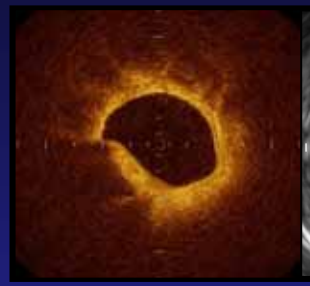
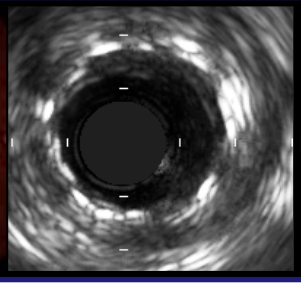
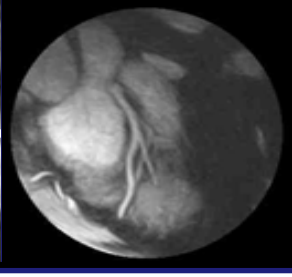
DES evaluation by OCT

Clinical surrogate endpoints

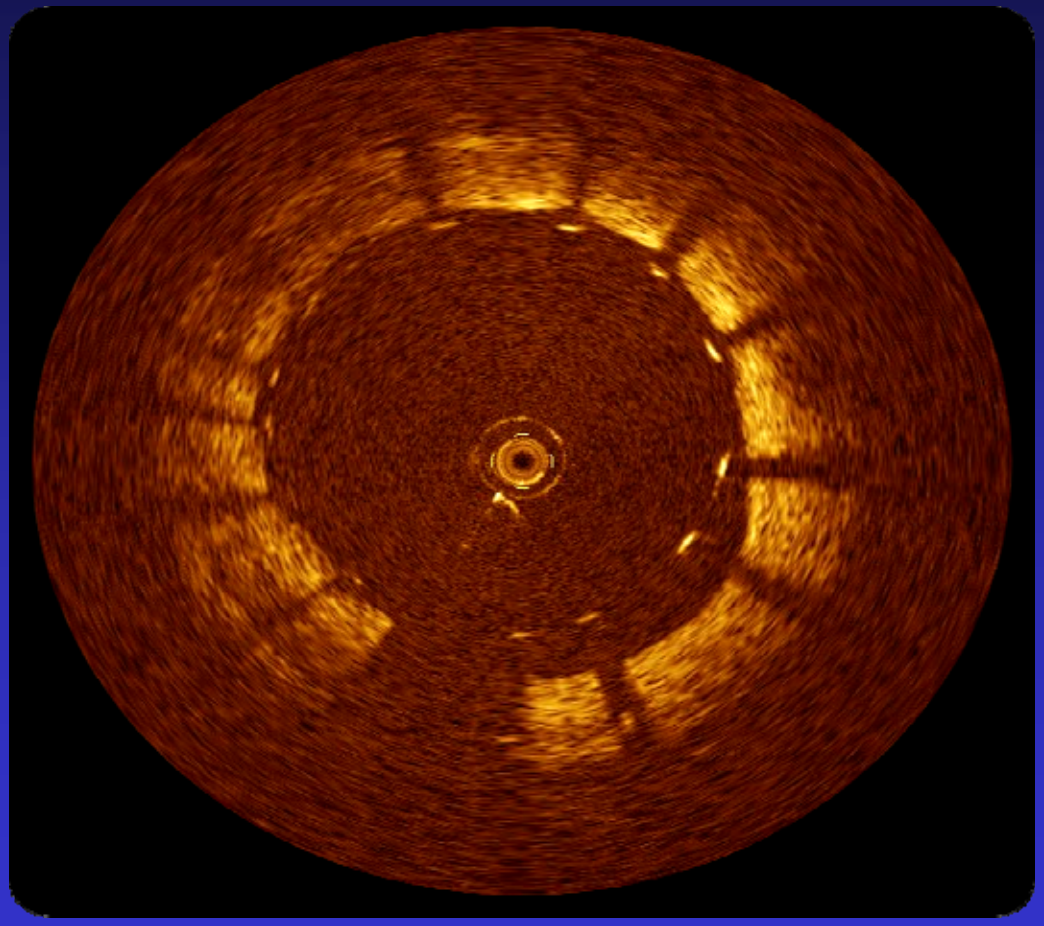
Takashi Akasaka, MD
Department of Cardiovascular Medicine
Wakayama Medical University, Japan

Comparison among coronary imaging techniques

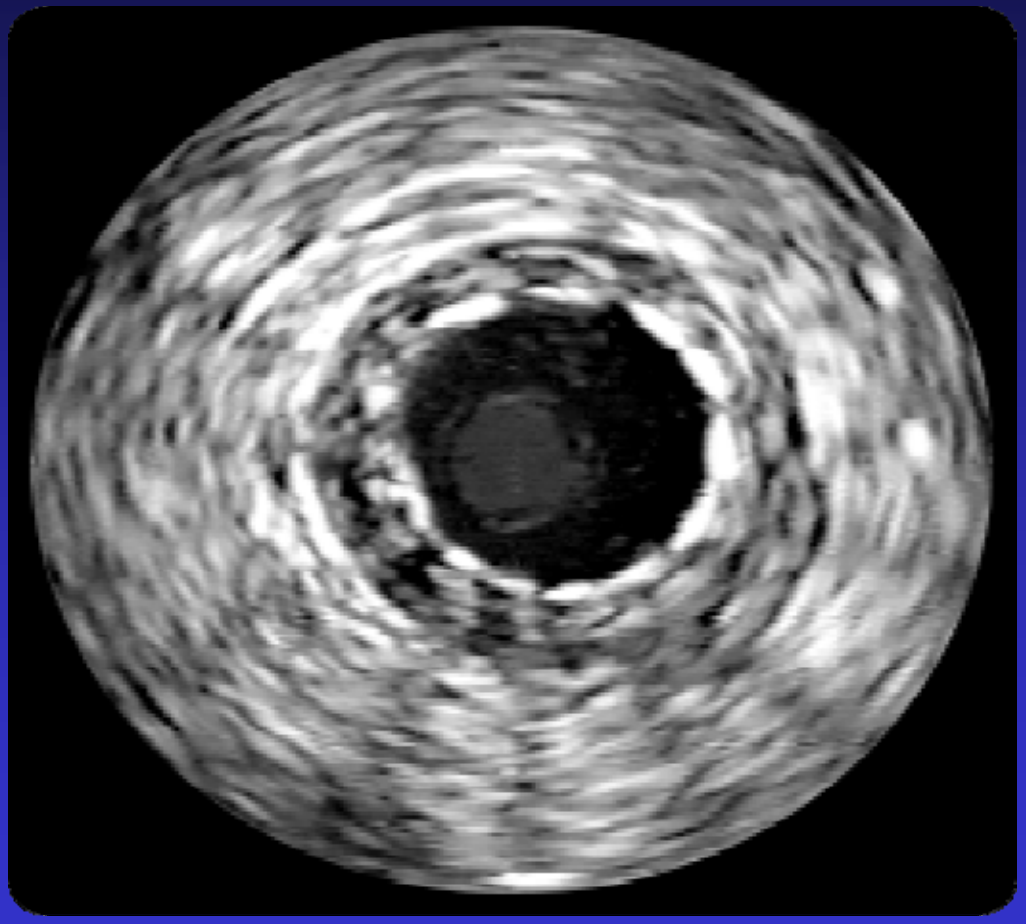
	OCT	IVUS	MRI	CAG	Angioscopy
					
Resolution	10 – 15	80 – 120	80 – 300	100-200	<200
Probe Size	140	700	1000	N/A	800
Contact	No	Yes	No	No	No
Ionizing Radiation	No	No	No	Yes	No
Other	Tissue Characterization	N/A	N/A	Flow Only	Surface Only

Advantages of OCT are its high resolution and accuracy of tissue characterization.

OCT vs IVUS

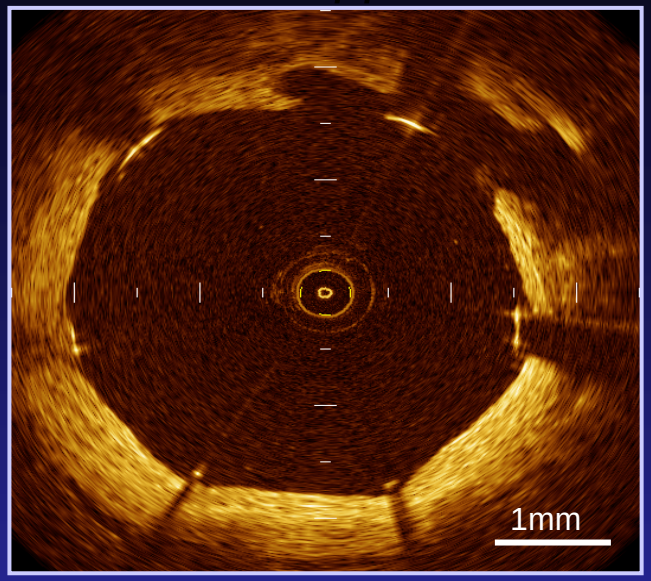


OCT

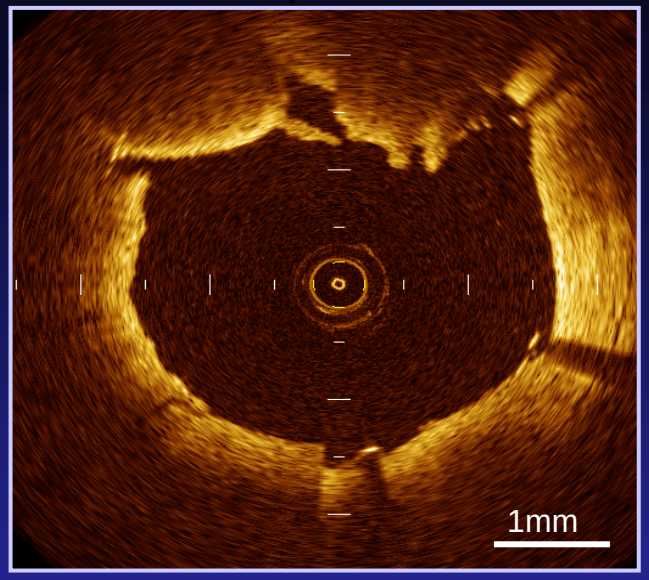


IVUS

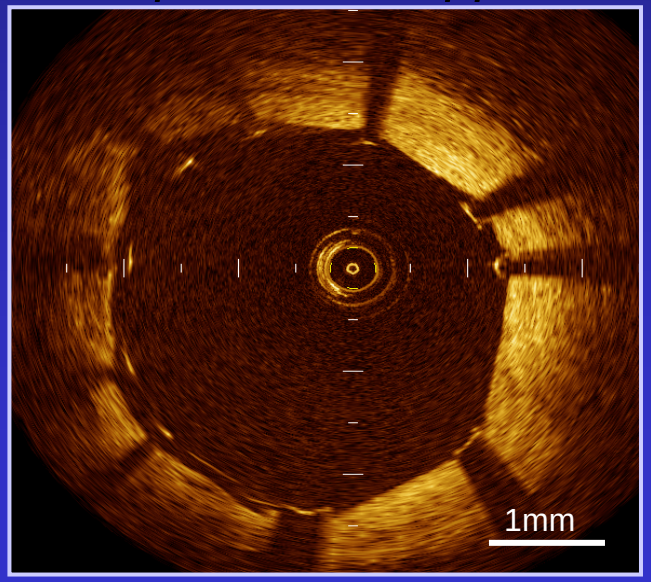
Stent malapposition



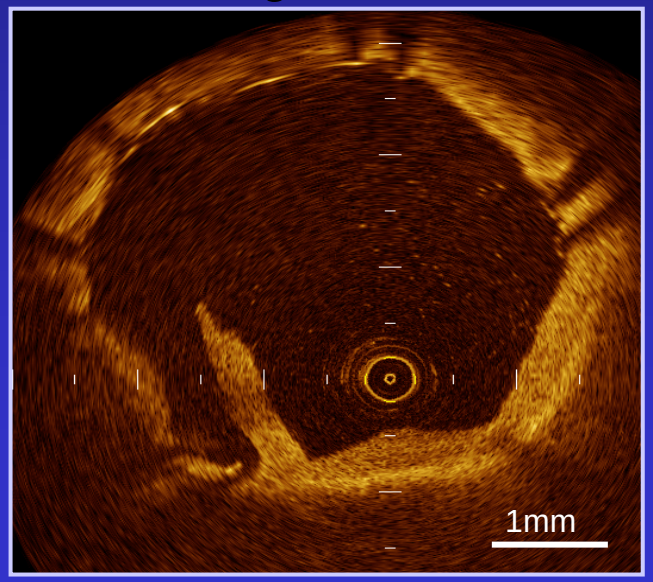
Tissue protrusion



Incomplete stent apposition



Stent edge dissection

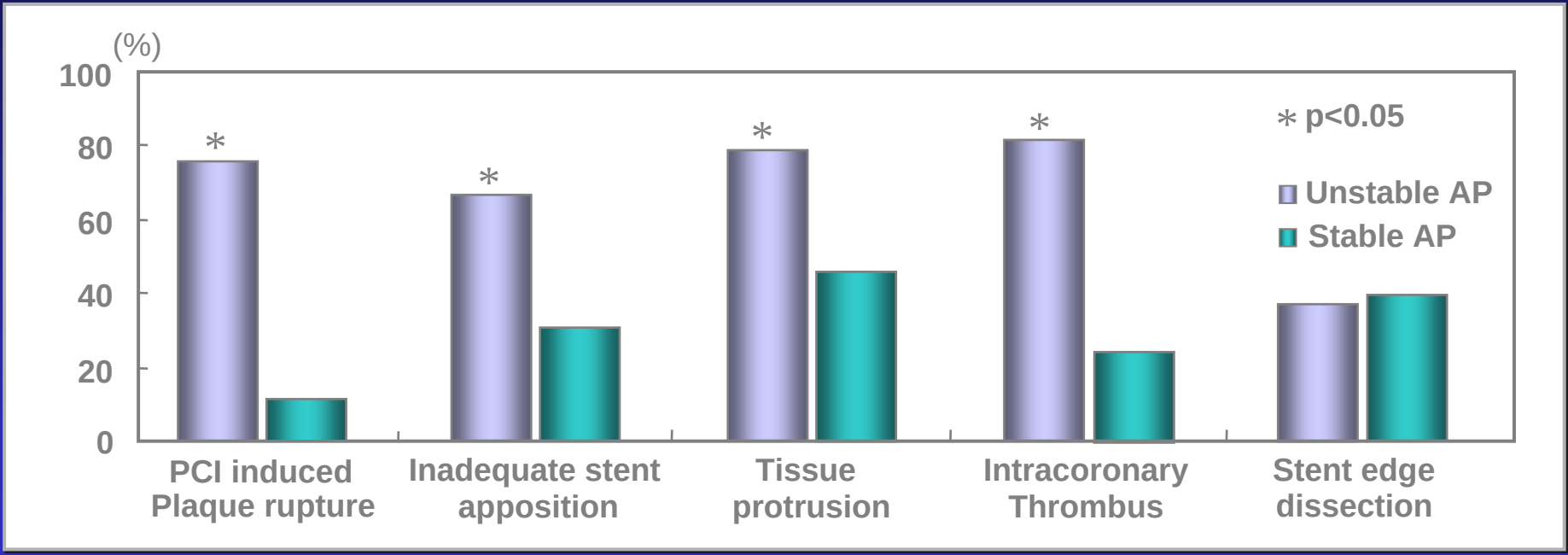


Kubo T, et al, JACC Img. 2008 1:475–484

Wakayama Medical University

Vascular response after stent implantation between unstable and stable AP

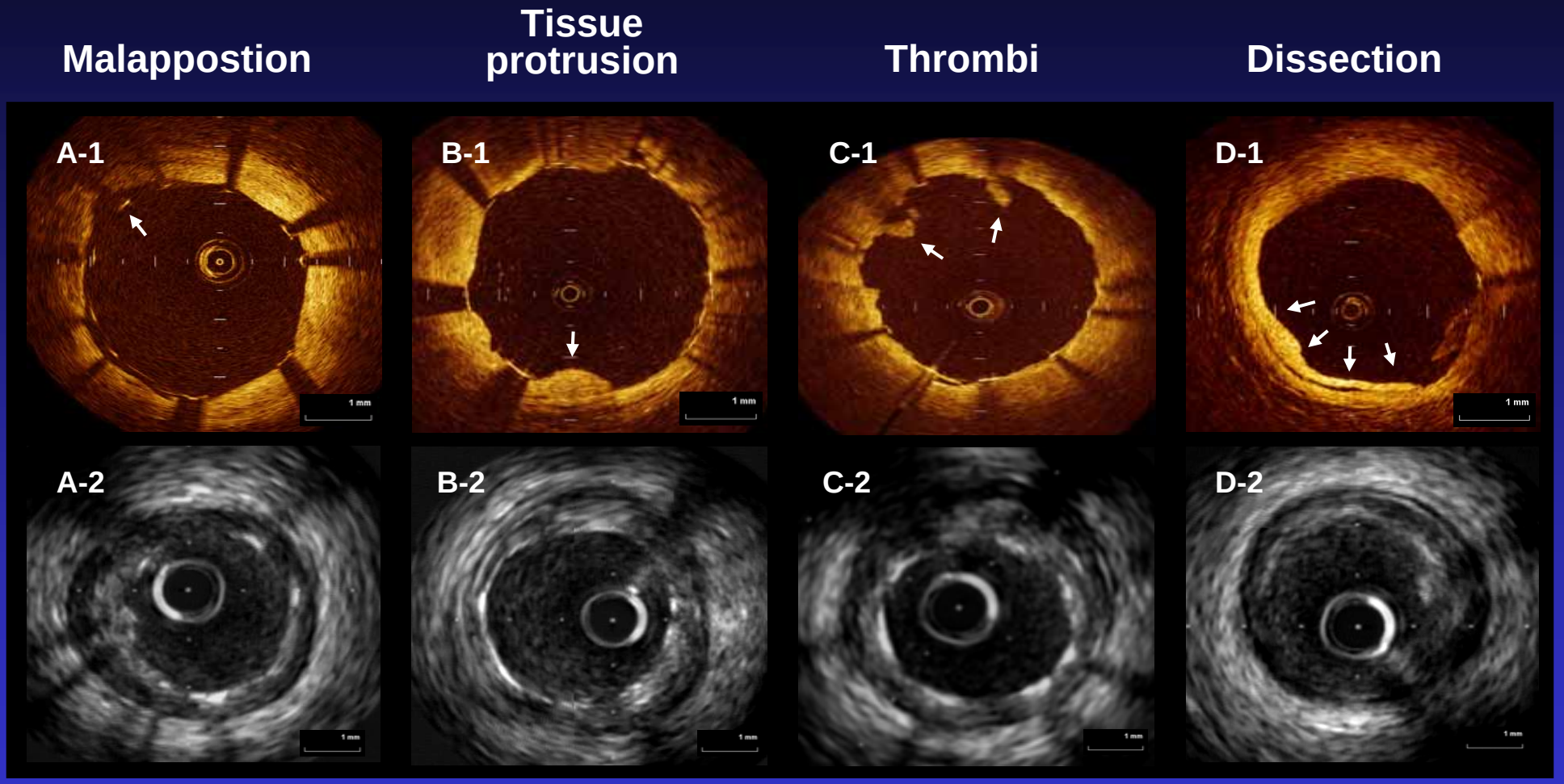
24 unstable and 31 stable AP patients were examined by OCT to evaluate lesion morphologies after stent implantation.



Conclusion: The inadequate lesion morphologies after stenting were observed more frequently in unstable AP patients.

Kubo T, et al, JACC Img. 2008 1:475–484

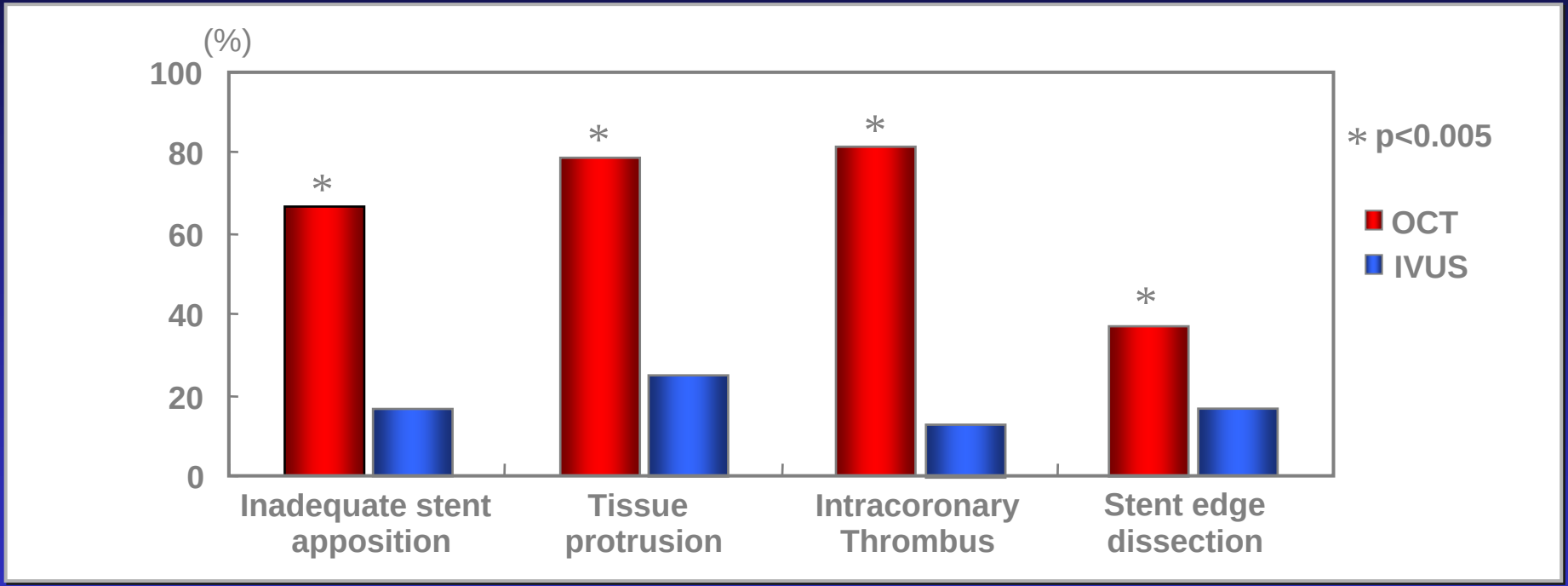
OCT and IVUS images of stented lesions



Kubo T, et al, JACC Img. 2008 1:475– 484

Comparison of the ability for monitoring stent deployment between OCT and IVUS

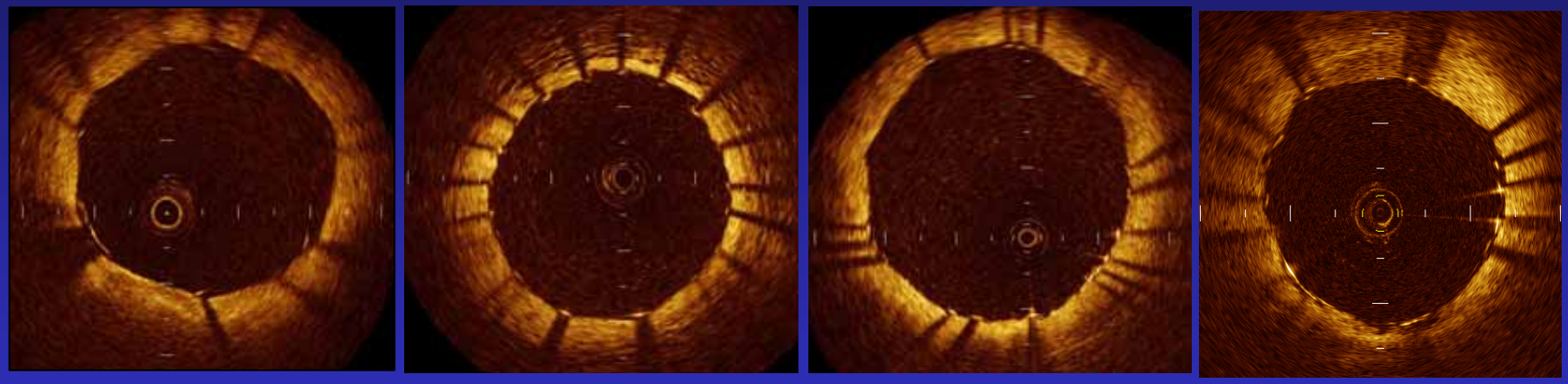
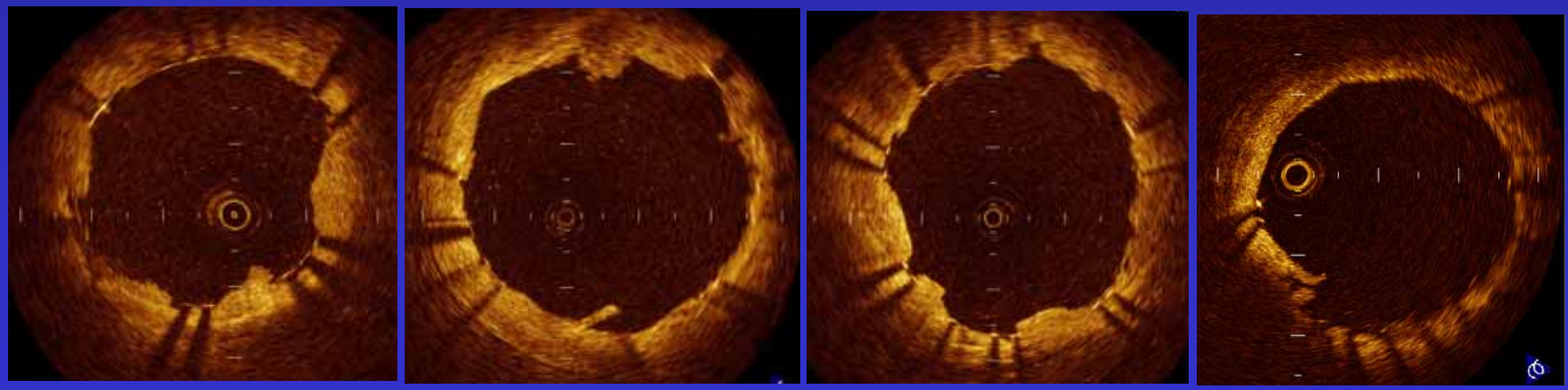
55 patients were examined by OCT and IVUS to evaluate lesion morphologies after stent implantation.



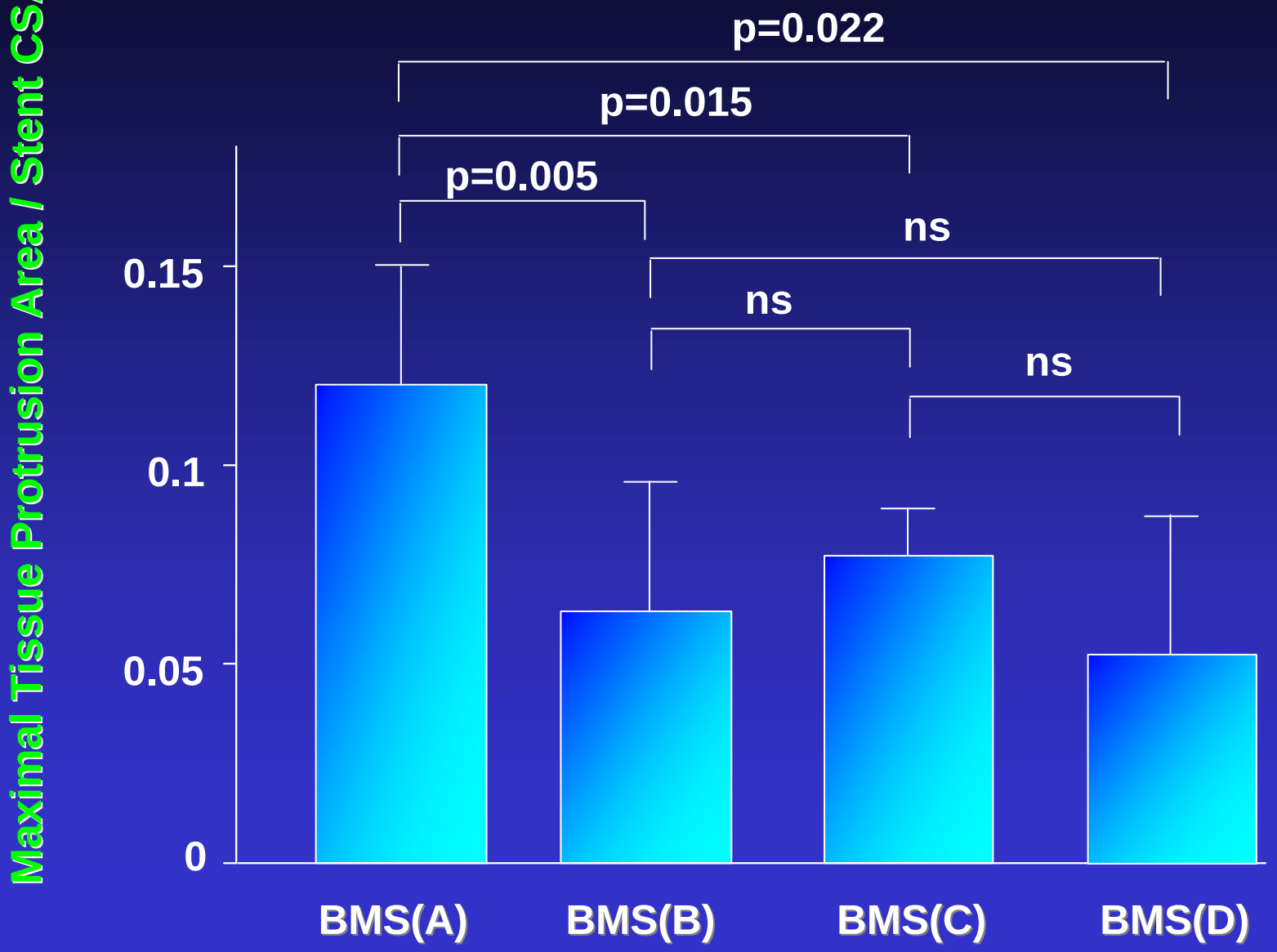
Conclusion: OCT can provide more detailed morphological information after stenting than IVUS.

