

CT Perfusion

'One-Stop Shop' with CT Imaging

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Disclosure

- Nothing to disclose related with this presentation

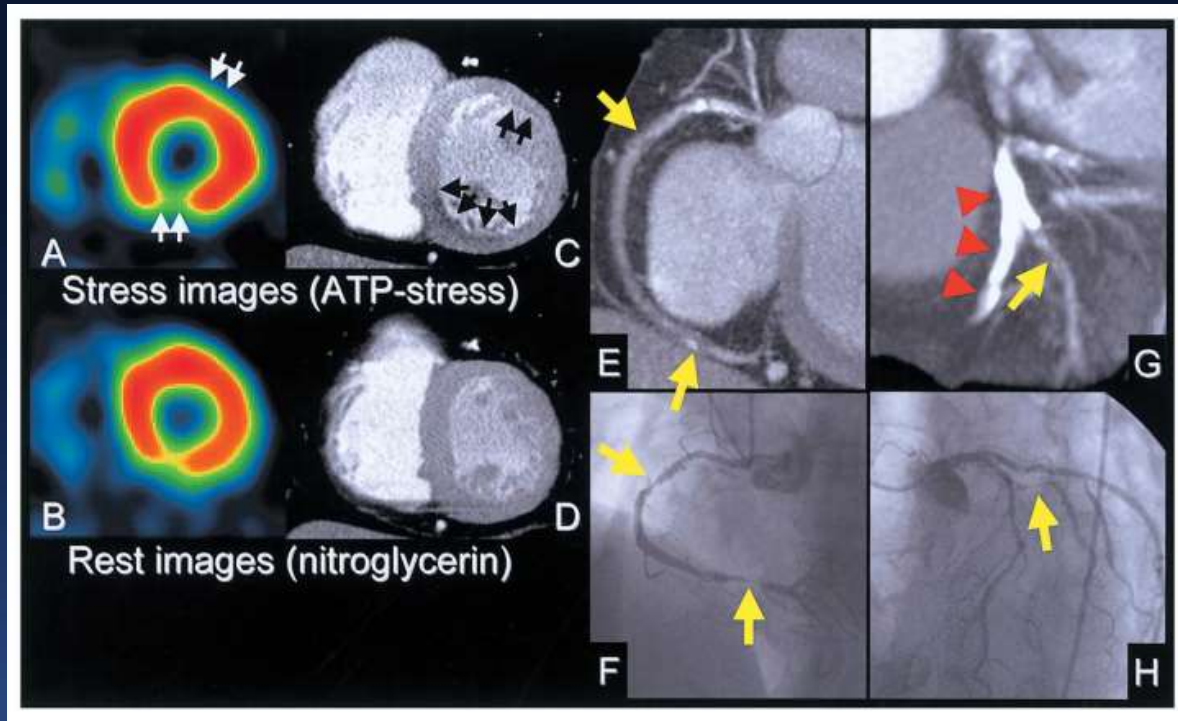
Diagnostic Accuracy to Detect CAD

Method	Sensitivity (%)	Specificity (%)
Exercise ECG	45 – 50	85 – 90
Exercise stress echocardiography	80 – 85	80 – 88
Exercise stress SPECT	73 – 92	63 – 87
Dobutamine stress echocardiography	79 – 83	82 – 86
Dobutamine stress MRI	79 – 88	81 – 91
Vasodilator stress echocardiography	72 – 79	92 – 95
Vasodilator stress SPECT	90 – 91	75 – 84
Vasodilator stress MRI	67 – 94	61 – 85
Coronary CT angiography	95 – 99	64 – 83
Vasodilator stress PET	81 - 97	74 - 91

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Vasodilator stress MRI	67 – 94	61 – 85
Coronary CT angiography	95 – 99	64 – 83
Vasodilator stress PET	81 - 97	74 - 91

First Article of CTP, 2005



Summary

16-ch CT (GE, LightSpeed 16)

12 patients

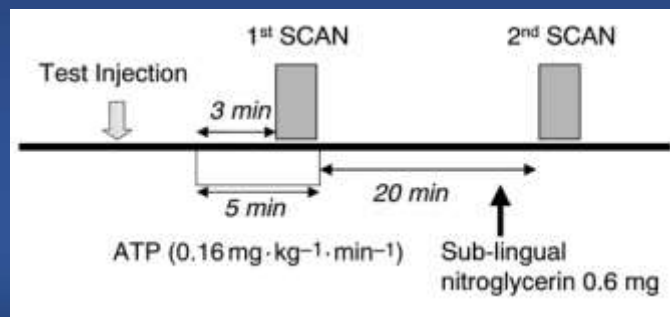
Reference: Thallium SPECT

Population: suspected CAD

Sensitivity (per-vessel): 90%

Specificity (per-vessel): 79%

First article



Kurata A. Mochizuki T. et al . 2005 Cir J 69:550-557

Published Data about CT Perfusion

Institution	Year	Pts	Sens / Spec (%)	Ref.	CT
MGH	2009	33	94 / 74	QCA/SPECT	64 DSCT (Siemens), Static
	2010	35	91 / 91	QCA	
Johns Hopkins	2009	27	81 / 85	QCA/SPECT	64 ch, 320 ch (Toshiba), Static
	2012	50	72 / 91	QCA/SPECT	
Monash H (Australia)	2012	42	91 / 72	FFR	320 ch , Static (Toshiba)
	2012	40	95 / 87	FFR	
Centro H. (Portugal)	2013	101	55 / 95 (CTP) 71 / 90 (CTP/CTA)	FFR	64 ch, single source (Siemens), Static
Grosshadern (Germany)	2012	36	93 / 87	FFR	128 DSCT, Dynamic (Siemens)
MUSC (South Carolina)	2010	10	86 / 98	MRI	128 DSCT, Dynamic (Siemens)
	2012	20	86 / 98	MRI/SPECT	
Mount Alvernia H. (Singapore)	2011	35	83 / 78	SPECT	128 DSCT, Dynamic (Siemens)
Cedars-Sinai, LA	2010	30	92 / 86	SPECT	64 DSCT (Siemens), Static
Korea (Kunkook U.)	2011	41	91 / 72	MRI	64 DSCT-DE mode (Siemens), Static
Innsbruck (Austria)	2012	39	96 / 95	MRI/QCA	128 DSCT-FLASH mode (Siemens)

Computed tomography stress myocardial perfusion imaging in patients considered for revascularization: a comparison with fractional flow reserve

	CTA \geq 50%	CTP (+)	CTA \geq 50% & CTP(+)	CTA \geq 50% OR CTP(+)	QCA \geq 50%
Sensitivity	93	76	68	100	71
Specificity	60	84	98	47	62
PPV	68	82	97	63	63
NPV	90	79	77	100	70
Accuracy	76	80	84	73	66

CTA \geq 50% & CTP(+) was 98% specific for ischemia.

CTA < 50% and normal CTP was 100% specific for ischemia.

CTP Protocol in AMC

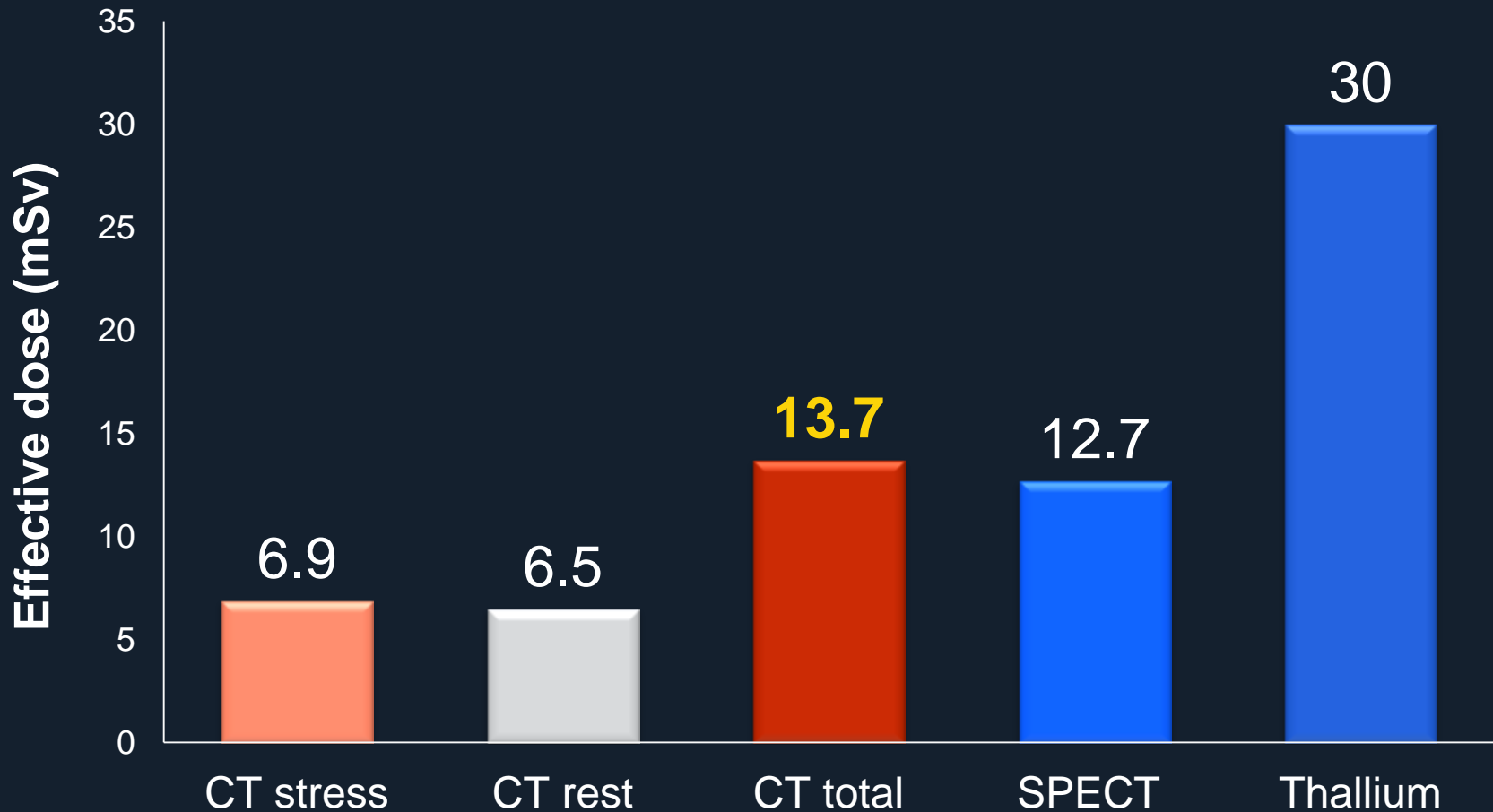
25 minutes
using dual-source 126 ch. CT (Siemens)

10 min. interval				
Calcium scoring	Adenosine infusion	Stress perfusion	Sublingual NTG	Rest perfusion (CTA)
Scan range	4 min. 30 sec	Retrospective ECG-gating	2 min. before	Retrospective ECG-gating

