CLINICAL AND IMAGING DIAGNOSIS AND GRADING OF HAMSTRING INJURIES

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Hamstring injuries occur commonly in sports that require interval sprinting such as in football codes from all over the world. Injury surveillance studies demonstrate that hamstring injuries result in the most lost playing time when compared to all other injuries in most of these codes. As players of football at the highest competition level are generally professional, these injuries and time lost from sport have important consequences for both the players themselves and their respective teams. Thus any clinical and imaging assistance in diagnosing and grading these injuries that may be useful in predicting time lost from sport would be beneficial in allowing for more effective and accurate rehabilitation programmes.

HISTORY

The original diagnostic grading scale for muscle injuries was conceived in the 1960s and as befitted the technology of the time, consisted solely of clinical grading with Grades 1 to 3, signifying minor, moderate and extensive/severe[1]. Subsequently, imaging use became prevalent, resulting in the development of ultrasound[2] and MRI grading systems[3]. Many grading systems have been proposed, more recently attempting to incorporate both clinical and imaging features[4,5].

CLINICAL DIAGNOSIS

The purpose of both history-taking and examination in sports medicine is to attain an accurate clinical diagnosis. With an accurate clinical diagnosis a management plan can be initiated and, in the case of muscle injuries, a plan that may allow an early return to play with a reduced risk of injury recurrence. Somewhat surprisingly, studies have shown that often, the clinical features of posterior thigh injuries are similar irrespective of whether hamstring injury was detectable on MRI or not[6,8]. Specifically, the classical clinical features of a sudden onset of posterior thigh pain, inability to continue playing and occurring

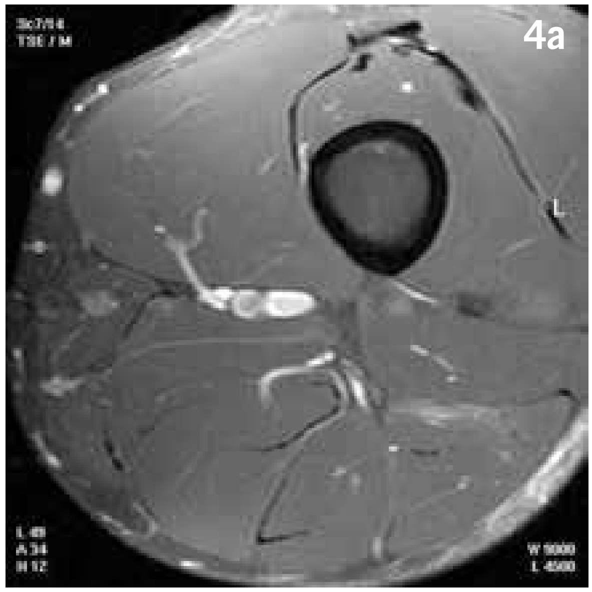
Figure 1: Active Range of Motion test: normal. With the patient supine. Hip flexion to 90°. Actively extend lower leg until resistance. The buttock should not elevate off the supine position. Normal leg.

Figure 2: Active Range of Motion test: injured. With the patient supine. Hip flexion to 90°. Actively extend lower leg until pain. The buttock should not elevate off the supine position. Injured leg. The difference in angle at the knee is the active range of motion deficit.

in a time of the game after at least 30 minutes of activity were associated with demonstrable MRI changes consistent with hamstring injury in over 90% of athletes[7]. However, there were still instances where these features, seemingly pathognomonic of structural injury, did not result in detectable changes on MRI. Paradoxically, an insidious onset of hamstring pain was associated with MRI-detected injury in 45% of cases[7]. Furthermore, all acute posterior thigh injuries, whether MRI positive or negative, are typically found to have tenderness upon palpation and pain with resisted hamstring contraction. In addition, clinical features have not been shown to be predictive of an increased risk for injury recurrence[8]. Remarkably, the current literature provides limited evidence for clinical examination findings being useful for either diagnosis or subsequent prognosis of hamstring muscle injuries.

Therefore, in the absence of high-level evidence for the value of history and examination, what can we use? From assessing the literature the following are considered useful clinical findings for both diagnosis and prognosis.

