Acquiring High-Quality Coronary CT Angiograms

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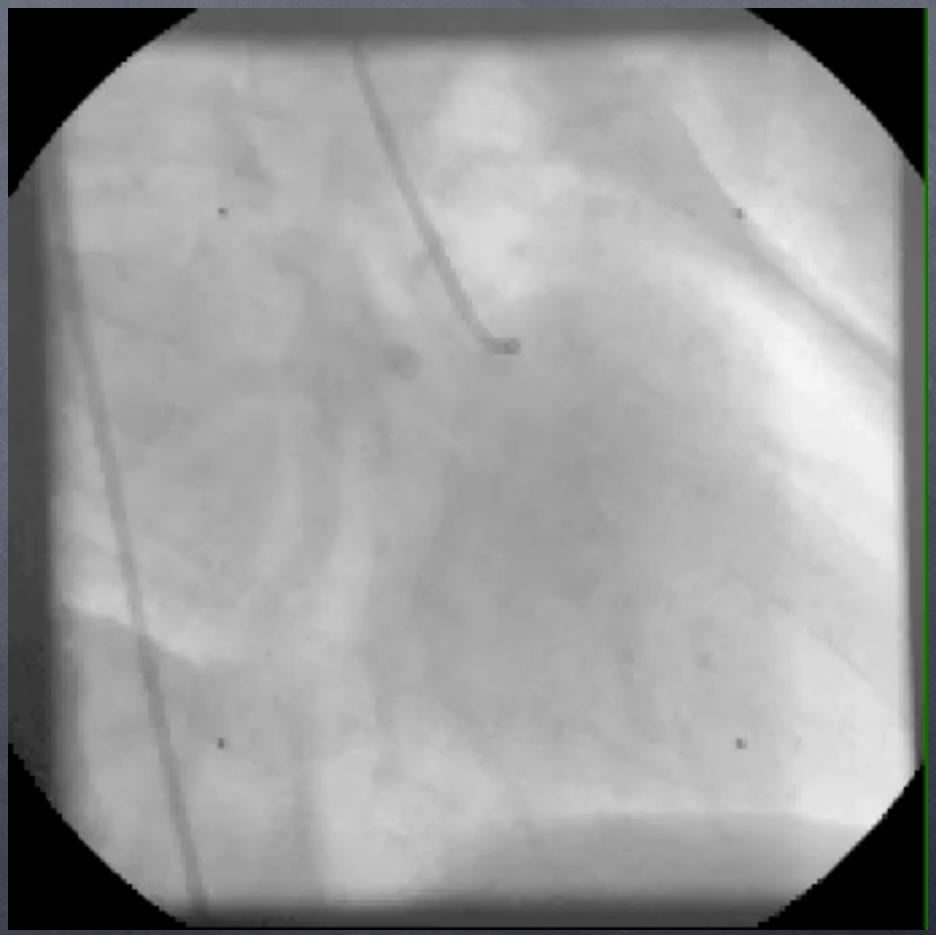
University of Arizona

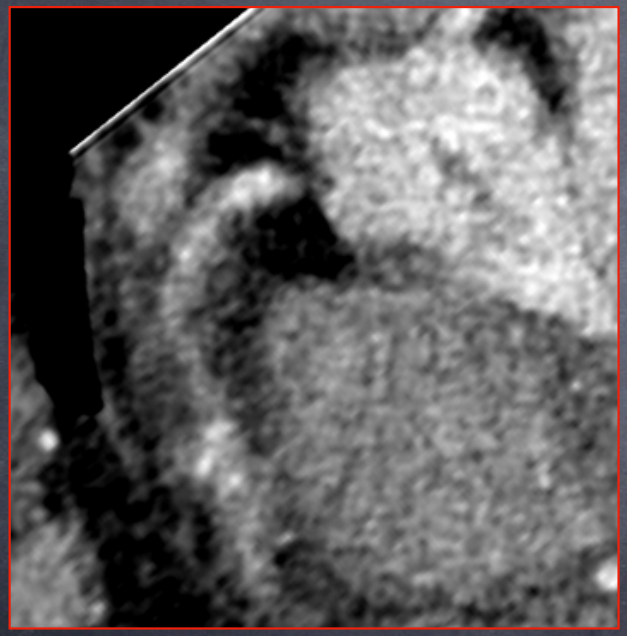
@GeoffRubin

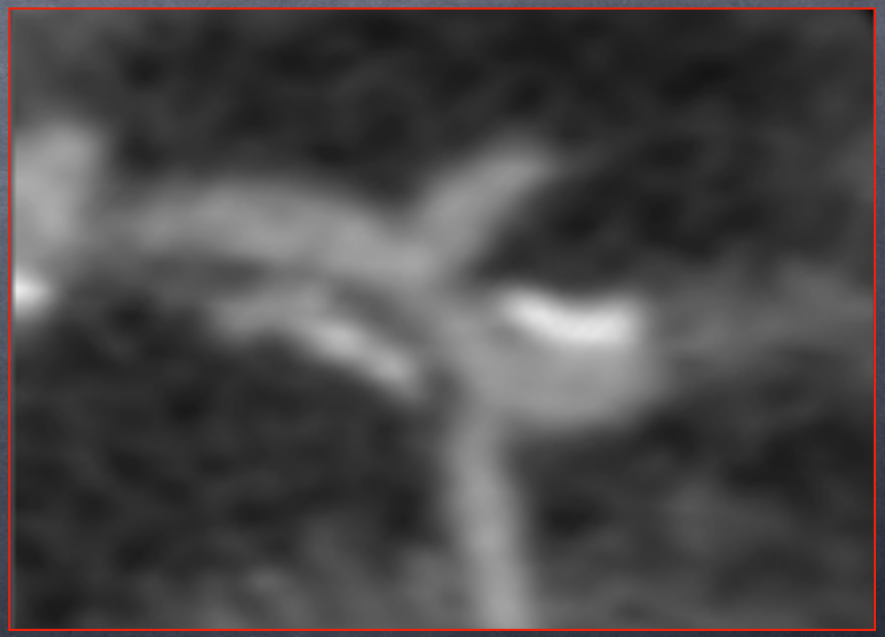
The cCTA Challenge

- Coronary arteries are small
- They are always moving



Which Study Would You Rather Read?





The Spectrum of CT Environments

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Quality Guidelines

Contents lists available at ScienceDirect

Journal of Cardiovascular Computed Tomography

journal homepage: www.JournalofCardiovascularCT.com

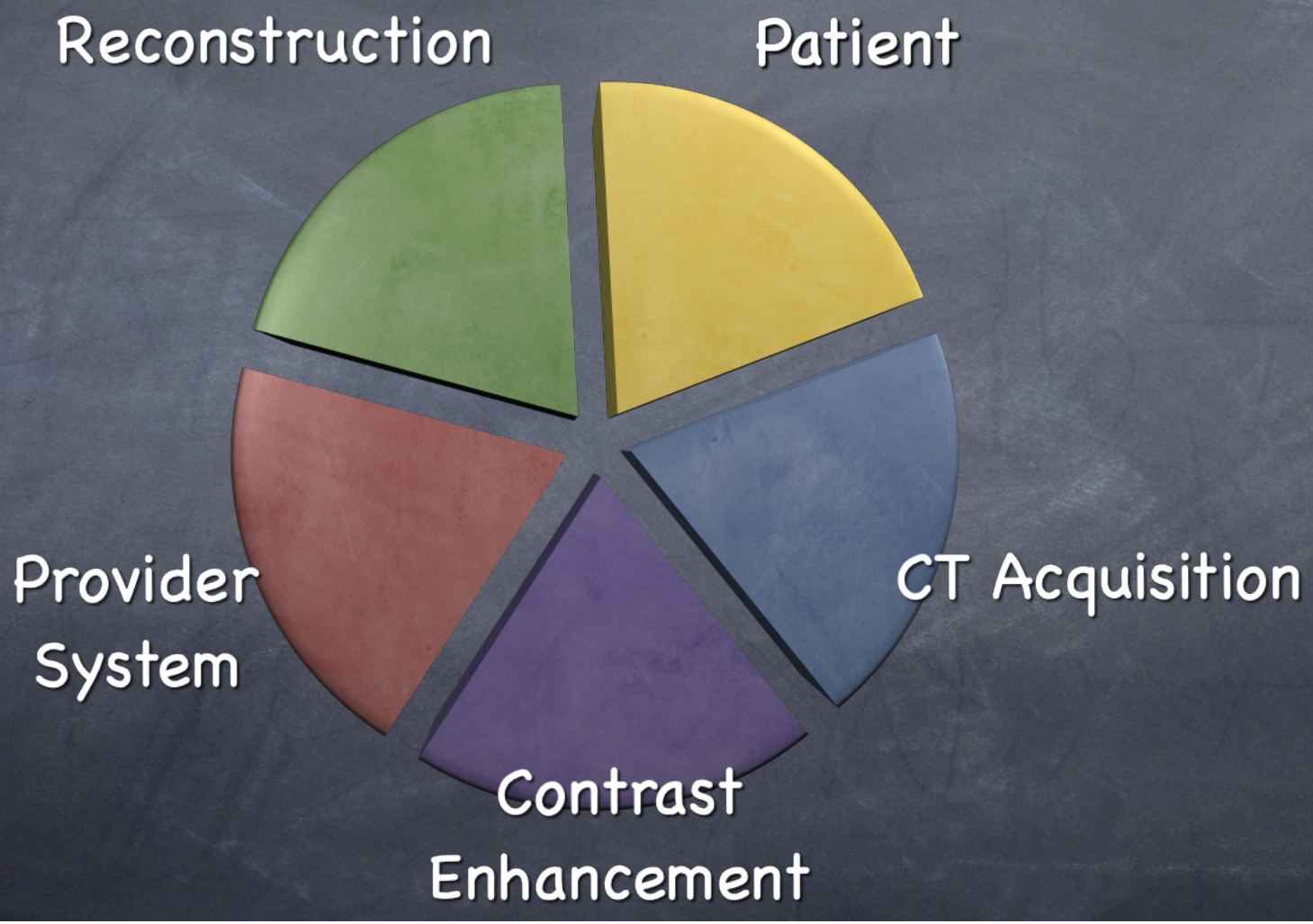
Guidelines

SCCT guidelines for the performance and acquisition of coronary computed tomographic angiography: A report of the Society of Cardiovascular Computed Tomography Guidelines Committee Endorsed by the North American Society for Cardiovascular Imaging (NASCI)

Suhny Abbara [a,*], Philipp Blanke [b], Christopher D. Maroules [a], Michael Cheezum [c], Andrew D. Choi [d], B. Kelly Han [e], Mohamed Marwan [f], Chris Naoum [g], Bjarne L. Norgaard [h], Ronen Rubinshtein [i], Paul Schoenhagen [k], Todd Villines [j], Jonathon Leipsic [b]

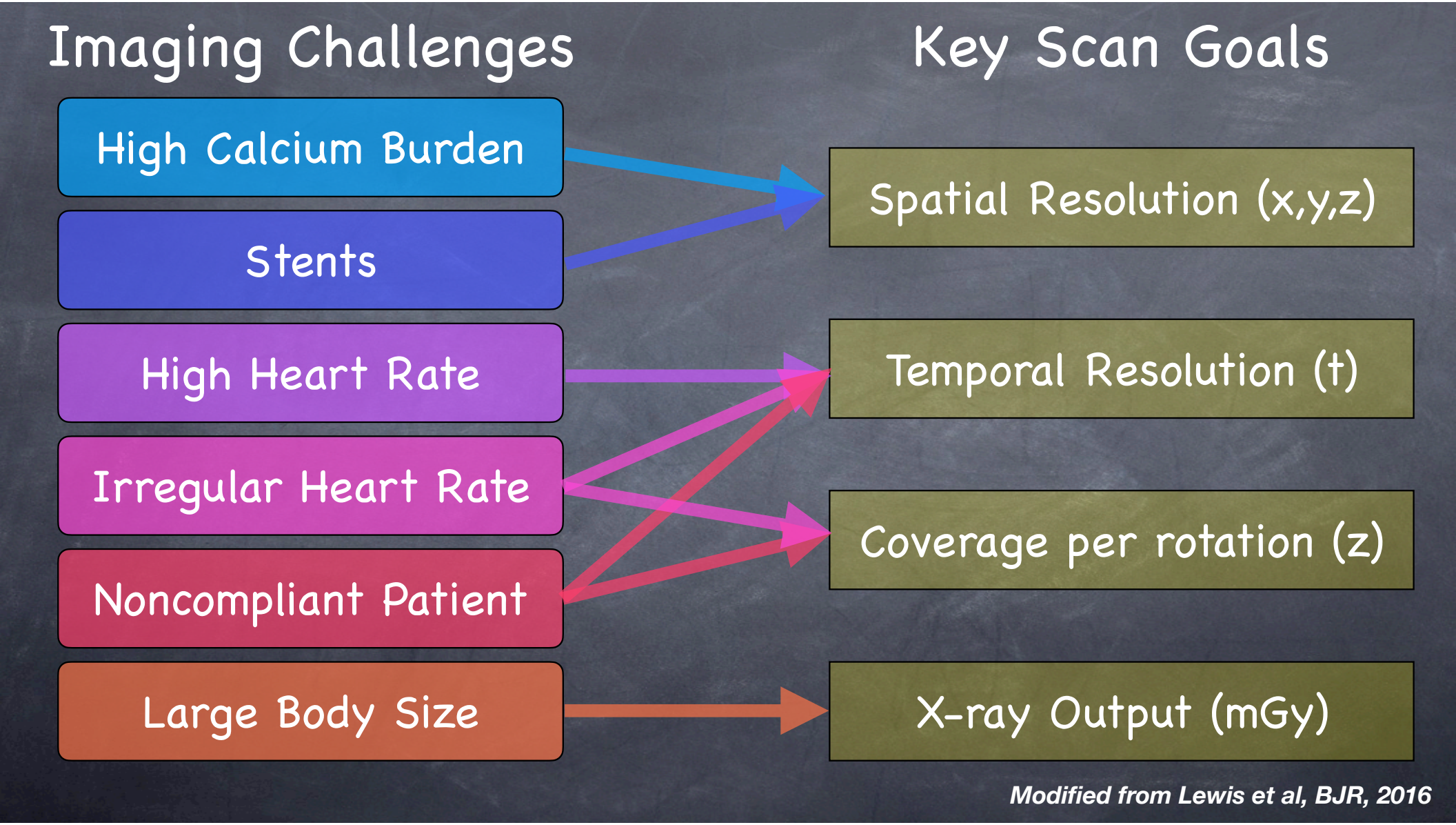
JCCT 10 (2016) 435-449

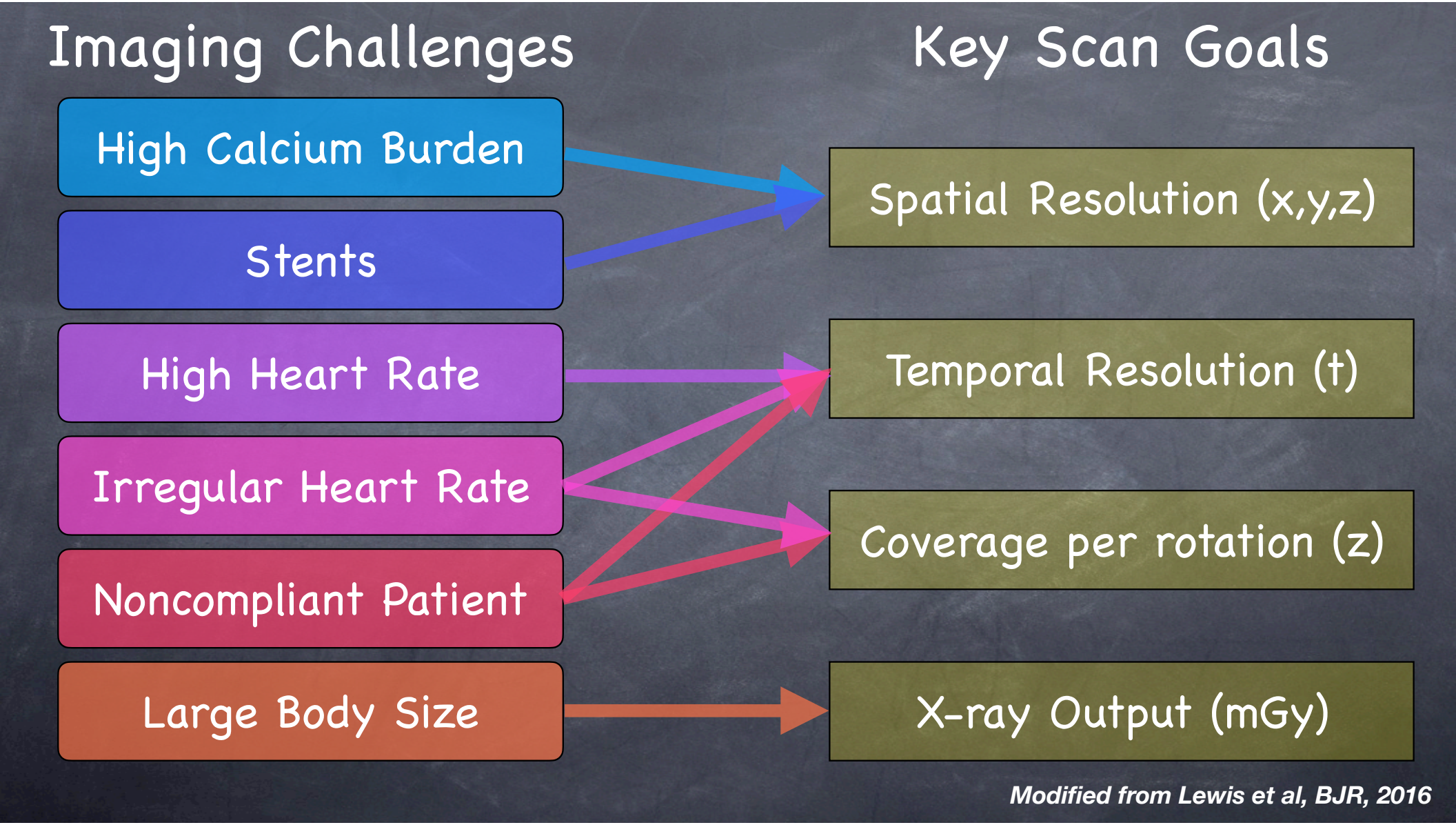
Determining CT Image Quality



Patient Factors

- Height
- Thickness - weight, BMI, chest circumference
- Age
- Heart Rate - basal & variation
- Heart Rhythm
- Health - allergies, heart, lung, or kidney disease
- Ability to follow instructions


