LAMELIS 2017
Lasers in Medicine and Life Sciences

Application of optical coherence tomography in coronary interventions

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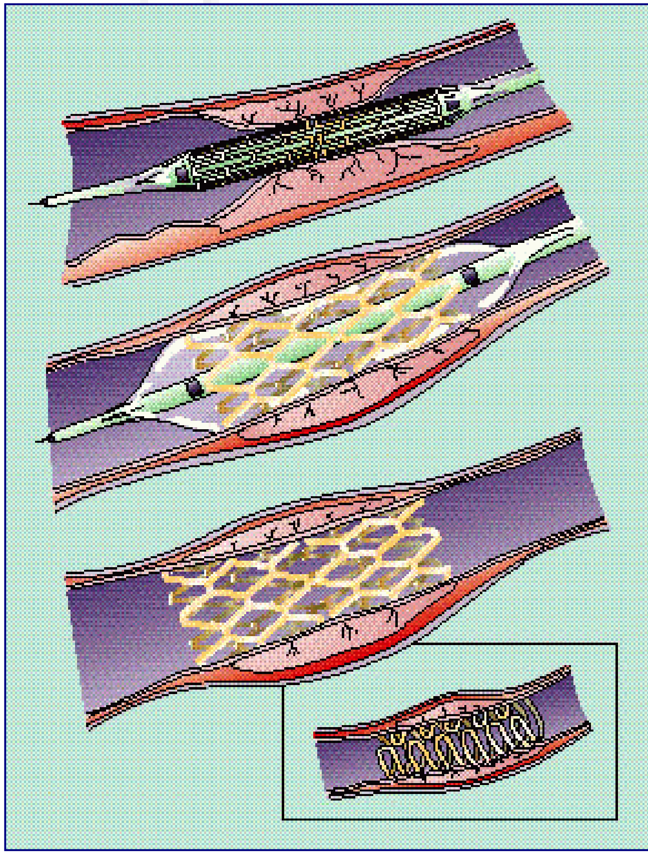
University of Szeged
Where knowledge and challenge meet

