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Pictorial review

MRI of plantar fasciitis

B. Roger, Ph. Grenier

Service de Radiologie Polyvalente Diagnostique et Interventionelle, Hôpital de la Pitié, 83, boulevard de l'Hôpital, F-75651 Paris Cedex 13, France

Abstract. At present, MRI is the only imaging method that can precisely visualize lesions of the superficial plantar aponeurosis, whether they be musculoaponeurositides, enthesopathies or tears, and whether they be acute or chronic, with or without complications. By its direct visualization of the lesion, MRI enables an accurate assessment of the injury to be made and thereby better orients the therapeutic strategy.

Key words: MRI – Superficial plantar fascia – Musculoaponeurositis – Enthesopathy – Traumatology

Introduction

Physical activities, be they for sport, work or normal movement, subject the foot to important constraints and all the anatomical structures rendered more fragile by these forces can become the sites of injury. Among the structures that can be affected, a lesion of the superficial plantar aponeurosis (SPA) represents a specific anatomical-pathological entity [1]. Although their true frequency is still underestimated [2], SPA lesions are becoming more well known because of the good visualization obtained by various imaging techniques, particularly magnetic resonance imaging (MRI).

Anatomy of the SPA

The SPA divides into three parts – one central and two lateral (outer and inner) – separated from one another by intermuscular septa [3]. Each compartment corresponds to a distinct muscle group: (1) the outer portion covers the muscles of the small (fifth) metatarsus; (2) the inner portion overlies the muscles of the big toe, especially the abductor hallucis muscle; (3) the central portion lies over the plantar flexors.

Correspondence to: B. Roger

The SPA is triangular in shape: its posterior peak is attached to the posterior inner tuberosity of the calcaneus (with the superficial muscles indicated above), while its base divides into five pre-tendinous processes – one for each toe – at the level of the metatarsophalangeal articulations (Fig. 1).

Superficially, the SPA is bounded by the plantar fatty cushion, which harbors three serous bursae facing the inner calcaneal tuberosity and spans all five metatarsi.

Biomechanical functions of the SPA

The foot serves as a shock absorber and as the push-off point to propel the body. In these two functions the intrinsic musculotendinous complex is put under tension to participate in both the movements of absorbing the shock and propulsion [4].

The existence of the functional bone-tendon-muscle chain – the sural-Achilles tendon-calcaneal-SPA system – is well established. The prolongation of Achilles tendon by the plantar fascia, facing the posterior inferior calcaneal tuberosity, increases the resistance of these tendinous structures, thereby assuring better transmission of the constraining forces and thus better equilibrium of the heel.

Among the different hypotheses concerning the specific mechanical function of the SPA, we have retained that of Kwong et al. [5] which accords the plantar aponeurosis a role in absorbing the shock during the first part of the step, whereas during the second part it acts as a spring. In addition, in these two positions the musculoaponeurotic system is under tension, thereby contributing to the protection of the foot.

Etiopathogenesis of SPA tears

Mechanical demands cause microtraumas and repeatedly put the fascia under high tension. Sudden impulsion,

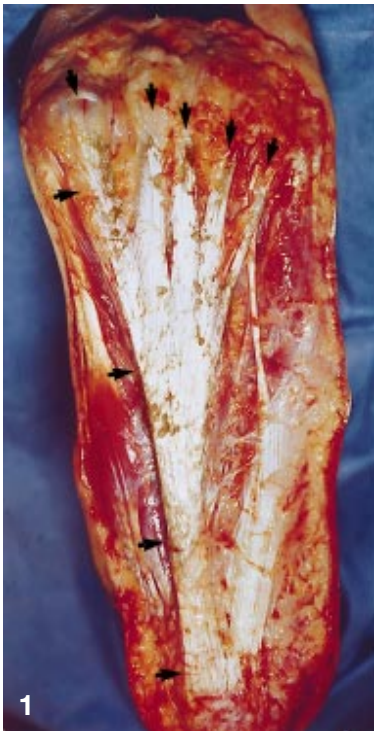


Fig. 1. Dissection of the superficial plantar aponeurosis (SPA) clearly showing the triangular shape, from its calcaneal summit to its broad metatarsal base

