An Imaging Review of Muscle Part 1: Trauma

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MINI PATHRIA
NORMAL MUSCLE ANATOMY

EACH COMPONENT HAS A CONNECTIVE TISSUE COVERING:
NORMAL MUSCLE

- SYMMETRIC
- SMOOTH CONVEX BORDERS
- SIGNAL INTENSITY:
  T1: fat > MUSCLE > water
  T2 nonFS: fat and water > MUSCLE
  IR and T2FS: water > MUSCLE > fat

THREE BASIC PATTERNS OF MUSCLE ABNORMALITY

EDEMA  MASS  ATROPHY
An Imaging Review of Muscle, Part 1: Trauma

Edema
- Traumatic strain
- Delayed onset muscle soreness (DOMS)
- Contusion
- Rhabdomyolysis

Mass
- Hematoma
- Myositis ossificans
- Muscle herniation
- Myonecrosis

Atrophy
- Remote muscle injury

Site-specific injuries:
- Novel lesion of the Infraspinatus
- PLaTe muscles
- Triceps
- Rectus femoris
- Hamstring avulsion
- Tennis leg

- Most common MR pattern
- Increased signal on fluid-sensitive sequences with or without architectural distortion
- Nonspecific
- Clinical history is the key to diagnosis
An Imaging Review of Muscle, Part 1: Trauma

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- Nonspecific
- Clinical history is the key to diagnosis
EDEMA: Muscle Strain

The most common muscle injury is a **MUSCLE STRAIN**

**HALLMARK:** Edema and/or interstitial hemorrhage centered at the myotendinous junction (MTJ)

Locations of myotendinous junction:
- Central/focal
- Surface/sheet-like at surface
EDEMA: Muscle Strain

The most common muscle injury is a **MUSCLE STRAIN**

**HALLMARK:** Edema and/or interstitial hemorrhage centered at the myotendinous junction (MTJ)

Locations of myotendinous junction:
- Central/focal
- Surface/sheet-like at surface

**MR APPEARANCE** of strain will depend on the:
- Location of injury
- Grade of injury
- Chronicity of injury
EDEMA: Muscle Strain

- LOCATION
  - MYOTENDINOUS JUNCTION
    - Epimysial
    - Grade
    - Chronicity

MYOTENDINOUS JUNCTION (MTJ):
- Where muscle fibers converge upon the tendon
- Shape varies in different muscles
- In many muscles, the tendon extends deep within the muscle belly creating a long myotendinous junction
- Site of MAXIMAL force concentration during ECCENTRIC exercise
EDEMA: Muscle Strain

- LOCATION
  - MYOTENDINOUS JUNCTION
    - Epimysial
- Grade
- Chronicity

CASE: 32-year-old man who suffered a football injury
FINDINGS: Strain of the biceps femoris myotendinous junction
EDEMA: Muscle Strain

- LOCATION
  - Myotendinous junction
  - EPIMYSIAL
- Grade
- Chronicity

EPIMYSIUM:
- Fibrous tissue that lies at the EDGE of the muscle
- It forms the muscle sheath that fuses with the tendon
- When there is a muscle tear, fluid tends to collect in the epimysium, and abnormalities are therefore found at the muscle PERIPHERY.
EDEMA: Muscle Strain

- **LOCATION**
  - Myotendinous junction
  - EPIMYSIAL
- Grade
- Chronicity

CROSS SECTION OF A MUSCLE
EDEMA: Muscle Strain

- LOCATION
  - Myotendinous junction
  - EPIMYSIAL
- Grade
- Chronicity

FINDINGS:
Epimysial strain of biceps femoris
Note the PERIPHERALLY LOCATED signal alterations
EDEMA: Muscle Strain

- LOCATION
  - Myotendinous junction
  - EPIMYSIAL
- Grade
- Chronicity

MUSCLE FIBER: individual contractile unit of the muscle

Each muscle fiber is covered by ENDOMYSIUM

A group of muscle fibers, or a FASCICLE...
EDEMA: Muscle Strain

- **LOCATION**
  - Myotendinous junction
  - **EPIMYSIAL**

- Grade
- Chronicity

**MUSCLE FIBER:** individual contractile unit of the muscle

Each muscle fiber is covered by **ENDOMYSIUM**

A group of muscle fibers, or a **FASCICLE**...
EDEMA: Muscle Strain

- LOCATION
  - Myotendinous junction
  - EPIMYSIAL
- Grade
- Chronicity

MUSCLE FIBER: individual contractile unit of the muscle

Each muscle fiber is covered by ENDOMYSIUM

A group of muscle fibers, or a FASCICLE...

