



Virtual Histology Observations after Stent Implantation: Plaque Components responsible for Stent Underexpansion and Plaque Shift

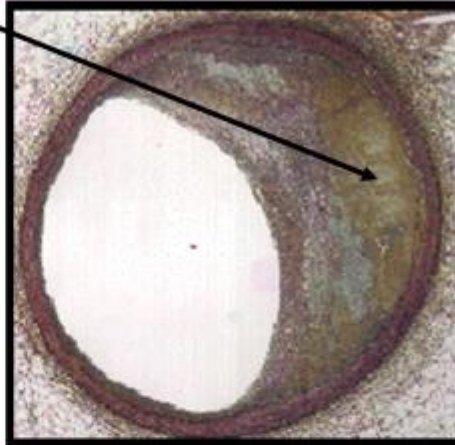
Chung-Ang University Hospital, Seoul, Korea*
Cardiovascular Research Foundation, NY**, USA
Washington Hospital Center, DC, USA

Sang-Wook Kim*, Gary S. Mintz**, Lowell F. Satler,
Kenneth M. Kent, William O. Suddath, Augusto D. Pichard,
Ron Waksman, Neil J. Weissman.

VH™ IVUS Plaque Composition

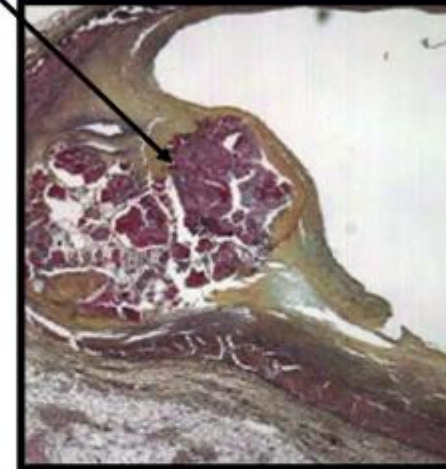
Fibrous

Densely packed bundles of collagen fibers with no evidence of intra-fiber lipid accumulation. No evidence of macrophage infiltration. Appears dark yellow on Movat stained section.



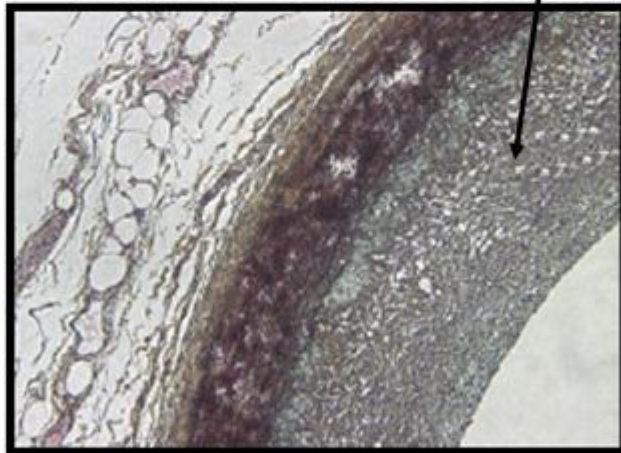
Necrotic Core

Highly lipidic necrotic region with remnants of foam cells and dead lymphocytes present. No collagen fibers are visible and mechanical integrity is poor. Cholesterol clefts and micro calcifications are visible.



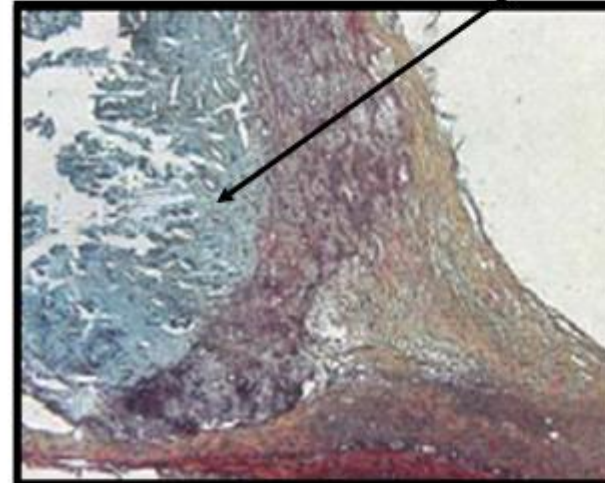
Fibro-Fatty

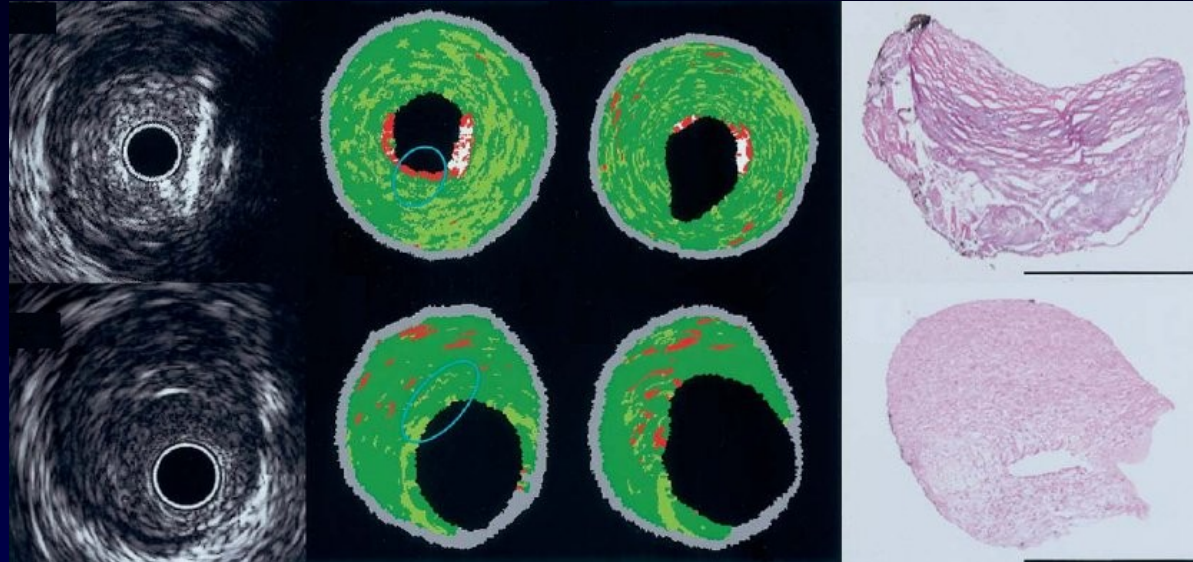
Loosely packed bundles of collagen fibers with regions of lipid deposition present. These areas are cellular and no cholesterol clefts or necrosis are present. Some macrophage infiltration. Increase in extracellular matrix. Appears turquoise on Movat stained section.



Dense Calcium

Focal area of dense calcium. Appears purple on Movat. Usually falls out of section, but calcium crystals are evident at borders.





Predictive Accuracy

	Total (n=307)	Stable AP (n=144)	ACS (n=163)
Fibrous	87.1	85.6	86.6
Fibro-fatty	87.1	85.5	88.6
Necrotic core	88.3	88.9	87.5
Dense Calcium	96.5	97.2	96.1

(Nasu et al, JACC 2006;47:2405-12)

Background

- ♣ Plaque redistribution is one of main mechanism of lumen enlargement after percutaneous coronary intervention.

(Mintz et al, Am J Cardiol. 1996;77:427-30, Maehara et al, Am J Cardiol. 2000;86:1069 -72. Dudek et al, Am J Cardiol. 2002;90:639-41, Ahmed et al. Circulation 2000;102:7-10).

Plaque shift may impact on acute complications and long-term events.

- ♣ Stent underexpansion ($MSA < 5.0 \text{ mm}^2$) is responsible for the majority of Silorimus-eluting stent (SES) restenosis. *(Sonoda et al, J Am*

Coll Cardiol. 2004;43:1959-63). The importance of adequate drug-eluting stent (DES) expansion was confirmed in both treatment of bare metal stent restenosis and de novo DES implantation. *(Fujii et al, Circulation. 2004;109:1085-8 , Kim et al, AJC 2006; 97:1292-8)*

- ♣ Evaluate the plaque components responsible for plaque shift and stent underexpansion during drug-eluting stent implantation

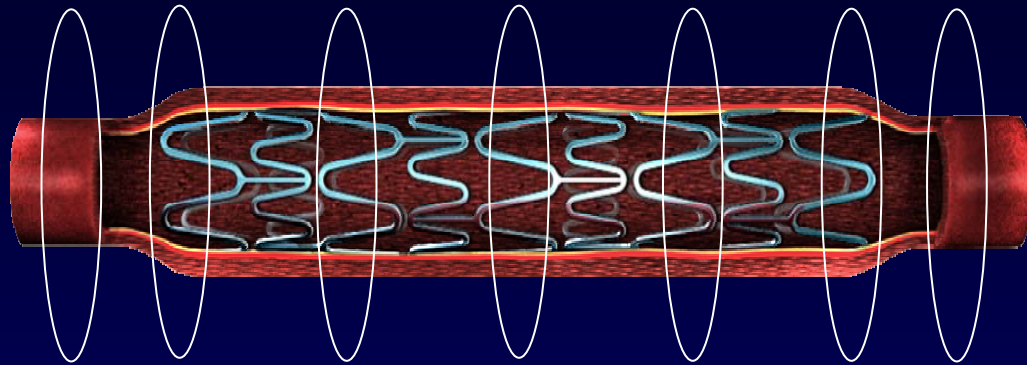
Methods

♣ 27 pts had 30 lesions that were amenable to VH-IVUS analysis before and after DES implantation.

