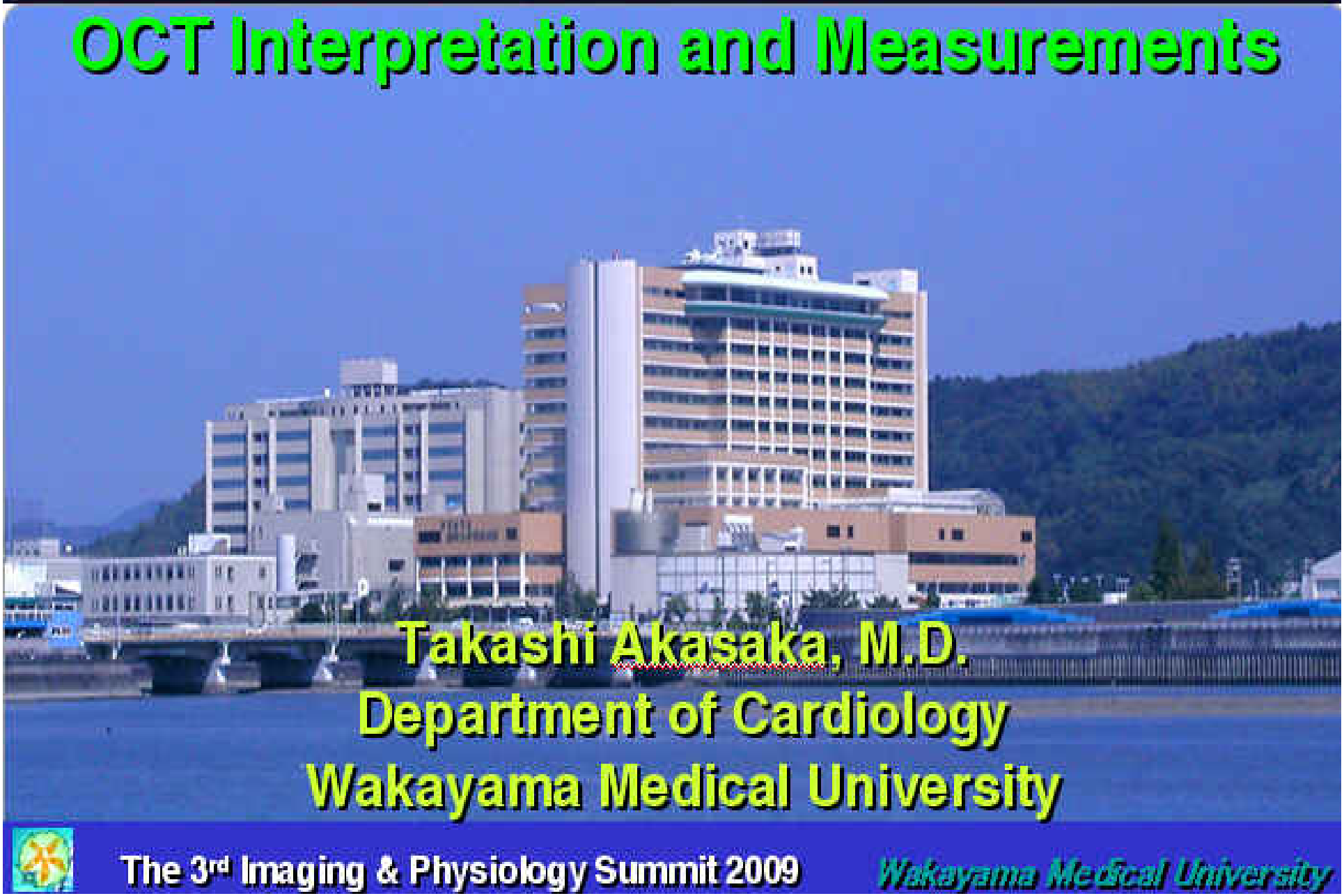
Fundamentals, Pitfalls & Limitations of OCT Interpretation and Measurements



Takashi Akasaka, M.D.
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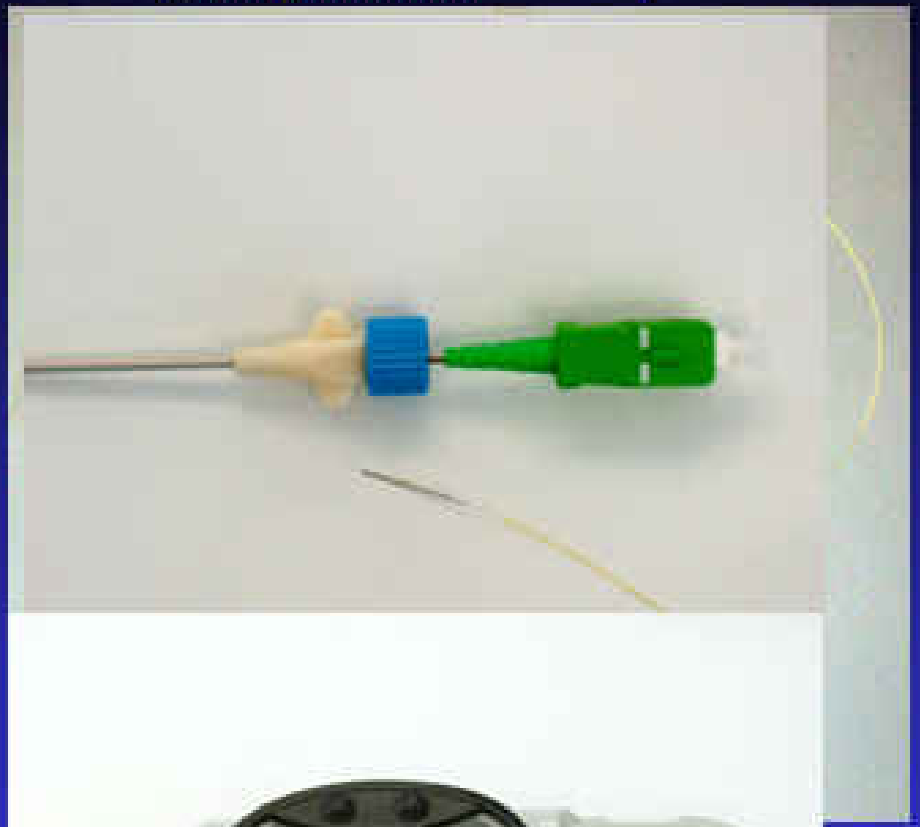
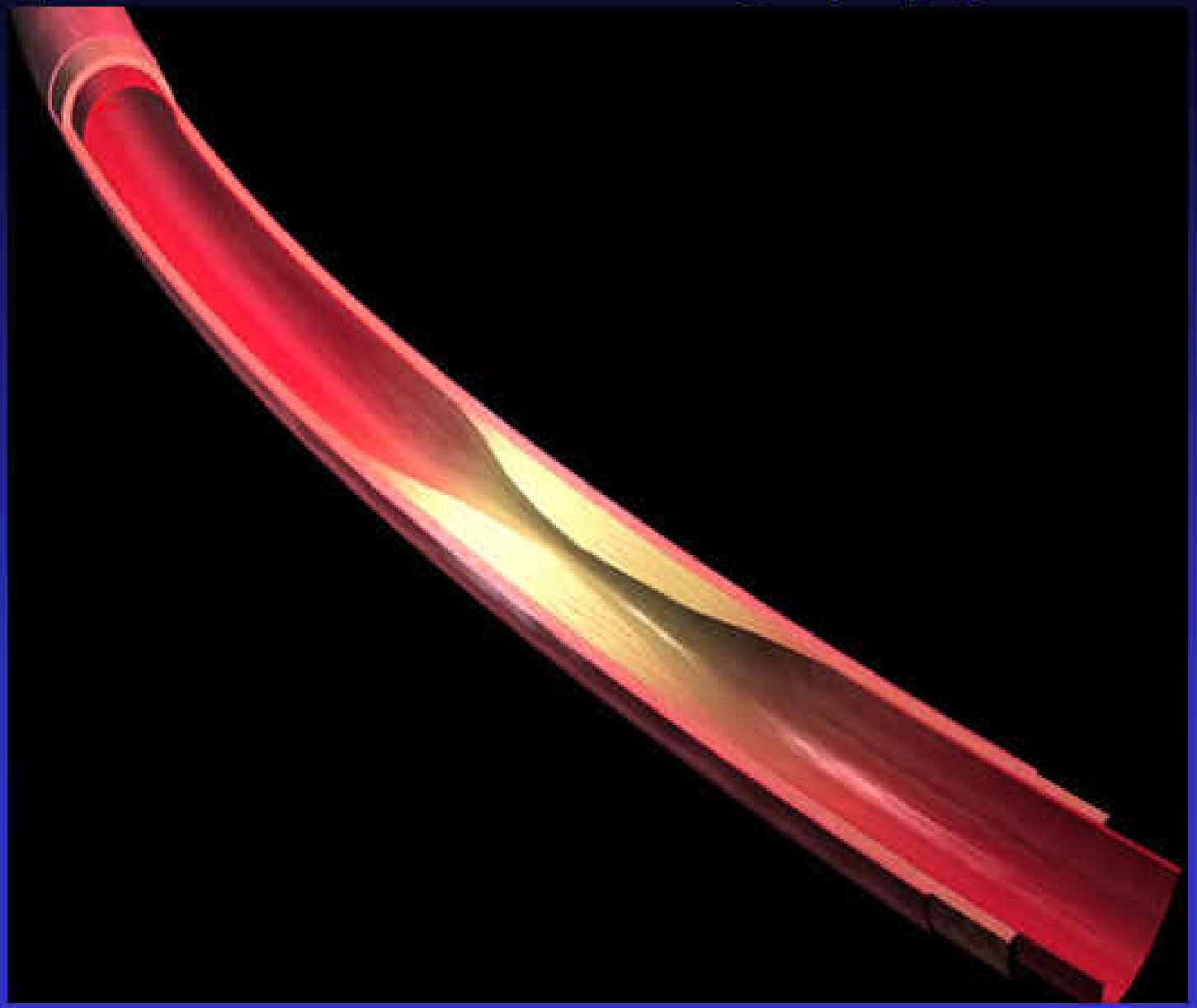
OCT system (M2 or M3, LightLab Co.)



Optical Coherence Tomography (TD-OCT)

- Size of imaging core (0.4 mm)
- Microscopic resolution (10-20 μm)
- Real time Imaging (15 frames/s)

Optical Coherence Tomography (TD-OCT)



Pitfalls for OCT data acquisition

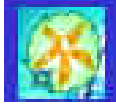
Use lactate Ringer's solution to flush the blood away from the imaging field to avoid ST changes and QT prolongation in ECG, and chest pain.

Put the flushing catheter in the proximal site to the lesion when you pass the imaging wire through the lesion if the culprit lesion is very severe and tight.

Wait a few second before flushing and balloon occlusion to recover from ischemia during the procedure of image acquisition.

Start the flush a few second before balloon inflation to obtain the image longer and to avoid the longer ischemia time.

Check the calibration (zero-offset) again after obtaining the image before finishing the procedure.



Limitations for OCT data acquisition

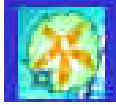
Limited length of image (maximum 3 cm) because of limited balloon occlusion time to avoid myocardial ischemia.

Difficult to obtain images of LM, and the proximal site of LAD and LCX, and RCA ostial potion because of balloon occlusion system.

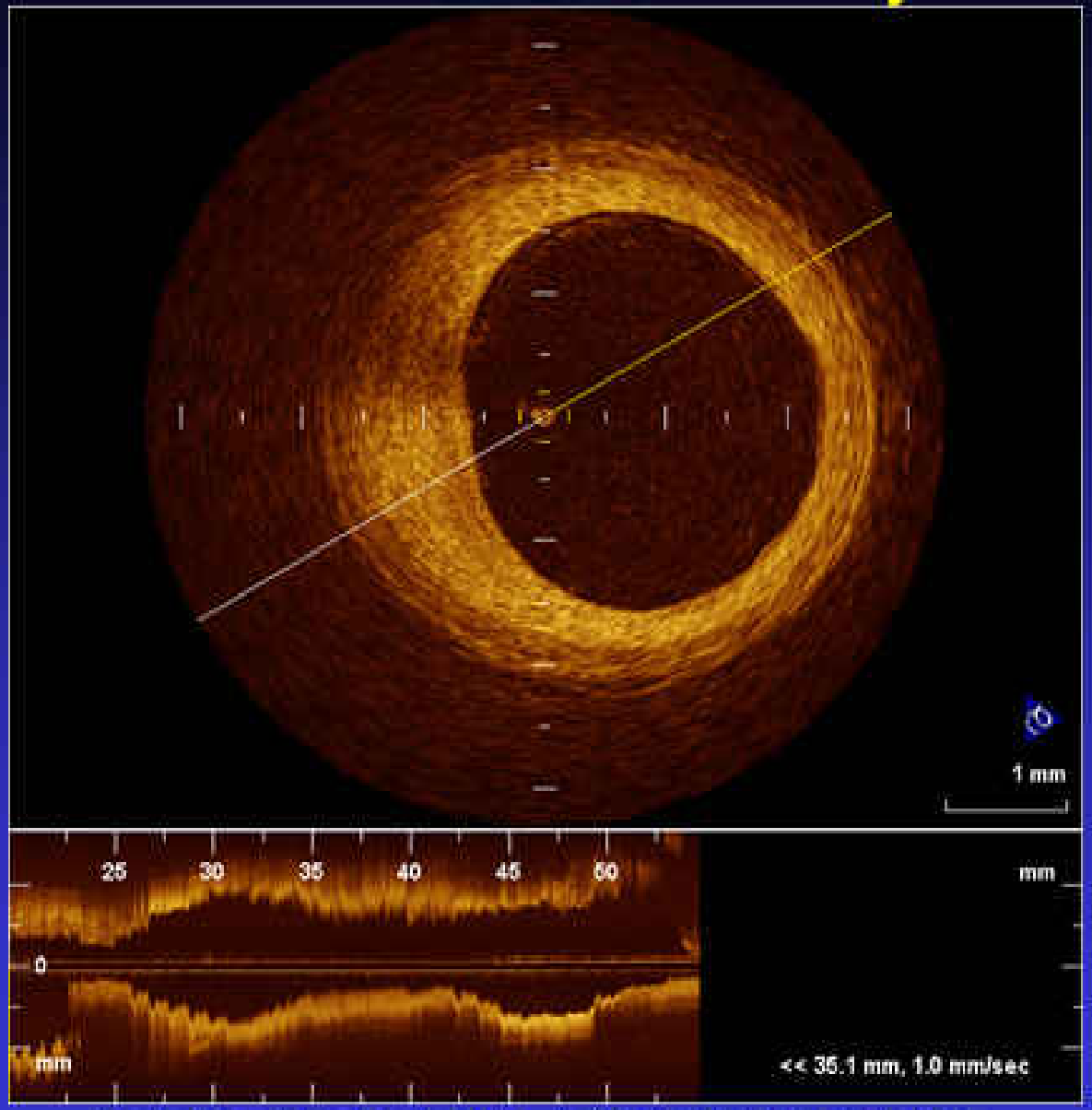
Limited depth of images because of the penetration of infrared light beam is very shallow (about 1.5mm).

Image distortion because of limited frame rate (15/sec).

Poor images at the opposite site if the image catheter is displaced to one site because of poor beam number in one sectional image.

