

# *Which is the Best Modality for the Ischemia-guided Functional Angioplasty?*

*: FFR, SPECT, FFR<sub>CT</sub> and Others*

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# Which is the Best Modality for the Ischemia-guided Functional Angioplasty?

: FFR, SPECT, FFR<sub>CT</sub> and Others

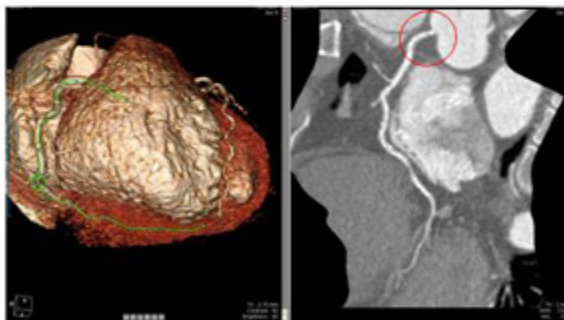
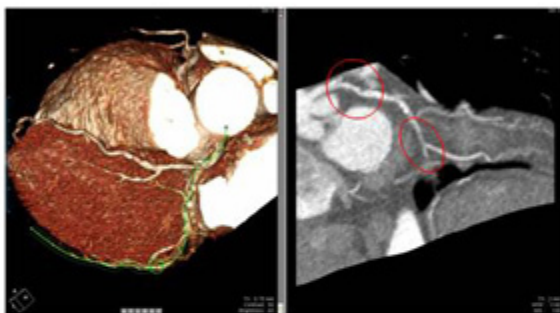
**“Ischemia-guided functional angioplasty”**

Stenting of ischemic lesions and medical treatment of non-ischemic ones

**Which is the best modality to define “ischemia-causing stenosis”?**

F/52

Stable angina for 4 years with recent aggravation



**[Conclusion] (CT coronary Angiography)**

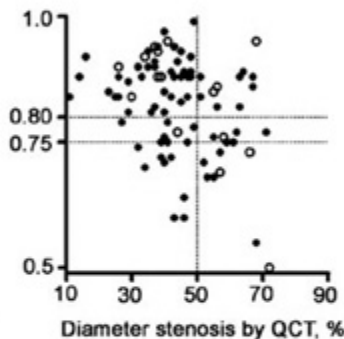
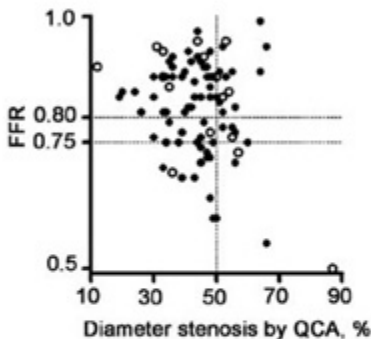
Atherosclerosis, **definite significant stenosis** in the coronary artery

**Proximal LAD:** mixed plaque with up to 50-60% stenosis

**Proximal and distal LCX:** multifocal stenosis up to 70%

**RCA os:** 40-50% stenosis with calcified plaque

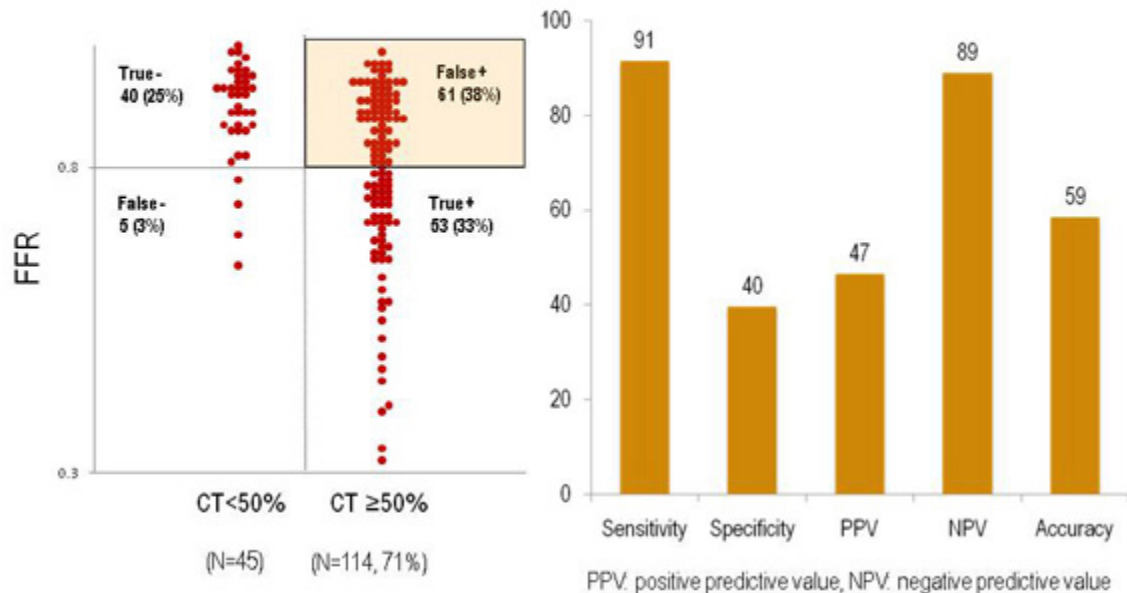
# Is significant stenosis by CCTA significant?



