Use of 320-slice MDCT in Vascular, Cardiac and Brain Studies: Initial Clinical Experience and Radiation Dose Assessments

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Disclaimer

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Acknowledgements

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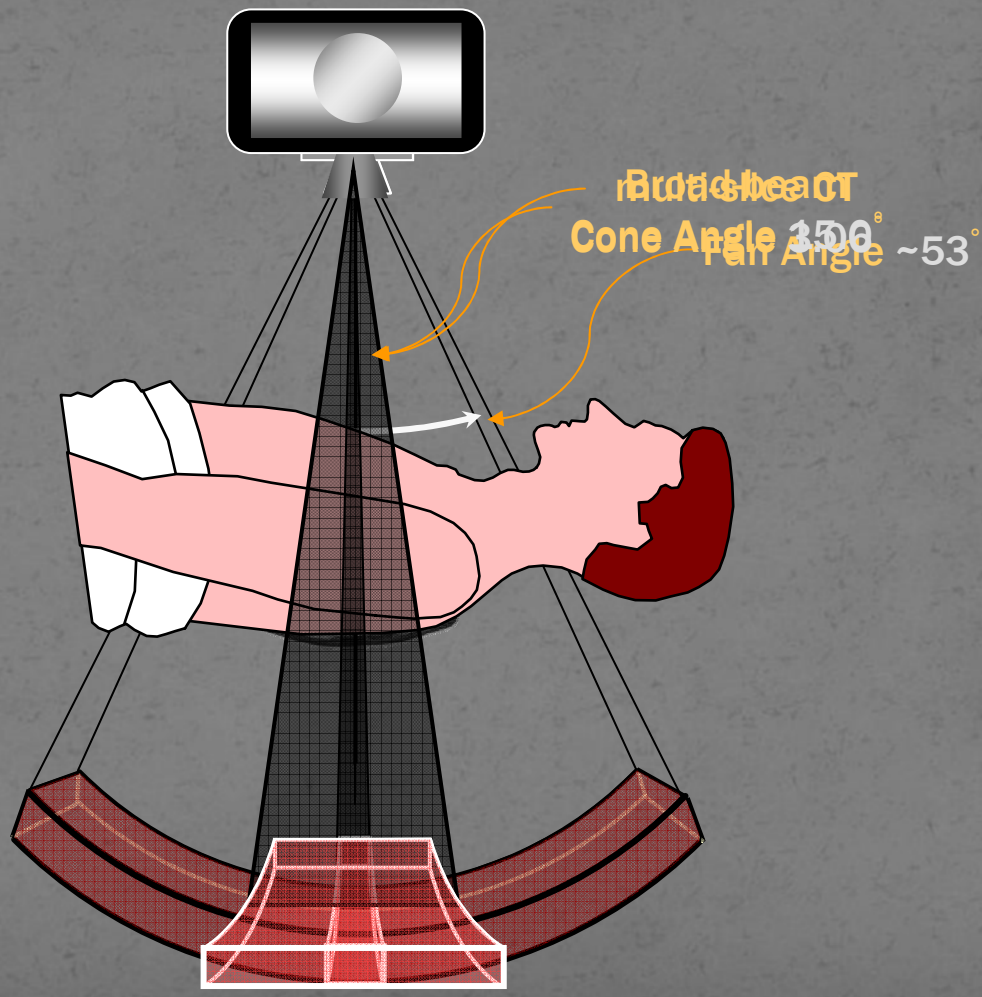
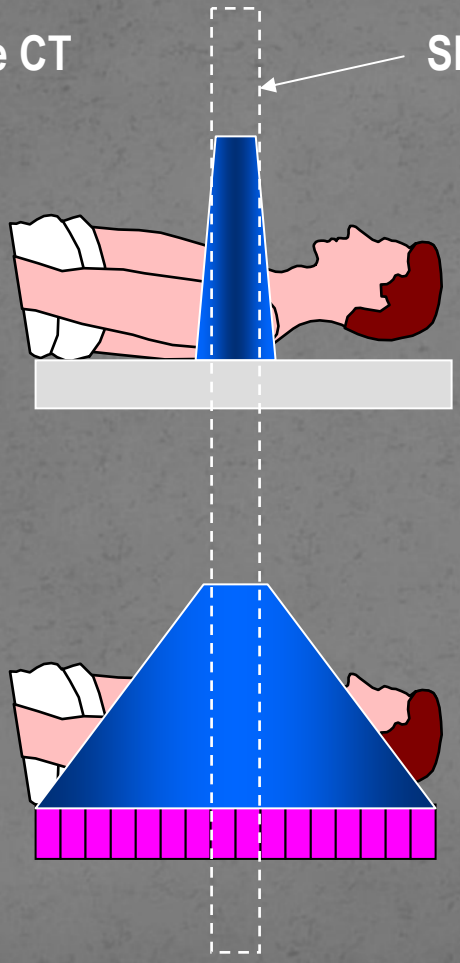
- Meryll Frost, UF PACS Designer/Administrator
- David Hintenlang’s Phantom Lab

Dynamic Volume Technology



Geometrical Issues of Broad Beams

Single Slice CT



1995:
1 x 1 mm @ 0.75 sec/rotation

1998:
4 x 1 mm @ 0.5 sec/rotation

MDCT

2001:
16 x 0.75 mm @ 0.42 sec/rotation

2004:
64 x 0.6 mm @ 0.33 sec/rotation

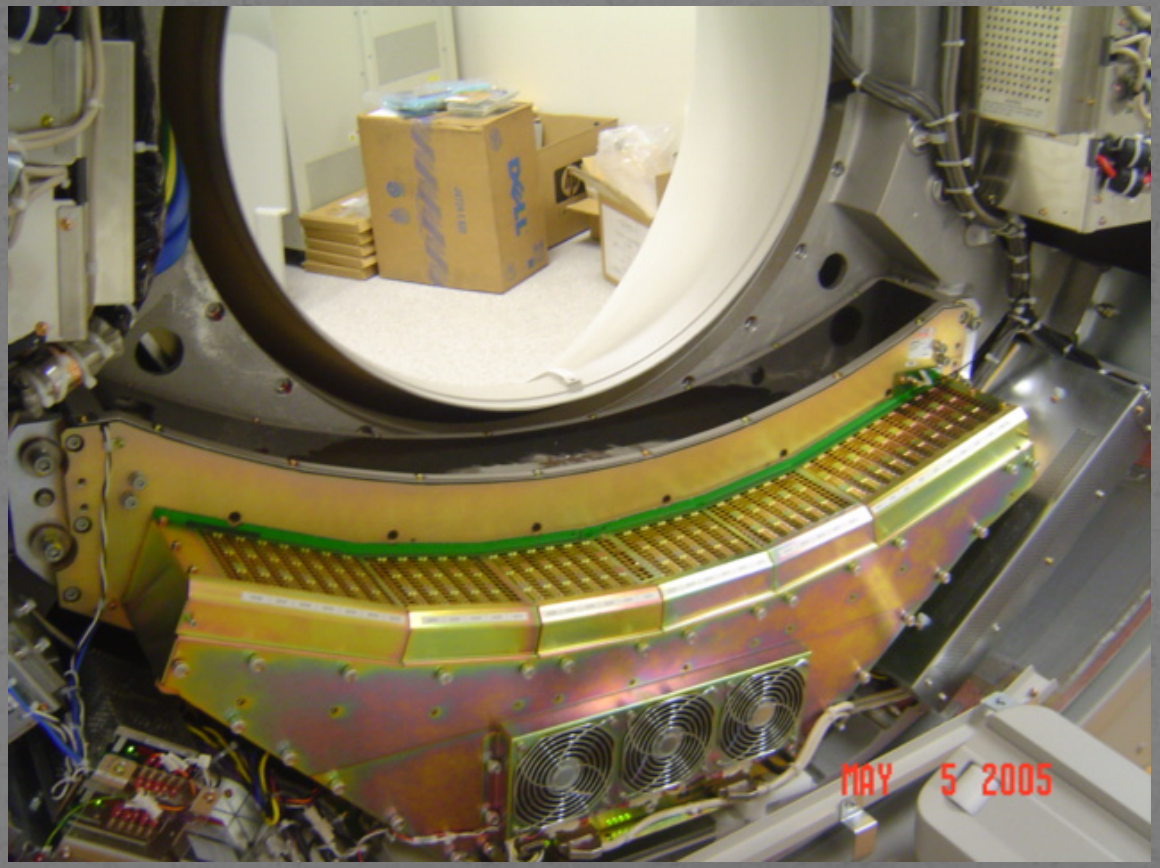
2008:
320 x 0.5 mm @ 0.33 sec/rotation

The Technological Challenges

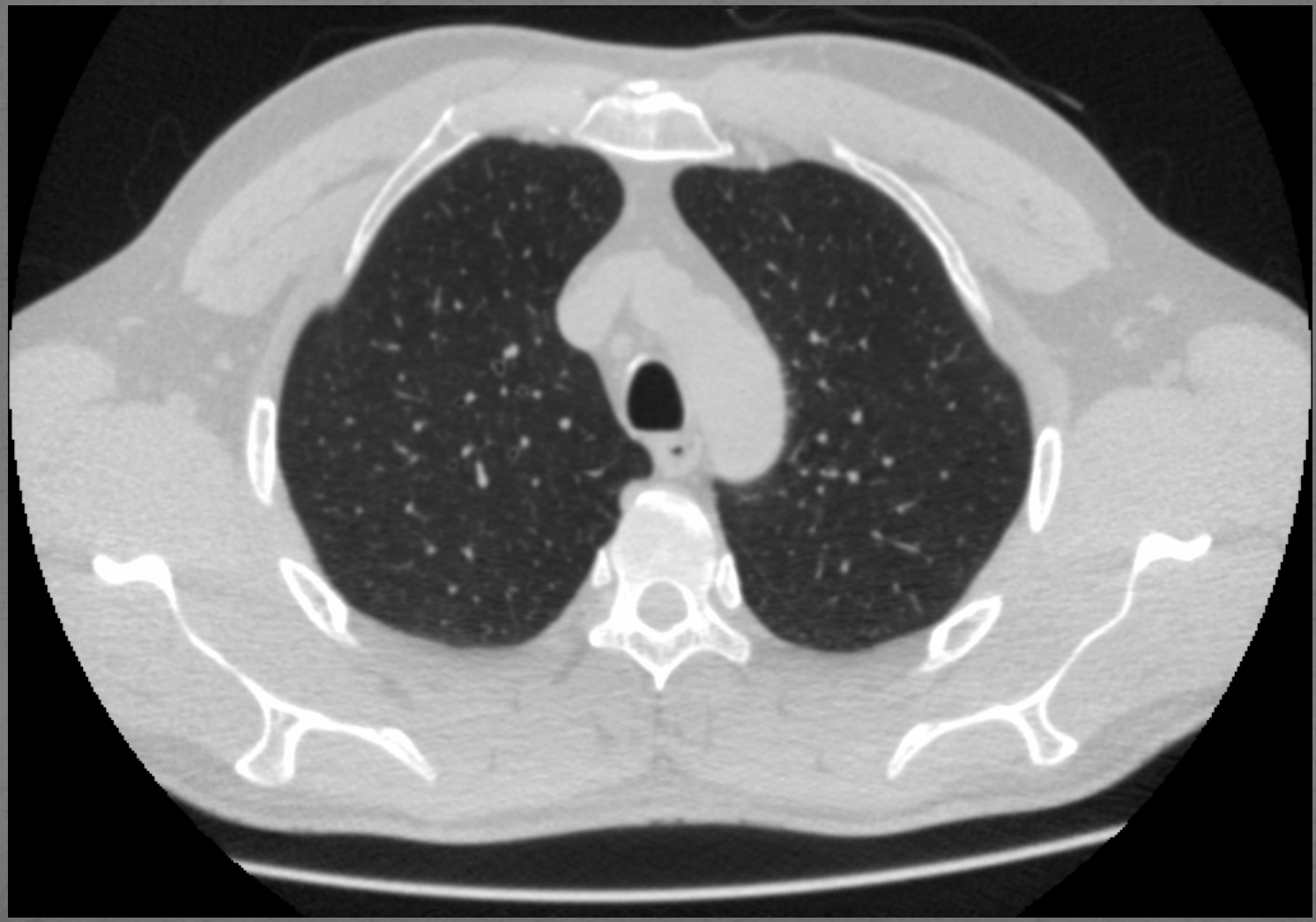
- Mechanical:
  - With ever increasing gantry speeds, there is an extremely high mechanical load on the tube bearings
  - Centrifugal forces in excess of 30g!!
- Electrical Power:
  - A modern CT tube has to sustain 60 – 80 kW for up to 20 s on a focal spot as small as 1.3x10 mm
  - In going to 300 ms rotations or shorter, heat load issues may appear
- Detector Array:
  - High absorption efficiency
  - High geometric efficiency
  - Fast response (i.e., short ”dead-time”)

30g Forces!!??

