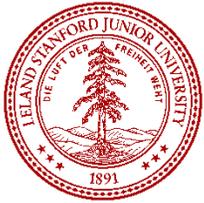


CT metal artifact reduction and other image post-processing applications



F. Edward Boas

Stanford Radiology Grand Rounds



Financial disclosures: None.

Note: Non-FDA approved software will be discussed.

2012-04-03

Image reconstruction and post-processing

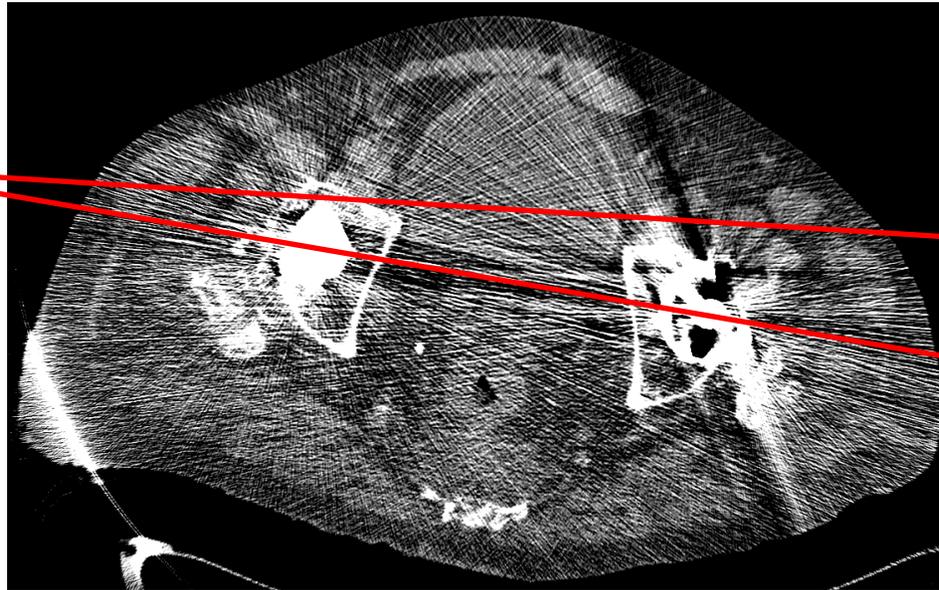
- **CT metal artifact reduction**
- Limited field of view CT
- Noise reduction
- TACE planning tool
- Color liver perfusion imaging

CT metal artifacts



CT metal artifacts


X-ray source



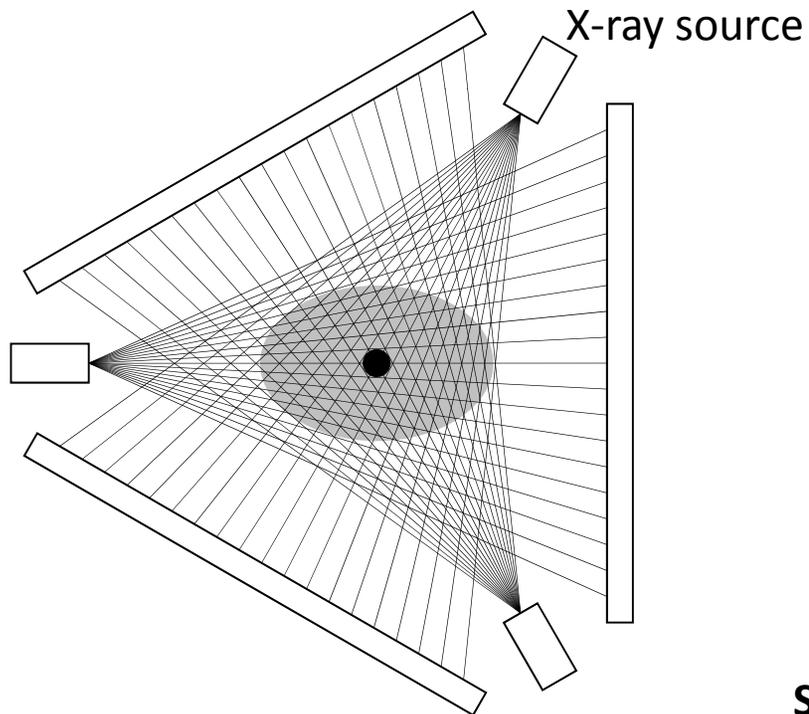
Low error

High error, due to:

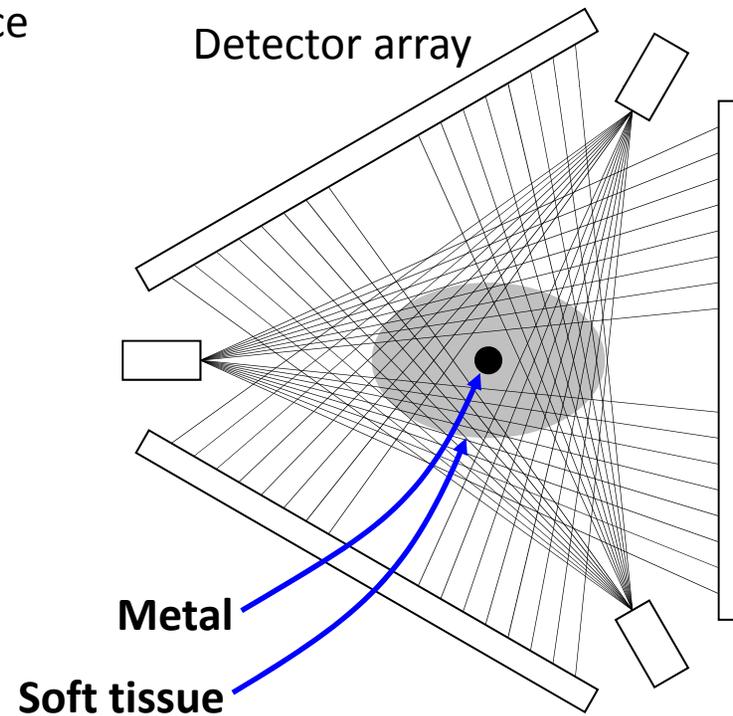
- Poisson noise
- Beam hardening
- Scatter
- Motion

Metal deletion technique (MDT)

Use all of the data to reconstruct the metal pixels ...



... but only use non-metal data to reconstruct non-metal pixels.



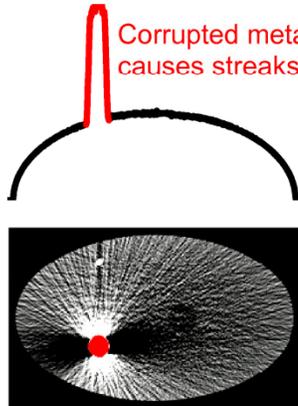
Metal deletion technique (MDT)

Delete metal pixels, then use forward projection iteratively to replace detector measurements that involve metal.

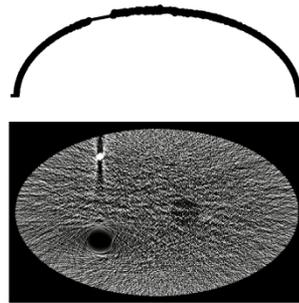
Metal deletion technique (MDT)

❶ Original projection data from the scanner.

Corrupted metal data causes streaks

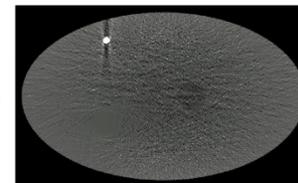


❷ Filtered backprojection



❸ Linear interpolation

❺ Forward project ❹

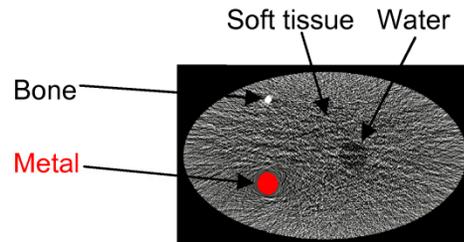


❹ Edge-preserving blur filter

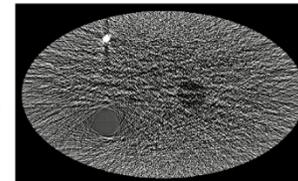
❻ Replace metal data from ❶ with values from ❺.



