Fundamentals, Techniques, Pitfalls, and Limitations of MDCT Interpretation and Measurement

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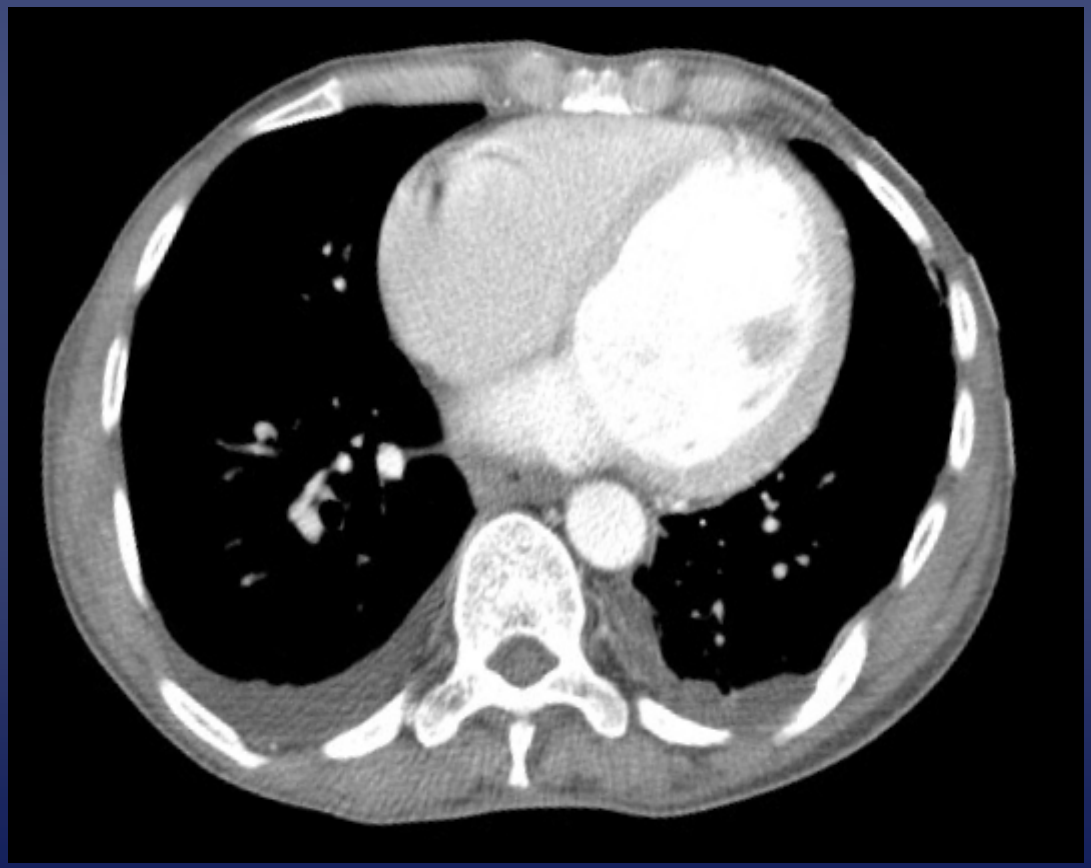
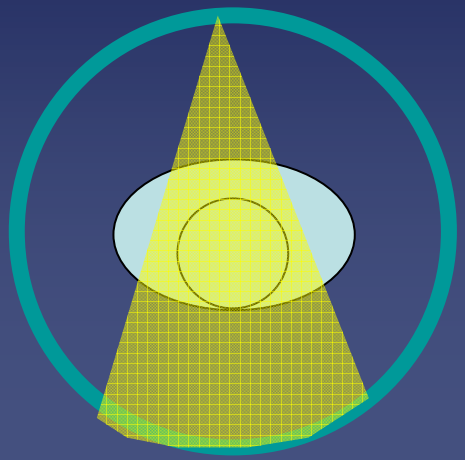
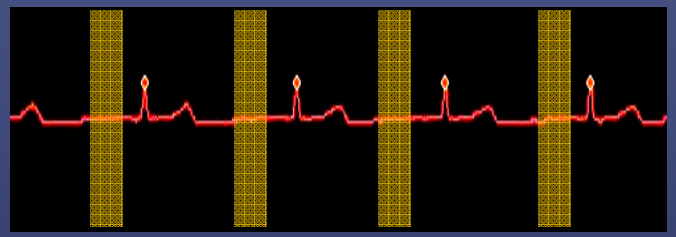
Traditional helical CT lacks sufficient temporal resolution to image the heart

Traditional recon algorithms *average* all of the acquired data (do not temporize the data)



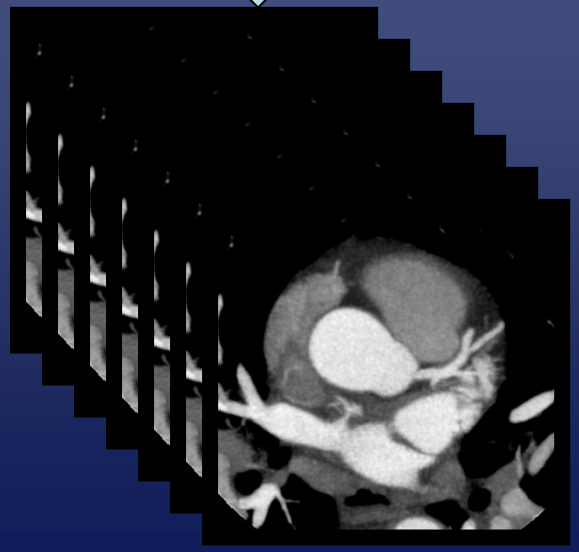
ECG Gating Permits Visualization of the Moving Heart



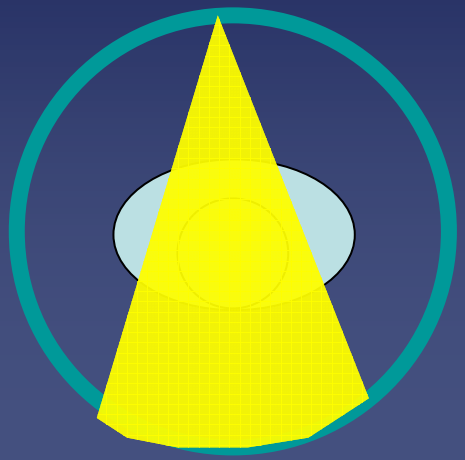


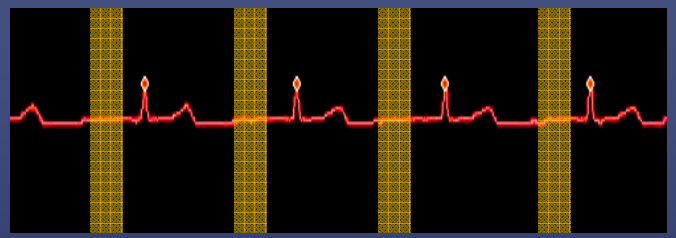
Selected Phase

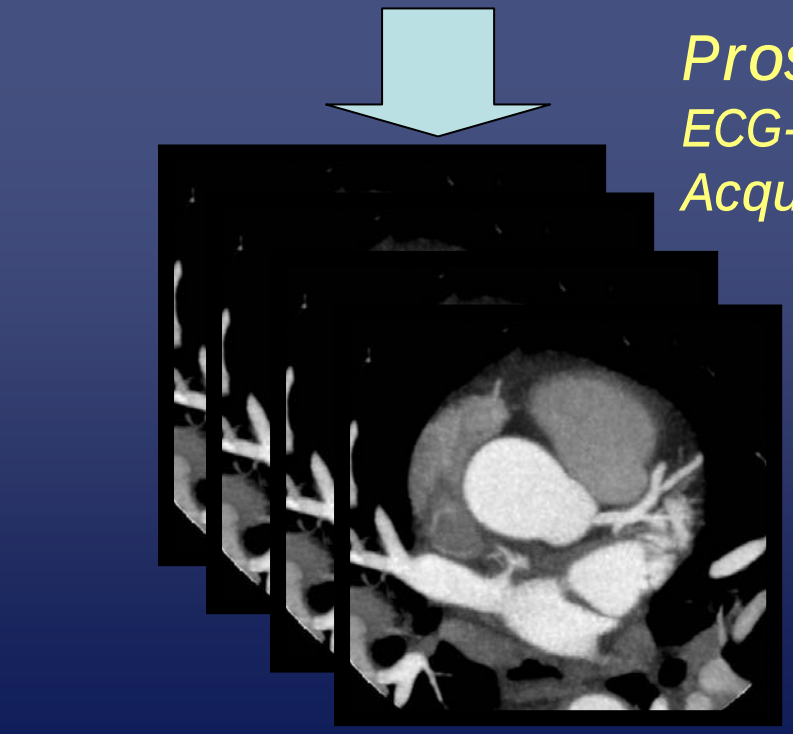
Retrospective
ECG-Gated
Reconstruction



Prospective Cardiac CT: X-Ray Tube Mostly Off







Prospective
ECG-Triggered
Acquisition

Pitfalls & Limitations

- Limitations
  - Noise
  - Motion Artifacts
  - Gating Artifacts
  - Beam Hardening
  - Volume Averaging
- Pitfalls
  - MIP pitfall
  - cMPR pitfalls
  - VR pitfalls

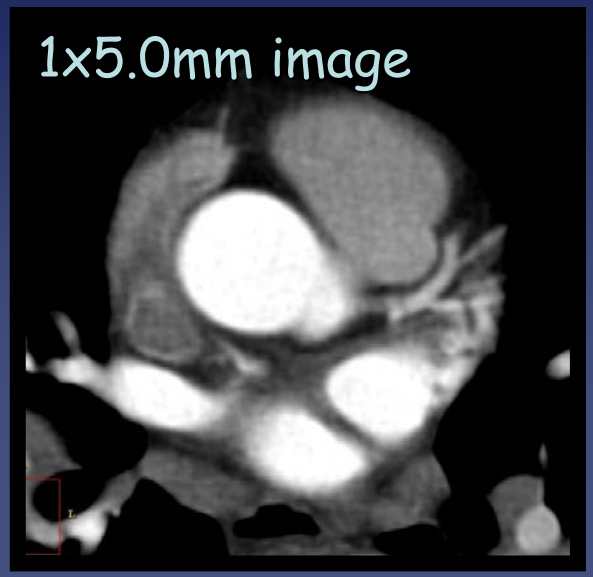
Limitations

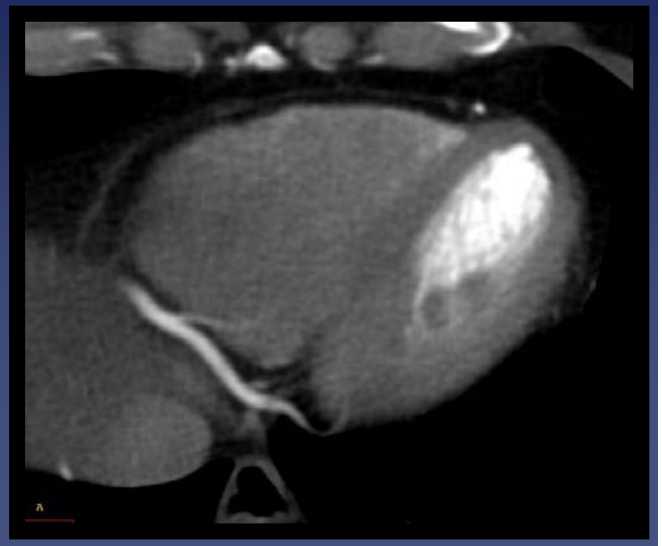
Noise

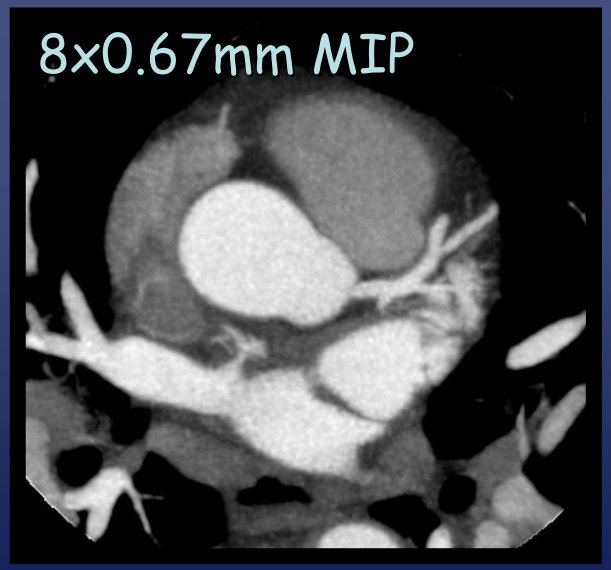
“Thin Slice” scanning is required for coronary CTA…
…but increases image noise

