

OCT in stented vessel

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Contents

- **Strut coverage:**
 - **apposed vs. malapposed**
 - **covered vs. uncovered**
- **Evaluation of neointima**

Traditional OCT image analysis

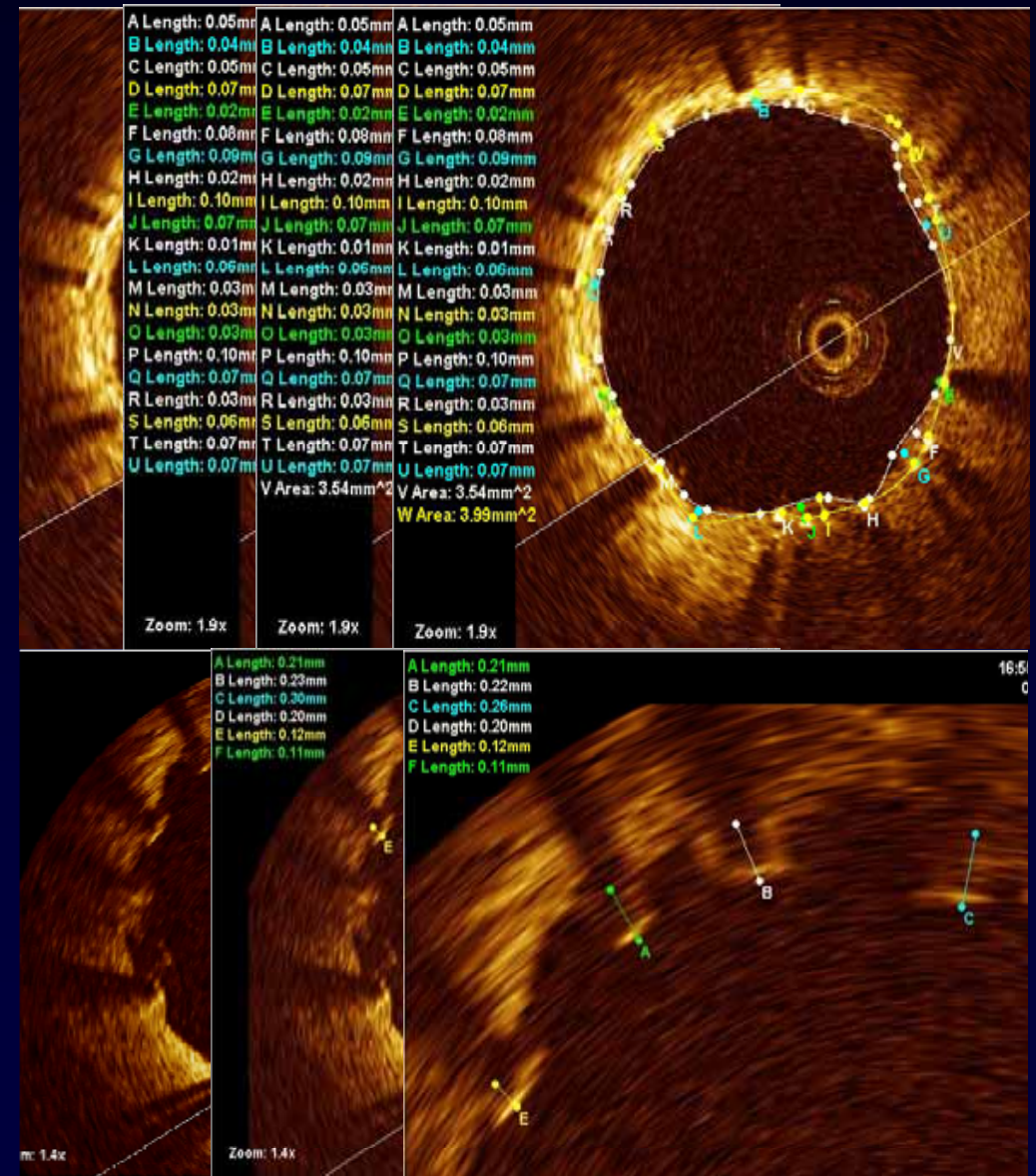
Analysis of cross-sectional OCT images at a 1-mm interval (every 15 frames).

1. Neointimal thickness

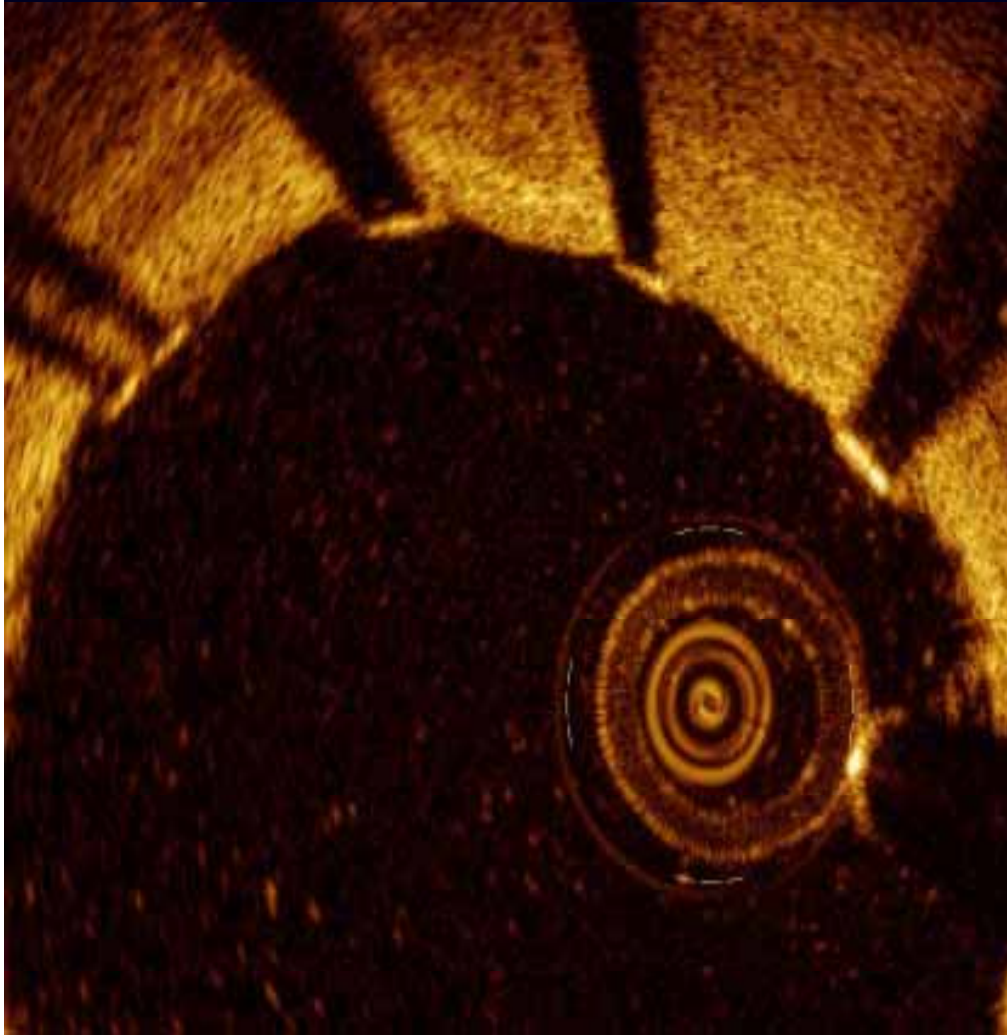
The distances between the endoluminal surface of neointimal and the strut reflection

2. Stent apposition

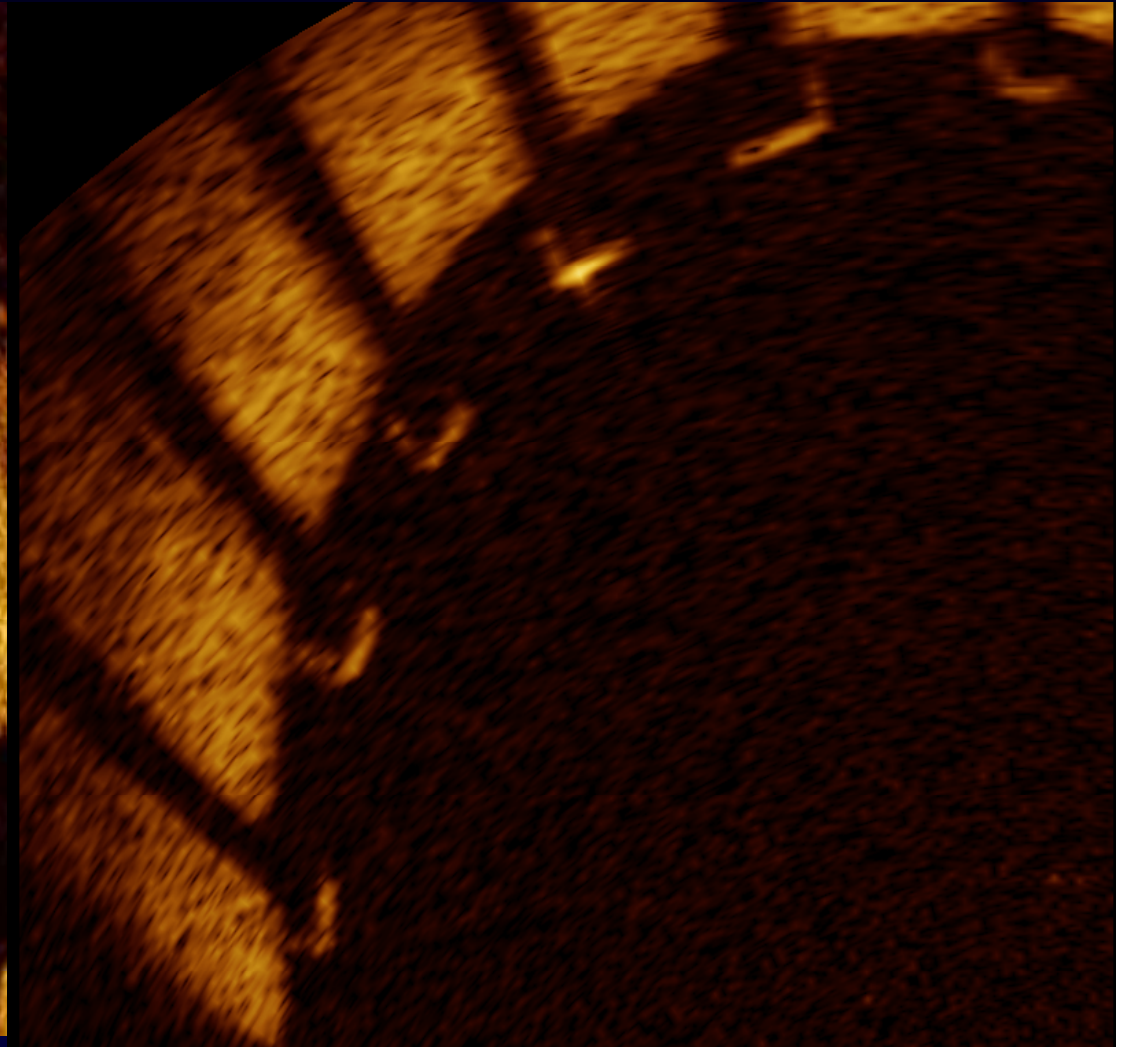
The distances between the endoluminal surface of the strut reflection and the vessel wall



