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Evaluation of the hamstring muscle complex following acute injury

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Abstract *Objective:* To evaluate the imaging findings following acute hamstring injury. *Design and patients:* We retrospectively reviewed the imaging findings of hamstring muscle complex (HMC) strain in 170 patients referred to our institution over a 3-year period. A total of 179 injuries to the HMC were demonstrated in 170 patients (154 male, 16 female, mean age 28.2 years). The mean duration of symptoms was 4.7 days (range 1–10 days). MR imaging was performed in 97 cases and sonography in 102 cases (both modalities were performed in 20 examinations). Attention was directed to the frequency of muscle involvement, the location of the injury within the muscle-tendon unit, the extent of the injury and discriminating avulsion from muscle injury. *Results and conclusions:* Twenty-one patients had proximal tendon injury, with sixteen avulsions and five partial tears. Sixteen of these patients had surgical confirmation of hamstring avulsion from the ischial tuberosity (14 conjoint, 2 biceps femoris alone) and all were reliably diagnosed with MR imaging (16/16), but less so with sonography (7/12). Four distal tendon avulsions were also observed (three semitendinosus, one biceps femoris). With respect to muscle injury, the biceps femoris was most commonly injured (124/154). Semimembranosus was an uncommon muscle injury (21/154) and semitendinosus rare (9/154). Imaging can discriminate a hamstring tendon avulsion from musculotendinous strain and helps identify which patients necessitate surgical management as opposed to conservative treatment.

Keywords Hamstring · Hamstring muscle complex (HMC) · Strain avulsion · Magnetic resonance imaging (MRI) · Sonography · Musculotendinous junction (MTJ)

Introduction

Muscle injury is common in athletes, both during training and in competition, but also occurs frequently in the general population as people increase their level of fitness. Strain is the typical pattern of injury, and of all such injuries, the hamstring muscle complex (HMC) is by far the most commonly involved [1, 2, 3]. Professional and elite athletes are often referred for imaging given the high prevalence of hamstring injuries, frequency of recurrence and the prolonged rehabilitation involved.

Several biomechanical and morphological aetiologies have been proposed, with a multifactorial basis to hamstring injury most likely. Discriminating tendon avulsion from muscle strain is vital, given that the former necessitates surgical repair. The imaging basis of strain to the hamstring muscle relies on demonstrating the features of myofibrillar disruption, while avulsion is based upon noting discontinuity of the bone-tendon unit. Currently, MR imaging and sonography are employed as the mainstay of radiological assessment. Evaluating the location, extent and severity of hamstring injury provides supplemental information to the clinical assessment and may potentially assist in defining the prognosis and guide rehabilitation. Such information is also crucial in the professional sporting context, given the pressure to return rapidly to competition. Conversely, the risk of recurrent injury following a premature return to activities is high in an inadequately assessed and rehabilitated athlete, which can result in a further prolonged period of convalescence [4, 5]. Recent literature has focused on the sensitivity of MR imaging, though only small numbers of patients have been examined [4, 6, 7].

This study was undertaken as a retrospective review of the sonographic and MR imaging findings in patients who were referred to our institution with a clinical impression of HMC injury. Our purpose was to identify the frequency of muscle involvement, the location of injury within the muscle-tendon-bone unit and the extent of injury. Furthermore, we investigated whether MR imaging and sonography could discriminate tendon avulsion from muscle injury.

