Integrated Use of IVUS and FFR for LM Stenting

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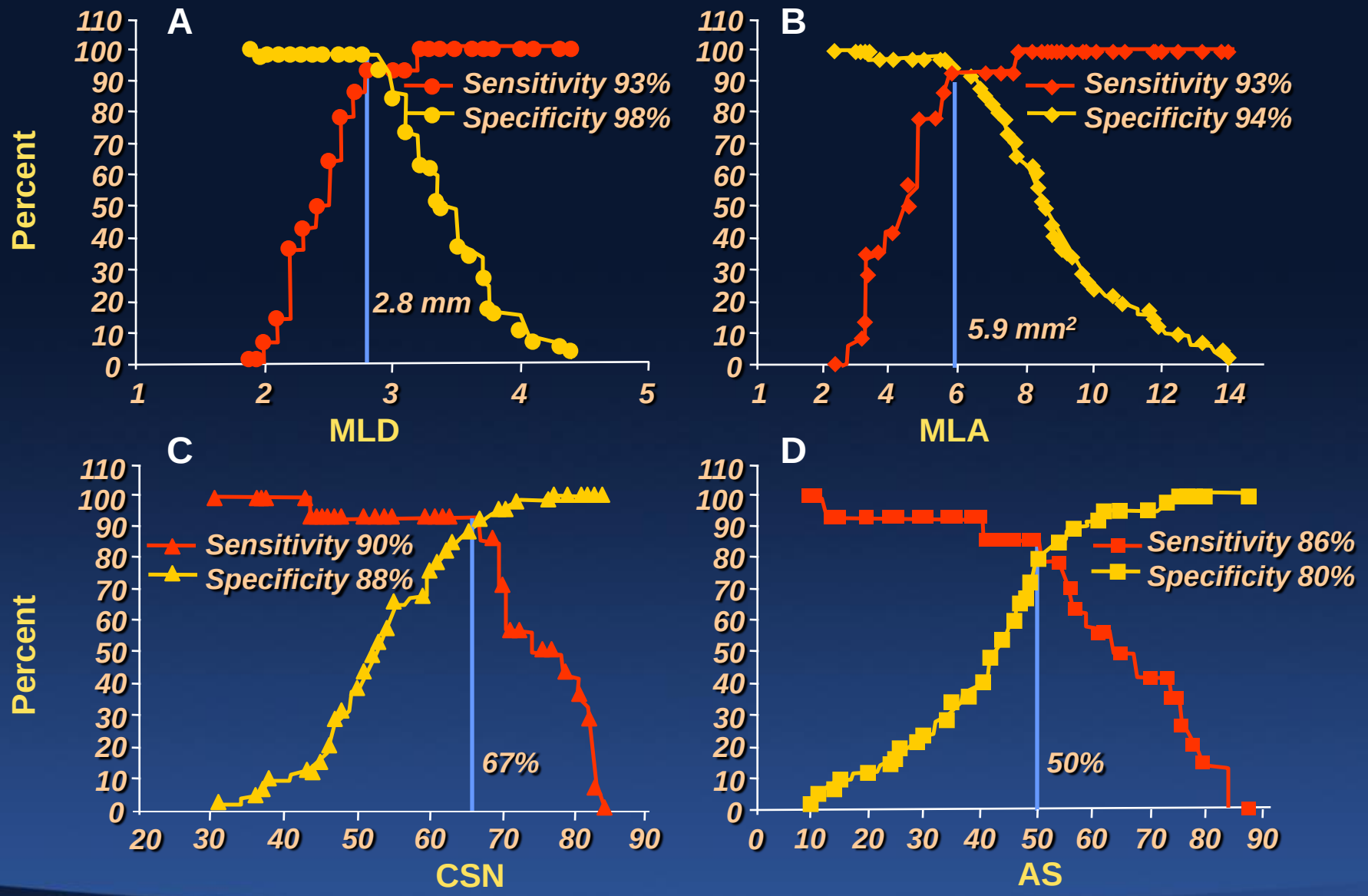
Four studies have highlighted the inaccuracy of angiography in the assessment of LMCA disease

- Fisher et al. Cathet Cardiovasc Diagn 1982;8:565-75
- Cameron et al. Circulation 1983;68:484-489
- Lindstaedt et al. Int J Cardiol 2007;120:254-61
  - In 51 patients unanimous correct assessment of LM severity by 4 experienced interventional cardiologists was only 29%
- Hamilos et al. Circulation 2009;120:1505-12
  - In 209 patients two reviewers either disagreed whether the LM was significant or they agreed and were wrong in their assessment of LM severity in 49%

IVUS vs FFR in LMCA Disease

- There is more agreement between IVUS and FFR in assessing LMCA than in assessing non-LMCA lesions
  - Limited variability in (short) LMCA length
  - Limited variability in large LMCA size
  - Limited variability in amount of supplied myocardium
- Both have theoretical and practical limitations
  - FFR
    - Proximal LAD and/or LCX disease may affect FFR of LMCA
  - IVUS
    - Especially in distal LMCA lesions, it is necessary to image from both the LAD and LCX
    - It is not possible to assess the LCX from an LAD-to-LM pullback, and it is not possible to assess the LAD from an LCX-to-LM pullback

IVUS Determinants of LMCA FFR <0.75



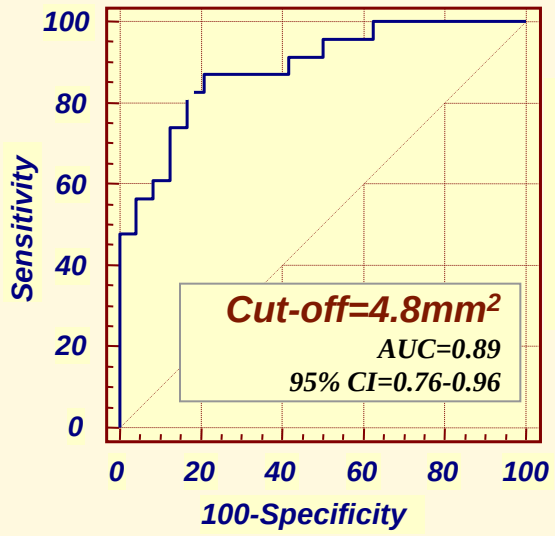
Jasti et al. Circulation 2004;110:2831-6

IVUS determinants of LM FFR (n=47)

Independent predictors for FFR (continuous variable)

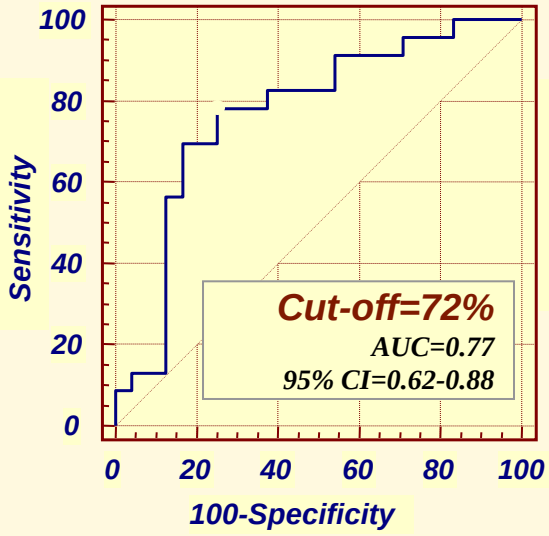
- MLA (β=0.58, 95% CI=0.02-0.04, p<0.001)
- Plaque rupture (β=-0.24, 95% CI= -0.09-0.01, p=0.036)

MLA predicting FFR<0.80



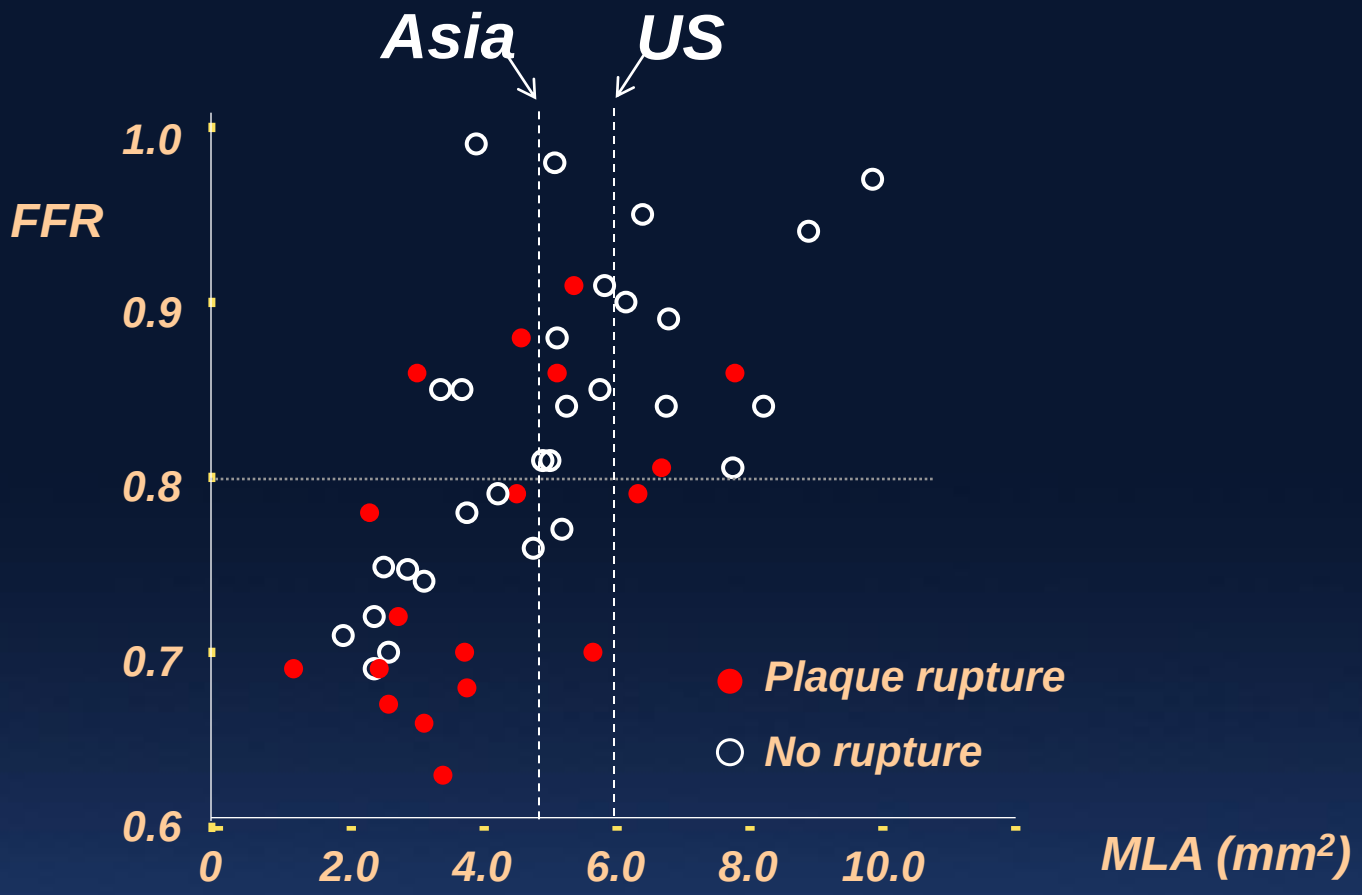
Sensitivity 83%
Specificity 83%
PPV 83%
NPV 83%
Accuracy 83%