Detector is Most Expensive Component of MDCT Scanners

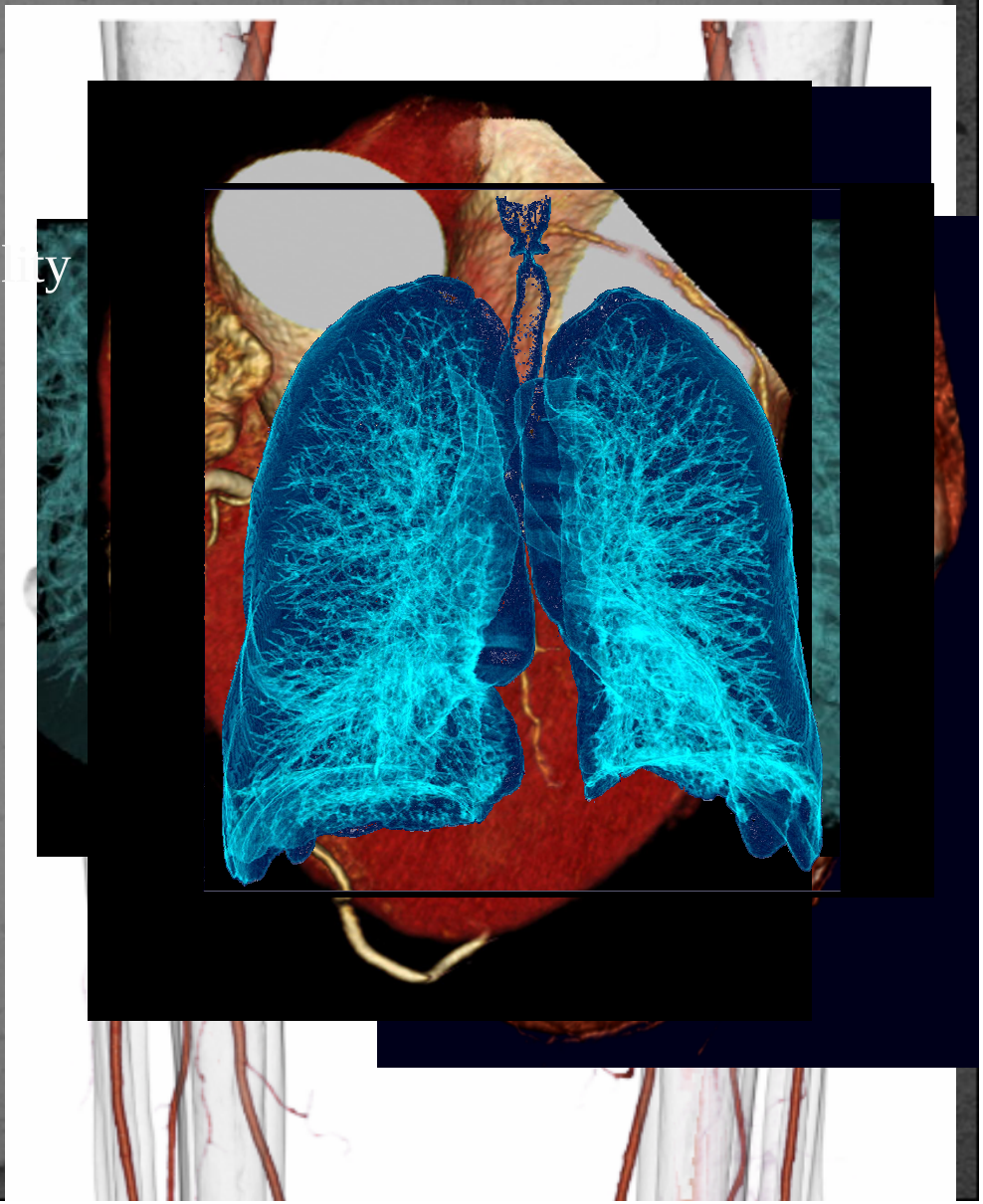


Bronchial Reconstruction

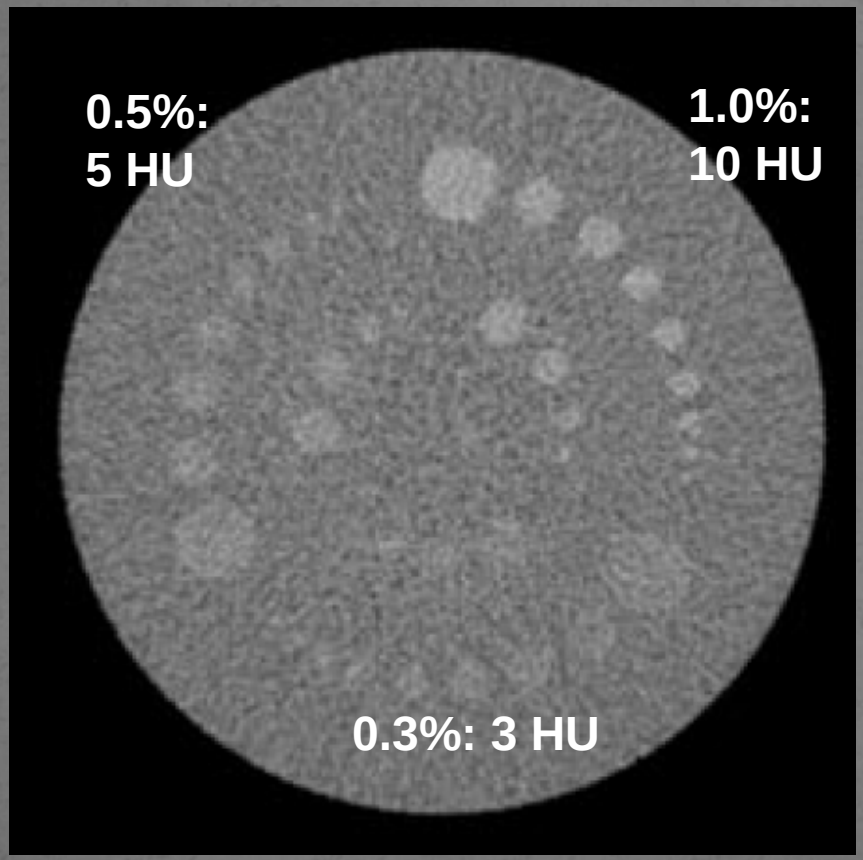


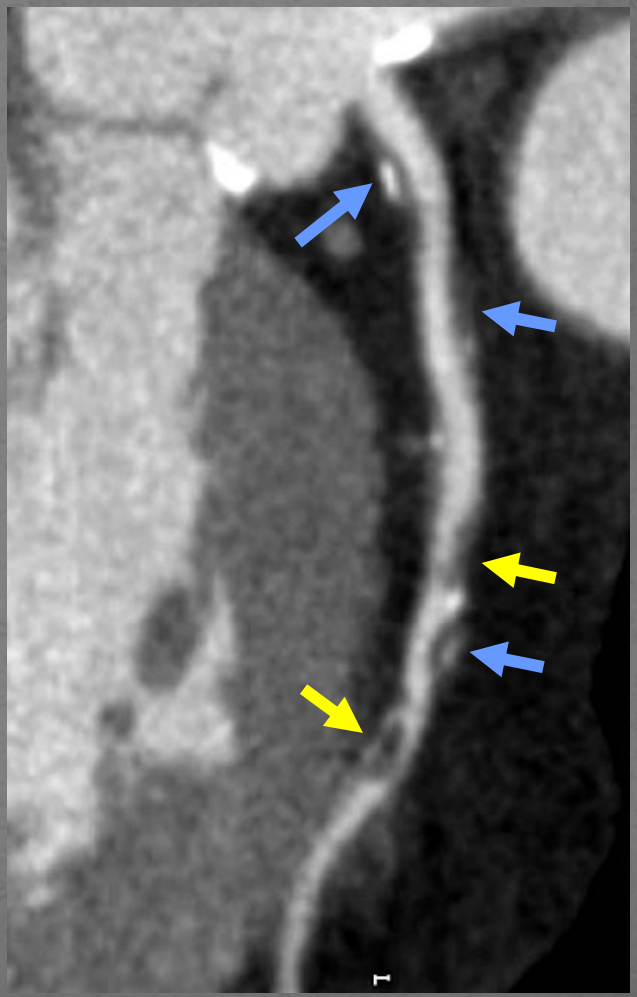
Demands of CT Imaging 64-slice and Beyond

- **Image Quality**
  - Improved Low Contrast Detectability
  - Extended Volume Coverage
  - Improved Spatial and Temporal Resolution
- **Radiation Dose and Workflow**



Low Contrast Detectability for Plaque

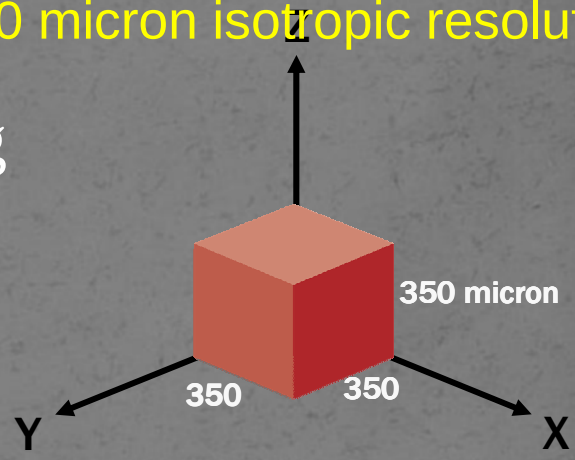


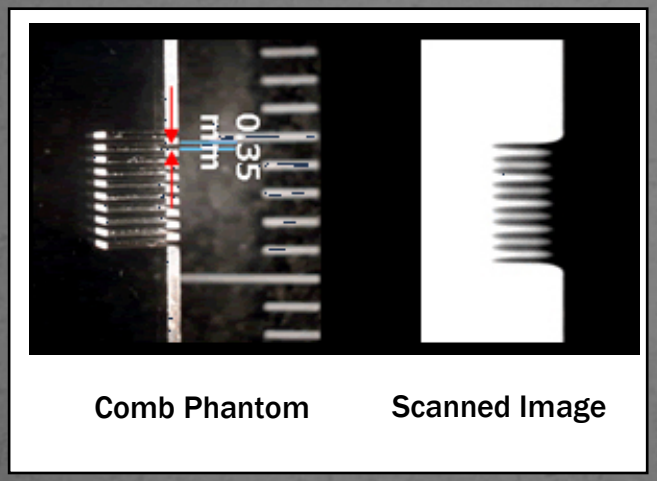


Spatial Resolution – Isotropic Resolution

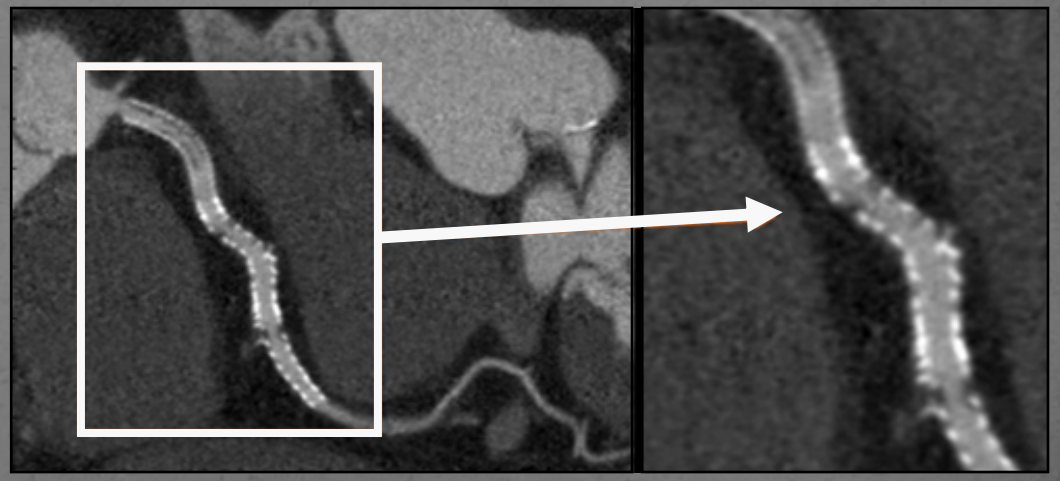
Thinnest isotropic slices at 0.5mm creates 350 micron isotropic resolution

- Good for coronary stent imaging
- Reduced blooming artifact from calcium and stents





Comb Phantom Scanned Image



The Shands at UF Experience

- Summer 2007: Initial assessment and approval of feasibility of technology by Chief Physicist and PACS Administrator
- Fall 2007: Administration approves Radiology's ROI plan and appropriates special funds for purchase of scanner
- January 2008: P.O. issued, initial plans drawn
- Issues found:
  - Weight of scanner for floor of room selected
  - Computer room dimensions and need for physical proximity to scan room
  - Cooling of computer room

The Shands at UF Experience

- Solutions:
  - Chairman gives up office space as there is no basement underneath his office
  - Cold room designed to hold scanners computers and Thin-Slice Archive
  - Dedicated AC for cold room
- Total delay: 6 months
- Installation time: 3 weeks
- Acceptance testing: September 2008

The Shands at UF Experience

- Press release and First clinical use: October 2008

Why a Thin-Slice Archive (TSA)?

- Scanner offers two basic modes of operation:
- 64-slice mode
  - Sequential
  - Helical
  - Slice thickness 0.5 mm and thicker
  - Coverage: 3.2 cm per rotation
- 320-slice mode
  - Volumetric (sequential)
  - Only slice thickness 0.5 mm
  - Coverage: 16.0 cm per rotation (10.0 cm pediatric)
- Temporal resolution 175 ms in all modes

Why a Thin-Slice Archive (TSA)?