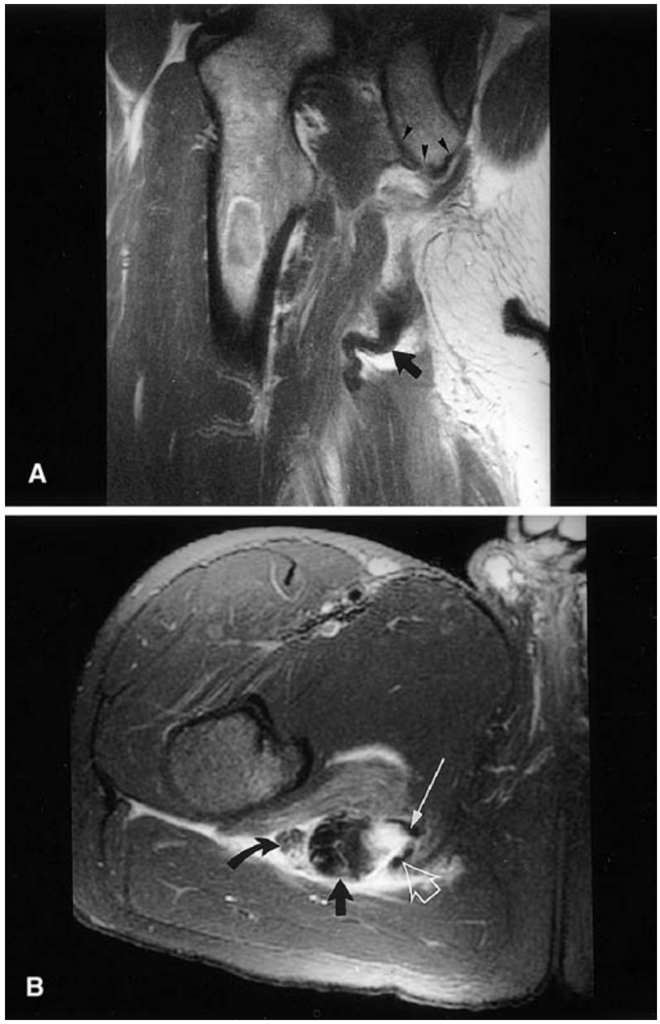

Fig. 1 A 32-year-old football player developed excruciating pain in the region of the ischial tuberosity whilst kicking (**A**). Oblique coronal MR images show a ligamentous avulsion of the conjoint tendon (*black arrow*). The amount of retraction can be estimated. The cortex of the ischial tuberosity remains intact (*arrowheads*). **B** Axial series also show the injury (*black arrow*) with abnormal signal in the region of the conjoint tendon secondary to haemorrhage, oedema and retraction. The adjacent adductor magnus (*white arrow*) and semimembranosus tendons are noted (*open arrow*) with the relationship of the muscles to the sciatic nerve (*curved arrow*) demonstrated. Note the oedema and haemorrhage manifesting as high signal in the surrounding soft tissues

Materials and methods

We retrospectively reviewed the imaging findings of 179 injuries in 170 patients (154 male, 16 female, mean age 28.2 years) performed at our institution from October 1998 to November 2001. The mean duration of symptoms prior to imaging was 4.7 days (range 1–10 days). Patients were commonly referred by sports medicine physicians or orthopaedic surgeons.

MR imaging was performed in 97 cases and sonography in 102 cases (both modalities were performed in 20 examinations). There were 96 injuries to the right hamstring complex and 83 injuries to the left. All injuries were acute, which was defined as having occurred within the previous 10 days. Nine patients had two injuries occurring in either different muscles or different sites within the same muscle at the time of presentation.

One hundred and twenty injuries were sustained whilst playing football, 32 with athletics, 17 with cricket and 10 with water skiing. The initial diagnosis was made on the basis of clinical findings and was confirmed with imaging. The choice of imaging modality was made by the referring doctor.

Patients were examined with a 1.5T superconducting unit (Signa LX, GE Medical Systems, Milwaukee, Wis.). A phased-array surface coil (Shoulder Array, Medrad, Indianola, Pa.) was strapped over the thigh and centred over the region of maximal tenderness as identified by the patient. A coronal localising image was obtained followed by: (1) axial and coronal oblique fast spin-echo imaging along the longitudinal axis of the HMC [TR/TE 4,000/45 (ef)], 512×384 matrix, two signals acquired, 20–24-cm field of view, 3.5–6-mm section thickness with no gap, echo train length of 8–12; (2) axial and coronal oblique fast spin echo inversion recovery imaging along the longitudinal axis of the HMC [TR/TE 5,000–6,500/35–55 TI 120] 256×224 matrix, two signals acquired, 20–24-cm field of view, 3.5–6-mm section thickness with no gap.