	True Positive	True Negative	False Positive	False Negative	kappa	Sensitivity, %	Specificity, %	Diagnostic Accuracy, %
FFR < 0.80 (n = 31)								
CT coronary angiography, visual score	29	28	30	2	0.35	94 (58-100)	48 (35-61)	64 (54-74)
Quantitative CT coronary angiography	14	46	12	17	0.25	45 (28-63)	79 (69-90)	67 (58-77)
Conventional coronary angiography, visual score	17	36	22	14	0.16	55 (37-72)	62 (50-75)	60 (49-70)
Quantitative coronary angiography	17	41	18	13	0.25	57 (39-74)	69 (58-81)	65 (55-75)

# Is significant stenosis by CCTA significant?

DISCOVER FLOW study: Per-vessel analysis (n=159)



## Myocardial ischemia? Which is ischemia-causing stenosis?

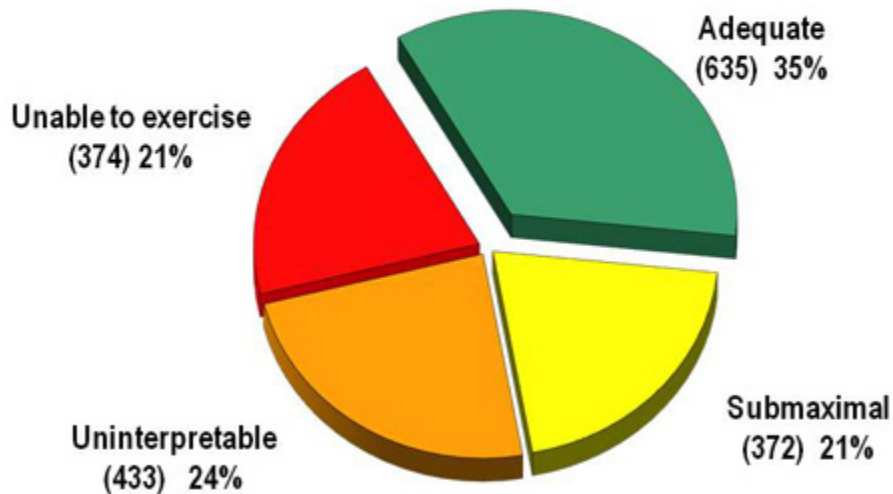
F/52 Stable angina for 4 years

Coronary CT angiography: Proximal LAD 50-60%, prx and dist LCX 70%, RCA os 40-50%



- Exercise was terminated at stage II (7METs) due to general weakness and chest pain
- **Conclusion:** Suggestive of positive test

# Proportion of patients with adequate Exercise ECG (n=1814)



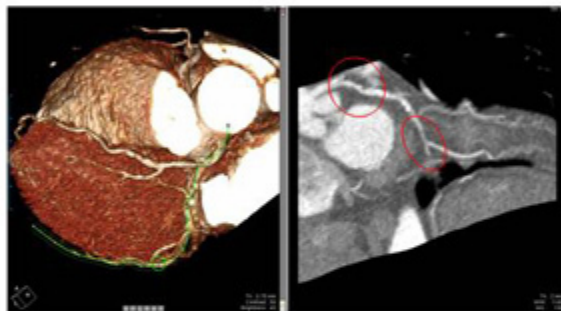
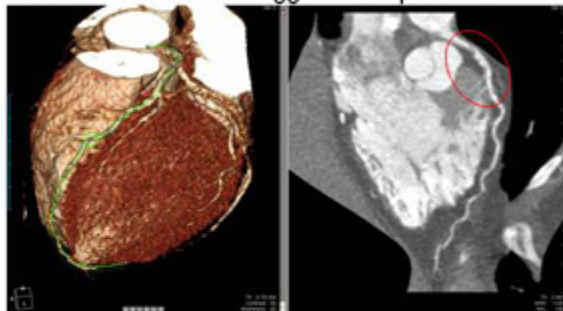


