How May Imaging Help in LM PCI?

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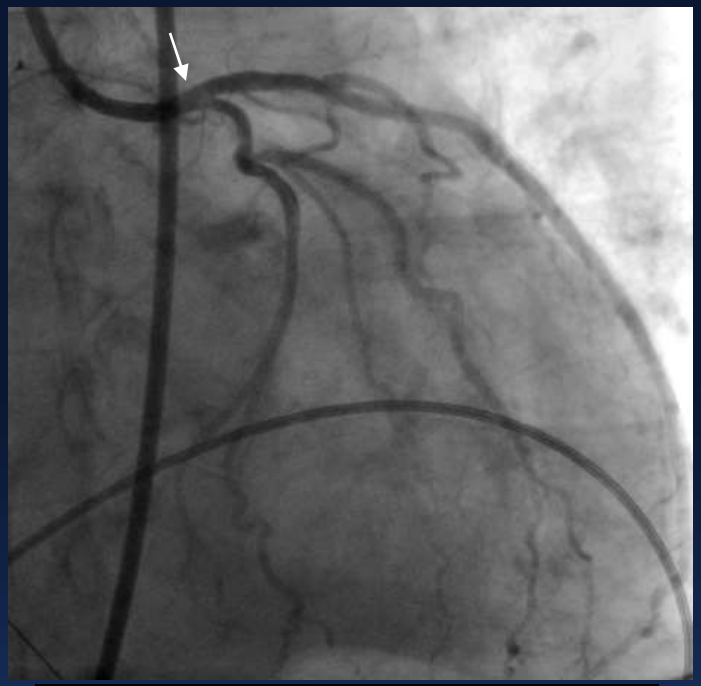
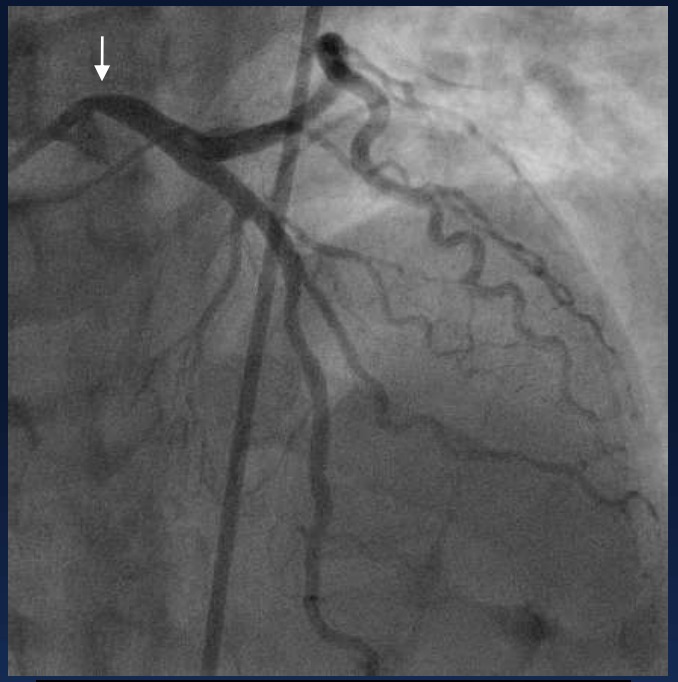
Disclosure Statement of Financial Interest

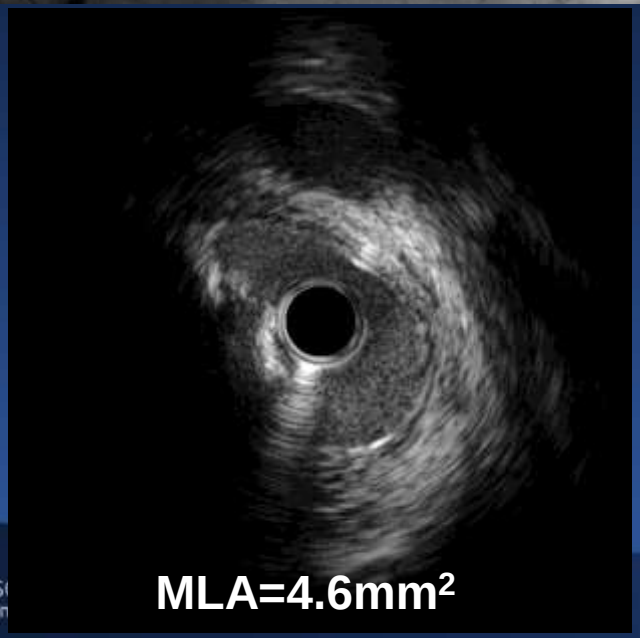
Within the past 12 months, I or my spouse/partner have had a financial interest/arrangement or affiliation with the organization(s) listed below.

Affiliation/Financial Relationship	Company
• Grant/Research Support	• Boston Scientific, St Jude Medical
• Consulting Fees/Honoraria	• Boston Scientific, OCT Medical Imaging Inc.

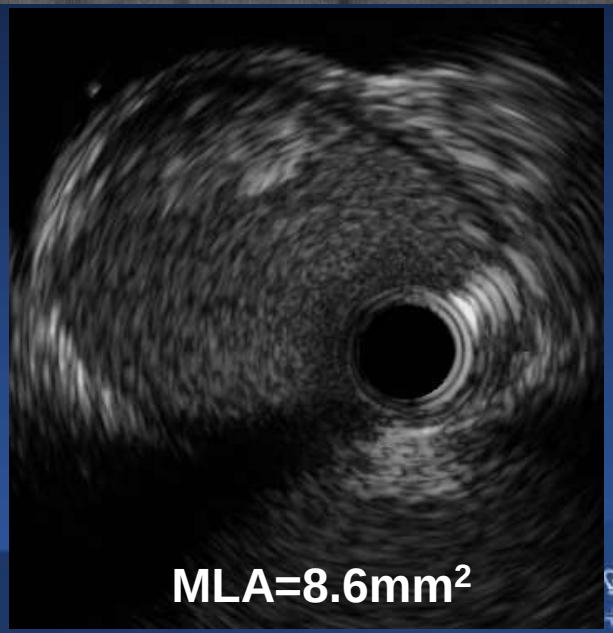
Discrepancy between Angio and IVUS







MLA=4.6mm^2



MLA=8.6mm^2

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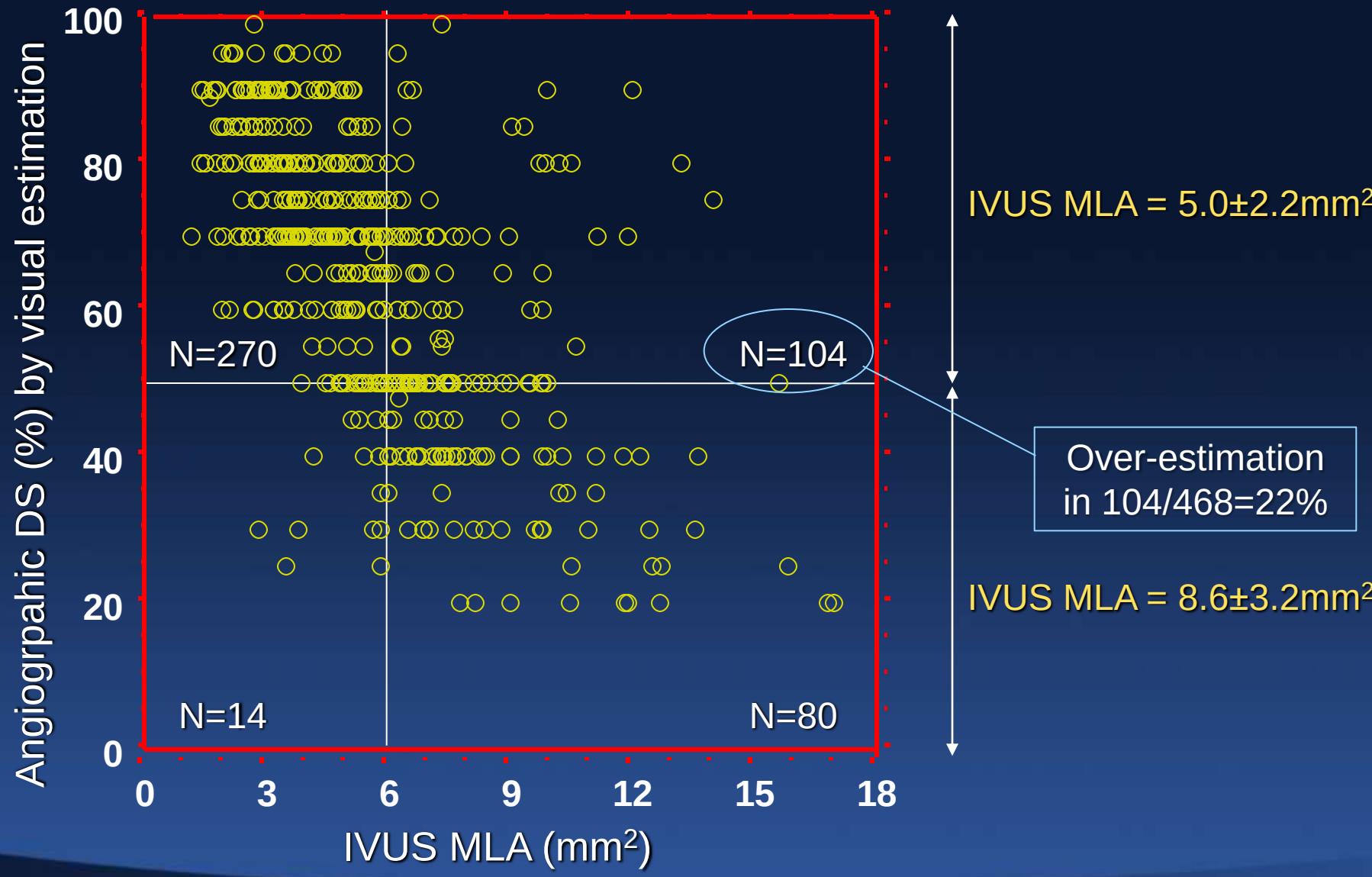
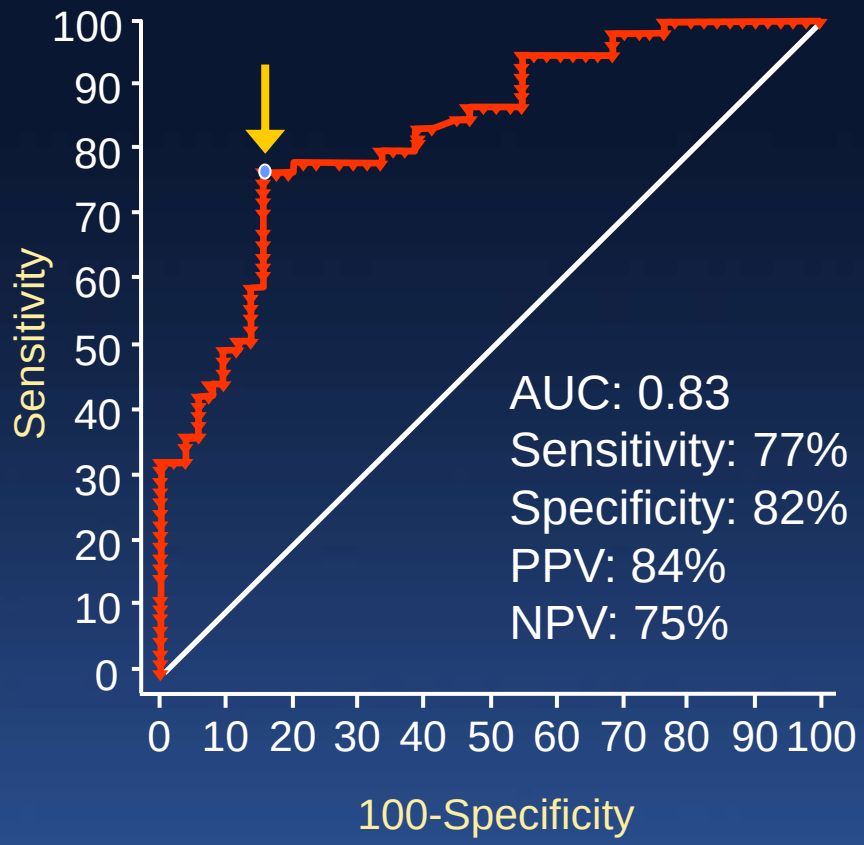
Comparison of Angiography vs IVUS (n=468)



IVUS MLA determinants of LM FFR (n=112)

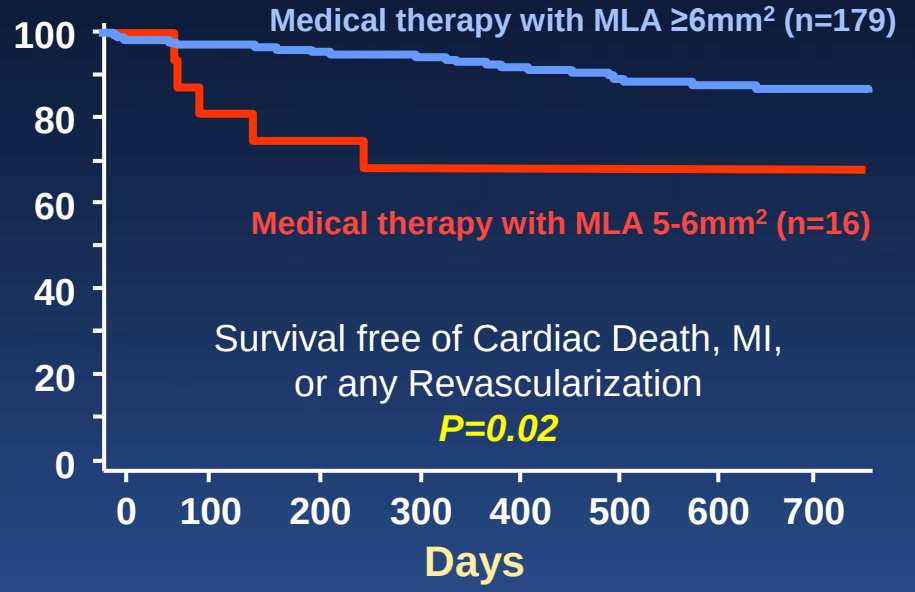
Cut-off value: 4.5 mm²



Park et al. J Am Coll Cardiol Intv 2014;7:868-74

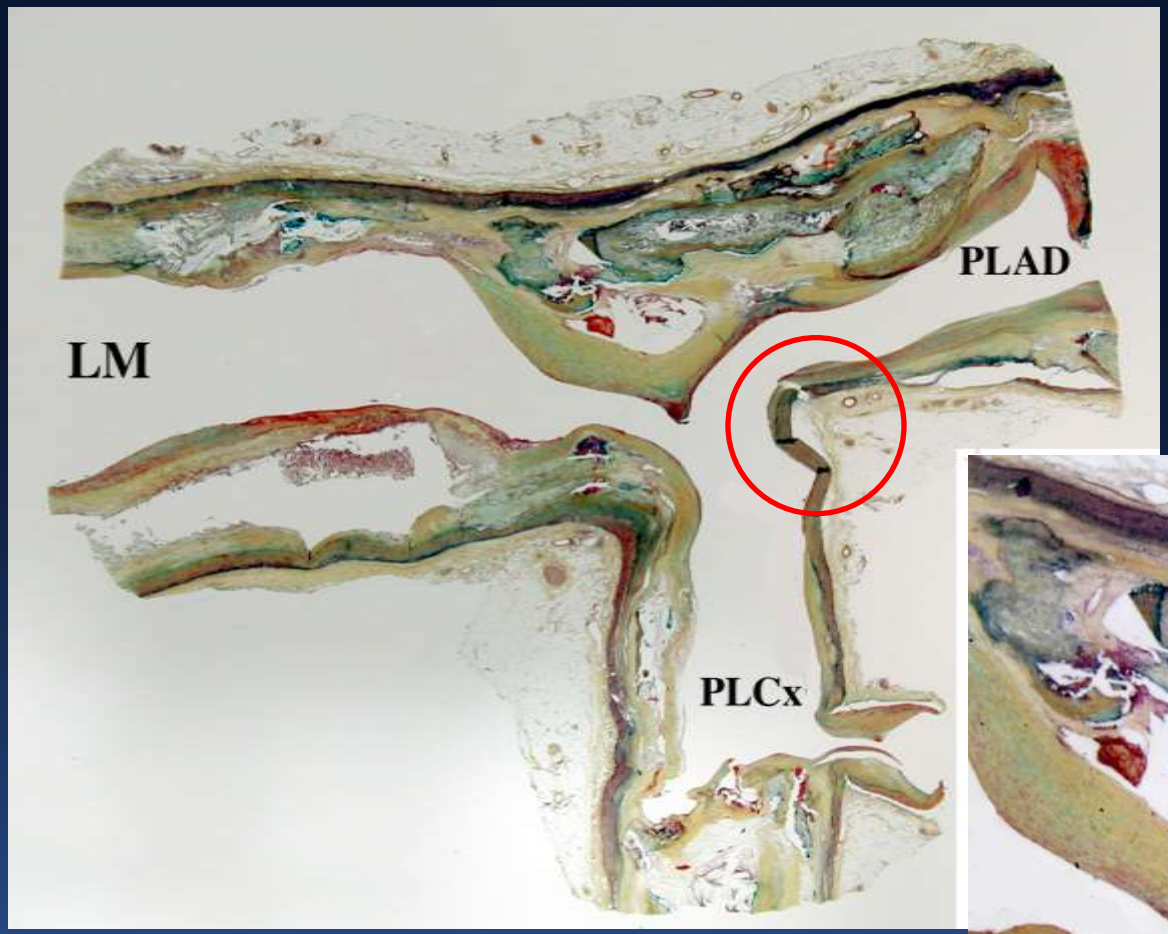
Clinical Outcome of Pts Treated Medically According to MLA (=195)