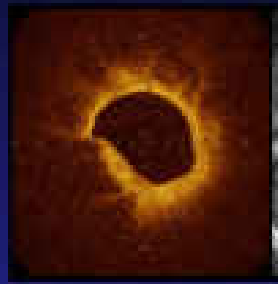
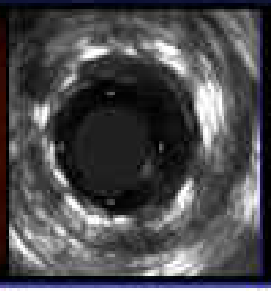
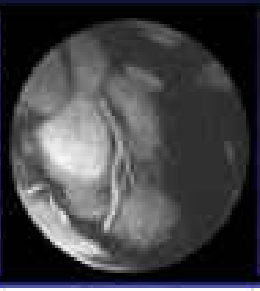
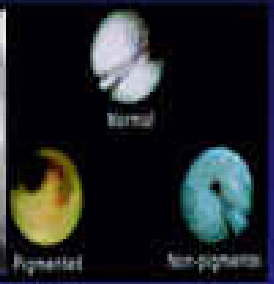


10% low molecular dextrose 3ml/s by auto injection



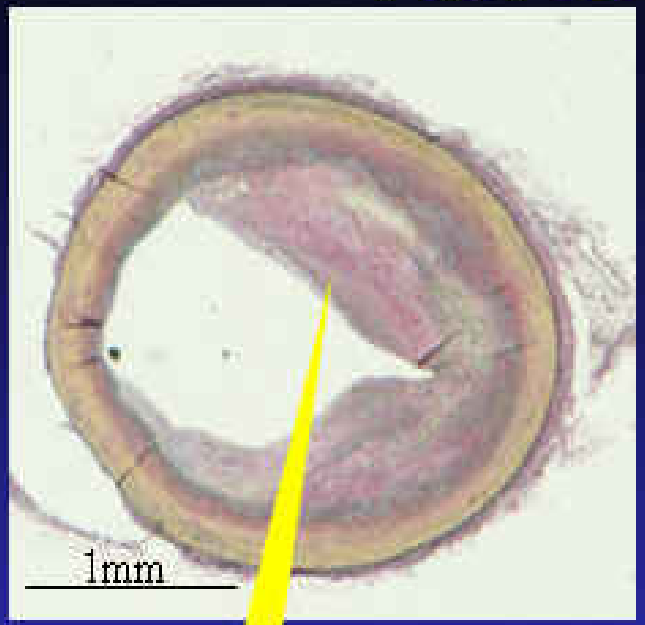
Kataiwa H, et al. Circ J 72:1536-1537, 2008

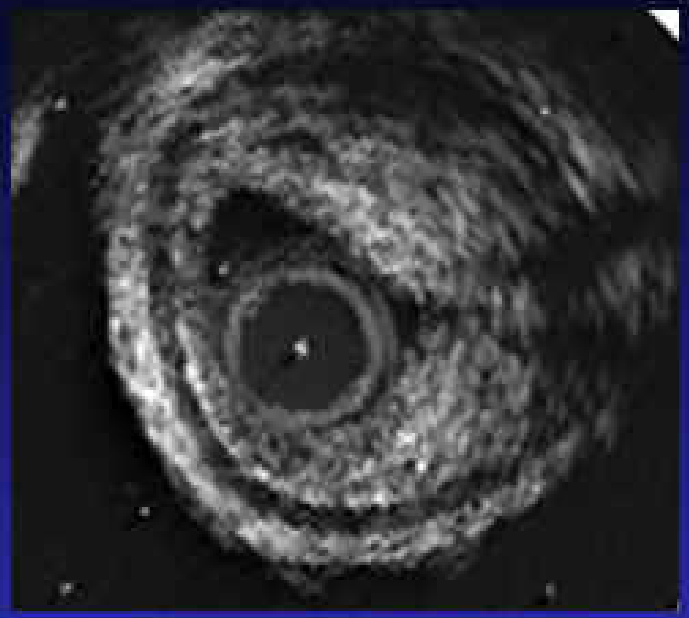
Comparison among coronary imaging techniques

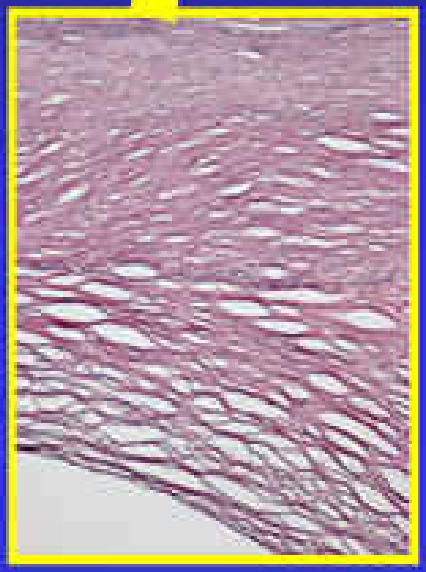
	OCT	IVUS	MRI	CAG	Angioscopy
					
Resolution	10 – 15	80 – 120	80 – 300	100-200	<200
Probe Size	140	700	1000	N/A	800
Contact	No	Yes	No	No	No
Ionizing Radiation	No	No	No	Yes	No
Other	Tissue Characterization	N/A	N/A	Flow Only	Surface Only

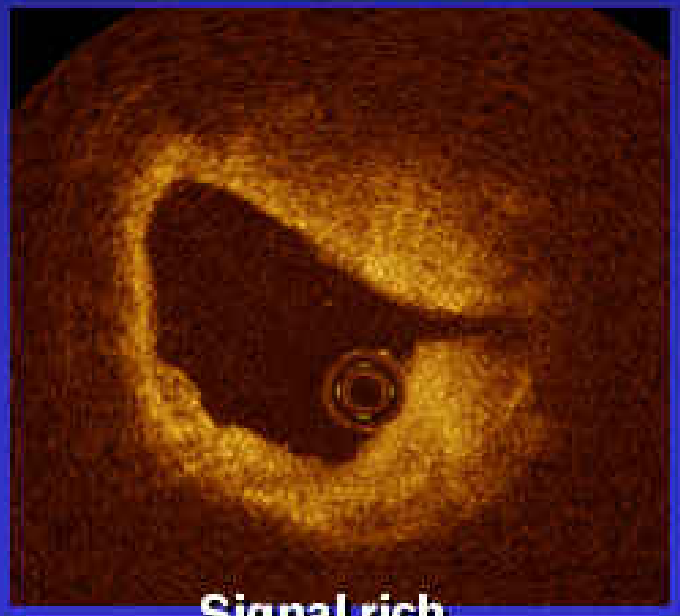
Advantages of OCT are its high resolution and accuracy of tissue characterization.

