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CLASSIFICATION AND US MANAGEMENT OF MUSCLE INJURIES IN SPORT

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Introduction

Muscle injuries are very frequent in sports [(1, 2)], with an incidence that varies between 10% and 55% of all injuries [(3, 4)]. The mechanisms of injury are varied and include bruising, stretching or laceration. Muscle lacerations are the least frequent injuries, while bruises and strains occur in 90% of all cases of muscle involvement [(5)].

Little information is available in the international literature about muscle injury definitions and classification systems. The establishment of a classification of sports injuries has always been an important topic for discussion. Additionally, muscle injuries have been difficult to define and classify because the muscles have different sizes and shapes with a complex functional and anatomical organisation [(6)].

The evaluation of muscle injury should begin with a complete medical history followed by a detailed physical examination including palpation, which allows one to detect the size of the muscle defect [(5, 7, 8)]. The ultrasound should be performed between 2 and 48 h after the muscle trauma [(9)], although it is acceptable to wait for a period of 48 - 72 h. This interval allows for the injury to get organised and the tissue show changes easily detected by ultrasound.

The choice of the transducer depends on the size and depth of the muscle to be examined. It is common to use multi-frequency probes between 7-12 MHz, for most cases. In very obese patients, those with hypertrophy of the musculature or in the study of deep muscles (piriformis), it may be necessary to use lower frequency transducers. In this chapter all the images have been made on the short and long axis of each muscle, using an 8 – 12 MHz multifrequency transducer.

MRI is also useful to confirm the location of the lesion and any compromise of the tendon [(7)], although not sensitively enough to accurately measure the extent of muscle tissue damage.

Old models of classification of muscle injury

These are the reasons why several classifications have been published in recent years, some supported by clinical signs such as the one published by O´Donoghue [(10)] that related the severity of the injury with the amount of tissue damage and the associated functional loss, establishing three grades. Grade 1 without appreciable tissue tearing, grade 2 with tissue damage and reduced strength of the musculotendinous unit and grade 3 with complete tearing of the musculotendinous unit and complete loss of function [(10)].

Another author, Ryan, applied the classification for the study of quadriceps lesions by dividing them into 4 degrees [(11)].

Takebayashi et al [(12)] published for the first time a classification supported by ultrasound. Grade 1 lesions with less than 5% of the muscle involved, grade 2 for a partial rupture with more than 5% of the muscle involved and up to grade 3 with a full tear. Peetrons in 2002 recommended a classification also supported by ultrasound [(9)].

However, the most commonly used classification is an MRI-based gradation system and establishes four grades: grade 0 without pathological findings, grade 1 with muscle oedema alone but without tissue damage, grade 2 a partial muscle tear and grade 3 with a complete muscle tear [(13)].

However, the classification of lesions that best suits the use of ultrasound as a diagnostic tool is that published in the Munich Consensus Statement [(14)]. Therefore, we recommend following this model in the management of muscle injuries in sport.

In the sports environment the first group of injuries are those caused by an extrinsic mechanism or direct shock, which includes muscle bruises, which are more frequent in occupational accidents and sports activities, especially in contact sports and in collective sports. The second group is made up of those injuries secondary to intrinsic trauma, as a result of violent movements and exaggerated contractions, which cause a sudden tension in the muscle groups, causing the breakage of their fibres. This lesion is very frequently observed in jumpers and sprinters, with hamstring muscles, the rectus femoris and the medial gastrocnemius being more frequently affected.

Classification of muscle injury based on ultrasound exam

In 2012, the Munich Muscle Injury Classification was developed by 15 international sports injury experts based on their combined experience with over 400 thigh injuries in professional athletes, dividing the injuries into 8 categories [(14)]. This system separates muscle injuries into three categories: functional disorders, strain, and contusion.

The Consensus Munich Statement is our usual classification model because, unlike other classifications, it adapts perfectly to ultrasound examinations. Within this consensus, injuries caused by an Indirect muscle disorder and those caused by Direct muscle injury are distinguished. The first group includes the functional muscle disorder and the structural muscle injury. We will describe the ultrasound characteristics of this muscle lesions following this consensus statement.

Direct muscle injury

Contusion is an acute injury caused by a direct nonpenetrating blow to the muscle, typically affecting the anterior thigh, posterior thigh, or anterolateral upper arm [(15)]. When the impact occurs on a muscle that is in the contraction phase, the lesion affects the most superficial fibres, while, if the impact is received in the relaxation phase, the lesion reaches the deep fibres that are located near the bone.