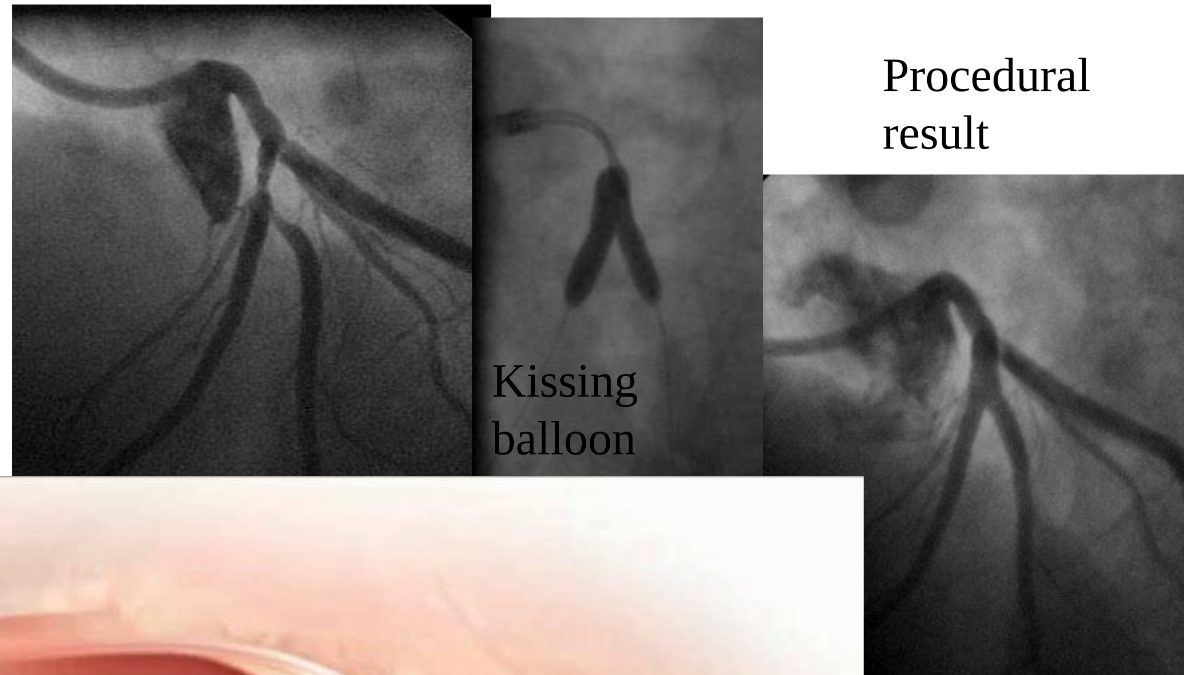
Laserlab Europe

eli attosecond

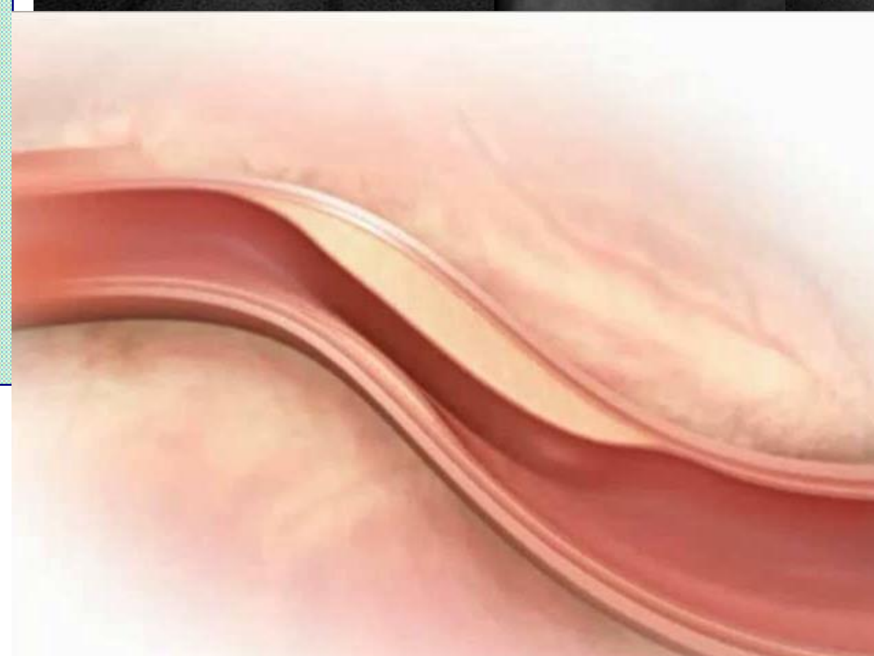
HUNGARIAN BIOPHYSICAL SOCIETY

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

