CTA of the Aorta and Lower Extremity

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Disclosures: None

Handout available at:

http://stanford.edu/~hallett

Choose "NMCSD"

Goals of this lecture:

- *Review of CTA acquisition parameters for the aorta and lower extremities*
- *Review of strengths and weaknesses of CTA in clinical care*
- *Case examples*
- *Recent advances that will shape CTA in the future*

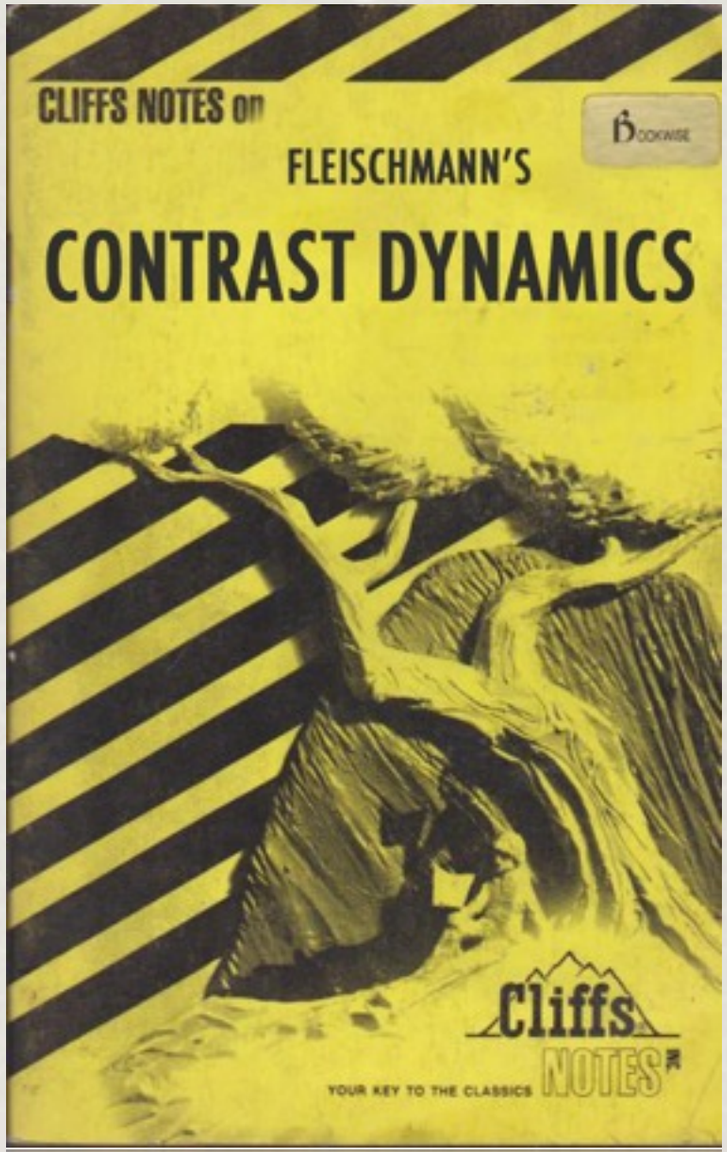
CTA Acquisition

- *Contrast Medium Dynamics*
- *Scan protocols*

Integrated Contrast / Scan Protocol

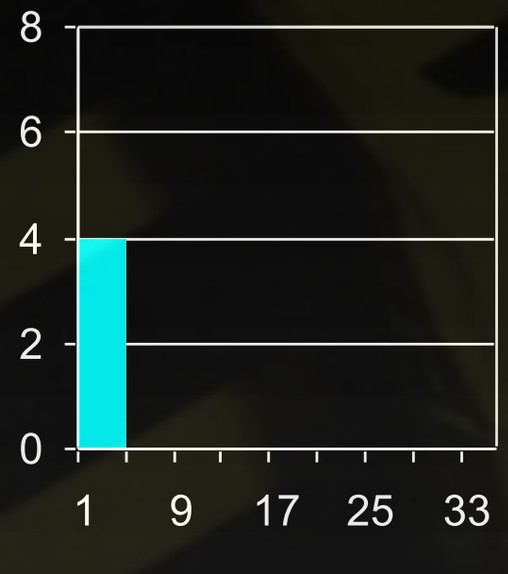
- *BENEFITS:*
  - *Decrease patient to patient variability in scan quality*
    - *Optimize imaging timing*
    - *Image all of the contrast given!*
  - *(Potentially) save contrast*

Contrast Administration for CTA

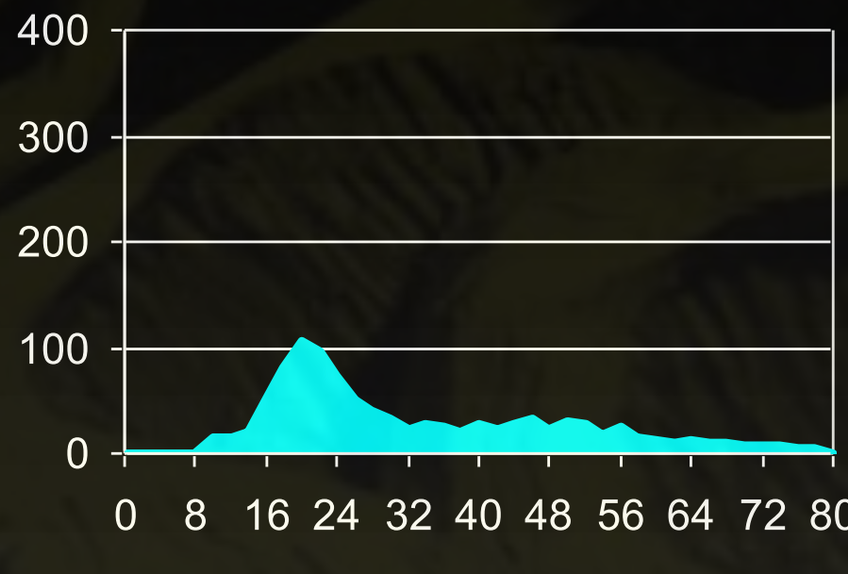


INPUT
intravenous
injection rate
(mL/s)

4 mL/s
(16 mL)



OUTPUT
arterial
enhancement
(ΔHU)



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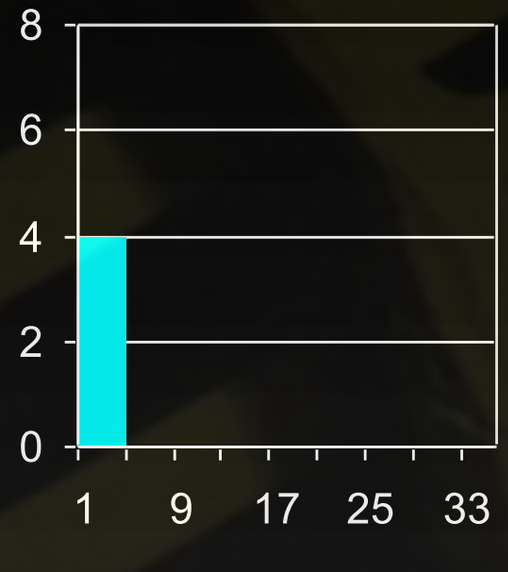

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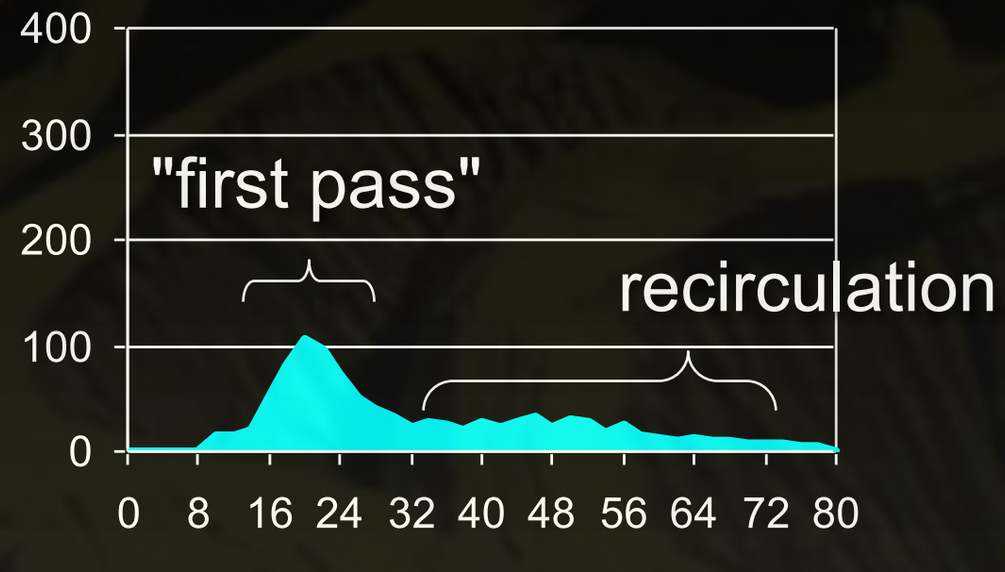

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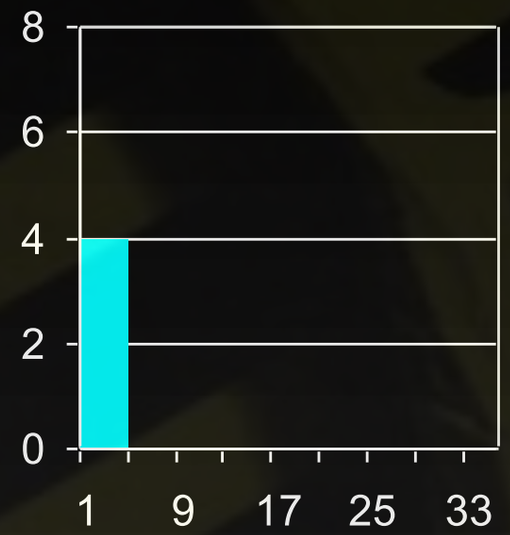
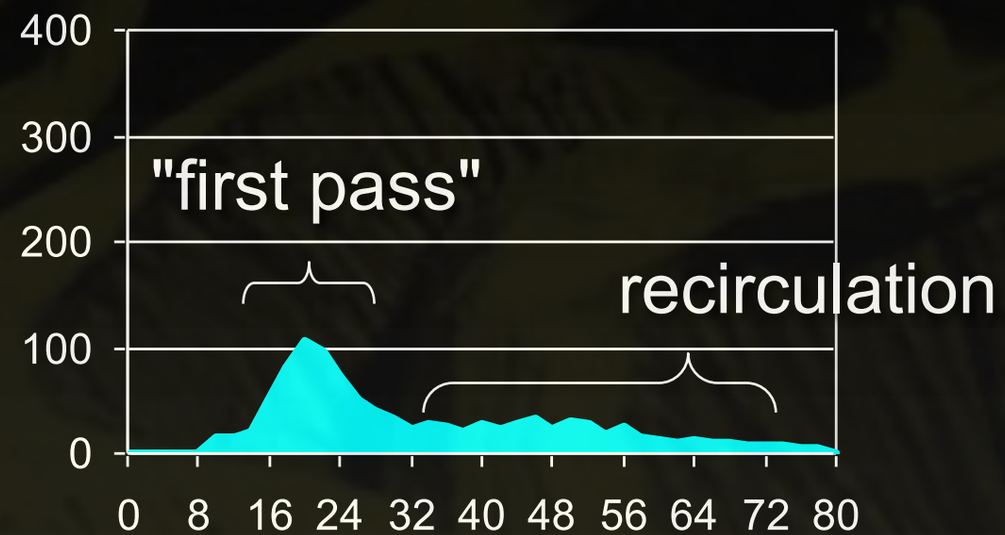
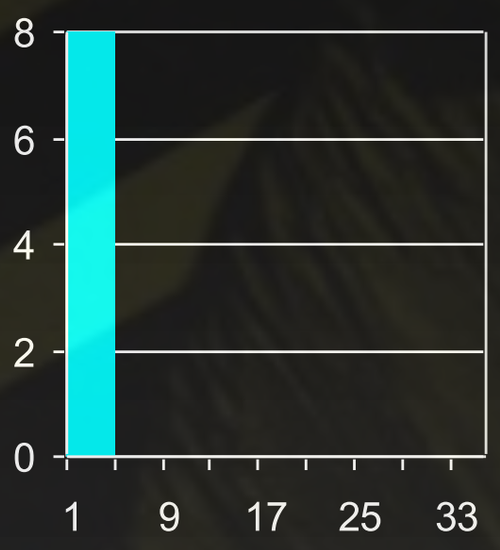
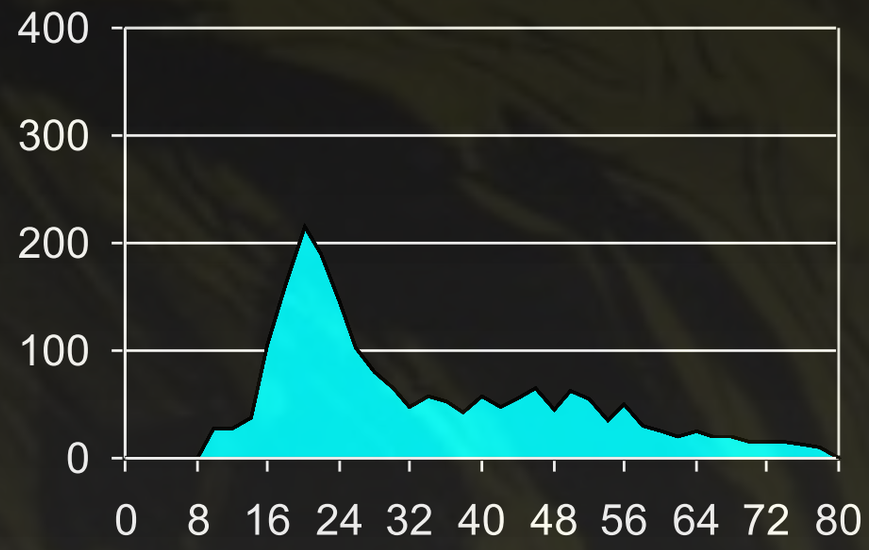




8 mL/s
(32 mL)





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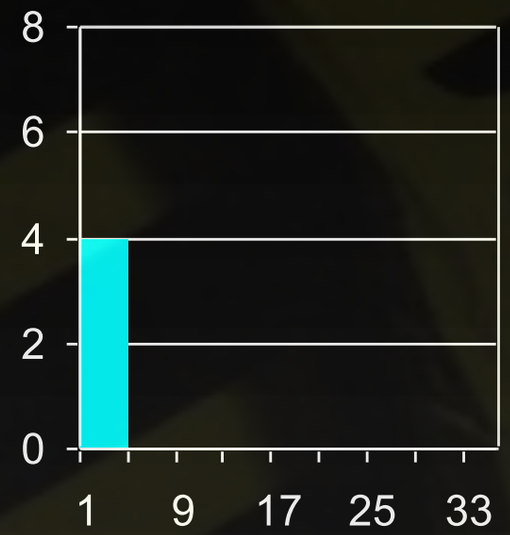

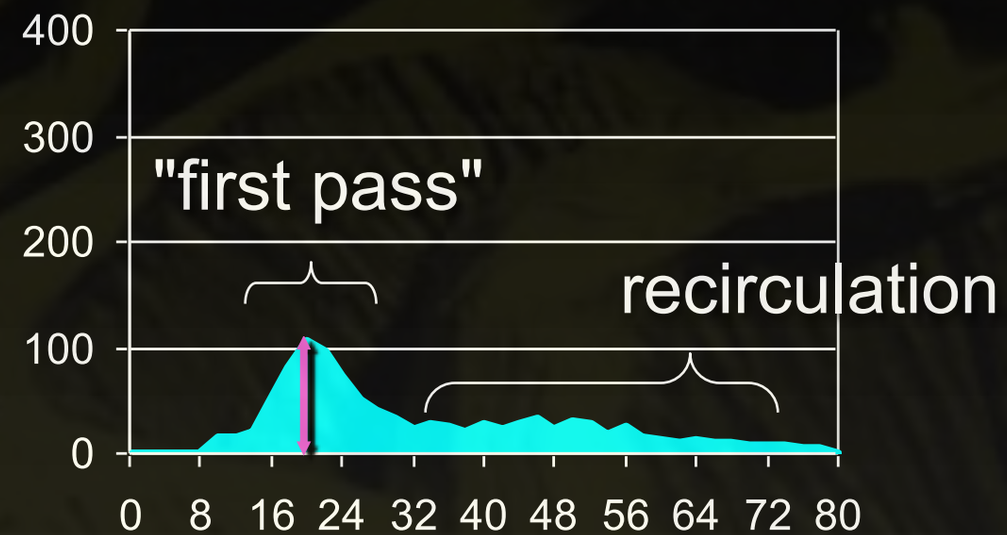

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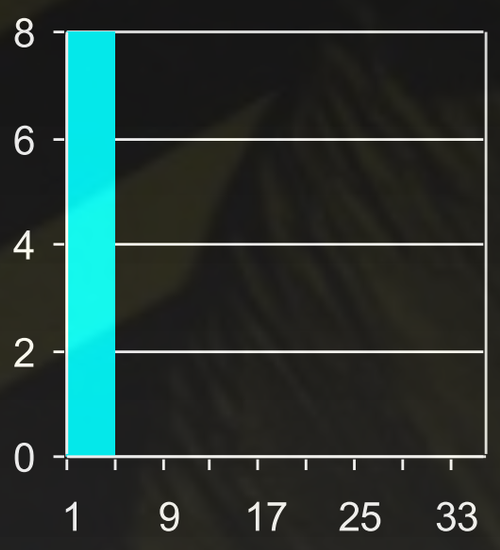

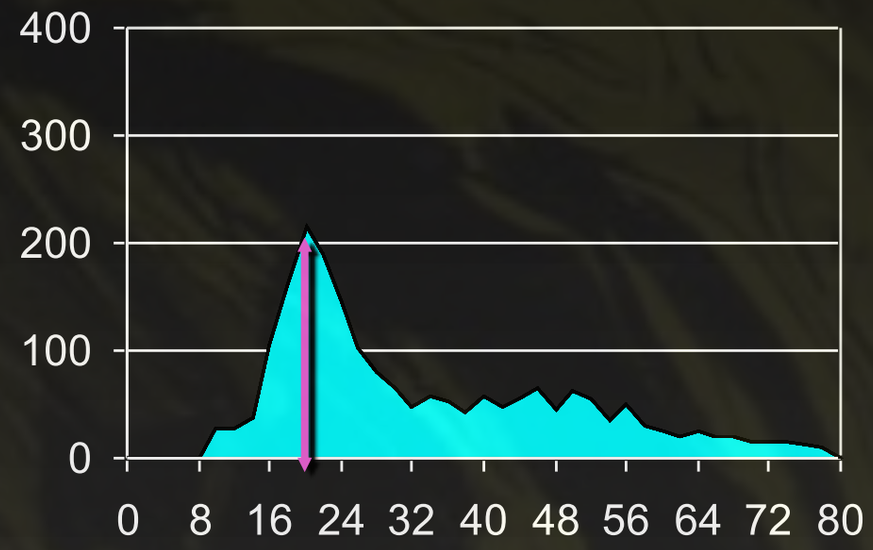

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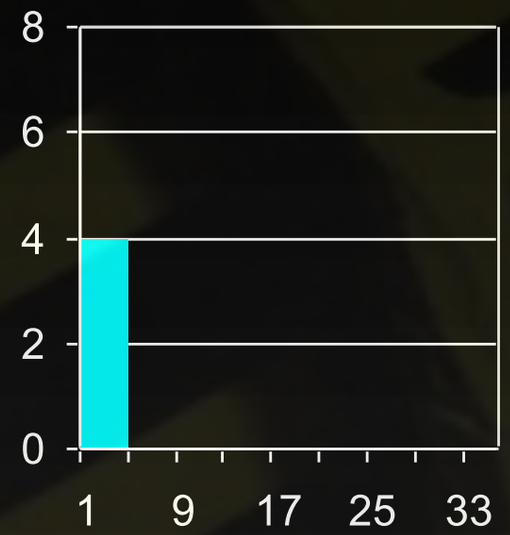

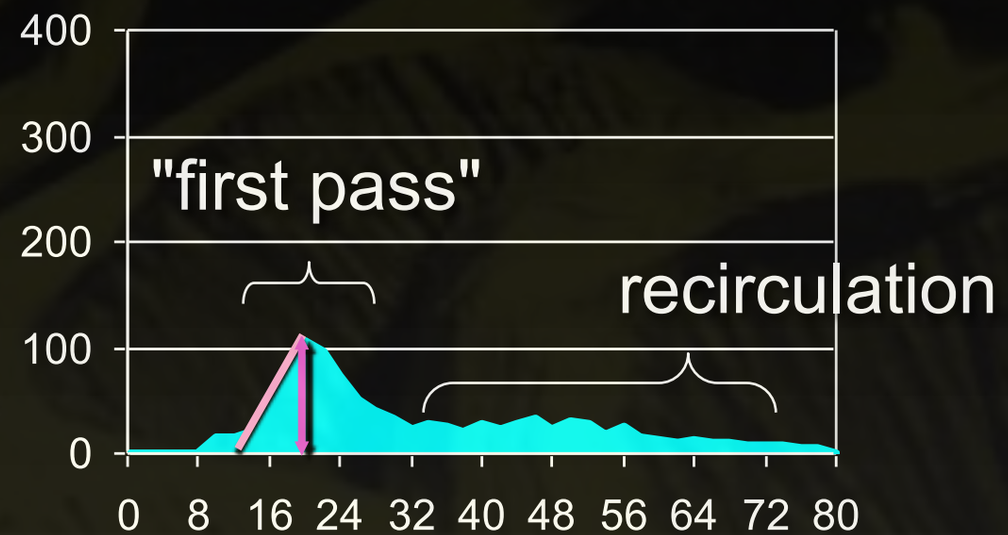

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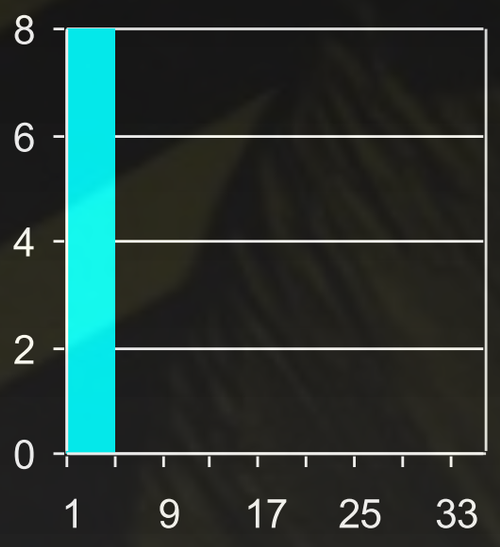

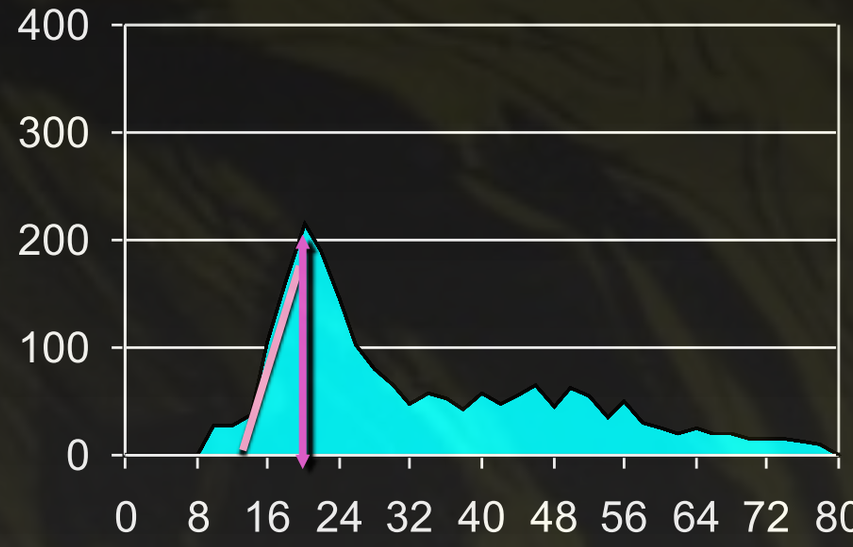

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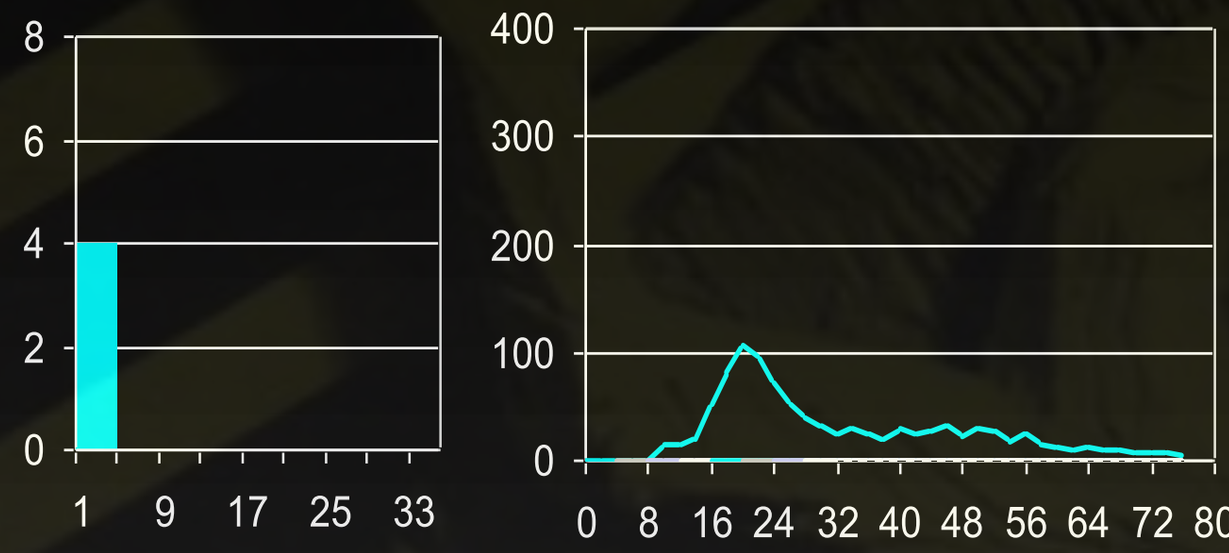

