Clinical Implementation of FFR

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What is FFR ?

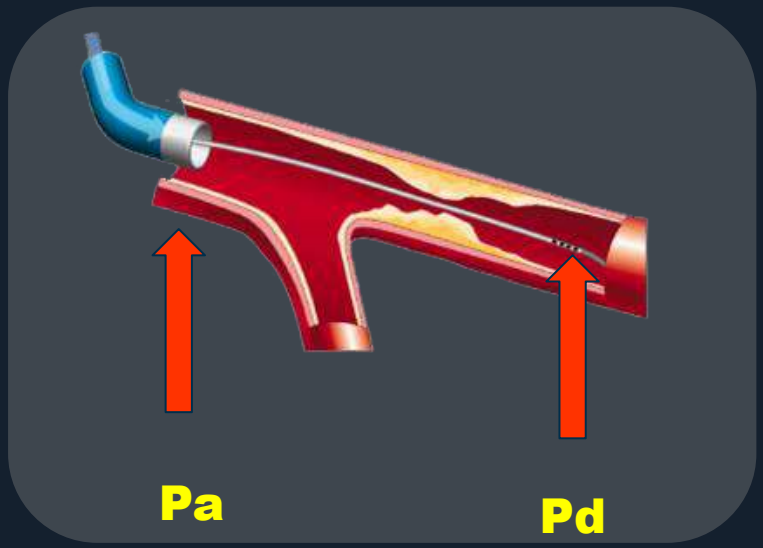
$$FFR = \frac{\text{Maxal Flow in Presence of a Stenosis}}{\text{Normal Maximal Flow}}$$

Fractional Flow Reserve

Under the maximal hyperemia

$$FFR = \frac{Qs_{max}}{Qn_{max}} = \frac{(P_d - P_v)/R}{(P_a - P_v)/R}$$

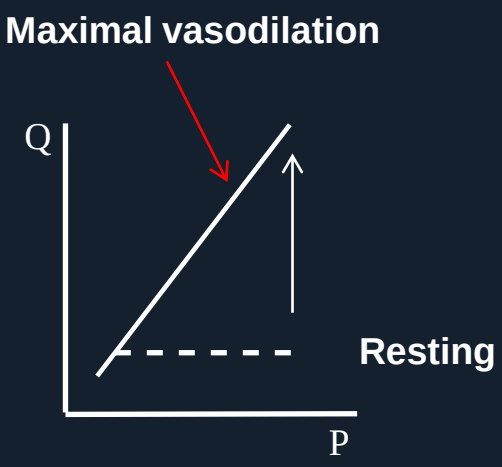
$$= \frac{Pd}{Pa}$$



Importance of Maximum Hyperemia

$$FFR = \frac{Q_S^{max}}{Q_N^{max}}$$

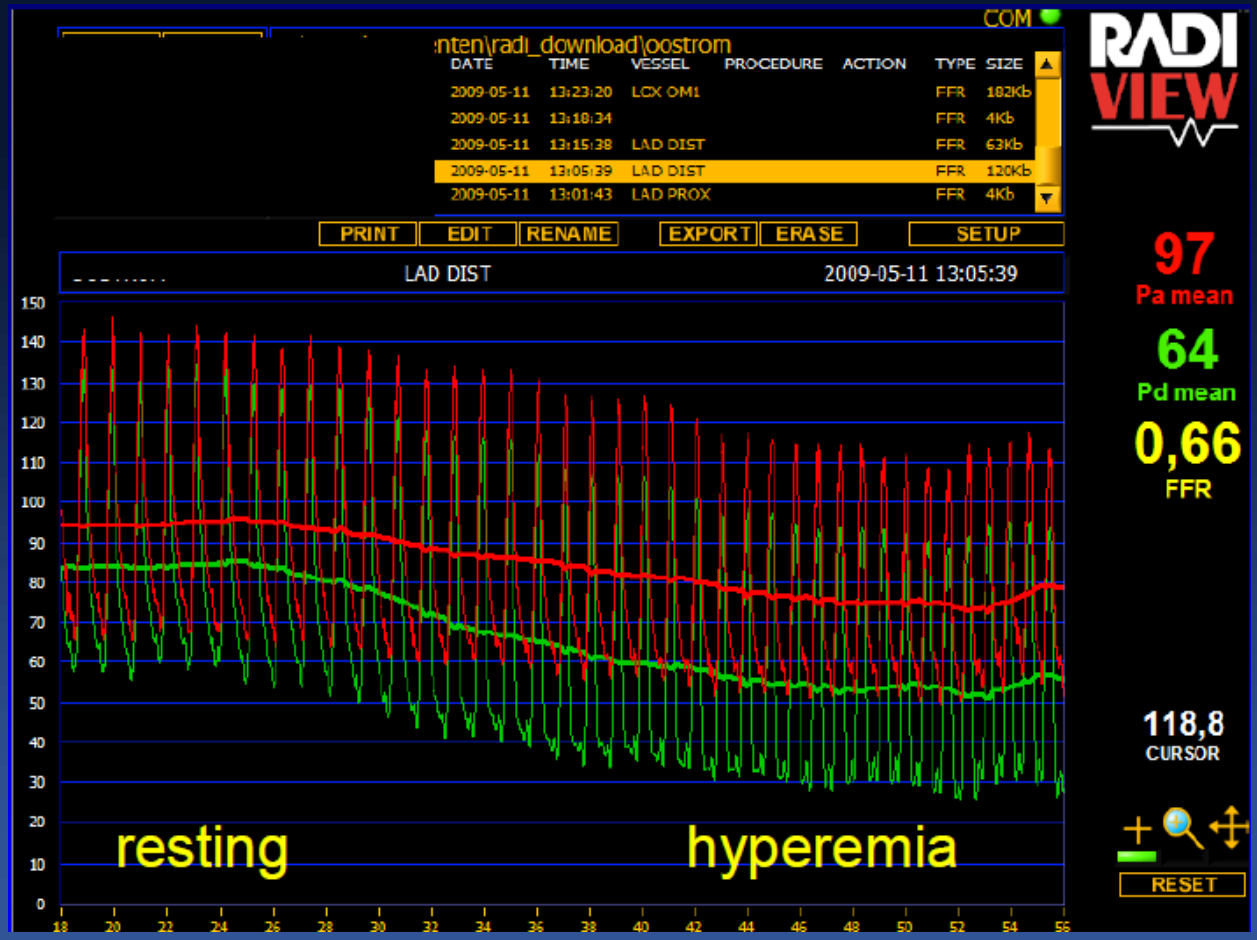
$$= \frac{Pd}{Pa}$$



During maximal vasodilation, the ratio of *stenotic flow* to n*or mal flow* is proportional to their respective driving pressures.

This is exactly the definition of the FFR: the ratio of *distal cor onary pressure* to *aortic press ure*.

Measurement of FFR



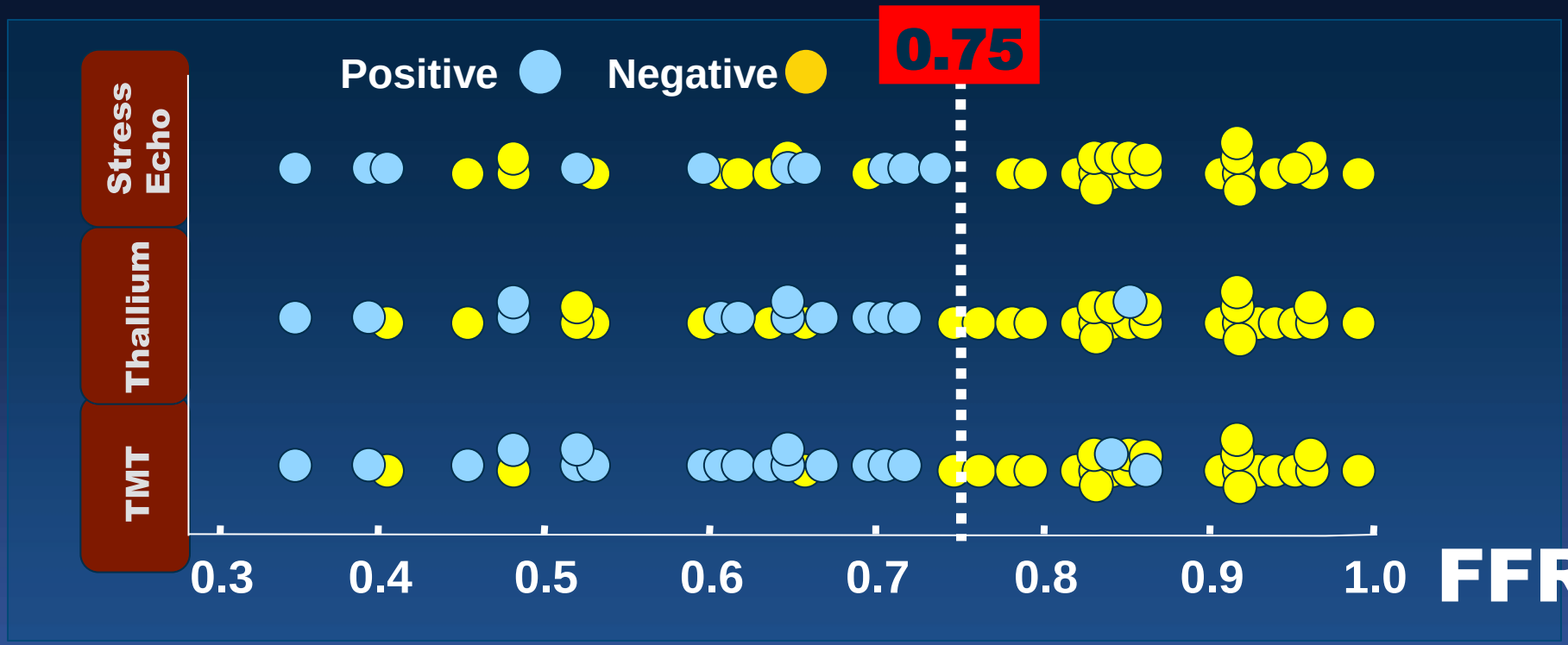
Advance pressure wire through stenosis and induce hyperemia

FFR 0.66 means

- Due to this particular stenosis, maximum achievable blood flow to the myocardium supplied by this artery, is only 66% of what it would be if this coronary artery were completely normal.

First Validation of FFR

Comparison with 3 non-invasive functional studies



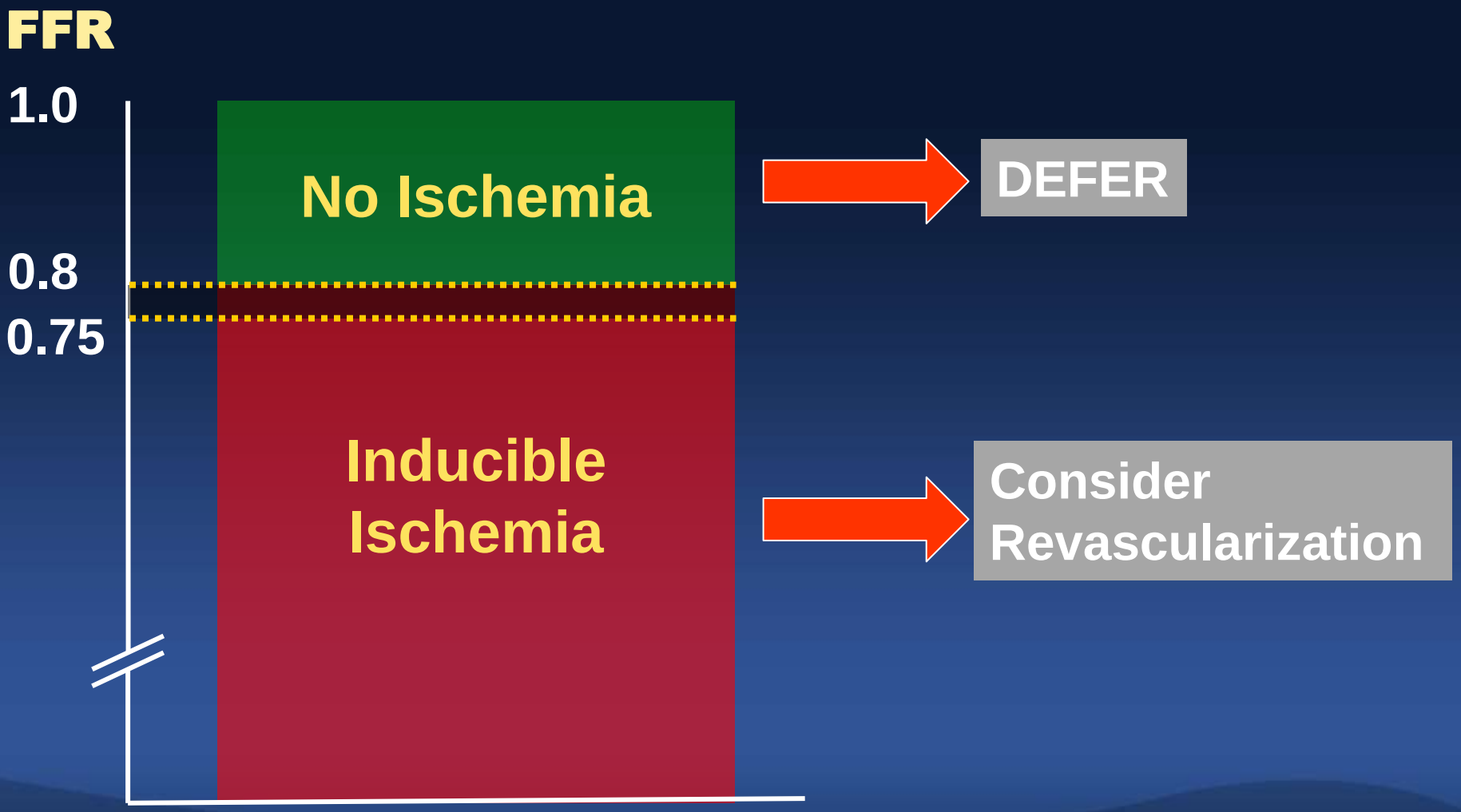
- **N = 45 patients**
- **Sensitivity 88%, Specificity 100%, PPV 100%, NPV 88%**

N Engl J Med 1996;334:1703-8

FFR Cut-Off Value

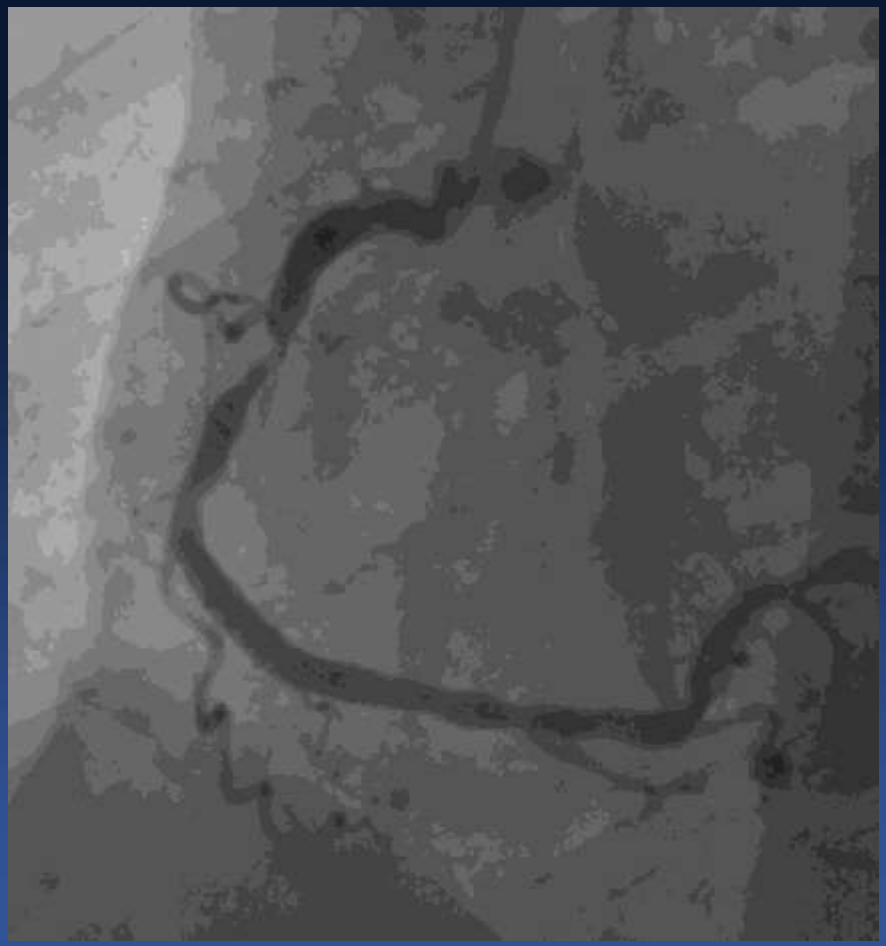
Author	Number	Stress Test	BCV	Accuracy
Pijls et al.	60	X-ECG	0.74	97
DeBruyne et al.	60	X-ECG/SPECT	0.72	85
Pijls et al.	45	X-ECG/SPECT/pacing/DSE	0.75	93
Bartunek et al.	37	DSE	0.68	90
Abe et al.	46	SPECT	0.75	91
Chamuleau et al.	127	SPECT	0.74	77
Caymaz et al.	40	SPECT	0.76	95
Jimenez-Navarro et al.	21	DSE	0.75	90
Usui et al.	167	SPECT	0.75	79
Yanagisawa et al.	167	SPECT	0.75	76
Meuwissen et al.	151	SPECT	0.74	85
DeBruyne et al.	57	MIBI-SPECT post-MI	0.78	85
Samady et al.	48	MIBI-SPECT post-MI	0.78	85

