IVUS: Pre-Intervention Assessment and Optimizing Final Result

Gary S. Mintz, MD

Cardiovascular Research Foundation
New York, NY

CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER

Most of the concepts used in IVUS-guided intervention are no different from those used in angiography-guided intervention. However, unlike angiography, IVUS is actually able to make precise measurements and assess lesion morphology.

- Weigh potential problems (i.e. LM disease, significant proximal or distal disease)
- Assess lesion severity
- Assess unusual lesion morphology (i.e., aneurysms, calcium, thrombi, in-stent restenosis, etc.)
- Measure vessel size
- Measure lesion length
- Determine and fine-tune the final result of interventions
- Assess complications

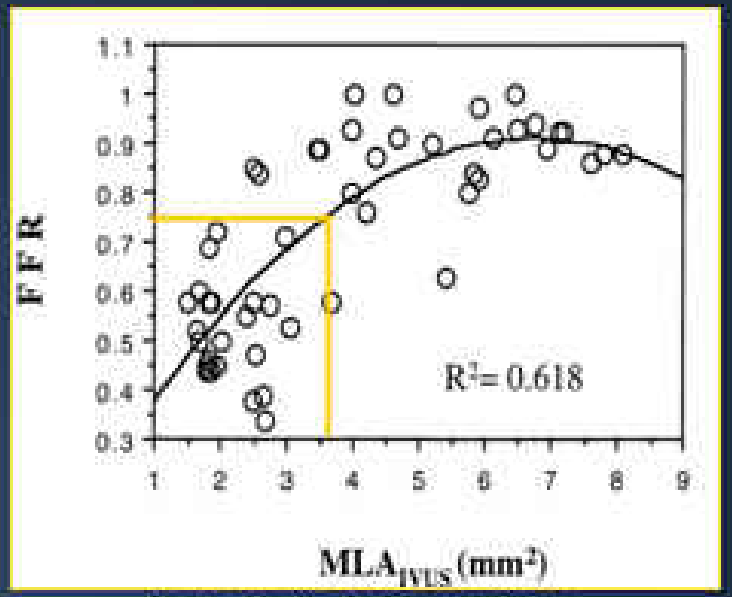
Validation of IVUS assessment of ischemia-producing stenoses (Doppler FloWire, SPECT, and Pressure Wire)

	IVUS MLA ≥4.0mm²	IVUS MLA <4.0mm²
CFR < 2.0	2	27
CFR ≥ 2.0	39	4

Diagnostic accuracy = 92%
Abizaid et al. Am J Cardiol 1998;82:42-8

	IVUS MLA ≥4.0mm²	IVUS MLA <4.0mm²
+ Spect	4	42
- Spect	20	1

Diagnostic accuracy = 93%
Nishioka et al. J Am Coll Cardiol 1999;33:1870-8



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

Clinical follow-up in 357 intermediate lesions in 300 pts with deferred intervention after IVUS imaging

- Death/MI/TLR @ (mean) 13 mos = 8% overall (2% death/MI and 6% TLR)
- Death/MI/TLR @ (mean) 13 mos = 4.4% in lesions with MLA >4.0mm^2
- Only independent predictor of death/MI/TLR was IVUS MLA (p=0.0041)
- Independent predictors of TLR were DM (p=0.0493) and IVUS MLA (p=0.0042)

Abizaid et al. Circulation 1999;100:256-61

IVUS Criteria for a 'Significant' Stenosis

- Based on the studies comparing IVUS to flow wire, pressure wire, or SPECT thallium and based on studies with clinical outcome - most feel that a lumen area greater than 4.0mm^2 in a proximal epicardial artery *excluding the Left Main* (and SVGs) is the criterion to defer an intervention

9-month minimum lumen area that predicts 3-year MACE-free survival in patients from TAXUS IV, V, and VI

n=348	BMS	
	C-statistic	Cutoff
Minimum lumen area	0.73	4.0mm^2

n=351	Taxus	
	C-statistic	Cutoff
Minimum lumen area	0.75	4.2mm^2

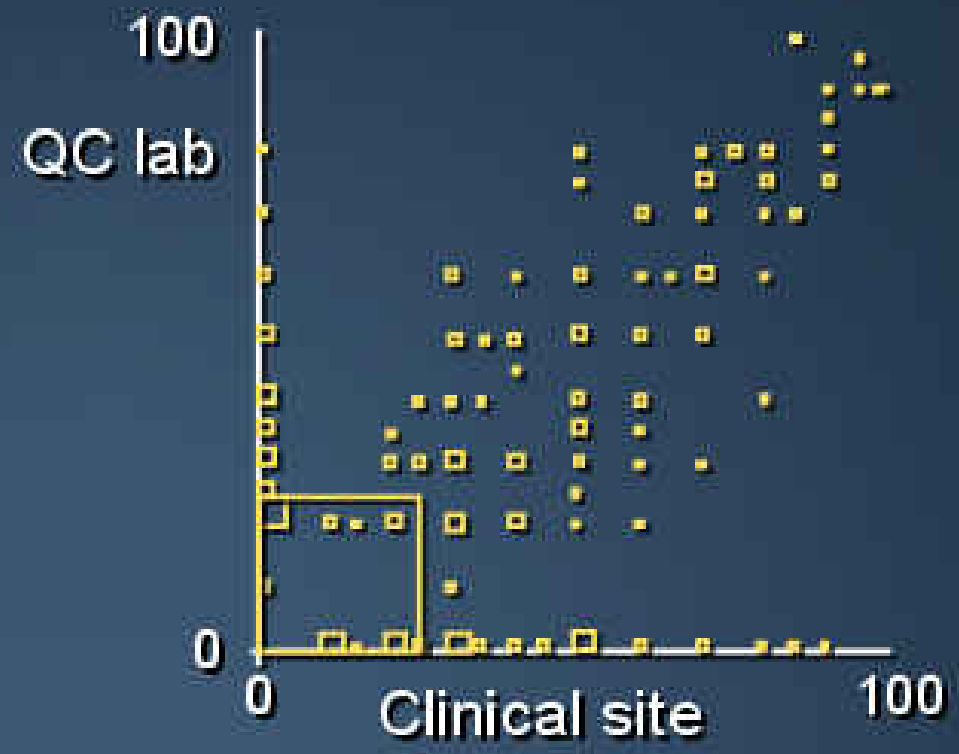
CARDIOVASCULAR RESEARCH FOUNDATION

Doi et al. Circ Cardiovasc Intervent 2008;1:111-8

COLUMBIA UNIVERSITY MEDICAL CENTER

Of all the coronary segments, the LM has the greatest angiographic variability - I

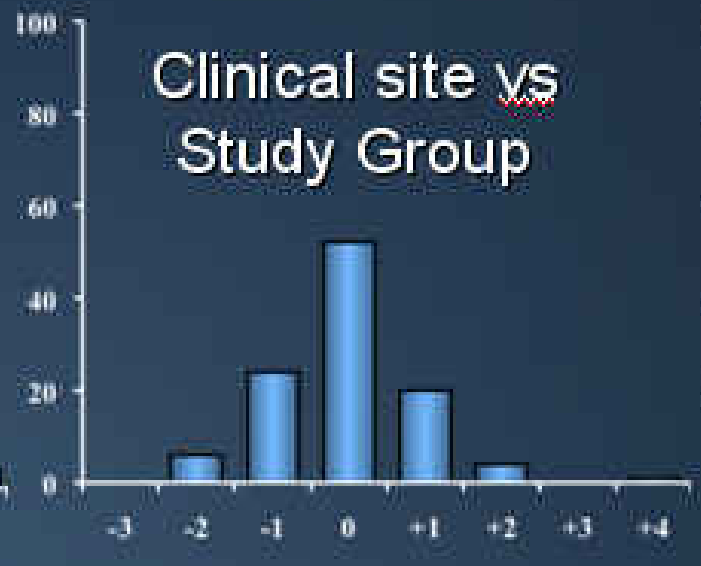
Comparison between percent stenosis assessment from the quality control (QC) lab vs the clinical site in the CASS Study



*area of the square is proportional to the number of cases

Fisher et al. Cathet Cardiovasc Diagn 1982;8:565-75

Of all the coronary segments, the LM has the greatest angiographic variability - II



Five grades of LM severity		# of grades of difference in assessment of LM severity	
1:	0-24% DS	0:	no difference
2:	25-49% DS	+1 or -1:	1 grade difference
3:	50-74% DS	+2 or -2:	2 grades of difference
4:	75-89% DS	+3 or -3:	3 grades of difference
5:	90-100%DS	+4 or -4:	4 grades of difference