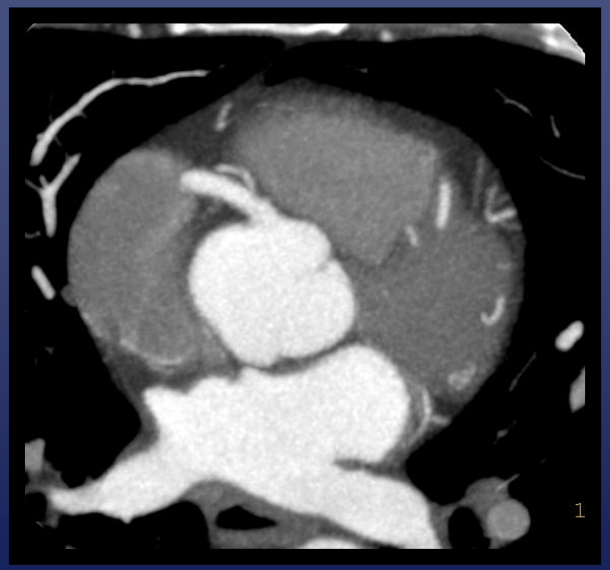
- Standard CT slice thickness = 5 mm
- Cardiac CT slice thickness = 0.5-0.75 mm
- Why?
  - Thin collimation = Better resolution of small structures (coronary arteries)

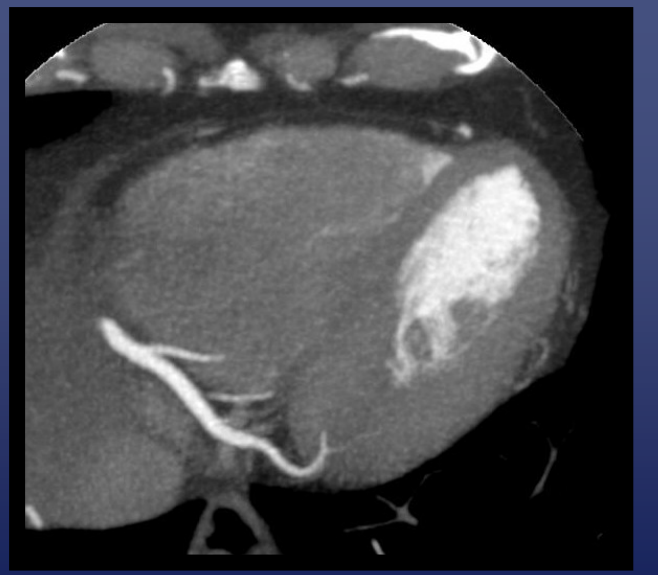
Axial Recons: Thin Slice = High Resolution



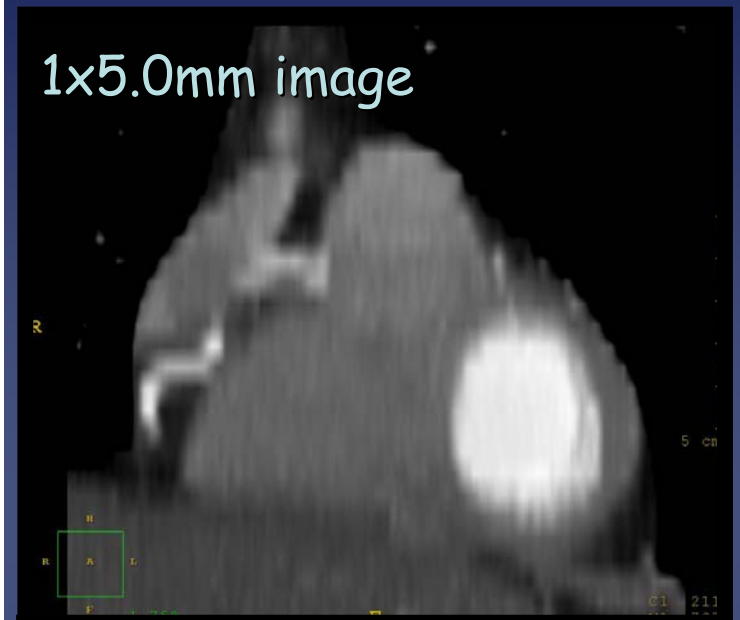


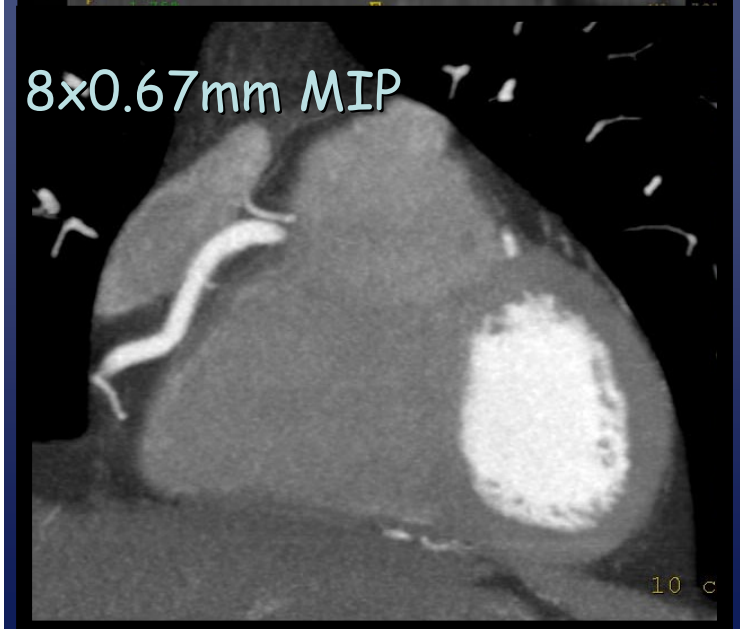






Coronal & Oblique Recons
Thin slice CT = preservation of z-axis resolution



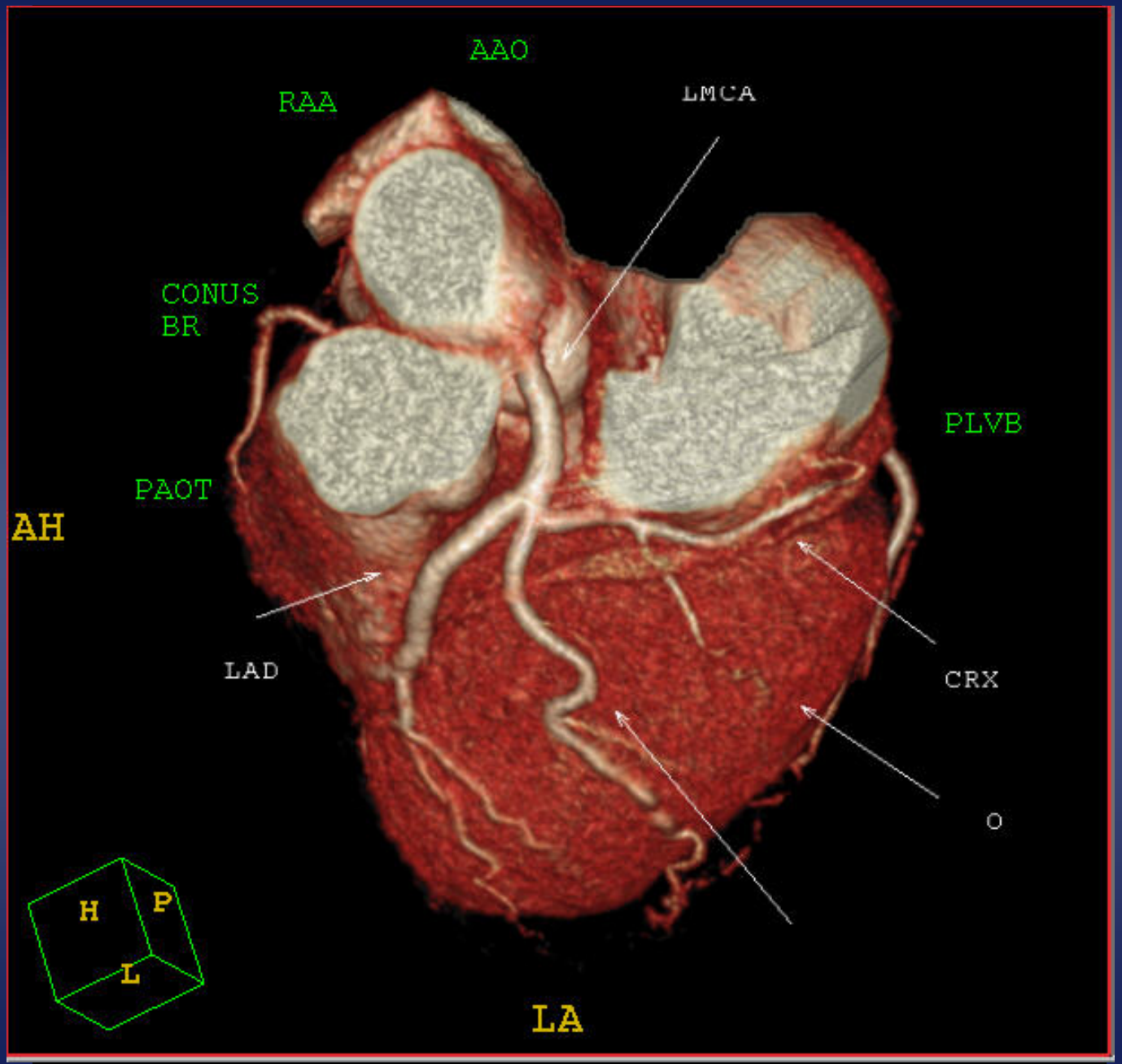


"Thin Slice" scanning is required for coronary CTA…
…but increases image noise

- Case Example
  - 37 yo woman
  - History of hypertension, diabetes
  - Symptom: palpitations during exercise
  - Treadmill stress test:
    - *Palpitations during exercise = PVC's*
    - *But also: mild ischemia, anterior wall → artifact?*

CT Scan

- 5’2” (1.57 m) tall and 272 lbs (124 kg)
- BMI = **50** kg/m^2
- Pulse 71 bpm (sinus rhythm)
  - 15 mg metoprolol i.v. → 55 bpm
- Tube settings:
  - 140 kVp, 425 mAs
- 85 mL contrast @ 5 mL/sec
- X-ray dose: 553 mGy (9.4 mSv)

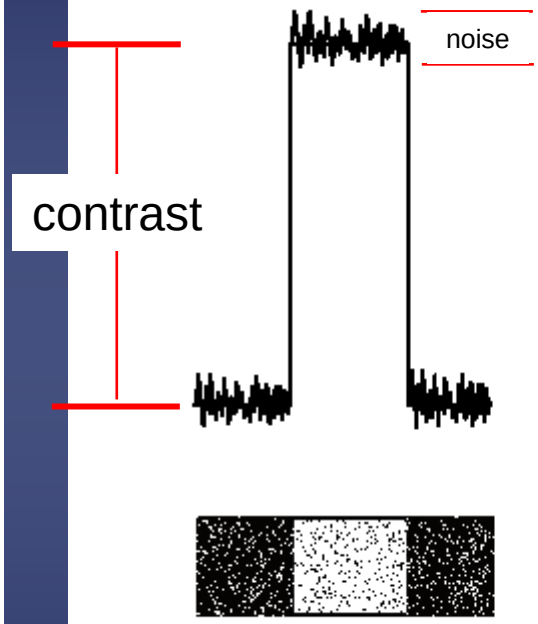

AAO
RAA
LMCA
CONUS
BR
PLVB
PAOT
AH
LAD
CRX
O
H
P
L
LA

Obesity Creates Excessive Image Noise

- Signal – to – noise problem
- Morbid obesity = ⇧⇧⇧ Image Noise
- + Weak “signal” = ⇩⇩⇩ SNR
- Poor SNR = Decreased test accuracy

Patient → Detector

Contrast-to-Noise Ratio



hi con
lo noise

Noise

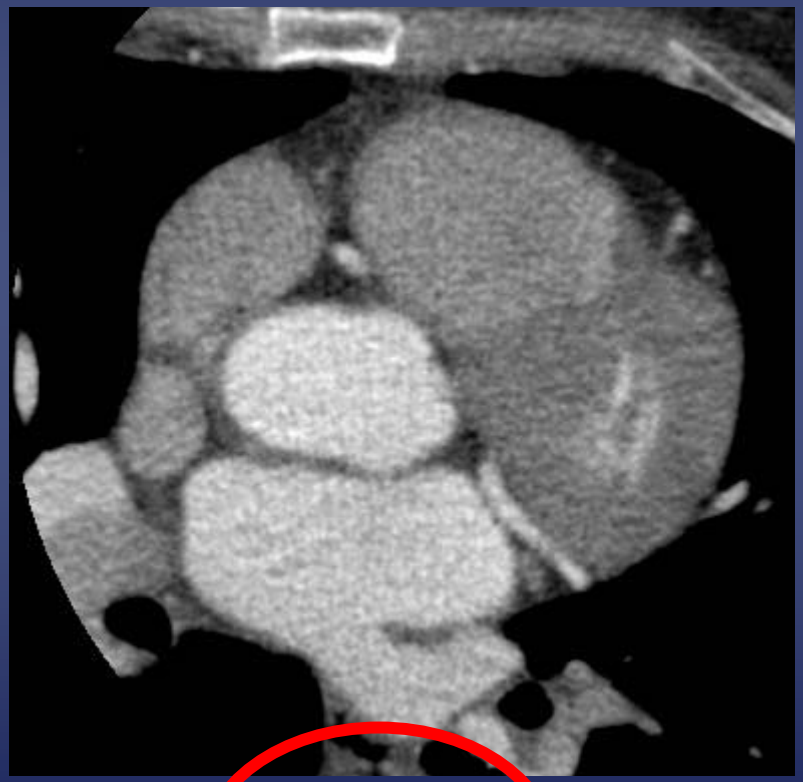
With optimal HR reduction and use of Dose Modulation, it is possible to obtain adequate image quality by using higher tube current…

