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Review Article

Imaging of Chronic Calf Strain Injuries and Adhesiolysis of Calf Aponeurosis Scarring

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Abstract

Chronic calf strain injuries are an uncommon but potentially debilitating injury which may result in significant functional impairment in runners and time lost from play in athletes. In athletes and runners with previous calf injury, we believe that scarring between gastrocnemius and soleus aponeuroses, particularly in relation to the plantaris tendon, may result in altered calf muscle biomechanics that may predispose to re-injury. Clinically, these patients may present with 'incipient' calf tears or recurrent calf tears. We describe the clinical and imaging findings in chronic calf strain injury and report on a new technique for the management of these injuries, calf aponeurosis adhesiolysis, which may help to restore the normal biomechanical relationship between the gastrocnemius and soleus aponeuroses and the plantaris tendon during activity.

Introduction

Anatomy

The triceps surae muscle complex is comprised of the two heads of the gastrocnemius muscle and the soleus muscle, which converge through their aponeuroses into a single tendon that inserts on the calcaneus [1-3]. The gastrocnemius muscle has a relatively simple morphology. The two heads of gastrocnemius take their origin from the medial and lateral femoral condyles above the knee [4]. As it descends, its fibres begin to insert into a broad aponeurosis that develops on its anterior surface [4]. The aponeurosis progressively tapers and receives the soleus aponeurosis on its deep surface [2,3].

The soleus muscle is more complex. Its origin lies below the knee, from a fibrous arch arising from the fibula and tibia [2,3]. Within the proximal calf, thin medial and lateral intra-muscular aponeuroses lie within the muscle belly in continuity with the tibial and fibular origins of soleus respectively [2,3]. Additionally, it has an anterior and a posterior aponeurosis and a central tendon that arises from the anterior aponeurosis within the proximal calf [2,3]. The central tendon joins the posterior aponeurosis in the lower quarter of the muscle, where the latter converges with the aponeuroses of the gastrocnemius muscles to form Achilles tendon [5].

Cadaveric study has identified that the proximal gastrocnemius and posterior soleus aponeuroses are separate structures [1]. On sonographic examination of the calf, a thin hypoechoic plane appears to be visible between the thin echogenic gastrocnemius and soleus aponeuroses, although this plane is beyond the resolution of MRI. Transverse collagen structures are present between the aponeuroses, resulting in an increasingly firm inter-aponeurotic connection distally, with these distal connections likely corresponding to the surgically described 'conjoint junction [1]. An *in-vivo* study has shown that the gastrocnemius and soleus aponeuroses undergo differential shear or displacement, particularly during maximal plantar flexion, inferring that significant sliding between soleus and gastrocnemius aponeuroses occurs during calf contraction [1].

The plantaris muscle is the often-forgotten structure of the calf and arises from the posterolateral proximal tibial metaphysic [1-3]. It has a small proximal muscle belly with a long tendon that passes obliquely downward and medially from its origin, lying edge to edge with the lateral head of gastrocnemius proximally [1-3]. It passes deep to the medial head of gastrocnemius near the midline of the calf to lie between the aponeuroses of gastrocnemius and soleus and emerges from the calf at the medial border of the Achilles tendon [3]. The plantaris tendon has also been shown to undergo differential displacement when compared to the Achilles tendon, causing shear of the plantaris against the muscles and tendons of gastrocnemius and soleus [6].

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Acute and Chronic Calf Strain Injury

Acute calf muscle strain injury is a relatively common muscle injury seen in the general community, as well as in athletes [7]. The prototypical calf injury ('tennis leg') typically occurs at the musculotendinous junction (MTJ), usually consisting of a small to moderate sized tear at the distal medial head of gastrocnemius [8]. Most 'tennis leg' injuries have a good prognosis and overall there is a low recurrence rate [9]. More recently, there has been increasing recognition of the greater incidence of soleus strains in calf injury presentations amongst athletes [10]. This recognition is likely related to the more appropriate use of MRI in the assessment of calf injuries and the appreciation that dual calf strain injuries of the gastrocnemius and soleus are also common [10,11].

