

CT Perfusion

'One-Stop Shop' with CT Imaging

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Disclosure

- Nothing to disclose related with this presentation

Ischemia-guided Revascularization *My Belief*

Kim YH, Park SJ.

Circulation. 2013;128:95-7.

Kim YH, Park SJ.

Circ J. 2013;77:1967-74.

Editorial

Paradigm Has Already Shifted to Ischemia-Guided Functional Approach

Seung-Jung Park, MD, PhD; Young-Hak Kim, MD, PhD

The anatomic Synergy Between Percutaneous Coronary Intervention With TAXUS and Cardiac Surgery (SYNTAX) score is a stratification score illustrating the complexity of angiographic stenosis. It was considered a surrogate for poor prognosis after percutaneous coronary intervention (PCI).¹ Accordingly, in patients with a high baseline SYNTAX score (bSS) requiring coronary revascularization,

analysis of the SYNTAX study by Farooq et al⁶ in this issue of *Circulation* provides important information on whether the rSS has a good discriminatory power for predicting outcomes in patients presenting with relatively stable symptoms. Patients with an rSS of >8 had a higher risk of 5-year mortality (35.3%) than those with an rSS of 0 (8.5%), >0 to 4 (8.7%), and >4 to 8 (11.4%). Given these findings, rSS appears to be



Circulation Journal
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REVIEW

Ischemia-Guided Percutaneous Coronary Intervention for Patients With Stable Coronary Artery Disease

Young-Hak Kim, MD, PhD; Seung-Jung Park, MD, PhD

Current evidence and guidelines support the strategy of ischemia-guided revascularization for treatment of patients with stable coronary symptoms. However, anatomical stenosis is often targeted in revascularization treatment using percutaneous coronary intervention or coronary artery bypass surgery without seriously considering objective evidence of myocardial ischemia. Particularly, for patients with multivessel disease, angiographic complete revascularization was traditionally considered an ideal objective of revascularization treatment. Recently, however, observational studies contradict the concept of angiographic complete revascularization and support the benefit of ischemia-guided selective revascularization based on noninvasive and invasive functional evaluation detecting ischemia-producing coronary lesions. In the absence of a trial specifically designed to assess the relative benefit of either strategy, the present review explores the current concepts about the strength and weakness of anatomical vs. functional revascularization. (*Circ J* 2013; 77: 1967–1974)

Key Words: Coronary artery disease; Ischemia; Stents

What is the best tool to detect ischemic lesion and vessel ?

- **Noninvasive method**

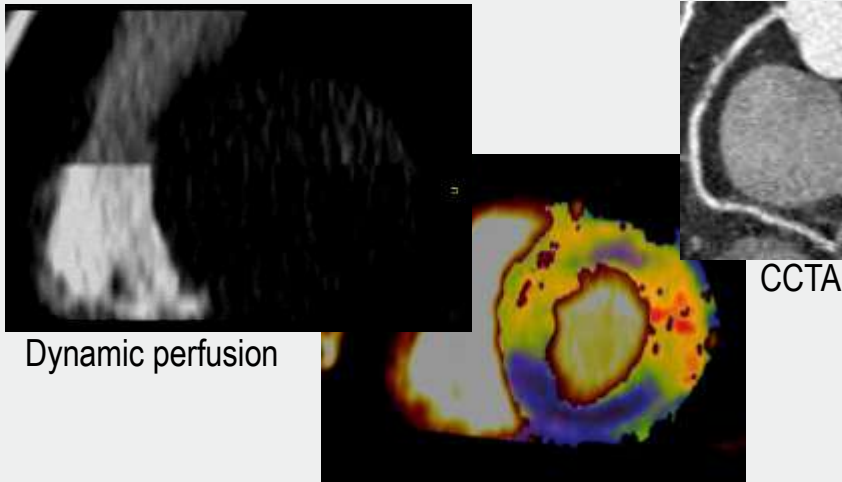
- SPECT
- PET
- MRI
- CT

Relatively high F(-) rate in multivessel and LM disease due to the balanced ischemia, low spatial resolution

- **Invasive method**

- FFR

CT-based Functional Imaging

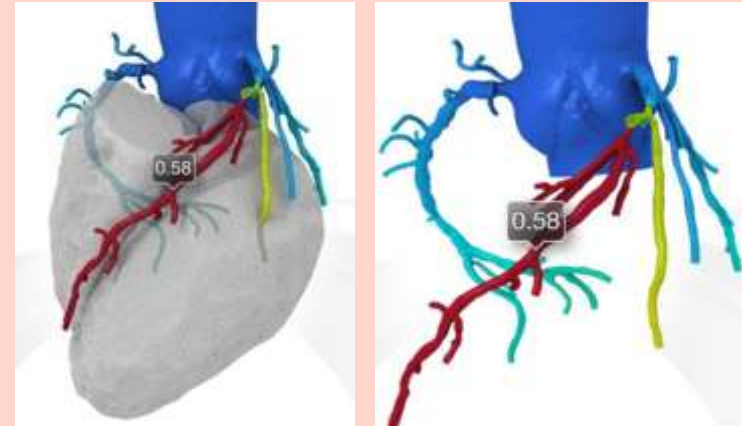


CT Perfusion (CTP)

- Pros**
- ✓ Direct view of myocardium
 - ✓ Easy to perform
 - ✓ No special software

- Cons**
- ✓ Radiation dose concern (two scans; stress + rest)
 - ✓ Requirement of adenosine

Computational fluid dynamics simulation

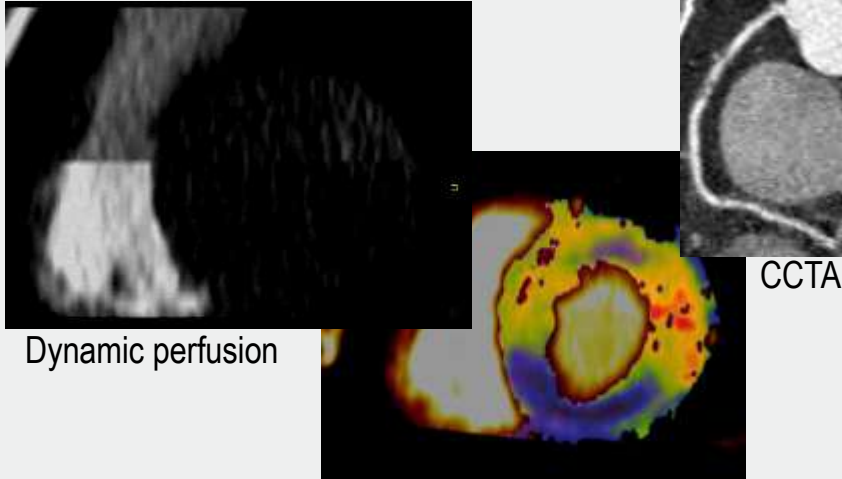


FFR-CT

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- Cons**
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 - ✓ Need supercomputer
 - ✓ No information on perfusion.