58yo F
6’ 250 lb BMI 36

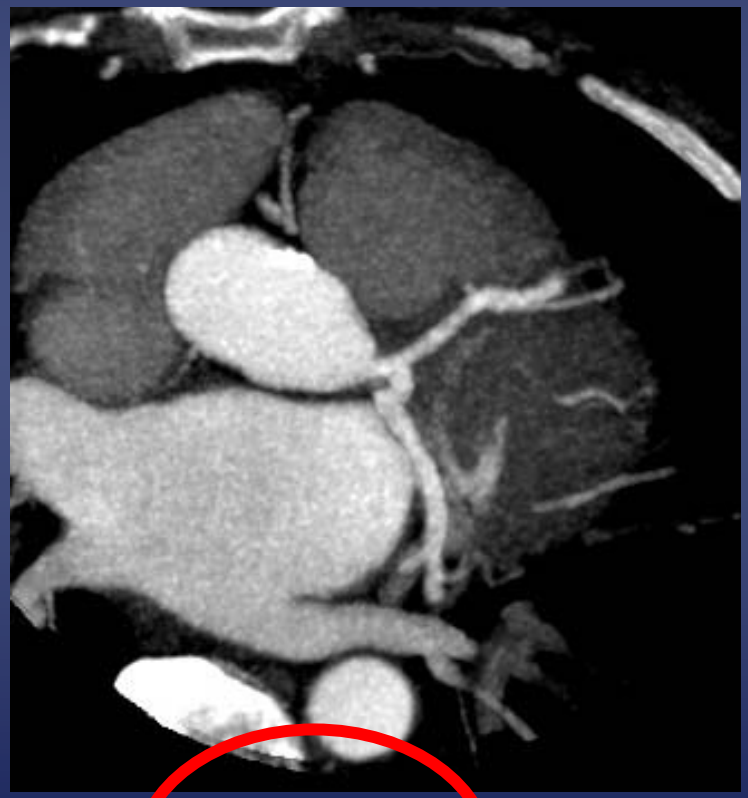
59yo F
5’3”’ 240 lb BMI 42

Noise

But only at the cost of significantly higher radiation exposure…

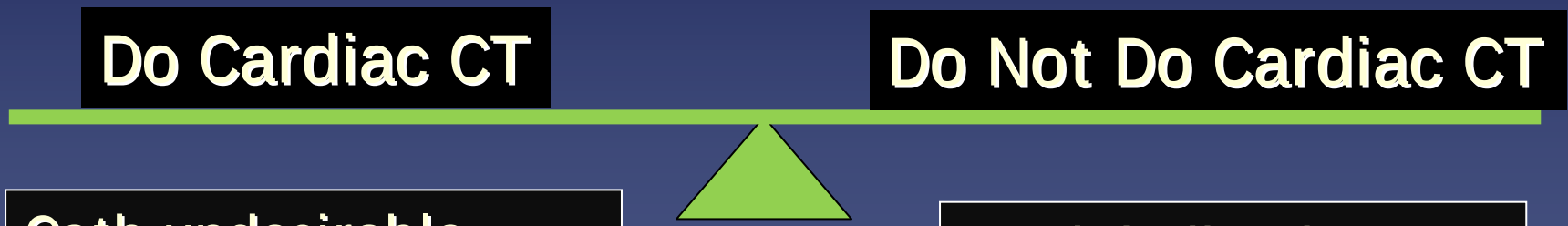


990 mGy
17 mSv



1229 mGy
21 mSv

The Obese Patient



- Cath undesirable
- Pulse < 65 bpm
- Regular rhythm
- Good IV access
- Normal renal function
- Older (>70)
- Men
- BMI < 40

- Weak indication
- High heart rate
- Irregular rhythm
- Elevated Cr
- CABG / Stent
- Younger (<50)
- Women
- BMI > 45

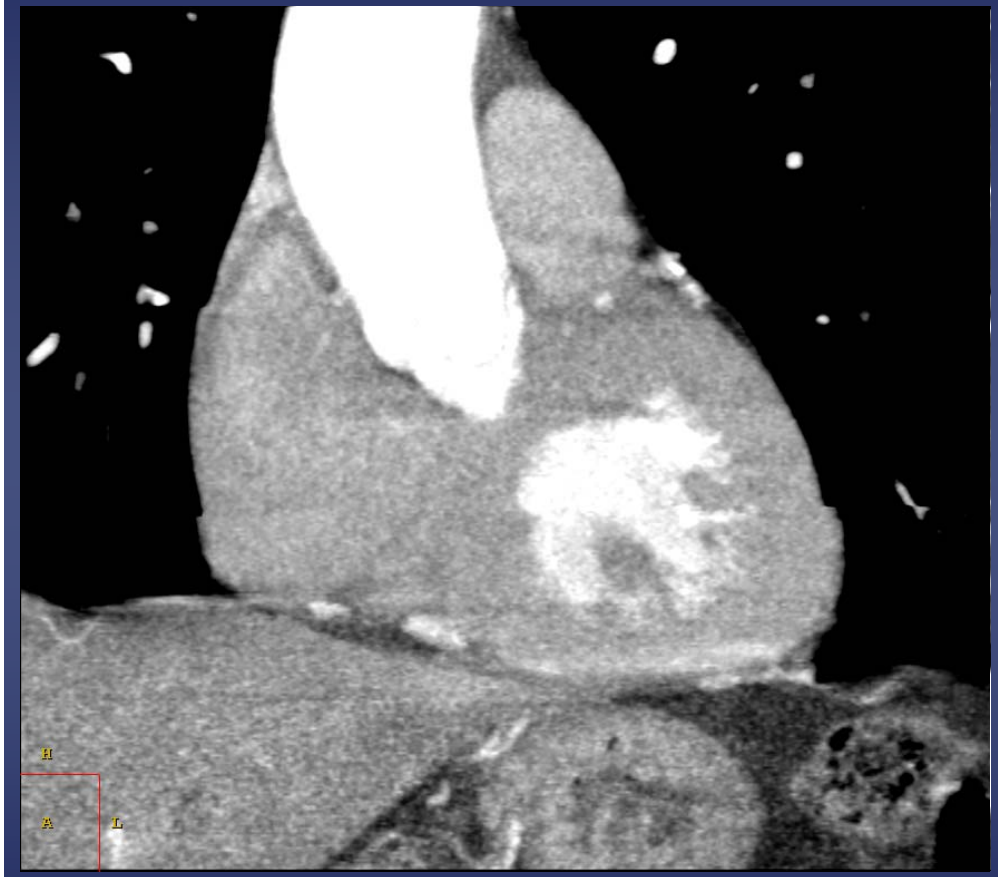
Limitations

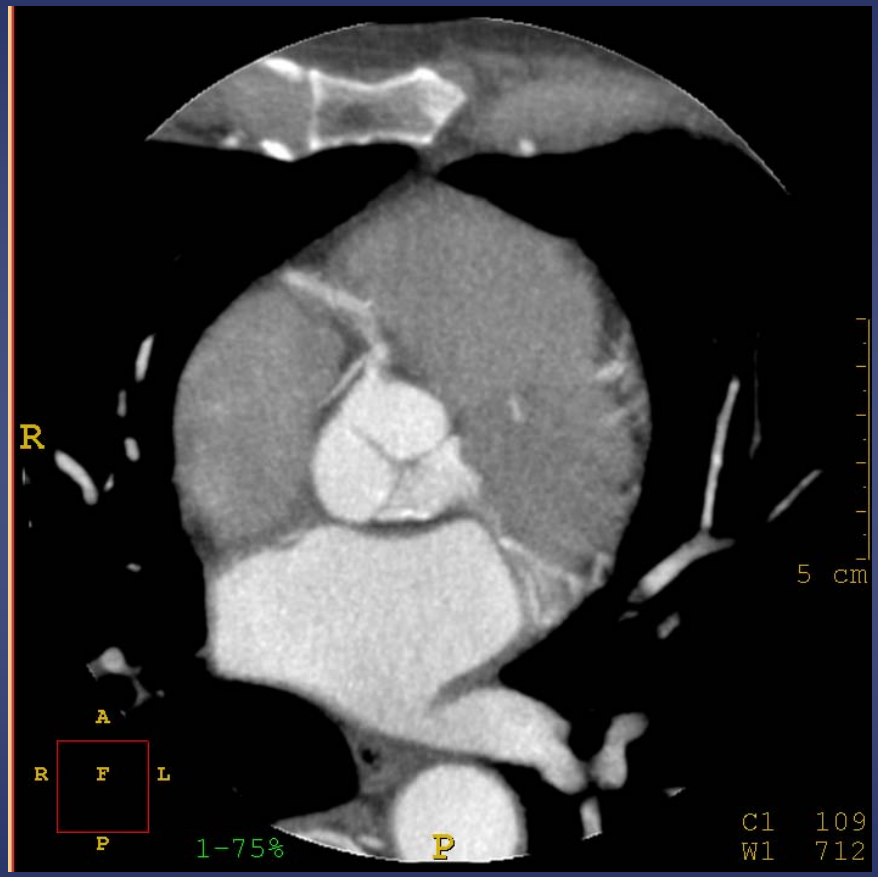
Motion

Motion Artifact: Concepts

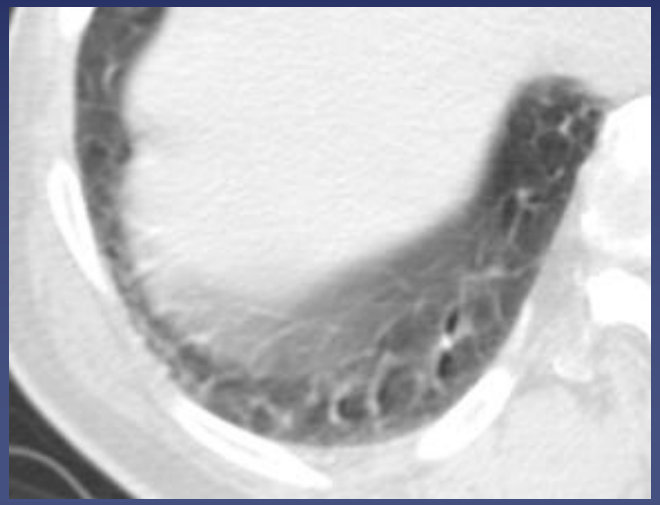
- Temporal resolution is like shutterspeed
- It takes time to acquire the image
  - Time required = temporal resolution
  - In CCT the time is 80-200 ms
  - In cineangiography the time is 10 ms
- Motion during acquisition creates artifacts which may be misinterpreted as pathology
- To prevent distortion:
  - (a) Breath-hold
  - (b) Heart rate modulation