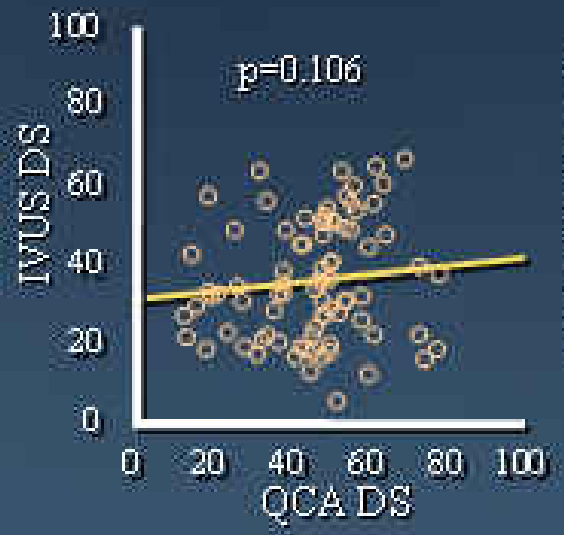
Cameron et al. Circulation 1983;68:484-489

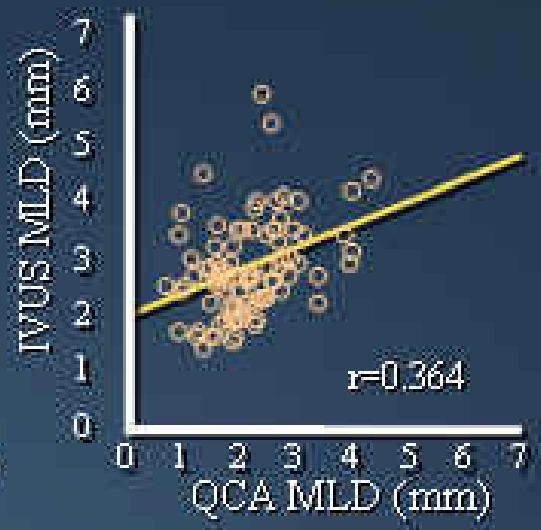
But surely we are better today!

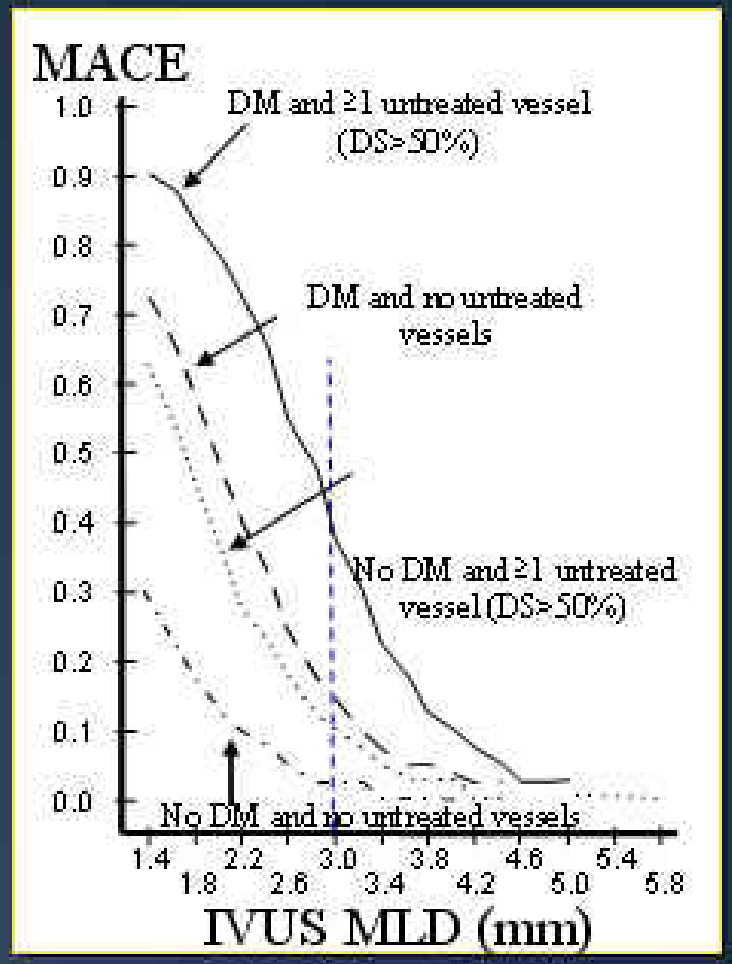
- 51 intermediate or equivocal LM lesions were evaluated by FFR and angiography. Four experienced interventional cardiologists visually classified lesions as 'significant', 'not significant', or 'unsure.'
- The 4 experienced interventional cardiologists achieved correct lesion classification in no more than ~50% of each case regardless of the FFR threshold (≤0.75 or ≤0.80).
- Interobserver variability was large, resulting in unanimous correct lesion classification in only 29%!

Lindstaedt et al. Int J Cardiol 2007;120:254-61

Follow-up of 122 patients with moderate LM disease



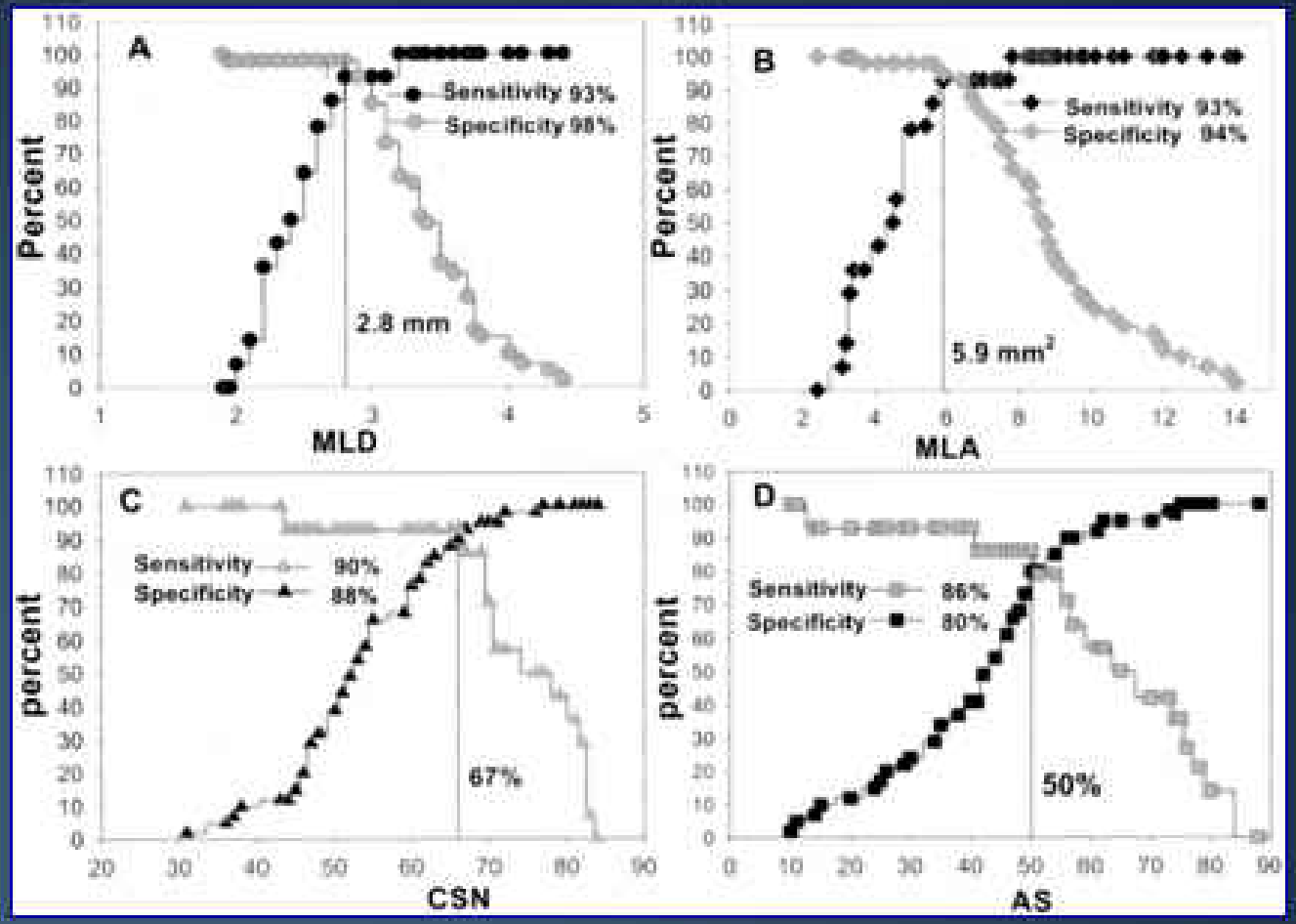




Independent predictors of MACE @11.7 months: DM (p=0.004), untreated lesion >50% (p=0.037), and IVUS MLD (p=0.005) – but NOT the plaque burden.

