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# FUNCTIONAL IMAGING OF ATHLETES

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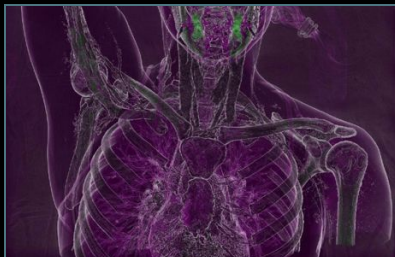
# Learning Objectives

- Identify anatomic and functional lesions that predispose to vascular entrapment and fibrotic syndromes in athletes.
- Describe methods to assess vascular entrapment and fibrotic syndromes using dynamic, functionally challenged CTA and MRA.
- Describe the imaging findings for diagnosis.

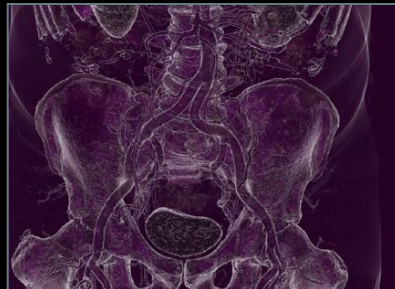
What is your experience with functional (dynamic) cardiovascular imaging?

- A. None
- B. A little- once or twice
- C. We perform these exams occasionally
- D. Extensive experience
- E. I do not know what functional imaging means

# Vascular Diseases in Athletes



- **Upper Extremity**
  - Thoracic Outlet Syndrome (TOS)



- **Pelvis**
  - Iliac Endofibrosis



- **Lower Extremity**
  - Popliteal Entrapment Syndrome (PAES)

Background.....

**DYNAMIC EVALUATION  
IS IMPORTANT !!**

- Vascular diseases are easily overlooked in athletes
- Thorough vascular H&P needed
- Deciding **WHEN (or IF)** to image vascular entrapment syndromes requires clinical judgment and multi-specialty coordination!!

# Dynamic Cross-Sectional Imaging

- **Principle**: simulate the predisposing motion / position and assess vascular response
  - “Stress” and “Relaxed” Imaging
  - Vary timing to assess arteries / veins

- Thoracic Outlet Syndrome (TOS)



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The most common anatomic location for vascular thoracic outlet syndrome is

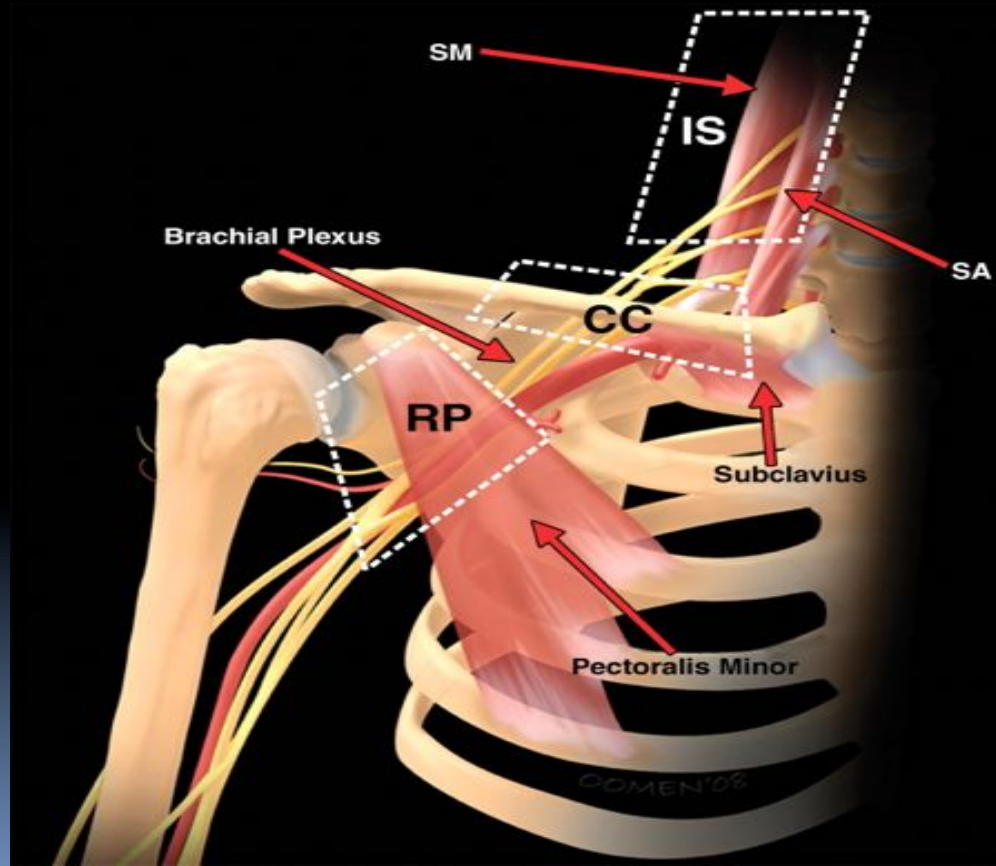
- A. Costo-clavicular space
- B. Retro-pectoralis minor space
- C. Interscalene Triangle
- D. Coraco-clavicular space

# Thoracic Outlet Syndrome (TOS)

- Symptomatic compression/entrapment of neurovascular structures by bone and/or soft tissue as they pass through the cervicoaxillary canal
- 90% Neurogenic (PT, postural Tx, NSAIDs)
- 10% Vascular
  - Venous > Arterial

# Components of Cervico-Axillary Canal

- Interscalene Triangle: #1 site of compression
- **Costoclavicular Space: #1 site for vascular TOS**
- **Retro-pectoralis minor space: #1 site for masses**



The most common anatomic location for vascular thoracic outlet syndrome is

- A. Costo-clavicular space **CORRECT ANSWER**
- B. Retro-pectoralis minor space
- C. Interscalene Triangle
- D. Coraco-clavicular space

# CTA for TOS: Combo Direct / Indirect CTA

- Ipsilateral IV, arm over head w/ palm taped up
- 120 mL full-strength @ 4ml/s
- Chase: 100 mL dilute (10%) contrast @ 2.5 ml/s
  - Can inject contralateral arm at same time (dilute)
- 65 sec empiric delay, scan caudo-cranial
- Arm down, immediate re-scan cranio-caudal
- **Volumetric Review**

