

Lower limb muscle injuries in Sports Medicine: the role of sonography in the follow-up

Poster No.: C-3104
Congress: ECR 2018
Type: Educational Exhibit
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Keywords: Musculoskeletal soft tissue, Trauma, Extremities, Ultrasound, Ultrasound-Colour Doppler, Diagnostic procedure, Hernia
DOI: 10.1594/ecr2018/C-3104

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Learning objectives

- Highlight the role of ultrasound in the follow-up of lower limb muscle injuries;
- Illustrate the normal muscle healing and frequent complications.

Background

MUSCLE INJURY

Muscular injuries are a common occurrence in sports medicine and a great concern for the health of the athlete, but also due to potential financial losses associated with competition time loss. The goal of the sports physician is to assure early return to competition with decreased risk of worsening the injury or re-injury. This can be challenging, especially in the elite athlete in which there might be a great pressure to return to completion as soon as possible.

Imaging plays now a great role in confirming the diagnosis, identifying complications as well as guiding clinical management and the prognosis.

- US technique

Following an adequate clinical history and short physical examination, the exam might be directed to the anatomical part of clinical suspicion. The patient should be placed in a comfortable position, allowing scanning of the muscles in question, from the proximal to the distal attachment, including dynamic evaluation if needed.

The symptomatic region as well as the entire muscle should be examined, including the myotendinous junction and myofascial junction. The surrounding vascular and nervous structures must also be studied, allowing a differential diagnosis and the assessment of complications (e.g. venous thrombosis in the calf can simulate a tear, but can also be its complication).

Both transverse and longitudinal sonographic evaluations are mandatory. Assessment of muscle injuries requires **high frequency linear probes** and, in our hospital, probes ranging from 6 - 17 MHZ are used. The adequate probe and frequency to be used depends on the balance between signal penetration and resolution, with the principle of choosing the highest frequency possible for a certain depth.

The **focus** should be placed slightly below the area of interest and multiple focus can be used to enhance the assessment of large areas with uniform resolution.

Harmonic imaging can be used to reduce artefacts, which might be especially tailored to distinguish between solids and liquids (e.g. hematomas).

The **extended** (Fig. 1) and **trapezoid field-of-view** are used for large lesions, creating an image that might be easier for the clinician to interpret.

Fig. 1: Extended Field-of-view demonstrating the adductor longus in longitudinal extended from its insertion in the superior pubic ramus. Normal hypoechoic muscle fibres are arranged in a parallel fashion and surrounded by hyperechoic perimysium (arrows). The epimysium is an hyperechoic fibrous fascia that envelops the entire muscle (arrowheads). AI - Adductor longus; P - Pubis.

References: Centro Hospitalar e Universitário de Coimbra - Coimbra/PT

Both **power** and **colour Doppler** might be used in assessing tissue vascularity, which might help identify the injury site (displaying increased vascularity), and also distinguish between solid and liquid lesions. It's also useful in the healing evaluation (an hypervascularization means an active healing process).

Dynamic study is, in certain cases, very important, allowing the detection of subtle tears or distinguishing between full-thickness and partial thickness tendon tears. Additionally it may allow the diagnosis of tendon or nerve subluxations that may become obvious only with certain positions/movements or the detection of small muscular hernias. It's especially important to avoid too much pressure, as it can mask a small tear (Fig. 2).

Fig. 2: Small elongated hematoma associated with muscular tear in the adductor brevis. This highlights the importance of gentle probe handling as increased probe pressure might cause the collapse of the fluid collection and a false negative result.

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Finally, comparison with the contralateral limb might be important for avoiding pitfalls.

- The use of MRI

Despite the good accuracy of ultrasound for detecting muscular lesions, MRI can also have an important role in selected patients. It is especially recommended if the clinical findings do not match the US findings or if there is absence of a muscular scar 5-7 weeks after the initial injury and other diagnosis should be considered. It can also be considered in elite athletes for which there might be an increased pressure for early return to competition, since MRI shows higher sensitivity for identifying muscle edema.

Images for this section:



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Findings and procedure details

HEALING

Muscle injury is followed by healing and this occurs in three stages.

1- The initial phase is a destructive or **inflammatory phase**. It starts immediately with the injury and is characterized by necrosis of the muscle fibres and hematoma formation.

2- **Reparative phase** ensues at the 2nd and 3rd days. Phagocytosis of the necrotic tissue associated with capillary ingrowth, differentiation of satellite cells into myoblasts and ultimately connective tissue deposition (scar formation).

3- **Remodelling phase** with reorganization of scar tissue and muscle functional recovery.

The follow-up imaging findings will depend on the type of the initial insult and its imaging presentation. Grade 1 Peetrans indirect injuries usually appear as increased echogenic areas. Over the time a reduction of size or disappearance is expected. In grade 2 and 3 lesions, there is an anechoic area representing fluid associated with torn fibers (hematoma). Decrease in the quantity of fluid represents normal healing, with a centripetal filling. Also, the margins of the muscle will become echogenic as this process develops (Fig. 3).

Fig. 3: Athlete with a hematoma between the medial gastrocnemius and sartorius muscles after injury (a and b). A small aponevrotic rupture is seen at the myo-tendinous junction of the medial gastrocnemius (arrow in a). After 6 weeks the patient returned and decrease in the hematoma size is noticeable, due to centripetal filling of the hematoma with fibrous tissue (arrowhead in c). Hypervascularity surrounding the hematoma is also identified, consistent in ongoing healing.

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Small tear will also be progressively replaced with scar tissue. There's also a decrease in the hypervascularization over the healing process. The presence of hypervascularity is sometimes the only sign of an incomplete or ongoing healing (Fig. 4).

Fig. 4: 14 years old male patient that referred intense pain in the thigh while kicking during a football match. The initial exam, done one week after the injury demonstrated

a septated fluid collection in the thickness of the rectus femoralis at the upper third of the thigh. This findings are consistent with a muscle rupture (Peetrons grade II). Four weeks after the injury shrinkage of the collection is seen with peripheral filling (c and d showing longitudinal and transverse sonograms, respectively). Six weeks following the injury event the patient returns and hyperechoic tissue consistent with fibrosis replaces the previously identified fluid collection, (arrowheads in e and f). Hypervascularity is still demonstrated (box in f).

References: Centro Hospitalar e Universitário de Coimbra - Coimbra/PT

Dynamic imaging can have a particular importance at this stage, demonstrating small hematomas not apparent with resting (Fig. 5 and video in image 6).

