



**DSCT application in adult heart
disease:
Asan Medical Center**

**Joon-Won Kang, MD
ASAN Medical Center
University of Ulsan, College of Medicine**



Introduction

- Defects of Currently used MDCT for CAG
 - Small dimension of coronary artery
 - Constant and rapid motion
 - Limited temporal resolution due to rotation time of currently used CT



4 channel CT

- 4 channel MDCT (1999)
 - Trot=500ms
 - Half-scan reconstruction algorithm (using data collected approximately 180° of rotation)
 - Prospective ECG-gated CT
 - Inadequate study up to 35% of patients
 - High heart rate, low image quality.



16 channel CT

- 375 ms gantry rotation time
- 3.0 mm table feed per rotation
- 16 x 0.75 mm collimation

64 channel CT

- Trot=0.33s
- Coronary CTA into routine clinical algorithm



Evaluation of coronary stenosis (16 slice MDCT)

Author	Journal	Sensiti'ty	Specif'ty	PPV	NPV
Garcia MJ	JAMA 2006	89%	65%	13%	99%
Kaiser C	Eur H J 2005	30%	91%	47%	83%
Nikolaou K	AJR 2006	80%	99%	57%	99%
Achenbach S	Eur H J 2005	94%	96%	68%	99%



Evaluation of coronary stenosis (64 slice MDCT)

Author	Journal	Sensitivity	Specificity	PPV	NPV	
¹ Leschka	Eur Hear J 2005	94%	97%	87%	99%	(segment)
² Mollet NR	Circulation 2005	99%	95%	76%	99%	(segment)
³ Raff GL	JACC 2005	86%	95%	66%	98%	(segment)
		95%	90%	93%	93%	(patient)

¹ 67 patients with suspected CAD or prior to CABG
All vessels ≥ 1.5 mm, β -blocker (+)

² 52 patients with stable, unstable angina or non-STEMI scheduled for CAG
All vessels regardless of size, β -blocker (+)

³ 70 consecutive patients undergoing elective CAG for suspected CAD
All vessels regardless of size, β -blocker (+)
26% ≥ 400 Agatston U, 25% HR > 70, 50% obese
Assessable: 773/935/1065 segments



Residual problems in 64 channel CT

- Motion artifacts
 - Administration of β -blockers
 - metoprolol in HR>70bpm
 - Target HR<65bpm
 - 95% sensitivity, 90% specificity, 93% PPV, 93% NPV
 - Good image quality in diastole when HR<65bpm, in end-systole when HR>75bpm
 - Needs more phase reconstruction to evaluate optimal results



Table 2. Relationship of Heart Rate and Segment (Vessel) Assessment by Multislice Computed Tomography

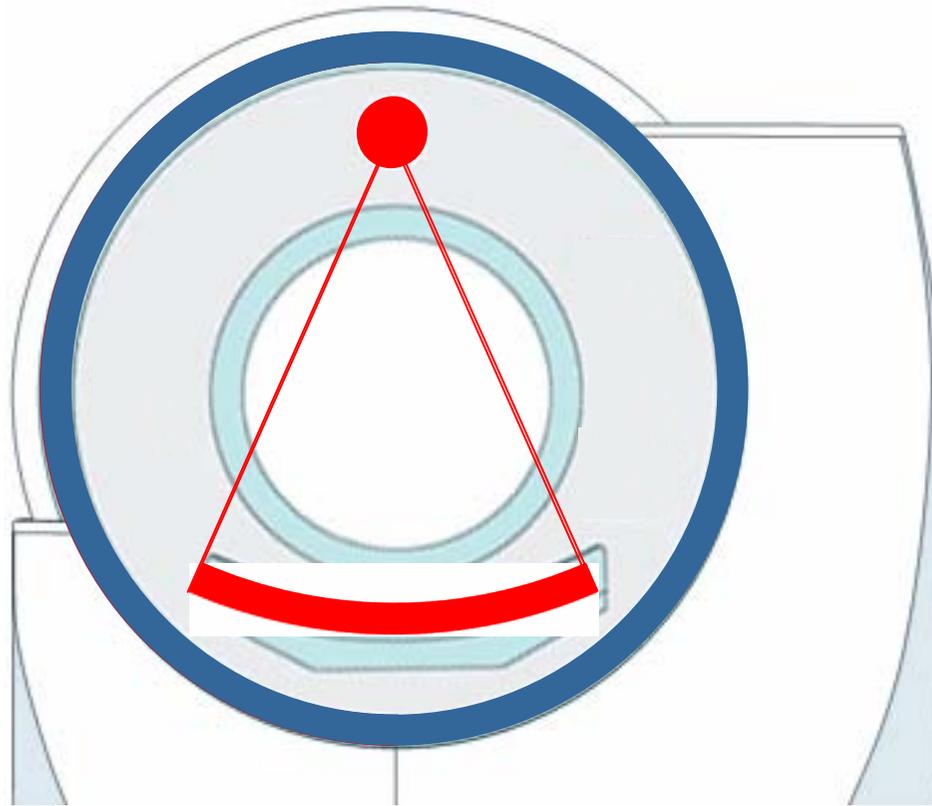
Assessment Level	No./Total (%)				Total
	Heart Rate, beats/min				
	<60	60-70	71-80	>80	
Segments	295/302 (98)	530/549 (97)	335/374 (90)*	136/159 (85)*	1296/1384 (93)
Vessels	81/88 (92)	143/159 (90)	85/109 (78)*	36/47 (77)*	345/403 (86)
Patients	18/22 (82)	30/41 (73)	19/28 (68)	8/12 (67)	75/103 (73)

*Statistically significant differences detected vs groups with heart rate ≤ 70 beats/min ($P < .01$ by χ^2 test). No significant differences were apparent for the patient groups.

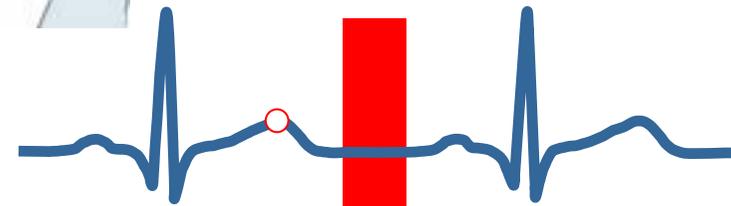
JAMA. 2005;293:2471-2478.

Single Source CT

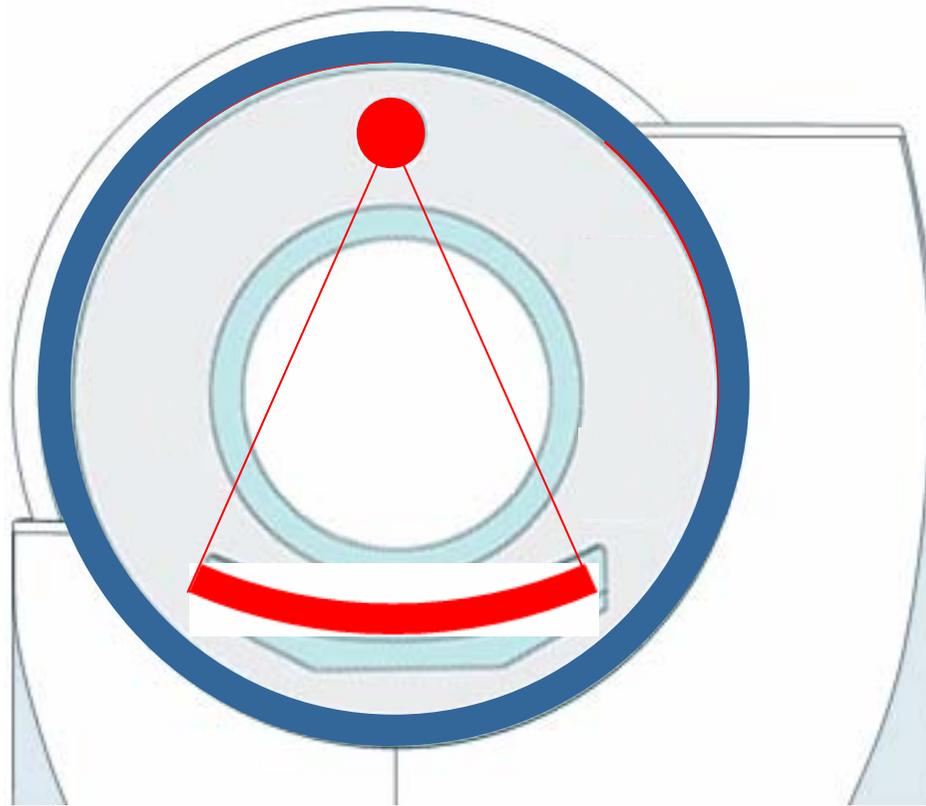
Temporal resolution of maximum 165 ms



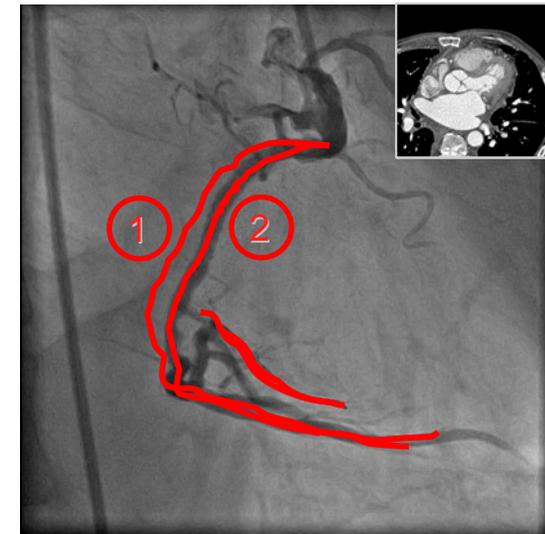
$$\text{Temporal Resolution} = \frac{\text{Rotation Time}}{2} = 165 \text{ ms}$$



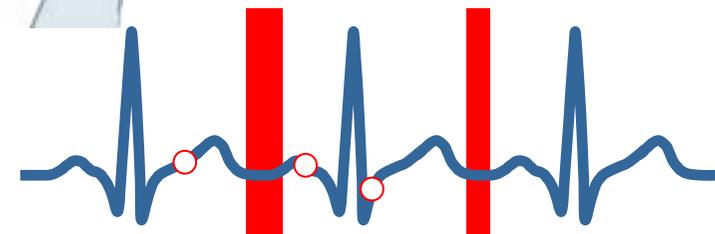
Single Source CT with Multisegment Recon. Software attempt to increase temporal resolution

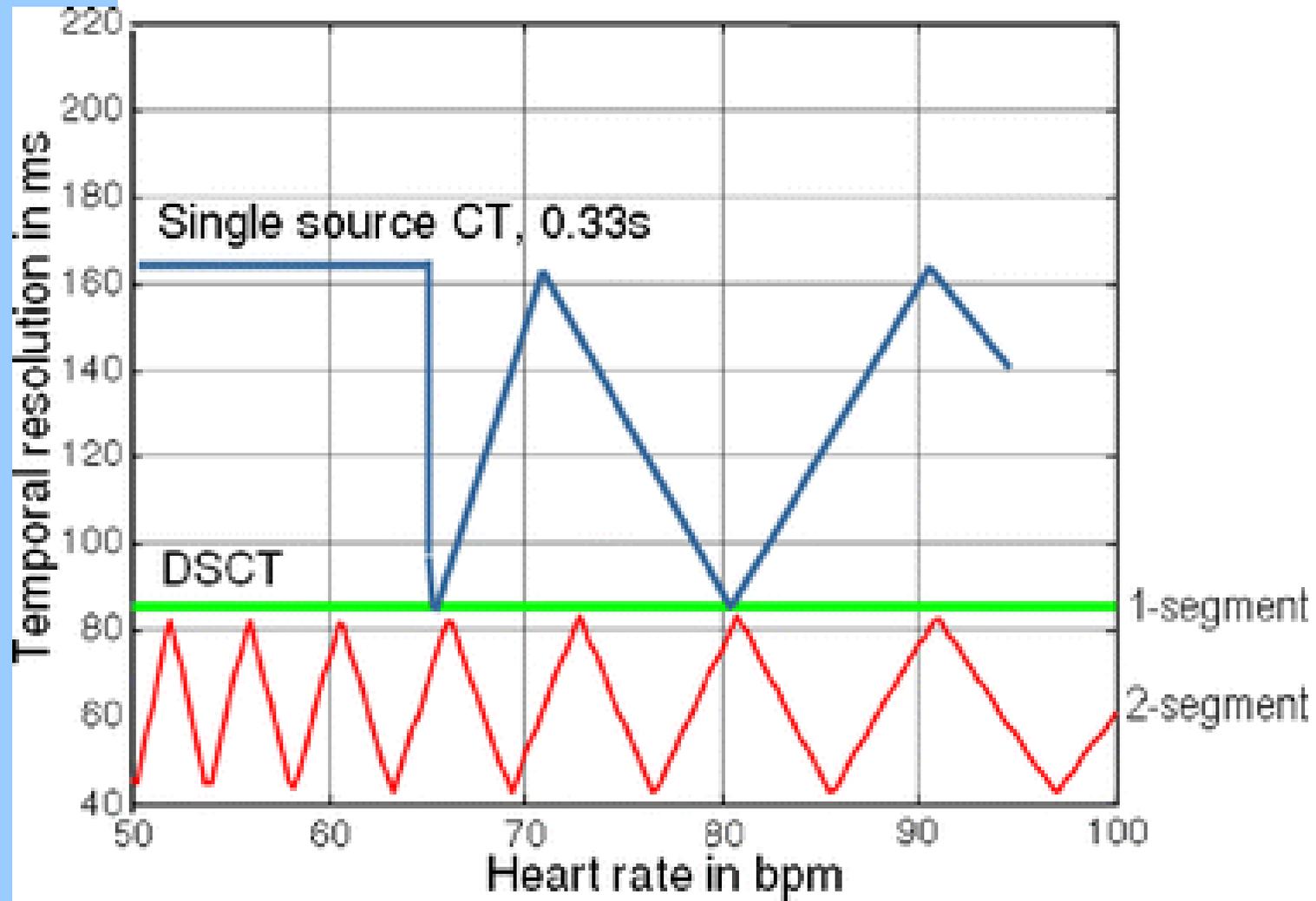


Temporal Resolution =
(2 Segment Recon)
varies between = 83 and 165 ms



Coronary arteries change
position between beats =
limited image quality







Effect of Bisegmental reconstruction

TABLE 3. Comparison of Image Quality (IQ) Scores Evaluated for Half-Scan and Dual-Segment

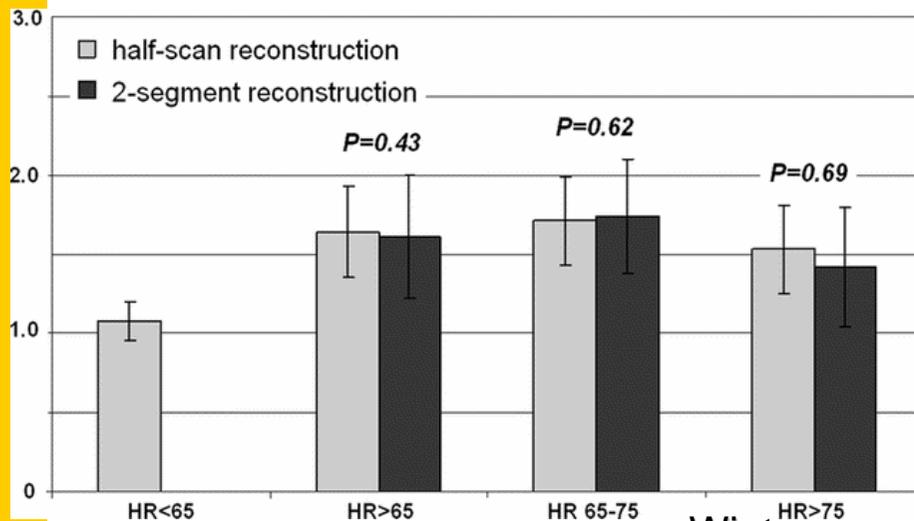
	All Patients (HR 47-92 bpm)			Group 1 (HR ≤ 65 bpm; n = 15)			Group 2 (HR > 65 bpm ≤ 75 bpm; n = 10)			Group 3 (HR > 75 bpm; n = 7)		
	Half-Scan	2-Segment*	Overall	Half-Scan	2-Segment	Overall	Half-Scan	2-Segment	Overall	Half-Scan	2-Segment	Overall
LAD IQ	1.25 ± 0.27 (1.17)	1.49 ± 0.43 (1.50)	1.18 ± 0.23 (1.00)	1.03 ± 0.13 (1.00)	NA	1.03 ± 0.13 (1.00)	1.48 ± 0.24 (1.50)	1.62 ± 0.47 (1.50)	1.38 ± 0.21 (1.50)	1.38 ± 0.19 (1.33)	1.31 ± 0.31 (1.33)	1.21 ± 0.21 (1.33)
LCX IQ	1.36 ± 0.40 (1.25)	1.59 ± 0.40 (1.50)	1.27 ± 0.19 (1.17)	1.06 ± 0.10 (1.00)	NA	1.06 ± 0.10 (1.00)	1.69 ± 0.40 (1.59)	1.68 ± 0.38 (1.50)	1.53 ± 0.27 (1.50)	1.55 ± 0.33 (1.50)	1.45 ± 0.41 (1.17)	1.33 ± 0.25 (1.17)
RCA IQ	1.52 ± 0.49 (1.33)	1.67 ± 0.38 [†] (1.67)	1.40 ± 0.38 (1.33)	1.16 ± 0.21 (1.00)	NA	1.16 ± 0.21 (1.00)	1.95 ± 0.43 (2.00)	1.75 ± 0.34 (1.67)	1.67 ± 0.31 (1.67)	1.69 ± 0.40 (1.83)	1.55 ± 0.43 (1.67)	1.55 ± 0.43 (1.67)
Overall	1.64 ± 0.29 (1.60)	1.61 ± 0.40 (1.65)	1.31 ± 0.32 (1.20)	1.08 ± 0.12 (1.00)	NA	1.08 ± 0.12 (1.00)	1.71 ± 0.28 (1.67)	1.75 ± 0.37 (1.65)	1.62 ± 0.27 (1.60)	1.53 ± 0.28 (1.60)	1.42 ± 0.38 (1.20)	1.36 ± 0.31 (1.20)

Data are given as mean ± SD plus median (in parentheses).

*Two-segment reconstruction only available in patients with HR > 65 bpm.

[†]P < 0.05 vs. half-scan reconstruction.

NA, not applicable.

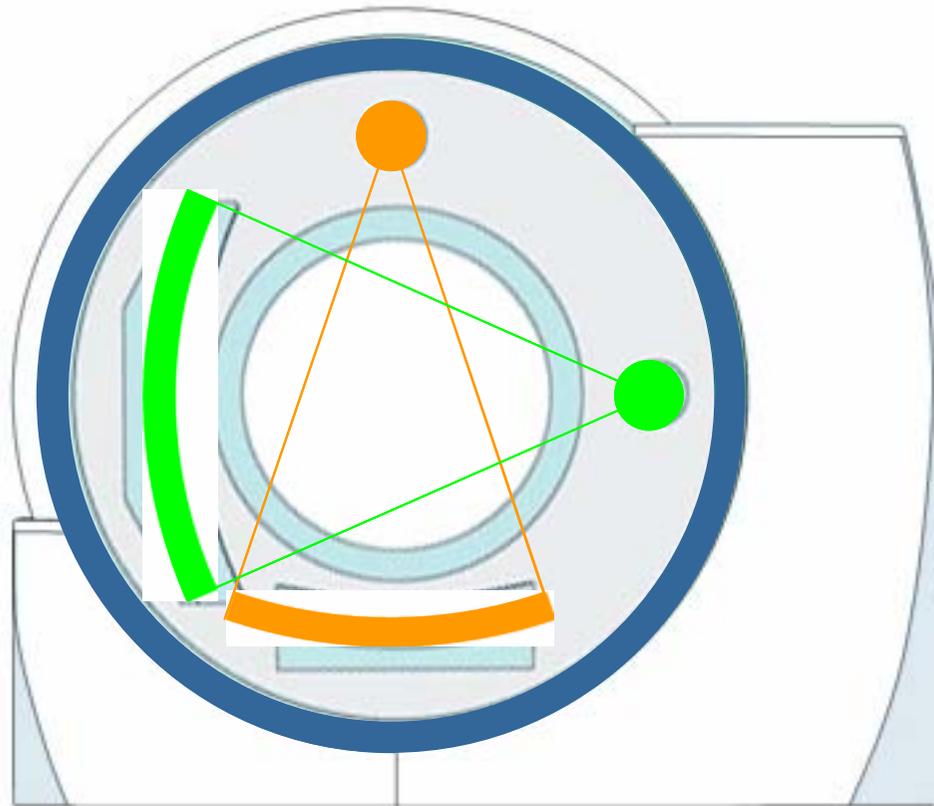


No significant difference on image quality!!