...is covered by PERIMYSIUM
EDEMA: Muscle Strain

- **LOCATION**
  - Myotendinous junction
  - **EPIMYSIAL**

- Grade
- Chronicity

**MUSCLE FIBER:** individual contractile unit of the muscle

Each muscle fiber is covered by **ENDOMYSIUM**

A group of muscle fibers, or a **FASCICLE**...

...is covered by **PERIMYSIUM**

A group of fascicles is covered by **EPIMYSIUM**
EDEMA: Muscle Strain

LOCATION
- Myotendinous junction
- EPIMYSIAL

FINDINGS:
Epimysial strain of biceps femoris
Note the PERIPHERALLY LOCATED signal alterations
# EDEMA: Muscle Strain

**Location**

- **GRADE**

- Chronicity

## OVERVIEW of previous muscle injury classification systems

Currently, the most widely used classification is MRI-based (four grades: 0, 1, 2, 3).

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>No appreciable tissue tearing, no loss of function or strength, only a low-grade inflammatory response</td>
<td>Tear of a few muscle fibers, fascia remaining intact</td>
<td>No abnormalities or diffuse bleeding with/without focal fiber rupture less than 5% of the muscle involved</td>
<td>MRI-negative=0% structural damage Hyperintense edema with or without hemorrhage</td>
</tr>
<tr>
<td>II</td>
<td>Tissue damage, strength of the myotendinous unit reduced, some residual function</td>
<td>Tear of a moderate number of fibers, fascia remaining intact</td>
<td>Partial rupture: focal fiber rupture more than 5% of the muscle involved with/without fascial injury</td>
<td>MRI-positive with tearing up to 50% of the muscle fibers Possible hyperintense focal defect and partial retraction of muscle fibers</td>
</tr>
<tr>
<td>III</td>
<td>Complete tear of myotendinous unit, complete loss of function</td>
<td>Tear of many fibers with partial tearing of the fascia</td>
<td>Complete muscle rupture with retraction, fascial injury</td>
<td>Muscle rupture=100% structural damage Complete tearing with or without muscle retraction</td>
</tr>
<tr>
<td>IV</td>
<td>X</td>
<td>Complete tear of the muscle and fascia of the muscle-tendon unit</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>


EDema: Muscle Strain

- Location
- Grade
- Chronicity

Low-Grade
Increased signal on fluid sensitive sequences and preserved muscle architecture on T1-weighted images

Findings:
MRI: Subtle edema in the lateral head of the gastrocnemius MTJ without fiber disruption
US: Small hypoechoic foci/serous cavities adjacent to the MTJ without disruption of the tendon’s normal fibrillar structure
EDEMA: Muscle Strain

- Location
- GRADE
- Chronicity

MODERATE-GRADE
Architectural distortion without fluid collection

FINDINGS:
MRI: EDEMA and ARCHITECTURAL DISTORTION in the myotendinous junction of the medial head of the gastrocnemius
US: ECHOGENIC appearance of the MTJ reflecting disrupted fibers
EDEMA: Muscle Strain

- Location
- GRADE
- Chronicity

MODERATE-GRADE
Architectural distortion WITH focal fluid collections/hematomas

FINDINGS:
MRI: Architectural distortion and hematoma in the adductor longus muscle
US: Hypoechoic foci representing fluid collections
EDEMA: Muscle Strain

- Location
- GRADE
- Chronicity

HIGH-GRADE
Complete disruption/full-thickness tear with or without tendon retraction

FINDINGS ON MRI:
Complete disruption of the proximal adductor muscles
EDEMA: Muscle Strain

- Location
- **GRADE**
- Chronicity

**LIMITATIONS** of previous classification systems:

1. Lack of subclassifications: injuries of DIFFERENT etiology, treatment pathway, and prognosis are grouped together

2. Some classification systems, such as the ultrasound-based (Takebayashi) system, are not consistently measurable

3. No terminology or grading system (sub)classified disorders without macroscopic evidence of structural damage, even though a muscle injury study of the Union of European Football Associations (UEFA) has emphasized their high clinical relevance in professional athletes
## EDEMA: Muscle Strain