T1-weighted sequences are not routinely performed at our institution due to the poor sensitivity in depicting soft tissue abnormalities, as most pathologic processes have long T1 relaxation times similar to muscle tissue. Intravenous contrast was not administered, which is in keeping with its non-routine use in the traumatic setting.

Sonography was performed by a musculoskeletal sonographer and sonologist with interpretation made by consensus, as is our routine clinical practice, using a HDI 5000 (ATL, Bothell, Wash.). Sonography was performed in the longitudinal and transverse planes with the patient prone following sonopalpation at the area of maximal tenderness. Sonography of all three muscles was performed routinely from the ischial tuberosity down to the knee joint.

Both sonography and MR imaging were used to discriminate tendon avulsion from muscle injury. Attention was directed to the frequency of muscle involvement, the location of the injury within the muscle unit and the extent of the injury. Injuries were divided into those occurring at the musculotendinous junction or eccentric epimysial covering. The thigh was divided into one-thirds, with a

Fig. 2 A 14-year-old boy presents unable to mobilise adequately following an over-enthusiastic kicking attempt. **A** Plain radiographs demonstrate an avulsion fracture of the ischial tuberosity with two osseous fragments (*curved arrows*) lying inferiorly. **B**, **C** This was confirmed dramatically on MR imaging in the axial and coronal images. Note the disrupted cortex of the ischial tuberosity (*asterisk*) with oedema and haemorrhage in the surrounding soft tissue. The free osseous fragment (*curved arrow*) is seen detached from the ischial tuberosity with the sciatic nerve (*small arrow*) lying adjacent. **D** Sonography in sagittal (*longitudinal*) section correlates with the above findings. The echogenic osseous fragment (*curved arrow*) with posterior shadowing is readily identified. The ischial tuberosity is noted (*asterisk*)

proximal, mid or distal site of injury recorded. The size of any abnormality was recorded in mm and the longitudinal extent of the tear measured. Both intra- and intermuscular extension of haematomas were noted. These areas were characterised by marked hyperintensity on MR imaging; however, haematomas varied considerably with the size and age of the haemorrhage on sonographic assessment. Involvement of the sciatic nerve was recorded. Sixteen patients underwent surgery following a preoperative diagnosis of avulsion. In such patients, plain radiographs were also obtained.

Patients with chronic enthesopathy of the ischial tuberosity, chronic hamstring injuries, tendinopathy and pes anserine bursitis were excluded from this retrospective review.

Results

One hundred and seventy-nine acute injuries were identified in 170 patients. Twenty-one patients had proximal tendon-bone injuries, 154 patients had muscle belly injuries and four patients had distal tendon injuries. There were 169 abnormalities in the 154 patients with muscle belly injuries (145 patients with solitary lesions, nine patients with two lesions).

Twenty-one patients from the study cohort had a proximal tendon-bone injury. Sixteen patients had avulsion from the ischial tuberosity, and five patients presented with partial tears. Fourteen of 16 avulsion injuries occurred in adults and involved avulsion of the conjoint tendon from the ischial tuberosity (Fig. 1). Two patients avulsed the bony ischium; both of these patients were skeletally immature (ages 14 and 16 years, Fig. 2). Of the patients that had avulsed the conjoint tendon, ten patients had avulsed all three tendons. Three patients had avulsed biceps and semitendinosus and incompletely torn semimembranosus with some fibres remaining intact with the ischial tuberosity. One patient had avulsed biceps alone with preservation of both semitendinosus and semimembranosus (anatomic variant). MR imaging correctly identified the avulsion in 16/16 cases, all of which were subsequently confirmed at surgery, where reattachment was performed. Sonography was less reliable