Abizaid et al. J Am Coll Cardiol 1999;34:707-15

IVUS determinants of LMCA FFR <0.75

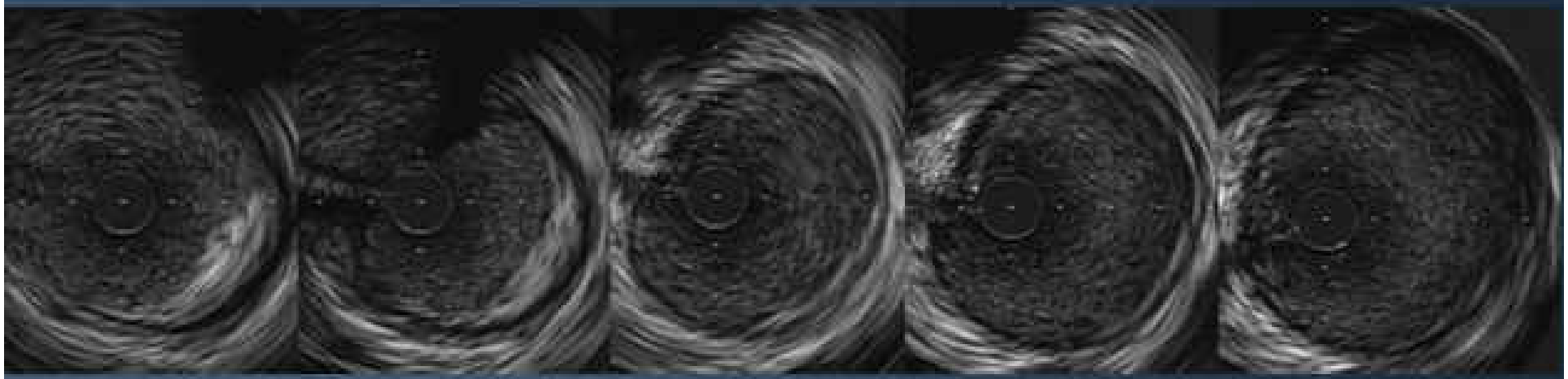


Jasti et al. Circulation 2004;110:2831-6

IVUS assessment of LM disease significance is based on lumen dimensions, not plaque burden

Plaque burden (P&M/EEM) = 68%
MLA=7.2mm^2

Which of these LMCA lesions is significant and, therefore, should be treated? And which is not??



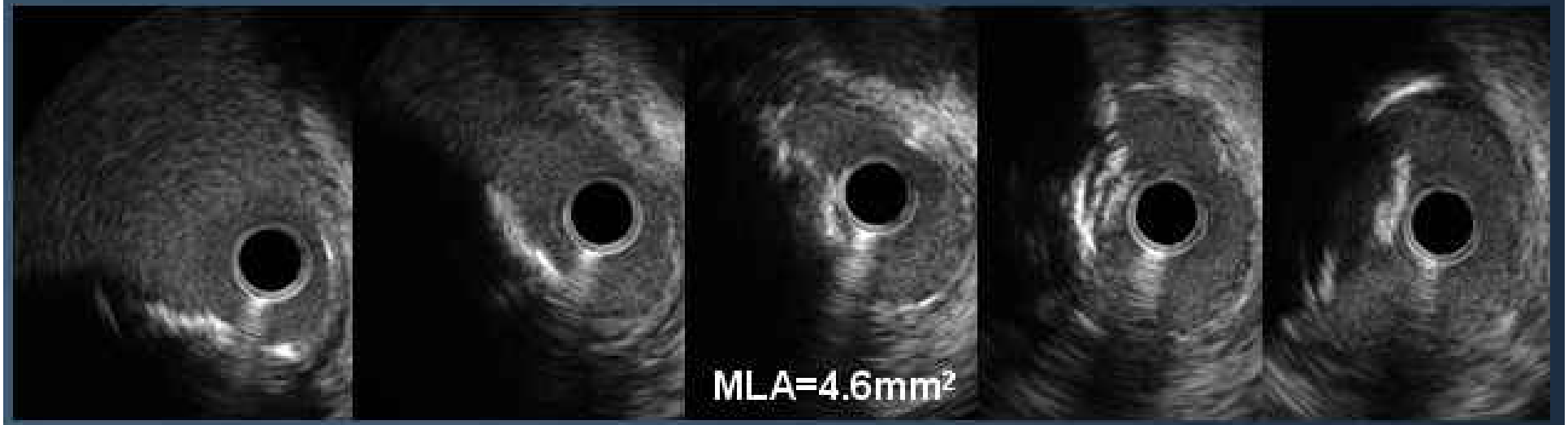
CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER

0 → 3.0 → 9.0mm

CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER



0 → 2.0 → 5.0mm

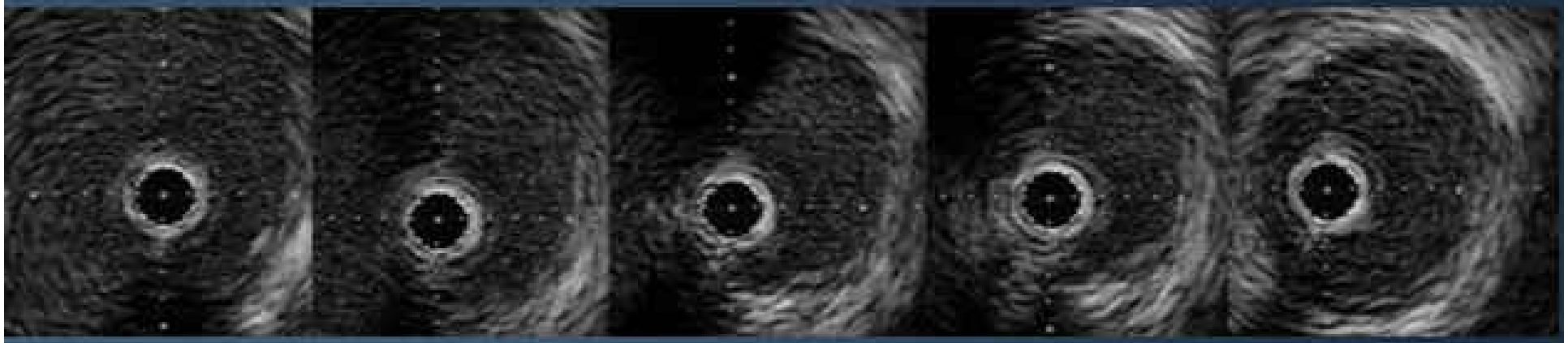
CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER

0 → 2.0 → 8.0mm

CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER



0 → 1.0 → 4.0mm

IVUS Criteria for a 'Significant' LMCA Stenosis

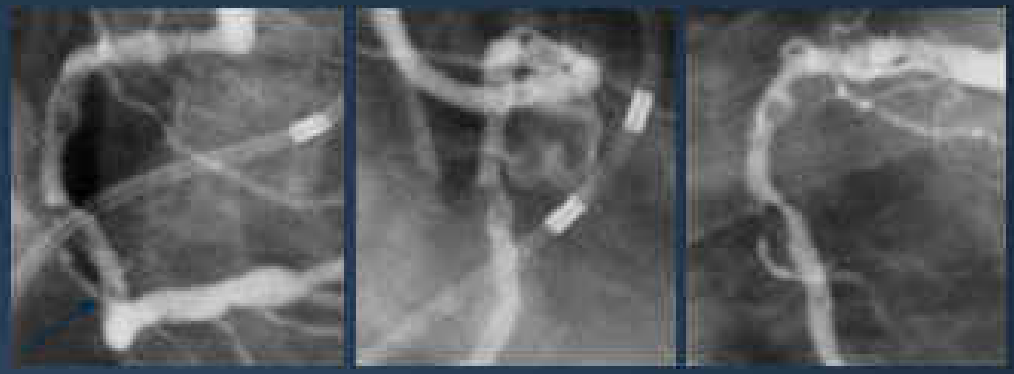
- Most IVUS LMCA studies show either insignificant disease or critical disease
- Absolute lumen CSA <6.0mm^2 (or MLD <3.0mm) is the suggested criterion for a significant LMCA stenosis
  - Correlates with a LMCA FFR<0.75
  - Murray's Law ($_{LMCA}r^3 = {}_{LAD}r^3 + {}_{LCX}r^3$)
  - Does not depend on finding a disease-free reference segment
- It is not clear whether the same criteria should be used for ostial LM lesions as for mid-shaft/distal bifurcation lesions and for positively vs negatively remodeled lesions

