DES Implantation in Long Diffuse Lesion

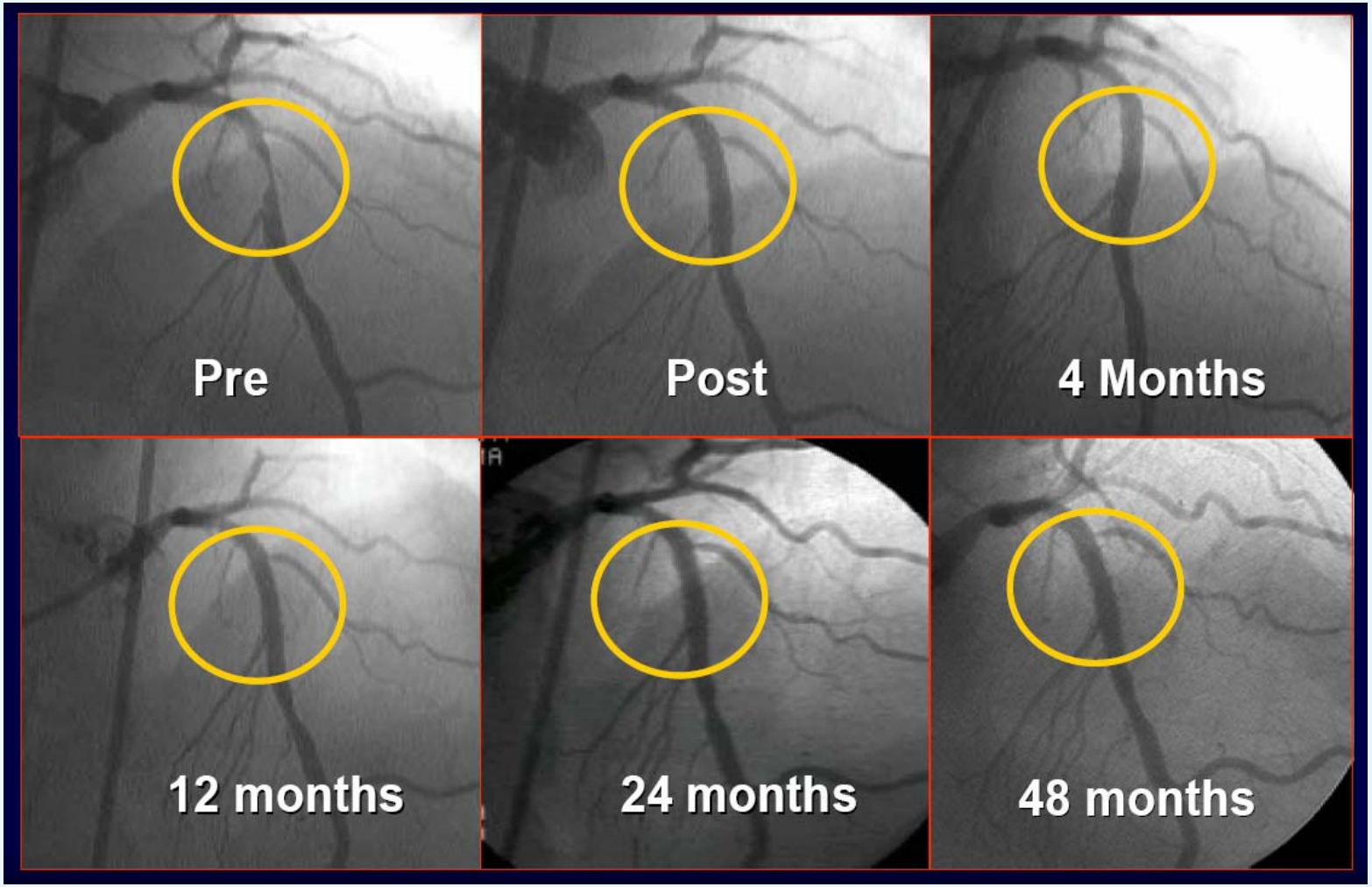
Can We Reach Optimal Stent Expansion With Conventional Stent Delivery System?

Seung-Jea Tahk, MD., PhD.

Ajou University Medical Center
Suwon, Korea

CPIS 2007

FIM .. 4 year follow-up



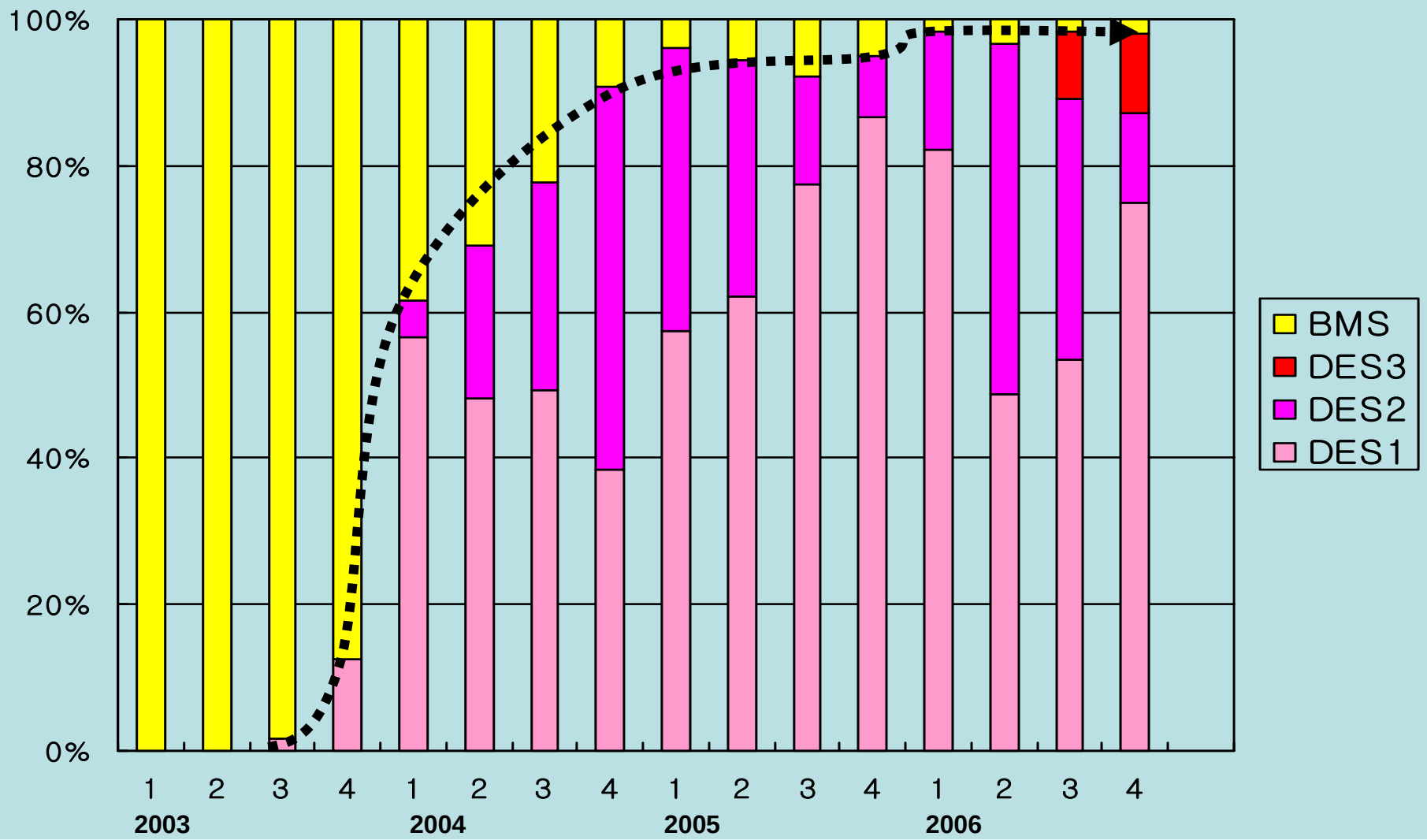
Sousa JE et al.

Are Drug-Eluting Stents Changing Your Daily Practice?