Considering the clinical and ultrasound signs, these lesions can be classified into three grades. Mild or first-degree bruises cause little capillary rupture with a small amount of bleeding that causes a small area of ecchymosis in the skin. Flexion pain only appears with full flexion and ultrasound shows small hyperechoic areas in the subcutaneous cellular tissue and muscle tissue due to the presence of an inflammatory changes that invade the interstitial space [Figure 1]. In second degree contusions, fibrillar crushing causes a bruise that produces a functional limitation, allowing flexion above 90 degrees. Ultrasound will show one or several cavities of anechoic content and irregular borders, sometimes occupied by hypoechoic areas [Figure 2]. Finally, in grade three contusions, the amplitude of the fibrillar and vascular damage is greater, which causes a limitation of flexion below 90 degrees and the ultrasound image shows large anechoic haematomas caused by the crushing of muscle fibres [Figure 3].

Figure 1 **First degree extrinsic muscle injury. The longitudinal image of the gastrocnemius medialis, shows the muscle with irregular borders and hyperechoic appearance, that corresponds to the contusion. The soleus muscle is also affected.**

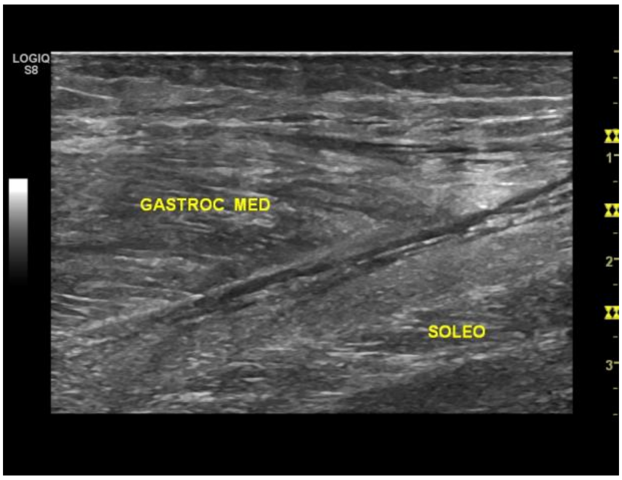


Figure 2 **Second degree extrinsic muscle injury. The longitudinal image of the vastus lateralis and rectus femoris muscles shows an anechoic area that infiltrates both muscles.**

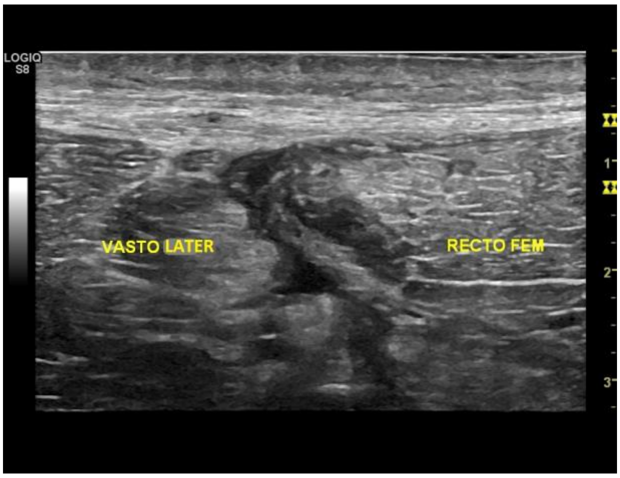
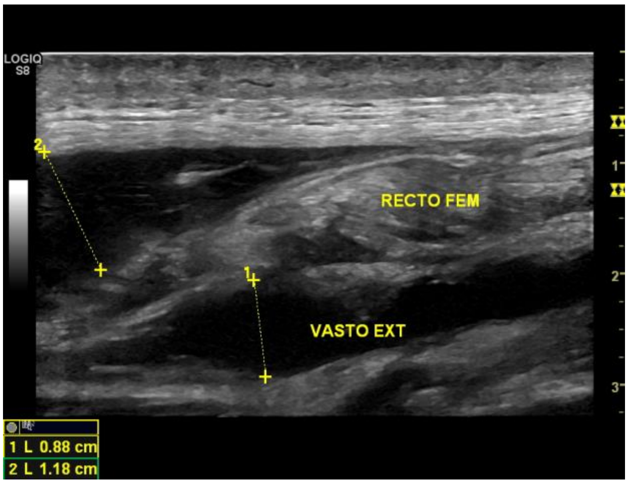
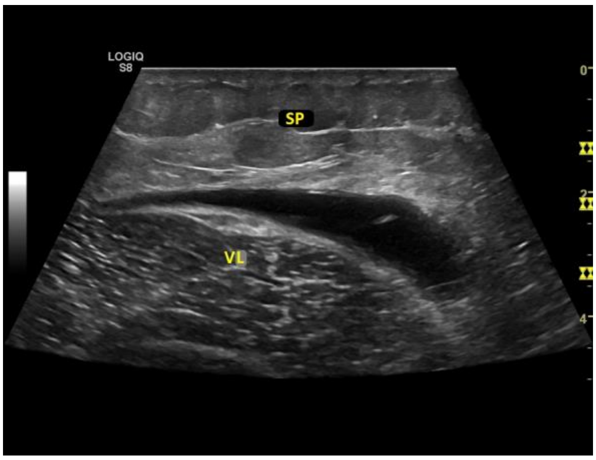


