MRI OF MUSCLE INJURY

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Role of MRI in muscle injury

Acute lesions
- Direct trauma: contusion, laceration
- Indirect trauma: strain, tear

Chronic lesions: scar, myositis ossificans, herniation

Other traumatic muscle disorders

Grading systems of muscle injury
Muscle Injury: Introduction

- Skeletal muscle is the single largest tissue in the body: 40-45% of total body mass.

- Conditions affecting muscles:
  - Traumatic
  - Inflammatory
  - Infectious
  - Neurologic
  - Neoplastic
Muscle Injury: Introduction

- Muscle injuries: 30% of all sports-related injuries

- In elite sport, important physical, psychological, and financial implications for athlete, coach, team

- Lower extremity most common: hamstrings, rectus femoris, gastrocnemius

- Thigh muscle strains most common injury after ankle sprains in Beijing Olympic games

**Muscle Injury: Introduction**

- Most acute muscle injuries diagnosed clinically, however MR imaging increasingly requested.
- MRI of muscle injuries influences therapy and outcome.


**Role of MRI In Muscle Injury**

1. Precise diagnosis, classification and grading:
   - when surgical repair considered
   - to plan rehabilitation, especially in the elite athlete, increasingly in recreational athlete

2. Exclude other injuries (e.g. stress fractures)

3. Diagnosis of chronic sequelae of injury:
   - Atrophy and fatty infiltration
   - Scar formation
**Muscle Injury: MRI Technique**

- Scan 1 limb
- Choose appropriate coil
- Varying protocols between institutions, but need to include
  - **STIR or FS T2**-weighted images: hemorrhage, edema (T2 prolongation due to increased intracellular or extracellular free water)
  - **T1**-weighted imaging: anatomic detail, blood products, atrophy/fatty infiltration, myositis ossificans
  - Axial + coronal and/or sagittal in axis of torn muscle
- No need for iv contrast
Muscle Injury: Two Main Mechanisms

Direct Trauma
- Contusions
- Lacerations

Indirect Trauma
- Strains
- Tears
- DOMS
DIRECT TRAUMA: MUSCLE CONTUSIONS

- Direct blow to muscle. History is specific
- Deep layers of muscle compress against bone: interstitial edema and hemorrhage
- MRI findings: characteristic feathery, infiltrative high signal; no muscle fiber discontinuity
- Often larger in size than strains/tears, but recovery shorter
- Myositis ossificans a recognized complication

Vastus intermedius muscle contusion

- Note high signal on T1

Images:
- STIR
- T1
- T2
Note: edema can affect different muscles, crosses fascial planes
53F - anterior thigh pain after direct trauma to thigh; on anticoagulation therapy
53F- Intramuscular Hematoma (vastus lateralis)
Role of a muscle: to generate force through active contraction, which is transmitted to bone via tendons.

Main area of weakness of muscle-tendon-bone unit varies depending on age:
- Young/athletes → Myotendinous junction
- Pediatric → Bone-tendon interface (avulsion fx)
- Older adults → Tendons

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Indirect Muscle Injury

- Result from excessive stretch or tension on myotendinous unit
- Muscles that cross 2 joints (e.g. rectus femoris, hamstrings, biceps brachii, medial gastrocnemius)
- Muscles that perform eccentric (vs concentric) contraction
  - when muscle forced to lengthen beyond the force it generates
- Muscles with high proportion of type 2 (fast-twitch) fibers
MUSCLE TEARS

- **GRADE 1**: Muscle strain
- **GRADE 2**: Partial muscle tear
- **GRADE 3**: Complete disruption of myotendinous junction

Grade 1 Muscle Injury (Strain)

- Microscopic injury without fiber disruption
- Intramuscular high T2 signal
- Feathery pattern around myotendinous junction and adjacent muscle
- Imaging findings and symptoms resolve completely

Grade 1 soleus muscle strain
19M “R/O gastroc tear”

Ax fat sat T2

Ax T1

* T1WI often normal *
Grade 1 Muscle Injury

- Edema at myotendinous junction of rectus femoris
Partial tear of myotendinous junction (macroscopic fiber disruption):

- More prominent intramuscular high signal
- Perifascial fluid/hematoma diagnostic
- Irregular thinning and mild laxity of tendon
- Little/no tendon retraction
Grade 2 Muscle Injury
19M basketball trauma

- Epimyseal pattern of edema and fluid (note fluid-fluid levels)
- Muscle tear visible on T1
GRADE 2 MUSCLE INJURY

- Partial tear vastus lateralis and medialis
- Hematoma
GRADE 3 MUSCLE INJURY

- Complete myotendinious rupture: separated tendon ends, bunching up of muscle
- Hematoma
- Will develop muscle atrophy and fatty infiltration, scar tissue, and loss of function
- Usually require early surgical intervention to prevent scar formation, permanent retraction
67M-injury with palpable anterior thigh mass
Grade 3 Muscle Injury: Rectus Femoris

- Complete rupture of myotendinous junction of rectus femoris
- Retraction of tendon and muscle with gap
- Surrounding muscle edema
- Hematoma
GRADE 3 RECTUS FEMORIS TEAR
Grade 3 Hamstring Muscle Tear:
62M- Left semimembranosus complete tear

Ax FST2

Ax T1
Grade 3 Hamstring Muscle Tear:
62M- Left semimembranosus complete tear

Sag STIR

Cor FS T2
HAMSTRING INJURIES

- Partial > complete tears/ avulsions in young
- Biceps femoris most common
- ~ 1/3 involve more than one component
- MRI good predictor of prognosis