Post-stent struts

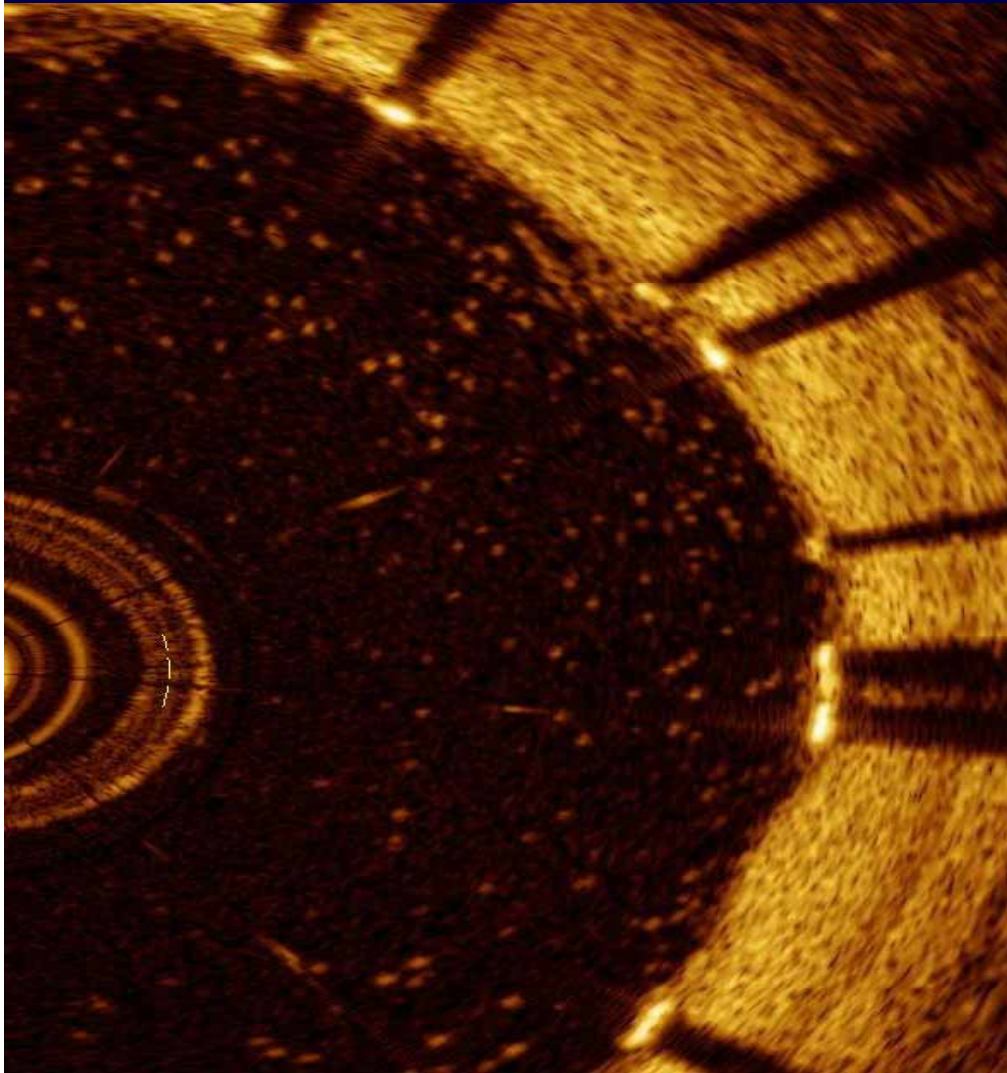


Well apposed

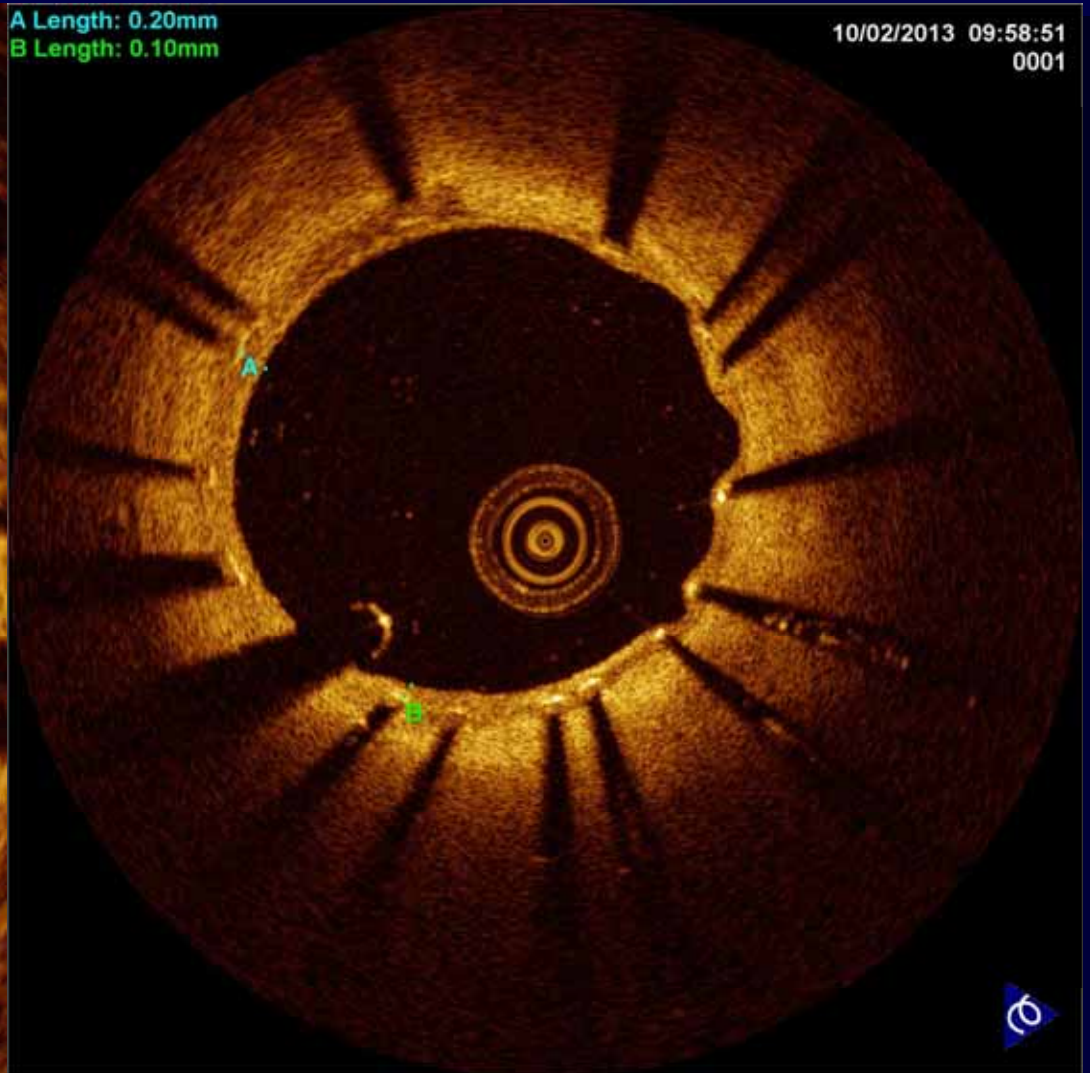


Malapposed

Follow-up apposed struts

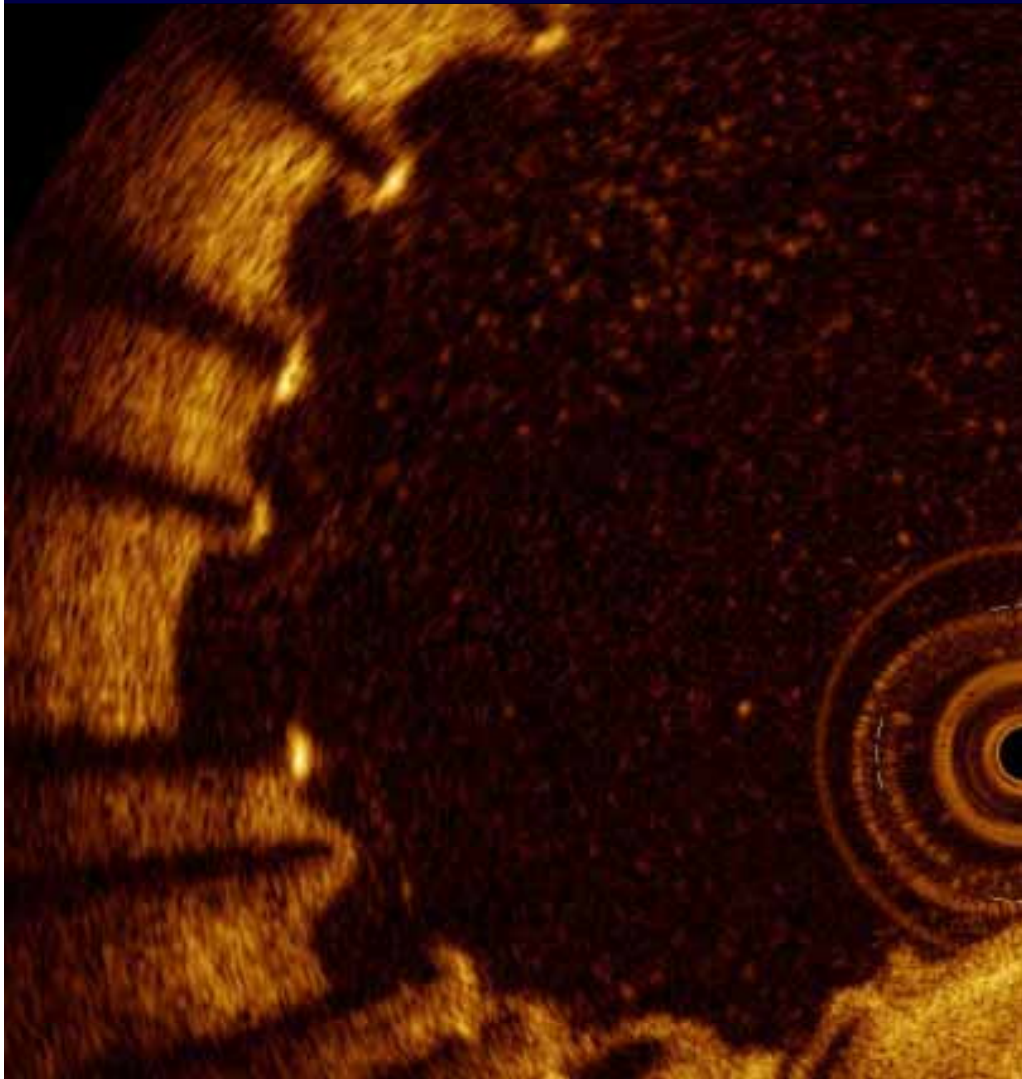


Uncovered

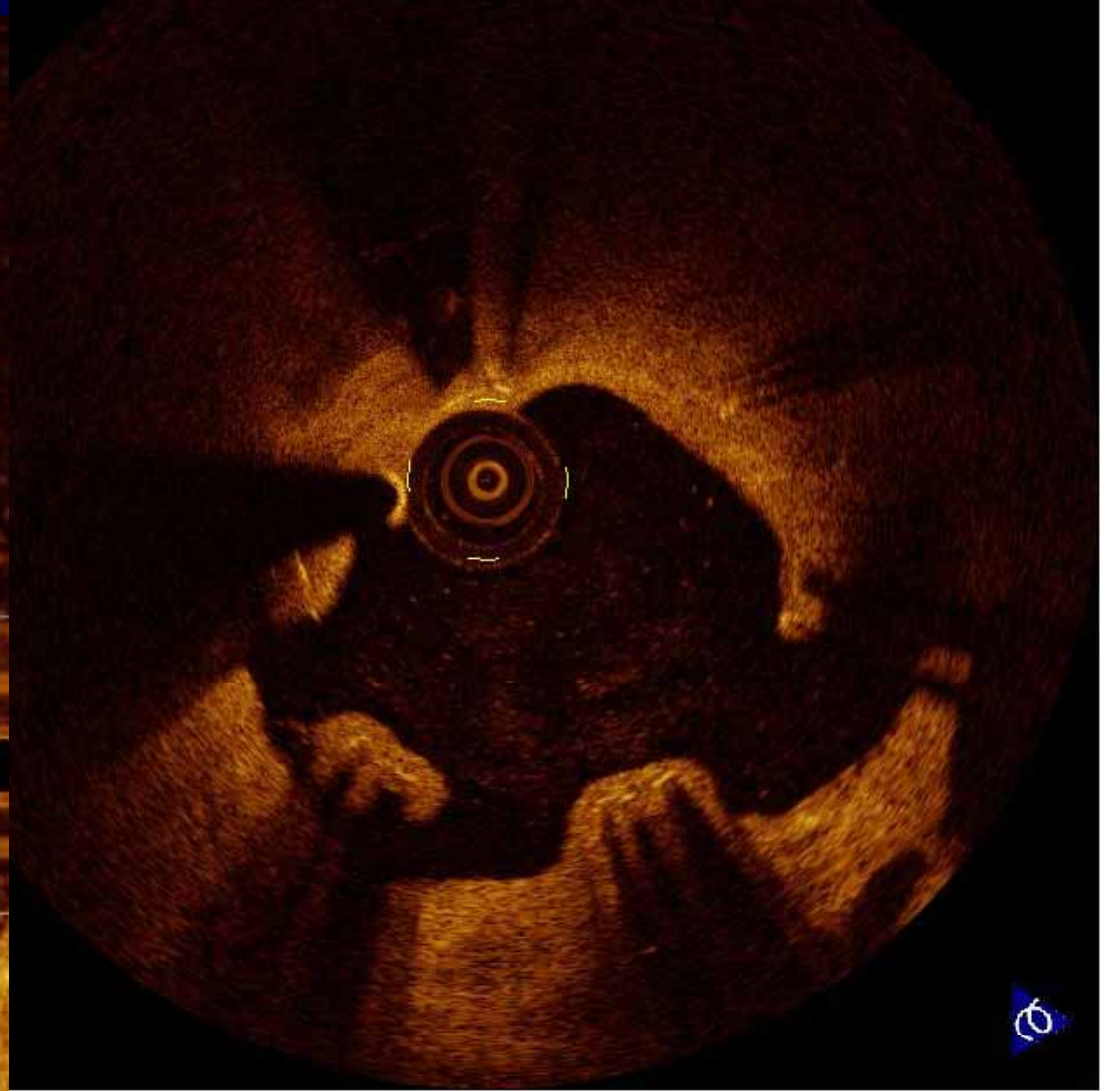


Covered

Follow-up malapposed struts



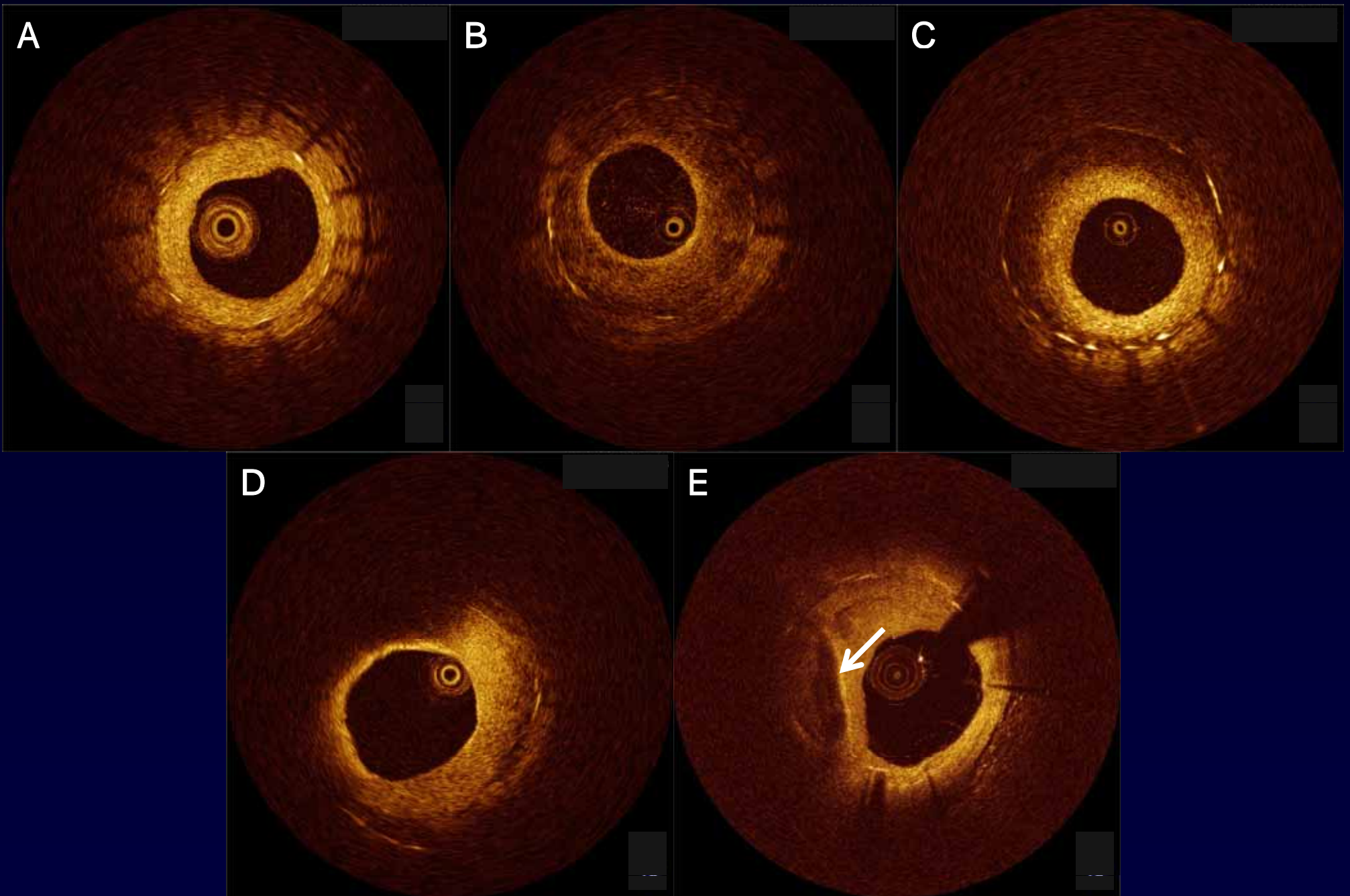
Uncovered



Covered

Neointima

- **Neointima without neoatherosclerosis**
 - **Homogeneous**
 - **Heterogeneous**
 - **Layered**
- **Neoatherosclerotic neointima**

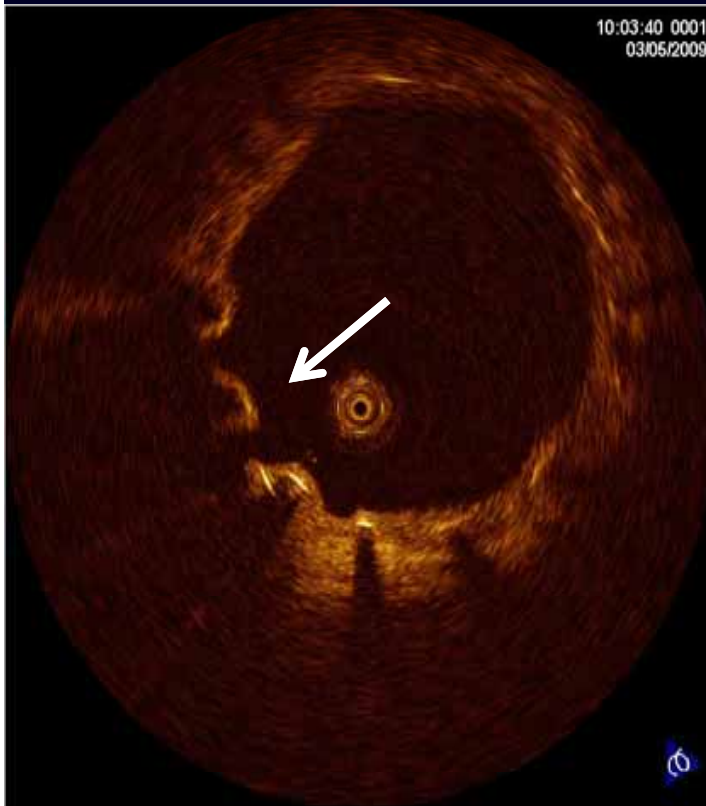