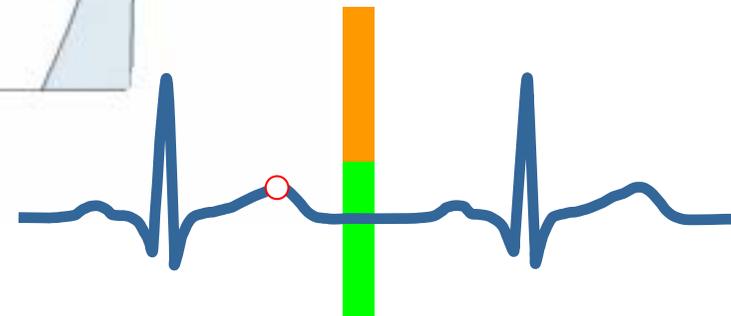


Dual Source CT

Heart rate independent temp. resolution of 83 ms



$$\text{Temporal Resolution} = \frac{\text{Rotation Time}}{4} = 83 \text{ ms}$$





Temporal Resolution

4-detector MDCT : 250 msec

16-detector MDCT : 210 msec

64-detector MDCT : 165 msec

EBCT : 100 msec

Dual source CT : 83 msec

Conventional CAG : ~ 20 msec



Spatial Resolution

EBCT : 3.0 mm

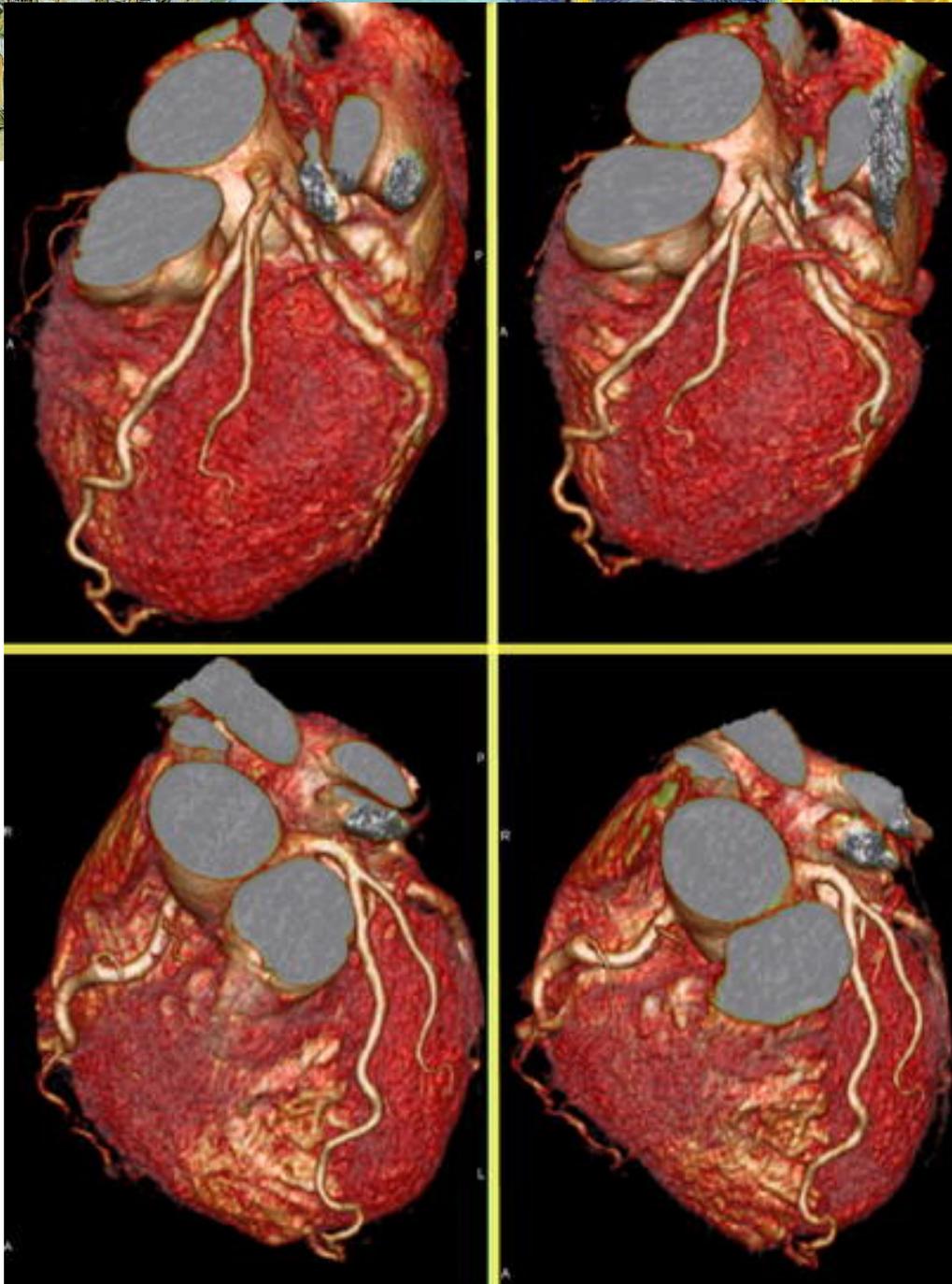
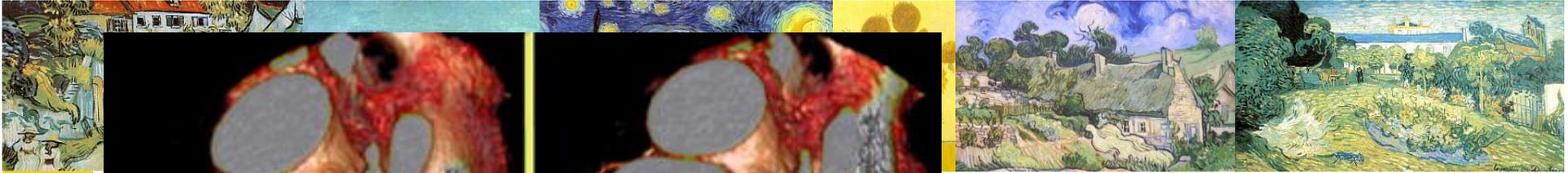
4-detector MDCT : 1.0 mm

16-detector MDCT : 0.75 mm

64-detector MDCT : 0.6 mm

Dual source CT : 0.6 mm

Conventional CAG : 0.1 ~ 0.2 mm



(VRT) of a 59-year-old man
suspicion of RCA stenosis

mean HR: 85 bpm.

Left: diastolic reconstruction
at 65%

Right: end-systolic
reconstruction at 28%

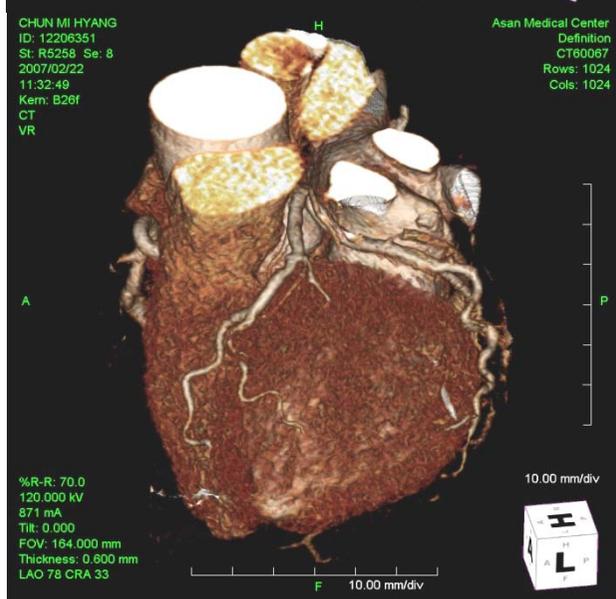
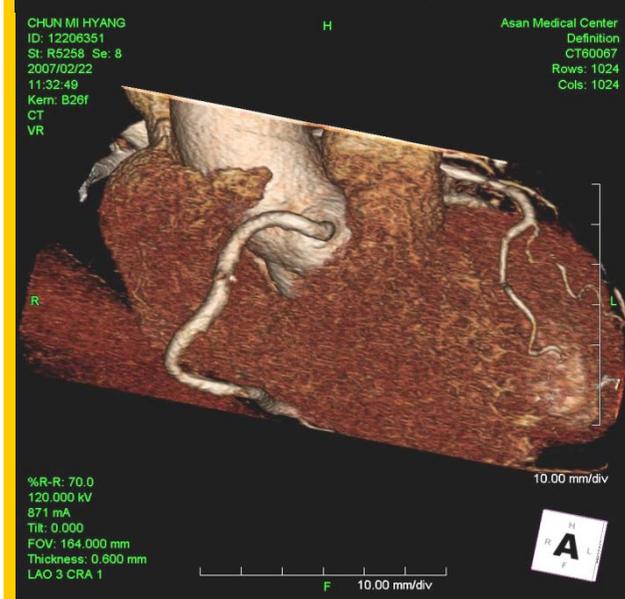
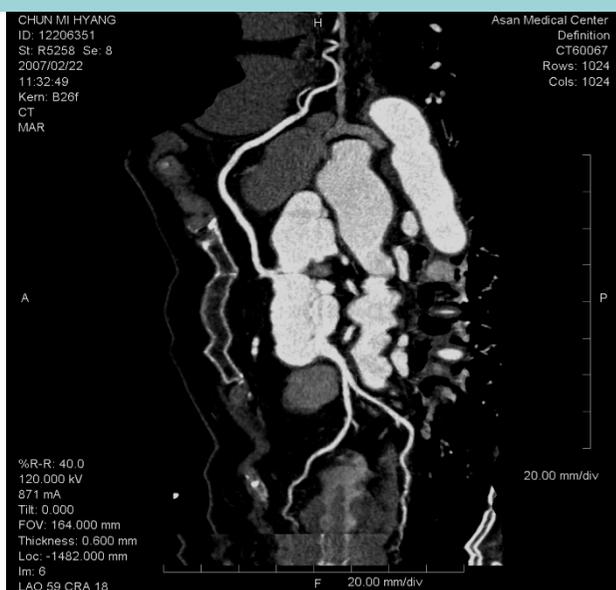
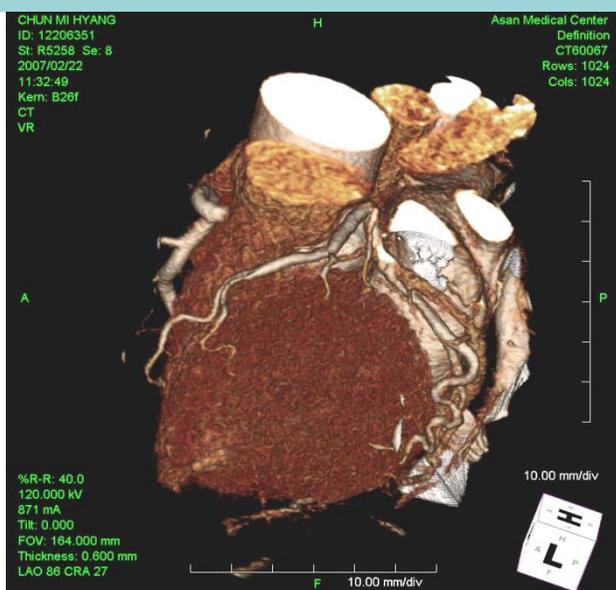
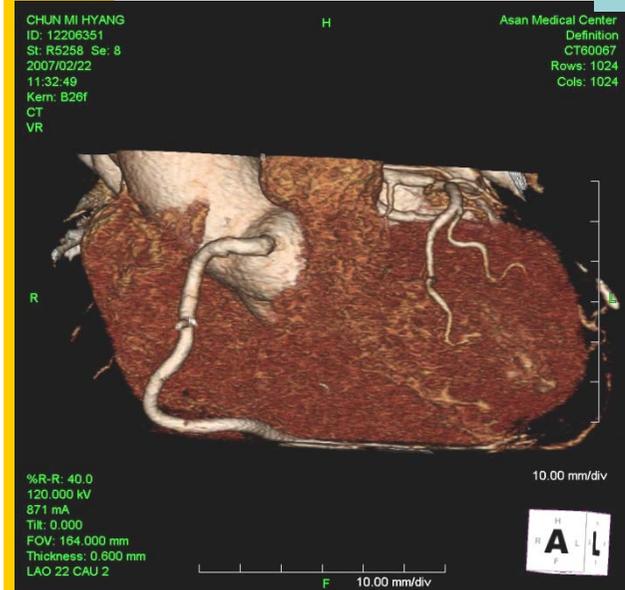
Flohr TG et al
Eur Radiol, 2006

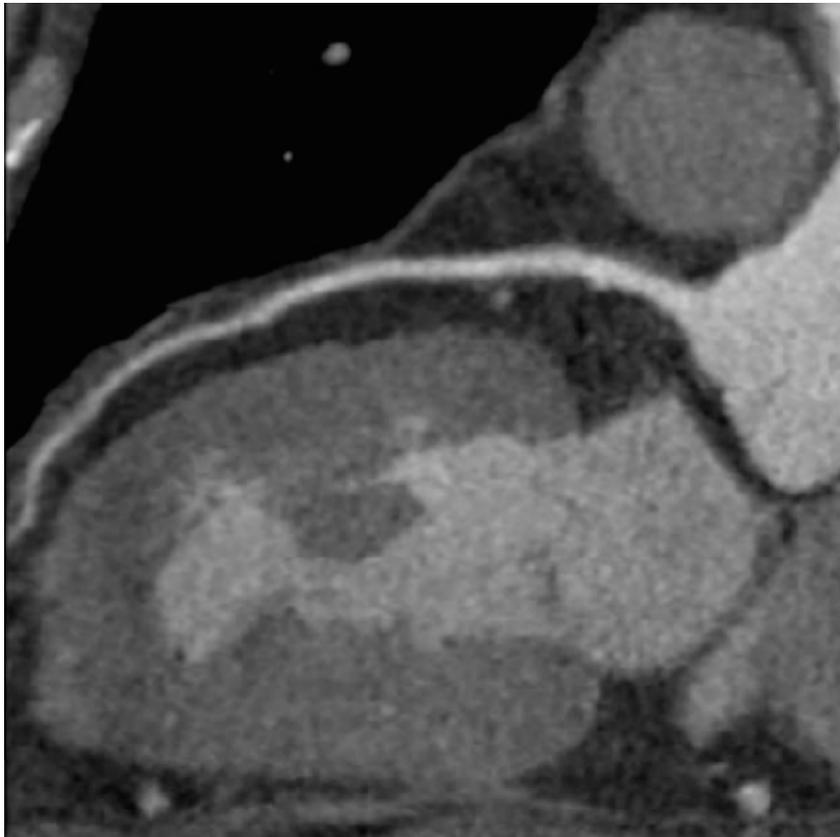
DSCT:AMC Experience



72-yr-woman suspicion of mLAD stenosis, mean HR: 77 bpm.

Up: systolic reconstruction at 40%
down: diastolic reconstruction at 70%





HR: 90 bpm

Achenbach et al
Eur J Radiol, 2006

DSCT:AMC Experience

65/M
HR: 76~85





20% of R-R

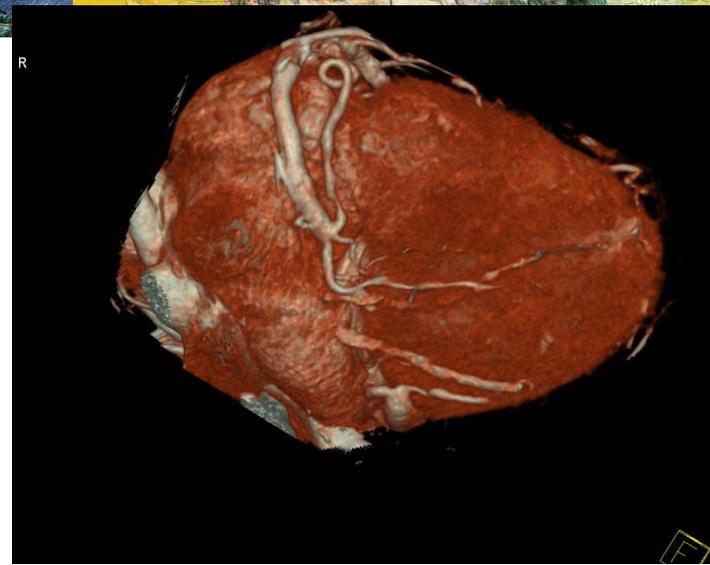


70% of R-R

Myocardial bridging with milking sign, mLAD
And significant stenosis at pLAD

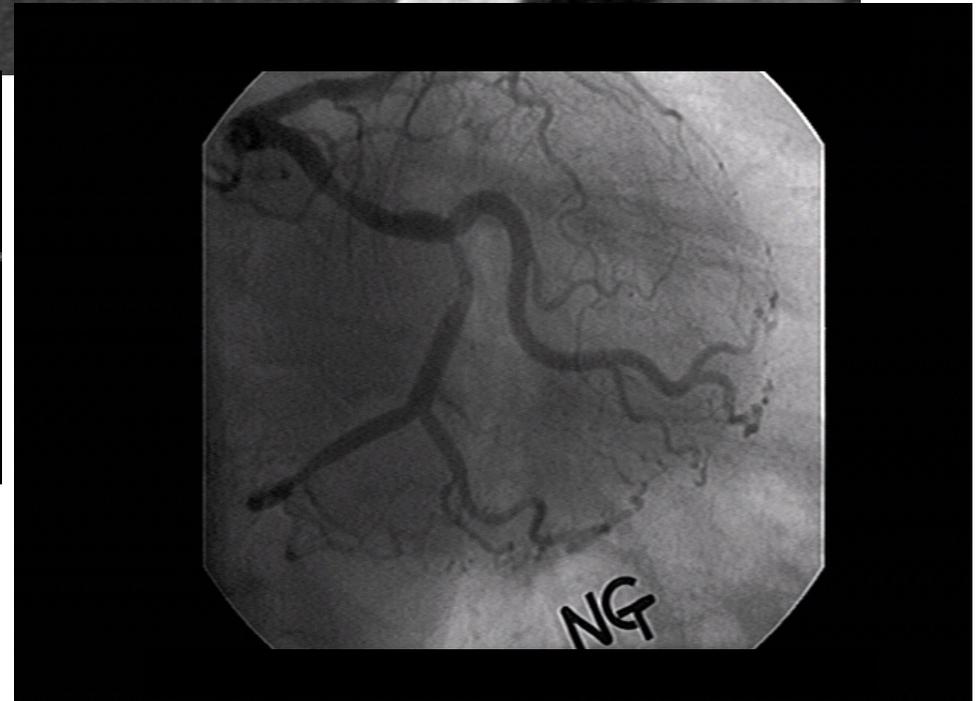
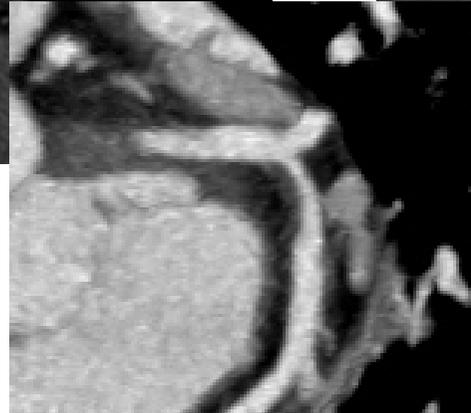
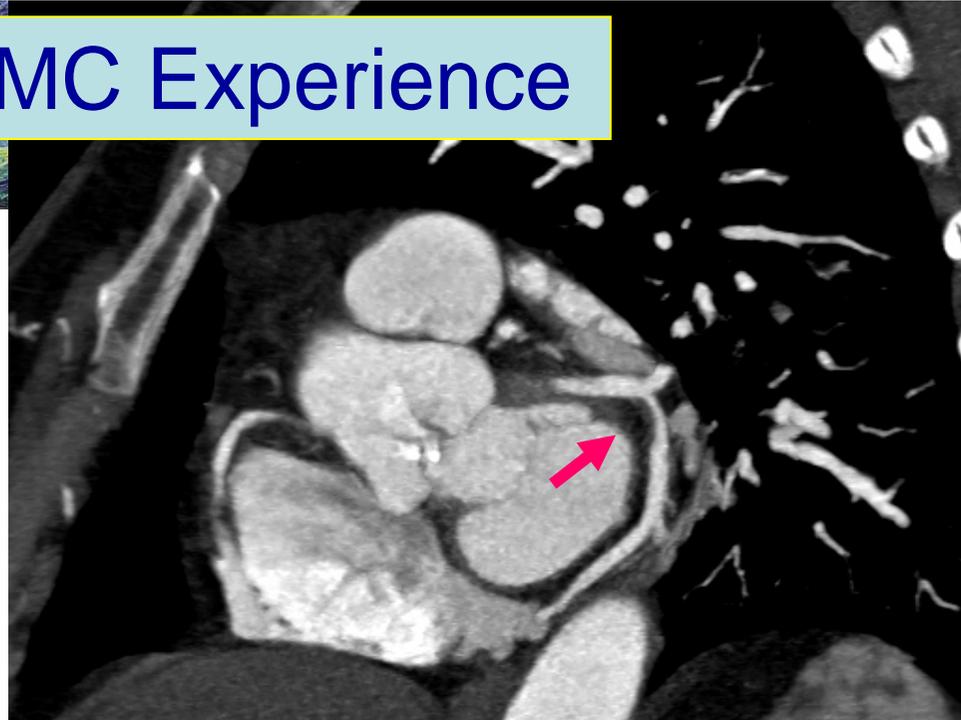
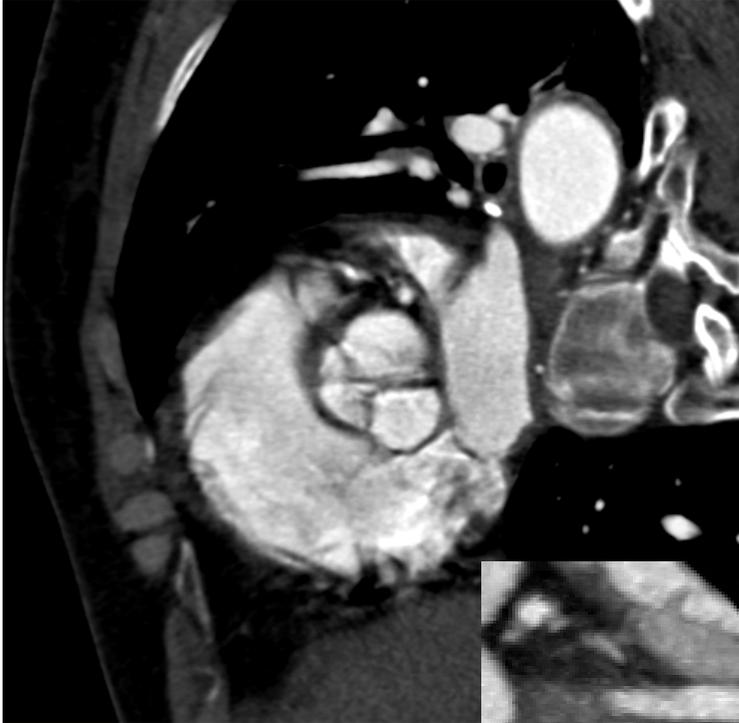
70/M,
post CABG 4 ds
HR: 78~80