# Myocardial ischemia? Which is ischemia-causing stenosis?

**F152 Stable angina for 4 years**

Coronary CT angiography: Proximal LAD 50-60%, prx and dist LCX 70%, RCA os 40-50%

Exercise stress test: suggestive of positive



## Exercise stress test

: Per-patient diagnosis

Cannot provide per-vessel or per-segment diagnosis



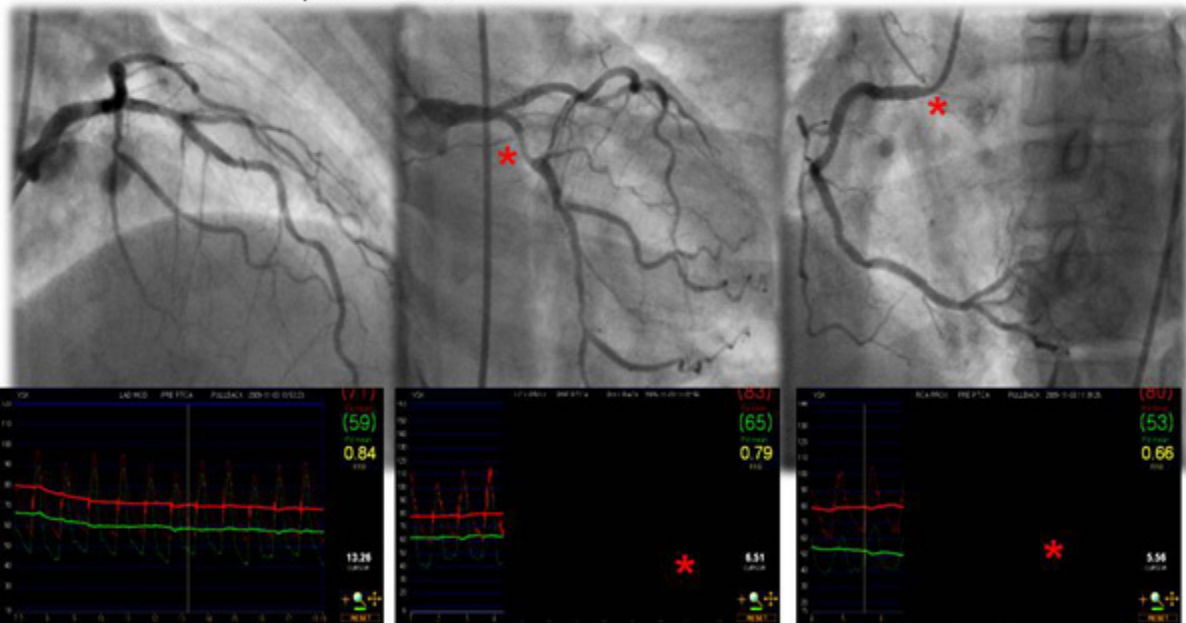
# Myocardial ischemia? Which is ischemia-causing stenosis?

F/52 Stable angina for 4 years

Coronary CT angiography: Proximal LAD 50-60%, prx and dist LCX 70%, RCA os 40-50%