**Comprehensive muscle injury classification: type-specific definitions and clinical presentations**


<table>
<thead>
<tr>
<th>Type</th>
<th>Classification</th>
<th>Definition</th>
<th>Symptoms</th>
<th>Clinical signs</th>
<th>Location</th>
<th>Ultrasound/MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Fatigue-induced muscle disorder</td>
<td>Circumscribed longitudinal increase of muscle tone due to overexertion, change of playing surface or training patterns</td>
<td>Aching muscle firmness increasing with continued activity Can provoke pain at rest during or after activity</td>
<td>Dull, diffuse, tolerable pain in involved muscles, circumscribed increase of tone, ‘muscle tightness’</td>
<td>Focal involvement up to entire length of muscle</td>
<td>Negative</td>
</tr>
<tr>
<td>1B</td>
<td>Delayed-onset muscle soreness (DOMS)</td>
<td>More generalized muscle pain following unaccustomed, eccentric deceleration movements</td>
<td>Acute inflammatory pain Pain at rest, hours after activity</td>
<td>Edematous swelling, stiff muscle Limited range of motion of adjacent joints Pain on isometric contraction</td>
<td>Mostly entire muscle or muscle group</td>
<td>Negative or edema only</td>
</tr>
<tr>
<td>2A</td>
<td>Spine-related neuromuscular disorder</td>
<td>Circumscribed longitudinal increase of muscle tone due to functional or structural spinal/lumbopelvic disorder</td>
<td>Aching muscle firmness increasing with continued activity No pain at rest</td>
<td>Circumscribed longitudinal increase of muscle tone Discrete edema between muscle and fascia Pressure pain</td>
<td>Muscle bundle or larger muscle group along entire length of muscle</td>
<td>Negative or edema only</td>
</tr>
<tr>
<td>2B</td>
<td>Muscle-related neuromuscular disorder</td>
<td>Circumscribed (spindle-shaped) area of increased muscle tone May result from dysfunctional neuromuscular control</td>
<td>Aching, gradually increasing muscle firmness and tension Cramp-like pain</td>
<td>Circumscribed (spindle-shaped) area of increased muscle tone, edematous swelling Therapeutic stretching leads to relief</td>
<td>Mostly along the entire length of the muscle belly</td>
<td>Negative or edema only</td>
</tr>
<tr>
<td>3A</td>
<td>Minor partial muscle tear</td>
<td>Tear with a maximum diameter of less than muscle fascicle/bundle</td>
<td>Sharp, needle like or stabbing pain at time of injury A ‘snap’ followed by a sudden onset of localized pain</td>
<td>Well-defined localized pain Probably palpable defect in fiber structure within a firm muscle band</td>
<td>Primarily muscle-tendon junction</td>
<td>Fiber disruption on high resolution MRI, intramuscular hematoma</td>
</tr>
<tr>
<td>3B</td>
<td>Moderate partial muscle tear</td>
<td>Tear with a diameter of greater than a fascicle/bundle</td>
<td>Stabbing, sharp pain, often noticeable tearing at time of injury Athlete often experiences a ‘snap’ followed by a sudden onset of localized pain</td>
<td>Well-defined localized pain Painful gap in muscle structure, often hematoma, fascial injury Stretch-induced pain aggravation</td>
<td>Primarily muscle-tendon junction</td>
<td>Positive for significant fiber disruption, probably including some retraction</td>
</tr>
<tr>
<td>4</td>
<td>(Sub)total muscle tear/tendinous injury</td>
<td>Tear involving the subtotal/complete muscle diameter/tendinous injury involving the bone-tendon junction</td>
<td>Null pain at time of injury Noticeable tearing at time of injury Athlete experiences a ‘snap’ and a sudden onset of localized pain</td>
<td>Large defect in muscle, hematoma, palpable gap, muscle retraction</td>
<td>Primarily muscle-tendon junction or bone-tendon junction</td>
<td>Subtotal/complete discontinuity of muscle/tendon with fascial injury, hematoma</td>
</tr>
</tbody>
</table>
### EDEMA: Muscle Strain

- **Location**
- **GRADE**
- **Chronicity**

#### Classification of acute muscle disorders and injuries


| A. Indirect muscle disorder/injury | Functional muscle disorder | Type 1: Overexertion related muscle disorder | Type 1A: Fatigue-induced muscle disorder  
Type 1B: Delayed onset muscle soreness (DOMS) |
|-----------------------------------|-----------------------------|-----------------------------------------|-----------------------------------------------|
| Structural muscle injury          | Type 2: Neuromuscular muscle disorder | Type 2A: Spine-related neuromuscular disorder  
Type 2B: Muscle-related neuromuscular disorder |
|                                   | Type 3: Partial muscle tear | Type 3A: Minor partial muscle tear  
Type 3B: Moderate partial muscle tear |
|                                   | Type 4: (Sub)total tear      | Subtotal or complete muscle tear  
Tendinous avulsion |
| B. Direct muscle injury           | Contusion                    | Laceration                            |

#### HIGHLIGHTS:

Delayed onset muscle soreness (DOMS) must be differentiated from fatigue-induced muscle injury
**EDEMA: Muscle Strain**