Iterate 4 times



Add back metal pixels from ❷



❼ Filtered backprojection

Cholecystectomy clips: FBP



Cholecystectomy clips: LI



Cholecystectomy clips: MDT



Embolization coils: FBP



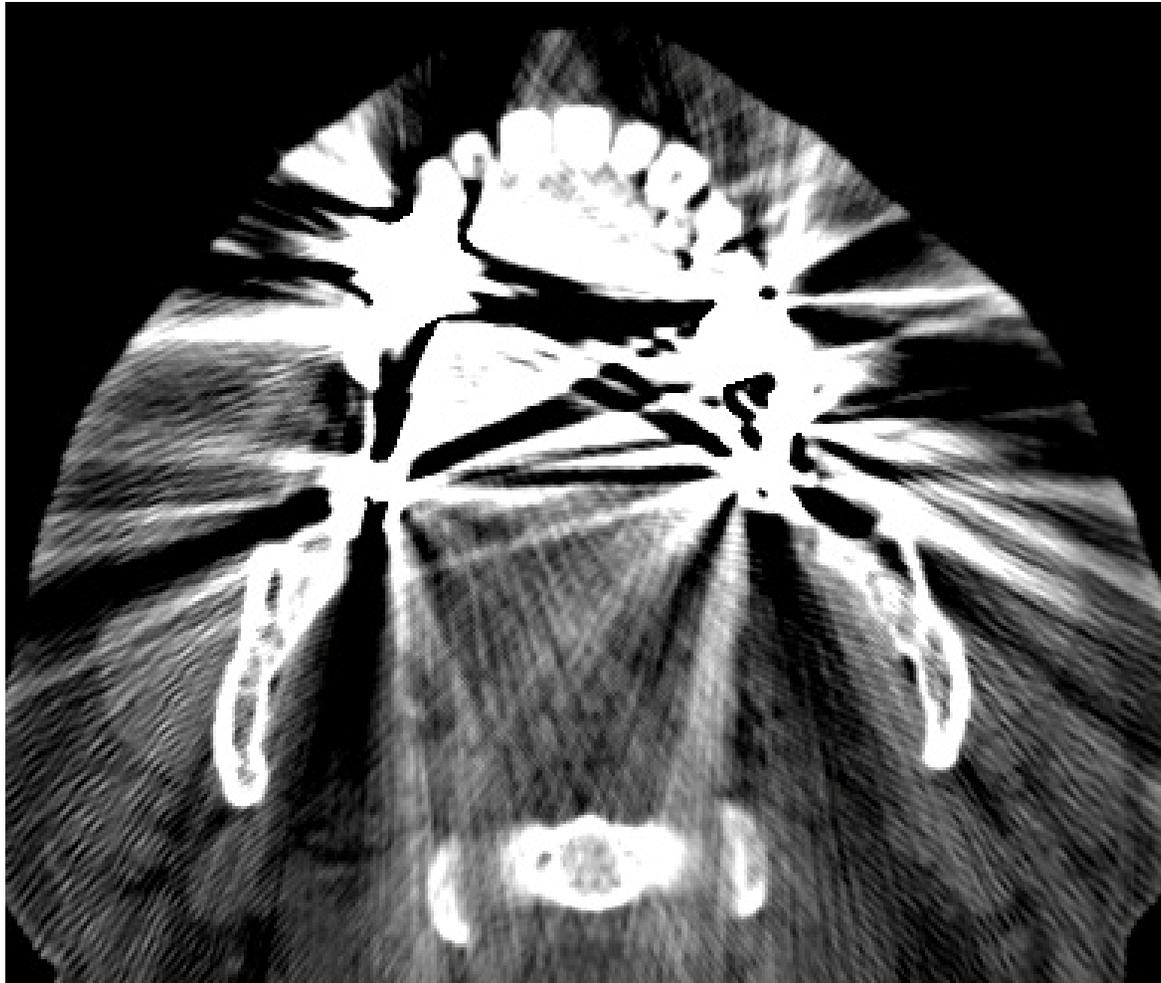
Embolization coils: LI



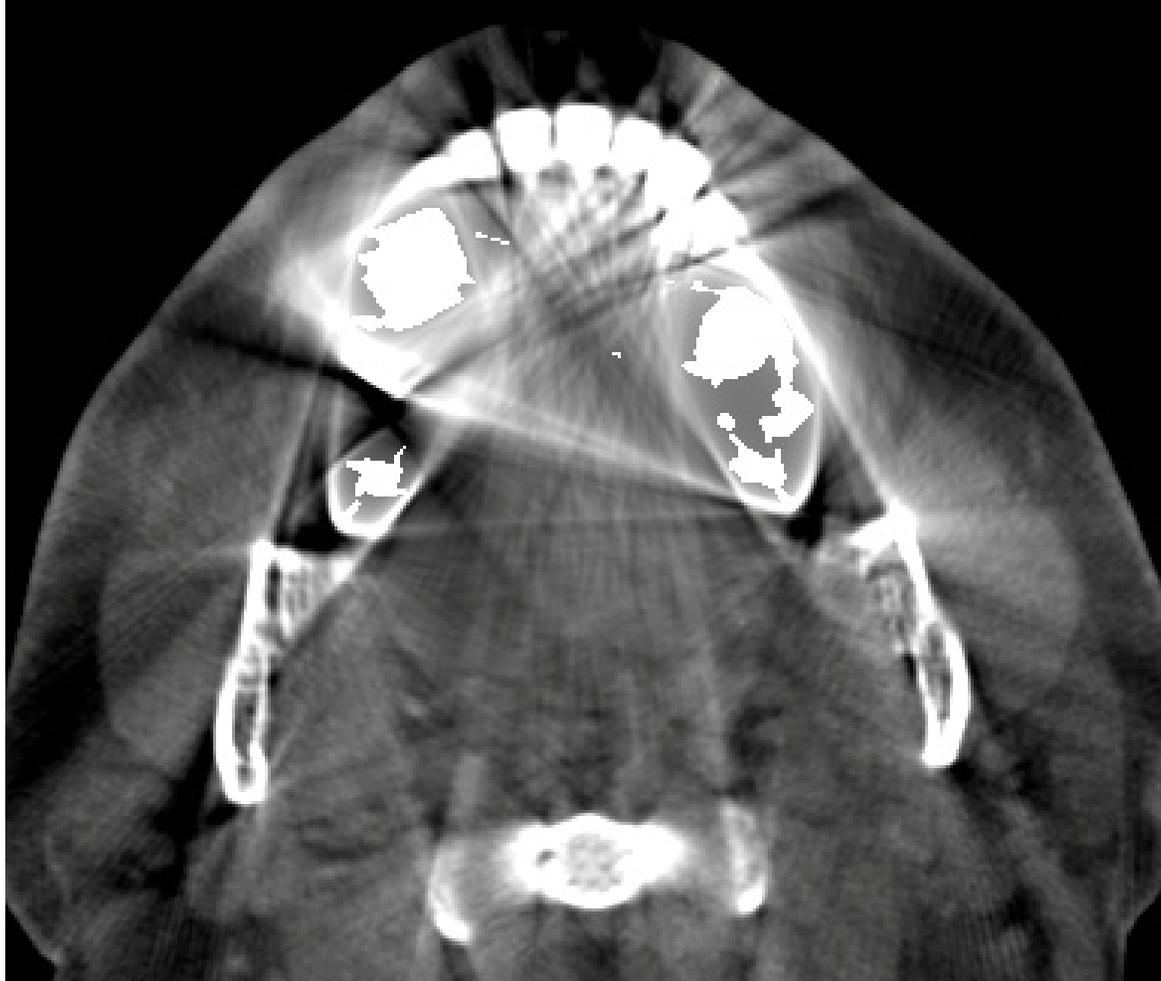
Embolization coils: MDT



Dental fillings: FBP



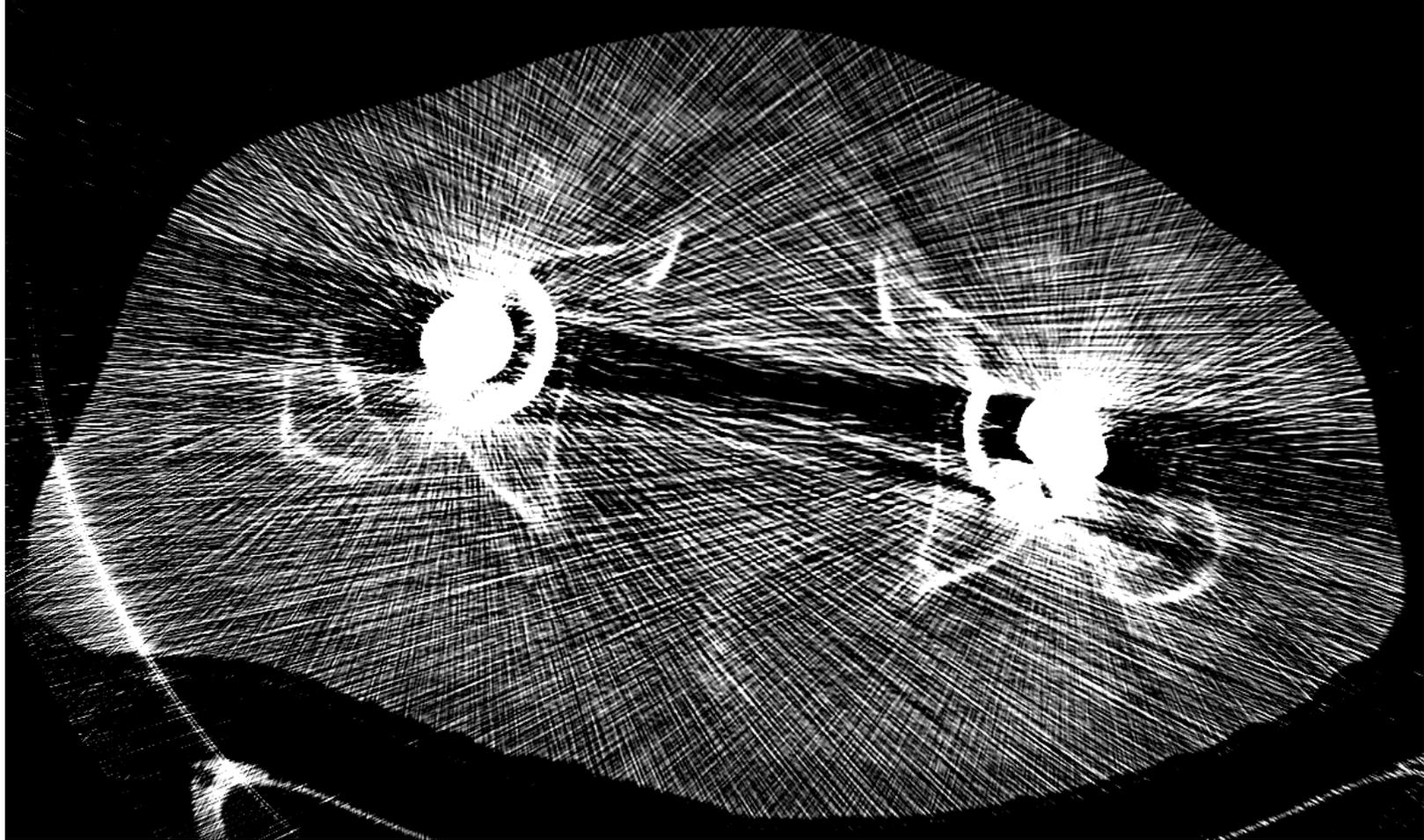
Dental fillings: LI



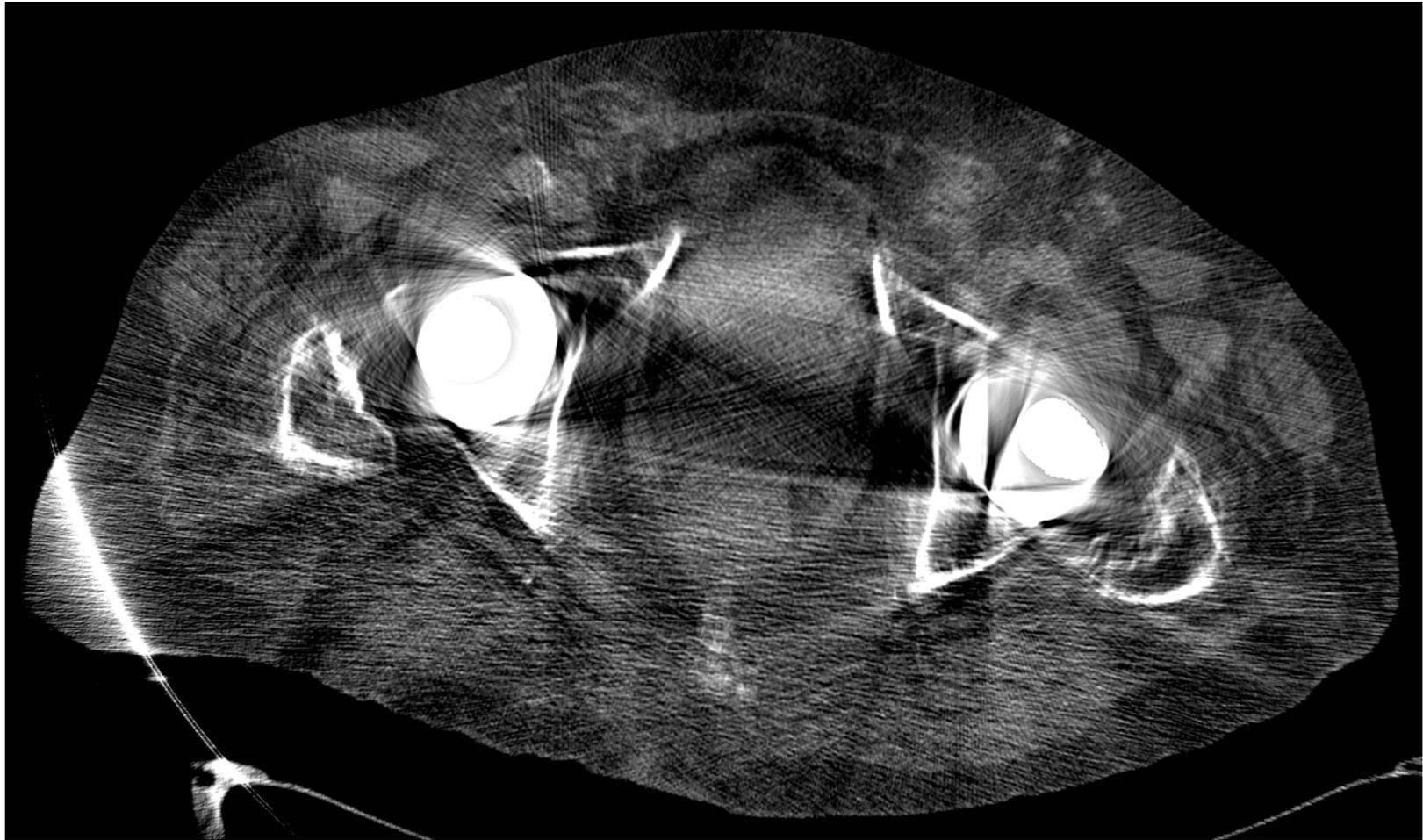
Dental fillings: MDT



