LAMELIS 2019
Lasers in Medicine and Life Sciences

Application of optical coherence tomography in coronary interventions

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University of Szeged
Where knowledge and challenge meet

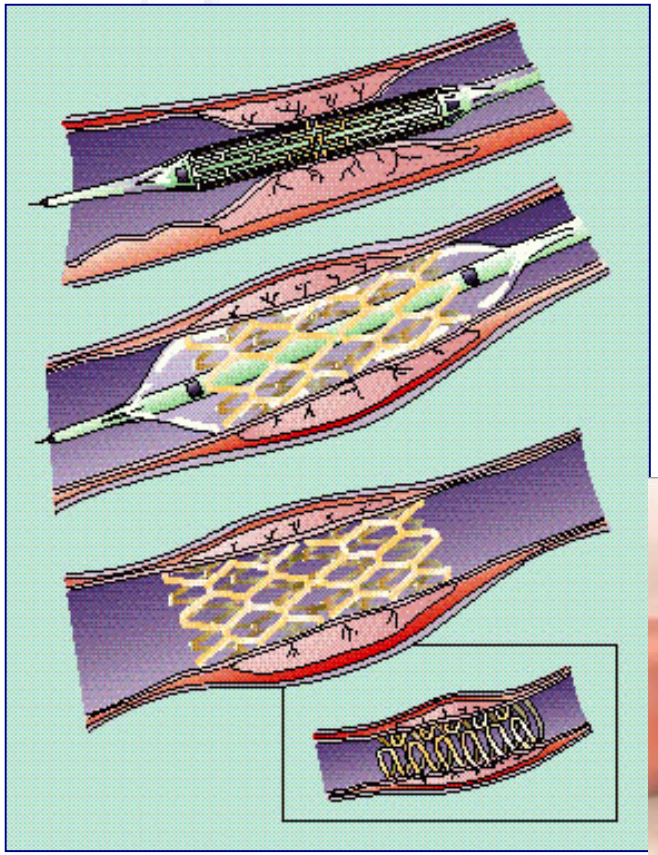
Laserlab Europe

eli attosecond

HUNGARIAN BIOPHYSICAL SOCIETY

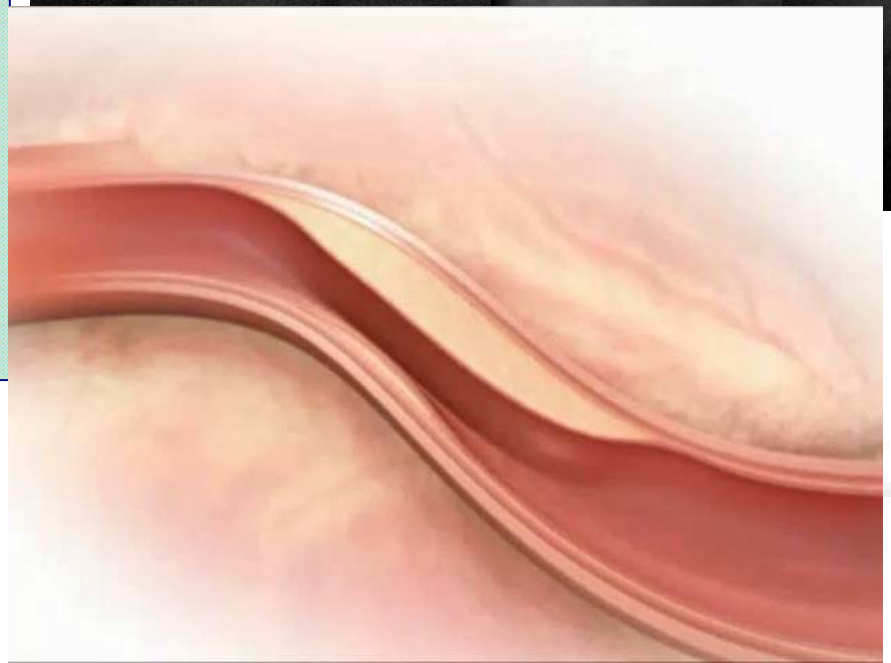
EÖTVÖS LORÁND FIZIKAI TÁRSULAT 1891

Percutaneous Coronary Intervention:
One the most frequently performed procedure in the world



Kissing balloon

Procedural result



Coronary angiography

Normal left main

Non significant left anterior descending stenosis

Irregular left anterior descending artery

Critical circumflex artery stenosis

Thrombus & ectatic malformation in the circumflex

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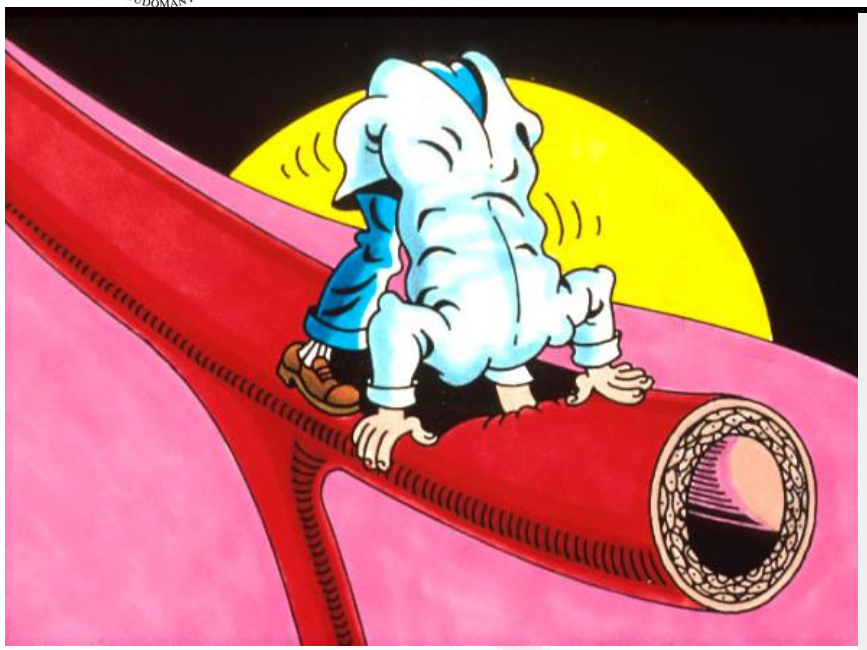
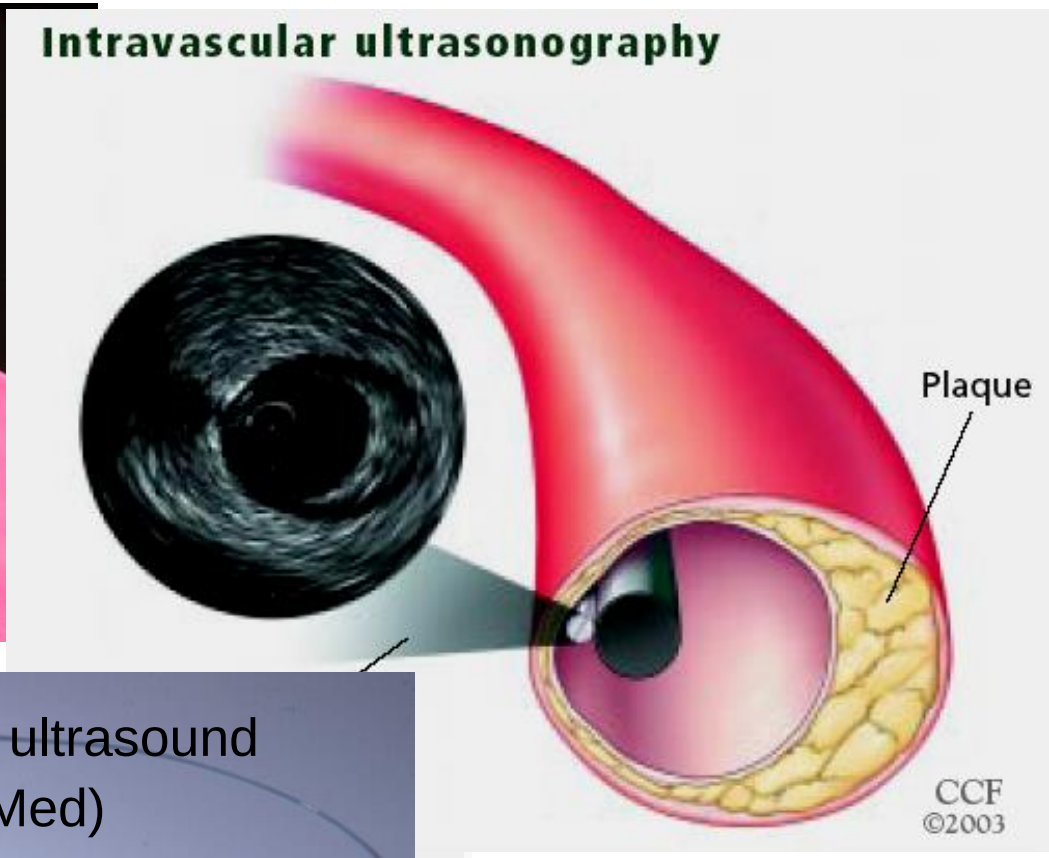
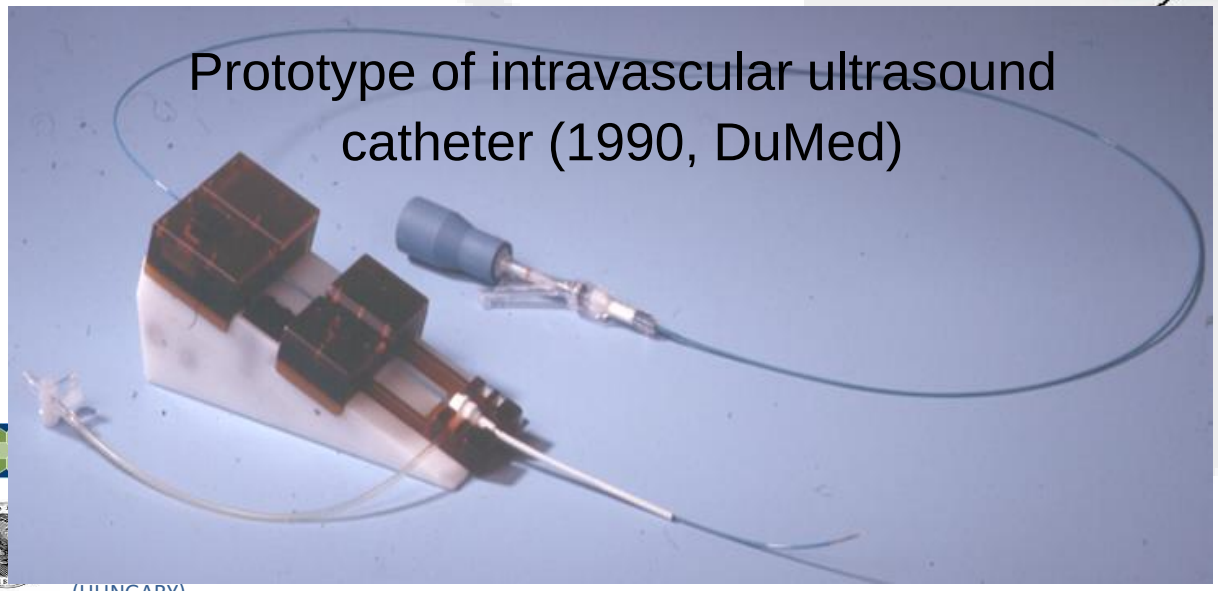
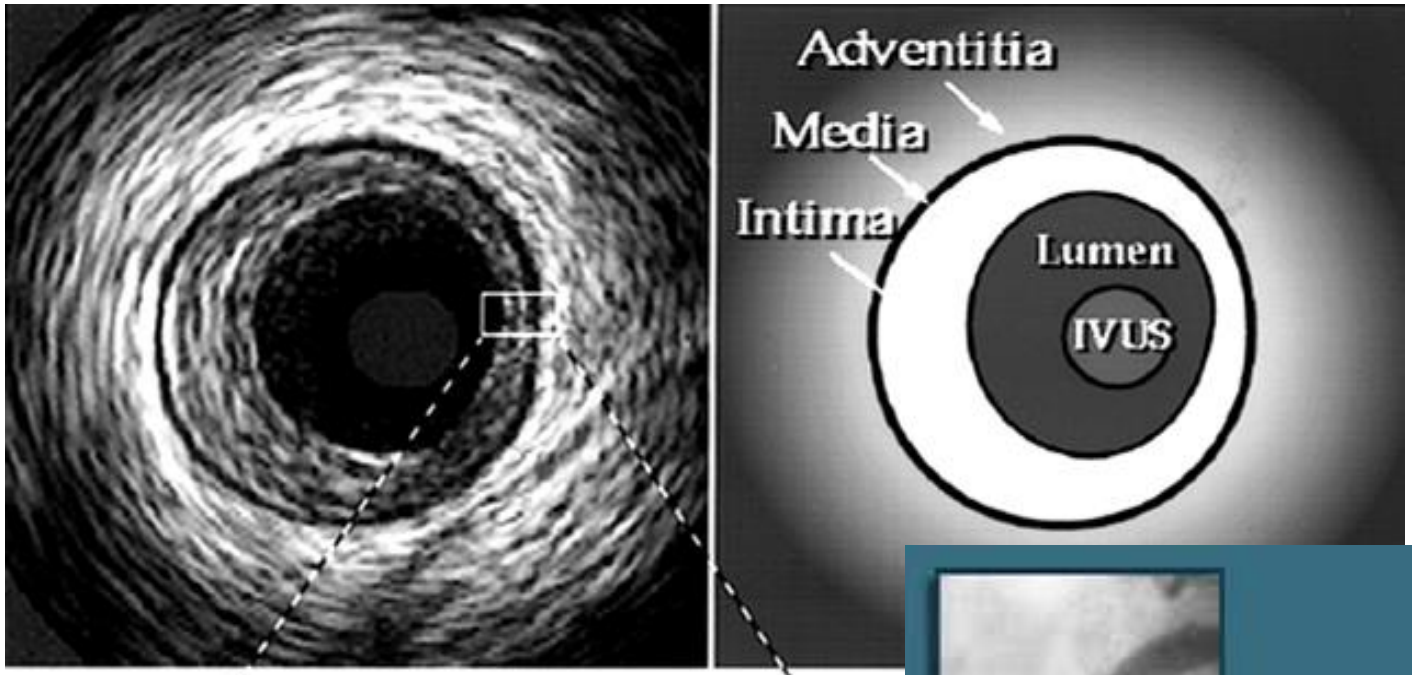
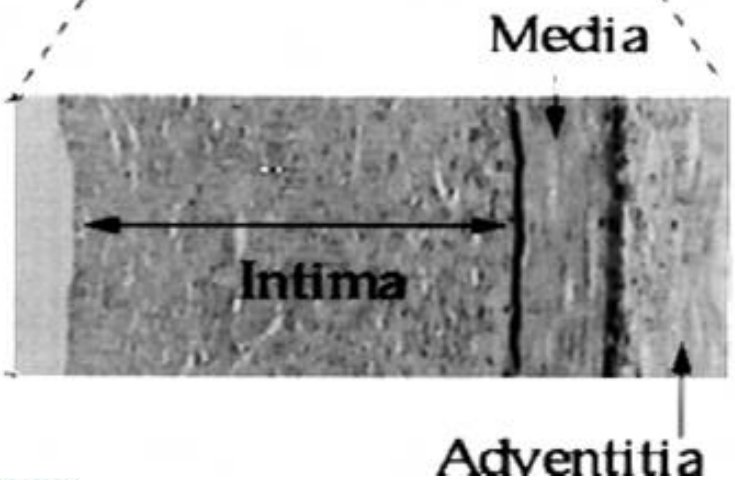
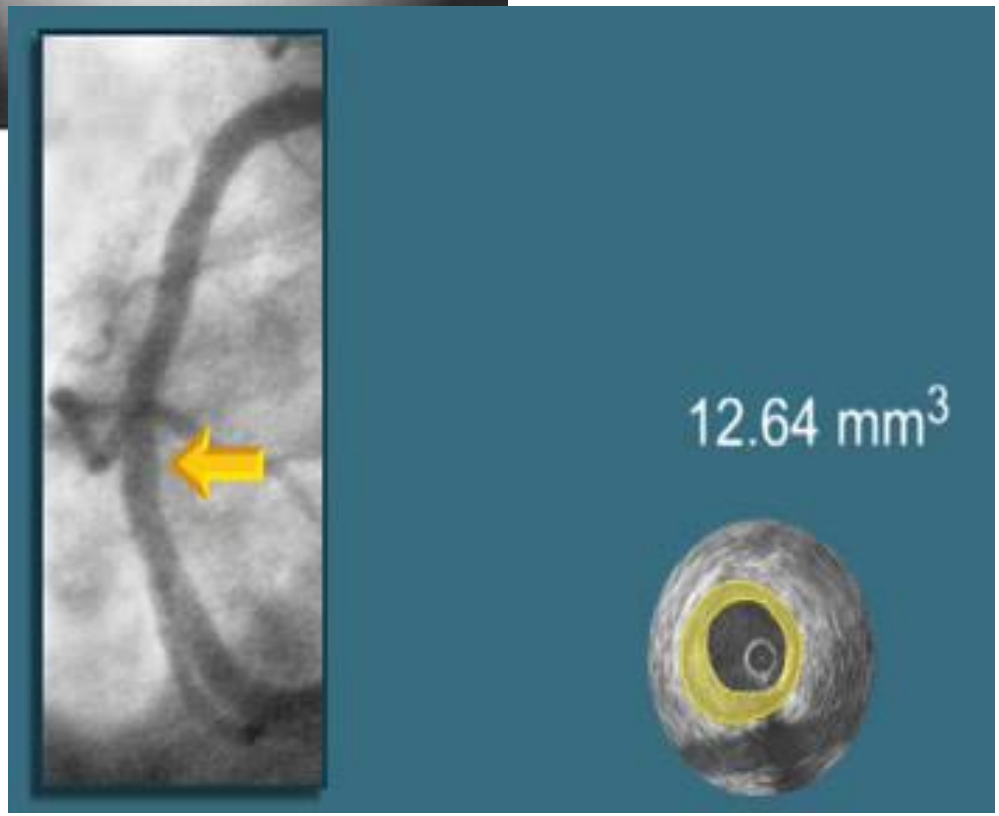



Intravascular ultrasonography
Plaque
CCF
©2003


Prototype of intravascular ultrasound catheter (1990, DuMed)


Adventitia
Media
Intima
Lumen
IVUS


Media
Intima
Adventitia


12.64 mm3

Intracoronary imaging & physiology in ESC guideline 2014

Recommendations	Class[a]	Level[b]	Ref.[c]
FFR to identify haemodynamically relevant coronary lesion(s) in stable patients when evidence of ischaemia is not available.	I	A	50,51,713
FFR-guided PCI in patients with multivessel disease.	IIa	B	54
IVUS in selected patients to optimize stent implantation.	IIa	B	7
IVUS to assess severity and optimize treatment of unprotected left main lesions.	IIa	B	
IVUS or OCT to assess mechanisms of stent failure.	IIa	C	
OCT in selected patients to optimize stent implantation.	IIb	C	

Eur Heart J. 2014;35:2541-2619

2018

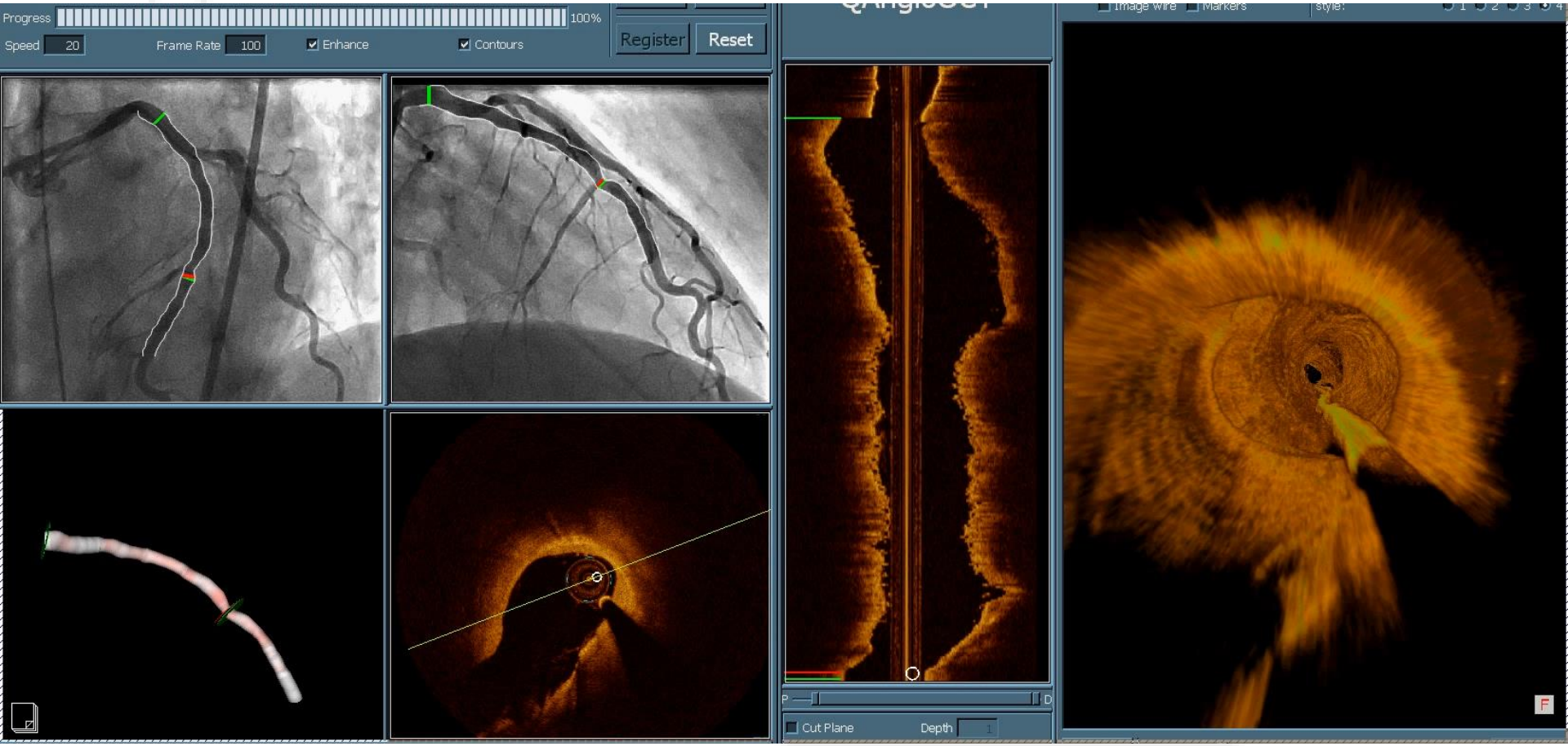
Recommendations on intravascular imaging for procedural optimization

Recommendations	Class[a]	Level[b]
IVUS or OCT should be considered in selected patients to optimize stent implantation.[603,612,651–653]	IIa	B
IVUS should be considered to optimize treatment of unprotected left main lesions.[35]	IIa	B

IVUS = intravascular ultrasound; OCT = optical coherence tomography.
[a]Class of recommendation.
[b]Level of evidence.