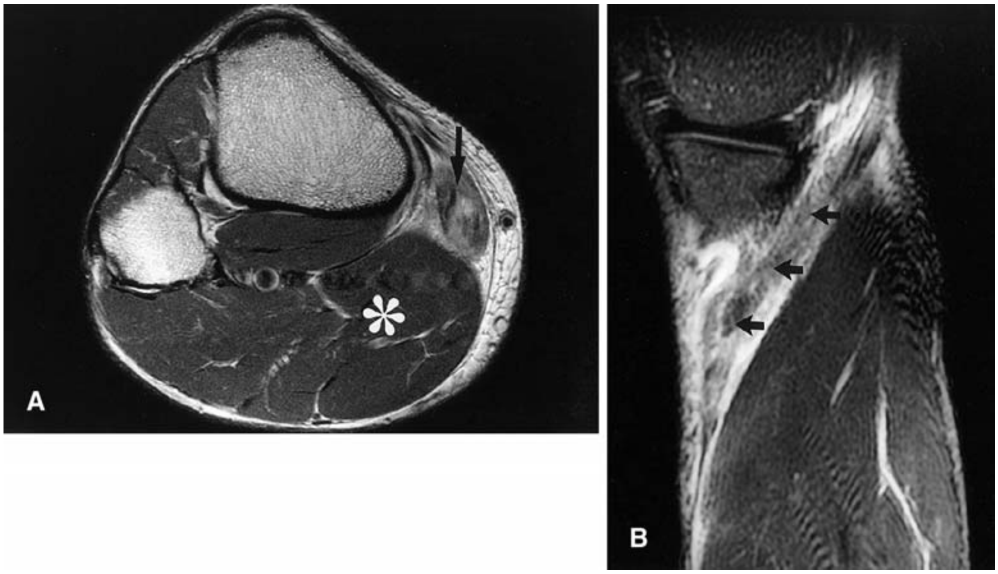

Fig. 3 Following acute medial joint pain, originally presumed to be a tear of the medial collateral ligament, a 25-year-old professional football player presents for imaging. **A**, **B** Axial and sagittal MR sequences demonstrate thickening and increased signal in the semitendinosus muscle (*arrows*). No normal tendon is identified, and the findings are in keeping with a distal avulsion. The player subsequently missed competition for 7 weeks. The medial gastrocnemius muscle is noted (*asterisk*)

