Cardiac Imaging

Transesophageal Echocardiogram
Cardic MRI
Cardiac CT

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Ways to visualize the heart

- Xray
  - Chest film
  - Computed tomography
    - Calcium evaluation
    - Coronary arteriography
  - Angiography/Fluorscopy
- Ultrasound
  - Transthoracic echocardiogram (TTE)
  - Transesophageal echocardiogram (TEE)
  - Intravascular ultrasound (IVUS)
  - Intracardiac ultrasound (ICE)
- Magnetic Resonance (CMR)
  - Too many types of sequences to list
- Angioscopy

Transesophageal Echo

Internal Medicine Boards perspective

- TEE/Cardioversion for atrial fibrillation
- Endocarditis
- The Stroke evaluation
  - Patent Foramen Ovale
  - Atrial Septal Defect
  - Cardiac source of embolus

- These will also be the situations most commonly faced by primary care physicians

Transesophageal Echo
Procedural description

- NPO overnight
- Oropharynx anesthetized
- Conscious sedation
  - 2mg versed +/- 25mg demerol or 25 mcg fentanyl
- TEE probe advanced gently into the esophagus
- Exam duration typically 10 minutes of probe activity
- Risks include esophageal perforation
  - Especially with zenkers diverticulum, webs, strictures
- Overall low risk of complecations

TEE/Cardioversion for atrial fibrillation

- General recommendations for atrial fibrillation with planned cardioversion
  - INR goal 2-3
  - 3 weeks before cardioversion
    - Unless onset of Afib <48 hours before cardioversion
  - 4 weeks after cardioversion
- Patients less tolerant of atrial fibrillation
  - Heparin/LWMH at diagnosis/admission
  - TEE to evaluate for Left Atrial appendage thrombus
  - Safe to cardiovert if no thrombus seen?

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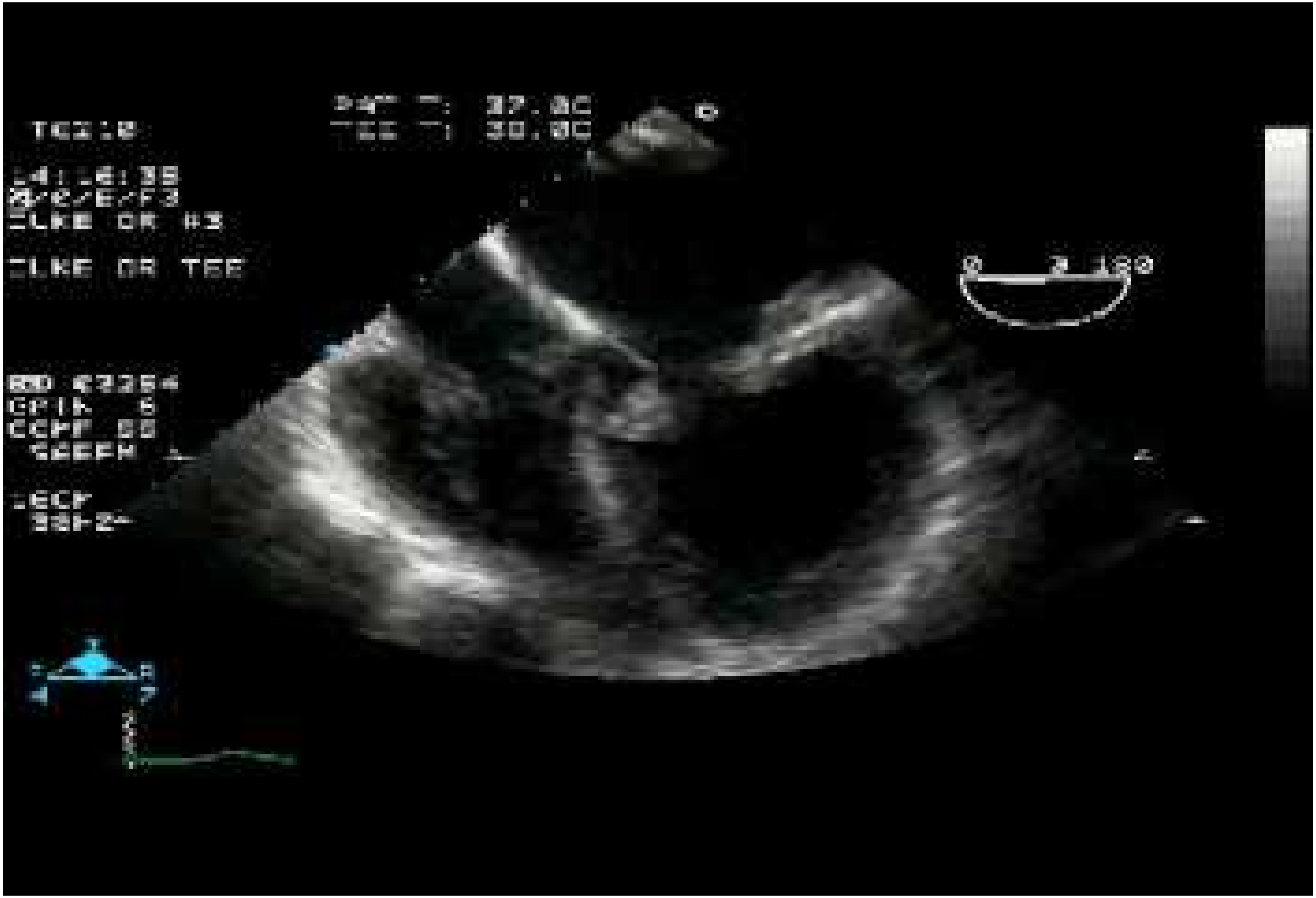
TEE/Cardioversion ACUTE trial

- Randomized, prospective
- Patients with atrial fibrillation
- Compared 3 weeks on anticoagulation prior to cardioversion vs TEE guided
- 70 sites, 1222 patients
- 8 weeks followup
- Primary outcome: Embolic events
  - 0.8%TEE, 0.5% conventional (p=0.5)
- Minor and Major bleeding
  - 2.9% TEE, 5.5% conventional (p=0.03)

Asher CR, Klein AL; ACUTE trial: Transesophael echocardiography to guide cardioversion in patients with atrial fibrillation: ACUTE trial update. Card Electrophysiol Rev 7(4): 387-391, 2003

Endocarditis

- Most often affects left sided valves
  - Ideally suited for TEE
  - Exception is IV drug users
- Typically vegetations occur on low pressure side of valves
- TEE more sensitive than TTE to see
  - Vegetations
  - Regurgitation
  - Leaflet damage/perforation
  - Abscess formation
  - Unstable prosthesis



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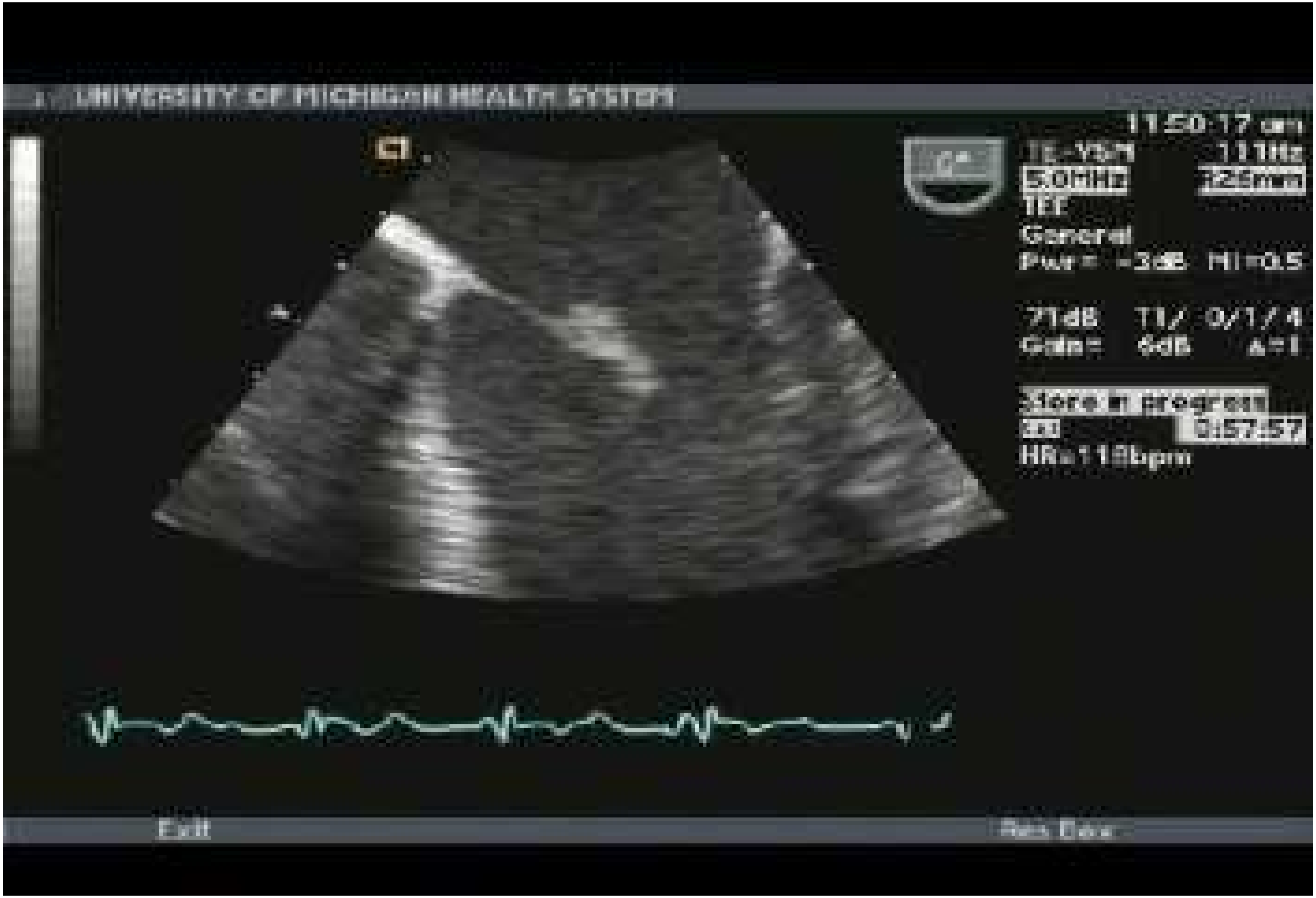

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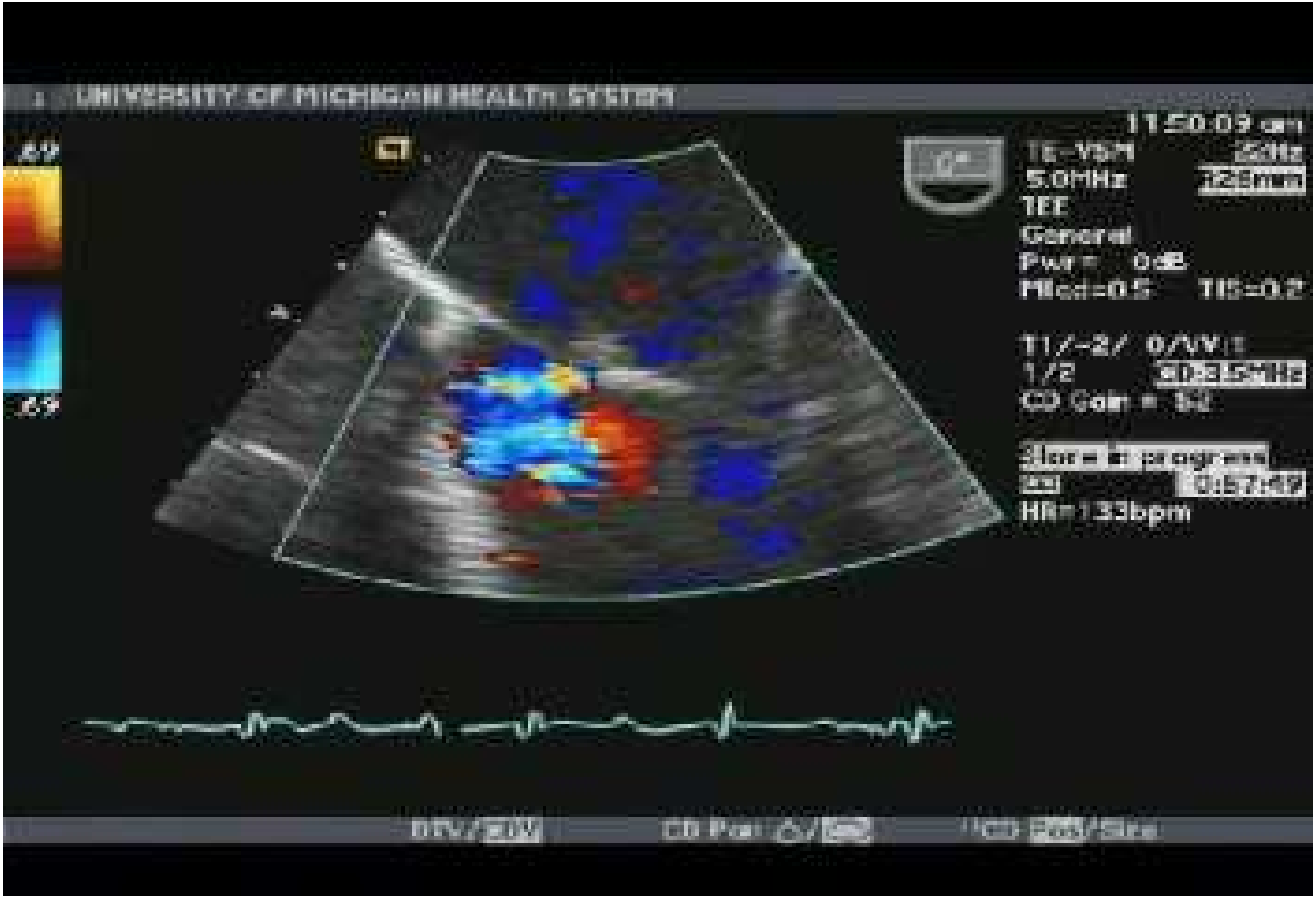

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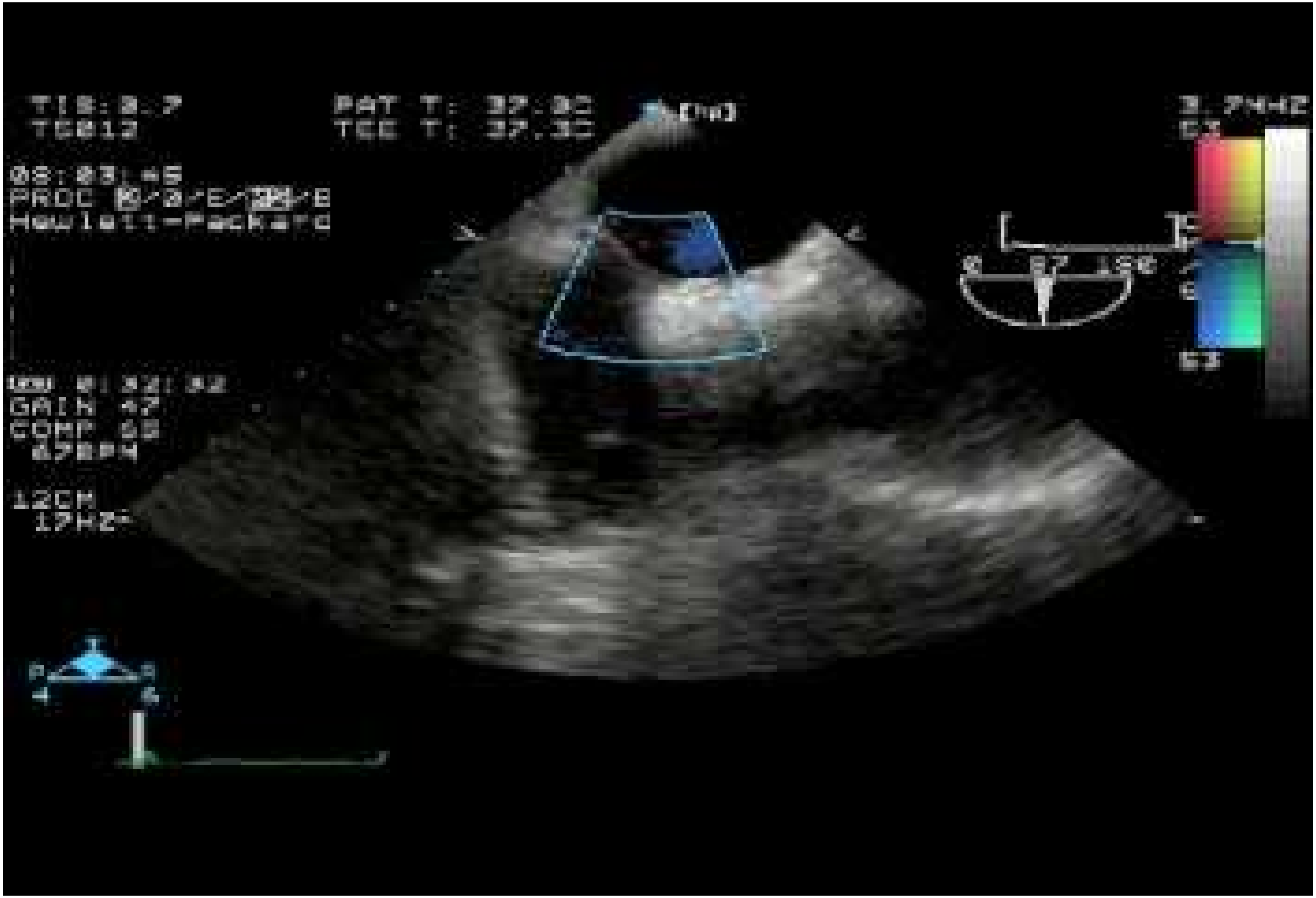
The stroke evaluation

