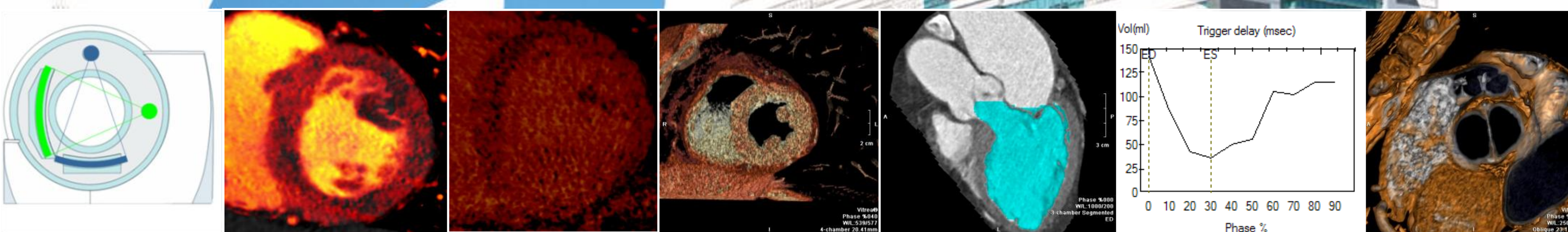
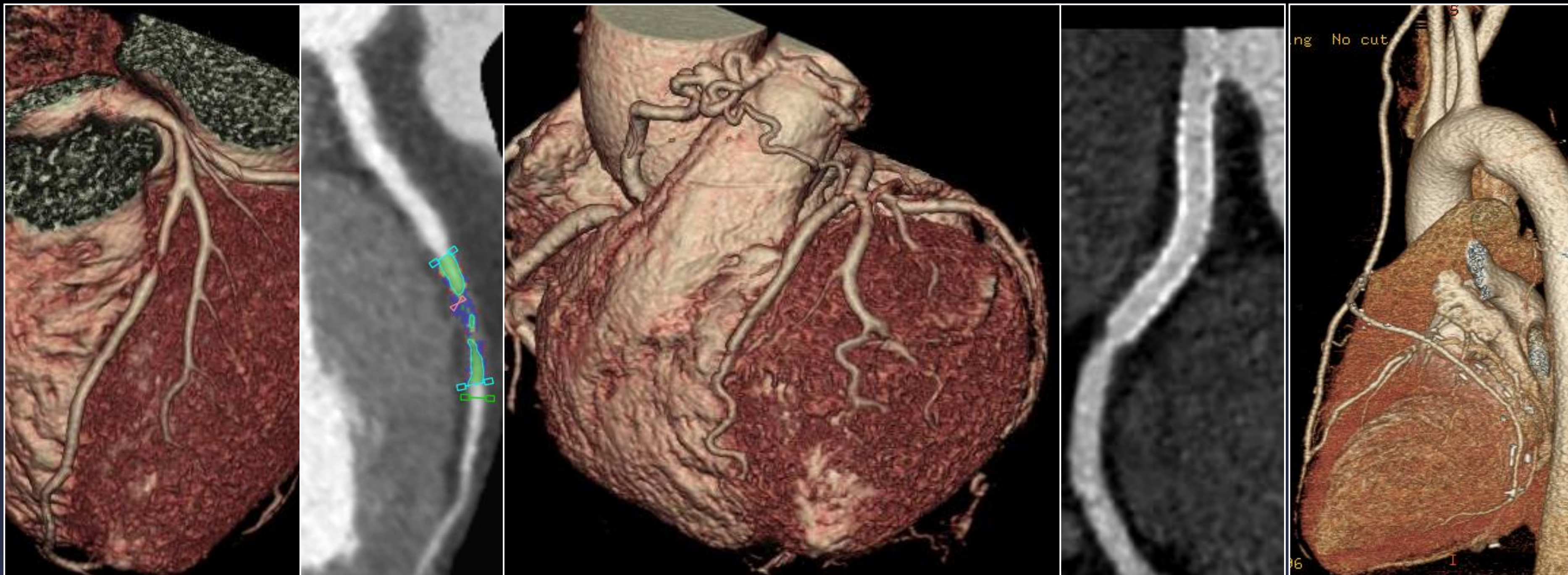
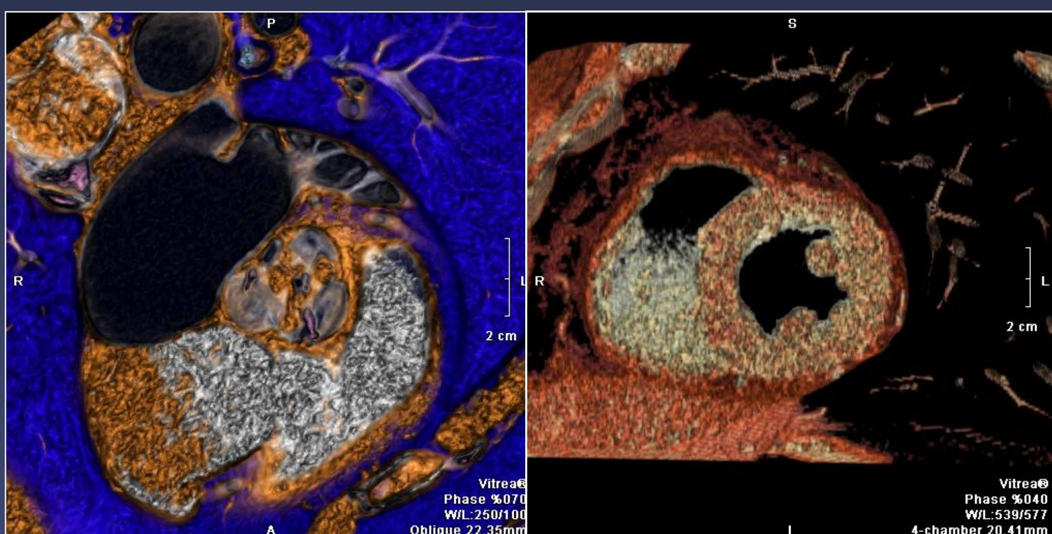
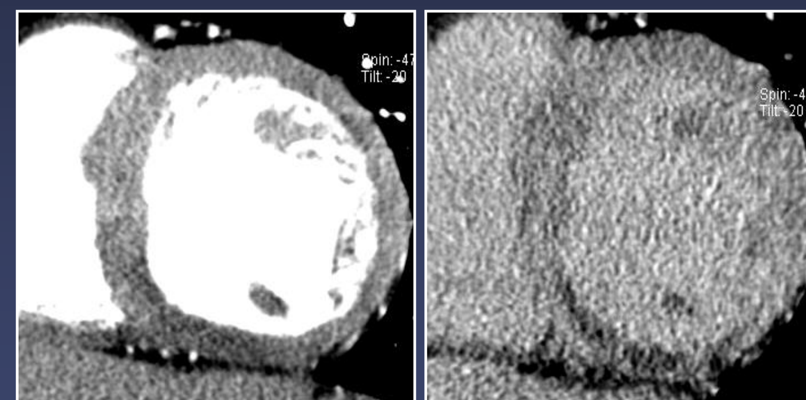
Comprehensive Cardiac Evaluation Beyond Coronry CT Angiography



건국대학교병원 영상의학과
고성민

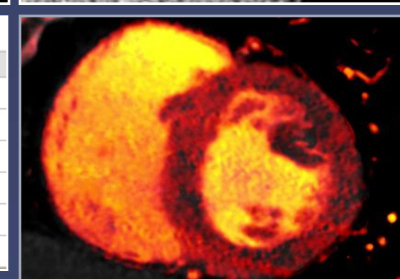






LEFT VENTRICULAR FUNCTION

Parameter	Measured Values
Ejection Fraction	63
End Diastolic Volume	158
End Systolic Volume	58
Stroke Volume	100
Cardiac Output	-
Myocardial Mass	151



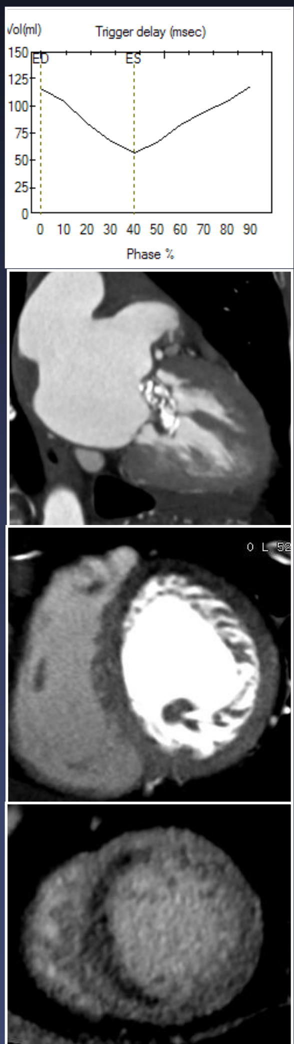
Cardiac CT applications

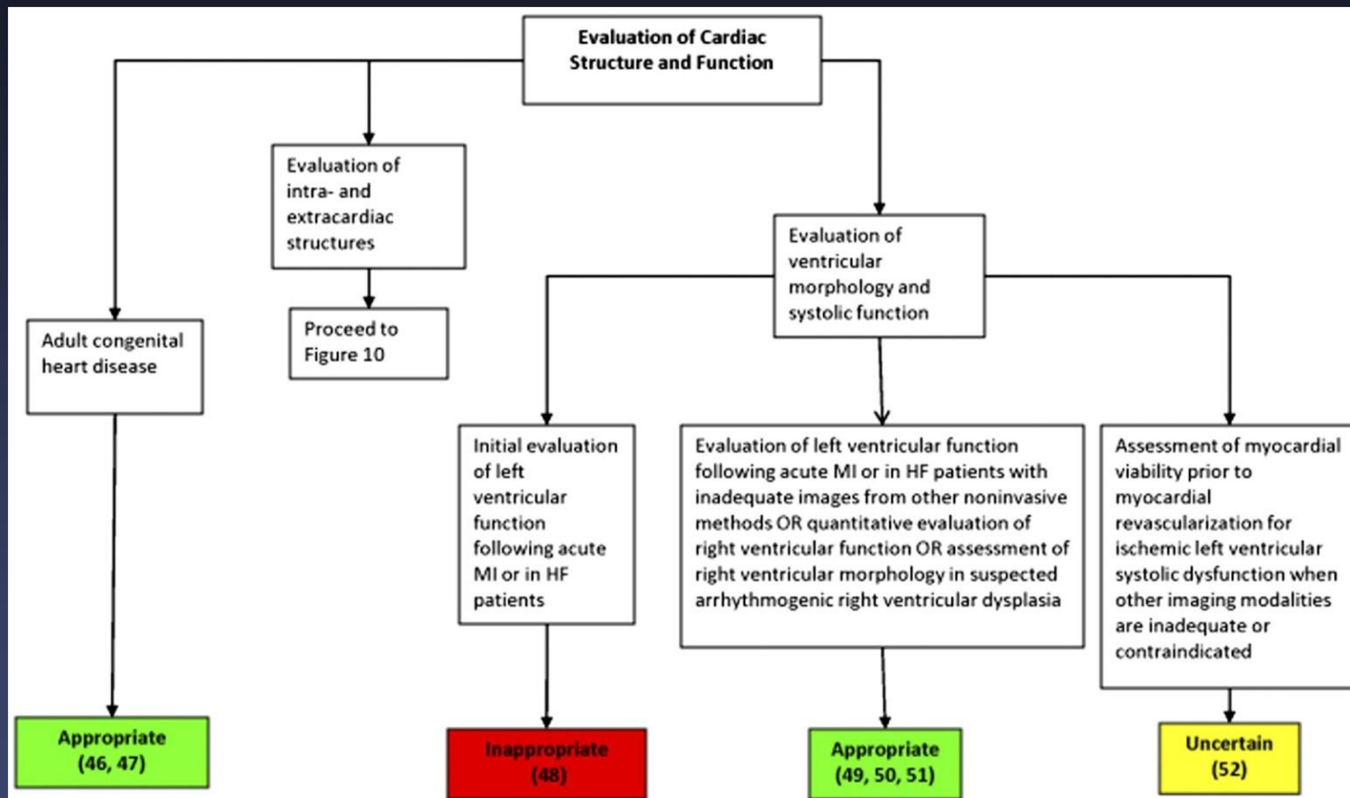
RSNA 2011 - Cardiac Radiology

- CAD - risk assessment and clinical implication
- Myocardial Perfusion and Infarction
  - Stress perfusion CT and DECT
- Heart Failure - Multimodality Imaging
- Acute Chest Pain
- Noncoronary Artery Imaging
  - Cardiovascular Morphology (LA, PV)
  - Cardiomyopathy, VHD
  - Cardiac Function
- Cardiac Nuclear Imaging - SPECT/ CT and PET/CT

Appropriate Use Criteria for Cardiac CT

ACCF/SCCT/ACR/AHA/ASE/ASNC/NASCI/SCAI/SCMR 2010
Appropriate Use Criteria for Cardiac CT . JACC 2010;23:1864-94

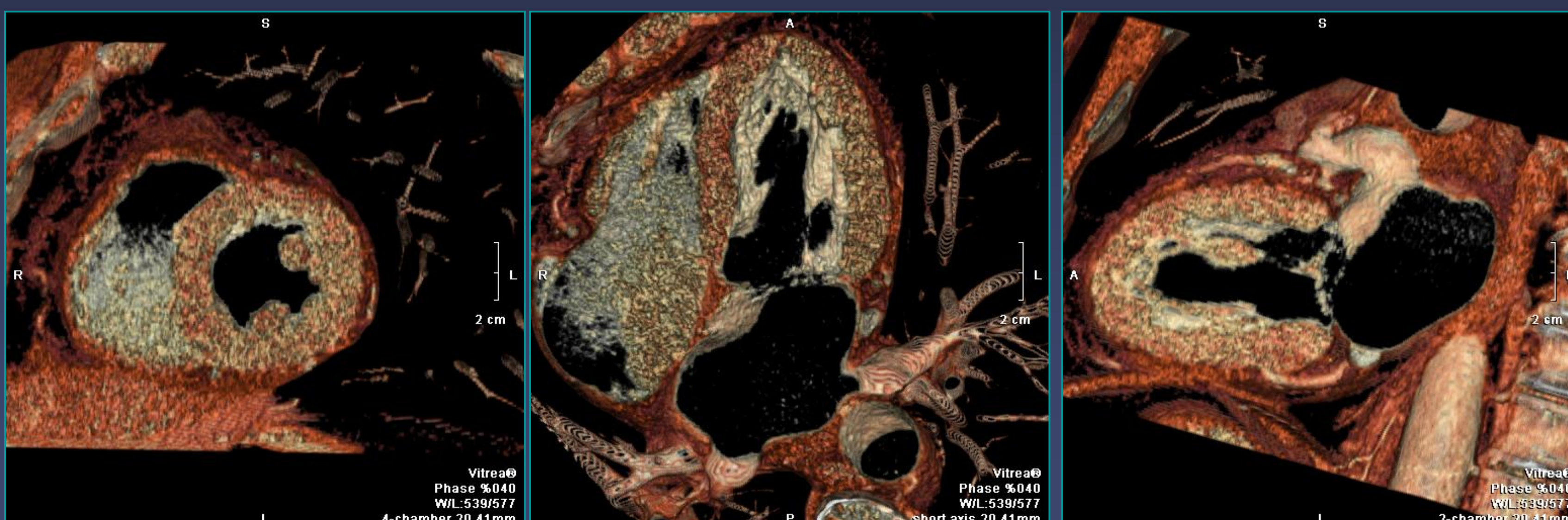




Characterization of native and prosthetic cardiac valves
Suspected clinically significant valvular dysfunction
Inadequate images from other noninvasive methods - A (8)

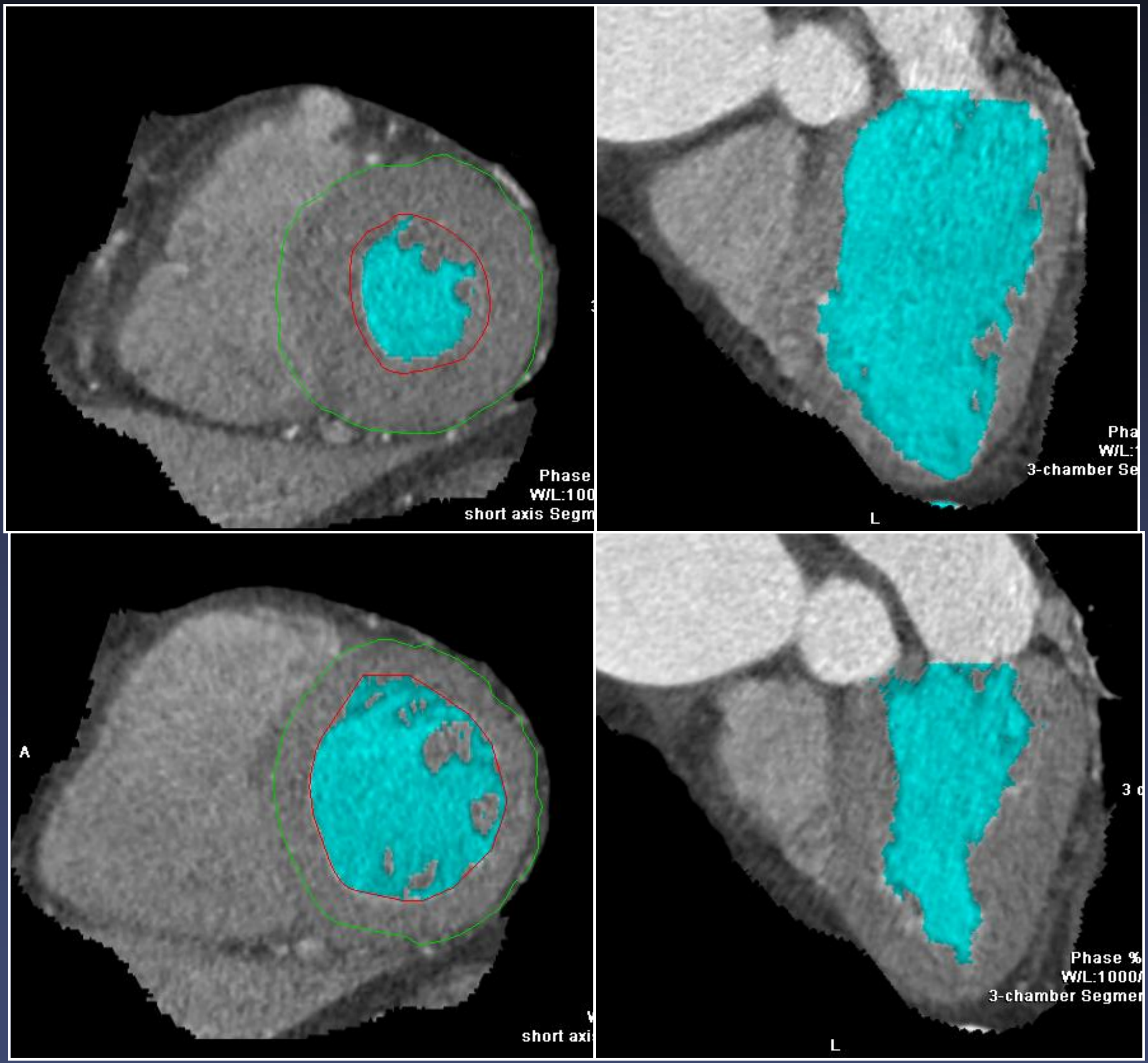
Ventricular function

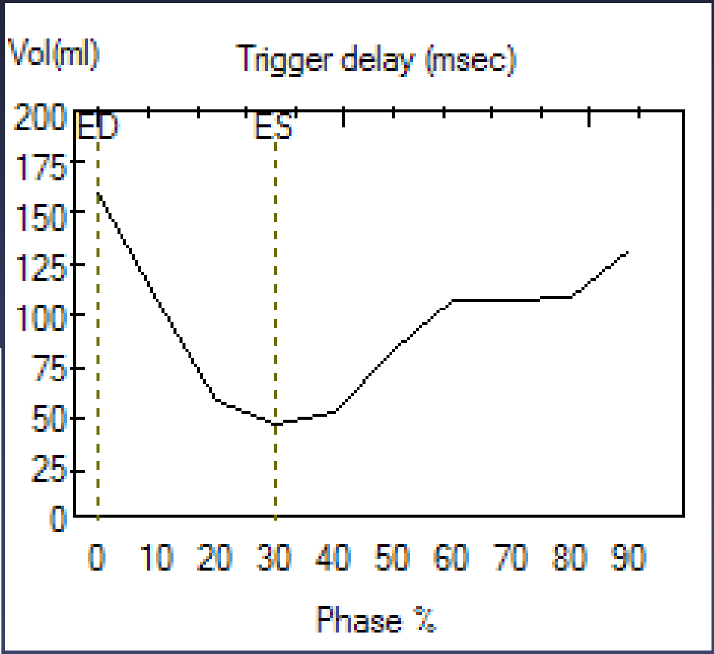
- End-systolic and end-diastolic images for LV volume
- Cine image for LV wall motion
- No indication for performing cardiac MDCT for the sole assessment of ventricular function
- LV functional assessment utilized as an adjunct to coronary CT angiography to obtain additional information on the patient



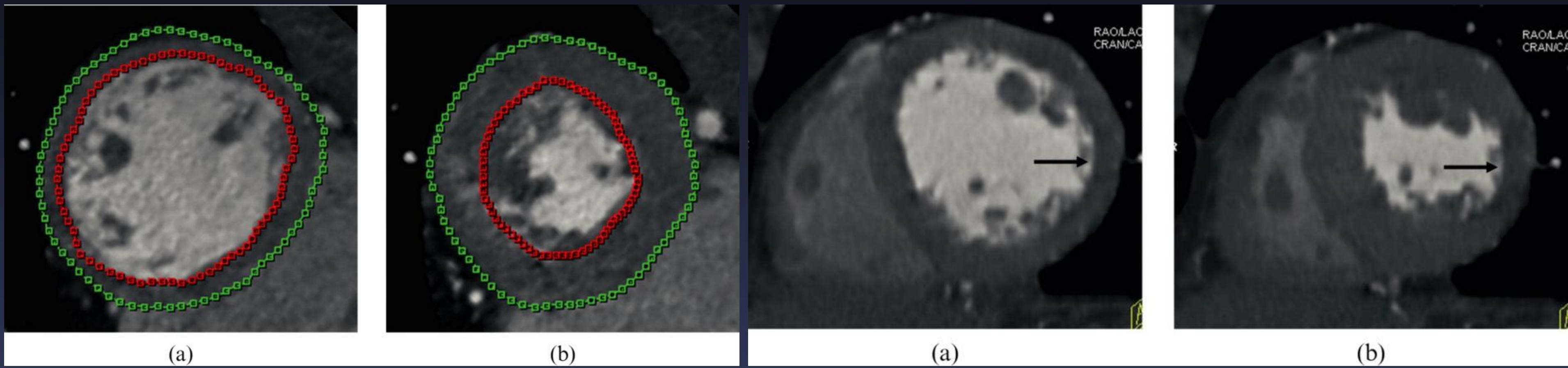
EF 63%, EDV 158 ml, ESV 58 ml, Myocardial mass 151 g

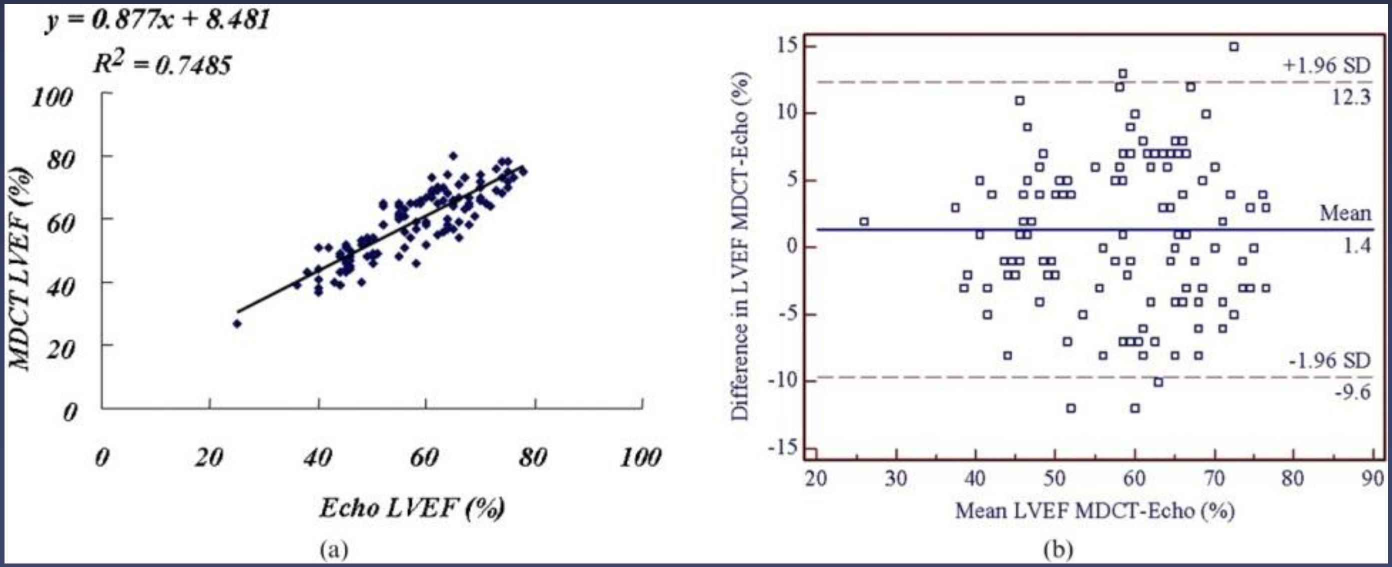
Threshold-based technique





Assessment of LV function with 64-slice MDCT: comparison with 2D-TTE (n=126)





SM Ko, et al. Br J Radiol 2010;83:28-34

Assessment of global function of LV with DSCT in patients with severe arrhythmia (n=54)

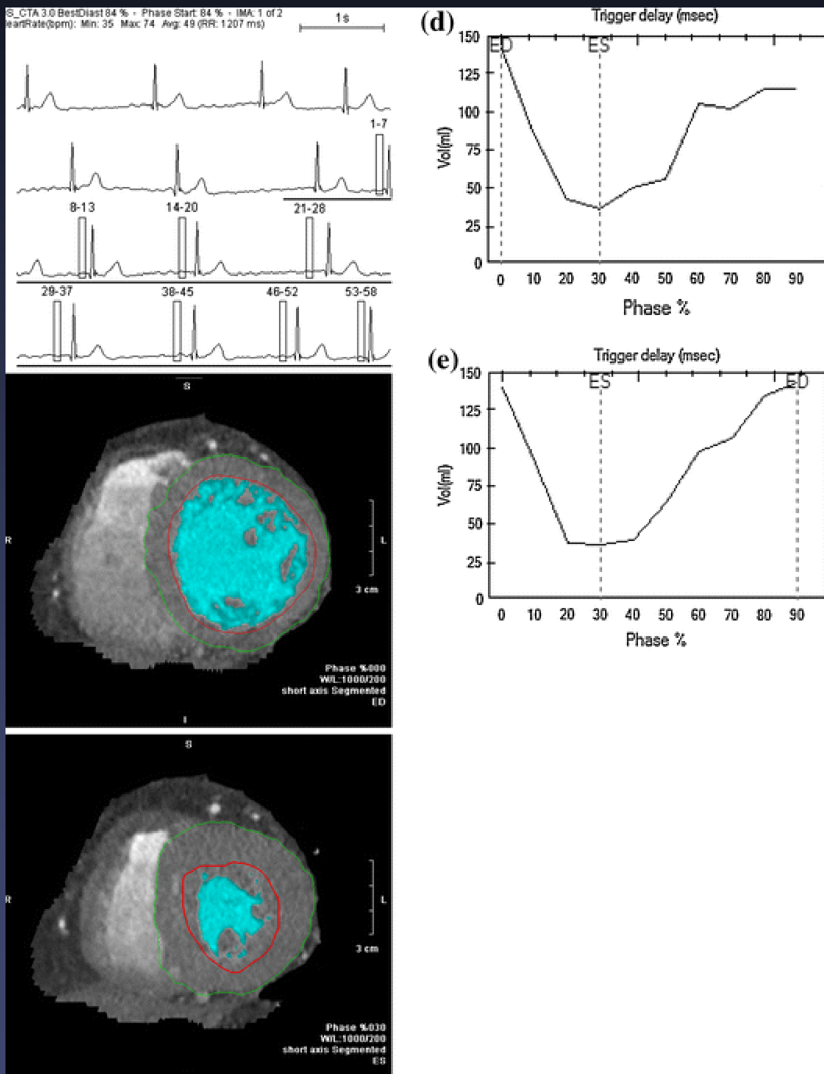


Table 2 Results of measurement using DSCT and 2D-TTE (*n* = 54)

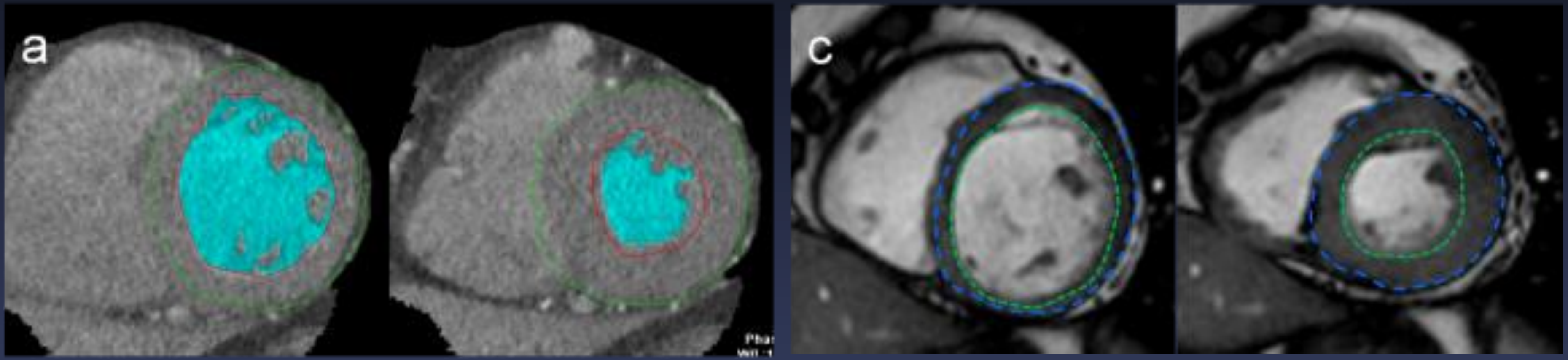
	DSCT			2D-TTE			*P* value
	Mean ± SD	Range	95% CI	Mean ± SD	Range	95% CI	
EF (%)	51.0 ± 11.4	25–76	47.9–54.1	55.8 ± 11.6	27–76.3	52.7–59.0	$P < 0.001$
EDV (ml)	179.5 ± 98.6	65–516	152.6–206.4	152.1 ± 73.8	48.5–406.5	131.9–172.2	$P < 0.001$
ESV (ml)	90.7 ± 60.7	24–299	74.2–107.3	69.1 ± 46.8	21.2–235.4	56.4–81.9	$P < 0.001$
SV (ml)	89.0 ± 48.1	31–217	75.8–102.1	82.9 ± 37.3	26.8–213.2	72.7–93.0	$P = 0.053$