PB predicting FFR<0.80



Sensitivity 78%
Specificity 75%
PPV 75%
NPV 78%
Accuracy 77%

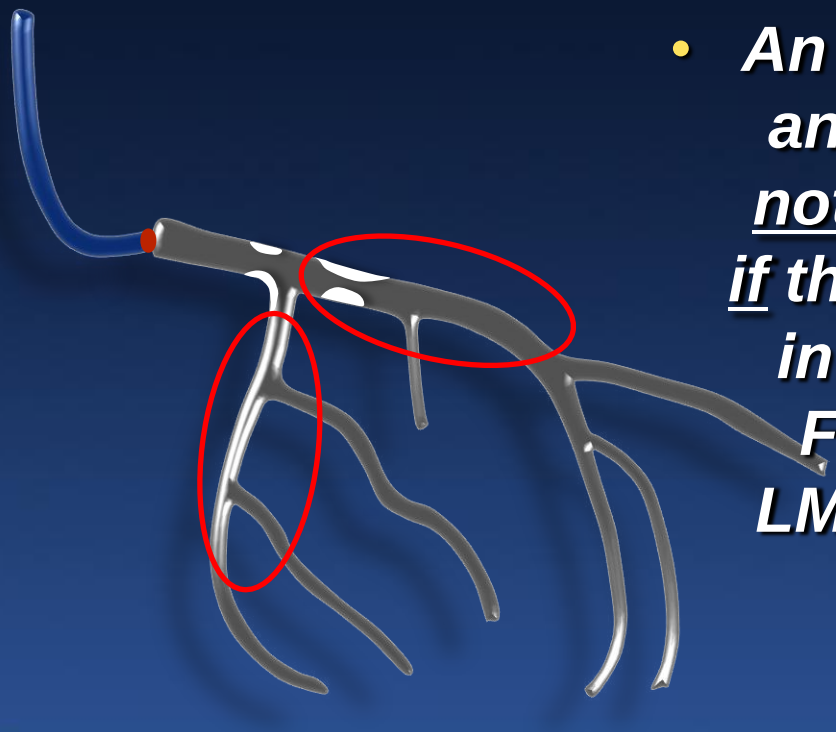
Kang et al. JACC Cardiovasc Interv 2011;4:1168-74



	Men	Women
South Korea	68.6 kg	56.5 kg
US	88.3 kg	74.7 kg
Heart weight correlates directly with body weight (r=0.8-0.9)		

Kang et al. JACC Cardiovasc Interv 2011;4:1168-74
Yoon et al. Korean J Path 1999;33:1-8
Seo et al. J Korean Med Sci 2000;15:641-6

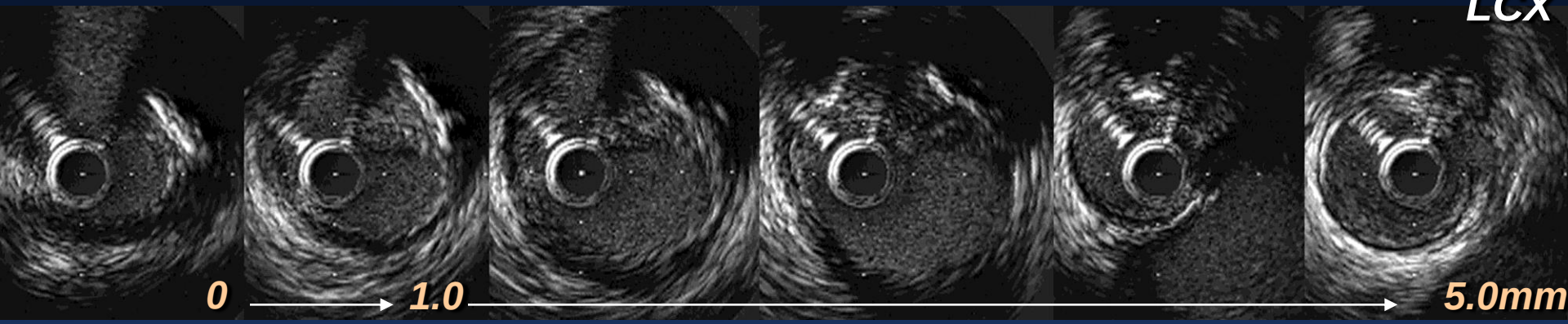
LMCA disease is rarely isolated (6-9%)

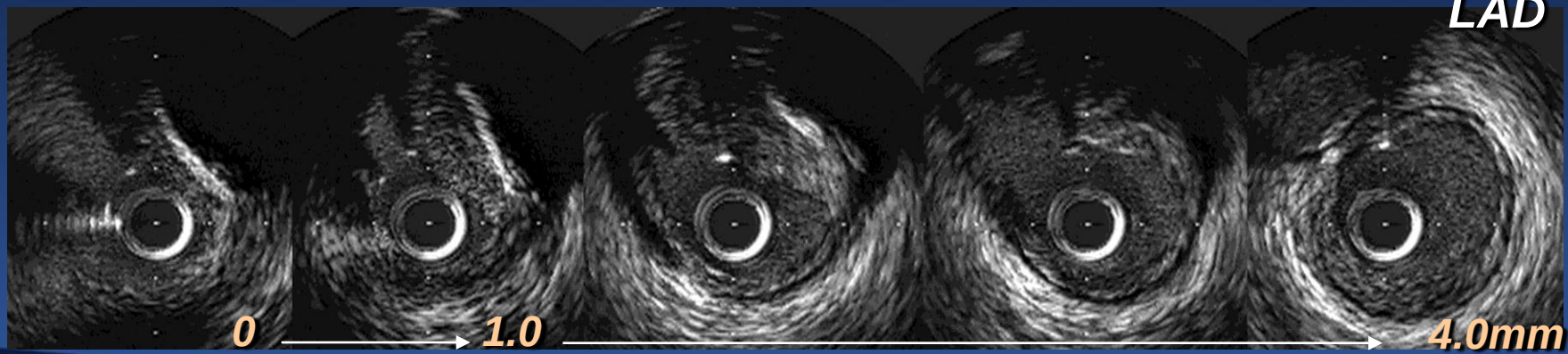


- *An in vitro model suggests that positioning the FFR guidewire in the LCX will not accurately reflect the LMCA only if the composite FFR in the LMCA+LAD is ≤0.65.*
- *An in vivo ovine model suggests that an FFR in the uninvolved artery will not accurately reflect the LMCA only if the composite FFR in the LMCA+the involved artery is ≤0.50 and that an FFR >0.85 would indicate that the LMCA is not functionally significant.*

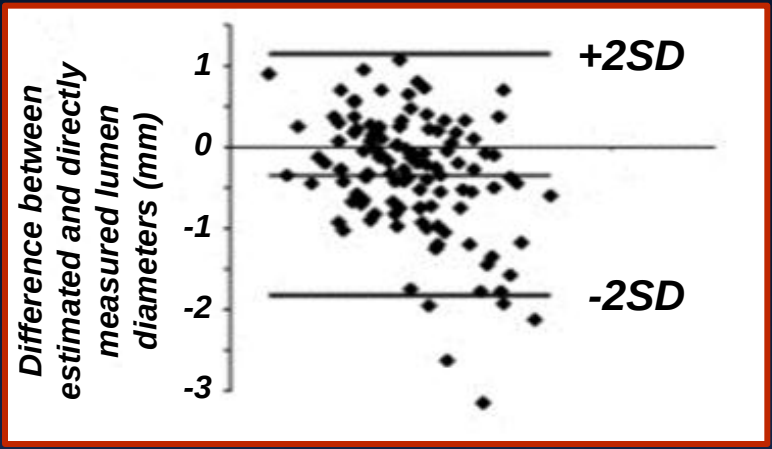
Ragosta et al. Catheter Cardiovasc Interv 2006;67:357-72
Capodanno et al. JACC Cardiovasc Interv 2009;2:731-8
Daniels et al. JACC Cardiovasc Interv 2012;5:1021-5
Young et al. Circ Cardiovasc Interv 2013, in press

- *In 25% of patients, MLA differs by 1mm^2 when imaged from a pullback beginning in the LAD vs the LCX.*
- *Since IVUS can artificially increase, but not decrease lumen dimensions, the smallest MLA is always the most accurate*



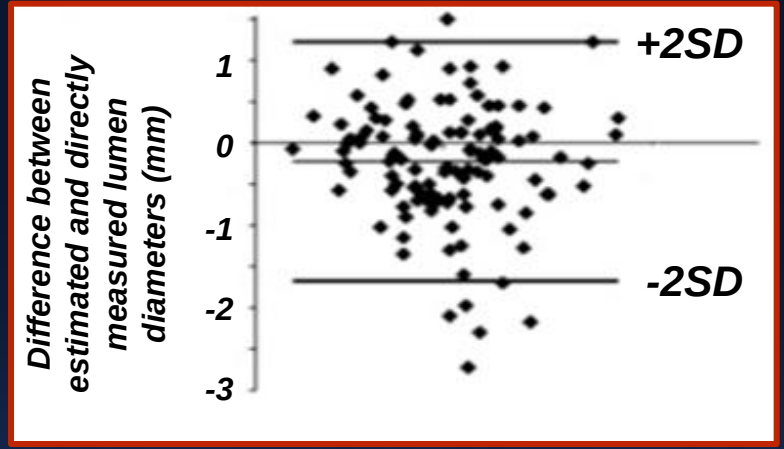


Evaluation of the LAD from the LM-LCX pullback



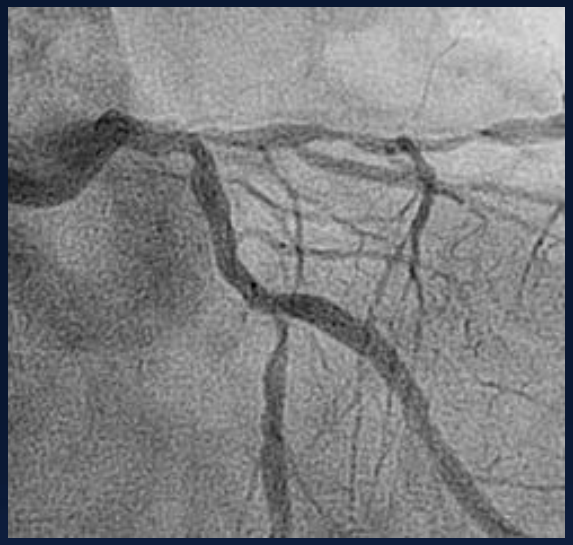
	Sensitivity	Specificity
Plaque burden >40%	59%	45%
Plaque burden >70%	78%	42%

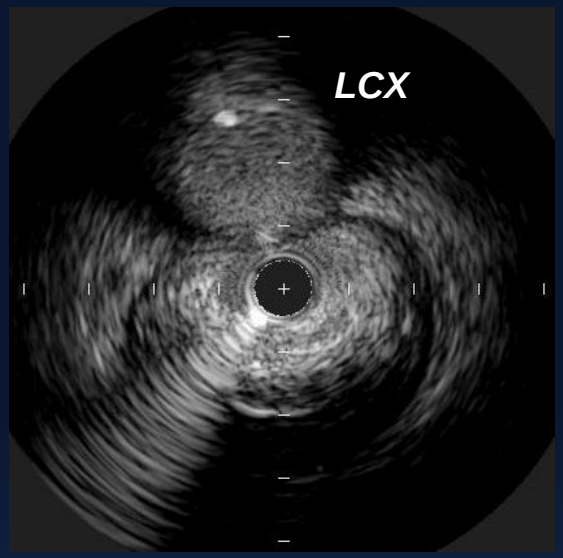
Evaluation of the LCX from the LM-LAD pullback