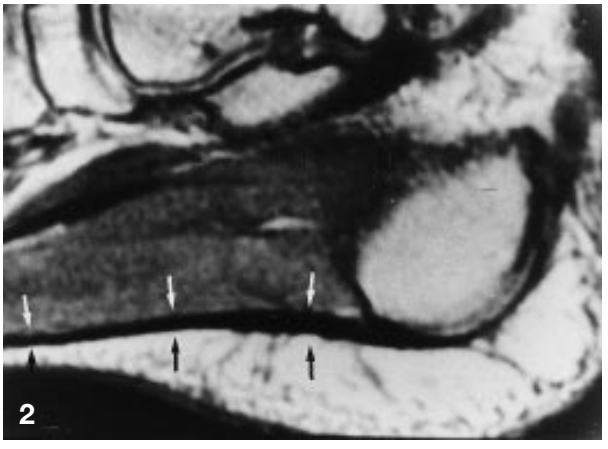


Fig. 2. T1-weighted sagittal section of the normal plantar fascia. The SPA is seen as a fine and regular homogeneous hyposignal that is slightly thicker at its calcaneal origin

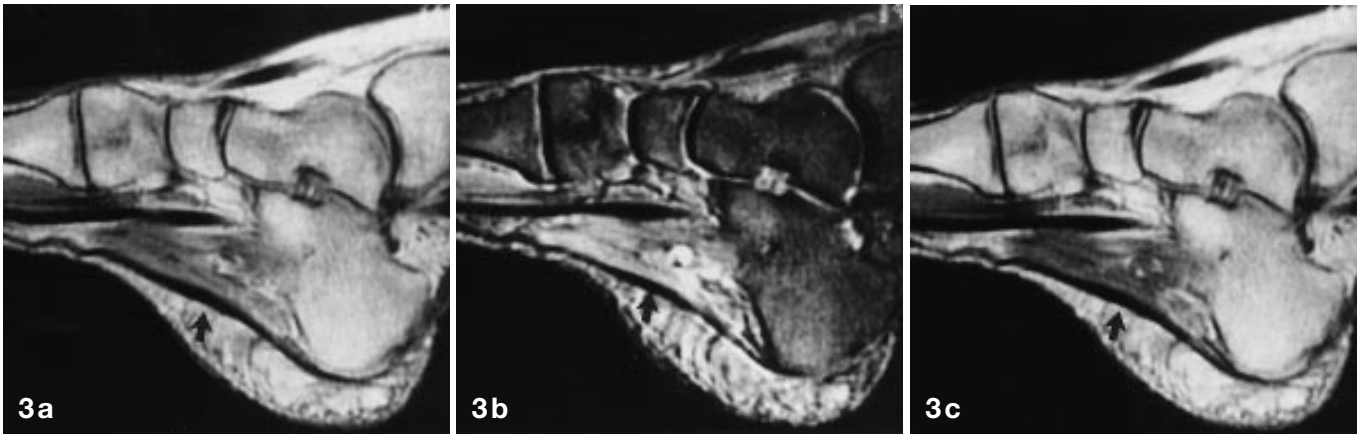


Fig. 3. T1- (**a**), T2- (**b**) and post-contrast T1-weighted (**c**) sagittal slices of a musculoplantar aponeurositis. The median portion of the SPA is thickened and irregular. The irregularity predominates on the muscle side and the signals generated by the SPA and adjacent elements are not modified