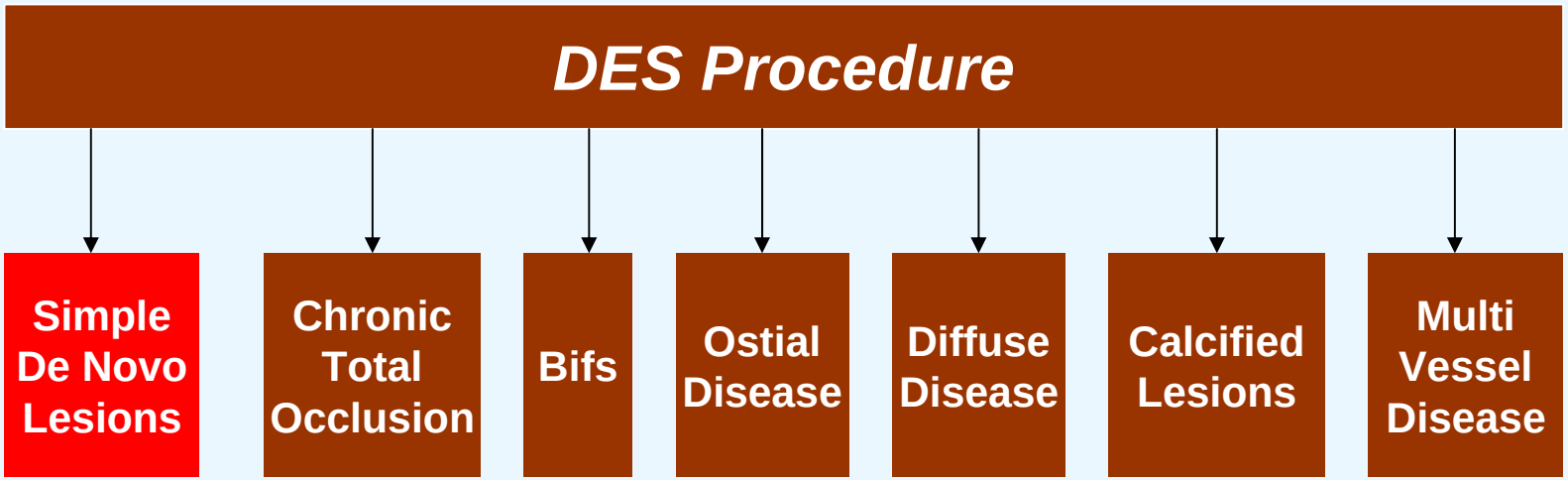
After 24 months of DES for all patients, the point of no return has been reached and we will not come back to bare stent.

Thank you

DES Penetration in Ajou University Medical Center



DES changes our pattern of PCI



More Complex Lesions
Small Vessels
and
Diabetic Patients

DES failure in the real worlds ..

- Target vessel failure

  Angiographic binary restenosis < 11.9% - 16.5%*

  Clinical restenosis or TLR < 8.3% – 12.0%*

- Stent thrombosis < 2.0%

  * in diabetic patients

Data from REALITY, SIRTAX, ISAR-DIABETES

The Goal of PCI with DES

- Reduce target vessel failure
  - Restenosis
  - TLR/TVR

- Maintain long-term lower MACE rates

Is pre or post-DES dilation needed ?

- Hypothesis
  - Optimize stent expansion

“Bigger is still Better”
in
DES era ?

following DES deployment with and without pre or postdilation.

Predictors of Restenosis and Target Vessel Revascularization after SES Implantation

Clinical variables
Diabetes
Angiographic variables
Small reference vessel diameter
Ostial location
Non–left anterior descending artery lesion
In-stent restenosis
Procedural variables
Long stent length
Small stent diameter or minimal stent area (MSA) by IVUS

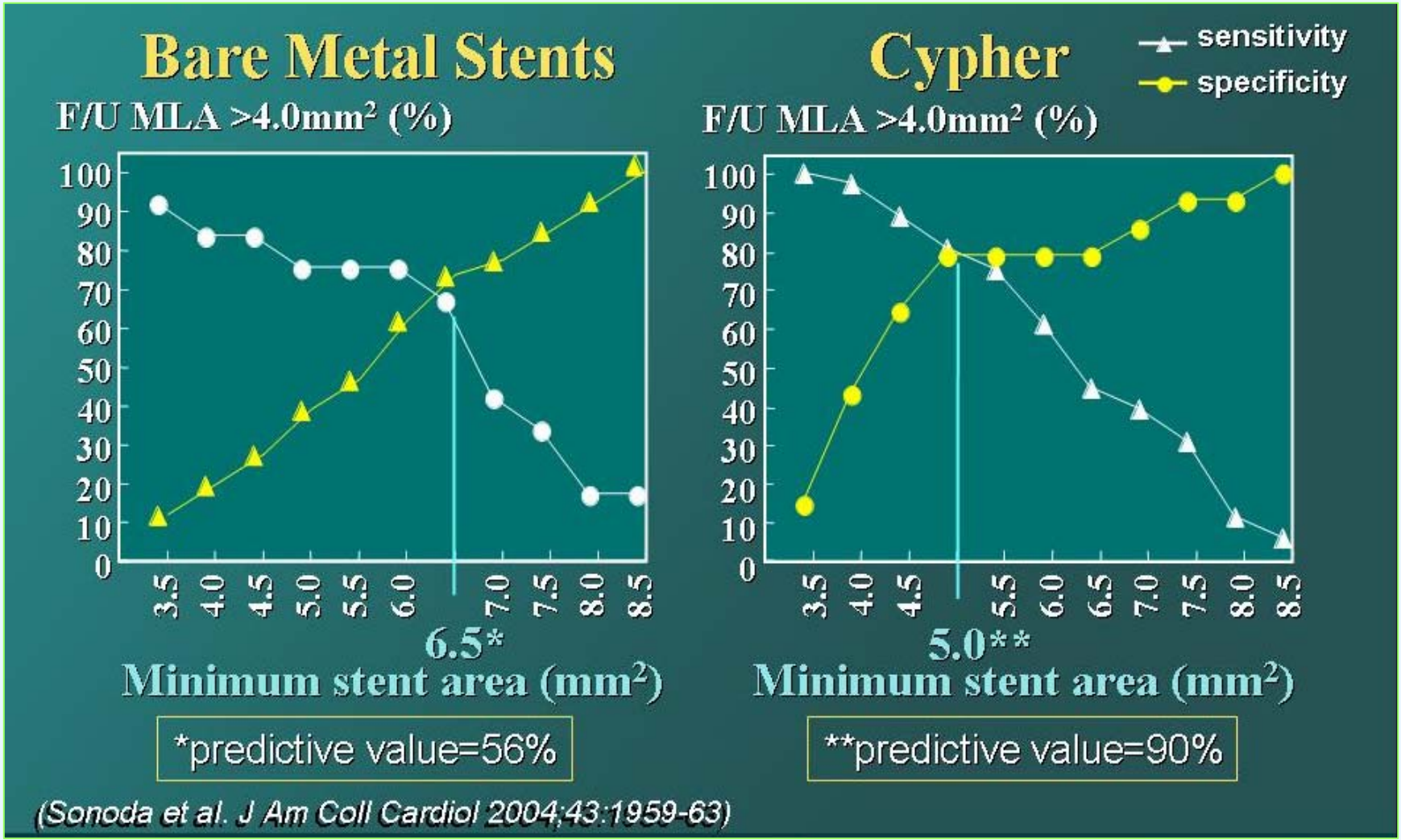
BR Brodie. J Interven Cardiol 2006;19:43–50)

IVUS analysis of Cypher failure

- 27 Cypher failure vs. 29 non-restenotic control
  - Diabetes 52% vs. 14% p<0.01
  - Unstable angina 22% vs. 0% p<0.01
  - Ostial location 19% vs. 0% p<0.05

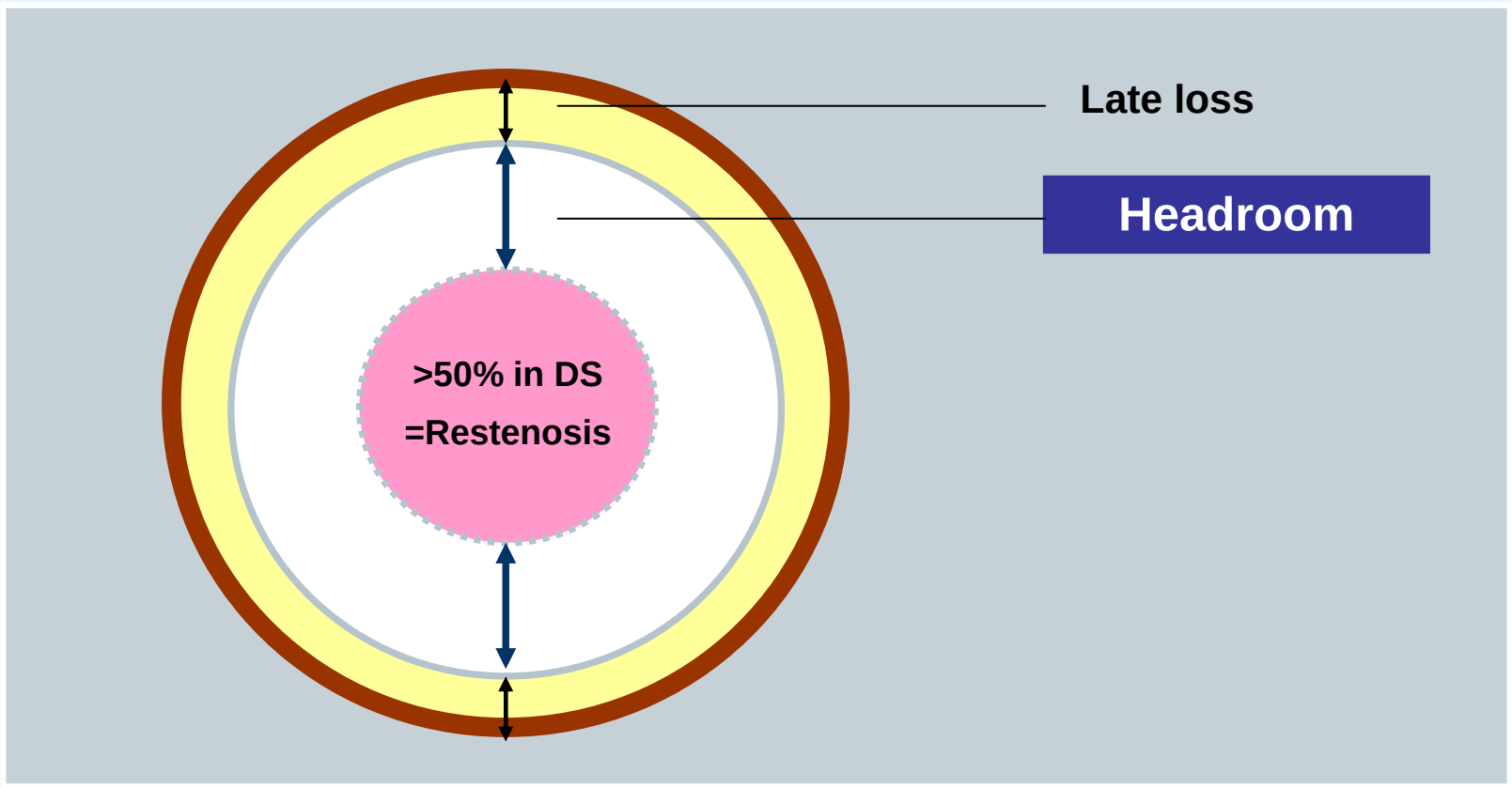
- IVUS findings
  - Minimal Stent Area (mm^2) 4.5±1.7 vs. 6.5±1.6 p<0.01
  - Stent underexpansion (<5mm^2) 67% vs. 21% p<0.01