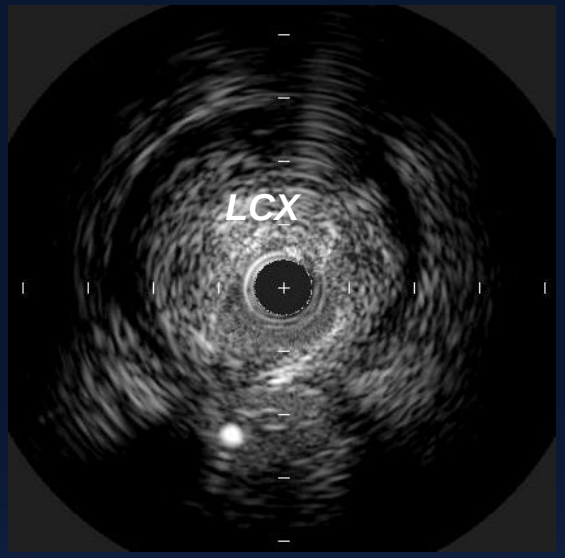


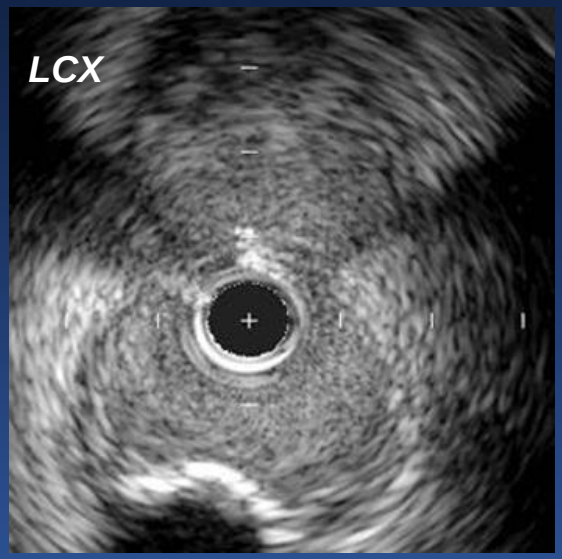
	Sensitivity	Specificity
Plaque burden >40%	67%	55%
Plaque burden >70%	88%	42%

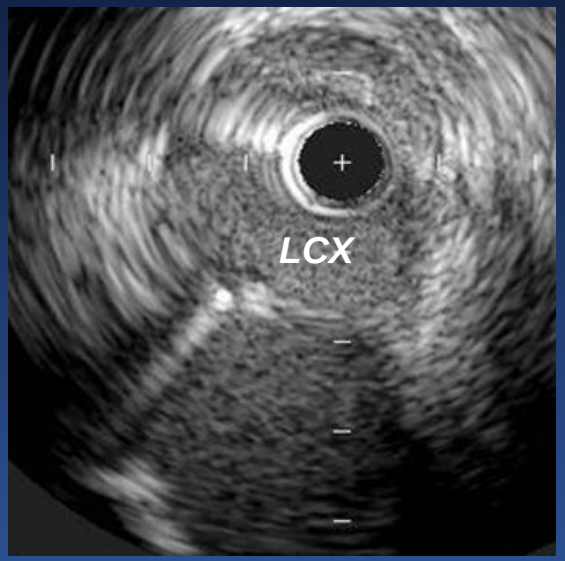
Oviedo et al. Am J Cardiol 2010;105:948-54



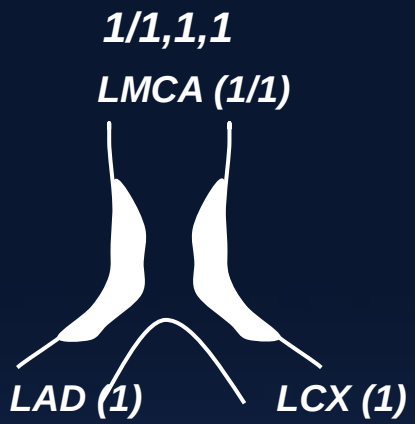

LCX


LCX

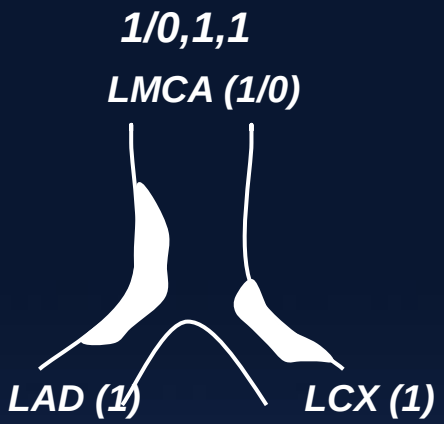

LCX


LCX

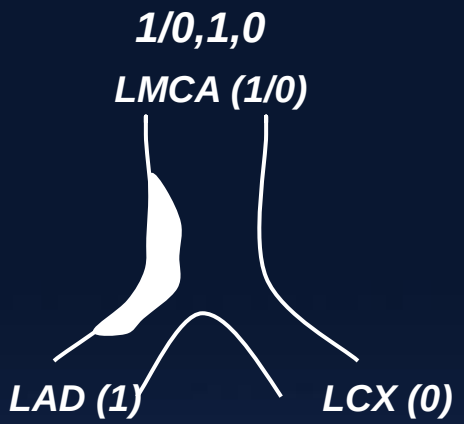
IVUS plaque distribution in 140 distal LMCA bifurcation lesions



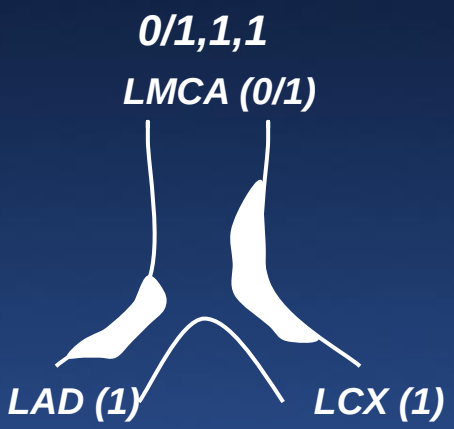
62%



14%



14%



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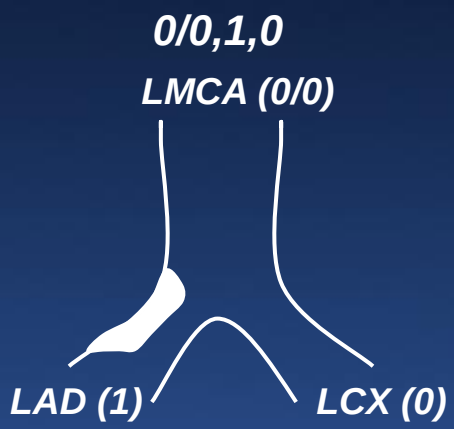

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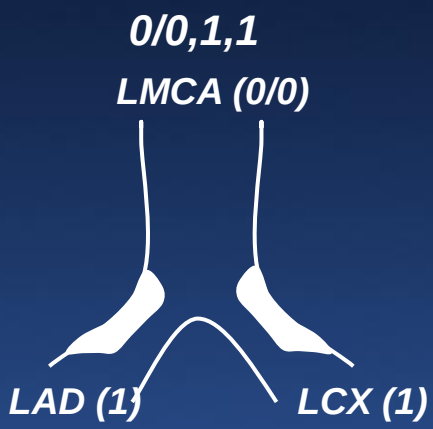

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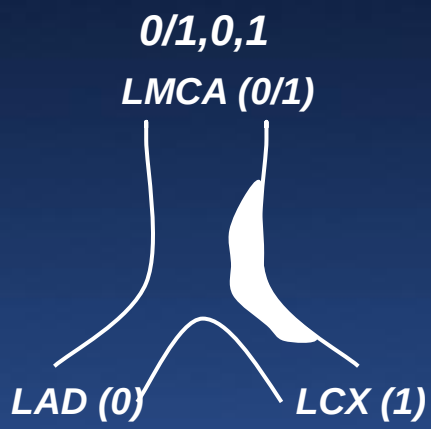
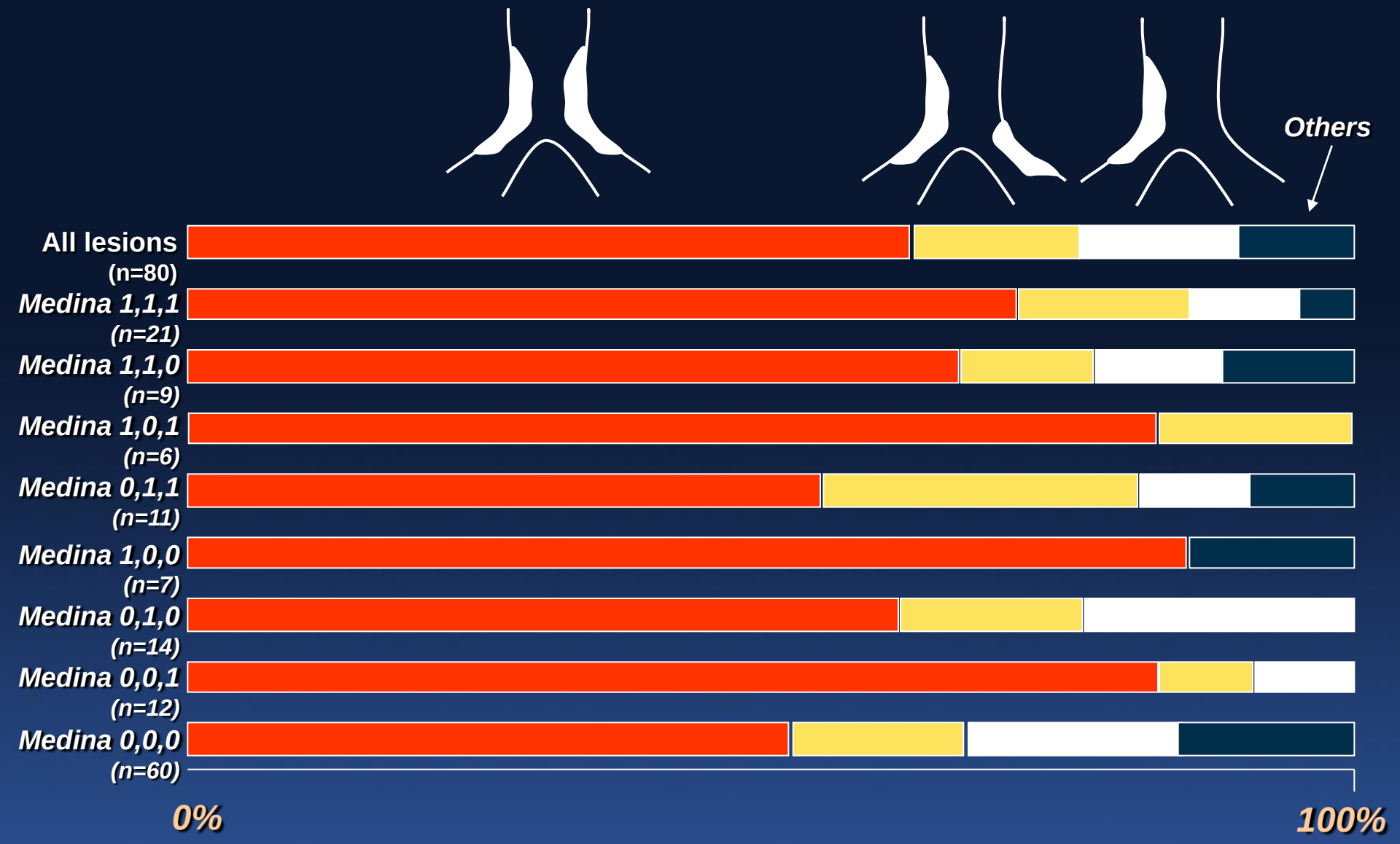
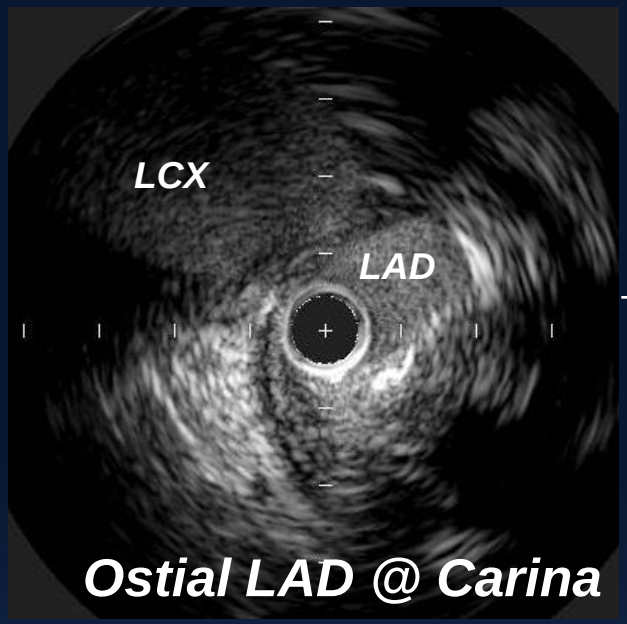