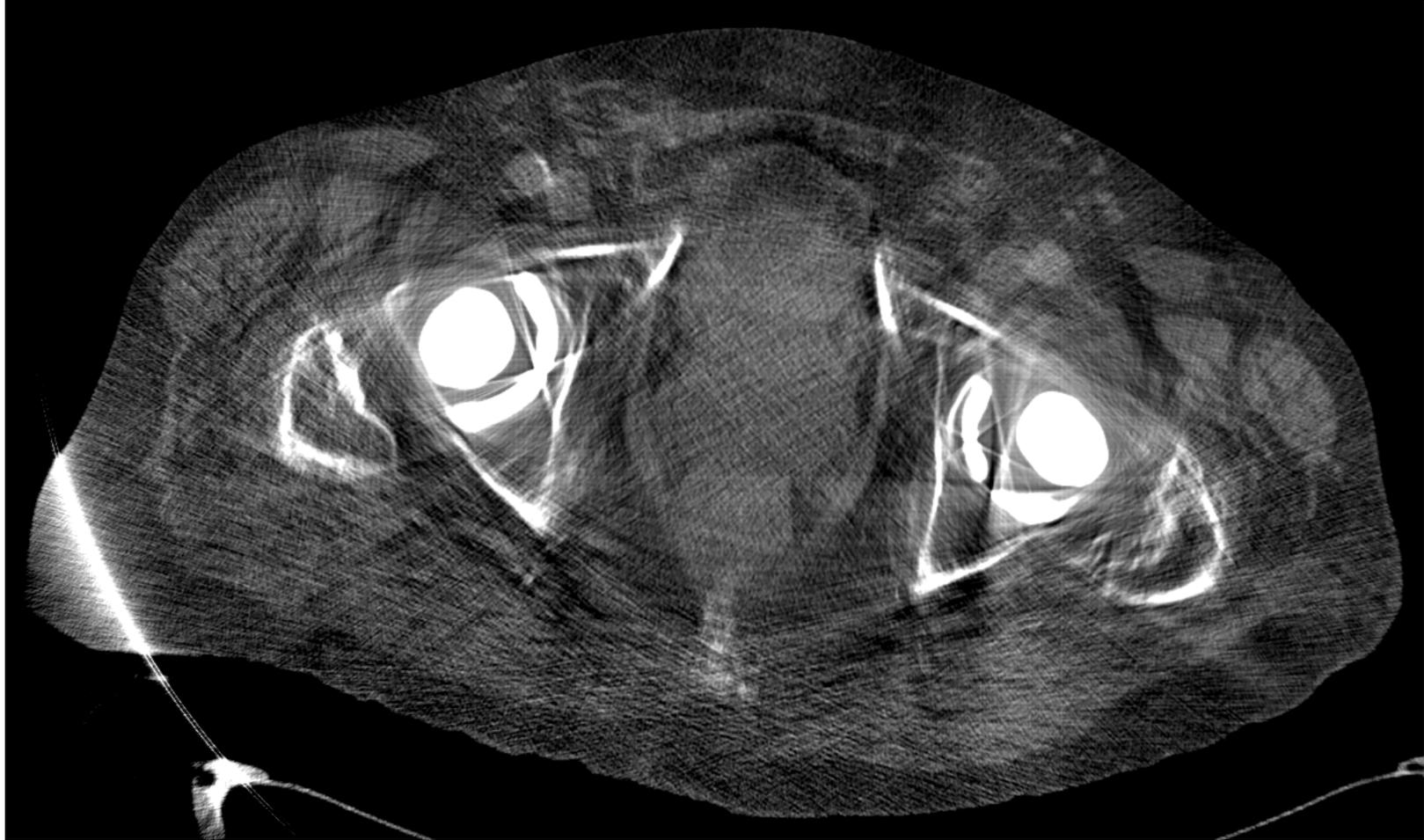
Hip replacements: FBP



Hip replacements: LI

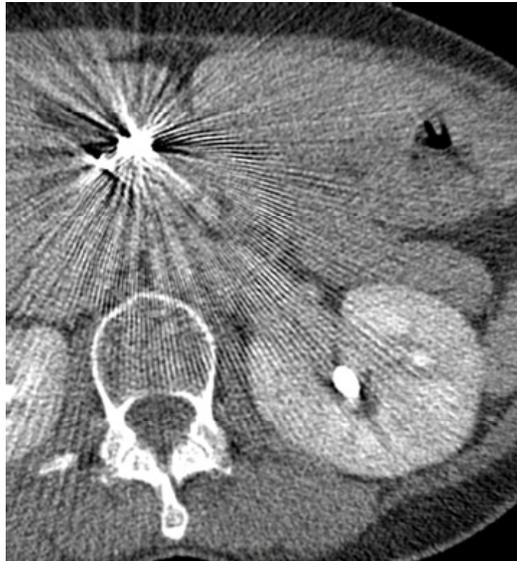


Hip replacements: MDT



MDT reduces metal artifacts

FBP



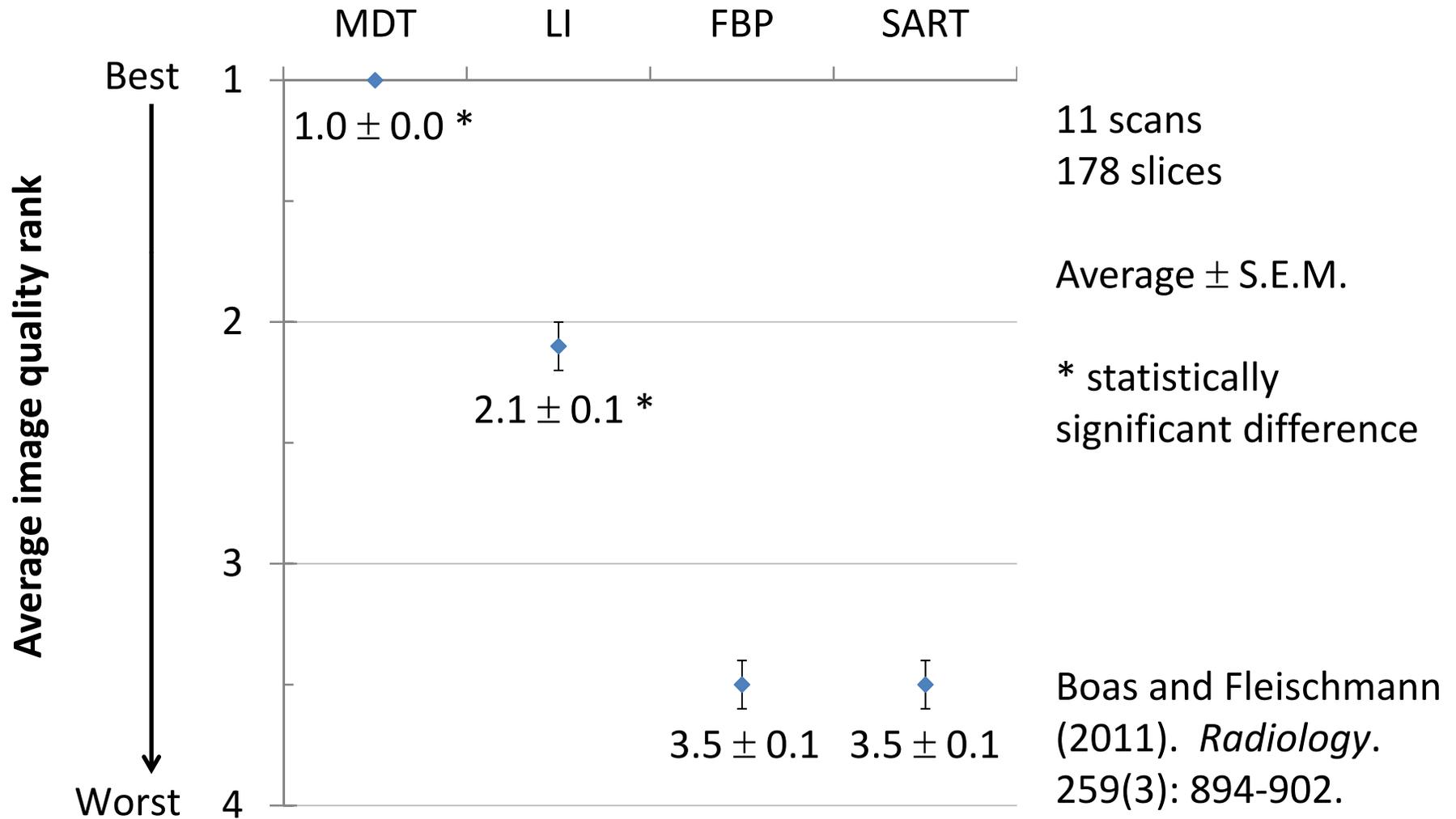
LI



MDT



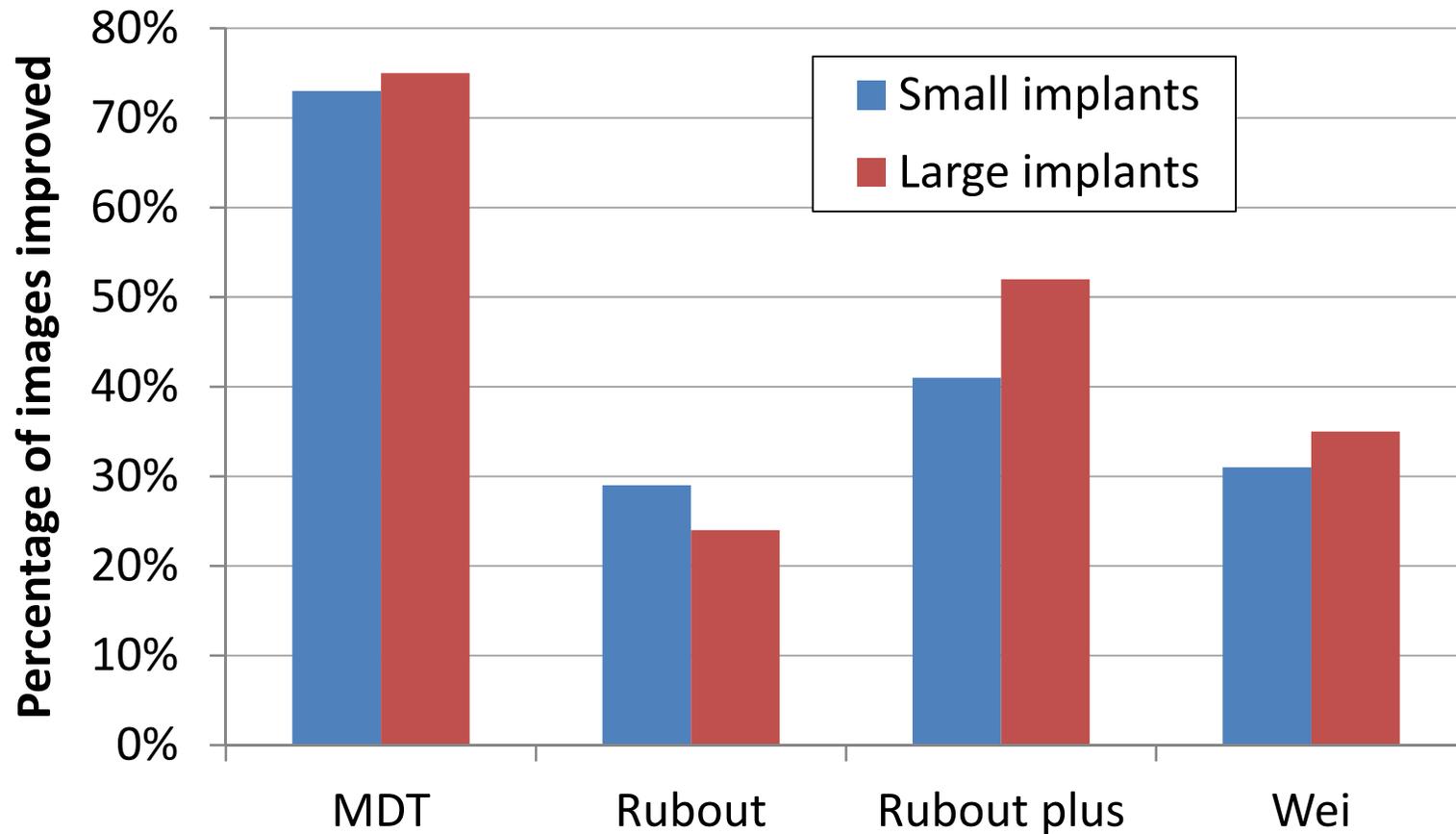
Image quality rank (raw data)



Metal artifact reduction from DICOM

If raw data is not available, it can be simulated by forward projecting DICOM files generated by the scanner.