Chronic calf injuries are less common and poorly described in sports medicine and musculoskeletal imaging literature. In our experience they are usually seen in the setting of previous moderate to severe calf tears. They are clinically important because they may have a significant effect on quality of life in community-level sportspeople whose running loads may be severely limited, and may be season or career-ending in elite athletes because of failure to progress in rehabilitation [12]. Imaging is often reported as 'normal' or 'negative' for acute injury however, scarring of the one or both of the gastrocnemius and posterior soleus aponeuroses and/or the plantaris tendon is usually visible. We believe that the presence of scar-related adhesions between the soleus and gastrocnemius aponeuroses, particularly in relation to the plantaris tendon, may alter the normal biomechanics of the triceps surae muscle complex.

Clinical and Imaging Findings

In patients presenting to our sports imaging clinic with chronic calf injuries, we have observed 2 main presentations - incipient calf tear and recurrent calf tear. We describe the clinical features and imaging appearances of these two injuries below and propose a new treatment for the management of patients presenting with chronic calf strain injury.

Incipient calf tear

In runners and sprinting athletes, patients with previous calf strains may present with an 'incipient calf tear', although the history of previous calf injury may not always be recalled. Athletes may experience calf tightness, pain and/or the feeling of an impending calf strain. Alternatively, they may stop due to the sensation of a calf tear ('pseudo-tear'). Symptoms are typically felt along the course of the plantaris tendon within the medial mid-calf. They are regularly described by runners as occurring at approximately the 4 kilometre mark (which we refer to as the '4k calf') or 15 to 20 minutes into a run. In sprinting athletes, incipient tears more commonly present as the inability to progress sprinting speeds during post calf-strain rehabilitation. An athlete will typically describe not being able to sprint beyond 70-80% of maximum speed without pain, significant tightness or the feeling that their calf will tear.

On clinical assessment, focal thickening may be palpable within the calf. This is usually at the site of scarring and is most often seen medially within the mid-calf, along the course of the plantaris tendon. There may be tenderness on palpation at the site of thickening, or occasionally lateral to the thickening, usually at the same level. Weight bearing ankle dorsiflexion, as measured by the 'knee to wall' test, is often usually reduced.

At imaging, no acute calf tear is seen, and scans are often reported as 'normal', although there are almost always features of injury. Subtle signs of acute injury, such as mild muscle swelling or vasodilatation, may be present and very subtle low-signal thickening of the aponeuroses, due to micro-tearing, may also be observed (Figure 1). Bilateral calf MRI is therefore required to accurately assess for the presence of low-grade calf muscle injury. We believe that the sensation of an incipient calf tear may be due to micro-tearing of the calf aponeuroses that is occult at imaging because routine calf MRI techniques lack the spatial and contrast resolution to detect low-level injury in these fine structures. Thickened scars of the soleus and/or gastrocnemius aponeuroses and inter-aponeurotic tissues related to previous calf strains are usually appreciable and may be marked in some cases (Figure 2). However, subtle thickening of the aponeuroses is not uncommon and readily overlooked (Figure 3). This is usually because the subtle aponeurosis scar, like the aponeurosis itself, is also a fine, low-signal structure, and therefore non-pathological looking, on MRI. It is also of similar echogenicity to the aponeurosis on ultrasound and again, may be difficult to perceive. Careful review of the gastrocnemius and soleus aponeuroses on ultrasound may also reveal loss of the hypoechoic plane between the aponeuroses,

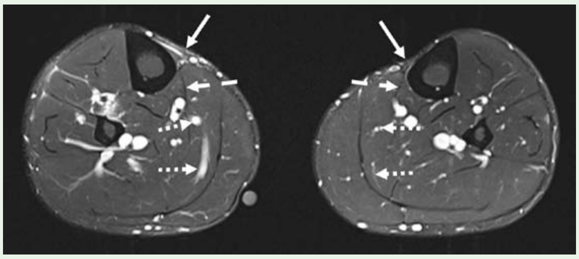

Figure 1a: 27-year-old elite national Australian Rules Football (ARF) player with right calf tightness post-game. Bilateral axial T2-FS calf MRI with oil bead indicating the region of clinical interest. No acute right calf tear has been demonstrated. However, there is evidence of low-grade right calf injury, with loss of soft tissue concavity at the posterior border of the tibia (arrow), indicating mild generalized calf swelling, and dilatation of the soleal veins, when compared to the left (dotted arrow). The right medial intra-muscular aponeurosis is subtly thickened when compared with the left (dashed arrow), indicating possible micro-tearing.