Imaging Challenges
Key Scan Goals
High Calcium Burden
Stents
High Heart Rate
Irregular Heart Rate
Noncompliant Patient
Large Body Size
Spatial Resolution (x,y,z)
Temporal Resolution (t)
Coverage per rotation (z)
X-ray Output (mGy)
Modified from Lewis et al, BJR, 2016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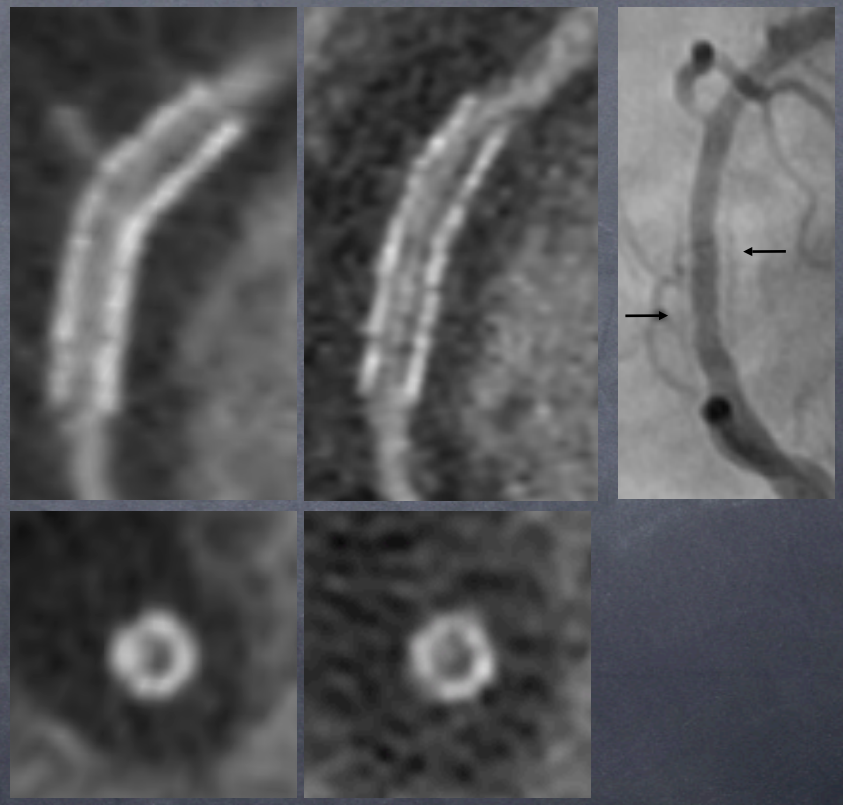
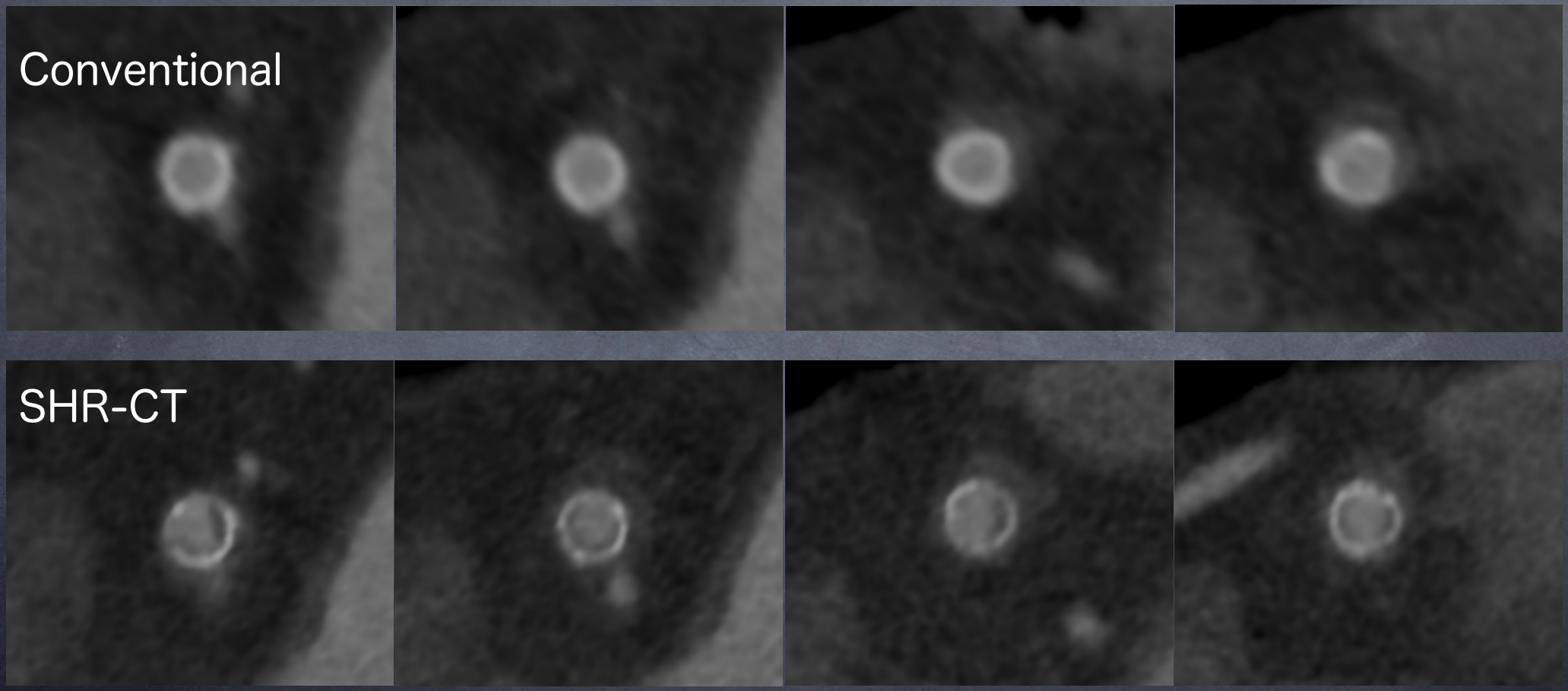
Spatial Resolution

- Detector Size and Composition- x, y
- Detector Width - z
- Reconstruction Type and Kernel



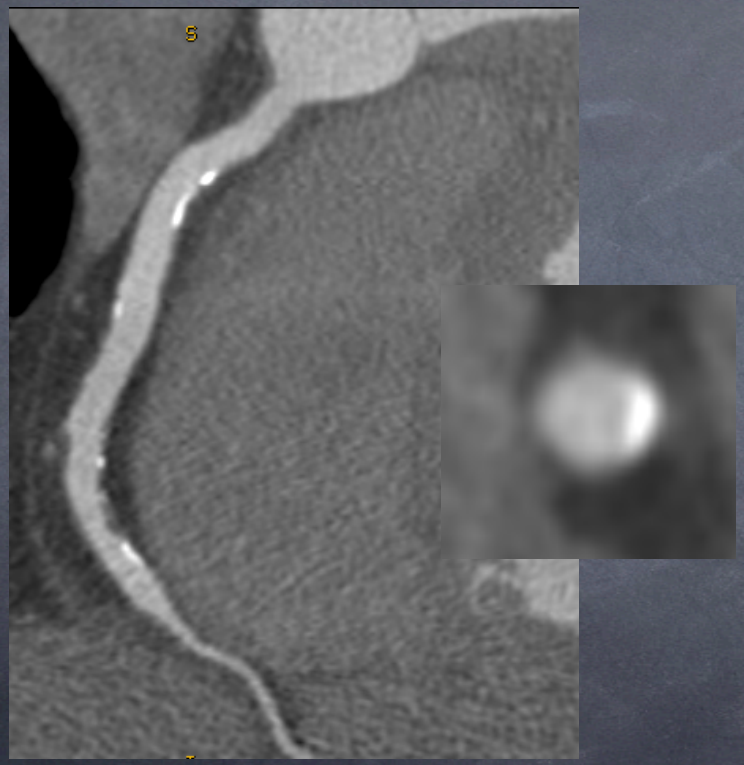
Centre Cardiologique du Nord - Saint Denis - France

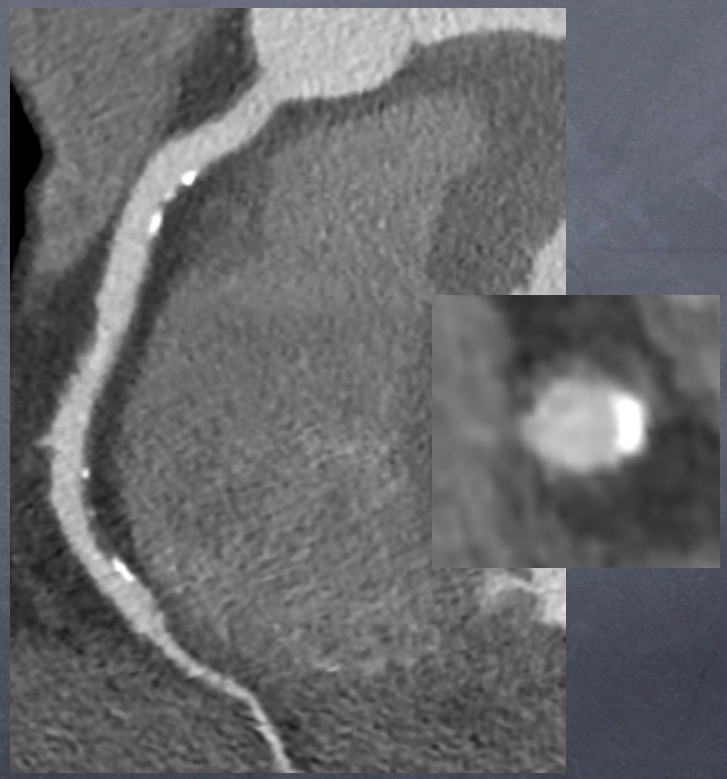
RCA Stent



K. Katada, Japan

Detector Composition & Size





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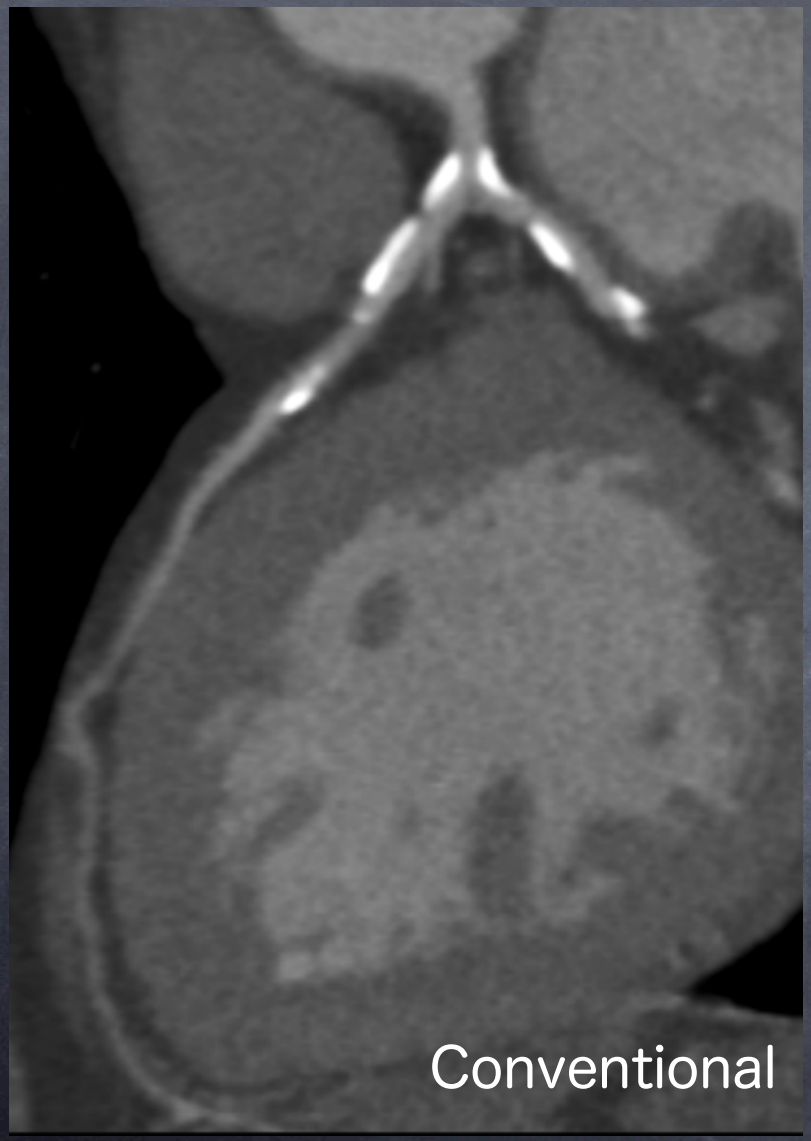
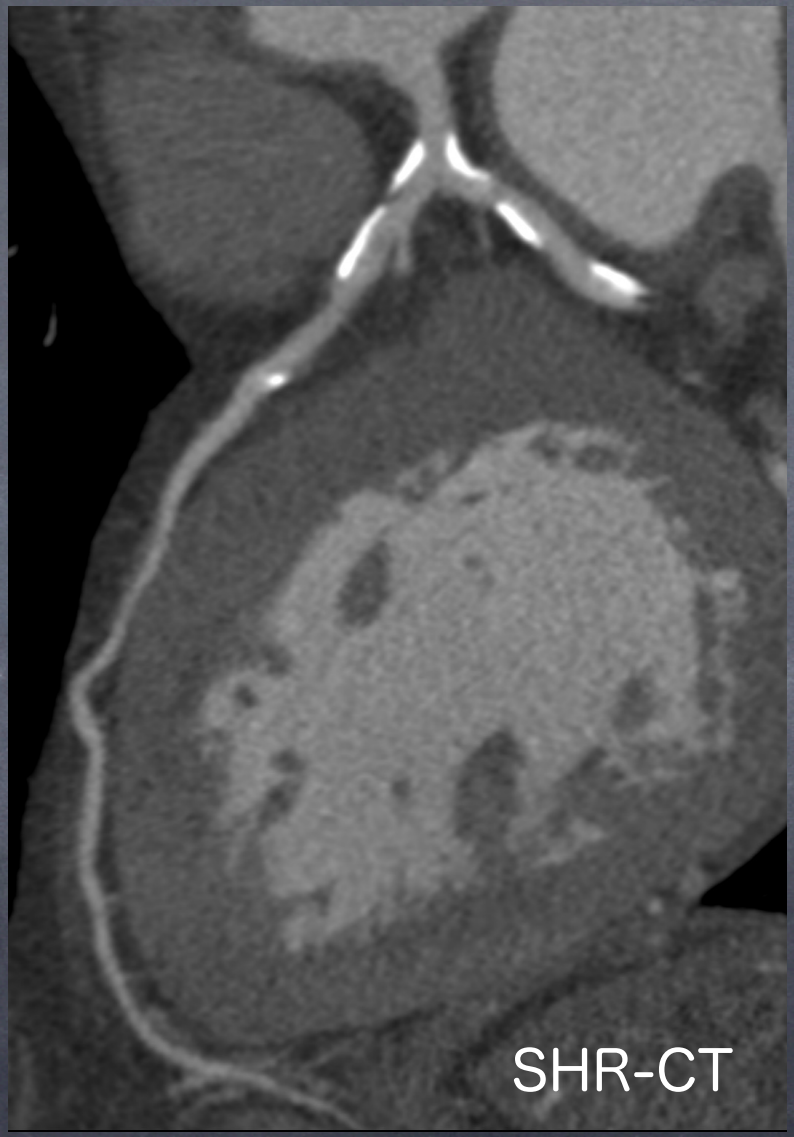
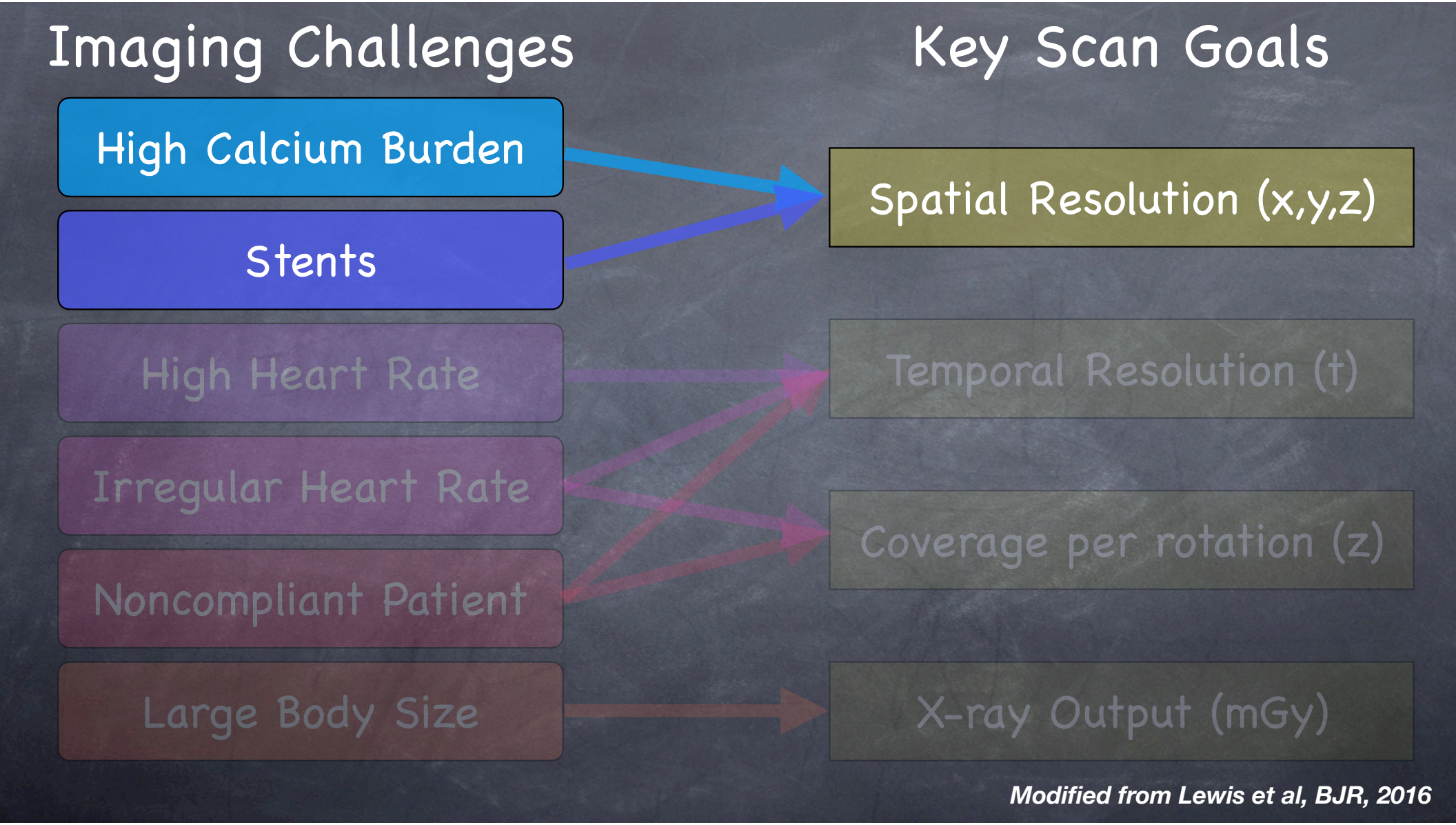