DSCT:AMC Experience



DSCT:AMC Experience

65/F
HR: 78~88



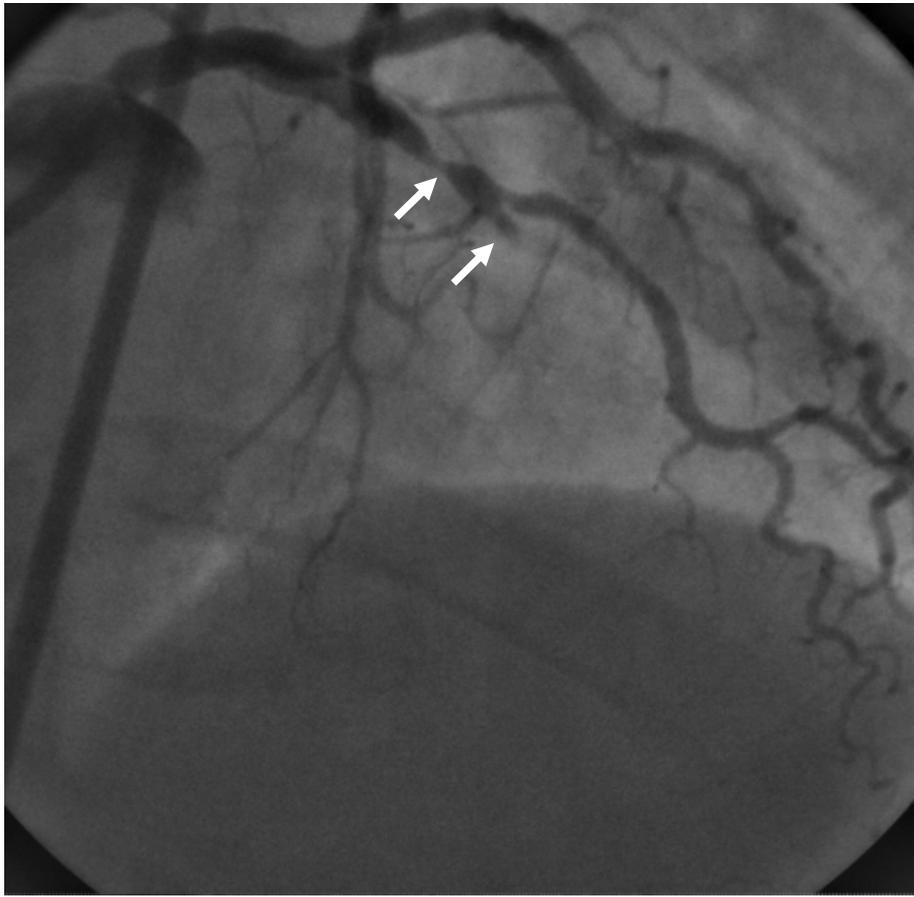
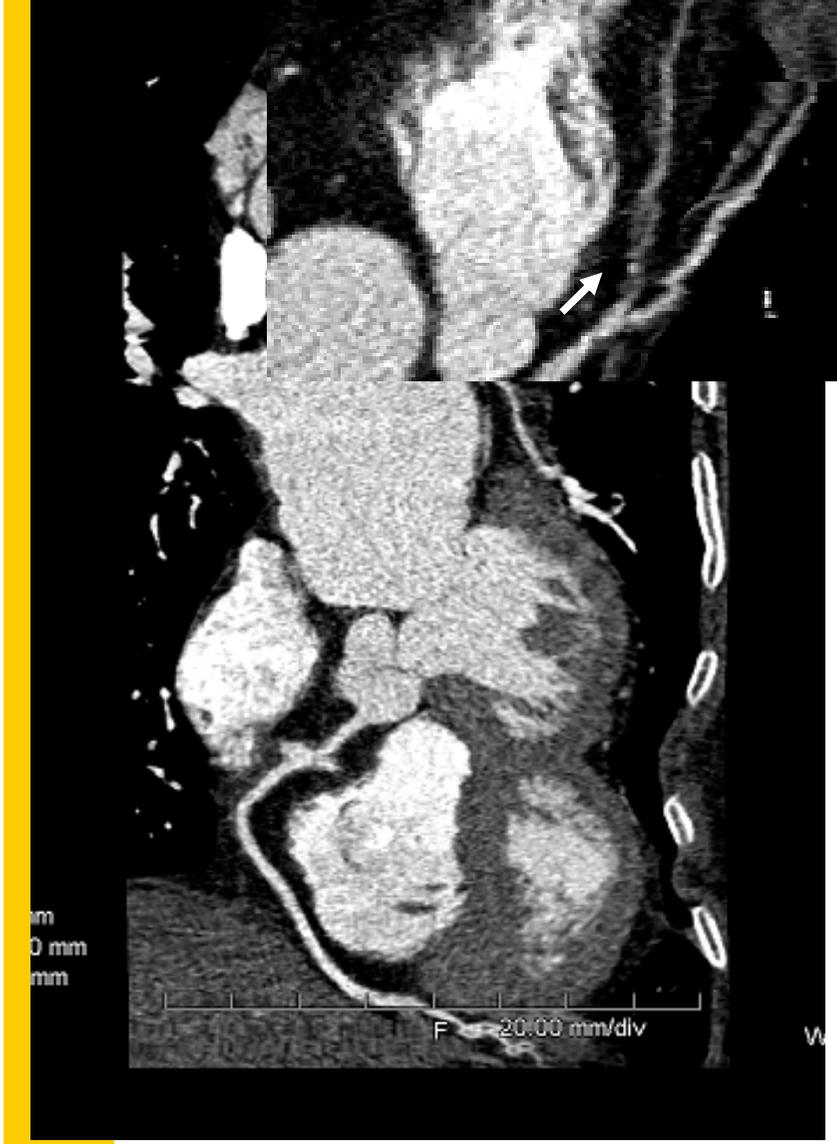
AsR with 60% stenosis at dLCx
→ AVR with CABG



AMC experiences

- F/51
- C.C.: Chest pain (1Yr ago, agravated since 3months)
- DM (+), hypertension (+)
- Ca score (Agaston's score): 4.4



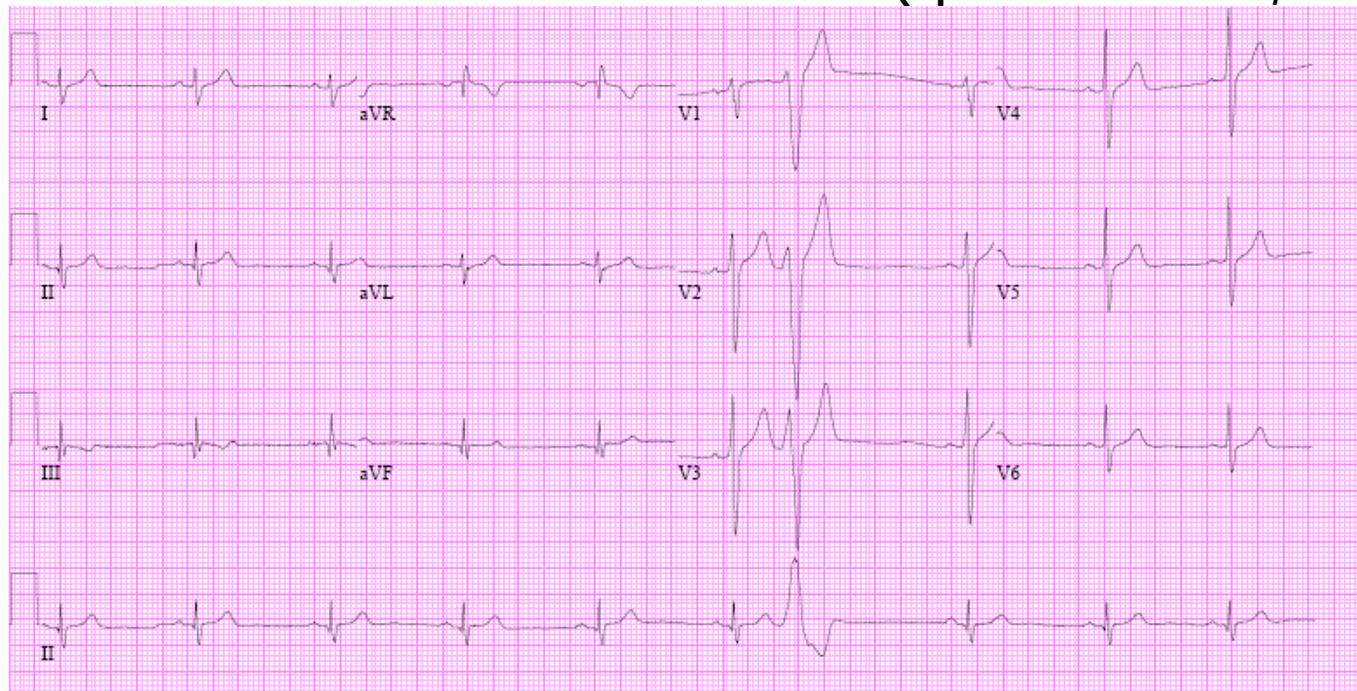


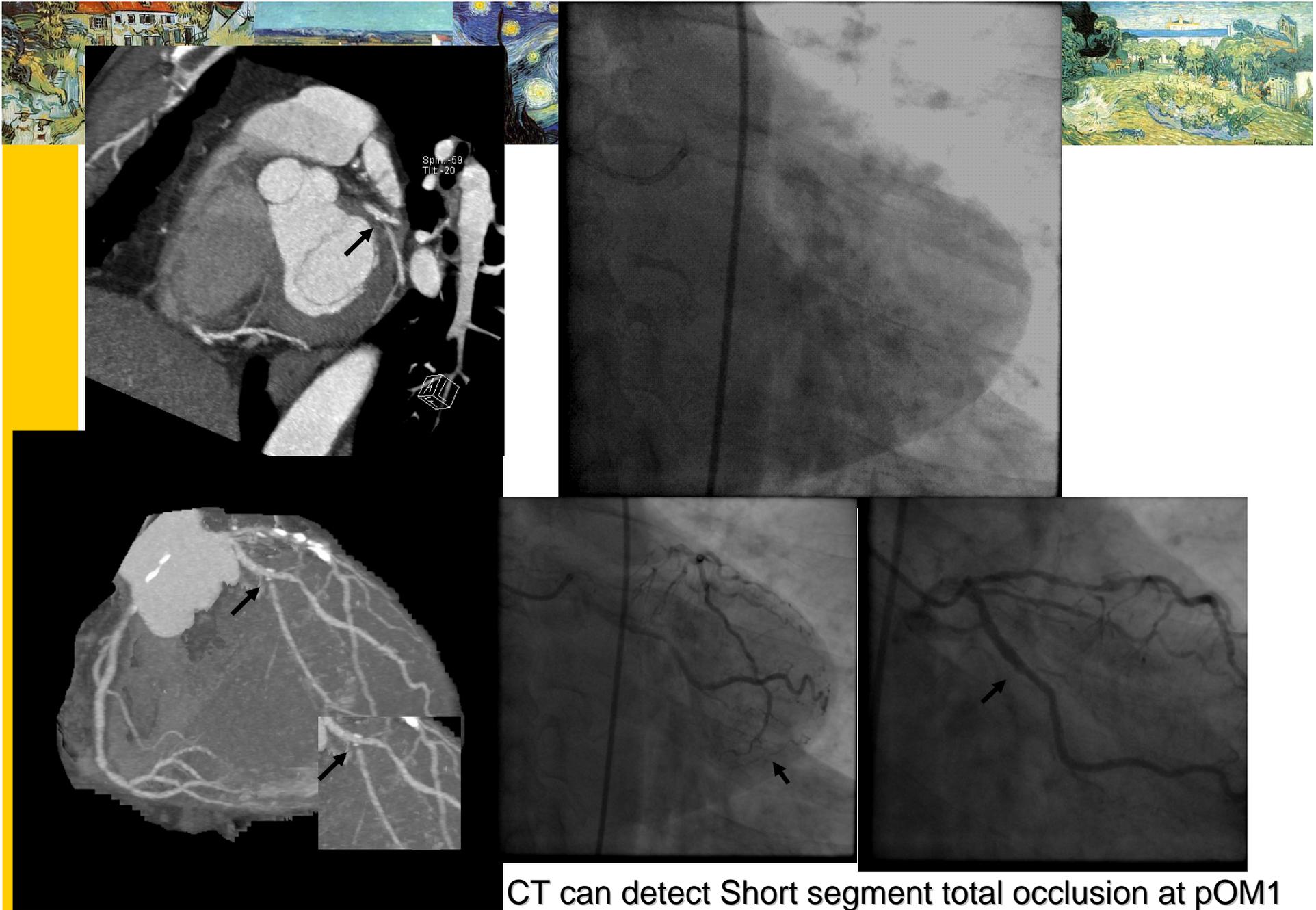
Total Occlusion mid to distal LAD , TIMI grade 0
Focal severe stenosis at pLAD



AMC experiences

- M/46
- ECG abnormality:
 - Possible inferior wall infarct (q wave at III, aVF)



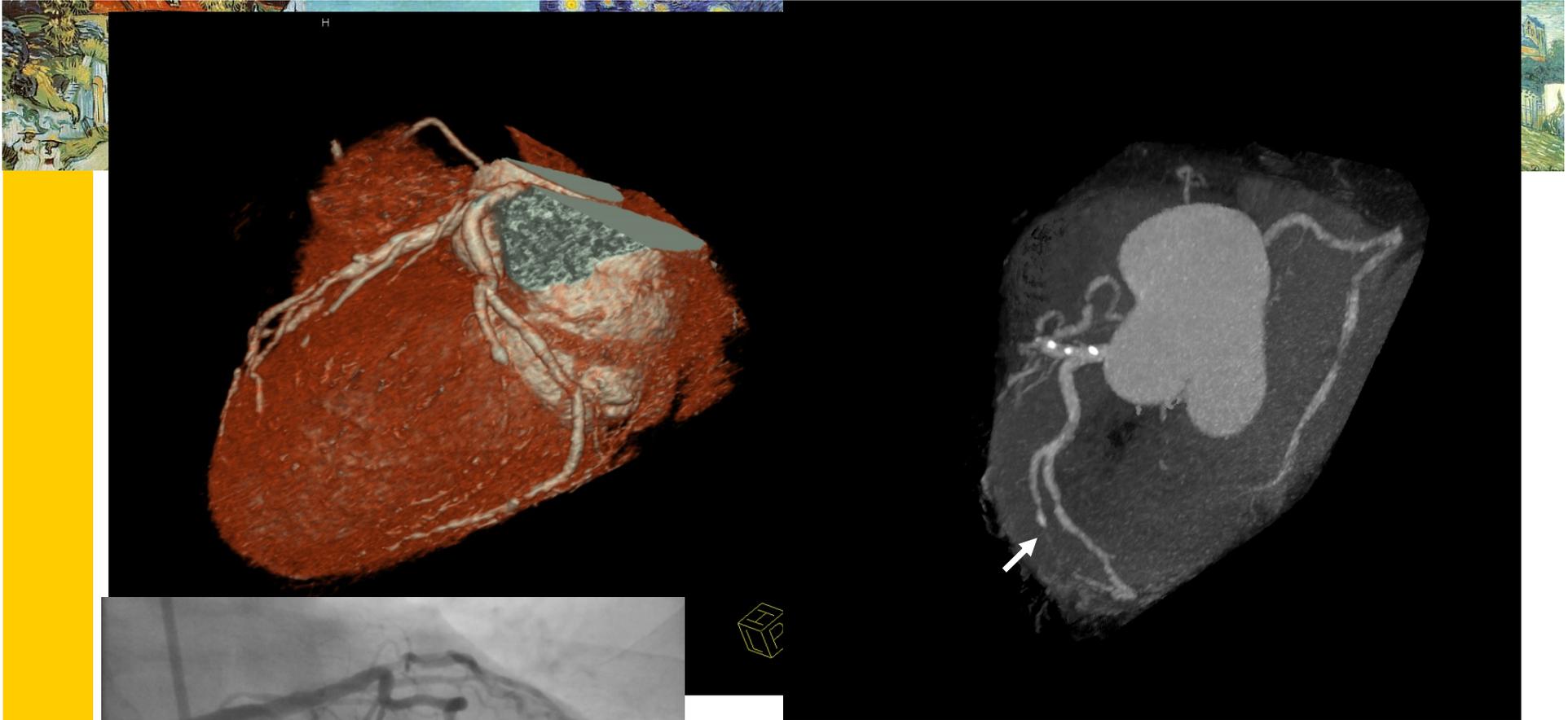


CT can detect Short segment total occlusion at pOM1
- Delayed, retrograde filling of OM2
- Stump of dLCx