Cardiogenic etiologies of stroke

- Left atrial thrombus
- Left ventricular thrombus
- Patent foramen ovale (PFO) or atrial septal defect (ASD)
  - Allows “paradoxical” emoblization
  - Venous thrombus passes through interatrial septum
- Cardiac masses
  - Endocarditis/vegetations
  - Tumors



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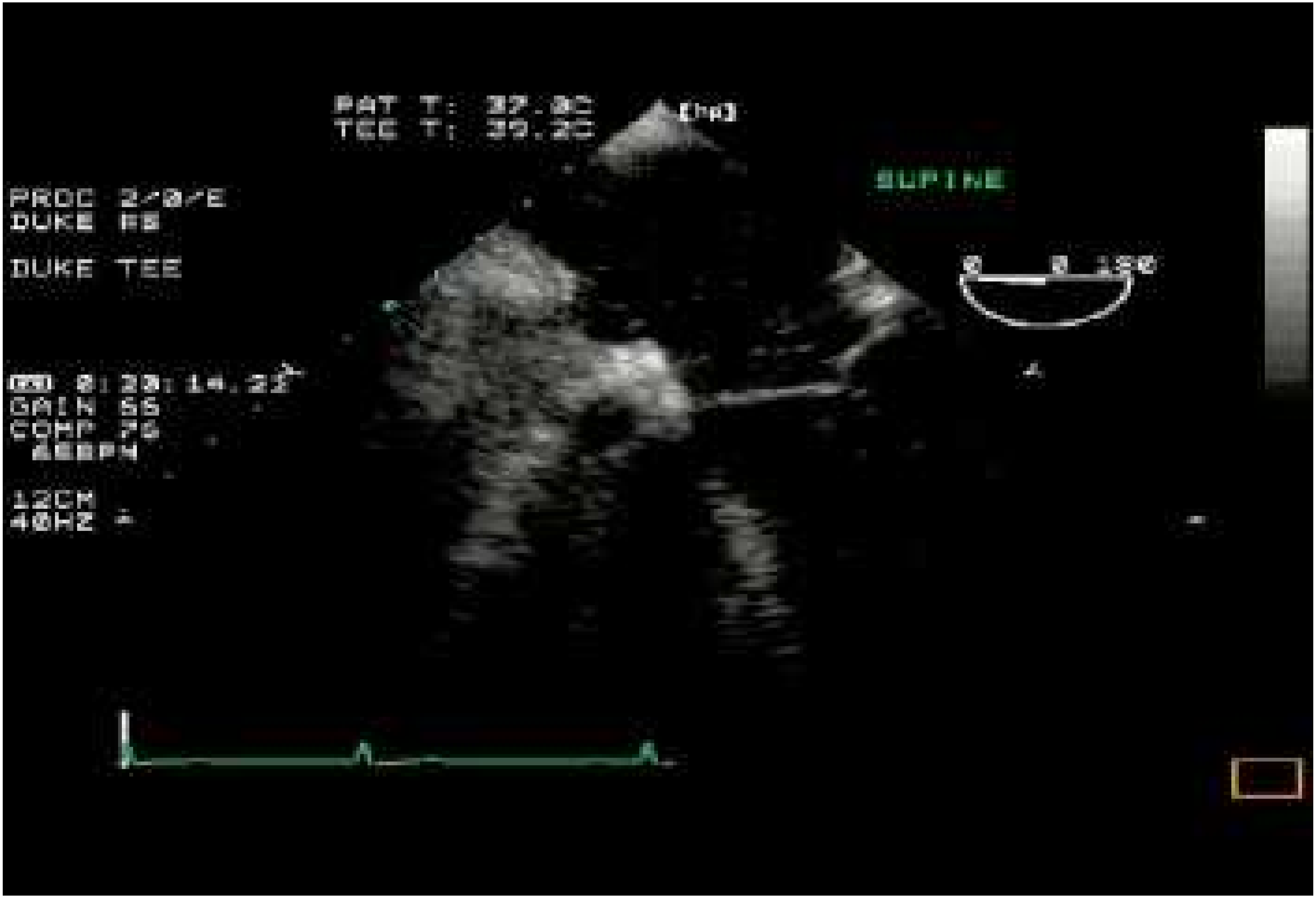

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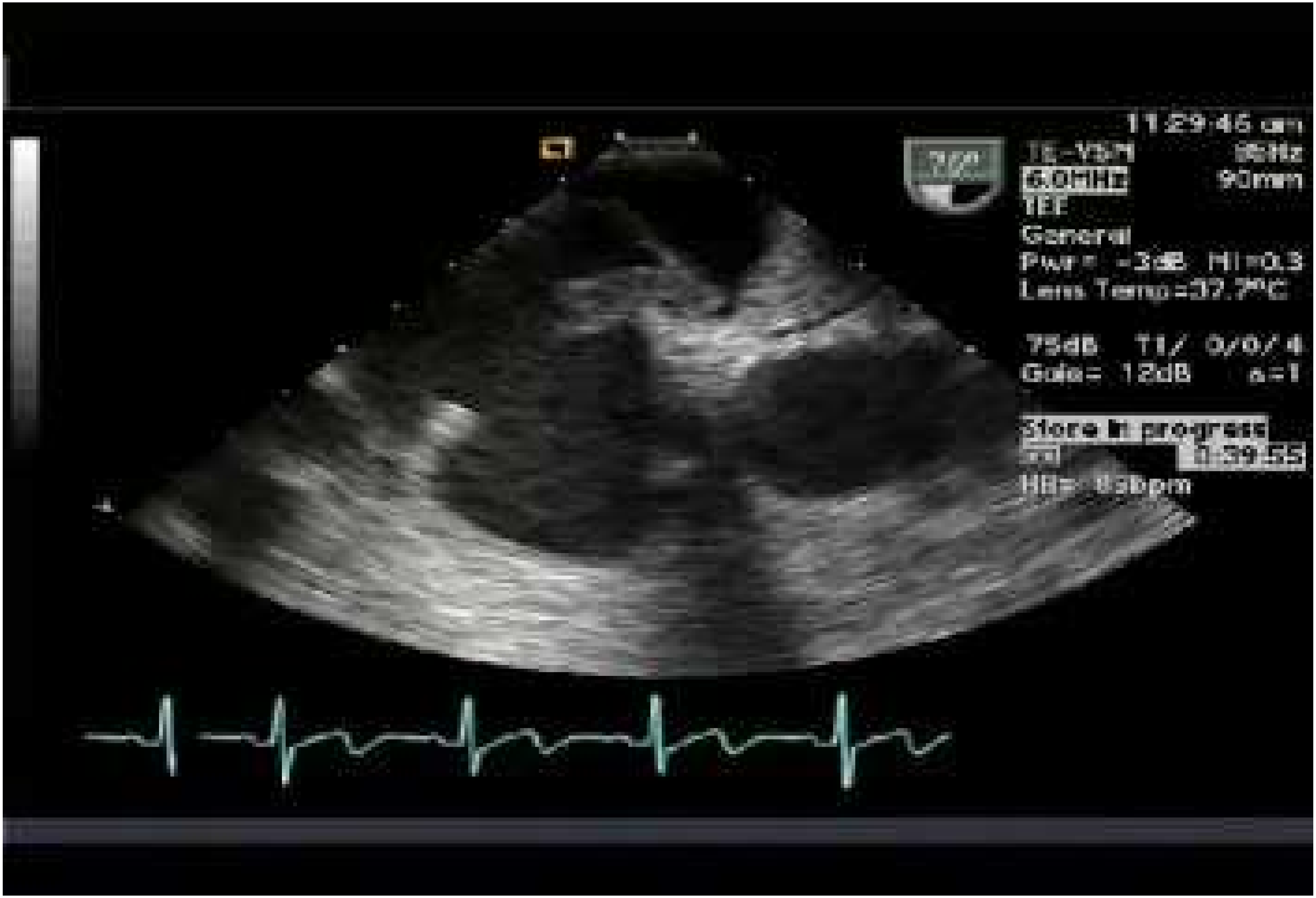

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Which TIA/stroke patients need a TEE?

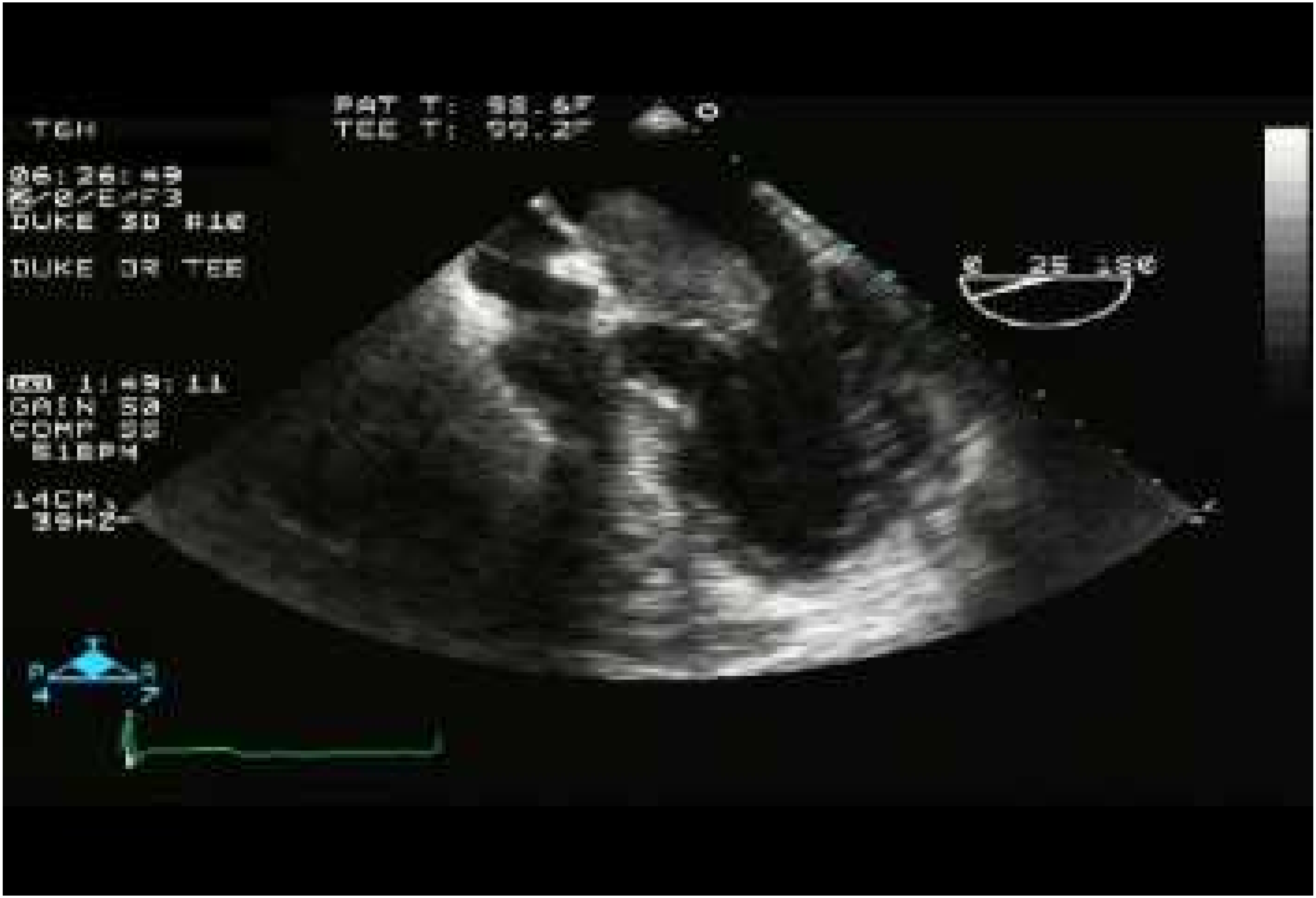
- Which patients need a TTE?
  - Almost everyone
- Who needs a TEE?
  - Patients younger than 45
  - Older patients without identified cause of CVA

- However
  - Controversial whether findings change management
  - Anticoagulation indicated for thrombus
  - Treatment/Surgery indicated for masses/vegetations
  - PFO/ASD
    - Closure may or may not be helpful
    - Anticoagulation usually not indicated for primary/secondary prevention
    - About 10-20% of general population have a PFO!

Other situations where TEE is useful

- When TTE is suboptimal to answer a clinical question
- Prosthetic valve evaluation
- Cardiac masses
- Pulmonary vein stenosis
- Native valve stenosis/regurgitation
- Cardiac Anuerysm, pseudoaneurysm
- Aortic dissection

- Evaluation of ejection fraction alone is challenging with TEE



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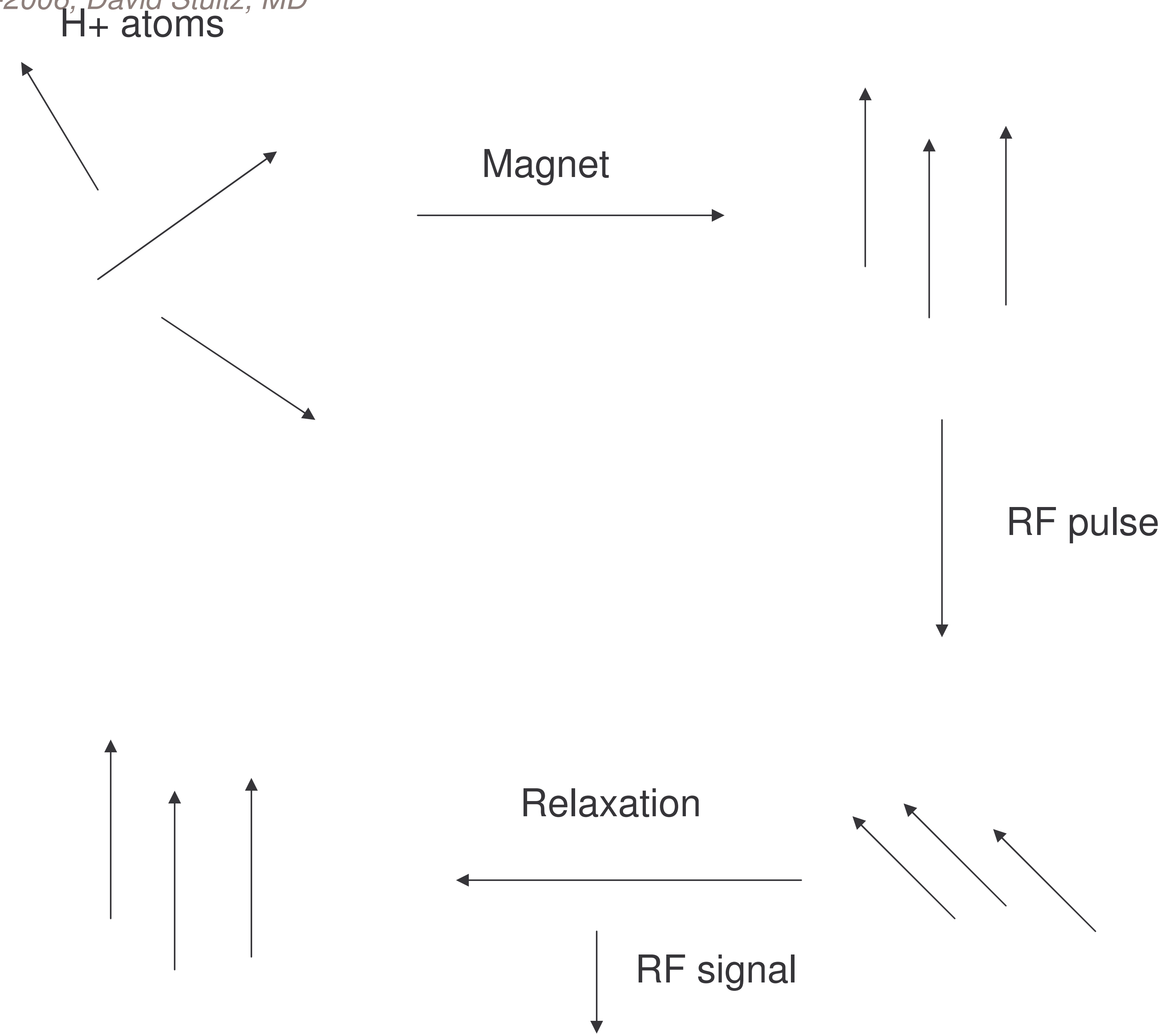
Cardiac MRI
Some modalities

- Coronary arteriography
- Cardiac tissue evaluation
- Cardiac masses
- Cardiac perfusion
- Infarct/viability assessment
- Quantification
  - Valve stenosis/regurgitation
  - Ejection fraction
- Great vessels
- Stress testing/wall motion

How does MRI/CMR work?

