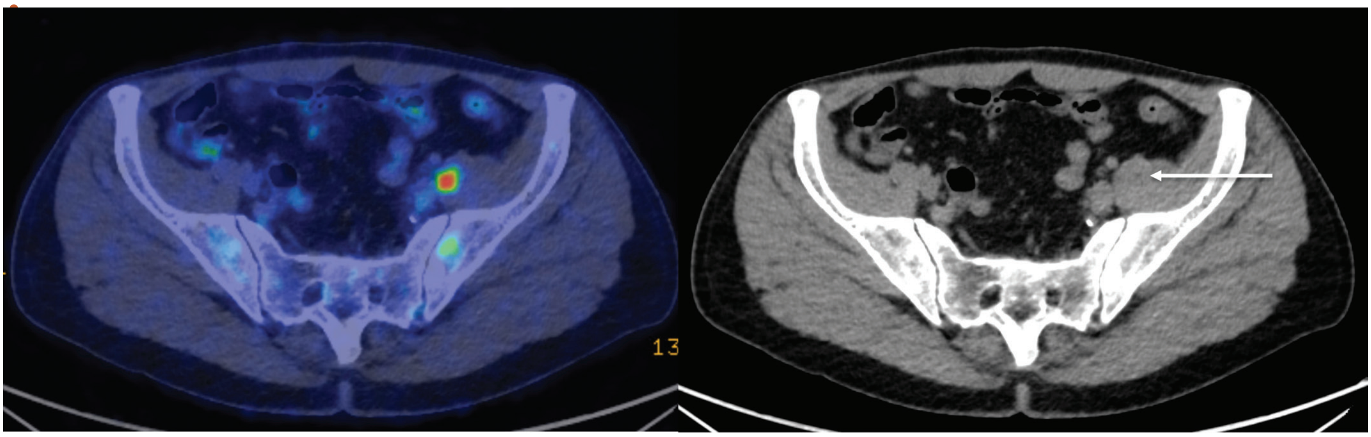
- **Tumor. Liposarcoma**

50 years man with left thigh pain, temperature and palpable mass on the left fossa iliaqua. Coronal (A) sagittal (B) and axial (C) injected CT showing a voluminous tumor with fatty component and calcifications, all along de iliopsoas muscle, invading the fat around the kidney and extending until the insertion on the lesser trochanter.



E.Mulkens, E.Cohen, Delta

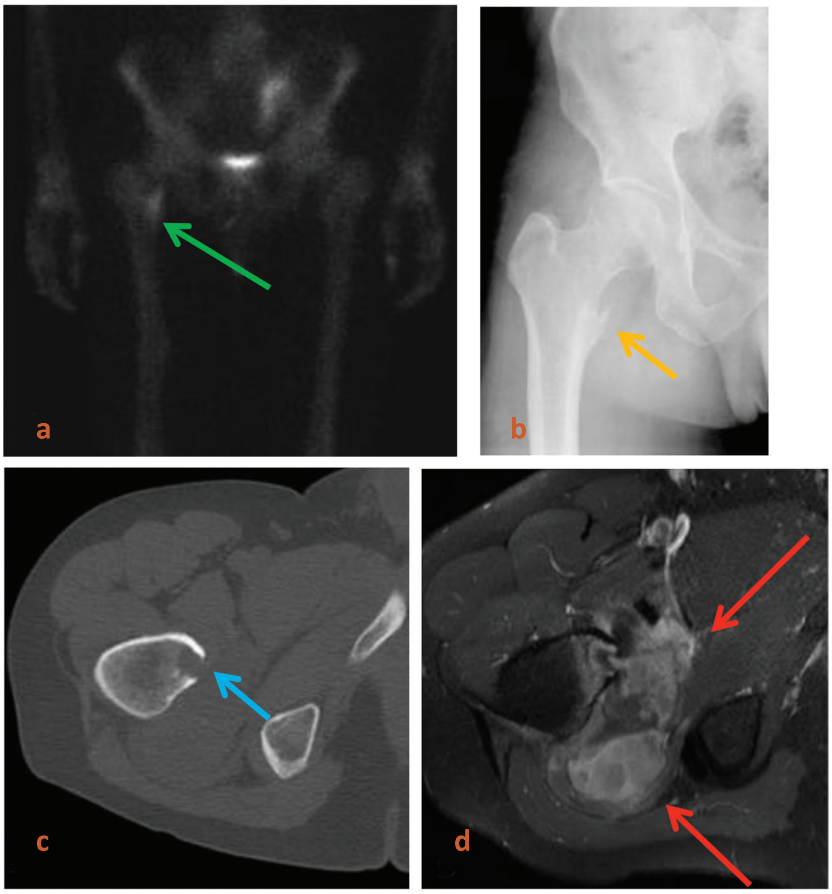
- **Tumor . Intramuscular metastasis of an adenocarcinoma of the lung**



PET - CT CT E.Mulkens, SARE

- **Iliopsoas lesser trochanteric attachment tumor**

Bone scan **(a)** *demonstrating increased uptake in the right lesser trochanter (arrow). Plain radiograph* **(b)** *of the right hip (AP view) demonstrating irregularity of the lesser trochanter and thickening of the distal iliopsoas tendon (arrow). Axial CT* **(c)** *of the right hip showing a lytic lesion in the right lesser trochanter (arrow). Axial T2 fat sat image of the right hip* **(d)** *demonstrating a large irregular predominately high signal lesion with extraosseous component insinuating into the distal iliopsoas tendon attachment (arrows). This was biopsy proven metastatic adenocarcinoma of the lung.*

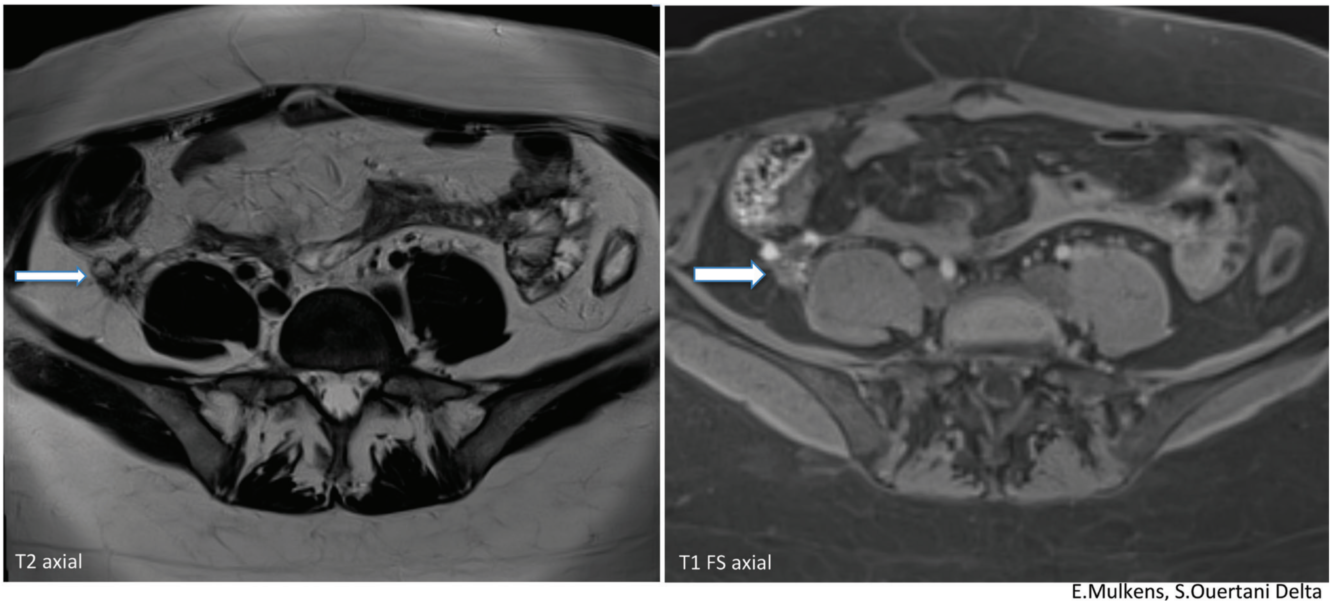


M.Cresswell

Point 4 : Iliopsoas extrinsic pathologies

- **Anterior region**

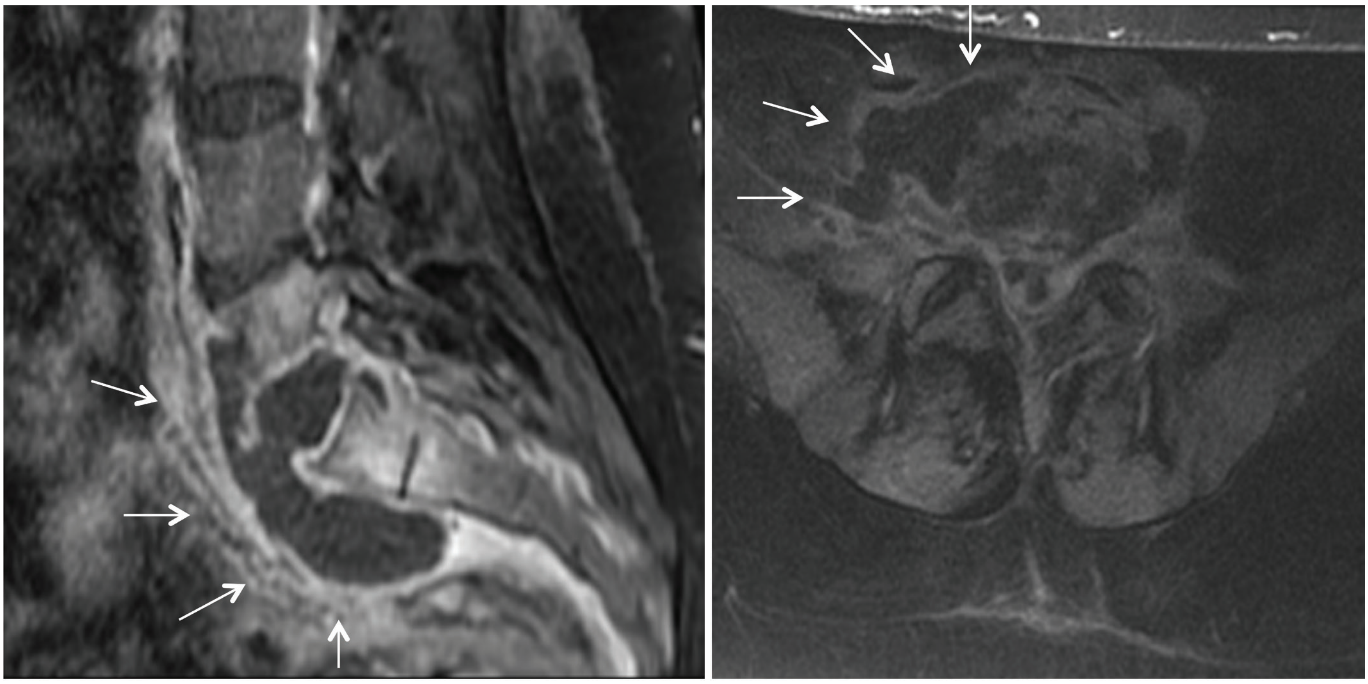
Endometriosis : Endometriotic settlement on an appendicectomy site, close to the right psoas. Differential diagnosis : appendicitis, tubo-ovarian abcess, peritoneal inflammation, renal or neurogenic masses.



E.Mulkens, S.Ouertani Delta

- **Deep region, proximal to the inguinal ligament.**

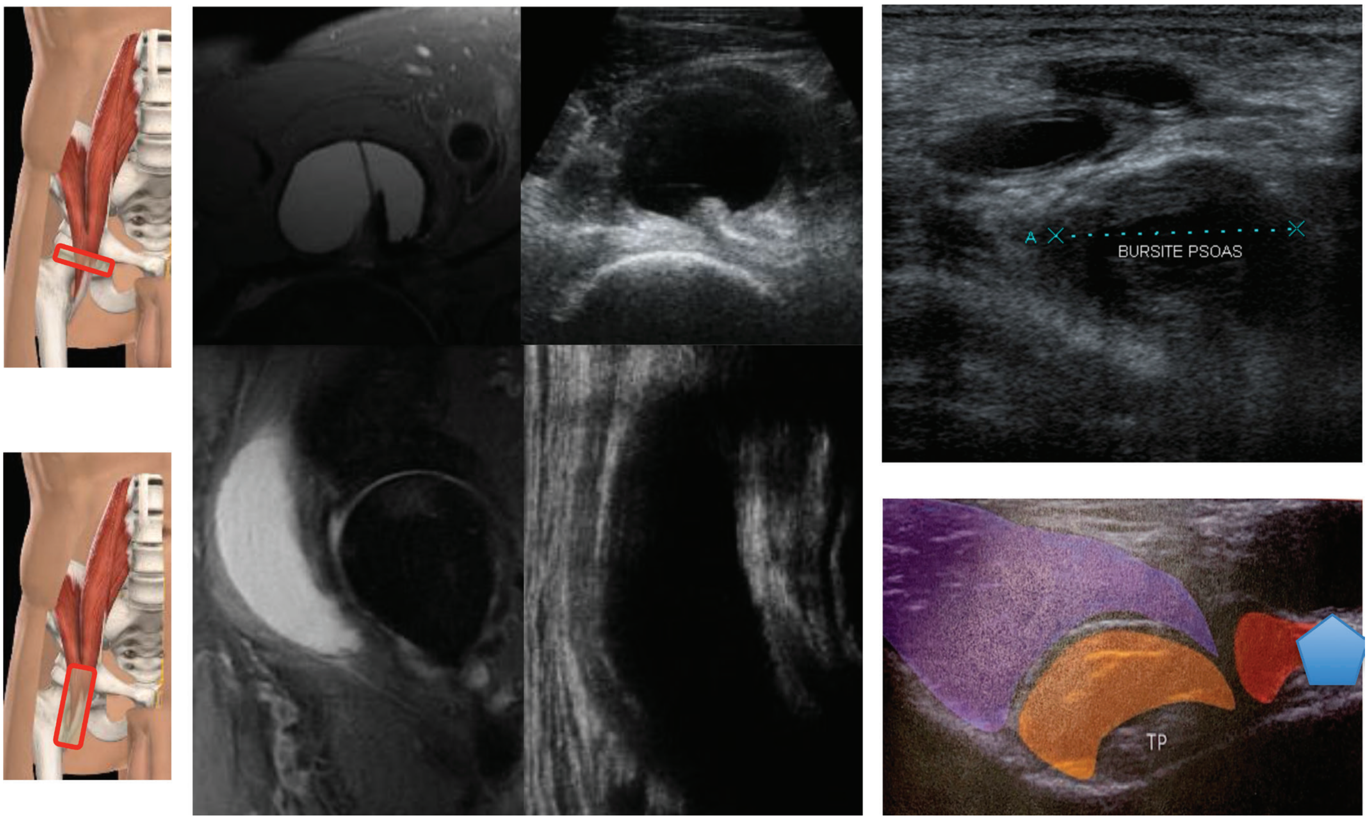
Lumbosacral septic dIscitis / Arthritis spreading into the psoas muscle



M.Cresswell

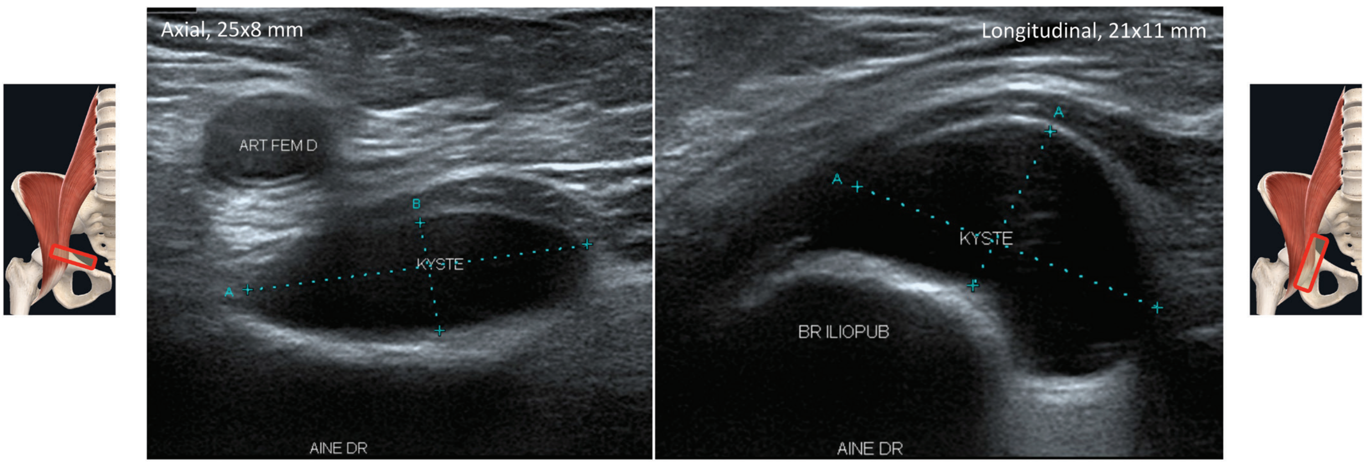
- **Deep region, distal to the inguinal ligament**

Bursitis with antérior development towards the femoral vessels



- **Deep region, distal to the inguinal ligament** (follow)

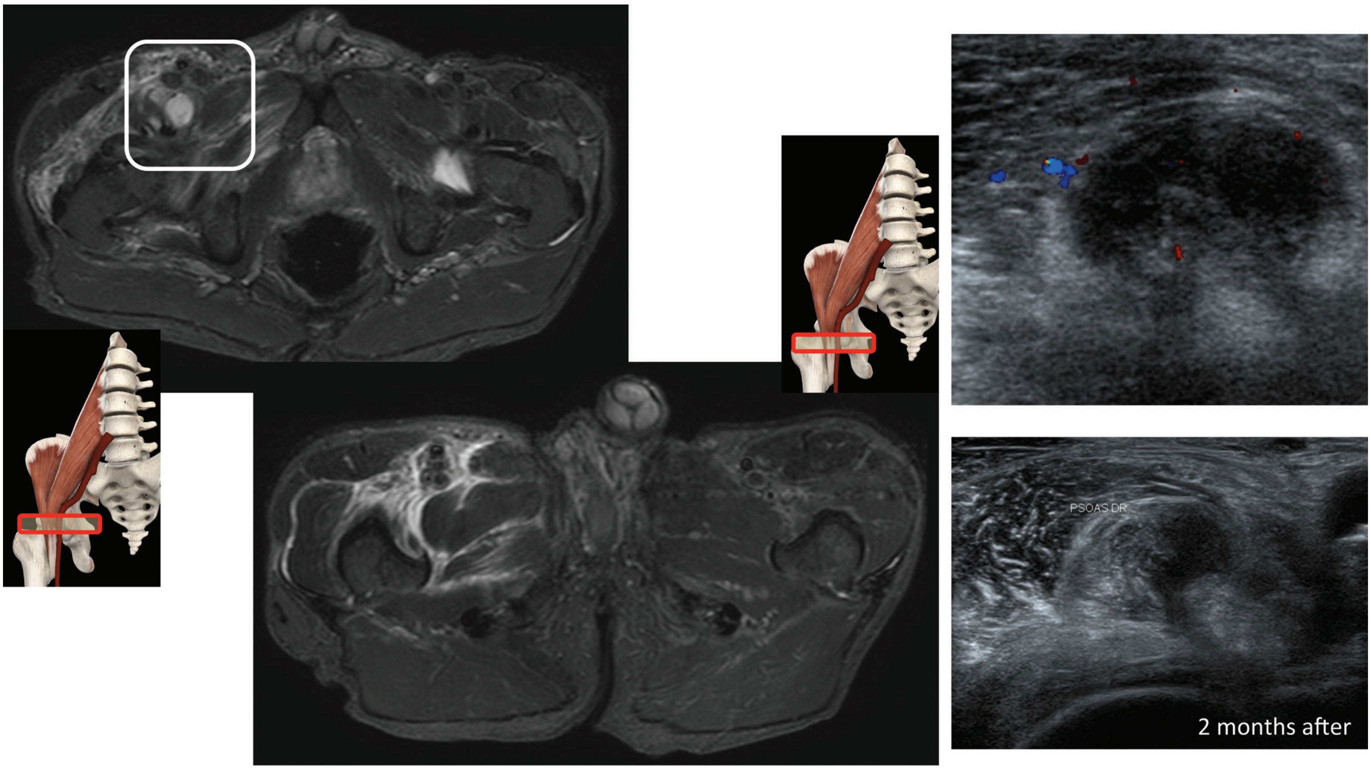
Bursitis with deep development towards the ilio-pubic branch



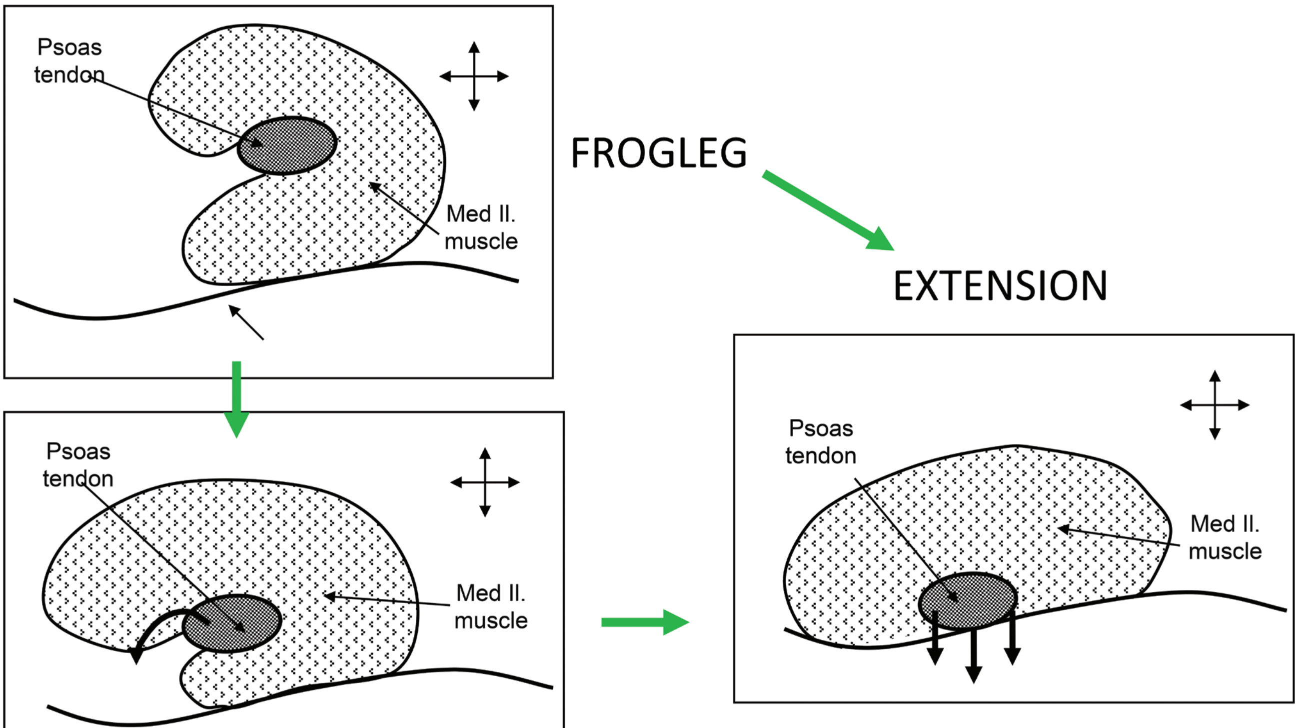
P.Peetrons

- **Deep region, distal to the inguinal ligament** (follow)

Psoas bursa rupture with a marked inflammatory syndrome inside and around the distal iliopsoas muscle



Point 5 : Medial snapping hip

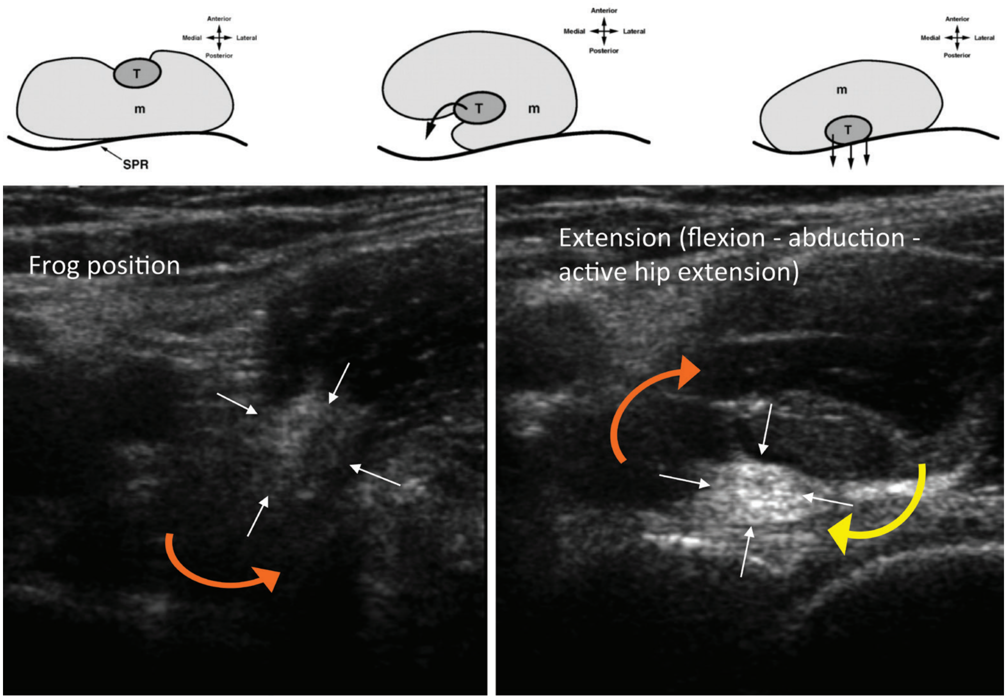


Modified from Deslandes M, et al: *AJR* 2008

- **Twist of the psoas iliac muscle around its tendon**:

In the « frog position », the muscular body slides between the tendon (white arrows) which lifts and the pelvic ring (orange curved arrow).

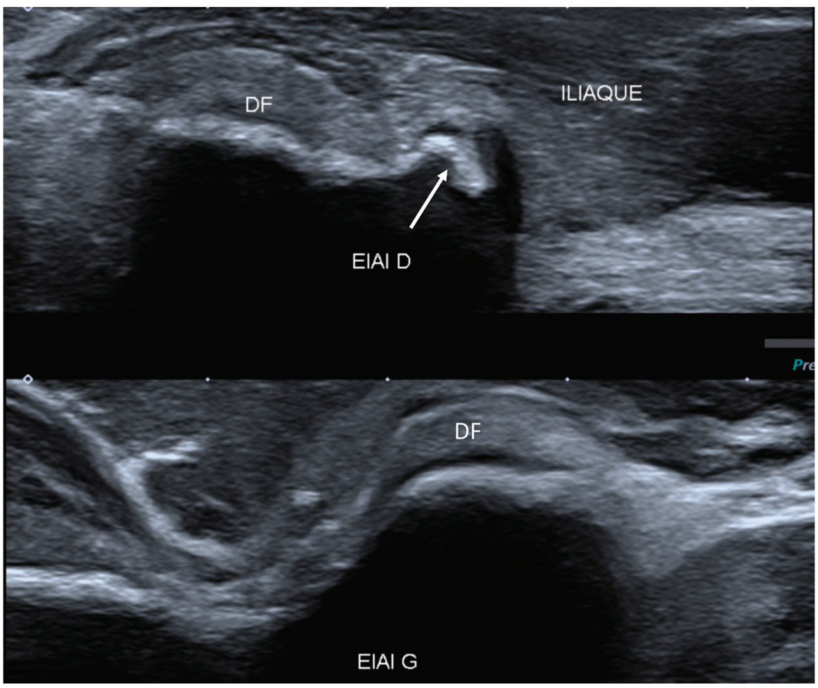
In extension there is a medial translation of the tendon which goes suddenly under the muscle and comes to «snap» on the pelvic ring (yellow curved arrow).



Point 6 : Impingements

- **Osteomuscular impingement**

16y old female gymnast with pain in her groin while flexing-extending the right hip. Old avulsion of the antero-inferior iliac spine impinging to the iliac muscle on flexion-extension ot the hip.