Cut-off value: 6.0 mm²

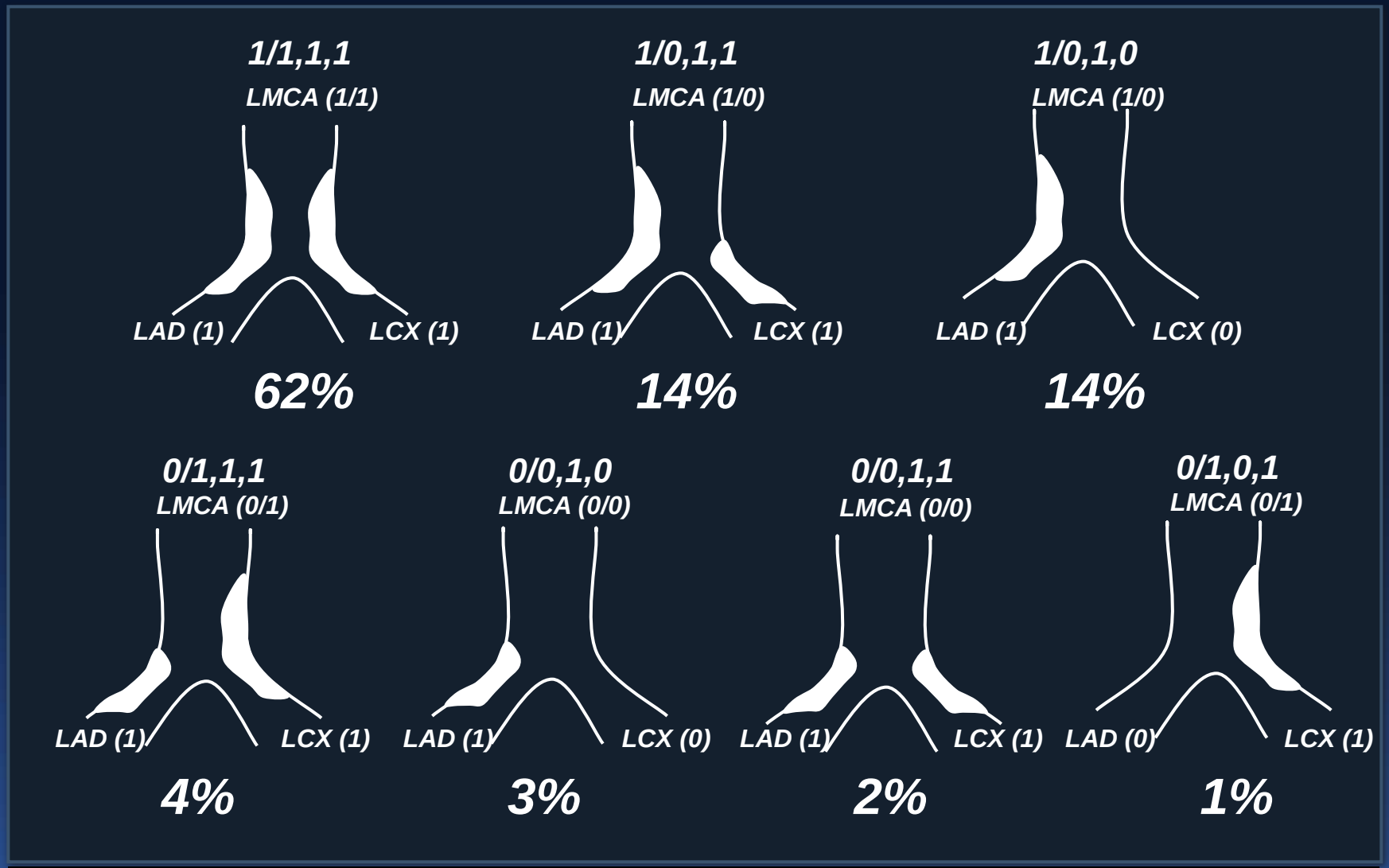


De La Torre Hernandez et al. J Am Coll Cardiol 2011;58:351-8

Plaque Formation



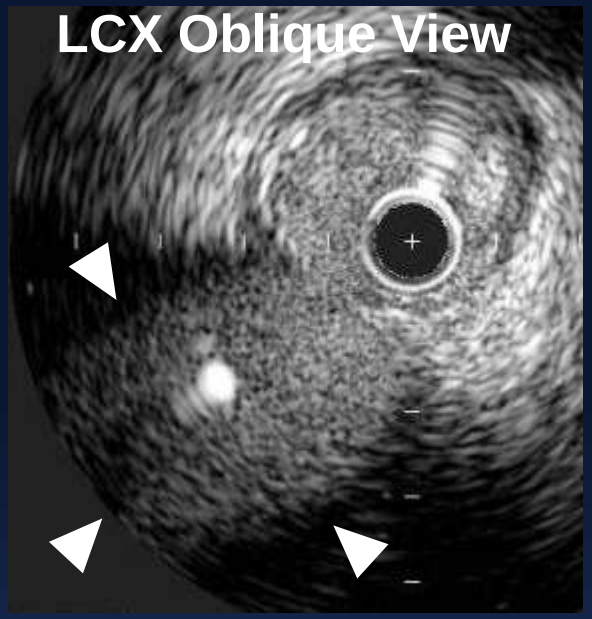
Plaque Distribution by IVUS (n=140)

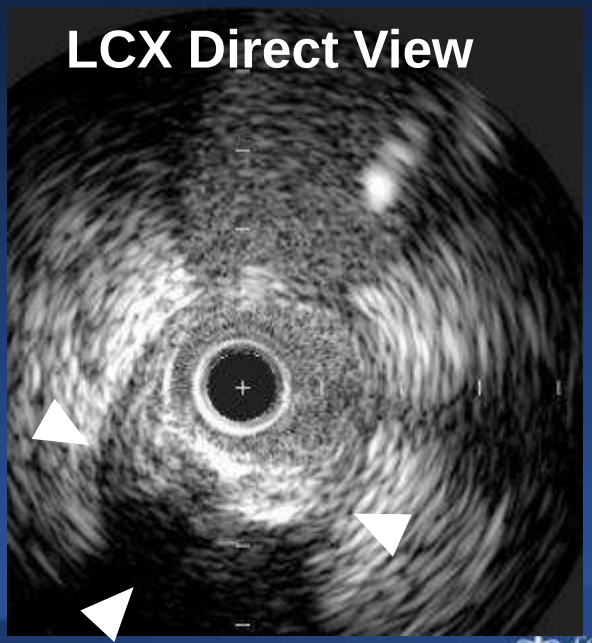


In 90% plaque extends from LMCA-LAD

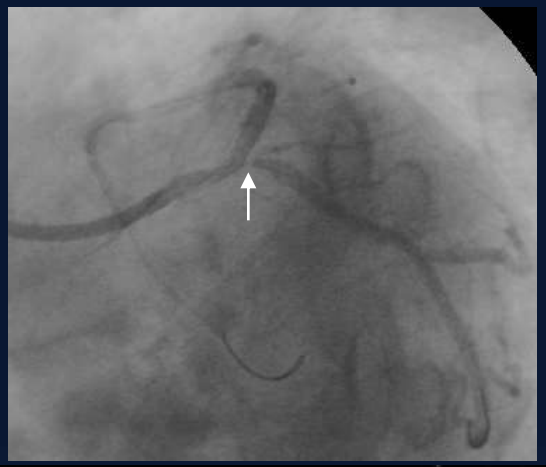
Oviedo C et al. Circ Cardiovasc Interv 2010;3:105-12.

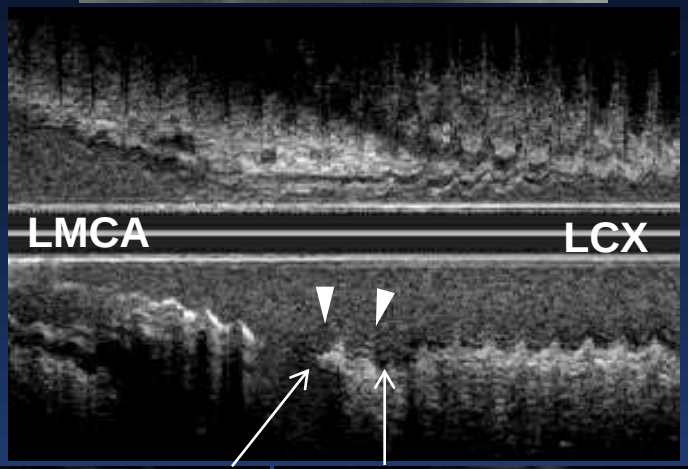
- **Though you don’t see anything, this is not true.**
- **If you see something, this may be true.**