Figure 3 **Third degree extrinsic muscle injury. The US examination of the lateral aspect of the thigh shows an anechoic defect that divides into two compartments (0.88 and 1.28 cm thick), corresponding to the haematoma produced by blunt trauma.**



Finally, in some bruises, the subcutaneous cellular tissue is affected with thickening taking on an hyperechoic appearance, sometimes accompanied by serous effusions trapped between the subcutaneous fat and the deep fascia also known as Morel-Lavallee effusion [Figure 4].

Figure 4 **Morel Lavallee serous effusion. In this patient, an anechoic area with regular borders is visualised, which is located below the subcutaneous plane (SP), without affecting the vastus lateralis muscle (VL). This image corresponds to a serous effusion of Morel Lavallee, as a result of a bruise on the leg.**



Indirect muscle disorder or injury

Strain is an acute indirect muscle injury that occurs during activity, typically related to excessive stretching of a contracted muscle during eccentric exercise while engaged in sports that emphasize speed and power, such as soccer, American football, rugby, and track and field [(16)]. In these situations, the elasticity of the muscle can be overcome, during an eccentric muscular activation.

The risk of injuries due to muscular distraction increases in high-demand sports and represents a high percentage of all acute sports injuries. The most commonly injured muscles are the hamstrings, the rectus femoris and the medial head of the gastrocnemius, all with a higher percentage of type II fibres, a bipennate architecture, which cross two joints and are usually injured during the eccentric phase of muscle contraction. Although the diagnosis is usually clinical, imaging allows to assessment of its extent and location, as well as the relevant prognostic factors in terms of recovery time, return to play after the injury and the risk of recurrence.

Through a classification based on the time of evolution, two types of indirect muscle disorder or injury are distinguished [(14)]. Functional muscle disorder that include overexertion-related, muscle disorder and neuromuscular muscle disorder (less frequent), and on the other hand, the structural muscle injury, including muscle tears.

Functional muscle disorder

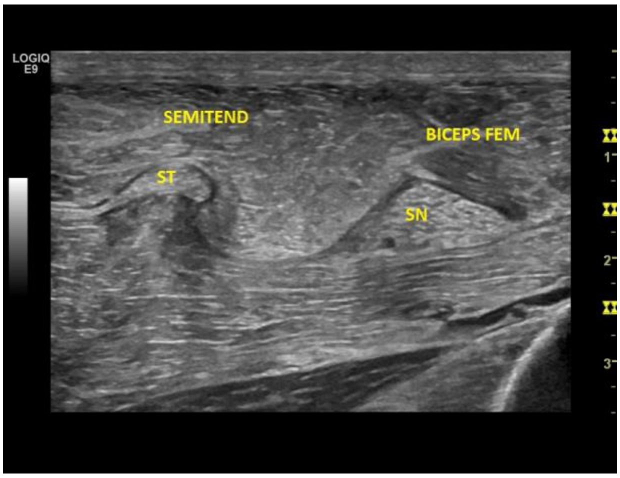
Functional muscle disorders, regardless of any structural muscle damage, can also be considered injuries since, the athlete loses time in sports activity according to Fuller's criteria [(17)]. These disorders produce a functional limitation for the athlete, such as the painful increase in muscle tone that can evolve if the athlete does not rest leading to a structural injury. There are no abnormalities seen on imaging such as magnetic resonance imaging or ultrasound, since they have no macroscopic evidence of structural damage [(14)].

