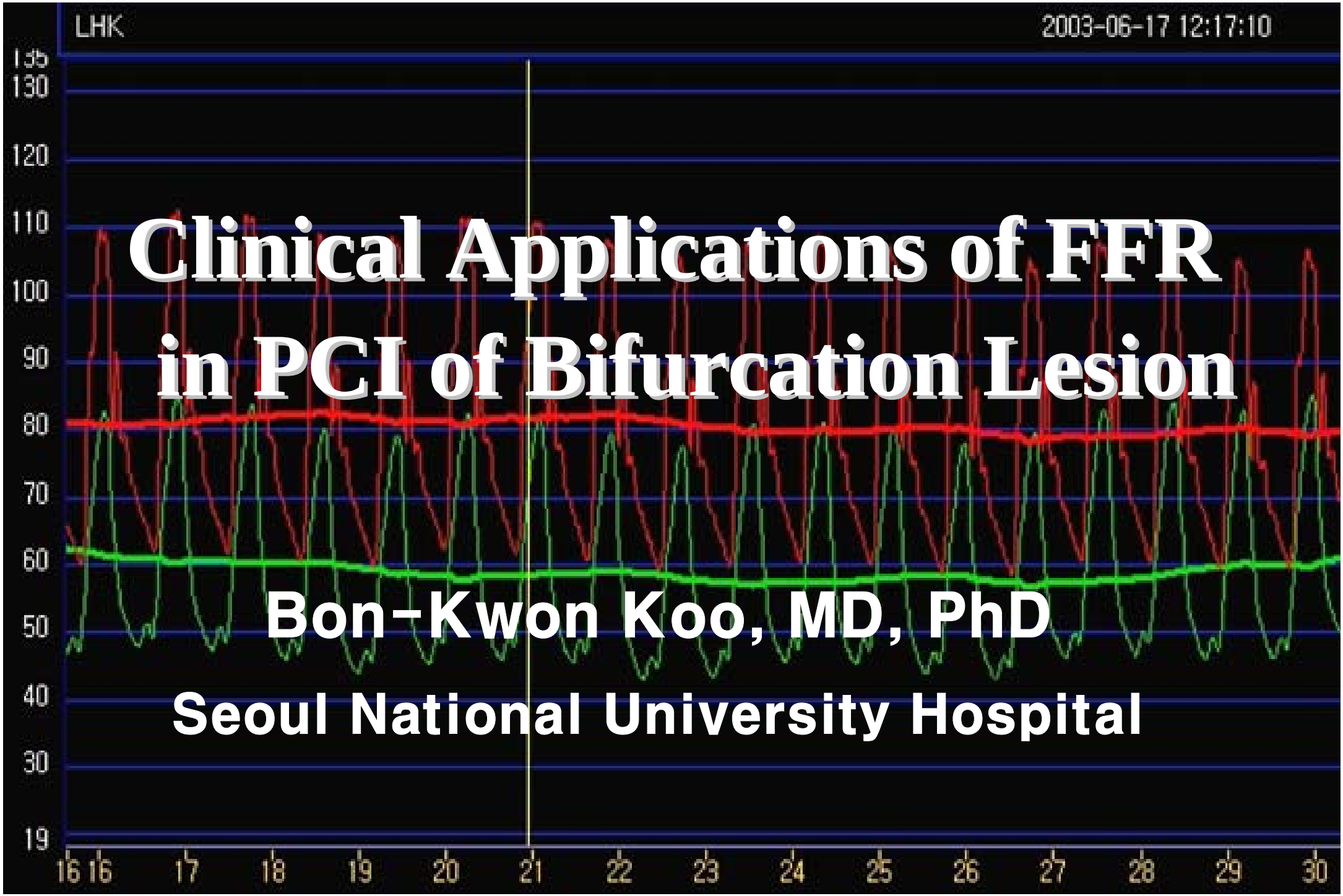


Clinical Applications of FFR in PCI of Bifurcation Lesion

Bon-Kwon Koo, MD, PhD

Seoul National University Hospital

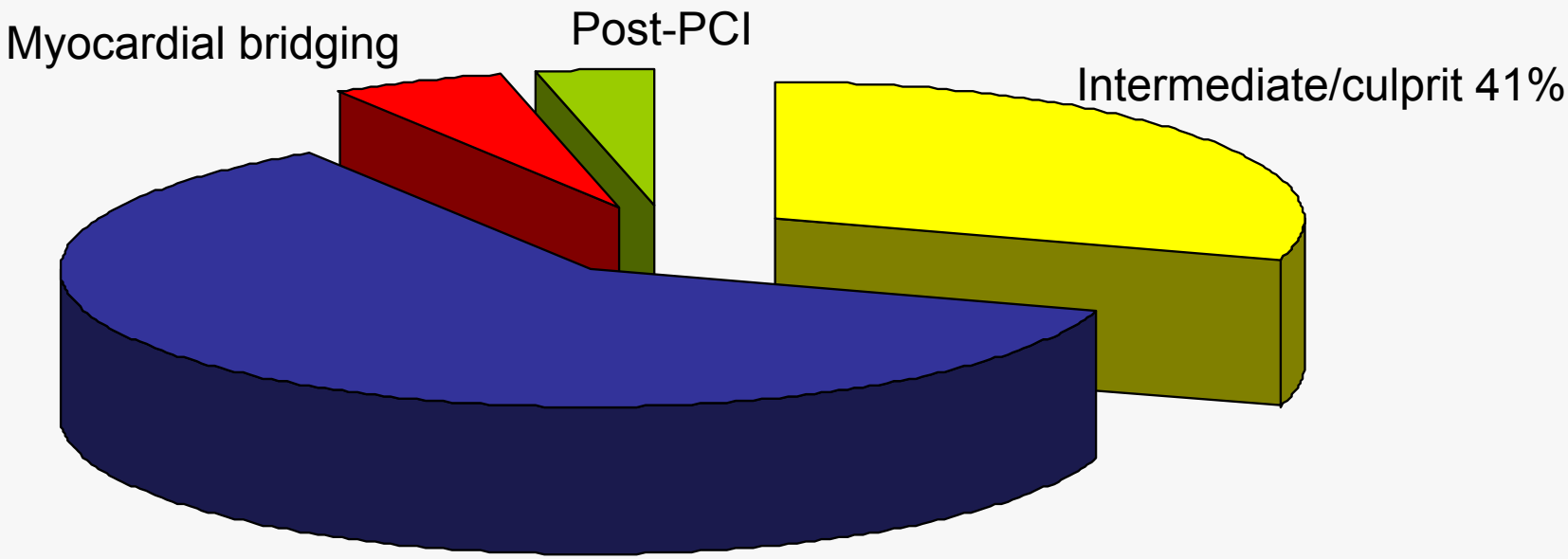
Clinical Applications of FFR

- ***Functional assessment will give valuable information in following situations*;**
  - Intermediate lesions
  - Optimizing PCI results
  - Complex anatomy
  - Identification of the culprit lesion in multiple lesions and in multivessel disease
  - ***Bifurcation lesions***

‘Pressure Wire in SNUH’

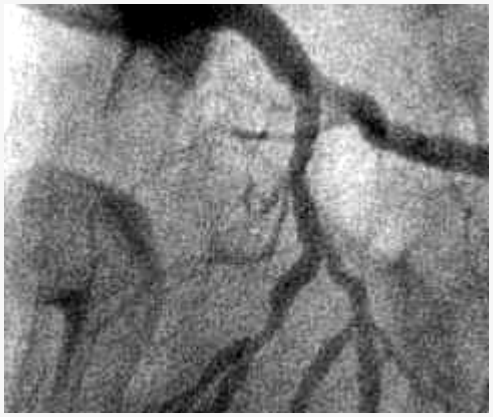
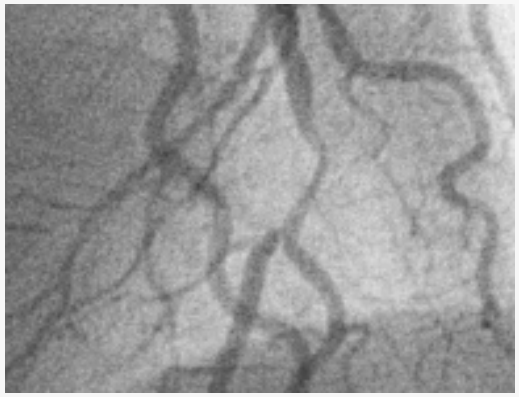
- **2003 Jun - 2006 Dec**

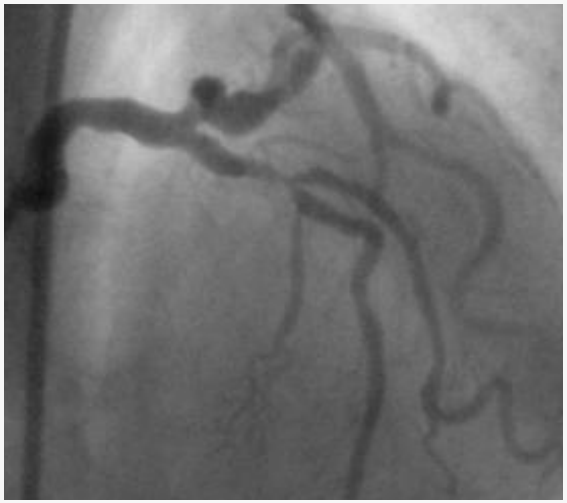
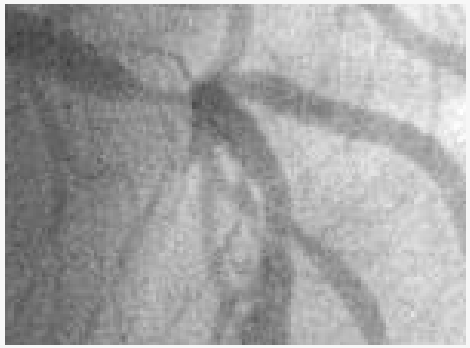
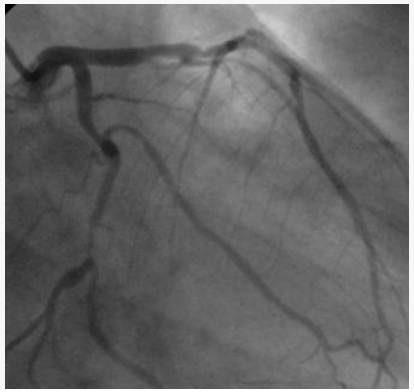
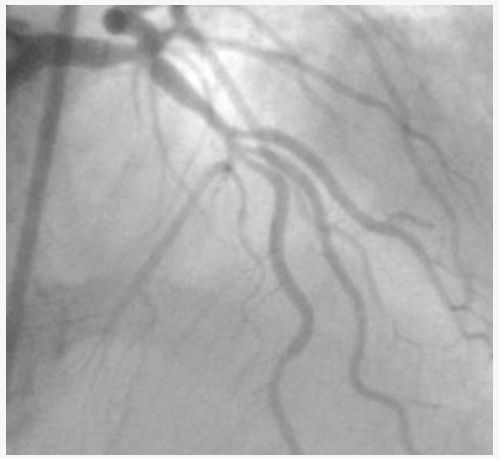
  FFR measurement: 445 lesions



Jailed Side Branch 55%

How to treat bifurcation lesions?


Bifurcation Lesion & Intervention

Problems to operators

Lesion itself is complex !

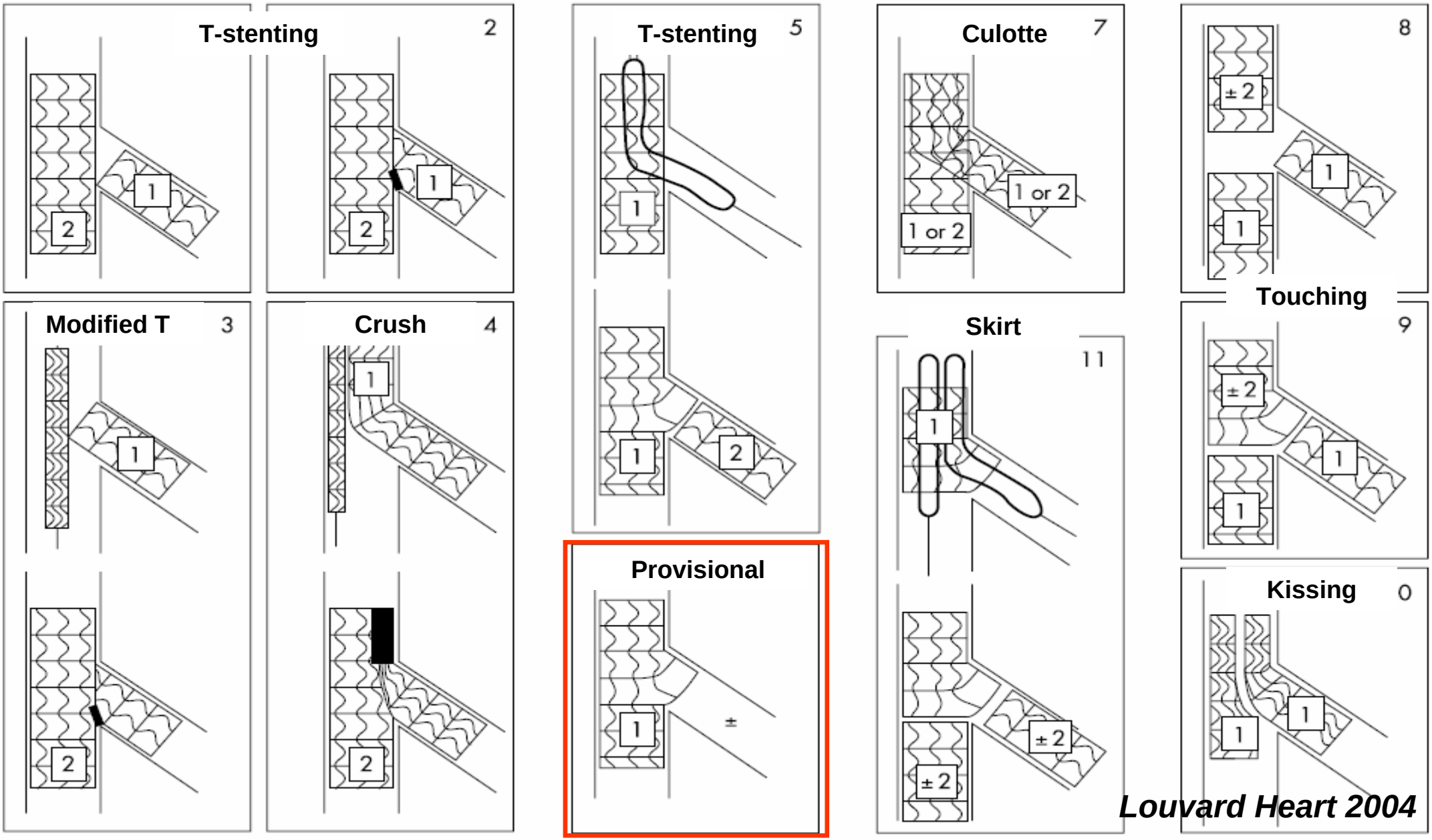
Classification is complex !

Too many treatment modalities !

Still a challenging lesion subset even in the era of DES

Complex procedure, Low procedural success, High events

Too many strategies……



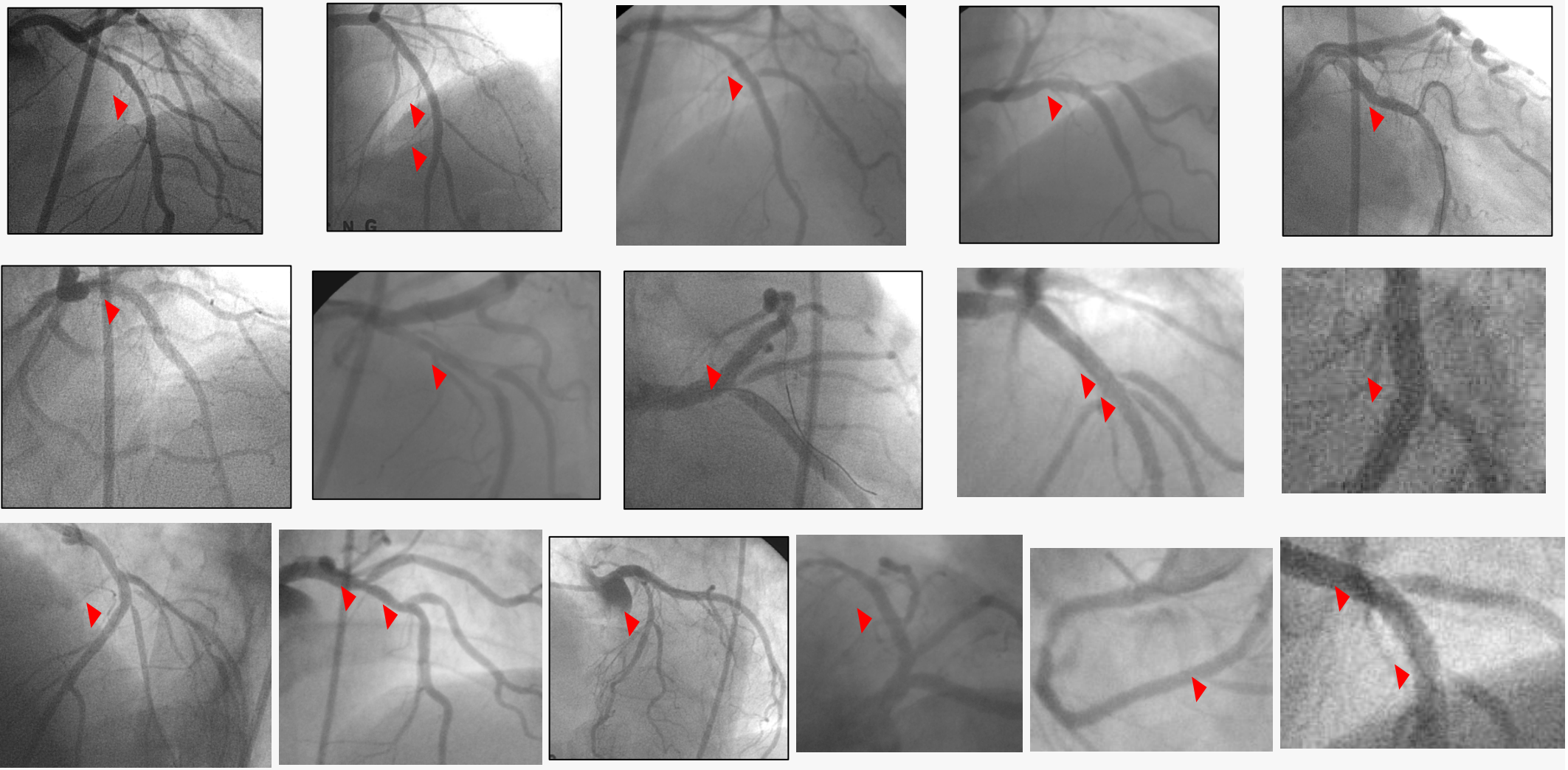
Louvard Heart 2004

Systemic 2 stenting vs. Provisional side branch intervention in DES era

Author	n	Stent	TLR rate	
			 2 stents	 1 stent
Colombo, *Circulation 2004*	85	Cypher	9.5%	4.5%
Ge, *AJC 2005*	127	Cypher	8.8%	5.4%
Pen, *AHJ 2004*	91	Cypher	5%	2%
Steigen, *Circulation 2006*	413	Cypher	2%	1.4%

Provisional T Stenting

In cases with significant narrowing of side branch after main branch stenting ?