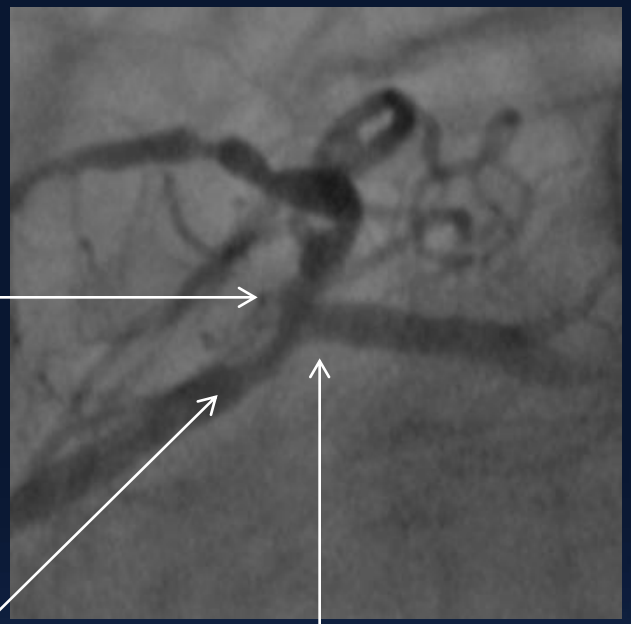
1%

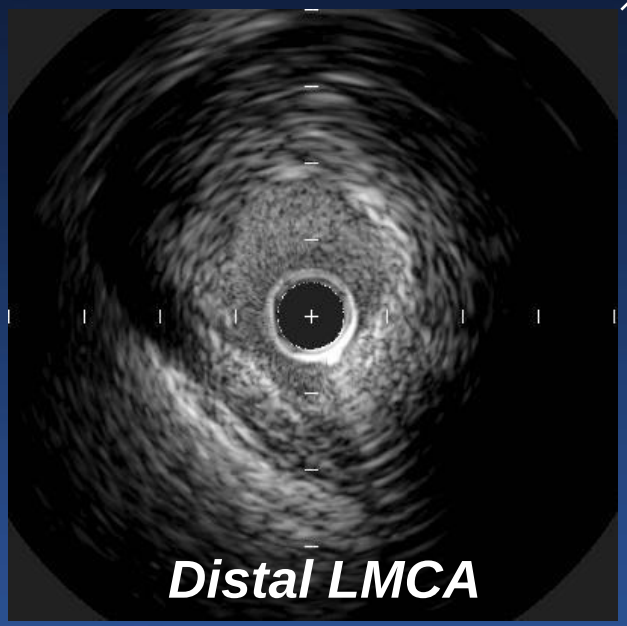
Oviedo et al. Circ Cardiovasc Interv. 2010;3:105-12

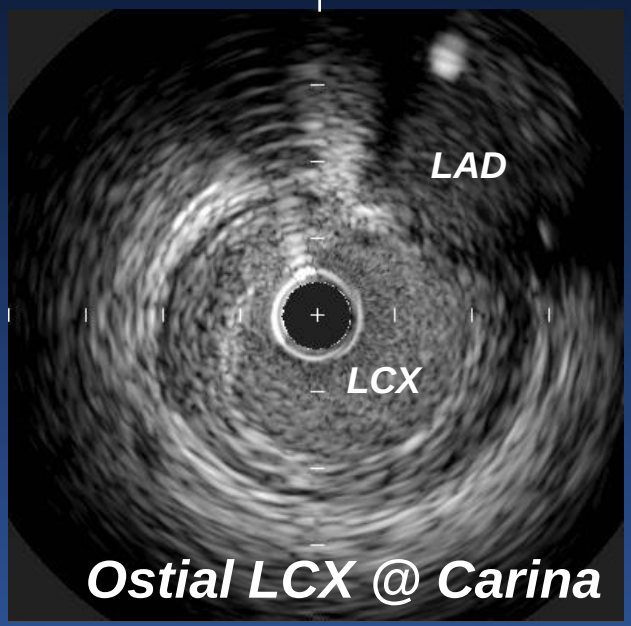


Oviedo et al. Circ Cardiovasc Interv. 2010;3:105-12

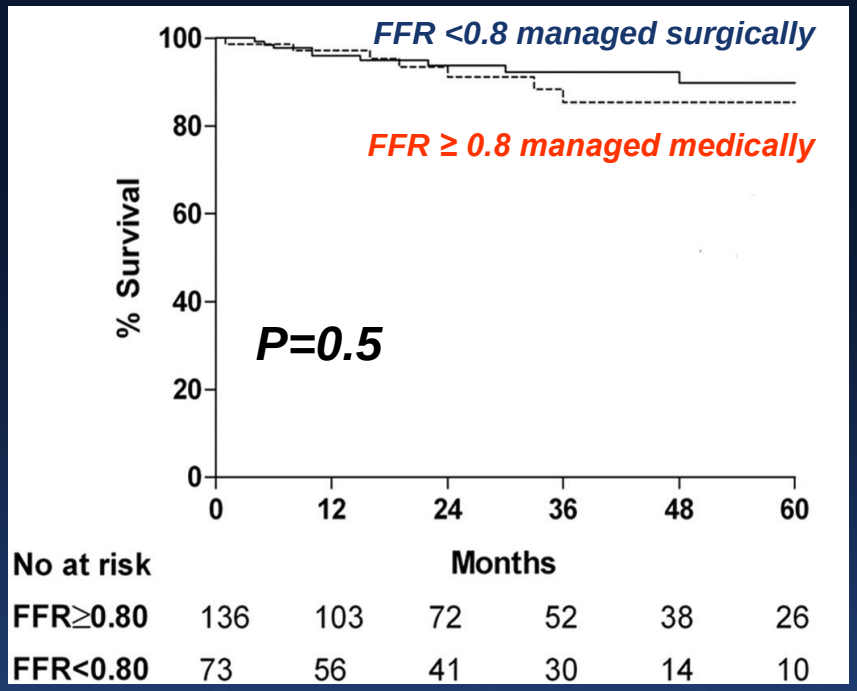

LCX
LAD
Ostial LAD @ Carina

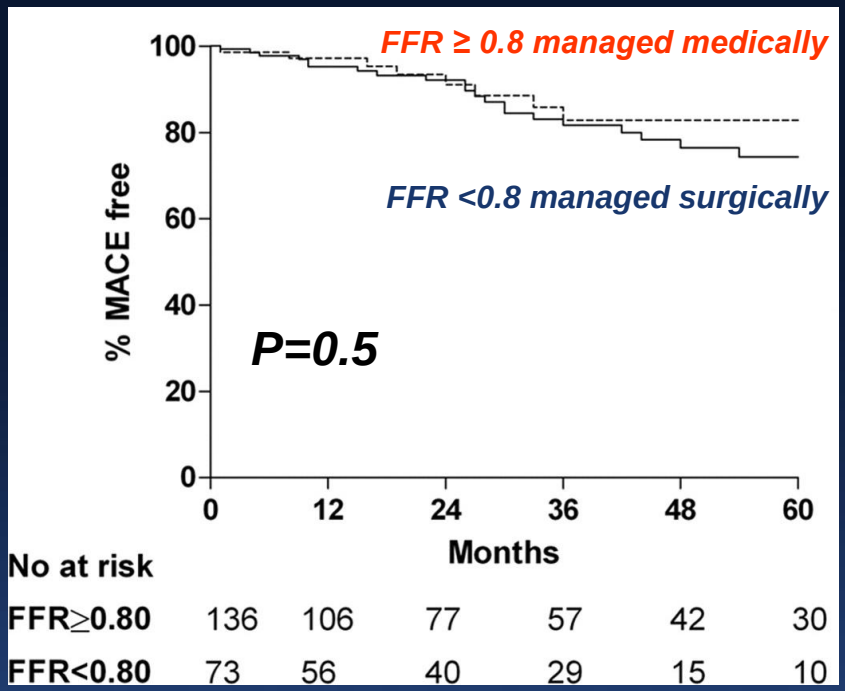



Distal LMCA


LAD
LCX
Ostial LCX @ Carina

Outcomes in 136 pts with an FFR >0.8 managed medically vs 73 pts with an FFR <0.8 managed surgically

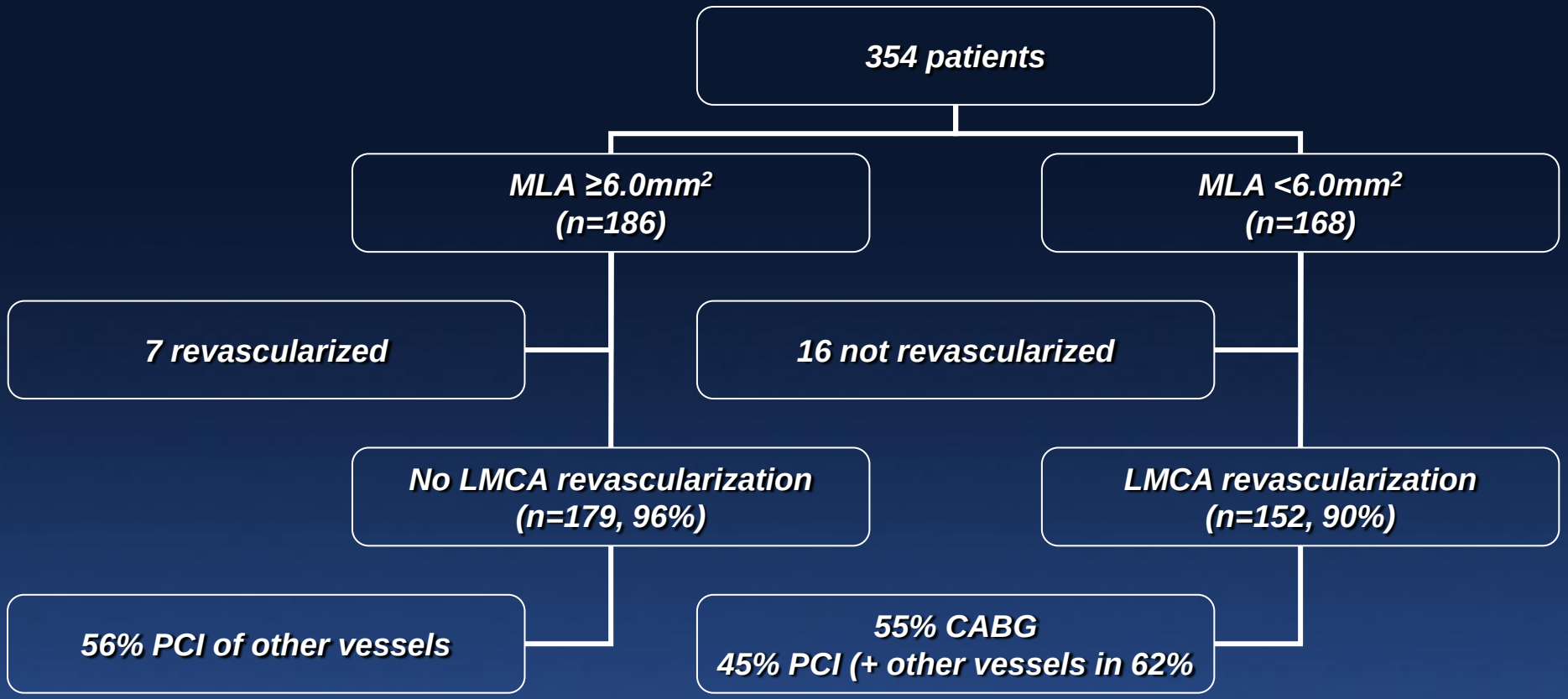




- *A RCA stenosis was the sole independent predictor for MACE.*
- *MACE survival rates at 5 years in the medical and surgical groups were 70% and 66%, respectively, P=0.54.*