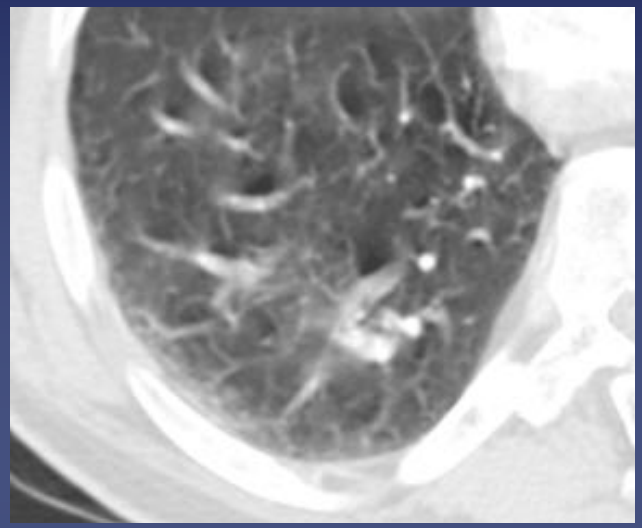
Respiratory Motion

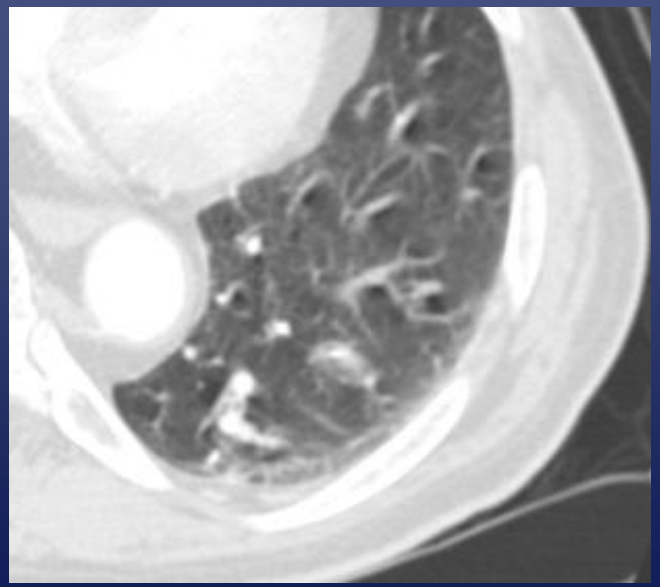


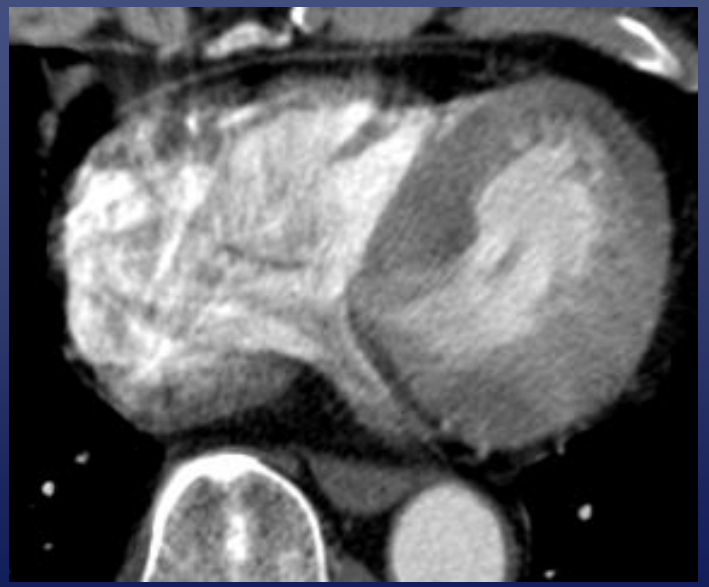


Respiratory motion



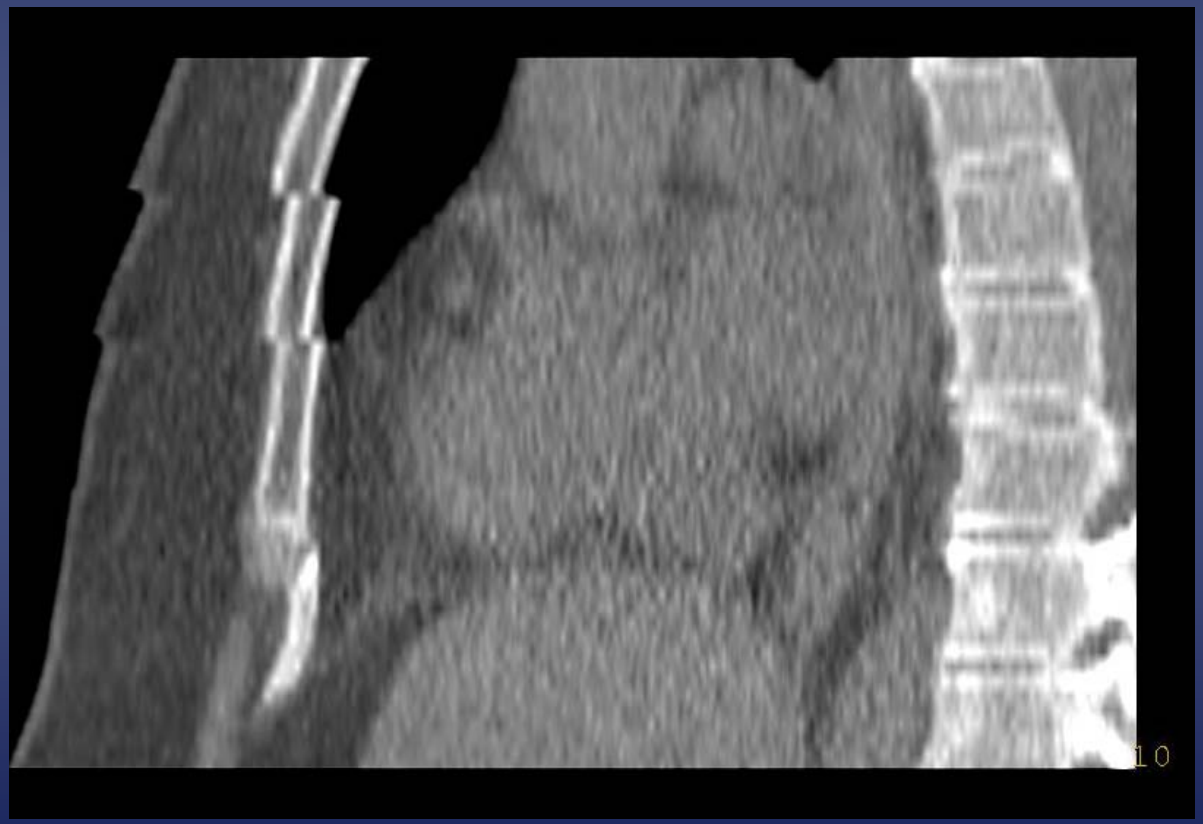




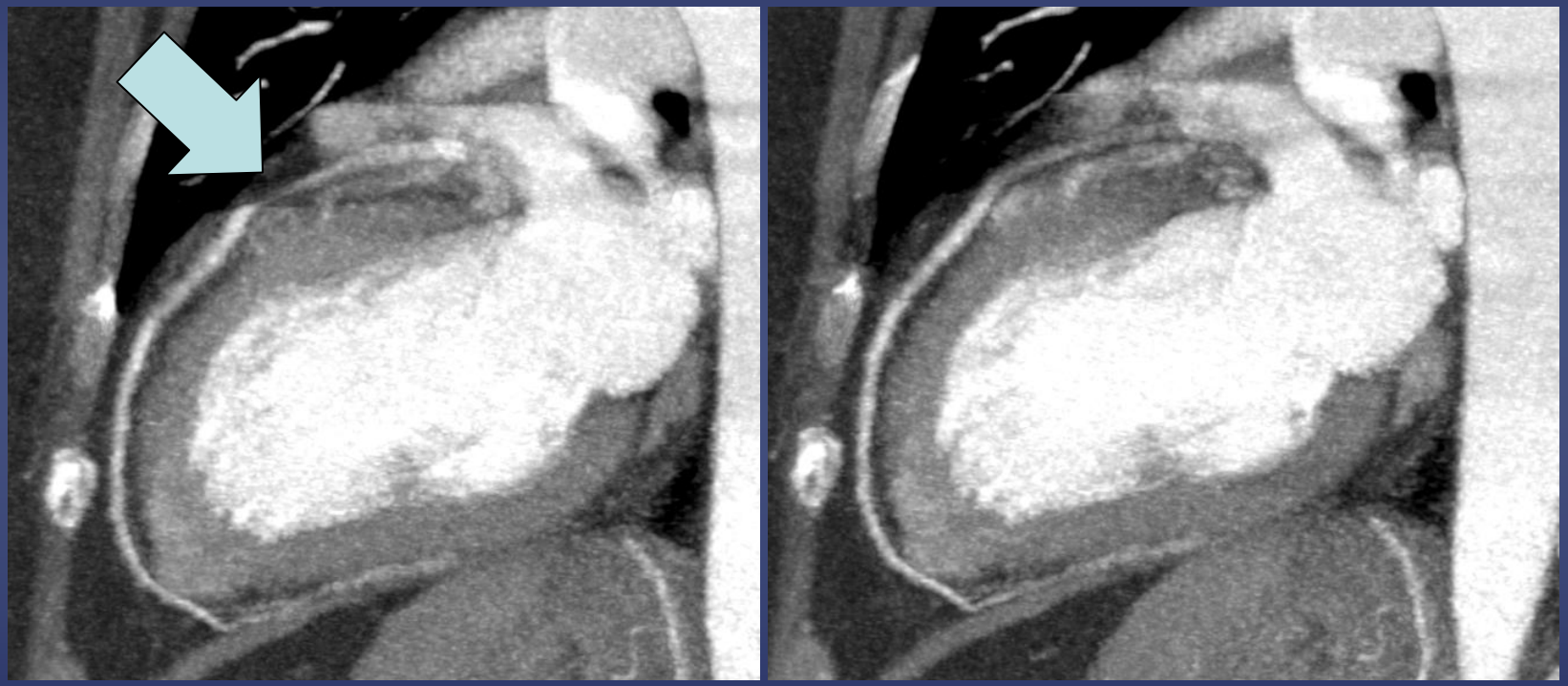


Respiratory motion

- CACS = 0
- Breathing during scan



Respiratory motion: pseudostenosis



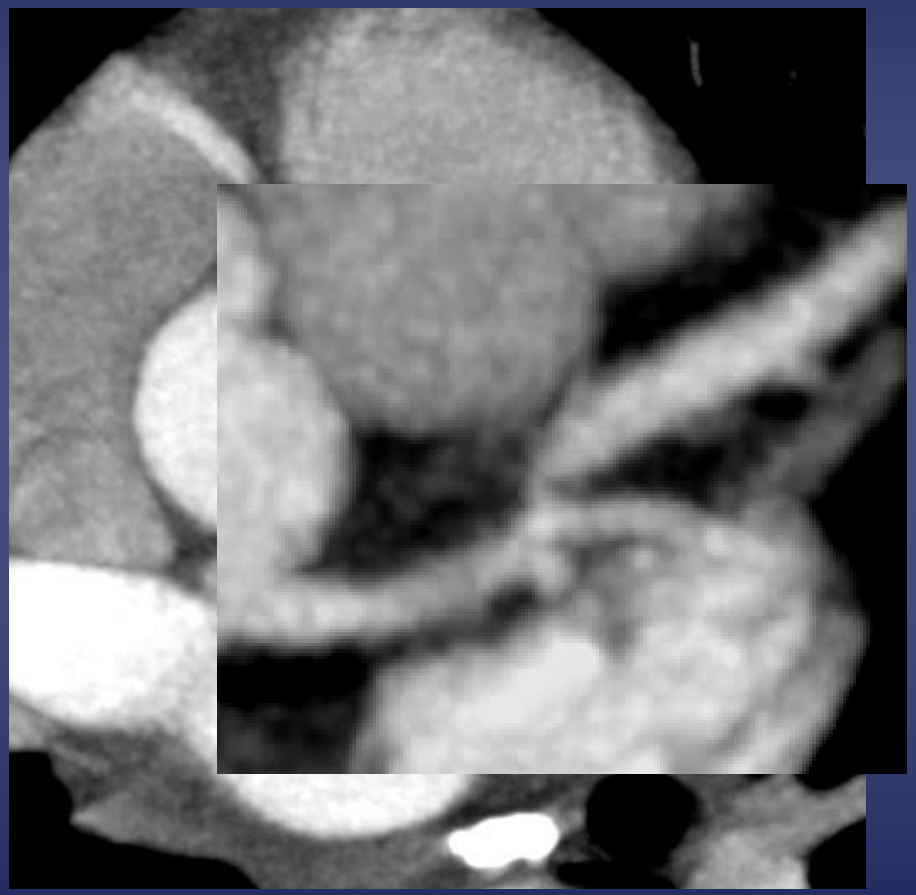
Respiratory Motion

- Avoid at all costs!
- Nurses & Techs should very carefully explain to patient
- ** Practice breath holding**

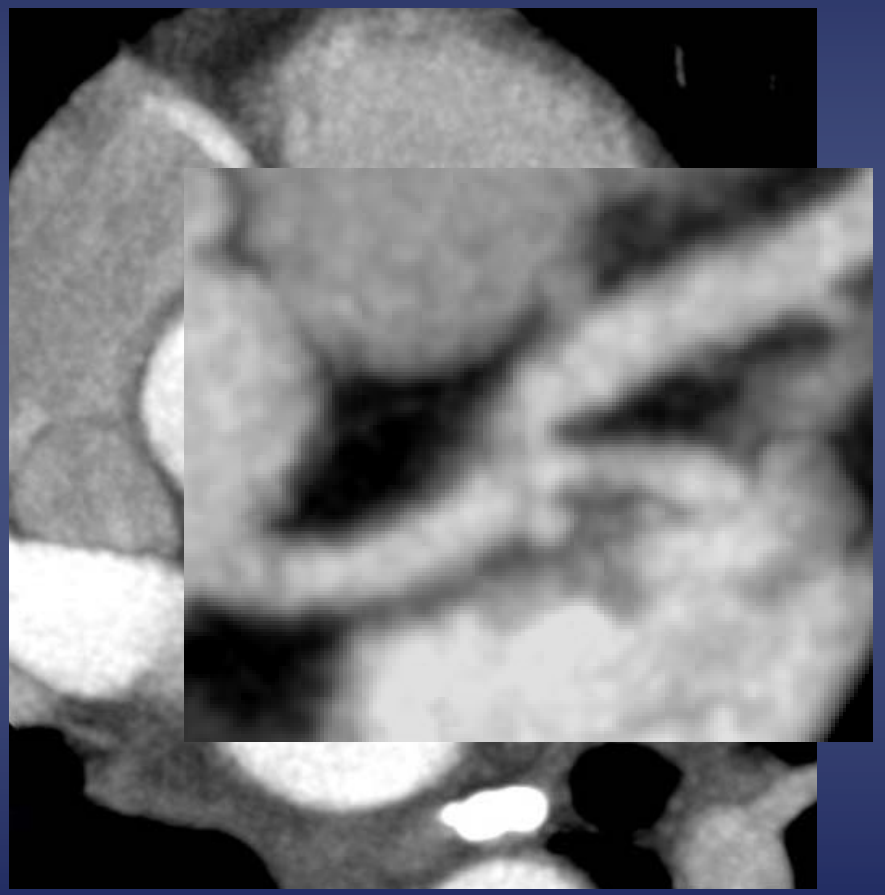
Cardiac Motion (phase specific)

Always review coronary CT angiograms in multiple phases (usually 3)

Cardiac Motion (phase specific)