What is the smallest acceptable minimum stent area?

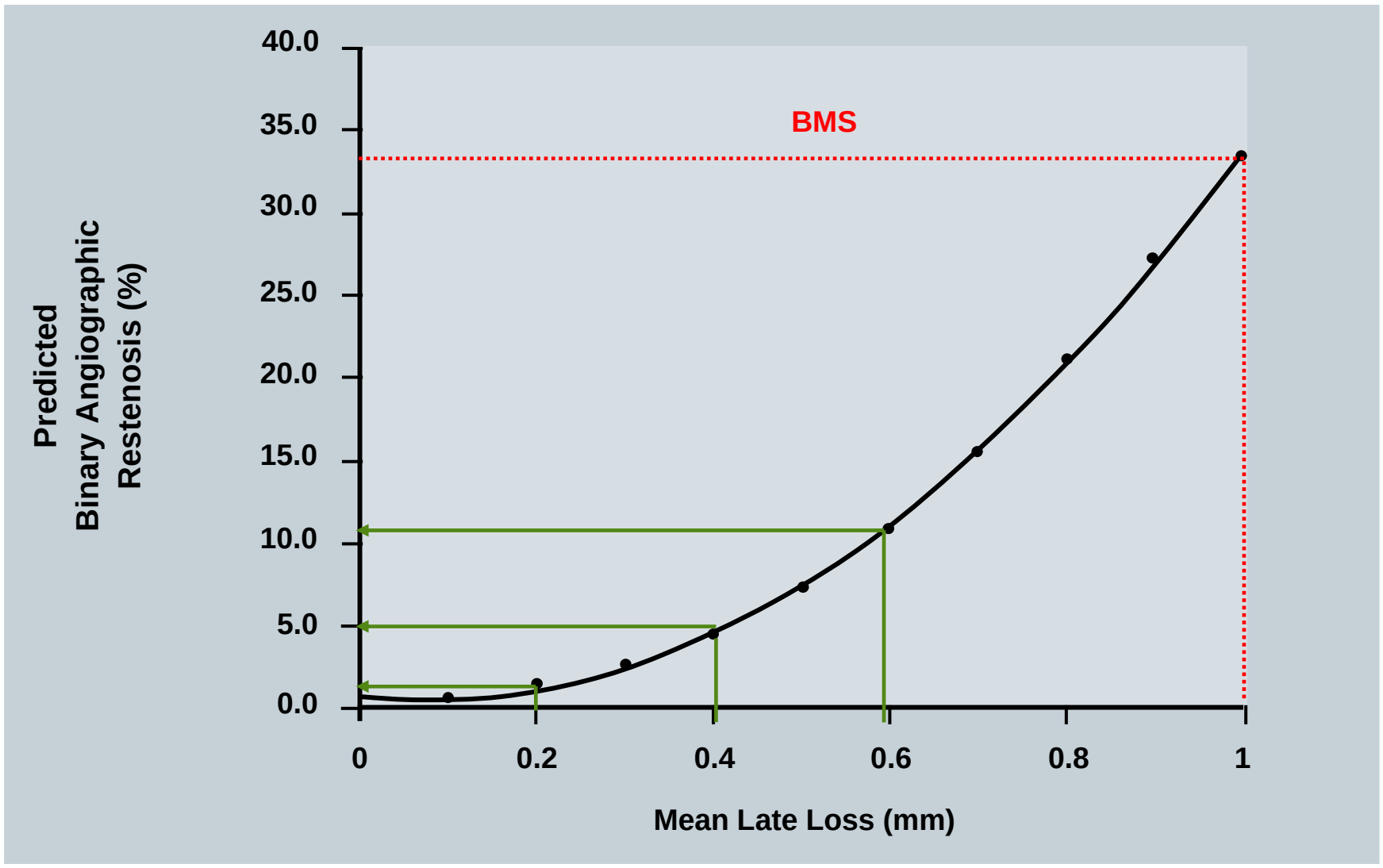


Late Loss and “Headroom” to Restenosis

- Late loss “headroom” is the space of extra late loss available for higher risk cohorts
- Headroom highest for large MSA and low in-stent late loss stent systems



Mean Late Loss and Risk of Restenosis



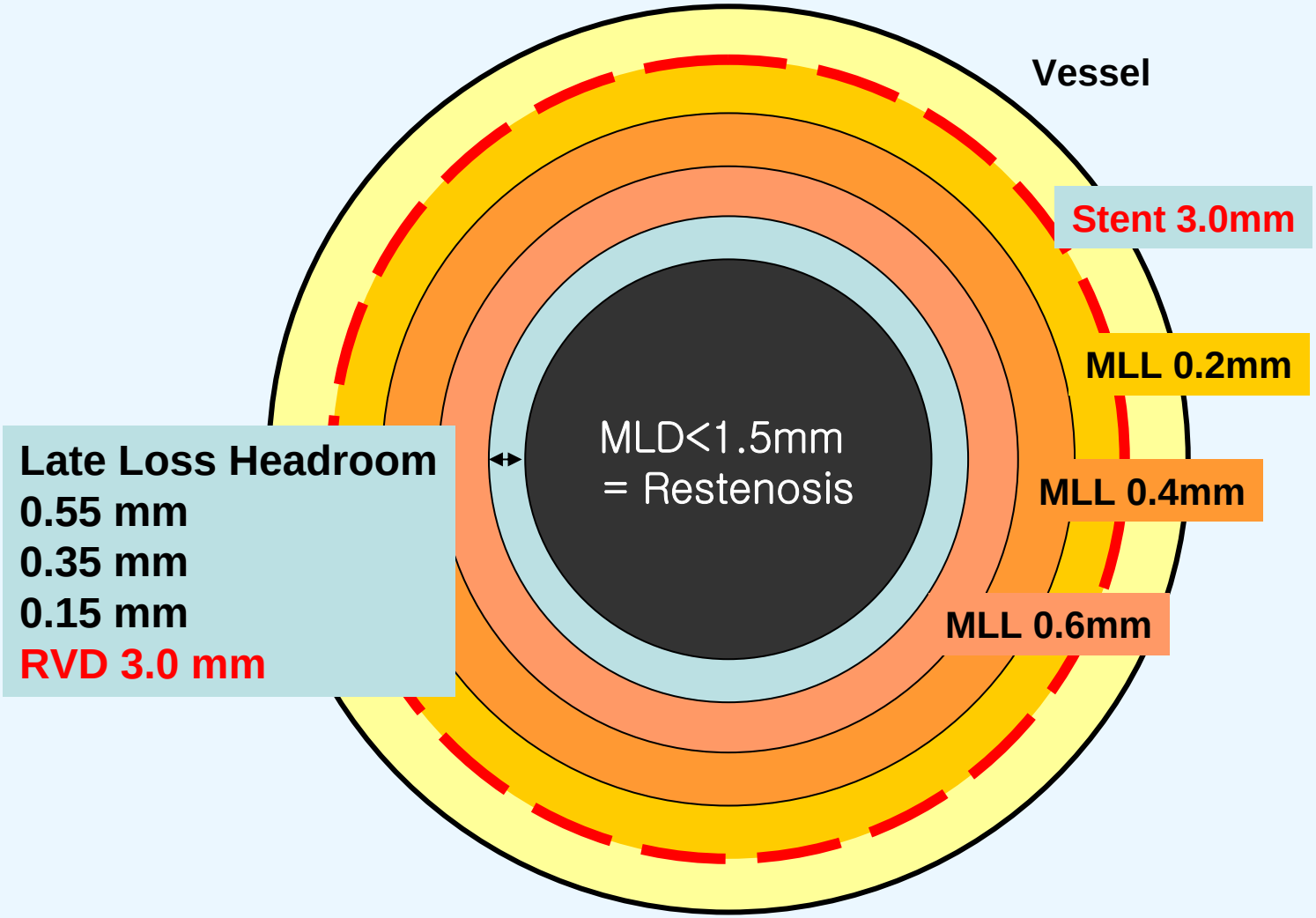
Mauri L, Orav JE, Kuntz RE. Circulation 2005; 111: 3435-3442