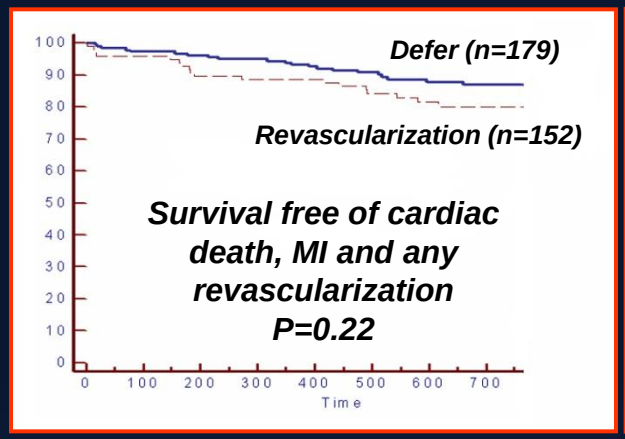
Hamilos et al. Circulation 2009;120:1505-1512

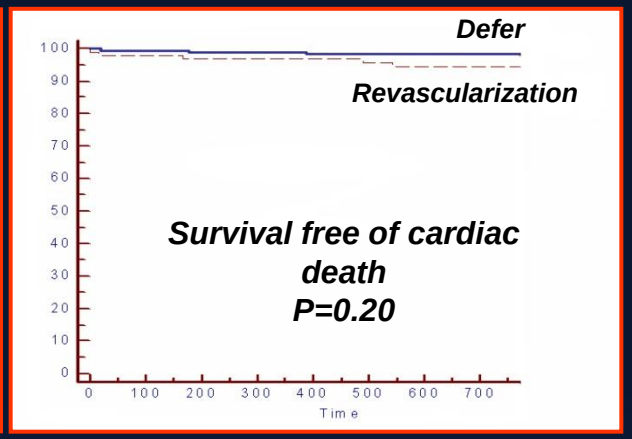
Prospective application of predefined IVUS criteria for revascularization of intermediate LM lesions: Results at 2 years from the LITRO study



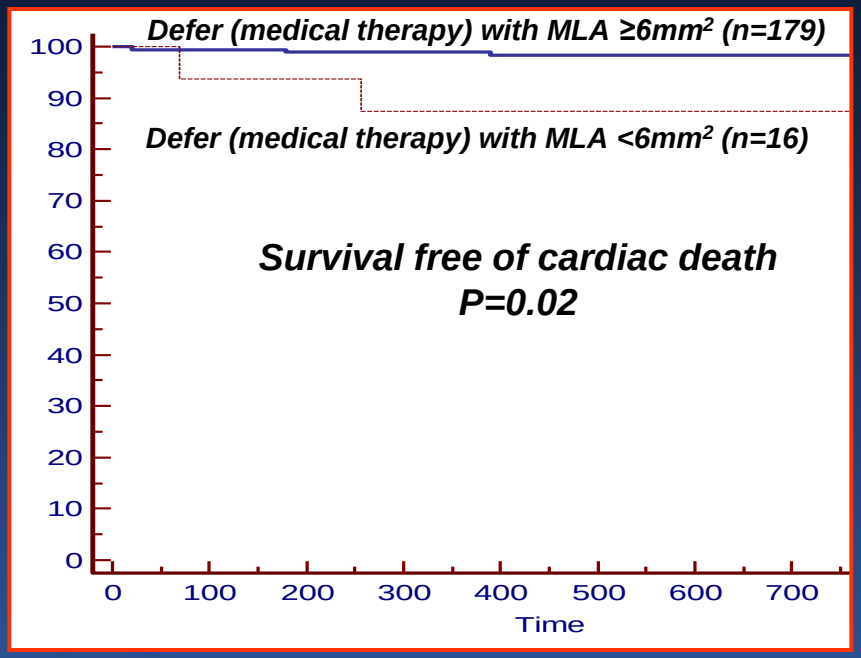
De La Torre Hernandez et al. J Am Coll Cardiol 2011;58:351-8

Clinical outcome of pts with vs without revascularization





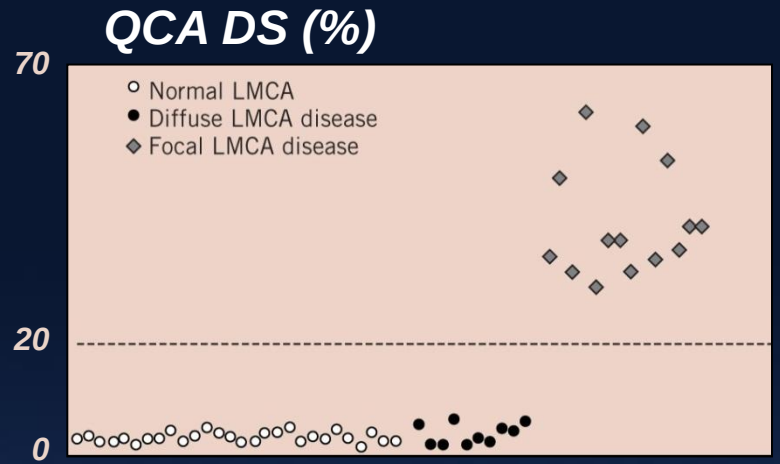
Clinical outcome of pts without revascularization according to the MLA

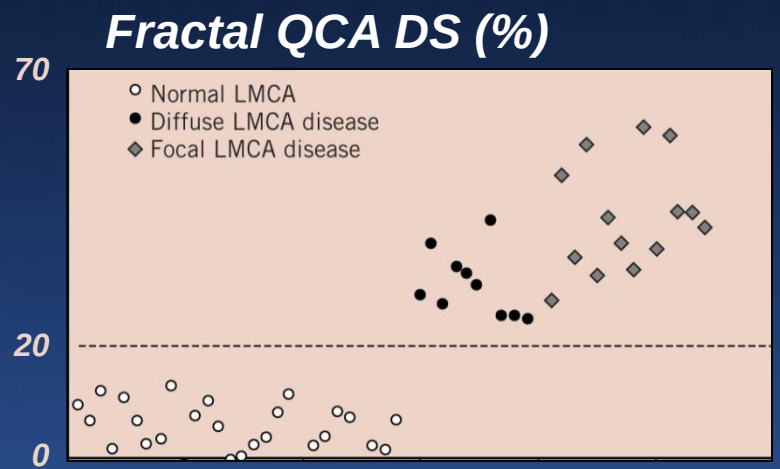


In the group of 16 patients with MLA <6mm² who were treated medically, cardiac death-free survival to 2 years was 86% (97.7% in the deferred group; p=0.04), and survival free of cardiac death, MI, and revascularization was 62.5% (87.3% in the deferred group; p=0.02).

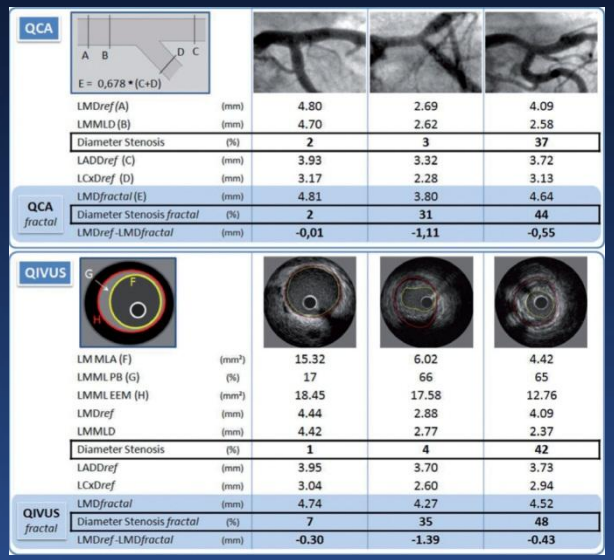
De La Torre Hernandez et al. J Am Coll Cardiol 2011;58:351-8

“Small” LM = Diffuse LMCA disease





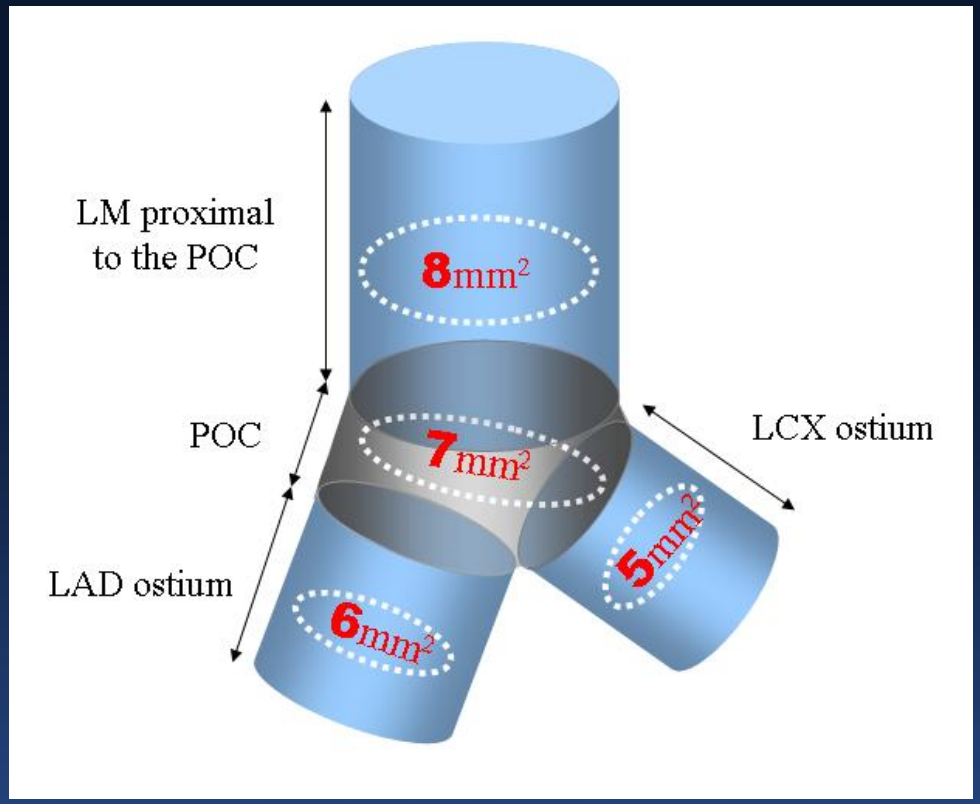
- Murray’s Law
  - $_{LMCA}r^3 = {}_{LAD}r^3 + {}_{LCX}r^3$
- Fractal Geometry
  - $_{LMCA}D = 0.678\ (_{LAD}D + {}_{LCX}D)$