Europ Radiol 2002; 12:S11-16

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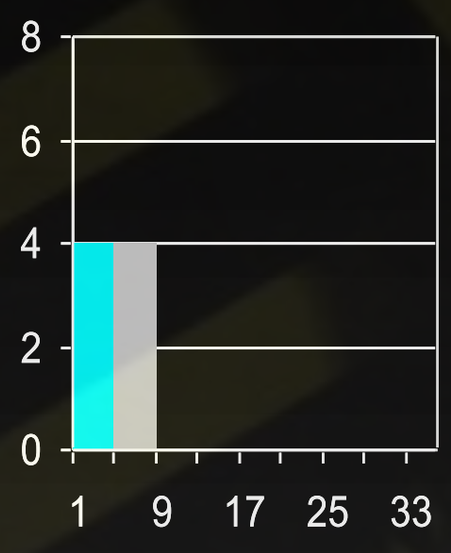

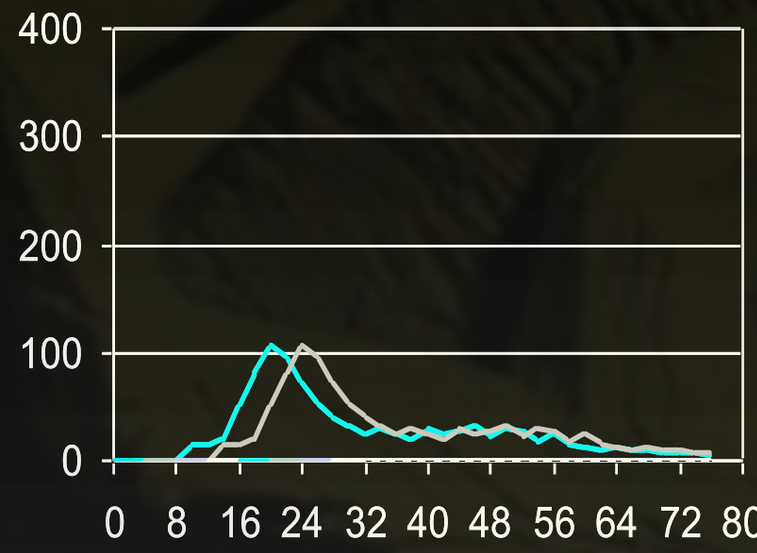

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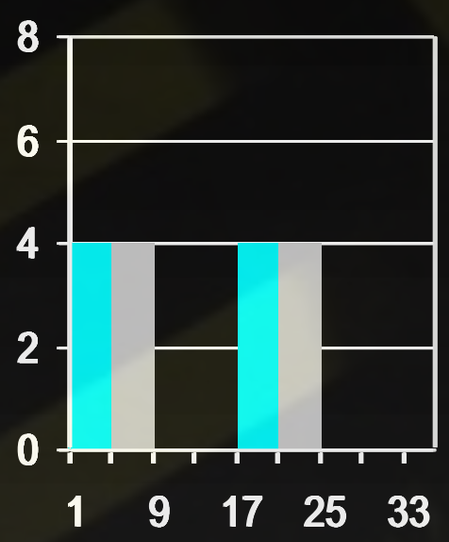

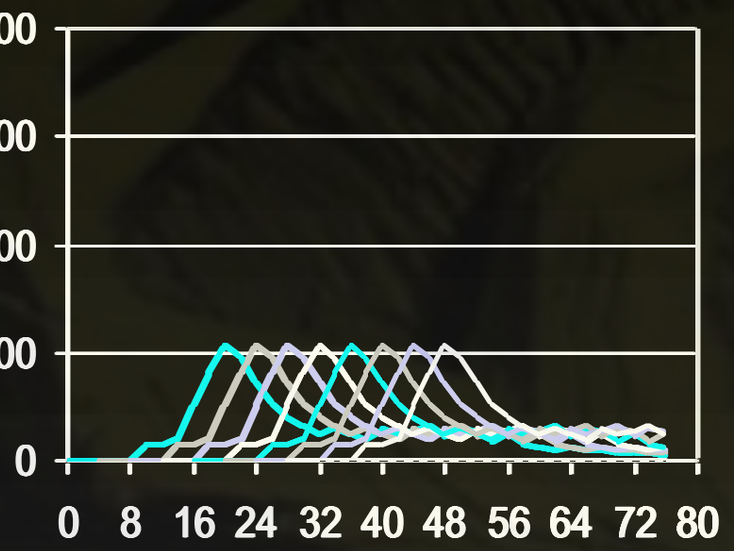

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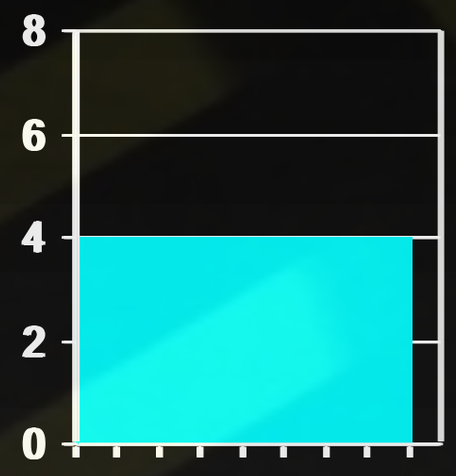

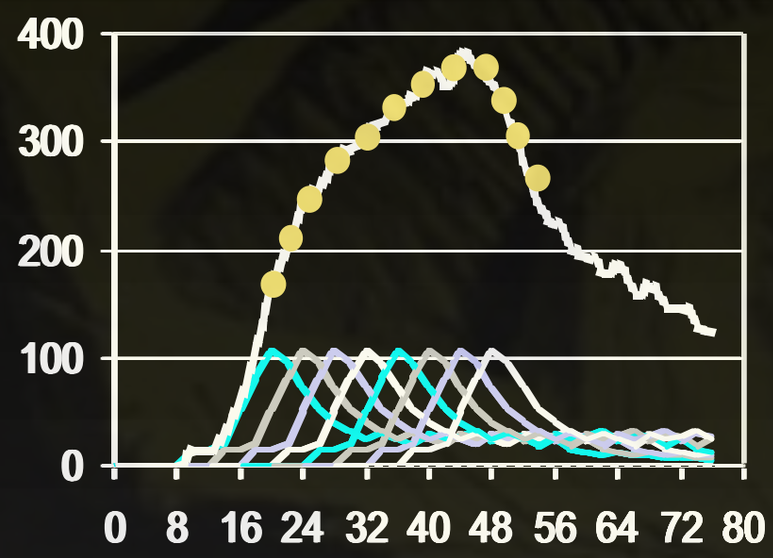

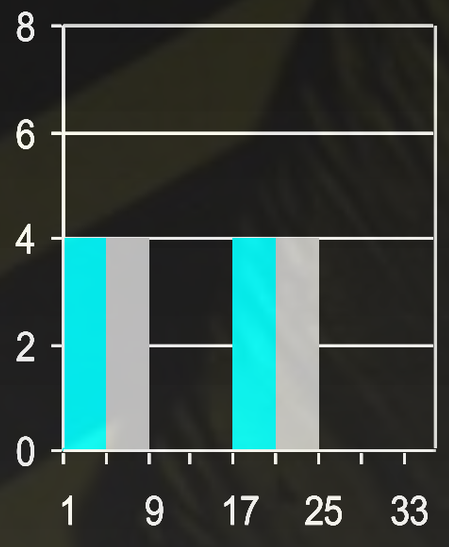

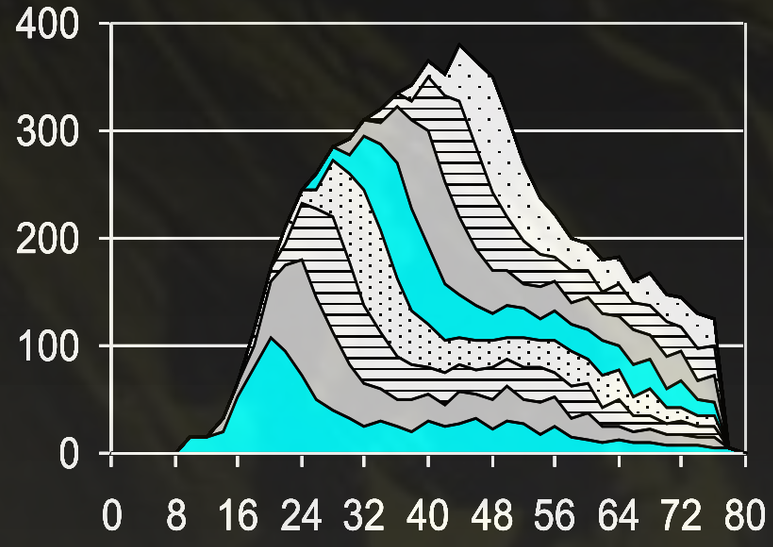

Europ Radiol 2002; 12:S11-16

Also: 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*

Also: Use Automated Tube Current Modulation!!

[1] Hittmair & Fleischmann, JCAT 2001

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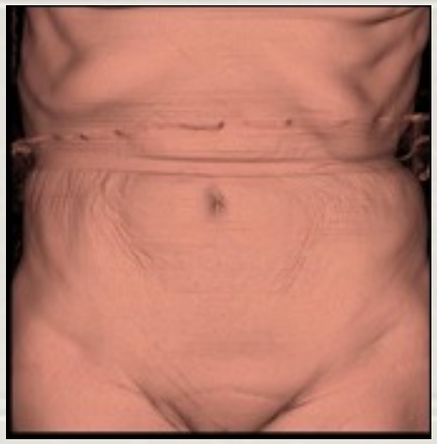

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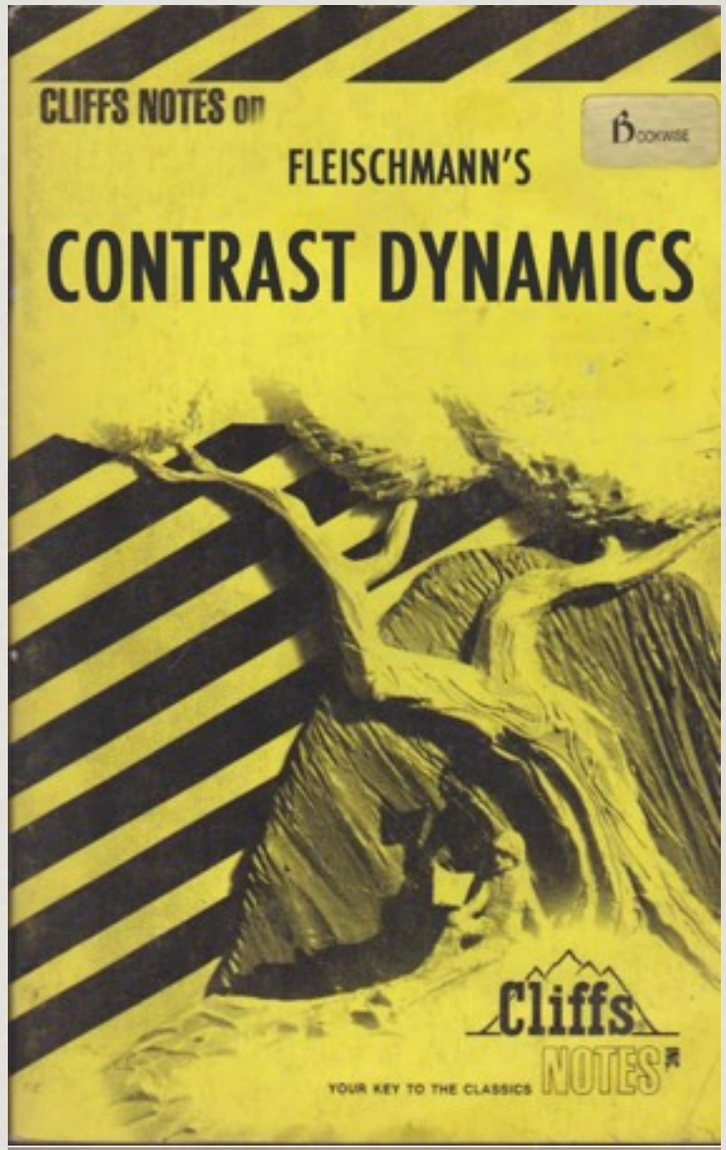
Key Points:
Contrast Medium Dynamics

- *Arterial enhancement is proportional to Iodine flow rate*
- *Enhancement increases (cumulative) over time*
- *"Inject Faster and/or wait longer"*
- ***adjust inj. rate and CM volume (±20%) for pts. ≤60kg and ≥90kg***



Result:
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*

Integrated Injection / Scan Protocol: Rule of Thumb

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- **Injection Duration = Scan time + 8 ± "Delay"**

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- **Injection Duration = Scan time + 8 ± "Delay"**
  - *NOTE: Need at least 10 sec injection for adequate filling*

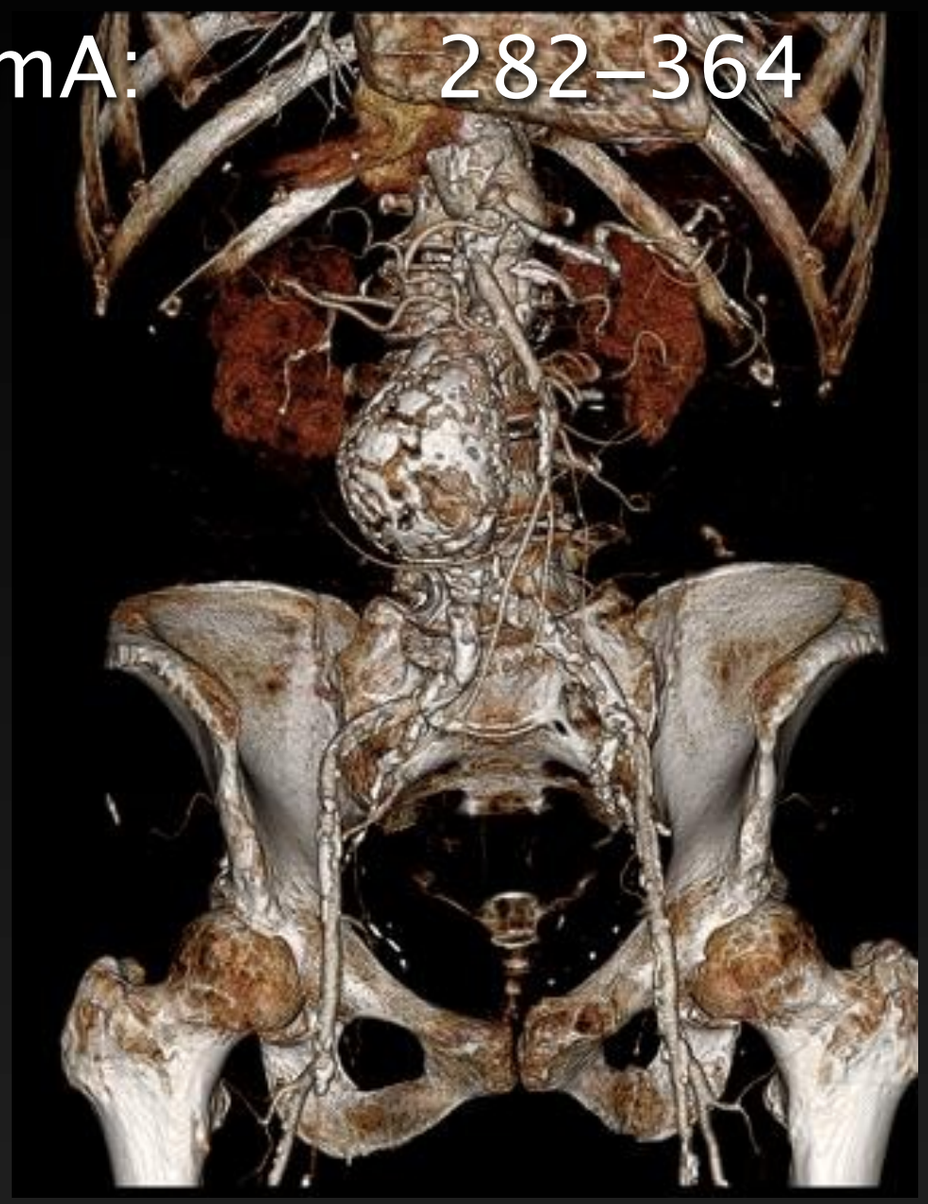
Integrated Scan/Injection Protocol:Abdomen

Acquisition	64 x 0.6 mm (channels x channel width); automated tube current modulation (250 mAs reference mAs)
Pitch	Variable (depends on volume coverage, usually <1.0)
Scan time	Fixed to 10 s (all patients)
Injection duration	Fixed to 18 s (all patients)
Scanning delay	t_{CMT} + 8 s (scan starts 8s after CM arrival, as established by automated bolus triggering)
Contrast medium	High concentration (350-370 mg I/mL)
Injection flow rates and volumes	**Individualized to body weight:**

Body Weight (kg)	**CM Flow Rate (mL/s)**	**CM Volume (mL)**
≤ 55	4.0	72
56-65	4.5	81
66-85	5.0	90
86-95	5.5	99
> 95	6.0	108

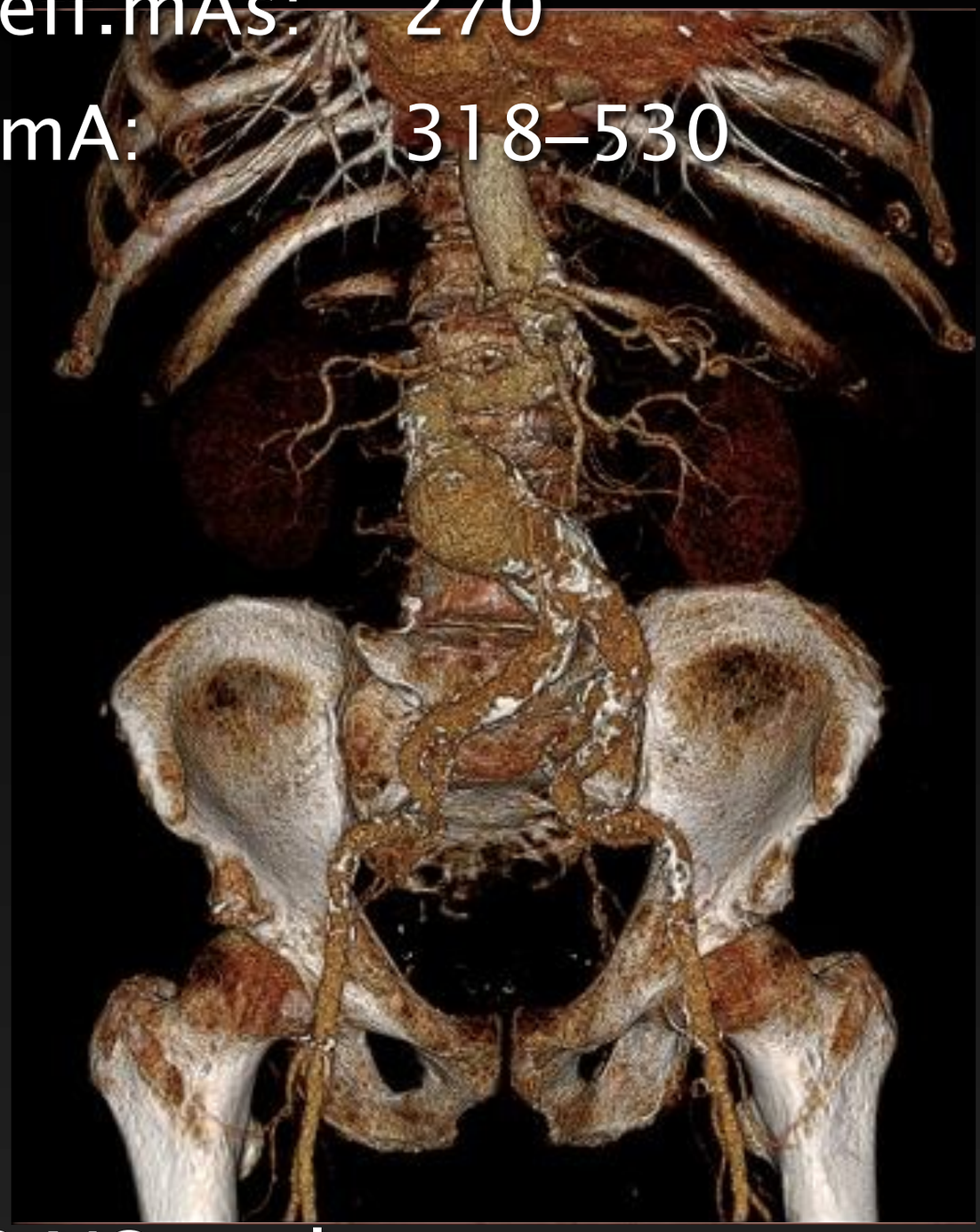
RESULTS: Integrated Scan/Injection Protocol

q-ref.mAs: 250
eff.mAs: 136
mA: 282–364



81 YO female
(161cm, 55 kg)

q-ref.mAs: 250
eff.mAs: 270
mA: 318–530



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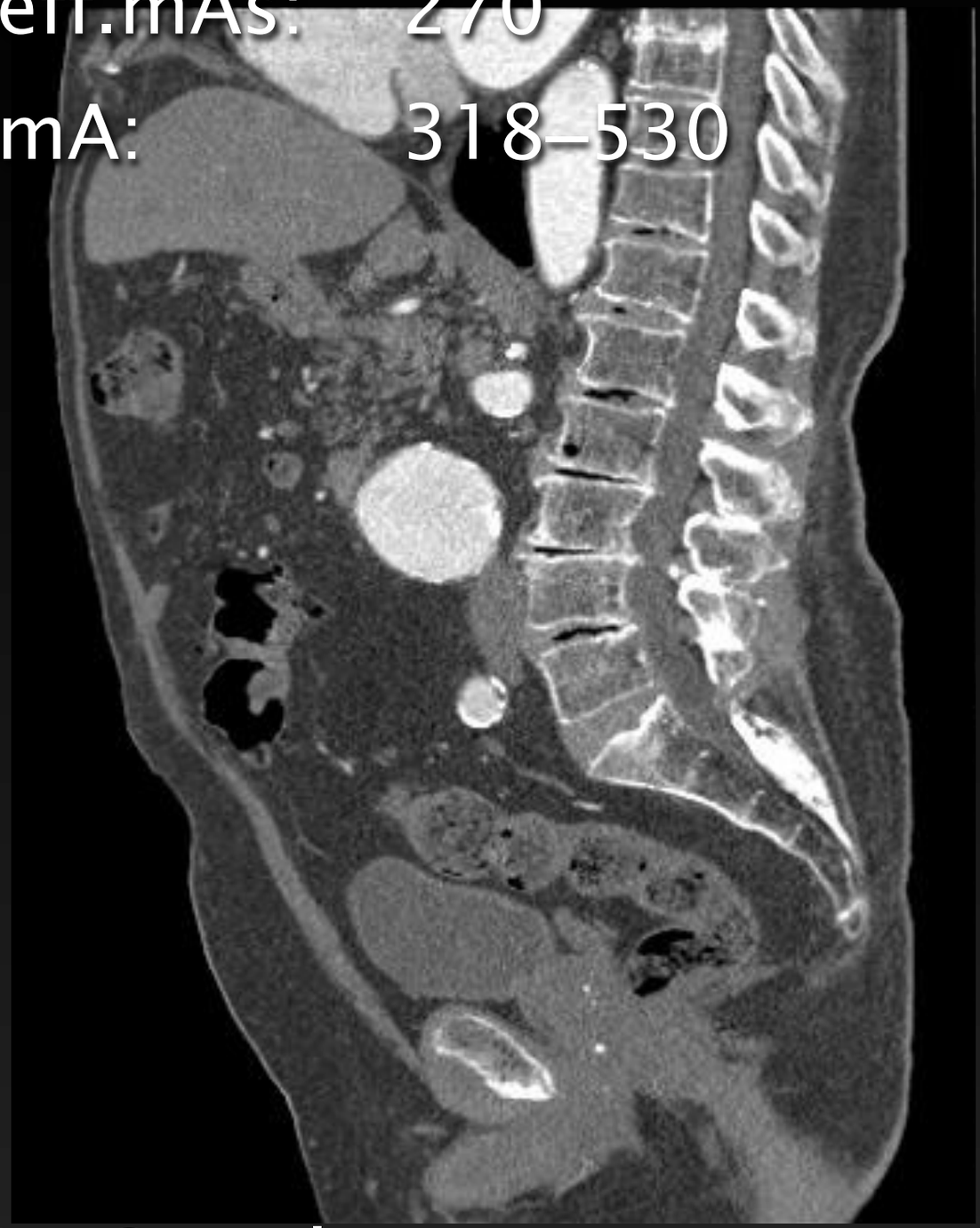

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STANFORD Integrated Scanning-Injection Protocol: (Siemens)

Scan time: 40s for ALL patients (pitch variable)

(automated tube current modulation)

Inj.duration: 35s for ALL patients

Delay: bolus triggering

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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

ST VINCENT Integrated Scanning-Injection Protocol: (GE HD-750, VCT)

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Add "diagnostic delay" to make 40 sec