Table 3 Pearson's correlation coefficient and Bland–Altman analysis from DSCT and 2D-TTE (*n* = 54)

DSCT versus 2D-TTE			
Pearson's correlation coefficient (all $P < 0.001$, except SV = .053)		Mean difference	Limits of agreement (±1.96 SD)
EF (%)	0.798	−4.8	9.5/−19.1
EDV (ml)	0.946	27.4	100.9/−46.1
ESV (ml)	0.898	21.6	76.1/−32.9
SV (ml)	0.891	6.1	50.2/−38.1

SM Ko, et al. Int J Cardiovasc Imaging 2010;26:213-221

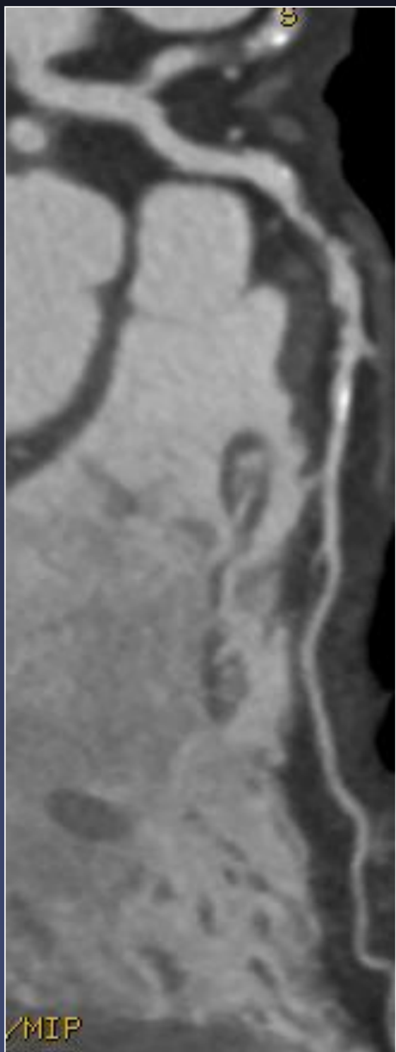
Evaluation of global left ventricular function with DSCT in patients with VHD: comparison with CMR (n=112)

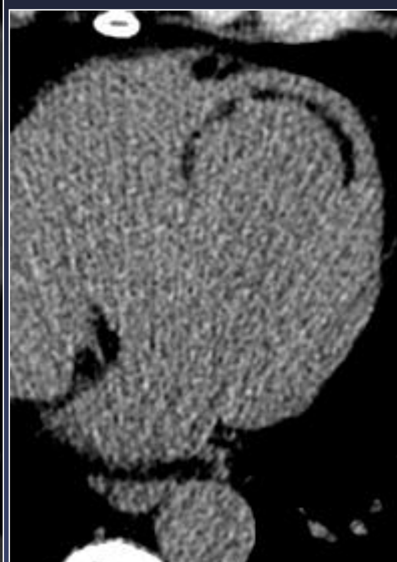


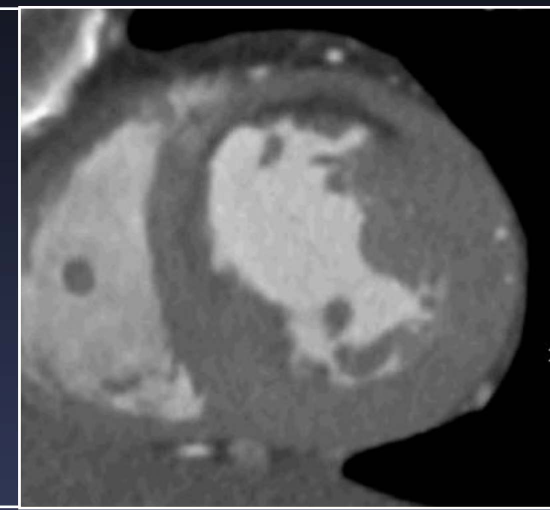
	DSCT	CMR	Mean difference	Pearson's correlation coeffienct	*P* value
	Mean ± SD	Mean ± SD			
EDV (mL)	170 ± 86.1	187.4 ± 101.1	16.3 ± 30.8	0.95	< 0.0001
ESV (mL)	61.8 ± 52.1	70.8 ± 61.7	8.5 ± 16.8	0.96	< 0.0001
SV (mL)	107.9 ± 39.2	117.2 ± 46.2	8.8 ± 19.3	0.90	< 0.0001
EF (%)	66.9 ±9.6	65.5 ± 10.1	-1.4 ± 4.0	0.92	< 0.0001

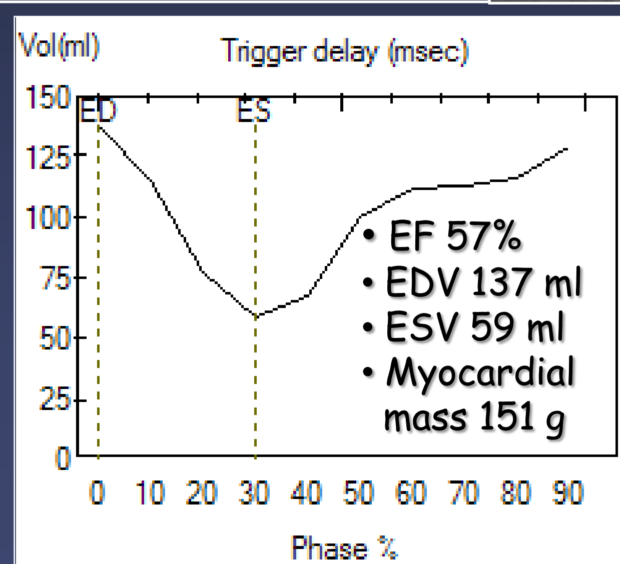
SM Ko, et al. Acta Radiologica 2011, minor revision

51M, old MI, chest pain

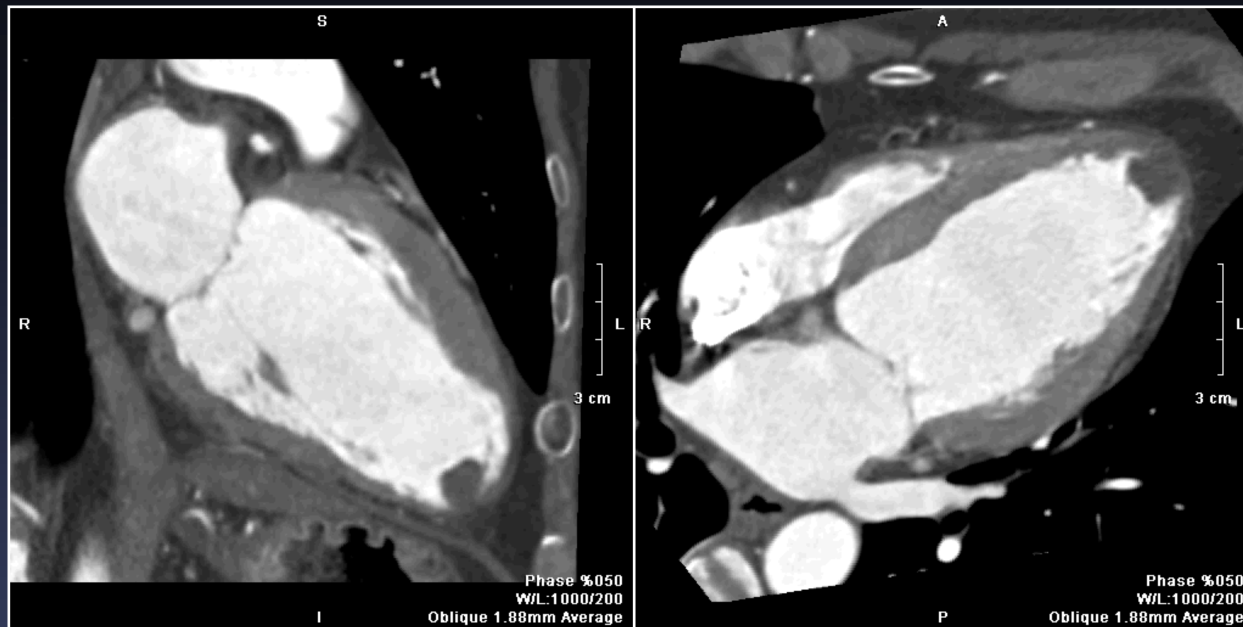


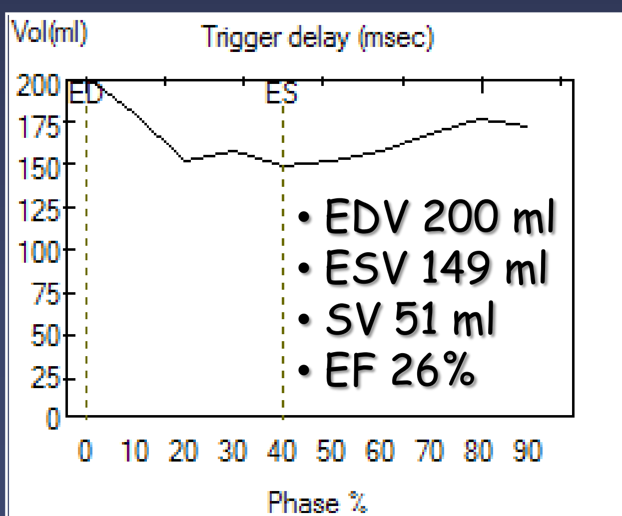




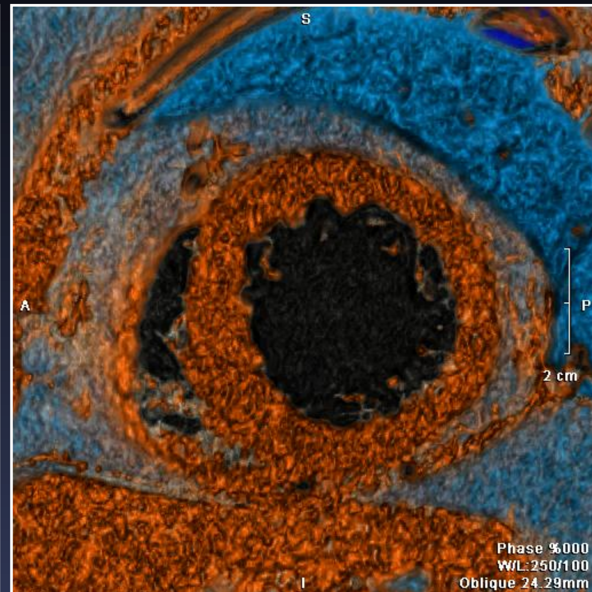


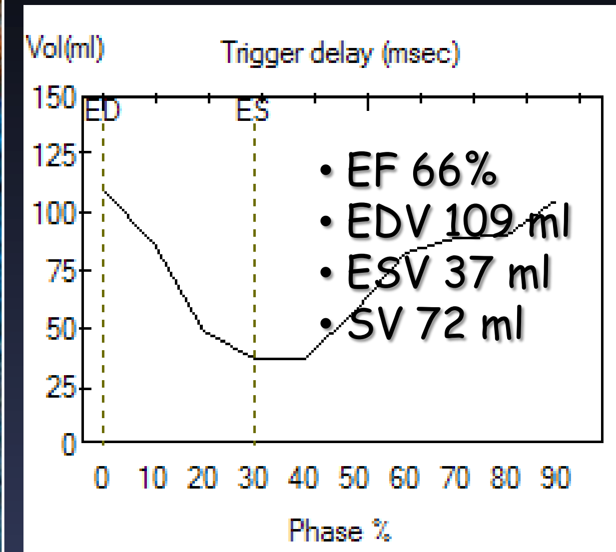
48M, Ischemic cardiomyopathy

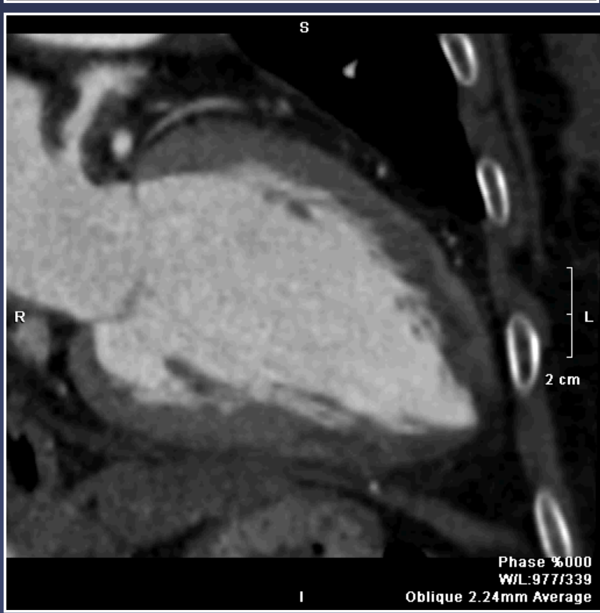


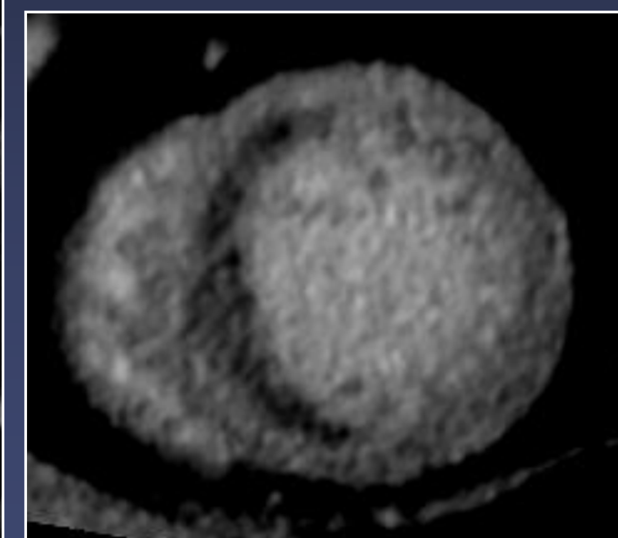


54M, AMI, chest pain

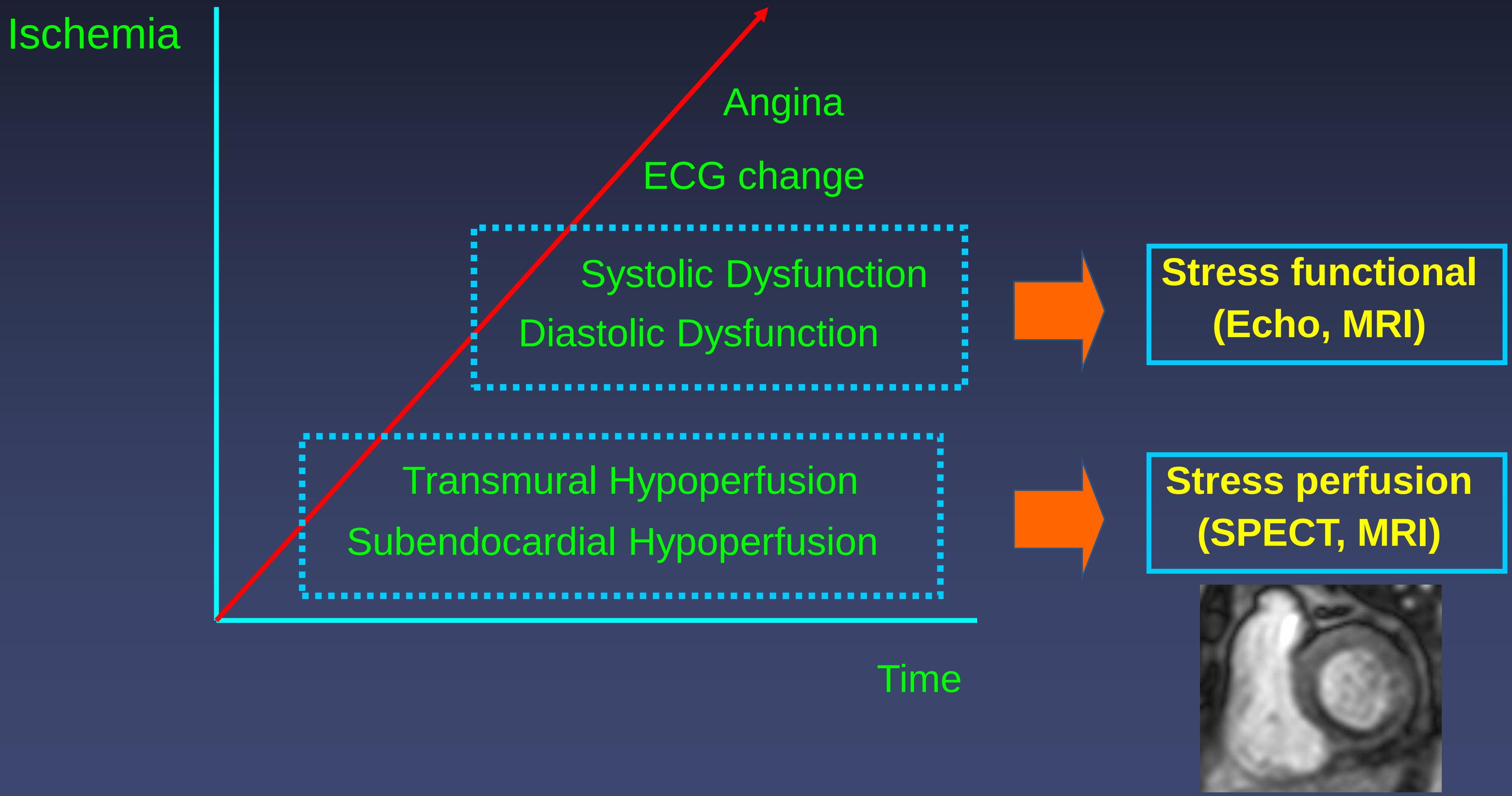




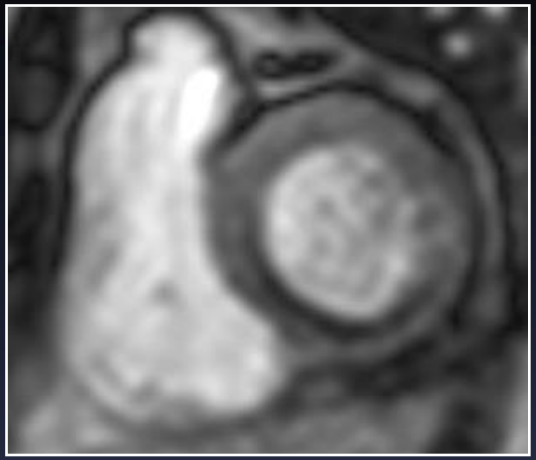


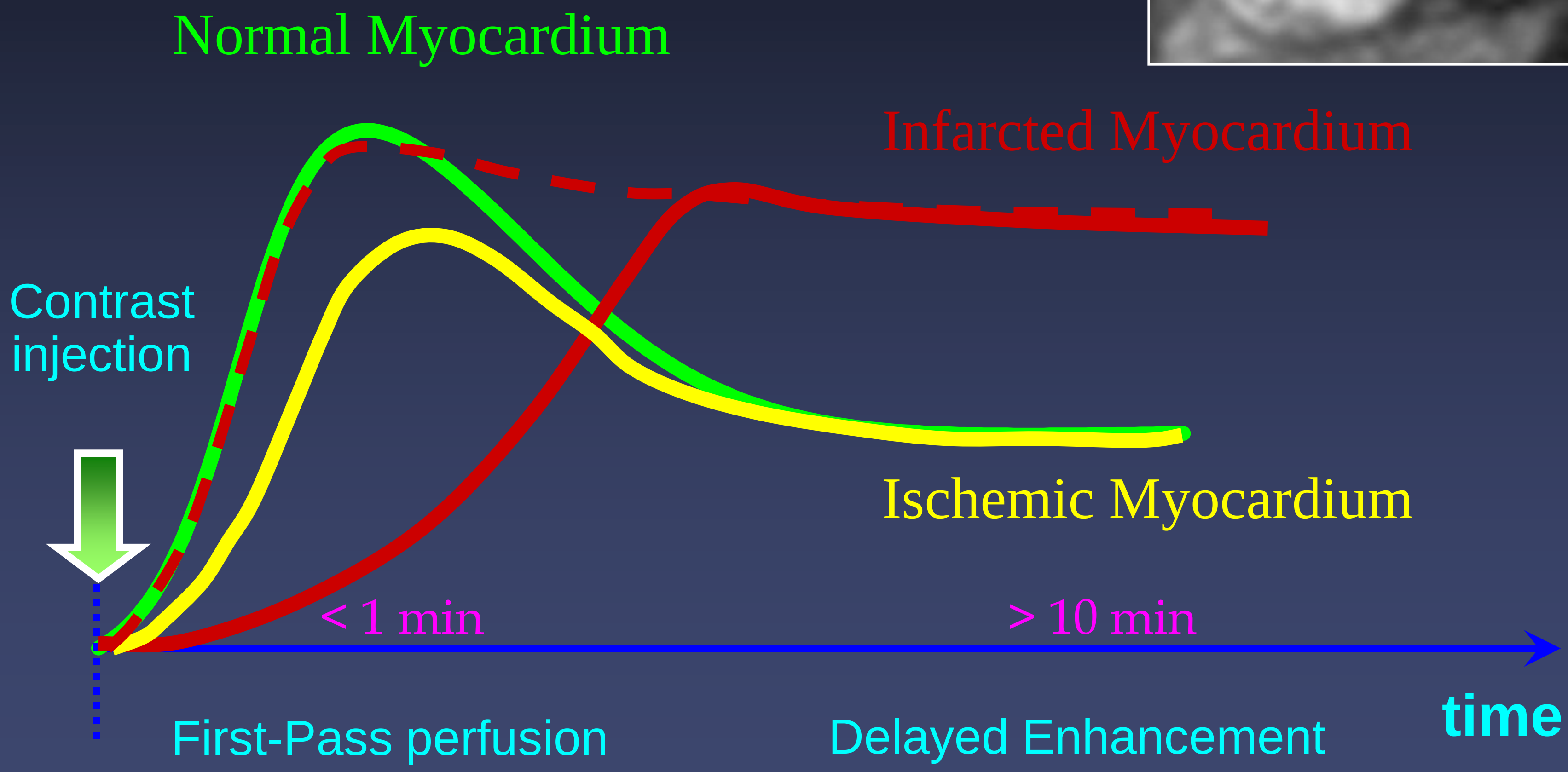


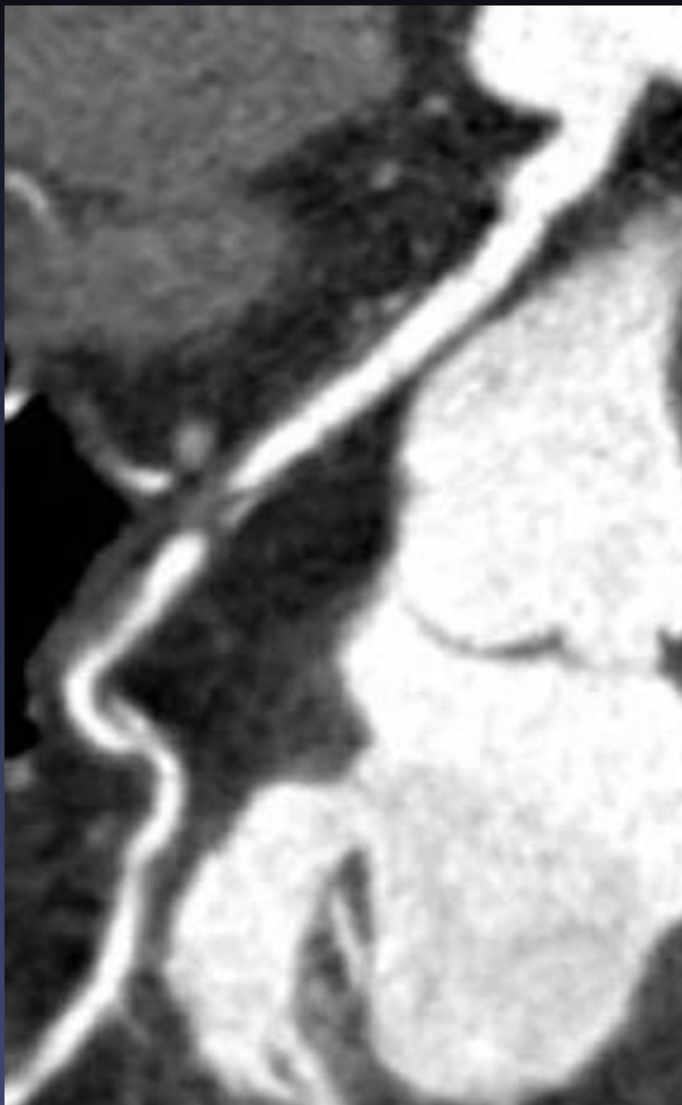
Ischemic cascade

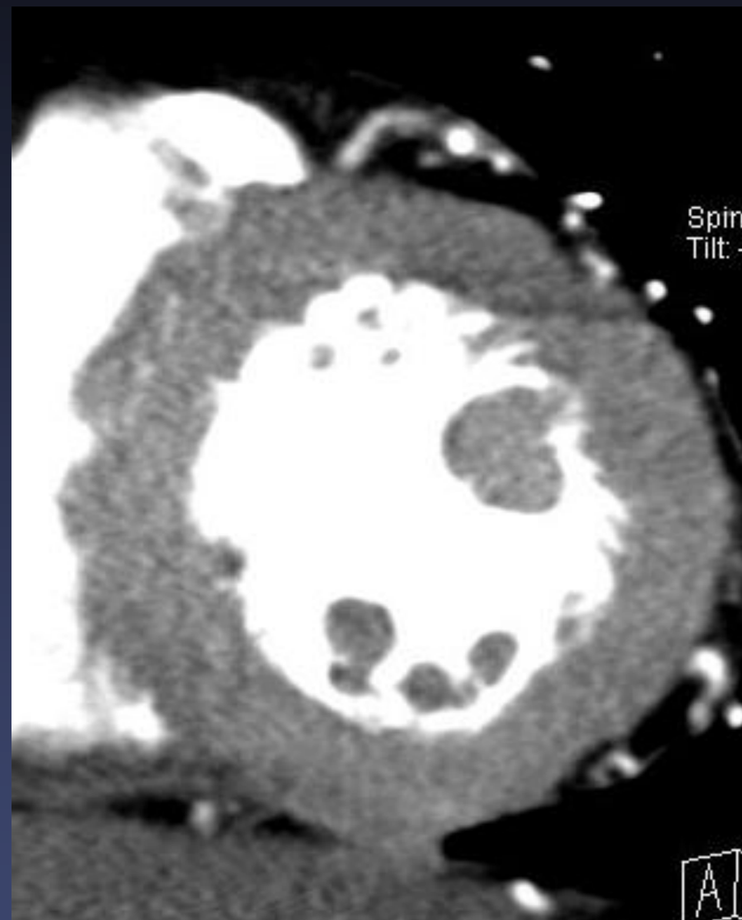


Time Intensity Curve









64/F chest pain

Myocardial Perfusion Imaging

- **Coronary CTA**

  - No physiological significance of coronary stenosis

- **Myocardial perfusion**

  - Important prognostic indicator for patient outcome in the management of coronary artery disease

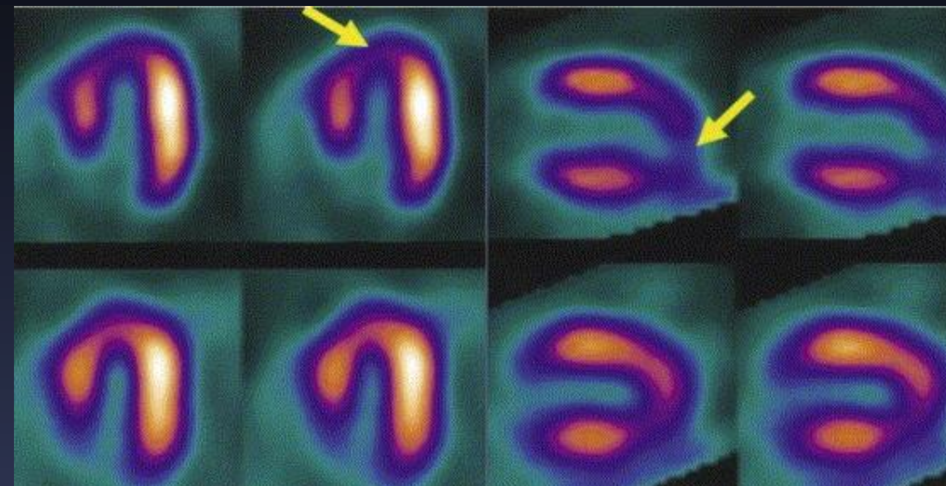
- **Hybrid imaging using SPECT and coronary CTA**