DES struts coverage crossing the side-branch vessels (n=51)

	SES (n=22)	PES (n=15)	ZES (n=14)	P
Side branch vessel side				
Total No. of struts, n	356	165	143	
Percentage of covered struts, %	65 ± 37	20 ± 31	83 ± 29	<0.001
Neointimal hyperplasia thickness, mm	0.04 ± 0.03	0.02 ± 0.02	0.08 ± 0.06	0.002
Mean No. of struts	16 ± 12	11 ± 7	13 ± 12	0.360
No. of covered struts	10 ± 10	1 ± 2	11 ± 11	0.010

Her AY, Hong MK et al, *Am J Cardiol* 2010;105:1565-69

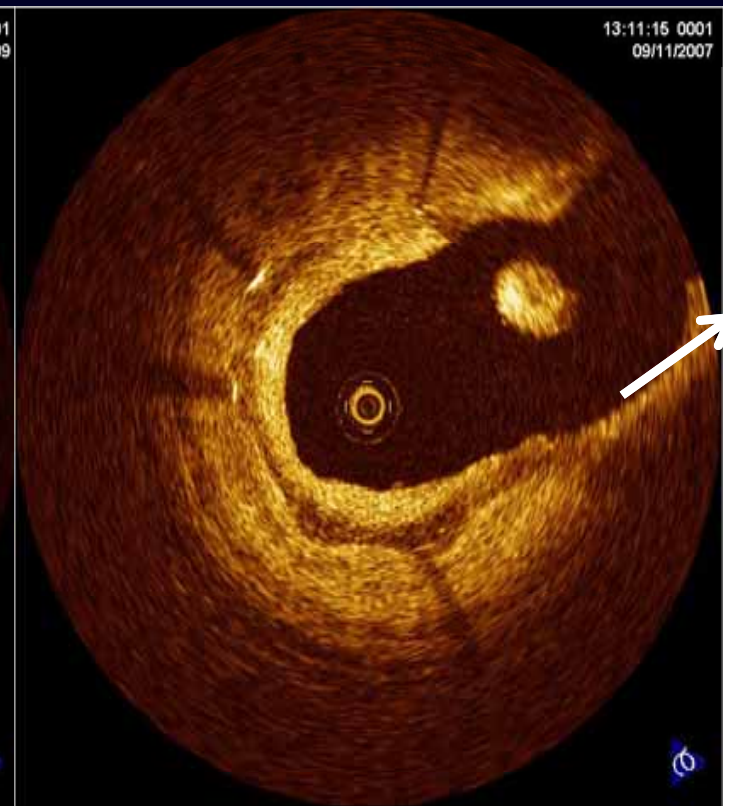
Comparison of neointimal thickness on unapposed struts crossing the side-branch



Cypher (SES)



