Clinical Use Perspectives & Future Direction of OCT

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Disclosure Statement of Financial Interest

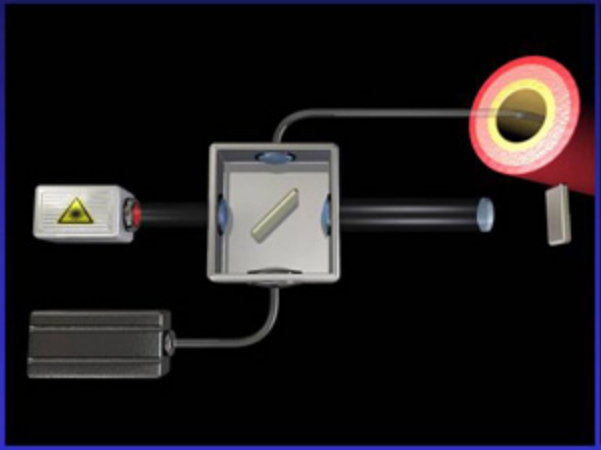
Within the past 12 months, I or my spouse/partner have had a financial interest/arrangement or affiliation with the organization(s) listed below.

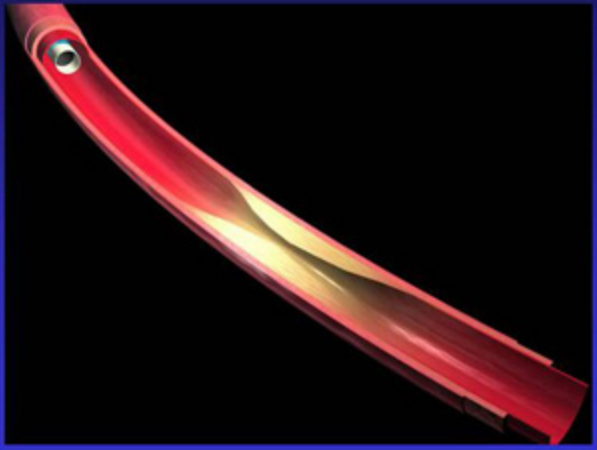
Affiliation/Financial Relationship

- **Grant/Research Support** : Abbott Vascular Japan
  Boston Scientific Japan
  Goodman Inc.
  Sent Jude Medical Japan
  Terumo Inc.

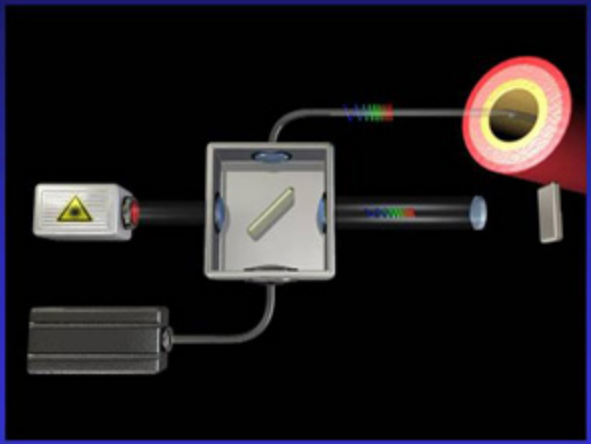
- **Consulting Fees/Honoraria** : Goodman Inc.
  GE Medical Healthcare
  Sent Jude Medical Japan
  Terumo Inc.

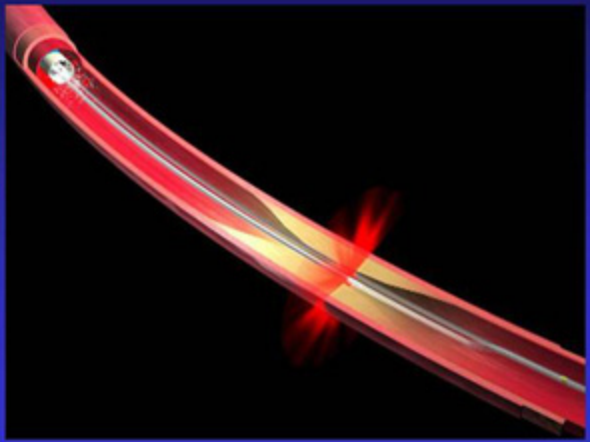
Frequency Domain OCT (OFDI)





Frequency Domain OCT (OFDI)





Recently available OCT systems

(A)

LightLab/
St. Jude

(B)

Terumo

(C)

Volcano

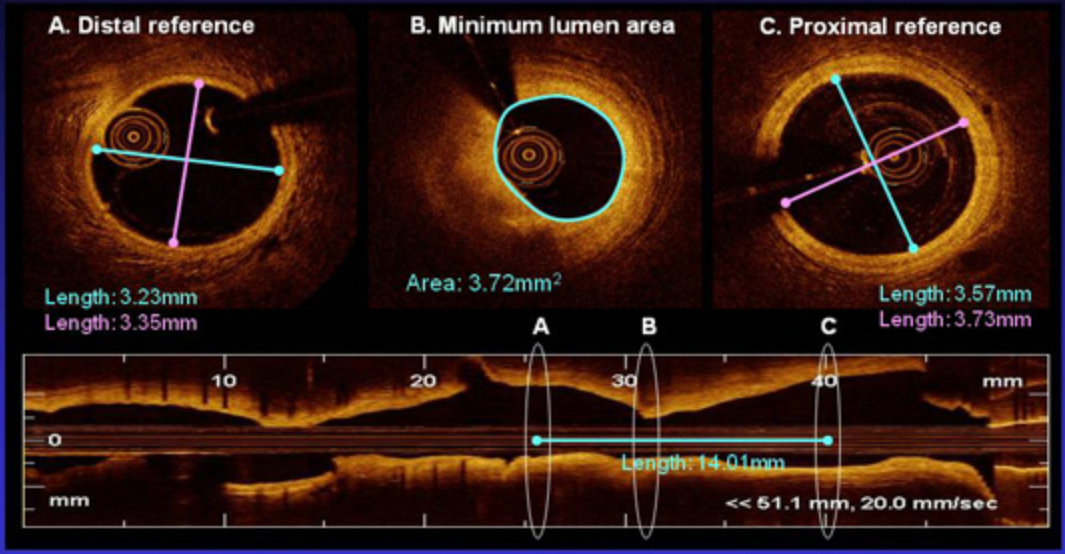
(D)

MGH

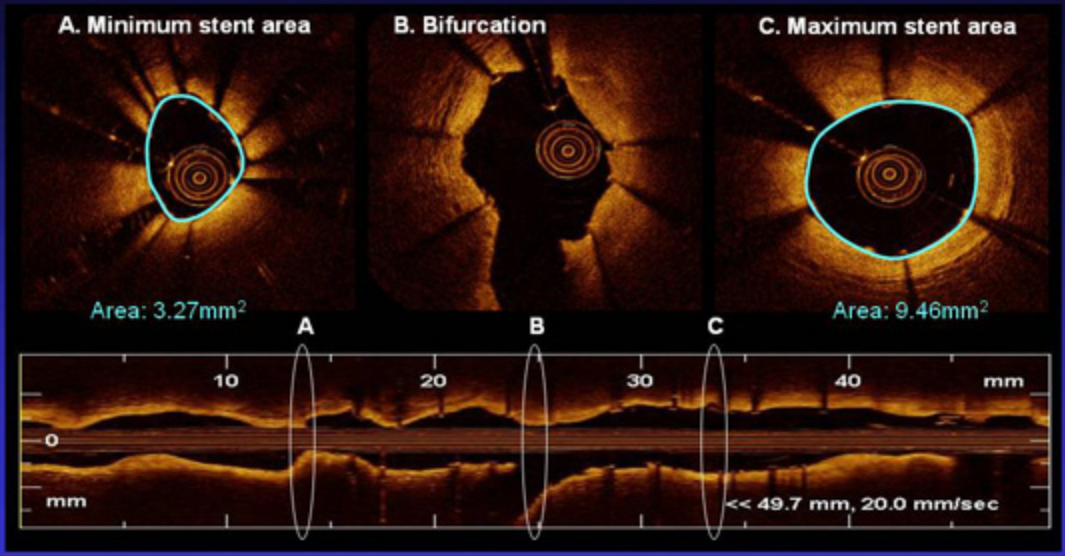
Comparison between SJM &Terumo FD-OCT

	SJM FD-OCT	Terumo FD-OCT
Frame Rate	100 fps	30 fps - 160 fps
Pullback Speed	*20 mm/s*	0.5 - 40 mm/sec
A lines/frame	*450*	512
Scan diameter (in saline)	8 mm	10 mm
Lateral Resolution @ Z = 2.5 mm	20-30 μm	20-30 μm
Axial Resolution	10-20 μm	10-20 μm
Imaging Window Profile (Catheter)	2.5 Fr	2.4 Fr (0.80 mm)