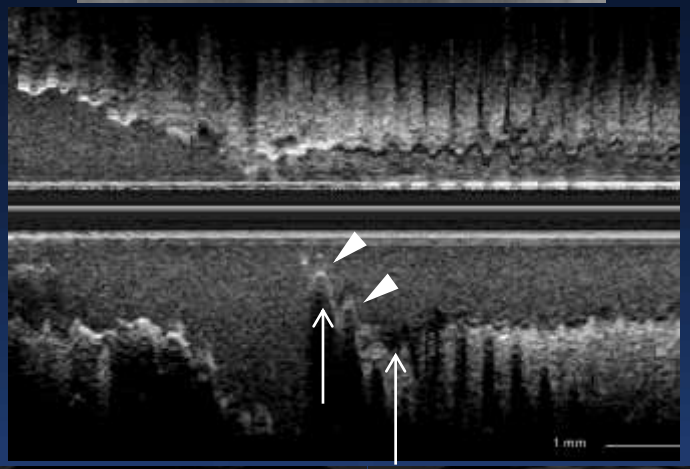


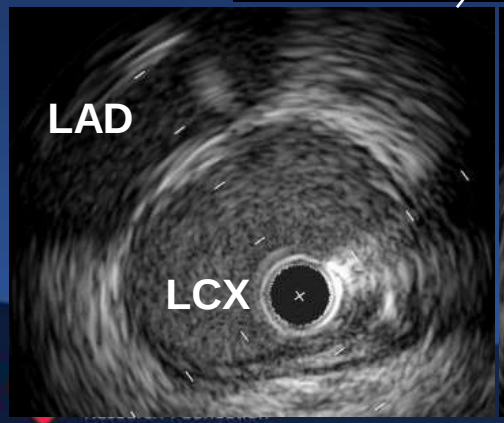


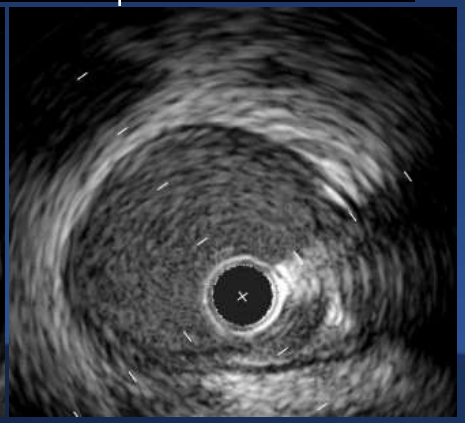
Carina Shift

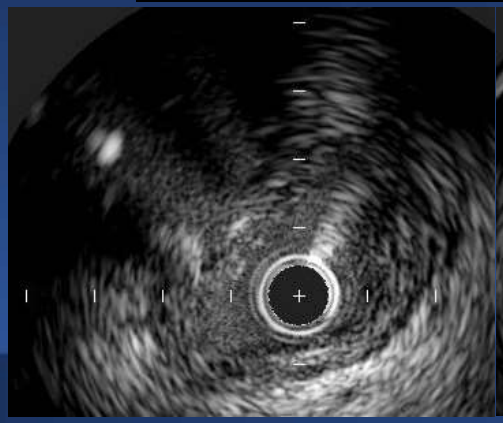


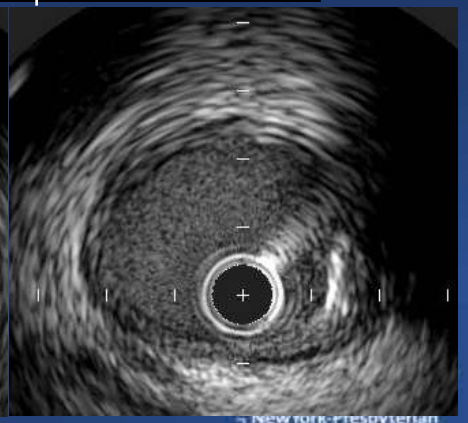




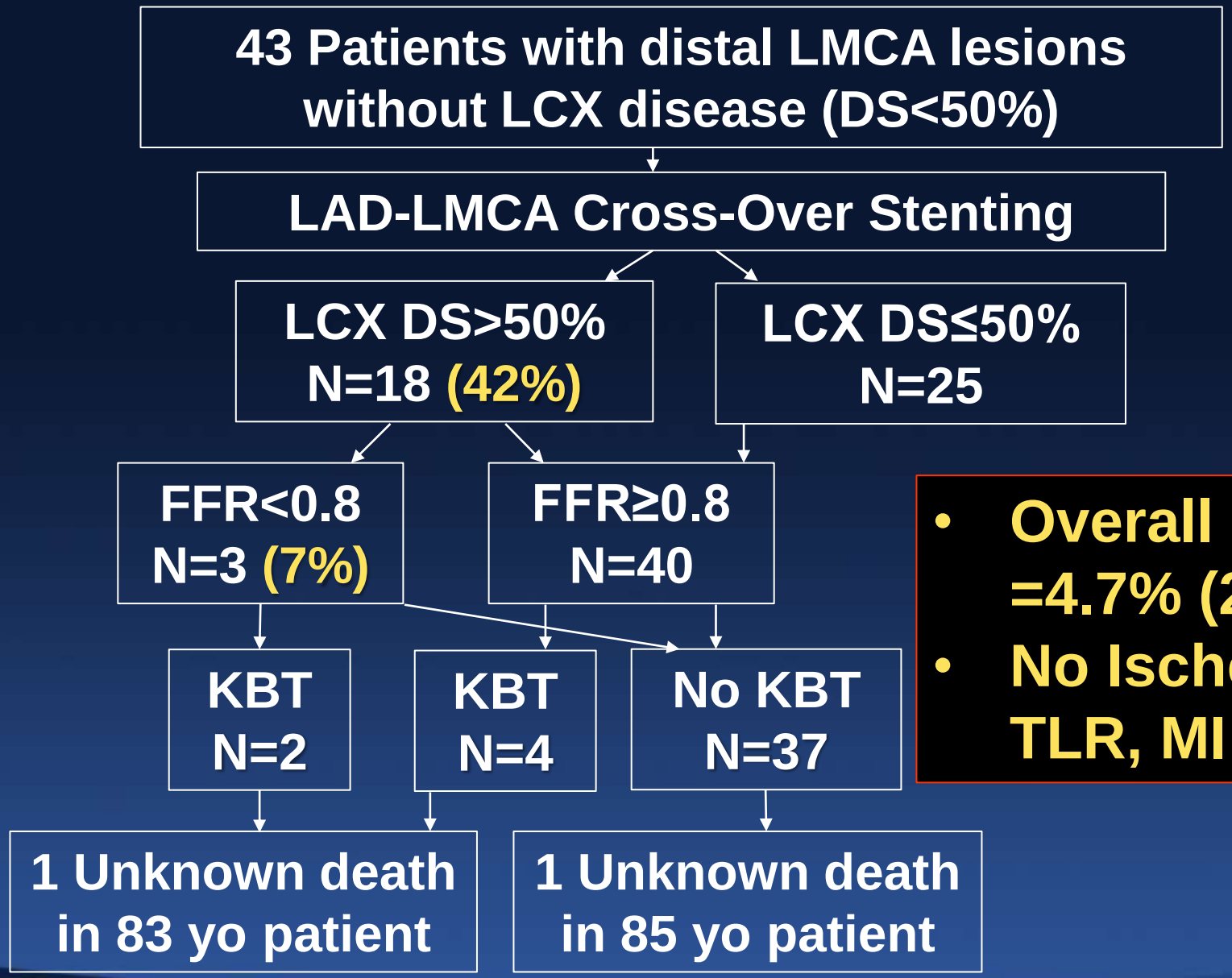








Outcome of LCX after Cross-Over Stenting



- Overall MACE =4.7% (2/43)
- No Ischemic TLR, MI

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Kang et al. *Catheter Cardiovasc Interv* 2013 on-line

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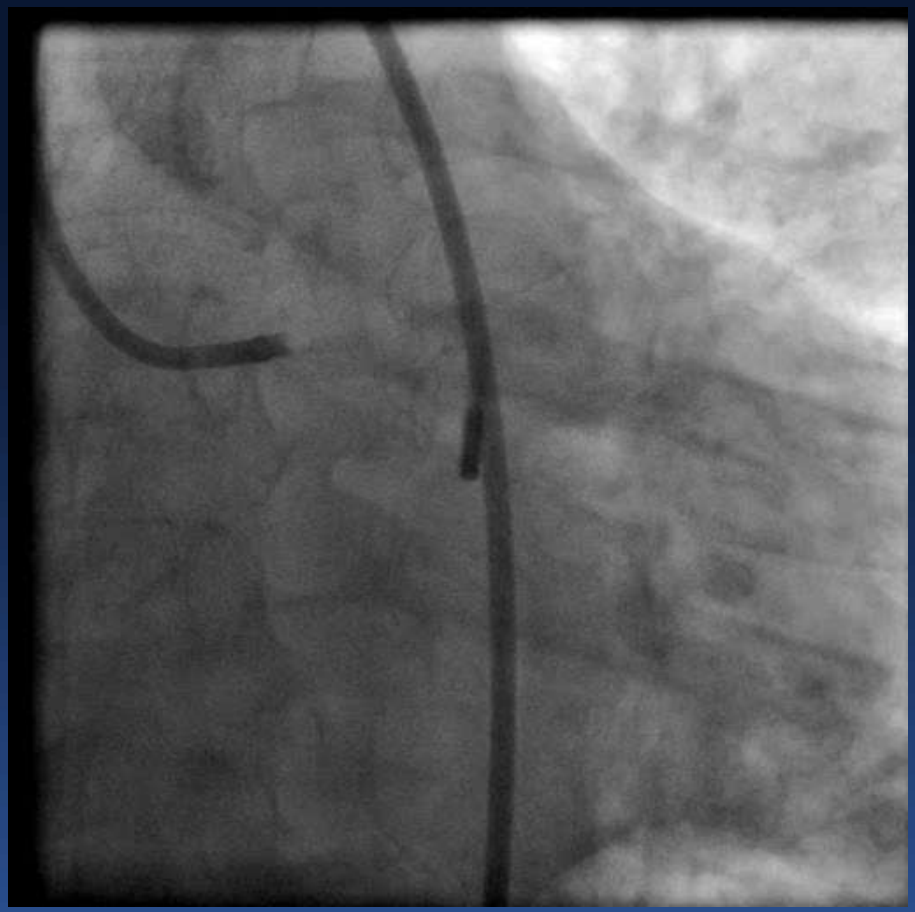
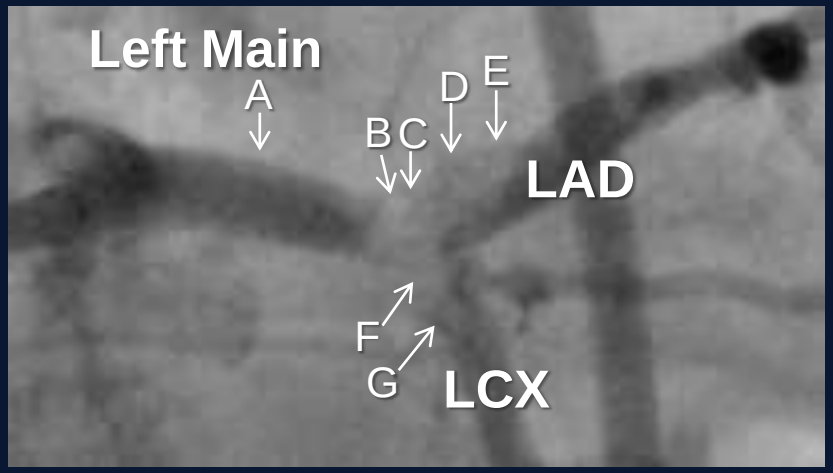
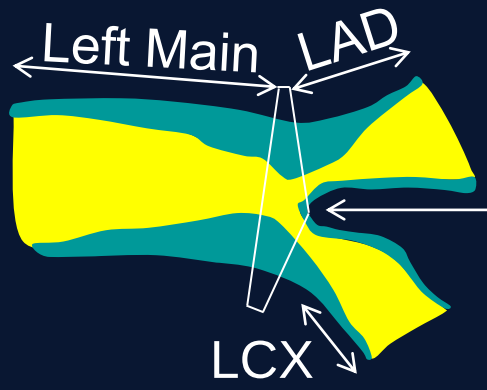
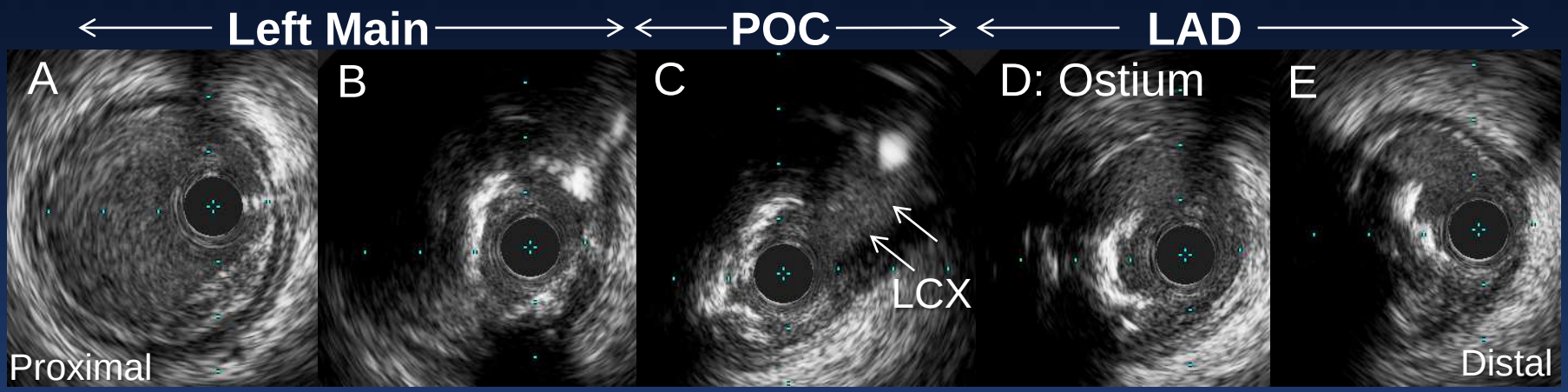
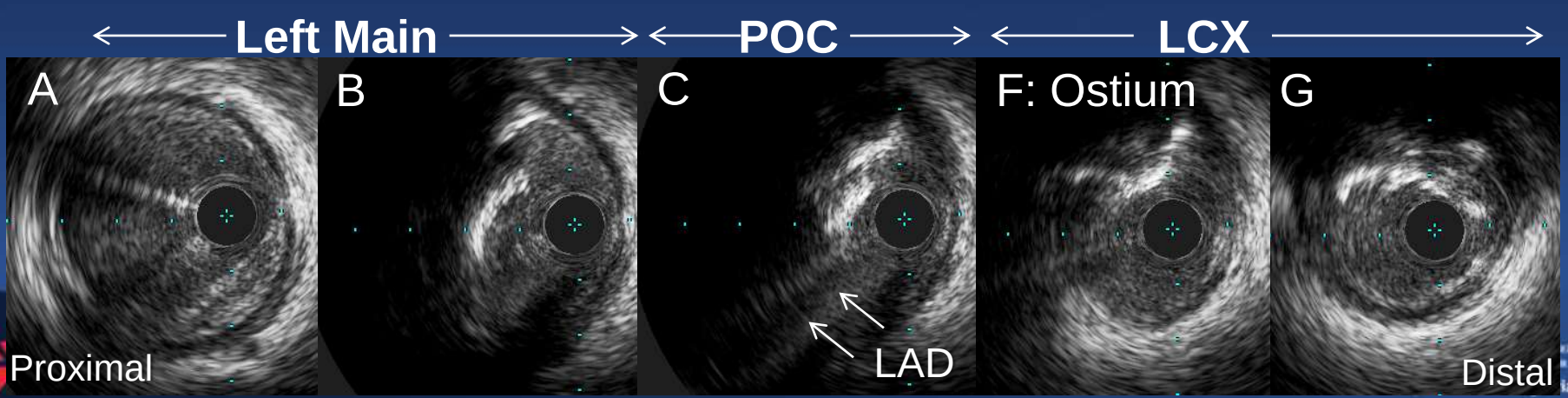
Optimal Stent Expansion

