MR Imaging of Exertional Leg Pain

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Disclosure

• Nothing to disclose

• No off label use of contrast
Exertional Leg Pain

- Common but often frustrating clinical problem
- Typically affects young active patients
  - “classic” patient is a young female athlete
- Multiple etiologies exist, often overlapping in an individual
- Diagnosis is often delayed
Exertional Leg Pain - DDx

- Stress reactions/ stress fractures
- Medial Tibial Stress Syndrome
- Popliteal Artery Entrapment
- Chronic Exertional Compartment Syndrome
  - Primarily anterior compartment

**Bone stress by far the most common etiology of exertional leg pain!**
Stress Fracture

• Tibial stress fractures represent the most common cause of lower extremity exertional pain (Gaeta, 2008)

• Radiographs are commonly negative initially with reported sensitivity of 56% (Kiuru, 2002)

• Radiographic findings are a late manifestation of the fracture
Stress Fracture

- Tc-99m MDP should demonstrate focal intense tracer uptake
- Bone scan is inferior in tibial stress injuries with reported sensitivity of 74% vs. 88% for MRI (Gaeta, 2005)
- Example shows intense MDP uptake (arrow) with very subtle periosteal reaction on the radiograph (bracket)
Stress Fracture

- MRI is gold standard for stress fractures
- More sensitive than bone scan with reported 100% sensitivity (Kiuru, 2002)
- MRI in acute/subacute stress fracture demonstrates linear decreased T1-weighted signal (arrow) with surrounding edema (bracket)
Medial Tibial Stress Syndrome (MTSS) “Shin Splints”

- Common etiology of chronic lower extremity exertional pain in athletes
- Overuse injury
- Typically presents with posteromedial leg pain that worsens with exercise
- Proposed etiology is repetitive traction on the tibial fiber attachments of the soleus muscle
Medial Tibial Stress Syndrome (MTSS)

- Treatment is conservative, but the restrictions are not as strict as with stress fractures.
- Imaging in MTSS is usually performed to exclude stress fracture.
- Conventional radiographs are typically negative in MTSS and the majority of stress fractures.
- CT, bone scan, and MRI have been proposed as advanced imaging tools for diagnosis.
Medial Tibial Stress Syndrome (MTSS)

• MRI is the best modality to evaluate tibial overuse injuries (Gaeta, 2005) (Aoki, 2004)

• The MRI appearance is a long segment of increased T2-weighted signal along the posteromedial tibial cortex (arrowheads) (Aoki, 2004)

• Often there is linear vertical subcortical edema (arrow)
Medial Tibial Stress Syndrome (MTSS)

- Bone scan is inferior to MRI in the evaluation of tibial stress injuries
- Typical bone scan finding is long segment, linear, posteromedial tibial uptake of tracer (arrows)
- Lateral planar images are helpful in the diagnosis
Popliteal Artery Entrapment Syndrome

- Primarily functional - aberrant anatomy is rare
  - Anomalous slip of the medial gastrocnemius muscle
    - Fibrous bands may exist but hard to see
  - Hypertrophied calf muscles
    - Common appearance in athletes with paucity of fat
Popliteal Artery Entrapment Syndrome

- Symptomatic compression of the popliteal vessels with exertion
- Classically considered a rare entity with a reported prevalence of 0.16% (Bouhoutsos, 1981)
  - Likely underdiagnosed
- Five categories of anomalous popliteal anatomy (Atilla, 1998)
- “Functional” PAES refers to symptomatic occlusion of popliteal vessels without an identifiable anatomic abnormality (Rignault, 1985) (Turnipseed, 2009)
Popliteal Artery Entrapment Syndrome

• Goal of imaging studies:
  • Demonstrate occlusion or compression of popliteal vessels
  • Exclude anomalous popliteal anatomy

• Imaging modalities:
  • Conventional angiography
  • Doppler ultrasound
  • CTA
  • MRI
    • MRA
    • Anatomic
Popliteal Artery Entrapment Syndrome

