The Optimal Use of IVUS Guidance in the Era of DES

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Diagnostic and Pre-intervention IVUS

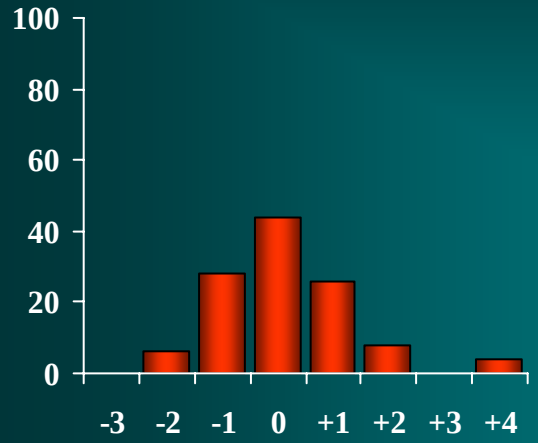
- Assess lesion severity
- Weigh potential problems (i.e. LM disease, significant proximal or distal disease)
- Assess unusual lesion morphology
- When the angiogram, non-invasive tests, and clinical symptoms do not agree
- Assess vessel size and lesion length

IVUS Criteria for a 'Significant' Stenosis

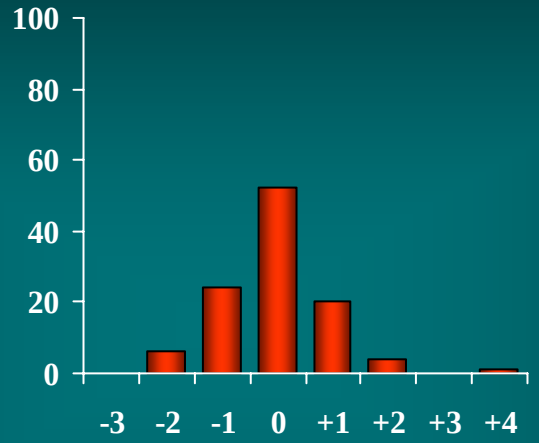
- **Based on the studies comparing IVUS to flow wire, pressure wire, or SPECT thallium and based on studies with clinical outcome - most feel that a lumen area less than 4.0 mm^2 in a proximal epicardial artery *excluding the Left Main* is a flow limiting stenosis**

As shown in the CASS study, LM lesions are associated with the greatest inter and intraobserver variability of any angiographic segment

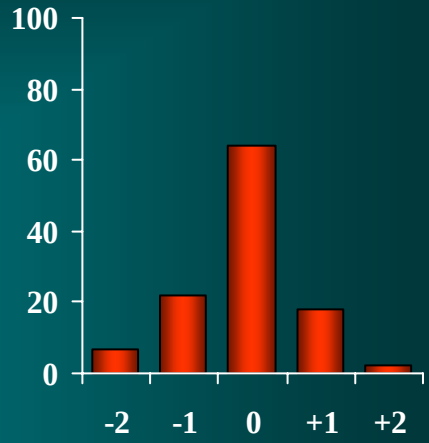
Clinical site vs Quality control



Clinical site vs Study Group



Study Group vs Quality control



Five grades of LM severity

1:	0-24% DS
2:	25-49% DS
3:	50-74% DS
4:	75-89% DS
5:	90-100%DS

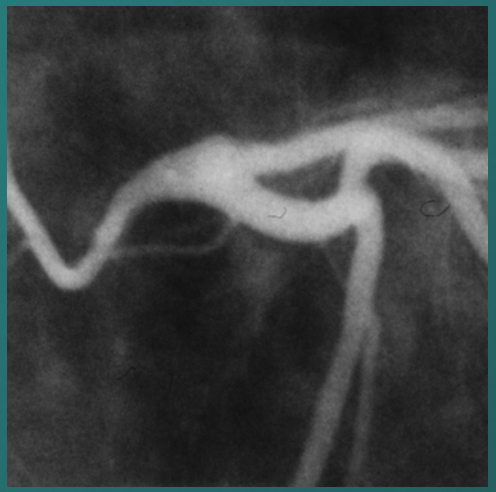
# of grades of difference in assessment of LM severity

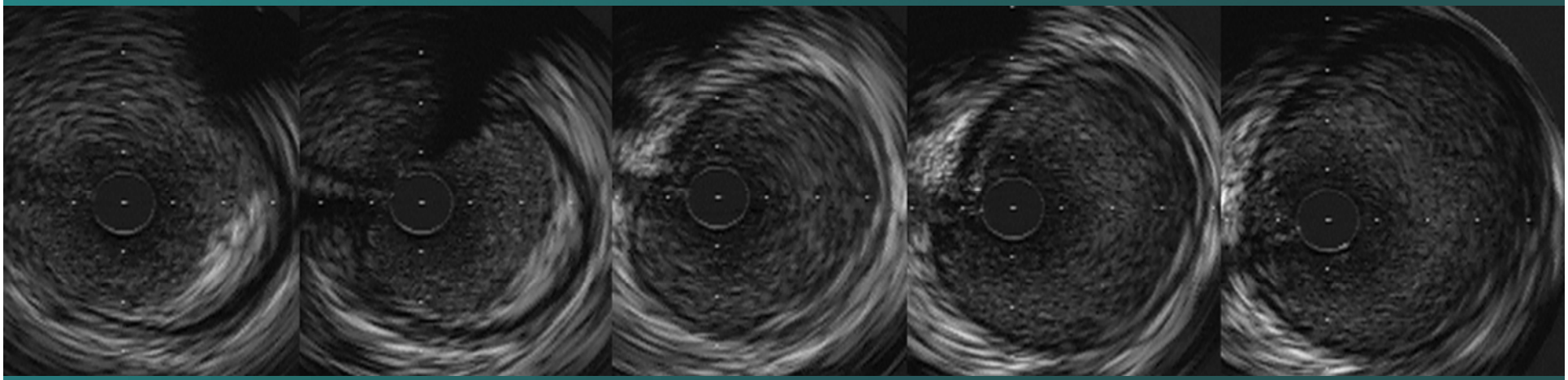
0:	no difference
+1 or -1:	1 grade difference
+2 or -2:	2 grades of difference
+3 or -3:	3 grades of difference
+4 or -4:	4 grades of difference

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

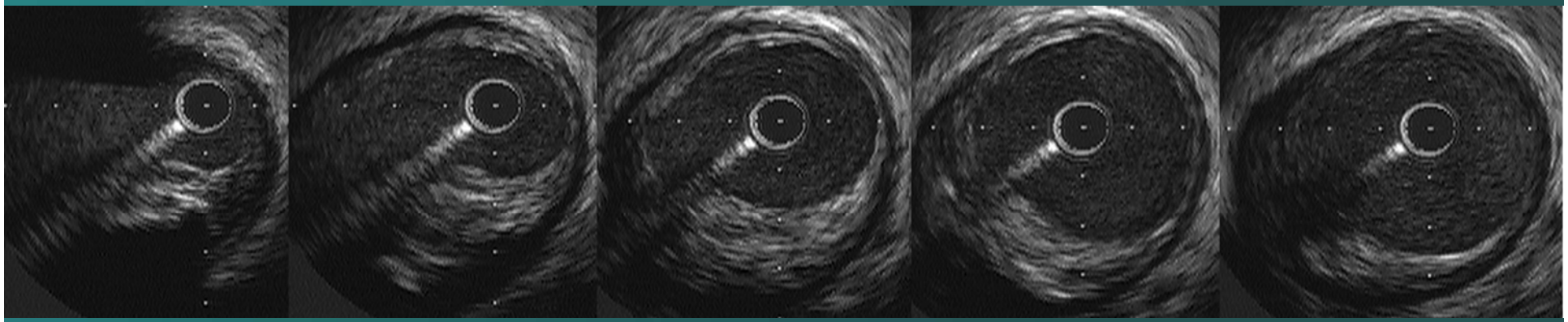
Suggested IVUS Criteria for a 'Significant' LMCA Stenosis

- Most IVUS LMCA studies show either insignificant disease or critical disease, only a minority require careful quantification
- Lumen CSA <6.0mm^2 or MLD <3.0mm are suggested criteria for a significant LMCA stenosis
  - The sum of the lumen areas of the two daughter vessels (LAD and LCX, each of which should be 4.0mm^2) = 150% of the parent (LM)
  - These correlated with an abnormal FFR.