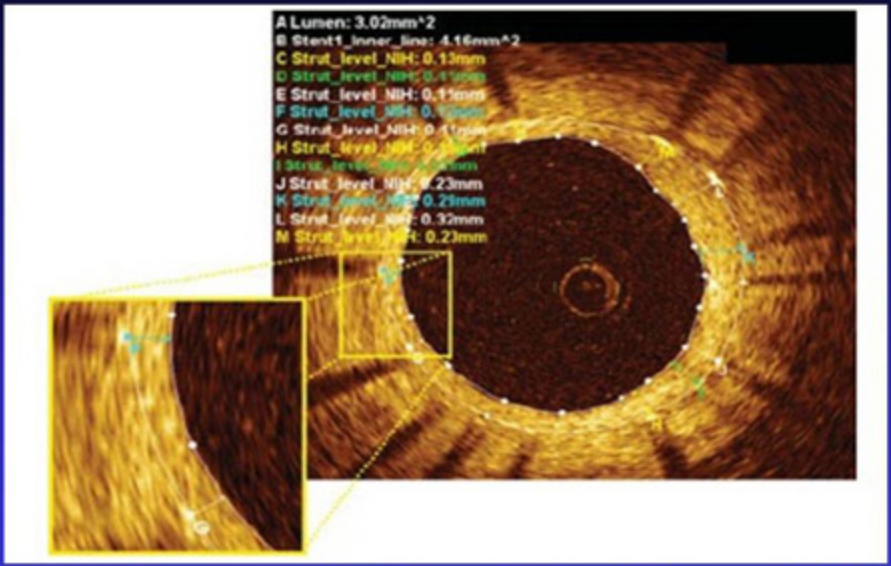
FD-OCT measurements at pre-intervention



FD-OCT measurements at post-stenting

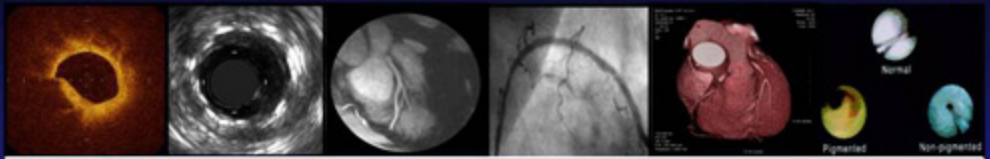


Quantitative Analysis by OCT



Automatical measurements of lumen, stent, neointima, and ISA areas.

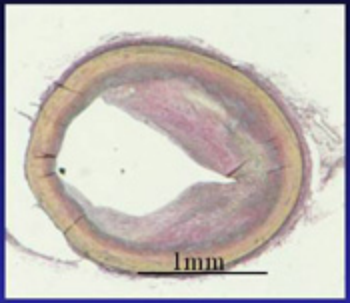
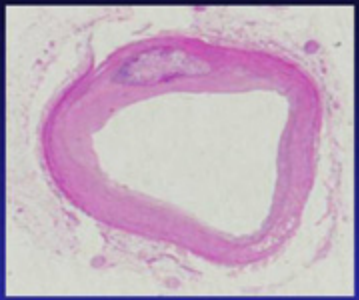
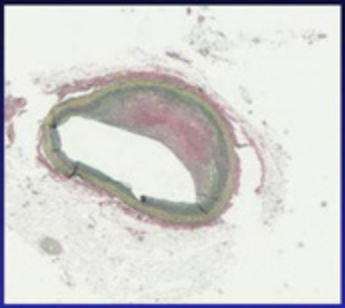
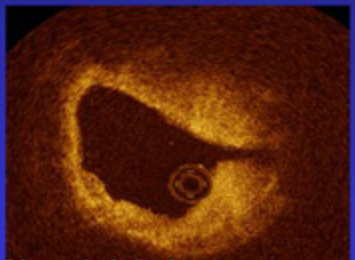
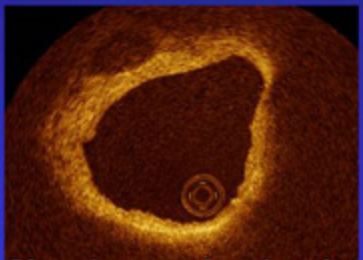
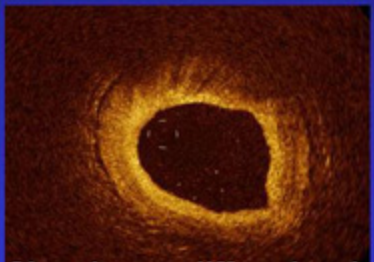
Comparison among coronary imaging techniques



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

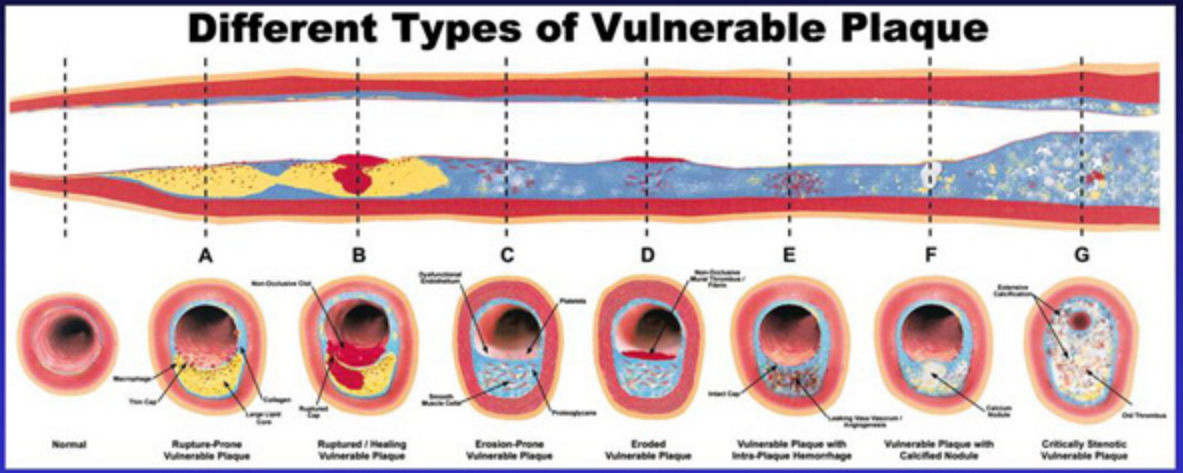
Advantages of OCT are its high resolution and accuracy of tissue characterization.

OCT vs histology

Fibrous plaque	Fibro-calcific plaque	Fibro-lipidic plaque
		
		
Signal rich, homogenous	Signal poor, clear border	Signal poor, diffuse border

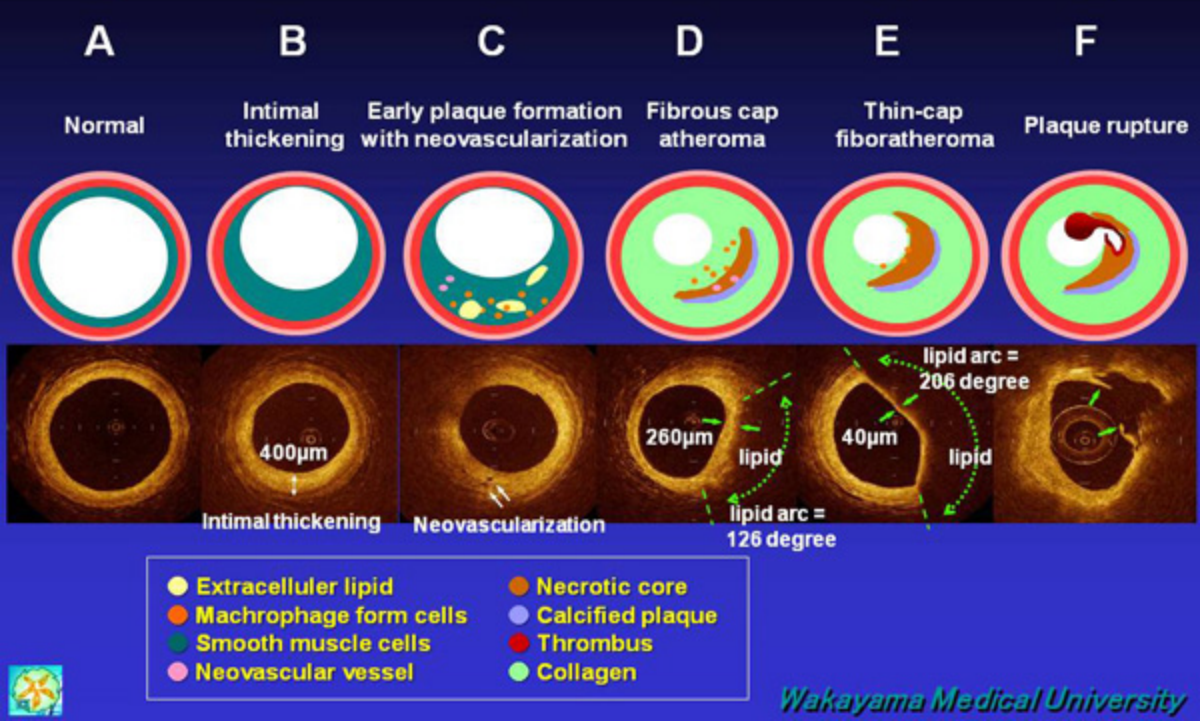
Yabushita H, et al. Circulation, 106:1640-1645, 2002
Kume T, et al. Am J Cardiol 97: 1172 - 75, 2006