• Conventional angiography:
  • Gold standard for diagnosis of PAES
  • Minimally invasive
  • Exam is performed in the neutral position and with plantarflexion and dorsiflexion
  • In chronic PAES, the findings may be difficult to differentiate from atherosclerotic disease
Popliteal Artery Entrapment Syndrome

Gadolinium bolus MRA

• Prolonged maneuvers may result in patient discomfort and suboptimal effort
• Previously required multiple injections
• Single injection possible now, with

Coronal MIP gadolinium bolus MRA
Popliteal Artery Entrapment Syndrome

Gadolinium bolus MRA

- Prolonged maneuvers may result in patient discomfort and suboptimal effort
- Time consuming with multiple bolus injections of contrast

Coronal MIP gadolinium bolus MRA
Popliteal Artery Entrapment Syndrome

Blood pool MRA with provocative maneuvers:

- May simplify technical component of the exam as multiple injections are not required
- Gadofosveset (Ablavar) MRA with 2D ARC acceleration and provocative maneuvers demonstrates right popliteal artery occlusion (arrow)
Chronic Lower Extremity Exertional MRI Protocol – provocative bSSFP

- Images of the popliteal fossae are acquired at rest and with plantar- and dorsiflexion
- A balanced steady state free precession (bSSFP) sequence without fat saturation is utilized
- TR=3.2-8.2, TE=minimum, Nex=1, FOV=To fit both calves, Matrix=224×256, Slice thickness/spacing=5mm/0mm
- Each image acquisition is approximately 20 seconds
Popliteal Artery Entrapment Syndrome

Non-contrast MRA:

- Balance steady state free procession MRI with provocative maneuvers
- Rapid
- Resistant to flow artifact
- Functions as a screening study, but inferior resolution to contrast techniques
Chronic Lower Extremity Exertional MRI Protocol – provocative bSSFP

- 50 year old male with chronic exertional leg pain
- Chronic exertional leg pain MRI was negative for CECS and there was no edema associated with a tibial stress syndrome
- bSSFP demonstrates patent popliteal vessels bilaterally in the neutral position (a) and with dorsiflexion (b). With plantar flexion there is nonvisualization of the bilateral popliteal vessels (c arrows)
Chronic Lower Extremity Exertional MRI Protocol – provocative bSSFP

- The 50 year old male with chronic exertional leg pain subsequently underwent a conventional angiogram that was positive bilaterally.

- Images from the left lower extremity runoff in the neutral position (a) and with plantar flexion (b) are shown.

- Arrows demonstrate areas of dynamic narrowing.
d. Anomalous muscle
Neutral

2D FIESTA
Resisted Plantarflexion

2D FIESTA

Functional – no muscle abnormality
26 year old chronic bilateral exertional calf pain

Rest  Plantar flexion
26 year old chronic bilateral exertional calf pain
Popliteal Artery Entrapment Syndrome

- Doppler US:
  - May show changes in waveforms with provocative maneuvers in patients with PAES (di Marzo, 1991)
  - Subsequently shown to be relatively poor exam with abnormalities of the Doppler waveform in a significant percentage of asymptomatic patients (Hoffmann, 1997)
  - Doppler US continues to be a common screening exam for PAES
    - Decreased sensitivity compared with MRI
      - PPV of FIESTA 1.0 compared with 0.64 for US
      - NPV of FIESTA 0.5 compared with 0.0 for US
Chronic Exertional Compartment Syndrome

- Multiple etiologies proposed but in general poorly understood
  - Complex clinical presentation
  - Diagnosis often delayed
- Theories include increased pressure in the compartment due to altered egress of water from muscle versus alteration in connective tissue/fascia
  - Correlation with PAES?
Chronic Lower Extremity Exertional MRI Protocol

• Exam is performed on a 1.5T GE clinical scanner (GE Healthcare, Waukesha, WI, USA)