Exercise stress test: suggestive of positive

CAG: 1 vessel disease – proximal and distal LCX

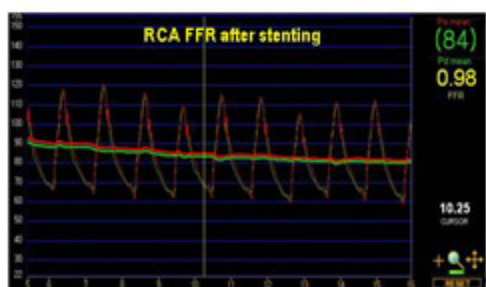
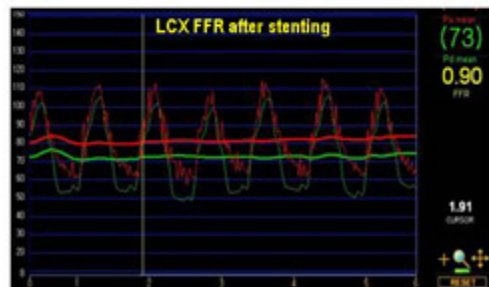
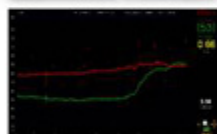
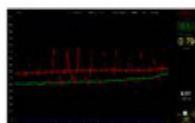
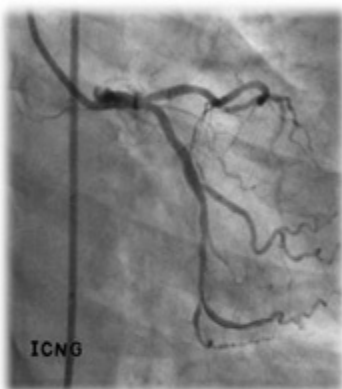
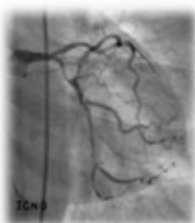


## F/52 Stable angina for 4 years

Coronary CT angiography: Proximal LAD 50-60% prx and dist LCX 70% RCA os 40-50%

Exercise stress test: suggestive of positive

CAG: 1 vessel disease – proximal and distal LCX



## F152 Stable angina for 4 years

Coronary CT angiography: Proximal LAD 50-60%, prx and dist LCX 70%, RCA os 40-50%

Exercise stress test: suggestive of positive

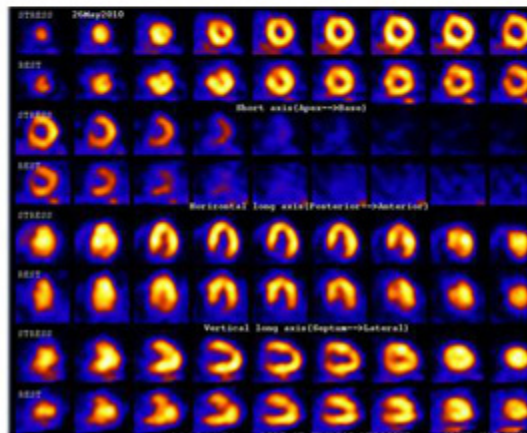
CAG: 1 vessel disease – proximal and distal LCX

FFR: 2 vessel disease – proximal LCX and RCA os

→ Functionally complete revascularization with 2 drug-eluting stents

→ Patient's symptom was improved

→ 6 mo after PCI, patient complained resting chest discomfort



[Stress image] No significant perfusion decrease.

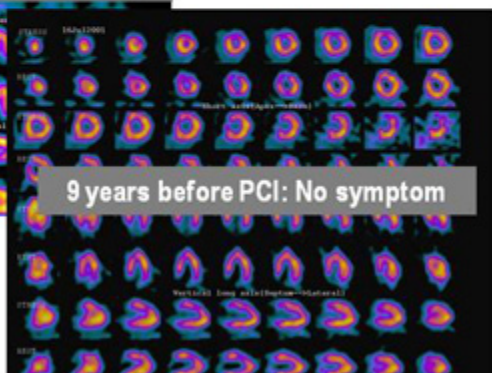
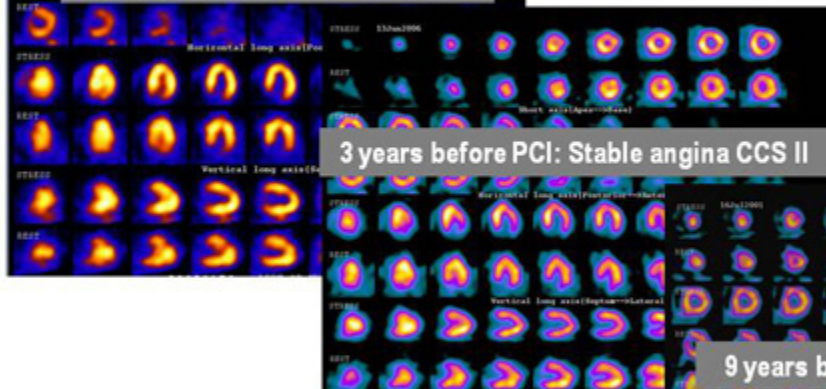
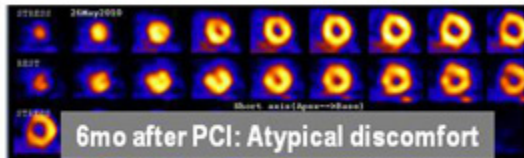
[Rest image] No significant perfusion decrease.