A brief overview

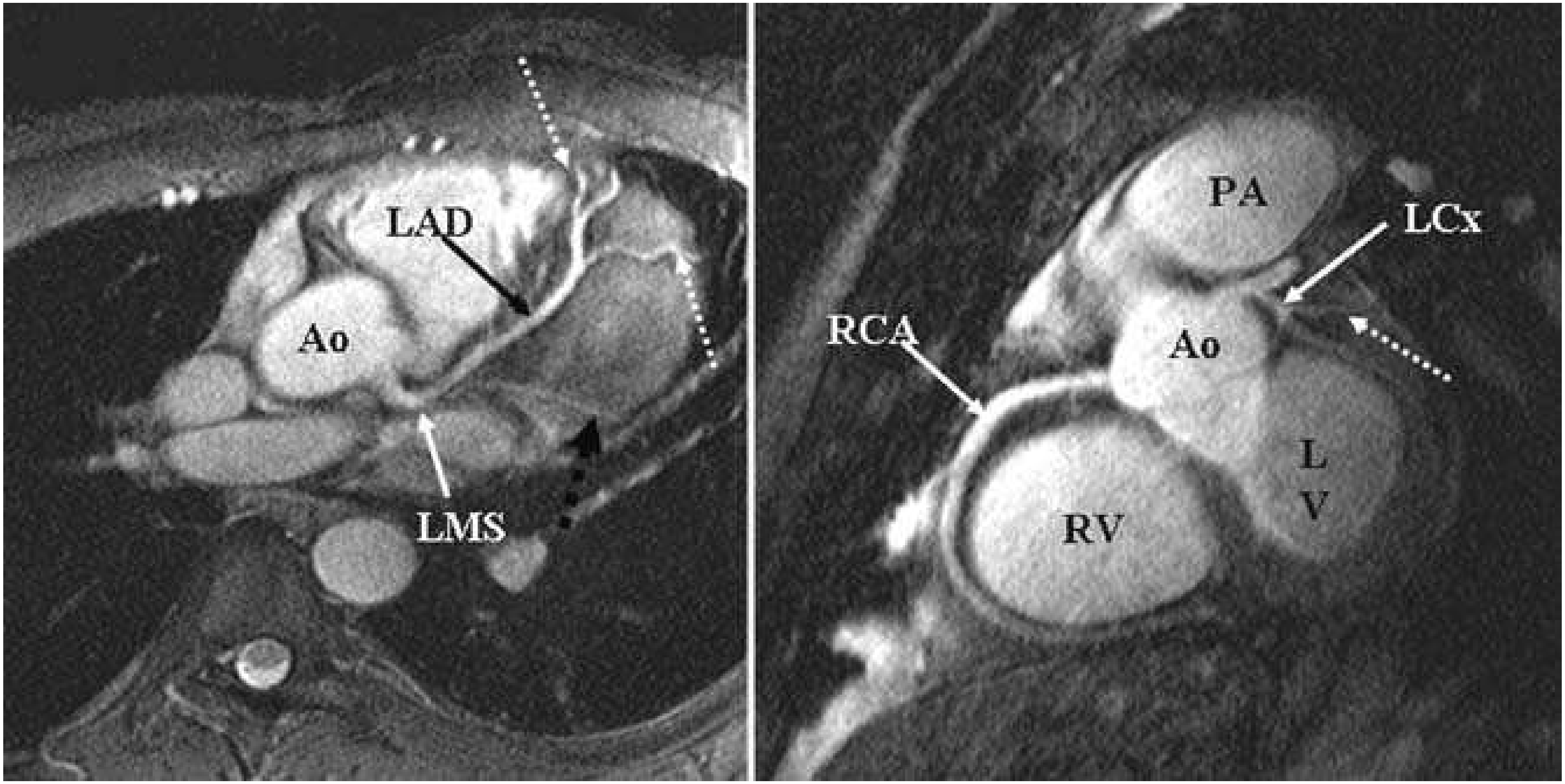
- Our body is mostly water
- Water has H+ atoms
- A magnetic field is used to align all H+ atoms
- A radiofrequency pulse hits these atoms and knocks them out of alignment
- As the atoms “relax” back toward alignment, they send out another radiofrequency signal which is detected


H+ atoms
Magnet
RF pulse
Relaxation
RF signal

CMR procedure

- NPO
- Specifics depend on protocols run
- CMR studies are pre-specified
  - Cannot ‘shotgun’ everything
- Gadolinium used if contrast is indicated
  - Non-nephrotoxic
  - But it is a heavy metal, which limits total amount given
- Duration of scan variable: 15 minutes – 1+ hours

CMR Coronary Arteriography



3 Tesla CMR of coronary arteries

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CMR tissue evaluation

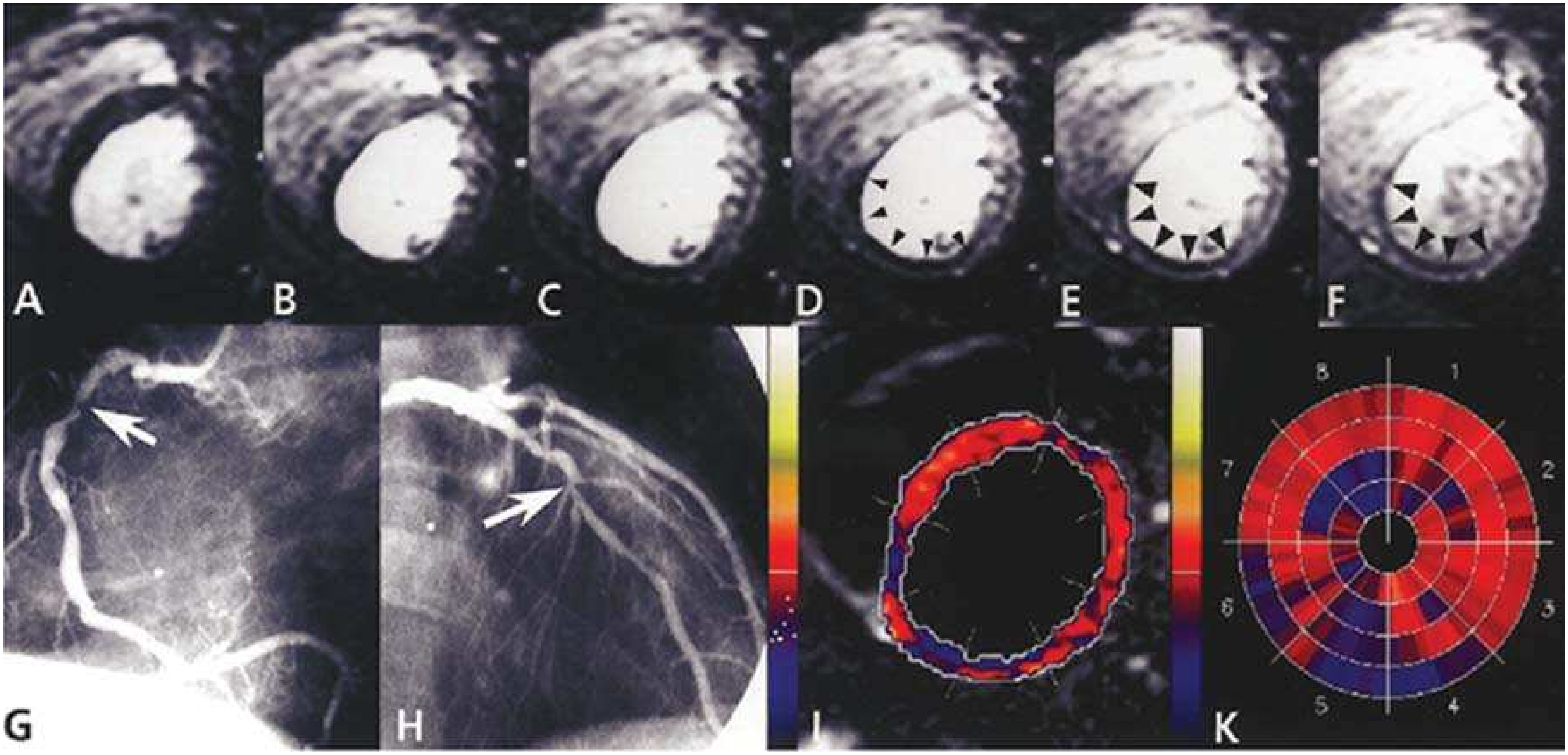
- Right Ventricular dysplasia
- Infiltrative cardiomypathies
  - Amyloid
  - Hemochromatosis
  - Sarcoidosis
- Cardiac Masses
  - Malignant/benign

CMR Cardiac Viability and perfusion

- Cardiac perfusion can be visualized by using gadolinium contrast
  - Can quantify perfusion
  - Infarcted segments perfuse slowly or not at all
  - Cardiac Syndrome X patients show slow perfusion

- An area that is infarcted is not viable, and will not benefit from revascularization
- Delayed enhancement
  - Gadolinium contrast injected, then imaging performed 10-15 minutes later

CMR Perfusion



Imaging after Gadolinium injection demonstrates lack of perfusion in the inferoseptal wall. Cath shows RCA and LAD stenoses

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CMR viability

Subendocardial infarct produced by ligation of a dog coronary artery
Infarcted area appears bright

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CMR Quantification

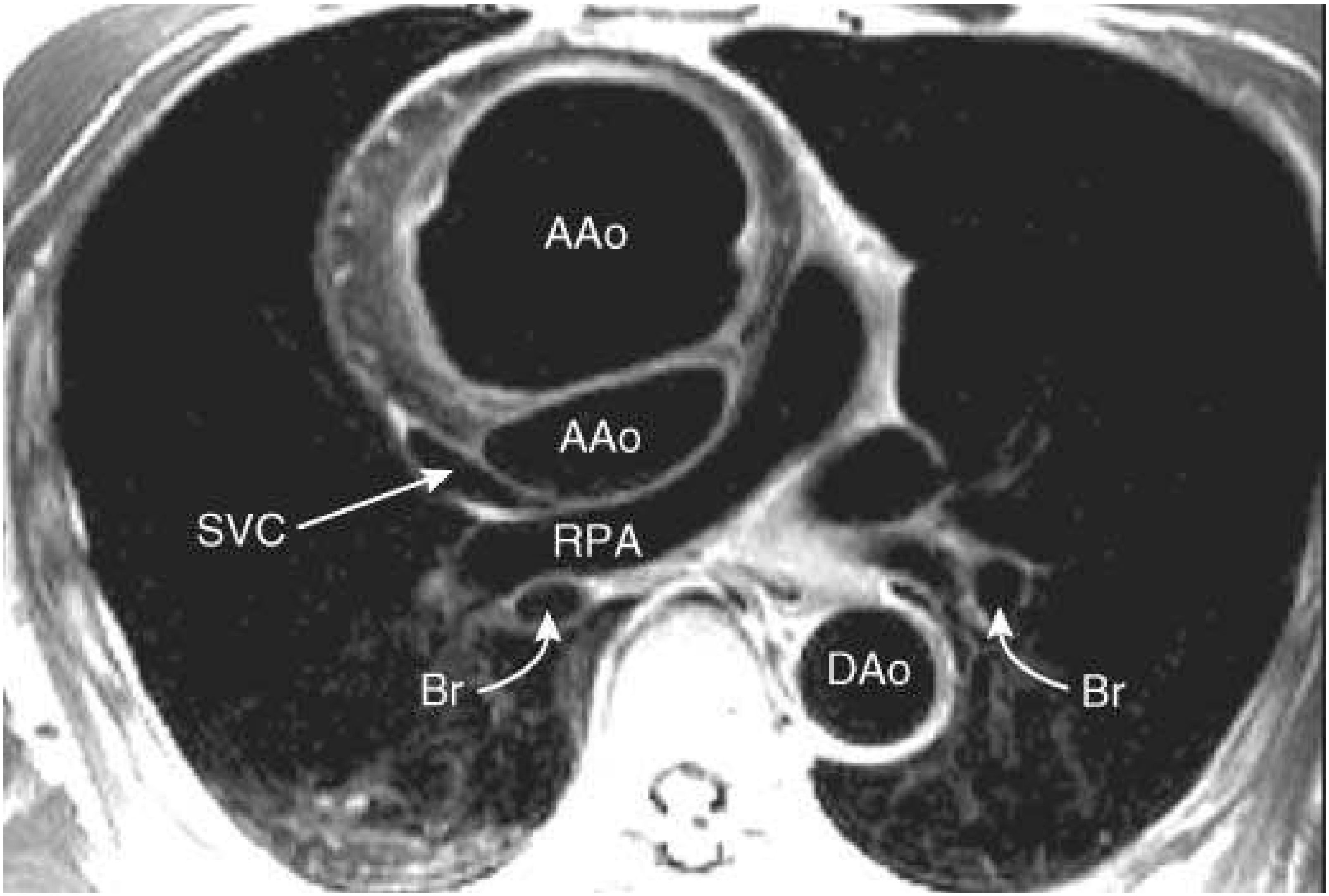
- 3D imaging allows volume calcuations
- Gold standard?
  - Right and Left ventricular ejection fractions
  - Stenotic valve areas (planimetry)
  - Valvular regurgitation volumes

Great vessel imaging

- High sensitivity for aortic detection
- Often can identify the site of intimal tear

- However
  - Limited monitoring available in MRI scan
  - Patient needs to be hemodynamically stable
  - Contraindicated with ICD, pacemaker

