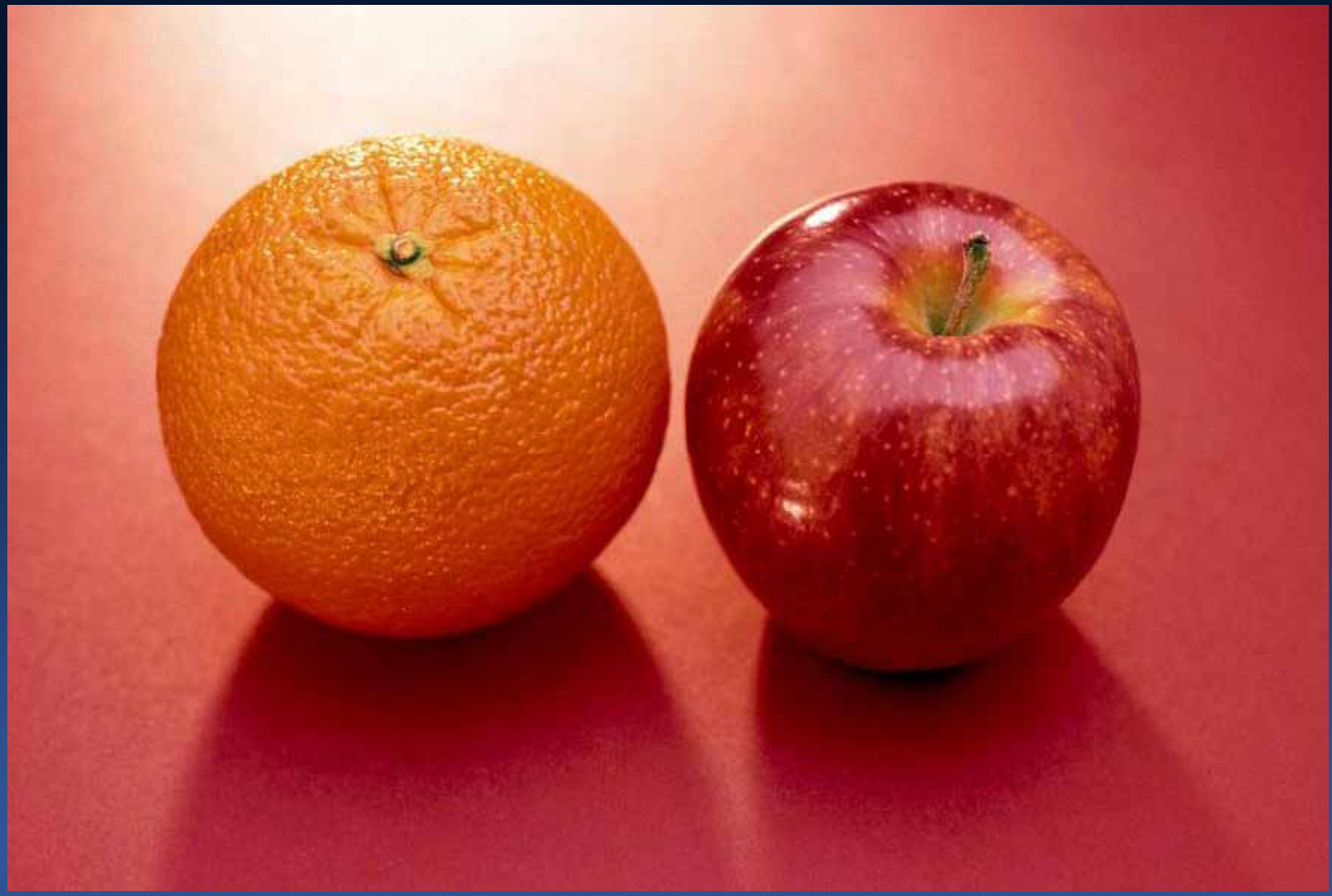
Anatomical - Functional Stenosis: How Much Discordant?

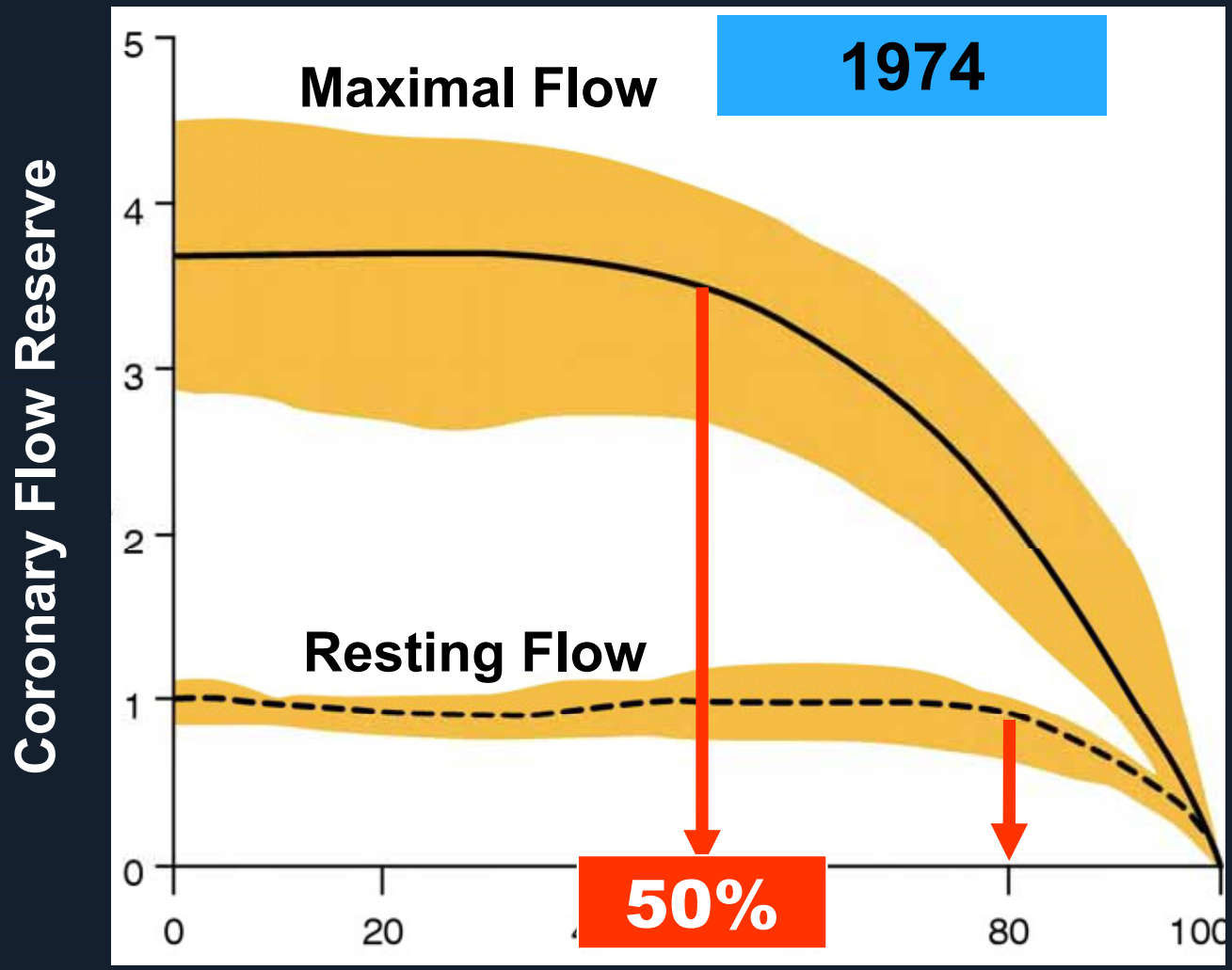
Jung-Min Ahn, MD.

University of Ulsan College of Medicine
Asan Medical Center, Seoul, Korea

Anatomy and Function

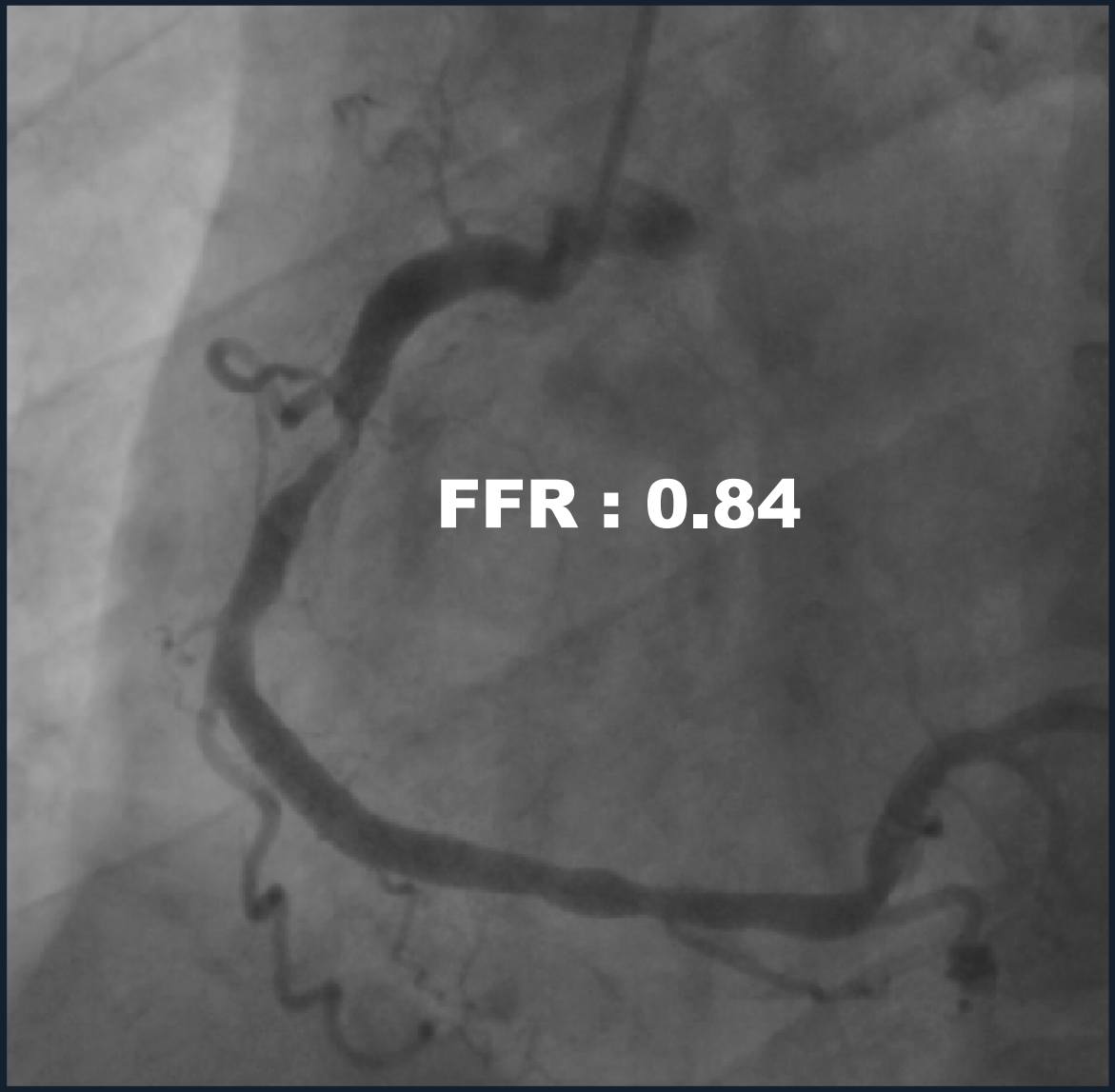


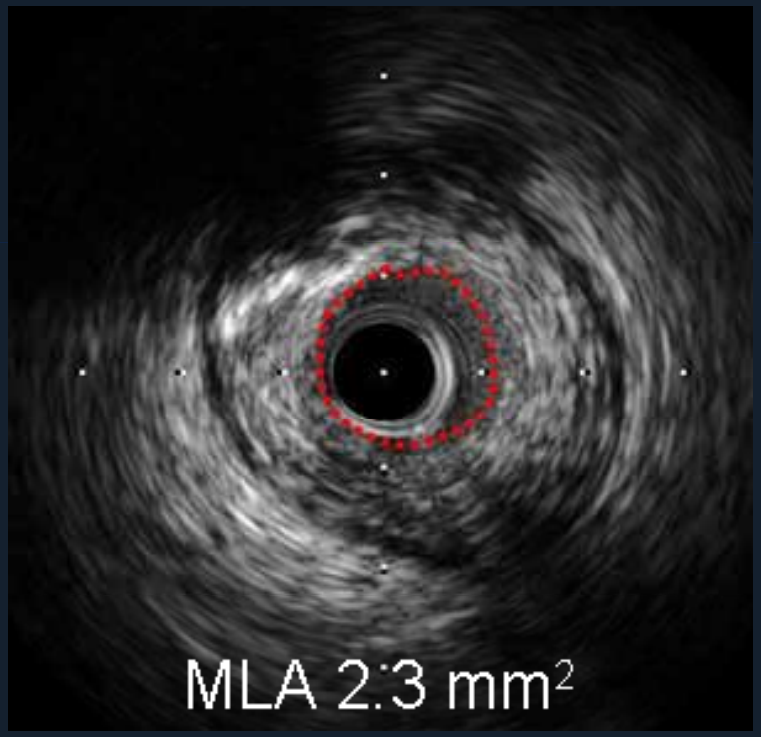
Coronary Blood Flow and Stenosis



Gould, K. L. J Am Coll Cardiol Img 2009;2:1009-1023

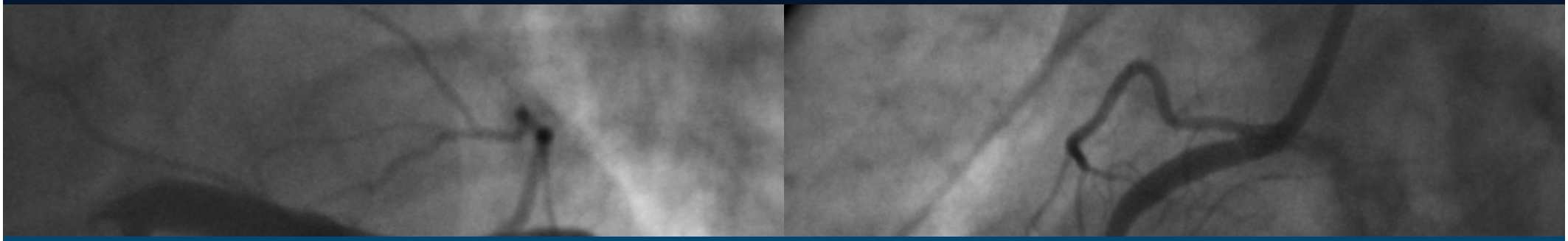
Visual-Functional Mismatch (1)
Coronary Angiography and FFR