Kubo T, et al, JACC Img. 2008 1:475–484

OCT images of Tissue Protrusion

	BMS(A)	BMS(B)	BMS(C)	BMS(D)
Cell type	closed cell	open cell	open cell	open cell
Strut thickness	0.0045 inch	0.0036 inch	0.0032 inch	0.0038 inch
Tissue Protrusion (−)				
Tissue Protrusion (+)				

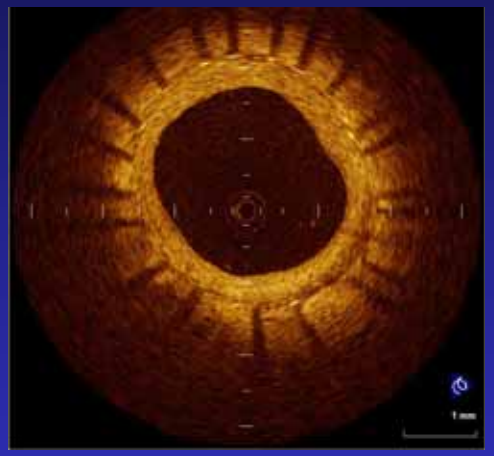
The Ratio of Maximal Tissue Protrusion Area to Stent CSA



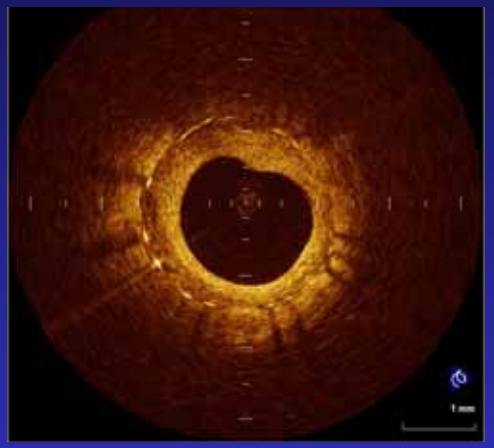
OCT images at 9-month follow-up

BMS(A)

BMS(B)



BMS(C)



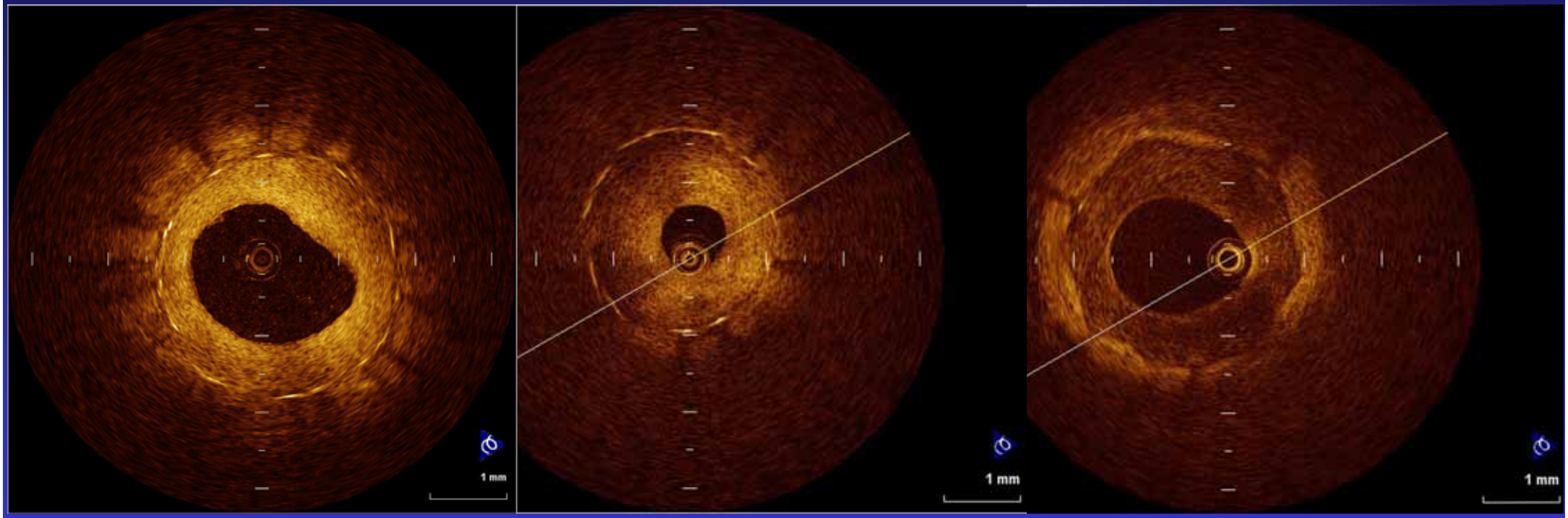
Late stent malapposition and unexposed struts with neointima were not observed in BMS 9-month after stent implantation.

Signal rich homogenous pattern neointima was observed in certain amount.

There was no significant difference in 9-month f/u among each different stent.

OCT findings of instent restenosis

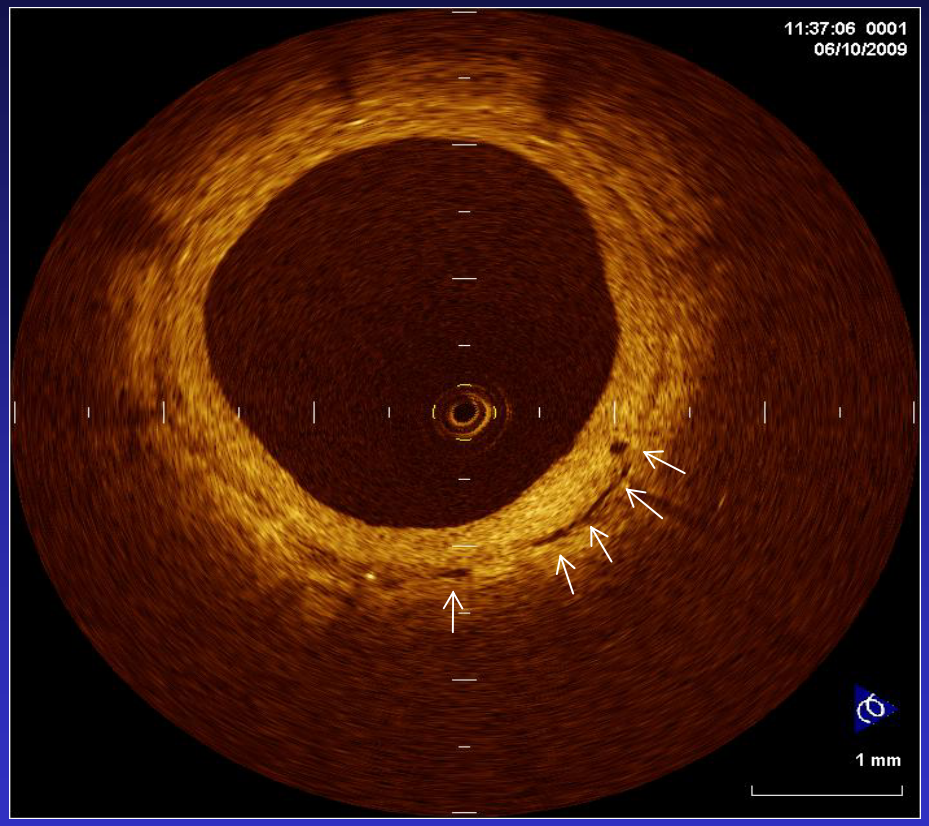
BMS SES PES



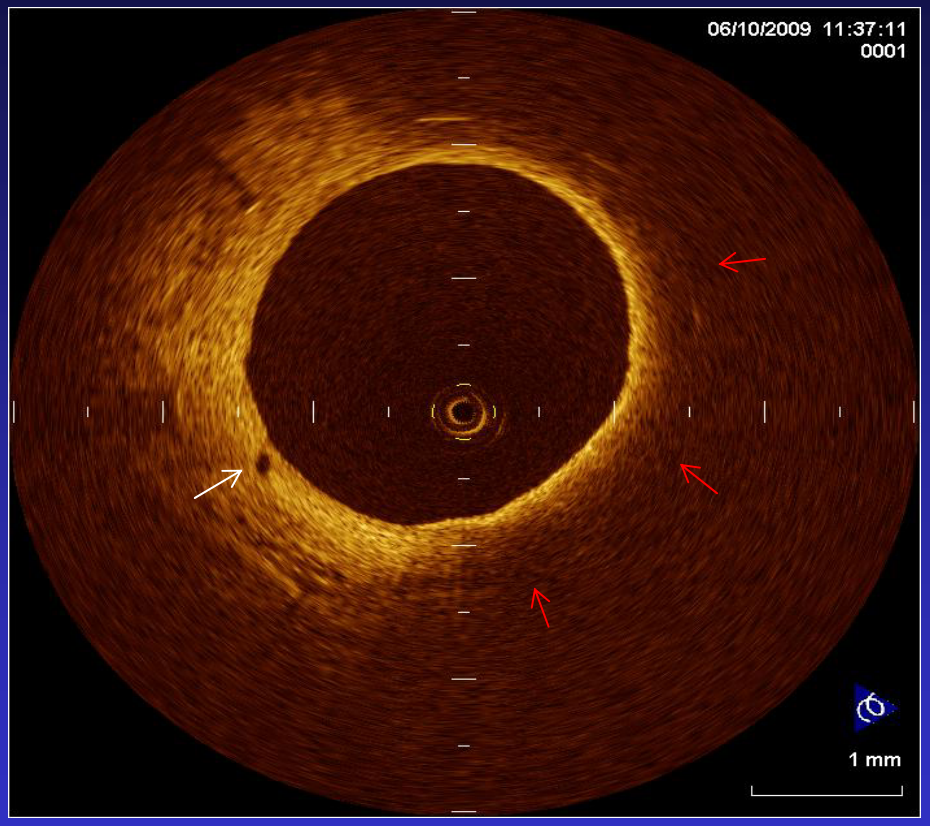
Instent restenosis is one of the problems after stenting, even in DES era.

Characteristics of the restenosis tissue is different among BMS & DESs.

Representative OCT images of atherosclerotic changes in neointima within BMS

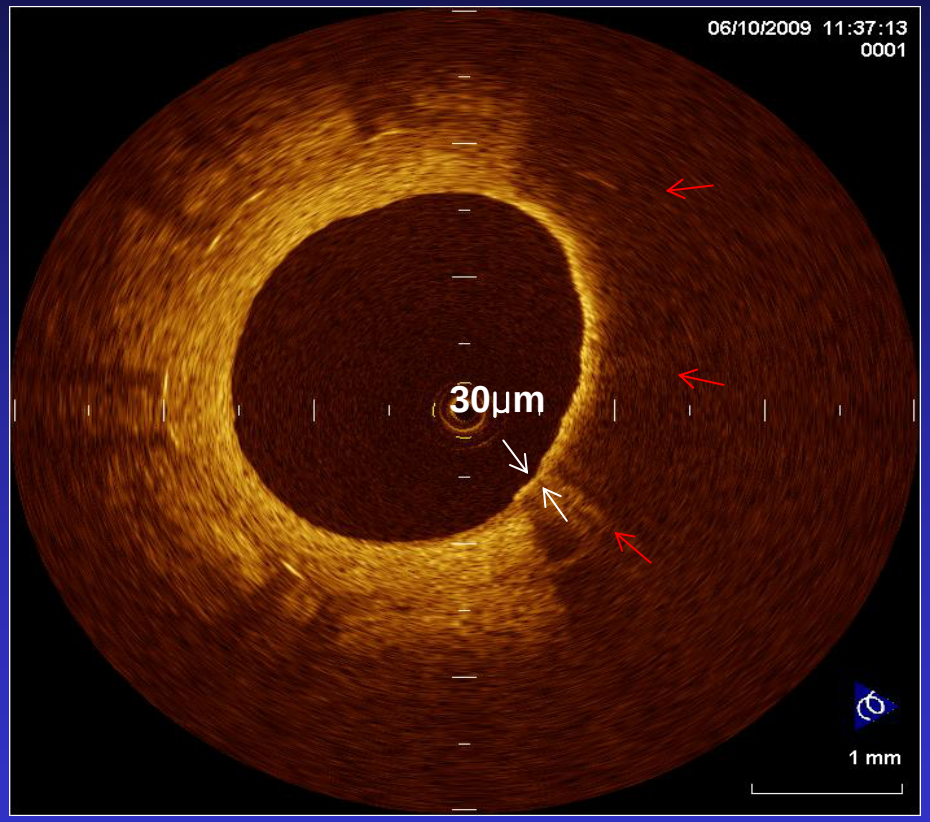


Peri-strut neovascularization

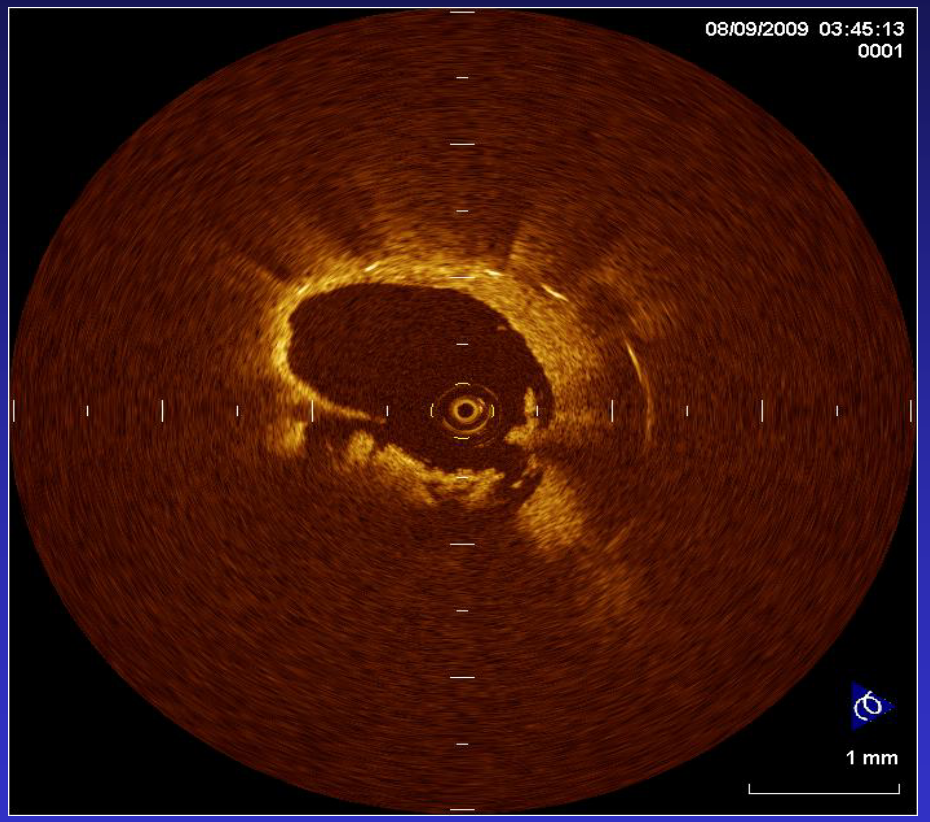


Lipid-laden intima with intra-intima neovascularization

Representative OCT images of atherosclerotic changes in neointima within BMS



TCFA-like intima



Intimal disruption with thrombus

Incidence of lipid rich plaques within neointima after BMS

Subjects: 39 pts (60 BMS) with recurrent ischemia
out of 1636 pts with BMS (from 1999-2006)

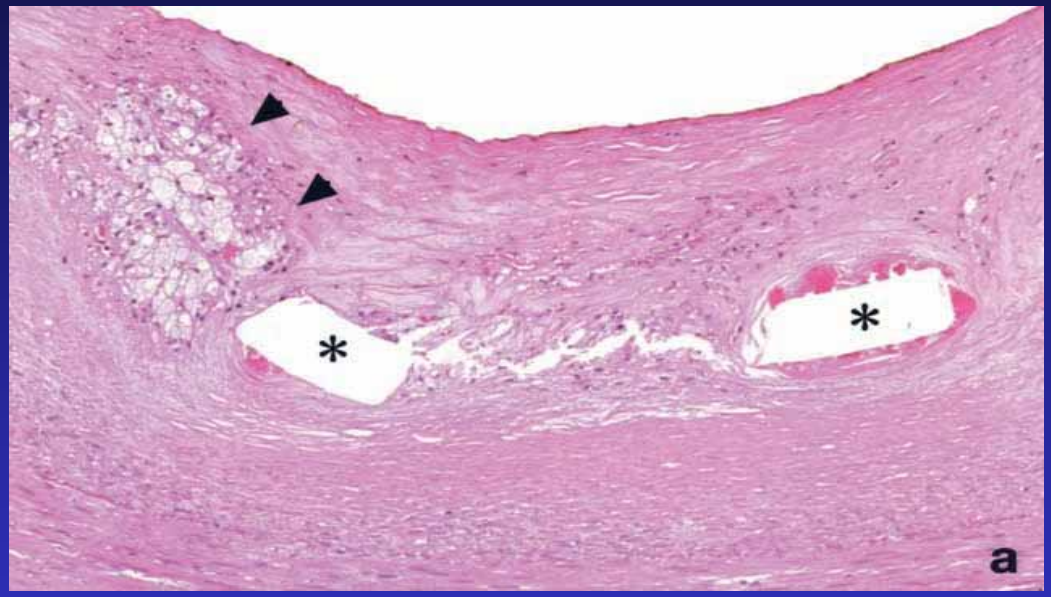
OCT findings:

Lipid-rich plaque: 16 pts (41%), 20 BMS (33.3%)
Cap thickness: 56.7±5.8
Lipid arc: 173±58

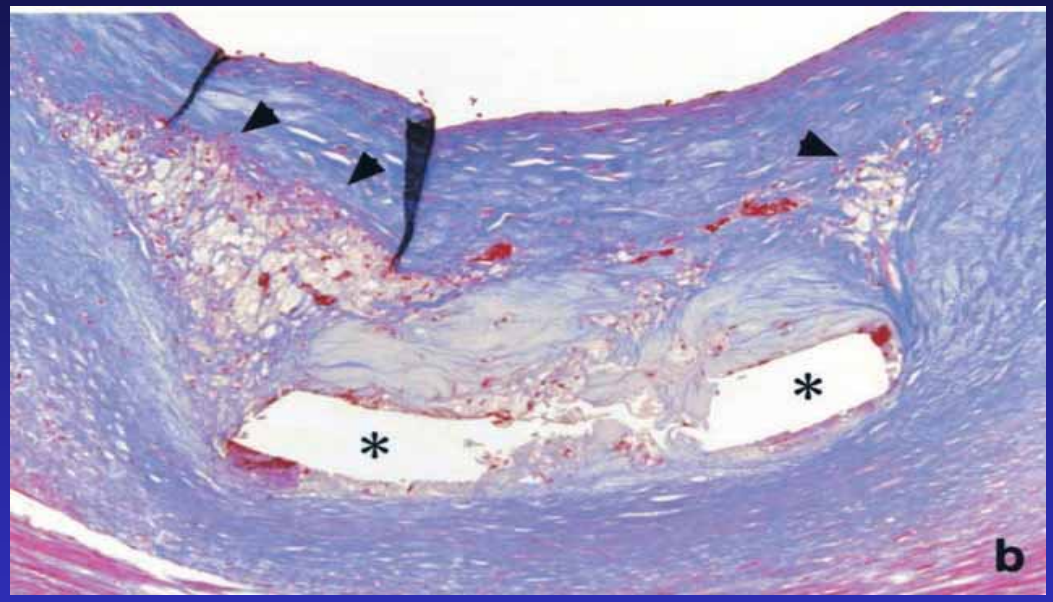
Fibrous plaque: 23 pts (59%), 40 BMS (66.7%)

Hou J, et al. Heart 2010;96:1187-1190

Pathological findings ≥ 4 years after BMS implantation



HE stain



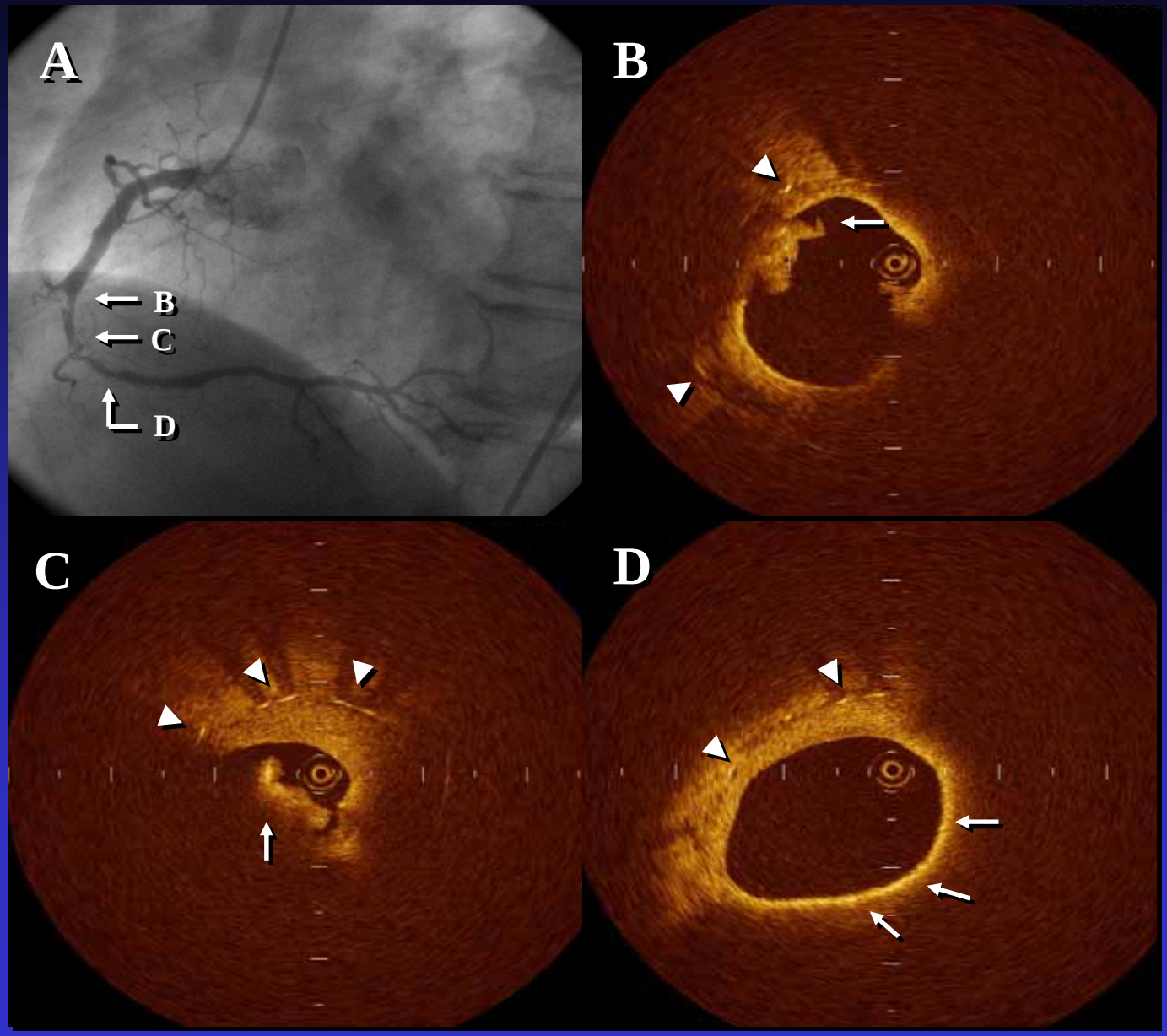
Masson trichrome stain

Heavy infiltration of foamy cells is observed around the stent struts.