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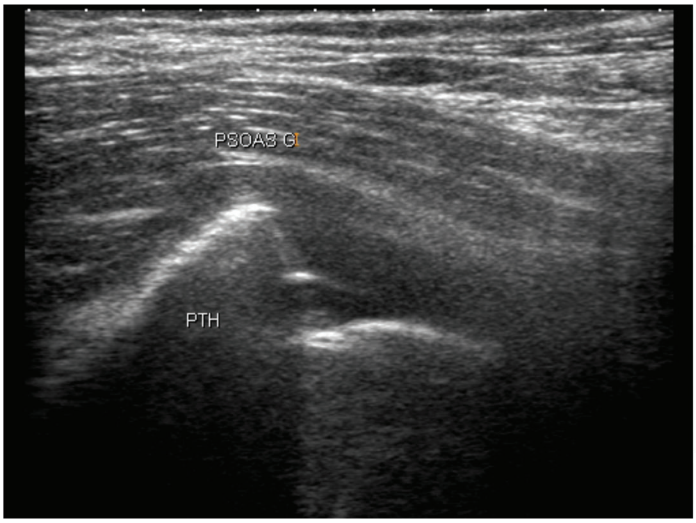
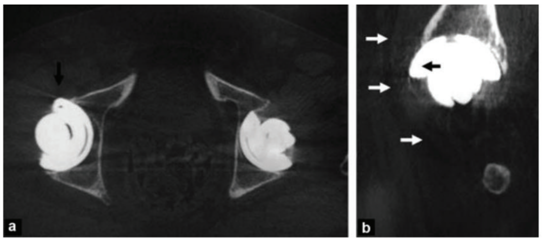
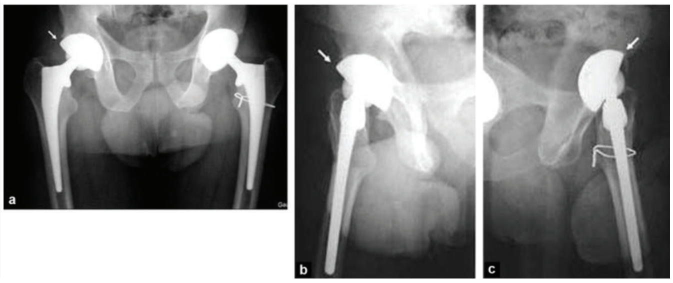
P. Peetrons

- **Total Hip Replacement impingement**

The acetabulum part can be too anterior regarding the surface of the iliac bone (X rays), impinging on the psoas tendon. Ultrasound easily sees the relationship between te tendon and the metallic part of the acetabulum, explaining the painful symptoms. A steroid injection can be done under US guidance around or close to the tendon.

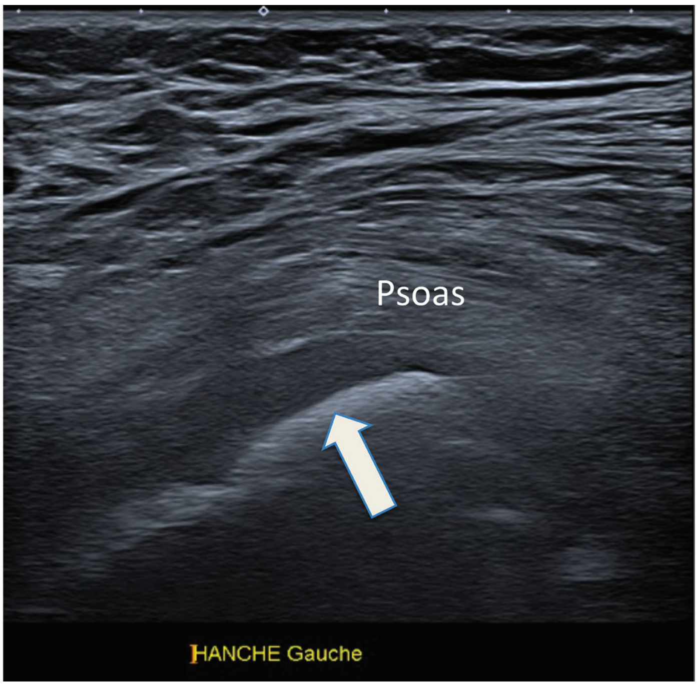






- **Total Hip Replacement (heterotopic ossifications) - Psoas conflict**

Important periproshetic ossifications (arrow) may occur and impinging the psoas tendon as shown in the US image. Once again a steroid injection can be done under US guidance but in this patient prosthetic replacement and cleaning of the zone was preferred .



07 Chest wall :anatomy and traumatic injuries

Catherine Cyteval

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Traumatic injuries to the chest wall are often caused by direct trauma, so the diagnosis is often apparent. With indirect mechanisms and overuse injuries such as those that are very common among sportspeople, a good understanding of the anatomic structures in the chest and their typical injuries is necessary. If we exclude the scapula and the deep aspect of the glenohumeral joint, the structures that make up the anatomy of the chest are superficial and can be almost entirely examined on ultrasonography (US). This makes US a modality of choice in post-traumatic examination.

1. US anatomy of the bones of the chest wall [1, 2]

The anterior cortices of the sternum, ribs and clavicle are clearly visible as thin hyperechoic outlines with a significant acoustic shadow that blocks underlying structures from being visible. The chondrocostal cartilage can also be clearly seen. This has a homogeneous echotexture bordered by a thin hyperechoic outline through which the underlying pleura and lung can be seen **(Fig. 1)**. Occasionally, small non-pathologic calcifications can be found within this cartilage. The cartilage of the vertebrosternal ribs (1 to 7) attaches these ribs to the sternum, the cartilage of the vertebrochondral ribs (8 to 10) is attached together, while the floating ribs (11 and 12) have a small cartilaginous stump at their anterior extremity.

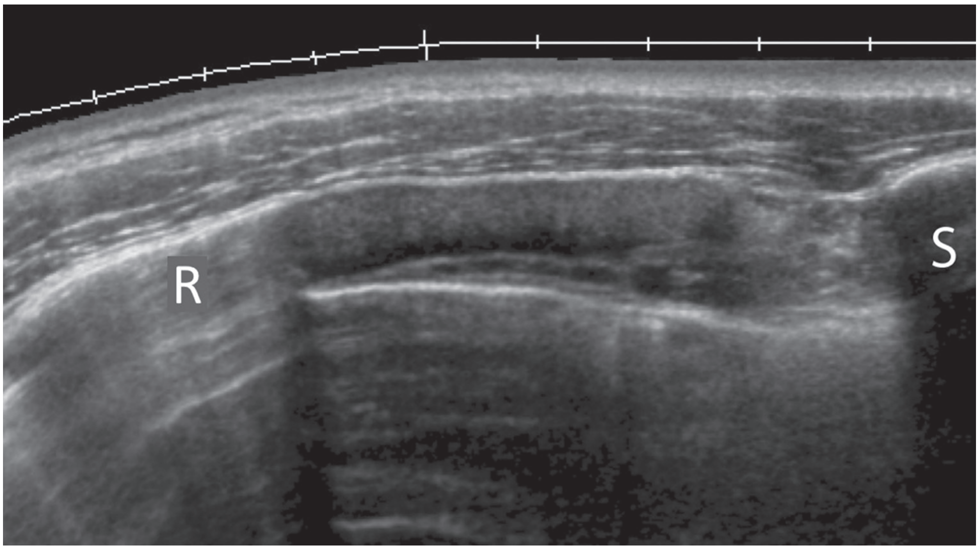

Figure 1: *Axial view of sternocostal cartilage. The bony structures of the rib (R) and sternum (S) are clearly visible along with significant acoustic shadowing blocking the sound waves, whereas the cartilage is a hypoechoic structure bordered by fine hyperechoic lines. The intercostal neurovascular bundle and the lung can be seen underneath.*

2. US anatomy of the pectoralis major[3]

This is the largest and most superficial muscle of the anterior chest wall. It is mainly an adductor and medial rotator of the arm. It extensively attaches directly through its muscle fibers to the anterior aspect of the upper half of the sternum **(Fig. 2, 3)**.

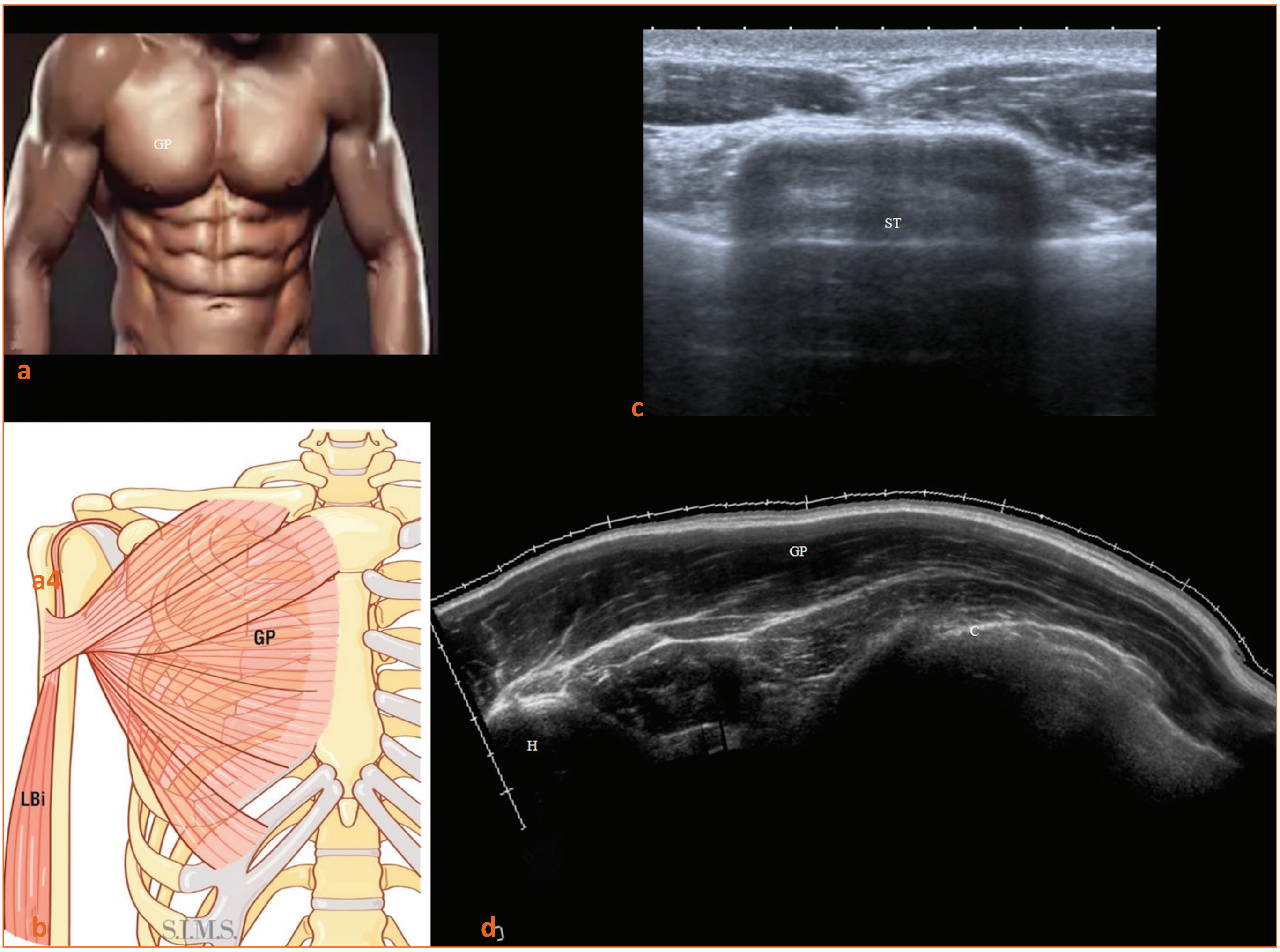

Figure 2: **(a)** *Pectoralis major (PM).* **(b)** *Diagram of clavicular, sternocostal and humeral insertions of the pectoralis major, which loops around the tendon of the biceps long head and presses it down into the bicipital groove.* **(c)** *Median transverse view. The pectoralis major muscles can be seen attaching directly onto the sternum (ST) via their muscle fibers.* **(d)** *Panoramic axial view of the pectoralis major, which spans almost the entire anterior chest wall, forms the anterior fold of the axillary fossa, and inserts via a large tendon onto the lateral lip of the bicipital groove of the humerus (H). Long head of the biceps et modifier GP : Pectoralis major.*

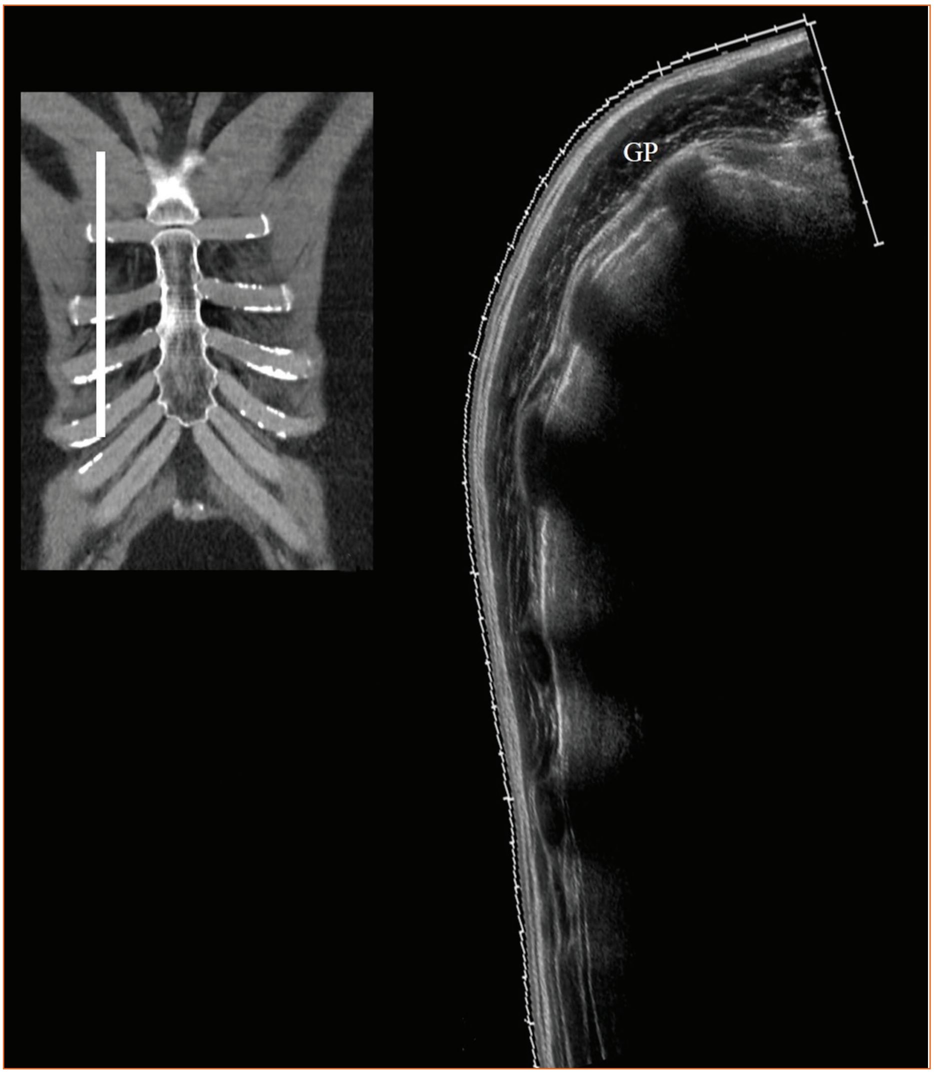

Figure 3: *Panoramic anterior sagittal view of pectoralis major spanning the entire anterior portion of the ribs and intercostal spaces. Pectoralis major (GP).*

Its attachment extends upward onto the medial third of the clavicle and downward onto both the chondrocostal cartilage of ribs 2 to 6 and the aponeurosis of the rectus abdominis. Laterally, it inserts via a tendon onto the lateral lip of the bicipital groove, crossing over the tendon of the biceps long head roughly 5cm below the point where that tendon enters the groove. The pectoral tendon pins the biceps long head tendon to the anterior cortex of the humerus, giving it an oval-shaped appearance. This lateral tendon of the pectoralis major is flat, 6cm long, and 1.5mm thick [4]. The superolateral portion of the muscle is divided from the deltoid by the deltopectoral groove. This groove is often poorly visible, but use can be made of the anisotropy artifact to distinguish the two muscles **(Fig. 4)**. Deep to the pectoralis major in the superolateral portion of the chest wall lie the three muscles that attach to the coracoid process: the biceps short head, coracobrachialis, and pectoralis minor **(Fig. 5)**.

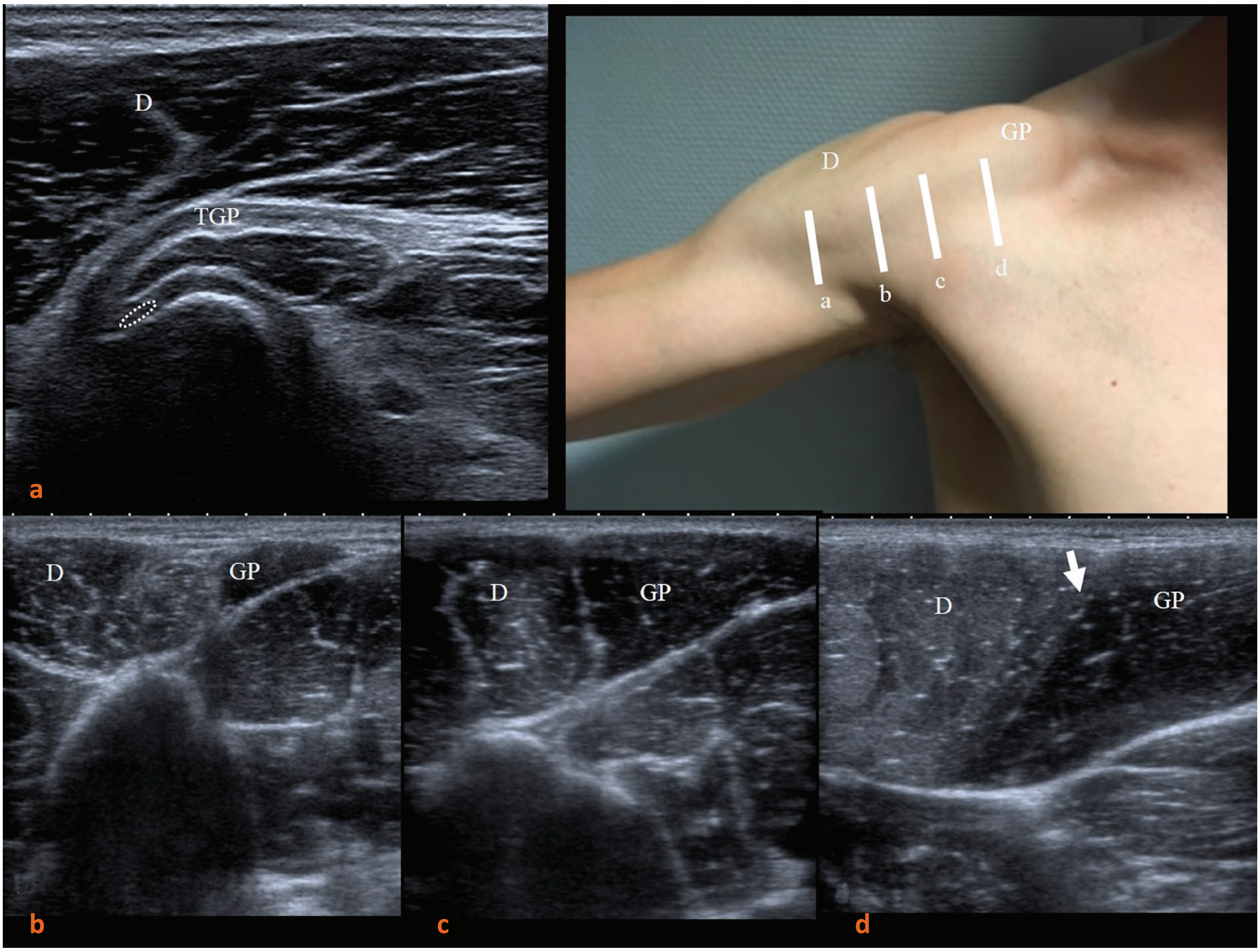

Figure 4: *Successive images perpendicular to the humerus of the lateral insertion of the pectoralis major (GP)***(a)**. *Tendon of the pectoralis major (TGP) crossing over the bicipital groove and inserting onto its lateral lip. Pectoralis major tendon presses the tendon of the biceps long head down into the groove (dotted oval).* **(b, c, d)** *Moving upward, the deltoid (D) and pectoralis major (GP) can be visualized, with the poorly visible deltopectoral groove (arrow) lying between them. The anisotropy artifact is used to distinguish the two muscles whose fibers course in different directions.*

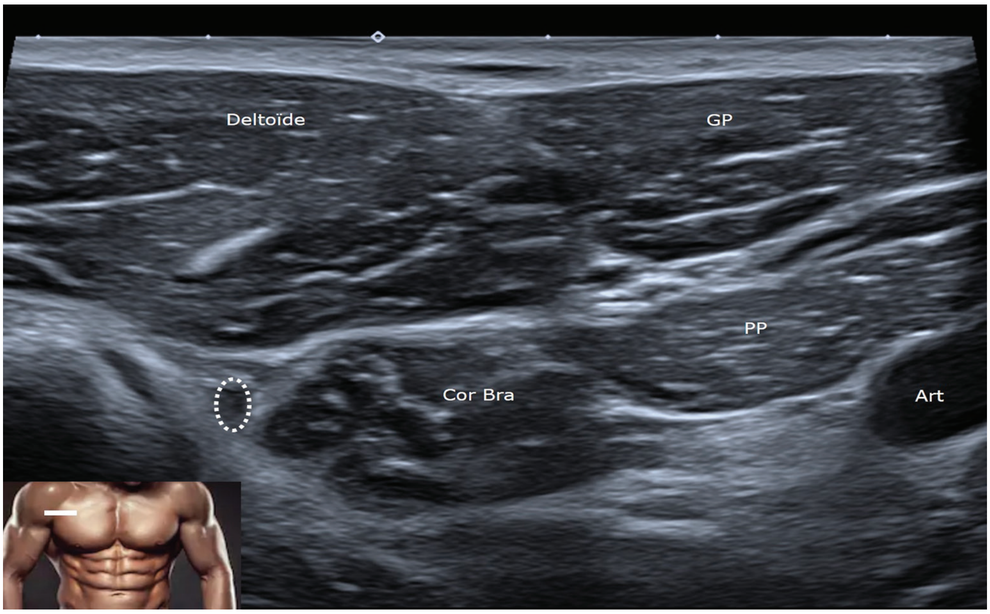

Figure 5: *Axial view of the axillary fossa. The deltoid (D) and pectoralis major (GP) lie superficially, with the three muscles that insert onto the coracoid process lying underneath. From lateral to medial, these are the tendon of the biceps short head (dotted), coracobrachialis (Cor Bra), and pectoralis minor (PP). Medial to these lies the axillary artery (Art).*

3. US anatomy of the pectoralis minor [5]

This muscle lies deep to the pectoralis major. It is vertically oriented, arising from the coracoid process and inserting onto the anterior chondrocostal junction of ribs 3, 4, and 5 **(Fig. 5, 6)**.

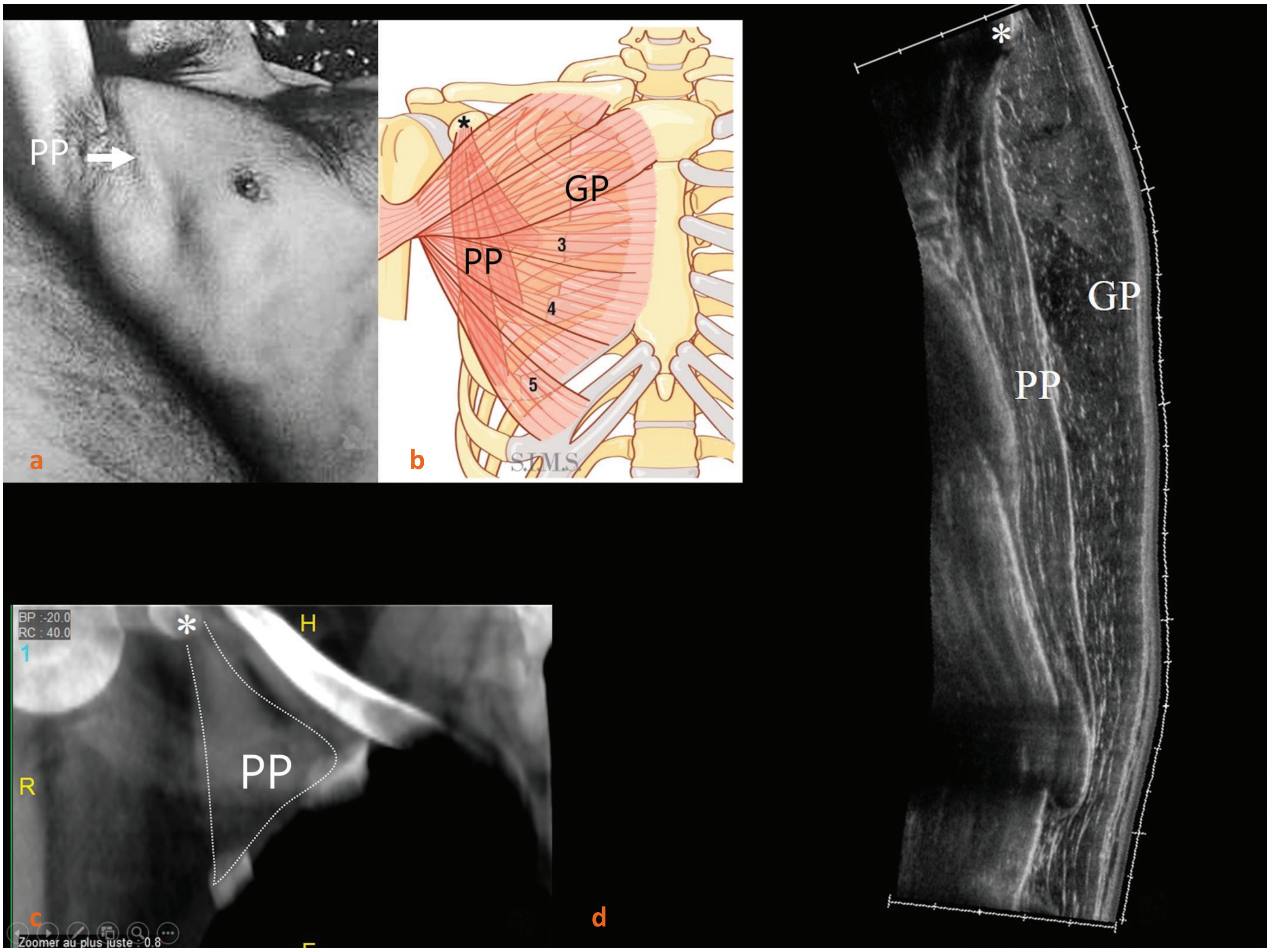

Figure 6: *(a) Pectoralis minor (PP) appears as a thin, vertically oriented band protruding anteriorly to the axillary fossa.(b) Diagram showing the pectoralis minor deep to the pectoralis major (GP), with its proximal attachment on the coracoid process (star) and distal attachment on ribs 3, 4 and 5. (c) Coronal CT. (d) Panoramic sagittal US. Pectoralis minor (PP) lies between the ribs and pectoralis major (GP).*

4. US anatomy of the serratus anterior [6,7]

This muscle forms the lateral portion of the rib cage and holds the scapula in place against the thorax. It lies just superficial to the rib cage and attaches onto the medial border of the scapula and lateral portion of ribs 1 to 9 or 10. It is innervated by the long thoracic nerve, which courses vertically across the surface of the muscle and is rarely visible on US **(Fig. 7)**.