- Option
1. **Static perfusion**
 2. Dynamic perfusion

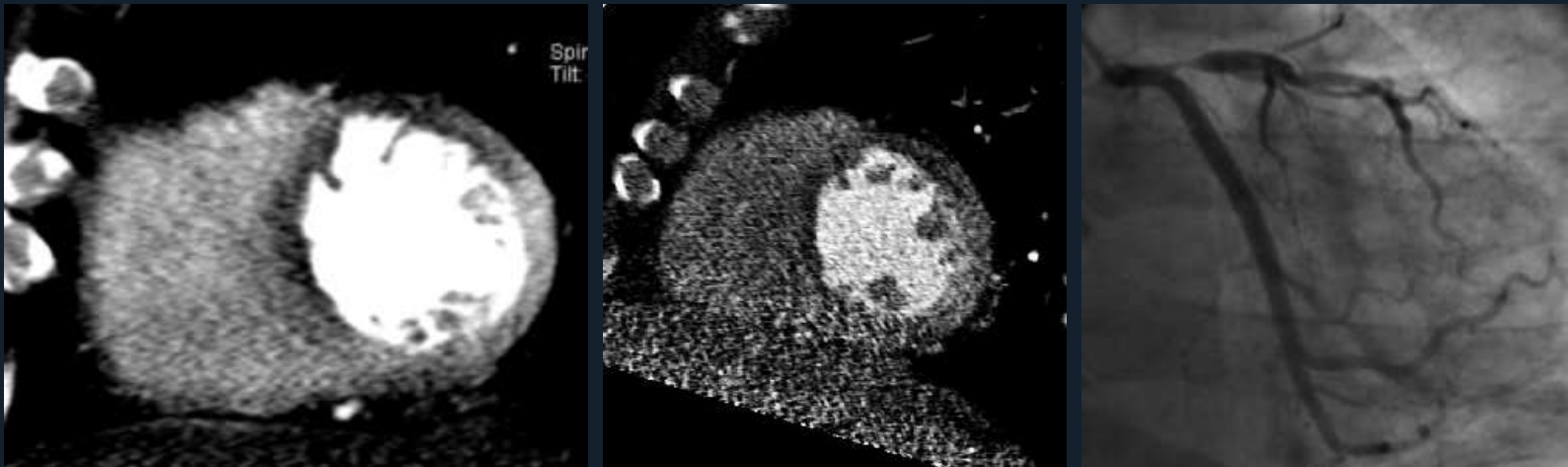
- Option
1. Retrospective mode
 2. Prospective mode
 3. High-pitch mode

Radiation Dose



Visual Analysis of CTP

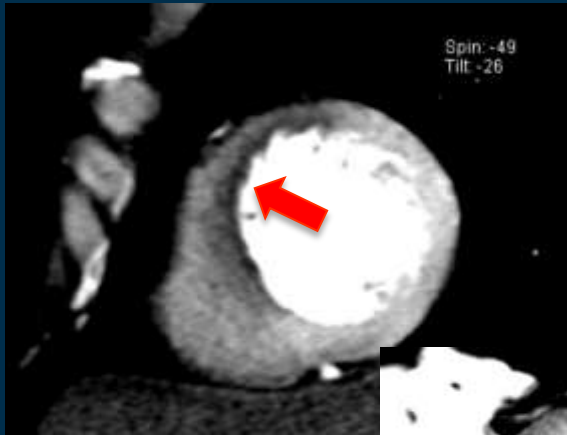
- Diagnostic indicator of myocardial ischemia
 - Low density lesion conforming coronary territory
 - Persistent lesion at systole and diastole
DDx) Transient motion or beam-hardening artifact
 - Wall motion abnormality (useful)



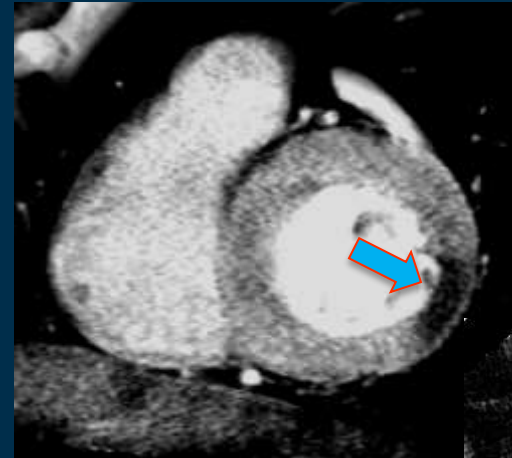
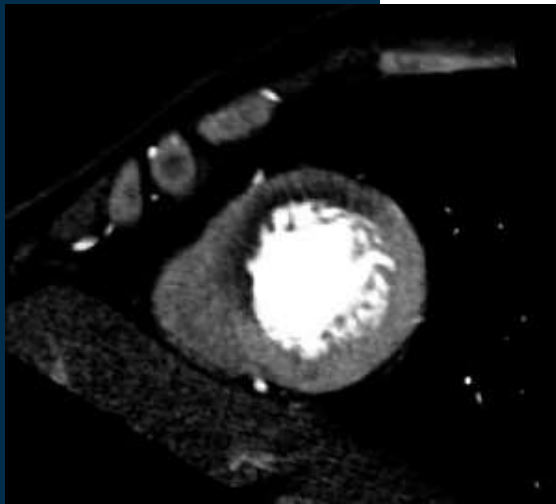
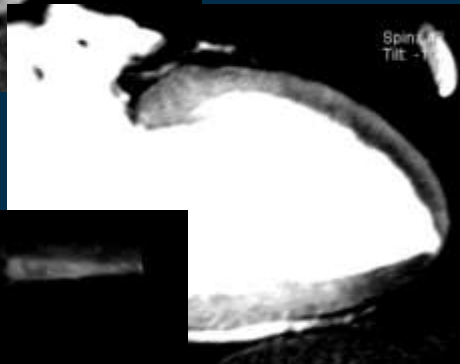
True Lesion

vs.