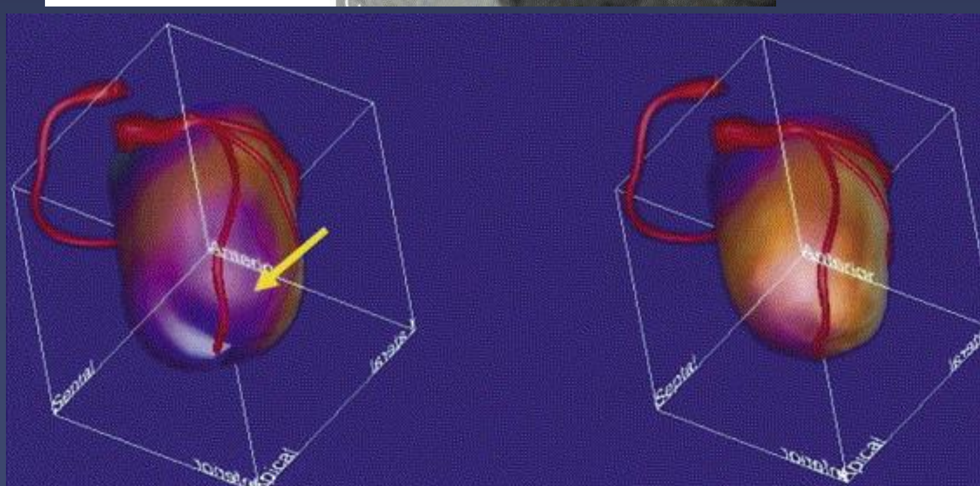
  - Incremental diagnostic value over either modality alone

- **Dual-Energy CT (DECT)**

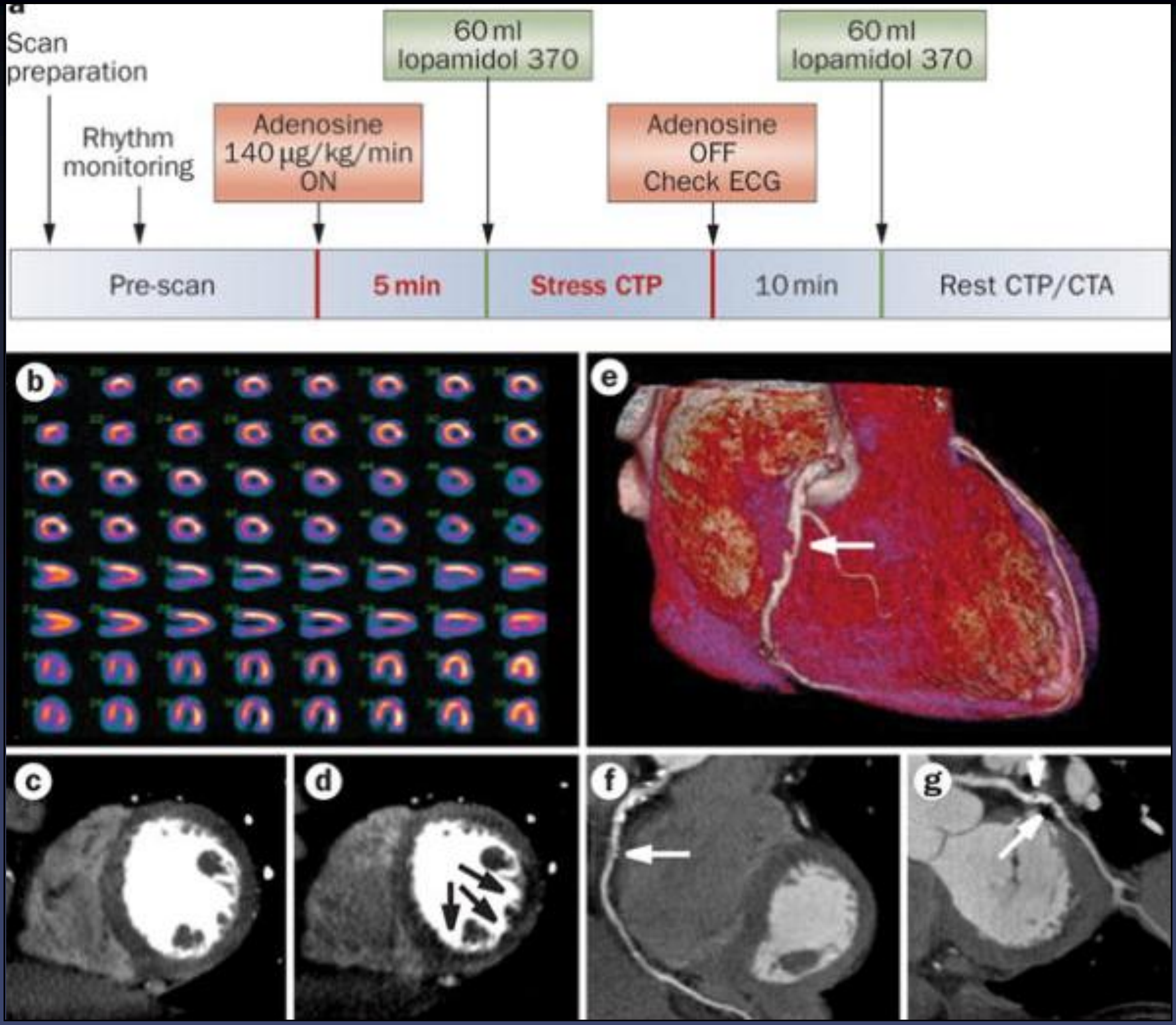
  - Detection of obstructive CAD and its hemodynamic effect simultaneously

Hybrid imaging using SPECT and CTA





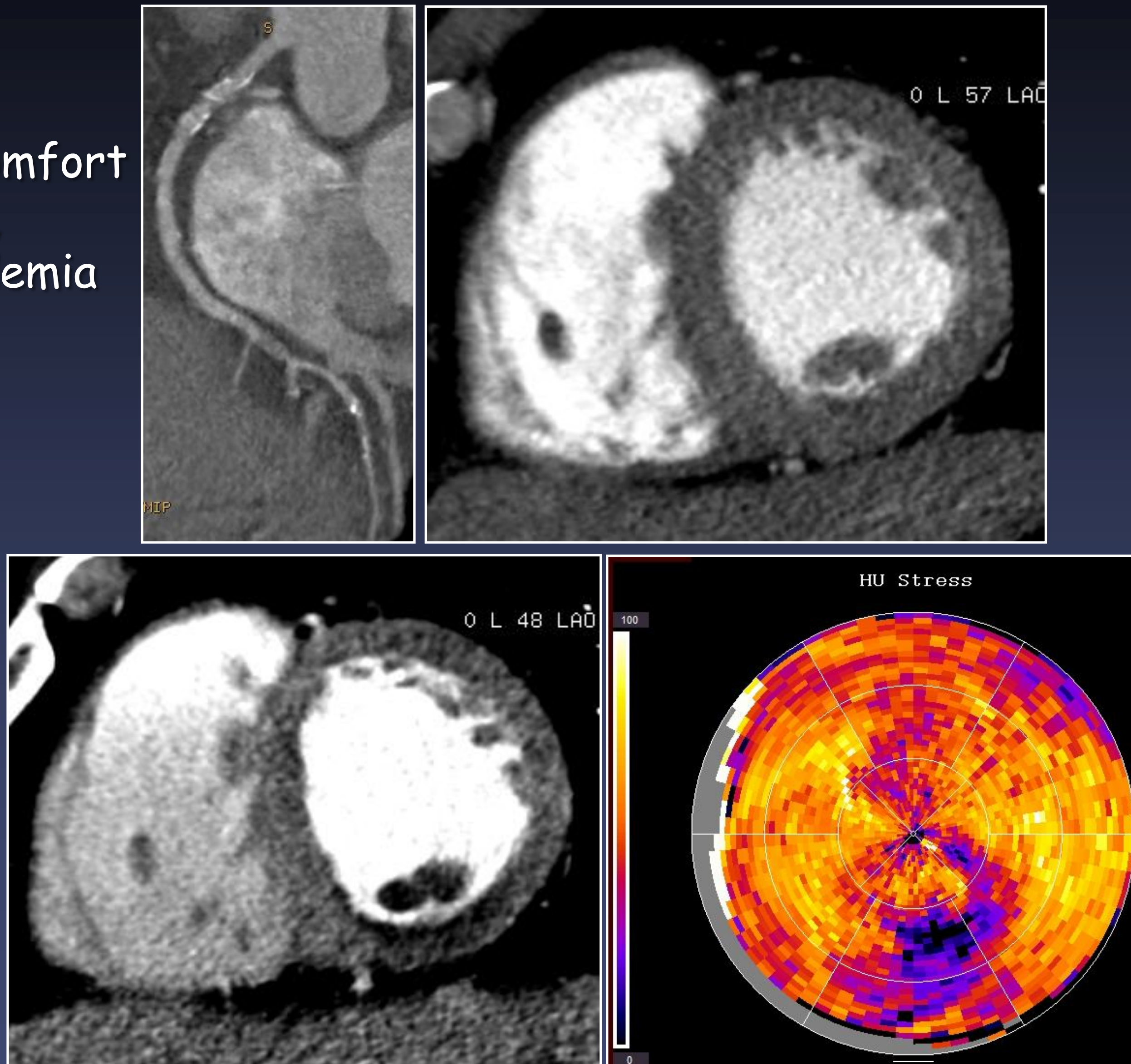
Rispler S et al. J Am Coll Cardiol 2007;49:1059-67

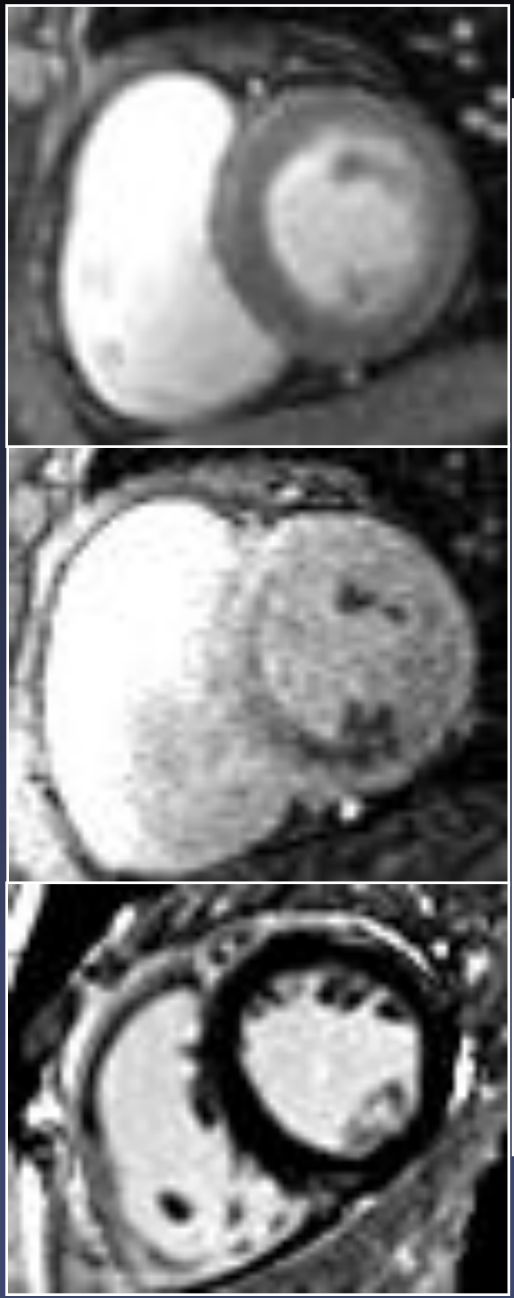
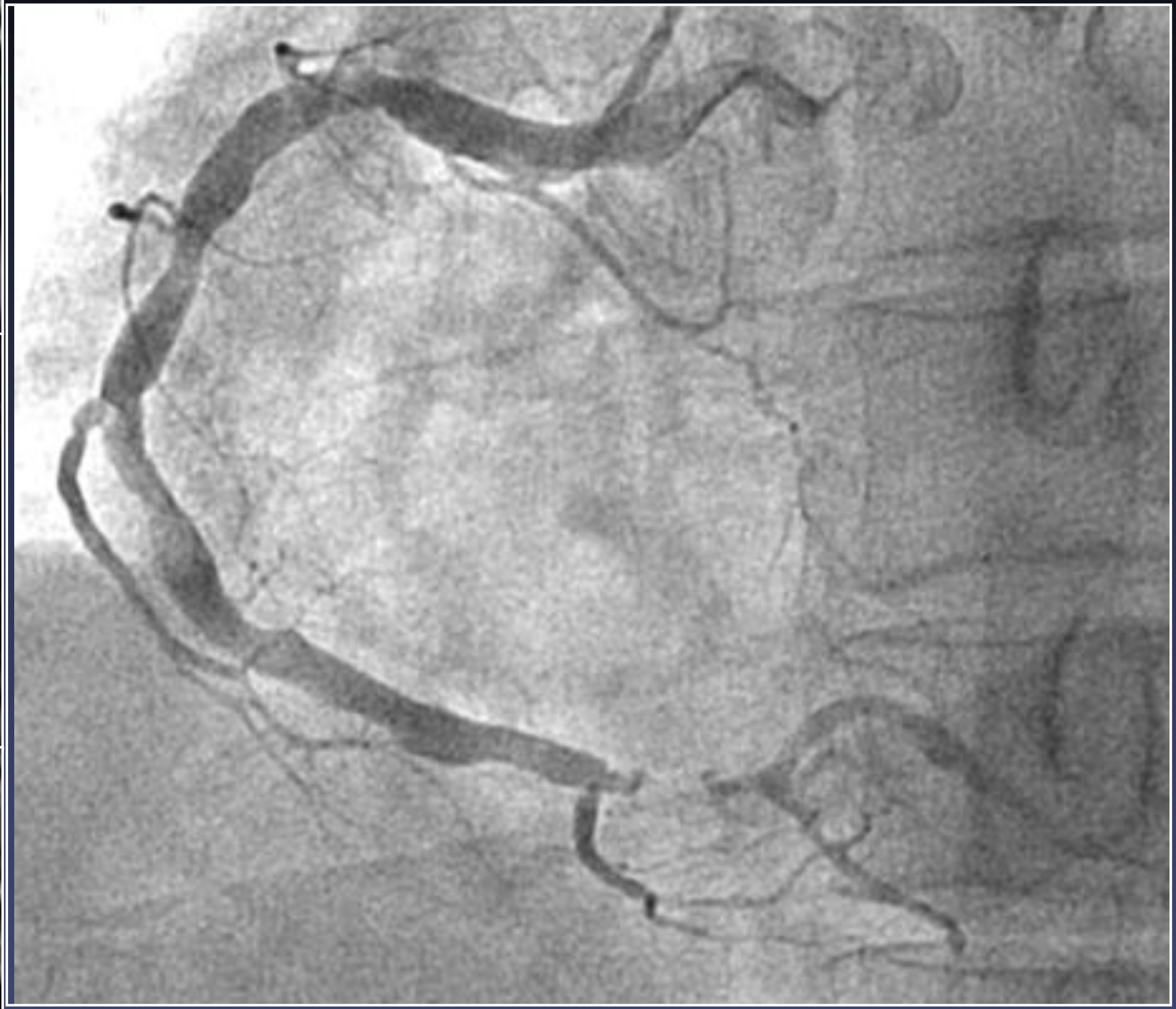


George RT, et al. Circ Cardiovas Imaging 2009;2:174-182

Stress perfusion CT and CMR

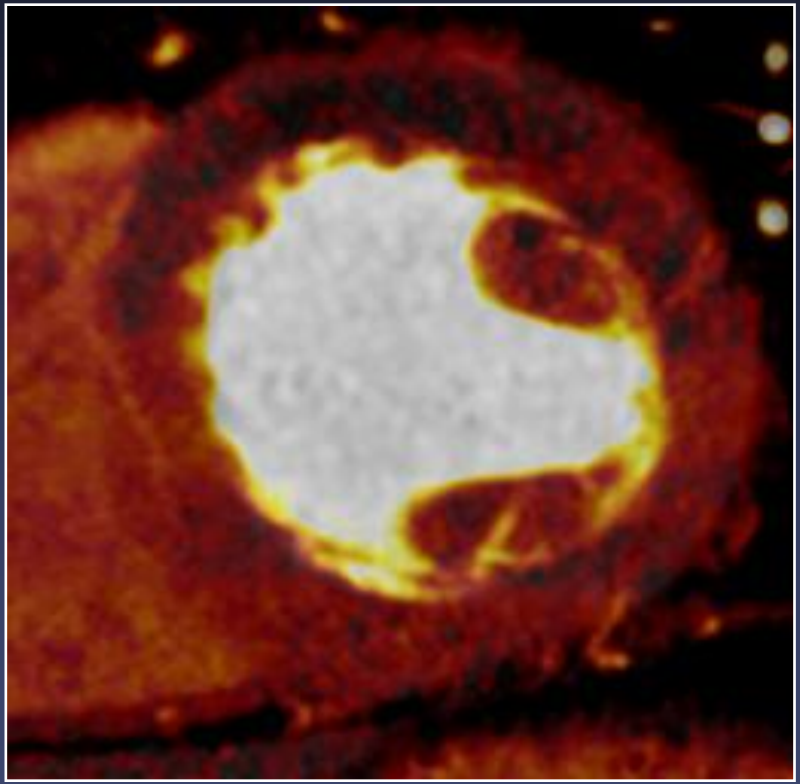
43M,
chest discomfort
HTN,
hyperlipidemia

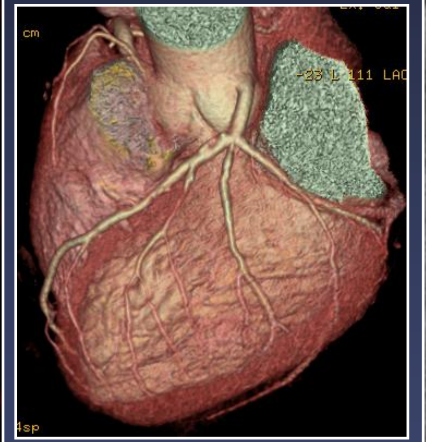


Dual-Energy CT

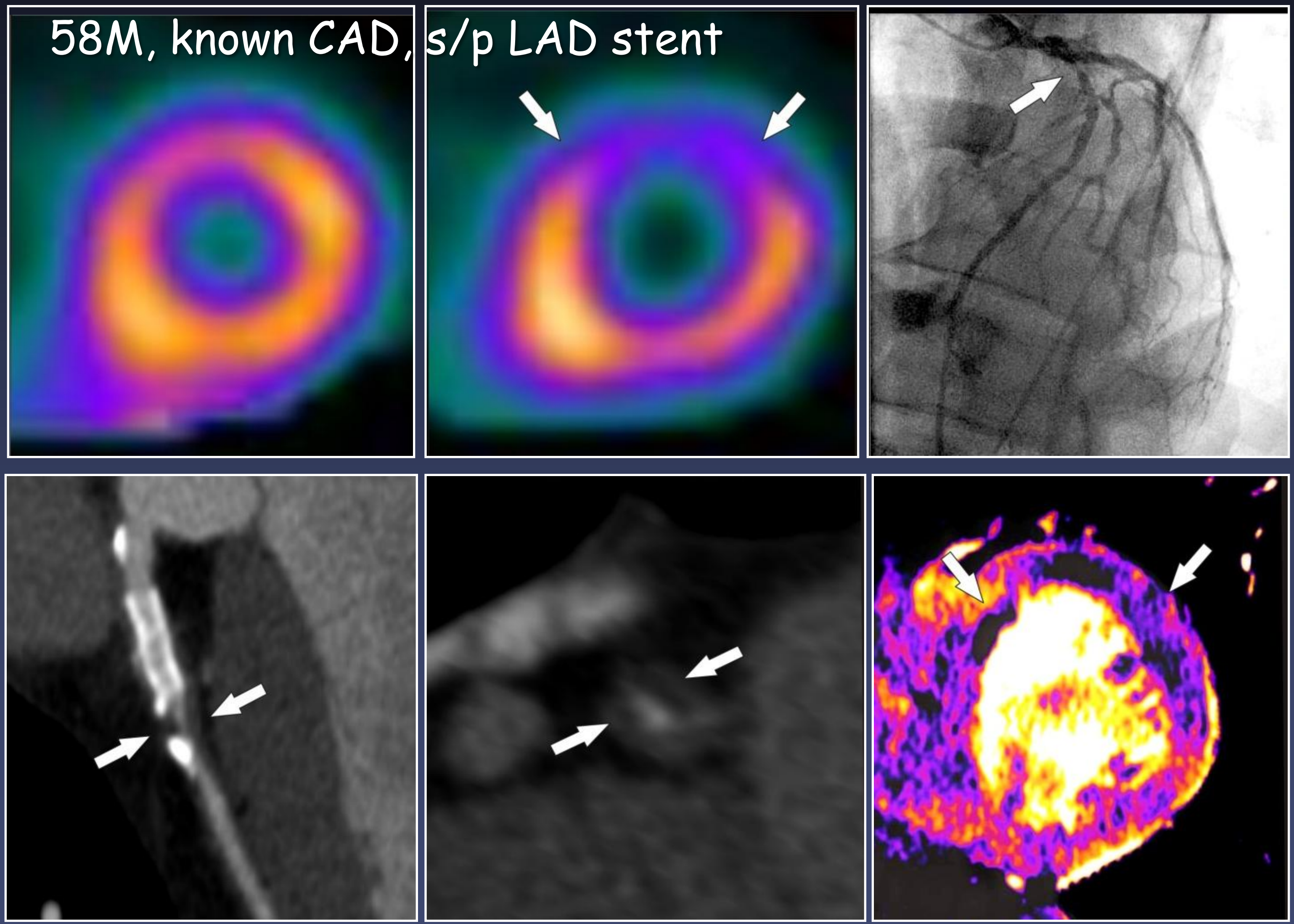
51M, ECG abnormality on routine checkup



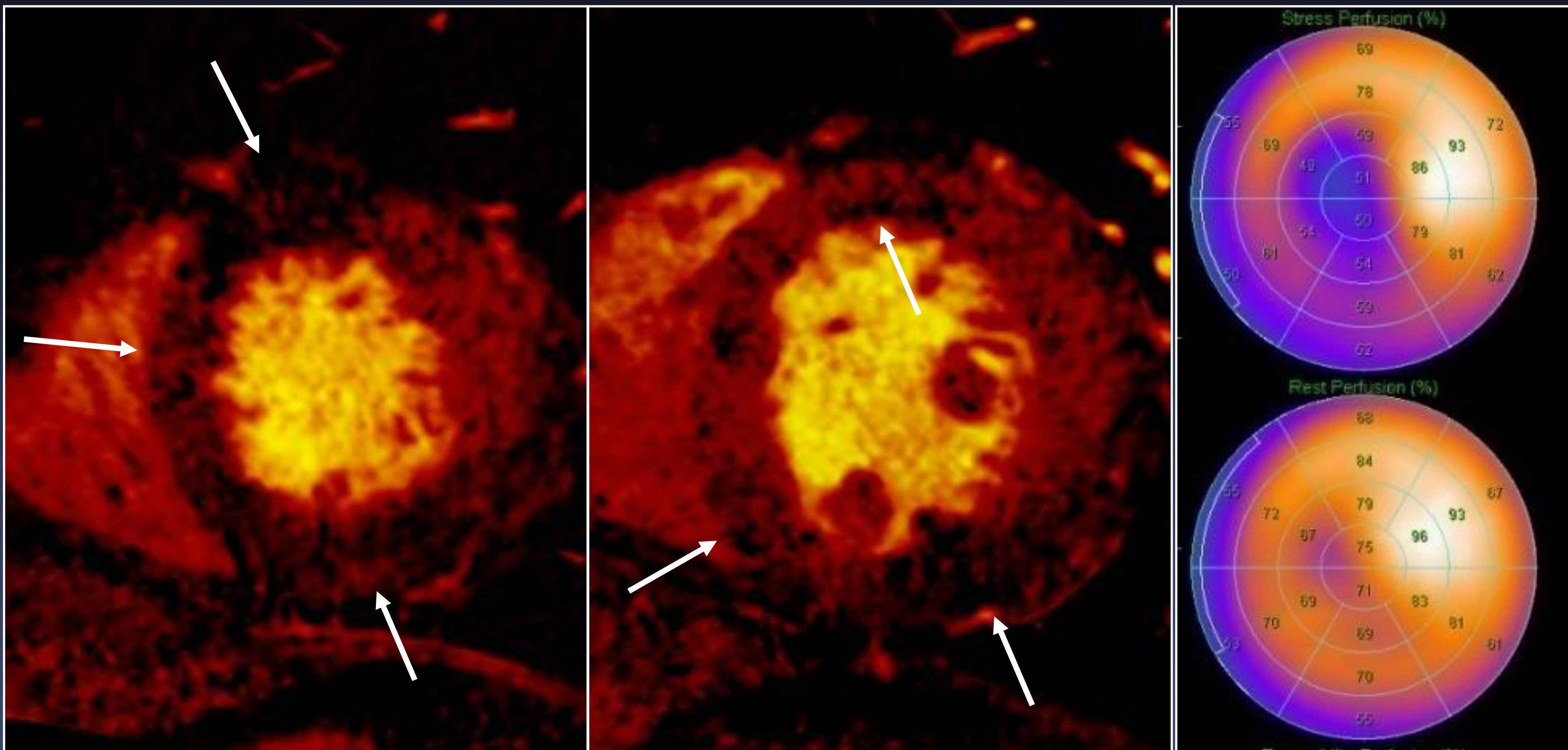


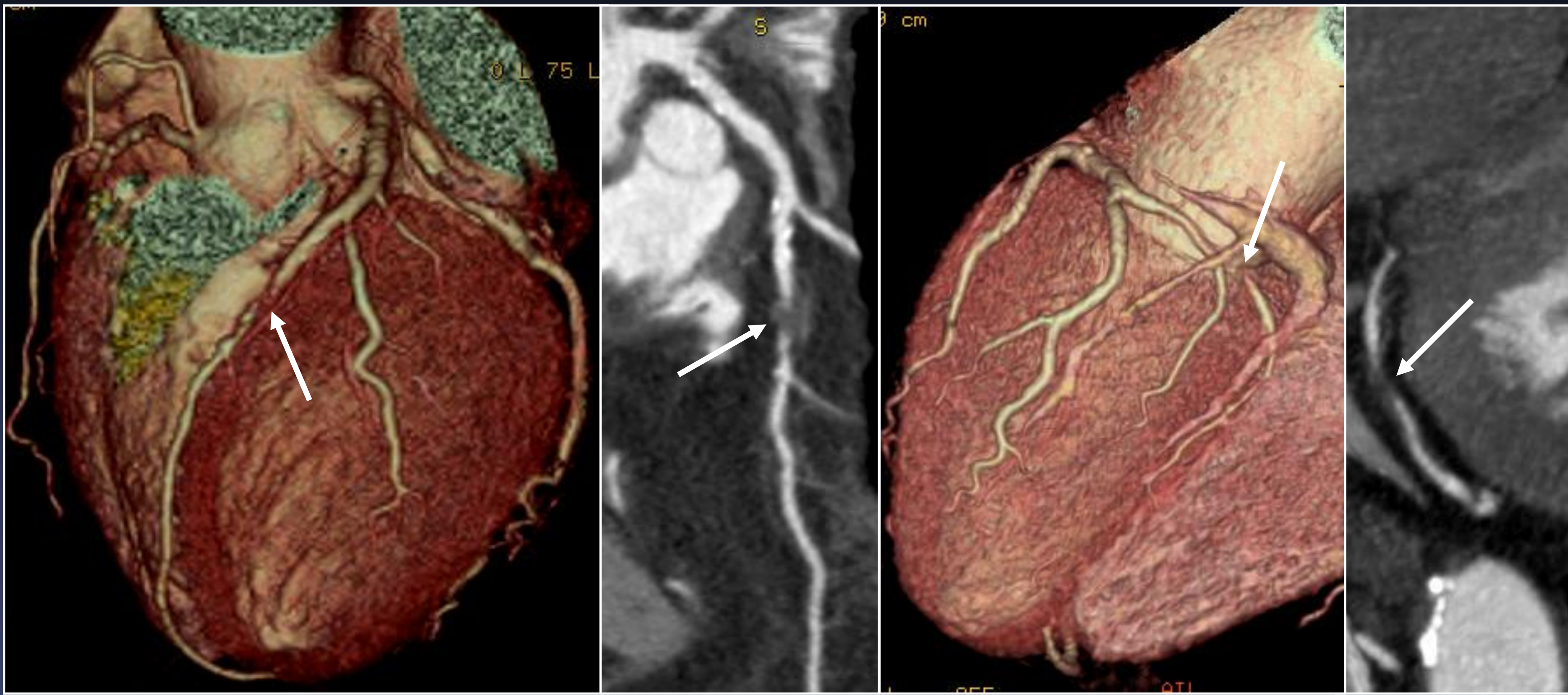
Ruzsics B, et al. Am J Cardiol 2009;104:318-26

Comparison of DECT of the heart with SPECT for assessment of coronary artery stenosis and of the myocardial blood supply



61M, known CAD




0 L 75 L
S
cm

Adenosine stress DECT

- **Iodinated contrast agents**

  - CT attenuation number directly proportional to the iodine content in tissue

- **Adenosine-induced stress perfusion CT**

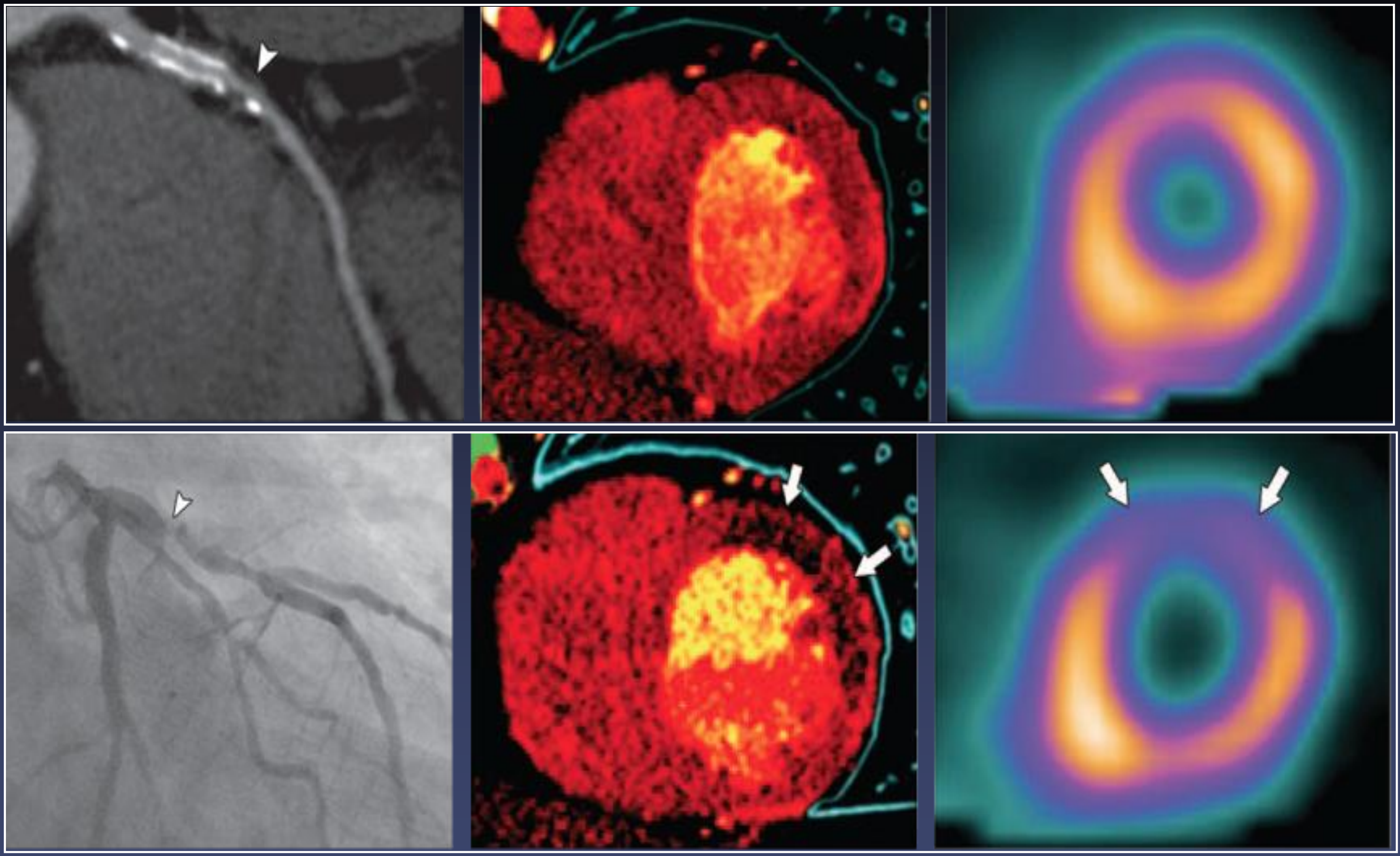
  - George RT, et al. JACC 2006;48:153-60
  - Kurata A, et al. Cir C 2005;69:550-7
  - Blankstein R, et al. JACC 2009;54:1072-84
  - Roch-Filho JA, et al. Radiology 2010;254:410-9

  → ***Promising potential future role in MPI for the detection of myocardial ischemia***

- **Adenosine stress DECT**

  - Two tubes emit X-ray spectra of different energy level
  - Assessment of myocardial blood volume

  → Is adenosine-induced stress perfusion DECT useful for evaluation of myocardial ischemia ?