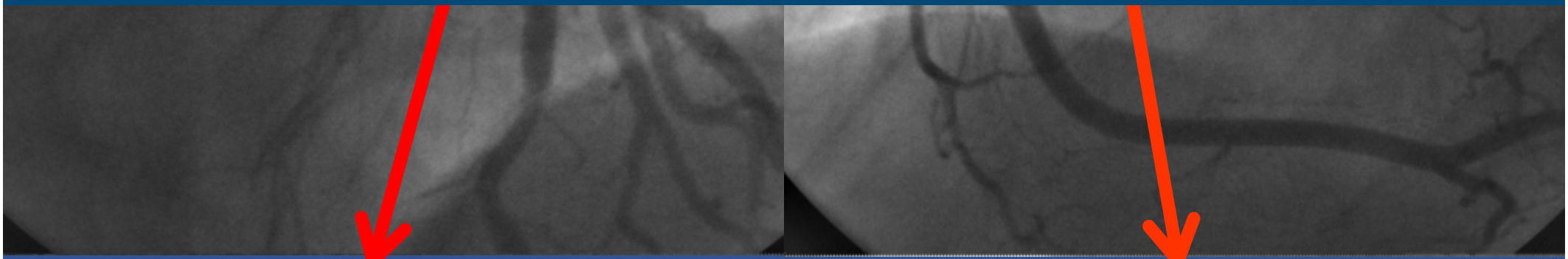


Visual-Functional Mismatch

Multivessel Disease



Angiographic 2 Vessel Disease
But, Functionally Normal Cornary

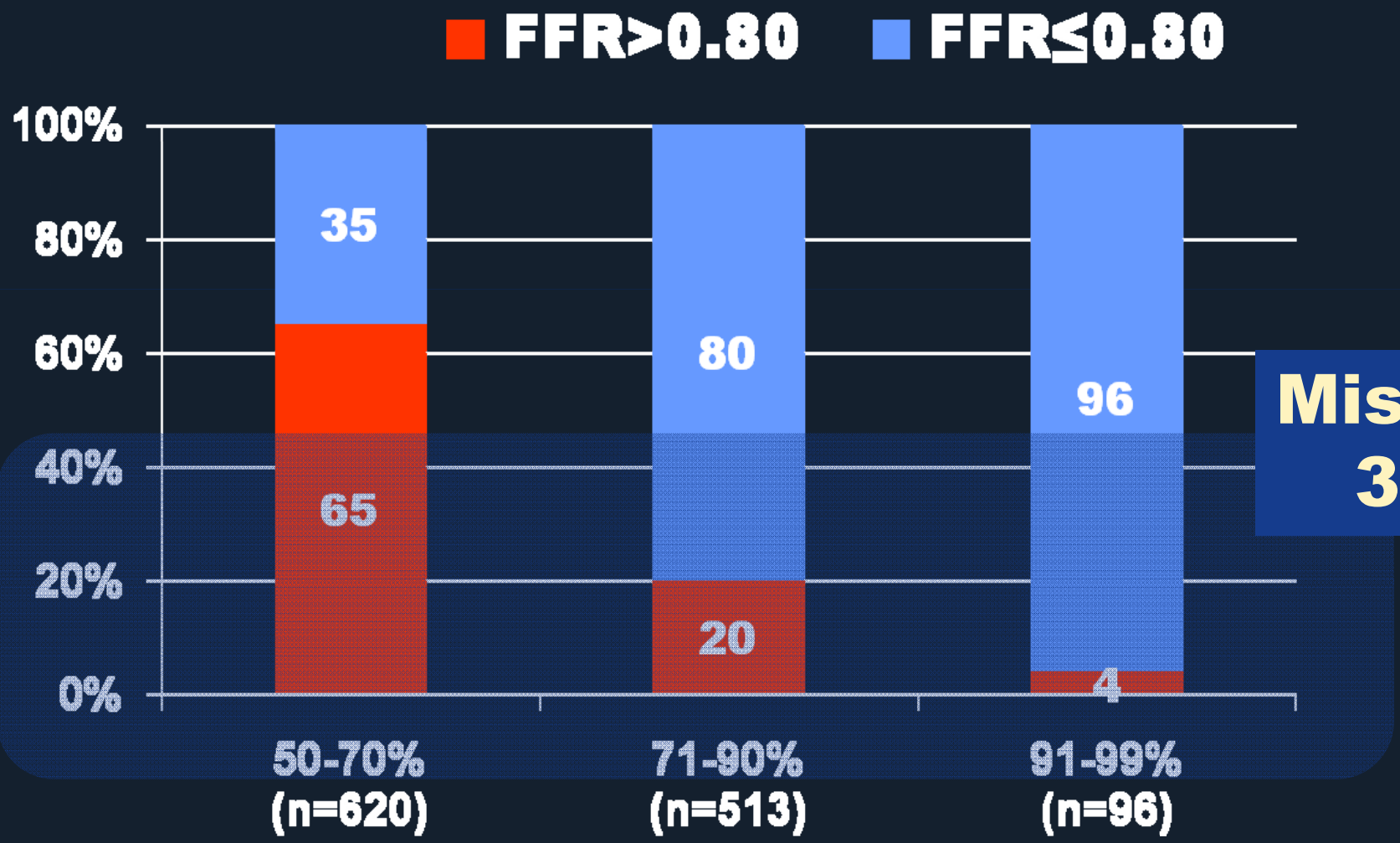


FFR : 0.84

FFR : 0.86

Visual-Functional Mismatch

From FAME Study

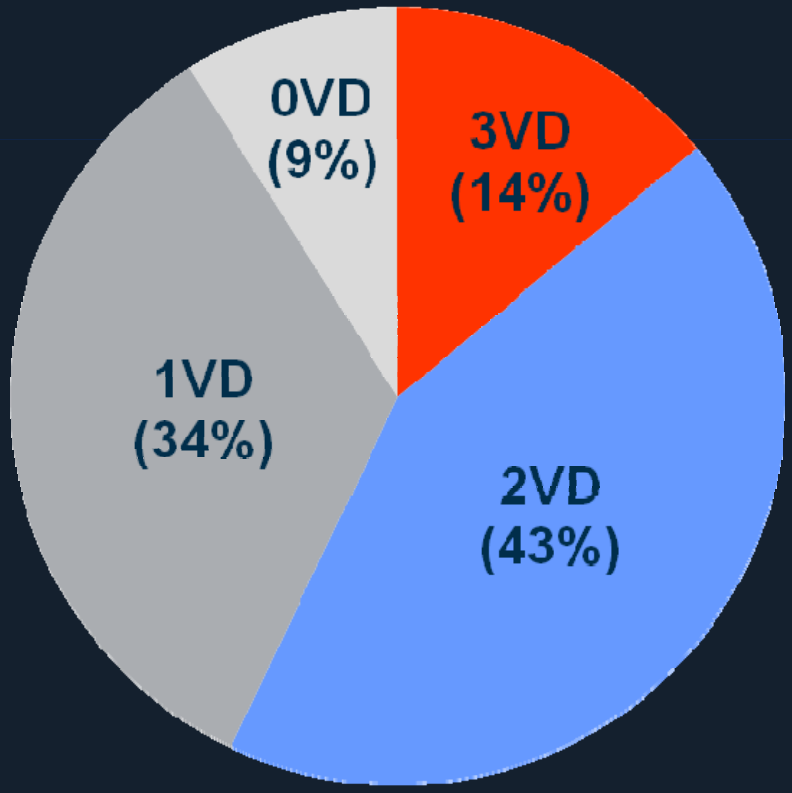


Mismatch 36.3%

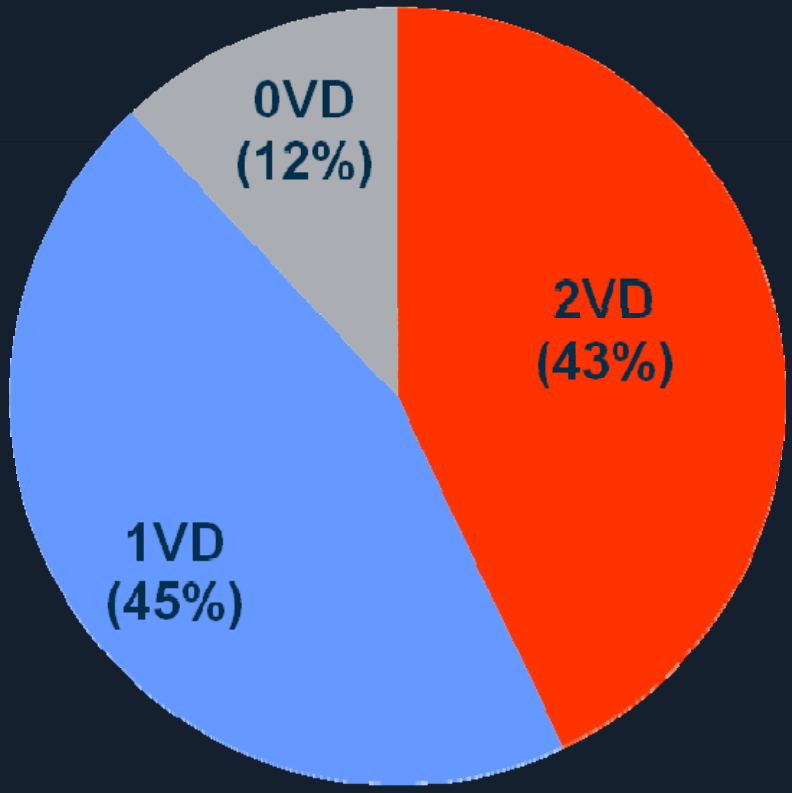
Visual-Functional Mismatch