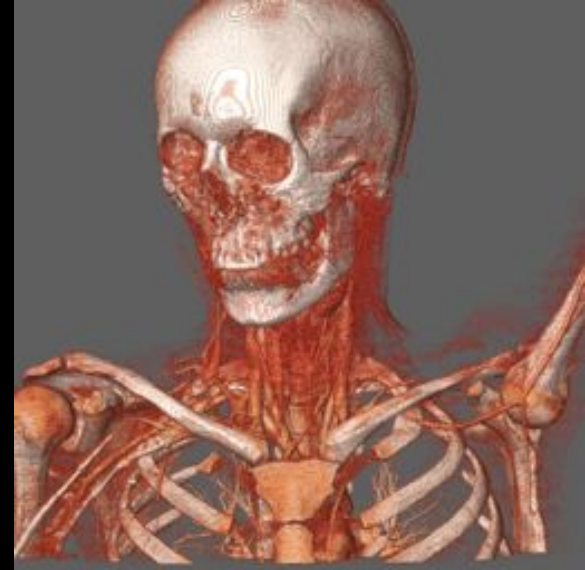


# Venous TOS: “Effort Thrombosis”

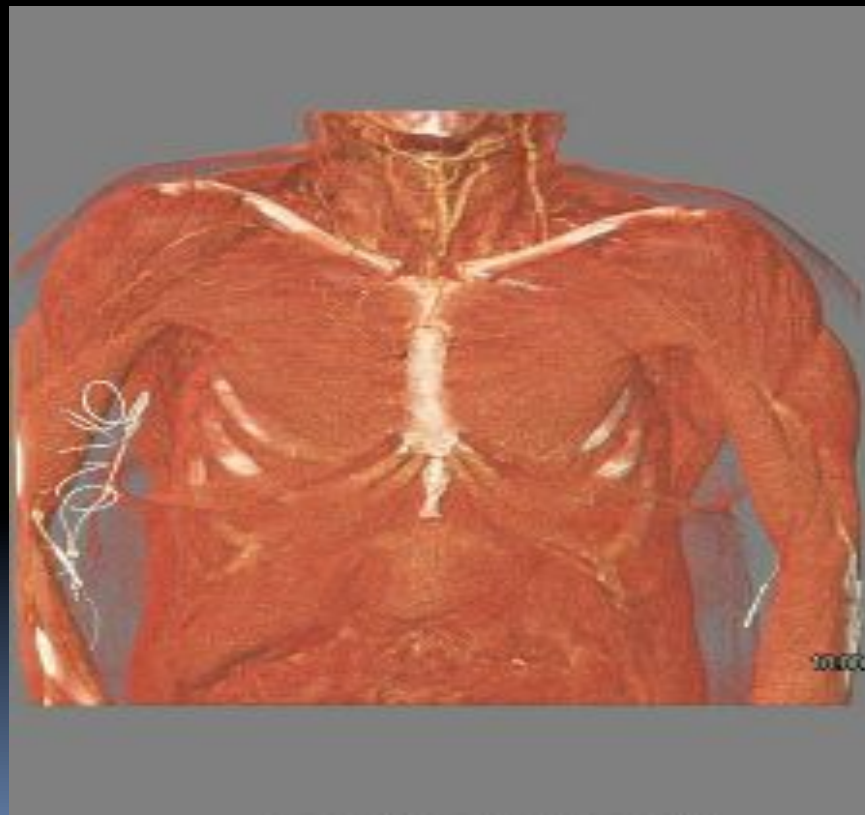
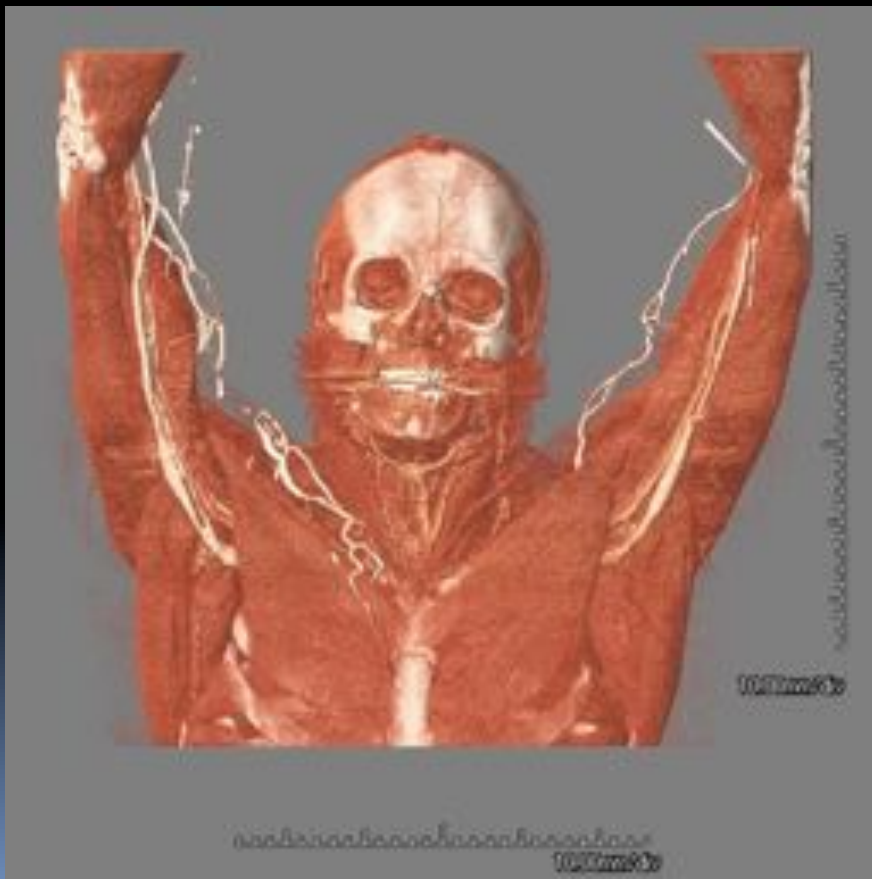
- Paget-Schroetter syndrome (PSS)
- AKA axillo-subclavian venous thrombosis
- “Overhead” athletes
- PE in up to 1/3!! \*
- Post-thrombotic syndrome (later)