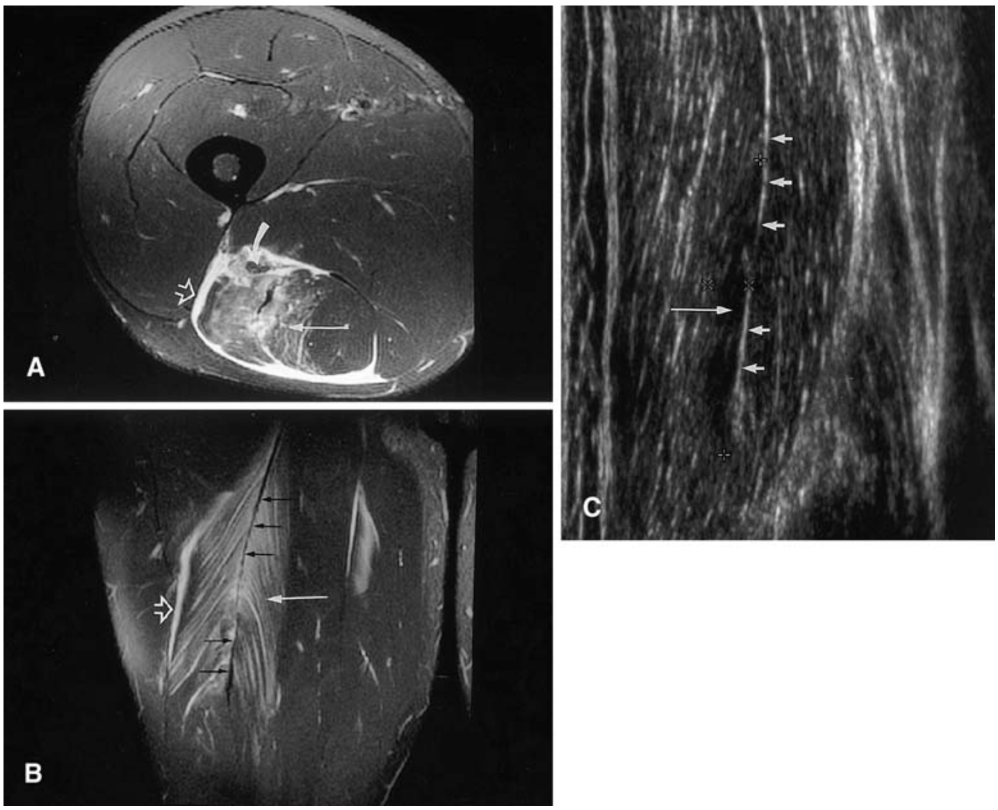

Fig. 4 An athlete presents for assessment of posterior thigh pain following a tearing sensation during sprinting. **A**, **B** Axial and coronal MR demonstrate the characteristic feathered appearance of a musculotendinous junction tear (*arrow*). Note the rim of haematoma extending around the muscle sheath on the axial study (*open arrow*) and the relationship of this to the sciatic nerve (*curved arrow*). The tendon slip is of uniformly low signal (*small black arrows*). **C** Ultrasound correlation demonstrates the tear as a hypoechoic feathered region within the muscle (*arrow*) oedema, with the normal tendon slip seen as a bright, uniformly echogenic structure (*small arrows*)

for showing conjoint tendon avulsion, often confusing torn hamstring with haemorrhage. Sonography identified 7/12 tendon avulsions and correctly identified the two osseous avulsions.

In addition, five patients (5/21) had partial tears of the hamstring origin. In all five cases there was involvement of biceps tendon with preservation of semimembranosus. In three cases there were imaging features of pre-existing enthesopathy. Partial tears were characterised by fluid-filled cleavage planes disrupting the normal uniform signal on MR imaging and fibril continuity on sonography.

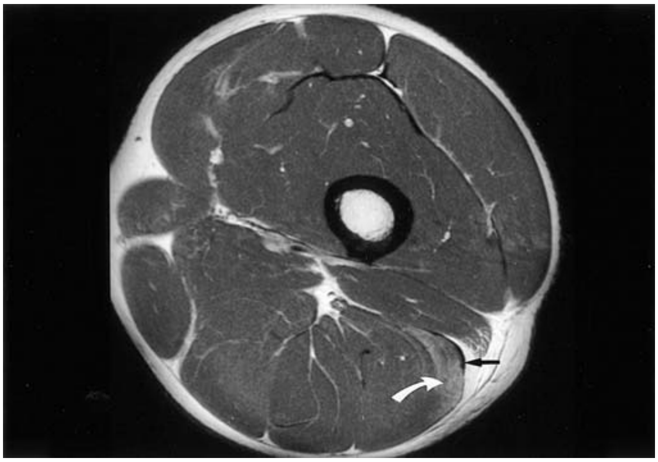

Fig. 5 A 23-year-old football player was referred for imaging following vague hamstring soreness with non-conclusive examination findings. Axial MR images confirm the presence of a focus of increased signal consistent with oedema (*curved arrow*) adjacent to the biceps femoris tendon (*black arrow*). The imaging findings are compatible with a subtle musculotendinous junction tear of this muscle