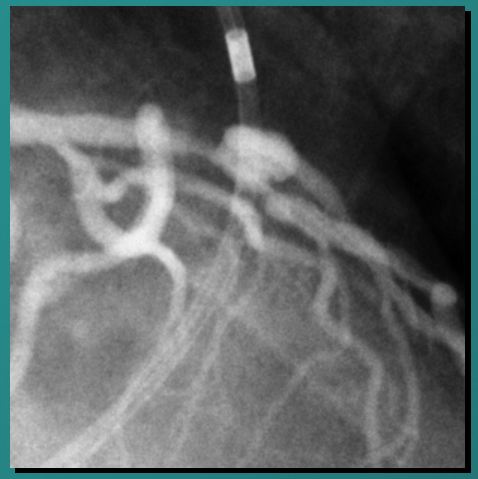
0 → 1.5 → 6.0mm

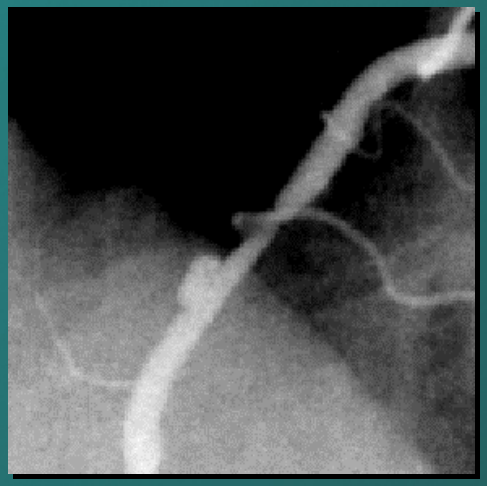


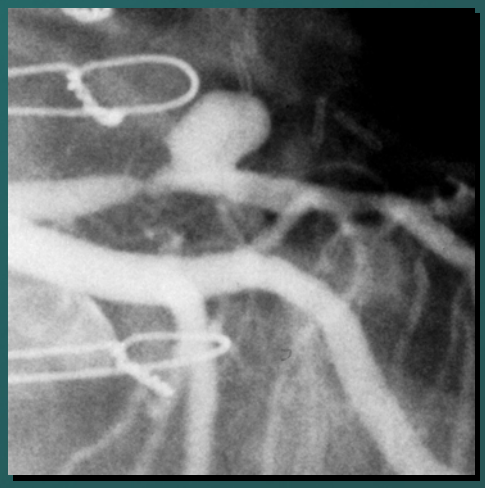
0 → 2.0 → 8.0mm

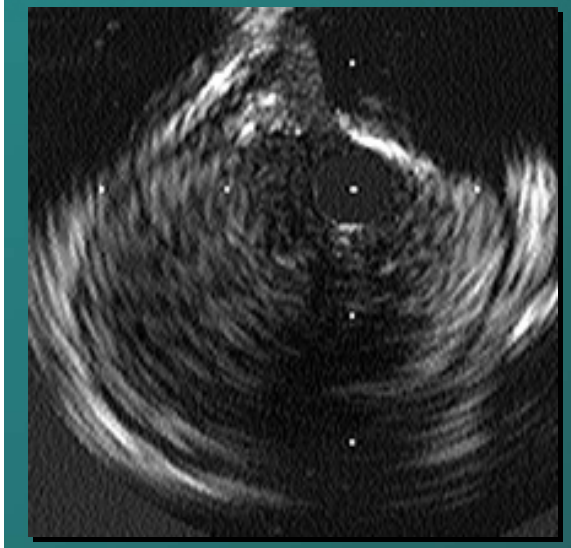
Unusual Lesion Morphology

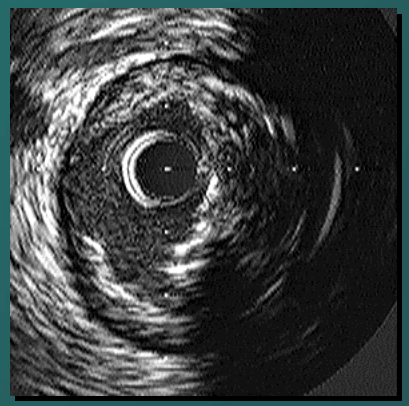
- Angiographic aneurysms
  - True aneurysms
  - Pseudoaneurysms
  - Complex/ruptured plaques
  - Normal segments adjacent to one or more stenoses
- Angiographic filling defects
  - Thrombi
  - Calcified nodules
- Acute coronary syndromes
- Spontaneous dissections
- Angiographic hazy lesions

