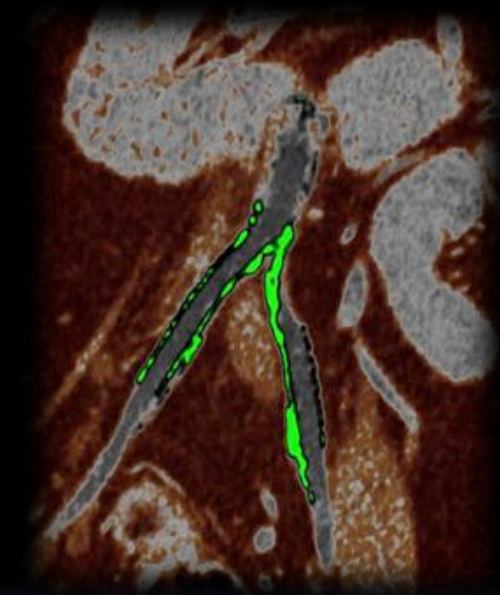


Richard L. Hallett, MD

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Northwest Radiology Network
Indianapolis, IN

Adjunct Assistant Professor – Radiology
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Stanford, CA



PERIPHERAL CTA



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Outline

- Goals of LE CTA
- CTA Acquisition Techniques
 - Scan Acquisition
 - Contrast Medium injection
- Clinical Efficacy in PAD
- Pre- and Post- Intervention Imaging

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Goals of CTA imaging in PAD

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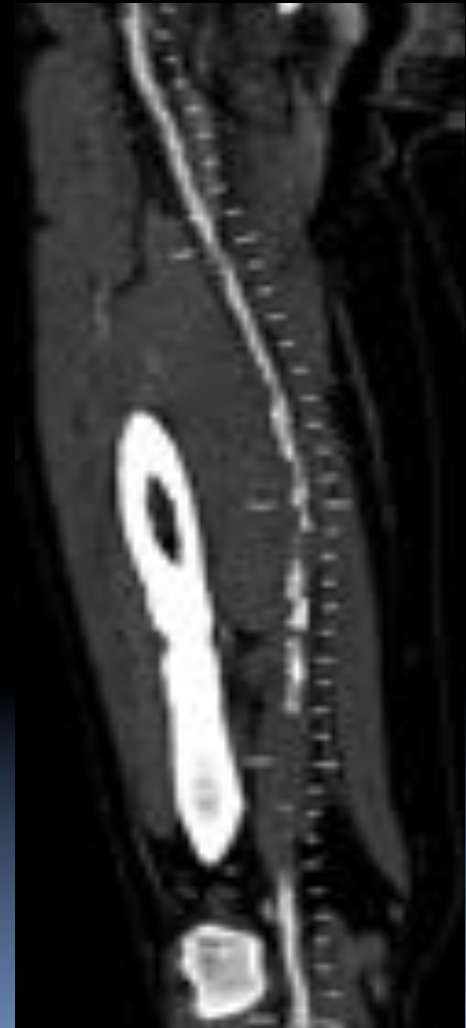


Diagnosis and Staging of PAD

= 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



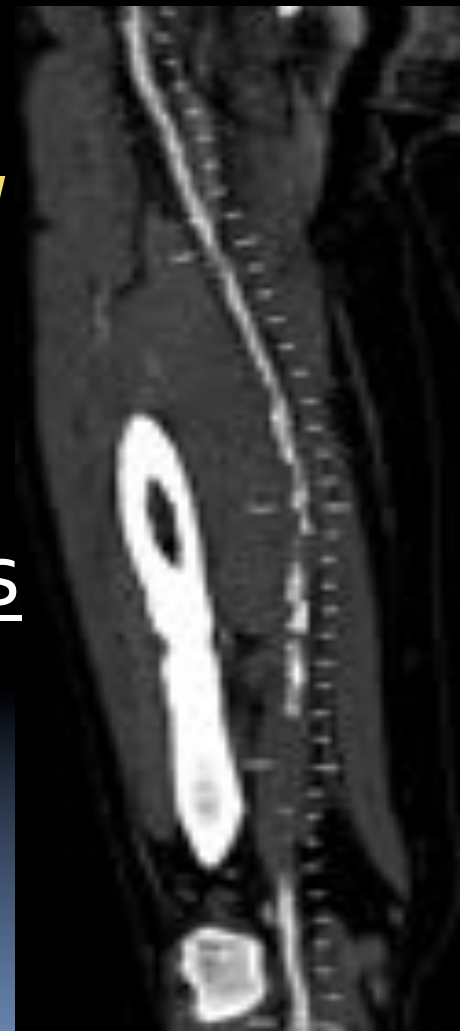


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Role of CTA Imaging is **NOT** diagnosis /
staging

The role of CTA is to map lesions
to the patient's symptoms
for treatment planning



TASC II Criteria

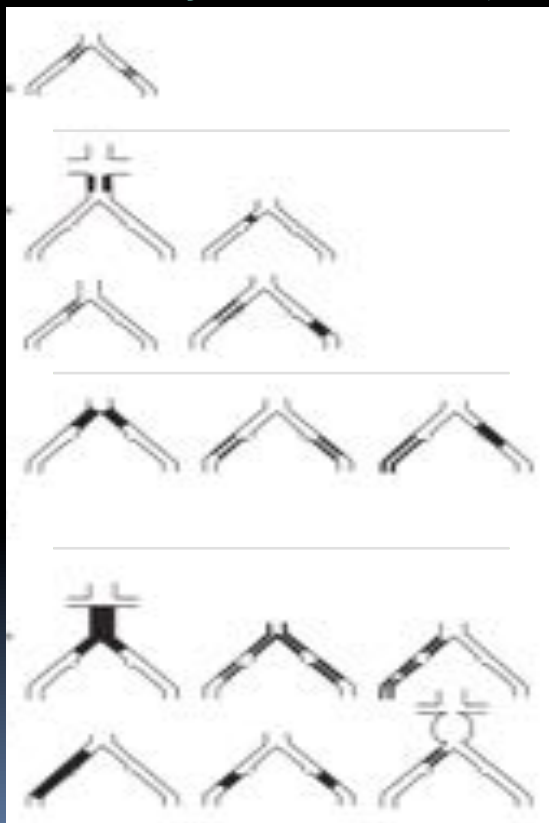
Transatlantic Society Consensus (2007)