Multivariable Predictors of in-Stent Late Loss

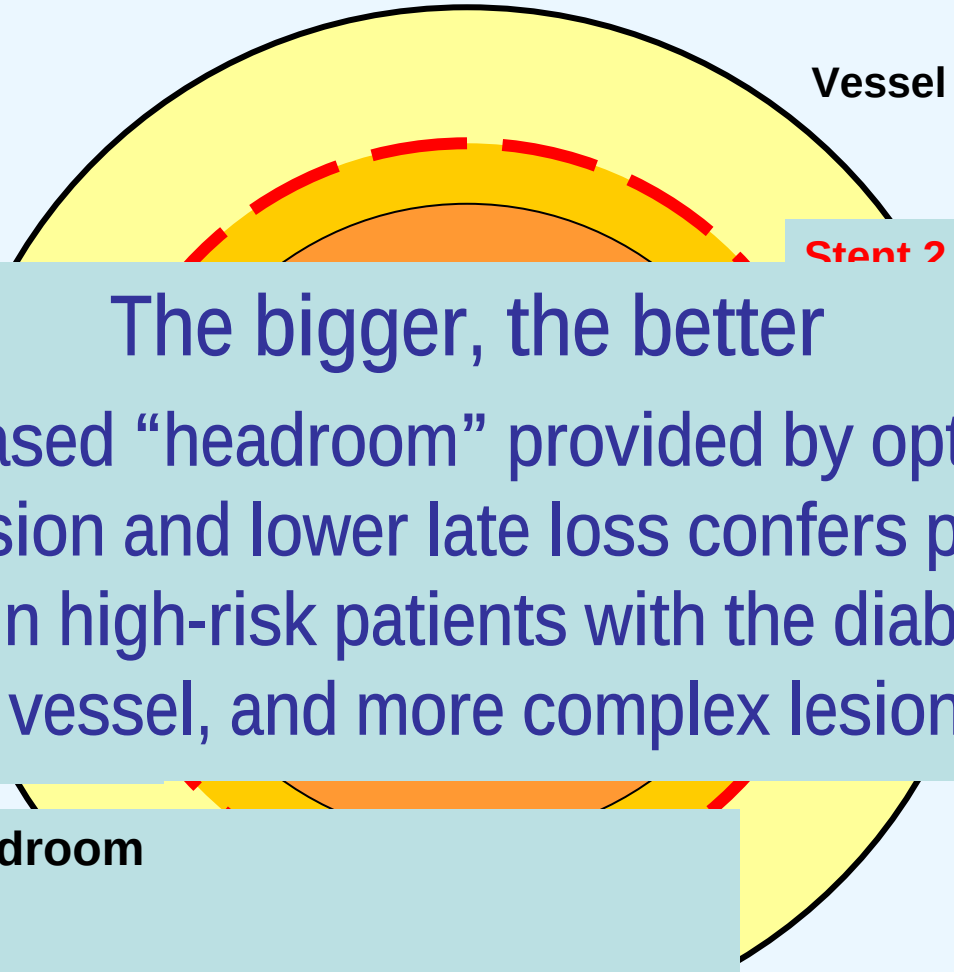
Characteristic	Effect estimate (mm)	SE	P
Stent type (sirolimus eluting vs bare metal)	-0.79	0.029	<0.0001
Diabetes mellitus	0.16	0.028	<0.0001
Lesion length (per 10 mm)	0.17	0.019	<0.0001
Acute gain (per mm)	0.17	0.029	<0.0001
Residual % diameter stenosis (per 1%)	-0.0097	0.0014	<0.0001
Reference vessel diameter (per mm)	-0.044	0.028	0.12

Mauri et al: Circulation 112:2833, 2005

Late Loss and “Headroom” to Restenosis



Late Loss and “Headroom” to Restenosis



The bigger, the better

The increased “headroom” provided by optimal DES expansion and lower late loss confers particular benefits in high-risk patients with the diabetes, small vessel, and more complex lesions

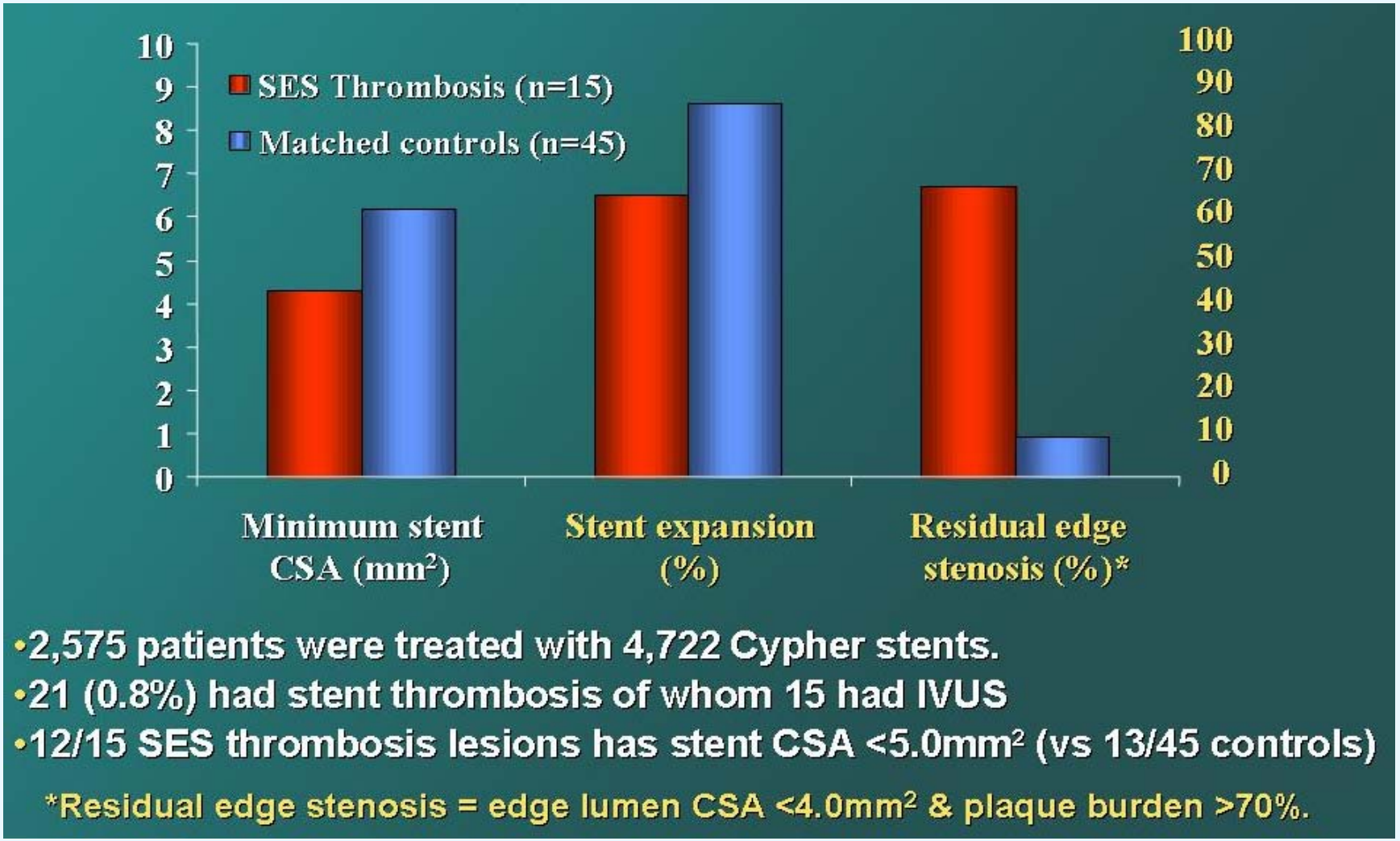
Late Loss Headroom
0.30 mm
0.10 mm
- 0.10 mm
RVD 3.0 mm with suboptimal stent expansion