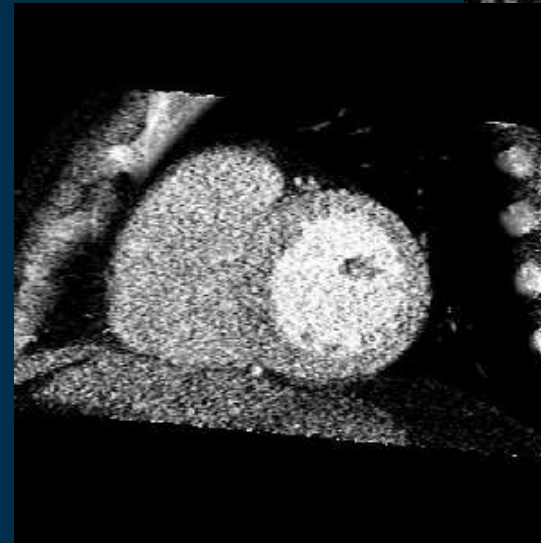
Artifact



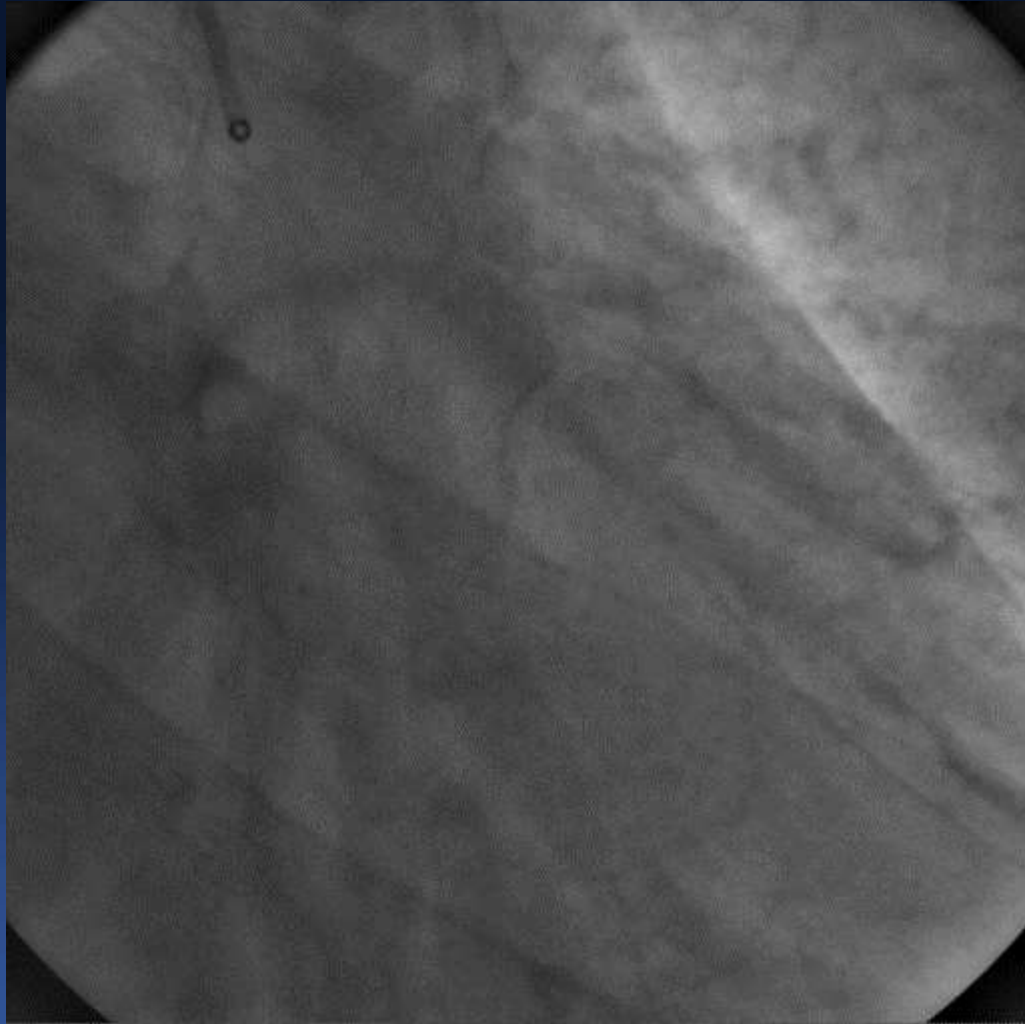
Persistent
&
RWMA



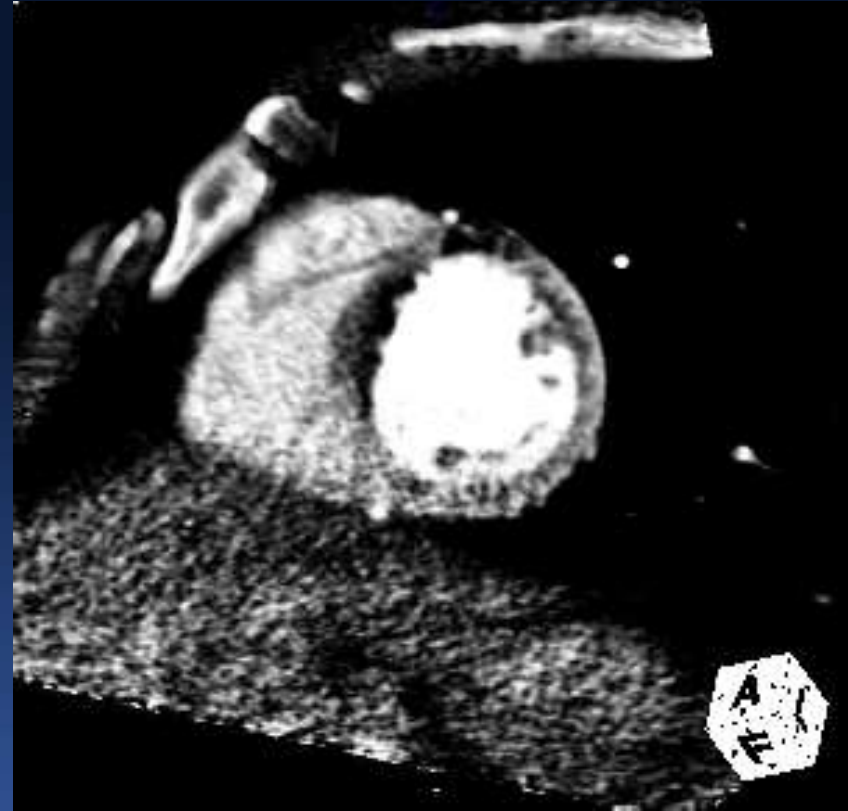
Transient
&
No RWMA



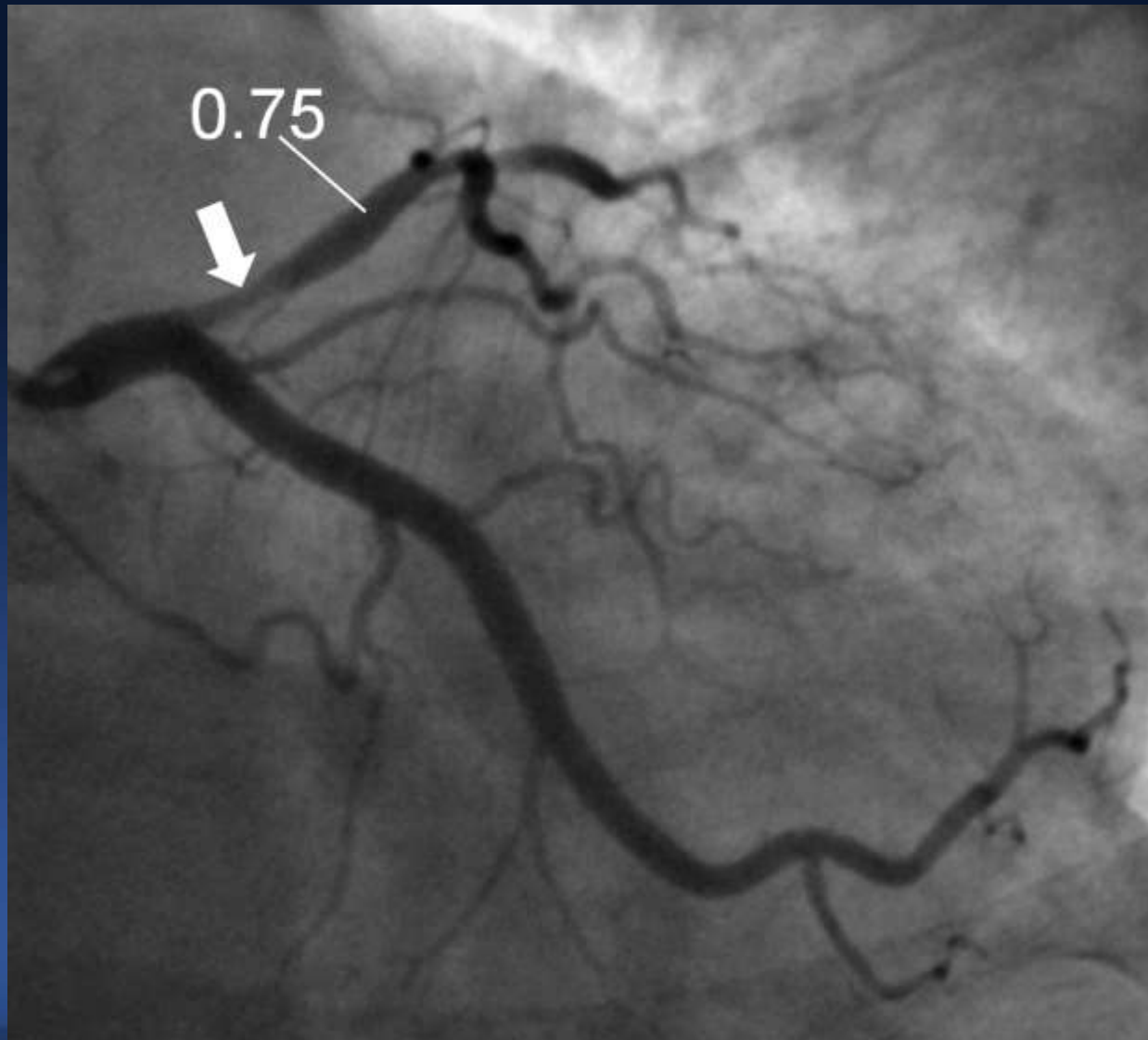
Typical severe stenosis



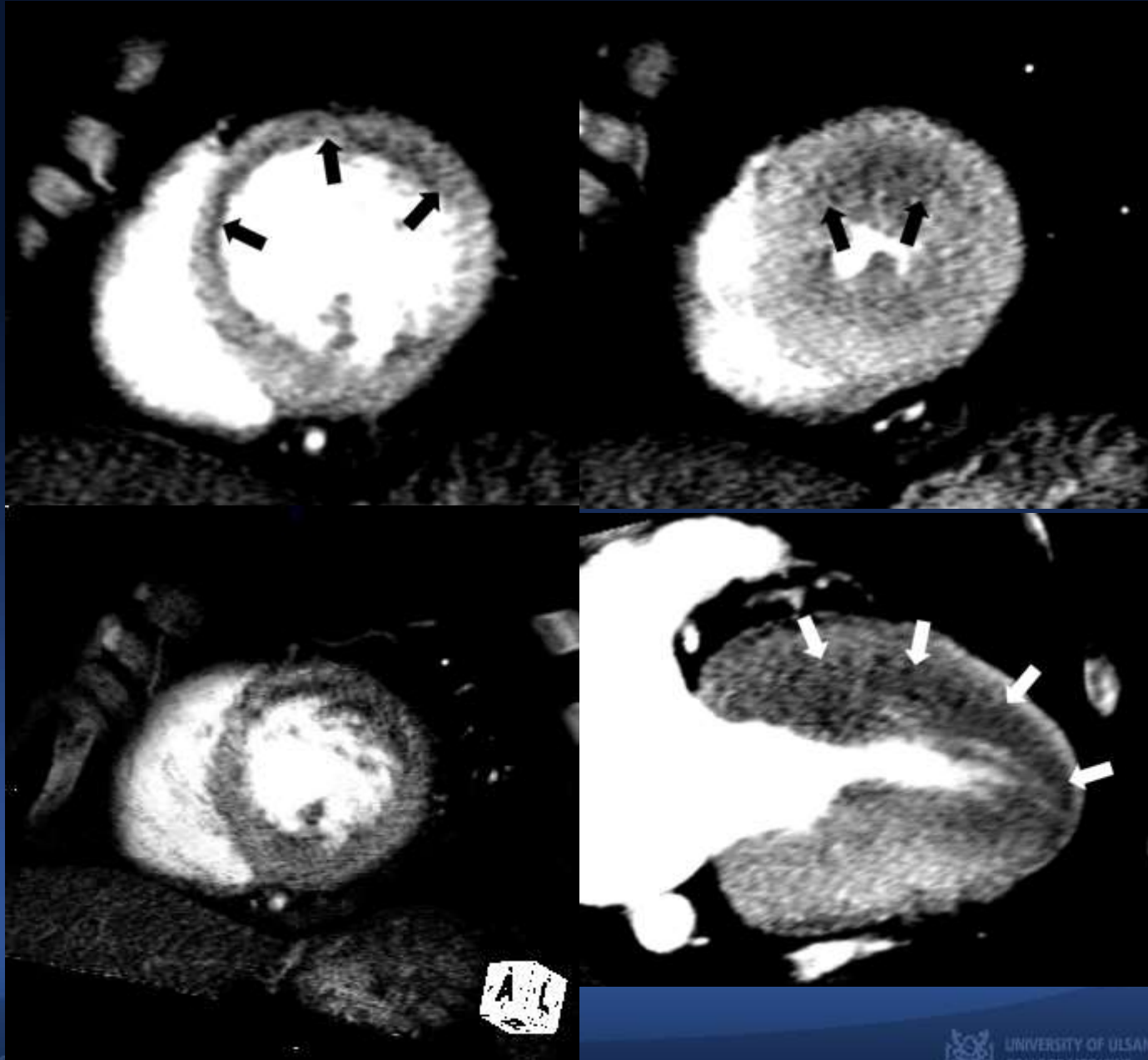
FFR 0.44 (pre-adenosine)