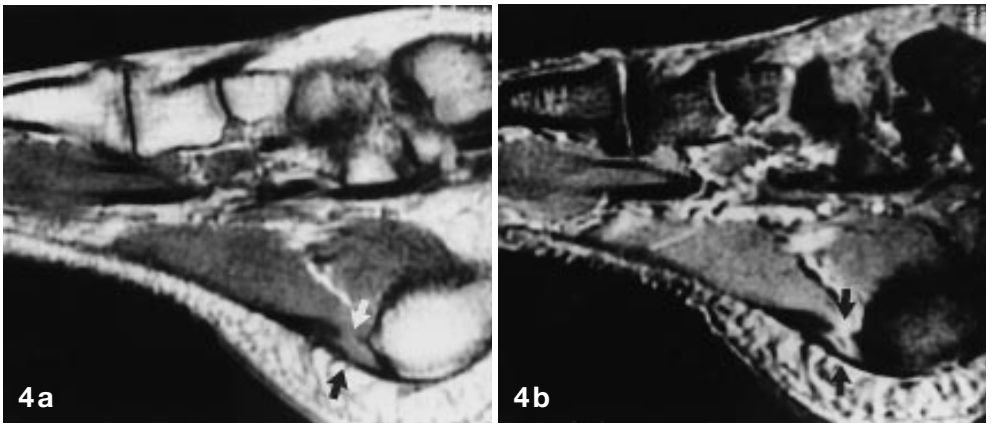


Fig. 4. T1- (**a**) and T2-weighted (**b**) sagittal sections of an enthesopathy. The SPA is thickened and irregular at its calcaneal origin. Within this thickening, the signal is abnormal – an isosignal on T1-weighted images and a hypersignal on T2-weighted sequences. A small calcaneal spur can be discerned above the origin

landing or take-off, movements that are aggressive to the SPA, are sometimes responsible for overstepping physiological boundaries, thereby explaining the frequency of these lesions among trauma pathologies in athletes [6–8].

Structural abnormalities may increase the constraints imposed on the SPA and favor the development of an aponeurotic lesion [5, 9]. Plantar flexion of more than 60° or diminished dorsal flexion is a good predictive factor, although no direct relationship seems to exist with

the height of the arch, an inequality of the length of the legs or pronation of the heel.

Injections of corticosteroids have classically been incriminated as a cause of SPA rupture.

Lastly, a pre-existing lesion, by rendering the SPA more fragile, can eventually lead to tearing. Indeed, this is the case in musculoplantar aponeuritis due to overexertion in athletes or fibrous degeneration [10].

MRI examination

Our MRI protocol [11] is as follows: (1) T1-weighted sagittal and transverse slices with gradient-echo (GE) imaging at 0.5 T [320/20 (TR/TE), 90° flip angle, 512 × 224 matrix, 17 × 17 FOV, two excitations] and with spin-echo (SE) sequences at 1.5 T [320/13 (TR/TE), 512 × 224 matrix, 17 × 17 FOV, two excitations]; (2) T2-weighted sagittal slices with GE imaging [320/20 (TR/TE), 25° flip angle, 256 × 192 matrix, 17 × 17 FOV, two excitations]; (3) T1-weighted sagittal and transverse slices with intravenous (IV) injection of contrast medium; (4) knee phased-array coil and the possibility of comparative planes, notably transverse; (5) contiguous 3-mm thick slices on GE images and 10 % gap on SE sequences.

In parallel with this MRI examination, all patients had weight-bearing profile plain radiographs of the foot.

MRI findings

On an MR image, the normal SPA is seen as a fine linear structure, emitting a hyposignal interposed between the muscle masses (intermediate signal) and the plantar fatty cushion (hypersignal) [2, 12]. On sagittal slices, its thickness is constant from its calcaneal origin and throughout its posterior half, and progressively thins until the metatarsal heads (Fig. 2).

The pathological presentation of the SPA on MRI varies according to the type of lesion – musculoaponeurositis and degeneration, enthesopathy or rupture – and its duration, especially the existence of complications [12, 13].

In musculoaponeurositis, the fascia is thickened over several centimeters, usually irregular and poorly delimited but continuous. It generates a hyposignal on T1-, T2- and postcontrast T1-weighted images, and inflammatory reactions are minor (Fig. 3).

In enthesopathy the lesion is located opposite the calcaneal origin and inflammatory reactions are strong. The SPA is thickened at its origin and the T2- and postcontrast T1-weighted images show an intense homogeneous hypersignal spanning the length of the interface with the muscles. The signal anomalies can also include the subperiosteal part of the enthesitis (Fig. 4).

In a recent rupture, the area of the tear is seen on the T1-weighted sequence as a widening of the SPA outline; in extreme cases there is a total obliteration of the hyposignal. A very clear hypersignal is seen on T2-weighted sequences opposite the rupture in the adjacent muscles. The postcontrast T1-weighted sequence allows an improved analysis of the details (rupture, edema, hematoma) (Fig. 5).