• Feet are affixed by Velcro®-type foot straps to a custom built rigid Plexiglas® foot plate for resistance
Chronic Lower Extremity Exertional MRI Protocol – T2-weighted in-scanner exercise protocol for CECS

- Resistance maneuvers are performed against Velcro®-type straps and Plexiglas® platform
- TR=400, TE=20, Nex=2, FOV=To fit both calves, Matrix=256×256, Slice thickness/spacing= 10mm/0mm
- Three slices are obtained at point of maximal calf musculature and the sequence is performed through cycles of exertion and rest
- T2-weighted signal intensity is measured in the anterior compartment at baseline and at the first recovery scan. A T2-weighted signal ratio of greater than 1.54 between the two sequences is considered positive (Litwiller, 2007) (Ringler, 2012)
  - 1.6 used clinically as threshold
Chronic Lower Extremity Exertional MRI Protocol – T2-weighted in-scanner exercise protocol for CECS

- 18-year-old male with chronic exertional leg pain
- CECS MRI positive bilaterally using greater than 1.54 as the cutoff ratio for T2-weighted signal (R=1.76, L=1.78)
- Note the change in T2 signal in the anterior compartments (arrows)

- Needle compartment pressures were subsequently positive and the patient underwent bilateral fasciotomies
Chronic Exertional Compartment Syndrome

• Muscular exertion results in increase compartmental T2-weighted signal

• The signal should resolve rapidly with rest

• Cases of CECS will have a delay in resolution of T2-weighted signal

• A relative T2-weighted signal intensity of 1.54 between rest and the first recovery scan has excellent sensitivity and specificity for CECS (Litwiller, 2007)
CECS +

R=2.01

L=2.11
MRI Imaging for Exertional Leg Pain

- Protocol at our institution **screens** for major causes of exertional leg pain
- In scanner exercise protocol for CECS and PAES
- Large FOV T1 and T2 for stress fractures/stress reactions
Chronic Lower Extremity Exertional MRI Protocol – T2-weighted images of calves

- Screening study for tibial stress injuries
- TR=3000, TE=60, Nex=2, FOV=To fit both calves, Matrix=256x224, Slice thickness/spacing=10mm/0mm, ETL=8

17-year-old with chronic anterior shin pain. Negative CECS MRI. Subtle edema bilateral medial tibiae suggestive of MTSS (arrows)
MRI Exercise Protocol

- T1 weighted image – anatomy
- T2 with FS – stress fractures, MTSS
- T2 SE x2 at rest, dorsiflexion, recovery, plantar flexion, recovery - CECS
  - Exercise is against resistance
  - Dorsiflexion may reproduce sx
    - Pain
    - Numbness
- FIESTA in neutral, resisted plantarflexion and resisted dorsiflexion - PAES
Recurrence After Surgery Possible

Multiple Etiologies May Co-Exist

• Approximately 20% of patients presenting for exertional leg pain protocol have had prior compartment releases
  • Some multiple!

• Approximately 10% will have co-existing PAES and CECS
34 year old female – exertional leg pain
Pre Exercise T2

Medial Tibial Stress Syndrome
1.8 R, 1.62 L
First recovery period after resisted dorsiflexion

CECS of the Anterior Compartments Bilaterally
Confirmed with Intra-compartmental Pressure Measurements
FIESTA
Neutral and Resisted Plantar Flexion

PAES, worse on the right (artery and vein)
MRA with “plantarflexion”

**Significant Caveat – She Misunderstood the Directions!**
Conclusion

• Imaging can help determine etiology of exertional leg pain
  • Comprehensive “screening” MRI at our institution
  • High sensitivity and specificity
    • Helpful before invasive testing
• The most common etiologies of chronic lower extremity exertional pain are:
  • Tibial stress injuries (stress fracture and medial tibial stress syndrome)
  • Chronic exertional compartment syndrome
  • Popliteal artery entrapment syndrome

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