Progression of atherosclerotic plaque

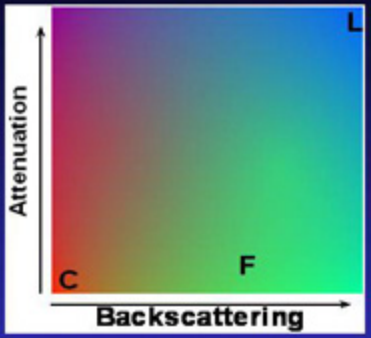


(Naghavi M, et al. Circulation 2003;108:1664-1672)

Progression of atherosclerosis & corresponding OCT Images



Colormap for combining backscattering and attenuation



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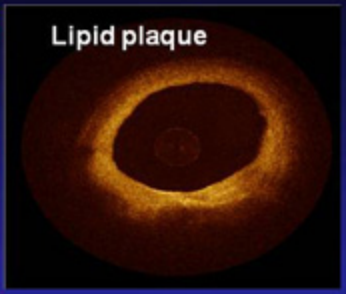
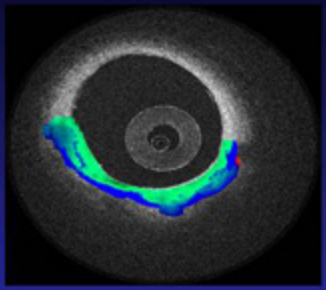
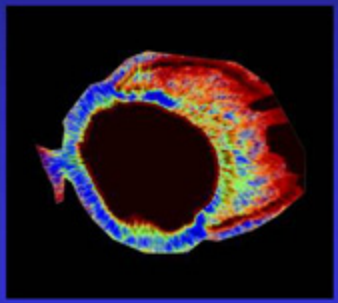






Red & white thrombus

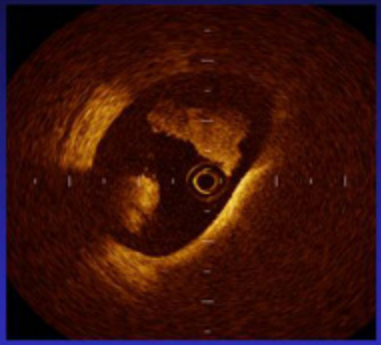
Red thrombus

Protrusion mass with shadow

White thrombus

Protrusion mass without shadow

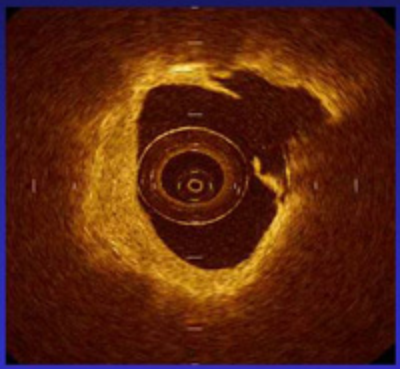
Mixed thrombus

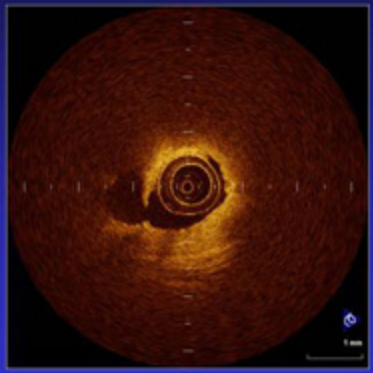


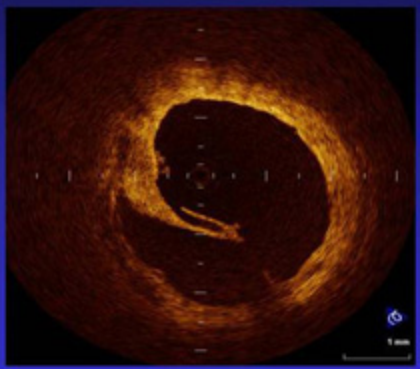
Protrusion mass with & without shadow

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)

Plaque rupture (Plaque disruption)

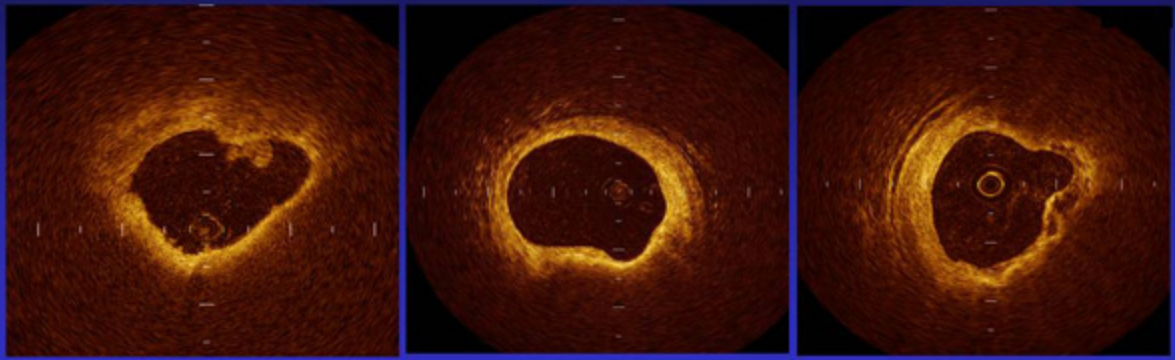






Plaque ulceration

Erosion



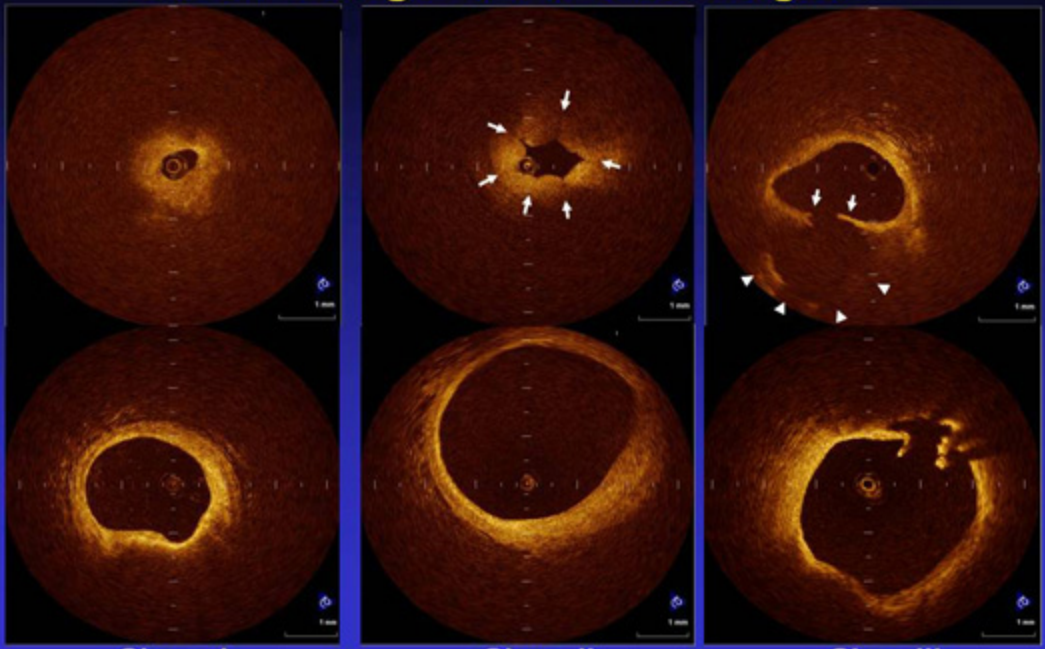
Comparison of plaque Images in AMI (OCT vs. CAS vs. IVUS) n=30

(Kubo T, Akasaka T, et al. J Am Coll Cardiol 50:933-939,2007)

	OCT	*CAS	**IVUS	*p	**p
Plaque Rupture (%)	73	47	40	0.035	0.009
Ulceration (erosion) (%)	23	3	0	0.022	0.005
Thrombus (%)	100	100	33	1.000	<0.001
Red thrombus (%)	100	90	-	0.076	-
White thrombus (%)	100	93	-	0.150	-
TCFA(≦65μm) (%)	83	-	-	-	-
Fibrous cap thickness (μm)	49±21	-	-	-	-
LRP (Lipid Arch＞180°) (%)	83	-	67	-	NS