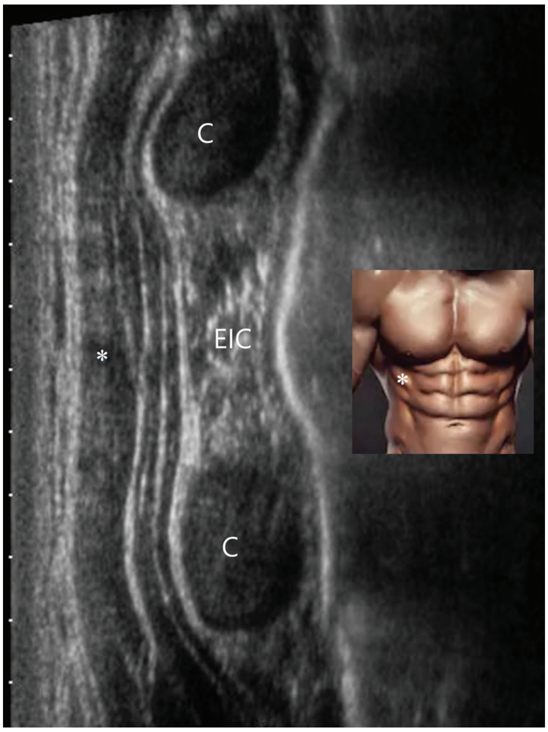

Figure 7: *Sagittal views through the anterolateral part of the chest wall showing the serratus anterior (star) lying superficially, covering the ribs (C) and intercostals muscles (EIC).*

5. US anatomy of the intercostal muscles

These are located between the ribs, with the external intercostals lying superficial to the internal intercostals. Deep to these, the innermost internal intercostals cannot always be distinguished, although the fine overlapping hyperechoic outlines of the pleurae and highly hypoechoic aerated appearance of the lungs are easy to make out underneath **(Fig. 8)**.

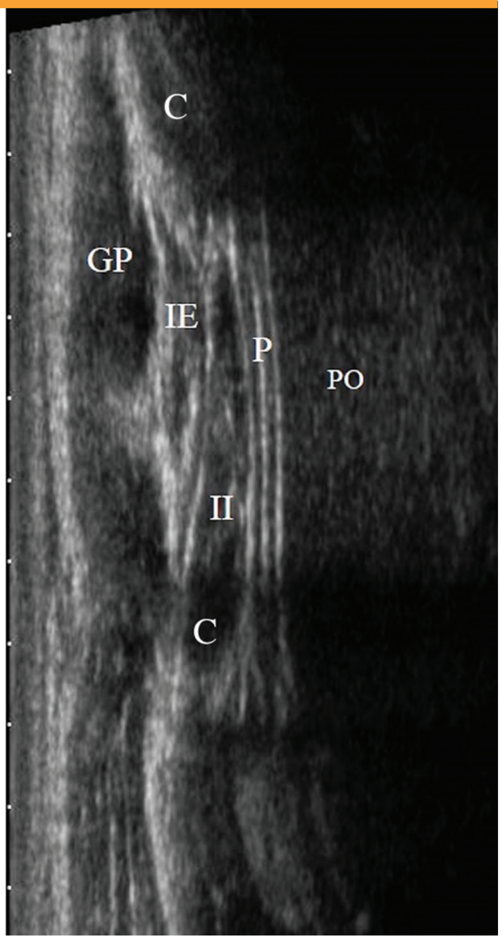

Figure 8: *Longitudinal view of an intercostal space with the pectoralis major (GP) superficial to it. Between two ribs (C), the external and internal intercostals muscles (EI and II) can be seen superficial to the fine hyperechoic outline of the pleura (P). The highly hypoechoic structure of the lung can be seen underneath (PO).*

6. US anatomy of the latissimus dorsi

This muscle lies in the posterior thoracolumbar wall. It is the agonist of the pectoralis major. It arises from the spinous processes of T6 to T12, thoracolumbar fascia, posterior iliac crest, posterior sacrum, and last four ribs. It then travels laterally, crossing the inferior angle of the scapula before inserting via a tendon onto the medial lip of the bicipital groove anterior to the teres major, around which it loops, and posterior to the radial nerve **(Fig. 9, 10, 11)**.

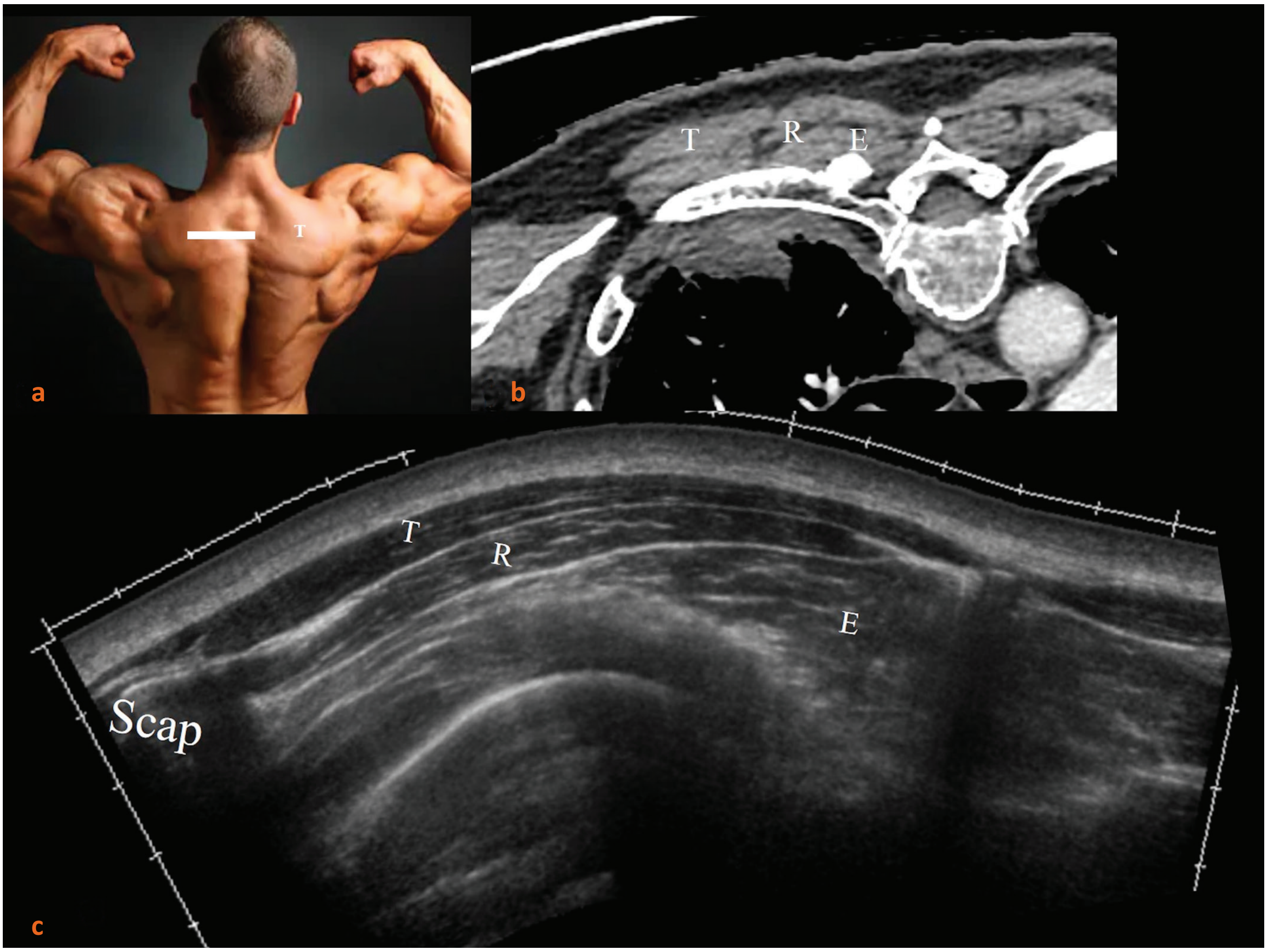

Figure 9: *Paramedian axial view of the upper scapula. From superficial to deep, the trapezius (T), rhomboids (R), and erector spinae (E), this last muscle lying lateral to the spinous process.*

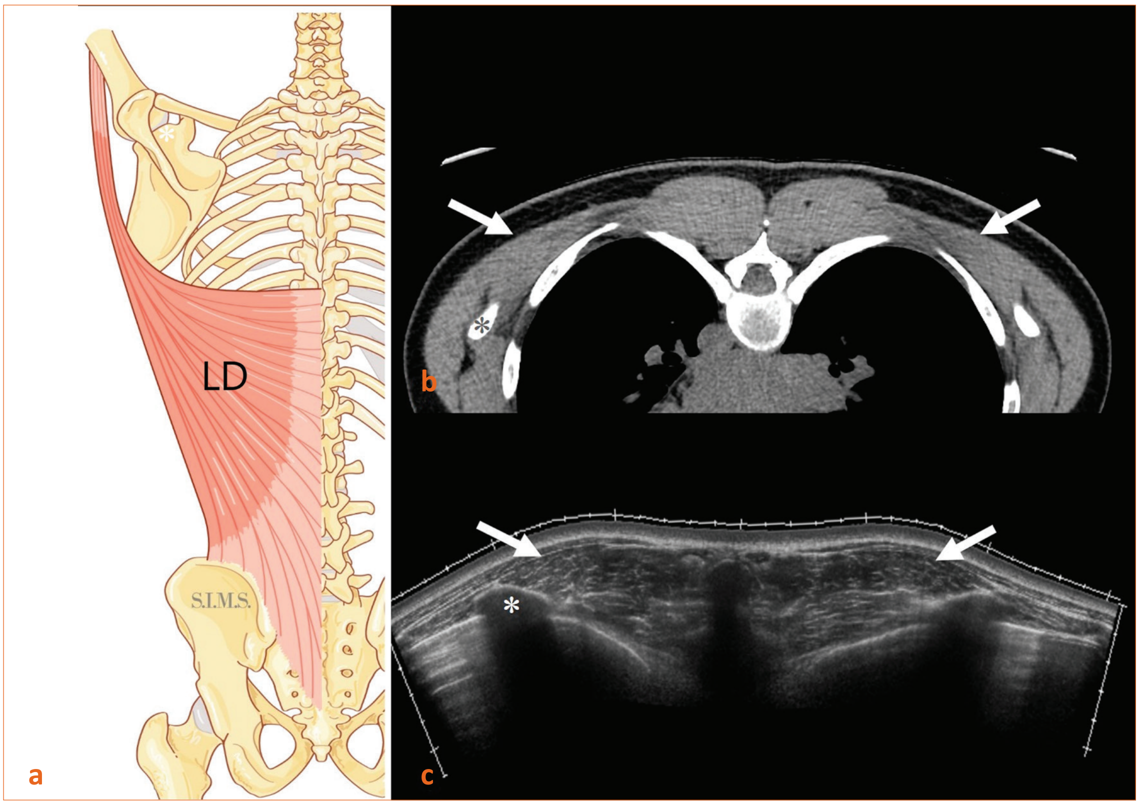

Figure 10: *The latissimus dorsi (LD).* **(a)** *Diagram of the origin of the latissimus dorsi on the spine, sacrum and iliac crest, and trajectory of the muscle as it courses to its lateral tendon on the medial lip of the bicipital groove.* **(b)** *Axial CT views through the inferior angles of the scapulae.* **(c)** *Panoramic axial US image through the inferior angle of the scapula (*) showing the latissimus dorsi arising from this portion of the scapula.*

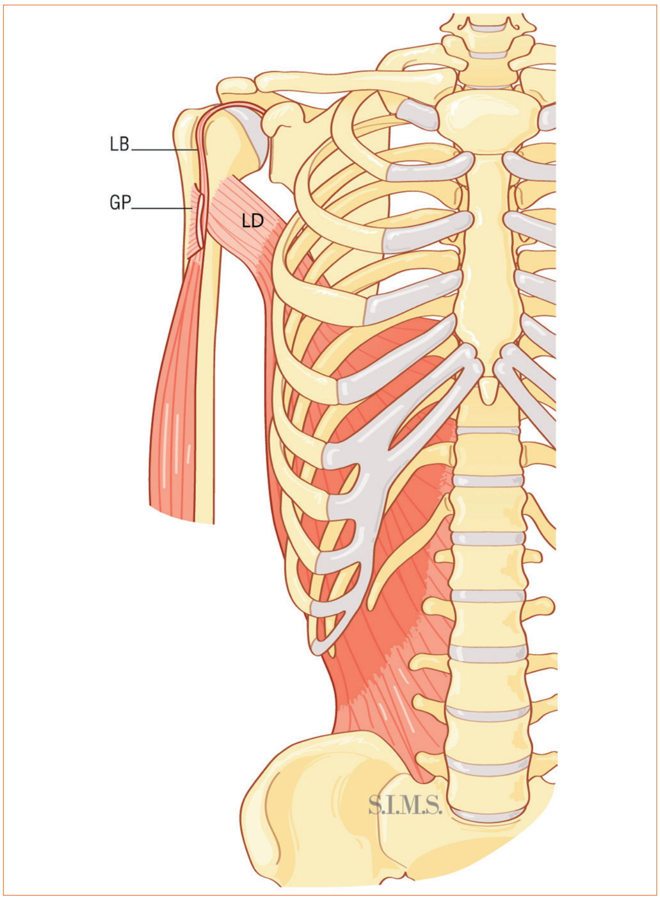

Figure 11: *Anterior diagram of the attachment of the lateral tendon of the pectoralis major (GP) onto the lateral lip of the bicipital groove. We can see the tendon of the biceps long head laterally (LB) and the sectioned tendinous insertion of the pectoralis major, which is the agonist of the latissimus dorsi (LD).*

7. Rib and sternum fractures [8]

US shows the acute phase of a rupture of the hyperechoic cortical line. Such ruptures may occur without the typical displacement of bone fragments. This particular rupture is accompanied by neighboring hypoechoic hematoma which may infiltrate adjacent muscles **(Fig. 12)**. Hematoma is sometimes the most clearly visible sign, accompanied only by a discreet deformity which represents a depressed fracture of the bone. Additionally, in some cases, all that may be visible in the area of pain is Doppler hyperemia near the costal cortex [9].

If the fracture is seen at a more chronic stage, it is possible to follow the successive stages of callus formation. The hematoma turns into a hypoechoic arc of gradually increasing echogenicity. During the consolidation phase, the callus rapidly vascularizes. New bone gradually forms causing acoustic shadowing, eventually becoming just a deformity in the contours of the bone.

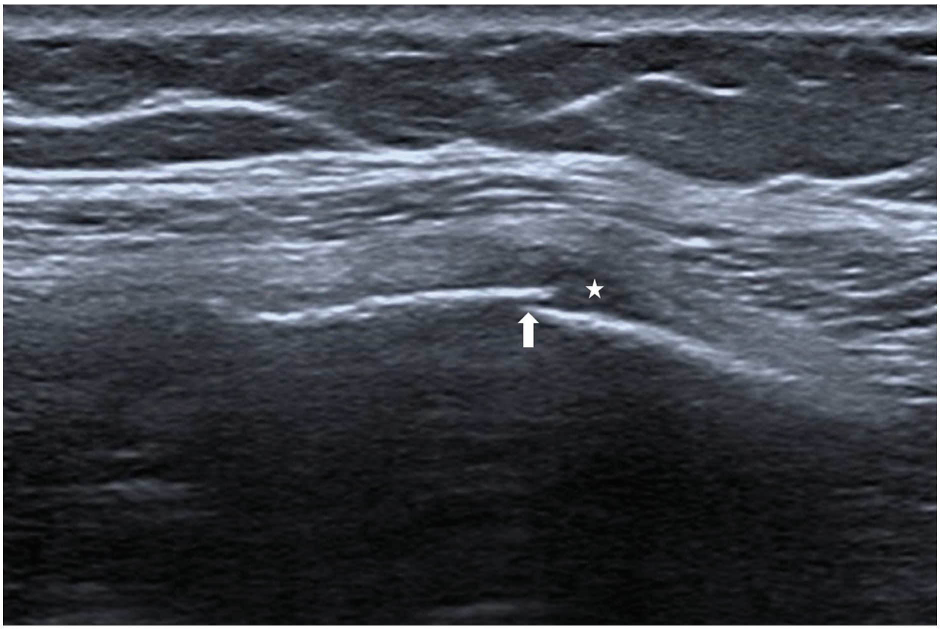

Figure 12: *Axial view of a rib. The cortical discontinuity indicates a fracture (arrow) accompanied by a discreet surrounding hematoma (star).*

Cartilage injuries are invisible on radiographs but particularly clear on US images. Fractures occasionally occur at the chondrocostal or chondrosternal junction. Displacement injuries may be discreet on static images and must always be checked for with a dynamic examination **(Fig. 13, 14)**. The best sign is loss of continuity in the superficial hyperechoic line. Chondral calcifications and in some cases gas bubbles may also be observed in the subacute or chronic phase.

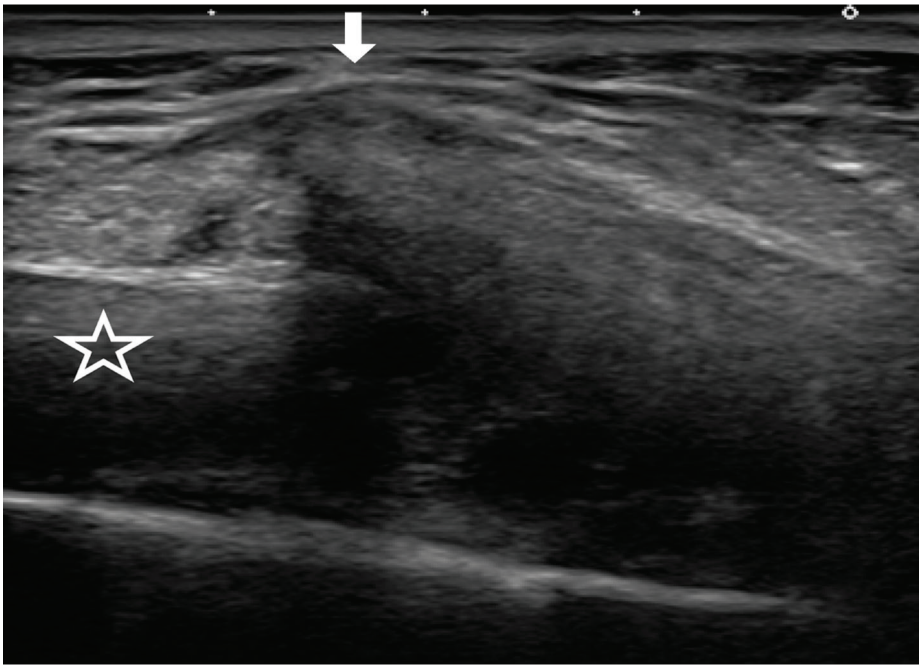

Figure 13: *Fracture (arrow) at the junction between a rib (star) and its cartilage which have displaced away from each other.*

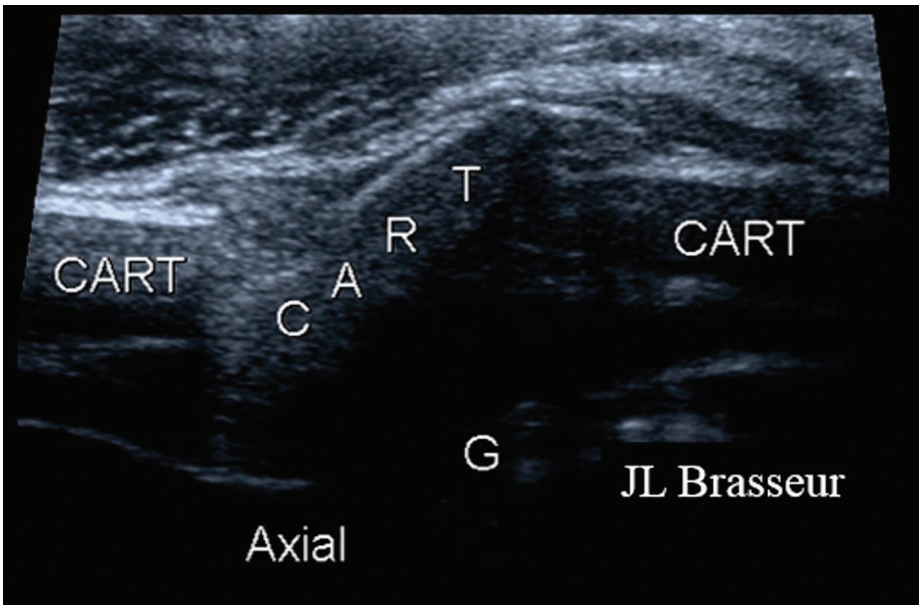

Figure 14: *Axial view of costal cartilage which has fractured in two places. The middle cartilaginous fragment has displaced.*

8. Traumatic muscle and tendon injuries [10]

These can be extrinsic but occur more often intrinsically due to excessive stretching or contraction. The most common site of injury is the pectoralis major [3], [11-14]. These injuries are predominantly intrinsic, occurring in the body of the muscle or at its attachment points.

- Intramuscular injuries classically occur in bodybuilders due to the use of anabolic steroids. Injury severity is graded as follows **(Fig. 15)**:
  - *Grade I:* Diffuse, often hypertrophic, hyperechoic changes without disruption of muscle architecture.
  - *Grade II:* Same image but with disruption of muscle architecture.

- *Grade III:* Hematoma with partial muscle tear.
- *Grade IV:* Complete muscle tear.

In chronic cases, hyperechoic scar tissue can be seen, and intramuscular ossifications may develop.

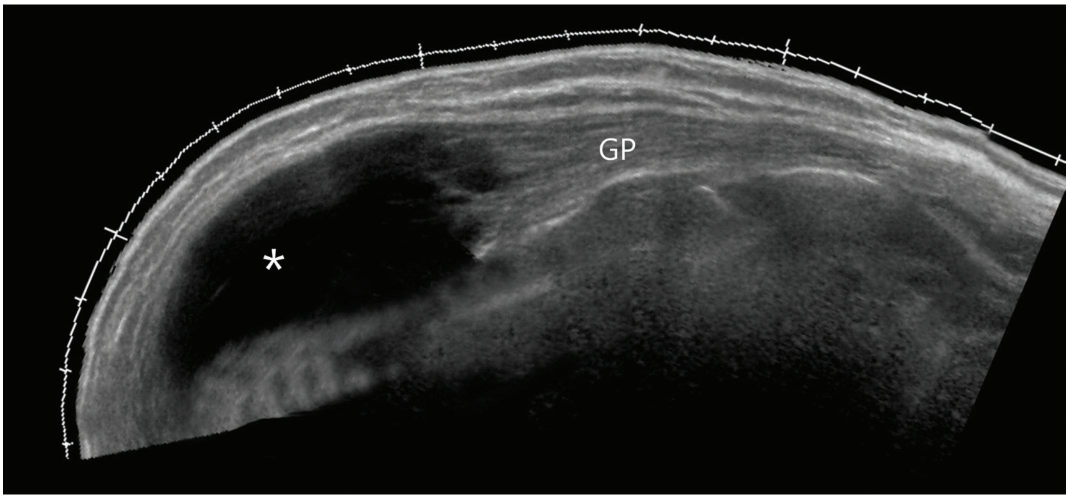

Figure 15: *Panoramic axial view of a large hypoechoic hematoma (star) in the pectoralis major (GP) of an elderly patient on anticoagulants.*

- Musculotendinous rupture may be partial or complete. Concomitant hematoma is typically abundant at the point of rupture. In discreet partial injuries, the reader should beware of the prominent anisotropy artifact at the musculotendinous junction. If there is significant retraction of the pectoralis major, an anterior bulging of the pectoralis minor may be visible.
- Rupture of the tendon and humeral attachment alter the morphology and location of the bicipital tendon, which becomes more rounded and lies more anteriorly and laterally from the groove. Such ruptures are easier to visualize when the pectoralis major is contracted **(Fig. 16)**.

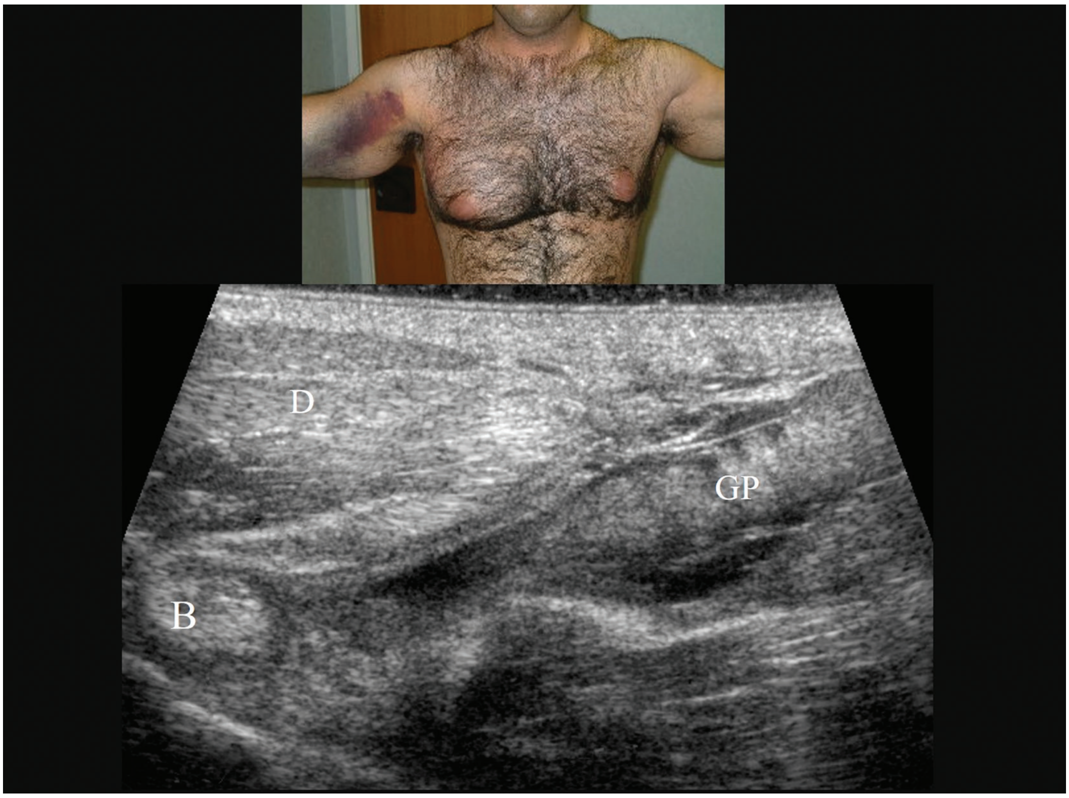

Figure 16: *Rupture of the tendinous insertion of the pectoralis major onto the humerus. Axial US of the upper humerus: the pectoralis major (GP) has retracted and its tendon cannot be seen. The biceps long head tendon (B) is no longer being pressed down into the bicipital groove. Superficially, the deltoid (D) is intact.*

Intercostal muscle injuries are classically intrinsic in nature and caused by excessive stretching or contraction. Discreet heterogeneous hyperechoic foci can be seen in the muscle. Comparison with the adjacent intercostal space or contralateral side is indispensable for confirming the accuracy of these images **(Fig. 17)**. If the aponeurosis is injured, a hernia may be observed as a focal bulge in a muscle contour **(Fig. 18,19)** owing to the protrusion of pleural fatty tissue. These discreet injuries can provoke chronic pain[15].