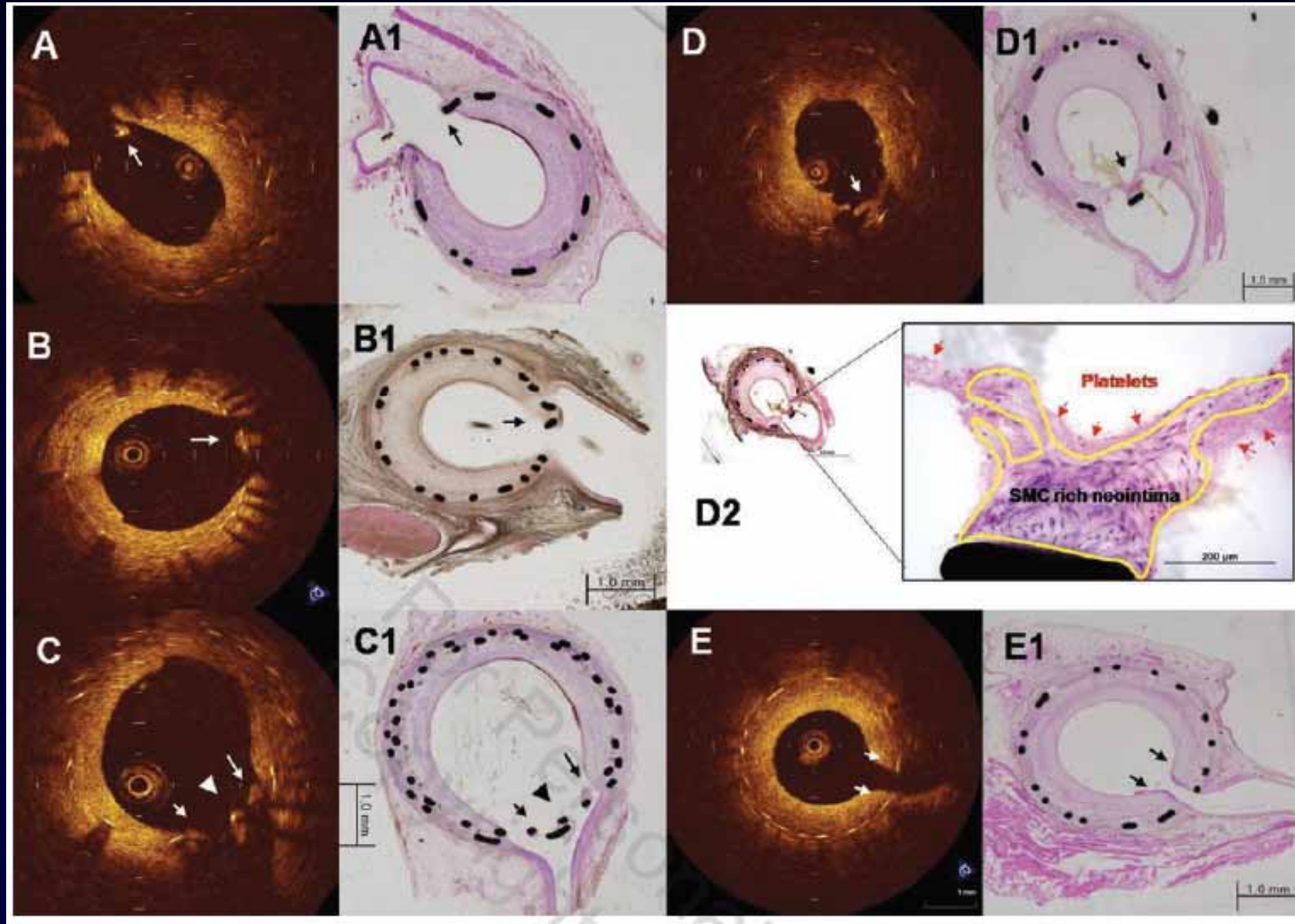
Taxus (PES)



Endeavor (ZES)

Her AY , Hong MK et al, *Am J Cardiol* 2010;105:1565-69

Strut coverage over non-apposed side branch stents



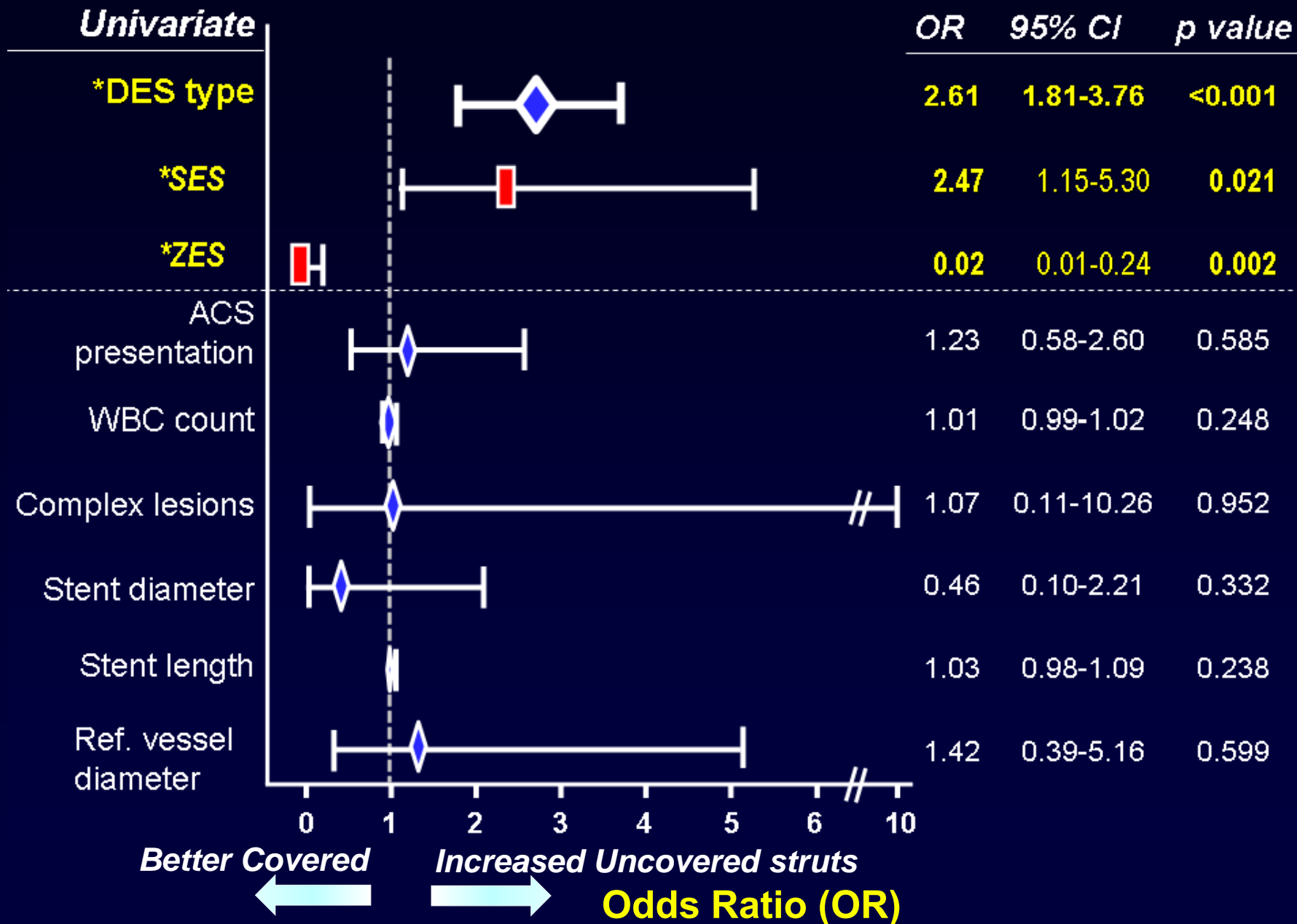
Her AY, Kim JS, Hong MK et al, *J Invasive Cardiol* 2013;25:364-366

OCT definition

**Uncovered strut = Neointimal hyperplasia (NIH)
thickness of 0 μm**

**The percentage of uncovered struts = (number of
uncovered struts/total number of struts in all cross-
sections of the lesion) \times 100**

Major determinants of uncovered struts (n=279 lesions)



Kim BK, Hong MK, *Int J Cardiovasc Imaging* 2012;28;715-723

Randomized comparison of early strut coverage between zotarolimus- and everolimus-eluting stents using OCT

40 Patients enrolled

OCT at post-intervention

ZES-R (20 patients)

EES (20 patients)

mean percentage of uncovered struts (ZES-R =6.2% vs. EES= 4.7%, p=0.62)

ZES-R

(18 struts in 17 patients)
No OCT follow-up in 3 patients

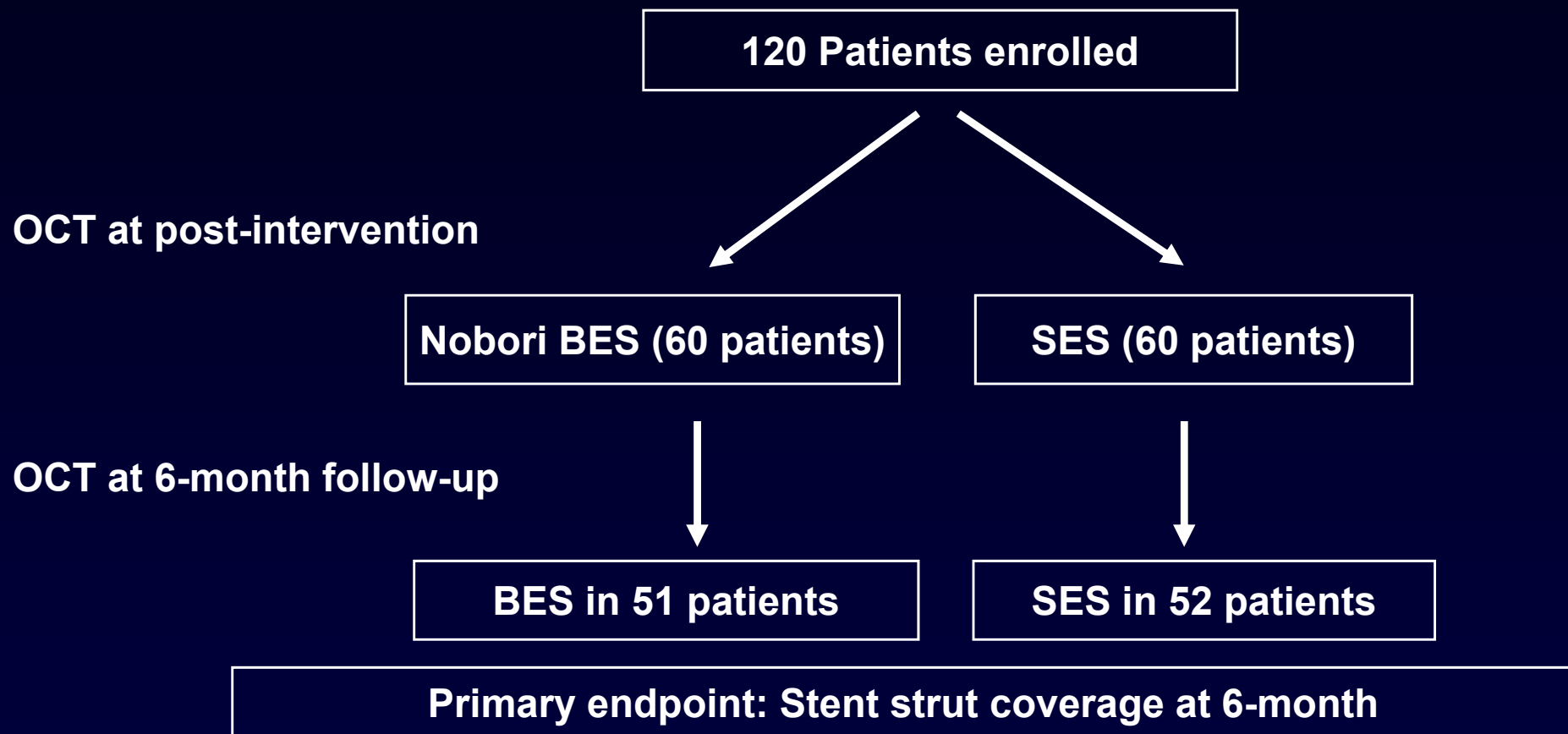
EES

(17 struts in 17 patients)
No OCT follow-up in 3 patients

Primary endpoint: Stent strut coverage at 3-month

Kim S, Hong MK, et al. Am J Cardiol 2013;111:1-5

Randomized comparison of strut coverage between Nobori biolimus- and sirolimus-eluting stents



mean percentage of uncovered struts (BES =15.9% vs. SES= 25.1%, p=0.003)

Kim BK, Hong MK, et al. *EuroIntervention* (in press)

Pathological Correlates of Late Drug-Eluting Stent Thrombosis

Strut Coverage as a Marker of Endothelialization

The most powerful histological predictor of stent thrombosis was endothelial coverage.

The best morphometric predictor of LST was the ratio of uncovered to total stent struts.