Improved image quality (DICOM)



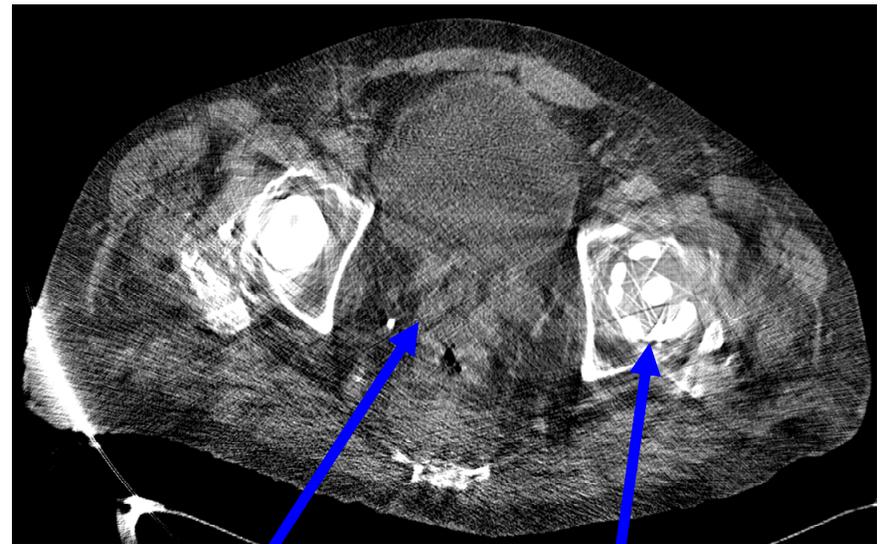
80 slices. Data from Caroline Golden, Sam Mazin, et al. *Proc. SPIE*. 7961: 79612Y

Improved diagnosis

FBP



MDT

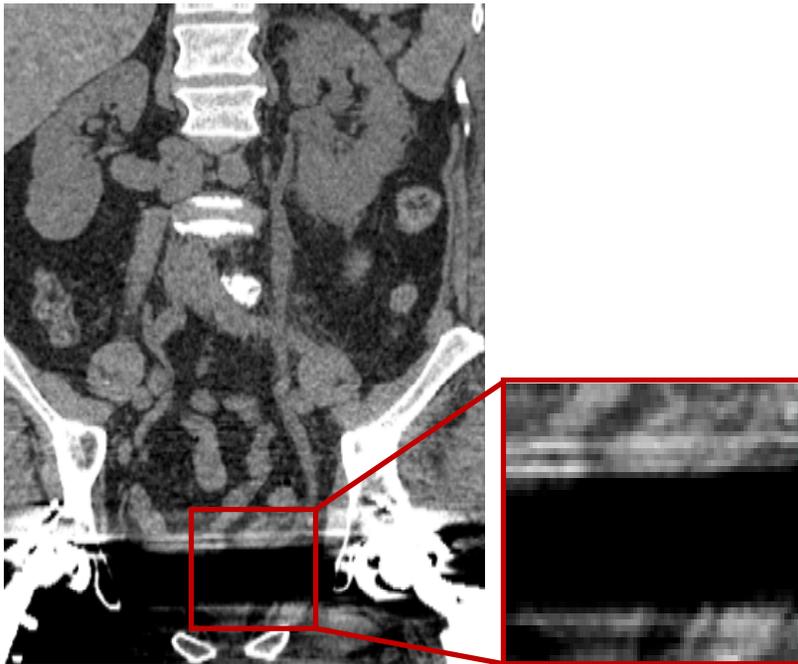


Rectal cancer

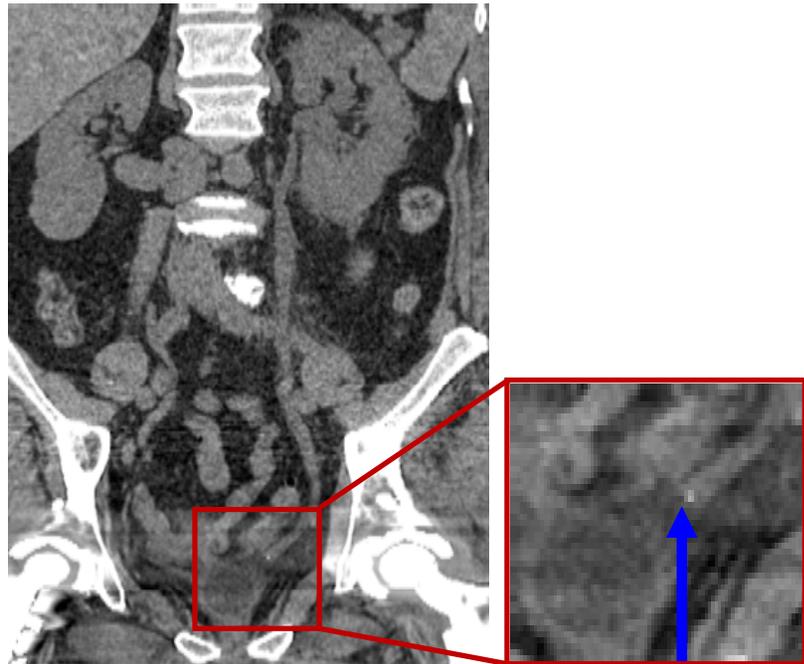
Hip replacement

Improved diagnosis (DICOM)

FBP



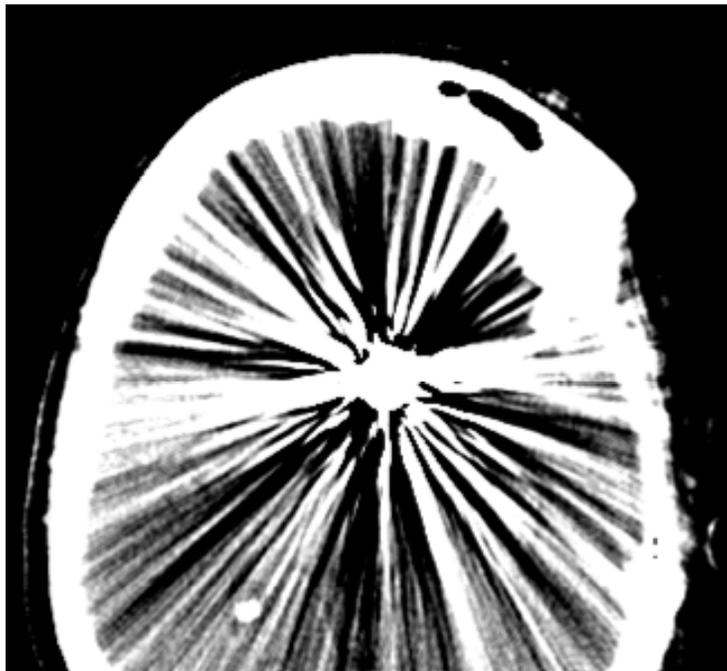
MDT



Obstructing stone

Improved diagnosis (DICOM)

FBP



MDT



Infarct

Aneurysm coil

Improved diagnosis (DICOM)

FBP



MDT

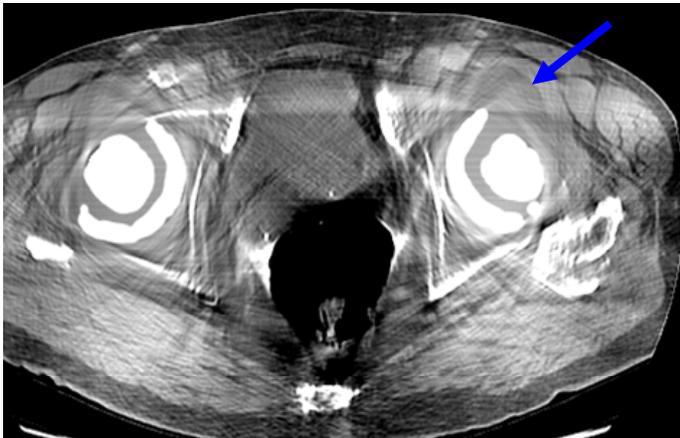
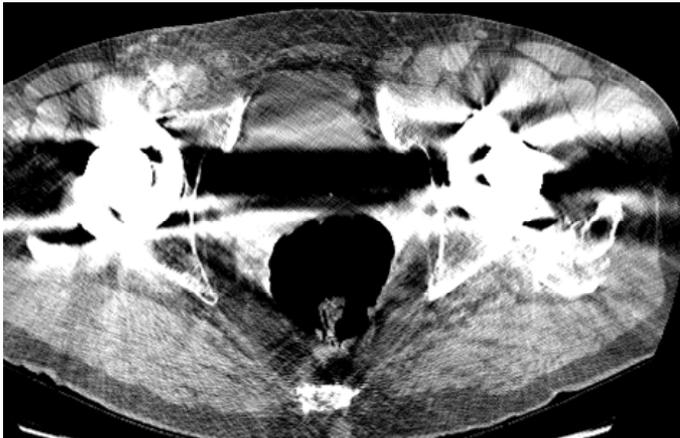


Coil

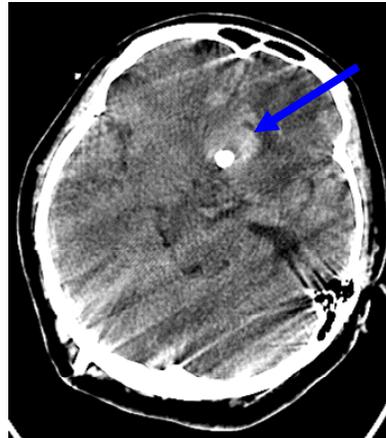
Hemorrhage

MDT reduces metal artifacts caused by multiple different mechanisms

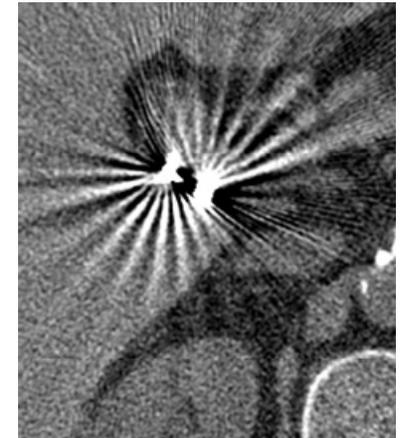
Beam hardening and scatter



Motion and undersampling



Windmill



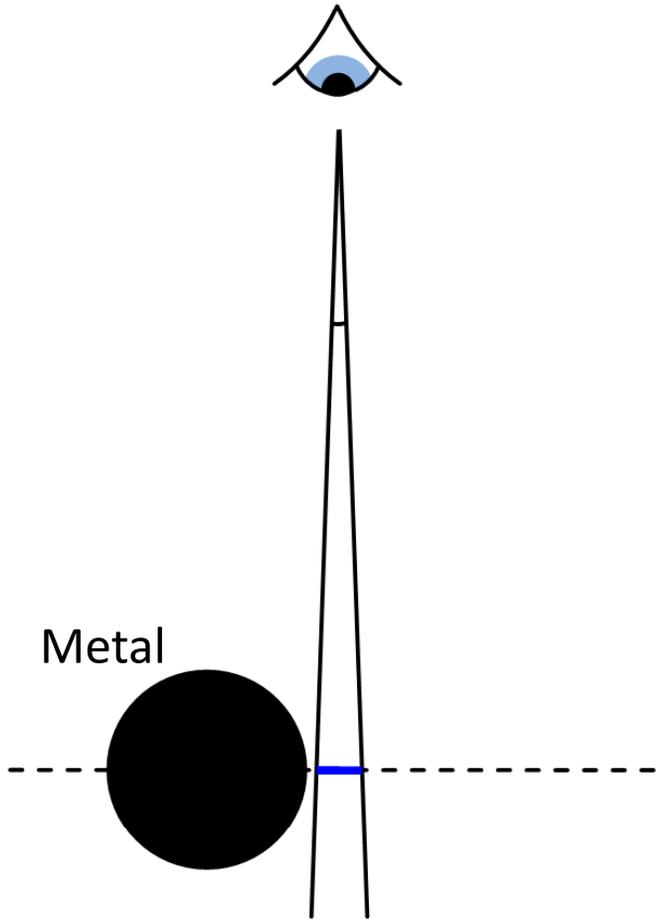
MDT performance by implant type

Improved in $\geq 75\%$ of cases		Improved in $< 75\%$ of cases
aneurysm clip (brain)	shoulder replacement	pedicle screws
aneurysm coil (brain)	hip replacement	depth electrodes (brain)
dental fillings	knee replacement	cryoablation probes
pacer wire	orthopedic plate(s)	iodinated contrast
ventricular assist device	femoral neck screw	
surgical clip(s)	spinal rods	
embolization coil(s)		
bullet(s) / schrapnel /		
lead shot		

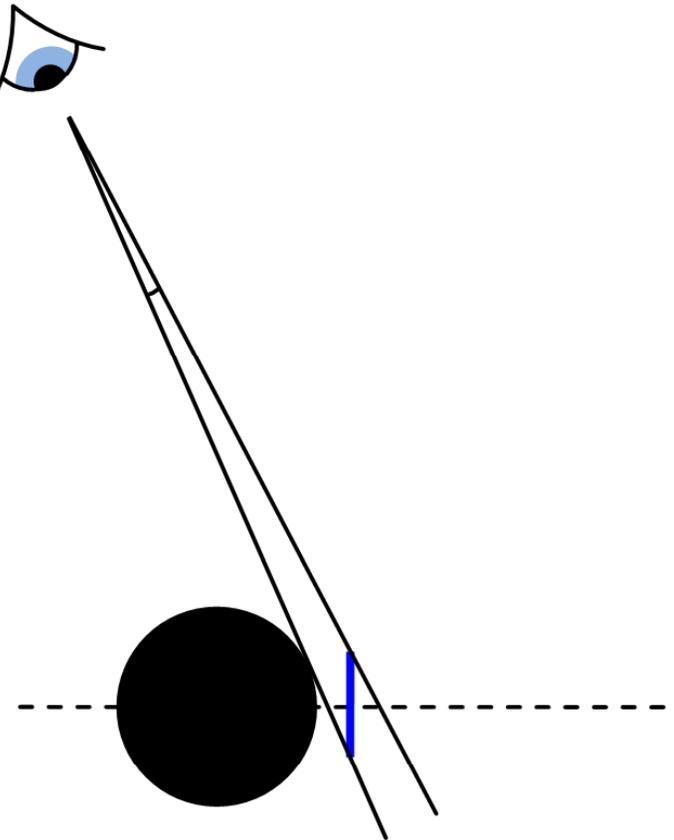
Based on a review of 102 cases.
 Boas and Fleischmann (2012). *Imaging in Medicine*. In press.