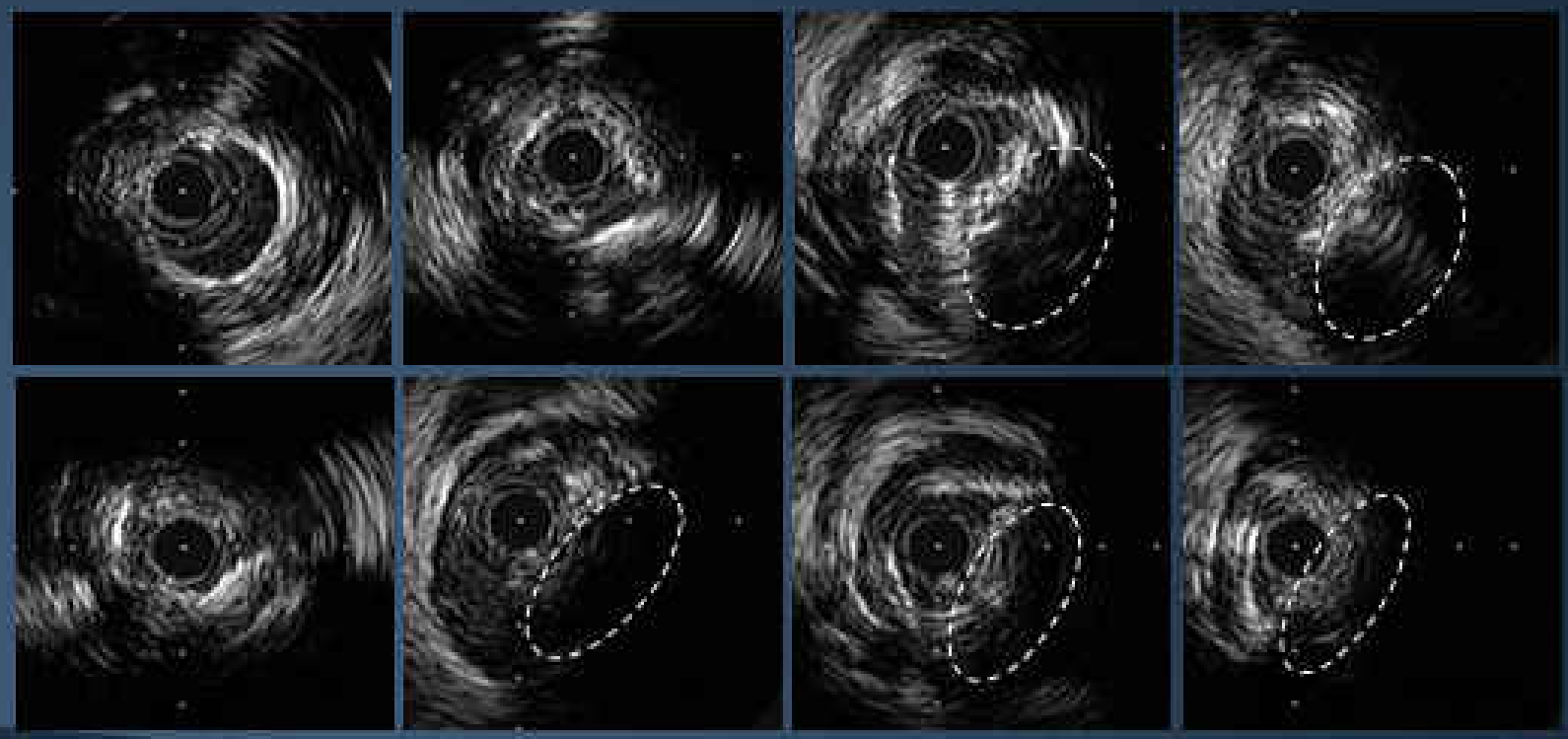
Unusual Lesions

- Filling Defects
- Aneurysms
- Acute Coronary Syndromes
- Spontaneous Dissections
- Hazy Lesions

CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER

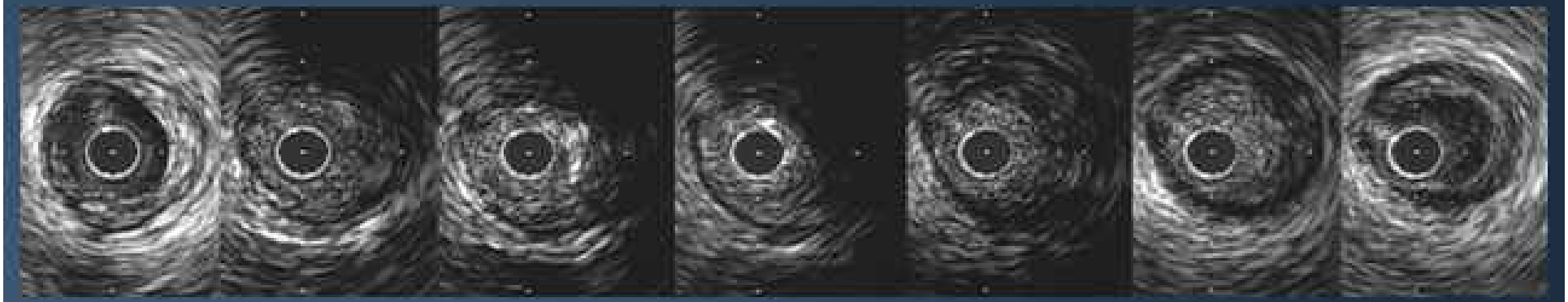




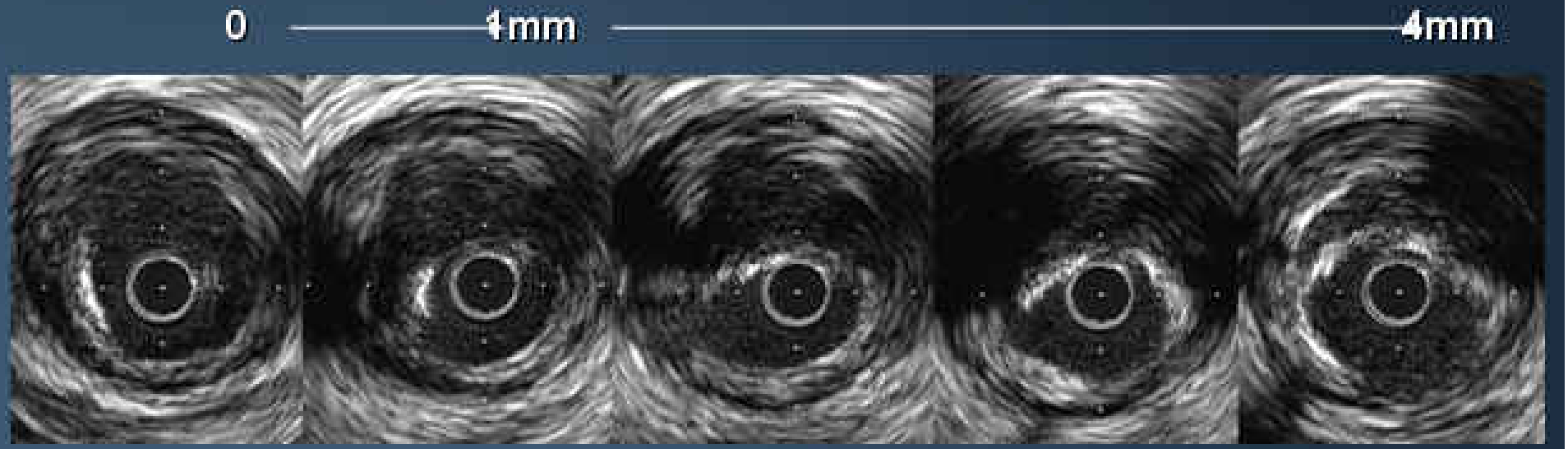
CARDIOVASCULAR RESEARCH FOUNDATION

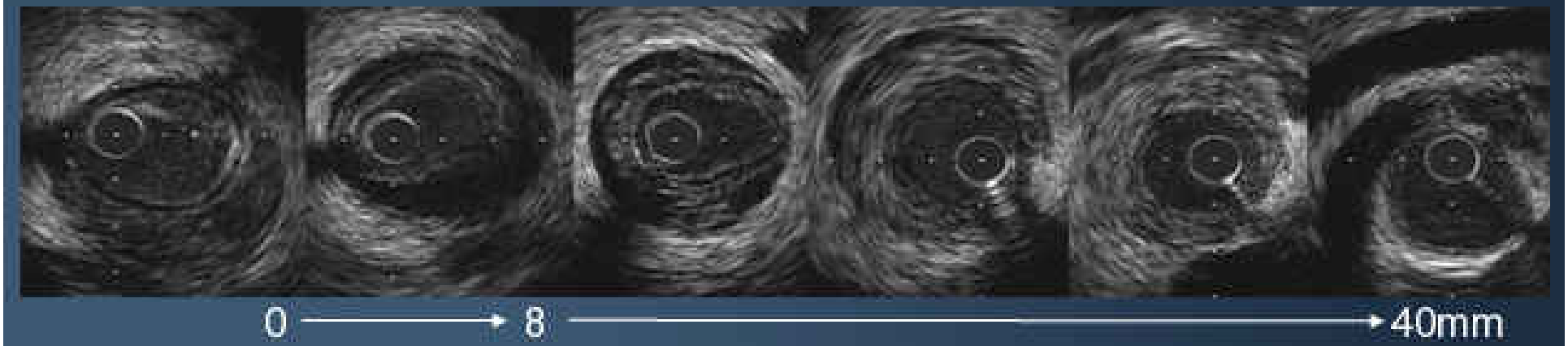
COLUMBIA UNIVERSITY MEDICAL CENTER

Attenuated Plaque



0 → 1.5 → 9.0mm


0
1mm
4mm


0
8
40mm

IVUS Classification of Angiographic Aneurysms

- Of 77 angiographic aneurysms
  - 21 (27%) true aneurysm
  - 3 (4%) pseudoaneurysm
  - 12 (16%) complex plaques or unhealed dissections
  - 41 (53%) normal segment adjacent to one or more stenoses