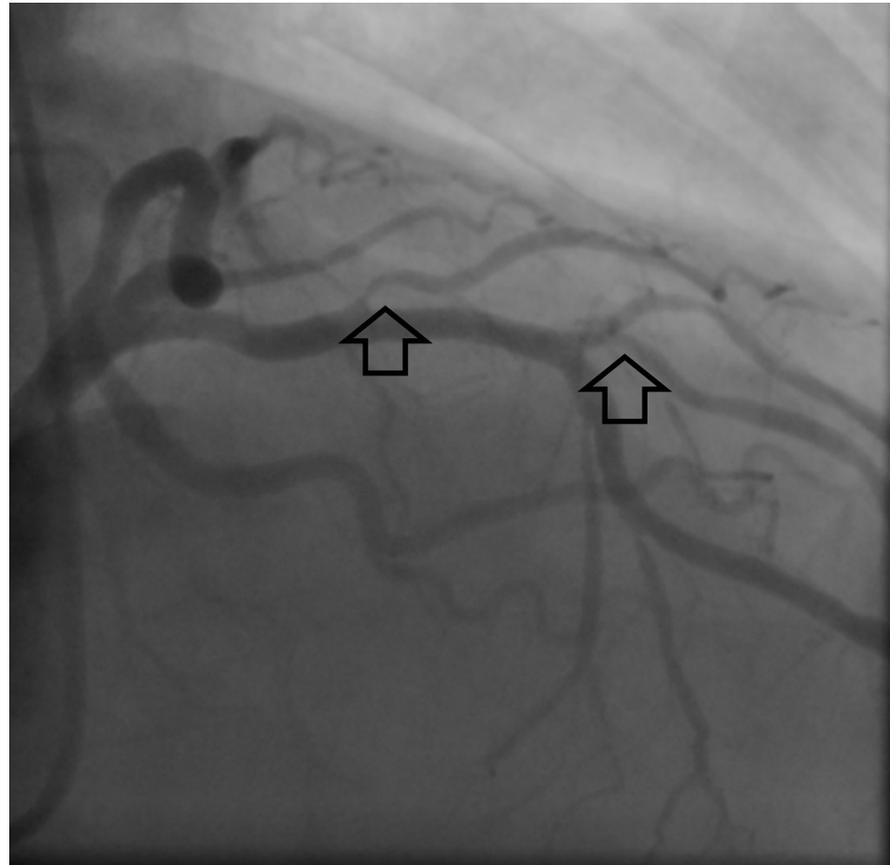
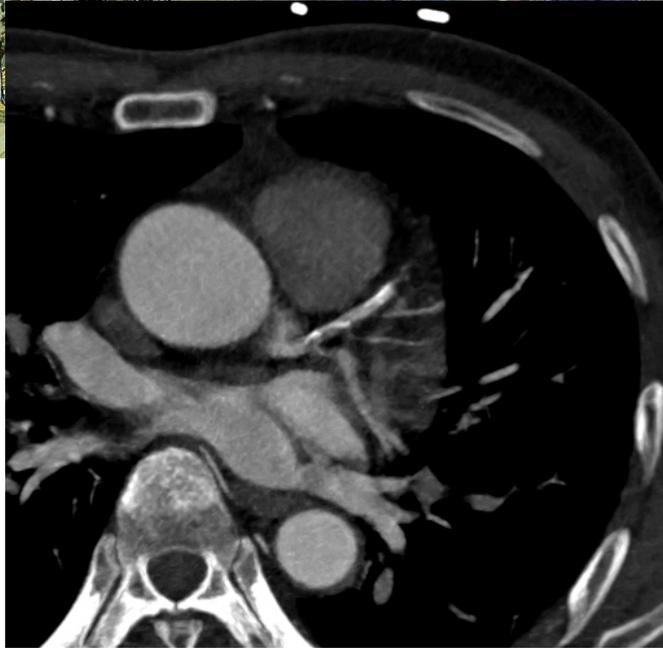


AMC experiences

- M/58
- Exertional chest pain from '07. 5
 - Progression to resting chest pain (10 /day)



Total occlusion at OM1



CT exaggerates stenosis at D2 and D3 than CAG (also significant stenosis)



Accuracy of DSCT in a High Pre-test Probability Population

	Total	Mean HR		Agatston score	
		< 70 bpm	> 70 bpm	< 400	> 400
No. of pts	30	17	13	15	15
Mean HR (bpm)	70.3 ± 14.2	59.7 ± 5.9	84.2 ± 8.4	70.6 ± 13.7	70.0 ± 15.1
Agatston score	821 ± 904	901 ± 991	674 ± 780	85 ± 118	1.483 ± 893
Sensitivity	96.4% (54/56)	97.2% (35/36)	95.0% (19/20)	100% (5/5)	96.1% (49/51)
Specificity	97.5% (335/364)	97.1% (203/209)	98.0% (152/155)	99.5% (208/209)	94.6% (147/155)
PPV	85.7% (54/63)	85.4% (35/41)	86.4% (19/22)	83.3% (5/6)	86.0% (49/57)
NPV	99.4% (335/337)	99.5% (203/204)	98.8% (152/153)	100% (208/208)	98.7% (147/149)

Evaluation : diameter >1.5mm
Prevalence: 15/30 patients

Scheffel H. et al, Eur Radiol 2006



Per patient analysis

	AMC (draft)	Scheffel's
Sensitivity	91.4 (53/58)	93.3 (14/15)
Specificity	81.0 (17/21)	100 (15/15)
PPV	93.0 (53/57)	100 (14/14)
NPV	77.3 (17/22)	93.8 (15/16)
Prevalence	73.4 (58/79)	50 (15/30)

Evaluation : diameter >1.5mm (Scheffel's) vs. all segments (AMC draft)

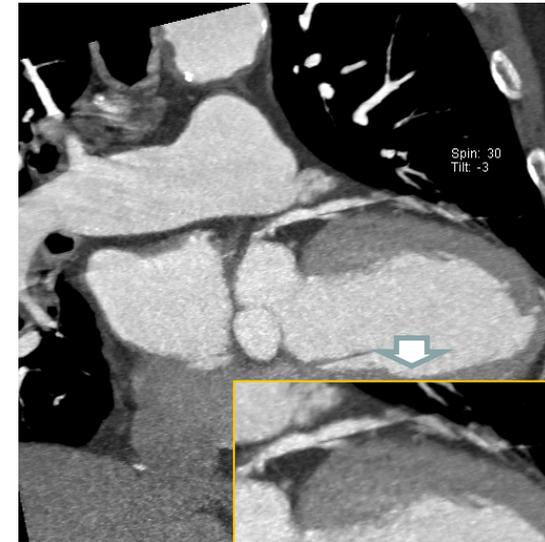


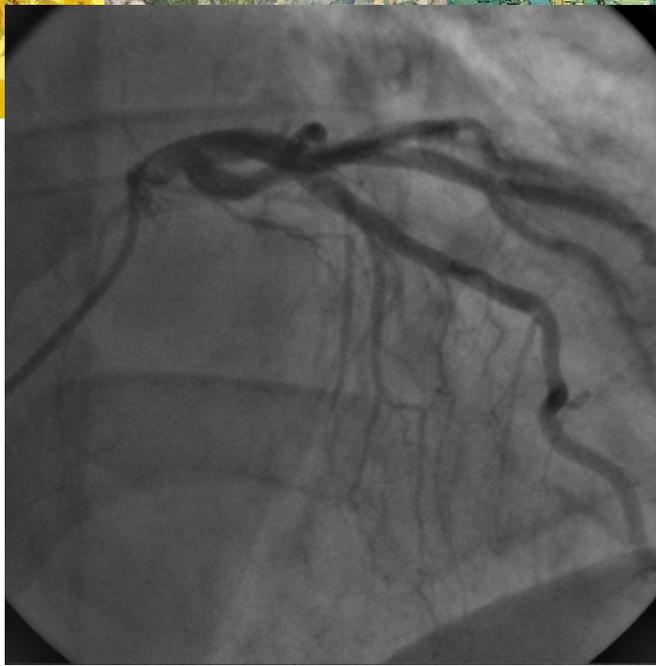
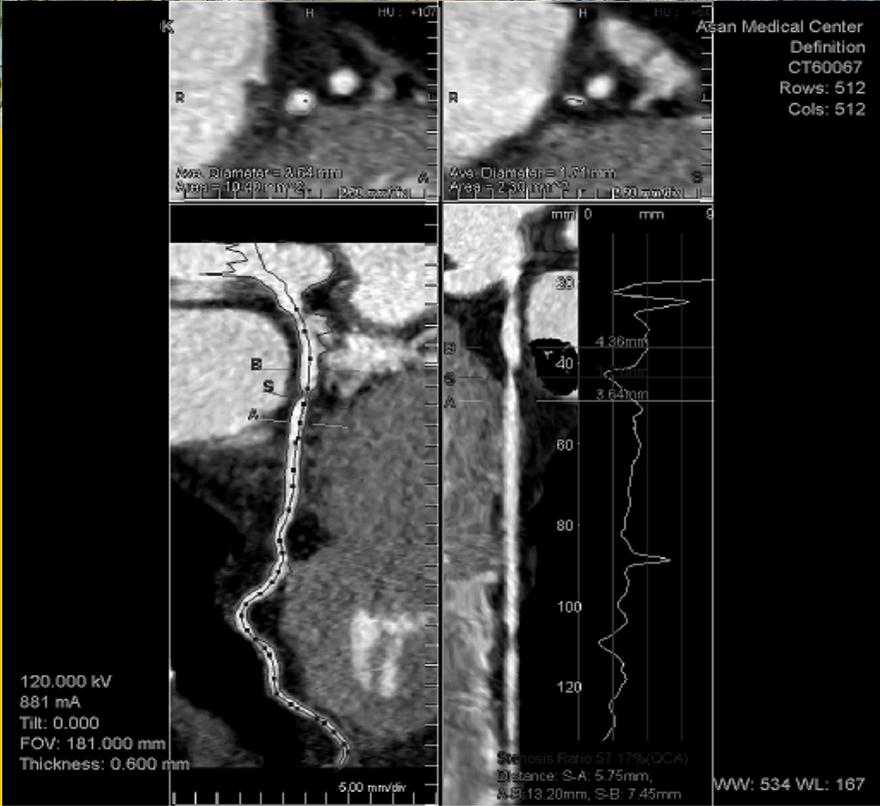
False Positive

- Step-Ladder artifact and band artifact
 - Mis-registration due to HR variation
- Dense Calcified plaque
- Inhomogeneous contrast enhancement
- Myocardial Bridge (?)
- Exaggeration of stenosis in CT



- M/83
- Atypical Chest pain

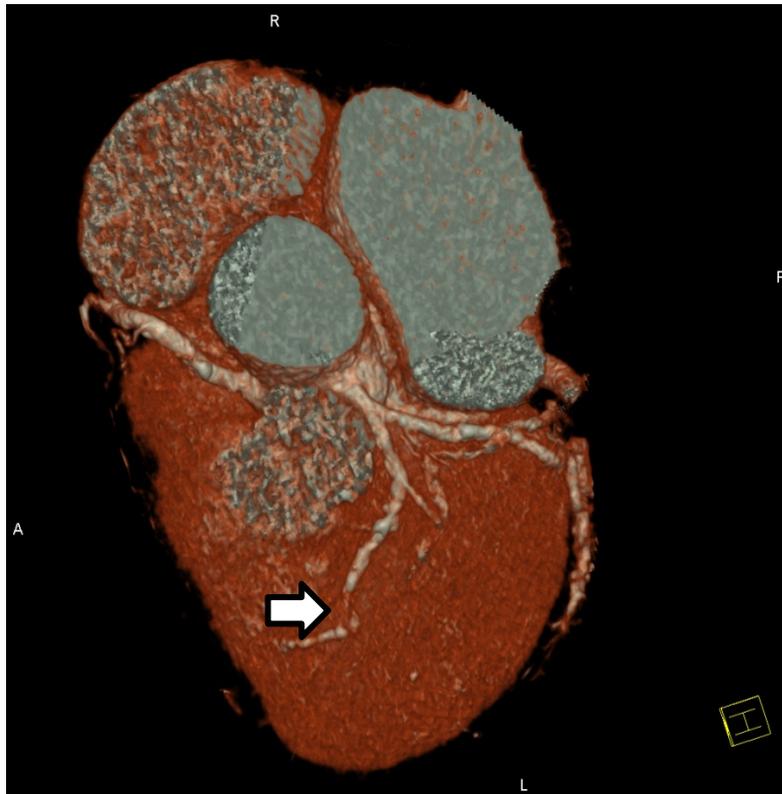


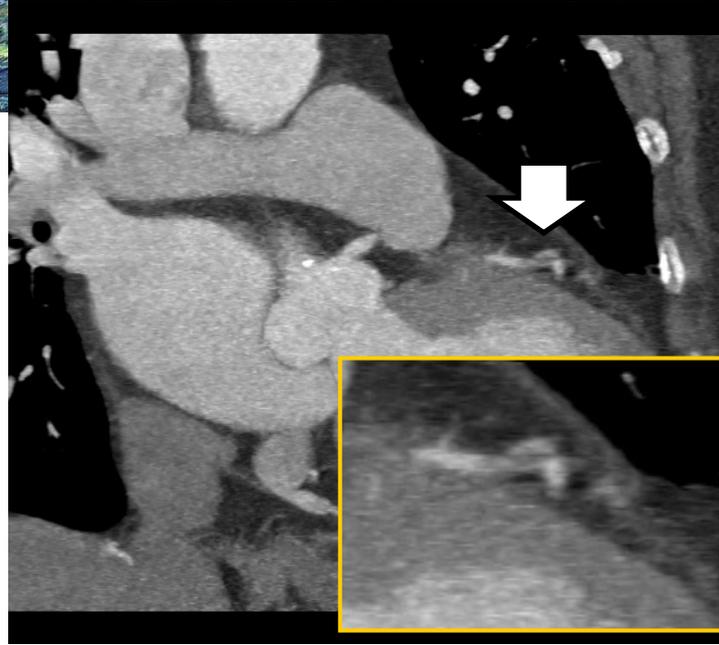
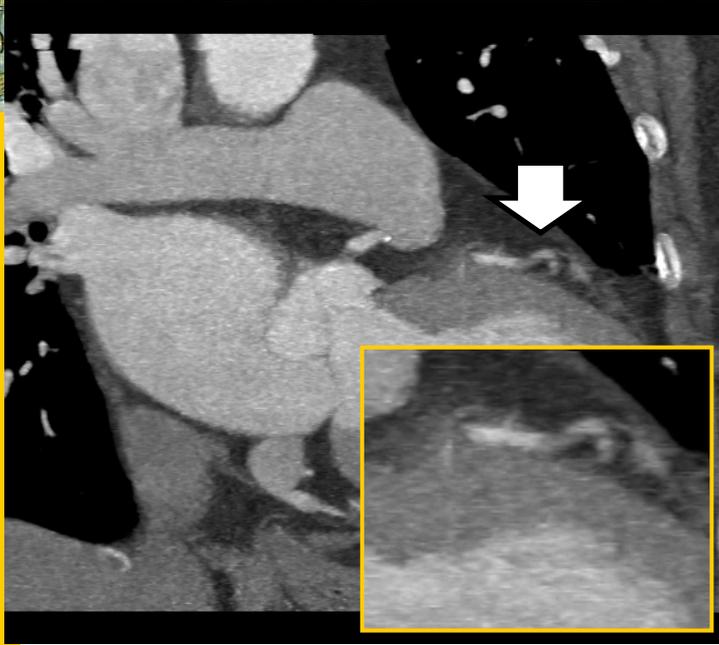
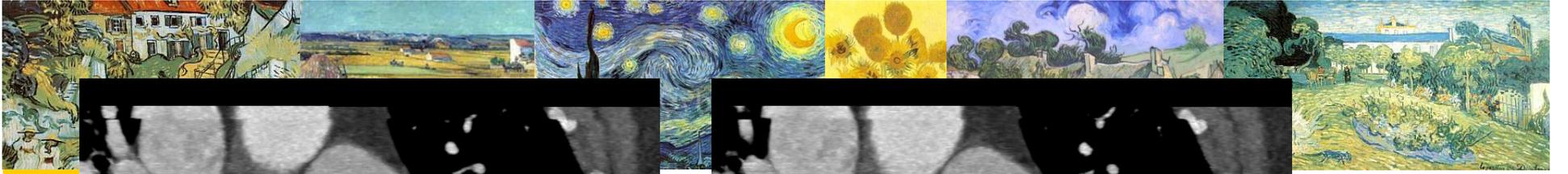


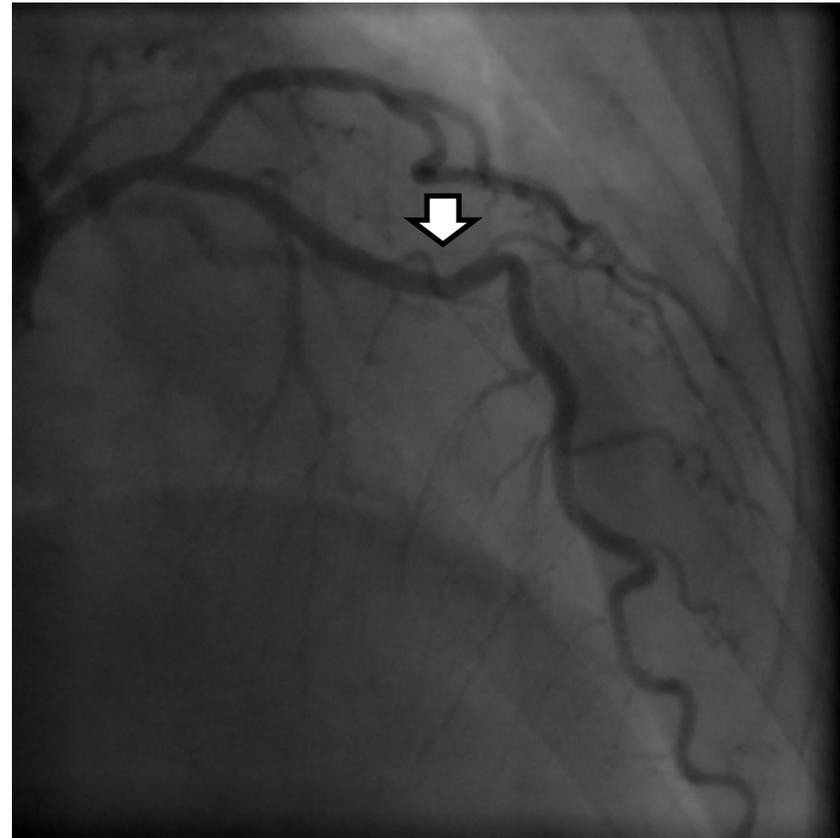
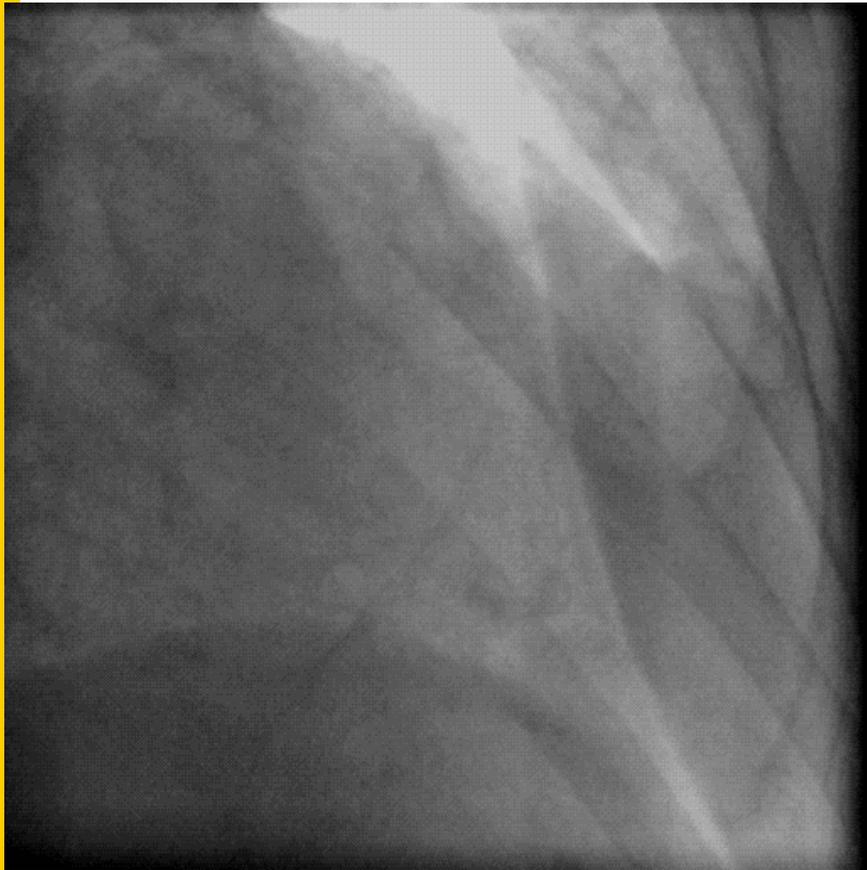
False positive in CT
→ Step-ladder artifact



