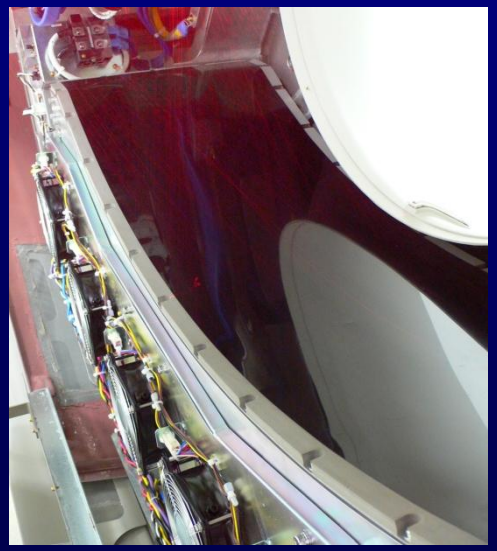
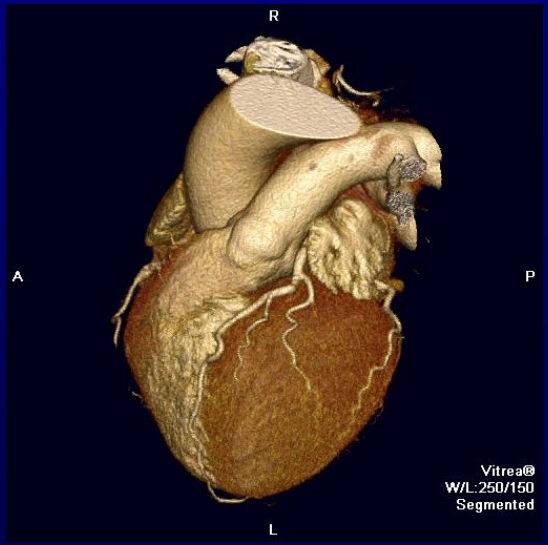
Cardiac CT - Optimal Use of Evolving Scanner Technologies



P. Rogalla, M.D.

Dept. of Medical Imaging
University of Toronto



Special thanks to

- Dr. Lembcke, Dr. Hein
  Charité, Berlin

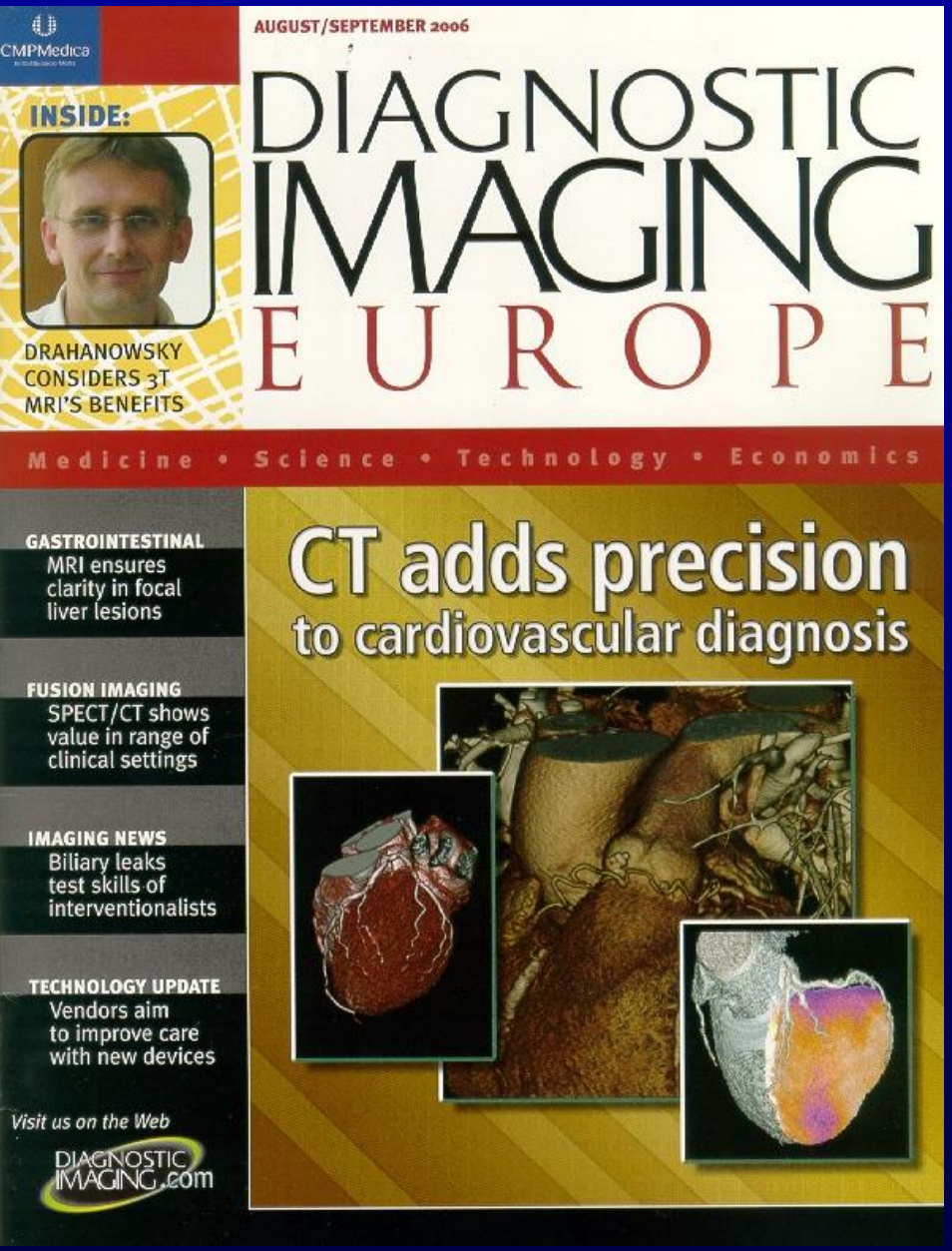
Disclosures

No salaries from:

- GE, Philips, Siemens, Toshiba

Occasional honoraria from:

- Pfizer, Bayer Schering, Sanofi, Elsevier, Springer, Merckle Recordati, Im3D, Toshiba, Philips, Siemens


CMPMedica
AUGUST/SEPTEMBER 2006
INSIDE:
DRAHANOWSKY CONSIDERS 3T MRI'S BENEFITS
DIAGNOSTIC IMAGING EUROPE
Medicine • Science • Technology • Economics
GASTROINTESTINAL
MRI ensures clarity in focal liver lesions
FUSION IMAGING
SPECT/CT shows value in range of clinical settings
IMAGING NEWS
Biliary leaks test skills of interventionalists
TECHNOLOGY UPDATE
Vendors aim to improve care with new devices
CT adds precision to cardiovascular diagnosis
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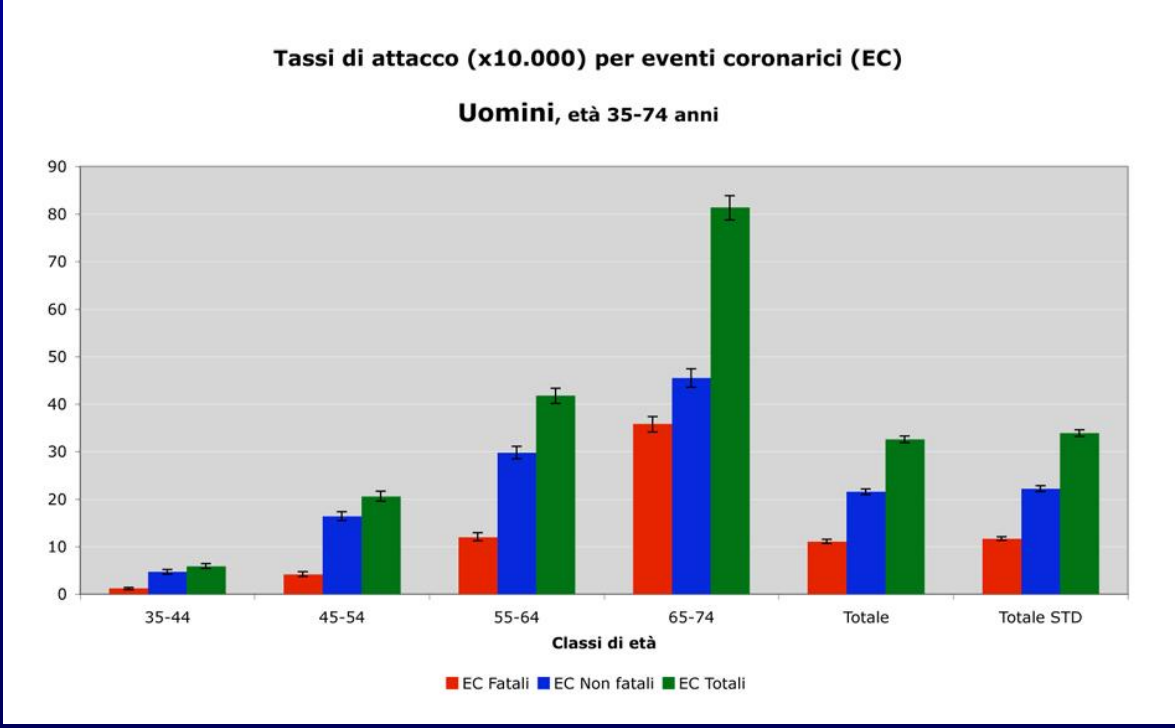
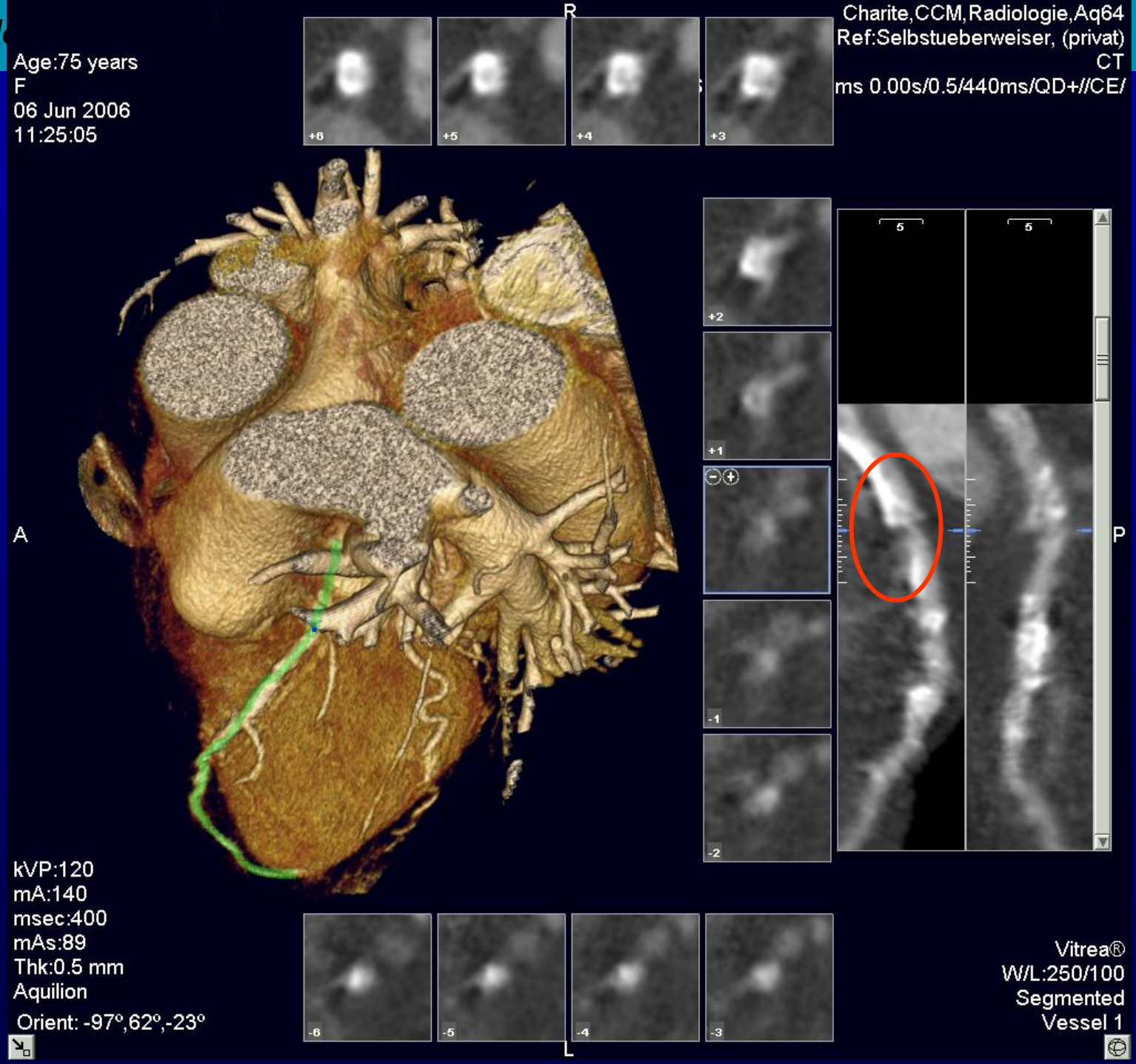
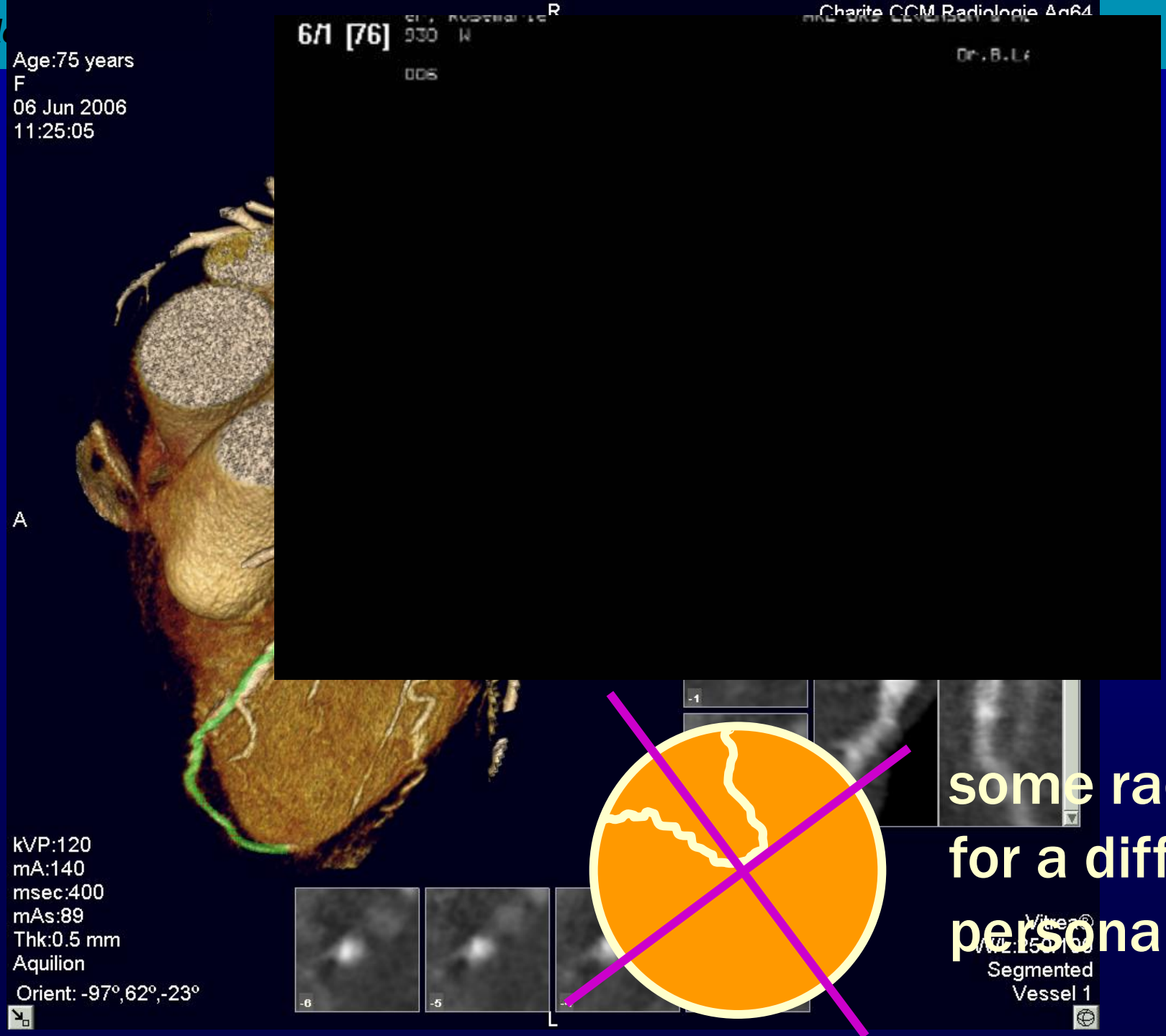

Tassi di attacco (x10.000) per eventi coronarici (EC)
Uomini, età 35-74 anni
90
80
70
60
50
40
30
20
10
0
35-44
45-54
55-64
65-74
Totale
Totale STD
Classi di età
EC Fatali
EC Non fatali
EC Totali


Age:75 years
F
06 Jun 2006
11:25:05
R
Charite,CCM,Radiologie,Aq64
Ref:Selbstueberweiser, (privat)
CT
ms 0.00s/0.5/440ms/QD+//CE/
+6
+5
+4
+3
+2
+1
-1
-2
-6
-5
-4
-3
A
P
L
kVP:120
mA:140
msec:400
mAs:89
Thk:0.5 mm
Aquilion
Orient: -97°,62°,-23°
Vitrea®
W/L:250/100
Segmented
Vessel 1



some radiation for a difficult personality

Age (years)	
35–39	0
40–44	6
45–49	11
50–54	16
55–59	21
60–65	26
LDL-Cholesterin (mg/dl)	
< 100	0
100–129	5
130–159	10
160–189	14
≥ 190	20
HDL-Cholesterin (mg/dl)	
< 35	11
35–44	8
45–54	5
≥ 55	0
Triglyzeride (mg/dl)	
< 100	0
100–149	2
150–199	3
≥ 200	4
Smoking	
Nein	0
Ja	8
Diabetes mellitus	
Nein	0
Ja	6
Family history	
Nein	0
Ja	4
Blood pressure	
< 120	0
120–129	2
130–139	3
140–159	5
≥160	8