- Manufacturer recommends and sells as an option
- In volumetric mode, each rotation generates 168 MB (uncompressed) of information
- Brain perfusion protocol, requires 19 volumetric acquisitions of the brain
  - Two separate reconstructions of acquired slices result in 6,000-12,000 slices per study
  - This does not include special perfusion and MIP datasets
  - Study size 3.2 to 4 GB uncompressed (1.5 to 2 GB compressed)

Why a Thin-Slice Archive (TSA)?

- Potential problems without a TSA:
  - Network bandwidth issues
  - Queue of studies at Main Archive, Study Worklist Servers and workstations would be unacceptable
  - Slowed-down workflow
- TSA capacity: 15 TB
  - Three year capacity
- Is it necessary to store all the thin-slice data?
  - TSA holds all original reconstructions, special perfusion and MIPs plus all other reformats done at the scanner
  - Selected reconstructions stored on Main PACS archive

Clinical Use of the Scanner at UF

- Current:
  - CTA
  - Cardiac-Gated Studies
  - Stroke Protocol Patients
    - Brain Perfusion
    - Head CTA
- Later this year:
  - Trauma
  - Cardiac perfusion

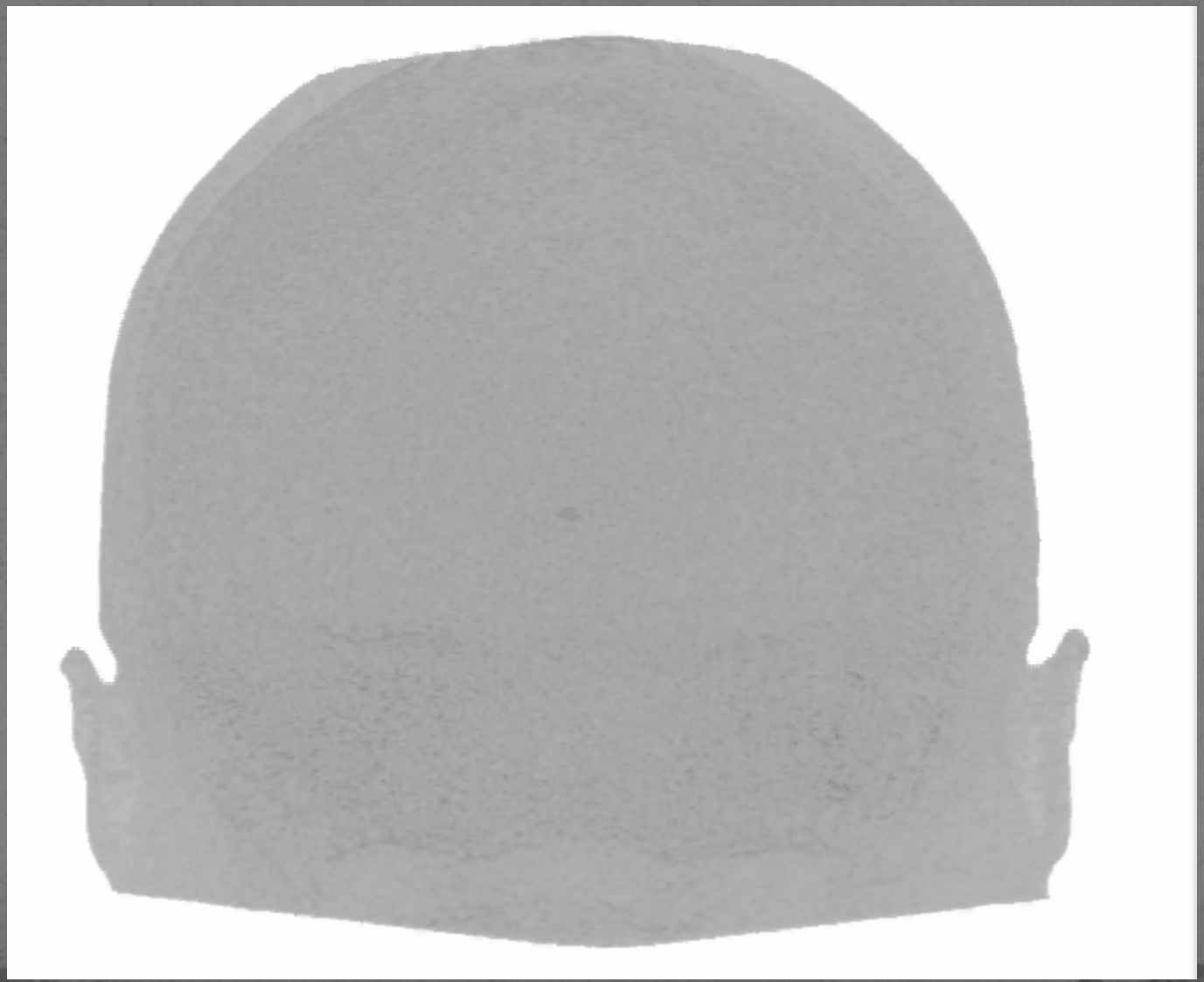
CTA

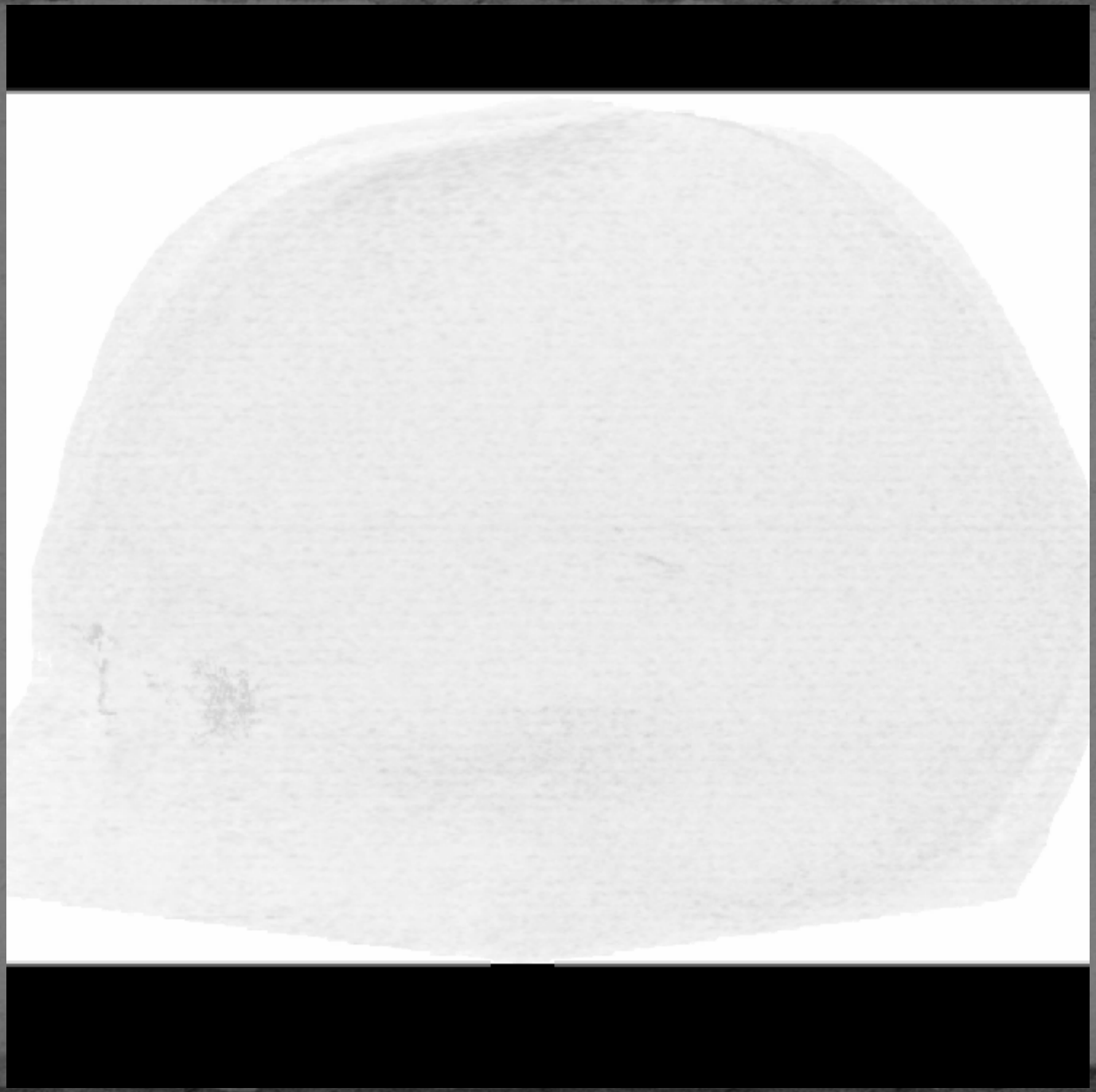
Clinical Examples

Dynamic Volume CT Angiography

- Angiography DSA –like imaging
- Functional, flow and anatomical imaging
- Whole Volume (organ) is captured at a single moment in time
  - Phase uniformity
  - Contrast uniformity
  - Phase and Physiological temporal uniformity

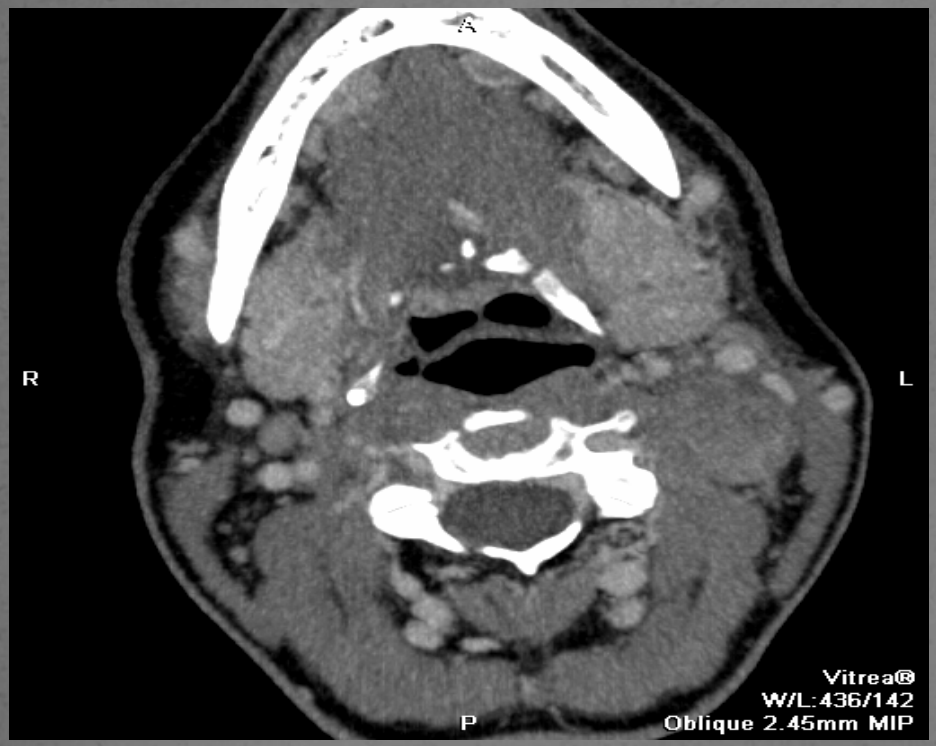
What is a dynamic volume?