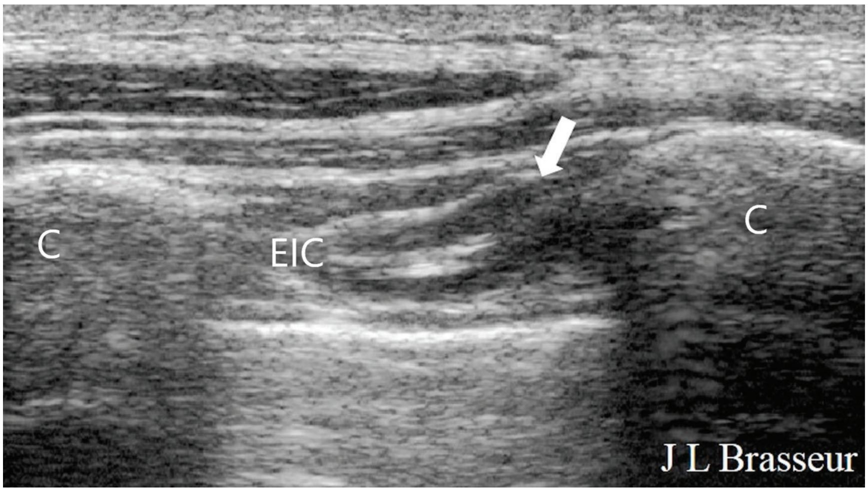

Figure 17: *Sagittal view of a painful intercostal space in a sportsman showing slight hypoechoic intercostal muscle (EIC) tears at the costal (C) attachment point (arrow).*

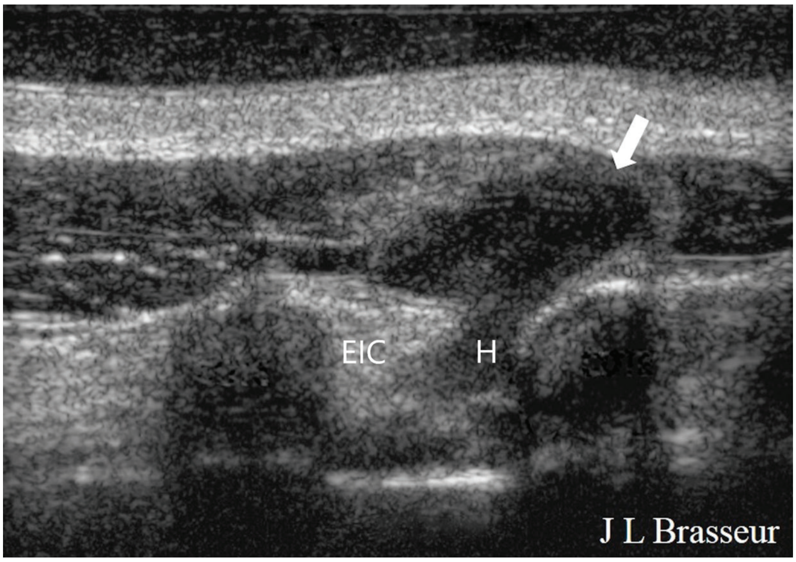

Figure 18: *Sagittal view of a painful intercostal space in a sportsman showing a fatty hernia (H) (arrow) protruding through an intercostal muscle (EIC) tear.*

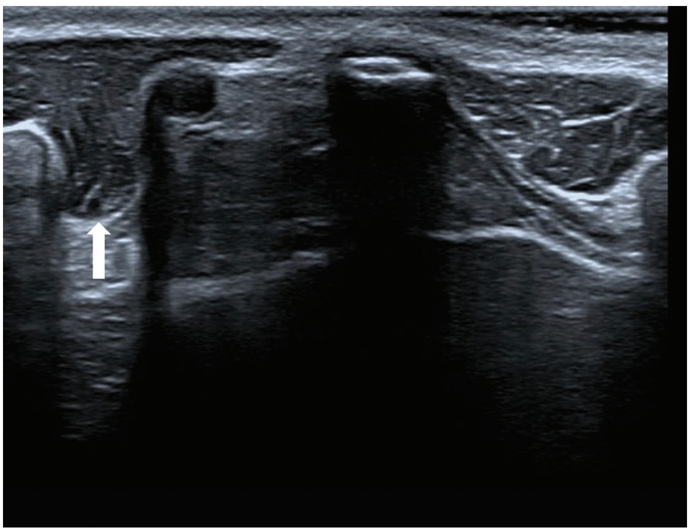

Figure 19: *Axial view of the proximal attachment of the rectus abdominis onto the lower ribs. Viewed from the right, a muscle hernia can be seen protruding through a tear in the aponeurosis (arrow).*

9. Enthesopathy and tendinopathy

These predominately involve the insertion of the pectoralis major onto the humerus and of the pectoralis minor onto the coracoid process. The reader should check for discreetly hypertrophic hypoechoic changes in the tendinous insertion, which is painful when palpated. There may also be moderate hyperemia on Doppler images.

10. Differential diagnoses[16]

Numerous causes of chest wall impingement

The xiphisternum presents a number of morphological variants. For example, there may be a cartilaginous extension that can only be seen on US which may impinge on subcutaneous tissue, on the upper extremity of the rectus abdominis, and even on the liver.

Slipping rib syndrome is an overlapping of costal cartilage owing to significant kyphosis in elderly patients, a population often with weakened bones owing to pre-existing conditions. The syndrome may in such settings lead to rib fractures secondary to microtrauma. US examination can directly visualize the overlapping cartilage, which may be accompanied by discreet intercostal bursitis [17].

Joint pathology

The sternoclavicular joint is subject to degenerative[18], infectious and inflammatory injury, particularly in the setting of SAPHO syndrome. All three cases can lead to joint fluid effusion and hypoechoic synovial hypertrophy with hyperemia on Doppler images. Degenerative injury may be secondary to chronic overuse and should be considered if there are osteophytes, with these tending to occur on the clavicular side of the joint. Conversely, in inflammatory settings, the sternal side of the joint is as frequently involved as the clavicular side, and US may show cortical erosion. Spondyloarthritis can affect the sternal angle, causing painful hypoechoic swelling, joint space irregularity, and hypervascularity which may enable diagnosis.

Tietze syndrome is painful swelling of the chondrosternal junction of the upper ribs. Its etiology has yet to be established [19].

Tumors and pseudotumors

In post-traumatic settings, the discovery of a growth on exploratory US usually requires further investigation.

A hyperplastic callus **(Fig. 20)** or asymmetry of the rib cage **(Fig. 21)**, whether congenital or secondary to scoliosis, may be found. This can be confirmed on radiography or computed tomography (CT).

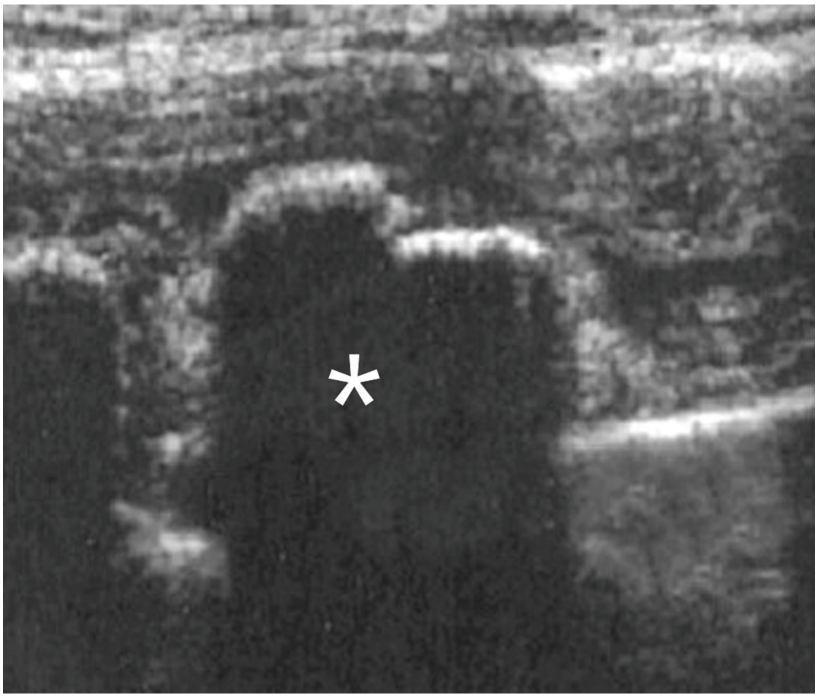

Figure 20: *Deformity of the cortical contours of a rib owing to a bony callus. Diagnosis must be confirmed on other modalities.*

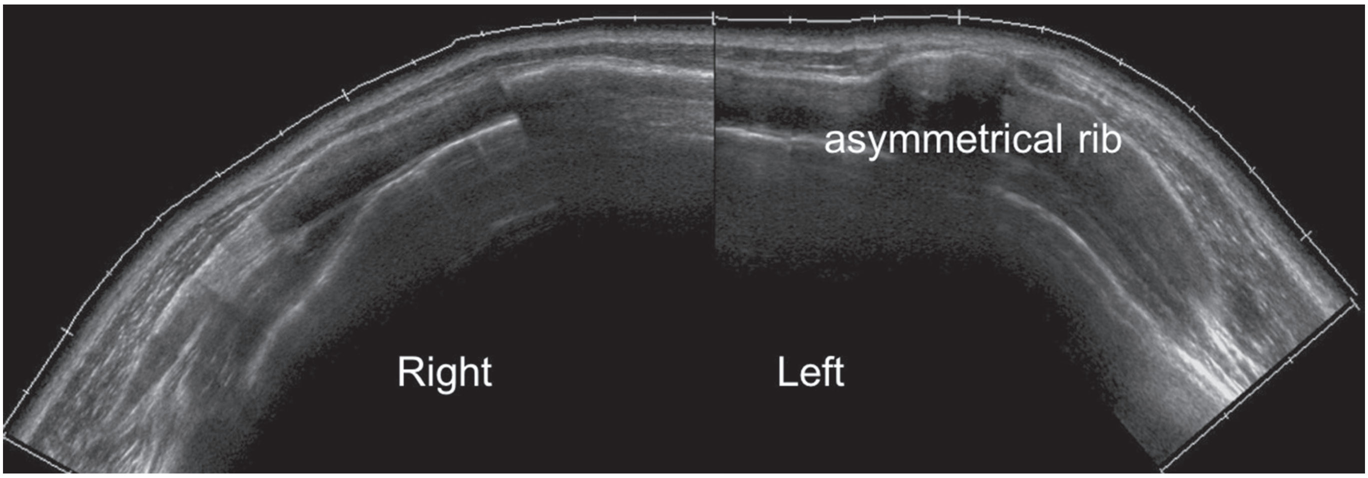

Figure 21: *Comparative axial views of the anterior arches of the seventh ribs. Congenital hypertrophy of the costosternal cartilage of the left rib mimicking a tumor.*

Elastofibroma dorsi is a classic pseudotumor typically found on the inferior angle of the scapula. It can be bilateral but is usually asymmetrical. Composed of layers of fibrous and fatty tissue, its stratified appearance can be identified on US as alternating hypoechoic and hyperechoic layers[20] (**Fig. 22)**.

Numerous chest wall tumors exist. They are usually benign[17], and the most common is subcutaneous lipoma. It is easily recognizable as a growth that is soft on sonopalpation. It is oval-shaped and localized within the subcutaneous fat, lying parallel to the skin surface. It is of varying echogenicity but is usually close to that of neighboring subcutaneous fat. It can be depressed with the transducer, and is avascular on Doppler images **(Fig. 23)**.

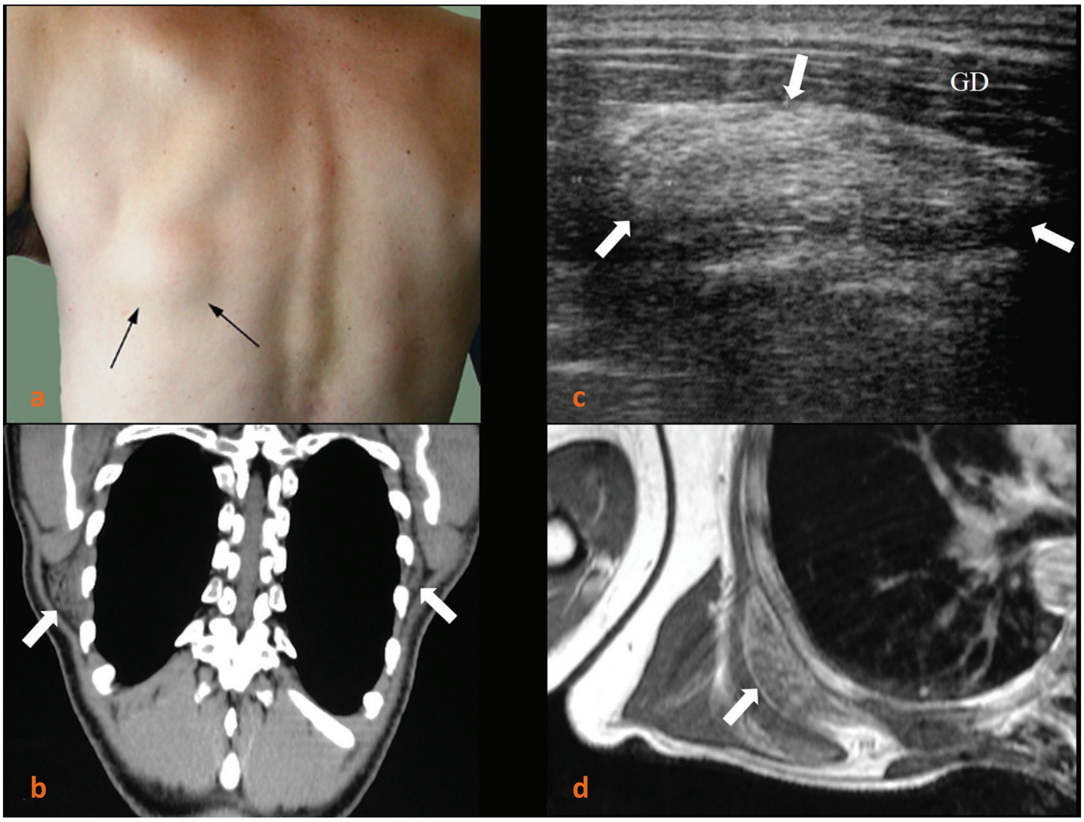

Figure 22: *Elastofibroma and its typical location on the inferior angle of the scapula (white and black arrows)***(a)**, *here seen on coronal CT* **(b)**. *It appears on US as alternating hyper- and hypoechoic bands* **(c)**. *Elastofibroma on T1- weighted axial MRI images* **(d)**. *Latissimus dorsi (GD)*

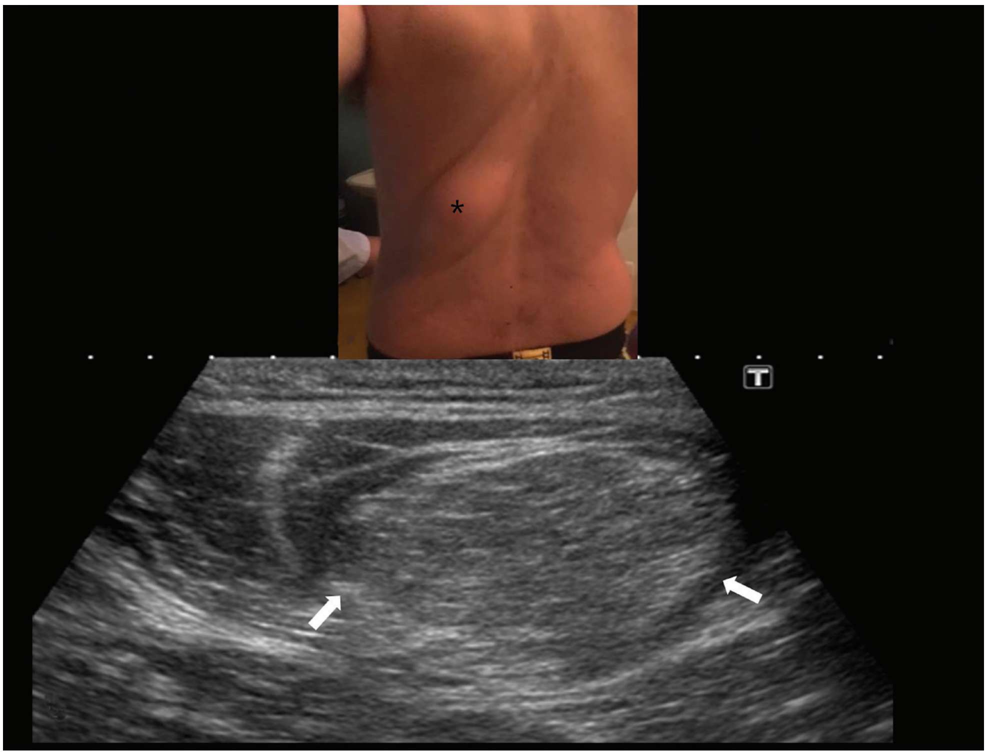

Figure 23: *US of a subcutaneous lipoma of the chest wall with a well-defined, homogeneous, oval-shaped hyperechoic appearance lying parallel to the skin surface (arrow). It must always be checked that hyperemia is absent on Doppler images.*

In conclusion

The chest wall is susceptible to a number of pathologies. These are predominantly traumatic injuries, especially of the intrinsic kind. Because US is a dynamic modality which allows the user to pinpoint the area of pain during the examination, it remains a modality of choice in this setting.

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08 Calf injury (gastrocnemius muscle)

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Point 1. Definition et epidemiology

Tennis leg (TL) is a traumatic tear of the medial head of the gastrocnemius (GMH)/plantaris tendon (PT) typically due to a sudden powerful muscle contraction such as during a sprint. The exact structure involved (GMH or PT) in TL is still a matter of debate. TL can be secondary to sport trauma (tennis, sprinter) or follow trivial injuries in everyday activities.

There is a great variation in the reported incidence of TL. In elite athletes, after the biceps femoris and rectus femoris the GMH is the third most commonly strained muscle.

Point 2. Anatomy **(fig. 1 a, b)**

The triceps surae muscle, the most powerful muscle of the calf, includes the superficial gastrocnemius muscle (GM) and the deep soleus muscle (SM). The GM includes the GMH and the lateral head (GLH). The GMH is larger and descends more distally that the GLH. Both origin from a short proximal tendon that insert on the supracondylar area of the posterior distal femur metaphysis. The two heads converge distally into a deep broad flat aponeurosis (GMA) separated from the SM aponeurosis (SMA) by loose connective tissue (arrow). More distally the GM and SM aponeurosis fuse to form the Achille's tendon (AT). The plantaris muscle origins close to the GLH and continues in a long thin tendon running between the GMH and the SM.

The GM cross two joints, the knee and the ankle while the SM cross only the ankle joint.

The organization of the muscle fibers and fibroadipous septa of the GM (curved white arrows) is shown in **Fig.1b**

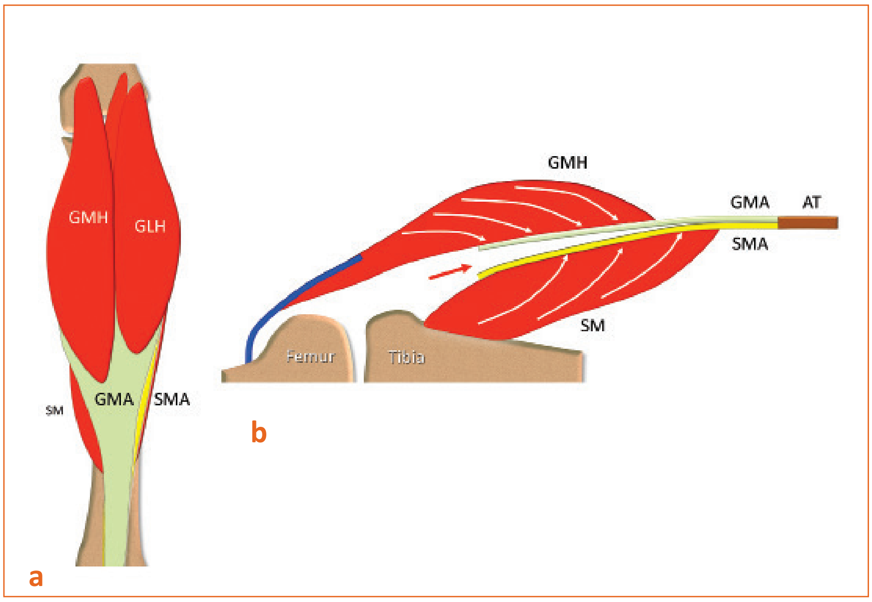

Figure 1:

Point 3. Physiology and physiopathology

The GM contributes as the main flexor of the foot, and it is also a flexor of the knee.

The GM type II muscle fibers are well suited for powerful rapid contractions such as in sprint or jumps.

TL occurs during powerful, explosive eccentric contractions of the GMH for instance while sprinting or jumping. Typically, it happens when a plantar flexed foot is suddenly forced into dorsiflexion while the knee is simultaneously extended.

Generally, TL affects the central or internal part of the myotendinous junction (MTJ) of the GMH.

Point 4. Clinical findings

The patient reports a sudden pulling pain (feeling as though someone has kicked the back of their leg) in the calf during a sprint and also eventually an audible « pop », possibly resulting in an immediate cessation of sports activity, depending on the size of the tear. When seen for US examination, patients present with a swollen calf, exquisite tenderness over the GMH, and pain on walking. The clinical findings are not specific. Differentials diagnosis include calf thrombophlebitis, a ruptured Baker's cyst, tears of the Achilles or plantaris tendon at the inferior third of the leg.

Point 5. US appearance normal anatomy **(Fig. 2)**

The examination is performed on a patient lying prone, with the knee flexed by a small pillow placed under the foot. This helps in decreasing the pain due to stretching of the GMH. US can easily show the normal anatomy of the muscle. Axial and longitudinal sonograms show the typical muscle structure made of normal regular hyperechoic lines (arrowheads) and hypoechoic bands, corresponding to fibroadipose septa and muscle fibers. On longitudinal images the distal part of the GMH has a pointed appearance. The fibroadipose septa insert on the GMA, seen as a hyperechoic line (curved arrows), well separated from the SMA, also visible as a hyperechoic line (black arrows) by a hypo anechoic stripe related to loosen connective tissue (white arrows).

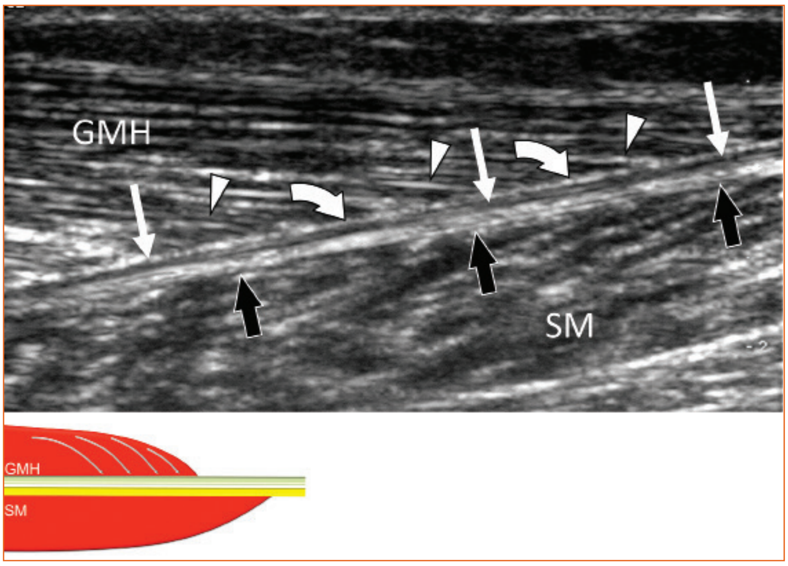

Figure 2:

Point 6.

US appearance pathologic changes

The US appearance of TL depends on the severity of the of the myotendinous junction tear.

As a rule, longitudinal sonograms are well suited to assess the proximal retraction of the muscle while axial images, in which the entire medial head is usually depicted in the same plane, are most useful for differentiating the partial lesions from complete lesions.

Acute tears

Small tears with no associated hematoma **(Fig. 3 a,b)**

The distal part of the medial third of the GMH is generally involved. US shows a focal irregular appearance of the muscle. The normal architecture is replaced by an ill-defined hypoechoic area (asterisks), corresponding to a small hemorrhagic infiltration. Accurate scanning reveals the retracted fibroadipose septa (arrowheads) that present a concave appearance. Usually in these patients the GMA (curved arrows) is not torn.

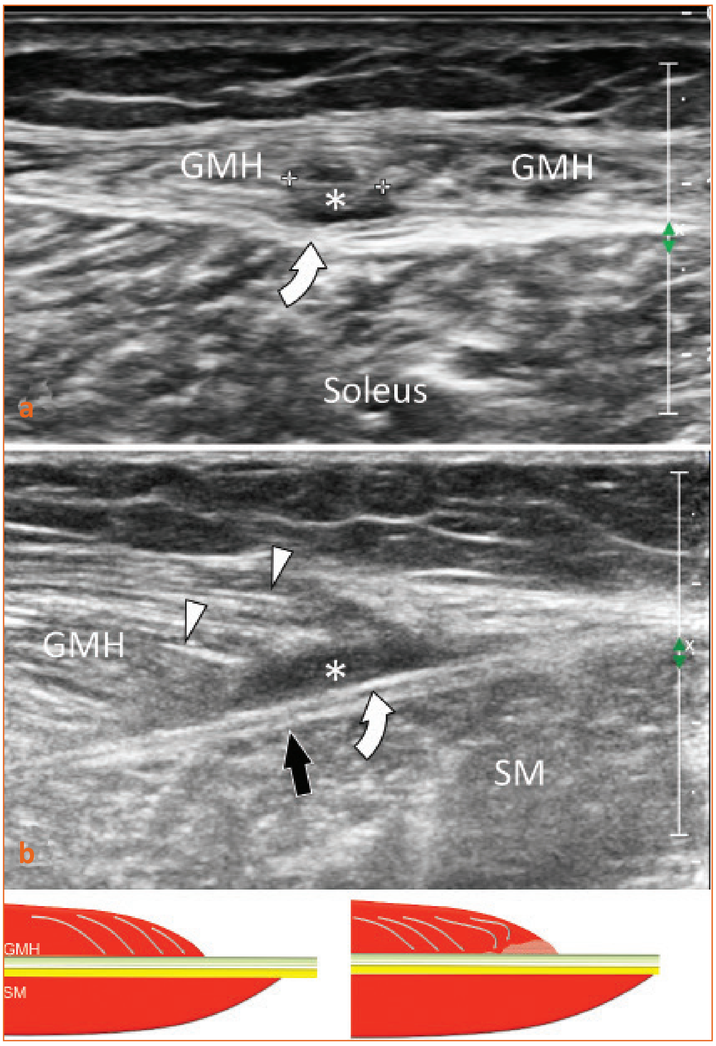

Figure 3:

Large tears with hematoma (Fig. 4)

In more severe trauma the wider tear can involve most of the GMH that shows variable proximal retraction. A hematoma (asterisk) is located distal to the muscle. In case of concomitant tear of the GMA the blood dissects and expands into the loose connective tissue located between the GMH and SM. The hematoma directs proximally and can measure up to 10-15 cm.

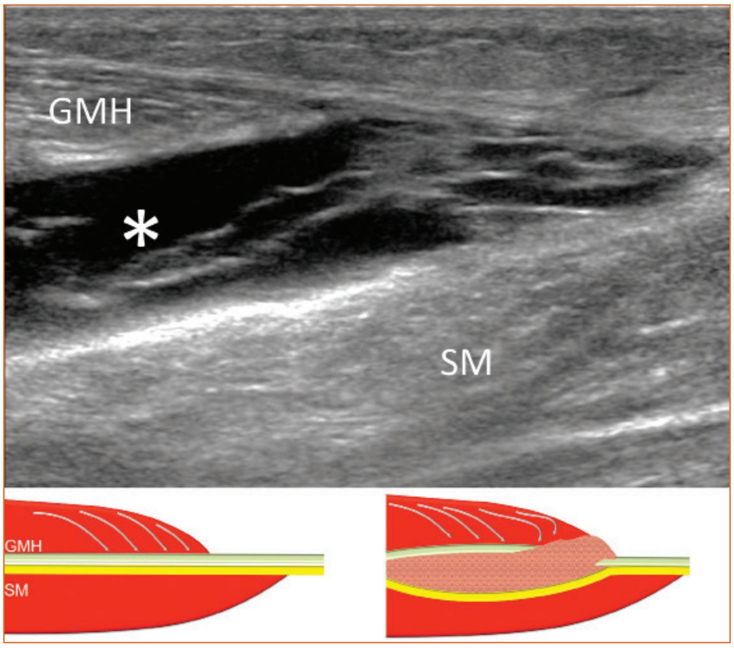

Figure 4:

Subacute tears (Fig. 5)

The intermuscular hematoma is slowly absorbed and then replaced by scar tissue. US shows the gradual formation of a peripheral hypoechoic halo (larger asterisks) and a slow volume decrease of the central hypo-/anechoic effusion (smaller asterisks). Hyper vascular changes can be detected in Doppler mode and relate to organization of the hematoma. Deep aponeurosis of the GMH (curved arrow), superficial aponeurosis of the SM (black arrows), GMH aponeurosis lesion (arrowheads).

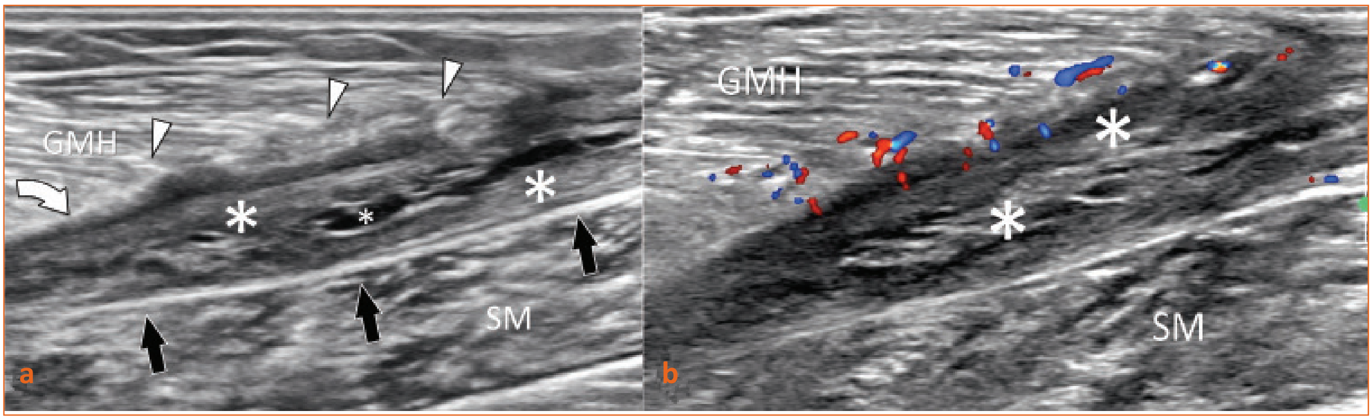

Figure 5:

Healed tears (Fig. 6)

healing US features are disappearance of the central fluid, replaced by a heterogenous hyperechoic content of the hematoma (asterisks). Absence of vascular local changes is the rule in healed tears.