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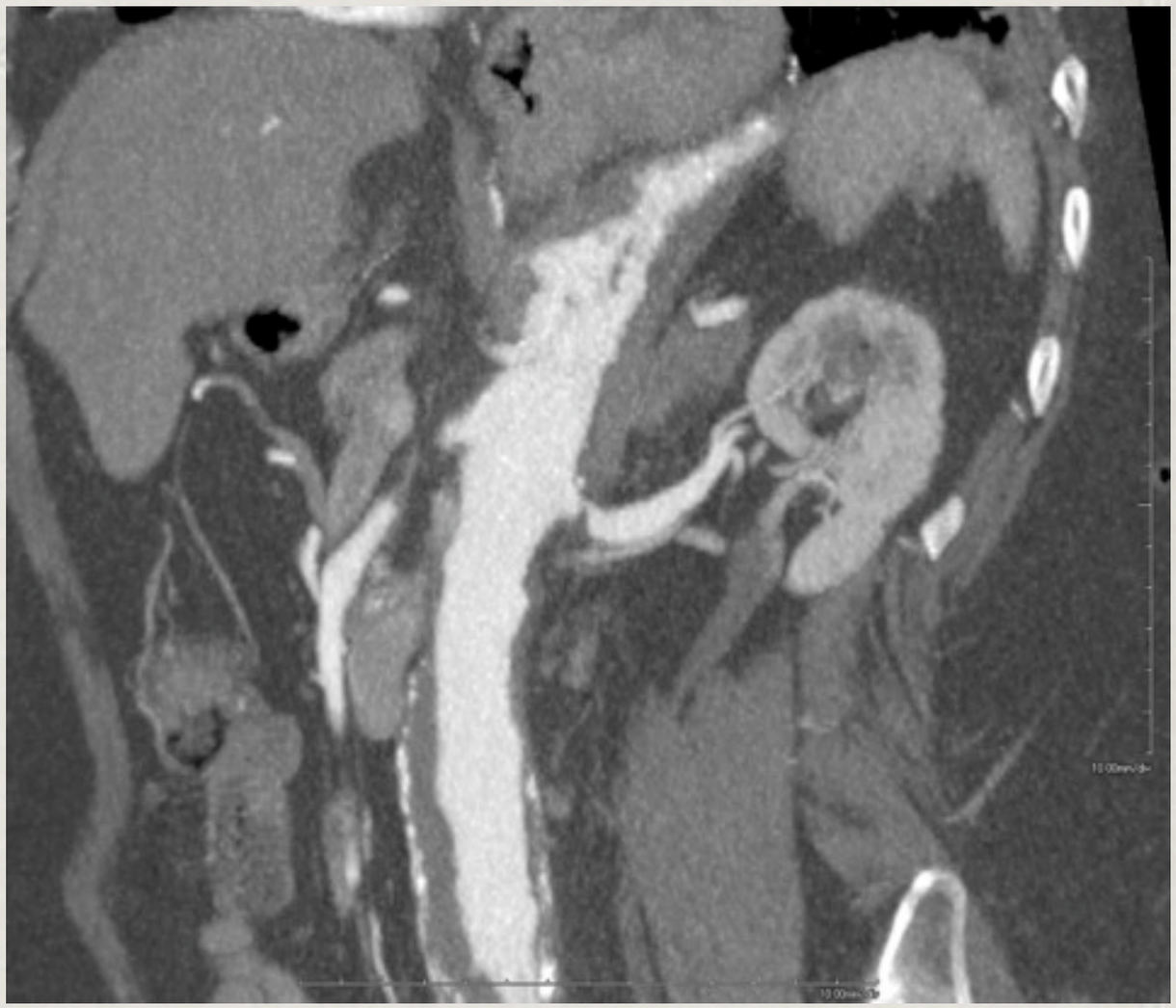
Collaborative Imaging: Renal Artery CTA

Handout available at:

http://stanford.edu/~hallett

Choose "NMCSD"



RENAL CTA: INDICATIONS

- *Renal Artery Stenosis*
- *Post-Stenting w/ worsening HTN*
- *Renal aneurysms*
- *Renal AVM / AVF*
- *Evaluation of UPJ Obstruction*
- *Transplant Donor evaluation*
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- *Tumor (extrinsic, intrinsic)*

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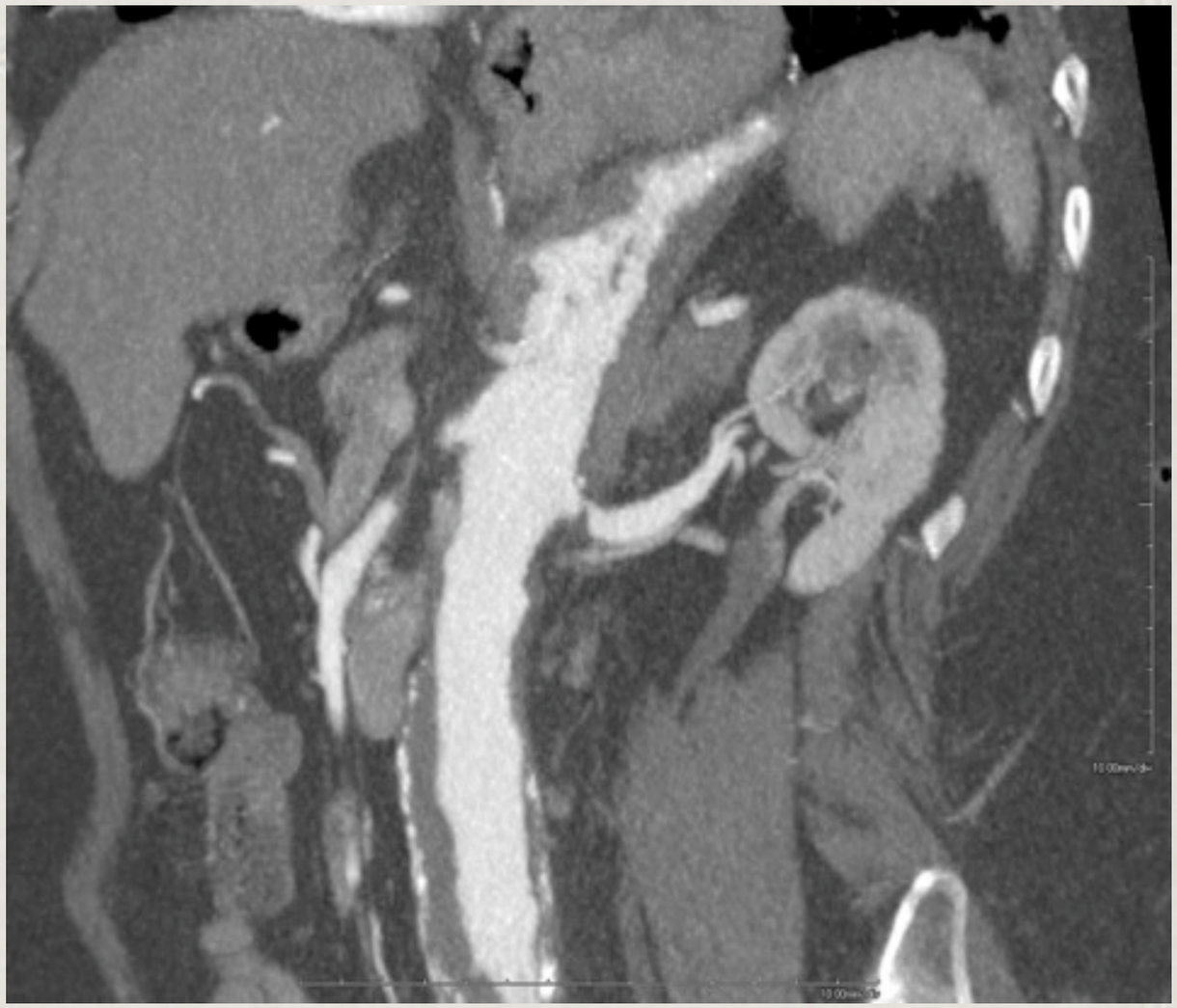

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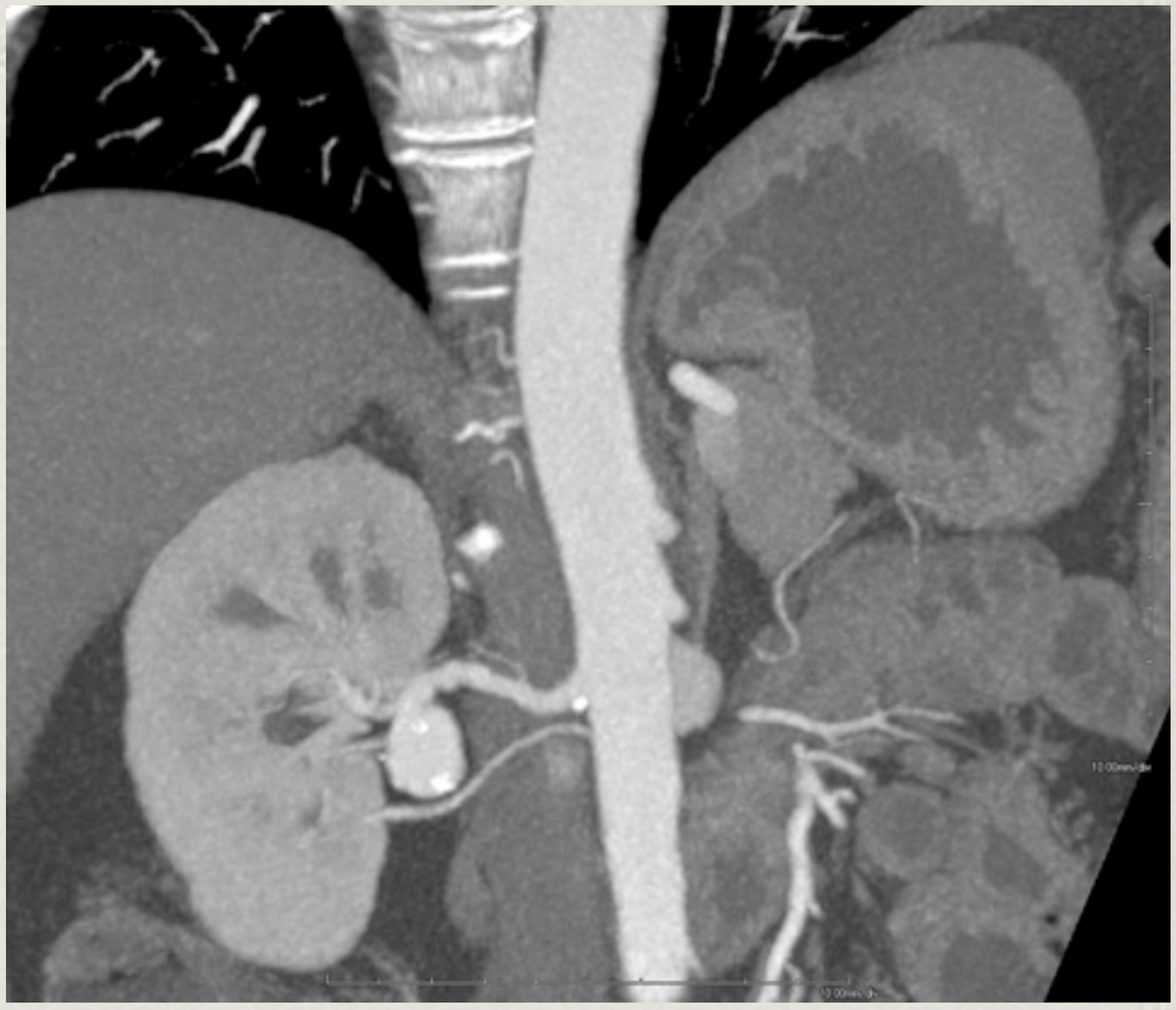

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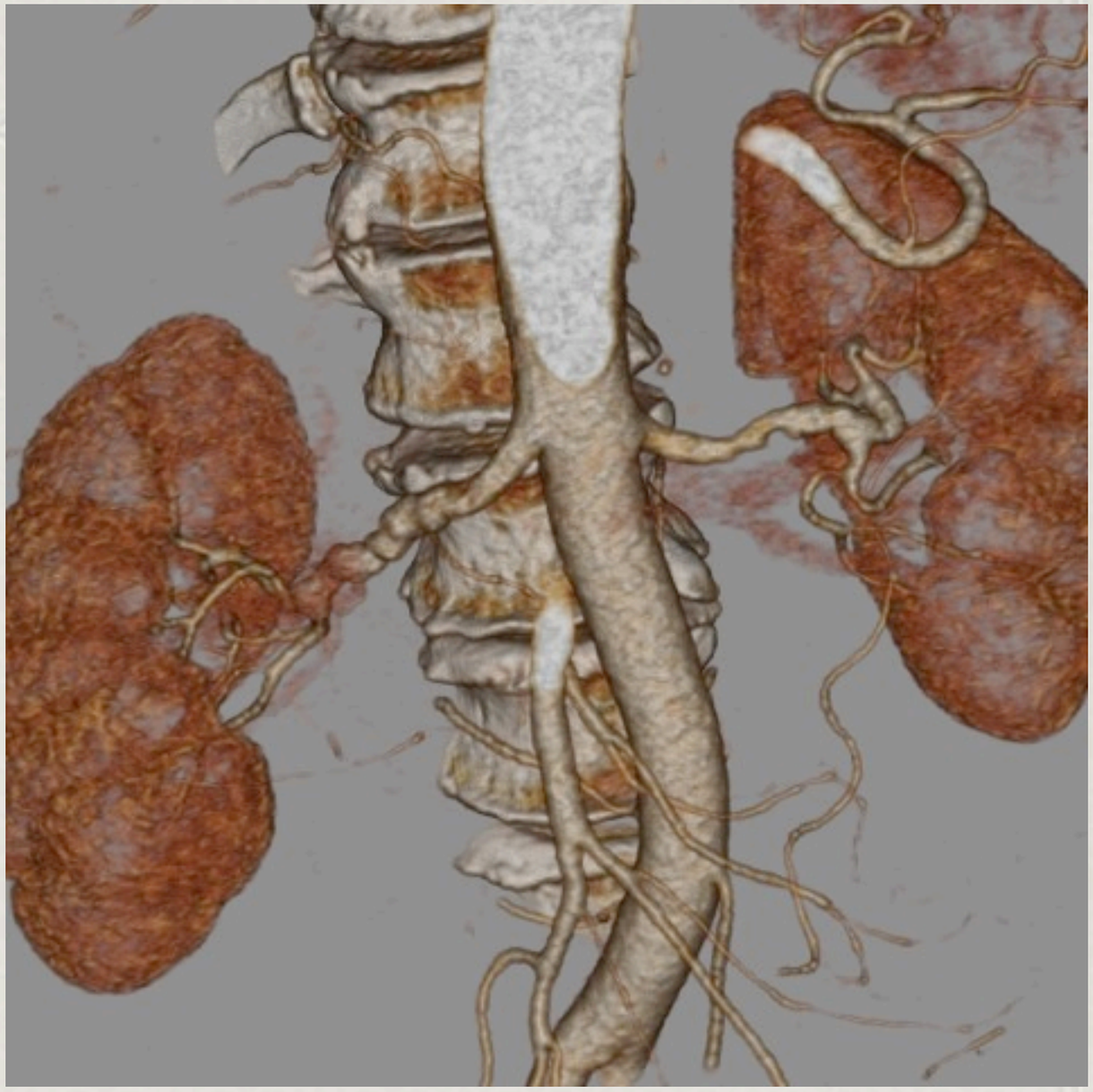

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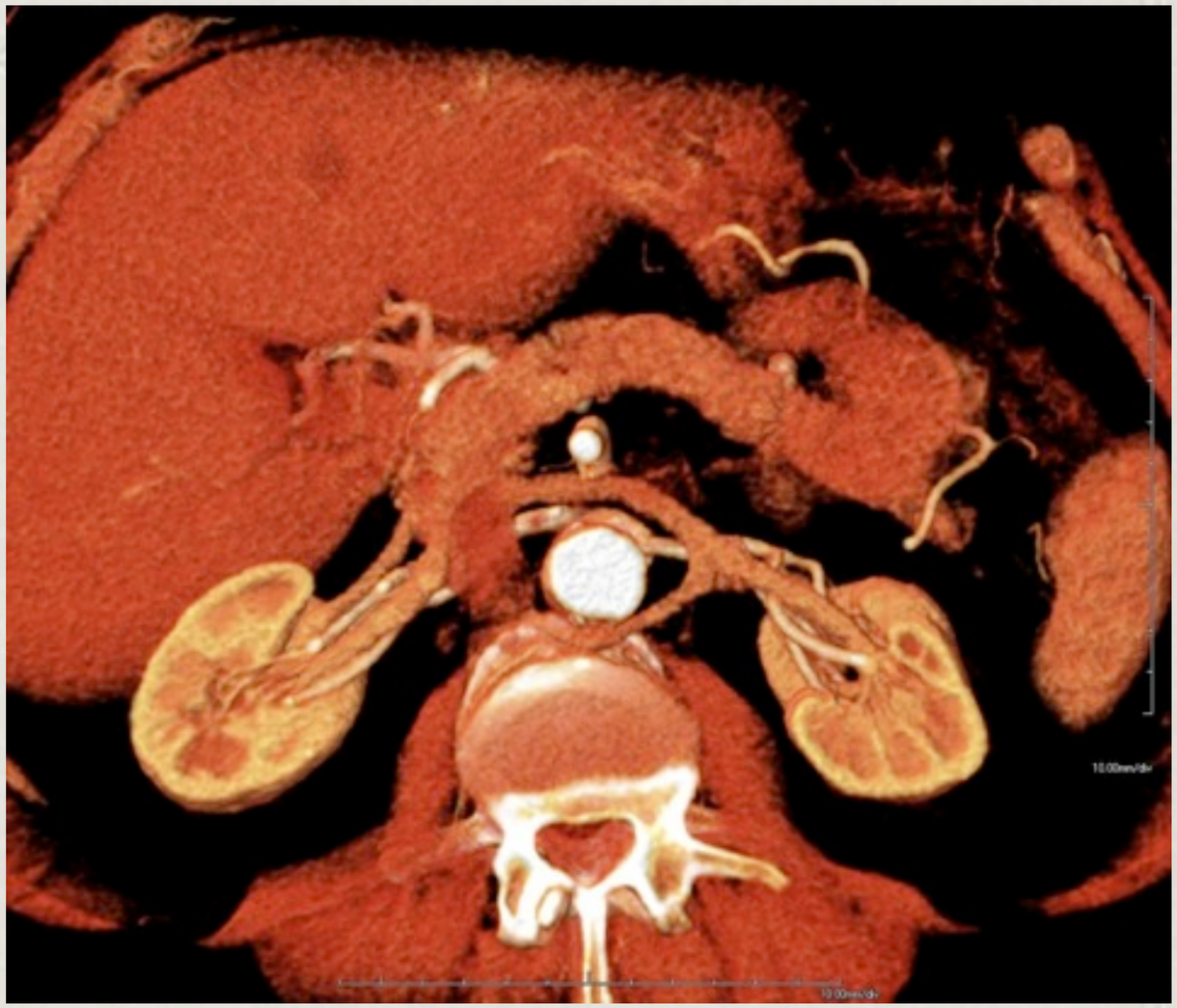

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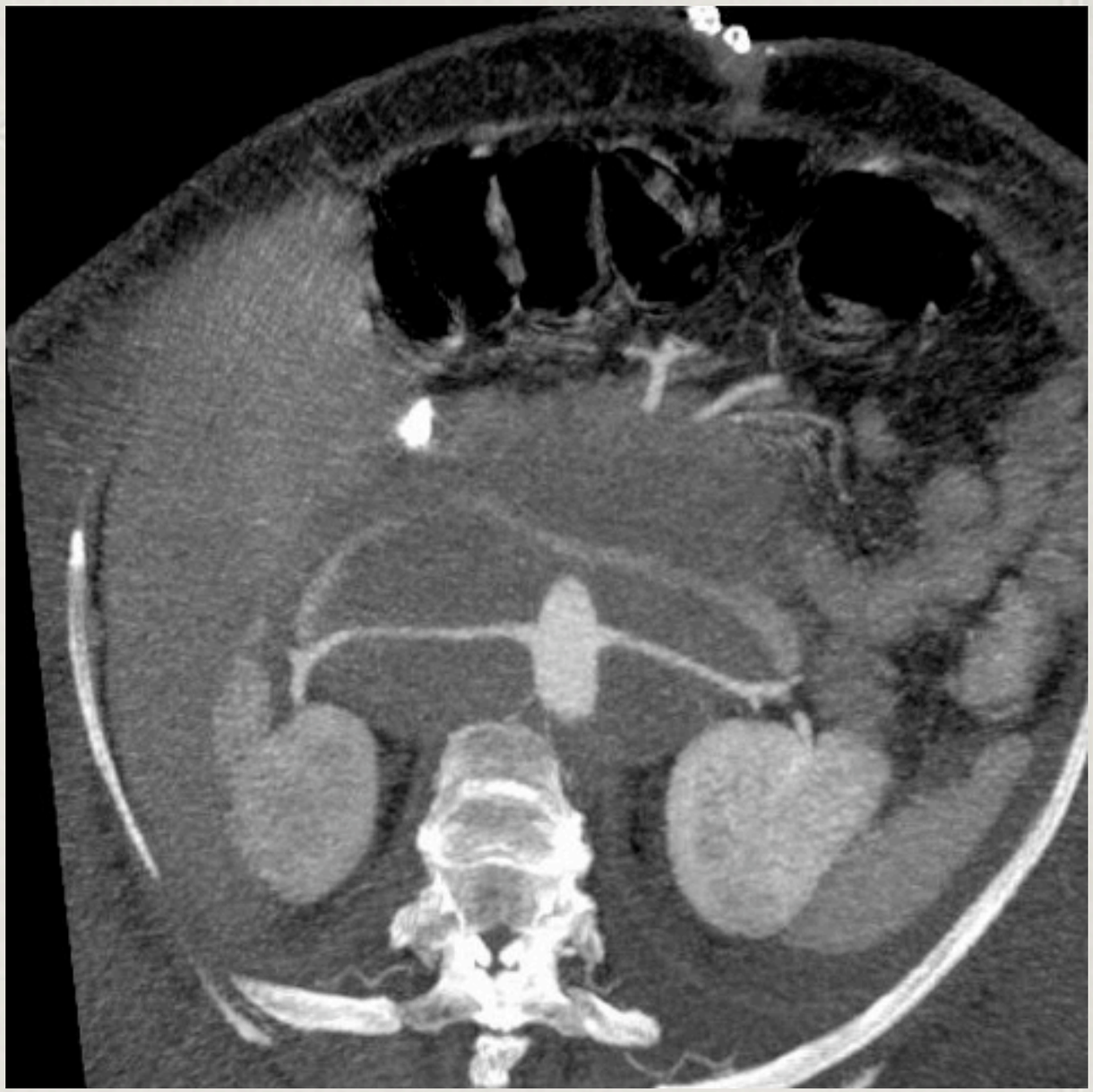

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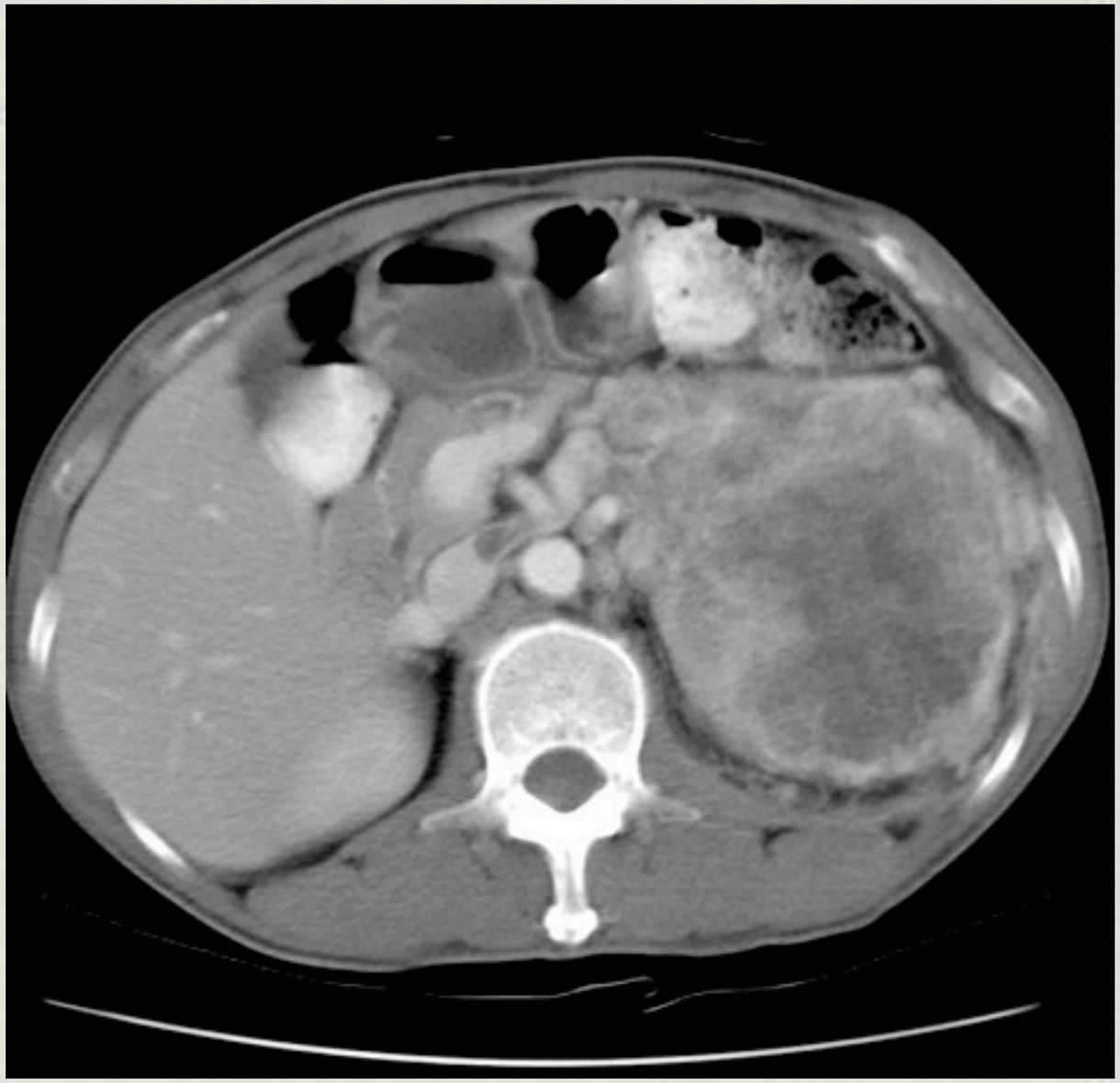


How good is renal CTA?
Direct Comparison: CTA vs. MRA vs DSA

"Aortoiliac and Renal Arteries: Prospective Intraindividual Comparison of Contrast-enhanced Three-dimensional MR Angiography and Multi–Detector Row CT Angiography"

Willmann et al. *Radiology* 2003

46 consecutive patients: DSA, MRA (ST< 3mm), MDCTA (4 CH)