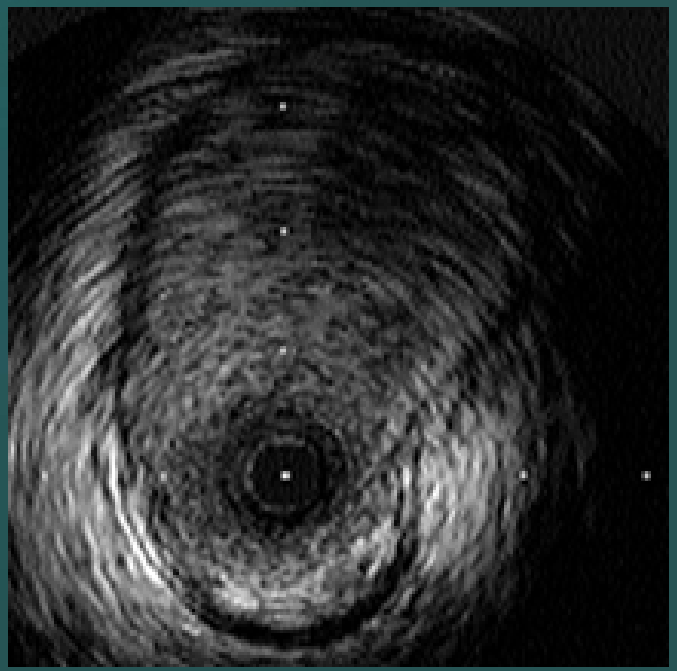


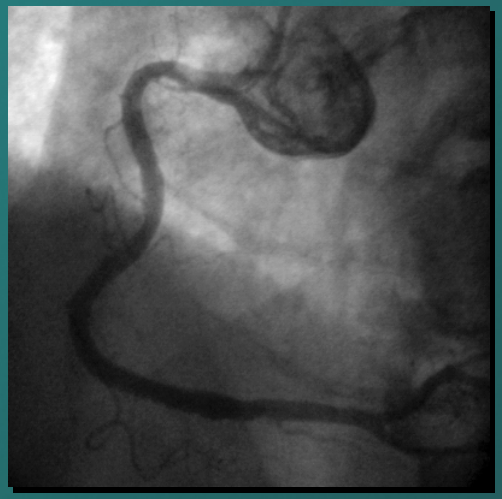


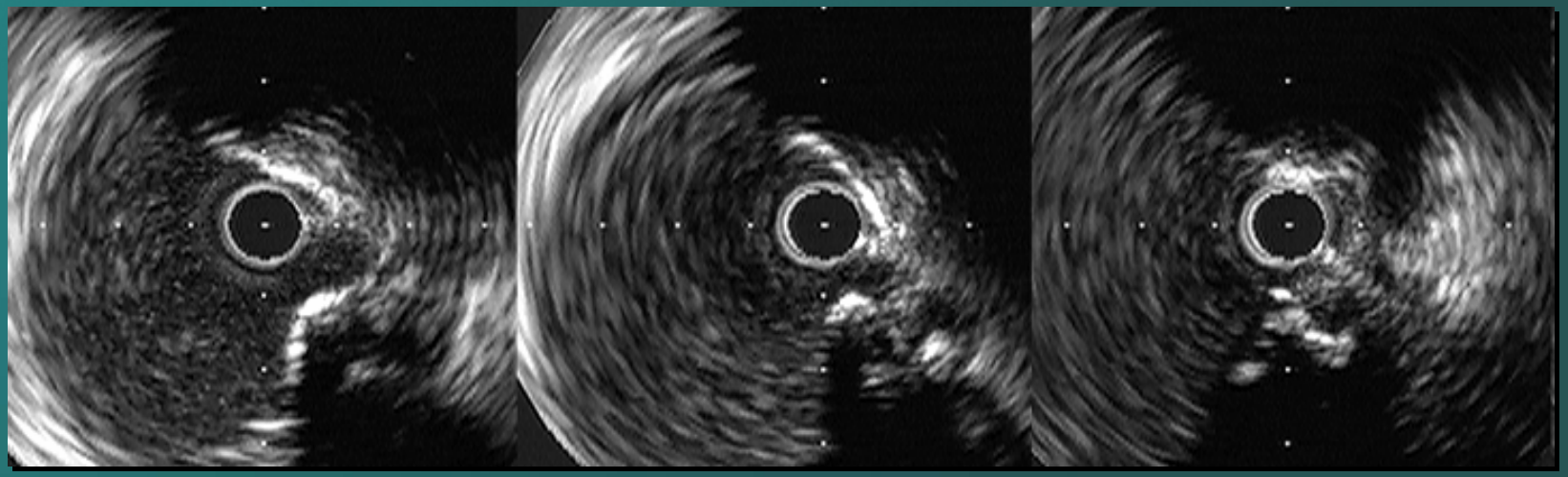




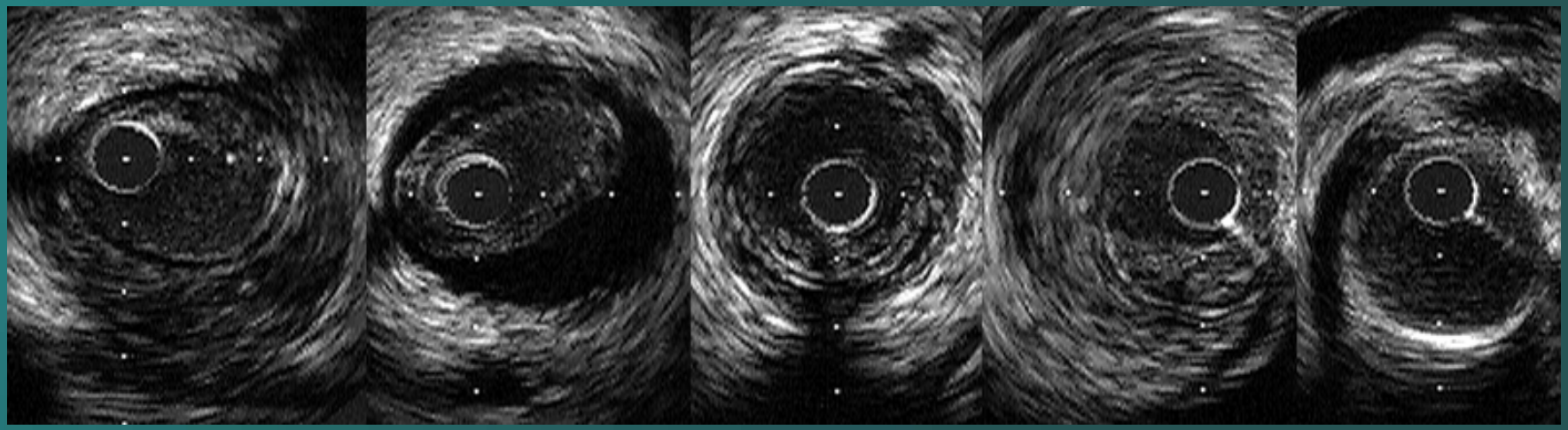








0 → 1.5 → 3.0mm

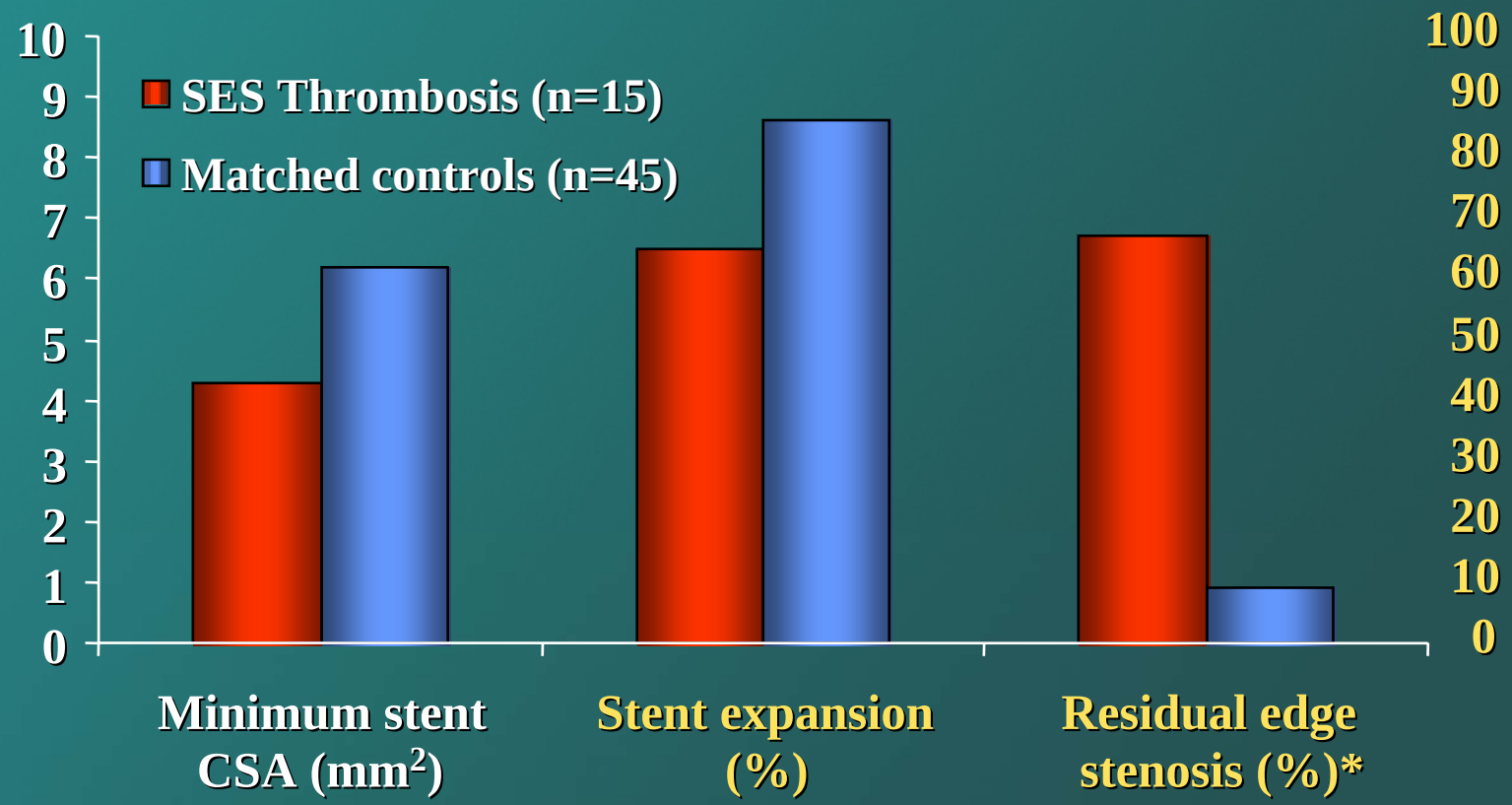


0 → 10 → 40mm

How does one use IVUS during drug-eluting stent implantation?

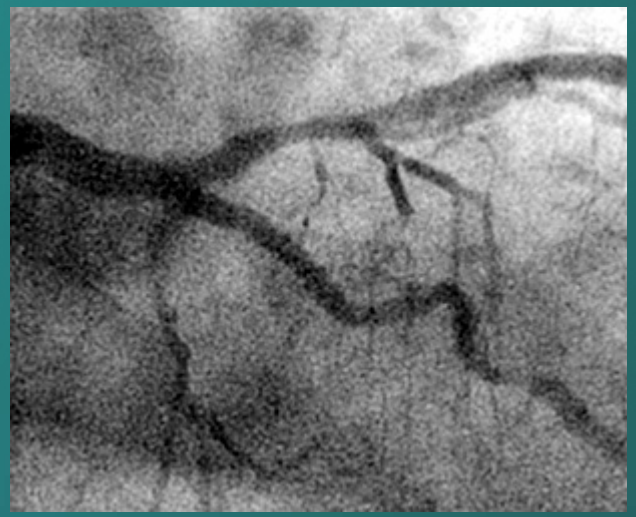
- Using pre-intervention IVUS, identify the proximal and distal reference segments
  - Largest lumen with least plaque
- Measure the reference segments to select stent size
- Measure distance between least diseased proximal and distal reference sites to select stent length (must use motorized pullback device to do this)
- After deploying stent, perform IVUS imaging to assess
  - Final stent CSA by IVUS (expansion)
  - Apposition
  - Lesion coverage
  - Complications
- Determine whether additional “work” is required to optimize stent dimensions, completely cover the lesion, or treat complications

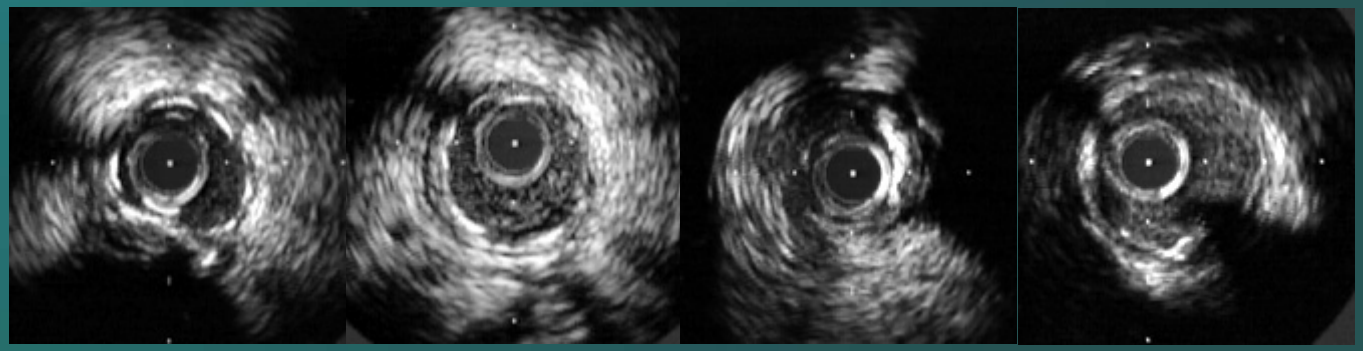
Predictors of Cypher Thrombosis @ CRF



- 2,575 patients were treated with 4,722 Cypher stents.
- 21 (0.8%) had stent thrombosis of whom 15 had IVUS
- 12/15 SES thrombosis lesions has stent CSA <5.0mm^2 (vs 13/45 controls)

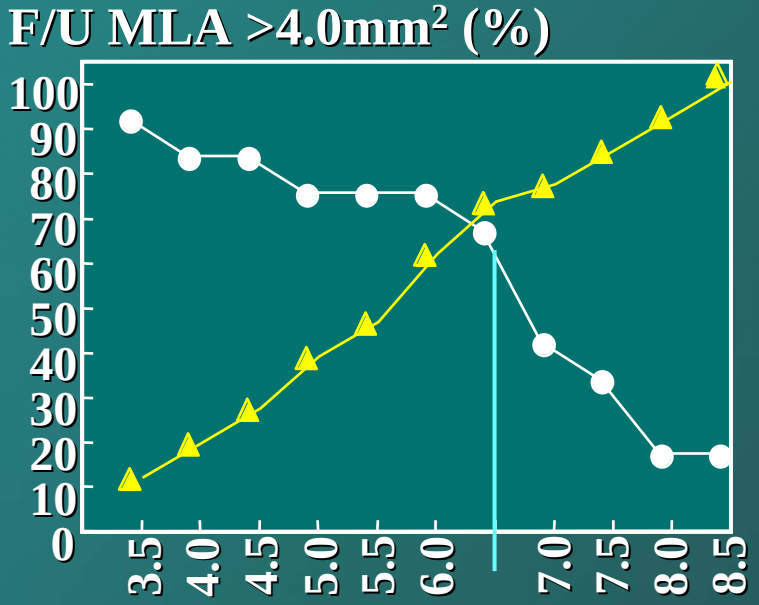
*Residual edge stenosis = edge lumen CSA <4.0mm^2 & plaque burden >70%.