TCFA; Thin Cap Fibro-Atheroma, LRP; Lipid Rich Plaque

OCT findings in unstable angina

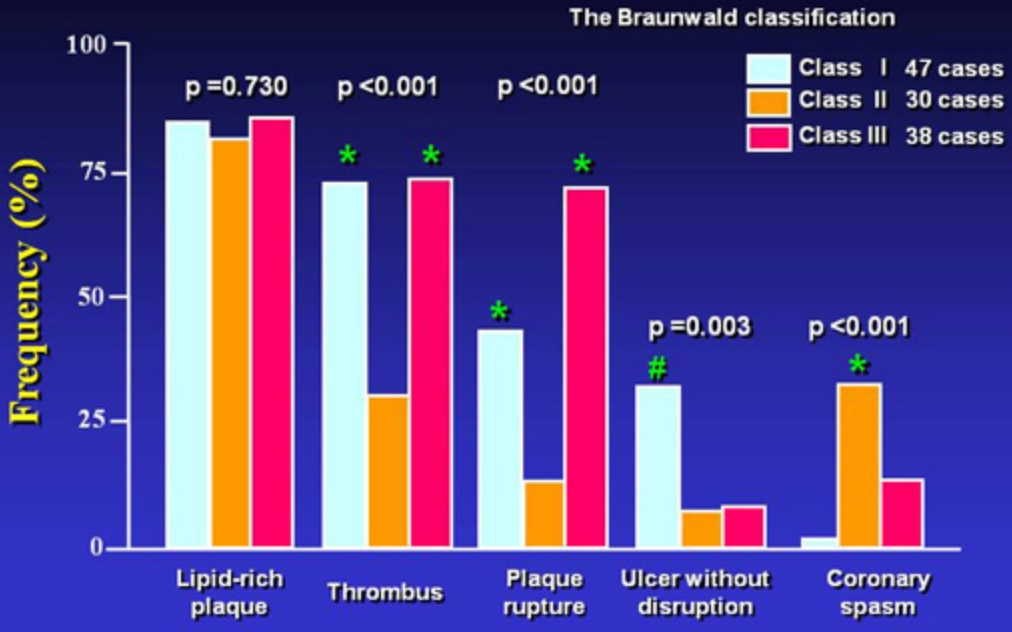


Class I | Class II | Class III

(Mizukoshi M, et al. Am J Cardiol 2010, 106: 323-328)

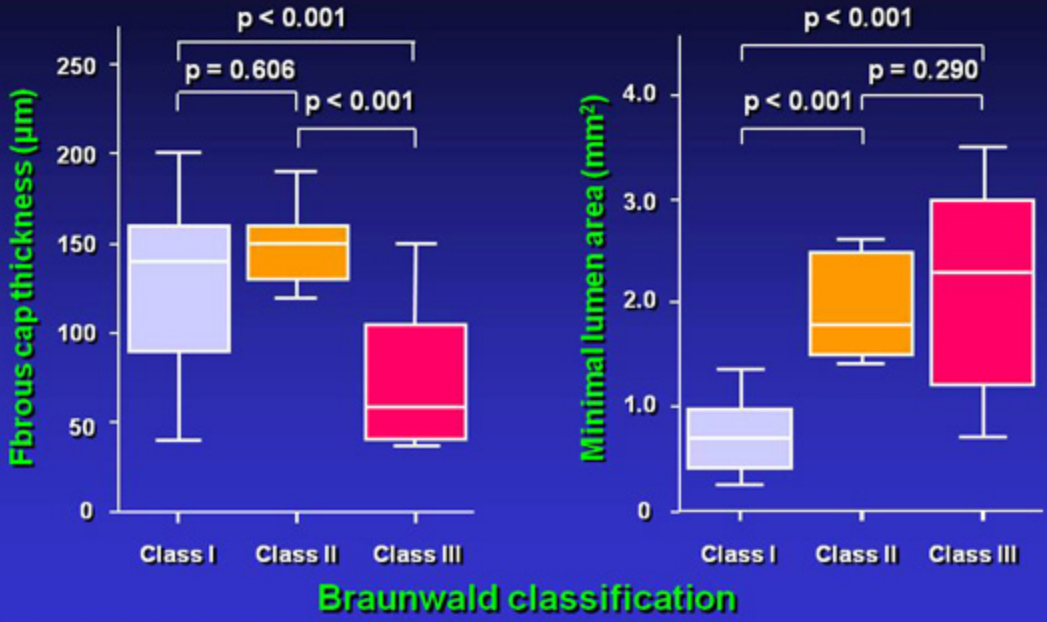
Wakayama Medical University

OCT findings in 115 cases with unstable AP



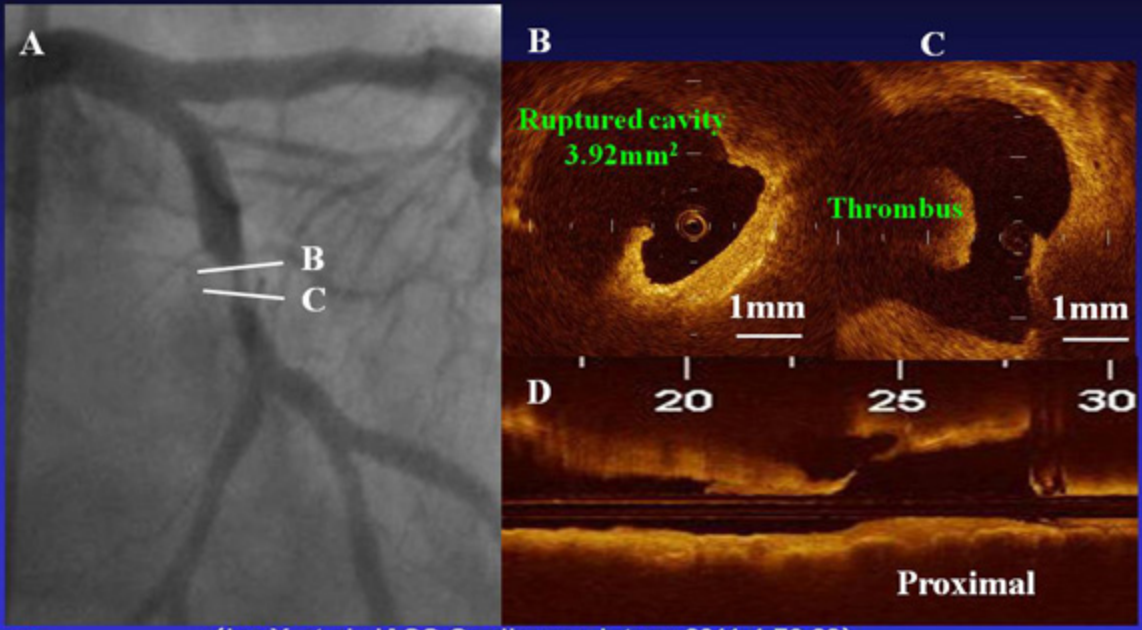
(Mizukoshi M, et al. Am J Cardiol 2010, 106: 323-328)

Clinical manifestation & Fibrous cap thickness, MLA of the culprit lesion



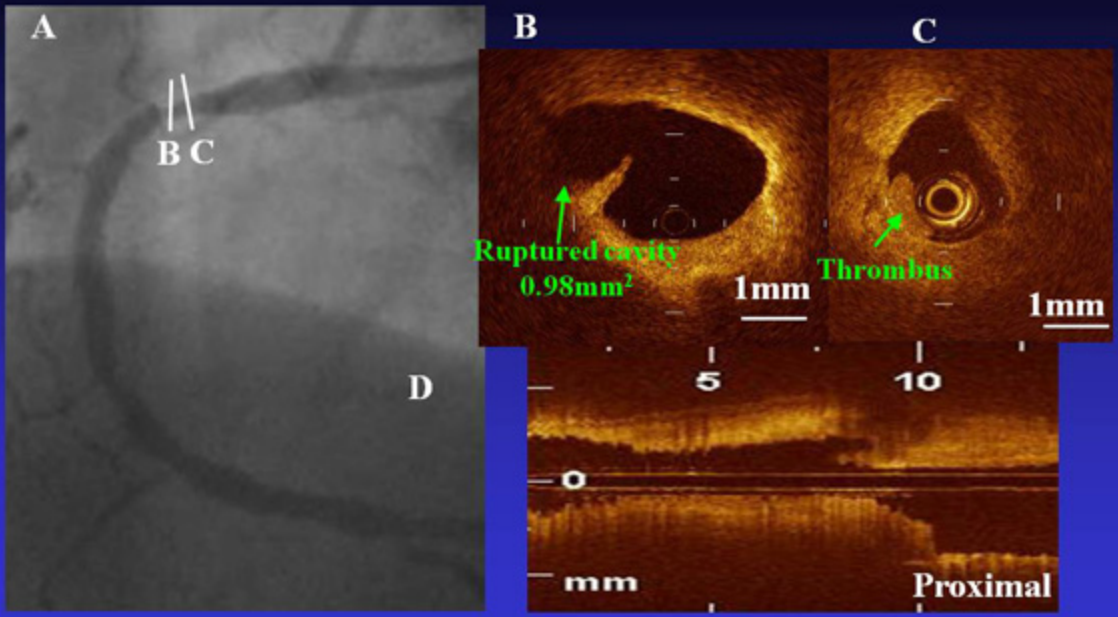
(Mizukoshi M, et al. Am J Cardiol 2010, 106: 323-328)

OCT Findings of Ruptured Plaque in STEMI



(Ino Y, et al. JACC Cardiovasc Interv. 2011;4:76-82)

OCT Findings of Ruptured Plaque in NSTEMI (UAP)