The criteria for SB intervention

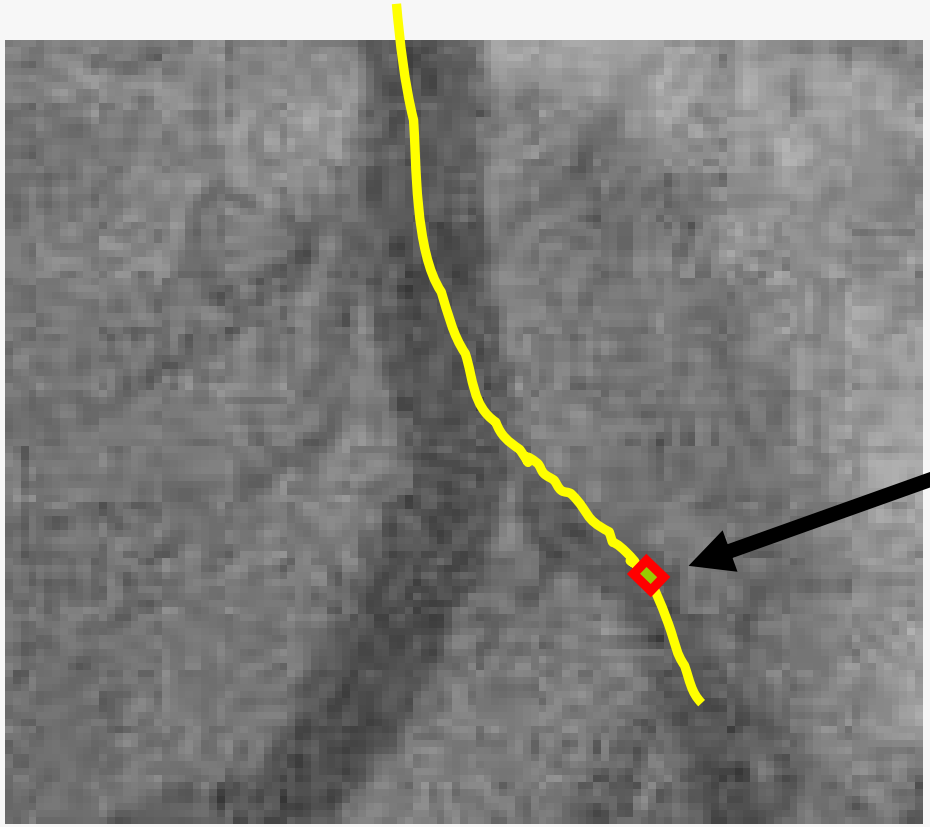
Author	N	SB intervention criteria
Colombo, *Circulation 2004*	43	**> 50% stenosis**
Pen, *AHJ 2004*	47	**> 50% stenosis**
Steigen, *Circulation 2007*	207	**< TIMI 3 flow**

Provisional side branch intervention

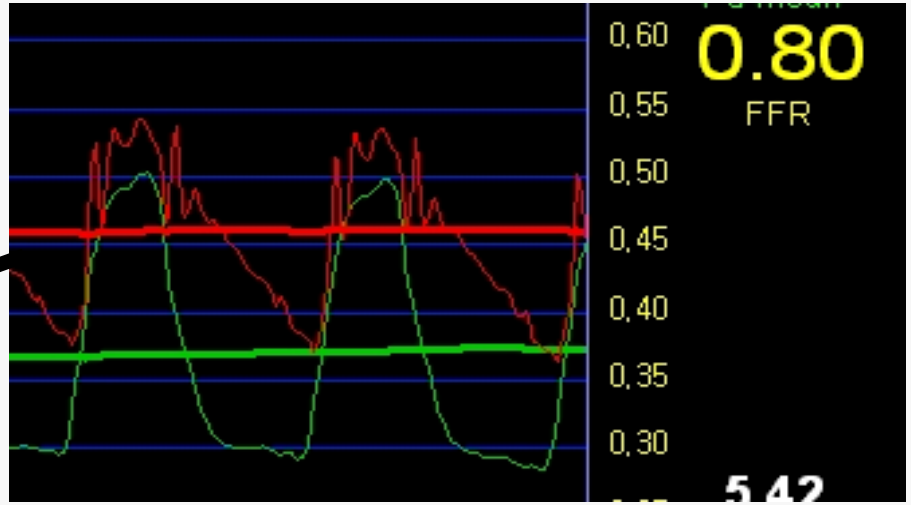
- **Which needs additional procedures?**
- **How to treat?**
  - Side branch balloon size?
  - Goal of treatment?
  - Criteria for SB treatment success at follow-up angiogram?

FFR in Jailed side branches

- Easily obtained, Stenosis specific, Simple(<0.75→ischemia)
- Reflects both degree of stenosis and myocardial territory



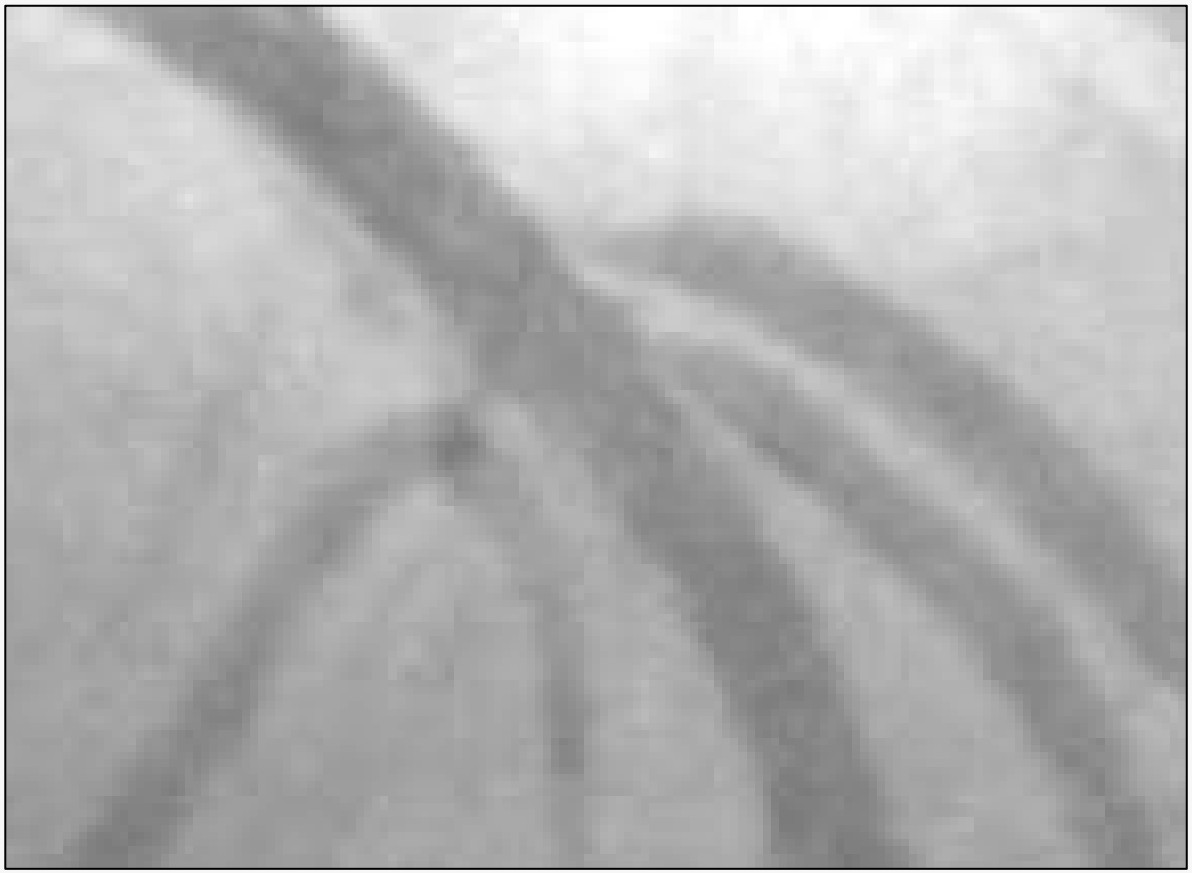
Pa: systemic pressure by guiding catheter



Pd: distal pressure by pressure wire

Question 1

To Treat? Or Not?



Subjects

Inclusion criteria

De novo, bifurcation lesion

Main branches

- Successful stent implantation
- No significant stenosis proximal to the stented segment

Jailed side branches

- **Stenosis > 50%**
- **Diameter > 2 mm**
- **Lesion length < 10 mm**
- Side branch length > 30 mm

Exclusion criteria

- Side branch slow flow after stenting
- Left main disease, CTO lesions
- Infarct related artery, thrombus
- Diffuse or distal lesion at SB
- RWMA at stented segments
- Myocardial disease, valvular disease
- Renal insufficiency

RADI pressure wire: Successful FFR measurement: 94/97 lesions (97%)

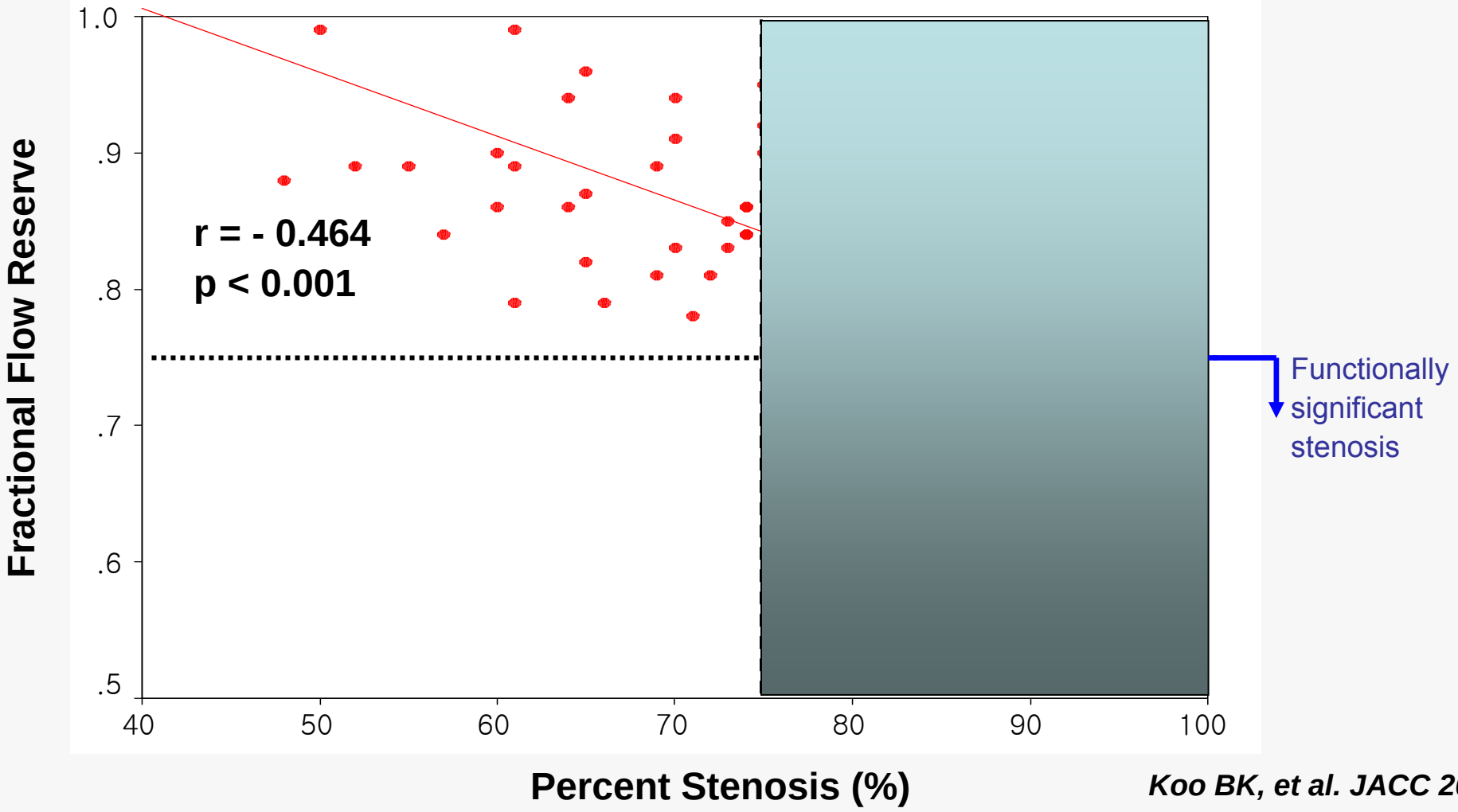
Characteristics of lesions (n=94)

Bifurcation type (ICPS classification)	
Type 1	**55 (58%)**
Type 2	12 (13%)
Type 3	17 (18%)
Type 4	10 (11%)
QCA of jailed branches	
MLD	0.45 ± 0.25 mm
Reference diameter	**2.2 ± 0.5 mm**
Percent stenosis	**79 ± 11 %**
Lesion length	7.0 ± 3.3 mm

Koo BK, et al. JACC 2005

QCA vs. FFR

in Jailed side branch lesions (n=94)



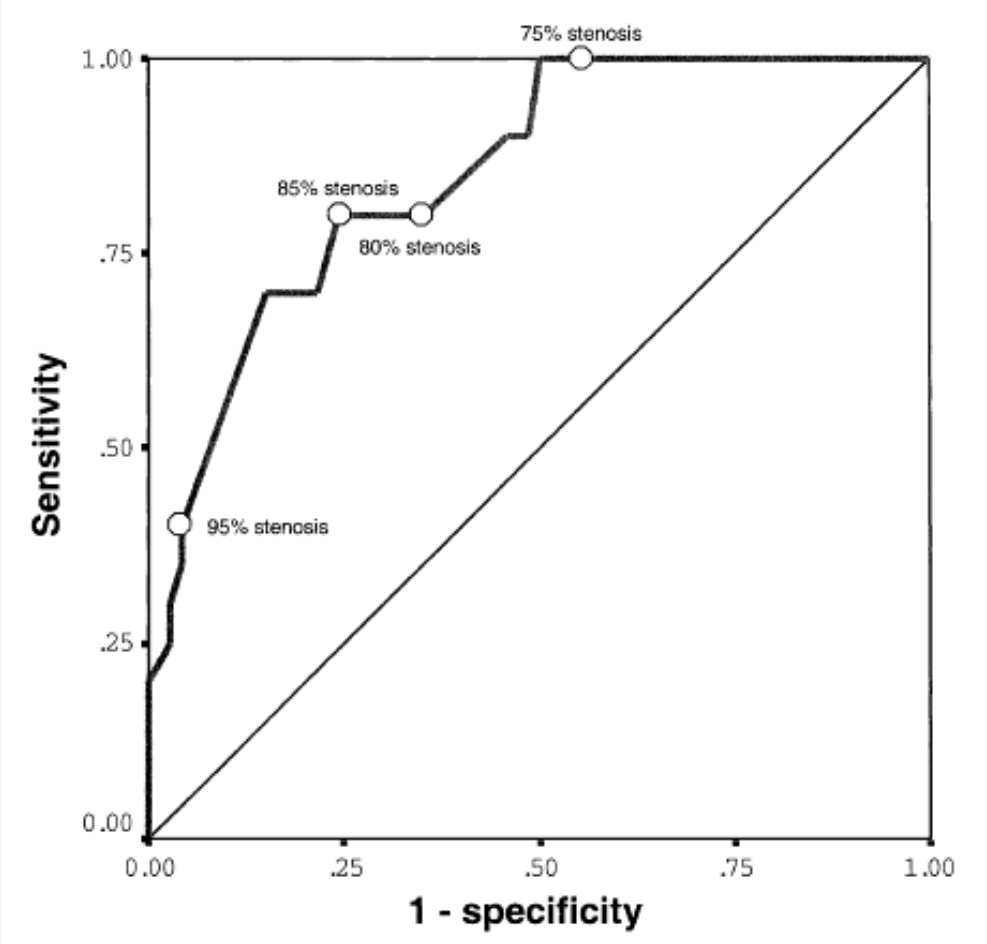
Koo BK, et al. JACC 2005

FFR vs. Percent stenosis by QCA

	Percent stenosis	
	<75%	**≥75%**
All lesions (n=94)		
FFR <0.75	0	**20(27%)**
FFR ≥0.75	20	53
Vessel size ≥2.5mm (n=20)		
FFR <0.75	0	8(38%)
FFR ≥0.75	7	13

Koo BK, et al. JACC 2005

FFR (< 0.75) vs. QCA (% stenosis)



AUC: 0.85 (95% CI: 0.76 - 0.94)

% stenosis	Sensitivity	Specificity
75%	1.0	0.39
85%	**0.8**	**0.77**

Best Cut-off Value

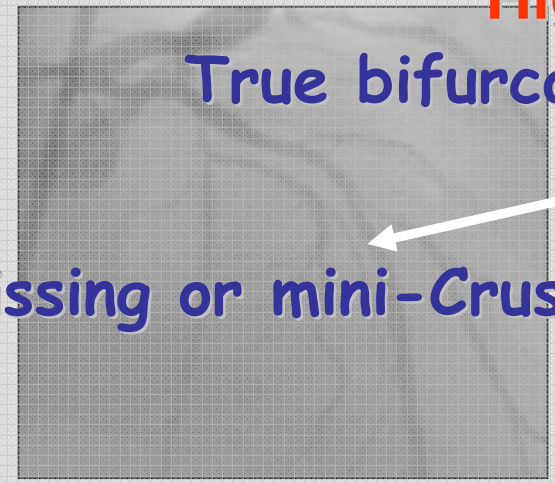
How to treat these lesions?

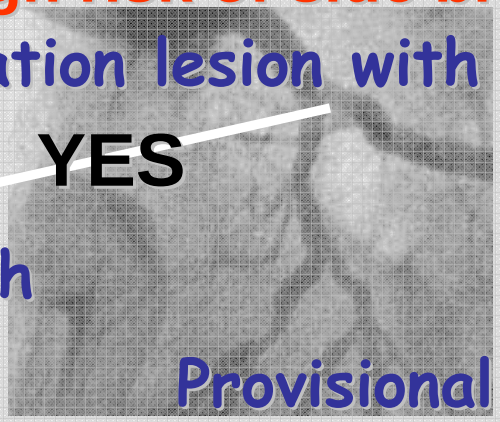
High risk of side branch occlusion?