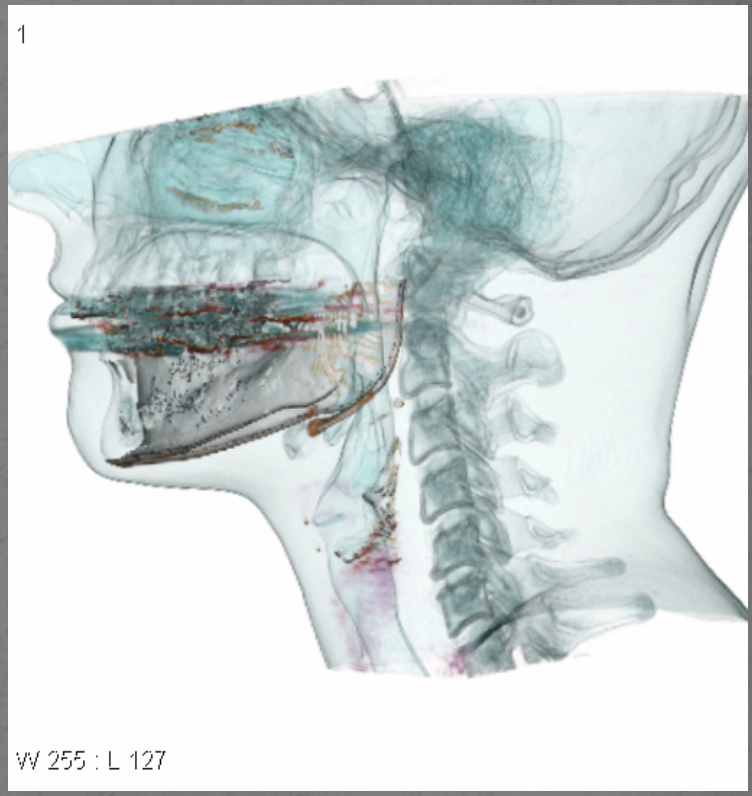




Dynamic CT Angiogram of Neck

- AVM



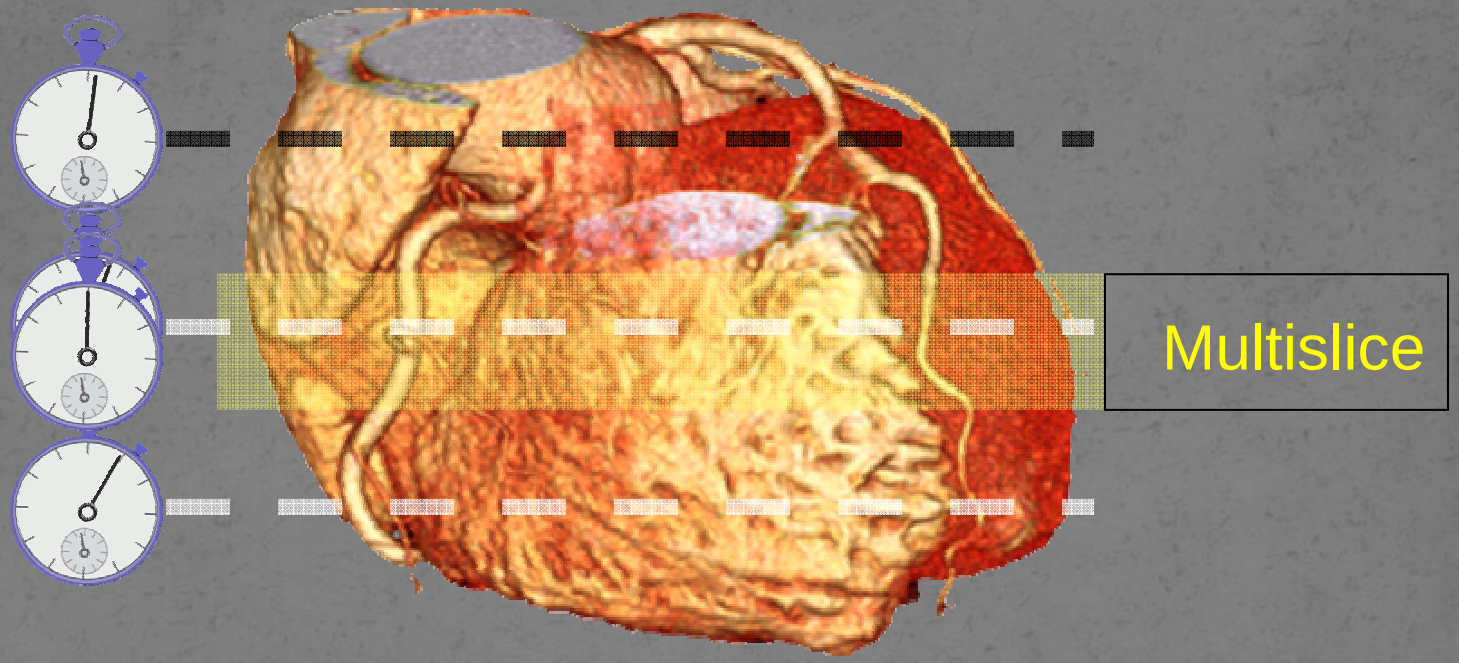


Dynamic Volume CTA Foot

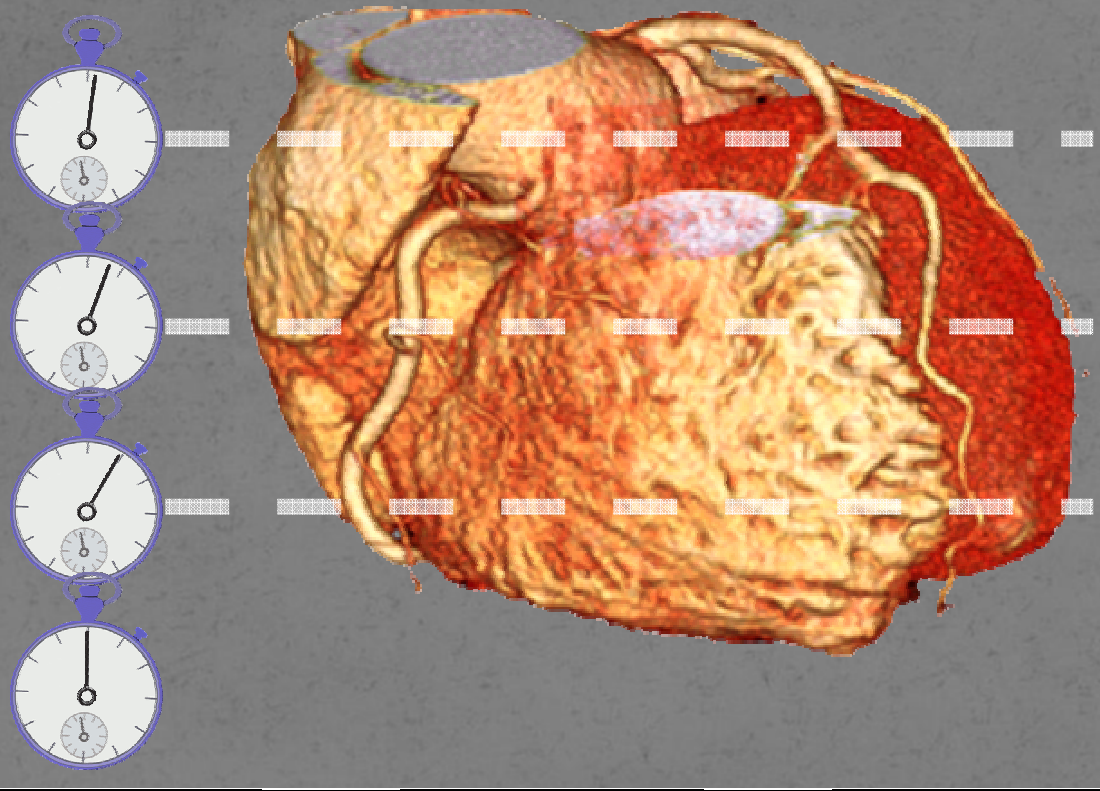
Cardiac Studies

Advantages and Clinical Examples

Helical Cardiac Scanning



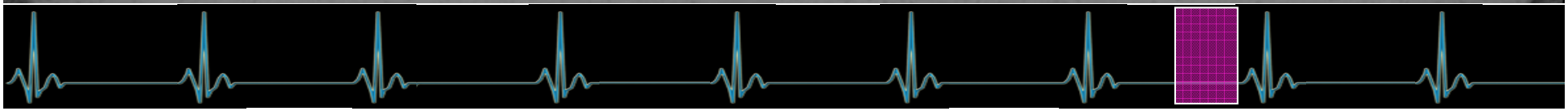
Helical Cardiac Scanning



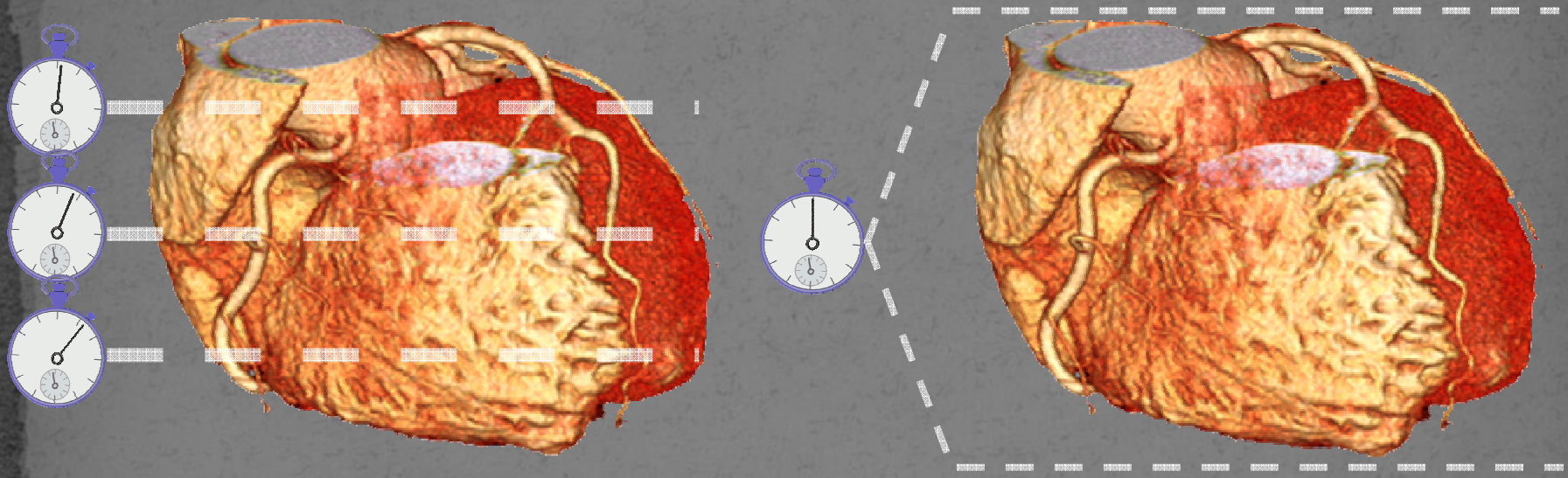
Multislice

Dynamic Volume Cardiac

As low as 175 msec for 16 cm



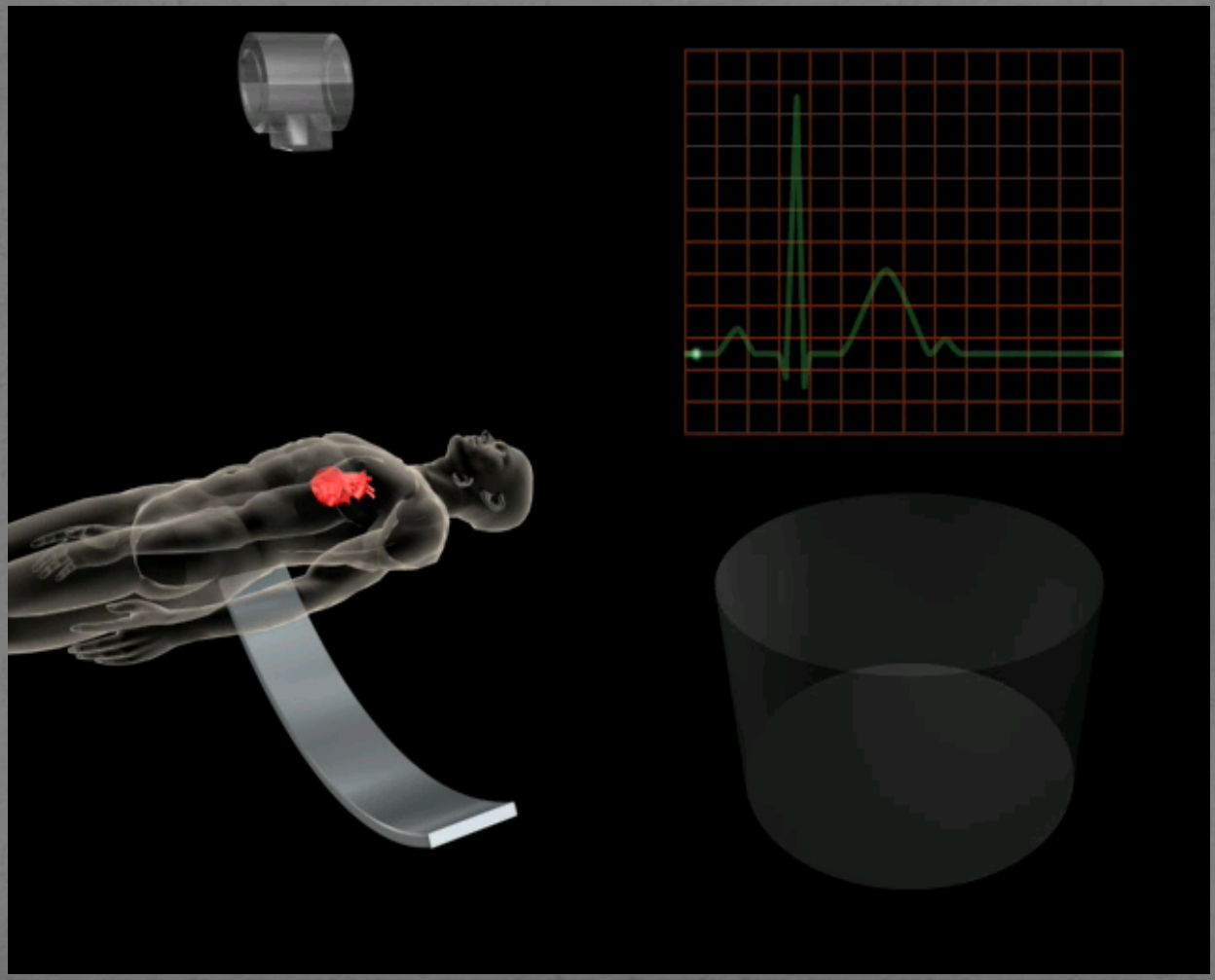
Temporal Uniformity