- Cypher stent (Cordis) in 22 cases and Taxus stent (BSC) in 8 cases
- High-pressure stent deployment (>14 atm) was performed in all pts
- Bifurcation lesions, ostial lesions, saphenous vein grafts, pre-stent debulking, and arteries with previous stent placement were excluded.

♣ VH-IVUS system: Volcano Corporation

VH-IVUS Analysis I

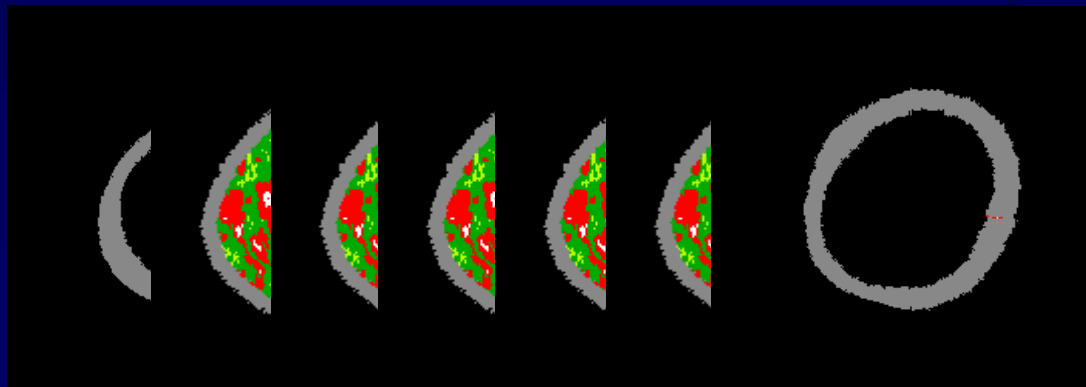


→ Measured Parameters

- Vessel area
- Stent area
- Lumen area

→ VH Parameters

- Fibrous area
- Fibro-fatty area
- Dense calcium area
- Necrotic core area



VH IVUS Analysis II

- ♣ Reproducible landmarks (usually the aorto-ostial junction, a large proximal side branch, and/or reference segment calcific deposits) were used as axial reference points.
- ♣ Remodeling index = lesion/reference external elastic membrane [EEM] area
- ♣ DES underexpansion = minimum stent area [MSA] < 5mm²
Well-expanded stent (n= 121), underexpanded stent (n= 27)
- ♣ Stent struts and their artifacts were excluded since these have not been validated for VH-IVUS analysis.

Baseline Characteristics I

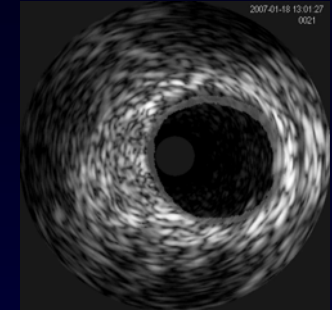
Age (years)	62.7±11.9
Male gender, n(%)	18 (60)
Risk factors, n(%)	
Diabetes mellitus	5 (17)
Hypertension	22 (73)
Current smoker	7 (23)
Hypercholesterolemia	29 (96)
Family history of coronary disease, n(%)	14 (46)
Stable angina, n(%)	14 (47)
Unstable angina, n(%)	14 (47)
Acute MI, n(%)	2 (7)

Baseline Characteristics II

	MSA >5 mm ²	MSA <5 mm ²	P-value
Age (years)	62.5±12.7	62.9±11.0	0.9
Male gender, n	11	8	0.588
Risk factors, n			
Diabetes mellitus	2	3	0.3
Hypertension	13	9	0.604
Current smoker	7	4	0.478
Hypercholesterolemia	17	12	0.6
Family history of coronary disease	10	4	0.206
Stable angina, n	9	5	0.407
Unstable angina, n	7	7	
Acute MI, n	2	0	

Angiographic Characteristics

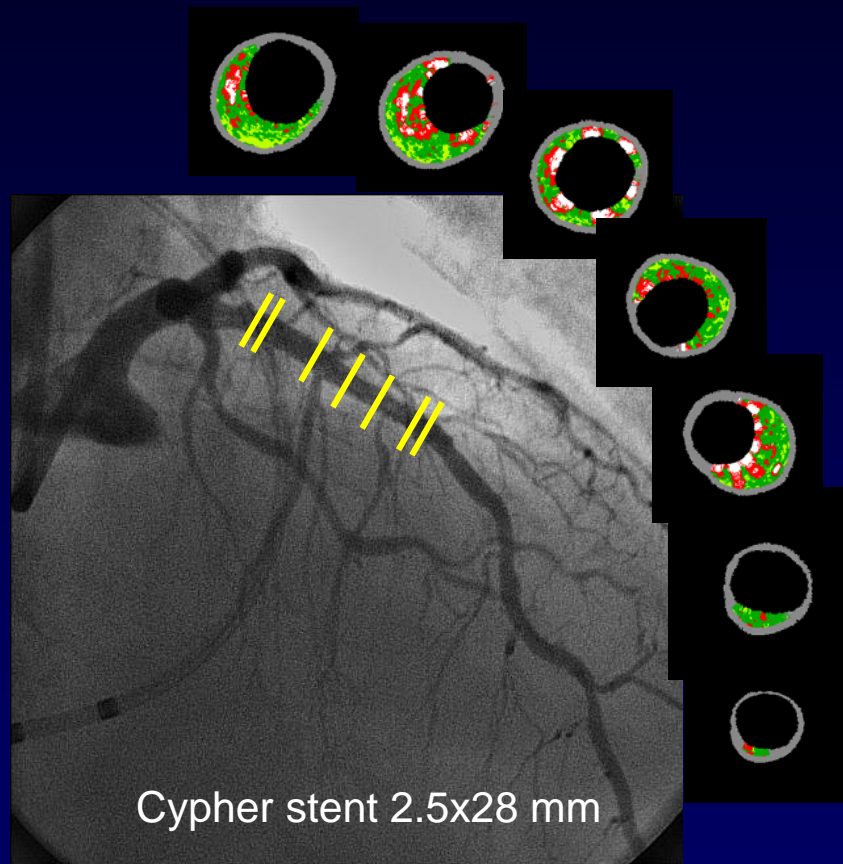
	MSA >5 mm ²	MSA <5 mm ²	P-value
Vessel treated			
LAD/RCA/LCX	13/5/0	6/4/2	0.038
Diseased vessel			
1 / 2 / 3	8/8/2	4/6/2	0.512
Lesion morphology, n			
A/B1/B2/C	9/4/1/4	8/3/0/1	0.55
Minimal lumen diameter (mm)	1.08±0.40	0.71±0.26	0.004
Lesion length (mm)	12.4±5.0	10.4±5.8	0.36
Reference vessel diameter (mm)	3.09±0.38	2.51±0.44	0.001
Diameter stenosis (%)	64±9.8	71±10.1	0.8
Final balloon size (mm)	3.55±0.32	3.23±0.29	0.009
Maximal balloon pressure (atm)	16.36±2.33	17.00±1.09	0.462



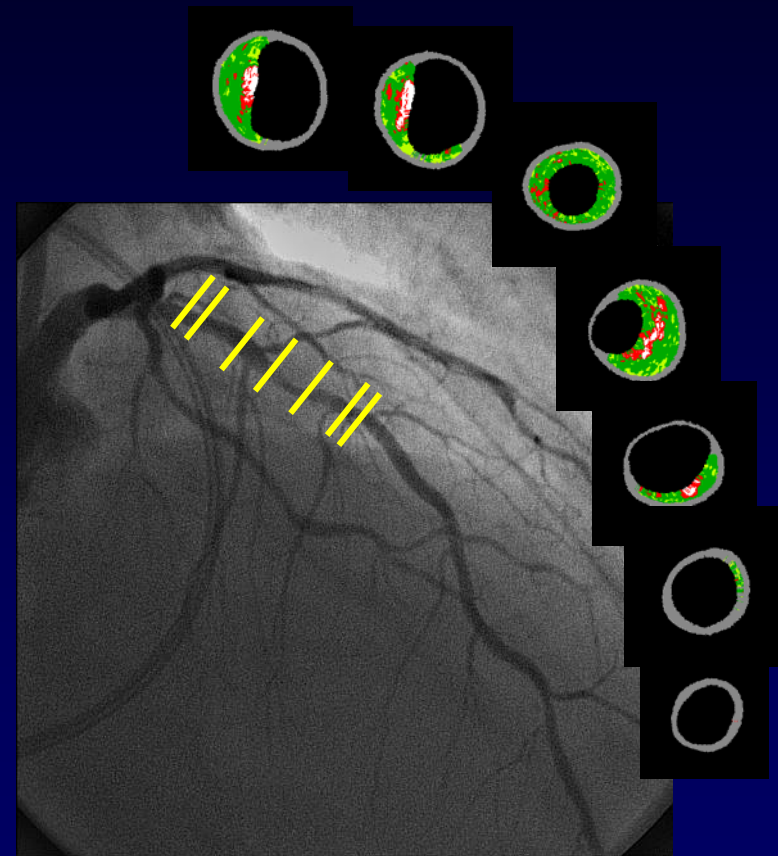
♣ Plaque Shift

♣ Stent underexpansion

VH IVUS (plaque shift)