Type A
endovascular

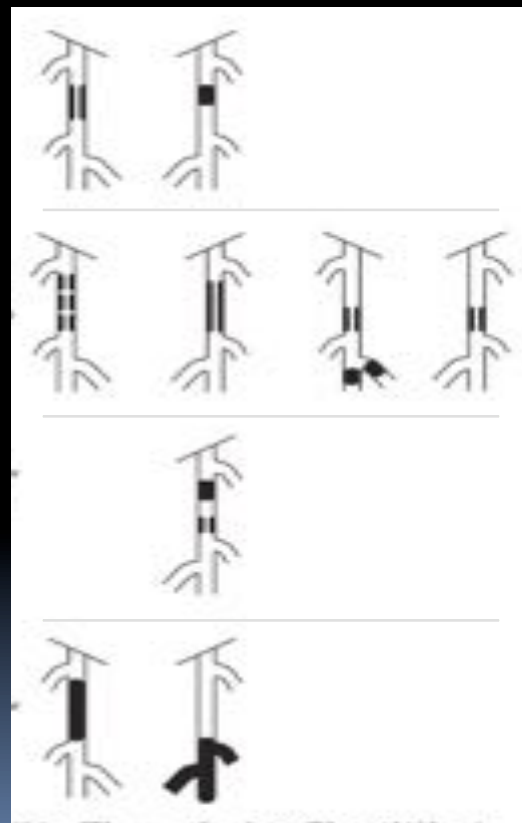
Type B

Type C

Type D
surgical



aortoiliac



femoropopliteal

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Indications for CTA in PAD

- Intermittent Claudication
- Critical Limb Ischemia
- Acute Ischemia (urgent)
- Monitoring of Therapy (complications)



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Which lesions matter?

Treatment Segment	AKA / utility
Aorto-iliac	"Inflow", "Supra-inguinal"
Common Femoral a.	Bypass target and source
Profunda Femoris a.	Important collaterals w/ SFA occlusion Important s/p amputation
Femoro-popliteal (SFA-Pop)	"Infra-inguinal runoff" Note level of reconstitution above (P ₁) or below (P ₃) knee
Trifurcation vessels	"Infra-popliteal runoff" Only relevant in CLI pts (not IC)
Pedal aa.	"2 vessels crossing ankle" (DP, PT) Only in CLI / bypass targets

CTA Scan Acquisition

- Scan Acquisition
- Contrast Medium Injection



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Peripheral CTA

Scan Acquisition / Recon

Scanning Range 1

celiac artery (~T12) → toes
(105 – 130 cm)

Optional Scanning Range 2

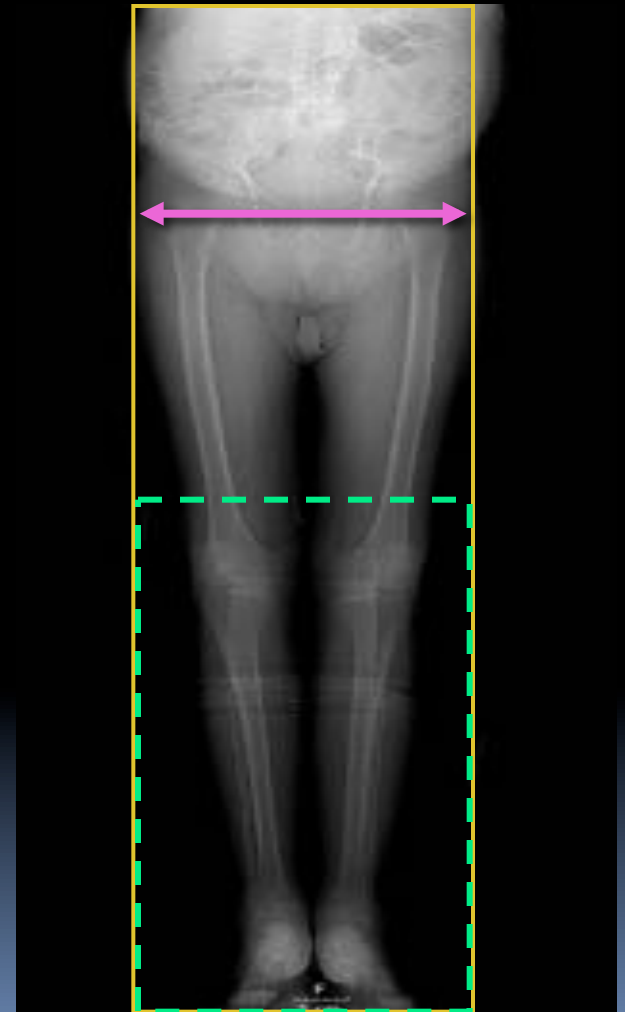
above the knees → toes

Always pre-programmed, but only initiated
by RT if no contrast in pedal vessels

Recons:

Thin, overlapped

FOV = greater trochanters



Detector Configuration (mm)

TI / 360° (mm)

Table Speed (mm/s)

Scan Time (s)