# Arterial TOS

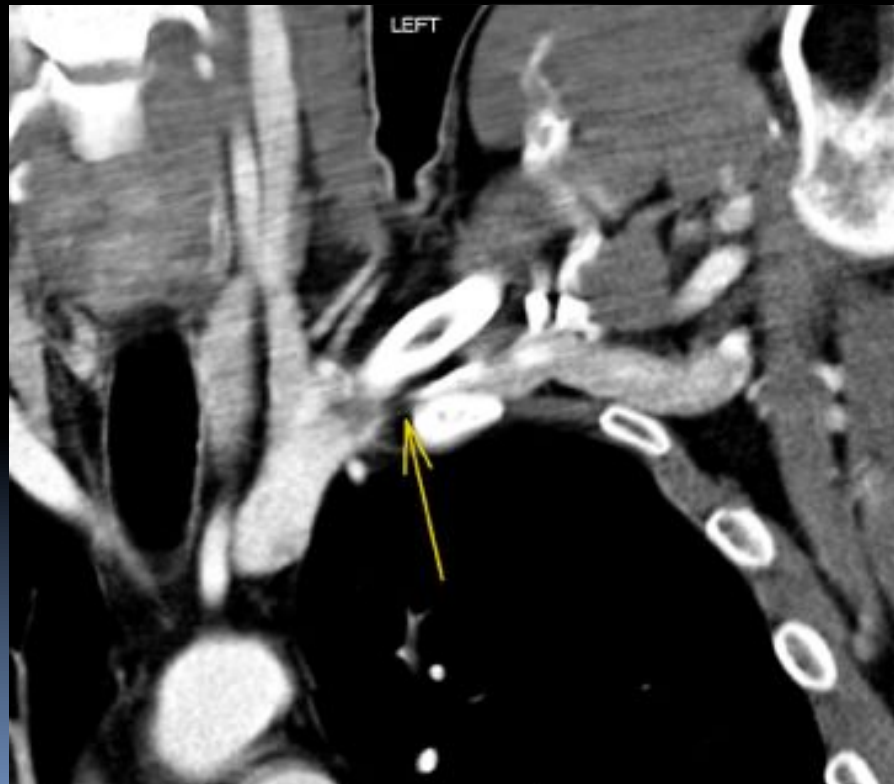
- “Overhead athletes”
- SX: Coolness, weakness, diffuse arm pain (ischemic neuritis)
- Cause: Repetitive compression injury
  - Anatomic predisposition (tight CCS)
  - Post-traumatic, bony callus
  - Scalene hypertrophy