	True Aneurysm	PSA	Complex Plaque	Normal Site with Adjacent Stenoses
No prior PCI	10	0	6	26
Prior PCI	11	3	6	15

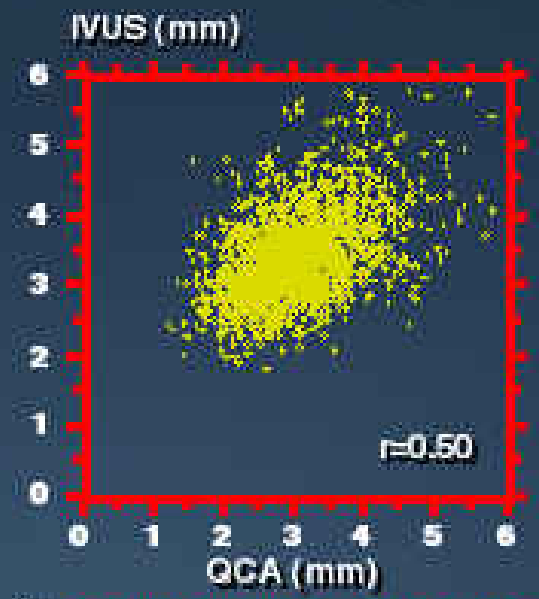
(Maehara et al Am J Cardiol 2001;88:365-70)

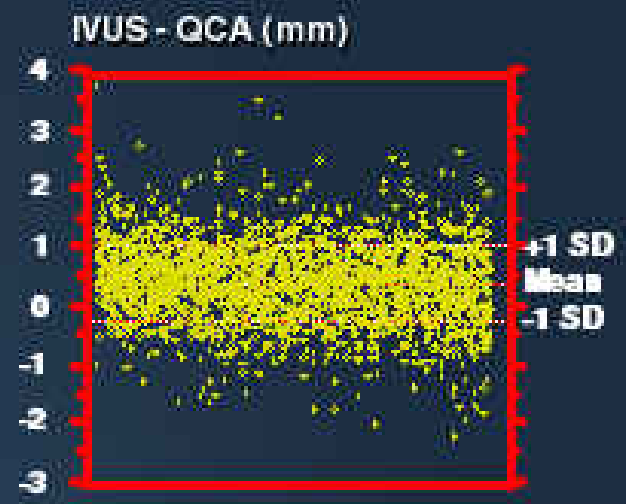
Pre-, Inter-, and Post-Procedure IVUS

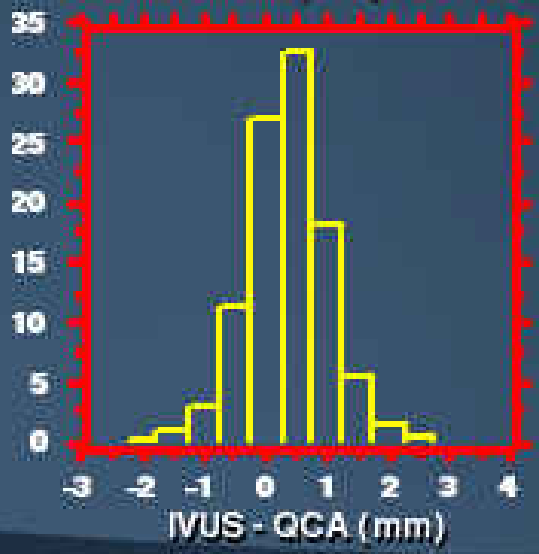
- Pre-intervention
  - Measure vessel size and lesion length to select DES size and length
  - Assess unusual lesion morphology
- Post-intervention
  - Expansion*: Absolute stent CSA or stent CSA relative to a pre-defined reference or target area/diameter
  - Apposition*: Contact between stent and vessel wall
  - Full lesion coverage
  - Complications

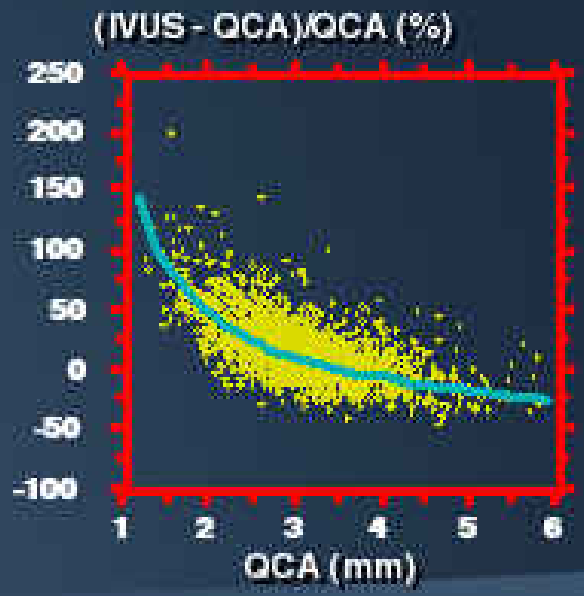
*While expansion and apposition can co-exist, they not the same. The prognostic implications are different, and the solutions are different. These terms should NOT be used interchangeably

IVUS vs QCA measurements of reference lumen dimensions (3311 nonostial lesions)