From FAME Study

Functionally Diseased Coronary Arteries



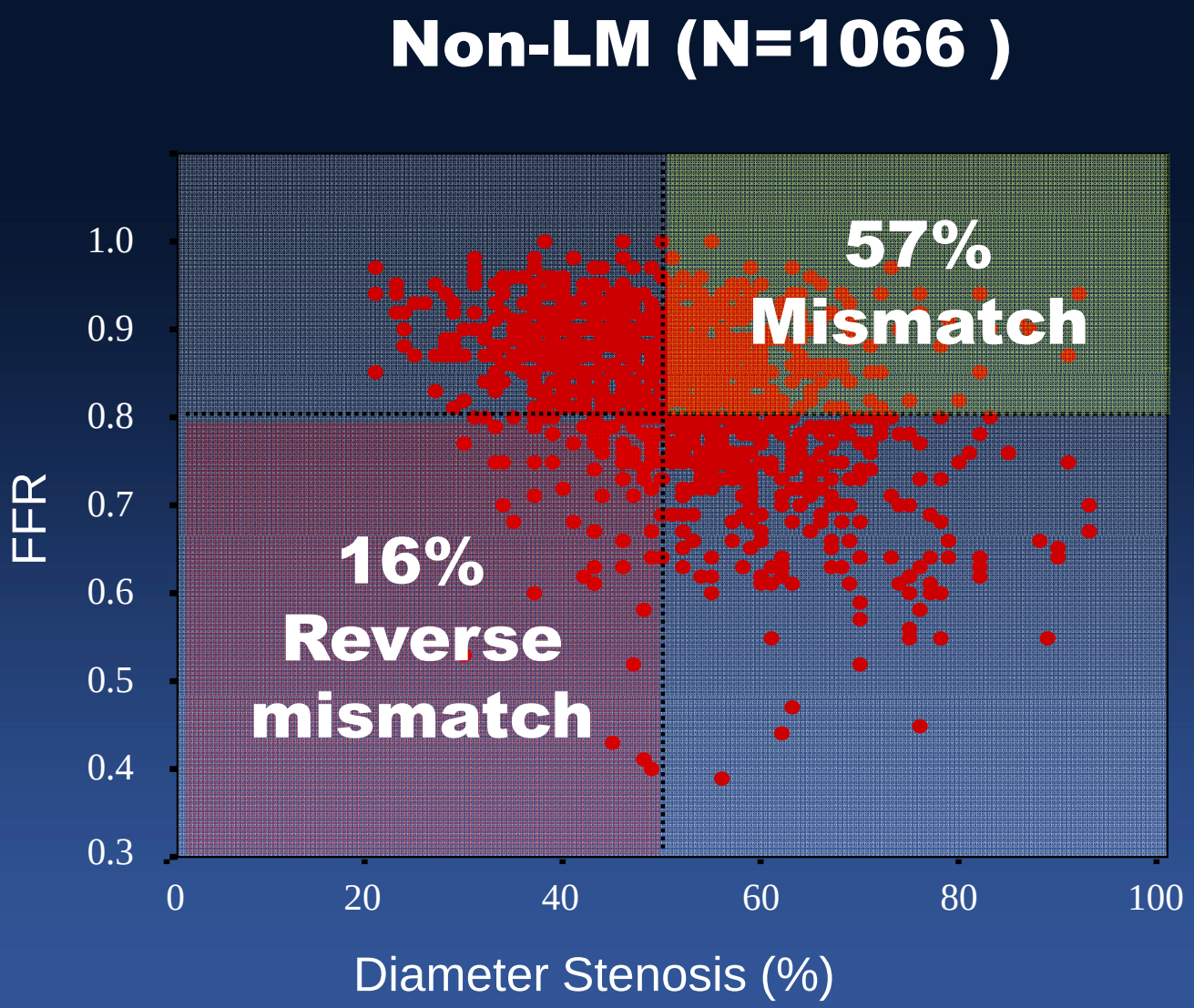
Angiographic 3VD



Angiographic 2VD

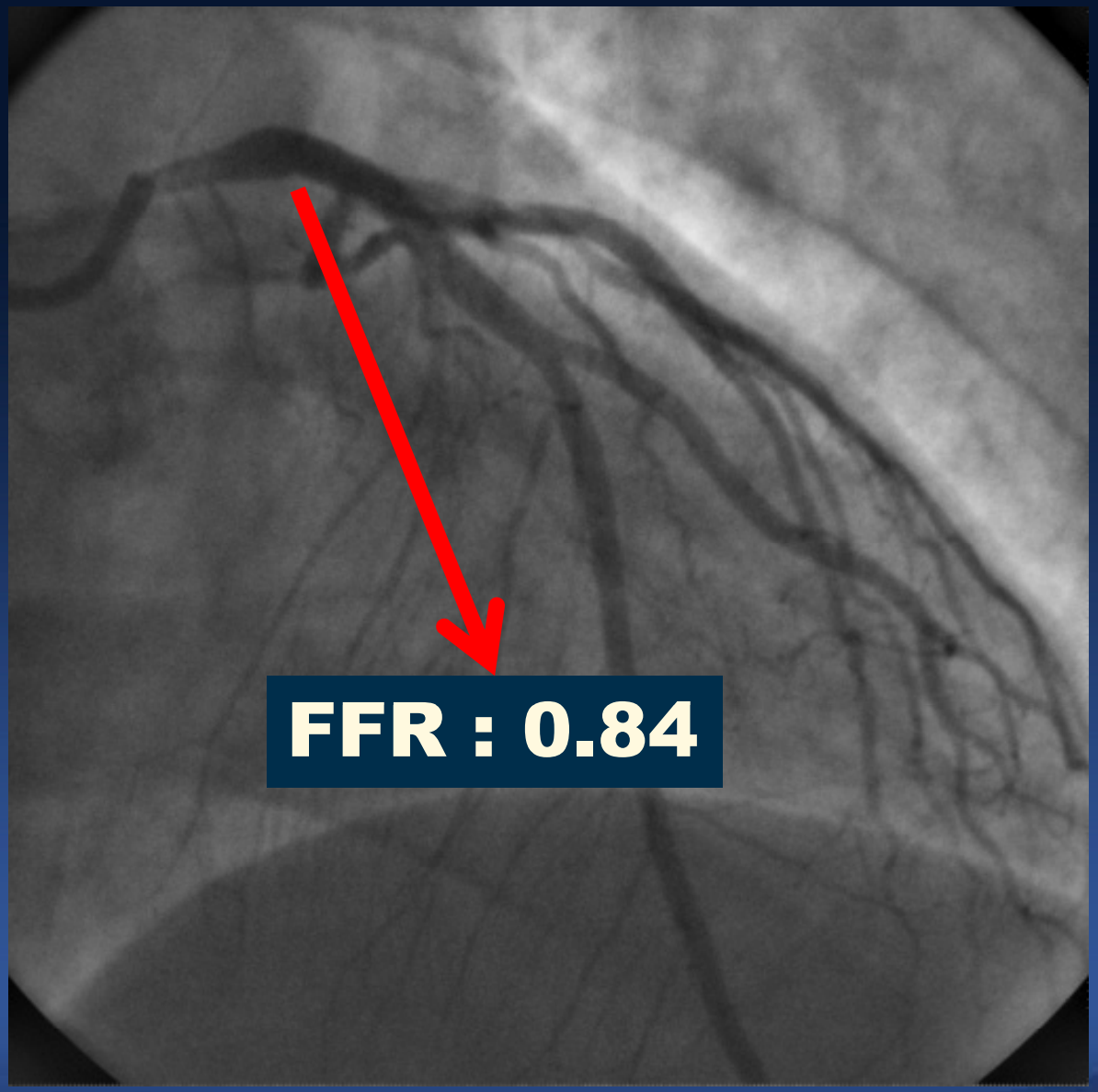
J Am Coll Cardiol 2010;55:2816–21

Visual-Functional Mismatch

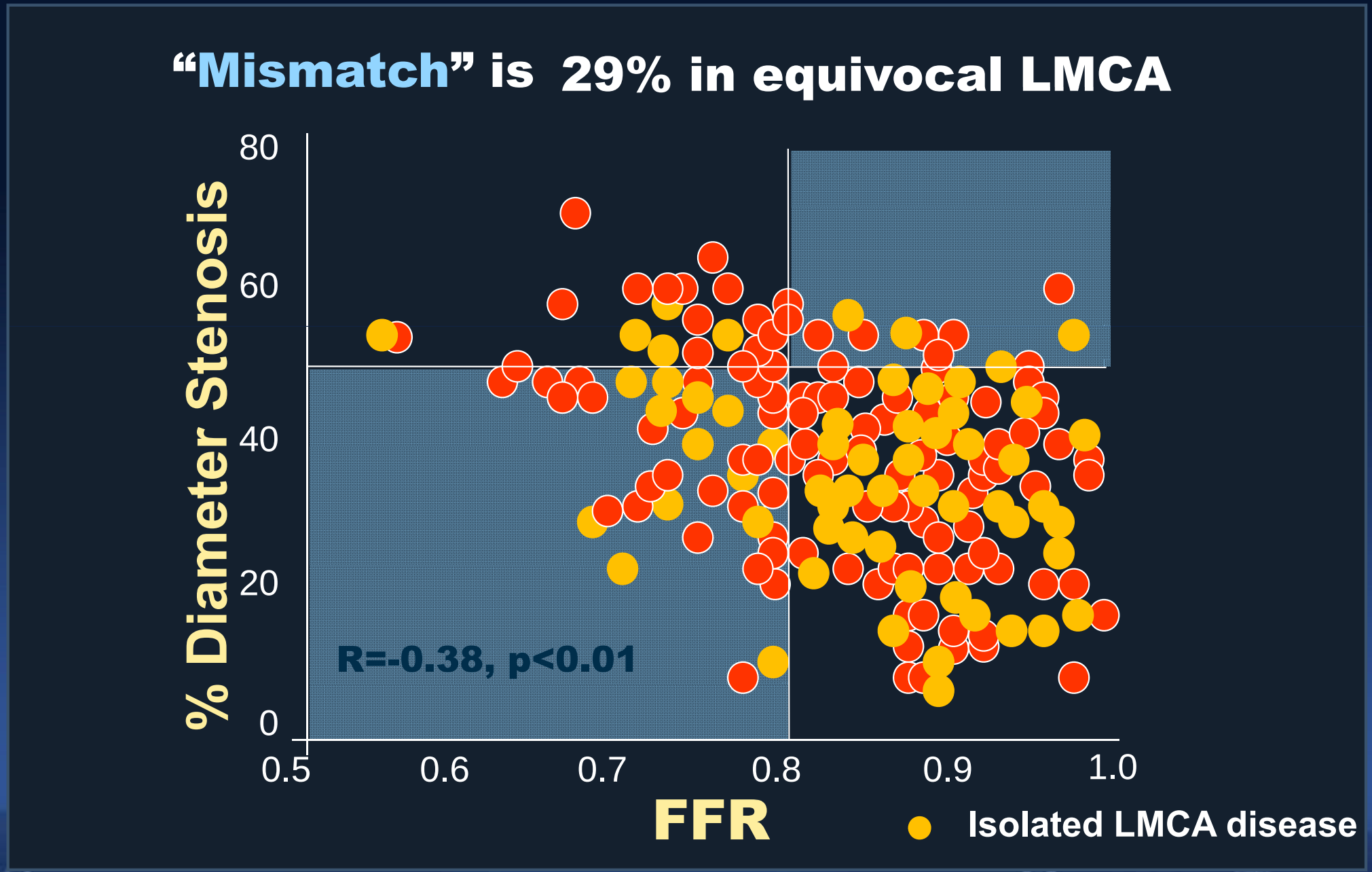


Park SJ, Kang SJ et al. JACC Cardiovasc Interv. 2012 Oct;5(10):1029-36

Left Main Coronary Artery Stenosis



FFR of the Equivocal LMCA