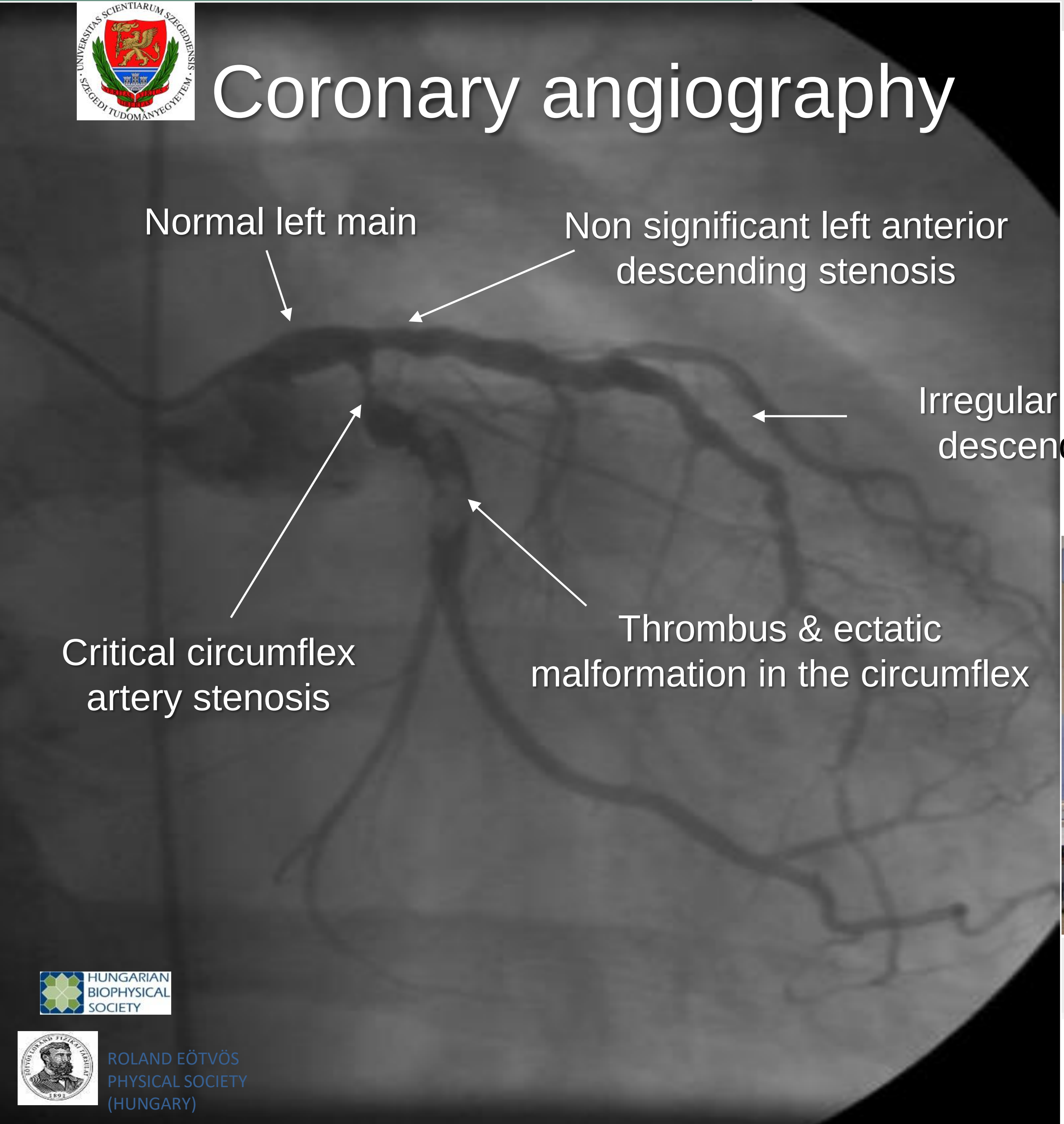


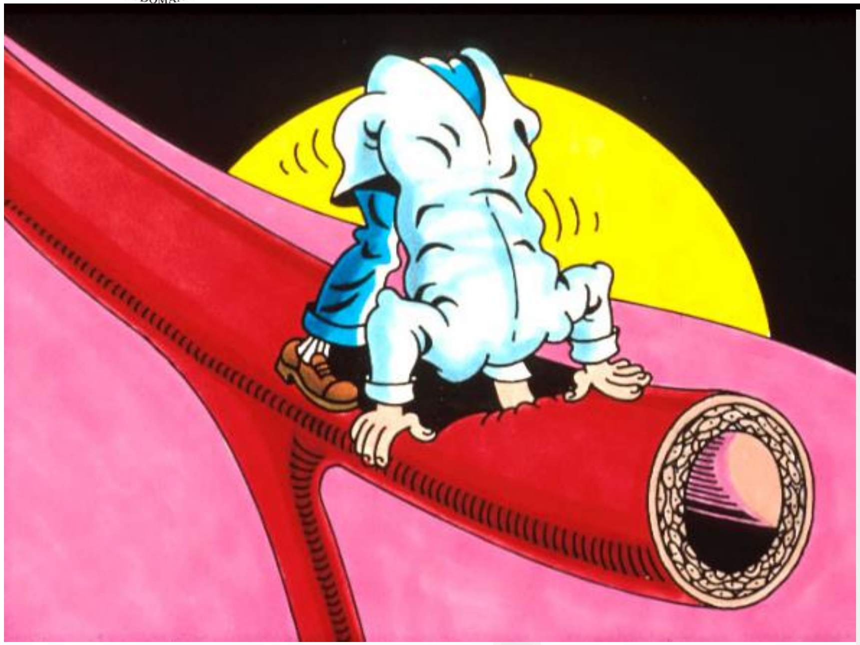


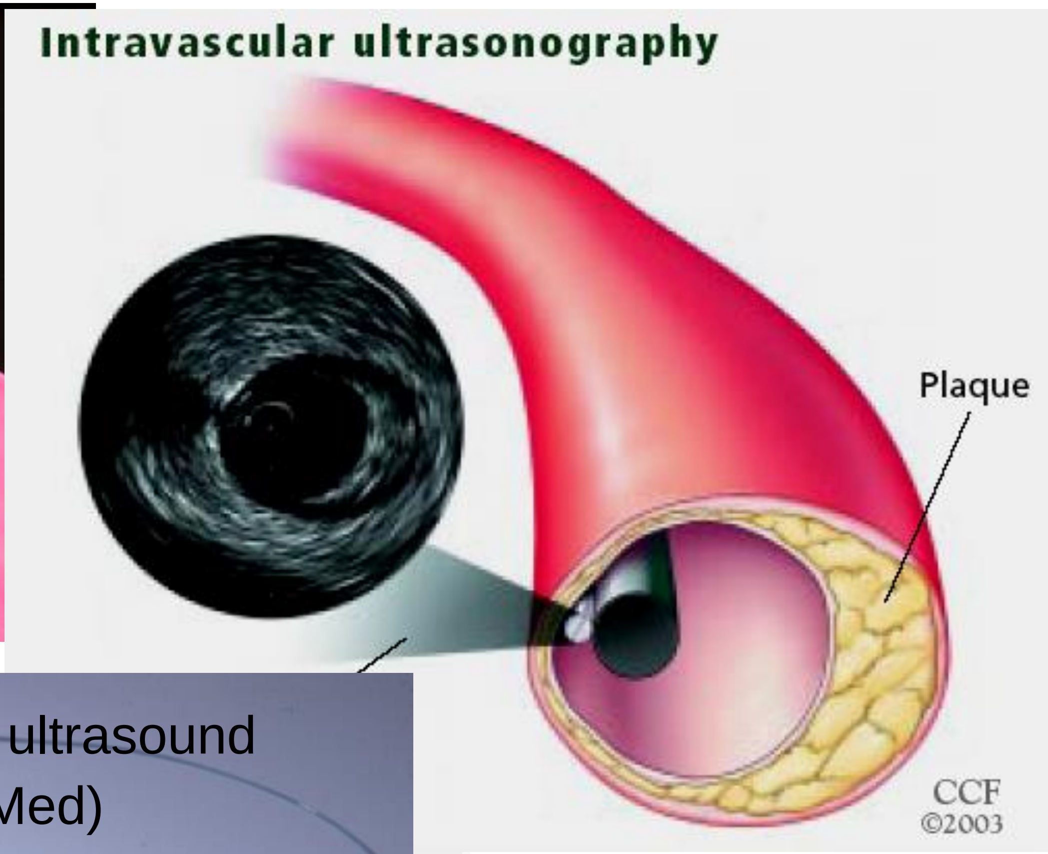
Procedural
result

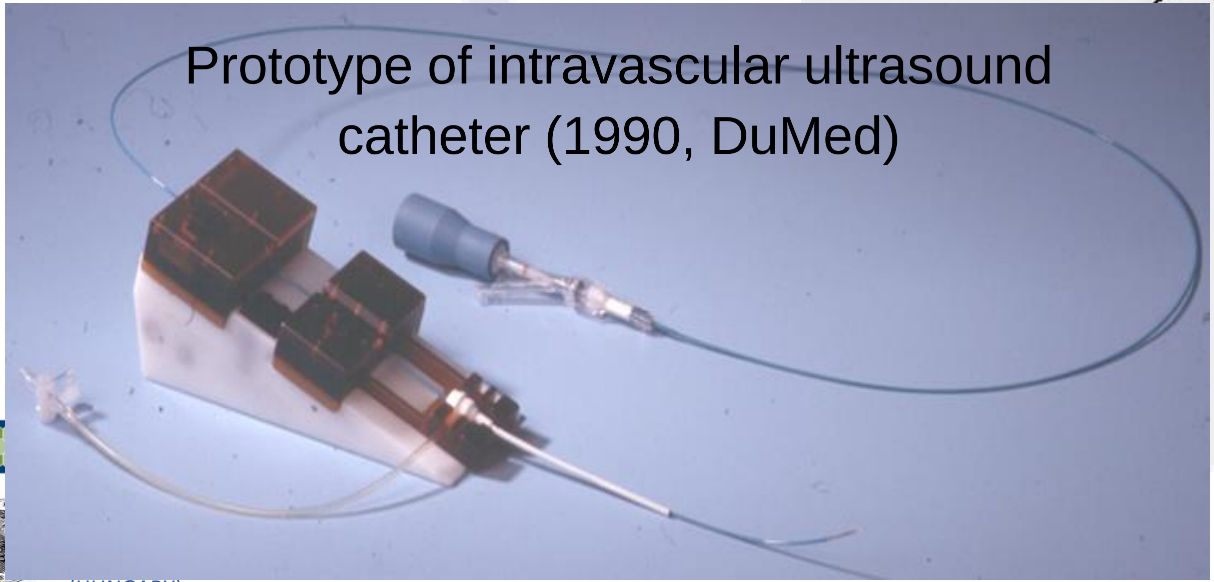


Coronary angiography