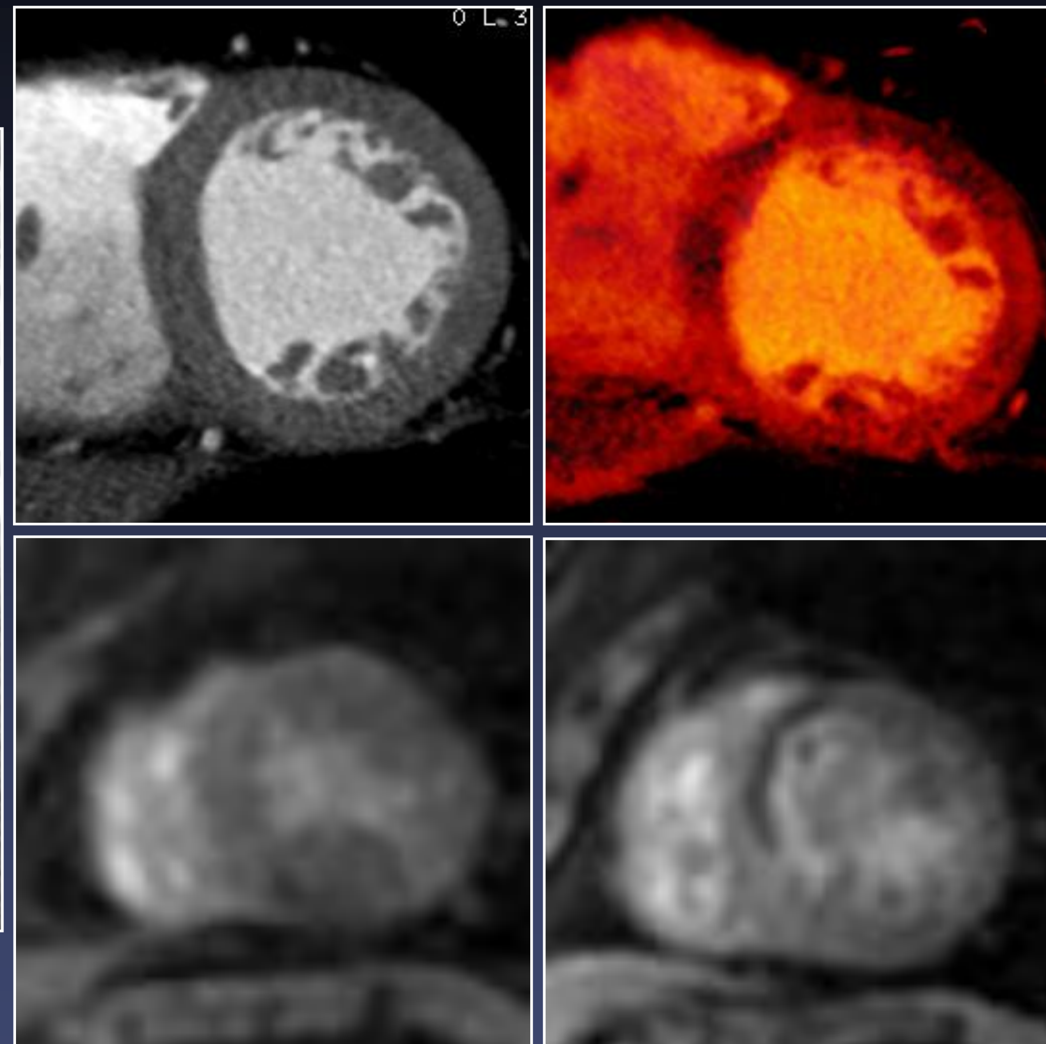
Bastarrika et al. Radiology 2009; 253: 317-38

Myocardial perfusion imaging using adenosine-induced stress DECT of the heart: comparison with CMR and CCA

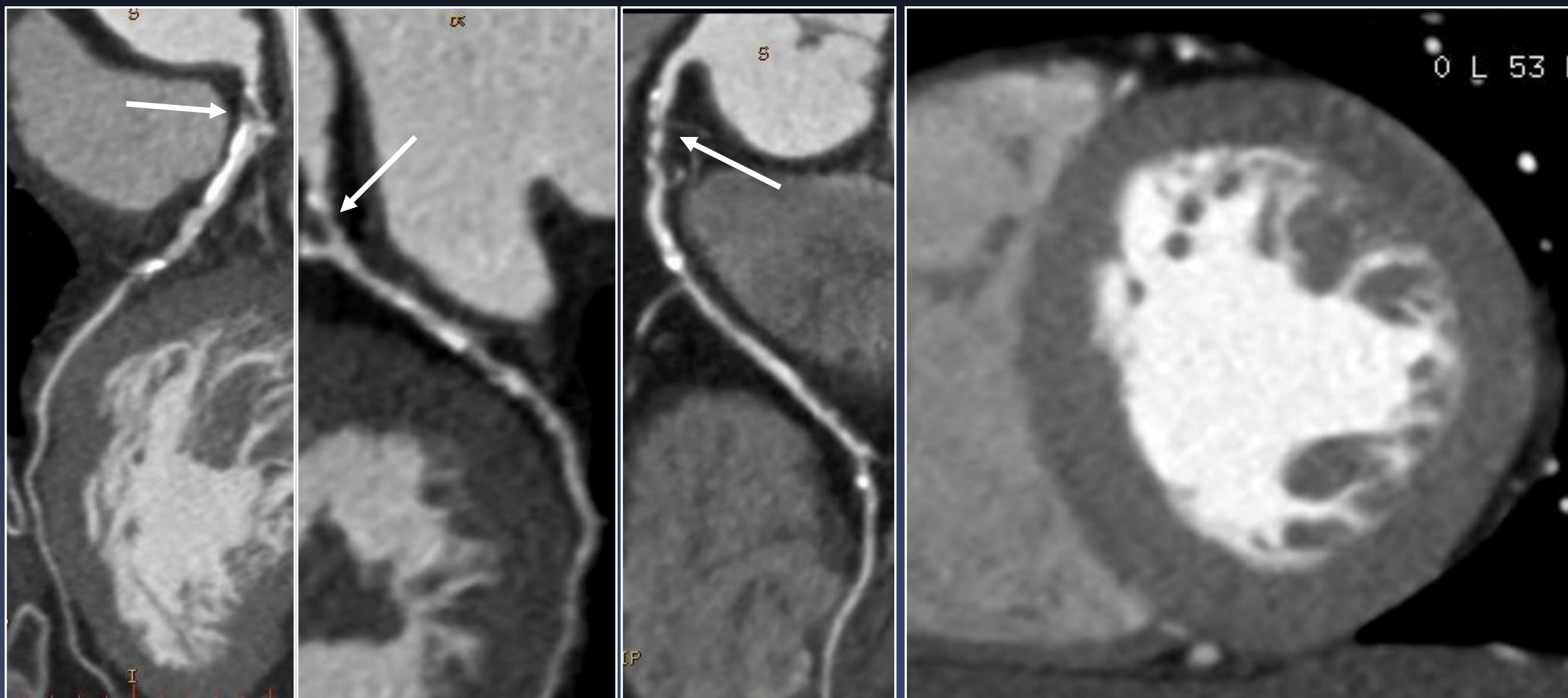
Stress DECT performance characteristics					
	Sensitivity	**Specificity**	**Accuracy**	**PPV**	**NPV**
CMR (n = 28)					
Segment	0.89	0.78	0.82	0.74	0.91
Territory	0.91	0.72	0.83	0.82	0.88
CCA (n = 41)					
Territory	0.89	0.76	0.83	0.81	0.86
Patient	0.97	0.5	0.93	0.95	0.67

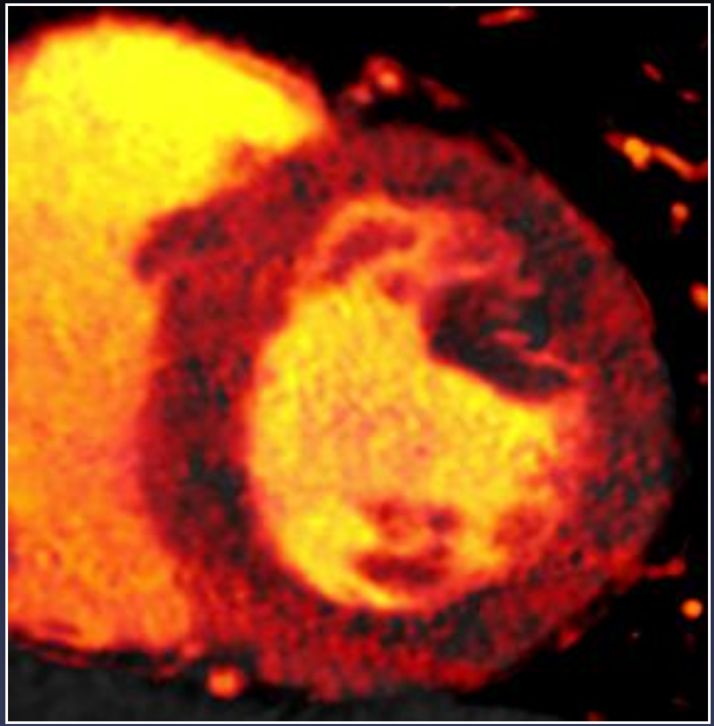
Ko SM, et al. Eur Radiol 2011;21:26-35

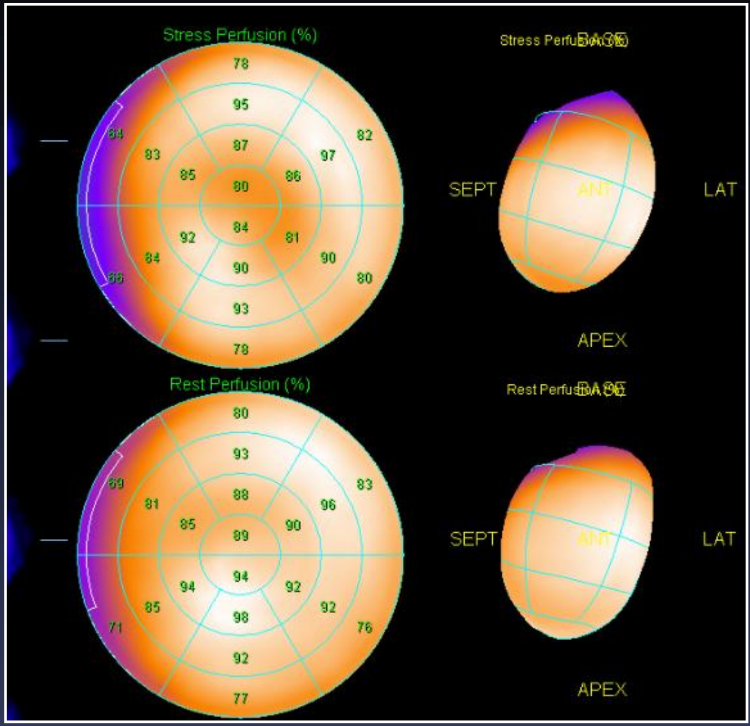
59/M, chest pain



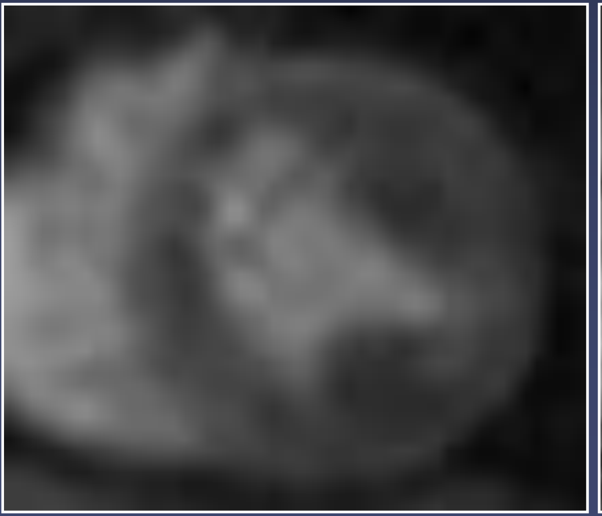
55/F, chest pain

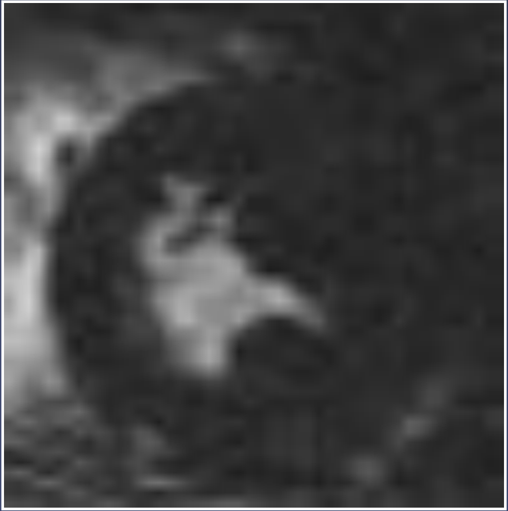


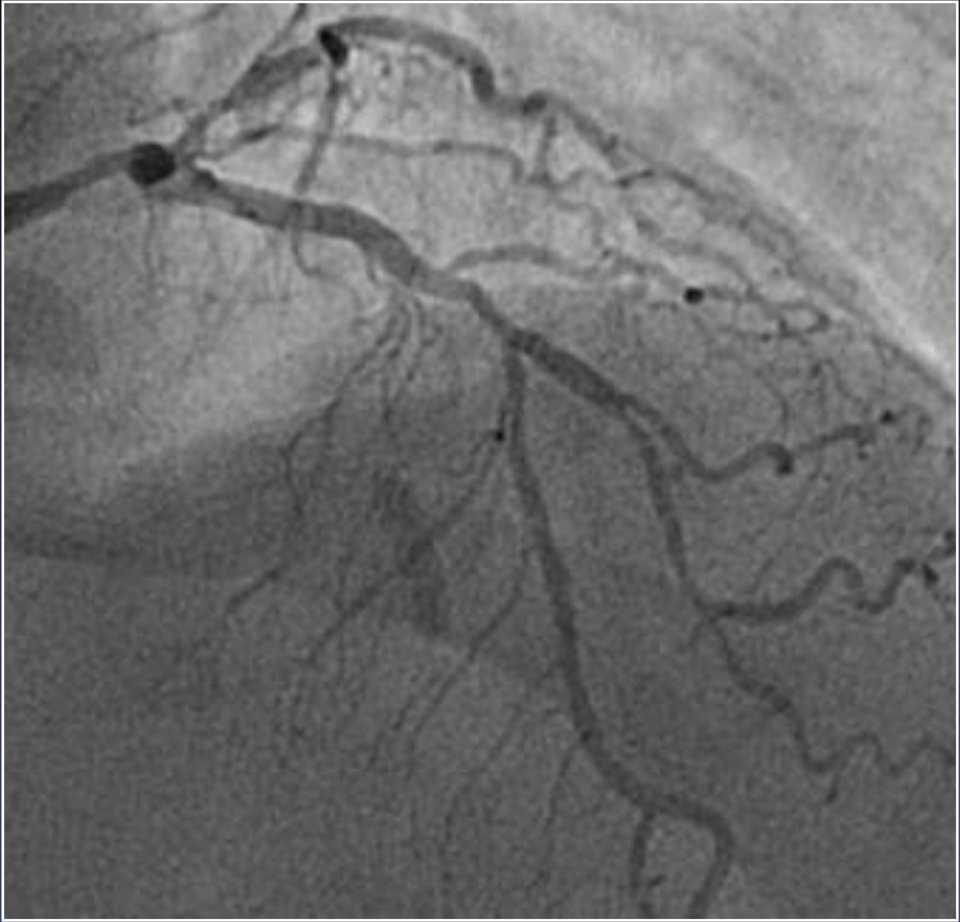




Stress Perfusion (%)
SEPT
LAT
APEX
Rest Perfusion (%)
SEPT
LAT
APEX

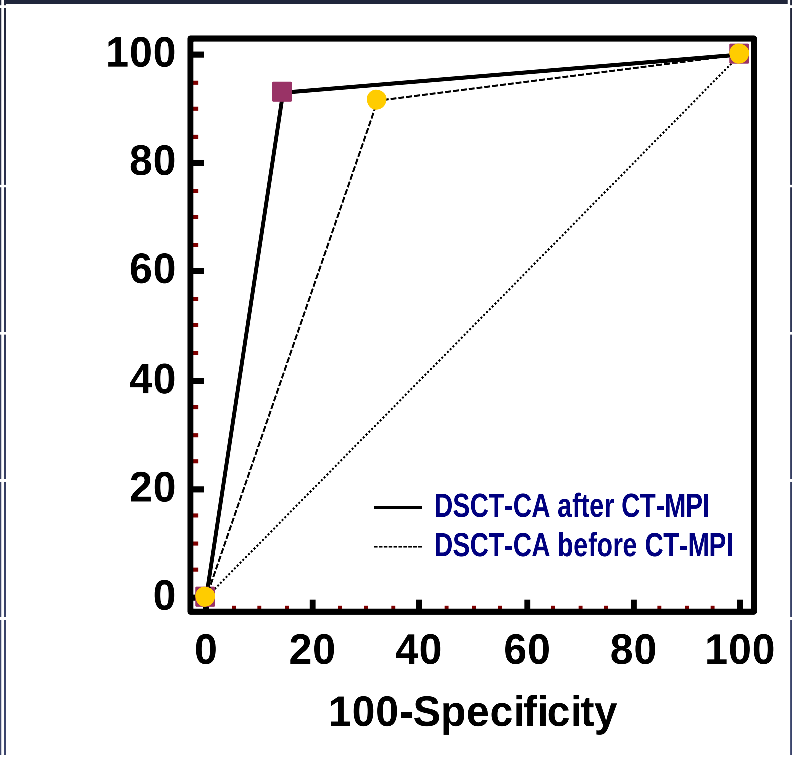







Diagnostic Performance of Combined Non-invasive Anatomical and Functional Assessment with DSCT and AIS-DECT for the Detection of Significant Coronary Stenosis (n=45)

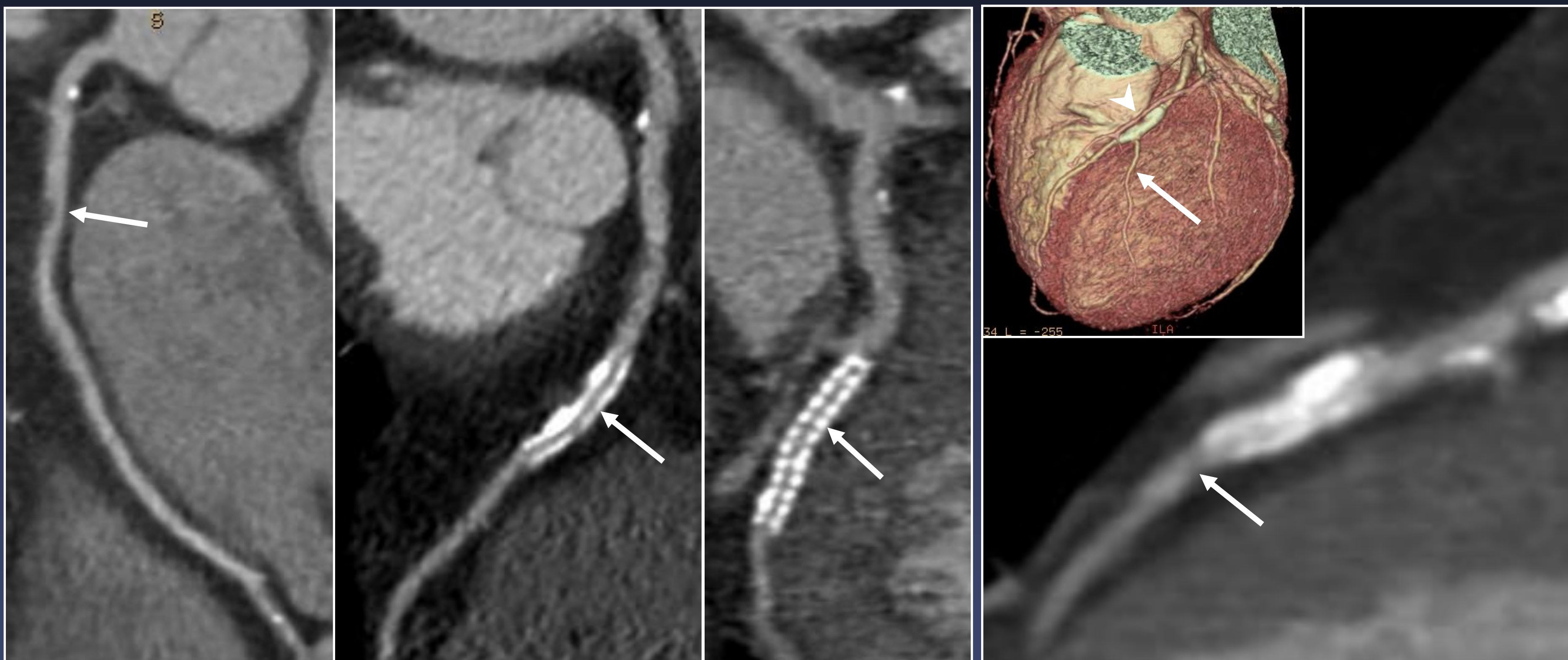
ROC	0.798 → 0.893 (p=0.004)	Per-Vessel Analysis	
		Before stress DECT	After stress DECT
Sensitivity (%)		91.8	93.2
Specificity (%)		67.7	85.5
PPV (%)		77	88.3
NPV (%)		87.5	91.4

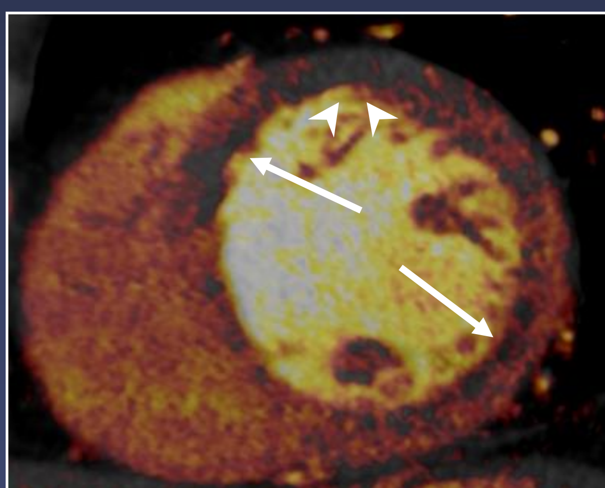


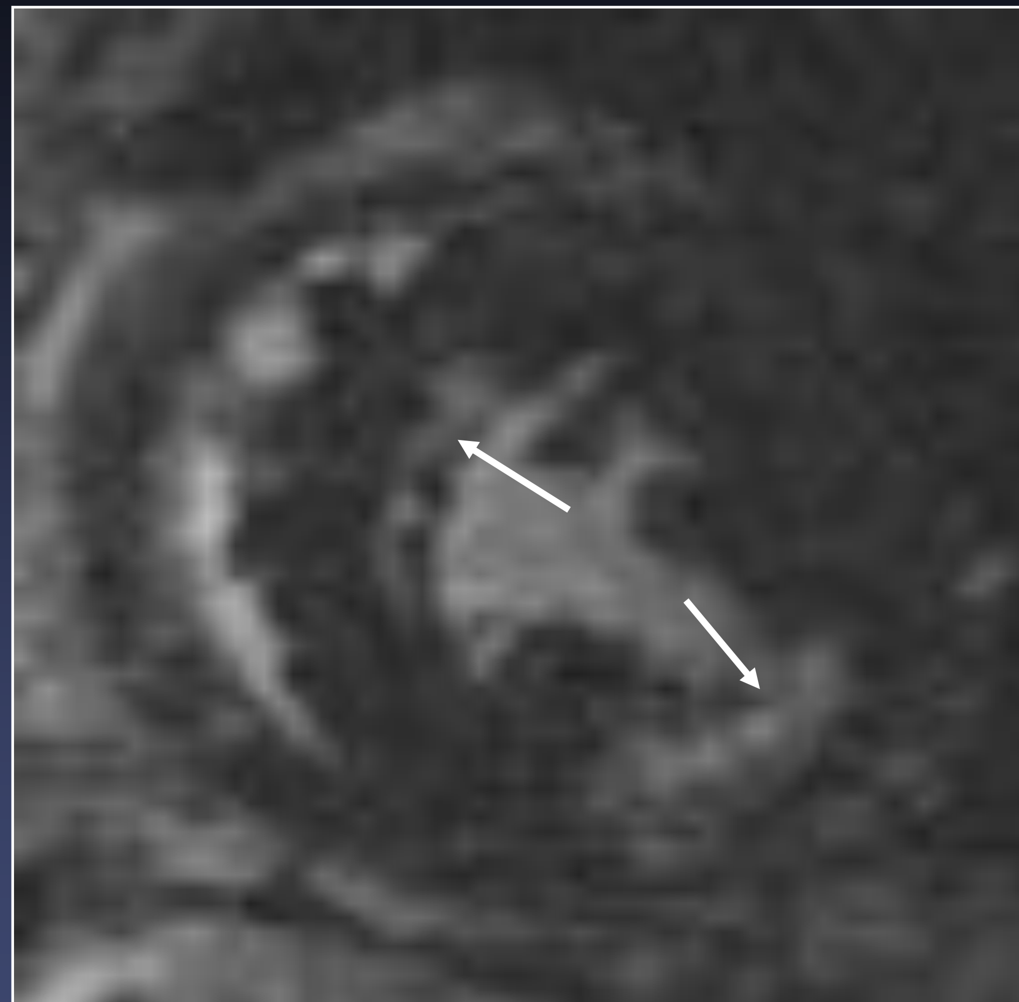
Ko SM, et al. AJR 2011, Accepted

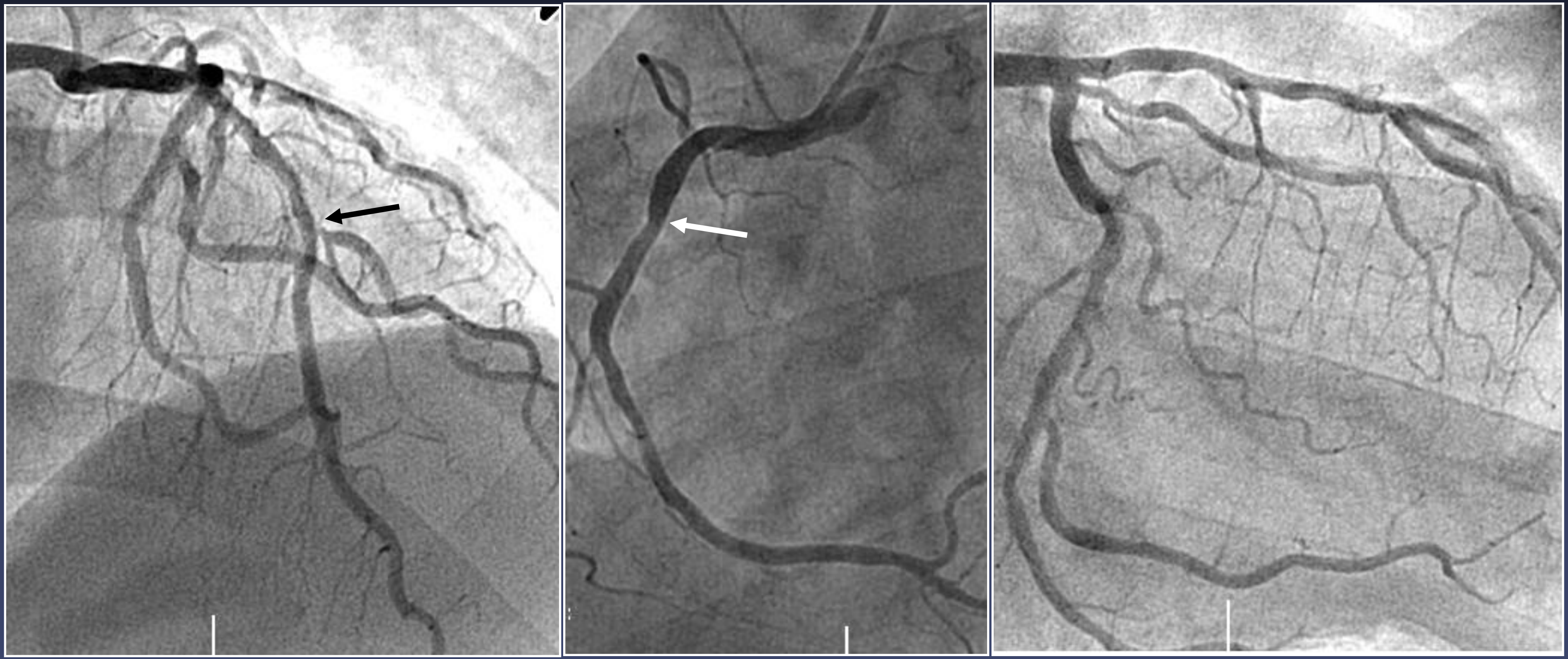
Ko SM, et al. 2010 RSNA scientific presentation