CMR of Aortic Dissection



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CMR stress testing

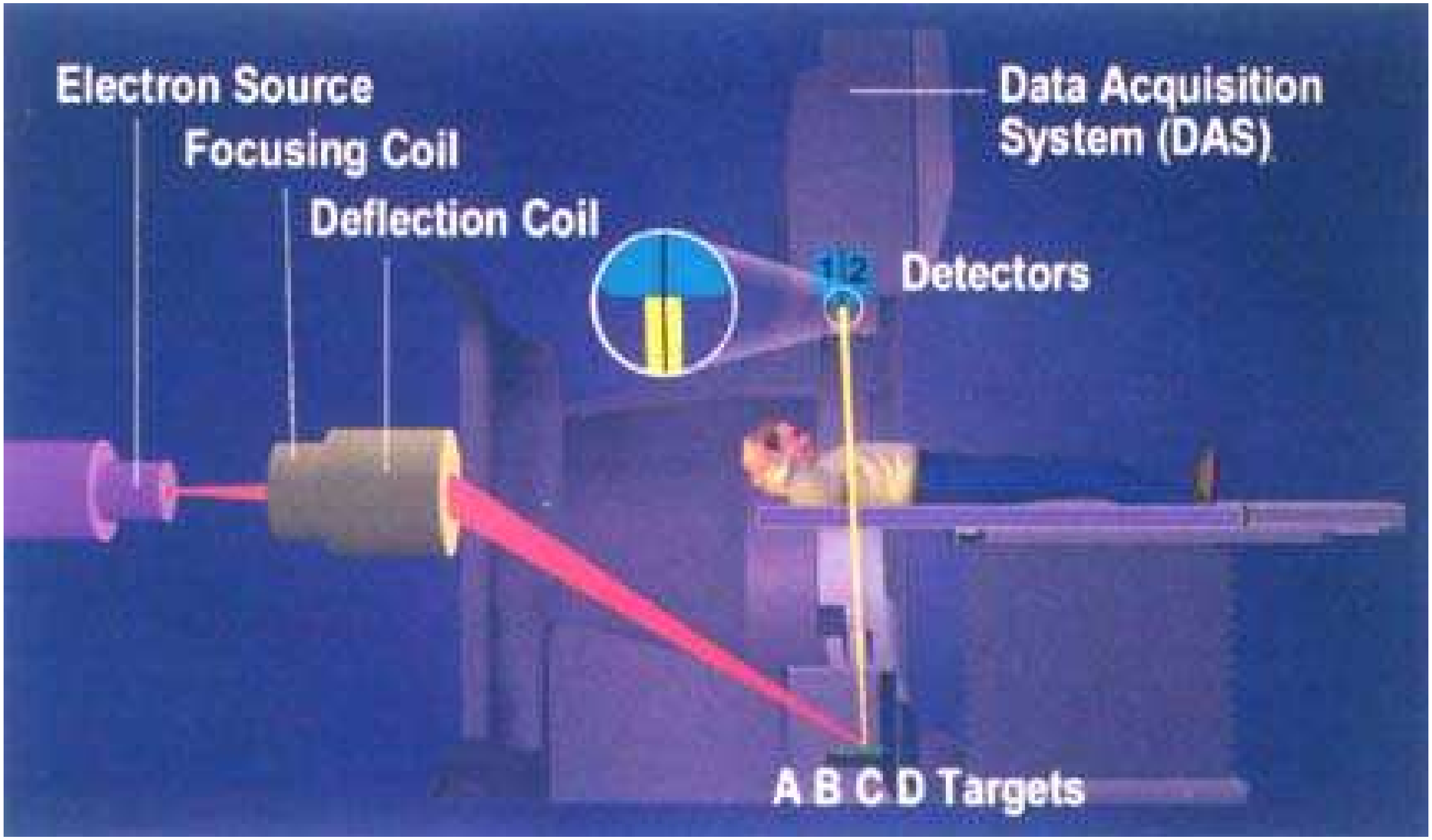
- Performed with dobutamine
- Analysis of wall motion
- Very uncommon in routine practice

Cardiac Computed Tomography

- Coronary artery calcium scoring
- Coronary arteriography
  - Atherosclerosis
  - Bypass grafts
  - Anomaly
- Pericardial imaging
  - Constriction/calcification
- Left atrial imaging
  - Appendage thrombus
  - Pulmonary vein anatomy
- Functional imaging
  - Chamber size, volumes, EF
  - Perfusion/Viability?

Cardiac Computed Tomography

- Calcium scoring
  - Non-contrast study
  - Multidetector CT, at least 16 slice
    - Most common, scanner can be used for any other application
  - Electron beam CT (EBCT)
    - Less common, exclusively used for calcium scoring
  - Scan time about 10-15 seconds



- Beam focused by electromagnetic coil
- Very rapid imaging (50-100ms)

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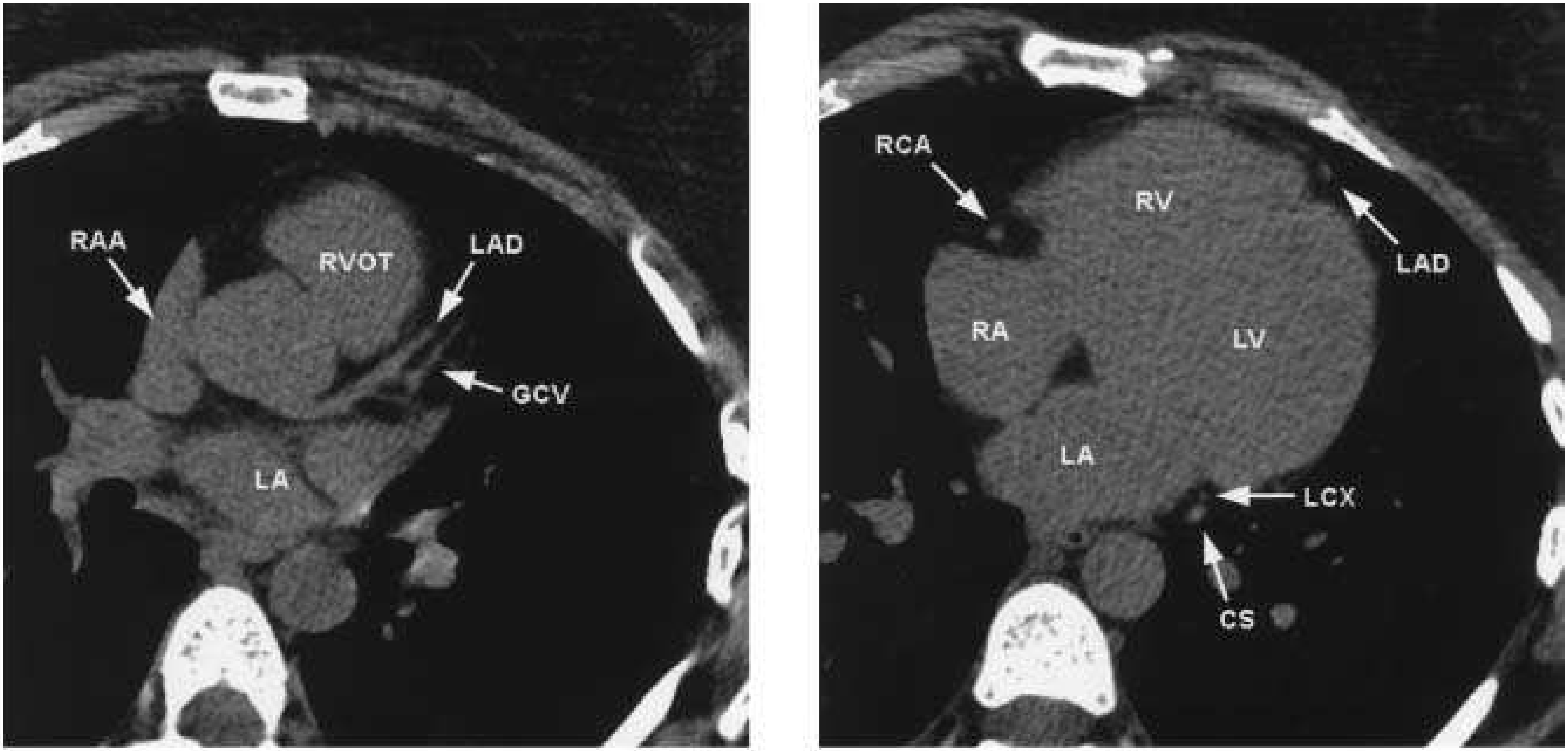
Noncontrast CT



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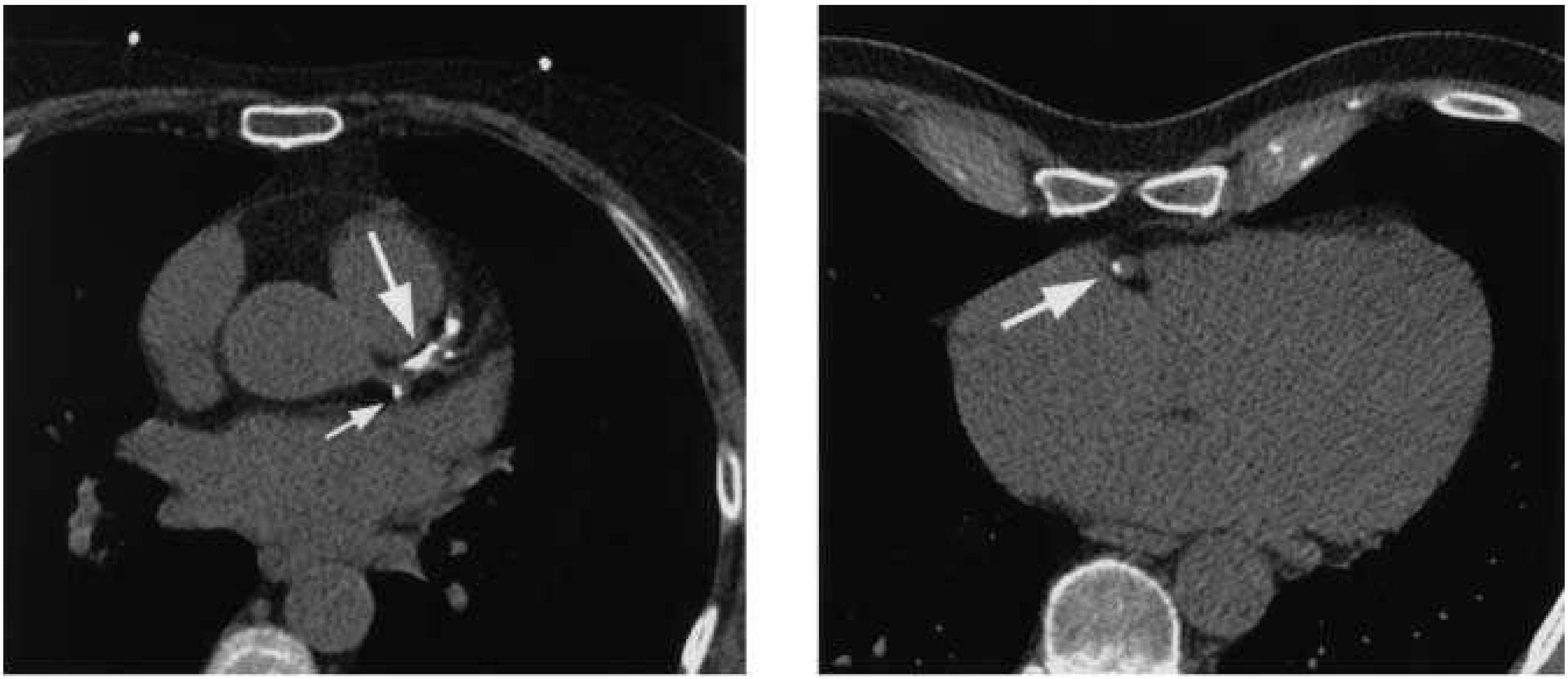
CT calcium scoring



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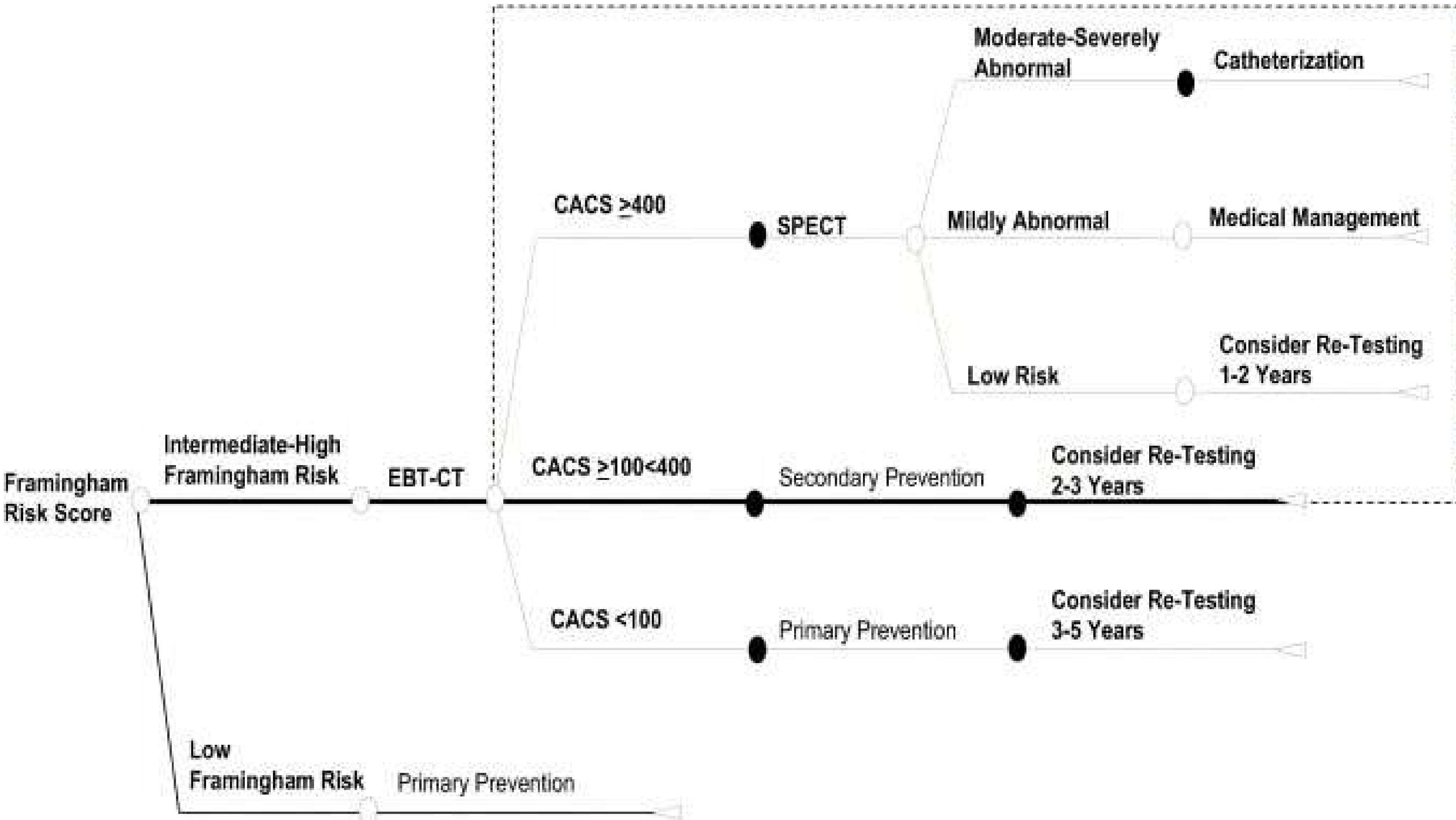
Calcium scoring

- Scoring is a combination of manual and automated calcium identification
- Scores generally reported as a number and an age-matched percentile
- Current guidelines use only the absolute number
  - <100 low risk/normal
  - 100-400 low-moderate risk; modify risk factors
  - >400 high risk; consider stress test

Interpreting Calcium Score asymptomatic patients

	Calcium Score	Annual coronary event rate
Low risk	0	0.12%
Mild risk	1-100	0.37%
Moderate risk	101-299 or 399	0.71%
High risk	>=300 or 400	1.56%

Shaw LJ, Taylor A, Raggi P, Berman DS. Role of noninvasive imaging in asymptomatic high-risk patients. J Nucl Cardiol. 2006 Mar-Apr;13(2):156-62.



Shaw LJ, Taylor A, Raggi P, Berman DS. Role of noninvasive imaging in asymptomatic high-risk patients. J Nucl Cardiol. 2006 Mar-Apr;13(2):156-62.