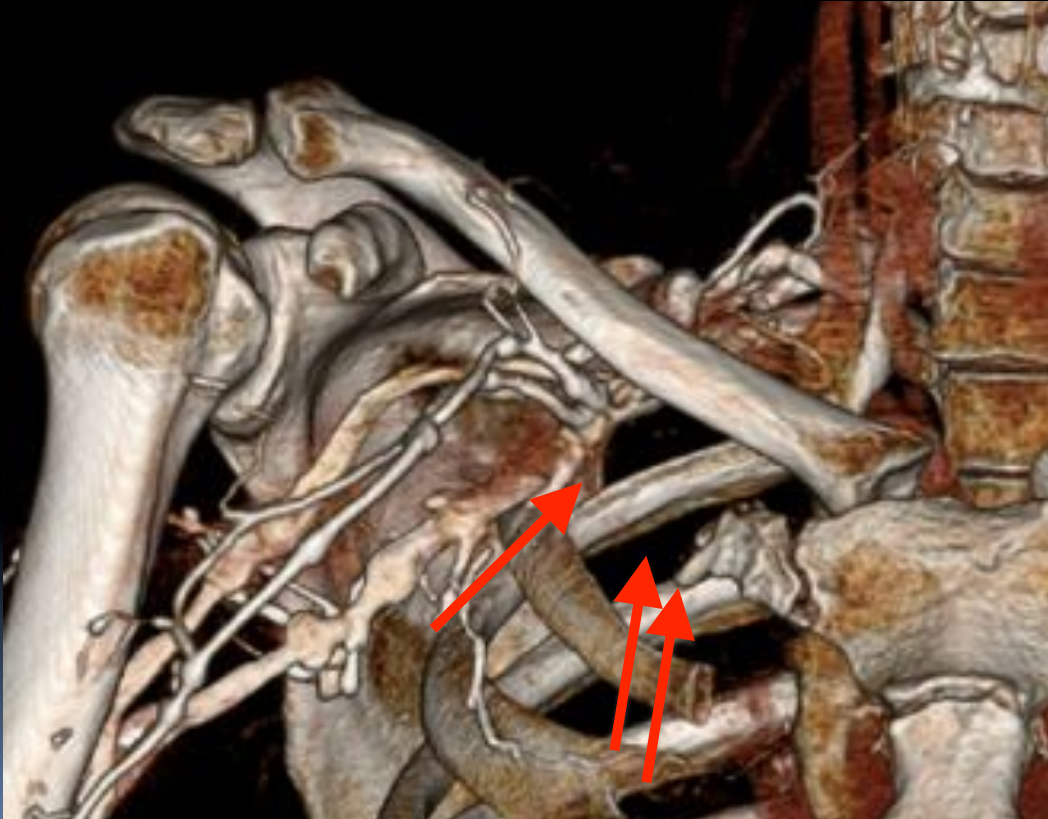
# Bilateral Direct / Indirect CTA



# Effort Thrombosis: 36 YO weightlifter



# Post-Op 1<sup>st</sup> rib resection



# Arterial and Venous TOS: 16 YO Volleyball Athlete

REST



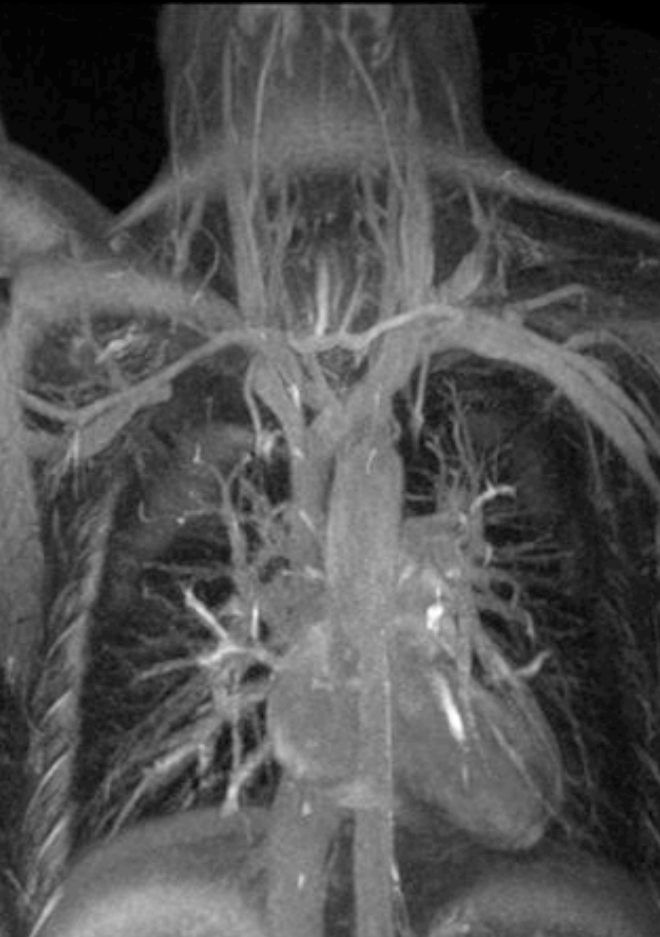
STRESS



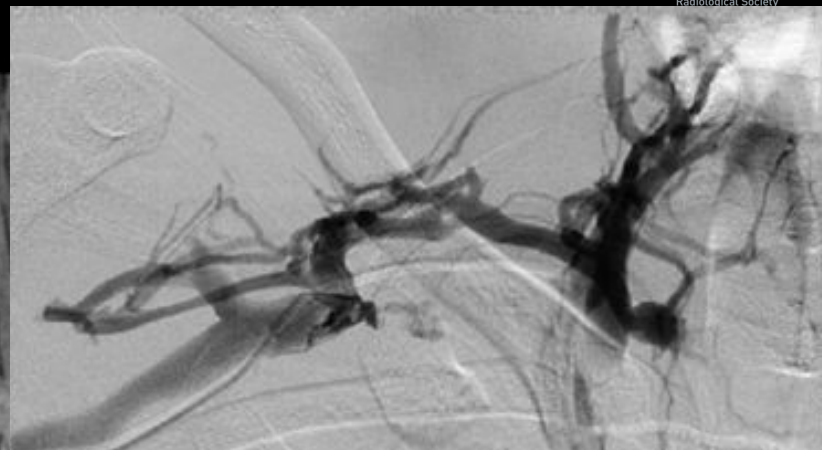
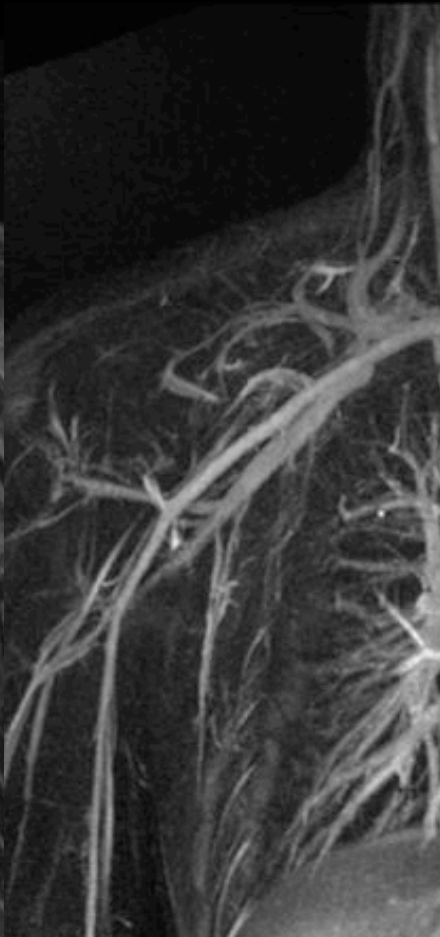
# MRA for TOS: Blood Pool MRA

- Anatomic imaging: Oblique sag and cor T<sub>1</sub>/T<sub>2</sub>
- Relaxed and Challenged imaging:
  - Gadofosveset (blood pool agent)
  - Breath-hold FSPGR, ECG-gated, high resolution (1.8 mm ST, 448 × 448 matrix) CORONAL acquisition
    - Challenged: Arm Abducted
    - Relaxed: Arm Down

Arm UP



Arm DOWN



# Iliac Endofibrosis



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# Iliac endofibrosis is a(n):

- A. Acute inflammatory vasculopathy
- B. Early (accelerated) atherosclerotic process
- C. Vasculitis related to HLA-B27 antibodies
- D. Non-inflammatory, non-atherosclerotic disease

# Flow limitations in the athletic pelvis

- Dynamic:
  - Elongated / tortuous vessels
  - Kinking with or w/o stenosis (elongation/tethering)
  - compression (psoas hypertrophy, ligaments)
- Static: **Iliac endofibrosis**

# Iliac Endofibrosis

- **90% of pts are cyclists**
  - >10,000 km/yr or 150,000 km lifetime
  - Also: speed skaters, runners, wt lifters, XC skiers, and rugby players
- **90% external iliac artery**
- Smooth, eccentric, non-calcified
- **Pathology:** intimal fibroplasia, medial hypertrophy, and adventitial hyperplasia. Involved segments universally free from atherosclerosis.



# Iliac endofibrosis is a(n):

- A. Acute inflammatory vasculopathy
- B. Early (accelerated) atherosclerotic process
- C. Vasculitis related to HLA-B27 antibodies
- D. Non-inflammatory, non-atherosclerotic disease **ANSWER**

# Endofibrosis CTA: Imaging technique

- Two phases: **relaxation and hip flexion**
- Coverage ~ 40 cm
- Relaxation – 100 kVp, flexion – 120 kVp
- ~ 80 mL of IV contrast at 4 -5 mL/s for each phase (20 sec injection)
- Saline flush at same rate
- Scan time 10 - 12 sec
- Volumetric Review

# CTA: Positioning

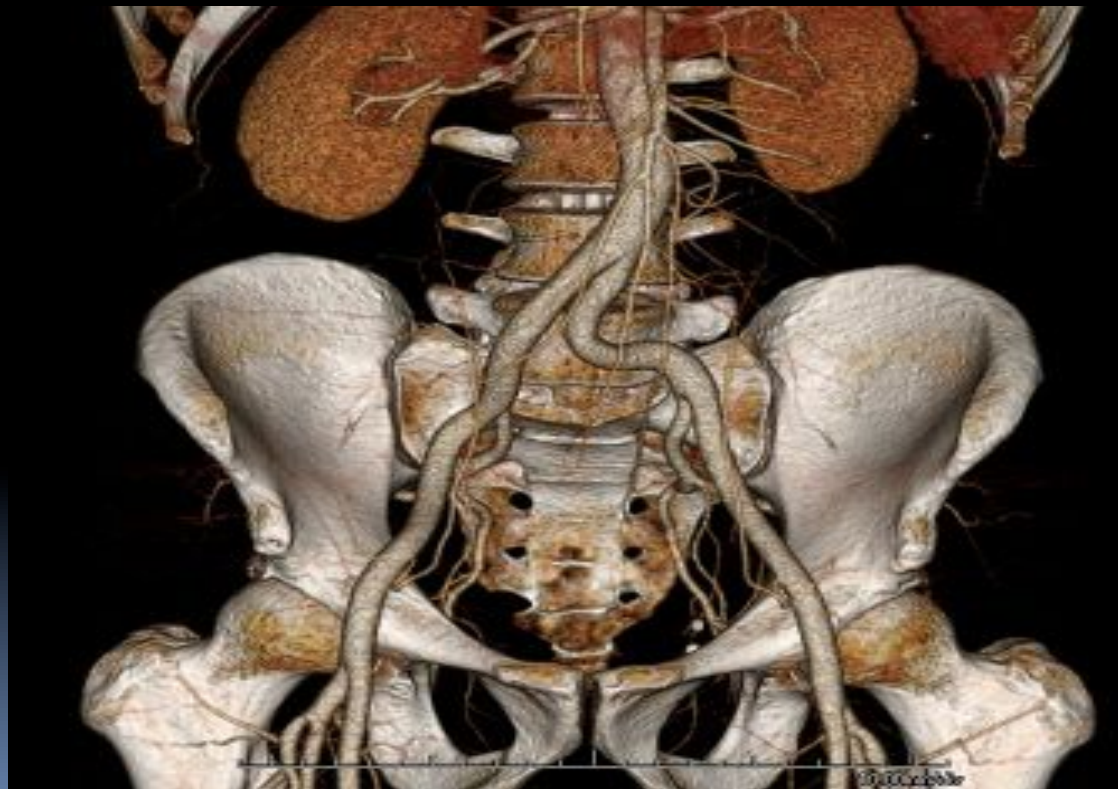
- Simulate cycling position as closely as possible considering space within CT gantry (almost 90°)