59 M, chest pain

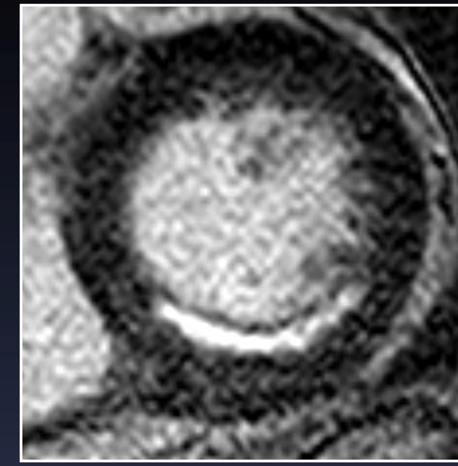


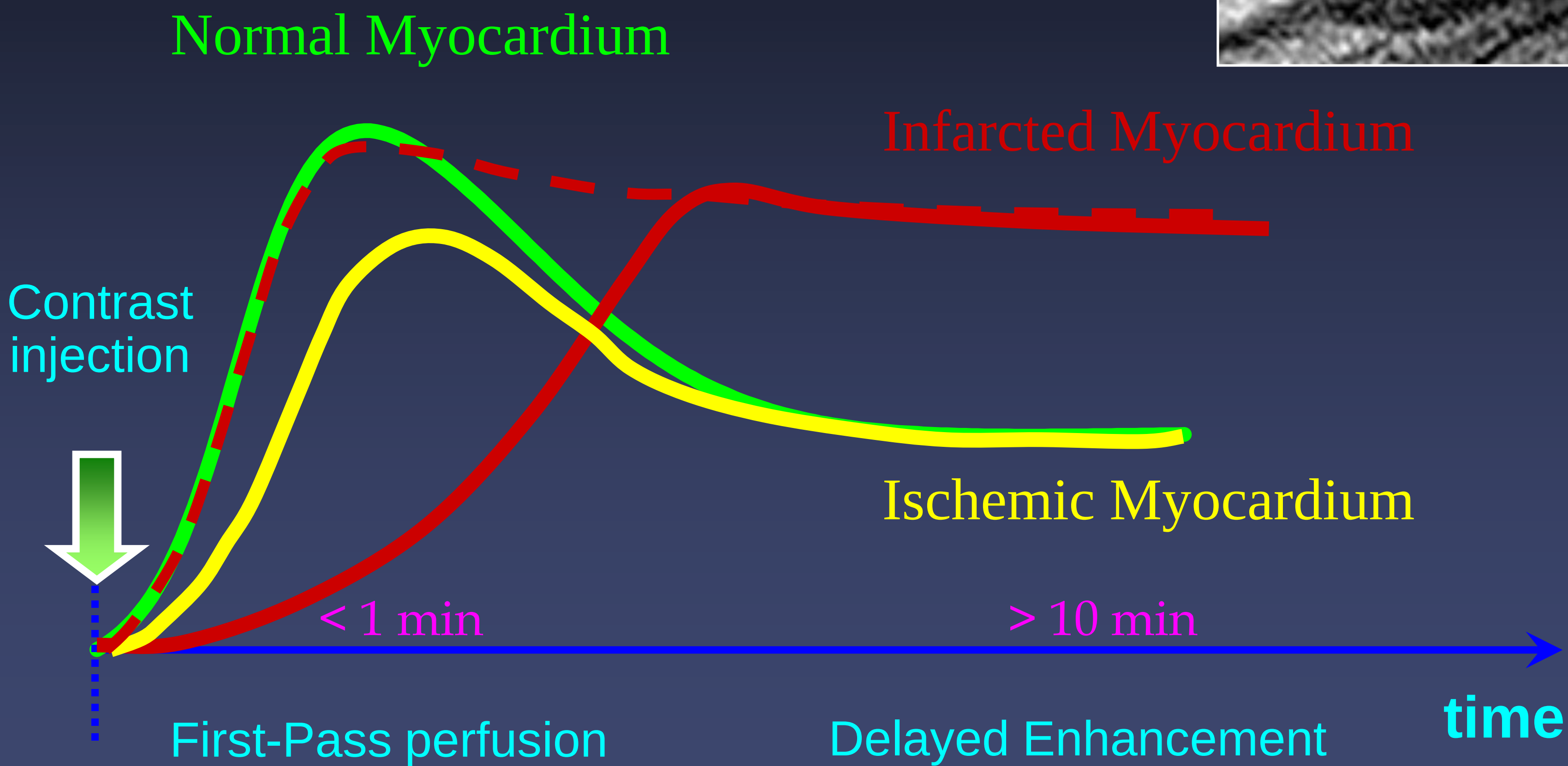






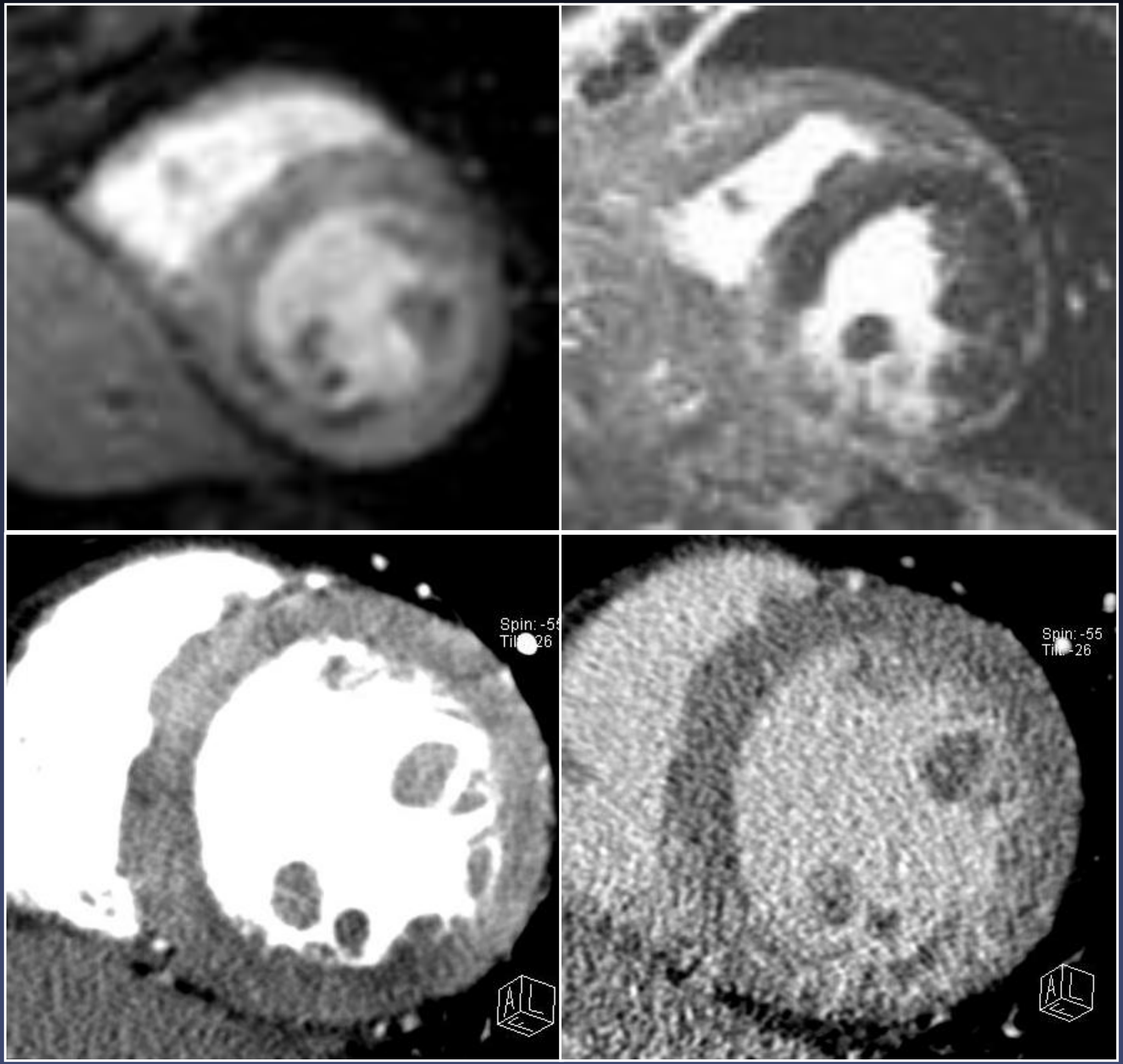
Time Intensity Curve



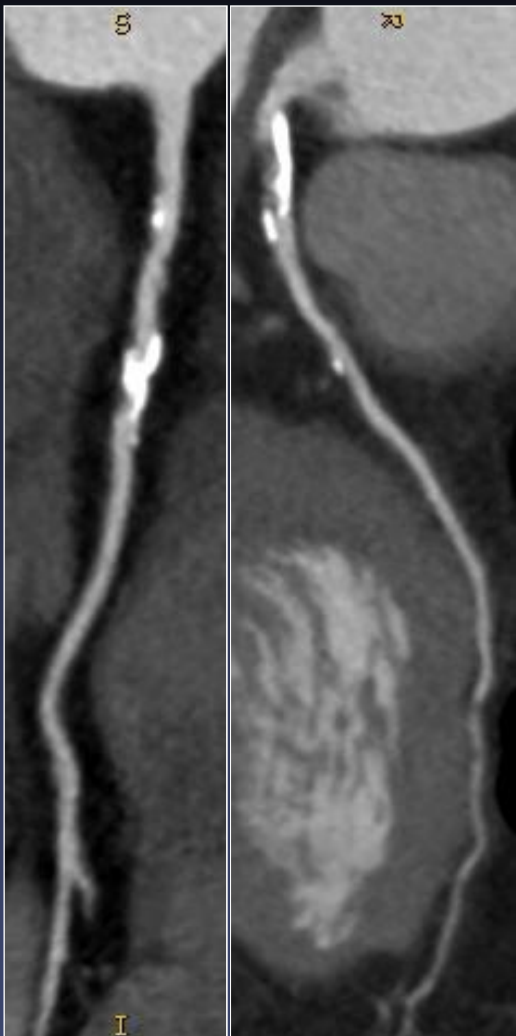


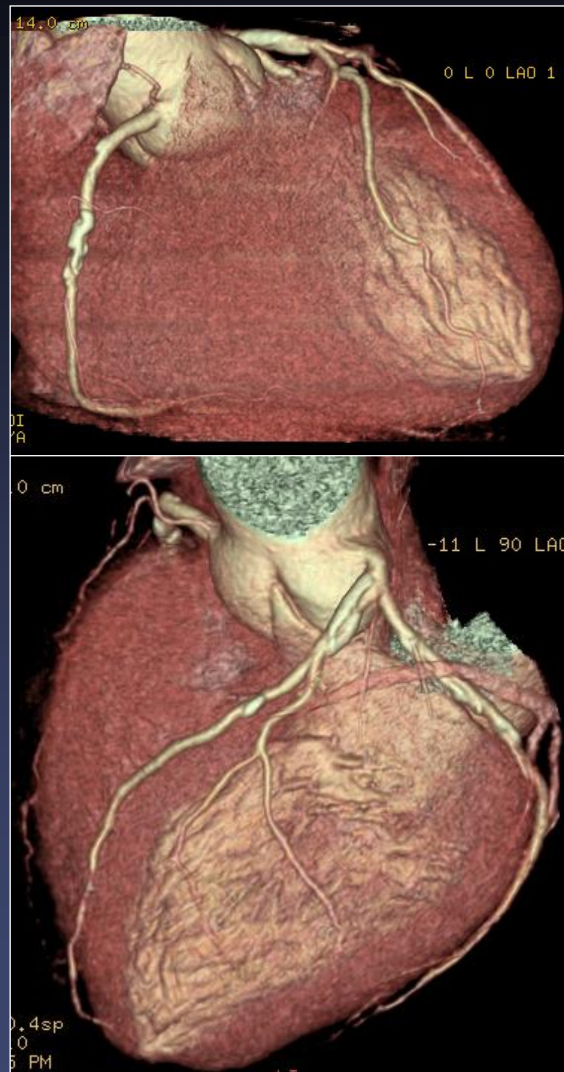
Myocardial perfusion and viability

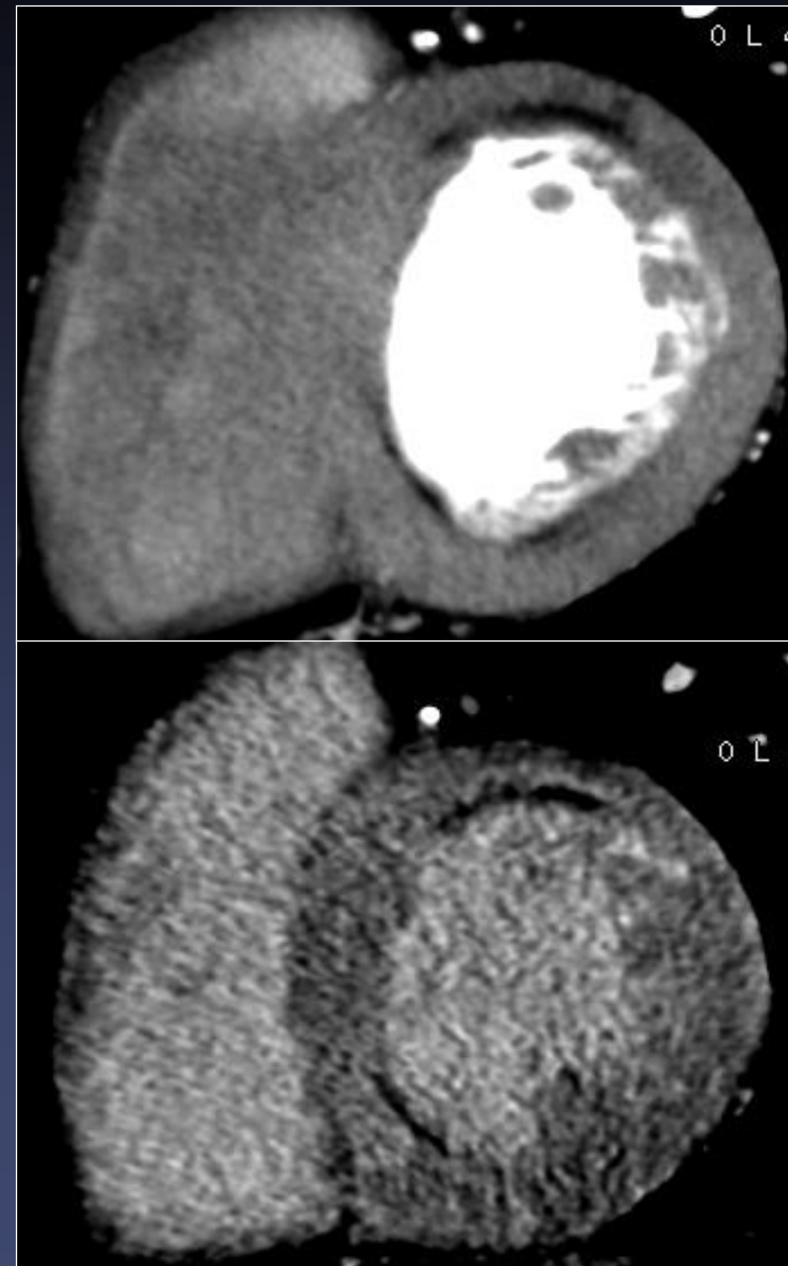
63/M, AMI



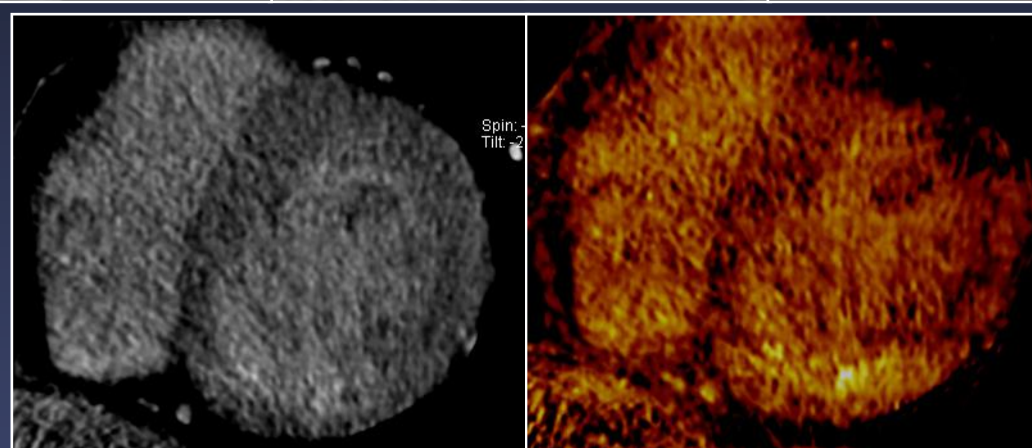
66/M, health check-up



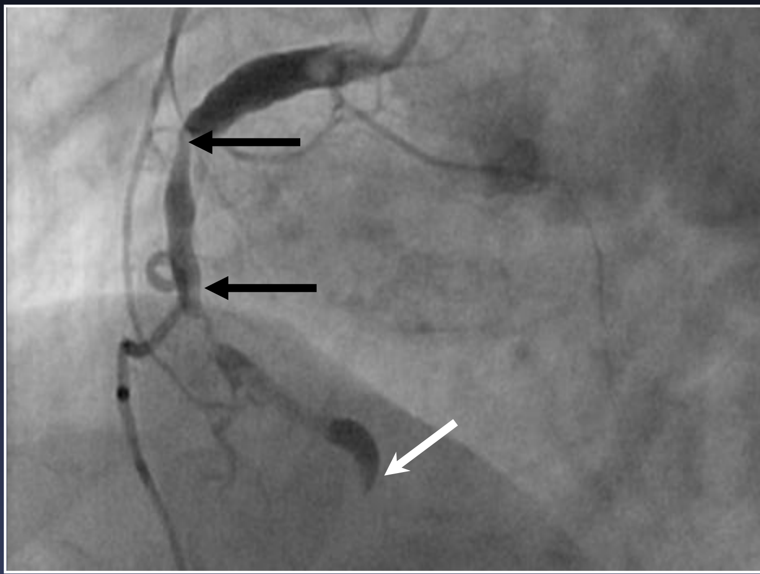


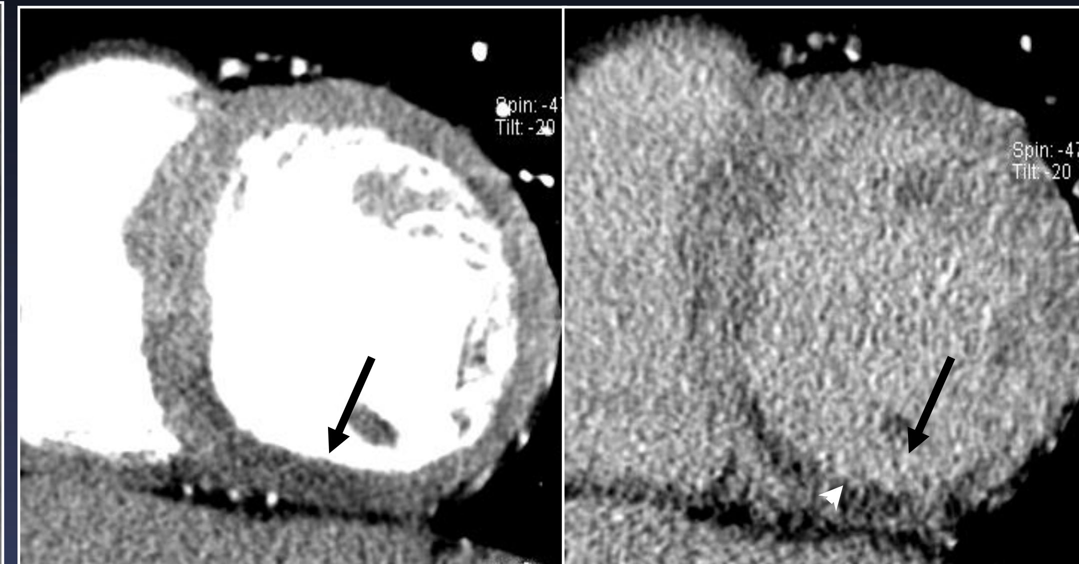


64M, Old MI



72/M, AMI



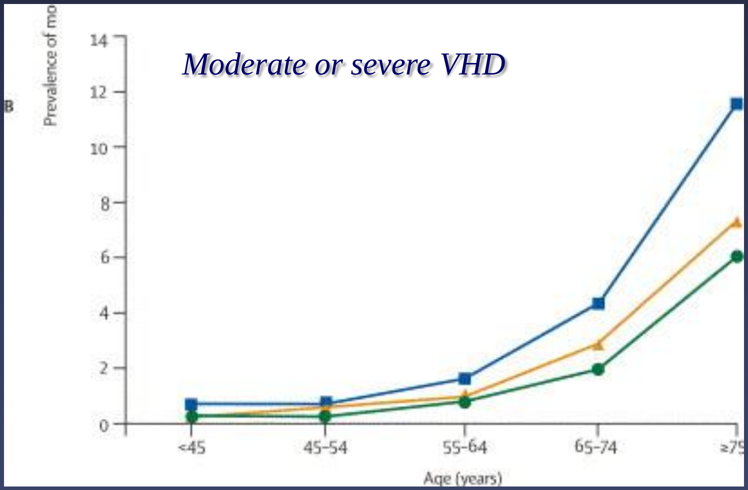


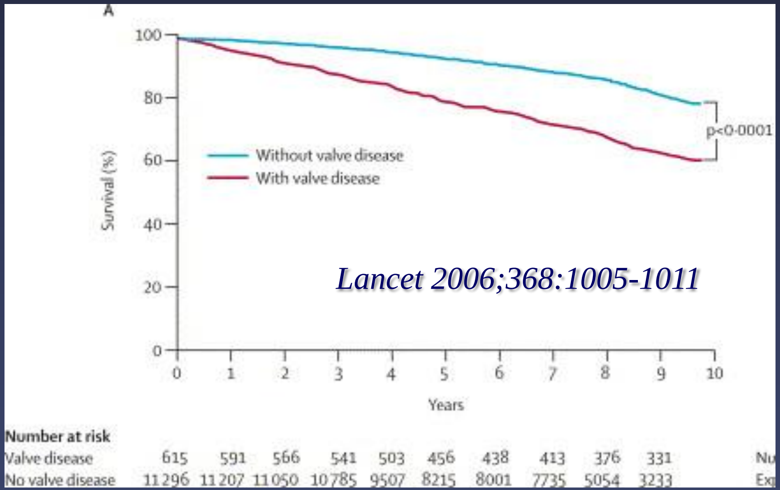
- Low-dose MDCT late-scan - reliably depicts size and transmural extent of microvascular occlusion and late enhancement in AMI
- Radiation dose and contrast material
- Clinical data are currently too limited to allow clinical recommendations on the use of CT for the assessment of perfusion and viability

Ko SM, et al. KJR 2007;8:94-102
Ko, et al. Clin Radiol 2006;61:417-422

Valvular heart disease

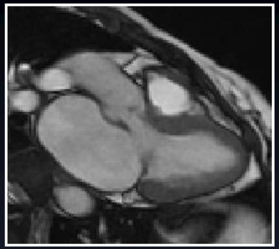
- In 2004, 99,000 valve replacement procedure and overall in-hospital mortality rate of 5.1% in USA
- Increasing number of valve surgery (4%-7% annually) d/t aging population with an increasing prevalence of degenerative VHD





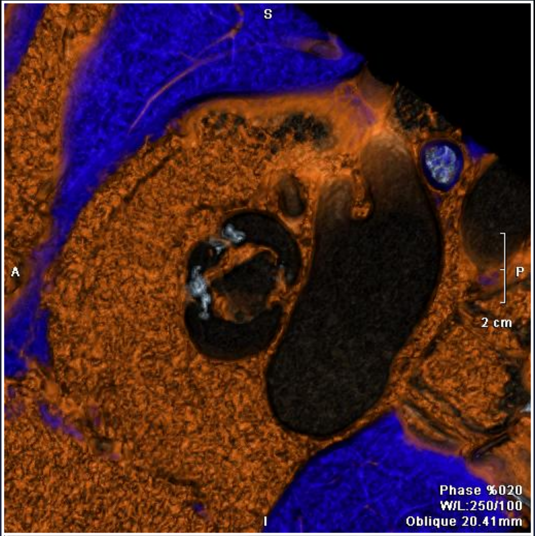
- Aortic stenosis
  - M/C indication for valve surgery
- Imaging modalities - Echo, CMR, CT

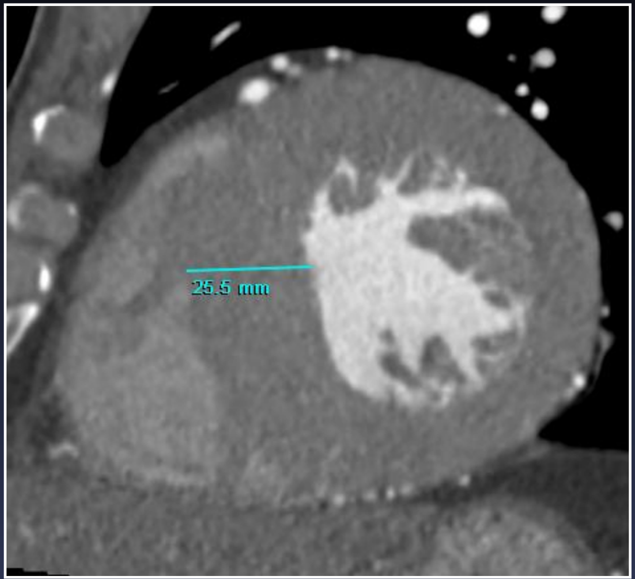
Vital data of VHD patients

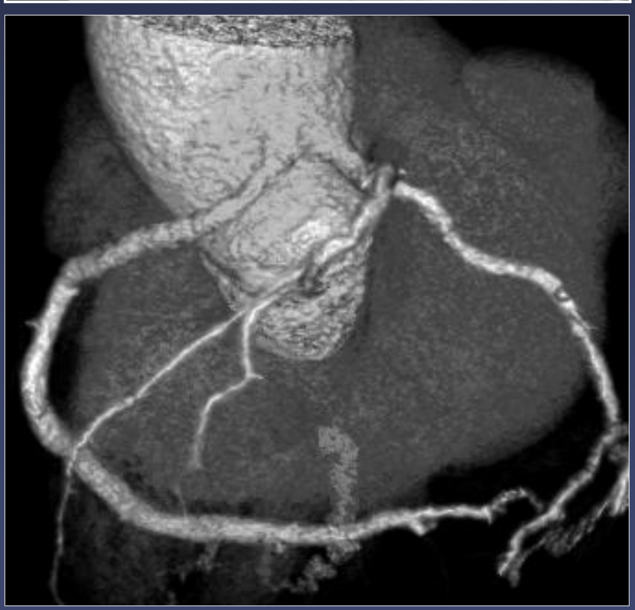


- **Valve morphology**
  - number of leaflets, integrity of leaflets and tendinous chords, pathologic features, perivalvular morphology
- Valve function
  - opening and coaptation pattern, valve orifice/valve circumference, mean/peak systolic flow + calculation of transvalvular gradient, regurgitant flow/fraction
- Ventricular function
  - volumes, systolic/diastolic function, wall mass, regional wall motion
- Additional information
  - great vessel, thrombi, CAD, MI, myocardial scarring

BAV with ASR

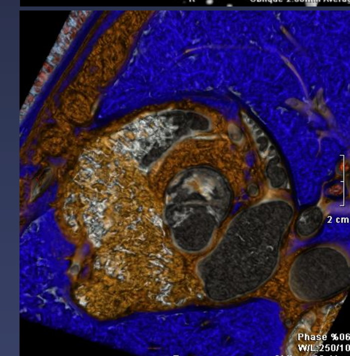






Cardiac Valves: CT

- **Excellent spatial resolution and improved temporal resolution**
  - valve morphology, motion, and cusps excursion/ apposition, and stenosis and regurgitant severity
- Valvular calcification, aorta abnormality, coronary artery anomaly or stenosis
- Limitation in daily routine
  - limited temporal resolution (70-175 ms)
  - Iodinated contrast media
  - Ionizing radiation
  - No functional information about valve disease severity