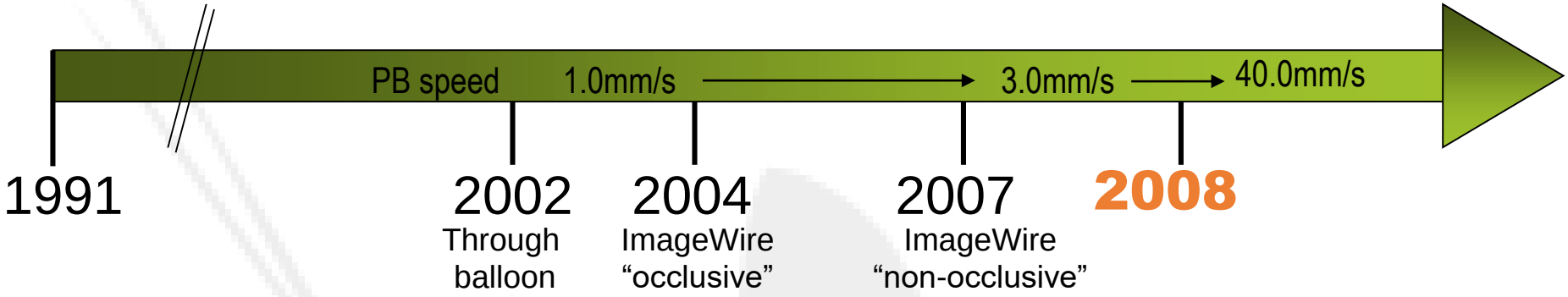
Optical Coherence Tomography (OCT) in coronary arteries

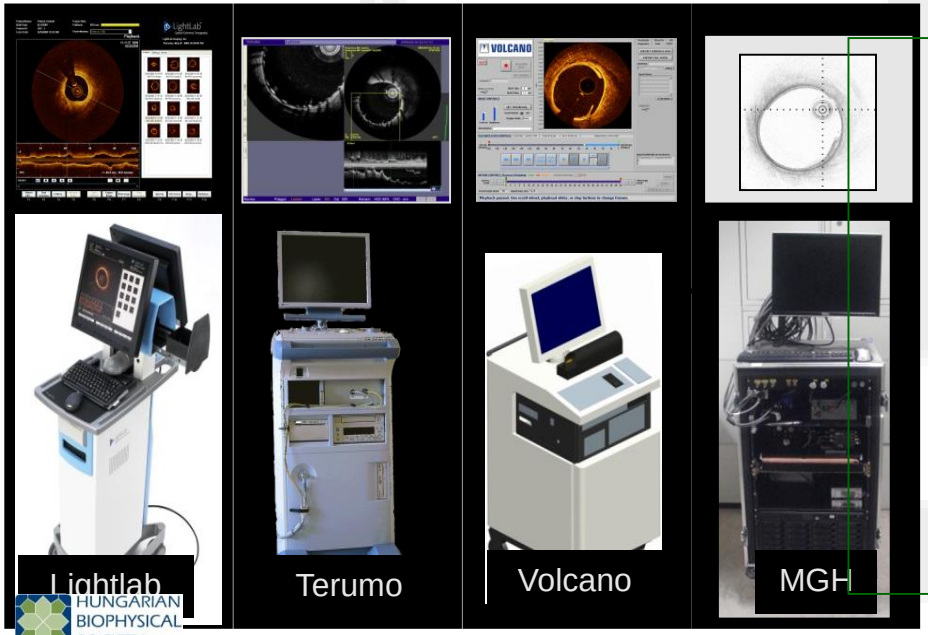
Today's State of the Art - 2019



Coregistration: Tu, Regar et al. Int J Cardiovasc Imaging 2012

Evolution of intracoronary OCT imaging





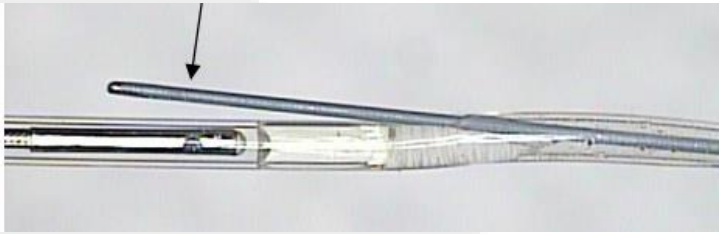
2nd Generation OCT

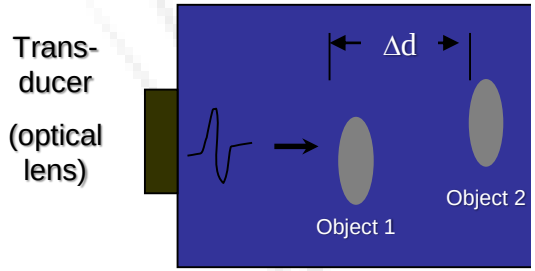
Fourier Domain OCT

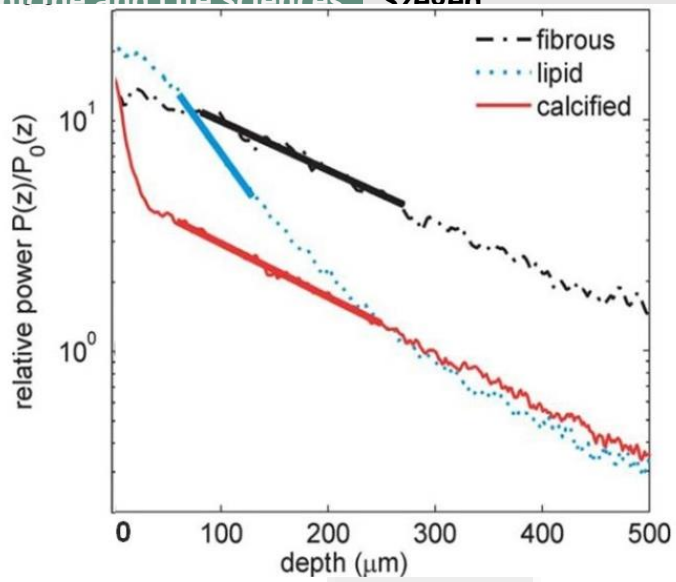
(OFDI/Frequency/Spectral Domain/Swept Source)

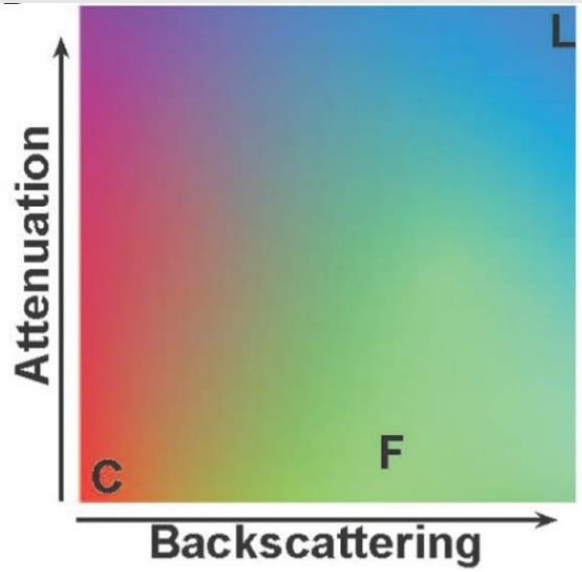
Monorail Imaging Catheter

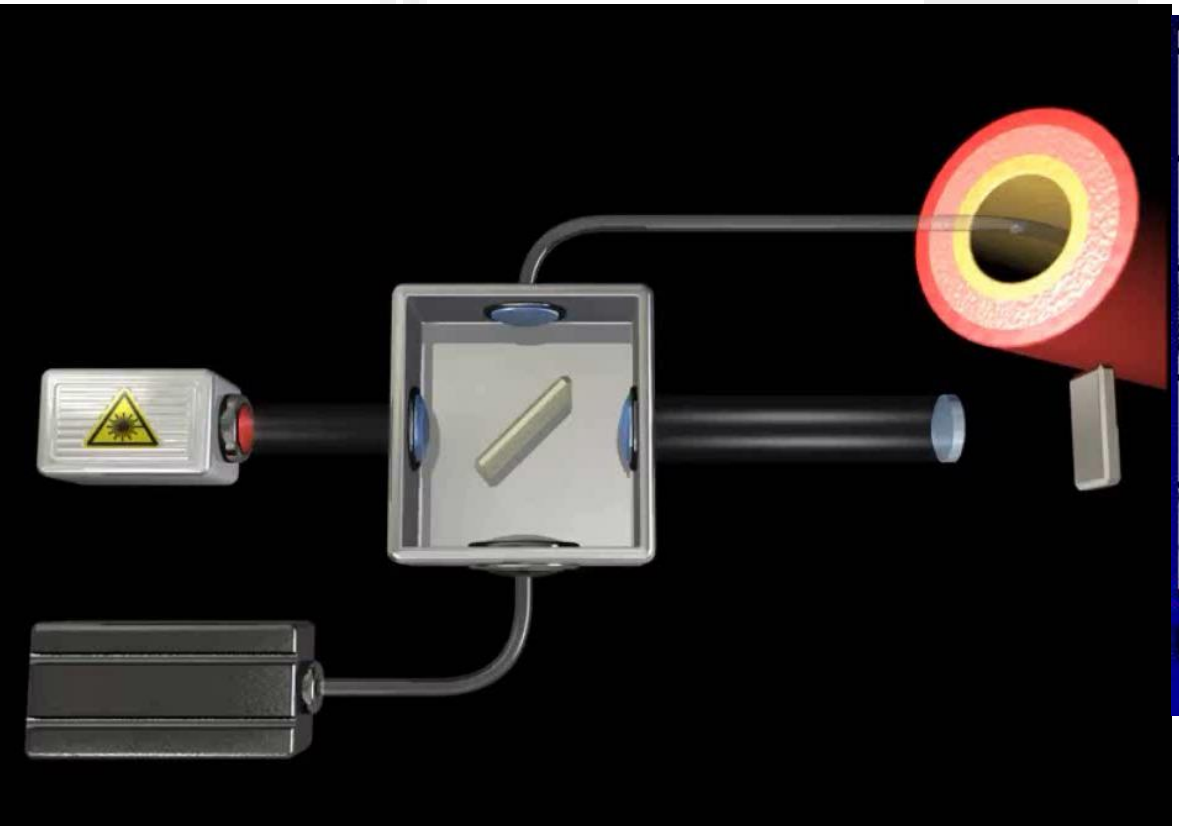
Non-Occlusive

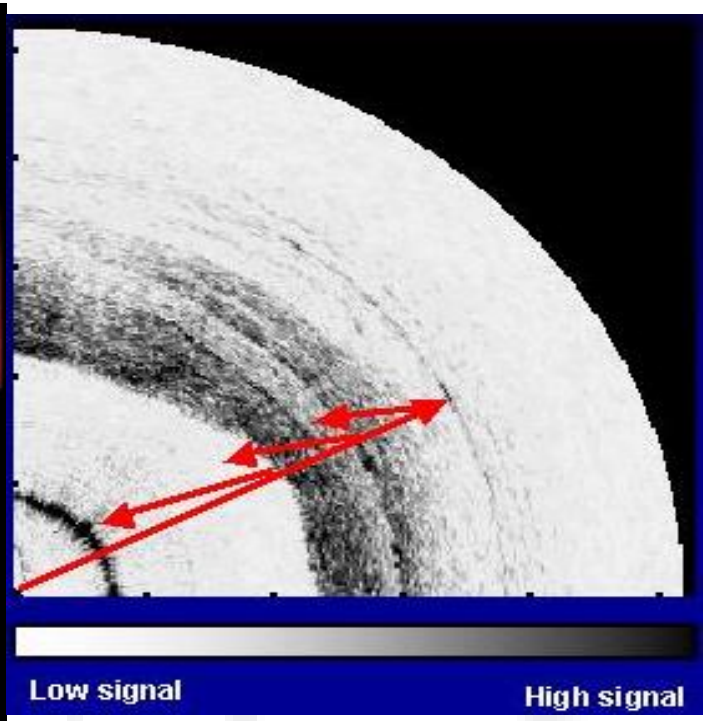



Trans-
ducer
(optical
lens)
Δd
Object 1
Object 2

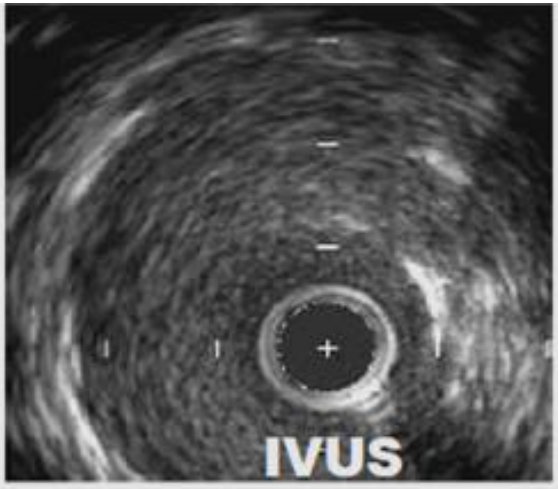

fibrous
lipid
calcified
relative power P(z)/P0(z)
10^1
10^0
0
100
200
300
400
500
depth (μm)

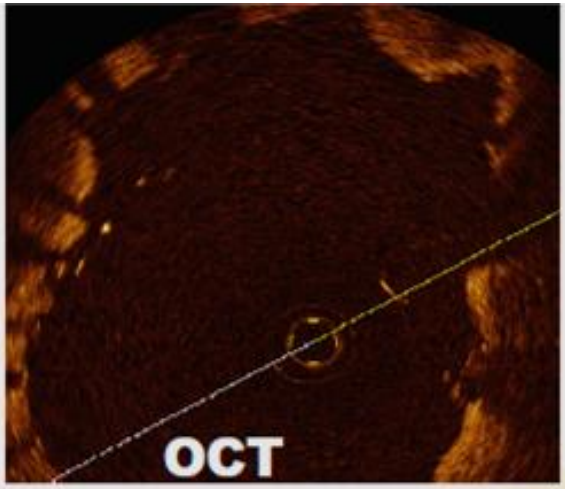

L
C
F
Attenuation
Backscattering




Low signal
High signal

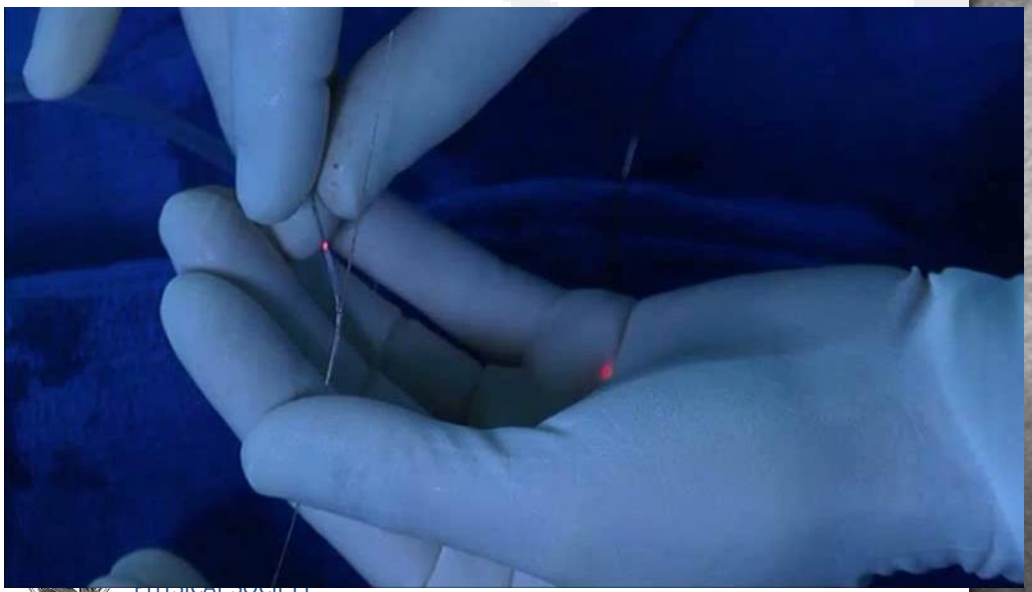
EBC

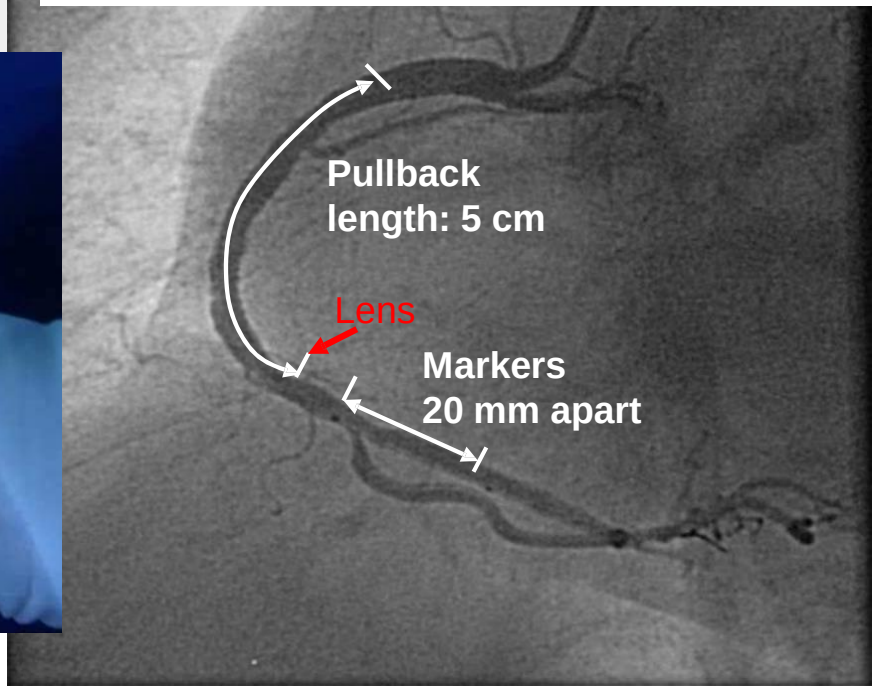




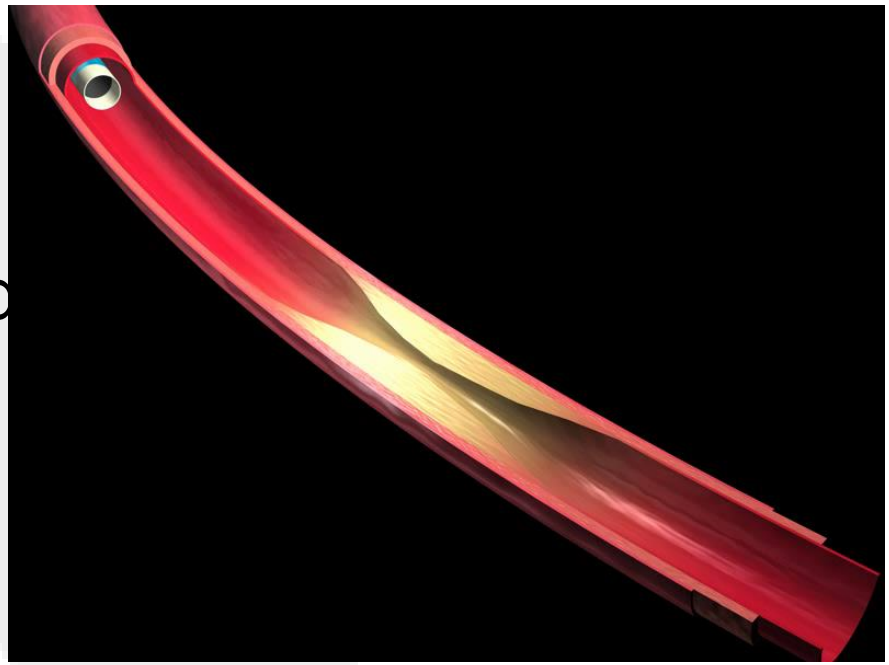
	IVUS	OCT
Dynamic range	40-60dB	90-110dB
Resolution (axial)	100-150μm	10-15μm
(lateral)	150-300μm	25-40μm
Penetration (tissue)	4-8mm	1.5mm
Frame rate	30/sec	100/sec
Pull-Back Speed	0.5-1.0mm/sec	20mm/sec
Wire artefacts	++	+