Fibrous plaque



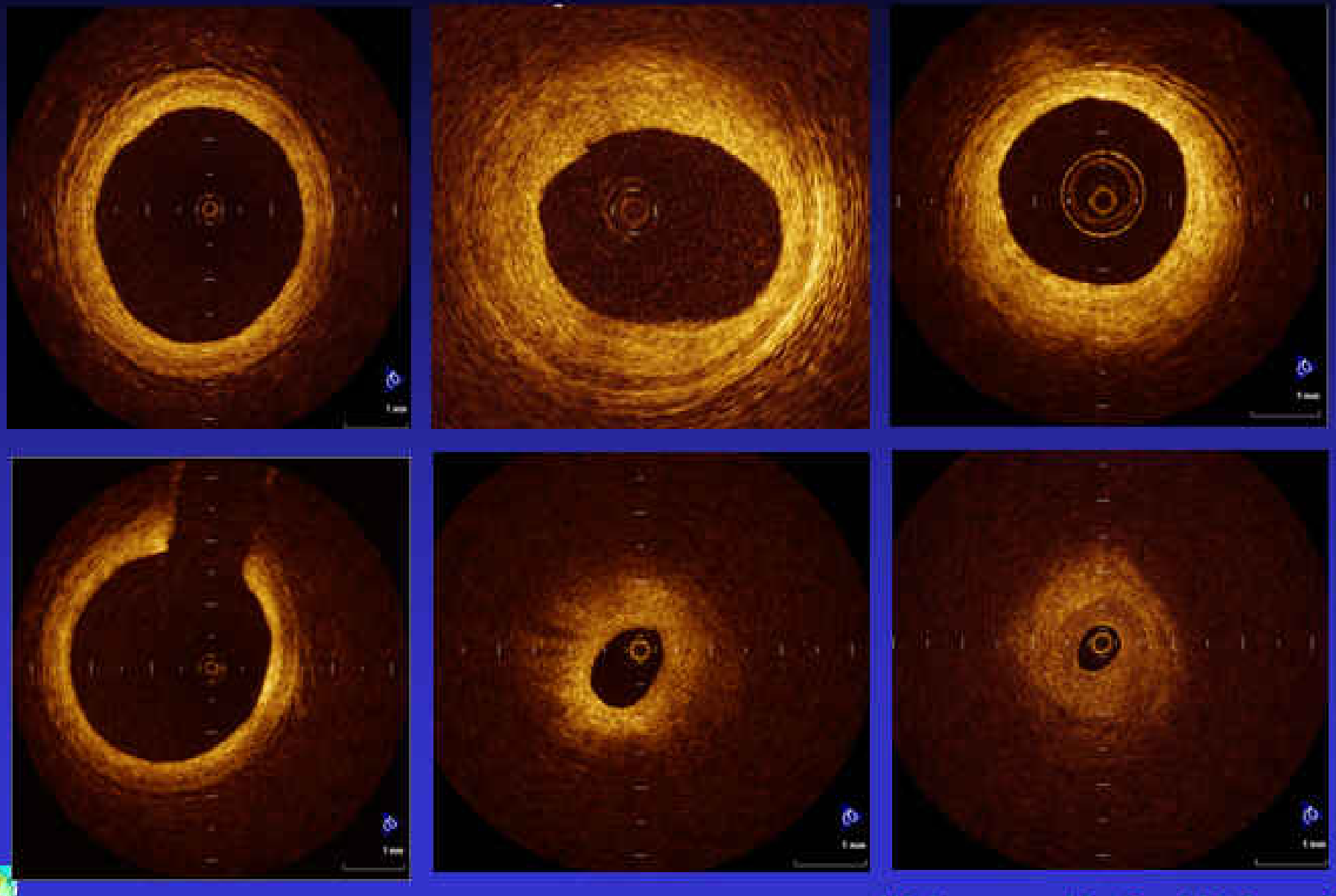




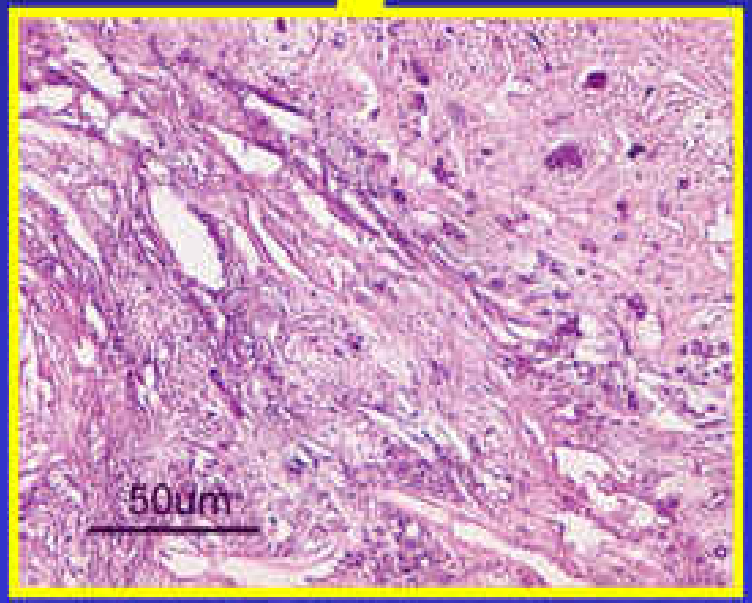


Signal rich

Fibrous plaque



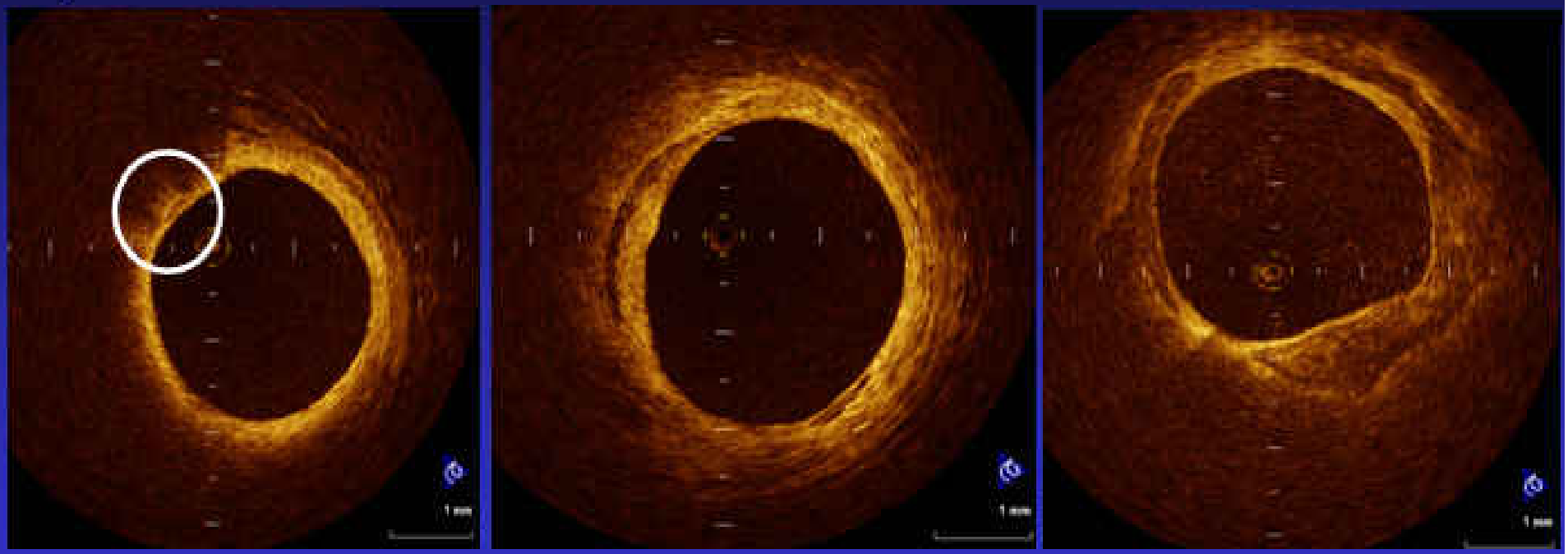
Fibrocalcific plaque



Signal poor, clear border

Calcified plaque

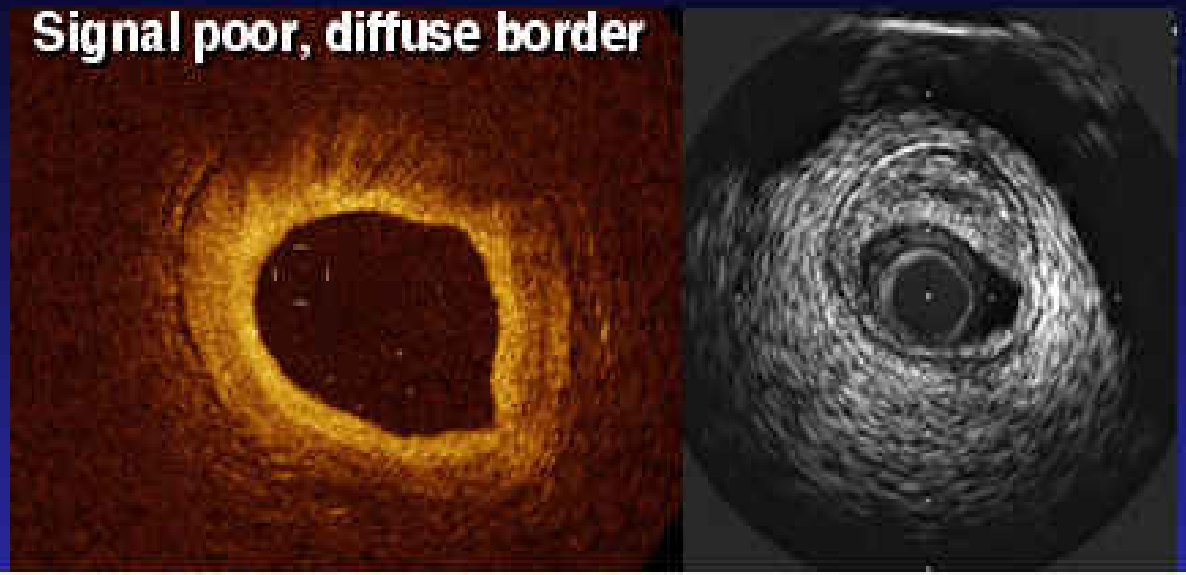
Superficial calcified nodule

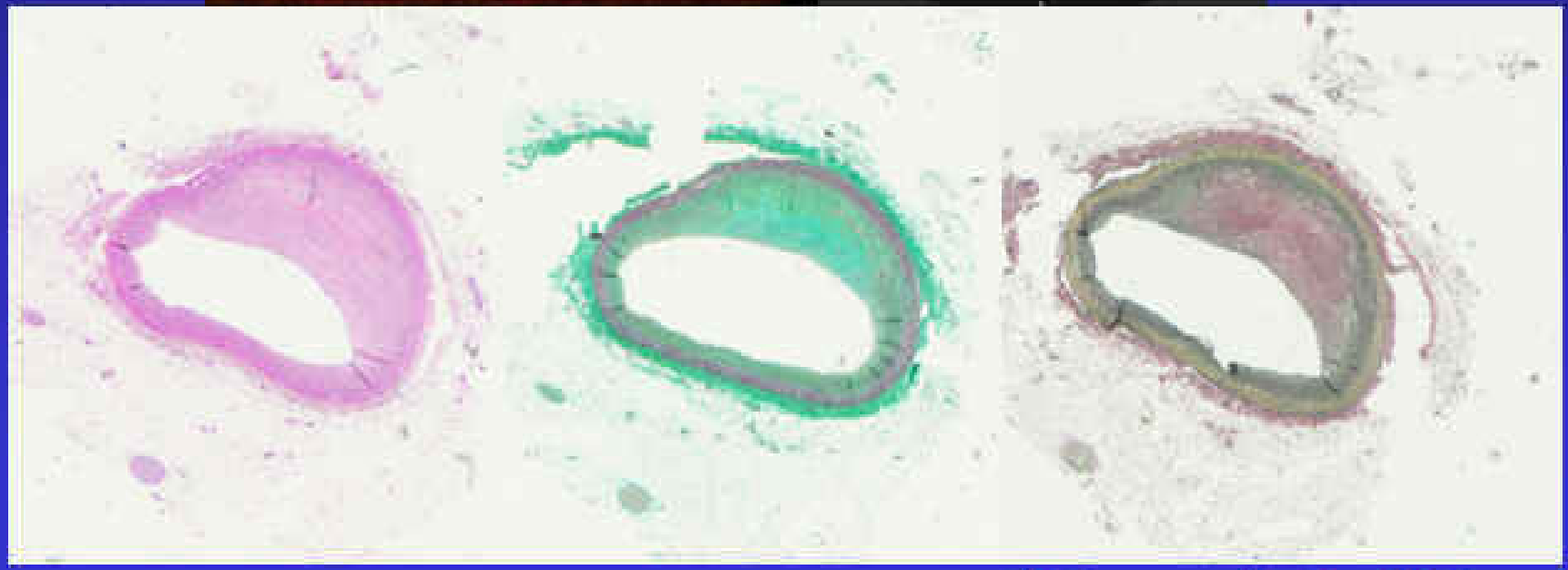


Images behind the calcium can be easily identified by OCT.

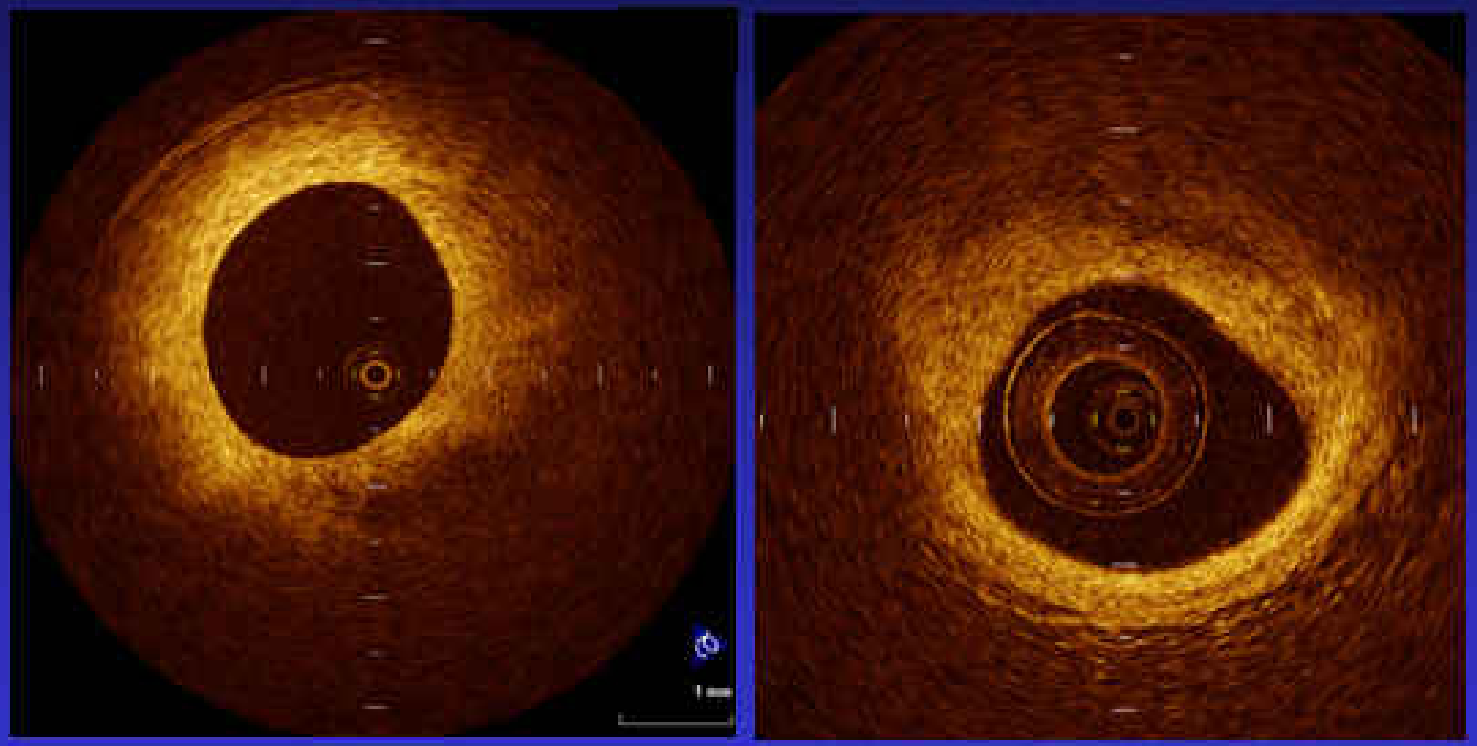
IVUS user sometimes miss this signal poor clear border lesion as lipid plaque.

Fibro-lipidic plaque

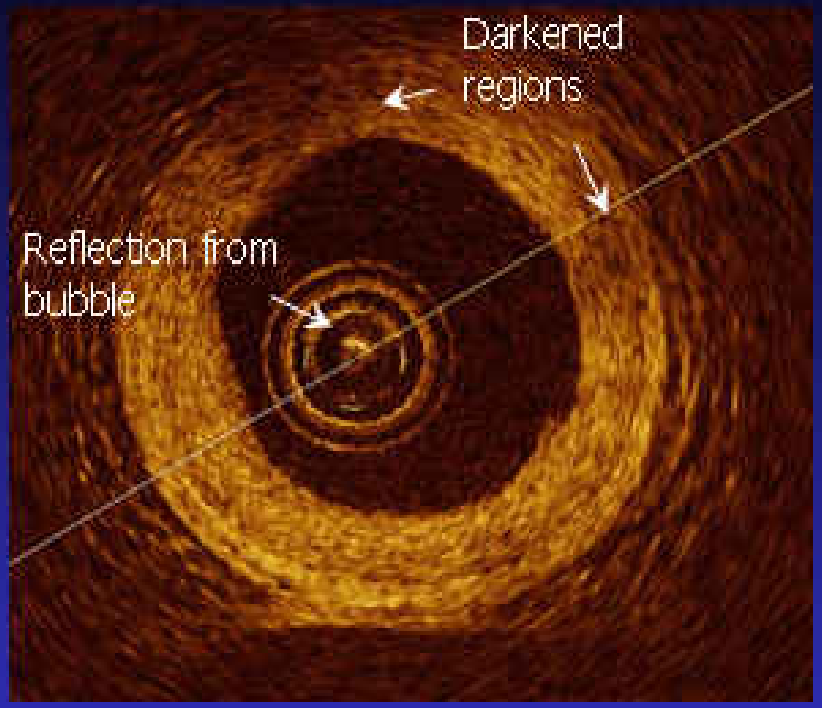




Fibrofatty plaque



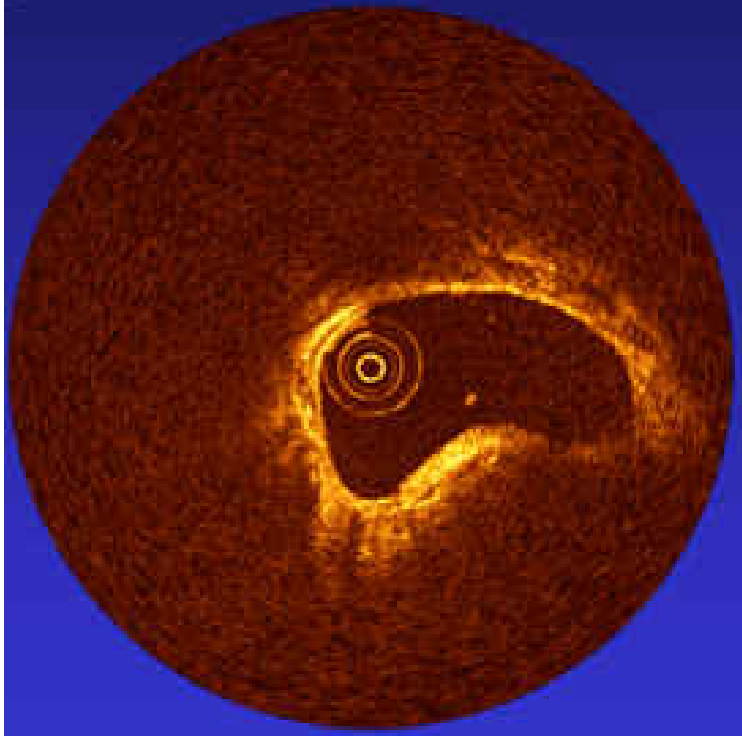
Bubble shadows

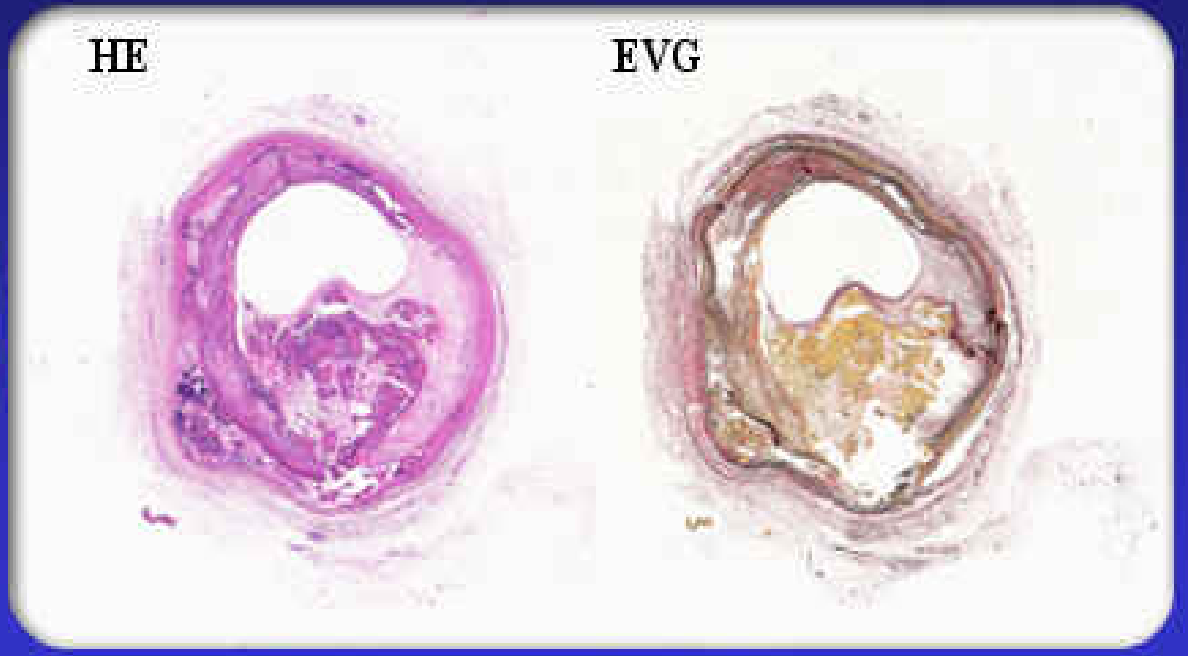


Cause: A gap can form in the silicone fluid that surrounds the optical fiber inside the ImageWire which scatters the light beam, casting a shadow. Note: this gap is not air and therefore does not compromise the patient.

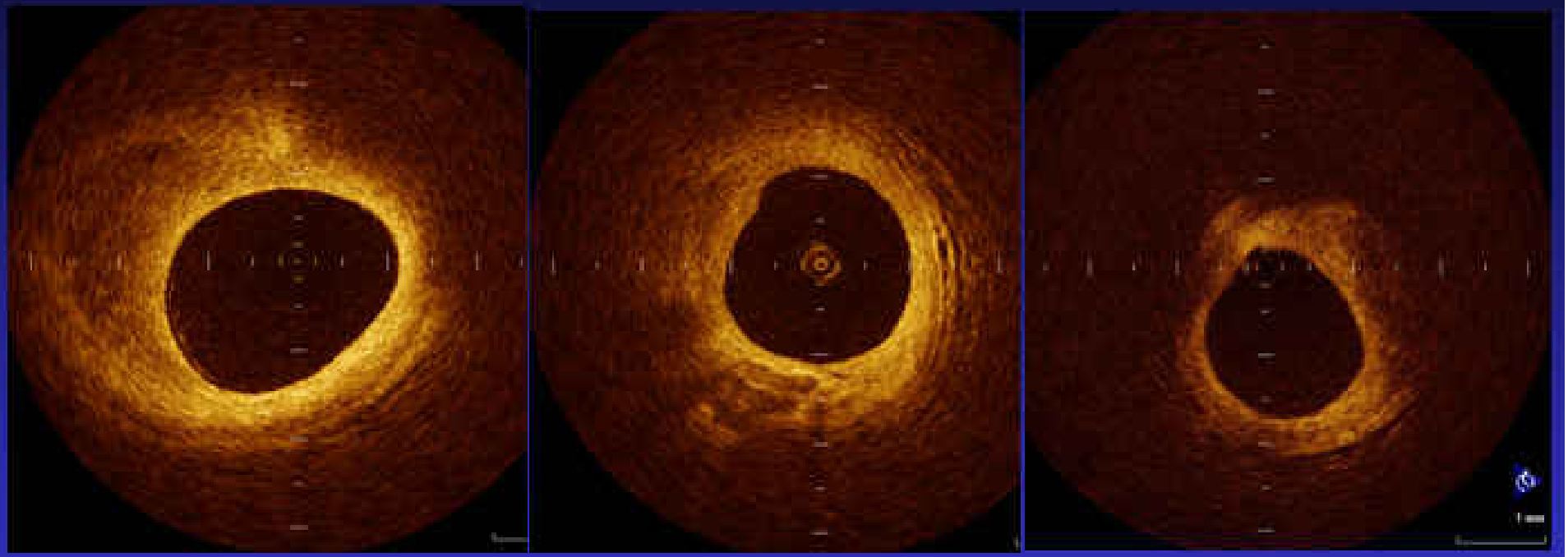
Effect: Darkens the region of tissue within the angle subtended by the gap, especially at the edges.