- Location
- **GRADE**
- Chronicity

**SUMMARIZED to:**

### Classification of acute muscle disorders and injuries

Terminology and classification of muscle injuries in sport:
A consensus statement (British Journal of Sports Medicine 2012)

| A. Indirect muscle disorder/injury | Functional muscle disorder | Type 1: Overexertion related muscle disorder | Type 1A: Fatigue-induced muscle disorder  
Type 1B: Delayed onset muscle soreness (DOMS) |
|-----------------------------------|----------------------------|-------------------------------------------|------------------------------------------|
|                                   | Structural muscle injury   | Type 2: Neuromuscular muscle disorder      | Type 2A: Spine-related neuromuscular disorder  
Type 2B: Muscle-related neuromuscular disorder |
|                                   |                            | Type 3: Partial muscle tear                | Type 3A: Minor partial muscle tear  
Type 3B: Moderate partial muscle tear |
|                                   |                            | Type 4: (Sub)total tear                   | Subtotal or complete muscle tear  
Tendinous avulsion |
| B. Direct muscle injury           |                             | Contusion Laceration                      |                              |

**HIGHLIGHTS:** Inclusion of DIRECT muscle injuries such as CONTUSIONS and LACERATIONS
EDema: Delayed Onset Muscle Soreness (DOMS)

- DOMS causes characteristic acute inflammatory pain HOURS to DAYS after exercise, INCREASES DURING REST, and resolves spontaneously usually within A WEEK.
- FATIGUE-INDUCED MUSCLE DISORDER leads to aching or stabbing pain, circumscribed firmness, INCREASES WITH CONTINUED ACTIVITY, can persist for a LONGER TIME and may cause structural injuries, such as partial tears.

CASE: 34-year-old man with severe thigh pain two days after exercise.

FINDINGS: Edema in both heads of the gastrocnemius muscles.
EDEMA: Delayed Onset Muscle Soreness (DOMS)

MR may show edema in various muscles although MUSCLE INTEGRITY is PRESERVED in DOMS

CASE: 33-year-old woman three days after running
FINDINGS ON MRI: Patchy muscle edema predominantly involving the anterior compartments of both legs
EDEMA: Contusion

- Due to a DIRECT BLOW
- Changes are seen at the SITE of INJURY
EDEMA: Contusion

- SEVERITY of the injury depends on the CONTACT FORCE and the CONTRACTION STATE of the affected muscle at the moment of injury.
- NOT necessarily accompanied by structural damage; even athletes with severe contusions can continue playing.

FINDINGS: CONTUSION and HEMATOMA in the vastus medialis muscle.
# EDEMA: Muscle Strain

**THE LATEST CLASSIFICATION SYSTEMS:**

**BRITISH ATHLETICS CLASSIFICATION**

1. **Length**
2. **Area**
3. **Localization** (i.e. myofascial, MTJ, or within the tendon)

<table>
<thead>
<tr>
<th>GRADE</th>
<th>DESCRIPTION</th>
<th>MRI Imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>0a</td>
<td>Focal area of muscle pain usually following exercise.</td>
<td>MRI normal</td>
</tr>
<tr>
<td>0b</td>
<td>Generalized muscle pain following unaccustomed exercise</td>
<td>MRI normal or patchy high signal change throughout one or more muscles</td>
</tr>
<tr>
<td>1a</td>
<td>Small myofascial tear</td>
<td>High signal change at the fascial border with less than 10% extension into muscle belly. Craniocaudal distance of &lt;5 cm.</td>
</tr>
<tr>
<td>1b</td>
<td>Small muscle tendon junction tear</td>
<td>High signal change of less than 10% cross sectional area of muscle at the MTJ. High signal change of craniocaudal length &lt;5 cm (may note fiber disruption of &lt;1 cm).</td>
</tr>
<tr>
<td>2a</td>
<td>Moderate myofascial tear</td>
<td>High signal change evident at the fascial border with extension into the muscle. High signal change cross sectional area of between 10-50% at maximal site. High signal change of craniocaudal length 5-15 cm. Architectural fiber disruption less than 5 cm.</td>
</tr>
<tr>
<td>2b</td>
<td>Moderate muscle tendon junction tear</td>
<td>High signal change evident at the MTJ. High signal change cross sectional area of between 10-50% at maximal site. High signal change of craniocaudal length 5-15 cm. Architectural fiber disruption less than 5 cm.</td>
</tr>
<tr>
<td>2c</td>
<td>Moderate-sized intratendinous tear</td>
<td>High signal change extends into the tendon with longitudinal length of tendon involvement &lt;5 cm. Cross sectional area of tendon involvement &lt;50% of tendon cross sectional area. No loss of tension or discontinuity within the tendon.</td>
</tr>
<tr>
<td>3a</td>
<td>Extensive myofascial tear</td>
<td>High signal change evident at the fascial border with extension into the muscle.</td>
</tr>
</tbody>
</table>
**EDEMA: Muscle Strain**