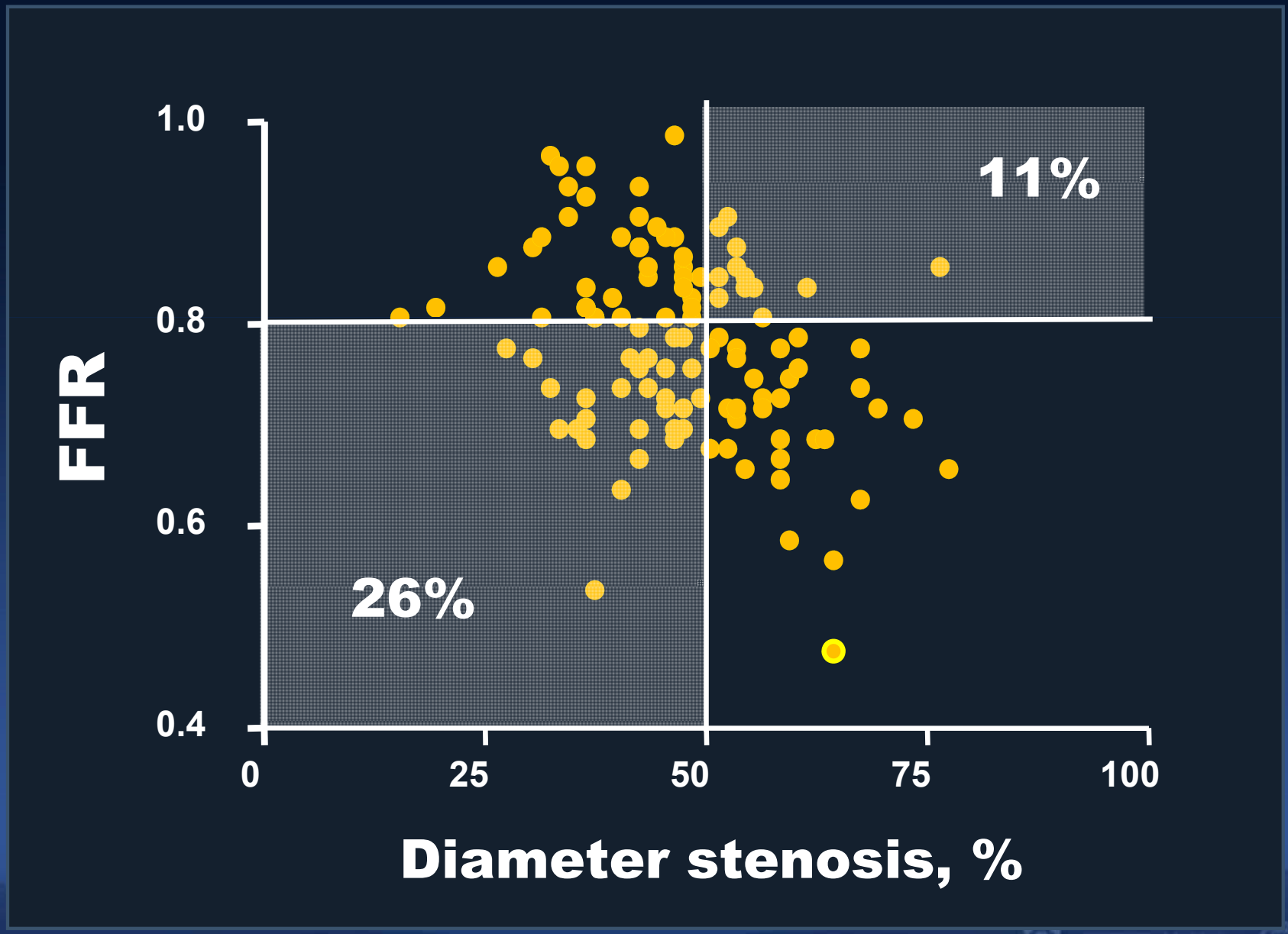


Circulation 2009;120:1505-1512

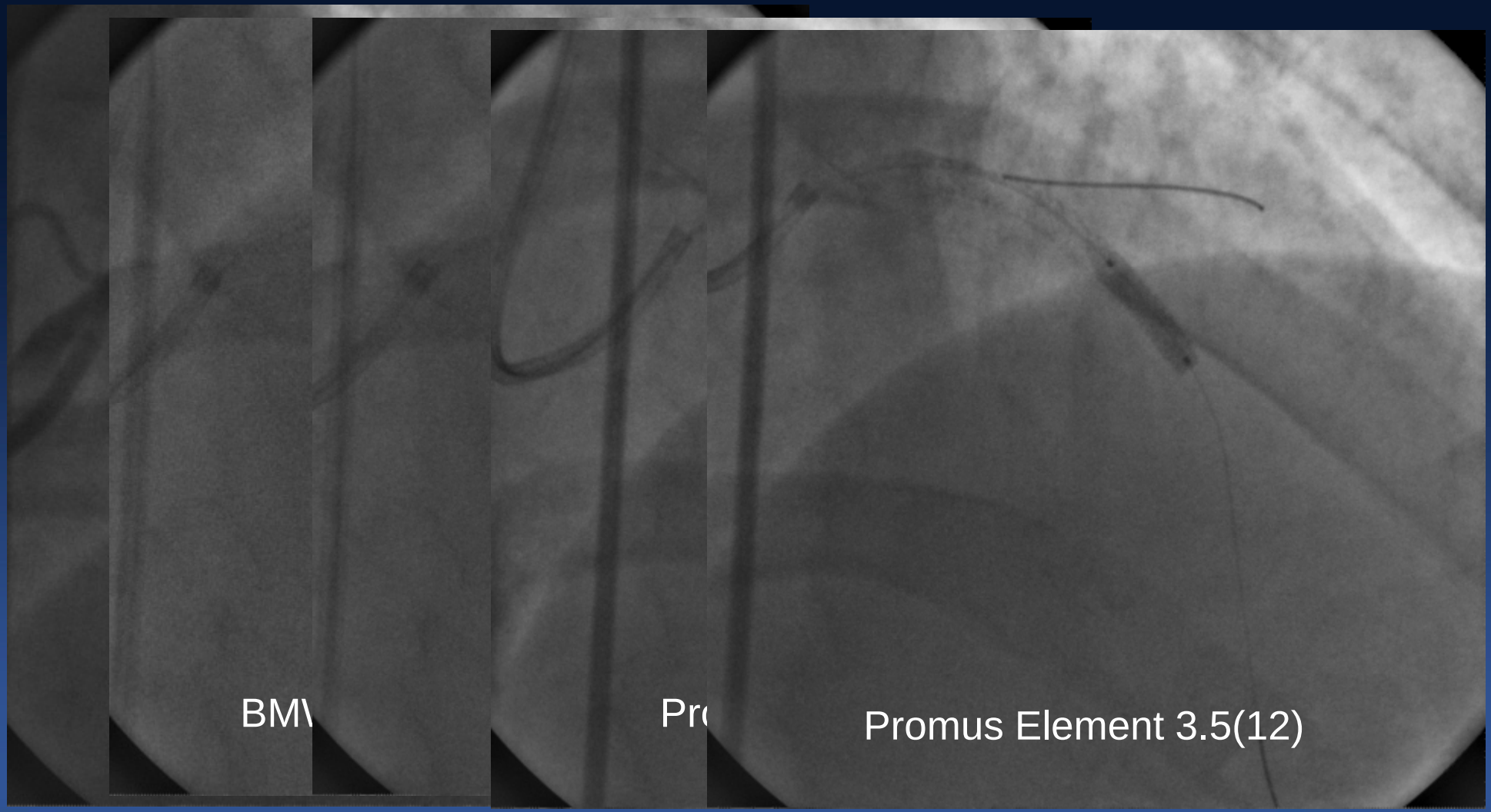
Mismatch

AMC data

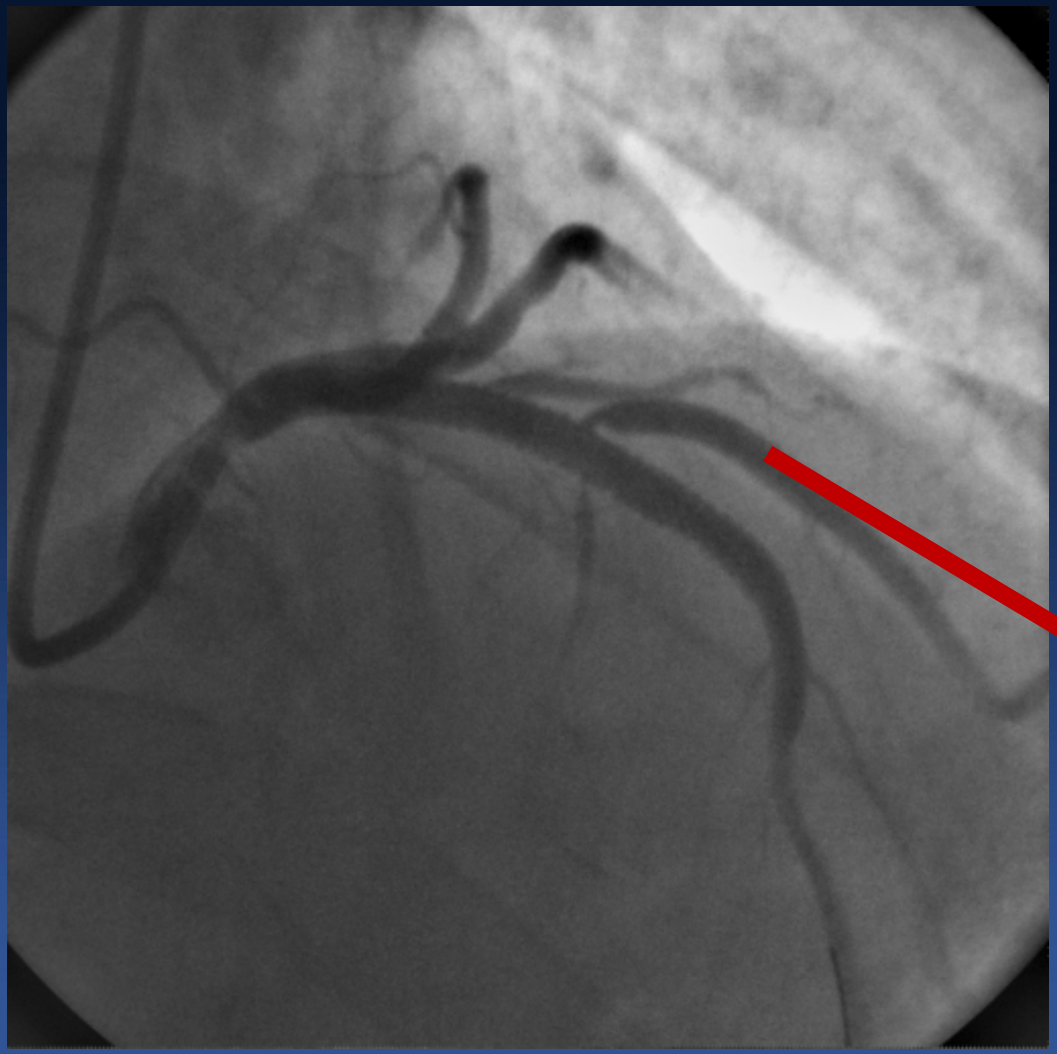
in Isolated intermediate LM Disease (n=112)

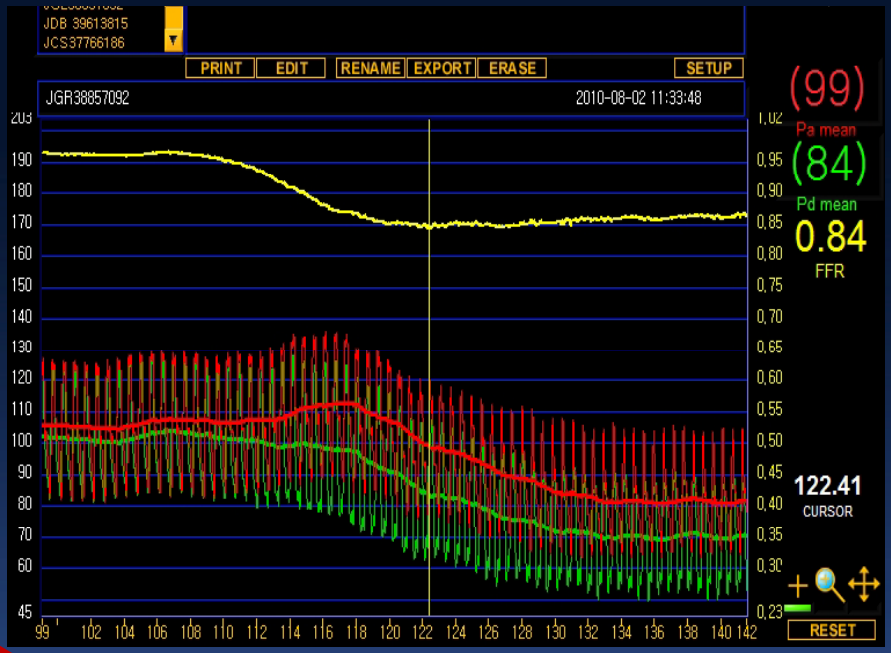


Bifurcation Lesions



After Stenting at Main Vessel



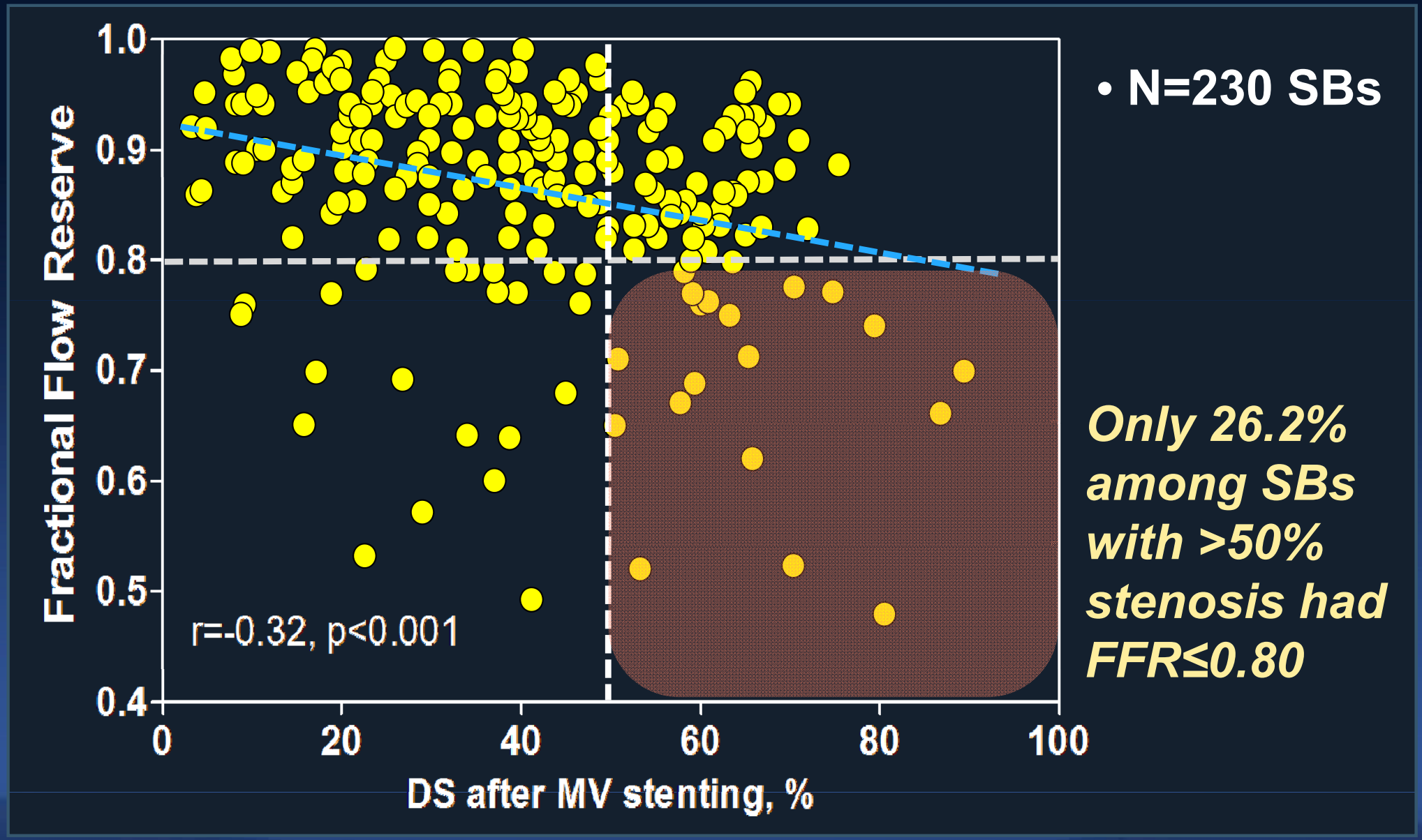


FFR 0.84

Leave it alone.