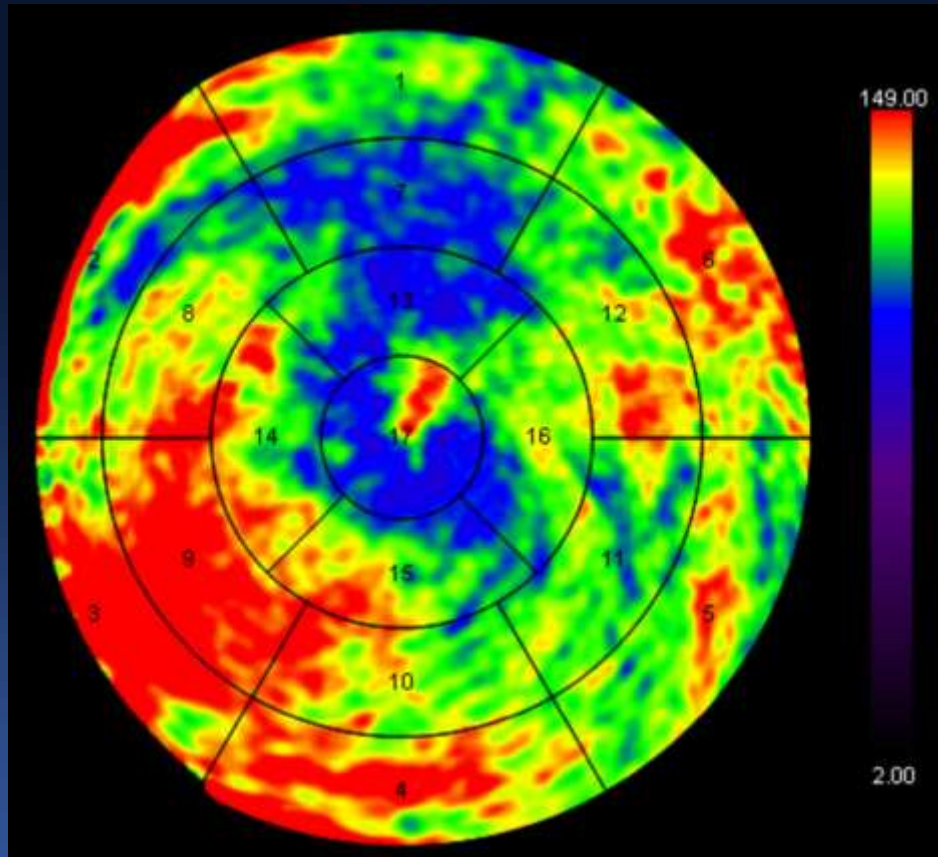
Cine



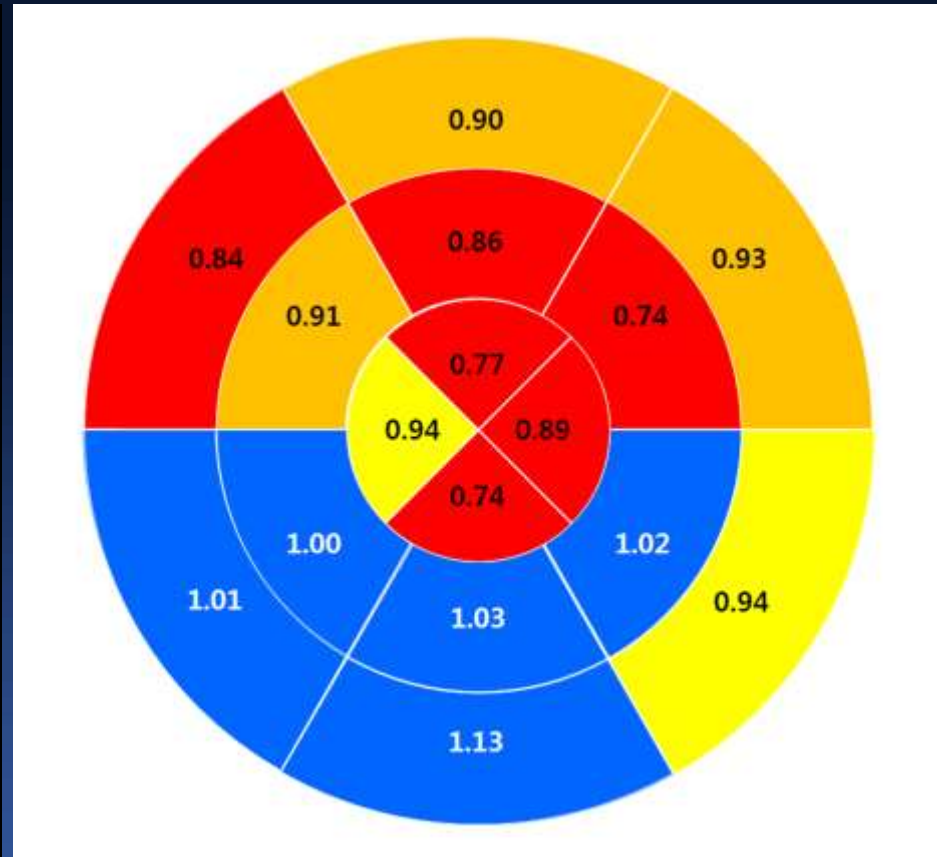
Intermediate stenosis



Quantitative Analysis

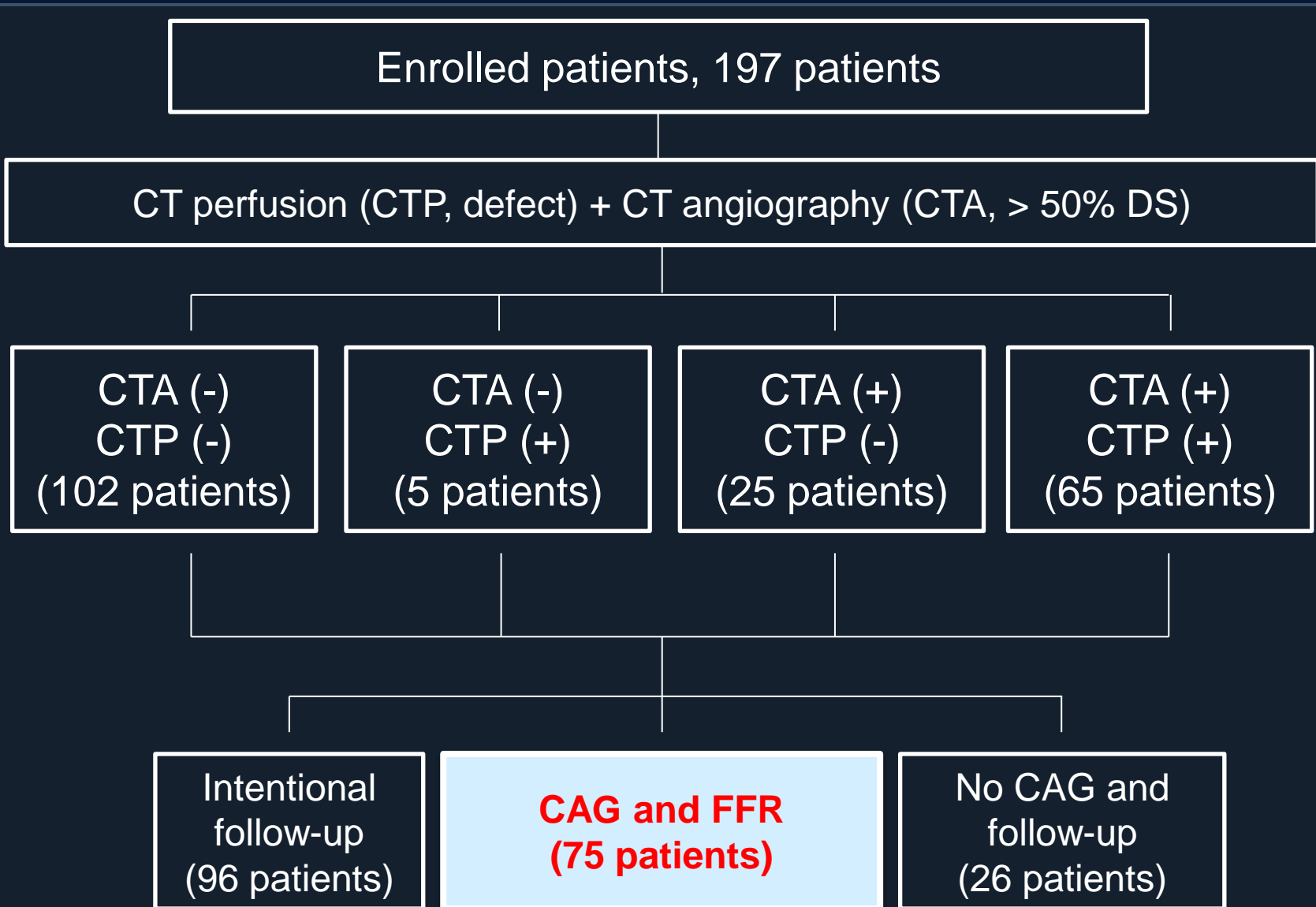


Density map
Syngo, Siemens



TPR map
Home-made, AMC

Early CTP Analysis in AMC



Early Results: CTP visual assessment

	CTP	CTA	CTP / CTA Integration	QCA, DS \geq 50%
True positive	69	85	77	74
False positive	6	33	14	11
True negative	118	91	110	113
False negative	17	1	9	12
Sensitivity,%	80	99	90	86
Specificity,%	95	73	89	91
PPV,%	92	72	85	87
NPV,%	87	99	92	90
Kappa statistic	0.77	0.68	0.78	0.77
Accuracy	89	84	89	88

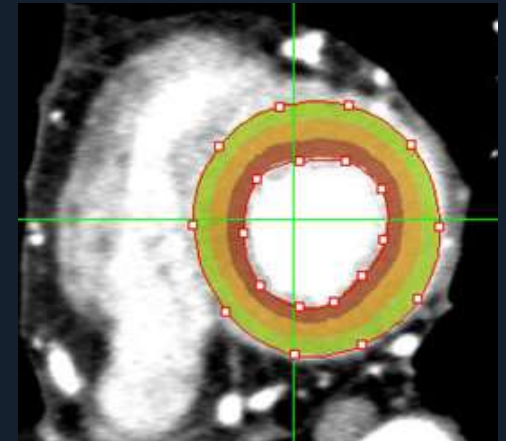
Subgroup Analysis

	High Agastone calcium score > 400 (N=63)			Multivessel disease (N=56)		
	Sensitivity	Specificity	IDI index	Sensitivity	Specificity	IDI index
CTP visual assessment	85	100	0.38*	76	91	-0.10
CTA, DS ≥ 50%	100	50	-	100	45	-
Integration of CTP and CTA	94	87	0.31*	89	82	0.01
QCA, DS ≥ 50%	87	83	-	84	73	-

IDI, integrated discrimination improvement

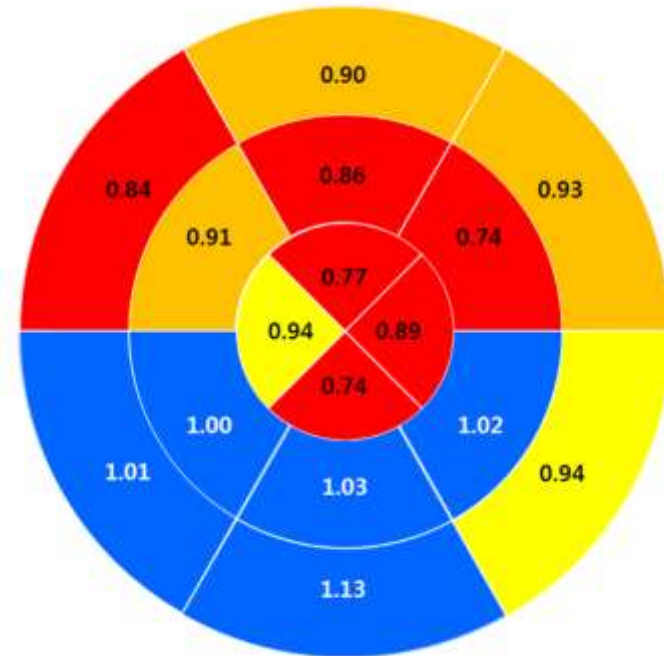
Quantitative Analysis

- Using customized software
 - Classification of whole myocardium into 16 segments and three layers
- Evaluation parameters
 - CT density on stress / rest CT
 - $\text{Density}_{\text{stress}} / \text{Density}_{\text{rest}}$, HU
 - Transmural perfusion ratio (TPR)
 - $\text{Density}_{\text{endocardial}} / \text{Density}_{\text{epicardial}}$
 - Myocardial perfusion reserve index (MPRI), %
 - $(\text{Density}_{\text{stress}} - \text{Density}_{\text{rest}}) / \text{Density}_{\text{rest}} \times 100$



Quantitative Analysis

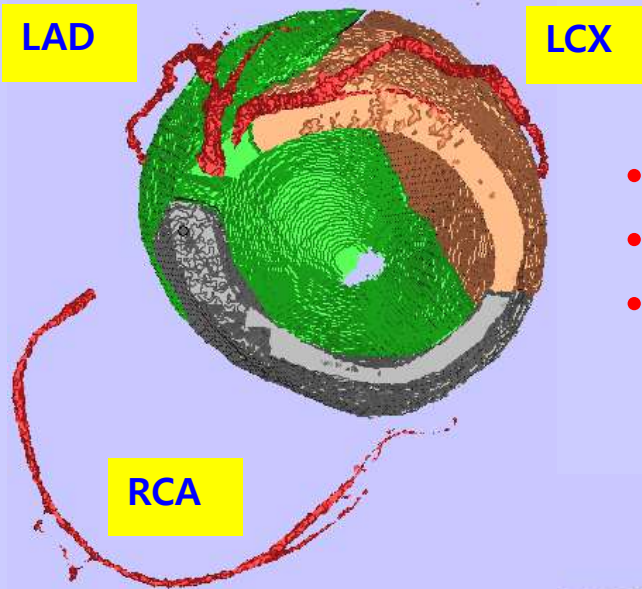
Parameter	AUC	Cut off	Sensitivity	Specificity
All patients (n=75)				
TPR				71
Density _{stress} , HU				66
Density _{rest} , HU				61
MPRI, %				62
Quantitative composite of TPR, Density _{stress} , or MPRI *				75
Combination of visual and quantitative composite **	0.878	-	89	73