Other characteristics of these disorders are that they have a self-limited evolution are without structural damage, and have a favourable prognosis. These include fatigue-induced muscle disorder (1A Munich Consensus) and delayed-onset muscle soreness or DOMS (1B Munich

Consensus). The fatigue induced muscle disorder produces aching muscle firmness, that increases with continued activity and can cause pain at rest, during or after activity.

Delayed-onset muscle soreness or DOMS is a pain that appears between 12 and 24 hours after performing a generally eccentric strenuous exercise, and is caused by tissue involvement of muscle fascicles and especially myotendinous junctions. The intensity, rather than the duration, of exercise is most closely related to the risk of developing DOMS [(18)]. The clinical signs include oedematous swelling, stiff muscles and pain on isometric contraction. Although the diagnosis is clinical, the imaging test plays an important role in the exclusion of a muscle injury. Ultrasound examination is normal, although sometimes diffuse muscular oedema can be seen [Figure 5].

Figure 5 **Diffuse muscular oedema. The ultrasound examination of the posterior aspect of the thigh allows us to see the hyperechogenic hamstrings. It is difficult to distinguish the echogenicity of the muscle with DOMS from the sciatic nerve (SN) and from the semimembranosus tendon (ST).**



Structural muscle injury

This group of indirect muscular lesions show structural damage, usually located at the muscle – tendon junction [(3, 5, 19)] and the presence of histological changes allows diagnosis by ultrasound and MRI. Within the process of repair of the muscular lesion, the first phase of degeneration lasts 2-3 days, before the start of the inflammatory process, hardly produces any histological changes. For this reason, unless the lesion is large or there is heavy bleeding, no changes on the ultrasound image will be seen [(20)]. In all cases, acute pain appears, and in some of them there may be oedema, haematoma and functional disability. This group includes the elongation or muscular stretching or minor partial rupture (3A of Munich), the moderate partial rupture (3B of Munich) and the total or subtotal muscular rupture, in many cases associated with tendon avulsion (4 of Munich) [(14)]. In all these cases imaging allows one to visualize the damaged area and to determine the size of the rupture, as well as the volume of the haematoma produced.

Minor partial rupture or stretching (3A of Munich)

Affects the primary fascicles formed by a set of muscle fibres surrounded by the endomysium. Of the cases of rupture this is the most benign and has the best prognosis. It is caused by muscular distraction as a result of excessive stretching of the muscle fibres. The clinical signs are pain, gradually increasing muscle firmness and tension and cramp-like pain, and functional impotence. The pain disappears with rest and increases with simple or contrary active mobility, although such movements are possible. In this lesion there is no swelling or bruising and palpation increases pain. Although the ultrasound signs are scarce, there may be thickening of the affected muscle, with the presence of small areas with greater or lesser echogenicity, which change the normal expected muscular pattern [Figure 6]. In addition, there is no interruption of the conjunctive septa, nor formation of blood collections. When a Power Doppler scan is performed, an increase in vascularity is usually observed [(21, 22)] [Figure 7].

Figure 6 Minor partial rupture. The transverse section on the medial side of the thigh, allows us to visualize in the adductor longus muscle (AL) an area of

hyperechogenicity (arrows). This image is above the brevis adductor magnus (AM) and near the gracilis muscle (GRAC).

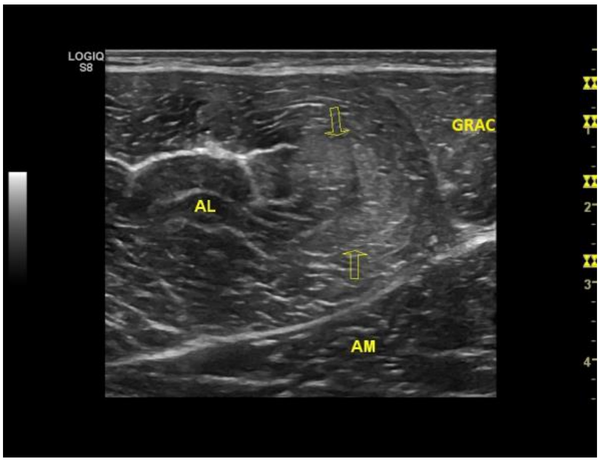
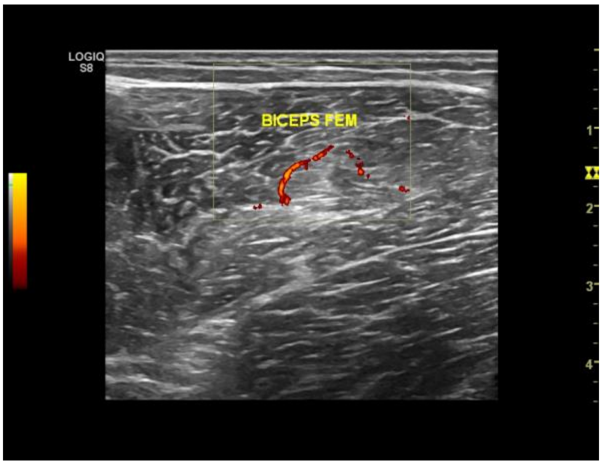