QCA	LMD*ref* (A)	(mm)	4.80	2.69	4.09
	LMMLD (B)	(mm)	4.70	2.62	2.58
	Diameter Stenosis	(%)	2	3	37
	LADD*ref* (C)	(mm)	3.93	3.32	3.72
	LCxD*ref* (D)	(mm)	3.17	2.28	3.13
	LMD*fractal* (E)	(mm)	4.81	3.80	4.64
QCA *fractal*	Diameter Stenosis *fractal*	(%)	2	31	44
	LMD*ref*-LMD*fractal*	(mm)	-0,01	-1,11	-0,55
QIVUS	LM MLA (F)	(mm²)	15.32	6.02	4.42
	LMML PB (G)	(%)	17	66	65
	LMML EEM (H)	(mm²)	18.45	17.58	12.76
	LMD*ref*	(mm)	4.44	2.88	4.09
	LMMLD	(mm)	4.42	2.77	2.37
	Diameter Stenosis	(%)	1	4	42
	LADD*ref*	(mm)	3.95	3.70	3.73
	LCxD*ref*	(mm)	3.04	2.60	2.94
	LMD*fractal*	(mm)	4.74	4.27	4.52
QIVUS *fractal*	Diameter Stenosis *fractal*	(%)	7	35	48
	LMD*ref*-LMD*fractal*	(mm)	-0.30	-1.39	-0.43

Matreff et al. Eurointervention 2010;5:709-15

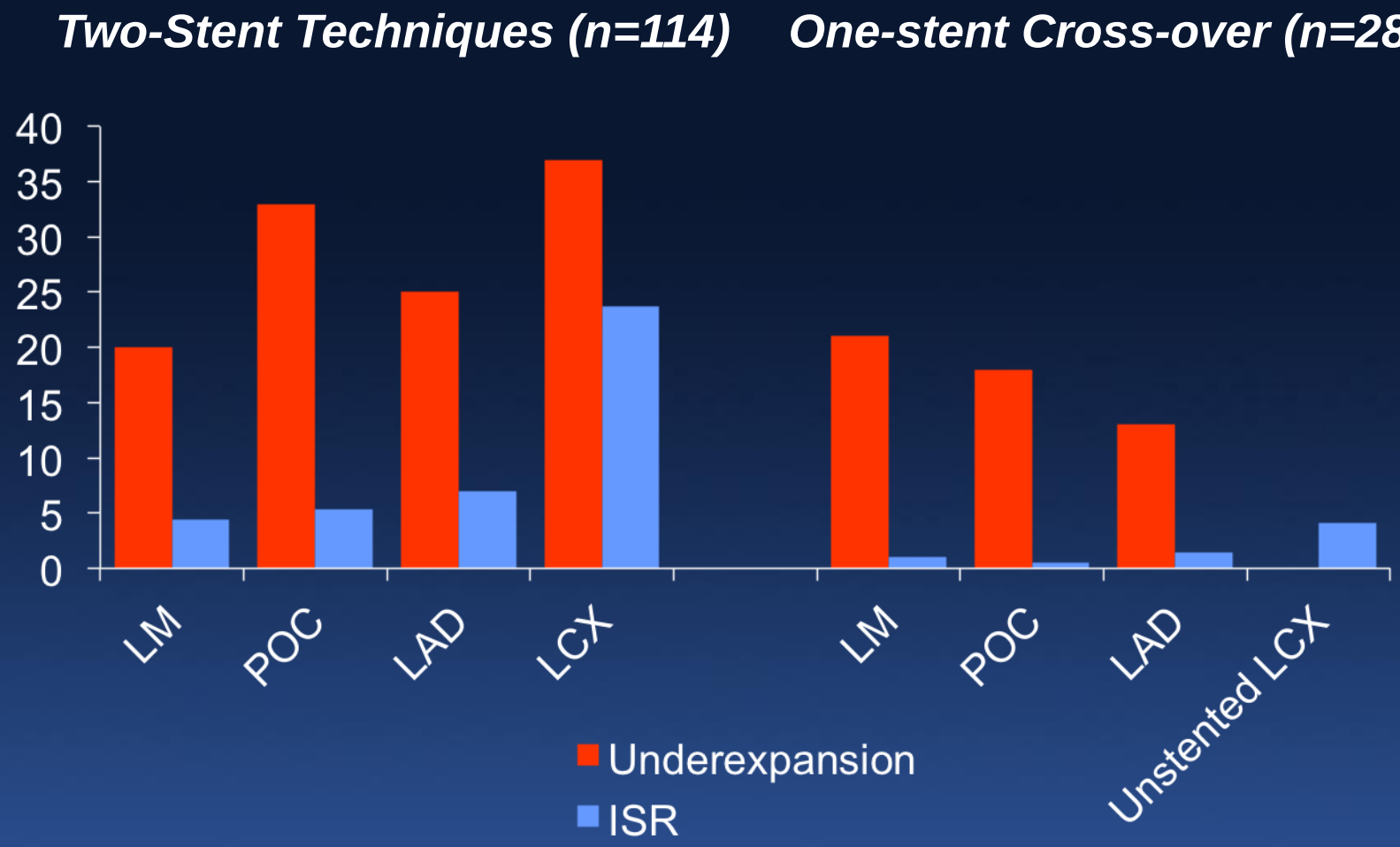
Criteria for stent underexpansion at the distal LMCA bifurcation (n=403)



- *MACE-free survival was lower in pts with underexpansion vs those without underexpansion (89.4% vs 98.1%)*
- *TLR-free survival was lower in pts with underexpansion vs no underexpansion (90.9% vs 98.5%).*
- *Although acute malapposition was observed in 28 pts, malapposition was not related to MACE at follow-up.*

Kang et al. Circulation Cardiovasc Interv. 2011;4:562-9

Impact of underexpansion on ISR in patients treated with either two stents or a single stent cross-over



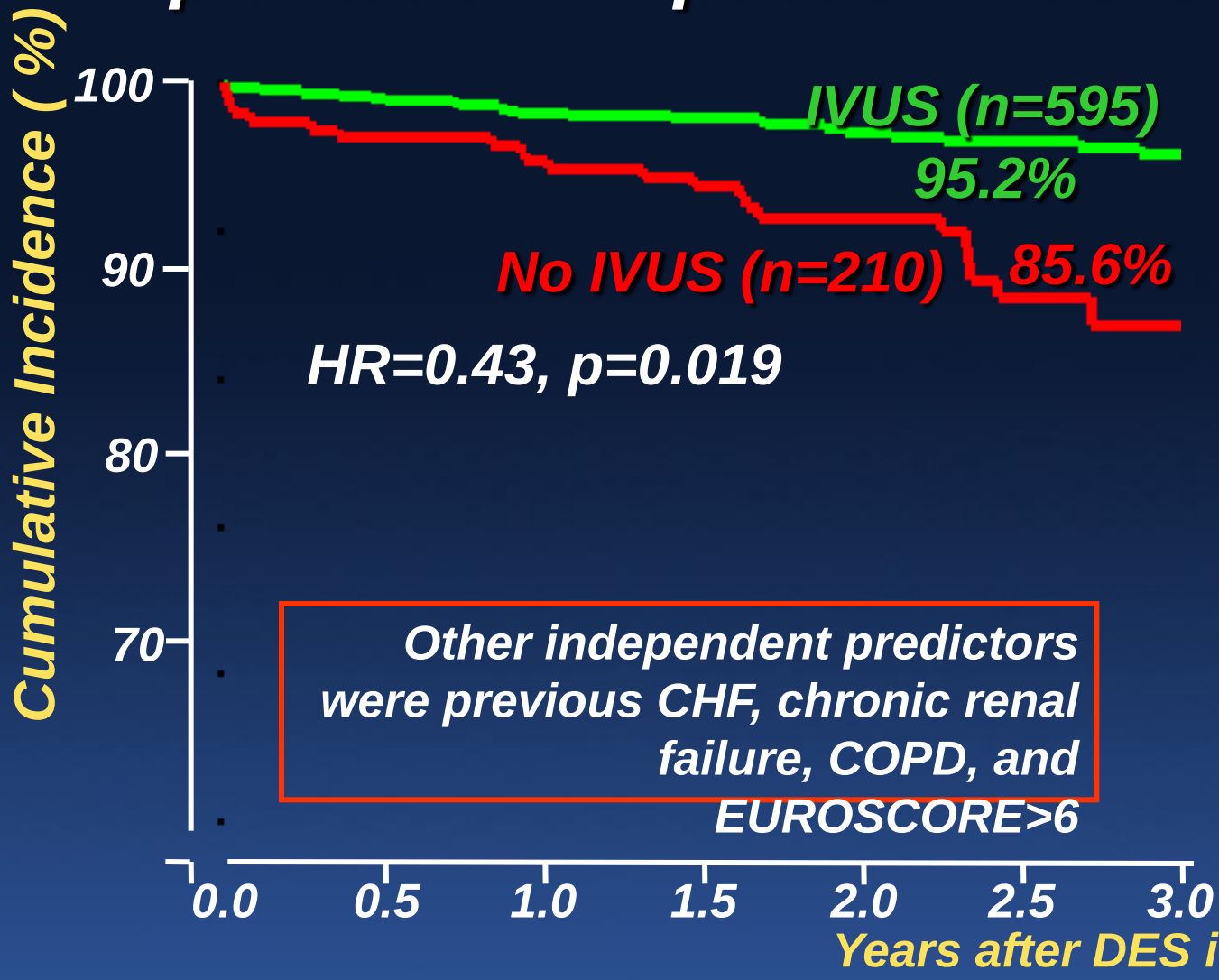
Kang et al. Circulation Cardiovasc Interv. 2011;4:562-9

MAIN-COMPARE Registry

- 975 pts with unprotected LMCA stenosis underwent elective stenting under IVUS (n=756) or angiographic (n=219) guidance and were followed for 3 years
- IVUS-guidance was significantly associated with reduced death (HR=0.31 overall and HR=0.27 in DES) as compared with angiography guidance
- However, the use of IVUS-guidance did not reduce the risk of myocardial infarction or target vessel revascularization.