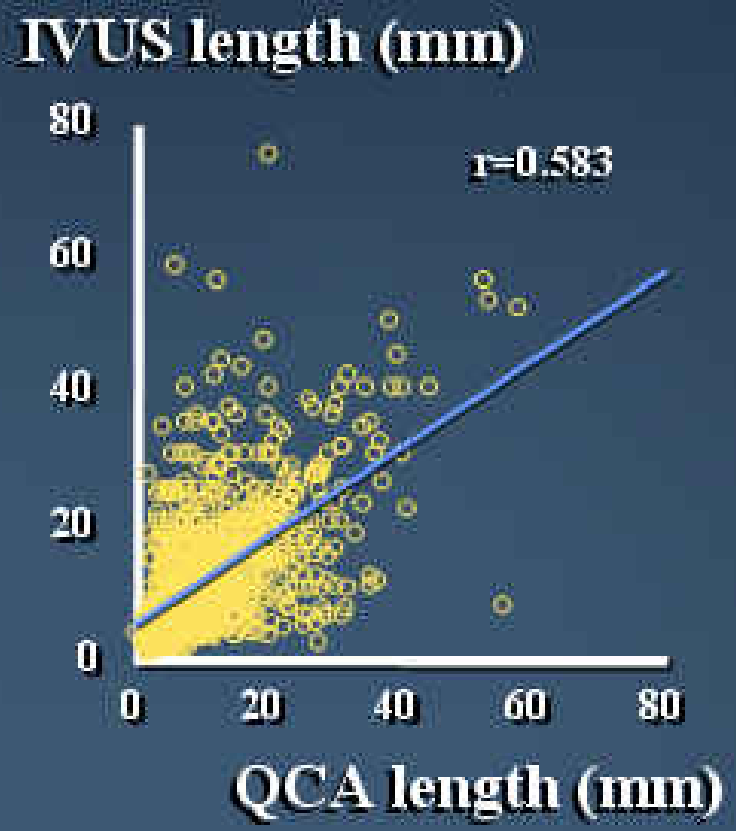


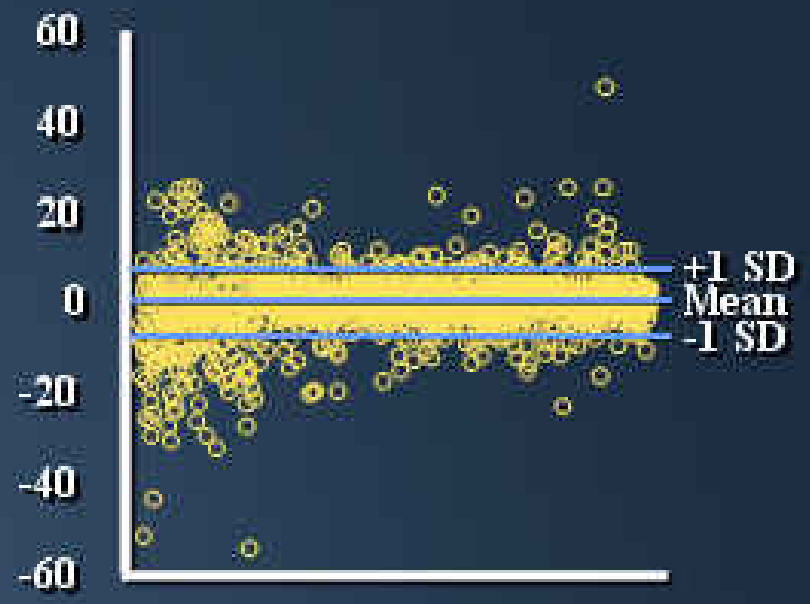




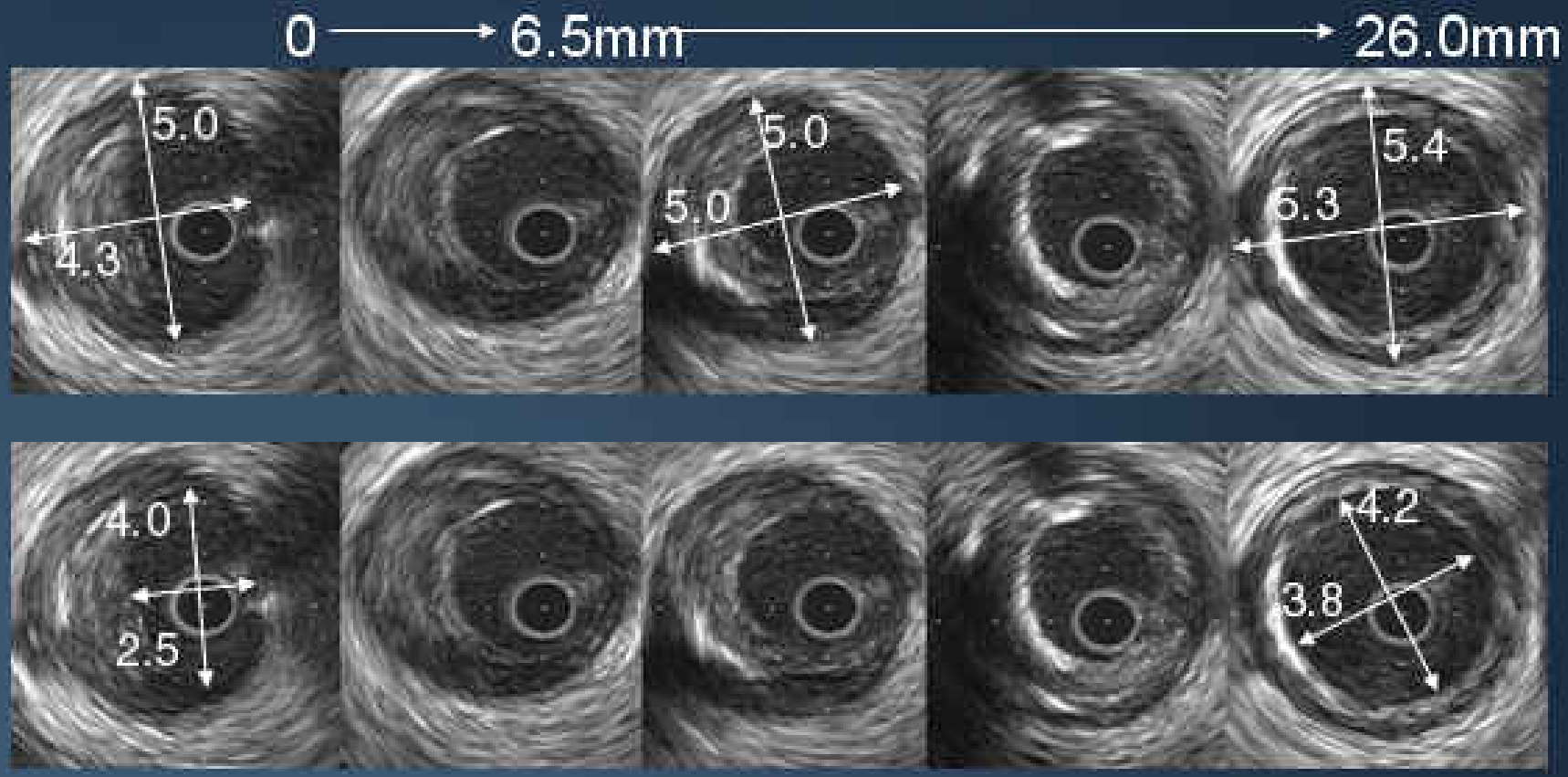


IVUS vs QCA measurement of lesion length





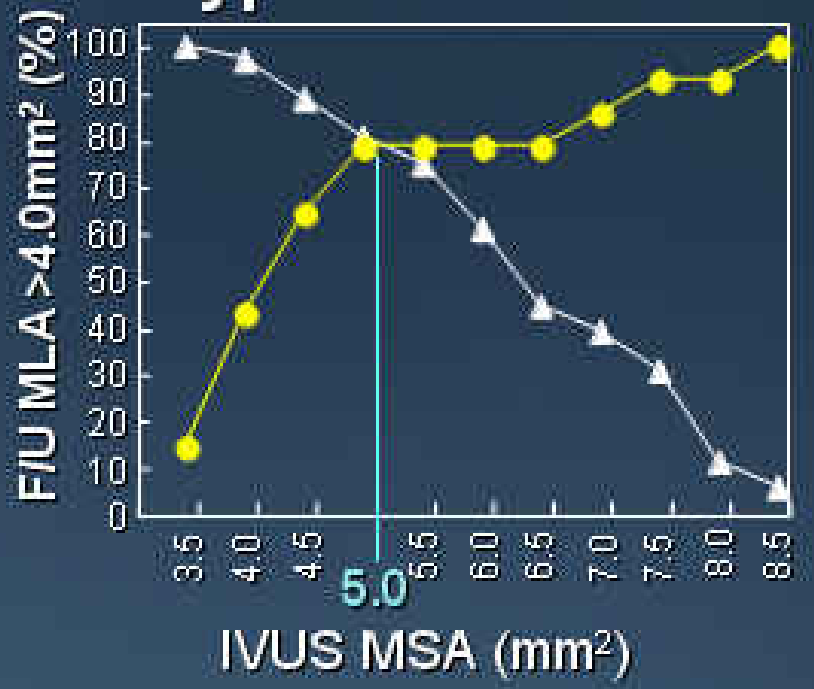
IVUS-QCA length=
0.6± 7.2mm


0
6.5mm
26.0mm
5.0
4.3
5.0
5.0
5.4
5.3
4.0
2.5
4.2
3.8

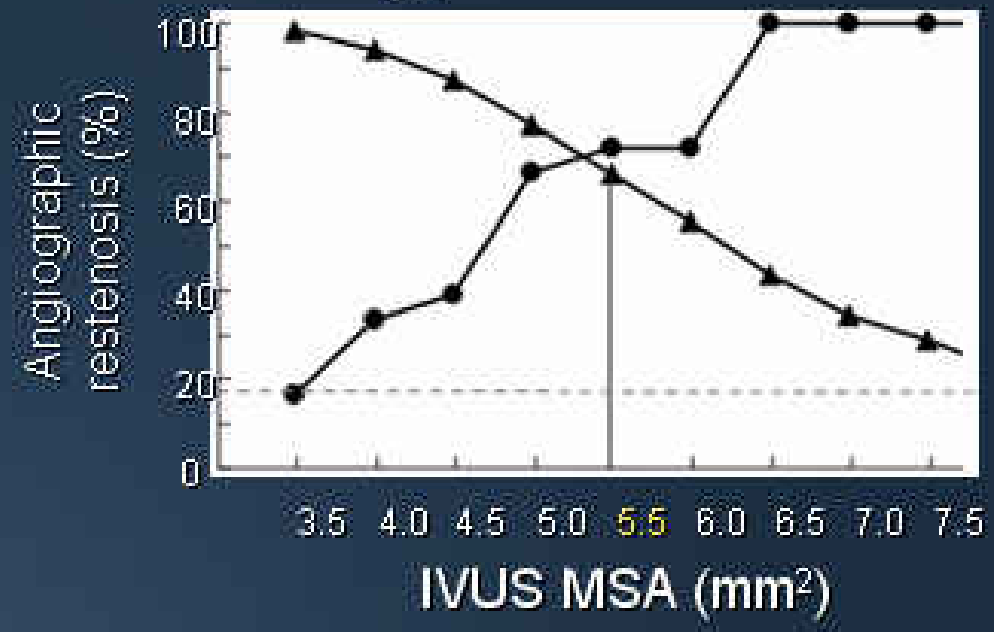
Predictors of DES

	DES Thrombosis	DES Restenosis
Underexpansion	•*Fujii et al. J Am Coll Cardiol 2005;45:995-8)* •*Okabe et al., Am J Cardiol. 2007;100:615-20* •*Liu et al., JACC Cardiovasc Interv. 2009;2:428-34*	•*Sonoda et al. J Am Coll Cardiol 2004;43:1959-63* •*Hong et al. Eur Heart J 2006;27:1305-10* •*Doi et al, JACC Cardiovasc Interv, in press* •*Fujii et al. Circulation 2004;109:1085-1088*
Edge problems (geographic miss, secondary lesions, large plaque burden, etc)	•*Fujii et al. J Am Coll Cardiol 2005;45:995-8)* •*Okabe et al., Am J Cardiol. 2007;100:615-20*	•*Sakurai et al. Am J Cardiol 2005;96:1251* •*Liu et al, Am J Cardiol. 2009;103:501-6* •*Costa et al, Am J Cardiol, 2008;101:1704-11*