FFR Guided Decision Making



Clinical Application

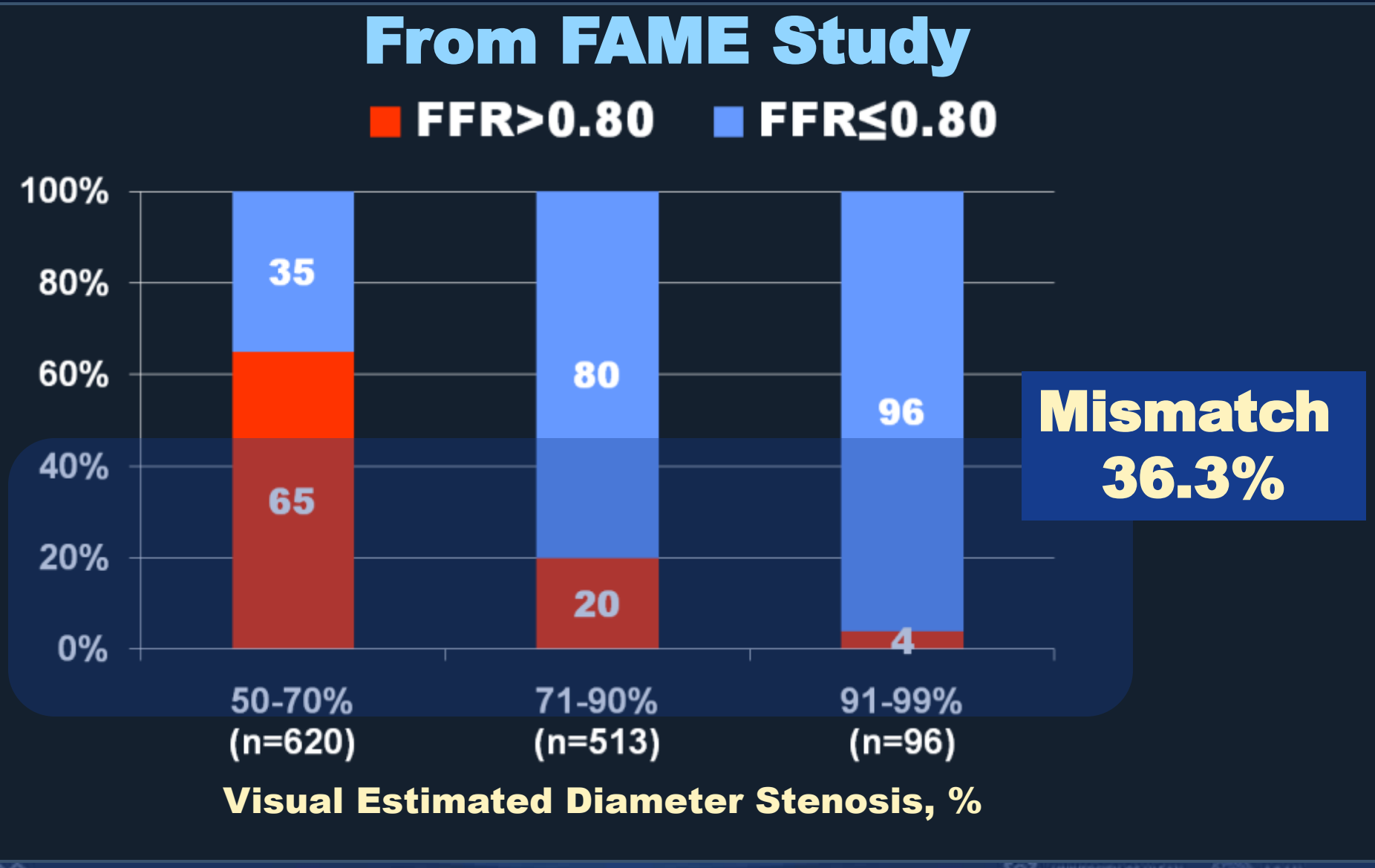
Single Vessel Disease



Angiographic DS(%) : 85%

FFR : 0.84

Visual-Functional Mismatch (I)



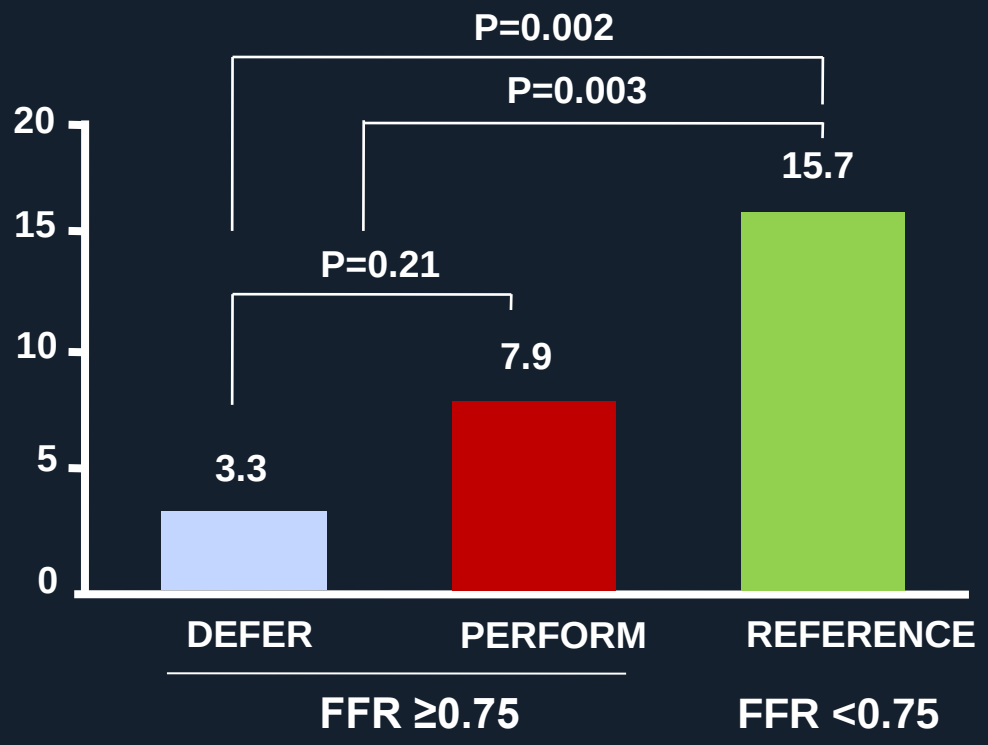
J Am Coll Cardiol 2010;55:2816–21

The DEFER Study @ 5yr FU

Cardiac Death and MI

In 325 patients

- **FFR≥0.75**
  - R → **DEFER (n=91)**
  - R → **PERFORMANCE (N=90)**
- **FFR<0.75**
  - **REFERENCE (N=144)**

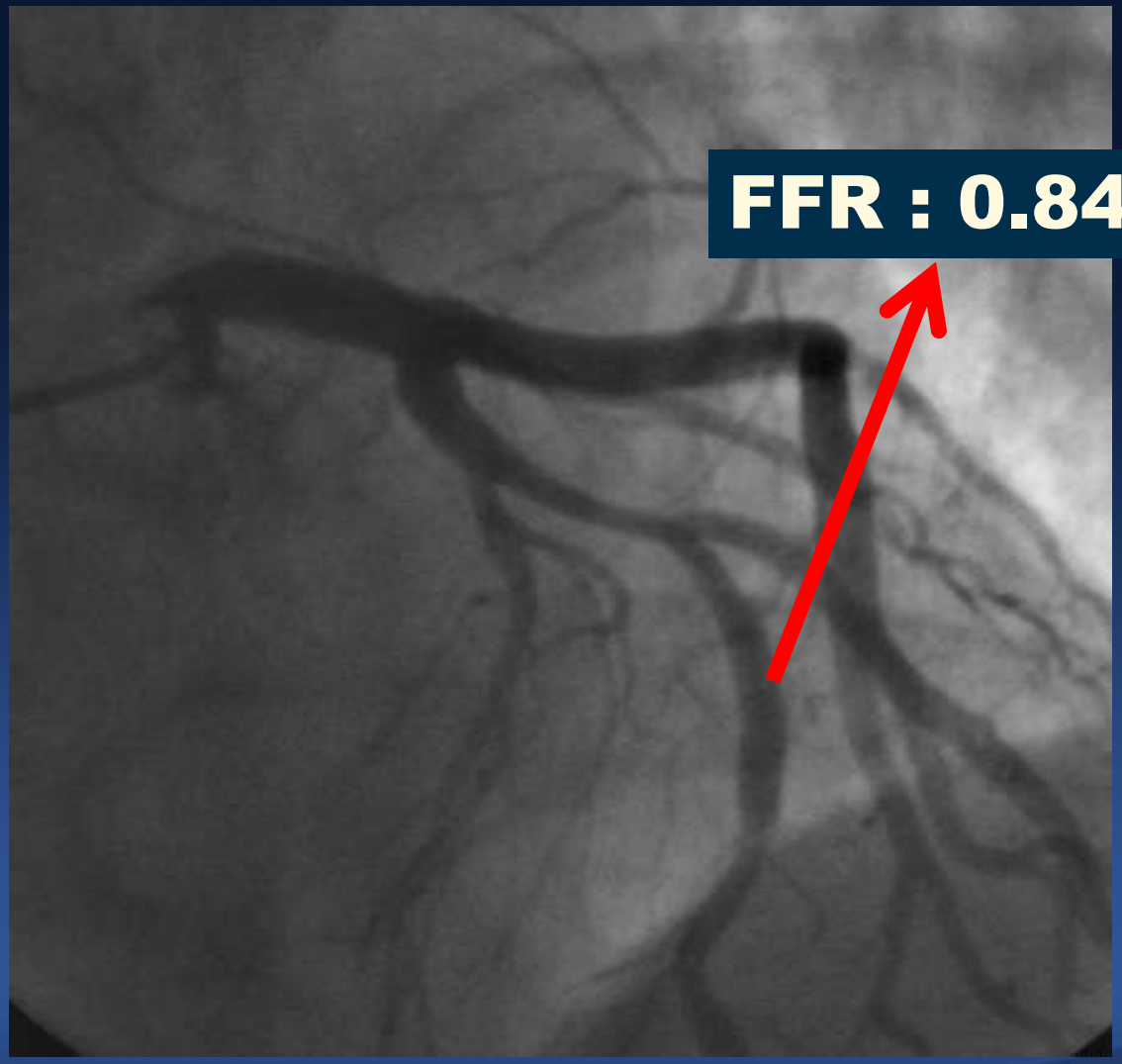


- **The risk of CD or MI related to this stenosis is <1%/year and not decreased by stenting.**

J Am Coll Cardiol 2007;49:2105–11

Multivessel Disease

LCA



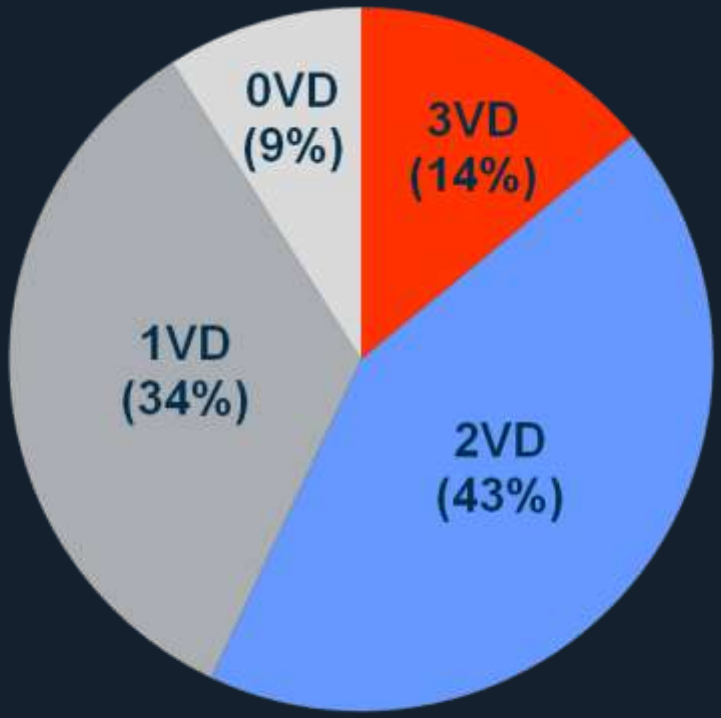
RCA

Angiographic 2 Vessel Disease
But, Functionally Normal Coronary

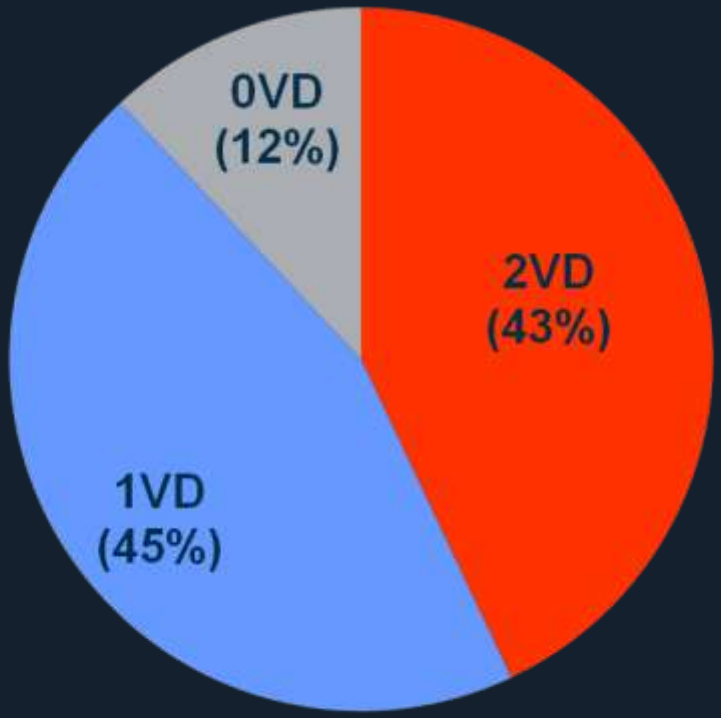
Visual-Functional Mismatch (II)

From FAME Study

Functionally Diseased Coronary Arteries



Angiographic 3VD



Angiographic 2VD

J Am Coll Cardiol 2010;55:2816–21

FAME @ 2 yr FU

- A total of 1,005 patients with multivessel CAD were randomly assigned

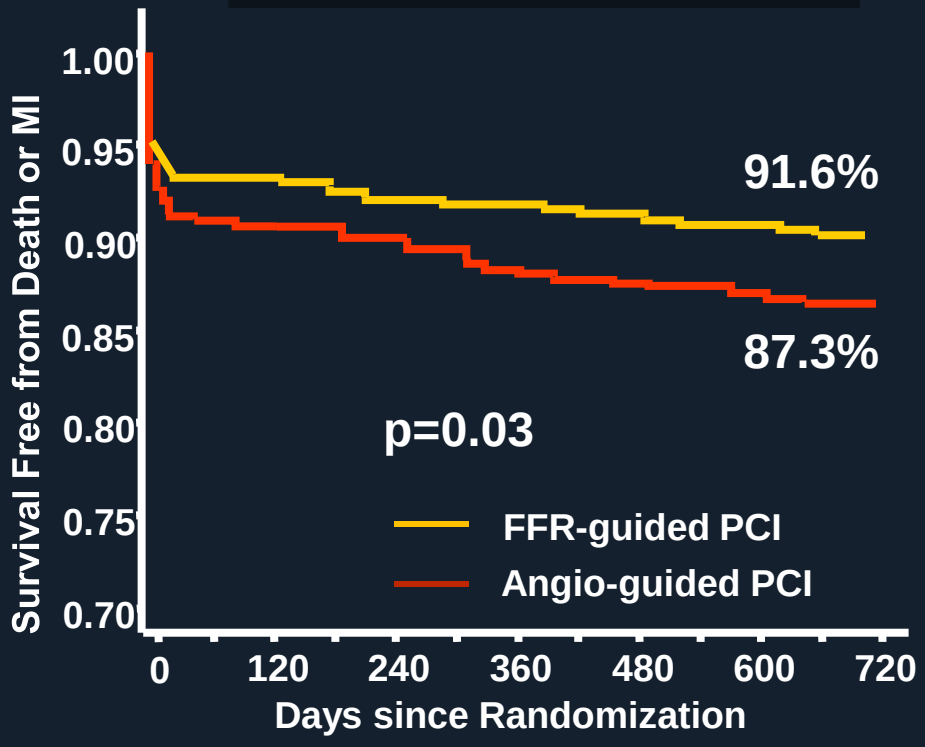
	Angio-Guided N=496	FFR-Guided N=509	p value
Total no. of MACE	139	105	
Individual Endpoints			
Death	19 (3.8)	13 (2.6)	0.25
MI	48 (9.7)	31 (6.1)	**0.03**
CABG or repeat PCI	61 (12.3)	53 (10.4)	0.35
Composite Endpoints			
Death or MI	63 (12.7)	43 (8.4)	**0.03**
Death, MI, CABG, or re-PCI	110 (22.2)	90 (17.7)	0.07
Total no. of MACE	139	105	