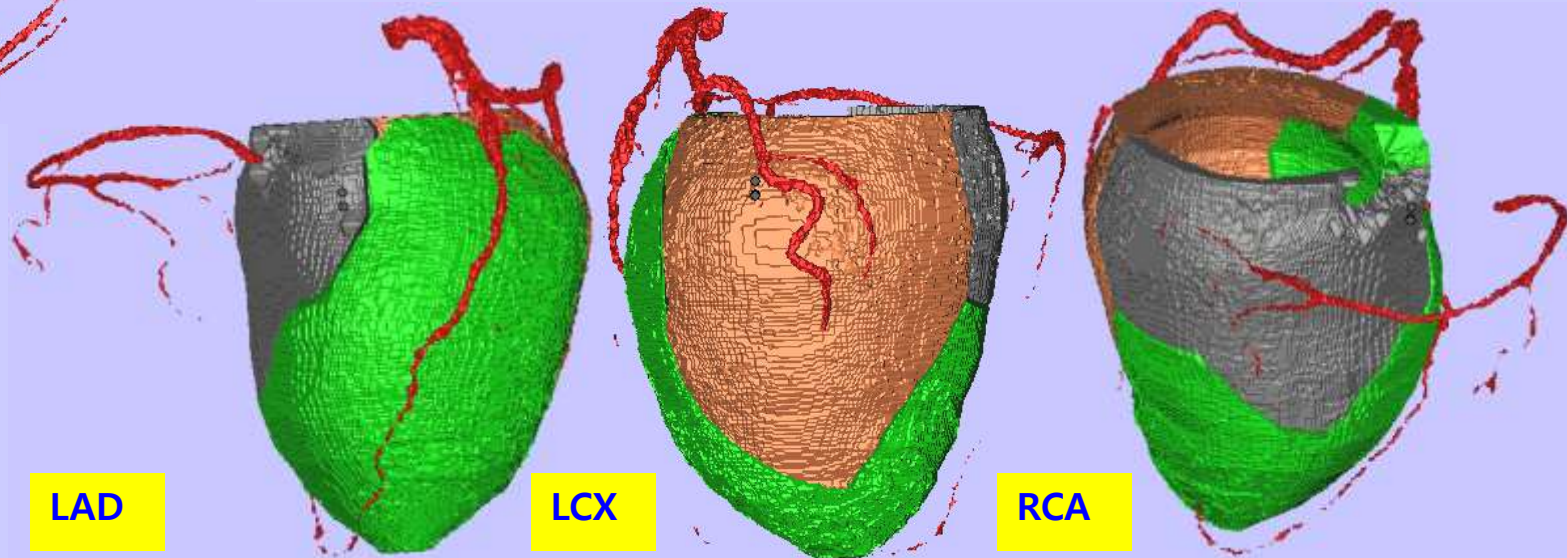
TPR: transmural perfusion ratio
 MPRI: myocardial perfusion reserve index

New Method for Coronary Artery Based Myocardial Segmentation

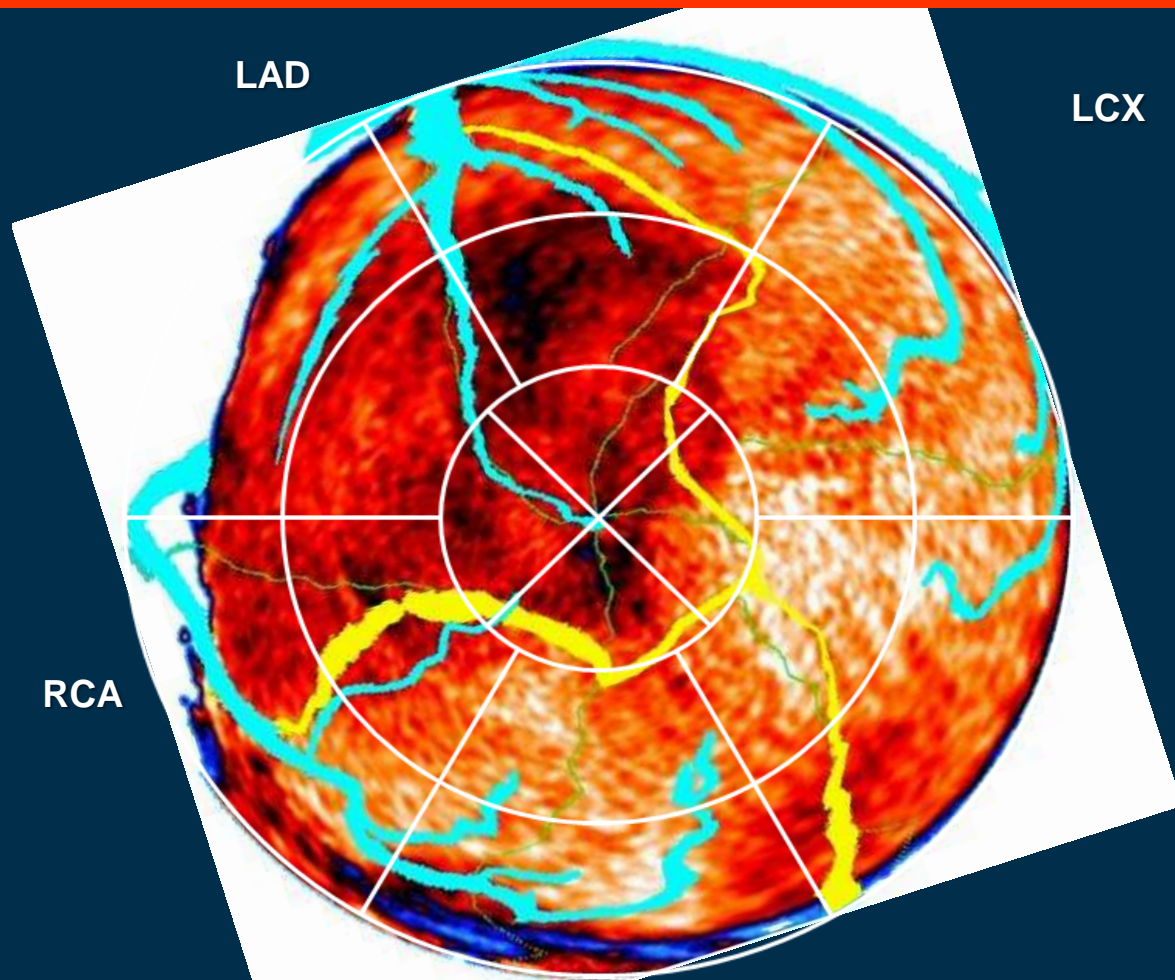
CAMS Method



- Indirect but, accurate prediction of ischemia area
- Estimation of ischemia area
- Prediction of residual ischemic area after revascularization

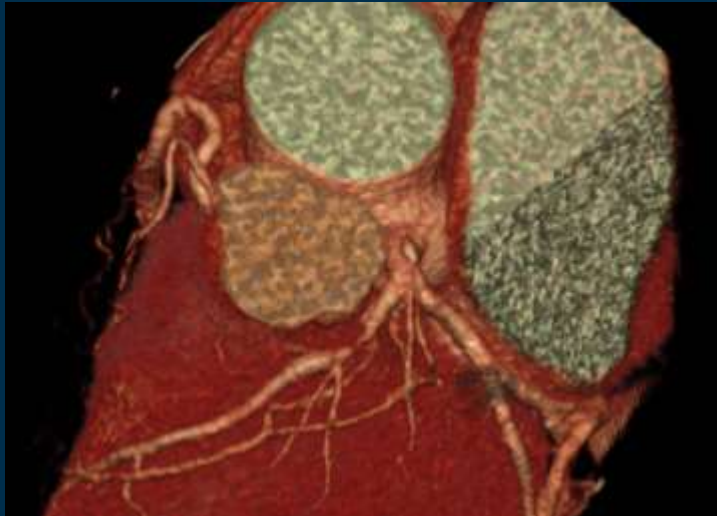


Bull's eye map in CAMS method

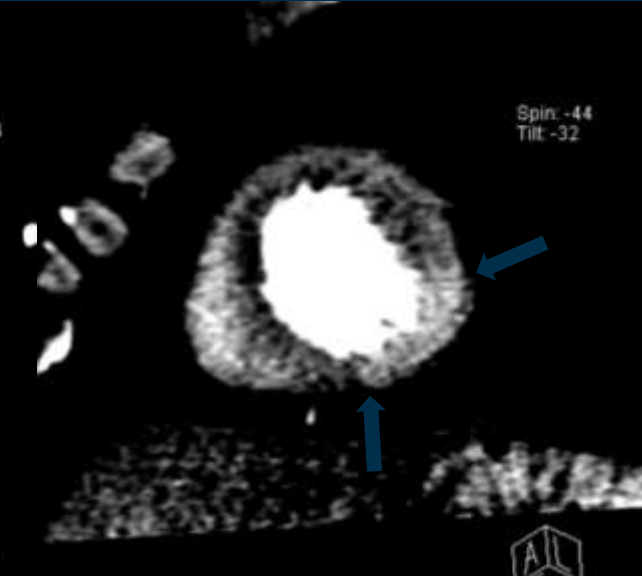
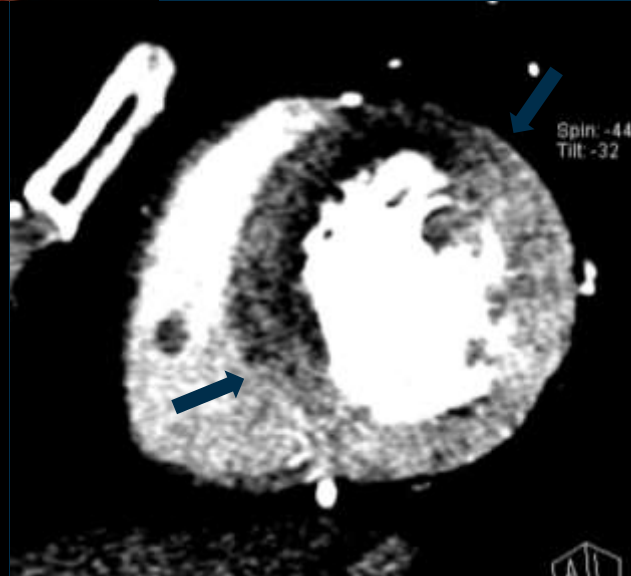
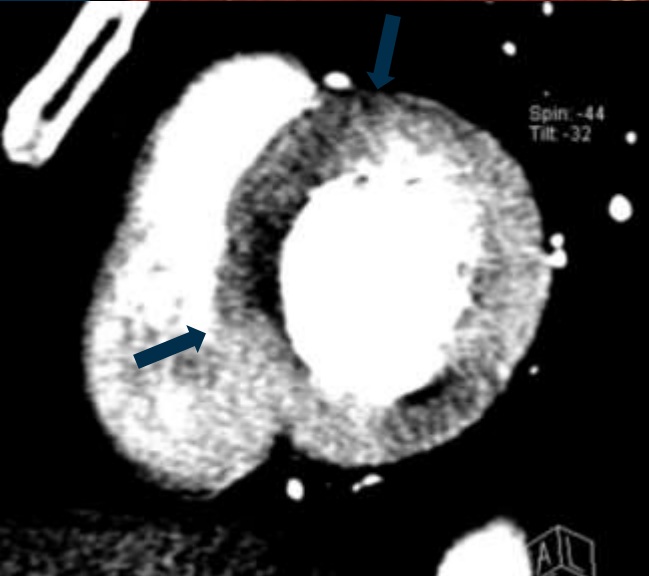


Excellent matching between perfusion defect in LAD territory and CAMS segmentation !!