Although the smallest acceptable DES MSA is less than with bare metal stents, the 90% predictive value means that most cases of DES failure will be stent underespansion

Bare Metal Stents

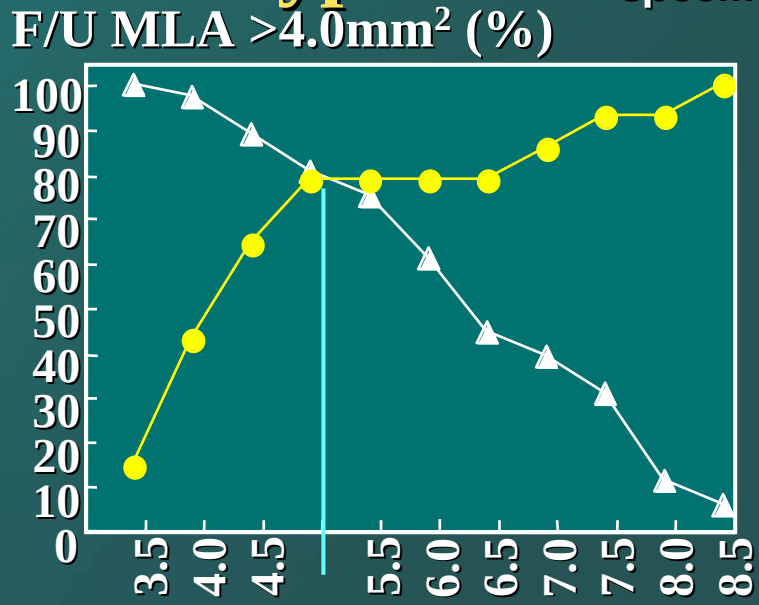


6.5*

Minimum stent area (mm^2)

*predictive value=56%

Cypher



5.0**

Minimum stent area (mm^2)

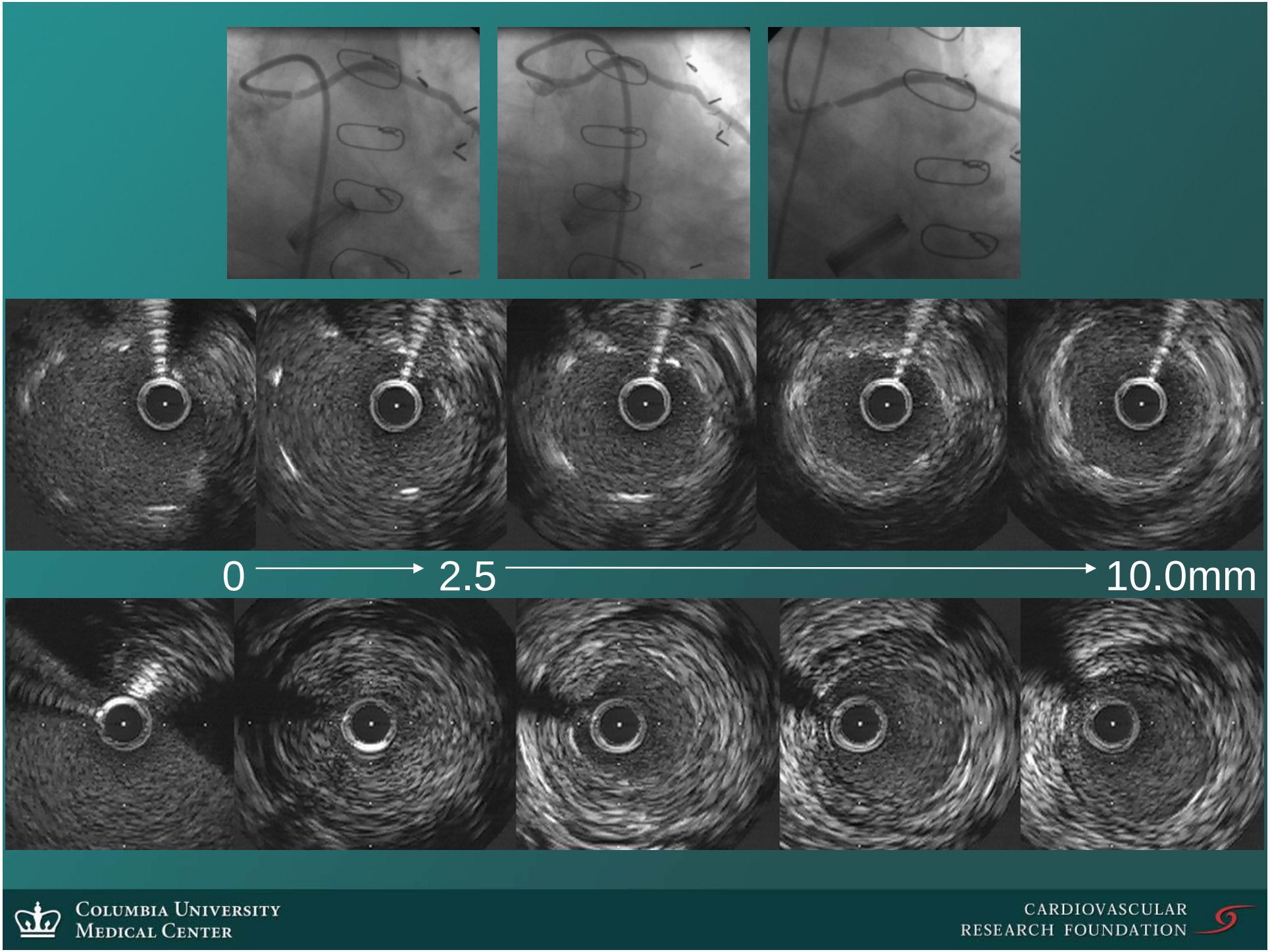
**predictive value=90%

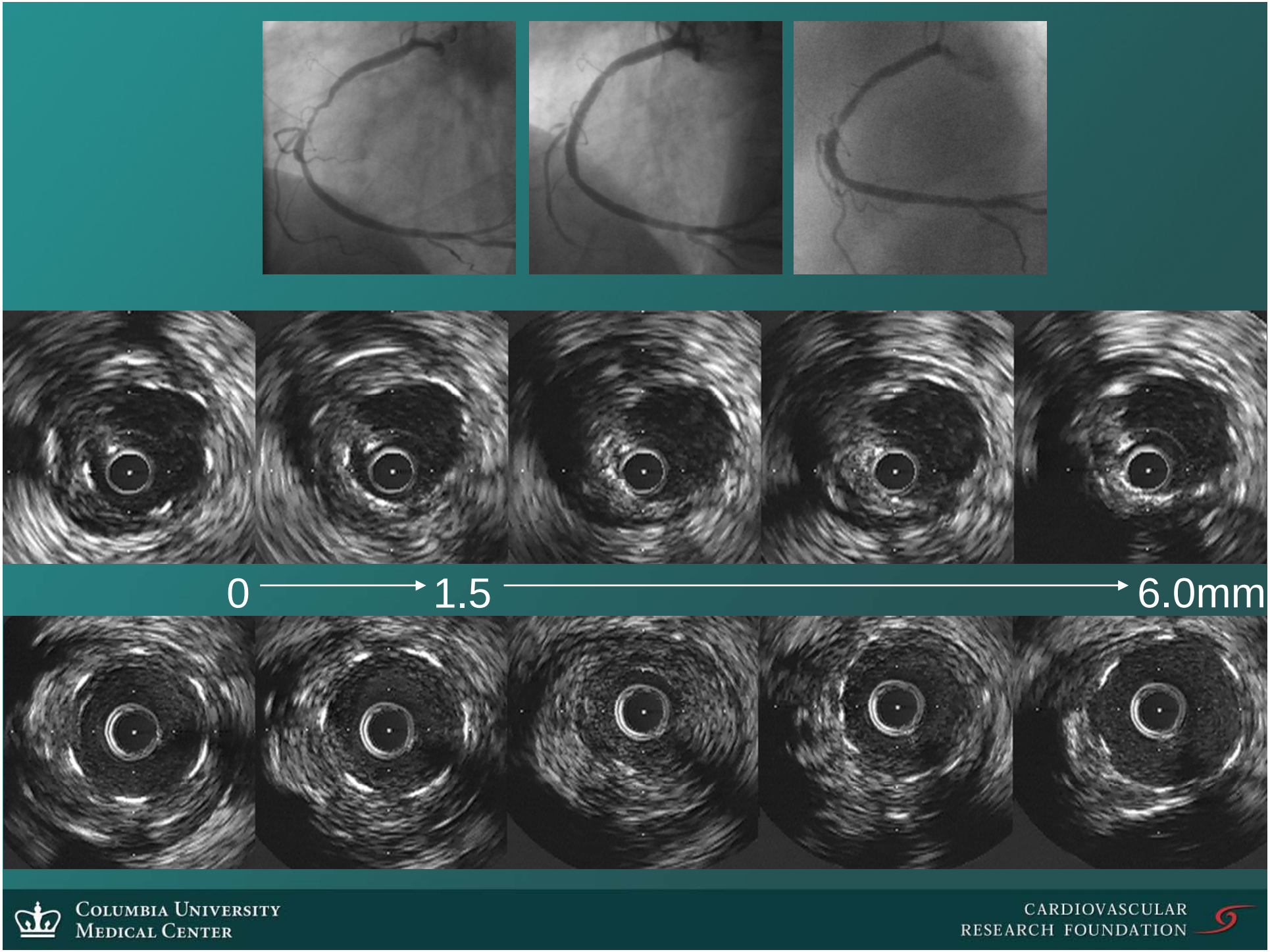
(Sonoda et al. J Am Coll Cardiol 2004;43:1959-63)