Park et al. Circ Cardiovasc Intervent 2009;2:167-77

All-Cause Mortality After LMCA DES Implantation: Impact of IVUS Guidance



(Park et al. Circ Cardiovasc Intervent 2009;2:167-77)

ADAPT-DES – IVUS vs No-IVUS Cohort -

Assessment of Dual AntiPlatelet Therapy with Drug-Eluting Stents

8,575 pts prospectively enrolled
No clinical or anatomic exclusion criteria
11 sites in US and Germany

↓

PCI with ≥1 non-investigational DES
Successful and uncomplicated

↙ ↘

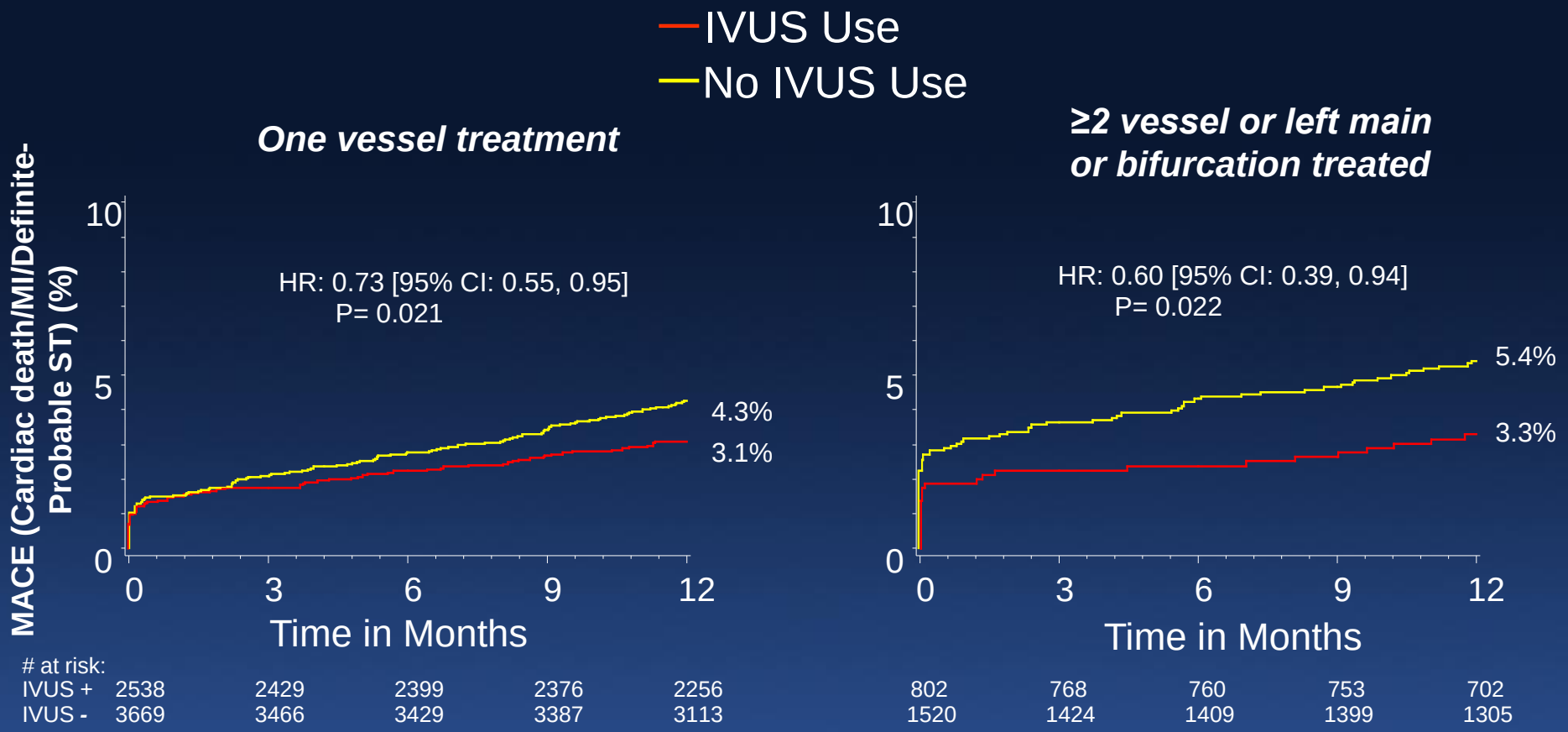
IVUS Use: 3349 pts | **No IVUS: 5234 pts**

↓ ↓

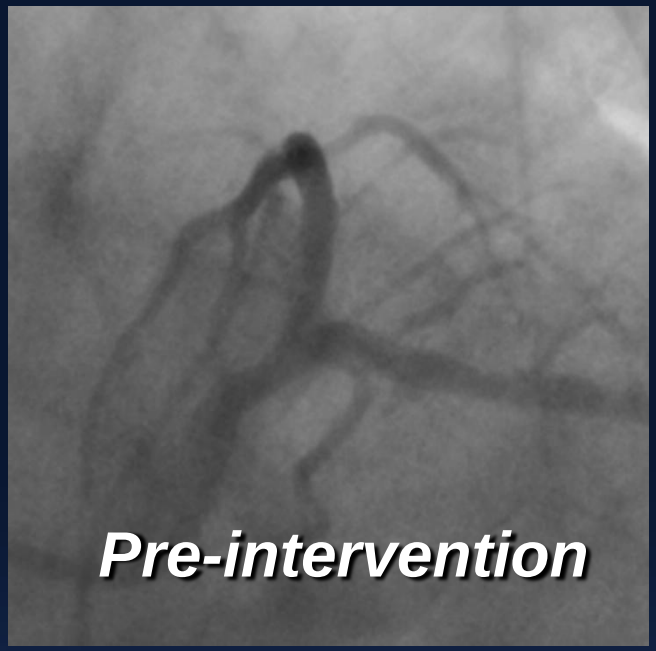
Clinical FU at 30 days, 1 year

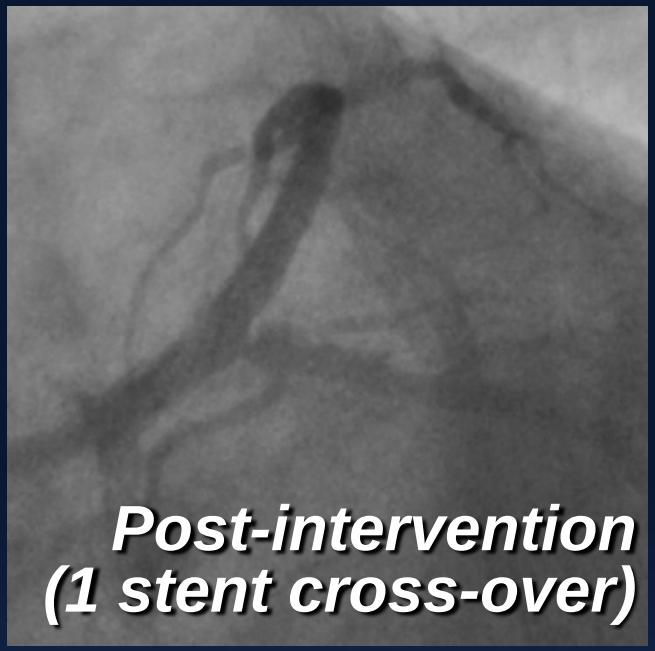
Witzenbichler, et al. TCT2012

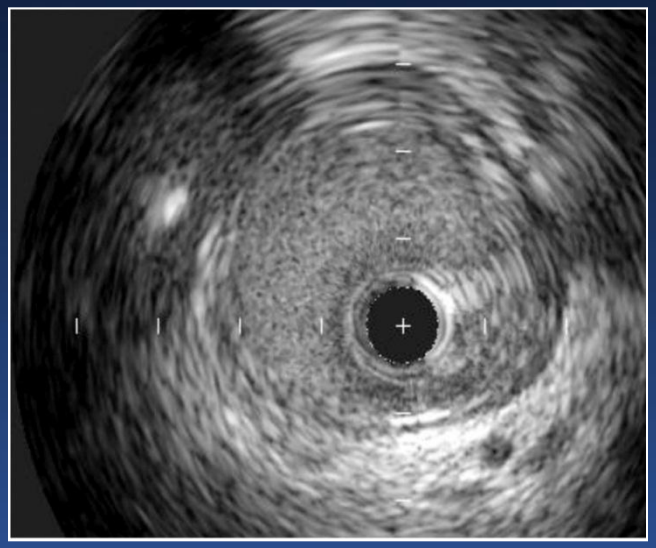
Impact of Complexity of Procedure on MACE

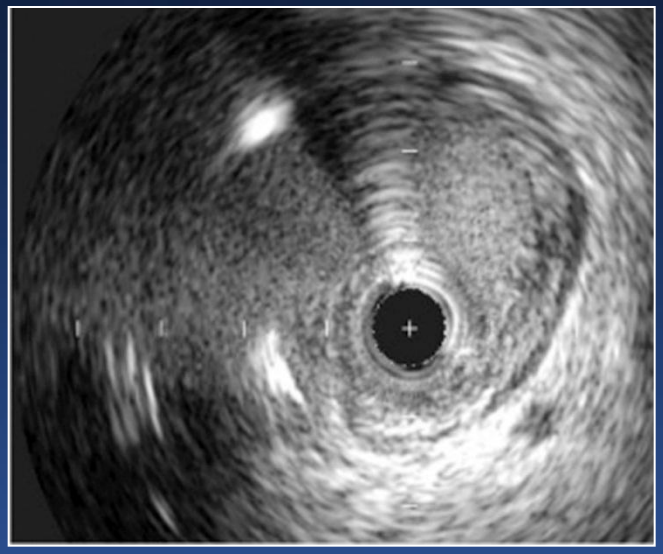


TCT2012

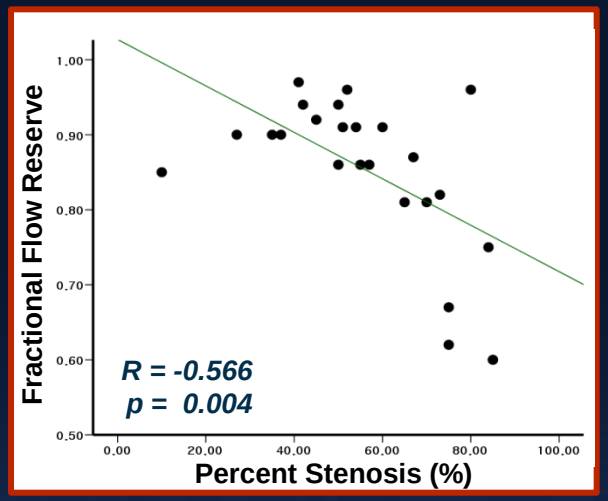

Pre-intervention


Post-intervention
(1 stent cross-over)