CT Perfusion Imaging

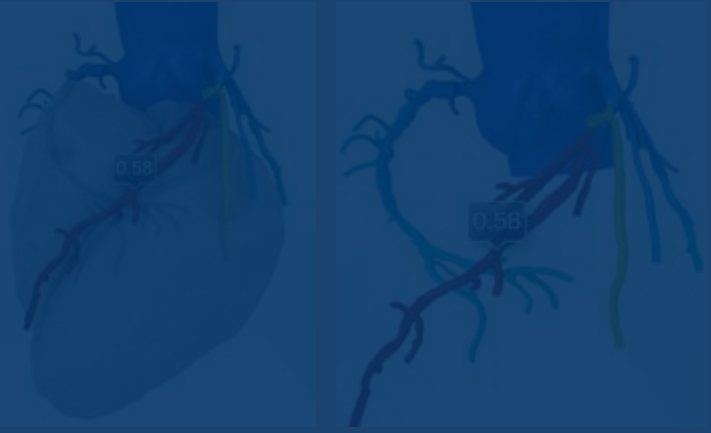


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Published Data about CT Perfusion

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)

CTP Protocol in AMC

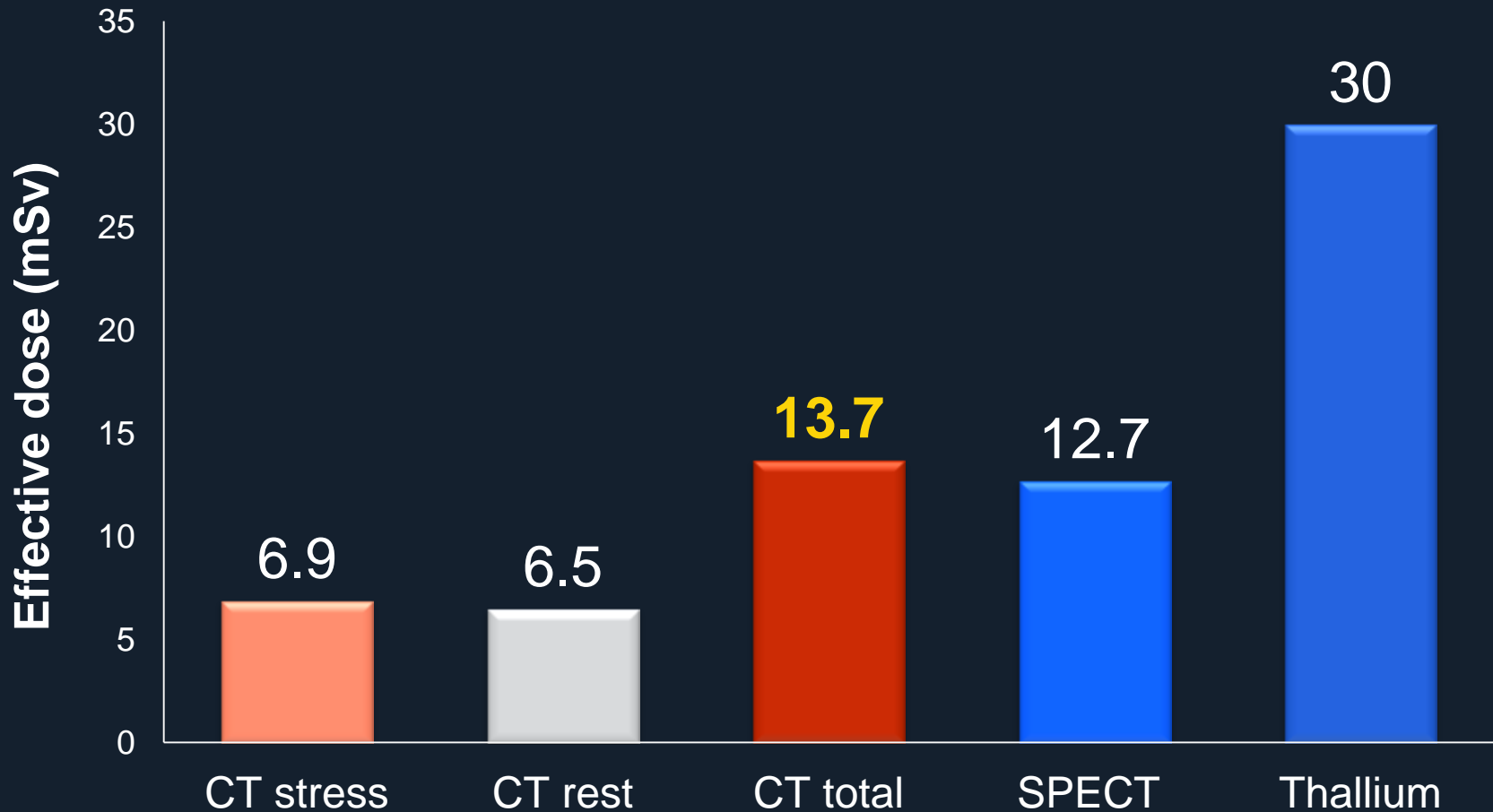
25 minutes
using dual-source 126 ch. CT (Siemens)

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

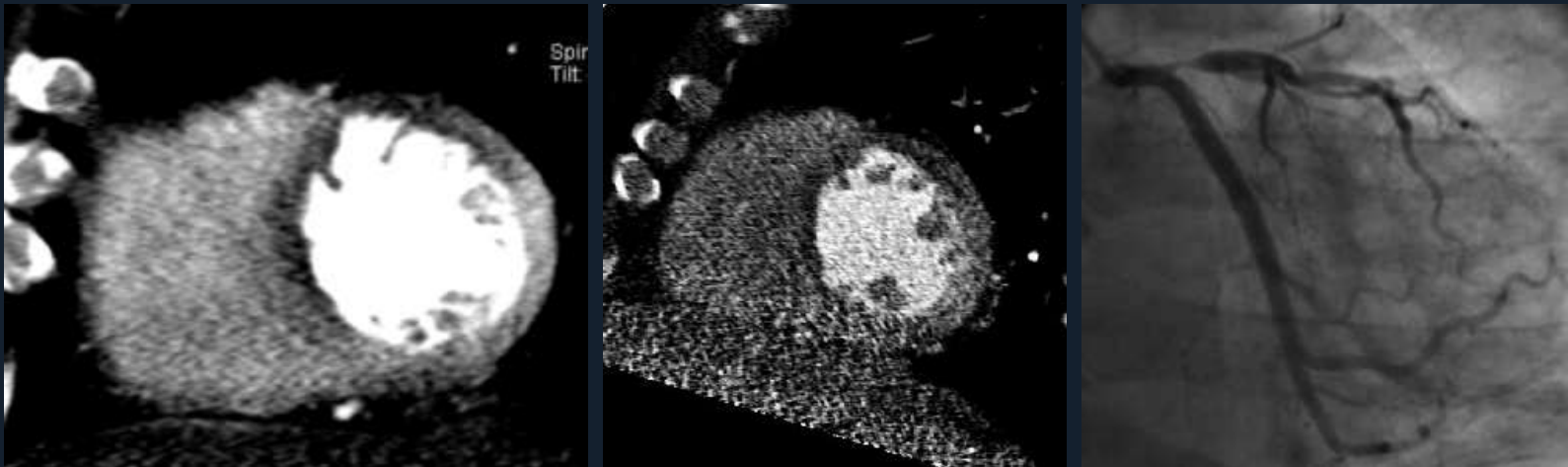
- Option
1. Retrospective mode
 2. Prospective mode
 3. High-pitch mode

Radiation Dose



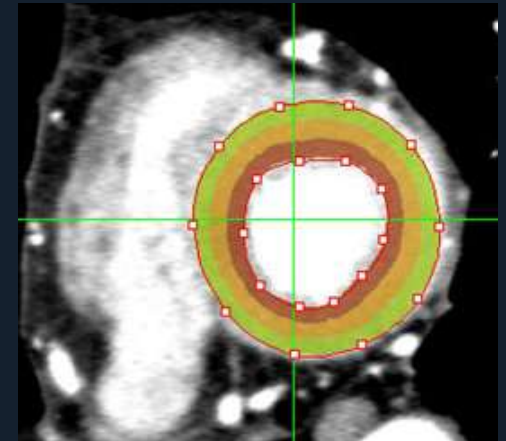
Visual Analysis of CTP

- 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)