Points	Risk (%)
≤ 20	≤ 1,0
21	1,1
22	1,2
23	1,3
24	1,4
25	1,6
26	1,7
27	1,8
28	1,9
29	2,3
30	2,4
31	2,8
32	2,9
33	3,3
34	3,5
35	4,0
36	4,2
37	4,8
38	5,1
39	5,7
40	6,1
41	7,0
42	7,4
43	8,0
44	8,8
45	10,2
46	10,5
47	10,7
48	12,8
49	13,2
50	15,5
51	16,8
52	17,5
53	19,6
54	21,7
55	22,2
56	23,8
57	25,1
58	28,0
59	29,4
≥ 60	≥ 30,0

relative CHD risk:

low increase

- ~10 cigarettes/day
- Cholesterine 200-300 mg/dl

medium increase

- ~20 cigarettes/day
- BMI >25

high increase

- history of CDH
- Diabetes mellitus Type 2
- coronary artery calcifications

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ACCF/ACR/SCCT/SCMR/ ASNC/NASCI/SCAI/SIR Appropriateness Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging*

A Report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, American College of Radiology, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, American Society of Nuclear Cardiology, North American Society for Cardiac Imaging, Society for Cardiovascular Angiography and Interventions, and Society of Interventional Radiology

CCT/CMR WRITING GROUP

Robert C. Hendel, MD, FACC
Manesh R. Patel, MD
Christopher M. Kramer, MD, FACC†
Michael Poon, MD, FACC‡

Hendel RC et al. *JACC* 2006;48

Table 1. Detection of CAD: Symptomatic

Indication		Appropriateness Criteria (Median Score)
Evaluation of Chest Pain Syndrome (Use of CT Angiogram)		
1.	• Intermediate pre-test probability of CAD • ECG interpretable AND able to exercise	U (5)
2.	• Intermediate pre-test probability of CAD • ECG uninterpretable OR unable to exercise	A (7)
3.	• High pre-test probability of CAD	I (2)
Evaluation of Intra-Cardiac Structures (Use of CT Angiogram)		
4.	• Evaluation of suspected coronary anomalies	A (9)
Acute Chest Pain (Use of CT Angiogram)		
5.	• Low pre-test probability of CAD • No ECG changes and serial enzymes negative	U (5)
6.	• Intermediate pre-test probability of CAD • No ECG changes and serial enzymes negative	A (7)
7.	• High pre-test probability of CAD • No ECG changes and serial enzymes negative	U (6)
8.	• High pre-test probability of CAD • ECG—ST-segment elevation and/or positive cardiac enzymes	I (1)
9.	• "Triple rule out"—exclude obstructive CAD, aortic dissection, and pulmonary embolism • Intermediate pre-test probability for one of the above • ECG—no ST-segment elevation and initial enzymes negative	U (4)

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34	3,5
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36	4,2
37	4,8
38	5,1
39	5,7
40	6,1
41	7,0
42	7,4
43	8,0
44	8,8
45	10,2
46	10,5
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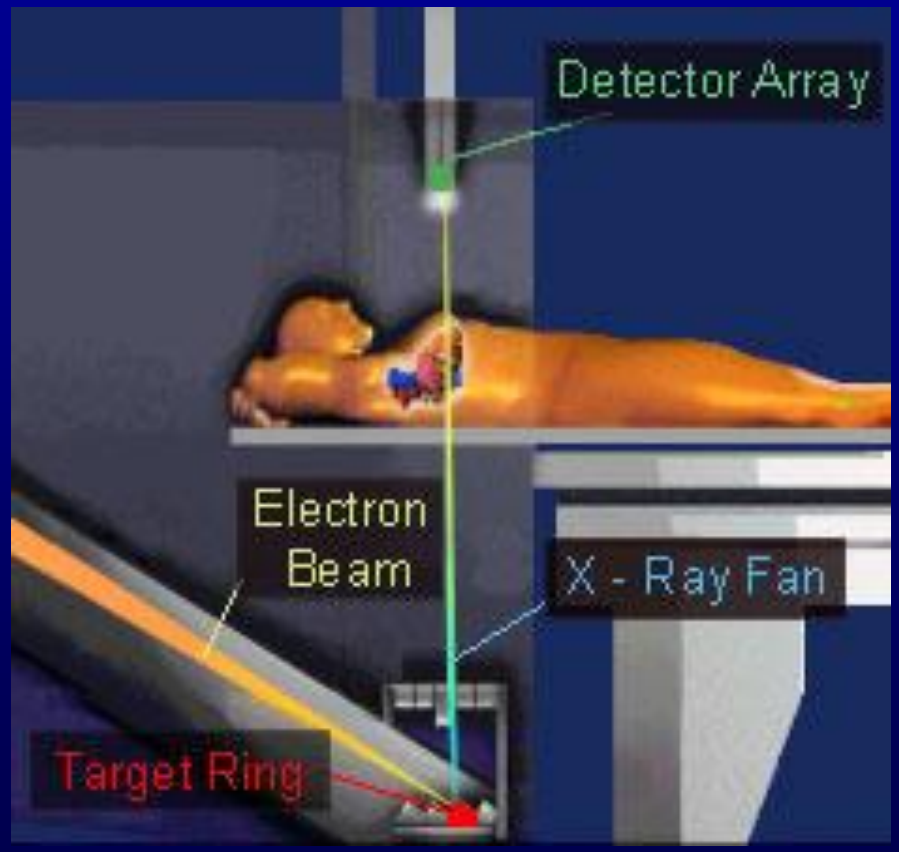
Electron-beam tomography (EBT, EBCT)



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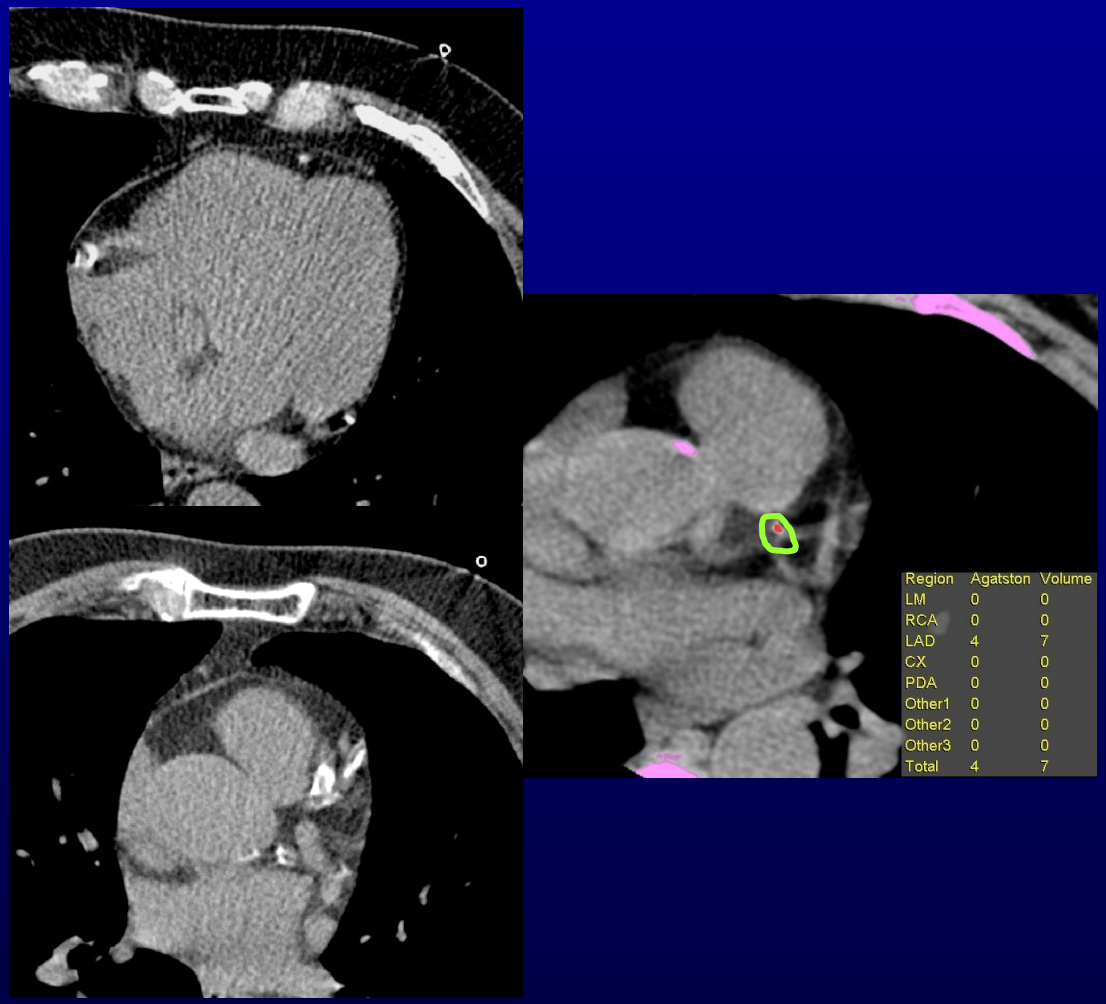

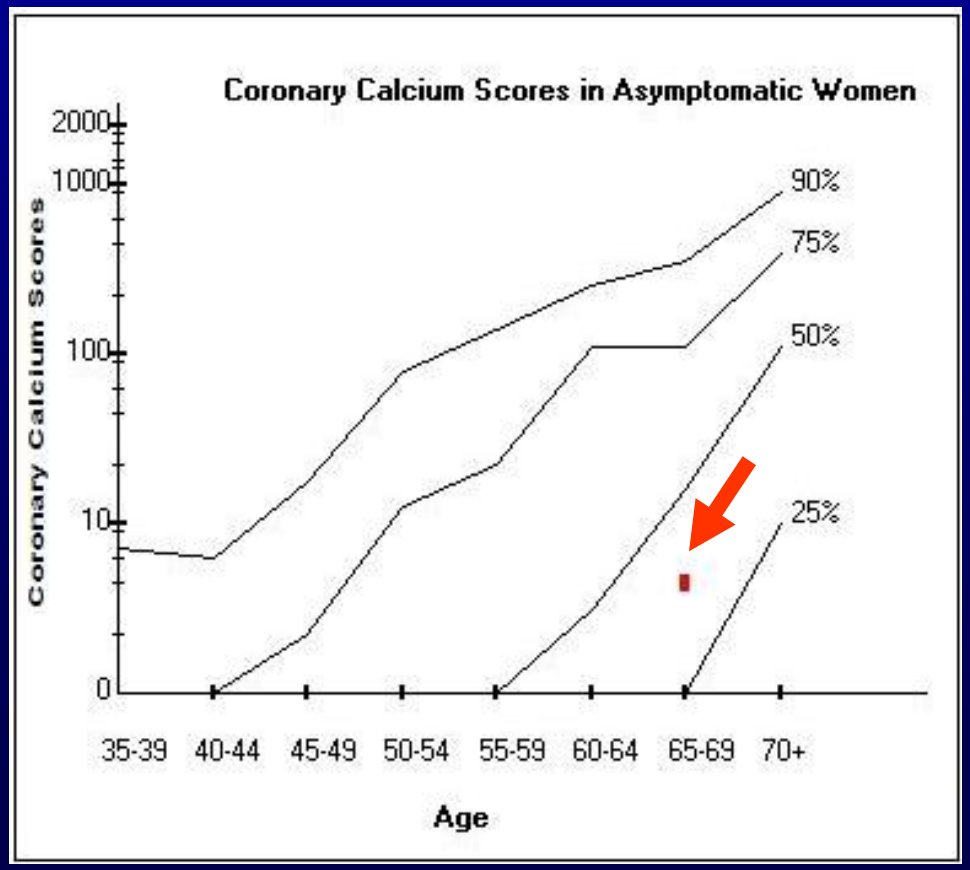

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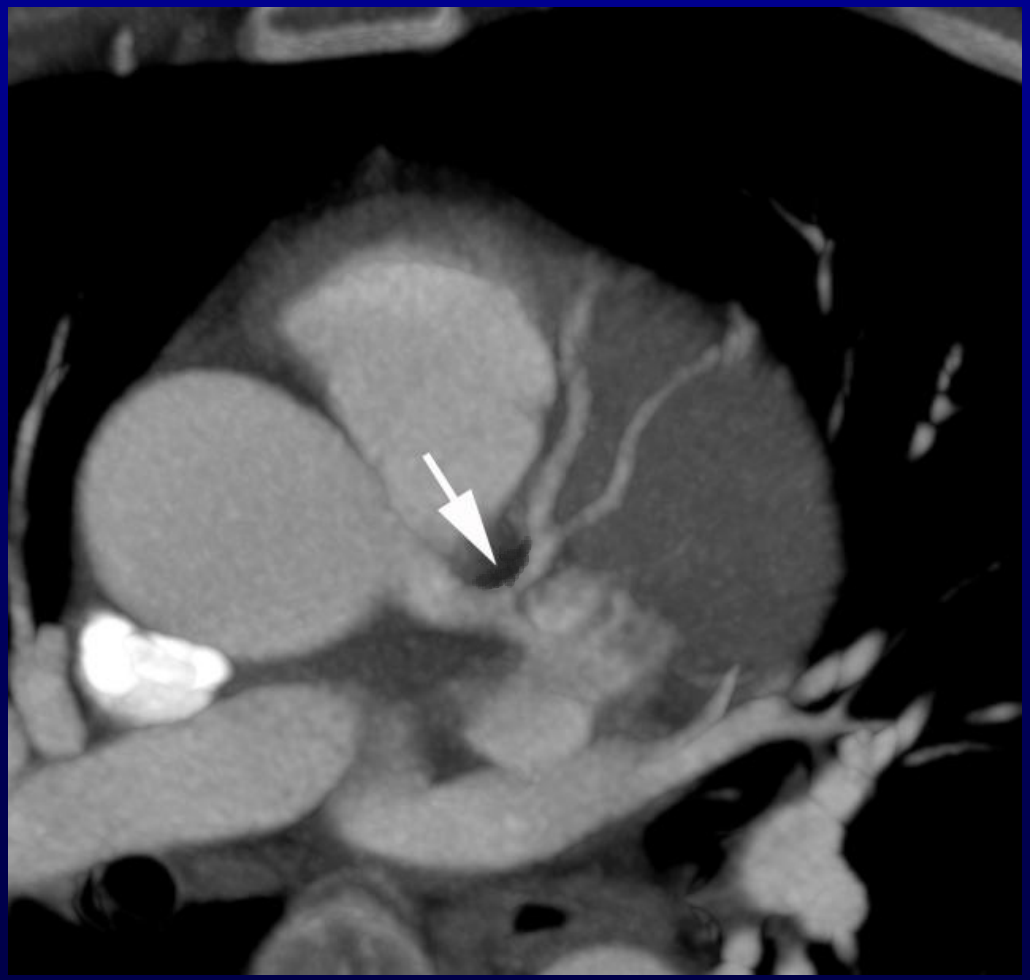
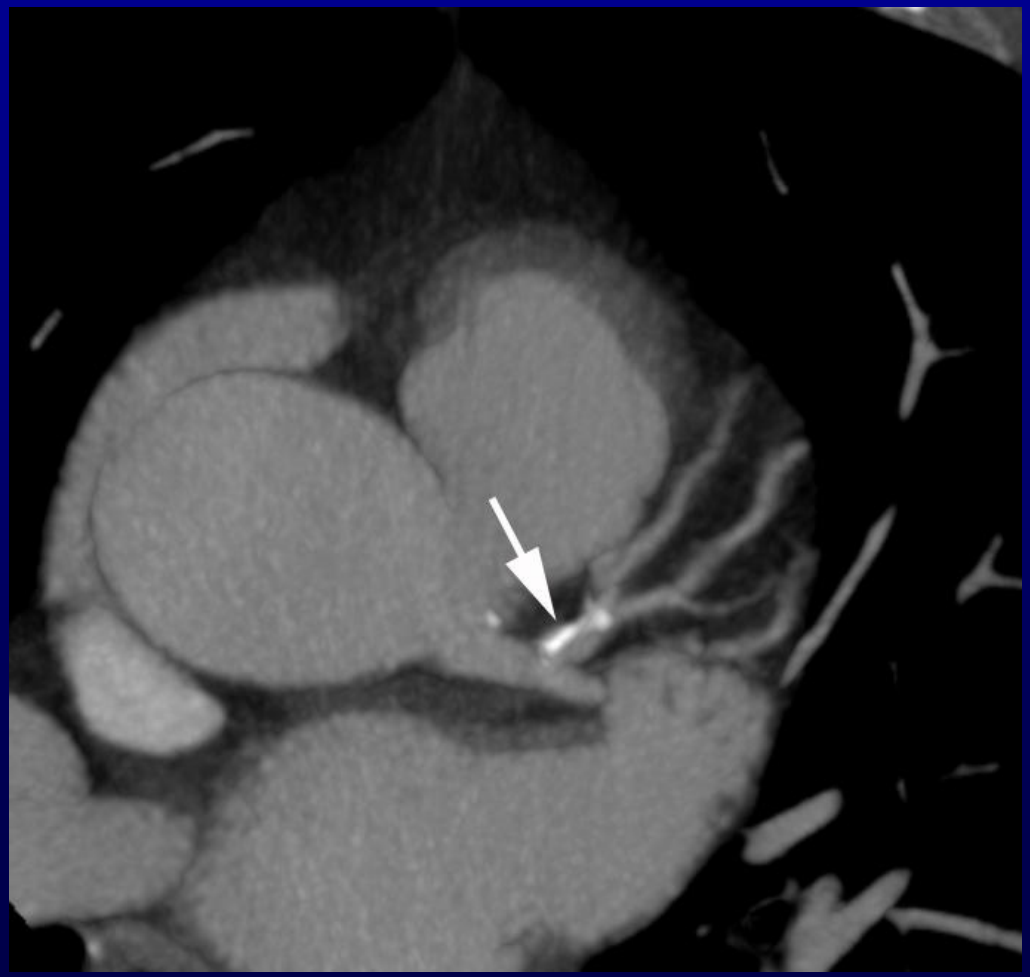
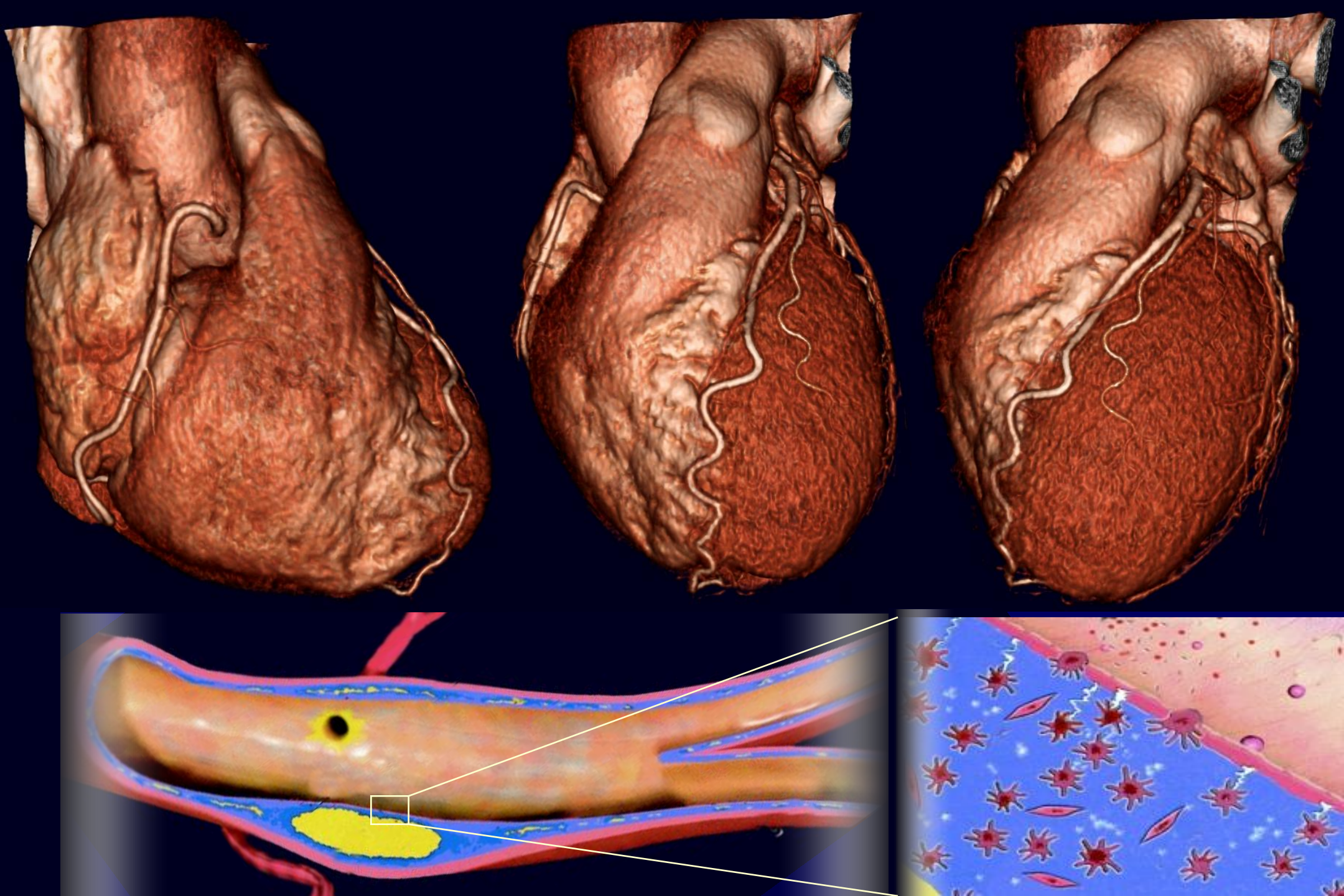
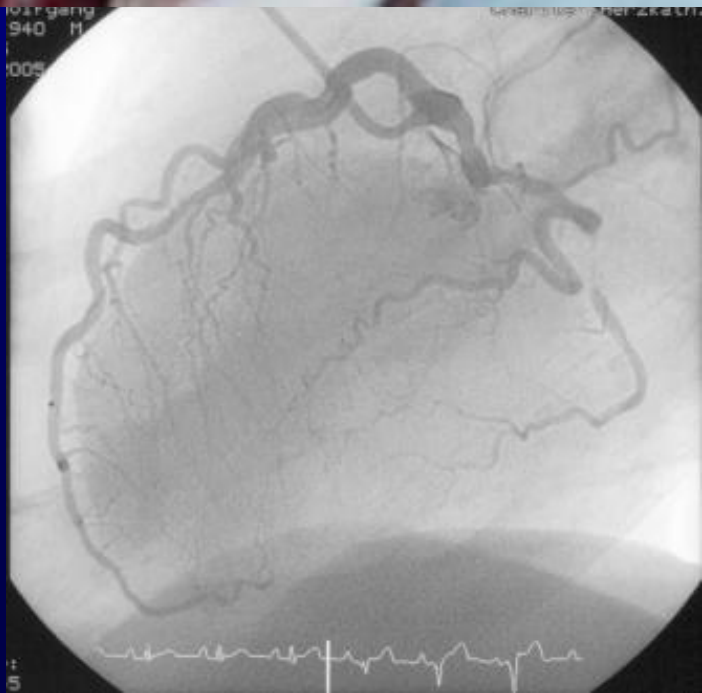




