PERIPHERAL CTA

Richard L. Hallett, MD

Chief, Cardiovascular Imaging
Northwest Radiology Network
Indianapolis, IN

Adjunct Assistant Professor – Imaging
Cardiovascular Imaging Section
Stanford University
Stanford, CA
Outline

- Goals of LE CTA
- CTA Acquisition Techniques
  - Scan Acquisition
  - Contrast Medium injection
  - Reconstruction
- Clinical Efficacy in PAD

Handout: stanford.edu/~hallett choose folder “RSNA2016”
Goals of CTA imaging in PAD
Diagnosis and Staging of PAD

= symptoms + ABI

poor correlation of symptoms and ABI with number, location and severity of lesions

Example: calf claudication can be caused by isolated disease or combination of iliac and/or femoropopliteal lesions
Role of CTA Imaging is **NOT** diagnosis / staging

CTA role is to **map lesions to the patient’s symptoms** for treatment planning
Goal of Reporting LE CTA

- Answer the clinical questions
  - NEED to get history
  - Intermittent Claudication vs Critical Limb Ischemia?
- Organize by leg:
  - Aorto-iliac (inflow)
  - Femoropopliteal
  - Below Knee runoff
  - Pedal vessels (2 cross ankle)
Indications for CTA in PAD

- Intermittent Claudication
- Critical Limb Ischemia
- Acute Ischemia (urgent)
- Monitoring of Therapy (complications)
### Which lesions matter?

<table>
<thead>
<tr>
<th>Treatment Segment</th>
<th>Aka, utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aorto-iliac</td>
<td>“Inflow”, “Supra-inguinal”</td>
</tr>
<tr>
<td>Common Femoral a.</td>
<td>Bypass target and source</td>
</tr>
<tr>
<td>Profunda Femoris a.</td>
<td>Important collaterals w/ SFA occlusion</td>
</tr>
<tr>
<td></td>
<td>Important s/p amputation</td>
</tr>
<tr>
<td>Femoro-popliteal (SFA-Pop)</td>
<td>“Infra-inguinal runoff”</td>
</tr>
<tr>
<td></td>
<td>Note level of reconstitution above (P1) or below (P3) knee</td>
</tr>
<tr>
<td>Trifurcation vessels</td>
<td>“Infra-popliteal runoff”</td>
</tr>
<tr>
<td></td>
<td><em>Only relevant in CLI pts (not IC)</em></td>
</tr>
<tr>
<td>Pedal aa.</td>
<td>“2 vessels crossing ankle” (DP, PT)</td>
</tr>
<tr>
<td></td>
<td><em>Only in CLI / bypass targets</em></td>
</tr>
</tbody>
</table>
CTA Scan Acquisition

- Scan Acquisition
- Contrast Medium Injection
Peripheral CTA
Scan Acquisition / Recon

**Scanning Range 1**
celiac artery (~T12) → toes
(105 – 130 cm)

**Optional Scanning Range 2**
above the knees → toes
Always pre-programmed, but only initiated by RT if no contrast in pedal vessels

**Recons:**
Thin, overlapped
**FOV =** greater trochanters
<table>
<thead>
<tr>
<th>Detector Configuration (mm)</th>
<th>TI / 360° (mm)</th>
<th>Table Speed (mm/s)</th>
<th>Scan Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>16-Channel MDCT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16×.75</td>
<td>18</td>
<td>36</td>
<td>30-40</td>
</tr>
<tr>
<td>16×.63</td>
<td>18</td>
<td>35</td>
<td>30-40</td>
</tr>
<tr>
<td>16×1.5</td>
<td>33</td>
<td>66</td>
<td>15-20</td>
</tr>
<tr>
<td>16×1.25</td>
<td>35</td>
<td>70</td>
<td>15-20</td>
</tr>
<tr>
<td><strong>64-Channel MDCT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64×.63</td>
<td>55</td>
<td>92</td>
<td>11-14</td>
</tr>
<tr>
<td>64×.60</td>
<td>29</td>
<td>78</td>
<td>13-17</td>
</tr>
<tr>
<td><strong>FLASH Modes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>128 x 2 x 0.60</td>
<td>128</td>
<td>458</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>192 x 2 x 0.60</td>
<td>184</td>
<td>737</td>
<td>&lt;2</td>
</tr>
</tbody>
</table>