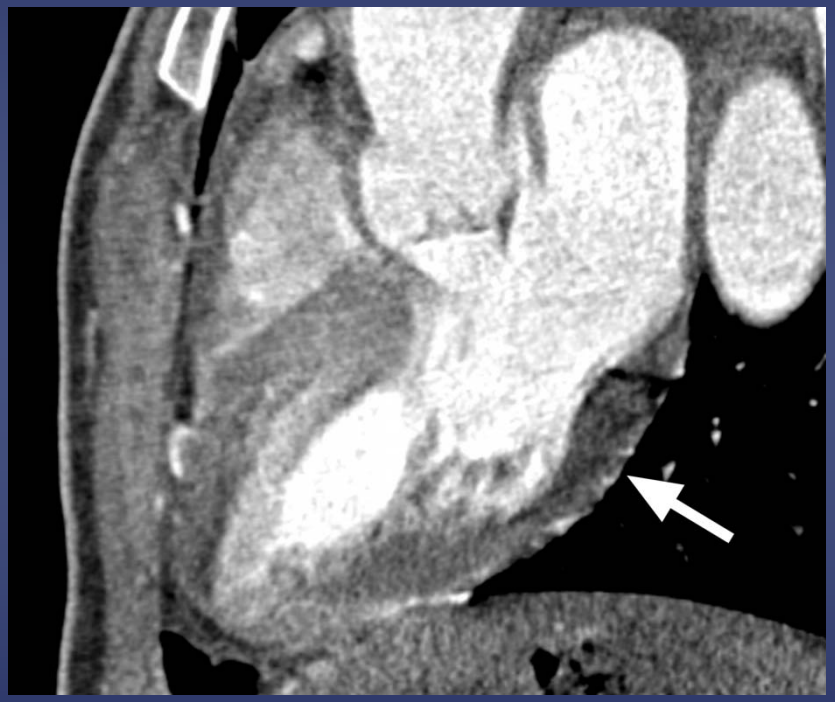


75% phase



80% phase

Non-Coronary Motion Artifact



Heart Rate Modulation for Cardiac CT

- Heart rate & rhythm significantly influence CCT image quality *
- High quality requires aggressive heart rate modulation
- Target heart rate << 65 bpm
- Nitroglycerin (800 ug)
- Review quality before discharging pt

*Hoffman MHK et al. Radiology 2005;234:86-97
Noninvasive coronary angiography with 16-detector row CT: Effect of heart rate

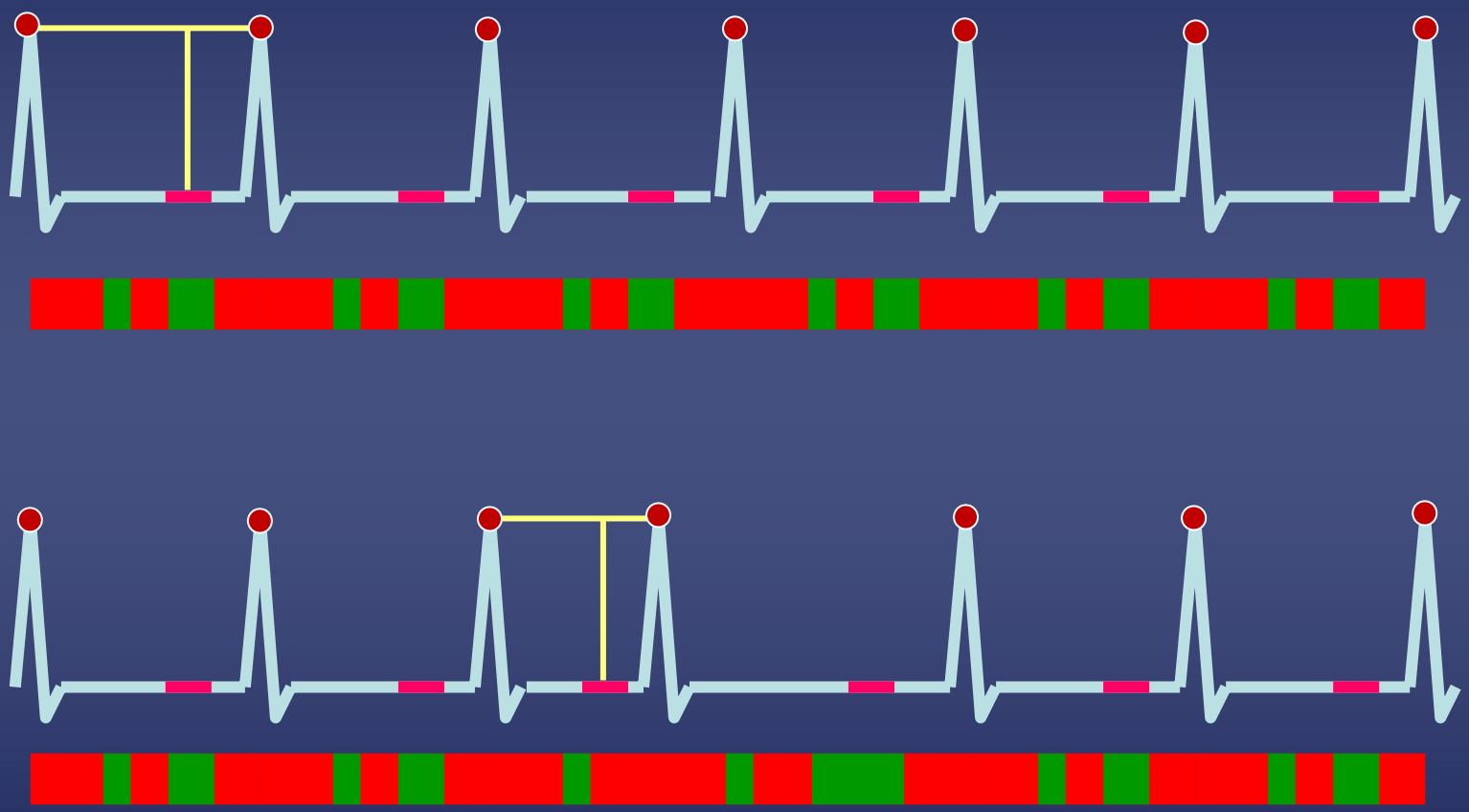
Limitations

Gating Artifacts

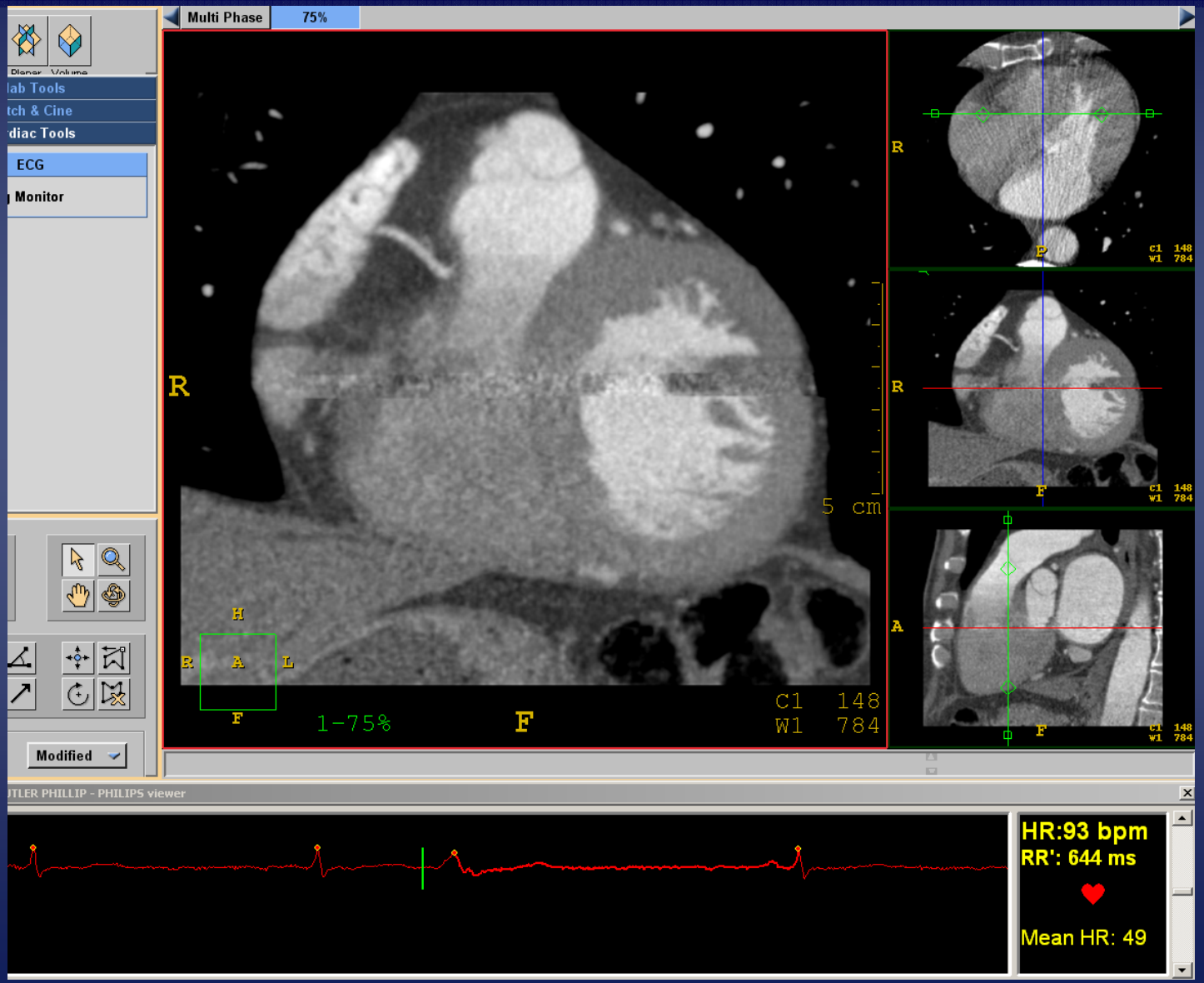
Gating Artifact Concepts

- Actually a form of motion artifact
- Entire cardiac CT is performed during one, single, brief acquisition
- Images are reconstructed after the fact, using the ECG time-stamp
  - Motion-free axial images are reconstructed from the data obtained during the end-diastolic portion of the cardiac cycle, as defined by the ECG
    - *Usually 75% of the length of the cardiac cycle*