1. The maximum amount of pain experienced by an athlete upon injury as measured by a Visual Analogue Scale 0 to 10 was associated both with more significant findings on MRI and a poorer prognosis with respect to days lost from competition[7]. This measure was demonstrated to be superior to clinician predicted time lost[7].
2. It has been demonstrated in running athletes[9] that after posterior thigh injury, the closer the palpation pain is to the ischial tuberosity, the longer time to recovery to pre-injury activity level. Interestingly, the length of palpated tenderness along the posterior thigh was not associated with longer convalescent intervals.
3. Knee active range of motion loss comparing the injured side to the uninjured side; findings of less than 20° difference (increased loss on the injured side) being associated with a better prognosis (less than 2 weeks injury time loss) when compared with greater than 30° (greater than 6 weeks injury time loss)[10]. (Figures 1 and 2)
4. Finally, persistent strength deficits, as measured by flexion/extension force measurements, have been demonstrated to elevate the risk of re-injury. However, the amount of actual deficit that predicts re-injury has been a subject of considerable speculation and has not been determined. It is not considered a practical measure compared to the previous three clinical findings.



MRI DIAGNOSIS

Recent studies have shown that the gold standard for diagnosis of hamstring injury is the use of the MRI scan. Although a definitive study has not been performed that compared MRI scans with ultrasound scans for the diagnosis of hamstring injury, it is generally accepted that MRI is superior, probably in part due to the operator-dependent nature of ultrasound examination[11]. Another reason is that when comparing ultrasound and MRI in minor strains of the hamstring muscle complex, the ultrasound operator needs to be able to distinguish between the low echogenicity of muscle oedema at the injury site and compare to the low to intermediate texture of the surrounding muscle architecture. This distinction is a finding in muscle injury that is much more readily-detected by MRI[11].

Before looking at prognosis it is important to understand the findings of a muscle injury as seen on MRI. The principal finding is on the T2 weighted images, with hyperintensity of the injured area suggestive of oedema[12,13]. In the majority of cases this is situated in the musculotendinous junction, however in a small number of cases, particularly in the biceps femoris muscle, there can be boundary tears that are poorly understood with respect to pathophysiology. In many cases oedema can be seen to extend between muscles (and this is often measured by MRI as the cranio-caudal extent) and is significant in that it suggests an extension of fluid through a fascicle (epimyseal) tear[13]. Although subjective architectural distortion is also commented upon in many cases there is currently no accepted definition of how to detect or describe this. In a similar manner, the distortion or injury to the central tendon is also considered an important MRI finding with respect to assessing injury severity. Finally, absence of blooming on gradient-echo images (not a commonly performed MRI sequence) or lack of hypointensity on T2 images suggest that in most hamstring injuries there is little or no haematoma formation[13].

MRI GRADING

Much information can be obtained from an MRI scan for athletic posterior thigh injuries. Information that has been shown to be useful include both the presence or absence of T2 signal intensity of the muscle, indicative of injury and muscle fibre damage, reflecting a more significant injury. In addition the anatomical structure or

Figure 3: Coronal T2 MRI of a hamstring strain showing cranio-caudal extent of injury and in this case some central tendon disruption. Tendon disruption, even in a relatively low grade injury (though this injury is at least a Grade 2), is significant for prognosis.

Figure 4: (a) Axial T2 MRI of a hamstring strain showing the percentage muscle injury on the worse-affected scan. In this case the injury is small and involves the boundary of the biceps muscle. (b) Coronal T2 MRI of a hamstring strain demonstrating cranio-caudal length of the injury. It must be remembered that this is an indirect measure of the amount of muscle injury involved as it demonstrates the epimyseal fluid.

> *Central tendon disruption has a worse prognosis in hamstring injuries*

structures injured and the involvement of both the free tendon ends and the central tendon can be determined. Other information obtained by direct measurements made by the reporting clinician at the MRI console include the extent of cranio-caudal oedema, percentage of muscle injured by direct measurement of the cross-sectional area and the volume of muscle injured as calculated using the formula of a prolate ellipsoid[13].