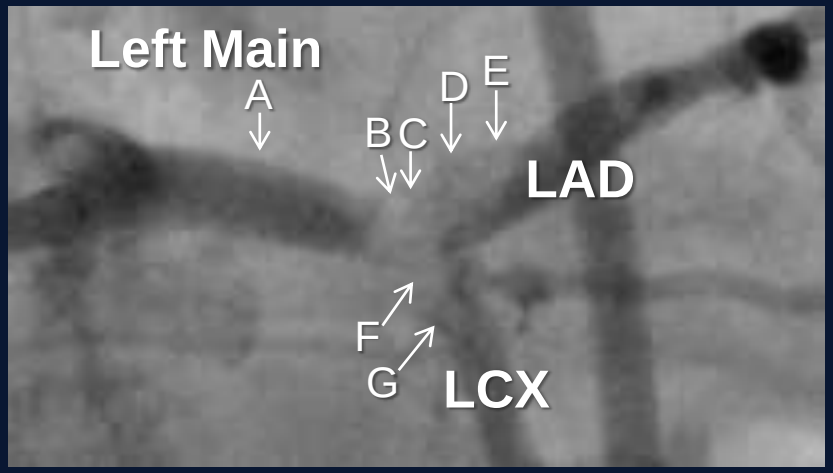


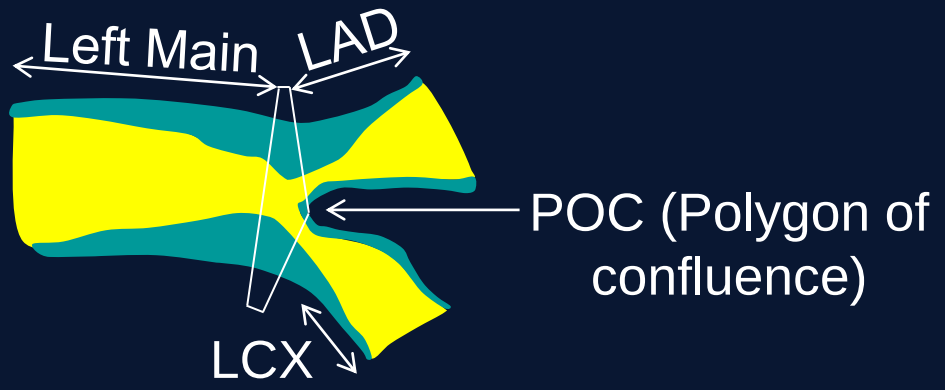

Left Main
A
B C
D
E
LAD
F
G
LCX

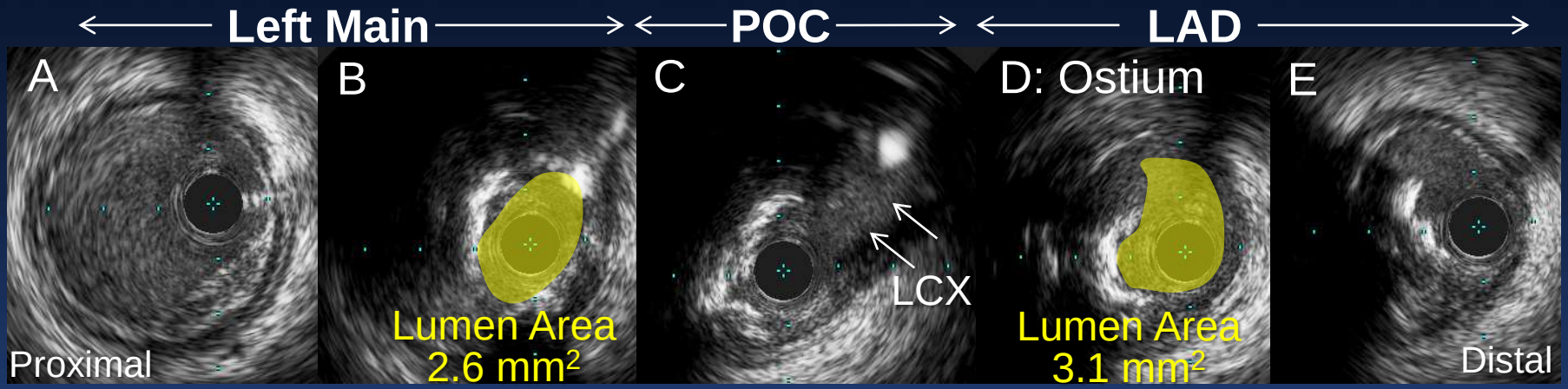

Left Main
LAD
POC (Polygon of confluence)
LCX

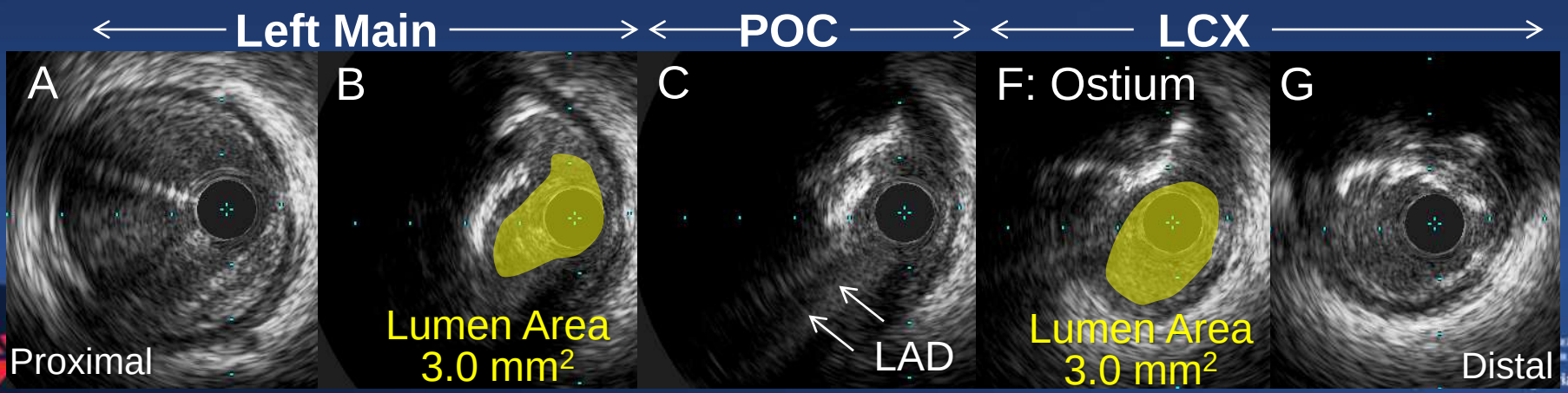

Left Main
POC
LAD
A
B
C
D: Ostium
E
LCX
Proximal
Distal

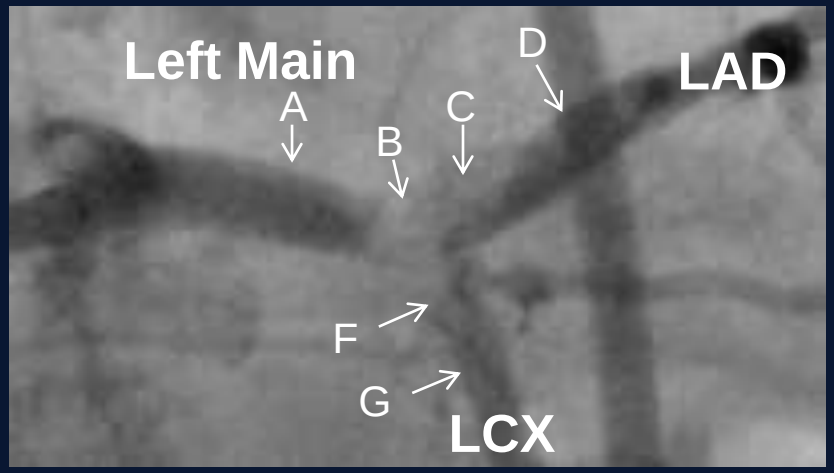

Left Main
POC
LCX
A
B
C
F: Ostium
G
LAD
Proximal
Distal

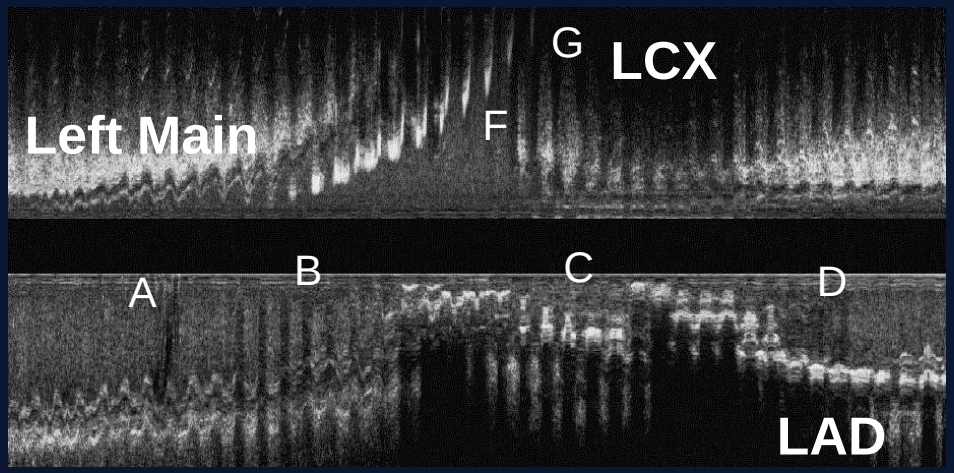

Left Main
A
B C
D
E
LAD
F
G
LCX


Left Main
LAD
POC (Polygon of confluence)
LCX


Left Main
POC
LAD
A
Proximal
B
Lumen Area
2.6 mm2
C
LCX
D: Ostium
Lumen Area
3.1 mm2
E
Distal


Left Main
POC
LCX
A
Proximal
B
Lumen Area
3.0 mm2
C
LAD
F: Ostium
Lumen Area
3.0 mm2
G
Distal

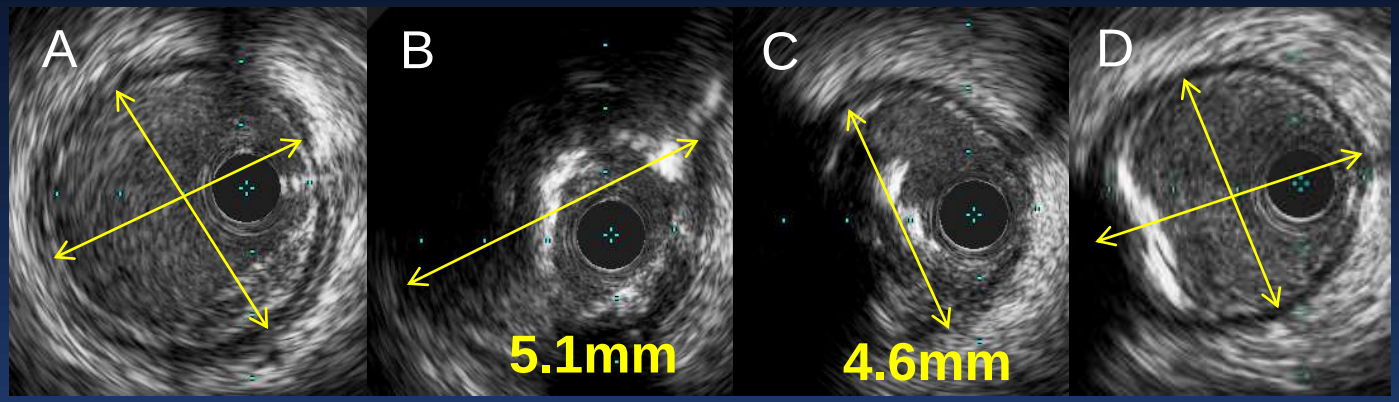




Left Main

LAD

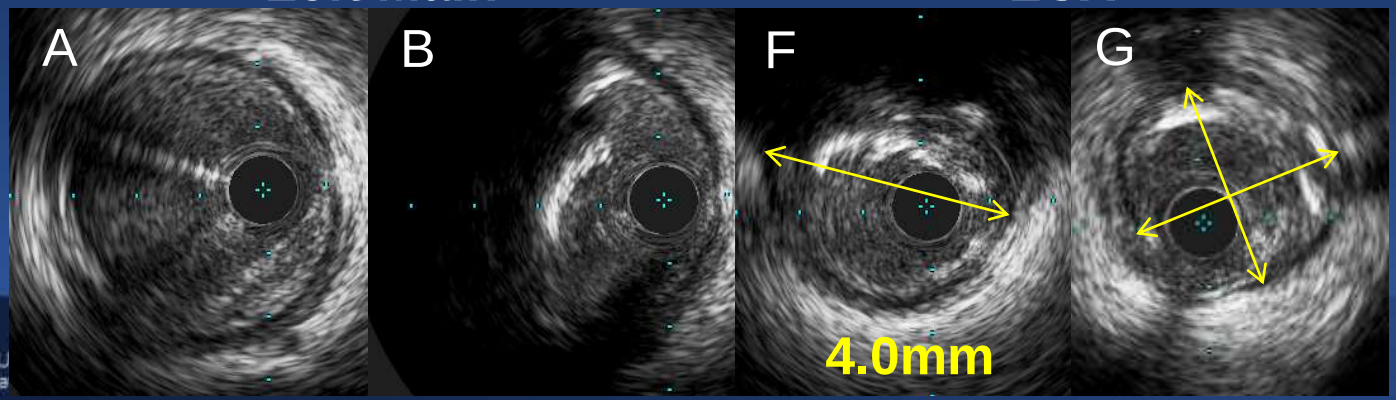
4.5mm×
4.6mm



4.6mm×
4.0mm

Left Main

LCX



3.5mm×
3.4mm

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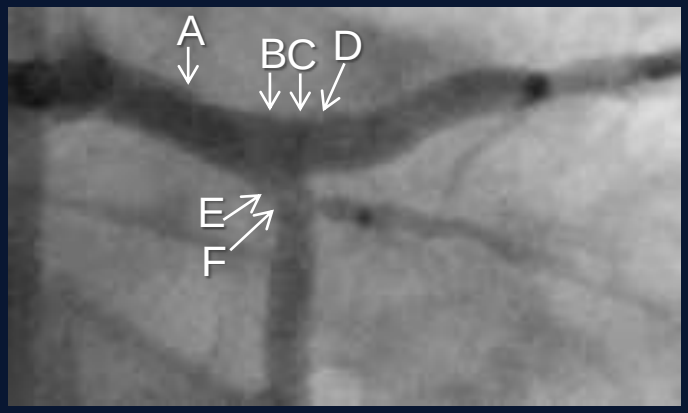
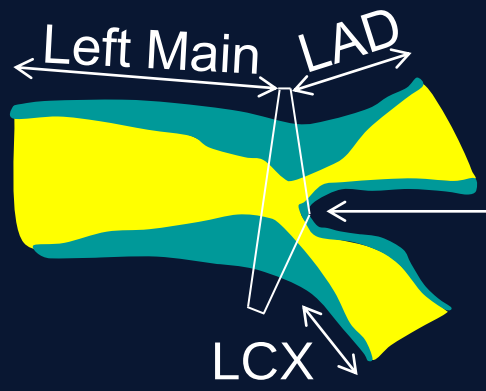
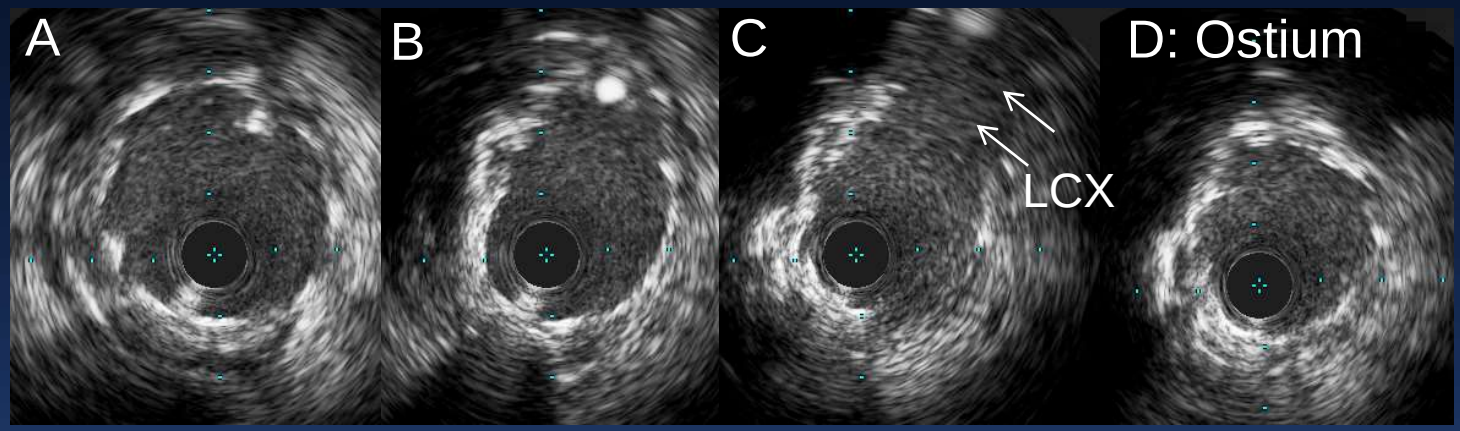


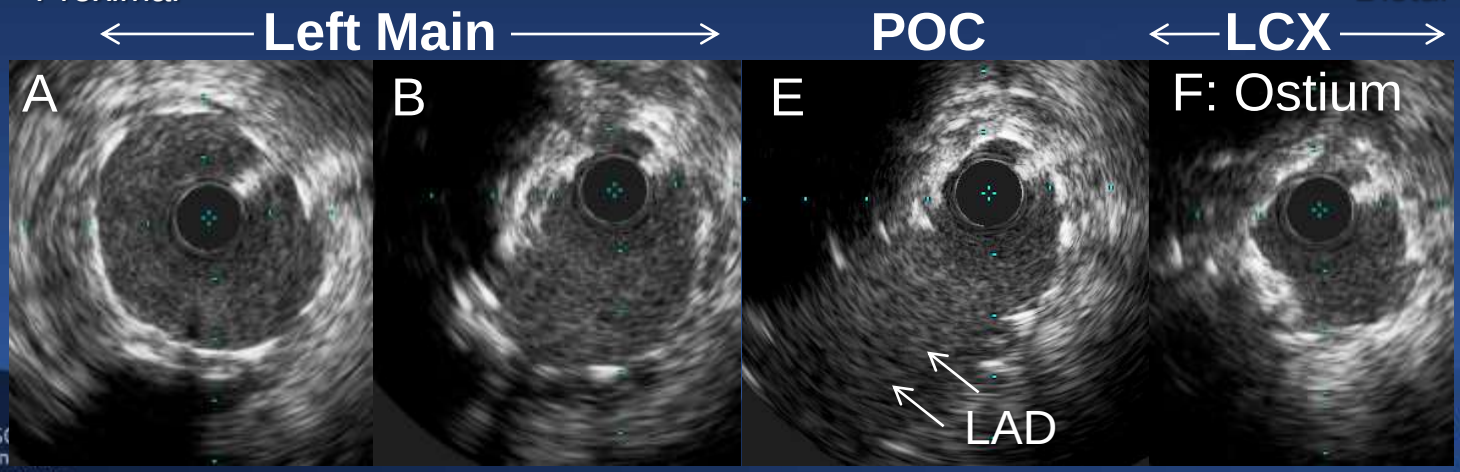


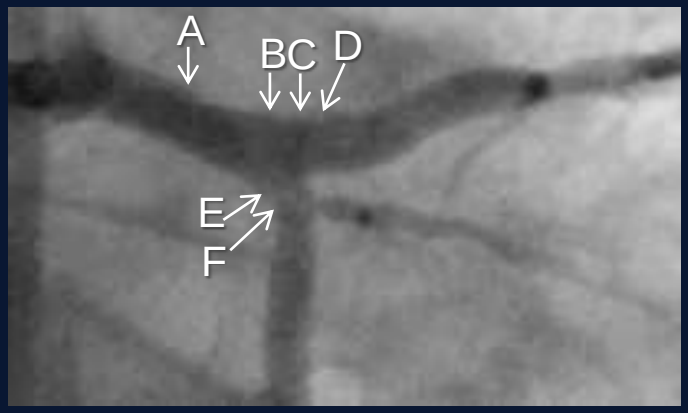
POC (Polygon of confluence)