Predictors of Drug-Eluting Stent Thrombosis

Clinical variables
Diabetes
Renal failure
Low ejection fraction
Angiographic variables
Bifurcation lesions
Procedural variables
Use of multiple stents
Use of long stents
Small final stent area (MSA) by IVUS
Stent underexpansion
Residual reference segment stenosis
Postprocedural variables
Premature discontinuation of antiplatelet therapy

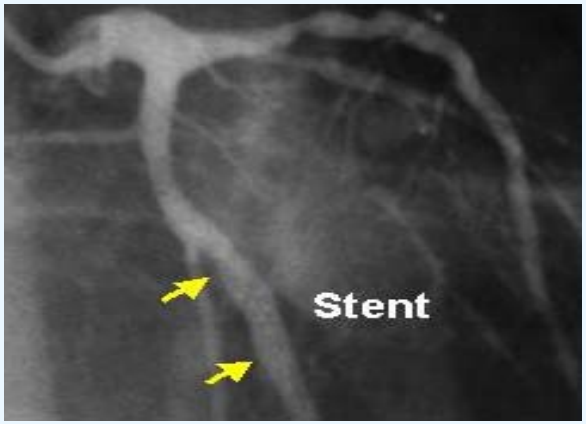
BR Brodie. J Interven Cardiol 2006;19:43–50)

Predictor of Cypher thrombosis

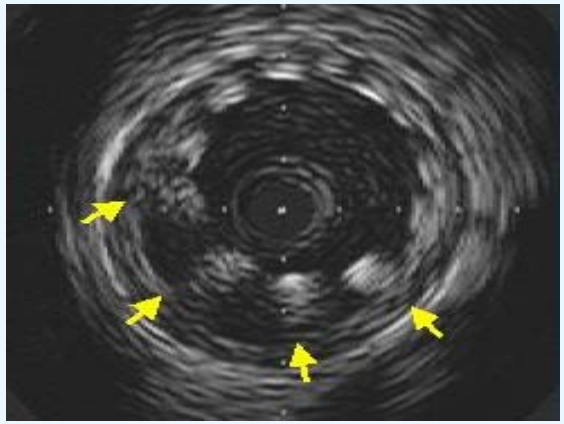


Fujii et al. JACC 2005;45:995-998

Why is optimal DES expansion and apposition important ..



Same Vessel



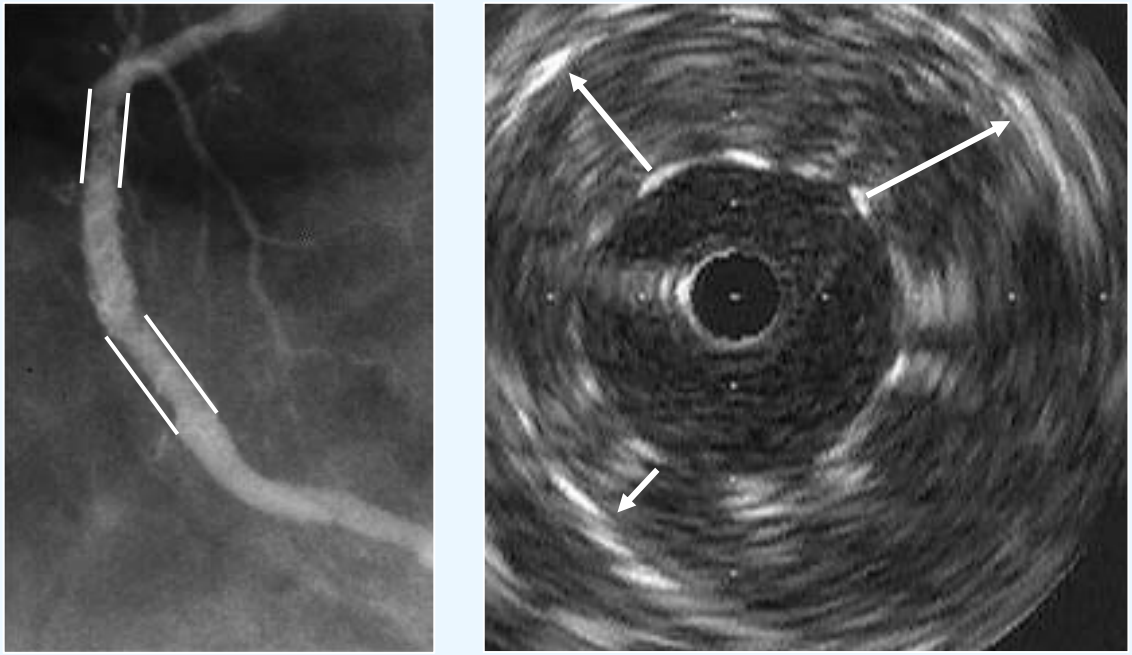
Under angiography, the stent *appears* fully expanded/apposed

Using IVUS, the stent demonstrates *sub-optimal* expansion/apposition

- Uniform stent apposition facilitates uniform drug absorption into endothelial tissue [2,3,4,5]
- Incomplete apposition may contribute to thrombosis formation & SAT's[1]
- Stent underexpansion may increase risk for restenosis[7]
- Optimal stent apposition may reduce target vessel revascularization (TVR) [6]

1. Cheneau, et al. Circulation 2003;108;43-47
2. Creel, et al. Circulation 2000;86:879.
3. Hwang, et al. Circulation 2001;104:600-605
4. Leon, M. *The basic "tips and tricks" for DES implantation;* TCT 2003 presentation
5. The TAXUS Stent Directions for Use
6. Fitzgerald, et al. Circulation 2000; 102:523-530
7. Fuji, et al. Circulation 2004; 109: 1085-1088

POSTIT Trial
Verification of stent expansion by IVUS



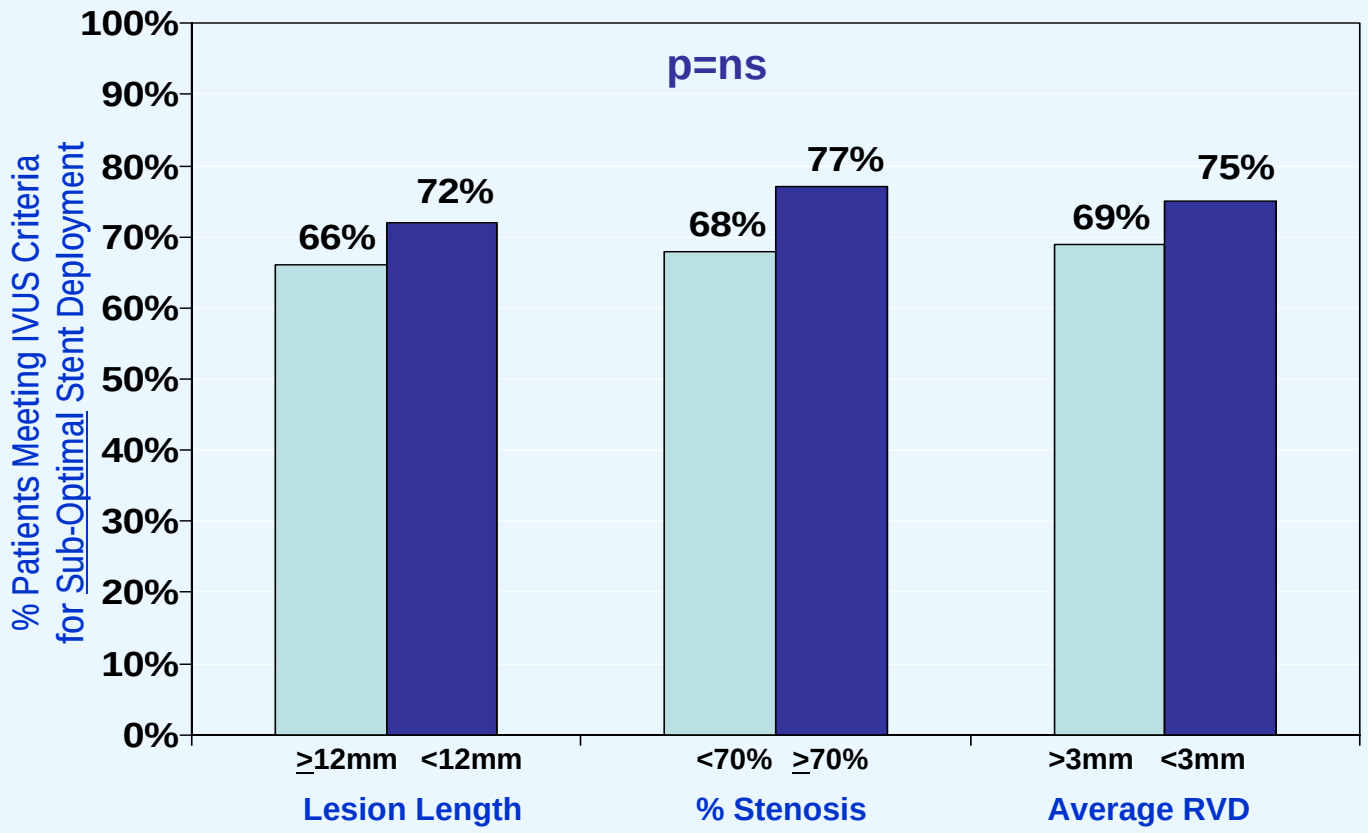
Optimal stent deployment* is only achieved in 29% of patients with current stent delivery systems; usually due to inability of stent delivery balloon to expand fully the stent to nominal size (n=256).