（＊）stent strut （▲）foamy cell

(Inoue K et al. Cardiovascular pathology 2004;13;109-115)

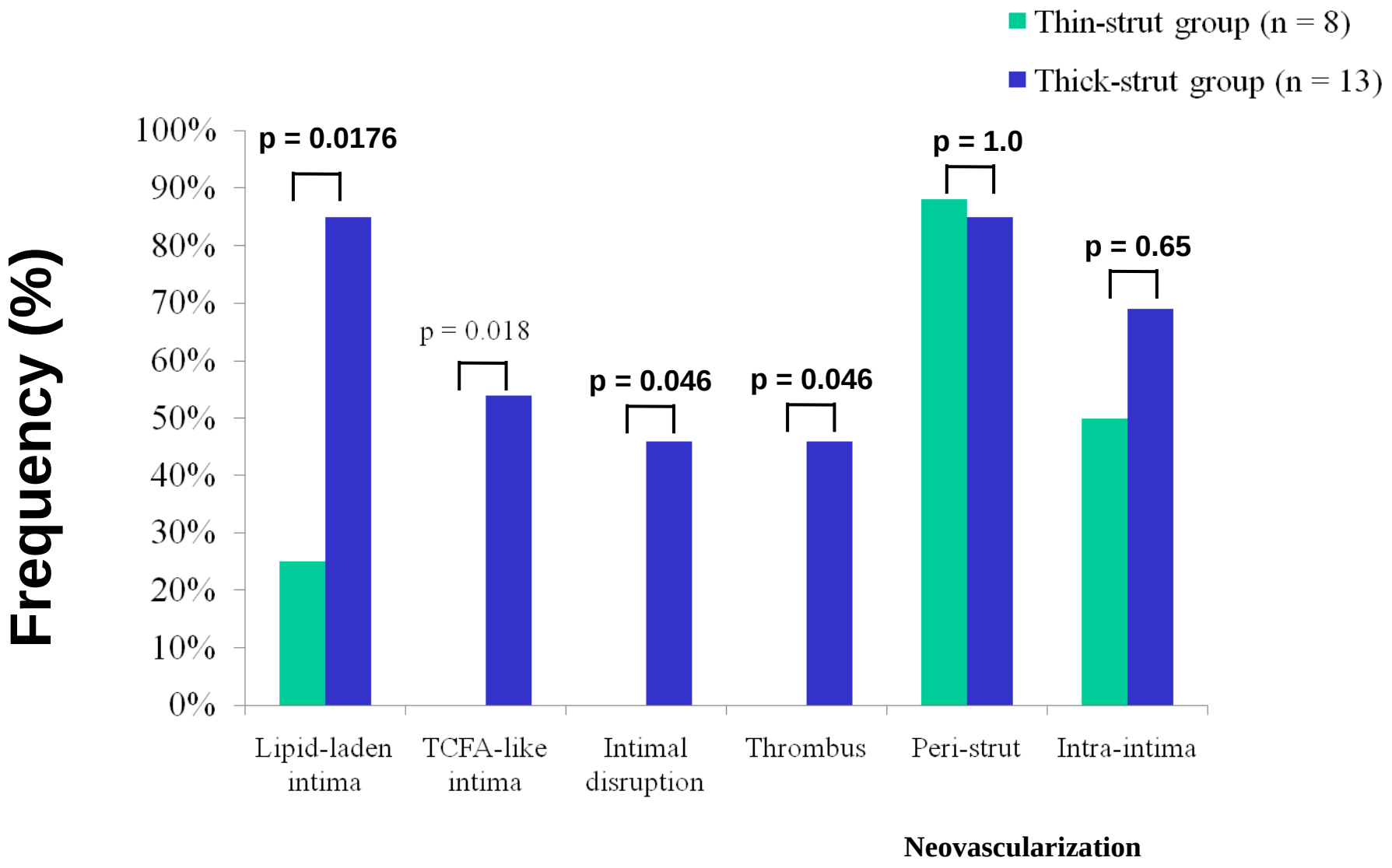
VLT in BMS (58 y.o. man)



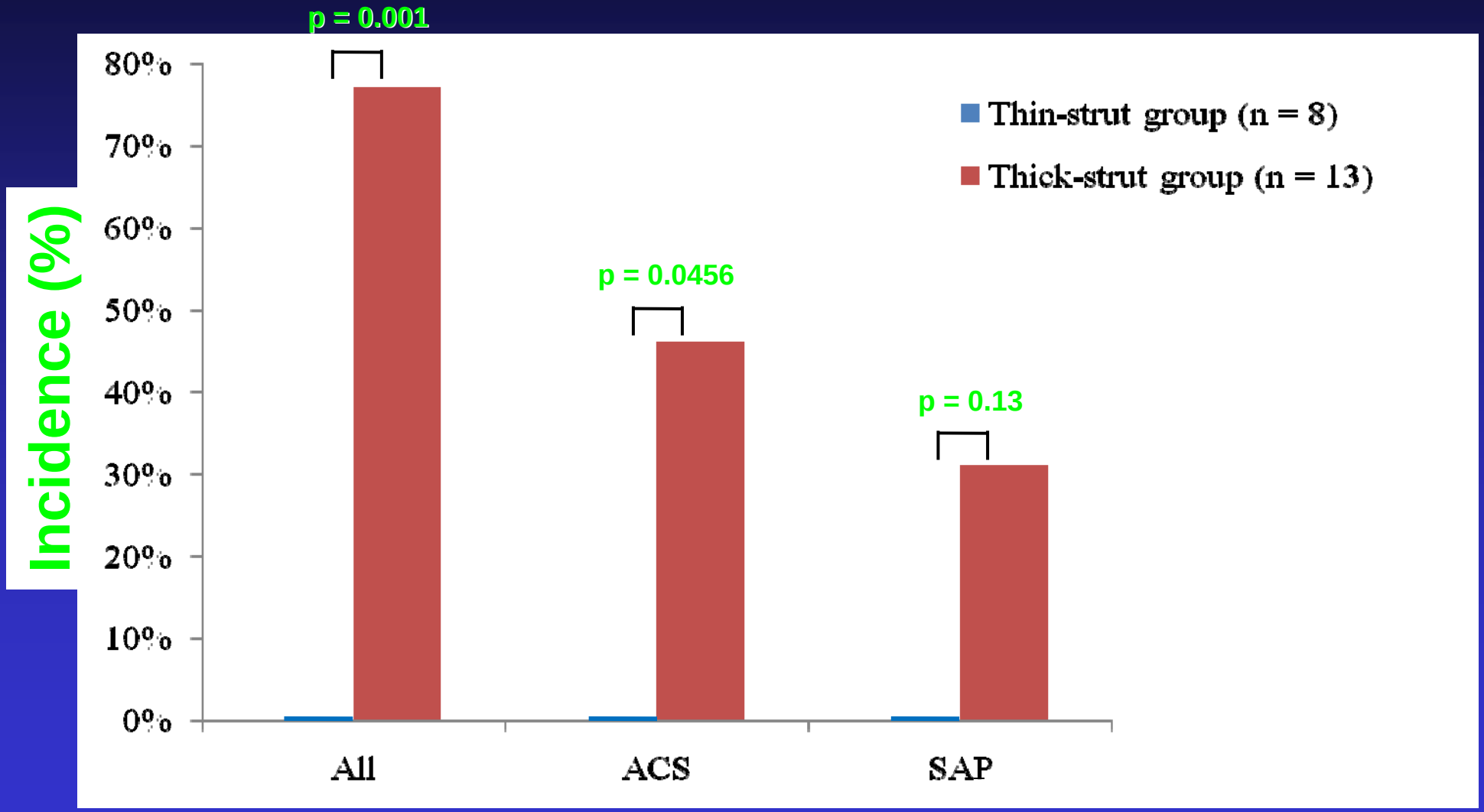
- STEMI 7 yrs ago
- BMS to RCA. (3.0 × 18mm)
- Recurrent CP (NSTEMI)

(Kashiwagi M, et al. JACC Imaging 2010;3: 525-527)

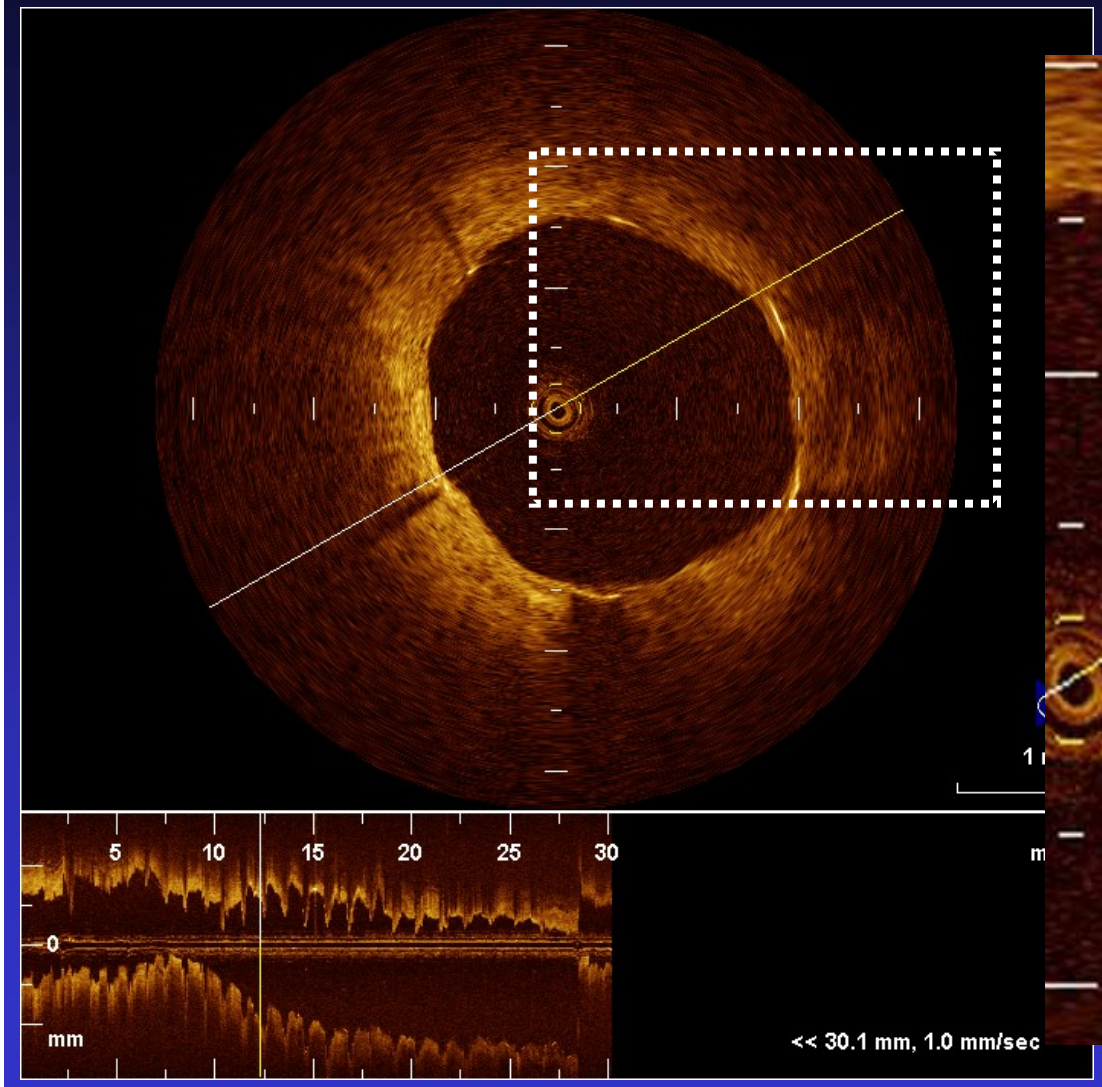
Frequencies of atherosclerotic findings

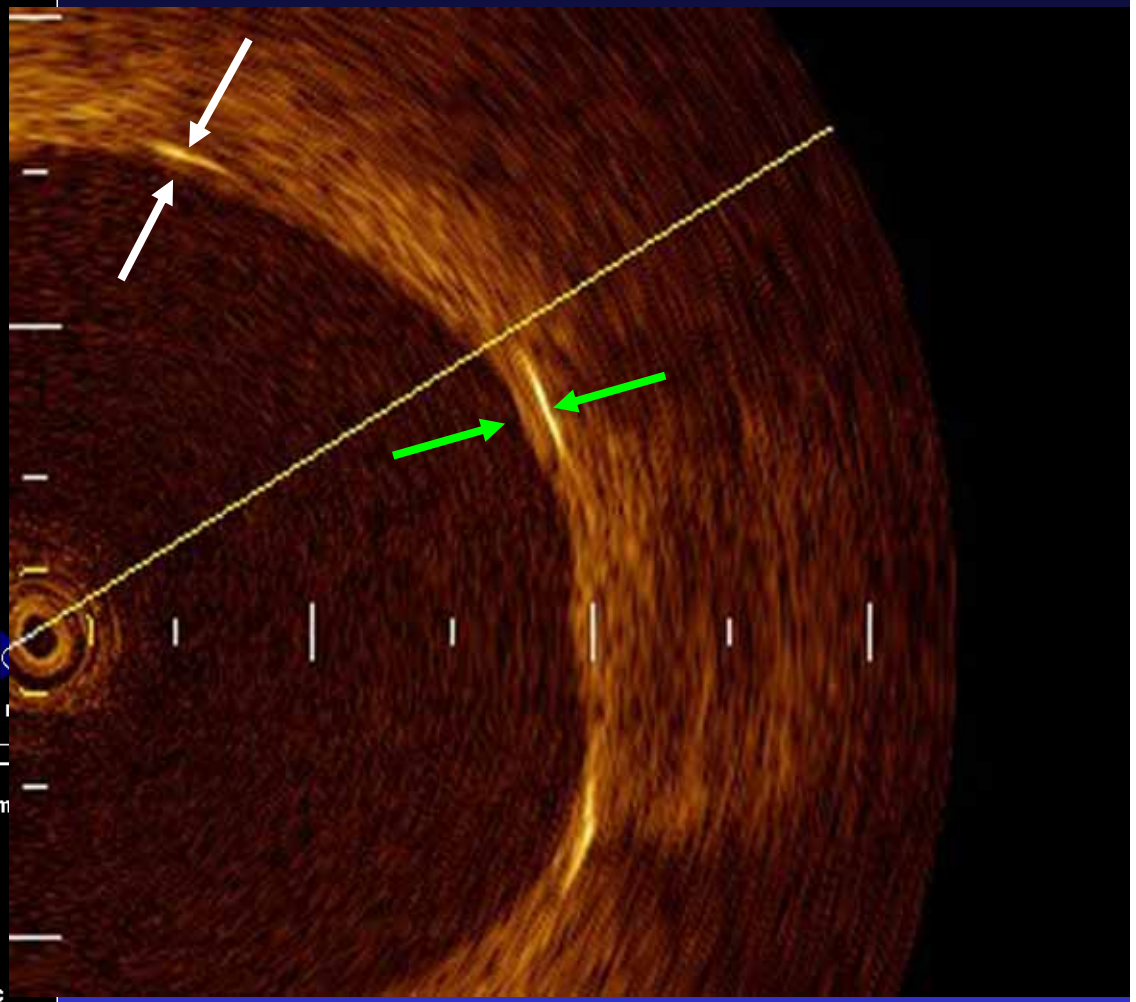


Incidence of symptomatic coronary events associated with the stented segment



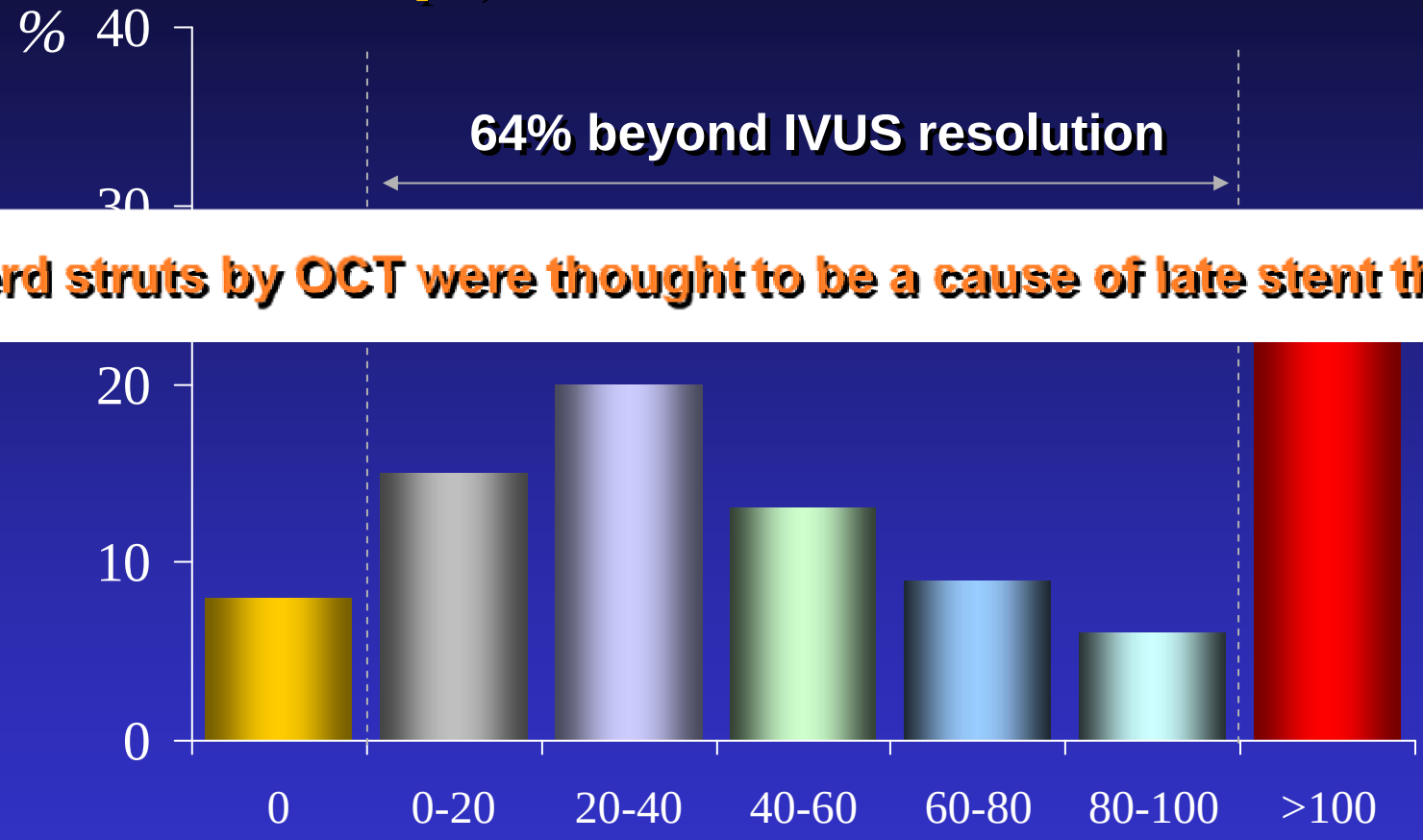
Post-stent follow up





Distribution of the neointima thickness on SES strut (6 months f/u)

34 pts, 6840 stent strut cross sections



Uncoverd struts by OCT were thought to be a cause of late stent thrombosis.

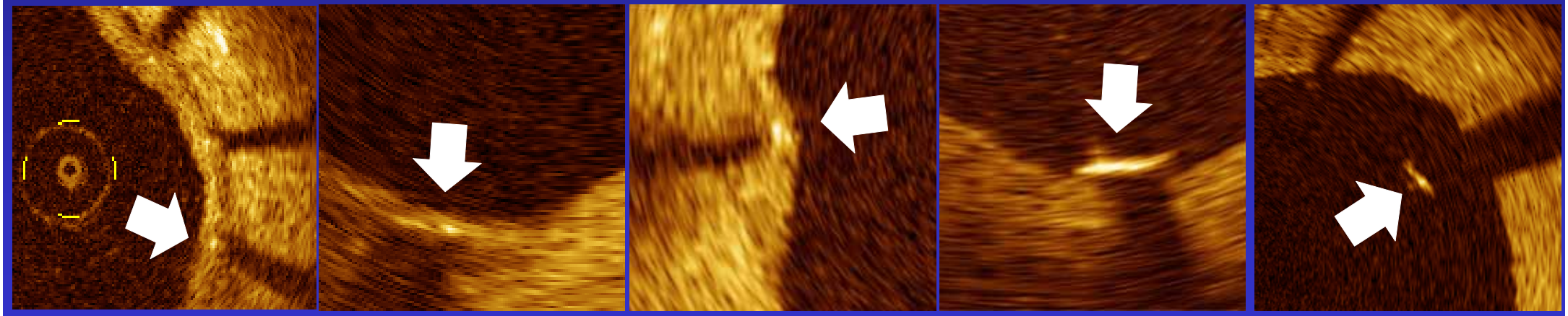
Matsumoto, D. et al. Eur Heart J 2007 28:961-967

Neointima thickness is under IVUS resolution in more than 70% pts.

Classification of strut condition

Qualitative Struts Analysis

Embedded	Protruding / Covered	Protruding/ Uncovered	Malapposed/ Uncovered
I/II	IIIa	IIIb	IV

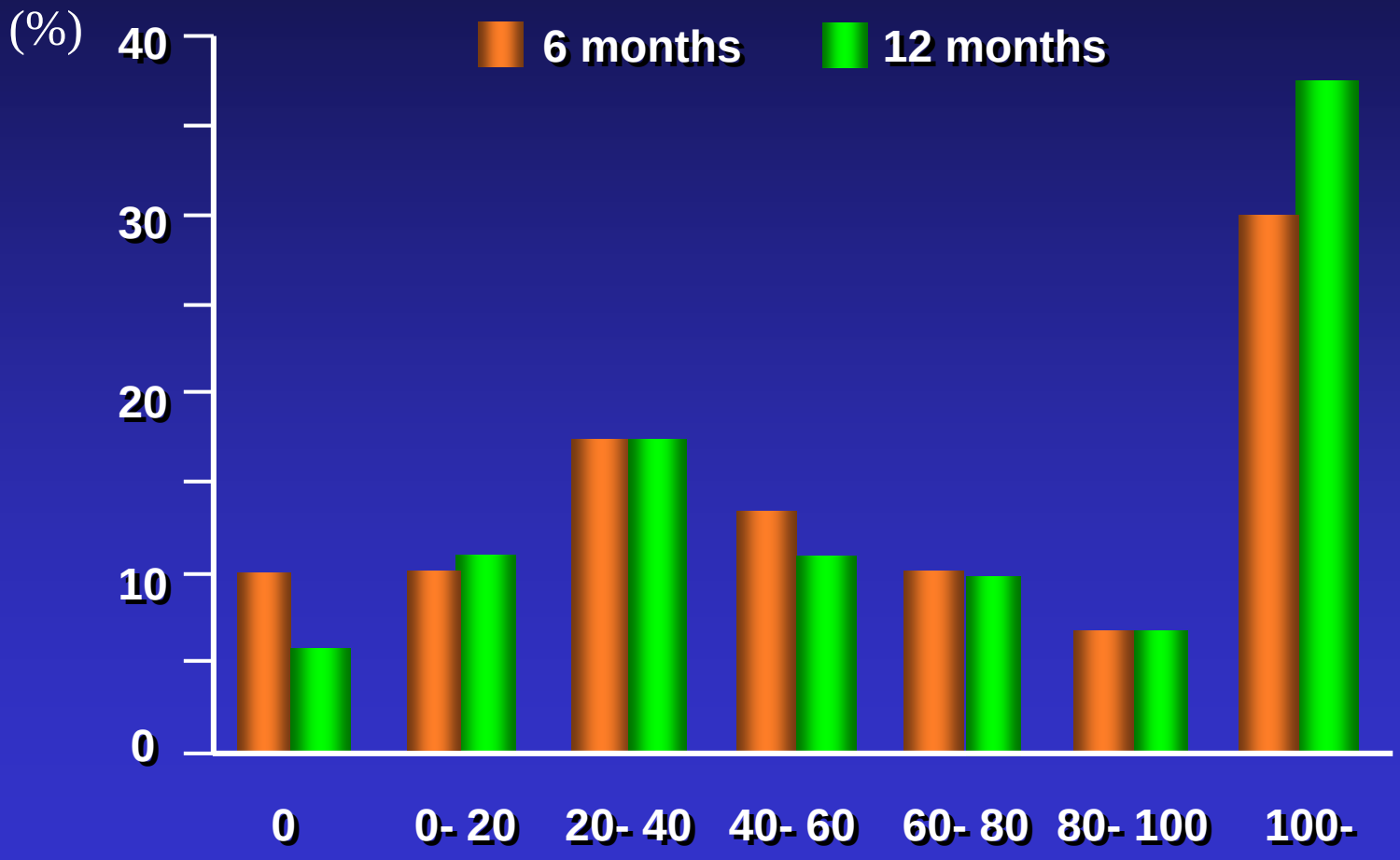


Guagliumi G, Sirbu V. Catheter Cardiovasc Interv. 72:237-247, 2008

Delayed Neointimal Healing in SES *(N=21)*

6 Months and 12 Months OCT FU

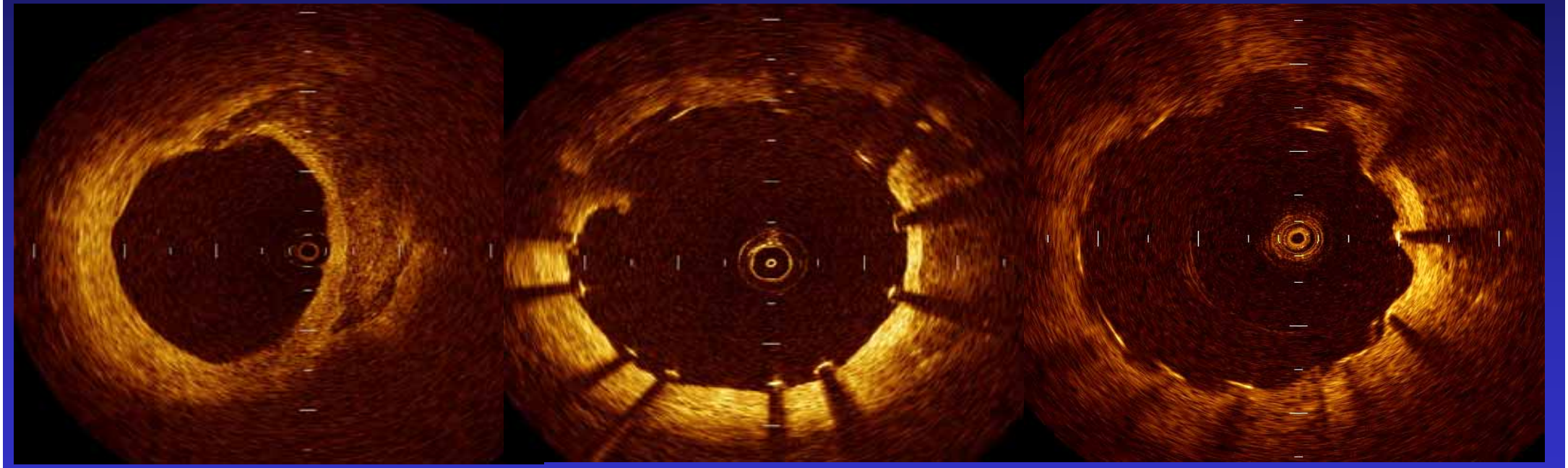
Rate of uncovered strut decreased from 10.4% to 5.7% (P<0.0001)



Katoh H. et al, Circ J 2009; 73:1033-1037

Delayed healing after SES implantation

Before stenting | Soon after stenting | 9 months after stenting



Lesion characteristics may relate to the long term results in DES?

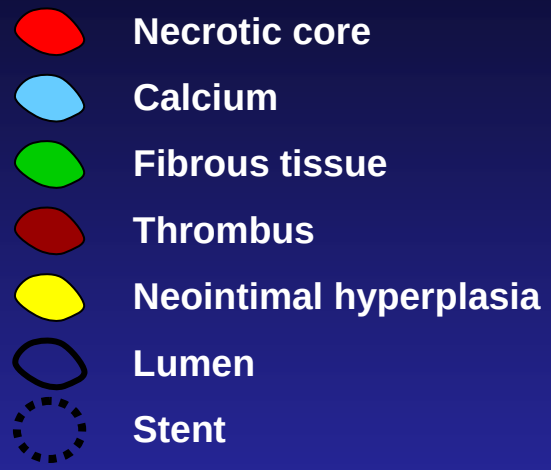
A. Unstable plaque

Ruptured plaque

Thin-cap fibroatheroma

Post-PCI

Follow-up

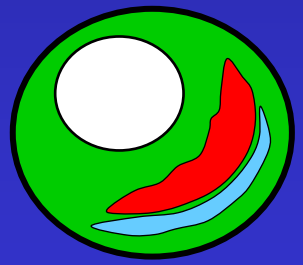


- Ruptured plaque cavity
- Inadequate-stent apposition
- Tissue protrusion
- Intracoronary thrombus

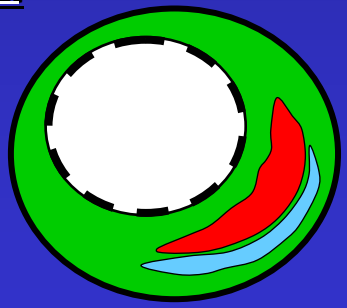
- Residual ruptured plaque cavity
- Inadequately-apposed stent struts without neointimal coverage

B. Stable plaque

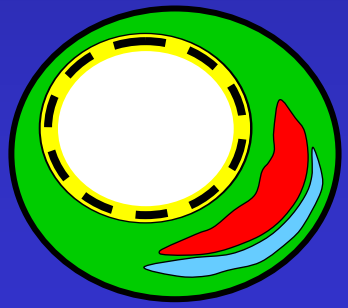
Thick-cap fibroatheroma



Post-PCI



Follow-up



- Well-stent appostion
- stent struts with neointimal coverage

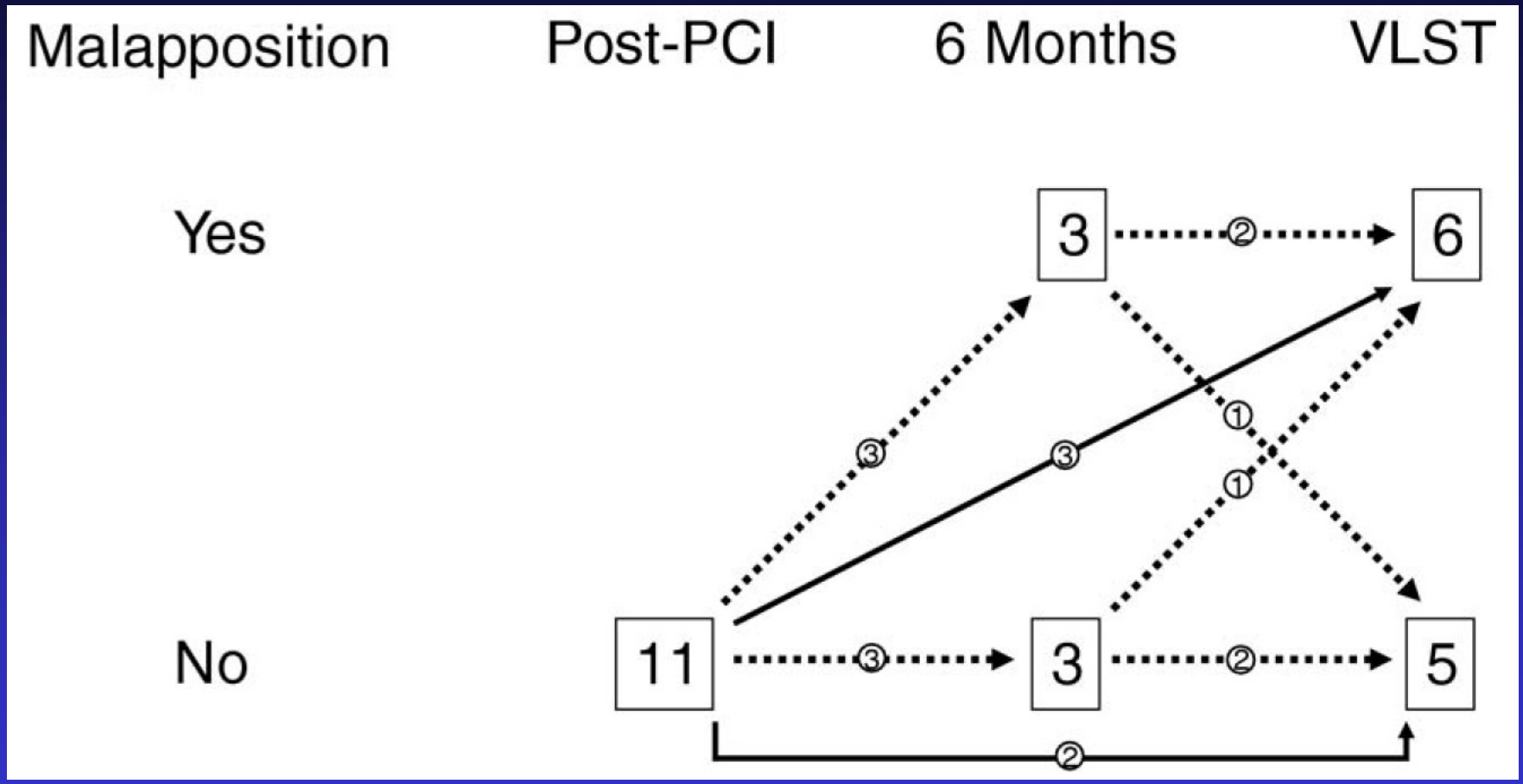
Kubo T, et al. J Am Coll Cardiol Img. 1:475-478, 2008