FFR of the Jailed Side Branch

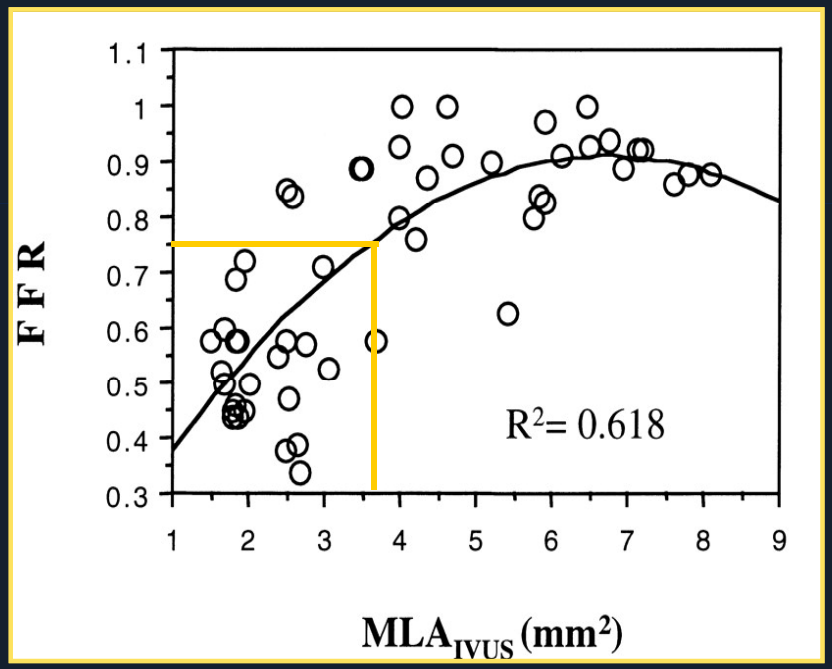
By Using Dedicated Bifurcation QCA



Ahn JM et al. JACC Cardiovasc Interv. 2012 Feb;5(2):155-61

Visual-Functional Mismatch (2)
IVUS and FFR

MLA 4.0mm²

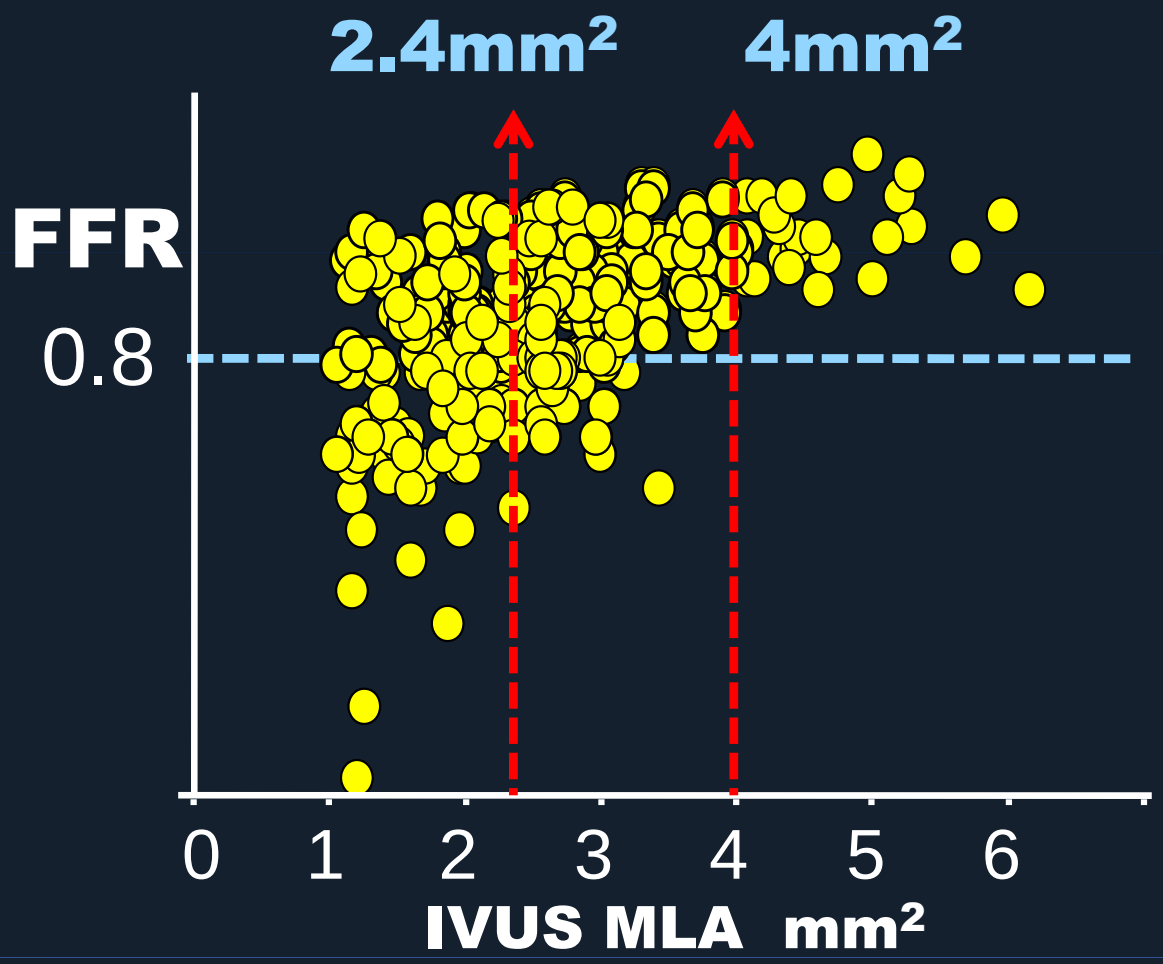


	Sensitivity	Specificity
AS > 70%	100%	68%
MLD < 1.8 mm	100%	66%
MLA < 4.0 mm²	82%	56%
Length > 10 mm	41%	80%

Takagi et al. Circulation 1999;100:250-5

Briguori et al. AJC 2001;87:136-41

New IVUS MLA for FFR <0.80 In Epicardial Coronary Artery



- 66% of analyzed lesions have MLA<4 mm² but FFR >0.80
- 30% of analyzed lesions had MLA <2.4mm² but FFR >0.80.
- Regardless of cutoff values, use of IVUS MLA criteria alone could not predict the result of FFR measurement

Kang SJ, Park SJ, Circ Cardiovasc Interv. 2011;4: 65-71

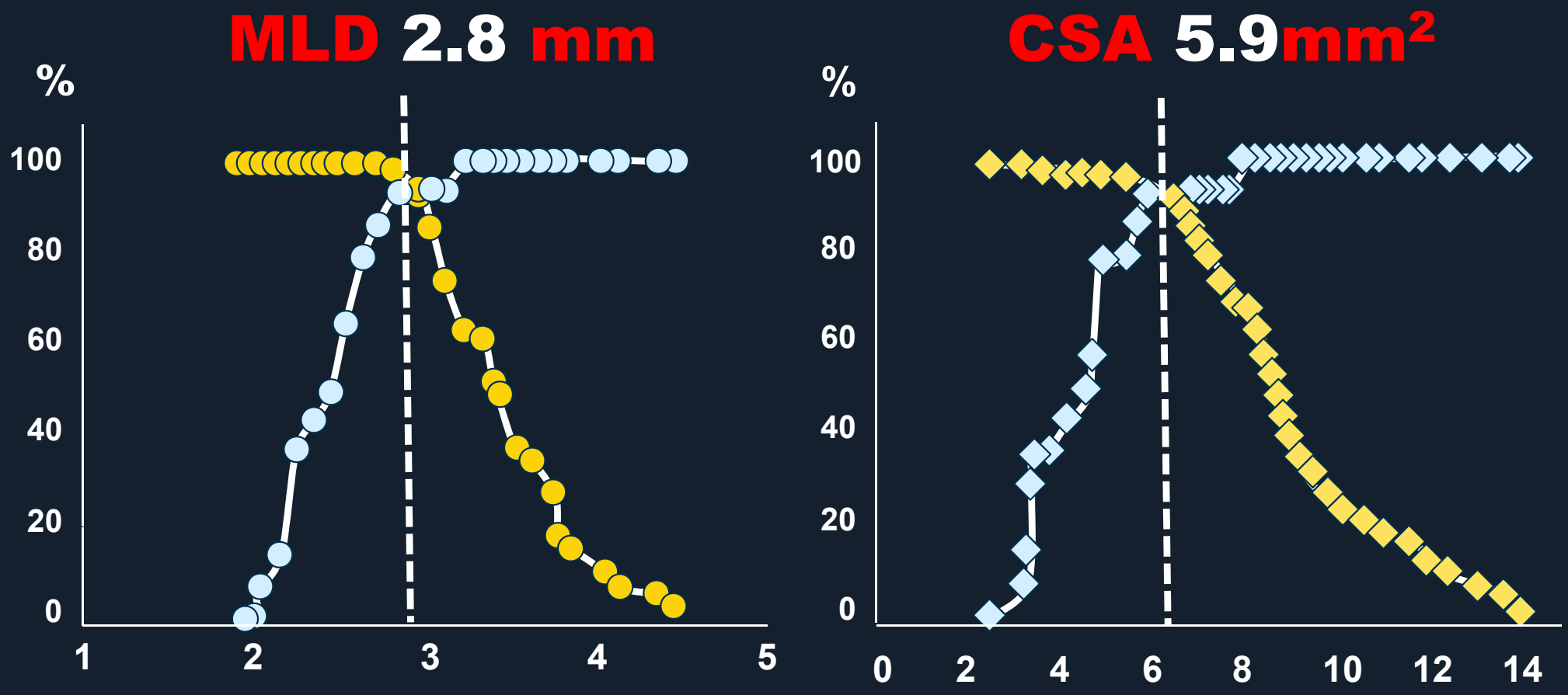
IVUS Minimal Lumen Area

	N	FFR	RLA	MLA	AUC	Sens	Spec	PPV	NPV	Accu
Takaki (1999 Circ)	51	0.75	9.3	**3.0**	–	83%	92%	–	–	–
Briguori (2001 AJC)	53	0.75	7.8	**4.0**	–	92%	56%	38%	96%	64%
Kang (2011 Circ int)	236	0.80	7.6	**2.4**	0.80	90%	60%	37%	96%	68%
(2011 JACC int)	267	0.80	6.8	**2.75**	0.81	69%	65%	27%	81%	67%
Gonzalo (2012 JACC)	47	0.80	7.1	**2.36 IVUS**	0.63	67%	65%	67%	65%	66%
Gonzalo (2012 JACC)	61	0.80	7.1	**1.95 OCT**	0.70	82%	63%	66%	80%	72%
Waksman (2013 JACC)	367	0.80	6.9	**3.07**	0.65	64%	65%	40%	83%	-

Furthermore, the accuracies of specific MLA criteria optimized by vessel size still remain poor