*MSD≥90% of average reference lumen diameter

POSTIT Trial, Brodie et al, Catheterization and Cardiovasc Int 2003;59:184

POSTIT Trial

71% of patients did NOT have optimum stent expansion



There are NO angiographic predictors of sub-optimal apposition, including:
- Lesion Length - % Stenosis - RVD - Type of Stent

POSTIT Trial, Brodie et al, Catheterization and Cardiovasc Int 2003;59:184

POSTIT Trial

What causes sub-optimal stent apposition?

A) Was the SDS (balloon) undersized for the target vessel? → **NO**

B) Was balloon deployment pressure too low? → **NO**

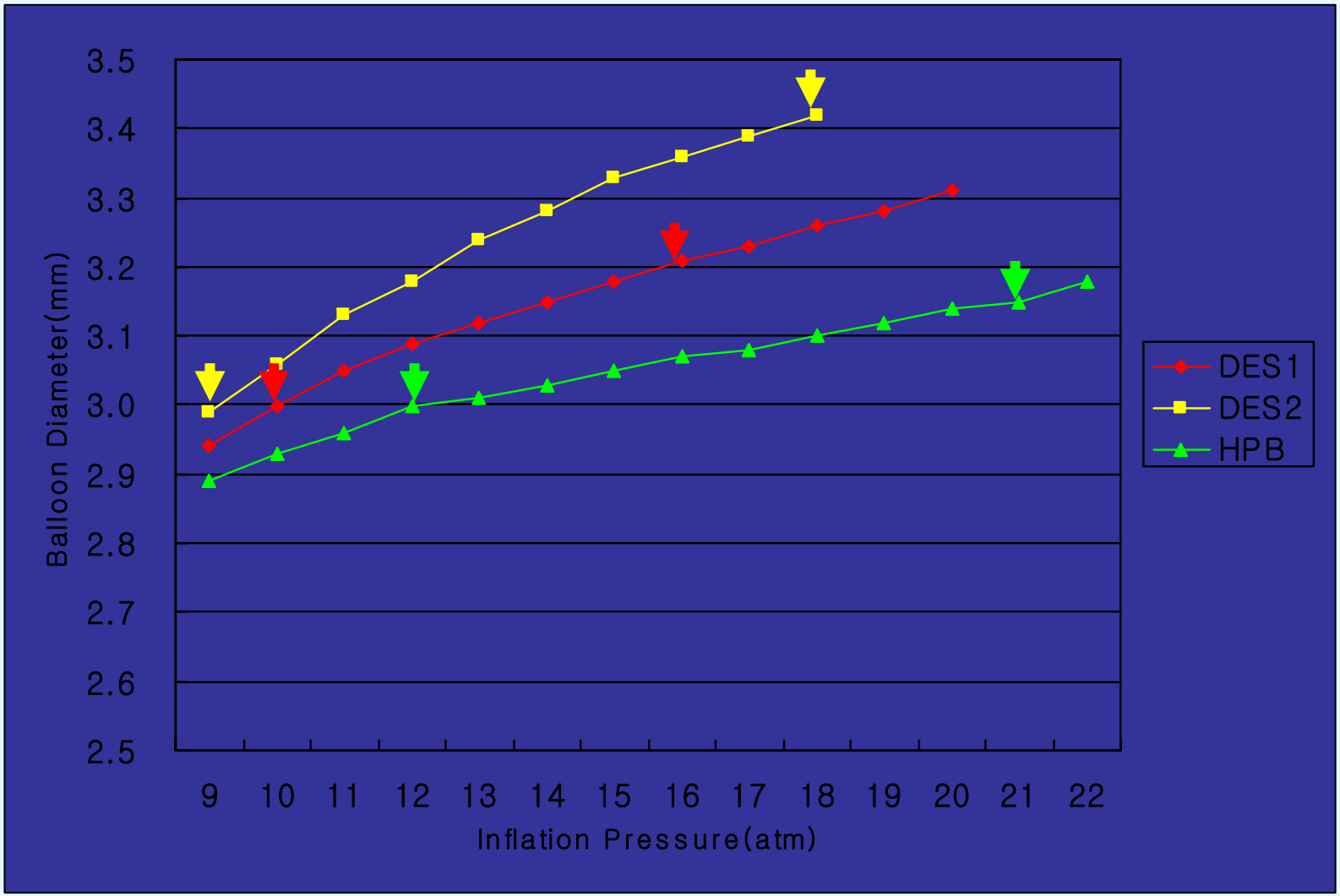
C) Does the semi-compliant balloon with SDS *not* provide the necessary force to reach optimal stent apposition? → **YES**

"With post-dilatation using **non-compliant balloons**, the frequency of achieving optimum stent deployment **doubles** and there are significant increases in MSA – maximum stent apposition.

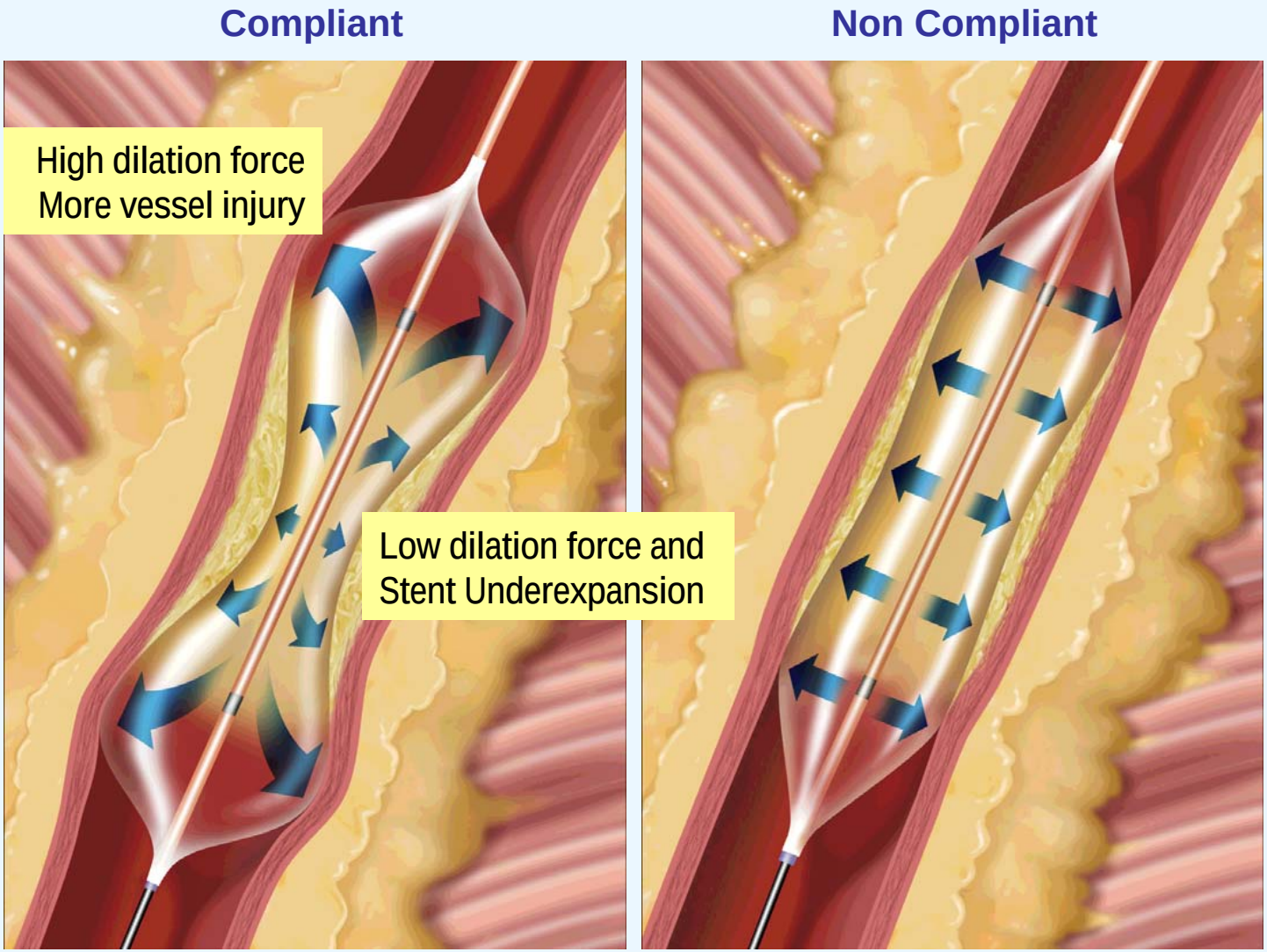
These data stress the continued need for adjunctive balloon post-dilatation with appropriate stent expansion balloons."[1]