IVUS findings in cases with very late stent thrombosis

Variables	DES (n = 23)	BMS (n = 7)	p Value
Proximal reference segment, mm^2			
Mean EEM CSA	18.30 ± 6.30	18.60 ± 5.87	0.856
Mean lumen CSA	7.81 ± 3.71	9.17 ± 4.68	0.689
Mean plaque and media CSA	10.50 ± 5.01	9.42 ± 3.52	0.799
Distal reference segment, mm^2			
Mean EEM CSA	9.31 ± 4.15	13.96 ± 5.66	0.078
Mean lumen CSA	3.51 ± 1.78	4.22 ± 1.84	0.438
Mean plaque and media CSA	5.79 ± 3.61	9.75 ± 4.26	0.028
Stent segment			
Total stented length, mm	32.9 ± 13.0	18.6 ± 4.2	0.001
Mean EEM CSA, mm^2	19.55 ± 6.07	18.31 ± 4.17	0.774
Mean stent CSA, mm^2	7.25 ± 1.79	9.75 ± 2.89	0.037
Mean lumen CSA, mm^2	4.20 ± 1.40	4.73 ± 1.64	0.564
Minimal stent CSA, mm^2	6.15 ± 1.58	7.42 ± 3.77	0.413
Mean neointimal area, mm^2	3.07 ± 1.15	5.03 ± 1.78	0.014
Neointima volume index	0.42 ± 0.12	0.51 ± 0.09	0.069
ISA **Incomplete stent apposition**	17 (73.9)	0 (0)	0.001
Length, mm	7.40 ± 5.49		
CSA, mm^2	4.58 ± 1.94		
Volume, mm^3	17.83 ± 4.99		
Arc of ISA, °	158.1 ± 50.8		
Location			
Proximal stent segment	6 (35.3)		
Stent body	7 (41.2)		
Distal stent segment	4 (23.5)		

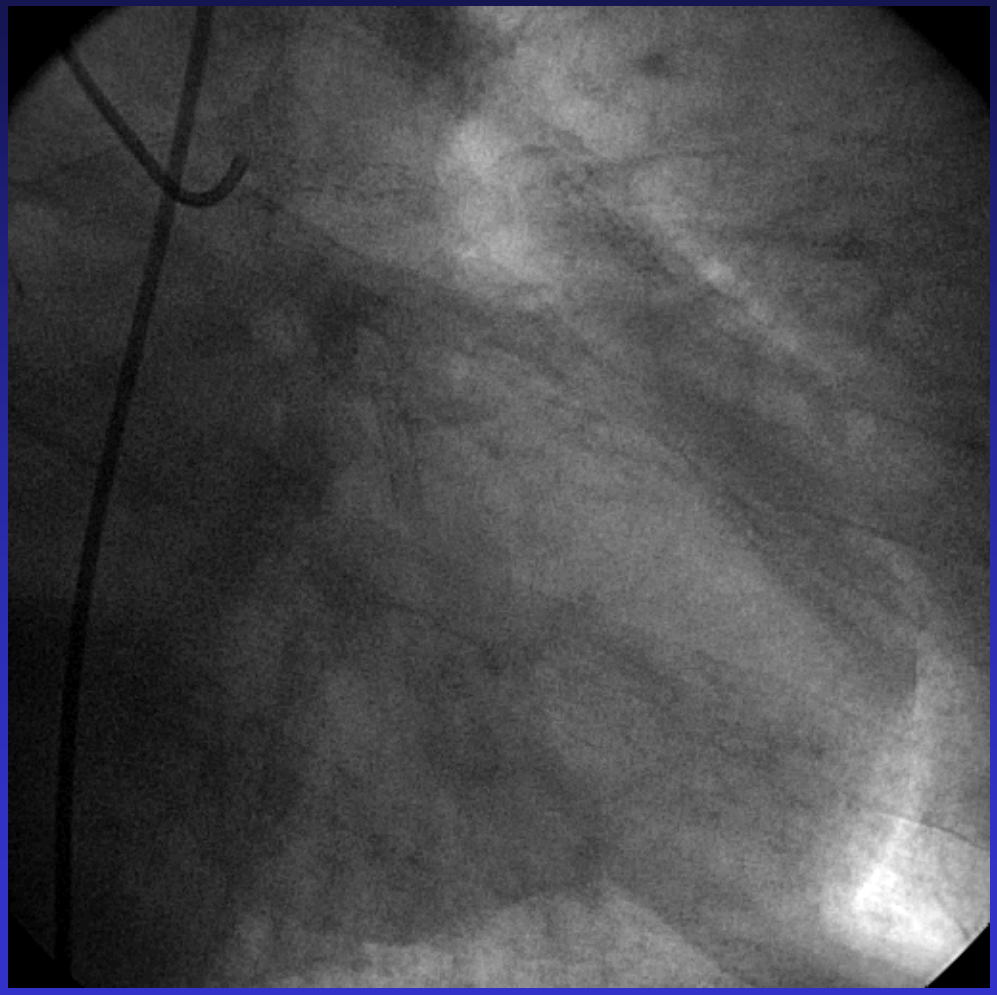
Lee CW, et al. J Am Coll Cardiol 2010;55:1936-1942

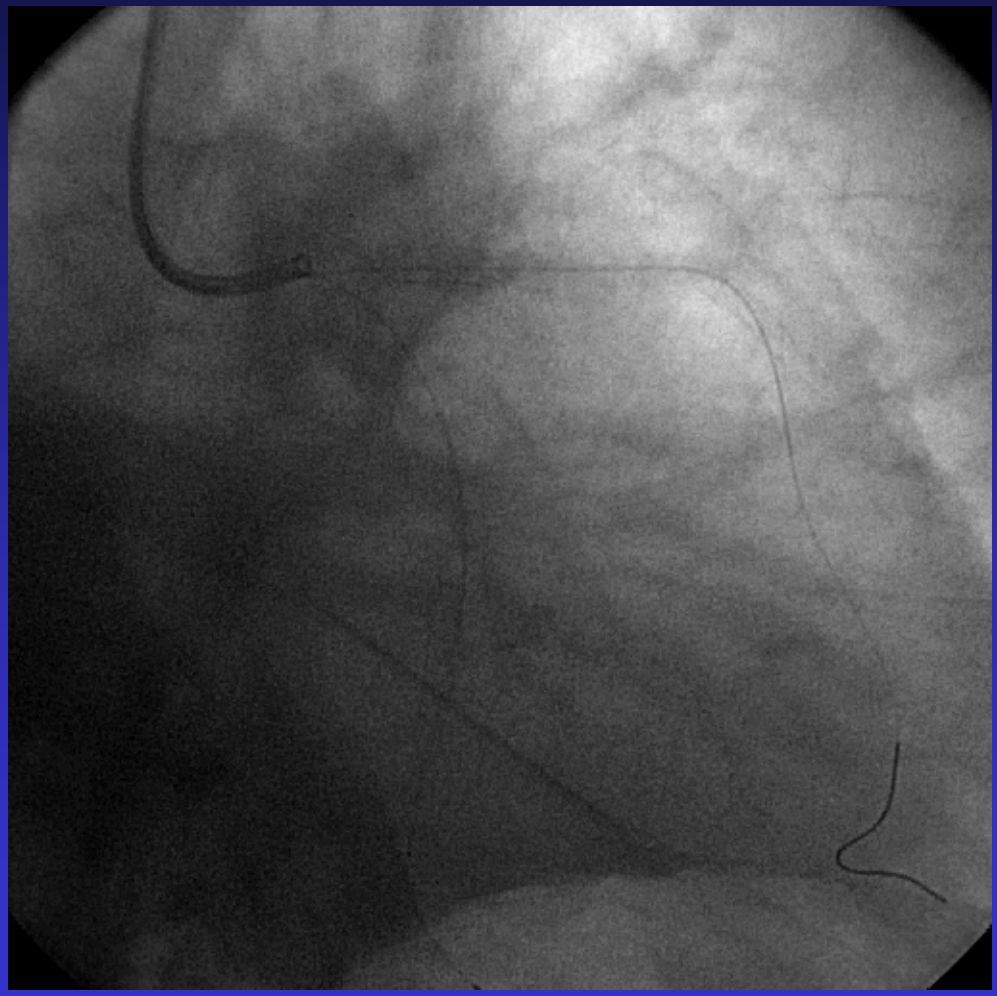
Serial changes of stent malapposition assessed by IVUS



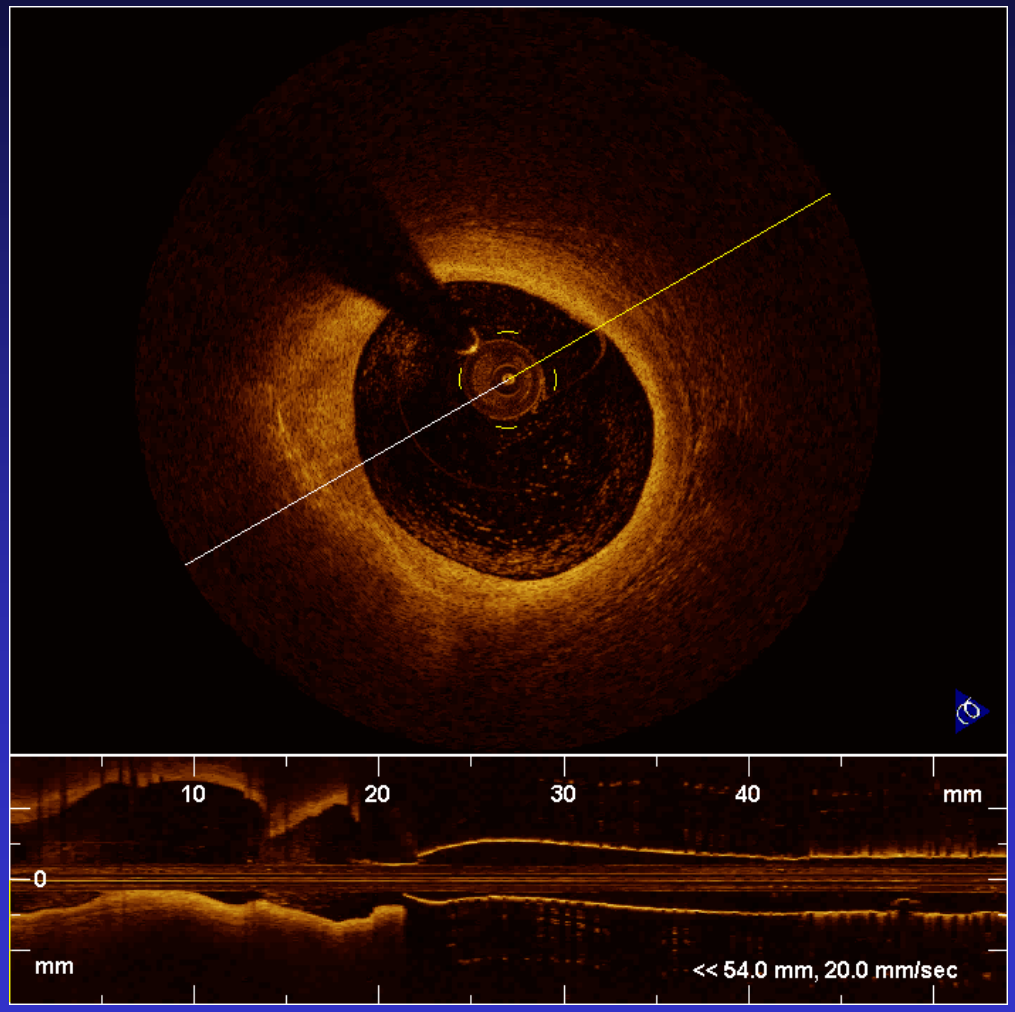
Lee CW, et al. J Am Coll Cardiol 2010;55:1936-1942