Cardiac CT coronary angiogram

a brief history

- Is it possible to get a coronary angiogram without the risk of a heart catheterization?
- Initial CT's had a single detector
- 1999 – 4 slice multidetector CT
  - 1st attempts at CT coronary angiograms
- 2001 – 16 slice multidetector CT
- 2004 – 64 slice MDCT

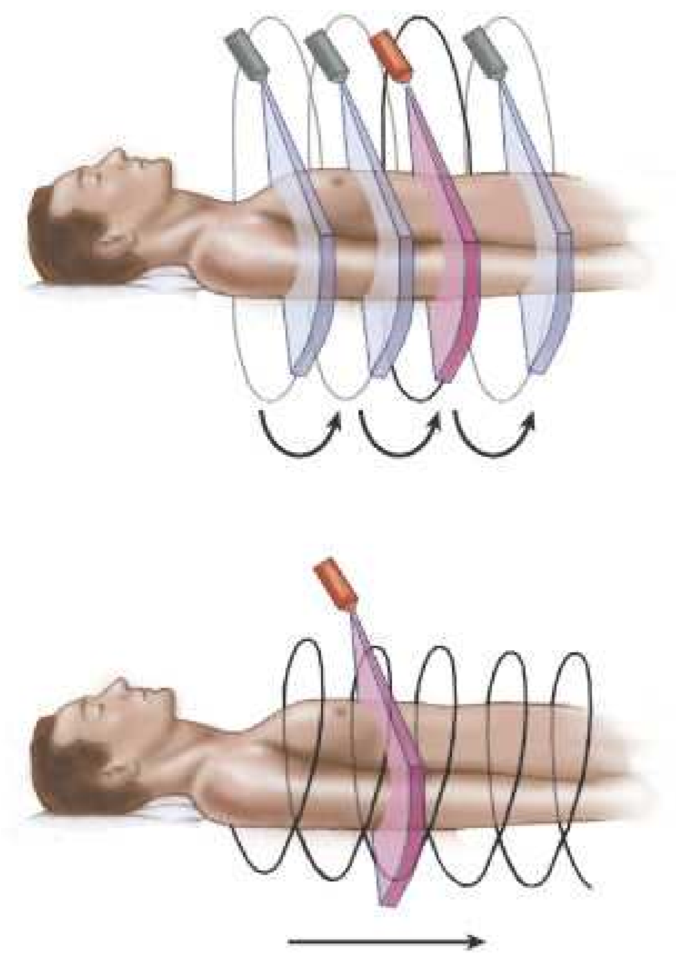
CT angiogram procedure

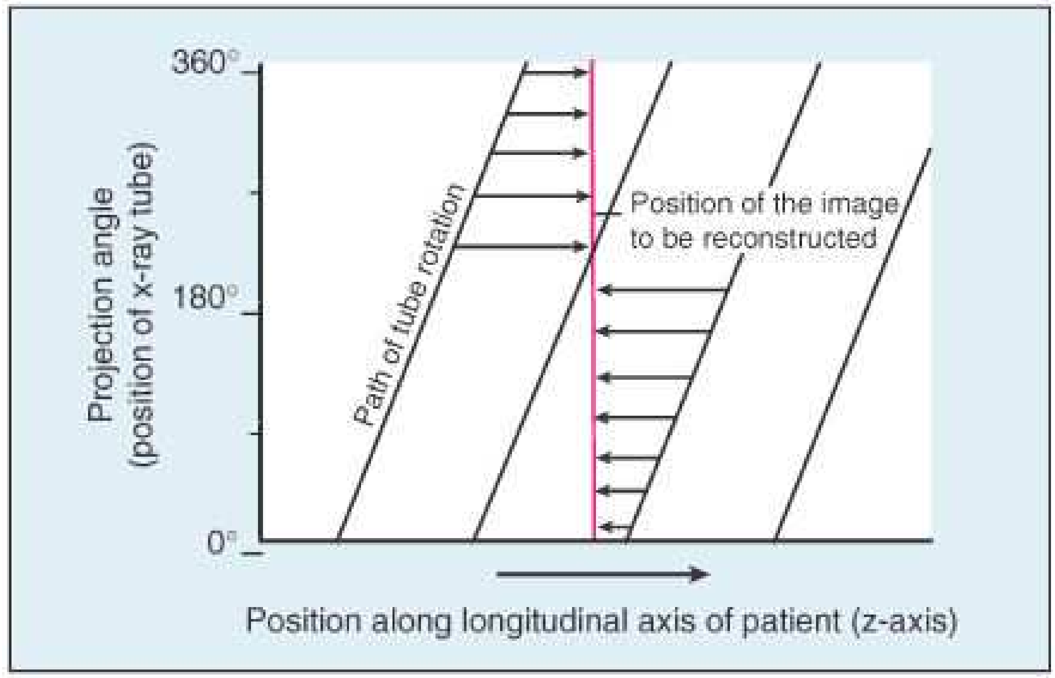
- NPO except fluids
- Give beta blockers to control heart rate
  - Target rate <65
  - Slower is better
- Before contrast injection, give SL NTG
  - Dilates coronary vessels for better imaging
  - No viagra, cialis, levitra use!
- Contrast injected
- Breath hold
- Scan time is approximately 15 seconds (64 slice)

Factors involved in coronary imaging

- Heart is a moving object
  - It beats
  - It moves with respiration
  - Temporal resolution and “number of slices”
- Coronary vessels are small
  - Smallest stent is 2.0 mm diameter
  - Spatial resolution

Sequential vs Helical CT scan





Temporal resolution depends on how quickly the scanner can image a "slice;" this correlates with speed of scanner revolution

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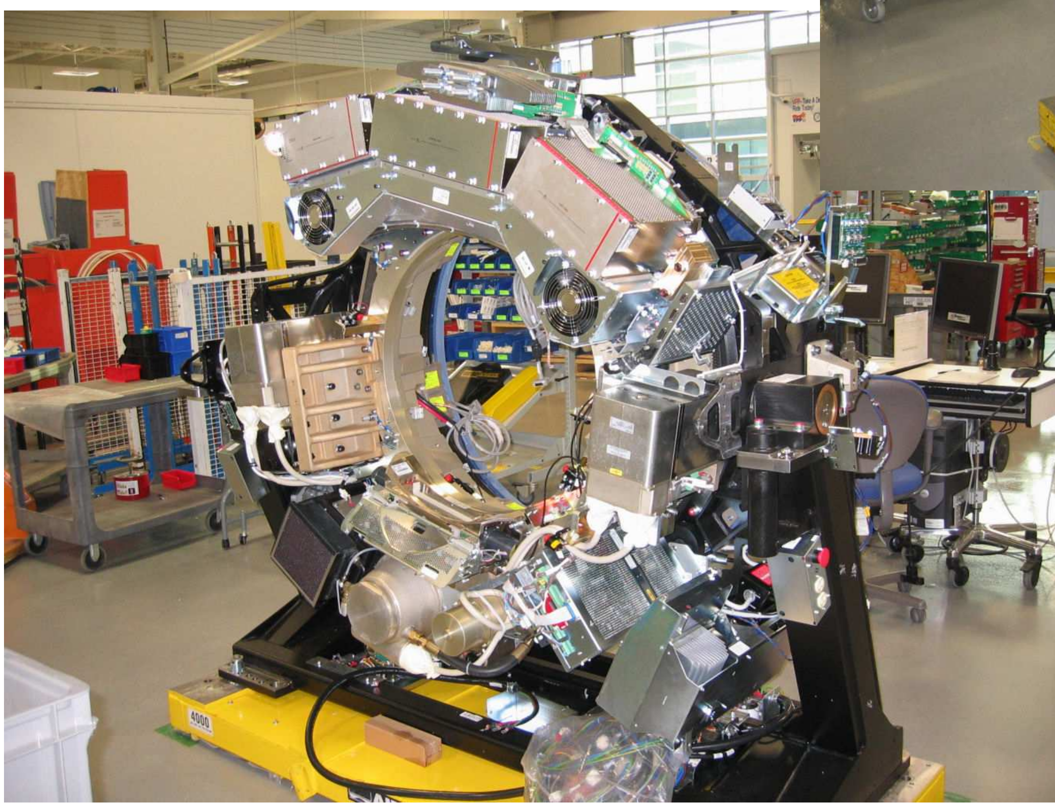
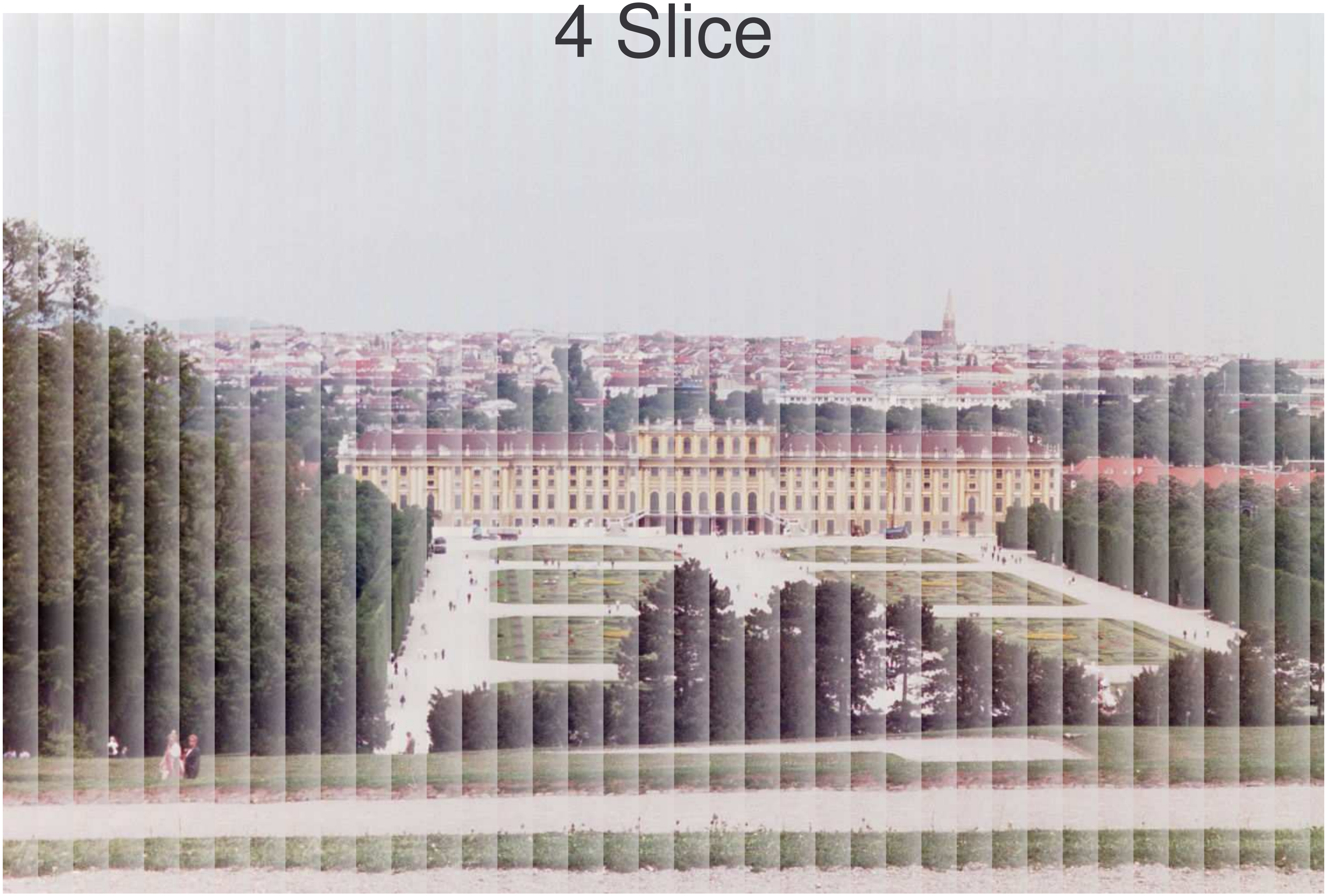
Inside a 64 slice CT scanner

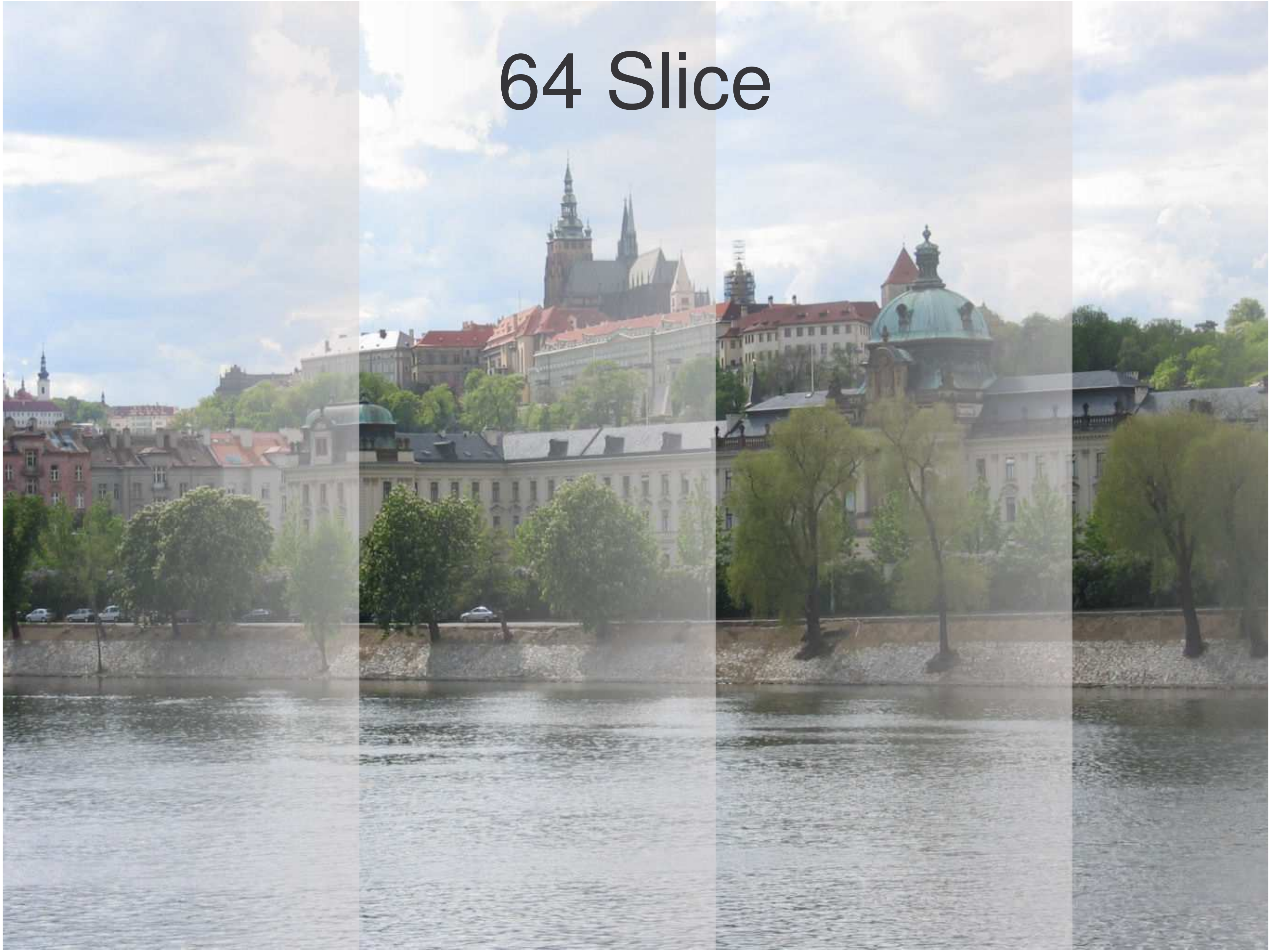


Effect of Slices
4 Slice



16 Slice

64 Slice



Effect of Spatial Resolution

“Fast” temporal resolution

“Medium” temporal resolution

“Slow” Temporal Resolution

Comparing the technology

	Coronary Calcium	Coronay Arteriography – 64 slice	Fluoroscopy (Cath)	CMR
Radiation	1.5 mSV	8-22 mSv (avg 10-12)	3-5 mSV	0
Spatial resolution	1.5mm	0.6mm (0.4mm)	0.2mm	
IV contrast	no	80-120cc	60-120cc	no
Breath Hold	10s	10s	no	
Temporal Resolution	50-100 ms	165ms (83ms)	Fast (<30ms)	