- Patterns
- **GRADE**
- Chronicity

**ASPETAR CLASSIFICATION**
1. Mechanism of injury
2. Re-injury concept
3. Proximal, middle, or distal third of tendon

<table>
<thead>
<tr>
<th>MECHANISM</th>
<th>LOCATION</th>
<th>GRADE</th>
<th>RE-INJURY</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (direct)</td>
<td>Dp</td>
<td>0</td>
<td>R0 1st episode</td>
</tr>
<tr>
<td></td>
<td>Dm</td>
<td>1&lt;10% CSA</td>
<td>R1 2nd episode</td>
</tr>
<tr>
<td></td>
<td>Dd</td>
<td>2 11-25% CSA</td>
<td>R......episode</td>
</tr>
<tr>
<td>I (indirect)</td>
<td>ITp</td>
<td>3 26-49% CSA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ITd</td>
<td>4 &gt;50% CSA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IJp</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IJd</td>
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<td>IF</td>
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</tr>
</tbody>
</table>

- Proximal third direct muscle injury
- Medial third direct muscle injury
- Distal third direct muscle injury
- Proximal tendon tear
- Distal tendon tear
- Proximal MTJ tear
- Distal MTJ tear
- Peripheral tear
EDEMA: Muscle Strain

- Patterns
- GRADE
- Chronicity

BRITISH ATHLETICS grade 1b
Less than 10% of the area of the muscle
Less than 5 cm craniocaudal length

ASPETAR Ijd1R0
Ijd: Indirect distal MTJ
Grade 1: less than 10% cross sectional area
R0: first episode
EDEMA: Muscle Strain

- Patterns
- GRADE
- Chronicity

BRITISH ATHLETICS grade 2b
Moderate myotendinous junction tear
10-50% of the area of the muscle
5-15 cm craniocaudal length

ASPETAR IJp2R0
Ijp: Indirect proximal MTJ
Grade 2: 11-25% cross sectional area
R0: first episode
EDEMA: Muscle Strain

- Patterns
- GRADE
- Chronicity

BRITISH ATHLETICS grade 4
Complete discontinuity of the muscle with retraction

ASPETAR Dd4R0
Dd: Direct distal third
Grade 4: >50% cross sectional area
R0: first episode
**EDEMA: Muscle Strain**

- Patterns
- **GRADE**
- Chronicity

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**BRITISH ATHLETICS grade 4c**
Complete discontinuity of the tendon with retraction

**ASPETAR ITp4R1**
ITp: Indirect proximal tendon
Grade 4: >50% cross sectional area
R1: second episode
EDEMA: Muscle Strain

Patterns
Grade
CHRONICITY

- ACUTE injury initially presents with edema and hemorrhage
- RESOLVING injuries may present with subsiding edema and, much later, atrophy, fibrosis, or calcification

CASE: 32-year-old woman after sports injury

INITIAL MR FINDINGS: Moderate-grade myotendinous junction tear with hematoma

FOLLOW-UP MR IMAGES after 1 month: Subsiding edema and resolving hematoma
EDEMA: Rhabdomyolysis

- Destruction of muscle fibers with release of myoglobin into the circulatory system, which may lead to renal failure
- ETIOLOGY: unresolved compartment syndrome, major trauma (caused by intense exercise in 6% of cases) and substance abuse (alcohol, cocaine and heroin)
- The mechanism of COCAINE-ASSOCIATED RHABDOMYOLYSIS potentially includes ischemia due to vasoconstriction, direct toxicity, hyperpyrexia, and increased muscle activity from agitation or seizure

CASE: Adult man, cocaine addict

FINDINGS: Diffuse, symmetric edema and myonecrosis involving the gluteal muscles bilaterally

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Edema
- Traumatic strain
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- Contusion
- Rhabdomyolysis

Mass
- Hematoma
- Myositis ossificans
- Muscle herniation
- Myonecrosis

Atrophy
- Remote muscle injury

Site-specific injuries:
- Novel lesion of the Infraspinatus
- PLaTe muscles
- Triceps
- Rectus femoris
- Hamstring avulsion
- Tennis leg

Severe trauma, particularly DIRECT injury, can lead to disruption of muscle fibers and the formation of intramuscular hematoma, resulting in a mass lesion superimposed on muscle edema.
MASS: Hematoma

- Severe muscle strains with fluid collections or grossly disrupted fibers can appear mass-like and be confused with a tumor.
- When in doubt, use INTRAVENOUS CONTRAST; a hematoma can show enhancement at times, but usually only at the PERIPHERY.
- FOLLOW-UP studies should be done until the hematoma completely resolves.

CASE: 35-year-old man with right thigh pain and swelling after a football injury.

FINDINGS:
Intramuscular hematoma in the thigh (notice the lack of enhancement on postcontrast/T1+C images).
Stage of hematoma determines its signal characteristics on MR.