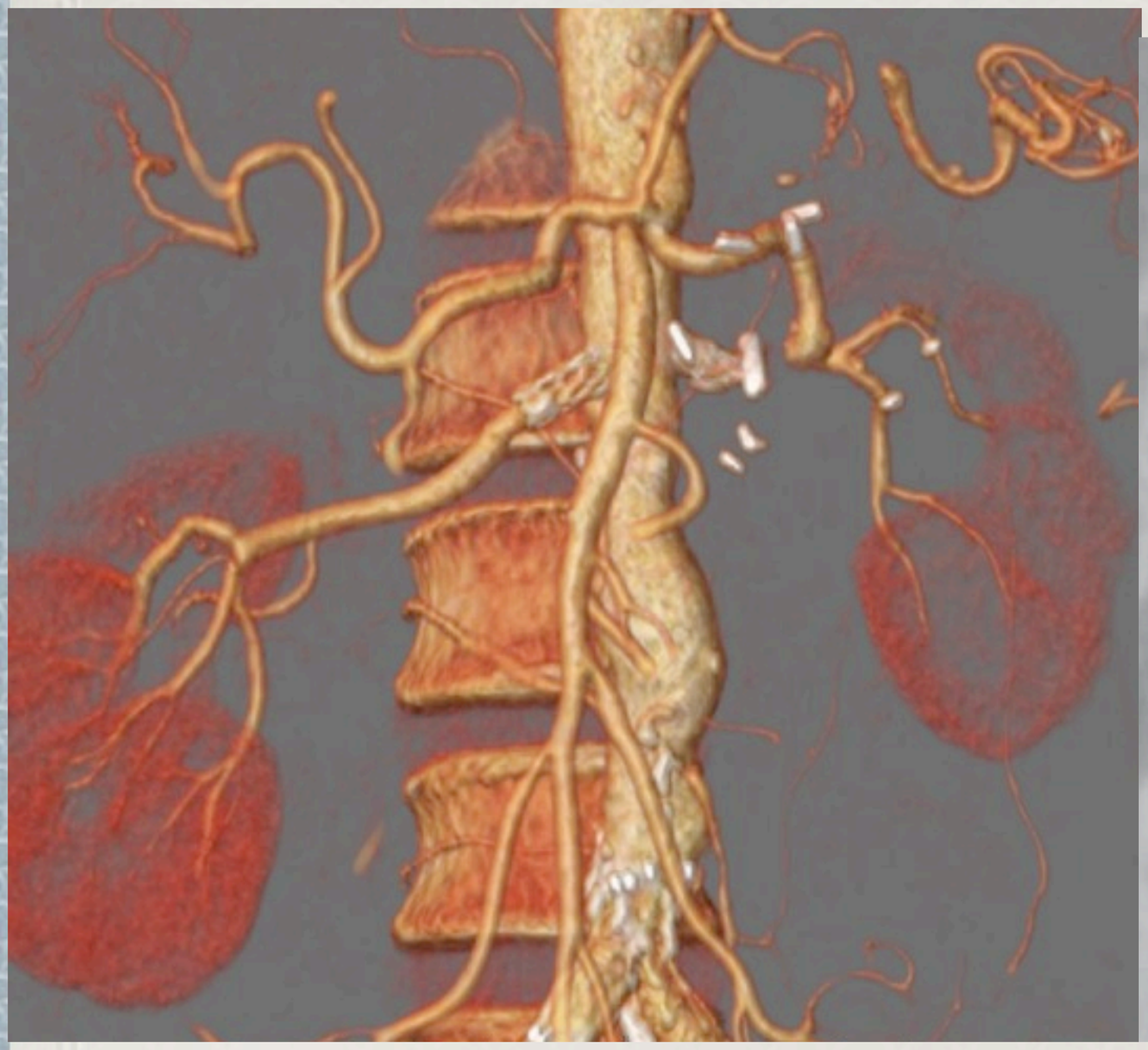
2 blinded readers; pt tolerance also assessed

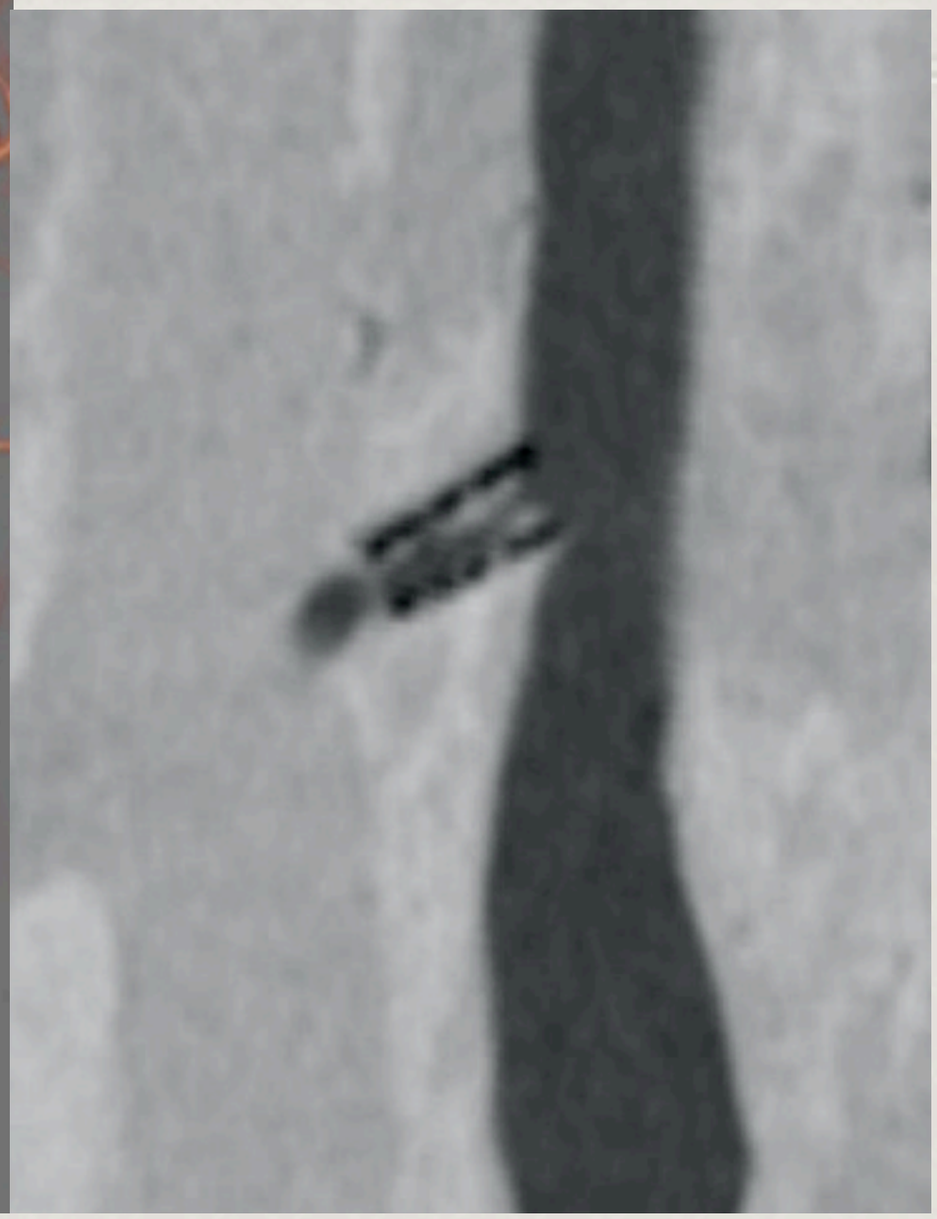
Results (vs. DSA):

	MRA	MDCTA
Sens	92-93	91-92
Spec	100-99	99-99
Tolerance	+	+++ (significant)

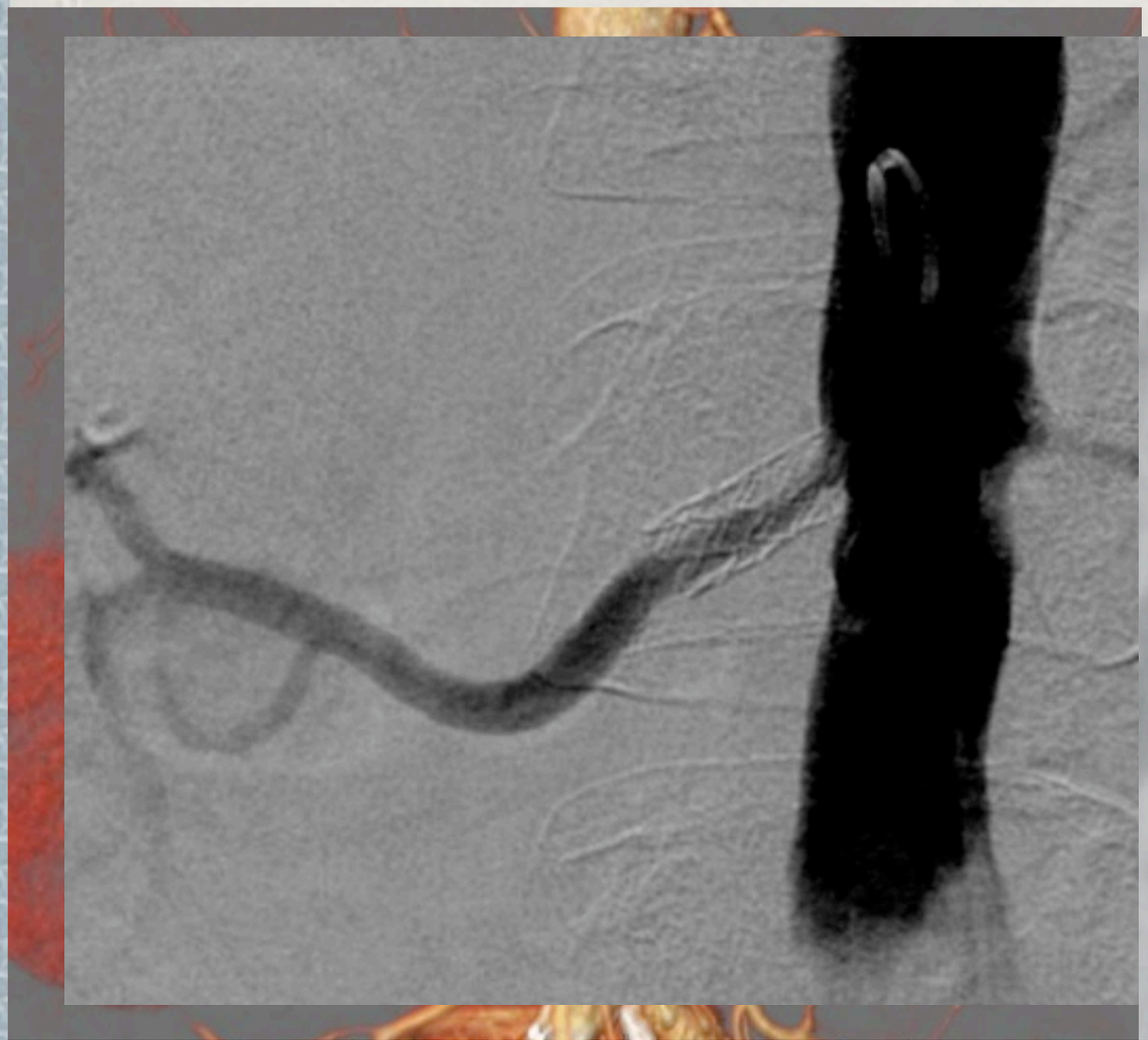
NS

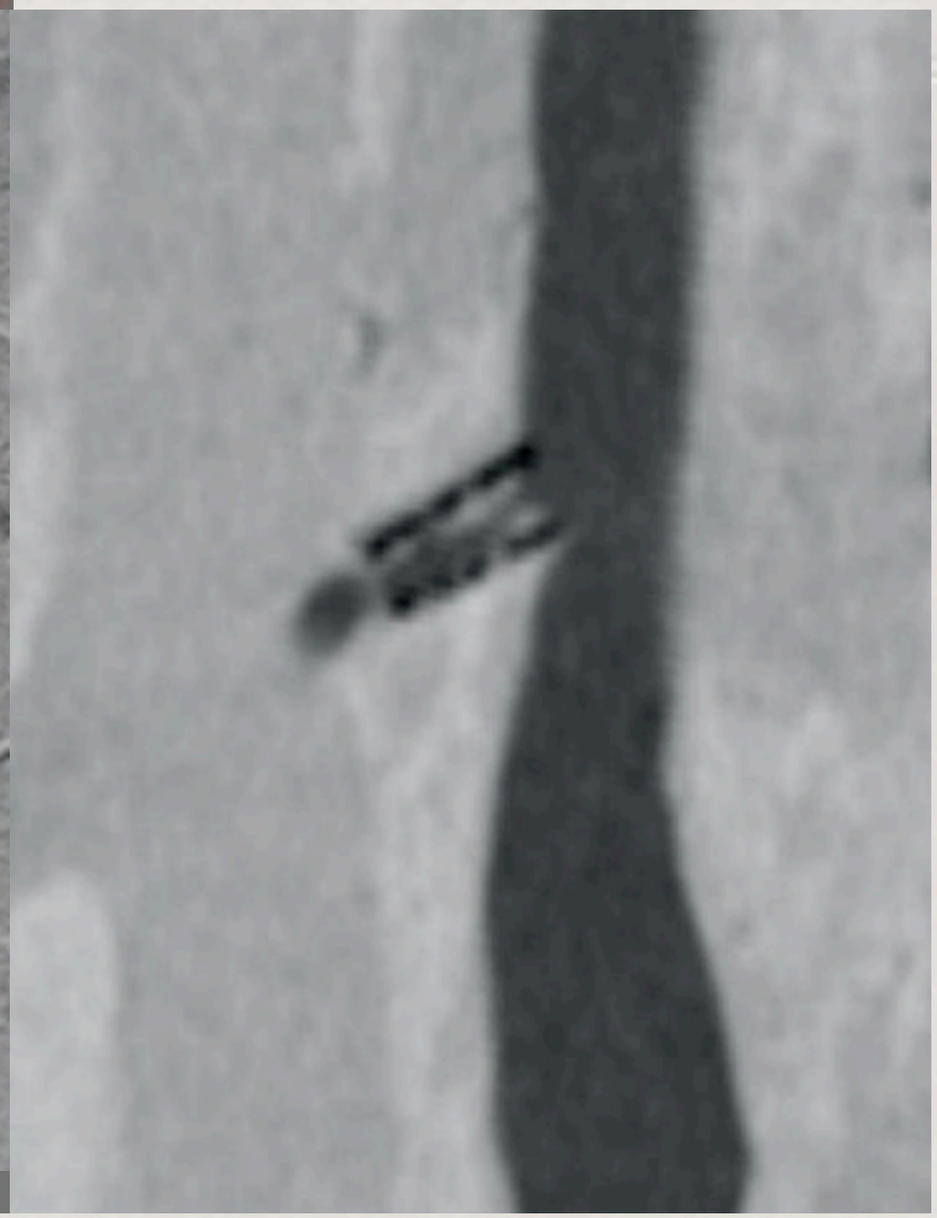
Stented RAS





Stented RAS

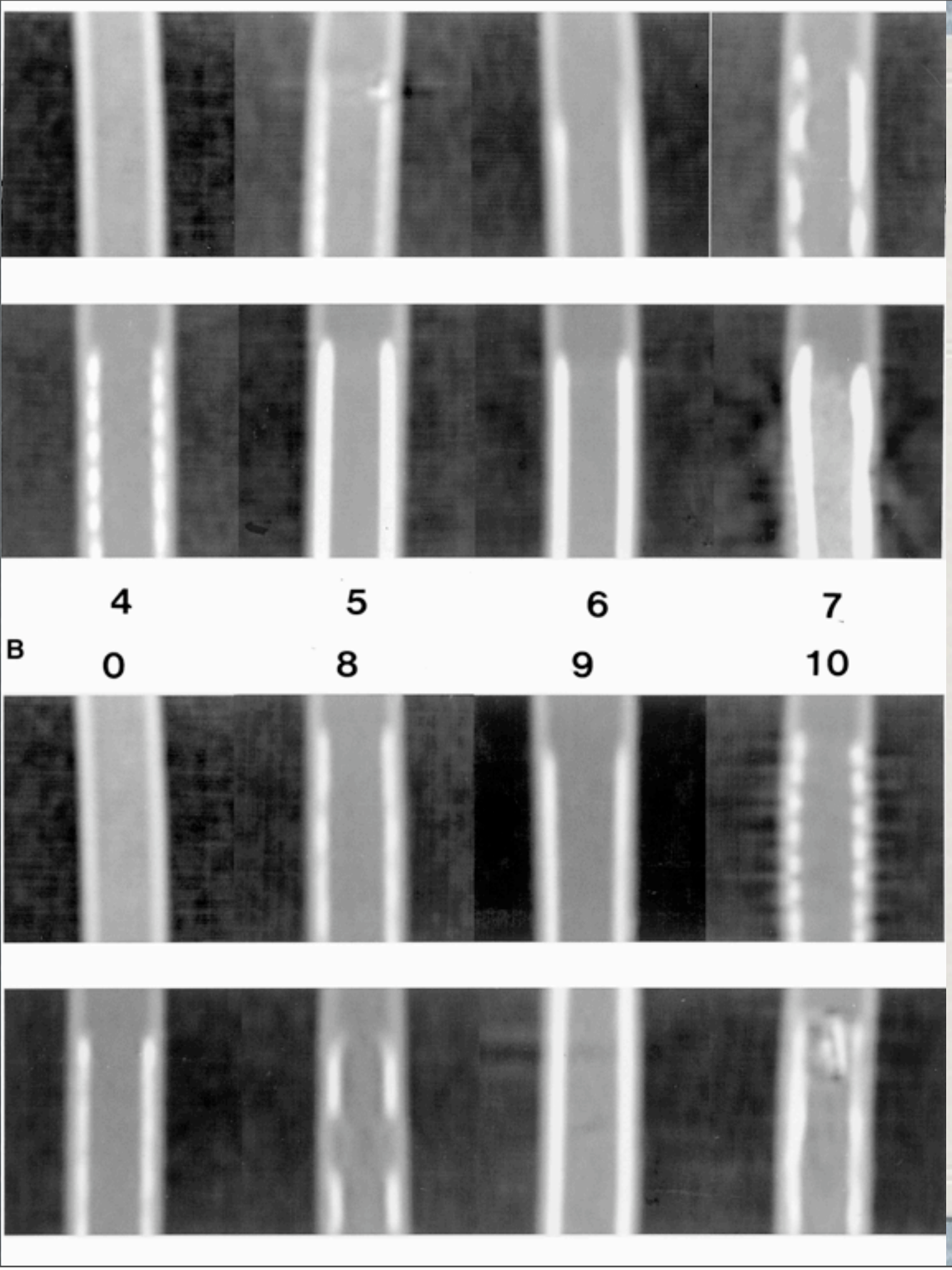




Stent Composition affects CTA performance

Strotzer: Invest. Radiol 2001:36(11) 652-658

- *CT of 14 different stents in vitro*
- *Tantalum stent (Strecker): INCREASED density in stent, could mask stenosis*
- *Platinum markers: severe bloom, difficult to evaluate*


4
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5 6 7

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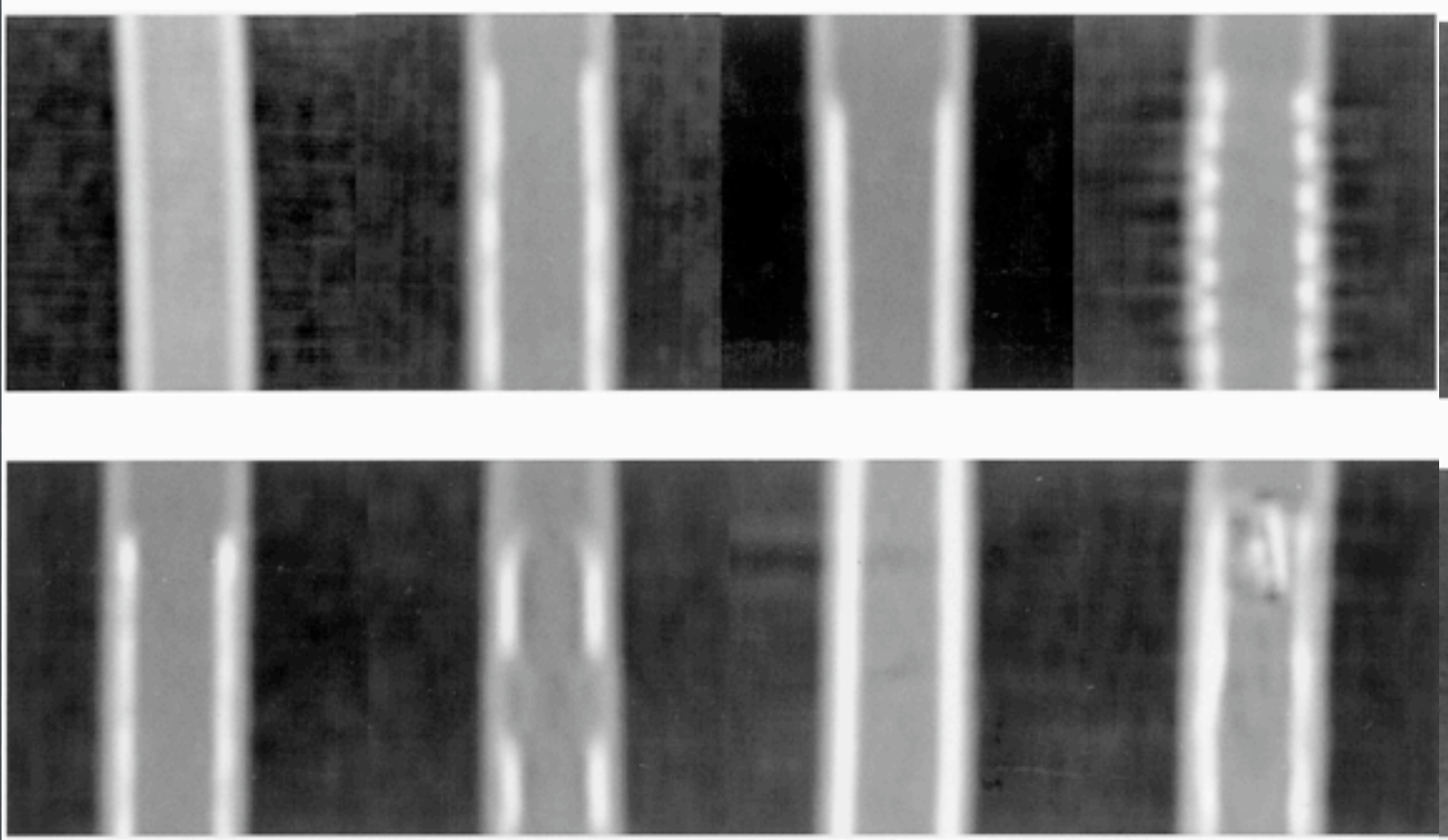
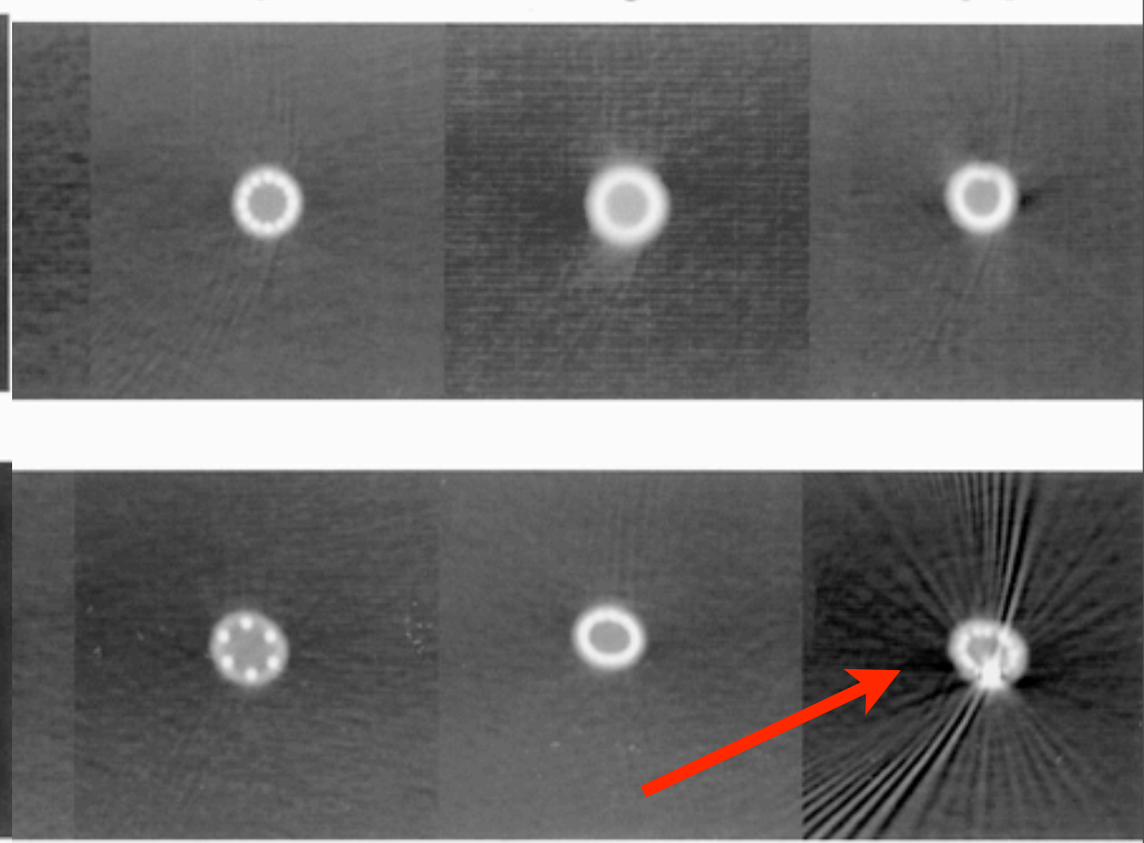
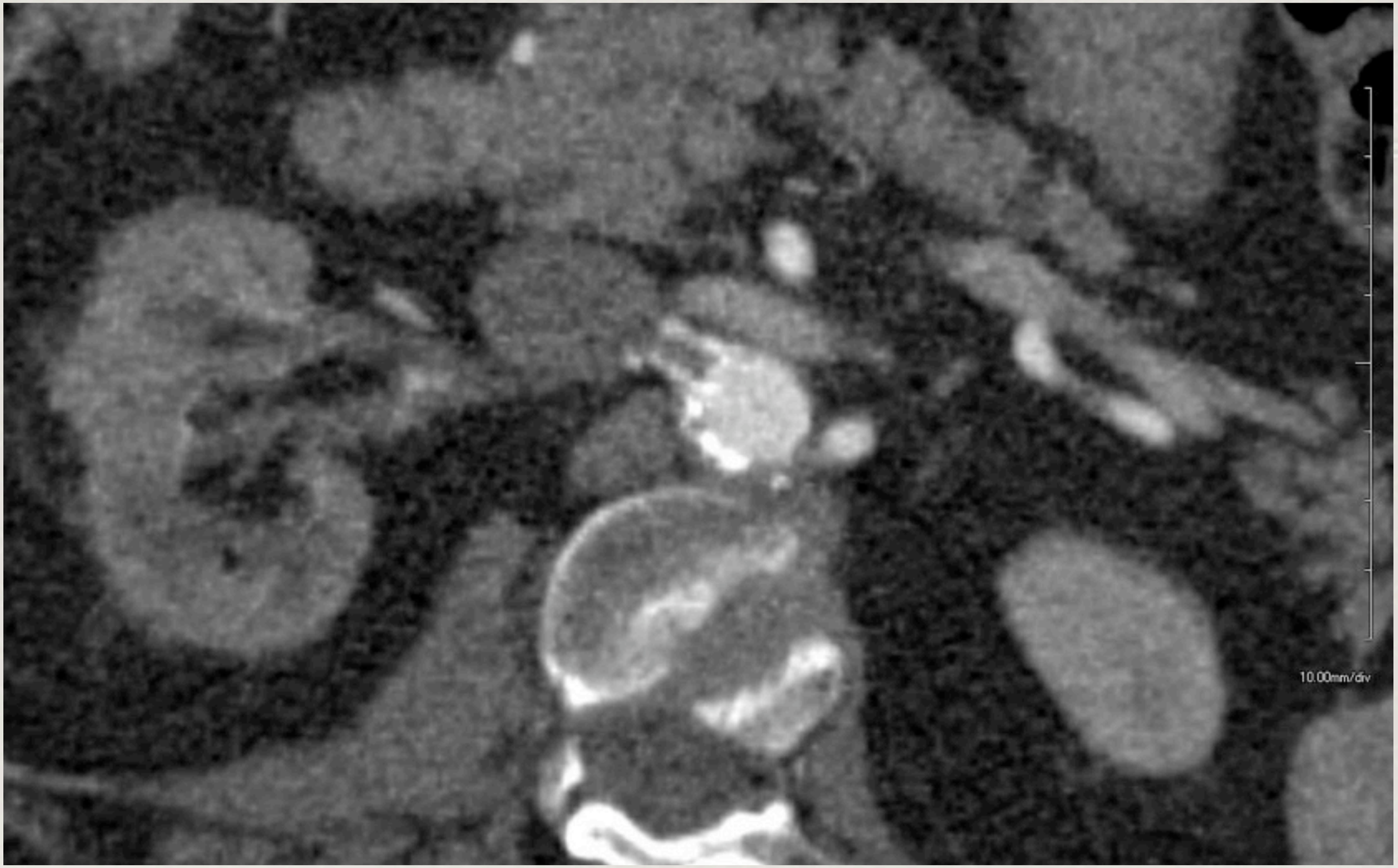