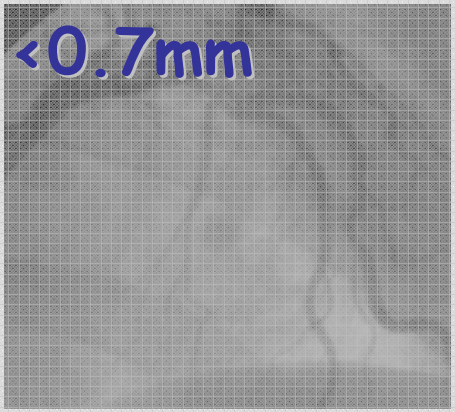
True bifurcation lesion with side branch MLD <0.7mm

YES → Kissing or mini-Crush

NO → Provisional intervention



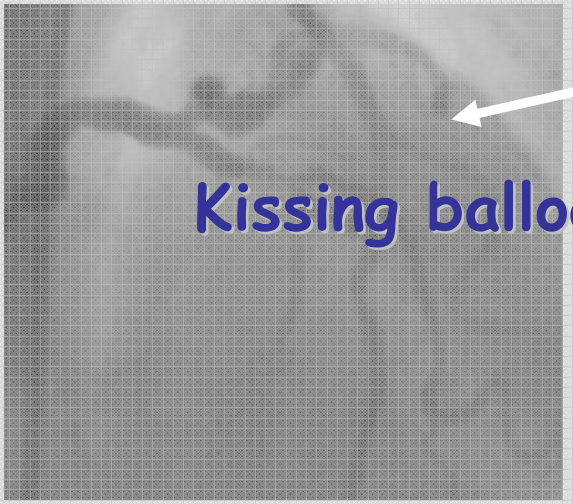


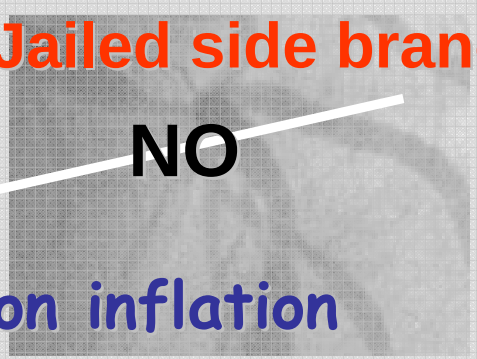


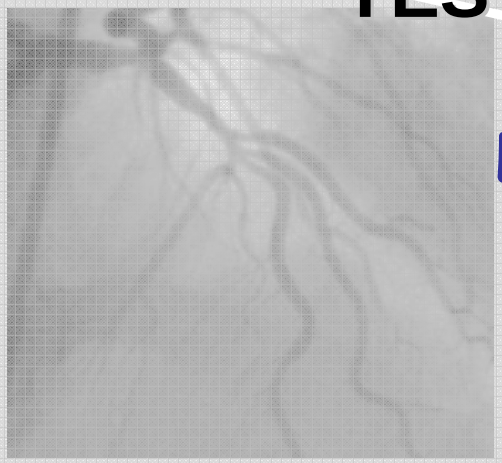
Jailed side branch stenosis < 85%?

NO → Kissing balloon inflation

YES → Leave it alone!!!

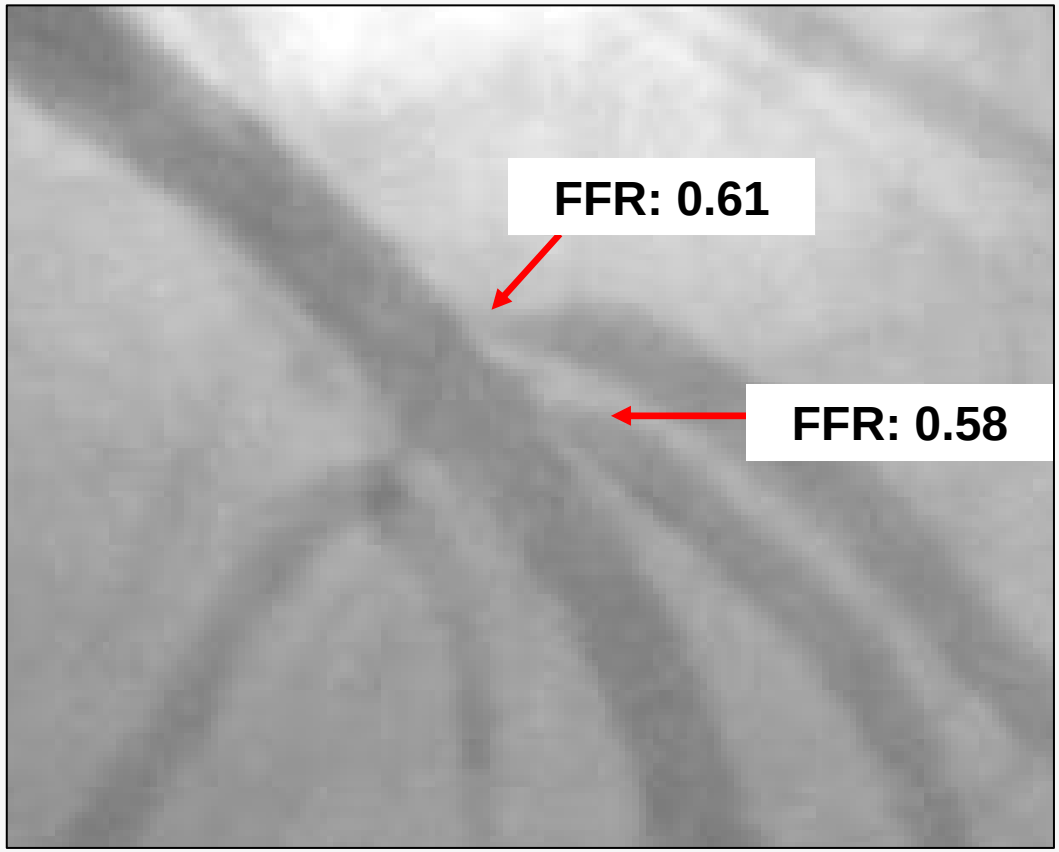


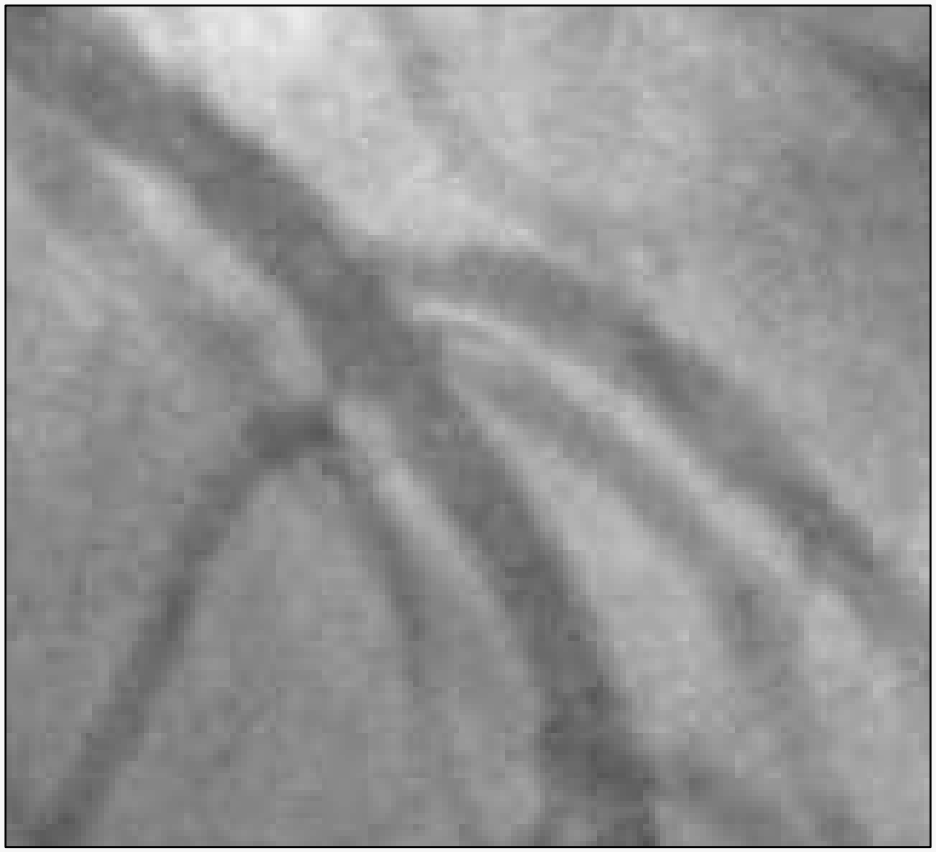




Question 2

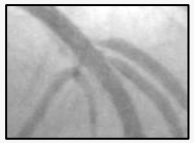
How to treat?





Balloon artery ratio? Goal of treatment?

Hypothesis



Large Balloon, High Pressure

Better angiographic results

Higher risk of dissection

More healing and inflammatory response → More late loss

- The treatment goal of jailed SB lesion may be to maintain < 75-85% stenosis.
- Therefore, balloon inflation with a relatively small size balloon would be enough, ***if the gain could be maintained during follow-up.***

FFR-guided Jailed SB Intervention

- Stenting the main branch with DES

→Measure FFR in jailed SB

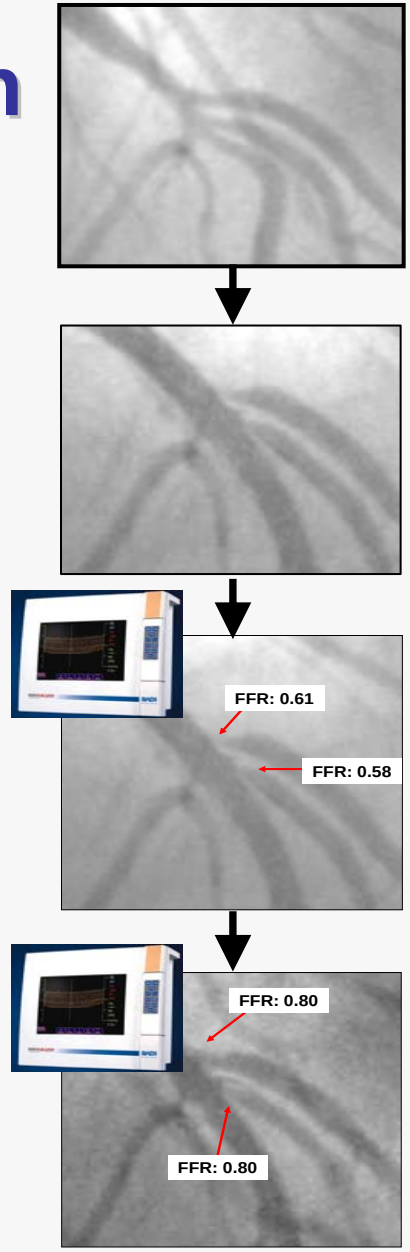
→Side branch intervention, when FFR<0.75

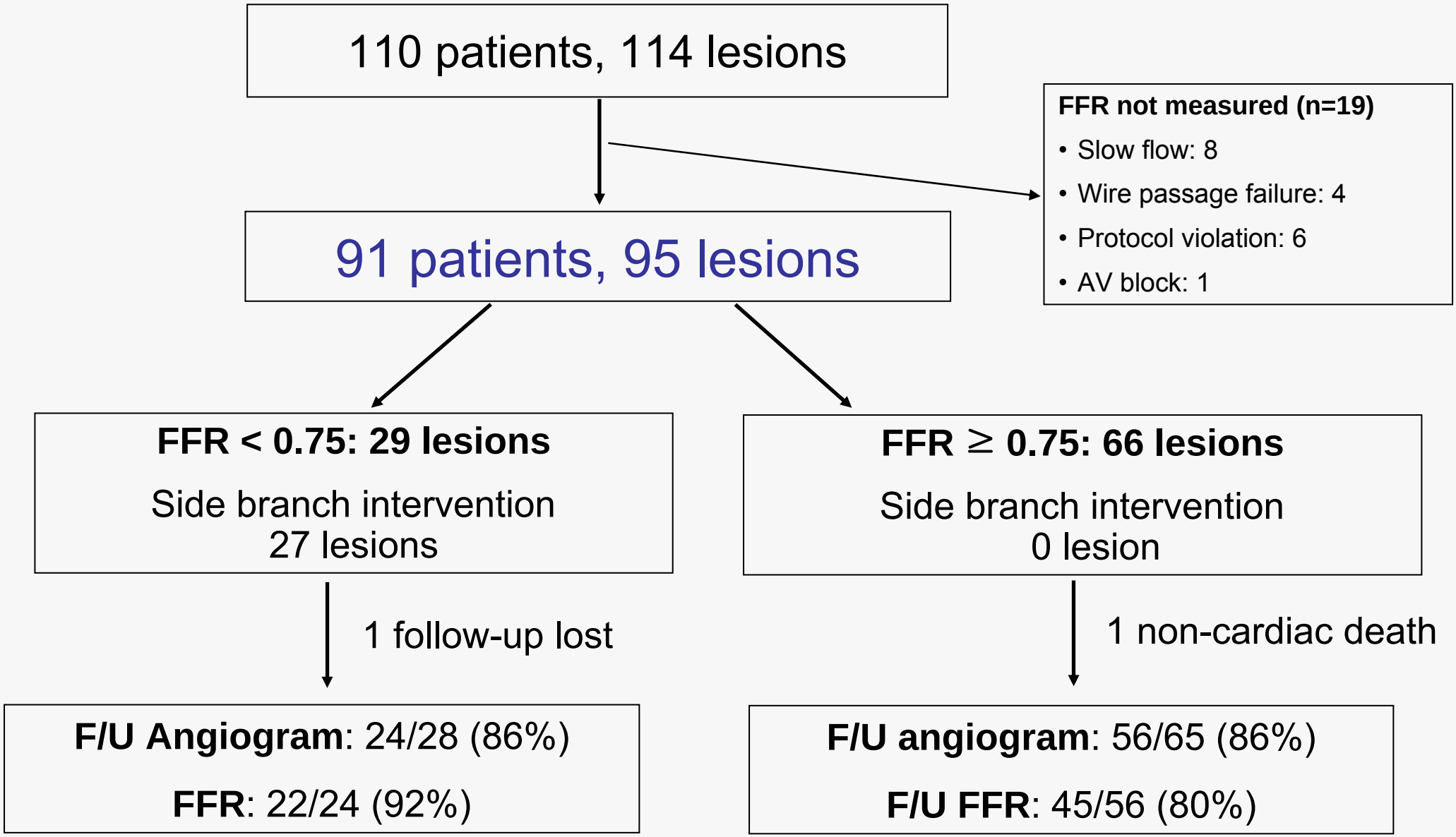
- Kissing balloon technique with a *relatively small balloon at side branch*

- If FFR < 0.75 after kissing balloon,

→use larger balloon, or stent implantation

→ 6 month f/u angiography and FFR




110 patients, 114 lesions
FFR not measured (n=19)
• Slow flow: 8
• Wire passage failure: 4
• Protocol violation: 6
• AV block: 1
91 patients, 95 lesions
FFR < 0.75: 29 lesions
Side branch intervention
27 lesions
FFR ≥ 0.75: 66 lesions
Side branch intervention
0 lesion
1 follow-up lost
1 non-cardiac death
F/U Angiogram: 24/28 (86%)
FFR: 22/24 (92%)
F/U angiogram: 56/65 (86%)
F/U FFR: 45/56 (80%)

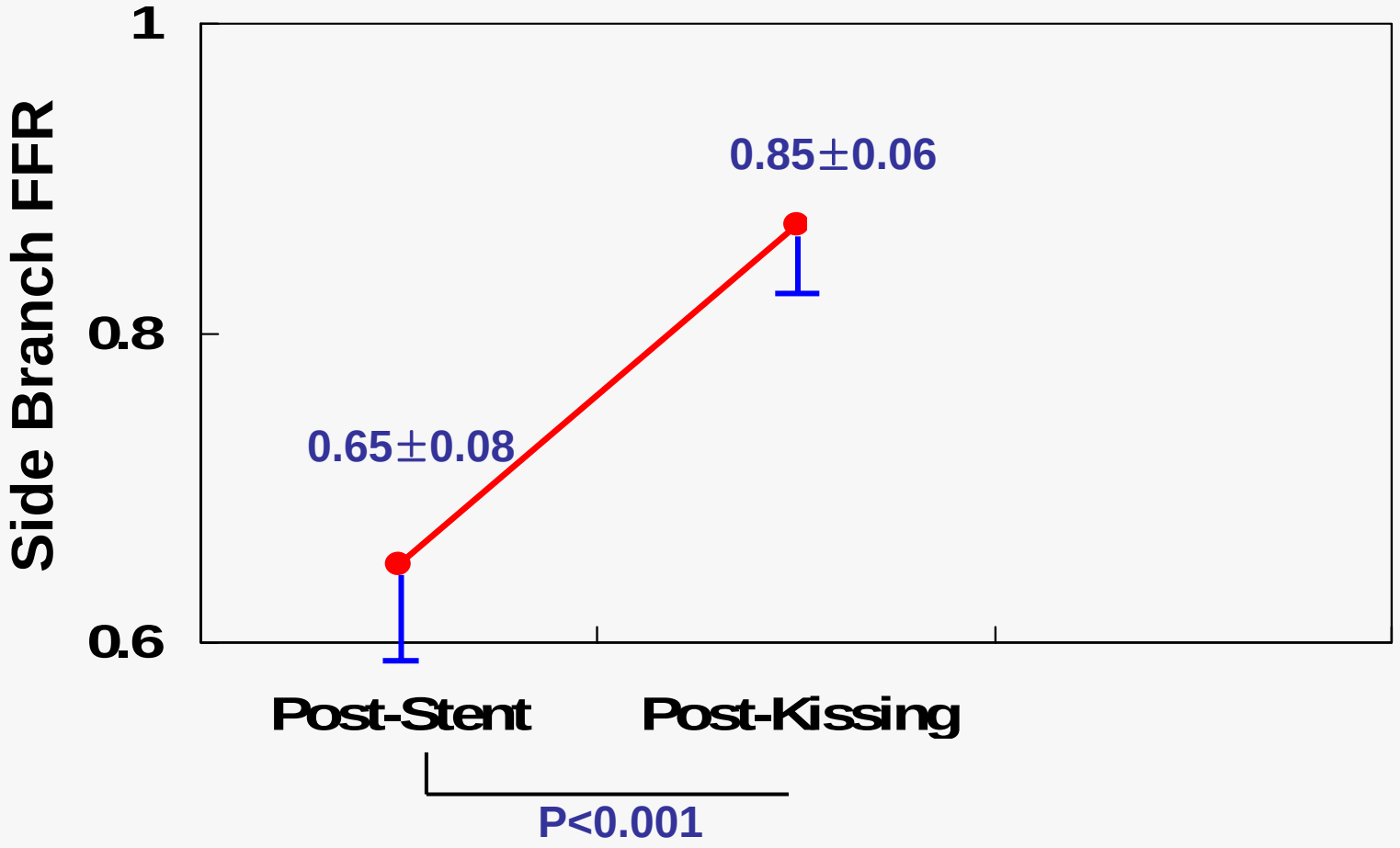
Lesions characteristics (n=95)