Grading systems principally look at the presence or absence of T2 hyperintensity, T2 hyperintensity with muscle fibre damage and muscle fibre disruption. In many of the recently published grading systems these measured MRI parameters are also included but do not form an integral part of the MRI grade

As noted above, over the last 15 years many attempts have been made to use an MRI grading system for posterior thigh injuries (particularly hamstring muscle injuries) and to relate this to prognosis. Unfortunately, significant methodological flaws exist in the majority of scientific studies that have attempted this. The common methodological flaw observed in studies, with one exception[13], is that the clinicians receive the results of the MRI scans prior to implementing a rehabilitation programme. While in some studies clinicians only received information whether the injury was MRI positive or negative for the presence of T2 hyperintensity[6,7], in all others the clinician received complete detail of the radiological report and grade[14–16] or their MRI grading/classification system did not even consider prognosis[3,5]. Currently there is scientific evidence for the use of MRI grading systems of posterior thigh injuries that are clinically and prognostically useful. Thus the use of MRI is appropriate in high performance athletes with posterior thigh injuries.

USEFUL MRI FINDINGS FOR THE DIAGNOSIS AND PROGNOSIS OF HAMSTRING MUSCLE STRAIN INJURIES

From assessing the literature the following are useful MRI findings for both diagnosis and prognosis. Classified in order of usefulness, the following findings are both diagnostically and prognostically relevant:

1. The presence or absence of MRI-detected T2 signal hyperintensity. A positive scan indicates muscle injury whereas a negative scan indicates a different diagnosis or an injury below the threshold of MRI to detect and prognostically suggests an earlier return to sport for those athletes with a negative scan[6,7].
2. An injury that involves some disruption to the central tendon. This demonstrates a higher grade injury with a longer rehabilitation time[17].
3. The location of the injury with respect to biceps femoris as opposed to the other muscles. As in running athletes, it seems (though this is not been scientifically proven) that biceps femoris injuries are more prone to recurrence and thus these injuries require a longer rehabilitation time
4. Isolated free tendon end injuries have a longer rehabilitation time, being tendon in nature[3].
5. Greater than 50% of muscle involvement measured on the worst affected transverse image and a volume of injury greater than 20 cm^3. These are related to a poorer prognosis and a higher recurrent injury rate[13,8].
6. Cranio-caudal length of signal change shown on T2 MRI images is related to prognosis[14]. However, it should be remembered that although this finding is for non-radiologists, the most visually identifiable and understandable finding it shows is that the injury has extended out from the epimysium. As such, it is really an indirect measure of the actual extent of the muscle injury rather than indicating or relating to the number of muscle fibres injured.

Measures considered not to be as useful with respect to MRI findings of hamstring muscle injuries include the presence or absence of muscle fibre damage (damage is often used to signify a higher grade injury) and the presence or absence in a musculotendinous injury of distal or proximal free tendon involvement (free tendon involvement is used to signify a higher grade injury). As stated, central tendon disruption has a worse prognosis in hamstring injuries. With respect to fibre damage, the presence of T2 hyperintesity on MRI almost certainly reflects sarcomere level disruption of the musculotendinous junction with subsequent oedema response. It seems arbitrary to use the MRI to macroscopically distinguish a more significant muscle injury with respect to fibre damage.

PITFALLS OF USING THE MRI SCAN FOR HAMSTRING INJURY DETECTION AND PROGNOSIS

Oedema

The most commonly reported finding on MRI for the purpose of classifying posterior thigh injuries is the presence of T2 hyperintensity or, in other words, oedema at the injury site. This oedema is considered to reflect inflammatory changes at the injury