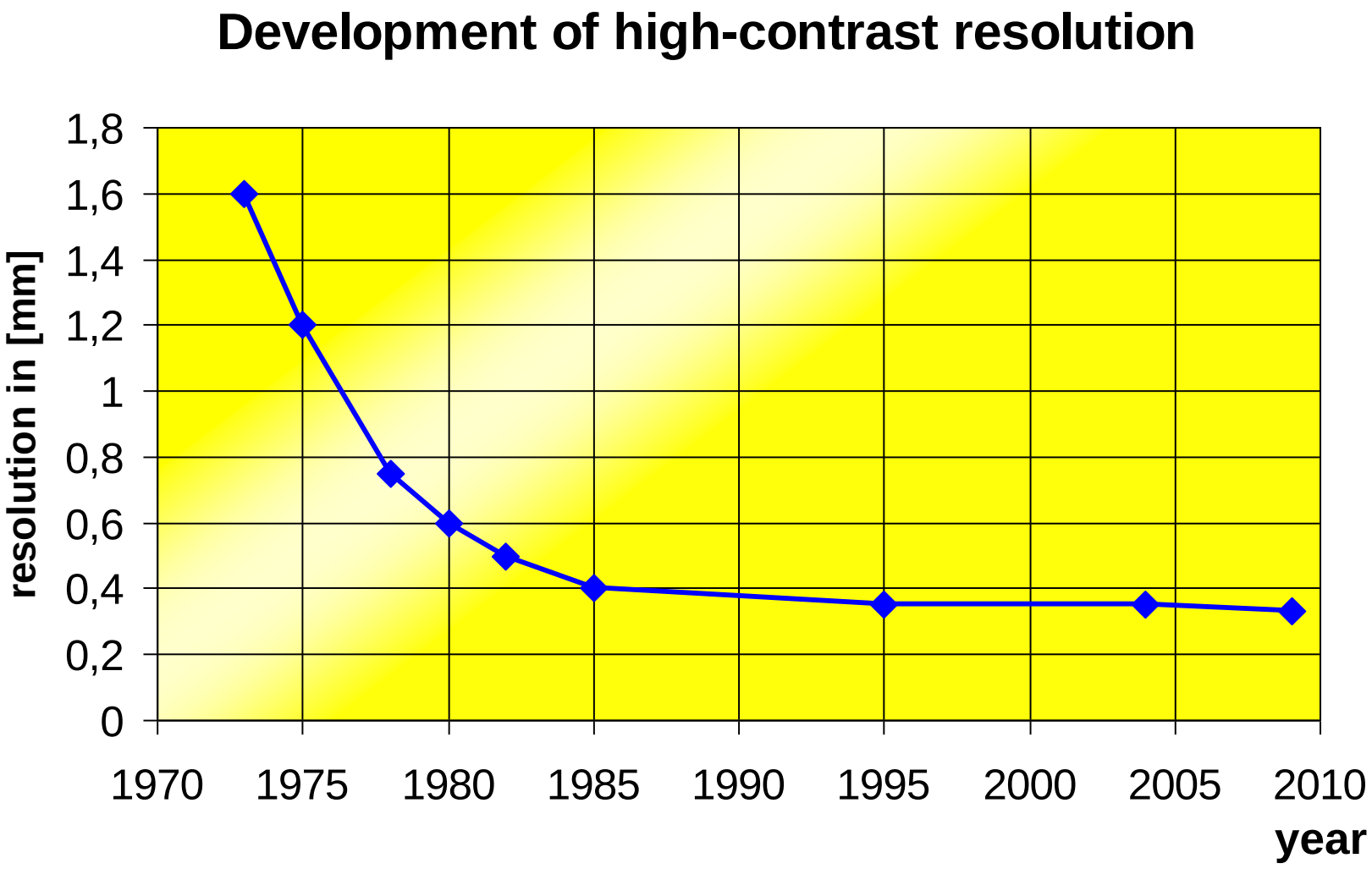


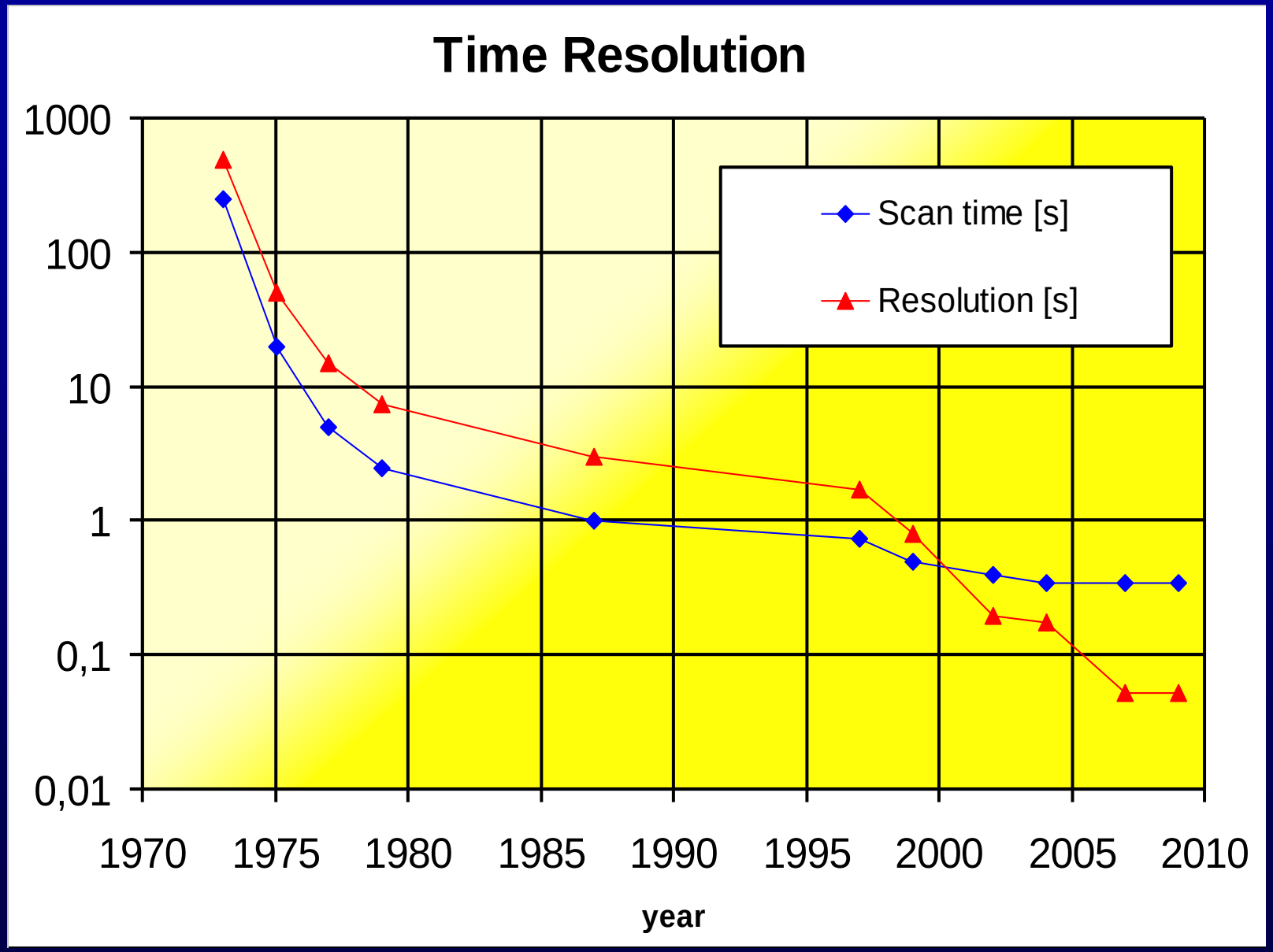


Problems:

- "invasive" access with associated risks
- resources (materials, personnel)
- costs

→ decreasing acceptance


Development of high-contrast resolution
resolution in [mm]
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
year


Time Resolution
1000
100
10
1
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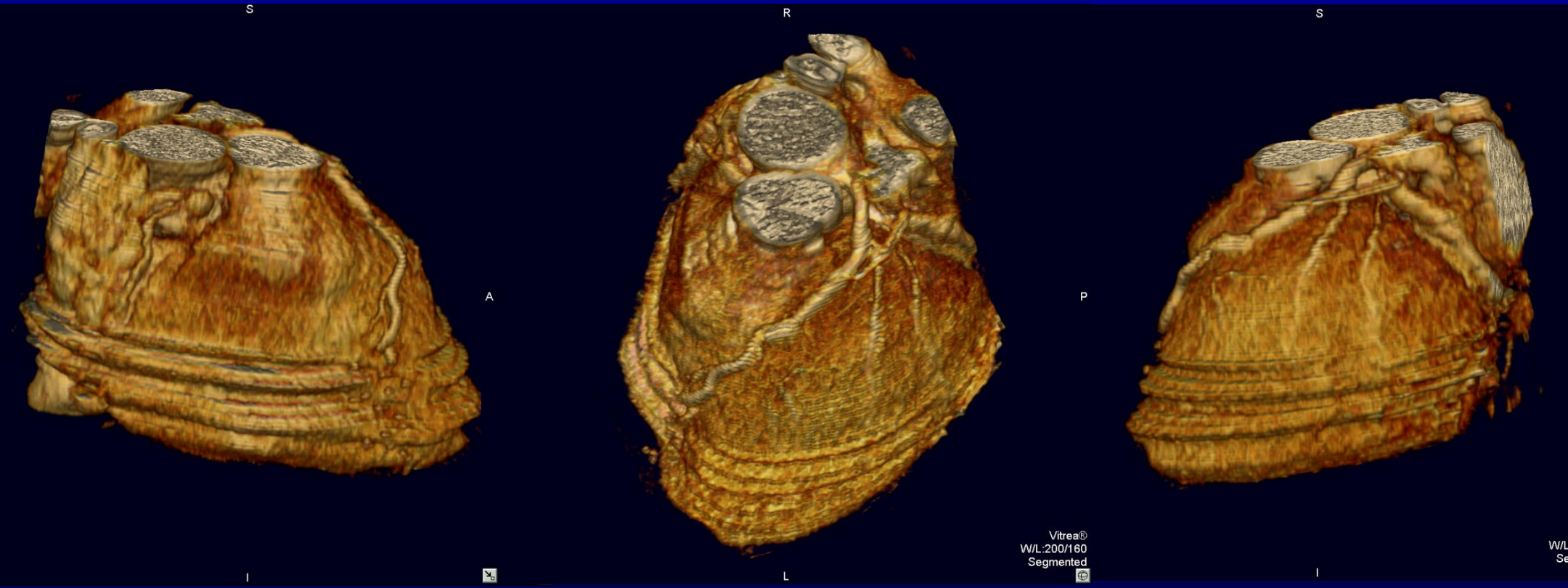
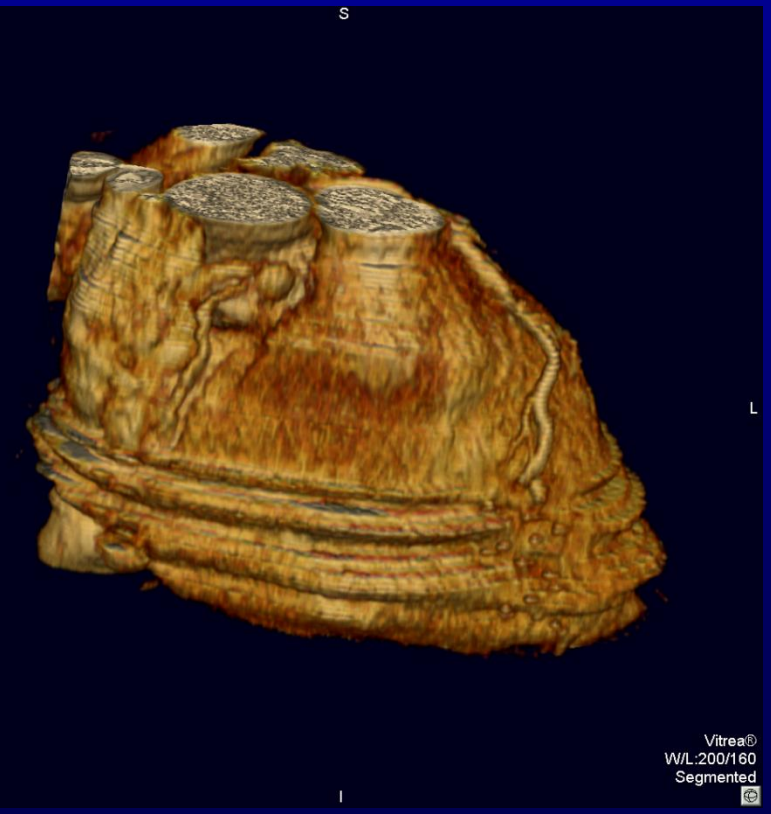
0,01
1970
1975
1980
1985
1990
1995
2000
2005
2010
year
Scan time [s]
Resolution [s]