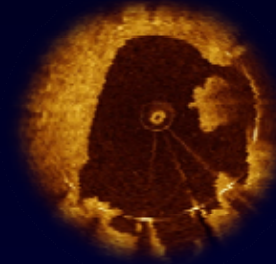
The odds ratio for thrombus with a ratio of uncovered to total struts > 30% 9.0 (95% CI , 3.5 to 22)

Finn AV, et al. *Circulation* 2007;115:2435-41

Clinical significance of uncovered struts

Examination of the In Vivo Mechanisms of Late Drug-Eluting Stent Thrombosis

Findings From Optical Coherence Tomography and Intravascular Ultrasound Imaging



- 18 patients with DES LST, Median 615 days after implant
- The presence of uncovered stent struts as assessed by OCT were associated with LST after DES
- OR of maximal length of segments with uncovered struts at OCT for LST → **2.5 (95% CI, 1.3 to 4.7)**

Guagliumi G, et al. *JACC Intv* 2012;5:12-20

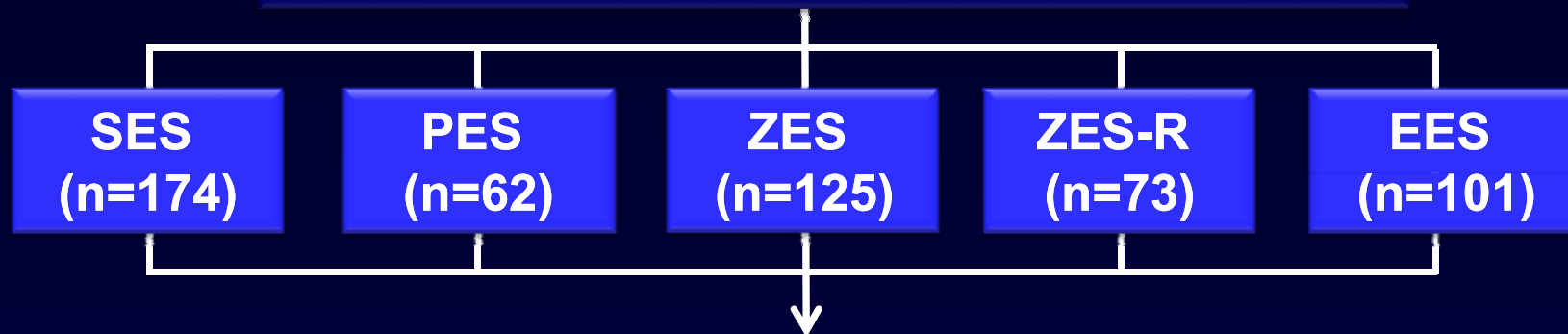
We need more information!

1. No clinical data regarding the long-term clinical outcomes in asymptomatic patients with follow-up OCT;
% of uncovered struts that predict adverse events in the condition of asymptomatic status vs. % of uncovered struts detected at the time of onset of stent thrombosis
2. Unknown about the practical impact of uncovered struts on long-term clinical outcomes in real clinical practice.
3. Unknown about cut-off value of uncovered strut.

Cut-off value of uncovered strut to predict clinical outcomes

Between Sep 2007 and July 2011, a total of 489 patients (535 lesions) enrolled in Yonsei OCT Registry

Patients with followed by an OCT between **6 and 18 months** after index PCI

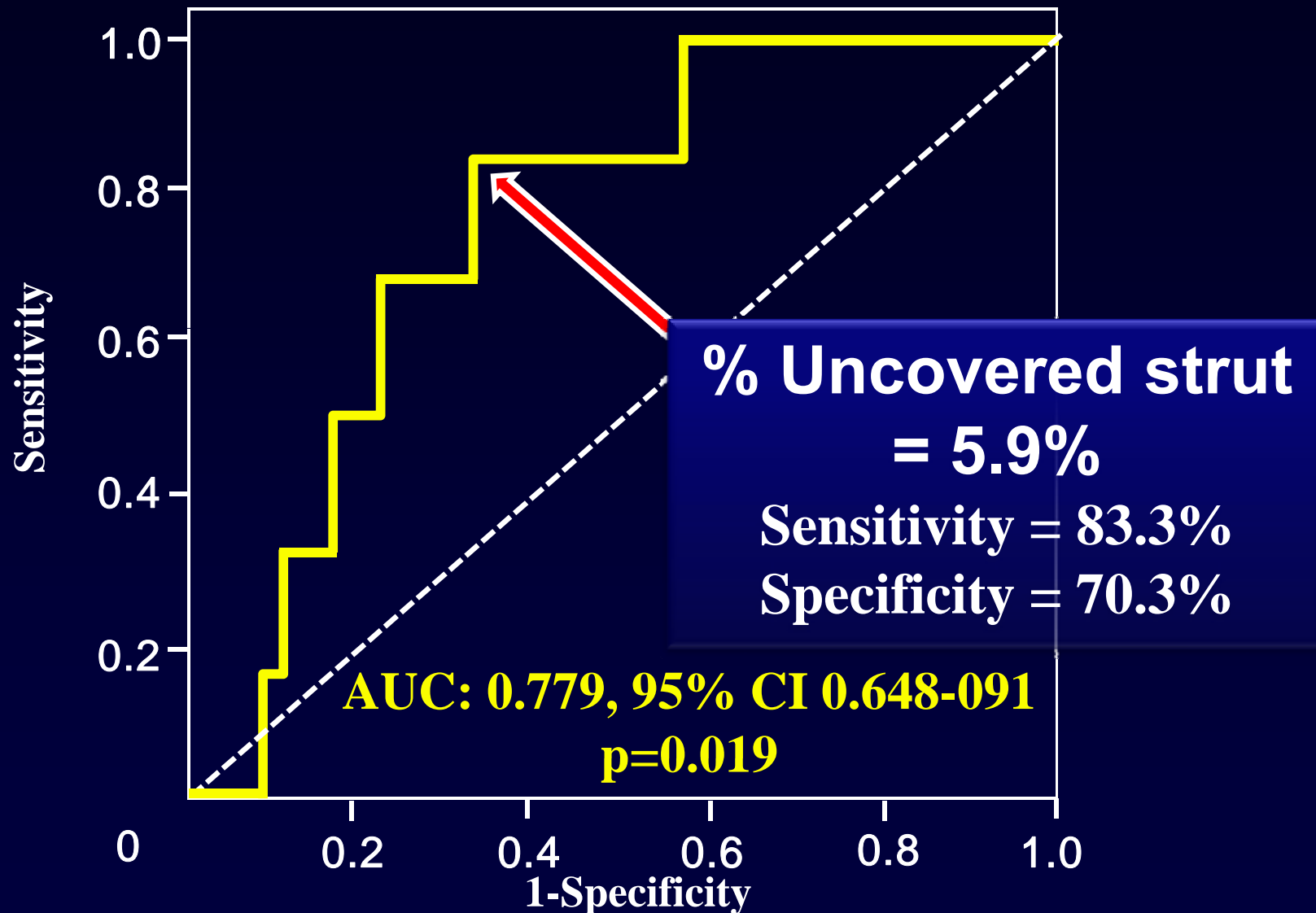


And then, we performed clinical follow up after follow-up OCT

Major adverse cardiac events: Composite of CV death, MI or stent thrombosis

Won H, Hong MK, et al. Int J Cardiovasc Imaging 2013;29:1255-1263

ROC curve of uncovered struts for prediction of MACE



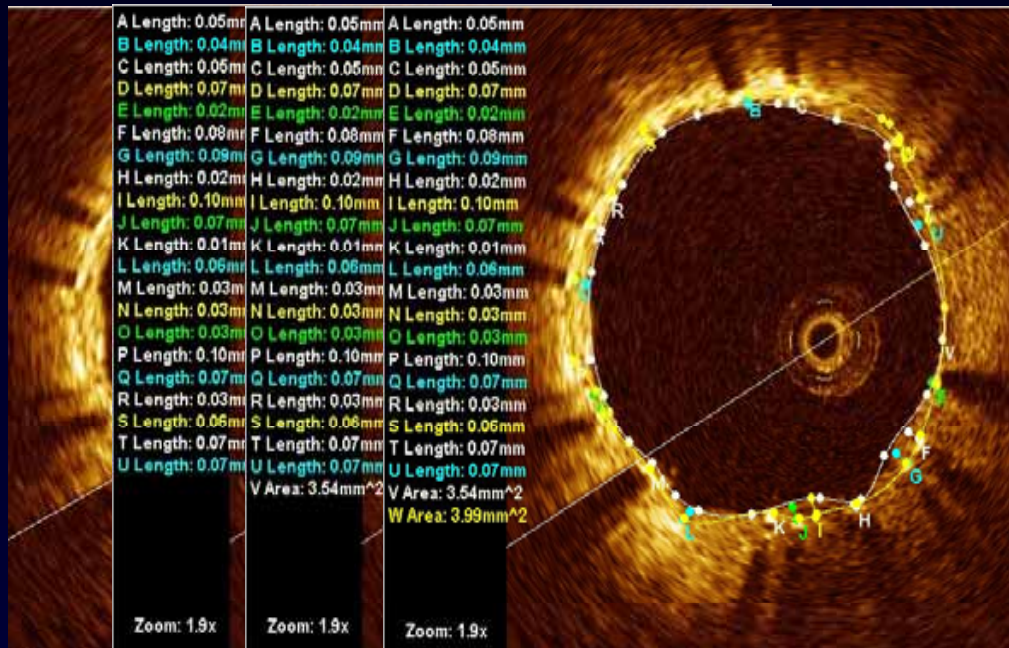
Won H, Hong MK, et al. Int J Cardiovasc Imaging 2013;29:1255-1263

Cox regression analysis

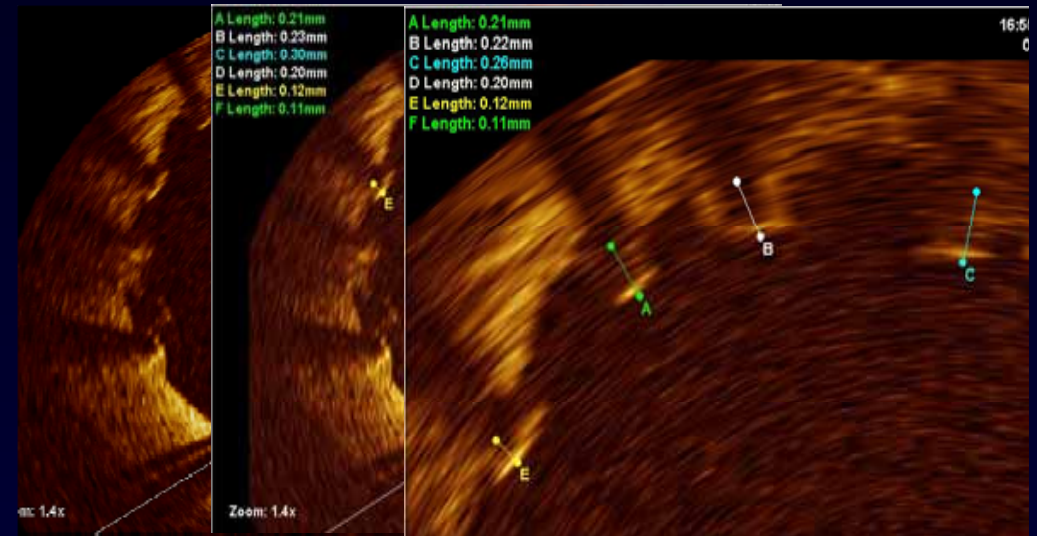
Won H, Hong MK, et al. Int J Cardiovasc Imaging 2013;29:1255-1263

Variable	Univariate			Multivariate		
	HR	95% CI	p	HR	95% CI	p
Age	1.050	0.960-1.148	0.287			
SES	4.248	0.773-23.362	0.096			
Pre-PCI MLD, mm	0.237	0.041-1.361	0.106			
Post-PCI MLD, mm	0.041	0.008-0.899	0.041	0.019	0.001-0.513	0.018
% NIH CSA	0.887	0.787-1.001	0.052			
% Malapposed struts	1.095	0.932-1.286	0.268			
Uncovered struts≥5.9%	17.300	1.969-152.039	0.010	19.781	2.071-188.968	0.010
Max length of uncovered struts, mm	1.232	1.010-2.436	0.049			

Is the traditional OCT analysis sufficient ?