Anatomic coverage:
105 – 130cm

16-Channel MDCT

16×.75	18	36	30-40
16×.63	18	35	30-40
16×1.5	33	66	15-20
16×1.25	35	70	15-20

slow

~35 mm/s

slow

fast

~65 mm/s

fast

64-Channel MDCT

64×.63	55	92	11-14
64×.60	29	78	13-17

very

~85 mm/s

fast

FLASH Modes

128 x 2 x 0.60	128	458	< 3
192 x 2 x 0.60	184	737	< 2

BLAZING

Speed considerations for ≥ 64 slice CTA

- Outrunning Bolus
- Delayed filling of distal arteries



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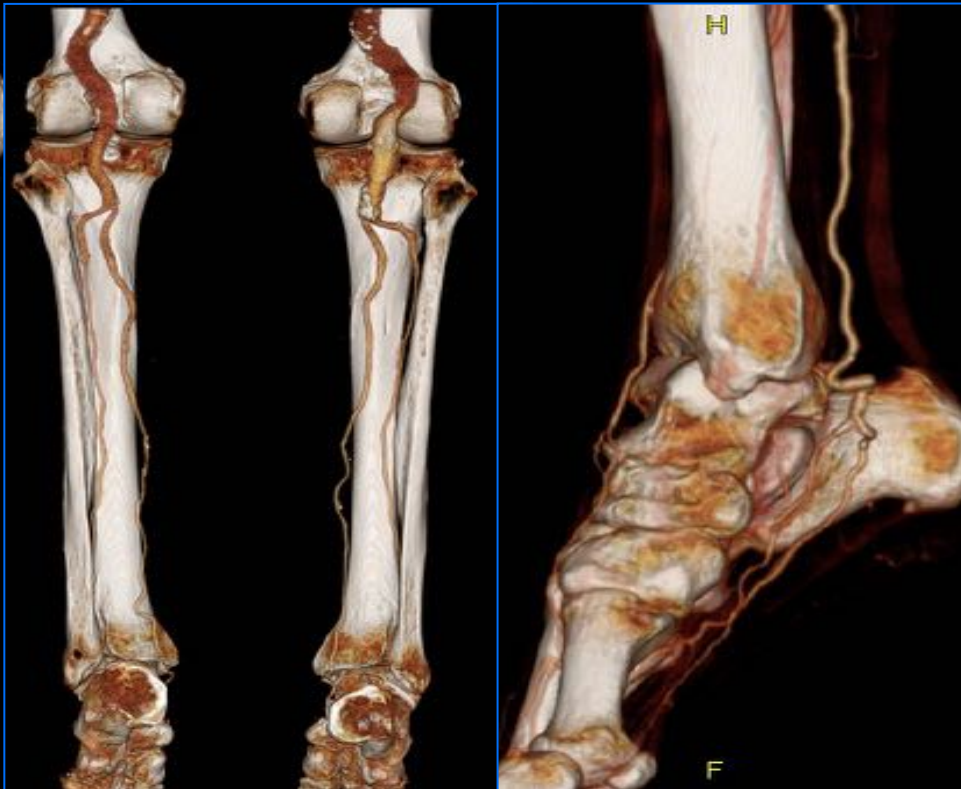
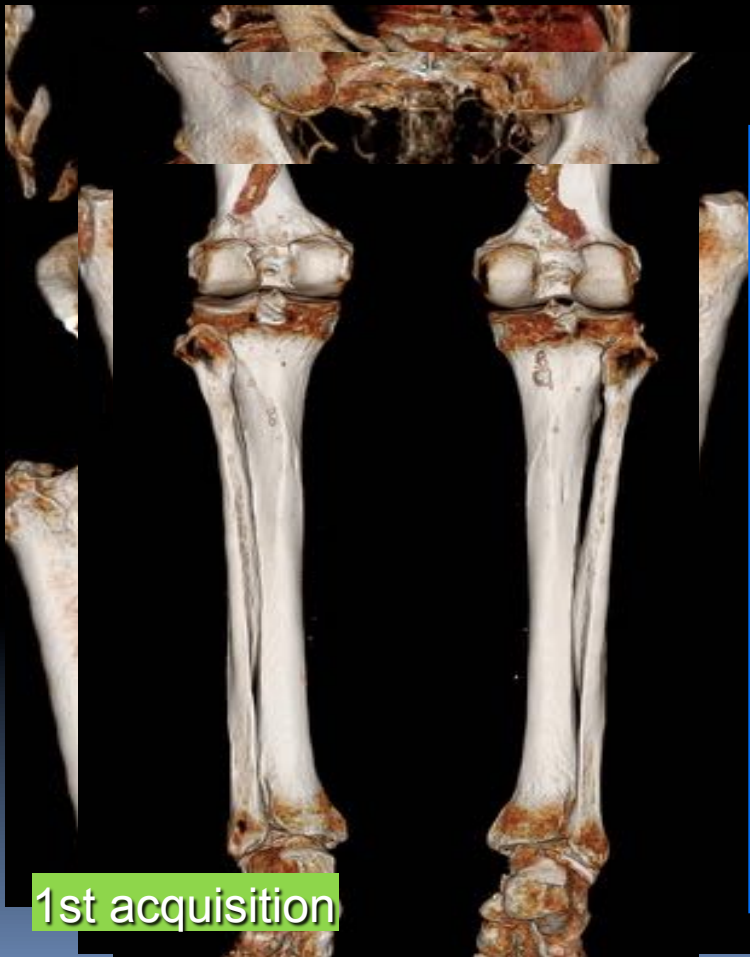