Decreased resolution near metal

Horizontal resolution

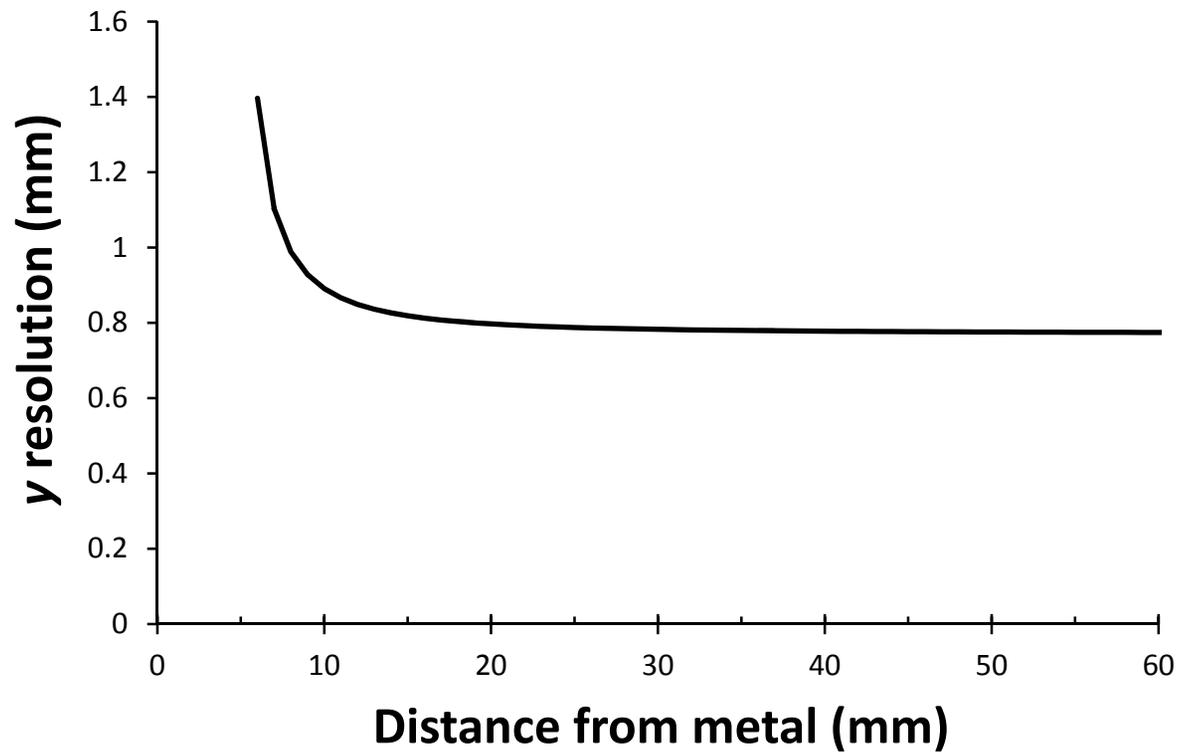


Vertical resolution

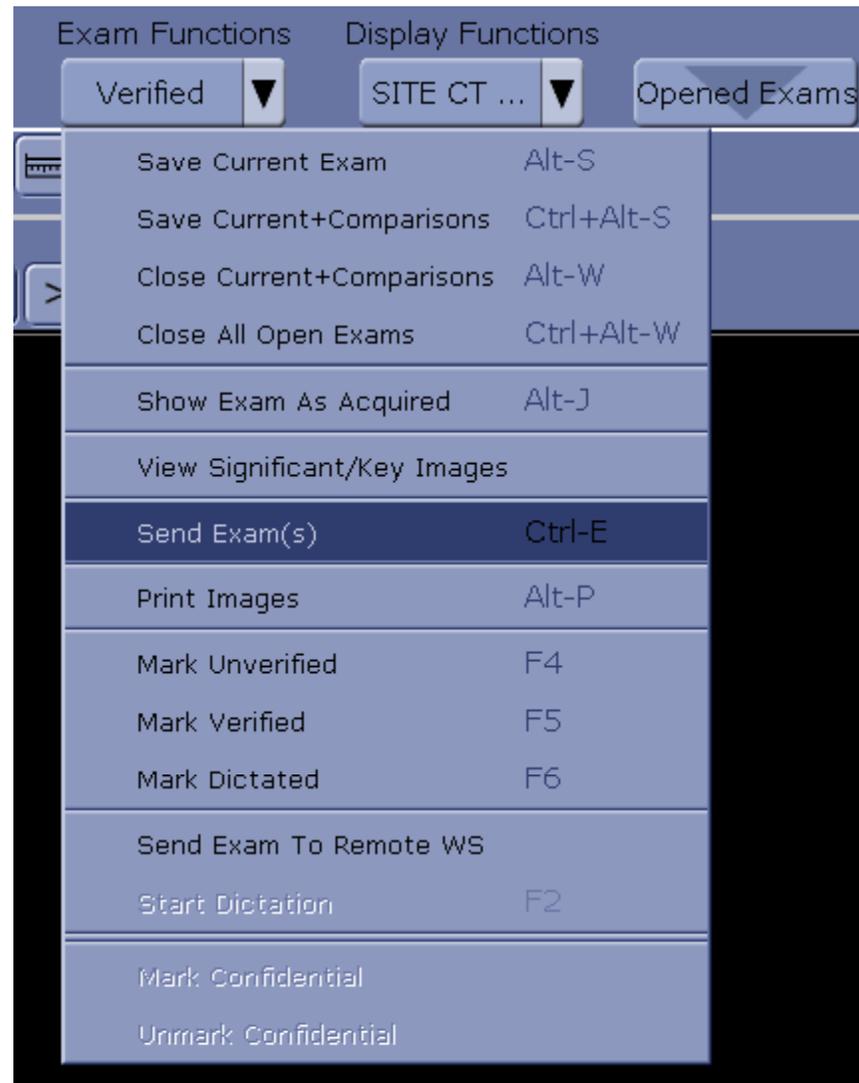


Decreased resolution near metal

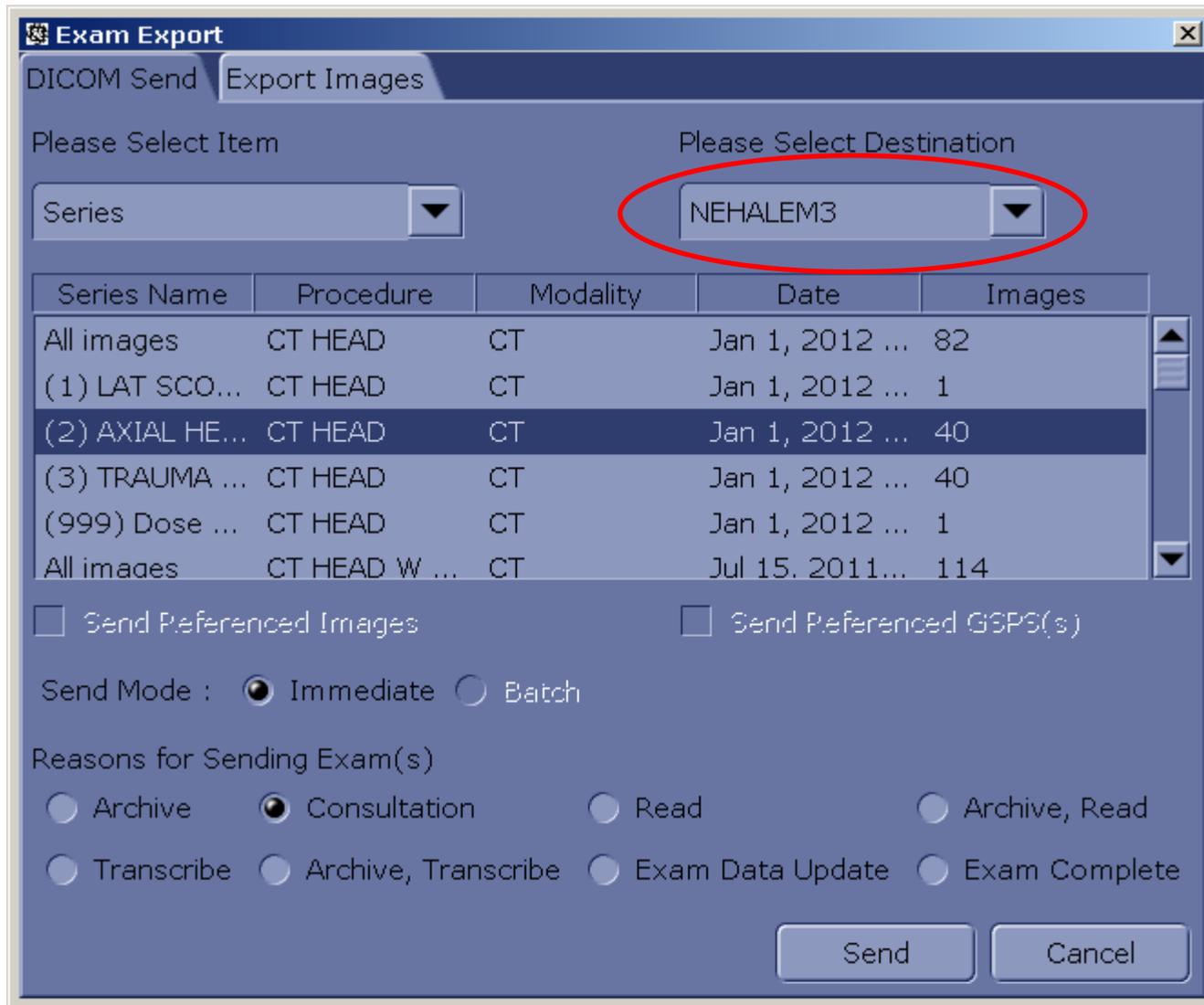
Resolution near a 10 mm metal implant



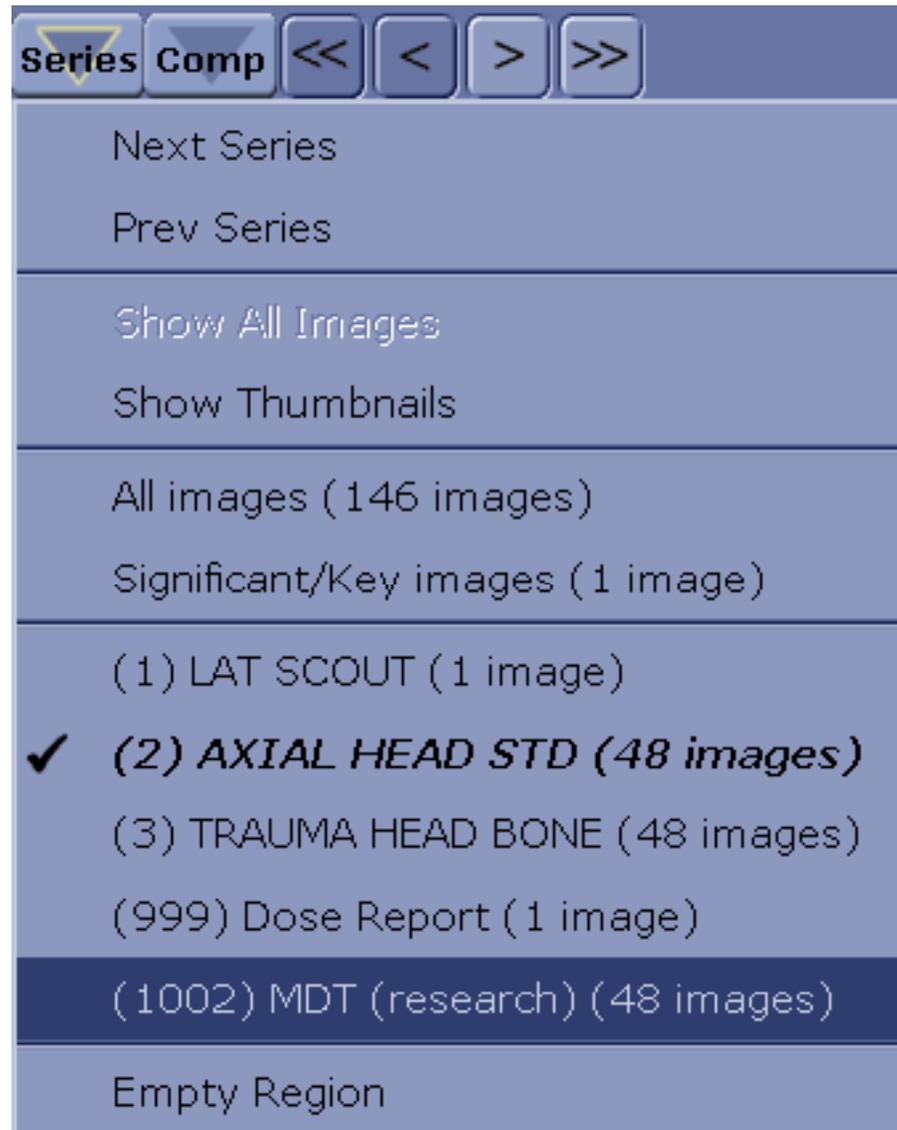
Integration with PACS



Integration with PACS



Integration with PACS



Clinical use of MDT

- 315 cases at Stanford
- 39 hospitals, of which 16 have licensed MDT for local use



Conclusions (MDT)

1. MDT reduces metal artifacts due to Poisson noise, beam hardening, and motion.
2. MDT has better image quality than other techniques ($p=0.0005$), and may change the diagnosis.
3. MDT works on a variety of scans, from hip replacements to moving pacer wires.