Quantitative Analysis

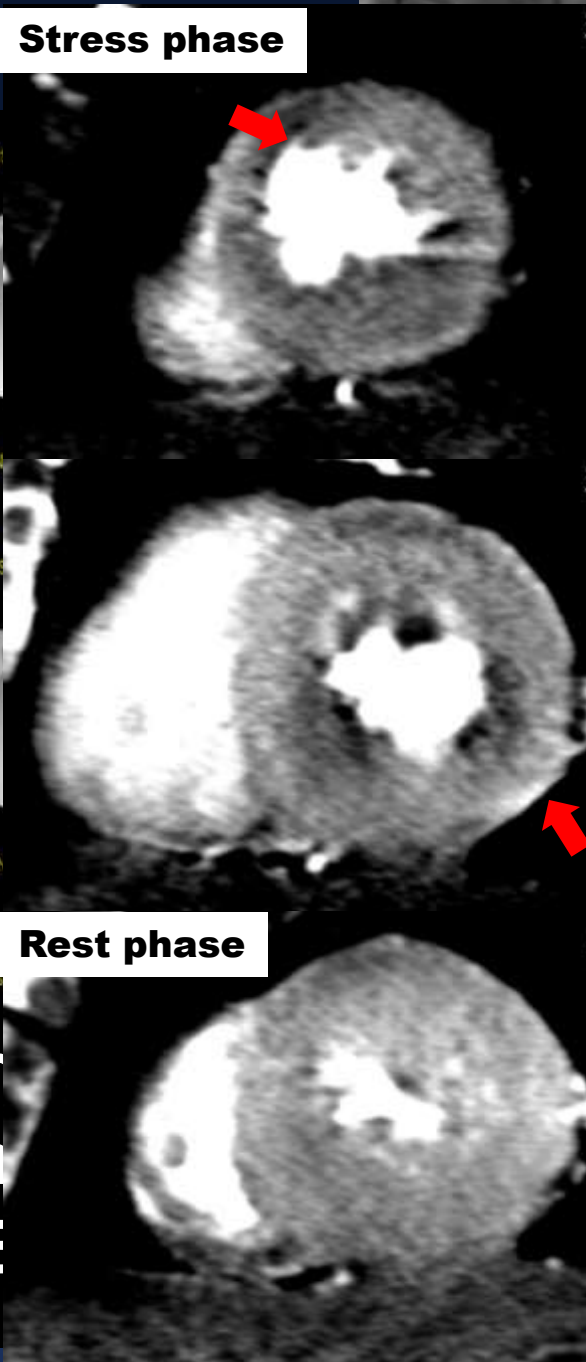
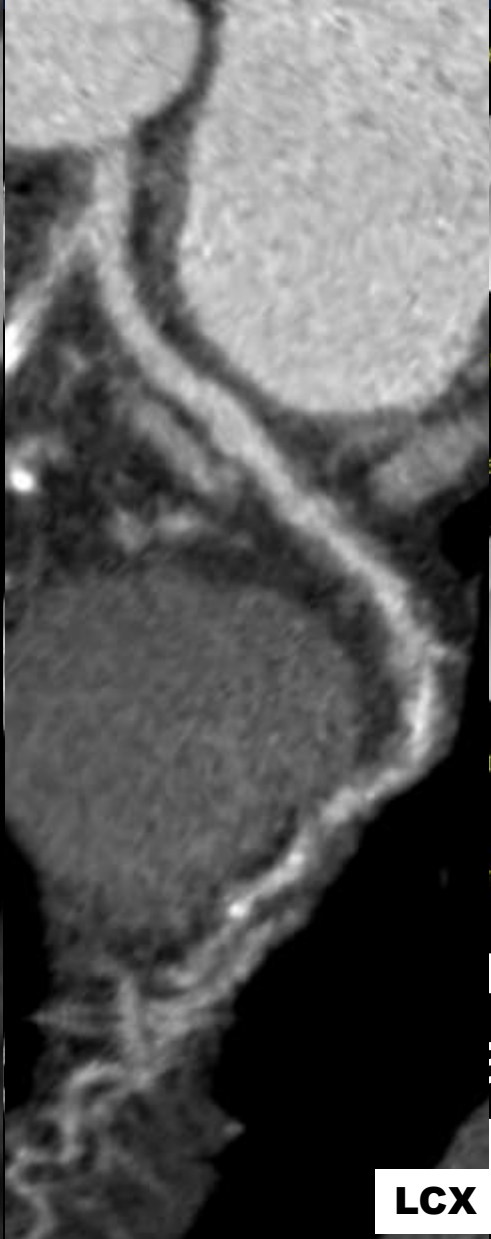
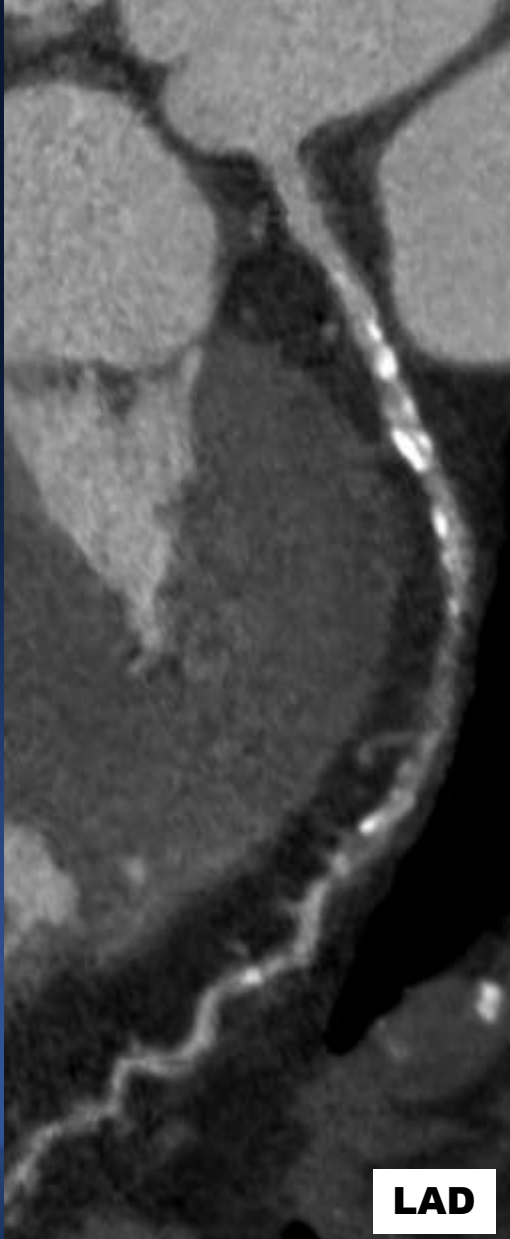
- Using customized software
 - Classification of whole myocardium into 16 segments and three layers
- Evaluation parameters
 - CT density on stress / rest CT
 - $\text{Density}_{\text{stress}} / \text{Density}_{\text{rest}}$, HU
 - Transmural perfusion ratio (TPR)
 - $\text{Density}_{\text{endocardial}}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