K. Katada, Japan



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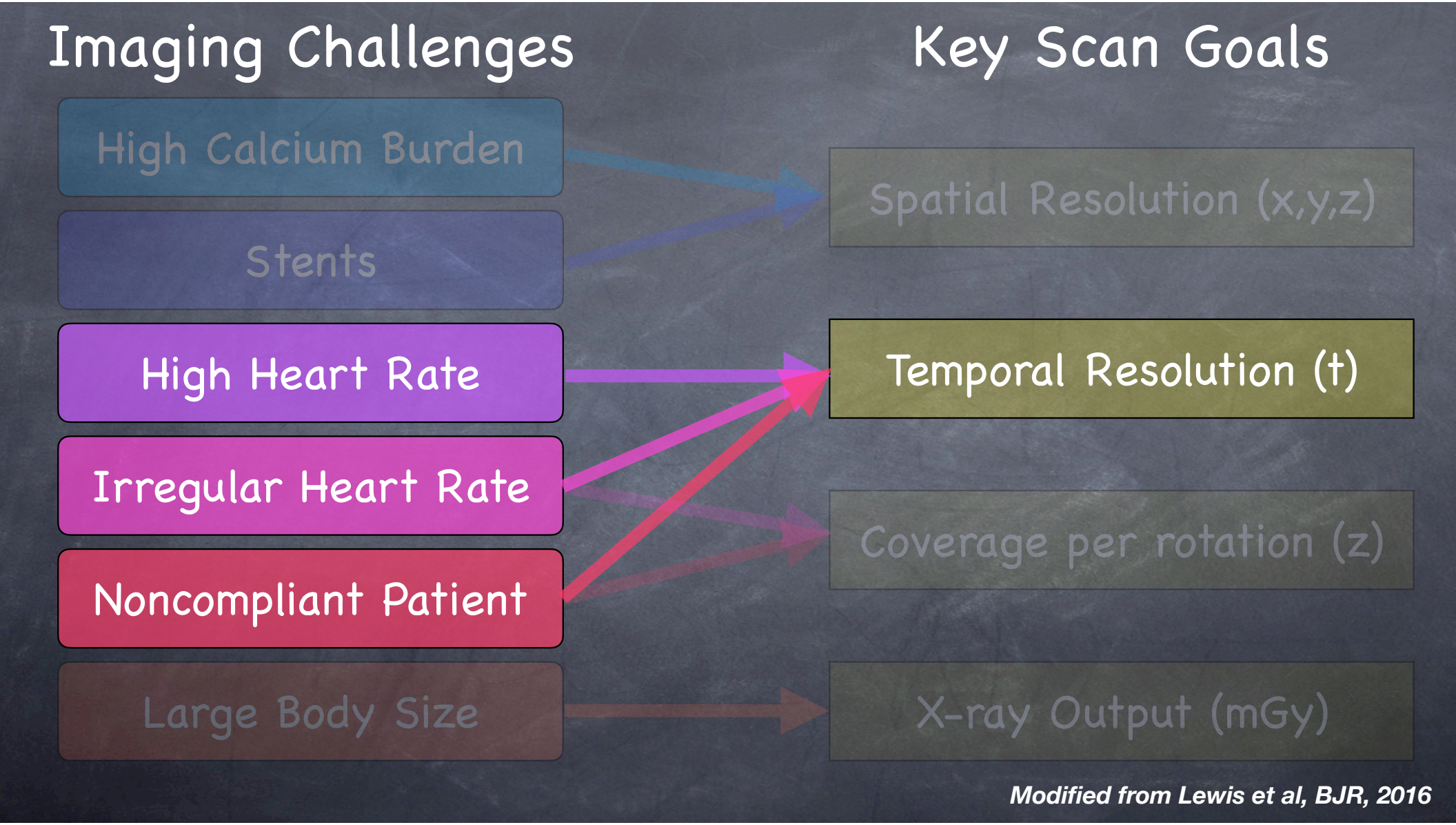


Modified from Lewis et al, BJR, 2016

Temporal Resolution

- The time required to reconstruct a transverse section
- Single heart or multiple heart beats
- Gantry rotation time is primary determinate, but multi-source scanners also have major influence
- Motion can be mitigated post scan with correction algorithms

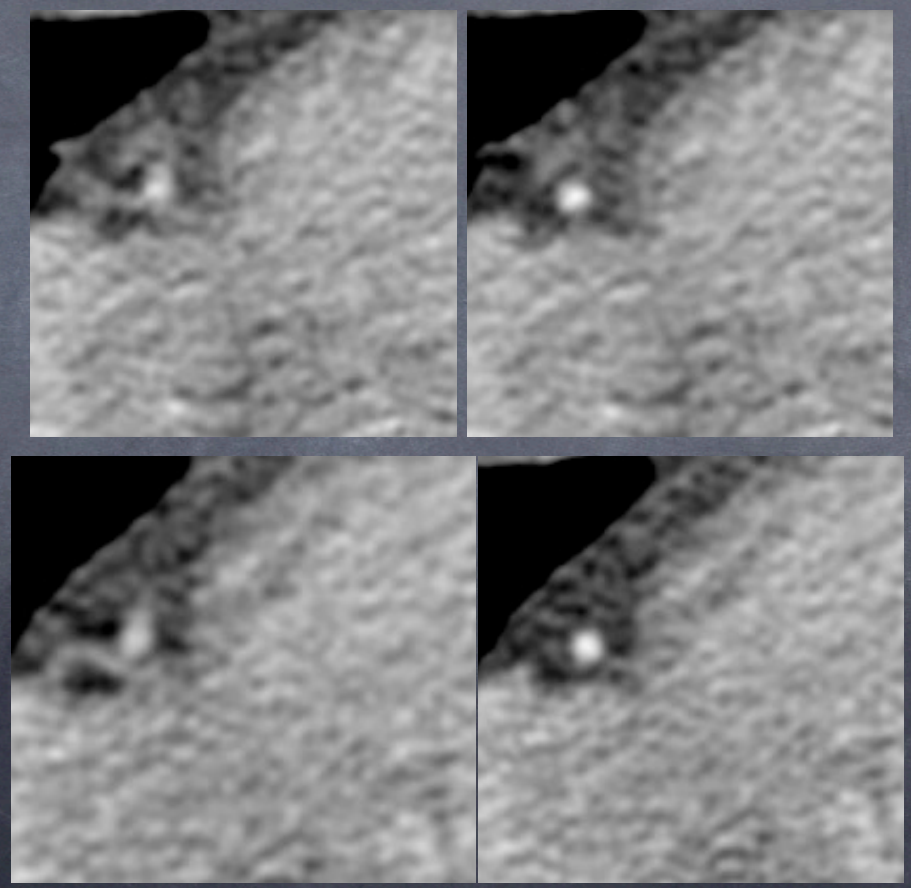

82 bpm


65 bpm

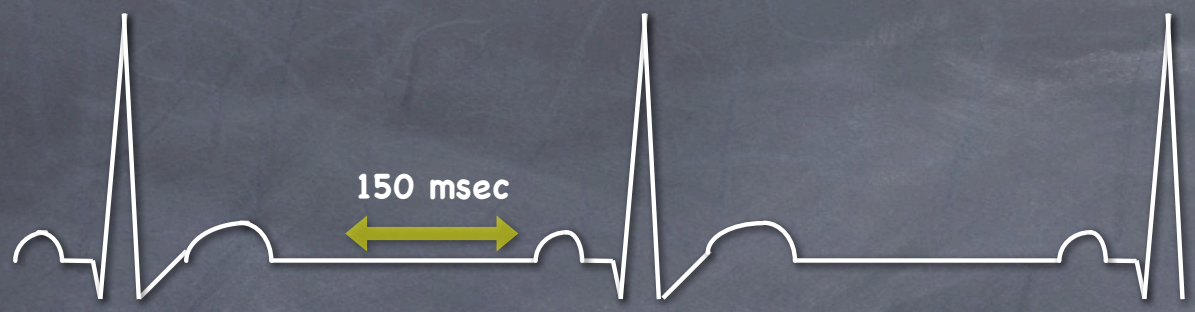
Beat to Beat Variability

70-84 bpm

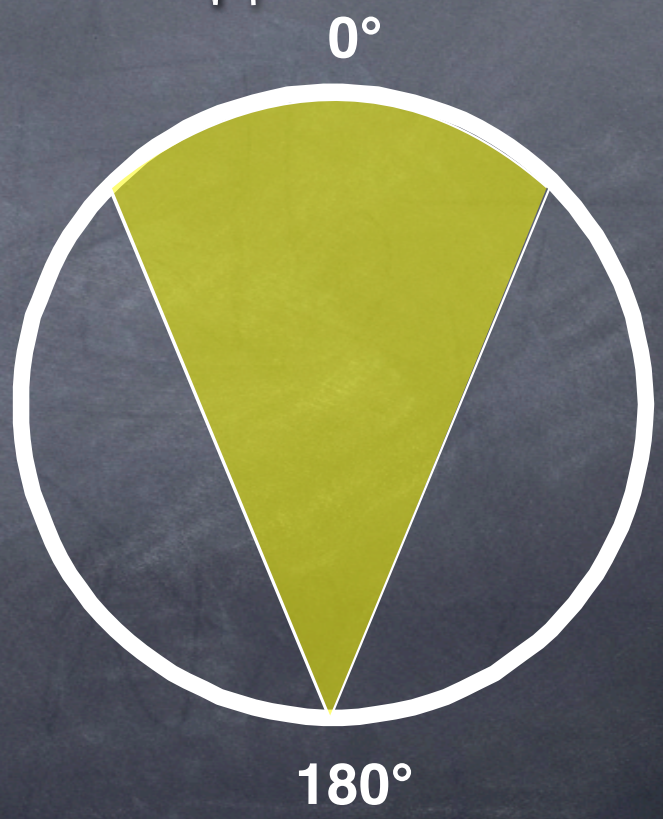
Standard Recon

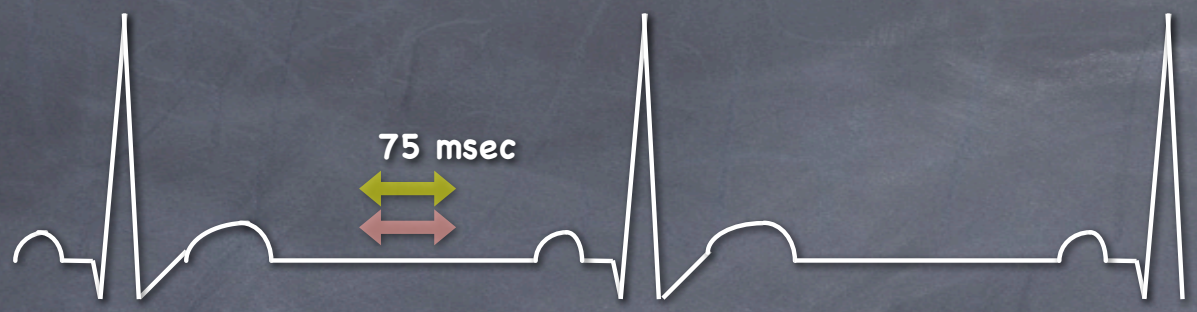


Post-processing Motion Suppression

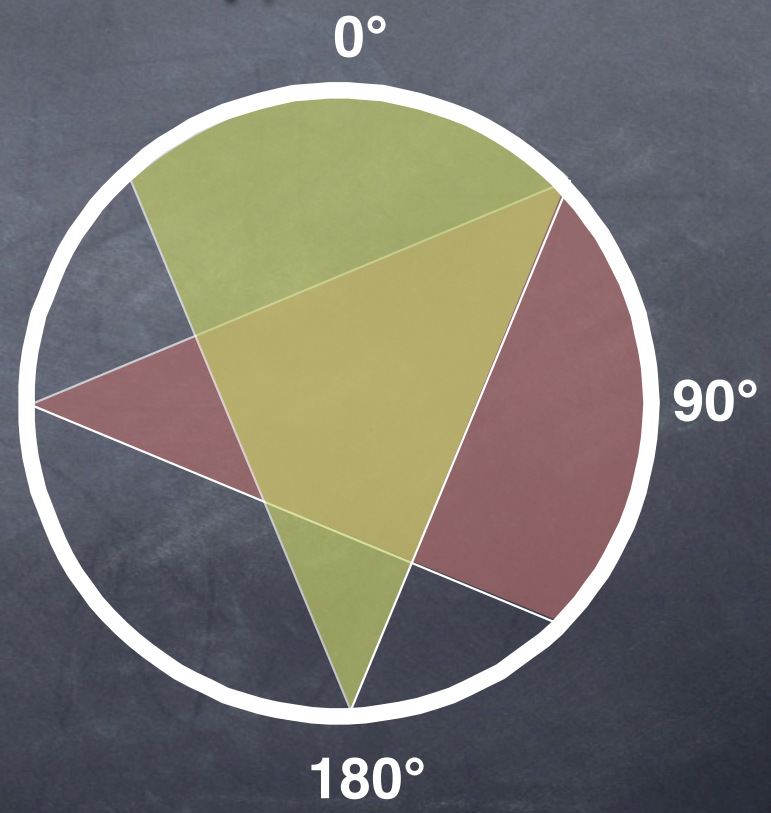


Half Scan Interpolation 0.3 s rotation





Dual Source CT
0.3 s rotation



Halfscan Reconstruction

Prospective Triggering (4-6 cm detector)

- Observe several beats and predict timing of next beat
- Image every other beat, advance table during beats in between
- The number of beats required depends upon the detector width and the length of the heart

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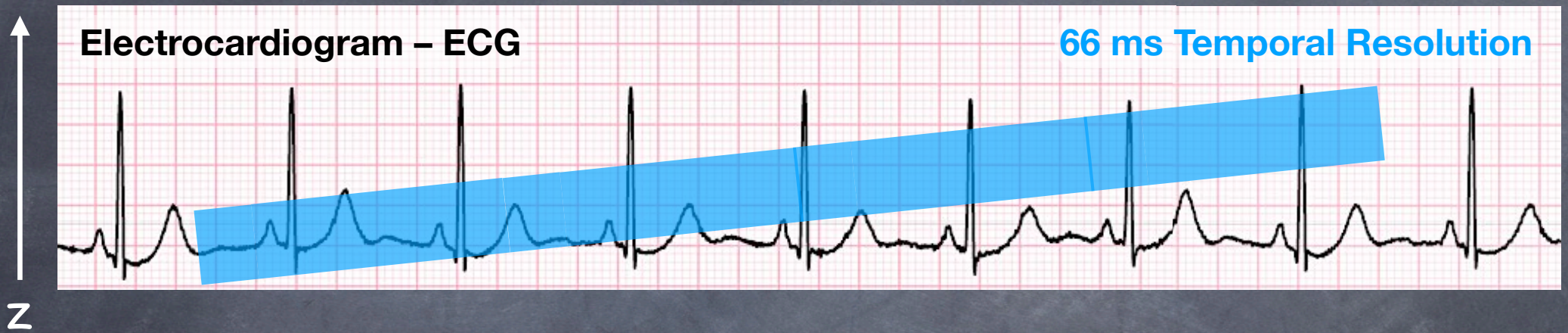
Prospective Triggering with Padding

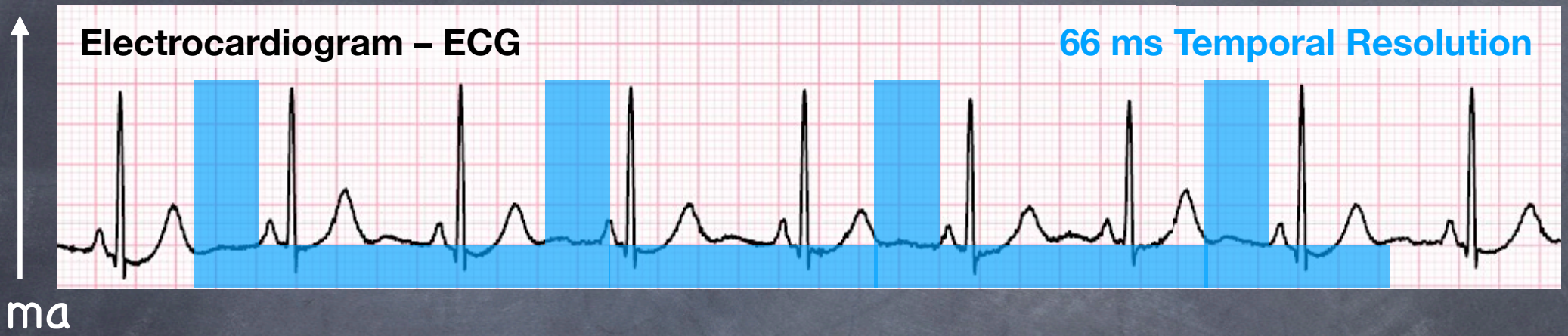
- Each gantry rotation is extended to expand the time window for reconstruction, e.g. for HR=60 bpm, a 300 msec scan centered at 65% of R-R interval provides reconstructions between 50-80% of R-R interval
- Greater temporal flexibility at a cost of radiation exposure

Retrospective Gating



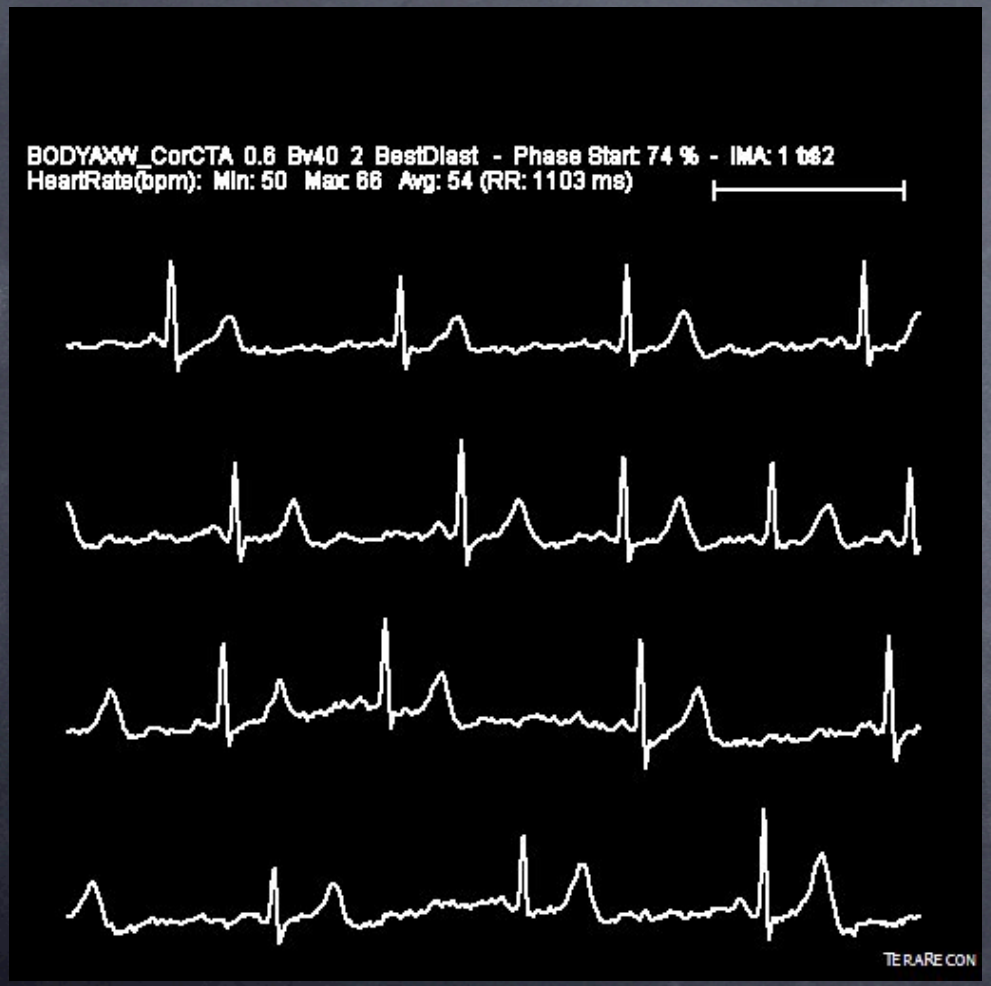
- Continuous helical scan, recons sorted out after the scan
- Maximal temporal flexibility, displays dynamic information
- Very high radiation exposure without x-ray pulsing