True bifurcation (ICPS 1, 4) 	51 (54%)
Bifurcation angle: Y type	81 (85%)
Used stents	
Cypher / TAXUS	71%/29%
Diameter/Length	3.0 ± 0.3/ 31 ± 12mm
Lesion Location	
LAD/LCX/RCA	75%/21%/4%
QCA	
MB pre-PCI PS/RD/LL	77 ± 11% /2.9 ± 0.4mm/27 ± 11mm
MB post PCI PS	7.0 ± 5.3%
SB pre-PCI PS/RD/LL	50 ± 21%/**2.3 ± 0.4mm/6.3 ± 2.9mm**
SB post-PCI PS	**78 ± 11%**

QCA: quantitative coronary angiography, MB: main branch, SB: side branch, PCI: percutaneous coronary intervention, PS: percent stenosis, RD: reference diameter, LL: lesion length

Changes of Side branch FFR after Kissing

Side branch balloon/artery ratio: 0.85±0.14



Achievement of FFR>0.75 after kissing:**24/26 lesions (92%)**

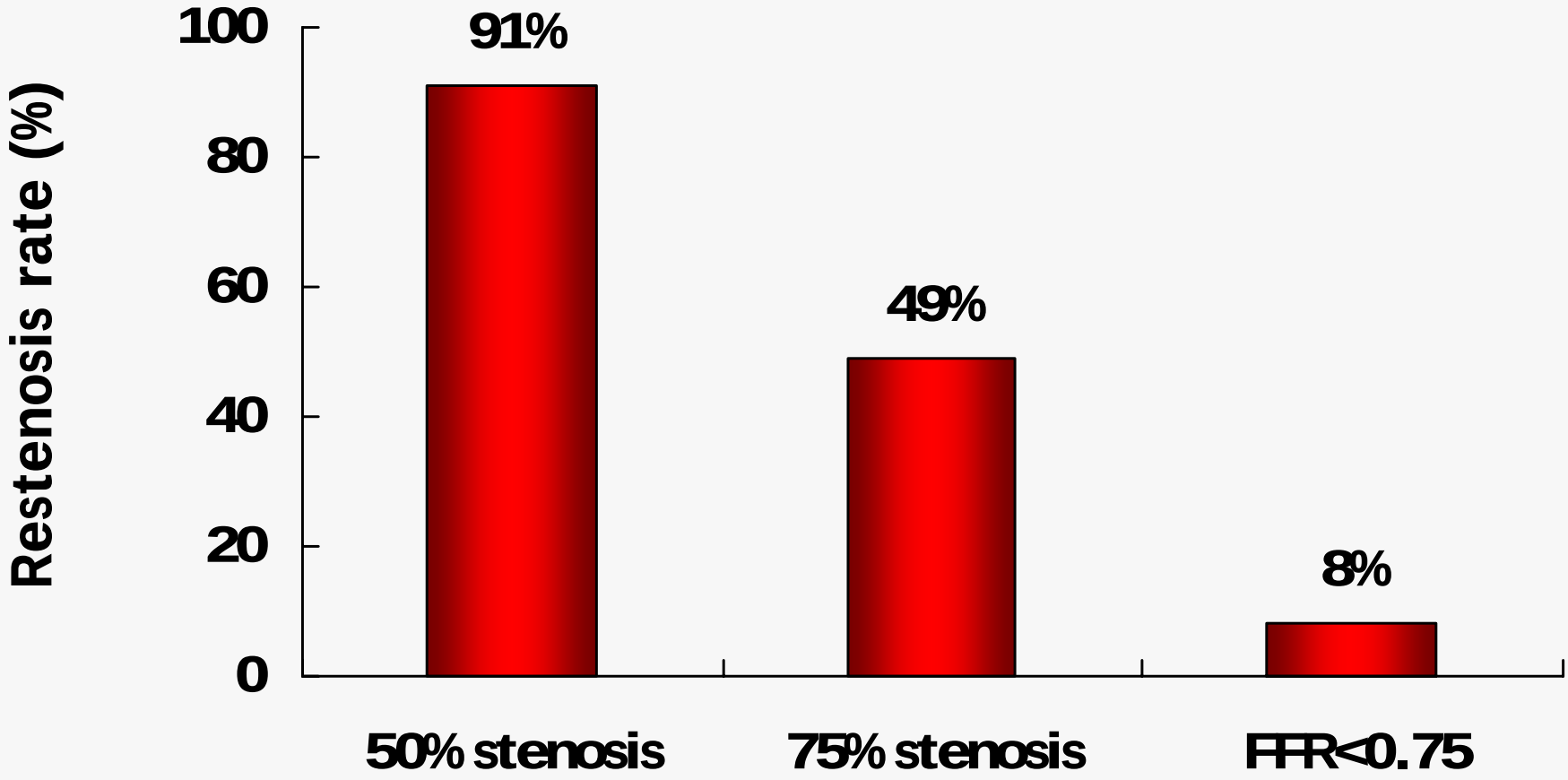
Changes of FFR during 6M follow-up

(67 lesions)

	Post-PCI	Follow-up	P value
Main branch	0.96 ± 0.04	0.96 ± 0.04	0.7
Jailed side branch	0.87 ± 0.06	0.87 ± 0.09	0.9
KB group	0.86 ± 0.05	0.84 ± 0.11	0.3
Non-KB group	0.87 ± 0.06	0.88 ± 0.07	0.1

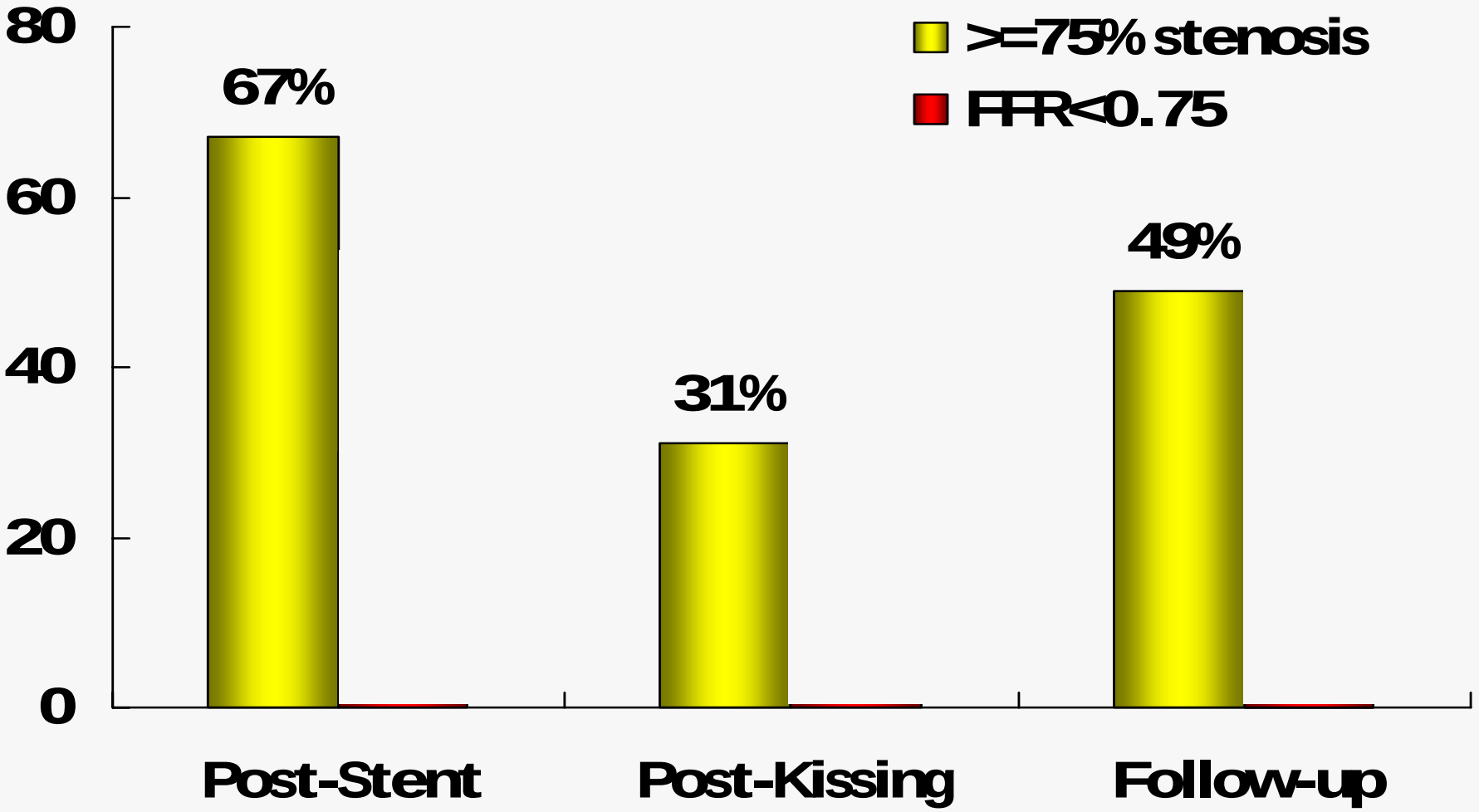
KB; Kissing balloon inflation (Balloon/artery ratio = 0.85)

Angiographic restenosis criteria for jailed side branch lesions: Are these relevant?



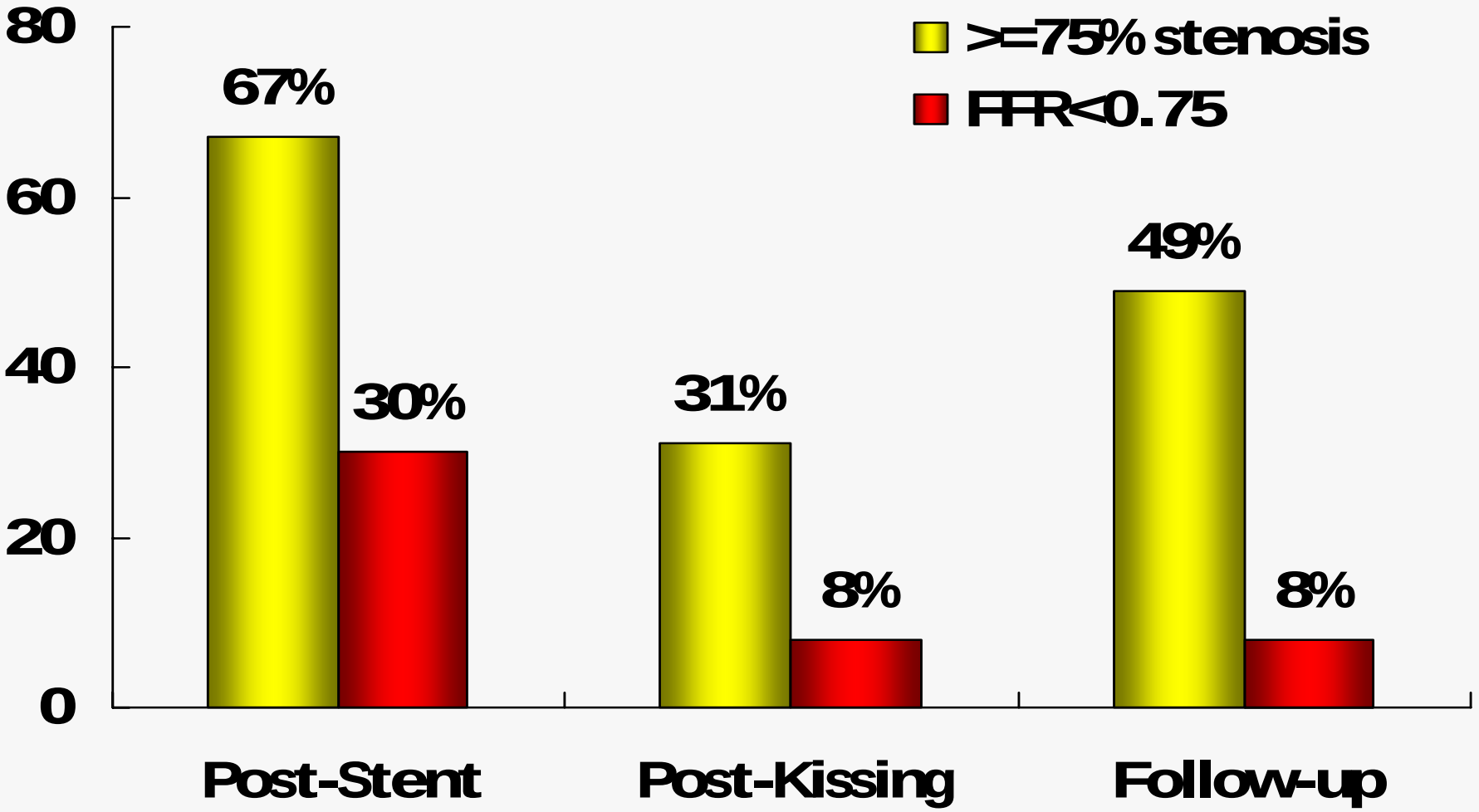
What you see is What it is?

% of Side branch lesions need further intervention

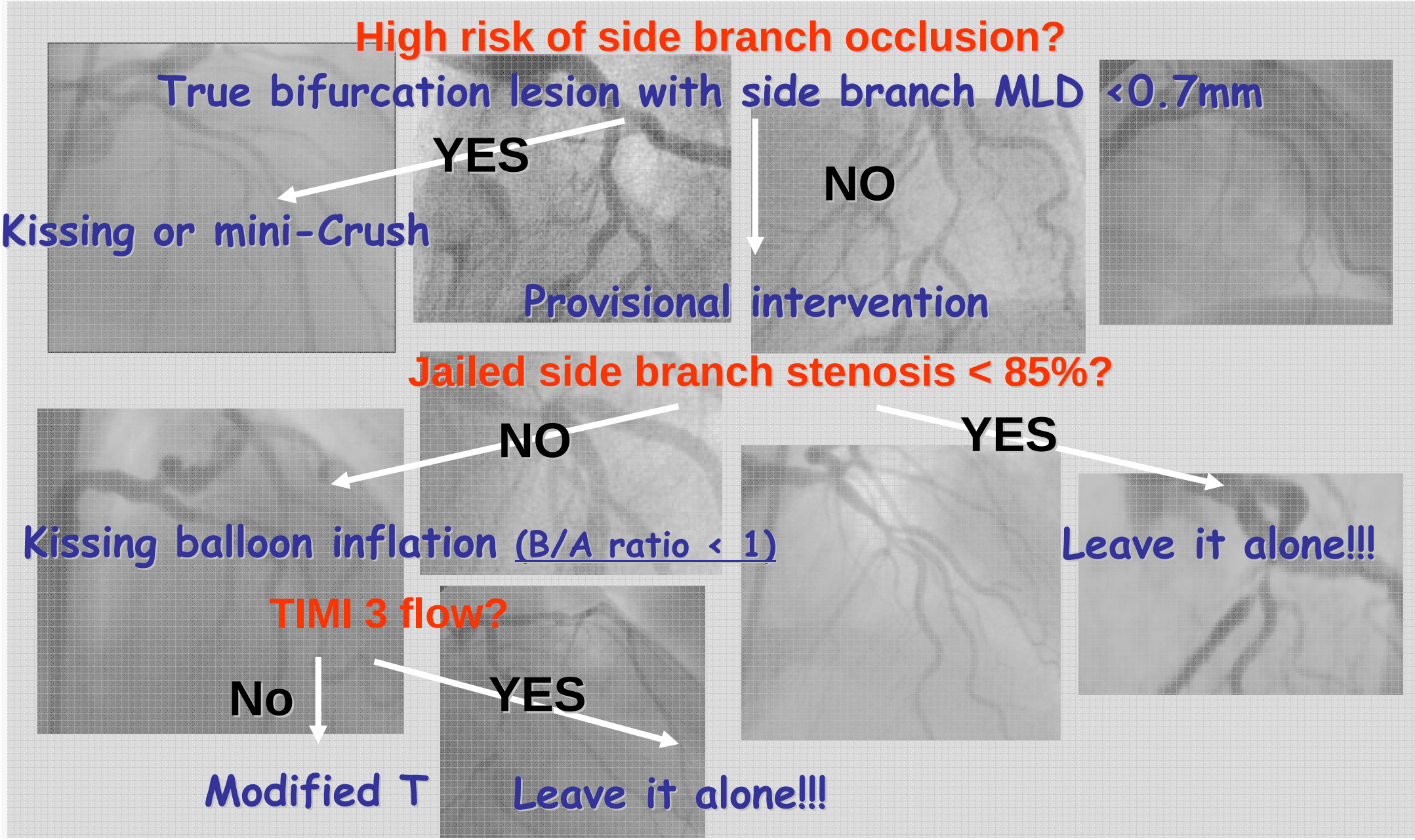


What you see is Not What it is!

% of Side branch lesions need further intervention



How to treat these lesions?



Question 3

Clinical outcome?