IVUS analysis of Cypher Failure @ CRF

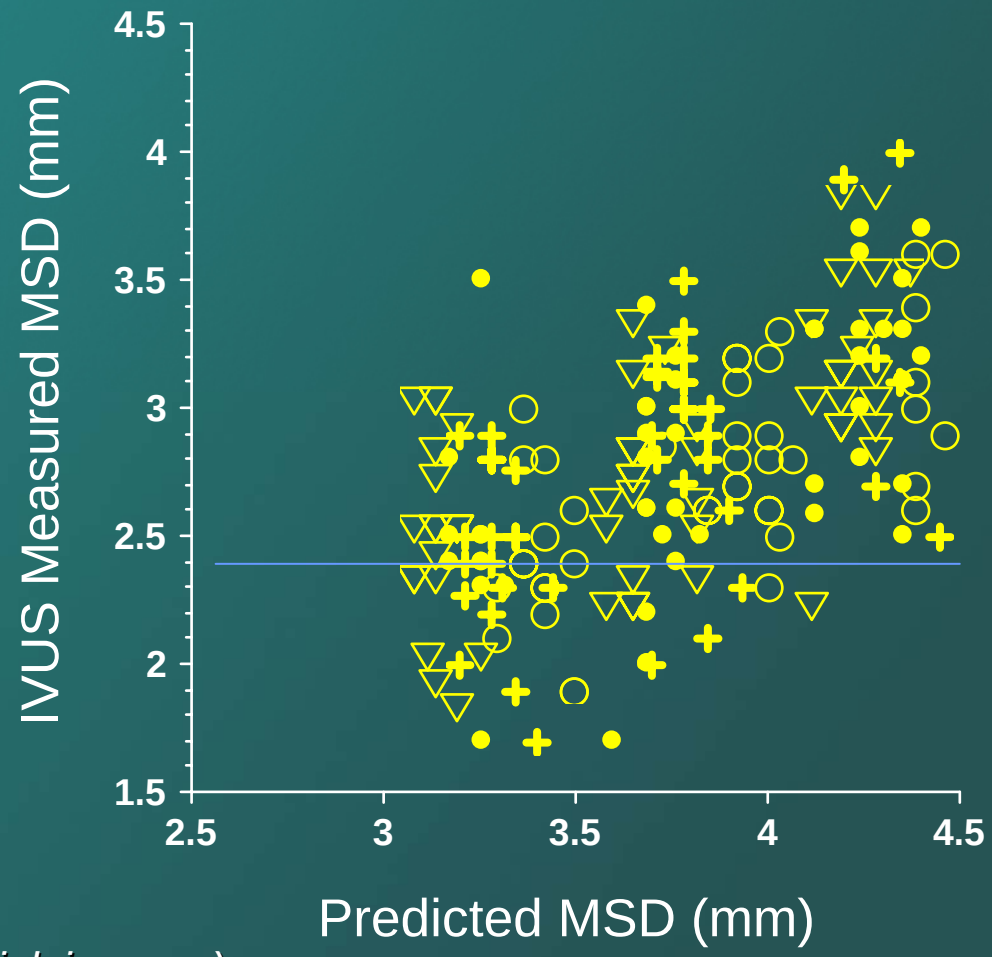
- 27 patients with Cypher failure and IVUS compared to 29 non-restenotic Cypher stents ("controls")
  - Diabetes in 52% (vs 14% of controls, $p<0.01$)
  - Unstable angina in 22% (vs 0% of controls, $p<0.01$)
  - Ostial location in 19% (vs 0% of controls, $p<0.05$)
- IVUS findings
  - Minimum stent area (MSA) measured $4.5\pm1.7mm^2$ (vs $6.5\pm1.6mm^2$ in controls, $p<0.01$)
  - Underexpansion ($MSA<5.0mm^2$) in 18 patients (67% vs 21% of controls, $p<0.01$)
  - No stent was seen in one patient at follow-up

Takebayashi et al. Am J Cardiol 2005;95:498-502


0
2.5
10.0mm


0
1.5
6.0mm
Columbia University
Medical Center
CARDIOVASCULAR
RESEARCH FOUNDATION

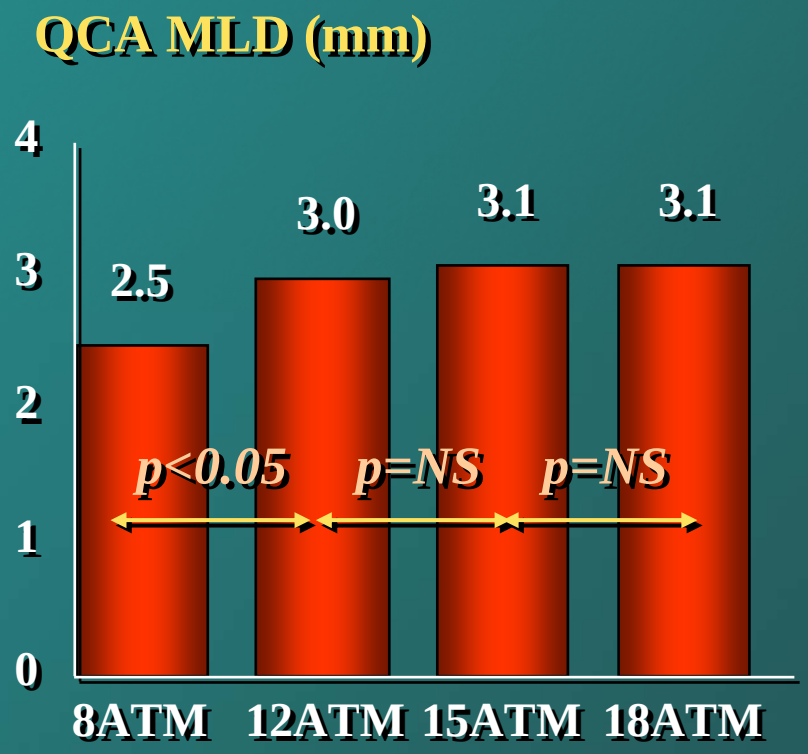
Comparison of IVUS-measured minimum stent diameter (MSD) with the MSD predicted from four manufacturers' compliance charts (n=212) shows that stents achieve an average of only 75% of the predicted MSD

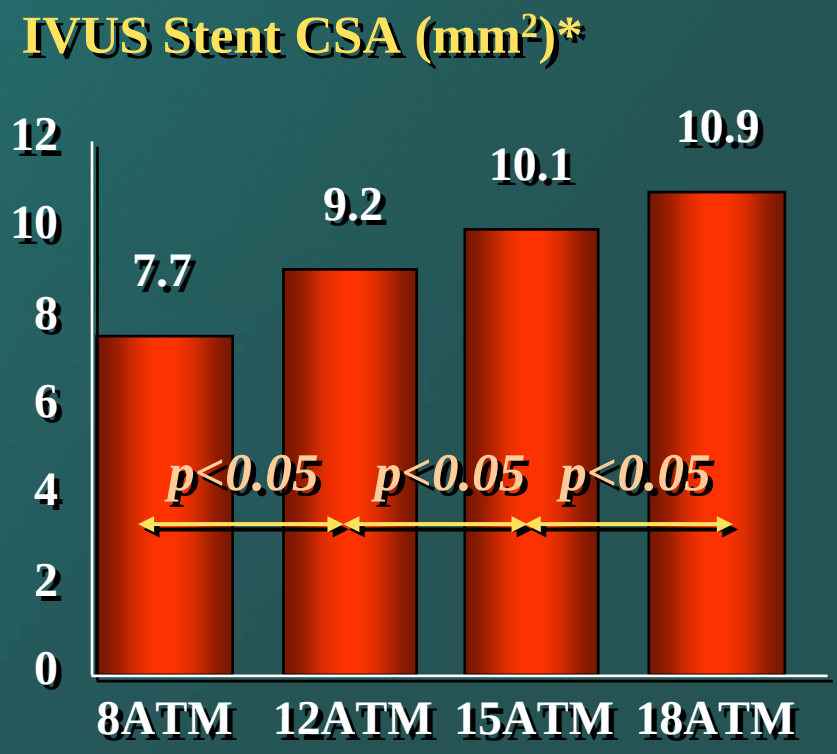


Equivalent to MSA of 5.0mm^2

(Costa et al. Am J Cardiol, in press)