Free-Flap Planning CTA

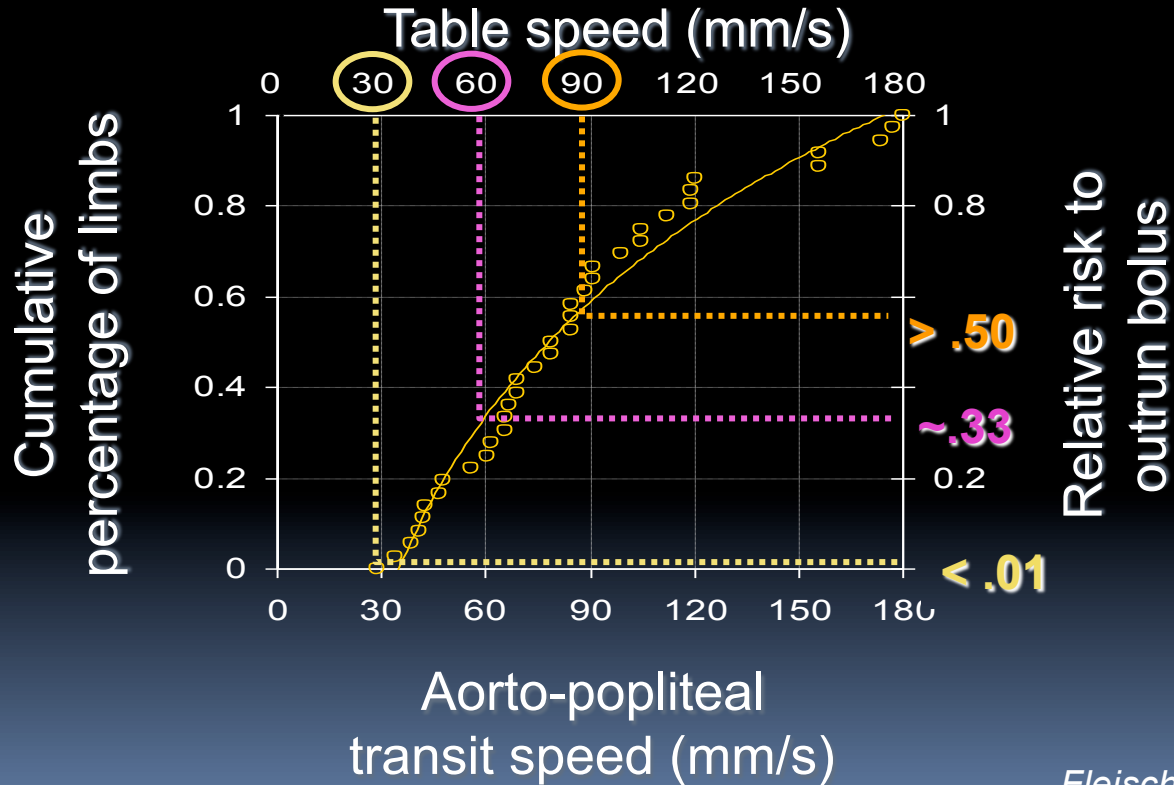


Arteriomegaly

preprogrammed,
optional 2nd acquisition



Peripheral arterial bolus propagation



Fleischmann D and Rubin GD.
Radiology 2005, 1076-1082

Contrast considerations for peripheral CTA

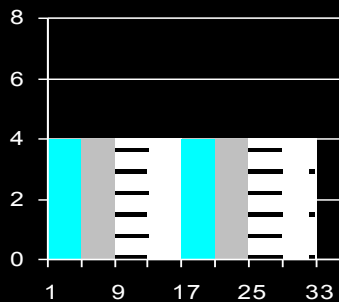
- Aorto-popliteal transit time: 4-24 sec (10 sec)
 - Contrast speed: 29-177 mm/s
- Biphasic injections yield more consistent enhancement profile

Biphasic Injection for Peripheral CTA

Fleischmann D. Eur. J. Radiol. 2003 Mar 1;45 Suppl 1:S88–93.

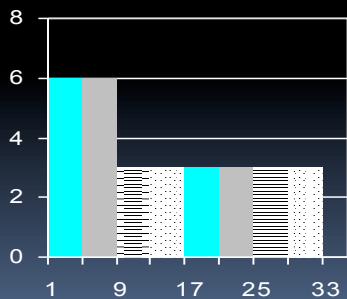
INPUT

intravenous
injection rate
(mL/s)

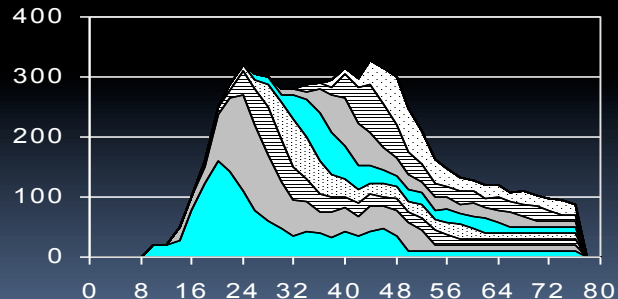
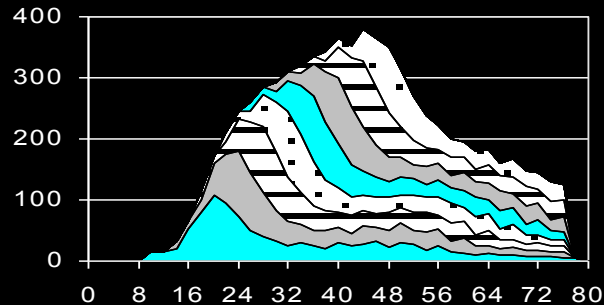


Biphasic Injection

Phase I
(surge phase)



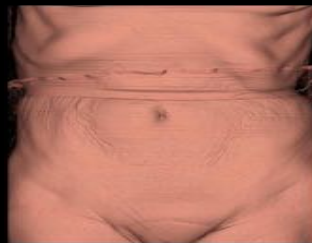
Phase II
(continuing phase)



OUTPUT

arterial
enhancement
(Δ HU)

Patient Factors



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

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 quality
 - ★ Optimize imaging timing
 - ★ Image all of the contrast given!
 - ★ (Potentially) save contrast

Integrated Scanning-Injection Protocol: (Siemens)

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

5 sec FAST + 30 sec SLOWER

weight

Biphasic Injection

<55kg

20 mL (4.0mL/s) + 96 mL (3.2mL/s)

<65kg

23 mL (4.5mL/s) + 108 mL (3.6mL/s)

75kg

25 mL (5.0mL/s) + 120 mL (4.0mL/s)

>85kg

28 mL (5.5mL/s) + 132 mL (4.4mL/s)

>95kg

30 mL (6.0mL/s) + 144 mL (4.8mL/s)

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

<u>weight</u>	<u>Biphasic Injection</u>
<55 kg	20 mL (4.0mL/s) + 96 mL (3.2mL/s)
55–95 kg	25 mL (5.0mL/s) + 120 mL (4.0mL/s)
>95 kg	30 mL (6.0mL/s) + 144 mL (4.8mL/s)



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Special Scenarios

- Renal Dysfunction
- Contrast Medium Savings

Adaptations for Renal Dysfunction: LESS IS MORE

- Decrease CM dose
- Decrease kV
- 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
- If eGFR < 60 ml/min/m² (e.g.CKD):

$$\text{MAX volume (mL)} = \text{eGFR} \times 2$$

(this is for 75 kg body weight)

Then, adjust for BW:

$$\text{MAX volume} = \text{eGFR} \times 2 \times (\text{BW}/75)$$

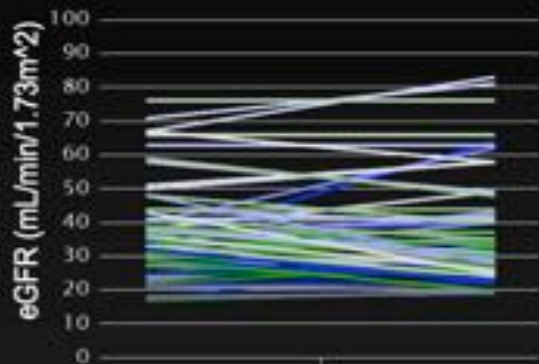
** Low concentration CM (300 mg/l/mL)

eGFR before and 3-14d after CTA in 185 pts undergoing TAVR

Non-contrast (n=60)
0 mL

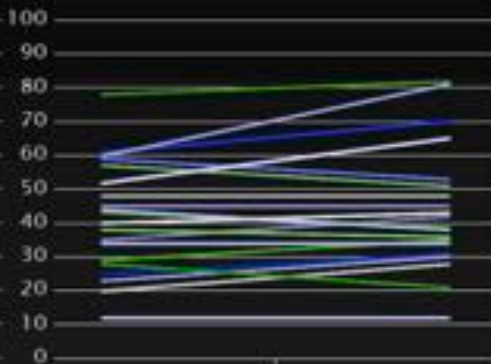
Low contrast (n=21)
64 ± 18 mL
(30mL-95mL)