Fig. 5: 25 years-old athlete with a grade II Peetrons indirect injury of the adductor longus. Loss of perimysial architecture, increased echogenicity and hematoma is seen at 48h (a). Increased surrounding hypervascularity is already noticeable (box in b). At 2 weeks b-mode ultrasound reveals only discrete peirmysial distortion (arrow in c), but no fluid collection is seen. There is still increased vascularity at the lesion periphery (box in d). AI - Adductor longus

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Fig. 6: Dynamic ultrasound during muscle contraction still displays the presence of a small collection of fluid (hematoma), not apparent during rest (arrows). Same patient in Fig. 5.

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When the hematoma is completely reabsorbed and there's no hypervascularity, complete sonographic healing can be reported.

COMPLICATIONS

Scarring and recurrence

Demonstration of scar tissue is important since it may be seen in the healing of larger lesions. It will be seen in US as an hyperechoic area with irregular borders (Fig. 7) without contraction on the dynamic study.

Fig. 7: One month follow-up ultrasound after rupture of the rectus femoris in a runner. US still displays an hyperechoic area consistent with fibrous scar within the muscle (area between calipers in a and b). No collections are seen at this moment.

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The presence of a muscular scar, that shows no contraction capacity, alters the normal muscle contraction vector, reducing strength and increasing fatigue (video in image 8). The greater the scar, the more abnormal will the muscle biomechanics be.

Fig. 8: Ultrasound done at 20 weeks follow-up of Achilles myotendinous junction rupture treated conservatively in a patient that refused surgical treatment. Proximal tendon thickening is seen, as well as tendon disruption (hematoma), corresponding to a clinically palpable gap. Dynamic ultrasound after passive plantar flexion demonstrates tendon edges with abnormal kinetics and a scar with absent contraction.

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Moreover, it provides a stronger layer than the muscle-tendon unit, explaining the increase number of the re-injuries after the scar formation.

Early recurrence is the most seen complication of muscle contusion, usually occurring after 1 or 2 weeks after injury, with an incidence around 30%. Both intrinsic (e.g. extensive scar tissue, weakened muscle) and extrinsic factors (e.g. inadequate or premature training, increasing age) may act together to originate recurrence.

Re-injury might happen also many weeks after the traumatic event, corresponding to **late recurrences**. This risk increases steadily after muscle indirect injuries, linked with the fibrotic scar formation and muscle atrophy (Fig. 9).

Fig. 9: Football player with a history of repeated injuries of the adductor longus muscle, demonstrating an area of fibrosis in the initial US (arrows in a and b - longitudinal and transverse sections, respectively). After some months we felt a sudden sharp pain in the medial part of the thigh while kicking. Bruising was noted at this region before the exam. A collection was seen separating the two ends of the retracted tendon (hematoma - arrowhead in c), corresponding to another tear, classified as Peetrans grade 3 lesion. AI - Adductor longus muscle

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Nevertheless, the recommendation of imaging follow-up in muscular injuries in athletes is controversial. Some authors claim that the management should be guided clinically and imaging should be reserved for persistence of unexpected clinical symptoms after rehabilitation and suspicion of re-injury. Other authors state the advantage of US follow-up to assess healing and to search for early complications.

Deep venous thrombosis

Deep venous thrombosis (DVT) is both an important differential diagnosis of muscle rupture, but can also be its complication.

The presence of edema and hematoma caused by fibre rupture may lead to compression of popliteal or gastrocnemius veins and predispose to DVT. Moreover, longer immobilization after severe injuries might also increase the risk for this complication. For this reason, US, particularly with Doppler, is a crucial imaging technique for the diagnosis of DVT of the lower extremities, including the gastrocnemius and soleus veins (Fig. 10).

Fig. 10: Ultrasound demonstrating solear muscle rupture with loss of perimysial striation (arrow in a). Trombosis complicating muscular injury is also demonstrated (asterisk in a and b), with discrete echoic content identified in the dilated posterior tibial vein and absence of flow (box in b).

References: Centro Hospitalar e Universitário de Coimbra - Coimbra/PT

Acute compartment syndrome

The hematoma resulting from muscle rupture, along with edema within the muscle leads to the rise of pressure within an inextensible compartment. This will lead to ischemia and ultimately tissue necrosis - acute compartment syndrome. Clinical signs are disproportionate pain resistant to medication, neurological abnormalities, tenderness and pulselessness. The anterior compartment of the leg is the most affected. The clinical diagnosis can be confirmed by direct intracompartmental pressure measurement and the role of ultrasound is to detect and eventually guide the drainage of collections to allow decompression.

Ossificant myositis

Hematoma formation after muscle tear may lead to heterotopic proliferation of bone and cartilage. It's a rare complication of contact sports and sometimes the traumatic event cannot be recalled (in about 50%). It's most frequent in the anterior and proximal muscular groups, usually in muscles in direct contact with bone, such as the vastus intermedius.

Three stages are recognized in its pathophysiology with characteristic imaging findings: acute or **pseudoinflammatory phase**; subacute of **pseudotumoral phase**; chronic **healing phase**. In the first two phases an inflammatory hyperechoic area can be visualized (Fig. 11). Ultrasound can show earlier signs, such as a mass with detectable Doppler signal mainly at the periphery, which can sometimes mimetize a tumor (radiography is frequently normal at this phase).

Fig. 11: Athlete with a contusion 4 weeks previously, in which US shows a fluid collection (between calipers) and amorphous peripheral hyperechoic areas. The radiography was normal at this time.

References: Centro Hospitalar e Universitário de Coimbra - Coimbra/PT

During the chronic phase, osteoid material is laid down at the periphery of the hematoma forming an elongated ossification parallel to the diaphysis (Fig. 12). A suggestive pattern can be identified at US in this phase chronic phase, called **zone phenomenon**. Three concentric zones were described, corresponding to: a hypoechoic peripheral zone with increased vascularity; a second hyperechoic zone in the heterotopic ossification formation; an inner hypoechoic area composed by the central stromal fibroblastic component. US is the most sensitive technique for demonstrating this zone pattern.

Fig. 12: During the chronic phase of ossificant myositis, osteoid material is is seen within the vastus intermedius muscle (replacing the previous hematoma), orientated parallel to the bone diaphysis. VI - Vastus intermedius muscle.

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A typical clinical history or US findings do allow the correct diagnosis in most cases. If a biopsy is done, it is important to choose the correct phase to do it, since earlier biopsy frequently give a false positive result of sarcoma. US findings might be used to choose the correct time window. It should be done in the late phase (usually starting between the second and fourth week), when there is a peripheral production of mature bone, allowing a correct histologic diagnosis.