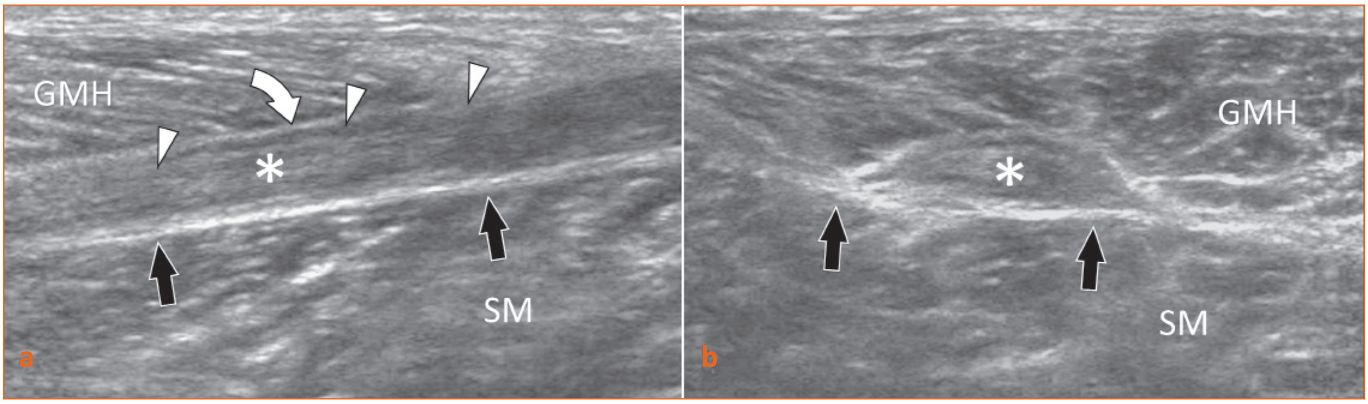

Figure 6:

Point 7. Differential diagnosis

Tears of the SM (Fig. 7 et 8)

Tears of the SM are less frequent compared to TL. They can affect the posterior aponeurosis of the muscle **(Fig. 7)**. In these patients, the hematoma (asterisk) is located deep to the SMA (arrows) that appears thickened. The fibroadipose septa of the SM (arrowheads) appear retracted. The GMA and GMH are normal.

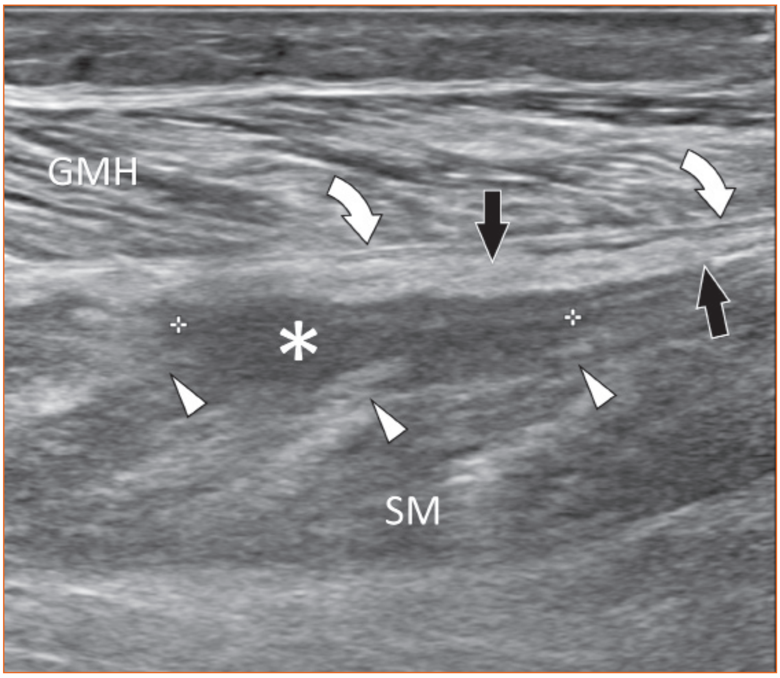

Figure 7:

When there is a tear of a small central aponeurosis located inside the muscle **(Fig. 8)**, the damaged muscle appears as an area of alterd muscle architecture (asterisk) surrounding the hyperechoic aponeurosis (arrowheads). In **(b)**, colour doppler shows a peripheral area of increased vascularity.

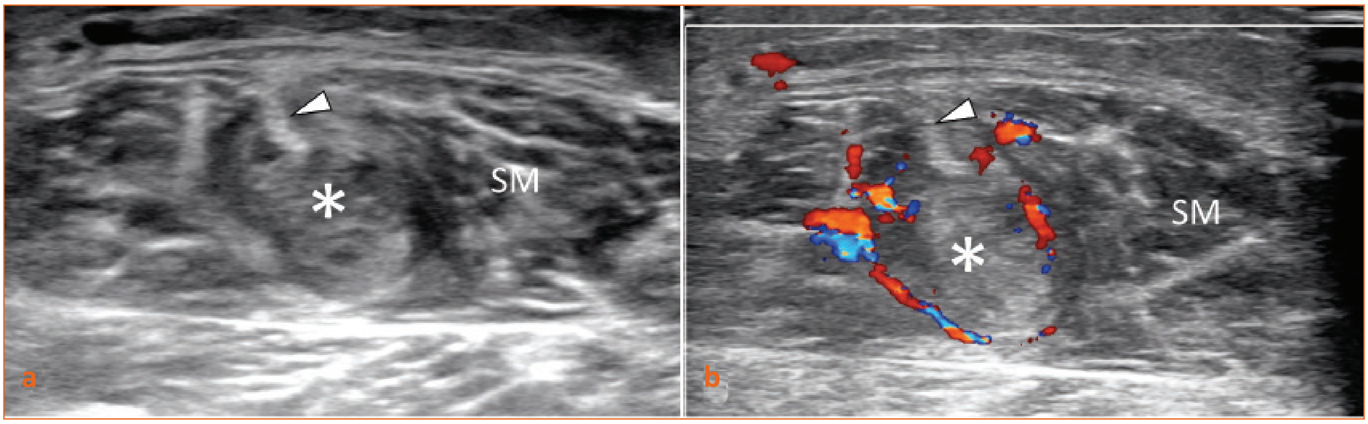

Figure 8:

Ruptured Baker's cyst (BC) (Fig. 9 a,b,c)

BC is a cystic mass of the semimembranosus-GMH synovial bursa. The bursa communicates with the knee joint in most patients. Intraarticular effusion can migrate posteriorly in the bursa particularly during weight bearing flexion. Due to a one-way mechanism, the amount inside the bursa can increase, leading to rupture of the « cyst » and subsequent fluid migration in the medial calf. The clinical features of a ruptured BC are very similar to thrombophlebitis and TL.

US easily demonstrates BC as a hypoechoic distension of the bursa (asterisks) that in case of rupture presents a pointed lower pole. Perifascial edema and fluid can be observed in the subcutaneous tissues just posterior to the GMH (asterisks in B and C).

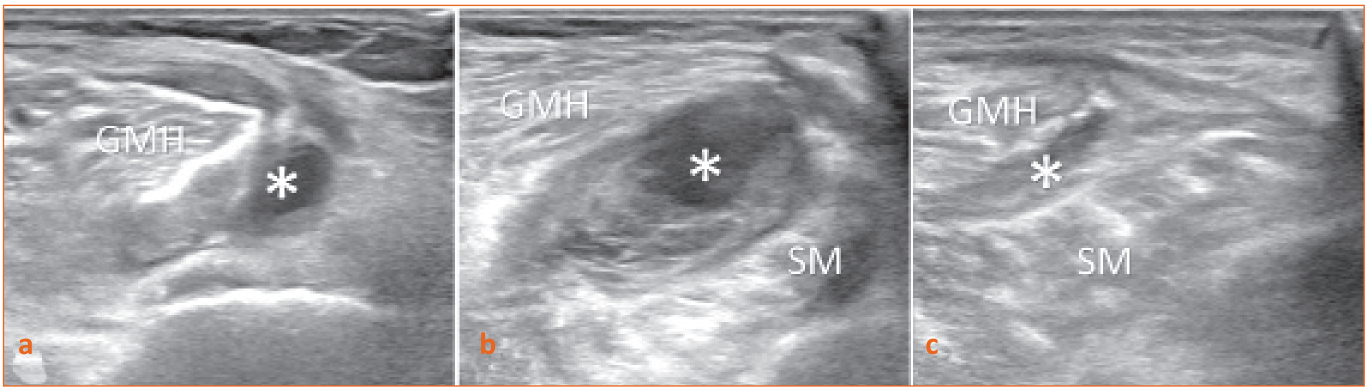

Figure 9:

Thrombophlebitis (Fig. 10)

US easily demonstrates an hyopoechoic thrombus (black arrowheds) filling the veins located within the GMH while the adjacent artery is normal (white arrowhead)

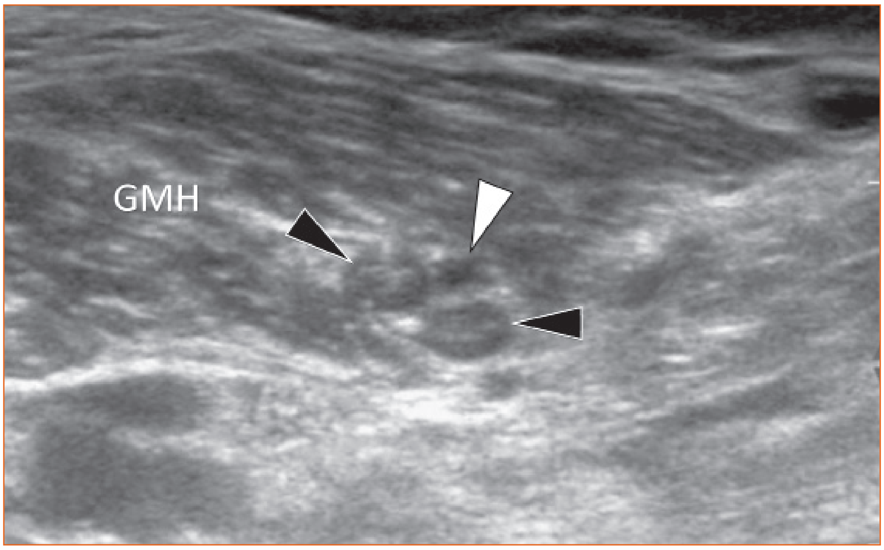

Figure 10:

Achilles tendon tear (Fig. 11)

Tears of the Achilles tendon are easily imaged by US. In complete tears the proximal (ATp) and distal (ATd) tendons stumps can be seen separated by an echoic hematoma (asterisk). Dynamic examination obtained during gentle plantar and dorsal flexion of the foot confirms the diagnosis in doubtful cases.

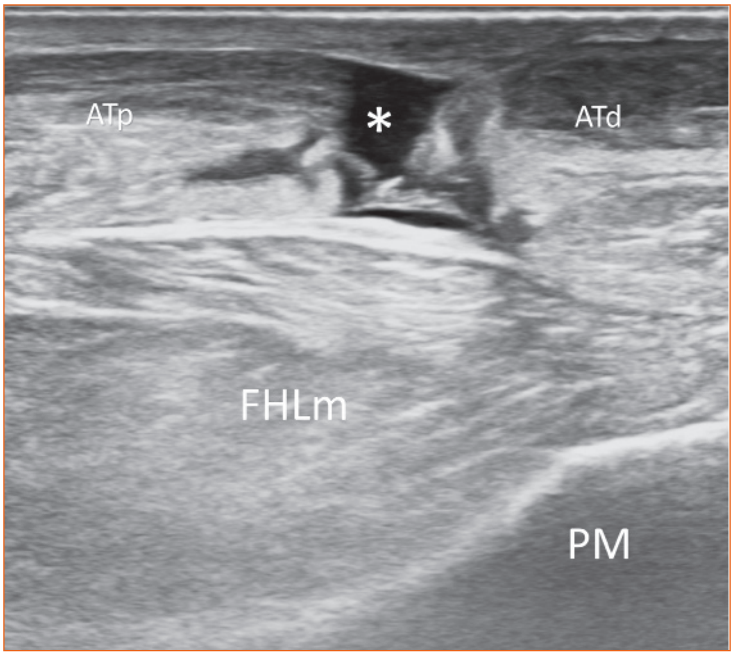

Figure 11:

Point 8. Treatment

- RICE
- Hematoma aspiration under US guidance.

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9 Calf injuries : the soleus, the forgotten muscle

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Injuries to the medial gastrocnemius (MG) are more common and more noticeable clinically that those to the soleus, which are more difficult to recognize and usually more discreet. Why?

1. A complex anatomy

The soleus is the deep component of the triceps surae, lying underneath the gastrocnemius in the upper portion of the calf before coursing superficially in the lower. It is a uniarticular antigravity muscle composed of fan-shaped connective tissue and type I slow-twitch muscle fibers. It is independent of knee flexion and originates on the fibula and tibia via two narrow tendons which descend to form two anterior intramuscular aponeuroses in the belly of the muscle. The muscle fibers have a bipennate structure.

In the lower portion, a sagittally oriented tendon can be distinguished which reinforces the posterior aponeurosis. The aponeuroses of the soleus and gastrocnemius join to form the Achilles tendon, which then rotates anticlockwise as it descends.

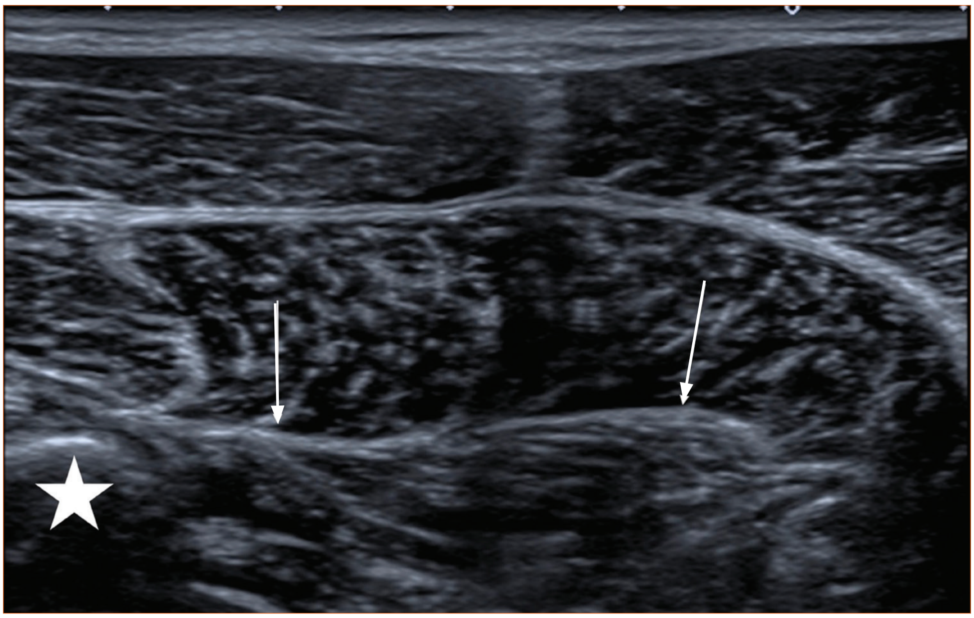

Figure 1: *Transverse ultrasonography (US) of a left calf. Anterior intramuscular aponeurosis of the soleus (white arrows) and the fibula (*) underneath the two heads of the gastrocnemius.*

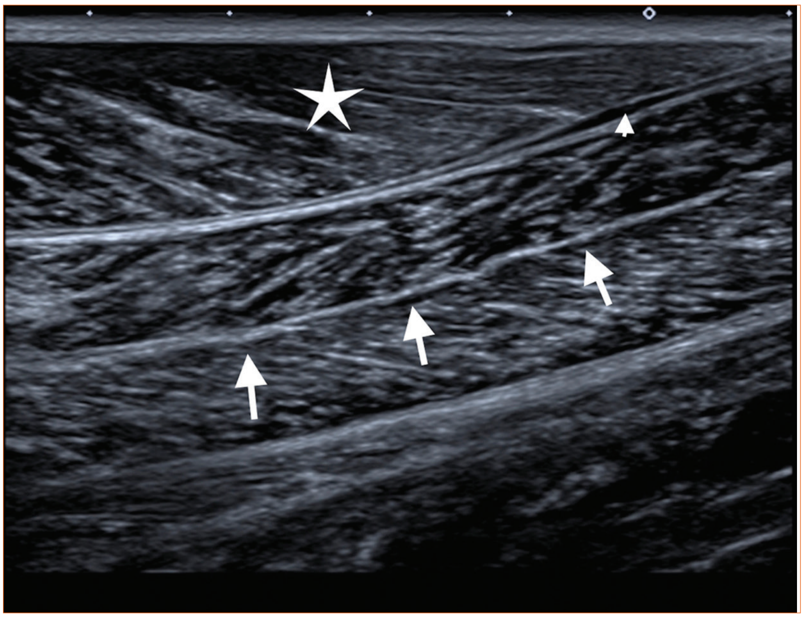

Figure 2: *Sagittal US of the calf showing the anterior aponeurosis of the soleus underneath the MG (*). Note the discreet hypoechoic scarring in the lower portion of the gastrocnemius (arrowhead).*

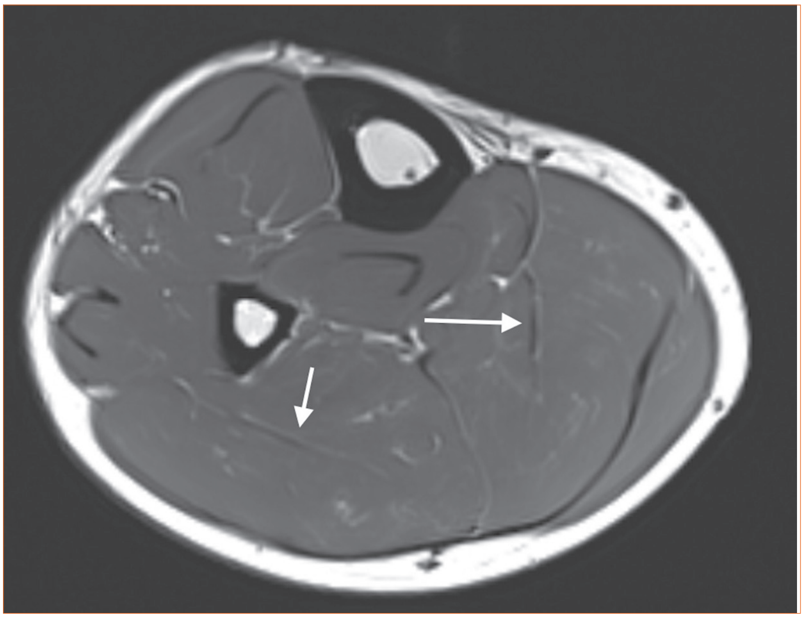

Figure 3: *T1-weighted axial MRI of a right calf. Anterior medial and lateral intramuscular aponeuroses appear as a thin low signal (arrows).*

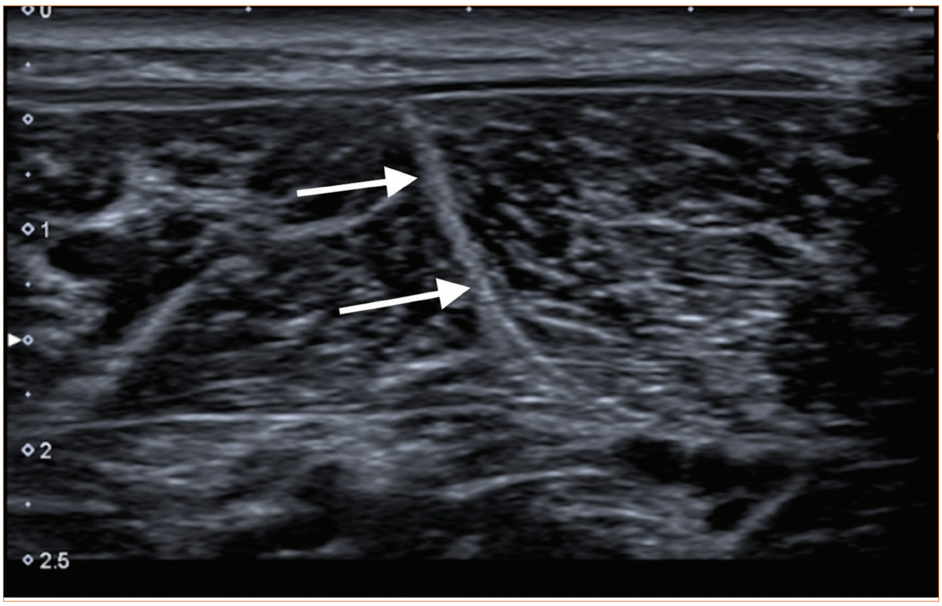

Figure 4: *Axial US of a left calf. Sagittal tendon of the soleus (arrows).*

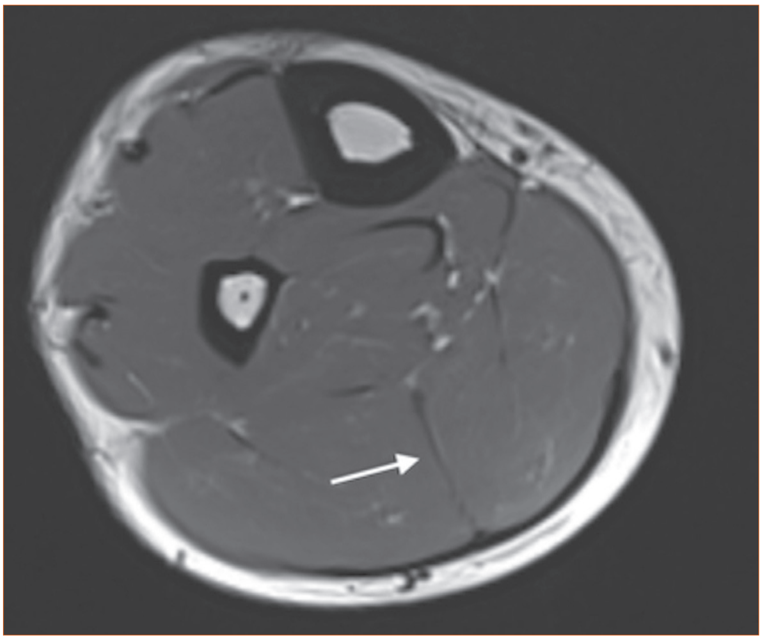

Figure 5: *T1-weighted axial MRI of the lower third of a right calf. Sagittal tendon (arrow).*

2. A misleading clinical presentation

Upper soleus injuries mainly affect runners such as joggers, long-distance runners and triathletes. This type of injury occurs when running at a moderate pace (slow-twitch fibers). The pain gradually appears in the medial or lateral calf. Functional impairment is less severe than with the MG, so the athlete can sometimes finish their session at a slower pace. The resolution of clinical symptoms often takes little time in daily life, leading to the mistaken belief that muscle soreness was all it was.

Conversely, injuries to the lower portion of the muscle or to the musculotendinous junction result in more pronounced functional impairment similar to the MG.

3. Multiple aponeurotic locations

Unlike MG injuries, which usually occur in the distal musculotendinous junction, soleus injuries can occur in several different aponeuroses, such as in the:

- anterior intramuscular aponeuroses, deep anterior aponeurosis or posterior aponeurosis, which is continuous with the MG aponeurosis in the upper calf.
- or in the more superficial inferior portion of the soleus, i.e. in the inferior sagittal tendon, posterior aponeurosis or distal musculotendinous junction with the Achilles tendon.

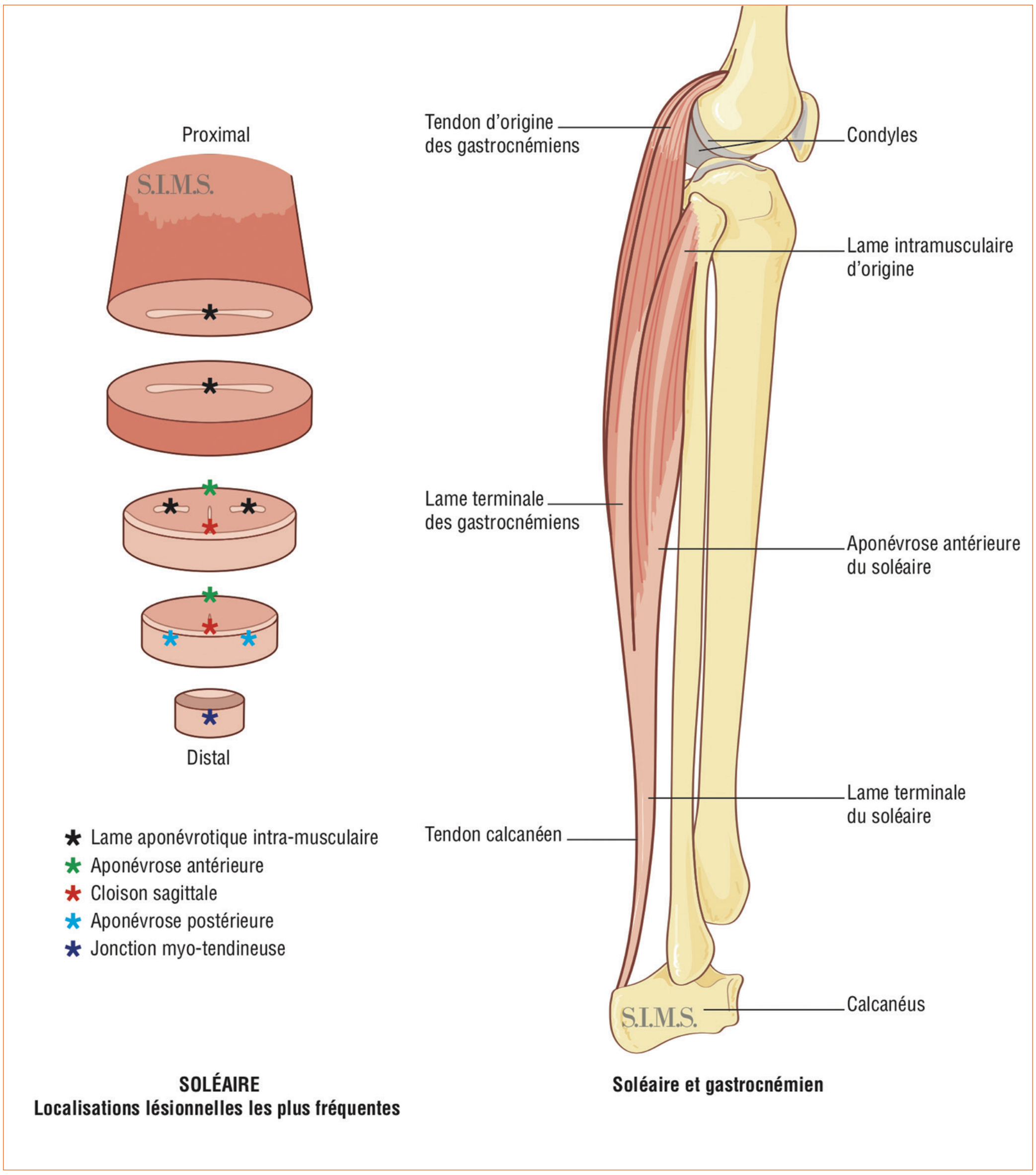

Figure 6: *Diagram of triceps surae and typical sites of traumatic injury to the soleus.Carole Fumat based on G. Morvan: «Imagerie normale et pathologique du système suro-achilléo-plantaire propulseur du pied.» J Radiol 2007;88:143-55.*

4. Pathology on imaging: appearance on ultrasonography

Traumatic injuries can occur in any of the soleus aponeuroses. Distal locations in the sagittal tendon or posterior aponeurosis are fairly easy to identify because of their superficial position. Typical findings include discontinuity of the tendon and a hyperechoic halo in contiguous muscle fibers, or aponeurotic thickening and hyperemia on color Doppler.