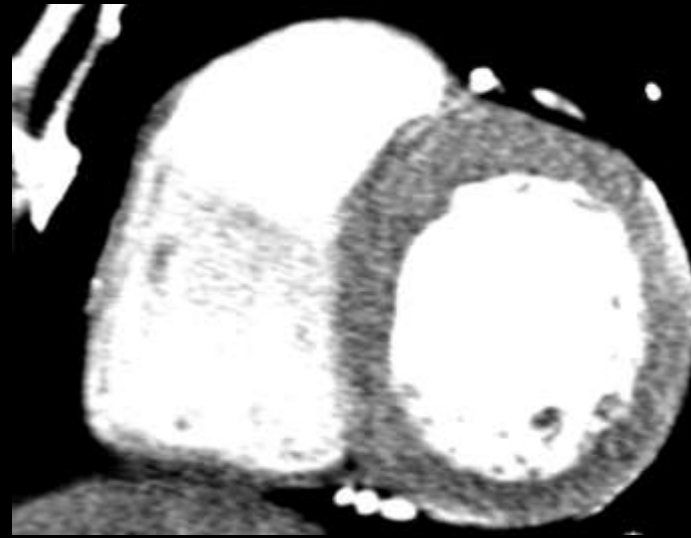
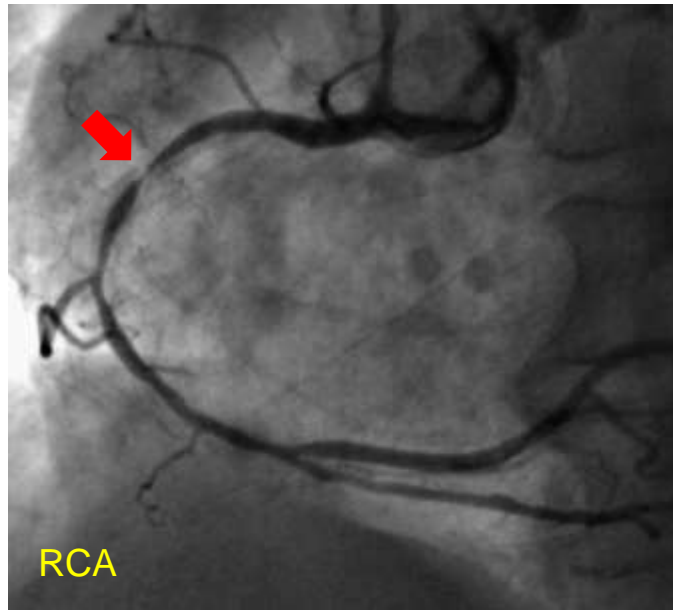
Case Examples of CTP

- **Multivessel disease**
- **Calcified lesion**
- **In-stent restenosis**
- **Anatomical variant**
- **Old infarction and peri-ischemia**

65/F, Effort chest pain

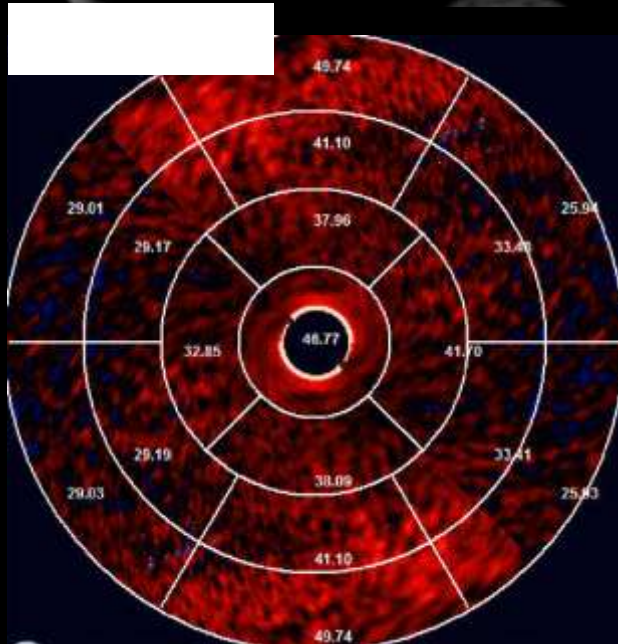
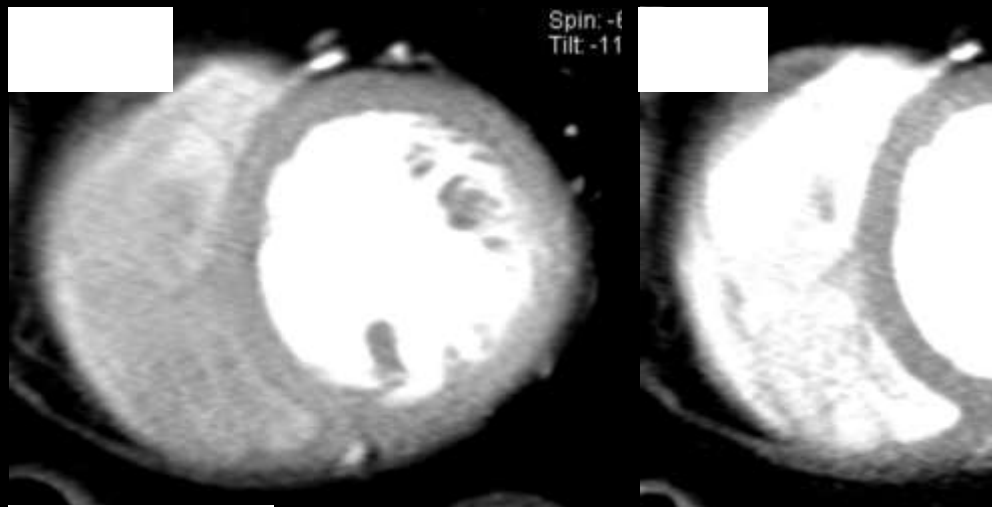


69/M, Effort chest pain



Reversible perfusion defect in **RCA** territory

74/M, Chest pain
PCI at RCA (pRCA Taxus; mRCA/dRCA Cypher)



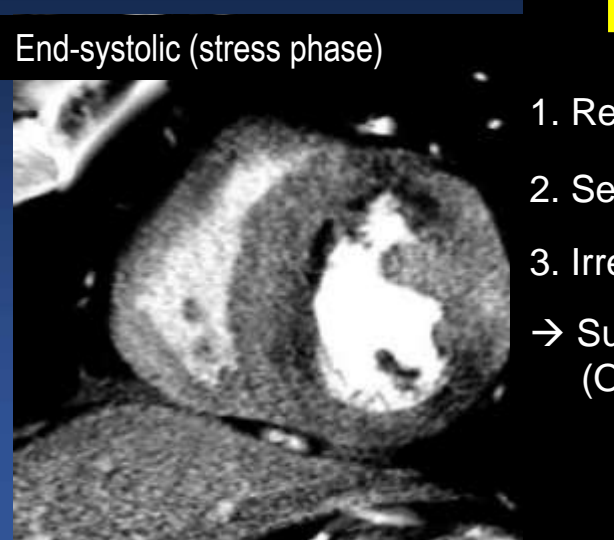
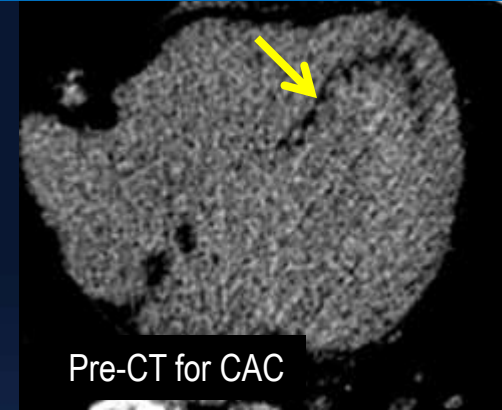
No perfusic