Case: LAD Territory Ischemia



- Tight stenosis in proximal LAD
- Reversible perfusion defect in LAD territory

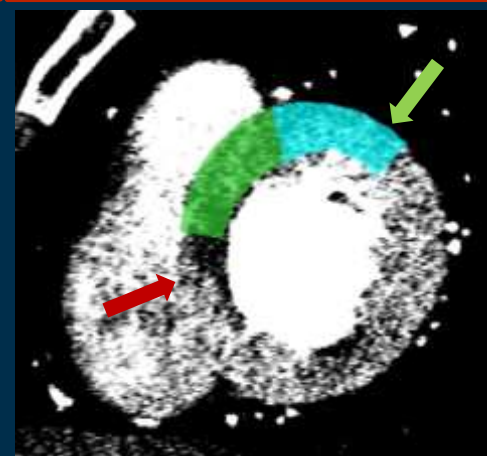
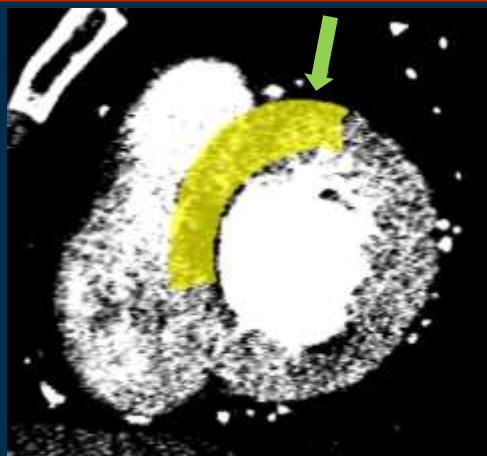
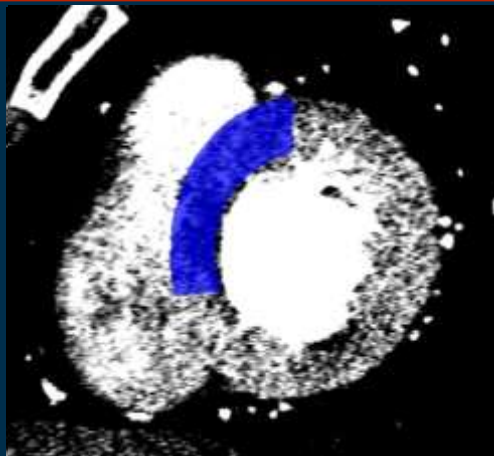


Perfusion defect

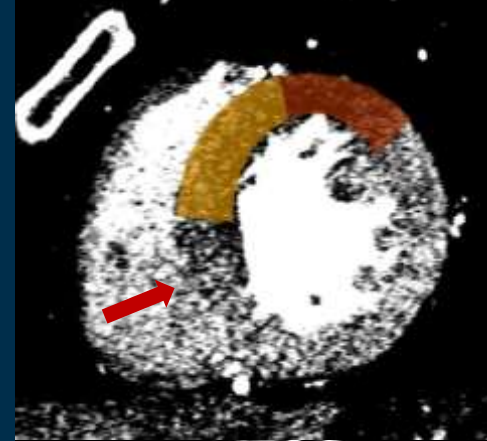
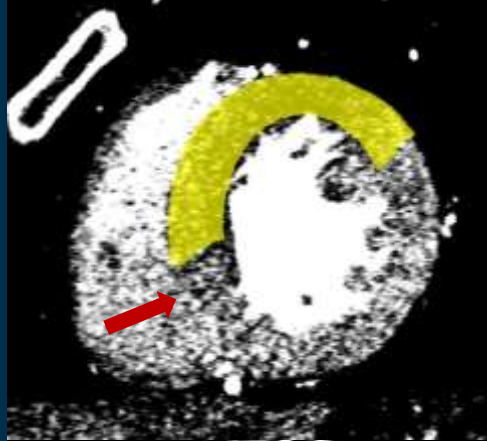
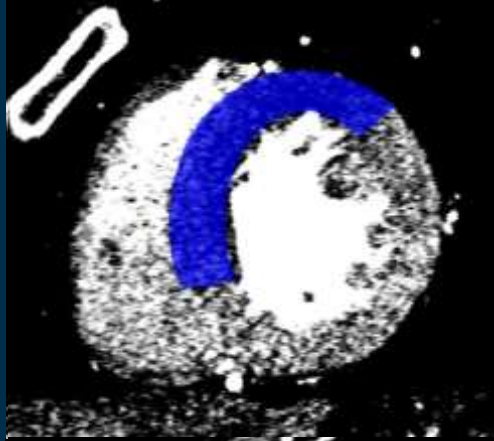
CAMS method

AHA classification

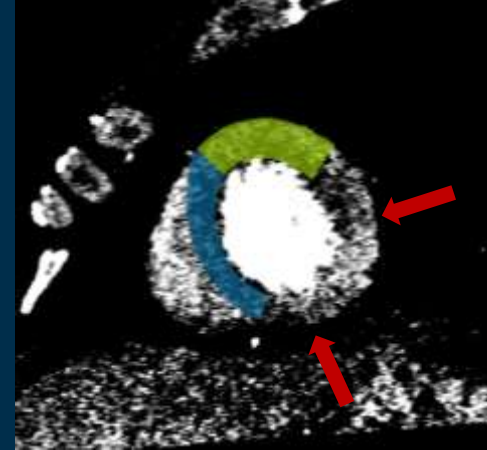
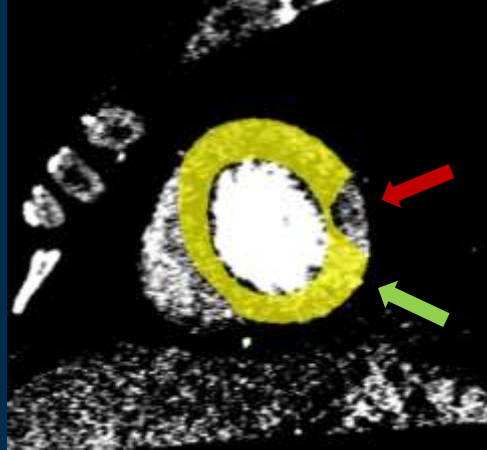
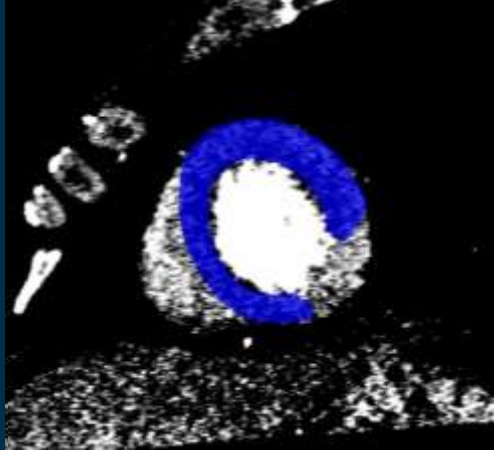
Basal



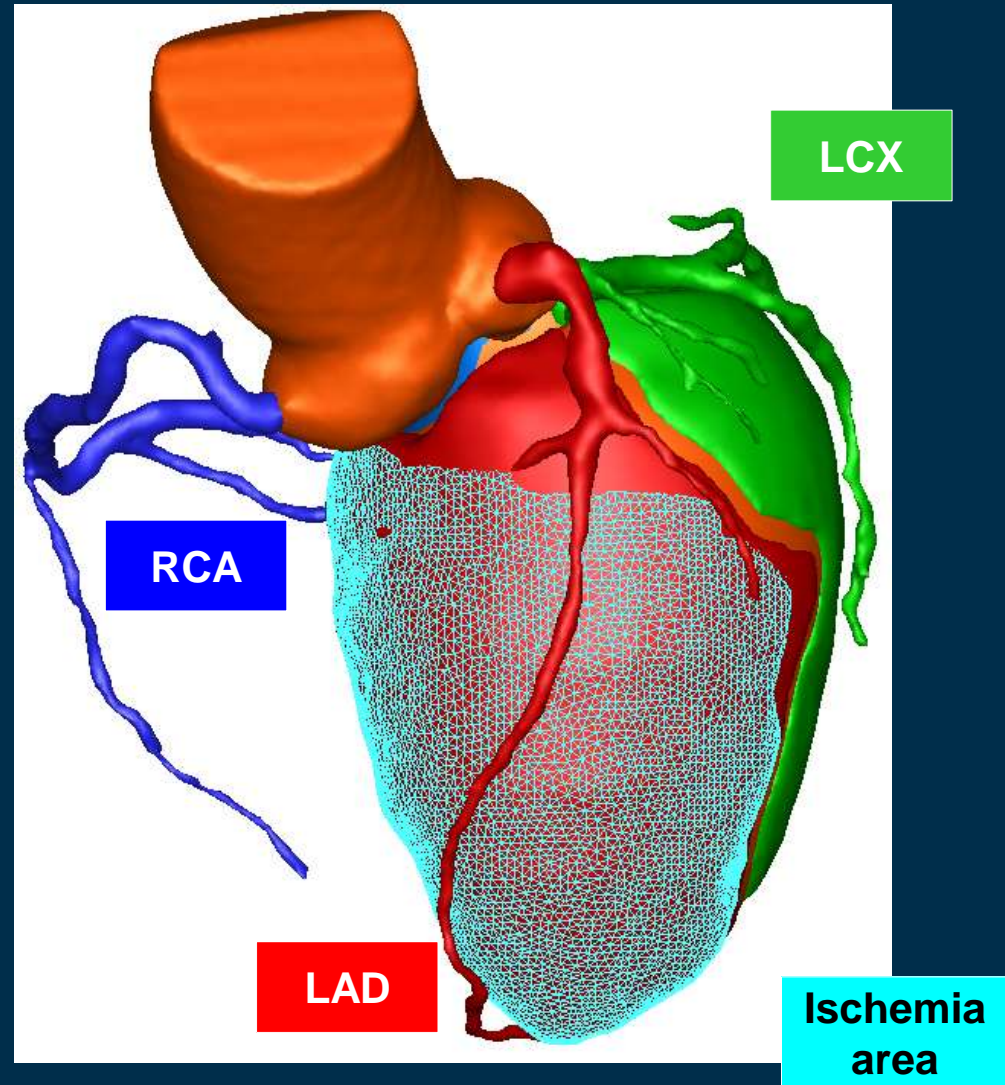
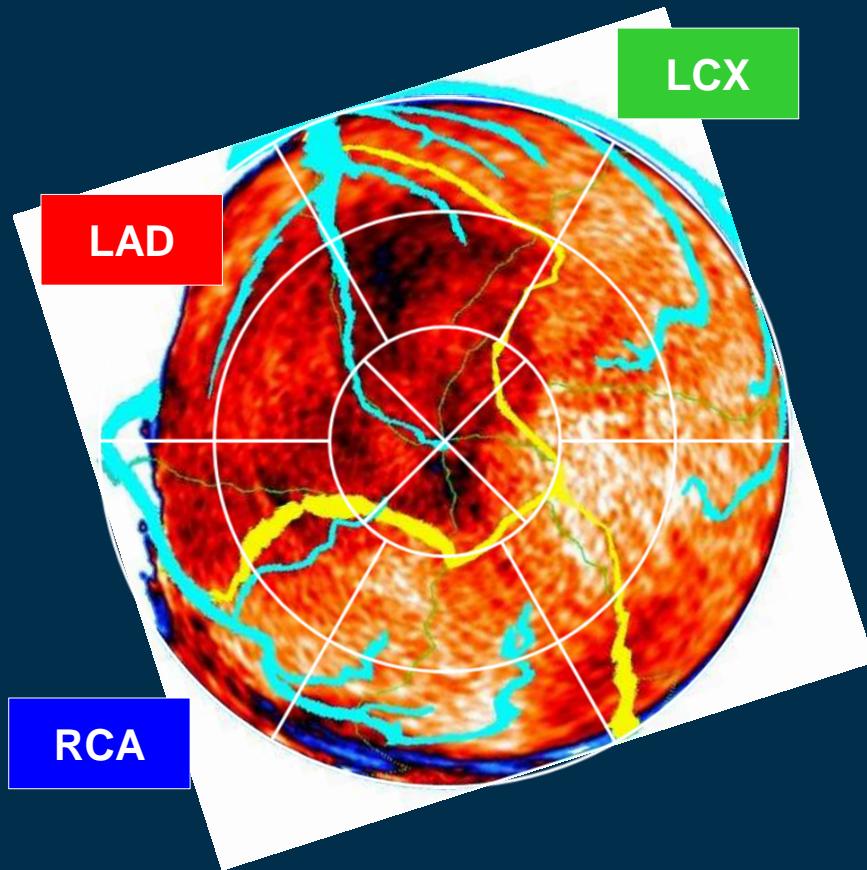
Mid