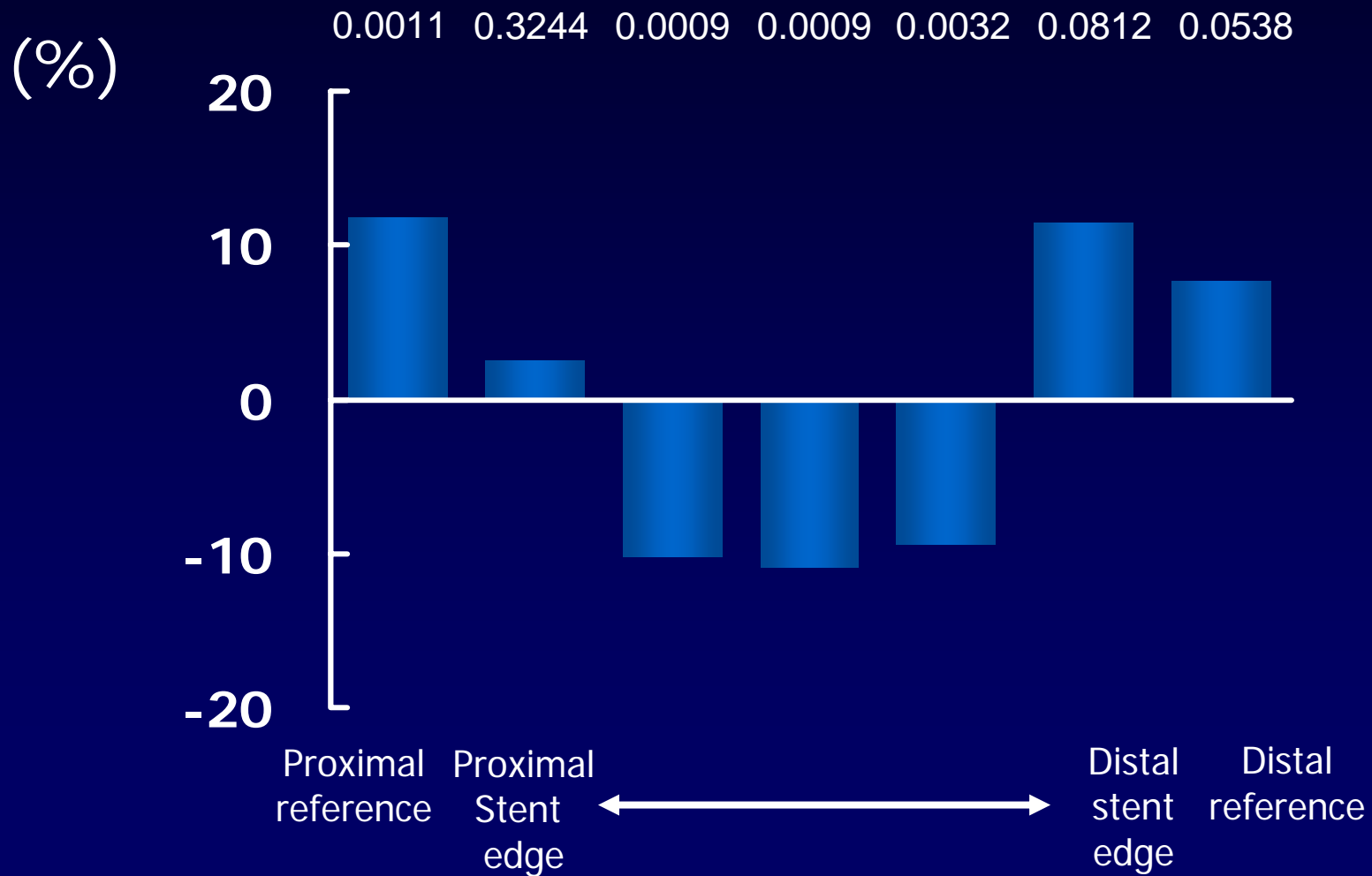
Post-stent



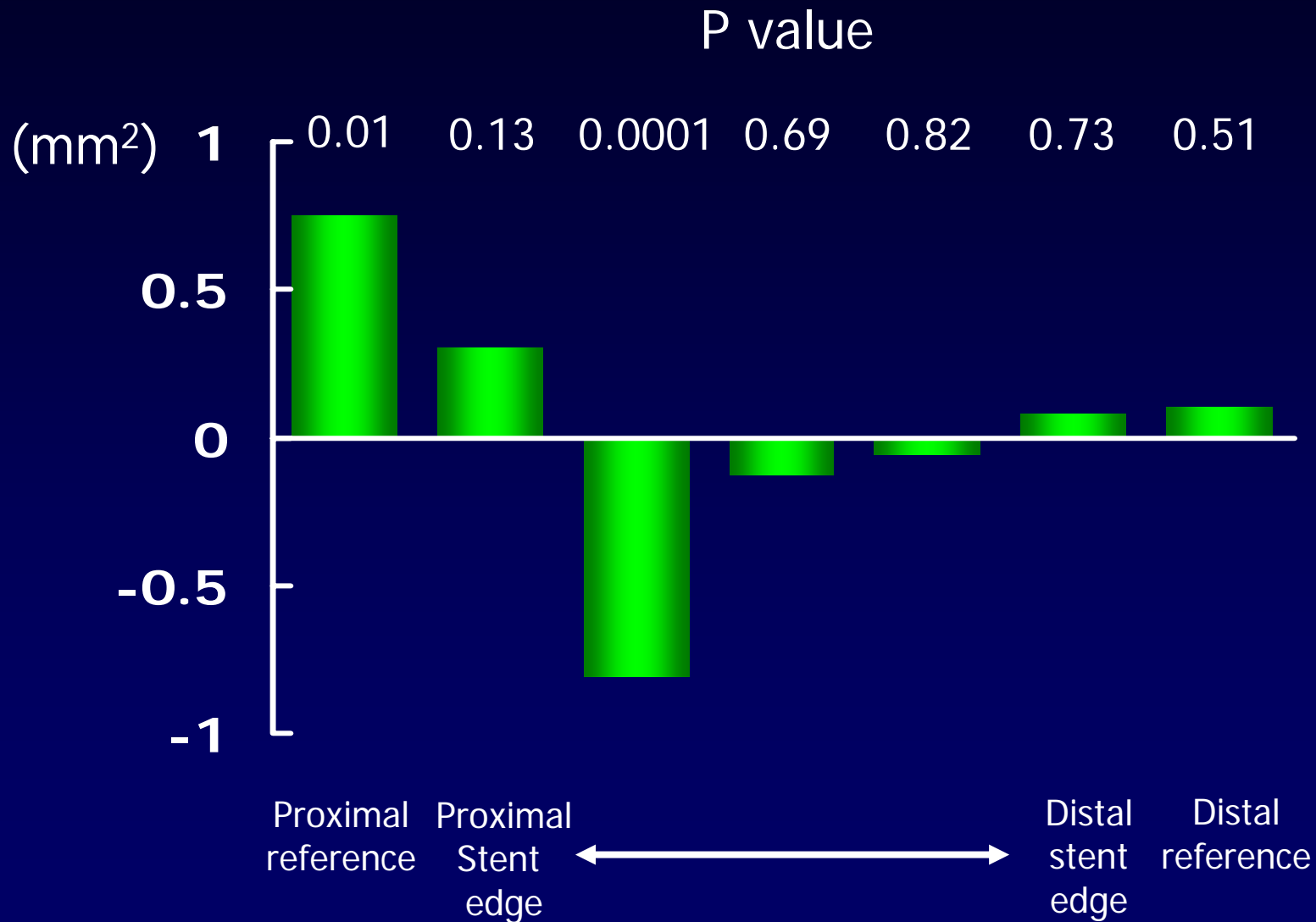
Pre-stent

% Changes in Plaque Area

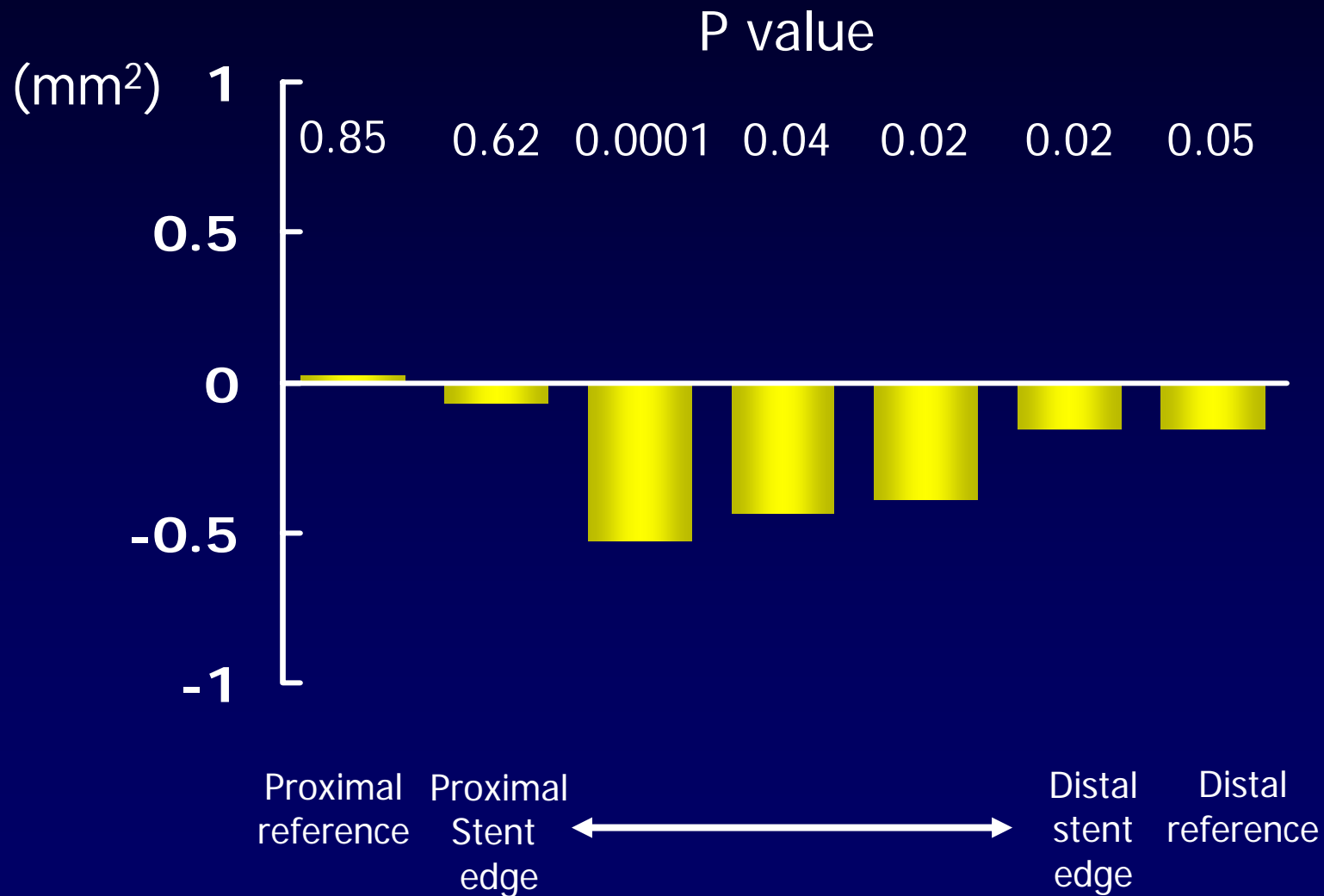
P value



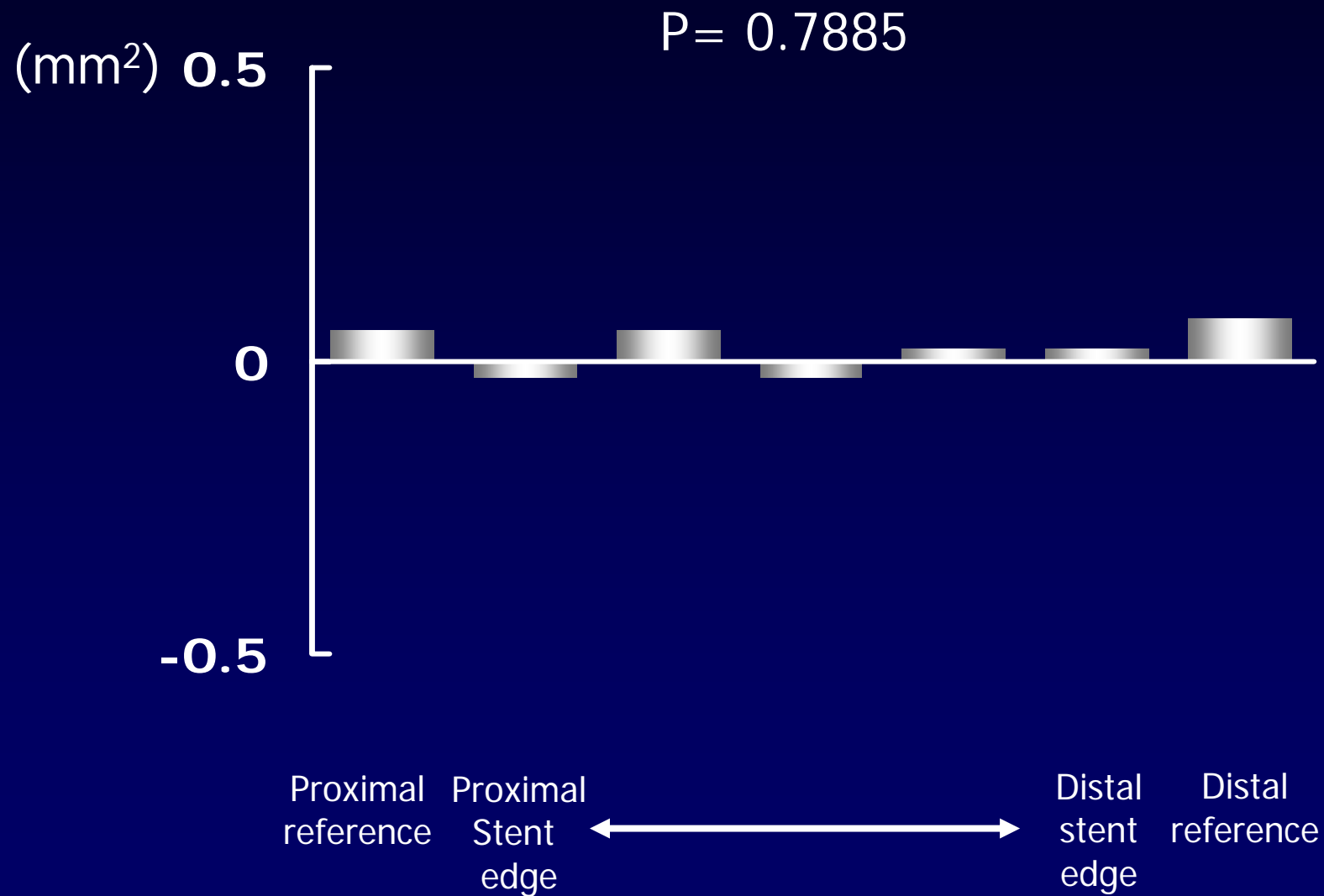
Changes in Fibrous Plaque Area



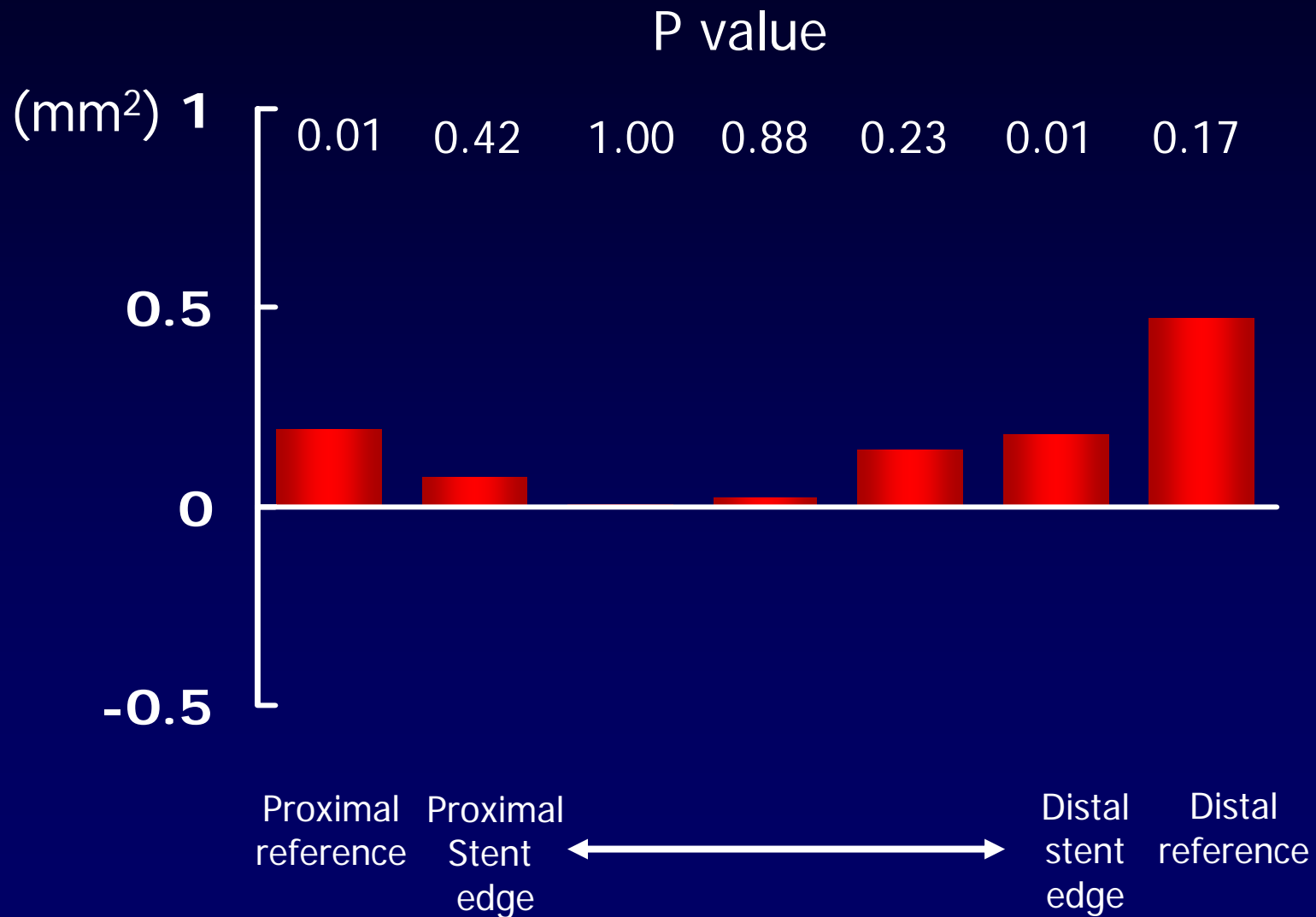