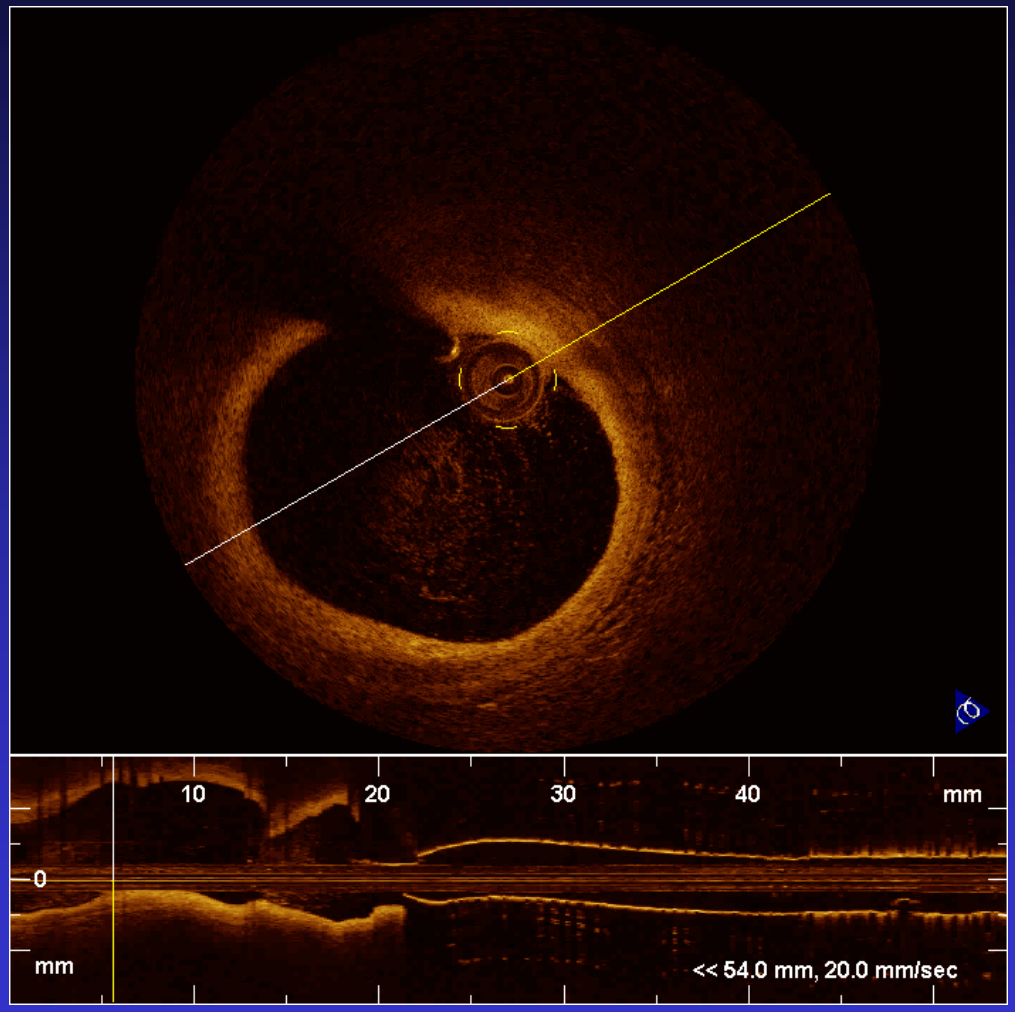
Very late thrombosis 4 years after SES



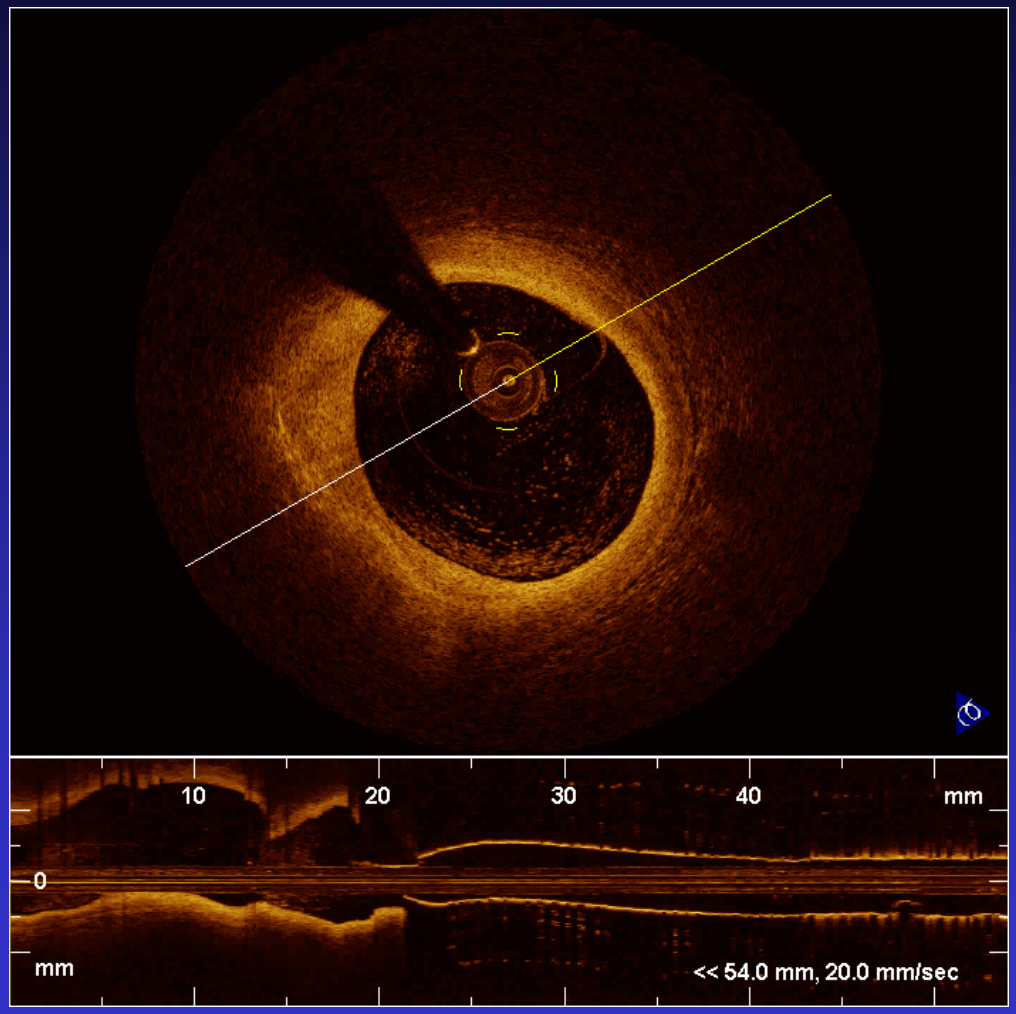


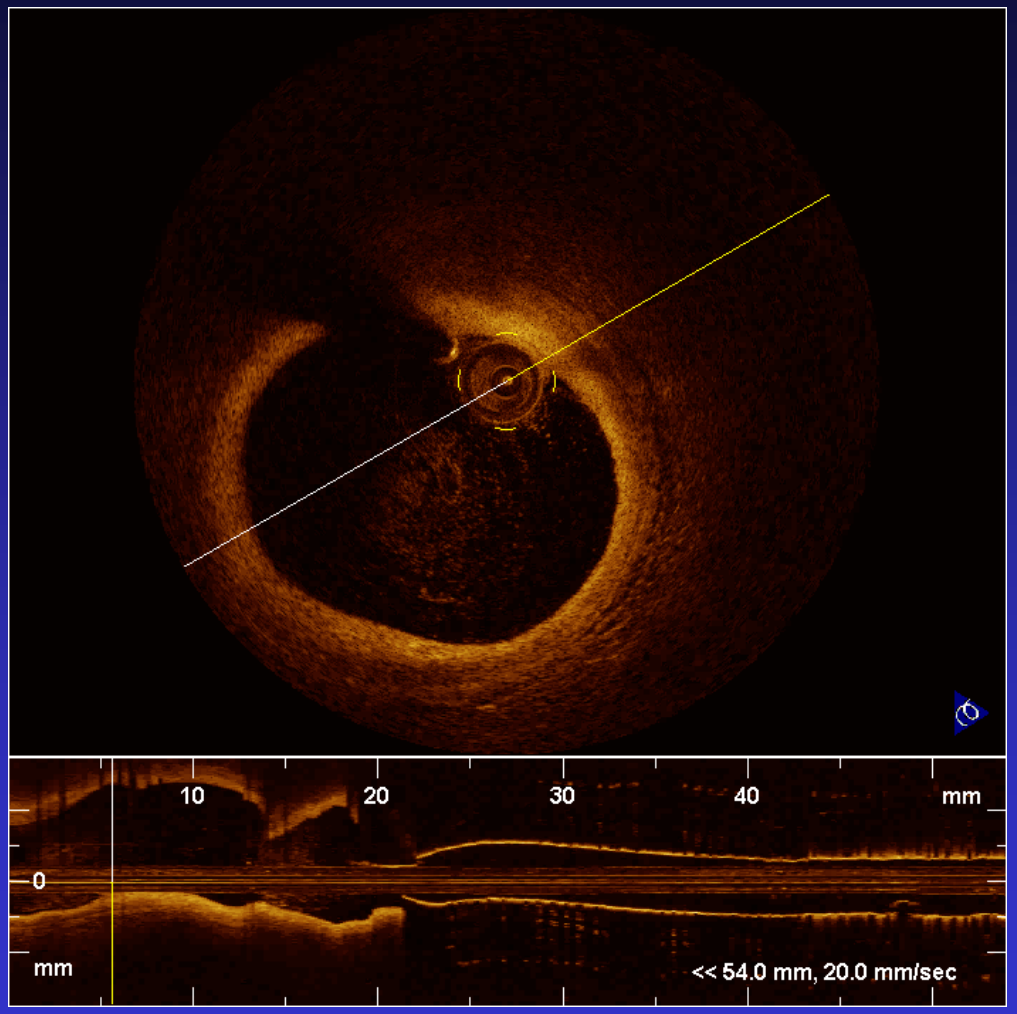
Very late thrombosis 4 years after SES



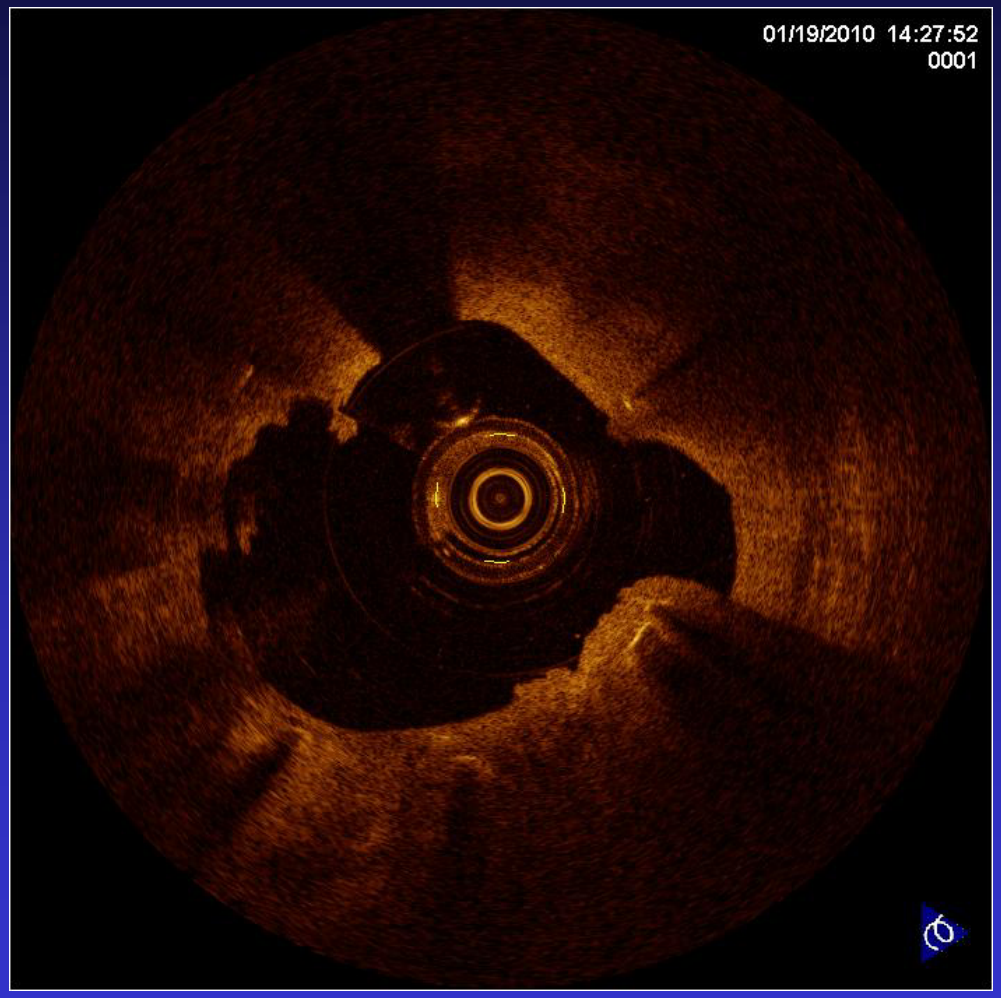


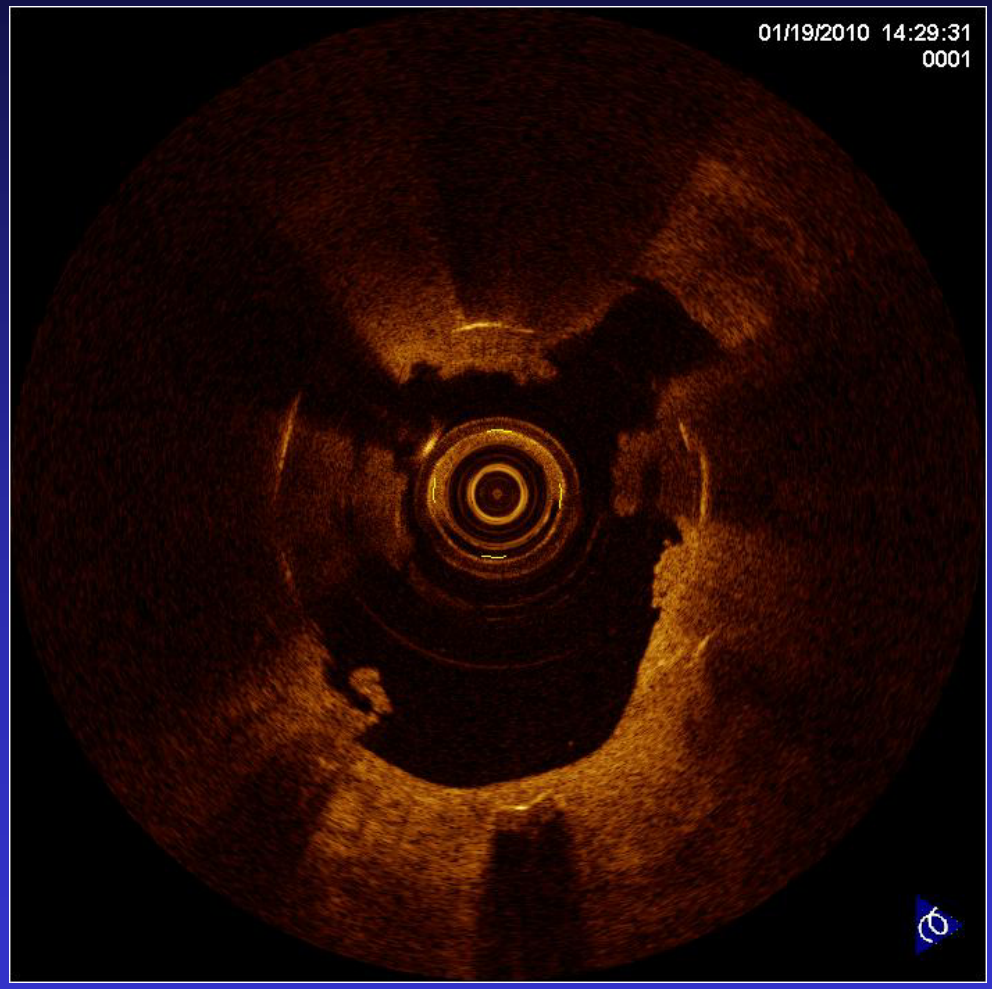
Very late thrombosis 4 years after SES





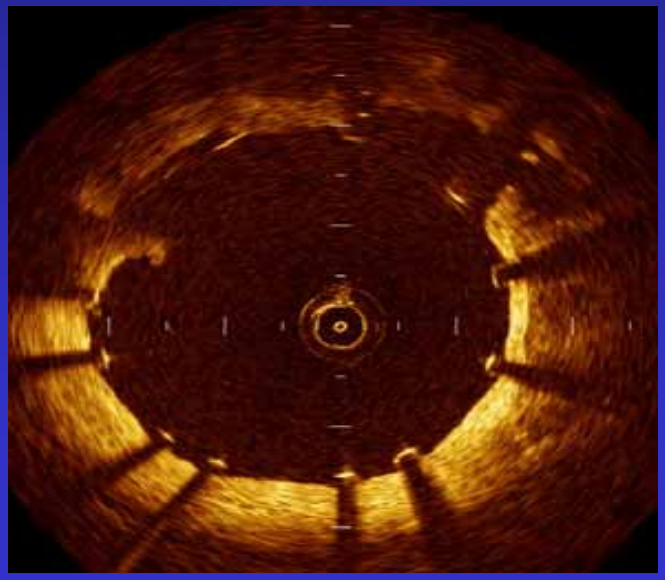
Very late thrombosis 4 years after SES

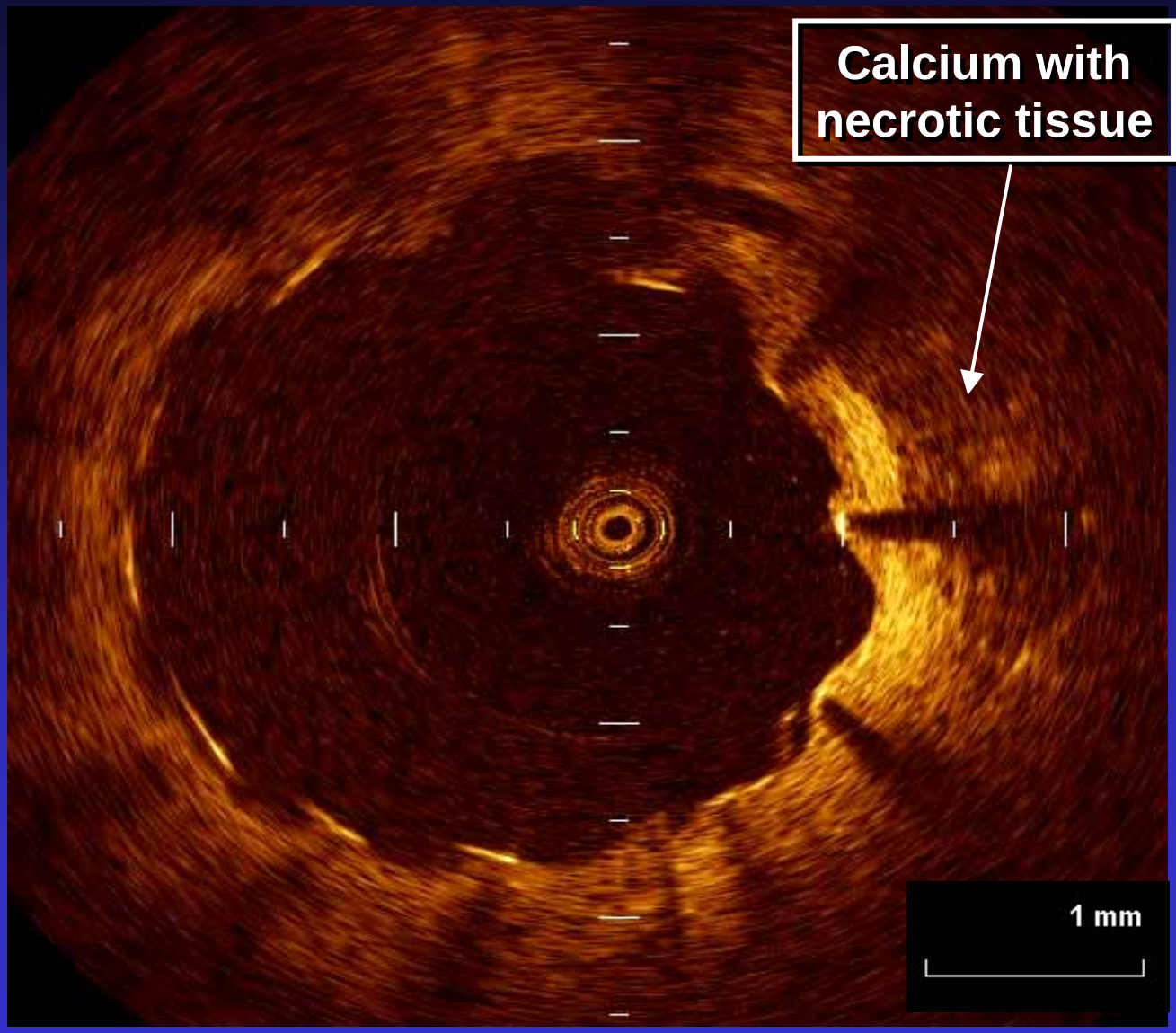




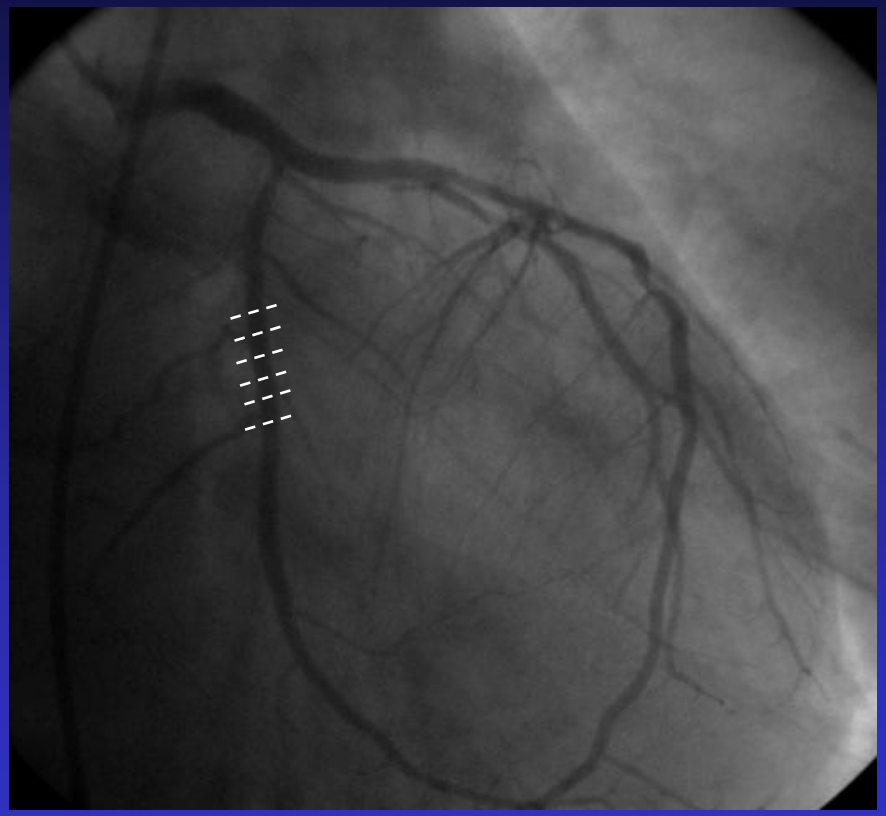
9 months after SES stent implantation

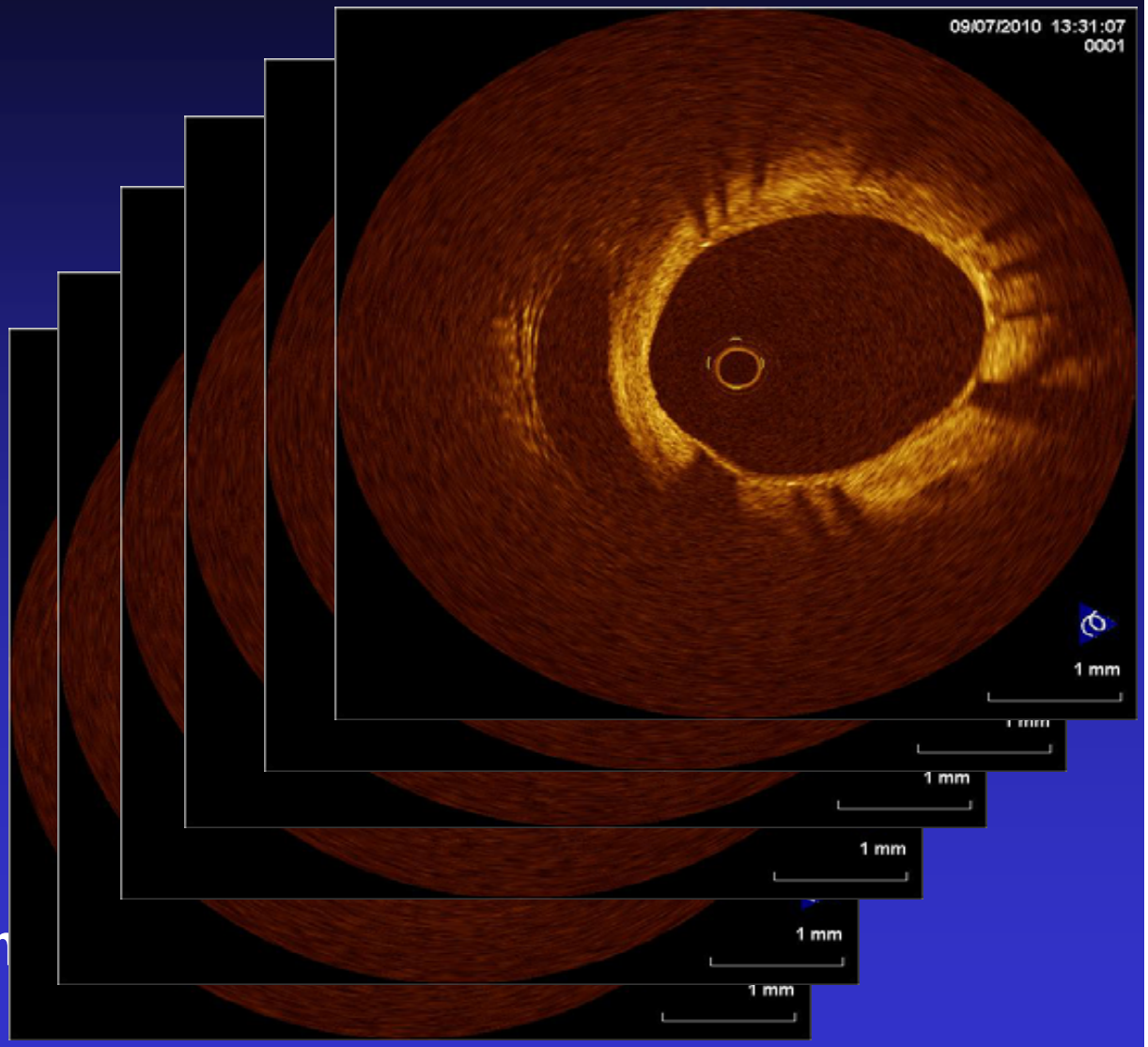
Soon after stenting





7-month follow-up OCT

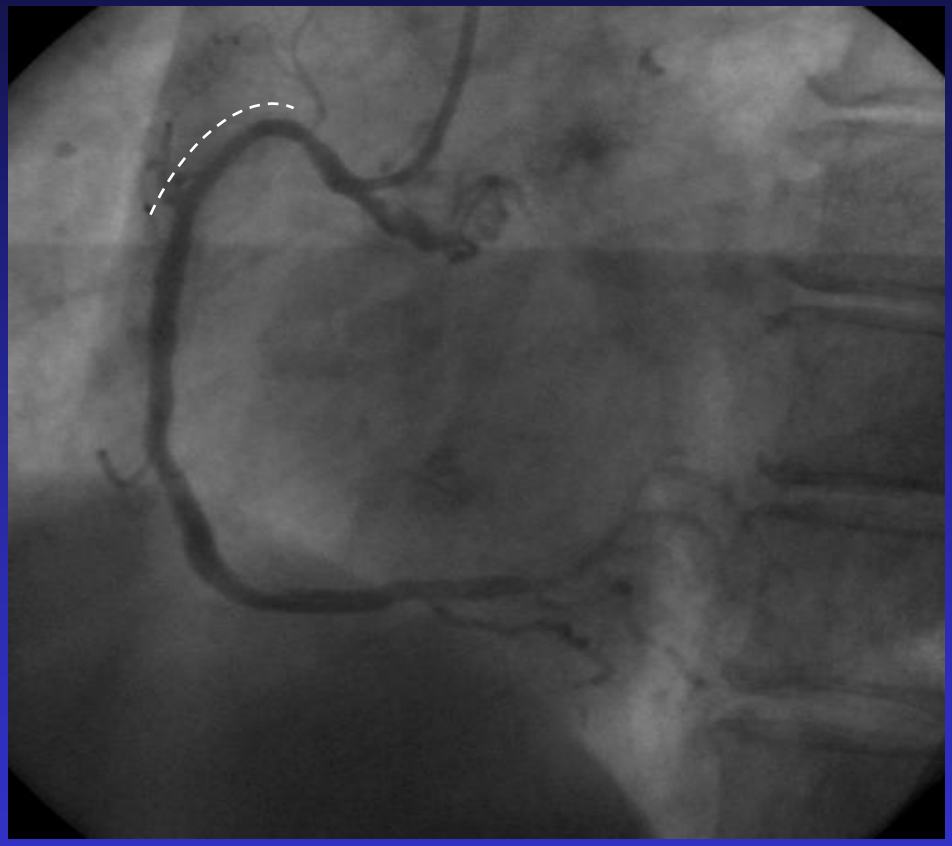




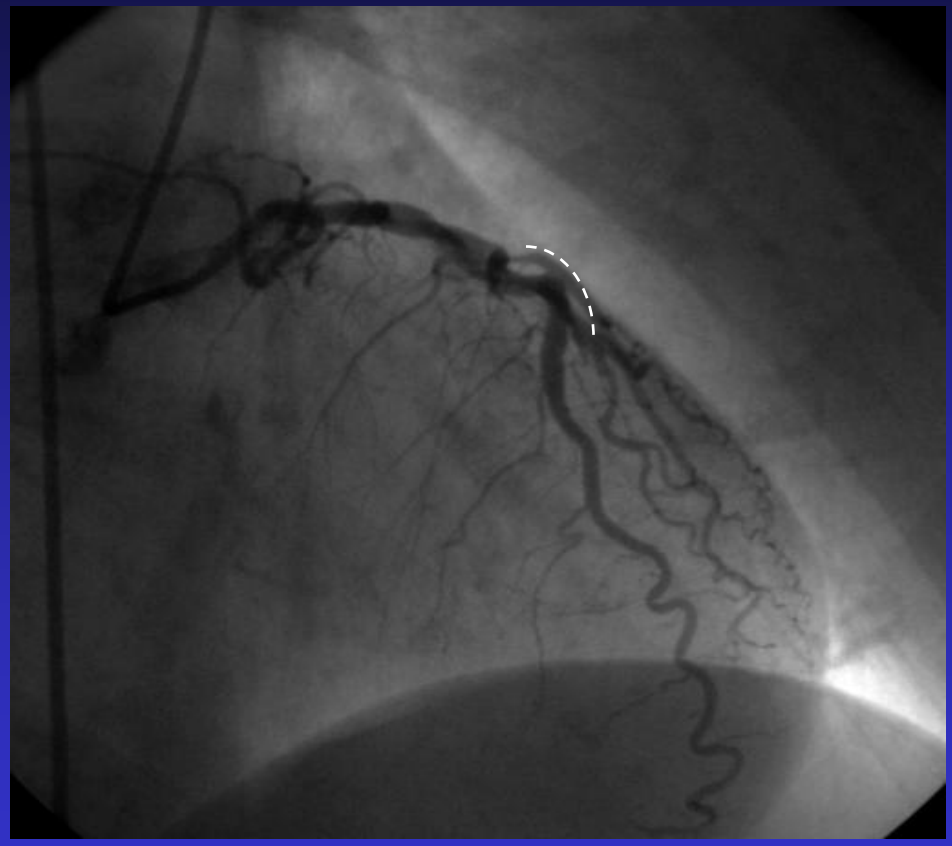
Follow-up (Xience V 2.5×23mm

distal → proximal

7-month follow-up



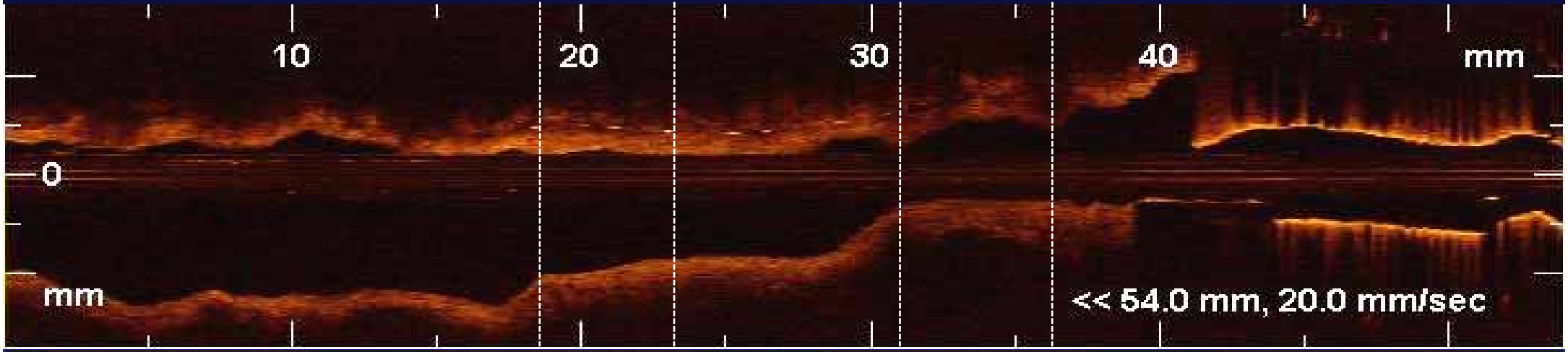
Vision
3.5×18mm

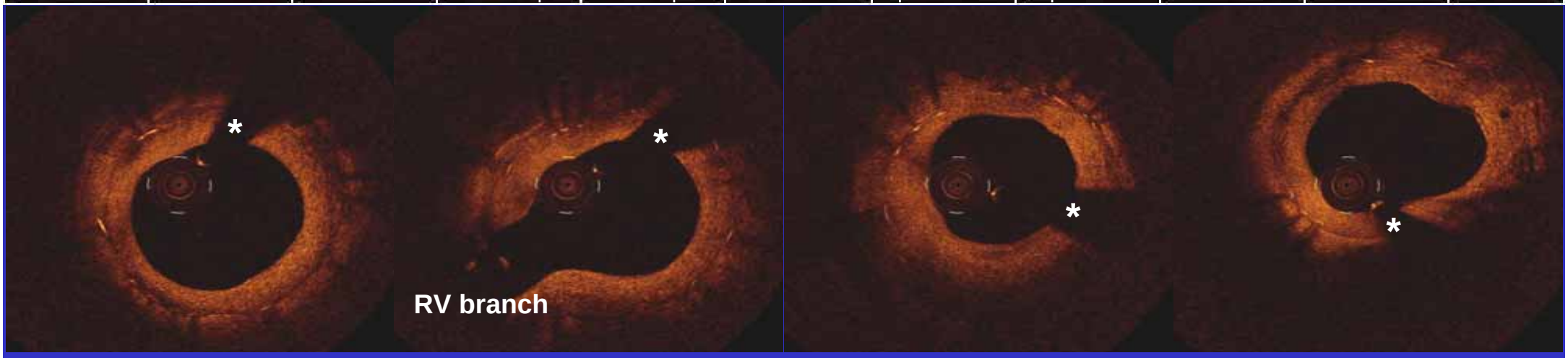


Xience V
3.0×15mm

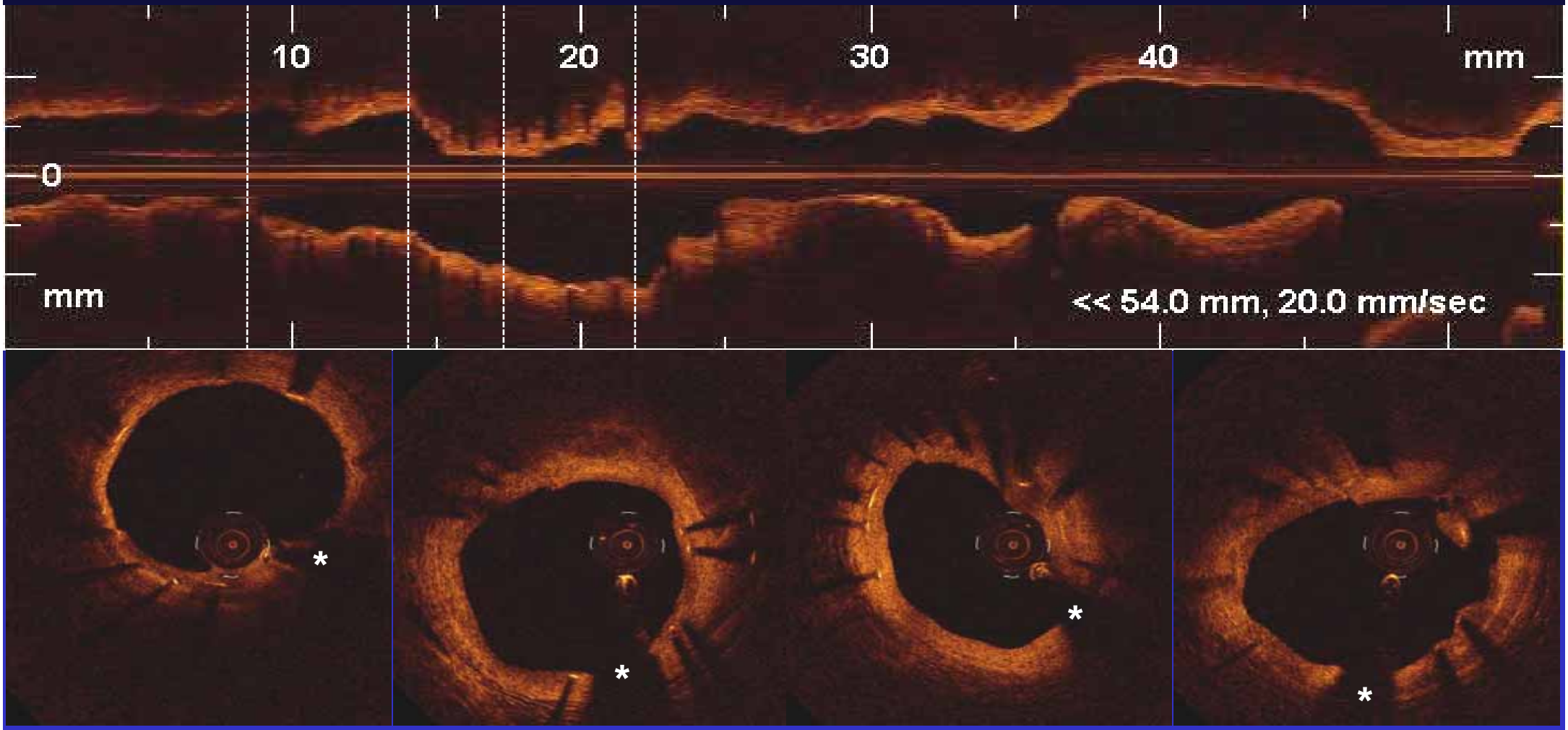
Wakayama Medical University

7-month follow-up OCT (Vision)

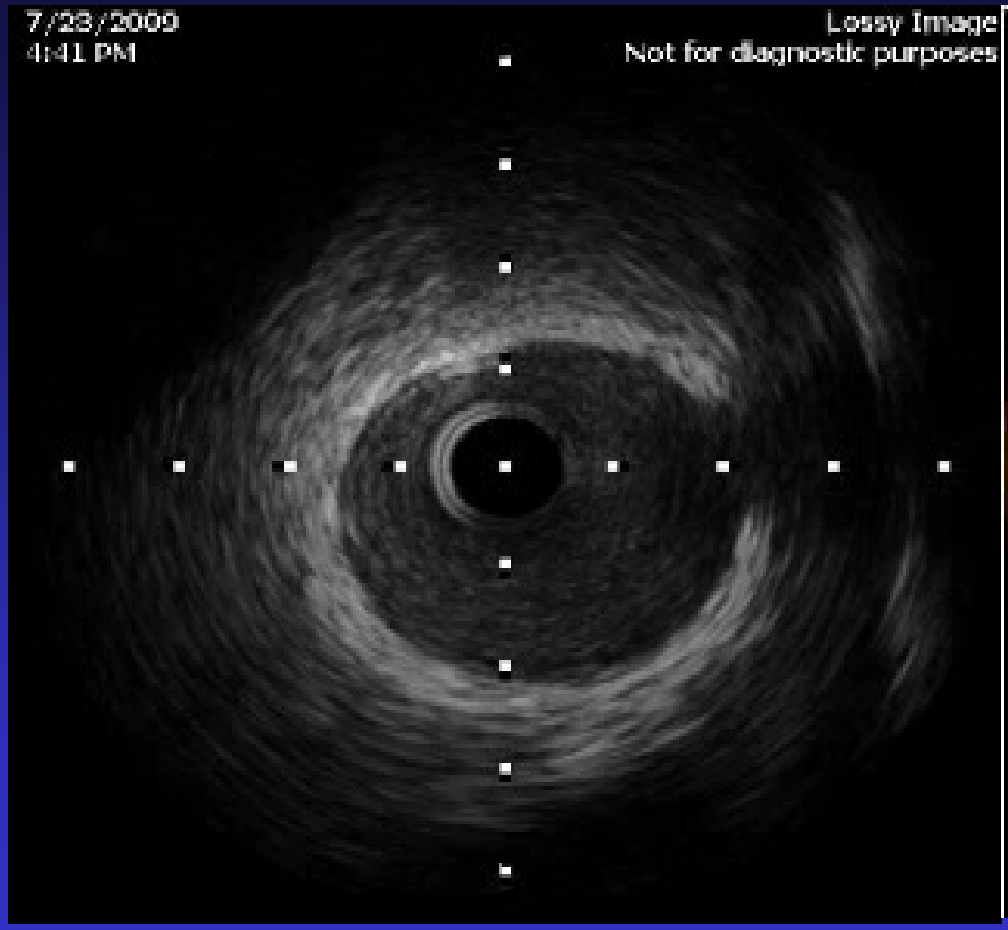


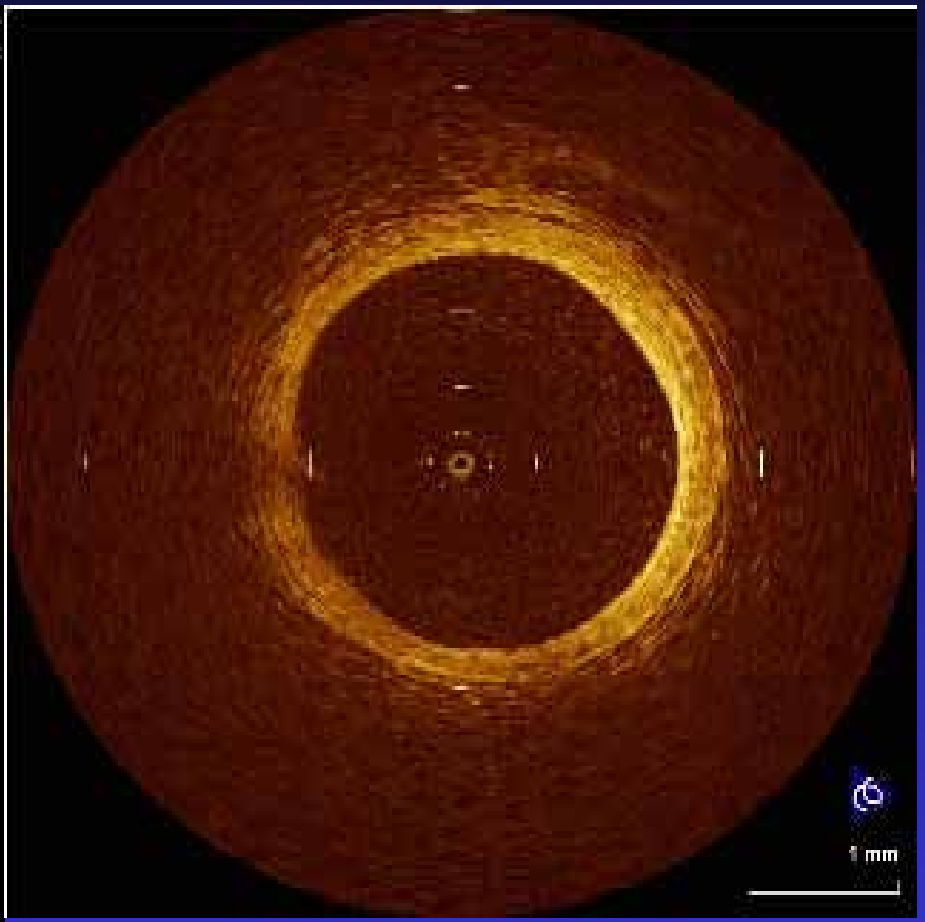


7-month follow-up OCT (Xience V)