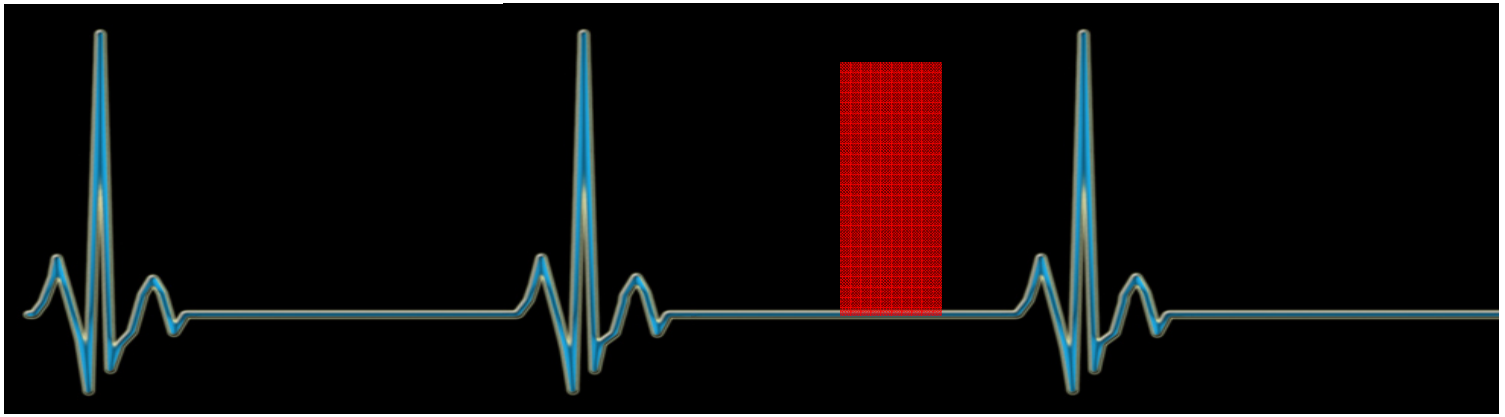
6 – 9 second acquisition

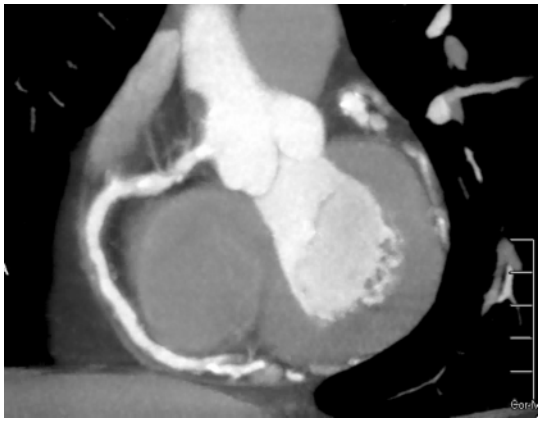
0.35 second acquisition

Dynamic volume scanning

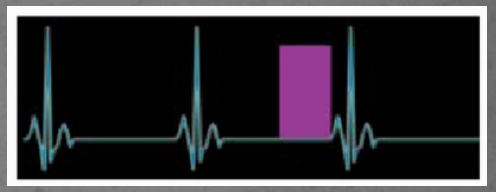


Prospective Cardiac Gating



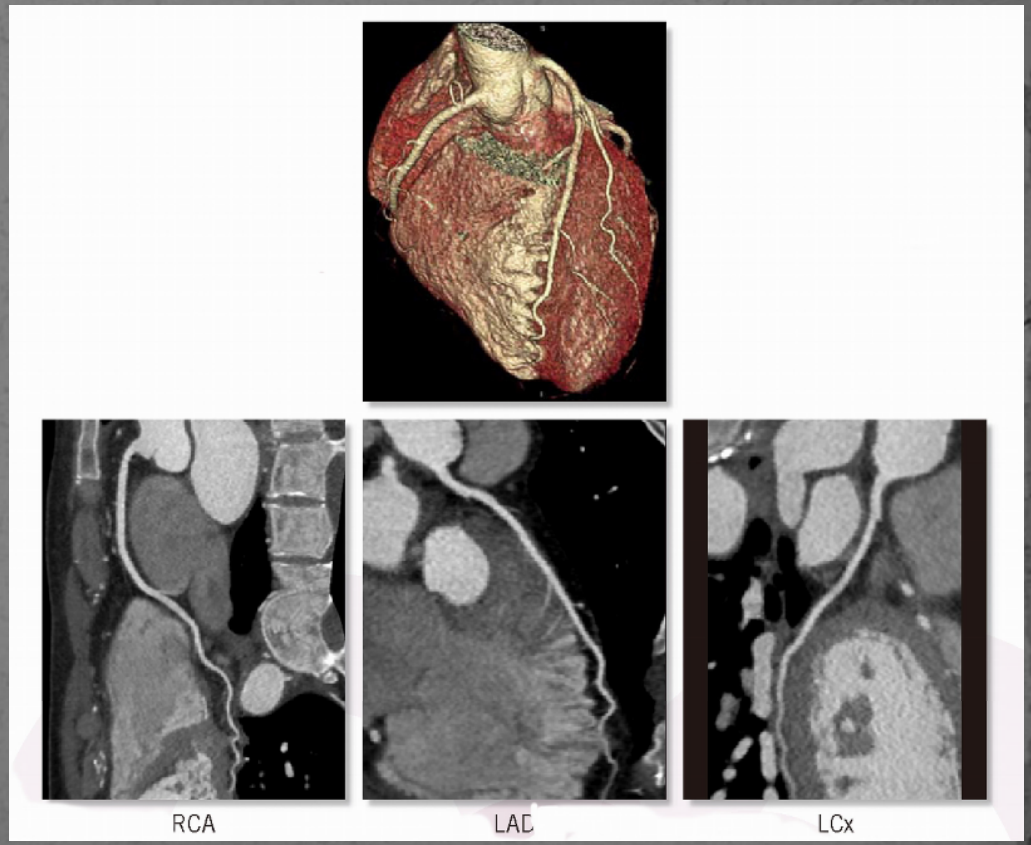


Prospective CTA

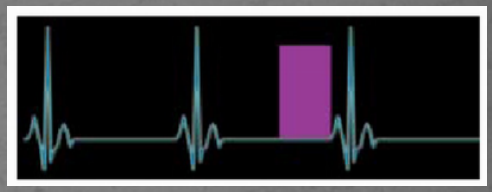


Patient assessed with low suspicion of cardiac Disease
Low dose prospective scan was done.
Normal coronary vessels are seen in these 3D and curved MPR views.