J Am Coll Cardiol 2010;56:177–84

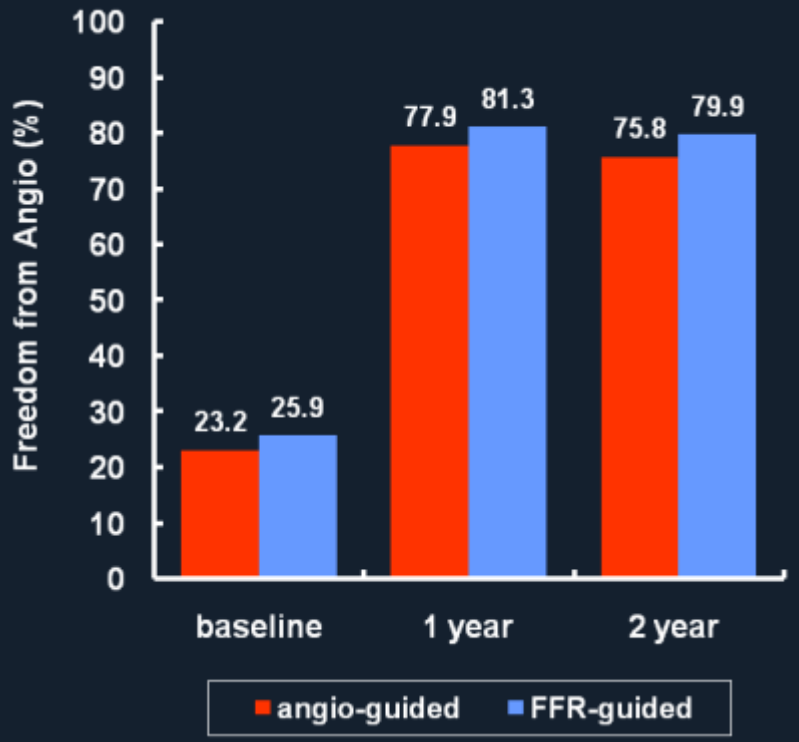
FAME @ 2 yr FU

- A total of 1,005 patients with multivessel CAD were randomly assigned

Death or MI

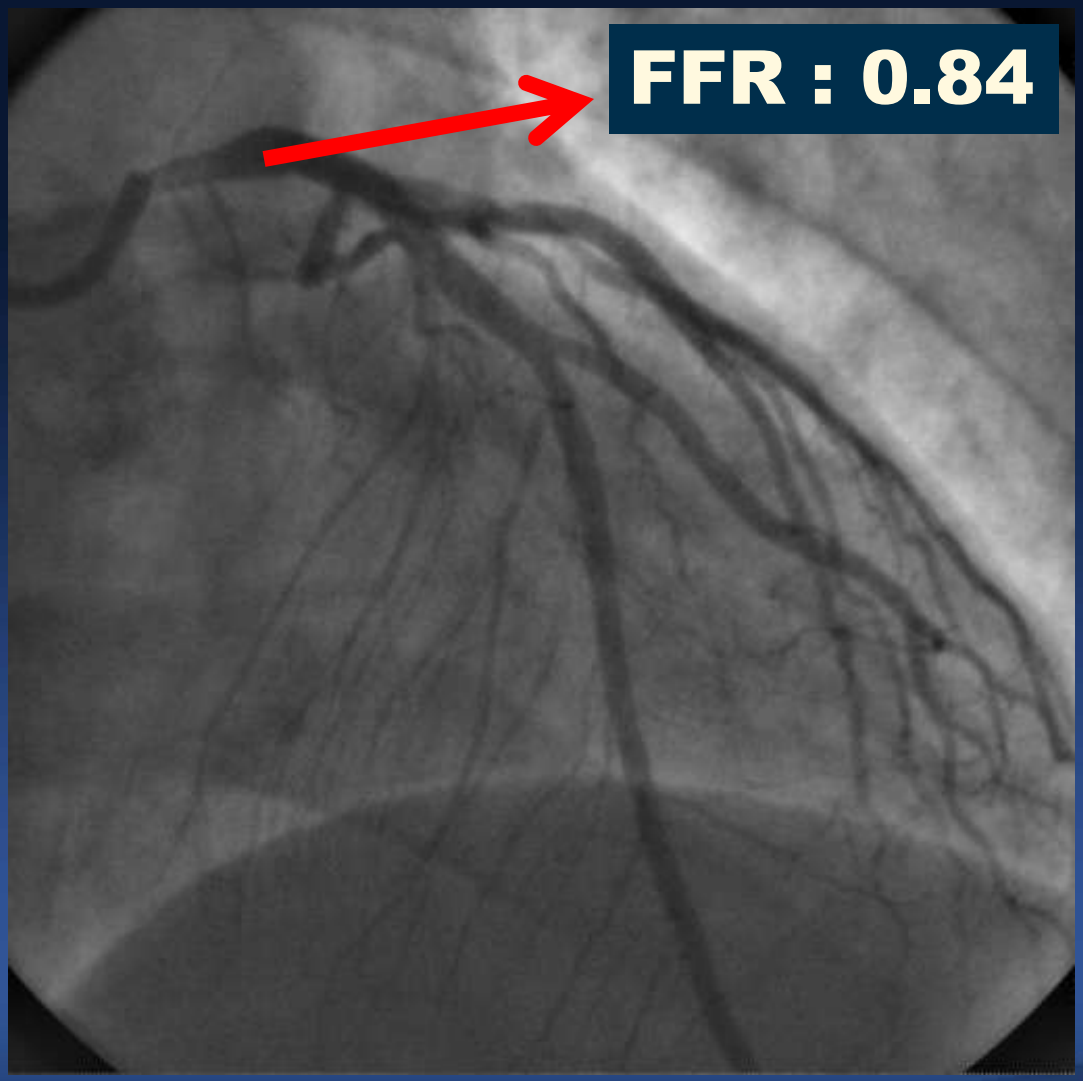


Free From Angina

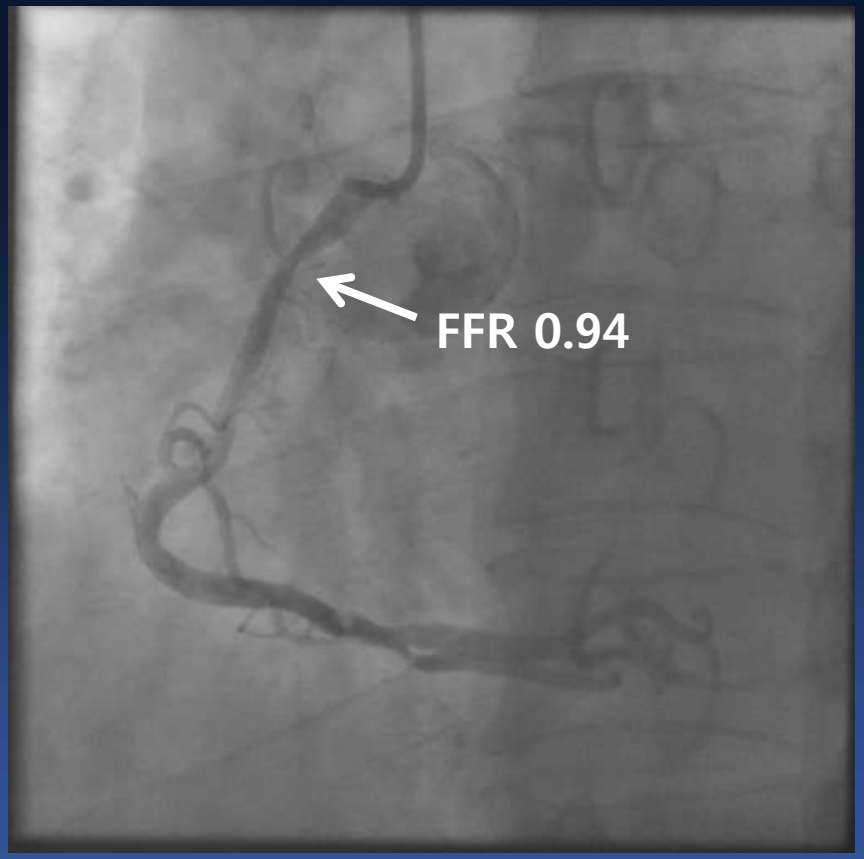


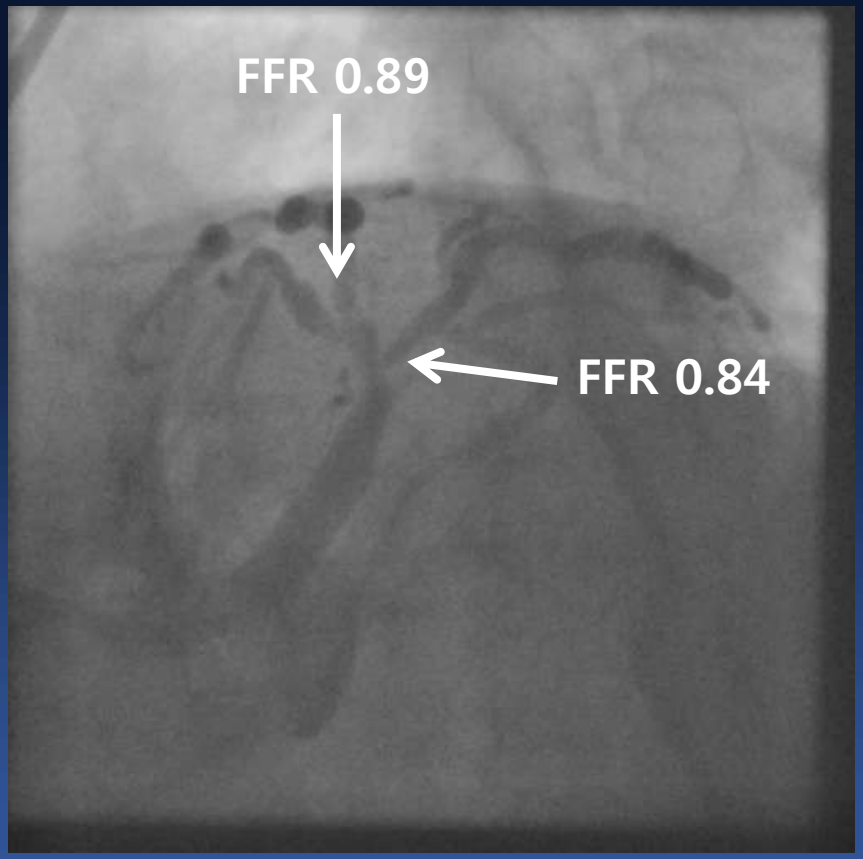
J Am Coll Cardiol 2010;56:177–84

LM Disease



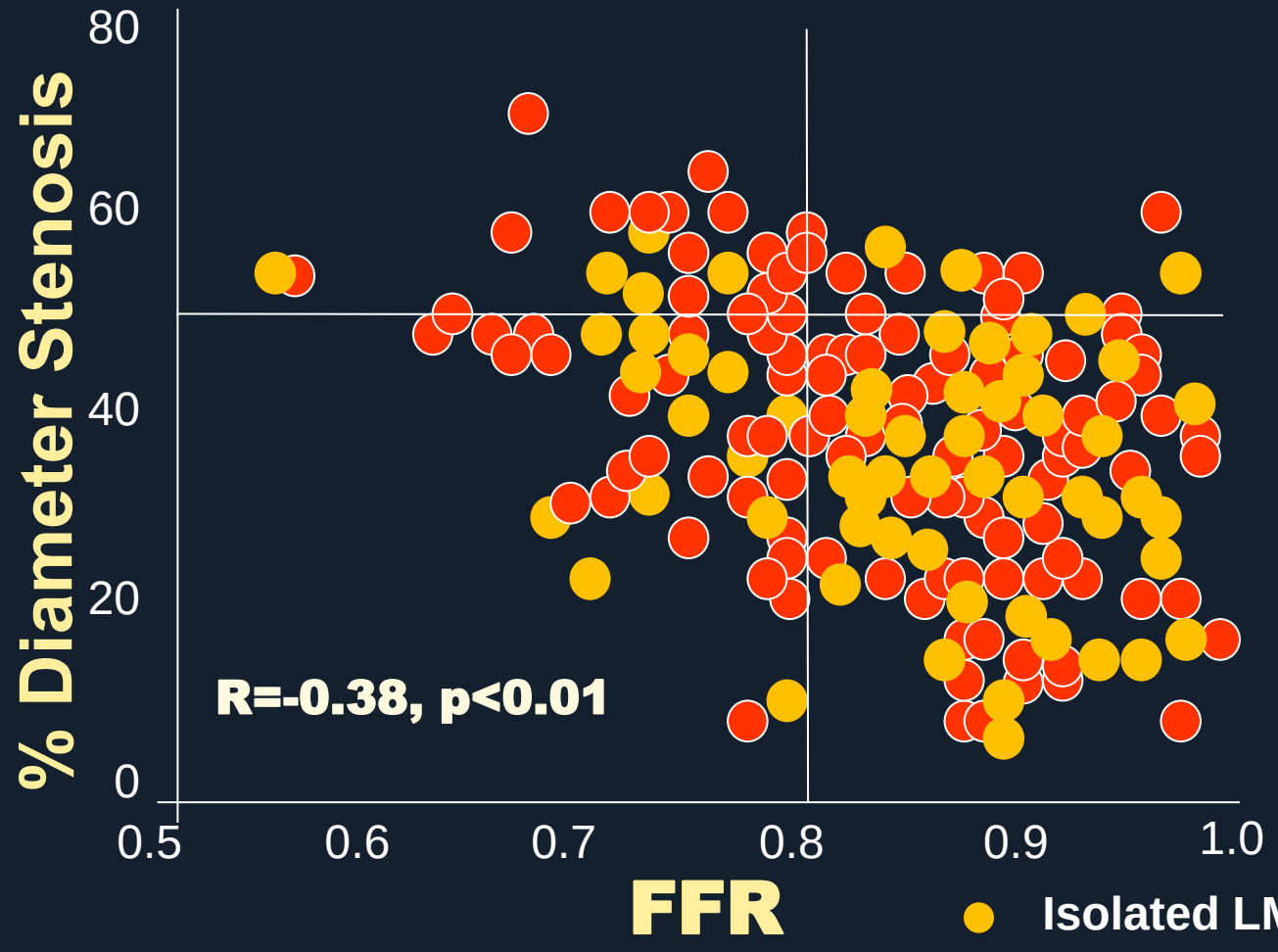
LM with 3VD





FFR of the Equivocal LMCA

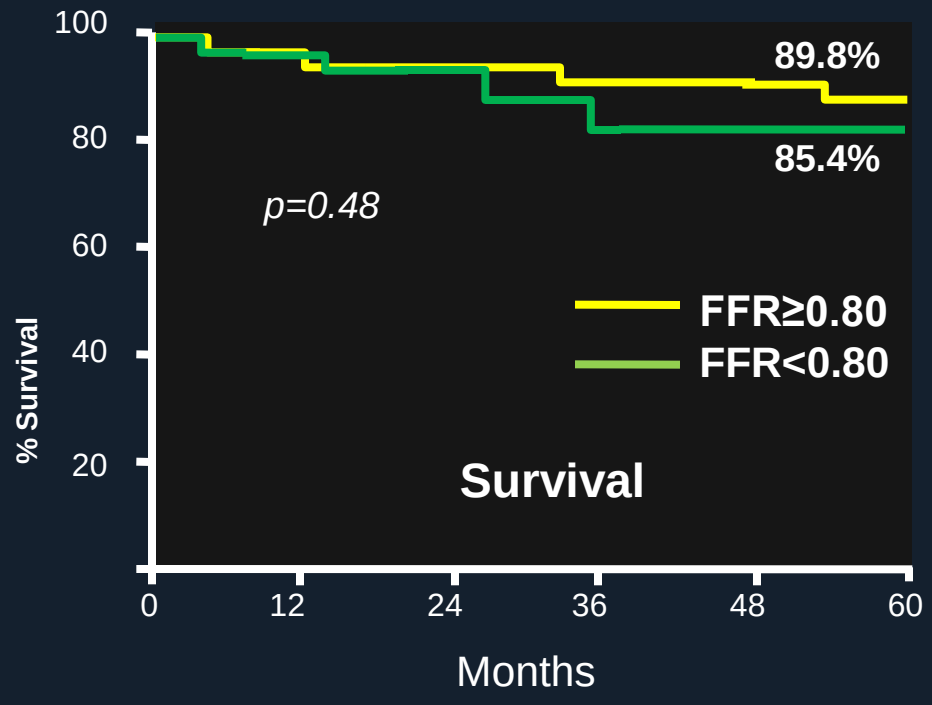
"Mismatch" is 29% in equivocal LMCA

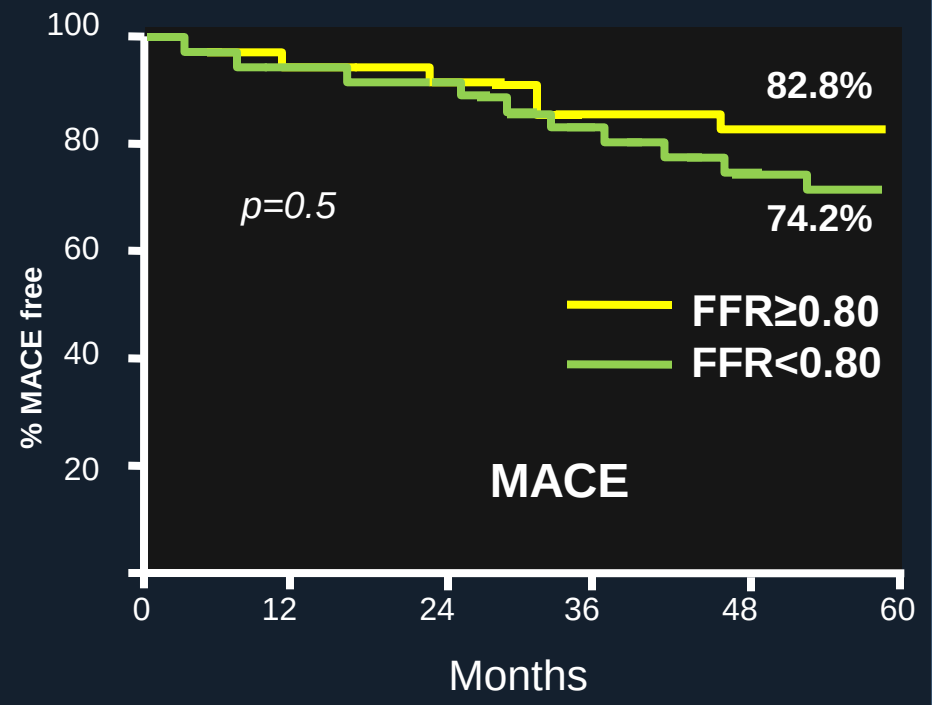


Circulation 2009;120:1505-1512

FFR guided PCI in Equivocal LMCA

- In 213 patients with an equivocal LMCA stenosis
- FFR ≥0.80: DEFER (n=138) vs. FFR<0.80: CABG (n=75)