Changes in Fibro-fatty Plaque Area

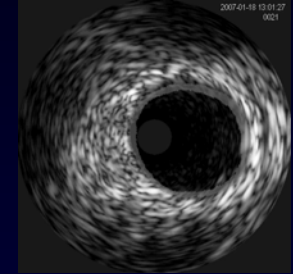


Changes in Dense Calcium Area



Changes in Necrotic Core Area

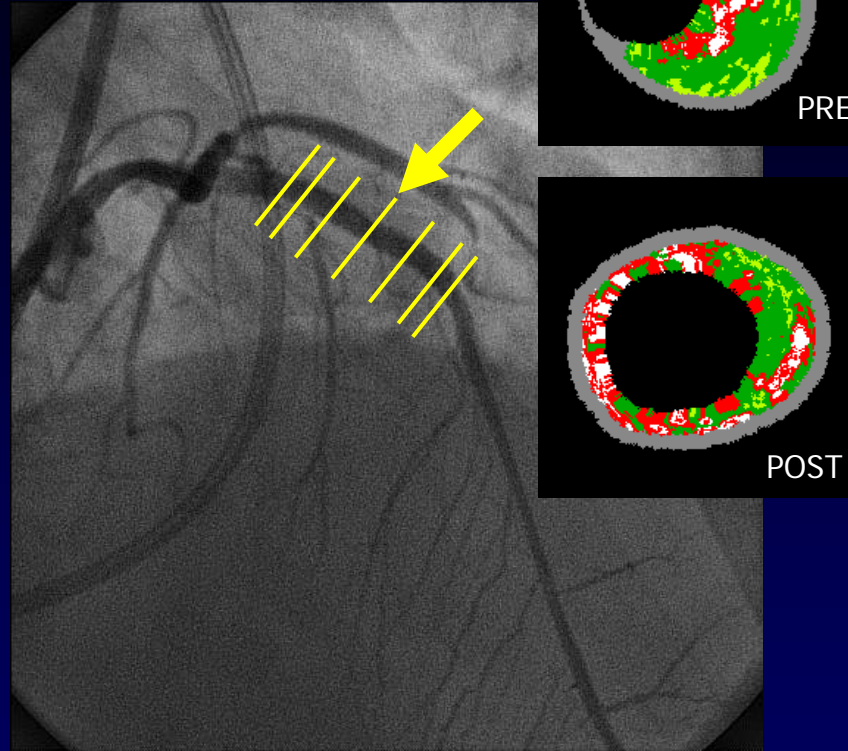




♣ Plaque shift

♣ Stent Underexpansion

Underexpanded



Taxus stent 2.75x24 mm

Minimum stent area: 3.8 mm²