# Case 1

- 45 yo avid cyclist
- Proximal thigh pain, cramping with exertion
- ABI drops with exertion

# Supine, legs extended



# Hip Dysplasia Flow Restriction



## Case 2

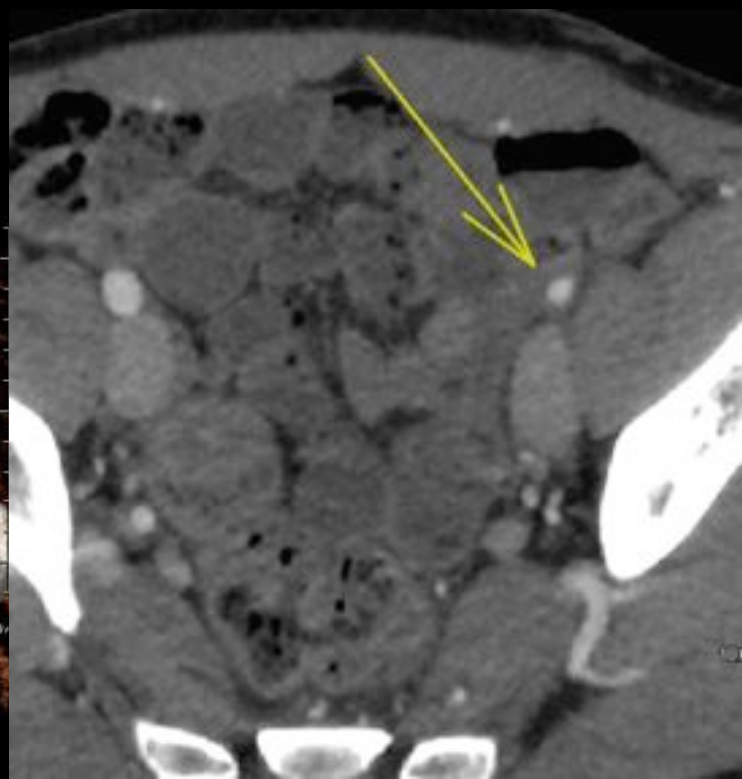
- 26 yo elite female cyclist
- left thigh and buttock pain at high performance levels.

# Case 2

NEUTRAL



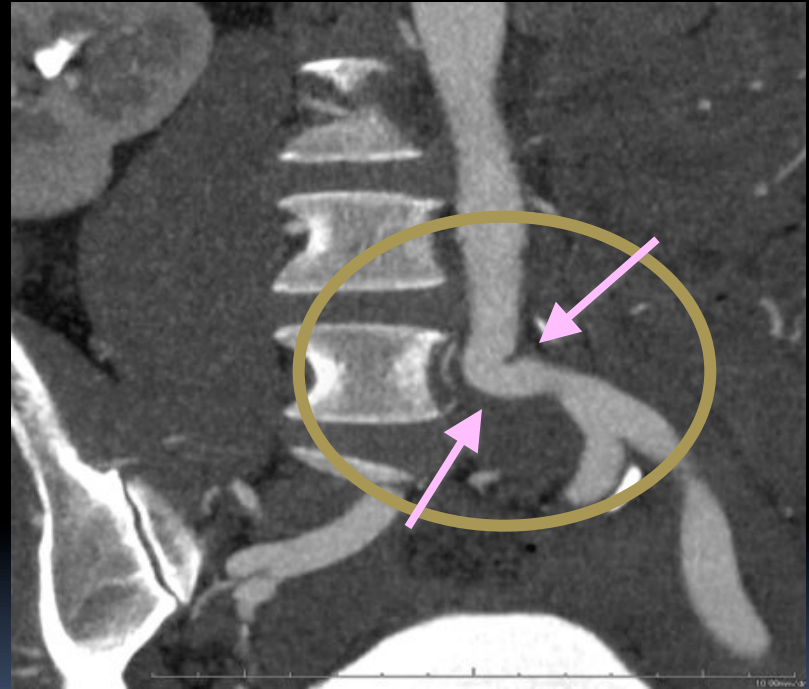
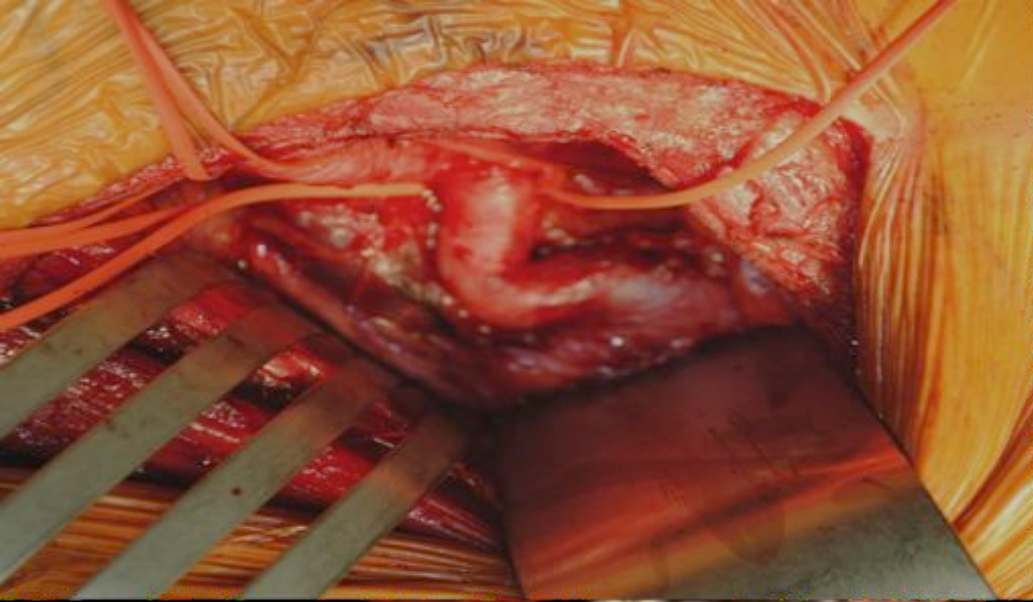
FLEXION