Saturday, July 9, 2011

Worsening HTN - CTA



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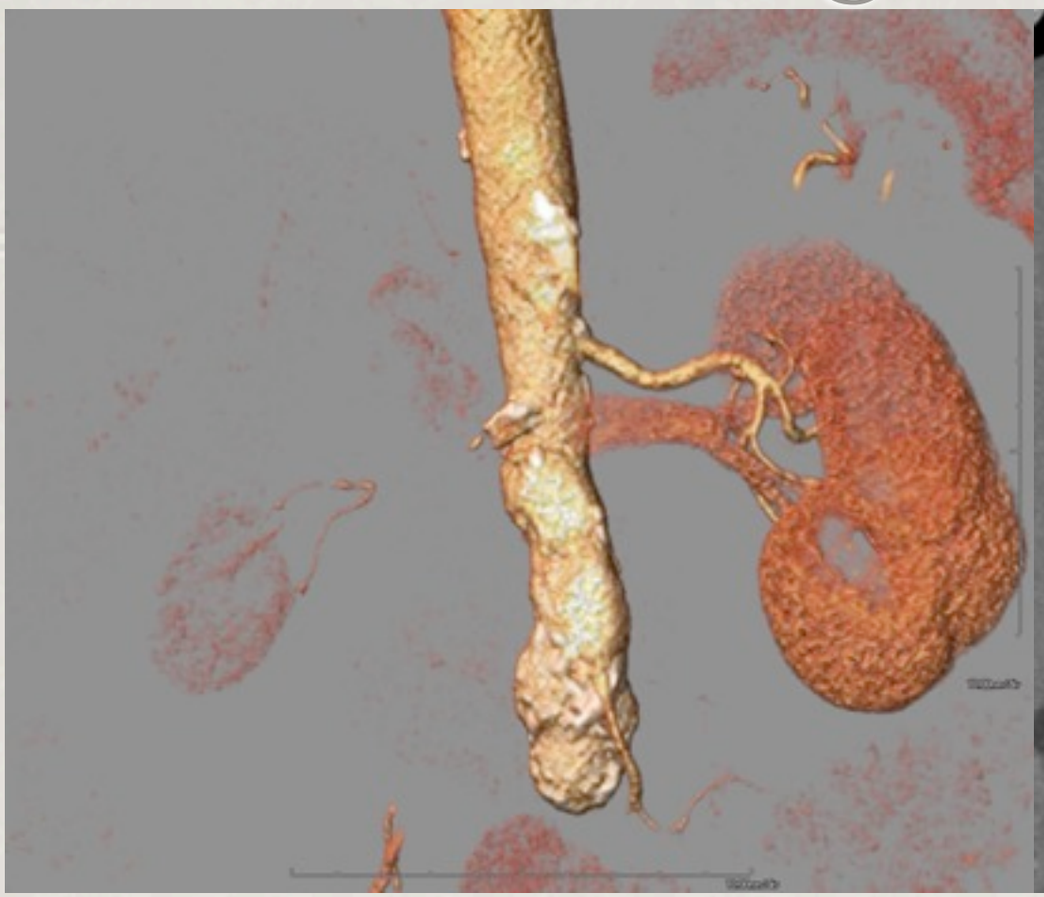
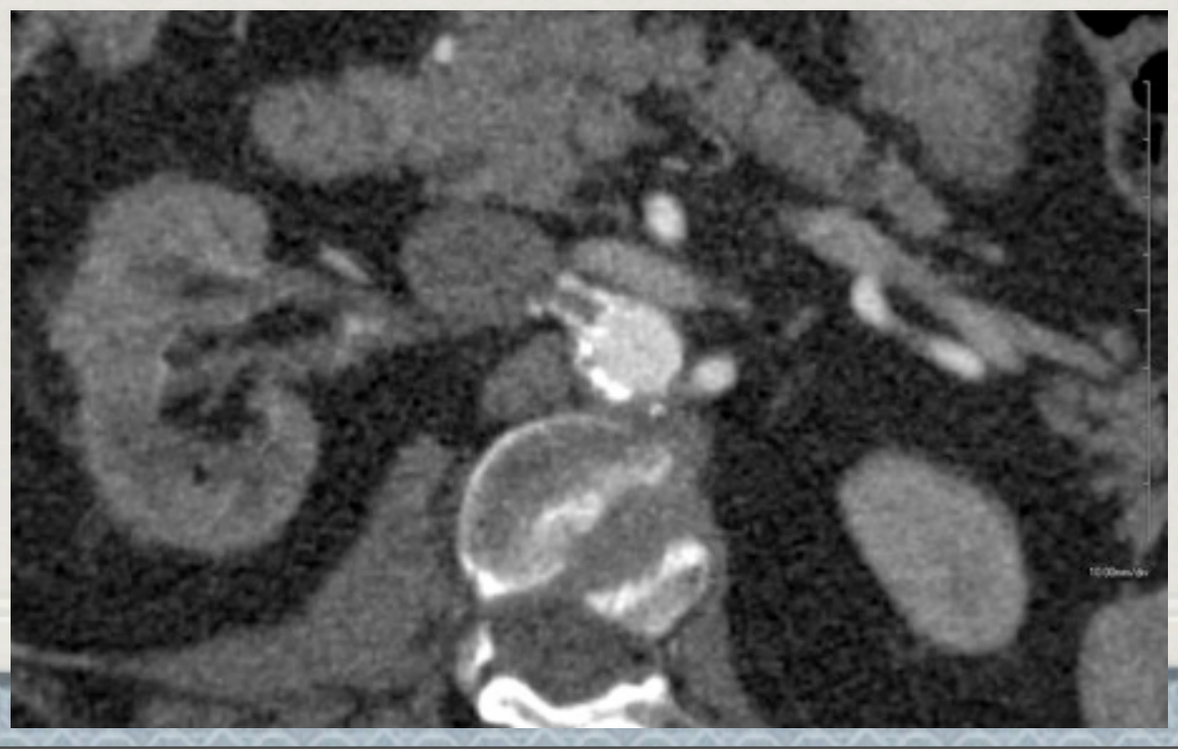
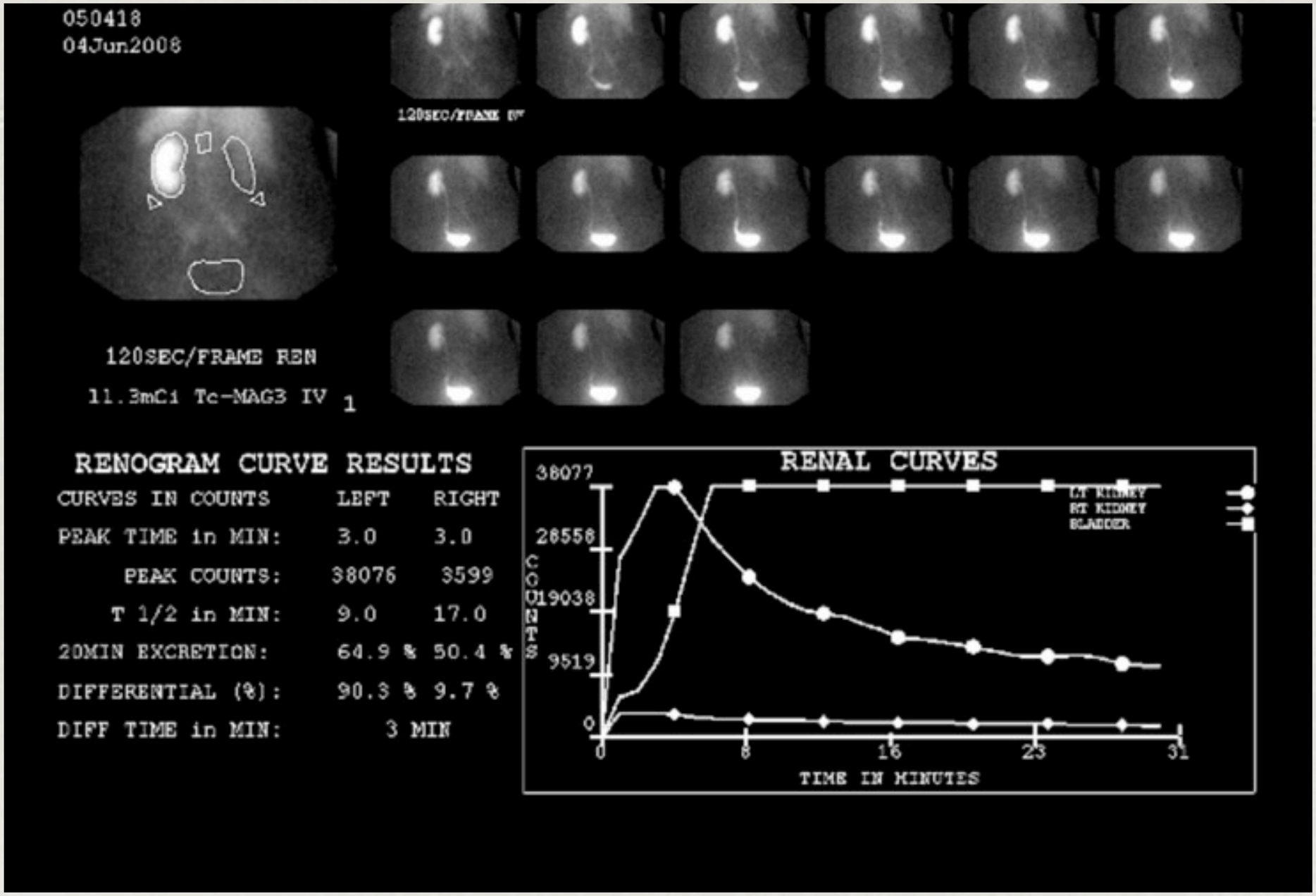