- Markedly increased risk of more severe injury
GRADE 3
PECTORALIS MAJOR TEAR

Cor FS T2

Ax FST2

Cor T1
Muscle Hematomas on MRI

<table>
<thead>
<tr>
<th>Stage</th>
<th>Blood product</th>
<th>T1 signal intensity</th>
<th>T2 signal intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperacute (&lt;4 h)</td>
<td>Intracellular oxyhemoglobin</td>
<td>Intermediate</td>
<td>Bright</td>
</tr>
<tr>
<td>Acute (4-6 h)</td>
<td>Extracellular oxyhemoglobin</td>
<td>Intermediate</td>
<td>Dark</td>
</tr>
<tr>
<td>Early subacute (6-72 h)</td>
<td>Intracellular methemoglobin</td>
<td>Bright</td>
<td>Dark</td>
</tr>
<tr>
<td>Late subacute (72 h-4 weeks)</td>
<td>Extracellular methemoglobin</td>
<td>Bright</td>
<td>Bright</td>
</tr>
<tr>
<td>Chronic (&gt;4 weeks)</td>
<td>Hemosiderin</td>
<td>Dark</td>
<td>Dark</td>
</tr>
</tbody>
</table>

The 3 grades of injury are simple and lacking in diagnostic accuracy and have limited prognostic information.

‘Strain’: a biomechanical term and used inconsistently.

British athletics classification:
- Grades 0-4
- Site of injury
  - a) Myofascial
  - b) Muscular/myotendinous
  - c) Intratendinous

The Munich consensus statement

Table 2  Classification of acute muscle disorders and injuries

<table>
<thead>
<tr>
<th>Classification of acute muscle disorders and injuries</th>
<th>Type 1: Overexertion-related muscle disorder</th>
<th>Type 1A: Fatigue-induced muscle disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Indirect muscle disorder/injury</td>
<td>Type 2: Neuromuscular muscle disorder</td>
<td>Type 1B: Delayed-onset muscle soreness (DOMS)</td>
</tr>
<tr>
<td>Functional muscle disorder</td>
<td>Type 2A: Spine-related neuromuscular Muscle disorder</td>
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</tr>
<tr>
<td></td>
<td>Type 2B: Muscle-related neuromuscular Muscle disorder</td>
<td></td>
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<tr>
<td>Structural muscle injury</td>
<td>Type 3: Partial muscle tear</td>
<td>Type 3A: Minor partial muscle tear</td>
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<tr>
<td></td>
<td>Type 3B: Moderate partial muscle tear</td>
<td>Subtotal or complete muscle tear</td>
</tr>
<tr>
<td></td>
<td>Type 4: (Sub)total tear</td>
<td>Tendinous avulsion</td>
</tr>
<tr>
<td>B. Direct muscle injury</td>
<td>Contusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td></td>
</tr>
</tbody>
</table>

Chronic Muscle Lesions

- Scar
- Myositis ossificans
- Muscle herniation
- Muscle atrophy and fatty infiltration
SAME 49M WITH PECTORALIS MAJOR COMPLETE TEAR - 4 MONTHS LATER

- Scar tissue formation (low SI on all sequences)
- Focal atrophy
Acquired focal defect in fascial layer (epimysium): muscle protrusion

Often asymptomatic, though can be painful

P/E: palpable mass that appears or protrudes with muscle contraction

Flexor Muscle Herniation

- Focal muscle protrusion through fascia
- Signal and appearance of muscle typically normal
Heterotopic ossification in muscle
2º trauma (contusion, burns, surgery); nerve injury; bleeding dyscrasias
Variable MRI appearance:
- Acute phase: pseudoinflammatory
- Subacute phase: pseudotumoral
- Chronic phase: fatty change, ossified rim
  ~ 6-8 weeks after trauma

Myositis Ossificans - biopsy-proven(!)
Other Traumatic Muscle Lesions
Ankle fracture-dislocation...
...severe lower leg pain
Increased interstitial pressure within an anatomically-confined muscle compartment
  - Fractures most commonly; occasionally with muscle rupture in athletes
- Pain out of proportion to injury
- Pain on passive motion
- Pulselessness
- Paresthesias
- Pallor (late, often irreversible)
- May become chronic

Whitesides, T. E. et al Clin Ortho 1975
69M - Slowly enlarging lower leg mass: 
Dx?
Calcific Myonecrosis

- Rare posttraumatic complication
- Replacement of muscle with central liquefaction and peripheral calcification
- Reported to develop 10 to 64 years after initial injury
- Sx: enlarging painful mass anterior lower leg
- May develop superinfection/spontaneous drainage
- May be continuum: post-traumatic cysts → expanding hematoma → calcific myonecrosis

Holobinko, J N et al Skel Rad 2003
Recent Advances: Functional Imaging of Muscles

- Diffusion-tensor imaging (DTI) and MR fiber tractography
- MR elastography
- BOLD imaging
- Proton or phosphorus spectroscopy
- Perfusion imaging

Muscle injuries are extremely common in the athletic population.

MRI is playing an increasing role in diagnosis, grading, and prognosis, and detection of complications of muscle injury.

Direct injuries (contusions): edema at site of direct blow, hematomas if more severe.

Indirect injuries almost always at myotendinous junction (weakest ‘link’):
- Feathery edema in muscle strain
- More severe injuries contain hematomas and grossly interrupted muscle

Future directions in functional MR imaging of muscle.