Significant LM Stenosis

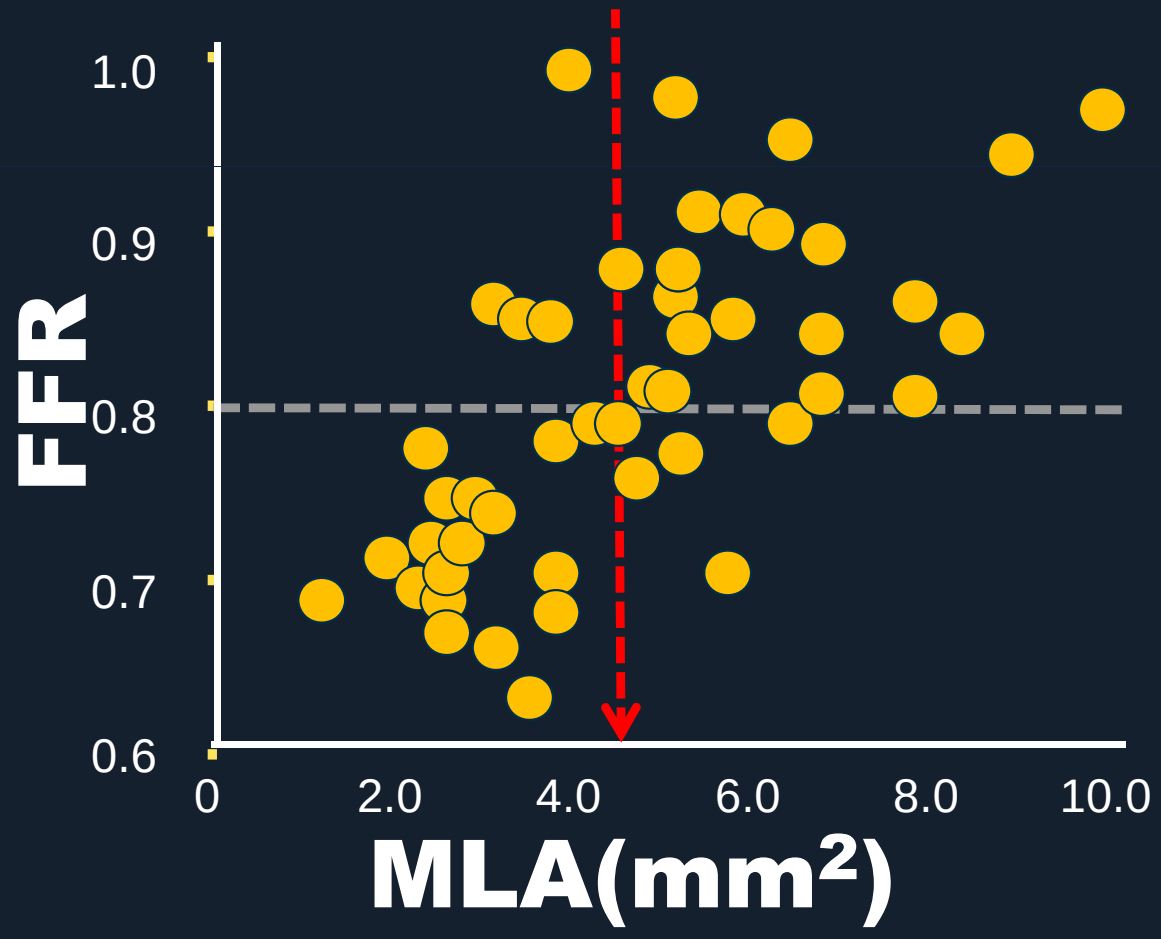
CSA <6.0mm² ≈ LM FFR<0.75



Jasti et al. Circulation 2004;110:2831-6

Significant LM Stenosis

MLA 4.8mm^2 New IVUS Criteria

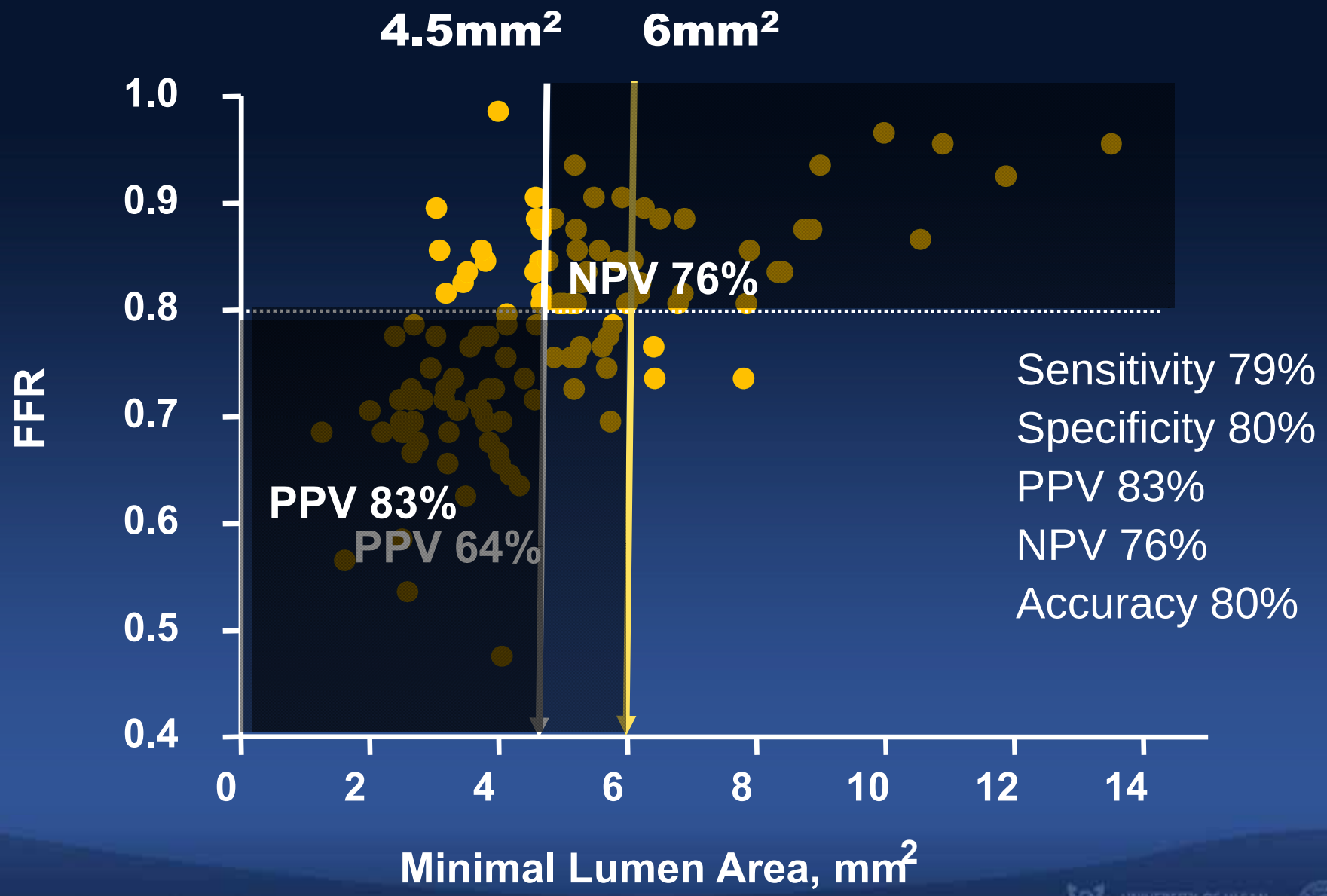


Sensitivity 83%
Specificity 83%
PPV 83%
NPV 83%
Accuracy 83%

47 isolated LM disease
With 30-80% stenosis

AMC data

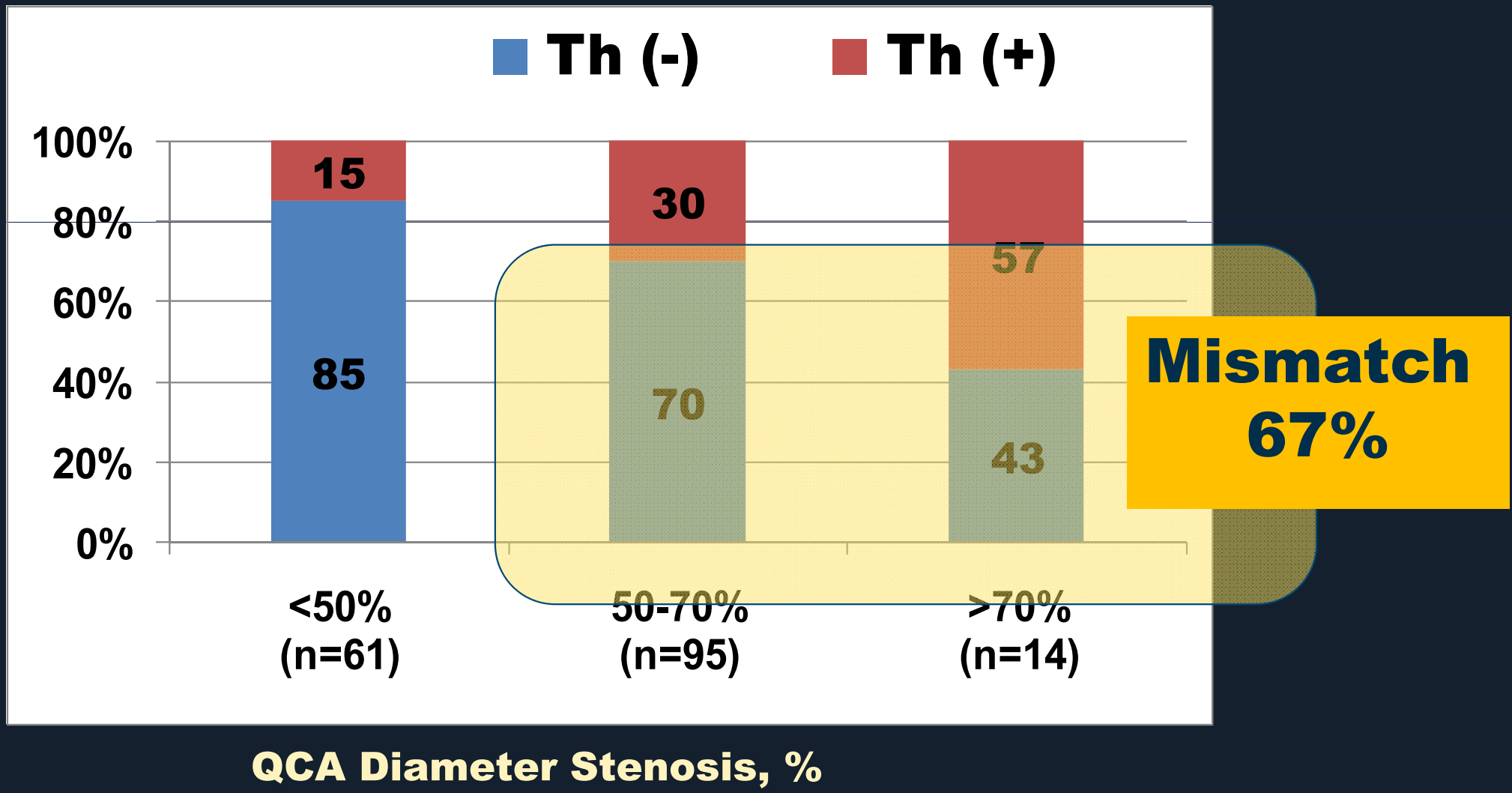
IVUS and FFR
Isolated intermediate LM Disease (n=112)



Sensitivity 79%
Specificity 80%
PPV 83%
NPV 76%
Accuracy 80%

Visual-Functional Mismatch (3)
Coronary angiography and Thallium SPECT

A total of 170 coronary lesions in 150 patients who underwent Thallium SPECT



Ahn et al. JACC Cardiovasc Interv. 2011 Jun;4(6):665-71

Thallium SPECT and IVUS/QCA

	AUC	BCV	Sensitivity	Specificity	PPV	NPV	K
QCA parameters							
MLD, mm	0.670	**≤1.26**	57.8	76.8	**47.3**	83.5	0.32
DS, %	0.692	**>58.2**	62.2	70.4	**43.1**	83.8	0.28
LL, mm	0.582	**>26.2**	43.2	79.2	**42.2**	79.8	0.21
IVUS parameters							
MLA, mm^2	0.690	**≤2.1**	86.7	50.4	**38.6**	91.3	0.27
PB, %	0.730	**>83.4**	73.3	64.8	**42.9**	87.1	0.31

Ahn et al. JACC Cardiovasc Interv. 2011 Jun;4(6):665-71

Determinants for Functional State of Coronary Narrowing

- Preliminary analysis from ASAN FFR registry
- 1756 lesions in 1470 patients
- Clinical, Angiographic, and Hemodynamic variables

Determinants for Functional State of Coronary Narrowing

FFR as continuous variables

R^2=0.73

	Beta coefficient	95% CI	p-value
Lesion location*	0.012	0.008-0.016	<0.001
Reference vessel diameter	-0.01	-0.017- -0.003	0.006
Minimal lumen diameter	0.025	0.015-0.035	<0.001
Diameter stenosis	-0.001	-0.001- -0.001	<0.001
Resting Pd/Pa	1.077	1.021-1.132	<0.001
Sex	0.011	0.001 – 0.020	0.027
Age	0.001	0.001 – 0.001	<0.001
Body surface area	-0.044	-0.07 - -0.018	0.001

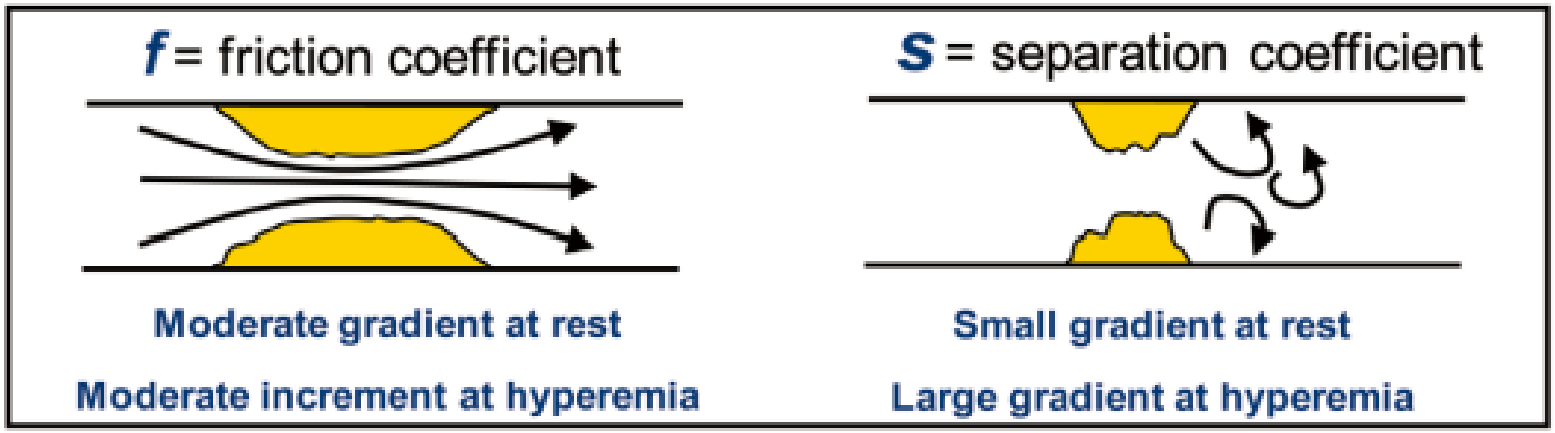
*Lesion location: LM(1)-LAD(2)-RCA(3)-LCX(4)-SB(5)

Anatomical factor

- Degree of diameter stenosis
- Reference vessel diameter (myocardium)
- Lesion morphology
- Eccentricity
- Lesion length
- Plaque burden, Plaque rupture
- Surface roughness
- Viscous friction, flow separation, turbulence, and eddies

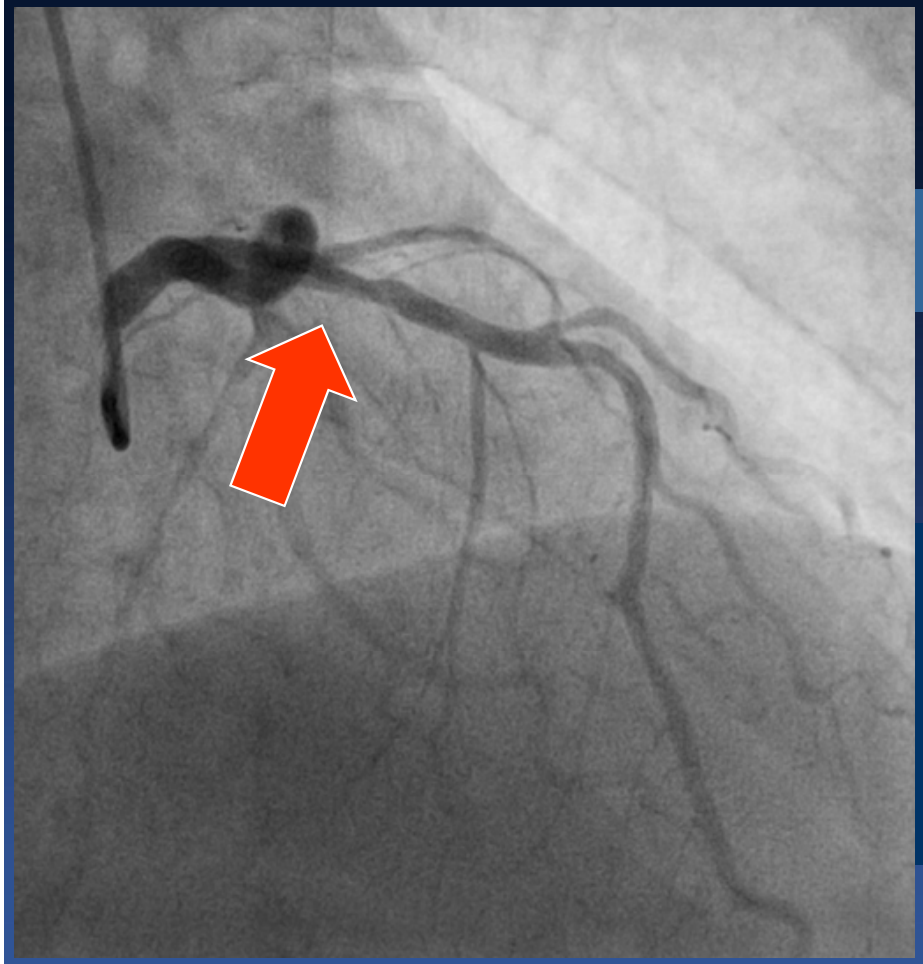
Fluid-dynamics equation
Cause of Energy Loss