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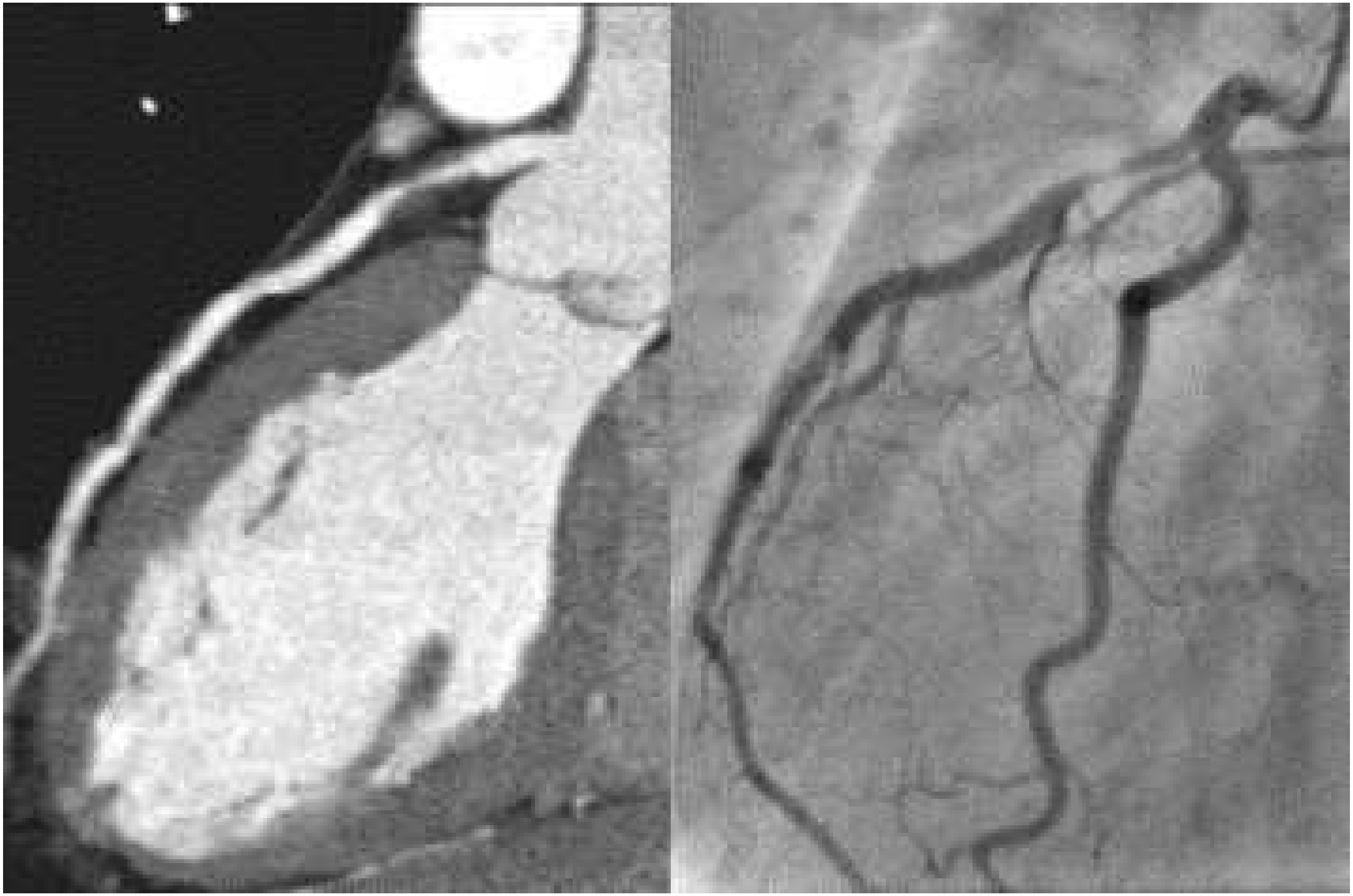
Limitations of CTA

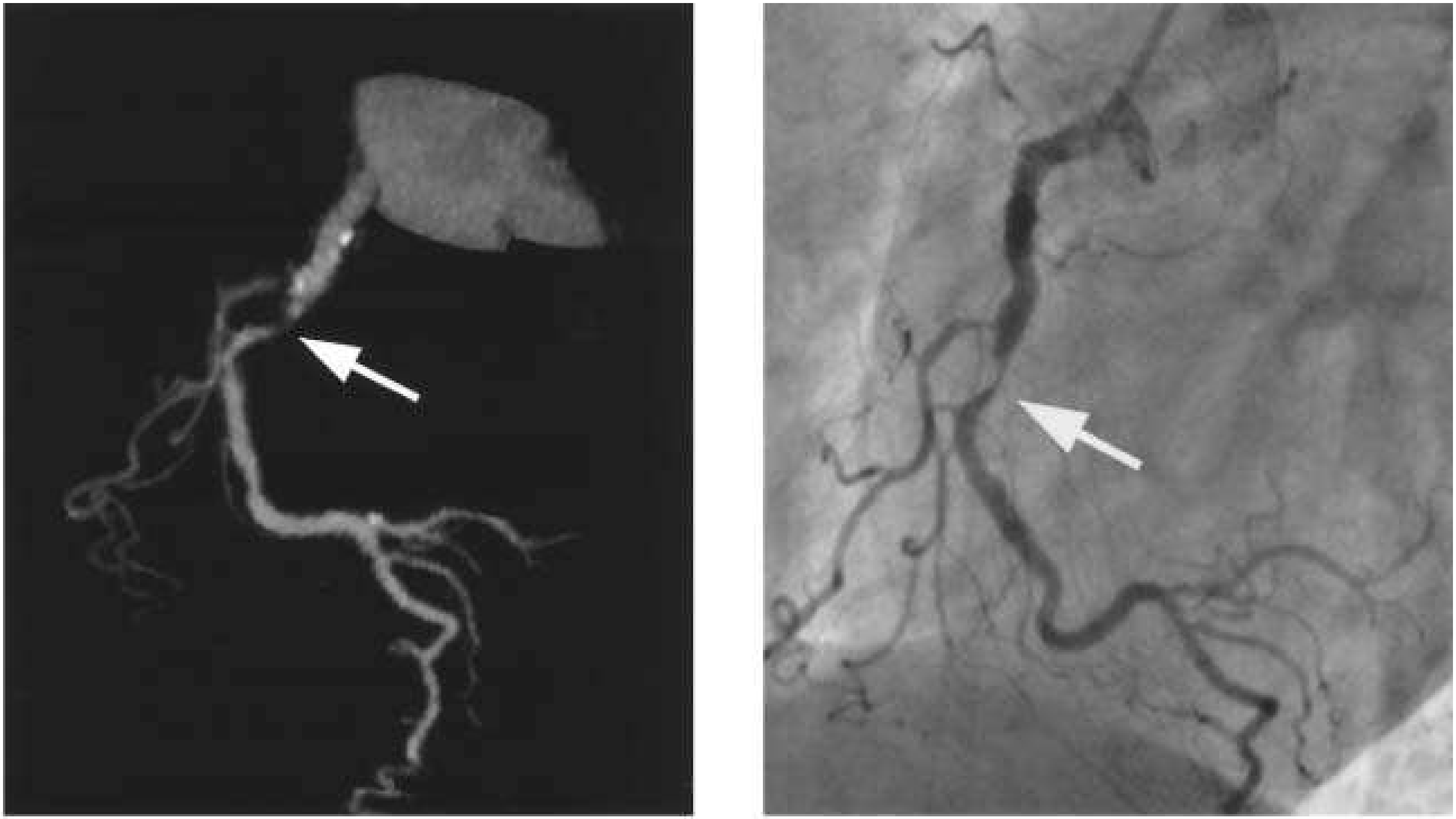
- Temporal resolution
  - Currently tube rotates at 330ms
    - Only need ½ rotation to obtain imaging, so temporal resolution is around165ms
  - This is limiting factor for temporal resolution
  - Dual source CT may improve this
  - Why not just rotate the tube faster?
    - Tube components weigh about 2000 pounds
    - At current speeds (180 rpm), about 18 G's generated
    - To improve rotation speed to 200ms, 75 G's would be generated

LAD stenosis



Raggi P, Thomas GS. Role of computed tomography and perfusion imaging in patients with known or suspected coronary artery disease. J Nucl Cardiol. 2006 Mar-Apr;13(2):170-5.

RCA stenosis



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CTA of stent

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How good is 64 slice coronary MDCT?

TABLE 2. Diagnostic Performance and Predictive Value of 64-Slice CT Coronary Angiography for the Detection of ≥50% Stenoses on QCA

	n	Sensitivity, %	Specificity, %	PPV, %	NPV, %	+LR	−LR
Segment-based analysis							
All segments	725	99 (94–98)	95 (93–96)	76 (67–89)	100 (99–100)	20.81	0.01
Proximal segments	204	100 (89–100)	97 (93–98)	83 (67–97)	100 (97–100)	29.00	0.00
Mid segments	142	97 (83–99)	94 (88–97)	81 (63–96)	99 (94–99)	15.47	0.04
Distal segments	121	100 (68–100)	97 (92–99)	73 (39–98)	100 (96–100)	37.67	0.00
Side branches	258	100 (87–100)	94 (90–96)	65 (48–85)	100 (98–100)	16.57	0.00
LM	51	100 (21–100)	100 (93–100)	100 (92–100)	100 (2–100)	∞	0.00
LAD	230	97 (85–100)	92 (88–95)	69 (53–86)	99 (96–99)	12.68	0.03
LCx	235	100 (88–100)	97 (94–99)	83 (66–97)	100 (98–100)	34.33	0.00
RCA	209	100 (89–100)	95 (91–97)	77 (60–95)	100 (97–100)	19.89	0.00
Patient-based analysis							
All segments	51	100 (91–100)	92 (67–99)	97 (86–99)	100 (73–100)	13.00	0.00

PPV indicates positive predictive value; NPV, negative predictive value; +LR, positive likelihood ratio; −LR, negative likelihood ratio; LM, left main coronary artery; LCx, circumflex coronary artery; and RCA, right coronary artery. For segment-based analysis, analysis of 725 segments visualized on the conventional angiogram and classified according to a 17-segment modified AHA classification was performed. Segments were further classified on the basis of their location within the coronary tree (proximal, mid, or distal segments of the main coronary artery arteries or side branches) and their location within a single vessel (LM, LAD, LCx, or RCA). For patient-based analysis, analysis of 51 patients was performed. Values in parentheses represent 95% CIs.

Mollet NR, Cademartiri F, van Mieghem CA, Runza G, McFadden EP, Baks T, Serruys PW, Krestin GP, de Feyter PJ. High-resolution spiral computed tomography coronary angiography in patients referred for diagnostic conventional coronary angiography. Circulation. 2005 Oct 11;112(15):2318-23. Epub 2005 Oct 3.

CT of Pericardium

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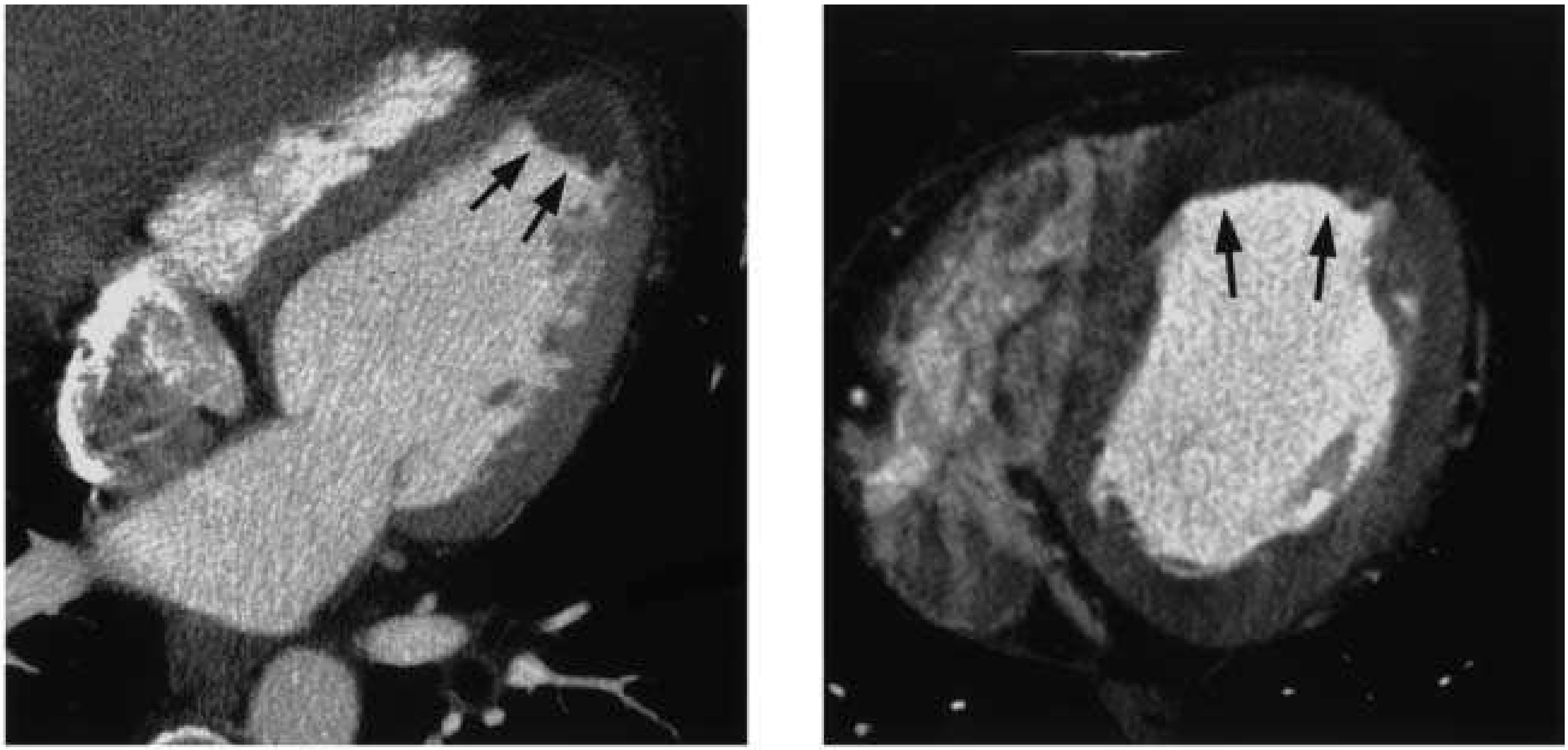
CT of LV thrombus