A long-standing rupture of the SPA may generate several images:

Hypertrophic scar: the SPA displays a fusiform or nodular thickening, seen as a homogeneous hyposignal on T1- and T2-weighted sequences that is not modified by IV contrast-medium injection. Clearly delimited, this scar is most often located close to the calcaneal origin and its size varies according to the extent of the tear (Fig. 6).

Cystic image: the SPA is the site of a localized, spherical thickening, with splitting of the superficial and deep elements forming a cavity emitting a signal isointense to adjacent muscles on T1-weighted sequences and a hypersignal on T2-weighted images (Fig. 7). During surgery, the cavity is found to contain a serous liquid corresponding to the MRI signal detected (Fig. 8).

Fibrillar and lamellar image: the thickening of the SPA is fusiform and lamellar, giving rise to a likeness resembling rails.

Encysted hematoma: rupture of the SPA involves the adjacent muscle harboring an encysted hematoma.

Microcalcifications: these sequelae indicate the evolutionary nature of the SPA rupture. Plain radiographs can detect them, whereas they are less consistently identified by MRI because calcifications contain few hydrogen protons and thus emit no signal.

In addition to these images, the fat pad of the heel is sometimes the site of inflammatory changes and exhibits abnormal vascularization.

Discussion

Clinical picture

Depending upon the extent of functional disability, partial or total, and its progressive or sudden onset, three clinical profiles corresponding to different types of lesions can be distinguished:

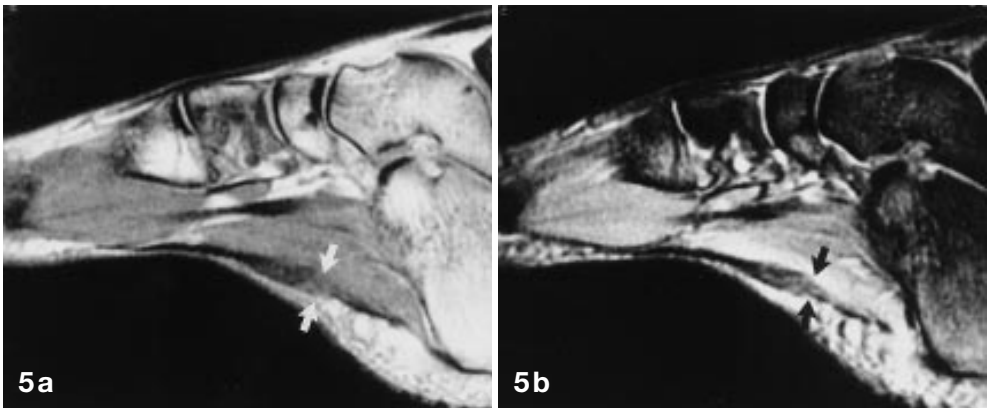
1) Partial functional disability: musculoplantar aponeurositis, which includes degenerative lesions (more or less inflammatory) of variable size situated within the body of the SPA, and lesions of tendinous origin (enthesopathies) associated with a diseased calcaneal socket and microtears of the insertion fibers with inflammatory reactions.

2) Total dysfunction in the context of preexisting pain: rupture of the SPA occurring on the background of musculoaponeurositis or enthesopathy.

3) Total functional disability without preexisting pain: rupture of the SPA.

In addition, as a function of the site of the clinical symptoms, two topographical forms are now recognized which give rise to separate clinical profiles with different prognoses [9]:

1) Posterior internal heel tear, the most common lesion (80 %), corresponds to a pathology affecting the aponeurosis and/or the muscles of the posterior third of the