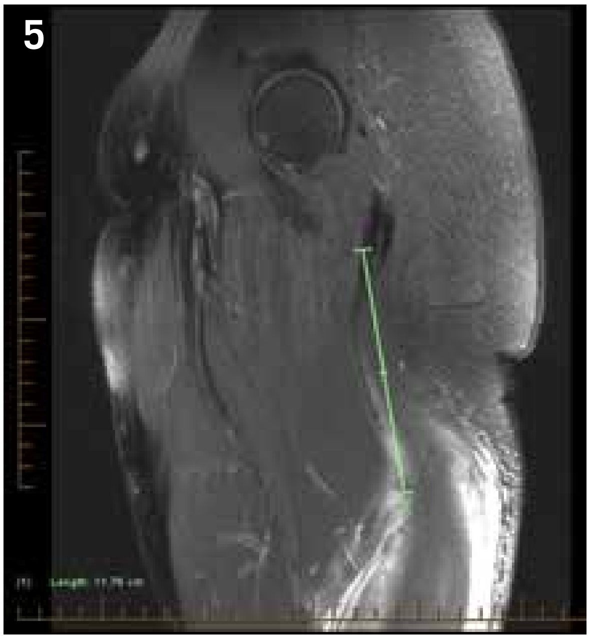
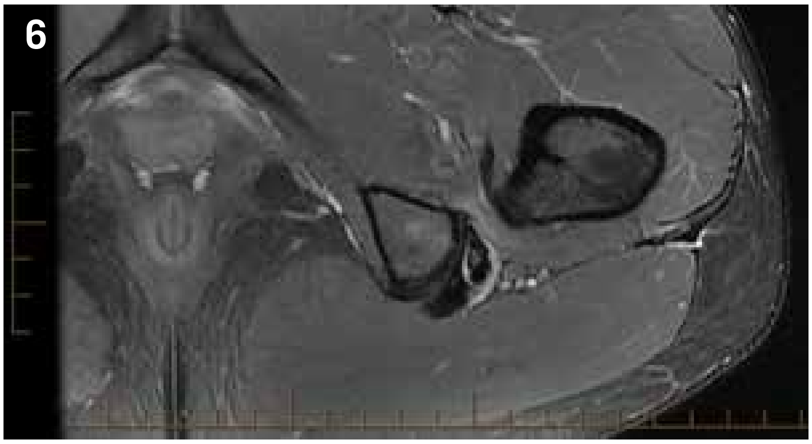


Figure 5: Complete avulsion of proximal hamstring complex showing semimembranosus retraction from the origin. This injury was from a water-skiing accident.

Figure 6: A case of insertional hamstring tendinopathy that shows tendon increased signal intensity, ischial tuberosity bone marrow oedema and in this case, signs of ischiofemoral impingement.



site and, as occurs with a normal inflammatory response, takes some time post-injury to develop. Thus, the optimal time to determine the extent of the posterior thigh injury is at least 48 hours post injury but prior to 96 hours[13].

Each sport is unique

Secondly, with respect to prognosis, it is difficult to translate findings of any given sport into the findings of another. Thus, the findings of Australian Rules football, where many of the original prospective and prognostic studies have been performed, would probably not translate to the same prognosis in soccer. In addition, this may also be true for different levels of play as, for example, elite compared to semi-professional athletes within the same sport.

Prognosis

Thirdly not enough research has been performed on the significance of the differing muscle injures (biceps femoris, semimembranosus and semitendinosus) in different sports and activities to give clear significance to prognostic features. Currently (at least in the football codes where most research has been performed) prognosis as calculated using MRI probably only applies to the biceps femoris muscle as these account for 75 to 90% of football sports injuries.

> ***The optimal time to determine extent of the posterior thigh injury is at least 48-96 hours post injury***

Mechanism of injury

Fourthly the mechanism of injury is typically not taken into account with respect to football injuries, their MRI grading and prognosis. Although most posterior thigh injuries occur during running, not all do. Insidious onset no mechanism injuries, injuries associated with an overstretch from a kick or forced trunk flexion and other mechanisms not yet described also cause hamstring strains. How this relates to grade and prognosis is not clear at this point of time.

Uncommon injuries

Finally there are injuries where not enough research has been performed to understand the significance of the MRI-detected injury and therefore the subsequent treatment and prognosis. These include but are not limited to:

1. Severe injuries associated with tendon avulsion at the origin (Figure 5).
2. Hamstring origin tendinopathies (Figure 6).
3. Where there is a clear link between a sport and mechanism and subsequent MRI finding.

Examples of the this include the overstretch injury associated with dancing[18], the proximal semitendinosus injury associated with trail leg during athletic hurdling (Figure 7) and distal semitendinosus tendon injuries associated with overuse injury in kicking sports e.g. pes bursitis.