Deep injuries to the anterior aponeurosis are typically more hypoechoic. Tendon injuries are more difficult to demonstrate. They can appear as discreet aponeurotic disruptions accompanied by local hyperemia. Comparative analysis muscle during contraction and relaxation is required.

Diagnosis is straightforward on magnetic resonance imaging (MRI) with comparative T2-weighted fat-saturated (T2FS) sequences.

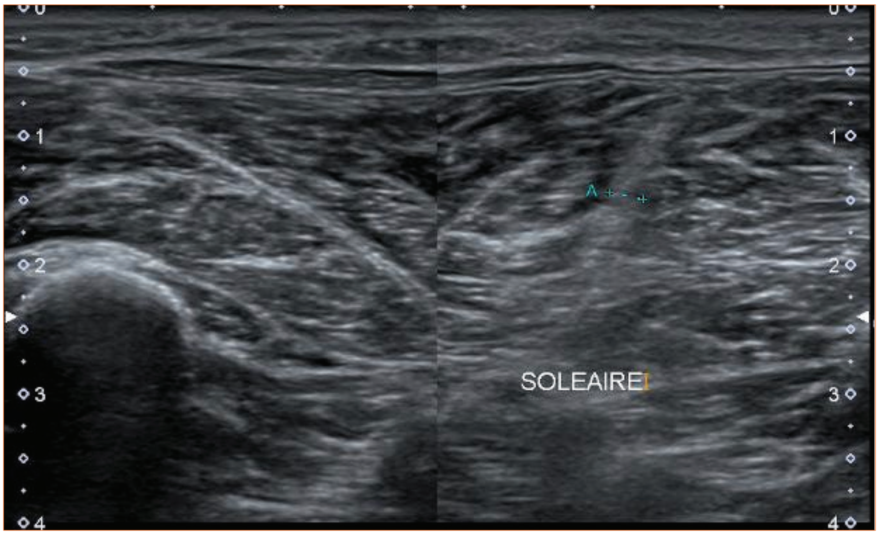

Figure 7: *Axial US. Injury to sagittal soleus tendon with a hazy appearance of the right calf compared to the healthy contralateral side (running injury).*

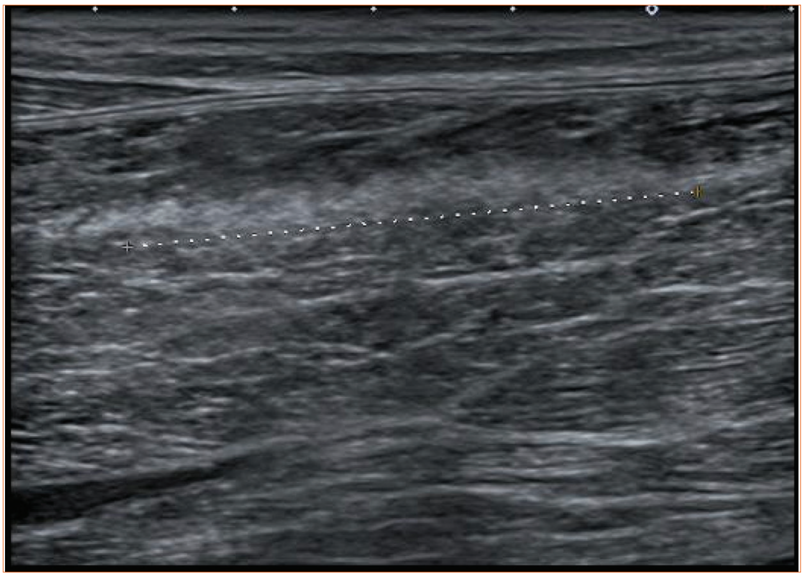

Figure 8: *Longitudinal view of the soleus in the same patient as Figure 7. Aponeurotic injury measures 4cm.*

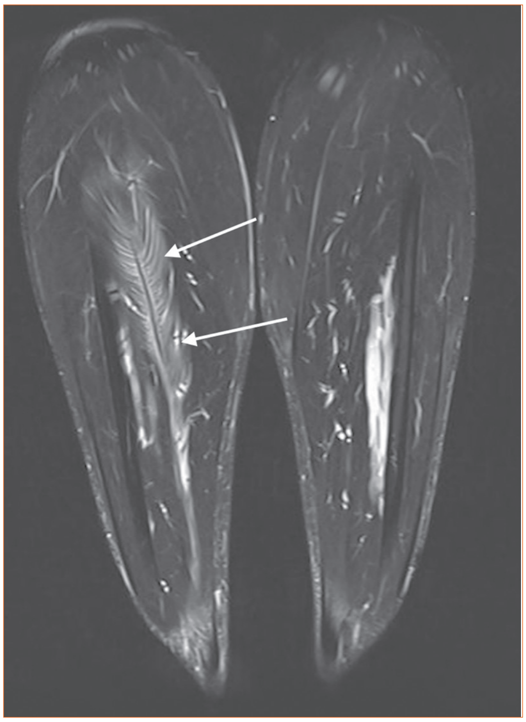

Figure 9: *Coronal short tau inversion recovery MRI of both calves. Injury to the sagittal tendon of the right soleus in a triathlete (arrow). Note the especially long length of this tendon, which reaches down to the upper third of the calf.*

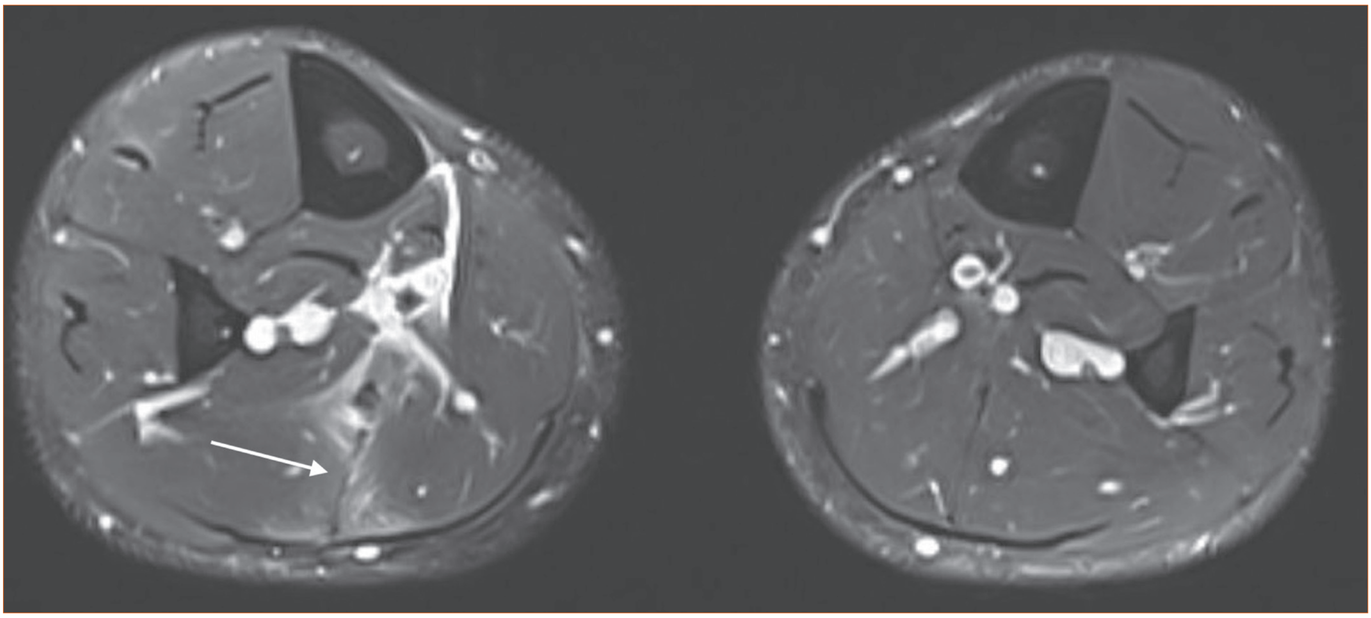

Figure 10: *T2FS axial MRI of the right half of the patient from Figure 9. Peripheral high signal and discontinuity of sagittal tendon.*

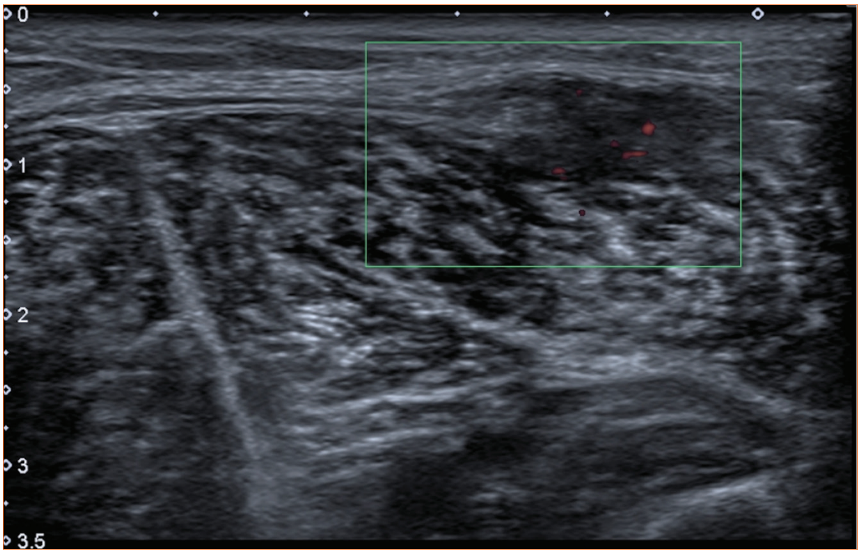

Figure 11: *Transverse US of the lower third of the calf. Rupture of the superficial (posterior) aponeurosis in a tennis player.*

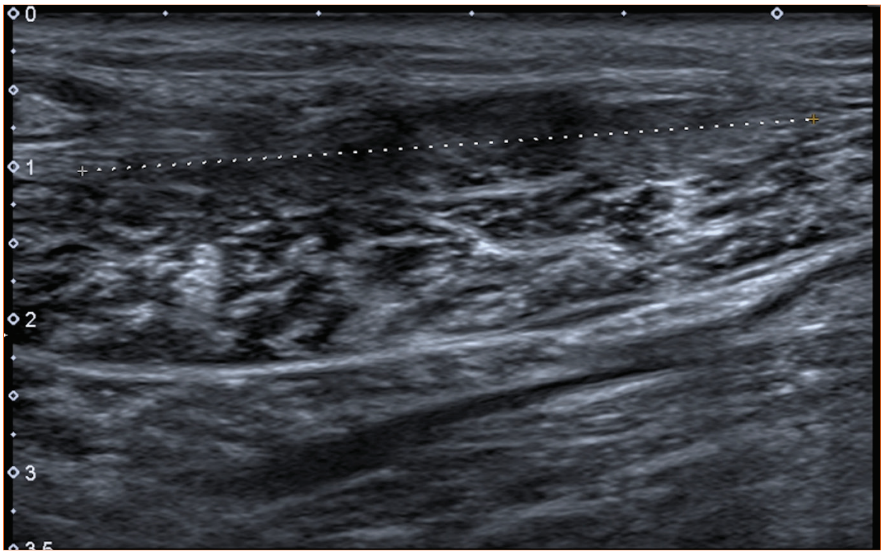

Figure 12: *Longitudinal US of the same patient. Full extent of injury*

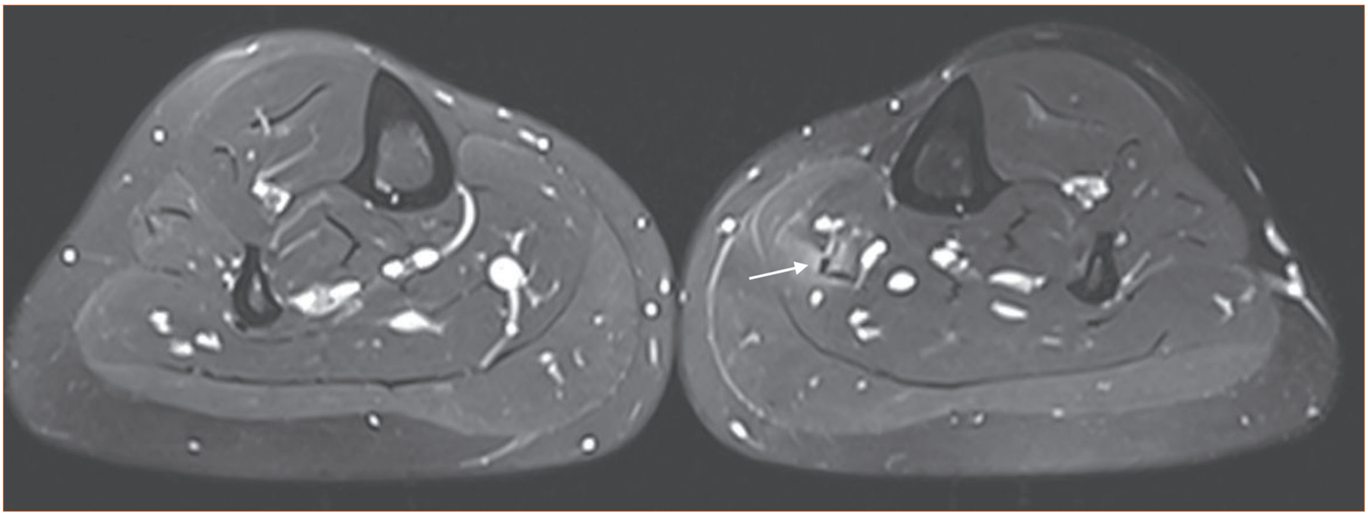

Figure 13: *Comparative T2FS axial MRI of both calves of a jogger. Injury to the medial intramuscular aponeurosis of the left soleus. This type of intramuscular site is harder to identify on US.*

5. An occasionally complicated course

One characteristic of soleus injuries is several weeks or months of functional impairment while running. This happens by returning to sport too early. These aponeurotic injuries require a break from running of 4 to 6 weeks, although cycling and swimming can usually be continued. Repeated injury to the soleus and/or Achilles tendon may eventually lead to atrophy and fatty infiltration of the soleus.

Unlike MG injuries, soleus injuries are rarely accompanied by hematoma but they can cause thrombophlebitis in muscle or leg veins.

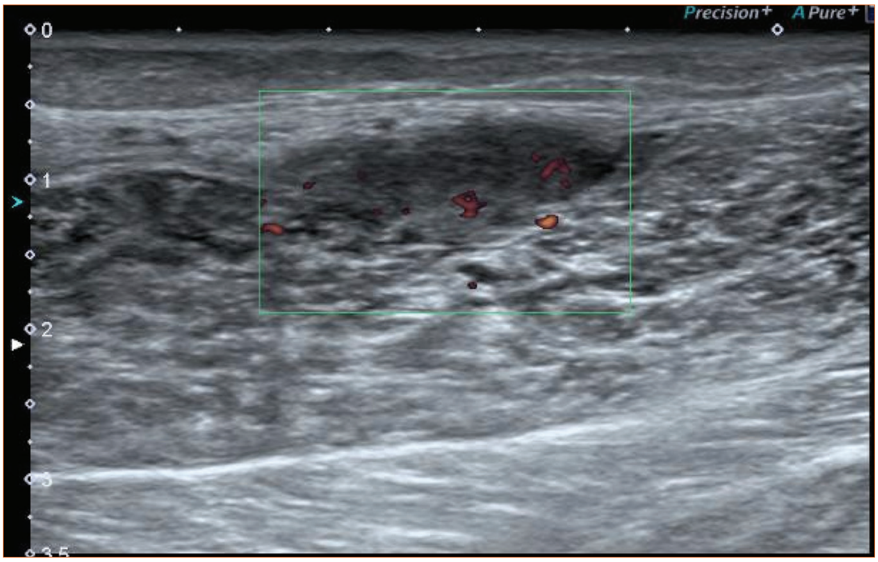

Figure 14: *Hypoechoic scarring of the superficial aponeurosis 2 months after initial trauma. Continuing pain during slow running and hyperemia on color Doppler at the site of scarring.*

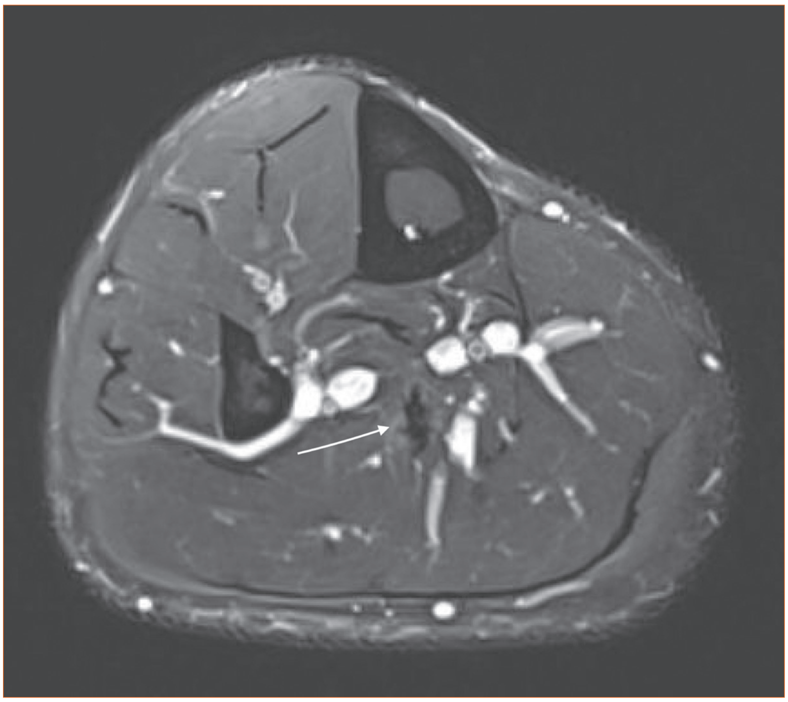

Figure 15: *Check-up 3 months later of the patient from figures 9 and 10. Persistent high signal in the sagittal tendon which has a thickened appearance (white arrow). Clinically, stiffness in the calf and impaired running.*

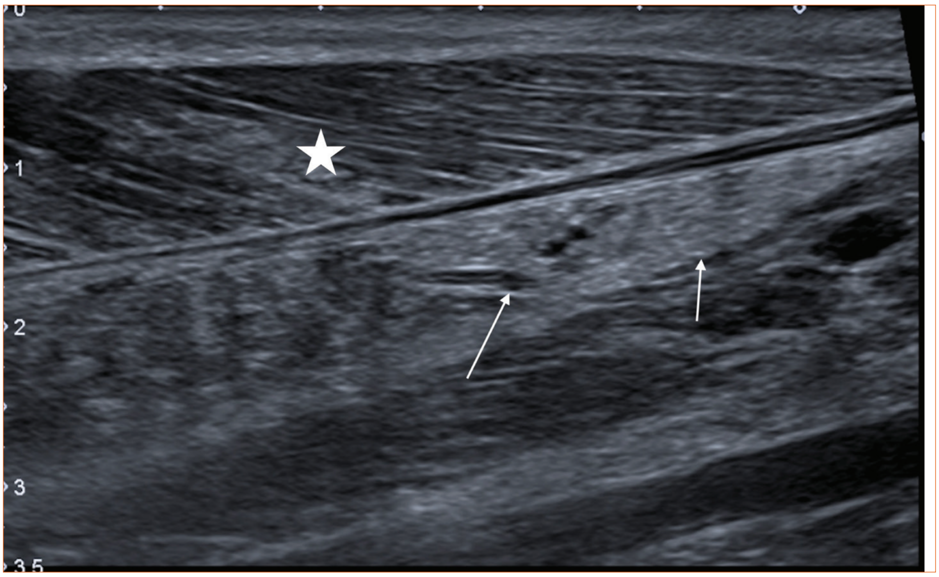

Figure 16: *Sagittal US of the calf. Hyperechoic fatty degeneration of the entire lower portion of the soleus (arrows) after multiple muscle and Achilles tendon injuries in a marathon runner. This is in contrast to the intact architecture of the MG (*).*

6. Differential diagnoses

Injuries to the MG are the most frequent calf injury. There is also the very rare case of injuries to the plantaris, the tendon of which lies between the soleus and MG.

Stress fractures may also occur in the posterior cortex of the tibia (or more rarely of the fibula) in this same population of sportspeople.

Extrinsic injuries caused by direct blows to the soleus are rare.

Thrombophlebitis can occur as a complication of a traumatic muscle injury and must always be checked for.

Ruptured popliteal cysts cause more diagnostic problems with MG injuries.

Exceptions: the distal soleus musculotendinous junction and accessory soleus muscles can sometimes be symptomatic in sportspeople.

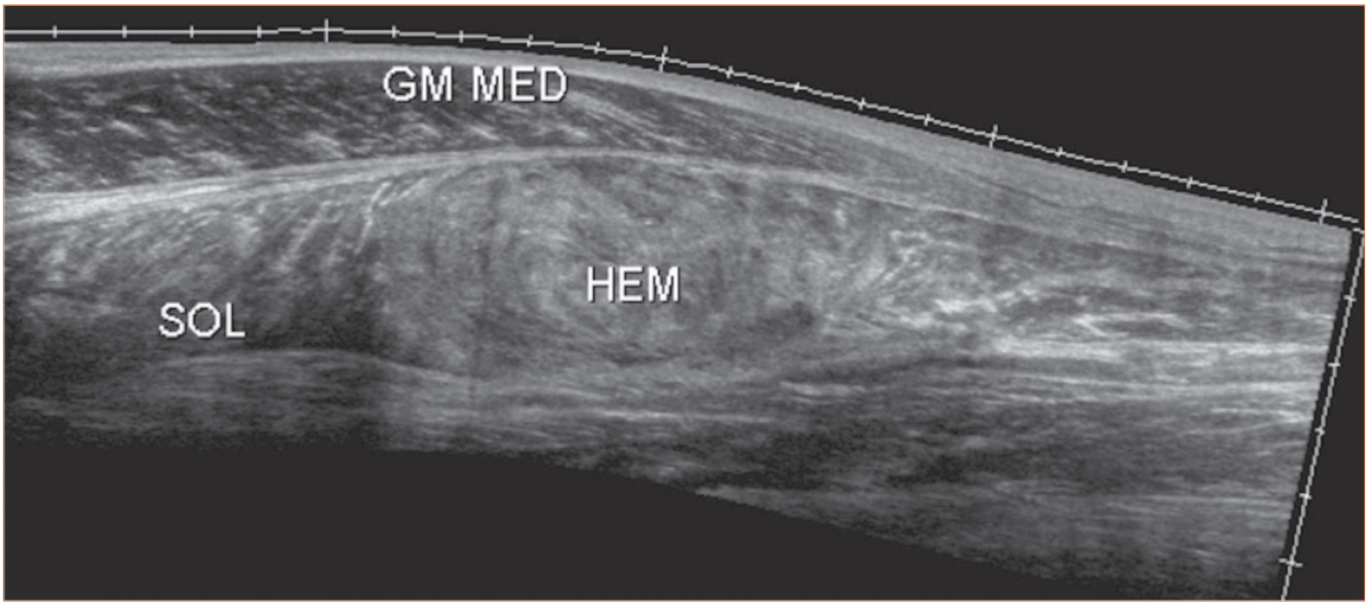

Figure 17: *Hyperechoic hematoma of the soleus after a direct blow to the calf (extrinsic injury).*

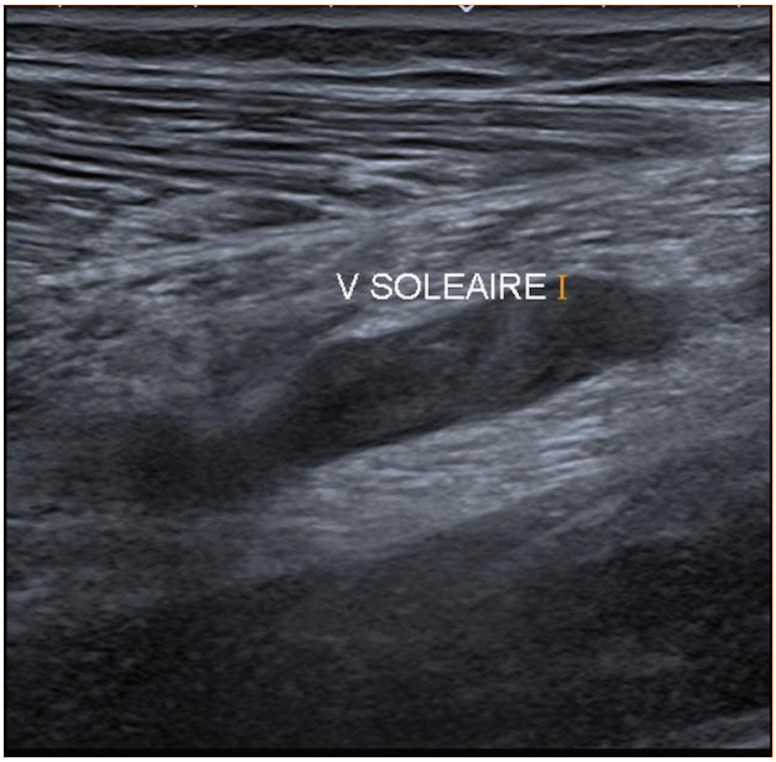

Figure 18: *Thrombosis of a soleal vein on US. This is usually concomitant to a calf muscle or Achilles tendon injury.*

Figure 19: *Accessory soleus muscle filling the Kager fat pad (arrow).*

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10 Unusual traumatic muscle lesions of the shoulder girdle

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1. Myotendinous tears in the rotator cuff

The classic appearance of rotator cuff tears is generally well known. Unusual tears, which are more difficult to diagnose, particularly on ultrasound, are represented by myotendinous tears, which by decreasing order of frequency affect the infraspinatus, supraspinatus, subscapularis and teres minor muscles [1].

Myotendinous tears are explained by the multifasciculated nature and the organization of the fibrous skeleton within the muscles of the rotator cuff. This organization has been recalled by several recent anatomical works, including those of Paul Michelin [2]:

- The supraspinatus consists of an anterior portion occupying ¾ of the supraspinous fossa with a bipennate muscular body joining a rounded central tendon and a smaller muscular posterior portion **(Fig. 1)**.
- The infraspinatus has a large central tendon, the anterior part of which overlaps the posterior portion of the supraspinatus before being inserted on the major tuberosity.
- The upper 2/3 of the subscapularis also include several tendon strips inserting on the lesser tuberosity, which are well identified in imaging. The lower third of the subscapularis inserts directly with muscle fibers on the proximal humeral diaphysis.

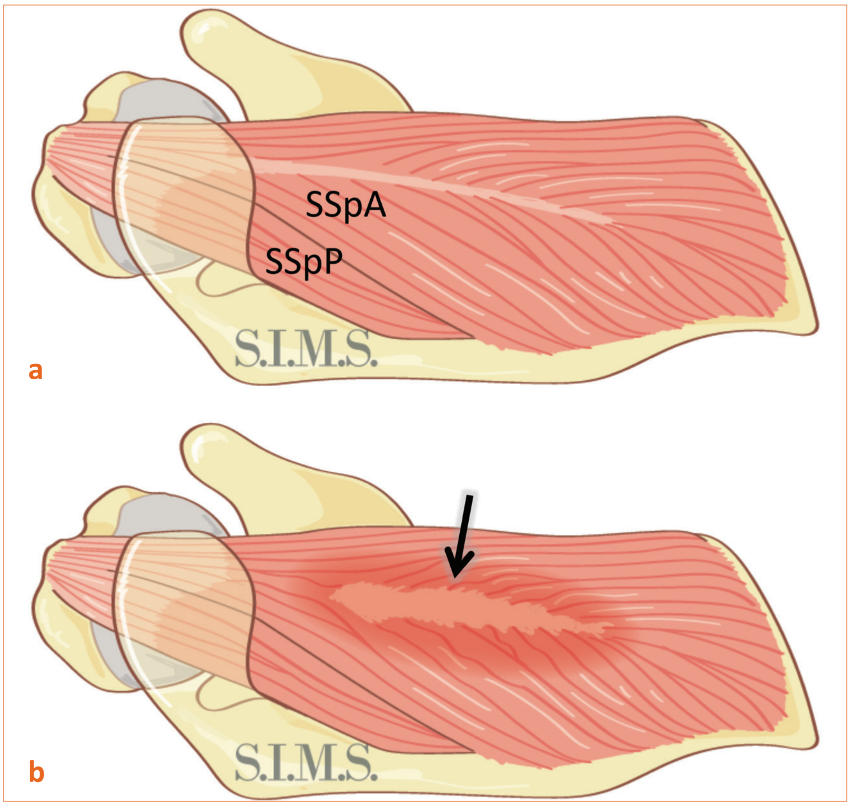

Figure 1: *Representation of the supraspinatus muscle and its fibrous frame.* **a:** *The supraspinatus encompasses an anterior head (SSpA), with bipennate muscle fibers converging towards a round central tendon, and a posterior head (SSpA), smaller with muscle fibers ending on a flat tendon.* **b:** *myotendinous tears of the supraspinatus (arrow) occur around the central tendon of the anterior muscle head.*

Myotendinous lesions of the rotator cuff are classified by increasing degree of severity in elongation (grade 1), partial tear (grade 2), and complete tear (grade 3) **(Fig. 2-4)**.