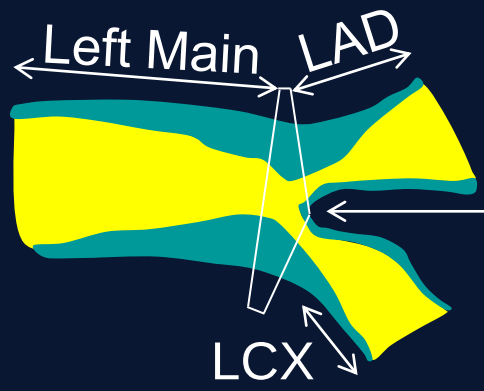


Proximal

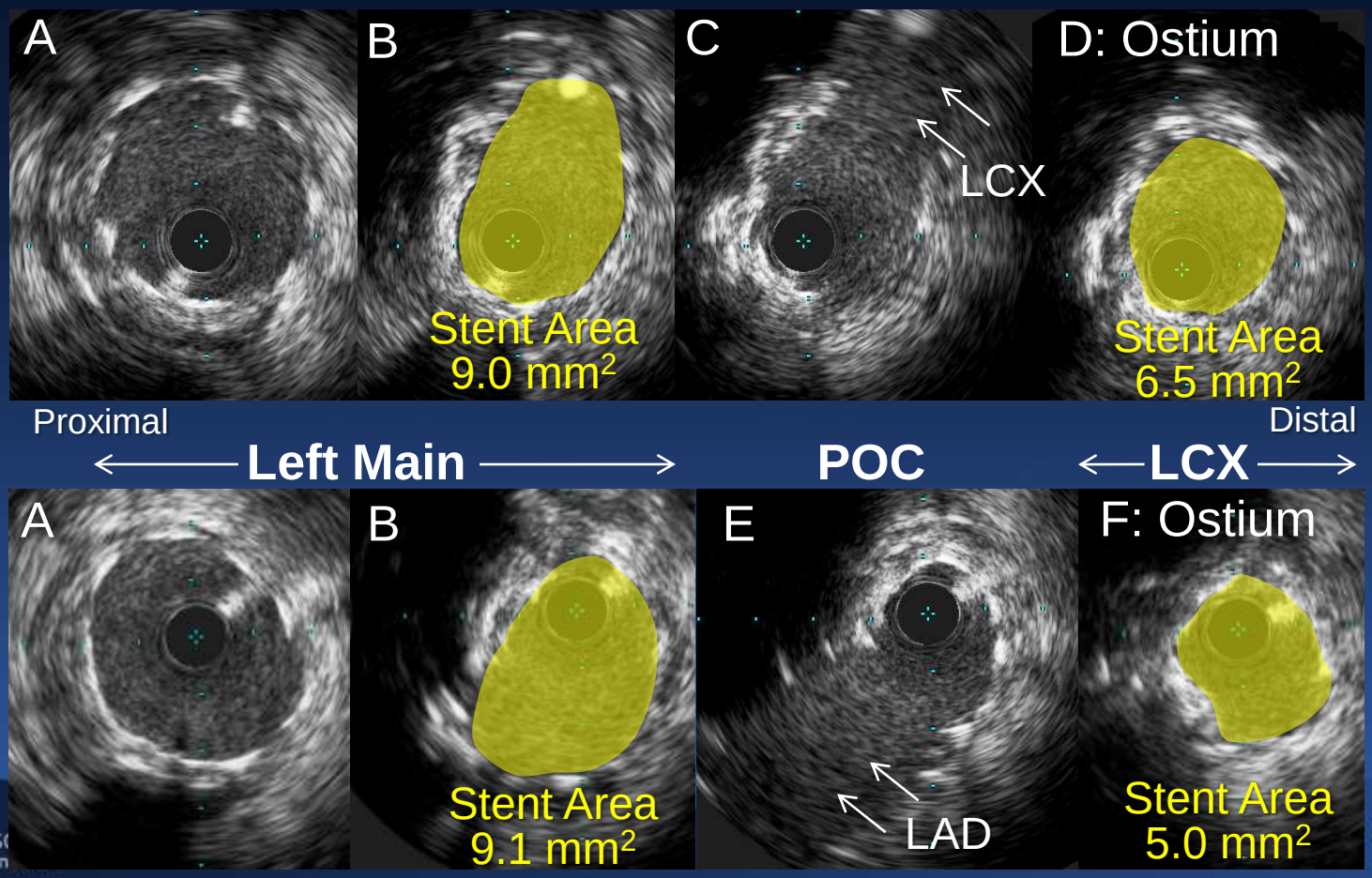
Distal







POC (Polygon of confluence)



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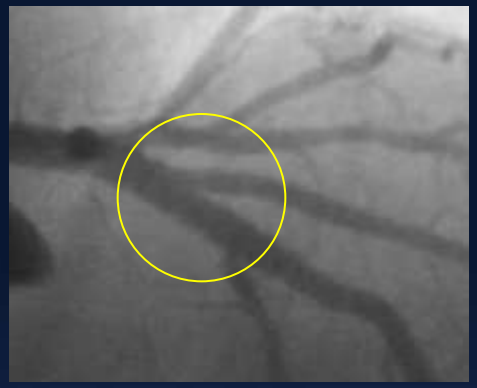
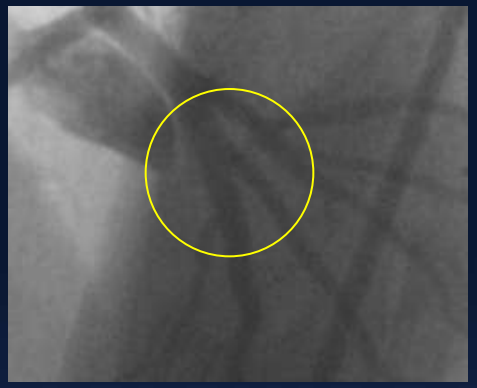
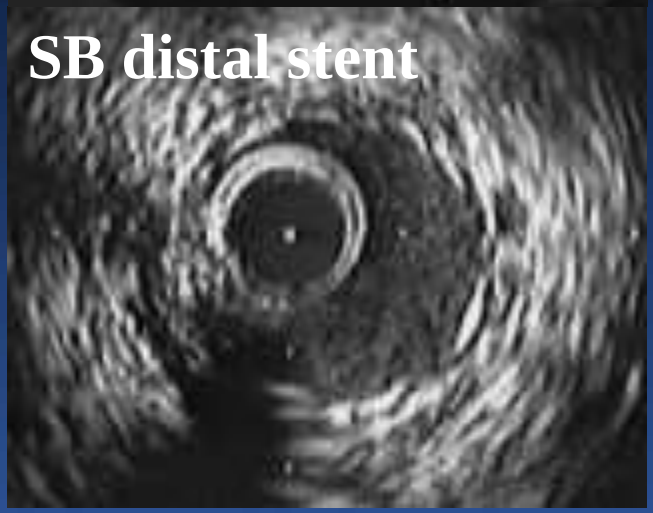
SB Stent Underexpansion After Crush

Final angiographic result



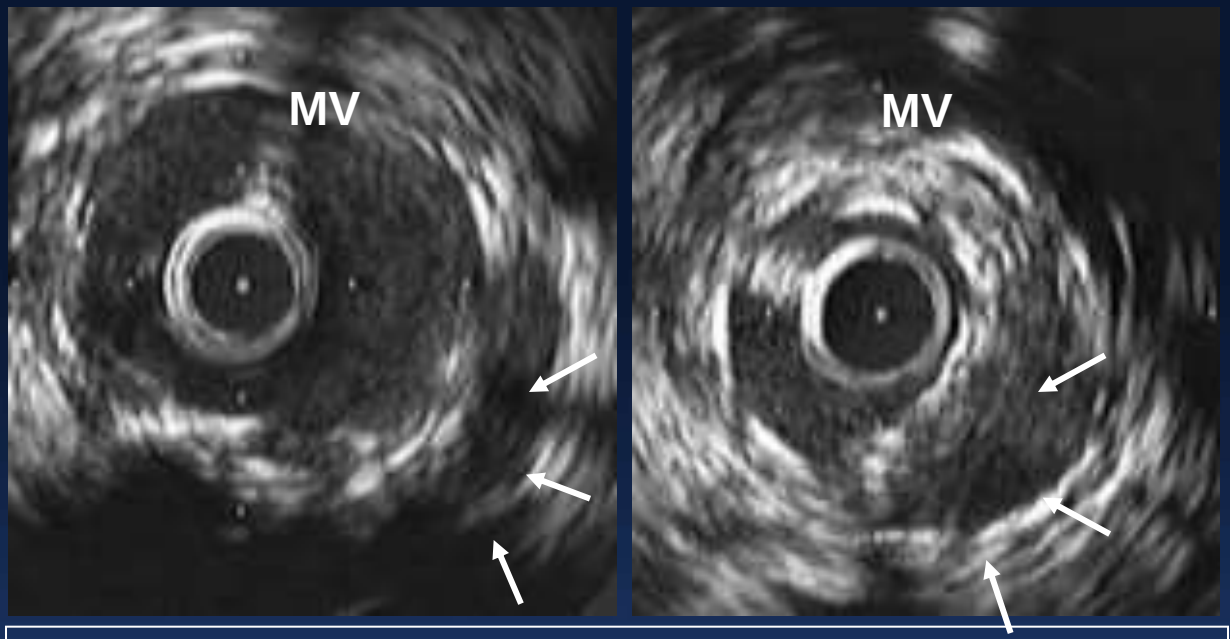


	MV	SB
MSA, mm^2	6.5±1.7	3.9±1.0
Stent expansion, %	92.1±16.6	79.9±12.3
MSA <4 mm^2	10% (2/20)	55% (11/20)
MSA <5 mm^2	20% (4/20)	90% (18/20)



Costa et al. J Am Coll Cardiol. 2005;46:599-605

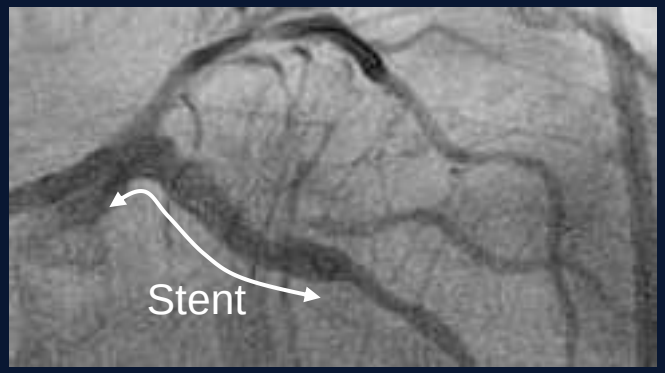
Incomplete Crush Apposition

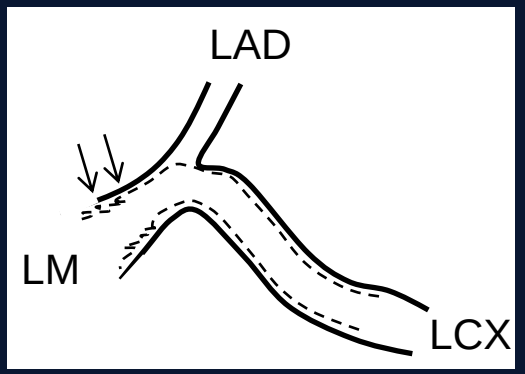


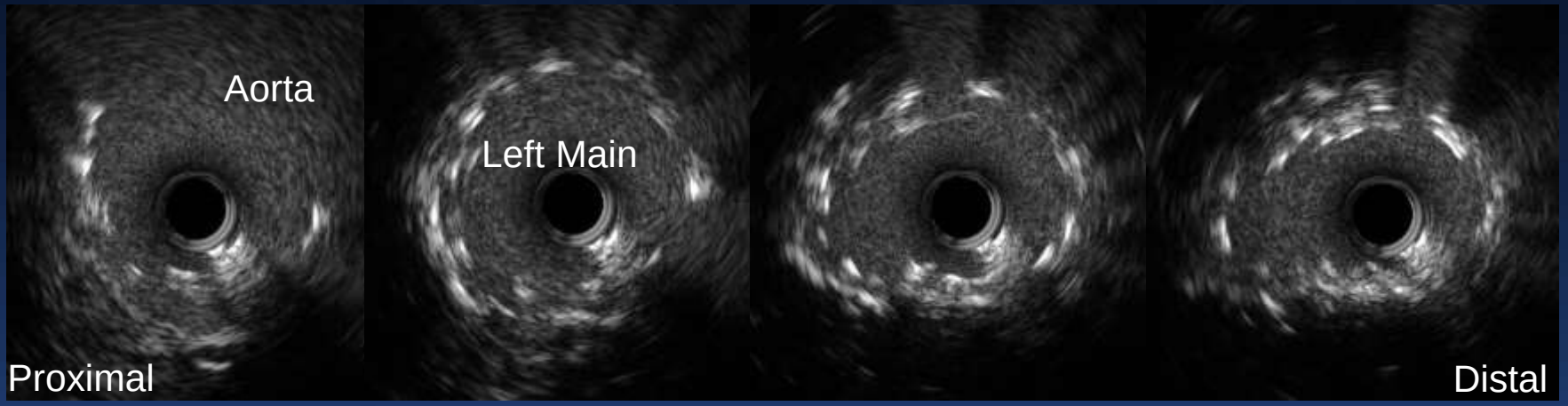
Incomplete crushing – incomplete apposition of the SB or MV stent struts against the MV wall proximal to the carina – was found in >60% of non-LM lesions

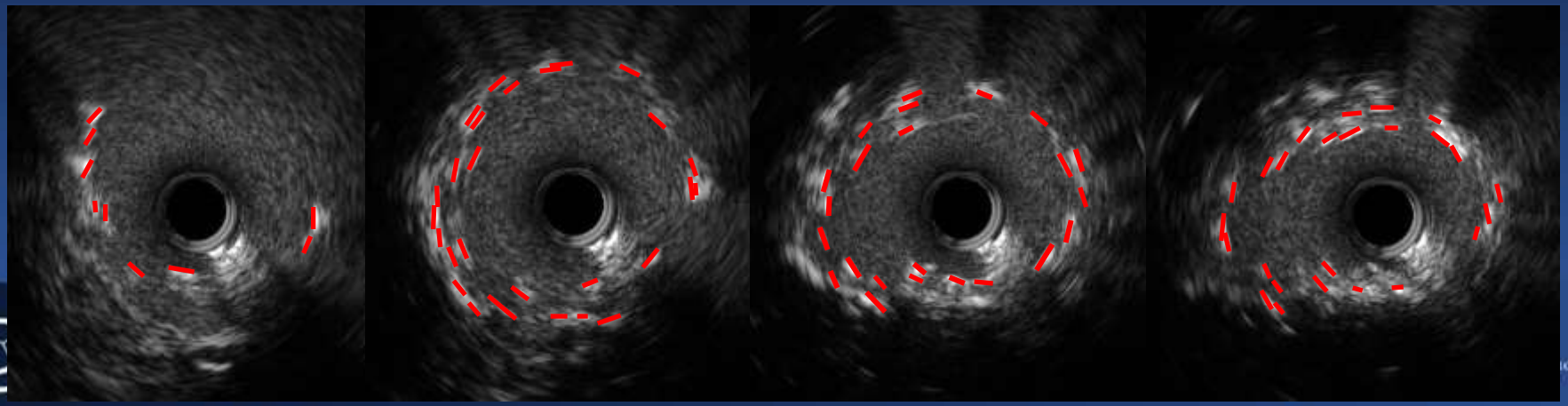
Costa et al. J Am Coll Cardiol. 2005;46:599-605

