Saturday, 10 May 2014 -- Weekend Educational Course
14:30-15:00 -- Muscle

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HIGHLIGHTS

- The study of sports-related muscle injuries continues to evolve, including [i] a new consensus statement on classification of muscle injuries, [ii] new research on acute MRI findings that predict return to sport, and [iii] new data regarding expected MRI findings when athletes return to sport

TARGET AUDIENCE

- Clinicians, radiologists, and researchers who wish to update their knowledge of how MRI relates to the study of normal and injured skeletal muscle

OBJECTIVES

- Review clinically relevant MRI findings in patients with sports-related muscle injuries, including how MRI establishes the diagnosis, impacts treatment, and helps predict prognosis
- Better understand relevant highlights from the peer-reviewed literature from the past year
- Identify strengths, weaknesses, and potential future needs of MRI in the diagnosis of muscle derangements

PURPOSE: To discuss the established uses, recent literature, and continuing challenges relating to muscle injuries in athletes, focusing particularly on strain injuries in the thigh.

METHODS: Review of the recent evidence-based medical literature, with an emphasis on the strengths, the weaknesses, and the potential future needs of MRI in the diagnosis of thigh strain injuries.

RESULTS/DISCUSSION:

General Remarks

A wide array of insults can affect muscles, including: traumatic tears and contusions; ischemia and necrosis; inflammation and infection; denervation; congenital and inherited conditions; neoplasms; and various iatrogenic insults.

In athletes, traumatic injuries are the most common type of muscle derangement. In the *acute* setting, a feathery appearance of high T2 signal in muscle is common, owing to interstitial hemorrhage and edema. In the *chronic* setting, low T2 signal is characteristic, due to fibrosis, hemosiderin, and/or heterotopic ossification. The most common types of injuries to the muscle-tendon-bone complex are strains, avulsions, and contusions. Less common traumatic derangements include laceration, muscle herniation, and delayed onset muscle soreness.

Muscle Strains

Muscle Strain - Mechanism of Injury. Strains are non-contact injuries that result from excessive stretch or tension on myotendinous fibers, usually during high-force eccentric (lengthening) muscle contraction. Strain injuries tend to occur in muscles that cross two joints, have a high proportion of fast twitch fibers, and undergo eccentric contraction.

Recent MR research has further investigated muscle behavior and strain injury susceptibility. For example, using cine DENSE dynamic MRI, hamstring muscle strain magnitudes are found to be (i) larger during active lengthening than during passive lengthening and (ii) larger for subjects with a relatively narrow proximal aponeurosis than a wide proximal aponeurosis [Fiorentino NM, 2012].

Muscle Strain - Spectrum of Injury. The degree of strain is commonly graded along a spectrum of injury -- from mild (grade 1, microscopic injury) to moderate (grade 2, partial tear) to severe (grade 3, complete tear). [Thus, in addition to "strain" being used as a biomechanical term (defined as the change in length resulting from application of a force), the term "strain" commonly refers to both the mechanism of injury (etiology) and the injury (tear) itself.]

Muscle Injuries in Sport – New Classification. A new classification system has been proposed by highly experienced clinicians that may impact daily practice and future research. The **Munich muscle injury classification system** is broadly inclusive of various causes of muscle-related pain and emphasizes the role of clinical evaluation, as "we lack high-level studies to confidently guide clinical management of muscle injuries" [Tol JL, Br J Sports Med 2013].

In the newly proposed classification, the term "strain" is intentionally eliminated. Rather, acute indirect muscle problems are divided into [I] functional ("non-structural") disorders (e.g., overexertion-related and neuromuscular) and [II] structural injuries (e.g., minor partial, moderate partial, and complete tears) [Mueller-Wohlfahrt HW, 2013].

"Functional muscle disorders", according to this "consensus group", result in a *functional* limitation for the athlete, for example, painful increase of the muscle tone, which can represent a risk factor for subsequent structural injury [Mueller-Wohlfahrt HW, 2013]. Since there is no macroscopic damage such as a tear, these "non-structural" disorders are not readily diagnosed by standard MRI.

Advanced MR techniques, however, have shown potential for studying functional disorders (e.g., diffusion techniques can show subtle post-exercise changes, such as Z-band streaming which is a histological index of damage) [Cermak NM 2012, Hata J 2013].