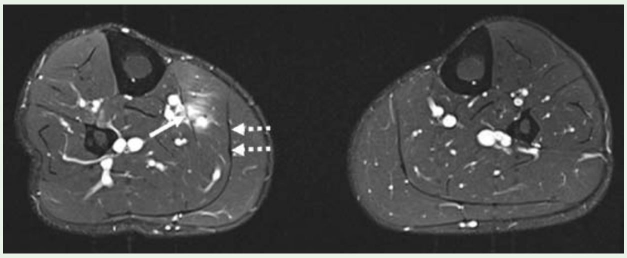

Figure 1b: Bilateral axial T2-FS calf MRI 3 weeks later, following acute right medial calf strain during a game. Image at the same level as Figure 1a showing a small tear of the right medial soleus intra-muscular aponeurosis (arrow). The plantaris tendon and adjacent gastrocnemius and soleus aponeuroses (dotted arrows) appear thickened bilaterally. The player underwent calf adhesiolysis for recurrent calf tightness on 2 occasions with initial improvement in knee to wall measurements from 12 to 14cm. Return to full training was affected by unrelated injury.

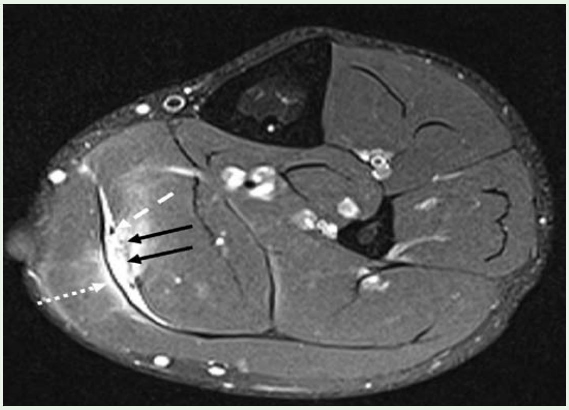

Figure 2a: 28-year-old elite national level ARF player with history of multiple left calf tears presenting with acute medial soleus and gastrocnemius aponeuroses tears. Axial T2-FS left calf MRI showing focal disruption of the medial soleus aponeurosis with myoaponeurotic tearing (black arrows) lateral to the plantaris tendon (dashed arrow). Low-grade signal changes are present within the Medial Gastrocnemius (MHG) aponeurosis and plantaris tendons compatible with micro-tearing, as well as low grade myoaponeurotic injury of the MHG (dotted arrow).

in addition to subtle aponeurotic thickening (Figure 3). Medial aponeurosis scarring is more common than lateral aponeurosis involvement and usually involves the plantaris tendon, which may be embedded within inter-aponeurotic scar (Figures 2 and 4). There may be fibrous scarring or adhesions extending from the aponeurosis to the plantaris tendon (Figure 4). Occasionally a chronic tear of the plantaris tendon itself, with thickening of the tendon due to previous injury and/or peritendinous scar, is the relevant finding at imaging (Figure 5).