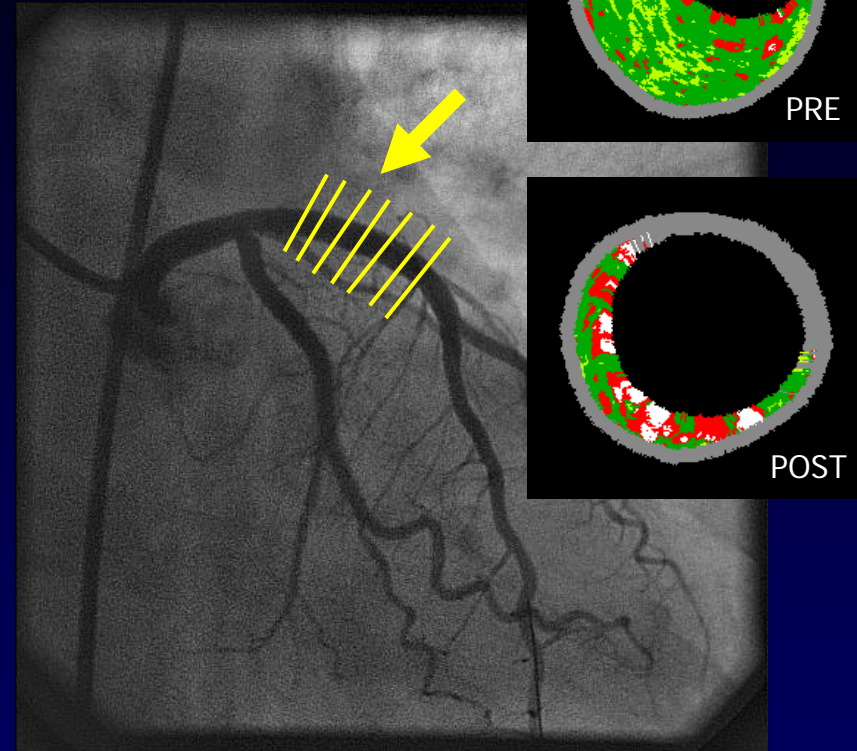
Fibrous area: 6.6 mm² (54 %)

Fibro-fatty area: 0.6 mm² (5 %)

Dense calcium area: 2.0 mm² (17 %)

Necrotic core area: 3.0 mm² (24 %)

Well-expanded



Cypher stent 3.5x13 mm

Minimum stent area: 7.3 mm²

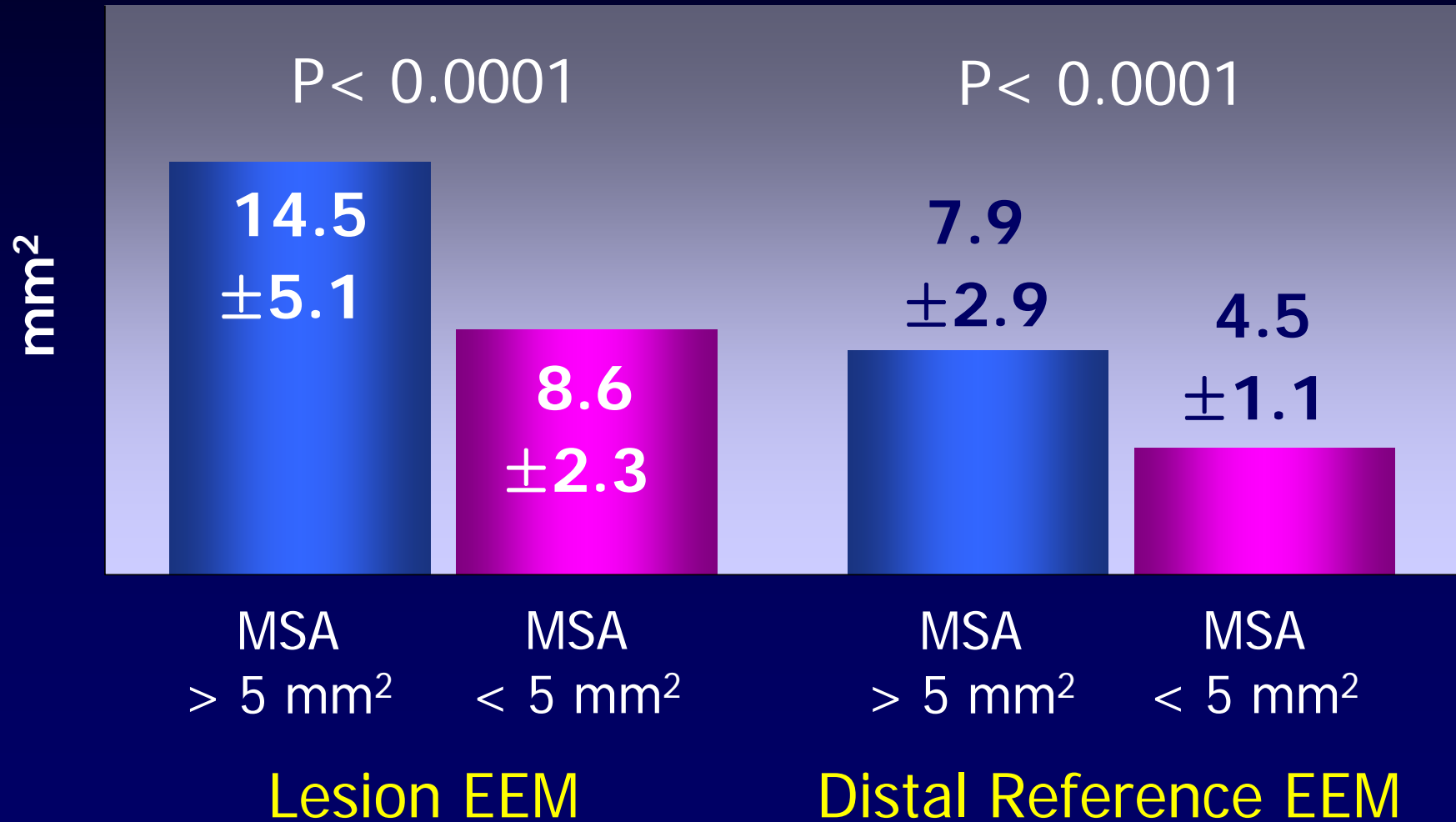
Fibrous area: 7.2 mm² (72 %)