Fractional flow reserve - guided side branch intervention vs. Conventional intervention in bifurcation lesions

: Comparison of clinical outcomes

Subjects

FFR-guided group

- N=110 patients, 114 lesions

Conventional intervention group

- Selected from 220 patients with bifurcation lesions in VERITAS database
- Same inclusion and exclusion criteria
- Treatment strategy: operators' discretion

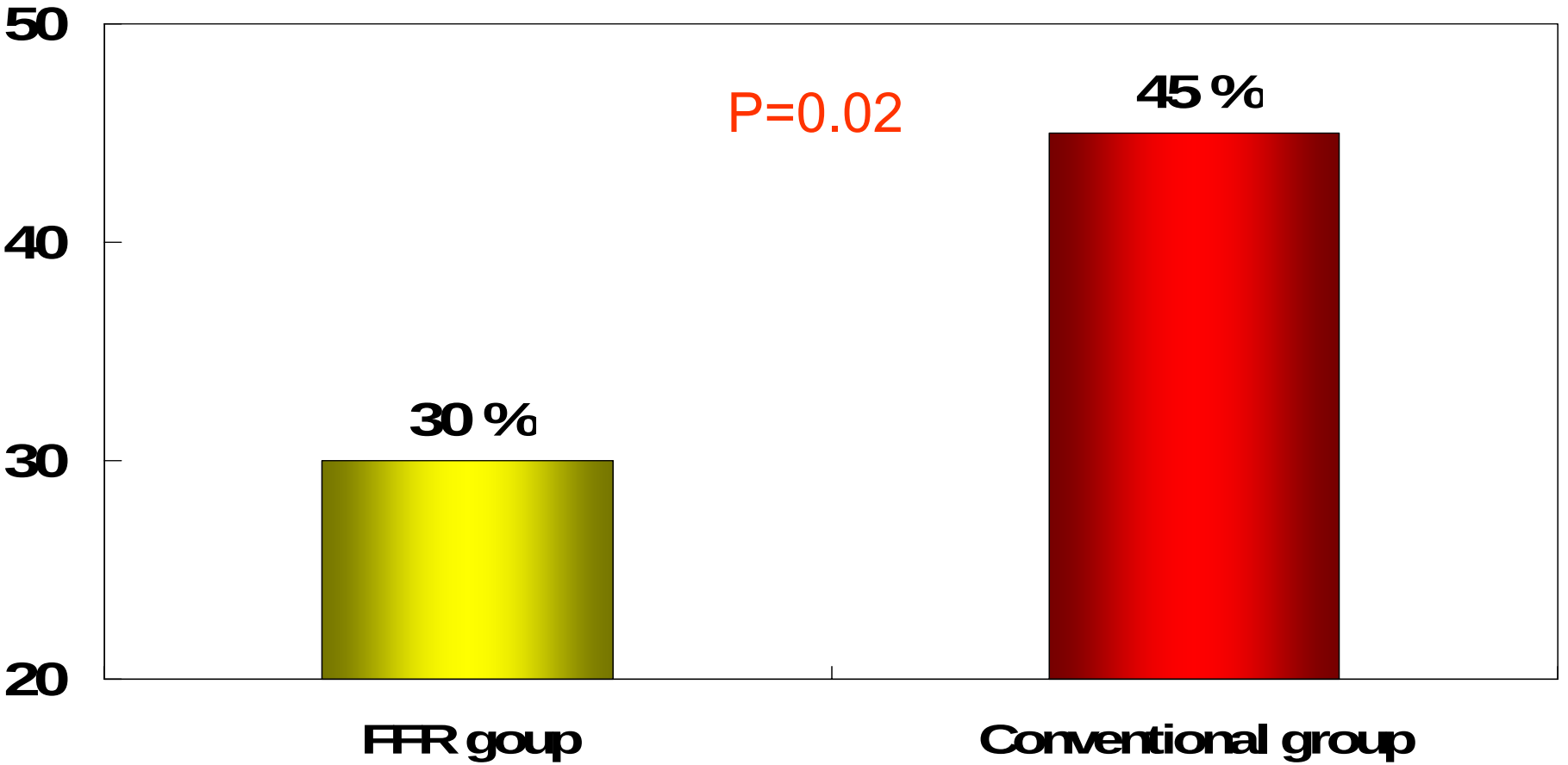
→ 110 patients, 118 lesions

Baseline characteristics

	FFR group	Conventional group	P value
Age, years	62 ± 9	63 ± 9	0.8
Male	68%	70%	0.8
Diagnosis			0.09
Stable angina	53 (48%)	51 (46%)	
ACS	41 (37%)	52 (47%)	
Risk factors			
DM/HT/Hyperlipidemia	28/58/46%	29/60/34%	0.8/0.8/0.05
Previous PCI	15 (14%)	12 (11%)	0.5
Multi-vessel PCI	35 (32%)	33 (30%)	0.77
Lesion location			
LAD/LCX/RCA	82/26/6	71/42/5	0.1
True bifurcation (ICPS 1,4)	68 (60%)	74 (63%)	0.3
Y type (angle <70º)	93 (82%)	92 (78%)	0.4

ACS: acute coronary syndrome, PCI: percutaneous coronary intervention

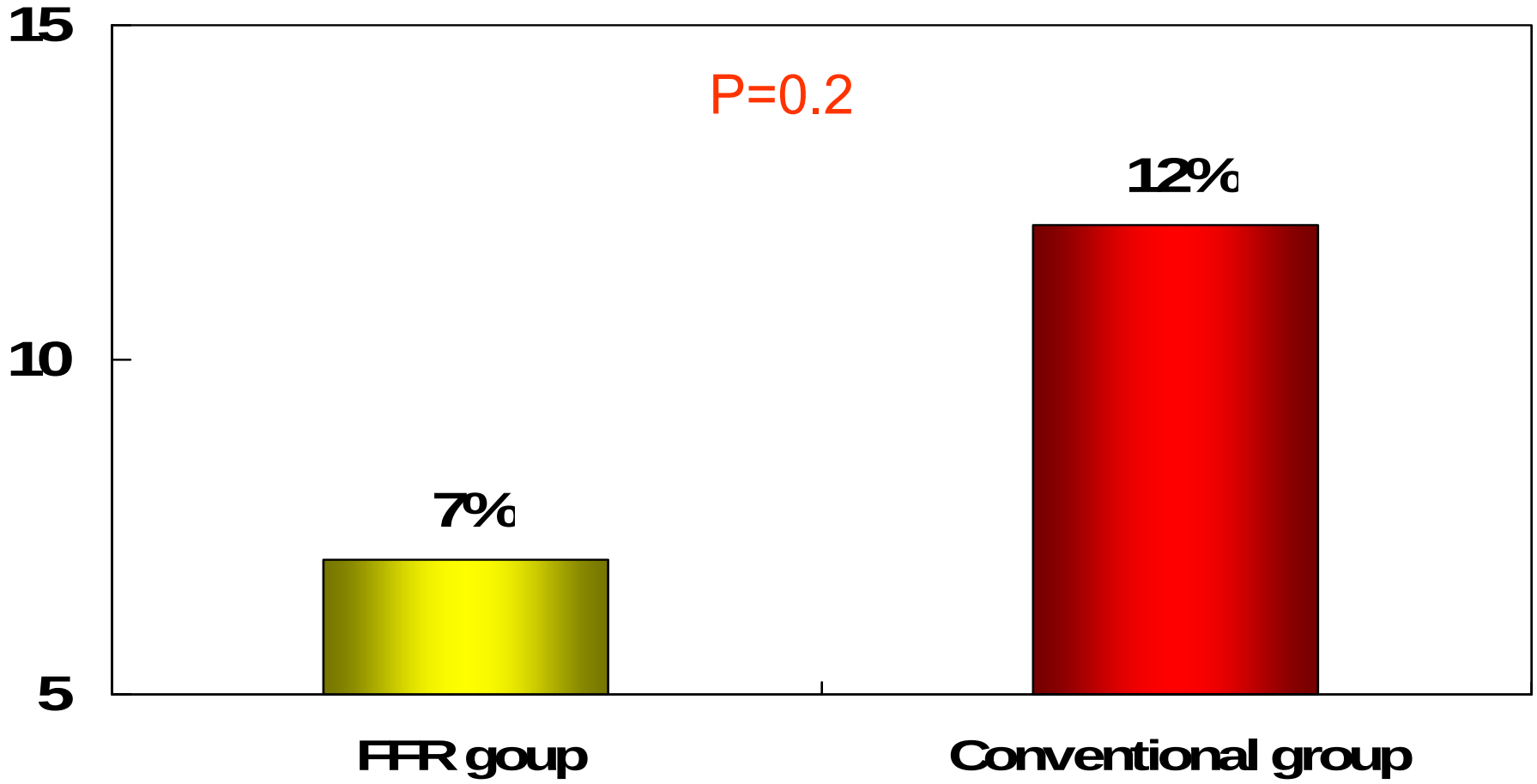
Side branch intervention



Angiographic and procedural characteristics

	FFR group	Conventional group	P value
Main branch stent			
Cypher	78 (68%)	85 (72%)	0.5
Diameter/length	3.0±0.3/31±12mm	3.0±0.3/30±11mm	0.3/0.6
Pre-intervention QCA			
MB percent stenosis	78±11%	79±11%	0.2
MB reference diameter	2.9±0.4mm	2.9±0.3mm	0.9
MB lesion length	26±10mm	23±9mm	0.01
SB percent stenosis	51±22%	55±21%	0.1
SB reference diameter	2.3±0.3mm	2.2±0.5mm	0.1
SB lesion length	**6.4±3.0mm**	**7.4±4.0mm**	**0.04**
Post-intervention QCA			
MB residual stenosis	7.1±5.5%	8.0±3.6%	0.2
SB residual stenosis	**74±12%**	**60±20%**	**<0.001**

Peri-procedural myocardial infarction



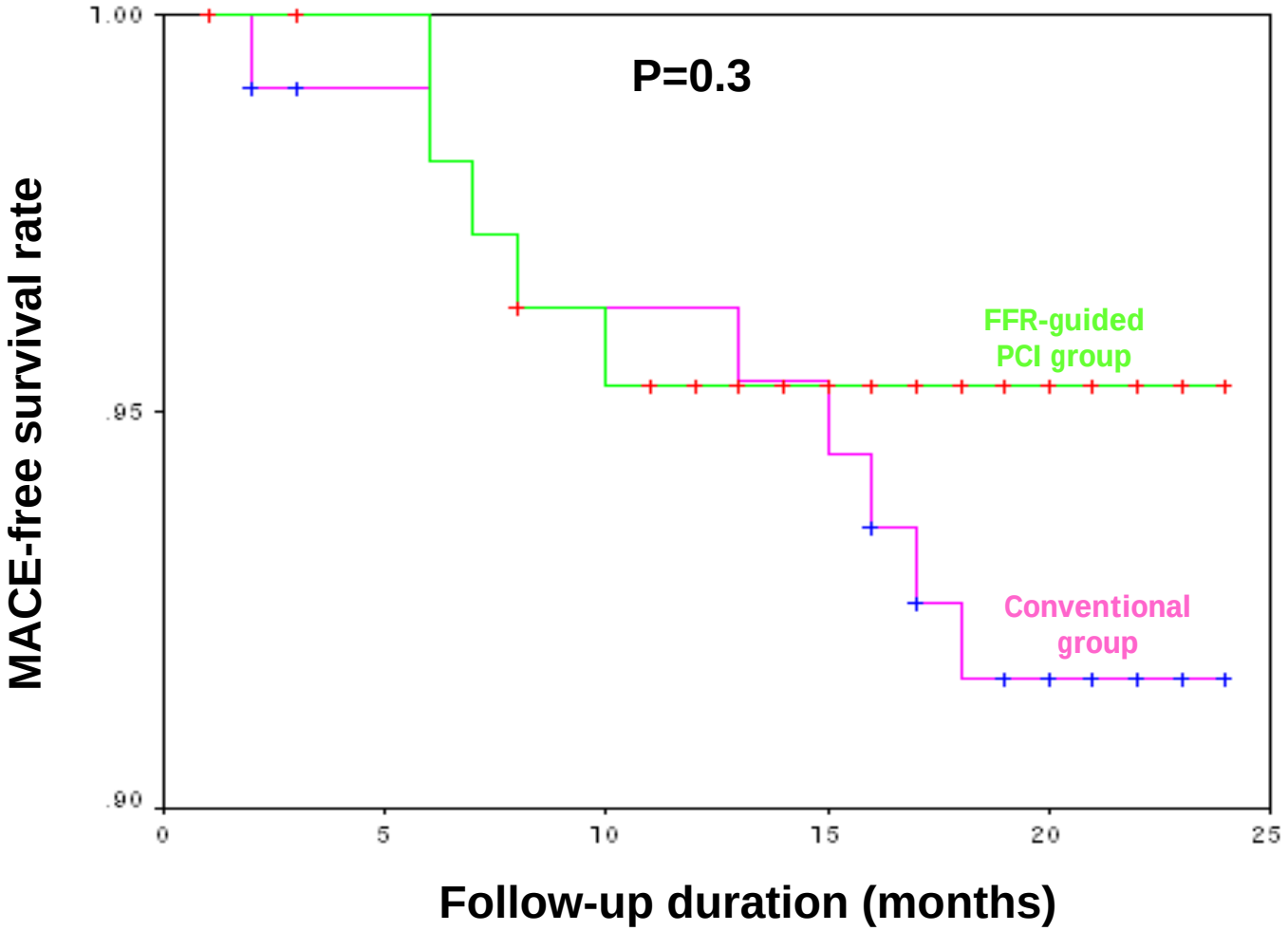
Nine month clinical outcomes

	FFR group	Conventional group	P
	N=108*	N=108**	
TVR	5 (4.6%)	4 (3.7%)	0.7
MI	0	0	1
Cardiac death	0	0	1

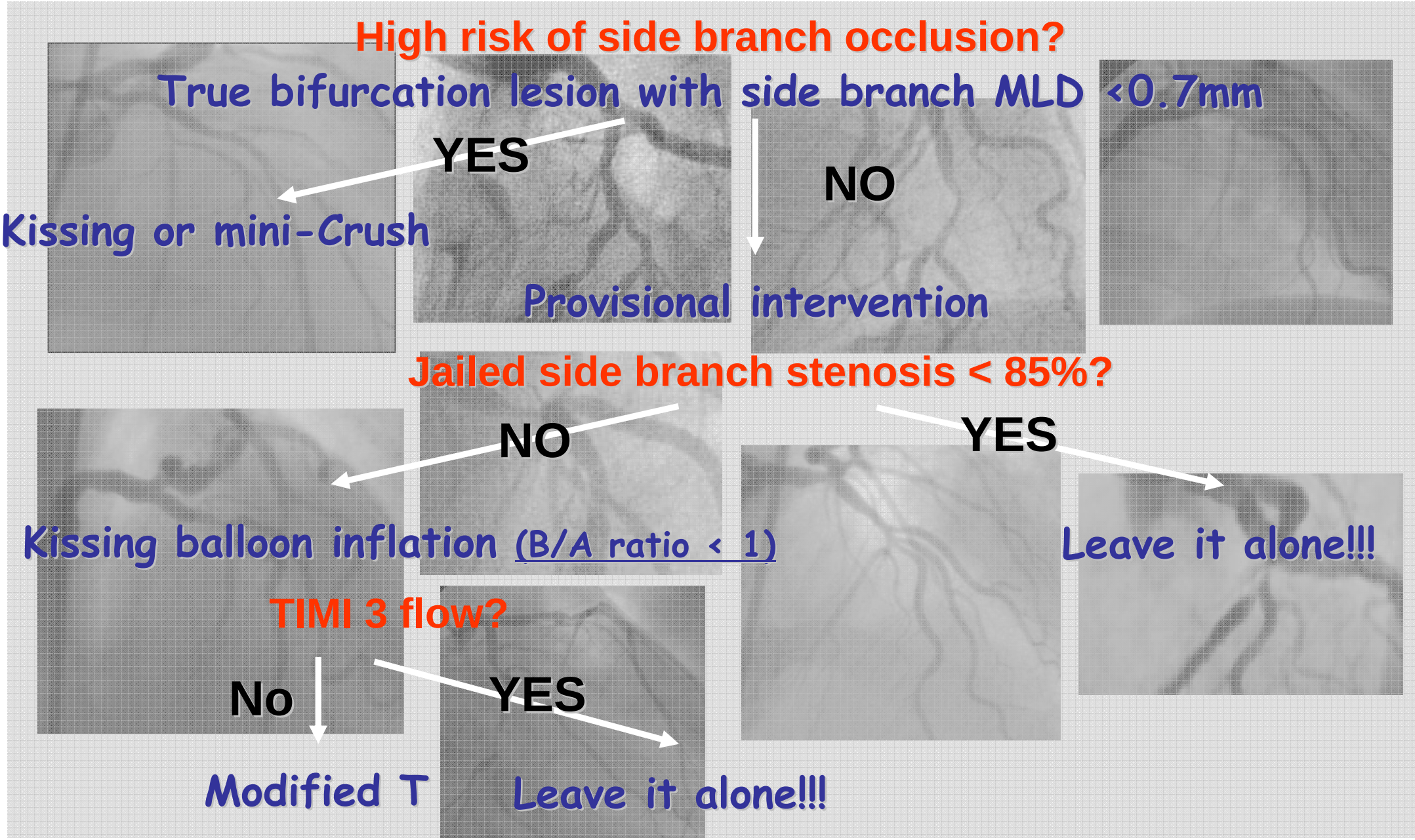
* 1 non-cardiac death, 1 follow-up loss

** 2 follow-up losses

2-year MACE-free survival

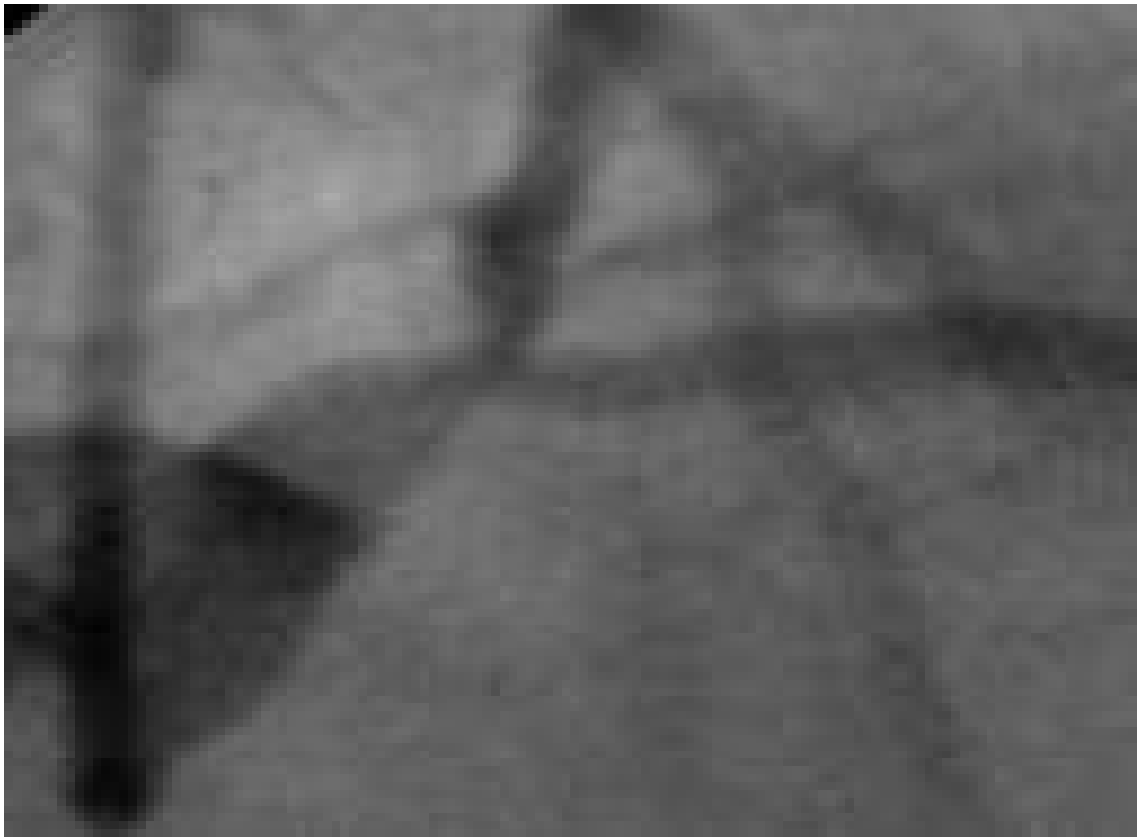


How to treat these lesions?