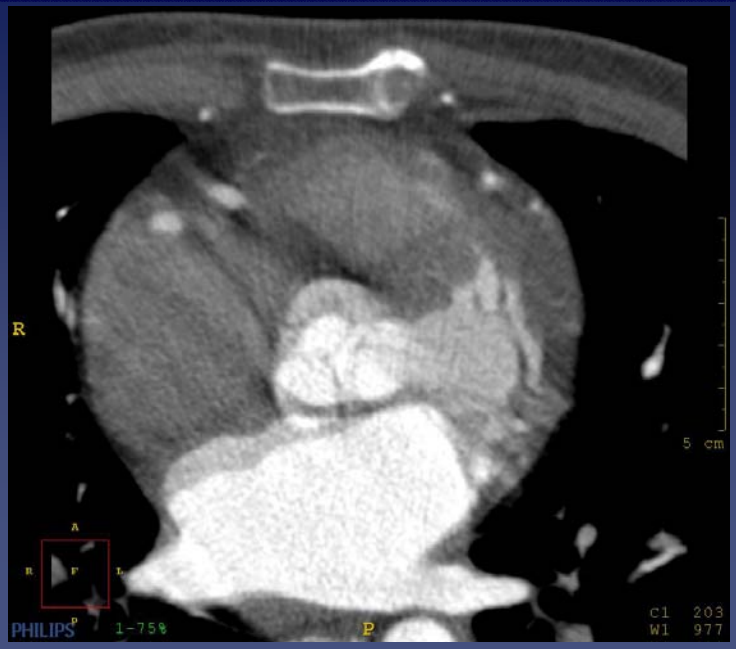
Gating

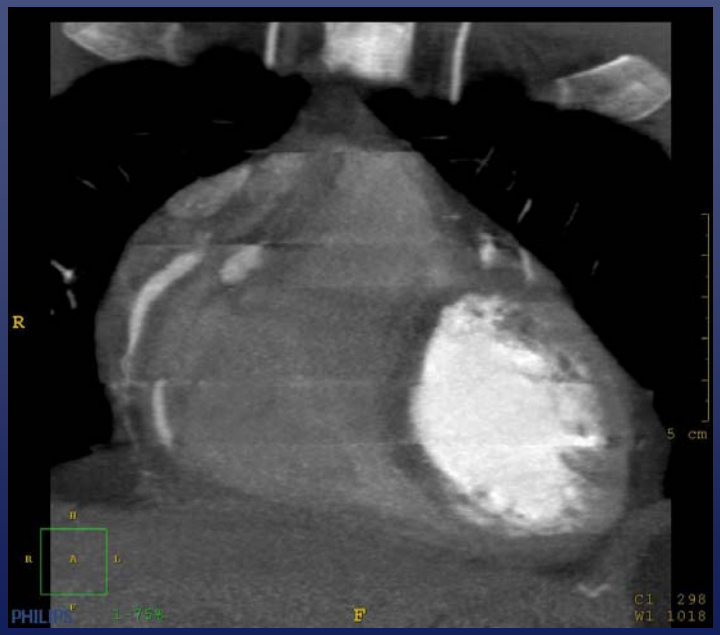


Example of Gating Artifact: PVC

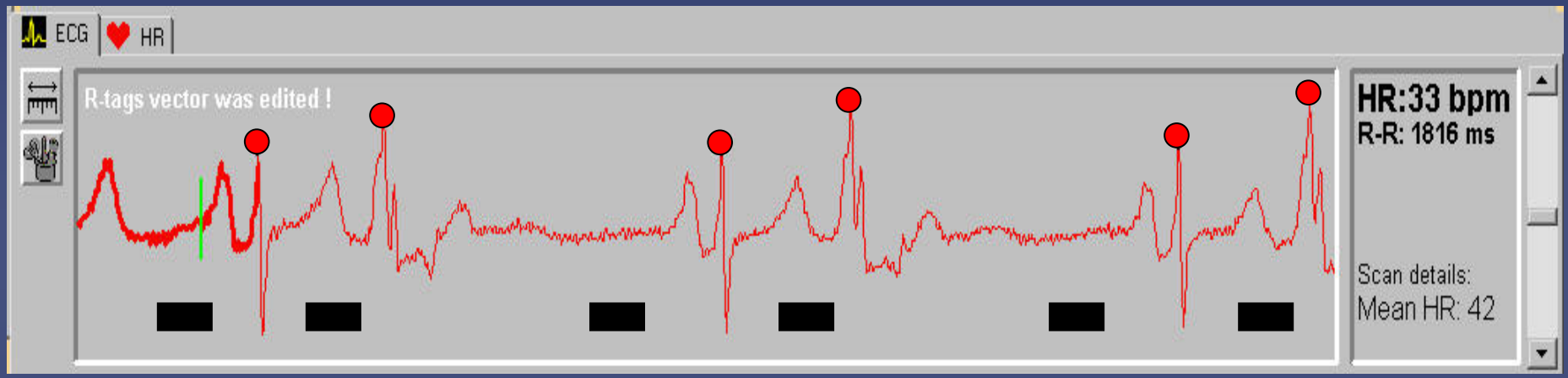


CCTA: Chest Pain

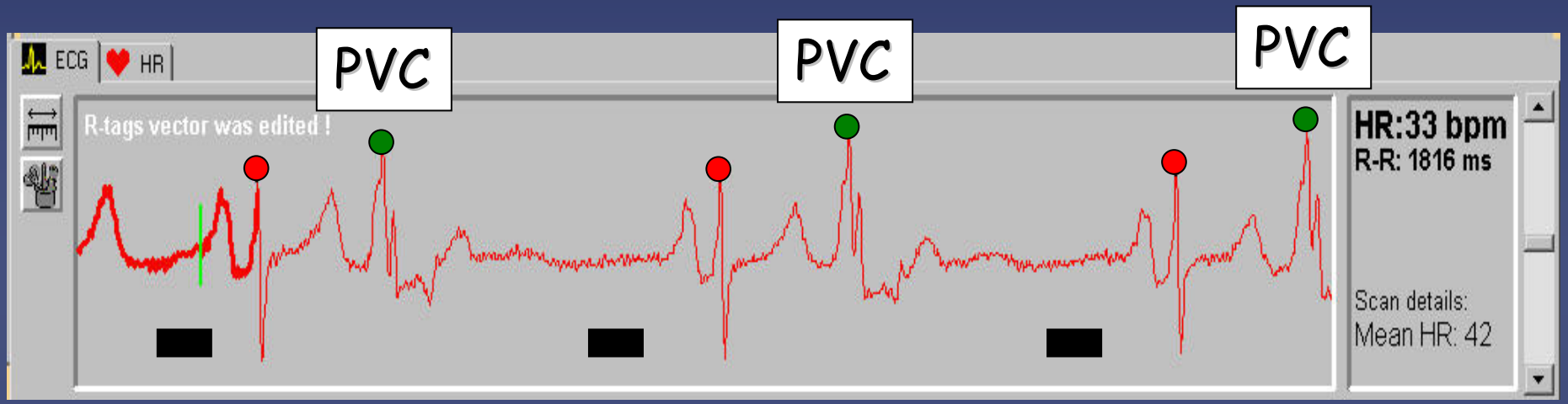




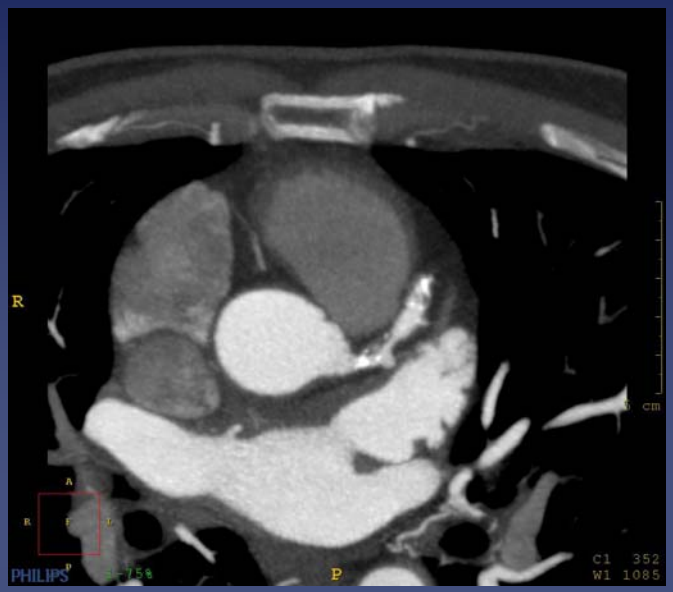
CCTA Chest Pain

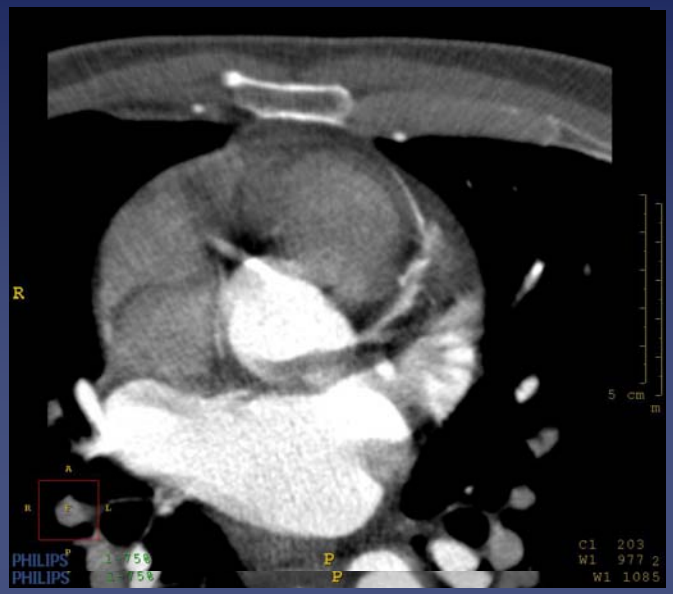


CCTA Chest Pain



CCTA Chest Pain

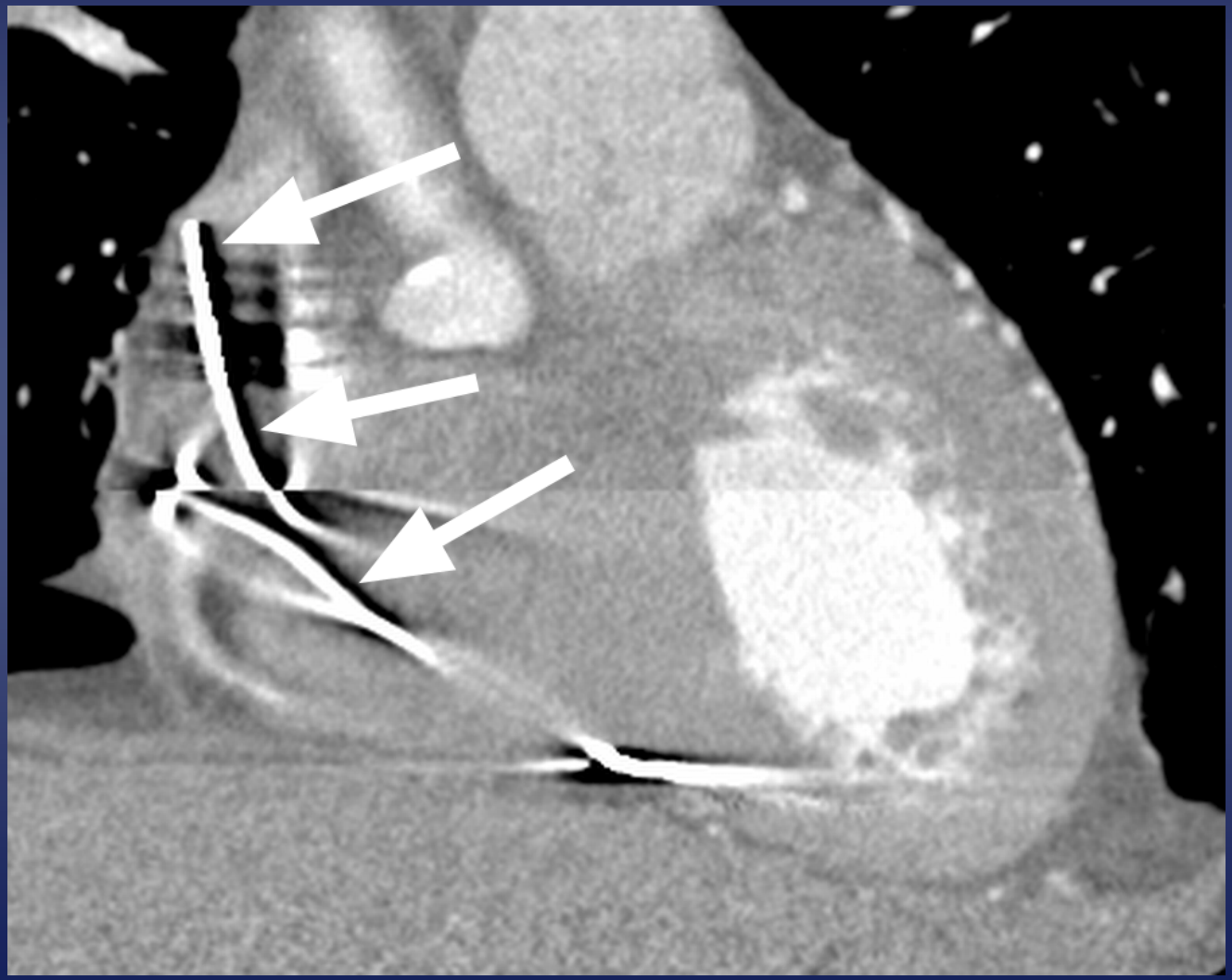




Limitations

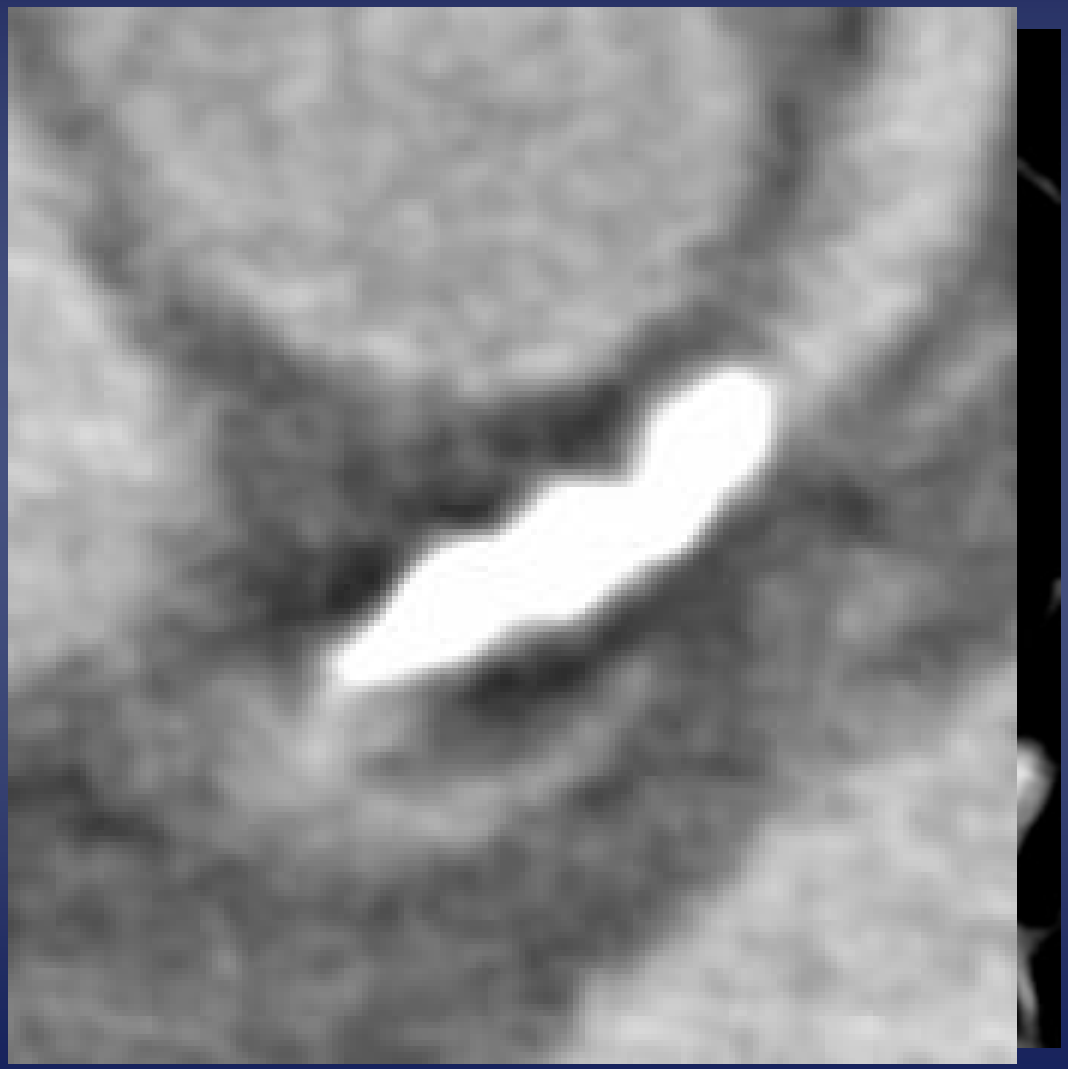
Beam Hardening

Beam Hardening (Metal Lead)