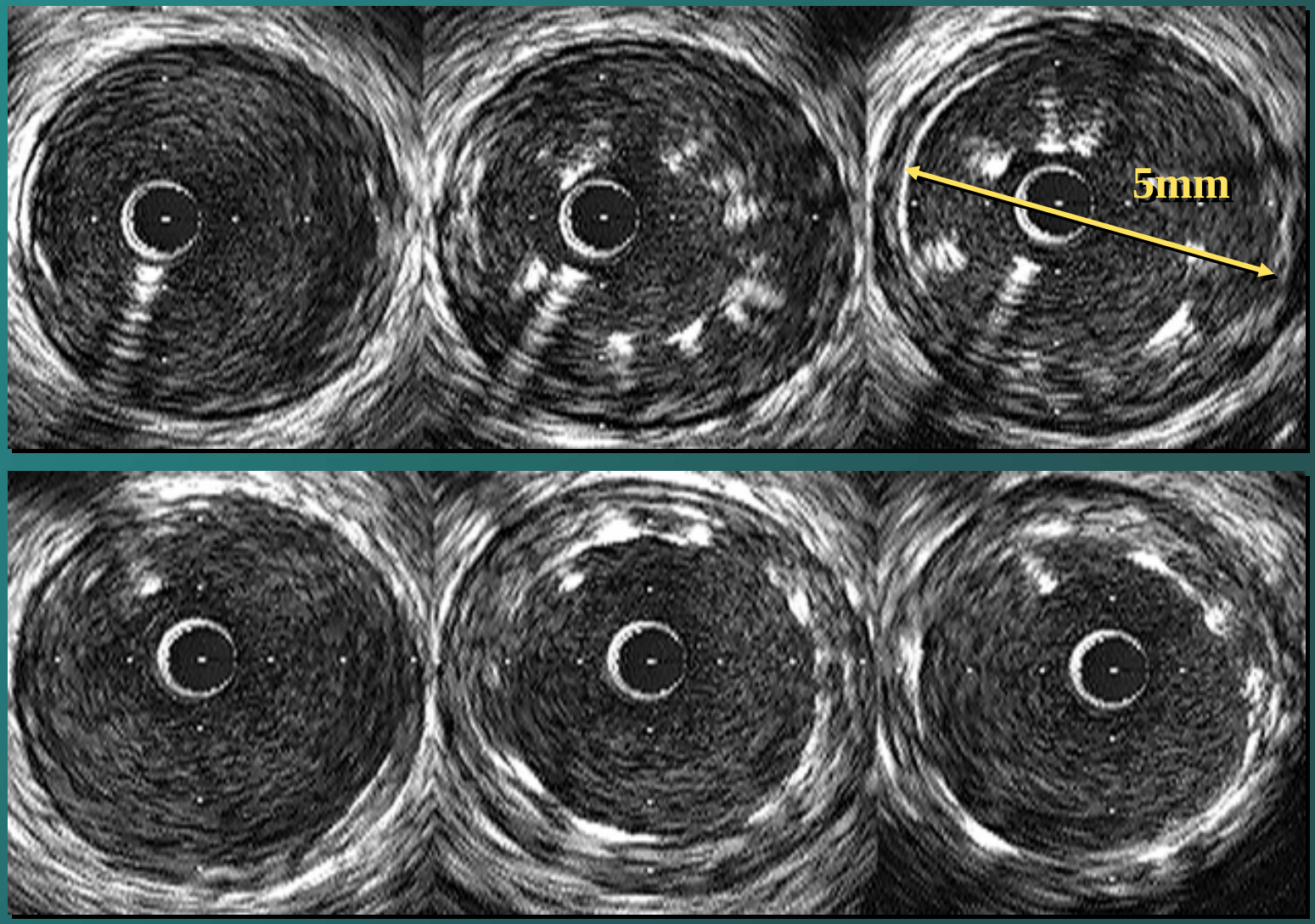
Iterative IVUS can be used to 'fine-tune' the final stent CSA and optimize expansion - Angiography cannot





**ANOVA P<0.0001*

Use larger balloons at low pressures for unapposed stents



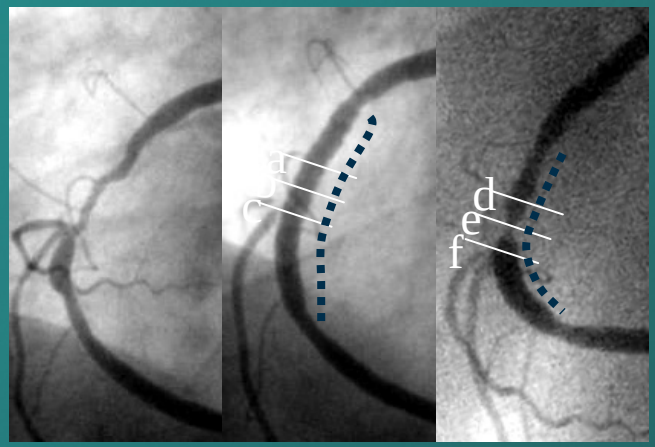
IVUS Predictors of Stent Edge Restenosis (>50% edge diameter stenosis @ 6 months) in SIRIUS

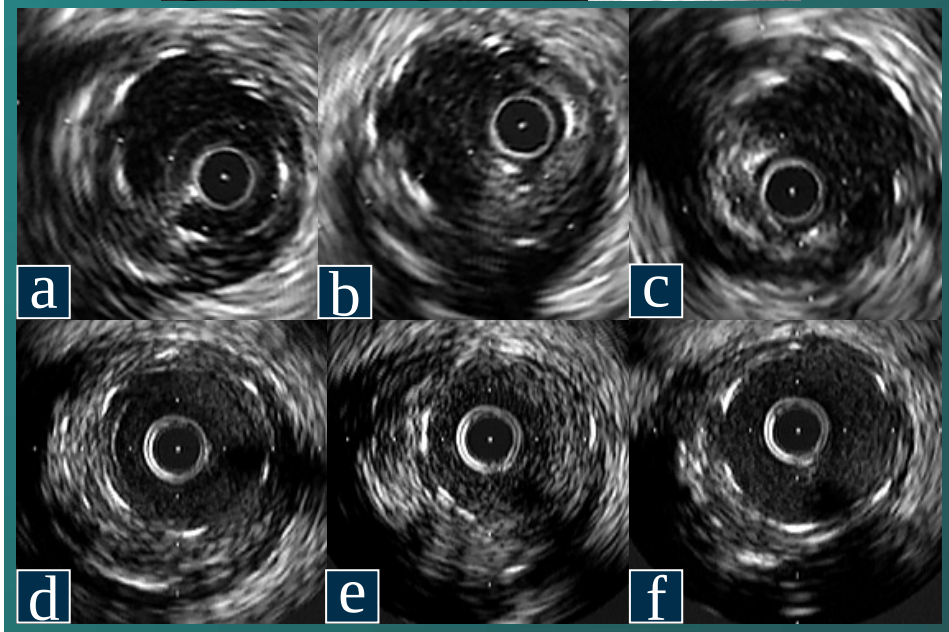
Edge restenosis occurs when the stent edge "lands" in a relatively diseased reference segment and is oversized relative to the reference lumen

Baseline Parameters	Stent Edge Restenosis	No Edge Restenosis	p
Reference MLA (mm^2)	4.7 ± 2.3	6.5 ± 2.3	0.06
Reference Residual Plaque (%)	*60.5 ± 9.0*	*49.1 ± 11.5*	*0.03*
Edge SA / Reference MLA	*1.5 ± 0.3*	*1.2 ± 0.3*	*0.03*
Maximum Pressure (mm)	15.4 ± 3.2	16.9 ± 2.7	ns
Balloon / Artery Ratio	0.9 ± 0.1	1.0 ± 0.1	ns

Sakurai et al. ACC 2004

When compared to either neointima-free sections in the same stent *or* non-restenotic stents, the maximum IH area correlated with fewer stent struts and with a larger angle between adjacent stent struts.