RECENT DEVELOPMENTS

Of most interest is the recent Munich classification that attempts a clinical and MRI classification[4,19]. A significant element of the classification is the distinction drawn between functional and structural injuries. Functional injuries are those posterior thigh injuries with negative MRI findings or those with only MRI oedema and no fibre tear detected. The term functional in this context means the function of the athlete rather than the traditional use of this term in medicine. Functional may mean a disease or disorder of physiological function having no known organic basis and/ or in psychiatry where functional is used for disorders that are

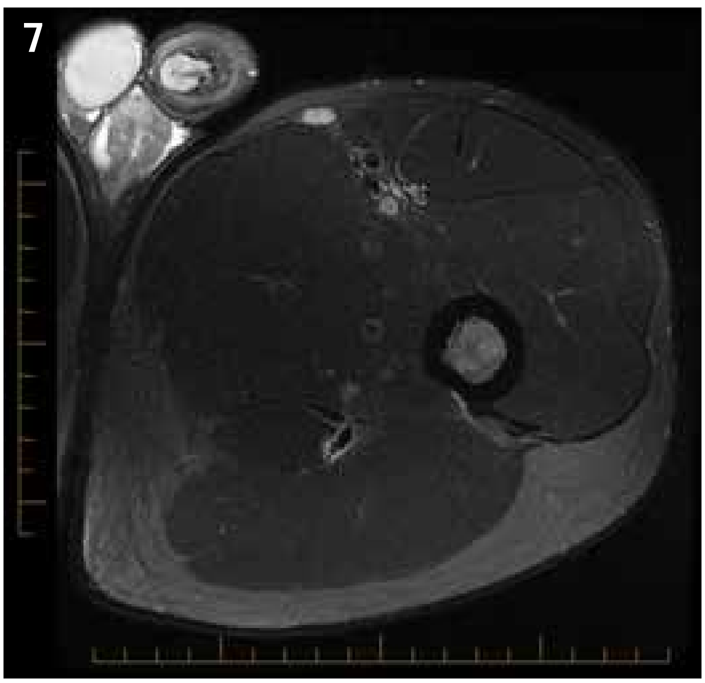


Figure 7: Proximal semitendinosus injury in a hurdling athlete. Trail leg proximal muscle injury.

psychogenic and in other branches of medicine functional may refer to disorders that are idiopathic in origin. Structural injuries are divided into minor partial muscle tear or moderate partial muscle tear and finally major injuries are designated as sub-total or total muscle tear/tendinous avulsion.

When recently applied, the classification was considered to be quite robust[19]. How practical this classification will be in linking clinical and MRI findings with prognosis and thus how useful in clinical practice is yet to be fully determined. However, in this classification three problems are readily identifiable:

1. Studies show that probably the most useful finding on MRI for the detection of posterior thigh injuries is when there is no identifiable MRI findings as these athletes have a better prognosis and a reduced convalescent time[6,7]. Clearly the presence of oedema removes doubt as to the cause, at least in part, of the posterior thigh injury. This is an evident weakness of a 'functional' classification. With respect to structural classification the detection of a tear of a muscle fibre (therefore progressing from functional to structural) and deciding between partial and moderate tear is dependent upon the sensitivity of the MRI used (the Munich classification suggests that a 1.5 to 3T MRI is used[4]) and the experience of the radiologist. Thus the classification remains subjective, not unlike previous experience with ultrasound classification.
2. The situations where the presence of muscle fibre damage has been used to distinguish between a MRI Grade 1 and 2 injury[4,19] and in addition where the presence or absence of T2 hyperintensity are both possible in Grade 1 injuries[4] has not yet been proven to be robust in terms of practical application and in some respects go against the current available literature.
3. Finally, the new classification has yet to be scientifically tested in a proper clinical trial.

SUMMARY

The diagnosis and prognosis of hamstring injuries is a field that has developed significantly over recent years. In particular, the availability of the MRI has seen a range of grading systems developed. Like most areas of sports medicine and sports injuries, further research is needed to elucidate a final diagnostic (clinical and MRI) pathway that enables useful information with respect to a safe (no recurrent injury) return to sport to be given to both the injured players and their treating doctors. Unfortunately there is no clinical or MRI system that has been proven to be useful and compelling with respect to being used in clinical practice.

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