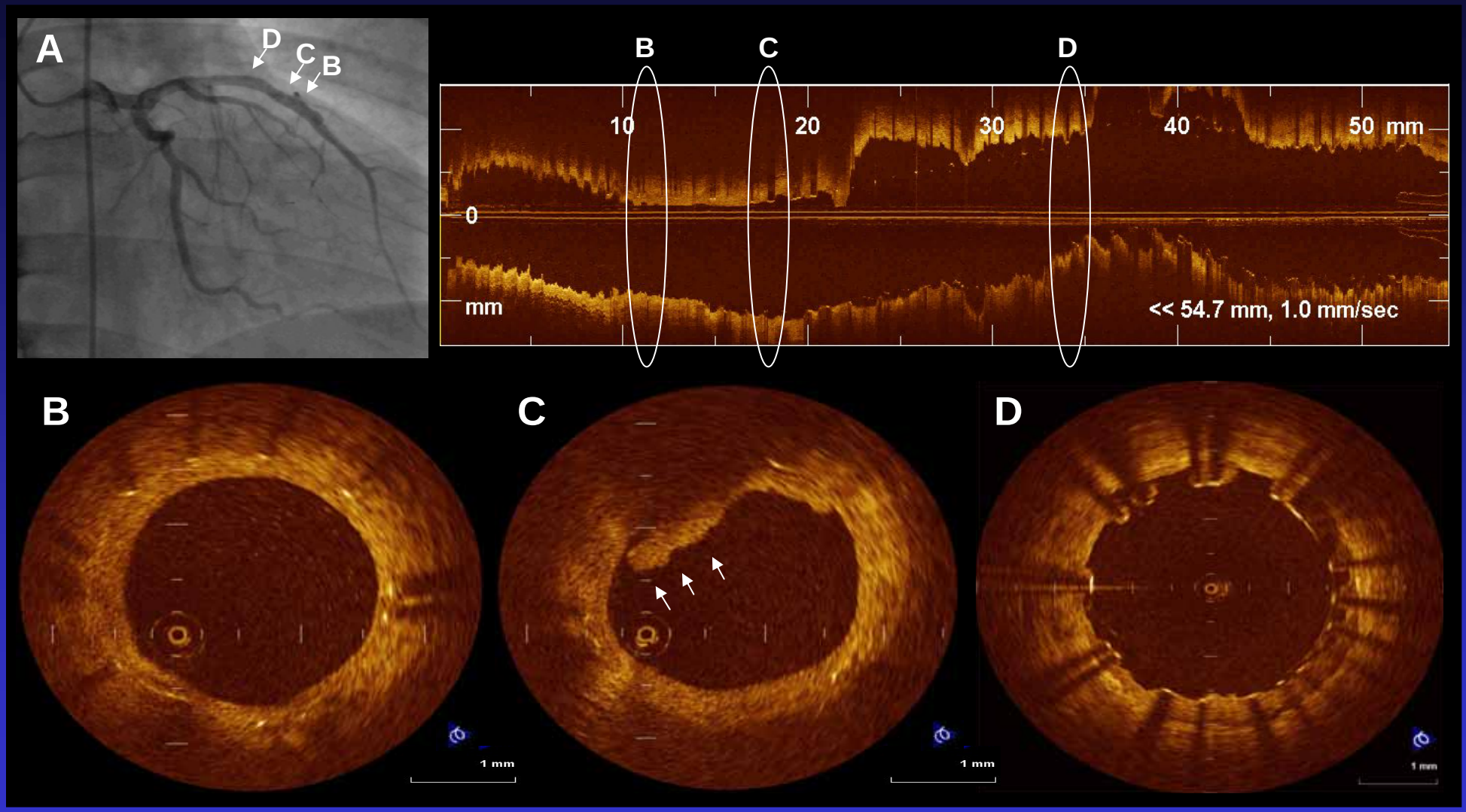


Late thrombosis in DES

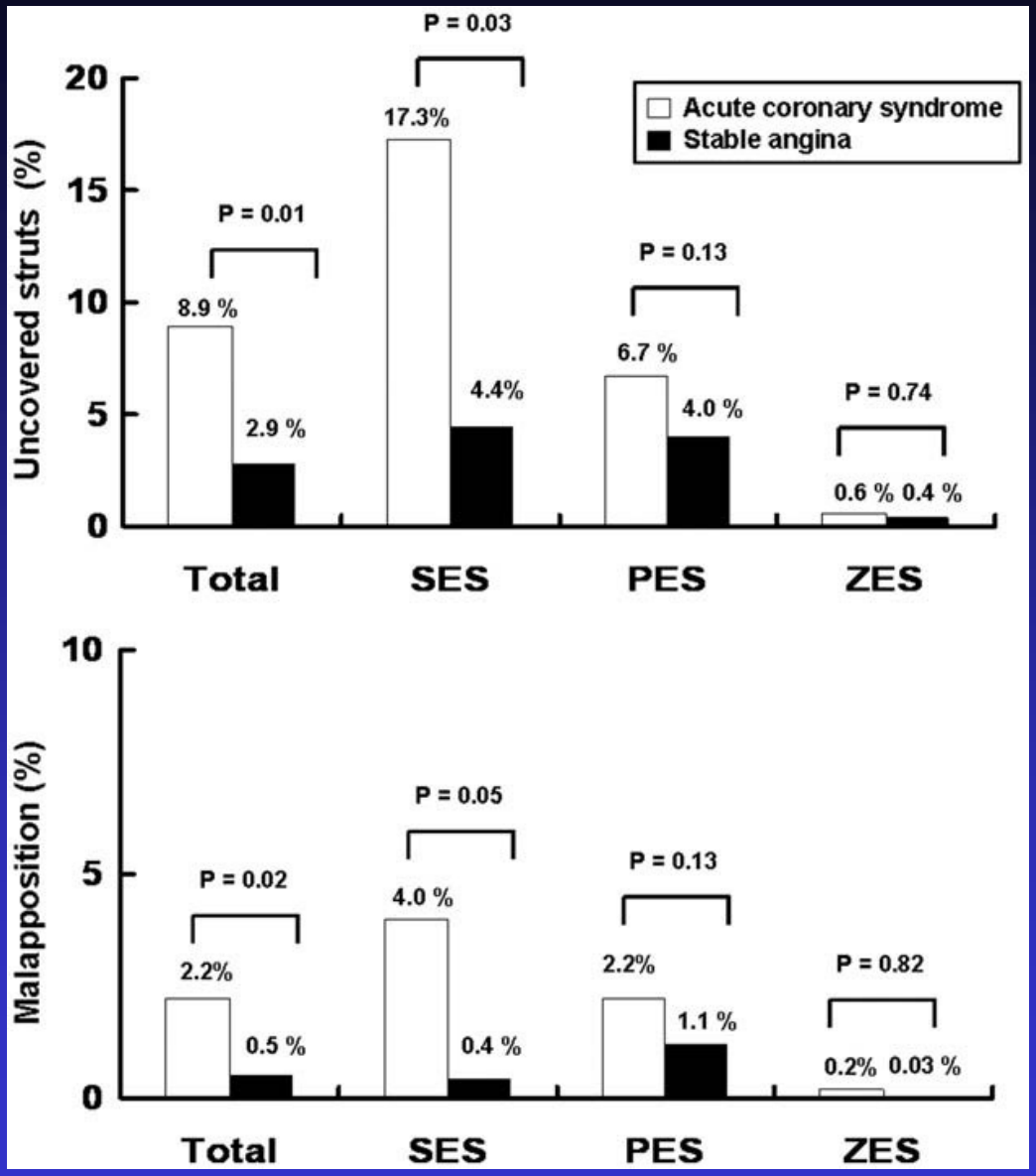




Late stent thrombosis after DES



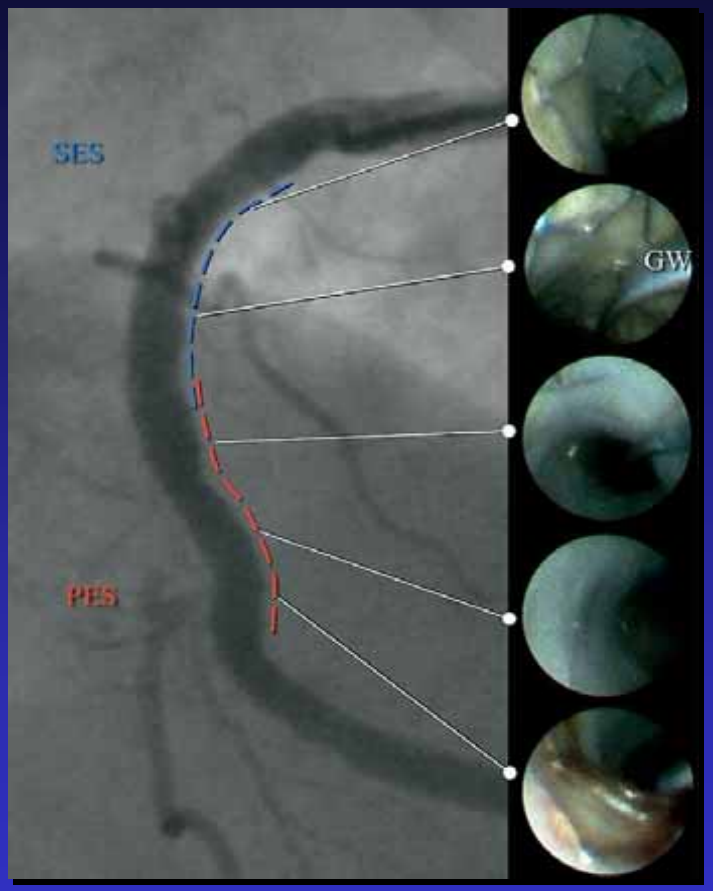
OCT findings in DES



Kim JS., et al., Int J Cardiol 2009

Asymptomiatic instent thombus by CAS

SES : 33% BMS : 8%

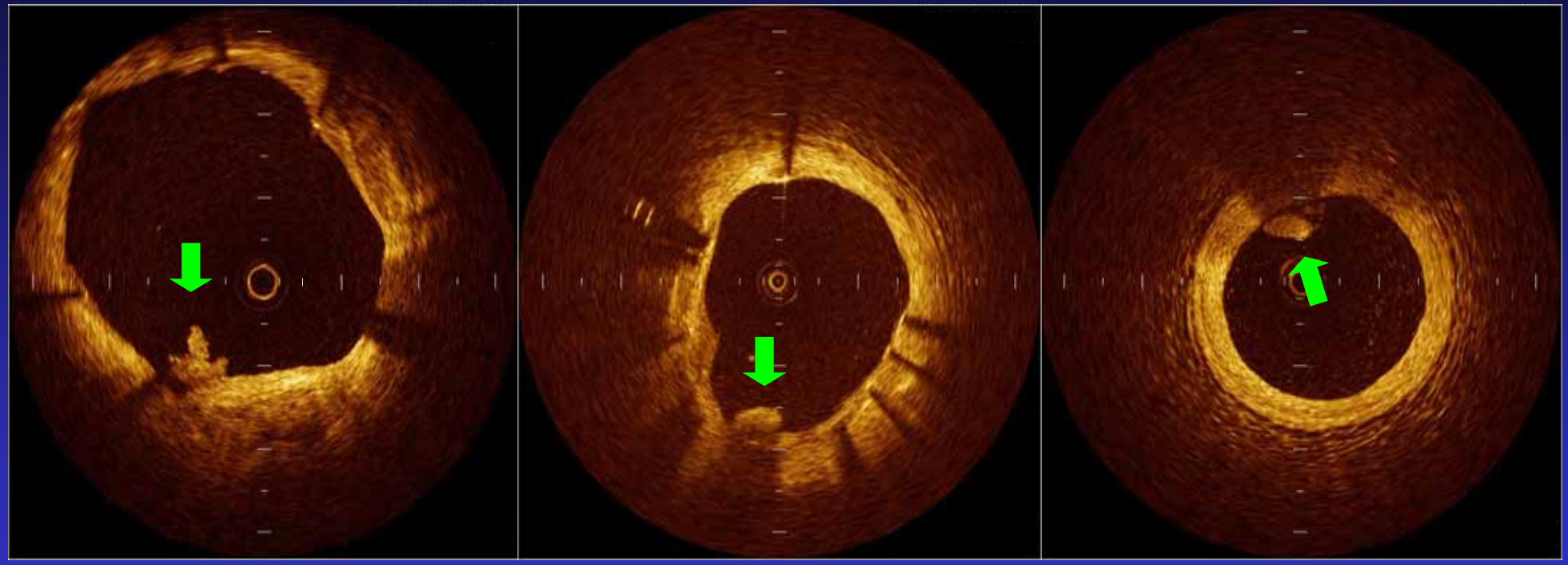


SES : 19% PES : 43%

Takano et al. Eur Heart J 2006; 27: 2189-2195

Awata et al. J Am Coll Cardiol Intv 2009; 2: 453-458

Instent thrombus

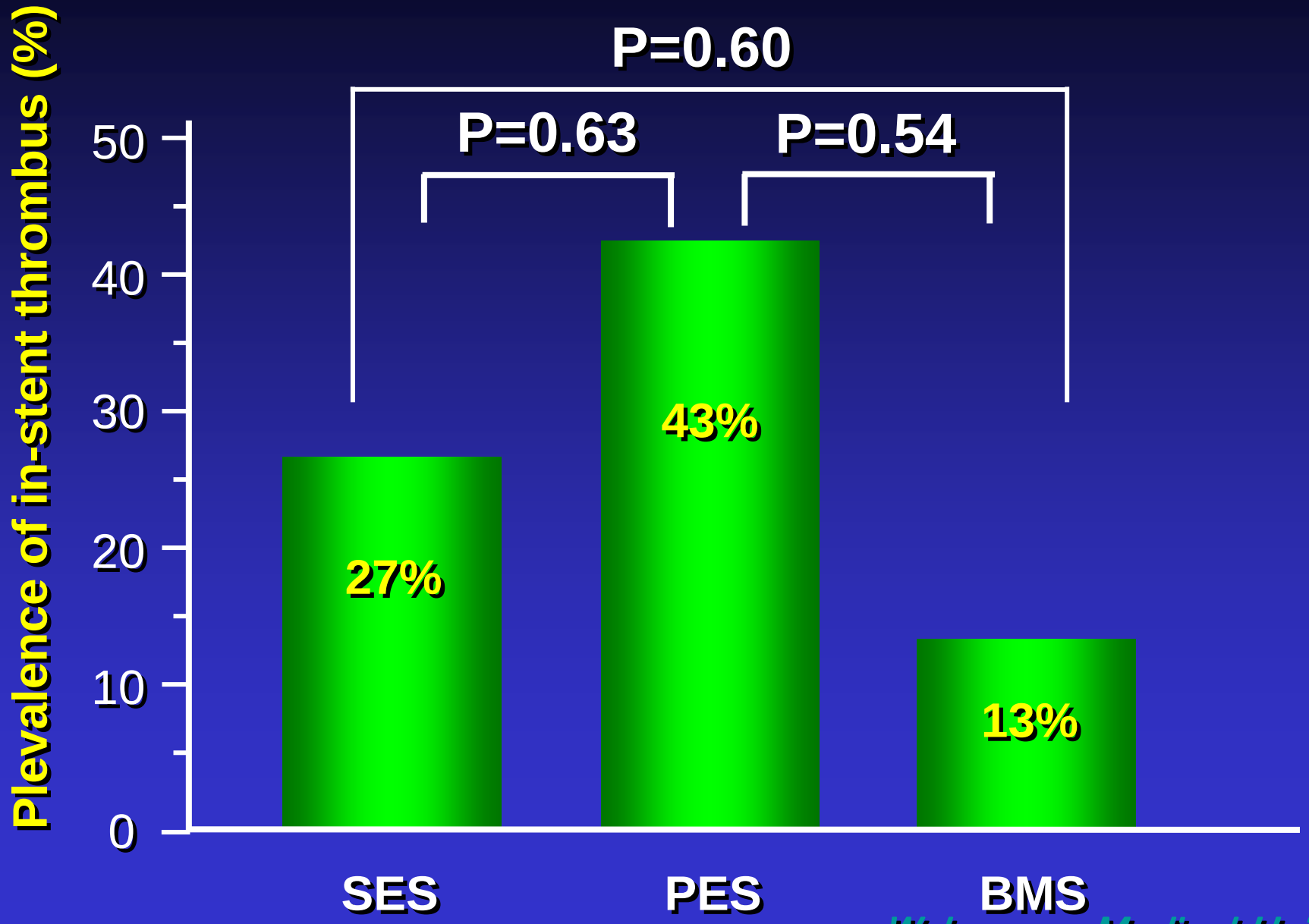


DES

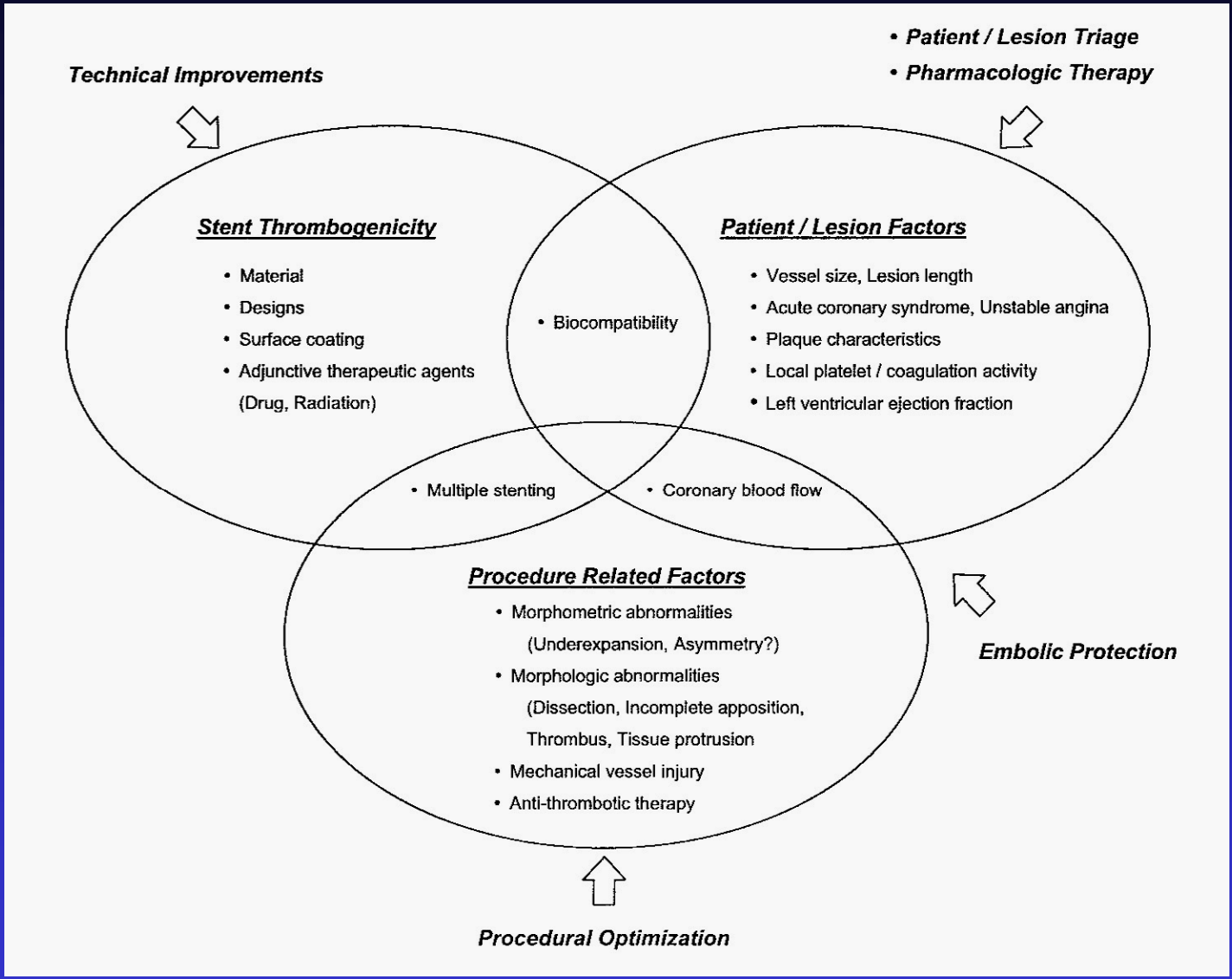
BMS

Distal to DES

Instent thrombus by OCT



Risk factors in the development of stent thrombosis



Honda Y & Fitzgerald P. Circulation 2003;108:2-5

Conclusions

By higher resolution (10 μ m) and superior ability of tissue characterization, OCT may allow us to

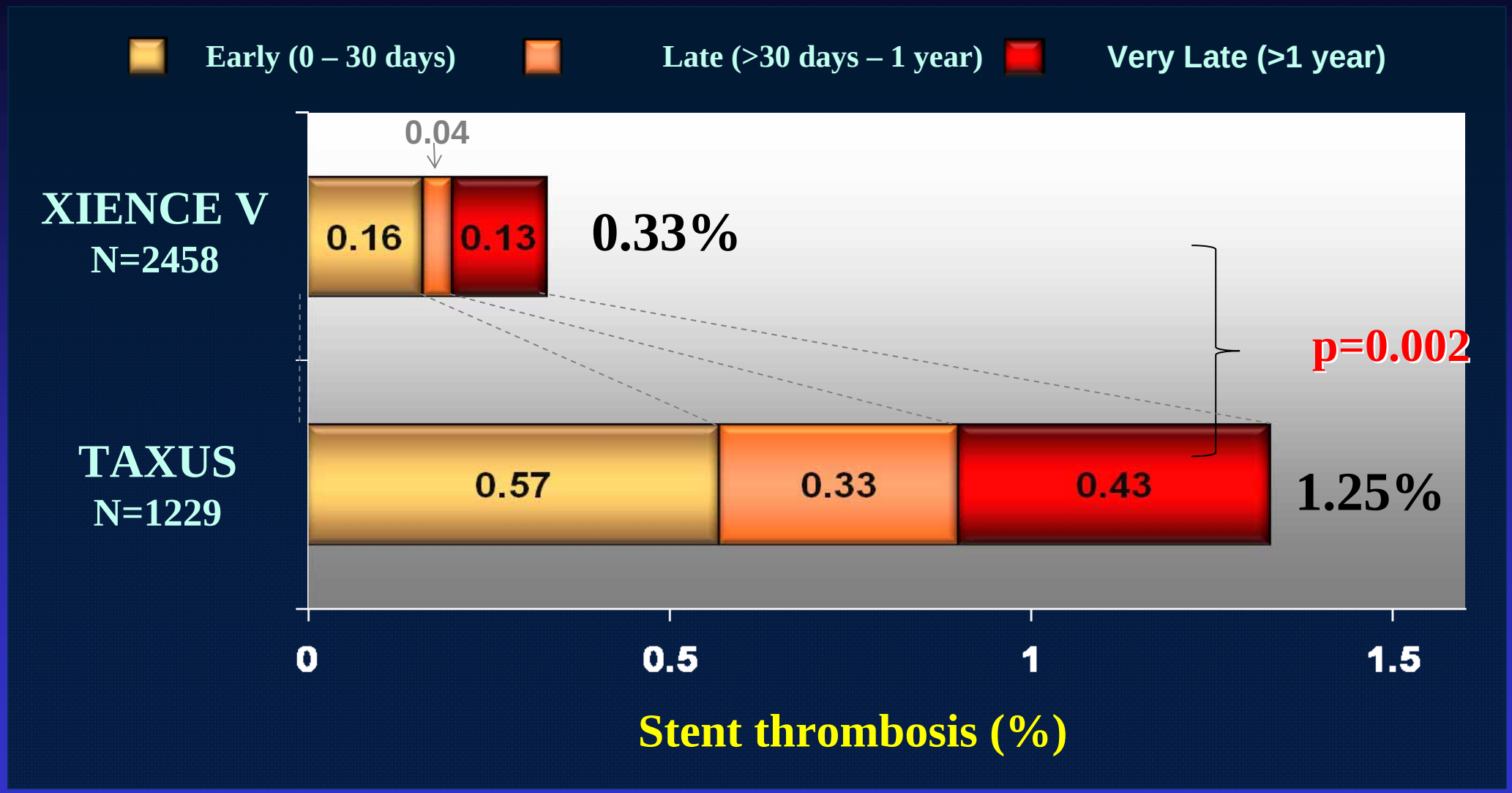
- assess coronary lesion morphology in detail.

- estimate the short & long term results after stenting;
  Soon after: tissue protrusion, incomplete apposition, small dissection, etc.
  Late after : mal-appositions, thin neo-intima formation, late thrombus formation.

- assess the pathophysiology of coronary artery, even after stenting.

These OCT findings may lead us to find the mechanism of stent thrombosis and to create new therapeutic strategies.

Stent Thrombosis (Protocol Definition)*



*ACS + angiographic thrombus, or unexplained death or STEMI/Q-wave MI in TL distribution within 30 days
Rates (%) are Kaplan-Meier estimates.

Limitations of PCI in DES era

- ACS might be one of the key issues which may relate to the prognosis after PCI.

→ How to predict & prevent ACS.

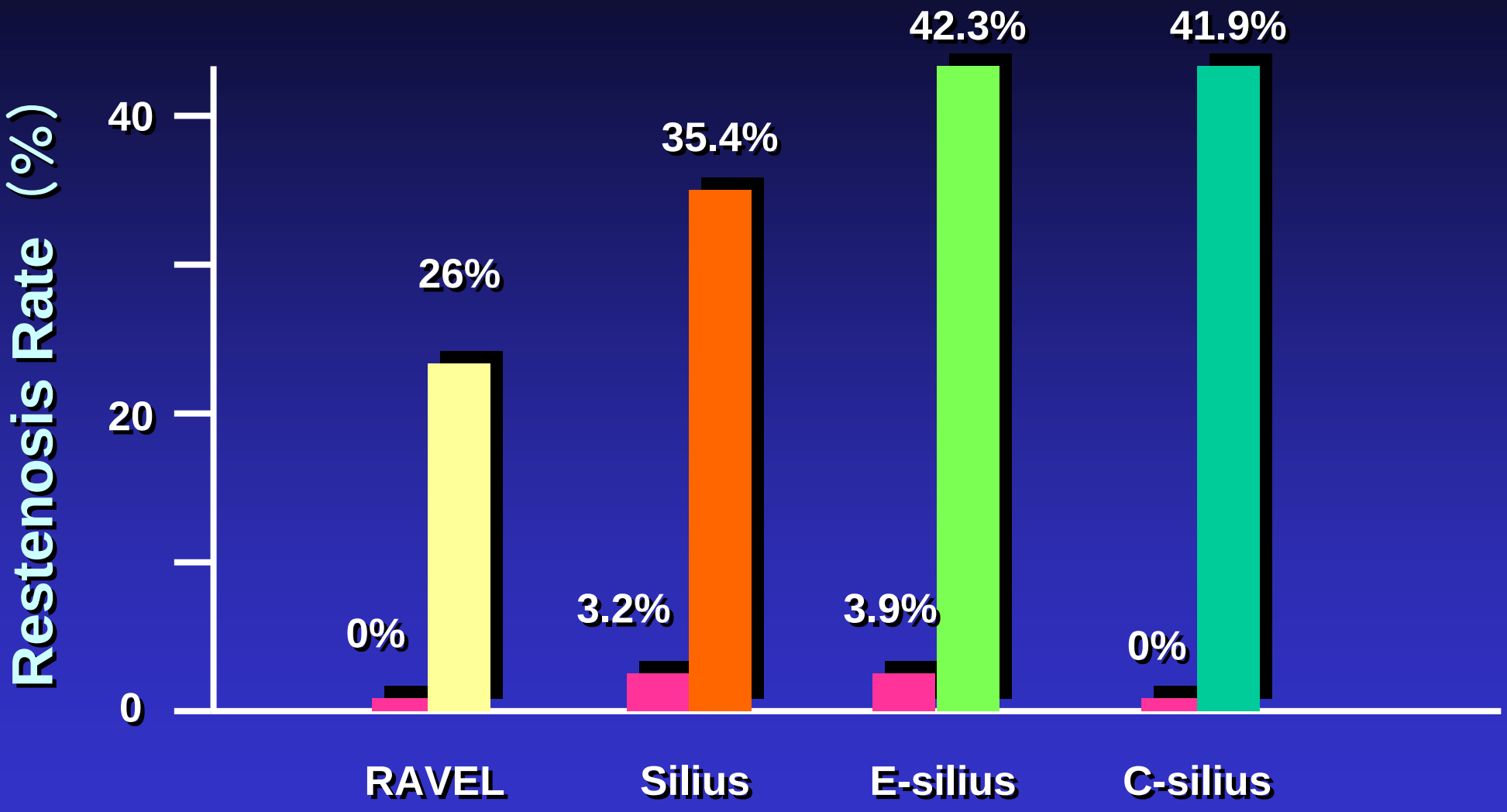
→ OCT may allow us to demonstrate the pathophysiology of ACS.