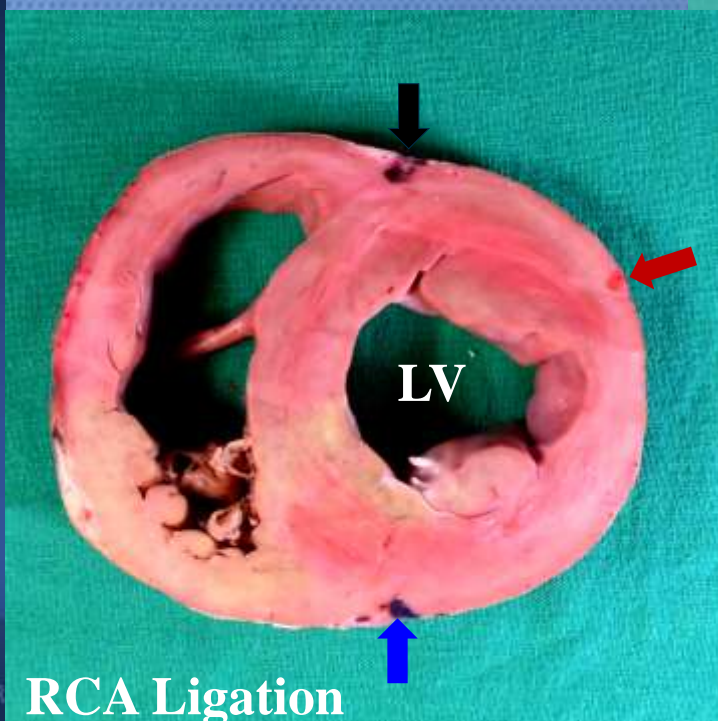
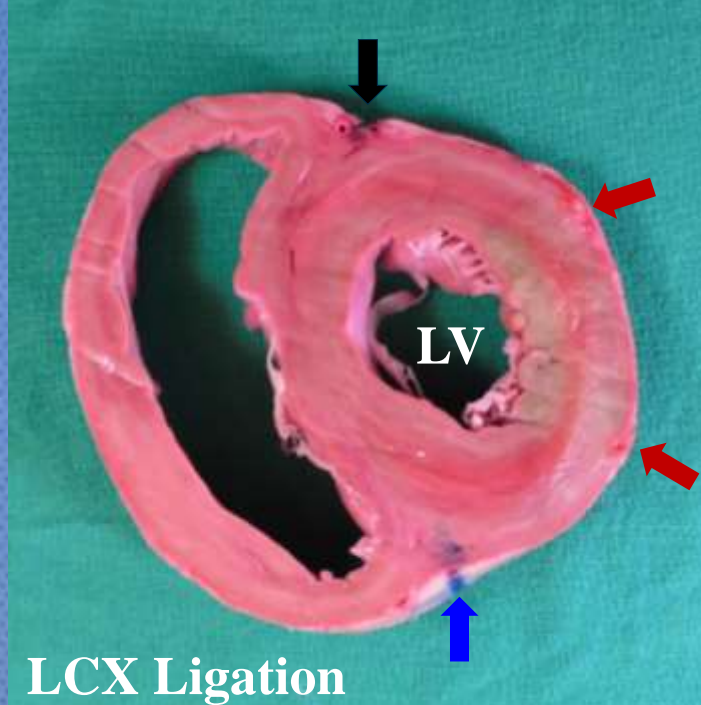
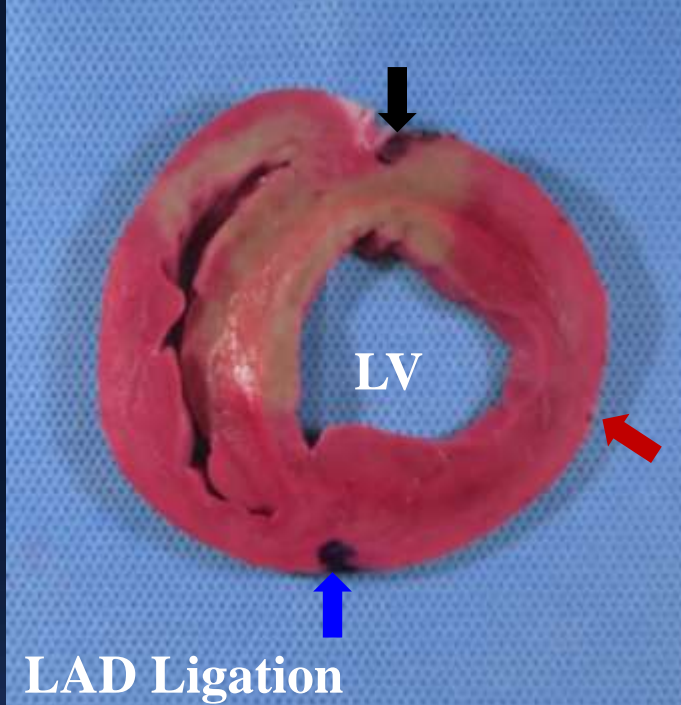


Apical



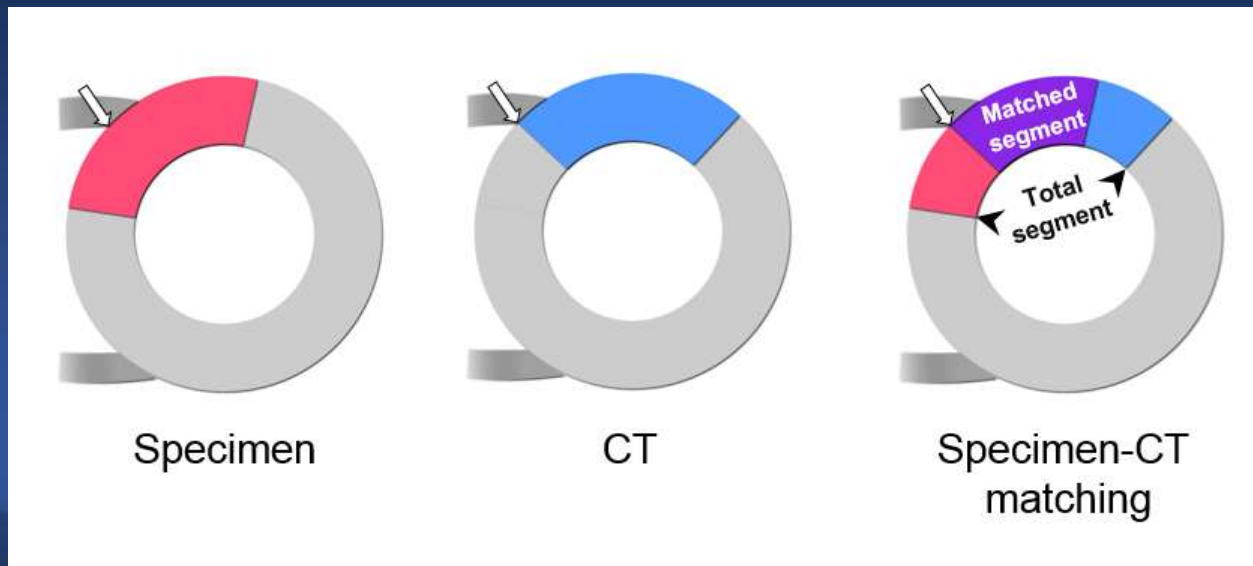
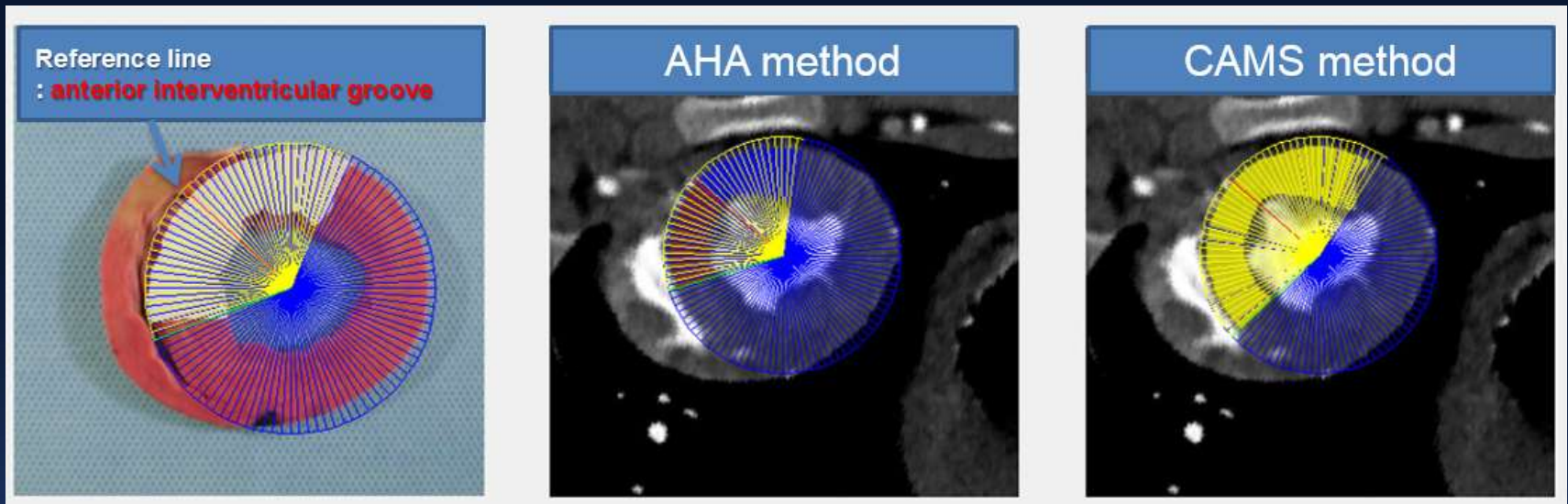
Ischemic Area: 42% of LV myocardium