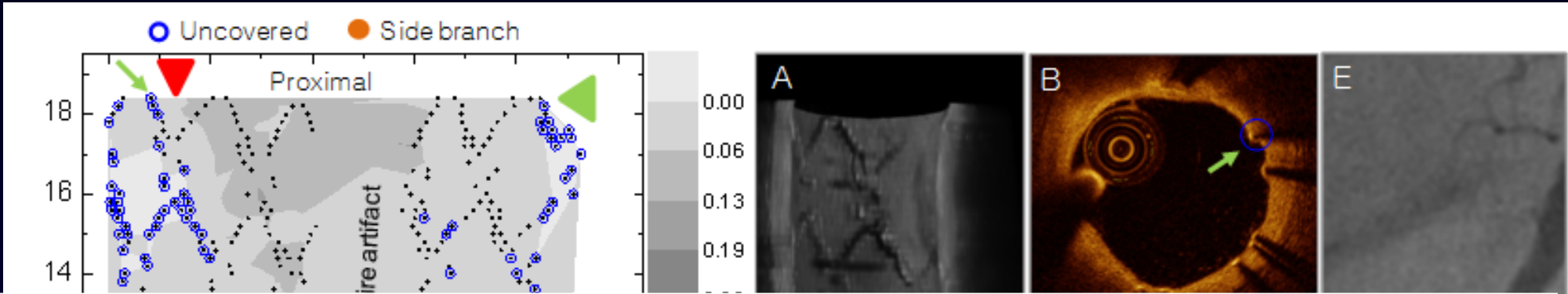
Neointimal thickness



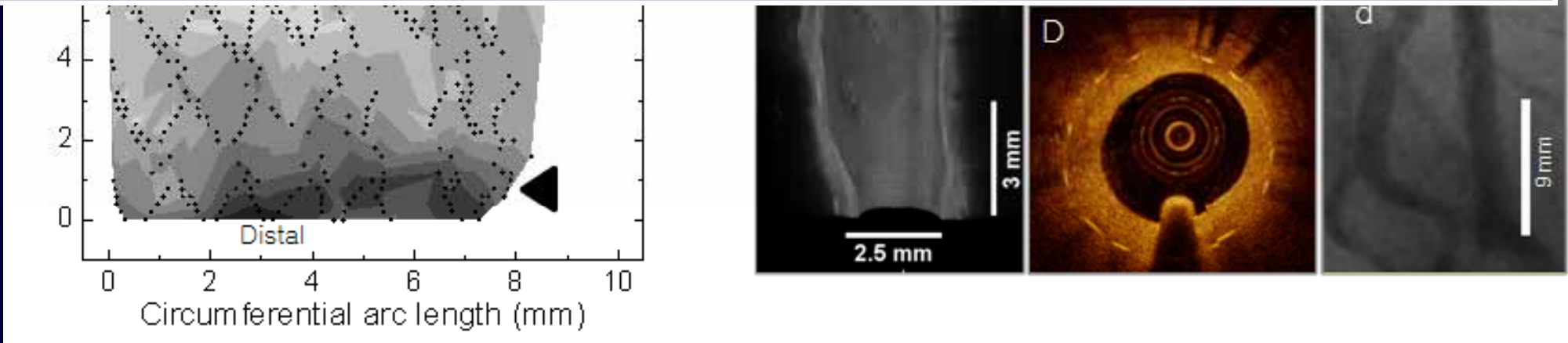
Stent apposition

What are the spatial distributions of uncovered or malapposed struts ?

Creation of contour map

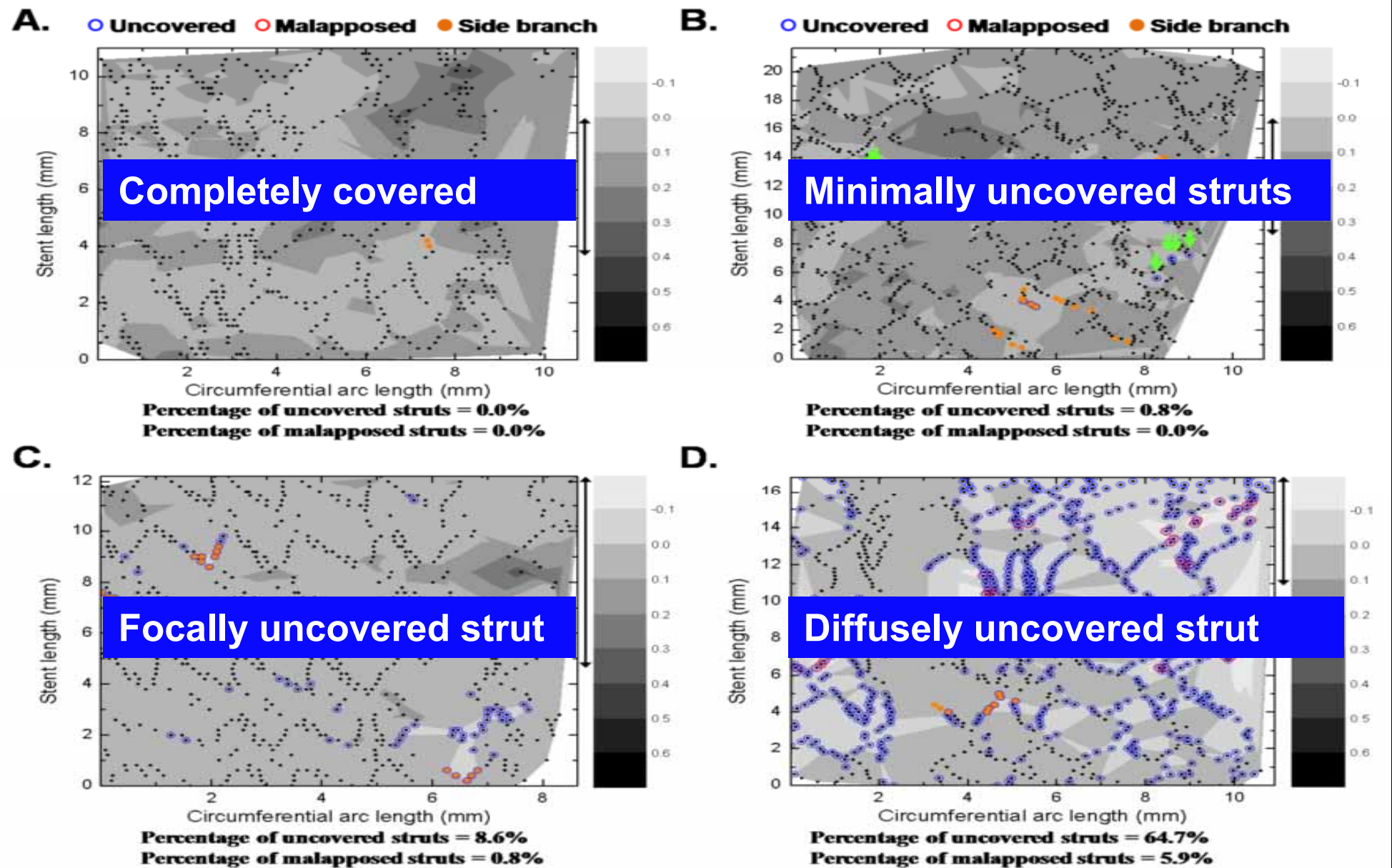


This technology provides detailed information previously obtainable only by gross pathologic examination.



HA J, Hong MK, et al. *J Am Coll Cardiol Img* 2012;5:852-853

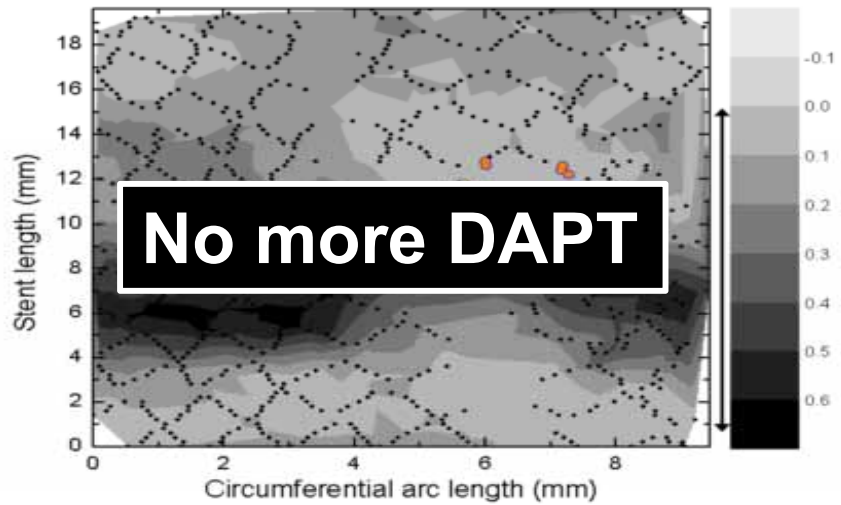
Contour map of SES at 6-month follow-up OCT



Kim BK, Hong MK, et al. *EuroIntervention* (in press)

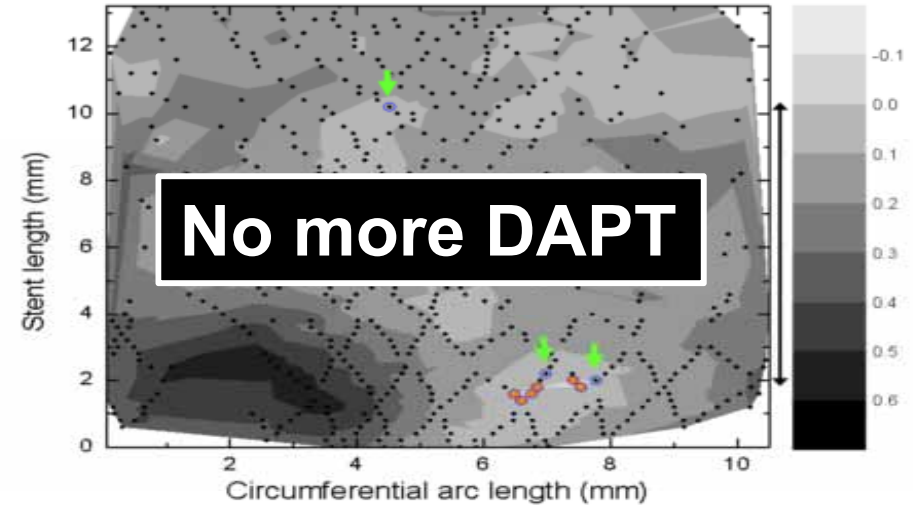
Contour map of Nobori BES at 6-month follow-up OCT

A. ○ Uncovered ○ Malapposed ○ Side branch



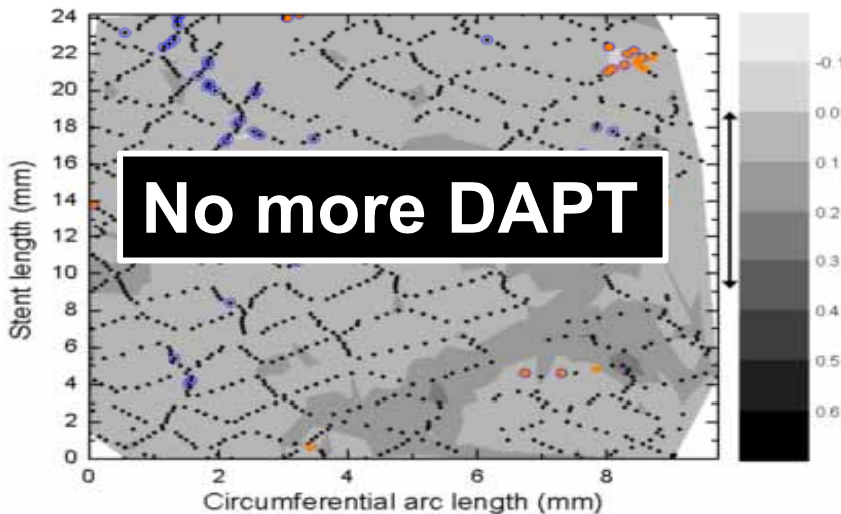
Percentage of uncovered struts = 0.0%
Percentage of malapposed struts = 0.0%