CASE: 81-year-old man with right knee pain and ecchymotic swelling.

FINDINGS: Hematoma in the vastus lateralis muscle.
**CASE:** 31-year-old man after knee injury

**FINDINGS:** Hematoma in the anterior aspect of the knee

**MASS:** Hematoma

- Iso- or hypointense to muscle on T1
- Hypointense signal on T2 is due to INTRACELLULAR DEOXYHEMOGLOBIN
MASS: Hematoma

CASE: 32-year-old man injured during basketball game

FINDINGS: Hematoma in the triceps muscle
CASE: 32-year-old man injured during basketball game
FINDINGS: Hematoma in the triceps muscle

Peripheral hyperintensity on T1 is due to METHEMOGLOBIN (forms within 3-7 days)
CASE: 36-year-old man with hemophilia B s/p right lower leg injury

FINDINGS: Hematoma centered between the soleus and gastrocnemius muscles

LATE SUBACUTE > 7 DAYS

T1
T2
MASS: Hematoma

CASE: Adult man after sports injury

FINDINGS: Hematoma between the soleus and medial head of the gastrocnemius muscles

DARK RIM on BOTH T1 and T2 images due to HEMOSIDERIN

CHRONIC > 14 DAYS
MASS: Hematoma

CASE: Adult man after sports injury

FINDINGS: Hematoma between the soleus and medial head of the gastrocnemius muscles

DARK RIM on BOTH T1 and T2 images due to HEMOSIDERIN
CASE: 30-year-old woman with a “lump” in the medial right arm

- Benign post-traumatic process characterized by delayed ossification, usually within large muscles
- Look for the classic ZONAL PATTERN OF CALCIFICATION that PROGRESSES CENTRIPETALLY, which can occur over months
CASE: 18-year-old man with helmet to thigh while playing football

- Appearance depends on its MATURITY
- During its EARLY PHASE, it can mimic more AGGRESSIVE lesions (e.g. infection or neoplasm) on MRI and be misdiagnosed as such
- Remember this is a DO NOT TOUCH LESION!
MAS: Muscle Herniation

CASE: 32-year-old man with a bump in the left lower leg
CASE: 32-year-old man with a bump in the left lower leg

- Muscle hernias are caused by a focal fascial sheath defect.
- Classified as either congenital (overall weakness in the fascia such as in mesodermal insufficiency) or acquired (most commonly secondary to trauma).

- On MR, muscle herniations exhibit signal isointense to that of NORMAL muscle.
- Intermittent muscle hernias may require the use of provocative maneuvers or dependent limb position in order to increase conspicuity and allow for a more confident diagnosis.
**MASS: Muscle Herniation**

**CASE:** 32-year-old man with a bump in the left lower leg

**FINDINGS:** Focused ultrasound examination in the area of concern demonstrates a contour abnormality involving a muscle of the anterior compartment of the lower leg.

- Muscle hernias are caused by a focal fascial sheath defect
- Classified as either congenital (overall weakness in the fascia such as in mesodermal insufficiency) or acquired (most commonly secondary to trauma)

- On MR, muscle herniations exhibit signal isointense to that of NORMAL muscle
- Intermittent muscle hernias may require the use of provocative maneuvers or dependent limb position in order to increase conspicuity and allow for a more confident diagnosis

Ultrasound is therefore of great use owing to its DYNAMIC capabilities.
CASE: 68-year-old woman with multiple sclerosis and difficulty ambulating after interferon injections to her left thigh

FINDINGS: Non-enhancing area of muscle without associated mass effect, consistent with focal myonecrosis of the vastus lateralis muscle

- Myonecrosis is a myopathy involving infarction of skeletal muscle and can have the appearance of an INTRAMUSCULAR MASS
- It has a variety of causes: idiopathic, sickle cell disease, poorly-controlled diabetes, severe ischemia, drug-induced and trauma
MASS: Calcific Myonecrosis (Chronic Compartment Syndrome)

CASE: 53-year-old woman with diabetes and antiphospholipid syndrome
MASS: Calcific Myonecrosis (Chronic Compartment Syndrome)

- Rare post-traumatic entity
- INITIAL COMPARTMENT SYNDROME decreases the circulation to a compartment, resulting in necrosis and fibrosis
- Over time, repeated intralesional hemorrhage may cause the mass to ENLARGE and CALCIFY
An Imaging Review of Muscle, Part 1: Trauma

Edema
- Traumatic strain
- Delayed onset muscle soreness (DOMS)
- Contusion
- Rhabdomyolysis

Mass
- Hematoma
- Myositis ossificans
- Muscle herniation
- Myonecrosis

Atrophy
- Remote muscle injury

Site-specific injuries:
- Novel lesion of the Infraspinatus
- PLAtE muscles
- Triceps
- Rectus femoris
- Hamstring avulsion
- Tennis leg

