Connective tissue injury in calf muscle tears and return to play: MRI correlation

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ABSTRACT

Objective The aim of our study was to assess a group of patients with calf muscle tears and evaluate the integrity of the connective tissue boundaries and interfaces. Further, we propose a novel MRI grading system based on integrity of the connective tissue and assess any correlation between the grading score and time to return to play. We have also reviewed the anatomy of the calf muscles.

Materials and methods We retrospectively evaluated 100 consecutive patients with clinical suspicion and MRI confirmation of calf muscle injury. We evaluated each calf muscle tear with MRI for the particular muscle injured, location of injury within the muscle and integrity of the connective tissue structure at the interface. The muscle tears were graded 0–3 depending on the degree of muscle and connective tissue injury. The time to return to play for each patient and each injury was found from the injury records and respective sports doctors.

Results In 100 patients, 114 injuries were detected. Connective tissue involvement was observed in 63 out of 100 patients and failure (grade 3 injury) in 18. Mean time to return to play with grade 0 injuries was 8 days, grade 1 tears was 17 days, grade 2 tears was 25 days and grade 3 tears was 48 days (p<0.001).

Conclusion The integrity of the connective tissue can be used to estimate and guide the time to return to play in calf muscle tears.

INTRODUCTION

Calf muscle is one of the four most commonly injured muscles in sportsmen.¹ MRI muscle injury pattern in hamstring and anterior thigh muscles have been researched and used to quantify prognosis and predict the time to return to play (RTP).²⁻⁶ However, little research has been performed for calf injury.

MRI of the calf may not be indicated in all patients presenting with calf injury, and time to RTP in injured athletes is mostly guided by clinical criteria. However, many elite athletes undergo MRI in suspected calf tears to confirm the diagnosis, access severity and guide rehabilitation. A previous MRI study has focused on size and site of tear, muscle component affected, intramuscular tendon tear and intramuscular haematoma,⁷ but did not focus on the integrity and severity of connective tissue injury.

Dense irregular and regular connective tissues form a scaffold to support the muscle fibres. This connective tissue scaffold is composed of surface covering (epimysium and aponeuroses) and intramuscular bands (intramuscular tendon and aponeuroses). Muscle fibres attach to these connective tissues, which connect to the tendon. The integrity of the connective tissue scaffold is therefore vital for muscle to function normally. Furthermore, muscle fibres are vulnerable to shear forces at these muscle fibre-connective tissue interfaces that can occur during eccentric loading or strain.⁸

Tendon, aponeurosis and epimysium heal slower than muscle. The status of the connective tissue (epimysium, aponeurosis, intramuscular tendon and free tendon) supporting the muscle fibres may well determine the healing time in muscle injury, not just in the calf but in other muscles too. We hypothesise that disruption of the muscle connective tissue is a higher grade injury and will result in longer recovery time and time to RTP.

The objective of this study was to assess the integrity of the calf muscle connective tissue in patients with acute calf muscle injury. We propose a grading system and its correlation with time to RTP.

REVIEW OF ANATOMY

The posterior compartment of the leg is divided by the deep transverse fascia into superficial and deep compartments. Collectively the superficial posterior compartment muscles of the leg are called the calf muscle or triceps surae and consist of gastrocnemius, soleus and plantaris. The aponeurosis and tendons of these muscles unite to form the Achilles tendon.⁹

Gastrocnemius is the most superficial muscle. It possesses a higher proportion of type II fast twitch fibres than soleus, reflective of its function in rapid locomotion, such as jumping and running.¹⁰ Its two heads arise from two proximal tendon attachments from the femoral condyles and the subjacent knee joint capsule. Both these tendons expand and spread out as thin aponeuroses on the posterior surface of the respective muscle and give origin to muscle fibres (figure 1A). These muscle fibres then attach to a broad aponeurosis on the anterior surface of the muscle (figure 1B–D). The anterior aponeurosis then gradually condenses as it extends inferiorly and unites with the posterior aponeurosis of the soleus to form the Achilles tendon.⁹ ¹¹ The gastrocnemius aponeurosis is distinctly shorter medially and longer laterally.¹¹