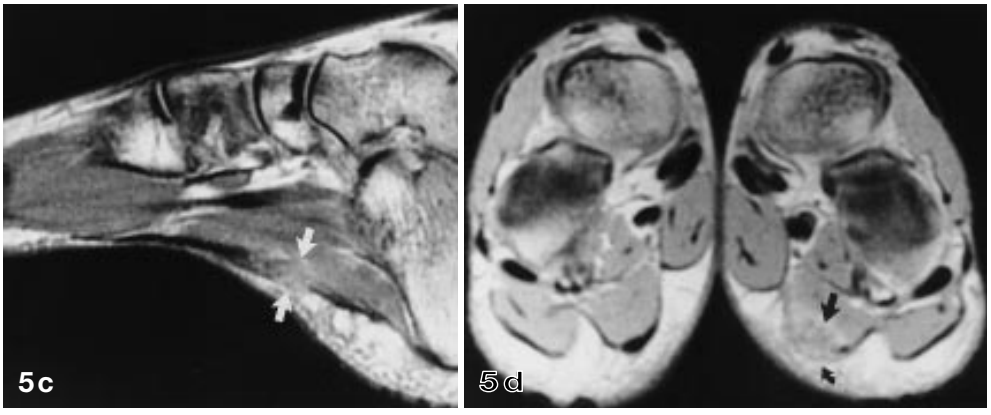
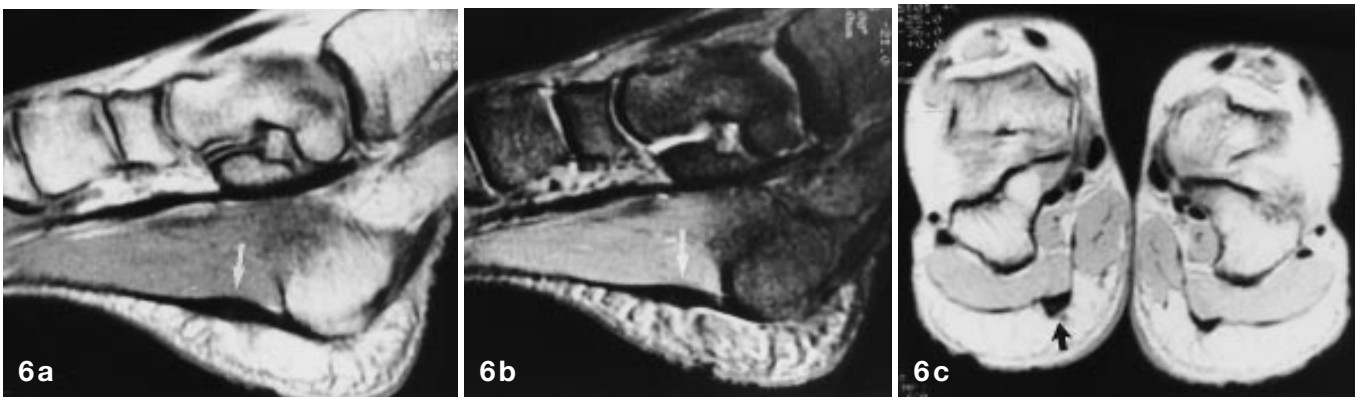


Fig. 5. T1- (**a**), T2- (**b**) and post-contrast T1-weighted (**c**) sagittal sections and comparative (left and right feet) frontal slices (**d**) of a recent complete rupture of the SPA along its internal border at the junction of its middle and posterior thirds. The lesion is seen as a progressive thickening, more or less fusiform, with an isosignal on the T1-weighted sequence, a heterogeneous hypersignal on the T2-weighted image and a clearly enhanced signal after the IV injection of contrast medium. The frontal views clearly show the asymmetry: on the right (lesioned side), the SPA hyposignal has completely disappeared

Fig. 6. Sagittal T1- (**a**) and T2-weighted (**b**) and comparative (left and right feet) frontal T1-weighted (**c**) sequences of a nodular hypertrophic scar. This long-standing tear with a fibrous, nodular thickening is seen as a hyposignal on T1- and T2-weighted images



foot. One must differentiate between a lesion located within the body of the SPA in the last 2 cm of the heel and SPA-insertion lesions on the posterior internal calcaneal tuberosity.

2) Anterolateral plantar injury, seen in 20 % of cases, is located more anteriorly and externally. This lesion is usually observed in high-level athletes and is characterized by its poor functional prognosis.

Complementary examinations

The diagnosis, be it based on anatomical pathology or topography, is primarily derived from clinical observations [1, 6]. The standard complementary examinations usually confirm the diagnosis, either by elimination (radiographs) or by positive identification (sonography). However, these imaging techniques do not generate images enabling a sufficiently fine analysis to describe the lesion precisely, as we demonstrated, with several rare exceptions, in 243 cases.