[24hour delay image] Not done

**[Compared with previous scan] No change**

[LV wall motion] Normal.

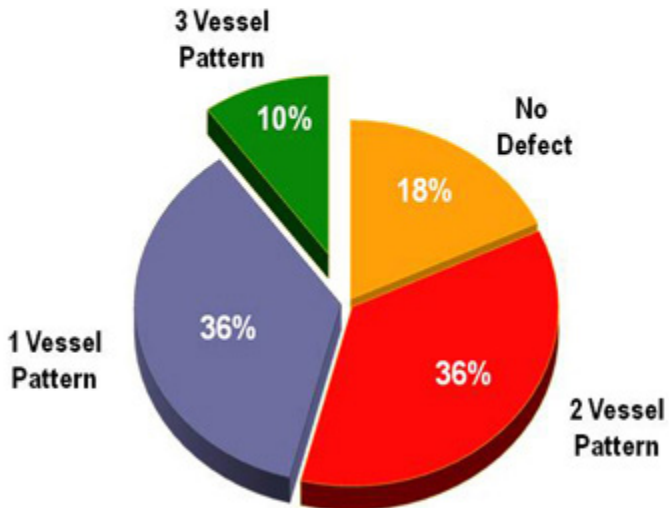
## F/52 Stable angina for 4 years



Always negative, regardless of patient's symptom!

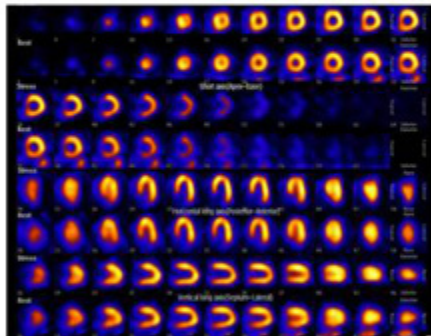
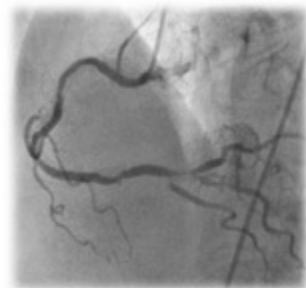
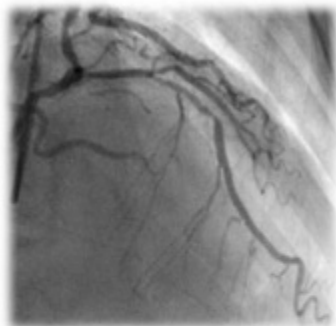
## Inaccuracy of perfusion SPECT in multi-vessel disease

143 severe 3-vessel disease patients and Tc-SPECT

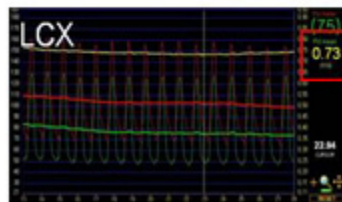
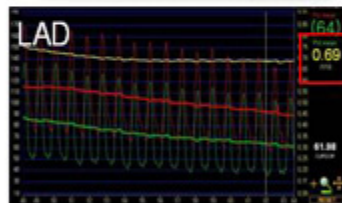