Anatomic coverage: 105 – 130cm

- slow: ~35 mm/s
- fast: ~65 mm/s
- very fast: ~85 mm/s

**BLAZING**
Speed considerations for >64 slice CTA

- Outrunning Bolus
- Delayed filling of distal arteries
Free-Flap Planning CTA
Arteriomegaly

preprogrammed, optional 2nd acquisition

1st acquisition
Peripheral arterial bolus propagation

**Aorto-popliteal transit speed (mm/s)**

*Cumulative percentage of limbs*

*Relative risk to outrun bolus*

Fleischmann D and Rubin GD. Radiology 2005, 1076-1082
Contrast considerations for peripheral CTA

- Aorto-popliteal transit time: 4-24 sec (10 sec)
  - Contrast speed: 29-177 mm/s
- Biphasic injections yield more consistent enhancement profile

Fleischmann et al. JVIR 2006, 17(1) 3-26.
**Biphasic Injection for Peripheral CTA**

- **INPUT**
  - intravenous injection rate (mL/s)

- **OUTPUT**
  - arterial enhancement (ΔHU)

**Biphasic Injection**

- **Phase I** (surge phase)
- **Phase II** (continuing phase)

Patient Factors

- Arterial enhancement is **inversely** related to:
  - Cardiac output (CO)
  - Central blood volume (CBV)
  - CO (and CBV) correlate with body weight
    - at least in pts. with ~ normal cardiac function
  - Weight-based dosing helps consistency

1) Hittmair & Fleischmann, JCAT 2001
Integrated Contrast/Scan Protocol

- Simple, weight based injection volumes and flow rates, combined with a fixed scan time or scan time/diagnostic delay sum.
- Automated bolus triggering
- Use physiology (not scanner speed)

**BENEFITS:**
- Decrease patient to patient variability in scan quality
  - Optimize imaging timing
  - Image all of the contrast given!
- (Potentially) save contrast
STANFORD Integrated Scanning-Injection Protocol: (Siemens)

- **Scan time:** 40s for ALL patients (pitch variable)
- **Inj. duration:** 35s for ALL patients
- **Delay:** bolus triggering

<table>
<thead>
<tr>
<th>weight</th>
<th>Biphasic Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;55kg</td>
<td>20 mL (4.0mL/s) + 96 mL (3.2mL/s)</td>
</tr>
<tr>
<td>&lt;65kg</td>
<td>23 mL (4.5mL/s) + 108 mL (3.6mL/s)</td>
</tr>
<tr>
<td>75kg</td>
<td>25 mL (5.0mL/s) + 120 mL (4.0mL/s)</td>
</tr>
<tr>
<td>&gt;85kg</td>
<td>28 mL (5.5mL/s) + 132 mL (4.4mL/s)</td>
</tr>
<tr>
<td>&gt;95kg</td>
<td>30 mL (6.0mL/s) + 144 mL (4.8mL/s)</td>
</tr>
</tbody>
</table>
### ST. VINCENT Integrated Scanning-Injection Protocol: (GE HD-750, VCT)

- **Scan time:** Variable (can’t specify time)
- Add “diagnostic delay” to make 40 sec
- **Inj. duration:** 35s for ALL patients
- **Delay:** bolus triggering

<table>
<thead>
<tr>
<th>weight</th>
<th>Biphasic Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;55 kg</td>
<td>20 mL (4.0mL/s) + 96 mL (3.2mL/s)</td>
</tr>
<tr>
<td>55–95 kg</td>
<td>25 mL (5.0mL/s) + 120 mL (4.0mL/s)</td>
</tr>
<tr>
<td>&gt;95 kg</td>
<td>30 mL (6.0mL/s) + 144 mL (4.8mL/s)</td>
</tr>
</tbody>
</table>
Special Scenarios

- Renal Dysfunction
- Contrast Medium Savings
Adaptations for Renal Dysfunction: LESS IS MORE

- Decrease CM dose
- Decrease kV imaging
- Decrease scan range
Background:

- There is clinical evidence that ratio of CM to eGFR can predict CIN occurrence
- **Best discriminator: CM dose (mL) \( \geq 3.7 \times eGFR \)**
  - Corresponds to \( 1 \times eGFR \) in grams of iodine (assuming 370 mg I / mL contrast)
- There is also evidence that CIN risk is not increased for volumes less than \( 2.0 \text{ mL} \times eGFR \) (PCI data)

eGFR-based CM calculation

- Determine eGFR: [http://touchcalc.com/e_gfr](http://touchcalc.com/e_gfr)
- If eGFR < 60 ml/min/m² (e.g. CKD):