POSTIT Trial, Brodie et al, Catheterization and Cardiovasc Int 2003;59:184

Compliance of current stent delivery system



Balloon compliance and dilation force



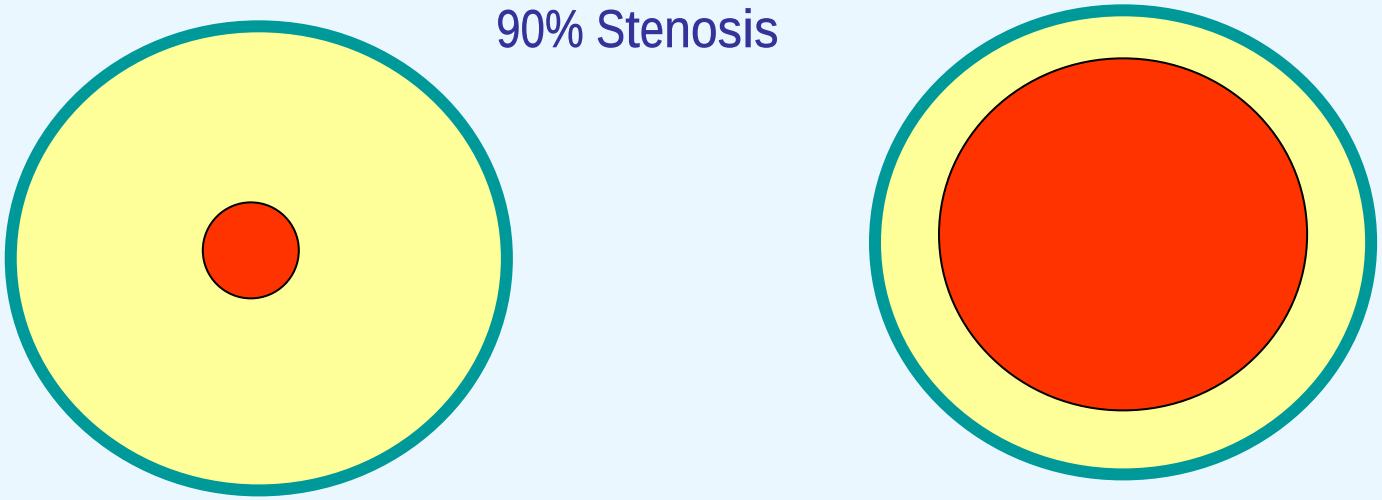
$$F = \frac{\text{Pressure} \times \text{Diameter}}{2 \times \text{Wall Thickness}}$$

Balloon inflation pressure and dilation force

No Preparation

3.2mm Vessel
90% Stenosis

Prepared by 2.5mm Burr



$$F = \frac{\text{Pressure x Diameter}}{\text{2 x Wall Thickness}}$$

$$\frac{\text{6 atm x 0.32mm}}{\text{2 x 1.44mm}}$$

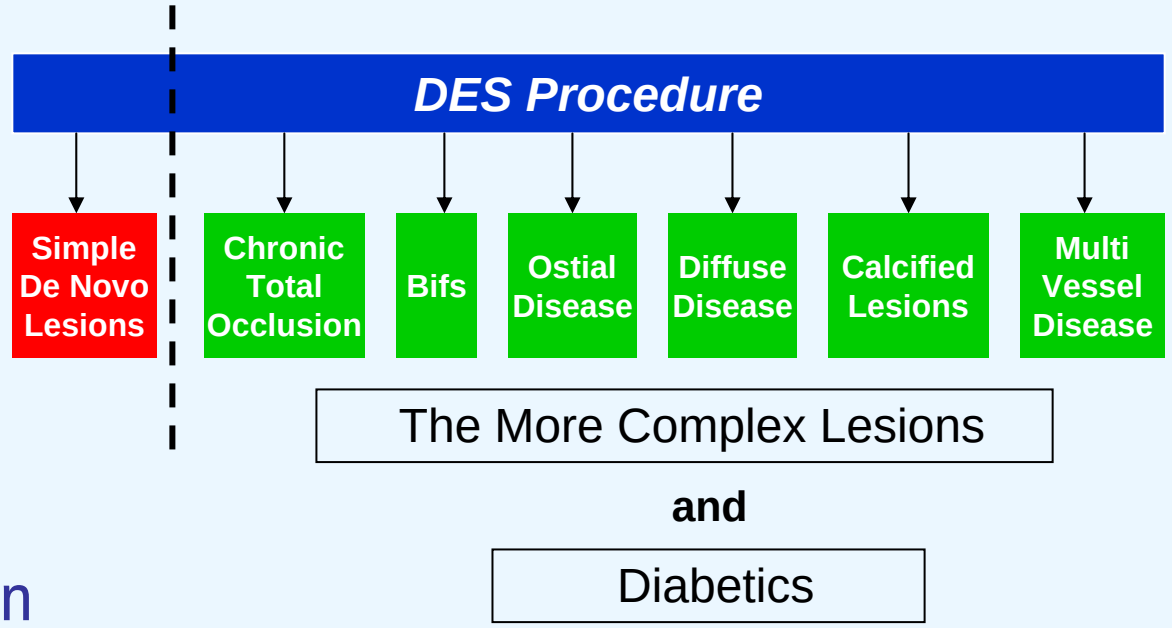
0.67 atm

$$\frac{\text{6 atm x 2.5mm}}{\text{2 x 0.35mm}}$$

21.43 atm

Which lesions need preparation before DES? ..

When to pre-dilate?



- Tips for pre-dilatation
  - Undersize balloon (0.5-1.0mm)
  - Select balloon shorter than length of stent
  - Focal, calcified lesions – Cutting balloon may be beneficial

Leon, M. The basic "tips and tricks" for DES implantation; TCT 2003 presentation

Long Diffuse Lesion
FFR and IVUS-guided DES Implantation

- PCI with current semi-compliant stent delivery system (SDS) in long diffuse lesion may result in stretching of the balloon around the lesion rather than concentrating the force at the lesion and cannot achieve optimal stent expansion.

- Conventional PCI in long diffuse lesion based on the visual angiographic estimation of stenosis may poorly correlate with anatomic and physiologic significance.

SJ Tahk, MH Yoon, et al. CCT 2006

Optimal stent implantation in DES era; Observations from the TAXUS IV

TAXUS Stent MDP Groups	<14 atm	14–16 atm	>16 atm	p value
MDP (atm)	11.6	14.2	17.4	<0.0001
Diabetes (%)	22.3%	22.2%	24.9%	0.73
RVD (mm)	2.63	2.75	2.84	<0.0001
Lesion length (mm)	13.11	13.32	13.56	0.75
Acute gain (mm)	1.13	1.33	1.43	<0.0001
Poststent analysis segment diameter stenosis	20.8%	19.4%	18.1%	0.02
9-month Angiographic Measures				
Late loss (mm), analysis segment	0.26	0.21	0.23	0.74
Binary restenosis, in-stent	11.1%*	3.5%	3.8%	0.06
Binary restenosis, analysis segment	13.9%†	5.9%	6.1%	0.10
1-year clinical outcomes				
Subacute thrombosis	1.1%	0.0%	0.7%	0.39
Target vessel revascularization	10.2%†	6.8%	5.4%	0.16
Major adverse cardiac events	14.9%*	10.4%	8.6%	0.11

*p <0.04 vs >16 atm.
†P = 0.06 vs >16 atm.

Kutcher MA et al. AJC 2004 TCT-462

Study Purpose

- Evaluate the incidence of suboptimal stent expansion with current drug SDS in long diffuse lesion.
- Evaluate effectiveness of post-stent adjuvant high-pressure non-compliant balloon dilatation.
- Identify the factors which was related with the suboptimal stent expansion.

SJ Tahk, MH Yoon, et al. CCT 2006

Study Population

- Inclusion Criteria
  - 37 consecutive angina patients, 41 de novo lesions
  - % DS on QCA >50% with evidence of myocardial ischemia
  - Stent length > 32mm
  - Informed consents for IVUS and FFR measurement.