- F/63
- Atypical Chest pain



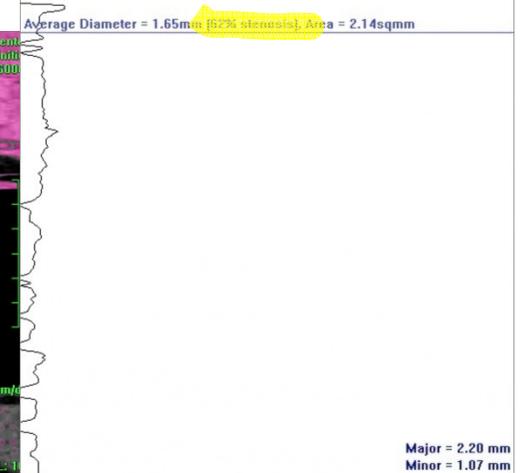
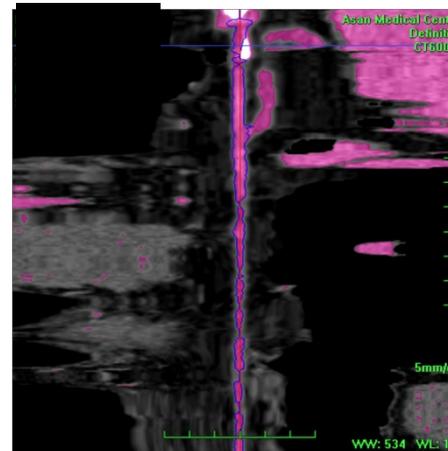
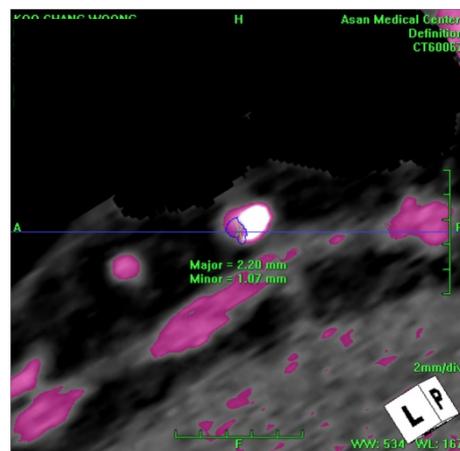
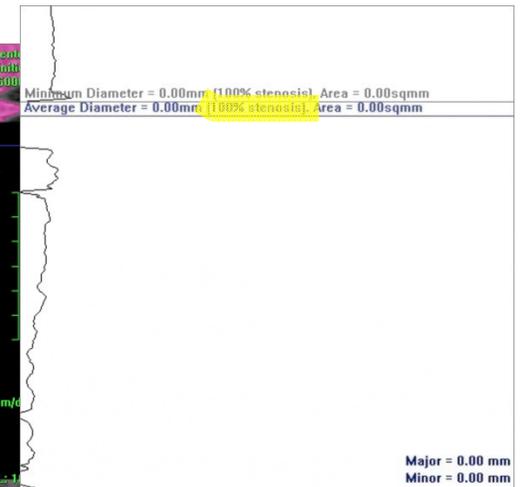
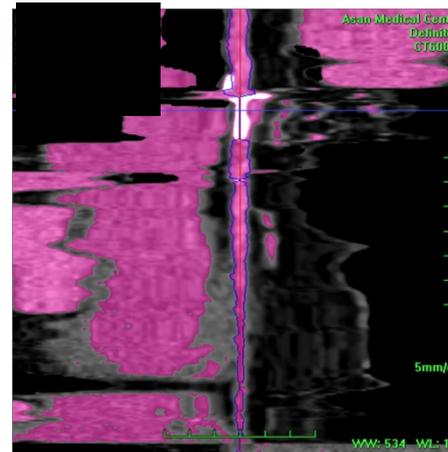
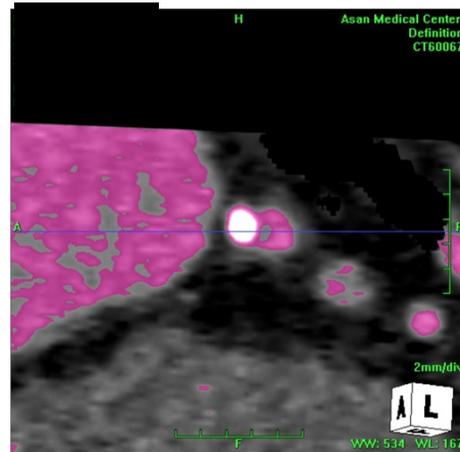


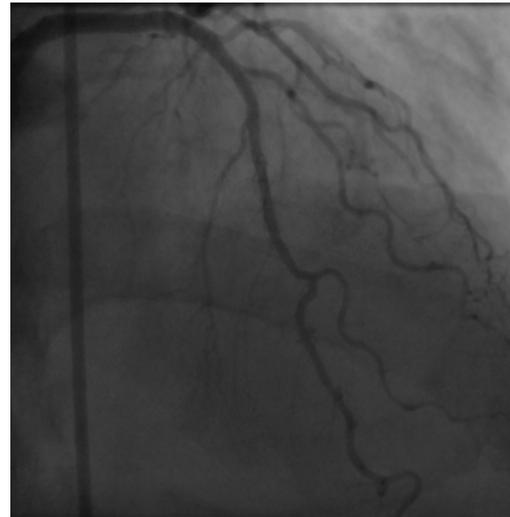
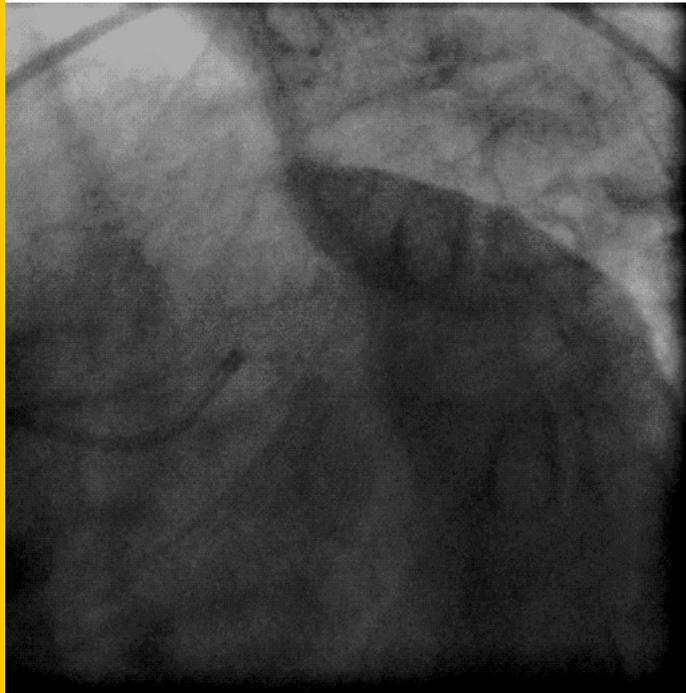


- No stenosis at dLAD (False Positive)**
- Step-ladder artifact
 - Inhomogeneous contrast enhancement

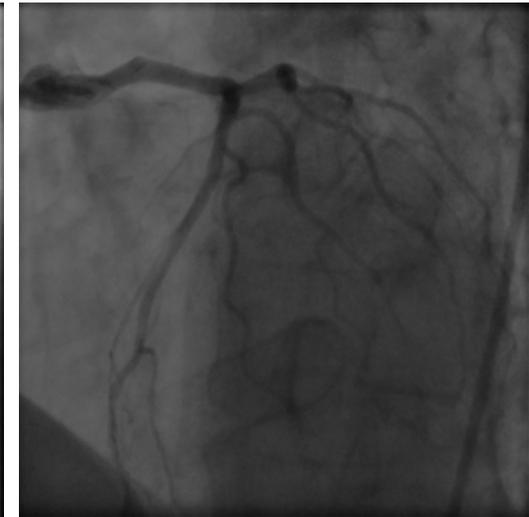


- M/66
- R/O Angina





LAD

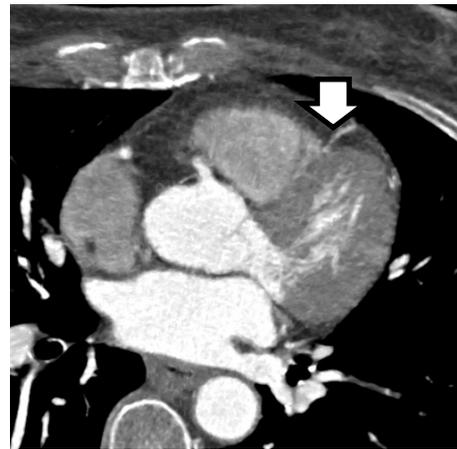
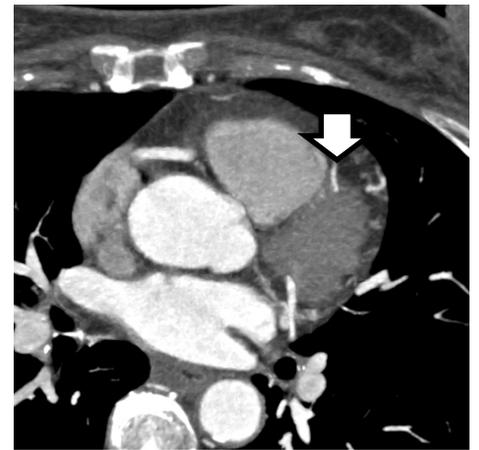


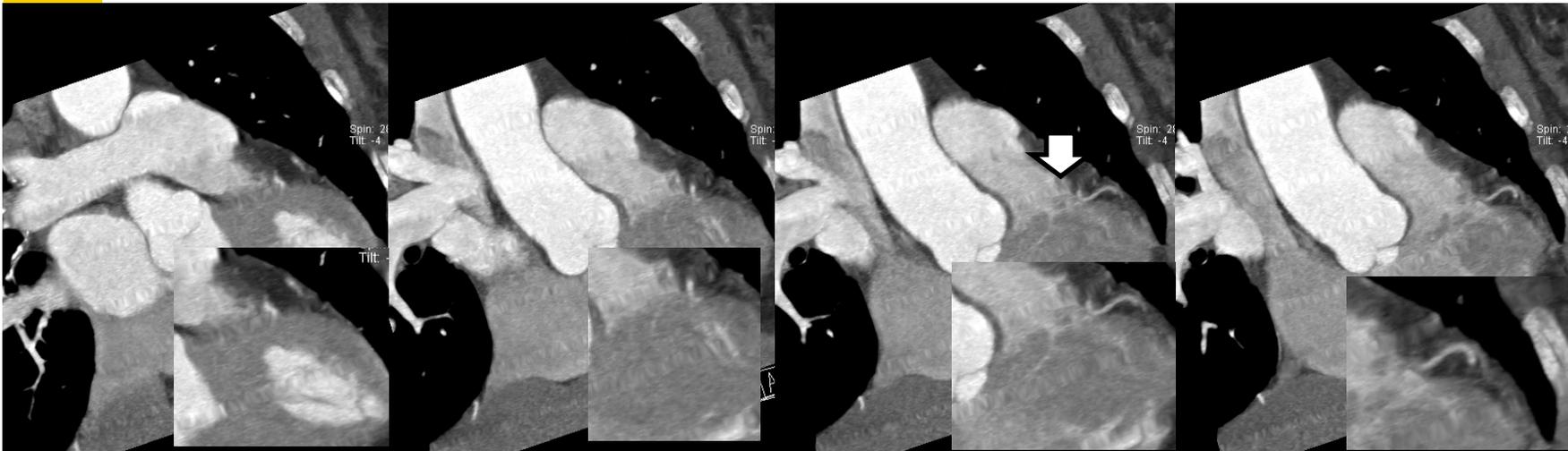
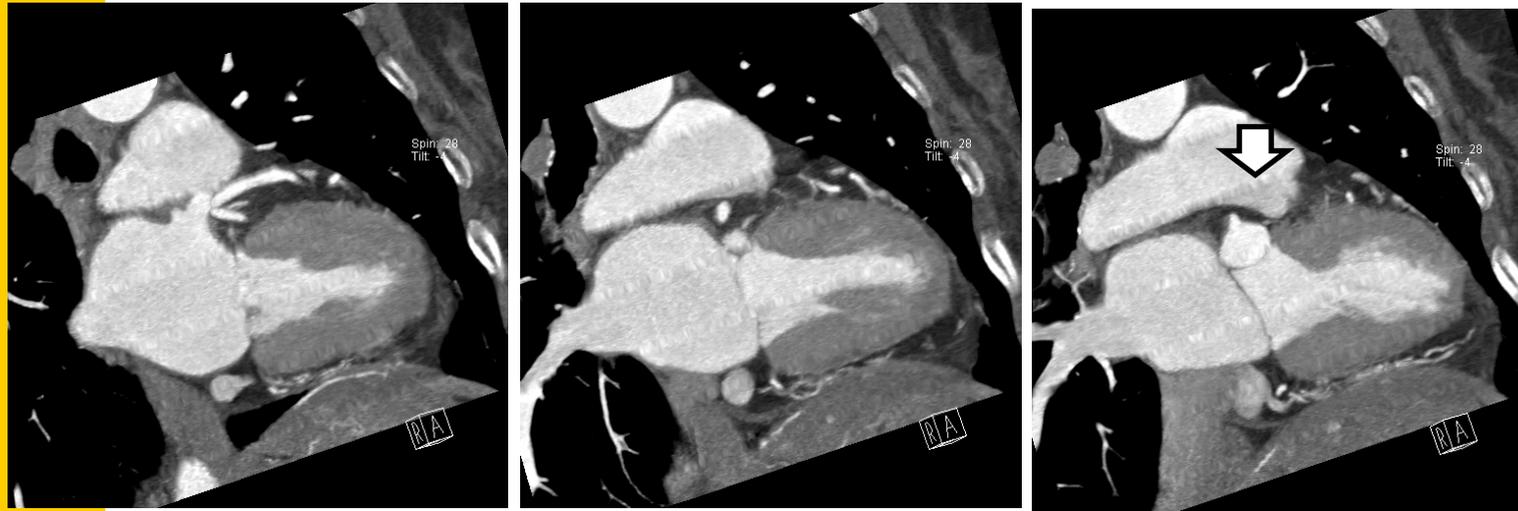
LCX

No stenosis at LAD, LCx (False Positive)
- Dense Calcified plaque

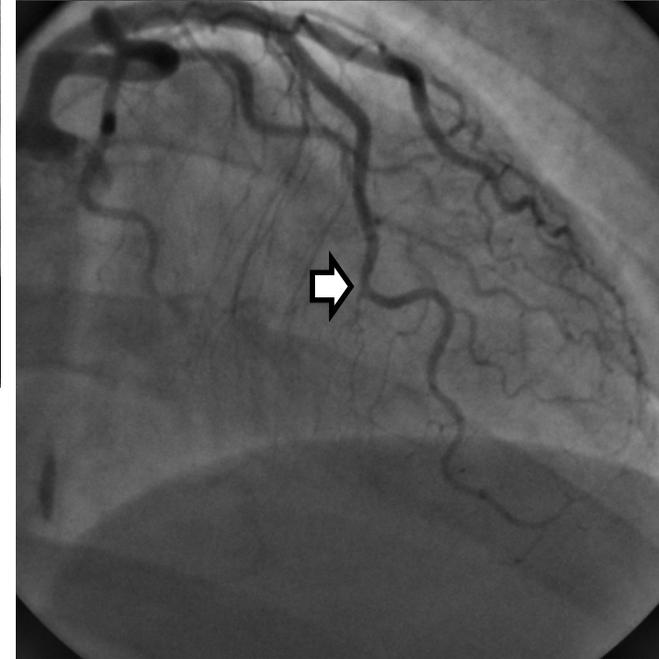
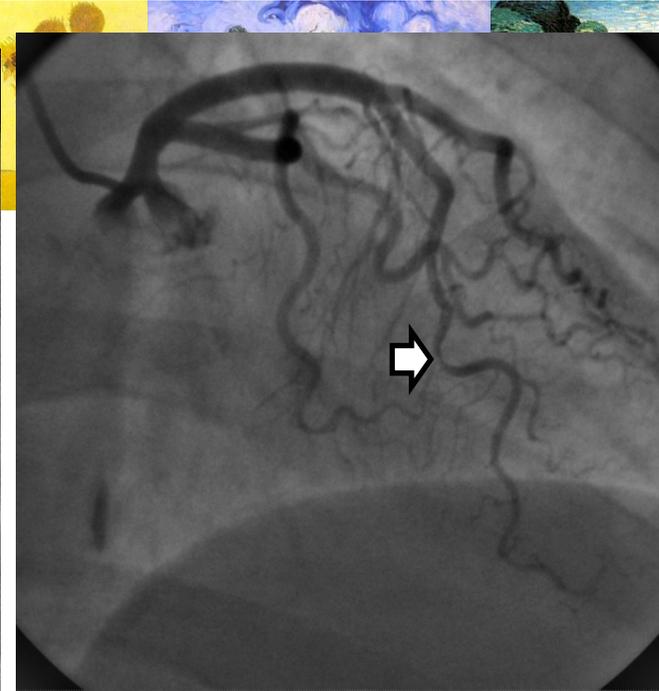
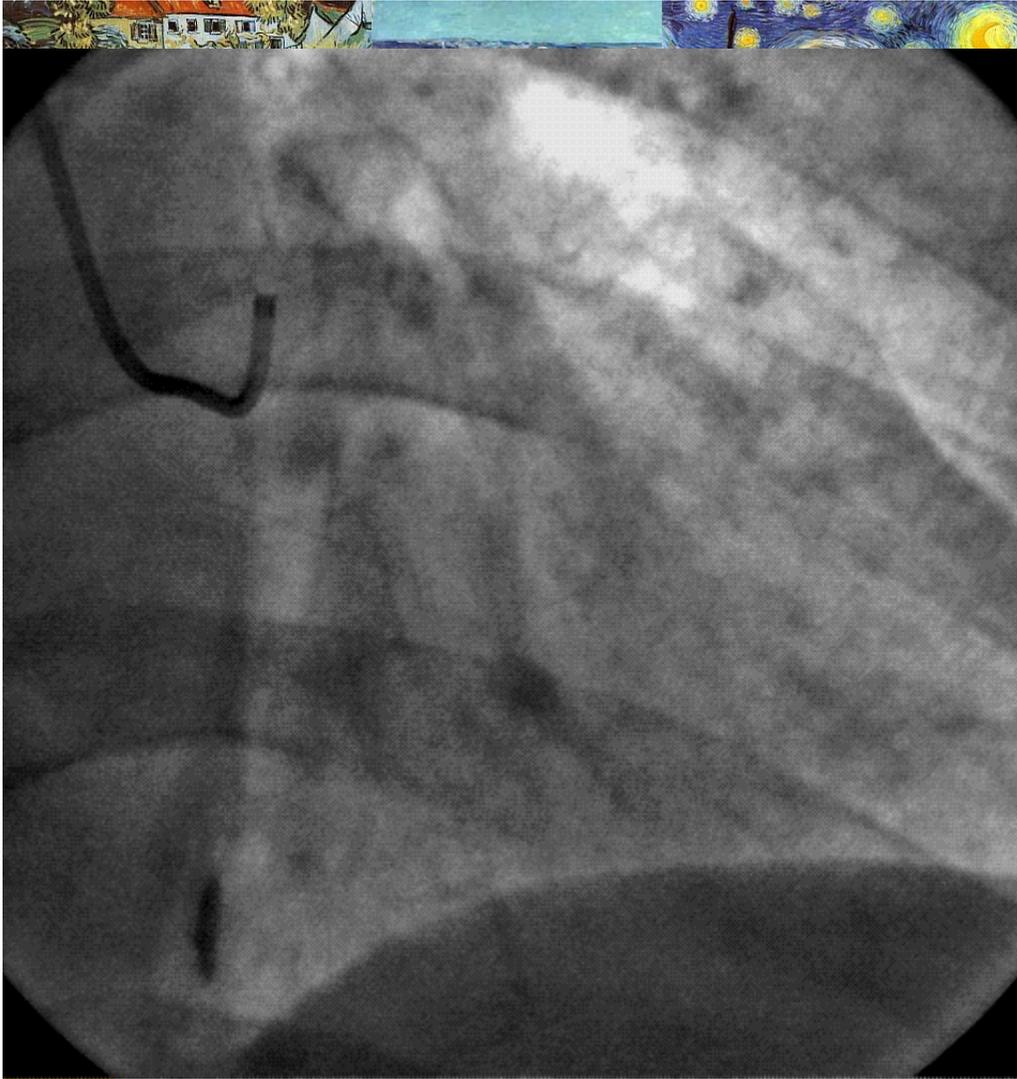


- M/57
- R/O Angina





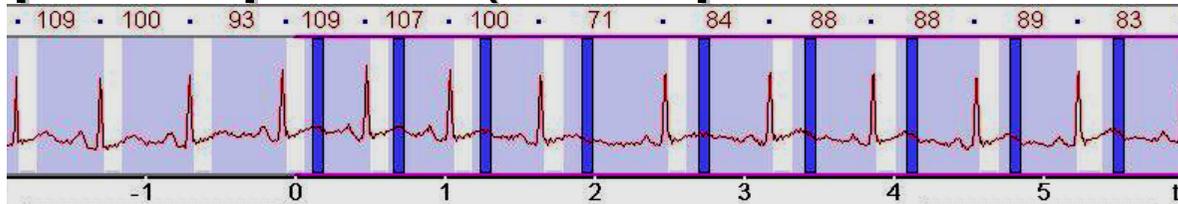
R/O tight stenosis at dLAD (CT)
Look "interpolation artifact" (arrow)



Short segment myocardial bridge



Adaptive pitch (Interpolation artifact)