Necrotic core





Lipid and necrotic core



Quantification of the amount of lipid could be difficult because of signal attenuation and penetration depth of the beam.

Significant correlation was demonstrated between the amount of lipid and the lipid arc.

Red & white thrombus

Red thrombus

Protrusion mass with shadow

White thrombus

Protrusion mass without shadow

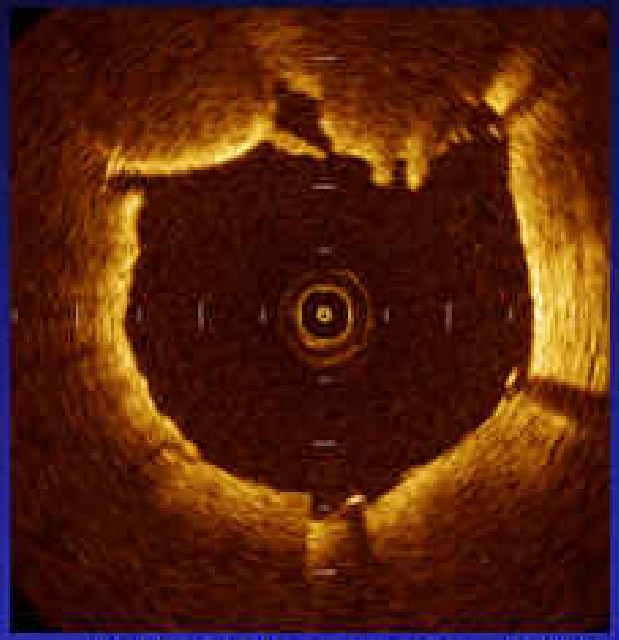
Mixed thrombus

Protrusion mass with & without shadow

Kume T, Akasaka T, et al (Am J Cardiol 97:1713-1717 , 2006)
Kubo T, Akasaka T, et al. (J Am Coll Cardiol 50:933-939,2007)

Tissue protrusion vs Thrombus

Tissue protrusion



Thrombus

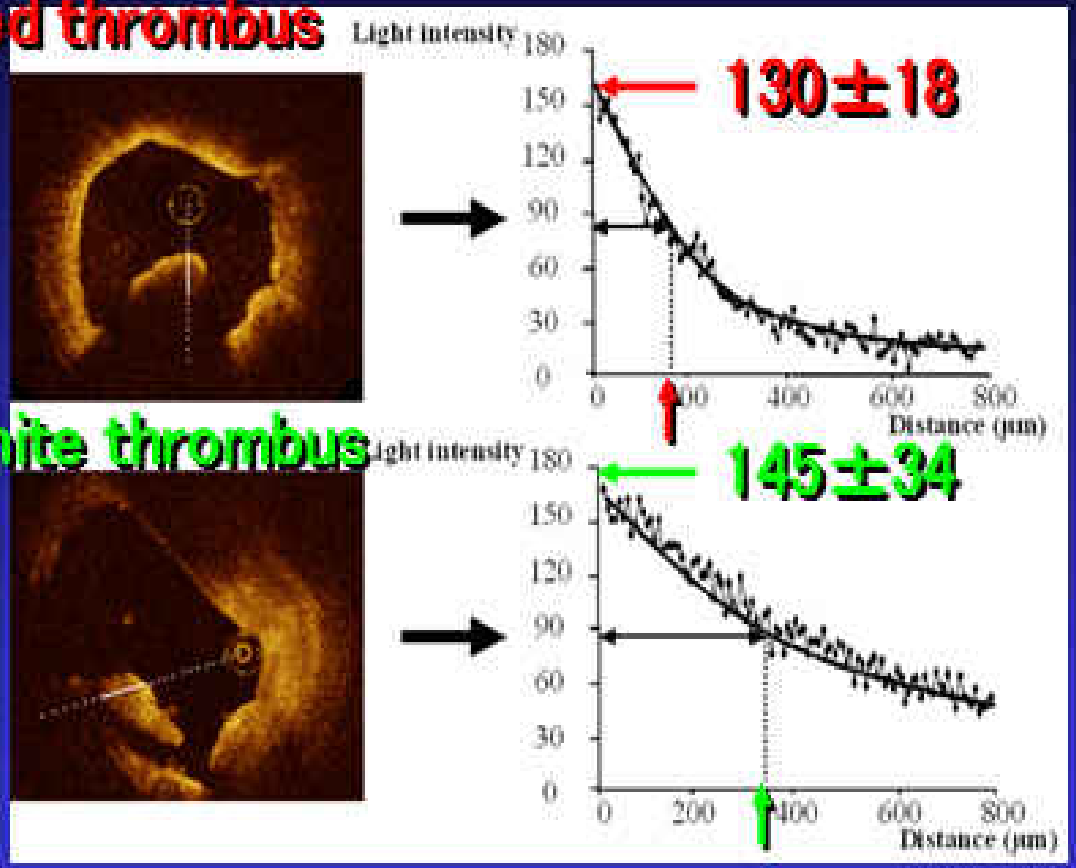
Thrombus

If there is a space between protrusion mass and vessel wall, or the maximum radius of the protrusion mass is grater than the length of attached potion to the wall, the protrusion mass can be identified as thrombus.

If there is no space between protrusion mass and vessel wall, and the maximum radius of the protrusion mass is smaller than the length of attached potion to the wall, it would be difficult to identify whether the protrusion mass is a thrombus or tissue protrusion.

Differentiation between red and white thrombus

	Peak intensity	Intensity half distance
Red thrombus	130±18	183±42
White thrombus	145±34	324±50 *



OCT image

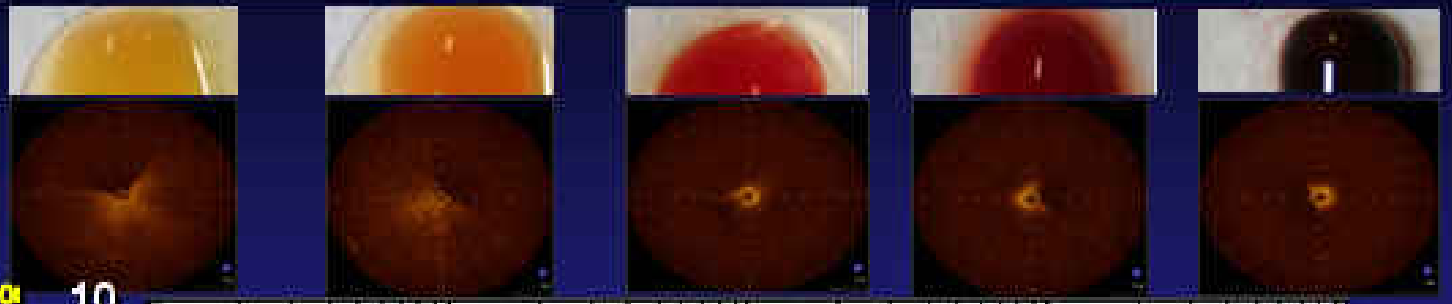
Signal attenuation curve by NIH image

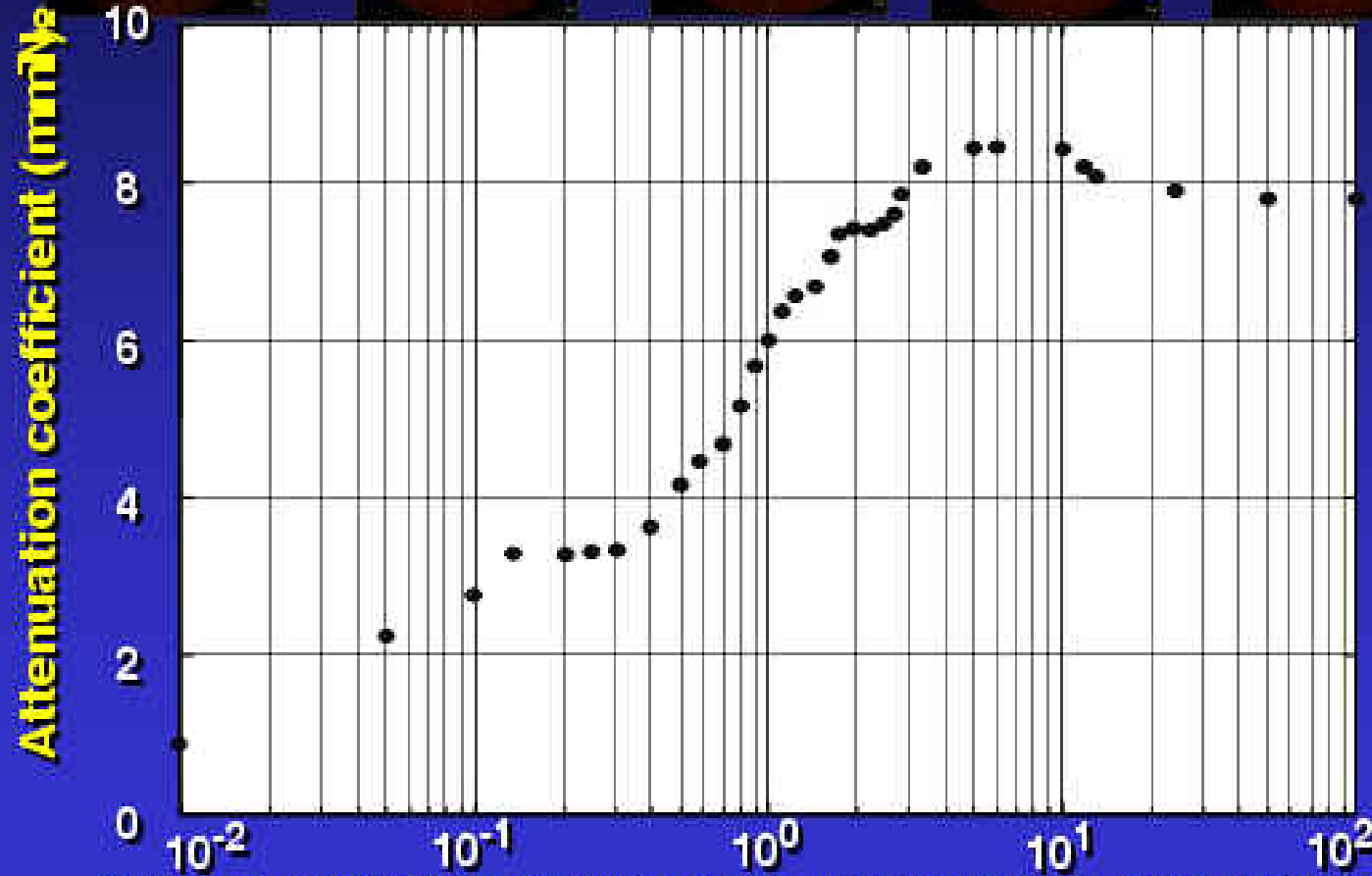
* p = 0.0001

Kume T, Akasaka T, et al (Am J Cardiol . 2006, 97:1713-1717)

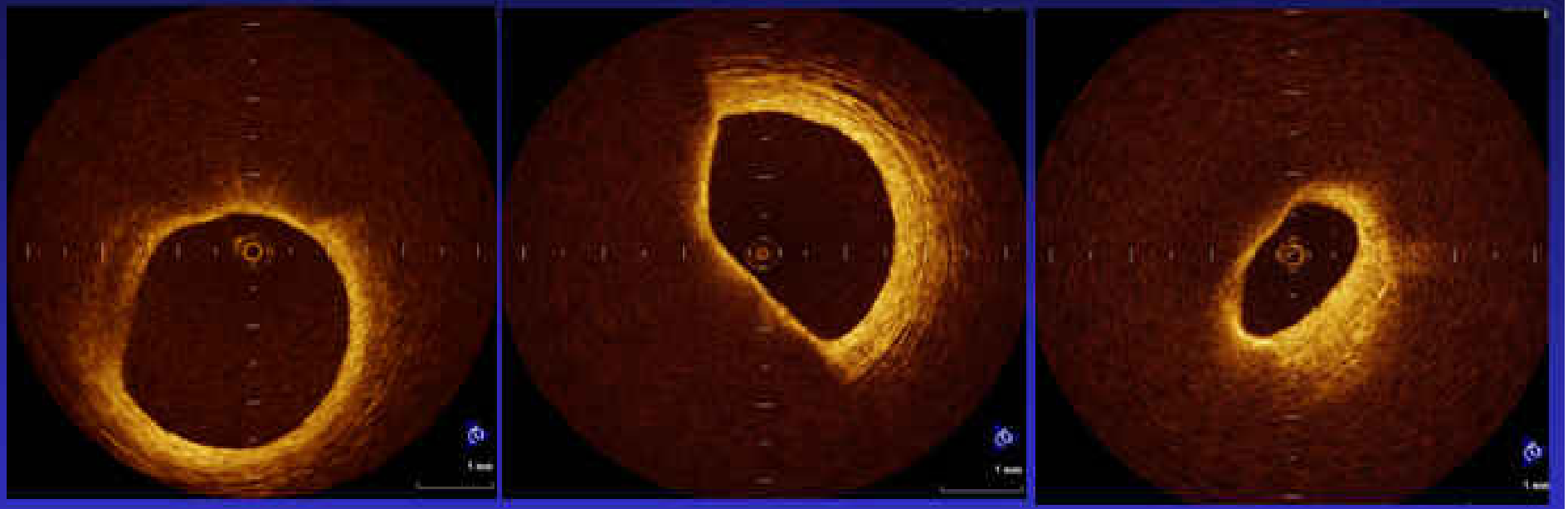
Differentiation between red and white thrombus

White thrombus — Red thrombus



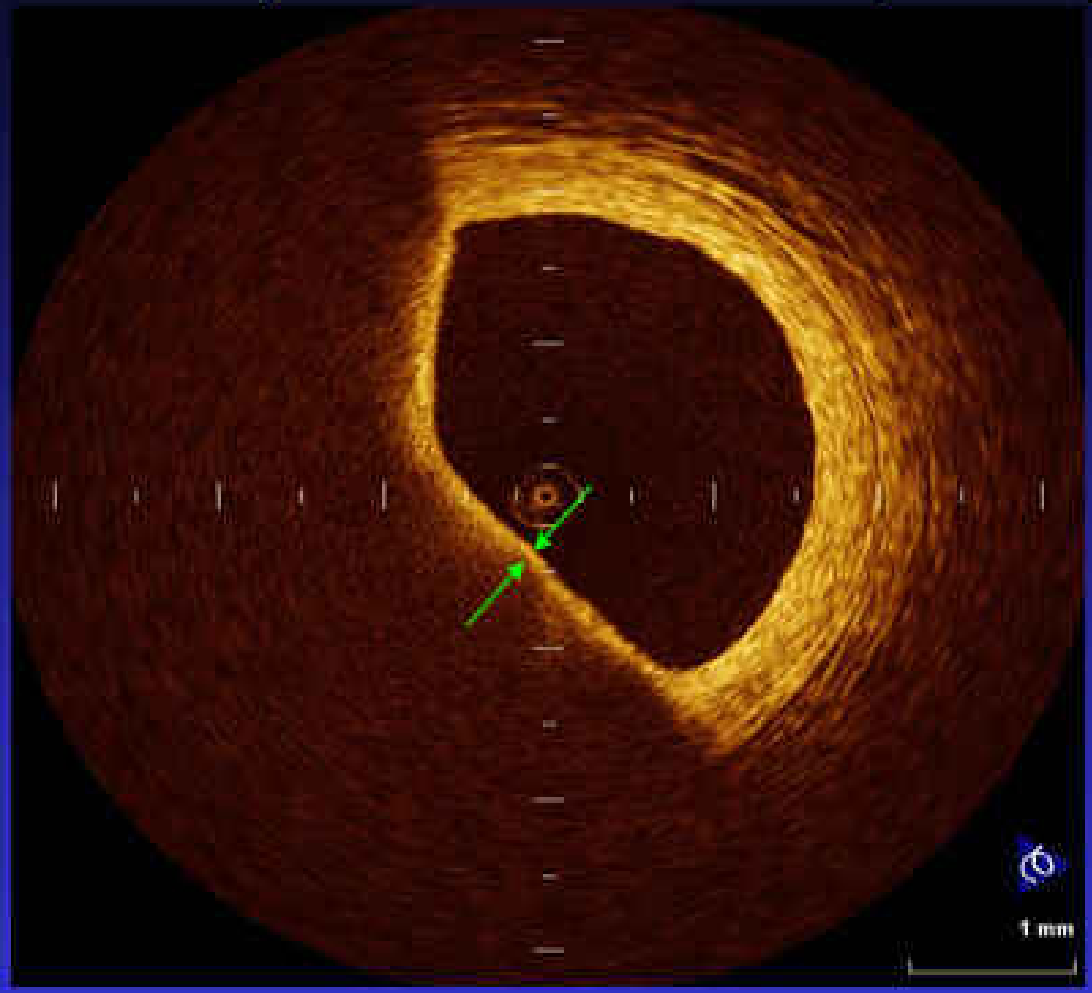


Thin-cap fibroatheroma (TCFA)



Possibility to identify TCFA has been demonstrated by several pilot studies.