- Exclusion Criteria
  - Restenotic lesion
  - Acute myocardial infarction or prior myocardial infarction
  - LV dysfunction: LVEF < 55%
  - Left main disease
  - Significant cardiac arrhythmia hampering physiologic study

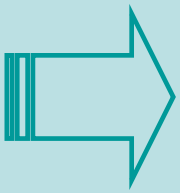
SJ Tahk, MH Yoon, et al. CCT 2006

Methods

Pre PCI

IVUS

FFR

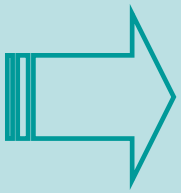


Stenting with SDS

(at RBP: 16-18 atm)

IVUS

FFR



Adjunctive High Pressure

(Quantum at 20-22 atm)

if Post Stent FFR<0.95

IVUS

FFR

Pressure measurement: RADI Medical System, Uppsala, Sweden

IVUS: 40MHz Atlantis™ SR Pro, Galaxy 2 Ultrasound Imaging System, Boston Scientific Corporation, Natick, MA, USA

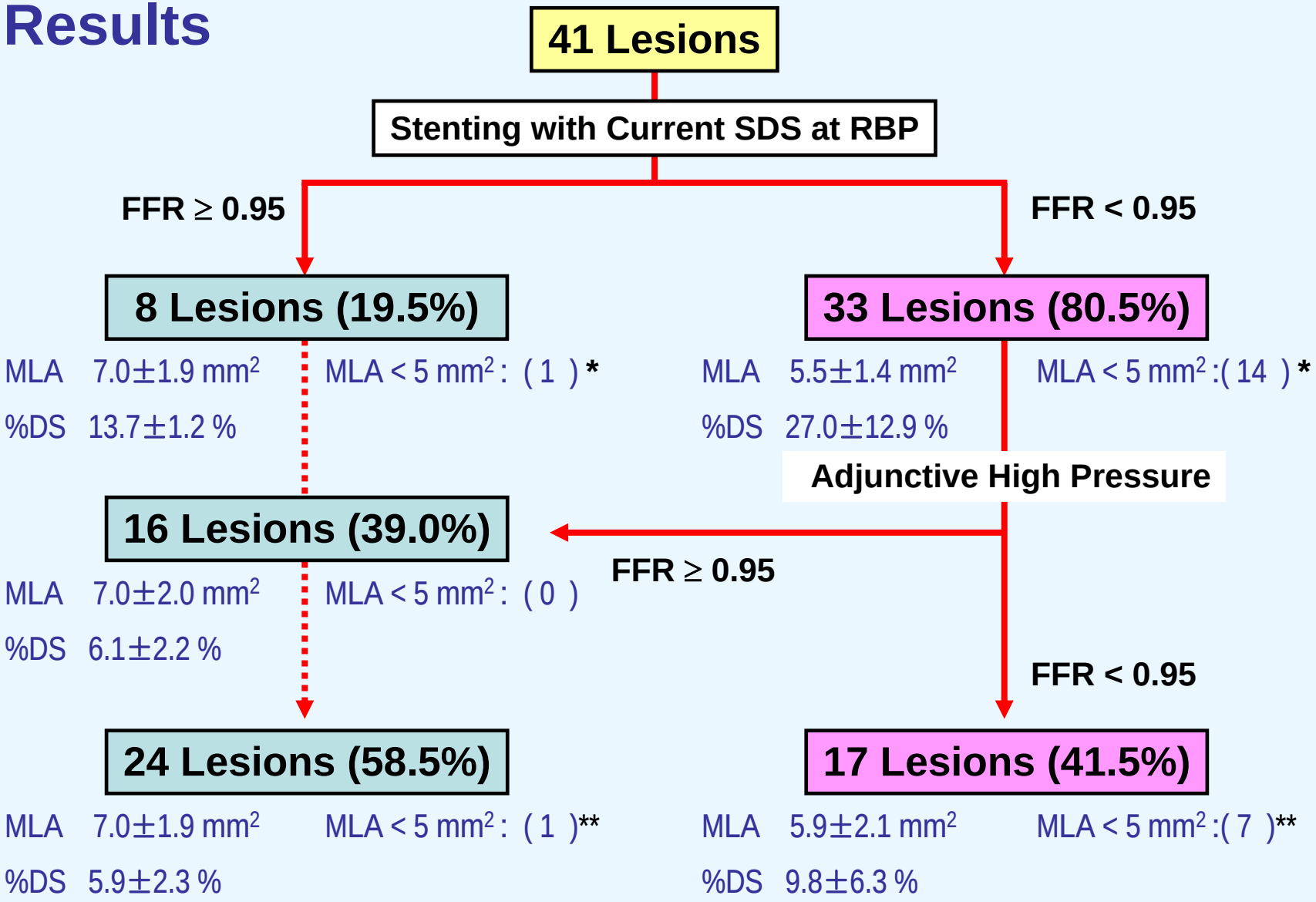
SJ Tahk, MH Yoon, et al. CCT 2006

Baseline Characteristics (n=37)

Age	61.4 ± 8.4
Gender (Male)	30 (81.1%)
Clinical Presentation	
Stable Angina	16 (43.2%)
Unstable Angina	21 (56.8%)
Coronary Risk Factors	
Hypertension	16 (43.2%)
Diabetes Mellitus	15 (40.5%)
Smoking	10 (27.0%)
Dyslipidemia	7 (18.9%)
Coronary Artery Studied (LAD/LCX/RCA)	30 / 2 / 9
Extent of CAD (1/2/3 VD)	21 / 9 / 11

SJ Tahk, MH Yoon, et al. CCT 2006

Results



*** 15/41 (36.5%) lesions could not reach MLA>5.0mm² on IVIS with SDS at RBP**

**** 8/41 (19.5%) lesions could not reach MLA>5.0mm² on IVIS with HP dilatation**

Angiographic and Procedural Findings

	Group A (FFR≥0.95, n=8)	Group B (FFR<0.95, n=33)	p Value
Pre-Stent			
MLD (mm)	0.57 ±0.11	0.59 ± 0.19	0.819
DS (%)	81.1 ± 4.5	81.5 ± 5.6	0.880
Post-Stent			
MLD (mm)	2.80 ± 0.46	2.32 ± 0.47	0.014
DS (%)	13.8 ± 12.1	27.0 ± 12.9	0.025
Reference Diameter (mm)			
Proximal	3.40 ±0.17	3.40 ±0.26	0.911
Distal	2.95 ±0.14	3.0 ±0.28	0.607
Lesion length (mm)	42.9 ±10.4	52.3 ±11.9	0.047
Stent number	1.75 ±0.46	2.0 ±0.56	0.250
Stent length (mm)	48.6 ± 58.7	58.7 ± 15.4	0.075

SJ Tahk, MH Yoon, et al. CCT 2006

IVUS Findings

	Group A (FFR≥0.95, n=8)	Group B (FFR<0.95, n=33)	p Value
Pre-stent			
MLA (mm^2)	2.44 ± 0.60	1.57 ± 0.56	0.001
AS (%)	74.2 ± 10.1	82.8 ± 6.0	0.007
Post-stent			
MLA (mm^2)	7.01 ± 1.89	5.53 ± 1.36	0.016
AS (%)	27.4 ± 12.8	38.9 ± 16.7	0.098
Ref Lumen Area(mm^2)	10.6 ±3.9	9.2 ±1.8	0.157
VA at Lesion(mm^2)	12.1 ±3.6	10.8 ±2.3	0.204
Plaque Burden	78.9 ±7.3	85.0 ±5.4	0.020
Ref Vessel Area (mm^2)	13.4 ± 4.6	13.4 ± 3.0	0.992
Remodeling Index	0.93 ±0.10	0.82 ±0.15	0.085

SJ Tahk, MH Yoon, et al. CCT 2006

IVUS Findings

	Group A (FFR≥0.95, n=8)	Group B (FFR<0.95, n=33)	p Value
Plaque Characteristics			0.115
Soft/Mixed	6(75%)	13(39.4%)	
Fibrous/Fibrocalcific	2(25%)	20(60.6%)	
Calcium Arc Grading	0.75 ±1.39	1.30 ±1.49	0.346
Eccentricity	0.24 ±0.18	0.17 ±0.16	0.334

SJ Tahk, MH Yoon, et al. CCT 2006

Independent Predictor for Suboptimal Stent Expansion

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.220	.599		2.038	.052
	L_LENGTH	.007	.006	.196	1.141	.264
	PLAQ_C	.055	.155	.065	.358	.723
	REMOD_IX	-.408	.486	-.138	-.839	.409
	MINLA	-.274	.110	-.435	-2.500	.019

a. Dependent Variable: G_95

SJ Tahk, MH Yoon, et al. CCT 2006

Summary

- After DES implantation with current SDS at RBP in long diffuse lesions;

  80.5% could not reached FFR $\geq$0.95, which was known as functionally successful result after BMS deployment.

  36.5% could not reached MLA>5.0mm^2, which was known as the smallest acceptable minimum stent area with DES.

- After high pressure ballooning with non-compliant balloon at 20-22 atm;

  41.5% and 19.5% of long diffuse lesions could not meet successful functional criteria (FFR $\geq$0.95) and IVUS criteria (MLA>5.0mm^2), respectively.

- Factors associated with suboptimal stent expansion with current SDS were lesion length, plaque burden, and minimal lumen area.

- Independent IVUS predictors for suboptimal stent expansion was minimal lumen area.

SJ Tahk, MH Yoon, et al. CCT 2006

Conclusion

- Routine adjunctive high-pressure ballooning might be required to achieve optimal functional and anatomic stent expansion, in number of long diffuse coronary stenoses.

- FFR and IVUS-guided PCI could potentially improve the procedural precision and decrease the rate of target vessel failure in DES era. However, the role of physiologic and IVUS study in DES era needs more randomized trials.

- Do not forget old lessons even in DES era.

Optimal DES Implantation in Long Diffuse Lesion

- Appropriate lesion preparation
- Adjunctive High Pressure Dilatation with Non Compliant HP Balloon

Thank You for Attention