$$\Delta P = f.Q + s.Q^2$$



Pijls et al. Circ J. 2013 Feb 25;77(3):561-9

Plaque Rupture

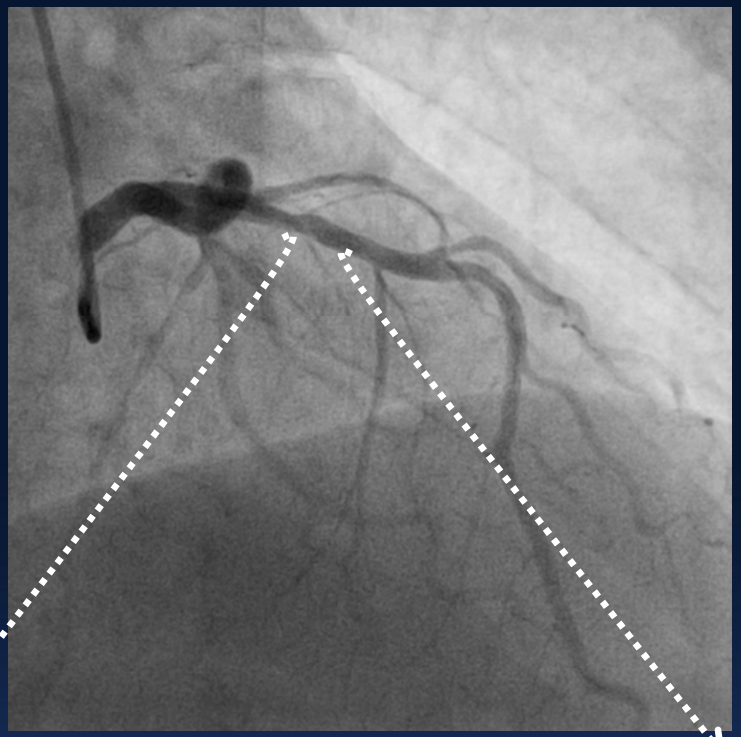


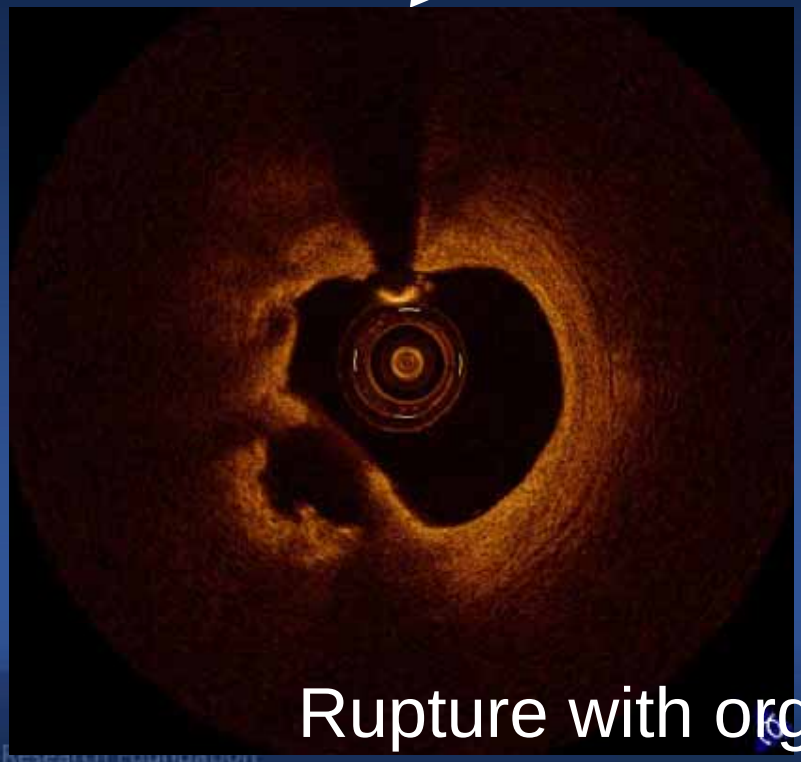
QCA DS(%) : 32%

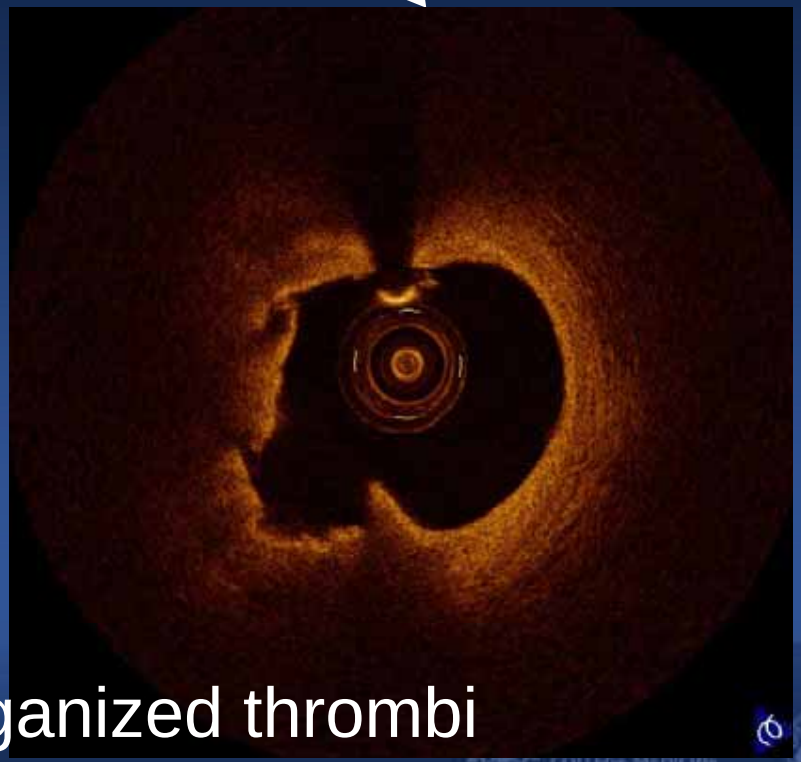
FFR : 0.73

Treadmill test : stage 3 +

Thallium spect : + LAD







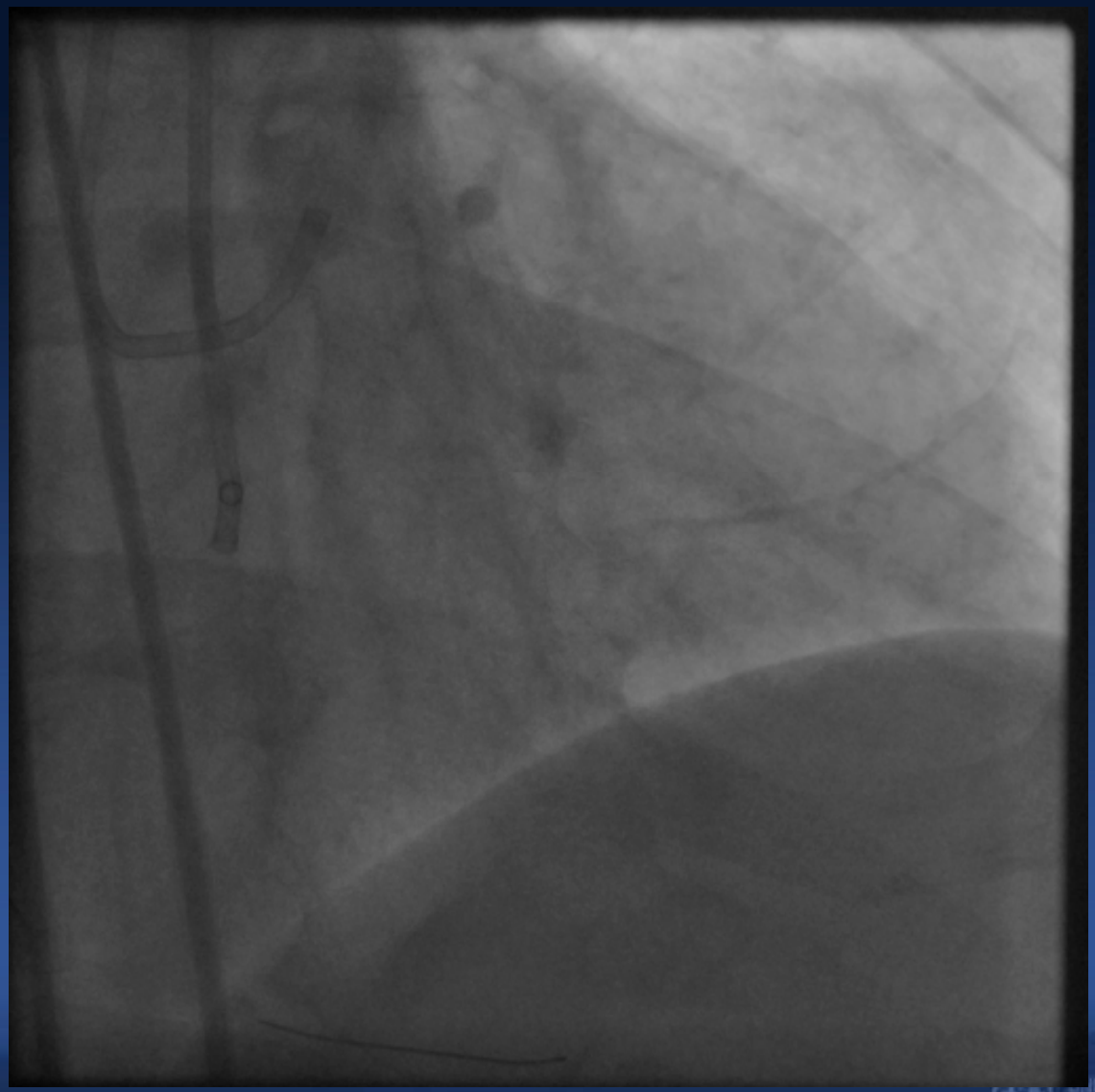
Rupture with organized thrombi

If we can perfectly describe the configuration of the coronary stenosis, we can predict the functional severity?

No, non-anatomical factors also affect the functional severity.