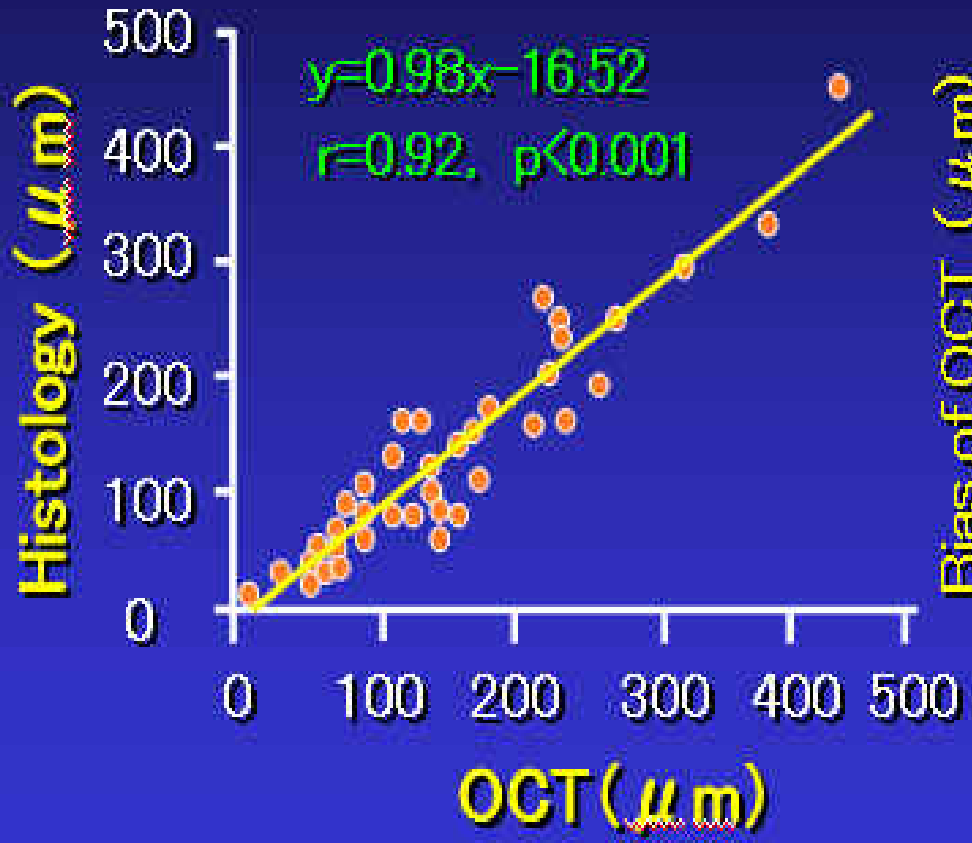
Thin-cap fibroatheroma (TCFA)

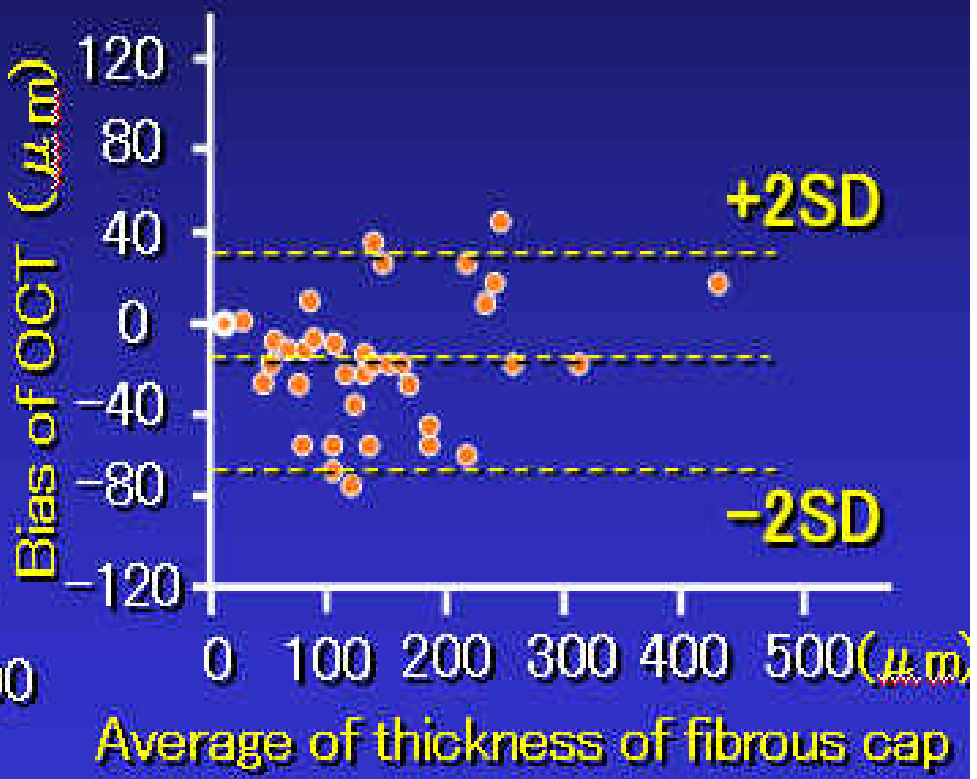


Cap thickness should be measured between the surface of the vessel wall and the potion where the signal is starting to regress.

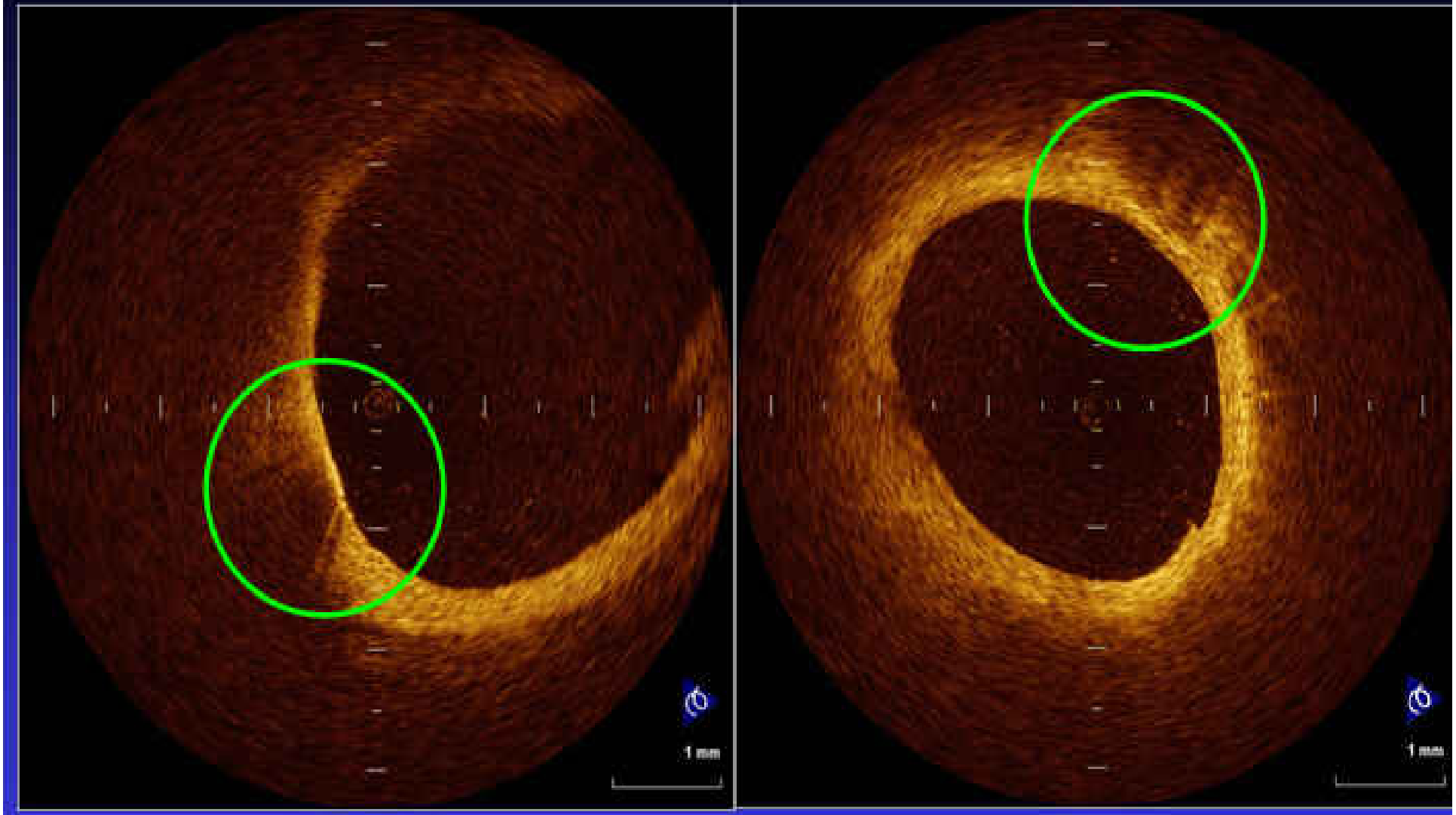
Thickness of fibrous caps
Histology vs OCT

Kume T, Akasaka T, et al (Am Heart J . 152:755, 2006)



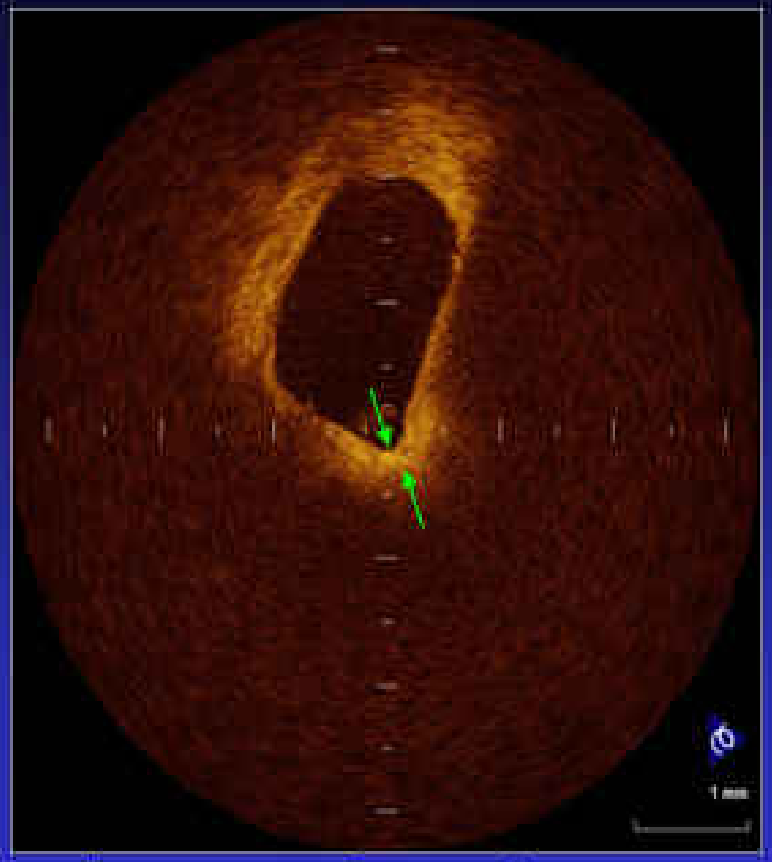


Identification of macrophage



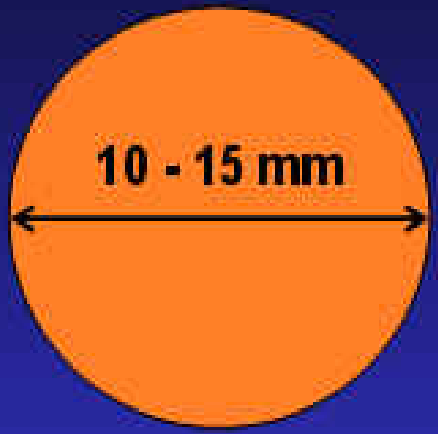
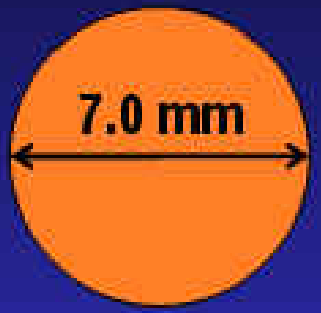
Extremely high signal with rapid attenuation on the surface of the vessel wall or within fibrous tissue might demonstrate macrophage accumuration.

Pitfalls in the identification of TCFA

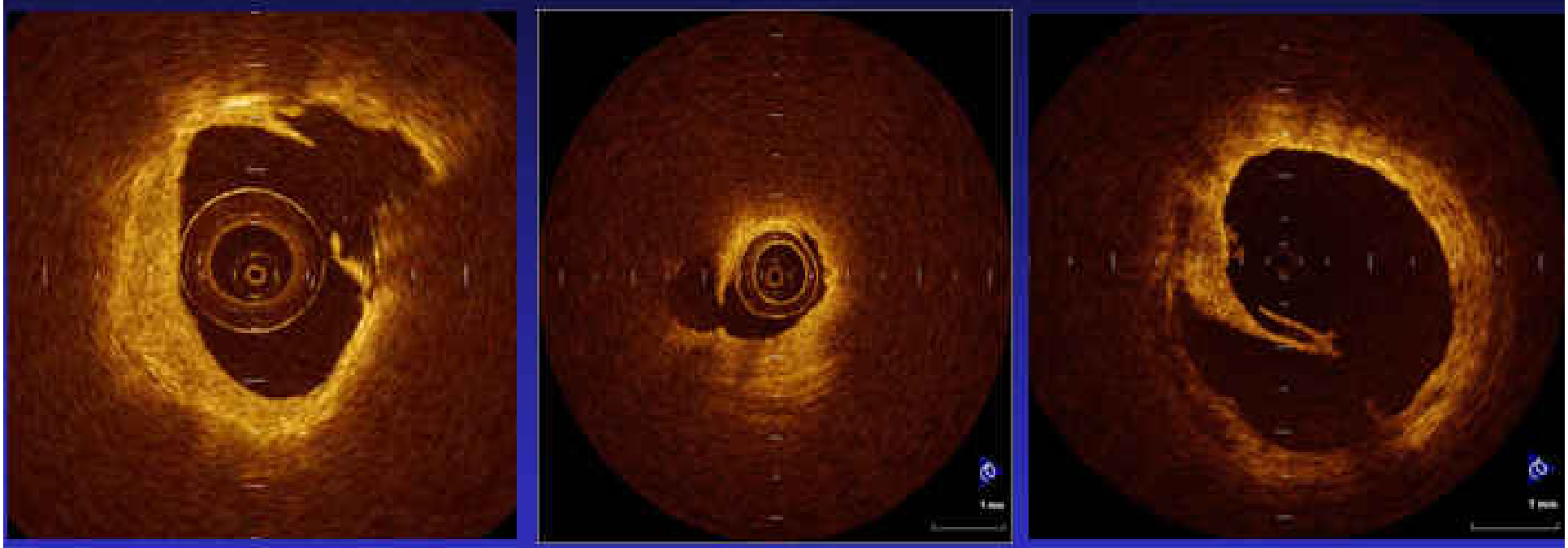


If the image catheter is extremely deviated to the vessel wall and the beam direction looks parallel to the plaque surface, we have to be careful to identify the TCFA, especially the fibrous cap thickness at the catheter potion is enough thick.