Figure 7 Minor partial rupture. An axial examination of the posterior aspect of the thigh, shows us an increase in echogenicity within the biceps femoris, with its poorly defined borders. Note the increase in vasculature when applying the Power Doppler.

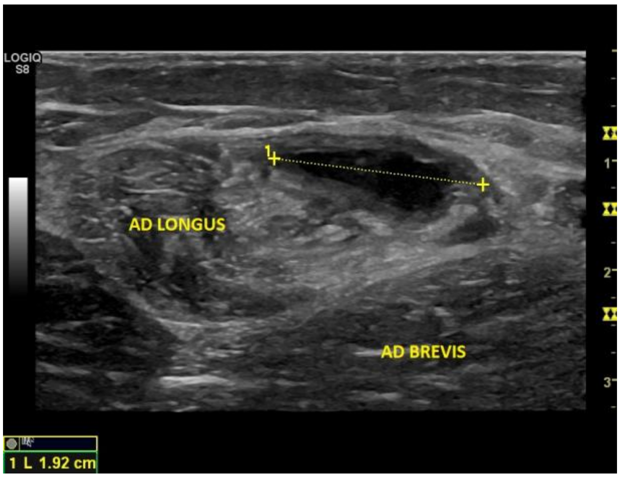


Moderate partial rupture or partial rupture (3B of Munich)

In this case, it affects secondary fascicles that are surrounded by perimysium. The main clinical sign is acute pain that does not improve with rest and appears during a run or jump [(23)].

Immediately, it becomes a stabbing discomfort, accompanied by functional impotence. In some cases, the inflammation can be fluctuating, thus confirming the production of a bruise. Typical ultrasound signs are the defect that disrupts the fibrillary pattern of the muscle and the presence of blood collections in the area of the injury [Figure 8].

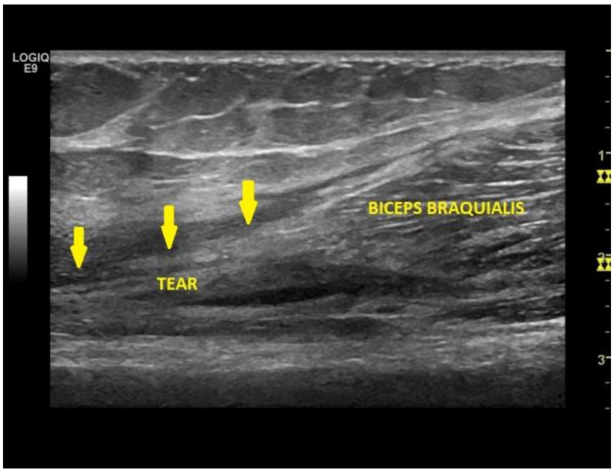
Figure 8 Partial rupture. By an examination in short axis on the adductor longus muscle, an irregular anechoic area is observed in the muscular belly, which corresponds to a fibrillar rupture and formation of a haematoma



Subtotal muscle tear or/and tendinous avulsions (4 of Munich)

In these patients tear involves the subtotal/ complete muscle diameter/ tendinous injury at the bone–tendon junction. The clinical signs are sudden syncopal pain and a tearing sensation. The athlete feels an audible "click" that prevents him/her from shows a depression and the retraction forms a bulge above the area of the interruption [Figure 9]. In these total muscle tears, the disruption usually affects the entire thickness of the muscular belly and the ultrasonic examination provides images showing the muscle retracted and hyperechoic, with the presence of a large muscular haematoma [Figure 9].