S
A
I
R
P
L
Vitrea®
W/L:200/160
Segmented
S
I


S
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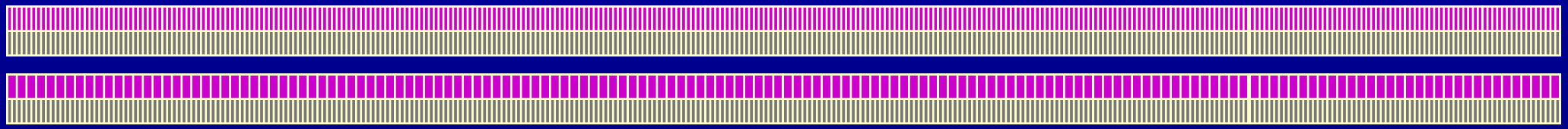
I
Vitrea®
W/L:200/160
Segmented

Vendor 1

160 mm

320 x 0.5 mm

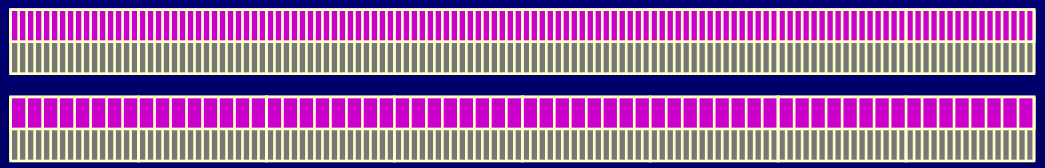


160 x 1.0 mm

Vendor 2/3

80 mm

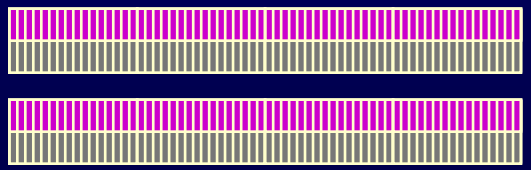
128 x 0.625 mm



64 x 1.25mm

Vendor 4

38.4 mm

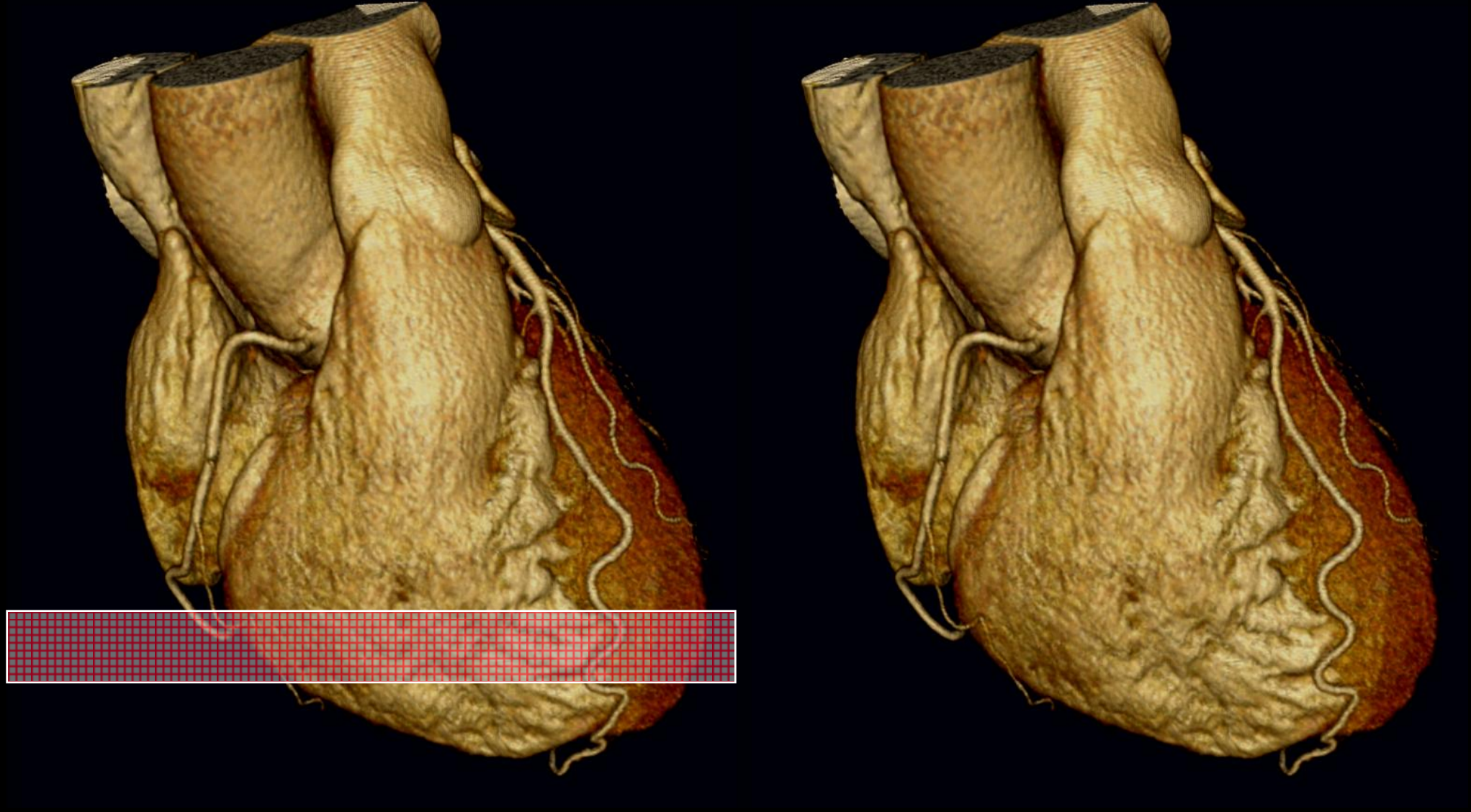


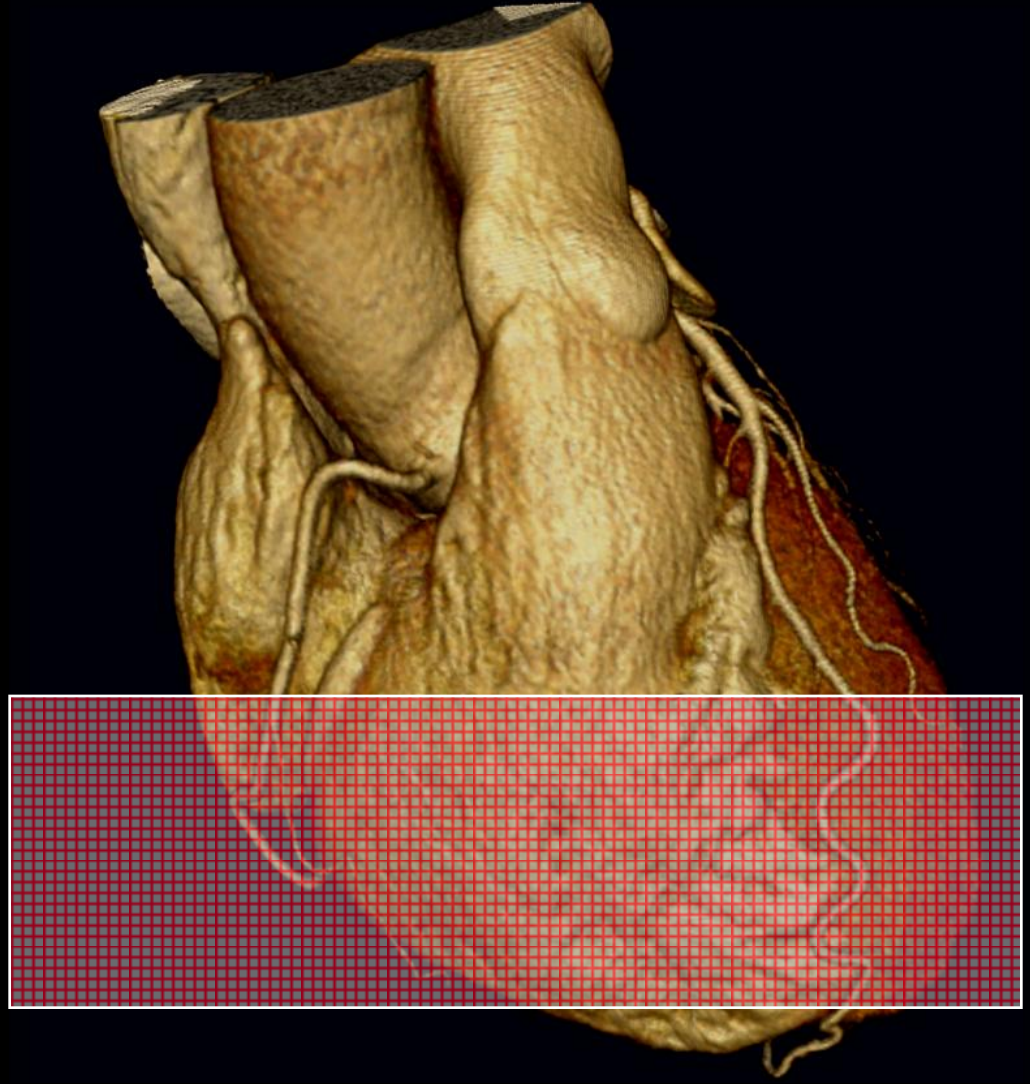
Tube 1: 64 x 0.6 mm

Tube 2: 64 x 0.6 mm

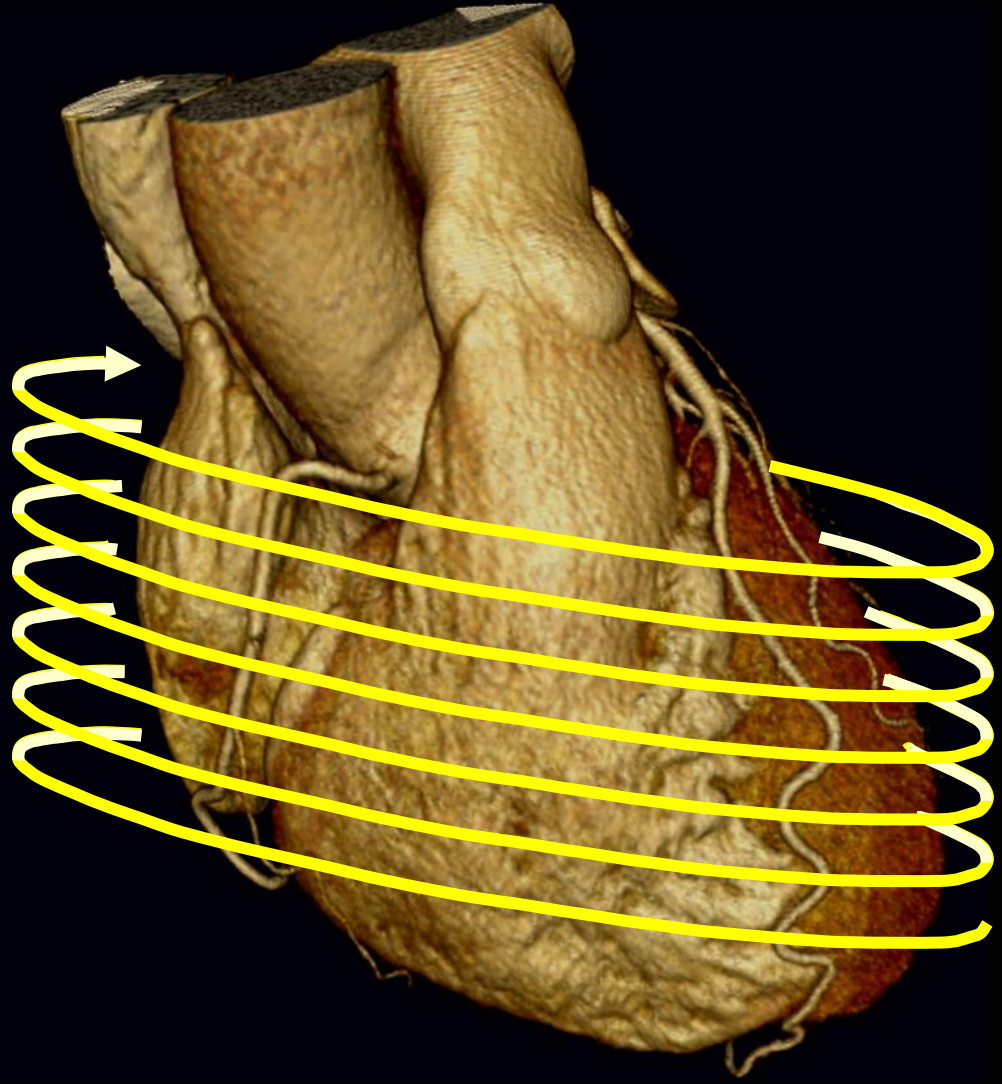
Cardiac CT: Technology with impact on radiation dose:

- kV, mAs adaptation
- dose modulation, cardiac phase
- retrospective vs. prospective scanning
- wide area detector vs. dual source fast helical





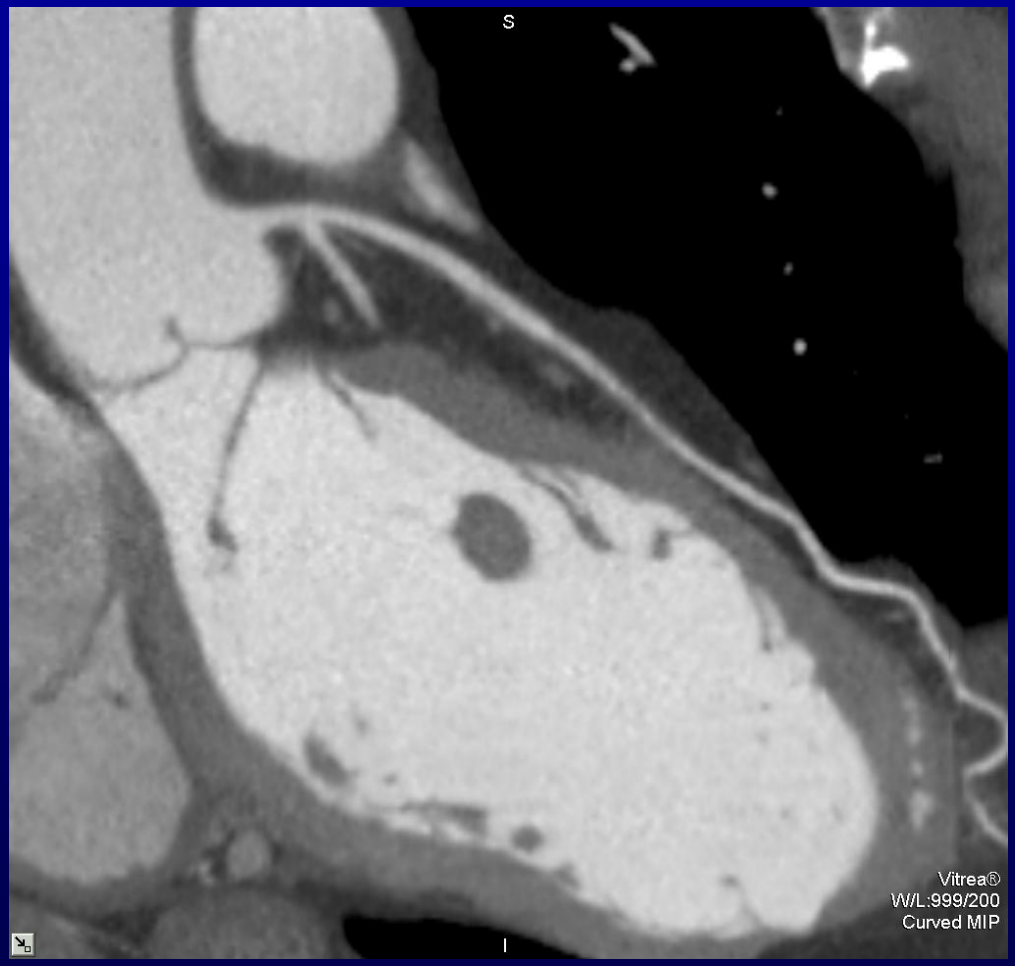
4- to 6-fold „oversampling"



4- to 6-fold higher dose

Selection of the best "cardiac" phase

12 seconds recording time



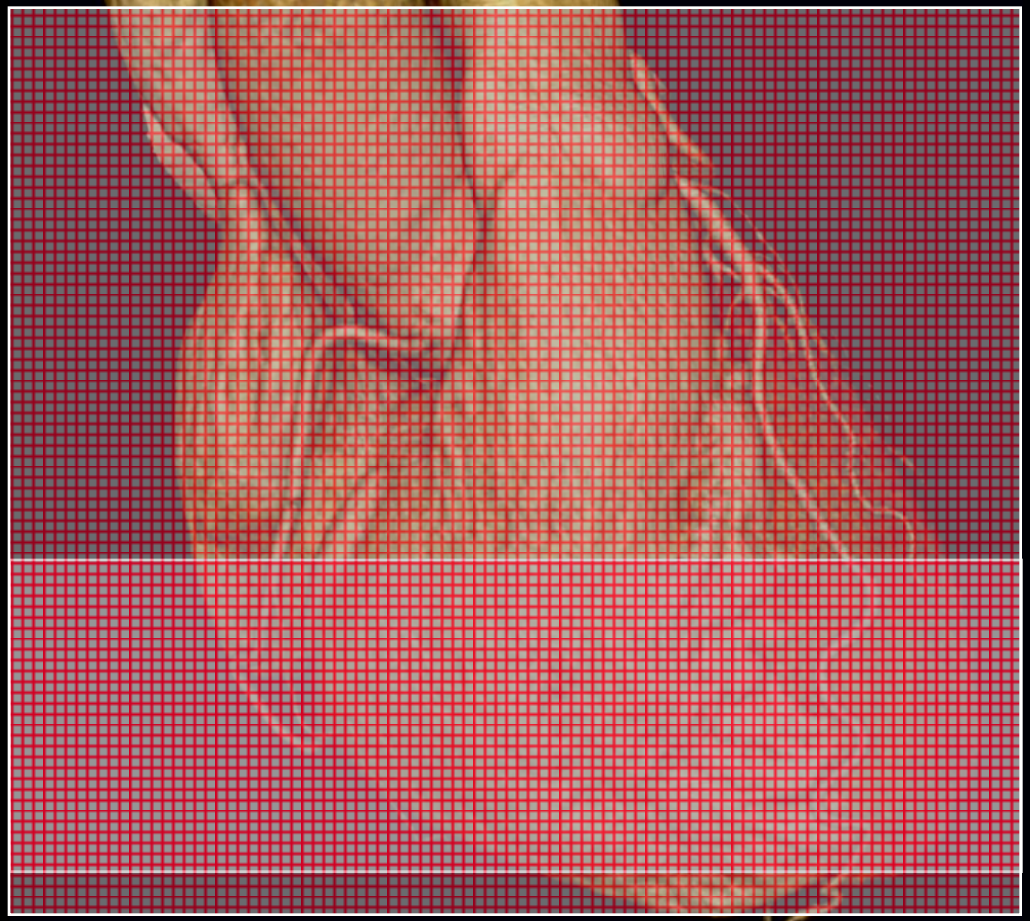
radiation dose:

- spiral overlapping scanning is the leading cause of 4 x higher radiation in cardiac CT

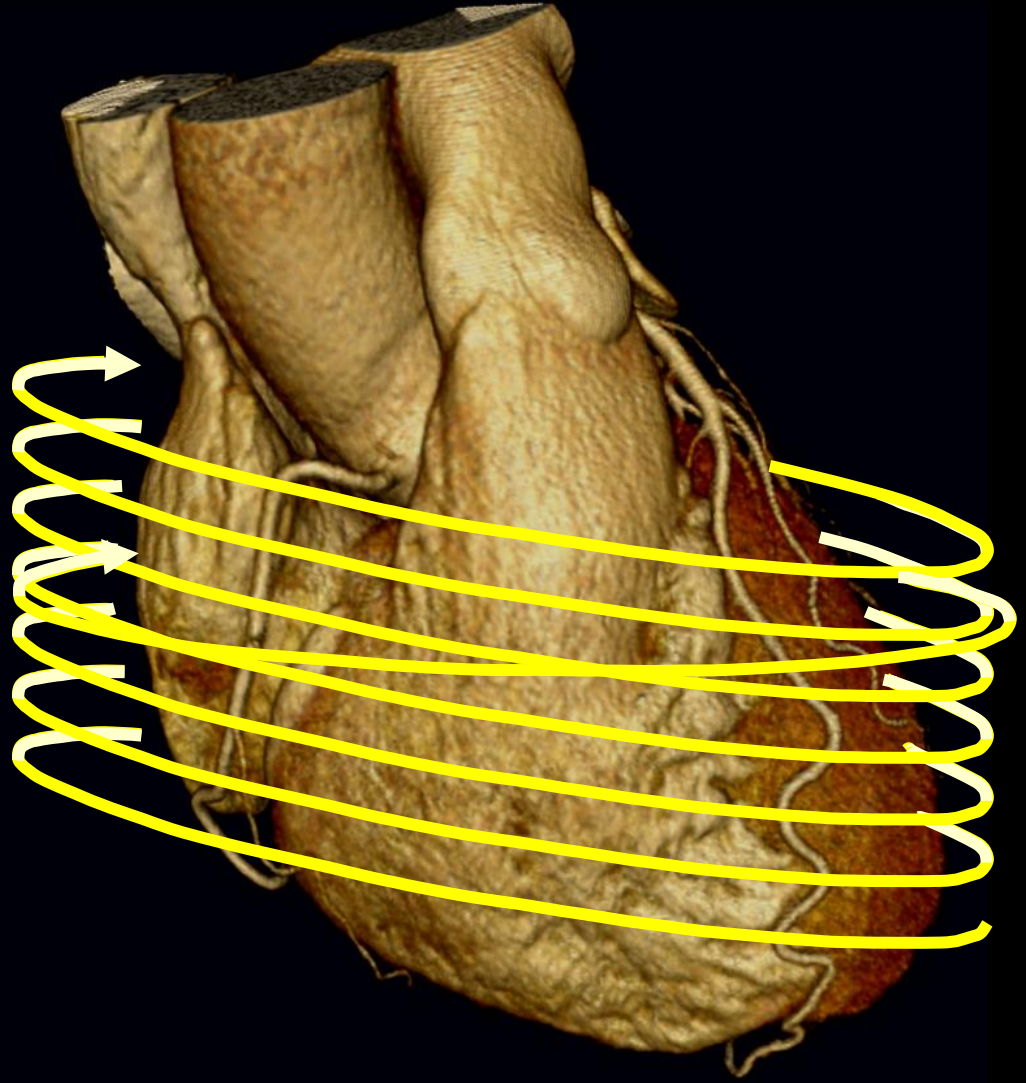
solutions:

- non-spiral scanning (fractioned or single beat)
- dual source high-pitch scannning

Solution 1

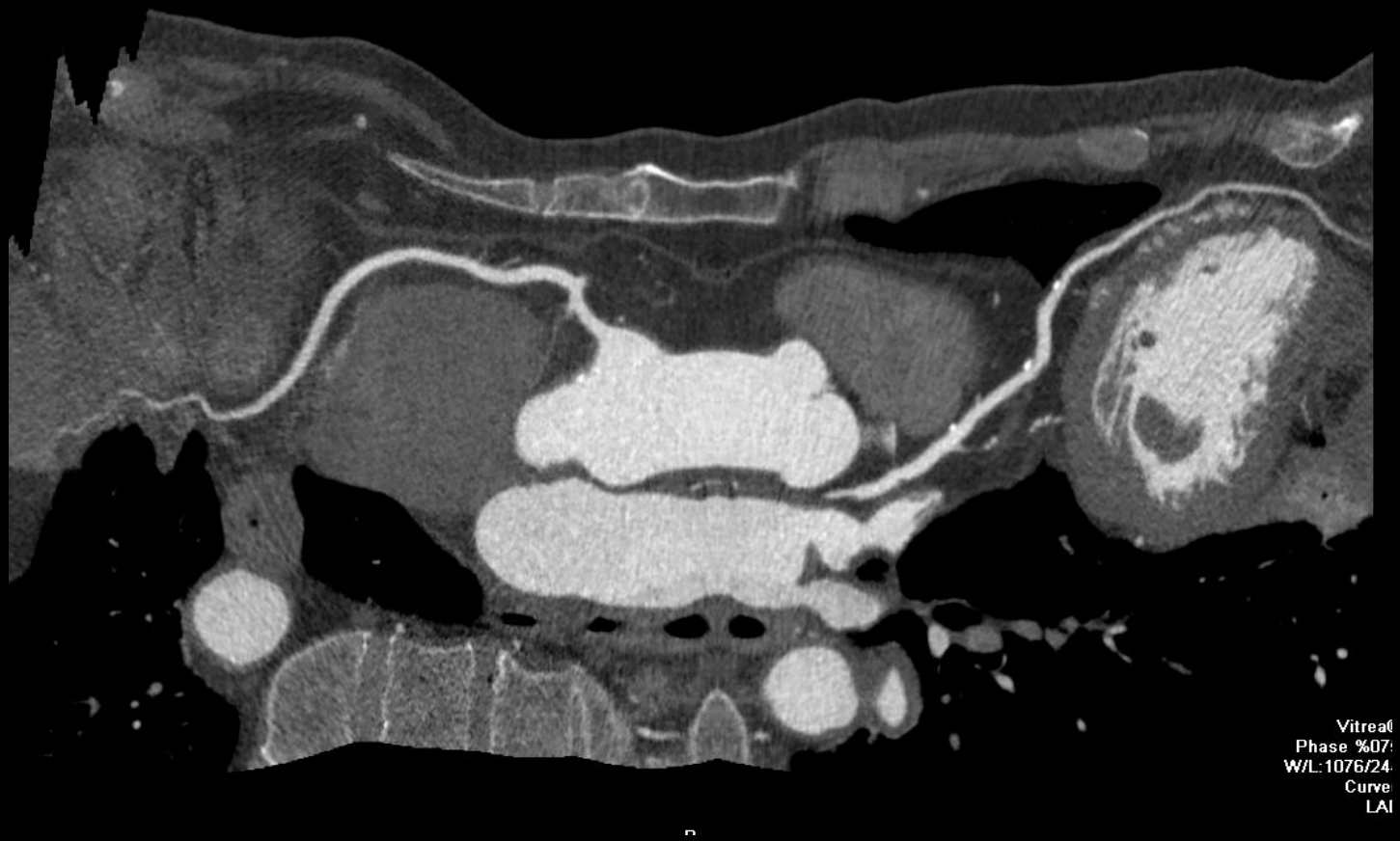


4- to 6-fold „oversampling"



< ¼ of the coronary CT dose

4- to 6-fold higher dose



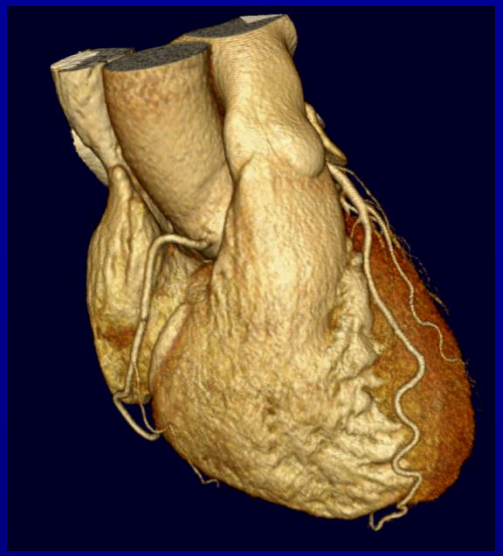
35 ml CM - 100 kV, DLP 94 - 1.6 mSv

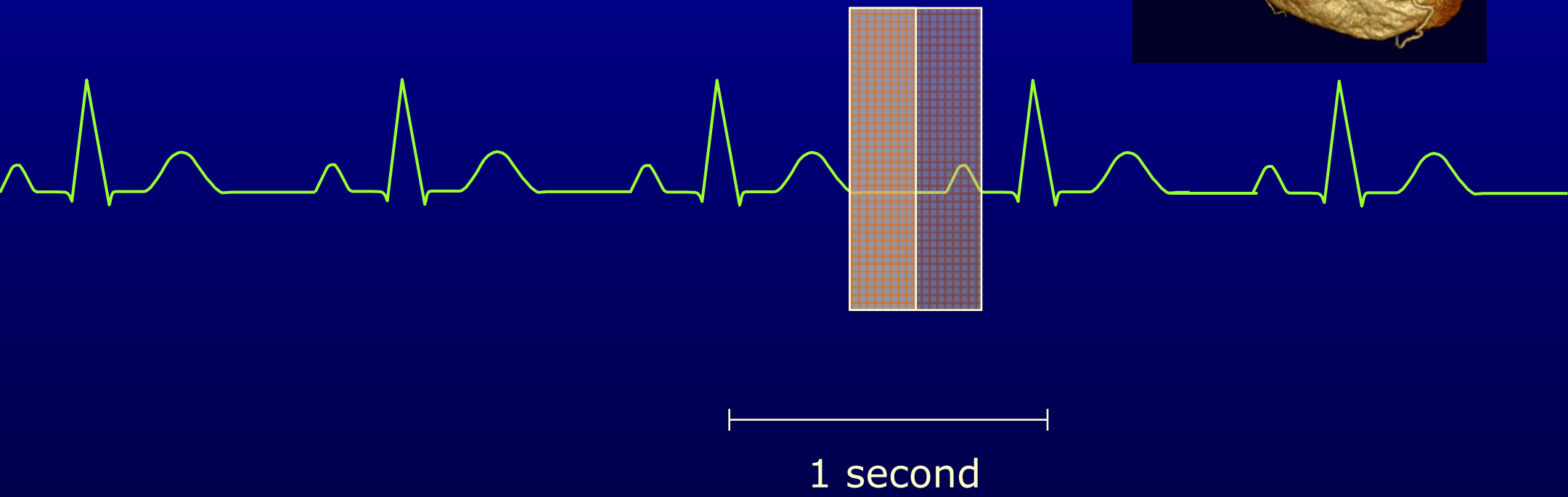
Lembcke et al. *ECR* 2009

cardiac frequency: 60 beats/min

Revolution time: 350 ms

Exposure time: 175 ms



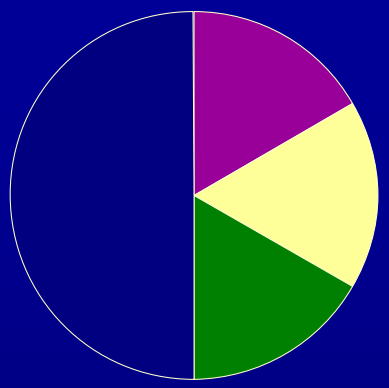


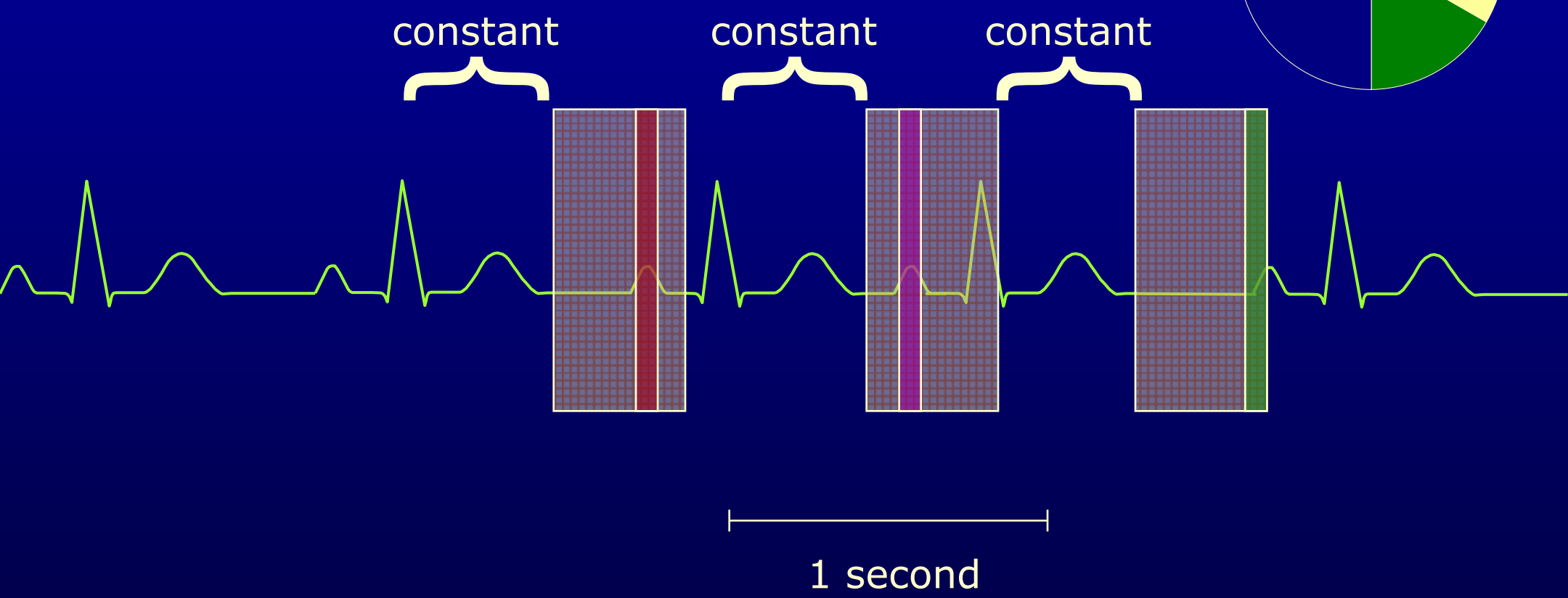
Effective dose: ~ 1-2 mSv

cardiac frequency: 60 beats/min

Revolution time: 350 ms

Exposure time: 58 ms



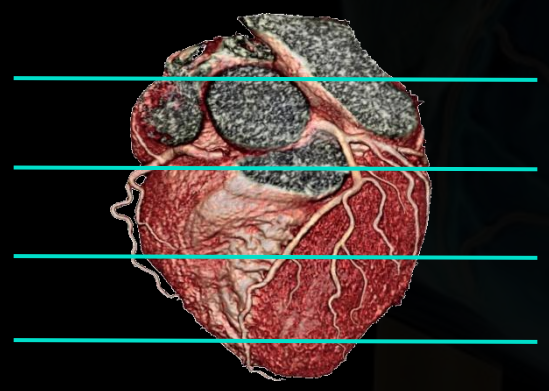


higher radiation dose

prospective single beat

prospective two beats

Sequential Mode



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Sequential Mode

ECG sync	Triggered
Pitch	Some overlap
Recon phase(s)	65%
Min mA	0%

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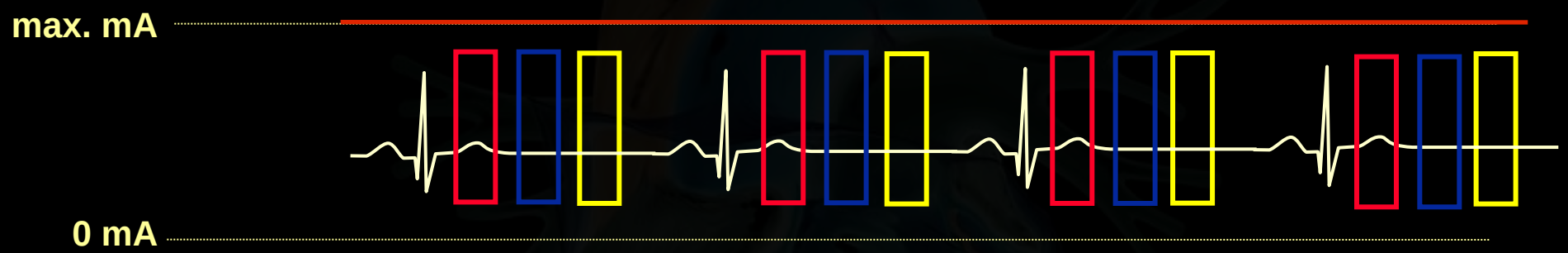
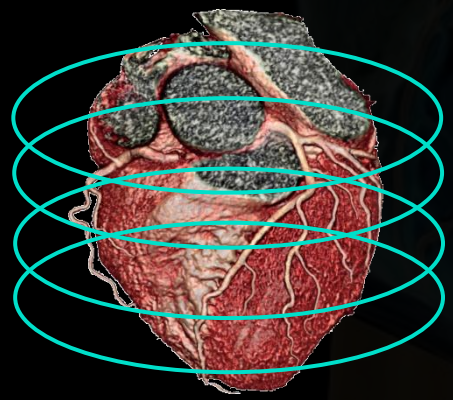
Spiral Mode