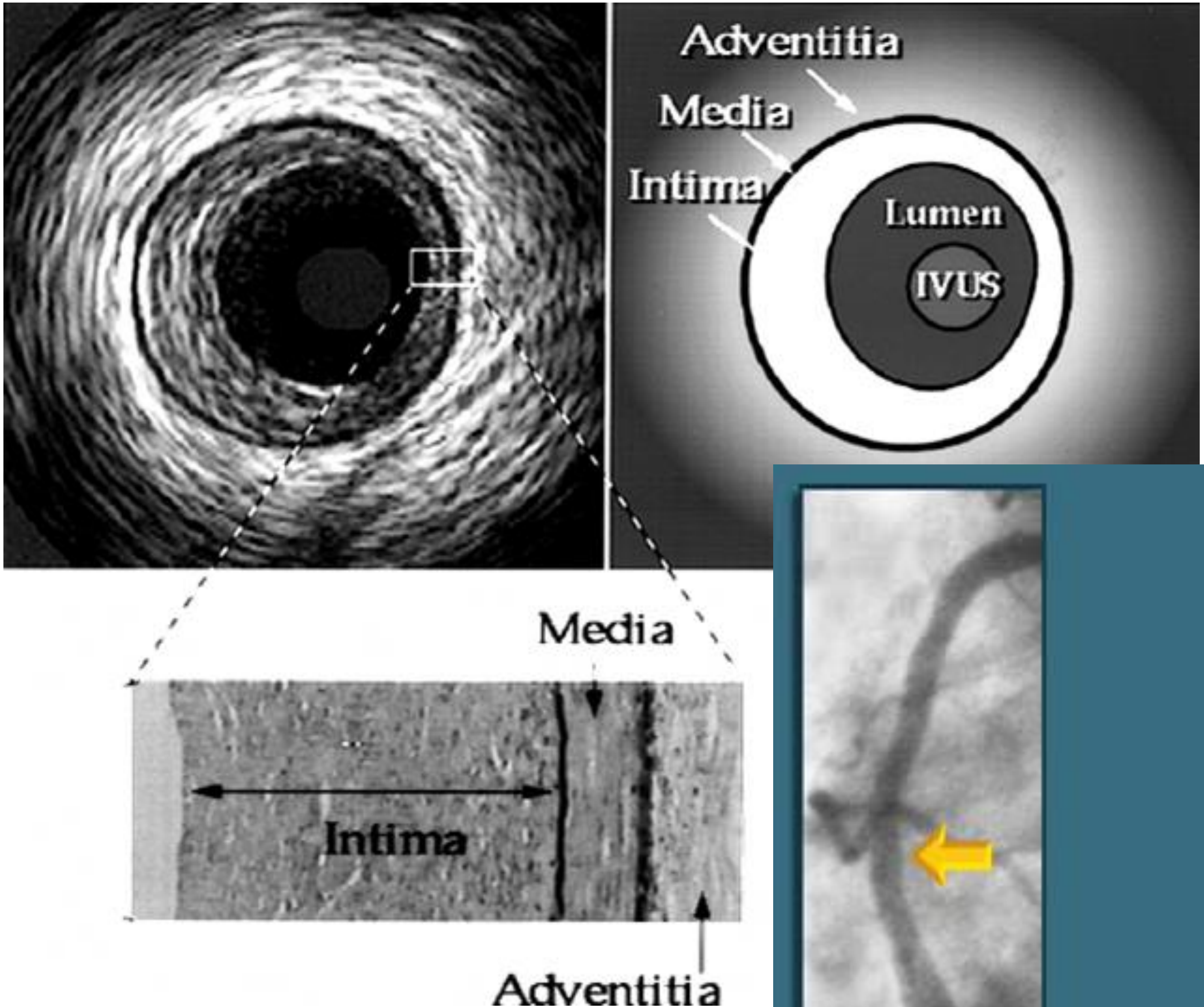


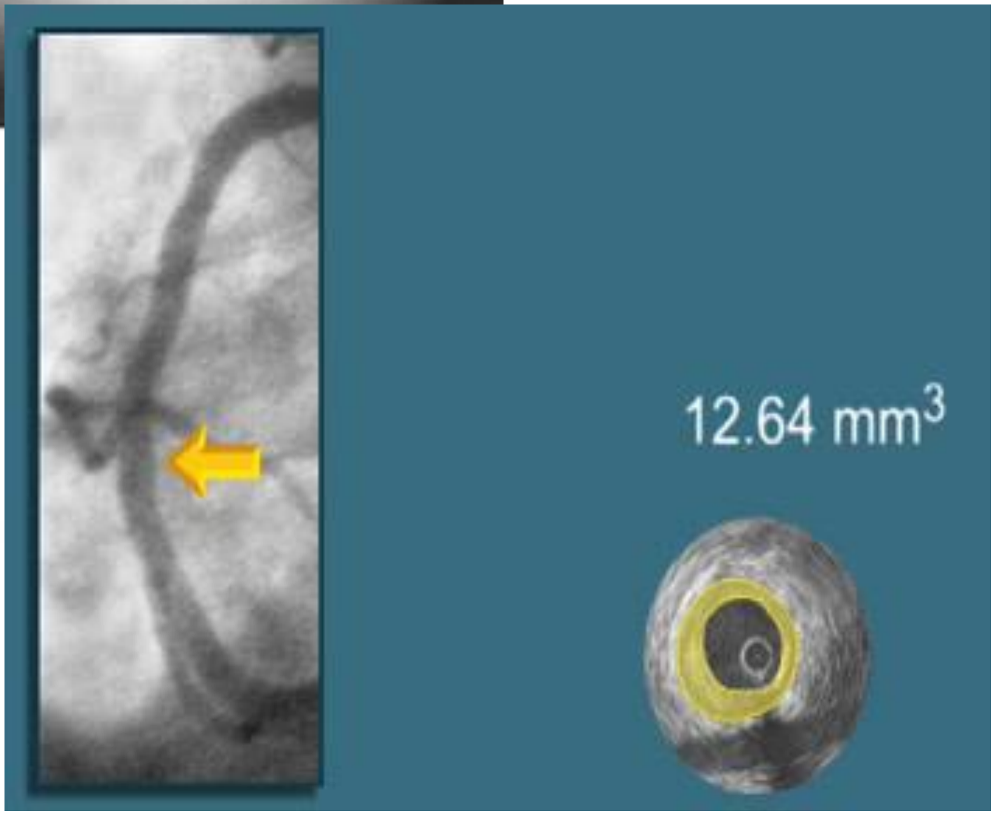



Intravascular ultrasonography
Plaque
CCF
©2003


Prototype of intravascular ultrasound
catheter (1990, DuMed)

(HUNGARY)