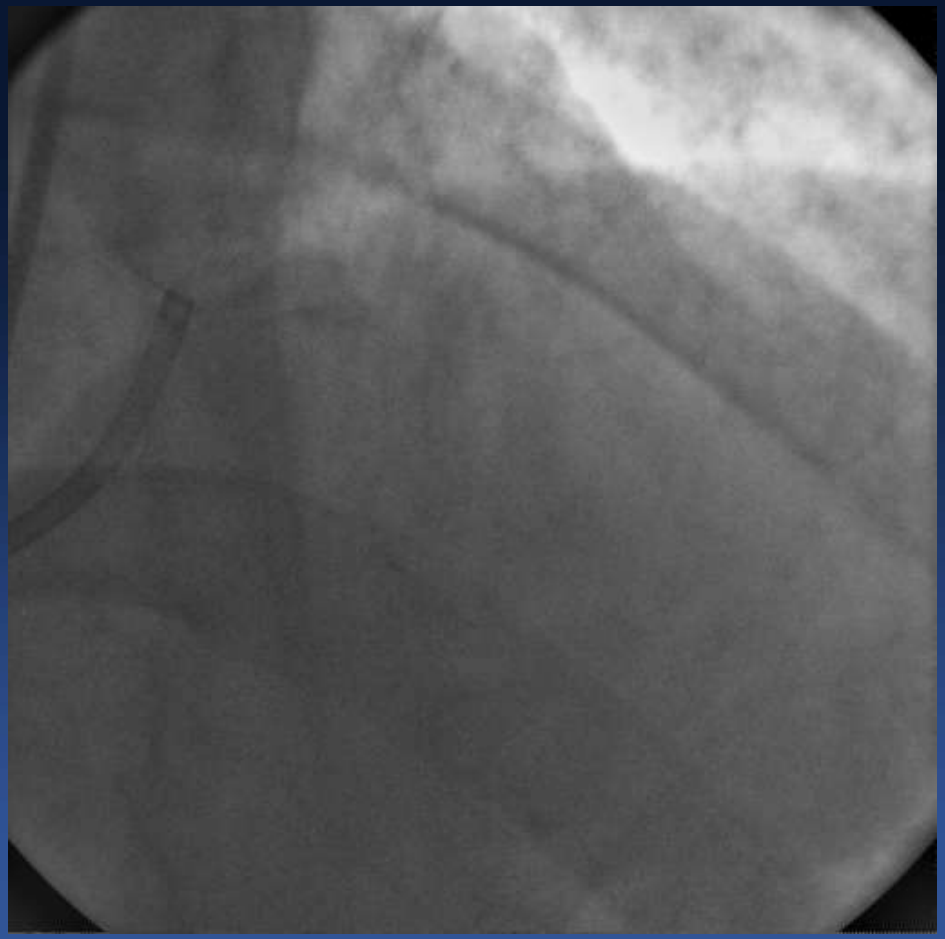




An FFR-guided strategy showed the favorable outcome.

Circulation. 2009;120:1505-1512

Coronary Angiogram



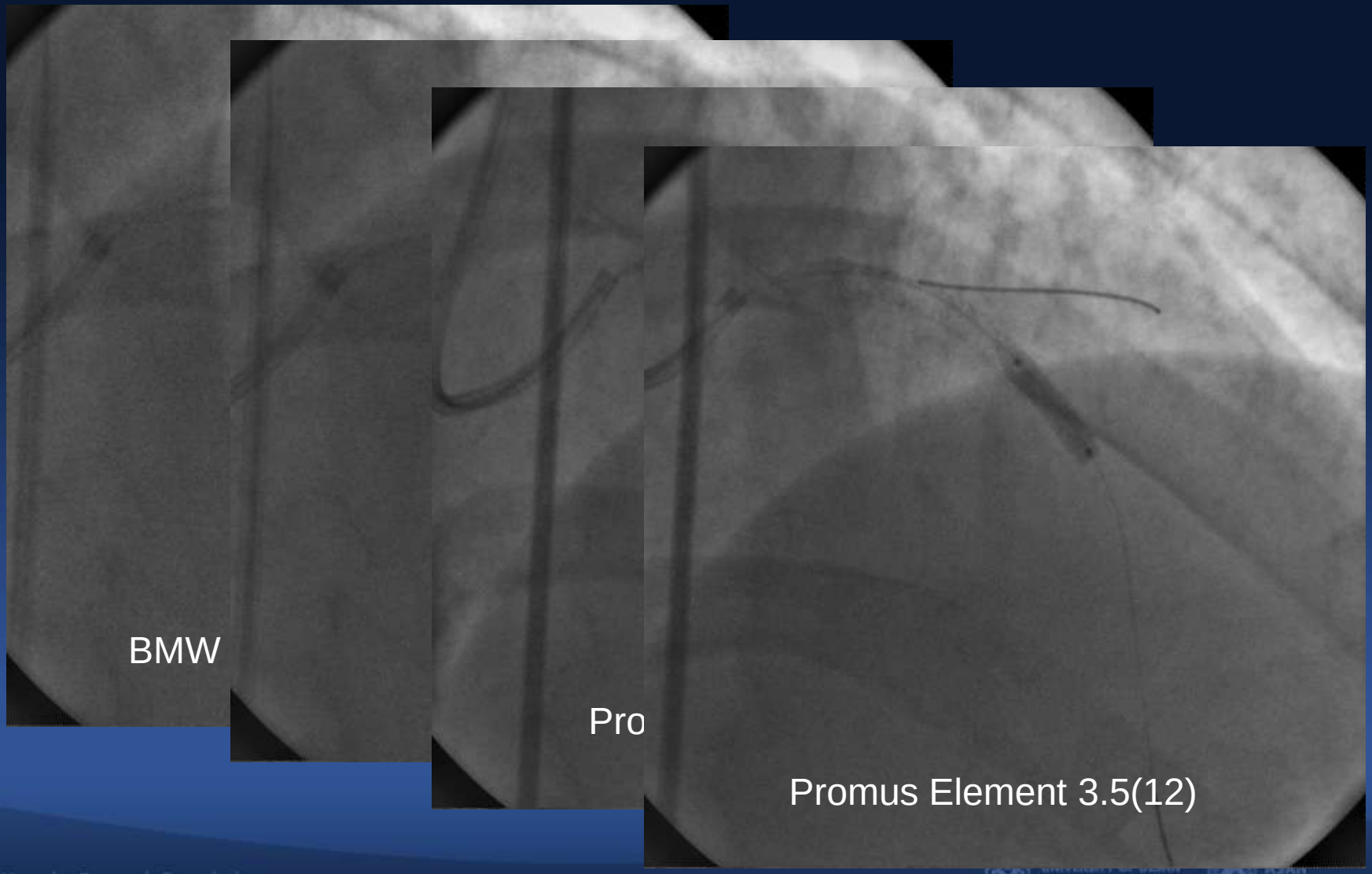
LAD FFR

0.71

How to Treat?

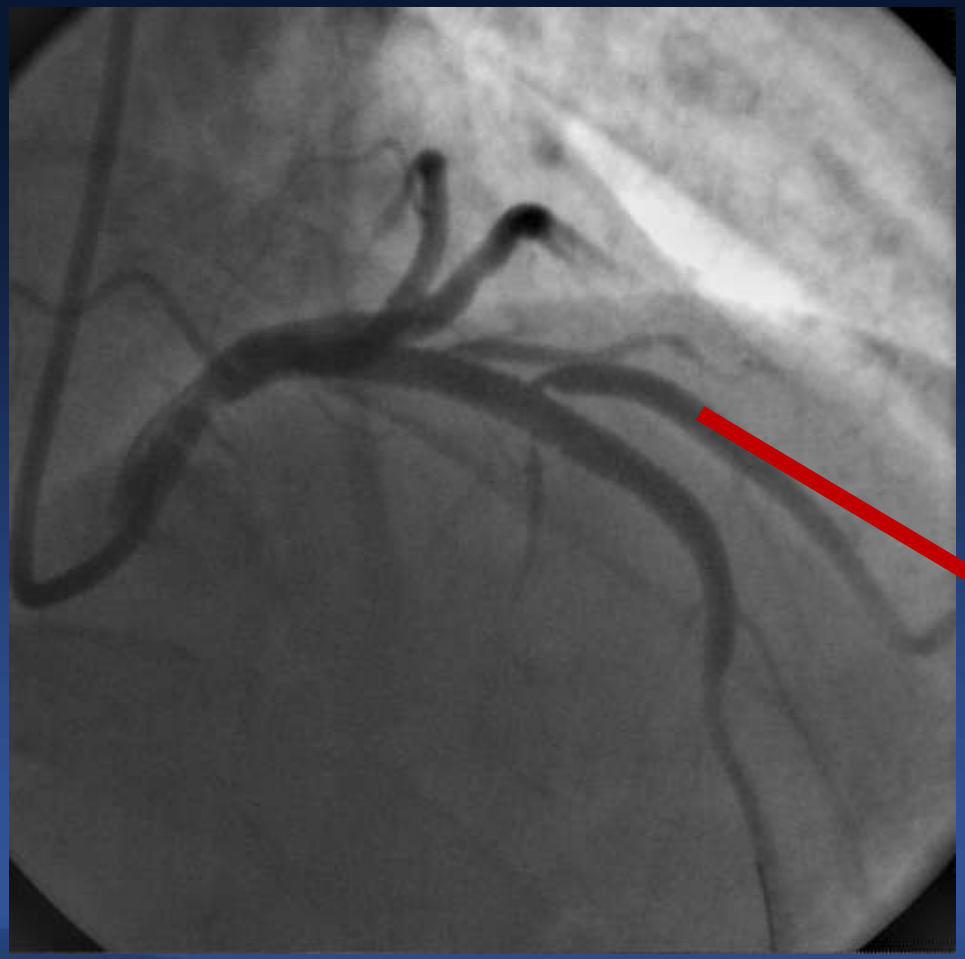
- Simple cross over ?
- Two stent technique ?
- Side branch protection ?

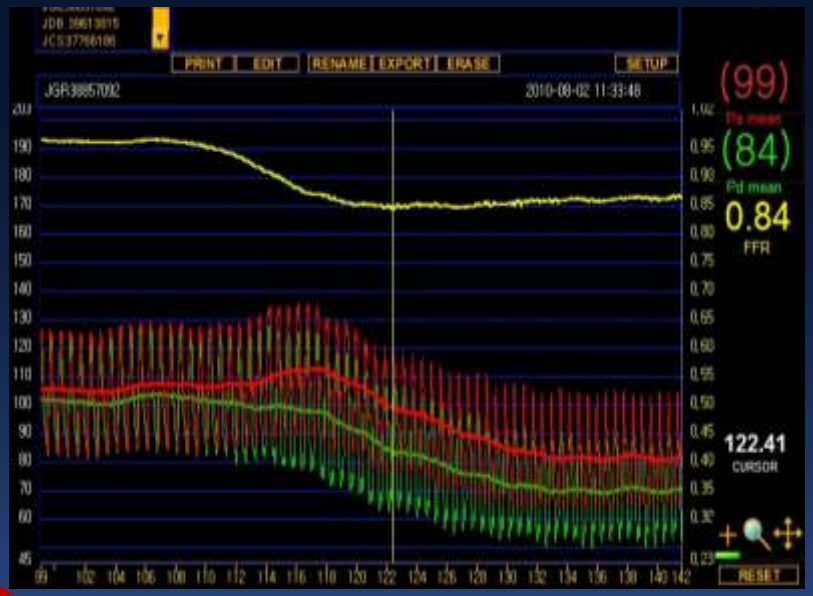
Procedure



After Stent at Main Vessel

What Would You Do?



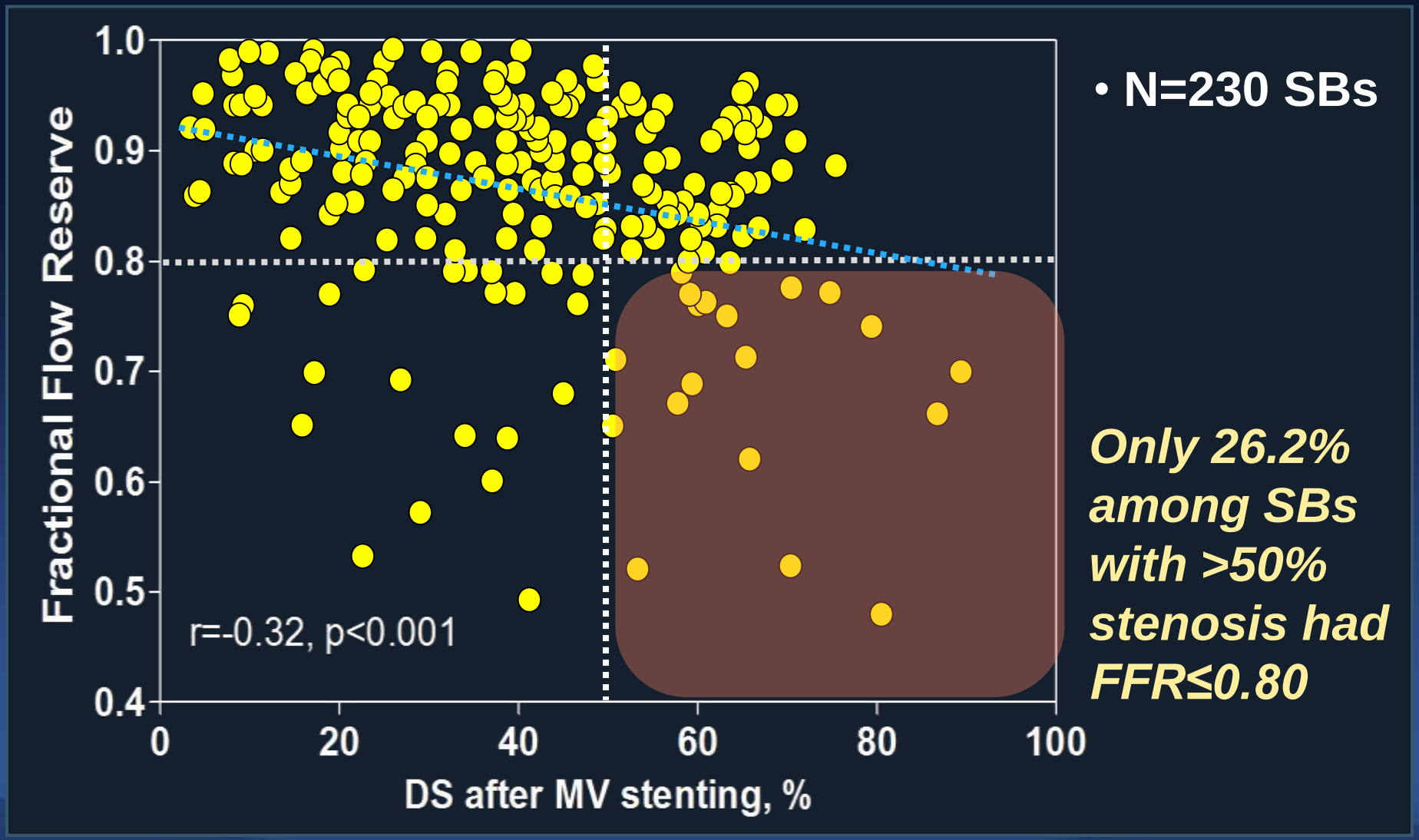


FFR 0.84

Leave it alone.