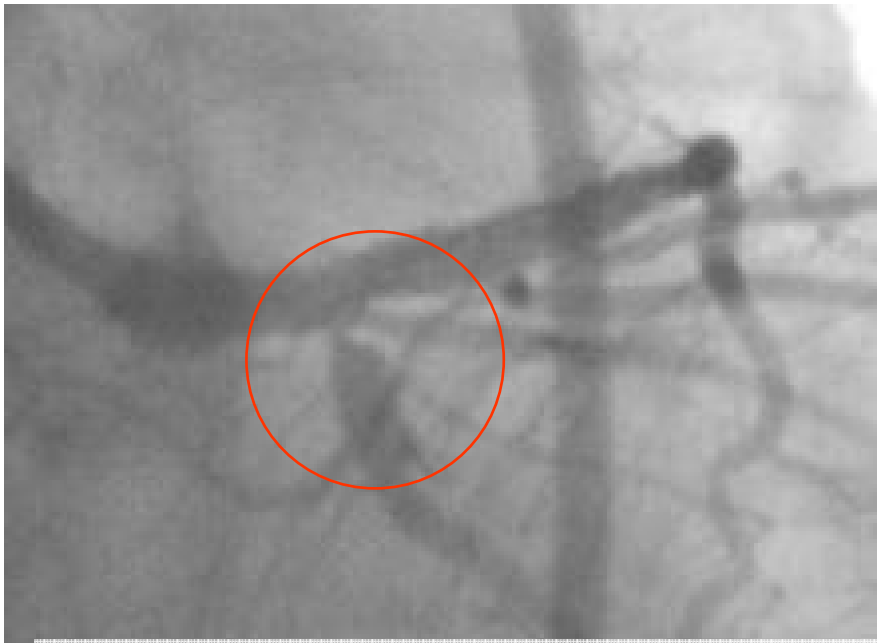


Question 4

What about left main?



What about “Left Main”?



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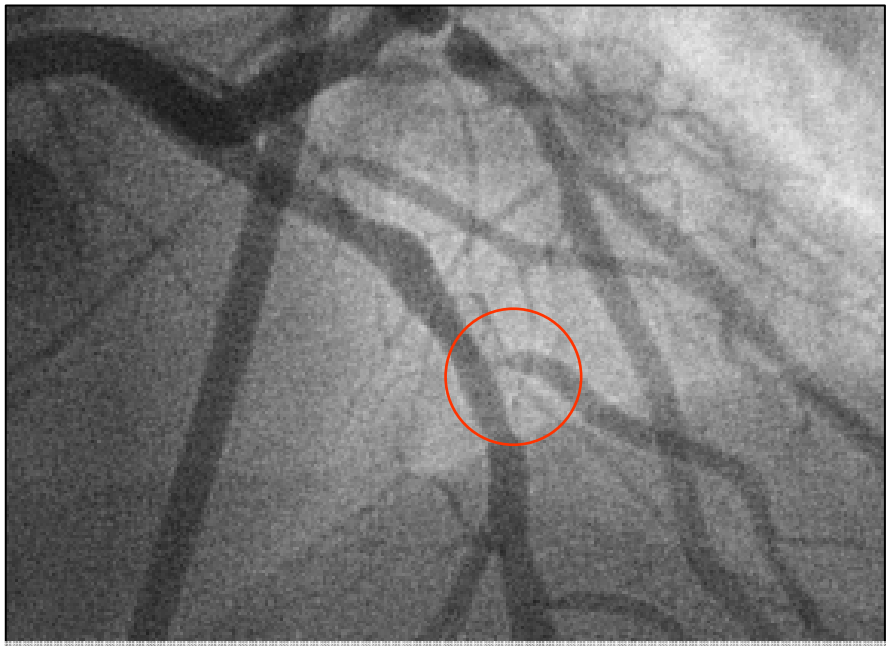
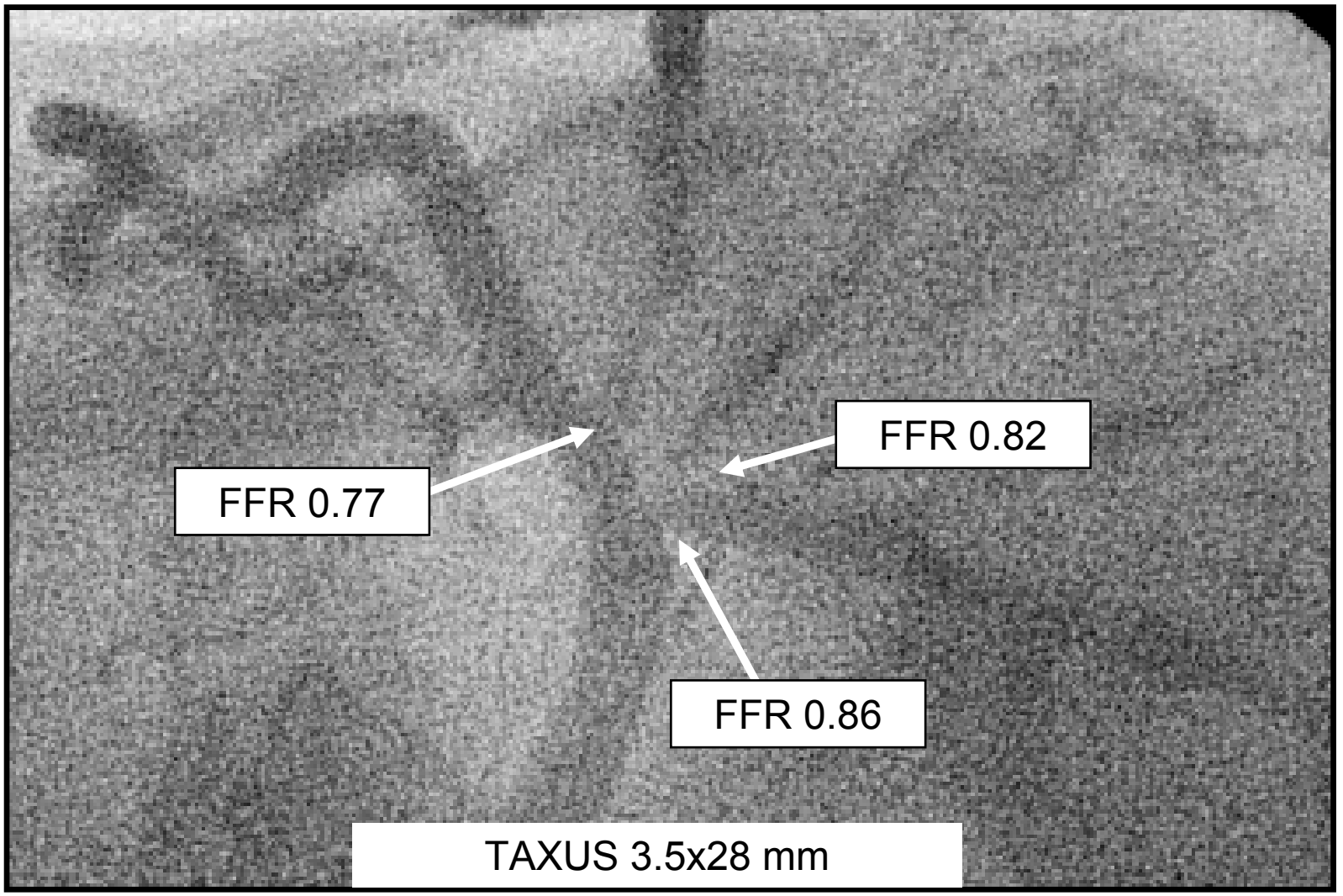


Fractional Flow Reserve (FFR)

Easily obtained, stenosis specific, simple (<0.75→ischemia)

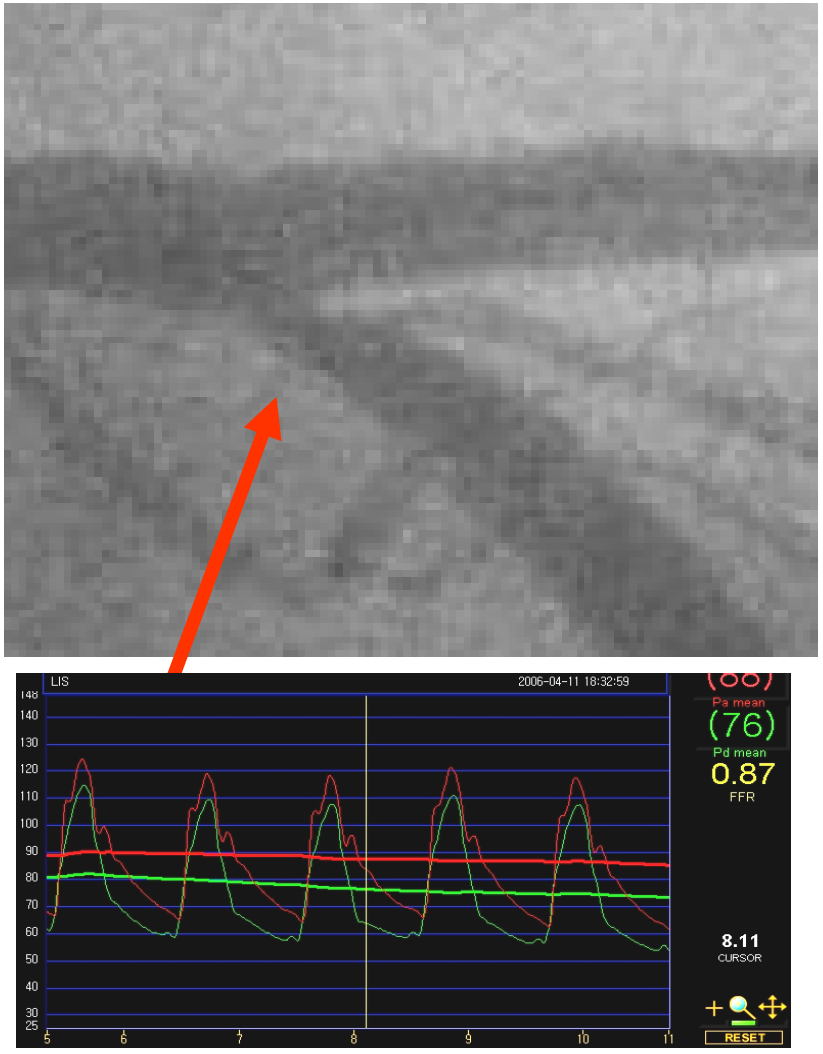
Reflects both degree of stenosis and myocardial territory