ECG sync	Gated
Pitch	0.2
Recon phase(s)	0-95%
Min mA	100%

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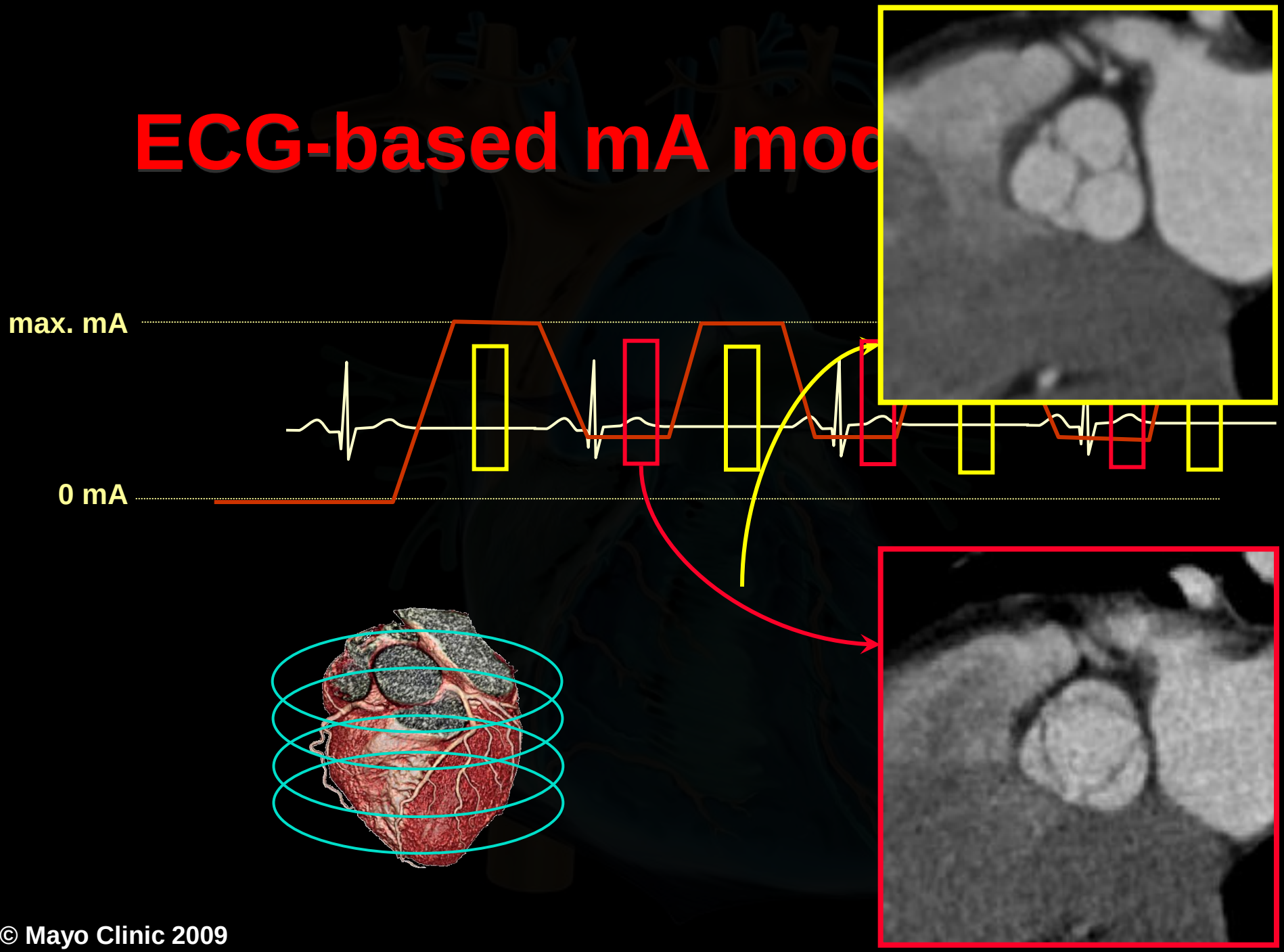
ECG-based mA mod



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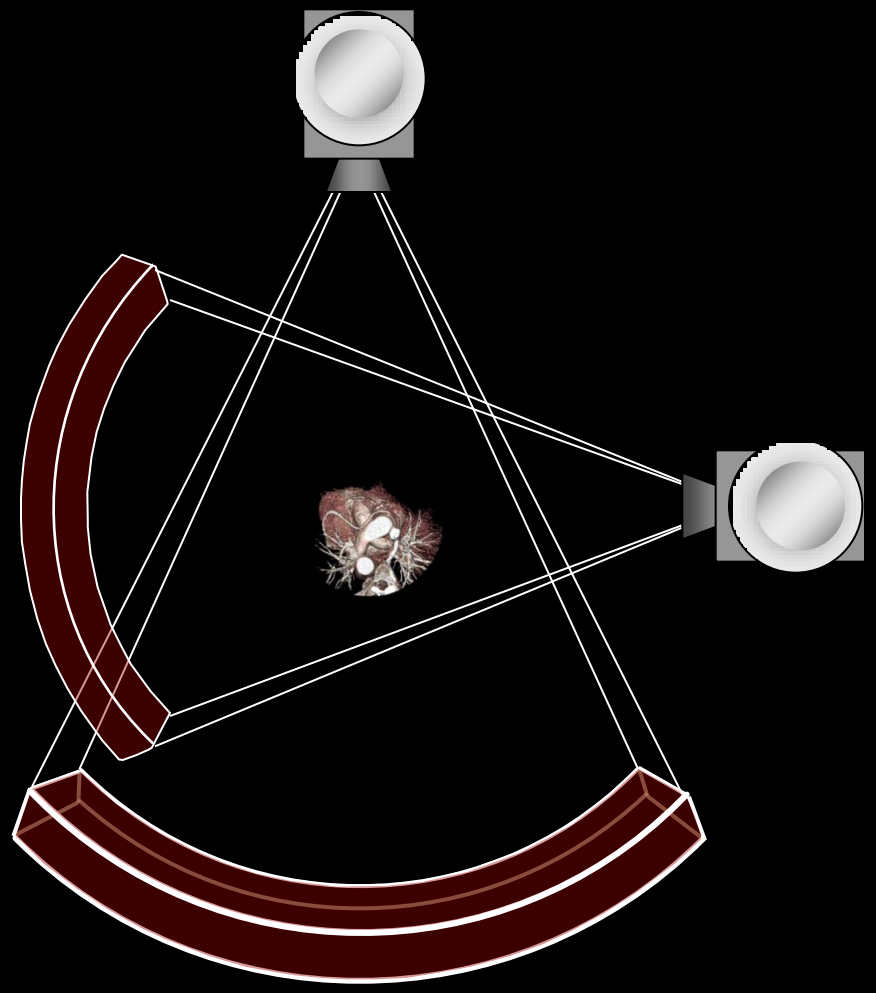
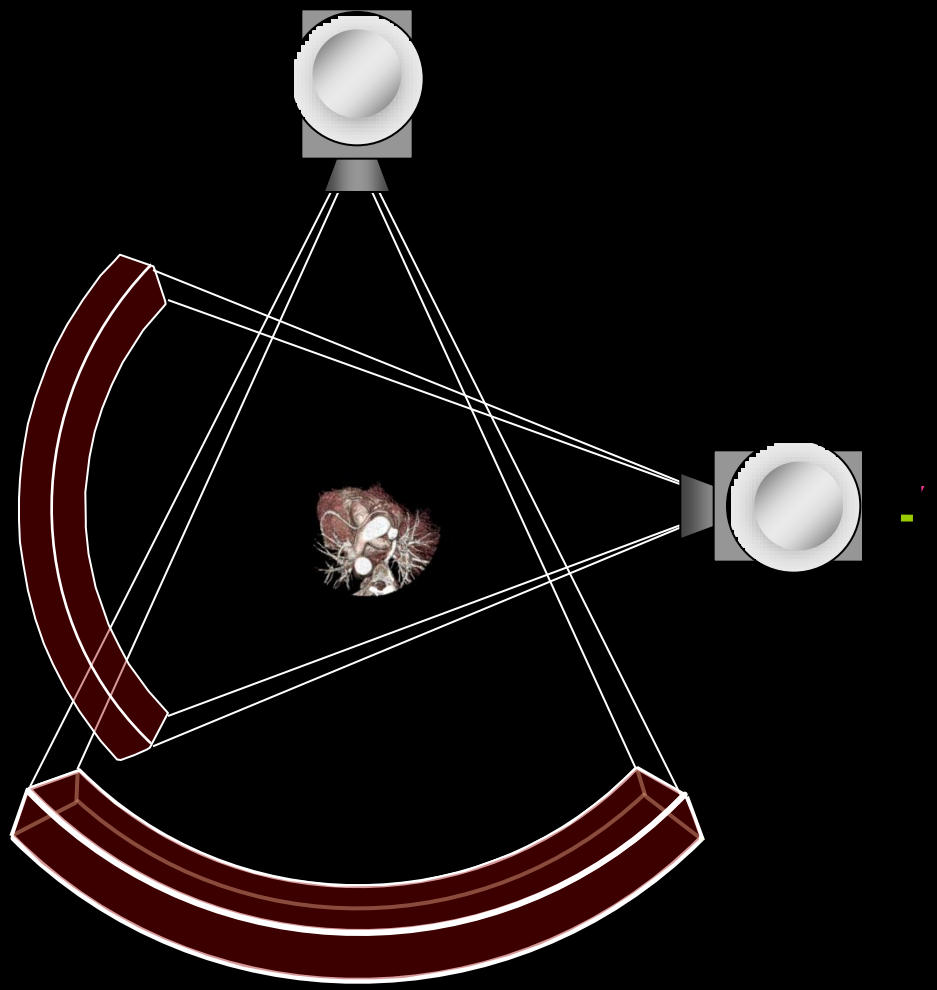
Solution 2

revolution time: 330 ms
time for 180°: 165 ms



Solution 2

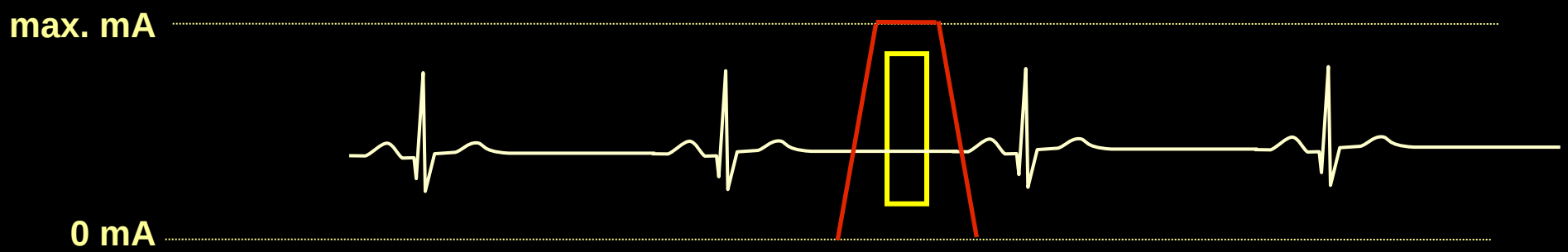
revolution time: 330 ms
time for 180°: ~~165 ms~~
time for 90°: 83 ms

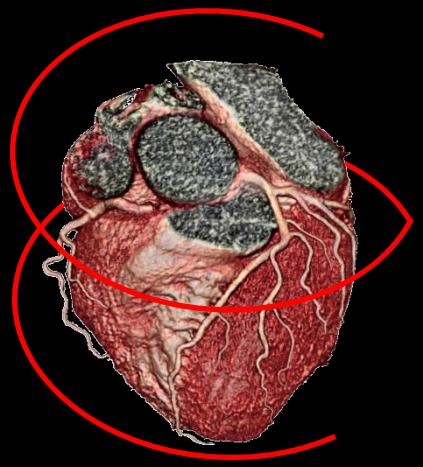


coverage

38.4 mm

Spiral high-pitch Mode





ECG sync	Triggered
Pitch	3.2
Recon phase(s)	65%
Min mA	0%

Solution 1 (wide area detector)

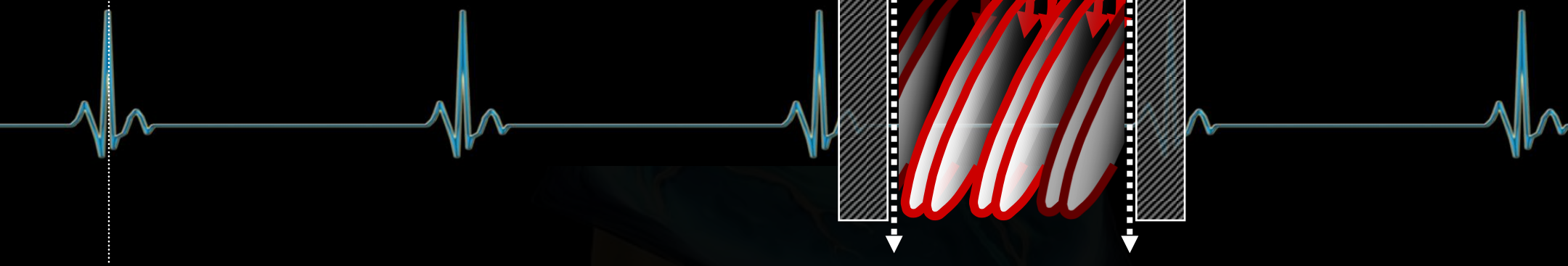
exposure window

no table motion

175 ms

Solution 2 (dual source fast helical)

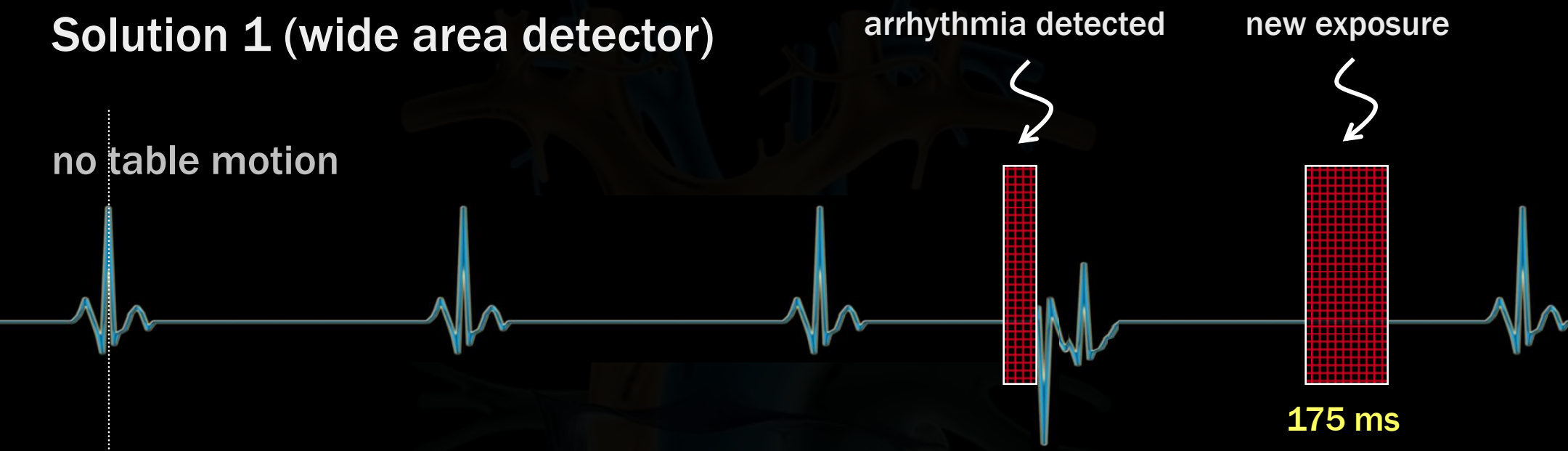
conventional pitch 3 helical
~40 cm/s, 16 cm coverage



~ 300 ms

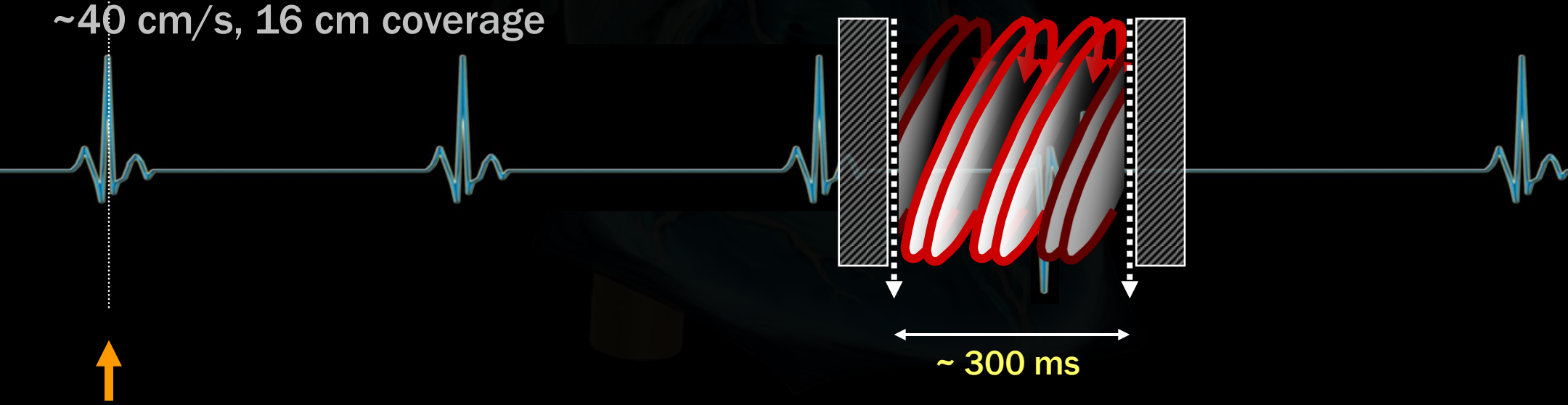
Solution 1 (wide area detector)