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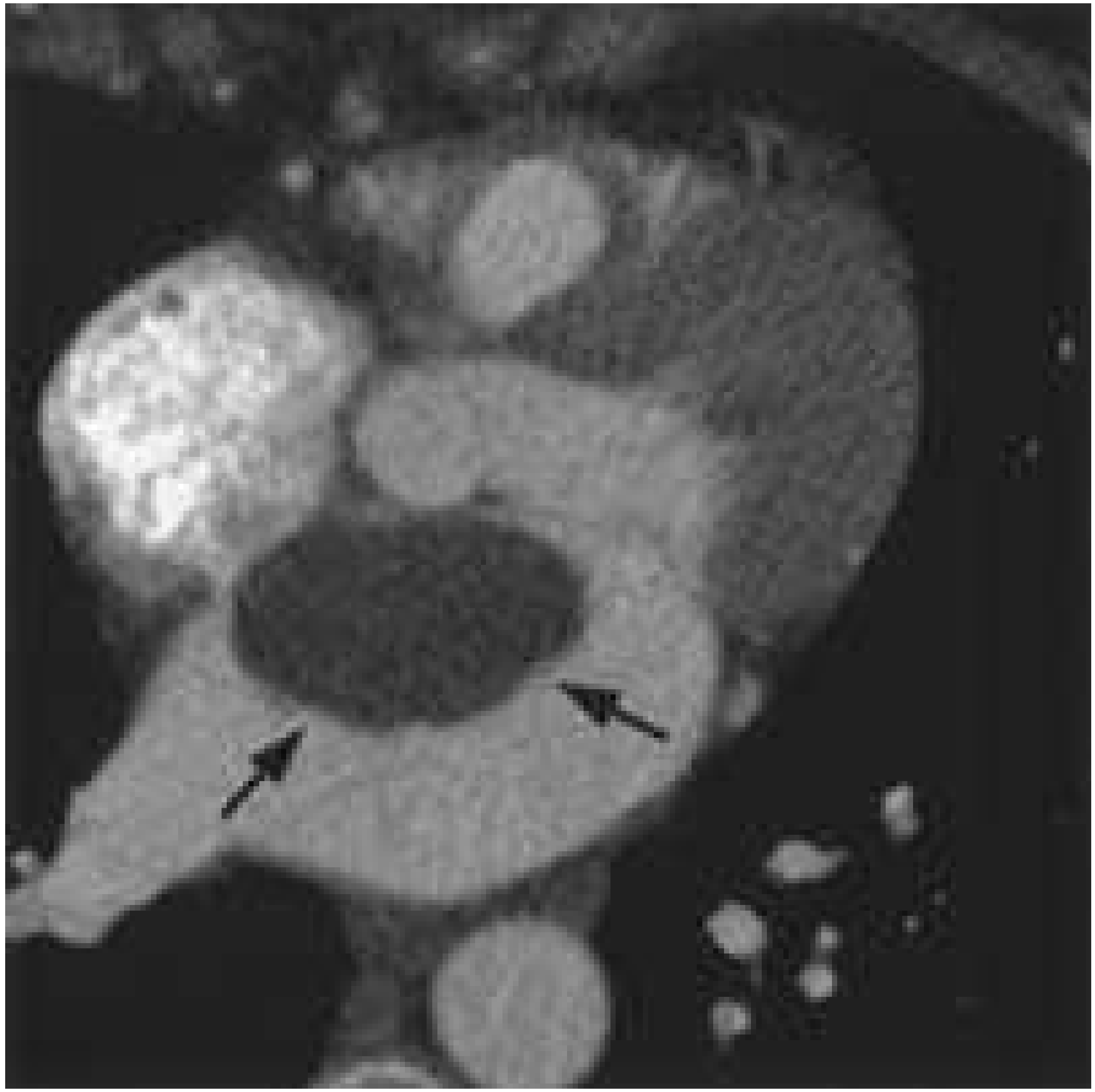
CT of LA Myxoma



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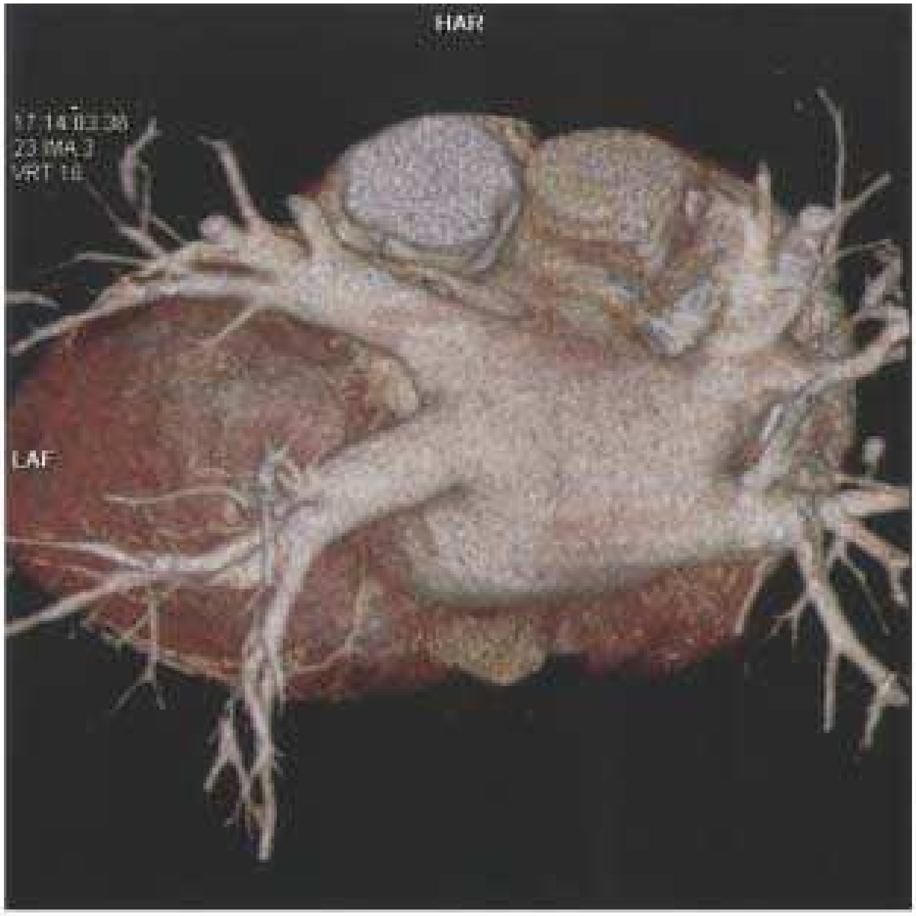
CT pulmonary veins



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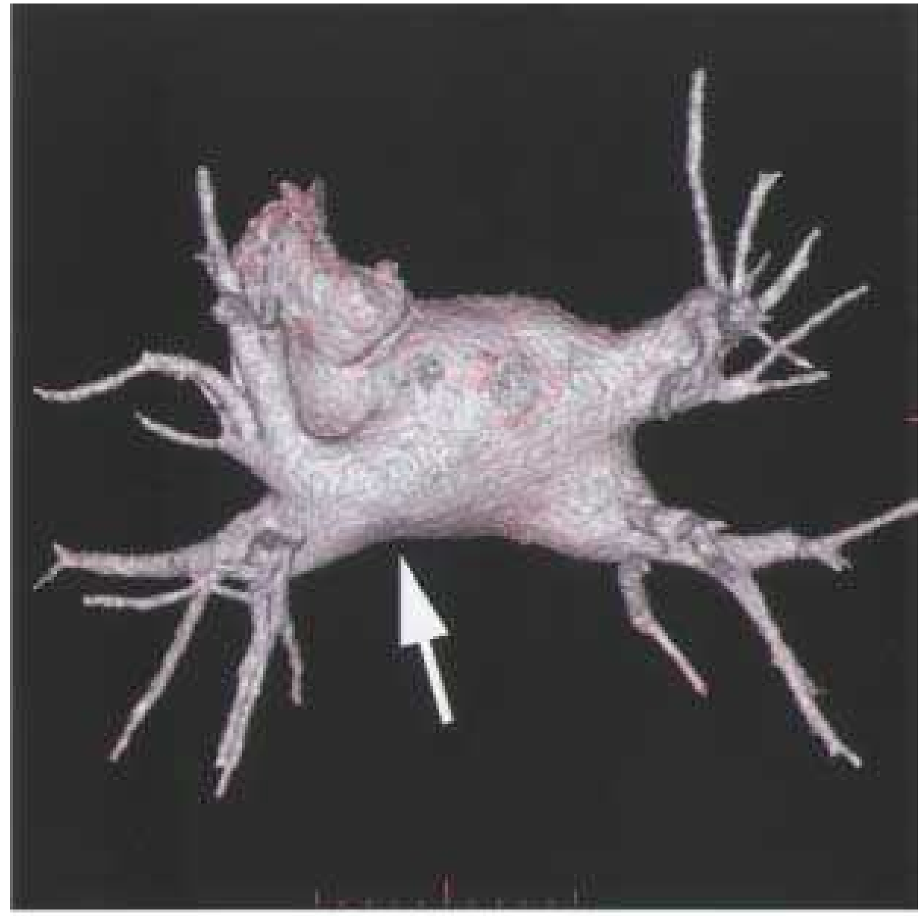

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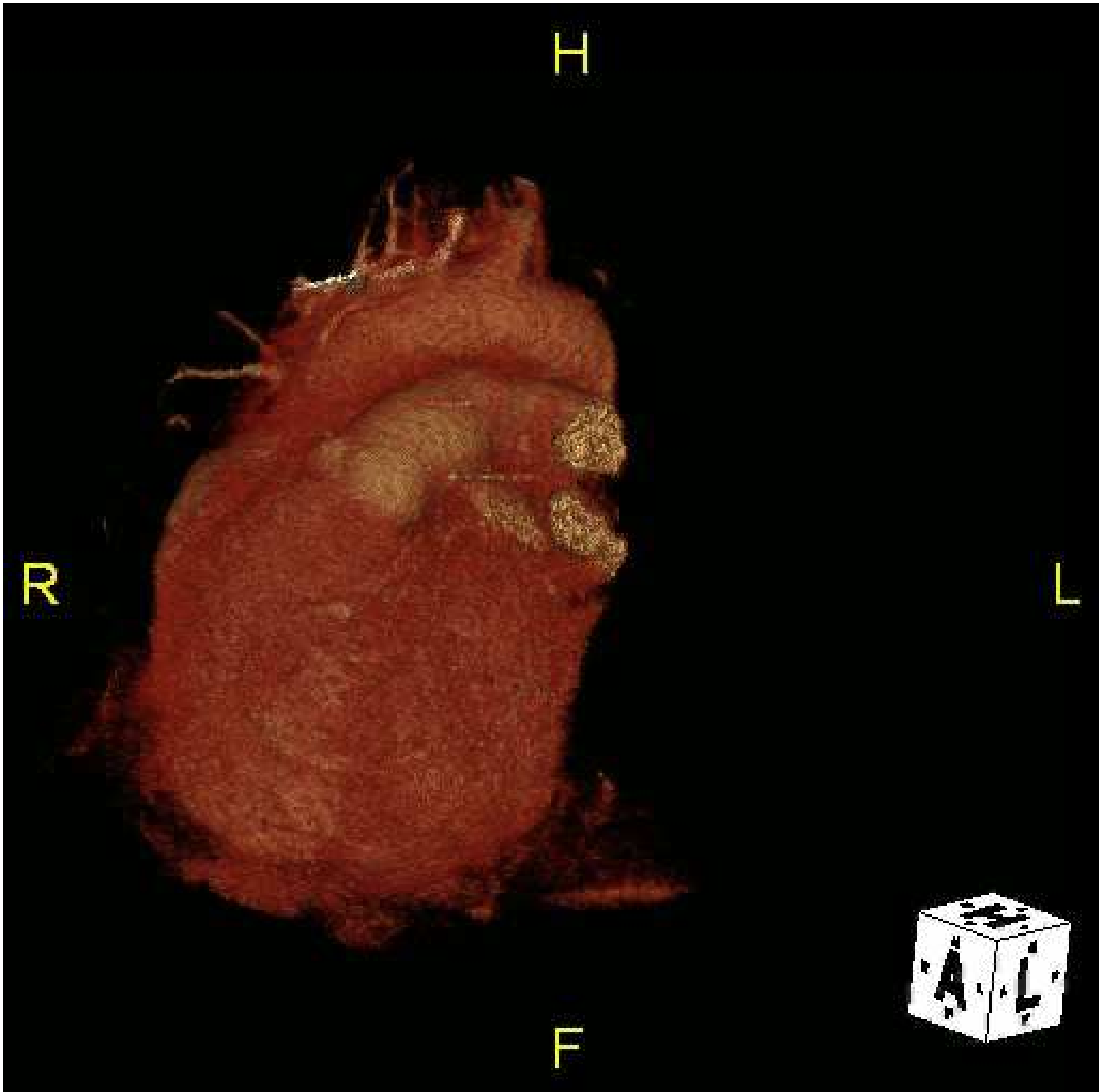
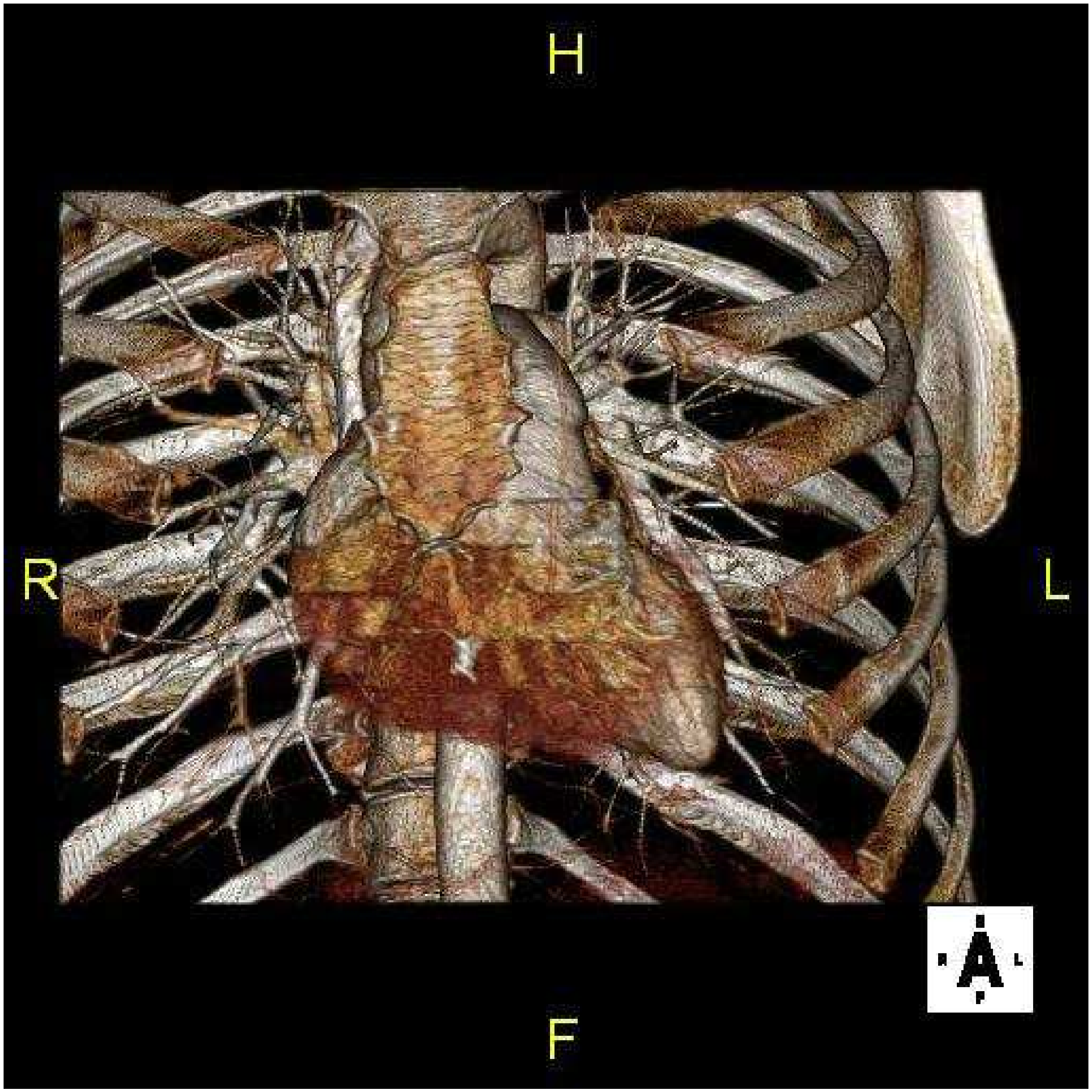
Now for some “real world” cases