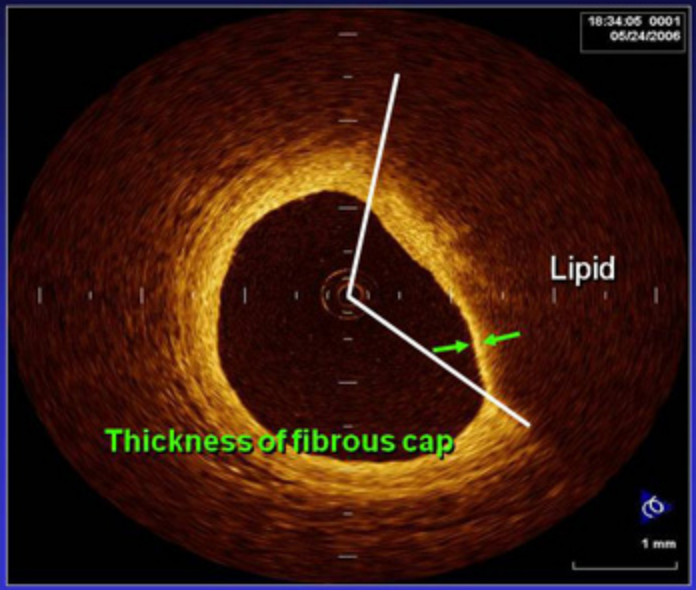


(Ino Y, et al. JACC Cardiovasc Interv. 2011;4:76-82)

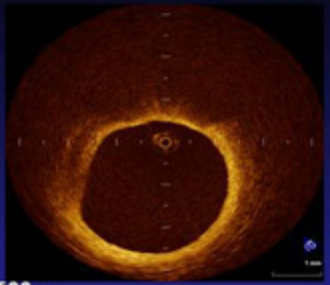
Thin-capped Fibroatheroma (TCFA)

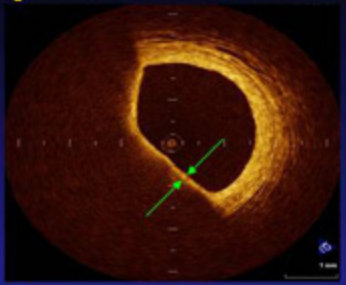
The TCFA was defined as a plaque with lipid content in more than 2 quadrants and the thinnest part of a fibrous cap measuring less than 65 μm by histology.

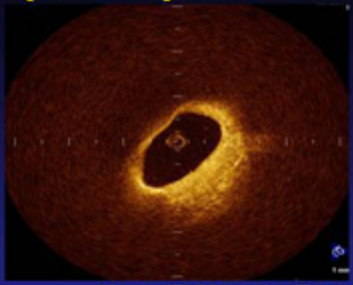
The cap thickness is measured from the surface of the lumen to the portion just starting the attenuation

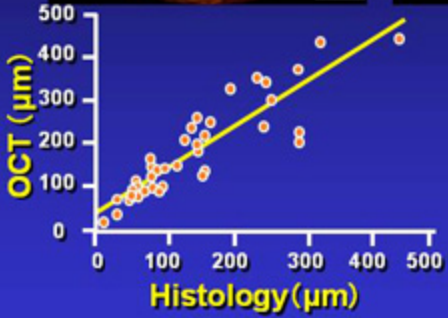


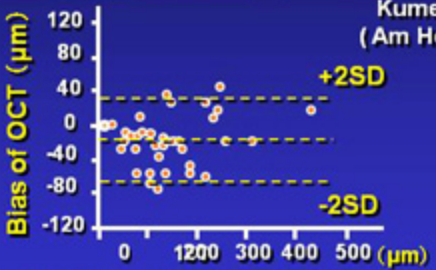
Thin-cap fibroatheroma (TCFA)







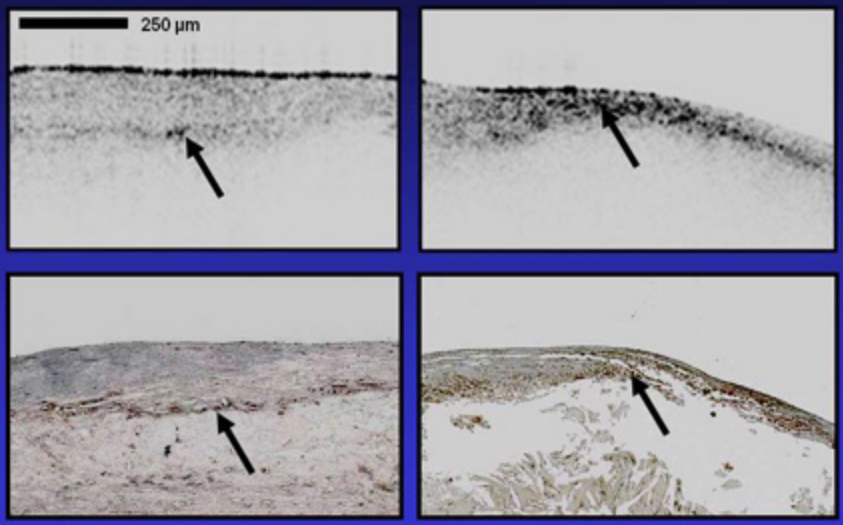




Kume T, Akasaka T, et al
(Am Heart J.152:755, 2006)

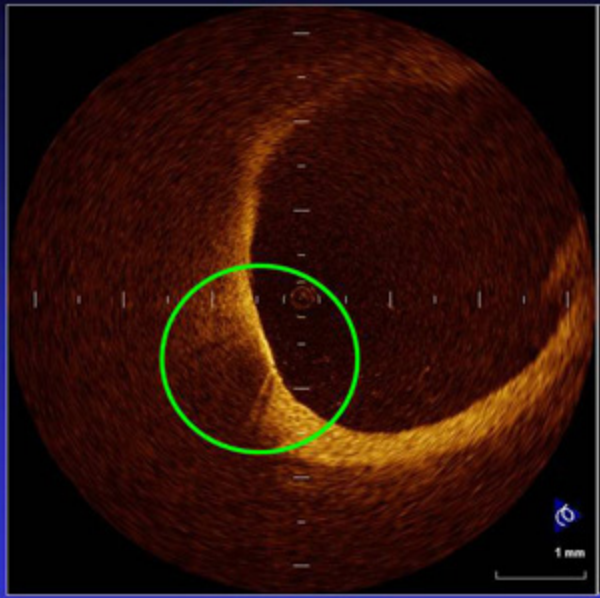
TCFA is thought to be vulnerable based on histological studies, and possibility to identify TCFA has been demonstrated by several pilot OCT studies.

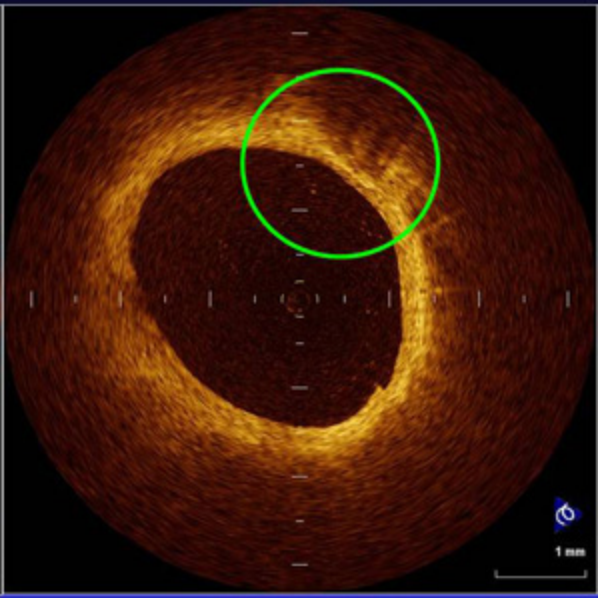
OCT findings of macrophages



Tearney GJ et al. Circulation, 107:113-119, 2003

Identification of macrophage





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

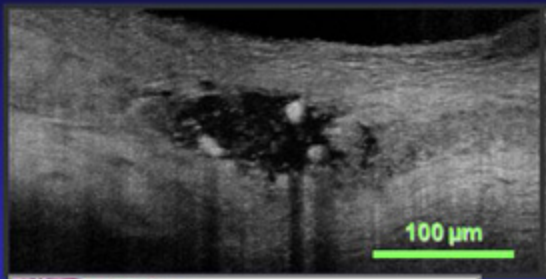
μOCT

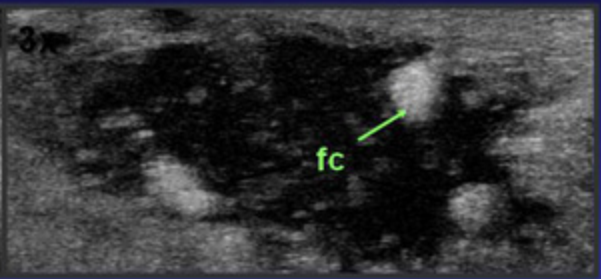
- Cross-sectional imaging technology with order of magnitude resolution improvement compared to OCT

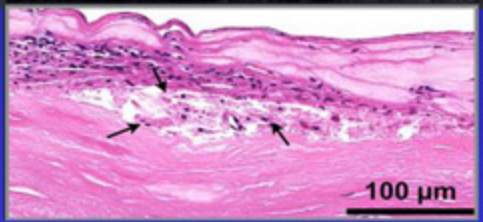
	Resolution (μm)		
	x	y	z
IVUS	250	250	100
Present OCT	30	30	10
μOCT	< 2	< 2	< 1