FFR = **0.83**, LAD

53/M, recurrent chest pain
s/p PCI at LAD, RCA, LCX

Peri-infarct ischemia

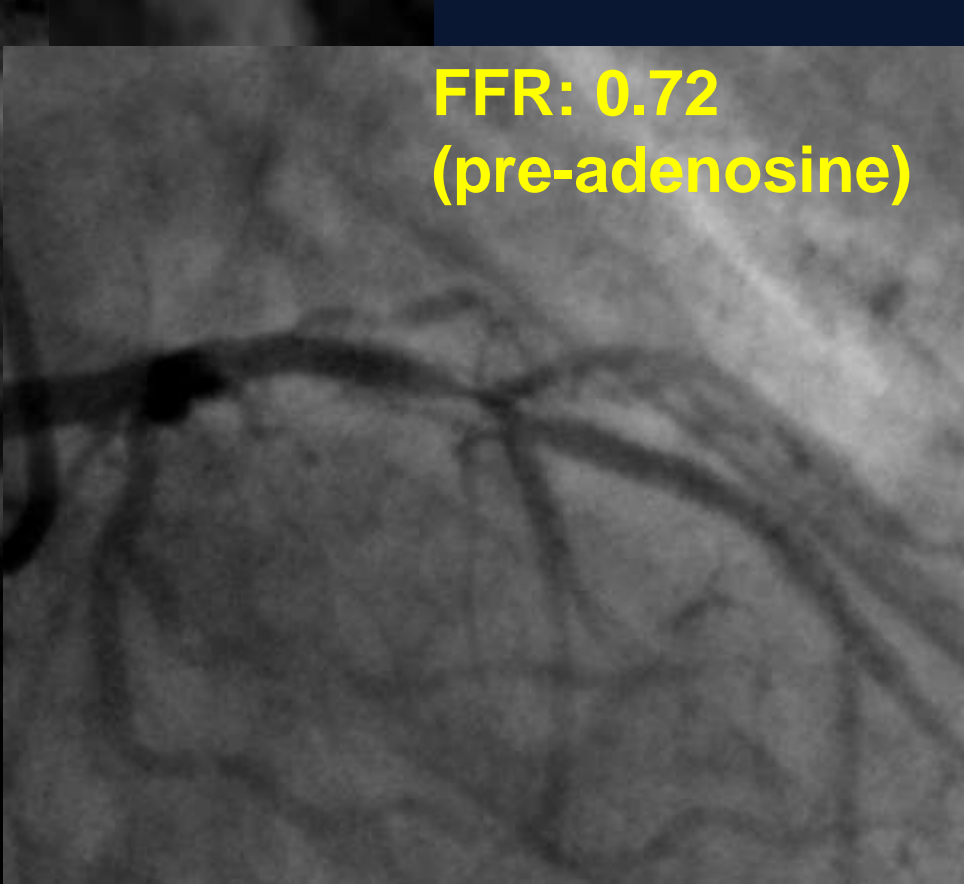
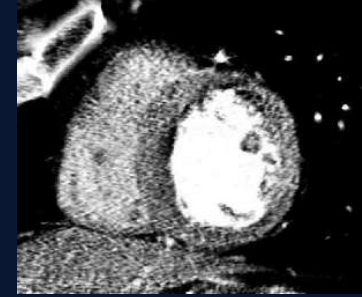


* Findings

1. Reversible perfusion defect
 2. Severe hypokinesia
 3. Irreversible perfusion defect
- Subendocardial fat
(Old infarct)