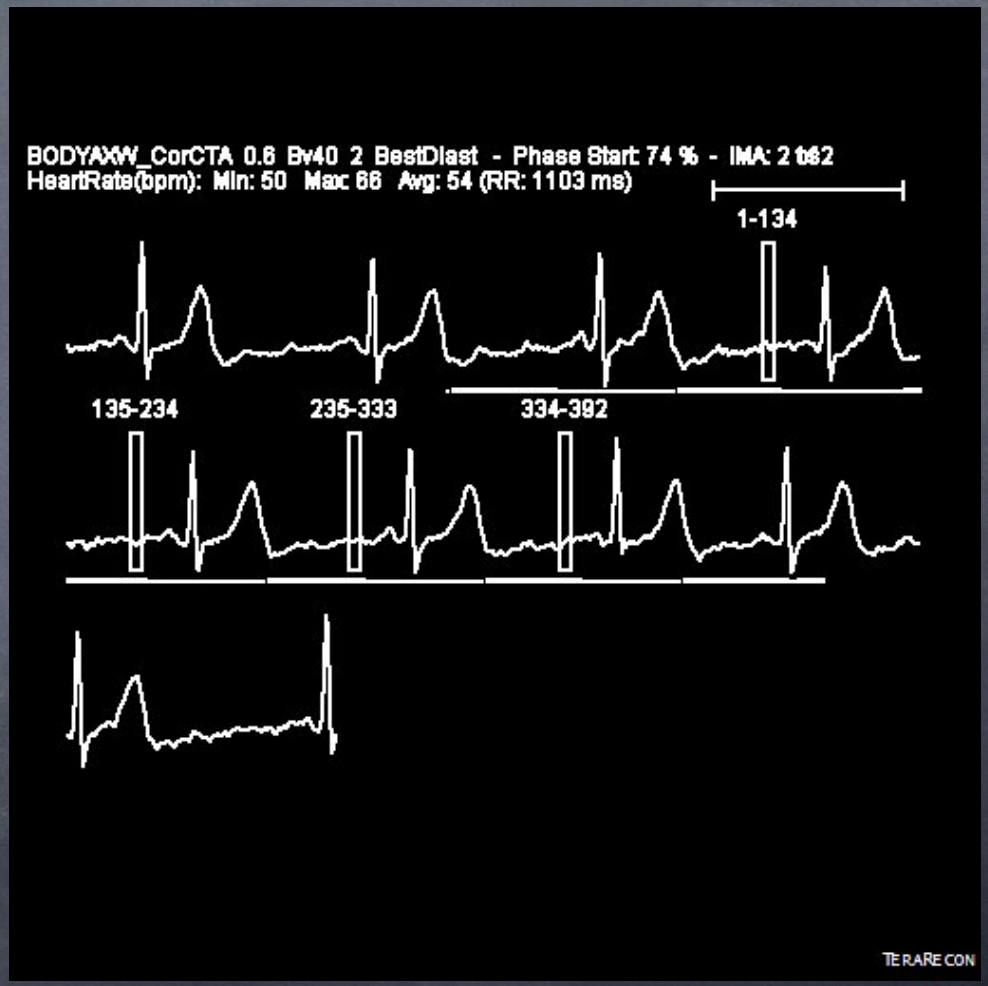
Retrospective Gating with X-Ray Pulsing



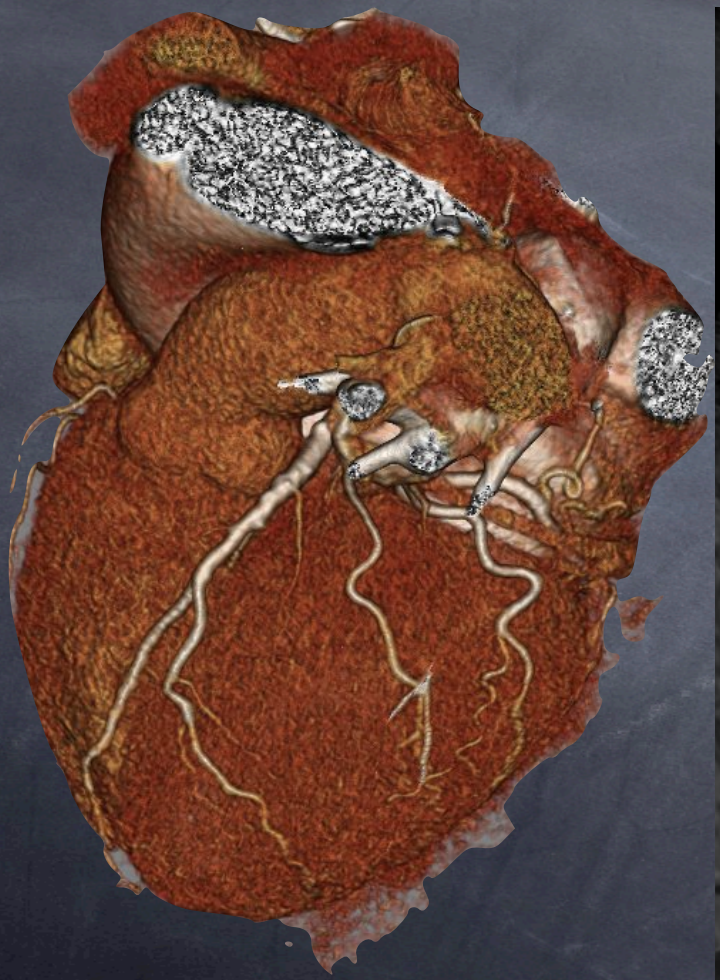
- Continuous helical scan, recons sorted out after the scan
- Maximal temporal flexibility
- Very high radiation exposure without x-ray pulsing

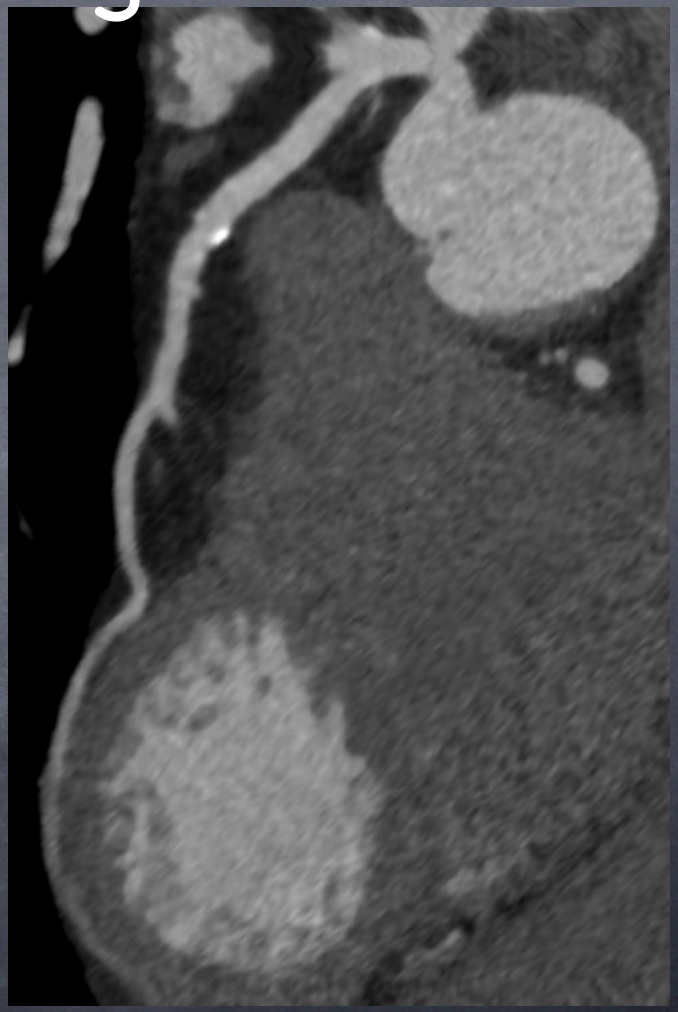
77 yo with SVT

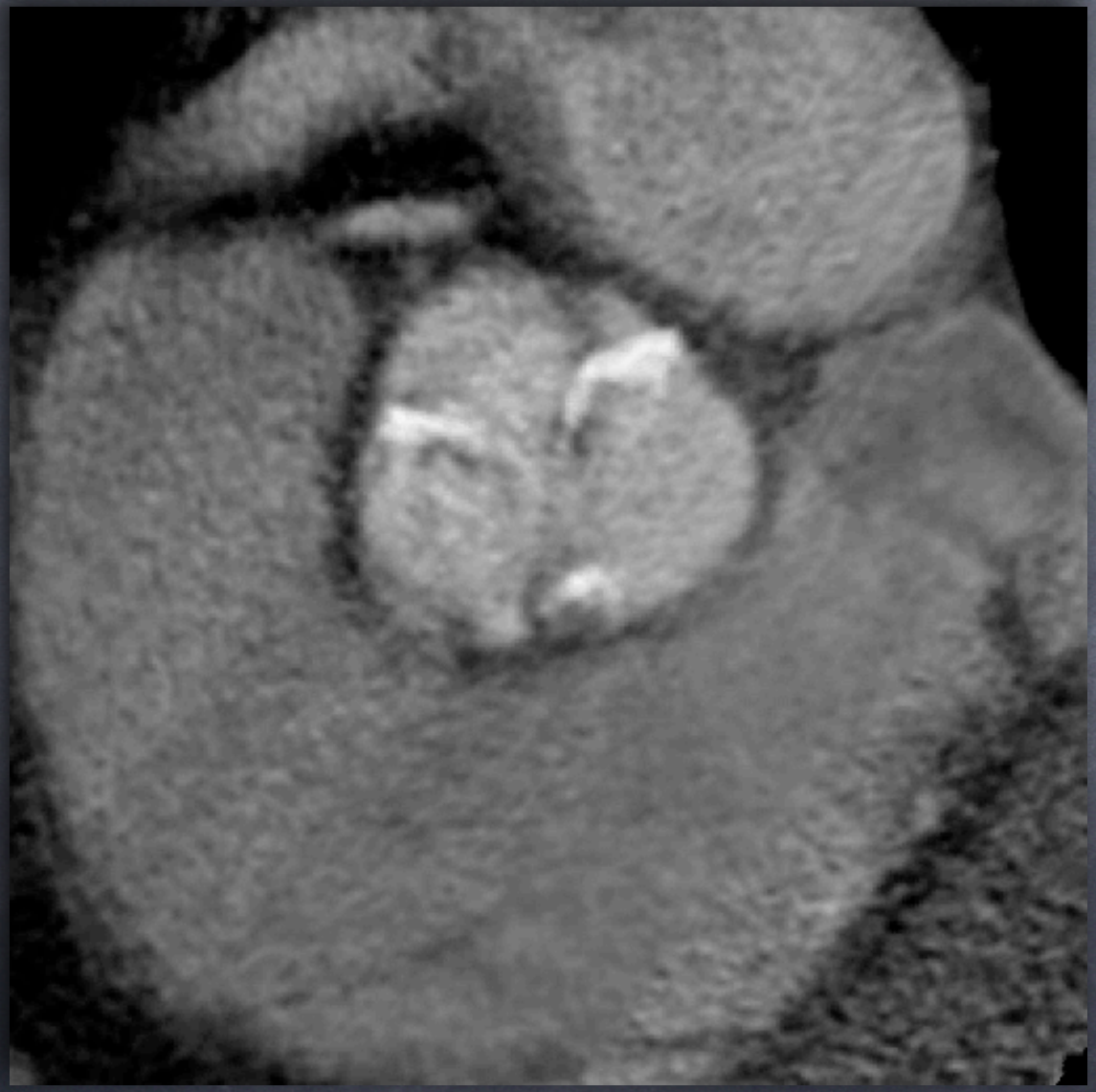


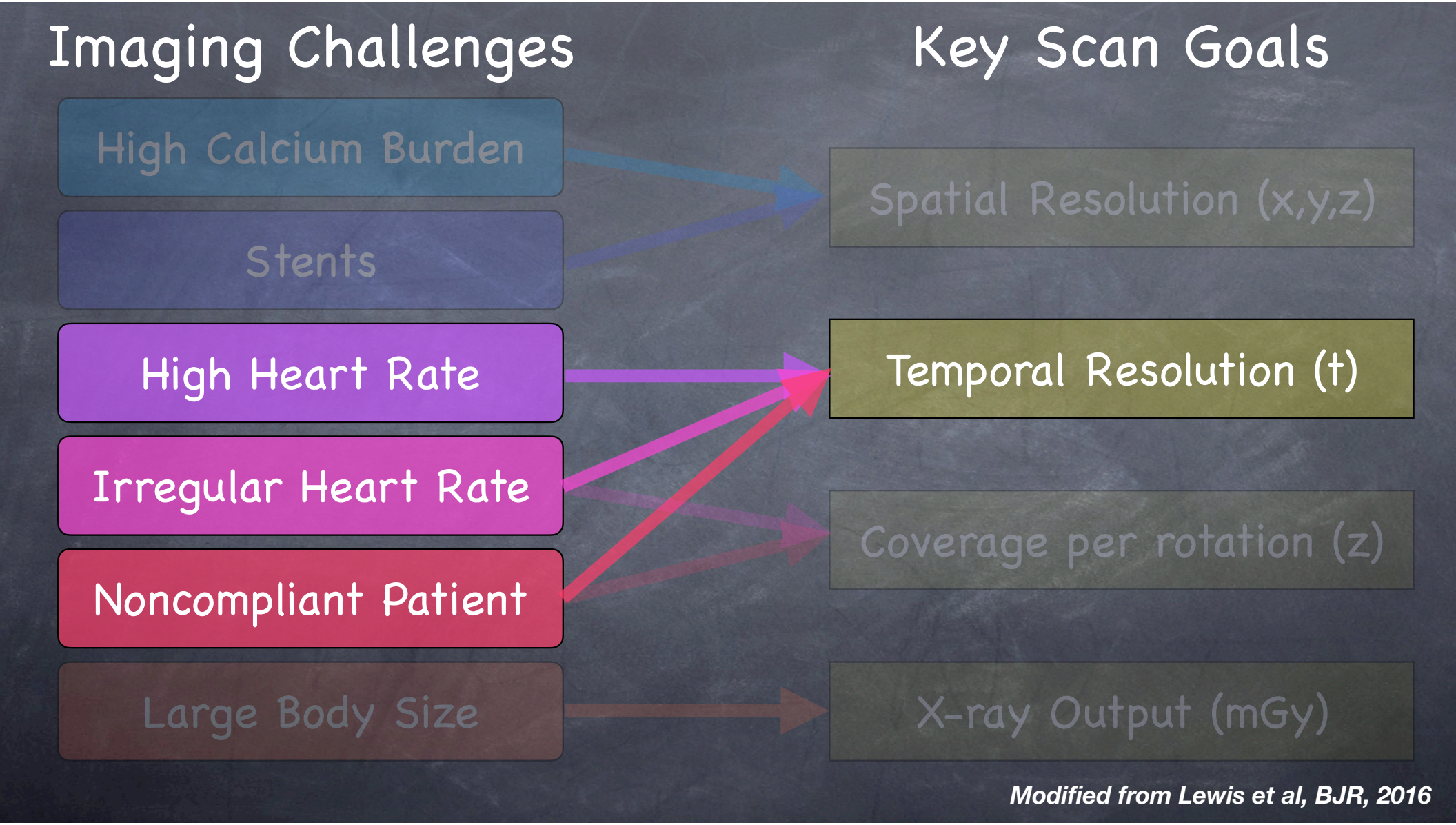


Retrospective Gating









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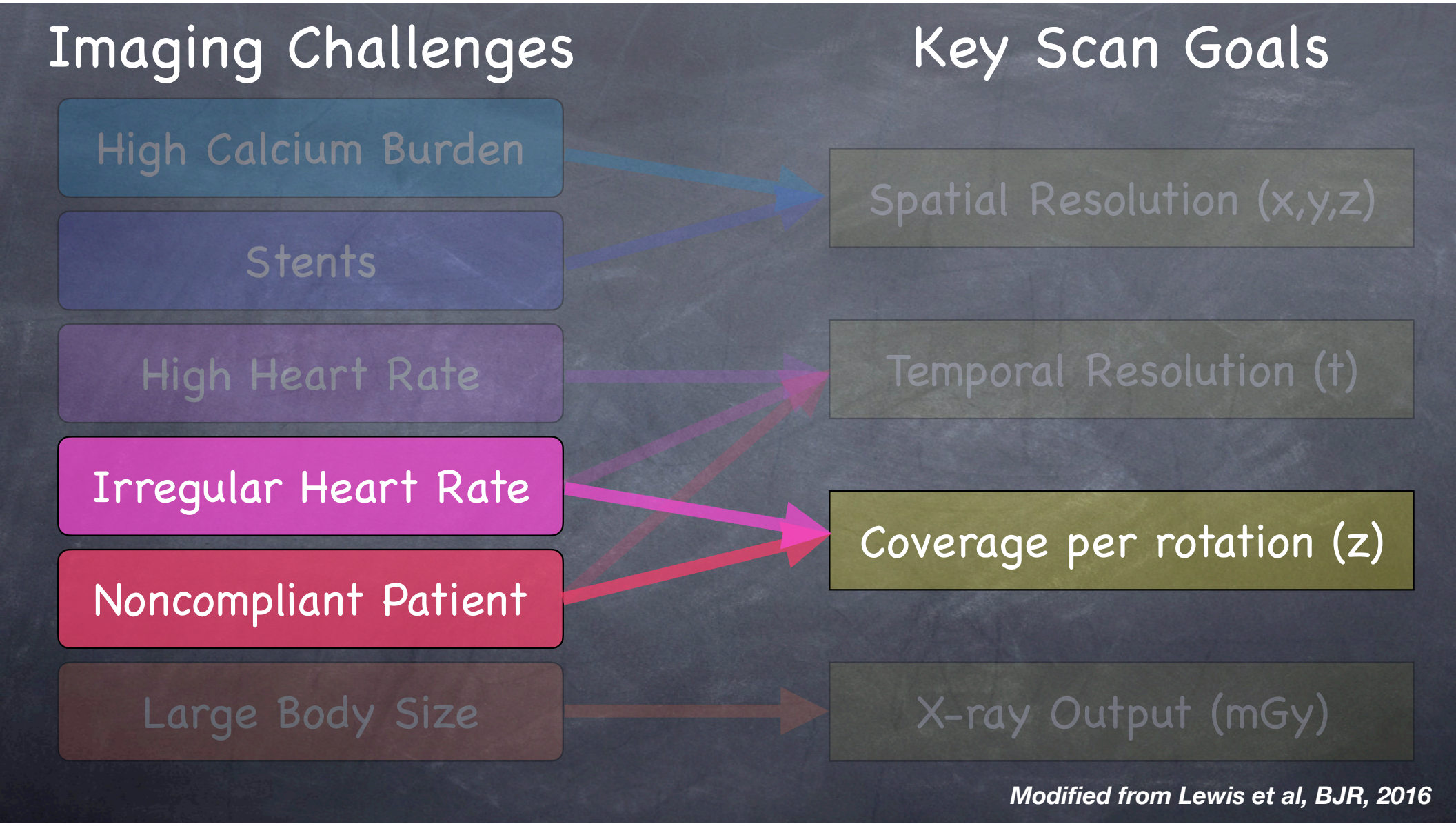