Calcifications become apparent on CT or radiography at 6 weeks and ossification starts at 6 months, showing a characteristic centripetal disposition. This centripetal ossification allows the differentiation from more aggressive lesions, such as paraosteal sarcoma, in which the calcification first occurs in the necrotic centre.

In cases of larger hematomas, US might also be used to guide fluid aspiration, reducing its complications and improving the healing.

Myositis

Muscle infections can be seen after trauma, especially with blunt trauma. Bacterial myositis (**pyomyositis**) is usually caused by *Staphylococcus Aureus* and is more common in immunocompromised patients. It usually affects large muscles of the lower limbs and develops over weeks. The clinical history is relevant and might allow the correct diagnosis. The sonographic findings are hyperechoic muscle fibres (due to edema and hyperemia) filled with hypoechoic exudates (reverse of the normal pattern). If untreated, abscess formation may follow (Fig. 13). The presence of gas bubbles within these areas may be seen with gas forming organisms.

Fig. 13: US imaging in a septic immunocompromised patient who reported a blunt trauma several weeks before. Diffuse thickening and hyperechoic muscle fibres are seen (due to edema and hyperemia - asterisk) filled with hypoechoic abscesses (arrowhead).

References: Centro Hospitalar e Universitário de Coimbra - Coimbra/PT

Muscle hernias

Direct trauma to muscle might cause fascial injury and rupture. This is a rare event, occurring especially in the lower limb (the tibialis anterior is the most frequently affected muscle). The diagnosis is usually clinical but ultrasound can be used in doubtful cases or to increase patient reassurance. During resting the muscle might display a normal structure. Dynamic ultrasound will reveal normal muscle extruding through a focal fascial defect after contraction (video in image 14).

Fig. 14: Dynamic US demonstrating a fascial defect (dashed line), from which the tibialis anterior muscle protrudes during contraction (arrow). Note the normal appearance of muscle fibers. Avoiding too much pressure with the probe is important to allow the hernia to become visible. TA - tibialis anterior muscle.

References: Cortesy of Miguel Castro

Muscle atrophy

Muscle atrophy can be seen after a tear or denervation. Ultrasound findings are hyperechoic muscle, demonstrating fat proliferation and shrinkage in size (Fig. 15).

Fig. 15: US findings in a young patient with severe muscle atrophy, displaying decreased size muscle with hyperechoic structure (due to fatty proliferation - asterisk). Compare to the normal appearing adjacent muscle, with hypoechoic structure and preserved size (arrowheads).

References: Centro Hospitalar e Universitário de Coimbra - Coimbra/PT

Comparison with the contralateral normal side can help the diagnosis.

Iatrogenic complications

Iatrogenic muscle infections are a great concern for the physician and the radiologist, especially after drainage of post-traumatic hematomas. Therefore, this risk should be taken into account when deciding to drain collections and a sterile technique must be assured.

US might also have a valuable role in detecting early post-surgical complications (video in image 16).

Fig. 16: Footballer with a complete rupture of the Aquiles tendon, treated surgically. One week after surgery the athlete complained of numbness on the lateral edge of the foot. US still reveals the presence of hematoma involving the Achilles tendon. The suture material can be identified (corresponding to double ecogenic lines seen). The sural nerve (sn) can be seen involved by the hematoma and the sutures, explaining the symptoms. S - Soleus muscle; sn - sural nerve.

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Images for this section:

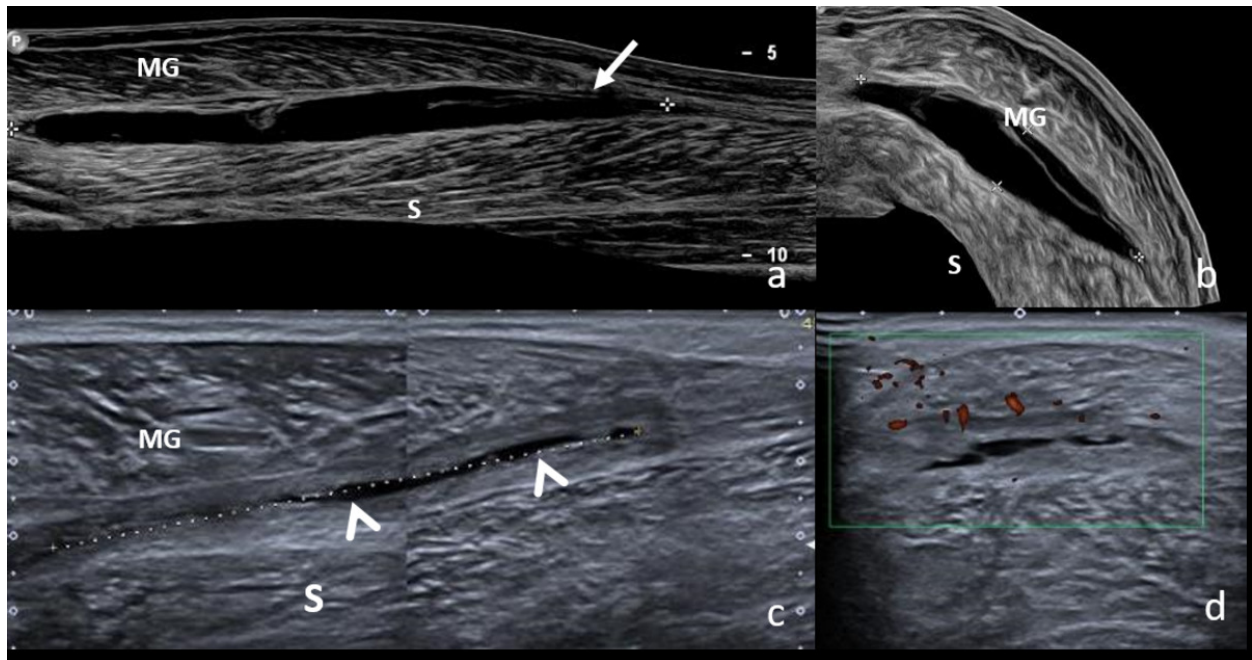


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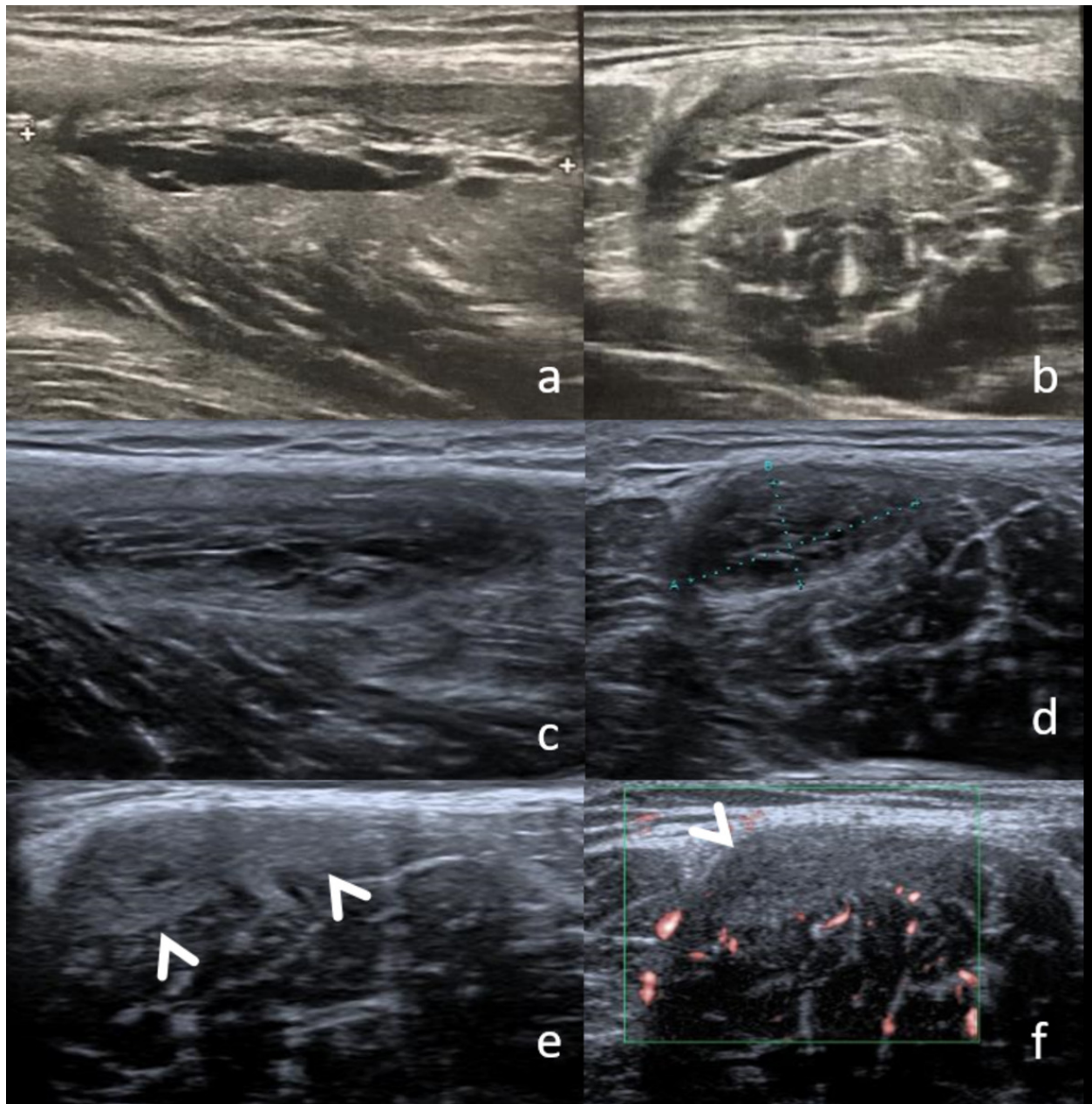


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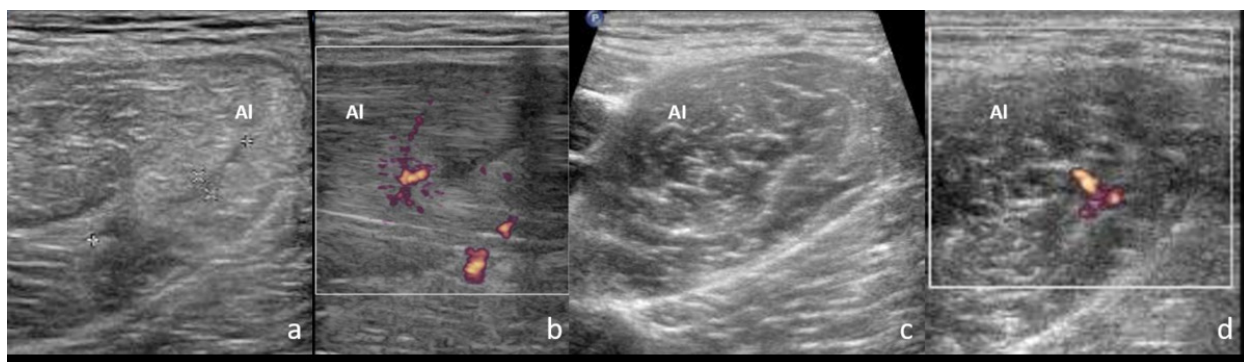


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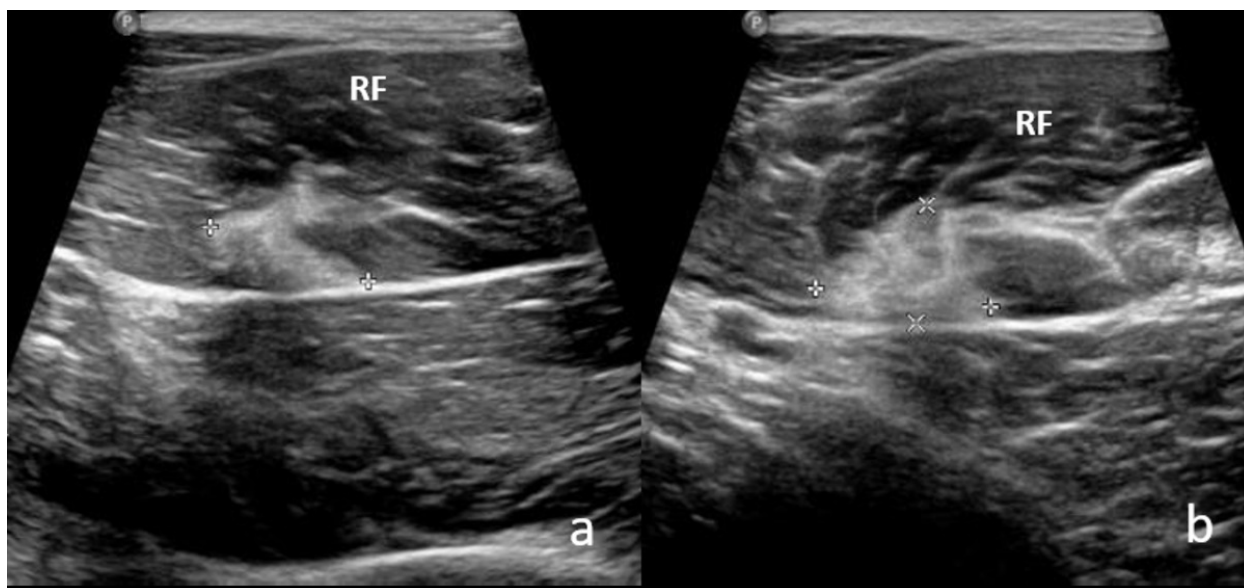