Fibro-fatty area: 1.6 mm² (16 %)

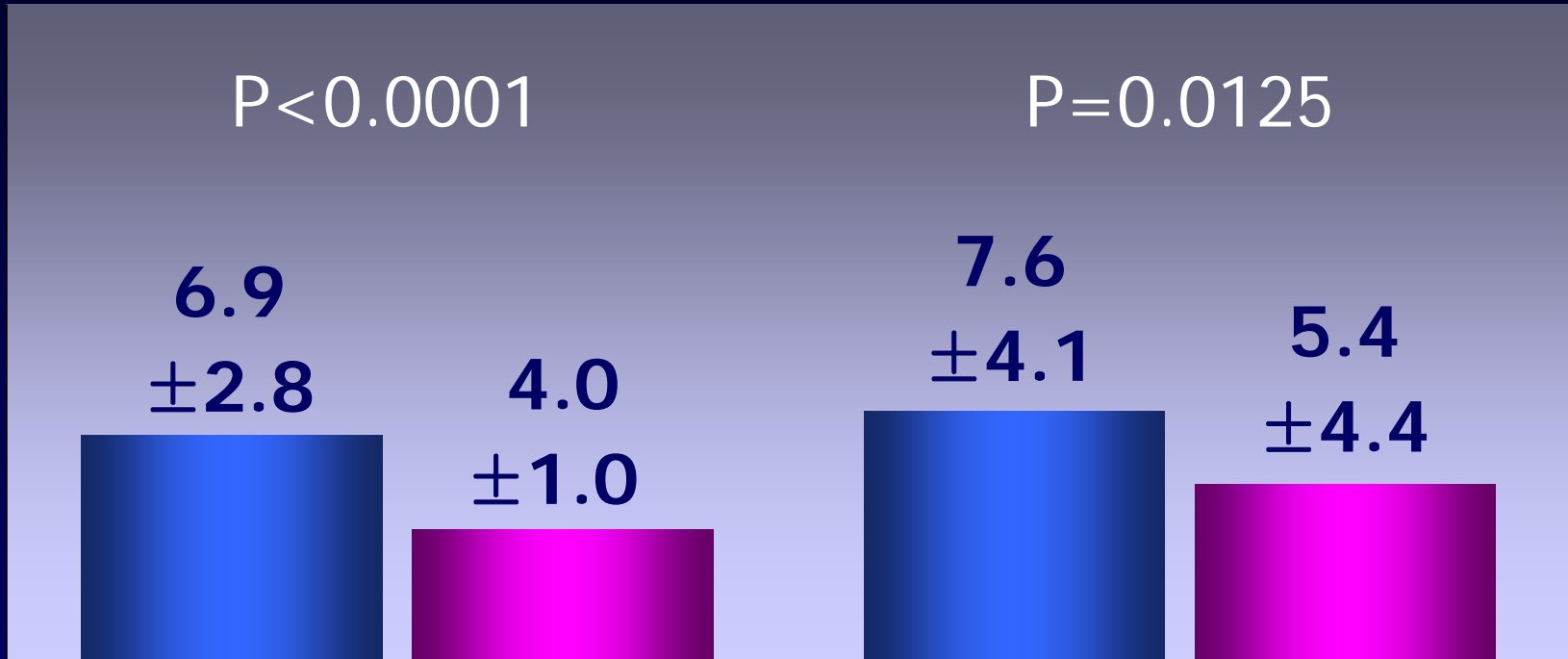
Dense calcium area: 0.0 mm² (0 %)

Necrotic core area: 1.1 mm² (11 %)

IVUS findings at the time of DES

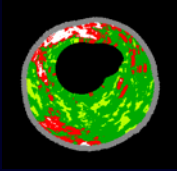


mm²



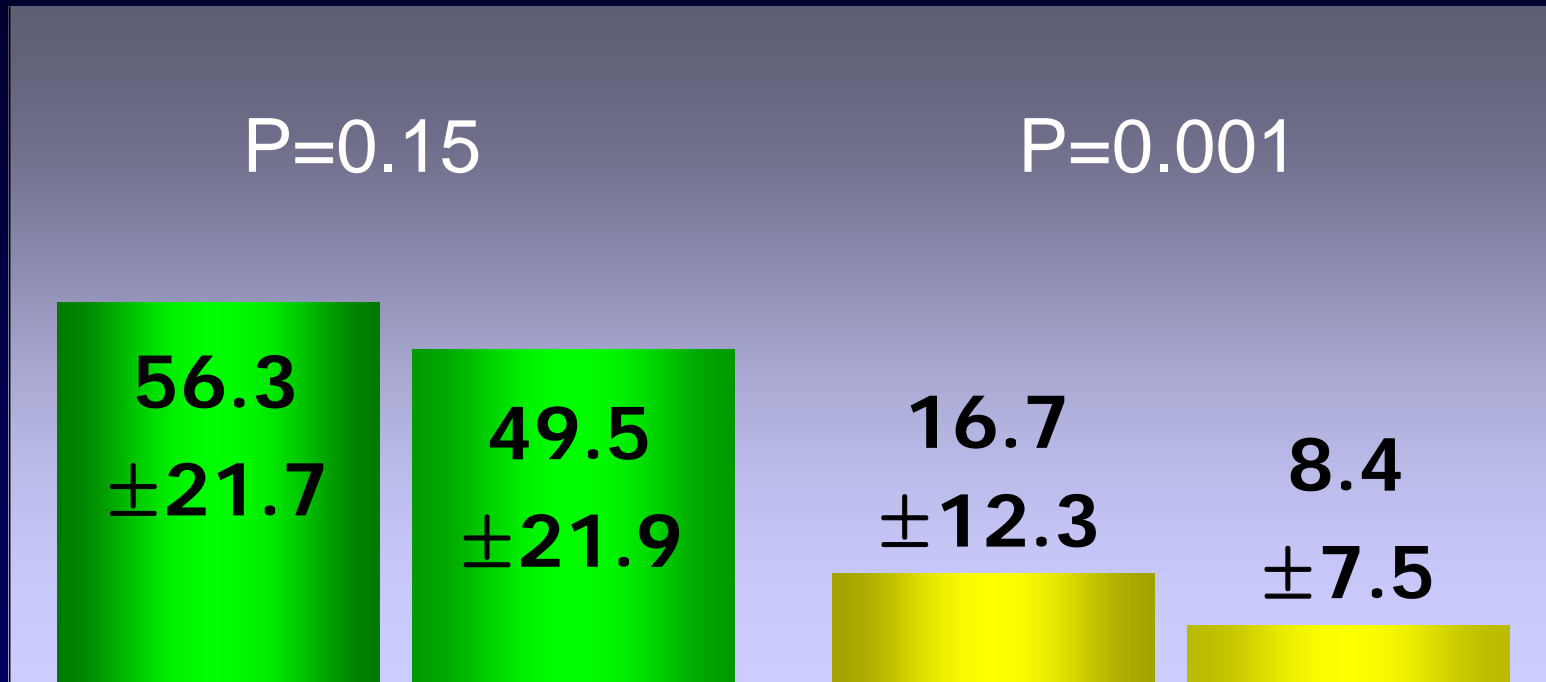
MSA > 5 mm² MSA < 5 mm²
Average Stent Area

MSA > 5 mm² MSA < 5 mm²
Plaque Area



VH-IVUS

(%)