Tanigawa J, Barlis P, Di Mario C. EuroIntervention. 2007




Pullback
length: 5 cm
Lens
Markers
20 mm apart

- Fast, safe & easy imaging procedure
- 2 OCT vendors
- Reliable diagnostic tool
- Important lesson‘s learned



6F guide catheter

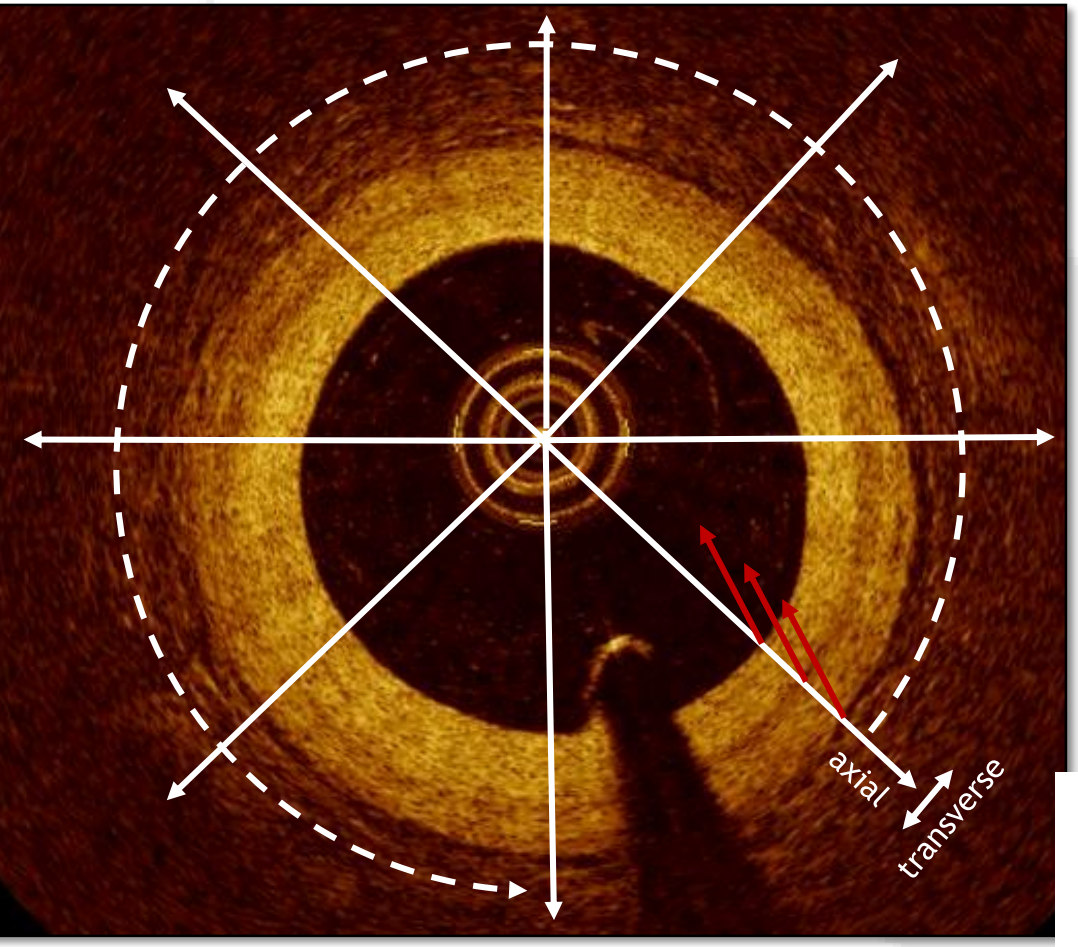
Guidewire of choice!

Sleek OCT catheter!

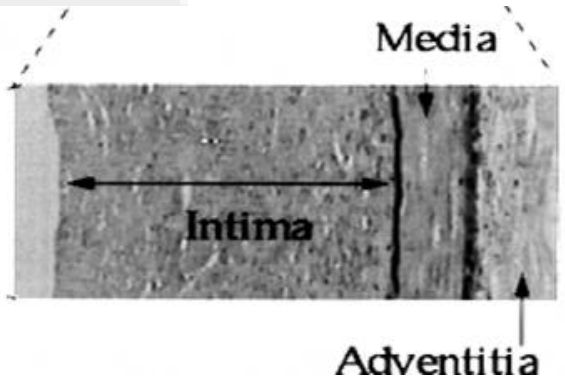
Imaging within 3 seconds

Limited contrast ~ 15ml

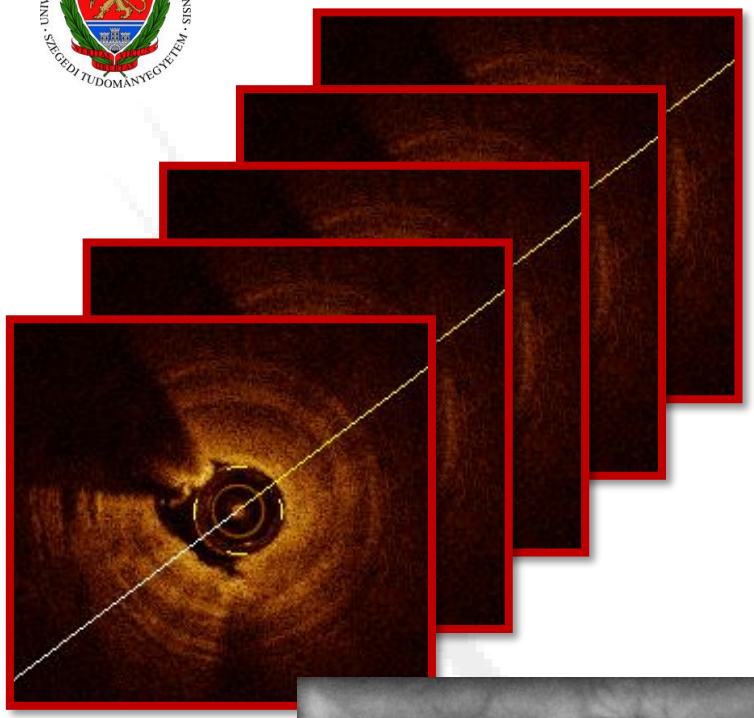
Image Generation

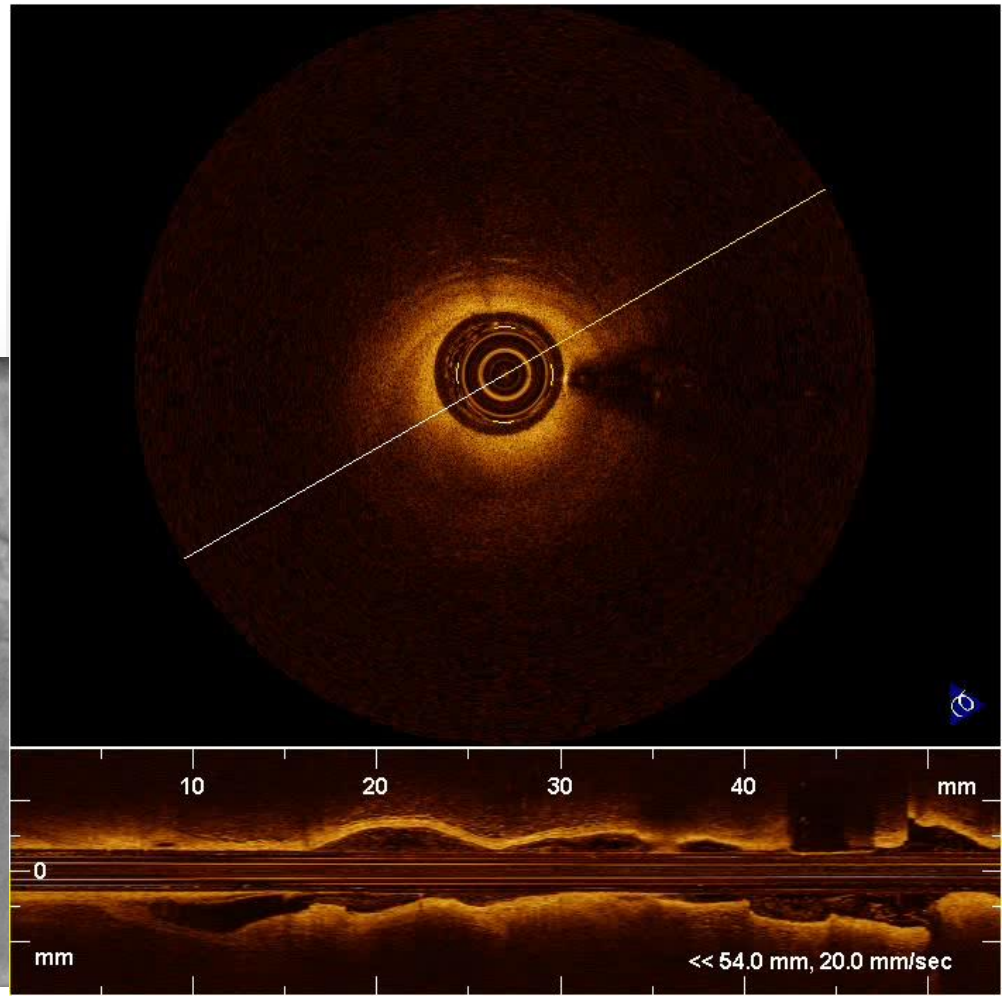


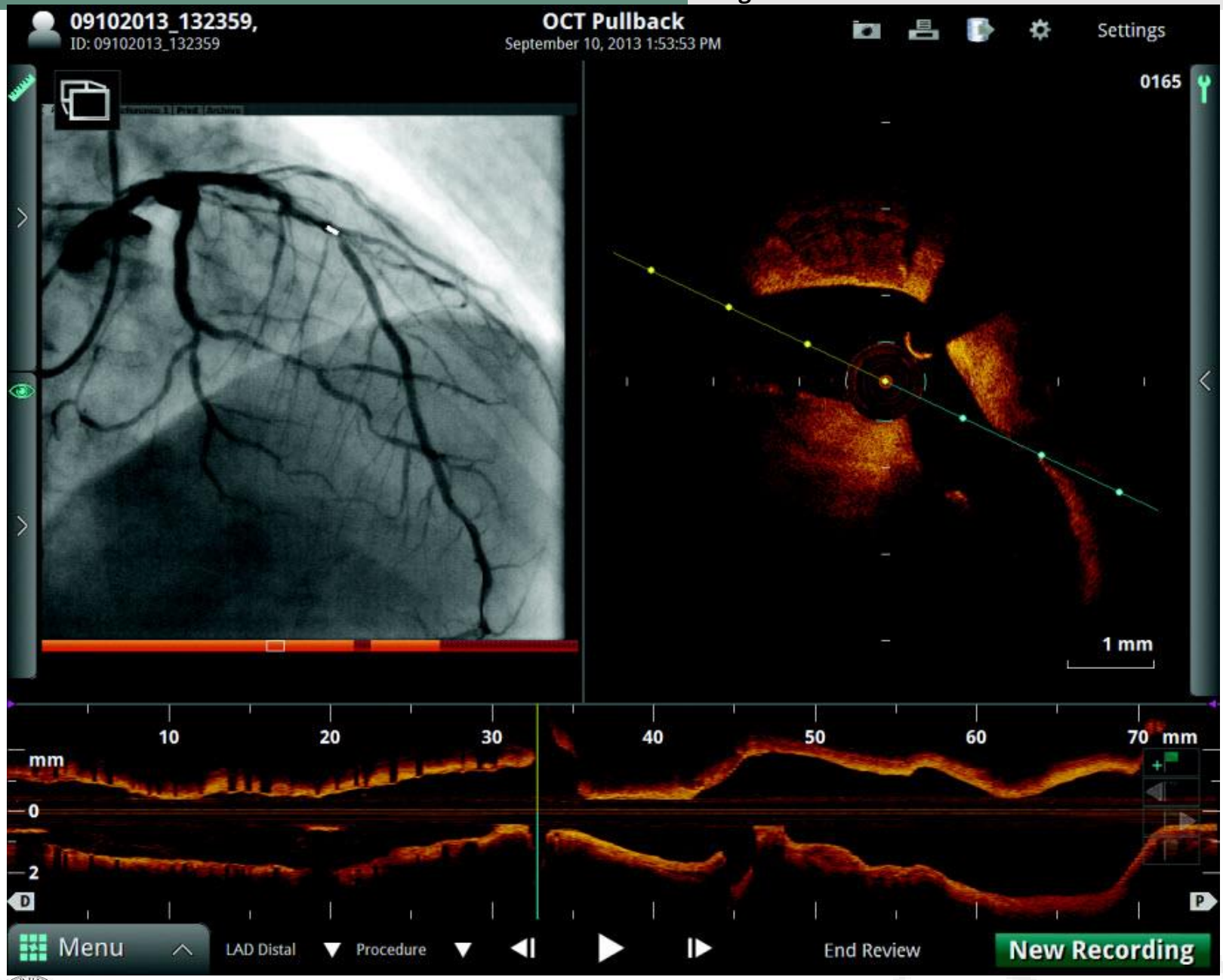
- Measure echo time delay of reflected light waves
- One pixel → 5 x 19 um
- One axial line → 1024 pixels
- One frame → 500 axial lines
- *Optical resolution → 15 axial, 20 to 40 um transverse*



Pullback – image generation







"B-Mode" cross-sectional view

"L-Mode" longitudinal view

OCT cross-sectional image of a „normal” coronary artery

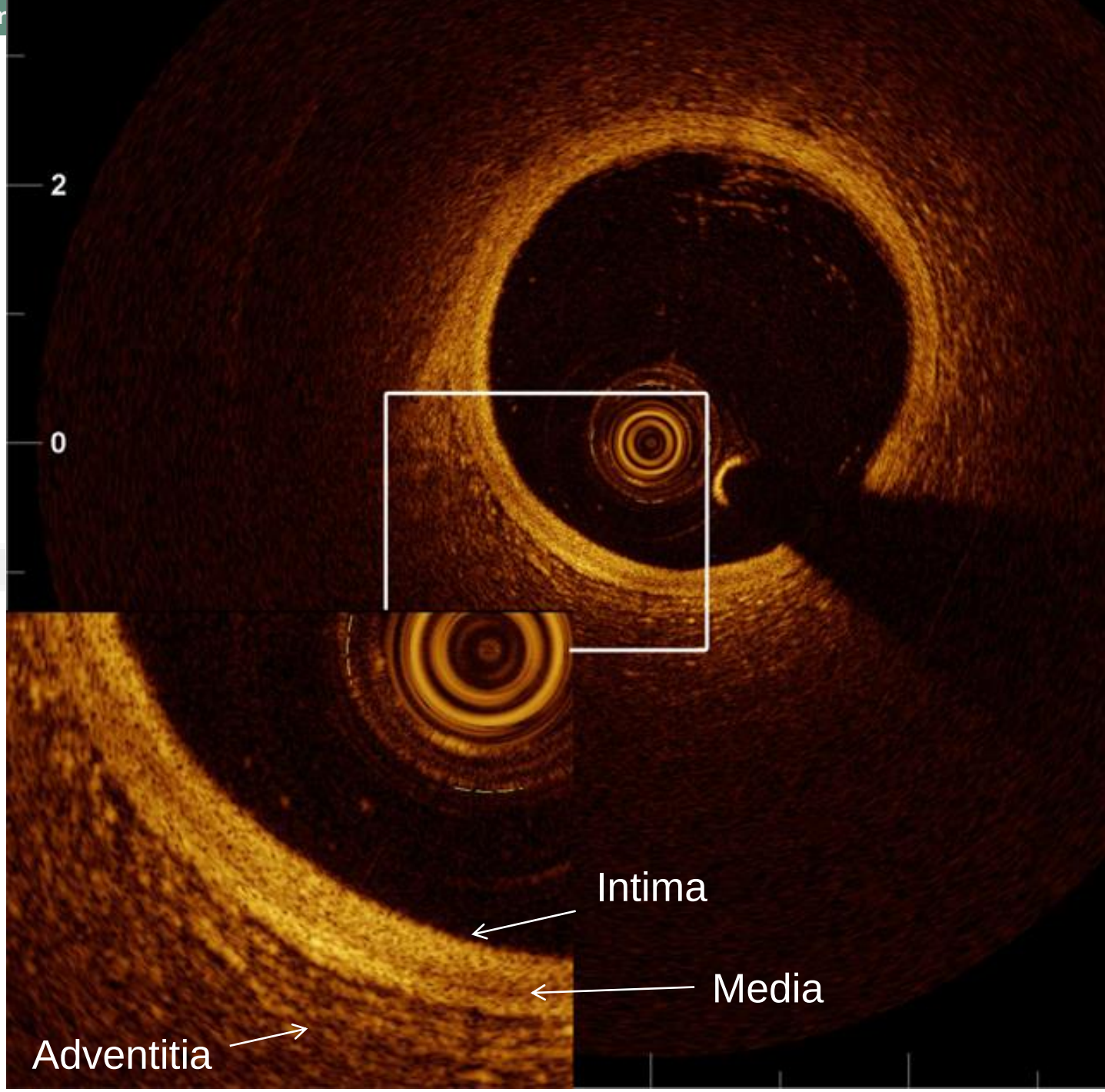


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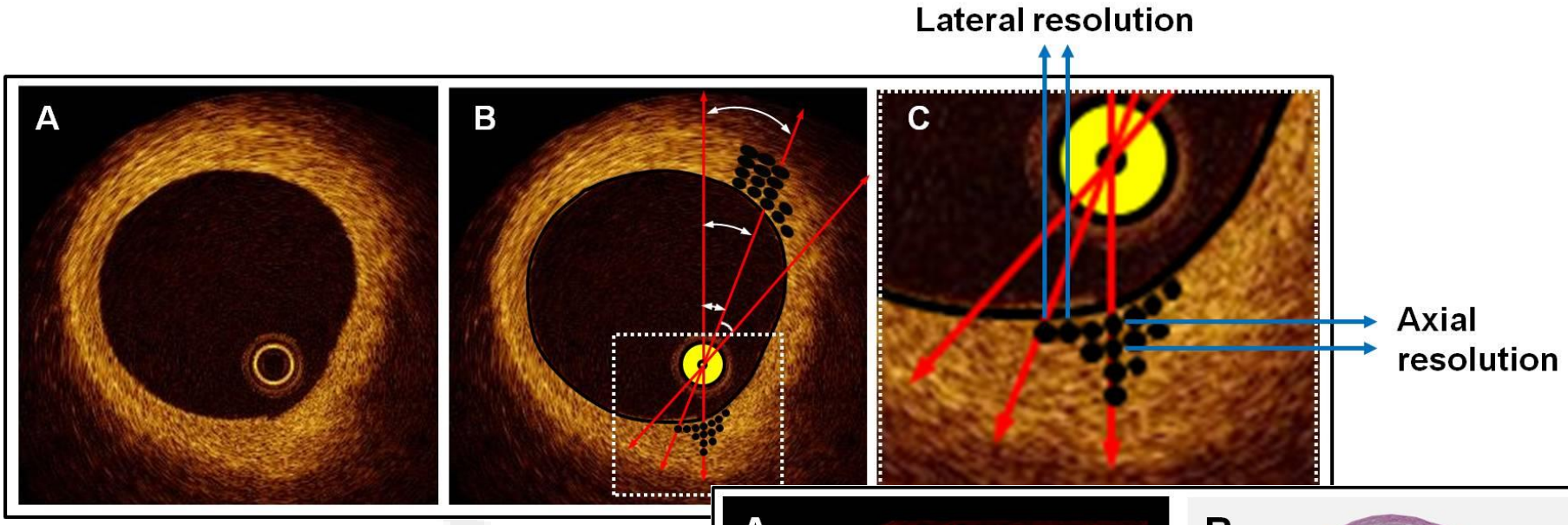
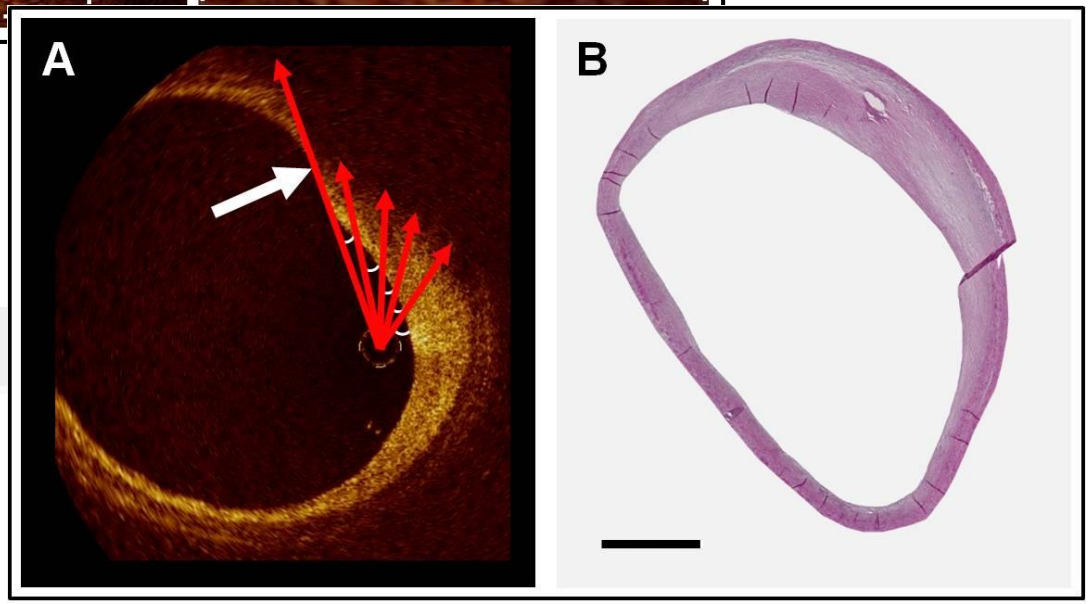
Image: pitfalls and potential artefacts