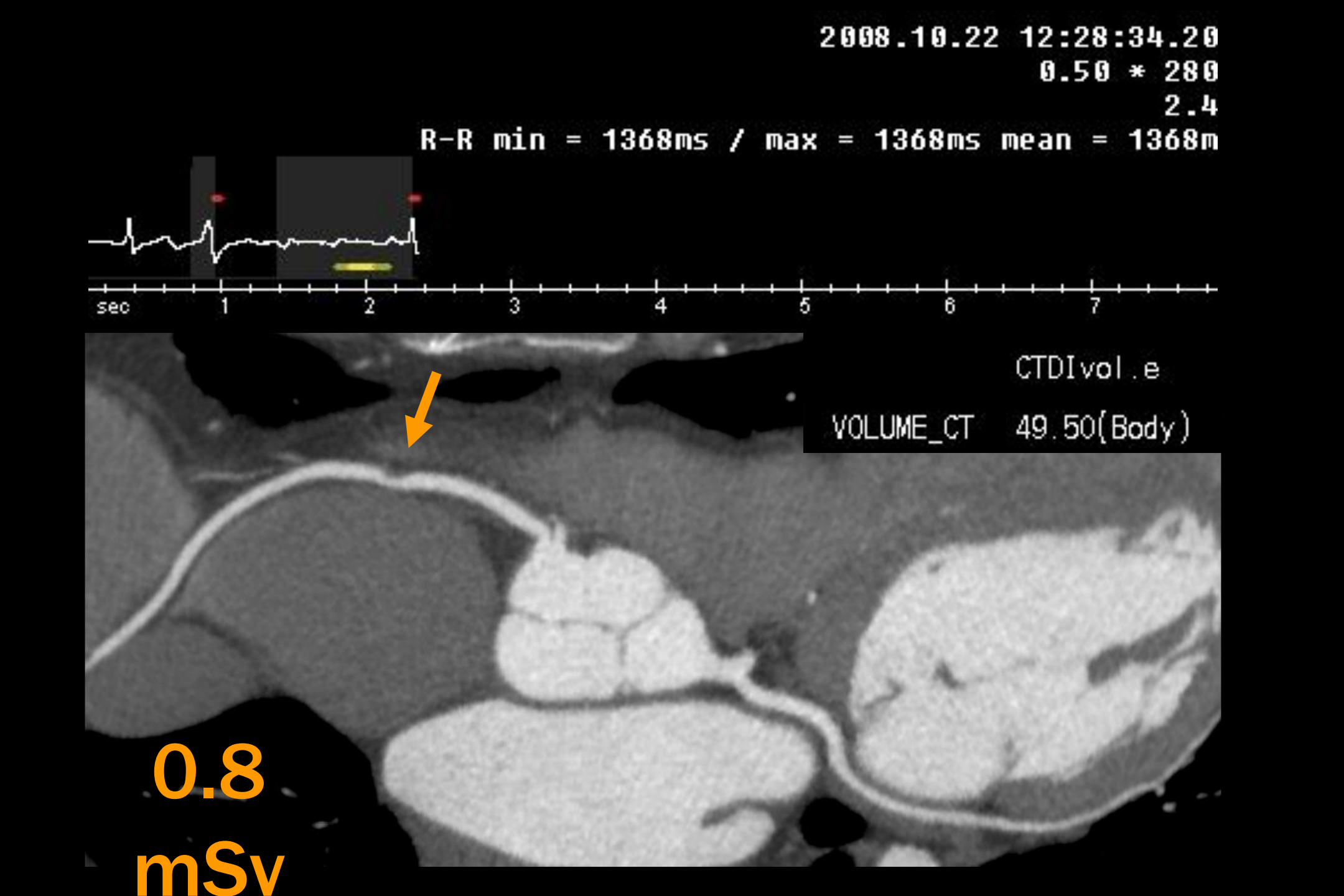
no table motion



Solution 2 (dual source fast helical)

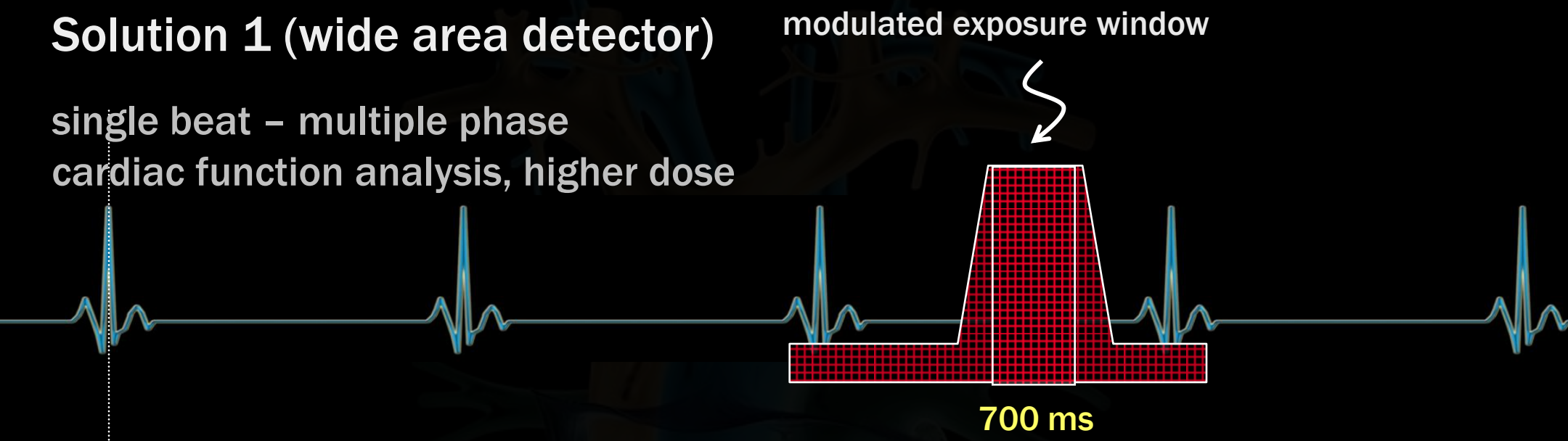
conventional pitch 3 helical
~40 cm/s, 16 cm coverage




2008.10.22 12:28:34.20
0.50 * 280
2.4
R-R min = 1368ms / max = 1368ms mean = 1368m
sec
1
2
3
4
5
6
7
CTDIvol.e
VOLUME_CT 49.50(Body)
0.8
mSv

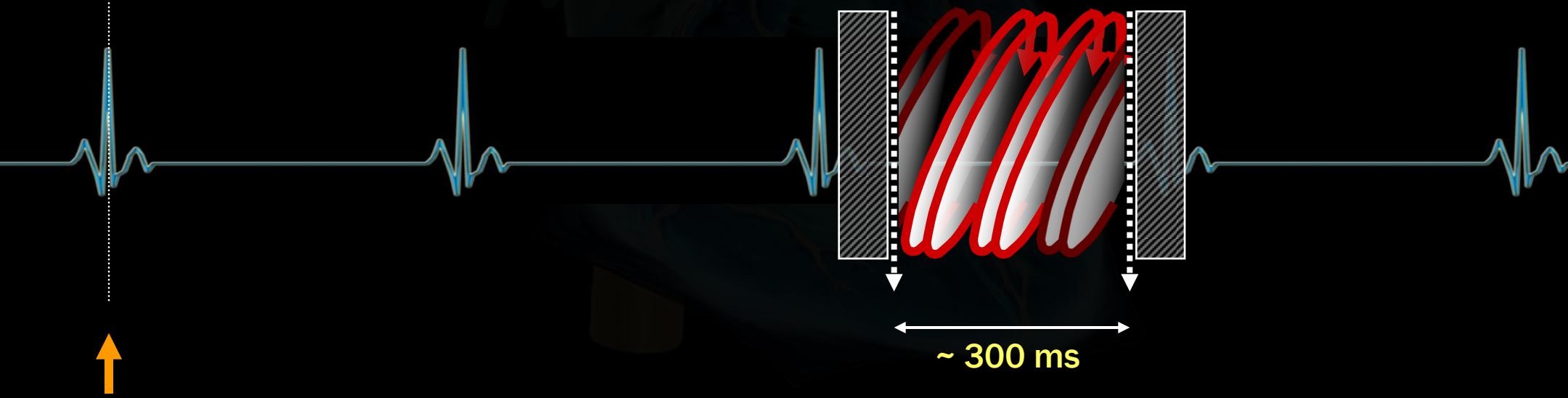
Solution 1 (wide area detector)

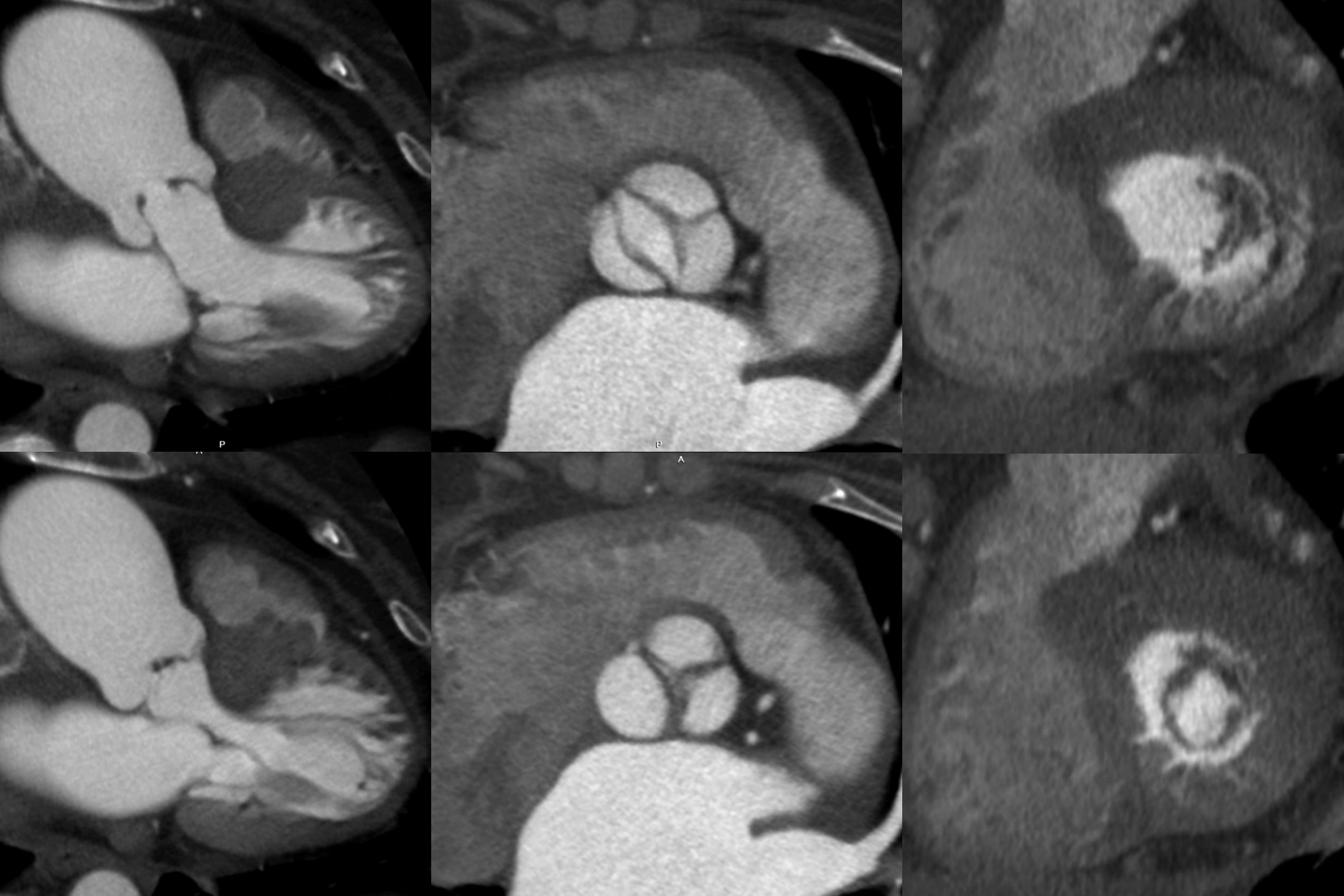
single beat – multiple phase
cardiac function analysis, higher dose

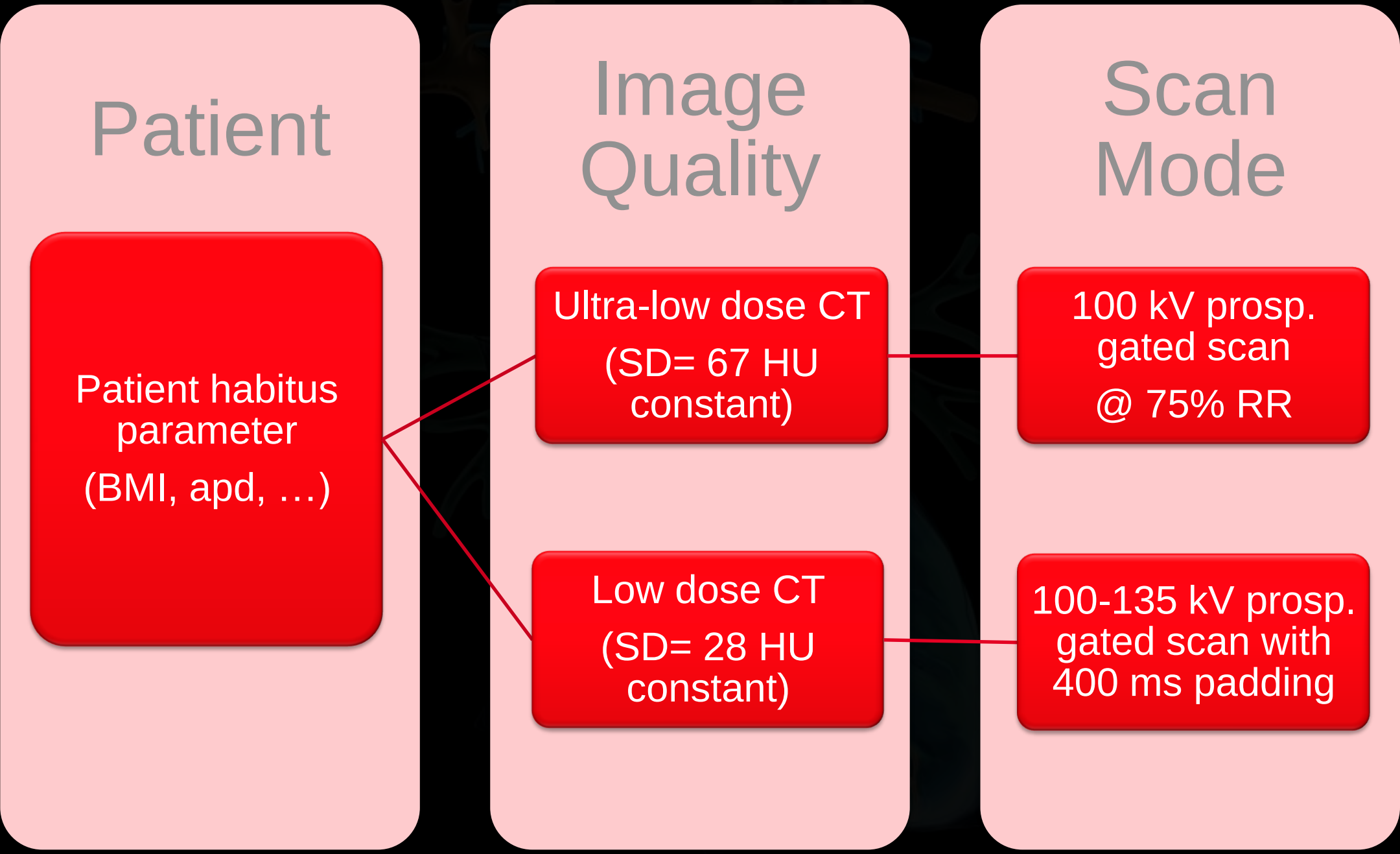


Solution 2 (dual source fast helical)

single beat – single phase, lower dose



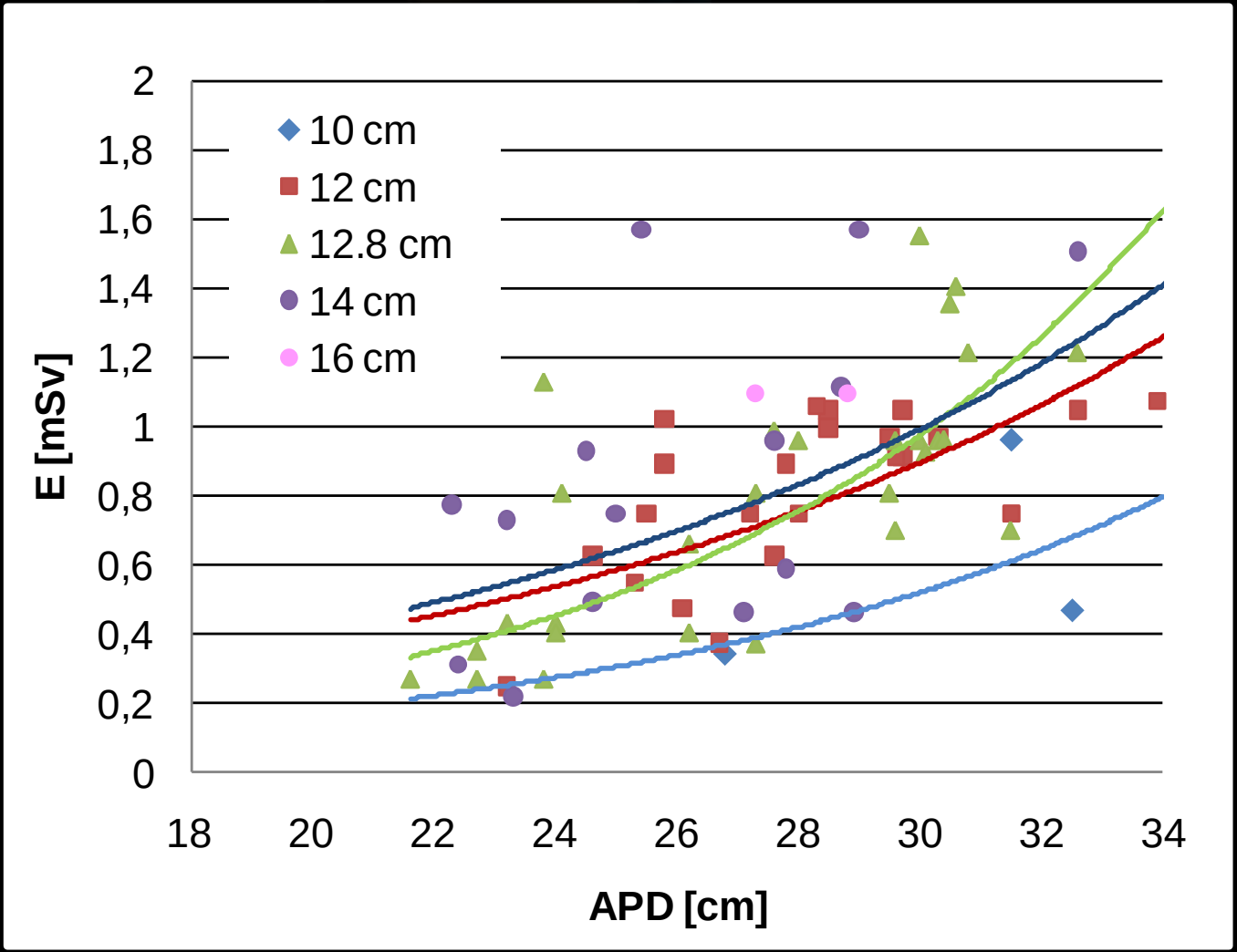

P
P
A


Patient
Image Quality
Scan Mode
Patient habitus parameter
(BMI, apd, …)
Ultra-low dose CT
(SD= 67 HU constant)
Low dose CT
(SD= 28 HU constant)
100 kV prosp. gated scan
@ 75% RR
100-135 kV prosp. gated scan with 400 ms padding