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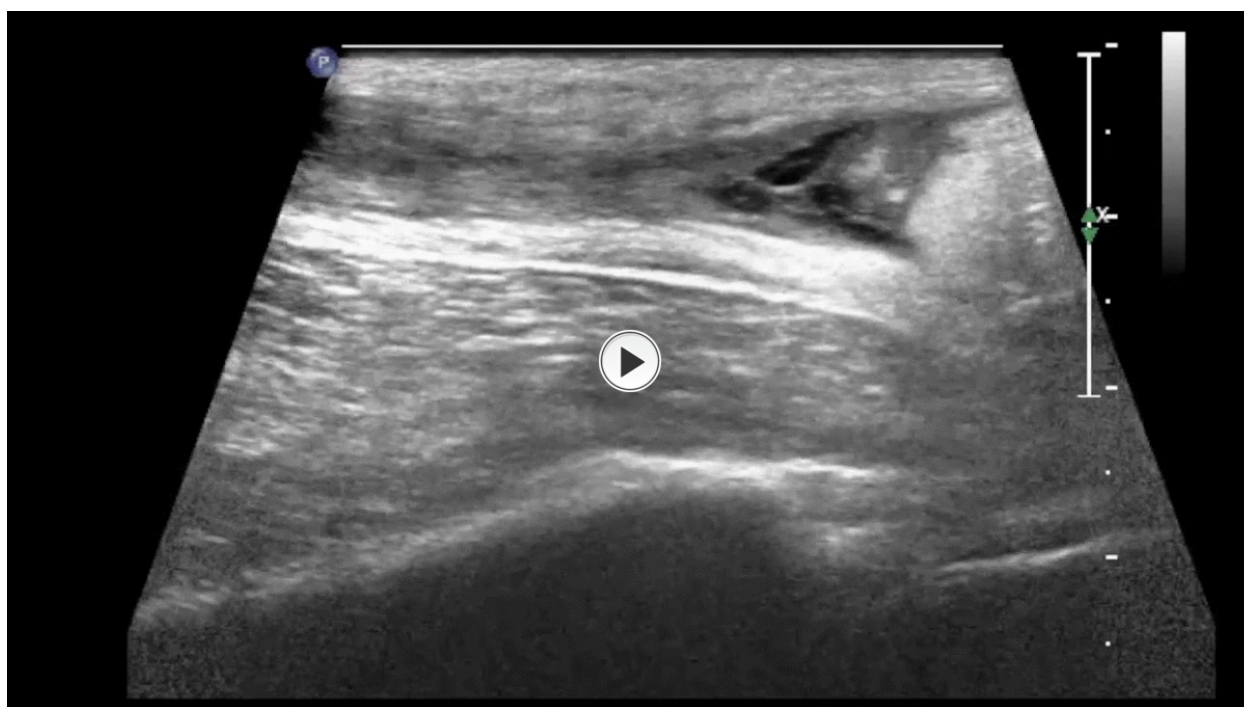


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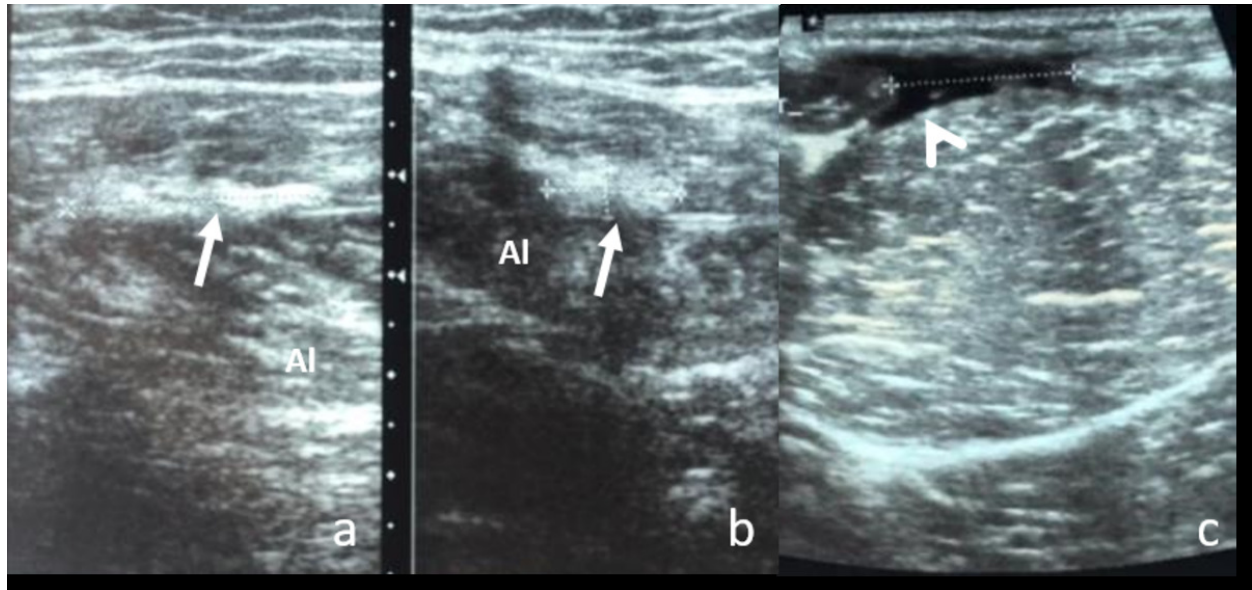