MDT development timeline

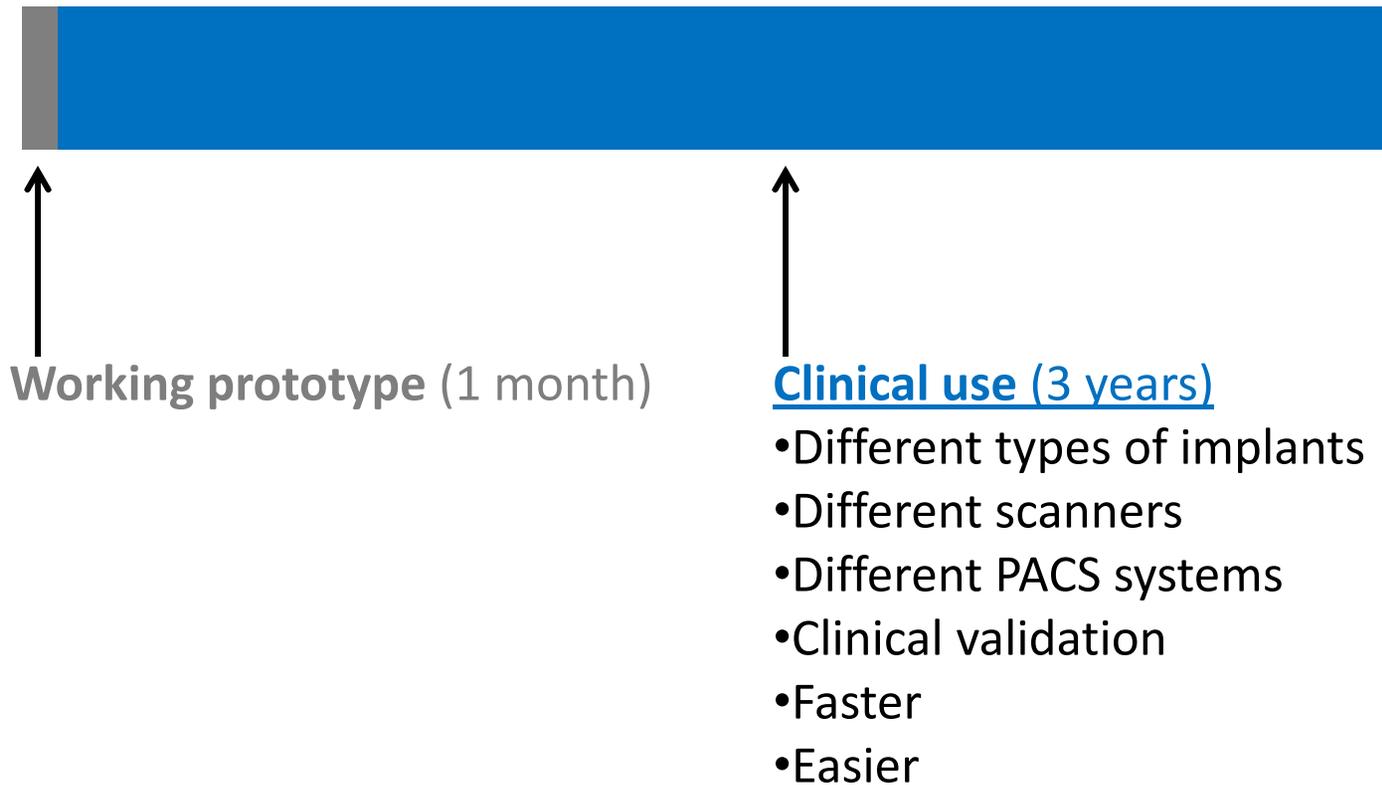
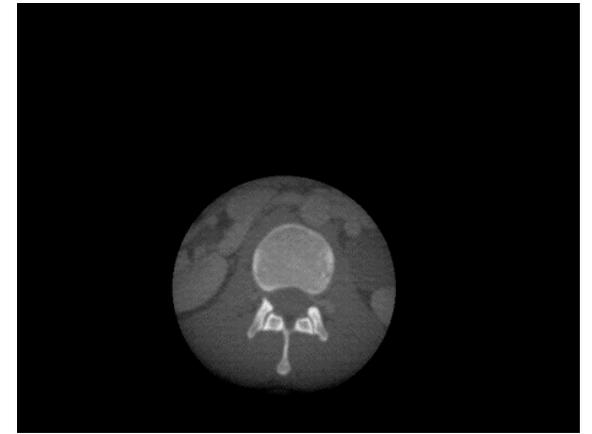
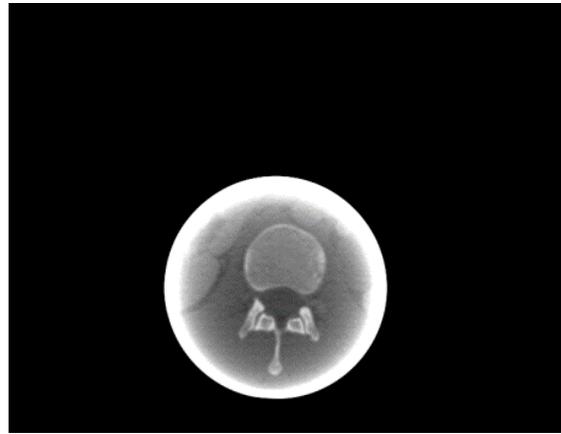
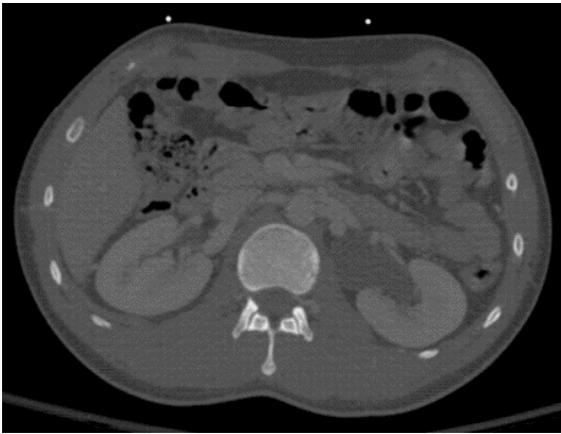


Image reconstruction and post-processing

- CT metal artifact reduction
- **Limited field of view CT**
- Noise reduction
- TACE planning tool
- Color liver perfusion imaging

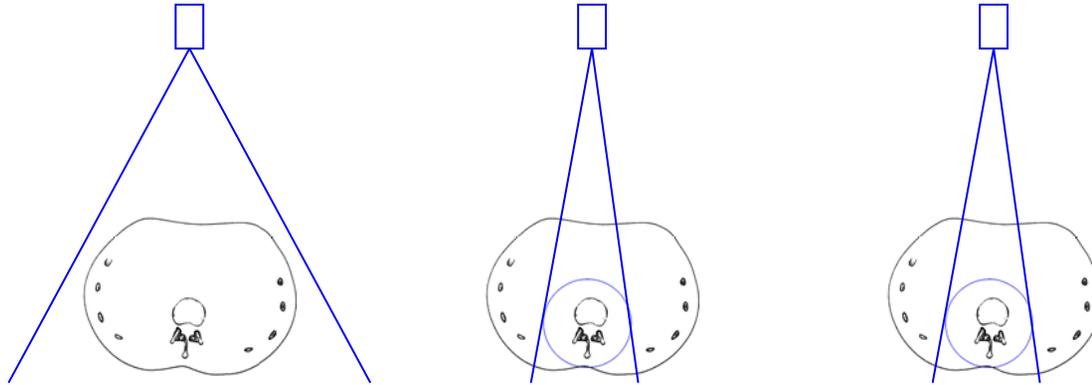
Limited field of view scans



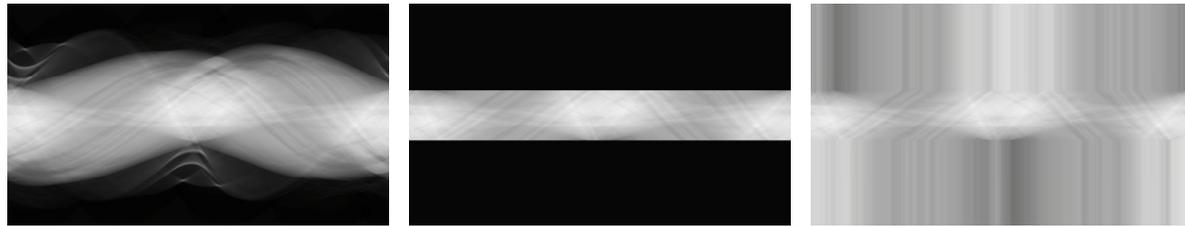
Boas and Fleischmann (2012). *Imaging in Medicine*. In press.

Limited field of view scans

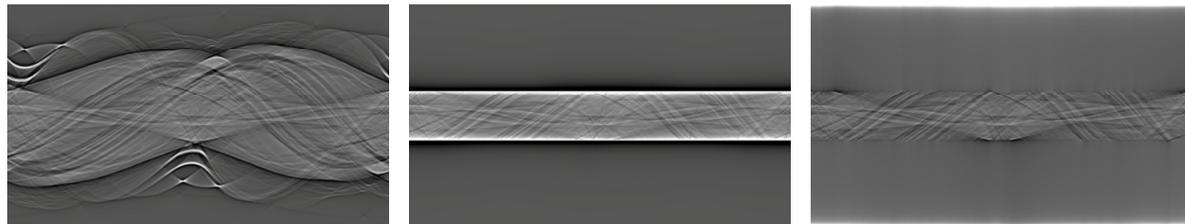
Field of view



Sinogram



Filtered sinogram



Reconstructed image

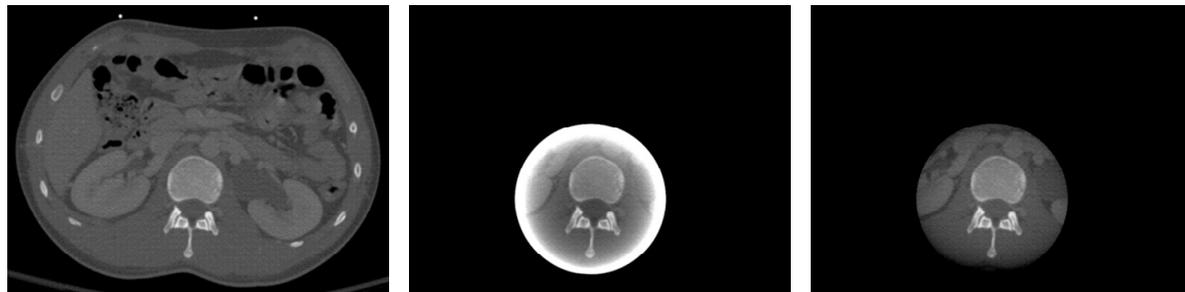


Image reconstruction and post-processing

- CT metal artifact reduction
- Limited field of view CT
- **Noise reduction**
- TACE planning tool
- Color liver perfusion imaging