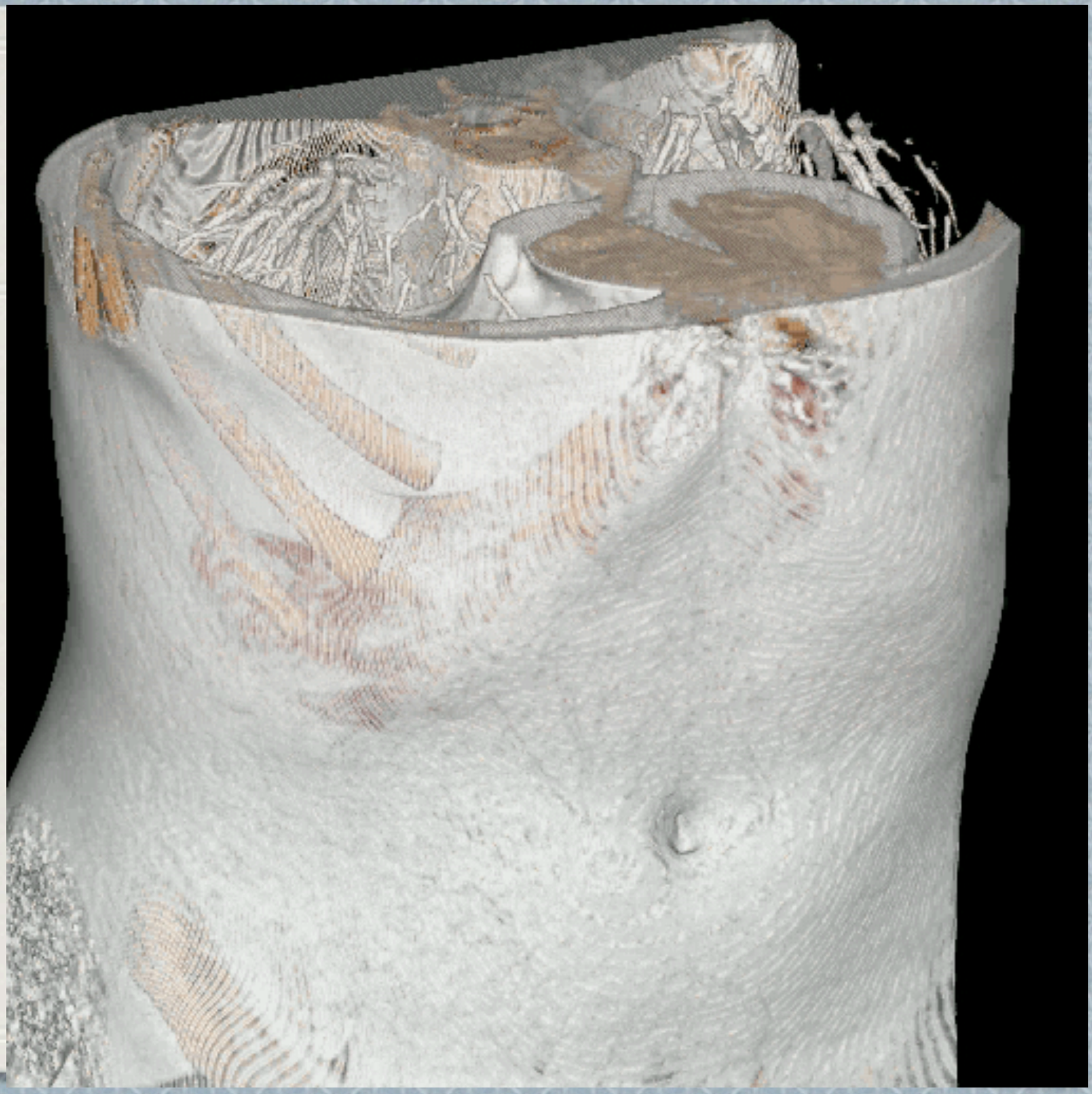
TC-MAG3 RENAL SCAN



Intervention Planning: 18 YO Male w/ HTN

ntervention Planning: 18 YO Male w/ HTN

ntervention Planning: 18 YO Male w/ HTN

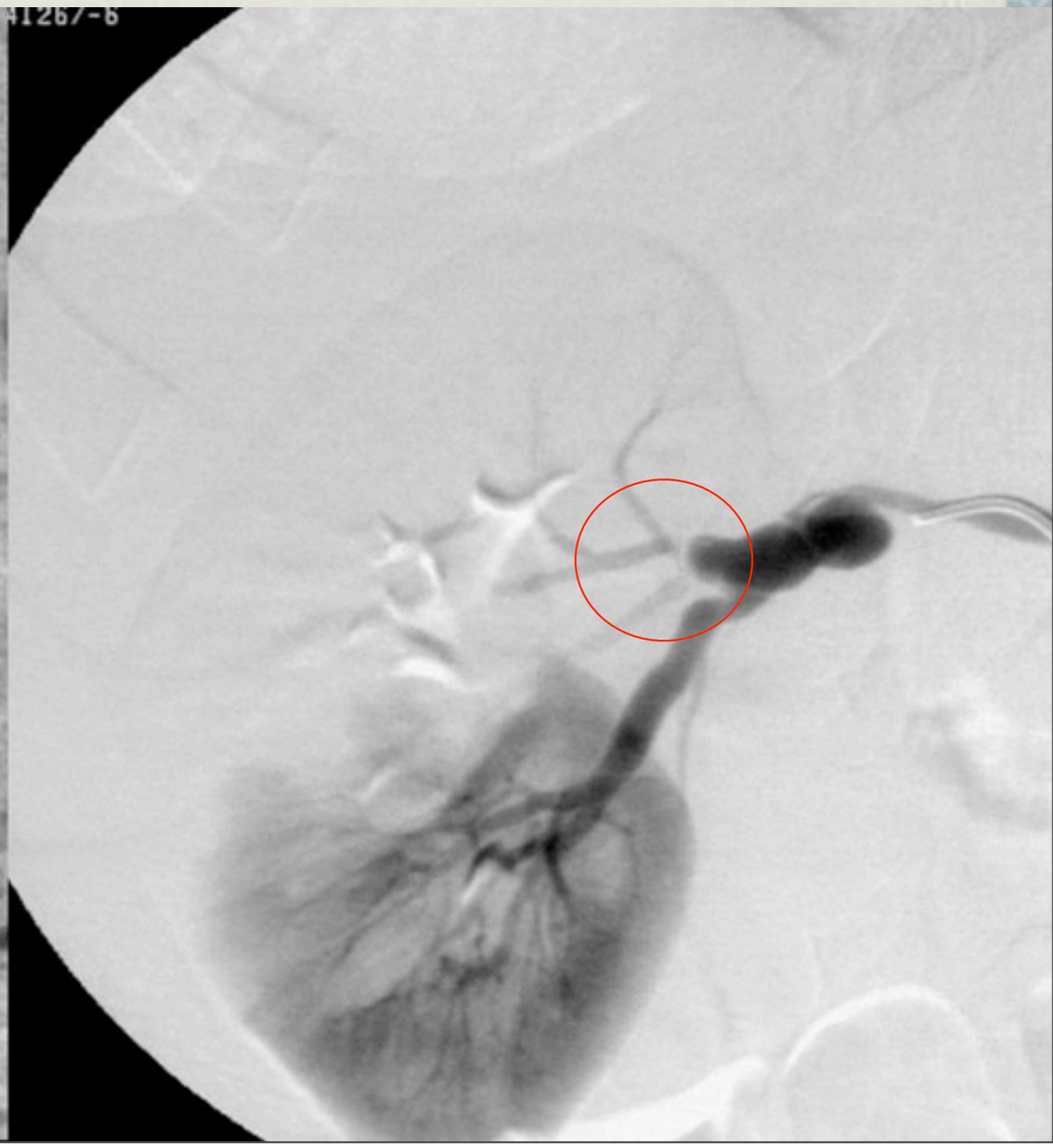


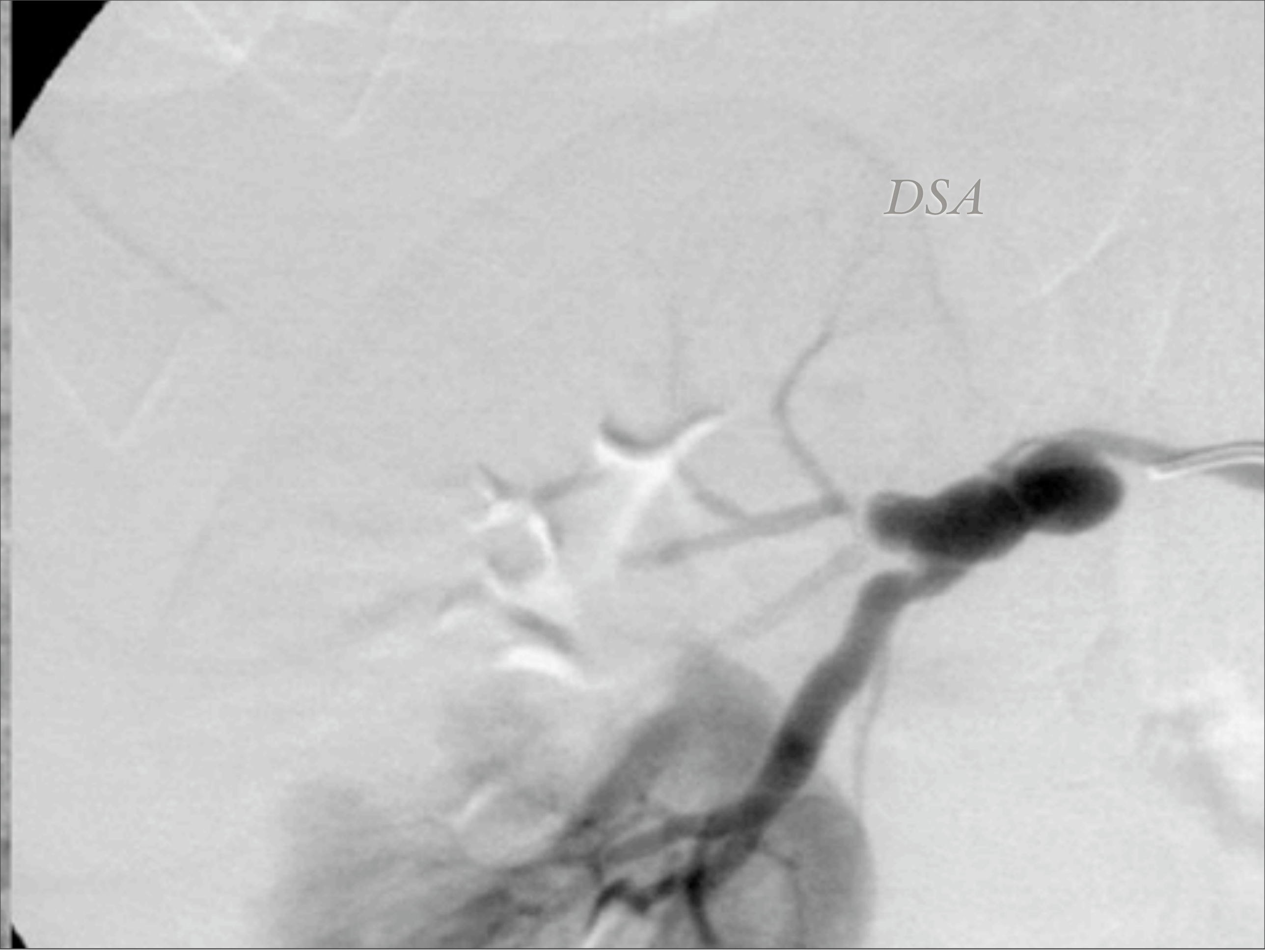
VR SLAB

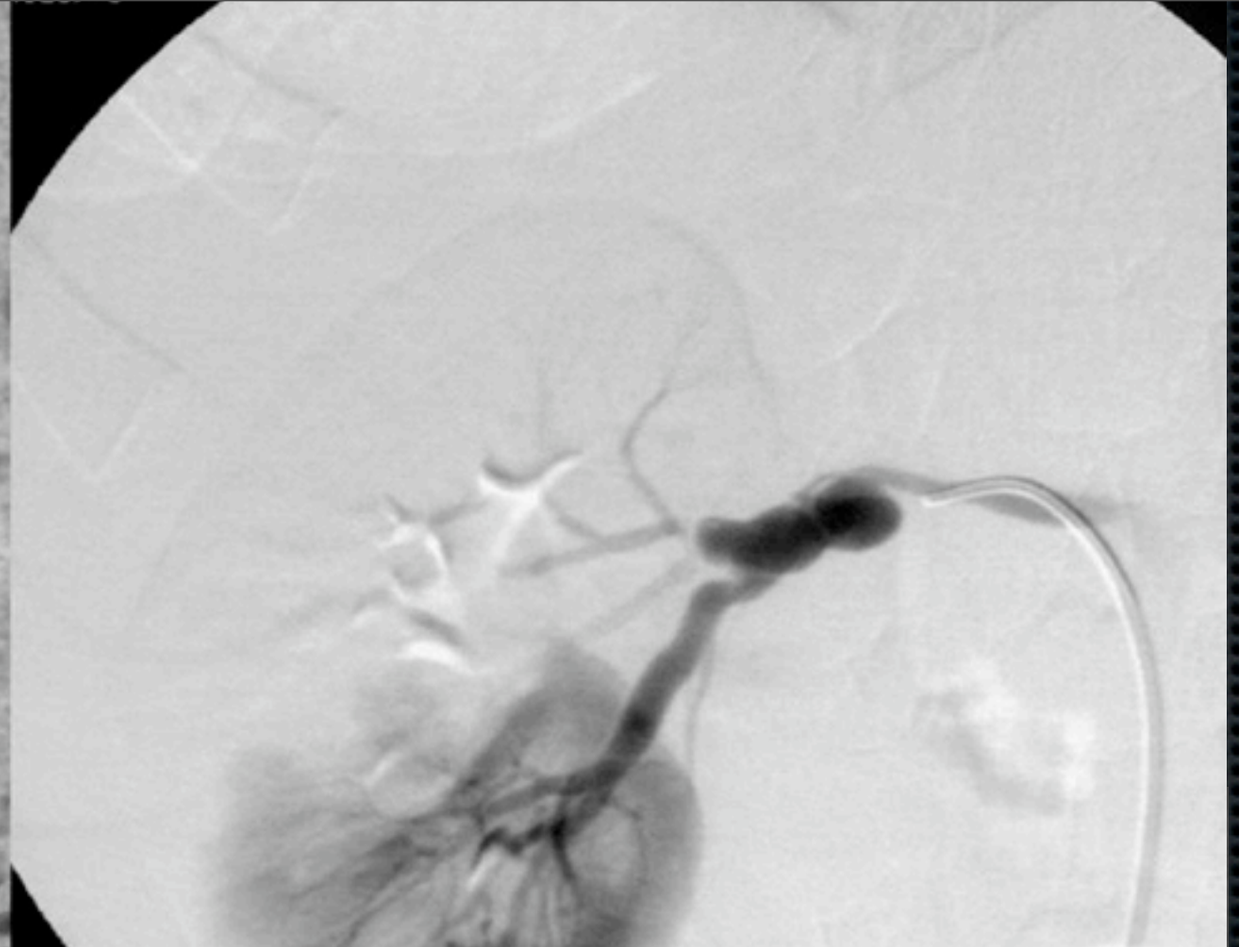
DSA

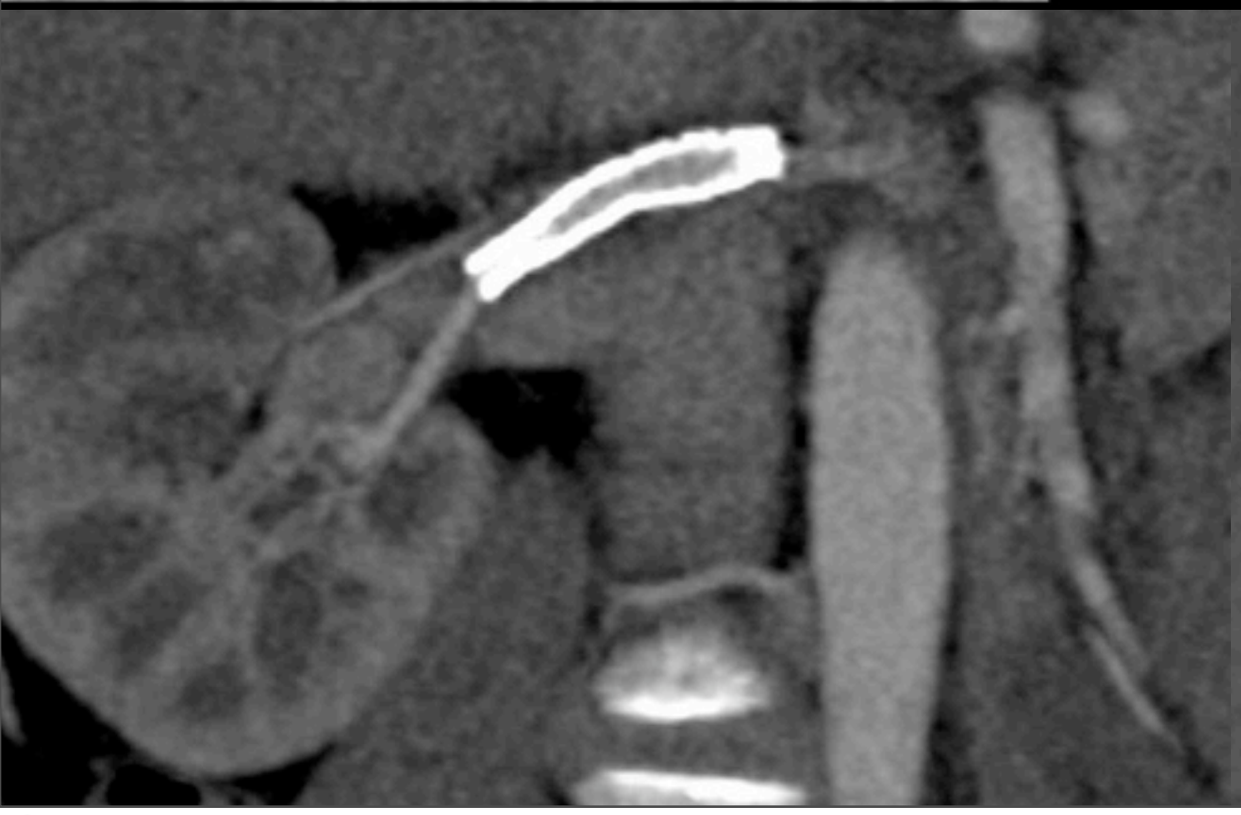
VR SLAB

DSA




DSA


RAO:



Collaborative Imaging: Lower Extremity CTA

Peripheral CTA Indications

- *Atherosclerosis (Dx and post-Tx)*
- *Thrombo-embolic*
- *Dissection*
- *Vasculitides (FMD, Takayasu, Buerger)*
- *Connective Tissue Disorders*
- *Entrapment syndromes*
- *Adventitial cystic disease*

Cost-effectiveness of CTA

- *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*
- *2007: Correct treatment recommendations for I.C.*[2]
- *2009: Correct recommendations for critical limb ischemia*[3]

[1] Kock, MC, et al. Radiology 2005. 237 (2) pp. 727-37
[2] Schernthaner, R, et al. AJR 2007; 189:1215-1222
[3] Schernthaner, R, et al. AJR 2009; 192:1416-1424

How good is CTA?

Handout available at:

http://stanford.edu/~hallett

Choose "NMCSD"

Meta-Analysis of Peripheral CTA:

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

Table 4. Subgroup Analyses Based on Execution of CTA (Number of Slices), Patient Population, Study Design, and Study Quality[a]

Characteristic	Sensitivity, % (95% CI)	*P* Value	Specificity, % (95% CI)	*P* Value
CTA				
2- to 4-slice CT	92 (88-96)	.03	93 (89-96)	.002
16- to 64-slice CT	97 (95-98)		98 (96-99)	
Patient population, %				
≥70 Fontaine II	94 (88-97)	.37	94 (89-97)	.71
<70 Fontaine II	90 (79-96)		93 (87-97)	
Study design				
Prospective	94 (90-97)	.34	96 (92-98)	.81
Retrospective	96 (93-98)		95 (91-98)	
Study quality 1				
High (>11 points)	93 (87-96)	.14	94 (91-96)	.28
Low (≤11 points)	96 (94-98)		96 (93-98)	
Study quality 2				
High (>10 points)	95 (91-97)	.81	96 (93-97)	.82
Low (≤10 points)	95 (91-98)		95 (90-98)	

Abbreviations: CI, confidence interval; CT, computed tomography; CTA, computed tomography angiography.
[a] Fontaine II is defined as mild to severe intermittent claudication without rest pain (Fontaine III) or tissue loss (Fontaine IV). High quality was defined according to the median quality score, which was 11.

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Detection of ≥50% Stenosis or Occlusion By Anatomical Region

Table 5. Diagnostic Accuracy of CTA in the Detection of More Than 50% Stenosis or Occlusion According to Anatomical Region[a]

Source, by Vessels	No. of Segments				%	
	True Positive	False Negative	False Positive	True Negative	Sensitivity	Specificity
Aortoiliac arteries						
Mesurolle et al,[27] 2004	18	0	1	29	100	97
Portugaller et al,[30] 2004	24	2	12	212	92	95
Willmann et al,[33] 2005[b]	75	3	6	267	96	98
Laswed et al,[4] 2008	20	1	0	139	95	100
Schernthaner et al,[5] 2008	58	3	4	157	95	98
Summary estimates (95% CI)					96 (91-99)	98 (95-99)
Femoropopliteal arteries						
Mesurolle et al,[27] 2004	31	1	4	55	97	93
Portugaller et al,[30] 2004	62	1	11	26	98	70
Willmann et al,[33] 2005[b]	98	3	10	201	97	95
Laswed et al,[4] 2008	53	4	5	106	93	95
Schernthaner et al,[5] 2008	221	3	2	364	99	99
Summary estimates (95% CI)					97 (95-99)	94 (85-99)
Tibial arteries						
Mesurolle et al,[27] 2004	3	4	3	19	43	86
Portugaller et al,[30] 2004	154	18	57	161	90	74
Schertler et al,[32] 2005	38	2	18	105	95	85
Willmann et al,[33] 2005[b]	177	7	22	496	96	96
Laswed et al,[4] 2008	238	6	15	161	98	91
Schernthaner et al,[5] 2008	200	0	2	337	100	99
Summary estimates (95% CI)					95 (85-99)	91 (79-97)
Femoropopliteal-tibial arteries						
Li et al,[24] 2008	110	2	4	100	98	96

Abbreviations: CI, confidence interval; CTA, computed tomography angiography.
[a] Summary estimates for the aortoiliac arteries were calculated by means of a fixed-effects model; summary estimates for the femoropopliteal arteries and tibial arteries were calculated by means of a random-effects model.
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Met, R. et al. JAMA 2009;301:415-424

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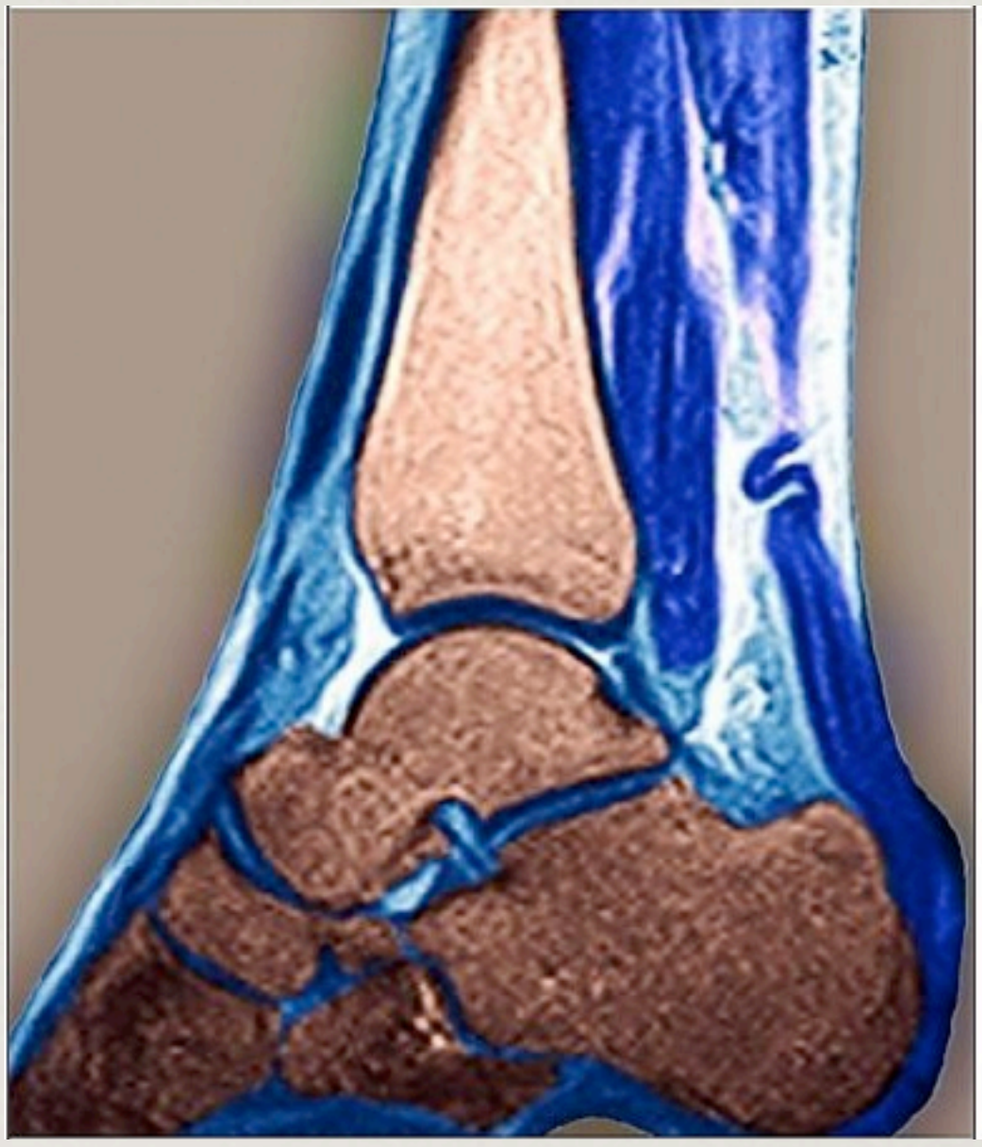
The Achilles' Heel of Extremity CTA.....



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

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

Predictors of Vascular Calcification

- ***Above knee:[1] Severe PAD** (Fontaine III-IV)*
- ***Below Knee:[1] Renal Failure, Diabetes***
- ***Also:[2] Age, cardiac disease***

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

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

Examples: Atherosclerotic Disease - Therapy Planning

Examples: Atherosclerotic Disease - Therapy Planning

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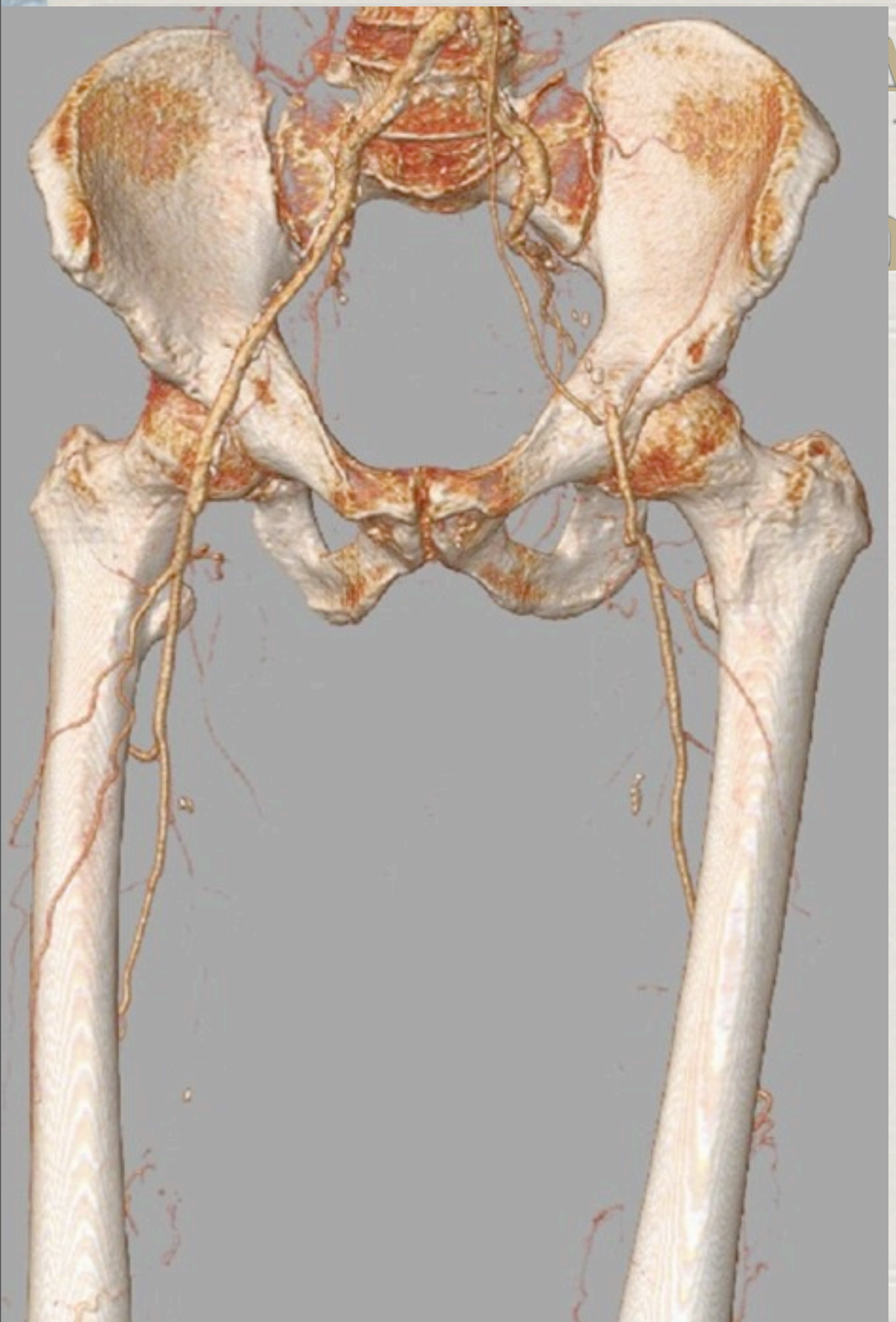
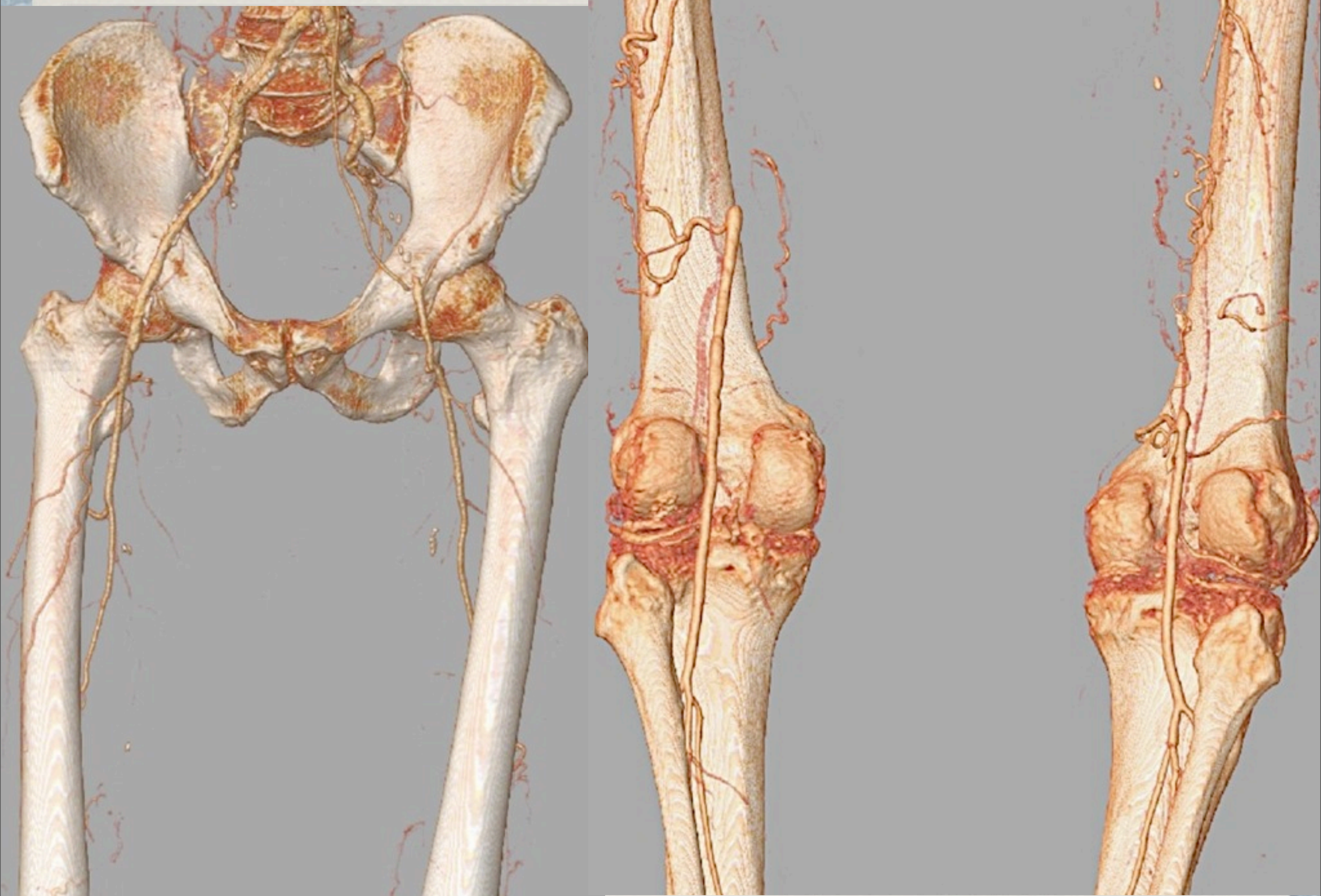
nning

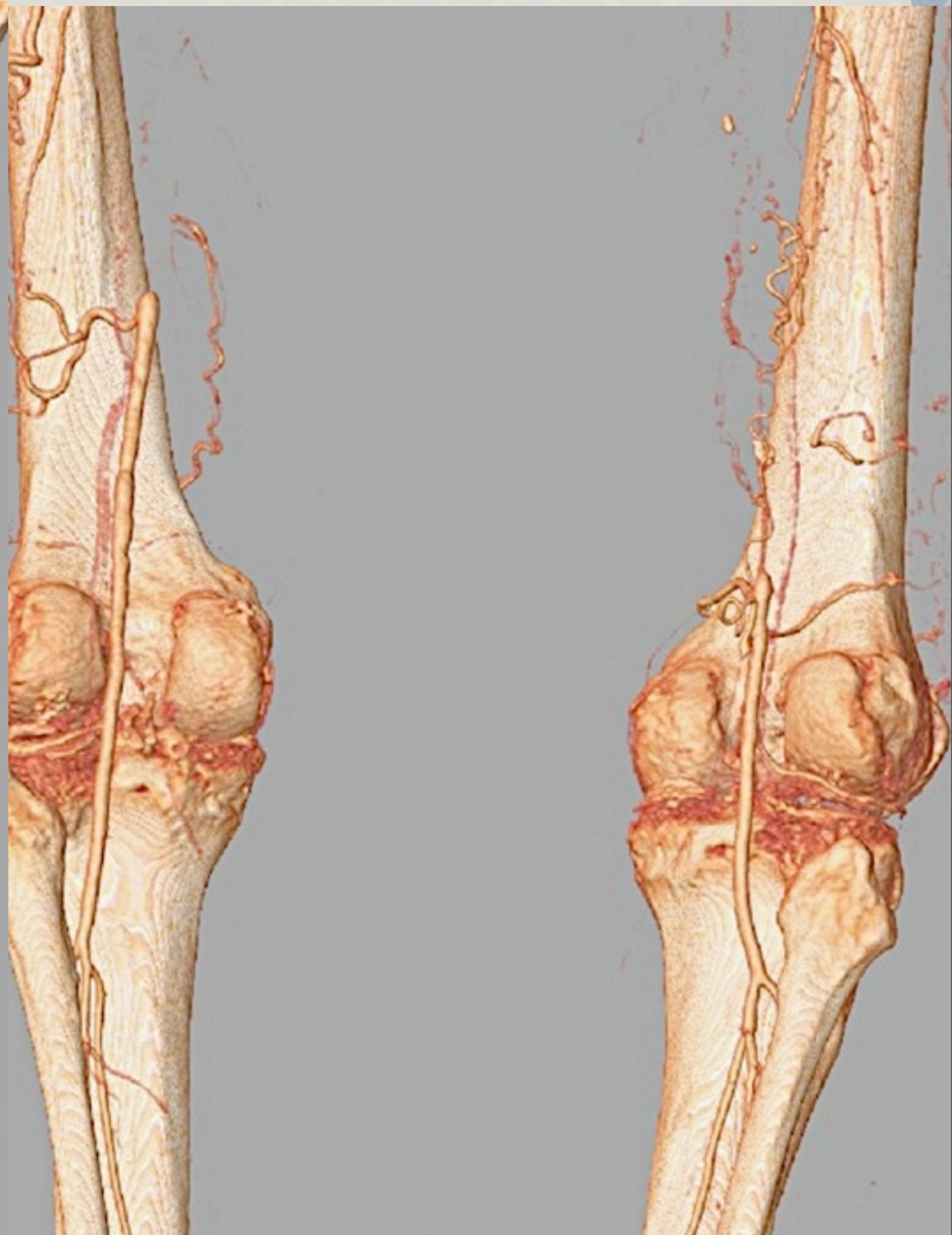
Examples: Atherosclerotic Disease - Therapy Planning