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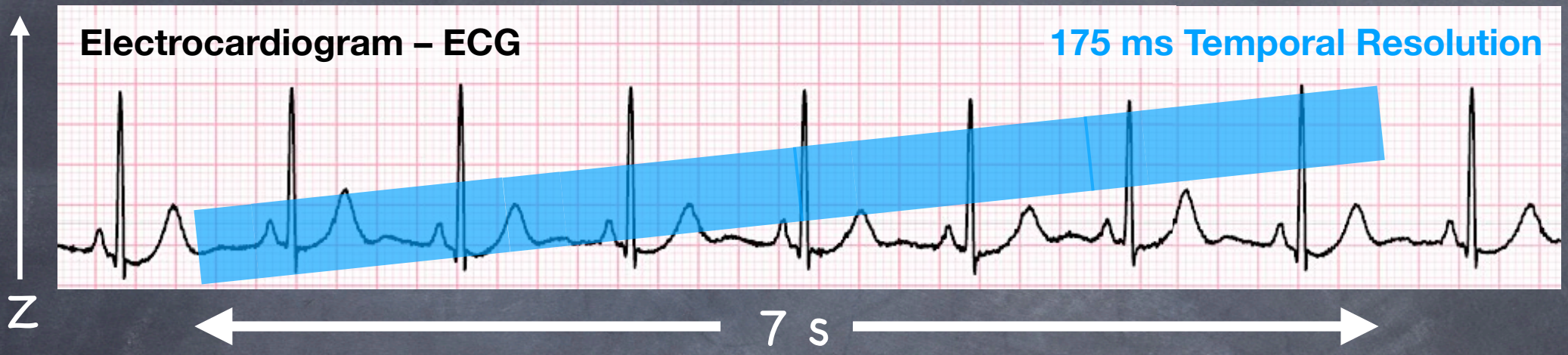
Retrospective Gating (4-6 cm detector)

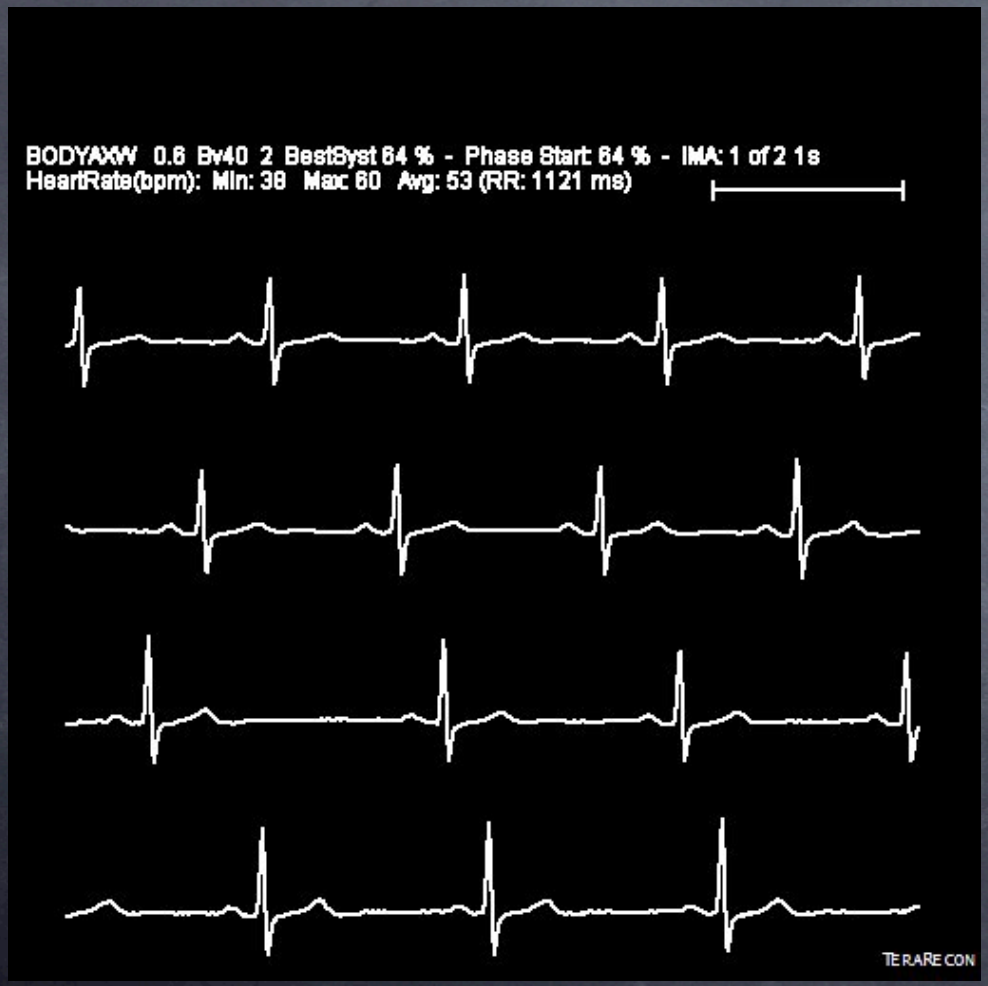


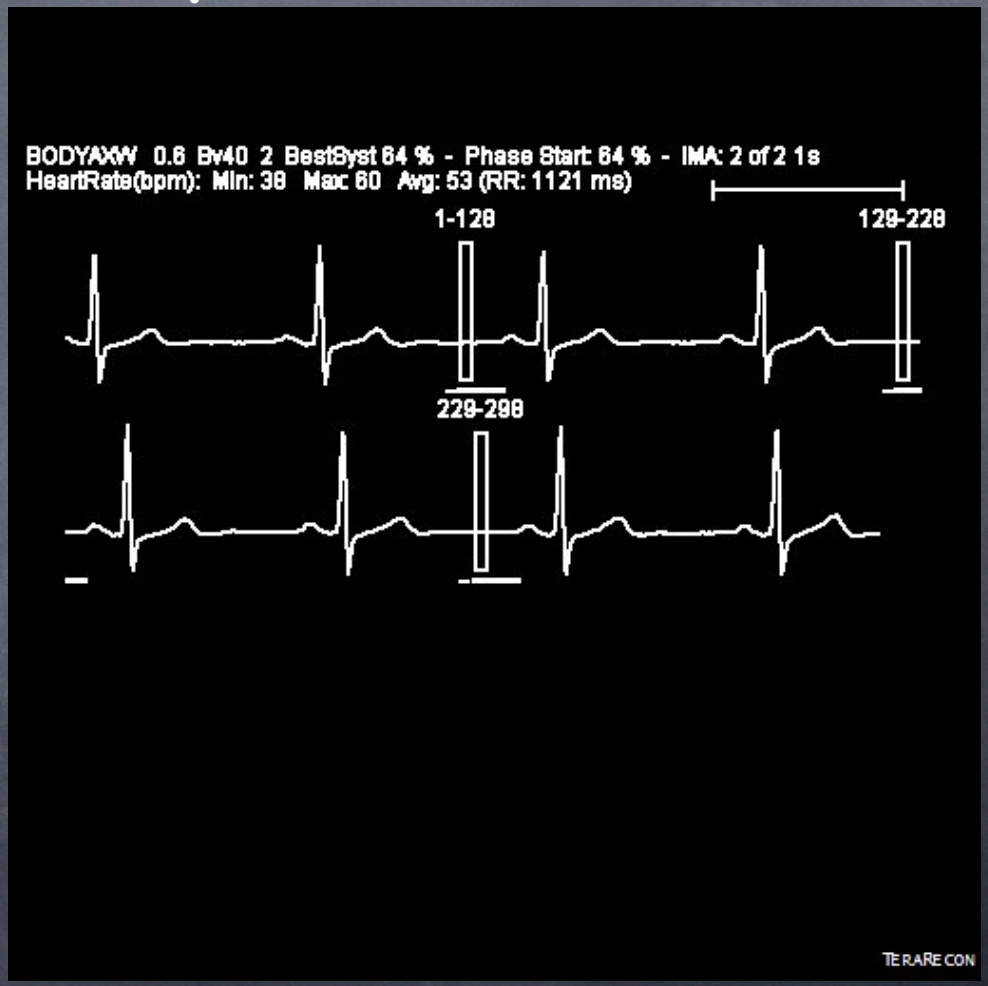
- Scanning requires 5-7 seconds regardless of temporal resolution or cardiac compensation mode (pro vs retro)

Prospective Triggering (4-6 cm detector)

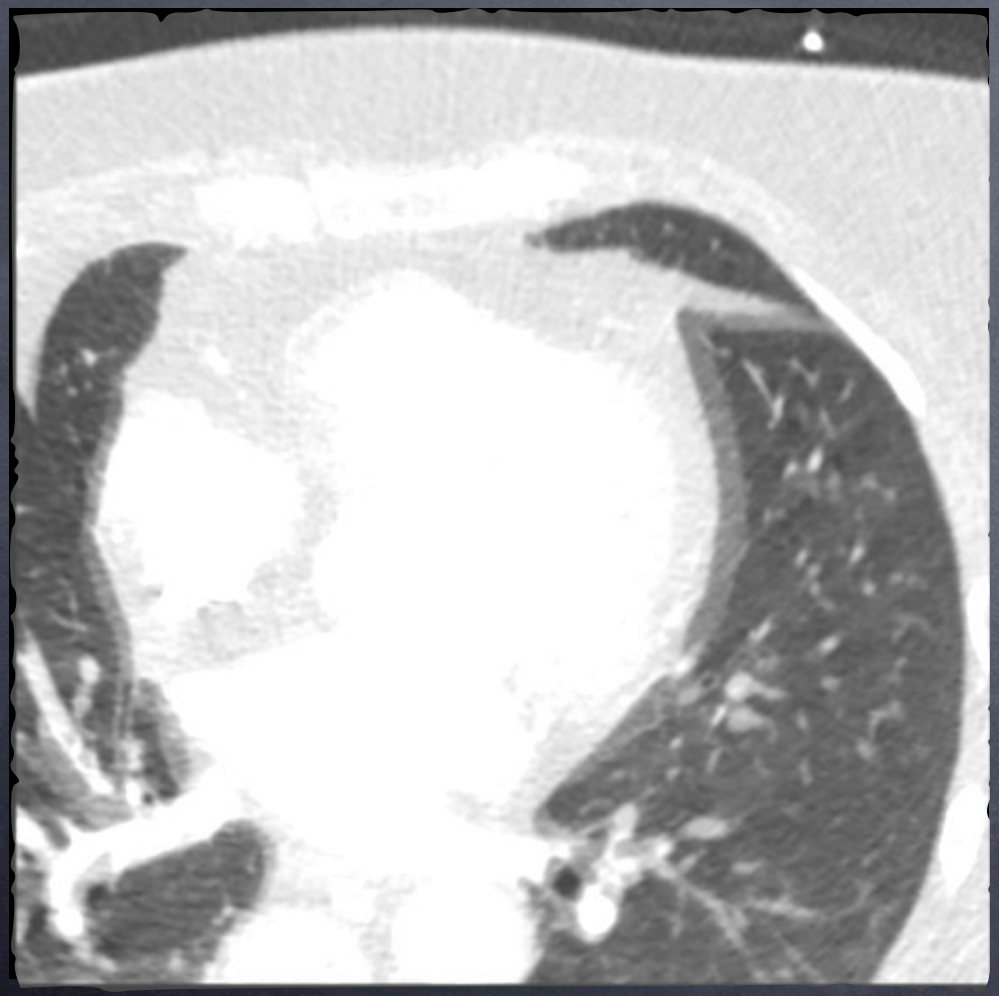
- Scanning requires 5-7 seconds regardless of temporal resolution or cardiac compensation mode (pro vs retro)

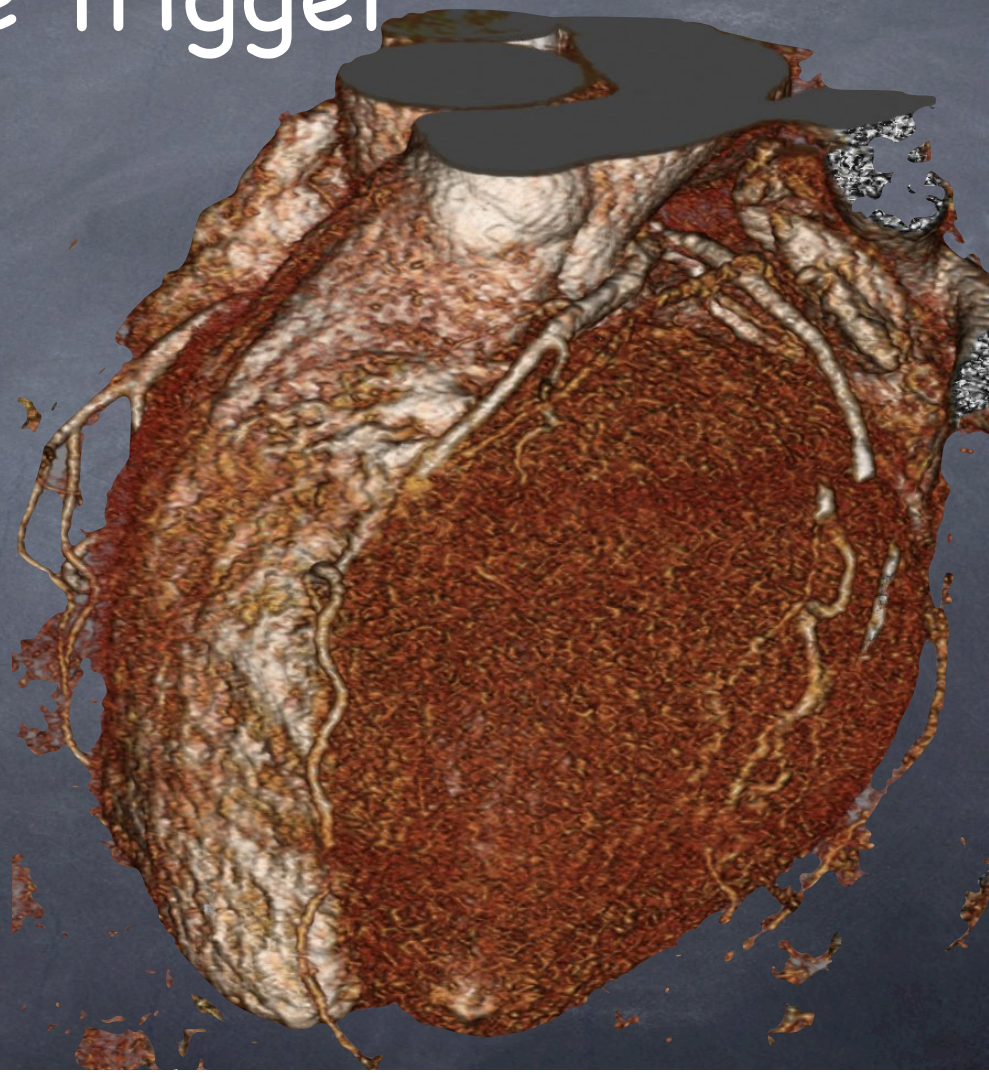
67 yo, 51 bpm


BODYAXW 0.6 Bv40 2 BestSyst 64 % - Phase Start 64 % - IMA: 1 of 2 1s
HeartRate(bpm): Min: 38 Max 60 Avg: 53 (RR: 1121 ms)
TERARECON

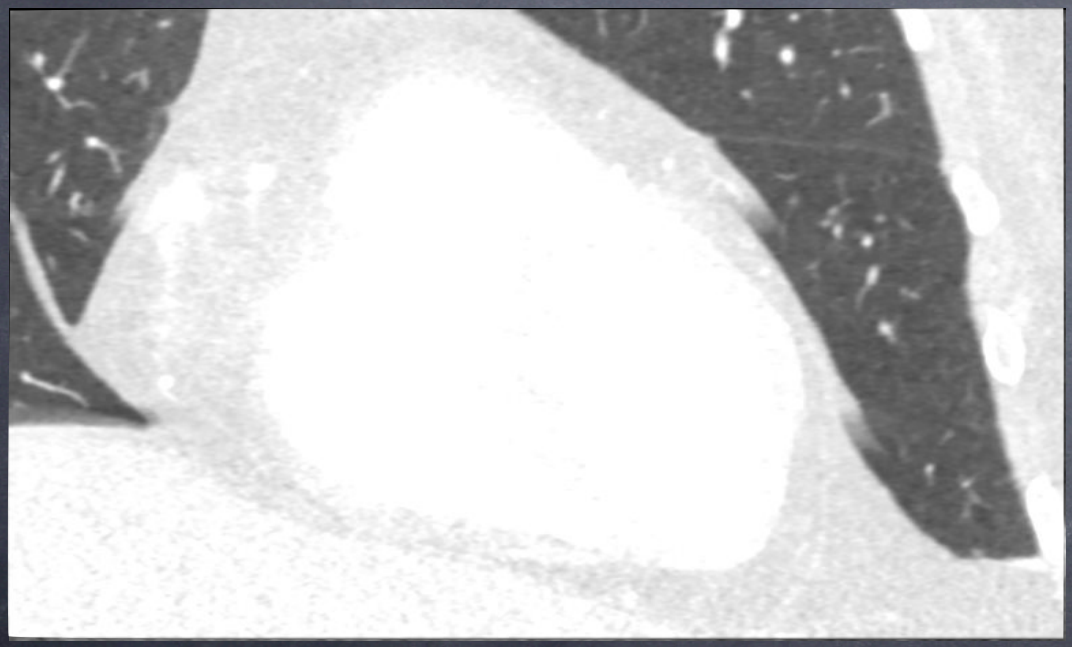

BODYAXW 0.6 Bv40 2 BestSyst 64 % - Phase Start 64 % - IMA: 2 of 2 1s
HeartRate(bpm): Min: 38 Max 60 Avg: 53 (RR: 1121 ms)
1-128
129-228
229-298
TERARECON