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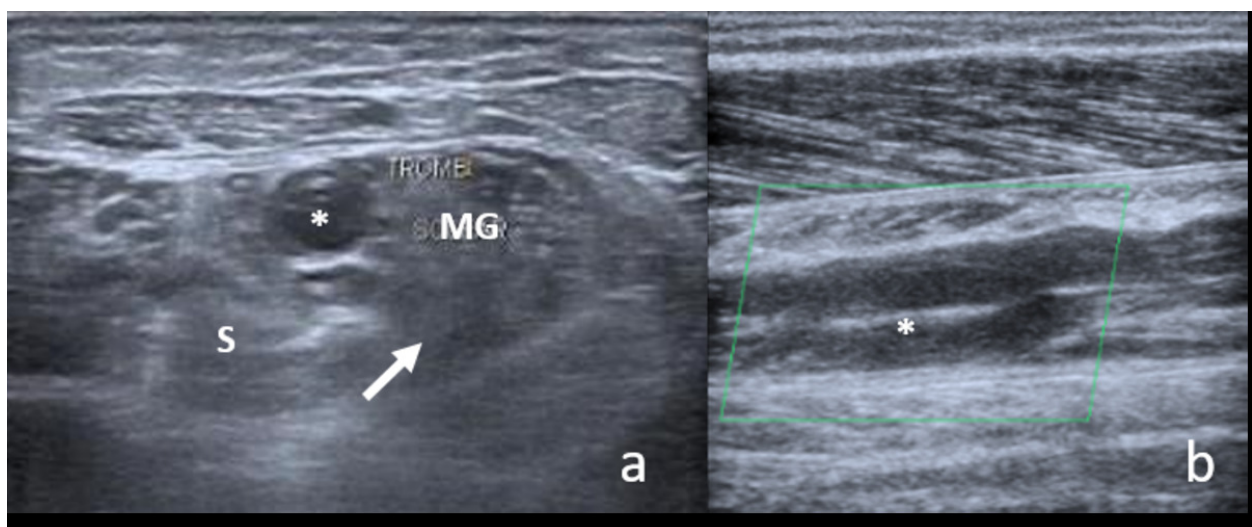


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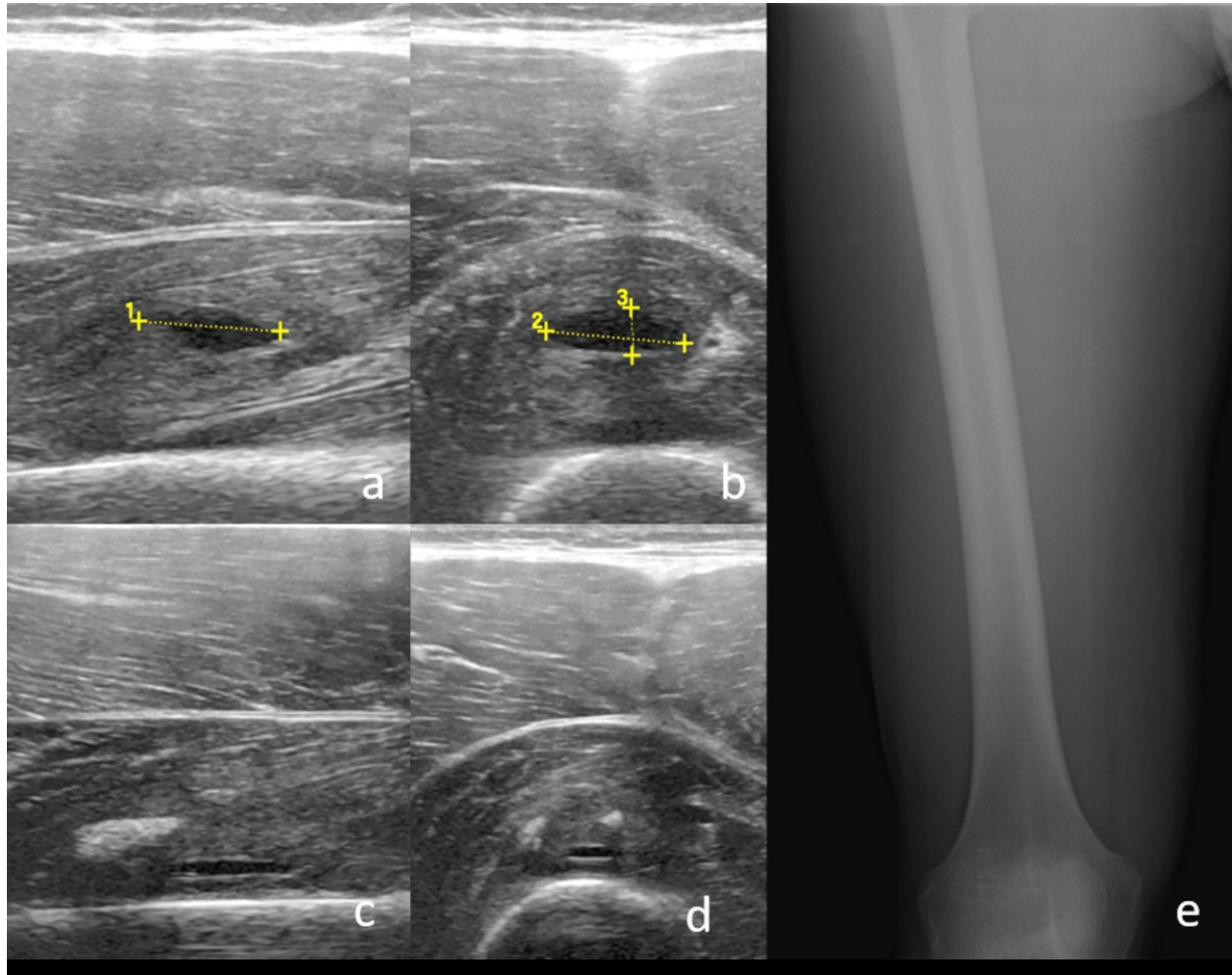