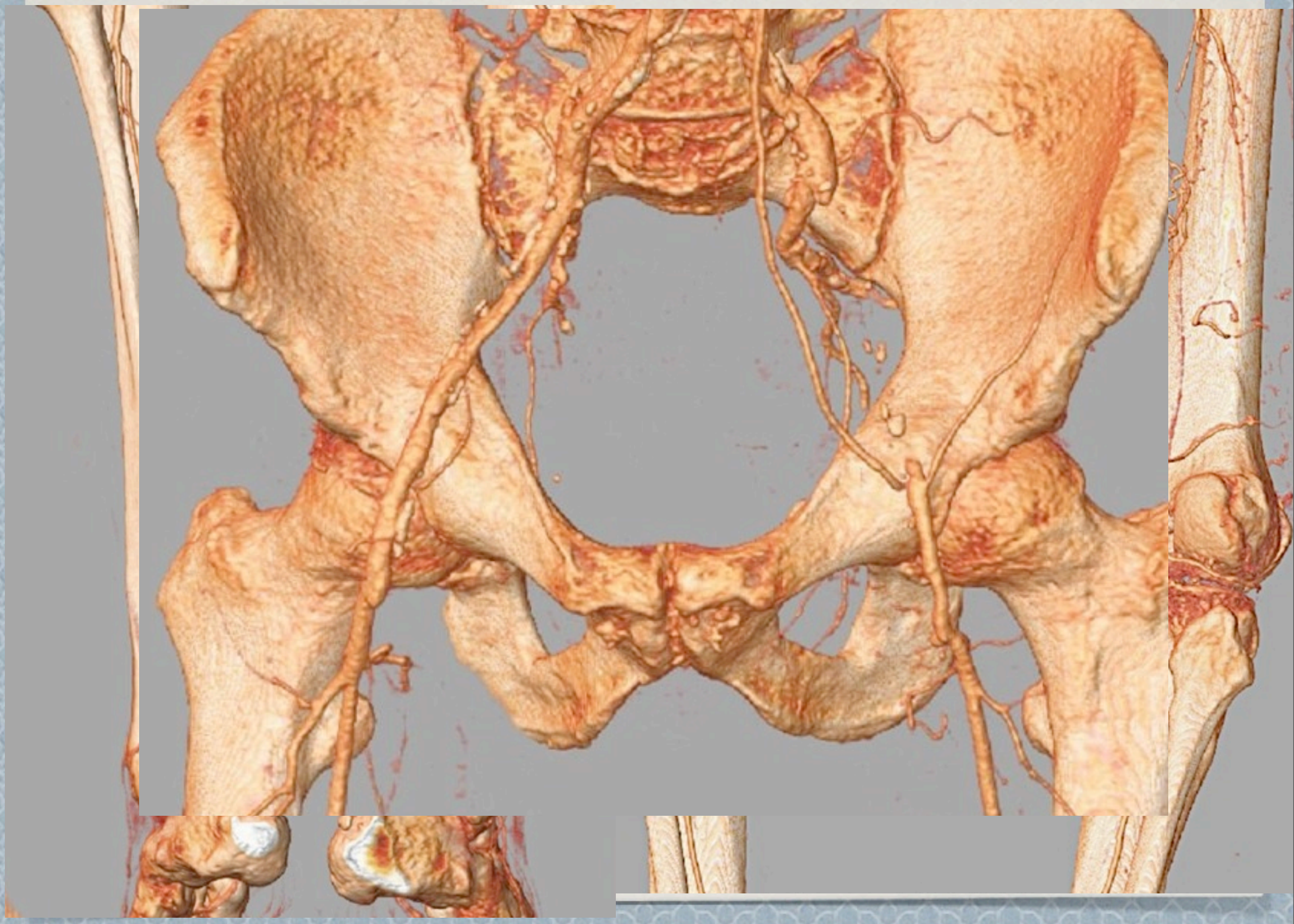
Examples: Atherosclerotic Disease - Therapy Planning



Atherosclerotic herapy Planning







Integrative Care: Acute LE Ischemia

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Integrative Care: Acute LE Ischemia

Example: LE CTA (Post-therapeutic)

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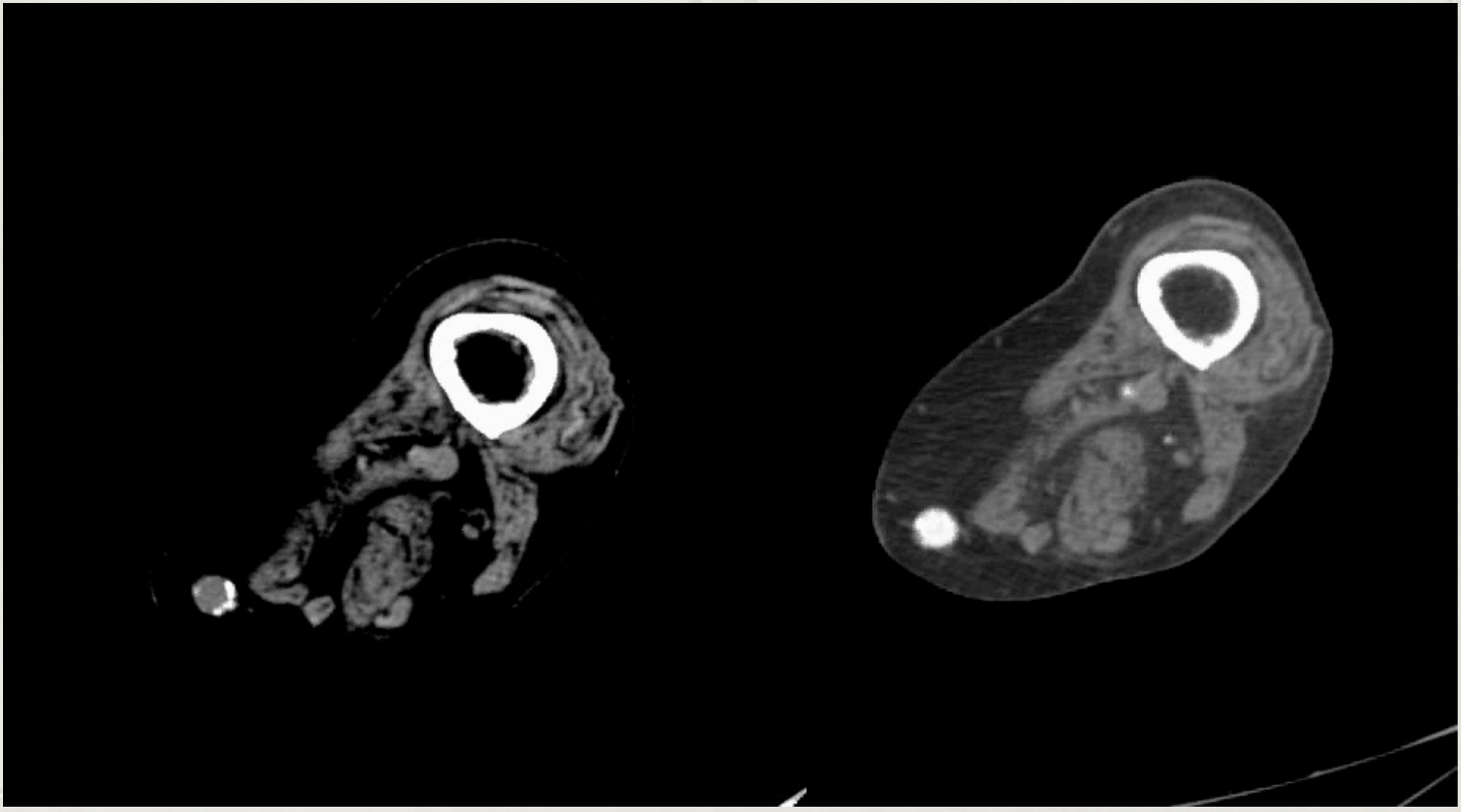
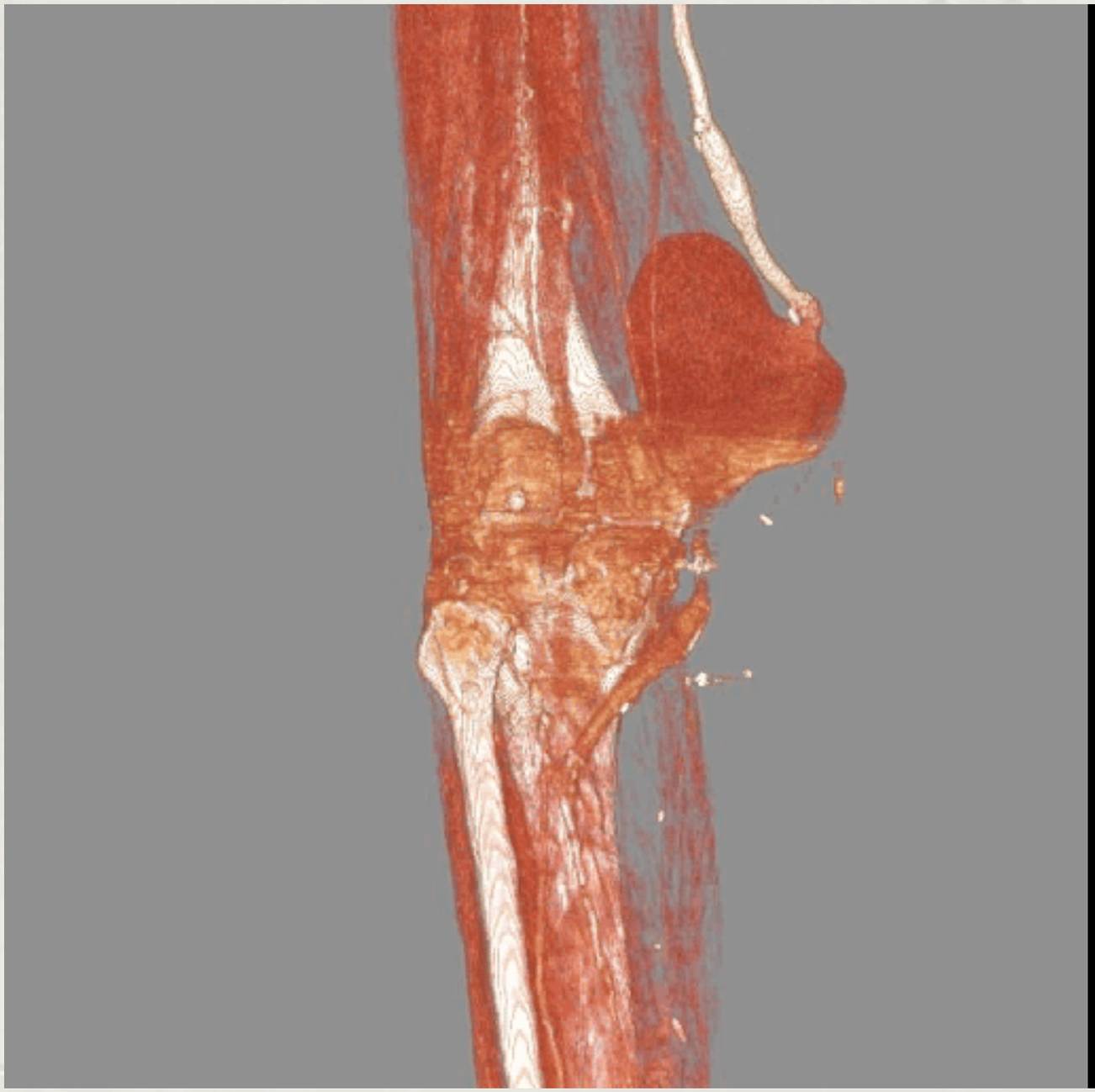
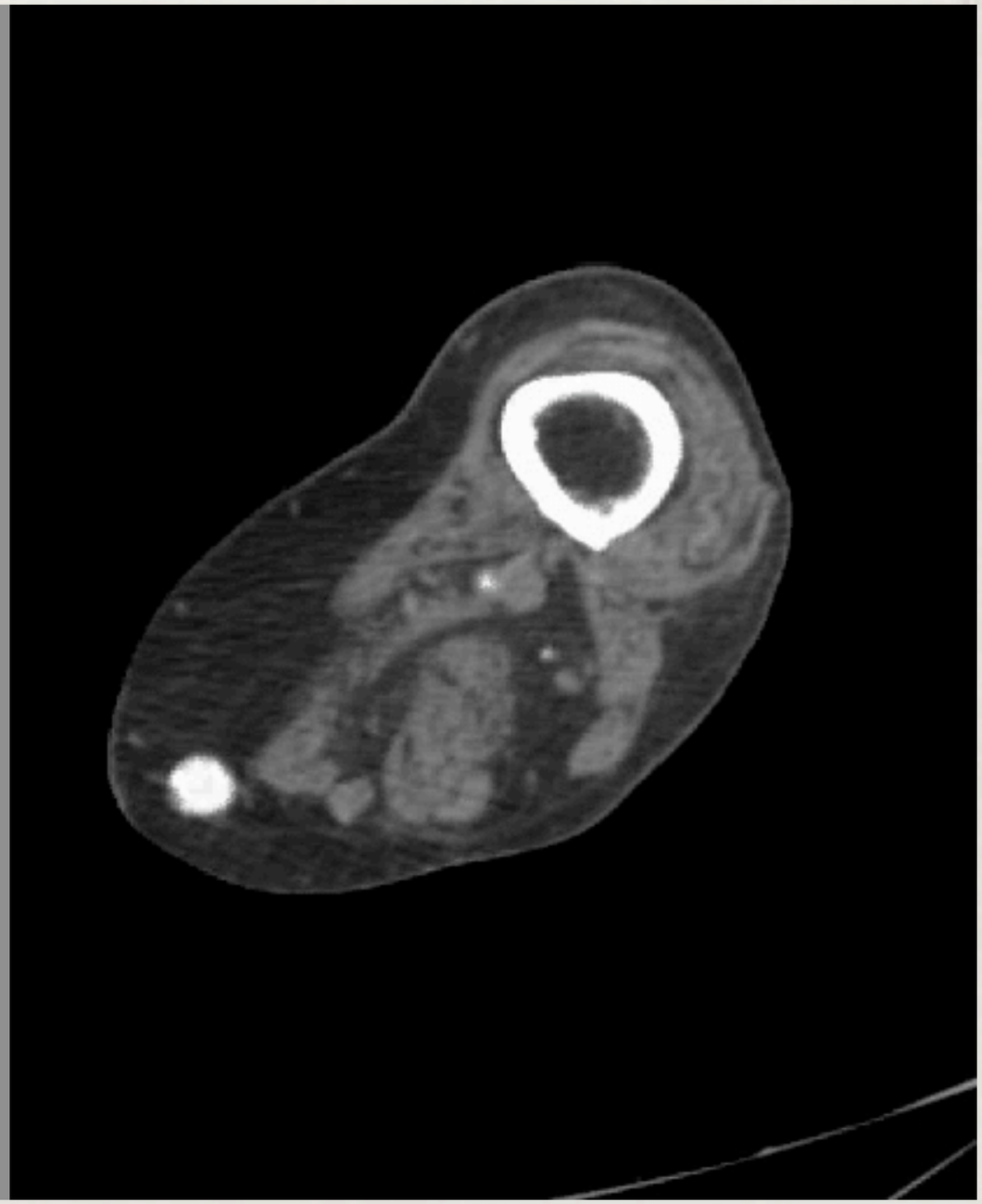


Example: LE CTA (Post-therapeutic)





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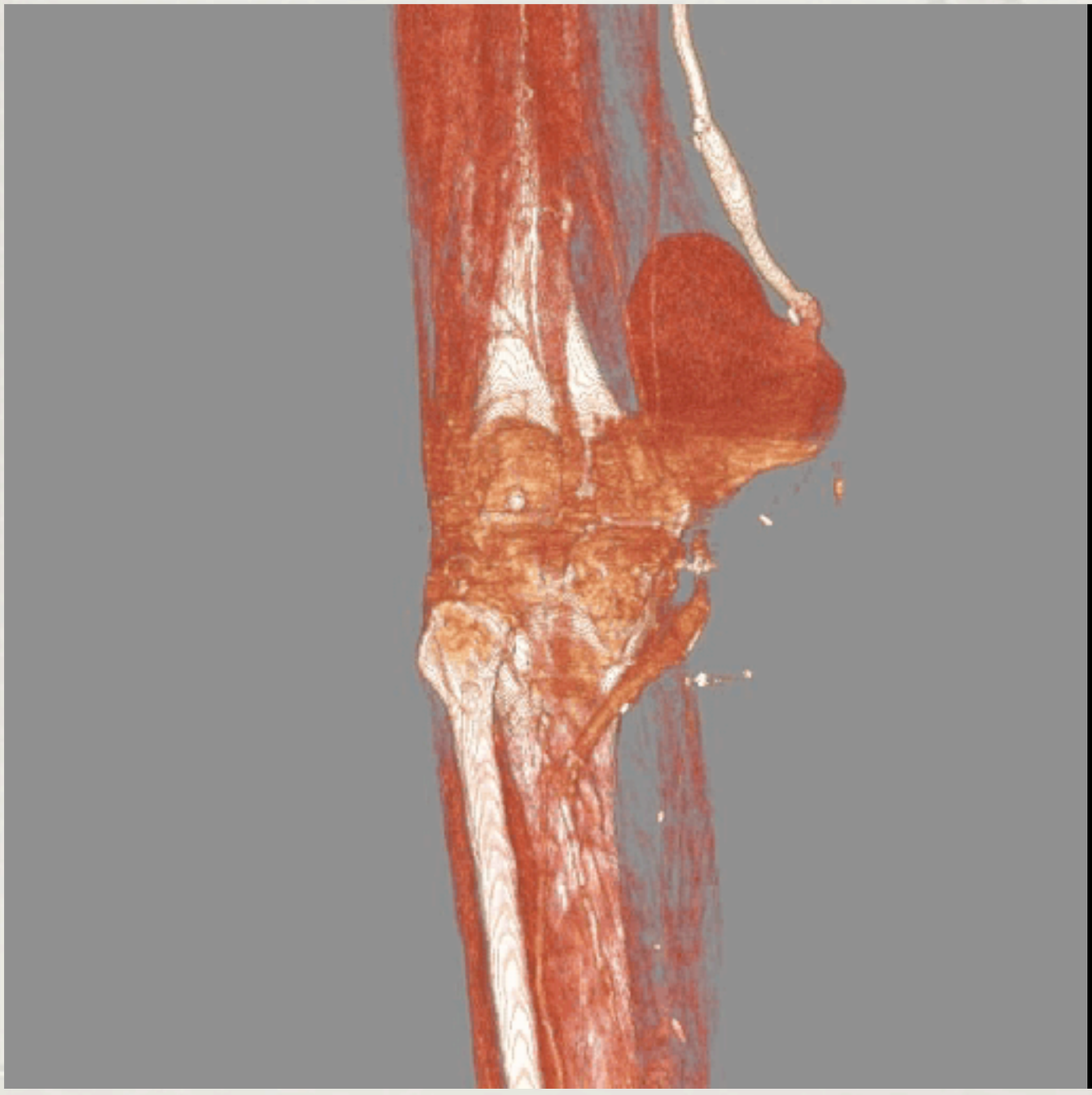

Integrative Imaging: Post-op Fibular Fracture Fixation

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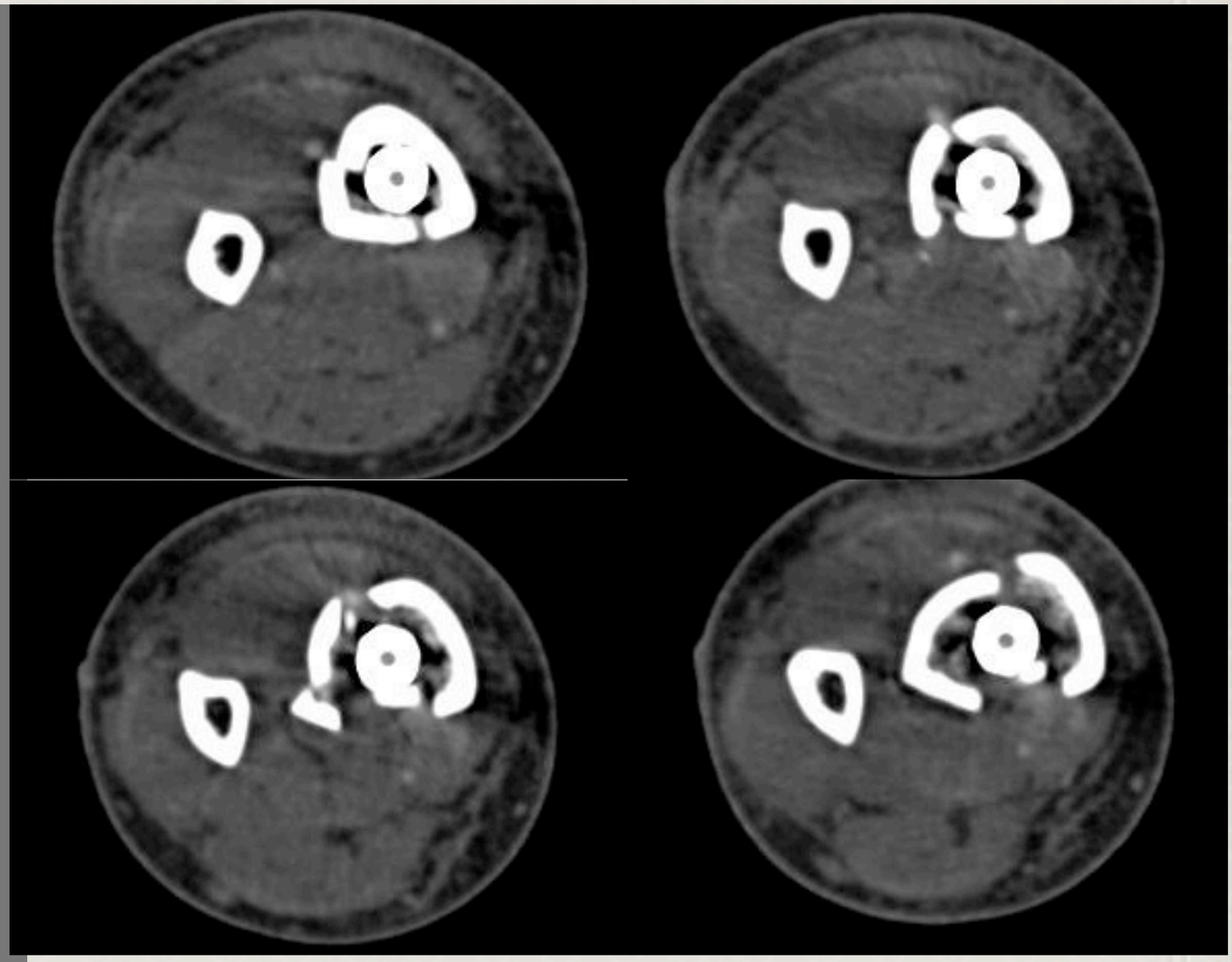
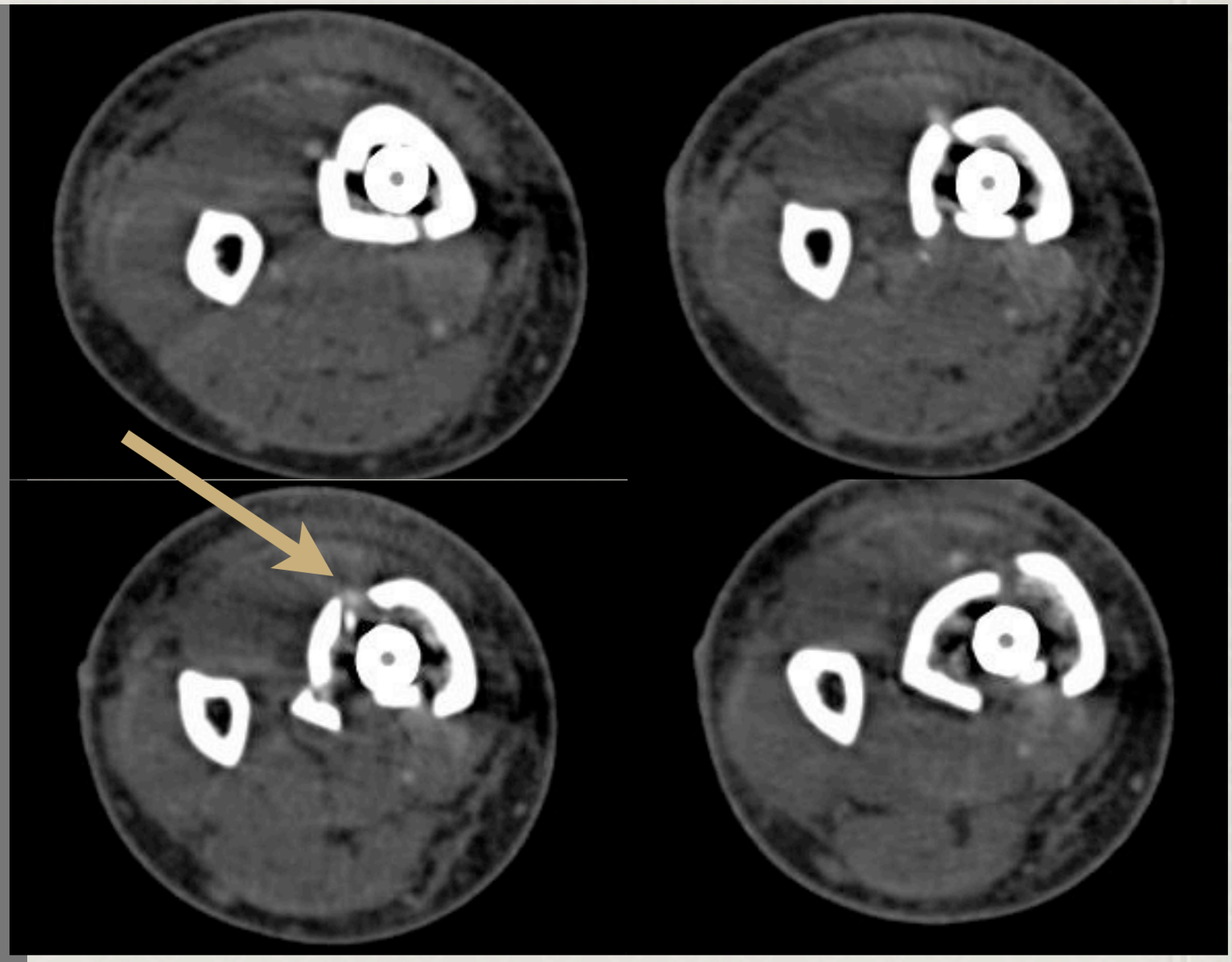