- Are there any other unknown mechanism to relate to the prognosis after DES ?

→ How to realize the unknown mechanism.

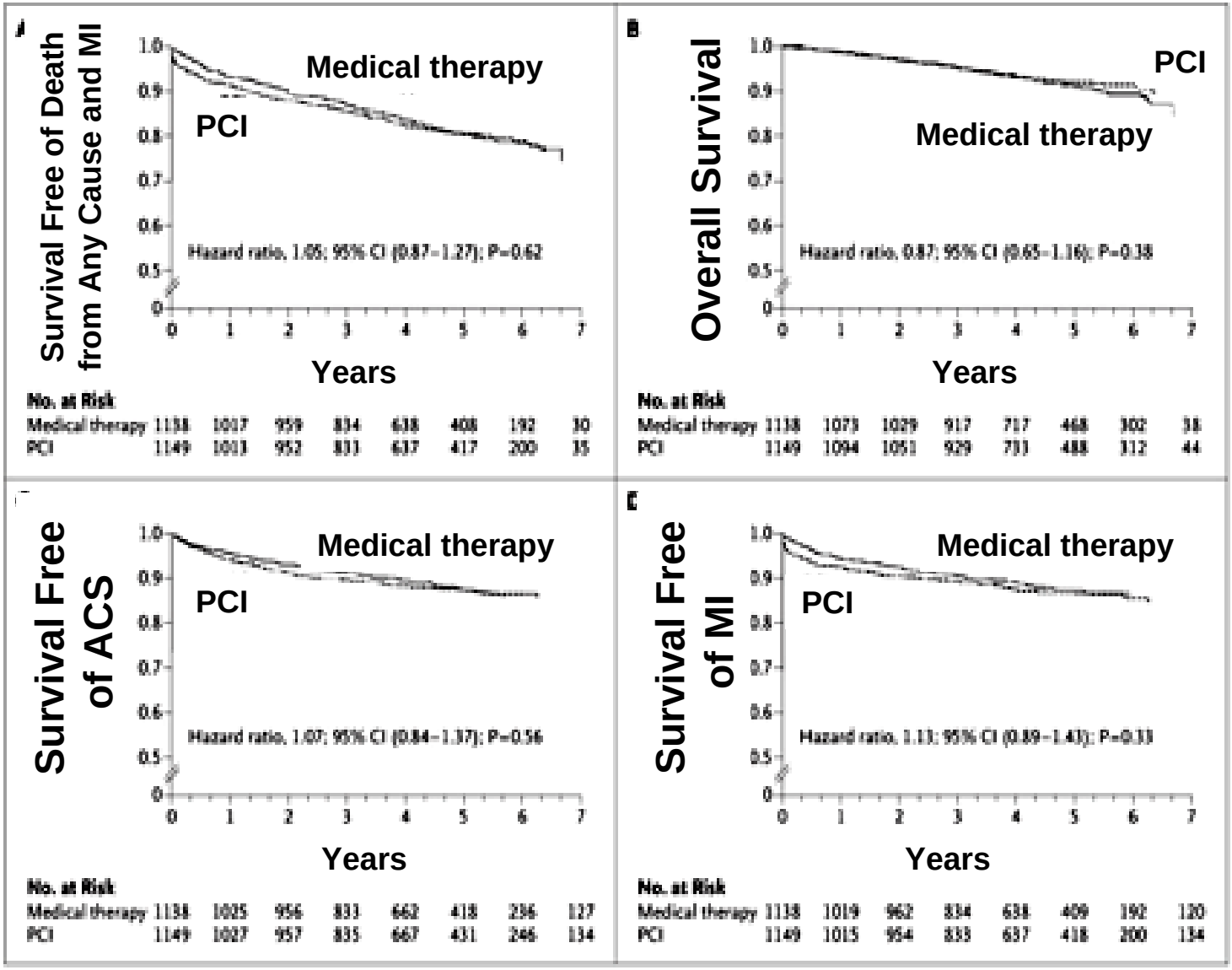
→ OCT may give us further information related to the prognosis after PCI by DES.

Rate of restenosis (SES vs BMS)



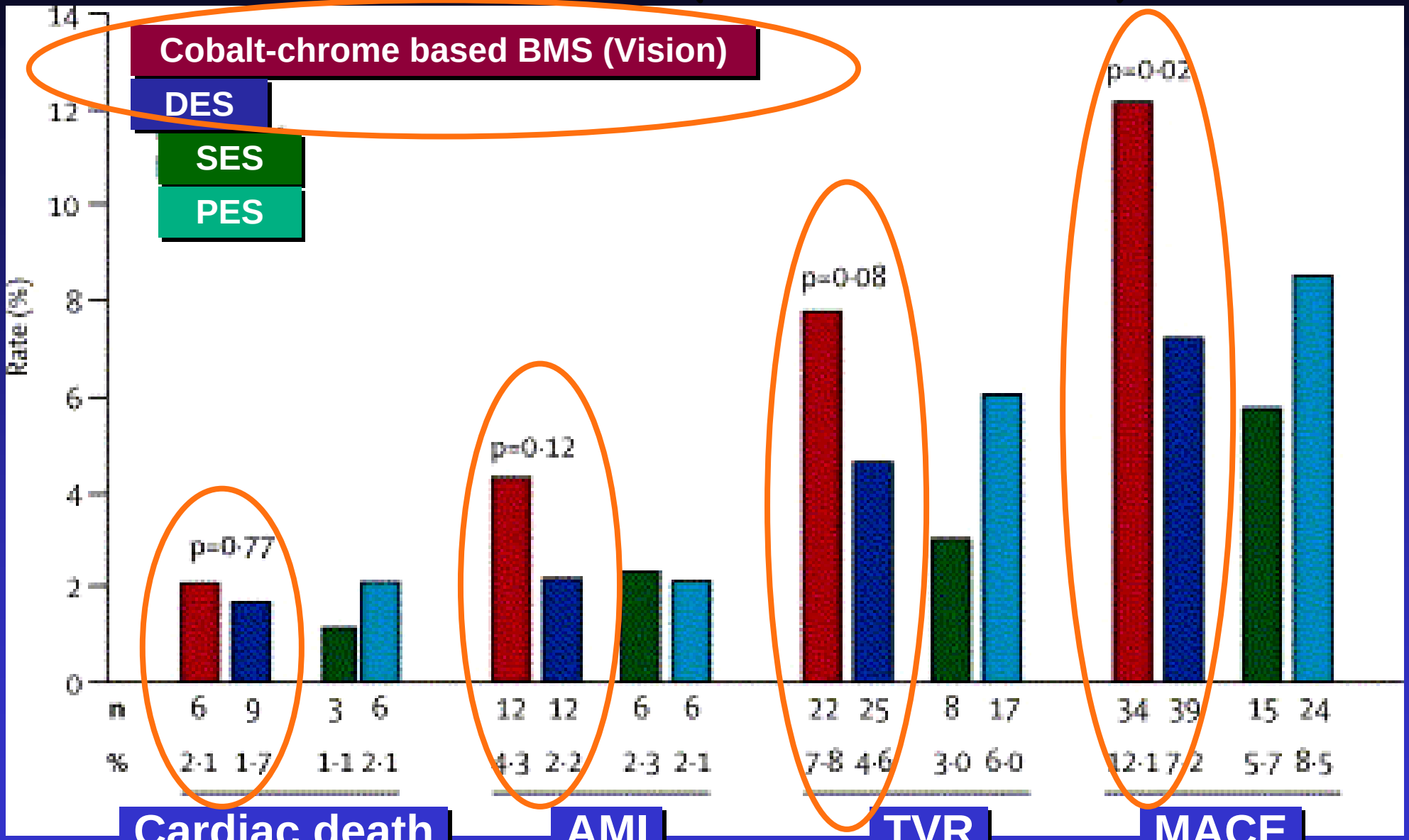
After development of DES, restenosis rate decreased dramatically.

COURAGE trial



No improvement in prognosis could be observed by PCI compared with aggressive medical therapy.

BASKET trial（DES vs BMS）



Limitations of PCI in DES era

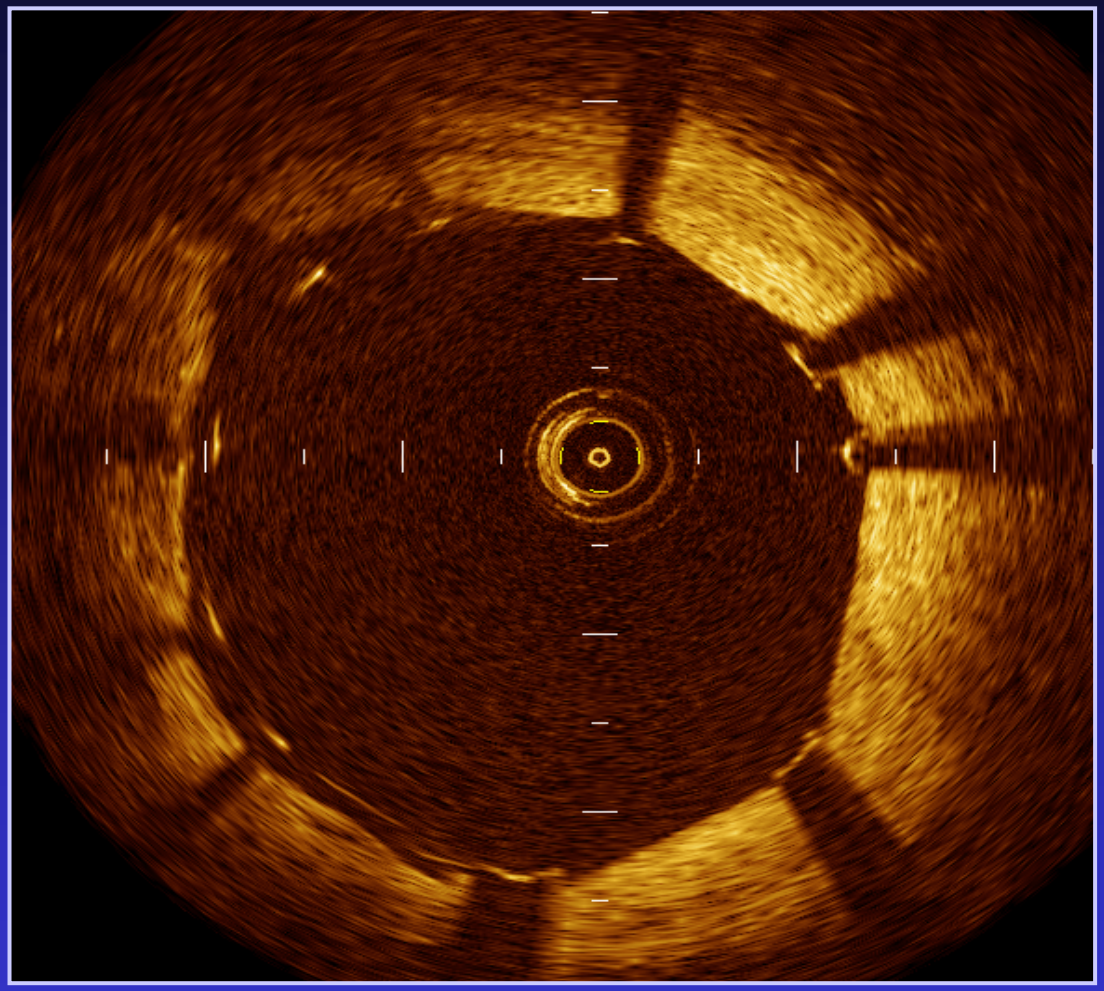
- ACS might be one of the key issues which may relate to the prognosis after PCI.

→ How to predict & prevent ACS.

- Are there any other unknown mechanism to relate to the prognosis after DES ?

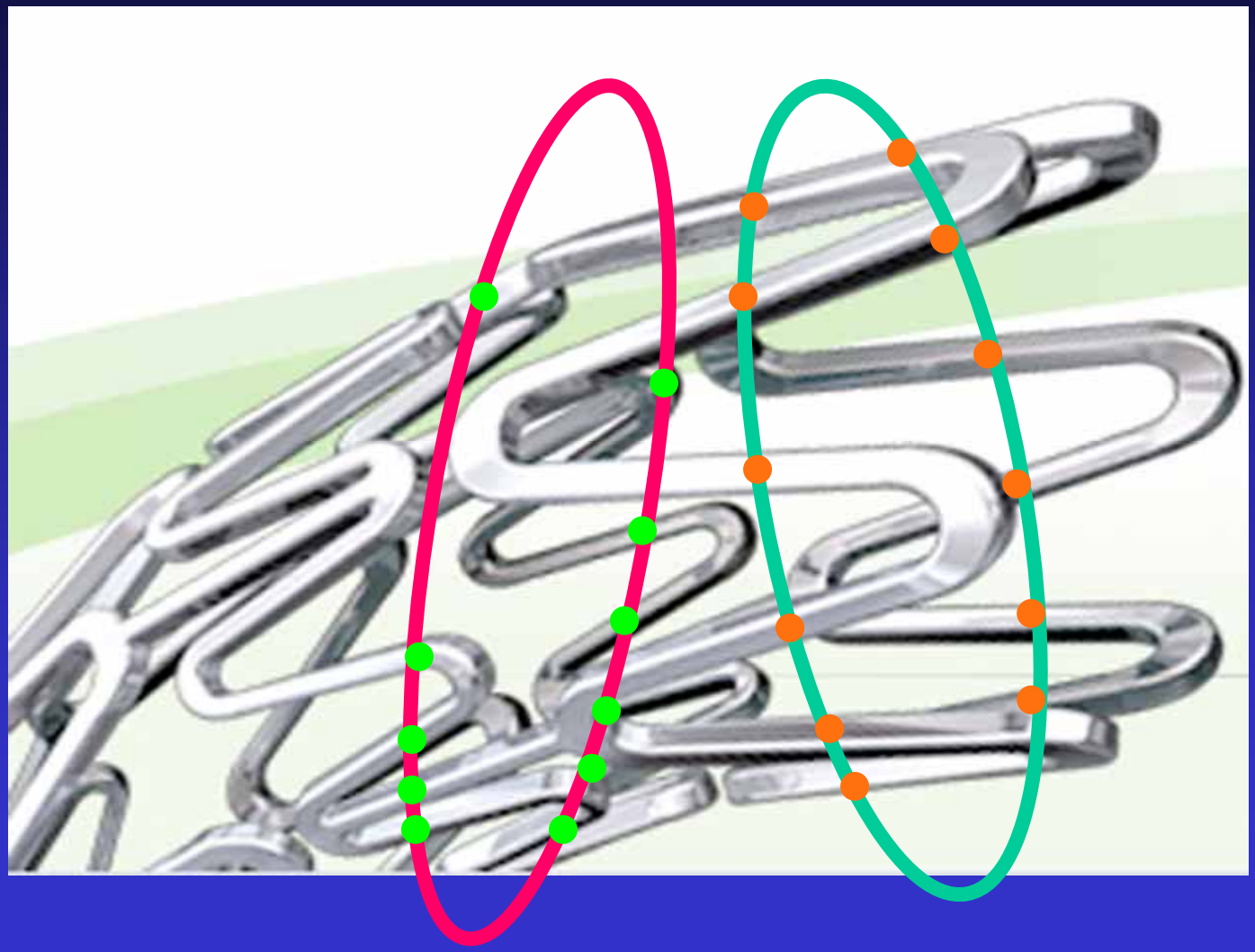
→ How to realize the unknown mechanism.

Inconsistent stent strut distribution

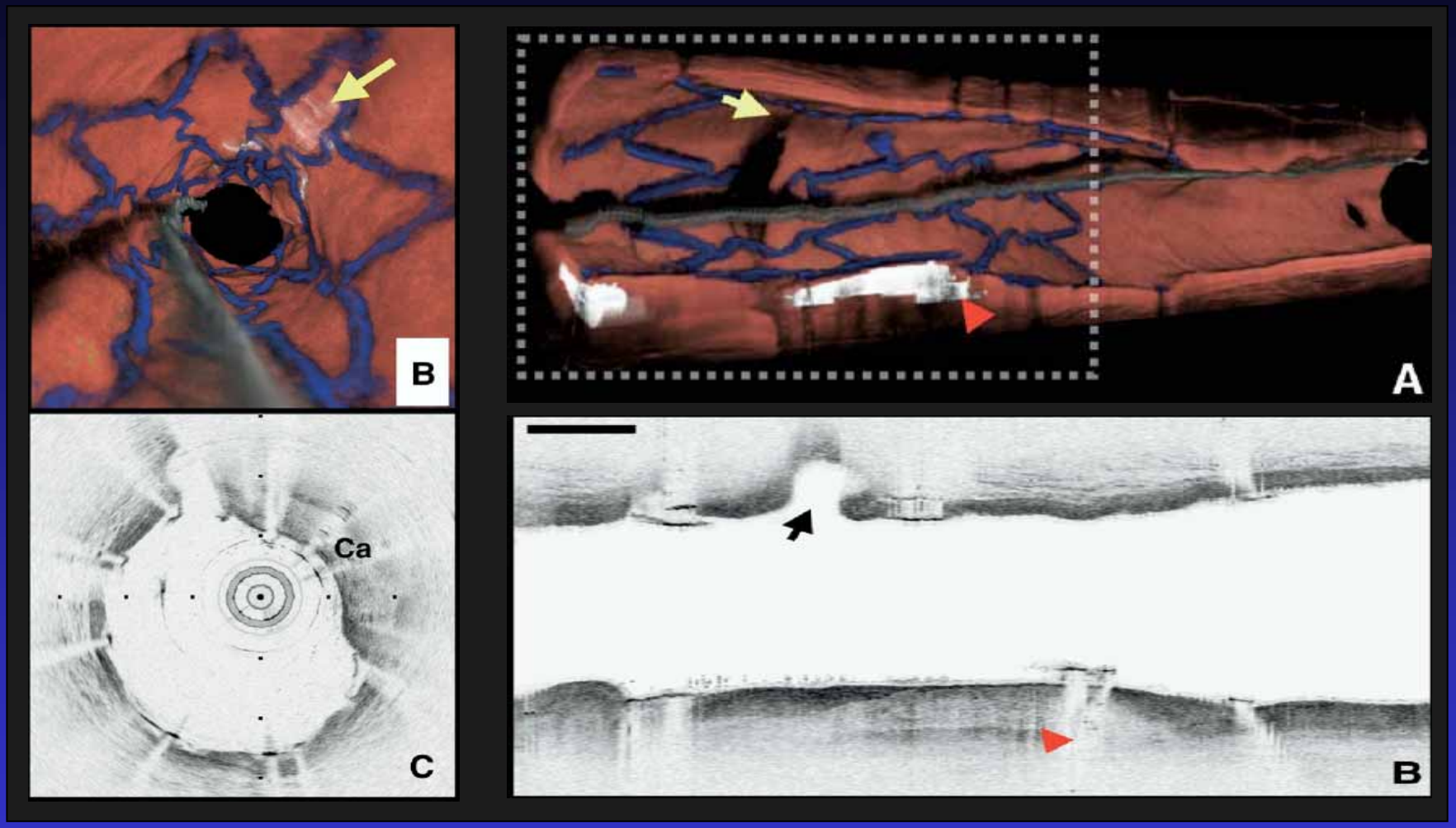


Does this findings demonstrate really the inconsistent stent strut distribution ?

Inconsistent stent strut distribution



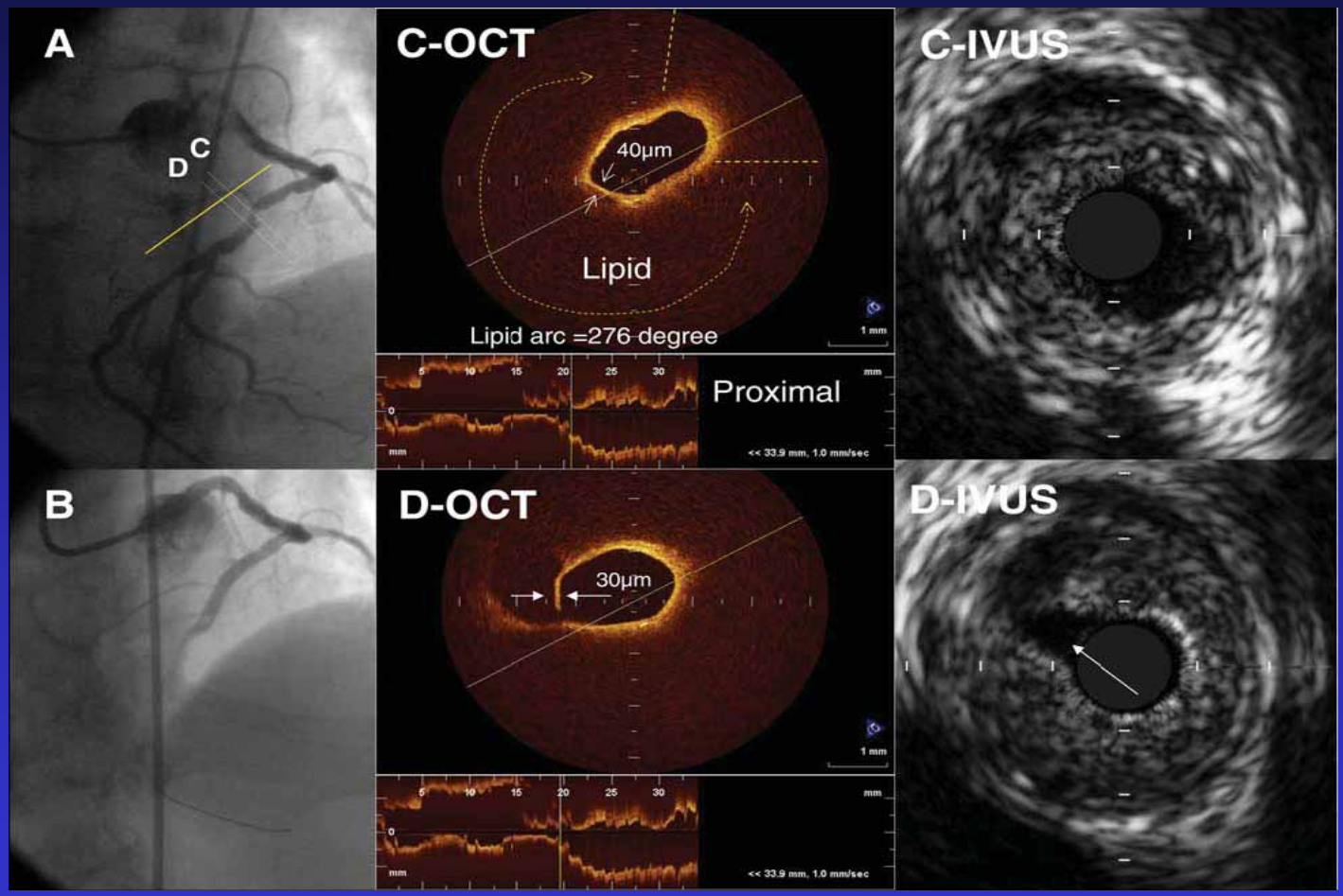
3D FD-OCT imaging



3D reconstruction should be useful to identify inconsistent strut distribution correctly. When this technology is fully exploited, OCT may be a powerful clinical tool for guiding coronary intervention.

Tearney et al, JACC imaging 2008;1:752-61

Pre-intervention OCT images of the culprit lesion in a case with no-reflow after PCI



Tanaka, Kubo et al, Eur Heart J. 2009;30:1348-55.

Wakayama Medical University

Comparison of baseline lesion morphologies between patients with reflow and no-reflow after PCI

83 ACS patients were examined by OCT
to investigate whether OCT could predict no-reflow after PCI.

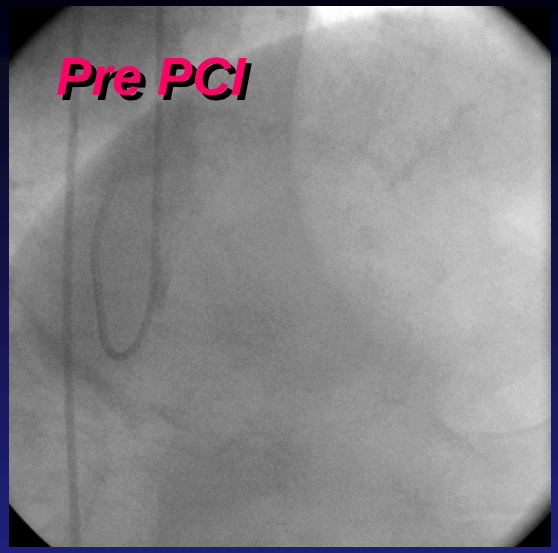
	No-reflow n=14	Reflow n=69	*p*-Value
Plaque rupture, %	71	48	0.053
Thrombus, %	79	80	0.567
TCFA, %	50	16	0.034
Lipid-arc, degree*	166	44	0.012

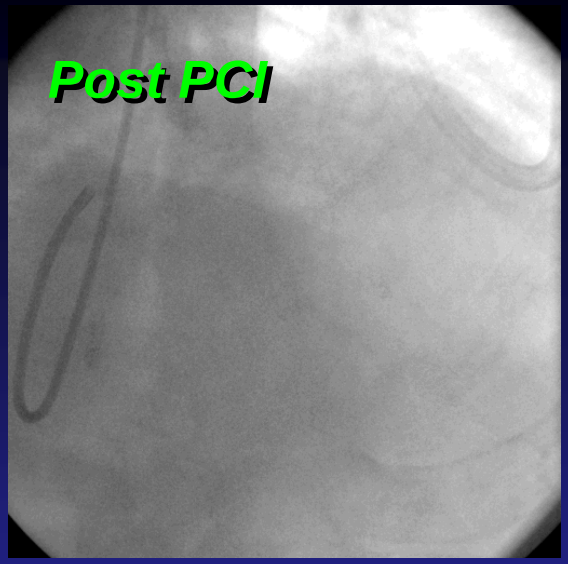
Conclusion: TCFA were more often observed in the no-reflow group than in the reflow group. The frequency of the no-reflow phenomenon increases according to the size of the lipid arc in the culprit plaque.