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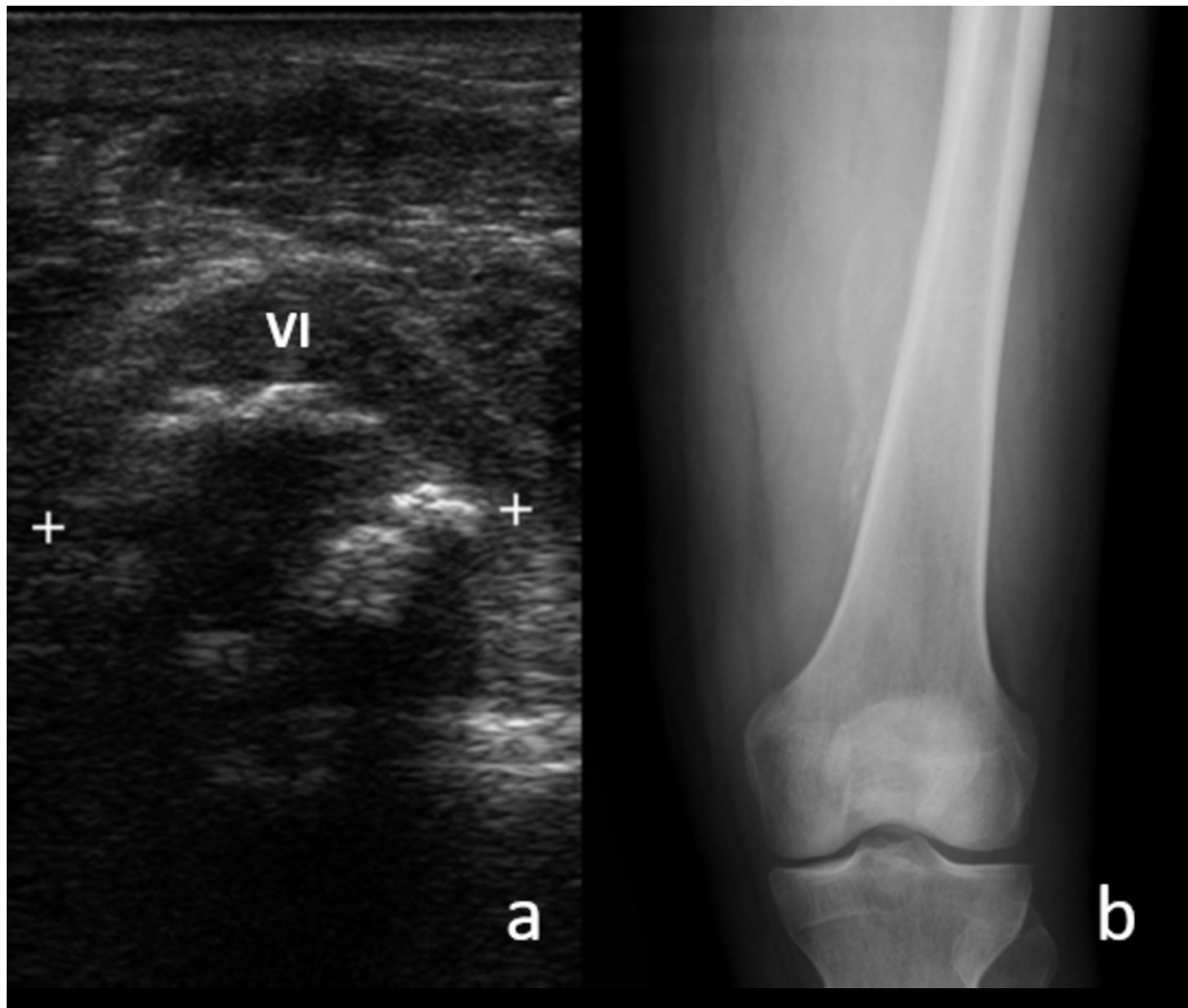


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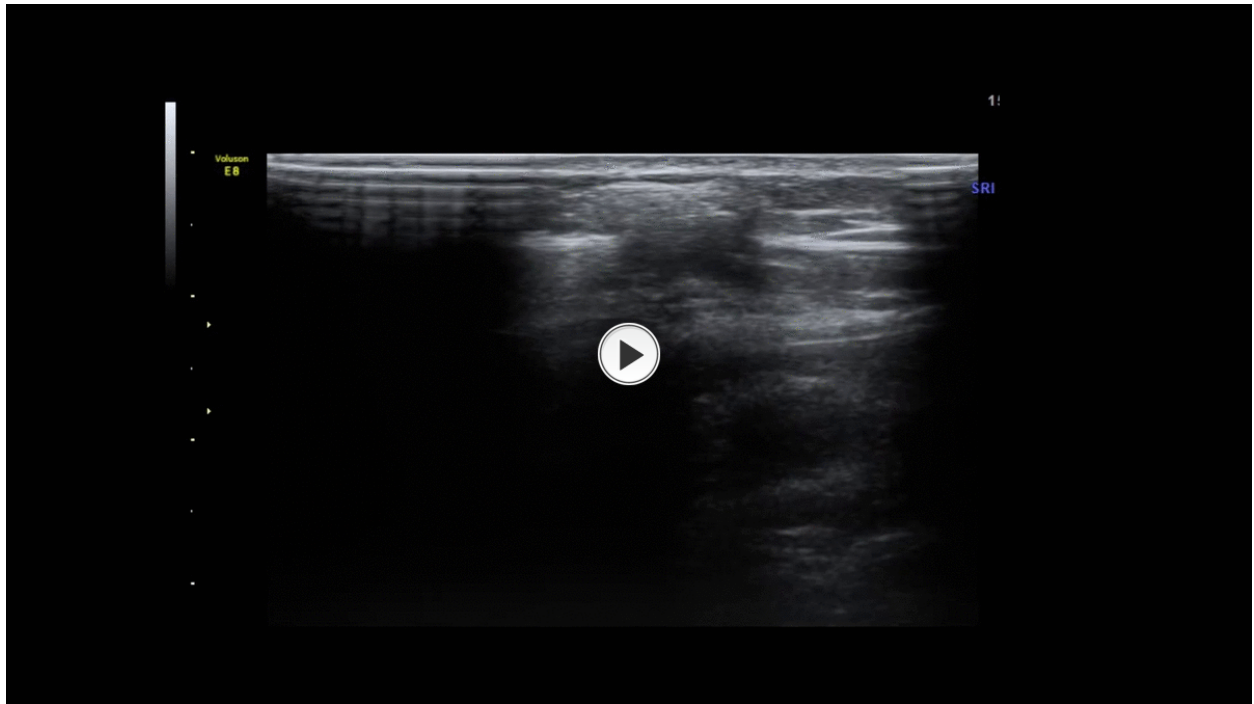