  **MAX volume (mL) = eGFR x 2**
  
  (this is for 75 kg body weight)

Then, adjust for BW:

**MAX volume = eGFR x 2 x (BW/75)**

** Low concentration CM (300 mgI/mL)
eGFR before and 3-14d after CTA in 185 pts undergoing TAVR

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre (mL/min/1.73m²)</th>
<th>Post (mL/min/1.73m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-contrast (n=60) 0 mL</td>
<td>eGFR: 37 ±14</td>
<td>37 ±16</td>
</tr>
<tr>
<td></td>
<td>p=.81</td>
<td></td>
</tr>
<tr>
<td>Low contrast (n=21) 64 ± 18 mL</td>
<td>eGFR: 42 ±16</td>
<td>45 ±18</td>
</tr>
<tr>
<td></td>
<td>p=.07</td>
<td></td>
</tr>
<tr>
<td>Standard contrast (n=64) 137 ± 25 mL</td>
<td>eGFR: 56 ±11</td>
<td>58 ±17</td>
</tr>
<tr>
<td></td>
<td>p=.37</td>
<td></td>
</tr>
</tbody>
</table>

>25% decrease of eGFR:
- Non-contrast: 8% (5/60)
- Low contrast: 0% (0/21)
- Standard contrast: 12% (8/64)
Low kVp Imaging

- K-edge of iodine: 33.2 KeV
- Attenuation of iodine increases by 25% from 120 to 100 kVp, and again from 100 to 80 kVp
- Each “step” down in kVp corresponds to ~ 25% less CM needed

<table>
<thead>
<tr>
<th></th>
<th>140 kVp</th>
<th>120 kVp</th>
<th>100 kVp</th>
<th>80 kVp</th>
<th>70 kVp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine Attenuation (compared to 120 kVp)</td>
<td>- 25%</td>
<td>-</td>
<td>+25%</td>
<td>+50%</td>
<td>+70%</td>
</tr>
</tbody>
</table>

Low kVp imaging - modifications

- Keep injection duration, scan-time, and scan delays constant
- For each “step” down in kVp, increase mAs 30-50%
- Noise Control options:
  - Slow pitch down
  - Slow gantry rotation time
  - Keep noise index the same
  - Match CTDI\textsubscript{vol} between protocols
Other issues in low kVp imaging

- Ca++ blooming / metal beam hardening worsens
- Larger focal spot requirement decreases spatial resolution (focal spot bloom)
  - Improved w newer scanner technology
CTA Reconstruction

Handout: stanford.edu/~hallett choose folder “RSNA2016”
Tips: CTA Reconstruction and Interpretation

- Use smaller FOV (trochanter to trochanter)
- Use Iterative Reconstruction
- Recon thin, overlapping images and review in 3D
  - VR / MIP overview then MPR, CPR
  - 3 - 5 mm Axials in A/P
- Recon larger matrix – 1024x1024

** Fleischmann D, Hallett RL, Rubin GR. JVIR 2006, 17: 3-26.**
CTA Post-processing Tips

- Big challenge in lower extremity CTA: difference between quick read vs. painful (literally) scrolling through images
- Axial (transverse) images inadequate, except in acute ischemia (i.e. thromboembolic)
- Volumetric review of volumetric datasets!
CTA Post-processing Tips

- need longitudinal cross sections (MPR/CPR)
- Map lesions with a ‘map’:
  - multipath curved planar reformations (MPCPR)
  - CPRs made on 3D Solution
- try to delegate (3D-Lab, trained technologist) if routinely performing runoff CTAs
The Achilles’ Heel of Extremity CTA.....
Predictors of Vascular Calcification

**Above knee:**
- Severe PAD (Fontaine III-IV), Diabetes

**Below Knee:**
- Renal Failure (esp. dialysis), Diabetes

**Also:**
- Age, cardiac disease

If heavy, significant decrease in SENS/SPEC in calf

Time-Resolved CTA - Runoff

• Technique
  timing bolus at popliteal artery
  50 mL at 5 mL/sec + 50 mL saline chaser
  12 low-dose CTA acquisitions over 30 sec
  Rapid “shuttle” of detector array

• Then: standard CTA runoff protocol

• Significantly greater enhancement, less venous overlap
• Significantly higher diagnostic confidence
• Directly visualize asymmetric / delayed / diminished flow

Efficacy of LE CTA in PAD

@CTterrific

Handout: stanford.edu/~hallett  choose folder “RSNA2016”
### CTA: Diagnostic Performance vs. DSA