Stent Deformation

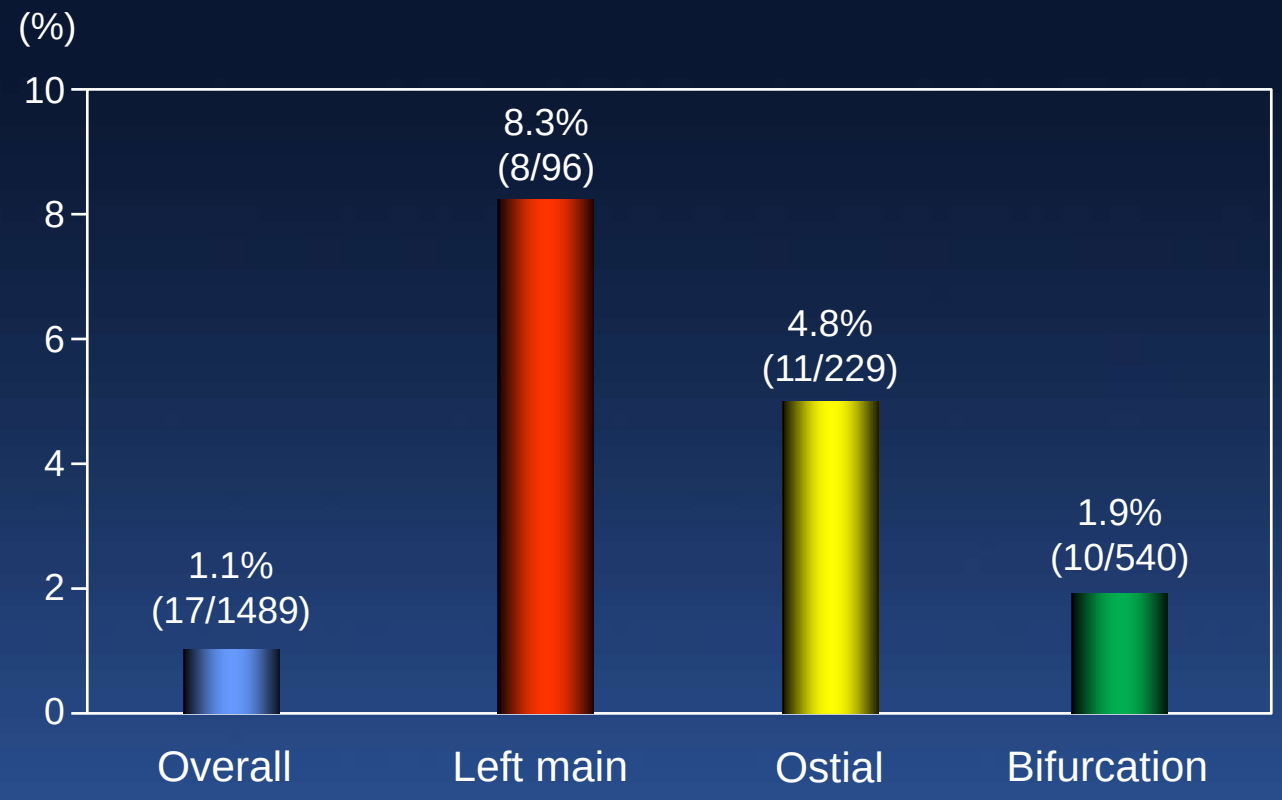






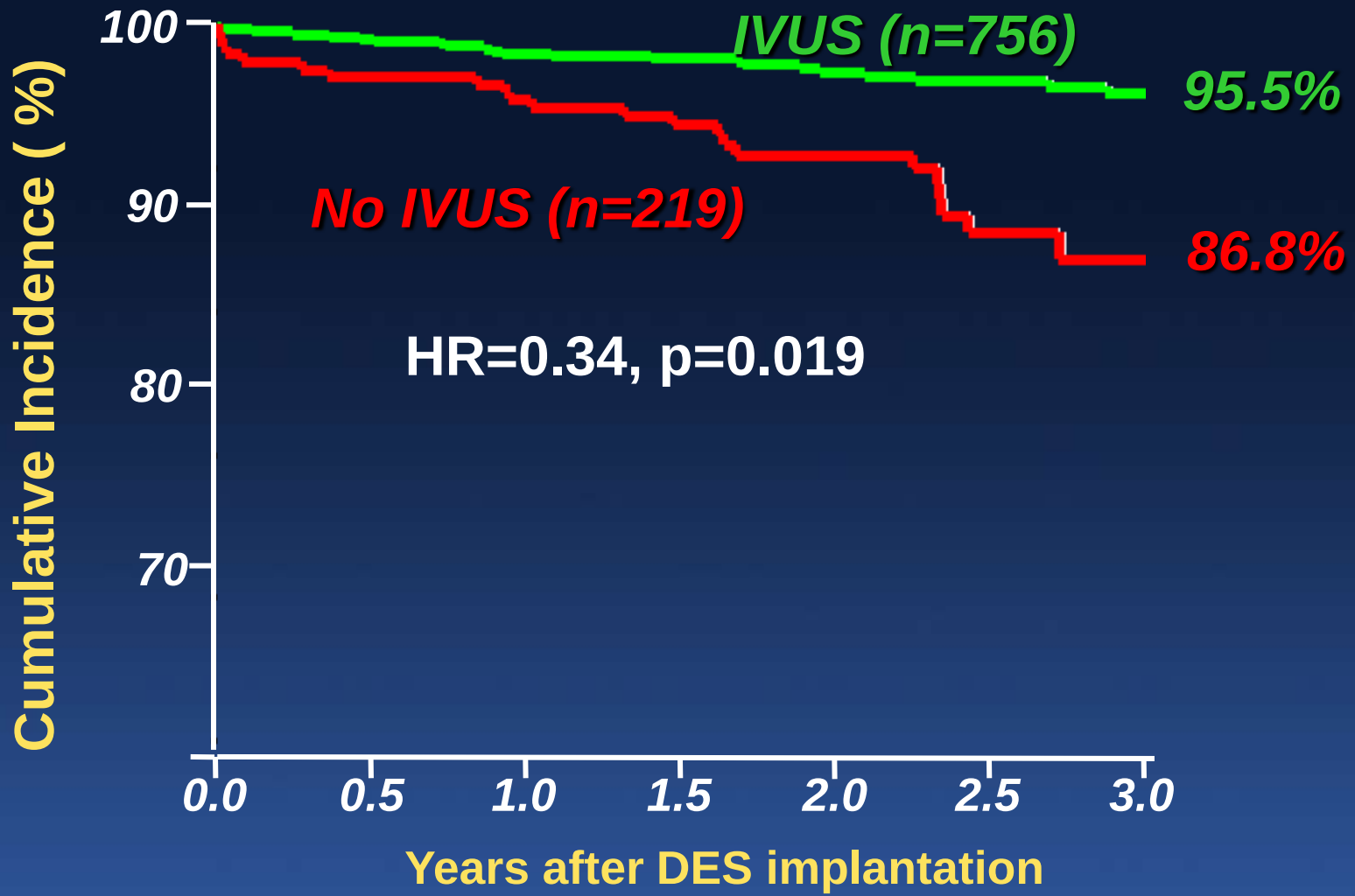


Prevalence of Stent Deformation



Inaba S. et al, *CCI 2014*

All-cause Mortality after LMCA DES Implantation: Impact of IVUS Guidance



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

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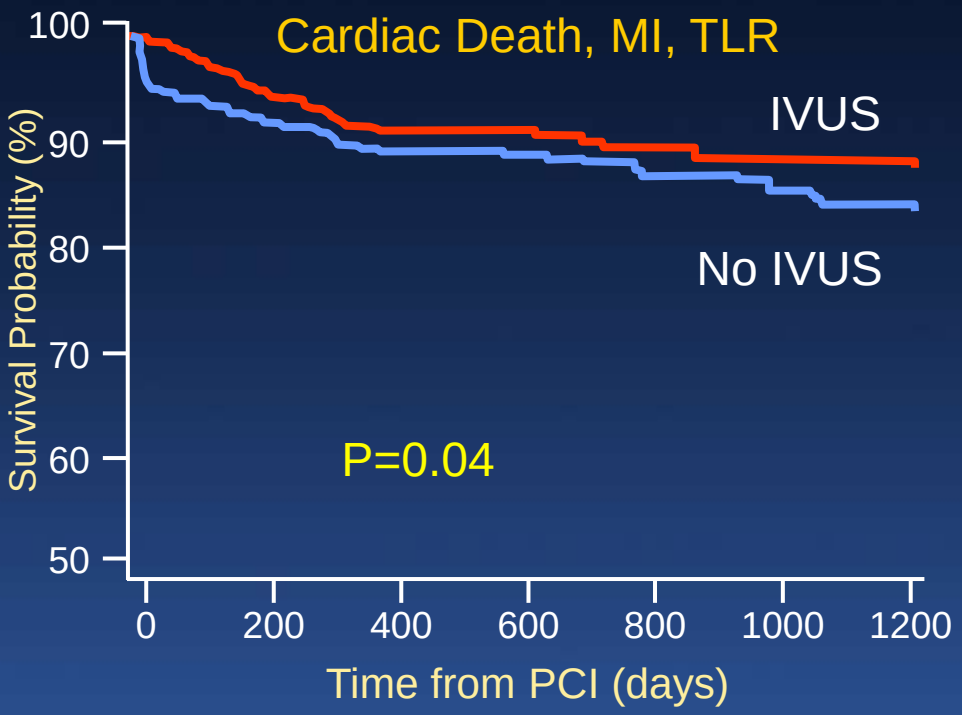
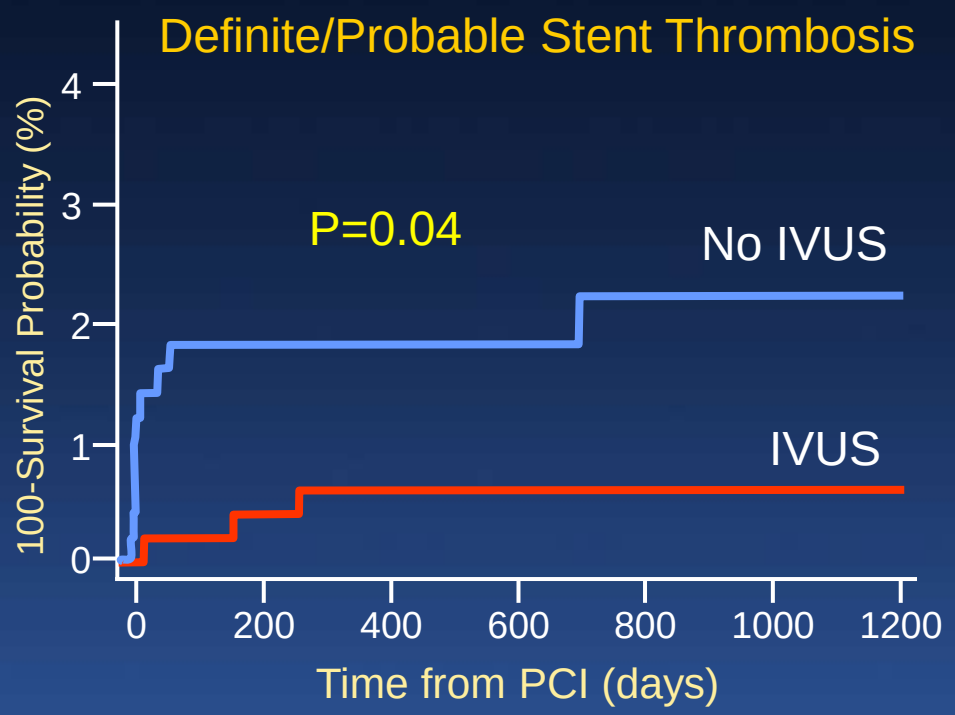
Impact of IVUS Guidance of Unprotected LM Propensity Matched 1010 pts from 4 Registries

- Distal LM lesion ~60%, 2 stent technique ~13%
- IVUS guidance was an independent predictor of MACE





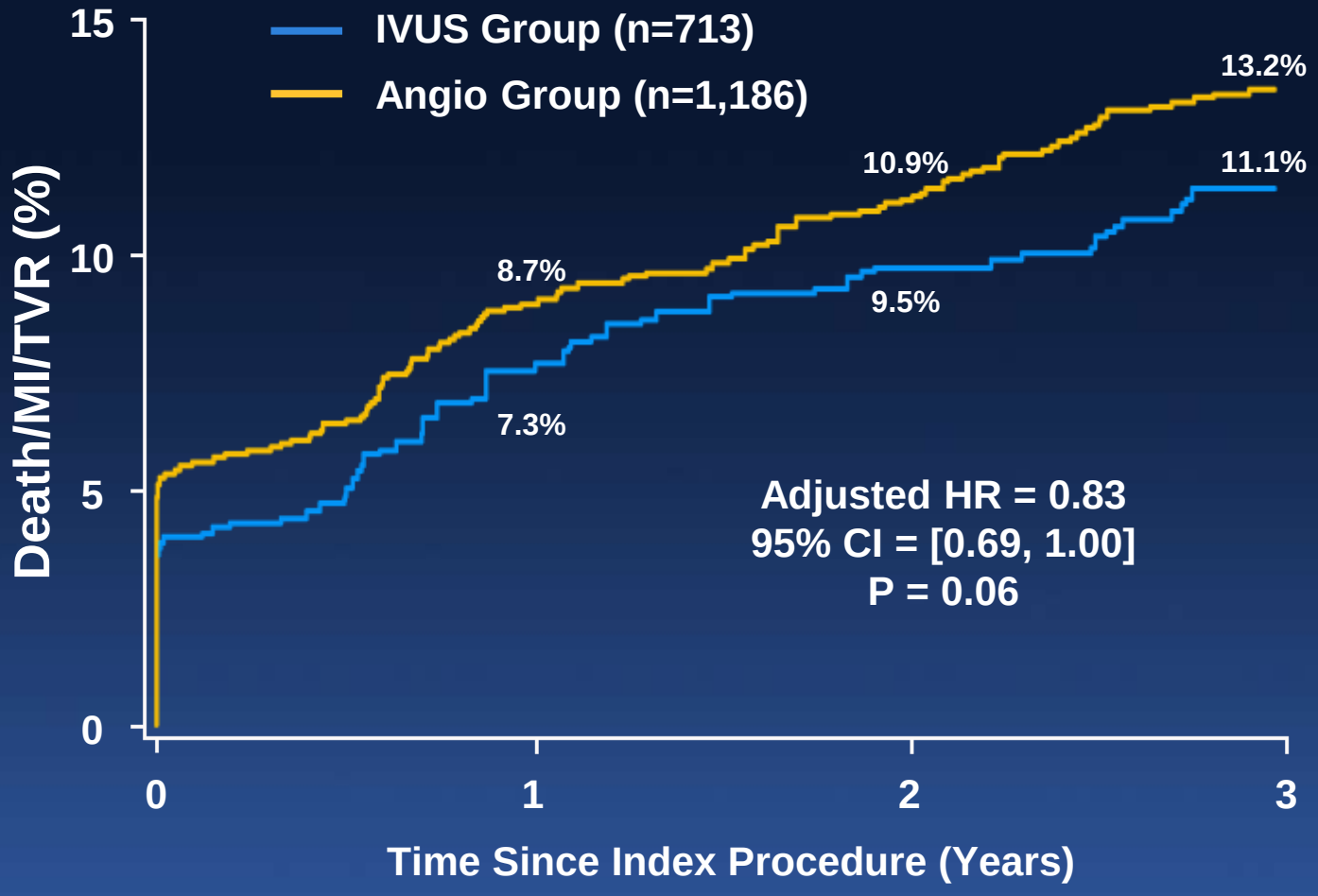
De la Torre Hernandez et al. J Am Coll Cardiol 2014:244-54