Streak Artifact (also associated with metal)

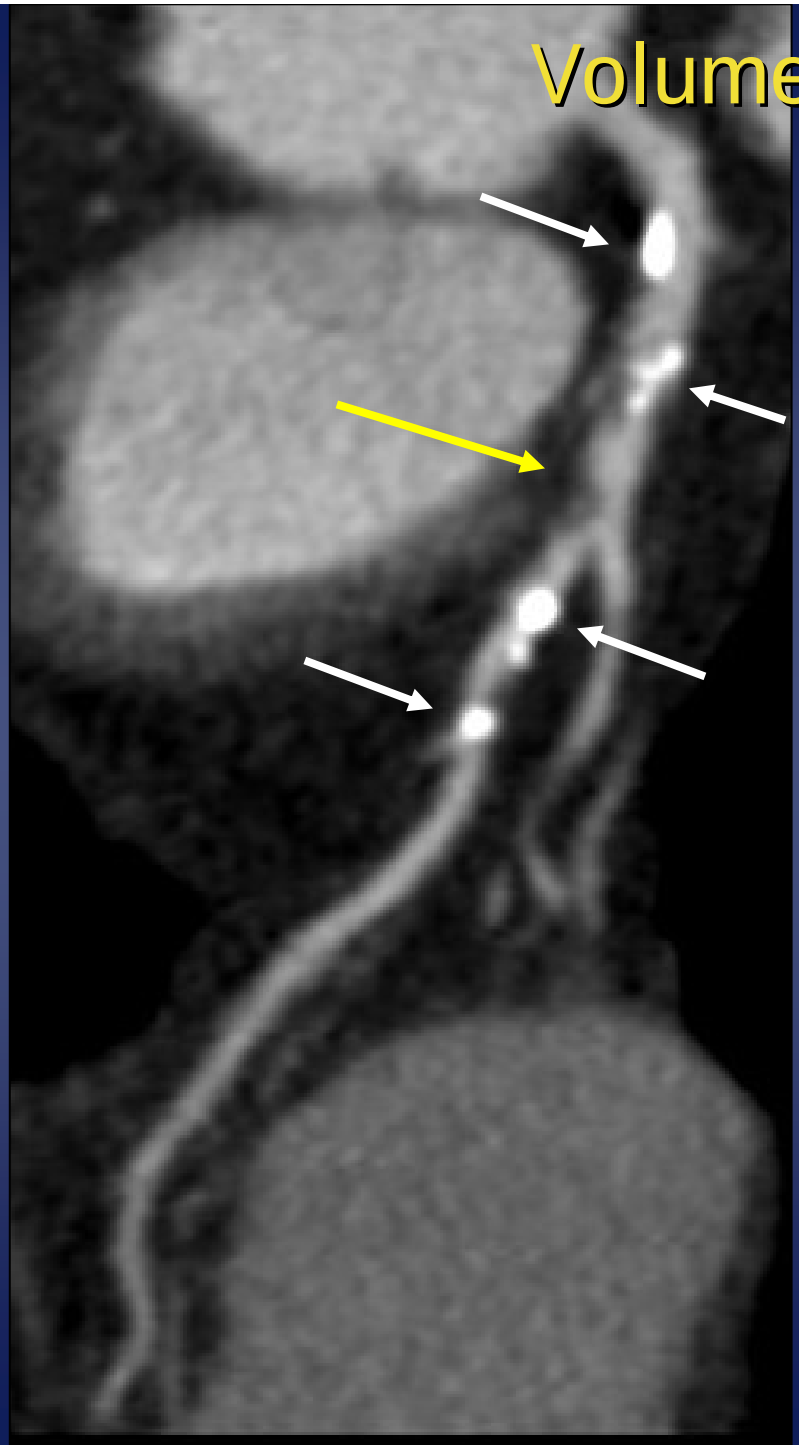
Beam Hardening

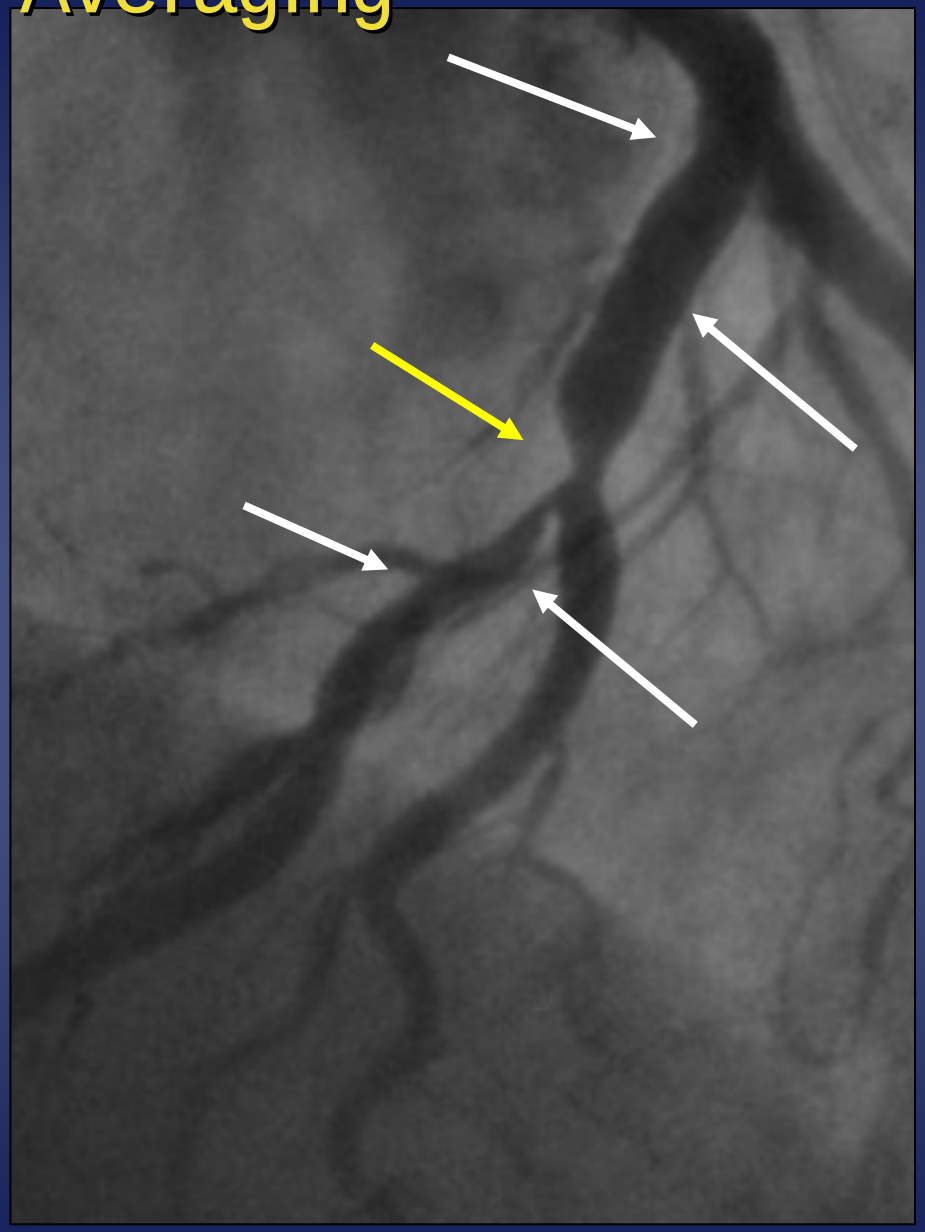


Limitations

Volume Averaging
("blooming artifact")