## Case 3

- 49 yo avid cyclist x 30 yrs
- left thigh and buttock pain at high performance levels.
- Pain described as a “deep burn”
  
- ABI R/L: 1.3/1.2
- Exercise ABI R/L: 1.5/1.2

# CTA at Rest



- Pathology: intimal thickening and fibrosis
- No inflammatory change

# Endofibrosis MRA: Imaging technique

- Anatomic imaging – T1
- Arterial Phase FSPGR
- Relaxed and Hip Flexion
  - Respiratory gated, steady state
  - Near-Isotropic
  - Blood Pool contrast Agent
- Volumetric Review



# Vascular Diseases in Athletes

- Lower Extremity

## Popliteal Entrapment Syndrome (PAES)

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# Most cases of Popliteal entrapment syndrome arise from:

- A. Chronic repetitive trauma to popliteal artery / vein
- B. Embryologic conflict between muscles and vessels
- C. Premature atherosclerotic disease
- D. Chronic exertional compartment syndrome

Macedo TA, et al. Popliteal Artery Entrapment Syndrome: Role of Imaging in the Diagnosis. American Journal of Roentgenology. 2003 Nov;181(5):1259–65.

# Popliteal Space - Embryology

- *In utero*: competition between popliteal neurovascular bundle and migrating muscles (medial head gastrocnemius) for space
- If delayed or abnormal migration → **MHG too far lateral**
- space is limited



# Causes of Popliteal Entrapment

- Anatomic Compression
  - Abnormal popliteal artery course
  - Abnormal muscle (MHG)
  - Both
- “Functional” compression

# Most cases of Popliteal entrapment syndrome arise from:

- A. Chronic repetitive trauma to popliteal artery / vein
- B. Embryologic conflict between muscles and vessels **ANSWER**
- C. Premature atherosclerotic disease
- D. Chronic exertional compartment syndrome

Macedo TA, et al. Popliteal Artery Entrapment Syndrome: Role of Imaging in the Diagnosis. American Journal of Roentgenology. 2003 Nov;181(5):1259–65.

# Classification of PAES

| Type | Anatomy   |
|------|---|
| I    | PA travels aberrantly, medial to normally positioned MHG                      |
| II   | Anomalous lateral and inferior origin of MHG, PA displaced medially           |
| III  | Normal PA compressed by muscular slip or aberrant band from MHG               |
| IV   | PA deep in popliteal fossa, entrapment from aberrant band or popliteus muscle |
| V    | Any type of entrapment <b>involving popliteal vein</b>                        |
| VI   | “Functional” Entrapment   |

# Functional Popliteal Entrapment (Type VI)

- Younger population, highly conditioned athletes
- Neurovascular compression by hypertrophic gastrocnemius +/- soleal sling
- Longer segment involvement (vs. anatomic PAES)
- Conservative Tx first, debulking if needed

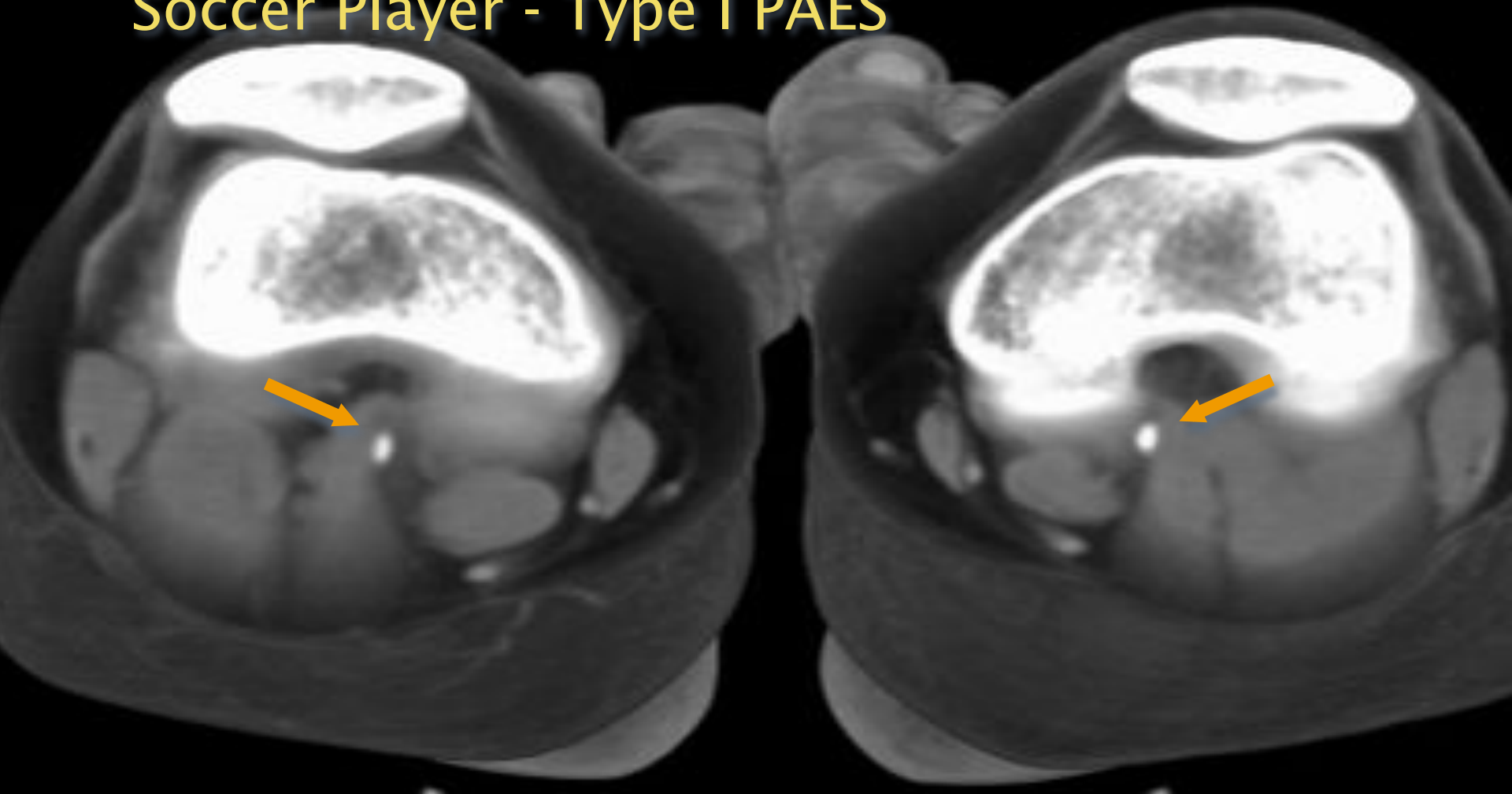
# PAES: CTA Imaging Technique

- 3 phases – relaxed, active plantar flexion, venous
  - Active plantar-flexion without bearing down (straps)
- ~ 80 mL of contrast (4mL/s) for 2 phases followed by saline flush at same rate
- Bolus track distal SFA
- Scan time: 12-15 sec on 64-MDCT
- Pulse oximeter on symptomatic large toe