Soleus is the deeper muscle of the superficial posterior compartment. It is a broad flat multipennate muscle, designed for power, with a predominance of slow twitch fibres and hence contributes to postural control and walking.¹² It arises by tendinous fibres from the posterior fibula head, proximal one-fourth of the shaft of fibula, middle one-third of the medial border of the tibial shaft and posterior surface of the tendinous arch between the tibia and fibula.⁹ At the origin, there is thickening or
localised aponeuroses on the anterior and posterior aspects of the muscle (figure 2A). Distal to the origin, there are proximal intramuscular medial and lateral aponeuroses (figure 2B). These medial and lateral intramuscular aponeuroses run inferiorly, are directed towards the midline of the muscle belly and fade out inferiorly. Proximal muscle fibres arise from these aponeuroses. Distally the muscle fibres insert into a long central intramuscular tendon (figure 2B,C), which arises from the anterior aponeurosis of the soleus, and also to the posterior aponeurosis of the soleus (figure 2C). The central intramuscular tendon and posterior aponeurosis merge to form the soleal contribution to the Achilles tendon.13 In our experience, the soleus intramuscular aponeuroses and tendon are subject to considerable variation in terms of number, position and dominance.

The plantaris arises from the lateral supracondylar line of the distal femur and from the oblique popliteal ligament. The small muscle belly lies deep to the lateral head of the gastrocnemius muscle, but the long thin plantaris tendon courses obliquely and medially, lying between the soleus and the medial head of the gastrocnemius muscles (figure 2A,B). Distally, the tendon inserts on the calcaneus just anteromedial to the Achilles tendon.14

MATERIALS AND METHODS
We retrospectively searched our database backwards from March 2017 to September 2015 for patients who were referred for MRI of the leg to our clinic.

Inclusion criteria
Consecutive patients in the age between 20 and 50 years, were referred for MRI of the leg with the clinical suspicion and MRI confirmation of acute calf muscle tear, and with injury occurring within the previous 2 weeks were included in the study.

Exclusion criteria
MRI-negative studies, patients with delayed onset muscle soreness or muscle overload MRI pattern, Achilles tendon tear, muscle contusion MRI pattern or history, bone stress reaction, pre-existing non-healed muscle tear in either leg and follow-up studies were excluded. Patients were also excluded if they were out of play for any other reason and if we could not obtain the RTP details.

Return to play
RTP was defined as time from the date of injury to return to full competition.

MRI technique
The MRI imaging technique included placing an external marker (vitamin E capsule) over the area of maximum symptom, as indicated by the patient. All scans were carried out using 3T MRI scanners. A dedicated surface coil was used to obtain high-resolution image with 2.5 mm axial proton density (PD) and PD fat saturated axial images, as well as 2 mm sagittal and coronal PD fat saturated images.

![Image of gastrocnemius aponeuroses](A) PD and (B) PD fat saturated images showing proximal posterior (arrowhead) and distal anterior aponeurosis (thin arrow) of the gastrocnemius. (C,D) PD fat saturated images of an athlete with grade 2 posterior soleus aponeurosis tear and sliver of fluid between gastrocnemius and soleus muscles; the intermuscular fluid clearly demarcates the anterior aponeurosis (thin arrow) of the gastrocnemius muscle.

![Image of plantaris tendon](A) PD fat saturated images obtained through normal (A), proximal (B), mid and (C) distal leg showing anterior (thin white arrow in A and C), posterior (curved white arrow in A, B and C), medial and lateral intramuscular (block arrows in B) aponeuroses and central intramuscular tendon (arrowhead in B and C). Plantaris tendon is shown by the thin black arrow in A and B.)
MRI evaluation and grading

Three experienced musculoskeletal radiologists evaluated the MRI of 100 patients meeting the criteria by consensus. They were blinded to the clinical history, sporting background and outcome. Each muscle tear was evaluated for muscle involved, location within the muscle, myofibril disruption and integrity of the connective tissue. The soleus muscle tear was designated as proximal or distal, the distal end of the lateral gastrocnemius muscle belly being the landmark. In addition, each calf muscle tear was graded 0–3 (table 1). Grade 0 injury was defined as oedema or fluid adjacent to an intact tendon/aponeurosis/epimysium without myofibril detachment (figure 3). Grade 1 injury was defined as myofibril detachment without tendon/aponeurosis/epimysium change (figure 4). Grade 2 injury was defined as myofibril detachment with adjacent tendon/aponeurosis/epimysium increased signal, delamination or defect but no retraction (figure 5). Grade 3 injury was defined as myofibril detachment with adjacent tendon/aponeurosis/epimysium retraction indicating failure (figures 6 and 7).