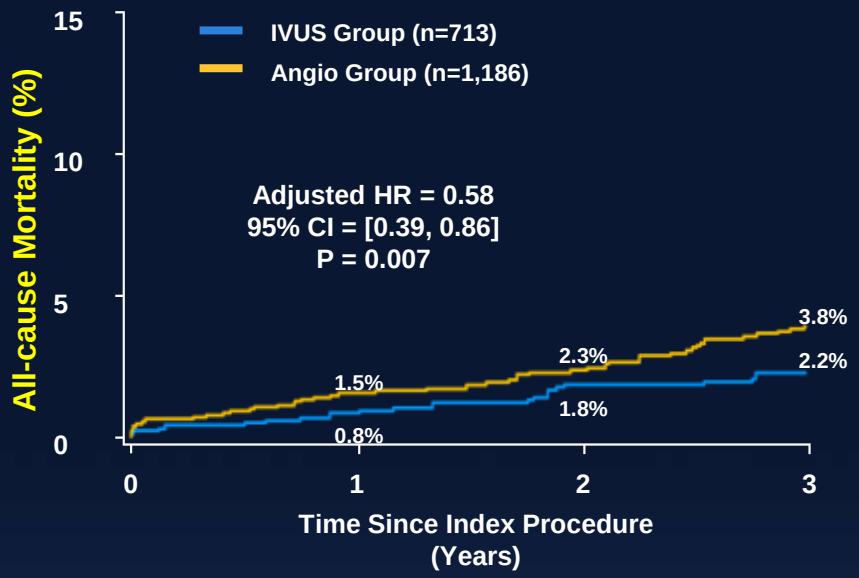
IVUS-guided LM PCI with DES vs a propensity score-matched group of pts treated without IVUS guidance from 4 Spanish registries

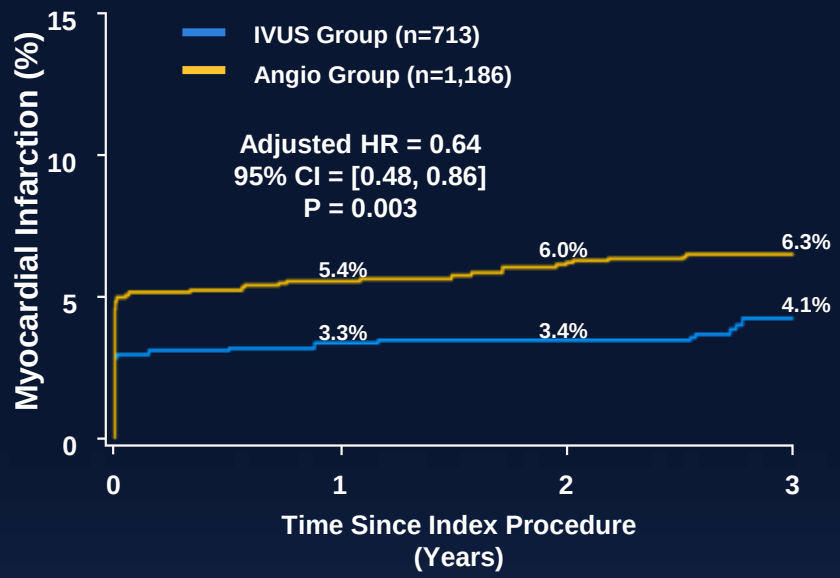
	IVUS	No IVUS	P
All lesions	505	505	
Cardiac death	3.3%	6.0%	0.07
MI	4.5%	6.5%	0.4
TLR	7.7%	6.3%	0.7
Definite/probable ST	0.6%	2.2%	0.04
Cardiac death+MI+TLR	11.7%	16.0%	0.04
Distal lesions	221	226	
Cardiac death+MI+TLR	11.0%	19.0%	0.03
Distal lesions - 2 stents	63	62	
Cardiac death+MI+TLR	16.7%	41.0%	0.02

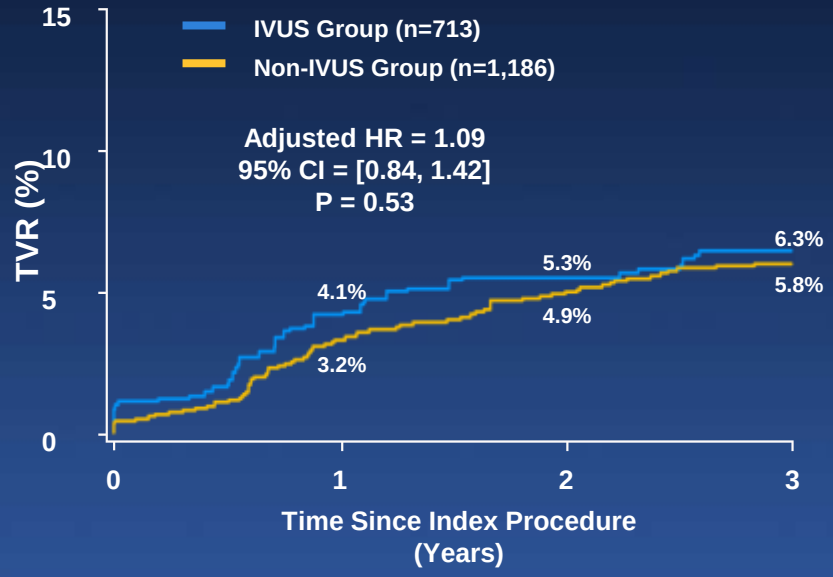
De la Torre Hernandez et al. J Am Coll Cardiol 2014:244-54

IVUS vs angiography-guided LMCA PCI at FuWai Hospital (N=1,899)







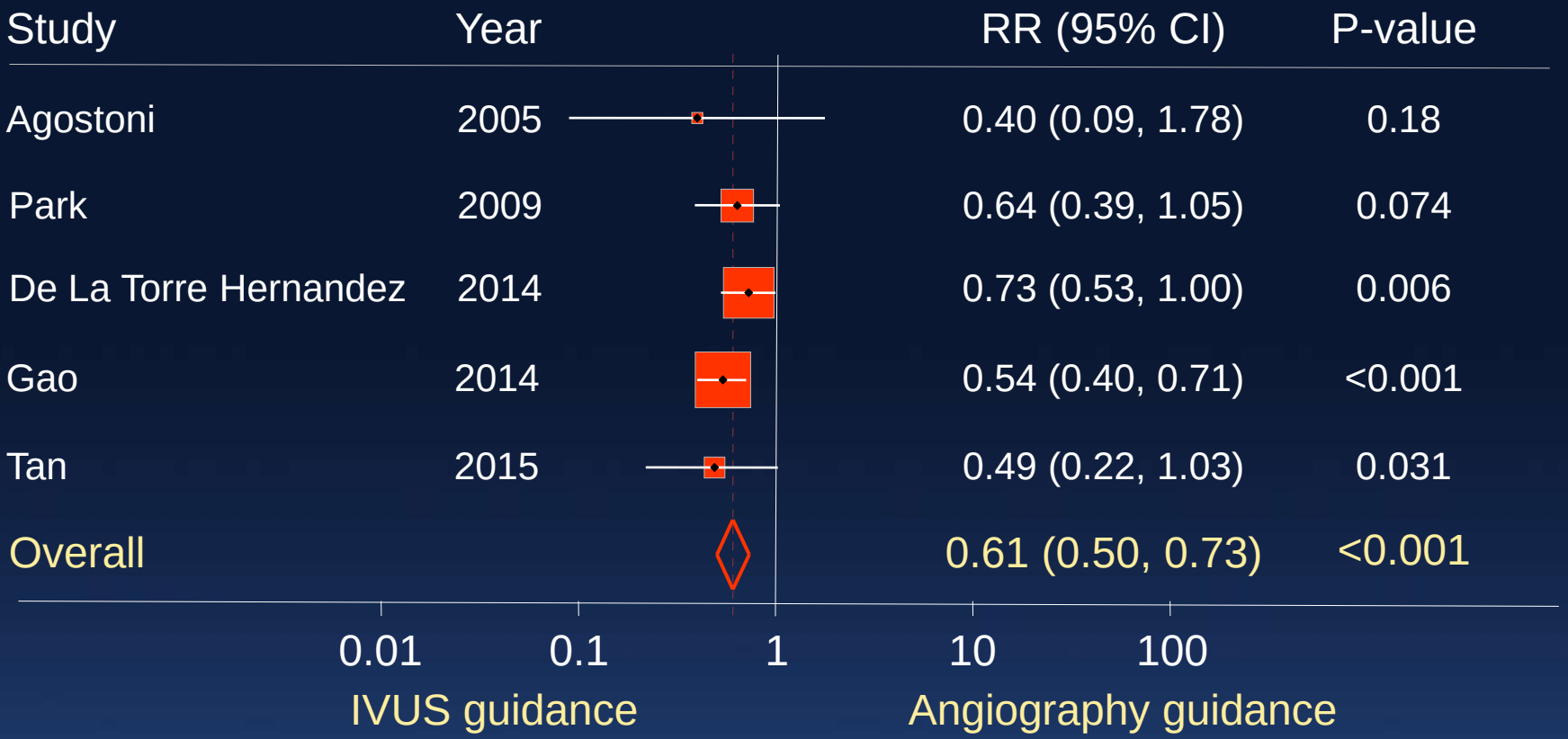


Cardiovascular Research Foundation

Xu Bo. TCT2015

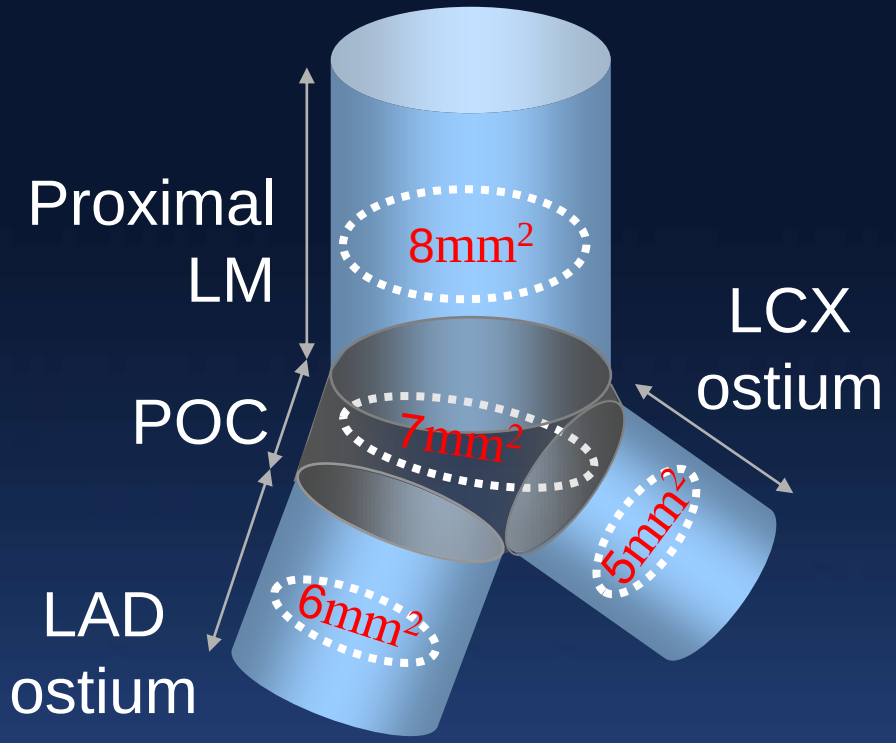
Columbia University Medical Center
NewYork-Presbyterian

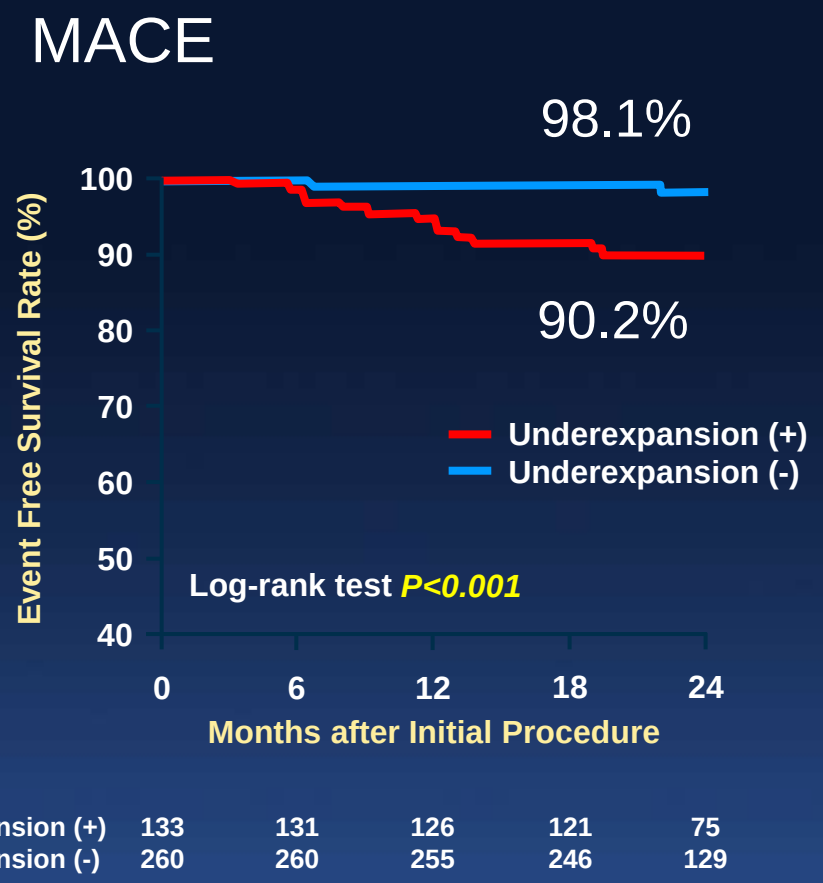
Meta-Analysis of MACE in 5 published studies



- IVUS-guided DES implantation into LMCA lesions was associated with a significant reduction in
  - MACE (RR: 0.61, 95% CI: 0.50 to 0.73, p<0.001)
  - All-cause Death (RR: 0.53, 95% CI: 0.37 to 0.76, p=0.001)
  - Cardiac Death (RR: 0.40, 95% CI: 0.24 to 0.64, p<0.001)
  - Myocardial Infarction (RR: 0.69, 95% CI: 0.53 to 0.89, p<0.001)
  - Stent Thrombosis (RR: 0.27, 95%CI: 0.11 to 0.65, p=0.004).
- However, there was no significant statistical difference regarding TLR (RR: 0.41, 95% CI: 0.09 to 1.91, p=0.255) and only a trend to reduced TVR (RR: 0.45, 95% CI: 0.16 to 1.27, p=0.132).