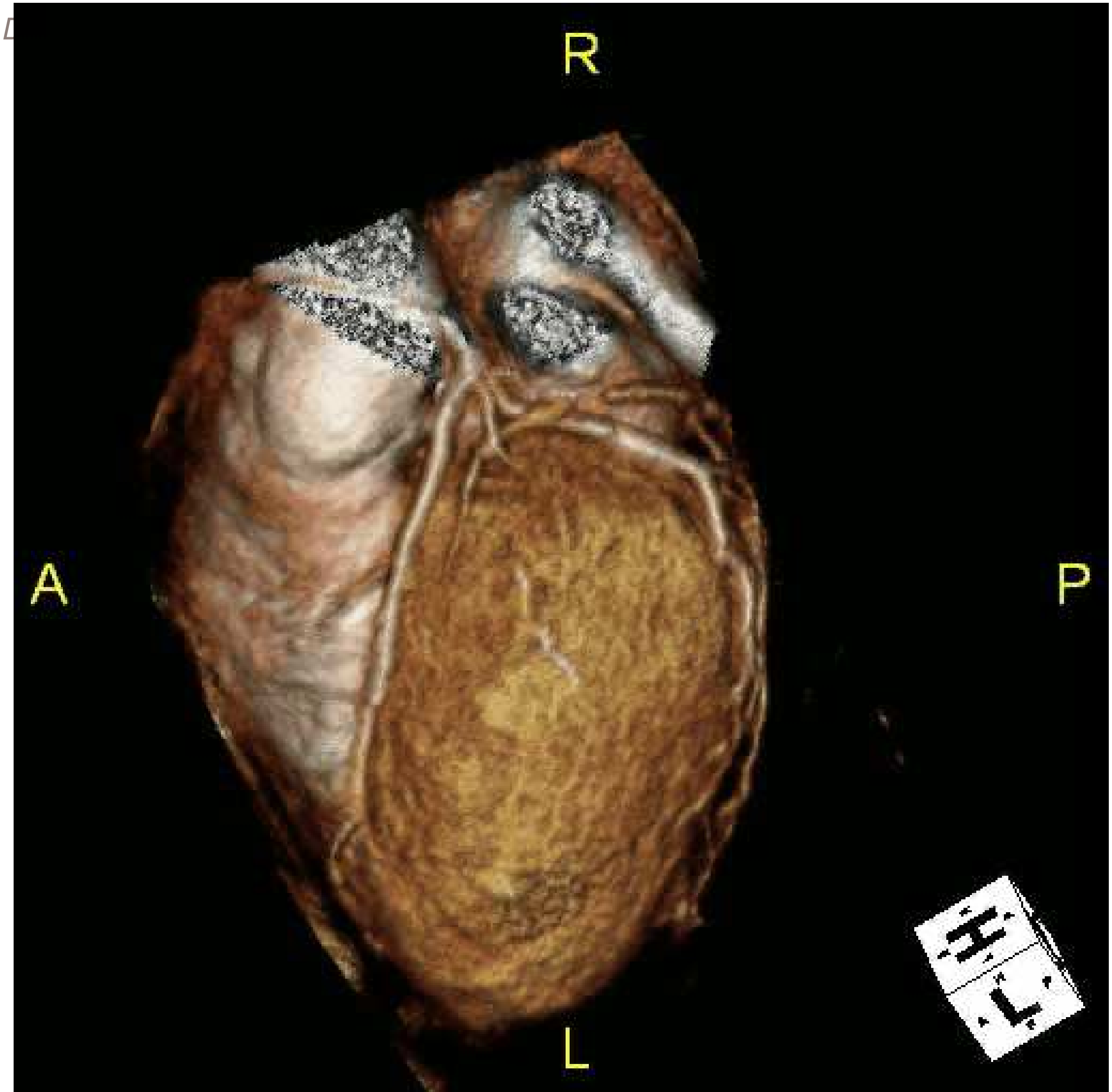
Obese patient



bad data set VR heart.avi

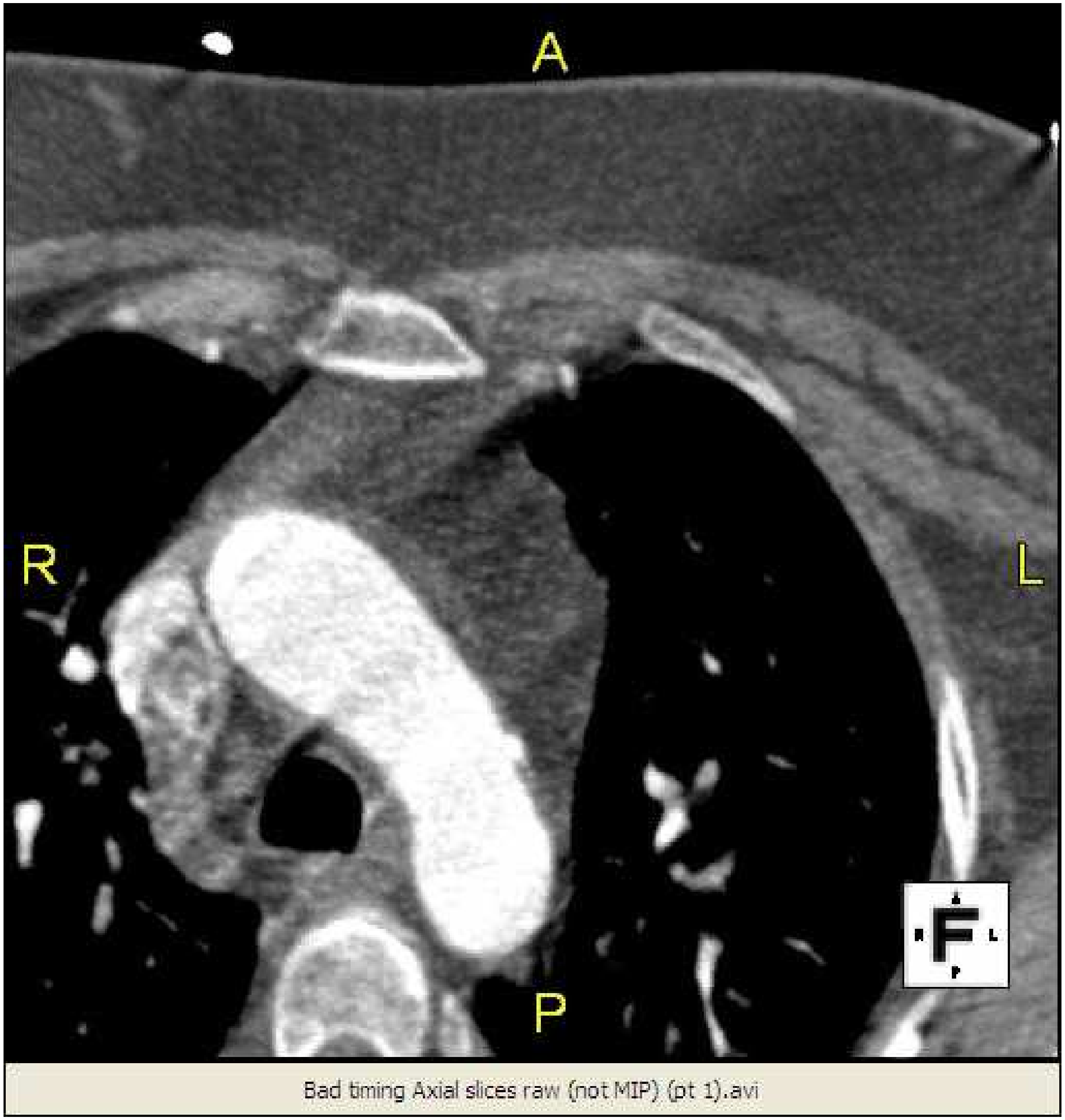
Misregistration
patient did not hold breath



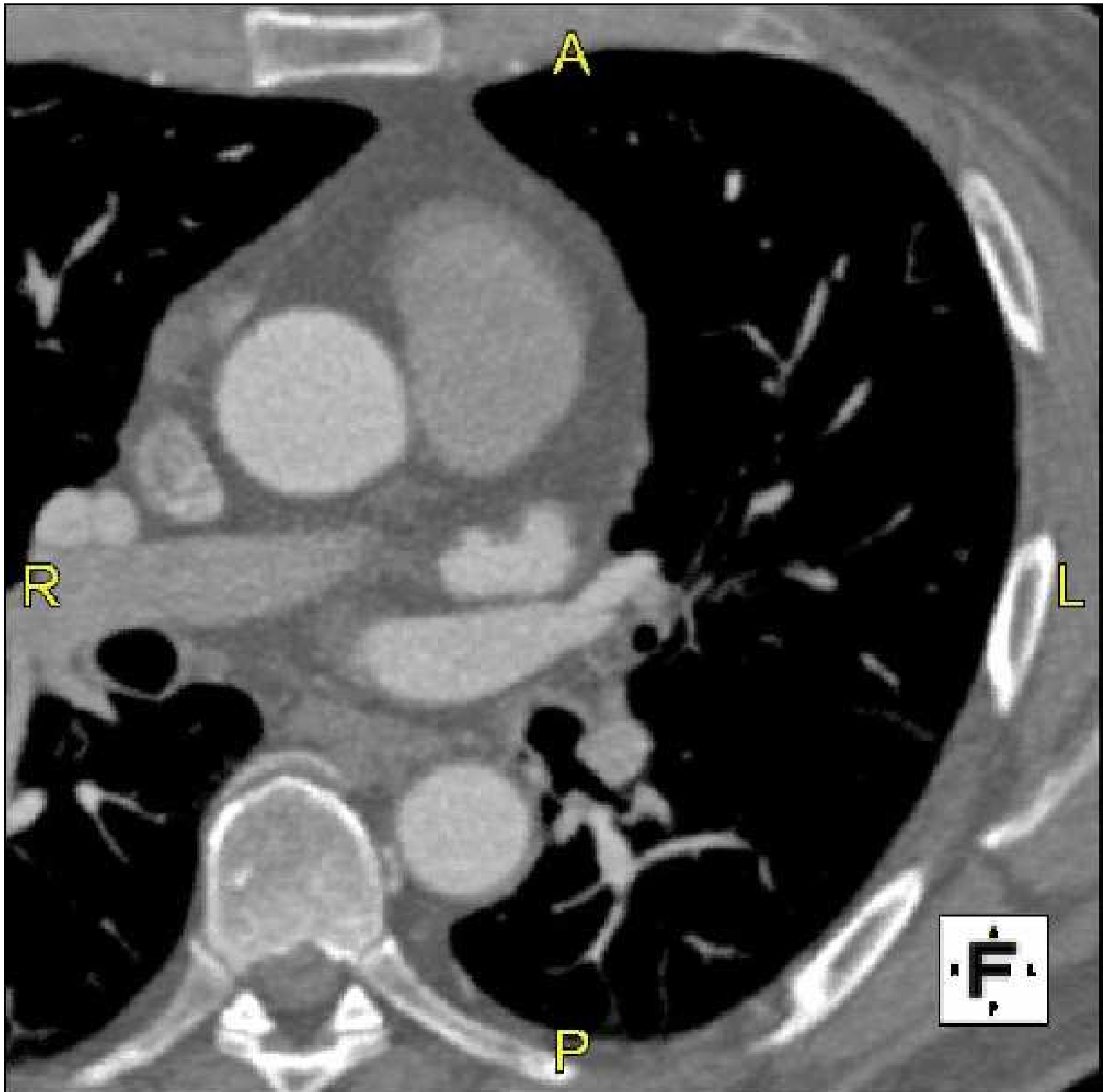


heart 3d VR.avi

How to analyze Cardiac CT

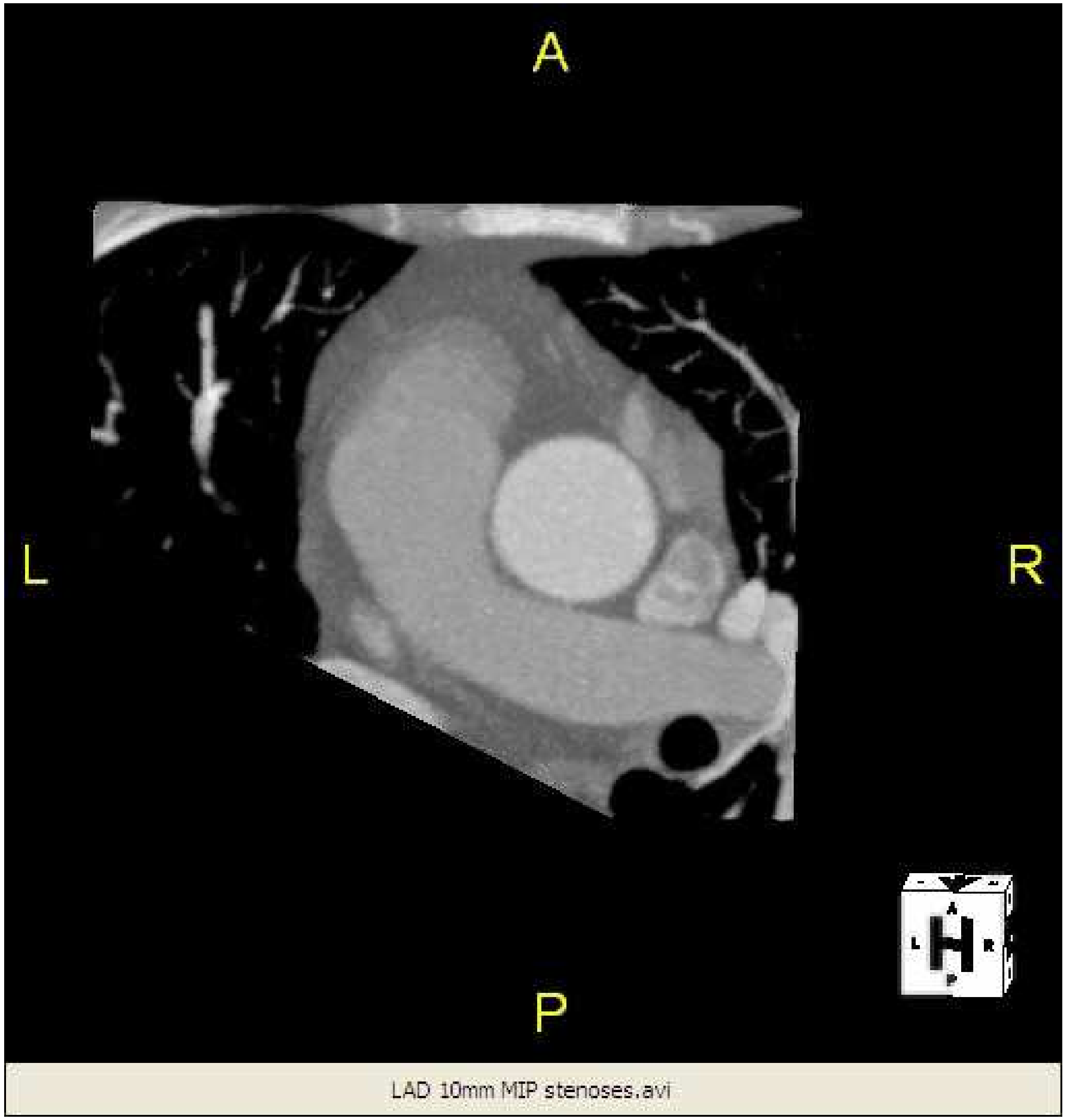


LAD Aneurysm and stenosis axial cuts



LAD axial anuerysm and stenosis.avi

LAD aneurysm MIP



Summary of Technologies

- TEE
  - Atrial fibrillation/cardioversion
  - Endocarditis
  - Aortic dissection
  - ASD/PFO
- CMR
  - Not widely available
  - Wide range of imaging techniques
  - No contrast, no radiation

Summary of Cardiac CT

- Calcium scoring
  - Low radiation, noncontrast
  - Risk stratification (>=400 is high risk)
  - Low/intermediate risk patients?
  - Not very useful over age of 65

Tips for the Boards

- CMR not likely to be on boards
- TEE
  - Atrial fibrillation
    - If pt is hemodynamically unstable, cardiovert without waiting for a TEE
  - Endocarditis
    - Should be 1st test in patients with hx of prosthetic valve or prior endocarditis
    - Use for any patient with hemodynamic or electrical complication of endocarditis
  - CVA
- CT
  - Calcium score >400 is high risk
  - Unlikely that CTA will be on boards

Patient selection for Cardiac CT Angiography

- Coronary arteriography
  - Higher radiation, contrast exposure
- Need slow, regular heart rhythm
- Factors limiting interpretation
  - Calcification (? Calcium score >700 uninterpretable)
  - Stents
  - Inability to hold breath for 10-15s
  - Obesity
  - Grafts can be identified and interpreted, but distal vessel evaluation can be challenging

Who should have CTA?

- No guidelines yet
- In my humble opinion
  - Lower risk patients with atypical/noncardiac chest pain
  - Patients <65 years of age
  - No prior known CAD/stent
  - Cooperative patient
  - Sinus rhythm

Interpreting a CTA

- A negative CTA almost certainly means that the patient does not have any coronary stenosis >50%
  - 99% Negative predictive value on per-segment basis
- A positive CTA has a 75% positive predictive value on a per-segment basis
- Calcium usually does not mean stenosis, but exceptions are possible

As you go into practice…

- Be cautious with CTA
- Do not use CTA when a stress test would be better
- Payers will not pay for tests that do not produce quality results
- We should not convert the current 2 step paradigm (stress test → cath) to a 3 step paradigm (CT → stress test → cath)
- Studies will hopefully guide our practice