Comparison between IVUS and OCT

	IVUS	OCT
Scan area		
Max. penetration depth	4 - 8 mm	1 – 1.5 mm
Blood clearing To obtain images	Not required	Required

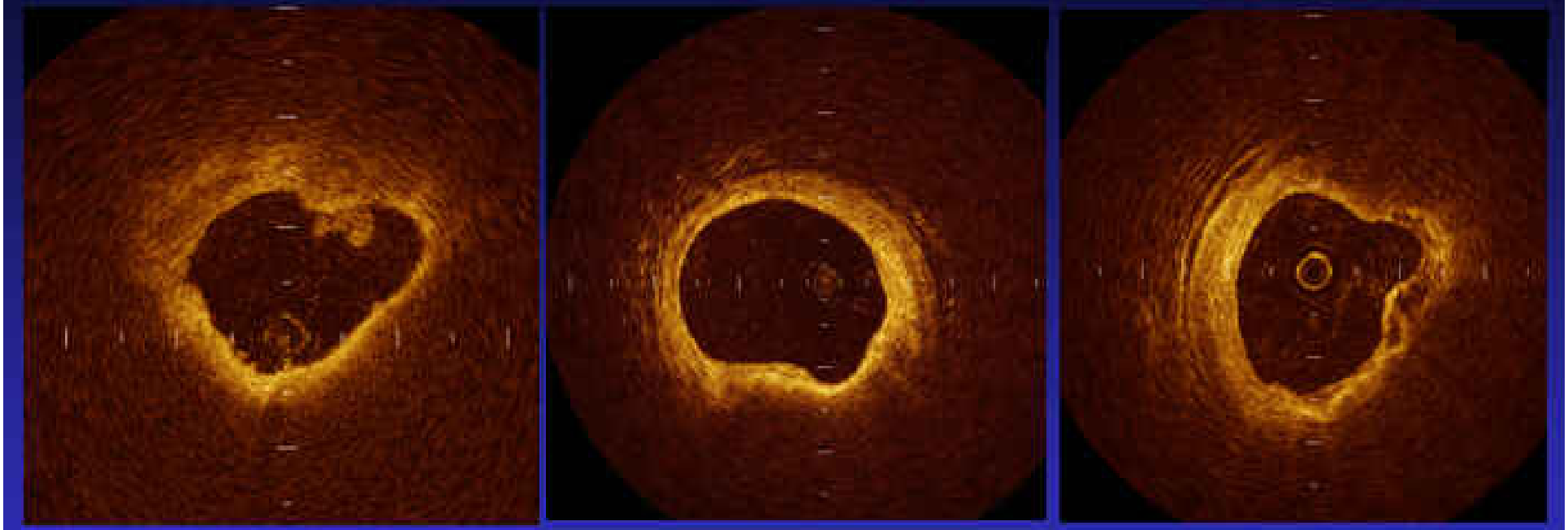
Plaque rupture (Plaque disruption)



Plaque rupture could be identified the findings of discontinuity of the fibrous cap and ulcer (cavity) formation at the site of the discontinuing fibrous cap.

Plaque ulceration

Erosion ?

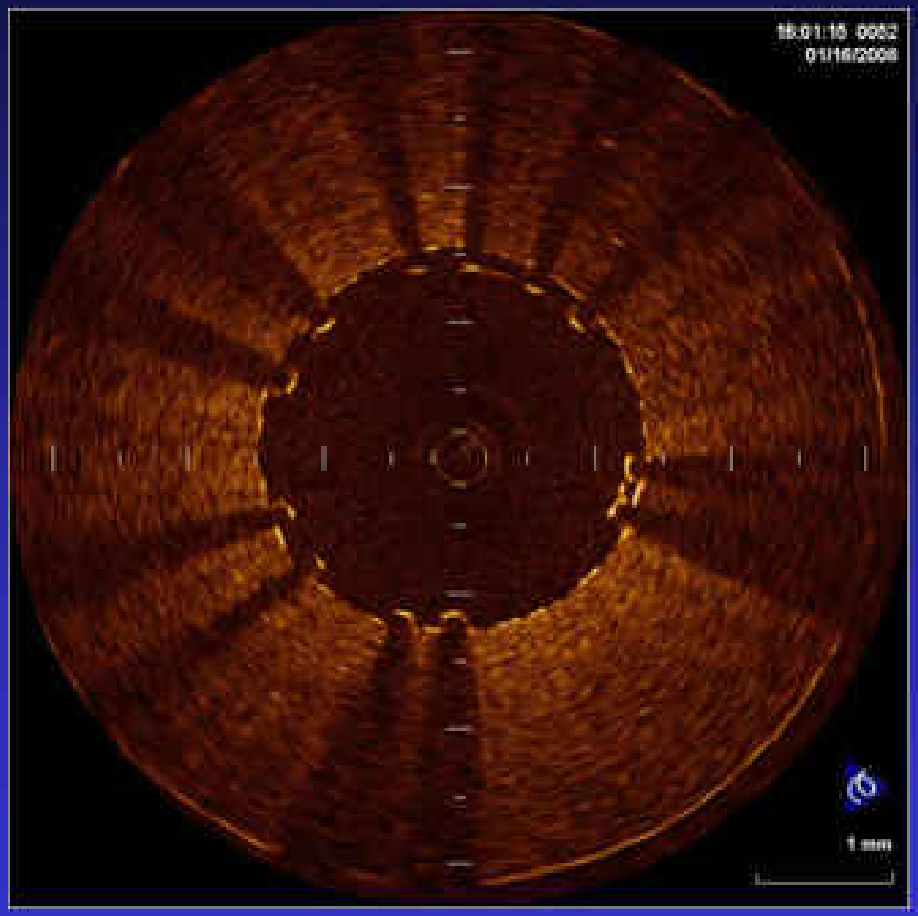


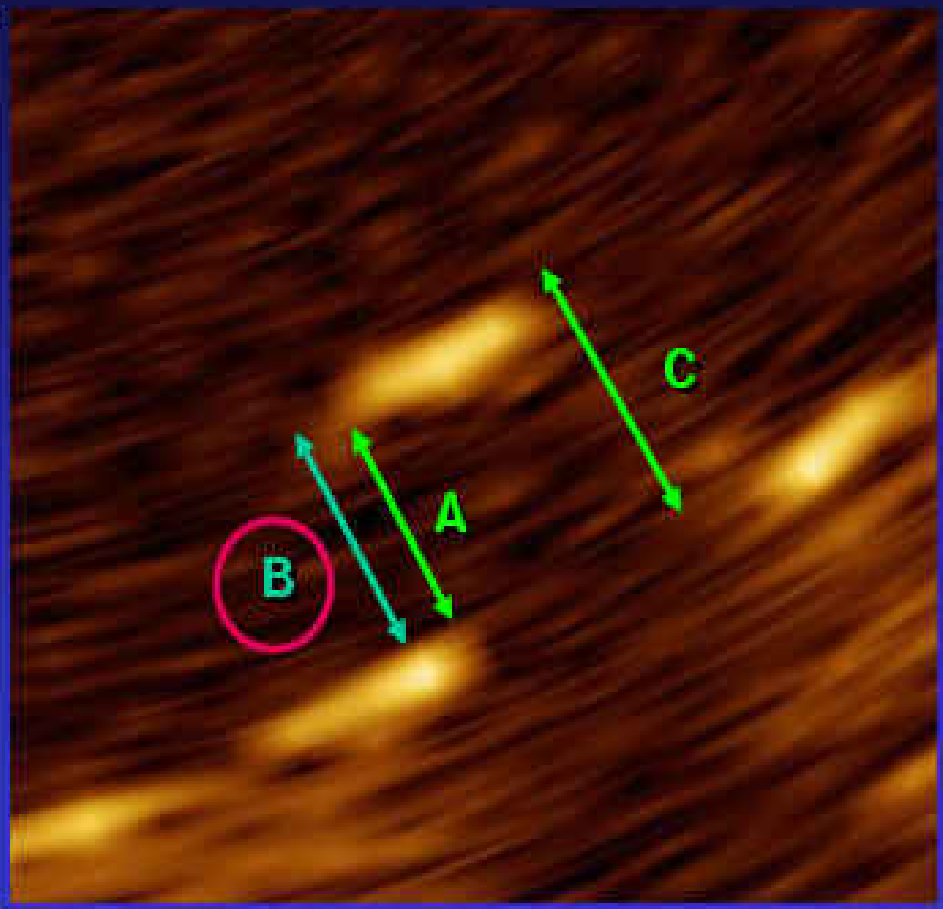
Plaque ulceration could be identified a hollow at the culprit site, especially if there is no rupture.

Plaque erosion could be identified in a broad band spectrum from denudation of several endothelium to ulcer formation without rupture in the culprit site.

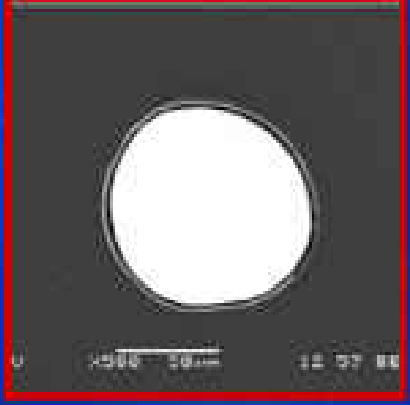
Assessment of stent apposition

Phantom model





Size of stent strut and Polymer Thickness

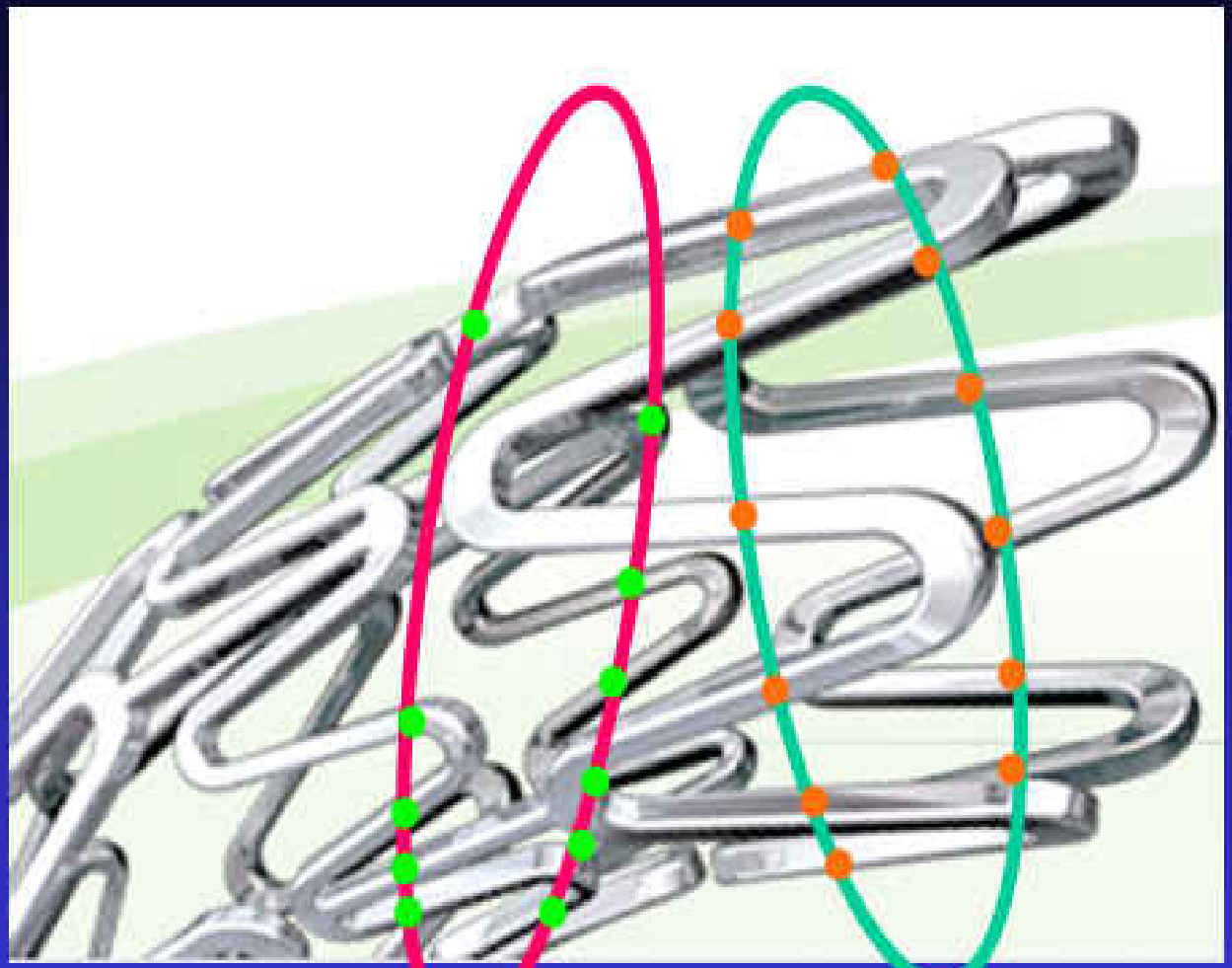
CYPHER®	TAXUS®	ENDEAVOR	XIENCE V
			
Strut Thickness:	Strut Thickness:	Strut Thickness:	Strut Thickness:
140 um	132 um	91 um	81 um
Polymer Thickness:	Polymer Thickness:	Polymer Thickness:	Polymer Thickness:
12.6 um	16 um	5.3 um	7.6 um
Total:	Total:	Total:	Total:
152.6 um	148 um	96.3 um	88.6 um