50cc's of contrast
1.7mSv



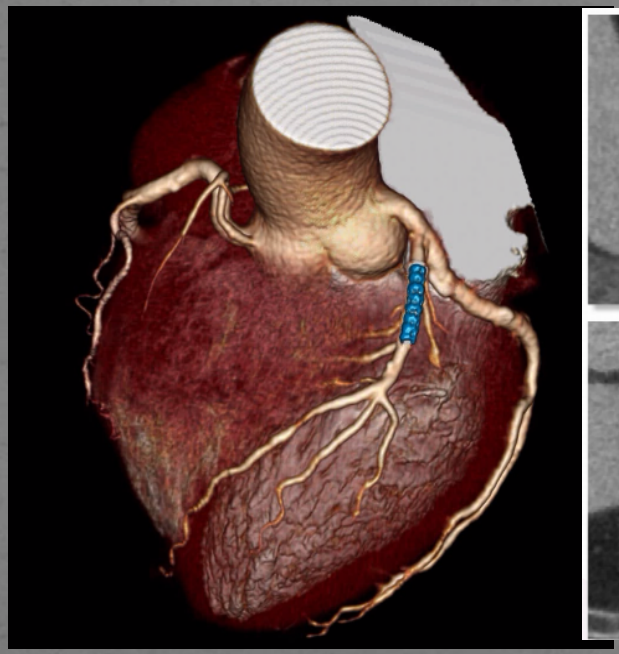
Prospective CTA

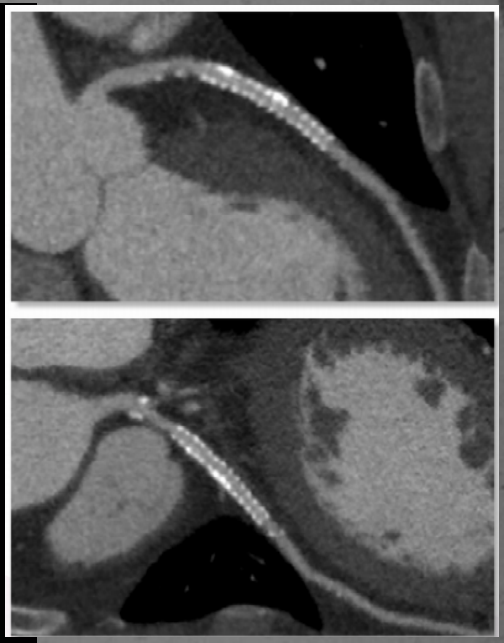


Another example

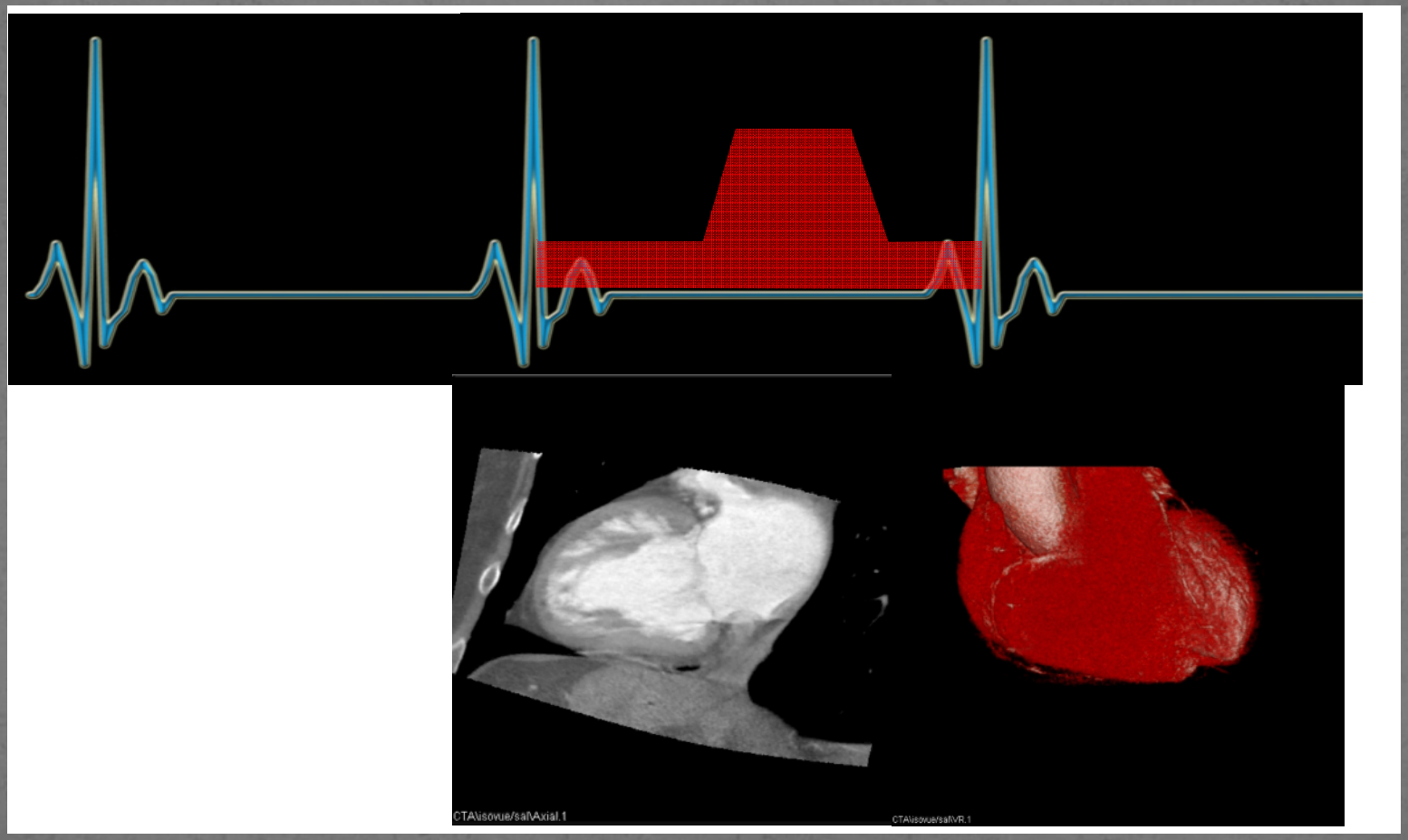
Stent and vessel lumen
Clearly observed

50cc's of contrast
4.6 mSv

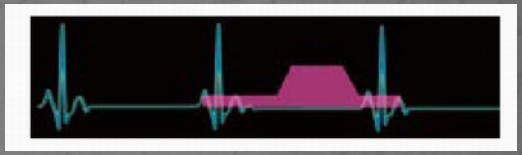




Gating with ECG Modulation



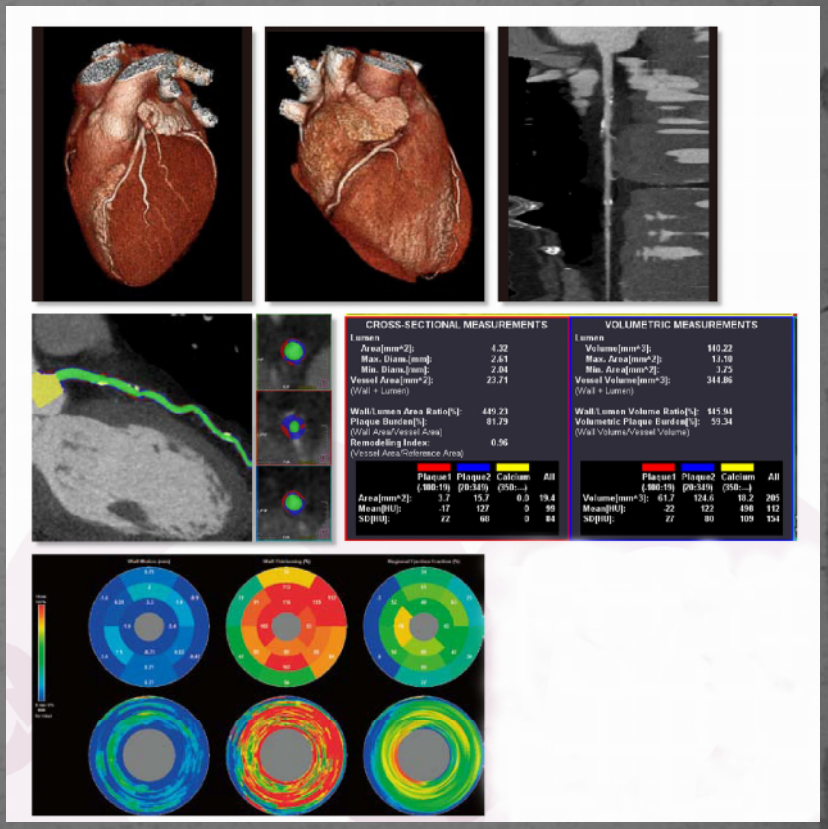
Gating with ECG Modulation



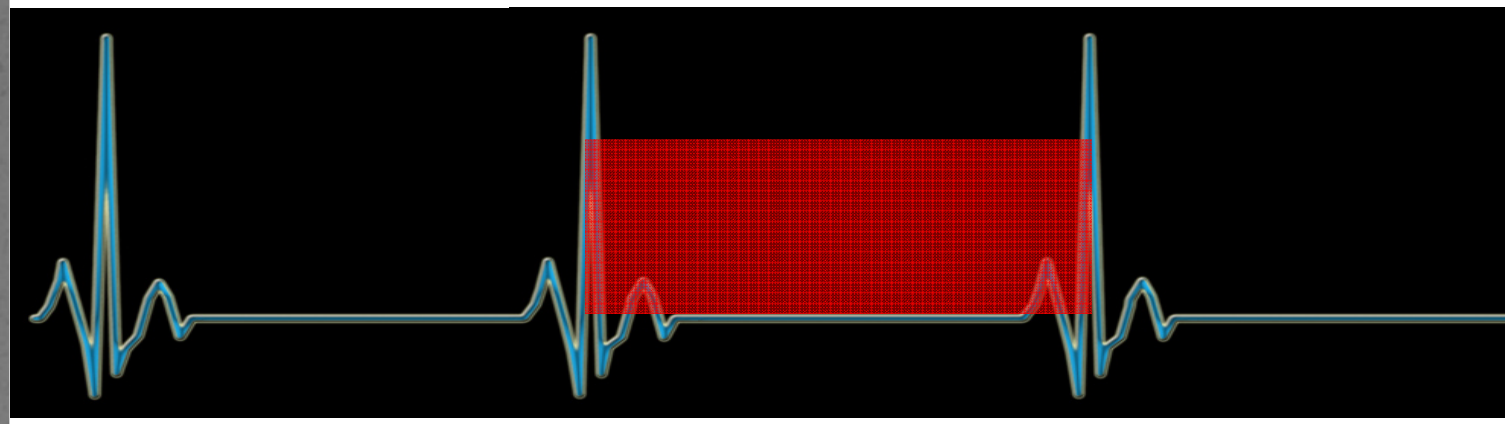
Modulation of the mA can be seen in the Cardiac MPR views.

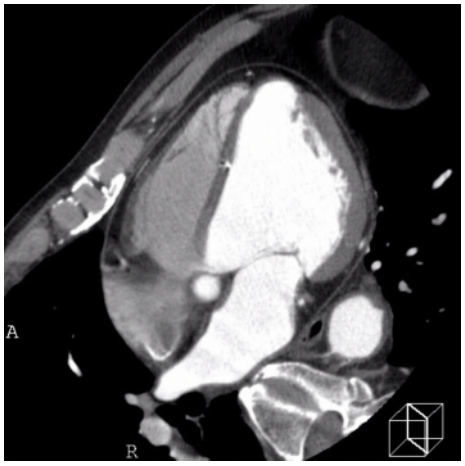
Special software is used to quantify the proximal LAD lesion.