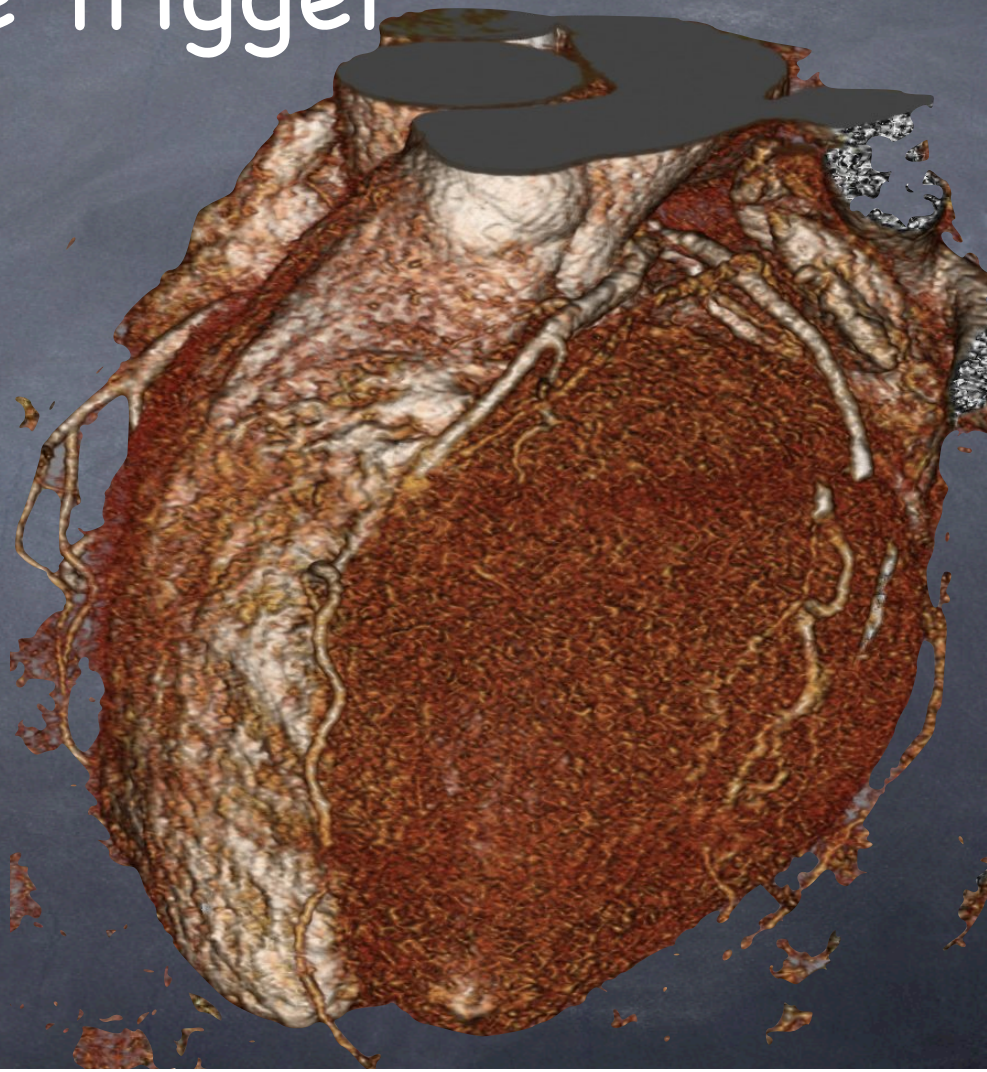
Prospective Trigger



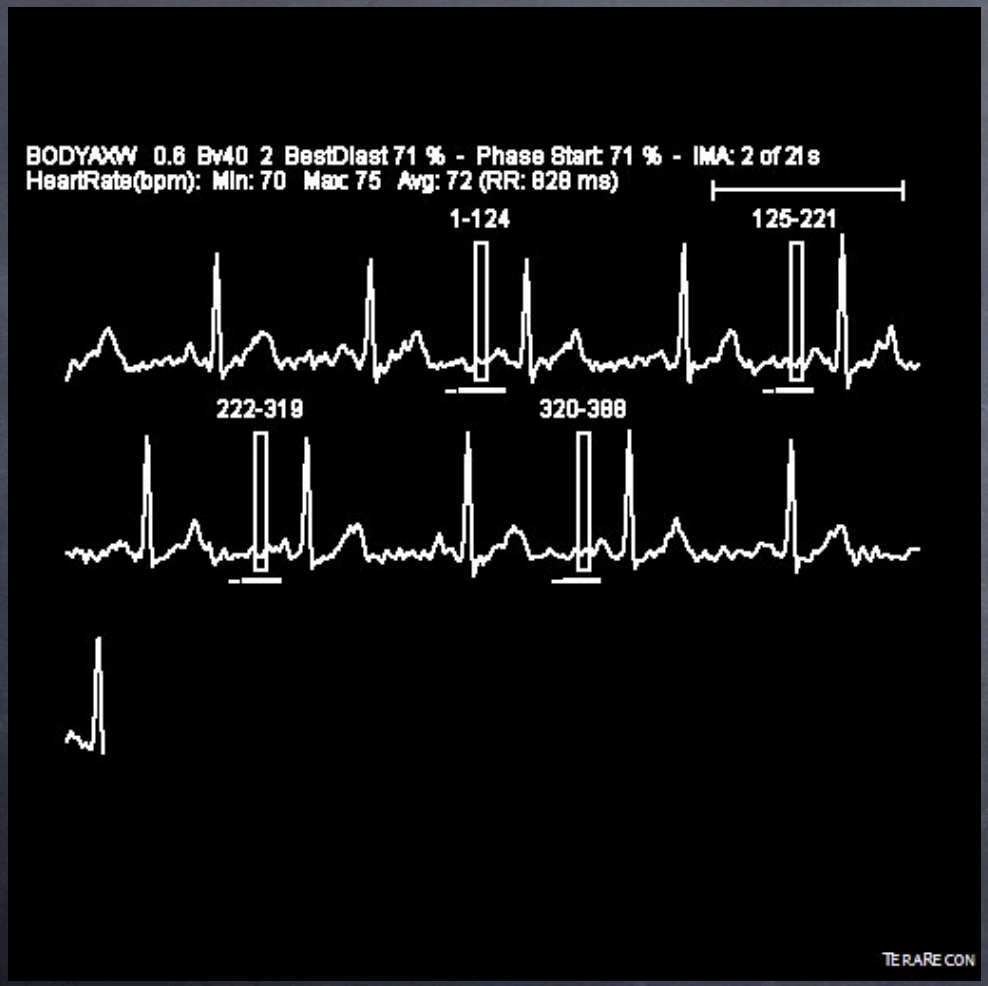


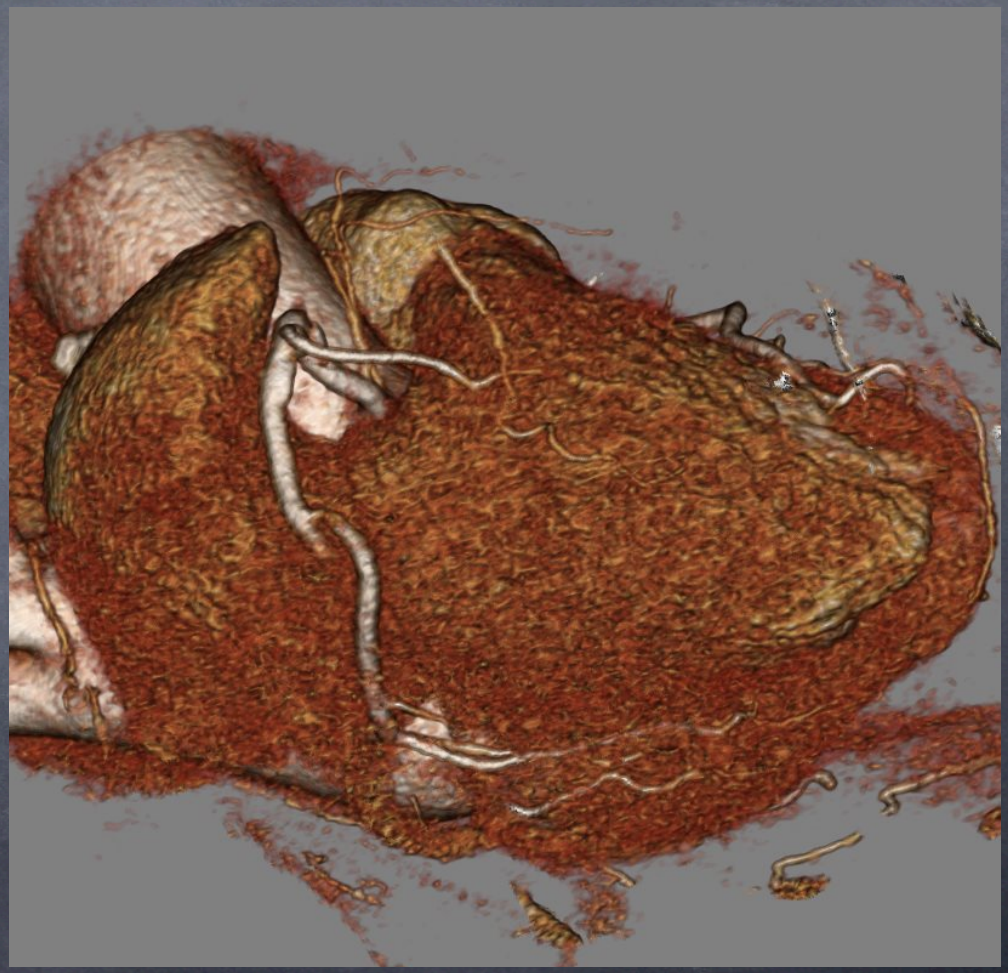
Prospective Trigger



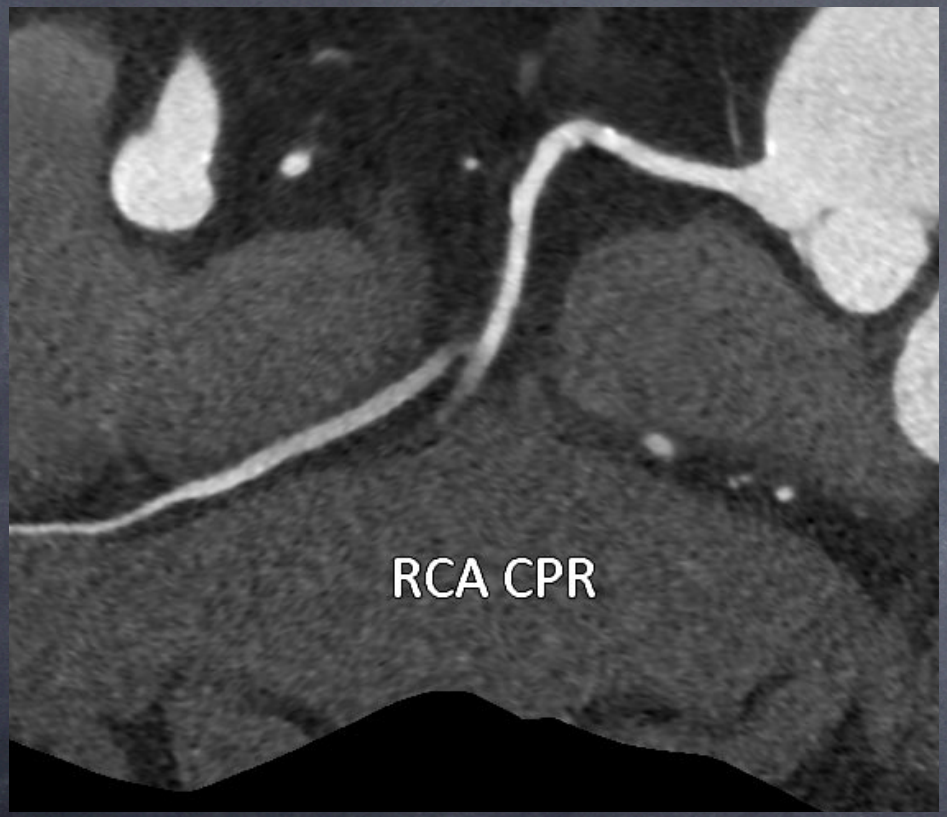


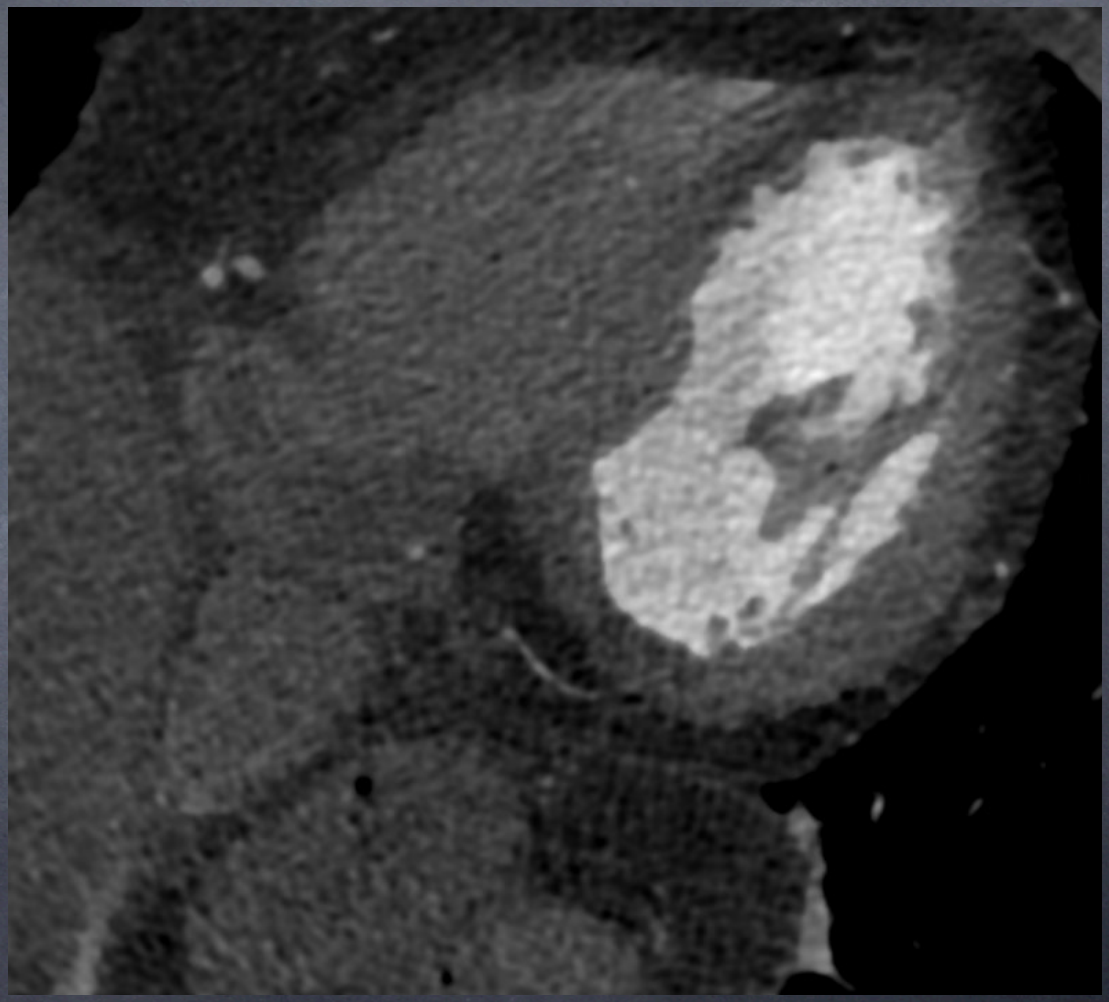
Misregistration between Beats





76 yo ♀ with chest pain





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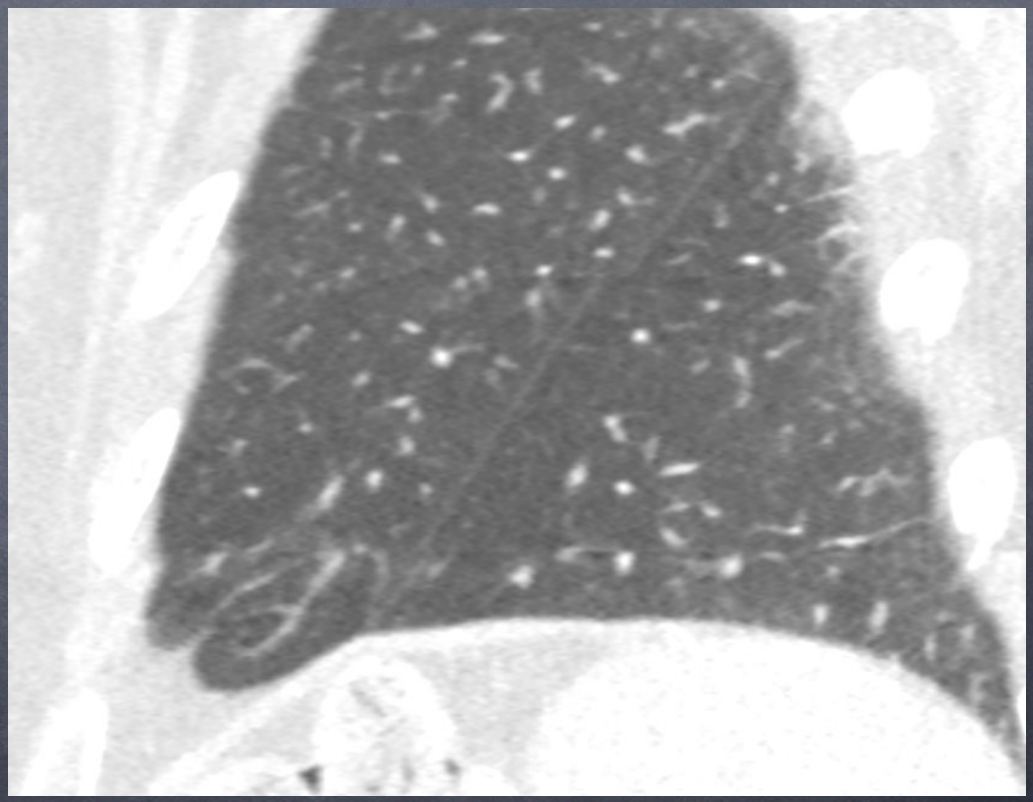
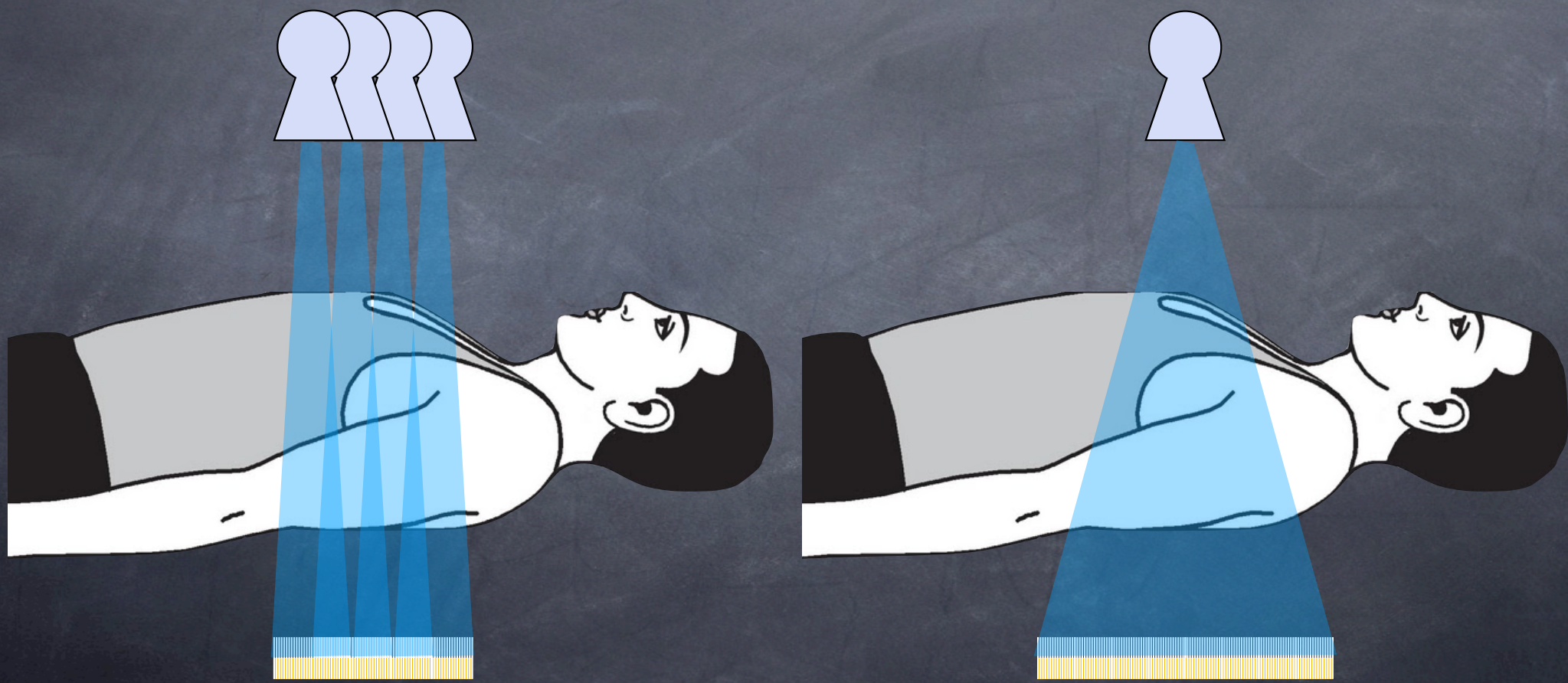