FFR of the Jailed Side Branch

By Using Dedicated Bifurcation QCA



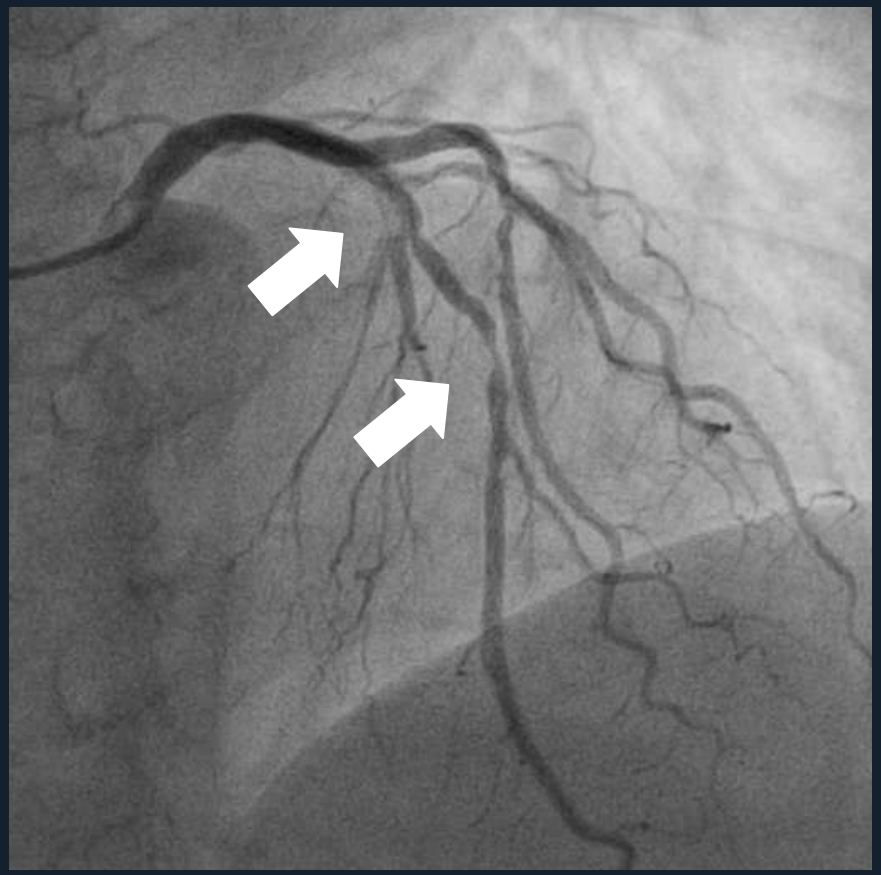
- N=230 SBs

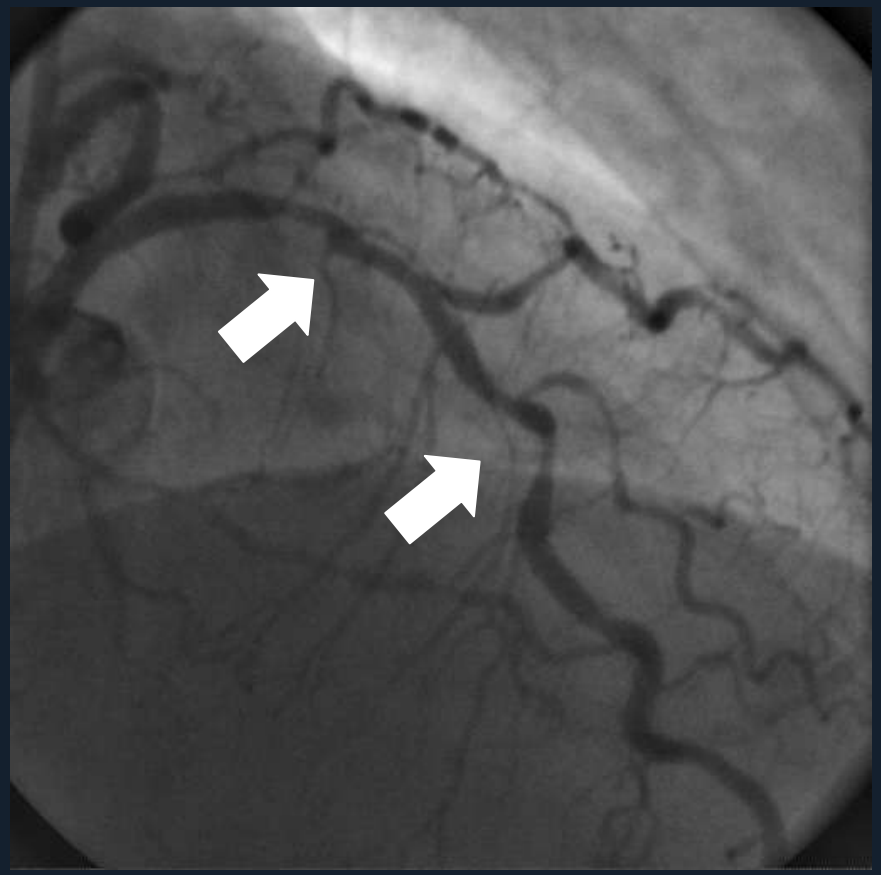
Only 26.2% among SBs with >50% stenosis had FFR≤0.80

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

Coronary Tandem Lesions

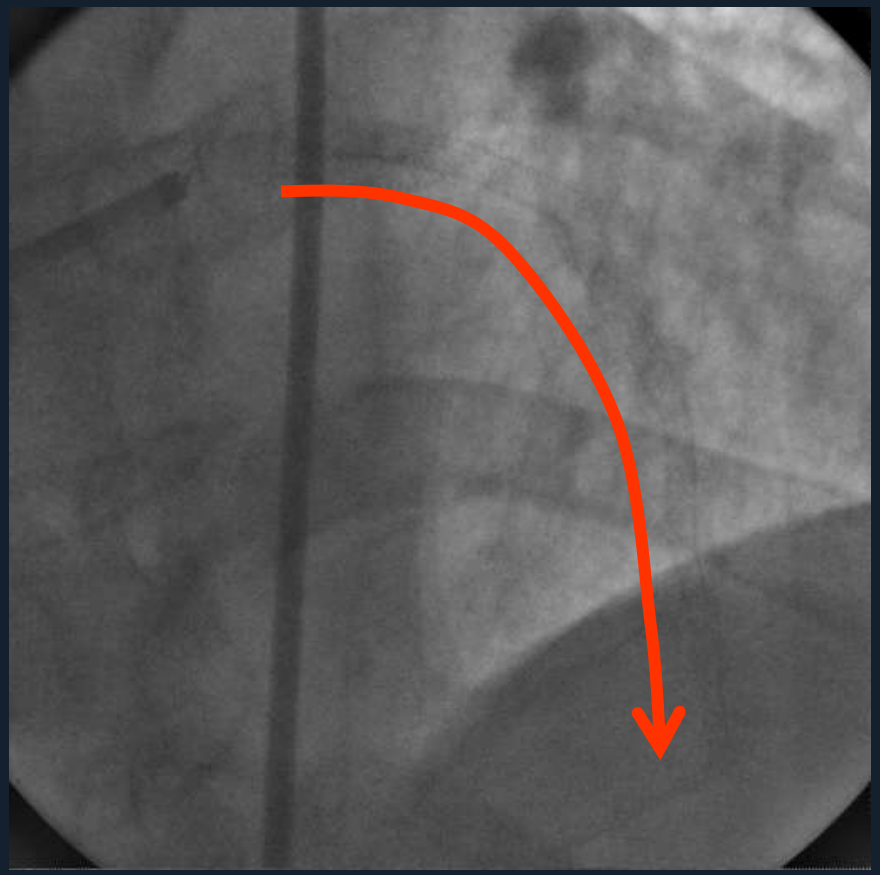
Multiple stenoses in series along one coronary artery



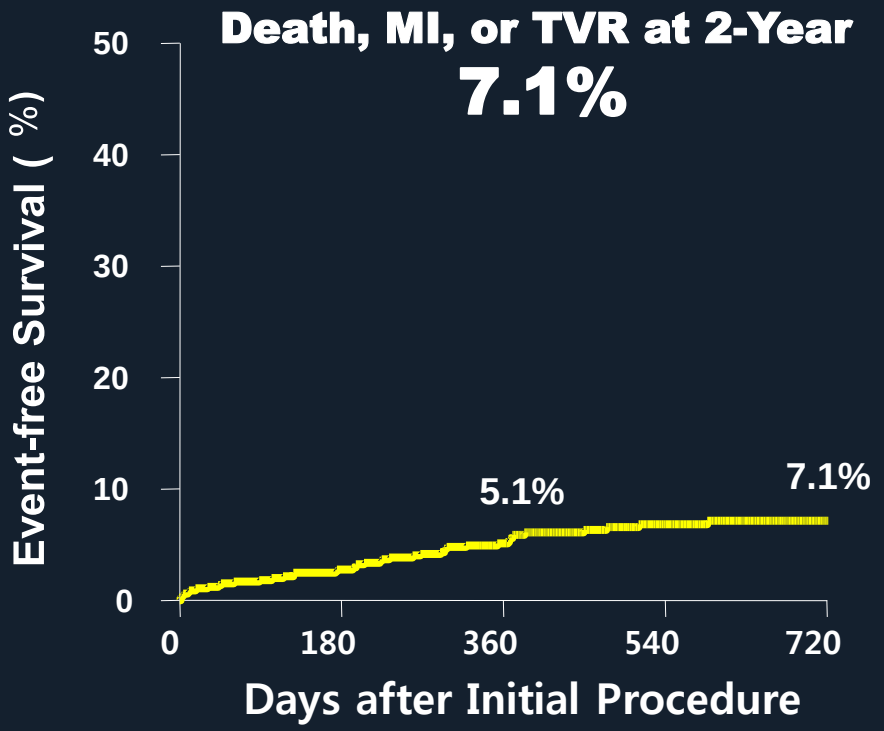


“Full Metal Jacket”

Multiple or overlapping stent implantation



Event rate is Quite acceptable…

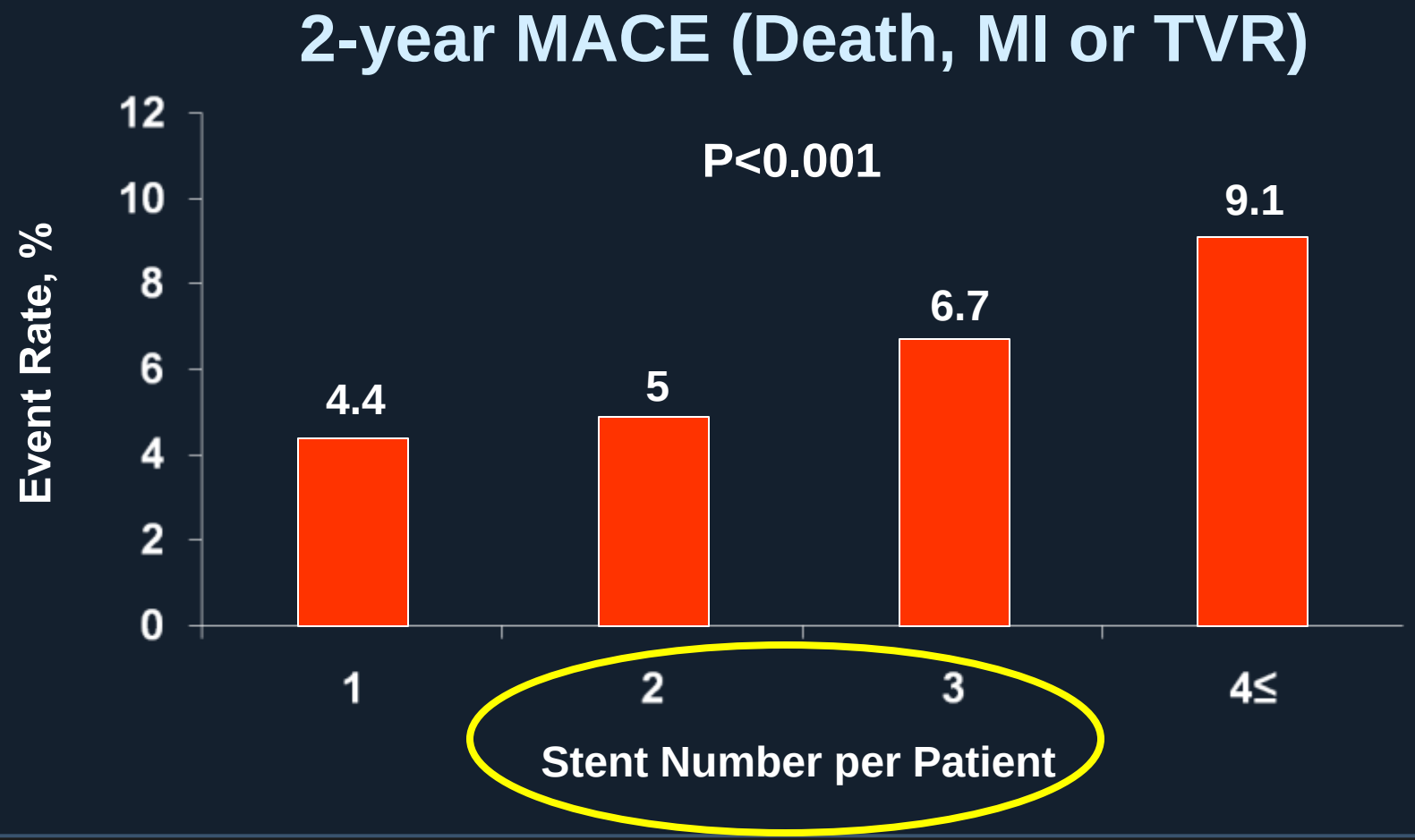


* The unpublished data from the IRIS-DES registry

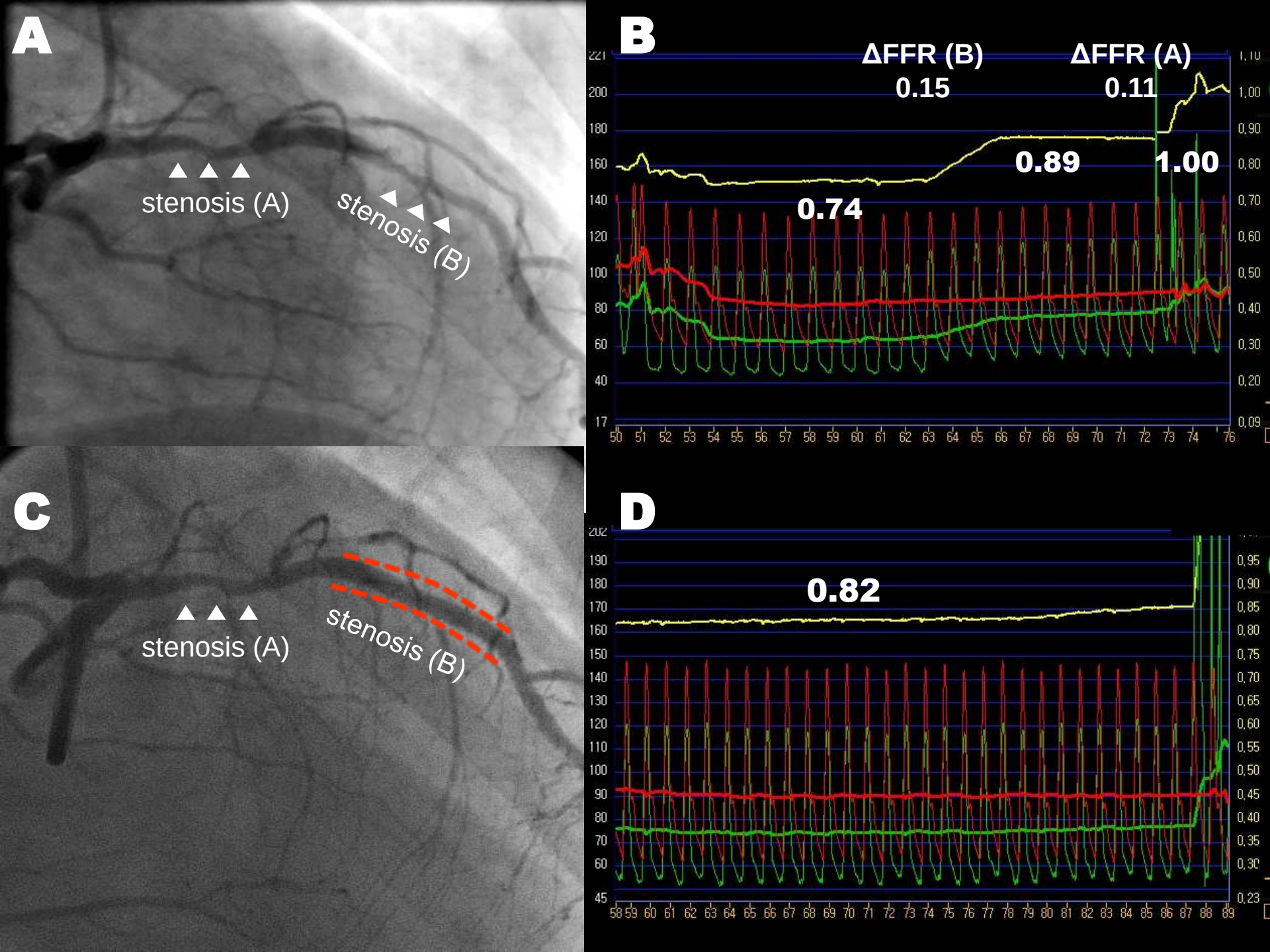
“Full Metal Jacket”

Multiple or overlapping stent implantation

However, Still…



* The unpublished data from the IRIS-DES registry


A
stenosis (A)
stenosis (B)
B
ΔFFR (B)
0.15
ΔFFR (A)
0.11
0.89
1.00
0.74
C
stenosis (A)
stenosis (B)
D
0.82

The Use of FFR

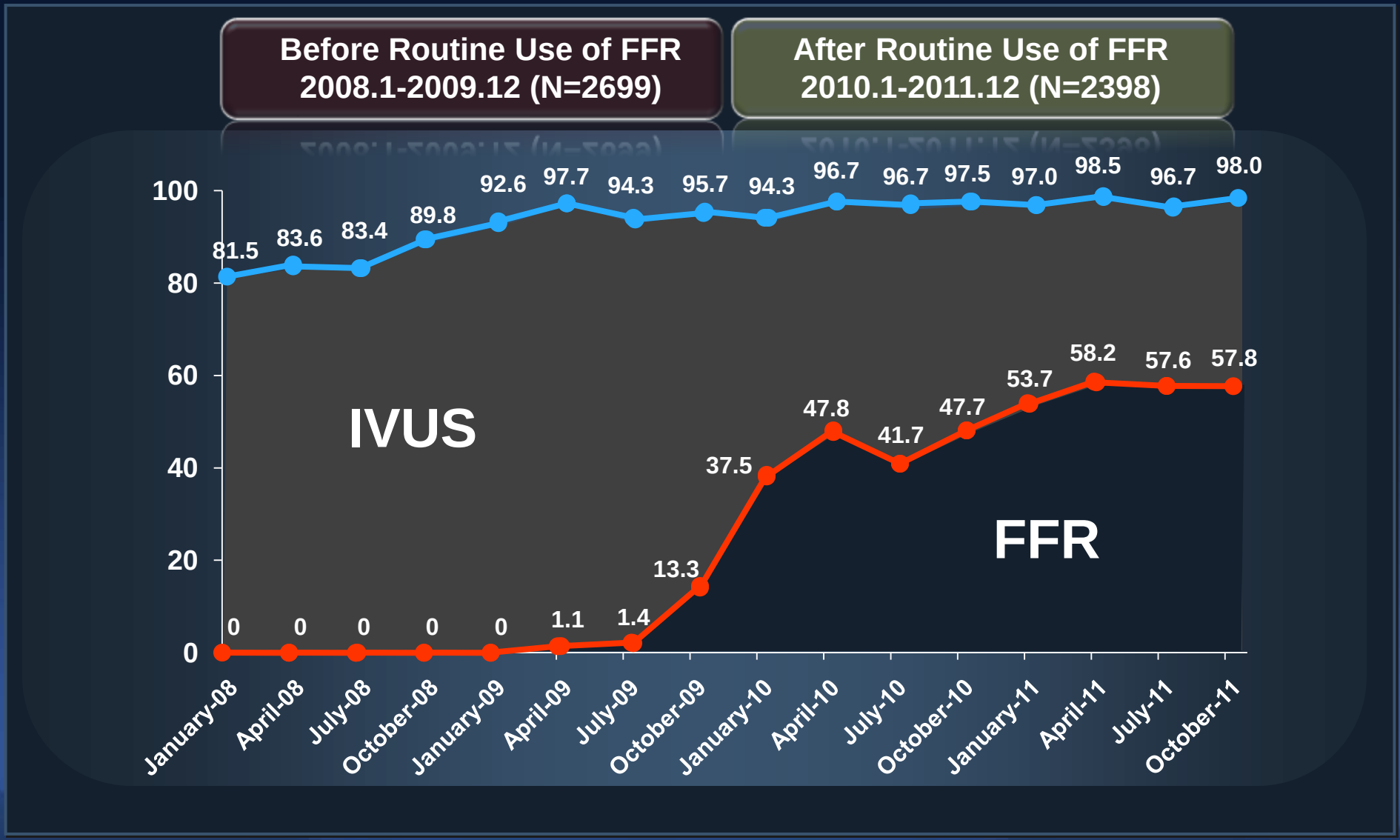
• Single Vessel Stenting	• Deferral of PCI under OMT
• Multivessel Stenting	• Single Vessel Stenting
• Complex Bifurcation Stenting	• Simple Bifurcation Stenting
• Full Metal Jacket	• Selected Stent Implantation

For the complex coronary anatomy, meticulous functional evaluation may lead to identify the simpler functional stenosis than the anatomical stenosis, which can avoid the complex and unnecessary coronary intervention strategy and related complications.