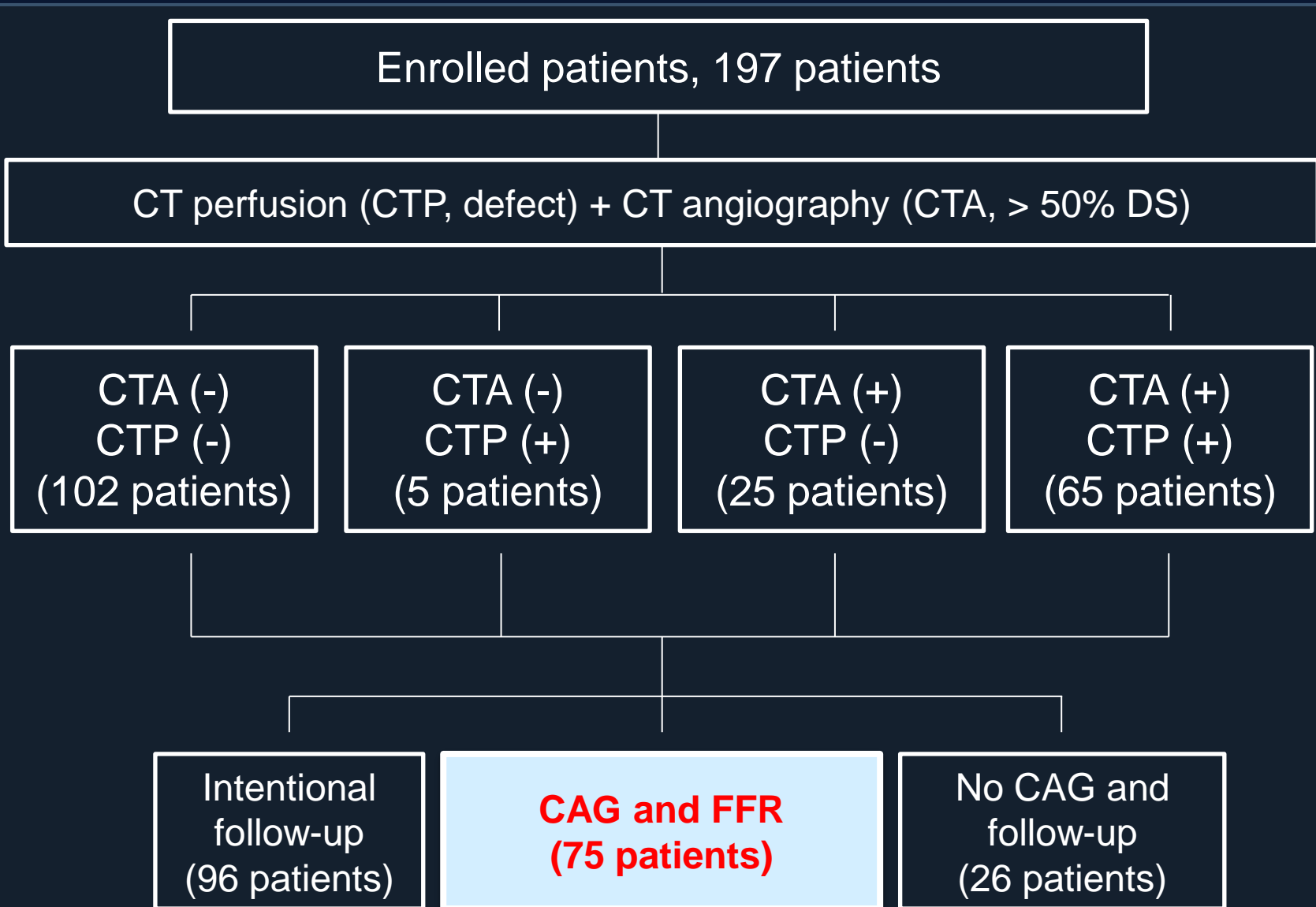
Perfusion CT

53/M, recurrent chest pain
s/p PCI at LAD, RCA, LCX



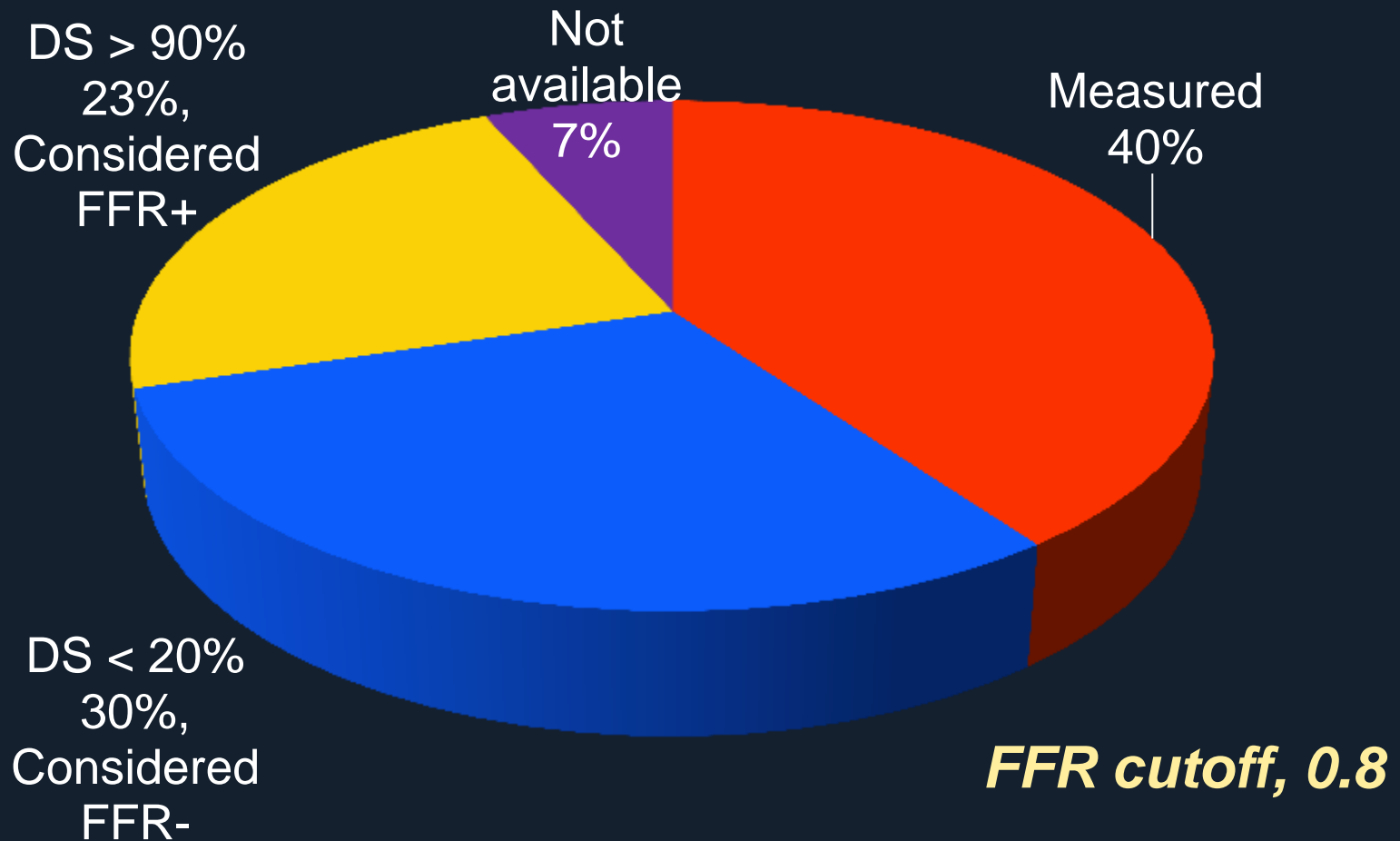
FFR: 0.72
(pre-adenosine)

CTP Analysis in AMC



Identification of Hemodynamically Significant Epicardial Artery

Of the 225 vessel territories,



Baseline Clinical Characteristics

Patients	N=75
Age, yr	63.1±10.3
Male gender	126 (64)
BMI, kg/m ²	25.7 ± 3.1
Diabetes	44 (22)
Hyperlipidemia	31 (16)
Hypertension	98 (50)
Family history	12 (6)
Current smoking	31 (16)
Typical chest pain	94 (48)
<i>Pre-test probability of CAD</i>	
Low (< 10%)	3 (2)
Intermediate (10-90%)	107 (54)
High (>90%)	87 (44)

Per-vessel Visual Assessment

	CTA, DS ≥ 50%		CTP, perfusion defect		QCA, DS ≥ 50%	
	Value	95% CI	Value	95% CI	Value	95% CI
Sensitivity,%	99	94, 100	80	70, 88	86	76, 92
Specificity,%	73	65, 81	95	90, 98	91	84, 95
PPV,%	72	63, 80	92	83, 97	87	78, 93
NPV,%	99	94, 100	87	81, 92	90	83, 94
Kappa statistic	0.68	0.59, 0.78	0.77	0.68, 0.86	0.77	0.69, 0.86
Accuracy	84		89		88	

Visual Assessment: CTP or CTA

	CTP	CTA or CTP	
	Values	Value	95% CI
Sensitivity,%	80	100	96, 100
Specificity,%	95	73	64, 80
PPV,%	92	71	63, 80
NPV,%	87	100	96, 100
Kappa statistic	0.77	0.68	0.59, 0.78
Accuracy	89	83	

Subgroups

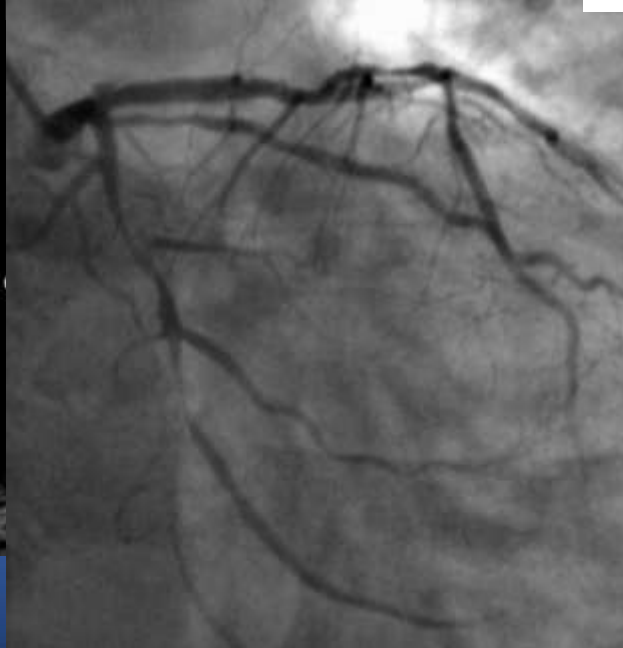
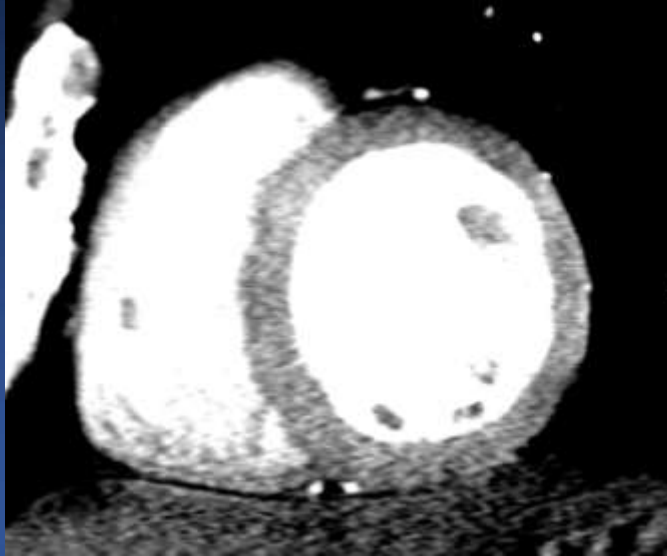
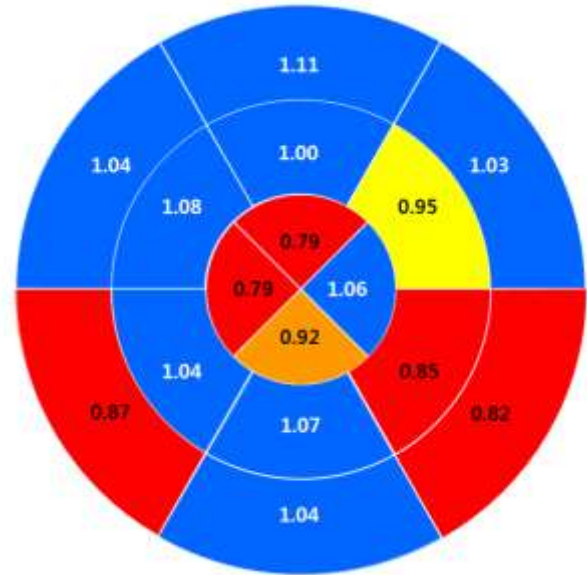
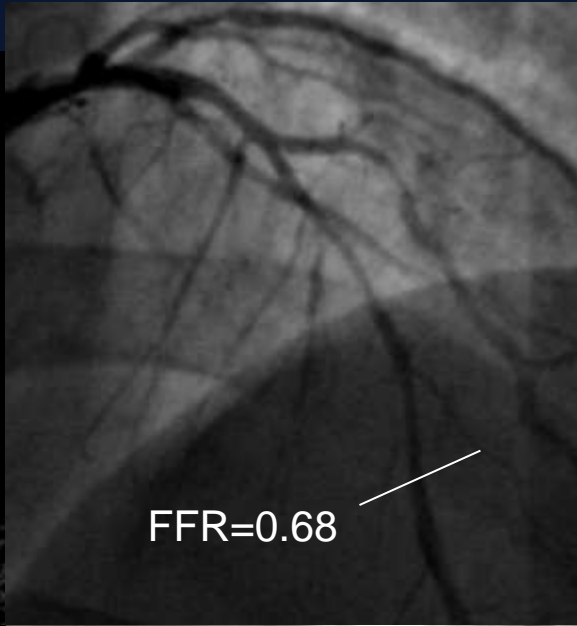
Per vessel	All patients (N=210)		High calcium score >400 (N=63)		Multivessel (N=54)	
	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity
CTP	80	95	85	100	76	91
CTA	99	73	100	50	100	45
CTP or CTA	100	73	100	50	100	45
CTP and CTA	90	89	94	87	89	82
QCA	86	91	87	83	84	73