F/67 Unstable angina, Left main distal to LAD os lesion

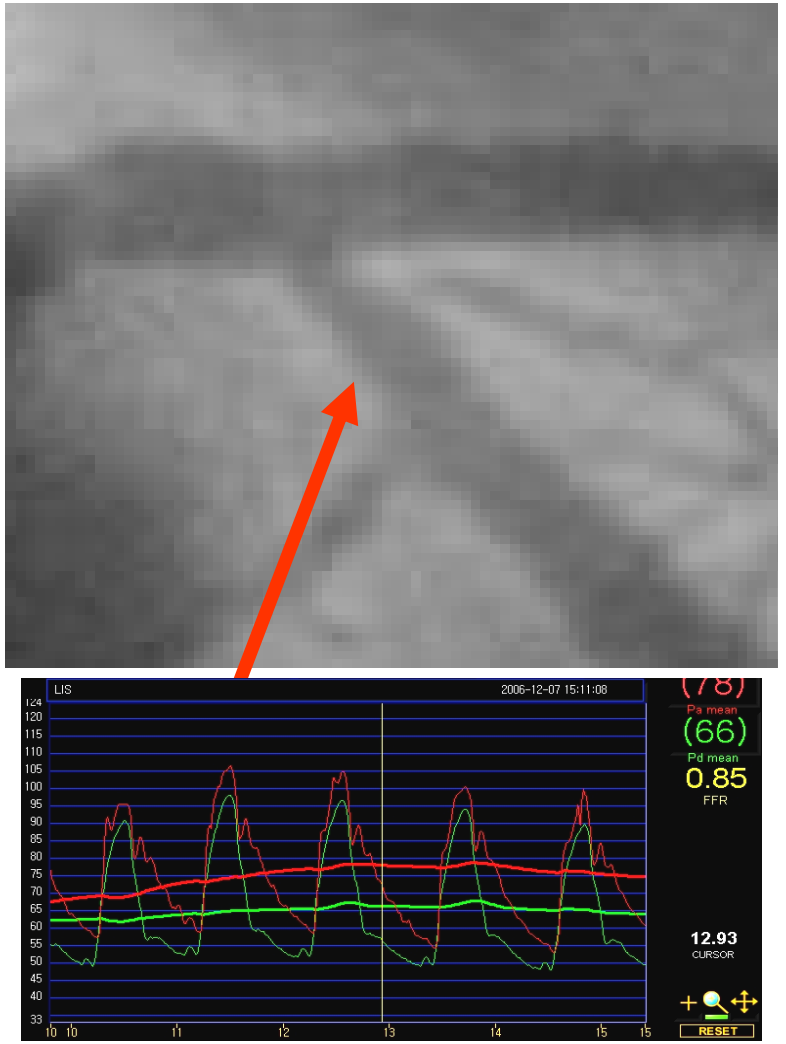


M/64 Crescendo angina

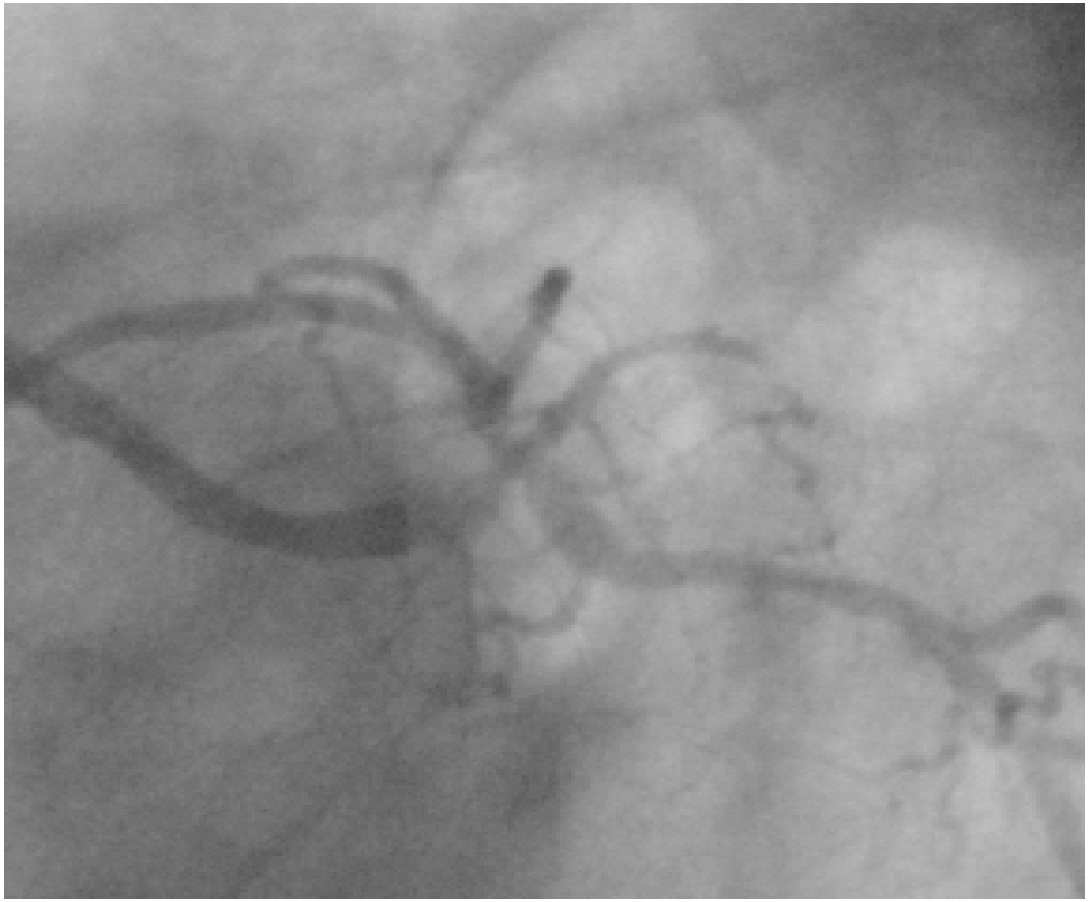
After cypher 3.5x18mm LCX cross-over



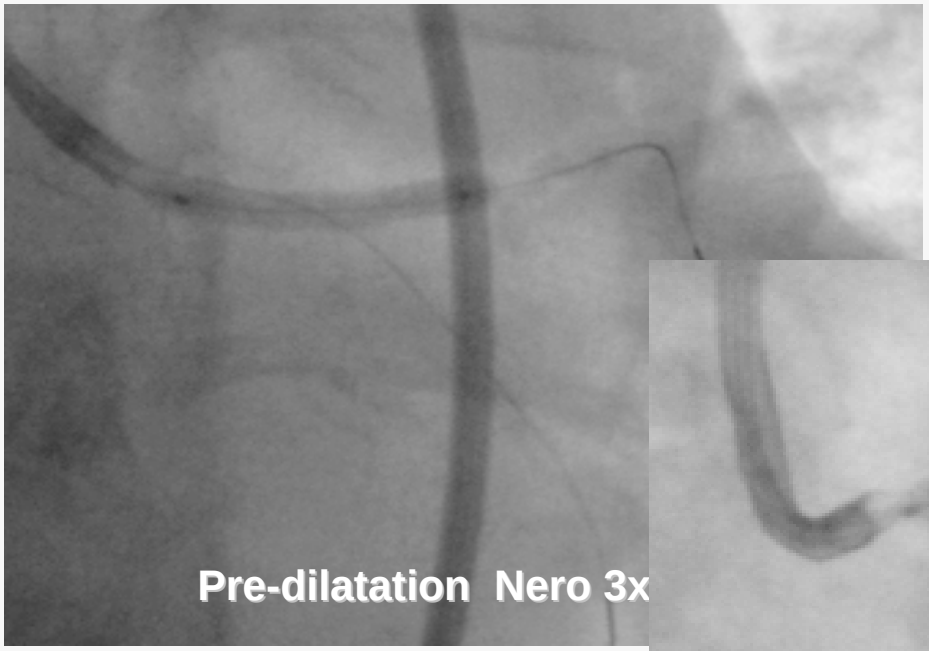
9 Month follow-up angiogram

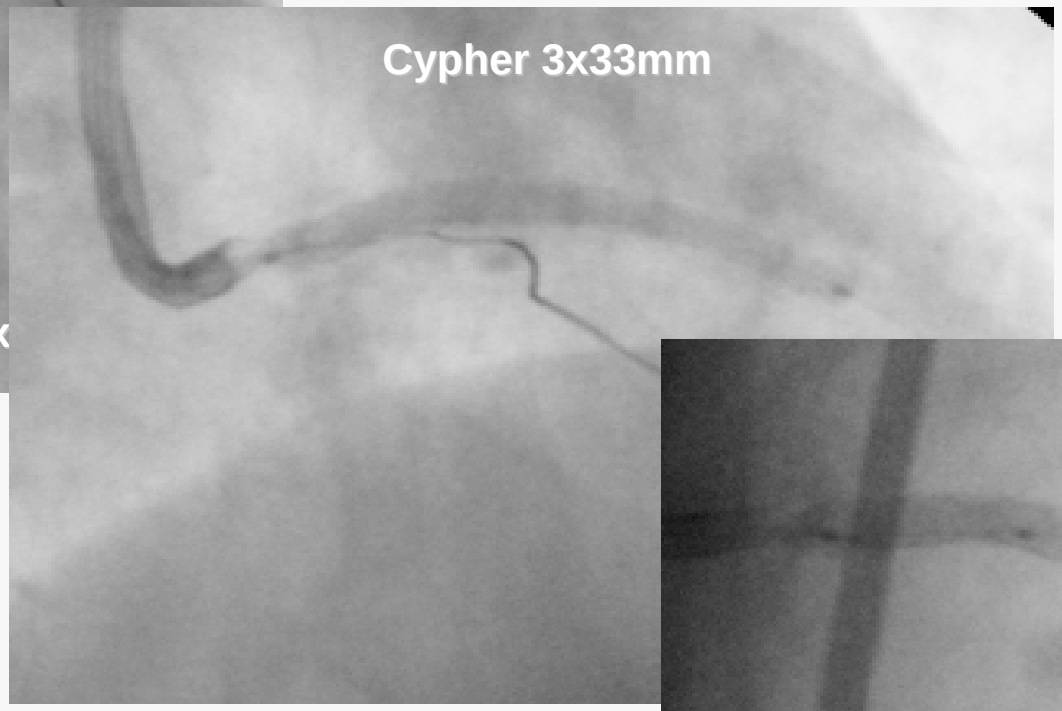


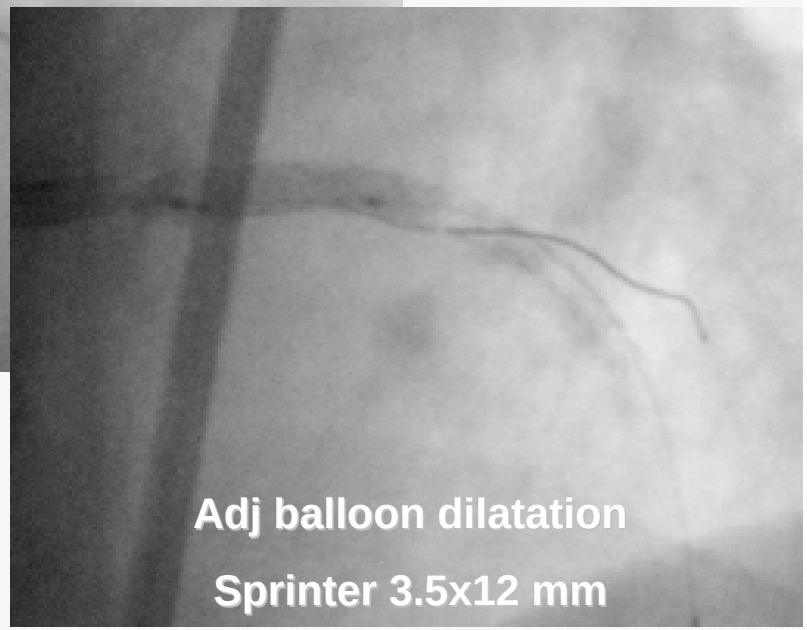
F/54 Crescendo angina



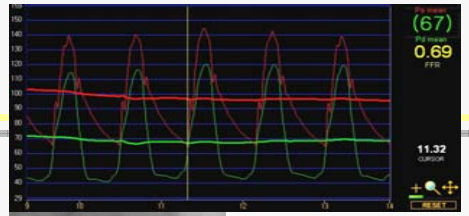
FFR-guided Left main intervention

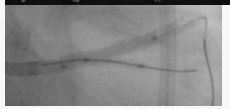




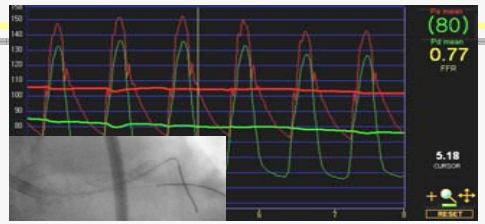


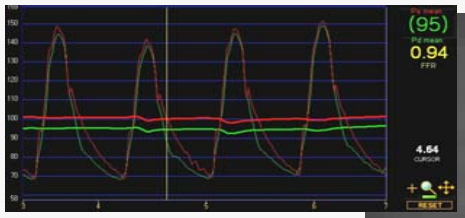
FFR-guided Left main intervention

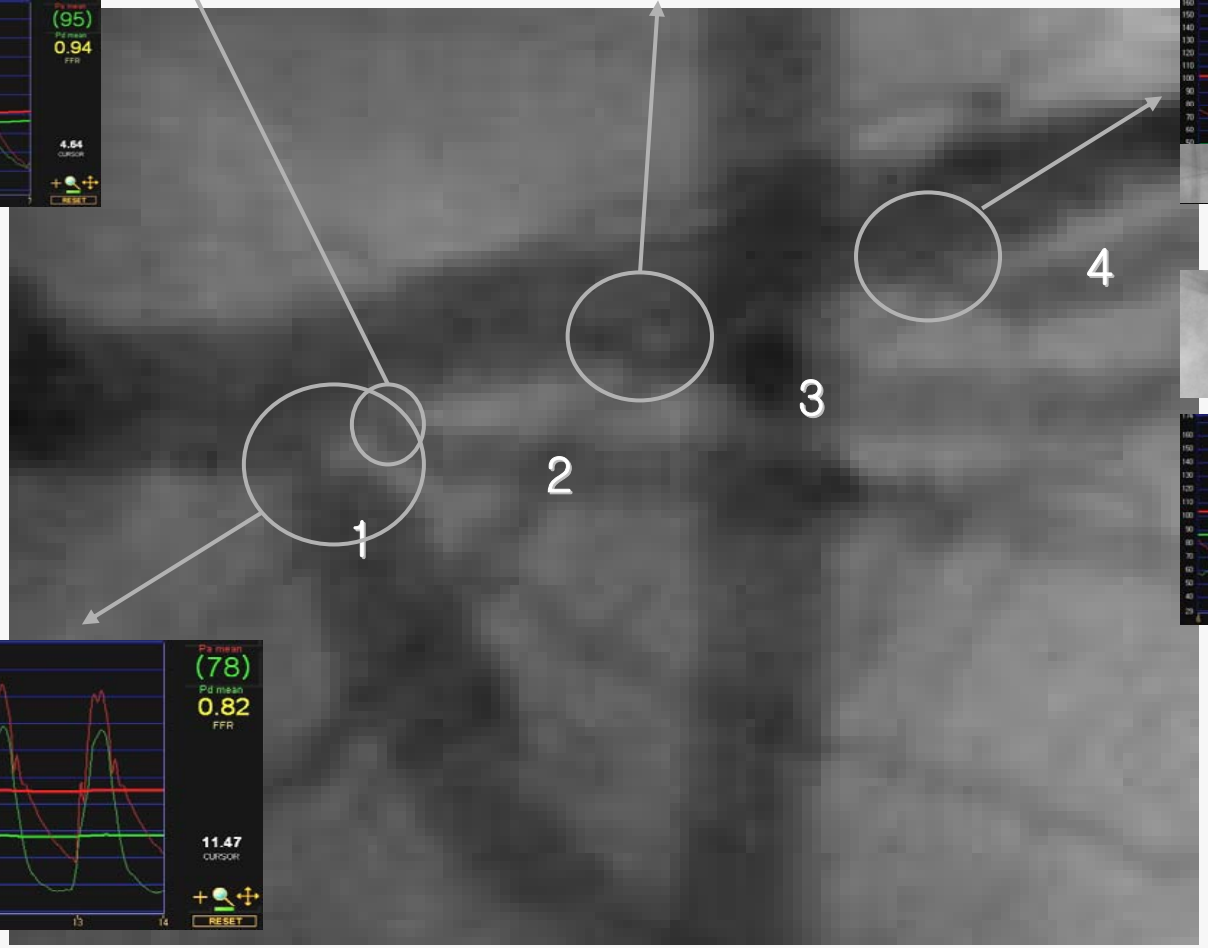


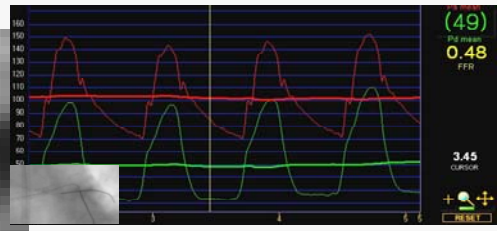


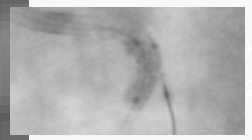
Kissing ballooning
2x12mm + 3x20mm



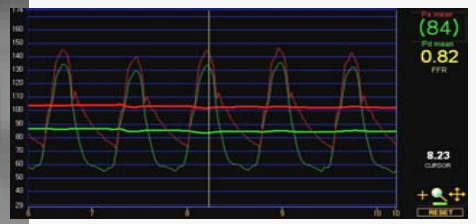


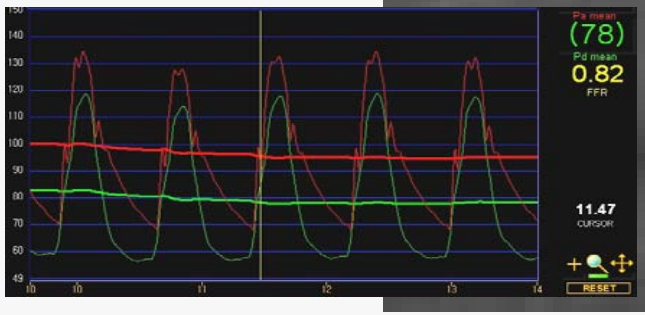






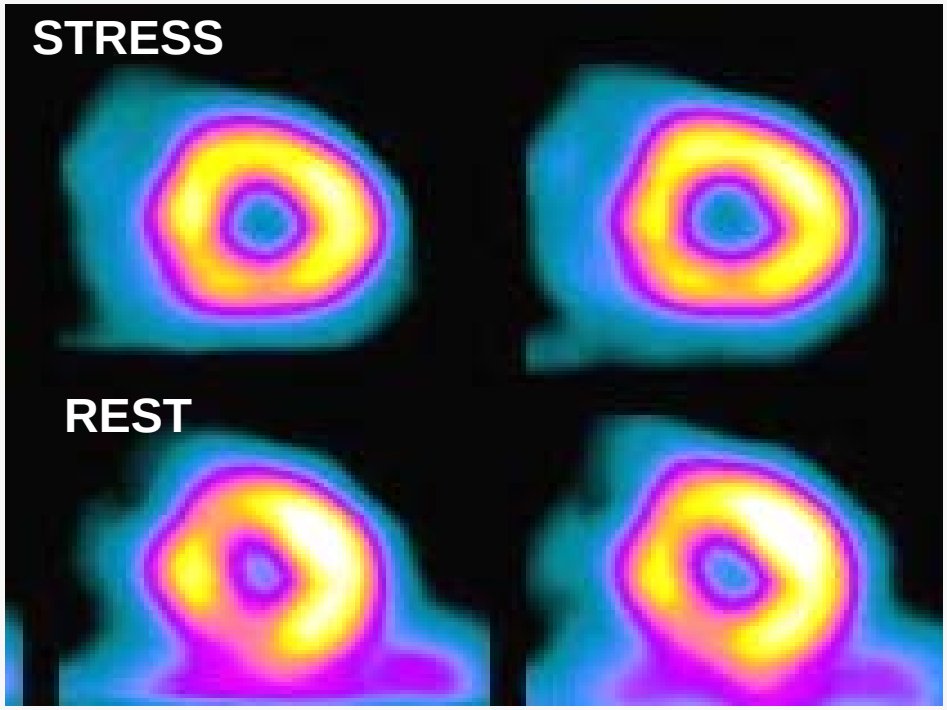
Kissing ballooning
2x12mm + 3x20mm

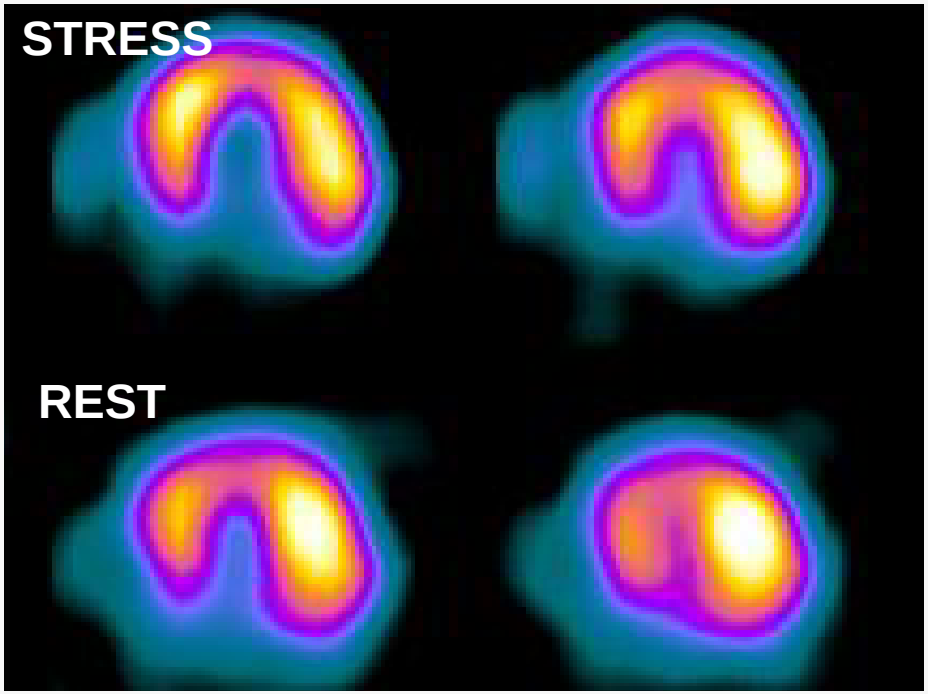




FFR measurement: 7 times, Kissing balloon inflation: 3 times → 25 min !