Standard contrast (n=64)
137 ± 25 mL
(82mL-145mL)



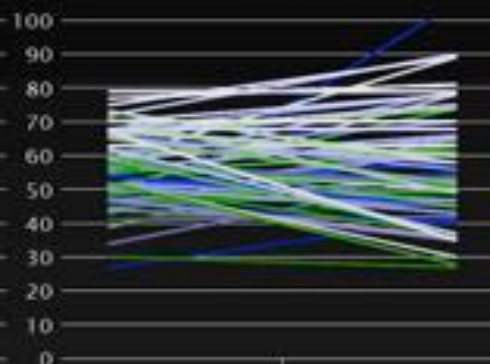
pre post
eGFR: 37 ± 14 37 ± 16
p = .81

>25% decrease
of eGFR: 8% (5/60)



pre post
eGFR: 42 ± 16 45 ± 18
p = .07

0% (0/21)



pre post
eGFR: 56 ± 11 58 ± 17
p = .37

12% (8/64)

Low kVp Imaging

	140 kVp	120 kVp	100 kVp	80 kVp	70 kVp
Iodine Attenuation (compared to 120 kVp)	- 25%	-	+25%	+50%	+70%

- 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

Chapter 3: Contrast Medium Injection Technique. In: Schoepf and Meinel, eds. *Multidetector-Row CT of the Thorax* (2016)

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 $CTDI_{vol}$ between protocols

CTA Reconstruction



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Tips: CTA Reconstruction

- 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.*



512

Area: 51.62 mm sq
Mean: -161.39
Max: -119
Min: -202
SDev: 14.77

1024

512

1024

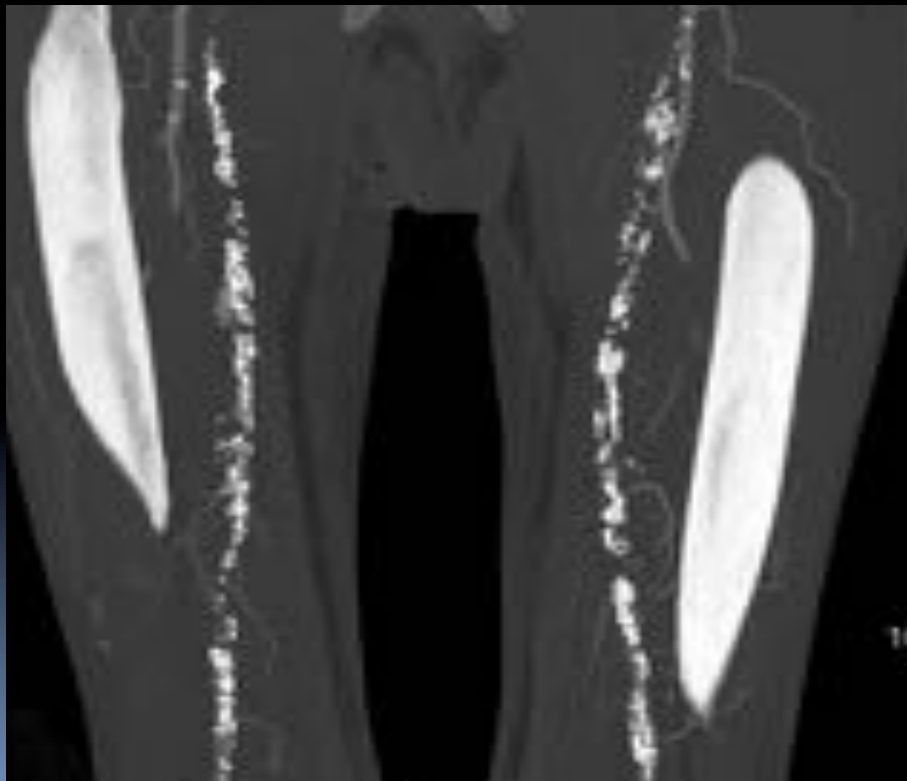




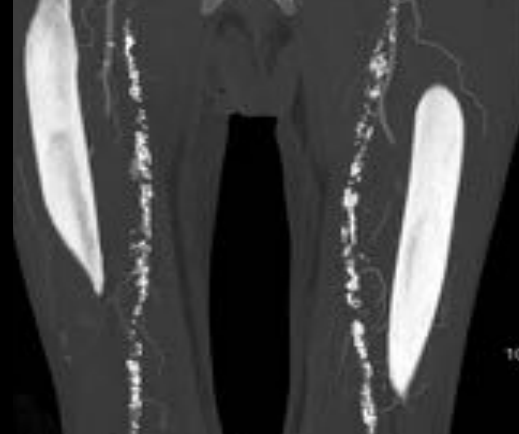
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The Achilles' Heel of Extremity CTA.....