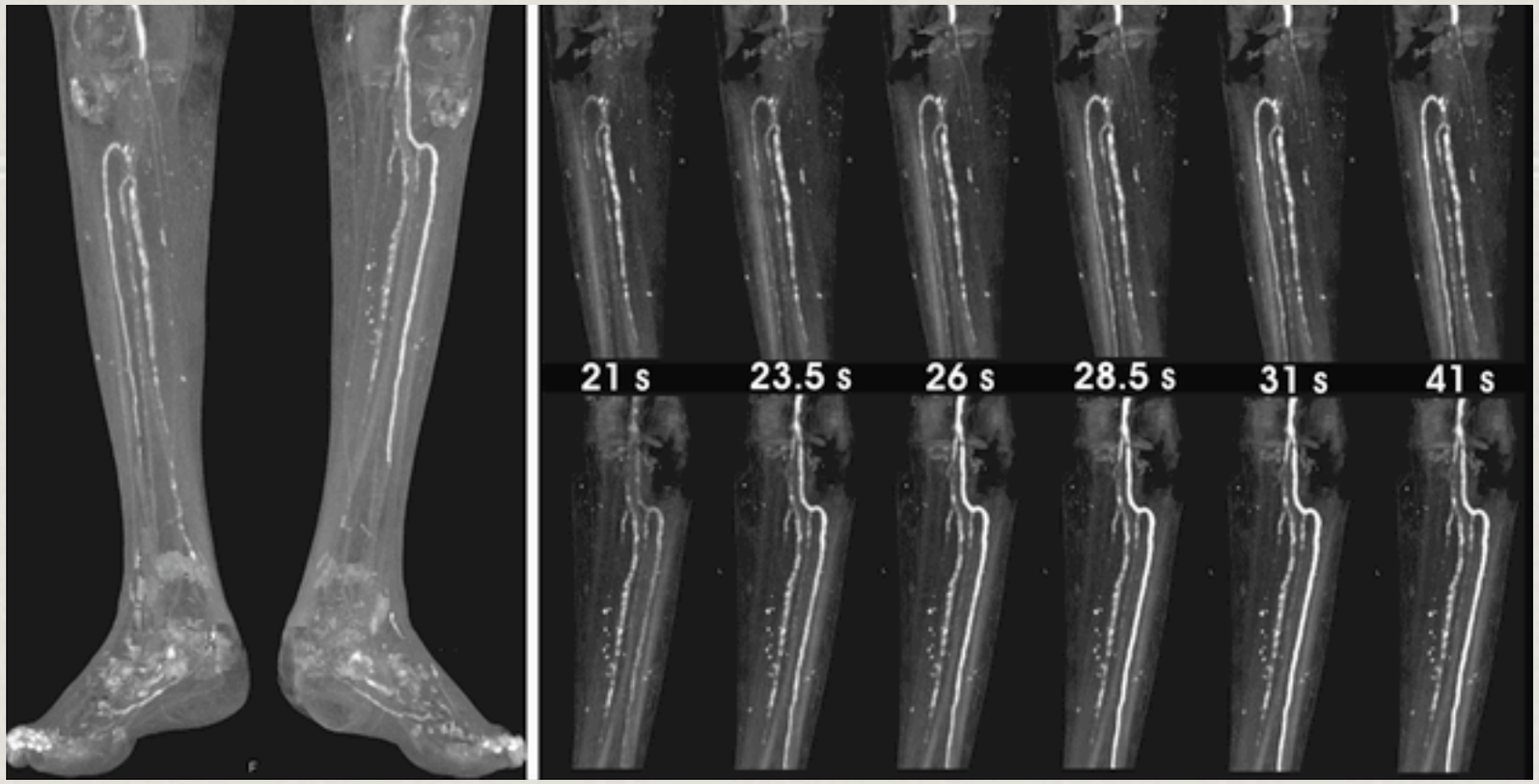
Integrative Imaging: Post-op Fibular Fracture Fixation



New Directions in CTA

- *Time-Resolved CTA*
- *Dual Energy Imaging*

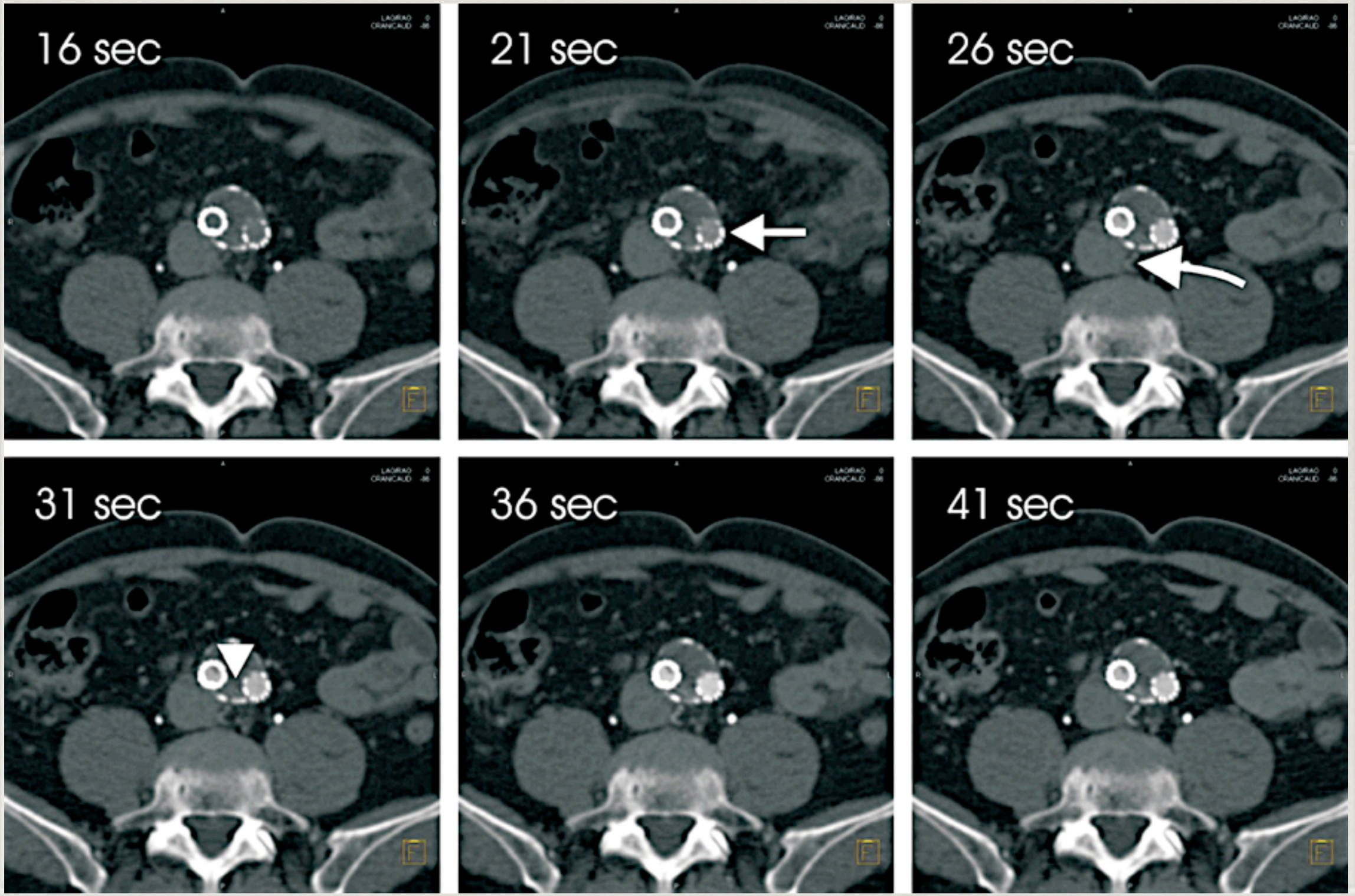
Time-Resolved CTA - Runoff



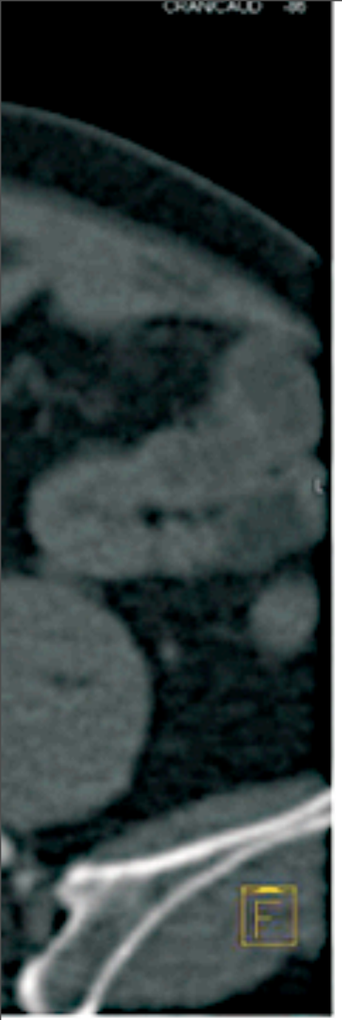
- *Significantly greater enhancement, less venous overlap*
- *Significantly higher diagnostic confidence*
- *Directly visualize asymmetric / delayed / diminished flow*

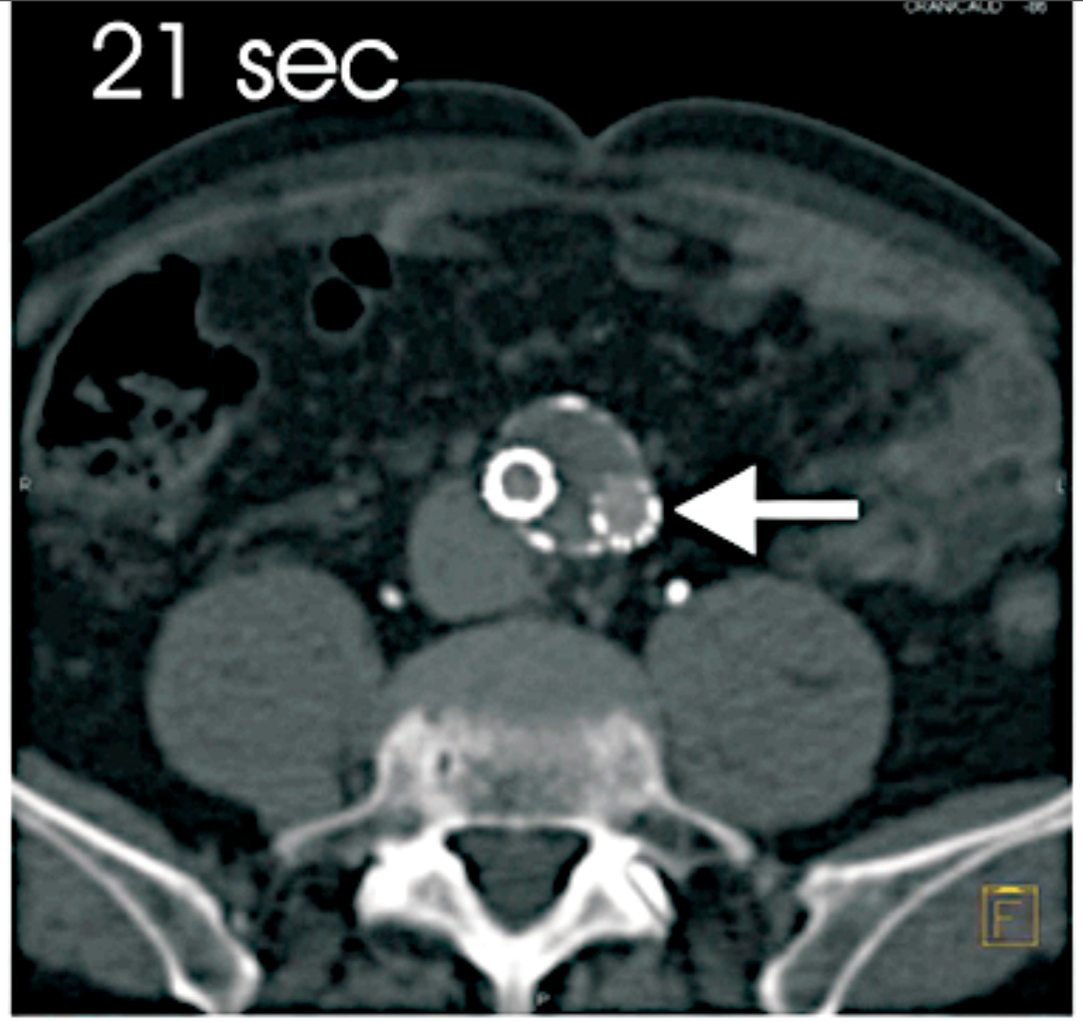
Sommer Eur. Radiol (2010) 20: 2876-2881

TR CTA - Type II Endoleak



Sommer W. Journal of Thoracic Imaging (2010) 25(2):161-167.

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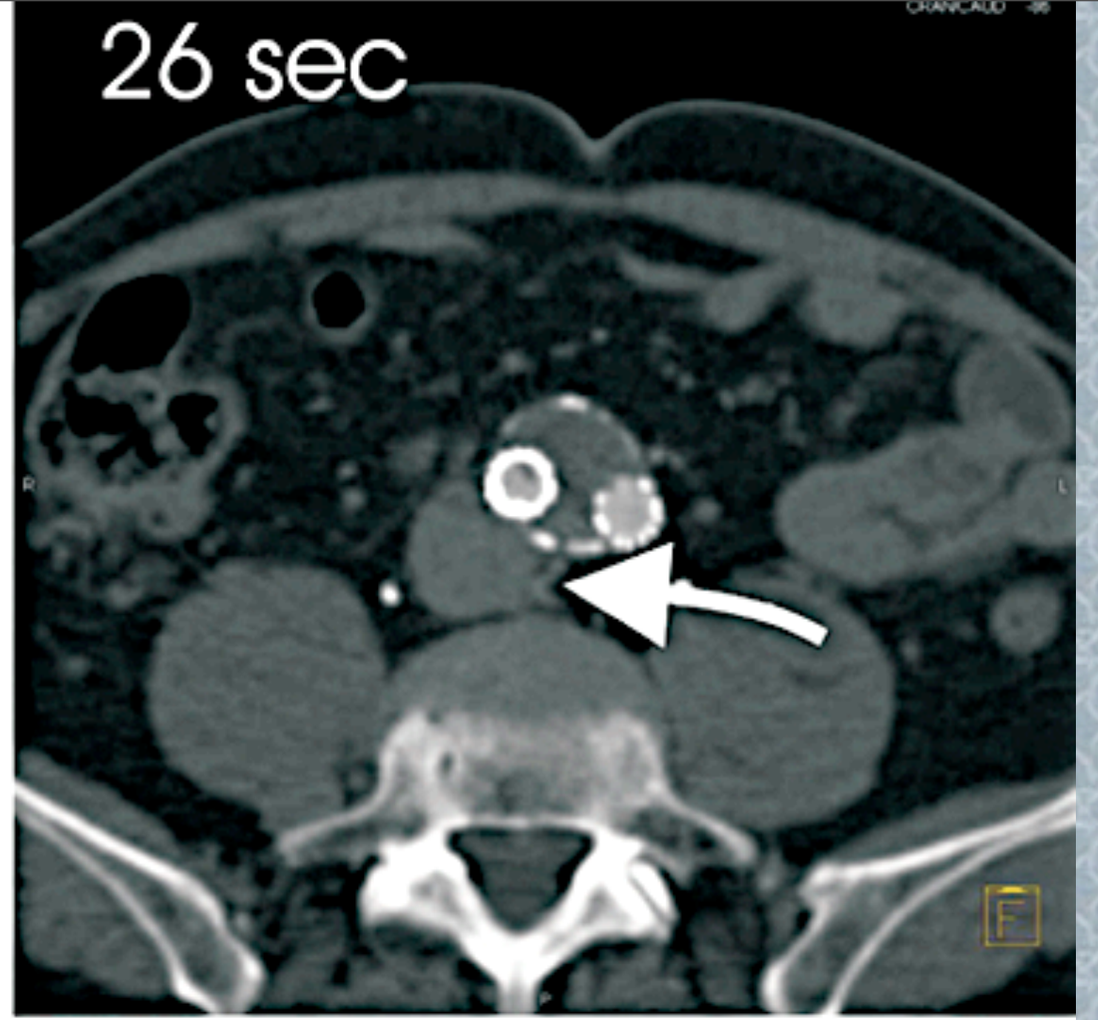
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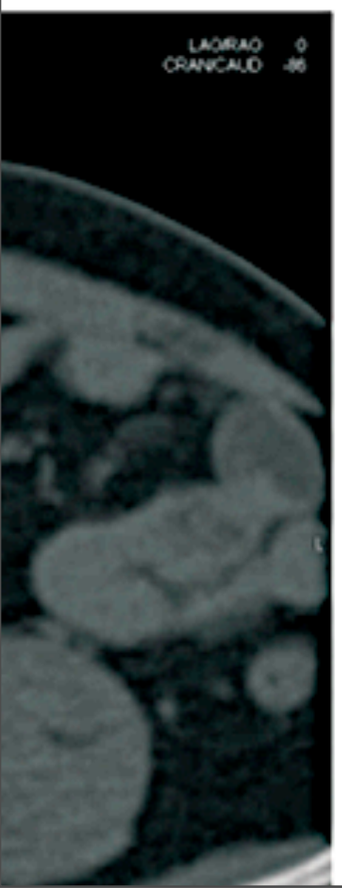

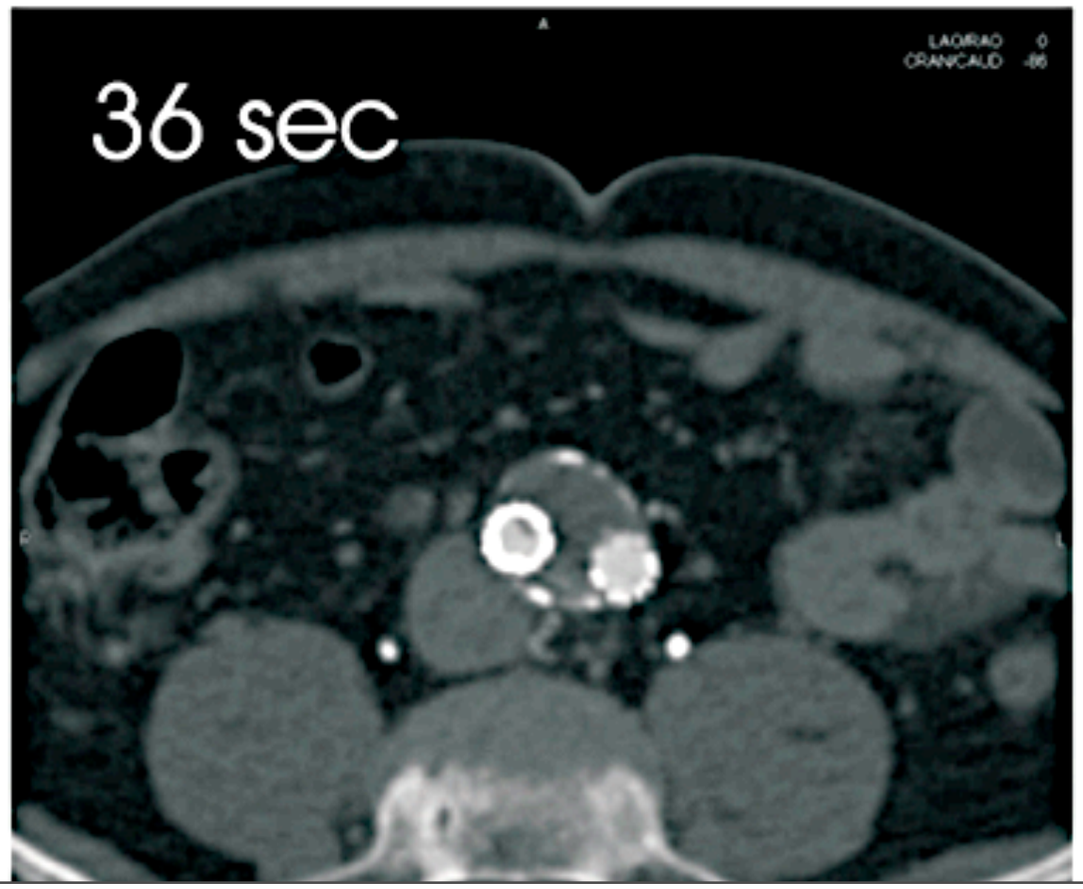
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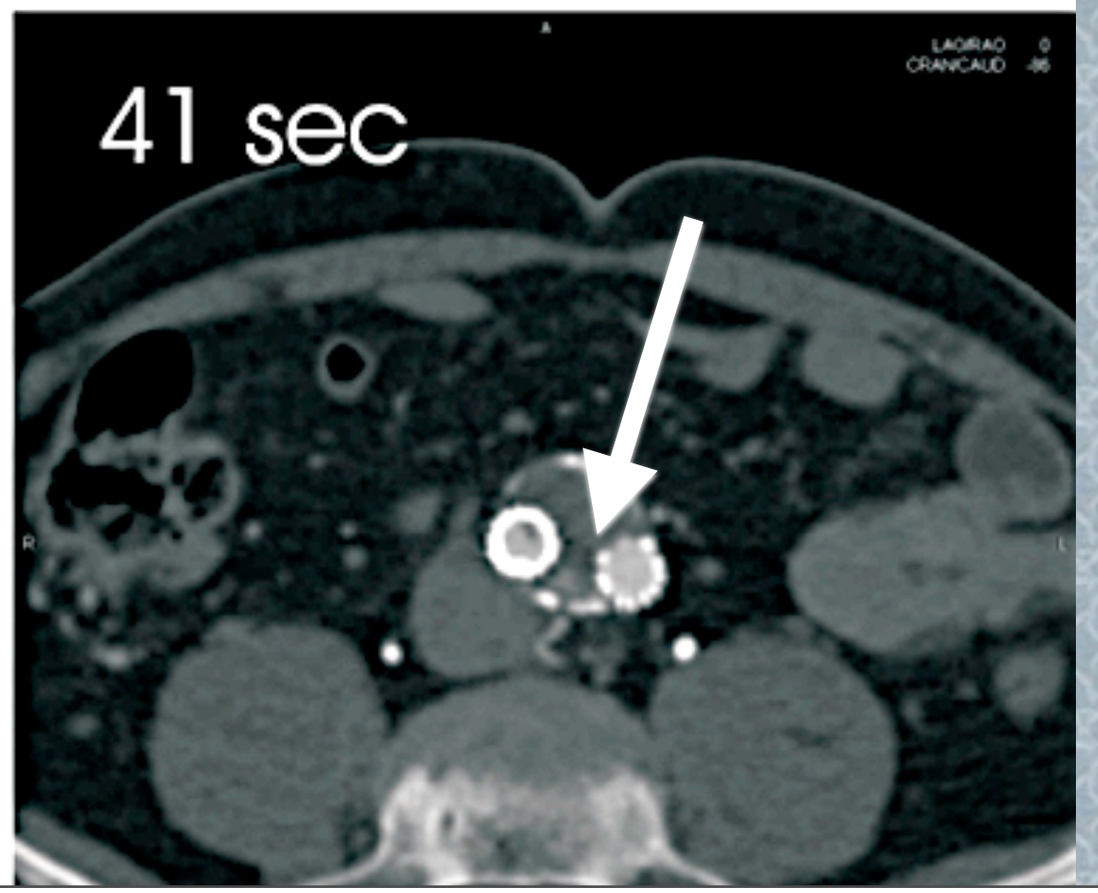

41 sec

Dual Energy Imaging

- *Via Dual Source CT or rapid kVp switching GSI*
- *differing absorption of 80 vs 140 kVp beam by iodine, fat, soft tissues*
- *Can generate "virtual non-contrast" images*
- *Enhanced detection of endoleaks*
- *Calcium Subtraction - Less robust when contrast is low*[2]

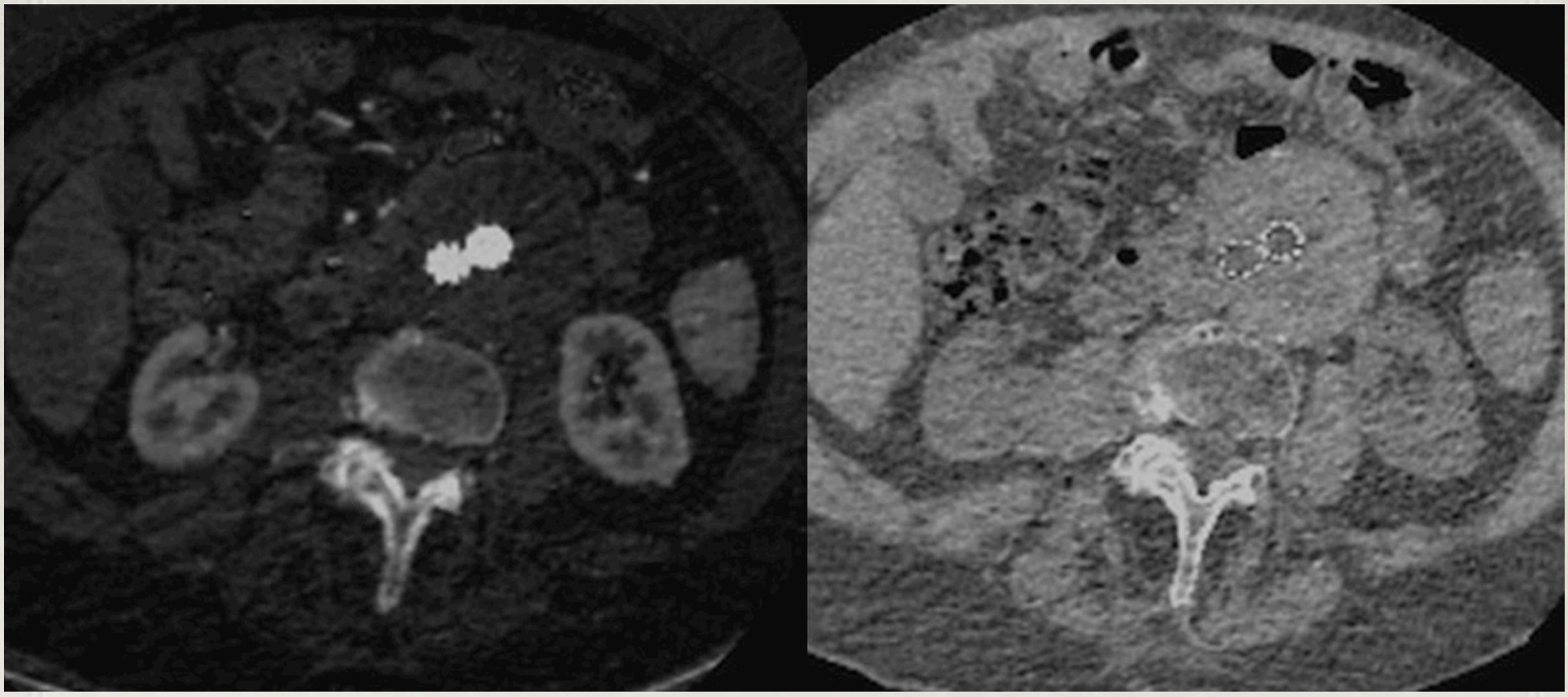
[1]Sommer W. J Vasc Interv Radiol. 2010; 21(3):315-21

[2]Tran DN. Acad Radiol. 2009; 16(2):160-71

DECT: Virtual Non-Contrast

Iodine Map

Virtual Non-Contrast



- $CT_{avg} - CT_{Iodine}$

Summary

- *CTA of the aorta and peripheral arteries is now a first-line, cost-effective imaging tool for a wide range of pathology*
- *The key to consistently reproducible CTA of the aorta and extremities is to have integrated contrast medium and scan protocol*
- *New developments promise further expansion of CTA value and utility in the near future*

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Handout available at:

http://stanford.edu/~hallett

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