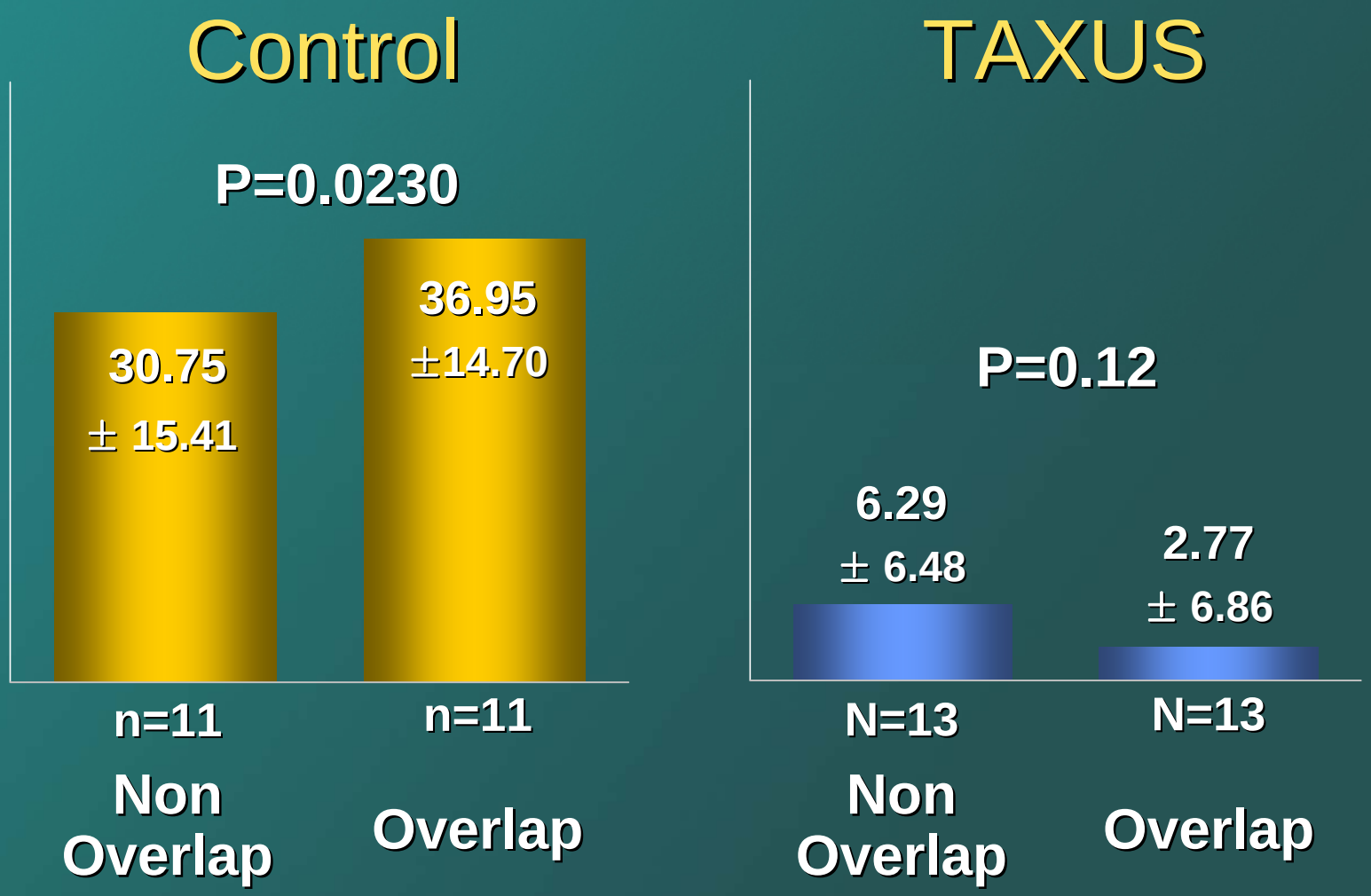


Independent predictors of IH CSA, IH thickness, and MLA

- EEM CSA ($p<0.05$)
- P&M CSA ($p<0.05$)
- Normalized # of struts ($p<0.0001$)
- Maximum interstrut angle ($p<0.0001$)

Takebayashi et al. Circulation. 2004;109:1244-9

% In-stent net volume obstruction in overlapping stents (Taxus IV)



- **While drug-eluting stents have nearly eliminated restenosis in clinical trials, there are still “real world” patients and lesions that have a relatively higher failure rate**

- **Follow-up angiograms were available in 238 patients (441 lesions) in the RESEARCH Registry. Binary restenosis rates were**

Treatment of in-stent restenosis	19.6%
Ostial location	14.7%
Diabetes mellitus	14.3%
Stent length >26mm	13.9%
Reference diameter <2.17mm	10.3%
Non-LAD lesion location	10.8%

Lemos et al. Circulation. 2004;109:1366-7

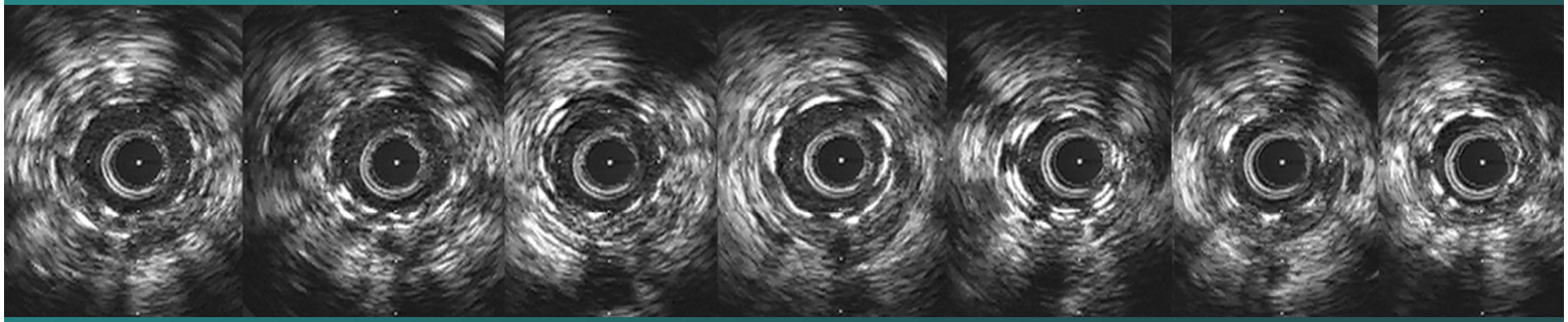
- **Restenosis rates of DES bifurcation stenting was 25.7% (17/66 with angiographic follow-up): 14 at the ostium of the side branch and 4 in the main branch.**

Colombo et al. Circulation. 2004;109:1244-9

Failure of Cypher Stent Treatment of In-stent Restenosis @ CRF

- Recurrence in 10 of 41 patients with in-stent restenosis treated with Cypher stents
  - ***Stent underexpansion (MSA <5.0mm^2) in 8/10 recurrence in-stent restenosis lesions*** (80% vs 12/38 [38%] of non-recurrent lesions, p=0.02) and 6/10 (60%) recurrent lesions had a MSA <4.0mm^2 vs 8/38 (18%) non-recurrent lesions (p=0.02)
  - ***Gap between multiple Cypher stents was detected in 3/10 recurrent lesions***: vs 1/38 non-recurrent lesion (p=0.005). The gap was not detectable angiographically, and it measured <1mm in length by IVUS.
- Therefore, complete lesion coverage and adequate stent expansion are important in the DES treatment of ISR.

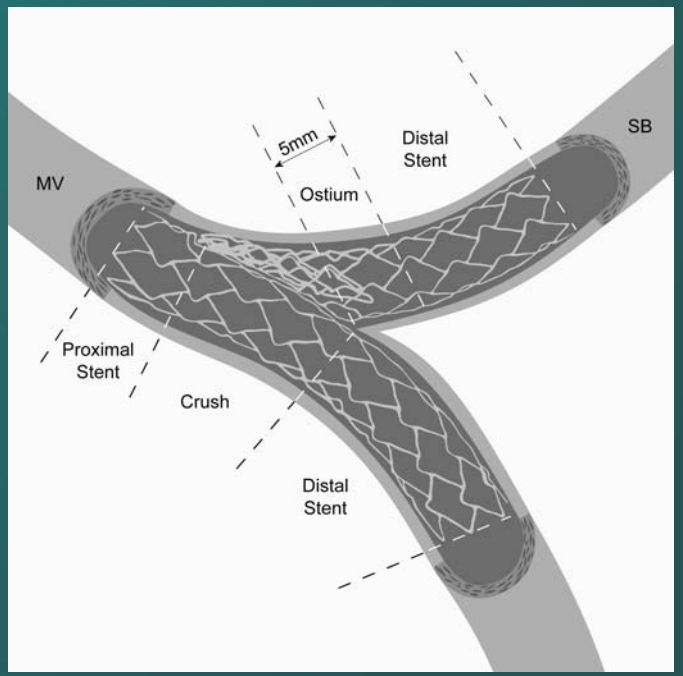
Fujii et al. Circulation 2004;109:1085-1088



0 → 2.0 → 12.0mm

20 pts with IVUS of both branches after non-LM "crush" DES implantation showed frequent stent underexpansion at the side branch ostium

