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 metaphysis [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].
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.
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).

**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 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...
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.

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Recreational runners and athletes may recommence training within the first week, unless rehabilitation is affected by the presence of co-existing 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).

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...
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.

References