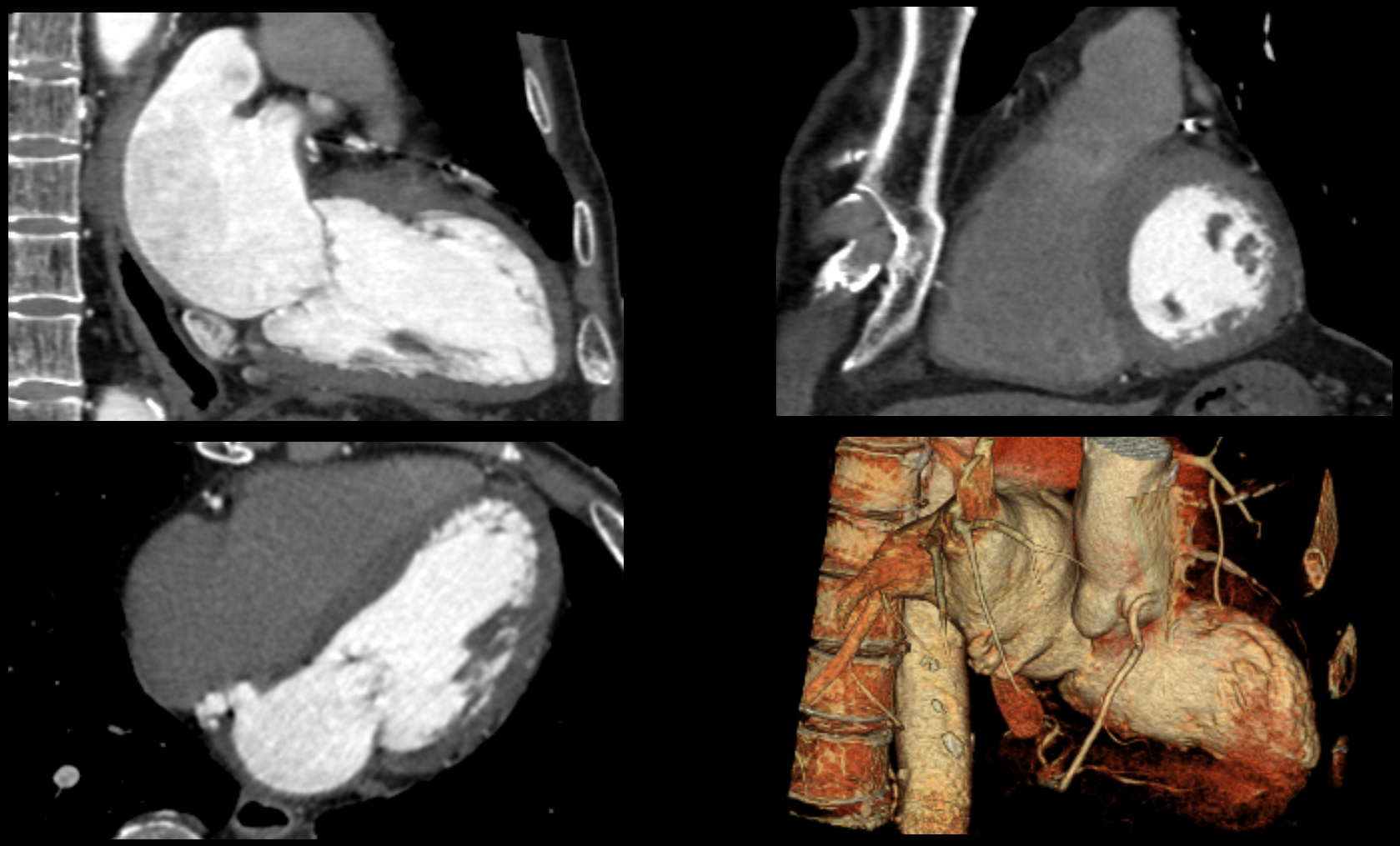
Longitudinal Coverage

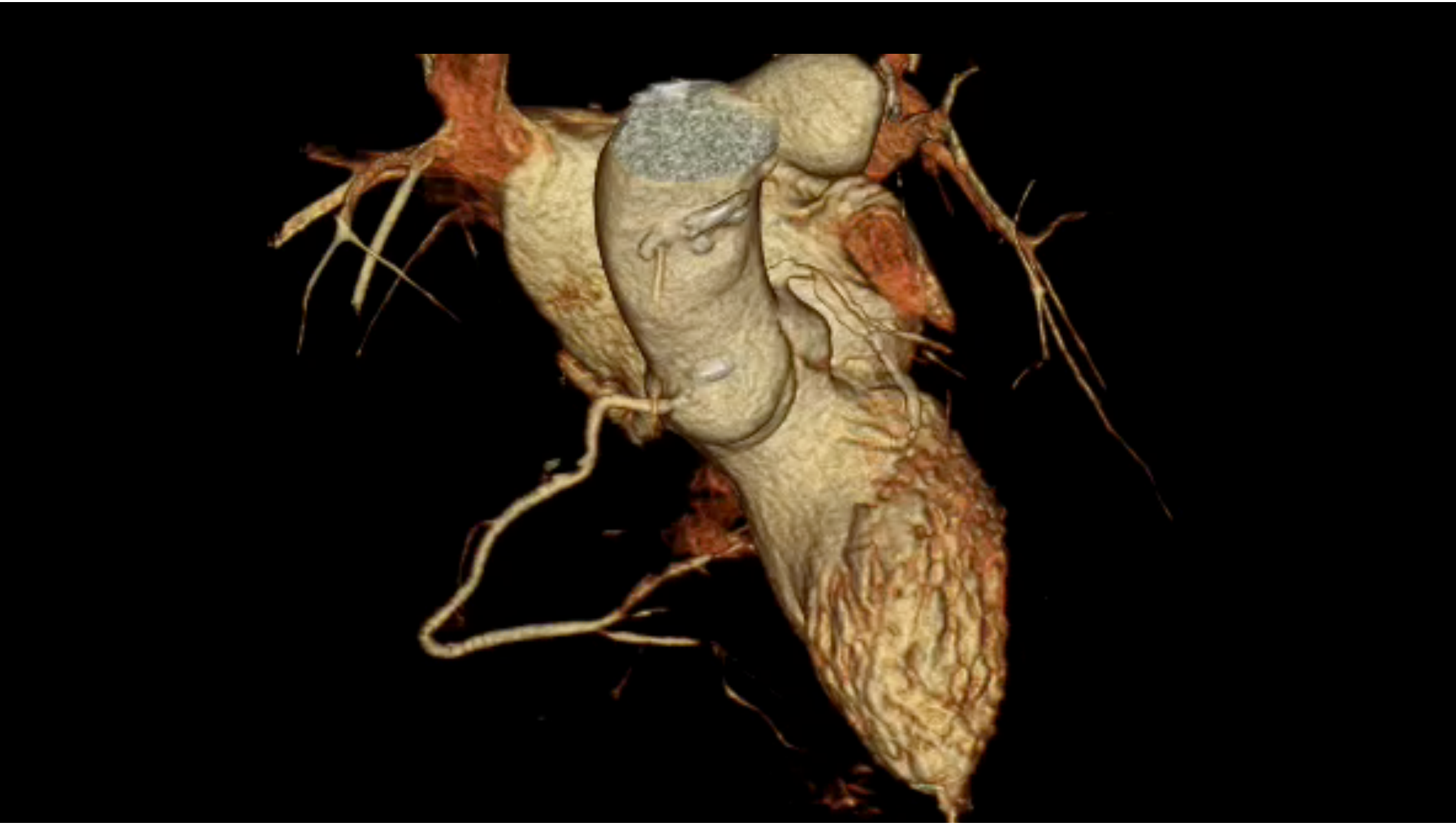


Prospective Triggering (16 cm detector)

- Single beat scanning requires minimum of 140 ms without padding

Chronic Atrial Fibrillation 320 row CT



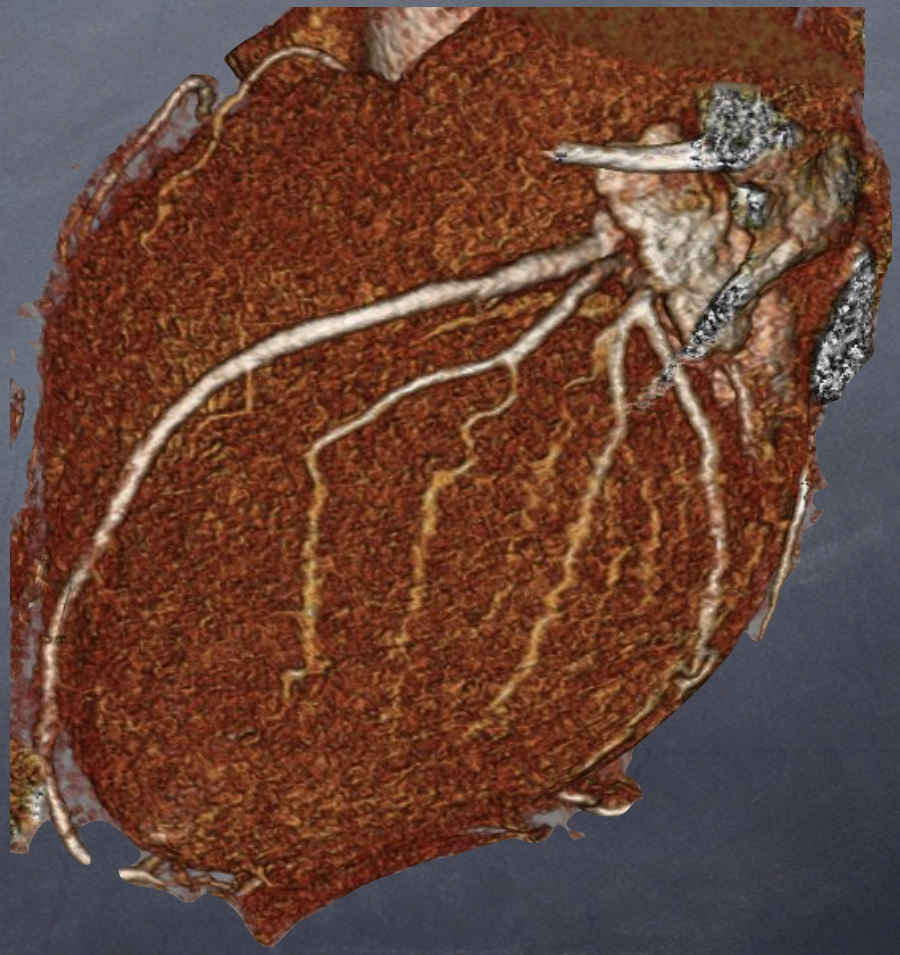


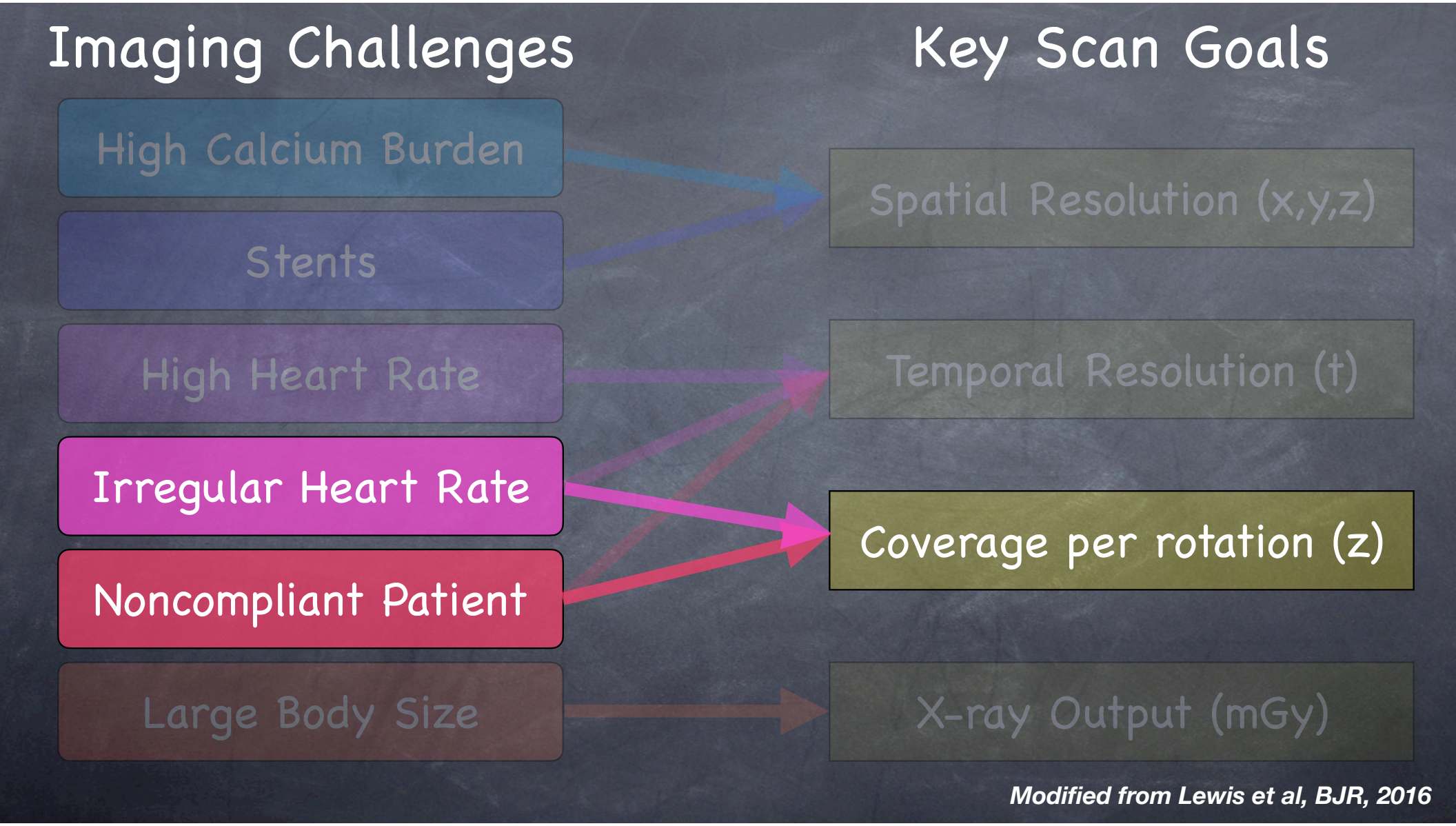
One Beat - High Pitch (5.7 cm detector)

z

- Scan duration (s) = $\frac{160 \text{ mm} \times 250 \text{ ms}}{3.2 \times 57 \text{ mm}}$ = 220 ms