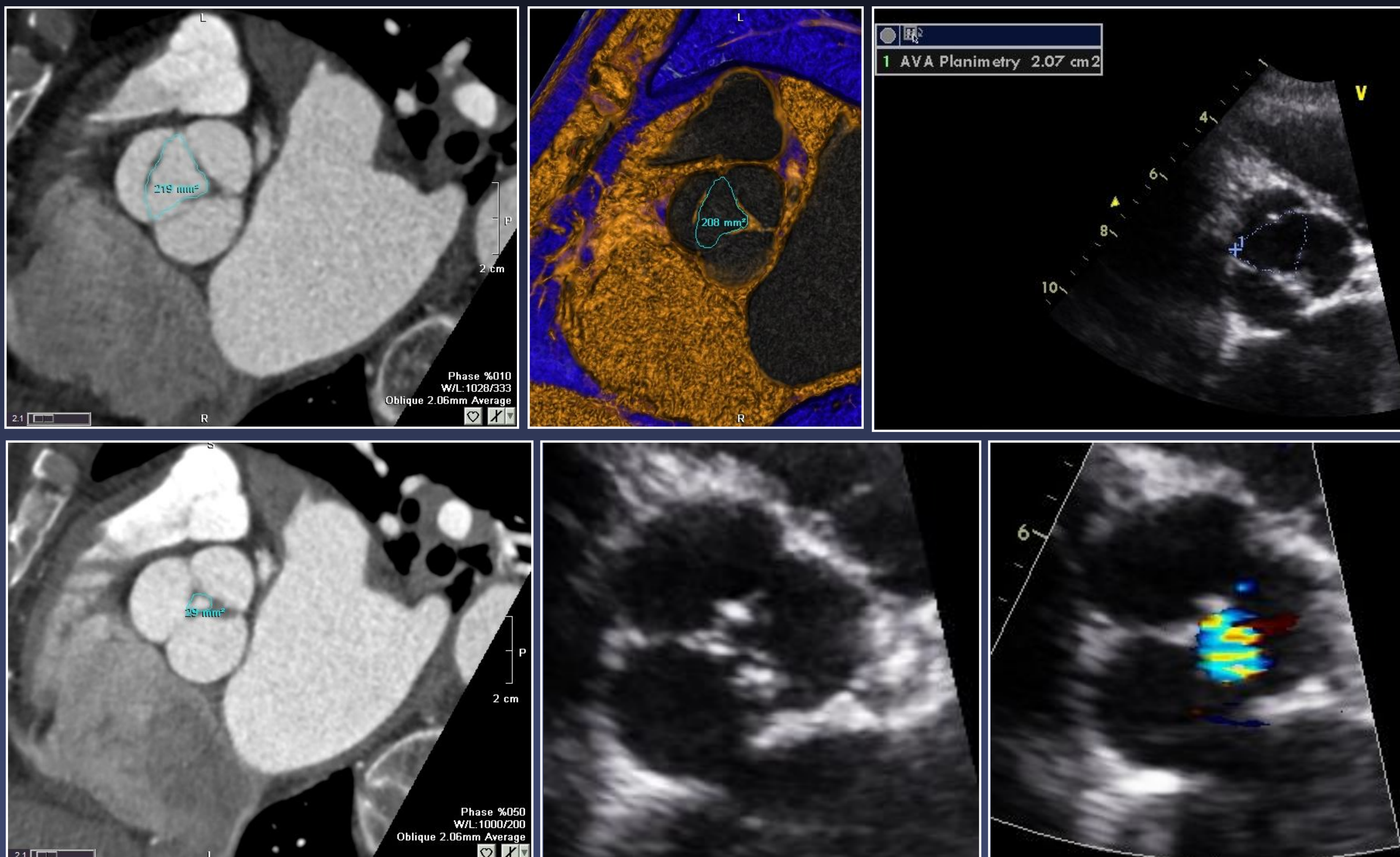
Valve morphology assessment

Table 1. Assessment of Aortic and Mitral Valve Stenosis and Regurgitation With MDCT

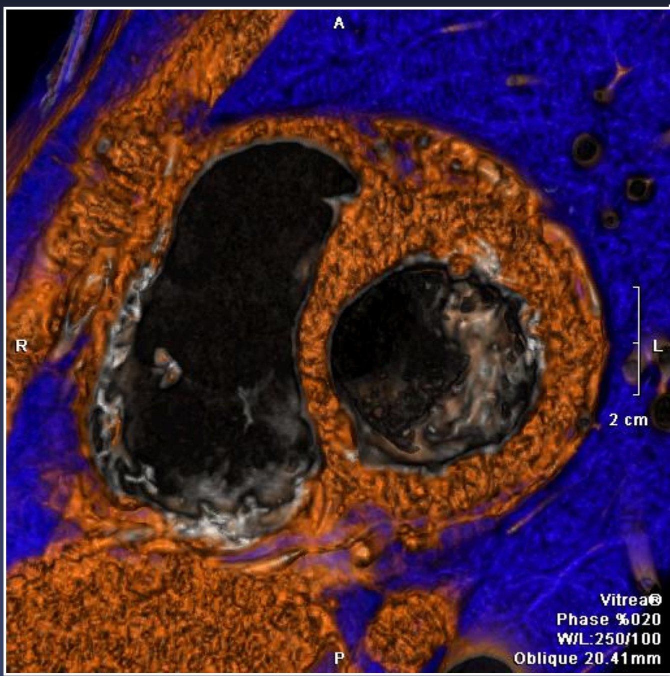
Authors (Ref. #)	Patients (n)	Referral Reason	CT Technique	Collimation (mm)	Comparison Technique	Correlation	Bland-Altman, Mean Difference (Limits of Agreement)
Aortic valve stenosis (correlation: AVA)							
Feuchtner et al. (21)	46 (30 AS)	Pre-operative (CABG)	16-slice	16 × 0.75	TTE	r = 0.89, p < 0.001	0.04 (−0.20, 0.29)
Alkadhi et al. (22)	40 (20 AS)	Coronary angiography	16-slice	16 × 0.75	TTE/TEE	TTE: r = 0.95, p < 0.001 TEE: r = 0.99, p < 0.001	TTE: 0.06 (−0.15, 0.26) TEE: −0.08 (−0.32, 0.16)
Bouvier et al. (23)	103 (30 AS)	Coronary angiography	16-slice	16 × 0.625	TTE/TEE*	N/A	−0.07 (−0.40, 0.25)
Piers et al. (24)	30 AS	N/A	EBCT	N/A	TTE	r = 0.60, p < 0.01	0.51 (−0.39, 1.41)
Laissy et al. (25)	40 AS	Pre-operative (AVR)	16-slice	16 × 0.4	TTE	r = 0.77, p < 0.001	0.06 (−0.23, 0.35)
Habis et al. (26)	52 AS	Pre-operative (AVR)	64-slice	64 × 0.6	TTE	r = 0.76, p < 0.001	0.13 (−0.35, 0.61)
Feuchtner et al. (27)	36 AS	Coronary angiography	64-slice	64 × 0.6	TTE/TEE†	TTE: r = 0.88, p < 0.001 TEE: r = 0.99, p < 0.001	TTE: 0.06 (−0.35, 0.47) TEE: −0.13 (−1.02, 0.76)
Aortic valve regurgitation (correlation: ROA)							
Feuchtner et al. (28)	71 (48 AR)	Several‡	16-slice	12 × 0.75	TTE	r = 0.95, p < 0.001	N/A
Jassal et al. (29)	64 (30 AR)	Coronary angiography	64-slice	64 × 0.6	TTE	r = 0.79, p < 0.001	N/A
Alkadhi et al. (30)	30 AR	Several§	64-slice	64 × 0.6	TTE	r = 0.84, p < 0.001	N/A
Mitral valve stenosis (correlation: MVA)							
Messika-Zeitoun et al. (31)	29 MS	N/A	16-slice	N/A	TTE	r = 0.88, p < 0.001	0.20 (−0.14, 0.54)
Mitral valve regurgitation (correlation: ROA)							
Alkadhi et al. (32)	44 (19 MR)	Coronary angiography	16-slice	16 × 0.75	TEE	r = 0.81, p < 0.001	N/A

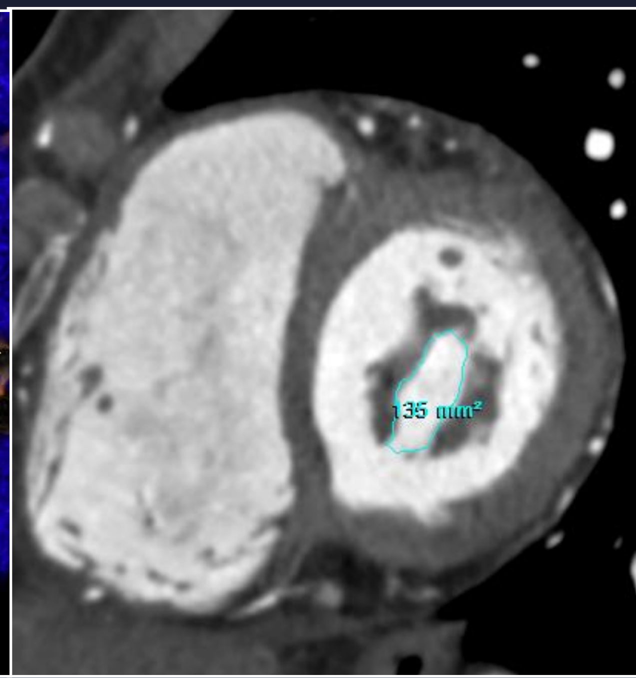
Tops LF, et al. J Am Coll Cardiol Img 2008;1:94-106

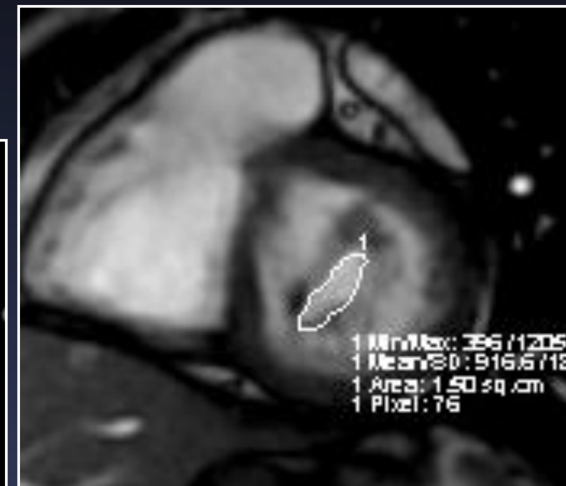
Aortic valve area measurement



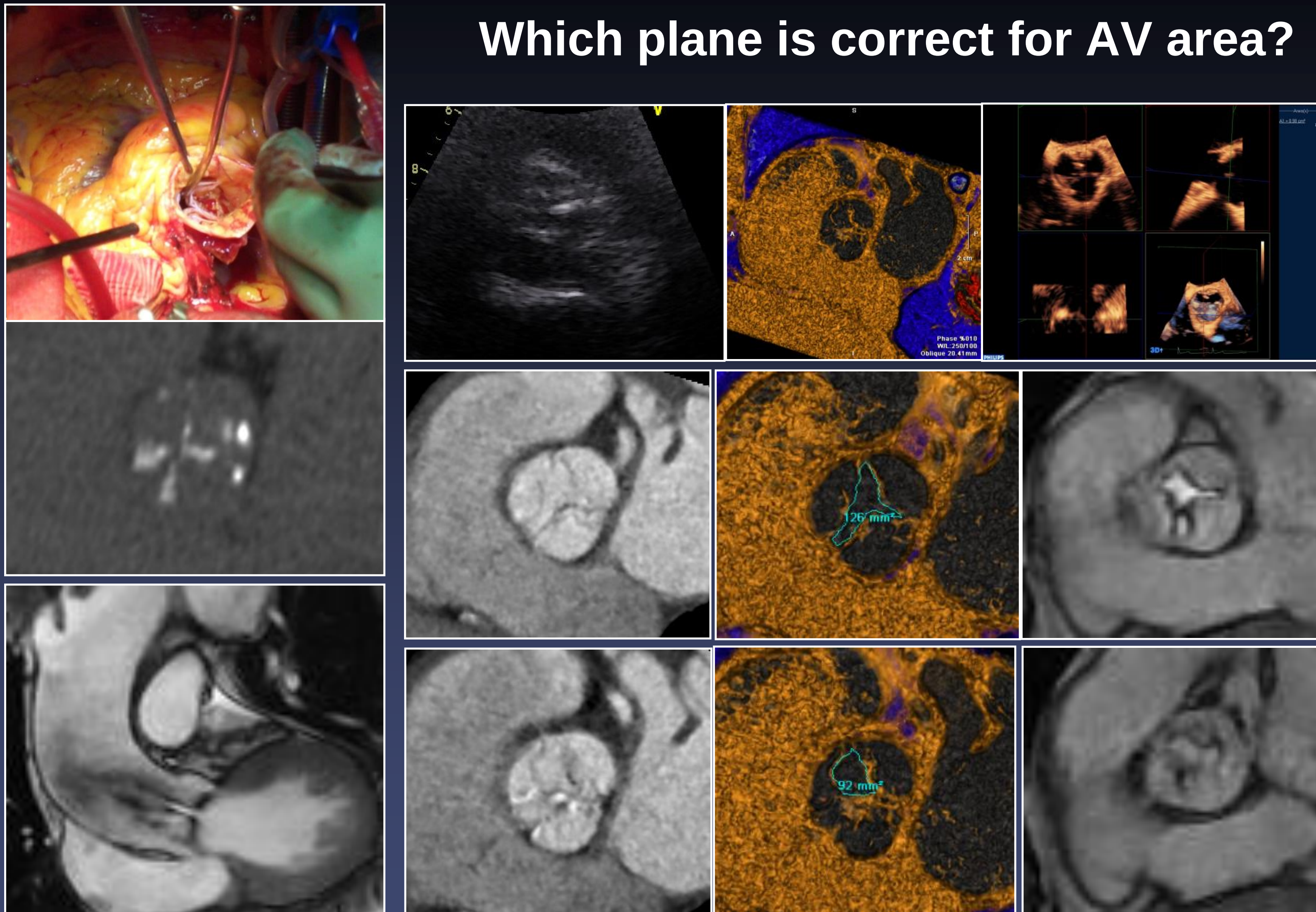
Mitral valve area measurement





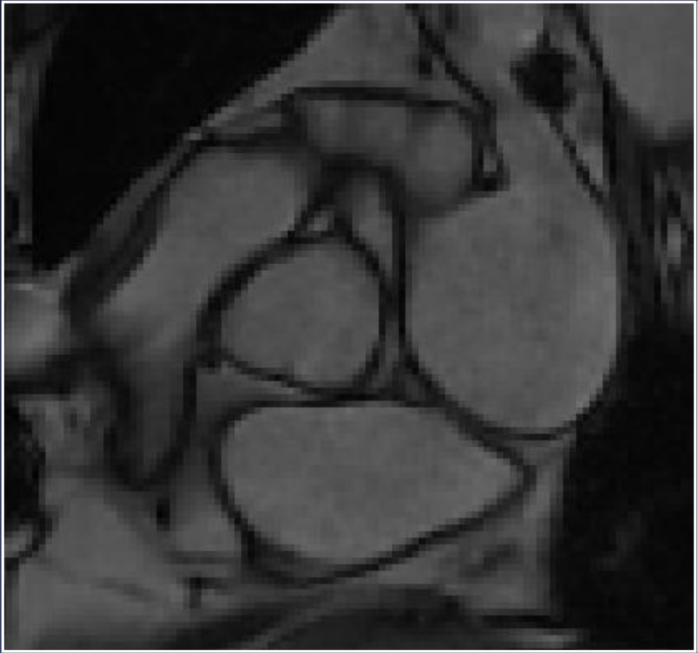


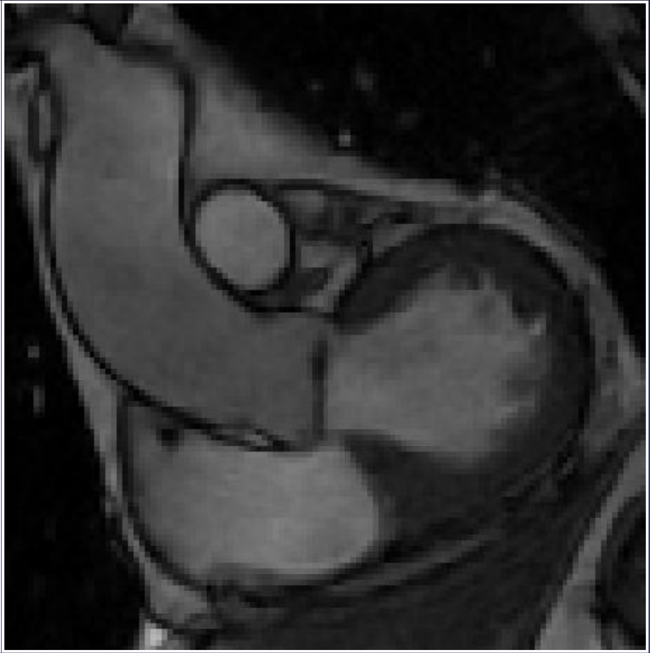
Which plane is correct for AV area?

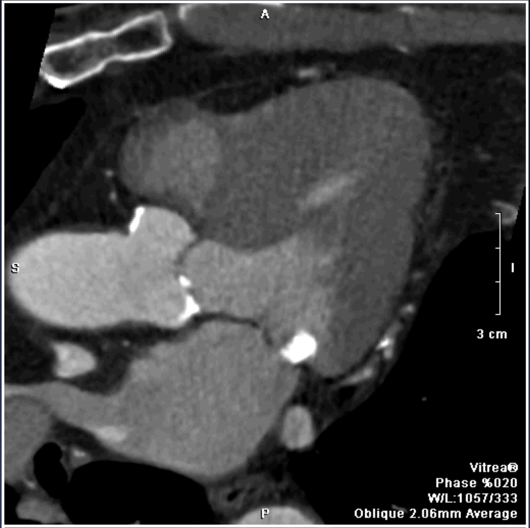


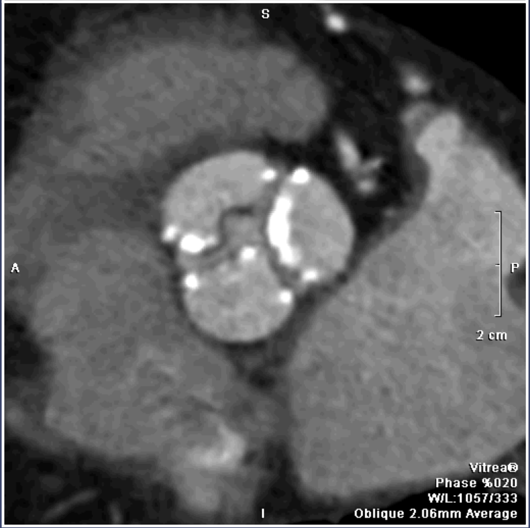
CMR - Vmax 2.2 m/sec, AVA 0.98 cm2 , TTE – Vmax 2.8 m/sec, AVA (2D/CE 1.4 cm2)

Degenerative calcified AS

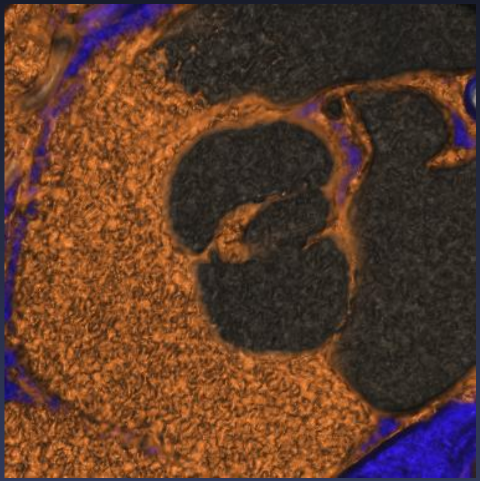


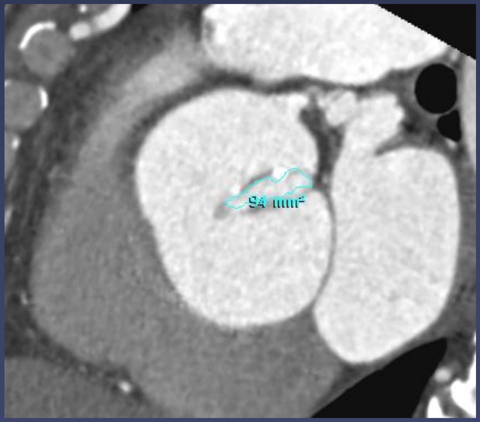






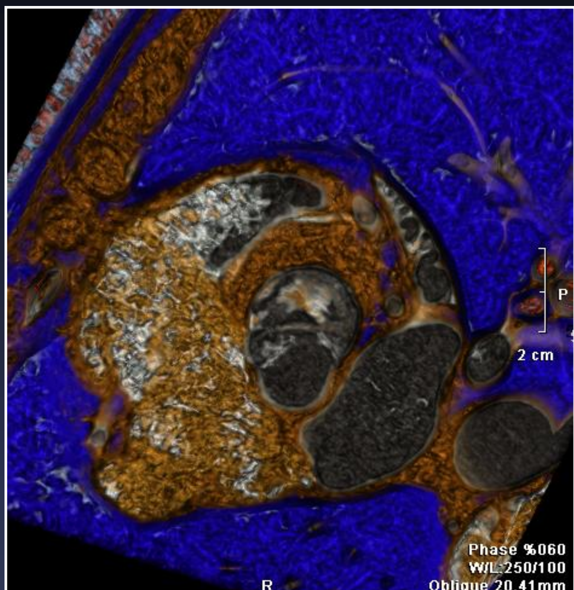
BAV with AS

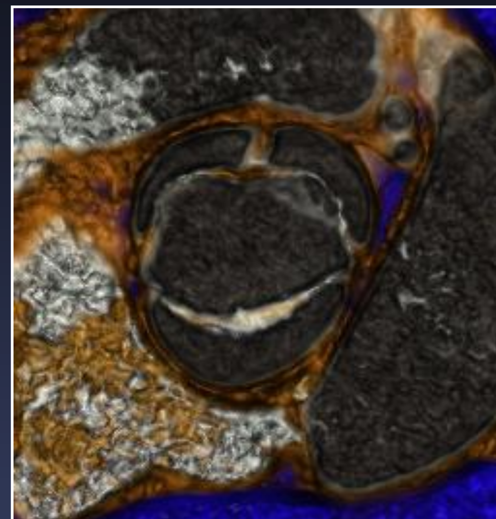


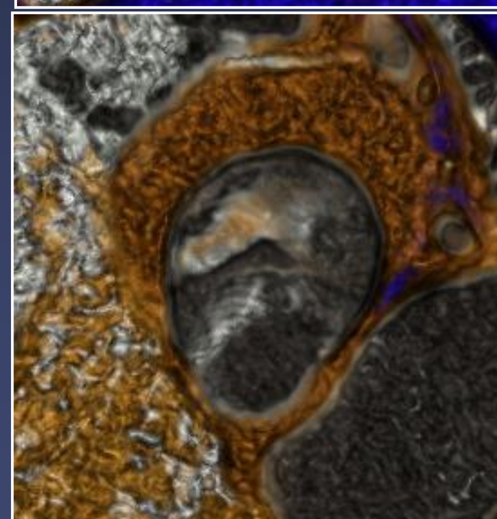


Ko SM, et al. RadioGraphics 2012
Invited

BAV with AR







Ko SM, et al. AJR 2012, Accepted

Int J Cardiol. 2006 Nov 18;113(3):320-6. Epub 2006 Jan 18.

Echocardiographic anatomy of ascending aorta dilatation: correlations with aortic valve morphology and function.

Della Corte A, Romano G, Tizzano F, Amarelli C, De Santo LS, De Feo M, Scardone M, Dialetto G, Covino FE, Cotrufo M.

Department of Cardiothoracic Sciences, Second University of Naples, Department of Cardiovascular Surgery and Transplants, Monaldi Hospital, Naples, Italy. aledellacorte@libero.it

Clin Res Cardiol. 2009 Feb;98(2):114-20. Epub 2008 Dec 12.

Dilatation of the ascending aorta in bicuspid aortic valve disease: a magnetic resonance imaging study.

Debl K, Djavidani B, Buchner S, Poschenrieder F, Schmid FX, Kobuch R, Feuerbach S, Riegger G, Luchner A.

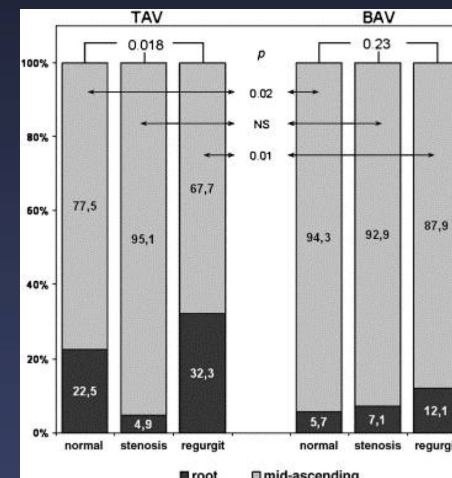
Klinik und Poliklinik für Innere Medizin II, Universitätsklinikum Regensburg, F.J.-Strauss-Allee 11, 93042 Regensburg, Germany. kurt.debl@klinik.uni-regensburg.de

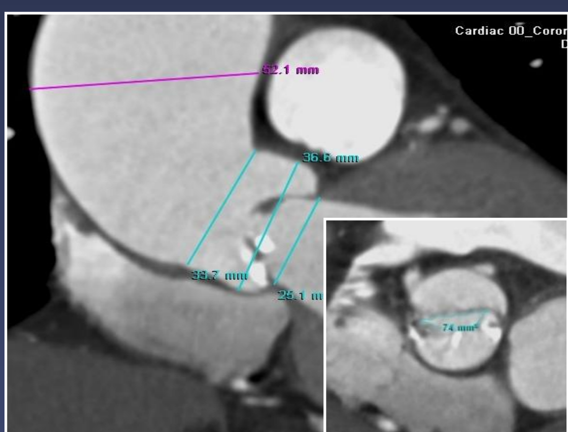
Am Heart J. 2004 Apr;147(4):736-40.

Dilatation of the aorta in pure, severe, bicuspid aortic valve stenosis.

Morgan-Hughes GJ, Roobottom CA, Owens PE, Marshall AJ.

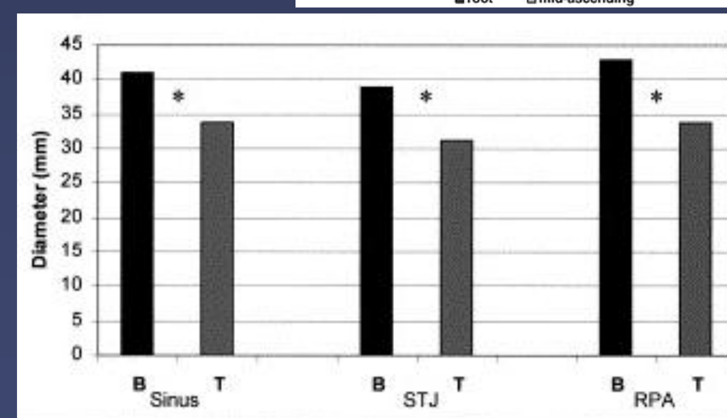
Department of Cardiology, South West Cardiothoracic Centre, Plymouth NHS Trust, Plymouth, United Kingdom. hughesgj@talk21.com