Adventitia
Media
Intima
Lumen
IVUS
Media
Intima
Adventitia


12.64 mm3

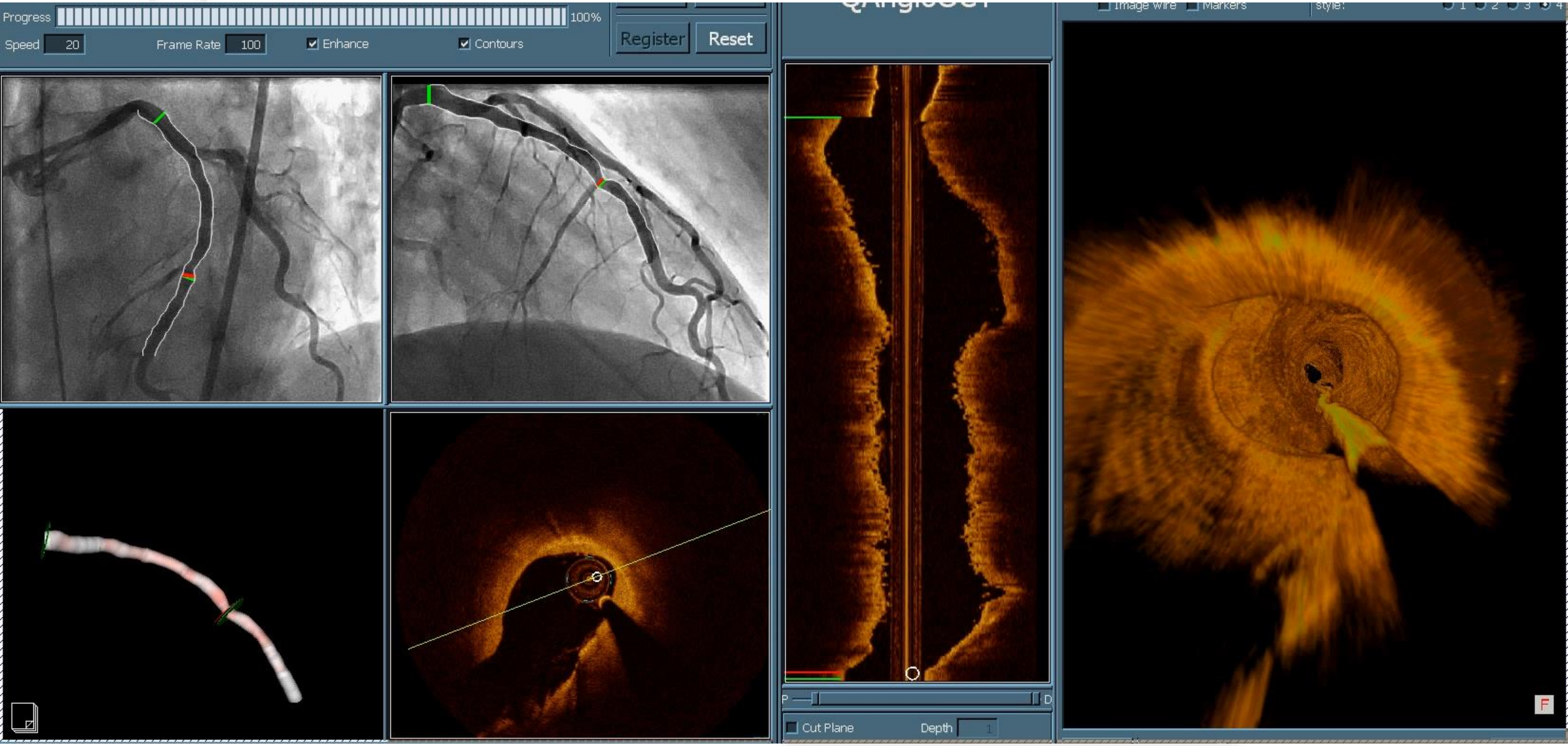
Intracoronary imaging & physiology in ESC guideline 2014

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	702,703,706
IVUS to assess severity and optimize treatment of unprotected left main lesions.	IIa	B	705
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