# Inaccuracy of perfusion SPECT in multi-vessel disease

F/67 Stable angina



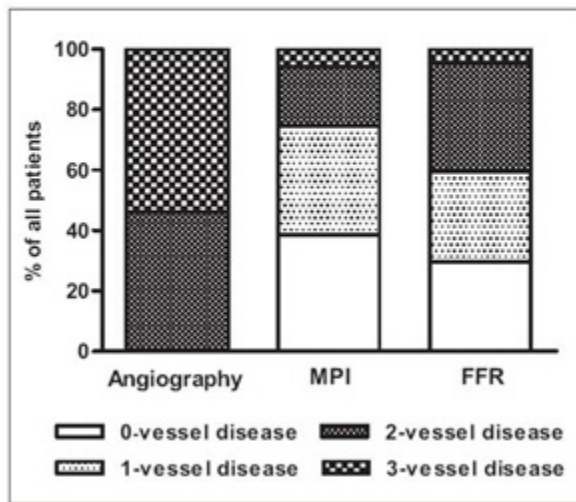
No perfusion defect





# Inaccuracy of perfusion SPECT in multi-vessel disease

Proportion of number of vascular abnormalities



## Per-Patient analysis

		MPI	
		positive	negative
FFR	< 0.80	31	16
	> 0.80	10	10

## Per-Vessel analysis

		MPI	
		positive	negative
FFR	< 0.80	38	42
	> 0.80	24	97

PPV 61%, NPV 70%



## Which is the Best Modality for the Ischemia-guided Functional Angioplasty? SPECT, CT, Exercise ECG, CAG and FFR

### F/52 Stable angina for 4 years

**Myocardial SPECT:** 9 years ago – no perfusion defect

**Myocardial SPECT:** 3 years ago – no perfusion defect

**Coronary CT angiography:** Proximal LAD 50-60%, prx and dist LCX 70%, RCA os 40-50%

**Exercise stress test:** suggestive of positive

**CAG:** 1 vessel disease – proximal and distal LCX

**Myocardial SPECT** 6 month after PCI: no perfusion defect

**FFR:** 2 vessel disease – proximal LCX and RCA os

→ Functionally complete revascularization with 2 drug-eluting stents

→ Patient's symptom was improved

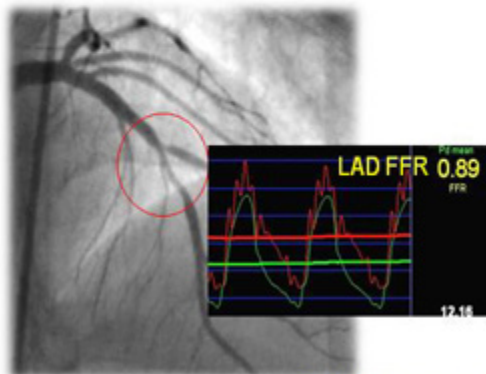


### Guidelines on myocardial revascularization

The Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS)

	Class <sup>a</sup>	Level <sup>b</sup>
FFR-guided PCI is recommended for detection of ischaemia-related lesion(s) when objective evidence of vessel-related ischaemia is not available.	I	A
DES <sup>d</sup> are recommended for reduction of restenosis/re-occlusion, if no contraindication to extended DAPT.	I	A
Distal embolic protection is recommended during PCI of SVG disease to avoid distal embolization of debris and reduce MI	I	B

But, FFR requires invasive procedure... cannot provide 3D anatomical information....



# Patient-specific non-invasive FFR using CT & CFD

## Computational Model based on CCTA

3-D anatomic model from CCTA

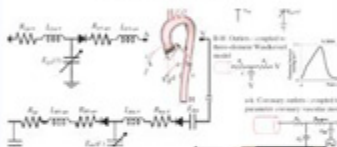


No additional imaging  
No additional medications



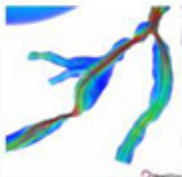
## Blood Flow Solution

Blood flow equations solved on  
supercomputer



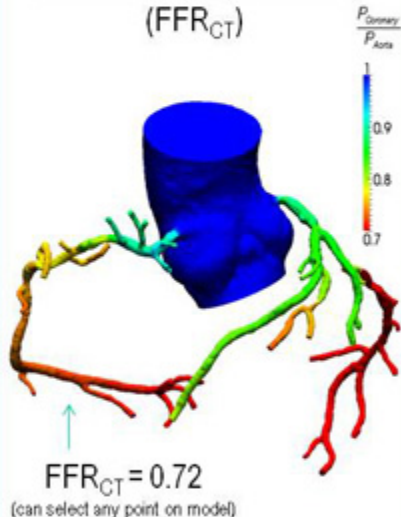
$$\rho \vec{v}_t + \rho \vec{v} \cdot \nabla \vec{v} = -\nabla p + \nabla \cdot \boldsymbol{\tau}$$