# PAES: CTA Imaging Technique



# Soccer Player - Type I PAES



# Type III PAES - Thrombosis of left popliteal artery

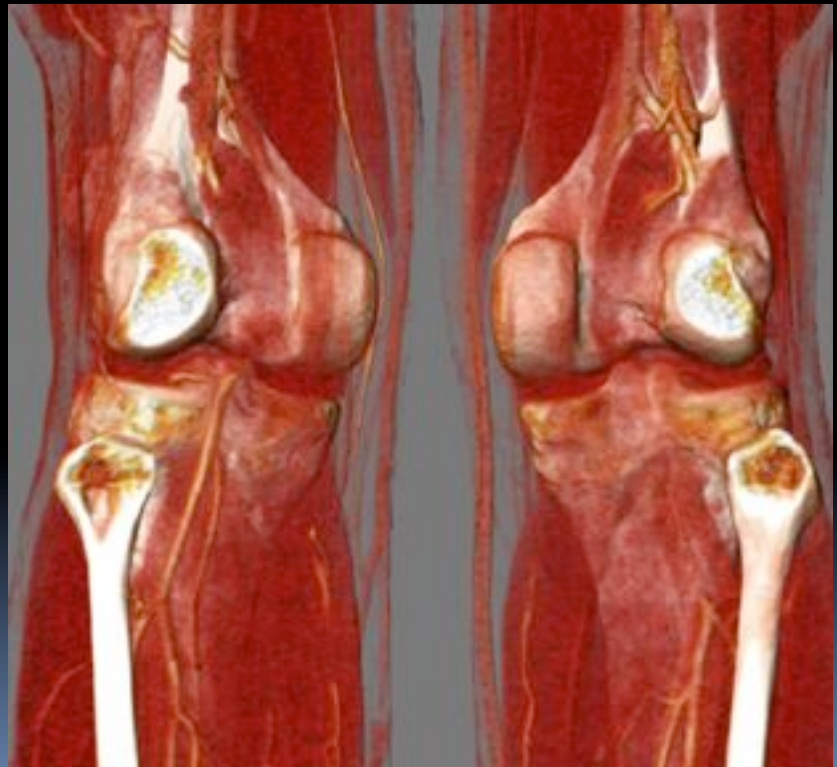
LEFT

RIGHT

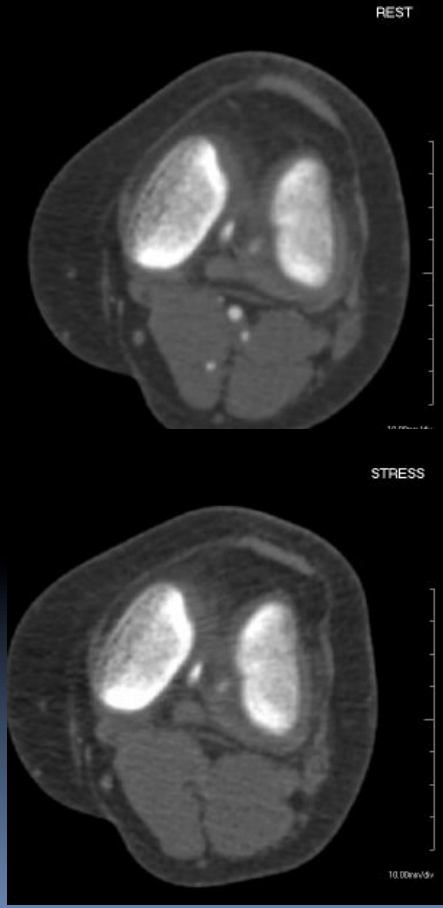
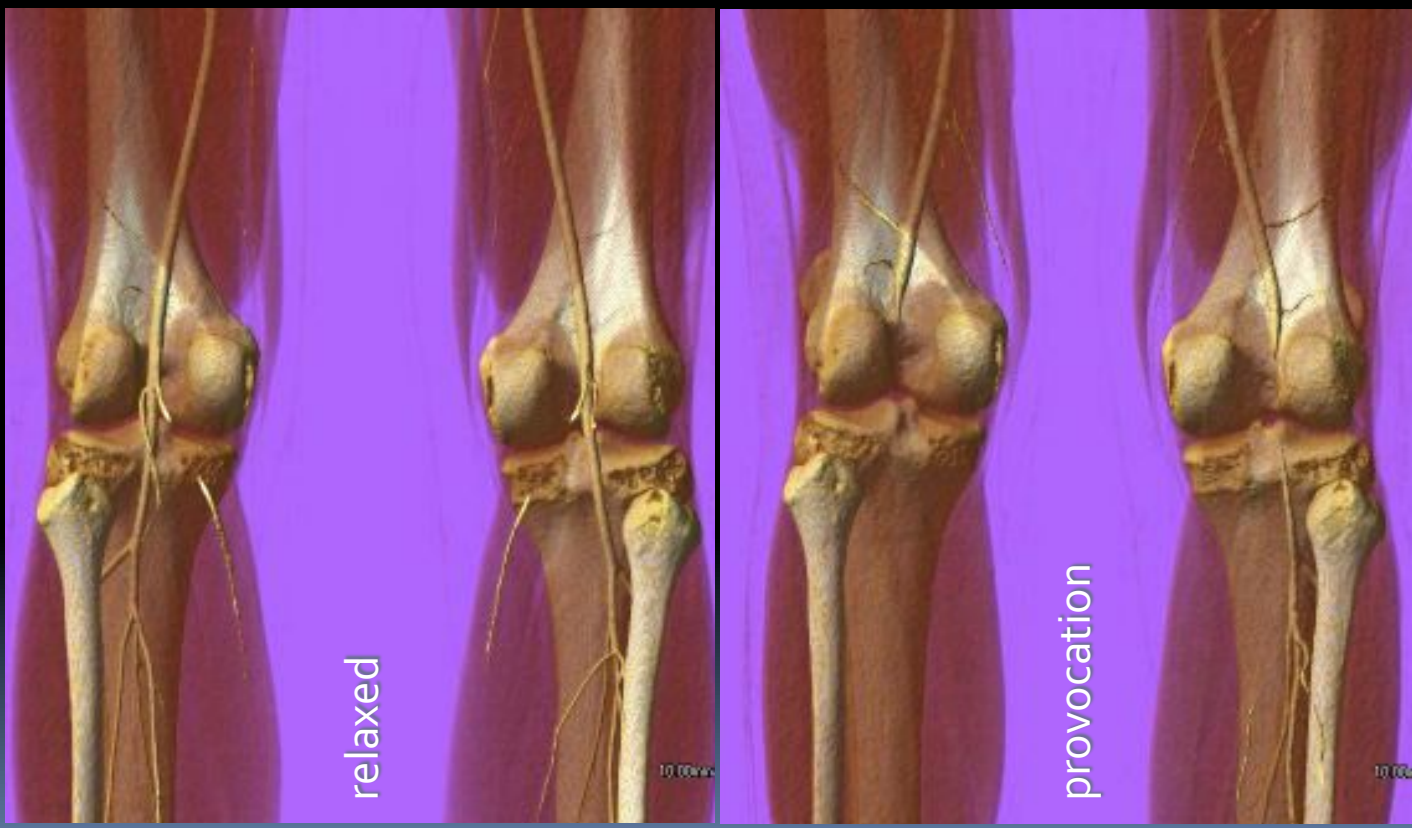
Relaxed - posterior view