HYPR for noise reduction

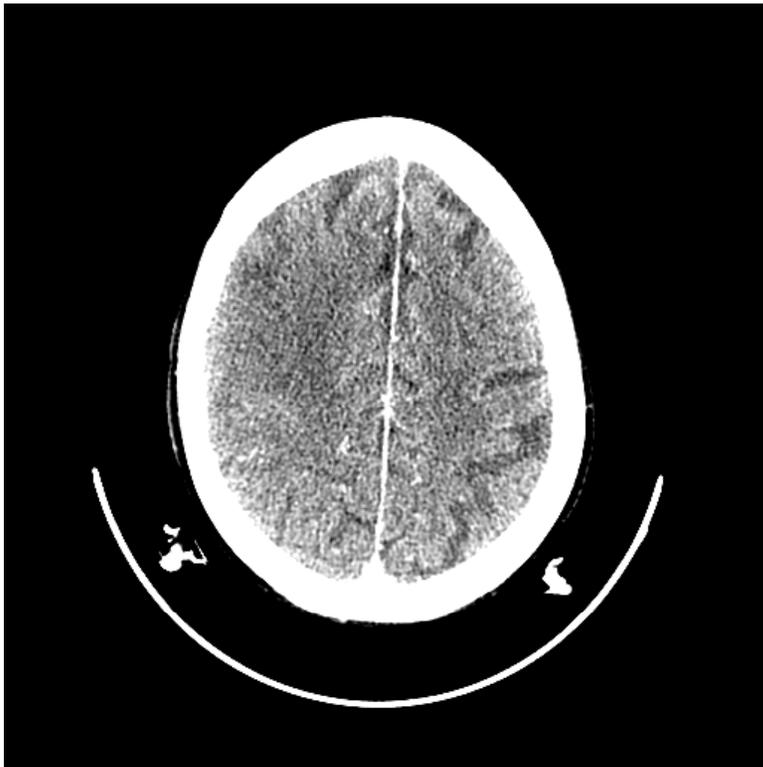
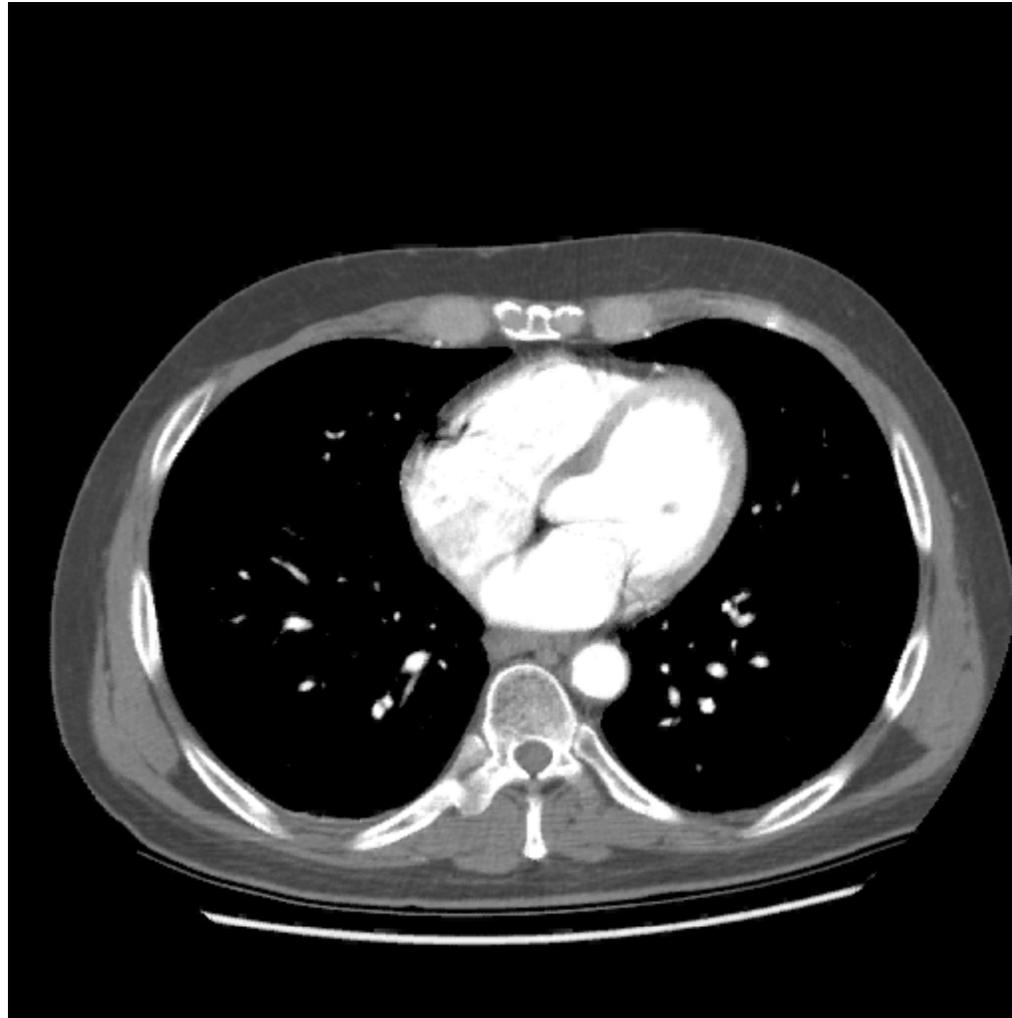


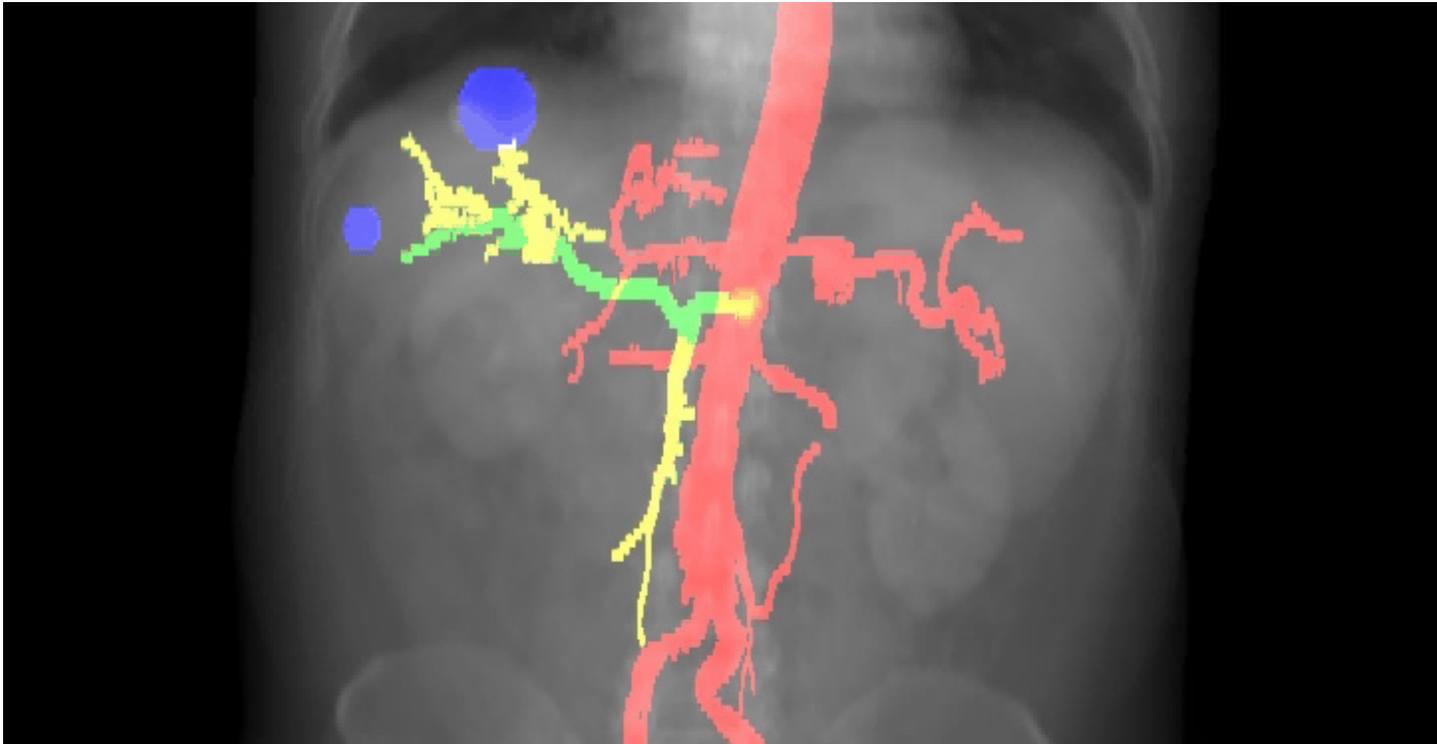
Image reconstruction and post-processing

- CT metal artifact reduction
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- Noise reduction
- **TACE planning tool**
- Color liver perfusion imaging

TACE planning tool



TACE planning tool



Target legions

Path to target

SMA angiogram

Aortic angiogram

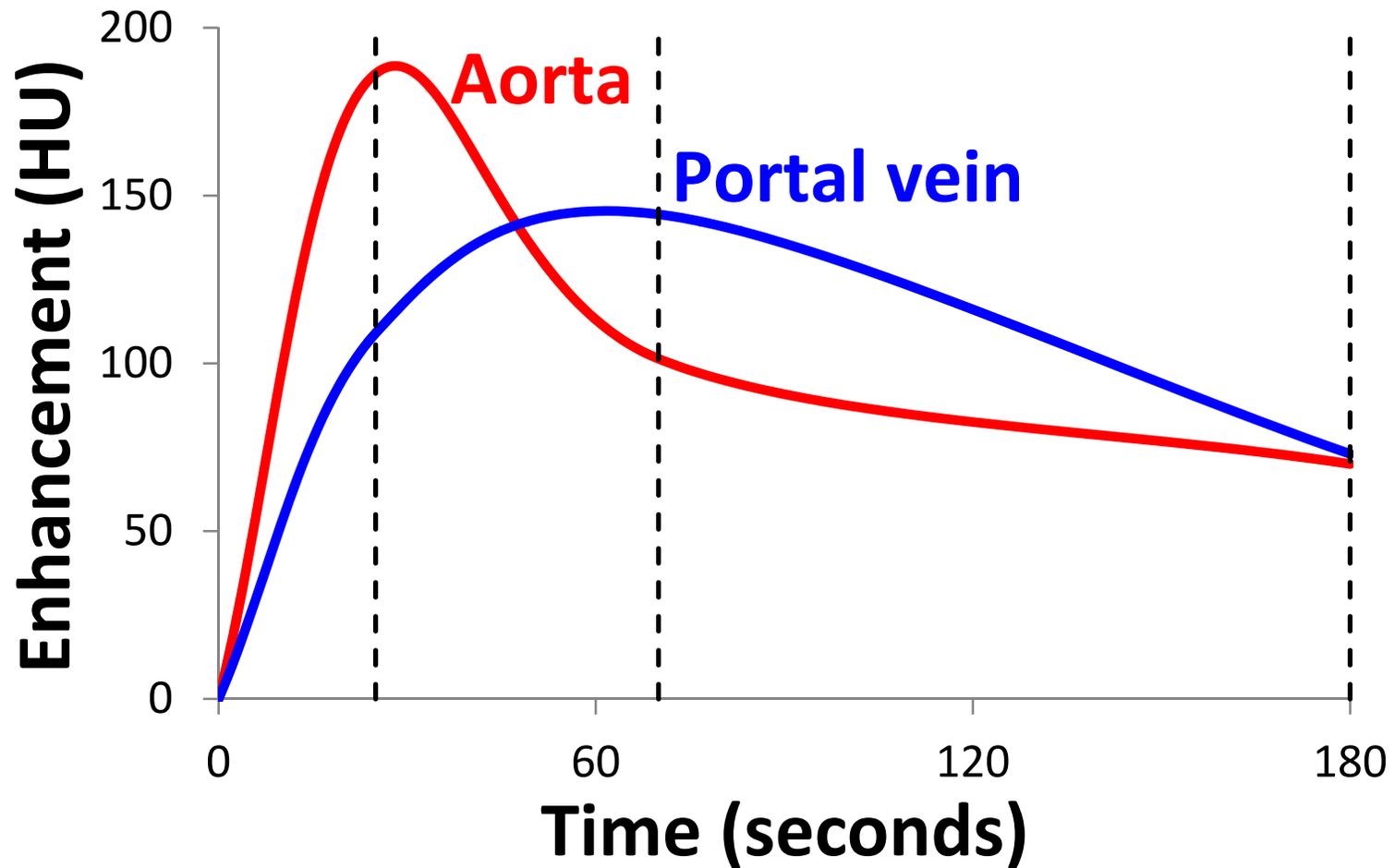
Image reconstruction and post-processing