100 kV

n=72

z-Cover	10 cm	12 cm	12.8 cm	14 cm	16 cm	All
Number	3	24	28	15	2	72
Mean	0,59	0,81	0,80	0,87	1,10	0,818
σ	0,29	0,24	0,33	0,47	-	0,34



	Modality	Sensitivity	Specificity	NPV	PPV	Excluded segments[a]
Schmermund et al. [14]	EBCT	82	88	96	57	28
Achenbach et al. [15]	16-slice CT	94	96	99	69	4
Hoffmann et al. [16]	16-slice CT	63	96	96	64	17
Martuscelli et al. [17]	16-slice CT	89	98	98	90	16
Mollet et al. [18]	16-slice CT	89	98	98	90	16
Morgan-Hughes et al. [19]	16-slice CT	83	97	97	80	0
Raff et al. [20]	64-slice CT	86	95	98	66	12
Mollet et al. [21]	64-slice CT	99	95	99	76	0

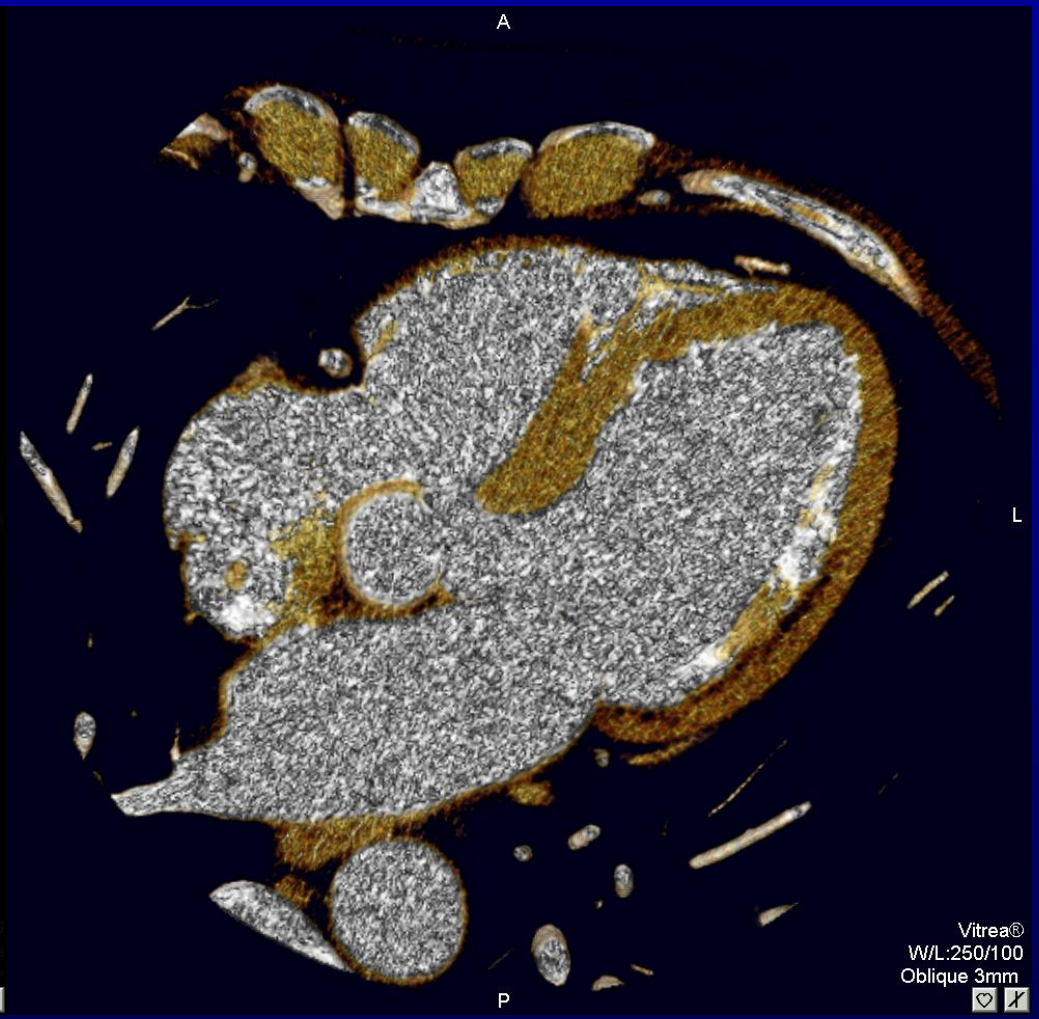
All numbers are given in %.

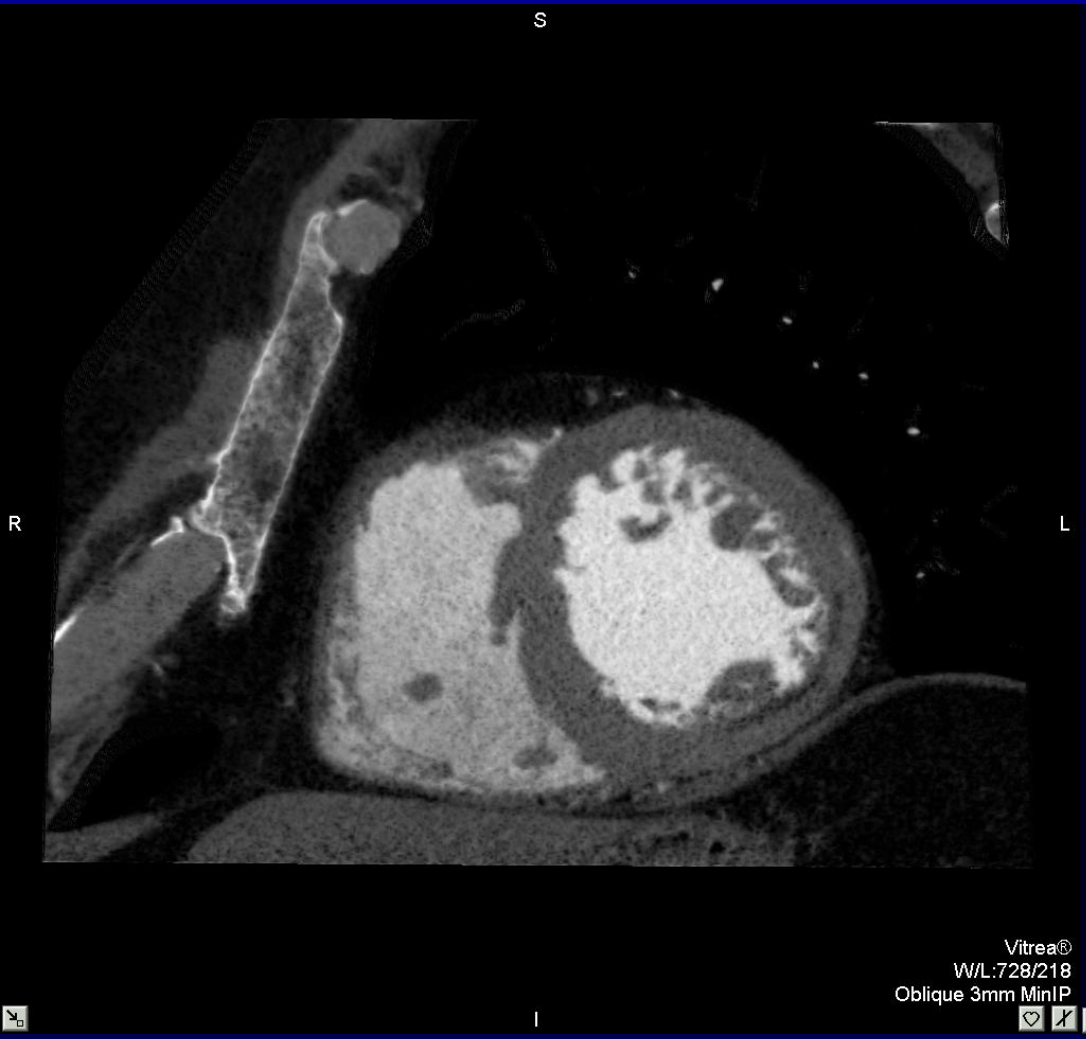
[a] Excluded coronary artery segments due to calcifications, motion artifacts, small lumen and inadequate filling.

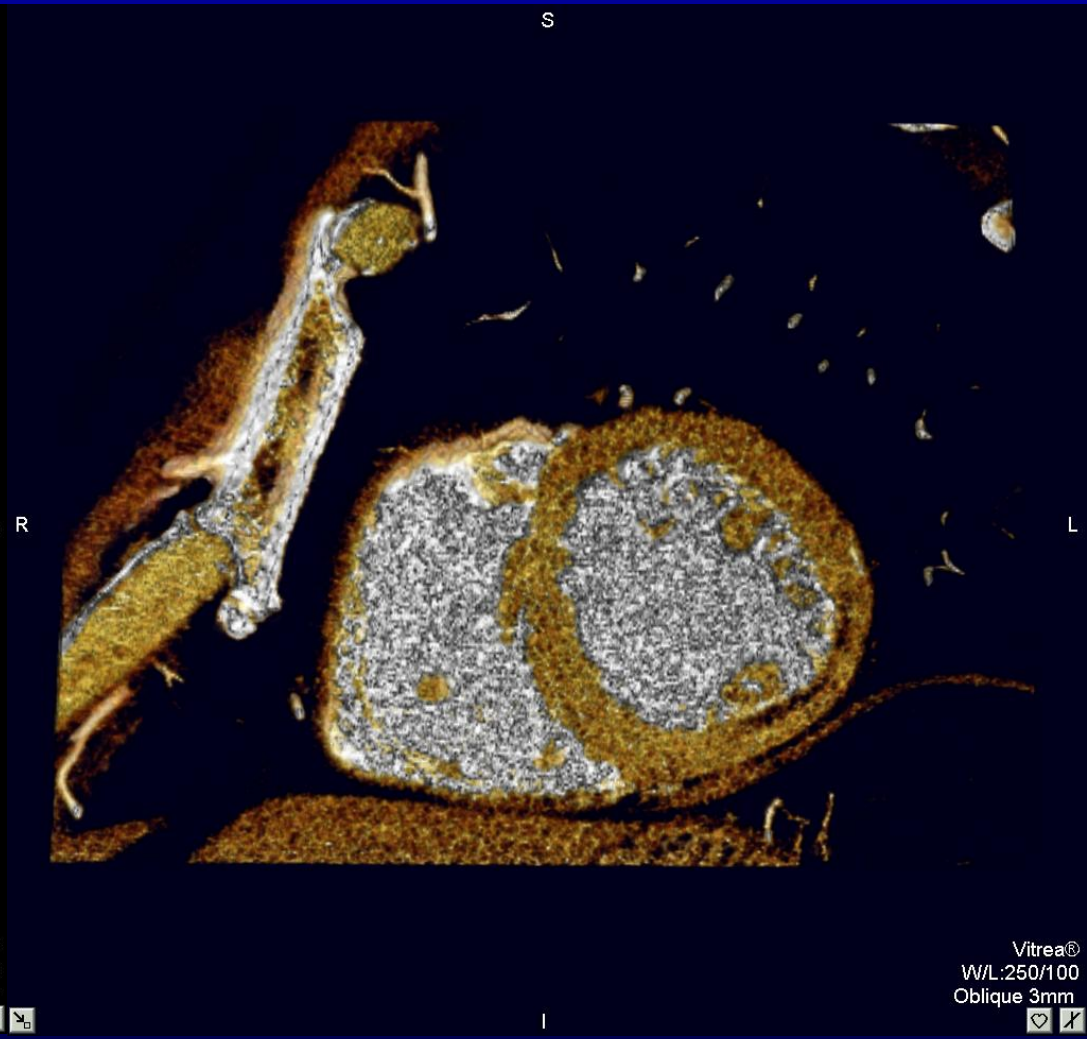
- improvement by technology
- sensitivity >90%, NPV >95%

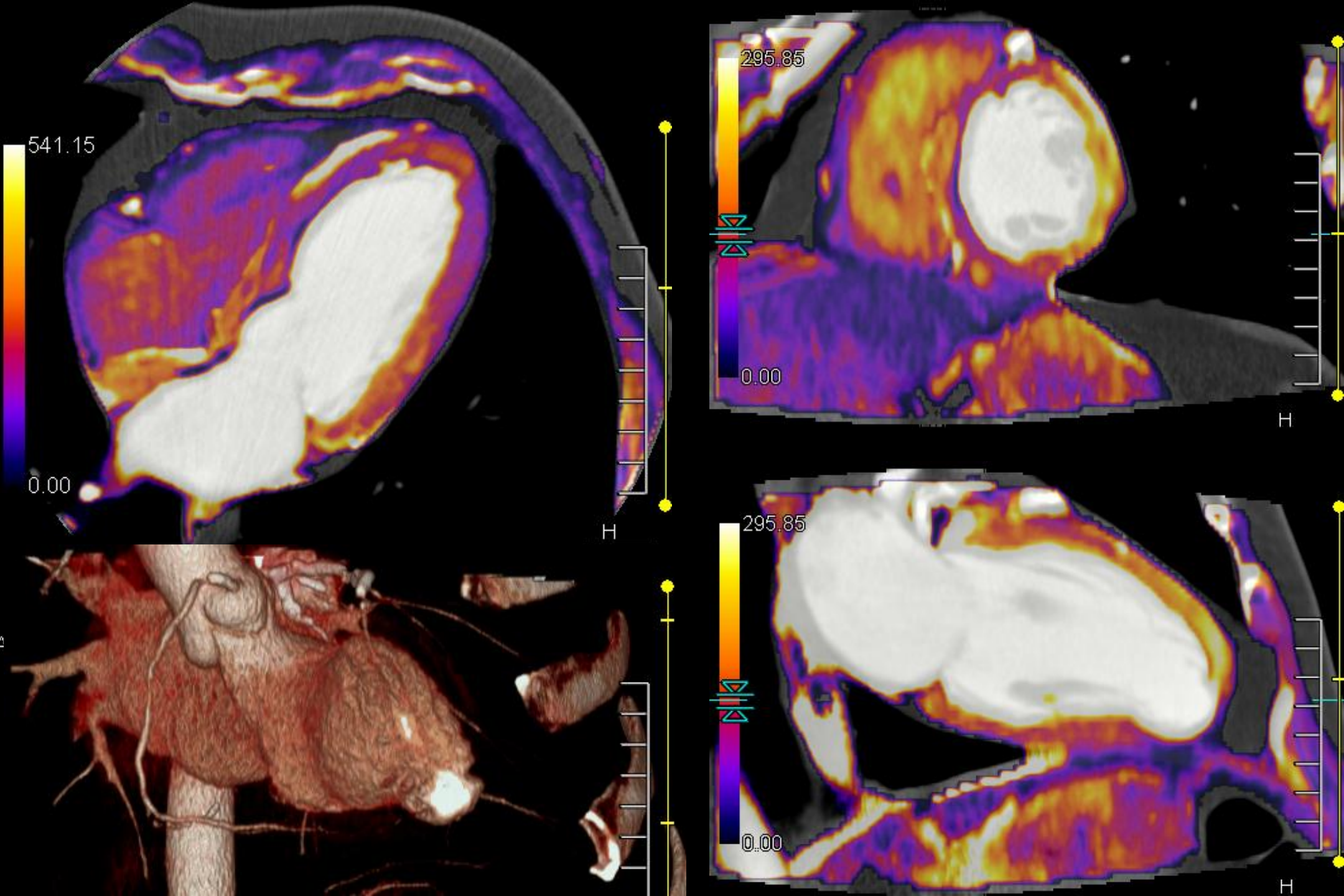
Lembcke A et al. *EJR* 2005;57:356-357

A
R
L
P
Vitrea®
W/L:728/218
Oblique 3mm MinIP


A
L
P
Vitrea®
W/L:250/100
Oblique 3mm


S
R
L
I
Vitrea®
W/L:728/218
Oblique 3mm MinIP


S
R
L
I
Vitrea®
W/L:250/100
Oblique 3mm


541.15
0.00
H
295.85
0.00
H
295.85
0.00
H

Summary

- standard helical cardiac CT significant source of radiation
- all dose reduction means useful (kV, mAs modulation/adaptation)
- dramatic dose reduction by:
  - wide area detector CT (non-helical), sequential
  - dual source fast helical
- new clinical possibilities: iodine maps, perfusion imaging