Predictors of Vascular Calcification



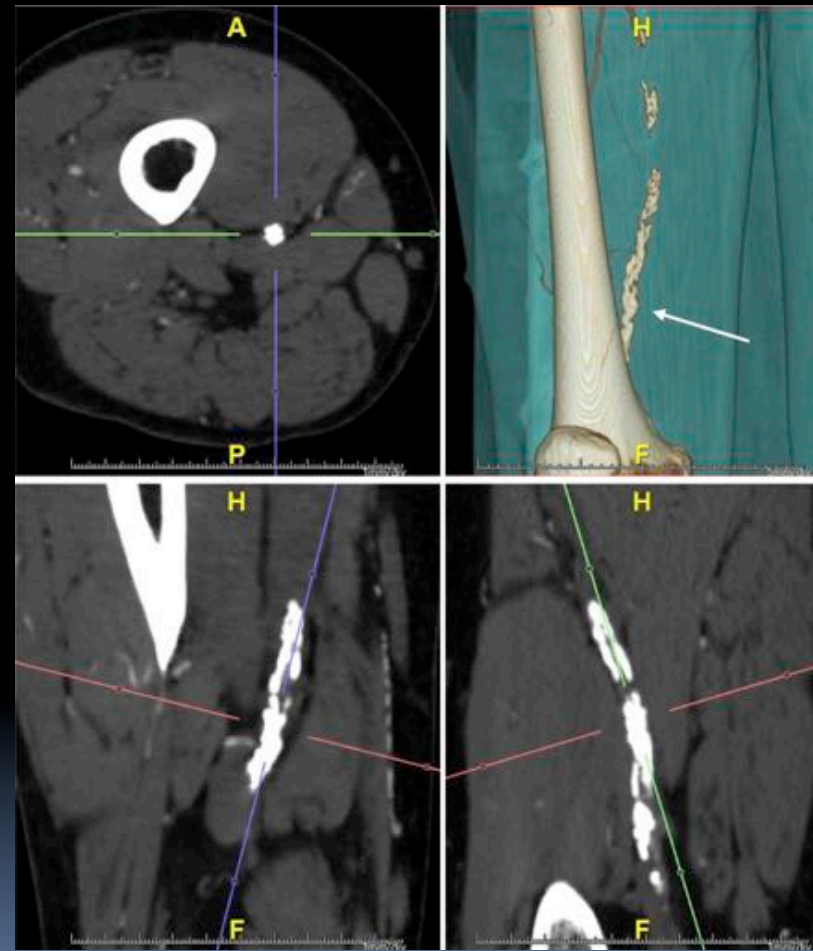
- ★ Above knee:¹ Severe PAD (Fontaine III-IV), Diabetes
- ★ Below Knee:¹ Renal Failure (esp. dialysis), Diabetes
- ★ Also:² Age, cardiac disease
- ★ If heavy, significant decrease in SENS/SPEC in calf ¹

¹ Meyer BC Eur Radiol (2010) 20:497-505

² Ouwendijk R. Radiology (2006) 241, 603-608

Effect of Calcium on Intervention

- Predictor of failure to cross lesion: **100% calcification on pre-op CTA**
 - NOT:
 - multiple occlusions,
 - negative remodeling
 - percentage calcification



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

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CTA: Diagnostic Performance vs. DSA

Performance

CT Channels	Sens (95% CI)	Spec (95% CI)
2-4	92 (88-96)	98 (95-99)
16-64	97 (95-98)	98 (96-99)

Detection of $\geq 50\%$
Stenosis or Occlusion
By Anatomical Region

Vessels	Sens (95% CI)	Spec (95% CI)
Aortoiliac	96 (91-99)	98 (95-99)
Femoropopliteal	97 (95-99)	94 (85-99)
Trifurcation	95 (85-99)	91 (79-97)

Met R et al. JAMA 2009;301:415-424

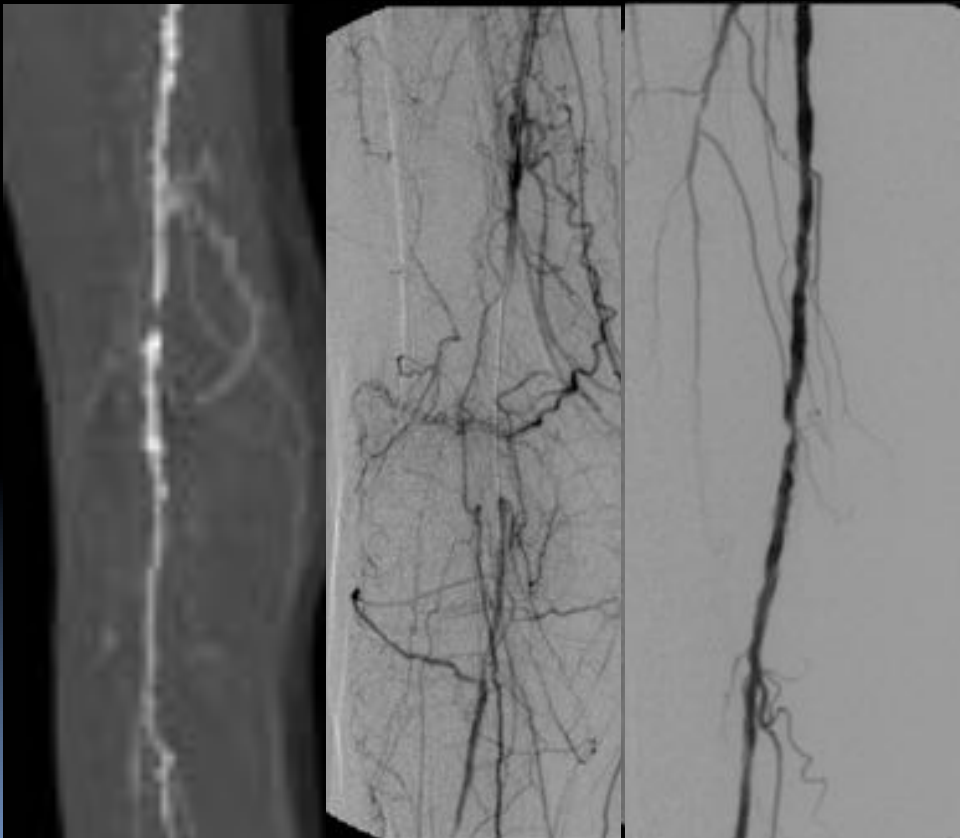
Diagnostic Performance: 64-slice CTA

- 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

CTA Directed Management of Intermittent Claudication



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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