MSA
> 5 mm²

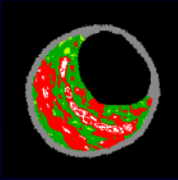
MSA
< 5 mm²

MSA
> 5 mm²

MSA
< 5 mm²

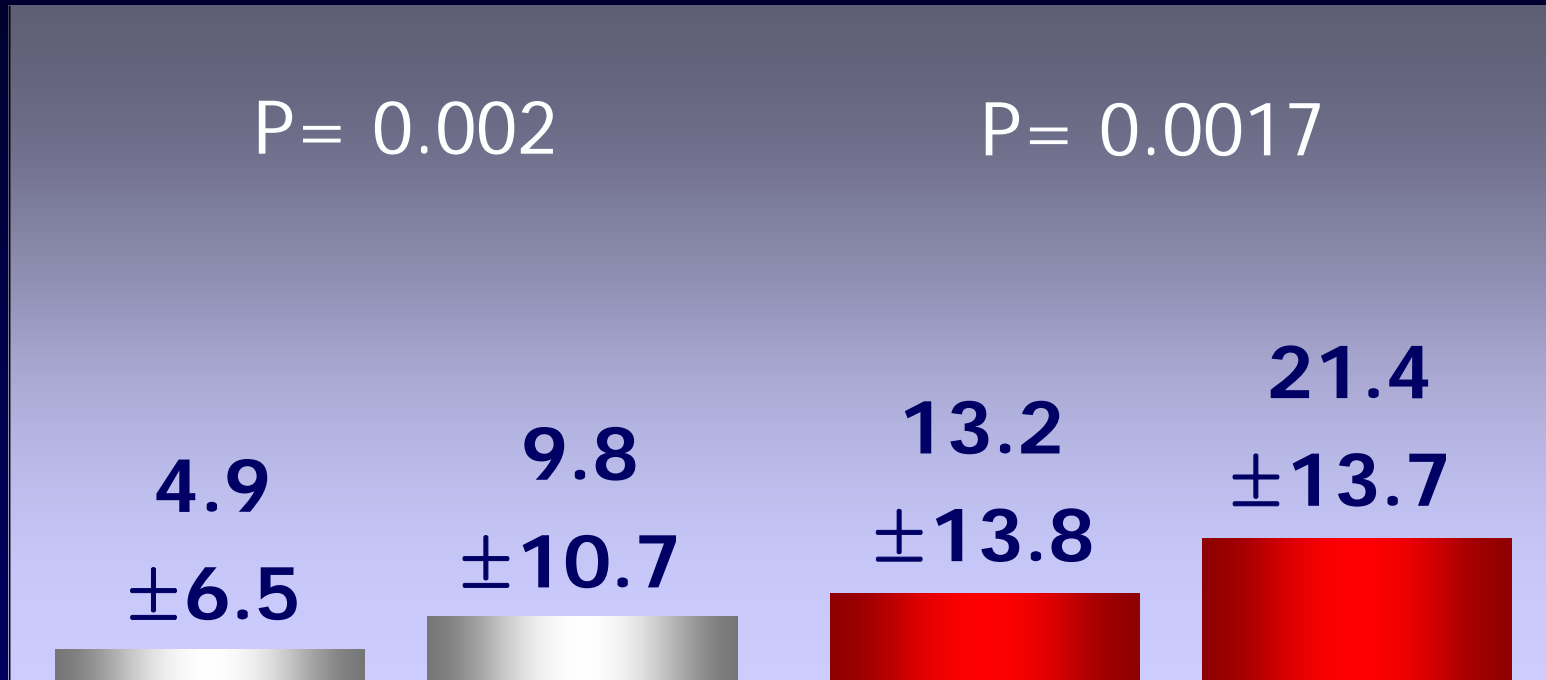
Fibrotic plaque area

Fibro-fatty plaque area



VH-IVUS

(%)