μOCT

Macrophages



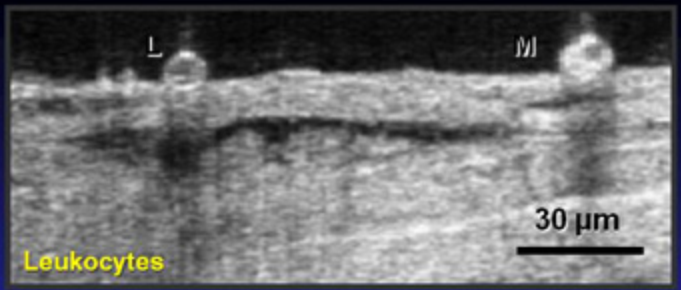


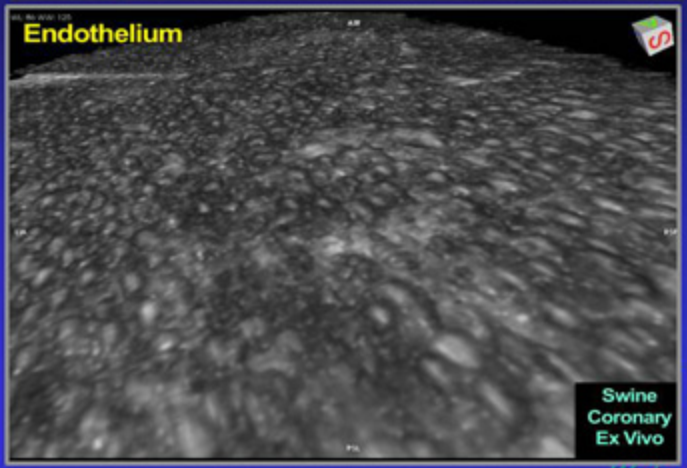


Courtesy by Prof. Tearney G

Wakayama Medical University

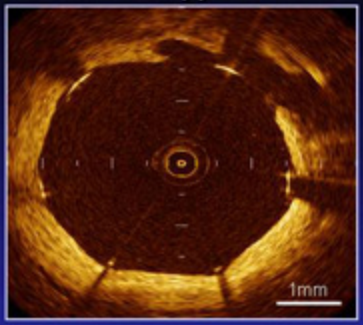
μOCT



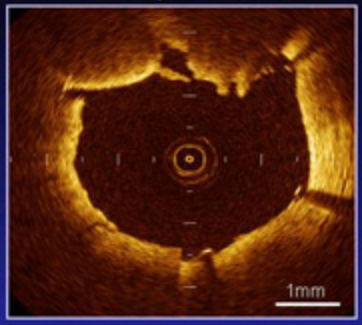


Courtesy by
Prof. Tearney G

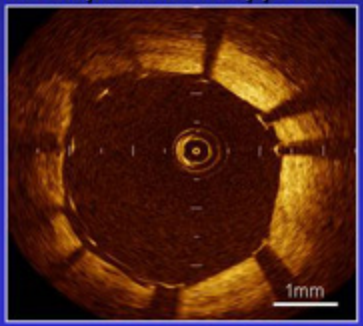
Stent malapposition



Tissue protrusion



Incomplete stent apposition

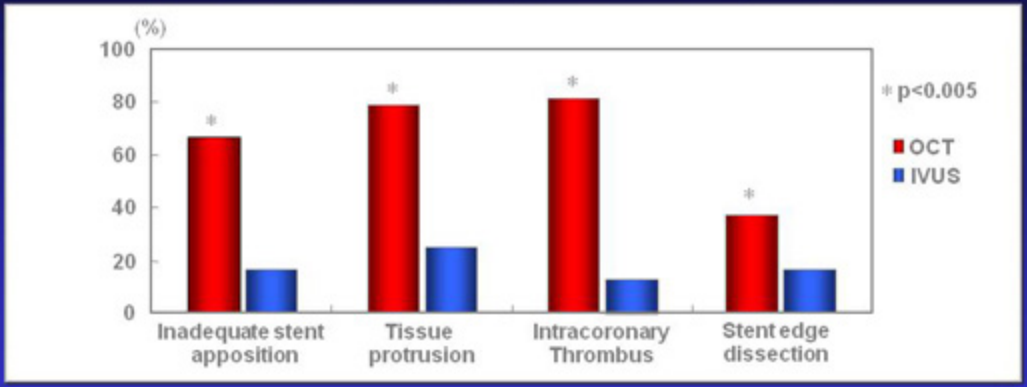


Stent edge dissection

Kubo T, et al, JACC Img. 2008 1:475–84

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.

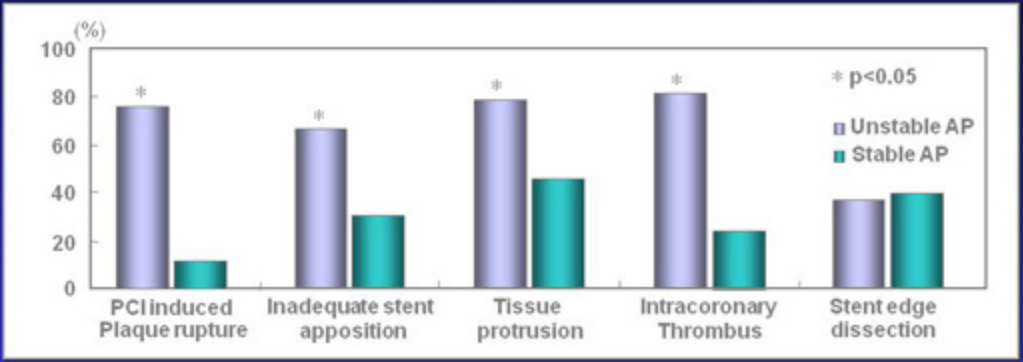


Conclusion: OCT can provide more detailed morphological information after stenting than IVUS.

Kubo T, et al, JACC Img. 2008 1:475–84

Vascular response after stent implantation between unstable and stable AP

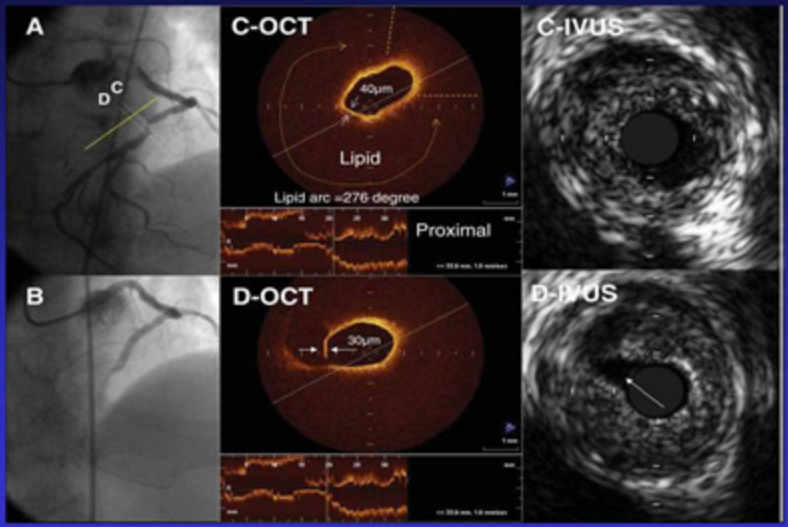
24 unstable and 31 stable AP patients were examined by OCT to evaluate lesion morphologies after stent implantation.



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

Kubo T, et al, JACC Img. 2008 1:475–84

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.

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

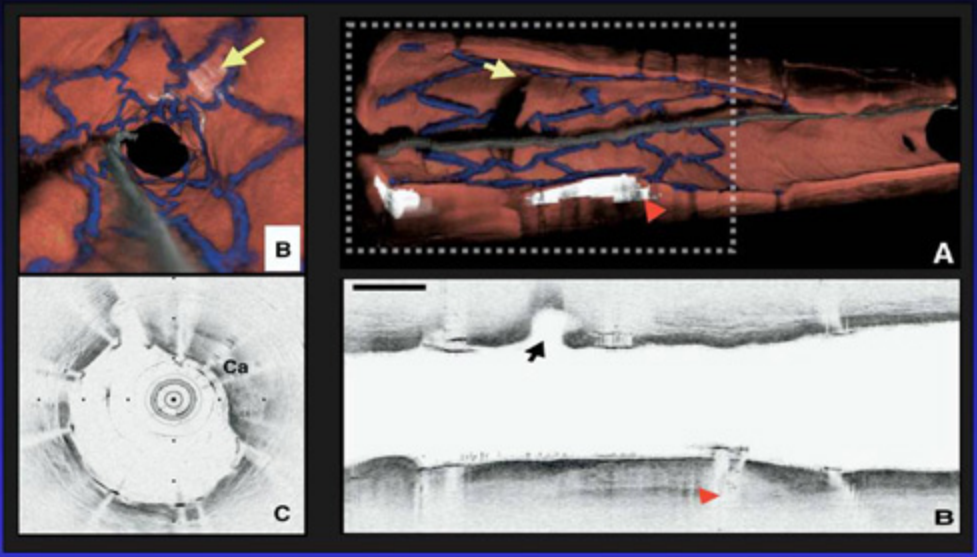
83 ACS patients were examined by OCT
to investigate whether OCT could predict no-reflow after PCI.