Figure 9 **Subtotal muscle tear. In this patient, the retraction of the tear in the biceps brachialis can be seen forming a distal stump (Popeye's sign). In the ultrasound image, the area of rupture between the broken ends is observed (arrows).**

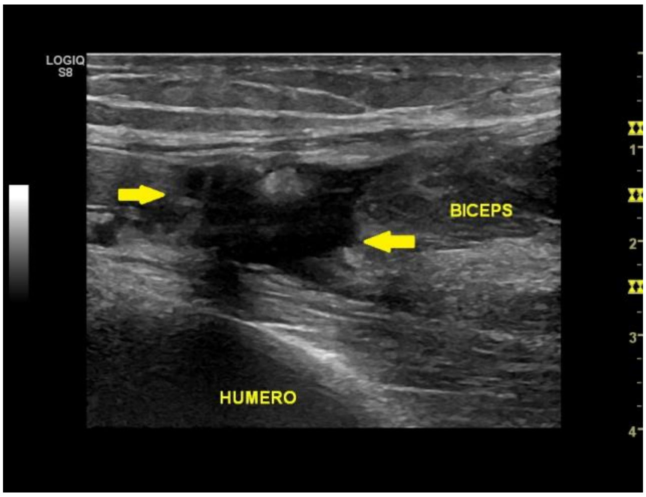


When the lesion evolves, the haematoma organises and inside the damaged muscle, scars appear that occupy its interior and sometimes take the appearance of a bell clapper [Figure 10]. A dynamic study and the compression manoeuvres, allow the demonstration of the mobility of the torn muscle end, as well as the floating character of the scars and remains of fibrin, which are seen inside the blood collection [Figure 11]. Over several days the haematoma is reabsorbed and the muscle adopts a very hypoechoic appearance with regeneration of some connective septa in its interior with a linear and hyperechoic pattern.

Figure 10 **Subtotal muscle tear. In the short axis of medial aspect of the thigh, a rupture of the adductor longus muscle (AL) is observed. A large haematoma completely**

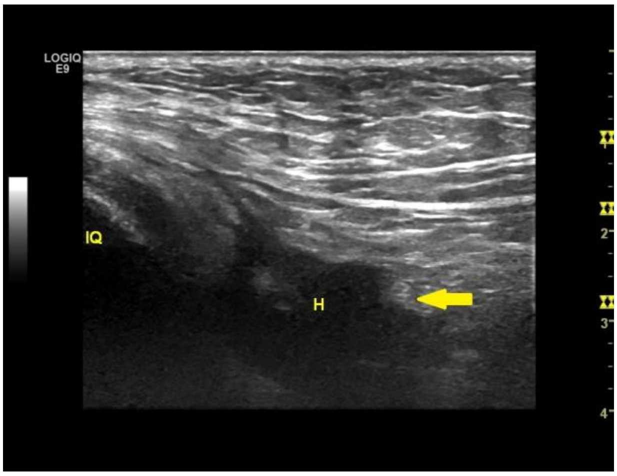
occupies the space of this muscle, unlike the adductor brevis (AB) and the adductor magnus (AM), which maintain their fibrillar pattern.

Figure 11 Subtotal muscle tear. In the longitudinal examination of the biceps brachialis (proximal portion), the area of rupture and the stump floating inside the haematoma can be seen (arrows).



This group includes avulsions, frequently seen at the proximal insertion of the rectus femoris, hamstrings, long adductor and distal insertion of the semitendinosus. The clinical signs are intense pain and loss of function, in addition to the palpable defect and ecchymosis. The ultrasound examination shows the defect that affects the entire thickness of the muscle and the fluid collection that interposes between the ends of the rupture [(24)] [Figure 12].

Figure 12 Tendinous avulsions. This image shows the rupture of the communis tendon, which appears separated from the ischium (arrow) by the haematoma (H). This is the appearance of a tendon avulsion.



Classification of the muscle lesion according to the place where the tear has occurred

The classification system described above does not define the exact location of the lesion, although with the imaging procedures, ultrasound and MRI, it can be accurately identified. Therefore, we must expand that classification, providing data on the size and exact location of the muscle lesion.

In the chain that connects muscles, tendons and bones, the weak place where the greatest number of injuries occurs vary with age. In children, when excessive stresses are applied on this chain, the biomechanical weakness of the growth plates can cause apophyseal avulsion fractures. In young people and adults, the mechanical deficit usually occurs in the myotendinous junction, causing breakage here. In general, strains and complete tears occur most frequently in these myotendinous junctions, in which the tendon detaches from the muscle belly. Generally, in eccentric muscular actions, when the muscular tension increases suddenly, the damage is located in the area under the epimysium.