Tangential signal drop-out



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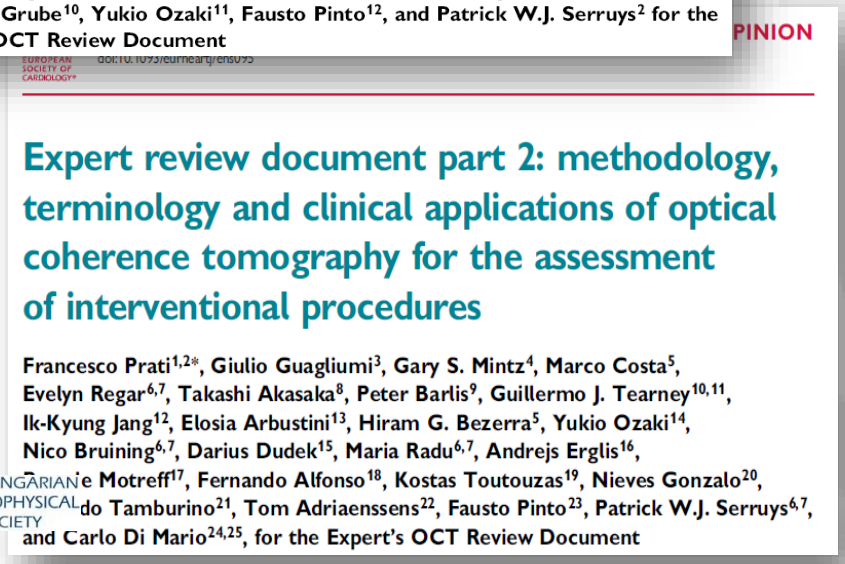
Today – 2019: Reliable Diagnostic Tool !

European Heart Journal
doi:10.1093/eurheartj/ehp433

REVIEW

Expert review document on methodology, terminology, and clinical applications of optical coherence tomography: physical principles, methodology of image acquisition, and clinical application for assessment of coronary arteries and atherosclerosis

Francesco Prati[1*], Evelyn Regar[2], Gary S. Mintz[3], Eloisa Arbustini[4], Carlo Di Mario[5], Ik-Kyung Jang[6], Takashi Akasaka[7], Marco Costa[8], Giulio Guagliumi[9], Eberhard Grube[10], Yukio Ozaki[11], Fausto Pinto[12], and Patrick W.J. Serruys[2] for the Expert's OCT Review Document



PINION

Expert review document part 2: methodology, terminology and clinical applications of optical coherence tomography for the assessment of interventional procedures

Francesco Prati[1,2*], Giulio Guagliumi[3], Gary S. Mintz[4], Marco Costa[5], Evelyn Regar[6,7], Takashi Akasaka[8], Peter Barlis[9], Guillermo J. Tearney[10,11], Ik-Kyung Jang[12], Elosia Arbustini[13], Hiram G. Bezerra[5], Yukio Ozaki[14], Nico Bruining[6,7], Darius Dudek[15], Maria Radu[6,7], Andrejs Erglis[16], [illegible]e Motreff[17], Fernando Alfonso[18], Kostas Toutouzas[19], Nieves Gonzalo[20], [illegible]do Tamburino[21], Tom Adriaenssens[22], Fausto Pinto[23], Patrick W.J. Serruys[6,7], and Carlo Di Mario[24,25], for the Expert's OCT Review Document

[illegible] of the American College of Cardiology
[illegible] 2012 by the American College of Cardiology Foundation
[illegible]ublished by Elsevier Inc.

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MINI-FOCUS ISSUE: OPTICAL COHERENCE TOMOGRAPHY

Clinical Research

Consensus Standards for Acquisition, Measurement, and Reporting of Intravascular Optical Coherence Tomography Studies

A Report From the International Working Group for Intravascular Optical Coherence Tomography Standardization and Validation

Guillermo J. Tearney, MD, PhD, *Writing Committee Co-Chair*,*
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Lukasz Koltowski, MD, Takashi Kubo, MD, PhD, Teruyoshi Kume, MD, Hiroyuki Kyono, MD,
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ROLAND EÖTVÖS PHYSICAL SOCIETY (HUNGARY)

EHJ 2010 & 2012

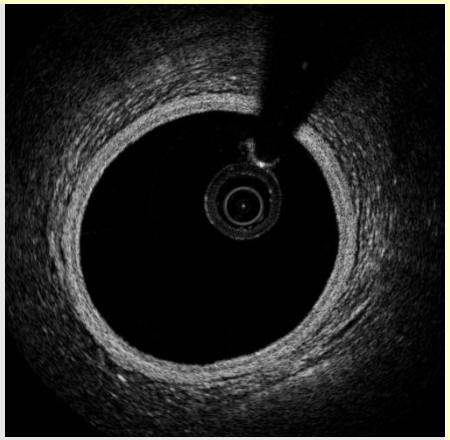
J Am Coll Cardiol. 2012

Optical Coherence Tomography (OCT)

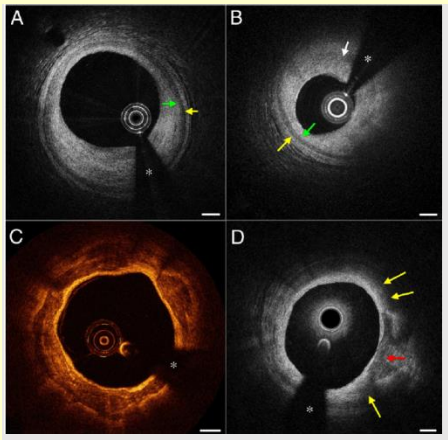
Today – 2019: Reliable Diagnostic Tool !

High Evidence Level

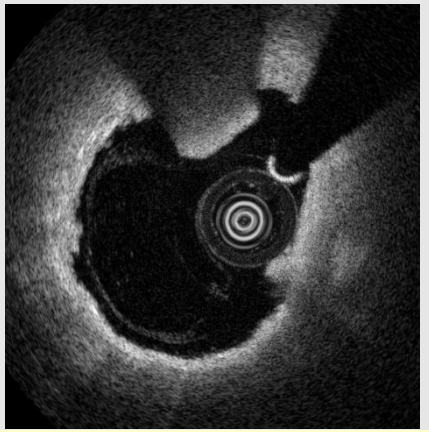
Normal vessel wall



Atherosclerosis



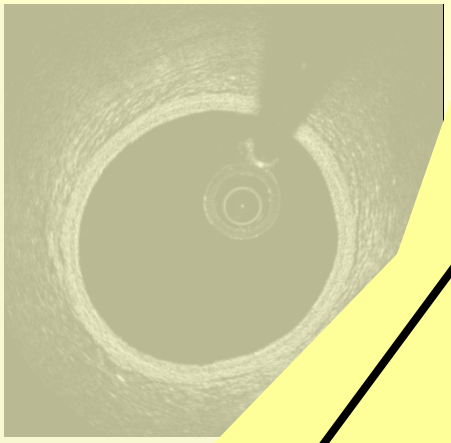
Thrombus



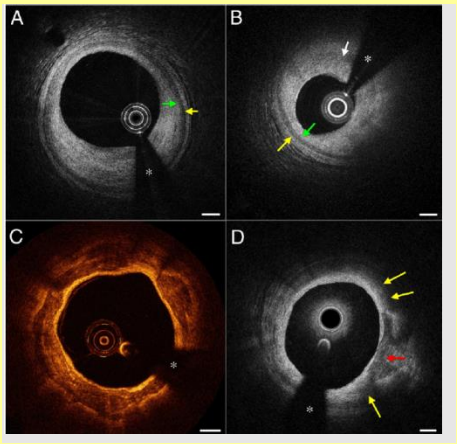
J Am Coll Cardiol. 2012

High Evidence Level

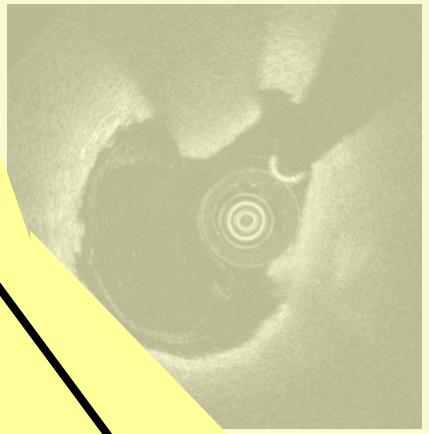
Normal vessel wall



Atherosclerosis



Thrombus



Fibrous

Fibrocalcific

Lipid pool

Fibrous cap

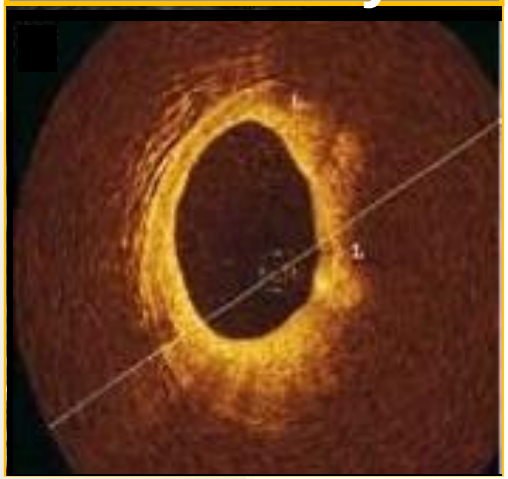
Rupture

J Am Coll Cardiol. 2012

2. Assess Plaque Composition

Fibrous

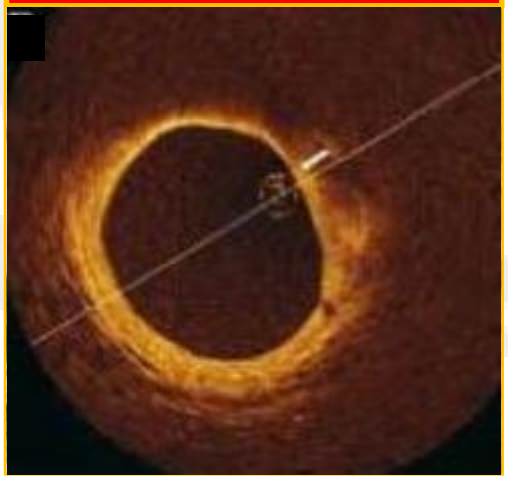
Fibro-Fatty



Calcific

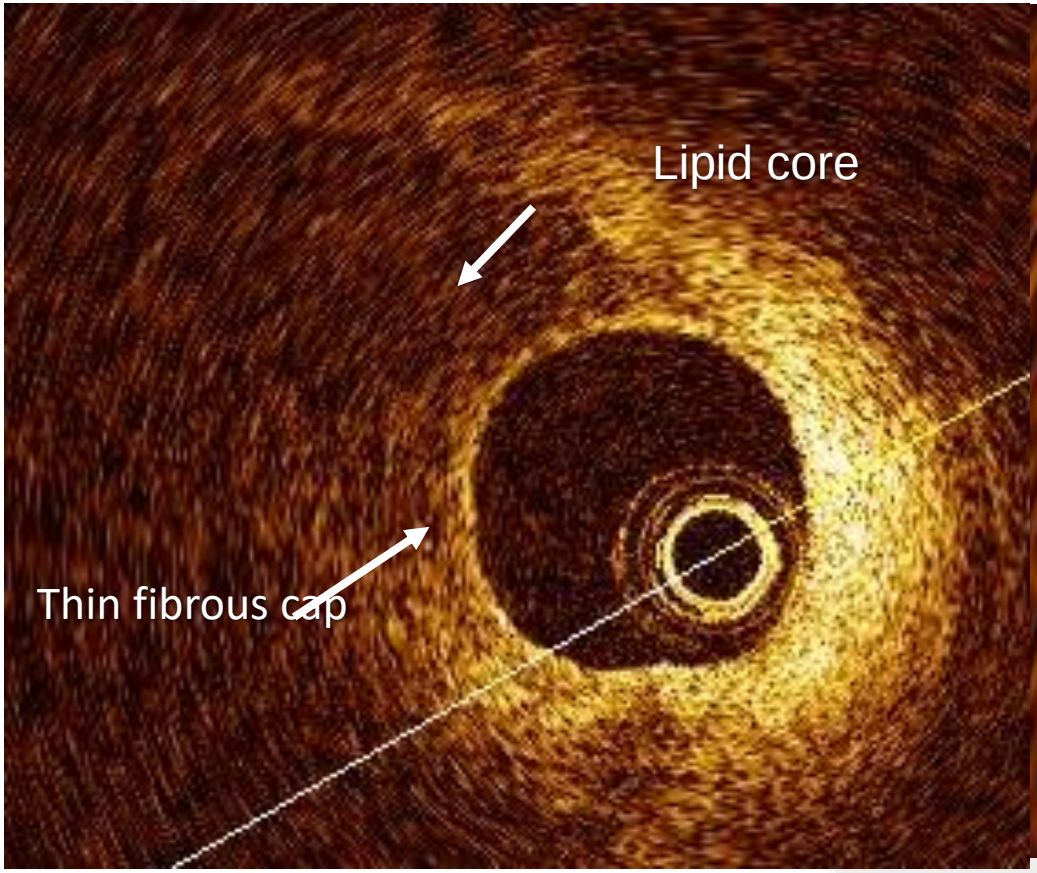
Rotablator

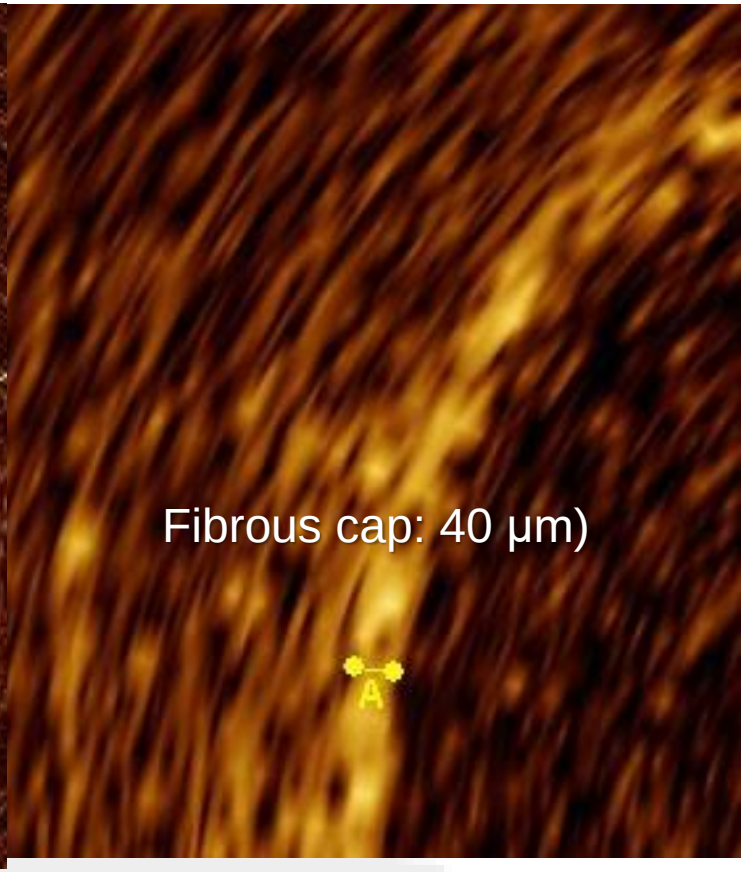
Necrotic Core



- **Cutting Balloon**
- **High Pressure**

Potential tool for detection of TCFA – pathological substrate for future myocardial infarction !





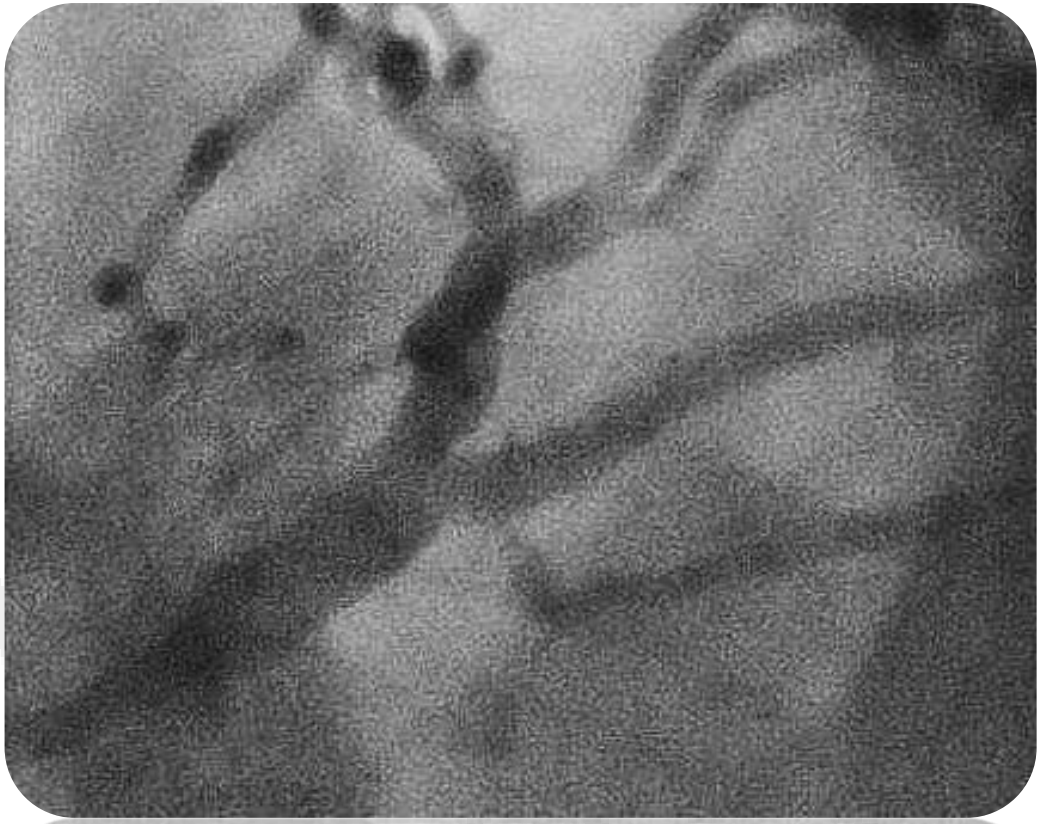
TCFA: lipid-rich atheroma with thin (< 65 μm) fibrous cap

Optical Coherence Tomography (OCT)

Today – 2019: Reliable Diagnostic Tool !

OCT is superior to angiography in LM

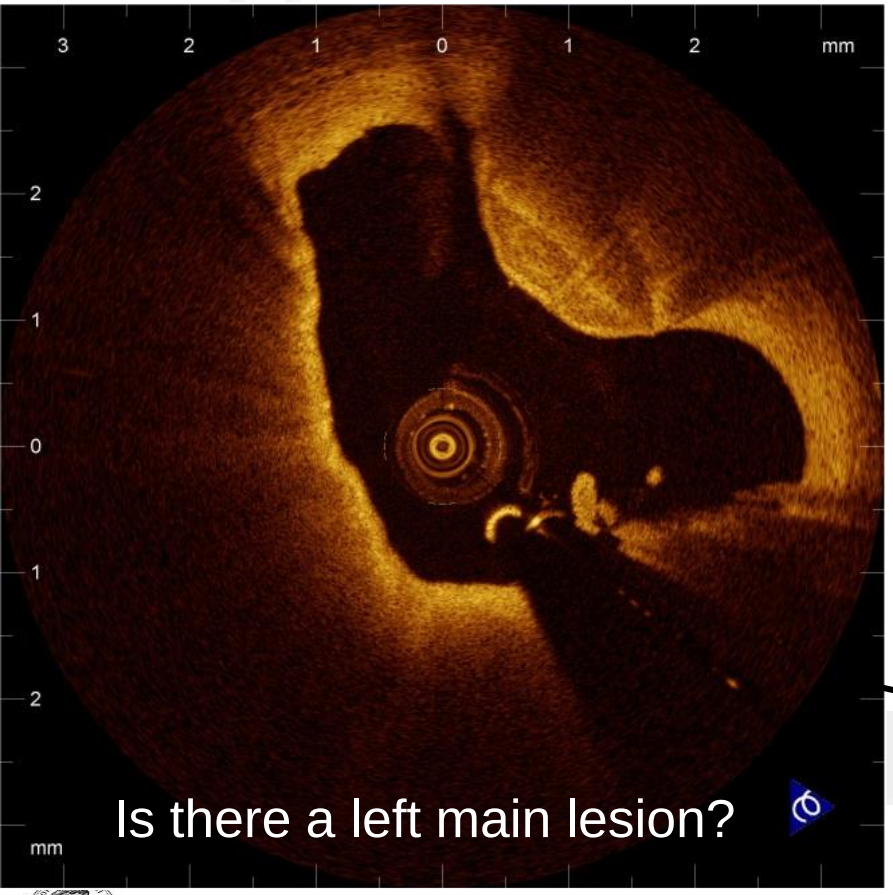
Is there a left main lesion?