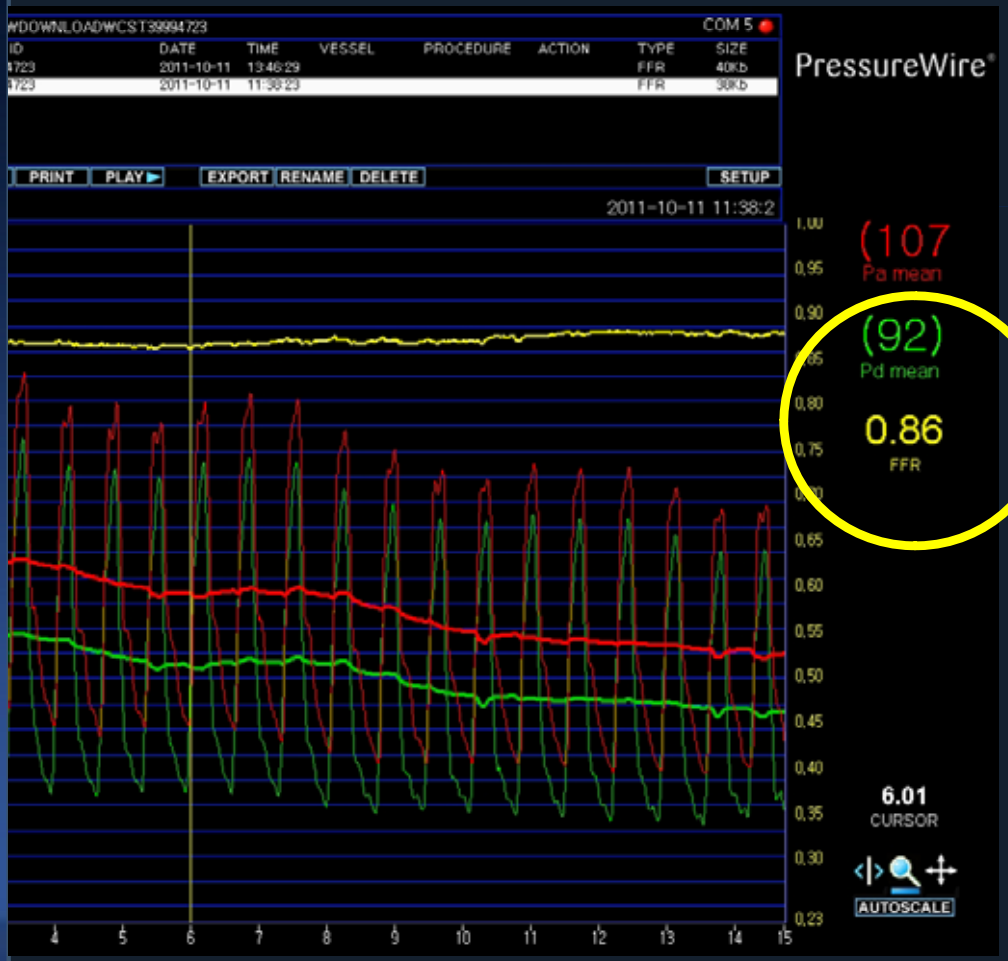
Supplying Myocardial Burden

FFR measurement in RCA



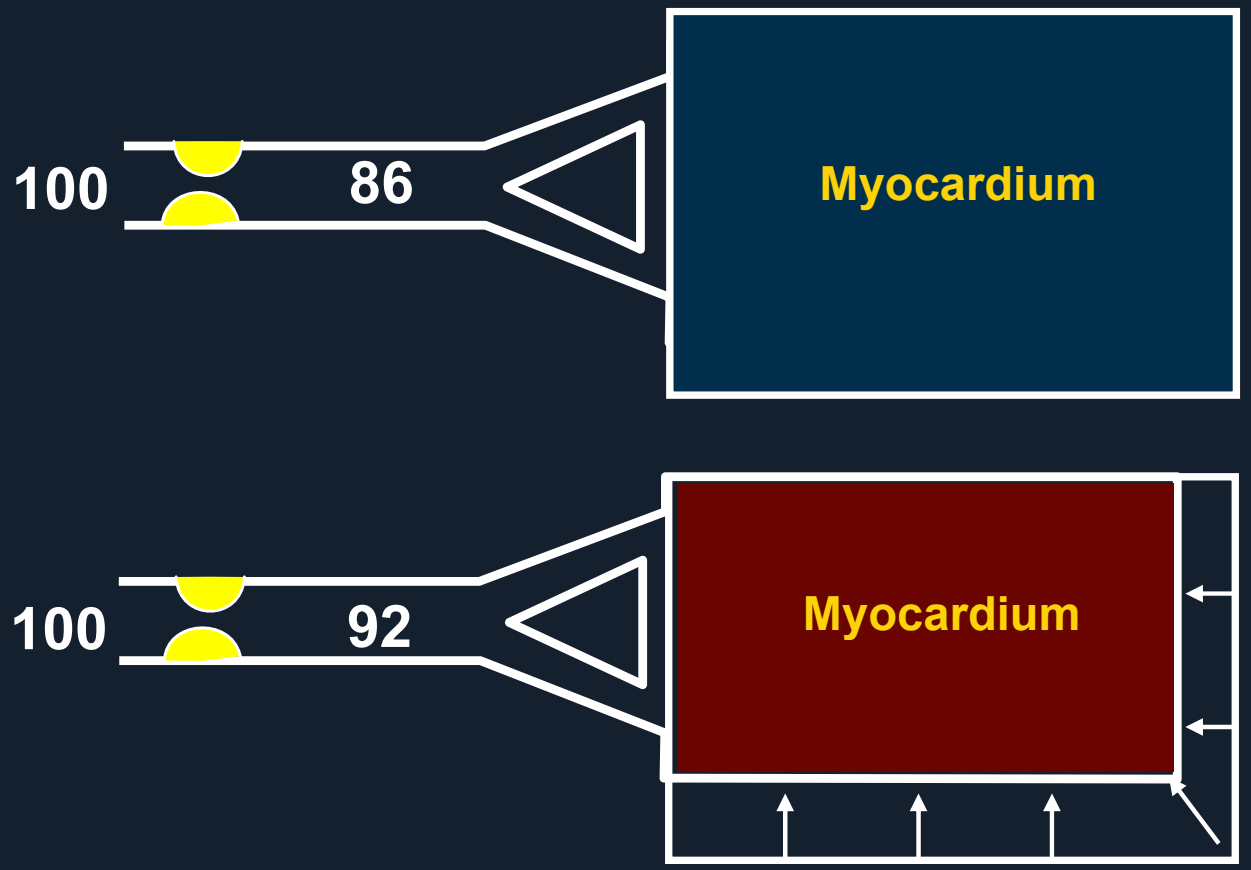
FFR in RCA

Before
Recanalization of LAD



After
Recanalization of LAD

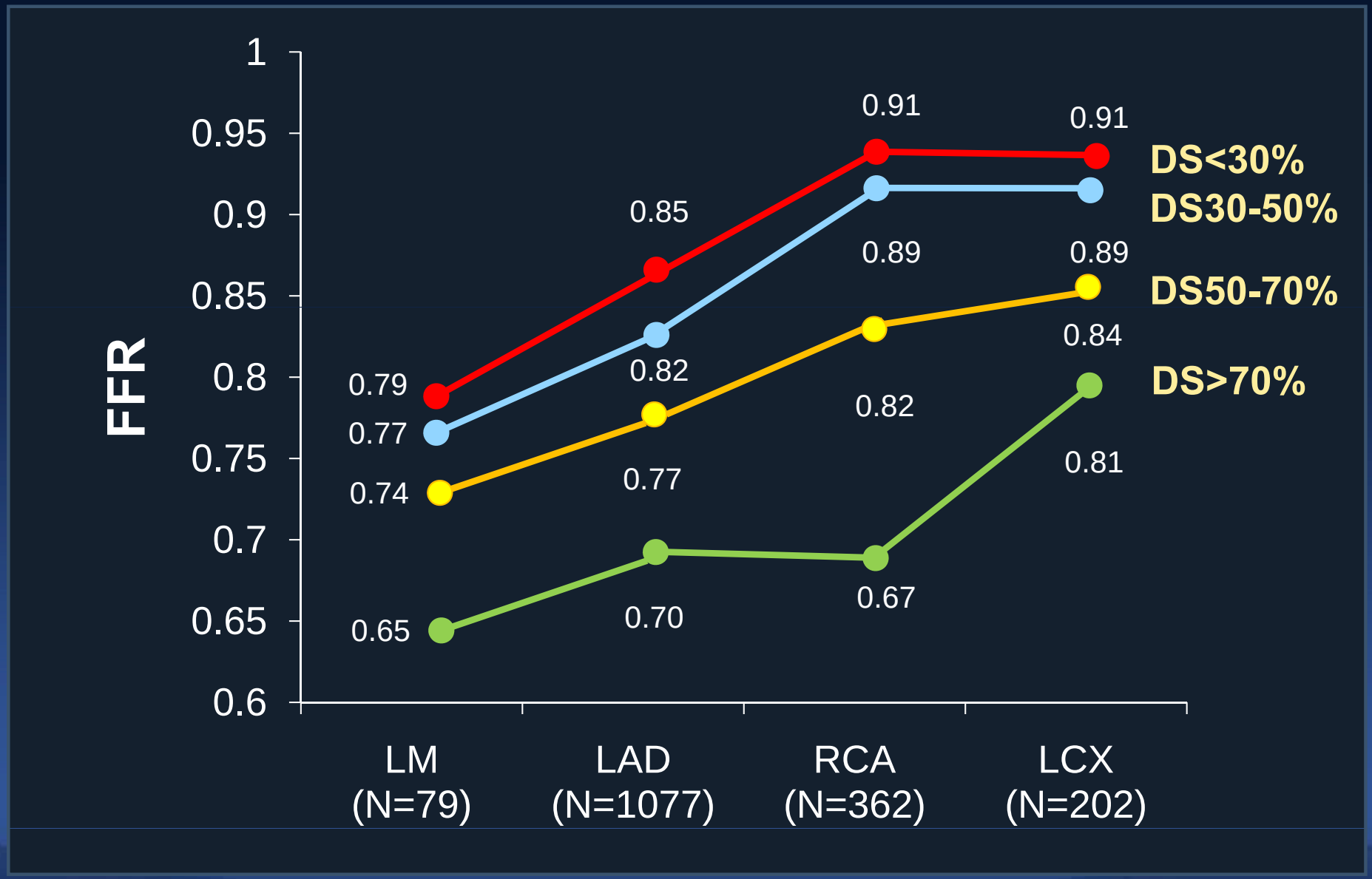
Supplying Myocardial Burden



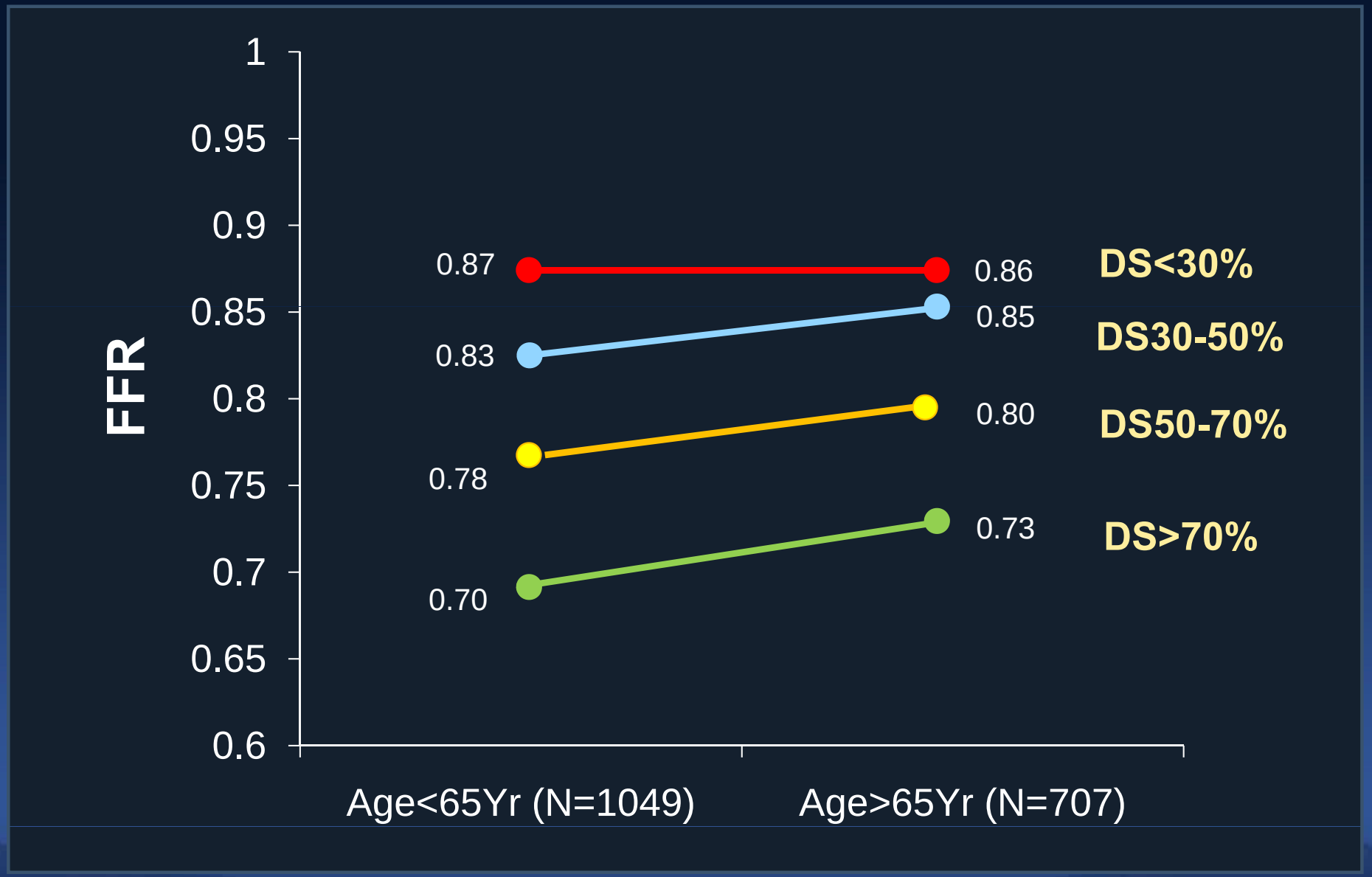
FFR=0.86

FFR=0.92

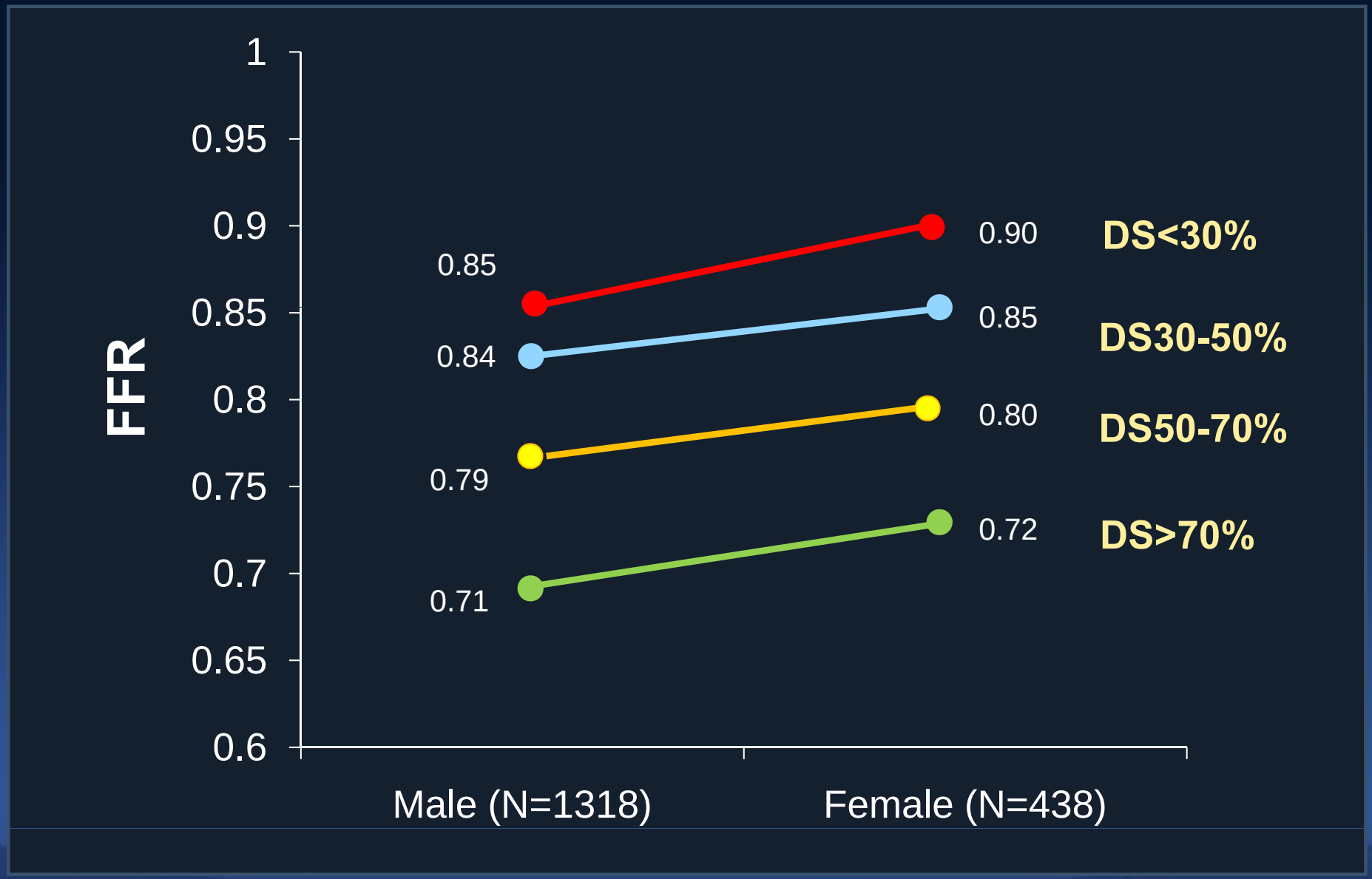
Location of Stenosis



Age


FFR
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.87
0.86
0.83
0.85
0.78
0.80
0.70
0.73
DS<30%
DS30-50%
DS50-70%
DS>70%
Age<65Yr (N=1049)
Age>65Yr (N=707)

Sex


FFR
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.85
0.84
0.79
0.71
0.90
0.85
0.80
0.72
DS<30%
DS30-50%
DS50-70%
DS>70%
Male (N=1318)
Female (N=438)

Summary

- Mismatch between anatomical and functional assessment was not uncommon,
- Because many anatomical and non-anatomical factors affected functional severity of coronary stenosis.
- Therefore, physicians should overcome their visual (anatomical) bias and
- Decision making in revascularization should depend on functional assessment.