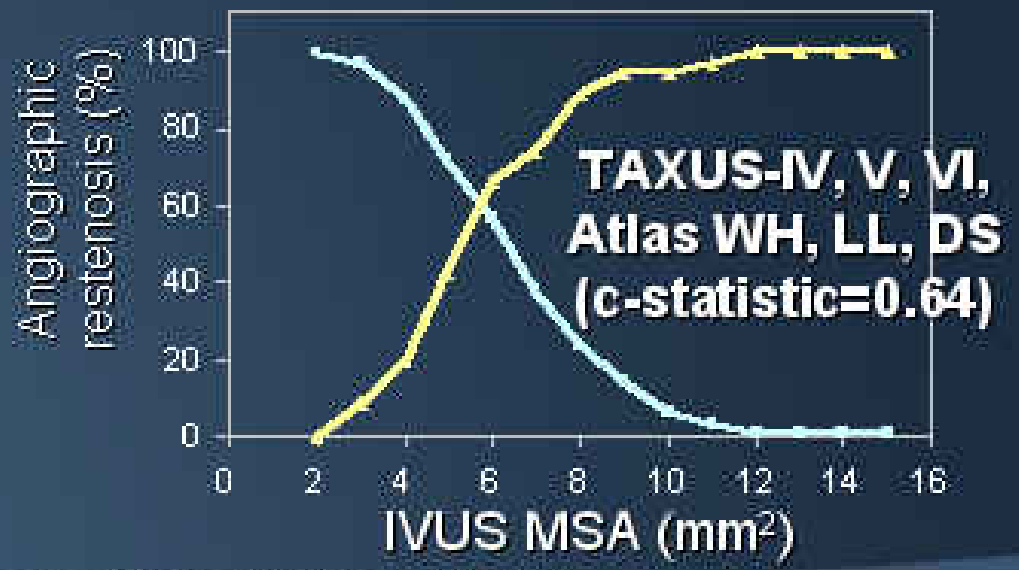
Cypher in SIRIUS



Cypher at AMC



By definition, sensitivity/specificity curve analysis "must" identify a single MSA that best separates restenosis from no restenosis.

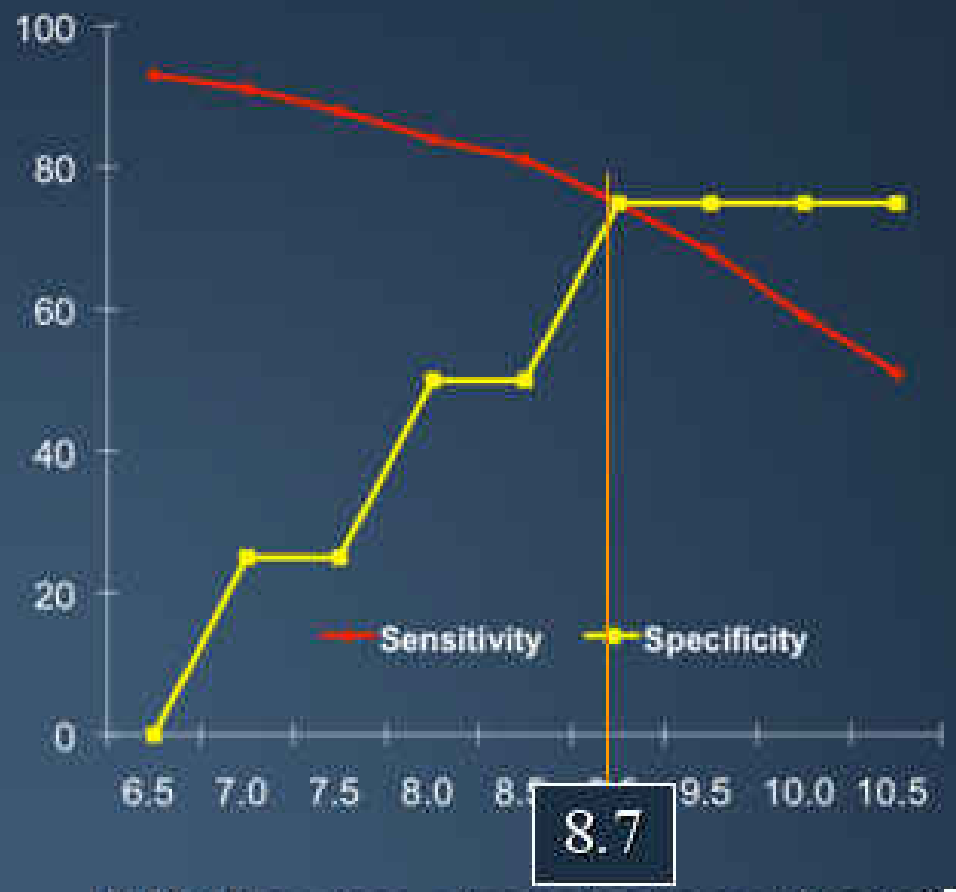


(Sonoda et al. J Am Coll Cardiol 2004;43:1959-63)
(Hong et al. Eur Heart J 2006;27:1305-10)
(Doi et al. JACC Cardivasc Interv, in press)

CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER

"Optimal" MSA and TLR after LMCA DES Implantation (n=595)

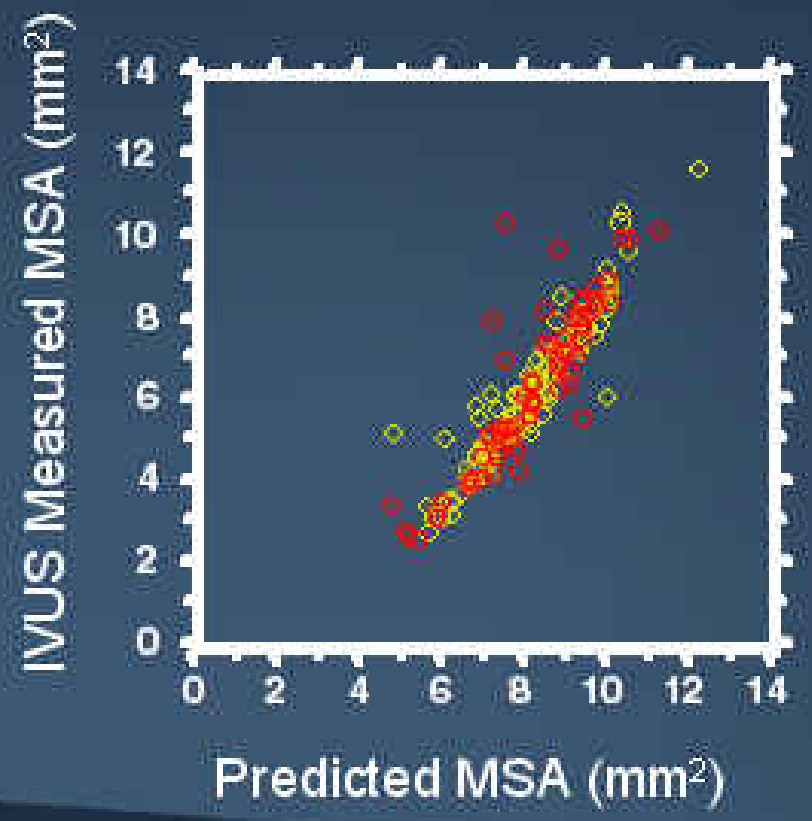


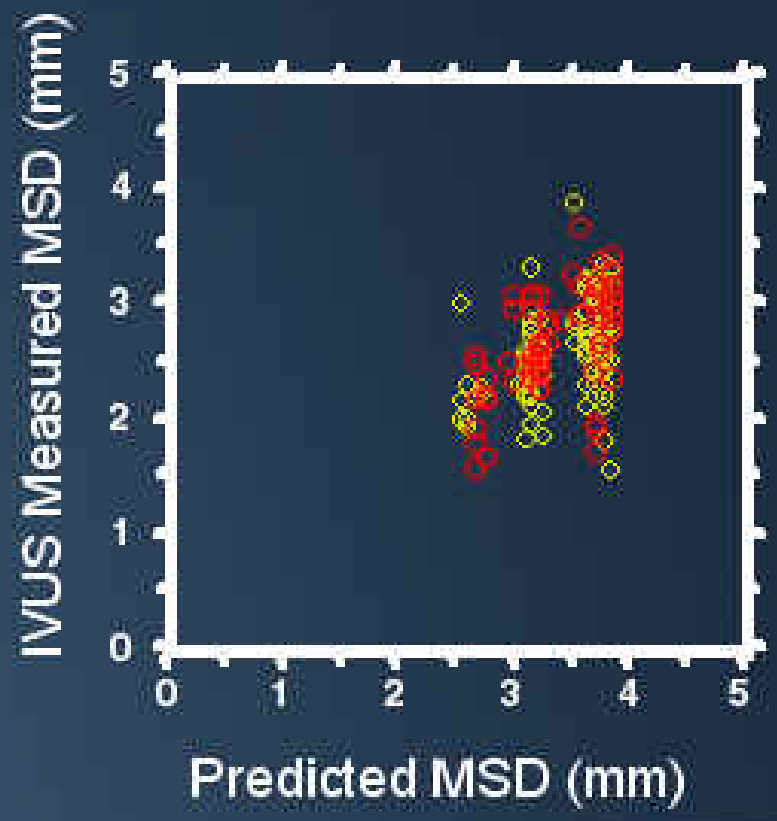
Minimum stent area (mm^2)