Volume Averaging

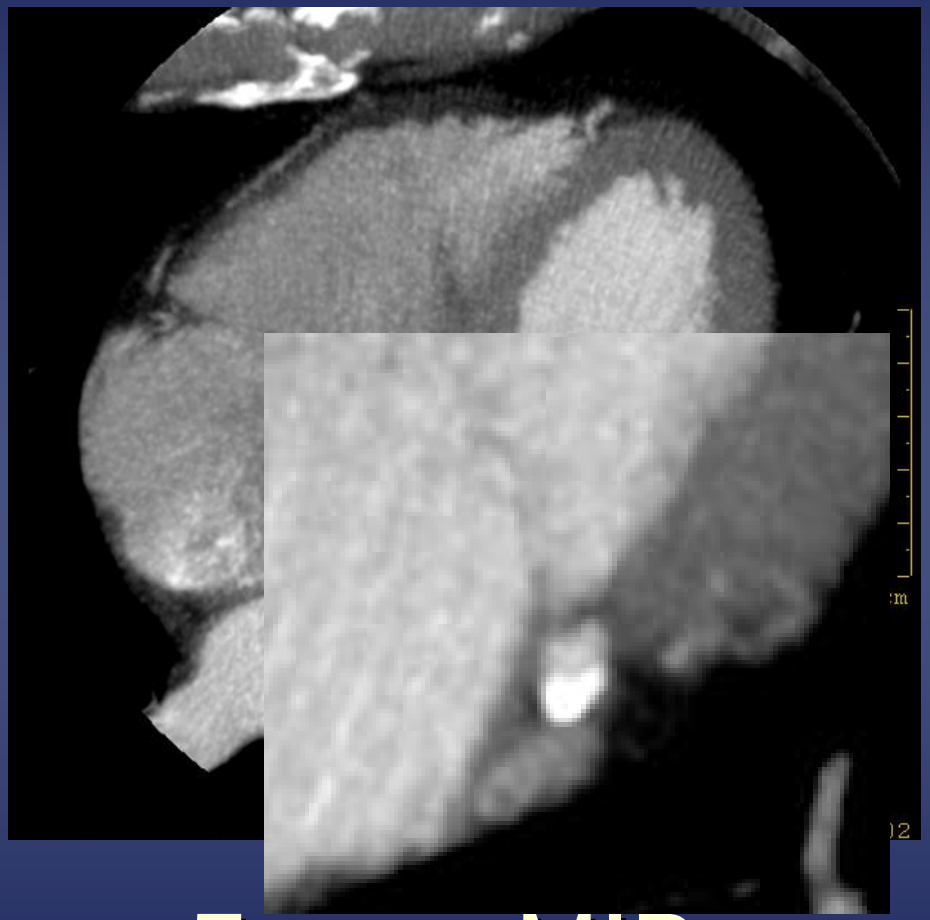




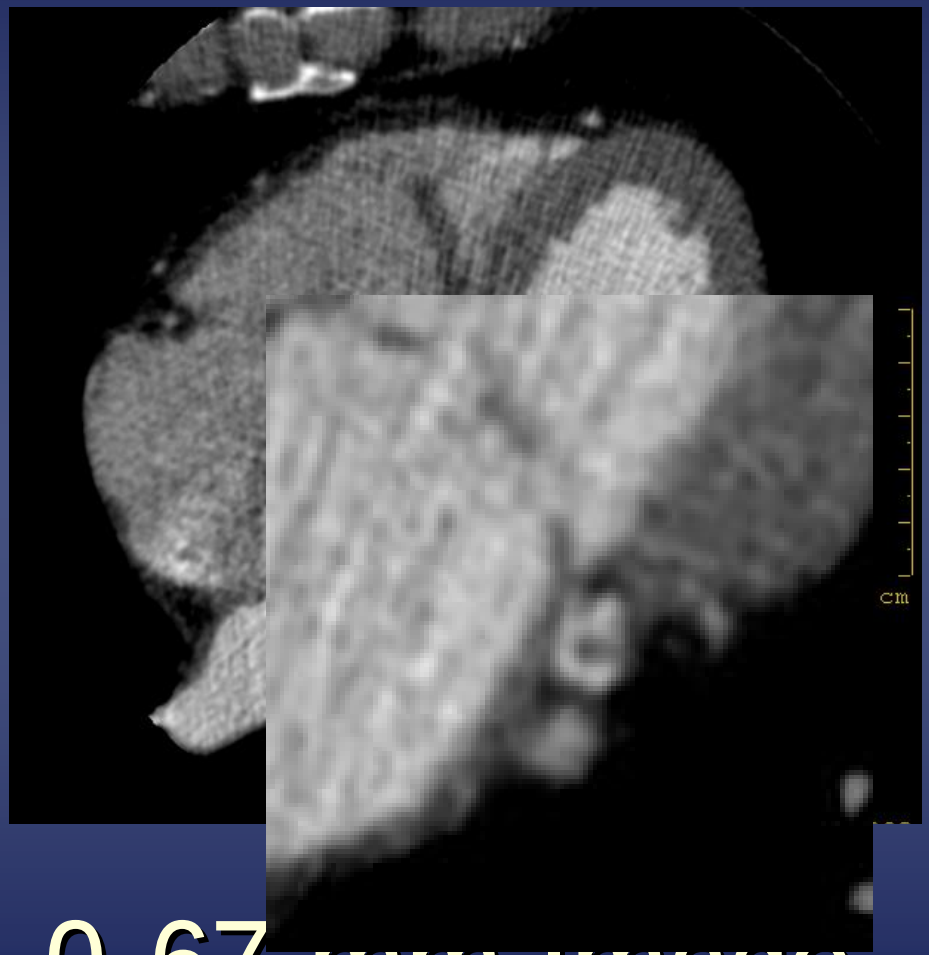
Pitfalls

MIP Pitfall

MIP Pitfall

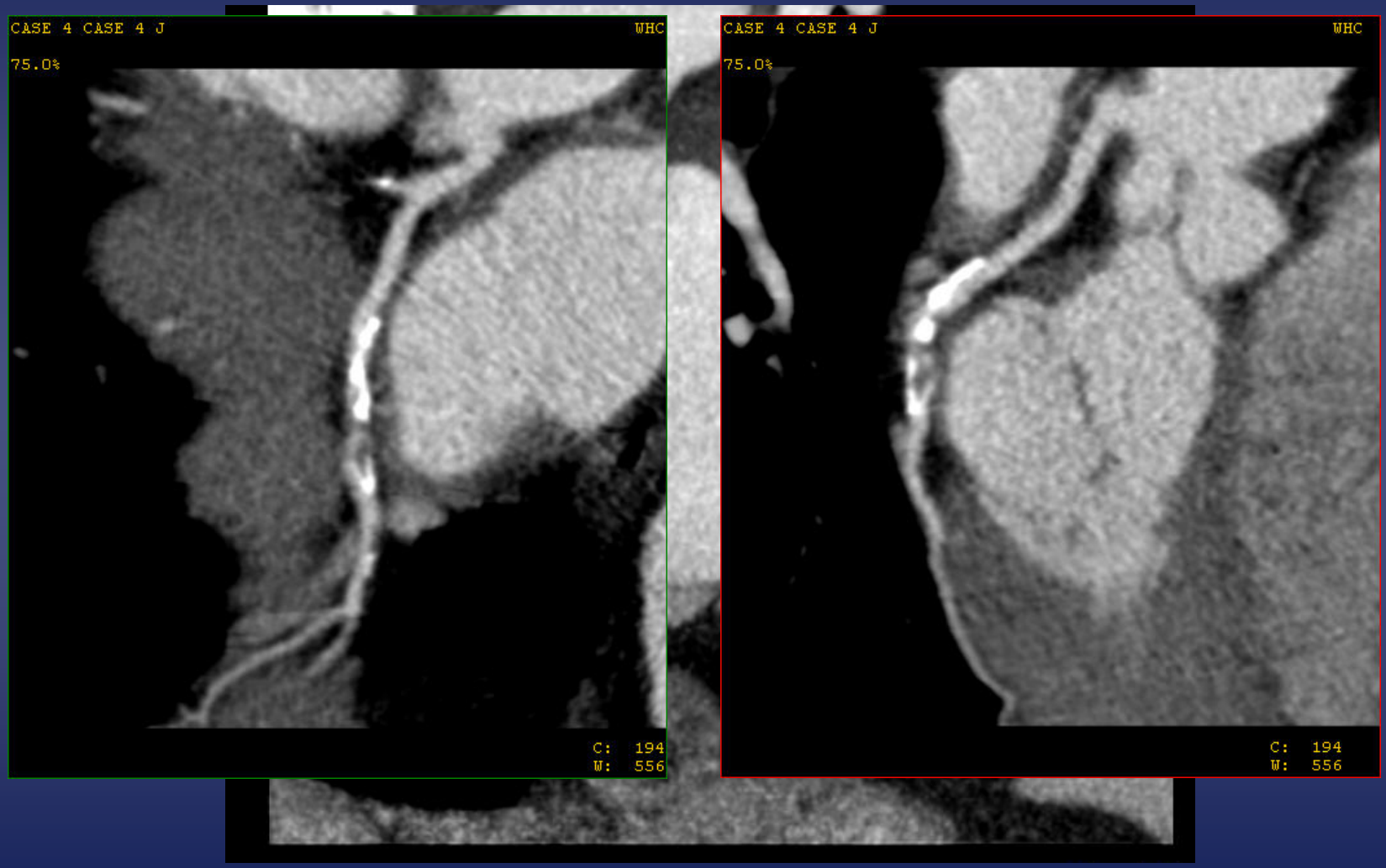


5 mm MIP



0.67 mm Image

MIP Pitfall

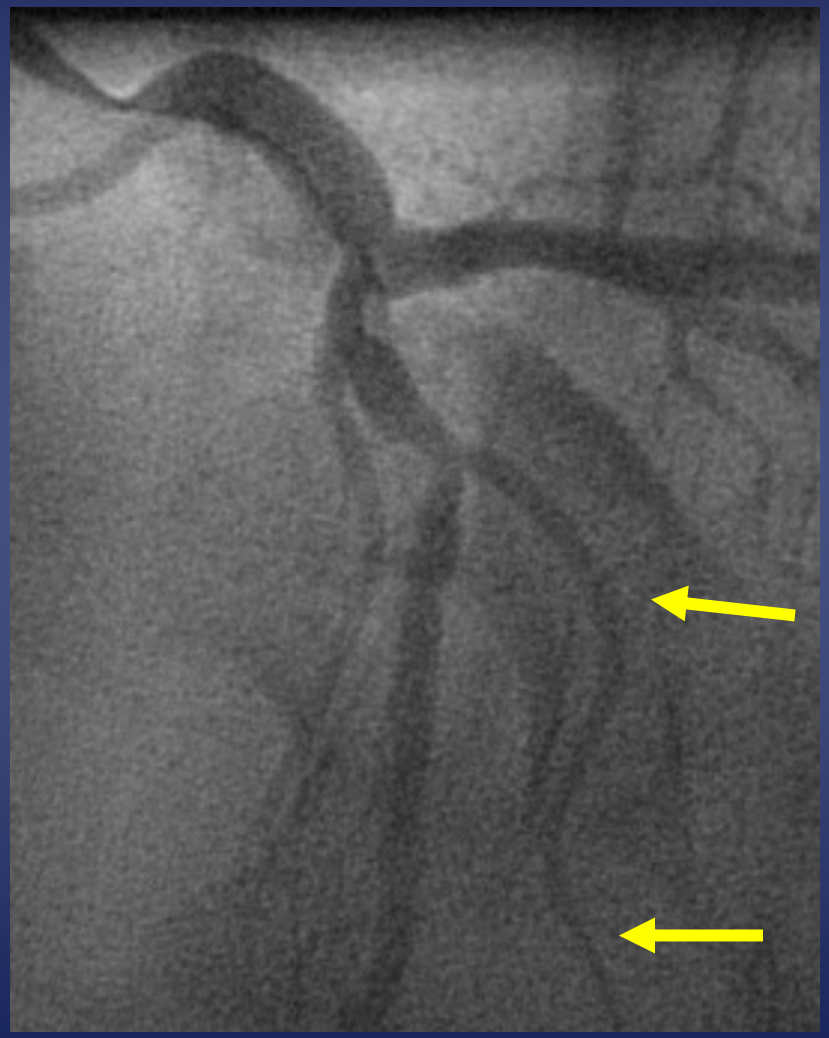

CASE 4 CASE 4 J
WHC
75.0%
C: 194
W: 556
CASE 4 CASE 4 J
WHC
75.0%
C: 194
W: 556

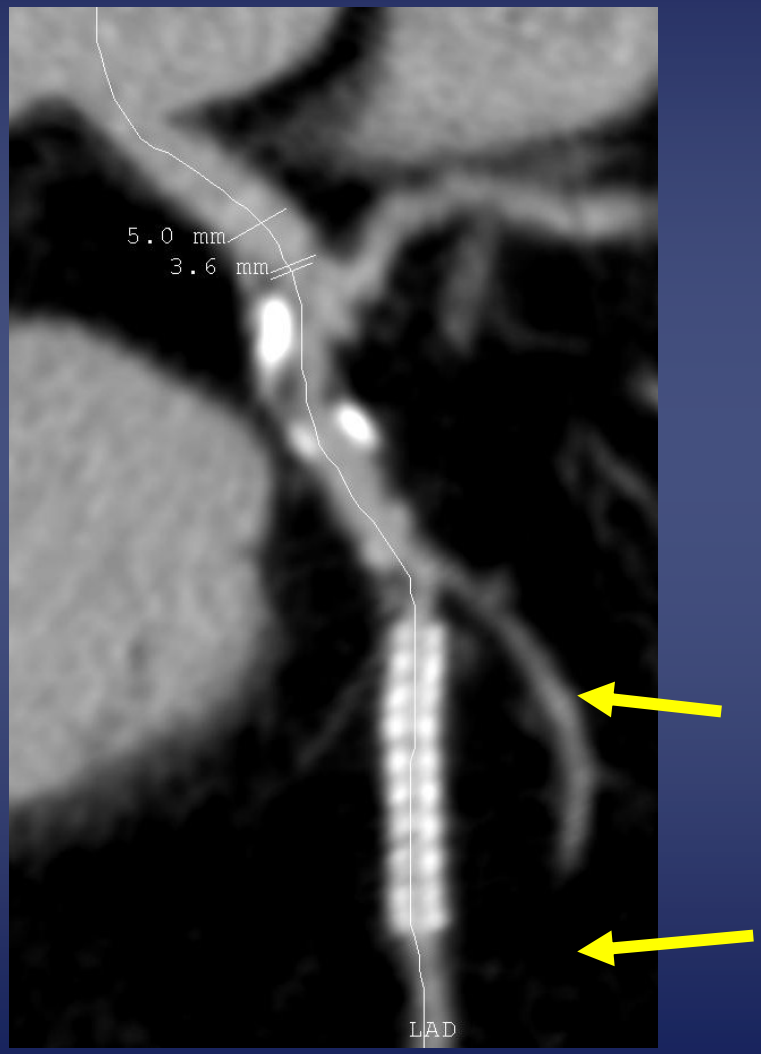
Pitfalls

CMPR Pitfall

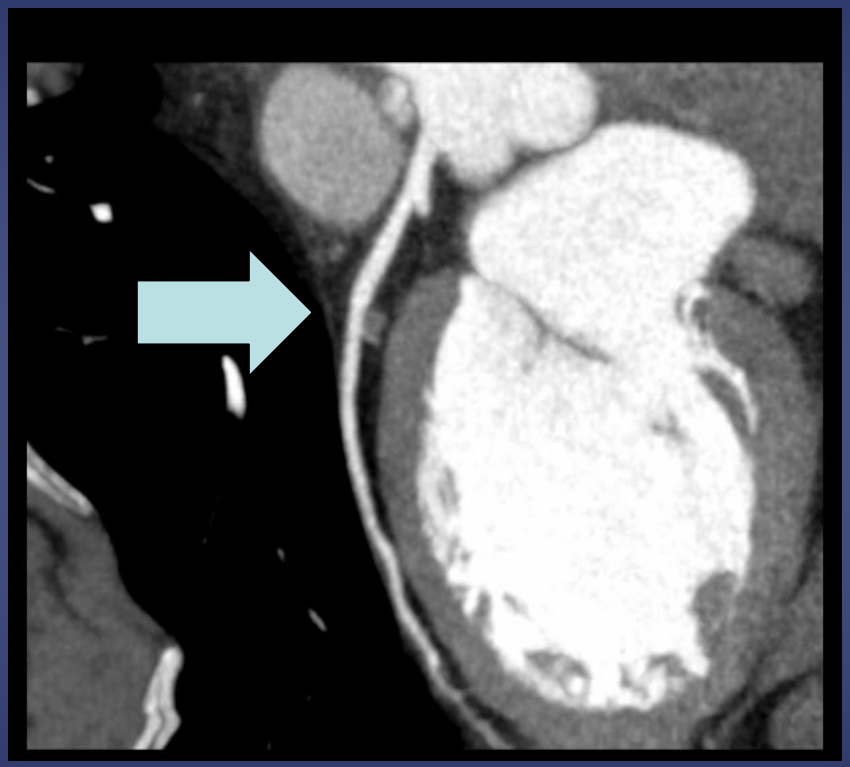
(Curved Multi-planar Reformation)

cMPR Pitfall





cMPR Pitfall: pseudostenosis



Pitfalls

VR Pitfall

(Volume Rendering)

VR Pitfall



Lesion “severity” can be increased or decreased!
Volume rendered images are **not** reliable for evaluating stenosis severity.

Common Limitations and Pitfalls in Cardiac CT

Limitation or Pitfall	Result	Resolution
Inadequate HRM	Non-dx study	Re-medicate & repeat
Arrhythmia	Incomplete study	Edit ECG
Morbidly obese patient	Non-dx study	Adjust parameters, or do not scan
Heavy Calcification	Incomplete study	Do not scan
Stairstep artifact	Overcall	Recognize artifact
MIP pitfall	Undercall	Never use only axial images for diagnosis
MPR pitfall	Overcall	Use multiple MPR projections
3D Volume pitfall	Over or Undercall	Never use only 3D volume for diagnosis

Conclusions

Careful attention to patient preparation & image acquisition will help avoid artifacts

A systematic approach to case interpretation will help avoid pitfalls