50cc's contrast
9.3mSv

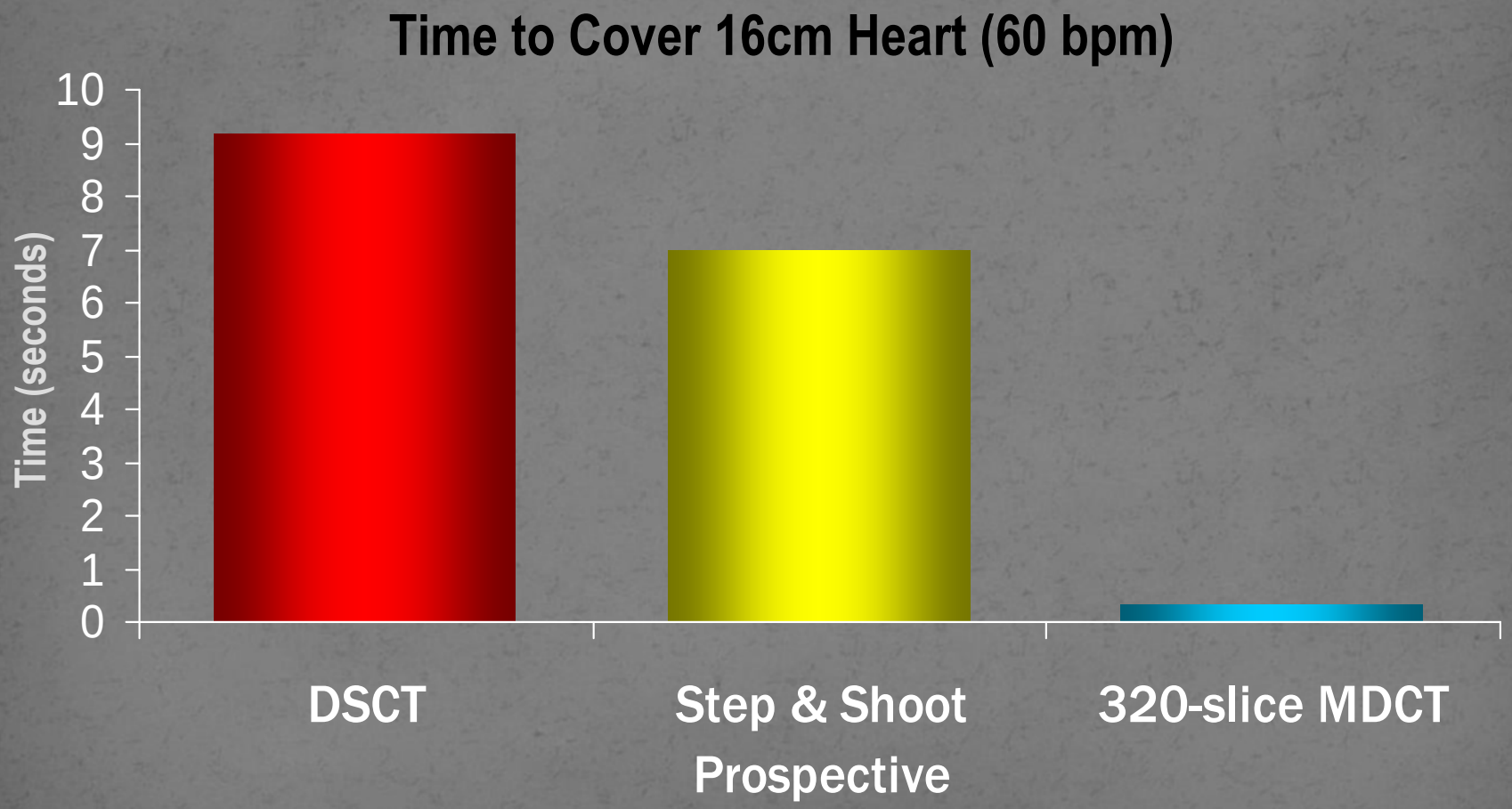


Retrospective Cardiac Gating



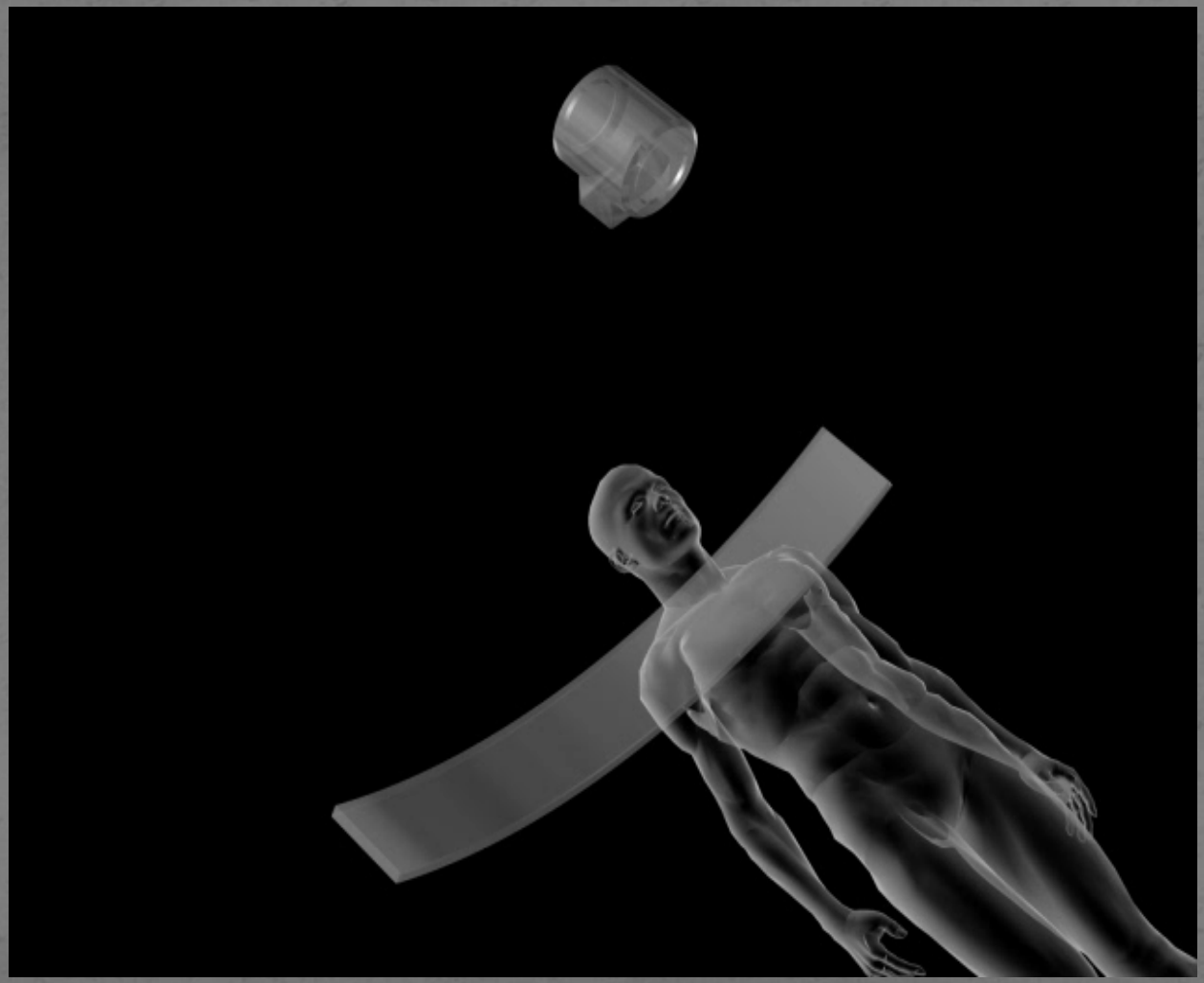


Cardiac Coverage Time



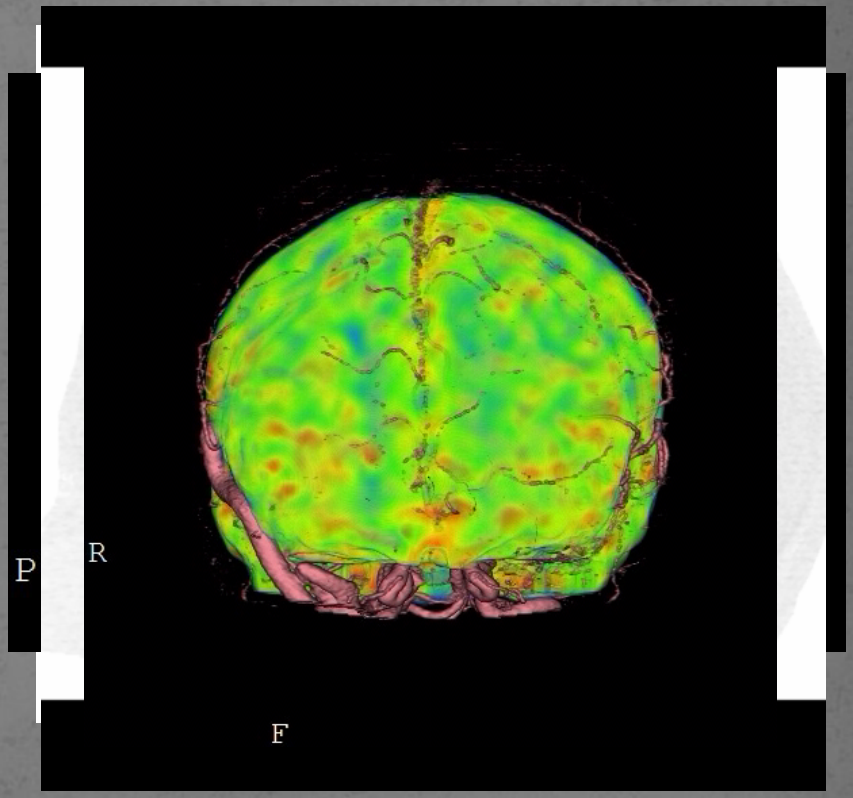
Brain Perfusion

Dynamic Volume Brain Perfusion



Dynamic Volume Brain Perfusion

1. Arteriogram
2. Venogram
3. 4D CT DSA
4. Whole Brain Perfusion



Dose: 5mSv, 50ml IV Contrast

What About Radiation Dose?

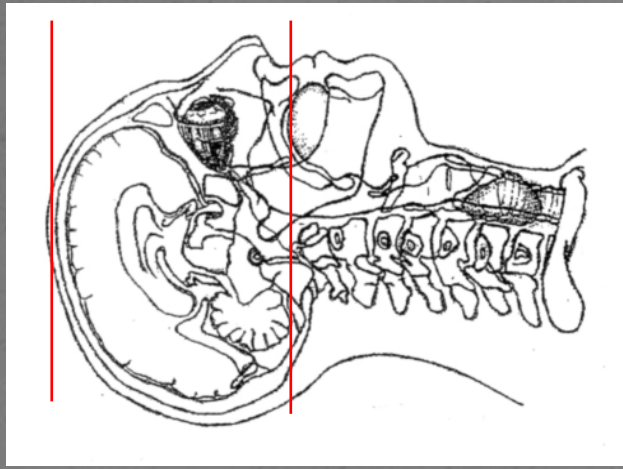
- DLP and $CTDI_{vol}$ estimated by scanner
- Recommendation is that radiation dose estimates, as calculated by scanner, be recorded for each patient
- DLP and $CTDI_{vol}$ are in DICOM header for each series in the study
- Clinical implementation process must take dose into account

Optimization of Protocols

- Validation of a protocol must have three components:
  - Clinical
    - Radiologists
  - IS
    - PACS administrator
  - Radiation Dose
    - Physicist

Initial Brain Perfusion/Stroke Protocol

Series A: Head without contrast

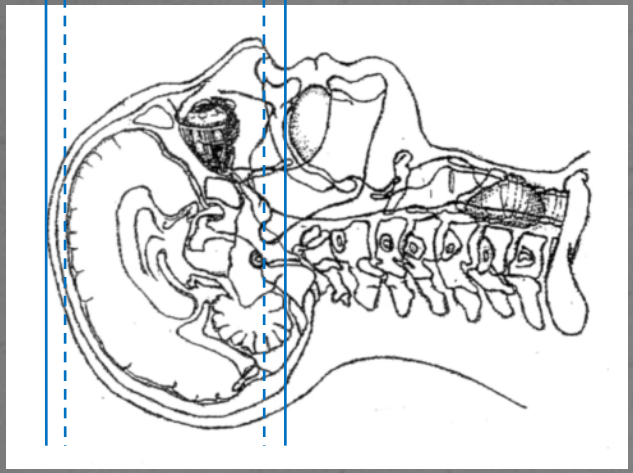


ALG/RECON	Brain
Slice Thickness	5.0 mm
Slice Spacing	5.0 mm
DFOV	240 mm

No Angle: Reposition patient if IOML is not approximately perpendicular.

Initial Brain Perfusion/Stroke Protocol

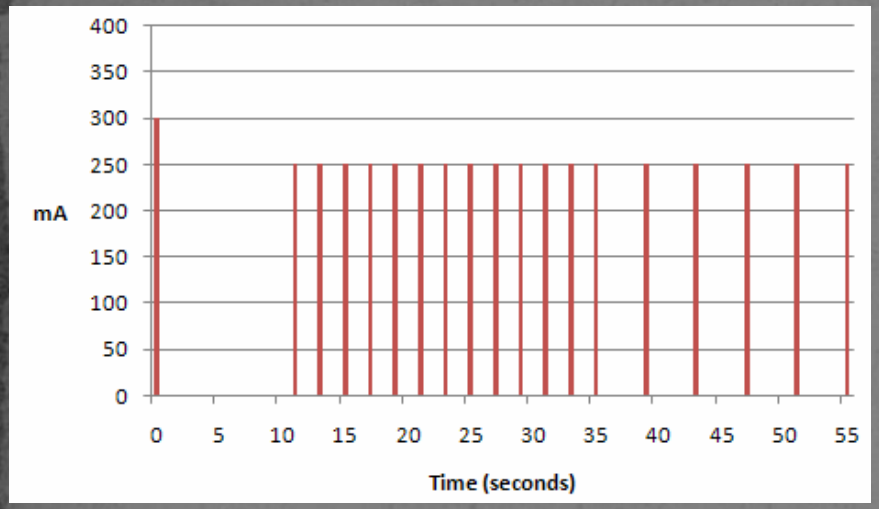
Series B: Volumetric Brain Scans (19)



ALG/RECON	Head CBP
Slice Thickness	0.5 mm
Slice Spacing	0.5 mm
DFOV	240 mm

Initial Brain Perfusion/Stroke Protocol

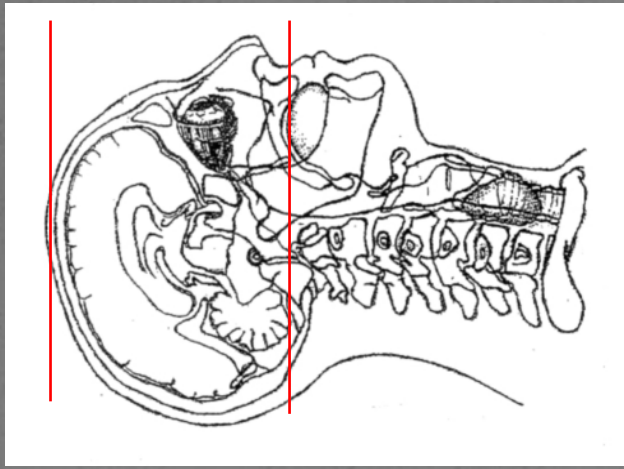
Series B: Volumetric Brain Scans (19)



- Injection / Scan Start
- 0 second delay
  - 1 Volume / 1 second scan time
- 10 second delay
  - 13 volumes / 1 second scans at 2 second intervals
    - (25 second total scan time)
- 4 second delay
  - 5 volumes / 1 second scans at 5 second intervals
    - (21 second total scan time)

Initial Brain Perfusion/Stroke Protocol

Series C: Head with contrast



ALG/RECON	Brain
Slice Thickness	5.0 mm
Slice Spacing	5.0 mm
DFOV	240 mm

No Angle: Reposition patient if IOML is not approximately perpendicular.

Clinical Assessment Stage

- Begin with manufacturer-recommended protocol
- PACS group, working with radiologists, to create process to generate collage of reconstructions
  - CBF
  - CBV
  - Mean Transit Time
  - Axial MIP or TTP
- Radiologists assess clinical adequacy and value of acquired and processed data

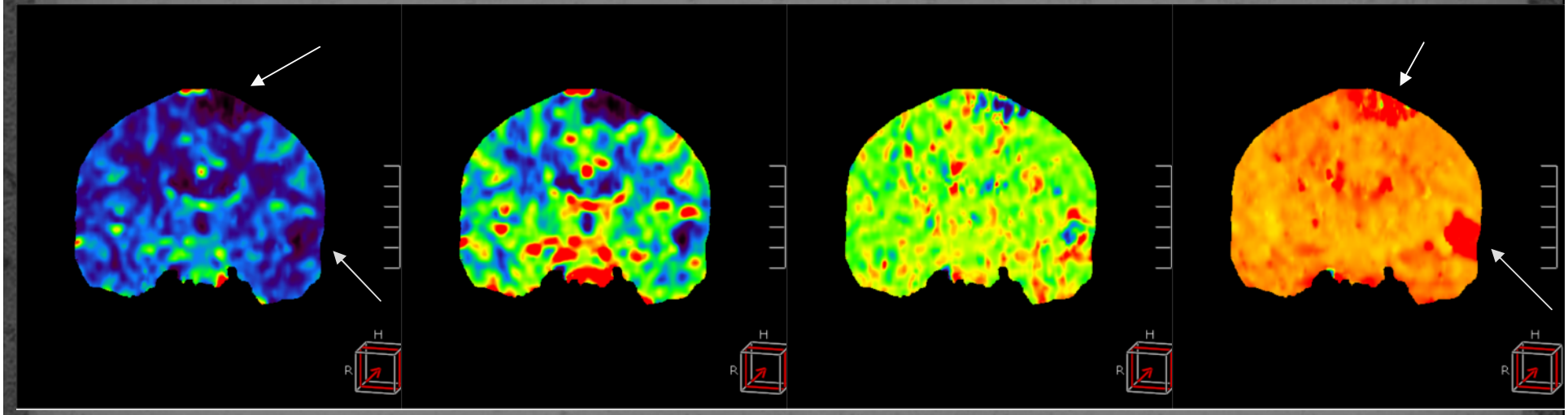
Clinical/IS Assessment Stage

- SERIES COLLAGE:
- Clinical tab
- 4-D Perfusion
- Load Volume
- Set Artery
- Set SSS
- Analyze
- Images will generate
- Settings
  - Color scale (Rainbow.CBP)
  - 5.0 thickness
  - CBF / CBV / MTT
  - Auto Transfer to:
    - PACS
    - PACS_TS
  - Select ‘OK’ (new image maps will take a few minutes to generate)
- Auto Export

- MIPS:
- Select single volume (320 images) from entire volume set. This single volume should best represent early maximum arterial flow and minimal venous return.
- This selected volume should be sent to PACS for the clinicians to view interactively.
- *Note that the entire volume set (6000+ images) is transferred automatically to PACS_TS (thin slice) for Neuro Rad.
- Use selected single volume (320 images) to generate MIPS
- **AXIAL MIPS: 5.0 X 5.0**
- * IMPORTANT: Start location for axial MIPs at **-80** and end at **80** for a total of 32 images. (These are combined in the PACS_TS with the Perfusion images automatically for anatomical reference collage.)
- **SAGITTAL MIPs: 5.0 x 5.0**
- **CORONAL MIPs: 5.0 x 5.0**
- Transfer all MIPs to PACS and PACS_TS

Brain Perfusion Image Collage

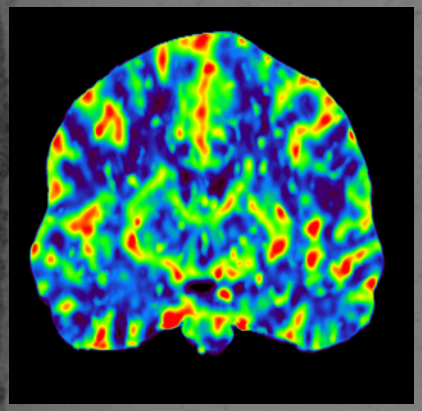
- Acute Stroke
  - New infarct in the left temporal lobe (yellow)
  - Old infarct in the apex of the brain (red)