Dual Source Single Beat





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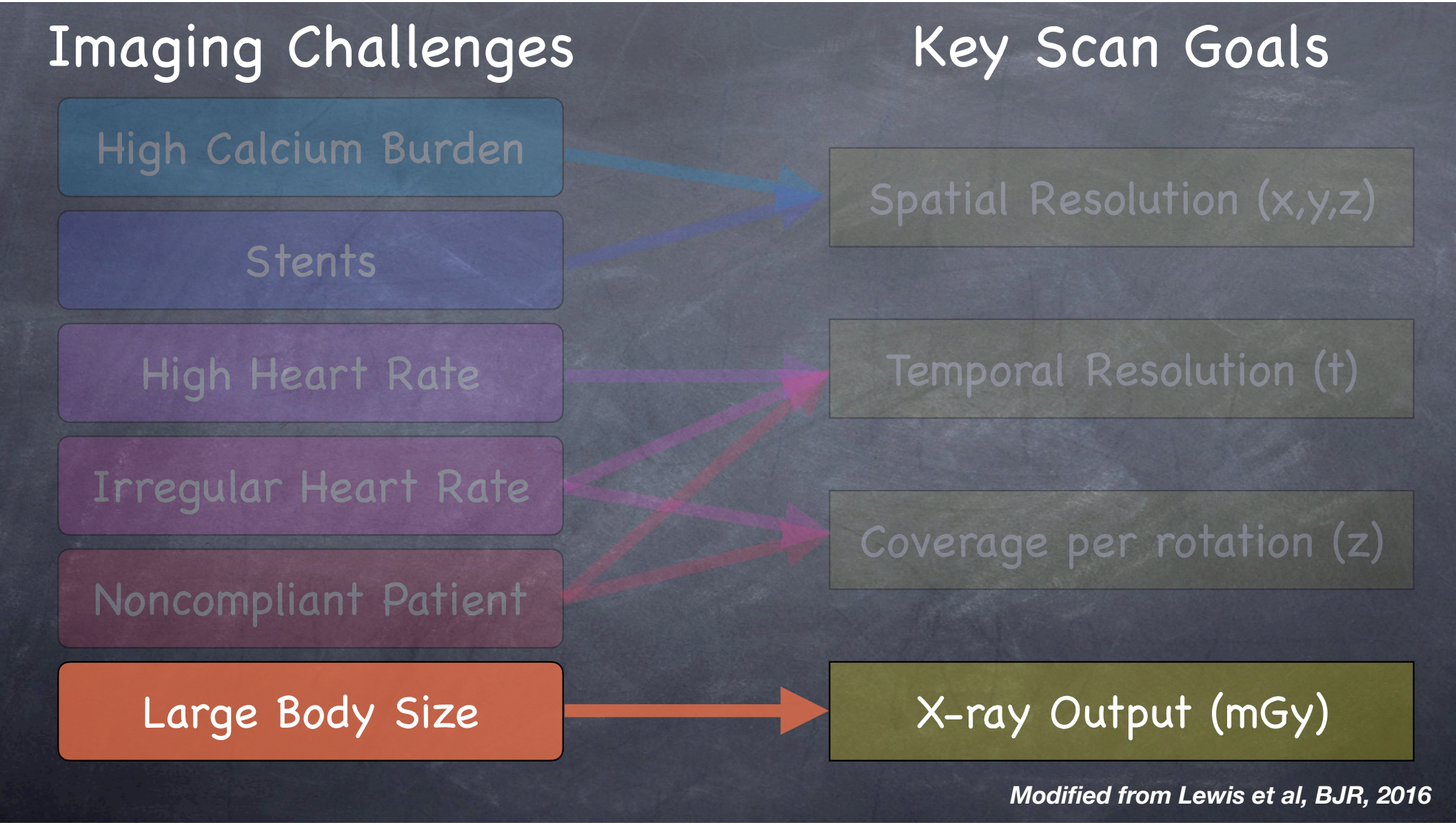


Modified from Lewis et al, BJR, 2016

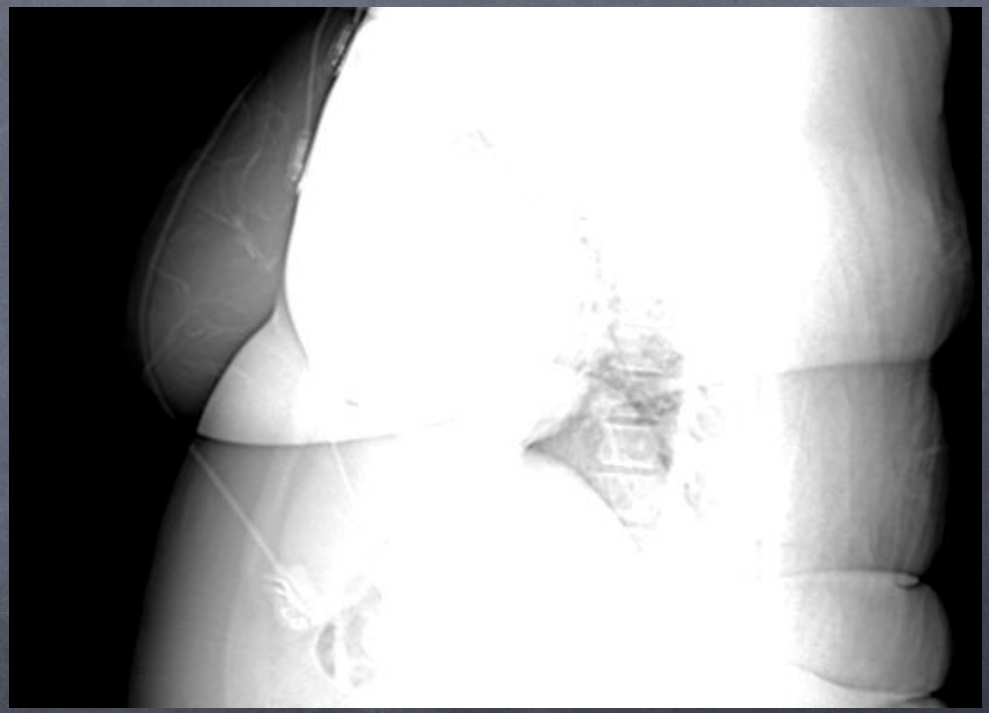
Exposure

Photography	CT & Radiography	Secondary Effects
Shutter Speed	Rotation Time (s)	Motion
ISO	X-Ray Tube Potential or "Beam Energy" (KV)	Brightness of calcium and iodine
Light, aperture	X-Ray Tube Current (mA)	Noise

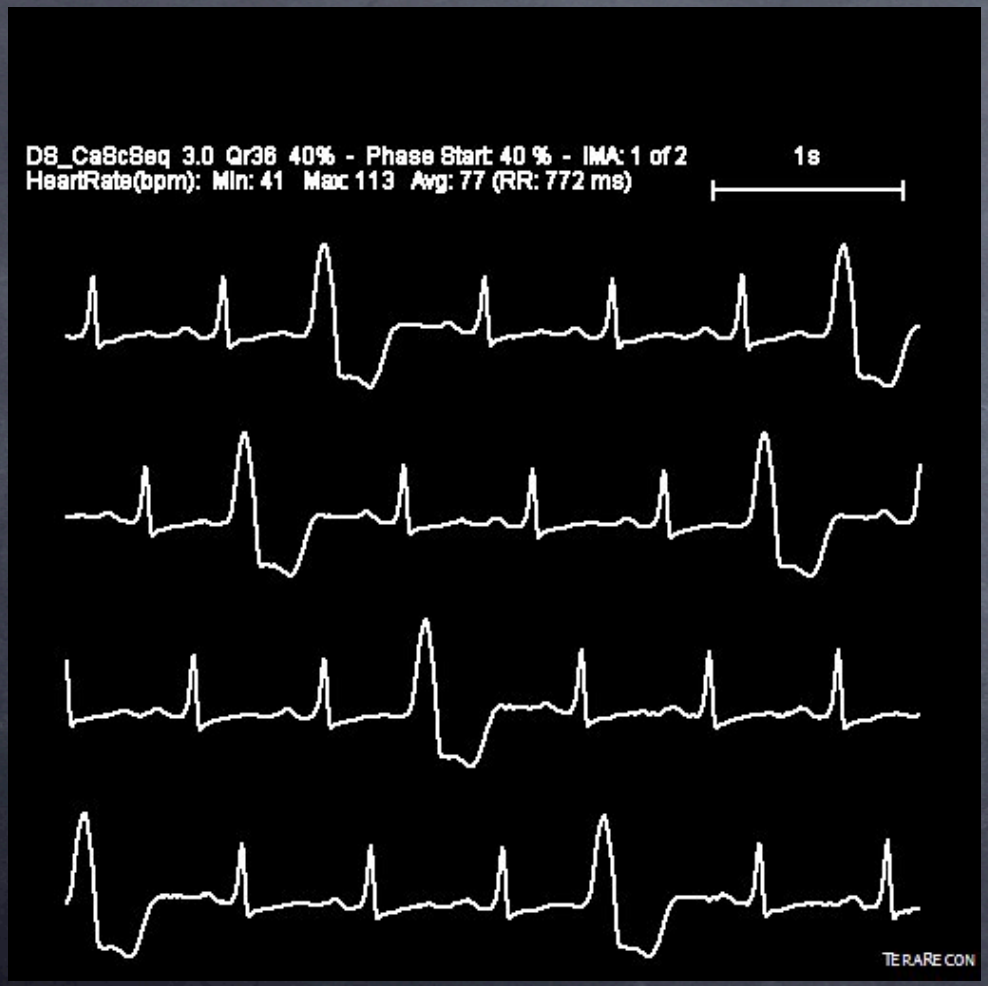
* All factors influence radiation exposure

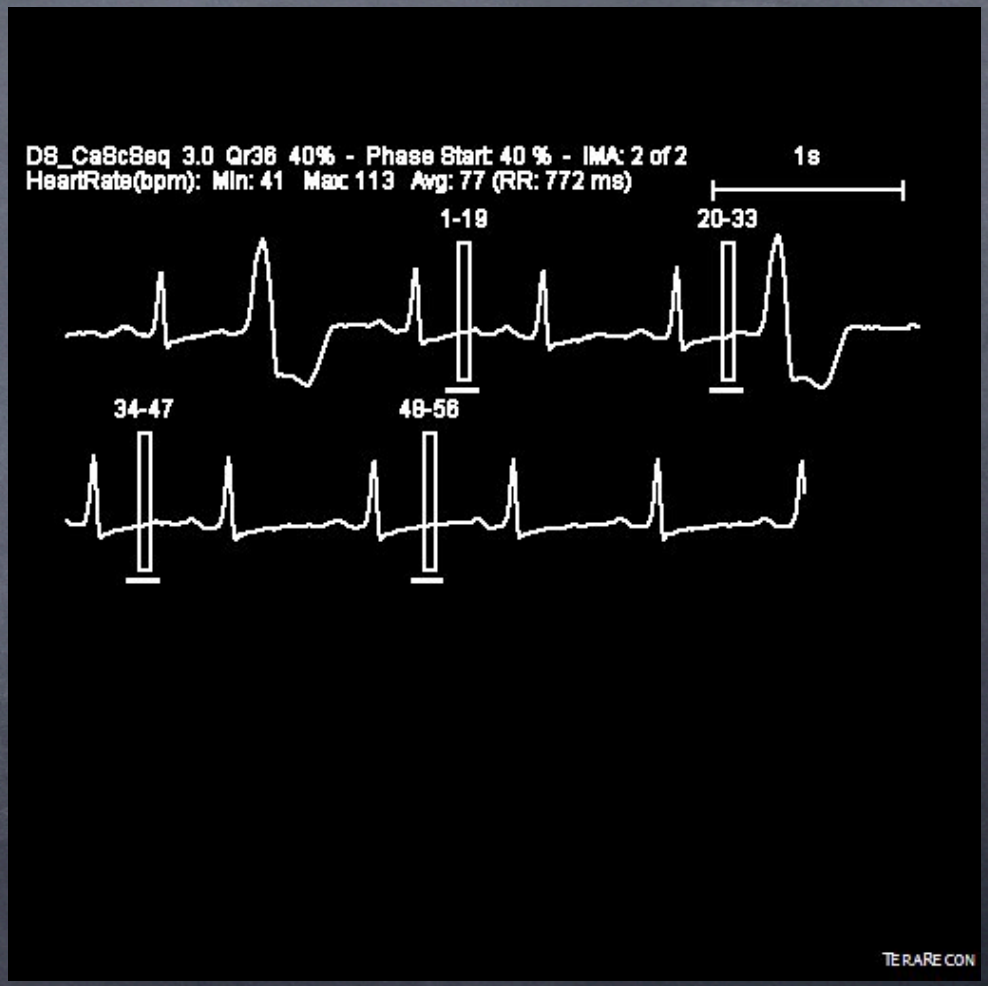
Maximum mA is dictated by x-ray generator power (100–120 kW)

46 yo, 398 lb (181 kg) ♀ with h/o VT

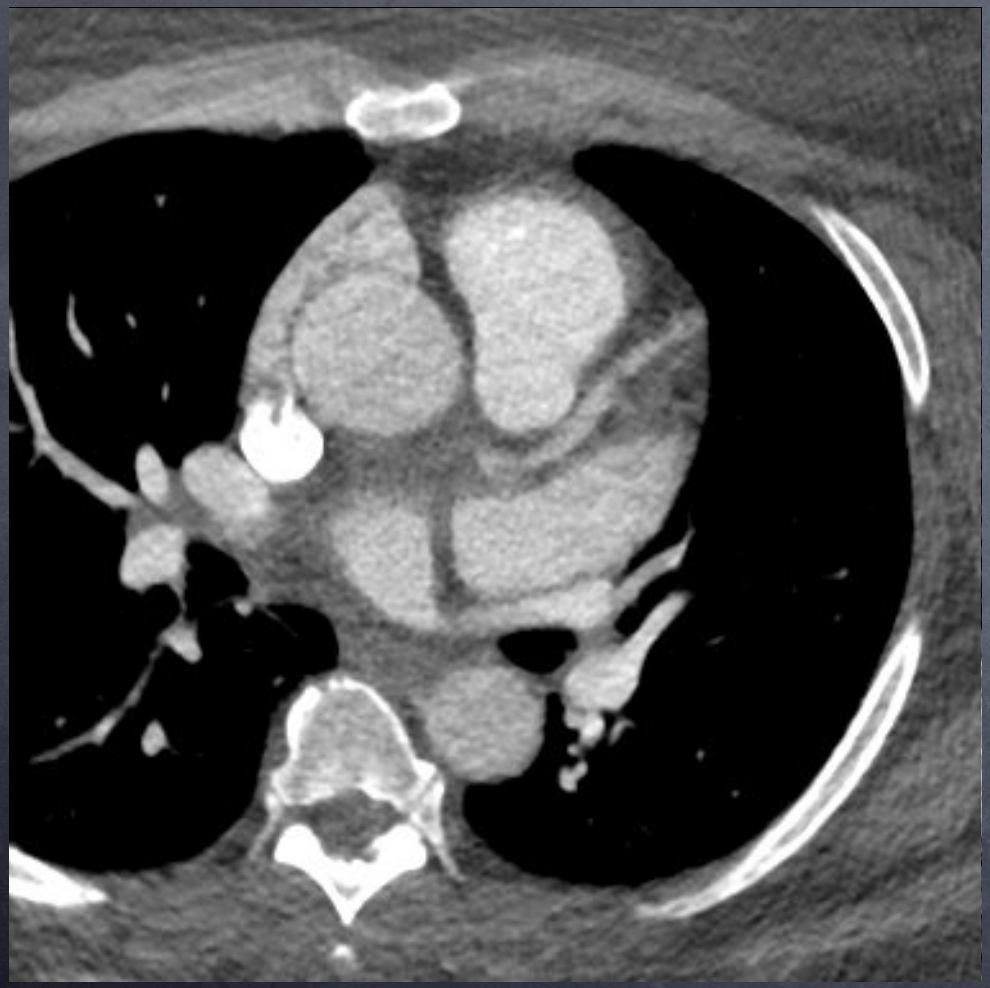


398 lb (181 kg) ♀ with h/o VT





120 kV, mAs = 412 (1,630 mA)

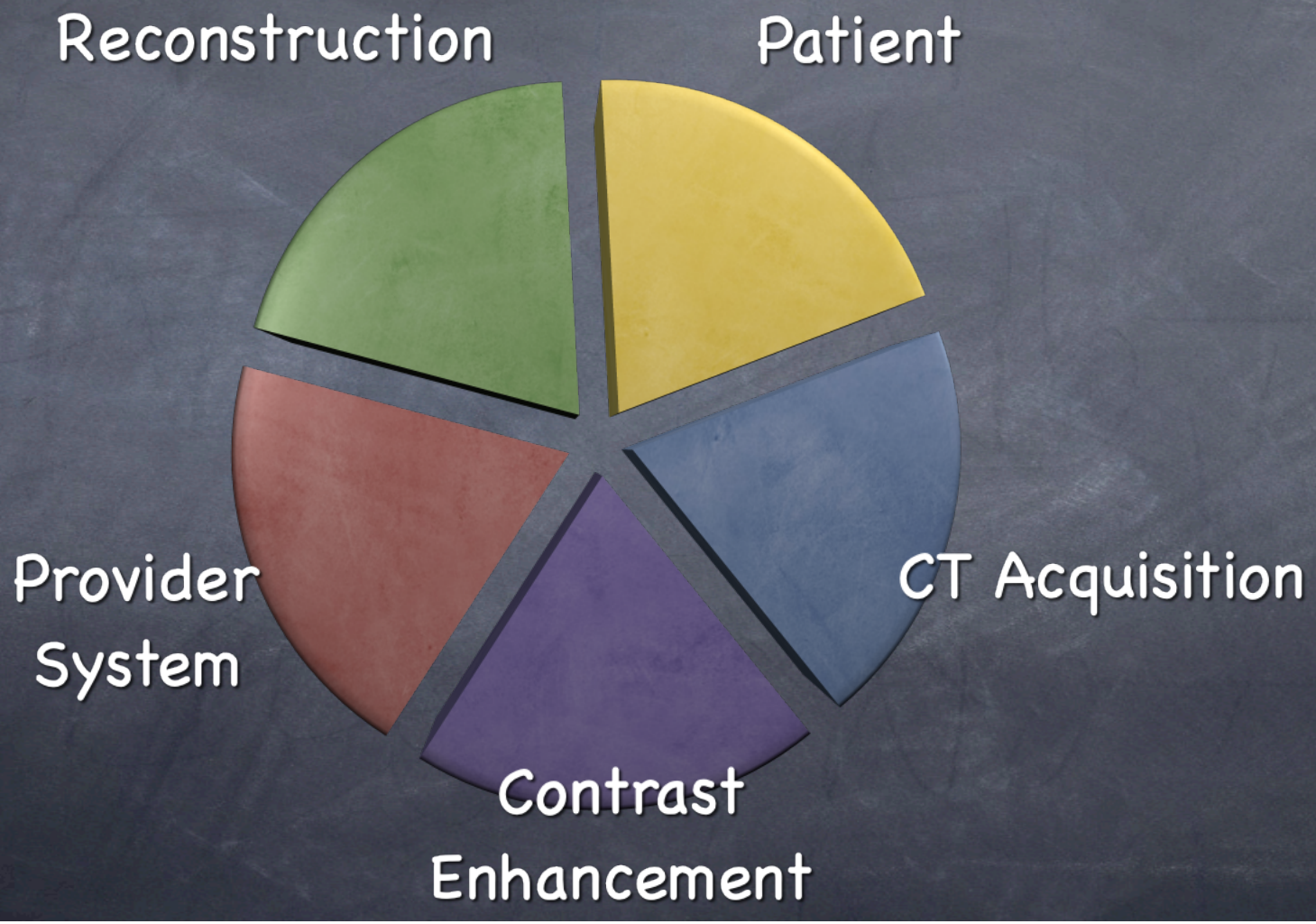


120 kV, ref mAs = 412 (>1,000 mA)

Acquisition Modes

Mode	ECG Comp	Flexibility	Radiation
Multi-Beat			
Step and Shoot	Pro	++	++
Helical (spiral)	Retro	++++	++++
Single Beat			
High pitch (Dual Source)	Pro	+	+
Wide area detector	Pro	++	++

Determining CT Image Quality



Summary

- Patients often present with anatomic and physiologic conditions that challenge CT image quality.
- CT acquisition choices should be made with full knowledge of these conditions and tuned to the characteristics of available CT equipment.