$$\nabla \cdot \vec{v} = 0$$

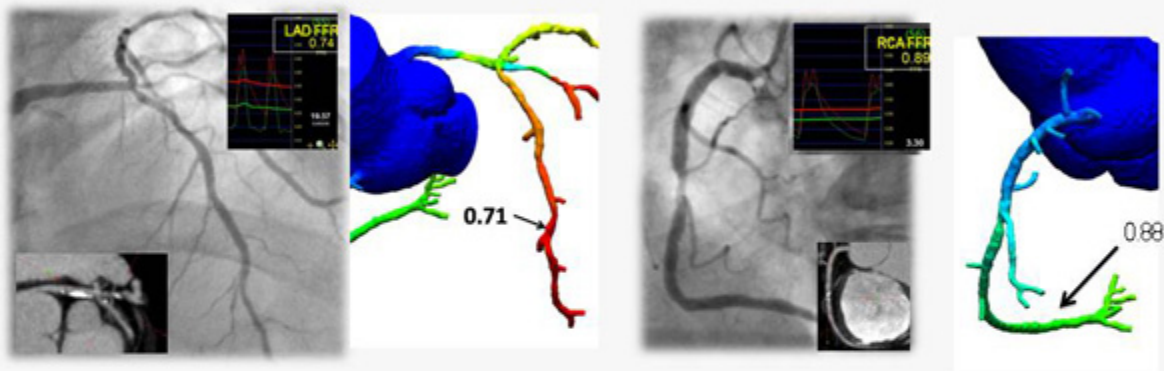


Physiologic models  
-Myocardial demand  
-Morphometry-based boundary condition  
-Effect of adenosine on microcirculation

## CT-derived computed FFR (FFR<sub>CT</sub>)



## Patient-specific non-invasive FFR using CT & CFD



CCTA: 2 vessel disease

Non-invasive  $FFR_{CT}$ : 1 vessel disease

Angiography: 2 vessel disease

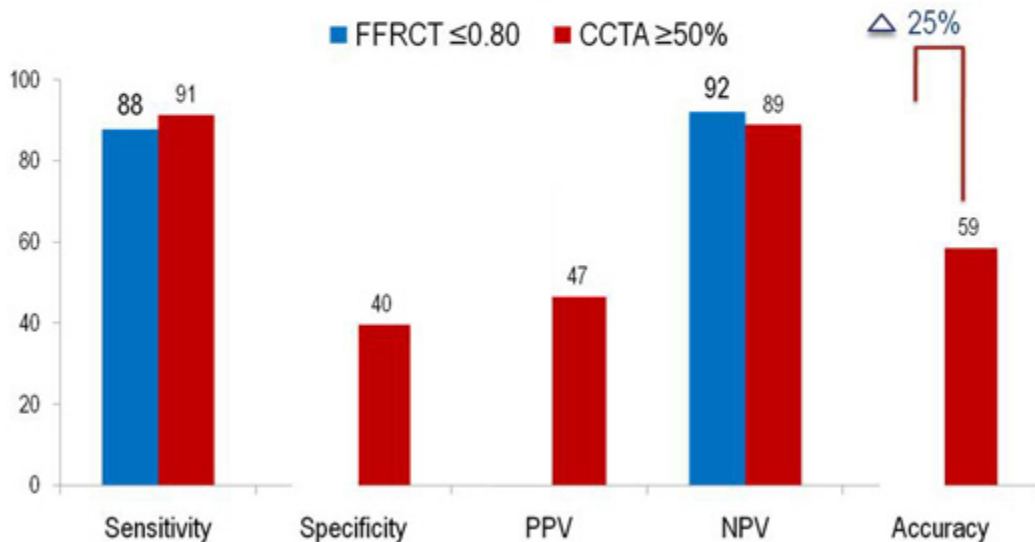
Invasive FFR: 1 vessel disease

} Non-invasive assessment prior to the cath lab

} Invasive assessment in the cath lab

## Diagnostic performance of FFR<sub>CT</sub> and CCTA

Per-vessel analysis (n=159)