Average HR : 101
Pitch : 0.5

HR : 86
Pitch : 0.42

HR : 71
Pitch : 0.33

Low HR artifact :
about 20bpm down

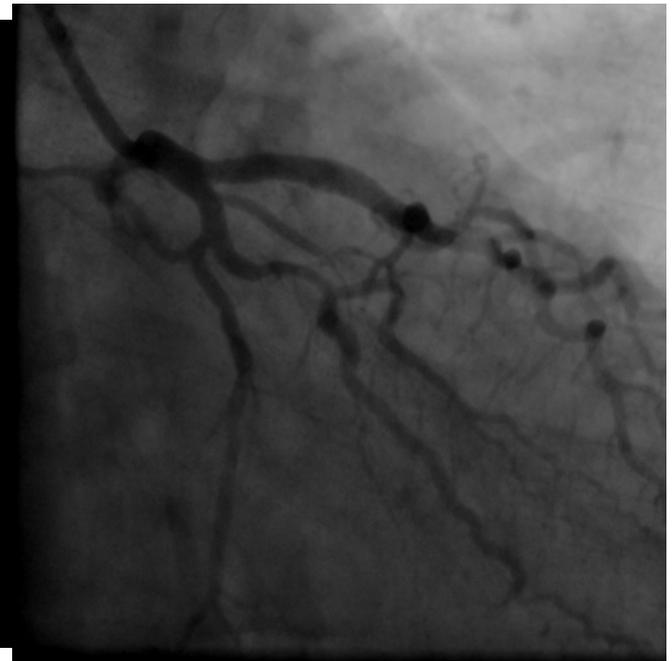
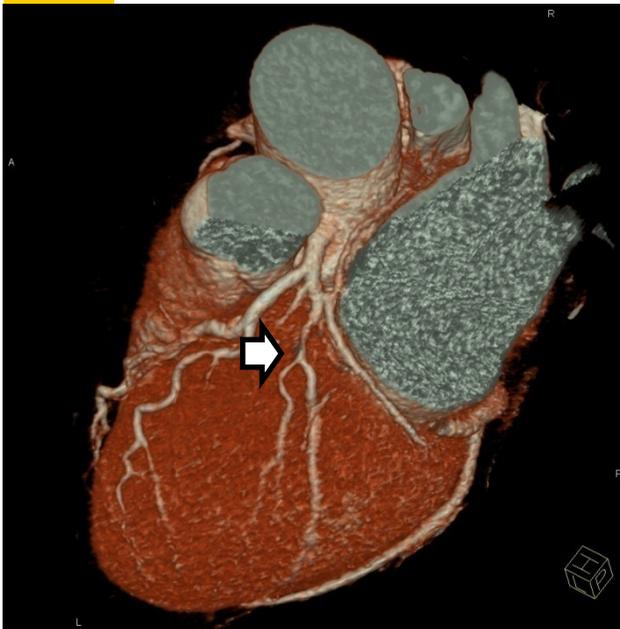


False Negative

- Step-Ladder artifact and band artifact vs. true stenosis
 - Missed registration due to HR variation
- Dense Calcified plaque
- Inhomogeneous contrast enhancement
- Simply missed lesion
- Discrepancy with CAG



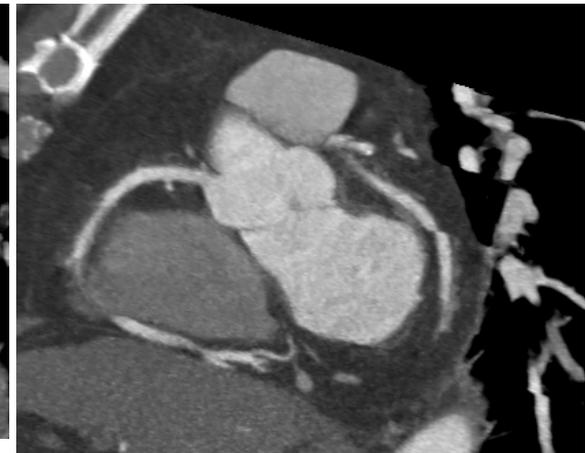
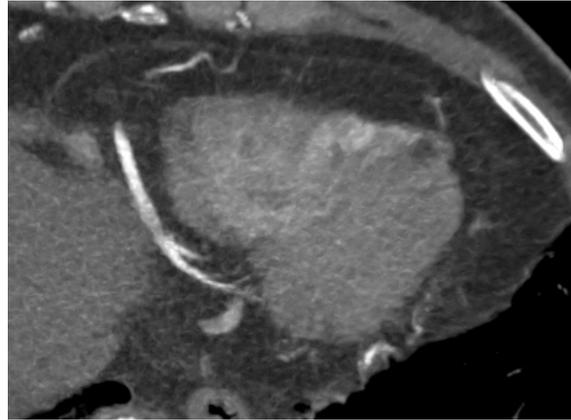
- M/67
- Evaluation of Angina



→ Missed OM1 lesion in CT interpretation
(False negative)



- M/69



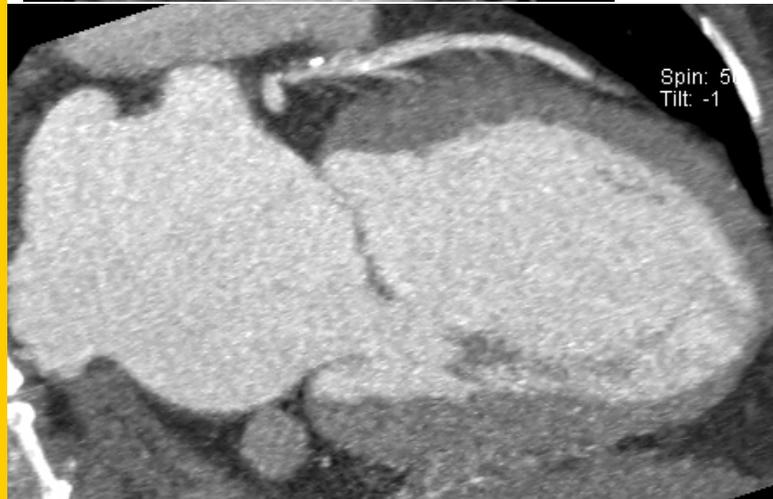
Step-ladder artifact > True stenosis , dRCA-PDA
(in CT interpretation)



True stenosis , dRCA-PDA
(False negative)



- F/60



Significant stenosis ,
with dense Ca plaque
(False negative)

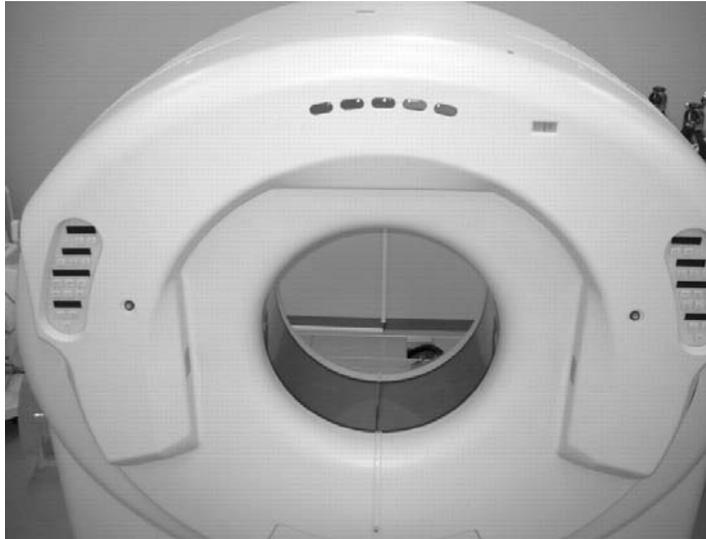


Reduce radiation dose: Changing concept?

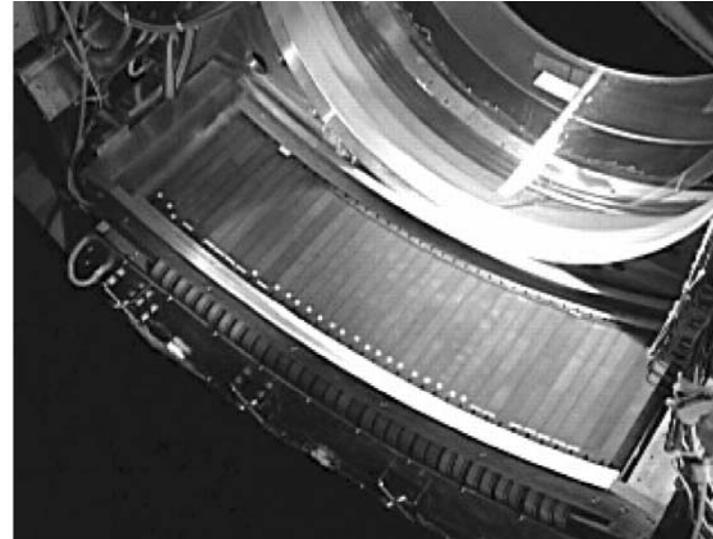
- Return to prospective gating (triggering)
 - 256-slice multi-detector CT (Toshiba)
 - Isophasic imaging with 12cm detector array
 - Right Vision with 256-slice detector (Philips)
 - Snapshot pulse (GE) / Step & Shoot (Philips)
 - 3 shots for entire scan
- Adaptive pitch, mindose (Siemens)



256 slice CT (Toshiba)



(a)



(b)

Examination	DPI _w (mGy·mm)		DPI _w percentage (%)
	256-slice CT	16-slice CT	
Head	6410	12127	52.9
Chest	1775	2462	72.1
Abdomen	4725	5773	81.9
Pelvis	7088	7981	88.8



Snapshot pulse (GE) / Step & Shoot (Philips)

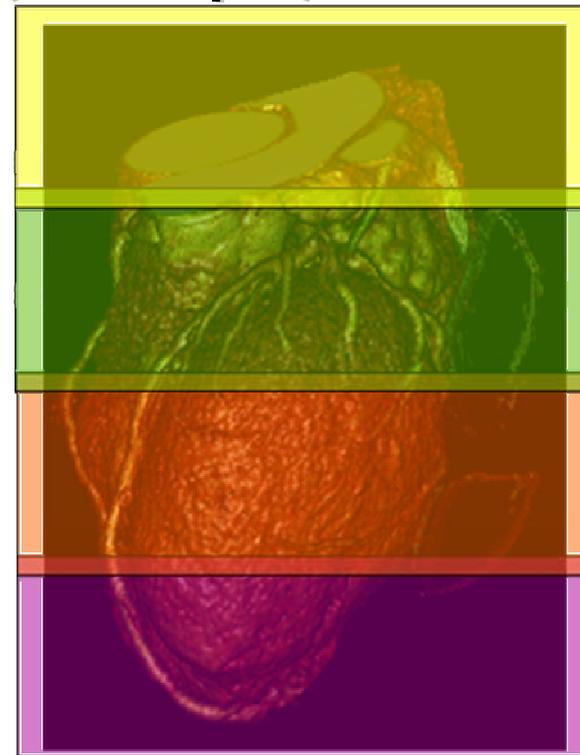
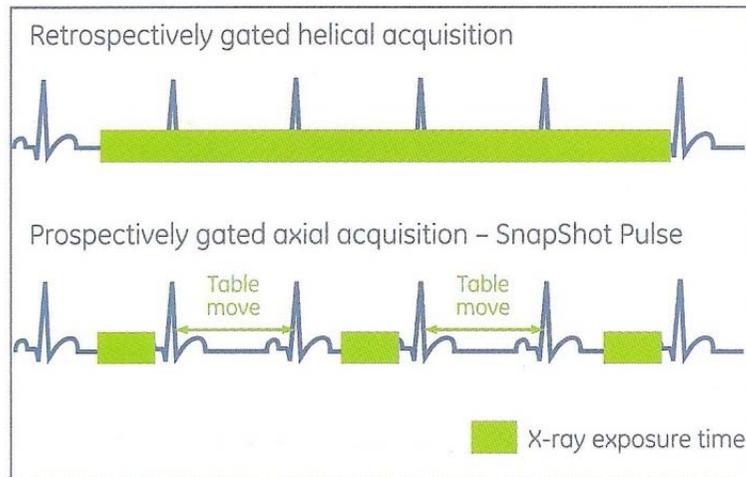
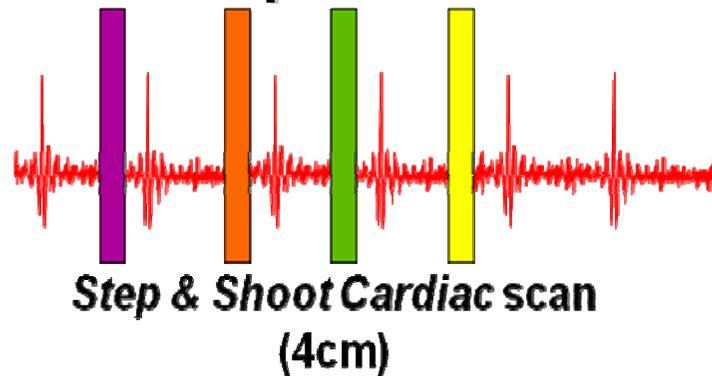


Figure 2 - Retrospective gating helical vs SnapShot Pulse acquisition



Siemens CVCT - Effective Dose

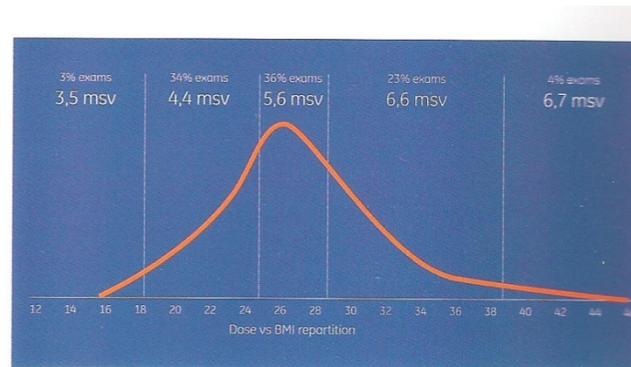
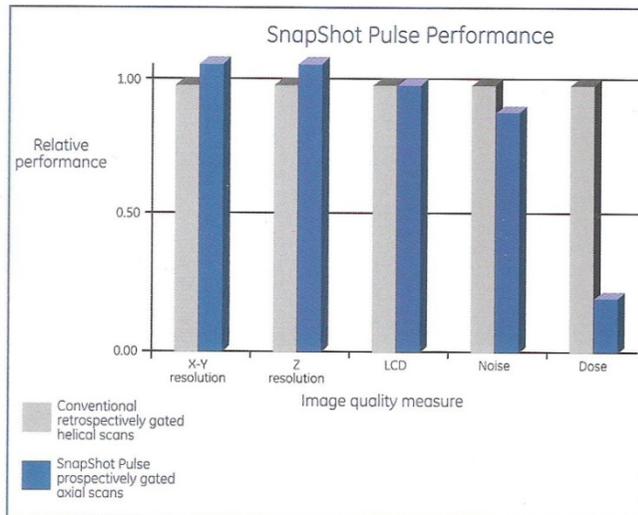
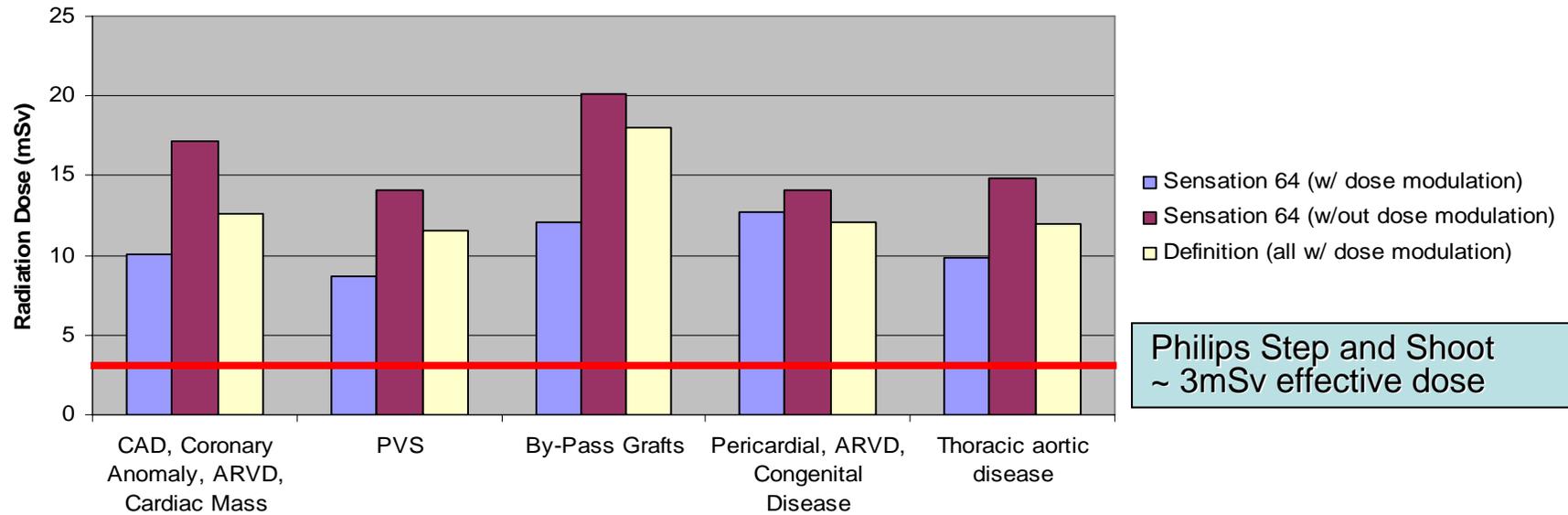


Figure 4 - Exam Repartition vs BMI and average corresponding dose.

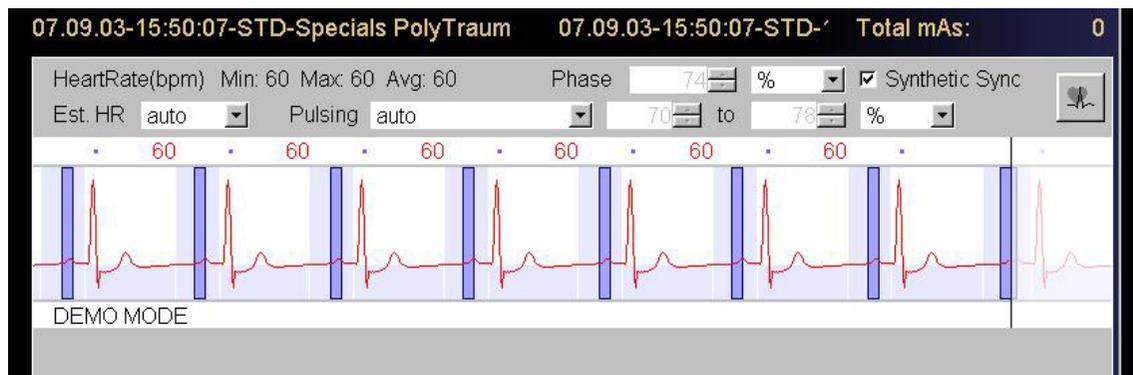
Stats from CCN, Saint Denis, France.