provocation

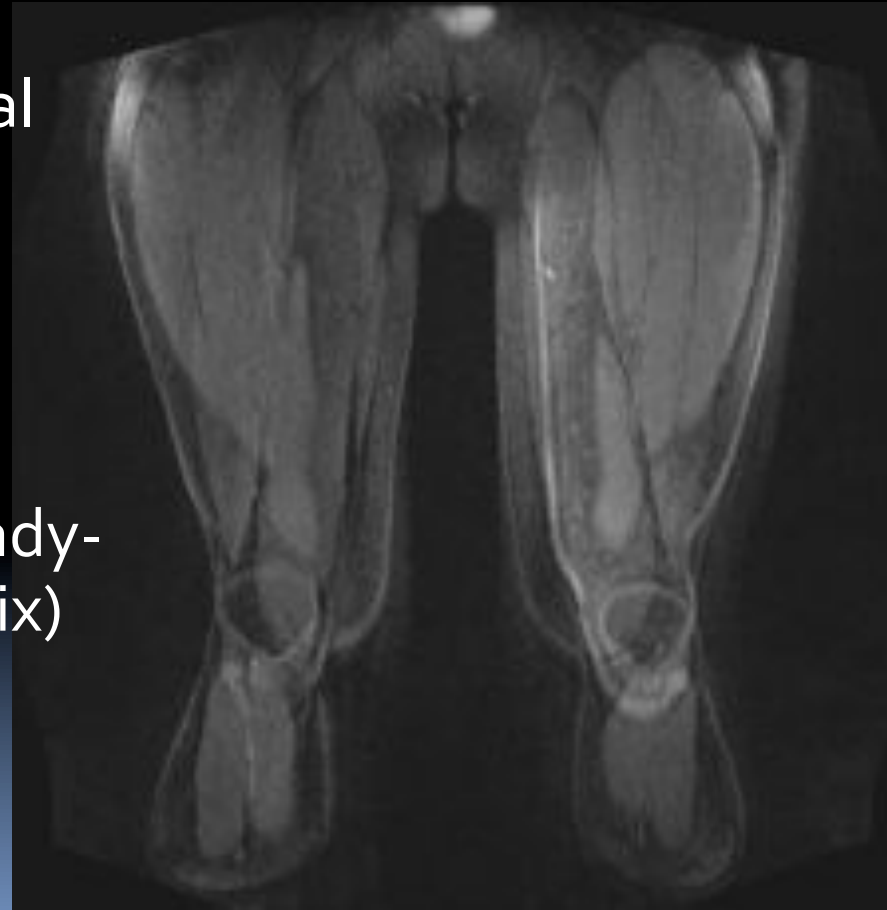


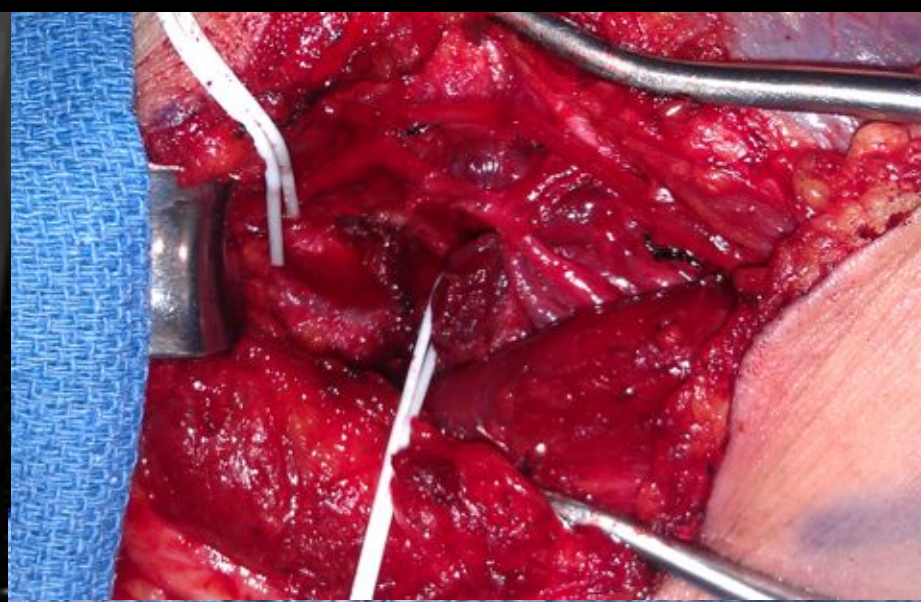
# Functional (Type VI) PAES



# PAES: Challenged MRA technique

- Anatomic imaging (axial/coronal T<sub>1</sub>/T<sub>2</sub>)
- Challenged and Relaxed Acquisition (like CTA)
- blood pool agent gadofosveset
- Thin-slice Coronal (1.4mm) steady-state acquisition (576x576 matrix)
- 3D assessment





# Conclusions

- Vascular diseases in athletes can be a significant source of disability and performance loss
- Functional imaging is important for accurate detection and characterization of vascular entrapment / stenotic syndromes
- CTA and MRA with functional techniques allow non-invasive assessment

# Thanks for Your Attention !!

An anatomical illustration of human legs, showing the muscles and bones. The legs are positioned side-by-side, with the right leg on the left and the left leg on the right. The muscles are rendered in a reddish-brown color, and the bones are in a light tan color. The background is dark, making the anatomical structures stand out.

Special Thanks to:  
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Deirdre Sheahan, MD  
Kevin Sheridan, MD

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