However, generally, fascia and muscular bellies suffer fewer injuries than myotendinous junctions. These fascial lesions affect the medial gastrocnemius and the biceps femoris more often because the differentiated contractions of the adjacent muscular bellies, cause a significant stretching of the fascia, giving rise to the aponeurotic lesions due to distraction.

The hamstring injuries at the proximal level typically occur in the myotendinous junction, which is a transition zone organised in a system of many folded membranes, designed to increase the area of the junction zone and thus dissipate the energy. Regardless of the type and direction of the applied forces, as well as the muscular architecture, the region adjacent to the myotendinous junction is the most susceptible to injury.

In short, an image classification method is currently proposed that precisely defines muscle lesions by the anatomical place where it has occurred, distinguishing different areas of injury [(25)].

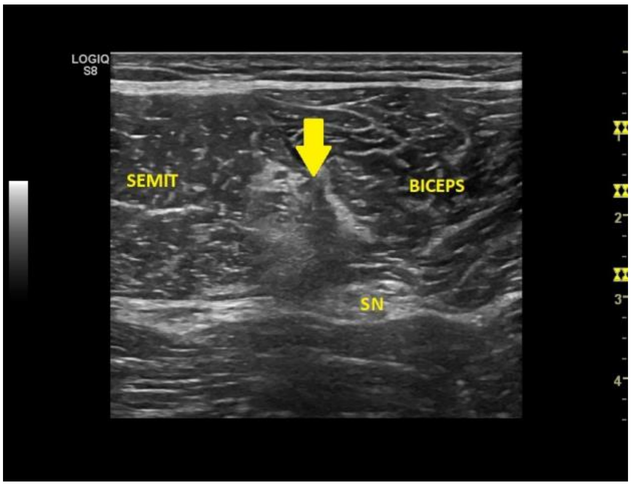
Therefore, to emphasise the concept that an ideal classification system should report on the extent, size and exact location of a muscle injury [(6)], we propose to add to the classification of the Munich Consensus, the location of the lesions as proposed by Chan [(26)], a system that is valid for images obtained through MRI and US. This classification defines more precisely the location of the rupture in the different areas of the muscle. The location of the area of injury performed by ultrasound is vital for treatment, prognosis and return to sport. Through this classification, the ruptures can be in the proximal and distal tendon, in the proximal and distal myotendinous junction (MTJ) and in the belly of the muscle. In addition, within the muscle itself, the lesion can be located at the intramuscular, myofascial, myofascial / perifascial, myotendinous or finally a combined level.

Proximal myotendinous junction

Leaving aside, injuries that affect the proximal and distal tendon, we will first see those that affect the proximal myotendinous junction (Figure 13).

Figure 13 Tear of the proximal myotendinous junction. In the short axis examination of the proximal communis tendon between the biceps femoris and semitendinosus

muscles (SEMIT), we can see the hypoechoic image (arrow), which corresponds to the rupture above sciatic nerve (SN).



Belly of the muscle

Secondly, the lesions that affect the muscle in its proximal, middle and distal part are described, and within these three types, the lesion can be intramuscular [Figure 14], myofascial [Figure 15], associated myofascial to peripheral [Figure 16], myotendinous and combined.

Figure 14 **Intramuscular rupture. In the short-axis study of the semitendinosus muscle (ST), the disruption of its fibres and the occupation of space by a hypoechoic haematoma can be seen (arrow).**

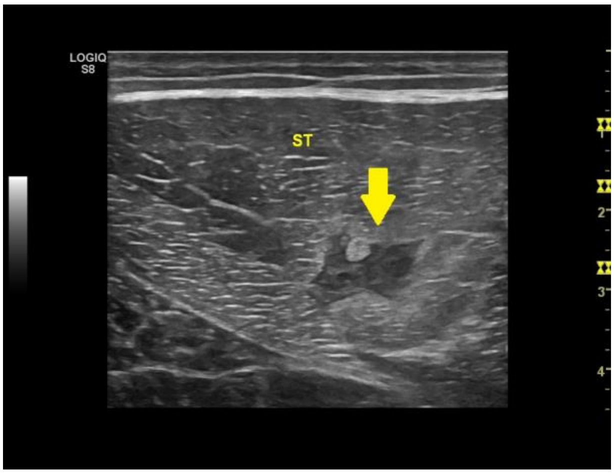


Figure 15 **Myofascial rupture. In the short axis examination of the distal biceps femoris muscle, we can see an area of myofascial rupture (arrow) that affects the long head of the biceps (LH).**