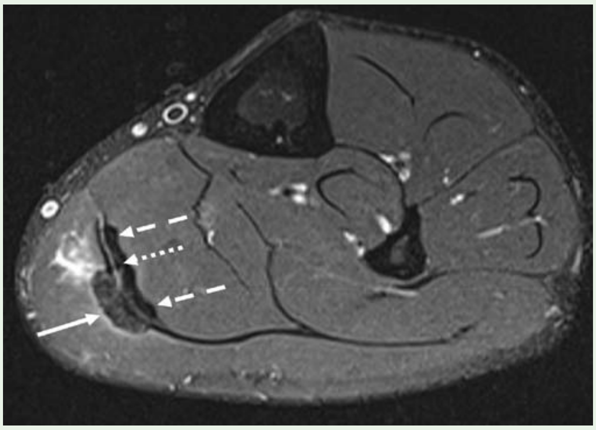

Figure 2b: Axial T2-FS left calf MRI at the same level 6 months following the previous injury showing thick maturing scars of the medial soleus and gastrocnemius aponeuroses. There has been clinically recurrent medial calf injury between scans, explaining the higher signal and thicker MHG scar (arrow) relative to the soleus scar (dashed arrows). There is a small recurrent MHG tear at the medial aspect of the scar, accounting for the acute presentation. The plantaris tendon (dotted arrow) is adherent to the soleus aponeurosis scar. Subsequently the player was not able to progress in rehabilitation due to inability to sprint >80% and calf adhesiolysis was performed with 20cc normal saline. There was improvement in knee to wall from 11.5cm to 12cm. Repeat adhesiolysis with 15cc normal saline was performed at 3 weeks for recurrent medial calf 'tightness' and full training was resumed at 1-week post procedure.

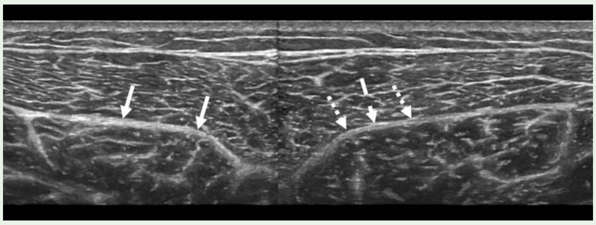

Figure 3a: 27-year-old elite state level ARF player with left lateral mid-calf tightness and the sensation of calf tearing following Grade II lateral calf tear, with inability to progress sprinting beyond 80% during rehabilitation. Composite transverse mid-calf ultrasound showing subtle echogenic thickening of the lateral gastrocnemius and soleus aponeuroses on the left (arrows) when directly compared with the right (dotted arrow). There is loss of the hypoechoic plane (dashed arrow) between the aponeurotic tissues.

Figure 3b: Transverse US during adhesiolysis of lateral soleus and gastrocnemius aponeuroses scarring, demonstrating thick bands of scar (arrows) tissue extending between the aponeuroses. 5cc normal saline was used to perform adhesiolysis. Knee to wall measurement improved from 6 to 9 cm and the player was able to return to full training at 1-week post procedure.

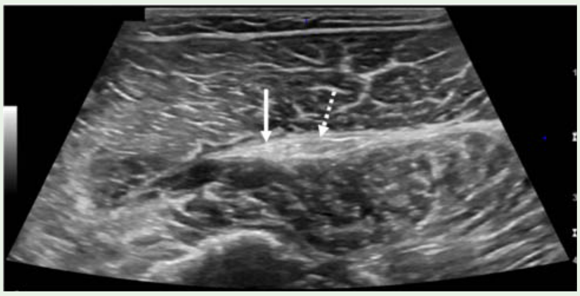

Figure 4a: 55-year-old long distance runner with right calf tightness and recurrent sensation of a calf tear occurring at 3-4km into a run. a Transverse ultrasound scan of the medial right mid calf showing thick echogenic scarring between the medial gastrocnemius and soleus aponeuroses (arrow) surrounding a mildly thickened plantaris tendon (dotted arrow) that is hypoechoic relative to scar.

Recurrent calf strain

In sprinting athletes, recurrent calf tears may occur at sites of scarring associated with previous injury. A systematic review by Green and Pizarri (2017) demonstrated that previous calf injury is a significant risk factor for recurrence [13]. Acute calf muscle re-tears are mostly seen in association with focal scars of the distal medial head of gastrocnemius and/or adjacent soleus aponeuroses. As in cases of incipient calf tear, a thickened plantaris tendon and

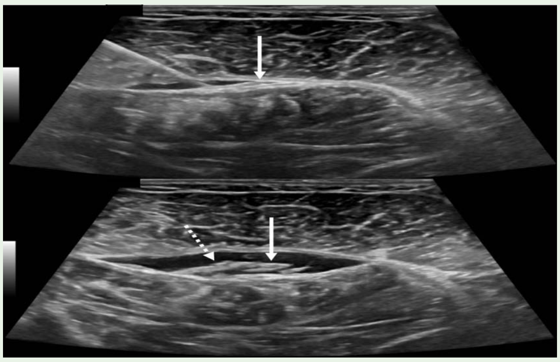

Figure 4b: Transverse calf ultrasound images during medial calf aponeurotic adhesiolysis. Top image showing early hydro-dissection of the scar on the left with the needle medial to the plantaris tendon (arrow) that is hypoechoic relative to the scar. Bottom image showing completed adhesiolysis of the plantaris tendon (arrow) from the MHG and soleus aponeuroses. There is a dense band of scar tissue (dotted arrow) extending between the plantaris tendon and the soleus aponeurosis.

adhesions between the aponeuroses and the plantaris tendon are also frequently present (Figures 2 and 4). Re-tears at sites of intra-muscular aponeurosis scarring also occur but are less common than distal tears in our experience.