- 600 patients
- 5 mSv average
- Low dose acquisition whatever patient morphology

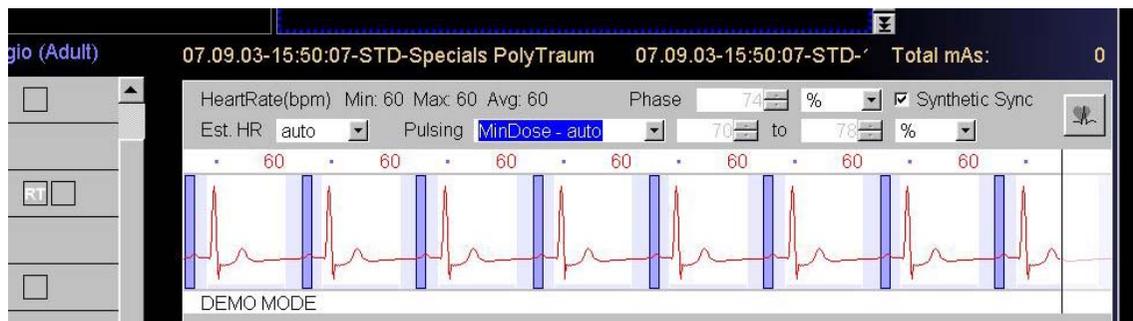


Mindose

- Low Dose plateau : 4% of max. dose



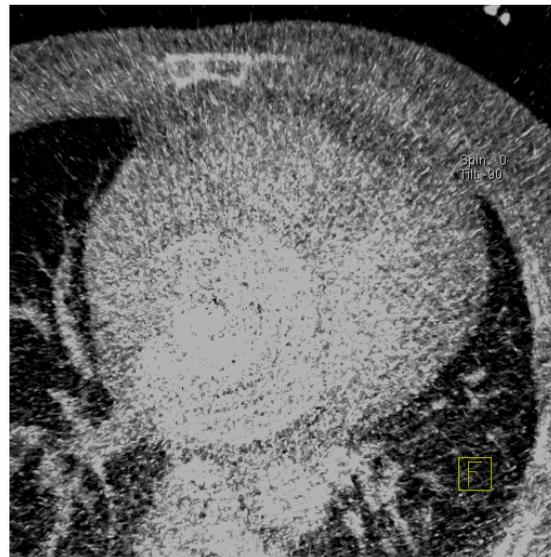
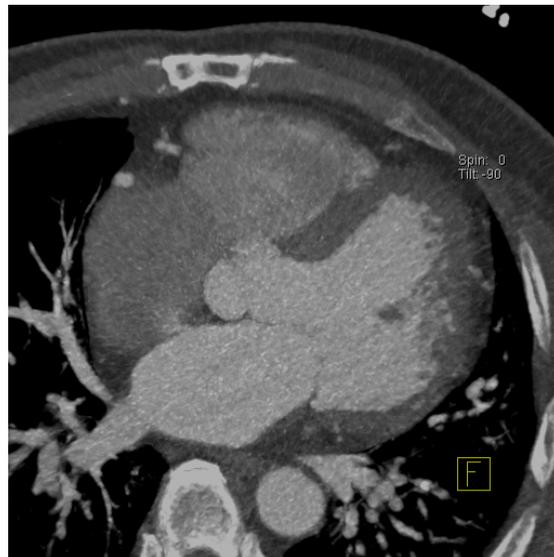
ECG-Pulsing



ECG-Pulsing (Mindose)



ECG-Pulsing



ECG-Pulsing (Mindose)
→ Not adequate for functional study



Adaptive pitch

Table 1 Heart-rate-dependent pitch and table feed settings for the evaluated dual-slice computed tomography (DSCT) scanner

Heart rate in bpm	Pitch	Table feed in mm/s
50	0.21	12.8
60	0.27	16.0
70	0.32	19.2
80	0.37	22.4
90	0.43	25.6

Eur Radiol 2006;16:256-268

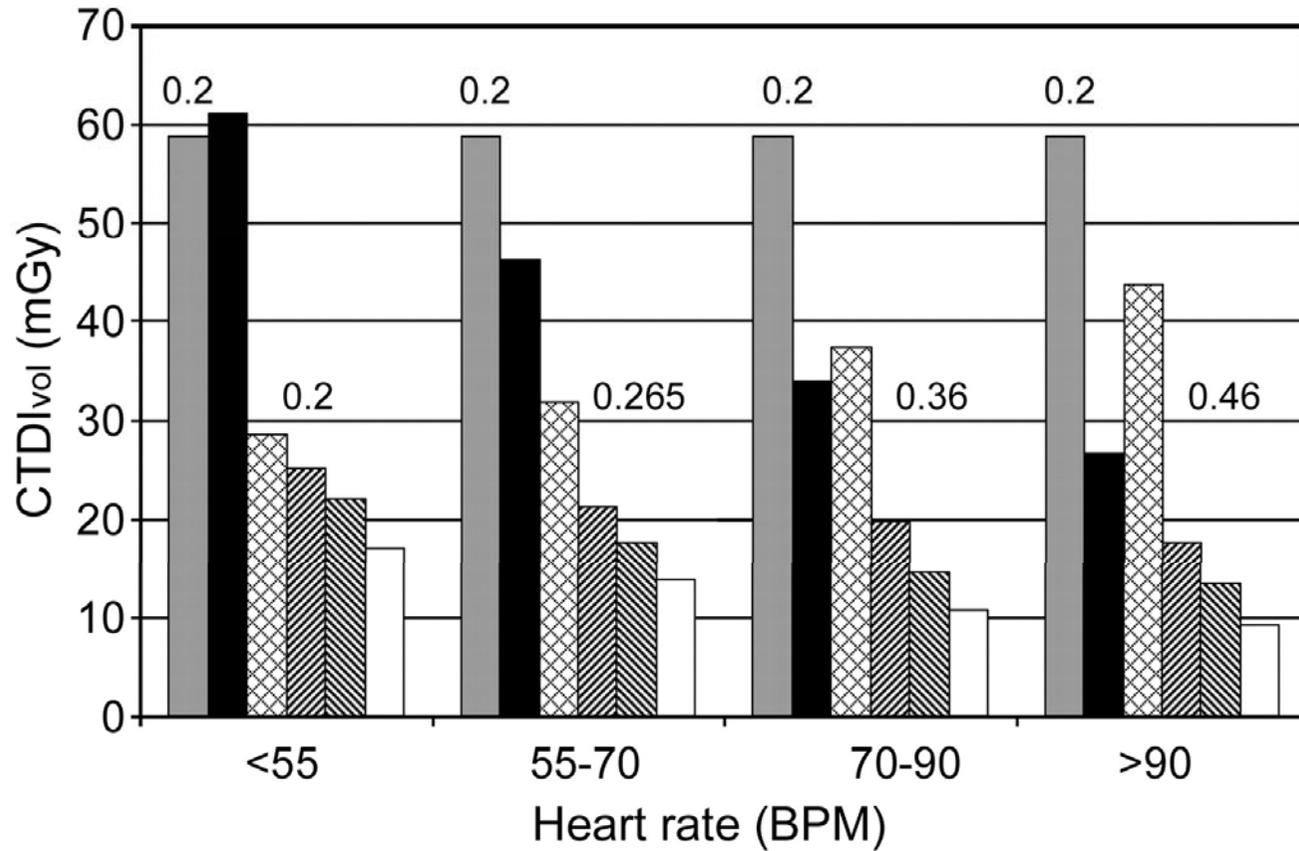
Heart Rate	Pitch
>40	0.2
>50	0.22
>60	0.28
>70	0.33
>80	0.39
>90	0.44
>100	0.5

Using in AMC

Up to 5mSv with
Mindose and
adaptive pitch



MDCT
 DSCT
 MDCT 400 ms
 DSCT 310 ms
 DSCT 210 ms
 DSCT 110 ms

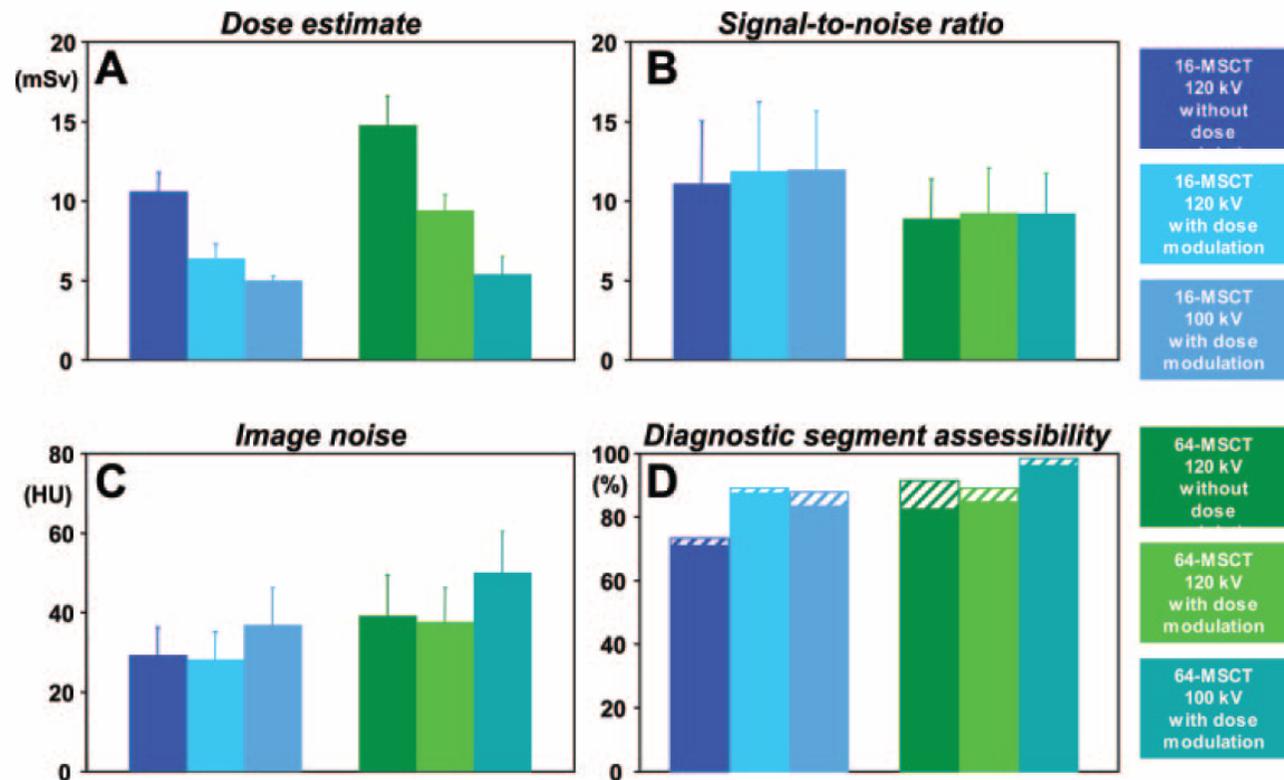


McCollough, C. H. et al. Radiology 2007;243:775-784
 DSCT 310ms, 210ms mean temporal window of maximum tube current (ECG-pulsing).



Using 100kVp instead of 120kVp

1308 *Circulation* March 14, 2006



Impact of different scanning protocols for cardiac CT angiographies on effective dose estimates (A), signal-to-noise ratio (B), image noise (C), and relative frequency of coronary segments with good (solid bars) and limited (hatched bars) diagnostic image quality for detection of stenosis with 16- and 64-slice CT systems (D). HU indicates Hounsfield units.



Factors that influence radiation dose; Beam Energy

- Direct influence on patient radiation dose

Table 1
Changes in CTDI_w in Head and Body Phantoms as a Function of Kilovolt Peak

Beam Energy (kVp)	CTDI _w in Head Phantom (mGy)	CTDI _w in Body Phantom (mGy)
80	14	5.8
100	26	11
120	40	18
140	55	25

Note.—All other factors were held constant at 300 mA, 1 sec, and 10 mm. Results are from a single-detector CT scanner.



Factors that influence radiation dose; Photon Fluence

- Direct influence
- Influenced by the tube current–time product (milliamperere-seconds)

Table 2
Changes in CTDI_w in Head and Body Phantoms as a Function of Milliamperere-Seconds Setting

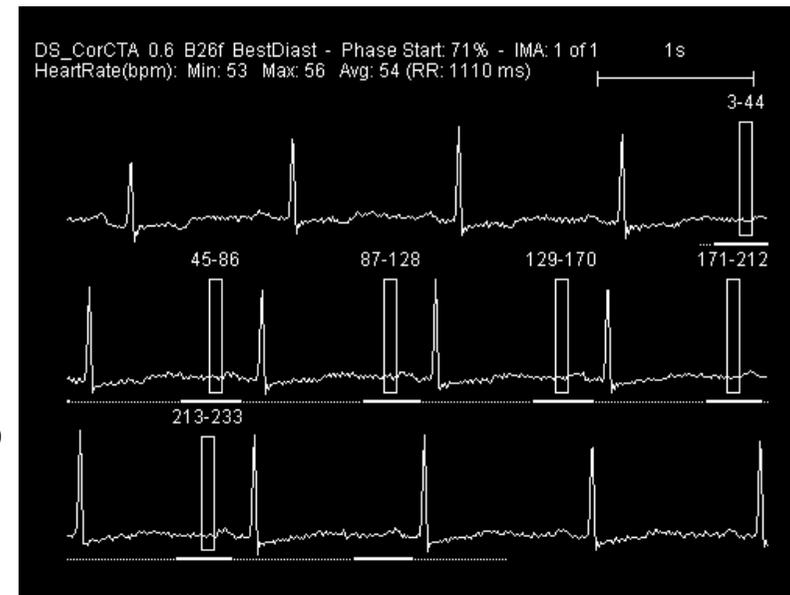
Tube Current–Time Product (mAs)	CTDI _w in Head Phantom (mGy)	CTDI _w in Body Phantom (mGy)
100	13	5.7
200	26	12
300	40	18
400	53	23

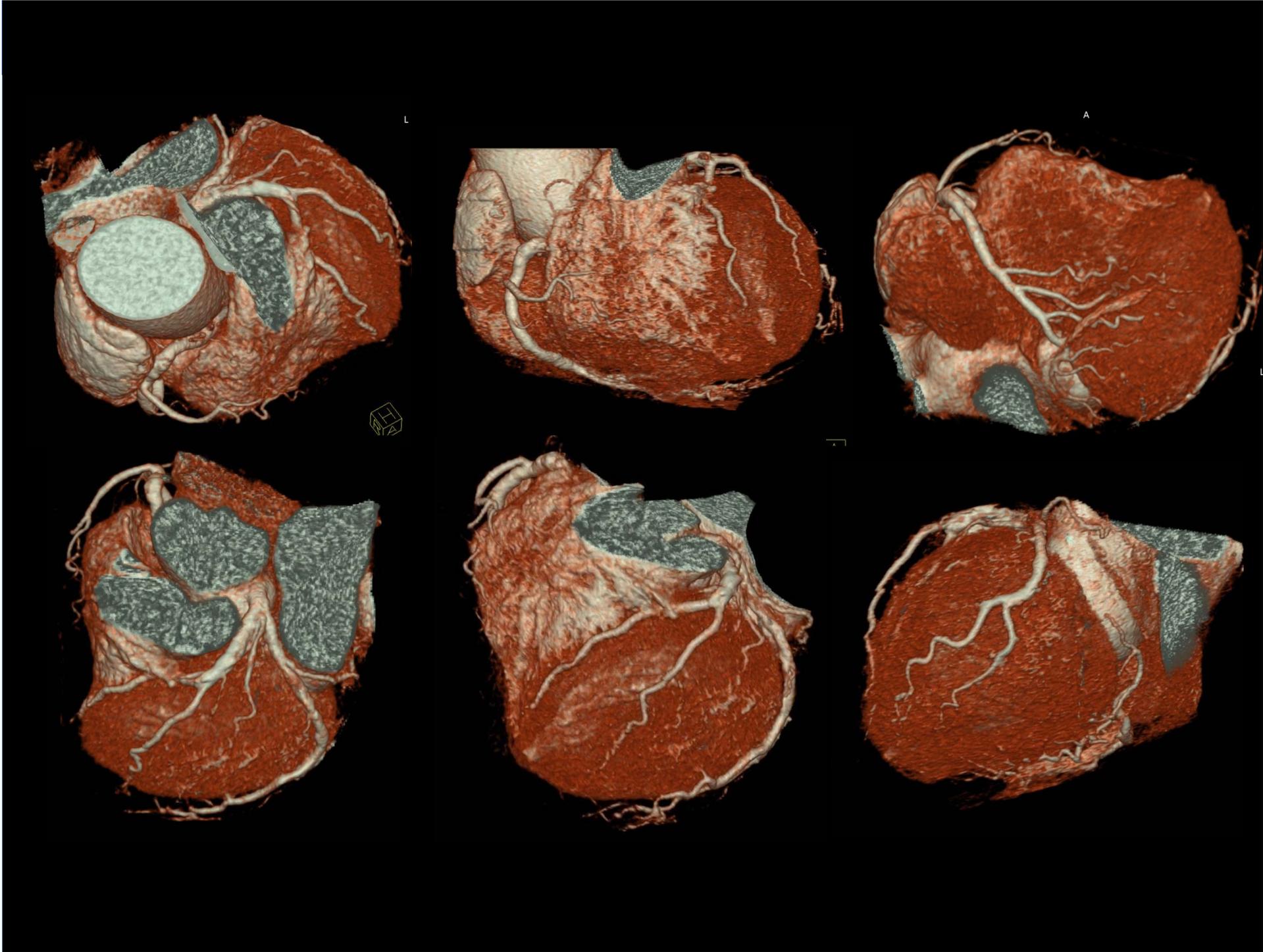
Note.—All other factors were held constant at 120 kVp and 10 mm. Results are from a single-detector CT scanner.



Case

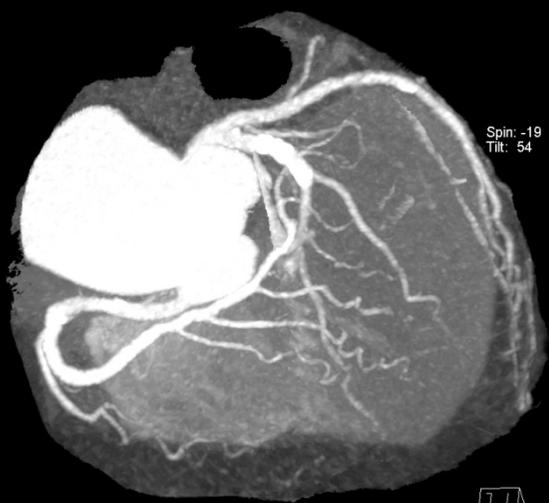
- F/78
 - Atypical chest pain
 - Height and Weight: 147cm, 55kg (BMI: 25.45)
 - Scan parameters
 - 100kVp, 300 mA/rotation
 - 0.6 mm collimation
 - Adaptive pitch
 - Mindose : Full dose at 70-78% of R-R



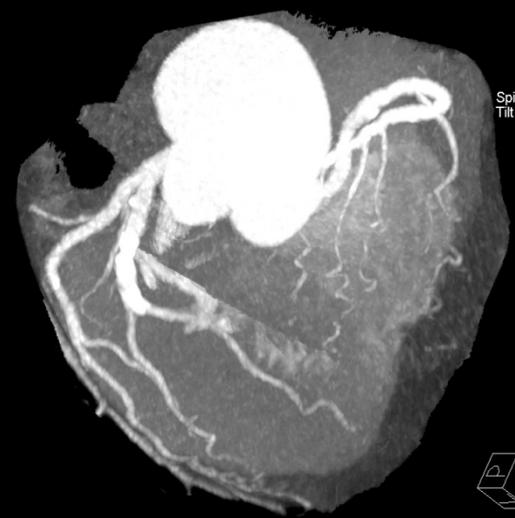




Spin: 15
Tilt: 44



Spin: -19
Tilt: 54



Spin: -
Tilt: -



Spin: 11
Tilt: -6



Spin: 66
Tilt: 43



Spin: 139
Tilt: 168



08-Jun-2007 10:48

Ward:
Physician: D950005
Operator: SDS

Total mAs 3809 Total DLP 246

	Scan	kV	mAs / ref.	CTDIvol	DLP	TI	cSL
Patient Position F-SP							
Topogram	1	120				5.3	0.6
DS_CaScSeq	2D	120	58 / 76	3.36	6	0.2	3.0
DS_CaScSeq	3D	120	61 / 76	3.54	45	0.2	3.0
PreMonitoring	10	100	20	1.25	1	0.33	0.6
I.V. Bolus							
Monitoring	11	100	20	2.51	2	0.33	0.6
DS_CorCTA	13D	100	300	16.50	192	0.08	0.6

Coronary CT with optimal scan range and ECG pulsing, 100kVp (=3.26mSv)

04-Jun-2007 15:41

Ward:
Physician: D003026
Operator: SDS

Total mAs 1465 Total DLP 242

	Scan	kV	mAs / ref.	CTDIvol	DLP	TI	cSL
Patient Position F-SP							
Topogram	1	120				5.3	0.6
Chest	2	120	94 / 100	6.25	242	0.5	1.2

Chest CT, AMC

Ward:
Physician: D970004
Operator: KHI

Total mAs 8519 Total DLP 1256

	Scan	kV	mAs / ref.	CTDIvol	DLP	TI	cSL
Patient Position F-SP							
Topogram	1	120				5.3	0.6
PRE	2	120	185 / 200	12.23	397	0.5	1.2
PreMonitoring	3	120	20	2.67	3	0.5	0.6
I.V. Bolus							
Monitoring	4	120	20	10.67	10	0.5	0.6
ARTERY	8	120	179 / 200	12.94	403	0.5	0.6
PORTAL 75s	9	120	177 / 200	12.80	443	0.5	0.6

Abdomen CT



Accession Number: 78779859

2007 Jan 15

Patient ID: 16951672

LightSpeed VCT

Exam Description: C.T Angio + 3D Coron

Dose Report

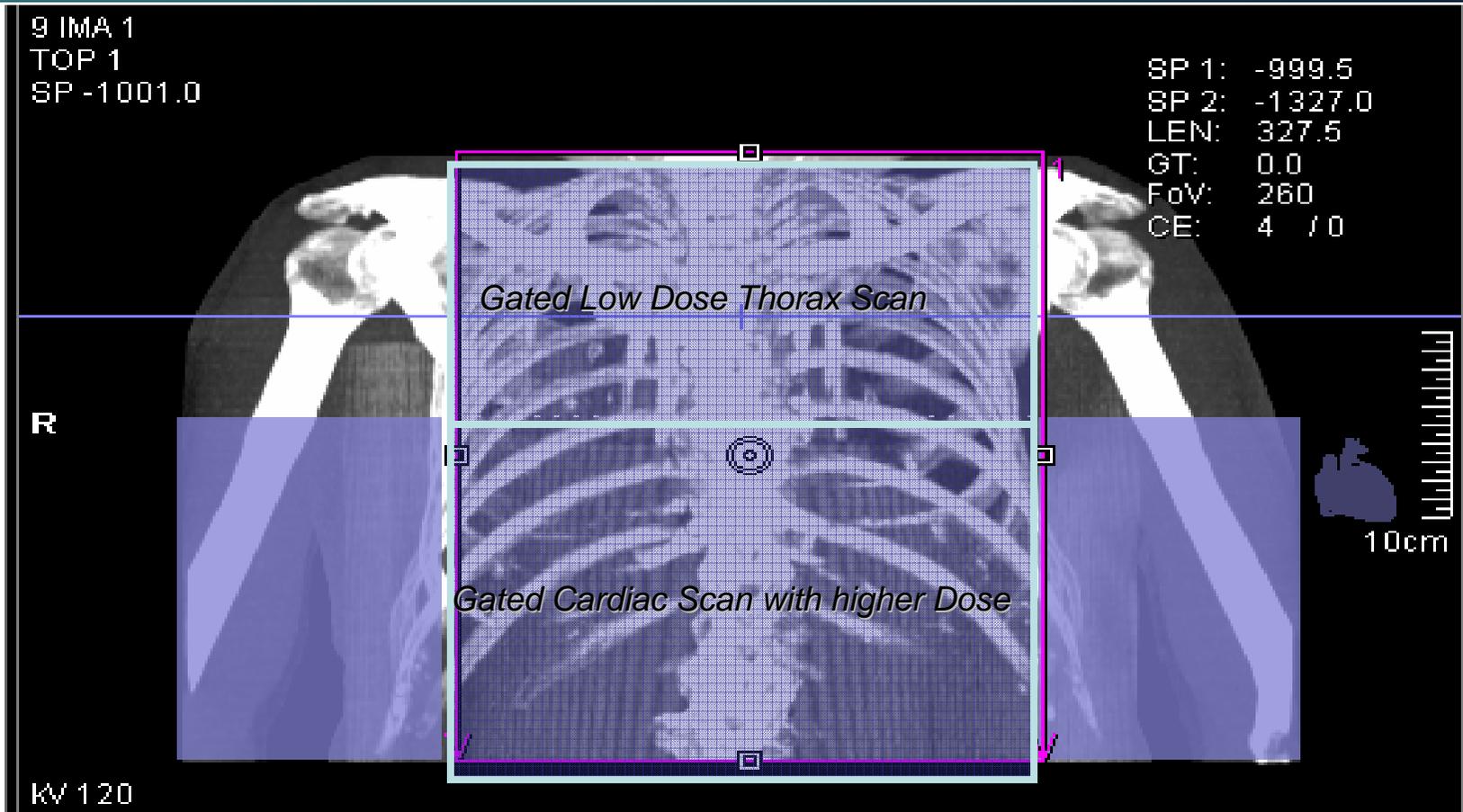
Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Cine	I164.750-I362.250	8.89	177.84	Body 32
3	Axial	I200.750-I200.750	138.74	69.37	Body 32
4	Cardiac Helical	I160.250-I347.750	85.40	1900.14	Body 32
Total Exam DLP:				2147.35	

Wide scan range with No ECG pulsing

Tailored Scan Protocol !! (Coronary, Valve, etc.)