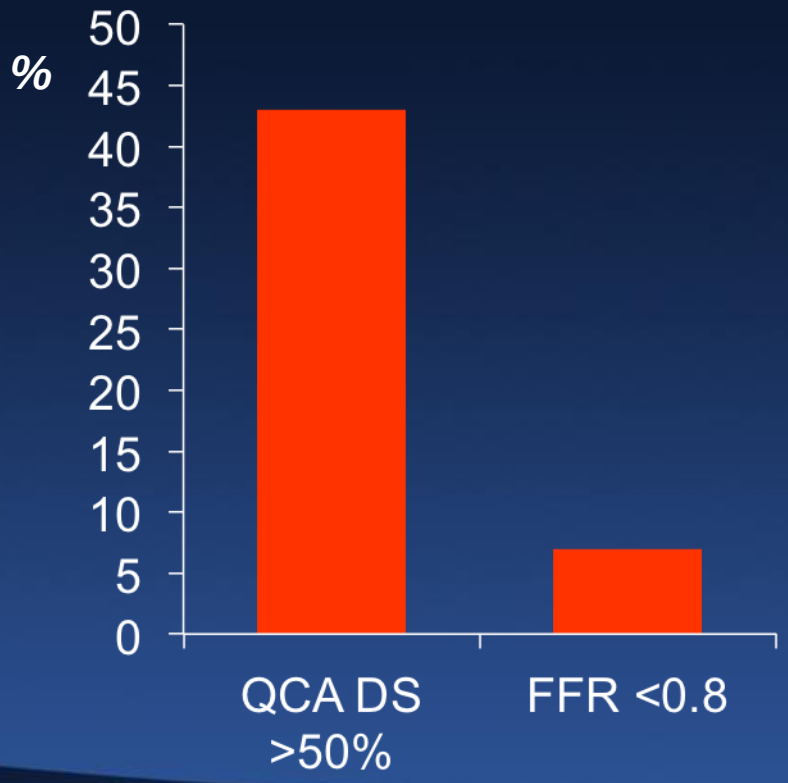


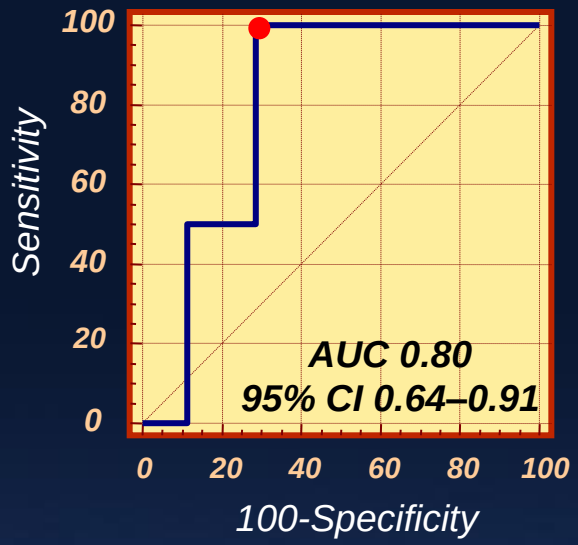
FFR of “Jailed” LCX



KNam et al. Korean Circ J 2011;41:304-7

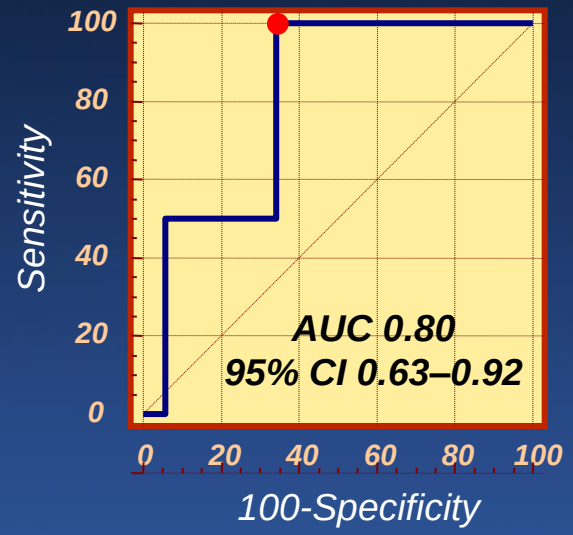
43 LMCA bifurcation lesions with a pre-PCI LCX ostial DS<50% were treated by single-stent cross-over





MLA <3.7mm²

- ***Sensitivity 100%***
- ***Specificity 71%***
- ***PPV 16%***
- ***NPV 100%***



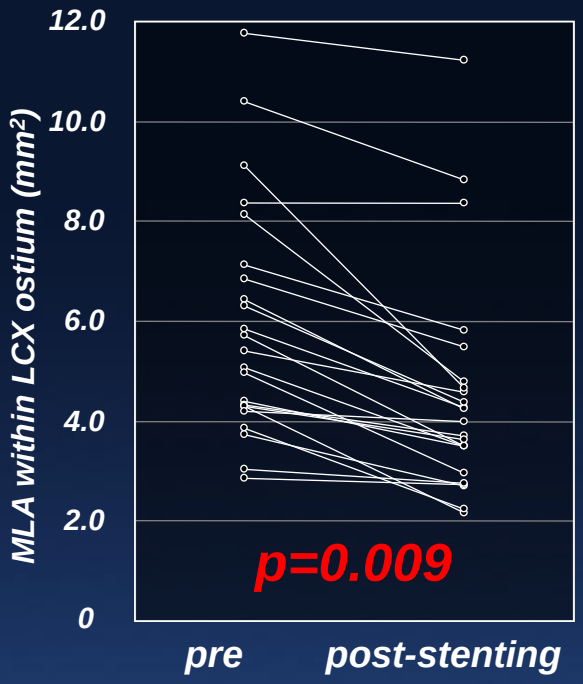
Plaque Burden >56%

- ***Sensitivity 100%***
- ***Specificity 65%***
- ***PPV 14%***
- ***NPV 100%***

Kang et al. Asan Medical Center, unpublished

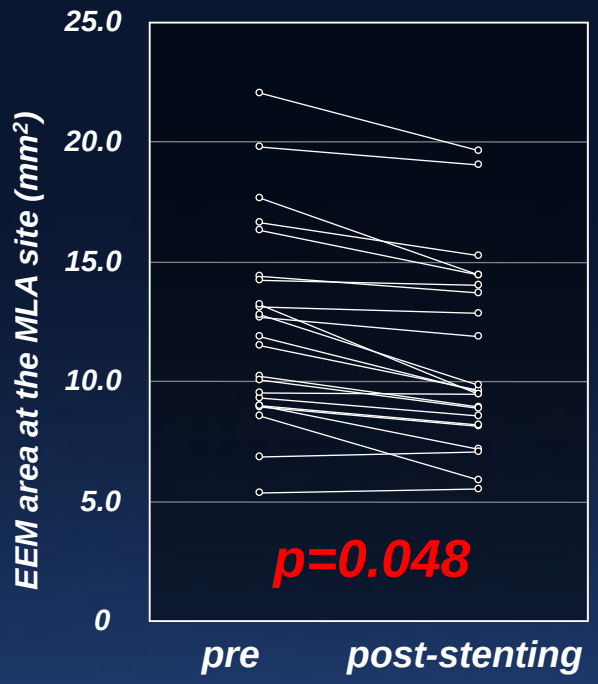
MLA within LCX ostium

5.4mm² → 4.0mm²



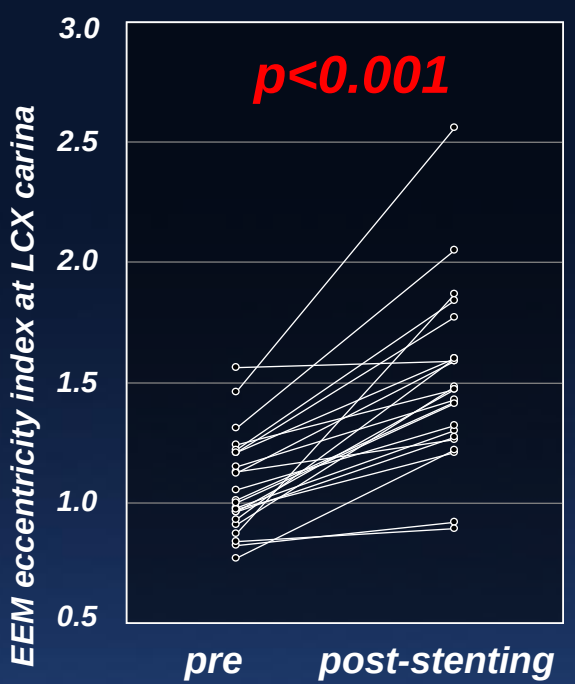
EEM area at MLA

11.8mm² → 9.6mm²



EEM eccentricity

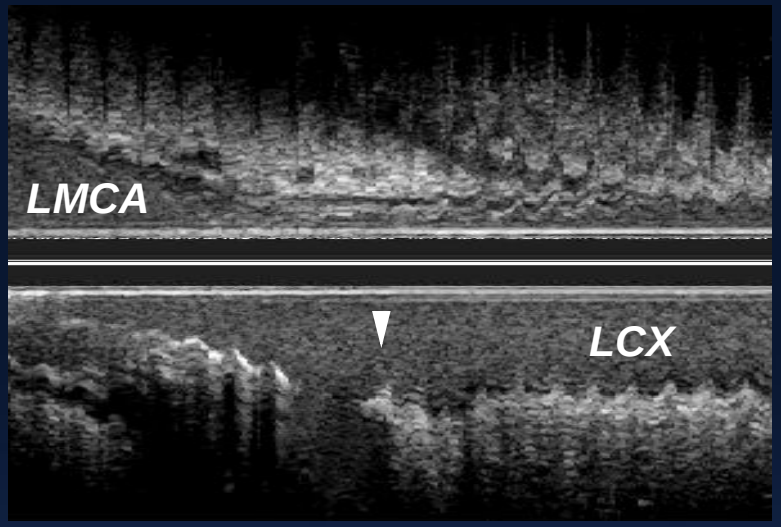
1.22 → 1.47

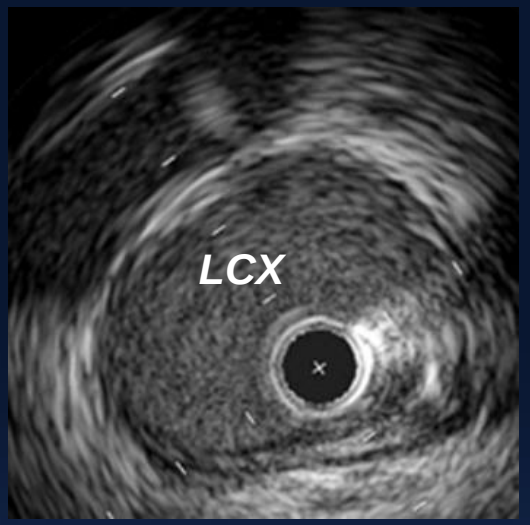


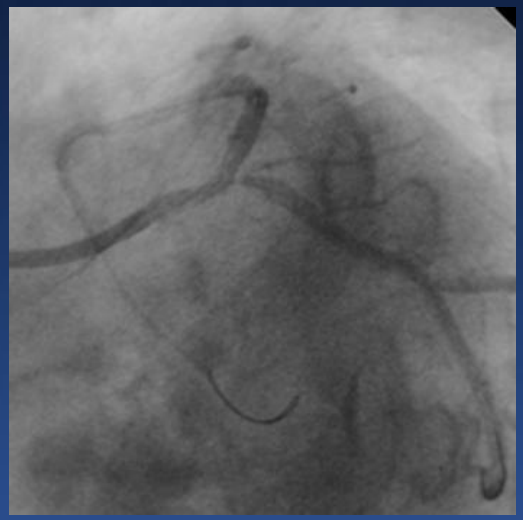
78% showed a >10% reduction of MLA within LCX ostium after cross-over stenting

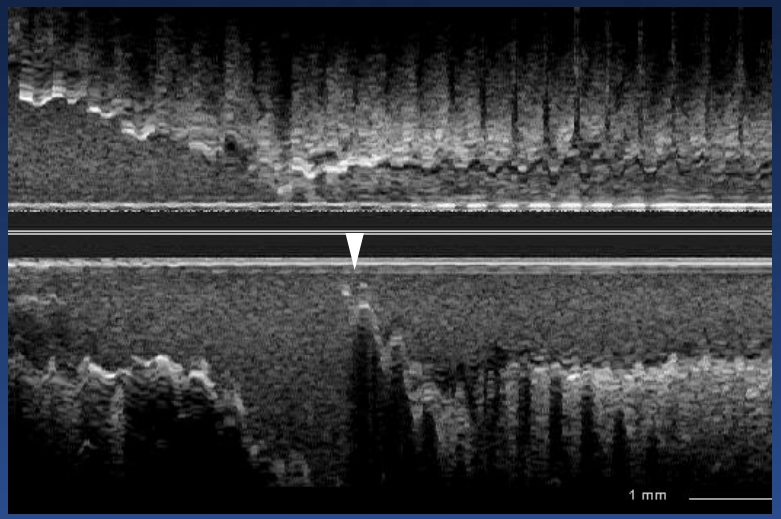
Kang et al. Circulation Cardiovasc Interv 2011;4:355-61

Carina shift









Conclusions

- *Use IVUS or FFR to assess LMCA severity*
  - *FFR <0.80*
  - *MLA <6mm^2 in Western patients*
  - *MLA <4.8mm^2 in Asian patients*
- *Perform pre-intervention IVUS from both the LAD and LCX to assess the extent of the atherosclerosis*
- *Perform post-intervention IVUS to optimize the implanted stent results*