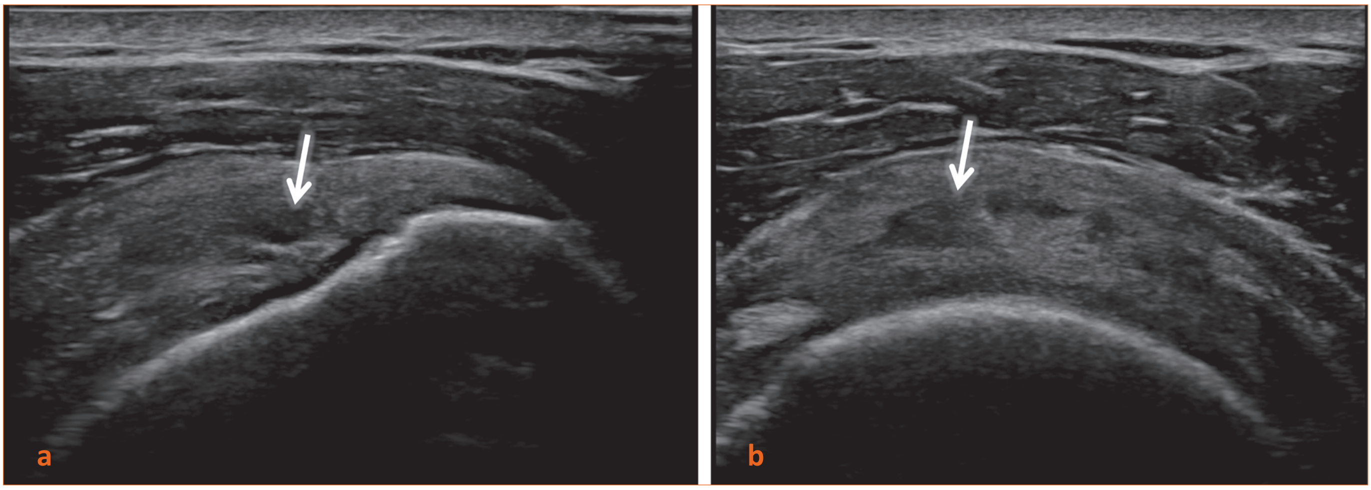

Figure 2: *50-year-old man with a tear of the central tendon of the left supraspinatus muscle. Longitudinal* **(a)** *and transverse* **(b)** *sonographic images demonstrate the interstitial defect (arrows) due to the retracted tear of the central supraspinatus tendon.*

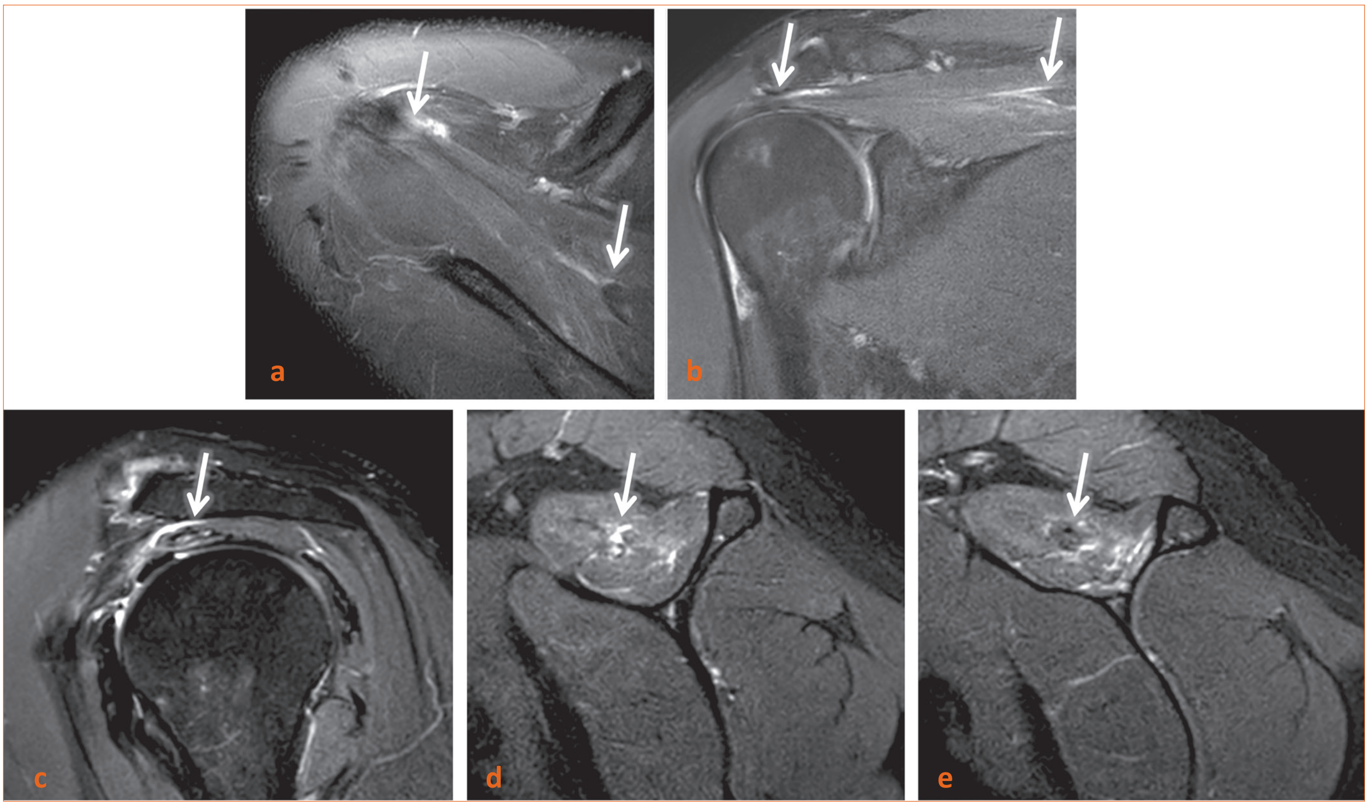

Figure 3: *54-year-old man with a tear of the central tendon of the left supraspinatus muscle. Fat saturated T2-weighted MRI images in transverse* **(a)**, *coronal* **(b)** *and sagittal* **(c-e)** *planes demonstrate the retracted tear of the central supraspinatus tendon (arrows).*

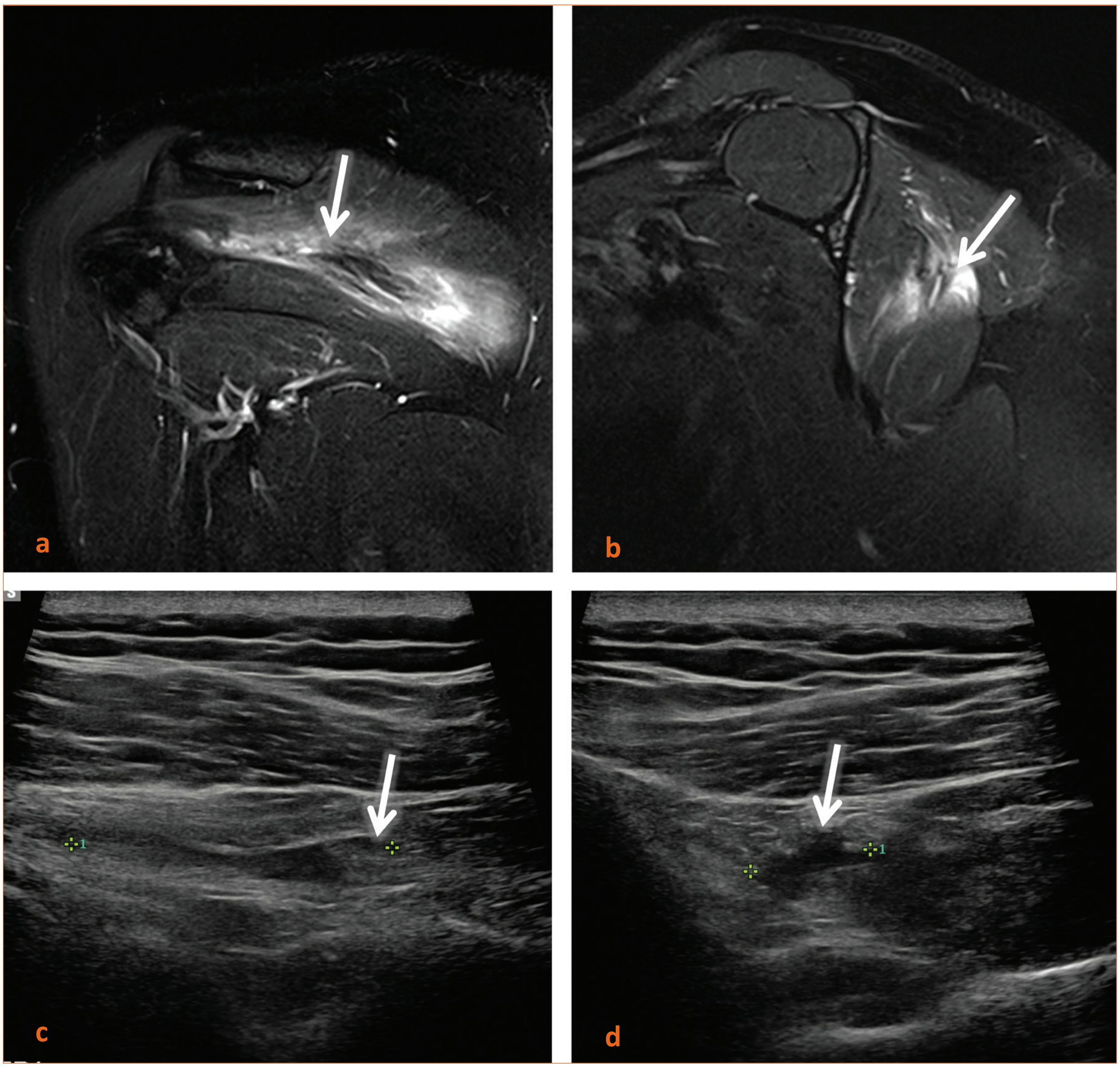

Figure 4: *28-year-old woman with a myotendinous tear of the infraspinatus. Fat saturated T2-weighted MRI images in coronal* **(a)** *and sagittal* **(b)** *planes demonstrate the retracted tear of the infraspinatus tendon (arrows) with surrounding edema. Companion case with sonography in longitudinal view* **(c)** *showing the tadpole sign corresponding to the retracted tendon (arrow) and transverse view* **(d)** *showing the blackeye sign (arrow) corresponding to the defect left by the retracted tendon.*

Myotendinous tears in the infraspinatus were initially reported with MRI in 2006 by Thierry Tavernier [3]. Henri Guerini subsequently showed their low prevalence in a large ultrasound series (15/2403 = 0.62%) and illustrated their semiology with the description of the tadpole sign (longitudinal section) and the black eye sign (cross section) [4].

A recent study by the Montreal team also showed the low prevalence of myotendinous lesions of the supraspinatus in a series of MRIs (4/843 = 0.47%) [5].

2. Deltoid tears

Deltoid tears are rare and poorly understood and can occur in two main pathological settings:

- Massive rotator cuff tears: the upper migration of the humeral head comes against the acromion promotes detachment of the deltoid; the abnormal contact of the greater tuberosity with the underside of deltoid causes muscle erosions and myotendinous tear **(Fig. 5, 6)**.

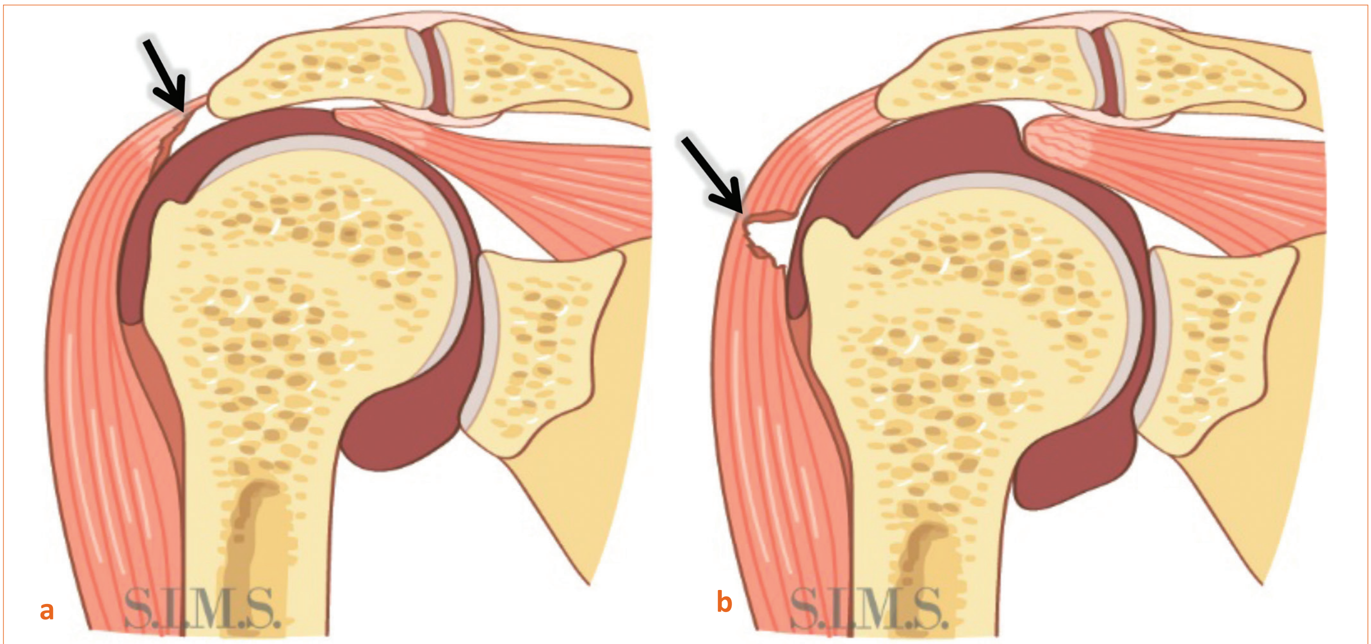

Figure 5: *Representation of deltoid injuries associated with full-thickness rotator cuff tears. Pathological mechanisms involve proximal migration of the humeral head against the acromial edge causing proximal detachment of the deltoid* **(a)** *or an abnormal contact between an irregular greater tuberosity and the undersurface of the deltoid* **(b)**.

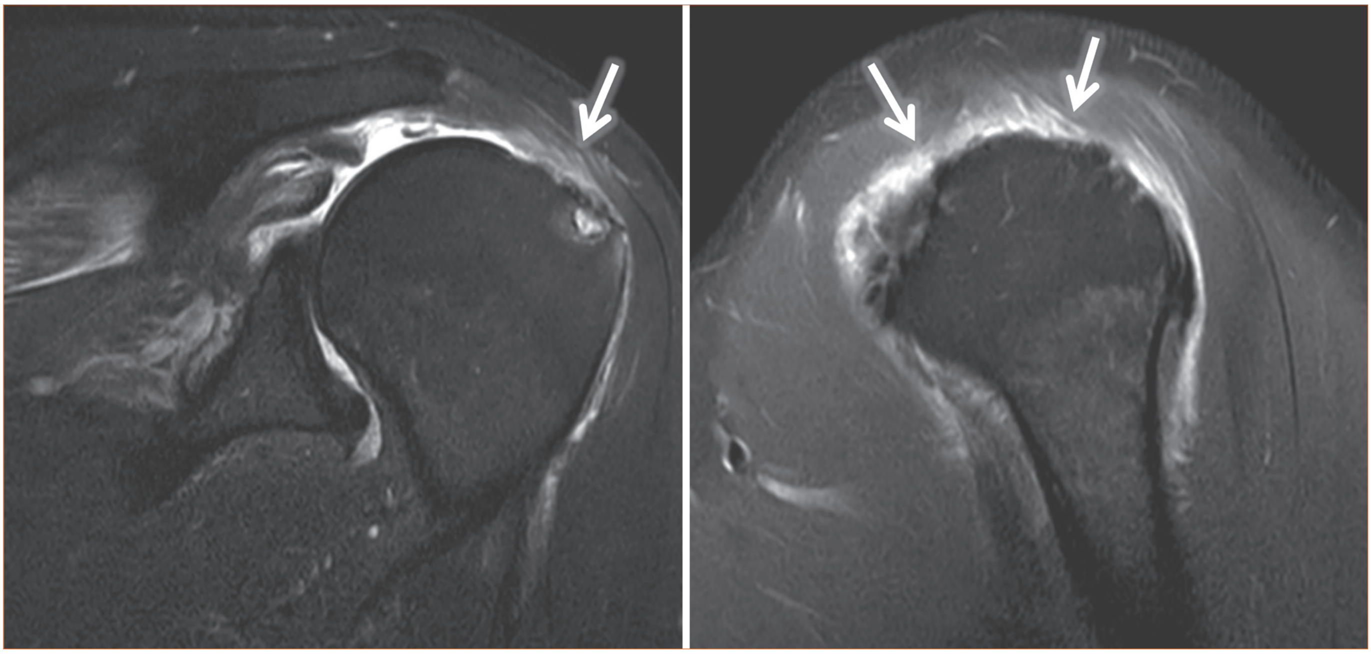

Figure 6: *77-year-old man with a partial deltoid tear secondary to a full-thickness cuff tear. Fat saturated T2-weighted MRI images in coronal (A) and sagittal (B) planes demonstrate tearing of the deltoid undersurface (arrows) in contact to the irregular greater tuberosity.*

- Isolated traumatic tear: exceptional **(Fig. 7)**

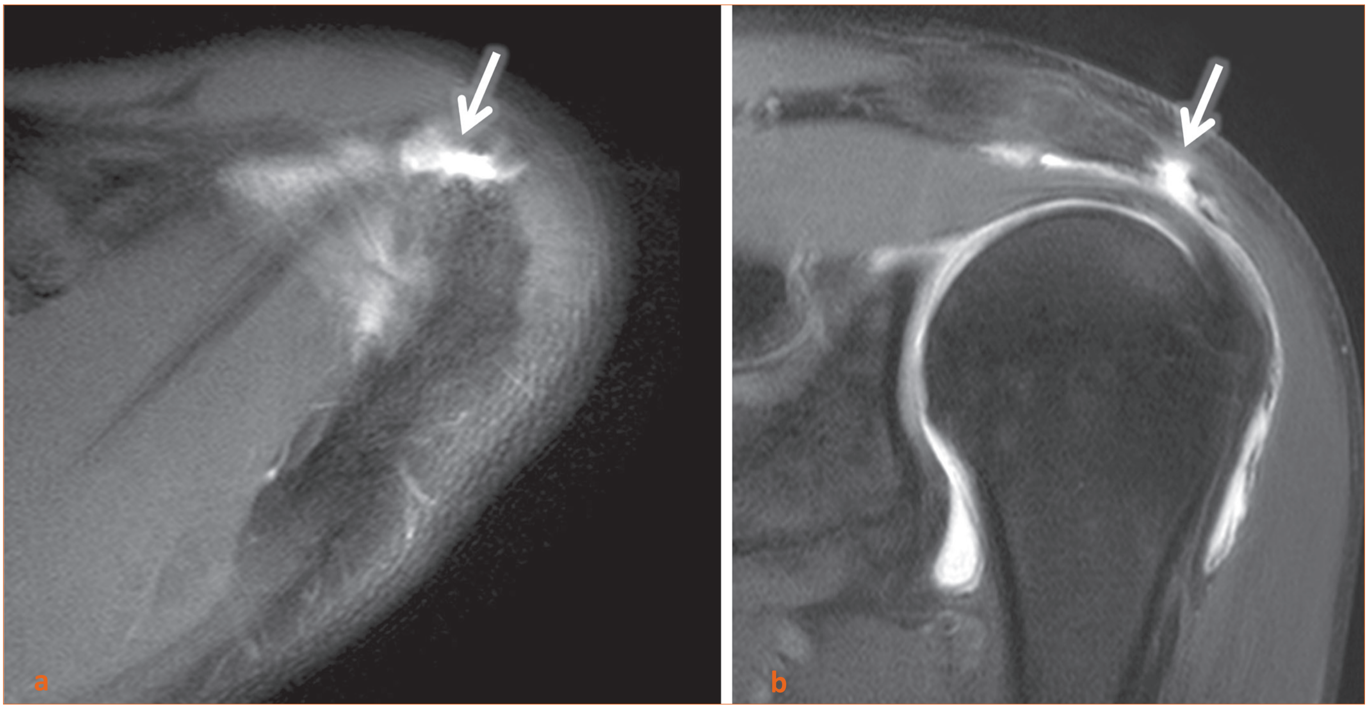

Figure 7: *34-year-old man with a traumatic proximal detachment of the deltoid. Fat saturated T1-weighted MR arthrography images in transverse* **(a)** *and coronal* **(b)** *planes demonstrate the opacification of the tear (arrows). Presence of contrast in the subacromiodeltoid bursa was due to a full-thickness subscapularis tear that is not illustrated.*

The prevalence of deltoid tears on MRI of painful shoulder exams ranges from 0.3% to 9.2%. They can be classified into low grade partial-thickness tears, high grade partial-thickness tears and full-thickness tears by increasing order of severity and decreasing order of frequency [6].

They mainly involve the middle portion of the deltoid which attaches on the acromion.

Stefano Bianchi reported the interest of dynamic ultrasound using the Leclerc maneuver (resisted abduction of the arm) for the diagnosis of these tears [7].

3. Tears of the pectoralis major

Tears of the pectoralis major are certainly the least rare of these unusual muscular lesions of the shoulder girdle and have been increasing in the recent years. They are most often associated with the practice of bodybuilding (bench press in particular).

The pectoralis major encompasses a clavicular head and a sternal head. The sternal head, which represents 80% of the muscle volume, is most frequently injured. The muscle fibers converge towards a U-shaped tendon formed, the surface layer of which consists of the clavicular and upper sternal fibers and the deep layer of the lower sternal and abdominal fibers. This tendon is inserted on the lateral lip of the intertubercular groove (bicipital groove) [8].

10 Unusual traumatic muscle lesions of the shoulder girdle

There are several types of traumatic injury [9] **(Fig. 8)**:

- Muscle tears: located at the origin or in the center of the muscles, they are rare and non-surgical
- Myotendinous tear
- Tendon tear **(Fig. 9)**: it can be partial and limited to the deep layer of the tendon (the fusion of the two tendon layers is observed at the level of the medial lip of the intertubercular groove)
- Distal tendon avulsion, with occasionally avulsion of a bone fragment

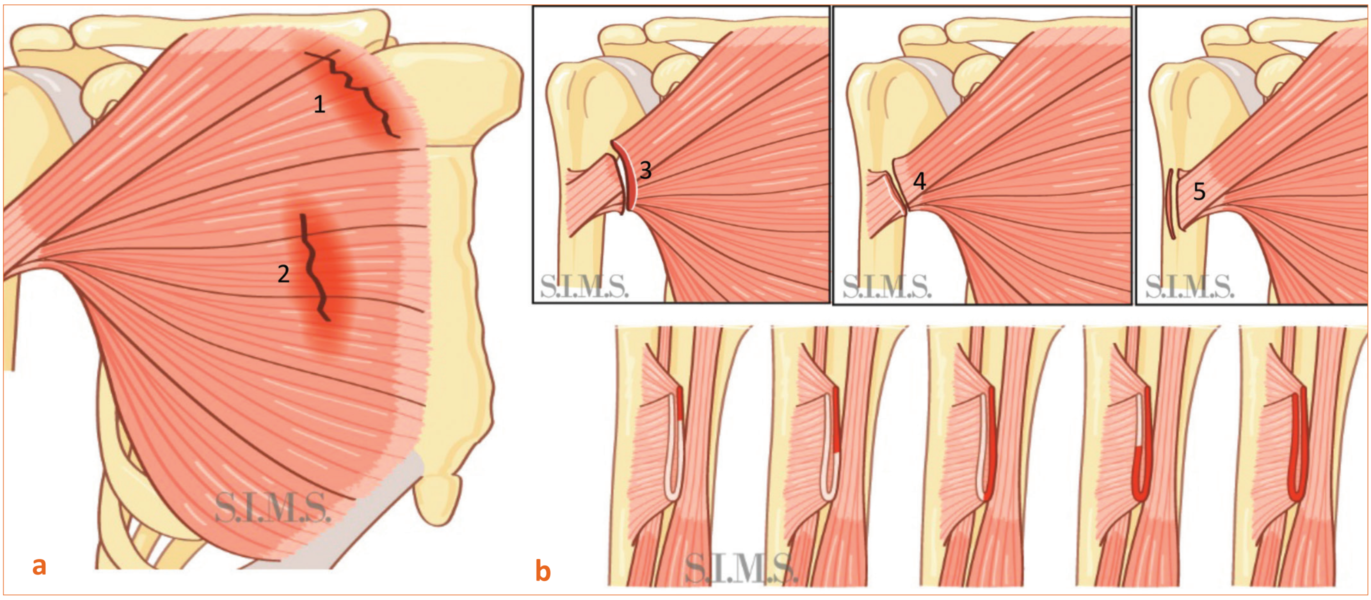

Figure 8: *Representation of different types of pectoralis major tears.* **a:** *Location can be the muscle attachment (1), within muscle body (2), the myotendinous junction (3), the tendon (4), the enthesis (tendon or occasionally bone avulsion, 5).* **b:** *Tears of the U-shaped tendon can be complete or partial (with preferential involvement of the deep fibers originating from the sternal head).*

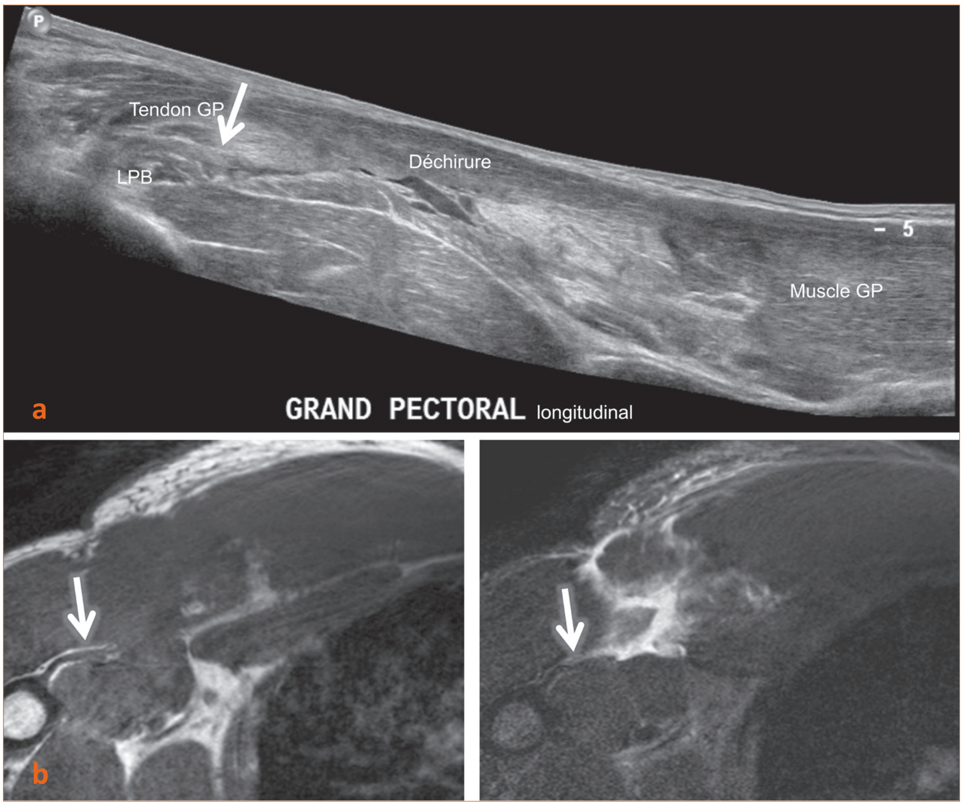

Figure 9: *Pectoralis major tears at bench press in a 37-year-old man and a 25-year-old man.* **a:** *transverse extended field of view sonographic image in the first patient demonstrating the complete tedon tear (arrow) and the retracted muscle.* **b:** *transverse T1 and fat saturated T2-weighted images in the second patient demonstrating the complete tendon tear (arrows).*

4. Tears of the latissimus dorsi and teres major

Tears of the latissimus dorsi are rare and occur during an eccentric contraction of the arm. They are mainly observed in professional baseball pitchers, but are also associated with the practice of cricket, basque pelota and crossfit. The teres major runs parallel to the proximal part of the latissimus dorsi, sharing the same mechanisms of injury. Lesions of these two muscles can be seen concomitantly, especially since they may share a common tendon [10].