MSA
> 5 mm²

MSA
< 5 mm²

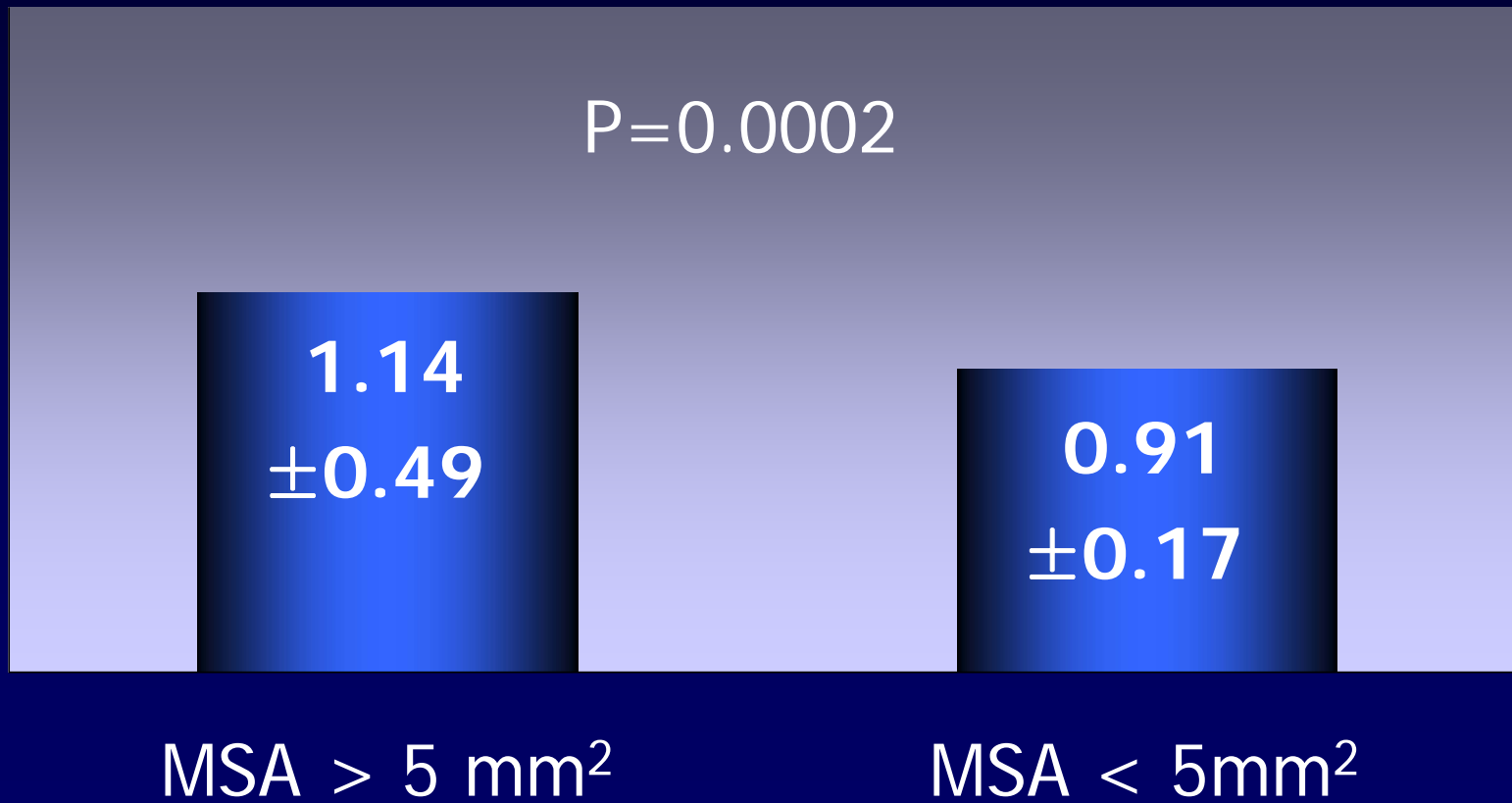
MSA
> 5 mm²

MSA
< 5 mm²

Dense calcium area

Necrotic core area

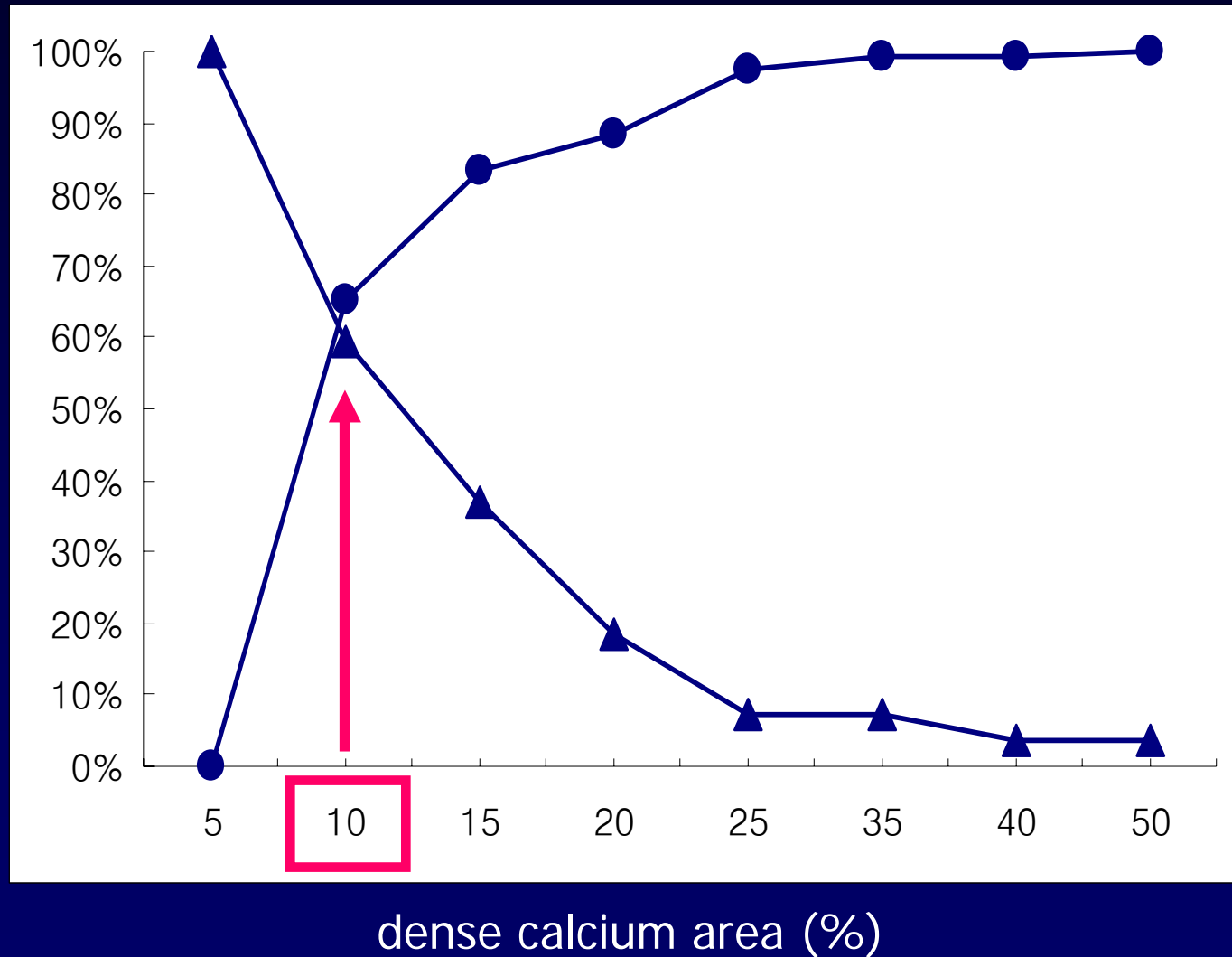
Remodeling index



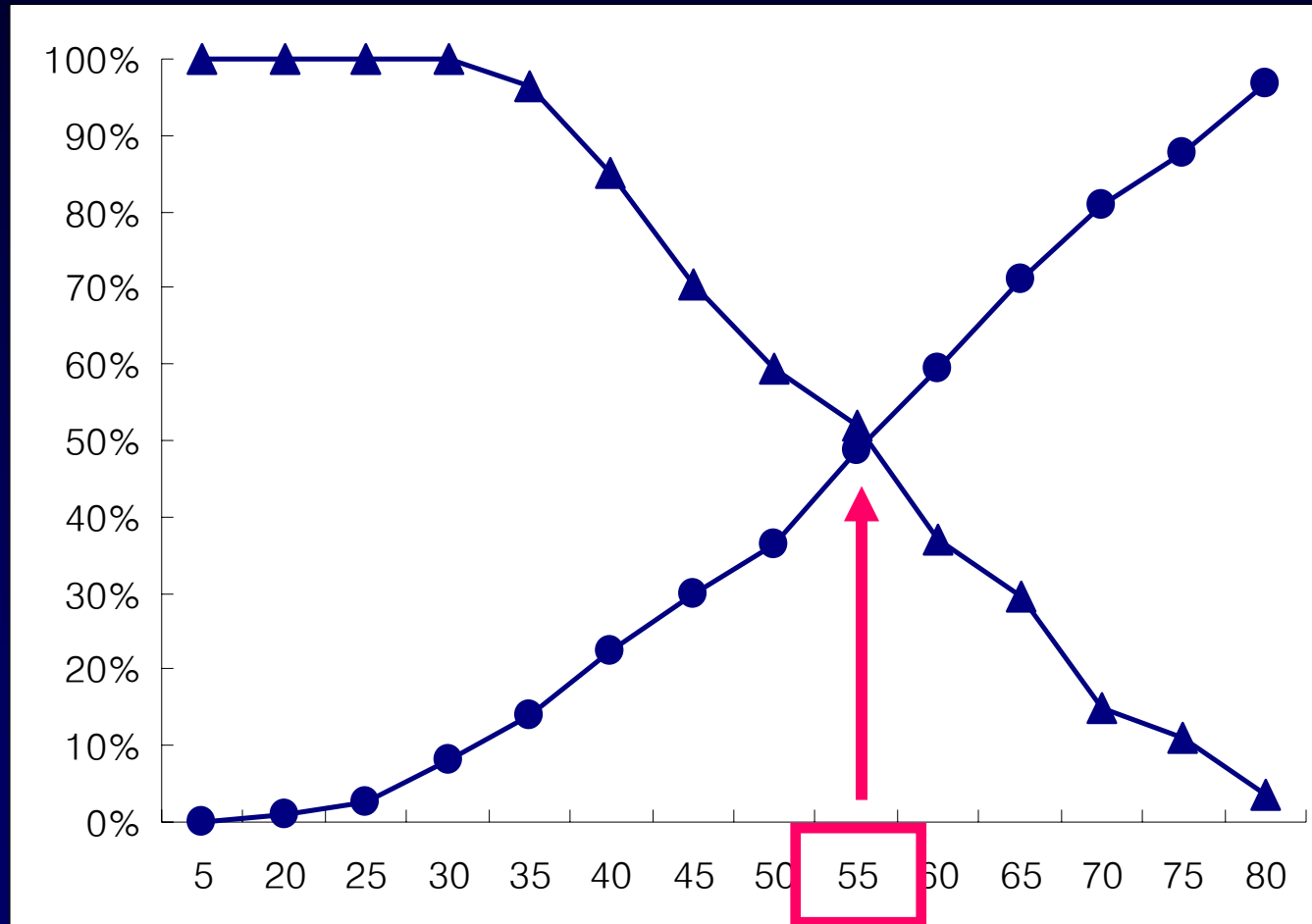
Independent predictors of stent underexpansion by multivariate analysis

	Partial OR	95% C.I.	P-value	Standardized Beta
Distal reference EEM	0.728	0.561-0.946	0.018	-1.0448
Lesion length	0.962	0.872-1.063	0.449	-0.2014
Plaque burden	1.104	1.015-1.199	0.020	0.8642
Remodeling	0.053	0.001-2.253	0.125	-0.6905
Fibrous (%)	0.996	0.958-1.035	0.839	-0.0448
Fibro-fatty (%)	0.887	0.736-1.068	0.205	-0.8122
Dense calcium (%)	1.112	0.986-1.254	0.083	0.3759
Necrotic (%)	0.996	0.928-1.068	0.901	-0.0304

Sensitivity and Specificity Curve identified Optimal Threshold
of Dense Calcium area(%) to predict DES underexpansion (MSA<5 mm²)

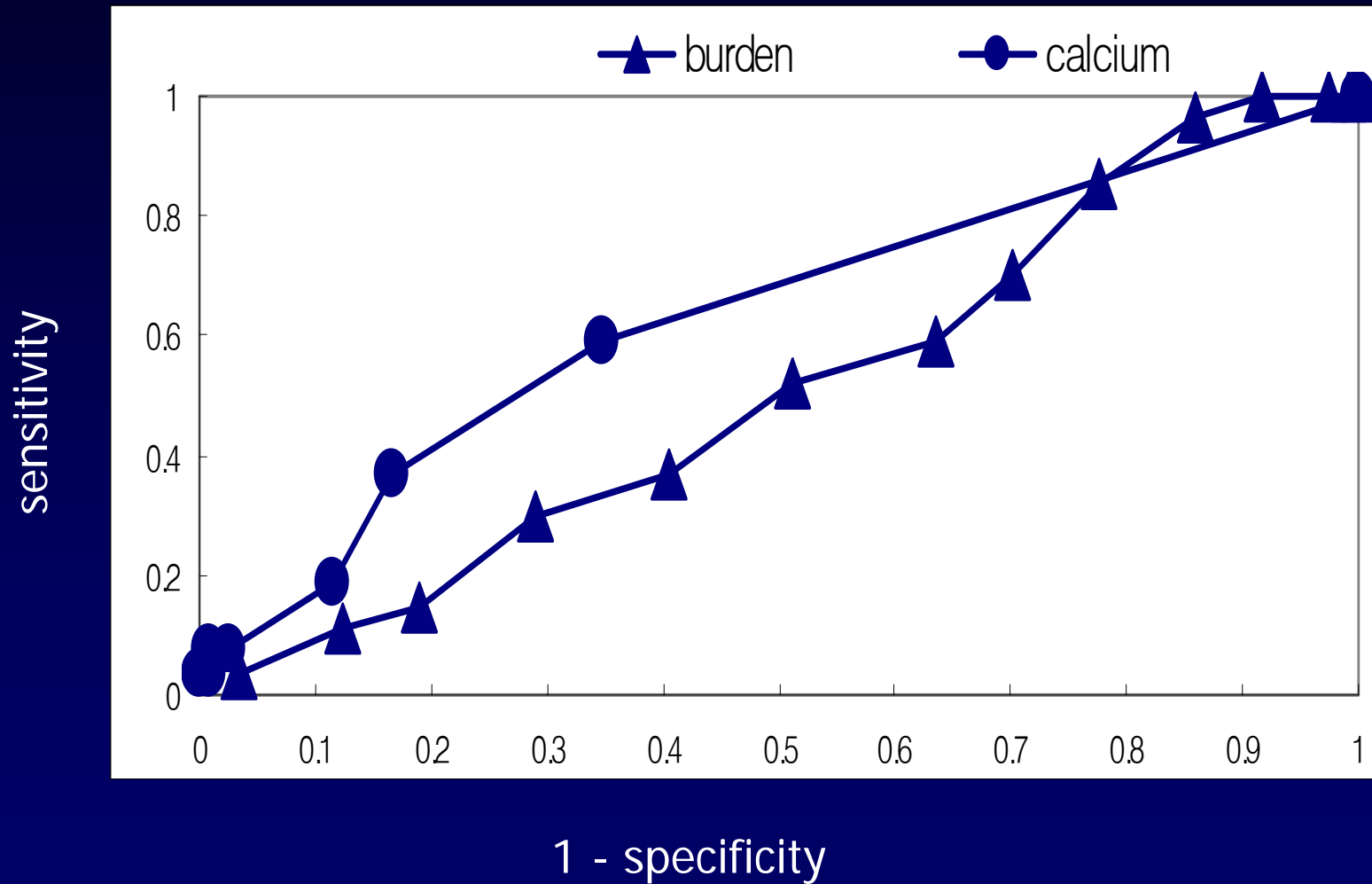


Sensitivity and Specificity curve identified Optimal Threshold of Plaque Burden (%) to predict DES underexpansion ($MSA < 5 \text{ mm}^2$)



Plaque burden (%)

ROC curves showed comparison of the diagnostic value between dense calcium area (%) and plaque burden(%)



Summary

- ♣ Stent implantation is associated with redistribution (extrusion) of the necrotic core out of the stent proximally and distally. This may impact on acute complications and long-term coronary events.
- ♣ In vivo VH-IVUS analysis indicates that stent underexpansion occurs especially at the site of increased amounts of dense calcium and larger plaque burden.