Statistical analysis

The data were analysed using SPSS V.23. Frequency analyses were carried out to identify the number of injury locations according to injury grades. Analysis of variance was used to compare the mean RTP duration periods according to injury grades. A p value <0.05 was used to afford significance.

RESULTS

Out of 260 studies during the time period, 100 patients met the criteria. Of the 100 patients, 89 were men and 11 women. The ages ranged between 20 and 49 years, with a mean age of 30.5 years. Injuries were related to various sports and included Australian Football League (AFL), soccer, rugby, hockey and running. The majority of the patients were professional or semi-professional footballers, or elite athletes. Right calf muscle was injured in 55 and left in 45 of the patients. A total of 114 muscle tears were detected in 100 patients. Of the 114 muscle tears, 79 (69.3%) were located in the soleus, 31 (27.2%) in the medial gastrocnemius and 4 (3.5%) in the lateral gastrocnemius. Ninety patients had a single injury, eight had two injuries and two had four muscle injuries in a single event.

Of the 79 soleus tears (in 71 patients), 43 (54.4%) involved the proximal soleus muscle and 36 (45.6%) involved the distal soleus muscle. Twenty (25.3%) involved the anterior epimysium/aponeurosis, 16 (20.25%) the posterior epimysium/aponeurosis, 15 (19%) the medial intramuscular aponeurosis, 16 (20.25%) the lateral intramuscular aponeurosis and 12 (15.2%) the central intramuscular tendon of the soleus.

Of the 35 gastrocnemius tears (in 34 patients), 1 (2.85%) involved the proximal myotendinous junction, 5 (14.3%) the posterior aponeurosis/aponeurosis, 15 (42.85%) the anterior aponeurosis/aponeurosis and 14 (40%) the distal myotendinous junction.

There were 66 patients who had injury to only soleus, 29 had injury to only gastrocnemius and 5 had injury to both soleus and...
gastrocnemius muscles. One patient had injury to both medial and lateral gastrocnemius muscles.

In patients with more than one injury, they were graded as per their highest injury. Eight patients had grade 0, 29 grade 1, 45 grade 2 and 18 had a grade 3 injury. Time to RTP according to the grade of injury is shown in table 2 for all calf muscles, in table 3 for the soleus and table 4 for only the gastrocnemius. There was a statistically significant difference between the injury grade and time to RTP (p<0.001). Figure 8 shows the grade of injury against days to RTP in a scatter plot.

**DISCUSSION**

Our study has demonstrated, for the first time, the importance of connective tissue integrity in calf muscle tears and its correlation with time to RTP. Our proposed MRI grading system shows correlation between higher grade of calf muscle injury and longer time to RTP.

Other authors have highlighted the importance of integrity of the connective tissue and time to RTP. Comin et al.15 focused on the integrity of the biceps femoris intramuscular connective tissue and showed significant longer recovery time in biceps femoris tears when the intramuscular tendon was disrupted.

Cross et al.16 found the rectus femoris central tendon injury identified on MRI was associated with a significantly longer rehabilitation time.

Similarly, we felt that the integrity of the connective tissue supporting the calf muscles could be linked to the recovery time. However, rather than a simple intramuscular tendon, the calf muscles have a complex scaffold of epimysial boundaries and flat aponeuroses which support muscle fibres. We therefore proposed a grading system for calf muscle tears concentrating on the integrity of the connective tissue as well as the myofibrils. Our study has shown that involvement and failure of calf muscle connective tissue are associated with longer time to RTP.

