Richard L. Hallett, MD

Chief, Cardiovascular Imaging
Northwest Radiology Network
Indianapolis, IN

Adjunct Assistant Professor – Radiology
Stanford University
Stanford, CA

PERIPHERAL CTA
Outline

- CTA Acquisition Techniques
  - Scan Acquisition
  - Contrast Medium injection
  - Reconstruction
- Clinical Efficacy in PAD
- Cost Effectiveness

Handout: stanford.edu/~hallett  choose folder “RSNA2015”
CTA Indications in PAD

- Intermittent Claudication
- Critical Limb Ischemia
- Acute Ischemia (urgent)
- Monitoring of Therapy (complications)
CTA Benefits / Limitations

**Benefits**
- Non-invasive (DSA)
- Spatial Resolution (MRA)
- Quick Acquisition
- (mostly) Operator Independent

**Limitations**
- Ionizing Radiation
- Nephrotoxic Contrast
- Spatial Resolution (DSA)
- No same session Tx
- No flow or pressure measurements
CTA Acquisition

- Scan Acquisition
- Contrast Medium Injection
CTA Scan Acquisition

Handout: stanford.edu/~hallett choose folder “RSNA2015”

@CTeriffic
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>Scanning Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-Channel MDCT</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>64-Channel MDCT</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>
</tbody>
</table>

Anatomic coverage: 105 – 130cm

- **16-Channel MDCT**
  - slow: ~35 mm/s
  - fast: ~65 mm/s

- **64-Channel MDCT**
  - very fast: ~85 mm/s
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

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

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>
CTA Reconstruction

Handout: stanford.edu/~hallett  choose folder “RSNA2015”
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, Hallet RL, Rubin GR.** *JVIR 2006, 17: 3-26.*
1024 Matrix Examples
Efficacy of LE CTA in PAD

@CTeriffic

Handout: stanford.edu/~hallett choose folder “RSNA2015”
# PAD Classification

<table>
<thead>
<tr>
<th>Fontaine Stage</th>
<th>Rutherford Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>IIa</td>
<td>Mild Claudication (&gt;200m walk)</td>
</tr>
<tr>
<td>IIb</td>
<td>Moderate to Severe Claudication (&lt;200m walk)</td>
</tr>
<tr>
<td>III</td>
<td>Ischemic Rest Pain</td>
</tr>
<tr>
<td>IV</td>
<td>Ulceration or Gangrene</td>
</tr>
</tbody>
</table>

**I.C.**

| I              | 0             |
| IIa            | 1             |
| IIb            | 2 (moderate)  |
|                | 3 (severe)    |
| III            | 4             |
| IV             | 5 (minor tissue loss) |
|                | 6 (major tissue loss) |
**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>

**Performance**

<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.
The Achilles’ Heel of Extremity
CTA.....
Predictors of Vascular Calcification

- Above knee:¹ Severe PAD (Fontaine III-IV), Diabetes
- Below Knee:¹ Renal Failure (esp. dialysis), Diabetes
- Also:² Age, cardiac disease
- If heavy, significant decrease in SENS/SPEC in calf ¹

**Time-Resolved CTA - Runoff**

**Technique - Initial:**
- 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

Clinical Utility of LE CTA in PAD

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

Handout: stanford.edu/~hallett choose folder “RSNA2015”
Intermittant Claudication (IC)

- Only $\frac{1}{4}$ progress clinically
- Amputation uncommon (unless diabetic)
- More likely ilio-femoral than trifurcation dz
Management of Intermittent Claudication by CTA

- 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
Critical Limb Ischemia (CLI)

- Duration > 2 weeks
- rest pain, tissue loss, ulcers, gangrene (TASC II)
  - Fontaine III / IV
- Higher incidence DM, trifurcation disease, comorbidities than IC
CTA assessment in CLI

- 41 pts, 1435 segments
- 64-CTA
- Fontaine IIb, III, IV
- 2.2% segments non-diagnostic
  - not included in calculation
  - 91% infrapop segments evaluable

For $>50\%$ stenosis:
- Sens 99%    Spec 98%    Acc: 98%

Management Decisions in 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
Buttock Claudication – Calcified Aorto-iliac Disease

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
CTA for assessment of complications

Acute R leg pain
Cost-Effectiveness of CTA

Handout: stanford.edu/~hallett choose folder “RSNA2015”
CTA as cost-effective care vs DSA

2005: Randomized, controlled trial: 4-DCT vs DSA

Dx confidence slightly lower with CTA (calcifications)

CT cost-effective and provides sufficient information for Tx planning

DSA costs (564 Euro) greater than CTA (363)

CTA as cost-effective care vs MRA

- 2005: RCT - 156 pts CTA vs MRA
- CTA/MRA utility similar
- CTA lower diagnostic costs /patient
  - Average costs: $199 vs $627
  - Difference from imaging test itself, not from additional procedures

CTA as cost-effective care (vs. US and MRA)

- 2008: DIPAD Trial (Multicenter RCT)
- 514 PAD pts, randomized to Doppler/MRA/CTA
- CTA and MRA:
  - significantly higher diagnostic confidence
  - less additional imaging needed
- Total costs lower for CTA

Integrating CTA into cost-effective care

- 2005: Randomized, controlled trial: 4-DCT vs DSA\(^1\)
  - Dx confidence slightly lower with CTA (calcifications)
  - CT cost-effective and provides sufficient information for Tx planning
  - DSA costs (564 +/- 210) greater than CTA (363 +/- 273)

- 2007: Correct TX recommendations for I.C.\(^2\)

- 2009: Correct TX recommendations for CLI \(^3\)

---

2 Schernthaner, R, et al. AJR 2007; 189:1215-1222
3 Schernthaner, R, et al. AJR 2009; 192:1416-1424
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

- LE CTA is an **accurate and cost-effective tool** for assessment of various forms of peripheral arterial disease
- Implementation of **integrated CM/scan protocol** will improve consistency
- Clinical integration and uses will continue to expand
Thanks for your Attention!

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

@CTeriffic

Handout: stanford.edu/~hallett choose folder “RSNA2015”