Strains - Sites of Injury. The age of a patient influences the location of injury along the biomechanical chain formed by the linkage of muscle to tendon and tendon to bone. In young adult athletes, the most commonly strained muscles in the extremities include the hamstrings, rectus femoris, adductors, and gastrocnemius muscles.

Thigh Muscle Injuries – What's New in the Literature?   A "Top 5 List" from the Past Year

Q. Does the Munich muscle injury classification system help predict prognosis?

A. The recently described Munich muscle injury classification was prospectively evaluated in 31 European professional male soccer teams [Ekstrand J, 2013]. Of the 393 thigh muscle injuries during a single season, "structural" injuries were more common (2/3) and were associated with longer lay-off times than "functional" disorders (median: 5-8 days). There was no significant difference in the lay-off time for anterior versus posterior thigh injuries.

The authors concluded that "functional muscle disorders are often underestimated clinically and require further systematic study".

Q. What standard MRI findings help predict the time needed to return to sport after an acute injury?

A. With muscle injuries, acute MRI findings have diagnostic and prognostic value. The time needed for an athlete to return to their sport is highly variable. Among the acute MRI findings that can be important prognostic factors: injury grade, greater craniocaudal length of the acute muscle tear on MRI, MRI-negative injuries, and trauma mechanism [Kerkhoffs GM 2013; Silder A 2013].

Another recent study on this topic emphasized the important distinction between injury to the hamstring *muscle* and injury to the hamstring *tendon*, which is underappreciated when injury involves the enclosed central portion of the tendon within the muscle [Comin J 2013]. Hamstring injuries that disrupt the central tendon enclosed within the muscle belly require a longer recovery time than injuries involving only muscle, epimysial fascia, or the musculotendinous junction.

Q. Is MRI reliable for grading and determining prognostic parameters?

Yes. Excellent interobserver and intraobserver reliability is found for grading and prognostic MRI parameters in acute hamstring injuries [Hamilton B 2013]. Thus, in daily practice and research, we can be confident that scoring hamstring injuries by experienced radiologists is reproducible.

Q. Can an athlete return to sport (RTS) if they have persisting intramuscular edema signal?

Yes. Clinically recovered muscle injuries may exhibit persistent abnormal signal intensity.

In a recent study of 53 athletes with hamstring injuries (approximately half grade 1 and half grade 2) [Reurink G 2013], the time needed for RTS ranged from 12 to 76 days (median 28 days). Despite clinical recovery, ~90% of athletes had intramuscular increased signal intensity on fluid-sensitive sequences with a mean longitudinal length of 77 mm (±53), and 42% had abnormal intramuscular low-signal intensity. A possible association between low signal fibrous tissue and re-injury risk has been hypothesized, but not definitively determined.

In the report by Silder et al [2013], at the time of RTS, all of the athletes showed a near-complete resolution of pain and return of muscle strength, but no subject showed complete resolution of injury as assessed on MRI. MRI studies also have showed edema signal involving 20% of the muscle cross-sectional area at RTS, with full resolution by the 6-month follow-up MRI [Sanfilippo JL 2013].

Q. Should partial avulsions at the proximal hamstrings be treated surgically?

A. Without MRI of the proximal hamstrings, it can be difficult for a physician to distinguish a myotendinous *strain* (treated non-surgically) from an *avulsion* at the hamstring origin (a potential surgical indication). Complete hamstring tendon tears/avulsions are best treated with early (<2-3w) surgical refixation to minimize muscle atrophy/weakness [Askling CM 2013]; delayed repairs tend to be less successful and more technically difficult due to scarring and the proximity of the sciatic nerve. The efficacy of surgical management for partial tendon tears/avulsions in the active and athletic population, however, has been debated.

In the most recently available study [Bowman KF 2013], performed after failure of at least 6 months of non-operative therapy, clinical follow-up showed that open debridement and primary tendon repair can lead to satisfactory functional outcomes, a high rate of return to athletic activity, and a low complication rate.

CONCLUSION

The cause and severity of muscle disorders vary widely in the general population. Even for athletes with a known history of direct or indirect trauma, MRI can pinpoint the appropriate pain generator, help determine the injury severity, and suggest the prognosis. Although much work has been accomplished in this field, research and optimization of MRI to evaluate muscle continues to have great potential.

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