B. ○ Uncovered ○ Malapposed ○ Side branch



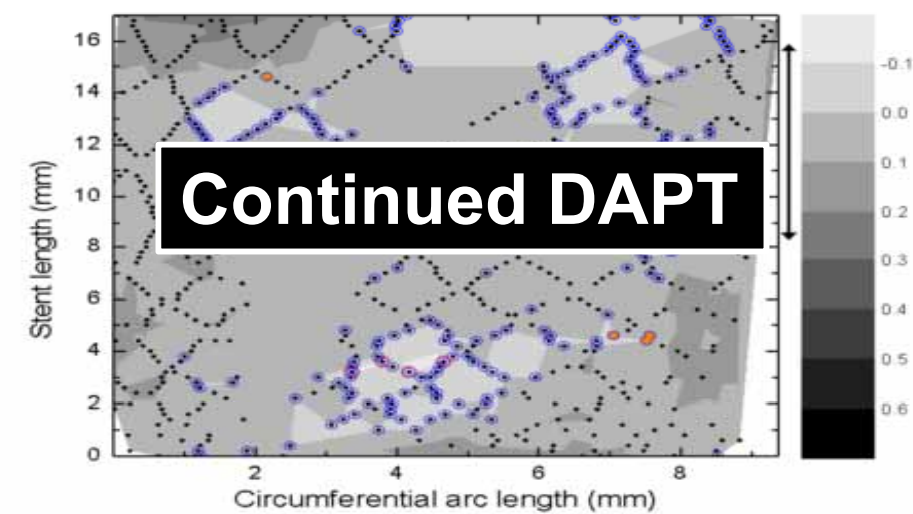
Percentage of uncovered struts = 0.4%
Percentage of malapposed struts = 0.0%

C.



Percentage of uncovered struts = 4.0%
Percentage of malapposed struts = 0.0%

D.



Percentage of uncovered struts = 32.0%
Percentage of malapposed struts = 0.8%

Kim BK, Hong MK, et al. *EuroIntervention* (in press)

Clinical implication of neoatherosclerosis: TLR and stent thrombosis

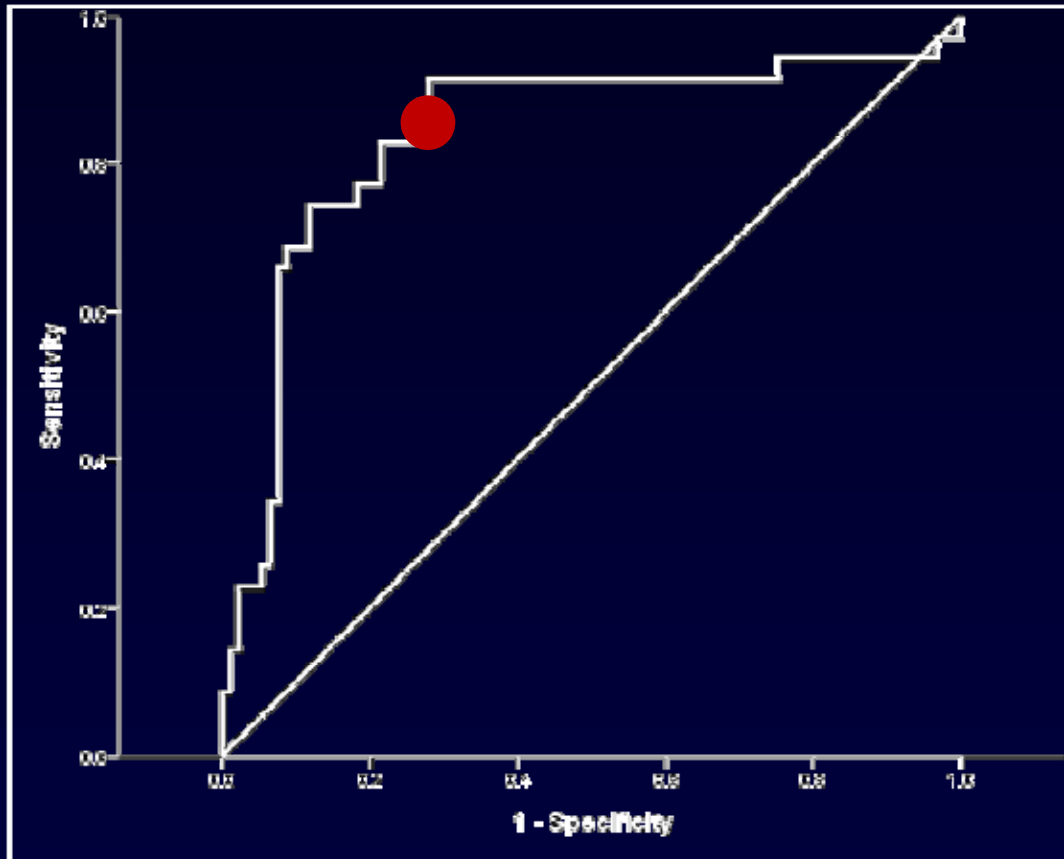
152 ISR lesions with NIH > 50% of stent area

	Presence of neoatherosclerosis (n = 54)	Absence of neoatherosclerosis (n = 98)	p
Time interval to FU OCT (months)	70.7 (54.4 – 120.4)	13.4 (10.6 – 39.6)	< 0.001
Clinical presentation at FU OCT, # (%)			< 0.001
Asymptomatic	4 (7.4)	22 (22.4)	
Stable angina	33 (61.1)	72 (73.5)	
Acute coronary syndrome	17 (31.5)	4 (4.1)	
Target lesion revascularization, # (%)	50 (92.6)	76 (77.6)	0.018
Stent thrombosis, # (%)	8 (14.8)	0 (0)	< 0.001

Lee SY, Hong MK, et al, *Eurointervention* (In press)

Cut-off time to predict neoatherosclerosis

152 ISR lesions with NIH > 50% of stent area



Area Under Curve: 0.839

95% Confidence Interval: 0.764 to 0.898

Optimal cut-off time: 30 months

Sensitivity: 91.4%

Specificity: 72.0%

Negative predictive value: 95.7%

Positive predictive value: 55.2%

Lee SY, Hong MK, et al, *Eurointervention* (In press)

Independent risk factors for neoatherosclerosis

152 ISR lesions with NIH > 50% of stent area

	Odds ratio	95% CI	p
Hypertension	4.223	1.354-13.170	0.013
Use of first-generation DES[†]	14.666	1.065-201.936	0.045
Use of next-generation DES[†]	10.149	0.398-258.629	0.161
Stent age (months)	1.054	1.028-1.081	< 0.001

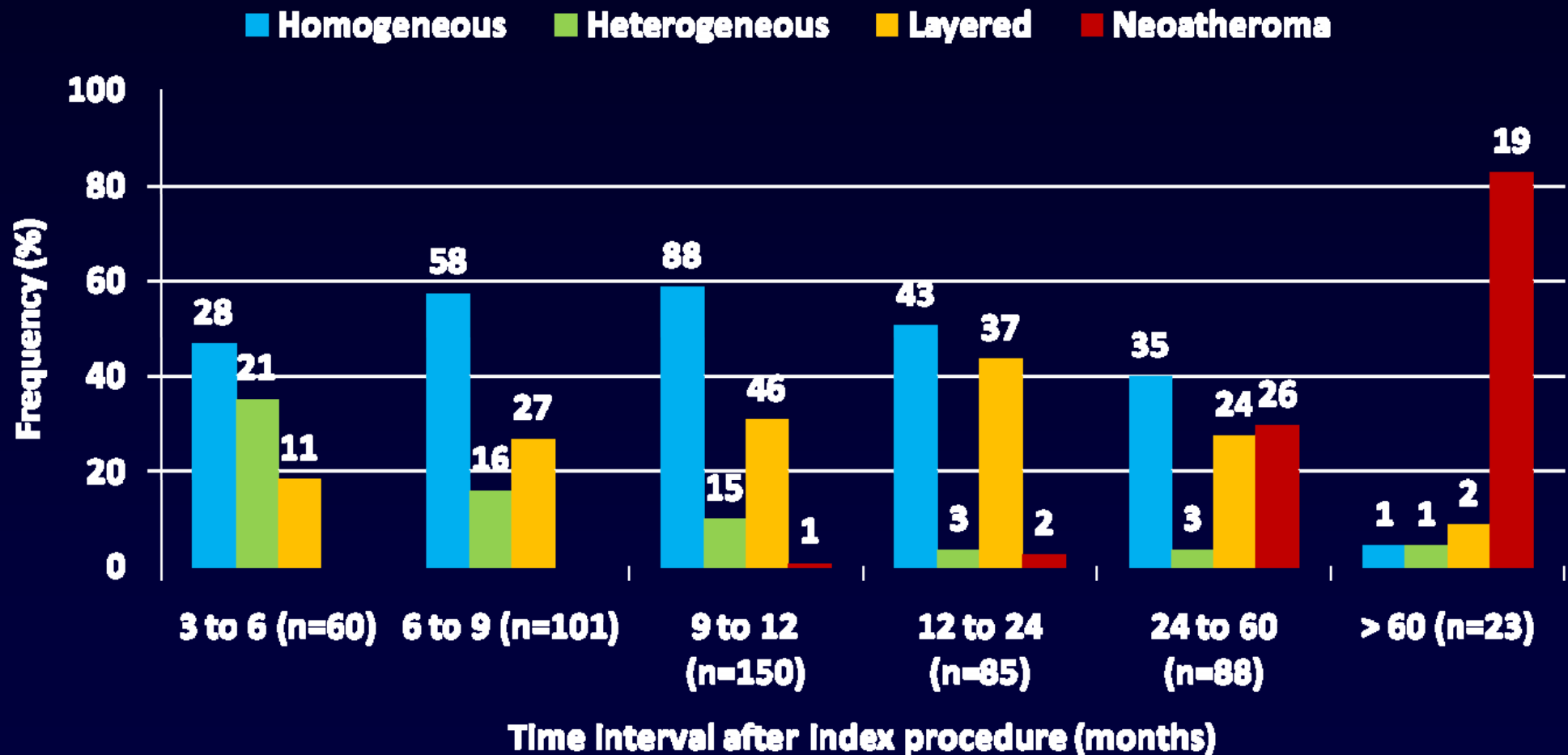
[†] vs. bare metal stent

Lee SY, Hong MK, et al, *Eurointervention* (In press)