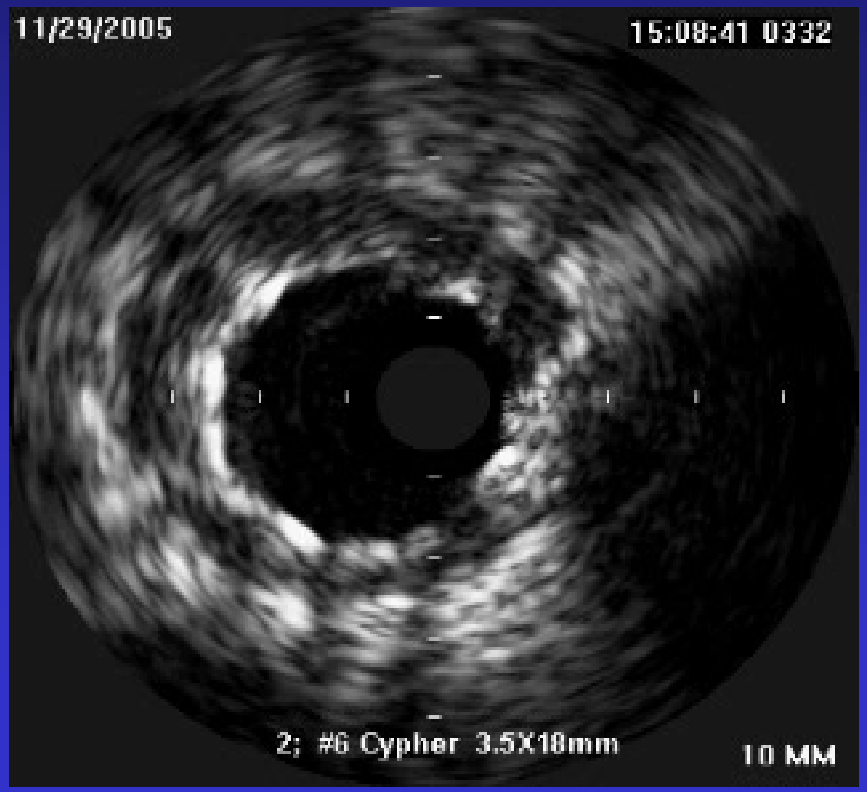
Tanaka A et al, Eur Heart J. 2009;30:1348-55.

ACS; 69 y.o. M

#6 Cypher 3.5 x 18 mm

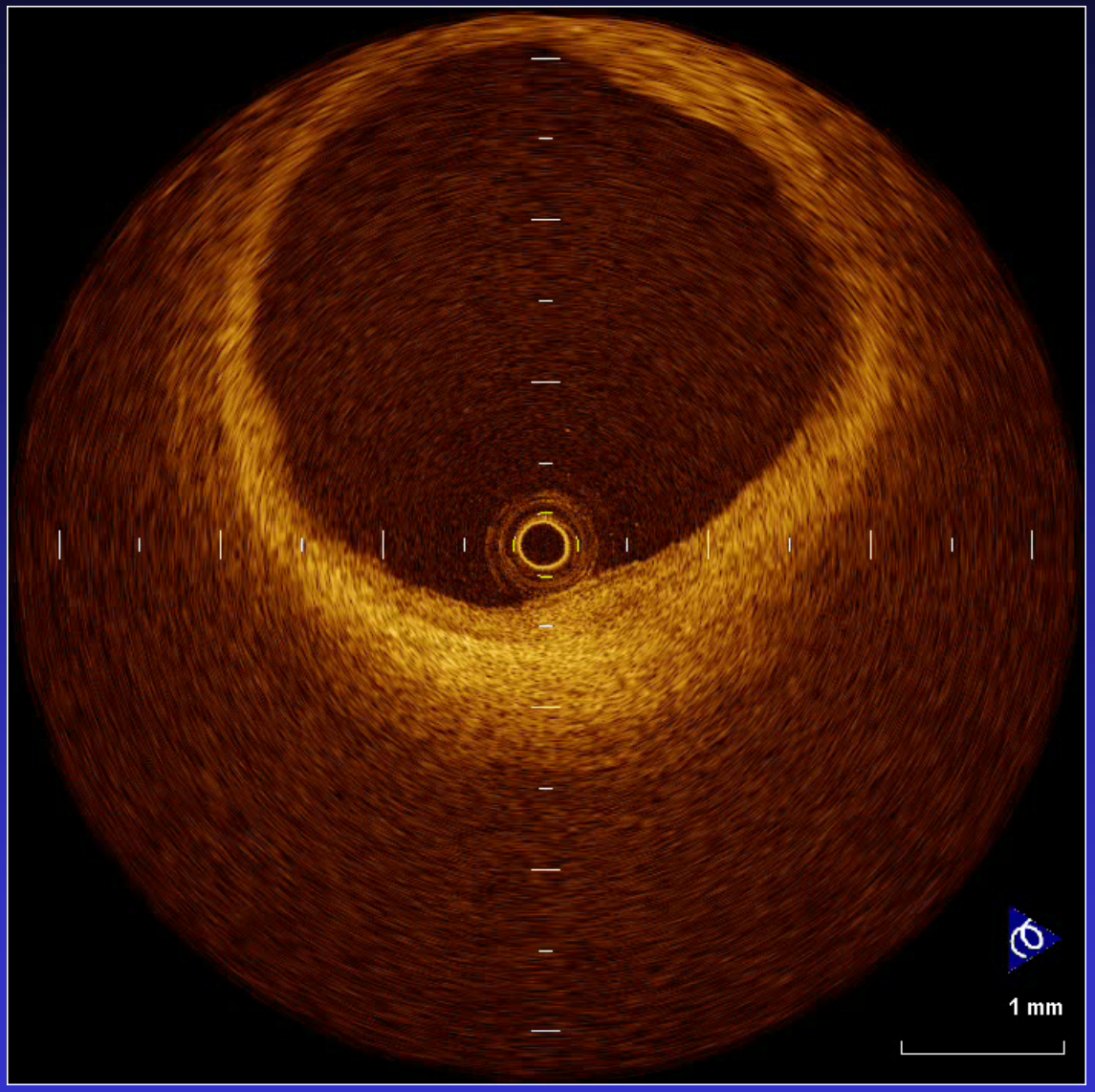




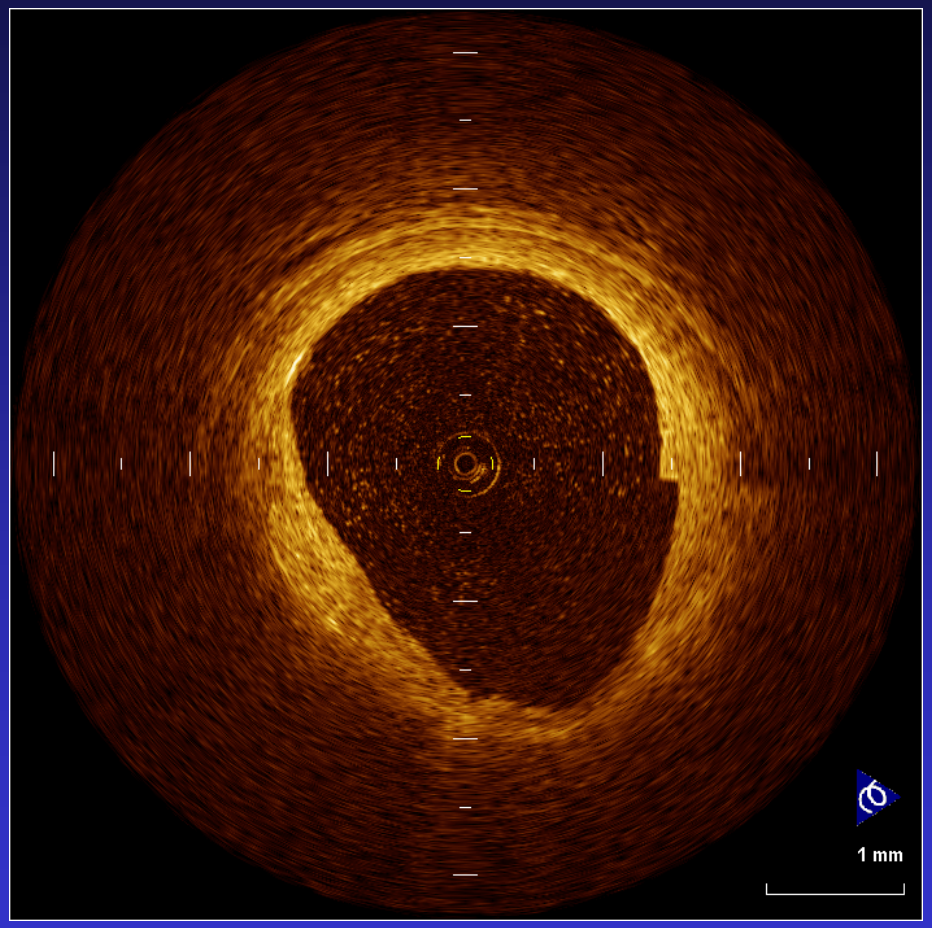


ACS; 69 y.o. M

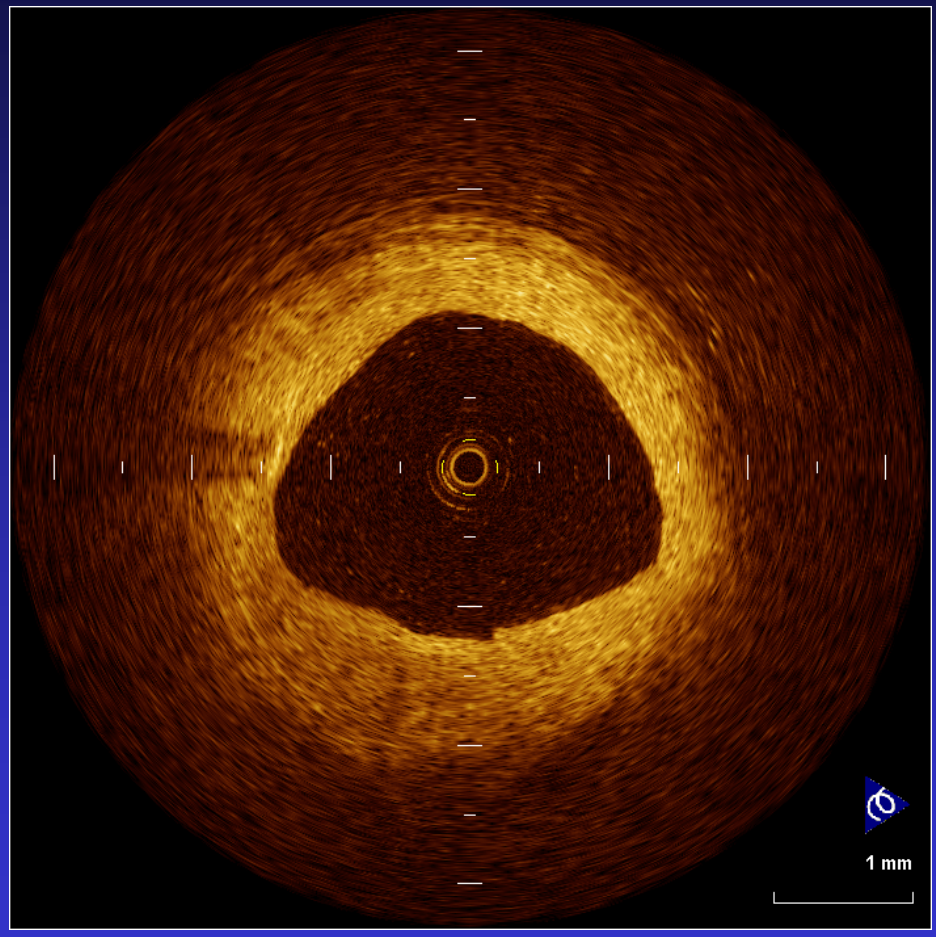
#6 Cypher 3.5 x 18 mm



Inadequate stent findings

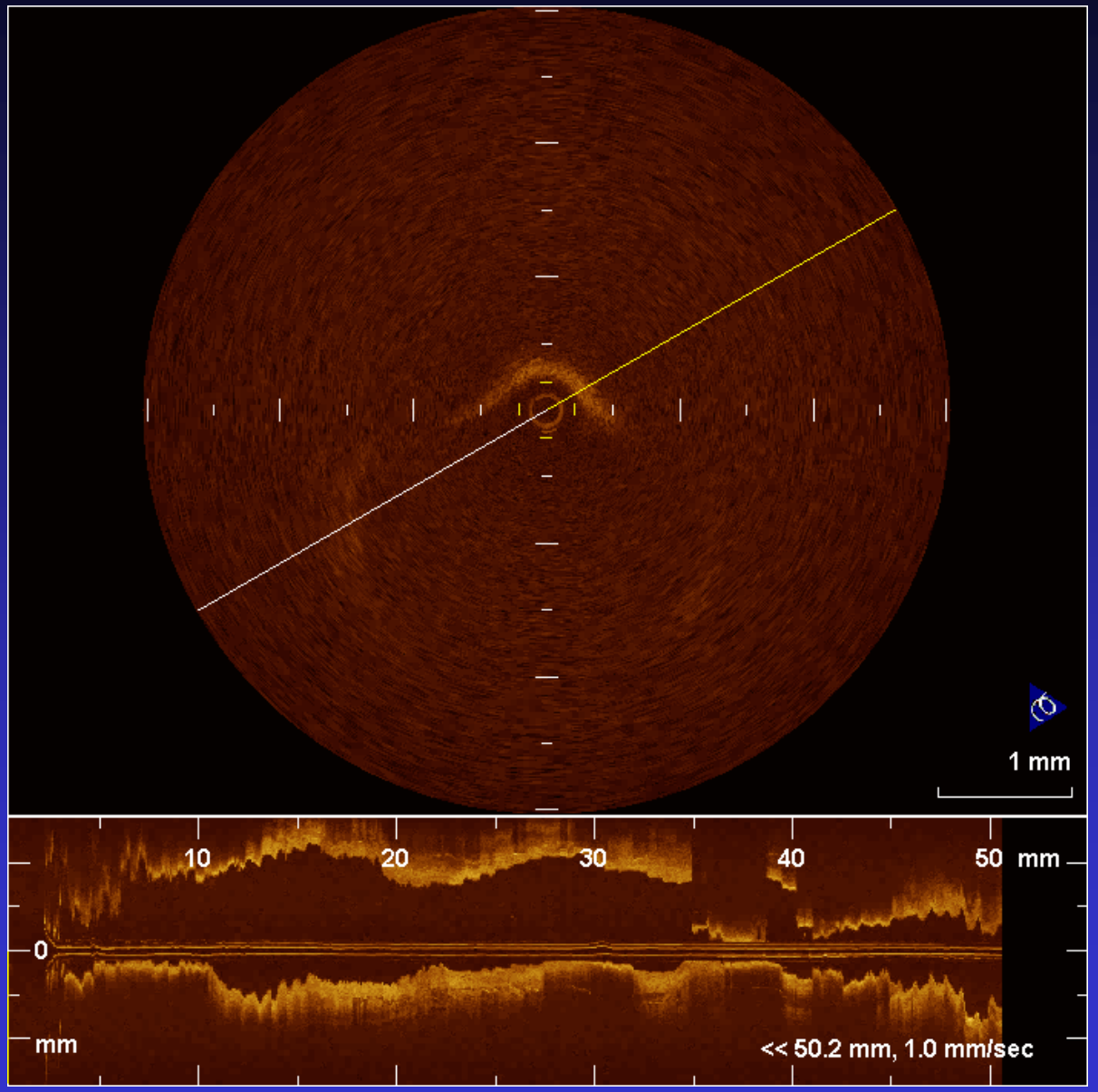


Tissue protrusion



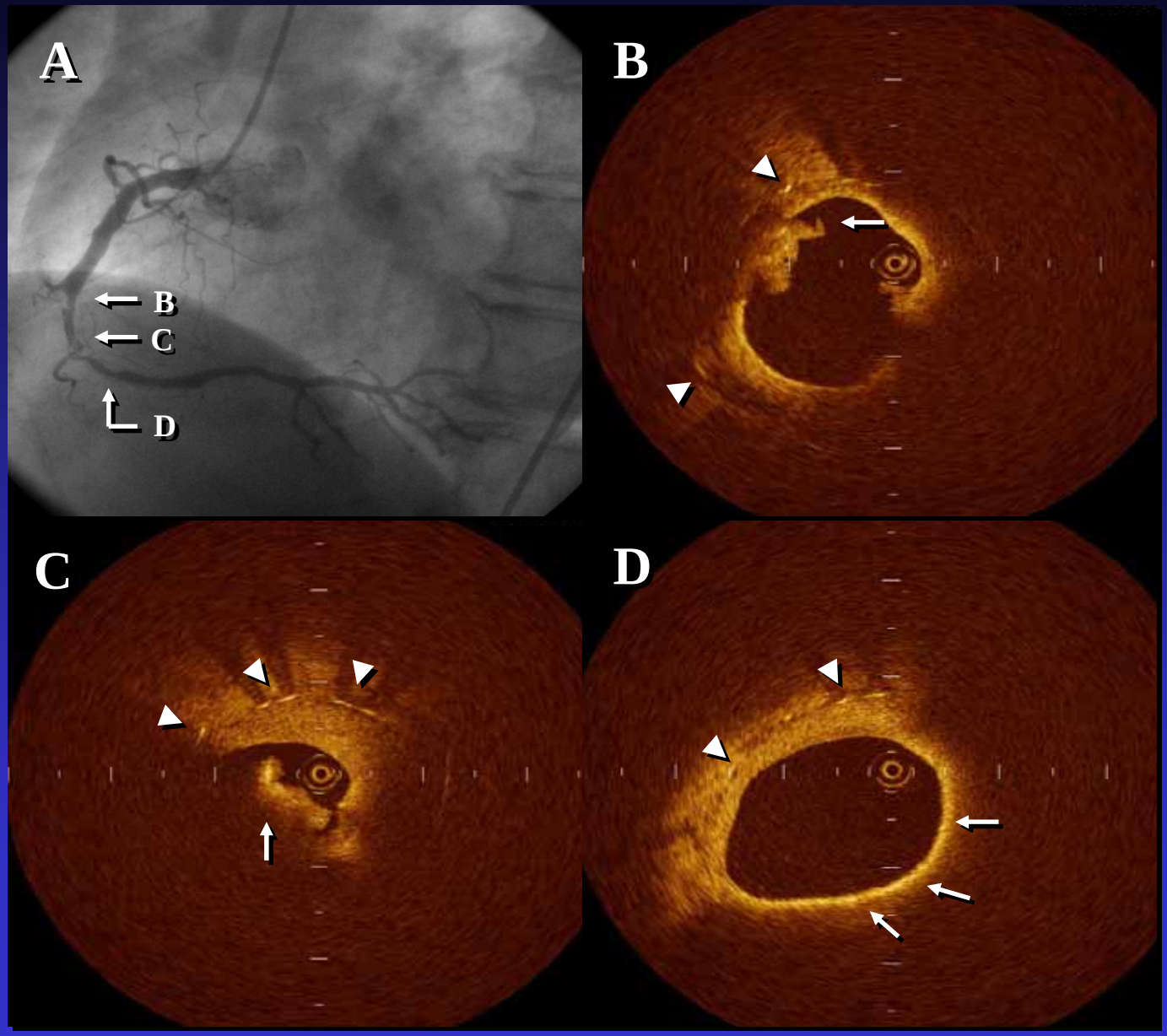
Edge dissection

VLT in BMS



(Kitabata H, et al. JACC Imaging 2010;3: in press)

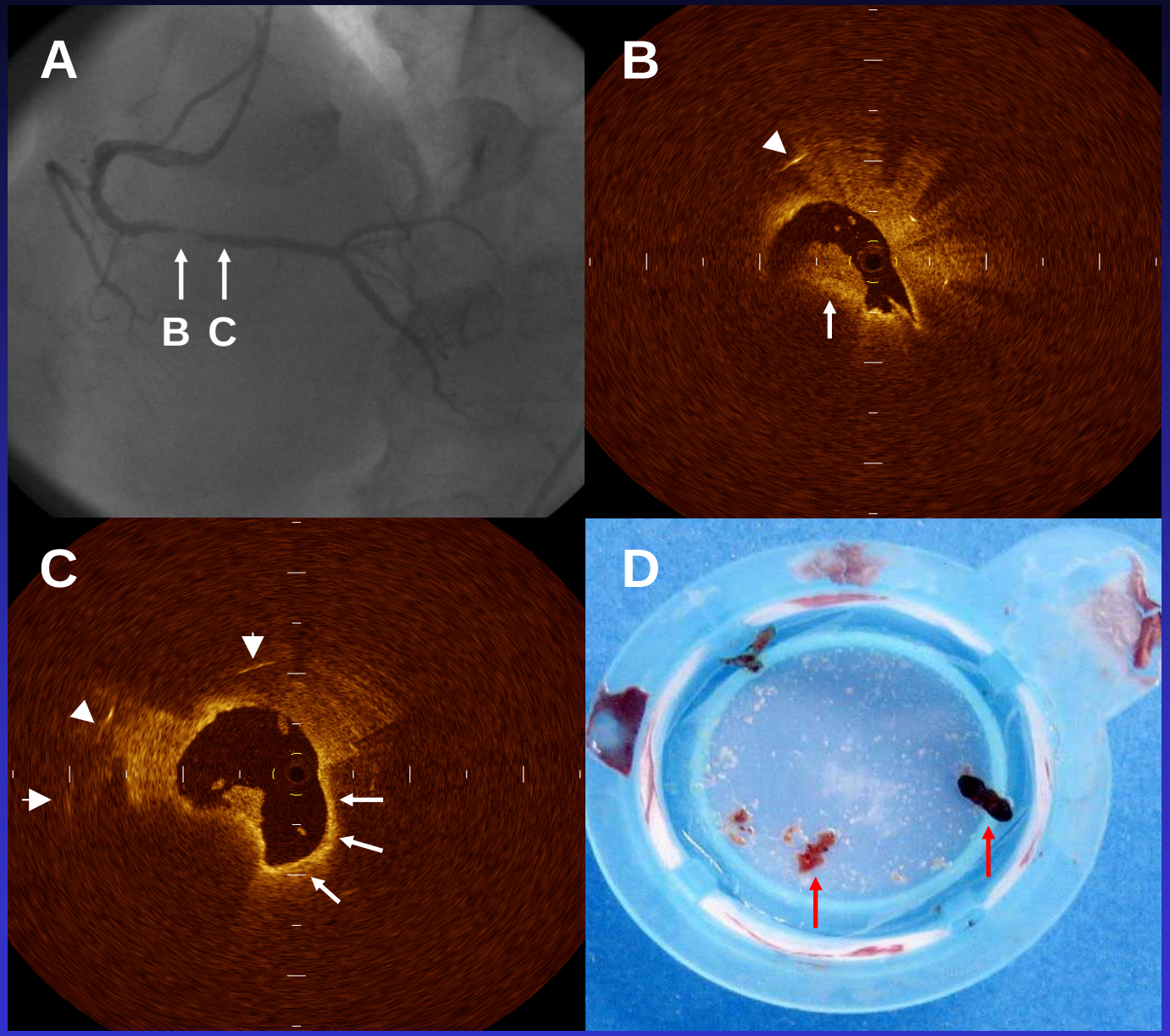
VLT in BMS (58 y.o. man)



- STEMI 7 yrs ago
- BMS to RCA. (3.0×18mm)
- Recurrent CP (NSTEMI)

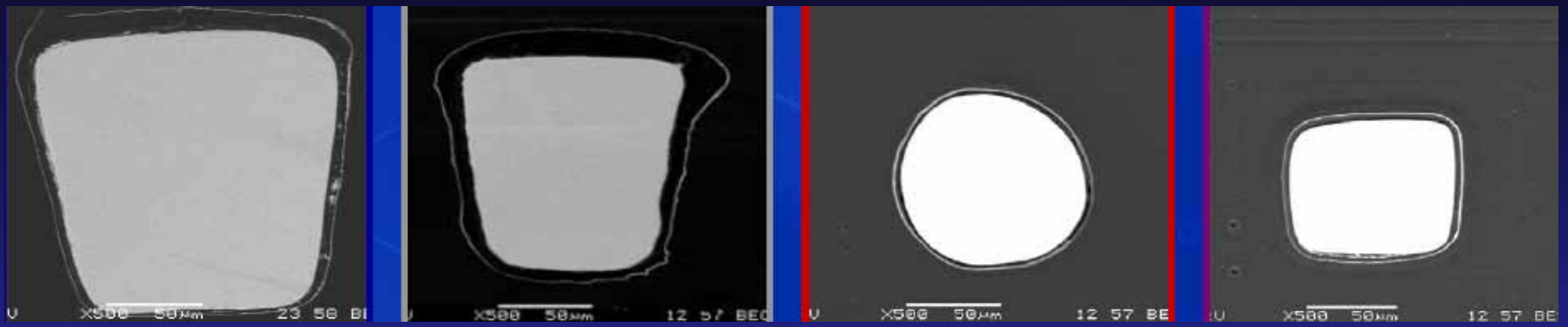
(Kitabata H, et al. JACC Imaging 2010;3: in press)

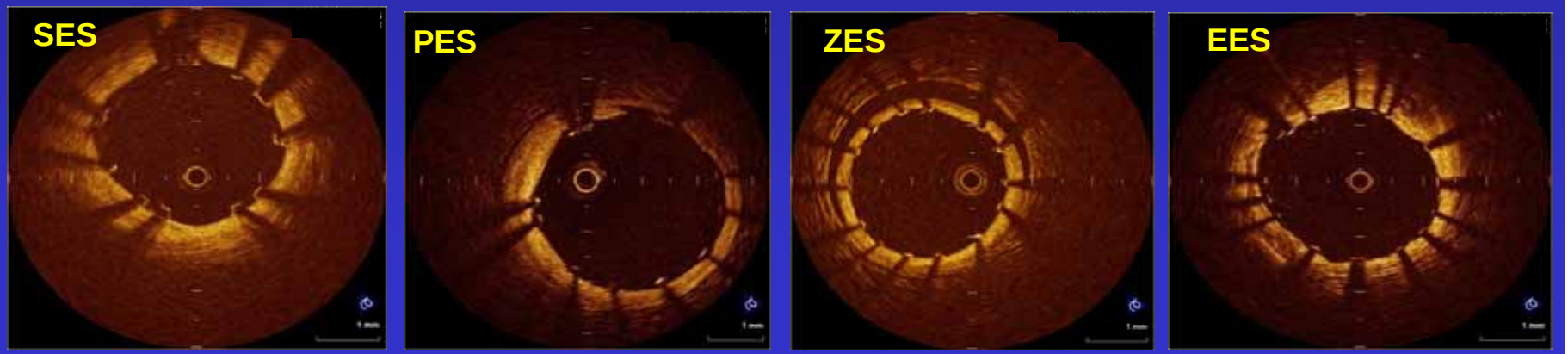
VLT in BMS (51 y.o. man)



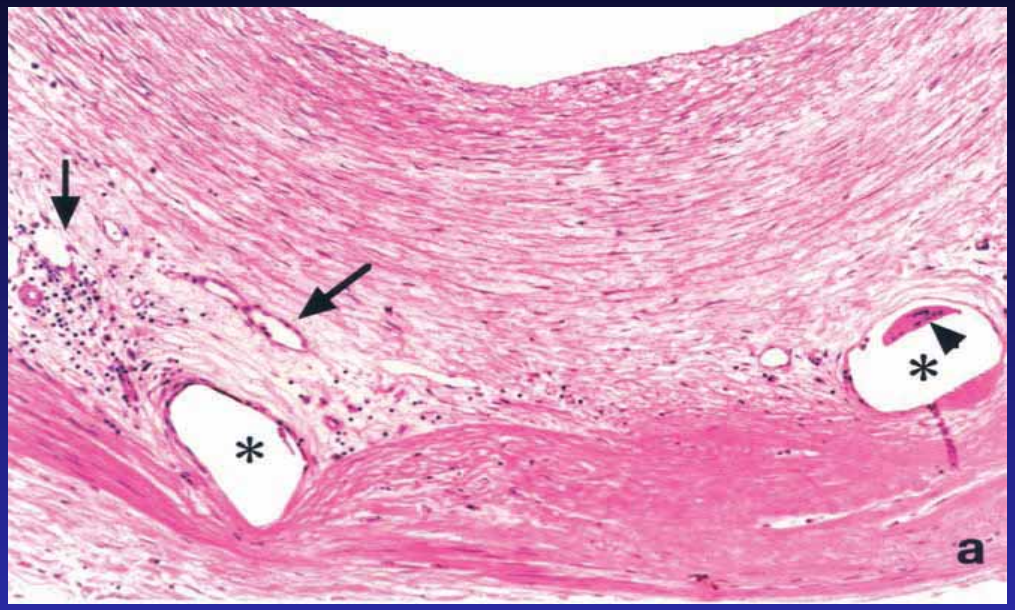
- STEMI 8 yrs ago
- 2 BMS to RCA.
  (3.0 × 30mm)
  (3.0 × 15mm)
- Recurrent CP
  (NSTEMI)

(Kitabata H, et al. JACC Imaging 2010;3: in press)

	SES	PES	ZES	EES
				
Strut thickness	140	132	91	81 (μm)
Polymer thickness	12.6	16.0	5.3	7.6
Total	152.6	148.0	96.3	88.6



Pathological findings 2-3 years after BMS implantation



Apparent chronic inflammatory cell infiltration (mostly T lymphocytes, occasional macrophages and multinucleated giant cells) and neovascularization was recognizable around the struts.

(→) neovascularization (＊) stent strut (▲) macrophage

(Inoue K et al. Cardiovascular pathology 2004;13;109-115)

Soon after SES implantation

Before stenting