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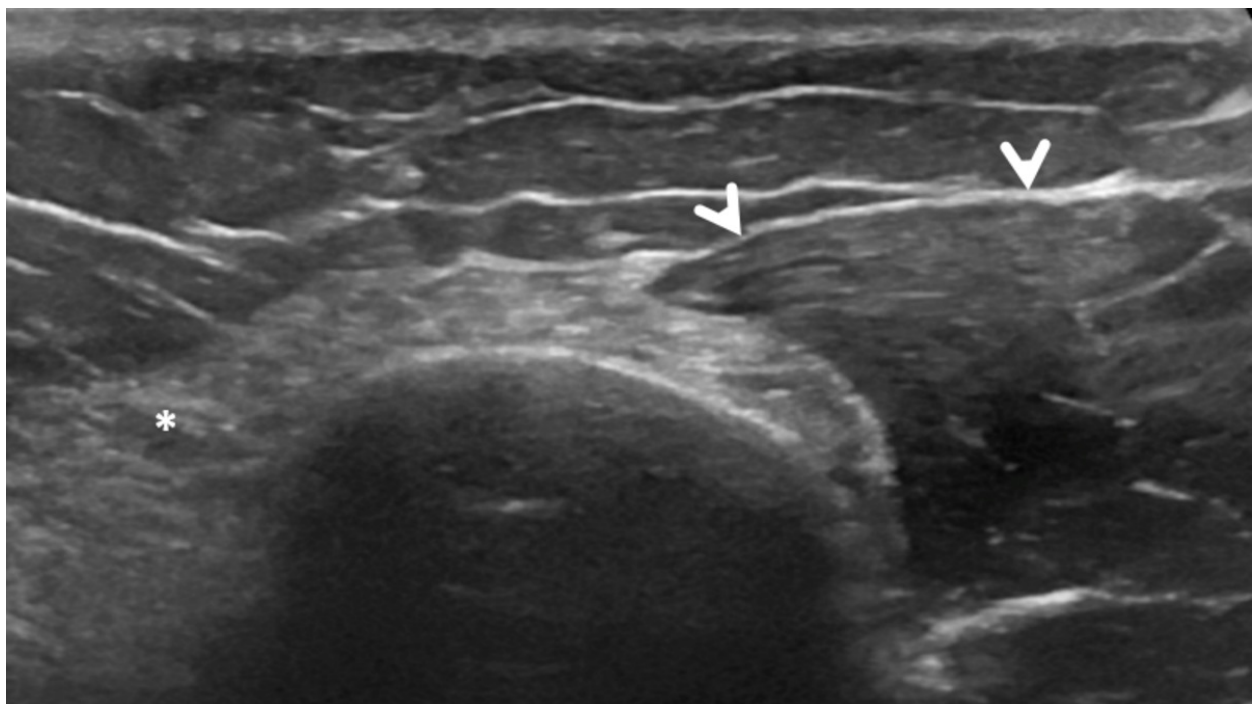


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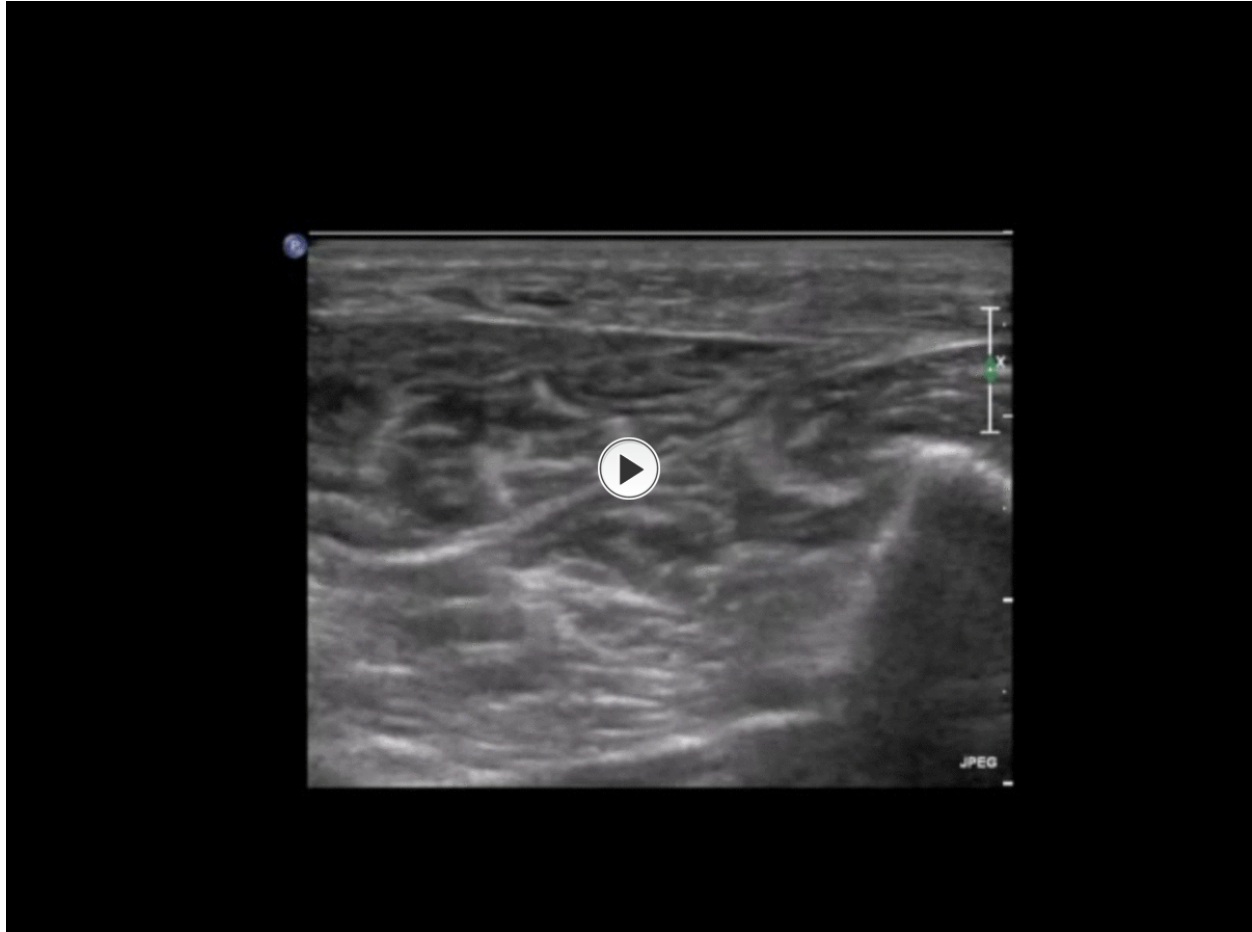


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Conclusion

Musculoskeletal experienced sonography operators can have a central role in the recovery of muscular injuries. Accurate injury grading, follow-up and early detection of complications may provide a great help for the management of the athlete and give information that may help to estimate the recovery time.

Personal information

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