- CT metal artifact reduction
- Limited field of view CT
- Noise reduction
- TACE planning tool
- **Color liver perfusion imaging**

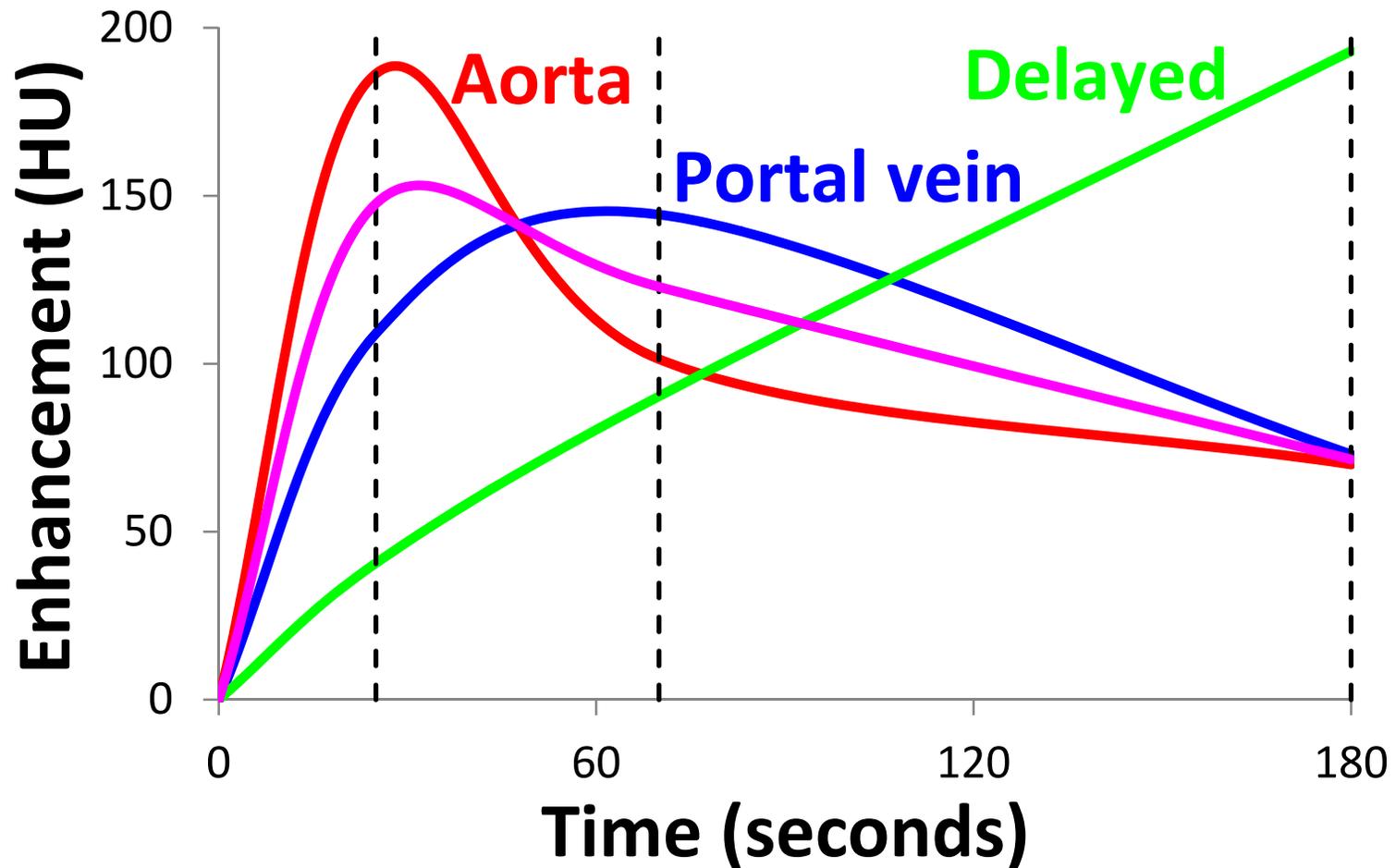
Color liver perfusion imaging

	Portal vein	Hepatic artery
Normal liver	80%	20%
HCC	37%	63%

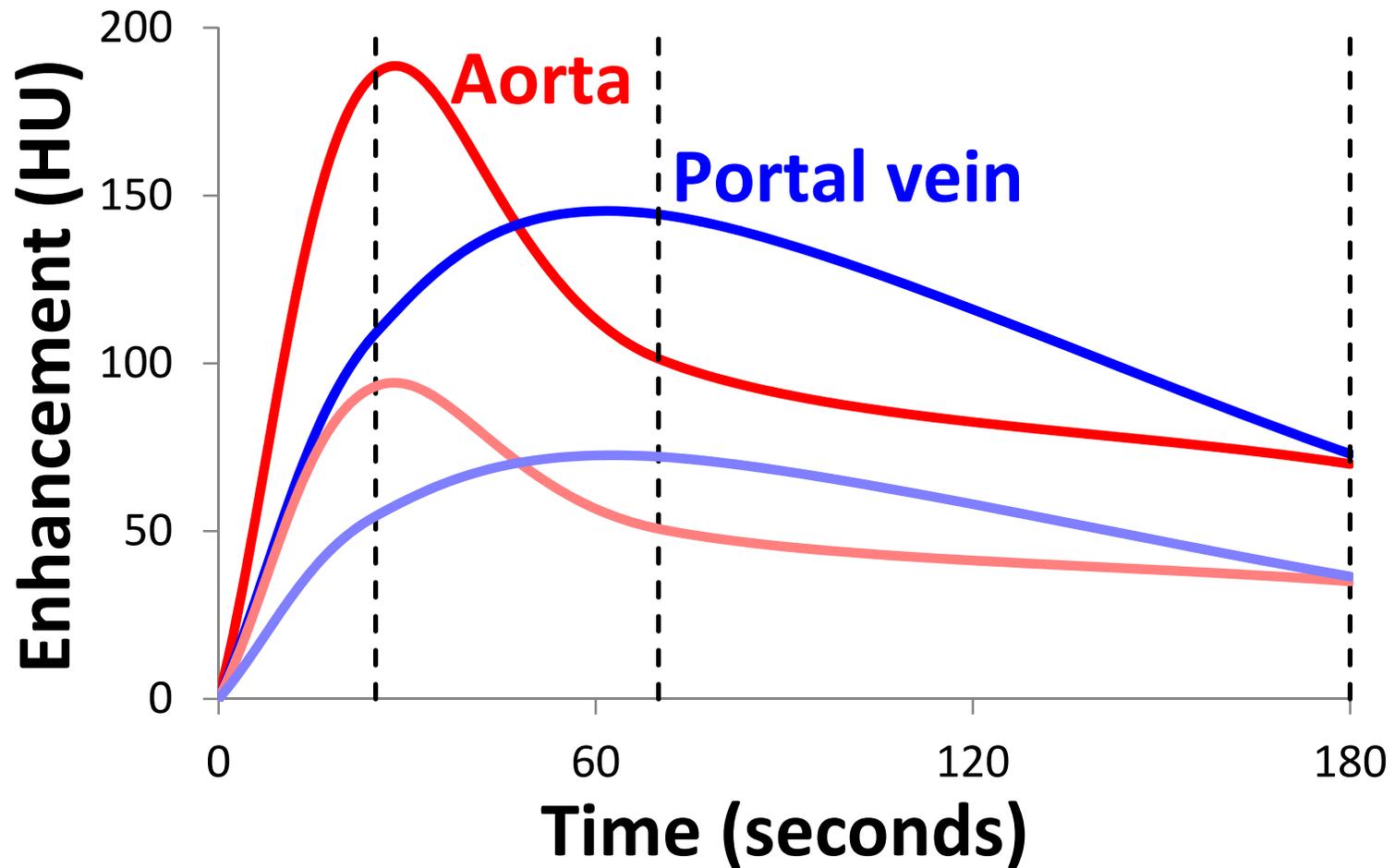
Color liver perfusion imaging



Color liver perfusion imaging



Color liver perfusion imaging



Color liver perfusion imaging

- Brightness = Hounsfield units
- Color = Phase of enhancement
- Saturation = Degree of enhancement

Enhancement

None —————> Intense



Aortic phase

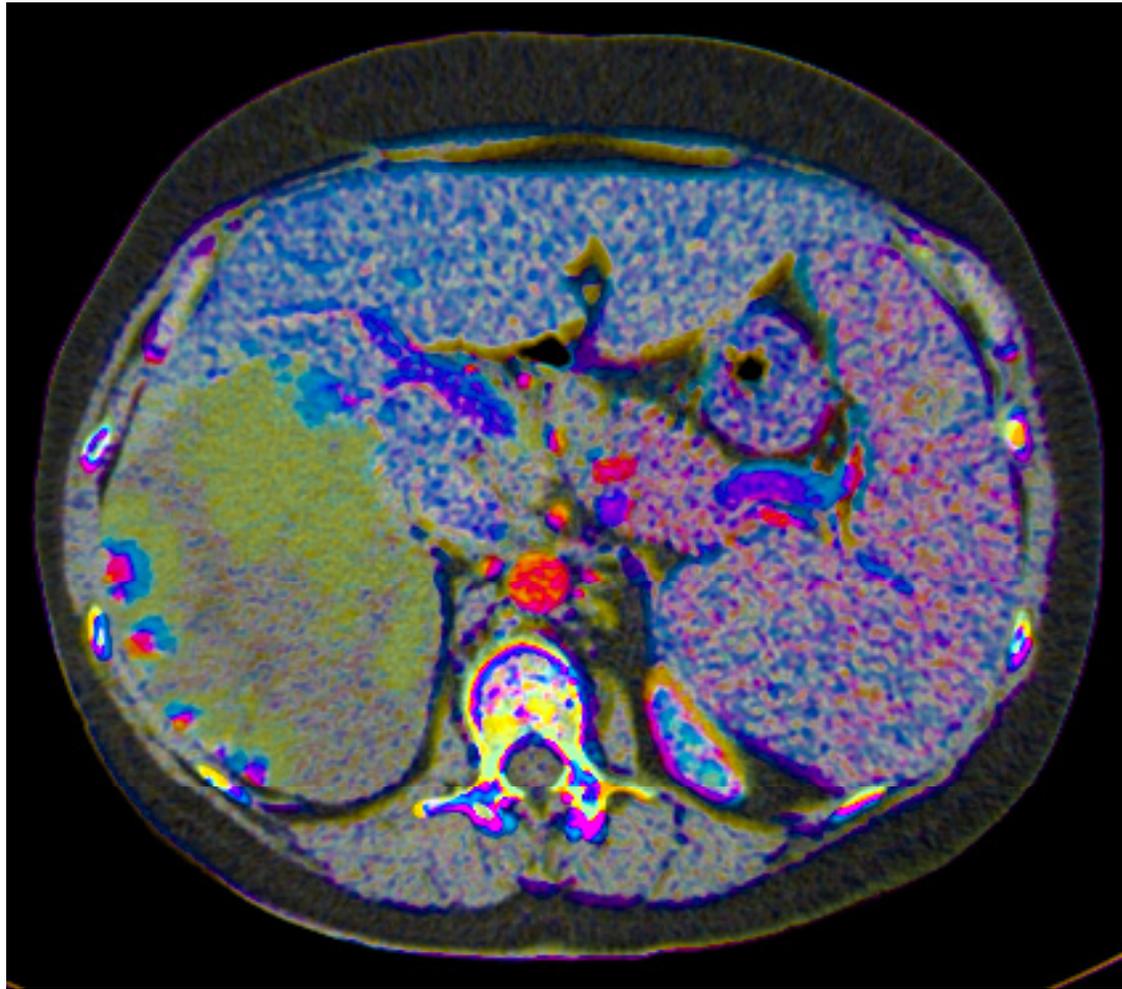


Portal venous phase



Delayed phase

Color liver perfusion imaging



Large hemangioma

Color liver perfusion imaging



HCC

Acknowledgements

Dominik Fleischmann

Roland Bammer

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Rick Kong

Christoph Panknin (Siemens)