Standard radiographs of the foot are usually normal. The presence of a calcaneal spur in 50 % of cases indicates the existence of excessive mechanical constraints at the aponeurotic and muscle insertion sites, but is in no way the element responsible for the newly developed symptoms (Fig. 9).

Calcifications of the soft tissues (15 %) located at the inferior face of the calcaneus and in front of the posterior tuberosity seem to reflect the existence of scarring phenomena following SPA rupture and only appear late in the natural history of the tear. The major contribution of radiographs is to eliminate the possibility of a fatigue fracture of the calcaneus, while keeping in mind the limitations of standard films for a recent injury.

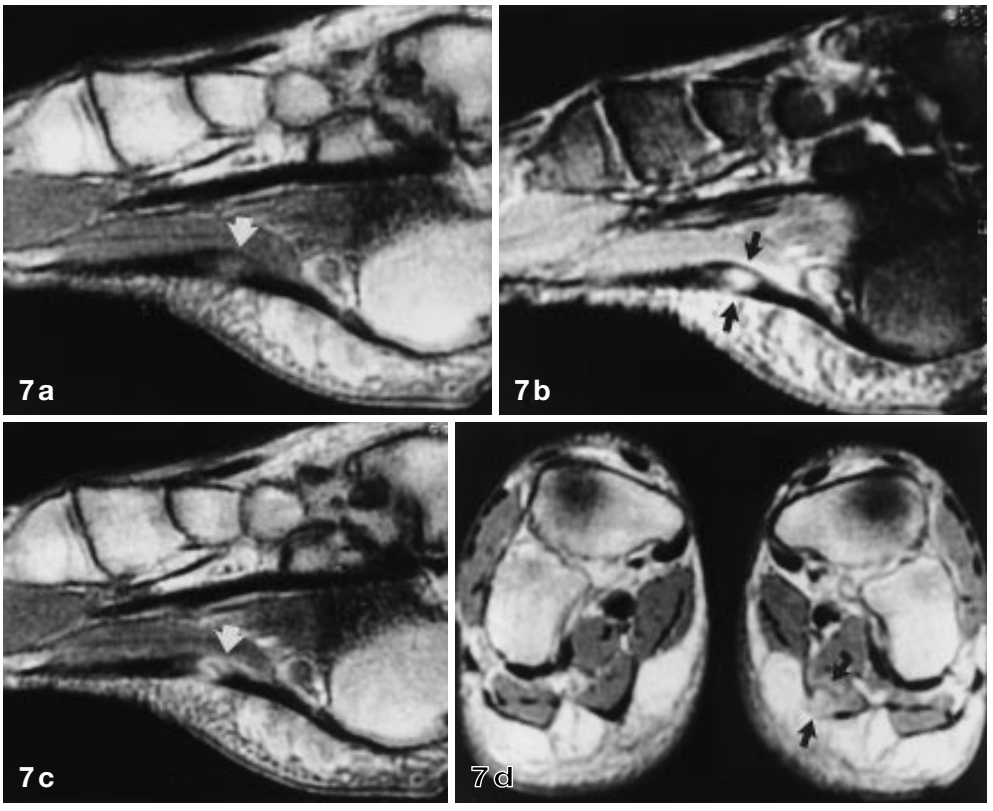


Fig. 7. Sagittal T1- (**a**), T2- (**b**), sagittal (**c**) and frontal (**d**) postcontrast T1-weighted (**C**) images of a cyst. The localized thickening of the SPA assumes the form of the cyst and generates an enhanced internal signal – seen as an isosignal on T1-weighted images and as a hypersignal on T2- and postcontrast T1-weighted sequences. This appearance corresponds to a tear with secondary formation of a cyst containing a serous liquid within the SPA, thus explaining the signal anomalies

Sonography, in a certain number of cases (55 %), has revealed modifications of the SPA, but the lesions are often poorly delimited and the descriptions too imprecise, without taking into account the fact that they are highly operator-dependent. These images can be normal or inadequate except in the presence of subcalcaneal bursitis (hypoechoic zone with posterior reinforcement) or recent total ruptures.