Severe BAV stenosis

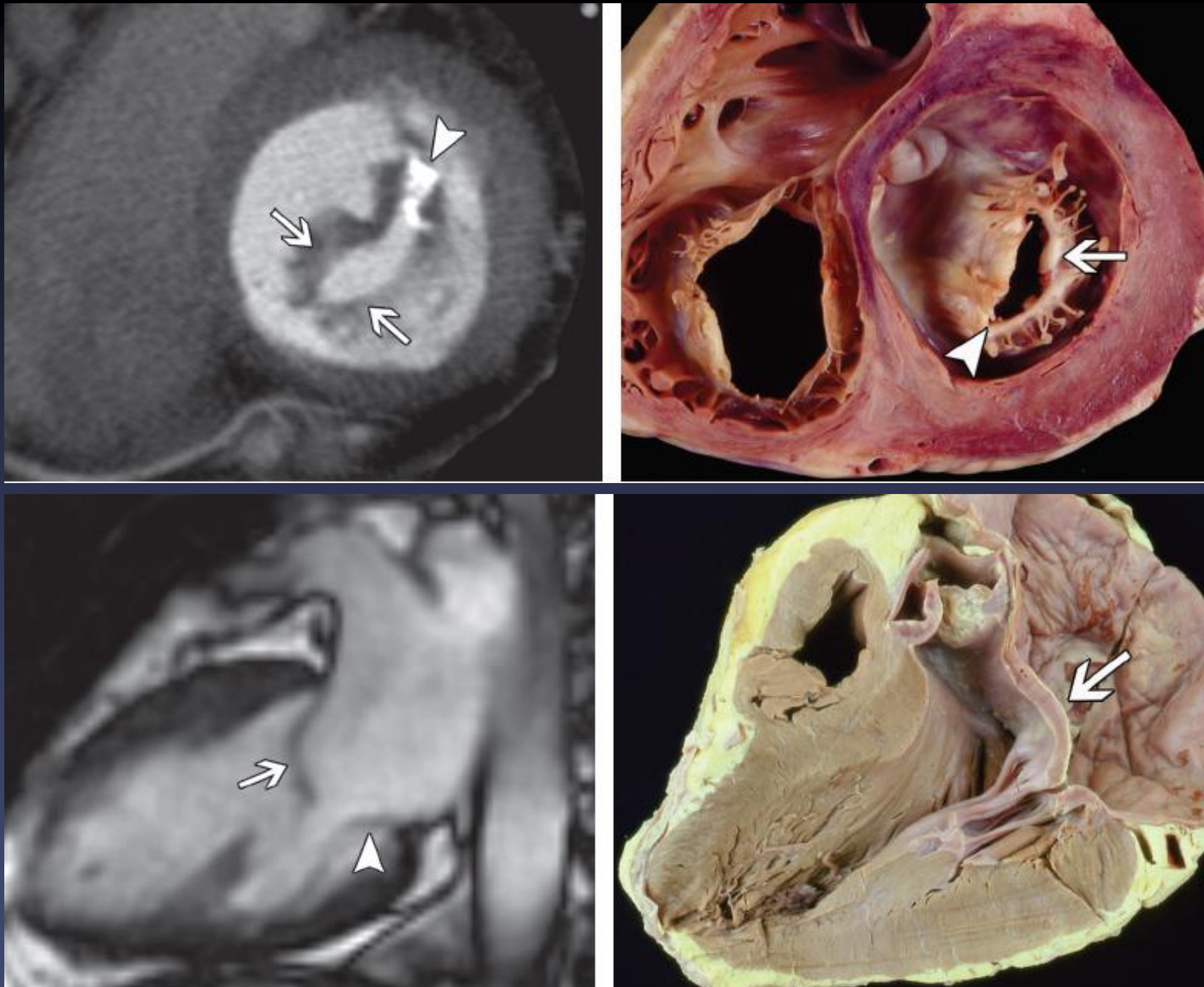
Severe TAV stenosis

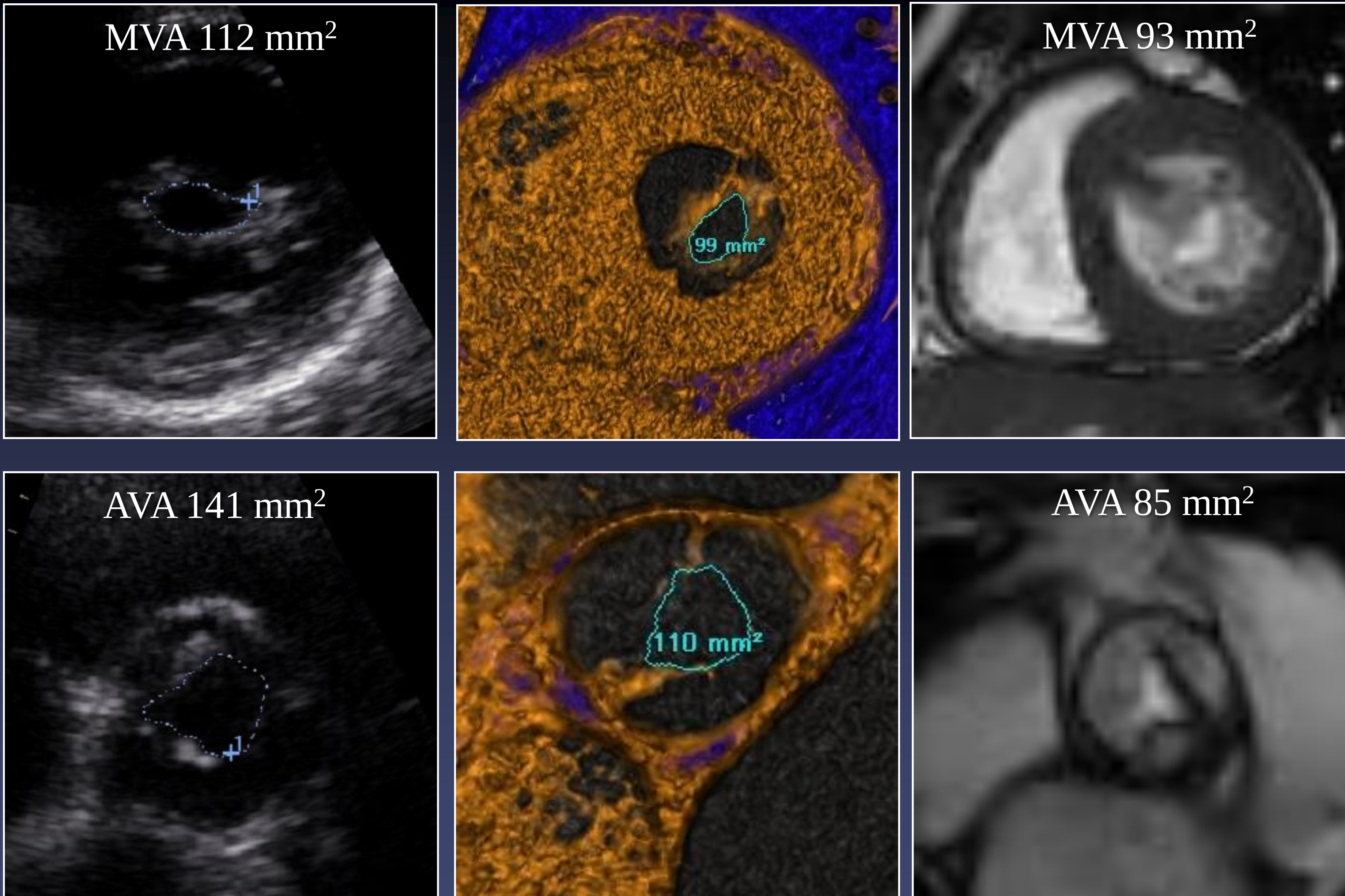


- **Incidence and location of ascending aorta dilatation in BAV and TAV using DSCT (n = 88)**

Characteristic	BAV (n = 53)	TAV (n = 35)	P value
AA diameter ≤ 45 mm	31 (58.5%)	33(94.3%)	0.0006
AA diameter > 45 mm	22 (41.5%)	2 (5.7%)	
Root	2	1	
Tubular	19	1	
Root + Tubular AA	1	0	

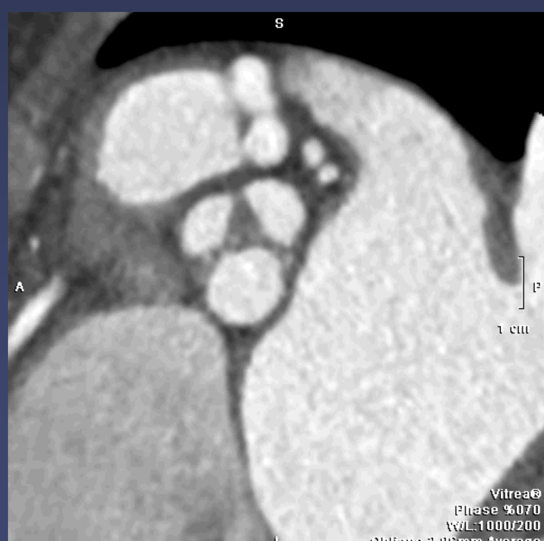
Ko SM, et al. Int J Cardiovasc Imaging 2011, in press



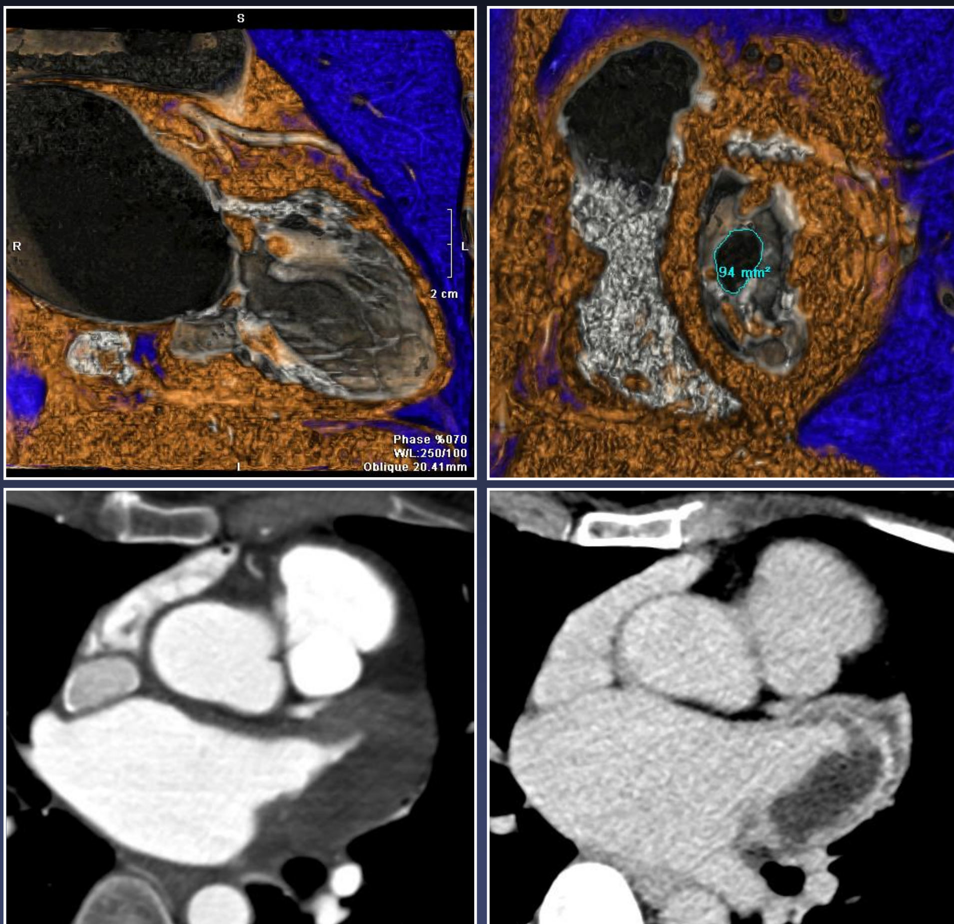


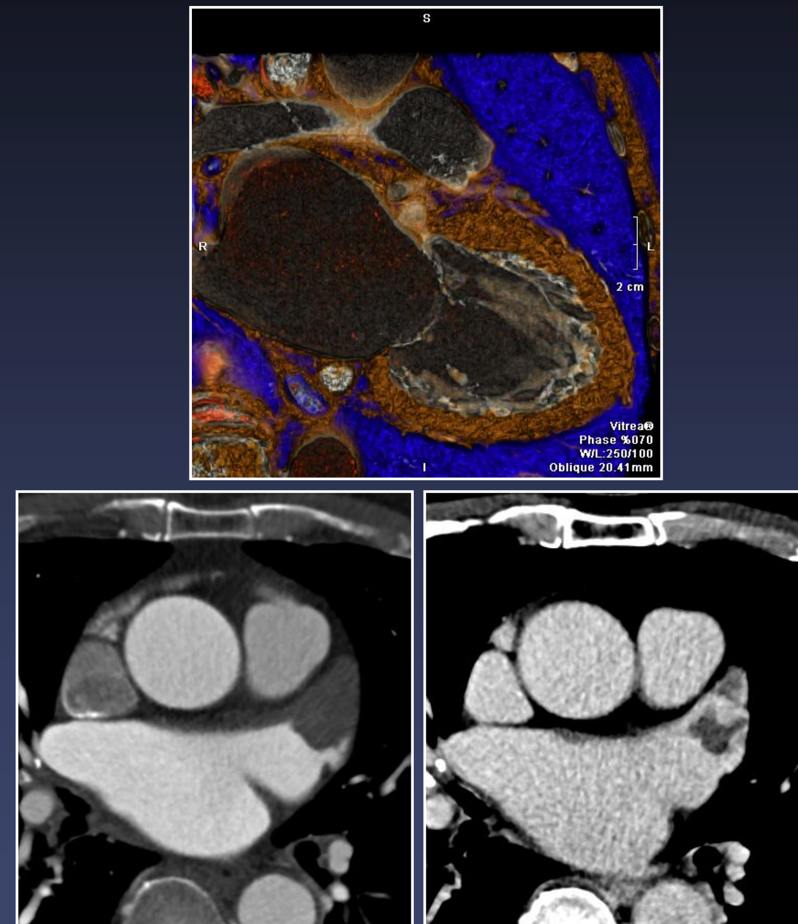
Ko SM, et al. RSNA 2011, oral presentation

Rheumatic VHD



LA thrombus in patients with rheumatic MS





- LAA spontaneous echo by TEE - strong predictor of thromboembolic risk in patients with MS
- Two-phase 64-MDCT - 100% Sens and 98% Spe for the detection of thrombus in LAA

Hur J, et al. Radiology 2009;251:683-90

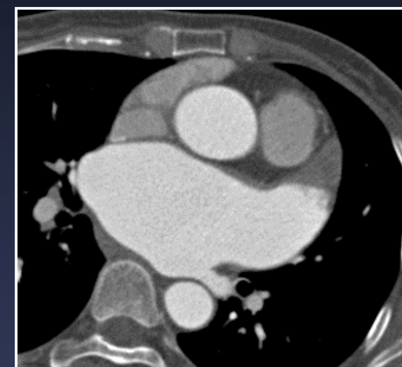
Two-phase DSCT for the detection of LAA thrombus in patients with MS and AF

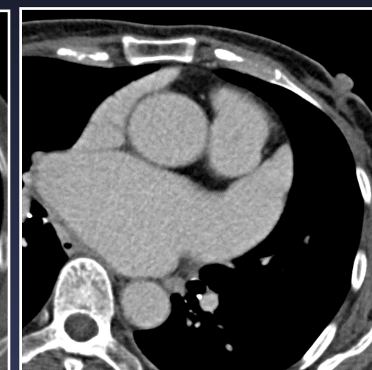
Negative

Early phase

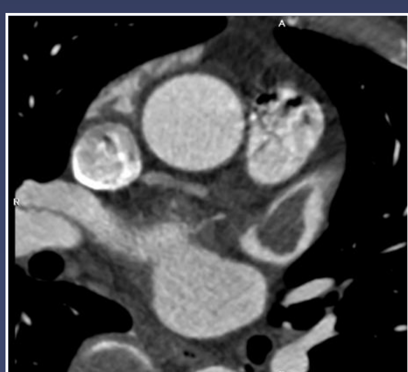
Late phase

Spontaneous echo contrast



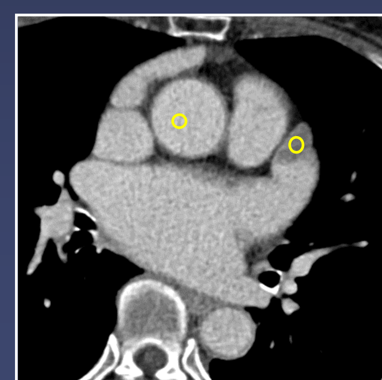


Thrombus



Early phase

Late phase



Quantitative analysis using LAA-AA attenuation ratio on late-phase CT images

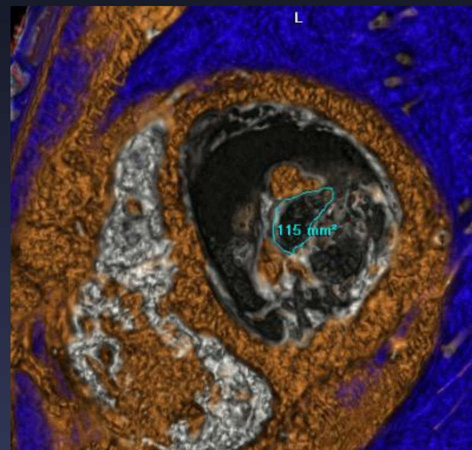
Concordance between DSCT and intraoperative finding for detection of thrombus in LAA (n=106)

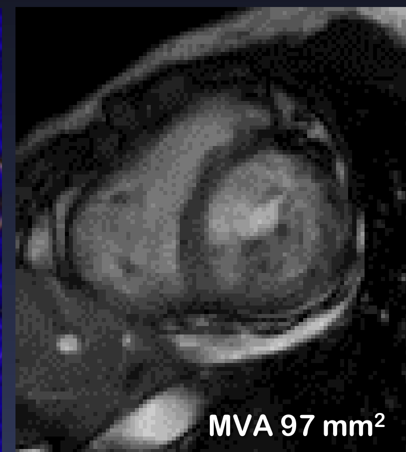
	Intraoperative Findings	
CT finding	Thrombus	No thrombus
Thrombus	27	6
No thrombus	0	73

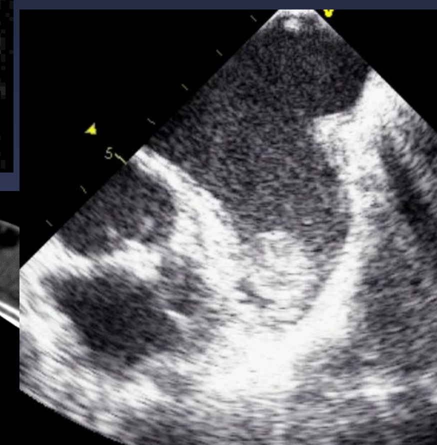
- Inter-rater agreement (k =0.86)
- Sensitivity 100%, Specificity 92.4%, Accuracy 94.3%
  Positive predictive value 81.8.2%,
  Negative predictive value 100%

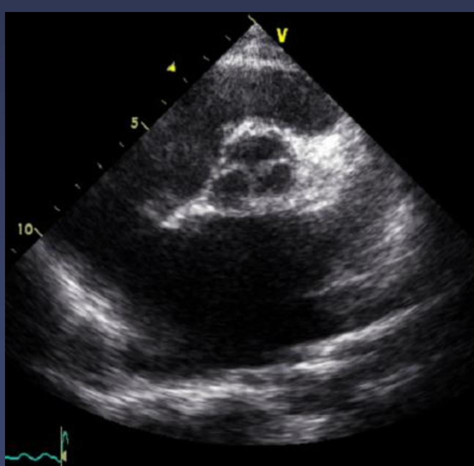
Ko SM, et al. RSNA 2011, scientific presentation
Ko, SM, et al. ESCR 2011, poster presentation