Routine FFR Guided PCI

How to Change Our PCI Practice

Rate of FFR and IVUS Use



What is the Routine Use?

Reasons for FFR not measured Between 2010 and 2011

	N=1183 (%)
Tight stenosis (visual estimated diameter stenosis>80%) or total occlusion	1115 (94.3)
Stenosis evaluated by non-invasive functional study	225 (19.0)
Unfavorable anatomy (e.g. severe calcified and/or tortuous vessel) or unstable hemodynamics for FFR measurement	75 (6.3)
Stenosis supplying small myocardium	47 (4.0)
No-specific reasons identified	**43 (3.6)**

ASAN PCI Registry

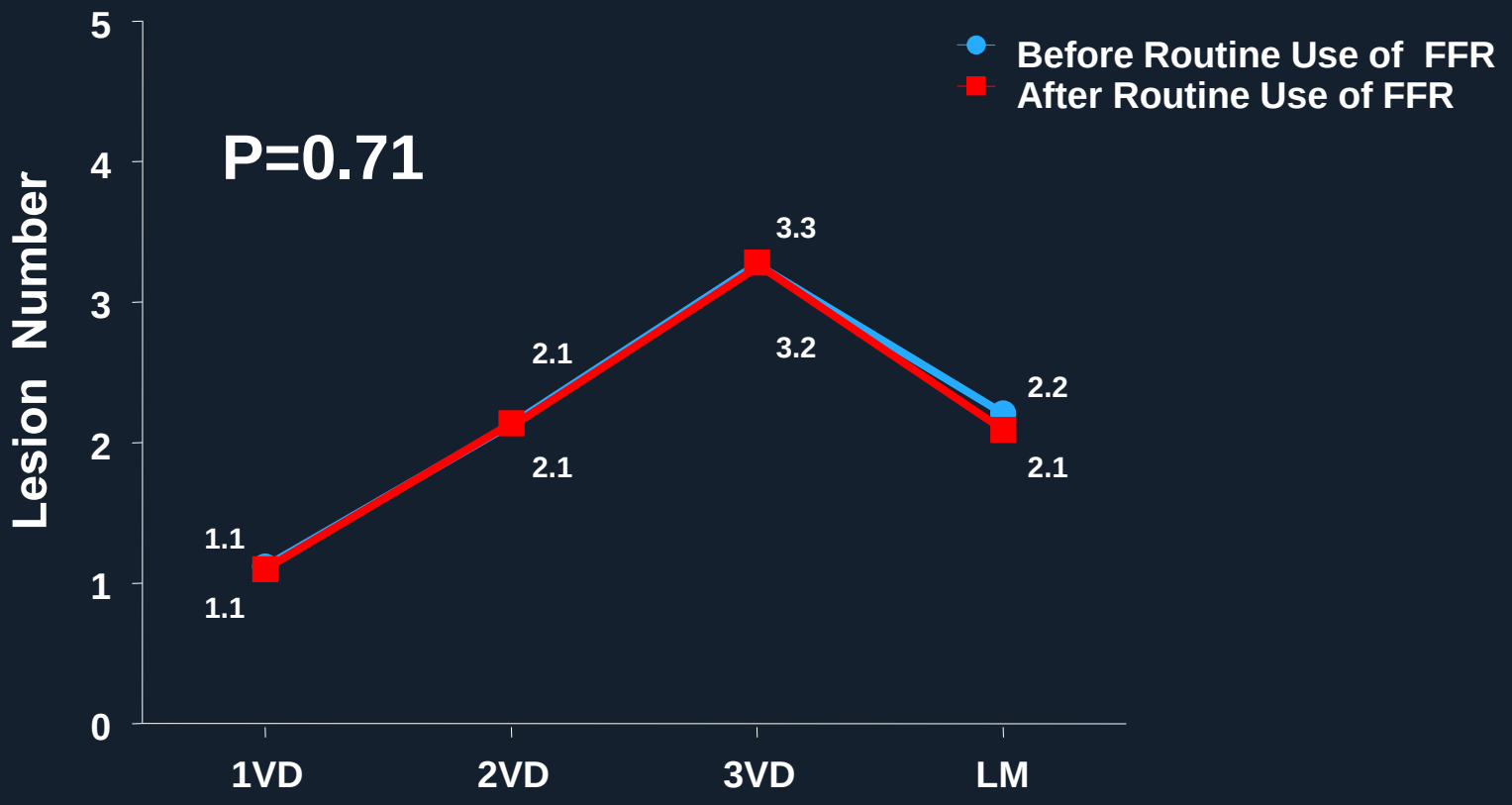
Total population: 5097 Patients

Propensity Matched Pairs: 2178 Pairs

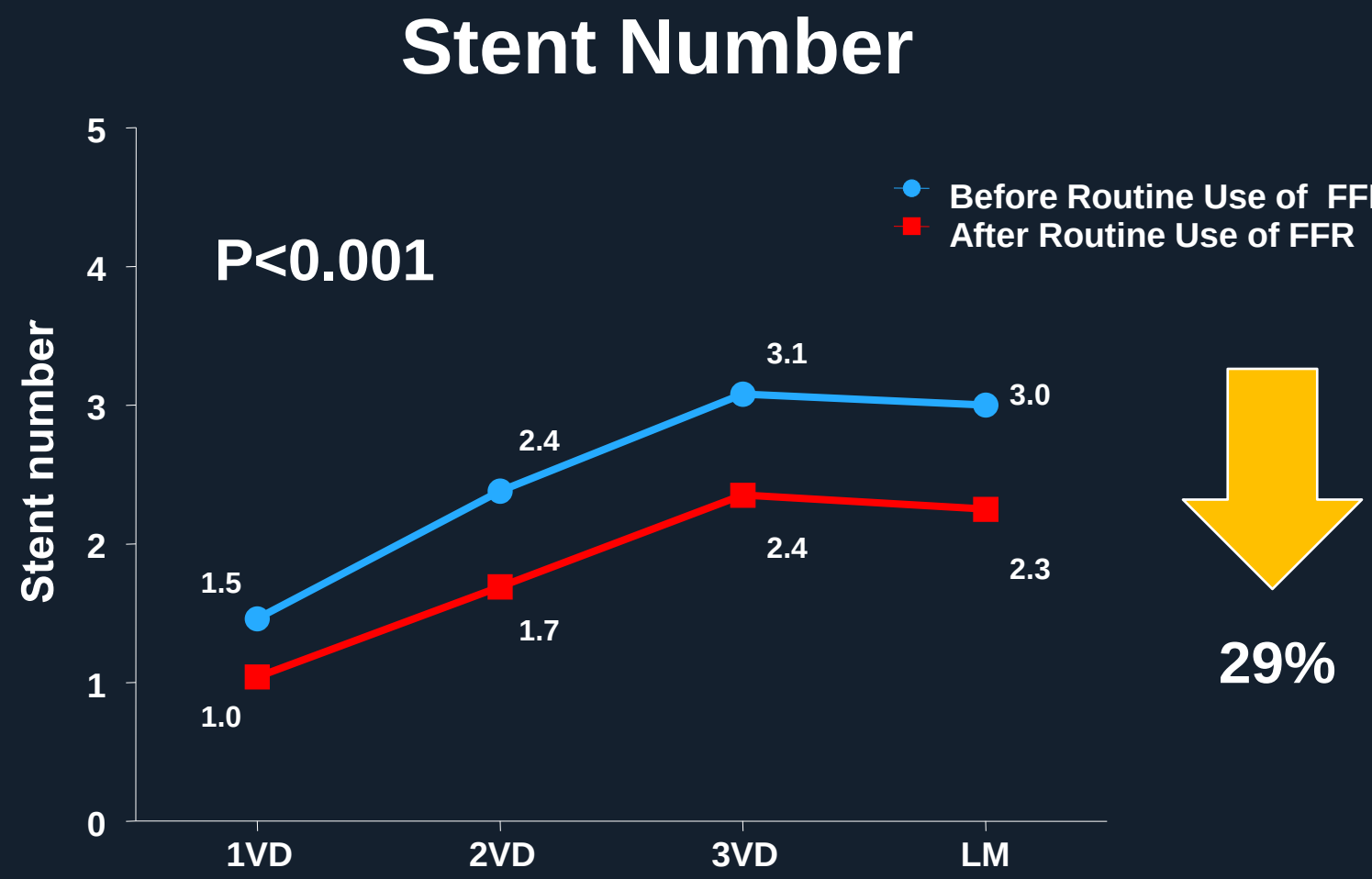
Park SJ, Ahn JM et al. Eur Heart J. 2013 Nov;34(43):3353-61