Unstained area of myocardium = Myocardial territory of occluded coronary artery

Specimen – CT Comparison

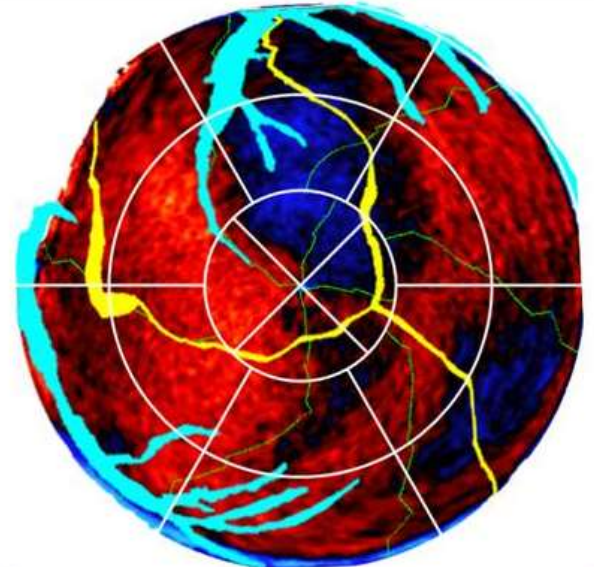
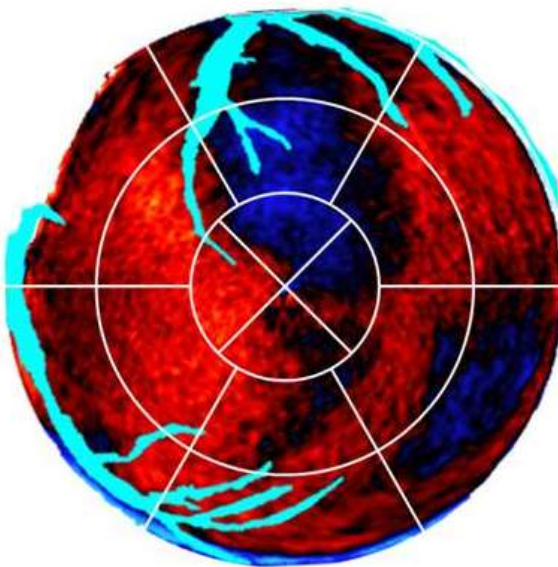
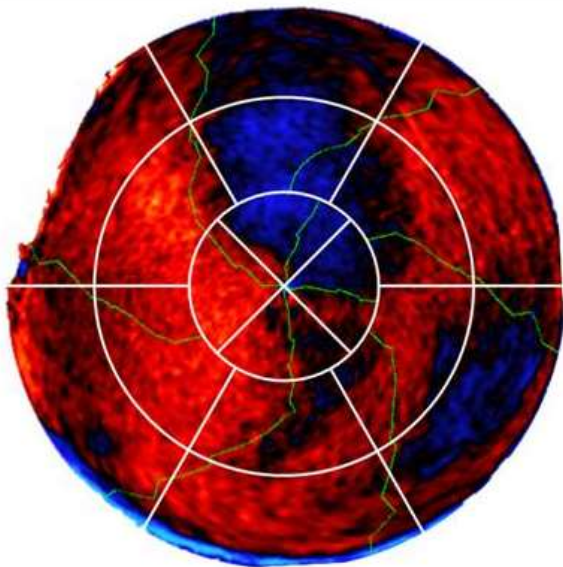
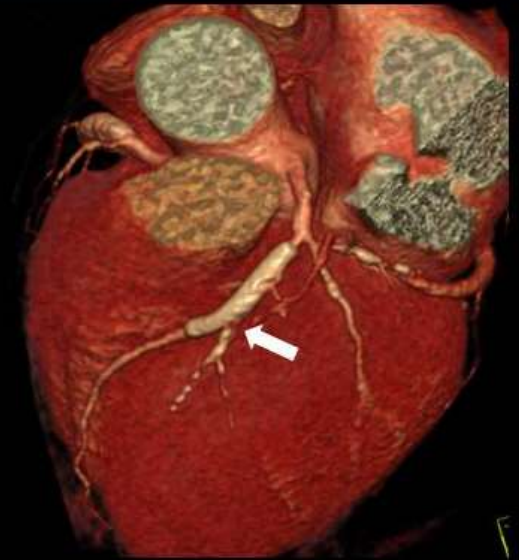
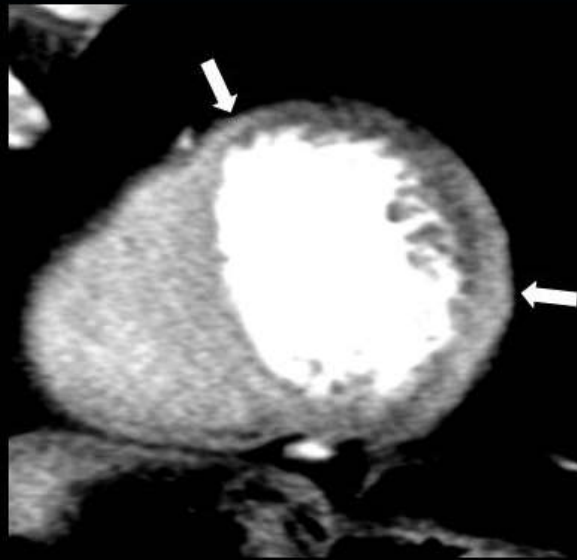
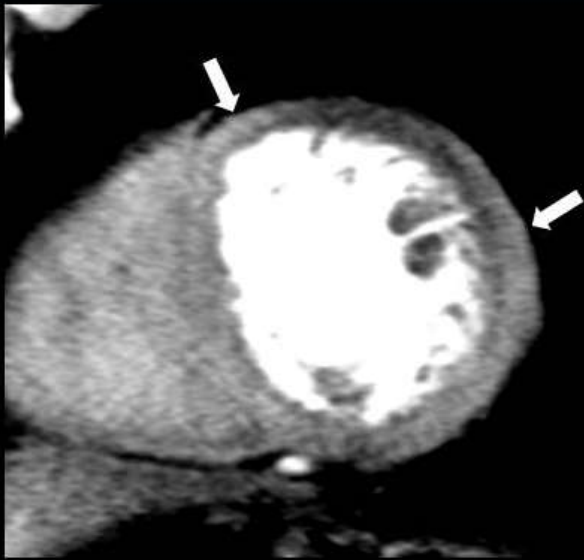


Agreement in Each Vascular Territory

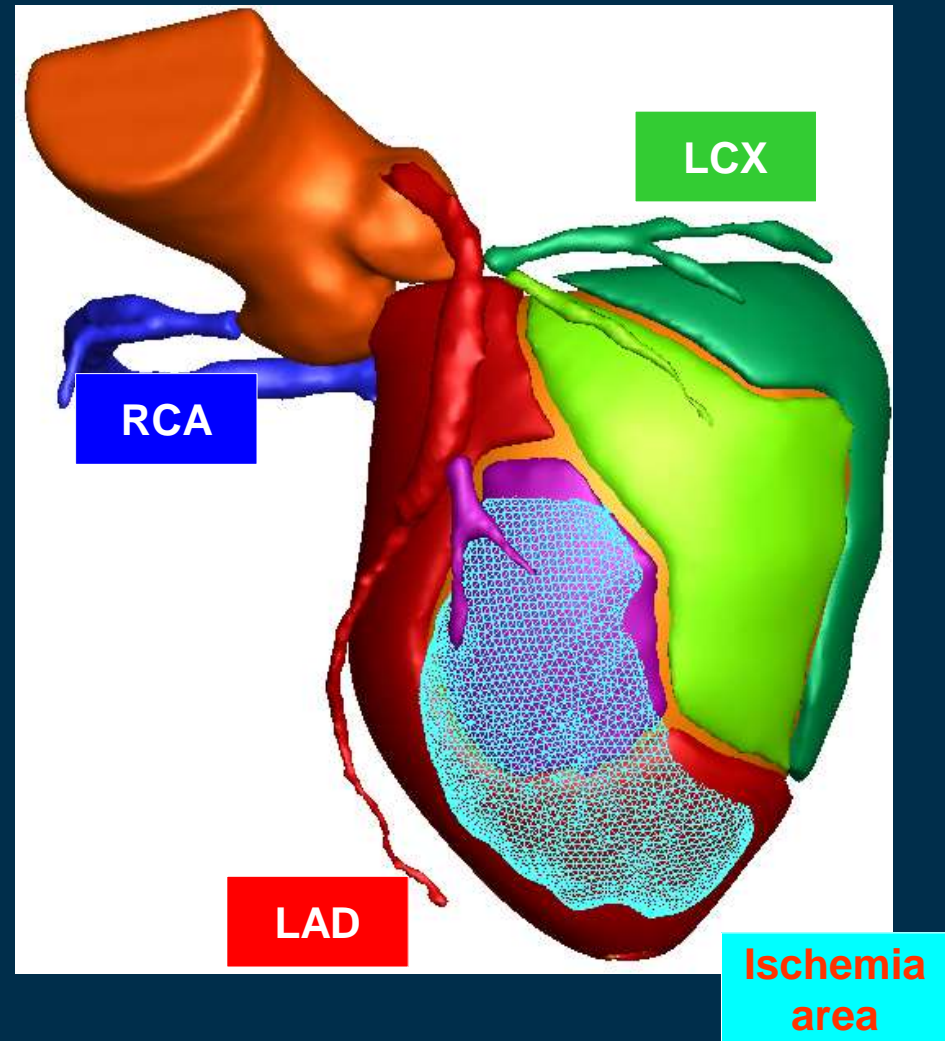
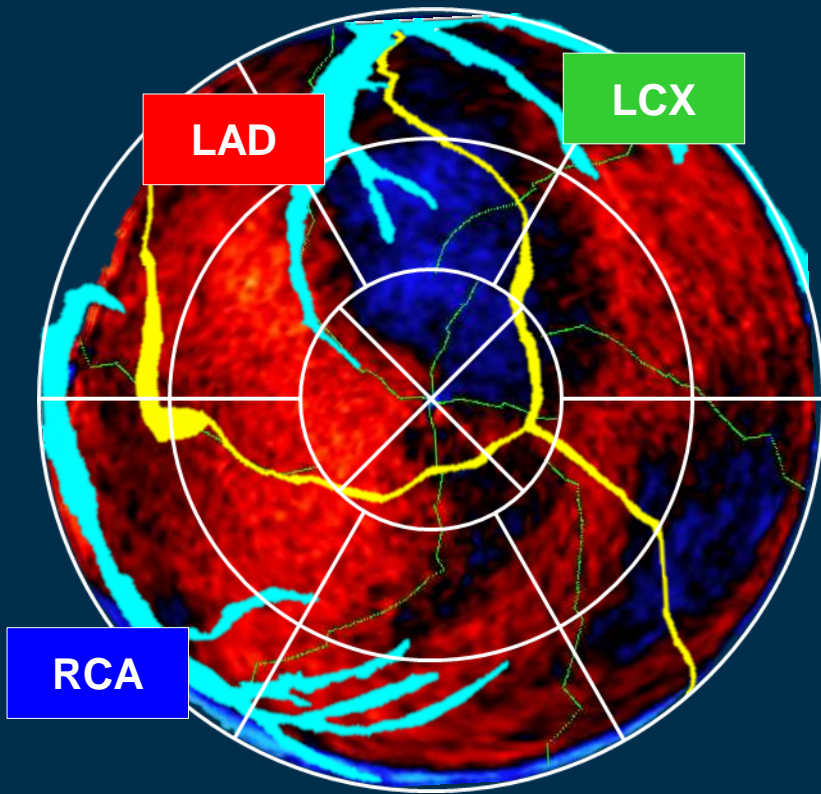
	Matched segment, Number of columns		P- value	Matched segment per specimen, %		P- value	Matched segment per total segment, %		P- value
	AHA	CAMS		AHA	CAMS		AHA	CAMS	
Territory			<0.001			<0.001			<0.001
LAD	32 (10~47)	42 (10~54)	0.006	77.3 (53.6~100)	100 (75.0~100)	<0.001	68.8 (29.4~90.4)	79.3 (37.0~93.0)	0.13
LCX	16.5 (0~33)	19 (1~40)	0.17	55.8 (0~100)	88.1 (4.8~100)	0.012	33.3 (0~85.7)	57.3 (2.1~84.1)	0.11
RCA	22 (1~33)	21 (12~30)	0.69	100.0 (6.7~100)	92.3 (57.1~100)	0.80	68.8 (2.4~97.1)	71.0 (23.1~90.9)	0.92

Traditional AHA segmentation method underestimate the LAD territory

Side Branch Stenosis



Ischemic Area: 8% of LV myocardium



PERFUSE RCT

Patients with typical chest pain but no acute MI (<7 days)

Coronary CTP with CTA

Screening or
Randomization failure

- De novo stenosis $\geq 70\%$ OR
- Perfusion defect

Yes

Parallel
Registry

Randomization
Cohort

- 1:1 Stratified by
- Number of diseased vs
 - Sites

FFR-guided
group
(N=500)

CTP-guided
group
(N=500)

Medication

FFR-guided PCI

CTP-guided PCI

Medication

Cardiac CT: One Stop Shop

Imaging Target	Conventional Technique	Limitation of CT
1. Coronary artery stenosis	CAG	<ul style="list-style-type: none"> • Temporal resolution • Spatial resolution • Radiation exposure • Contrast material • Blooming artifact from calcified plaque
2. Plaque evaluation	IVUS, OCT	
3. Ventricular function	ECHO, MRI	
4. Myocardial ischemia (CT perfusion)	SPECT, MRI	
5. Fractional flow reserve (CT- FFR)	Invasive FFR	
6. Valve, Structural abnormality	ECHO, MRI	