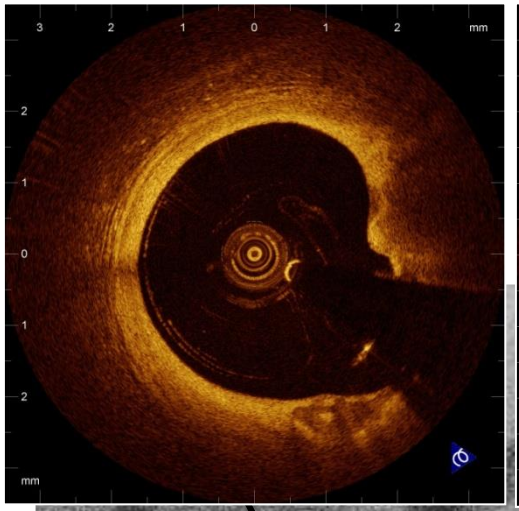


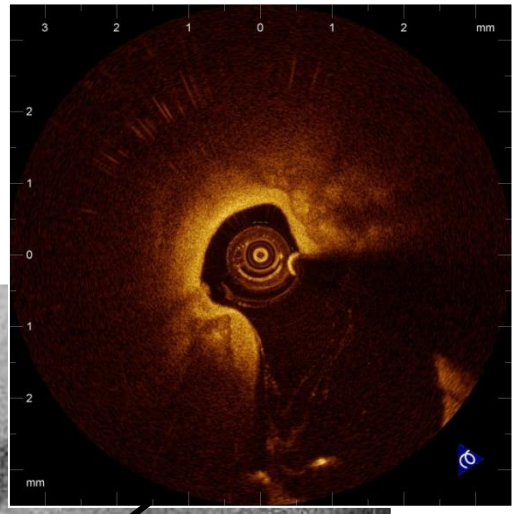
OCT: LightLab/St.Jude

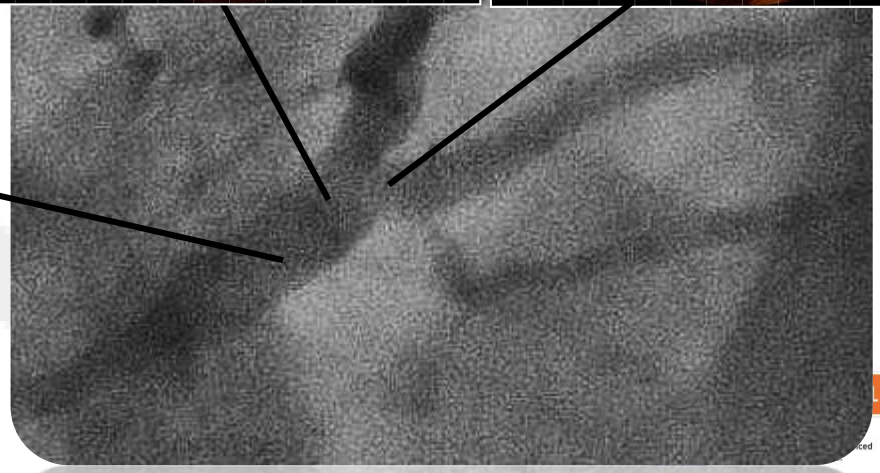
Today – 2019: Reliable Diagnostic Tool !

OCT is superior to angiography in LM









OCT: Lightlab/St.Jude

Today – 2019: Reliable Diagnostic Tool !

OCT is superior to angiography

Left Main stem lesions
Complex lesions

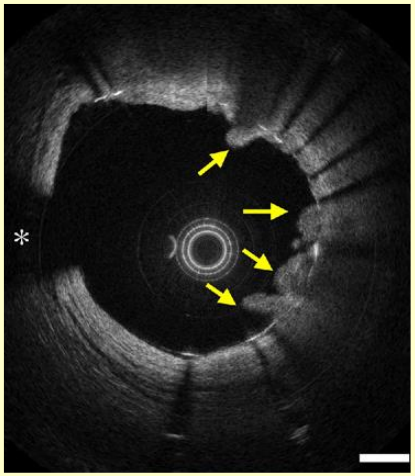
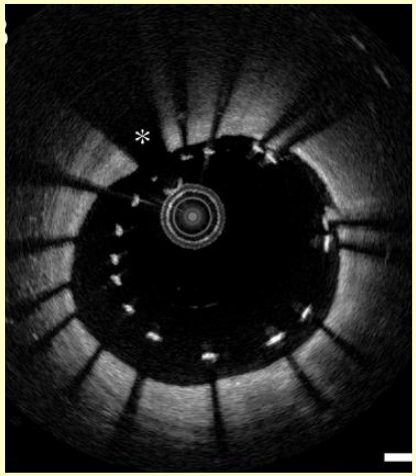
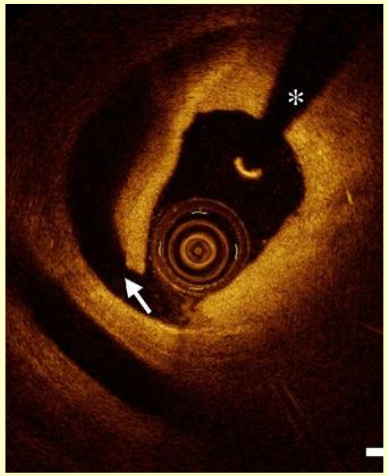
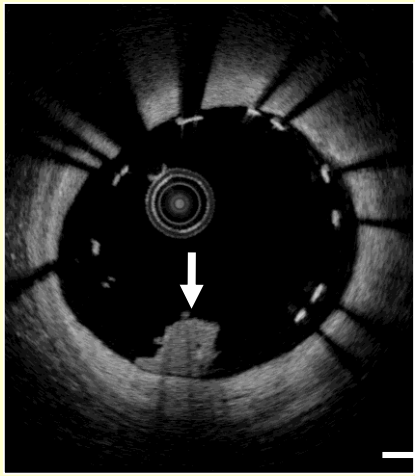
OCT is prognostic in stenting

Periprocedual complications
Clinical outcome

?

Today – 2019: Guidance in PCI (after stenting)

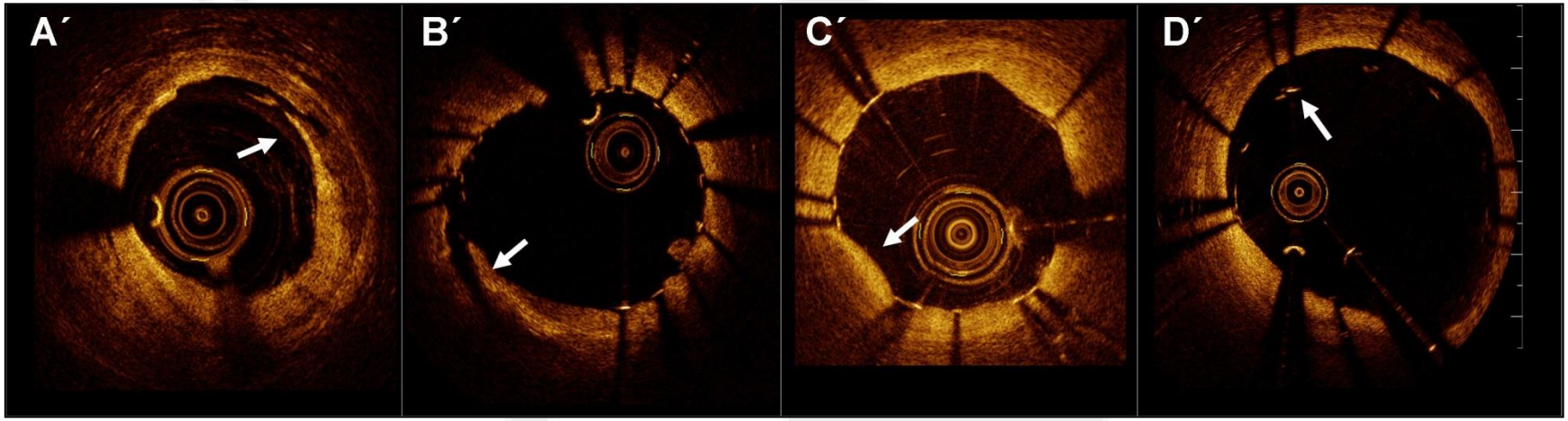
High Evidence Level

Prolapse	Apposition Malapposition	Dissection	Thrombus
			

J Am Coll Cardiol. 2012

Today – 2019: Guidance in PCI (after stenting)

Suboptimal acute stent result is frequent and missed by angiography



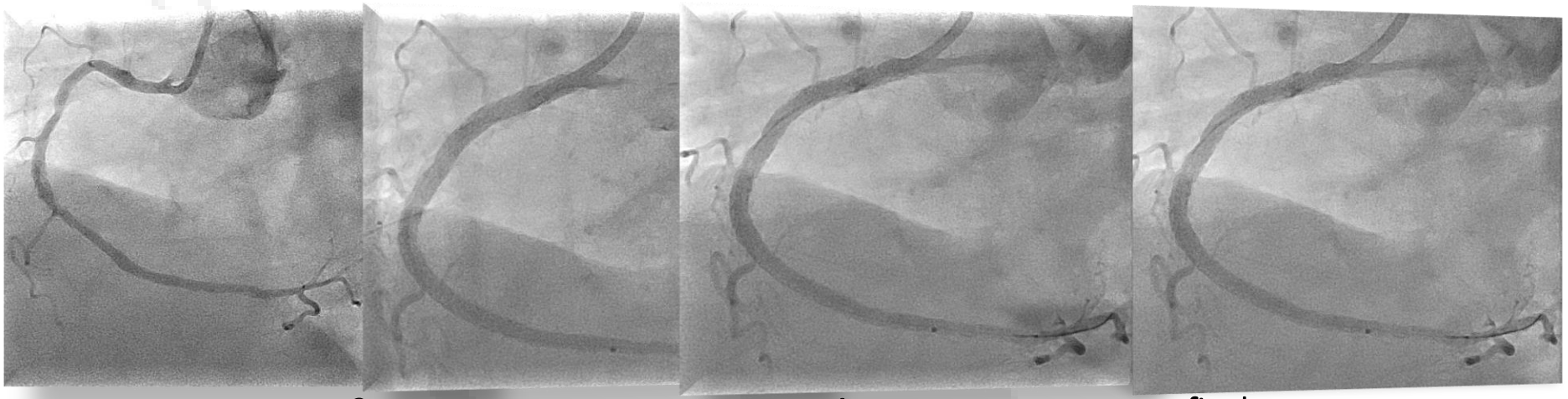
Edge dissection	Intra-stent dissection	Tissue prolapse	Strut malapposition
26.0%	87.5%	97.5%	65.5%

Gonzalo N et al., Heart 2009

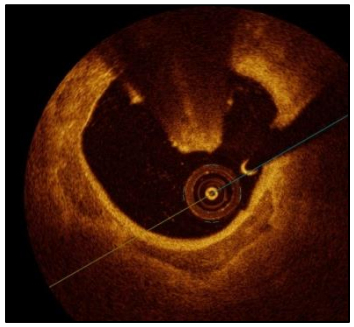
OCT: Lightlab/StJUDE

Today – 2019: Guidance in PCI (after stenting)

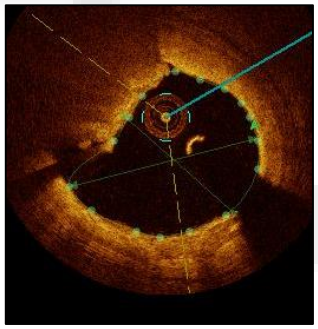
Suboptimal acute stent result is frequent and missed by angiography



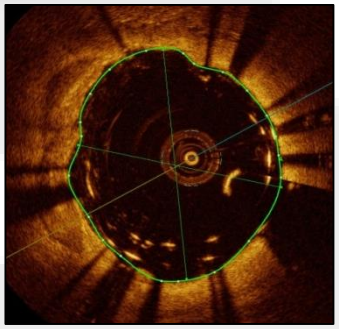
pre 3 stents 4 stents final



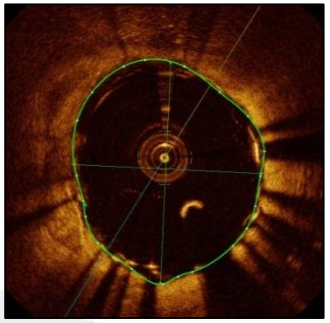
thrombus



gap



malapposition



optimal

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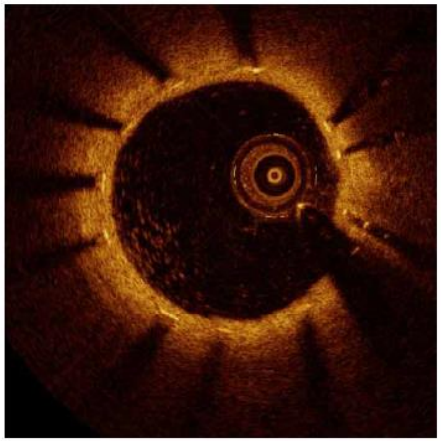
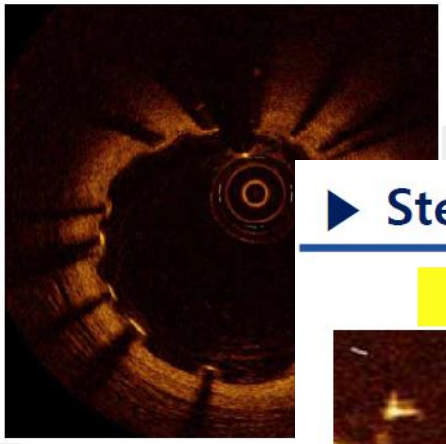
OCT: Lightlab/StJUDE

Today – 2019: Guidance in PCI (long after stenting)

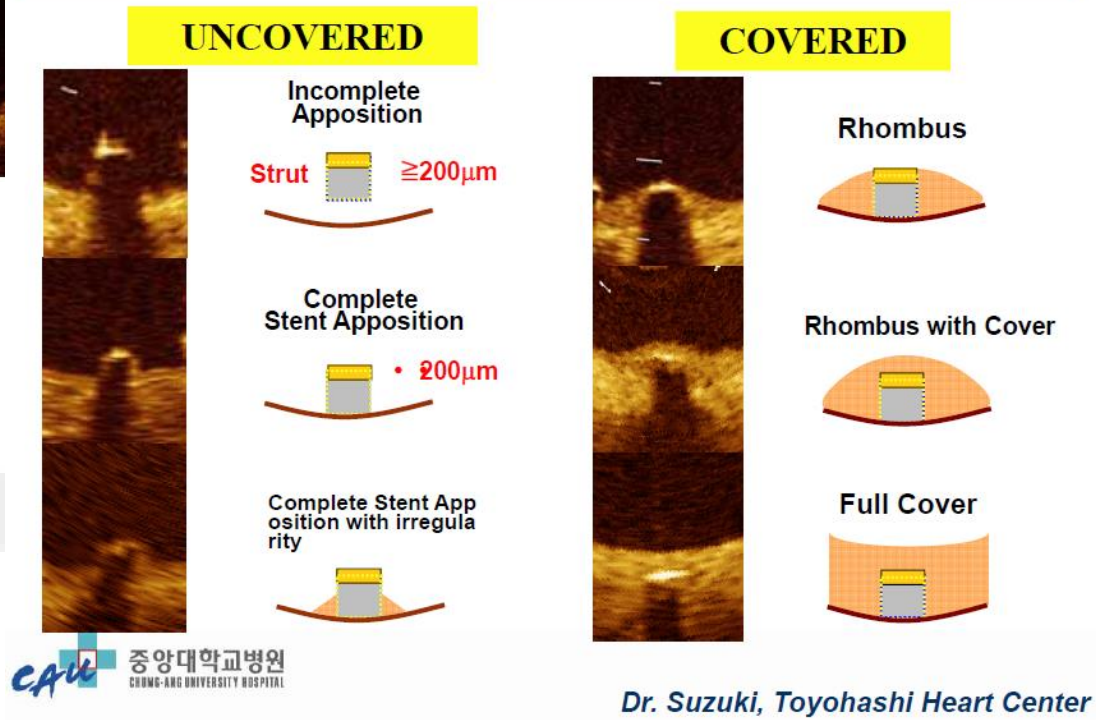
Coverd stent



Uncoverd stent



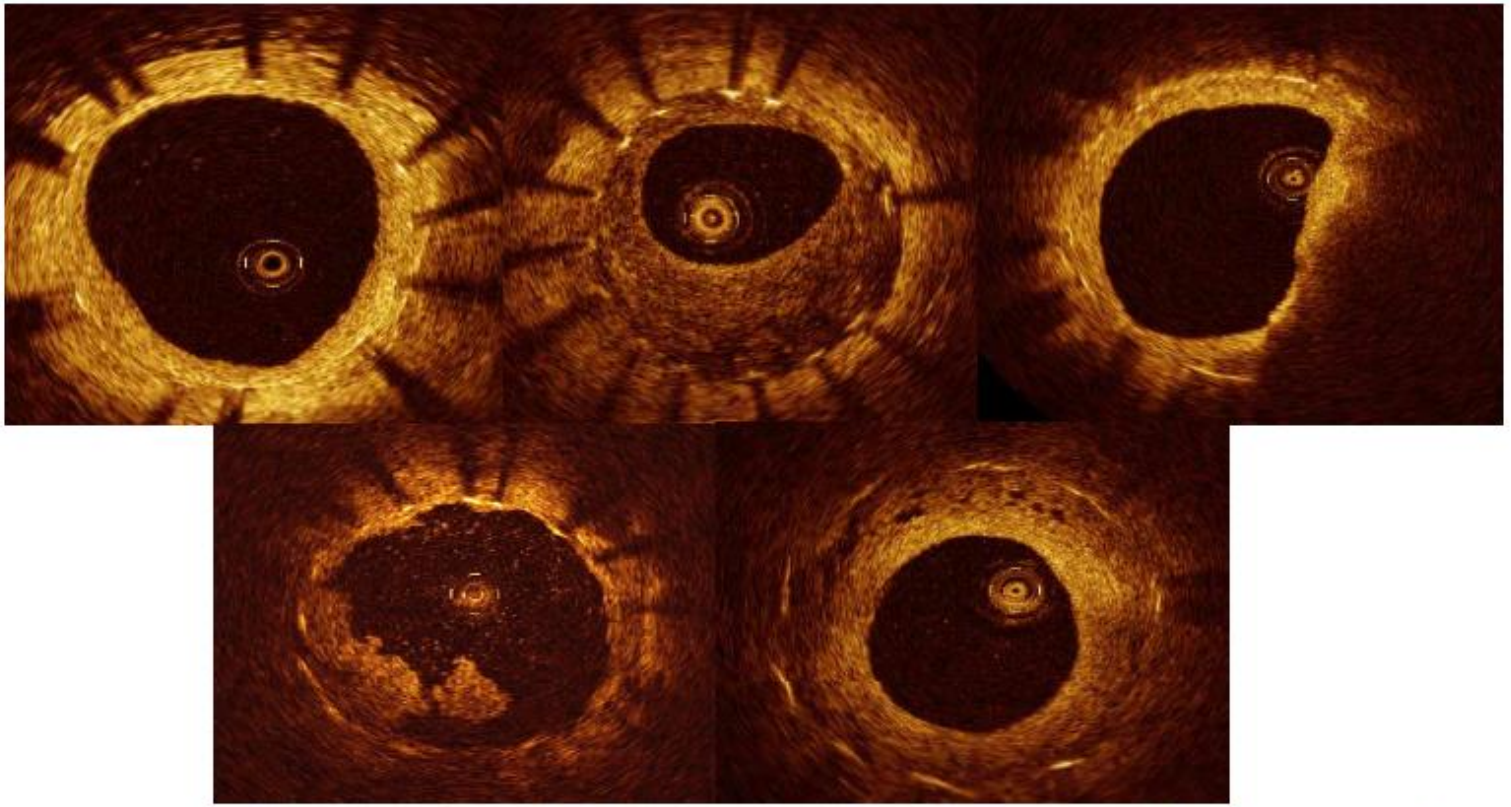
Stent Strut Coverage Patterns



Dr. Suzuki, Toyohashi Heart Center

Today – 2019: Guidance in PCI (long after stenting)

Qualitative neointimal Evaluation



(A) Homogeneous , (B) heterogeneous , (C) TCFA-like neointima (arrows) and lipid laden neointima (a rrowheads), (D) intracoronary thrombi (arrow), (E) neovascularization (arrows).