Changes in PCI procedure

Lesion Number

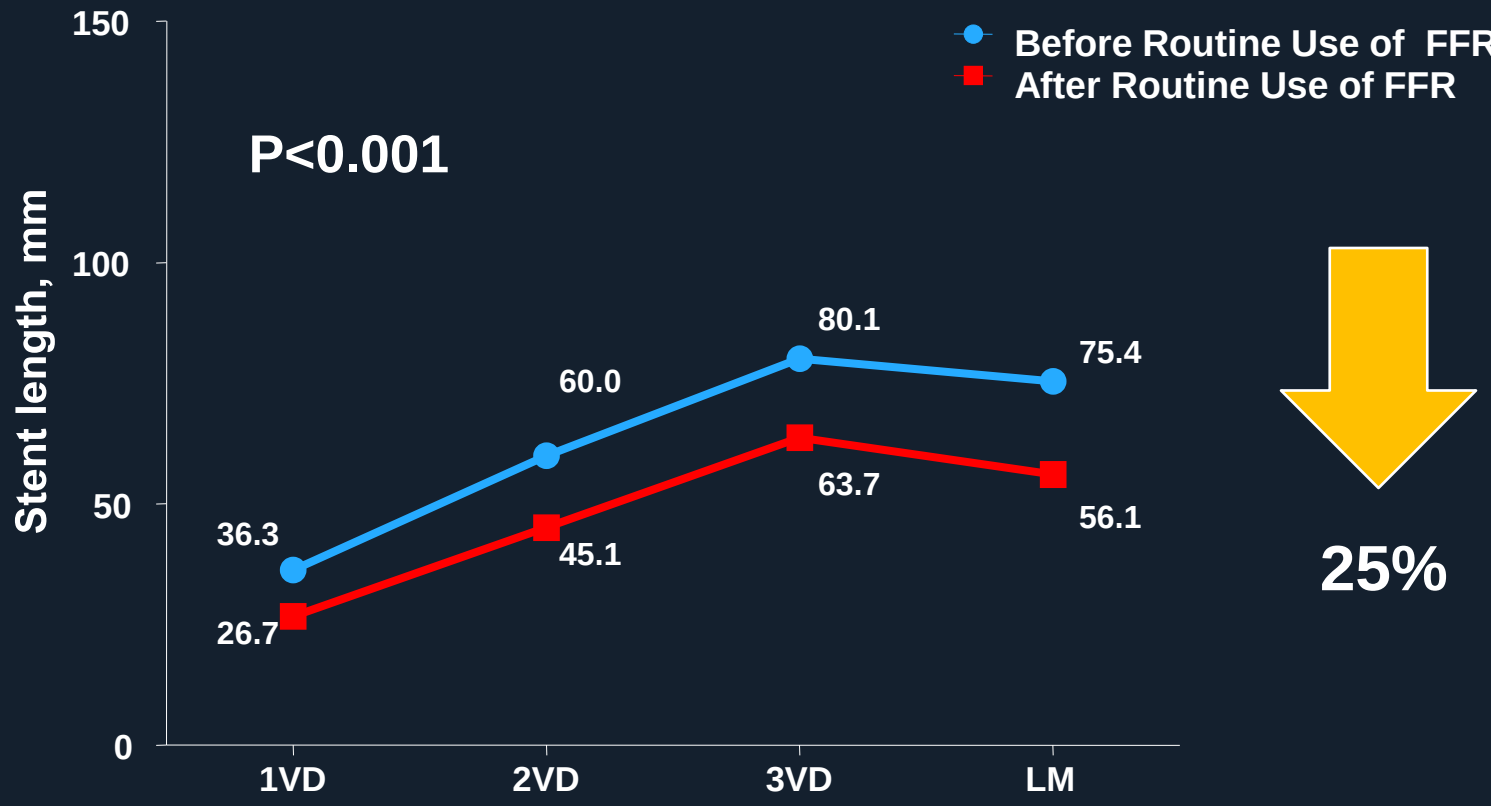


Changes in PCI procedure



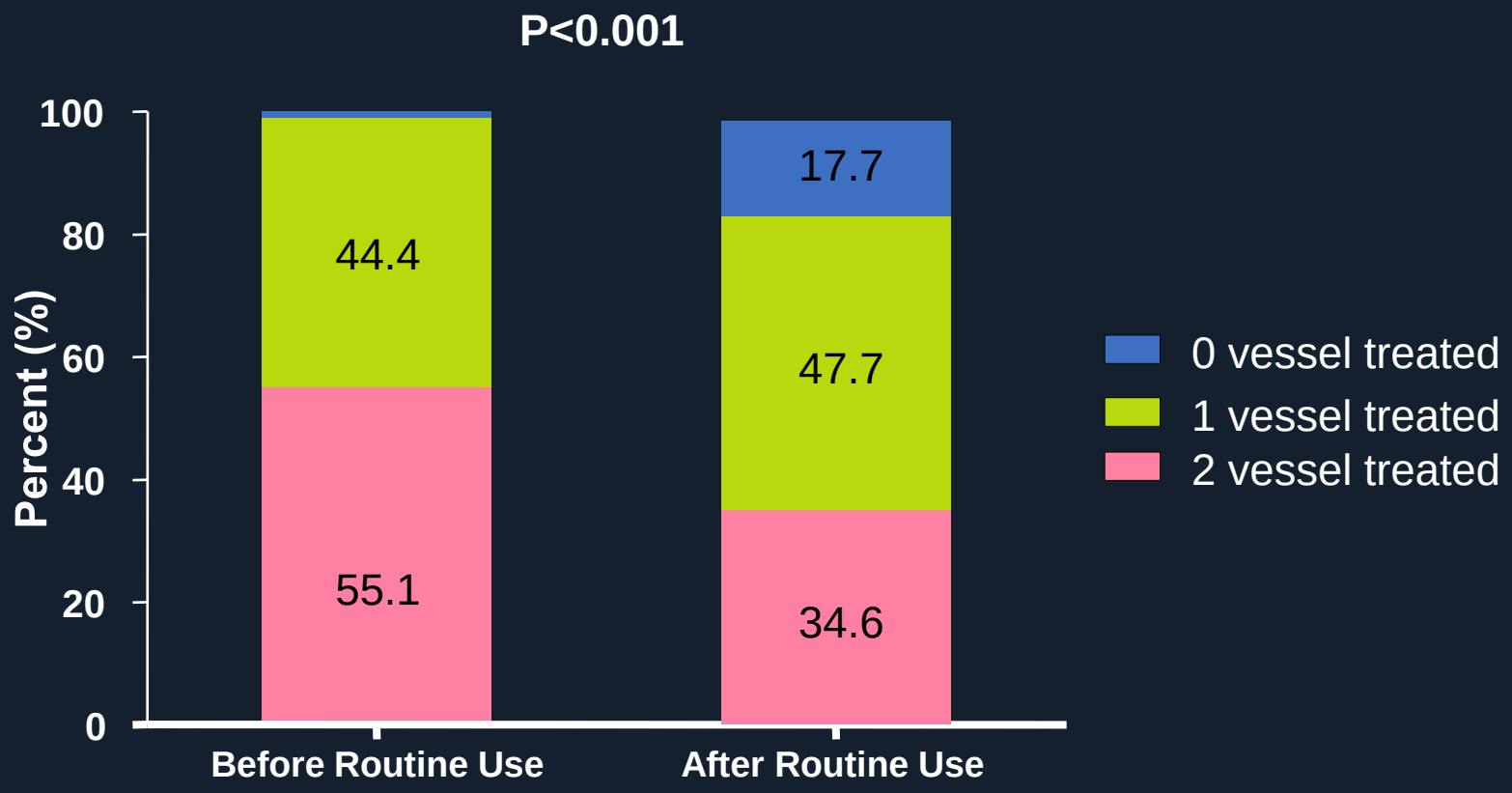
Changes in PCI procedure

Stent Length

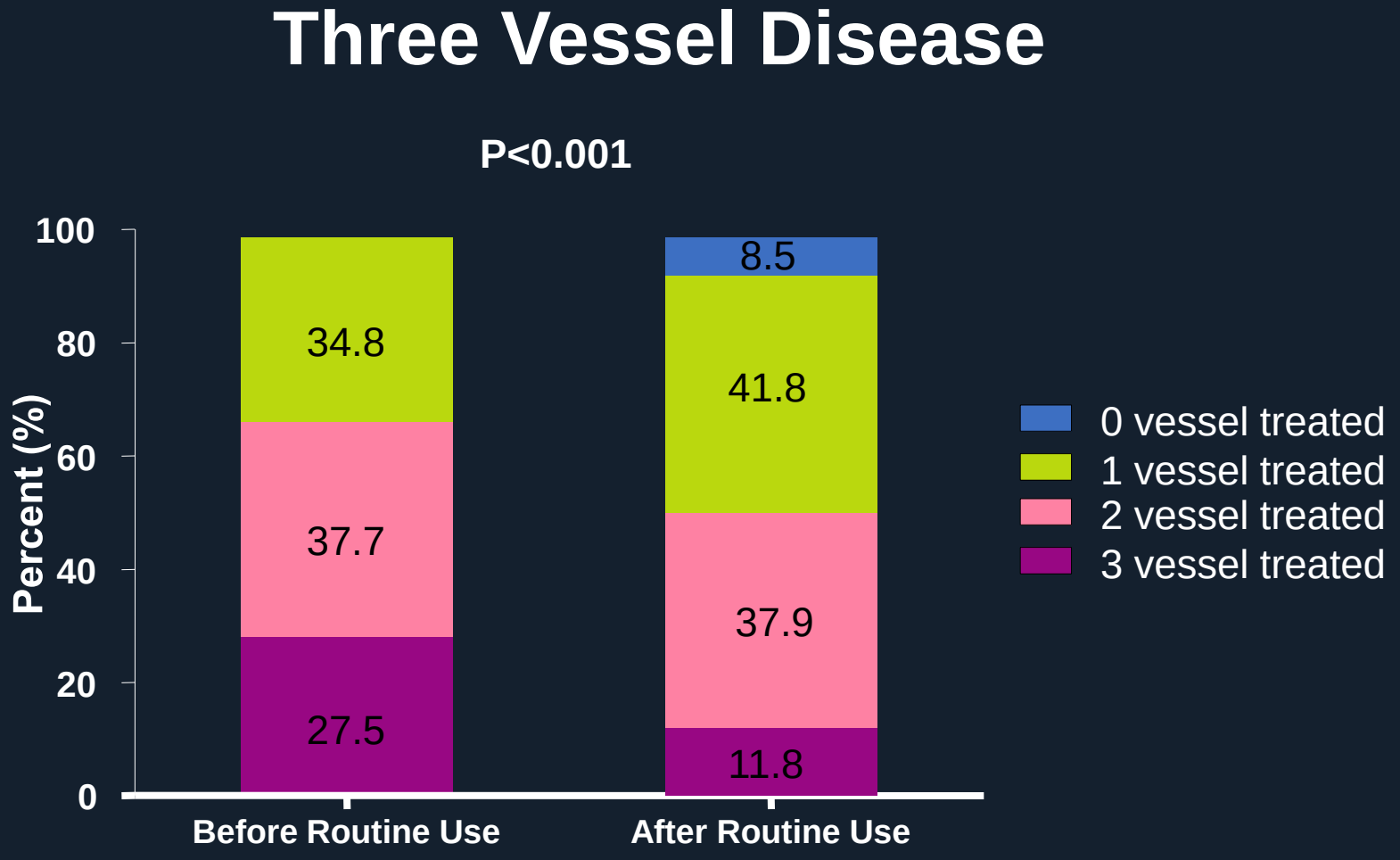


Changes in PCI procedure

Two Vessel Disease

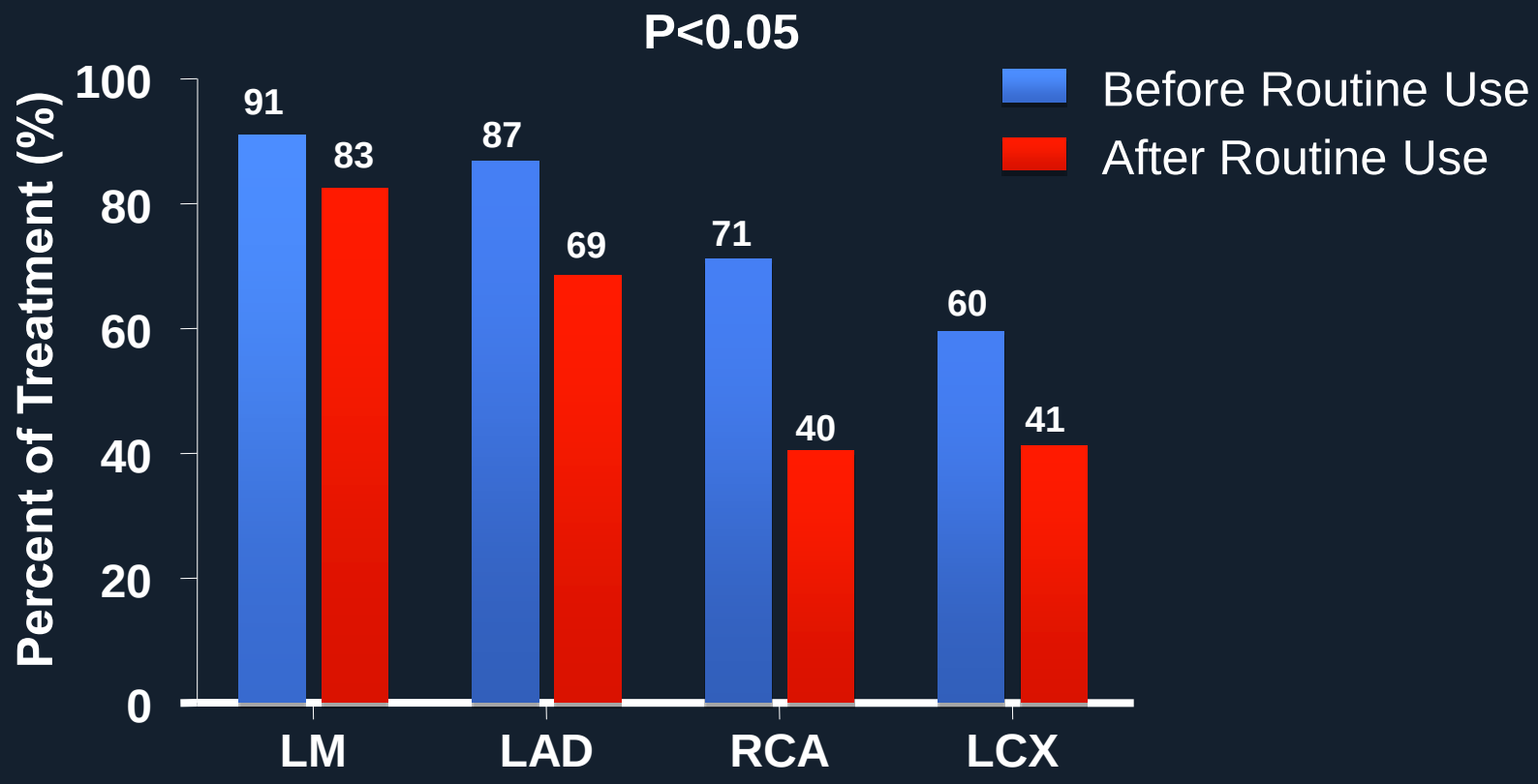


Changes in PCI procedure

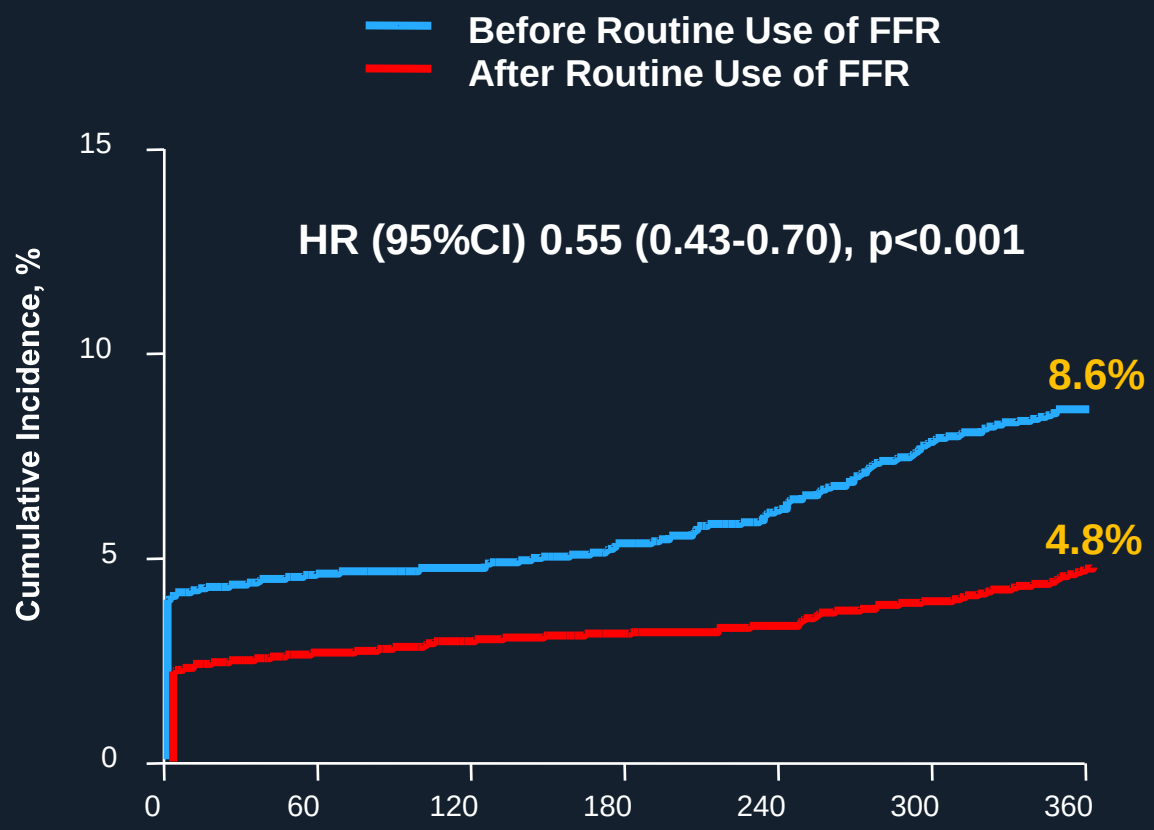


Changes in PCI procedure

Diseased Vessel Territory

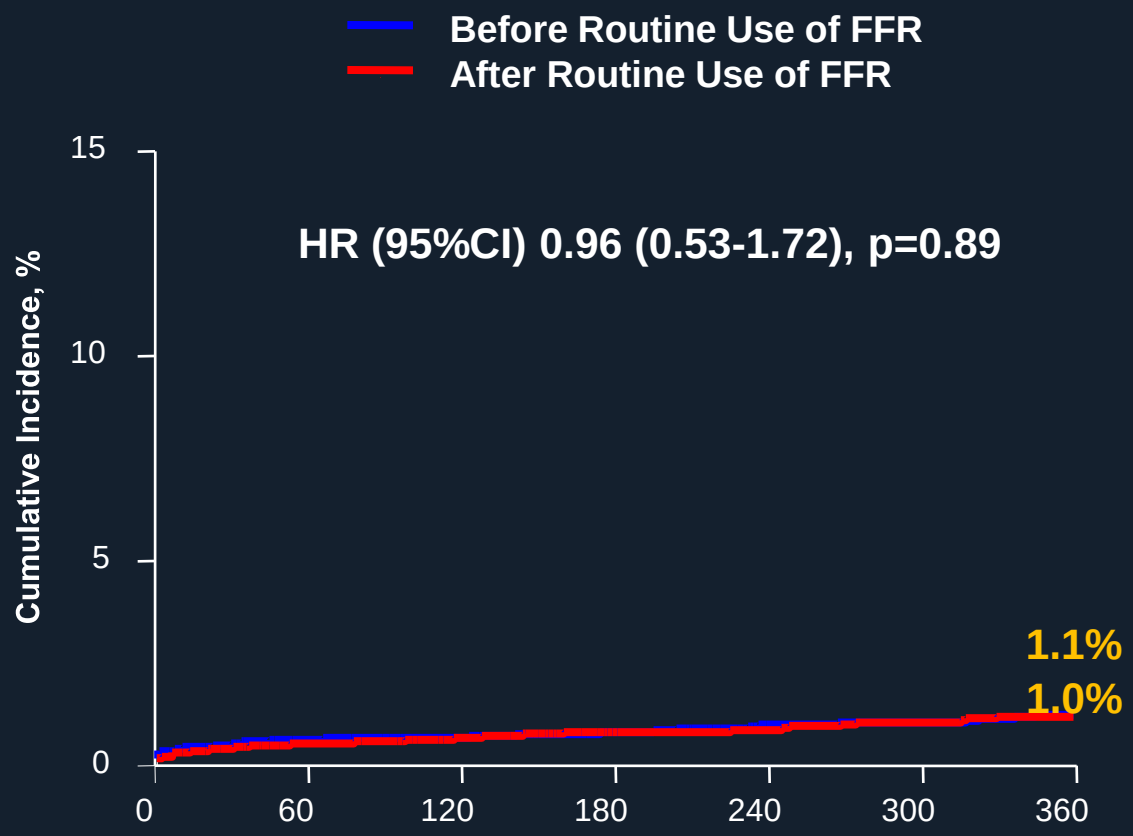


Primary End Point
(Death, MI, or Repeat Revascularization)



No. at Risk				
Before Routine Use	2178	2066	2011	1960
After Routine Use	2178	2092	2067	2037