Distribution of neointima

507 DES-treated lesions >100 μ m of mean NIH thickness on follow-up OCT

Grouped by stent age

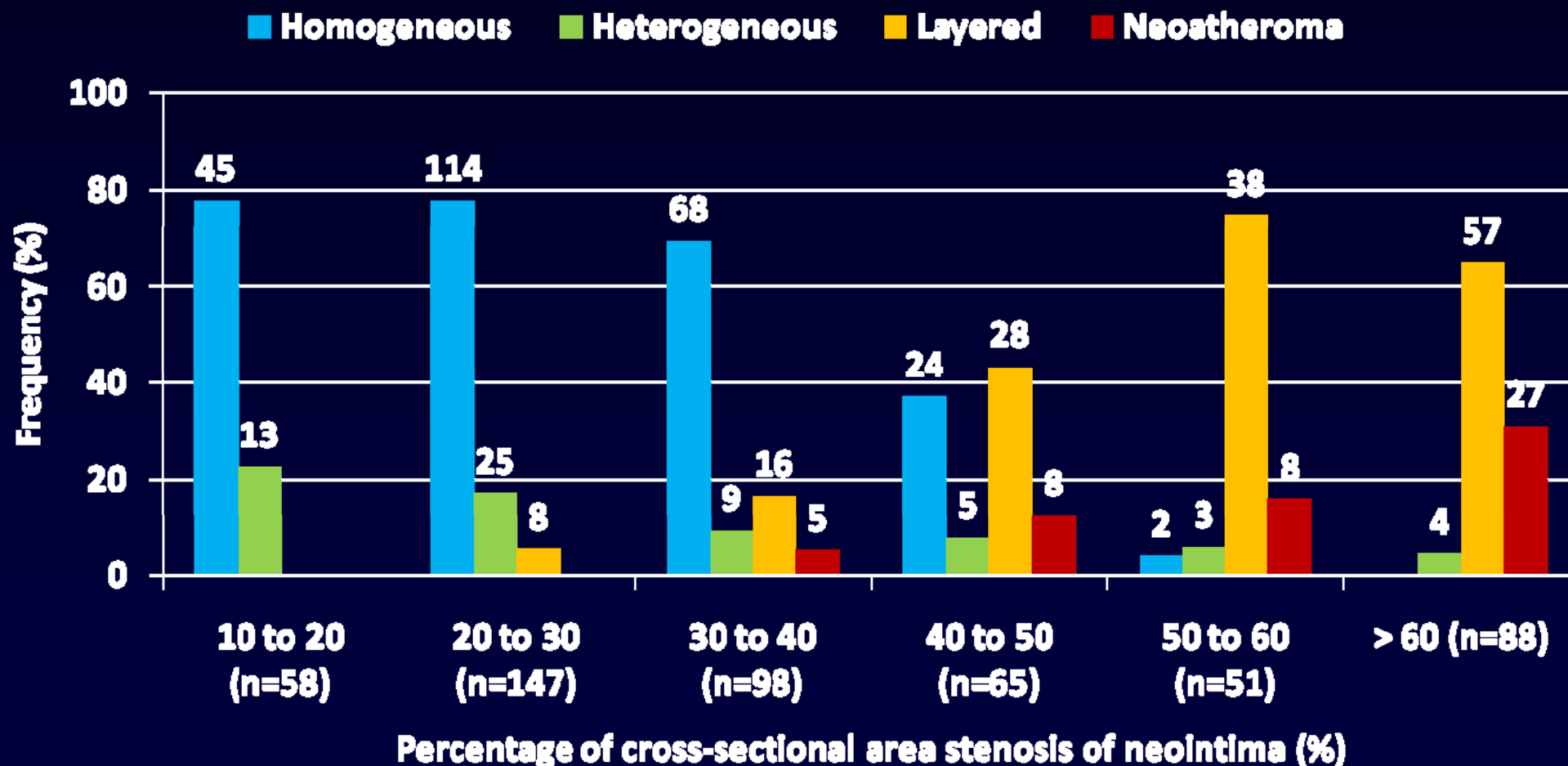


Lee SY, Hong MK, et al. *Yonsei Med J* (in press)

Distribution of neointima

507 DES-treated lesions >100 μ m of mean NIH thickness on follow-up OCT

Grouped by CSA stenosis

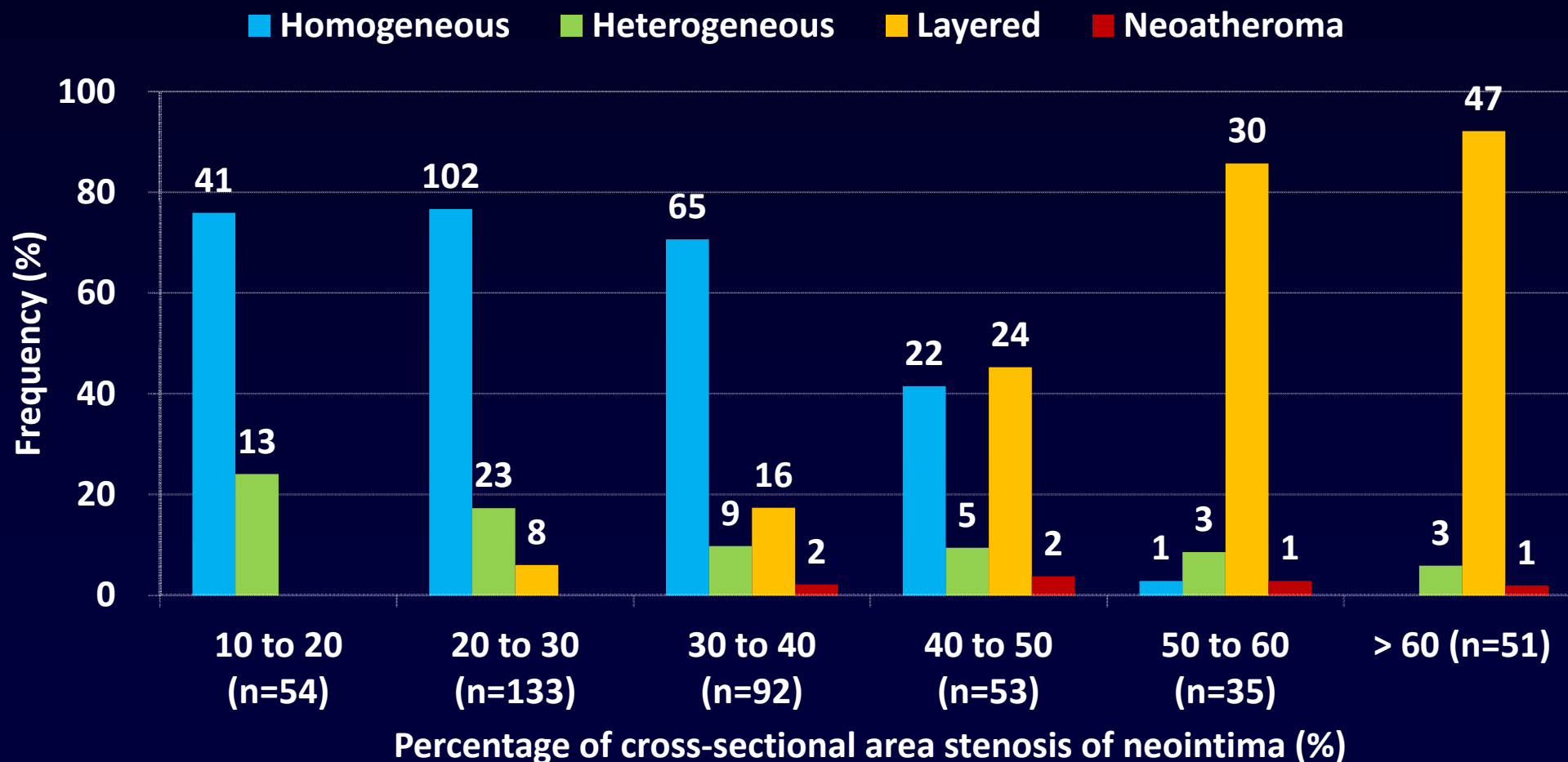


Lee SY, Hong MK, et al. *Yonsei Med J* (in press)

Distribution of neointima

507 DES-treated lesions >100 μ m of mean NIH thickness on follow-up OCT

Under 30 months of stent age

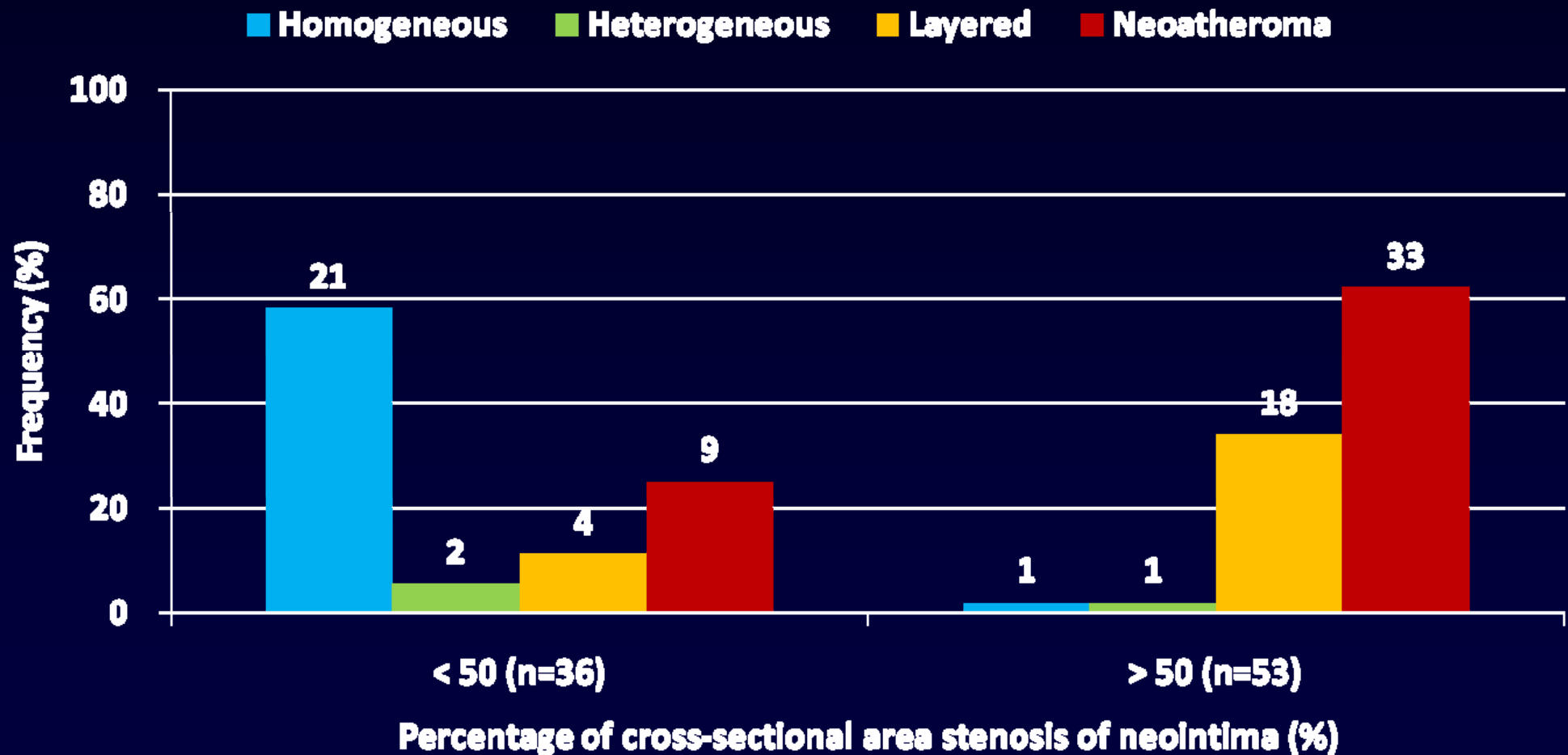


Lee SY, Hong MK, et al. *Yonsei Med J* (in press)

Distribution of neointima

507 DES-treated lesions $>100\mu\text{m}$ of mean NIH thickness on follow-up OCT

Over 30 months for stent age



Lee SY, Hong MK, et al. *Yonsei Med J* (in press)

Main findings

Dominant neointimal type of DES

Stent age	< 30 months	> 30 months
< 50% neointimal CSA stenosis	homogeneous	homogeneous
> 50% neointimal CSA stenosis	Layered	neoatheroma

Lee SY, Hong MK, et al. *Yonsei Med J* (in press)

Serial OCT: DES

Total (n = 76)	9 months FU	2 years FU	P
Qualitative analysis			
Intracoronary thrombus	8 (10.5%)	7 (9.2%)	0.79
Lipid-laden neointima	11 (14.5%)	21 (27.6%)	0.047
TCFA-like neointima	3 (3.9%)	10 (13.2%)	0.04
Heterogeneous pattern	49 (64.5%)	47 (61.8%)	0.73
Neovascularization	34 (44.7%)	56 (73.7%)	<0.001
Extrastent lumen	15 (19.7%)	21 (27.6%)	0.25

Kim JS, Hong MK, et al. JACC Cardiovasc imaging 2012;5:1145-55

Conclusions

- **OCT is an useful tool to evaluate the status of DES struts and characterization of neointimal tissue.**

Dreams will come true