The latissimus dorsi is the largest muscle in the upper half of the body. It attaches widely to the lower part of the spine and the pelvis via the thoracolumbar fascia, inconsistently on the lower corner of the scapula, and ends in a tendon inserted at the bottom of the intertubercular groove. An interesting variant is the presence of an axillary arch in 7% of cases; an accessory muscle connecting the latissimus dorsi to the pectoralis major and the coraco-brachial by crossing the axillary vessels [11].

The teres major ends on the medial lip of the intertuberculous groove of the humerus **(Fig. 10)**.

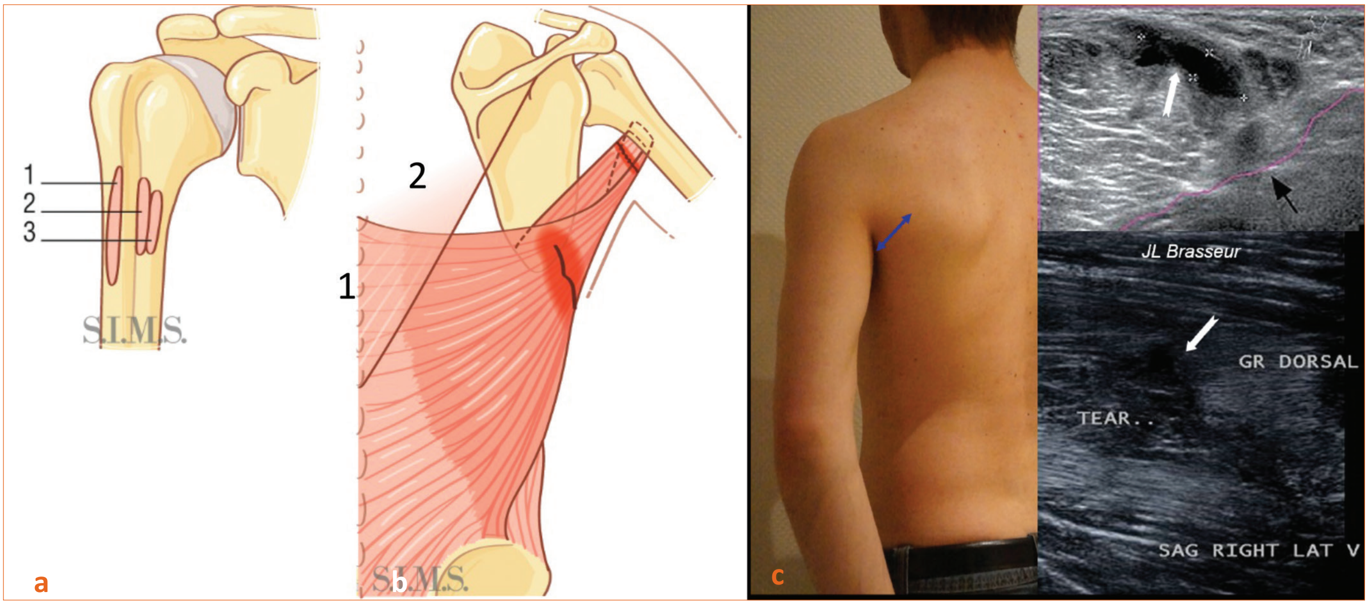

Figure 10 : **a:** *Representation of tendon insertions around the bicipital groove of the pectoralis major (1), latissimus dorsi (2) and teres major (3).* **b:** *Representation of latissimus dorsi and teres major tears. They occur at the myotendinous junction of the latissimus dorsi (1) and at level of the tendons of the latissimus dorsi and teres major (2).* **c:** *Example of a latissimus dorsi tear diagnosed with sonography (case courtesy Jean-Louis Brasseur, MD).*

The tears are located at the myotendinous junction or at the level of the humeral insertion **(Fig. 10)**. They can be partial or complete and a classification has recently been proposed [12]. Complete tears represent a surgical indication.

At the acute stage, the diagnosis of these lesions by ultrasound or MRI is relatively easy when we think of looking for them [13,14]. In the subacute or chronic stage, the retracted muscle, the organized hematoma and the heterotopic ossification can mimic a sarcoma [15].

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11 Aponeuroses of anterior and medial thigh muscles

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I. Anterior compartment

Within the anterior compartment of the thigh lies a large muscle called the quadriceps. This muscle is subdivided into four smaller muscles: the rectus femoris, which is the most superficial; and the vastus medialis, intermedius and lateralis, which lie deeper.

The rectus femoris is a biarticular muscle, it extends the knee and flexes the hip. It lies in the center of the thigh on top of the vastus intermedius and is mainly composed of type II muscle fibers [1].

It is the most frequently injured anterior muscle in direct trauma to the thigh [2,3].

a. Rectus femoris muscle: Proximal insertion

The rectus femoris attaches proximally via two different tendons [4] :

- The straight tendon, which is short, vertically oriented, and originates on the anterior inferior iliac spine. As it descends, it gives rise to a peripheral, superficial aponeurosis which covers the anterior aspect of the proximal two-thirds of the muscle, giving it a convex appearance, which flattens out distally.

  The fibers of this superficial anterior aponeurosis remain peripheral and form a unipennate structure.
- The reflected tendon is long and thin. It originates on the acetabular groove above the acetabular roof, and courses along the joint capsule. It gives rise to the central sagittal median aponeurosis [5].

  This comma-shaped central aponeurosis is located on the superficial aspect of the proximal two-thirds of the muscle belly. From it spring muscle fibers which form a bipennate structure on either side of the central septum **(Figs. 1, 2, 3, and 4)** [1,4,6].

These two tendons then join 2cm distal to the anterior inferior iliac spine to form a common tendon, which in turn gives rise to a vertically oriented, fusiform muscle belly.

The rectus femoris is often called a «muscle within a muscle» because it contains two separate muscles, with the peripheral unipennate muscle wrapping around the central bipennate one [7,8].

11 Aponeurosis of anterior and medial thigh muscles

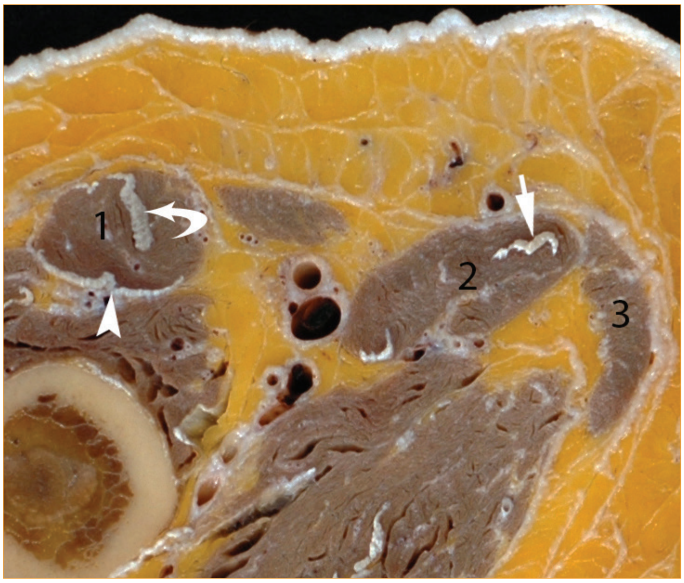

Figure 1: *Axial anatomic section of the antero-internal part of the upper third of the right thigh representing the rectus femoris muscle (1), the adductor longus (2), the gracilis (3) and their aponeuroses. Curved arrow: the central aponeurosis of the rectus femoris; arrowhead: peripheral posterior aponeurosis of the rectus femoris; arrow: the central aponeurosis of the adductor longus.*

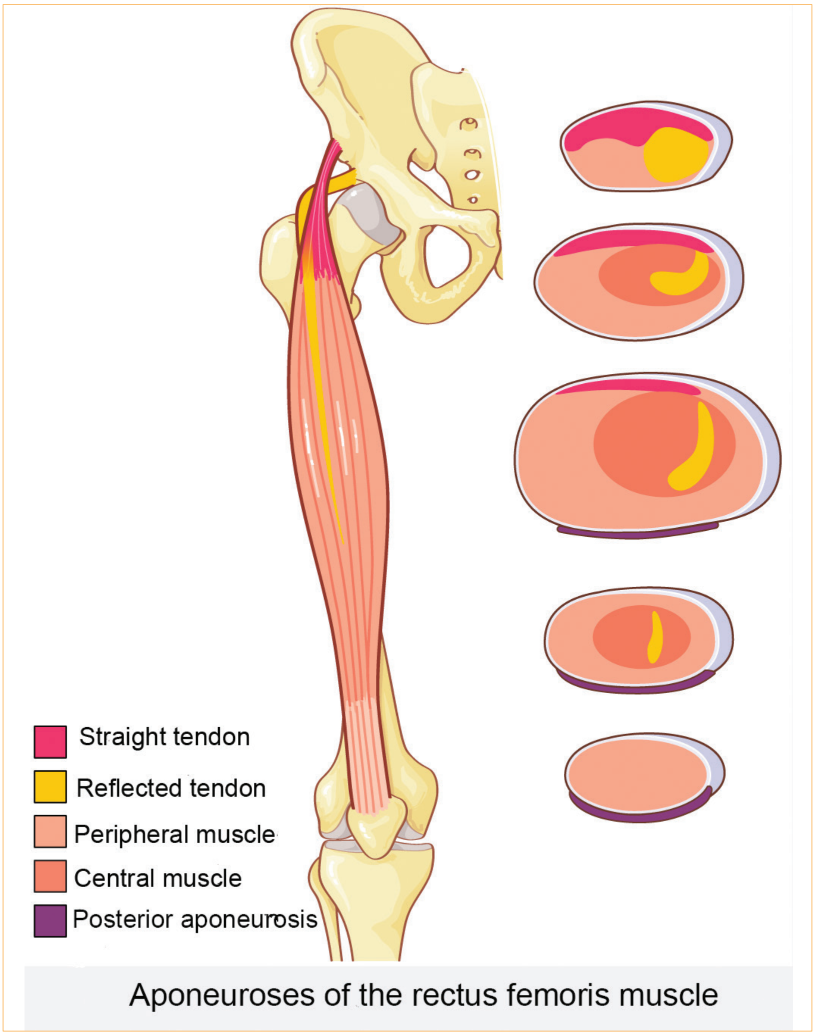

Figure 2: *Schematic drawing of the right rectus femoris and lower views of axial sections showing the aponeuroses localization. The direct tendon continues with the peripheral anterior aponeurosis whereas the intramuscular aponeuroris comes from the indirect tendon.*

b. Rectus femoris muscle: Distal insertion

At the distal part, the aponeuroses and quadriceps components join to form a single flat tendon which arises from the deep peripheral aponeurosis located in the lower two-thirds of the muscle. This deep aponeurosis lends a convex shape to the posterior aspect of the muscle and forms part of the distal quadriceps tendon, which inserts onto the base of the patella **(Figs. 2, 3, and 4)** [4,7].

Figure 3: *Lower views of axial anatomical sections of the right rectus femoris showing the peripheral anterior aponeurosis (arrow), the central aponeurosis (curved arrow), and the peripheral posterior aponeurosis (arrowhead).*

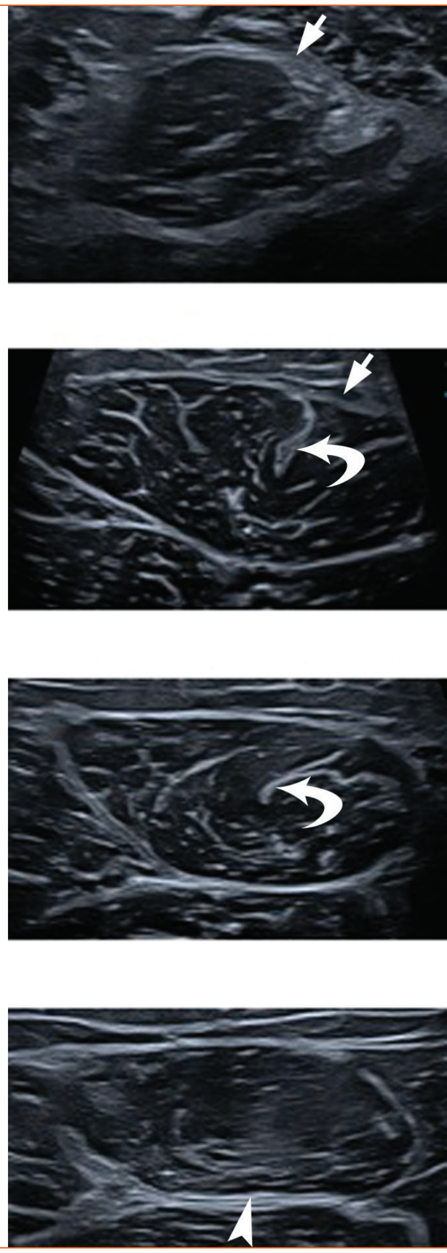

Figure 4: *Axial sonographic sections from proximal to distal part of the right rectus femoris indicating the peripheral anterior aponeurosis (arrow), the central aponeurosis (curved arrow), and the peripheral posterior aponeurosis (arrowhead).*

2. Medial compartment

The medial compartment of the thigh comprises the adductor muscles. In the superficial plane lie the pectineus, gracilis and adductor longus **(Figs. 1, 5)**, in the intermediate plane the adductor brevis, and in the deep plane the adductor magnus. They are all uniarticular and thigh adductors.

Of the medial compartment we will only consider the aponeuroses of the most commonly injured muscles, namely the adductor longus and gracilis [3,5].

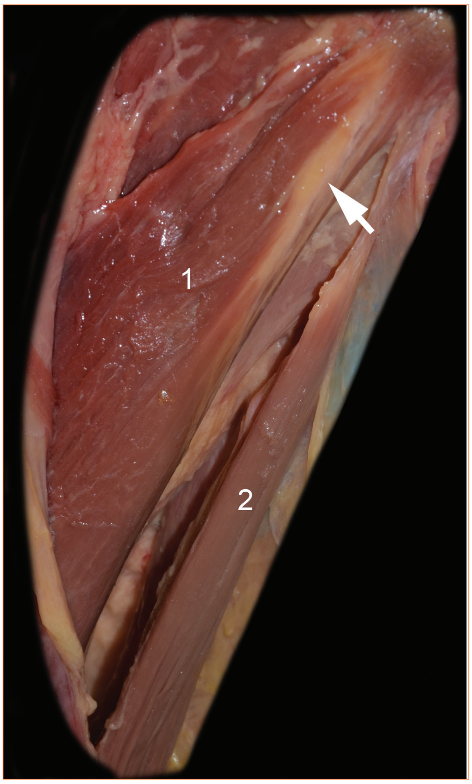

Fig. 5: *Anterior view of the medial part of the right thigh from a cadaveric dissection representing the adductor longus (1) and the gracilis (2) muscles. Note the antero-internal and proximal aponeurosis of the adductor longus (arrow).*

a. Adductor longus muscle

The adductor longus arises from a short fibrocartilaginous tendon on the anterior aspect of the body of the pubis below the pubic tubercle. It then forms a peripheral anteromedial aponeurosis which gives rise to a central aponeurotic septum spanning the upper two-thirds of the muscle. This aponeurosis is thin and curvilinear **(Figs. 6 and 7)** [9].

The belly of the muscle forms a laterally based triangle and describes a thin, oblique plane inferiorly, laterally and posteriorly.

It inserts onto the middle third of the medial lip of the linea aspera on the femoral diaphysis [6,10].

Fig. 6: *Lower views of axial anatomical sections from proximal to distal part of the right adductor longus indicating the aponeurosis, first peripheral anterior, and then central (arrow).*

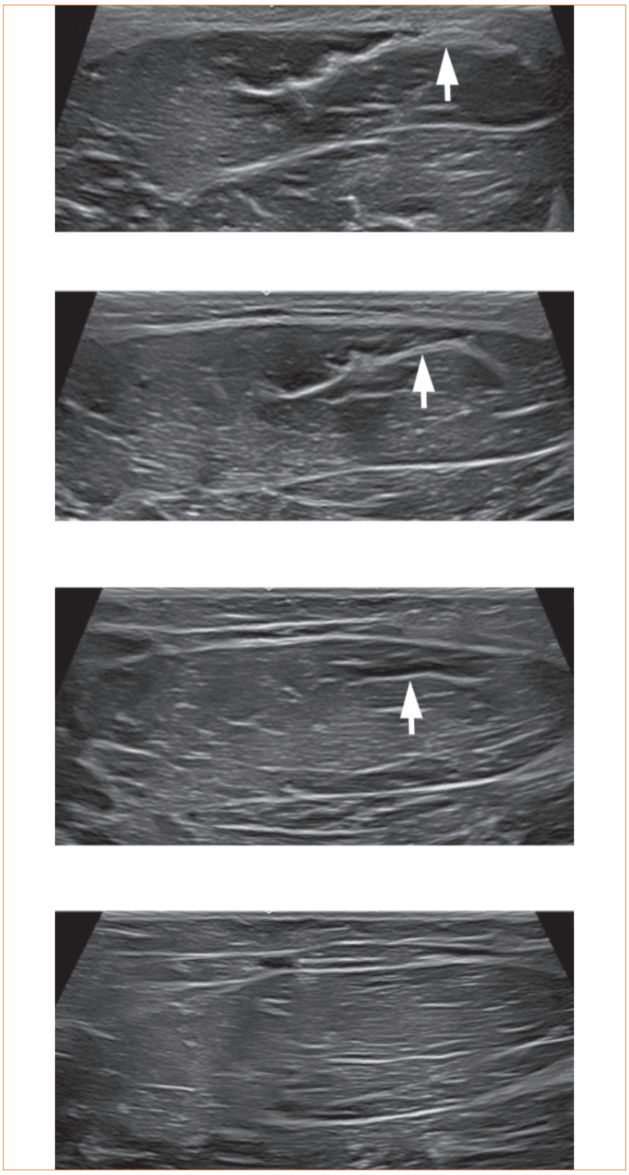

Fig.7: *Axial sonographic sections from proximal to distal part of the right adductor longus indicating the peripheral anterior aponeurosis which continues with then central one (arrow).*

b. Gracilis muscle

The gracilis is the most medial and spindly of this muscle group. It originates on a short, wide, thin fibro-cartilaginous enthesis on the anteroinferior aspect of the pubis body and medial third of the lower margin of the ischiopubic ramus.

Aponeurosis of anterior and medial thigh muscles

The body of the muscle is thin, flat, vertically oriented and strap-like, and has an oblique course inferiorly, laterally and posteriorly. It comprises a peripheral posteromedial aponeurosis which gives rise to a broad central septum visible in the lower two-thirds of the muscle **(Figs. 8 and 9)**.

Myoaponeurotic tears in this region most commonly occur in dancers.

Along with the other tendons of the pes anserinus, it ends in a long tendon in the distal third of the thigh on the superomedial aspect of the tibia, posterior to the sartorius [6,10].

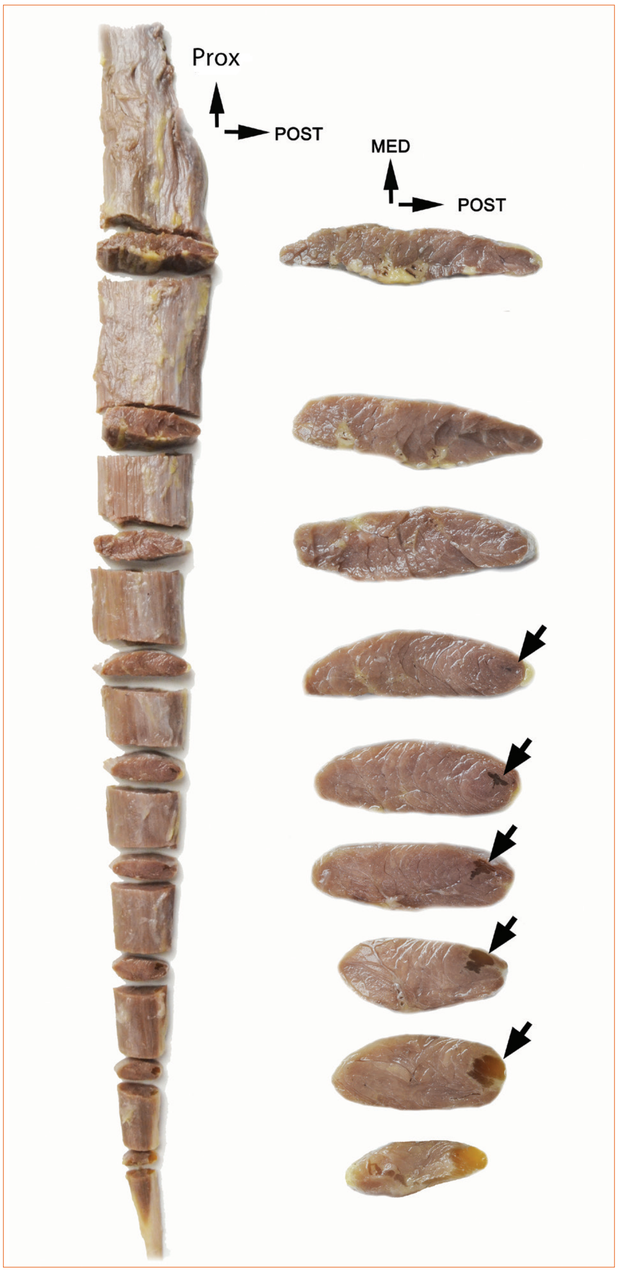

Fig. 8: *Lower views of axial anatomical sections from proximal to distal part of the right gracilis showing the central aponeurosis (arrow).*

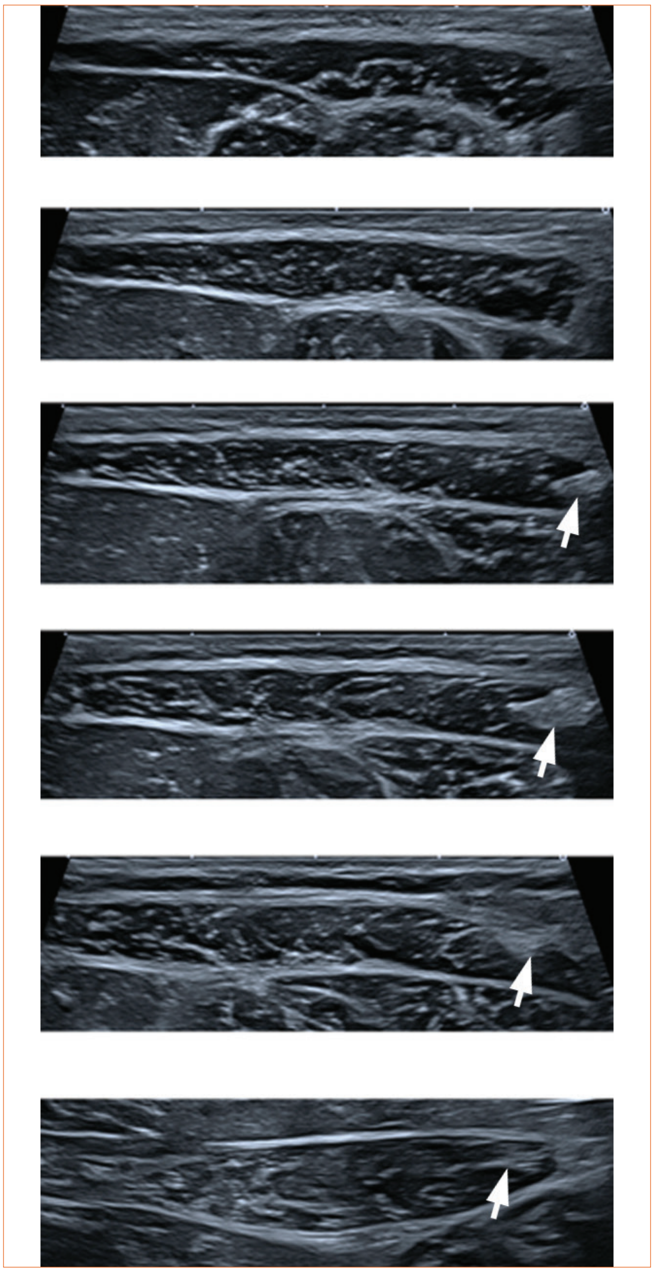

Fig. 9: *Axial sonographic sections from proximal to distal part of the right gracilis showing the central aponeurosis (arrow).*

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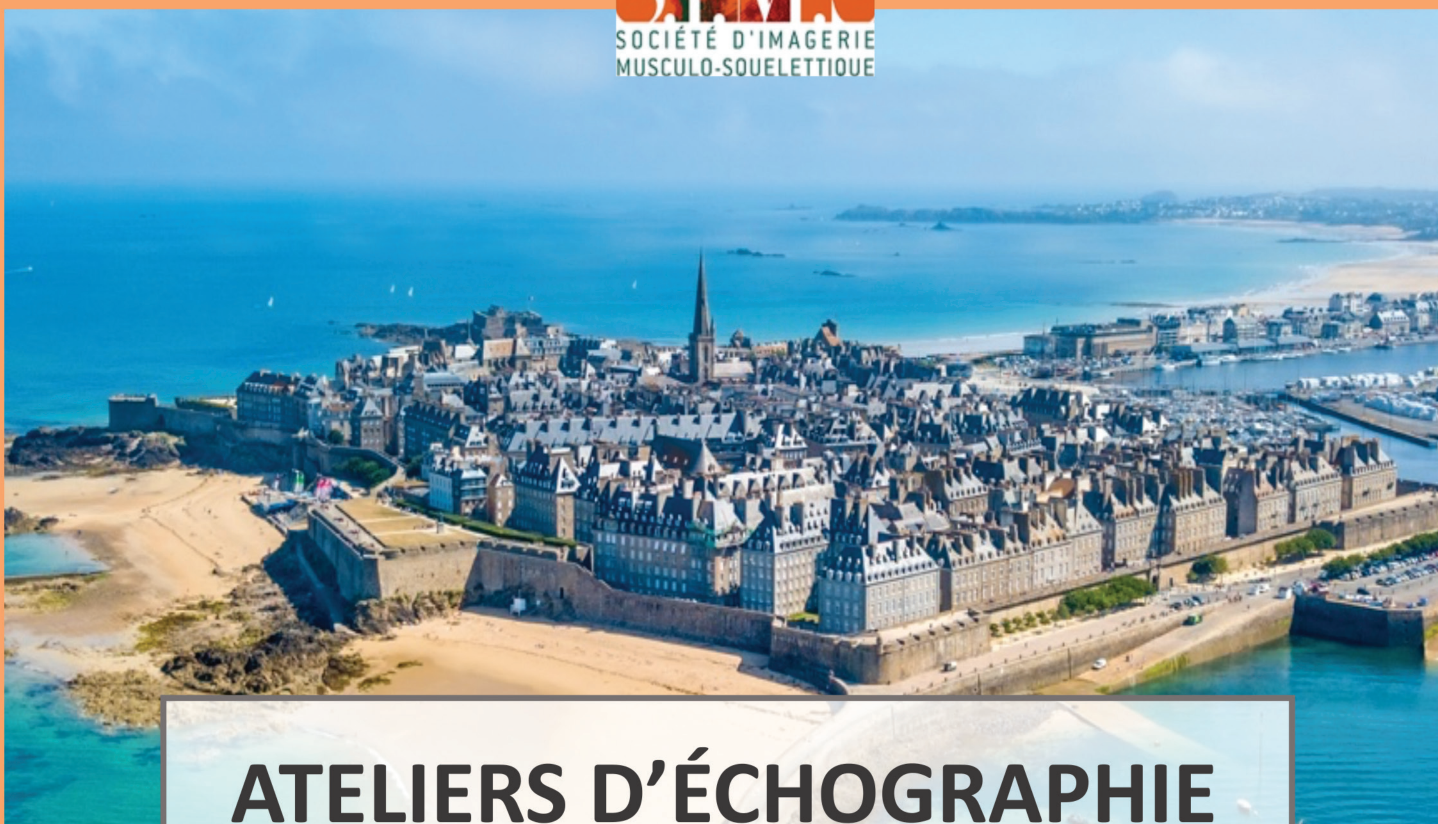

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