Optical Coherence Tomography (OCT)

Today – 2019: Lesson's Learned

OCT is superior to angiography

Left Main stem lesions
Complex lesions

OCT is prognostic in stenting

Periprocedual complications
Clinical outcome

?

OCT changed the paradigm of DES failure

Neoatherosclerosis

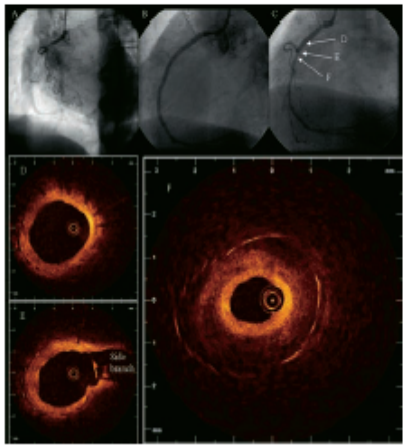
EuroIntervention

Paclitaxel-eluting stent restenosis shows three-layer appearance by optical coherence tomography

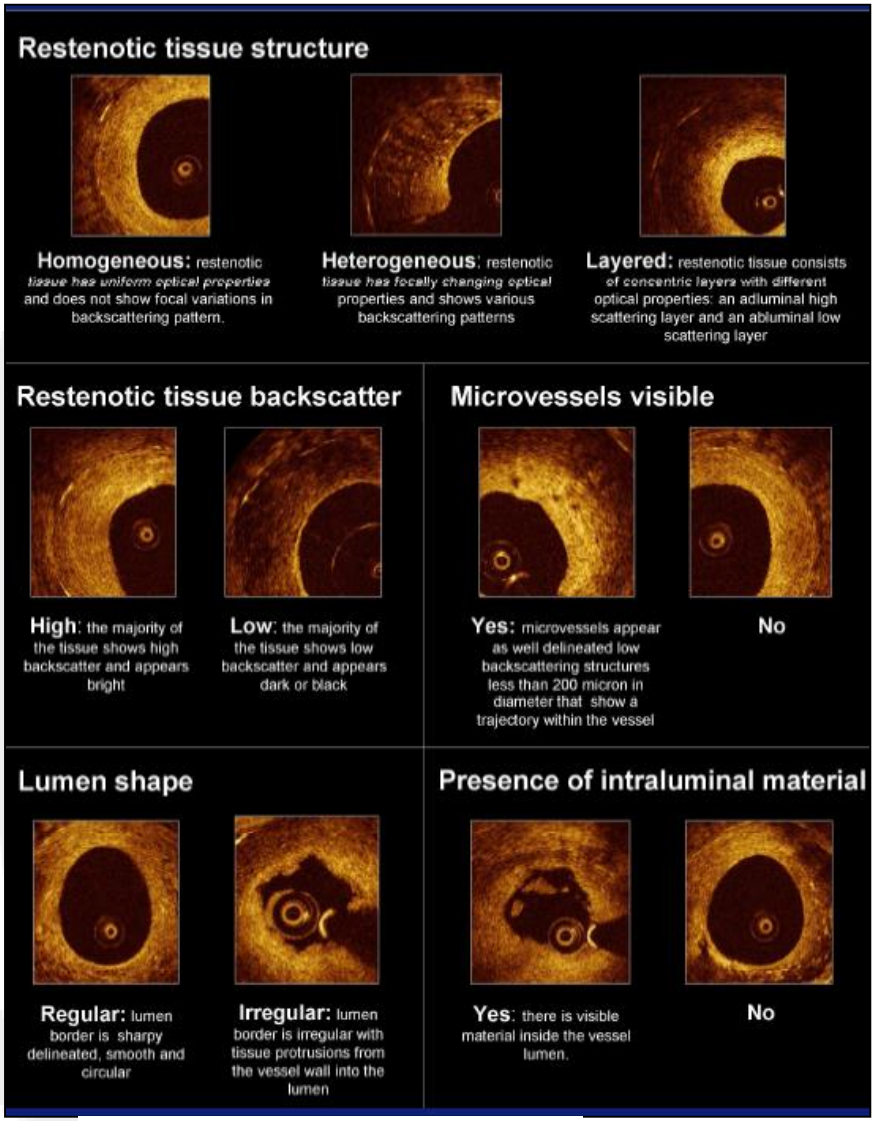
Shuzou Tanimoto, MD; Jiro Aoki, MD; Patrick W. Serruys, MD, PhD; Evelyn Regar*, MD, PhD

Thoraxcenter, Erasmus Medical Center, Rotterdam, The Netherlands.

A 73-year-old woman with hypertension, hyperlipidemia and positive familial history of coronary artery disease presented with Canadian Cardiovascular Society class III angina and underwent coronary angiography, which showed a chronic occluded right coronary artery (Panel A). The vessel was recanalized and treated with three paclitaxel-eluting stents (TAXUS®, Boston Scientific: 3.5 x 32 mm distally, 3.5 x 28 mm in the middle part, 3.5 x 12 mm proximally). Postintervention coronary angiography showed a good result (Panel B). Twelve-month follow-up angiography revealed focal in-stent restenosis (Panel C). Intracoronary optical coherence tomography (OCT: LightLabImaging™, Boston, MA, USA) pullback displayed well-expanded stents covered with a thin, homogenous, highly reflective neointimal layer (Panel D, E). In contrast, the narrowest lesion site (minimal lumen area 1.1 mm^2; stent area 9.0 mm^2) showed a three-layer appearance of the neointima (Panel F). The inner luminal layer appeared concentric, homogenous and signal-rich (maximal thickness 0.27 mm). A second layer consisting of a low-reflective area with poorly delineated borders followed. The third layer was in direct contact with the stent struts and revealed only minimal signal intensity. These signal-poor areas (maximal thickness 1.18 mm) might represent acellular fibrinoid deposition that has been well described in experimental studies. The patient was re-treated with repeat paclitaxel-eluting stent implantation. OCT is an analogue of intravascular ultrasound with an ultra-high resolution (10 µm) superior to any current available imaging modalities. This imaging device may be useful in visualizing neointimal growth in drug-eluting stents and improve our understanding of its underlying physiopathology in the future.



Tanimoto et al. Eurointervention 2006



Gonzalo et al. Am Heart J 2009

Optical Coherence Tomography (OCT)

Today – 2019: Lesson's Learned

Accepted Manuscript

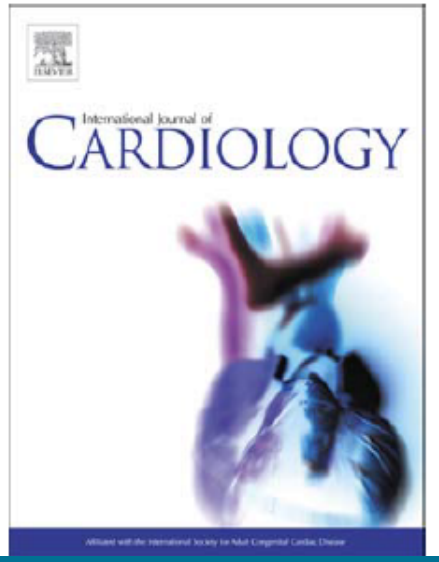
Intracoronary thrombus on optical coherence tomography in a patient with variant angina; treatment and follow-up

Péter Hausinger, Imre Ungi, Gyula Szántó, László Hajtman, Tamás Forster, Evelyn Regar, Attila Thury

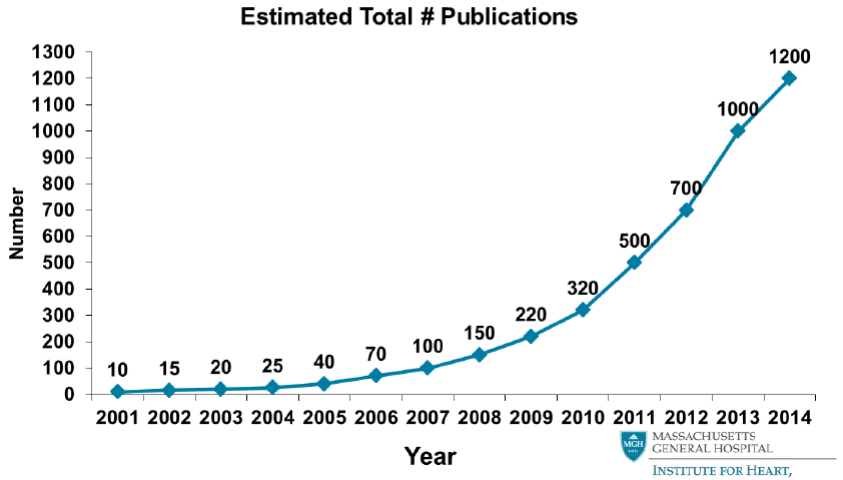
PII: S0167-5273(14)01242-X
DOI: doi: 10.1016/j.ijcard.2014.07.050
Reference: IJCA 18368

To appear in: *International Journal of Cardiology*

Received date: 18 May 2014
Accepted date: 5 July 2014



Intra-Coronary OCT Publications



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MASSACHUSETTS GENERAL HOSPITAL INSTITUTE FOR HEART,

Clinical data

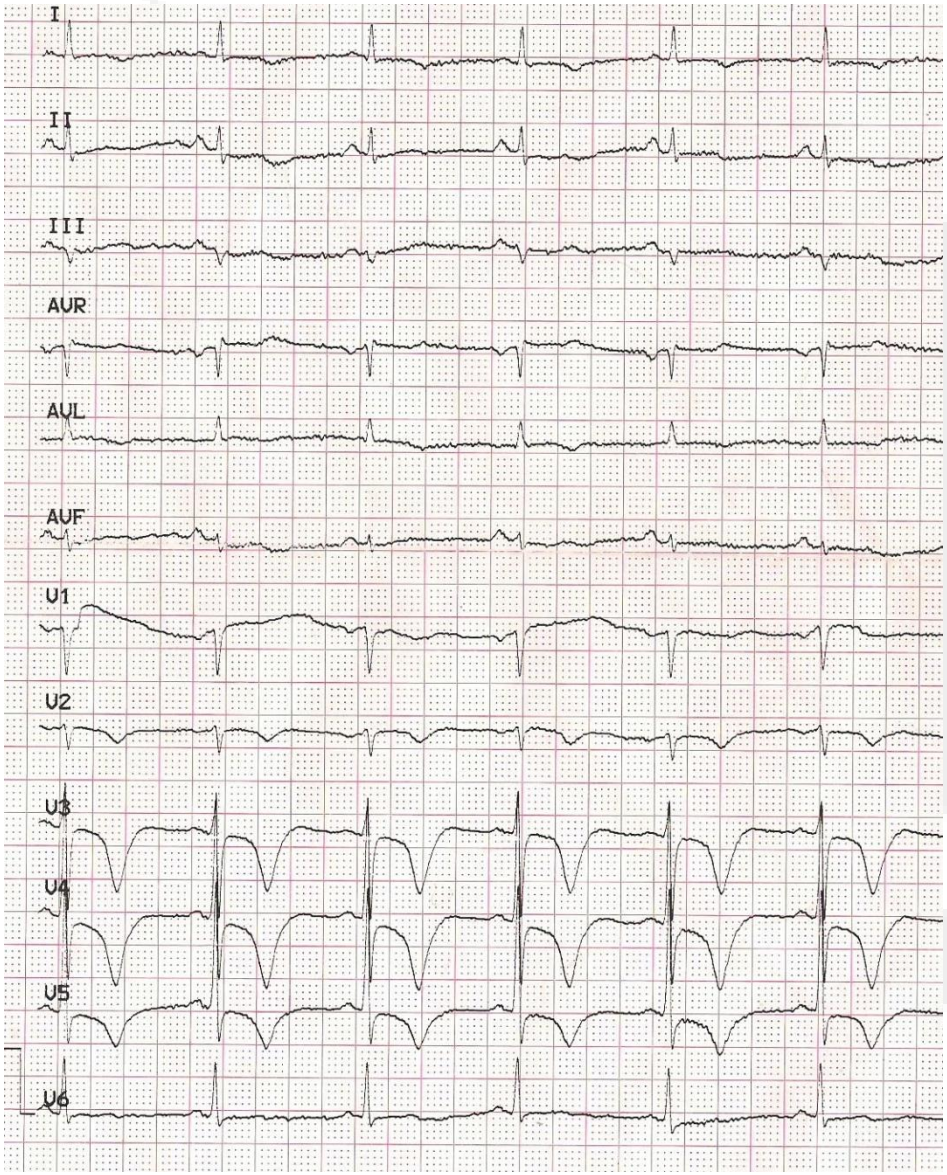
80-year-old male

Risk factors:
-hypertension
-smoker

Three-week history of occult gastrointestinal bleeding (active peptic ulcer)

One-week history of unstable angina (CCS4)

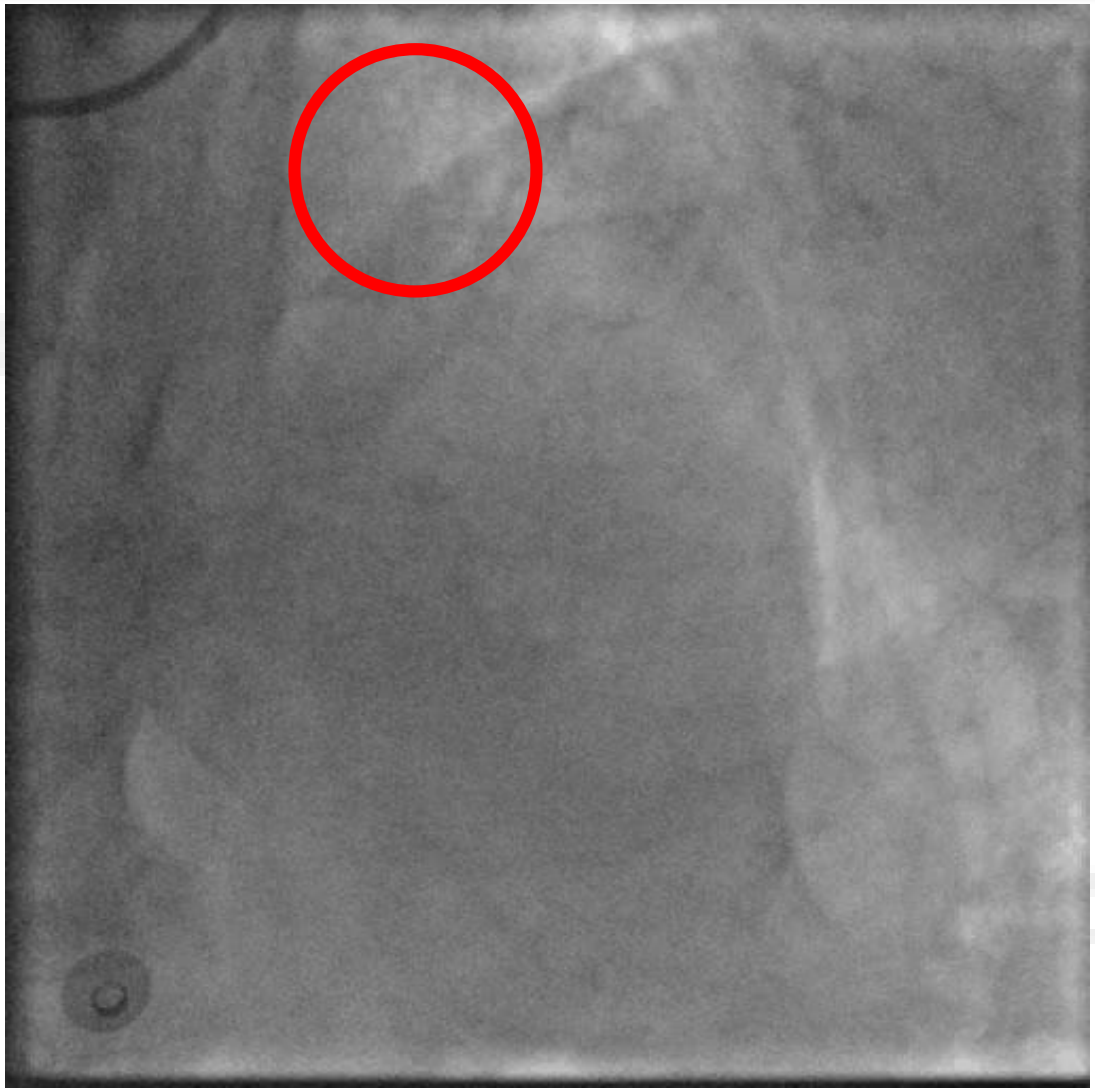
On admission



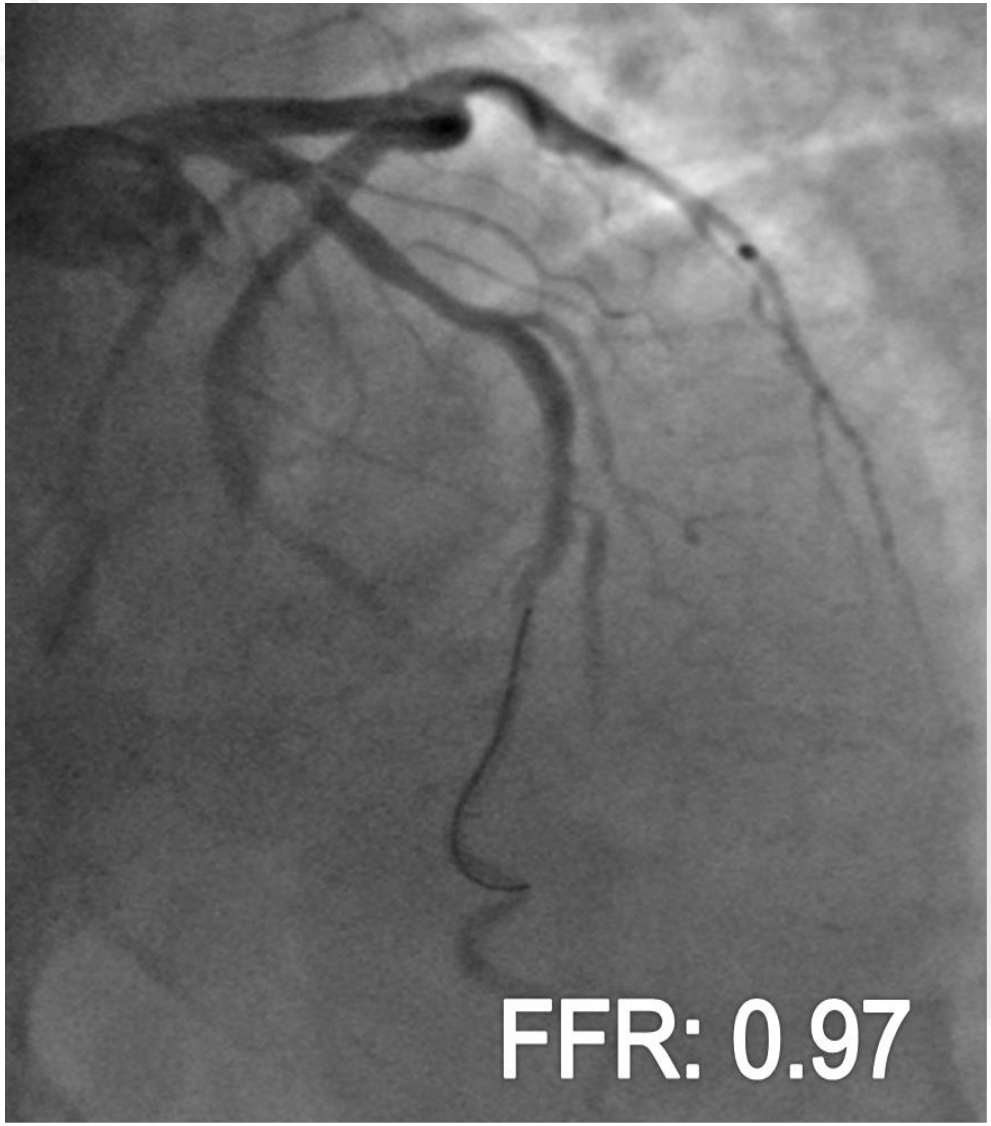
Baseline ECG on admission:

- **T wave inversion in precordial leads**
- **Patient free of angina**

Diagnostic Cardiac Catheterization



FFR measurement

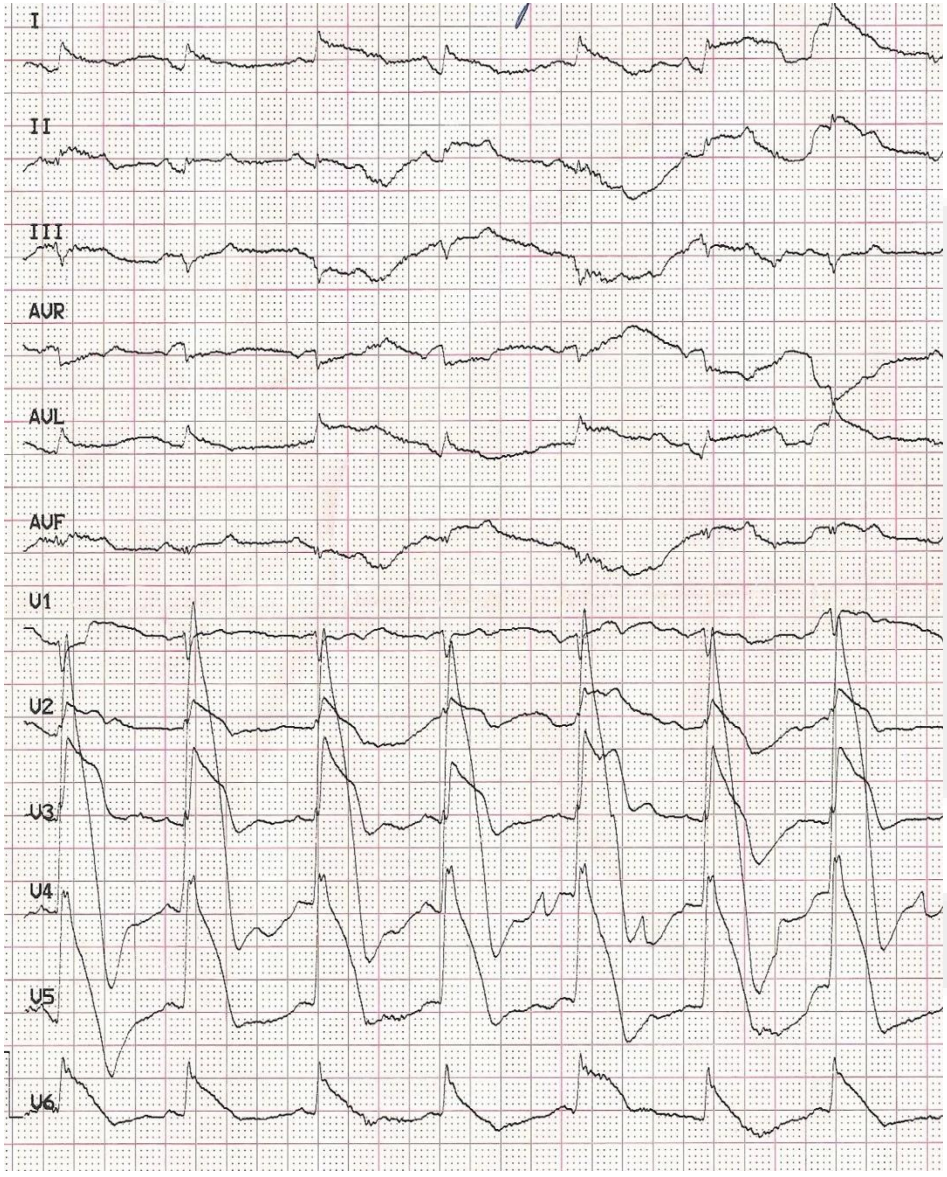


200 ug NTG +
240ug adenosine

Patient discharged to step-down unit with complete medication

- ASA 1x100mg
- Clopidogrel 1x75mg
- LMWH 2x0.6ml s.c.
- Ramipril 1x2.5mg
- Rosuvastatin 1x20mg
- Nebivolol 1x5mg

Recurrent angina at rest



- Immediately relieved by s.l. NTG

+

- Complete resolution on ECG

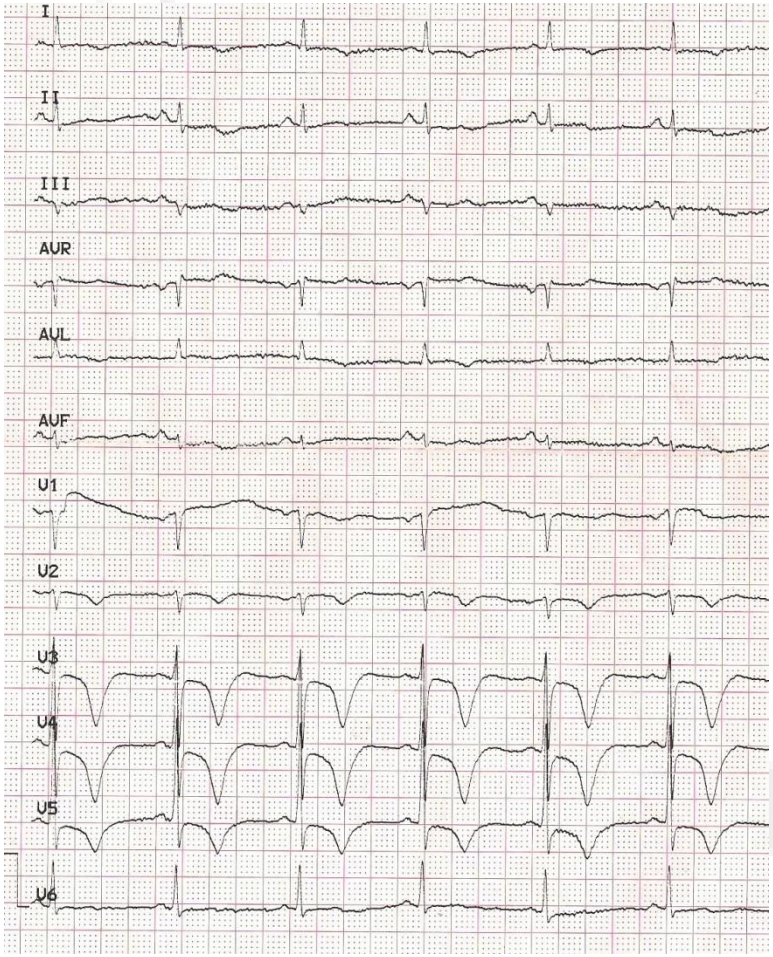
- ASA 1x100mg
- Clopidogrel 1x75mg
- LMWH 2x0.6ml s.c.
- Ramipril 1x2.5mg
- Rosuvastatin 1x20mg
- ~~Nebivolol 1x5mg~~