Optical Coherence Tomography (OCT) in coronary arteries

Today’s State of the Art - 2017



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

Evolution of intracoronary OCT imaging

PB speed 1.0mm/s → 3.0mm/s → 40.0mm/s

1991

2002 Through balloon

2004 ImageWire "occlusive"

2007 ImageWire "non-occlusive"

2008

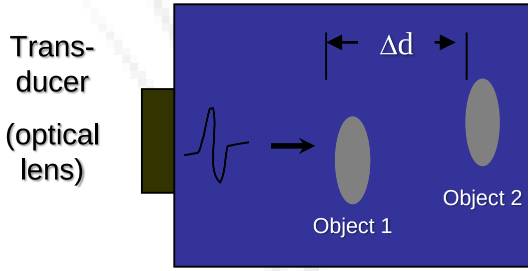
2nd Generation OCT

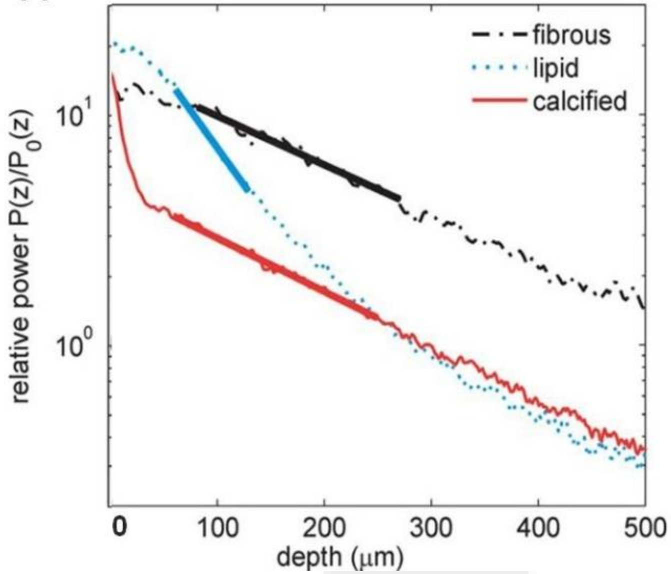
Fourier Domain OCT

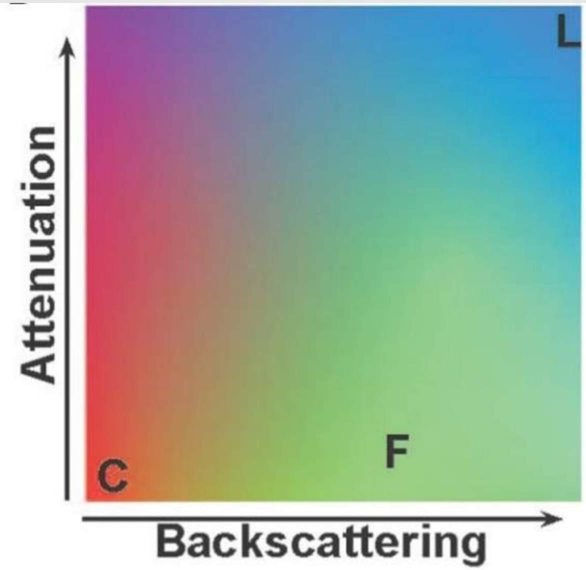
(OFDI/Frequency/Spectral Domain/Swept Source)

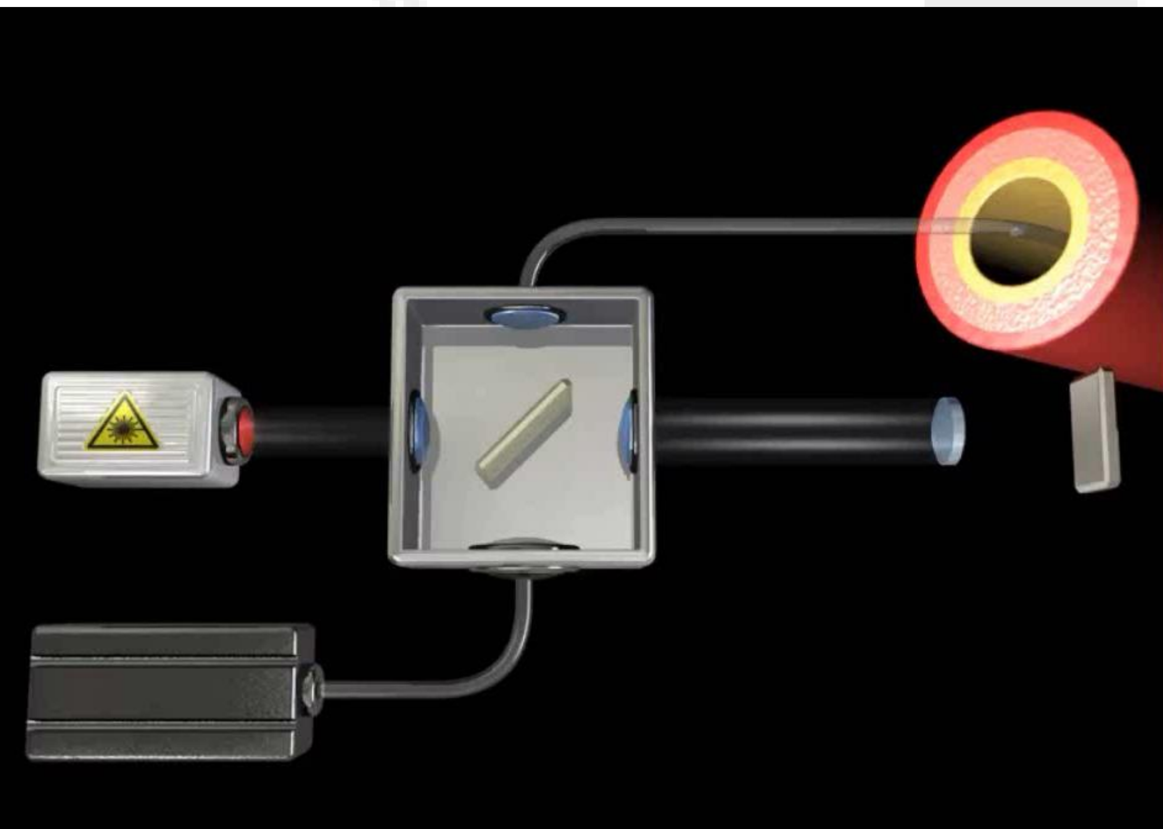
Monorail Imaging Catheter

Non-Occlusive

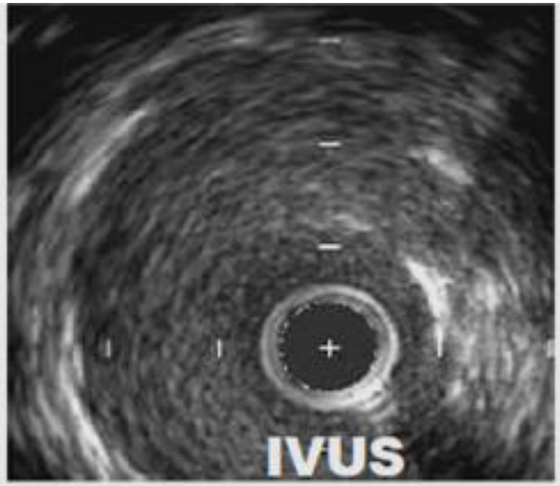

Trans-
ducer
(optical
lens)
Δd
Object 1
Object 2

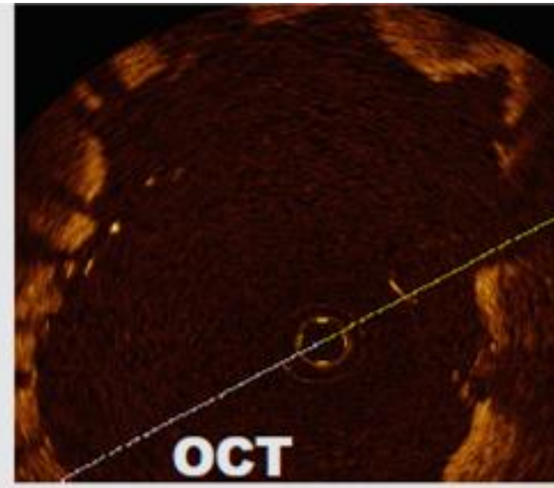

fibrous
lipid
calcified
relative power P(z)/P0(z)
10^1
10^0
0
100
200
300
400
500
depth (μm)