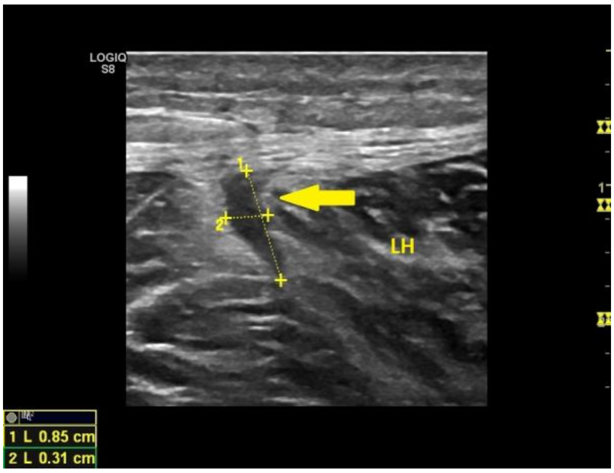
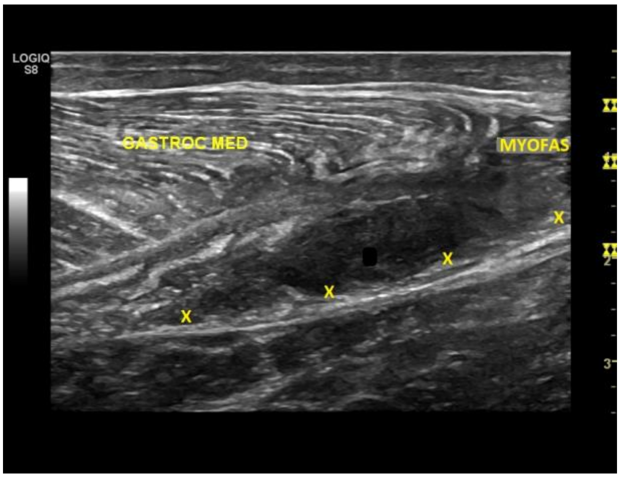


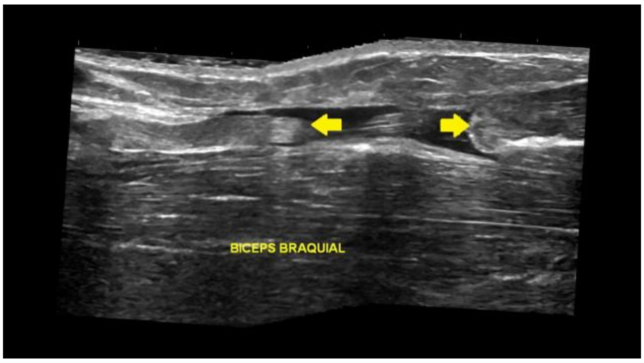
Figure 16 **Myofascial injury associated with myoaponeurotic rupture. In the study in the long axis of the leg, the myofascial rupture of the gastrocnemius medialis muscle can be seen, combined with the myoaponeurotic tear (X).**



Distal myotendinous junction

Finally, in the last type of lesion, the distal myotendinous junction is affected, causing the tendon fibres to disintegrate from their own epimysium [Figure 17].

Figure 17 Tear of the distal myotendinous junction. The longitudinal study of the distal portion of the biceps brachial demonstrates the presence of a haematoma between the stumps of the torn muscle (arrows).



Conclusions

Repeated physical exercise and sport causes a large number of muscle injuries. Clinical studies regarding their treatment and resolution are sparse.

The mechanism of injury may be secondary to multiple causes, although, it is much more frequent in polyarticular muscles, in conditions related to increased fatigue and in the presence of unfavourable environmental conditions.

We recommend following the Munich classification of muscle injuries. It divides the lesions into those of a functional type that do not demonstrate changes on imaging and those of a structural type that are visible on ultrasound and MRI. In addition, they are classified according to size.

It is also necessary to add the location of the lesion. For this, the classification of Chan allows, using ultrasound to divide them according to the affected area. This diagnostic information is very important because it may determine the type of treatment, the prognosis and the period of rest before a sports person plays again.

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