Nisoldipin 2x10mg

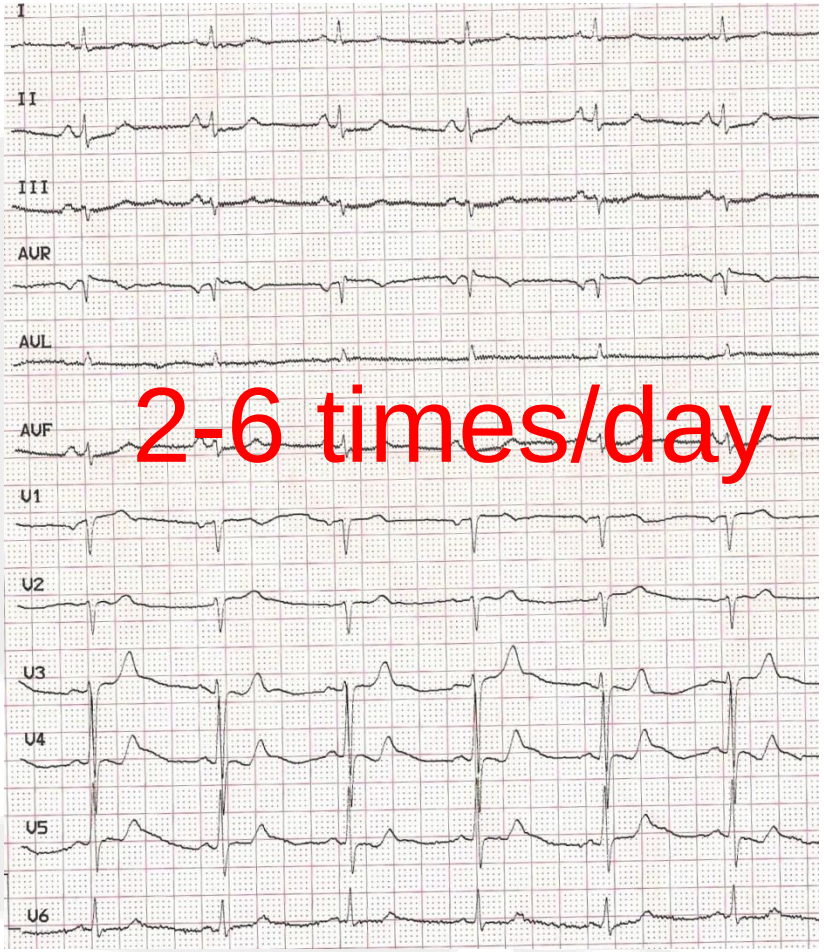
+

Iv NTG

Despite medical therapy

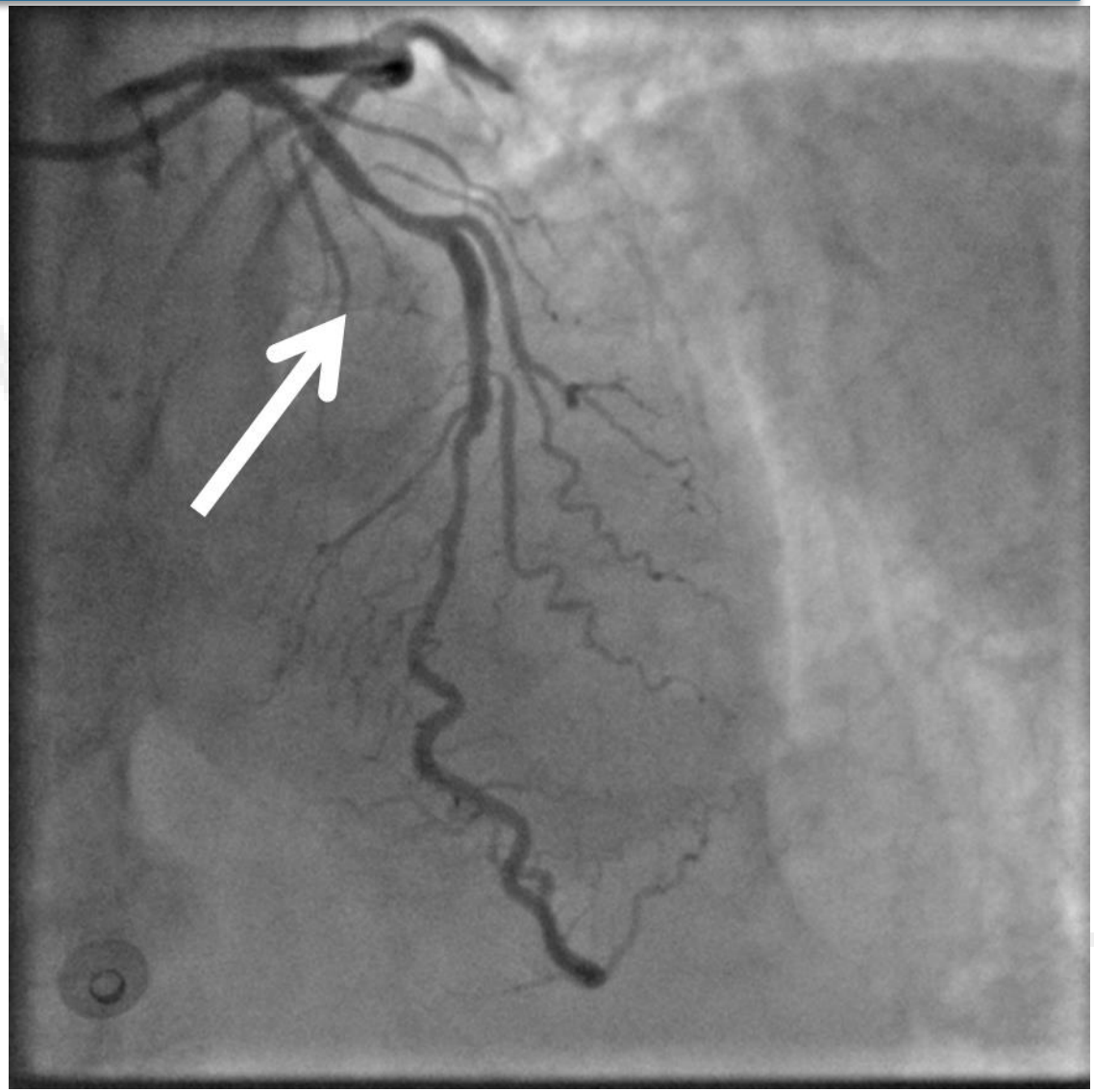


No angina

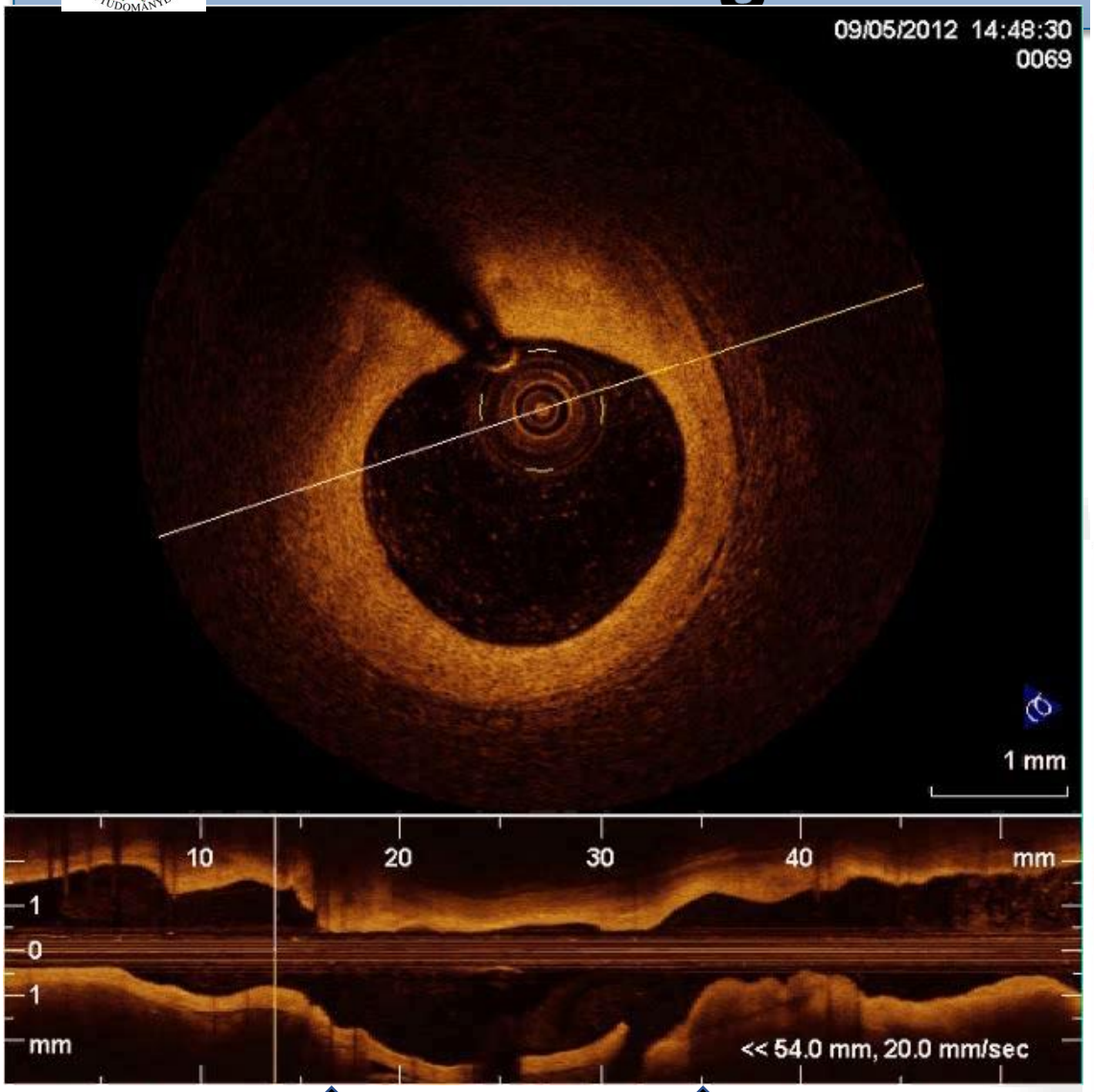


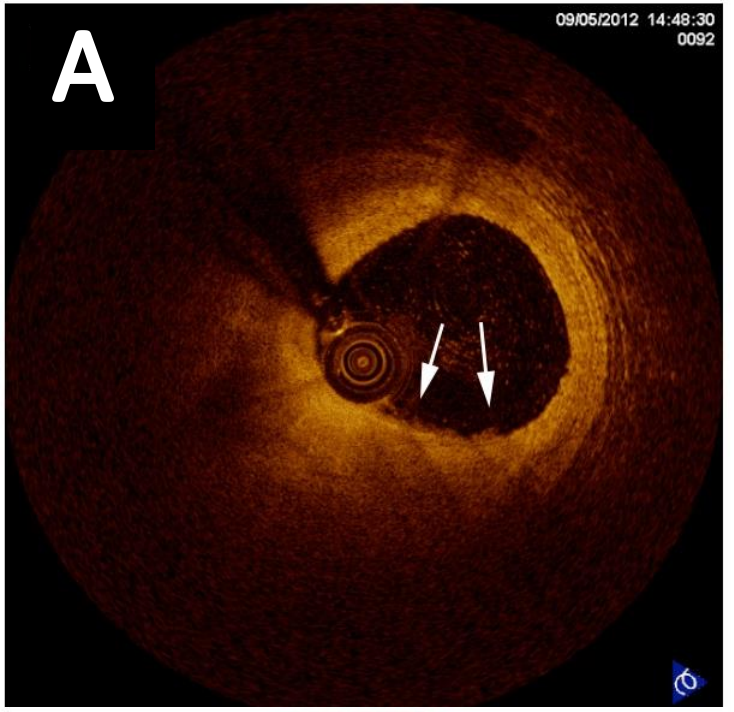
Angina

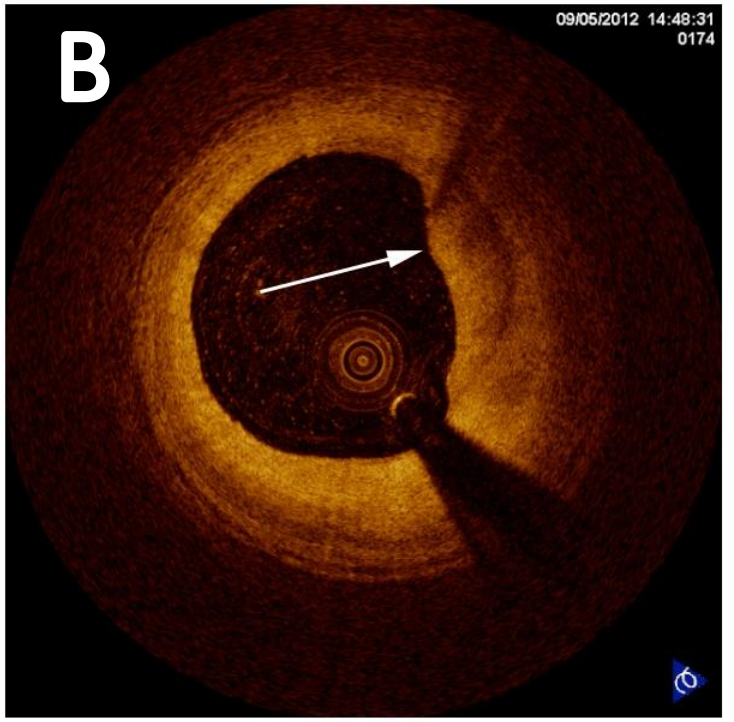
Repeated Cardiac Catheterization

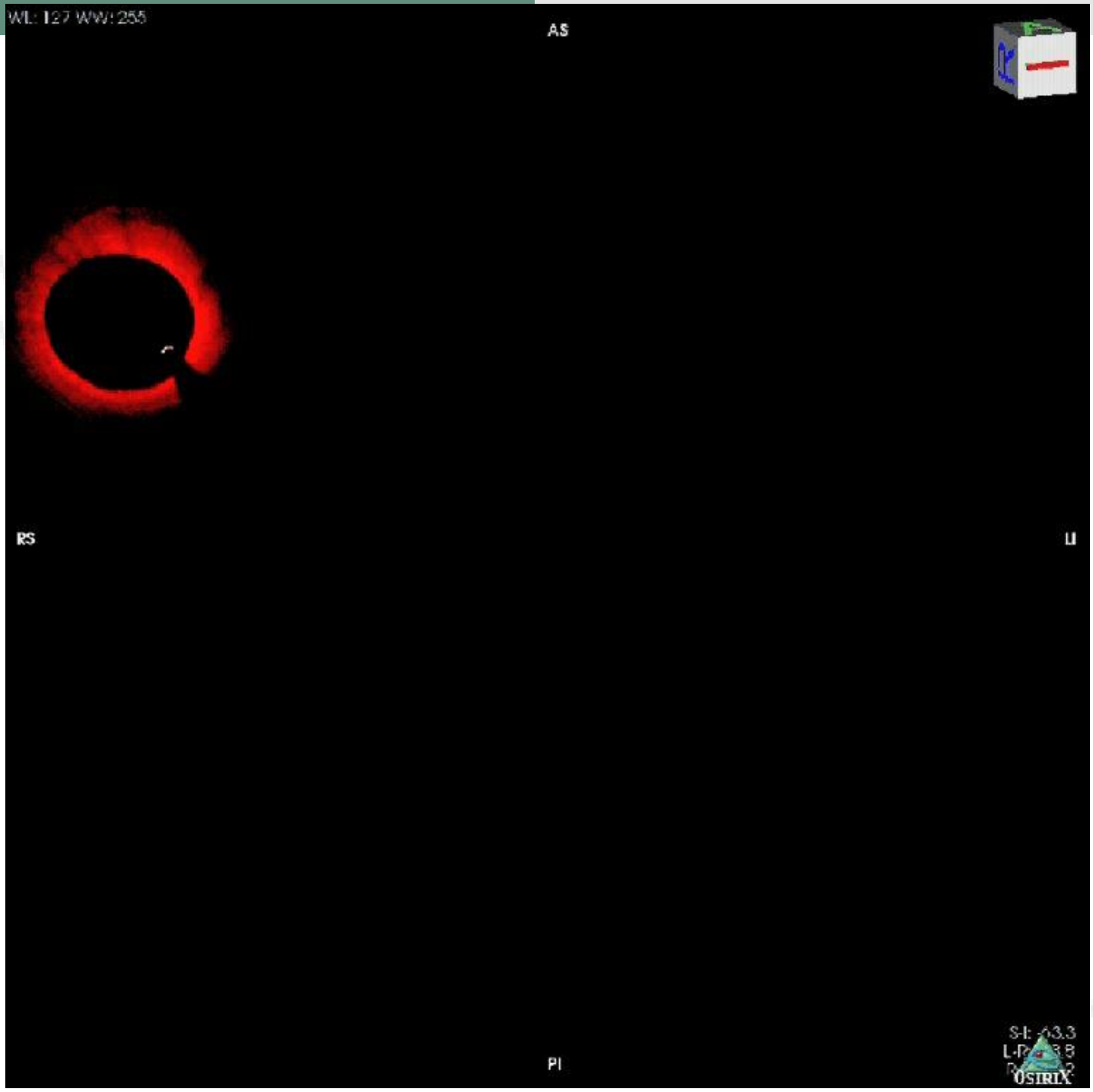


OCT Interrogation

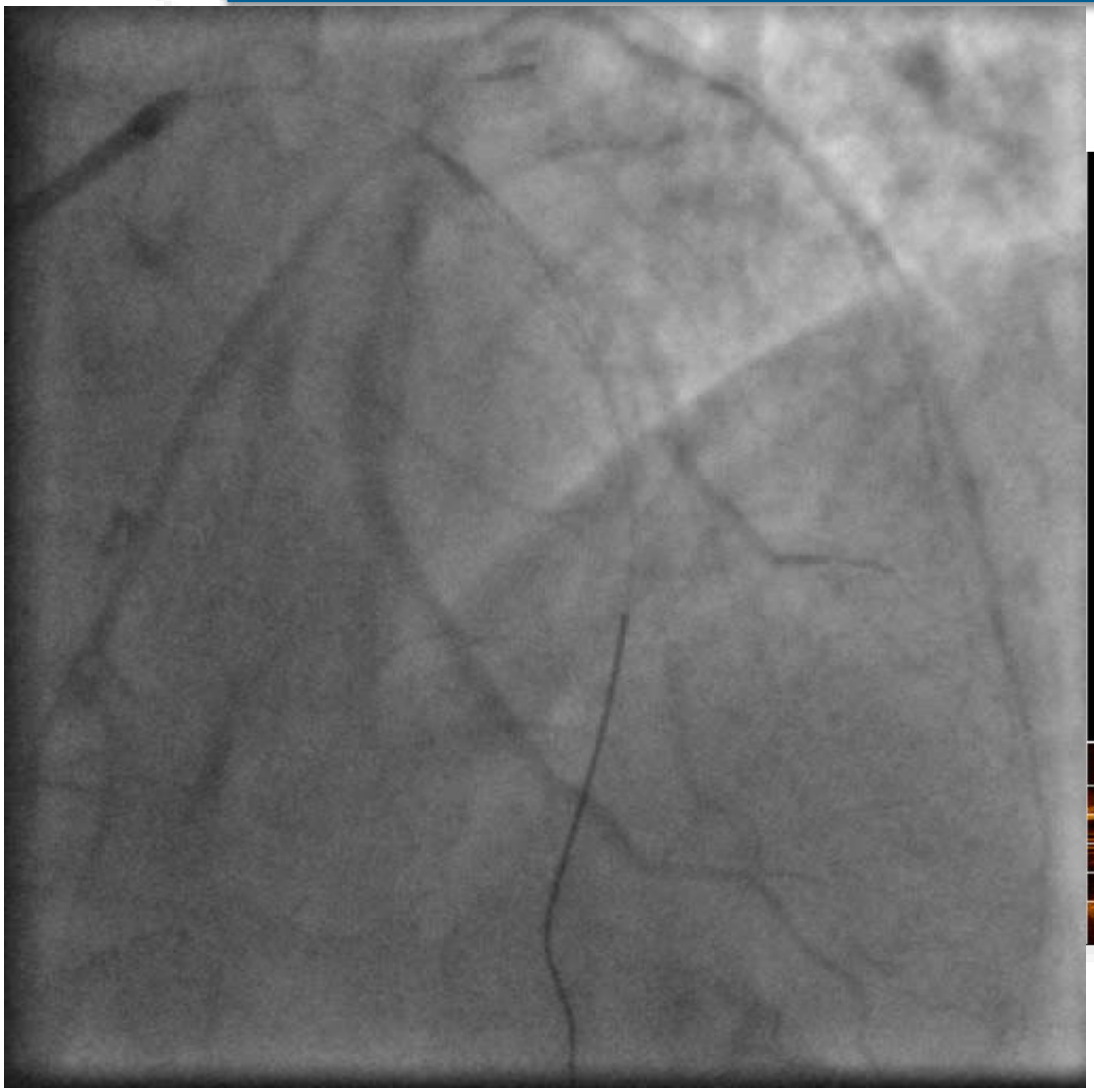


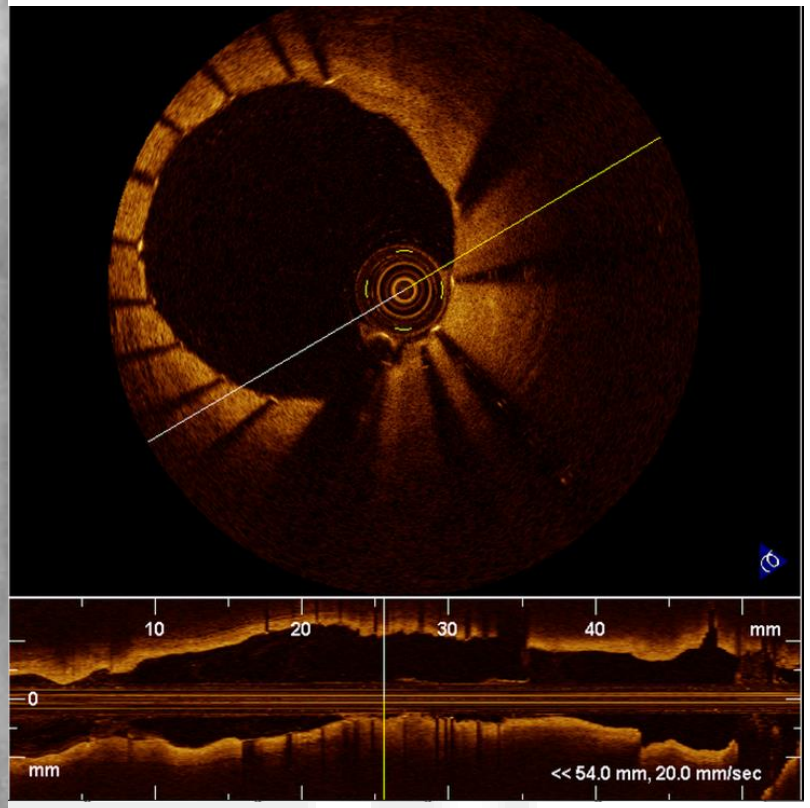





WL: 127 WW: 255
AS
RS
LI
PI
OSIRIX

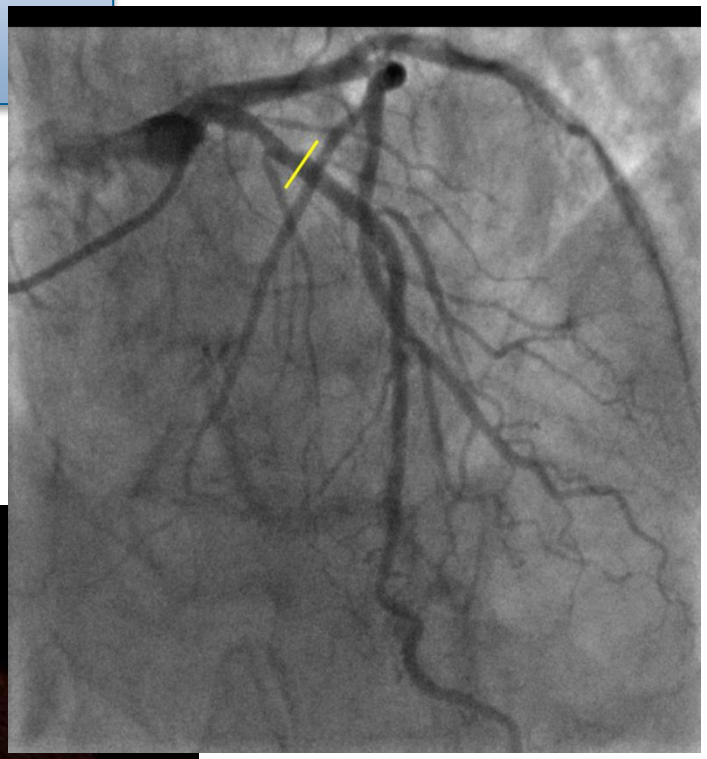
Interventional Management

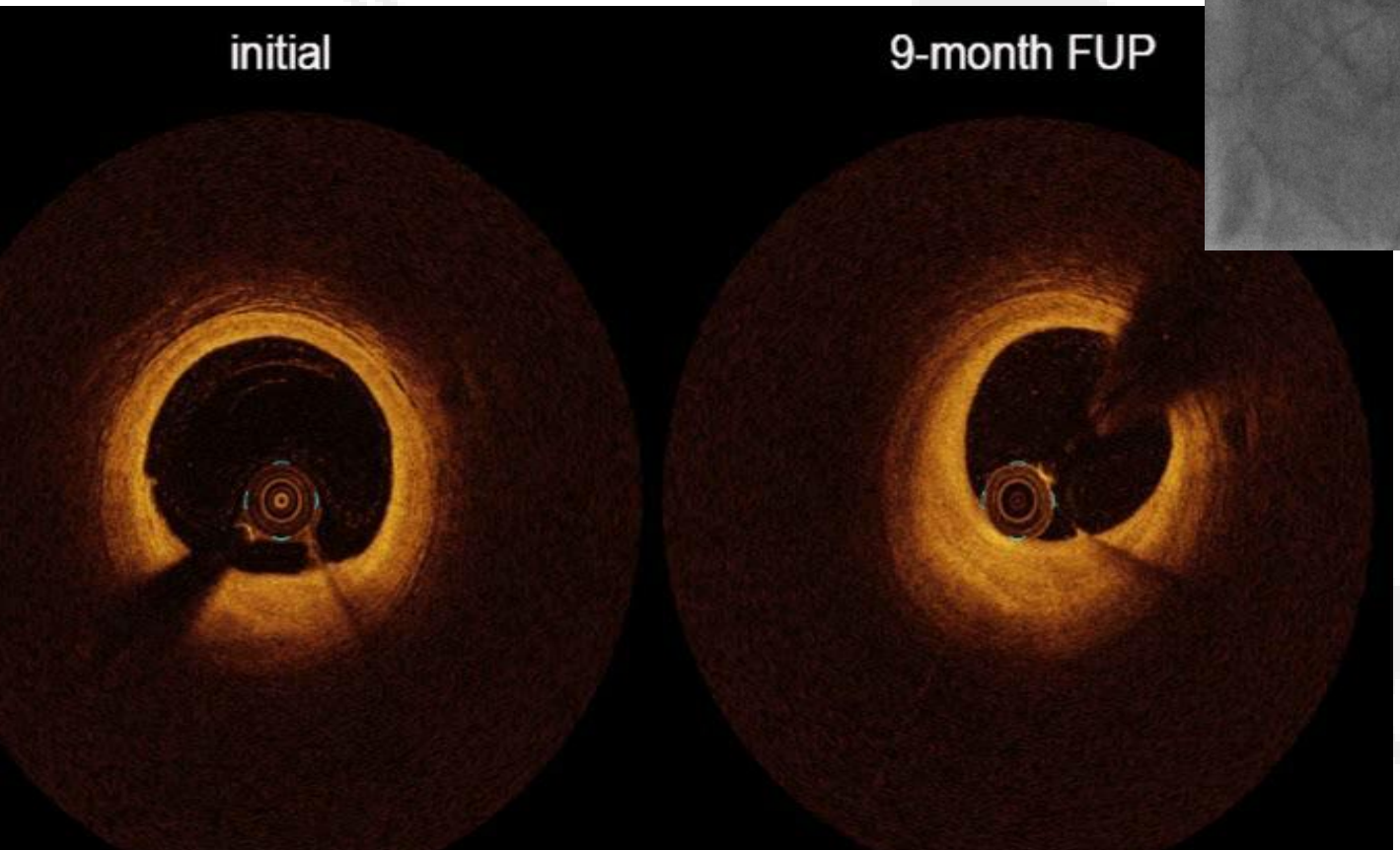


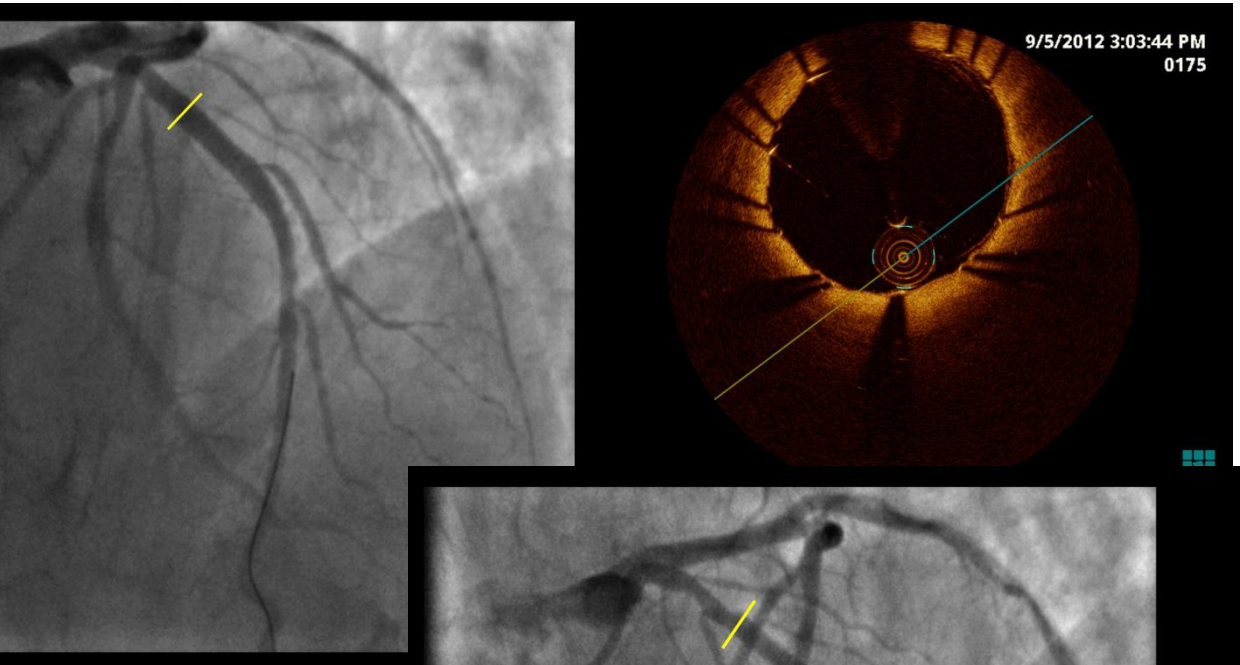


ine-month follow-up

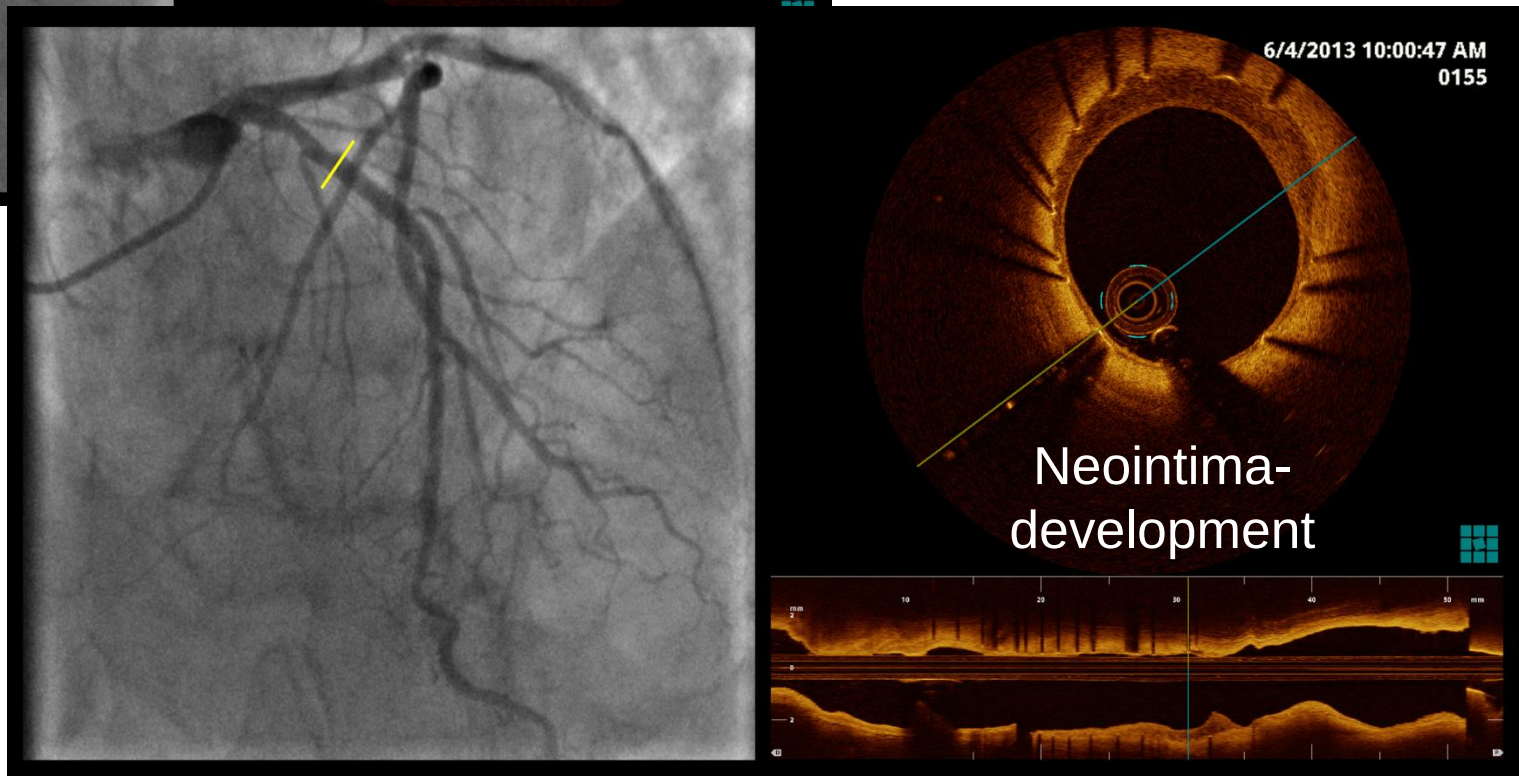
Patient is free of angina







Neo-
atherosclerosis ?



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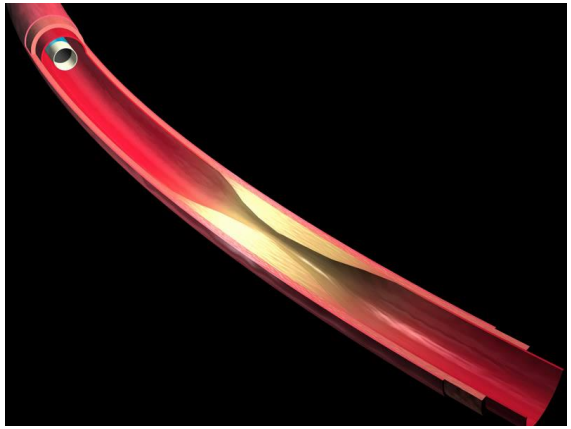
Optical Coherence Tomography (OCT) in coronary arteries



Today – 2019: Reliable Diagnostic Tool !

- Extremely fast (a couple of seconds!)
- Reliable
- Provides a clear answer
- User-independent
- Superior to angiograpy
- All relevant quantitative/qualitative data
- As physician, I can focus on therapy!