Attenuation
Backscattering
L
C
F



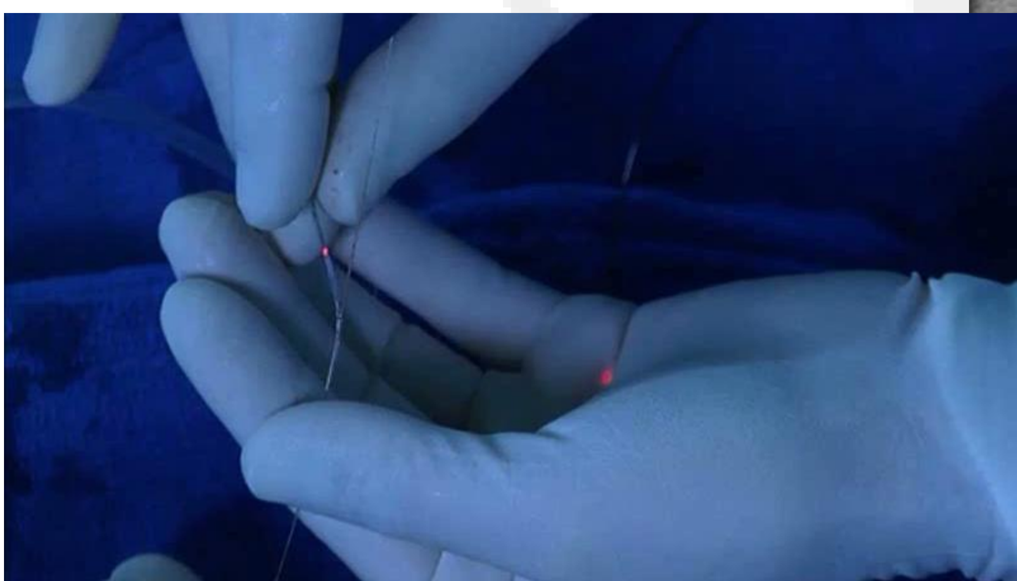

Low signal
High signal

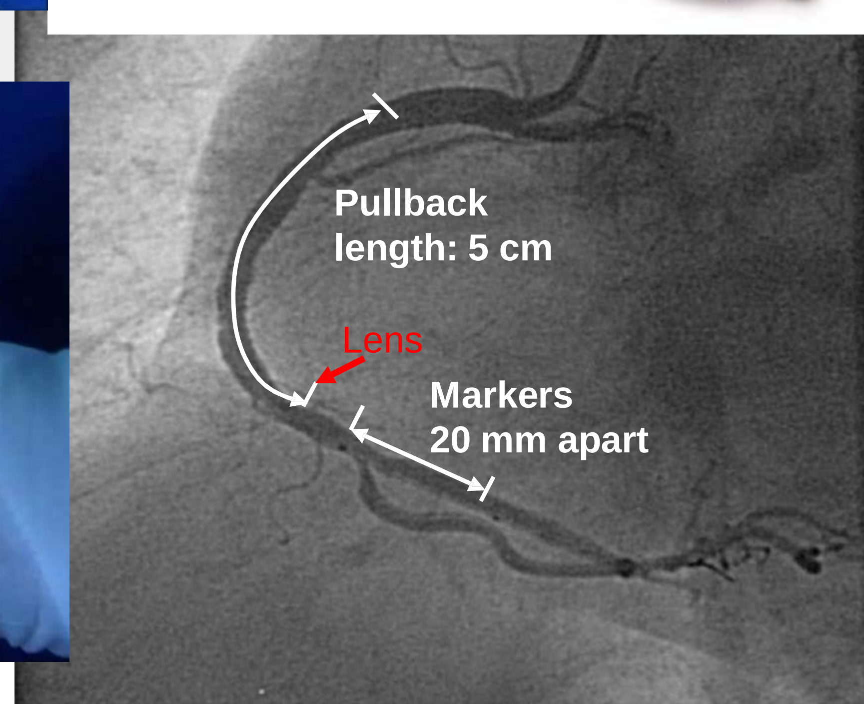




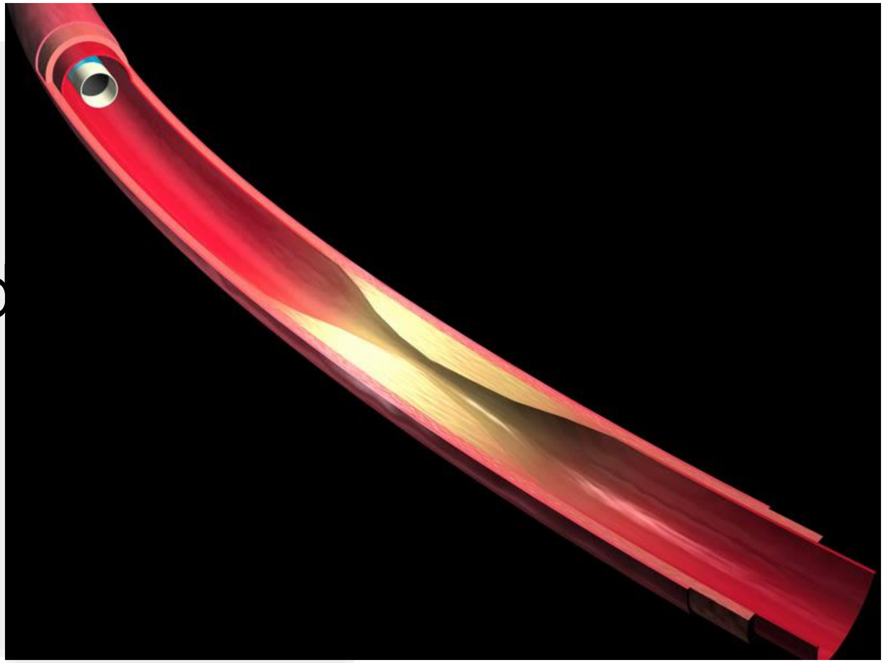
	IVUS	OCT
Dynamic range	40-60dB	90-110dB
Resolution (axial)	100-150μm	10-15μm
(lateral)	150-300μm	25-40μm
Penetration (tissue)	4-8mm	1.5mm
Frame rate	30/sec	100/sec
Pull-Back Speed	0.5-1.0mm/sec	20mm/sec
Wire artefacts	++	+