We believe that measuring the extent of muscle oedema or bleeding for grading a muscle tear is inaccurate. Blood fluid products travel well beyond the margins of the actual myofibril tear and the margin is usually ill-defined. An analogy can be drawn with muscle contusions, in which the size of an intramuscular haematoma does not always correlate with loss of muscle function and the usual MRI grading systems used for indirect muscle injury cannot be applied to direct injuries.17 Likewise, measurements in the craniocaudal or transverse plane do not necessary reflect the true extent of muscle injury.

In our study, the soleus muscle was much more commonly injured than the gastrocnemius. This is in contrast to previous reports that have reported a higher incidence in medial gastrocnemius injury.10,12,18–20 Our study cohort of patients came from a variety of sports and therefore this outcome is unlikely to be related to a particular sport or activity. It is probably related to the increased use of MRI and detection of otherwise occult soleus tears. A higher incidence of soleus tears was also noted in studies by Koulouris et al.12 and Waterworth et al.7 However,
our study did not show a significant difference in time to RTP between soleus and gastrocnemius injuries.

The findings in our study did not show any particular soleus aponeurosis or epimysium being significantly more commonly injured than others. However, in gastrocnemius, most tears were located in the anterior aponeurosis and distal myotendinous junction. There were no isolated lateral gastrocnemius tears in our cohort. In addition, there were no plantaris tears in our cohort; in our experience this is an uncommon injury. While the soleus was the more commonly injured muscle, the incidence of grade 3 injury was higher in the gastrocnemius, particularly failure of the distal aponeurosis.

Our results show that the time to RTP is significantly longer in patients with higher grades of connective tissue injury. An earlier study among AFL players with calf injuries identified an association between missing at least one game and injury involving multiple muscles, musculotendinous junction strains, deep strain location and intramuscular tendon tears.7 Balius et al21 studied 55 cases of soleus injury by MRI and ultrasound (US), and concluded that US is not a sensitive technique for detecting and assessing soleus traumatic tears compared with MRI. Pedret et al22 evaluated the association of different typical locations of the soleus muscle tears and their recovery times, which showed wide variation. However, soleus central intramuscular tendon injuries had a significantly longer recovery time. They did not grade the injuries in their study. We think severity of connective tissue injury is more important than just the location of the injury. It is a topic for future research to correlate between similar grades of calf injury at different locations with time to RTP.

Our study has a number of limitations. Majority of our patients were professional and elite athletes; therefore our findings may not be representative of the general population. The number of higher grade injuries in this study group may be over-represented due to bias in the patient population recruited, as clinically higher grade injuries were more likely to be referred for MRI. MRI evaluation was done by consensus between three radiologists; the intraobserver and interobserver reliability is therefore not known. The doctors deciding the time to RTP were not blinded to the MRI findings. We did not correlate between MRI and clinical findings; we therefore do not know if the MRI clinical findings add to clinical evaluation. We recognise that time to RTP in players may slightly vary during preseason, season and postseason. Time to RTP may also be influenced by players’ motivation to RTP and pressure to play exerted by the clubs. We did not follow up patients in this study for reinjury.

CONCLUSION

Calf muscle injuries involve muscle fibre disruption at the interface with the connective tissue structures, such as epimysium, aponeurosis and intramuscular tendon. These connective tissue structures are likely to fail with higher grade muscle injuries. Attention should be directed to the connective tissue integrity rather than focused solely on the characteristics of the injured muscle fibre component. We propose a MRI grading system that can be used to assess the extent of injury and integrity of the connective tissue structures involved. As demonstrated in this study, higher grades of connective tissue injury have a longer time to RTP and are important in determining the duration of rehabilitation among athletes.

Competing interests None declared.

Ethics approval Monash University Human Research Ethics Committee, Victoria, Australia.

Provenance and peer review Not commissioned; externally peer reviewed.

What are the findings?

MRI-detected connective tissue injury in calf muscle tears is associated with longer time to return to play.

How might it impact on clinical practice in the future?

The proposed MRI grading system for calf muscle tears can be used to guide the time to return to play in athletes.
REFERENCES