- Decrease in the size of a muscle and FATTY replacement
- TOO MUCH FAT → ESSENTIAL to obtain T1-weighted images
- Amount of fat in muscle may vary according to level of activity (i.e. athlete versus sedentary individuals)
- Seen in the LATE stages of many pathologic conditions involving skeletal muscle
**ATROPHY: Remote Muscle Injury**

- Atrophy with fatty infiltration may be seen in the chronic stages of muscle denervation, chronic disuse, or as a late finding after a severe muscle injury or chronic tendon tear.
- Although resolving injuries may initially present with subsiding edema, tendon thickening and peritendinous ATROPHY may be seen in later stages.

**FINDINGS:**
Peritendinous ATROPHY (arrowhead) and FIBROSIS (arrow) in the myotendinous junction of the direct head of the rectus femoris after tendon tear (not shown).
CASE: 20-year-old woman with right thigh pain

FINDINGS: Acute on chronic injury of the reflected head of the rectus femoris muscle

FINDINGS: Edema on fluid-sensitive sequences

FINDINGS: Peritendinous atrophy on T1-weighted images
An Imaging Review of Muscle, Part 1: Trauma

Edema
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Site-specific injuries:
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- Hamstring avulsion
- Tennis leg

Thorough knowledge of the ANATOMY, LOCATION and PATTERNS of injuries can aid in:
- Correct description and radiologic reporting of injuries, thereby...
- Leading to correct management (operative versus conservative)
SITE-SPECIFIC INJURIES: Infraspinatus

**CASE:** 59-year-old man with right shoulder pain, weakness, and difficulty with abduction

- Tendinous or myotendinous lesion with edema of the infraspinatus muscle
- Important to CORRECTLY CHARACTERIZE and DESCRIBE this lesion as the majority of these patients will develop SEVERE FATTY ATROPHY of the infraspinatus muscle
SITE-SPECIFIC INJURIES: PLaTe Muscles
SITE-SPECIFIC INJURIES: PLaTe Muscles

- Pectoralis Major
- Latissimus Dorsi
- Teres Major
SITE-SPECIFIC INJURIES: Pectoralis Major

A previously rare injury, rupture of the pectoralis major muscle is becoming more common due to increasing numbers of intense weight-training and high-performance athletes.

CASE: Young man with acute right arm pain after a waterskiing accident.
SITE-SPECIFIC INJURIES: Pectoralis Major

A previously rare injury, rupture of the pectoralis major muscle is becoming more common due to increasing numbers of intense weight-training and high-performance athletes.

FINDINGS: Complete pectoralis major MTJ tear with retraction
**SITE-SPECIFIC INJURIES: Pectoralis Major**

A previously rare injury, rupture of the pectoralis major muscle is becoming more common due to increasing numbers of intense weight-training and high-performance athletes.

**FINDINGS:** Complete pectoralis major MTJ tear with retraction

![Image showing normal anatomy and a tear in the pectoralis major muscle with retraction](image)

**NORMAL**

- Pectoralis Major muscle
- Pectoralis Major tendon

**LOCATION AFFECTS MANAGEMENT:**

<table>
<thead>
<tr>
<th>Location</th>
<th>Conservative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle origin, muscle belly</td>
<td>Operative (direct suture, bone tunnel, bone anchor)</td>
</tr>
<tr>
<td>MT Junction, intratendinous, humeral insertion</td>
<td>Operative (internal fixation)</td>
</tr>
</tbody>
</table>

SITE-SPECIFIC INJURIES: Latissimus Dorsi

CASE: Active female with 1 month of shoulder pain
SITE-SPECIFIC INJURIES: Latissimus Dorsi

**FINDINGS:** Tear of the Latissimus Dorsi tendon

- In Latissimus Dorsi tears, the diagnosis is COMMONLY NOT SUSPECTED and a routine shoulder study is requested.
- It is therefore important for the radiologist to identify the INCLUDED portions of the Latissimus Dorsi muscle and tendon to rule out injury.
Madsen et al. recently described a surgical observation and subsequent anatomic study confirming that the MEDIAL HEAD OF THE TRICEPS (dashed white lines) has a separate insertion that is positioned anterior/deep to the COMMON TENDON OF THE LATERAL AND LONG HEADS.