	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.

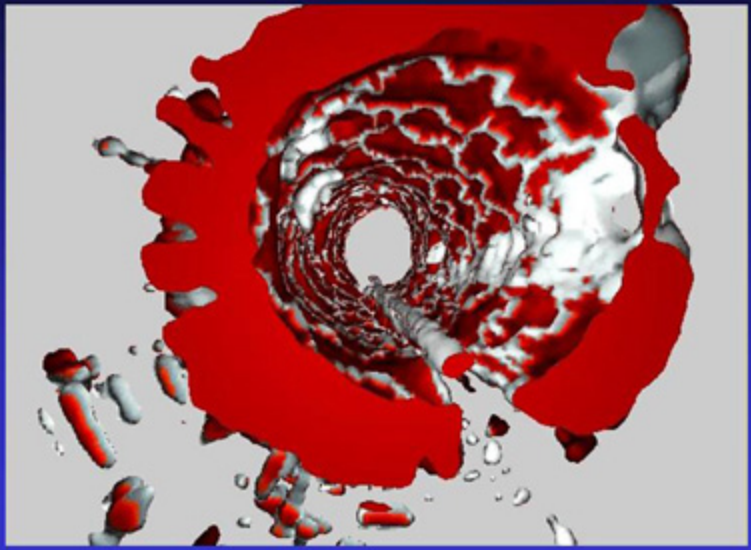
3D FD-OCT imaging



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.

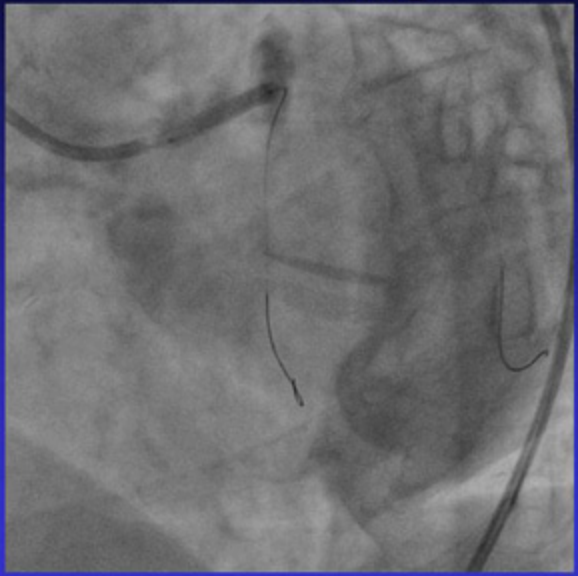
Tearney et al, JACC imaging 2008;1:752-61

Inconsistent stent strut distribution

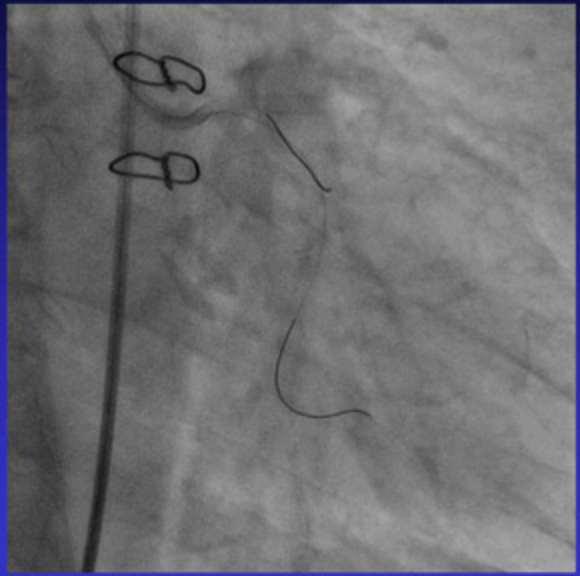


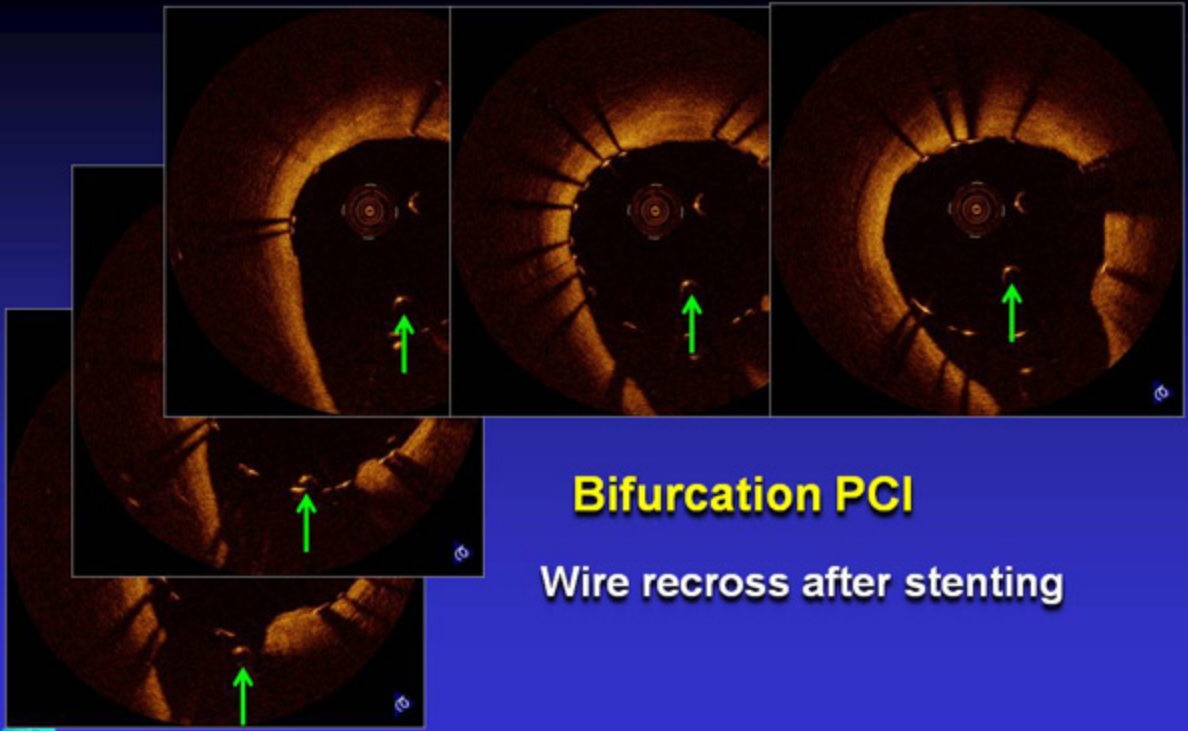
Bifurcation PCI

Post stenting



Recross after stenting

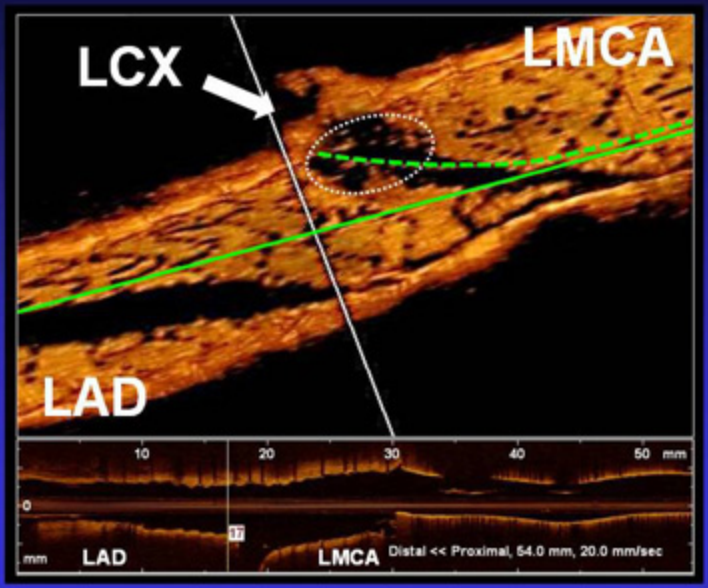




Bifurcation PCI

Wire recross after stenting

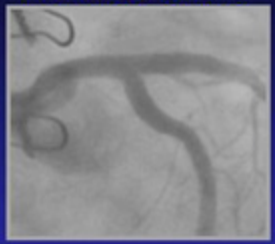
Re-wiring through stent struts into jailed LCX