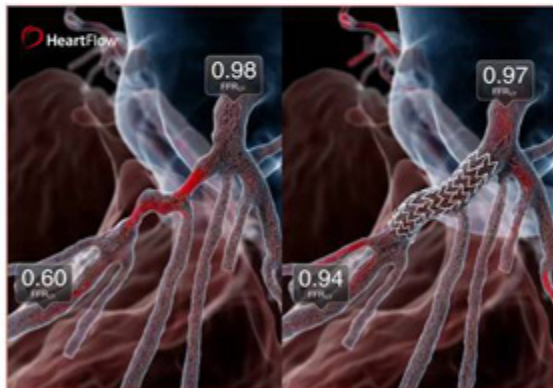


PPV: positive predictive value, NPV: negative predictive value

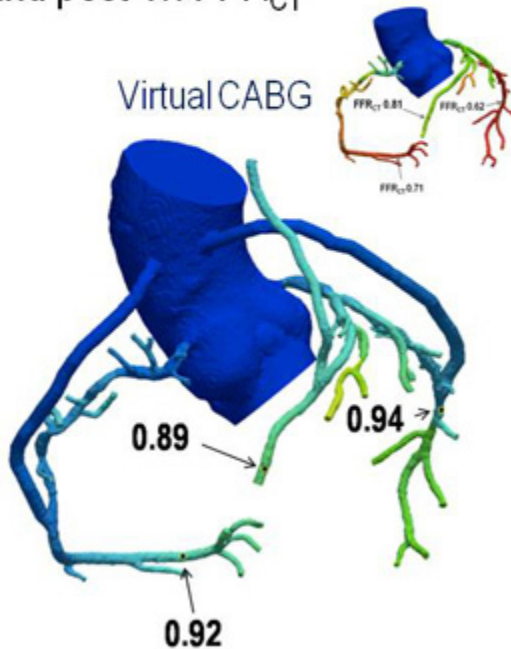
# Treatment planning prior to invasive procedures

## Virtual revascularization and post-Tx $FFR_{CT}$

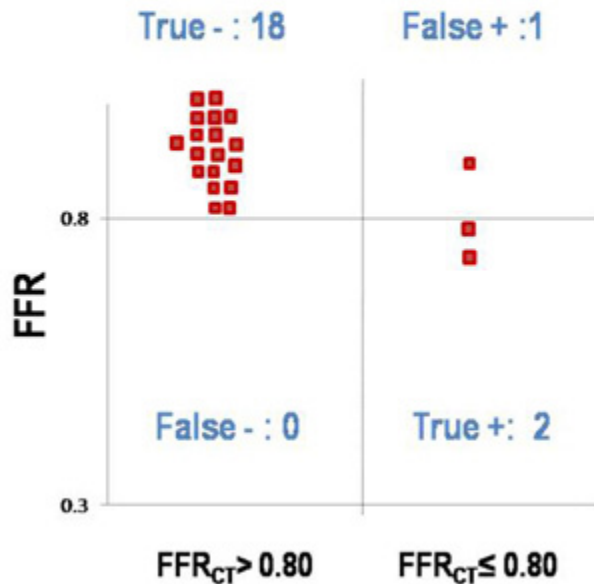
### Virtual stenting



### Virtual CABG



# Invasive FFR vs FFR<sub>CT</sub> after stenting

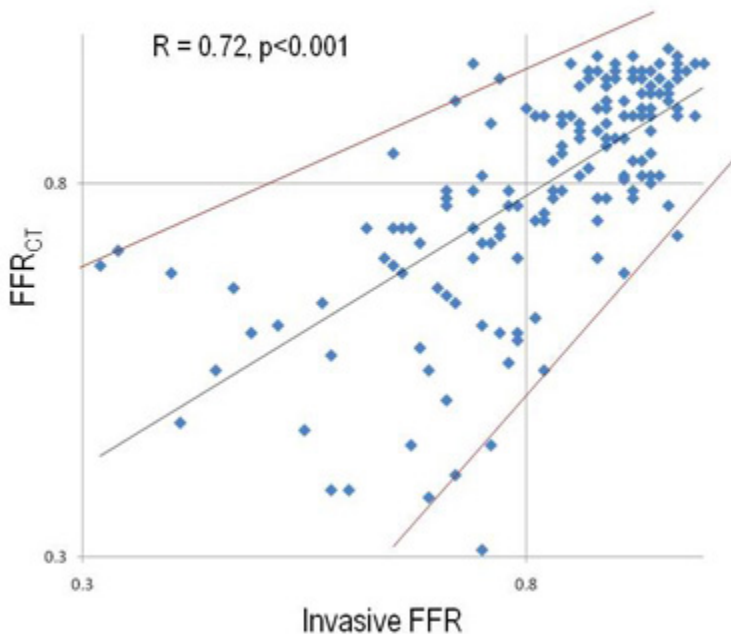


## Diagnostic performance of FFR<sub>CT</sub>

- Diagnostic accuracy 95%
- Negative predictive value 100%
- Positive predictive value 67%



# Invasive FFR vs. Non-invasive FFR<sub>CT</sub>



## Which is the Best Modality for the Ischemia-guided Functional Angioplasty?

### *In a catheterization laboratory,*

- FFR is the gold standard to define the functional significance of coronary stenosis and to perform the ischemia-guided functional angioplasty

### *Outside the catheterization laboratory,*

- Non-invasive CT-derived computed FFR can predict the functional significance of coronary stenoses and can be helpful in planning the treatment strategy. However, further studies are needed to validate this novel technology.