CTA Directed Management of CLI



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Explore



Invent



Transform

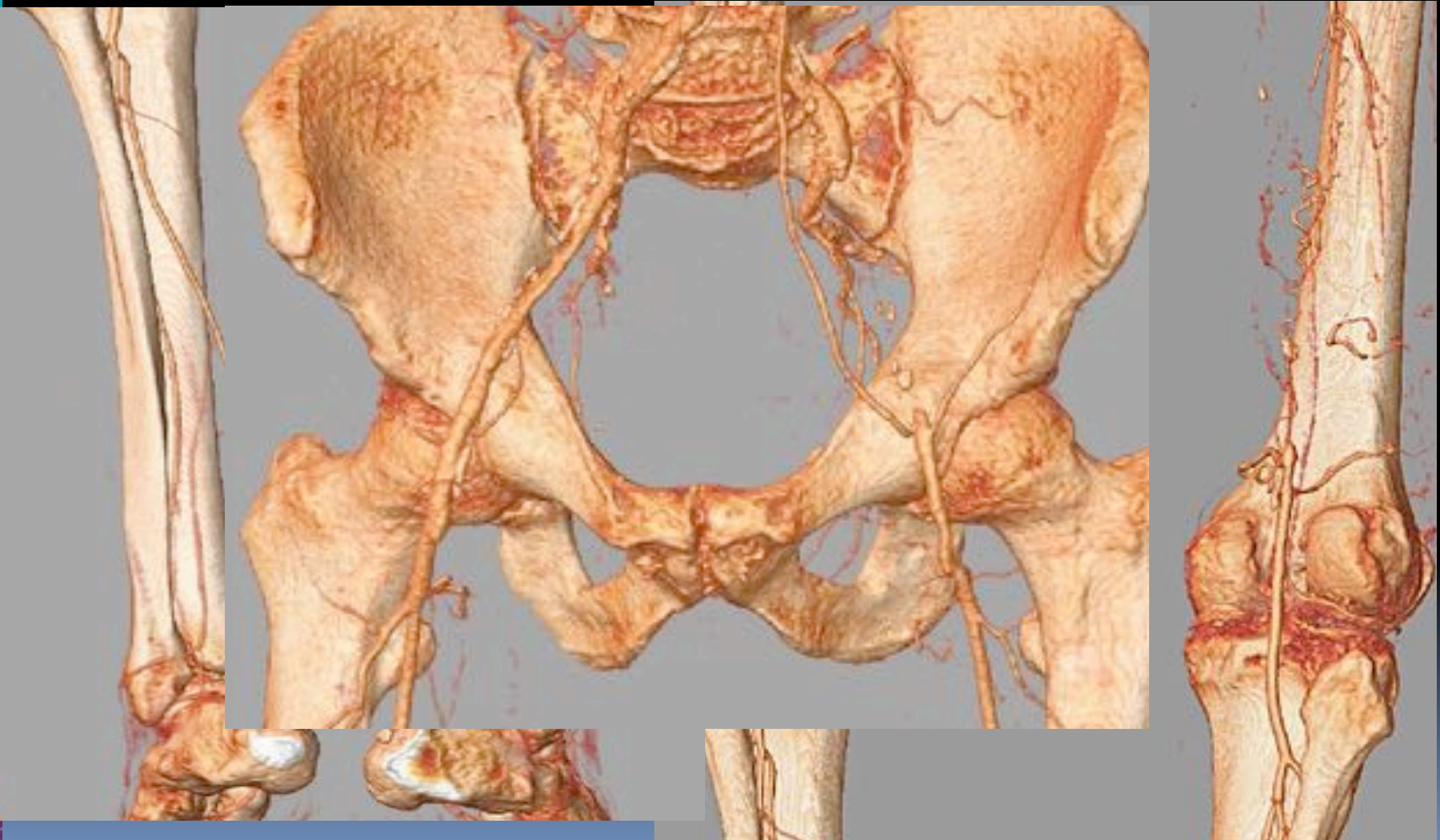
CTA Directed Management of CLI

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



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



CTA for post-treatment followup



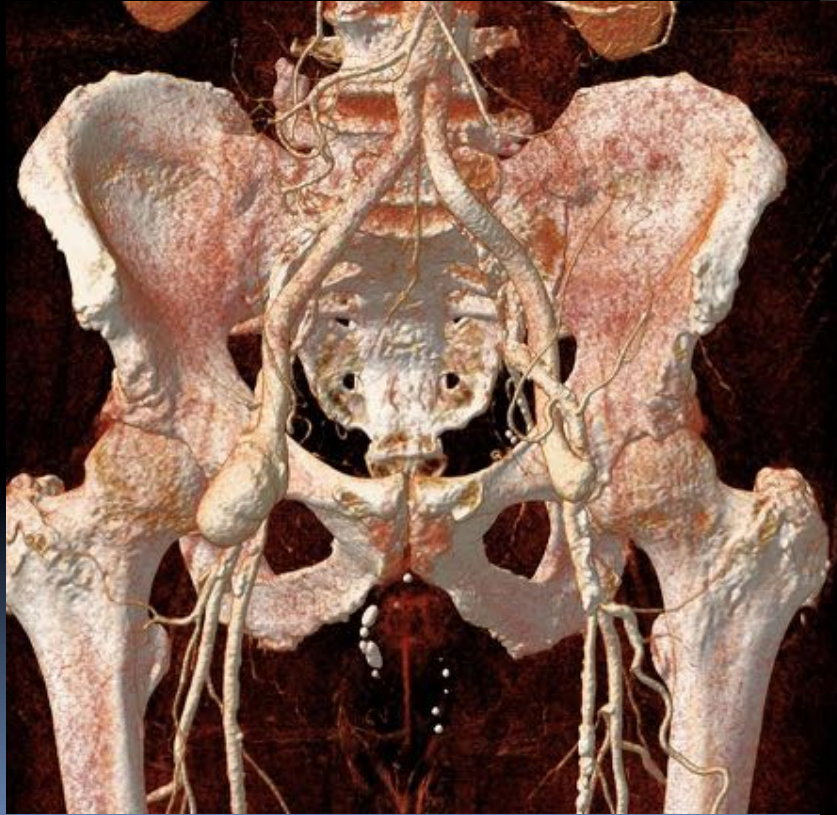
Explore Invent Transform

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Post-TX Assessment by CTA



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CTA for stent assessment

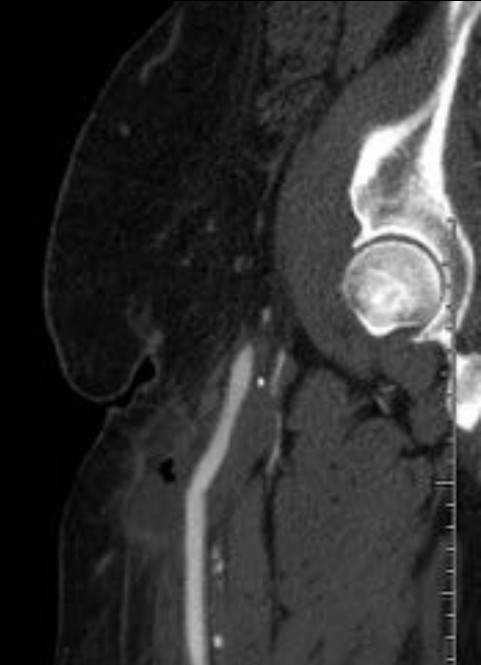
- Most stents assessable (76%) by CTA
 - Gold / platinum markers
 - Motion
 - Strecker stent (Tantalum): Increased luminal density²
- If evaluable, **sens/spec ~ 95%** for significant in-stent restenosis (vs. DSA)