Injuries are rarely reported in the literature:
- No reports of isolated conjoined tendon rupture
- The components may be injured SEPARATELY, resulting in varying clinical presentation(s) which may affect surgical approach.
CASE: 60-year-old woman who jammed her left elbow, now with pain and swelling

FINDINGS: Full thickness tear of the CONJOINED TENDONS OF THE LONG AND LATERAL HEADS OF THE TRICEPS (in blue) with SPARING of the TENDON OF THE MEDIAL HEAD.
SITE-SPECIFIC INJURIES: Triceps

CASE: 60-year-old woman who jammed her left elbow, now with pain and swelling

FINDINGS: Full thickness tear of the CONJOINED TENDONS OF THE LONG AND LATERAL HEADS OF THE TRICEPS (in blue) with SPARING of the TENDON OF THE MEDIAL HEAD.
CASE: 60-year-old woman who jammed her left elbow, now with pain and swelling

FINDINGS: Full thickness tear of the CONJOINED TENDONS OF THE LONG AND LATERAL HEADS OF THE TRICEPS (in blue) with SPARING of the TENDON OF THE MEDIAL HEAD

- An injury sparing the anterior component/medial head may be simply reported as an incomplete tear leading to underestimation of the severity of injury
- The components of the triceps are best described SEPARATELY
The RECTUS FEMORIS myotendinous anatomy is unique and consists of TWO HEADS:
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DIRECT or STRAIGHT HEAD: A UNIPENNATE MUSCLE, which arises from the anterior inferior iliac spine (AIIS) (red dot)
The RECTUS FEMORIS myotendinous anatomy is unique and consists of TWO HEADS:

DIRECT or STRAIGHT HEAD: A UNIPENNATE MUSCLE, which arises from the anterior inferior iliac spine (AIIS) (red dot)
INDIRECT or REFLECTED HEAD: A BIPENNATE MUSCLE, which arises from the superior acetabular ridge and the posterolateral aspect of the hip joint capsule (pink dot)

This anatomic configuration may result in a pattern of injury unique to the rectus femoris muscle—the DEGLOVING injury
SITE-SPECIFIC INJURIES: Rectus Femoris
SITE-SPECIFIC INJURIES: Rectus Femoris

A CIRCUMFERENTIAL TEAR occurs through the peripheral fibers of the inner bipennate muscle, separating it from the surrounding unipennate muscle.
SITE-SPECIFIC INJURIES: Rectus Femoris

A CIRCUMFERENTIAL TEAR occurs through the peripheral fibers of the inner bipennate muscle, separating it from the surrounding unipennate muscle.

This DISSOCIATION of the INNER BIPENNATE INDIRECT HEAD from the OUTER UNIPENNATE DIRECT HEAD results in an INTRAMUSCULAR DEGLOVING INJURY (finger being withdrawn from a glove) with FLUID separating the two muscles.
SITE-SPECIFIC INJURIES: Rectus Femoris
SITE-SPECIFIC INJURIES: Rectus Femoris

FLUID separating the two muscles
SITE-SPECIFIC INJURIES: Hamstrings

- The hamstrings (biceps femoris, semitendinosus and semimembranosus) are commonly injured in sports activities such as water skiing and football.
- These tears tend to heal slowly and recur; therefore these injuries can be a significant cause of lost playing time.
- The hamstrings span two joints, and tears can occur at different and multiple levels.
CASE: 45-year-old man with rheumatoid arthritis and acute left hip pain after standing up from the lotus position.

FINDINGS: Complete hamstring avulsion from the ischial tuberosity.
CASE: 26-year-old woman with pain after playing volleyball
FINDINGS: High-grade tear of the biceps femoris-semitendinosus musculotendinous junction
CASE: 58-year-old male with right calf pain

FINDINGS: Fluid interposed between the medial head of the gastrocnemius and soleus muscles with a low-signal focus which may represent the remnant of a ruptured plantaris tendon or a blood clot.

Tennis leg was classically described as being due to a ruptured plantaris tendon.
SITE-SPECIFIC INJURIES: Tennis Leg

CASE: 50-year-old man with lower leg pain

FINDINGS: Moderate-grade tear of the medial head of the gastrocnemius MTJ

- The term is now more generally used to refer to a strain of the medial head of the gastrocnemius/soleus
- The distinction between a ruptured plantaris tendon and other calf muscle injuries is important; gastrocnemius or soleus injuries are more severe and require a longer time to heal
An Imaging Review of Muscle, Part 1: Trauma

TAKE HOME POINTS

- Normal muscle has a characteristic morphology (symmetric with smooth convex borders) and signal
- Patterns of MR abnormality may involve alterations in either morphology (mass or atrophy) or signal (edema)

Edema
- Most common MR abnormality
- Nonspecific; biopsy and clinical history are essential to diagnosis

Mass
- Wide spectrum from normal variants, to benign and malignant lesions
- May necessitate use of IV contrast to aid in differentiation

Atrophy
- Important to obtain T1-weighted or non-fat suppressed images

Site specific injuries
- Knowing the anatomy, patterns, and location of certain injuries can aid in accurate radiologic reporting and proper clinical management
References