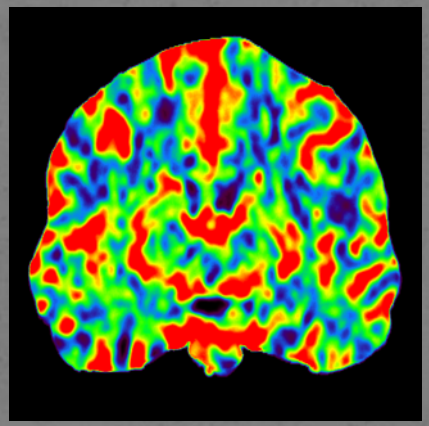
CBF CBV MTT TTP

Brain Perfusion Image Collage

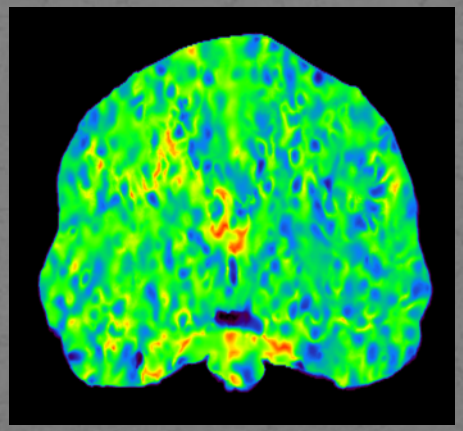
- Occluded Right Carotid Artery
  - Normal CBF, Normal CBV
  - Slightly prolonged MTT and delayed TTP



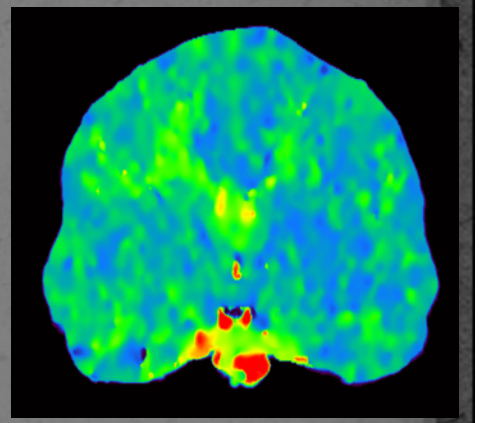
CBF



CBV



MTT



TTP

Clinical/Dose Assessment Stage

- Image Perfusion Collage and MIPs integrity verified by PACS group
- All series evaluated for clinical quality by radiologists and neurosurgeons
- Initial protocol done at 80 kVp and 300 mA
- Initial assessment indicated the apparent need to increase beam energy (kVp) to improve signal-to-noise levels
- Decision on kVp setting based on clinical plus radiation dose assessment

Dose Assessment Stage

- NCRP report/NEJM paper talk about increased risks of cancer
- Anecdotal information about skin erythema and epilation
- Effective Dose is best assessment of potential risk
- Thus, measurement of organ doses is the best way to assess dose

Dose Determination: Measurements

- Physics uses UF anthropomorphic tissue equivalent phantoms (Bolch, Hintenlang) for accurate organ measurements
- Optically-stimulated dosimeters allow real-time dose measurements

Step One: kVp Increase Assessment

	Dose (mGy)		
	Eye	**Skin**	**Thyroid**
REFERENCE: Brain Perfusion on 64-slice Scanner	201.3	725.1	65.8
Initial Protocol at 80 kVp, 300 mA	363.3	334.0	21.2
Initial Protocol at 100 kVp, 300 mA	462.5	413.7	19.6
Initial Protocol at 120 kVp, 300 mA	661.2	594.5	29.3

Step One decision: scan at 80 kVp clinically inadequate, doses at 120 kVp unacceptable (100% increase) → Use 100kVp

Clinical/Dose Assessment Stage

- Protocol modified to use 100 kVp and 300 mA
- Second clinical assessment deemed arterial phase information inadequate
- Radiologists request addition of Head and Neck CTA prior to Head w/contrast series
- Manufacturer proposes use of new mA boost volumetric protocol
  - Uses 100 mA
  - Volumetric acquisitions during arterial phase done at increased value of 300 mA
- Decisions based on clinical plus radiation dose assessment

Step Two: Additional Scan vs. mA Boost

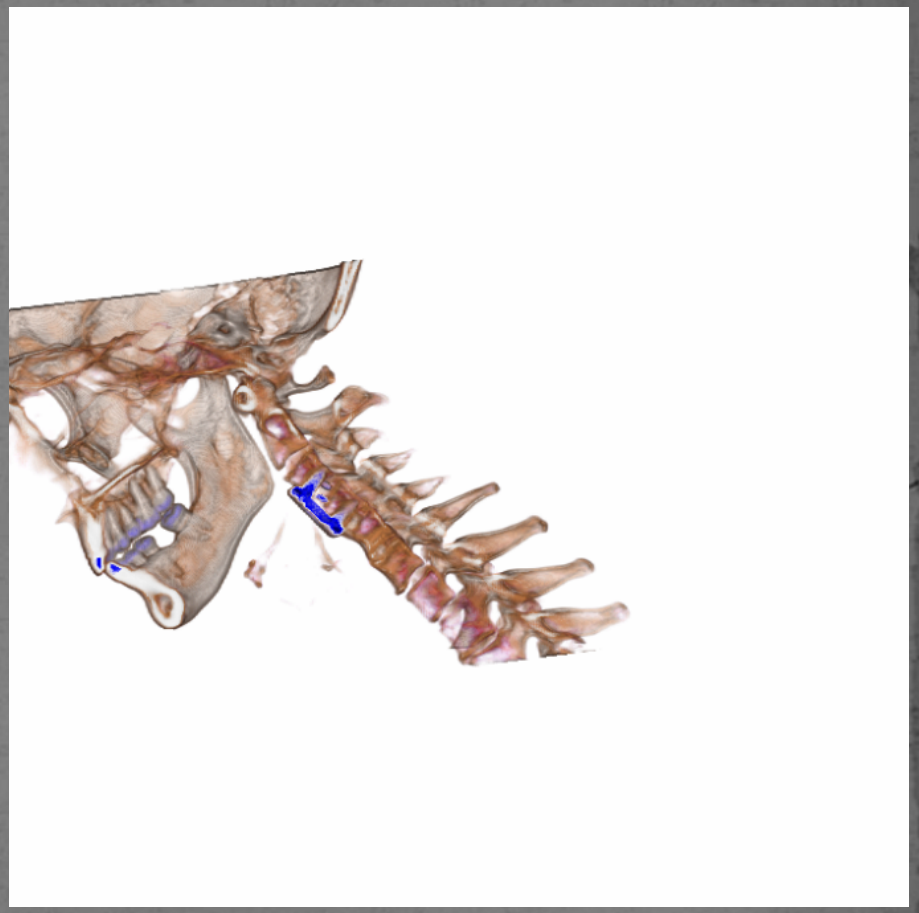
	Dose (mGy)		
	Eye	**Skin**	**Thyroid**
REFERENCE: Brain Perfusion on 64-slice Scanner	201.3	725.1	65.8
Head w/o + Fixed 300 mA + CTA Head/Neck + Head w/	294.3	259.7	92.5
Head without + mA Boost + CTA Head/Neck + Head w/	282.5	248.3	92.0
Head without + mA Boost + Head w/	232.7	206.3	8.7

Step Two decision: Head/Neck CTA deleted use mA boost mode

Other Applications
Preliminary Examples

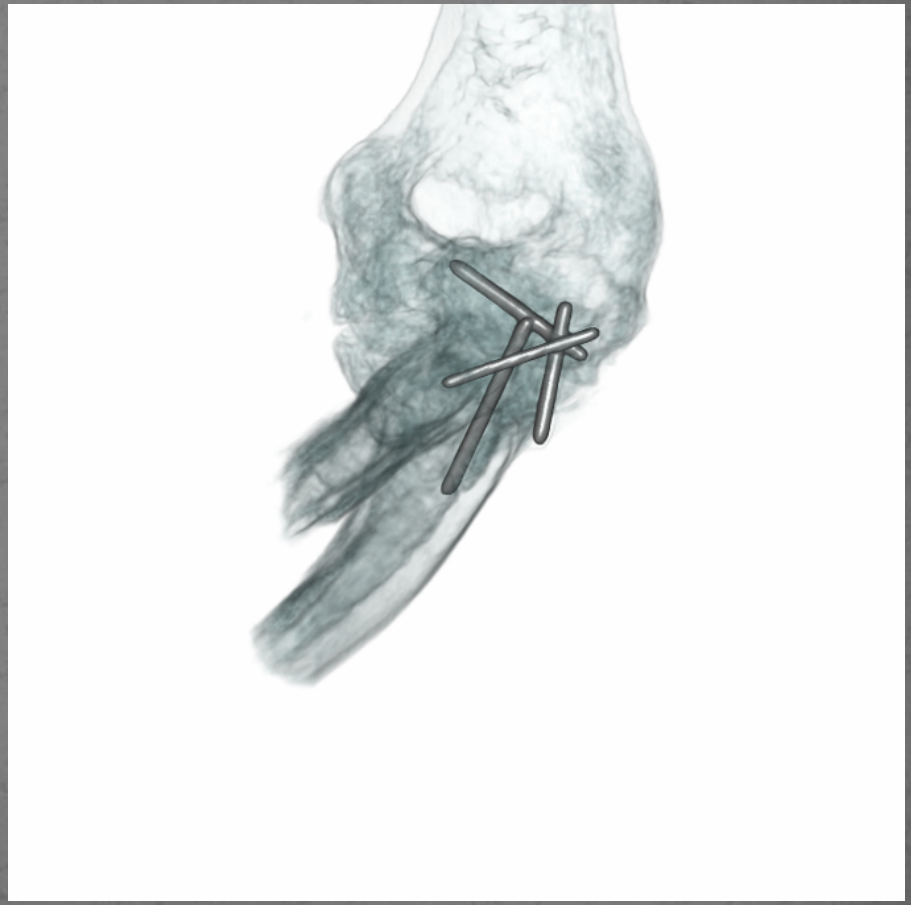
Dynamic Volume Imaging Spine

- Dynamic volume Imaging of the cervical spine flexing and extending
- The ability to dynamically visualize metallic fixation devices during articulation
- Previously two static scans would be acquired. One at flexion and one at extension



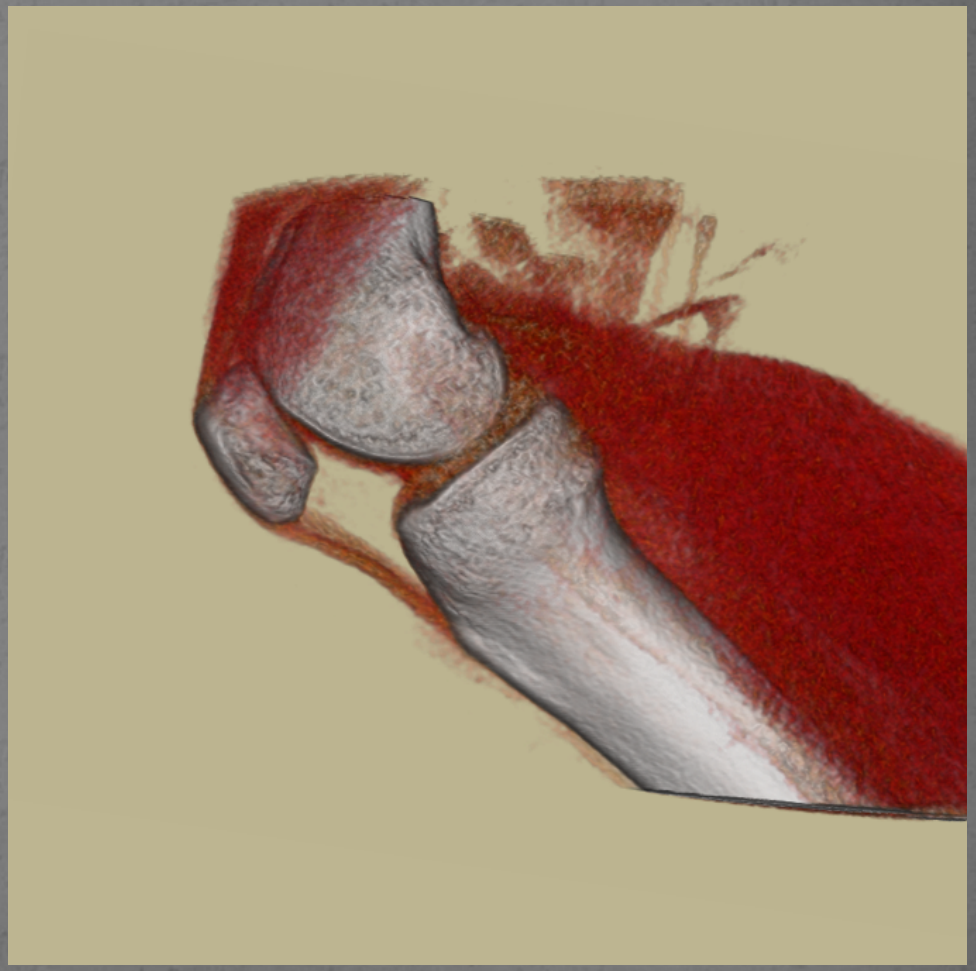
Dynamic Volume Scanning Elbow

- Internal Fixation device of the proximal ulna and radius
- The relationship of the joint and the internal metal hardware can be evaluated during movement of the joint using dynamic volume CT



Musculoskeletal Imaging-Knee

- Kinematic examination of the knee joint during flexion and extension
- The patellar ligament observed during movement in this lateral view



Questions?

Thank you!