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



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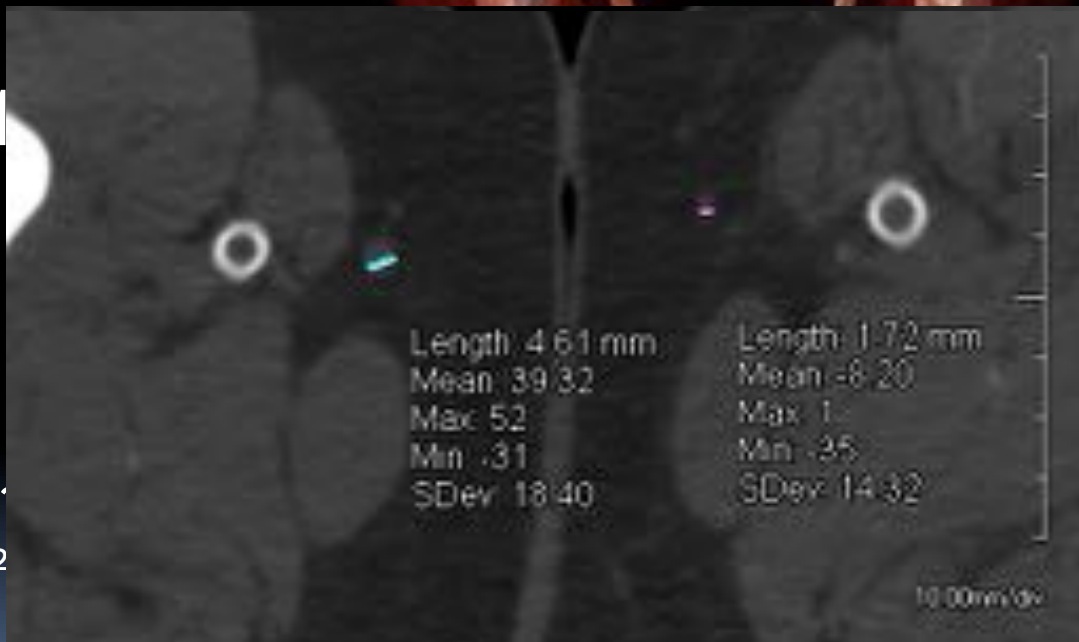
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10.00mm/d

Value-Added Info from CTA: GSV mapping¹⁻²

- Pre-Op CTA: Adeq evaluation of GSV
 - SENS/SPEC >90% (thigh)
 - Charge savings of authors site alone²
 - If GSV \leq 2 mm, then do Doppler US

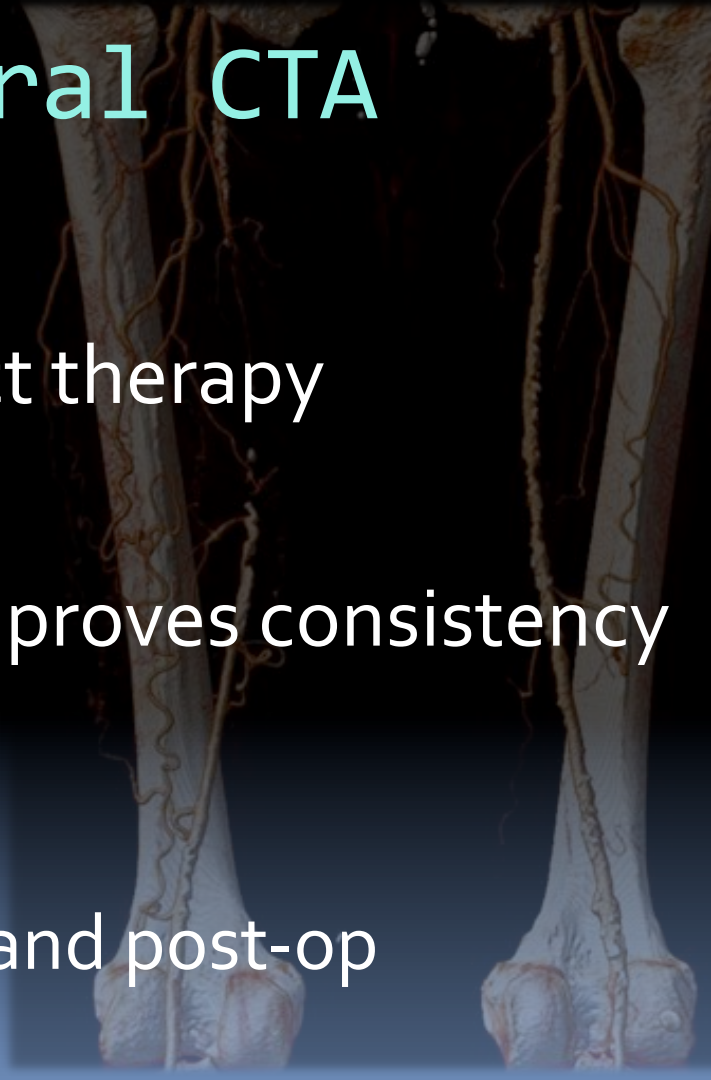


¹DeFreitas DJ, et al. *J Vasc Surg* 2013; 57(1): 5-55.

²Johnston WF, et al. *J Vasc Surg* 2012; 56(5): 1331-37.

Conclusions: Peripheral CTA

- Goal of peripheral CTA:
map lesions to symptoms to direct therapy
(Answer the clinical questions)
- **Integrated CM/scan protocol** improves consistency
 - Inject long, scan slow
 - Weight-based CM dosing
- CTA is useful for pre-op planning and post-op evaluation



Thanks for your Attention!

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



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