3.0 mm diameter stents, 500x magnification

Data on file at Abbott Vascular

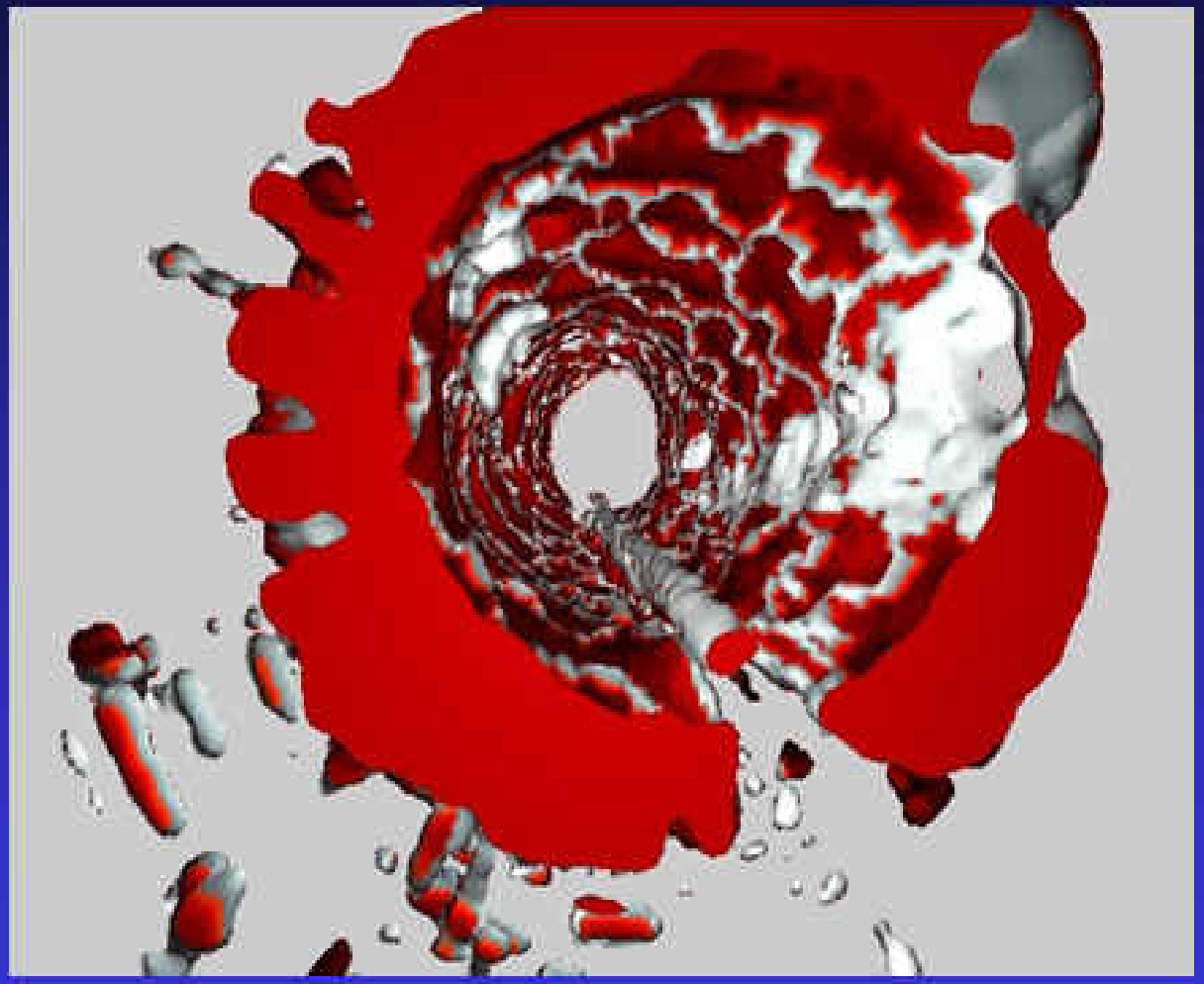
Thickness of stent strut Is different In each stent.
Different identification of incomplete stent apposition would be required.

Inconsistent stent strut distribution

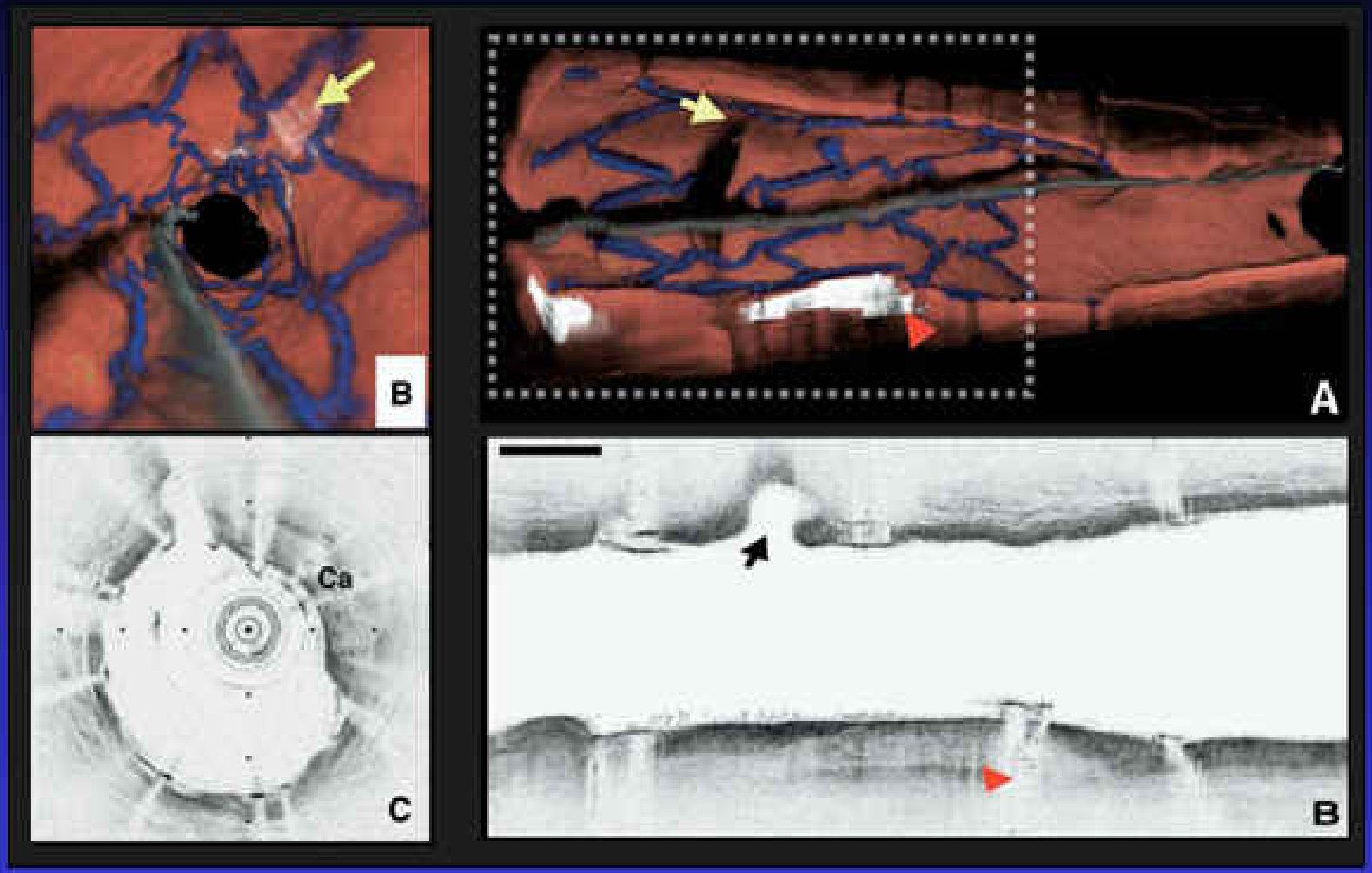


Be careful to diagnose inconsistent stent strut distribution because image section cannot always be guaranteed as perpendicular to the vessel axis.

3-D image analysis & Inconsistent stent strut distribution



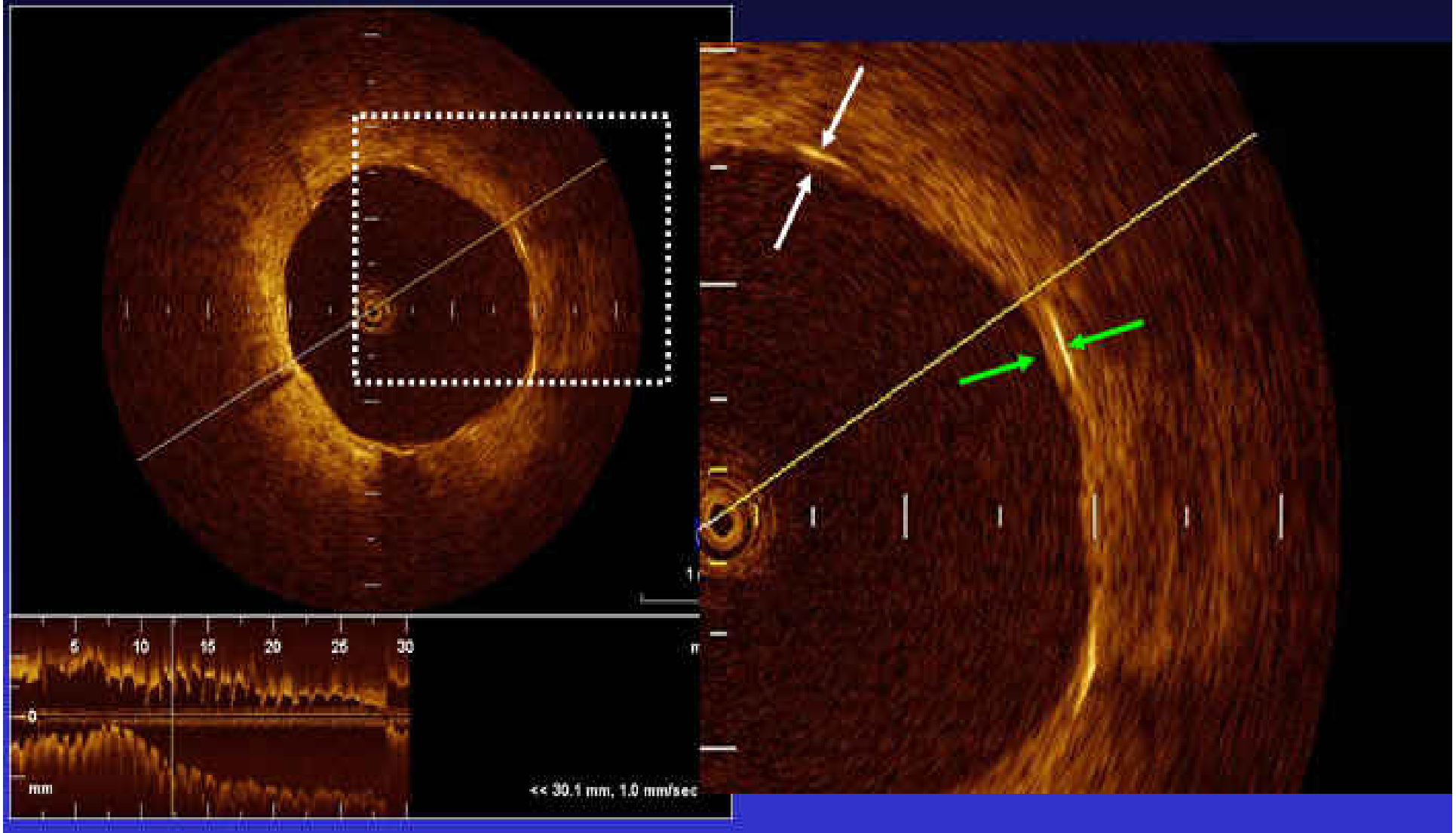
3D FD-OCT imaging



When this technology is fully exploited, OCT may be a powerful clinical tool for guiding coronary intervention.

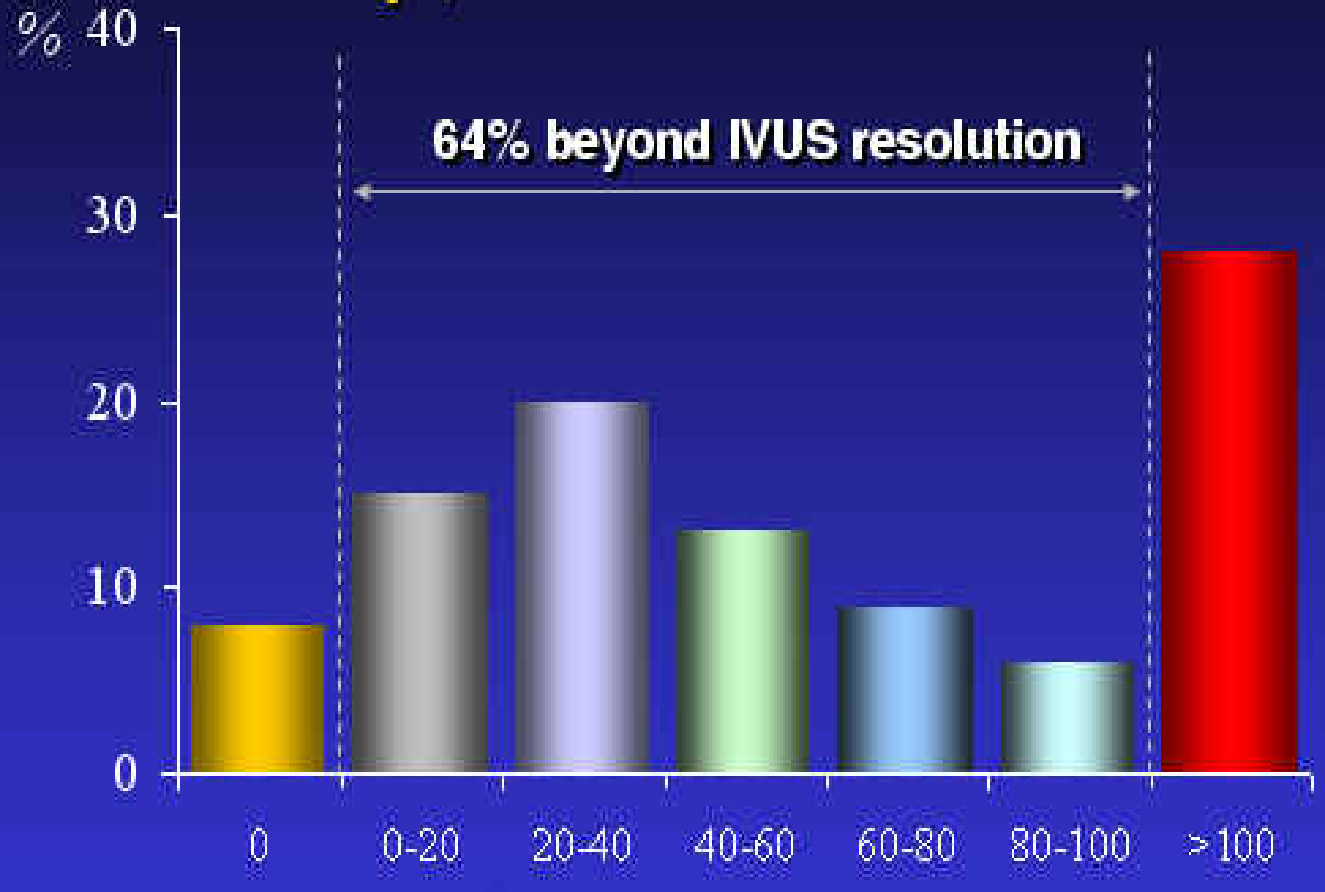
Tearney et al. JACC imaging 2008;1:752-61

Post-stent follow up



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

34 pts, 6840 stent strut cross sections



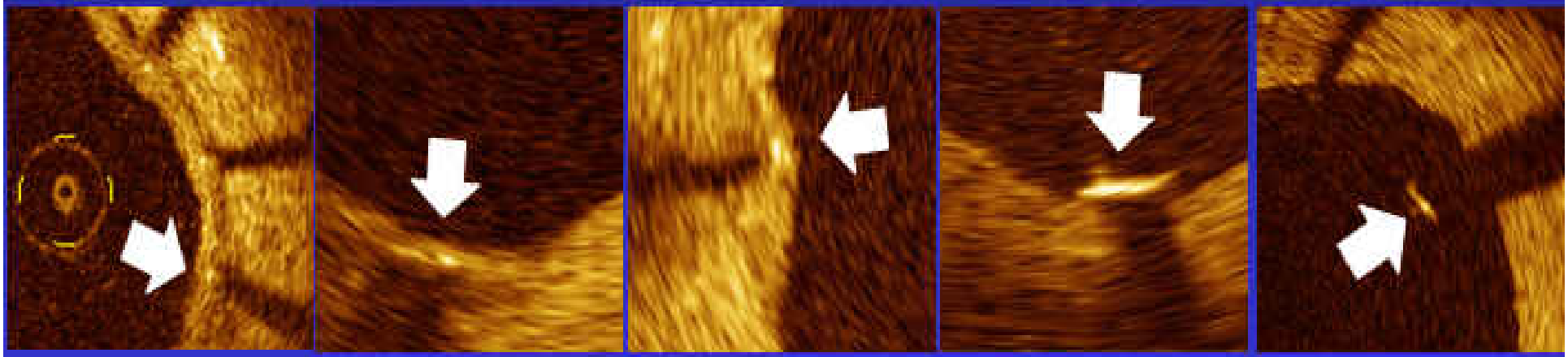
Matsumoto, D. et al. Eur Heart J 2007 28:961-967