In addition to recurrent distal calf tears directly associated with focal aponeurotic scars, we have observed in several athletes proximal intra-muscular aponeurosis tears that appear to be associated with scarring of the functionally adjacent distal soleus and gastrocnemius aponeuroses. Feathery fluid signal is observed tracking obliquely from the acute intra-muscular aponeurosis tear, along perimysial fascial planes, directly towards an area of focal scarring at the posterior soleus aponeurosis (Figures 1, 6 and 7). If significant inter-aponeurotic scarring is present, reduction in the differential displacement or shear potential at the aponeuroses during running or sprinting may result in transfer of shear forces elsewhere in the kinetic chain, for example to the myo-aponeurotic junctions of the soleus or gastrocnemius locally or to the soleus intra-muscular aponeurosis [14]. We postulate that this scarring may result in altered biomechanics of the muscle unit extending between the intra-muscular aponeurosis proximally and posterior soleus aponeurosis distally and may therefore contribute to some calf tears involving the soleus intra-muscular aponeuroses (Figures 1, 6 and 7).

Figure 4c: Extended field of view longitudinal ultrasound image of the right calf post adhesiolysis showing extensive, thick echogenic bands of scar tissue (dotted arrows) between the medial gastrocnemius and soleus aponeuroses, separated by saline. 40cc normal saline was used for adhesiolysis and the patient was able to resume running symptom free with graduated a training load at 1-week post procedure.

Adhesiolysis of Calf Aponeurosis Scarring

In patients with incipient calf tear or recurrent calf tears who have scarring of the gastrocnemius and soleus aponeuroses and/or plantaris tendon, we have performed ultrasound guided saline hydrodilatation or 'adhesiolysis' of areas of scarring with the intention of restoring the ability of the aponeuroses to undertake more physiological shear or differential displacement. Pre-procedural imaging and imaging guidance is undertaken with a linear high frequency probe (8-17Mhz). Typically, 10-20mls normal saline is used to release the aponeurotic scarring, along with Betamethasone 5.7mg to reduce post-treatment scar recurrence. However, for small areas of scarring, less than 5mls may be required and for multifocal scarring up to 50mls. A 50mm 22gauge needle is usually required to gain adequate access to the width of the aponeurosis. After local anaesthesia to the skin and gastrocnemius muscle belly, the needle tip is placed in the plane between the soleus and gastrocnemius aponeuroses adjacent to the scar. The plane between the aponeuroses is developed with gentle finger-pressure injection and the adhesions are dissected by the saline as the needle is advanced (Figure 1). The plantaris tendon is clearly separated from both posterior soleus and gastrocnemius aponeuroses, in those patients where plantaris involved (Figures 4 and 5). Sonographically, it is normal to see fine echogenic bands of tissue between the gastrocnemius-soleus aponeuroses with saline hydrodilatation, possibly related to the presence of the transverse aponeurotic connections seen in cadaveric studies. When adhesions are present, thicker bands of echogenic tissue are seen between the aponeuroses and the plantaris tendon (if involved), and greater resistance is felt with saline injection (Figures 3 and 5). During injection, a visible 'pop' as the scar releases may be observed dynamically. With dense scars, very thick echogenic bands of tissue are observed within the anechoic saline, extending between the aponeuroses and plantaris tendon (Figure 4). In many patients, a sensation of 'release' or loss of calf tightness may be felt immediately during or post-procedure. Knee to wall measurements may increase by 2-3cm (up to 25%), usually greatest several days post procedure.