71F

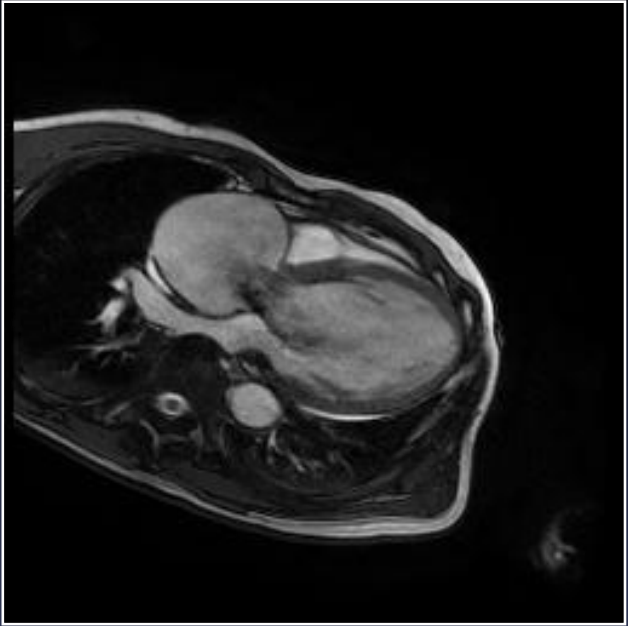


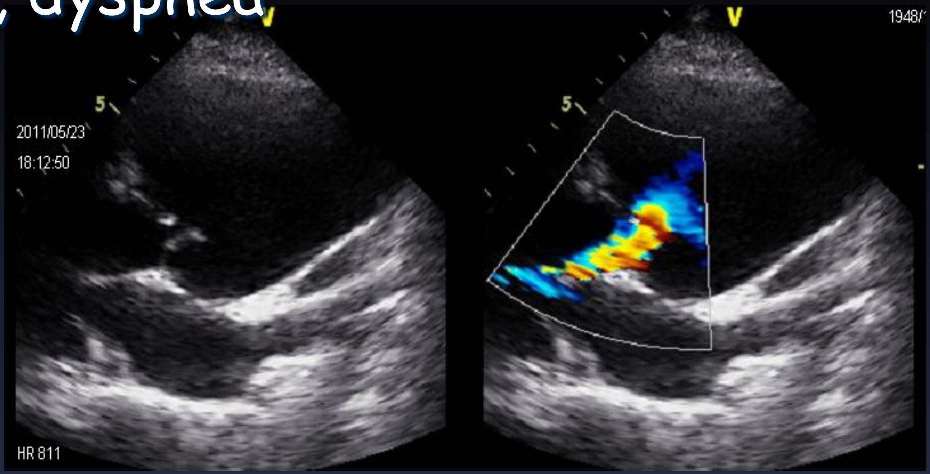


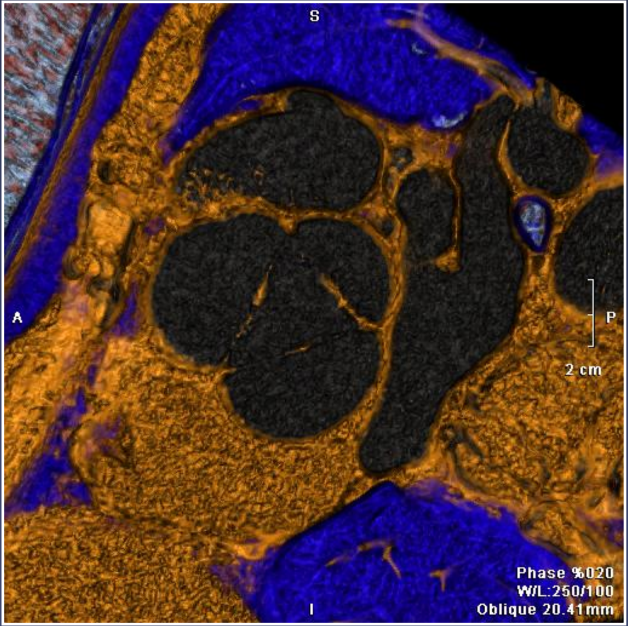


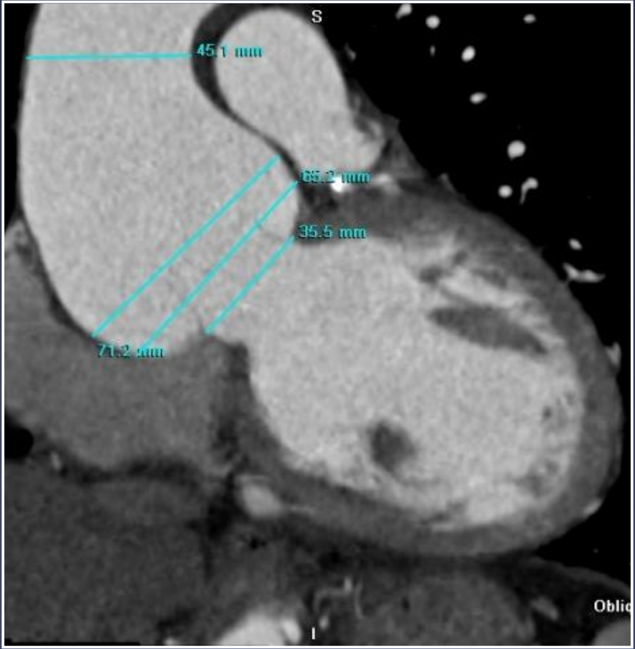


63/M, dyspnea

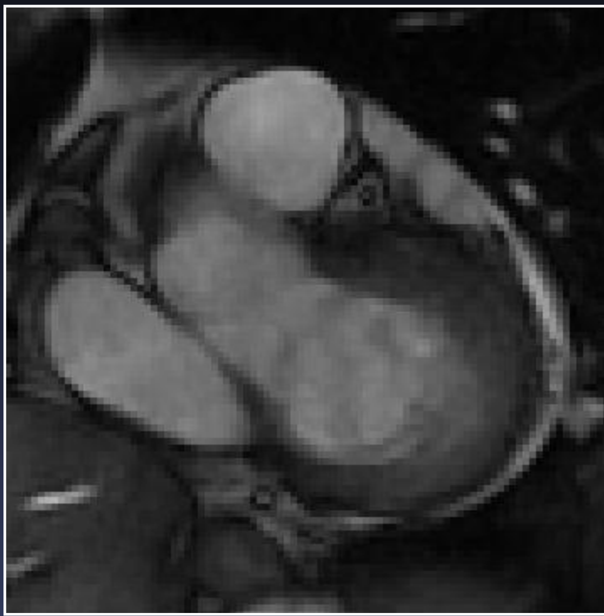


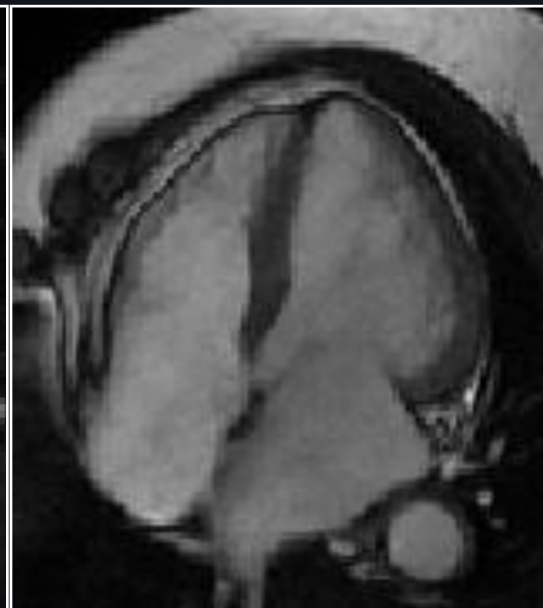

2011/05/23
18:12:50
HR 811

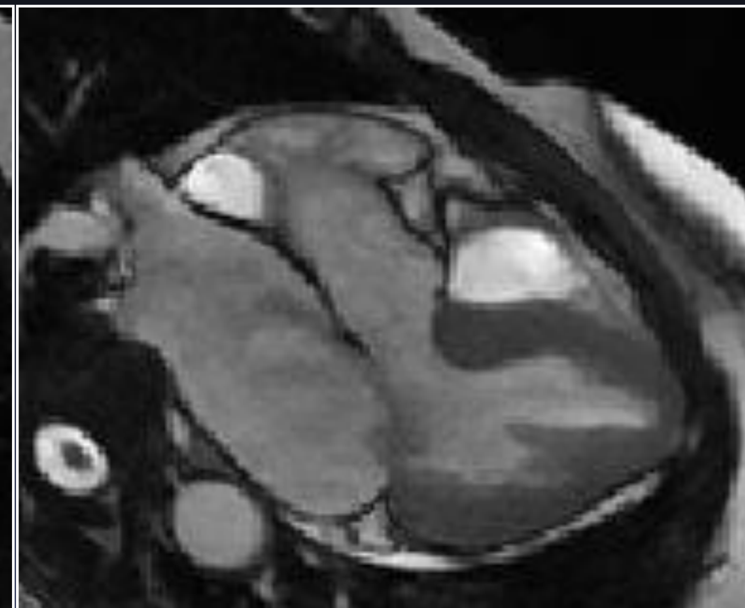

S
A
P
2 cm
I
Phase %020
W/L:250/100
Oblique 20.41mm

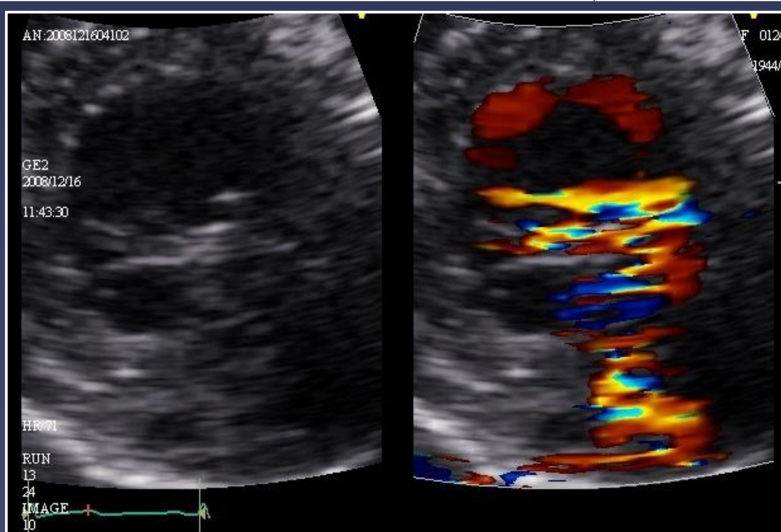

S
45.1 mm
35.5 mm
71.2 mm
I

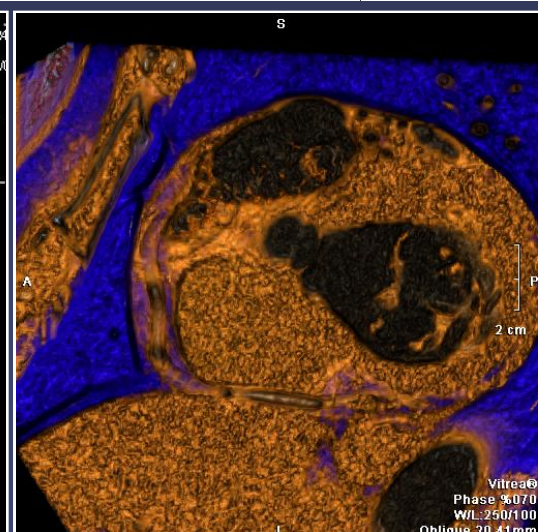
MVP

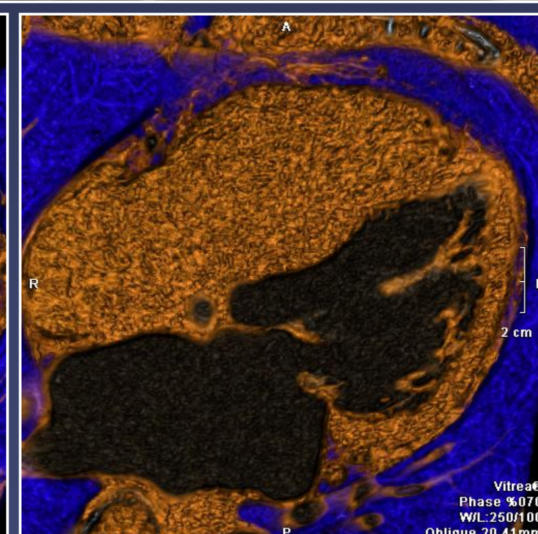




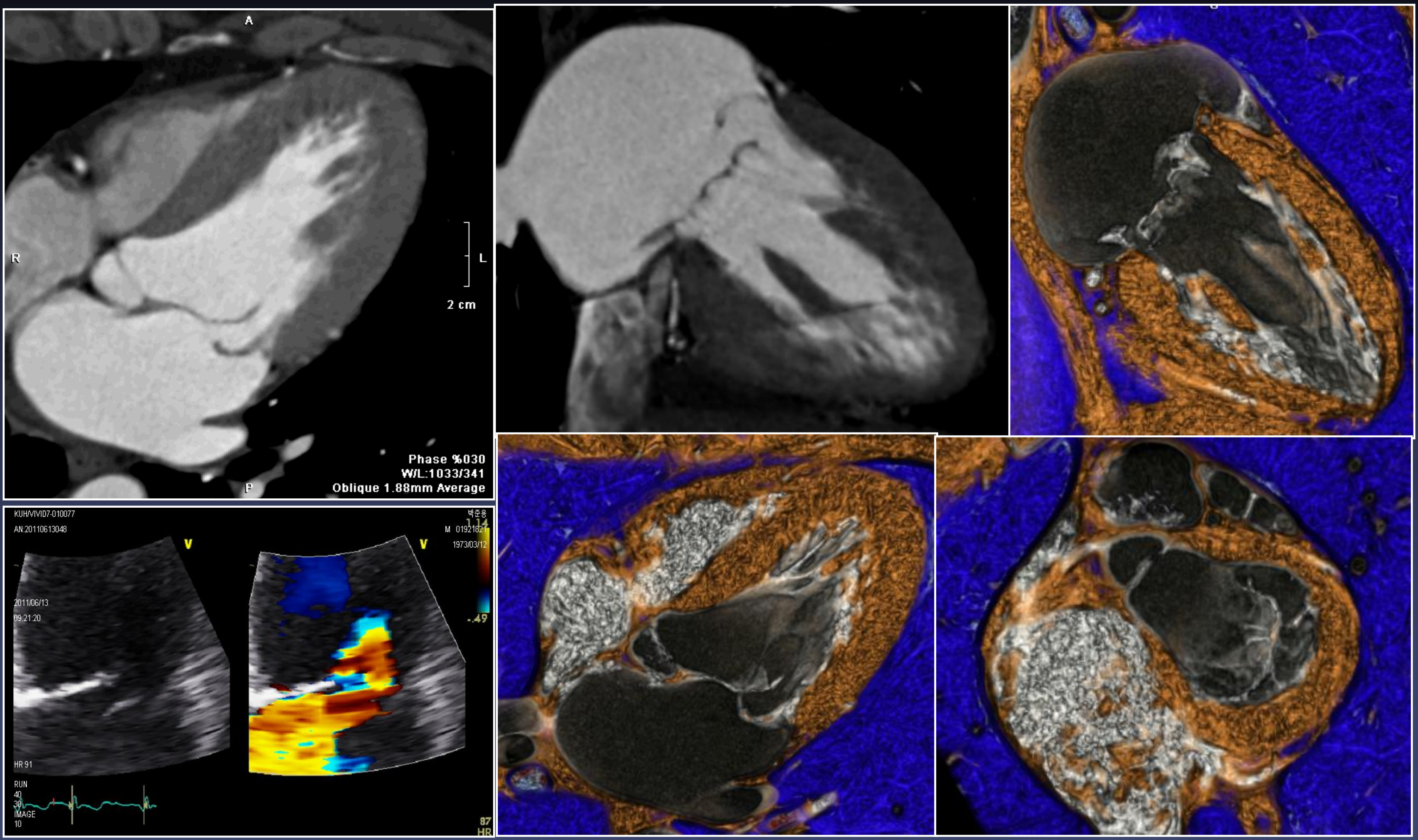



AN:2008121604102
GE2
2008/12/16
11:43:30
HR 71
RUN
13
24
IMAGE
10


S
A
P
2 cm
I
Vitrea®
Phase %070
W/L:250/100
Oblique 20.41mm

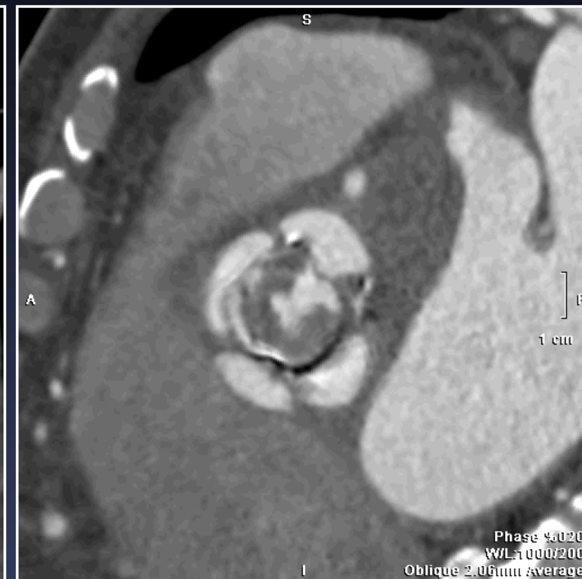

A
R
L
2 cm
P
Vitrea®
Phase %070
W/L:250/100
Oblique 20.41mm

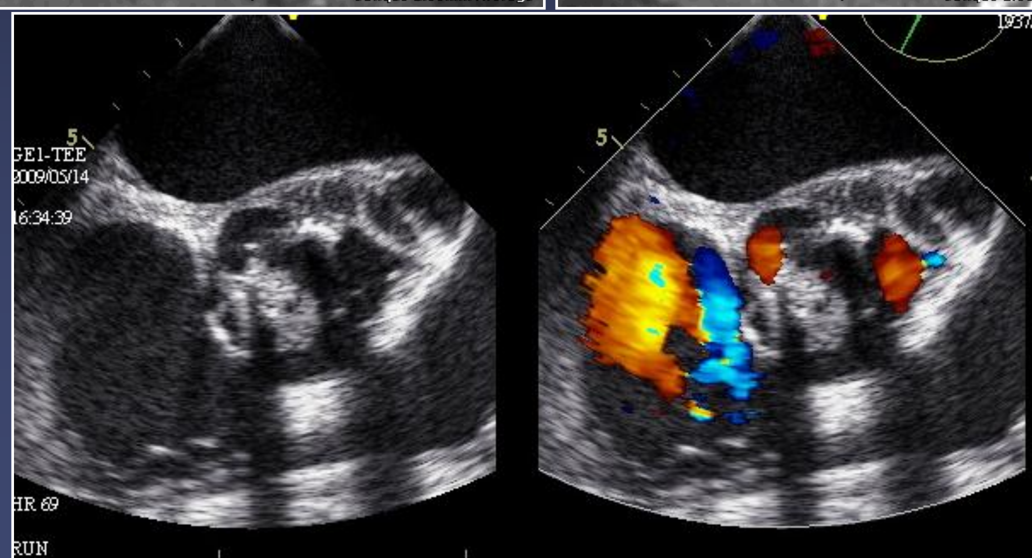
MVP due to P1 chorda rupture



63/M, dyspnea

Infective endocarditis

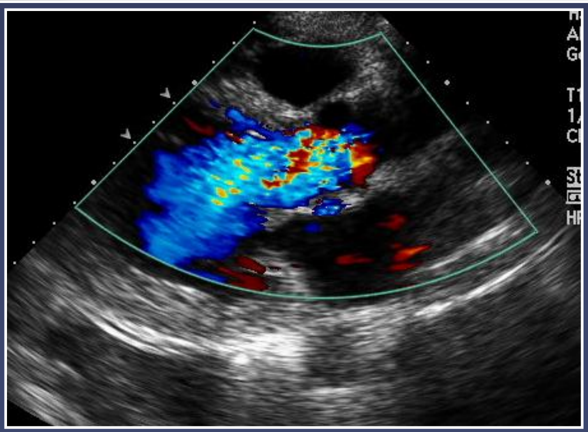


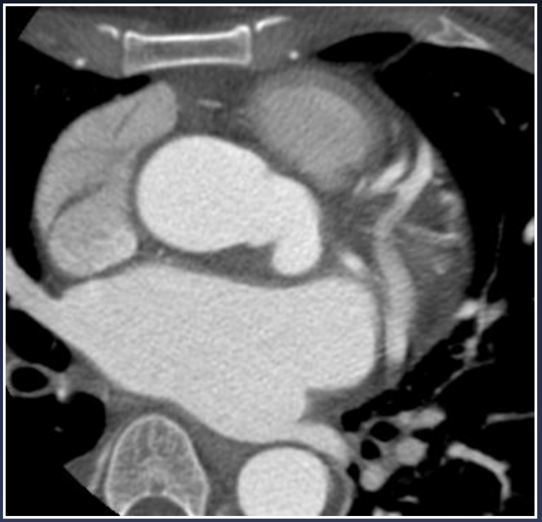


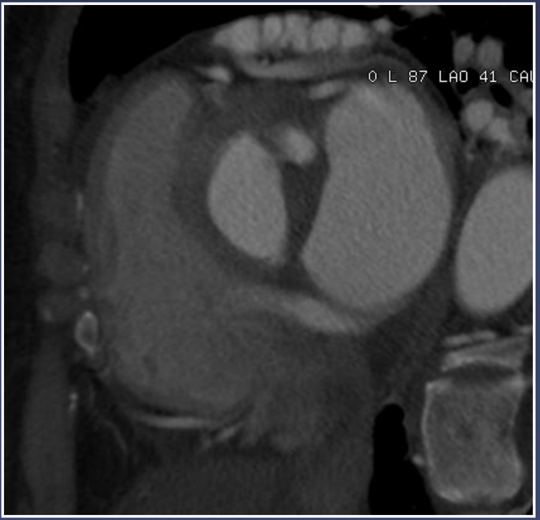
Infective endocarditis

F/45

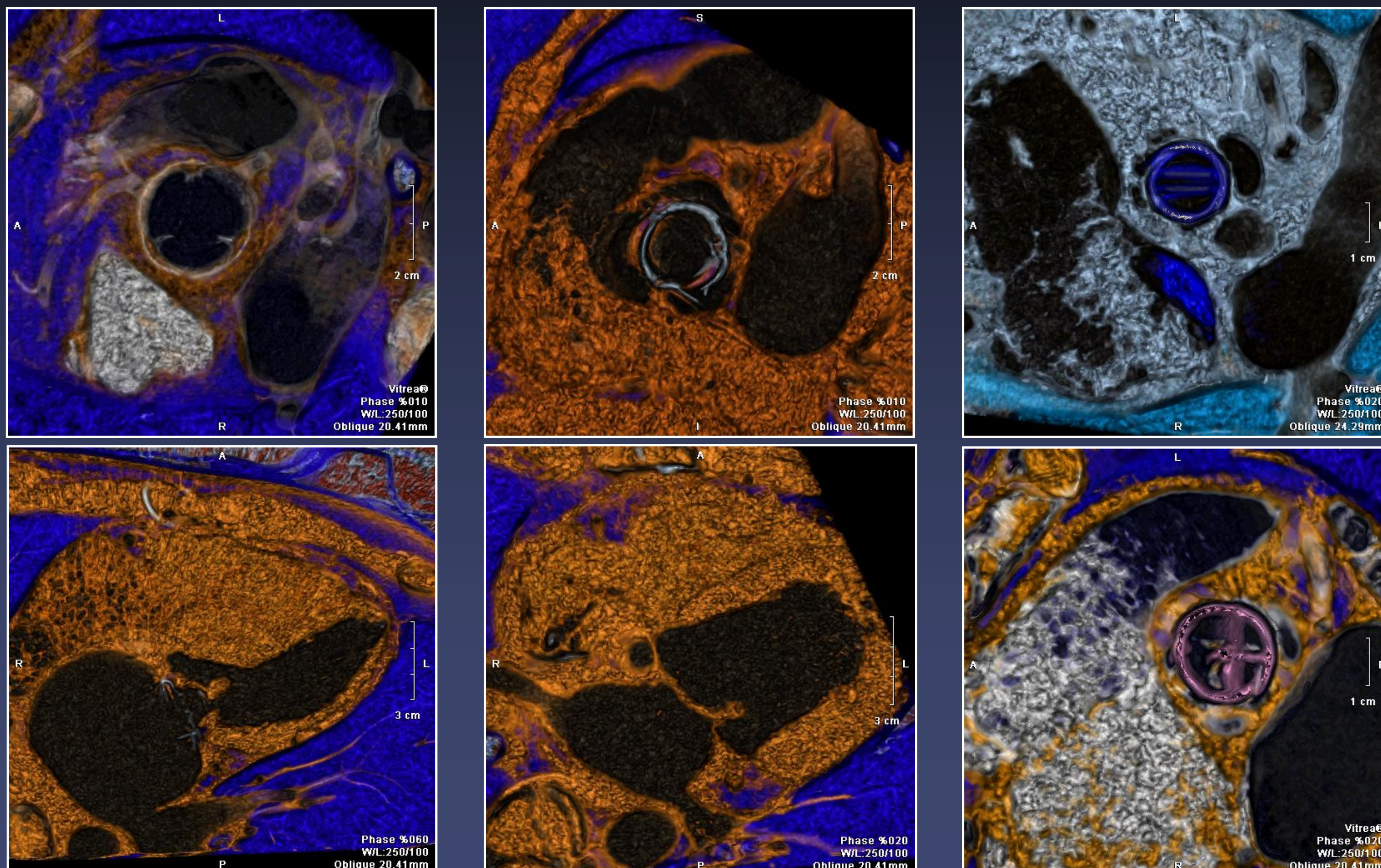
CC : dyspnea , 15 days ago



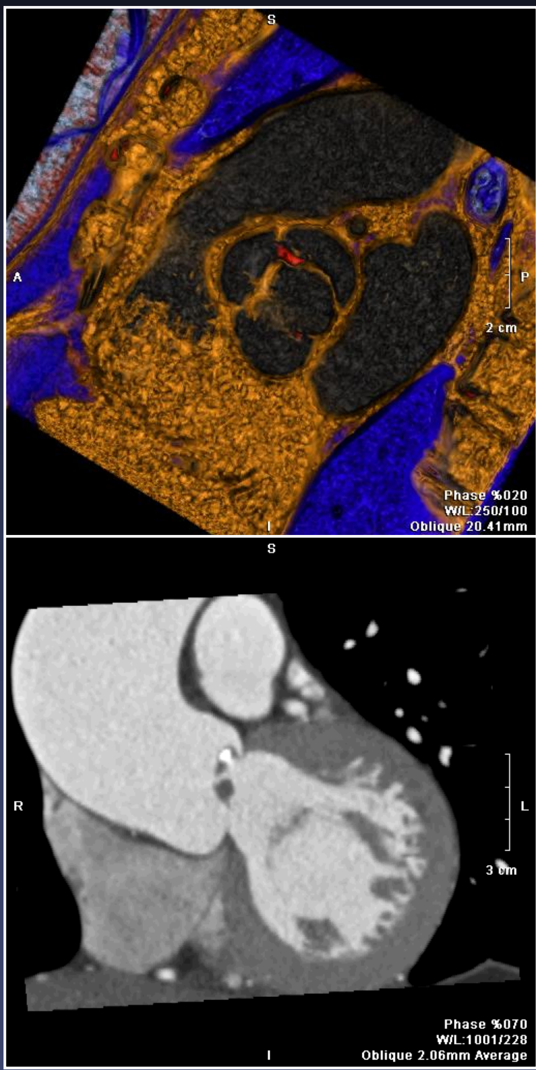


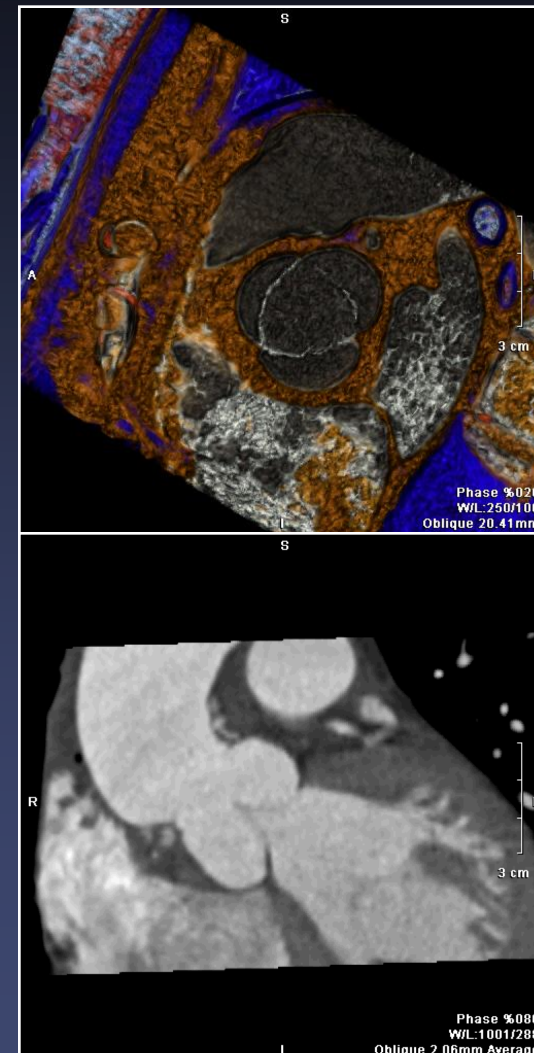


Assessment of Prosthetic Valve and Valvuloplasty using MDCT



Aortic valvuloplasty





Eur Radiol. 2009 Apr;19(4):857-67. Epub 2008 Nov 27.

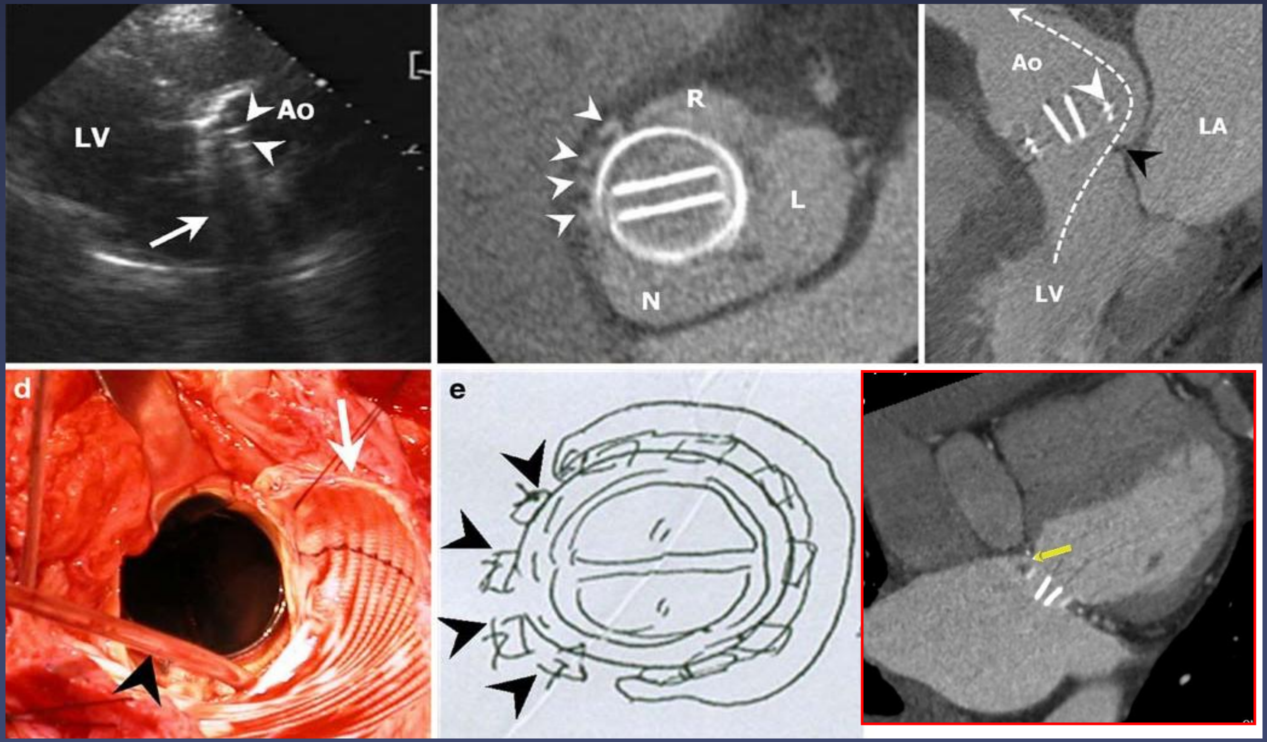
Correctness of multi-detector-row computed tomography for diagnosing mechanical prosthetic heart valve disorders using operative findings as a gold standard.

Tsai IC, Lin YK, Chang Y, Fu YC, Wang CC, Hsieh SR, Wei HJ, Tsai HW, Jan SL, Wang KY, Chen MC, Chen CC.

Department of Radiology, Taichung Veterans General Hospital, Taichung, Taiwan, Republic of China. sillyduck.radiology@gmail.com

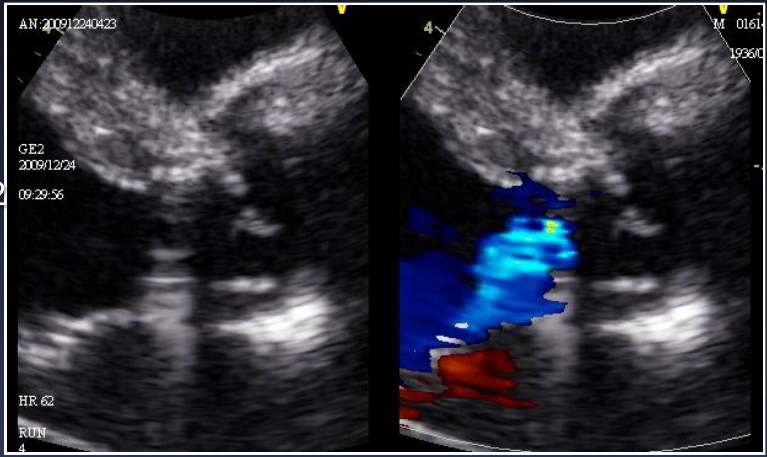
Abstract

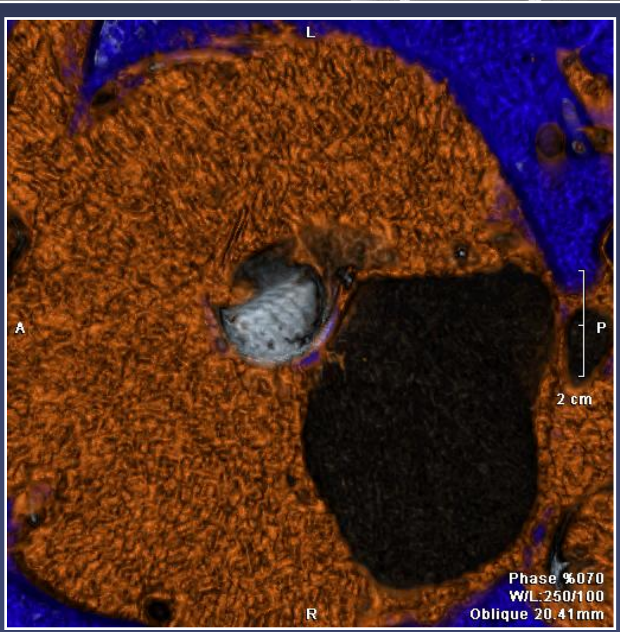
The purpose was to compare the findings of multi-detector computed tomography (MDCT) in prosthetic valve disorders using the operative findings as a gold standard. In a 3-year period, we prospectively enrolled 25 patients with 31 prosthetic heart valves. MDCT and transthoracic echocardiography (TTE) were done to evaluate pannus formation, prosthetic valve dysfunction, suture loosening (paravalvular leak) and pseudoaneurysm formation. Patients indicated for surgery received an operation within 1 week. The MDCT findings were compared with the operative findings. One patient with a Björk-Shiley valve could not be evaluated by MDCT due to a severe beam-hardening artifact; thus, the exclusion rate for MDCT was 3.2% (1/31). Prosthetic valve disorders were suspected in 12 patients by either MDCT or TTE. Six patients received an operation that included three redo aortic valve replacements, two redo mitral replacements and one Amplatzer ductal occluder occlusion of a mitral paravalvular leak. The concordance of MDCT for diagnosing and localizing prosthetic valve disorders and the surgical findings was 100%. Except for images impaired by severe beam-hardening artifacts, MDCT provides excellent delineation of prosthetic valve disorders.

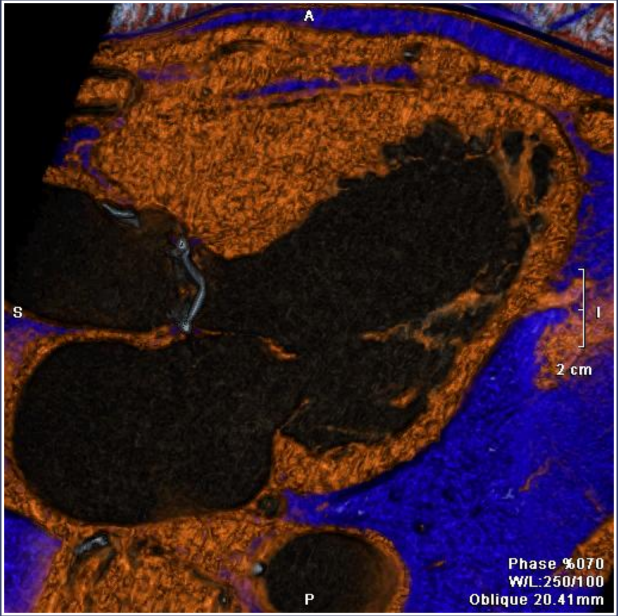


Prosthetic heart valve dysfunction (thrombus formation)

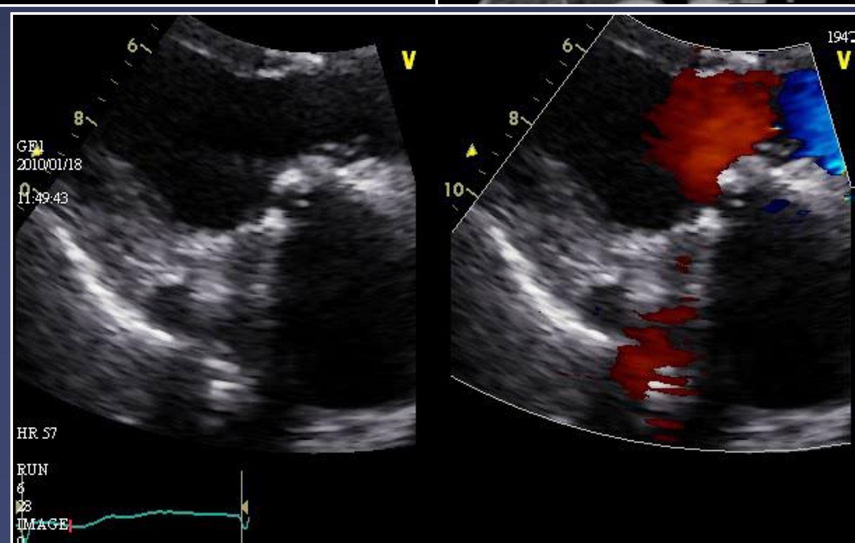
AVA
0.5 cm^2





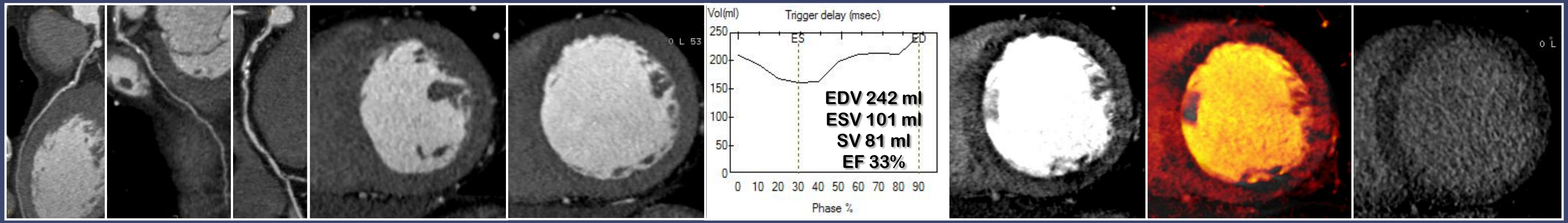


Prosthetic heart valve dysfunction (Pannus formation)

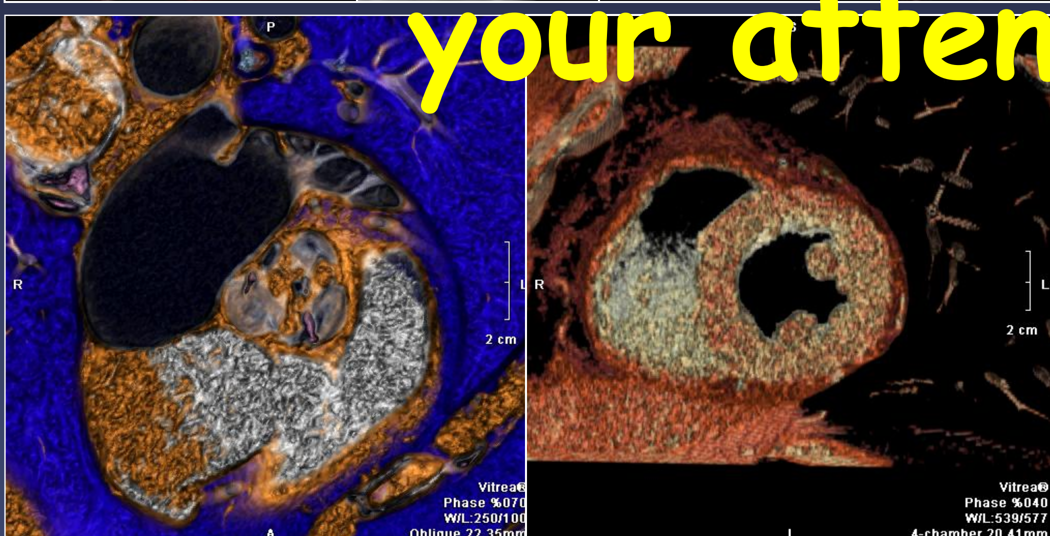


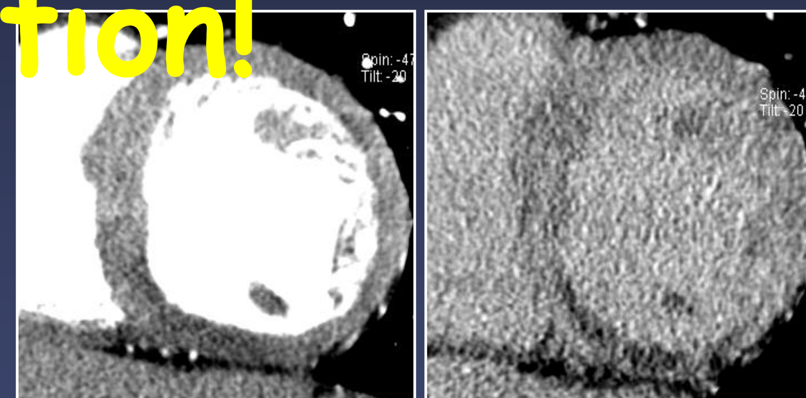
Conclusion

- Integration of myocardial CT perfusion and delayed enhanced CT is capable of detecting myocardial ischemia and infarction.
- Cardiac CT is promising in selected VHD as adjunct to echocardiography, particularly AS and mechanical valve.
- CT measurements of global LV function using threshold-base technique are highly reproducible and accurate.
- Cardiac CT has a potential for the “one-stop shop” for the evaluation of ischemic heart disease.



Thank you for your attention!





LEFT VENTRICULAR FUNCTION

Parameter	Measured Values
Ejection Fraction	63
End Diastolic Volume	158
End Systolic Volume	58
Stroke Volume	100
Cardiac Output	-
Myocardial Mass	151