Scintigraphic images completely lack specificity and in no case can they provide the diagnosis alone; in combination with radiographs they can orient the diagnosis towards a fatigue fracture of the calcaneus at an early stage (localized strong uptake) (Fig. 10).

Computed tomography can visualize modifications of the SPA and the sites of these changes, but is restricted to identifying small lesions and does not allow a fine and precise analysis of the exact relationship between plantar muscles and the SPA. In contrast, this technique can show the presence of small calcifications (5 %).

Frontal slices are rarely used to study the SPA along its entire length (examination too long) and sagittal sections are not always easily obtained.

MRI contributes in several ways to the diagnosis of SPA pathology: (1) it specifies the exact site of the lesion (posterior and internal near the origin on the calcaneal tuberosity or in contact with the latter indicating detachment, or more anterior and external; Fig. 11); (2) it can determine the type of lesion – musculoaponeurositis, enthesopathy, rupture, etc.; (3) it allows a precise analysis – nodule, cyst, inflammation, etc.

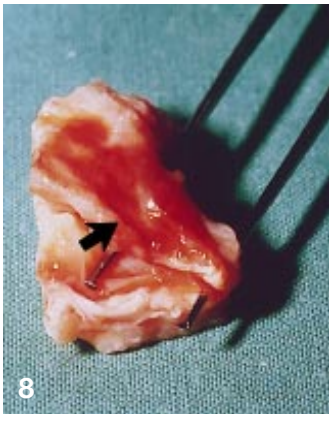
Simultaneously, MRI can also evaluate the tissue surrounding the lesion. In particular, it is able to recognize associated muscle involvement or small hematomas in the soft tissues. This specific and complete assessment is essential in the case of diagnostic uncertainties or to unmask another etiology, either subcutaneous retrocalcaneal or interachilles-calcaneal bursitis, tendinitis of the posterior tibial muscle, fatigue fracture of the calcaneus, involvement of the flexor hallucis longus tendon or a lesion of the tarsal navicular.

On the basis of these observations, the therapeutic approach can be clearly defined.

Conclusion

An SPA lesion, be it a musculoaponeurositis, enthesopathy or rupture, compromises physical, athletic or professional activity. Although medical or orthopedic treatment is often sufficient, once the diagnosis is confirmed, refractory forms do exist and they must be treated surgically [14, 15].

At present, the study of SPA lesions benefits from the contributions of MRI, which is the only technique that can provide the precise, complete and early diagnosis necessary for the optimal choice of the most appropriate therapy. Thus the importance of the role of MRI in diagnosing SPA pathologies is clearly established, especially in chronic forms and ruptures for which surgery may be indicated to alleviate a major functional loss.



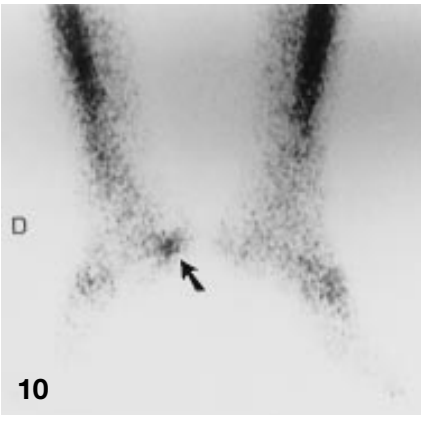


Fig. 8. The surgically removed SPA cyst visualized by MRI in Fig. 7

Fig. 9. Standard radiograph of a musculoplantar aponeurositis subsequently diagnosed by MRI (Fig. 3). The radiograph detected an asymptomatic calcaneal spur

Fig. 10. Scintigraphy of the two heels. The moderately intense uptake of the tracer facing the right calcaneus could indicate a stress fracture. However, in this case, the lesion is an enthesopathy of SPA origin (Fig. 4)

Fig. 11. T1- (**A**) and T2-weighted (**B**) sagittal images of the ruptured SPA of a professional basketball player. This tear is located in a very anterior position in the middle third of the SPA

The excellent correlation found between the elements described on MR images and the observations made during surgery and histological examination of excised tissues justifies the use of this technique every time an SPA lesion is suspected or to evaluate its status.

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