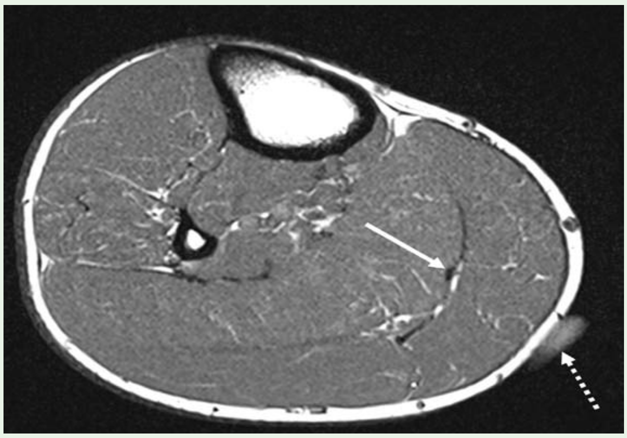

Figure 5a: 43-year-old professional boxer in training for a fight, presenting with recurrent lateral right calf tightness preventing him from running, with a history of medial calf strains. **a** Axial PD right calf MRI several months prior to calf adhesiolysis showed thickening of the plantaris tendon (arrow) within the medial calf aponeuroses, due to peritendon scar tissue. Note the oil bead (dotted arrow) adjacent to the thickened plantaris, indicating symptomatic medial calf at the time of MRI, which was reported as 'normal'.

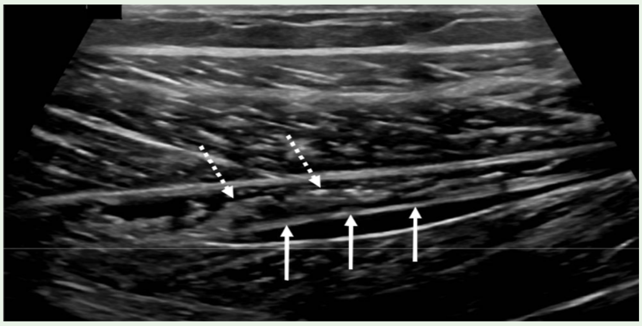

Figure 5b: Longitudinal US medial right calf post adhesiolysis of plantaris tendon showing posterior peritendon scar (dotted arrows) resulting in the thickened appearance of the plantaris tendon on MRI. The plantaris tendon (arrows) and medial soleus and gastrocnemius aponeuroses are normal. Compensatory lateral calf overload, with physiological de-loading of the medial calf, was thought to underlie lateral calf symptoms in this case. 20cc normal saline was used for adhesiolysis and the athlete was able to resume full training at 1-week post procedure.

Recreational runners and athletes may recommence training within the first week, unless rehabilitation is affected by the presence of co-exiting acute calf or other injury. In athletes with incipient tears who are in advanced rehabilitation with failure to progress sprinting, resumption of full training post procedure may be particularly rapid, and accordingly 'return-to-play' times may be substantially reduced. Patients may require repeat adhesiolysis because of symptom or tear recurrence or because of incomplete release in extensive or multi-focal adhesions (Figures 2 and 6).

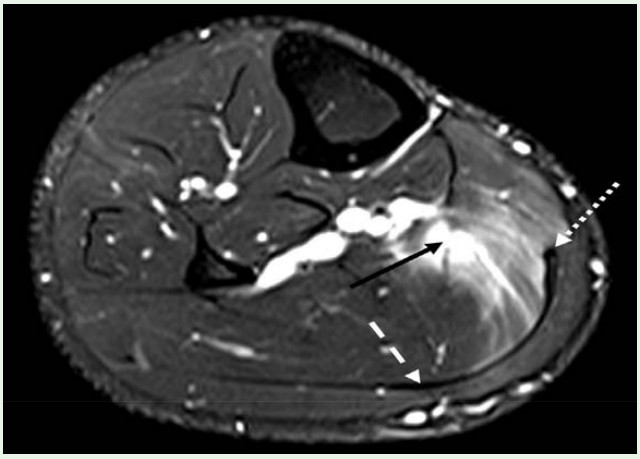

Figure 6: 24-year-old elite national ARF player with recurrent calf tears. Axial T2 FS MRI of the right calf showing a tear of the posterior aspect of the medial soleus intra-muscular aponeurosis (black arrow). Fluid is seen tracking directly along perimysial planes directly to focal scarring of the medial calf aponeuroses and plantaris tendon complex (dotted arrow). The player underwent medial calf adhesiolysis of plantaris and medial calf aponeurosis scarring with 20cc normal saline with improvement in knee to wall measurement from 13 to 16 cm. Initial rehabilitation was affected by unrelated injury. Large volume adhesiolysis (60cc) for more extensive aponeurotic scarring (dashed arrow) thought to be contributing to recurrent right calf tears at the lateral soleus intramuscular and plantaris-medial calf aponeuroses was subsequently been preformed with clinical improvement.