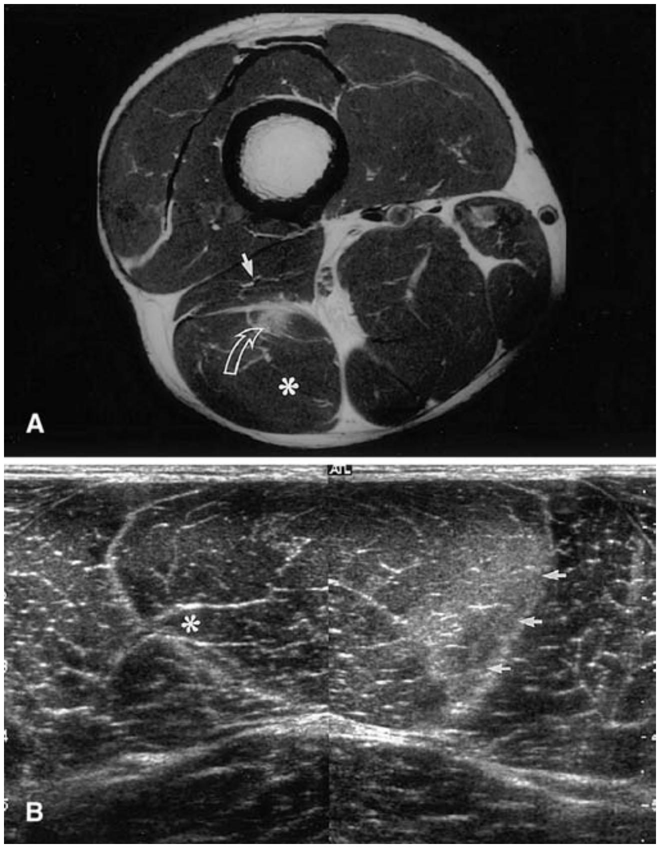

Fig. 6 A 27-year-old elite female sprinter complained of a vague and ill-defined pain following a training session. **A** Axial MR demonstrates an eccentrically located tear of the biceps femoris (*curved open arrow*) consistent with a epimysial strain of the long head of biceps (*asterisk*) just superior to where it merges with the short head (*straight arrow*). **B** Ultrasound of this region shows a similar region of abnormality characterised by an increase in echogenicity (*short arrows*) consistent with haematoma at the border between the two components of biceps femoris. The contralateral side (*asterisk*) is provided for comparison

Distal tendon avulsions were less common, with three patients demonstrating a distal rupture of semitendinosus tendon with retraction (Fig. 3). One patient demonstrated an avulsion of the distal biceps tendon. Thus, we identified in total 20 patients with an avulsion injury.

The biceps femoris was the most common muscle injured, seen in 80.5% of cases (124/154). Seventy-six patients of these 124 patients (61.3%) had injuries of the MTJ of biceps (Fig. 4); 43/124 (34.7%) had epimysial injuries (Fig. 5) and 5/124 (4%) had intramuscular haematomas alone (Fig. 6). The longitudinal extent of the tear ranged from 30–152 mm (mean length 95 mm). Proximal muscle injuries of the biceps (54/124) were slightly more common than mid (48/124) or distal (22/124) injuries.

Thirty patients (30/154) had injuries to the muscle bellies of either semimembranosus (21/154) or semitendinosus (9/154). Of the 21 muscle injuries involving semimembranosus, 16 involved the mid portion of the muscle and 5 (5/21) involved the distal third. Seventeen of these injuries (17/21) involved the musculotendinous junction. The longitudinal extent of the injury ranged from 30 to 115 mm (mean 84 mm).

Nine muscle injuries of semitendinosus were identified (9/154). Eight (8/9) injuries involved the middle third of the muscle. There were five musculotendinous injuries and three epimysial tears. The longitudinal extent ranged from 45 to 135 mm (mean 87 mm). Haematoma was observed in 7/9 cases.

Haematoma was a common finding in patients with muscle injury (136/154), with varying amounts of haemorrhage noted. With increasing injury, blood was seen to track down to and around the epimysial boundaries and often made its way to the subcutaneous fascial boundary. Intermuscular haematoma was felt to be a reliable sign for hamstring injury. Haematoma frequently came in contact with the sciatic nerve (24/155) patients (Fig. 7).

Nine patients had more than one site of muscle injury, of which five had injuries of the biceps and semimembranosus, three had two injury sites within the biceps and one had an injury of the biceps and semitendinosus.

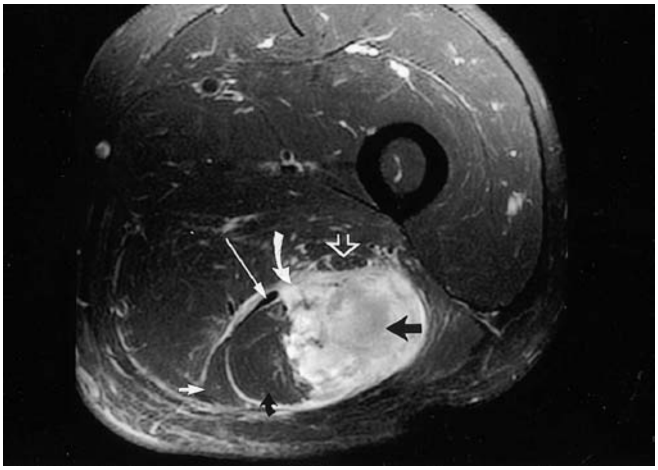

Fig. 7 A 23-year-old professional male cricketer presented with acute onset of hamstring pain whilst sprinting; he was unable to continue competing. Examination revealed markedly reduced ability to flex the knee. Axial MR demonstrates a significant tear of the biceps femoris muscle (*black arrow*) involving 75% of the muscle area. Note the rim of free haematoma (*curved arrow*) as well as its relationship to the sciatic nerve (*open arrow*), which accounted for the patient's symptoms of radiculopathy. The tendon of semitendinosus is located medially (*long white arrow*) along with its muscle belly (*short white arrow*)