Quantitative Assessment

	AUC	Cut Off	Sensitivity	Specificity
TPR	0.759	0.98	75	71
Density _{stress}	0.687	102.1	77	56
Density _{rest}	0.559	113.9	65	51
MPRI	0.691	-4.0	67	62
Combined quantitative results (TPR, Density _{stress} , MPRI)	0.746	-	63	75
Integration of qualitative and quantitative results	0.878	-	89	73

Quantitative Assessment: Multivessel

N=20	AUC	Cut Off	Sensitivity	Specificity
TPR	0.7209	0.97	71	67
Density _{stress}	0.6260	113.56	59	67
Density _{rest}	0.6423	109.19	51	67
MPRI	0.6243	5	73	56
Combined quantitative results (TPR, Density _{stress} , MPRI)	0.7433	-	68	78
Integration of qualitative and quantitative results	0.8266	-	81	89



TPR map

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

FFR_{CT} Imaging

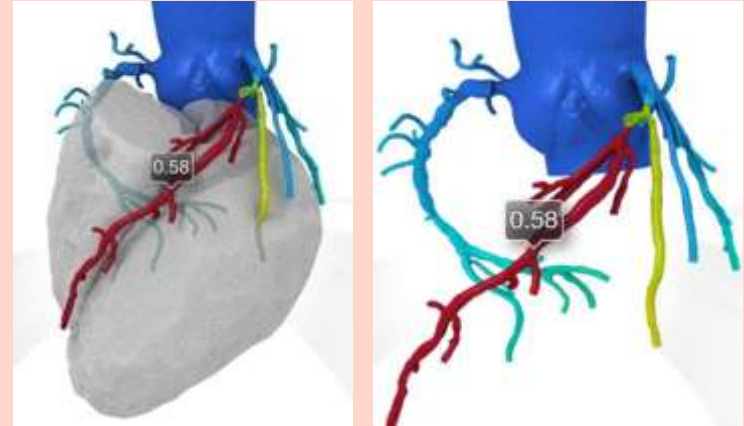


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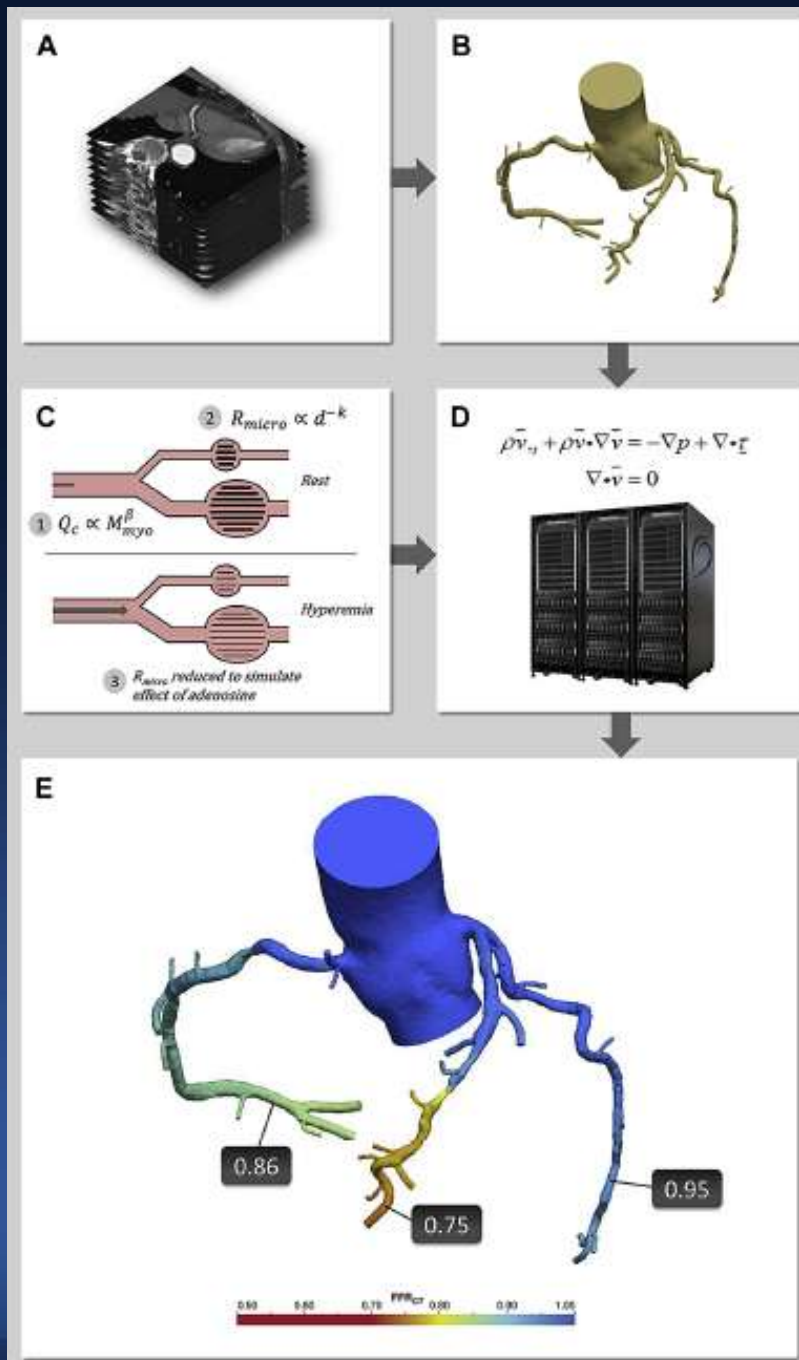