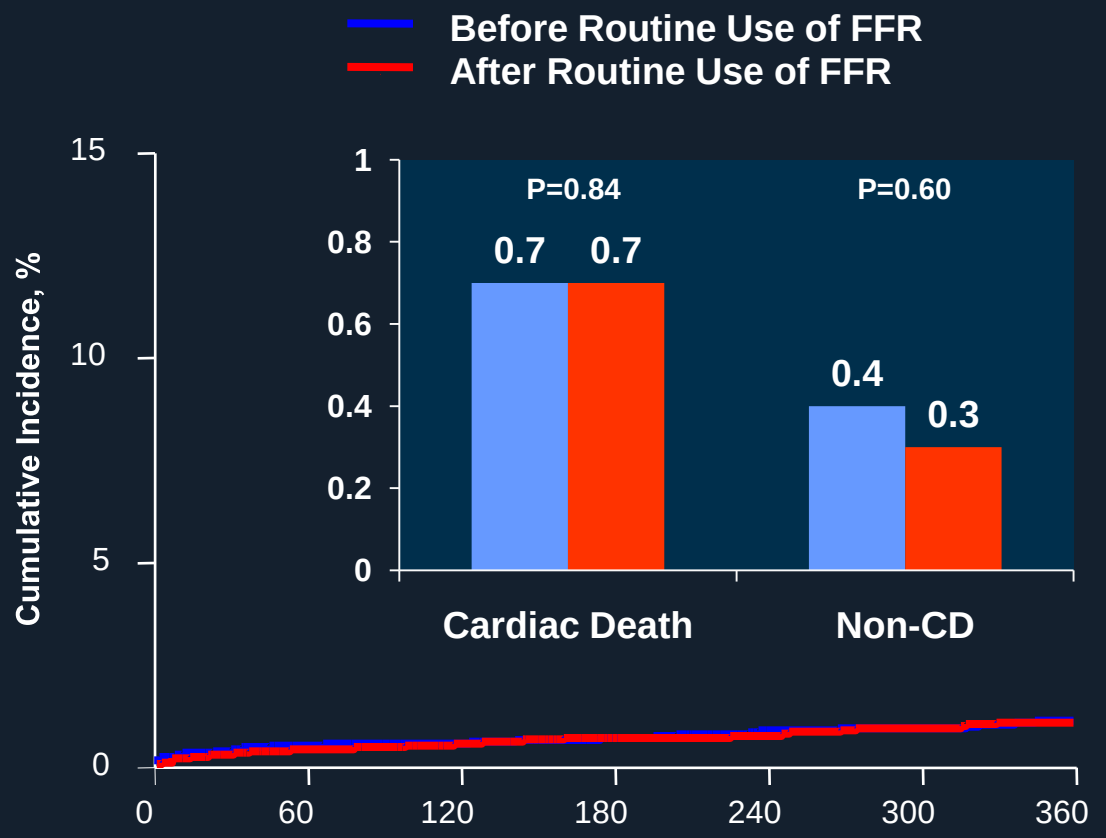
Death



No. at Risk

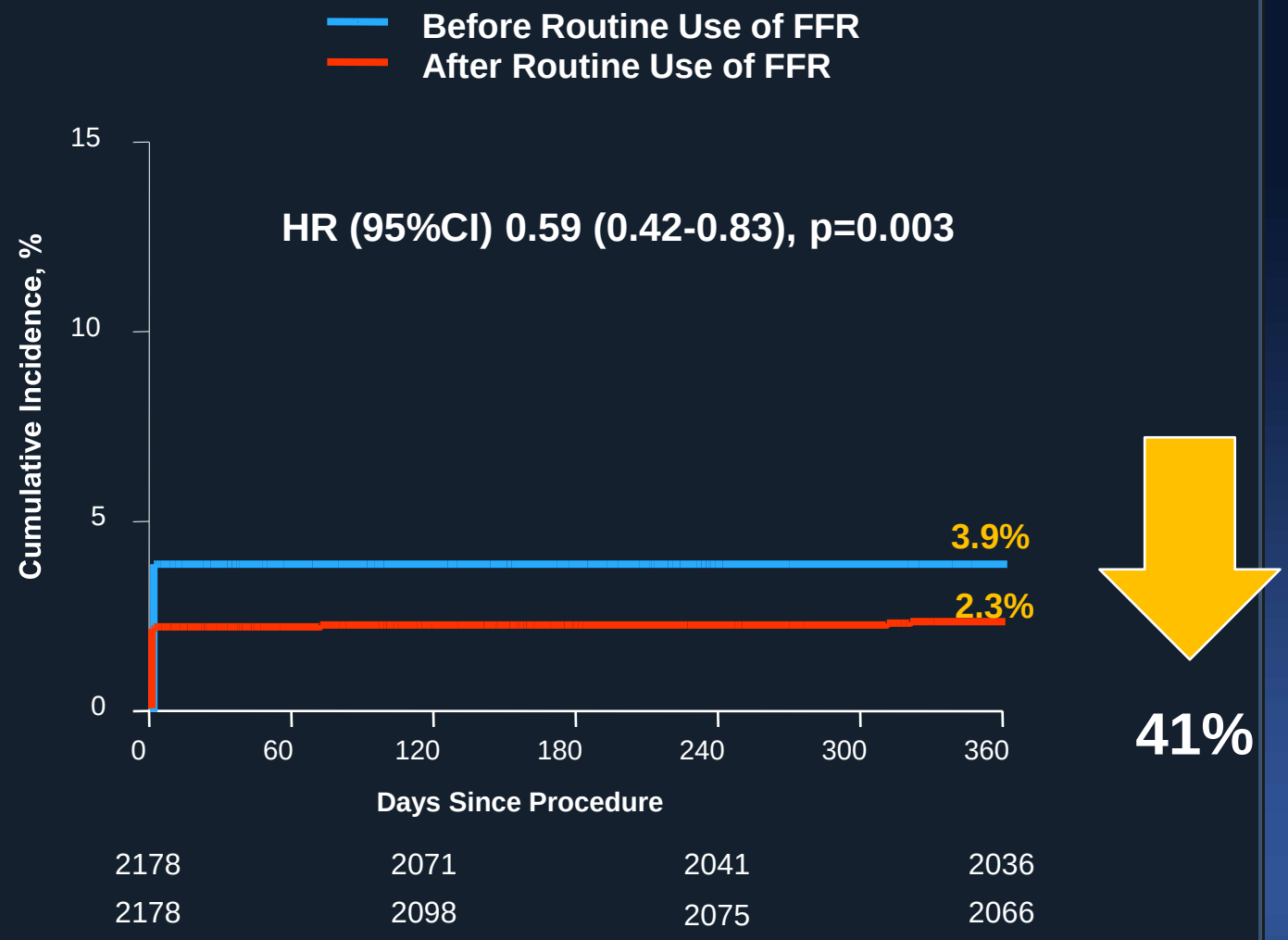
Before Routine Use	2178	2156	2126	2121
After Routine Use	2178	2143	2120	2113

Death



No. at Risk				
Before Routine Use	2178	2156	2126	2121
After Routine Use	2178	2143	2120	2113

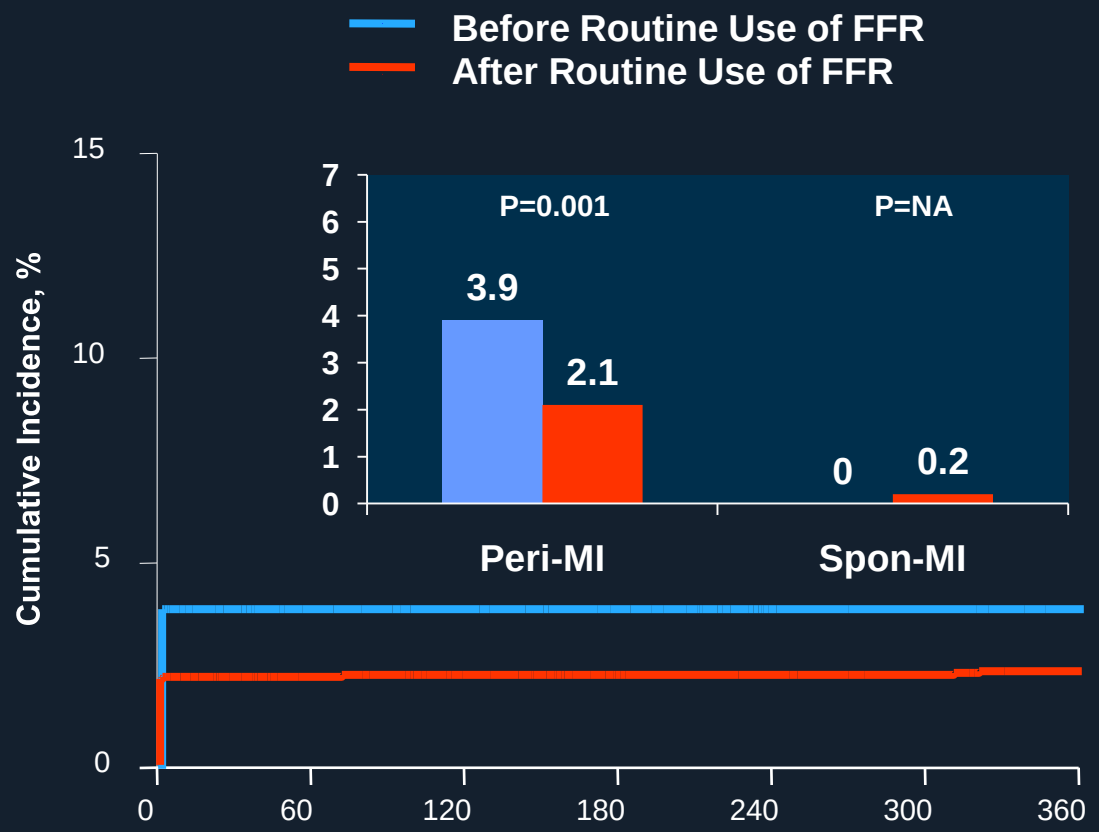
Myocardial Infarction



No. at Risk

Before Routine Use	2178	2071	2041	2036
After Routine Use	2178	2098	2075	2066

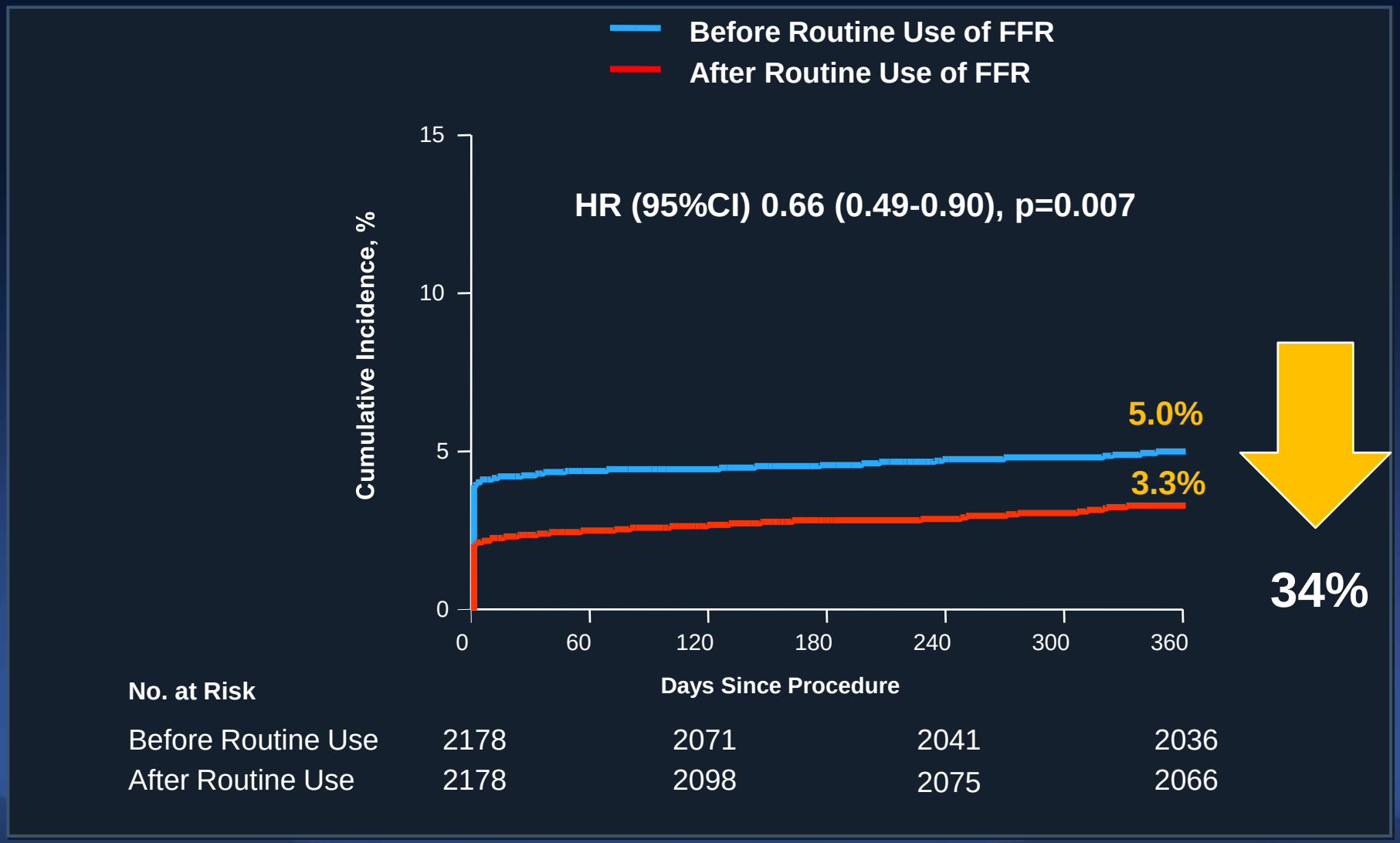
Myocardial Infarction



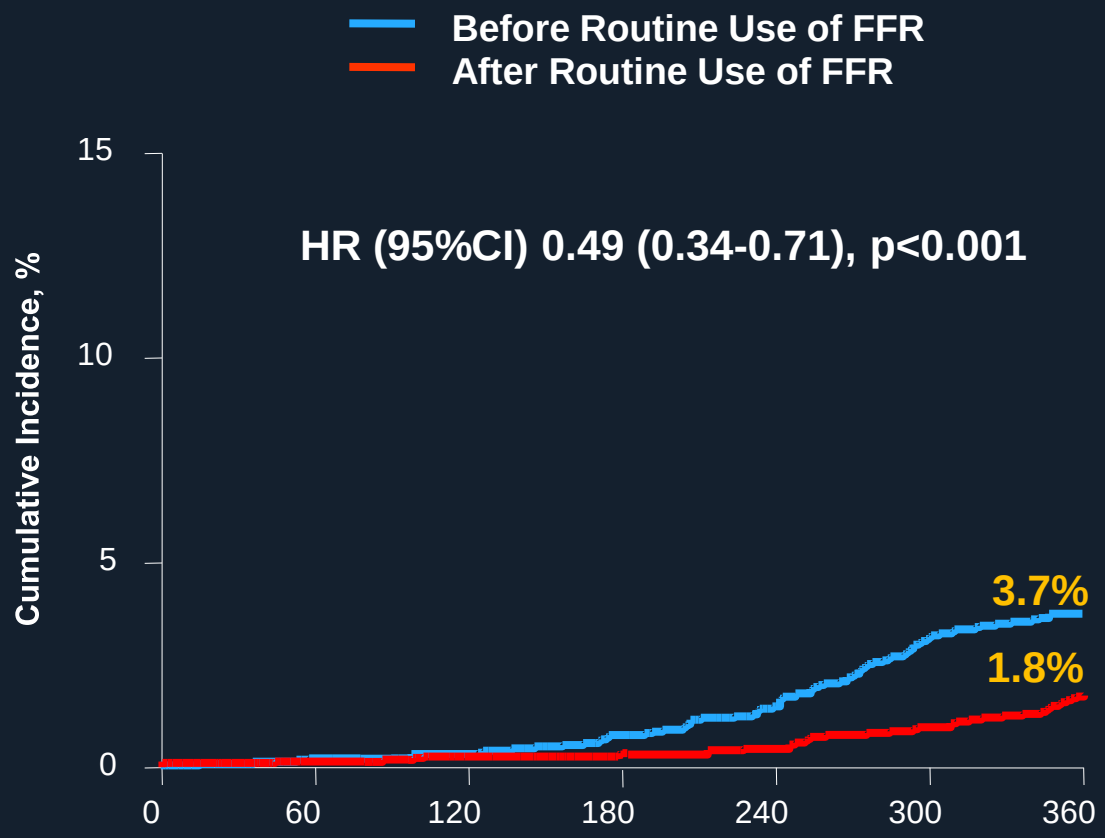
No. at Risk

Before Routine Use	2178	2071	2041	2036
After Routine Use	2178	2098	2075	2066

Death or Myocardial Infarction

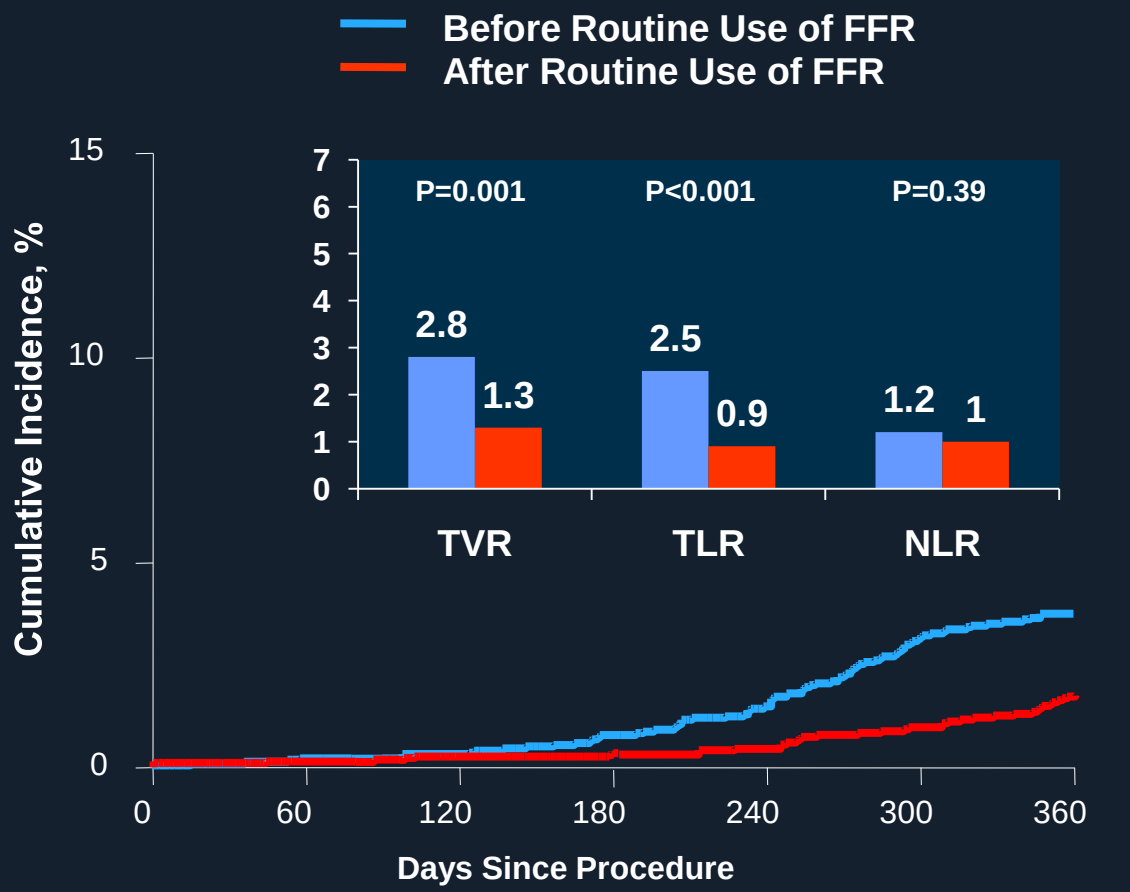


Repeat Revascularization



No. at Risk				
Before Routine Use	2178	2151	2095	2048
After Routine Use	2178	2136	2110	2083

Repeat Revascularization



No. at Risk

Before Routine Use	2178	2151	2095	2048
After Routine Use	2178	2136	2110	2083

Conclusion

- The routine use of FFR during PCI procedure reduced the risks of death, MI, or repeat revascularization at 1 year.
- The benefit is primarily due to a reduced number of stents used per patients and a subsequent decreased risk of peri-procedrual MI and repeat revascularization.
- Therefore, we have to measure FFR prior to PCI if there is no objective evidence of ischemia.