Discussion

Sixteen cases of hamstring avulsion injuries from the ischial tuberosity were observed and had subsequent surgical confirmation. The amount of tendon retraction and the tendon edge morphology are important features for preoperative assessment. Coronal oblique imaging is useful for assessing the degree of retraction. MR can confidently identify which muscle has been injured and the amount of tendon retraction in all cases. With sonography, only 7/12 (58%) avulsions were diagnosed despite the examination being performed by experienced musculoskeletal sonologists. The cause for such a low yield is attributed to the mixed echogenic pattern characteristic of large haematomas, which are present with avulsion, making detection of the retracted tendon difficult. Further, a combination of loss of sound as it penetrates through soft tissue is a contributing factor.

Three avulsions of semitendinosus tendon and one avulsion of biceps were observed in this study. The semitendinosus is proposed as being the most commonly avulsed muscle distally as a result of its long tendinous portion. No avulsion of the distal semimembranosus was identified in our study. This is a rare injury, with only three such cases reported in the literature [8]. Sonography was particularly useful for imaging the distal hamstring tendons, reflecting the superficial nature of the tendons around the knee.

On MR, muscle injury is manifest by high signal on T2-weighted imaging (T2WI) secondary to oedema, although haemorrhage may contribute to the abnormal signal. The high signal of oedema contrasts against the isointense grey signal of normal muscle and has superior contrast resolution compared to the hypoechoic change seen on sonography. High resolution imaging will hence show focal areas of myofibril disruption [6, 9].

Haematoma in skeletal muscle has a variable appearance on MR imaging according to injury age, which differs from the predictable time course reported in the brain. This often results in difficulty accurately discriminating haematoma from muscle oedema when the tear is limited to within the muscle. Blood degradation products are inevitably reabsorbed over a period of 6–8 weeks, and often fluid-fluid levels are observed. Haematoma can also cause mass effect upon the sciatic nerve, directly irritating it to commonly causing a radiculopathy. Such collections may rarely persist as a seroma [6, 10].

The high signal characteristic of strain injury as a result of myofibrillar disruption usually dissects between the fibrils of isointense skeletal muscle [11, 12] near the MTJ forming a feathered appearance. These findings are compatible with a minor tear and when the sole finding, usually imply a rapid recovery. Such tears can be subtle and thus are often undetected on ultrasound. With increasing injury, a rim of blood and oedema often tracks along muscle bundles to become limited by the surrounding fascial compartment of the muscle [6]. This is a characteristic and reliable sign of muscle injury, which can be used to differentiate strain from tumour and myositis.

An increasing degree of muscle disruption is manifest as an increase in the longitudinal extent of the tear, which is an effective way of assessing the severity of the injury and has shown to be of prognostic value [4]. If severe enough, free blood extravasates between the fascial layers and with gravity tracks down the leg. This acts as a chemical irritant, thereby becoming symptomatic. Should it be of sufficient magnitude, oedema and haemorrhage can extend further, through the fascial sleeve into the subcutaneous tissue, where bruising becomes visible, which is pathognomic clinically of muscle injury.

The depiction of muscle injury on sonography relies on macroscopic disruption of the normal fibrillar pattern resulting in the presence of oedema or haematoma in the acute setting. Sonography is sensitive for detecting muscle tears in the presence of fluid collections or haematoma. Clinical minor (grade one) tears are notoriously difficult to diagnose sonographically, as the small degree of injury results in a minimal amount of oedema, manifesting as low echogenic signal characteristic of fluid, on a background of normal dark grey muscle. Similar challenges are presented in chronic injuries with areas of fibrosis and scar tissue. High frequency probes dedicated for musculoskeletal imaging have improved high spatial resolution and soft tissue contrast and together with multiple focal zones, image quality is improved, particularly in the deep soft tissue of the posterior thigh, which is a considerable advantage in the muscular athlete. Sonography remains a highly operator-dependant modality, and considerable experience with technical expertise as well as image interpretation is required.