FFR-CT

- Pros**
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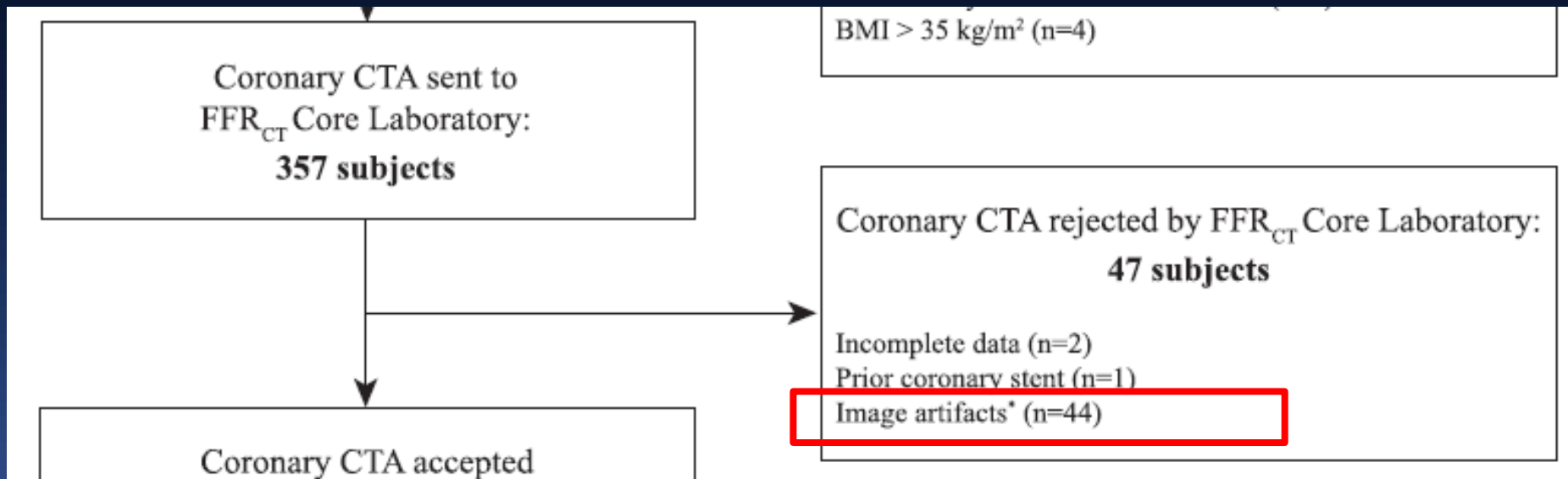
- Cons**
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 - ✓ Need supercomputer
 - ✓ No information on perfusion.

HeartFlow FFT_{CT}



Nørgaard BL et al.
J Am Coll Cardiol
2014;63:1145

NXT Trial



Siemens FFR-CT (cFFR) Analysis in AMC

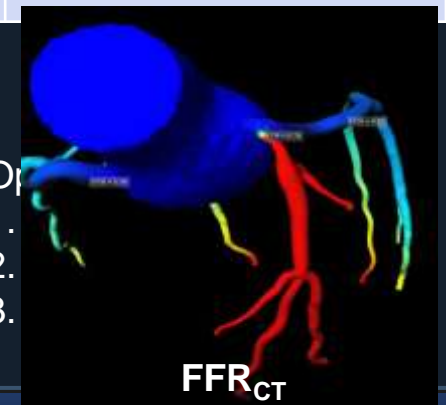
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Scan range	4 min. 30 sec	Retrospective ECG-gating	2 min. before	Retrospective ECG-gating

Option

1. **Static perfusion**
2. Dynamic perfusion



CT-Derived Fractional Flow Reserve

New Modality to Detect Ischemia

	HeartFlow	Siemens
Published Data	Yes (DISCOVER-FLOW, DeFACTO)	No
Commercial version	Available	Not available
Supercomputer requirement	Yes	No : Stand-Alone workstation
Installing at local site	Impossible	Possible
Processing time per case	6 hours*	0.5 – 1 hours

Siemens cFFR Analysis Compared with CTP and FFR

Multicenter Registry for Stable Angina

CT Coronary Angiography with Perfusion CT
(N=748)

Exclusion
Prior stenting
CABG

Diseased vessel
without FFR

Invasive FFR Or
occlusion/normal

No angiography

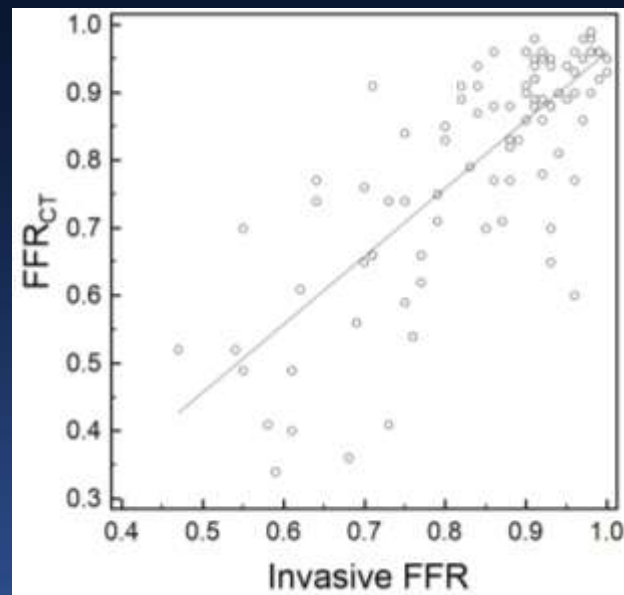
FFR-CT Analysis

**Available
(N=57)**

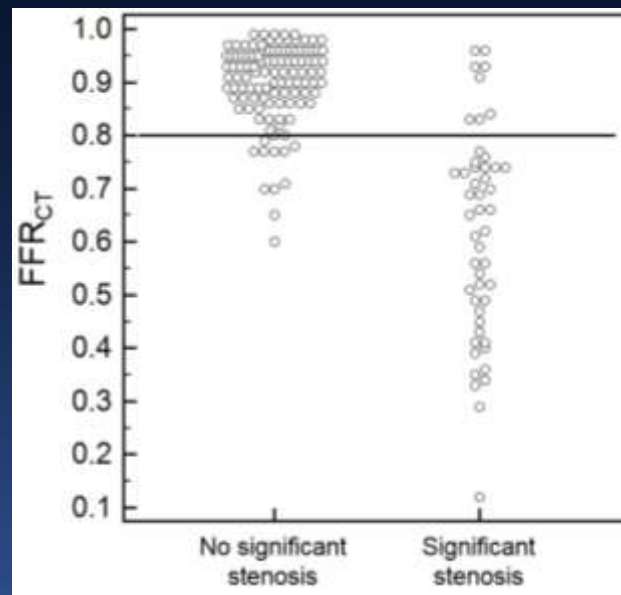
**Not available
(N=46)**

Exclusion
Proximal occlusion (n=30)
Severe calcified plaque (n=12)
Calculation error (n=4)

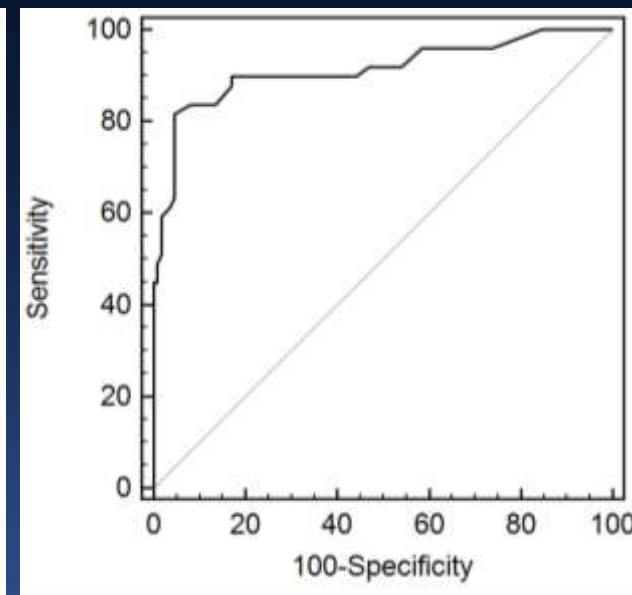
Siemens cFFR by Compared with invasive FFR



$R=0.7815$
 $p < 0.001$



Sensitivity 84%
Specificity 88%



AUC 0.913
 $p < 0.001$

Conclusions

- With technology improvement, CT-based functional imaging become a new feasible method to detect myocardial ischemia.
- CTP showed a good diagnostic accuracy for detection of myocardial ischemia even in patients with severely calcified coronary lesions, which is hardly evaluated using CT angiography or FFR_{CT} .
- Further researches are required to improve the performance of CT-based 'one-stop' coronary imaging using CTA, CTP and FFR_{CT} .
- Ongoing RCT will provide the clinical relevancy of CTP in the diagnosis and treatment of stable coronary artery disease compared with invasive functional evaluation of FFR.

Thank you very much

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