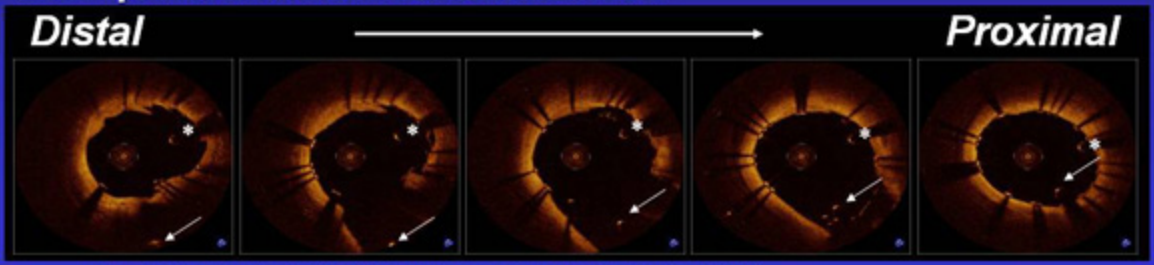
OCT pullback from LAD to LMCA after KBT

Kissing balloon angioplasty

Final angiography

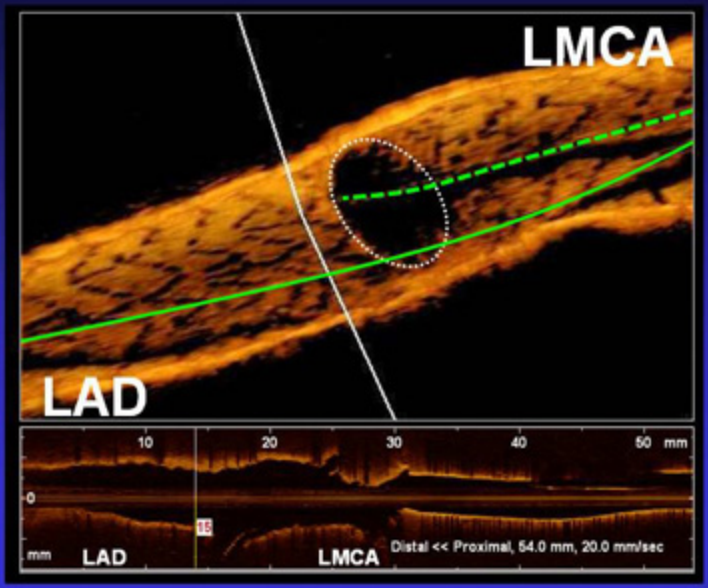


OCT pullback from LAD to LMCA

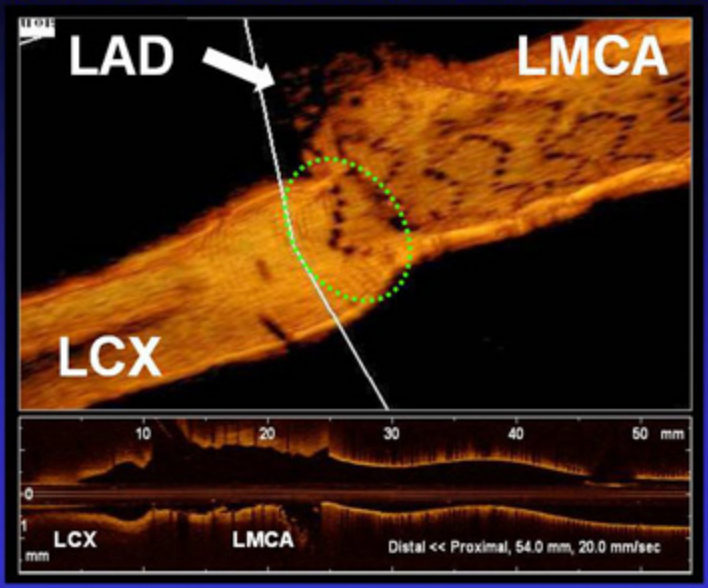


∗ = guidewire in LAD; Arrow = guidewire in LCX

OCT pullback from LAD to LMCA after KBT



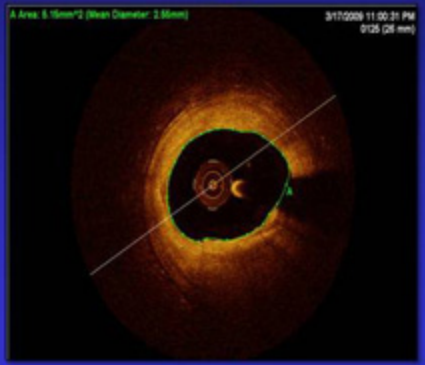
OCT pullback from LCX to LMCA after KBT

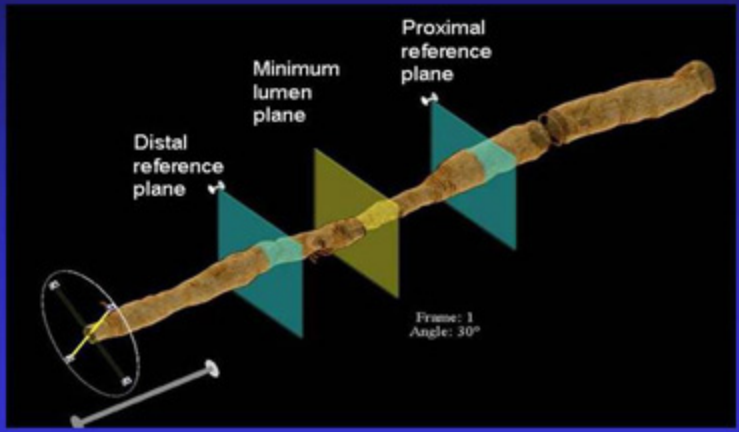


Mechanism of SAT and the restenosis could be demonstrated in bifurcation site by 3-D OCT analysis.

Real-time 3D Lumen Morphology

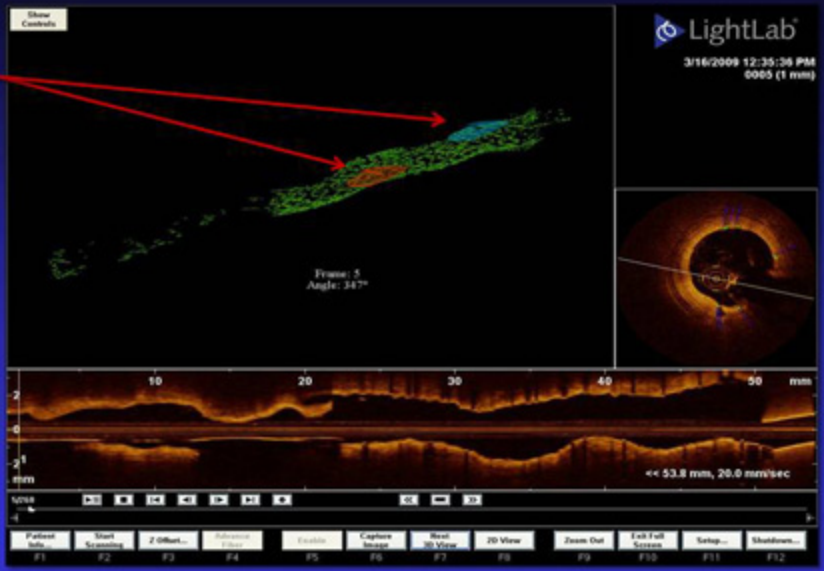
Fully automated 3D lumen contours for clearer visualization, with automatic calculation of vessel dimensions





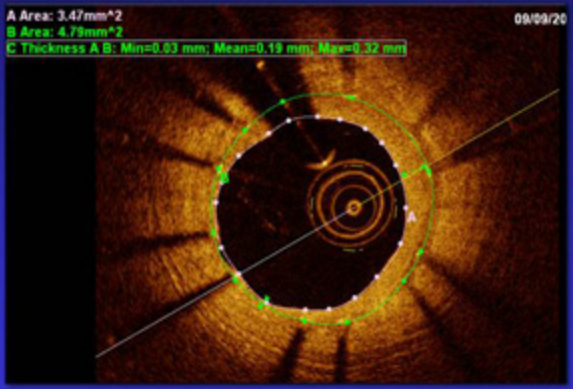
Auto Stent Malapposition

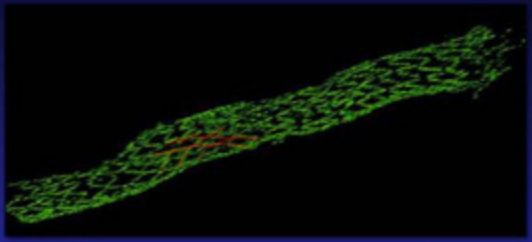
Location and degree of malapposition appear as color-encoded volumes.

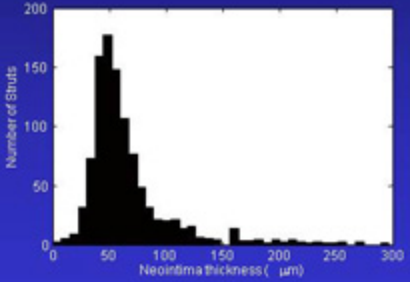


Auto Stent Coverage

Automated segmentation of buried struts and measurement of coverage for follow-up assessment







Conclusions

- Tissue characterization would become much easer by developing color coded representation.
- Much more higher resolution images up to 1 μm could be expected after development of micro-OCT.
- 3-dimensional display may allow us to understand complex anatomy in detail and lead us complete PCI.

Further development of OCT may play important roles in the assessment of pathophysiology of atherosclerosis in vivo in human and lead us to new therapeutic strategies.