MACE-free Survival in LMCA Lesions





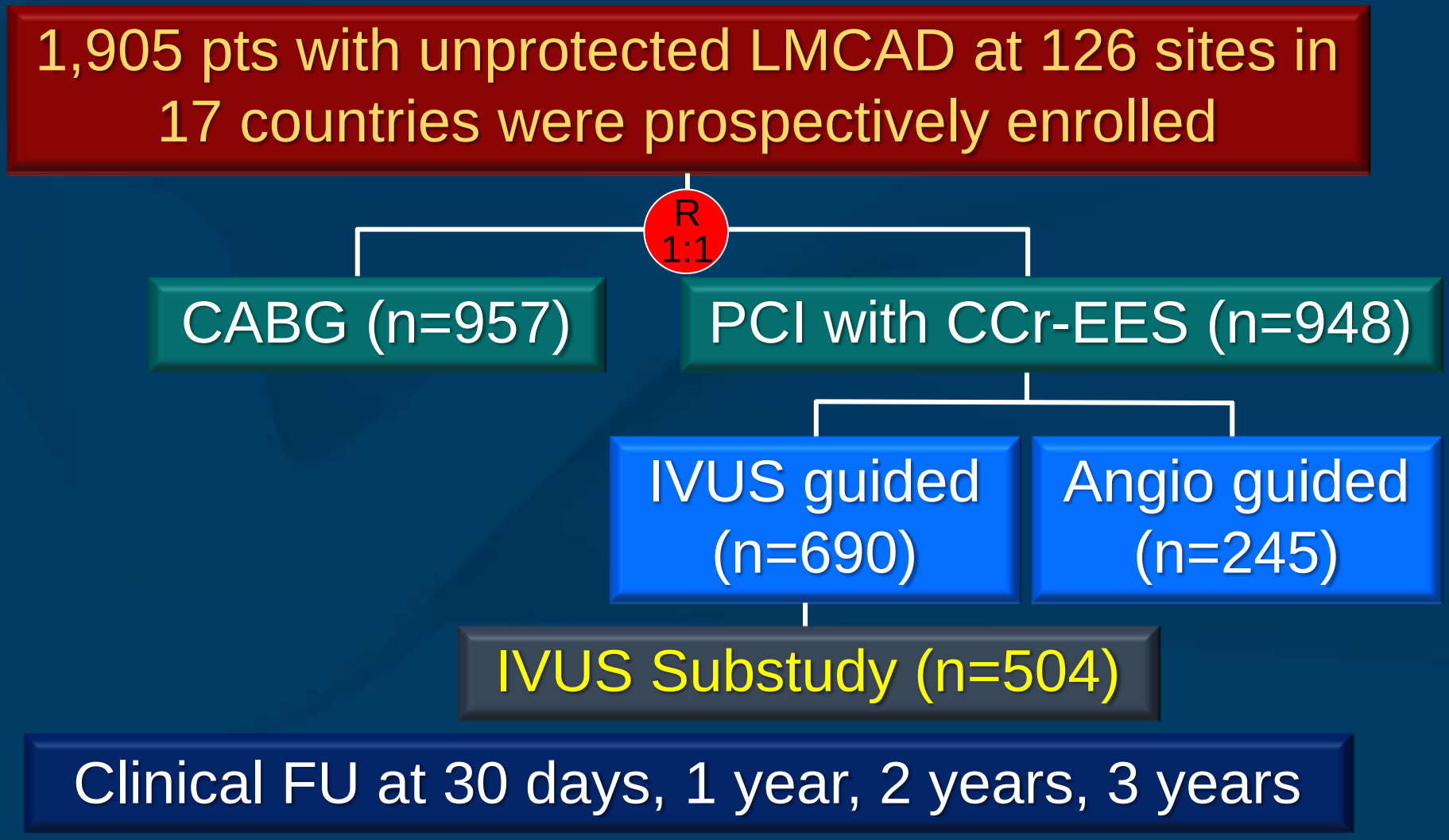
No. at risk

Underexpansion (+)	133	131	126	121	75
Underexpansion (-)	260	260	255	246	129

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

EXCEL Trial

Evaluation of Xience versus Coronary Artery Bypass Surgery for Effectiveness of Left Main Revascularization



Major Inclusion Criteria

- Unprotected LMCAD with ≥70% DS, *or* ≥50% - <70% with either i) non-invasive evidence of LM ischemia, ii) IVUS MLA ≤6.0 mm^2, or iii) FFR ≤0.80

PCI recommendations

- Complete revascularization of all ischemic territories with EES
- Provisional LM bifurcation treatment preferred
- IVUS guidance strongly recommended
- Routine angiographic follow-up not permitted

Primary and Secondary Endpoints

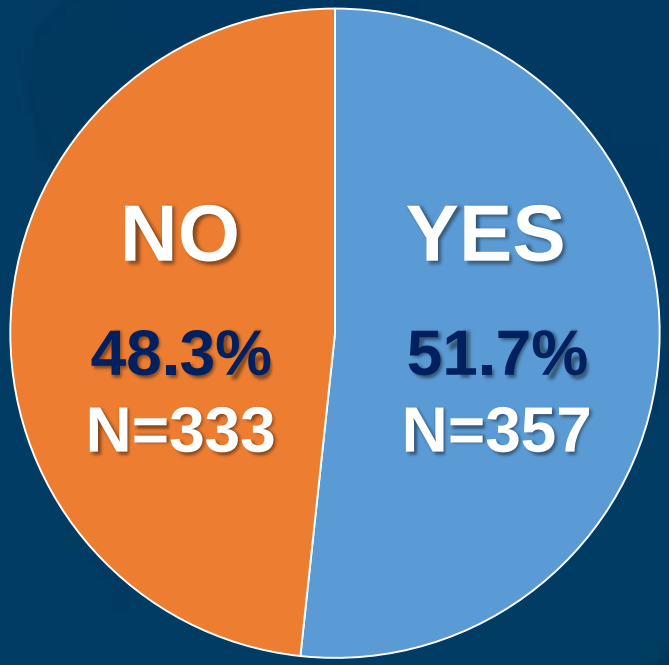
Tested hierarchically to preserve alpha

Endpoint	Timing of follow-up	Powered for
Primary endpoint: Death, stroke or MI	Median 3 years, minimum 2 years	Non-inferiority
Secondary endpoint #1: Death, stroke or MI	30 days	Non-inferiority
Secondary endpoint #2a: Death, stroke, MI or IDR	Median 3 years, minimum 2 years	Non-inferiority
Secondary endpoint #2b: Death, stroke or MI	Median 3 years, minimum 2 years	Superiority
Post-hoc endpoint: Cardiac death, MI/stent thrombosis/IDR relates to LM lesion	Median 3 years, minimum 2 years	NA

If the primary endpoint and secondary endpoint #1 both pass, secondary endpoints #2a and #2b are tested simultaneously

IDR = ischemia-driven revascularization

Change in LMCAD stenting by IVUS



Any IVUS usage for LM lesion (n=690)

- Used larger balloon: 30% (107)
- Post-dilated: 29% (102)
- Used higher pressure: 17% (62)
- Treated stent under-expansion: 16% (57)
- Led to provisional 1 stent strategy rather than planned 2 stents: 11% (41)
- Led to planned 2 stent strategy rather than provisional 1 stent: 9% (33)

Patient Characteristics

IVUS MSA tertiles (range)	Low: 4.4-8.7 (n=172)	Inter: 8.8-10.9 (n=169)	High: 11.0-17.8 (n=163)	P Value
Age (years)	65.5±9.8	65.3±9.2	65.7±9.7	0.94
Female	32.0%	22.5%	24.5%	0.11
Diabetes mellitus	33.7%	29.0%	24.5%	0.18
Insulin treated	9.9%	7.7%	4.3%	0.14
Hyperlipidemia	76.6%	68.7%	73.6%	0.26
Hypertension	76.5%	77.4%	67.5%	0.08
Current smoking	25.7%	27.9%	23.6%	0.68
Renal insufficiency*	18.0%	15.5%	14.9%	0.72
Prior MI	16.5%	22.3%	16.3%	0.27
Prior PCI	17.4%	17.9%	21.5%	0.59

*Defined as Cockcroft-Gault equation<60ml/min

Angio and Procedural Characteristics

IVUS MSA tertiles (range)	Low: 4.4-8.7 (n=172)	Inter: 8.8-10.9 (n=169)	High: 11.0-17.8 (n=163)	P Value
Distal left main lesion	81.7%	77.4%	78.4%	0.60
Ostial LAD ≥50%	45.3%	44.4%	47.9%	0.81
Ostial LCX ≥50%	44.8%	35.5%	37.4%	0.18
LM + 2 vessel disease	36.0%	32.0%	25.8%	0.13
LM + 3 vessel disease	16.3%	20.7%	15.3%	0.39
Syntax score baseline	26.8±8.4	26.9±8.4	26.5±9.0	0.92
>32	21.8%	26.1%	23.9%	0.67
Residual Syntax score	6.1±5.8	6.3±6.0	6.3±6.5	0.96
Total LM stent length (mm)	27.3±15.2	27.8±15.6	27.3±16.4	0.96
LM stent diameter (mm)	3.3±0.4	3.5±0.4	3.7±0.4	<0.01
PCI for non-LM lesions	54.7%	53.8%	52.1%	0.90
Total non-LM stent length (mm)	35.6±25.1	40.7±28.7	36.2±26.5	0.40

IVUS Characteristics

IVUS MSA tertiles (range)	Low: 4.4-8.7 (n=172)	Inter: 8.8-10.9 (n=169)	High: 11.0-17.8 (n=163)	P Value
Left main segment				
Distal bifurcation location	84.3%	81.7%	78.5%	0.52
MSA, mm^2	7.5±1.0	9.9±0.7	12.5±1.4	<0.01
Vessel area at MSA, mm^2	19.3±4.0	21.8±3.7	24.8±4.2	<0.01
Mean stent area, mm^3/mm	8.9±1.5	11.2±1.2	13.6±1.6	<0.01
Mean vessel area, mm^3/mm	19.0±3.5	22.1±3.7	25.1±4.1	<0.01
Any target lesion segment				
Attenuated plaque	75.6%	76.3%	69.9%	0.35
Tissue protrusion	8.1%	10.1%	11.7%	0.56
Stent malapposition	18.6%	21.3%	23.3%	0.57
Stent deformation/fracture	9.4%	4.7%	5.6%	0.18
Edge dissection	13.4%	12.4%	12.3%	0.95

Overall 3-Year Outcomes

IVUS MSA tertiles (range)	Low: 4.4-8.7 (n=172)	Inter: 8.8-10.9 (n=169)	High: 11.0-17.8 (n=163)	P L vs I	P L vs H
Death/MI/stroke	19.4% (32)	16.1% (26)	9.6% (15)	0.45	0.01
Death/MI/stroke/IDR*	26.6% (44)	23.8% (39)	18.3% (29)	0.66	0.08
All cause death	13.8% (22)	10.0% (16)	5.2% (8)	0.34	0.01
Cardiovascular death	7.4% (12)	4.8% (8)	4.0% (6)	0.39	0.16
MI	10.5% (17)	8.2% (13)	3.7% (6)	0.49	0.02
Stroke	1.8% (3)	1.2% (2)	2.1% (3)	0.66	0.98
Stent thrombosis (D/P)	3.1% (5)	1.2% (2)	0.0% (0)	0.26	0.03
Target lesion IDR	12.0% (19)	8.3% (13)	8.8% (14)	0.30	0.41
Target vessel IDR	12.0% (19)	10.8% (17)	9.4% (15)	0.79	0.52

*IDR: ischemia driven revascularization

3-Year Left Main Related Outcomes

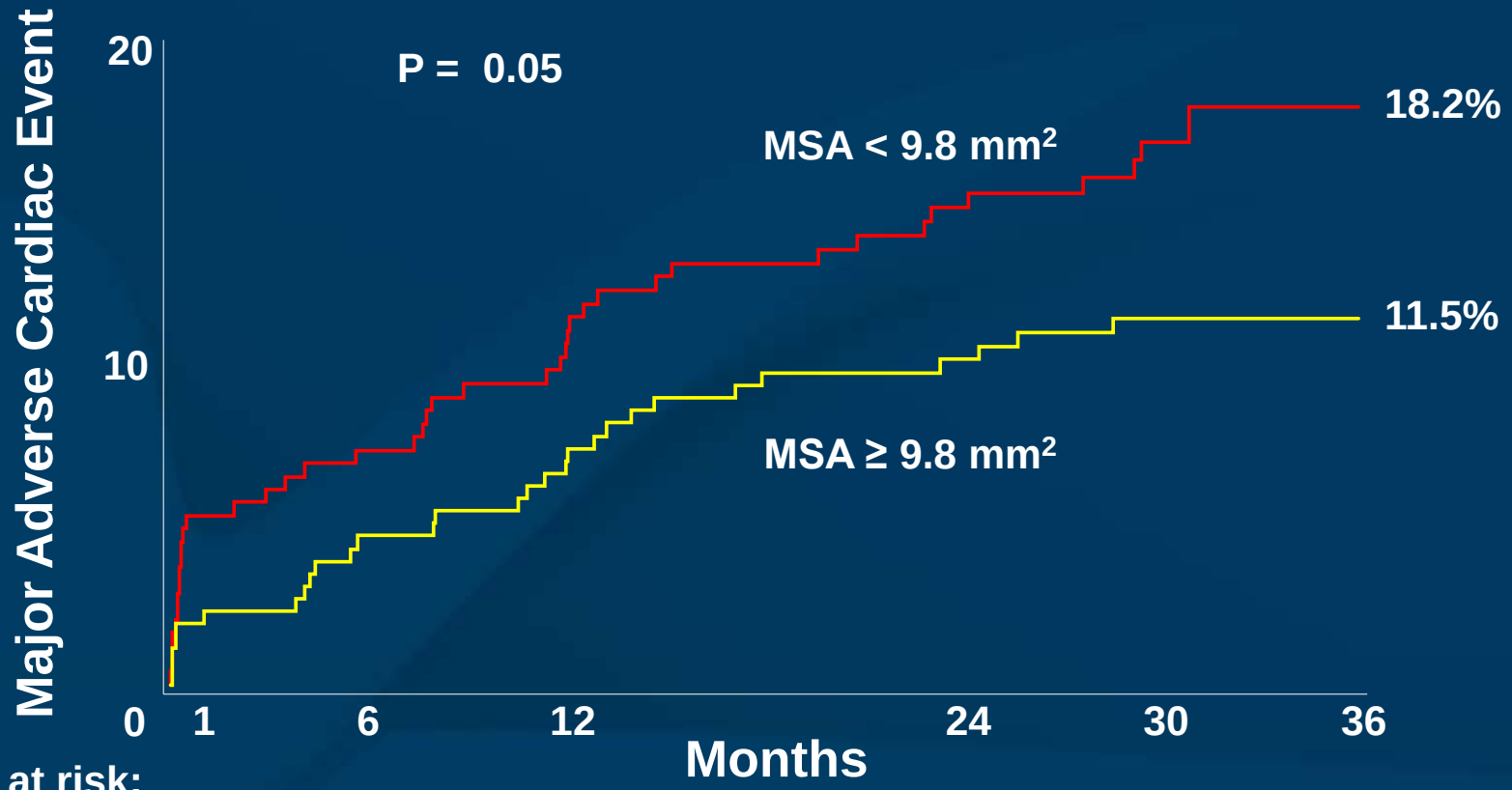
IVUS MSA tertiles (range)	Low: 4.4-8.7 (n=172)	Inter: 8.8-10.9 (n=169)	High: 11.0-17.8 (n=163)	P L vs I	P L vs H
Cardiac death, MI/ST/IDR of LM	19.7 (32)	12.9% (21)	11.3% (18)	0.14	0.05
Cardiac death	6.8% (11)	3.0% (5)	1.9% (3)	0.14	0.03
MI of LM	9.4% (15)	4.3% (7)	3.1% (5)	0.09	0.03
Peri-procedural	4.1% (7)	2.4% (4)	1.8% (3)	0.38	0.23
Spontaneous	4.5% (7)	1.2% (2)	0.6% (1)	0.10	0.03
Stent thrombosis (D/P)	3.1% (5)	0.6% (1)	0% (0)	0.11	0.03
LM ischemia driven TLR	10.2% (16)	8.3% (13)	7.6% (12)	0.61	0.47
LM ischemia driven TVR	10.2% (16)	10.2% (16)	8.2% (13)	0.94	0.61

LM MSA to predict LM related Events

	Adjusted Hazard Ratio (95% CI)	P-value
Final IVUS LM MSA (mm^2)	0.89 (0.80-0.99)	0.03
Distal left main lesion location	2.10 (1.0-5.33)	0.05
Diabetes mellitus	1.63 (1.0-2.64)	0.049
Acute coronary syndrome presentation	0.60 (0.36-0.99)	0.045
Male	0.69 (0.41-1.12)	0.16
Age (years)	1.01 (0.99-1.04)	0.32
History of heart failure (NYHA III/ IV)	1.23 (0.38-3.99)	0.73
Left main with 3 vessel disease	1.21 (0.67-2.20)	0.53

Cut off of LM MSA= 9.8 mm^2 (AUC:0.58)

KM-Curve stratified by MSA Cut-off



Number at risk:

MSA < 9.8	245	232	224	212	188	97
MSA ≥9.8	259	252	244	235	220	139

Conclusions

1. IVUS is useful for the diagnosis of severity and distribution of left main disease, optimization of stent, and evaluation of complication.
2. In the EXCEL trial, 68% of PCI cases were performed using IVUS guidance. In the half of IVUS guidance cases, the procedure was changed by the IVUS findings.
3. After treatment with CoCr-EES, a small final MSA of the left main coronary artery measured by IVUS was strongly associated with cardiac death, MI, stent thrombosis, and TLR related LM during 3 year follow-up.