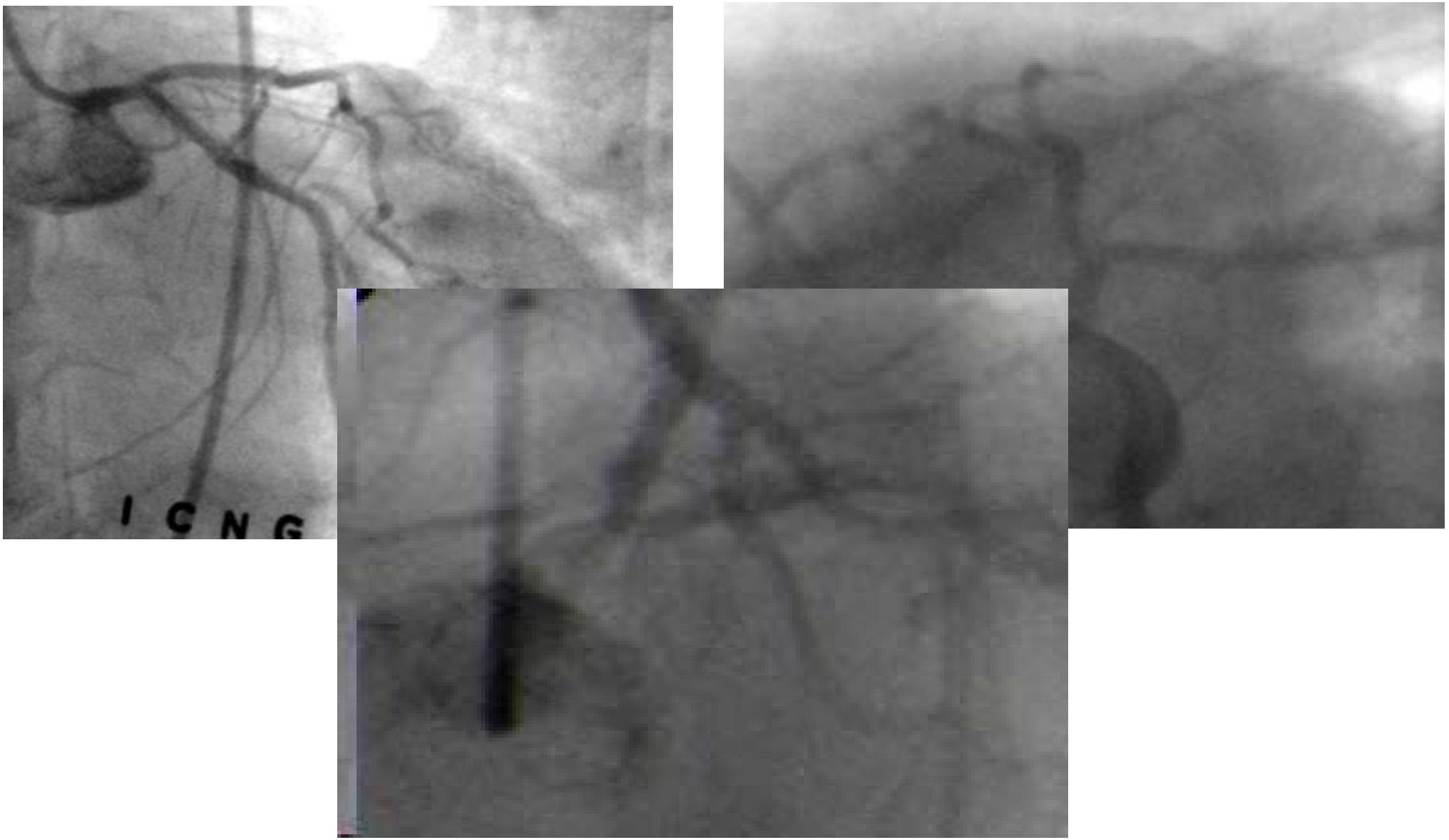
Myocardial SPECT after PCI

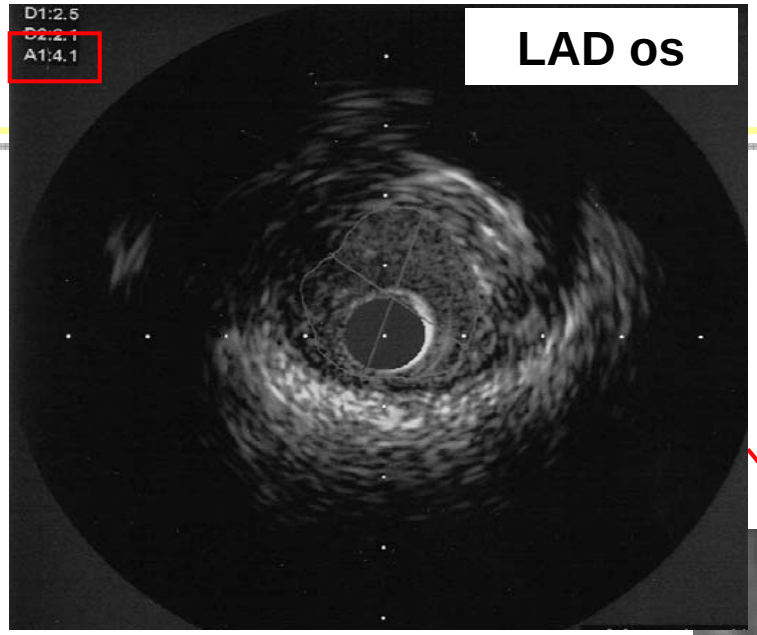


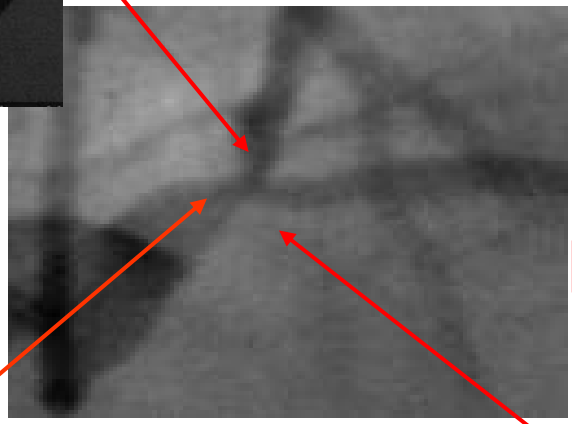


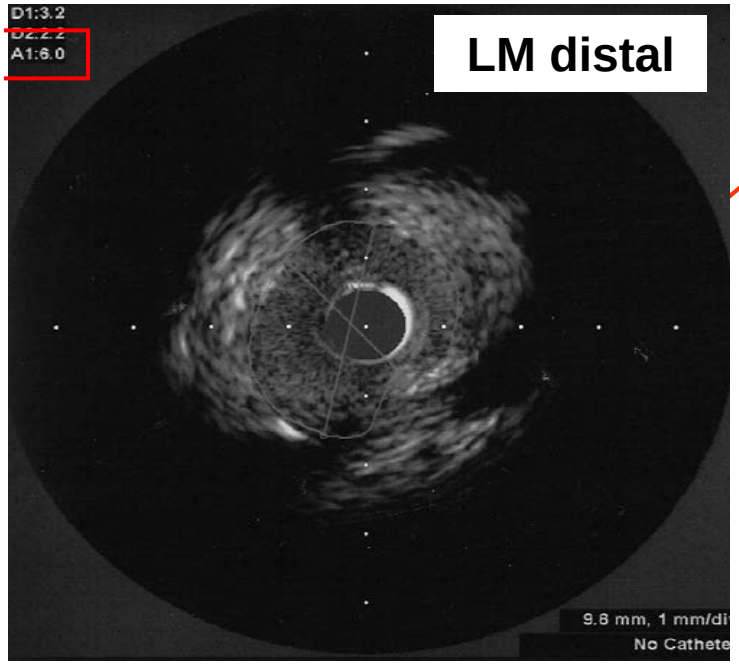
No chest pain with ASA, clopidogrel, carvedilol and statin!

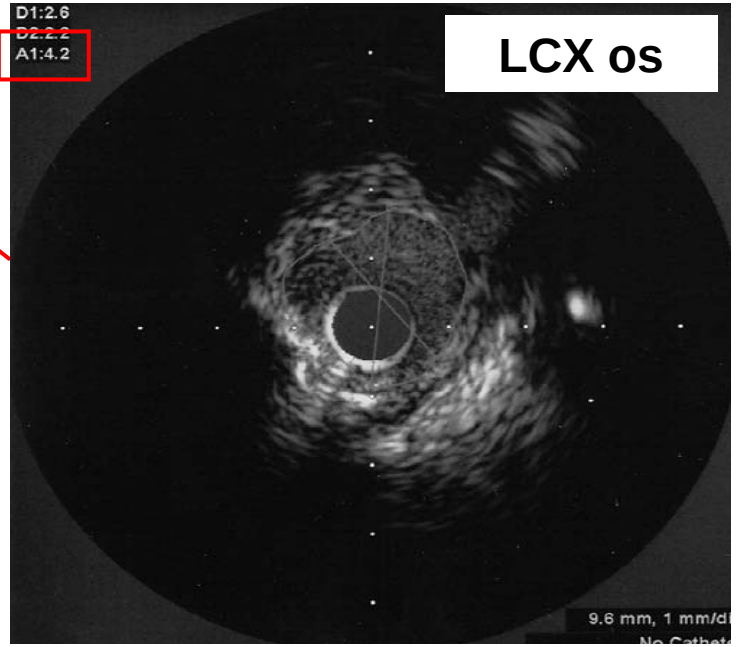
M/65 Stable angina



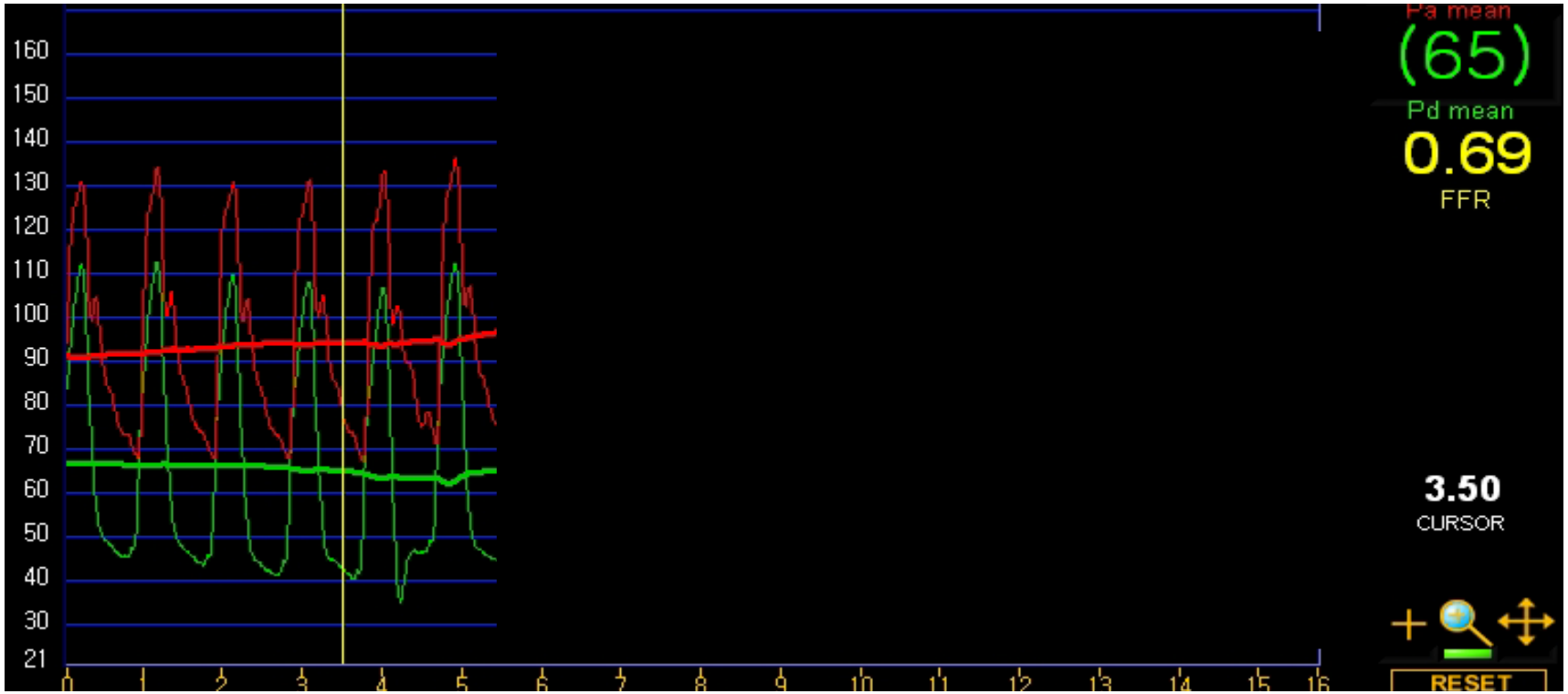

D1:2.5
A1:4.1
LAD os

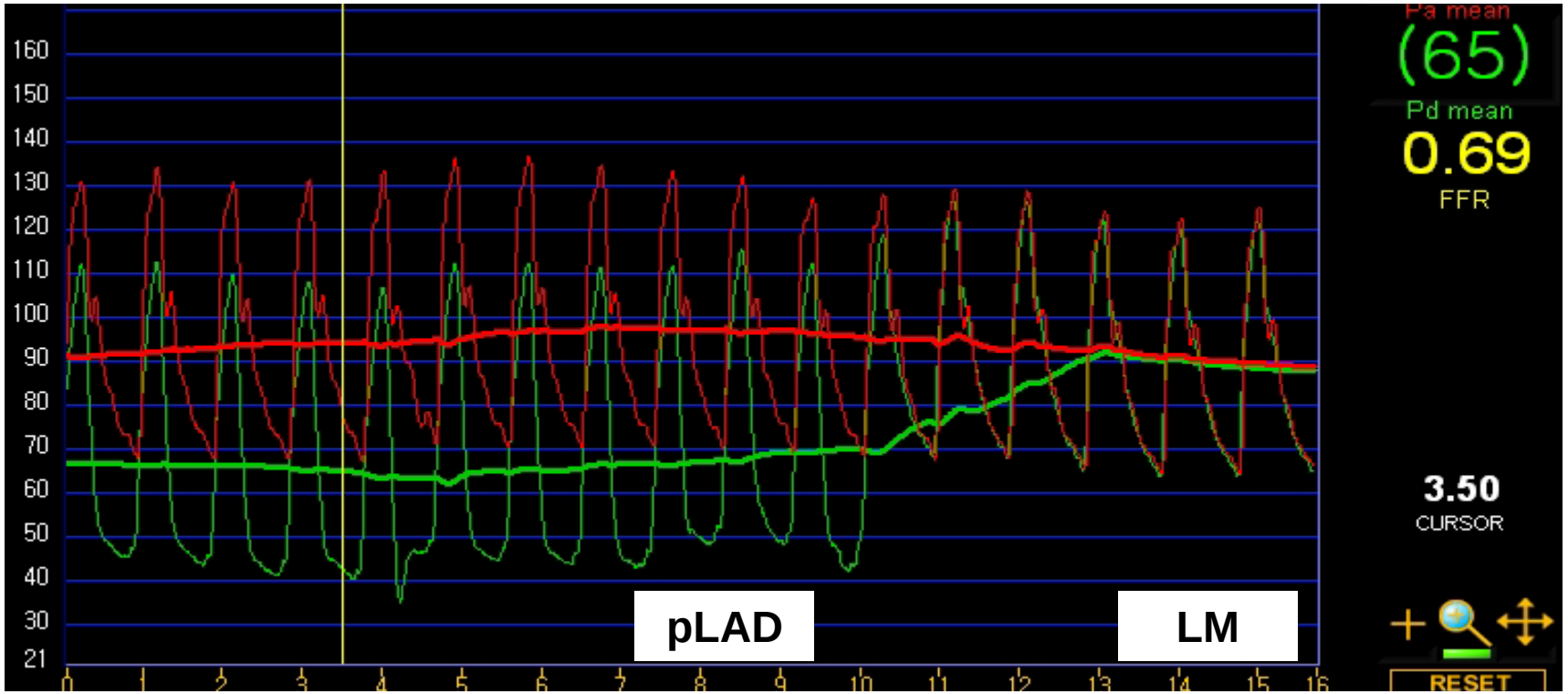


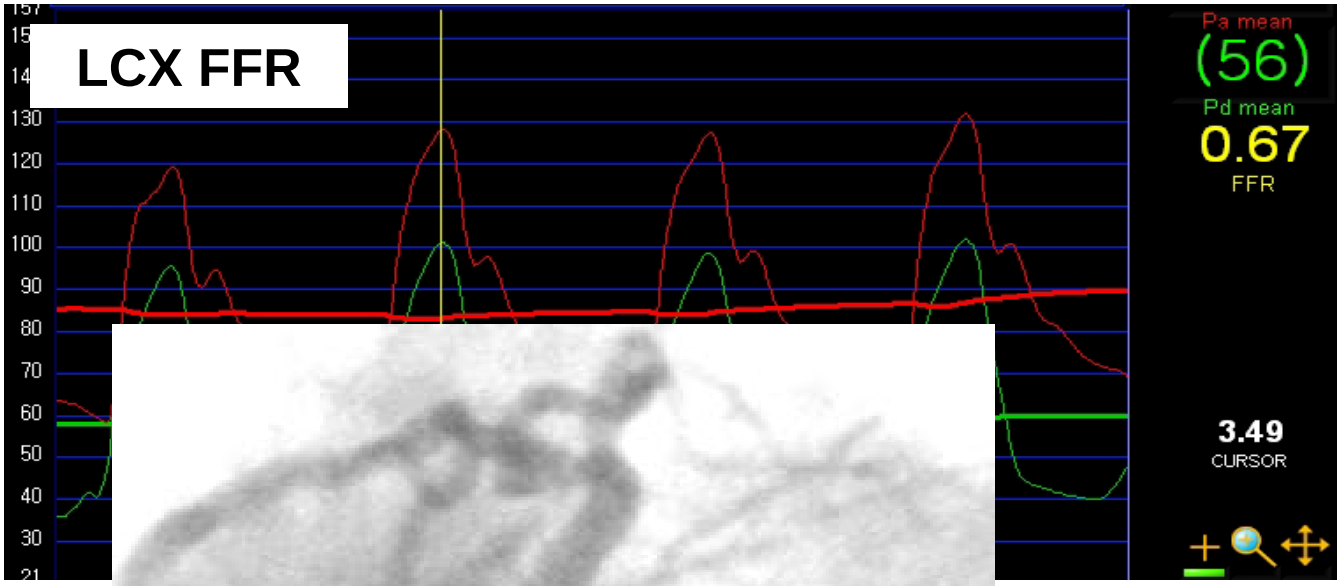

D1:3.2
A1:6.0
LM distal
9.8 mm, 1 mm/di
No Cathete


D1:2.6
A1:4.2
LCX os
9.6 mm, 1 mm/di

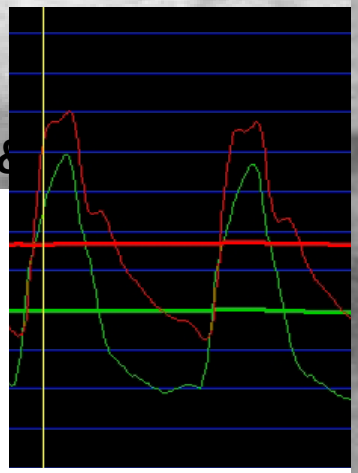
FFR at mid LAD

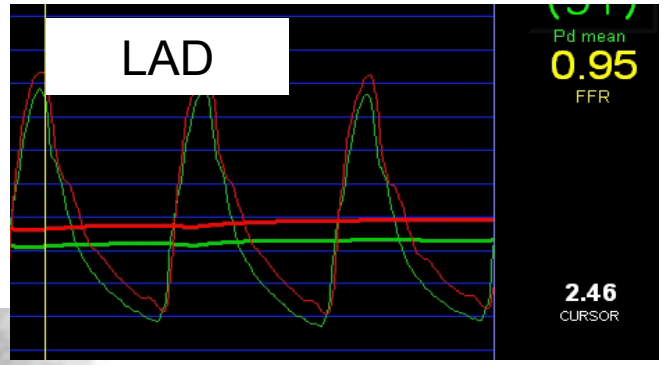


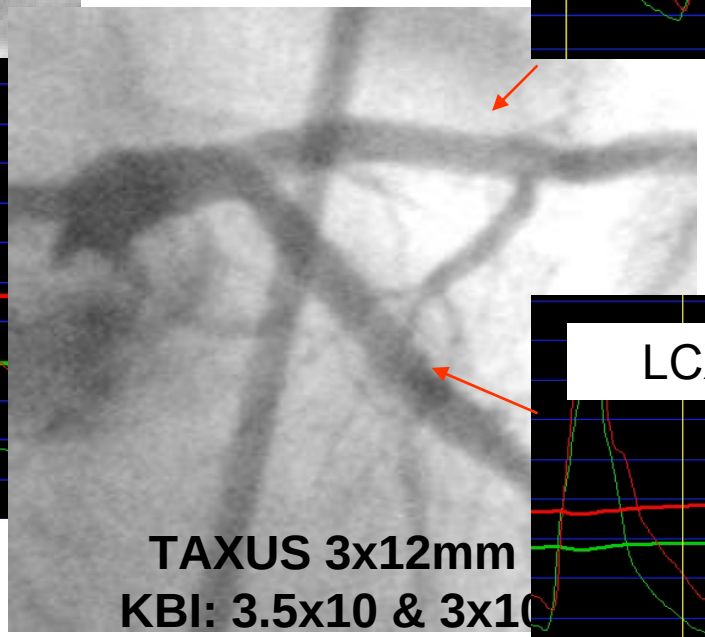

Pa mean
(65)
Pd mean
0.69
FFR
3.50
CURSOR
RESET
pLAD
LM
160
150
140
130
120
110
100
90
80
70
60
50
40
30
21
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

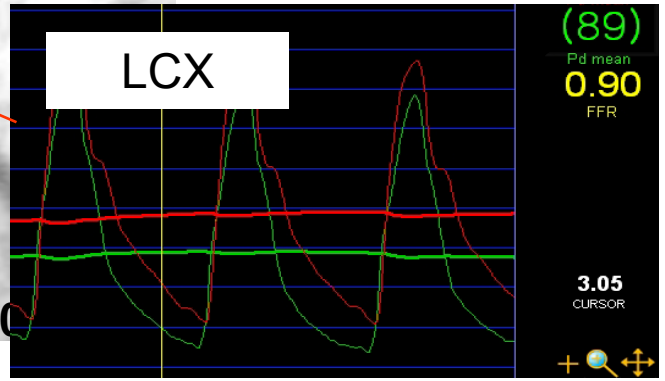

LCX FFR
Pa mean
(56)
Pd mean
0.67
FFR
3.49
CURSOR


KBI: 3.5x10 &




LAD
Pd mean
0.95
FFR
2.46
CURSOR


TAXUS 3x12mm
KBI: 3.5x10 & 3x10


LCX
(89)
Pd mean
0.90
FFR
3.05
CURSOR

Conclusion

- FFR gives us new insights into our understanding and treatment of bifurcation lesion
- In some lesions, like left main disease, FFR should be measured to accurately assess the functional significance of the lesion.

When you go with provisional strategy for bifurcation lesions;

Don’t be too aggressive and

if you are in a doubt, measure the “FFR”!