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

Classification of strut condition

Qualitative Struts Analysis

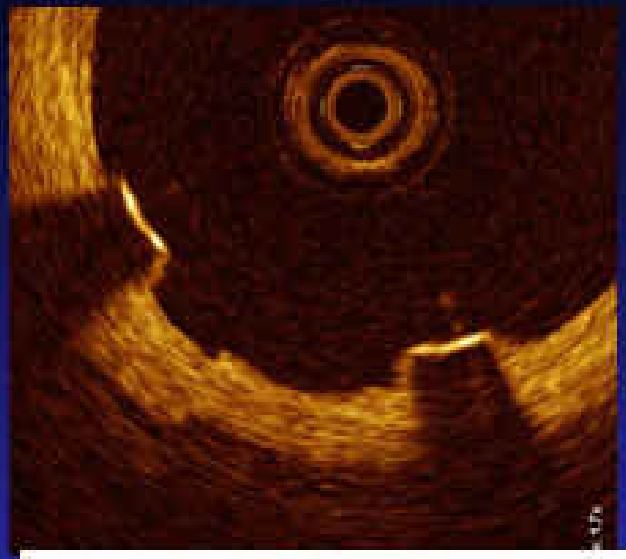
Embedded	Protruding / Covered	Protruding/ Uncovered	Malapposed/ Uncovered
I/II	IIIa	IIIb	IV



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

Classification of strut condition

Wellapposed with neointima

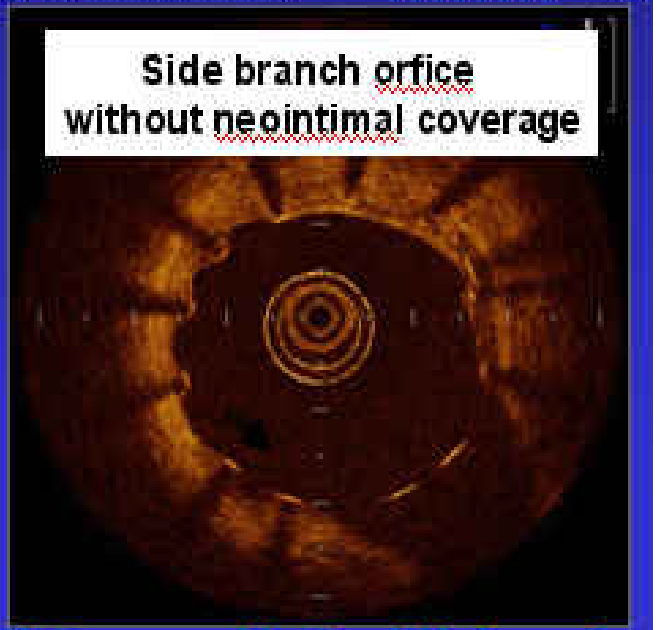


Wellapposed without neointima

Malapposed with neointima

Malapposed without neointima

Side branch orfice
with neointimal coverage

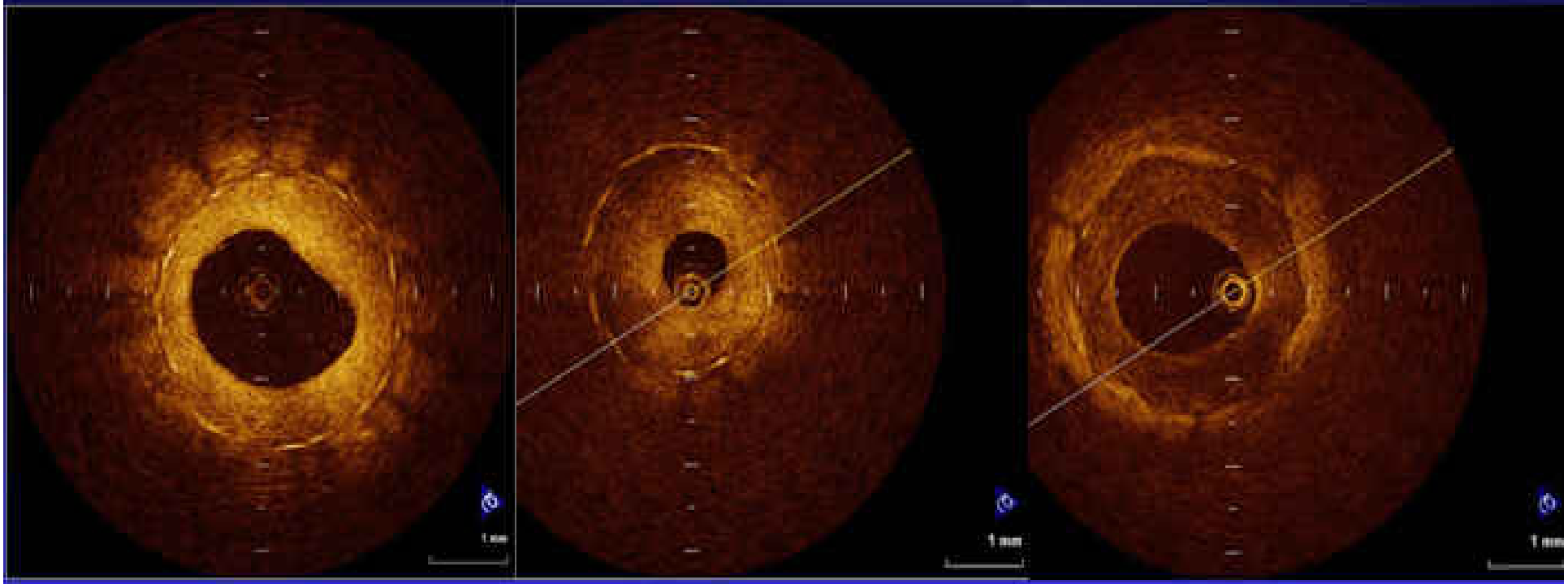


Side branch orfice
without neointimal coverage

Wakayama Medical University

OCT findings of instent restenosis

BMS SES PES



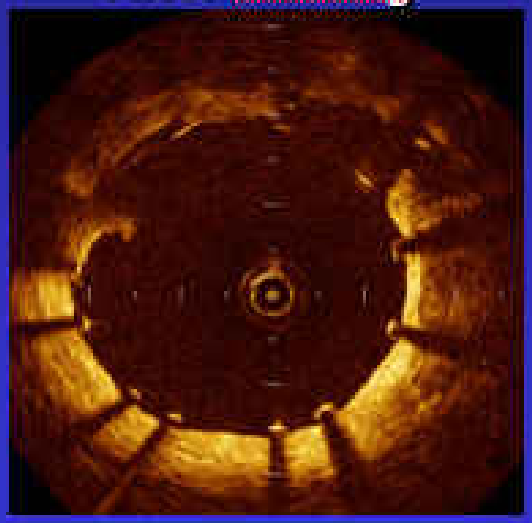
Fibrin deposition, organized thrombus and proteoglycan-rich neointima were proposed as signal poor homogenous neotissue.

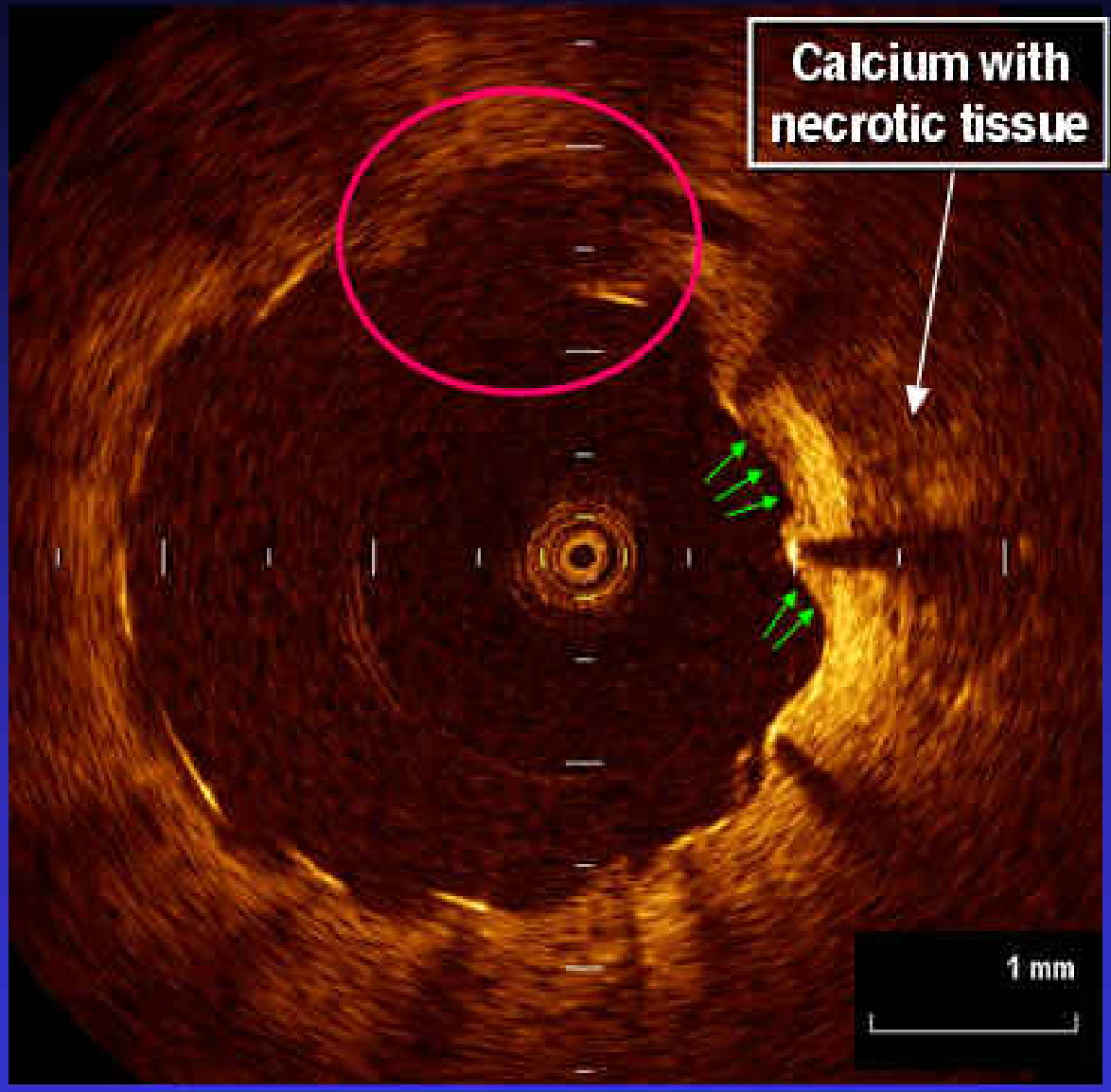
Further comparative investigation with histology could be required to identify these signal poor homogenous neo-tissue within DES.

9 months after SES stent implantation

Before stenting

After stenting

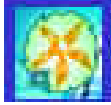




There are no data in neo-tissues around the strut.

Conclusions

- There are some pitfalls and limitations in data acquisition, interpretation and measurements in OCT images.
- Further comparative studies with histology and much more clinical experiences may improve these pitfalls and limitations.
- Development of new generation OCT and new analyzing system may resolve these limitation in some degree.
- It would be very important to interpret and measure OCT images after understanding these pitfalls and Limitations in detail.



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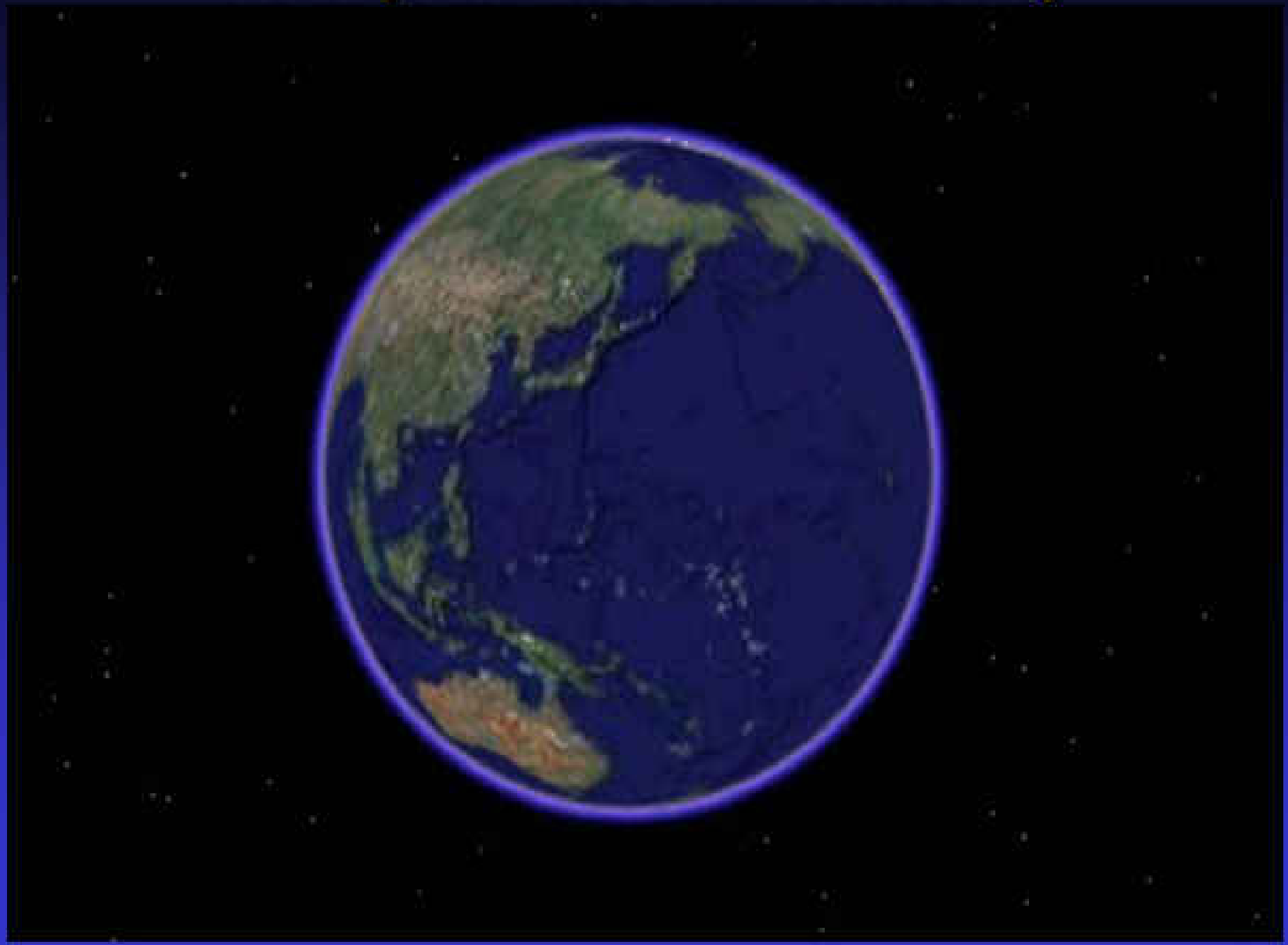

Difference between IVUS and OCT

IVUS

OCT