#### Detection of ≥50% Stenosis or Occlusion by Anatomical Region

<table>
<thead>
<tr>
<th>Vessels</th>
<th>Sens (95% CI)</th>
<th>Spec (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortoiliac</td>
<td>96 (91-99)</td>
<td>98 (95-99)</td>
</tr>
<tr>
<td>Femoropopliteal</td>
<td>97 (95-99)</td>
<td>94 (85-99)</td>
</tr>
<tr>
<td>Trifurcation</td>
<td>95 (85-99)</td>
<td>91 (79-97)</td>
</tr>
</tbody>
</table>

#### CT Channels

<table>
<thead>
<tr>
<th>CT Channels</th>
<th>Sens (95% CI)</th>
<th>Spec (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4</td>
<td>92 (88-96)</td>
<td>98 (95-99)</td>
</tr>
<tr>
<td>16-64</td>
<td>97 (95-98)</td>
<td>98 (96-99)</td>
</tr>
</tbody>
</table>

---

Met R et al. JAMA 2009;301:415-424
Diagnostic Performance: 64-slice CTA

- Symptomatic PAD: 242 pts, 7420 segments
- CTA and DSA performed
- For >70% stenosis:
  - SENS/SPEC 96%  PPV 98%  NPV 99%
  - No sig difference vs DSA findings
  - Results similar in Ca++ vs. Non-Ca++ lesions

Napoli A. Radiology. 2011 Dec 1;261(3):976–86.
Clinical Utility of LE CTA in PAD

- Intermittent Claudication (IC)
- Critical Limb Ischemia (CLI)

Handout: stanford.edu/~hallett choose folder “RSNA2015”
CTA Directed Management of Intermittent Claudication
CTA Directed Management of Intermittent Claudication

- Fontaine IIb patients, Tx decisions by TASC II criteria
- 57/58 correct Tx decision-making by CTA
  - One CFA stenosis missed
  - 29 endovasc/surg Tx
  - 29 conservative mgmt

Schernthaner R, et al. AJR 2007; 189:1215-1222
CTA Directed Management of CLI
CTA Directed Management of CLI

- 41 pts, 1435 segments
- 64-CTA
- Fontaine IIb, III, IV
- 2.2% segments non-diagnostic
  - not included in calculation
  - 91% infrapopliteal segments evaluable
- For ≥ 50% stenosis:
  - Sens 99%  Spec 98%  Acc: 98%

CTA Directed Management of CLI

- 28 pts, Fontaine IV
- 64-detector CTA
- 14/28 → endovascular and/or surg. Tx
- correct decision-making for interventions, amputation, and medical Tx based on DSA and Tx response

Schernthaner R, et al. AJR 2009; 192: 1416-1424
Management of both IC and CLI by CTA

- Treated using TASC II guidelines
  - 49 conservative TX
  - 87 Endovascular
  - 38 surgery
  - 17 hybrid

- Tx recommendations from CTA same as DSA in all but ONE

Napoli A. Radiology. 2011 Dec 1;261(3):976–86.
Examples:
- Atherosclerotic Disease Therapy Planning
CTA for post-treatment followup

Post-TX Assessment by CTA
CTA for stent assessment

- Most stents assessable (76%) by CTA
  - Gold / platinum markers
  - Motion
  - Strecker stent (Tantalum): Increased luminal density

- If evaluable, sens/spec ~ 95% for significant in-stent restenosis (vs. DSA)

1 Li X, et al. Eur J Radiol 2010; 98-103
2 Strotzer, Invest. Radiol. 2001:36(11)
CTA for assessment of complications
Acute R leg pain
Value-Added Info from CTA: GSV mapping$^{1-2}$

- Pre-Op CTA: Adequate for evaluation of GSV
  - SENS/SPEC >90% (better in thigh)
  - Charge savings of ~50K at authors site alone$^2$
  - If GSV ≤ 2 mm, then do Doppler US

Conclusions

- Goals:
  - Map lesions to symptoms to direct therapy
  - Answer the clinical questions

- Implement:
  - Integrated CM/scan protocol to improve consistency
    - Inject long, scan slow
    - Weight-based CM dosing

- 3D Volumetric Review of Datasets needed
Thanks for your Attention!

- Special thanks to.....
  Dominik Fleischmann, MD

@CTterrific

Handout: stanford.edu/~hallett choose folder “RSNA2016”