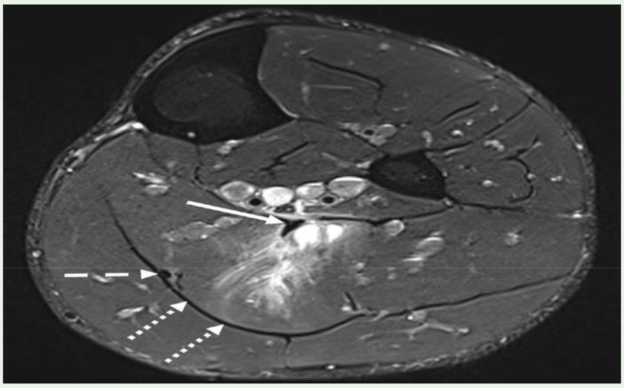

Figure 7a: 34-year-old elite national ARF player with recurrent medial intra-muscular aponeurosis tear. **a** Axial T2-FS MRI of the left calf showing recurrent tear at a medial intra-muscular aponeurosis scar (arrow). Feathery fluid signal is seen extending towards a thickened medial posterior soleus aponeurosis (dotted arrows) and plantaris tendon (dashed arrow) with adjacent scarring. The player did not require adhesiolysis.

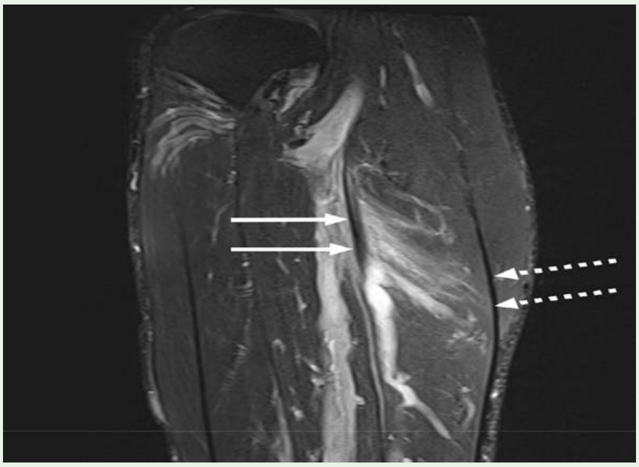

Figure 7b: Sagittal T2-FS MRI of the left calf showing thick scarring of the intra-muscular aponeurosis (arrows) and associated recurrent muscle strain with feathery high T2 signal extending obliquely along the muscle fascicles to the functionally adjacent and thickened soleus aponeurosis (dotted arrow).

Conclusion

Chronic calf strain injuries are a relatively uncommon but debilitating cause of chronic calf pain and symptoms in runners and sprinting athletes and may present as incipient calf tears or recurrent calf tears. The imaging findings with regard to chronic calf strain injuries have not been described previously and we report on our findings in relation to calf aponeurosis and plantaris tendon scarring in athletes with these presentations. Scarring related to previous calf injury may result in reduced physiological shear between the gastrocnemius and soleus aponeuroses and/or plantaris tendon, resulting in recurrent injury at the site of scarring, or potentially at the functionally adjacent intra-muscular aponeurosis, due to transfer of shear forces. Adhesiolysis of calf aponeurosis scarring may help to restore the normal biomechanical relationship between these structures during activity. Our early experience with this procedure

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in athletes with chronic calf muscle strain injury suggests that adhesiolysis appears effective in improving symptoms of chronic calf strain injury and calf muscle range, and may facilitate earlier return to play in athletes. A more comprehensive study of calf aponeurosis adhesiolysis is recommended.

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