FUNCTIONAL VASCULAR IMAGING OF ATHLETES
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@CTeriffic
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)
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 multispecialty 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. Costco-clavicular space
B. Retropectoralis 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

Linda D D et al. Radiographics 2010;30:1373-1400
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

Linda D D et al. Radiographics 2010;30:1373-1400
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
Bilateral Direct / Indirect CTA
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)

Effort Thrombosis:
36 YO weightlifter
Post-Op 1\textsuperscript{st} rib resection
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
Arterial and Venous TOS: 16 YO Volleyball Athlete

REST

STRESS
MRA for TOS: Blood Pool MRA

- Anatomic imaging: Oblique sag and cor T1/T2
- Relaxed and Challenged imaging:
  - Gadofosveset (blood pool agent)
  - Breath-hold FSPGR, ECG-gated, high resolution (1.8 mm ST, 448 x 448 matrix) CORONAL acquisition
    - Challenged: Arm Abducted
    - Relaxed: 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 Athlete’s 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 Flexion 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
• Pathology: intimal thickening and fibrosis
• No inflammatory change
Endofibrosis MRA: Imaging technique

- Anatomic imaging – T1/T2
- Arterial Phase FSPGR MRA (bolus track)
- Relaxed and Hip Flexion imaging
  - Respiratory gated, steady state acquisition
  - Near-Isotropic
  - Blood Pool contrast Agent
- Volumetric Review

Naehle CP. J Am Coll Cardiol Img. 3 2010:504-513
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

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

## Classification of PAES

<table>
<thead>
<tr>
<th>Type</th>
<th>Anatomy</th>
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<tbody>
<tr>
<td>I</td>
<td>PA travels aberrantly, medial to normally positioned MHG</td>
</tr>
<tr>
<td>II</td>
<td>Anomalous lateral and inferior origin of MHG, PA displaced medially</td>
</tr>
<tr>
<td>III</td>
<td>Normal PA compressed by muscular slip or aberrant band from MHG</td>
</tr>
<tr>
<td>IV</td>
<td>PA deep in popliteal fossa, entrapment from aberrant band or popliteus muscle</td>
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<tr>
<td>V</td>
<td>Any type of entrapment <em>involving popliteal vein</em></td>
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<tr>
<td>VI</td>
<td>“Functional” Entrapment</td>
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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
Type III PAES - Thrombosis of left popliteal artery
Functional (Type VI) PAES
PAES: Challenged MRA technique

- Anatomic imaging (axial/coronal T1/T2)
- Challenged and Relaxed Acquisition (like CTA)
- Blood pool agent gadofosveset
- Thin-slice Coronal (1.4mm) steady-state acquisition (576x576 matrix)
- 3D assessment
STRESS PAGES: Challenged MRA technique
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!!

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