DSCT for "Triple Rule Out"



MDCT: Shows coronary, pulmonary arteries and aorta in one scan (10-15sec scan with one breath hold)



Cost-effectiveness of triple rule-out

- Decrease number of invasive study

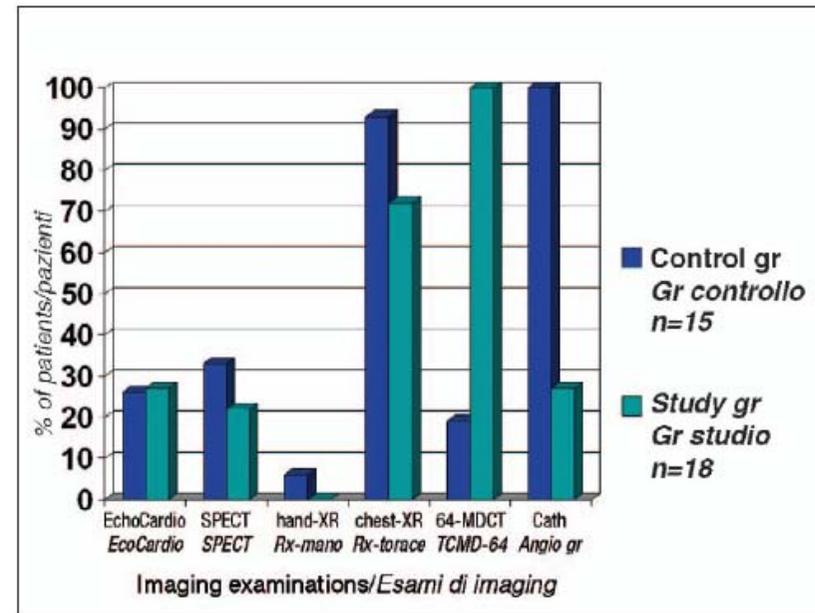
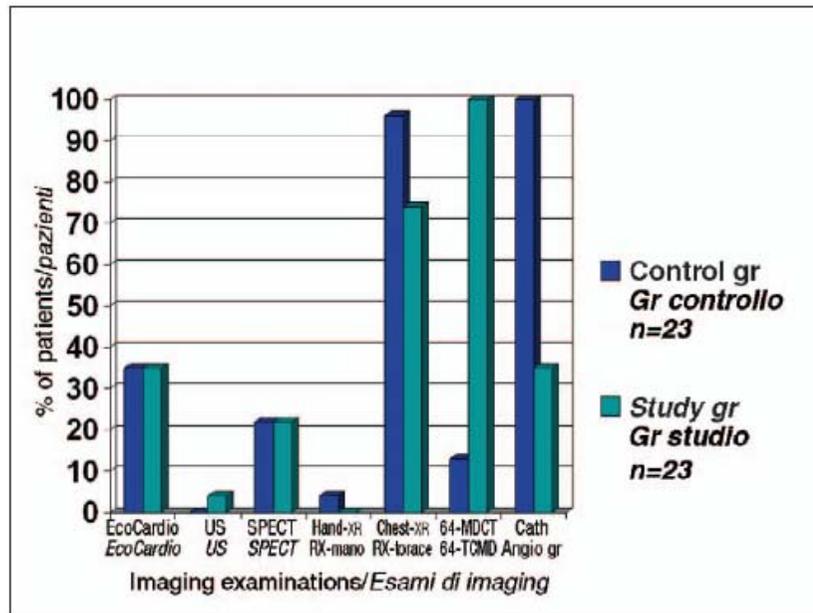
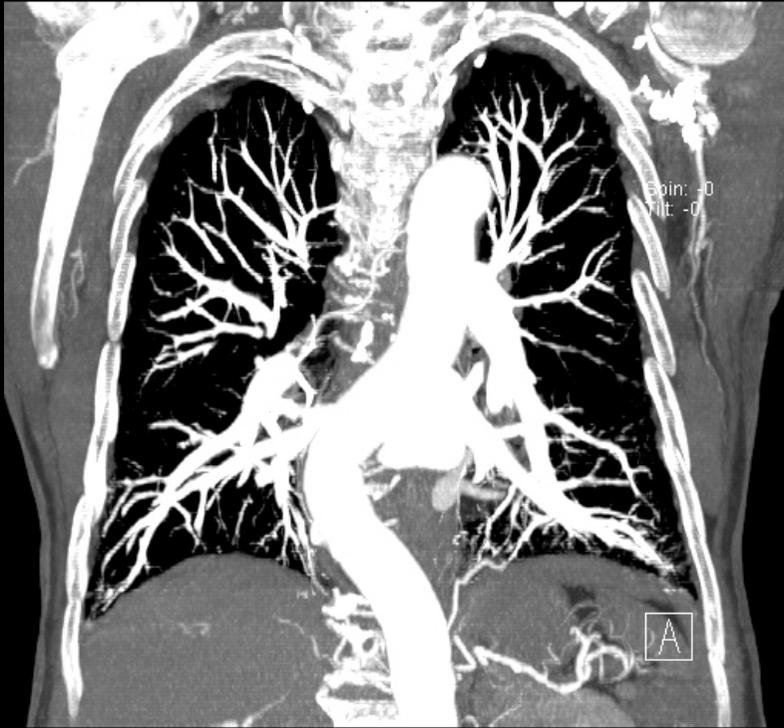


Fig. 5a Imaging examinations performed for the diagnostic work-up in the emergency room. b Imaging examinations performed in the groups excluding patients who underwent intervention.

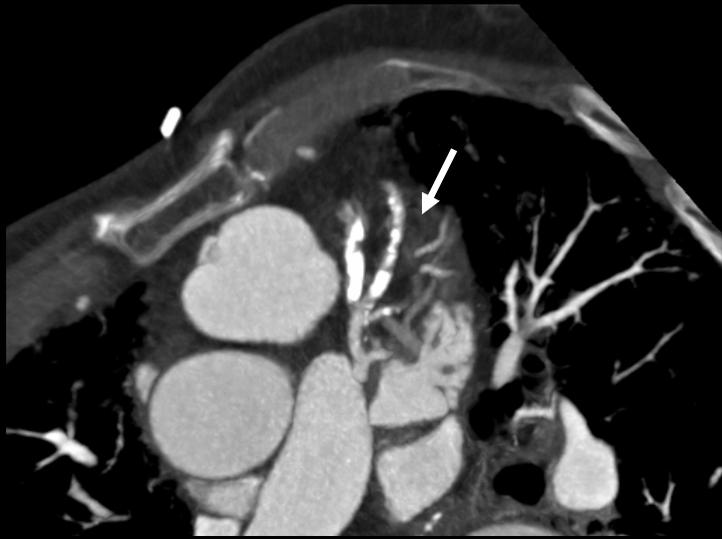
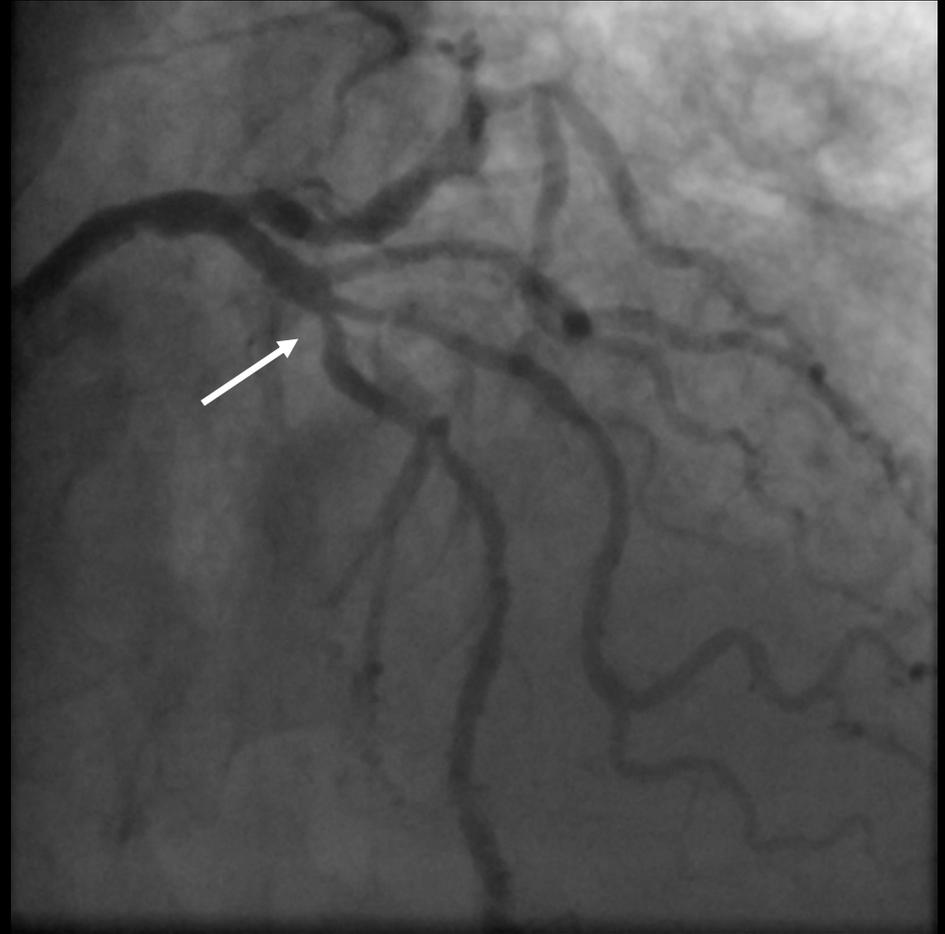
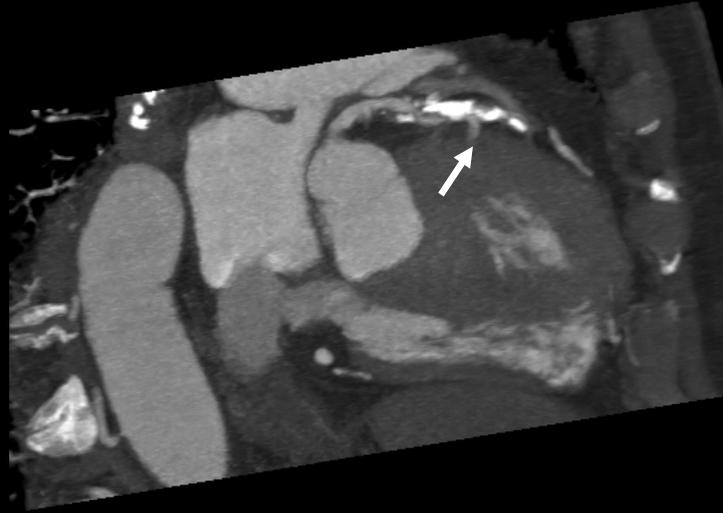


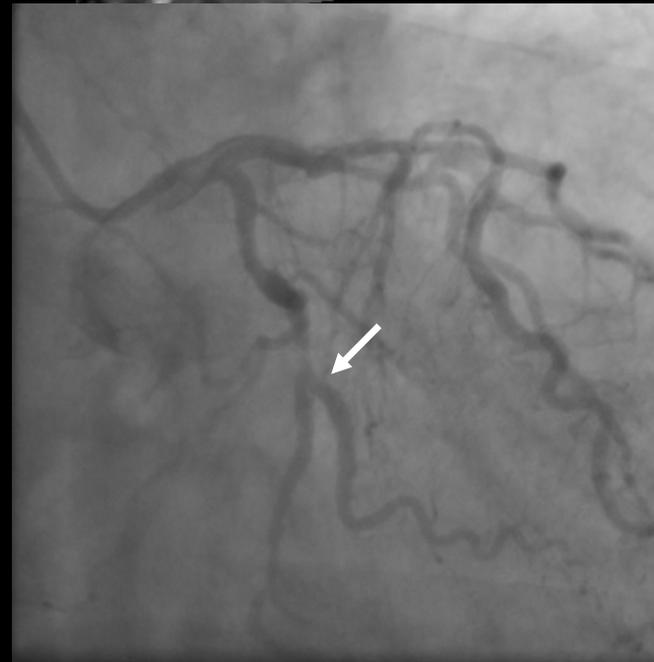
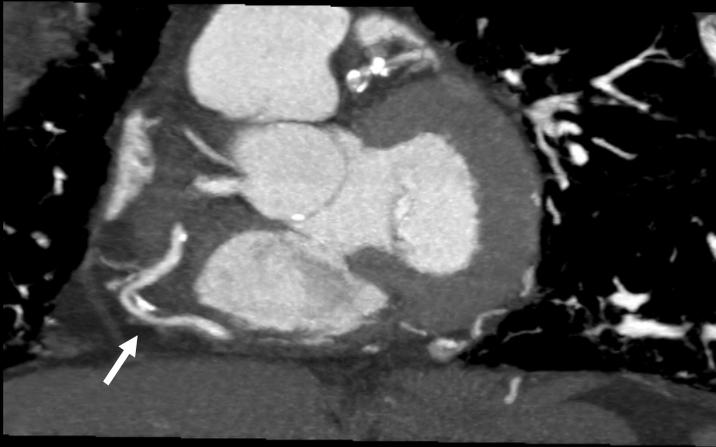
Case at AMC

- M/64
- C.C: Resting chest pain (8 hours ago)
- Past history: IPF patient
- DM (-), HT (-), Hyperlipidemia (+)
- Troponin -I: 0.009 ng/mL, CK-MB : 0.9 ng/mL
(normal range , checked in Emergency Room)
- HR during CT: 73 BPM
- DLP 723 mGy*cm (= 10.12mSv)



- No Pulmonary thromboembolism
- No Aortic dissection nor aneurysm





3 vessel disease diagnosed at CT



Stent Follow-up

- sensitivity : 50%, specificity: 57% (51 of 90) [46-67%]
- Accuracy among 'evaluable' stents:

Table 2 Number of evaluable stented lesions in MDCT, and for evaluable stented lesions, accuracy for detection of restenosis in comparison with QCA

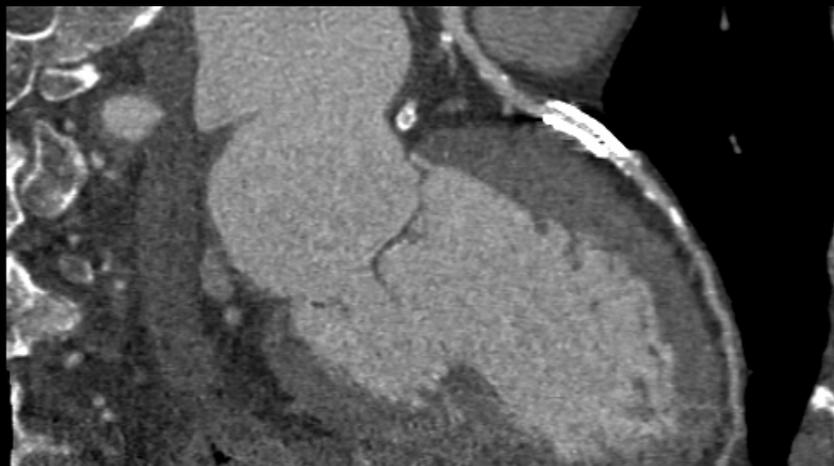
	Number	Evaluable (%)	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
All stents	102	59 (58)	86 (42-99)	98 (88-100)	86 (42-99)	98 (88-100)
≥3.5 mm	32	35 (78)	<u>100 (5-100)</u>	<u>100 (83-100)</u>	<u>100 (5-100)</u>	<u>100 (5-100)</u>
3.0 mm	57	33 (58)	<u>83 (36-99)</u>	<u>96 (79-99)</u>	<u>83 (36-99)</u>	<u>96 (79-99)</u>
<3.0 mm	13	1 (8)	—	<u>100 (5-100)</u>	—	<u>100 (5-100)</u>
Per patient ^a	64	33 (52)	83 (36-99)	46 (33-60)	10 (5-30)	96 (79-99)

Confidence intervals are given in parentheses.

^aIn the per-patient analysis, unevaluable stents were regarded as having significant in-stent restenosis in MDCT.

72yr-man, work up for post-stent.

HR 62



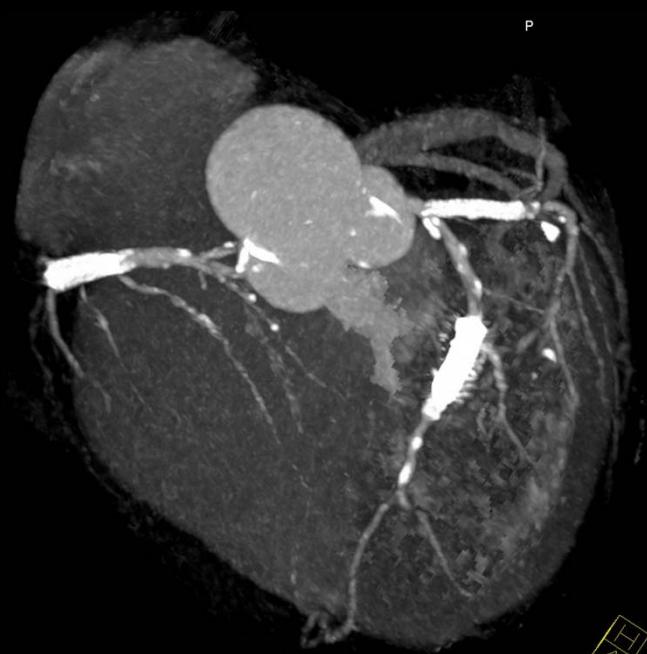
LAD



RCA



LCx





Scan Protocol in AMC

- Coronary artery evaluation
 - Check BP for using NTG
 - 18G IV line, antecubital vein
 - Oral Nitroglycerine sublingual, **No β -blocker**
 - Topogram
 - Ca-score: retrospective gating
 - Contrast media injection
 - ^ Achenbach: 5mL/sec * scan time (sec) + 20mL (320) at 5mL/sec
 - ^ AMC: 4mL/sec * scan time (sec) + 25mL (370 or 400) at 4mL/sec
 - ^ Not less than 45cc in total amount
 - ^ Saline chaser: To remove right chamber contrast media (40mL at 4mL/sec)
- Main scan
 - Range : Pulmonary artery to heart inferior margin (10-12 cm)
 - Using ECG-pulsing and adaptive pitch to lower radiation dose
 - **Now: 100kVp with 300mA/rot**