Previous researchers agree with our observation that the biceps femoris is consistently the most commonly injured muscle of the HMC [1, 4, 6, 7, 9]. Semimembranosus was the next most common single injury that we noted, a finding supported by other authors [4, 9], but not consistently so [7]. The high incidence of injuries in these two muscles is accounted for by their anatomic configuration, that is, the MTJ, be it proximal or distal, spans the entire muscle length. We noted that only 9/170 (5%) demonstrated more than one muscle injured, of which all involved at least the biceps femoris. This figure is low when compared with previously reported statistics of 33% [7]. Dual injuries of the biceps and semitendinosus again were noted in our series to be the most common tandem injury [1, 7]. Proximal injuries of the hamstring muscles have been reported as being more common than distal [1, 2, 3], in keeping with our findings, though this has not always been observed [4]. Importantly, these injuries have been previously reported as being associated with a shorter period of convalescence [4].

This study showed that MTJ injuries of the biceps femoris muscle are the most common hamstring muscle injury. Tears involving the proximal MTJ are more prevalent than those involving the distal counterpart, which has a fascial contribution from both the short and long heads. A common site of epimysial injury is at the septal interface between the short and long heads.

Discriminating the type of muscle injury may be important for prognosis, as patients with deep muscle tears remained out of competition longer than those with superficial tears. Other findings that resulted in prolonged convalescence included fluid or haemorrhagic collections, greater than 50 per cent cross sectional involvement and distal MTJ injury [4]. Our study did not evaluate the prognostic value of the imaging features.

This study reviewed acute injuries although in three cases there were features of a preexisting enthesopathy. Enthesopathy is characterised by tendon enlargement with high signal on MR and hypoechoic change on sonography, the result of repetitive micro-trauma [13]. This probably represents collagen degeneration, although we have no histopathological correlation of this. Microscopic tears may then coalesce to become obvious as macroscopic tears, which invariably result in tendon weakening. Repeated forces through this region may further extend the tears and result in a localised inflammatory reaction, reflecting attempts to heal. As a result of tendon weakening, the athlete is predisposed to complete tendon avulsion, which was clearly present in 3/5 cases with partial tearing of the origin. MR demonstrates an enlarged hamstring tendon origin with increased signal, which corresponds to hypoechoic change on sonography. Partial tears at the hamstring origin manifest as discrete cleavage planes, usually in the transverse direction. Fluid collections surrounding the hamstring muscle origin may help to identify the partial tear.

Our research is limited by the fact that our data was collated retrospectively and a predominantly elite athletic population was investigated. In particular, there was a heavy representation of professional Australian Football League players (120/170), this game being characterised by prolonged aerobic activity interspersed with regular periods of sprinting and kicking. This lends the players of this sport to a high incidence of hamstring strain. Furthermore, there was a lack of clinical and surgical correlation, and both sonographic and MR imaging interpretation was made by consensus, as opposed to independent observation.

The significance of abnormalities detected on MR imaging and sonography require correlation and assessment relative to the clinical findings, and prognostic value has yet to be evaluated, specifically whether a linear relationship with the area injured can be made with the period of convalescence.

Conclusion

Hamstring tendon avulsion was demonstrated more accurately by MR than by sonography. Differentiation of hamstring tendon avulsion is important because surgical management as opposed to conservative treatment is required. Both MR imaging and sonography can be used to identify the muscle injured and assess the severity of muscle tearing. Musculotendinous junction strain of the biceps femoris muscle is the most common injury, with haematoma a reliable imaging sign. Imaging has been limited in the past to the elite athletic population, However as sporting participation in the general population is on the rise, it is incumbent upon the musculoskeletal radiologist to be familiar with the imaging findings of muscle injury, in particular, of the hamstring muscle complex.

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