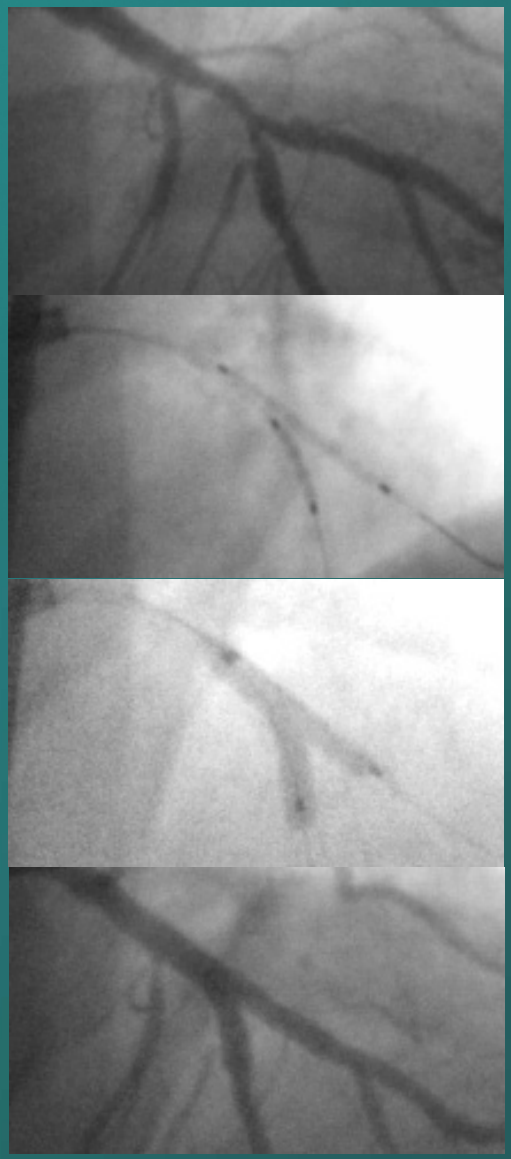
- Main vessel
  - Stent expansion= 92±17%
  - MSA <5mm^2 in 20%
  - MSA <4mm^2 in 10%



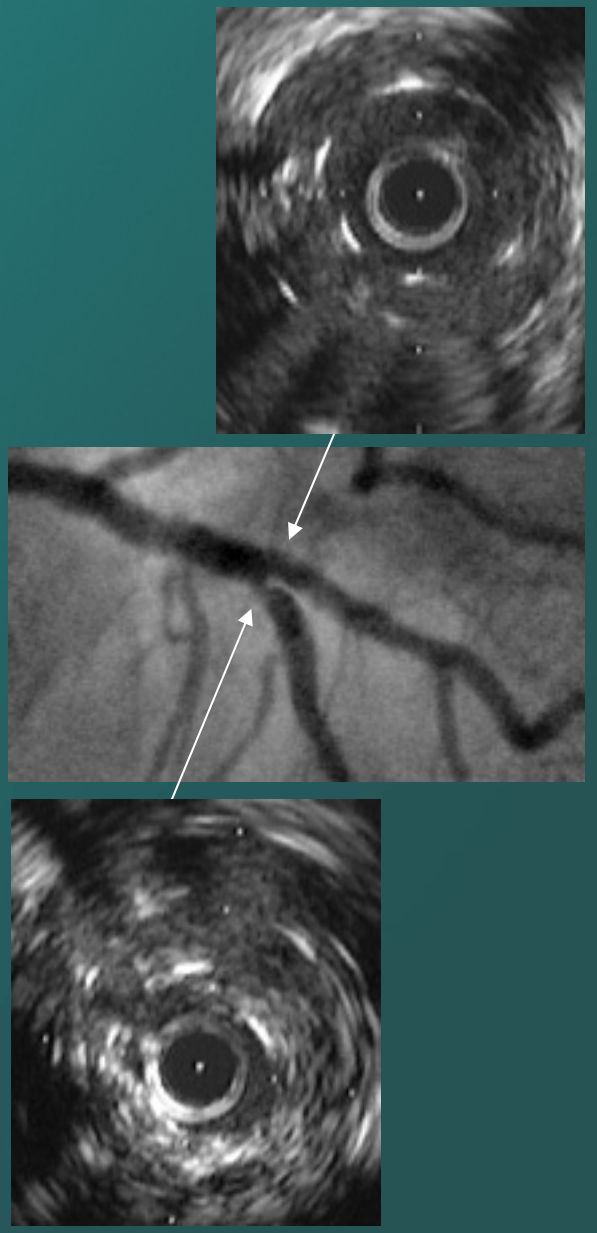
- Side branch
  - Stent expansion= 80±12%
  - MSA <5mm^2 in 90%
  - MSA <4mm^2 in 55%
  - Ostium is the site of MSA in 65%

Costa et al. J Am Coll Cardiol (in press)

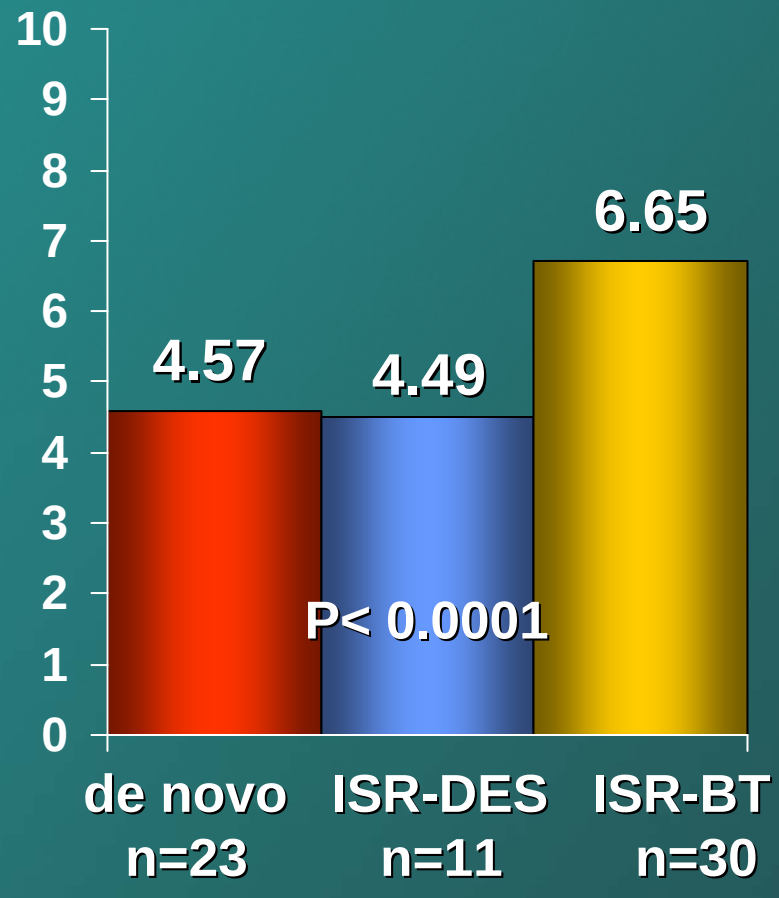
Bifurcation stenosis treated with 2 Cypher stents



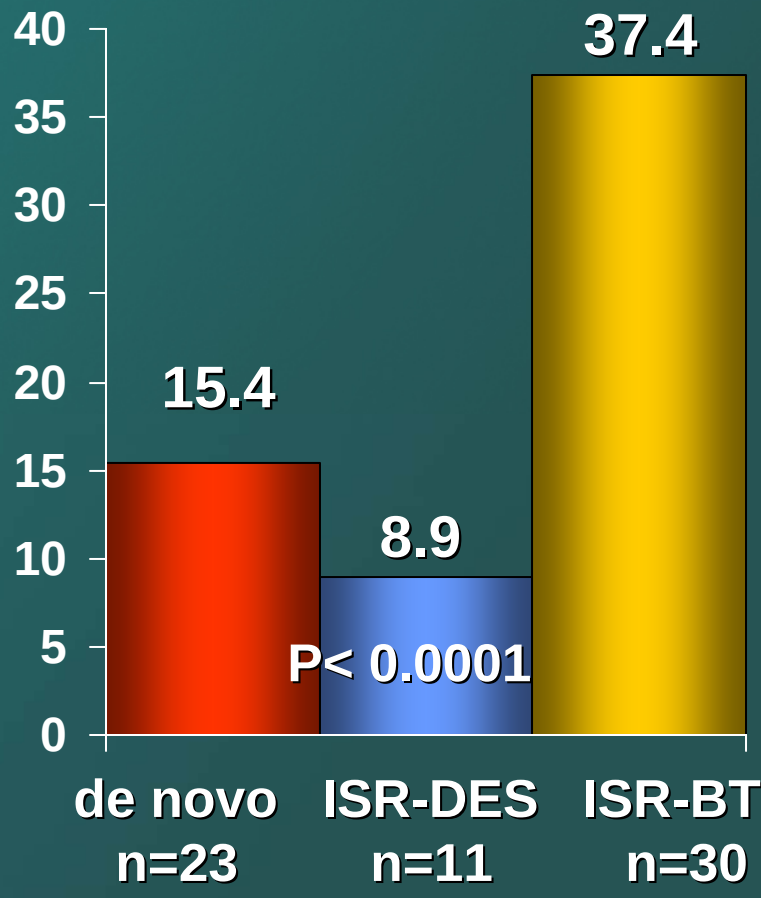
7-month Follow-up



Impact of MSA on DES Failure (WHC)



Minimal Stent CSA (mm^2)



%IH Volume

So, when is IVUS most appropriate?

- Diagnostic purposes
- High risk patient and lesion subsets
  - Diabetics
  - Ostial lesions
  - Long lesions
  - Small vessels
- Treatment of in-stent restenosis
- Drug-eluting stent failures

How should IVUS be used?

- Perform pre-intervention imaging to assess lesion severity, measure vessel size, and measure lesion length
- Select DES size based on vessel size
- Select DES length to end the proximal and distal ends of the stent in the least diseased sections
- Perform post-intervention imaging to assess minimum stent CSA, apposition, and lesion coverage
- Fine-tune the results as necessary