(SJ Park et al. TCT 2007)

Manufacturer's Compliance Charts Cannot Be Used to Guarantee Adequate Stent Expansion

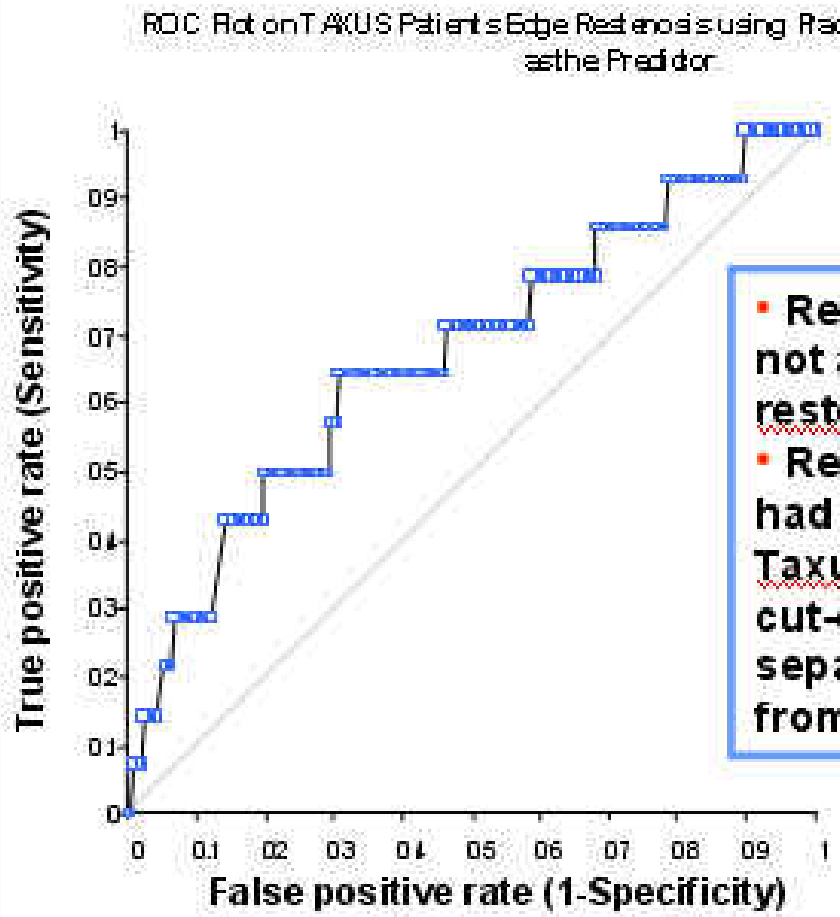
Comparison of IVUS-measured minimum stent diameter (MSD) and minimum stent area (MSA) with the predicted measurements from Cordis (Cypher in yellow, n=133) and BSC (Taxus in red, n=67). DES achieve an average of only 75% of the predicted MSD (66% of MSA)





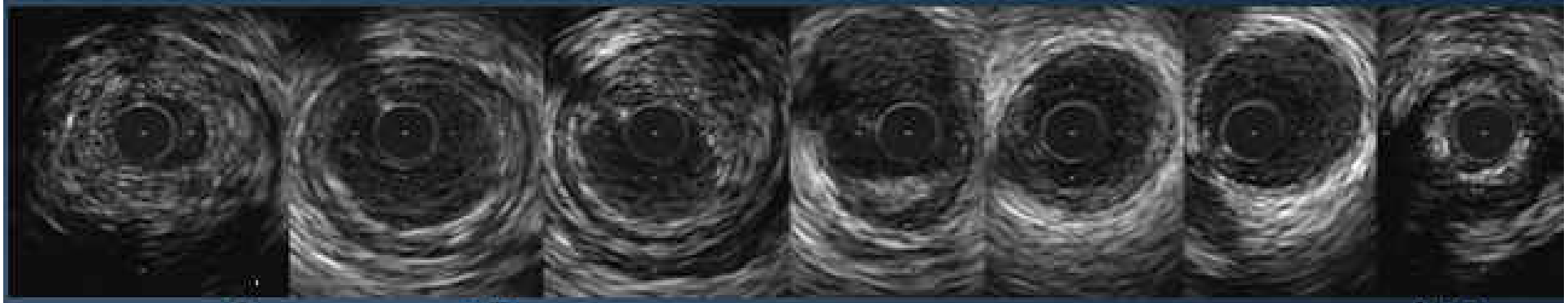
(de Rebamar Costa et al, Am Heart J 2007;153:297-303)

Comparison of 9-month QCA edge restenosis vs reference lumen area and plaque burden in TAXUS-IV, V, and VI (n=810)

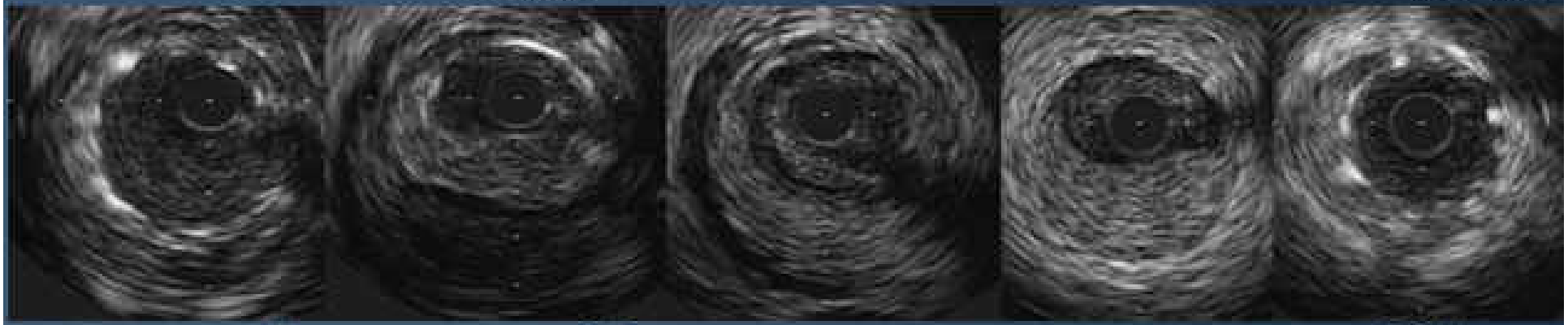


- Reference lumen area did not affect Taxus edge restenosis (c=0.55)
- Reference plaque burden had a moderate effect on Taxus edge restenosis; a cut-off of 42% best separated edge restenosis from no restenosis (c=0.67)

(Liu et al, Am J Cardiol 2009;103:501-6)



0 → 7.5mm → 45.0mm

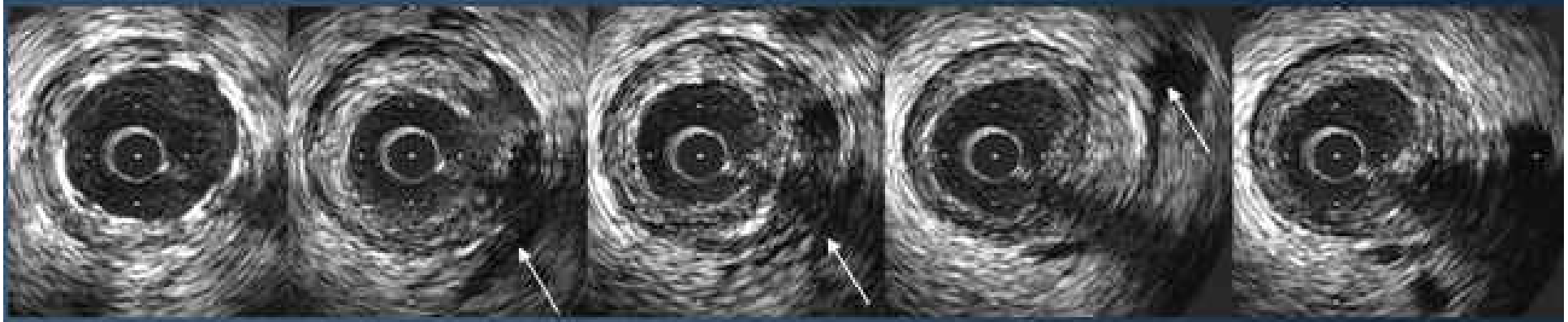


0 → 8.0mm → 32.0mm

CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER

Perforation



0 → 1.5mm → 6.0mm