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

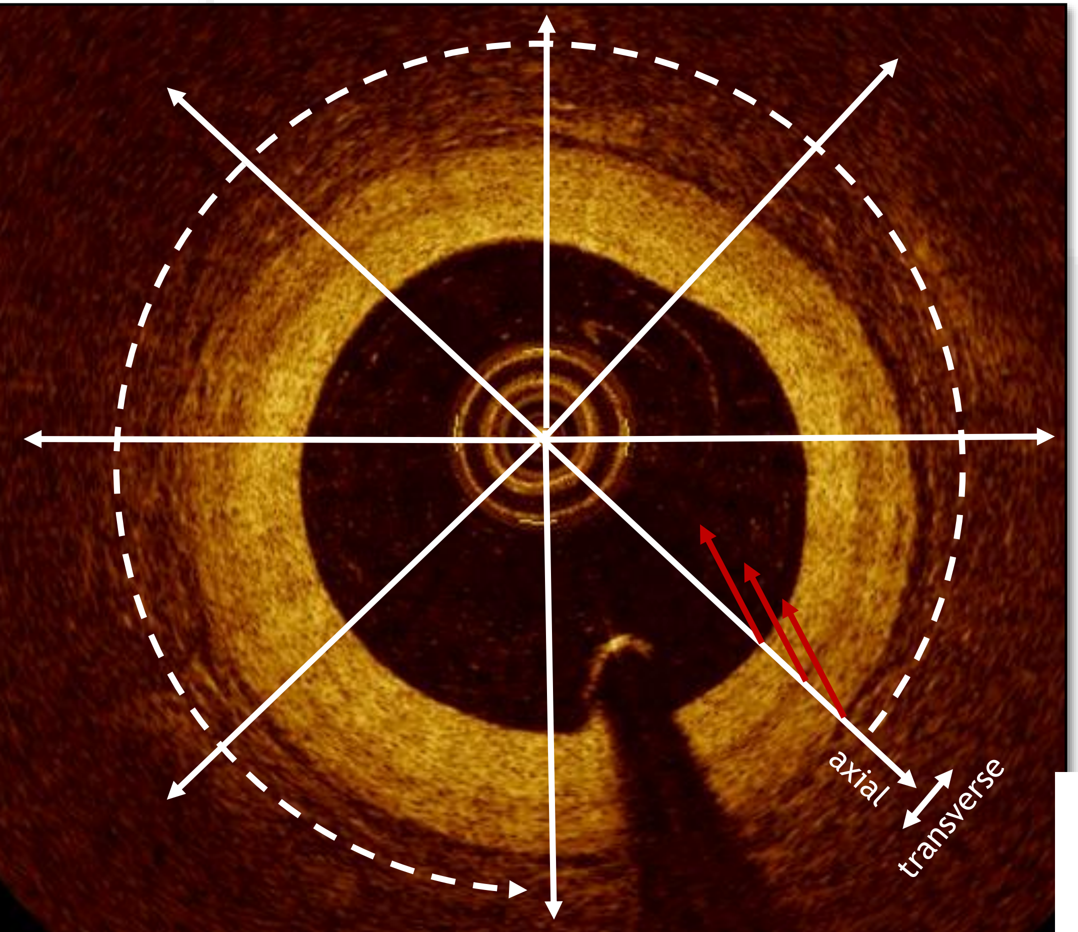
Guidewire of choice!

Sleek OCT catheter!

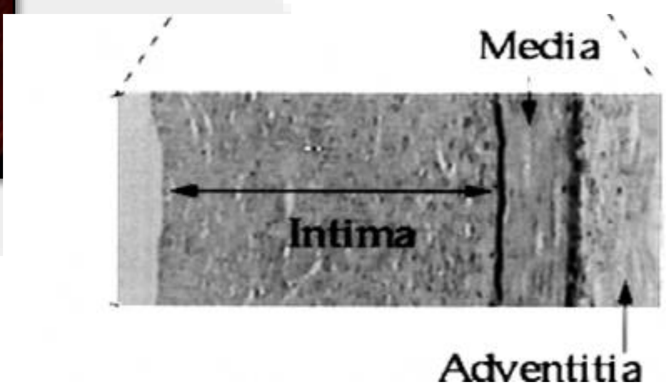
Imaging within 3 seconds

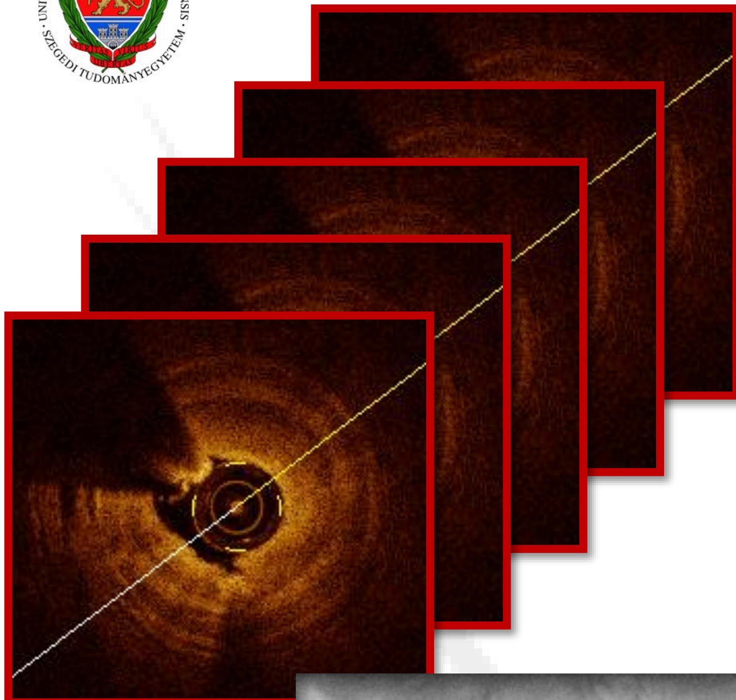
Limited contrast ~ 15ml

Image Generation

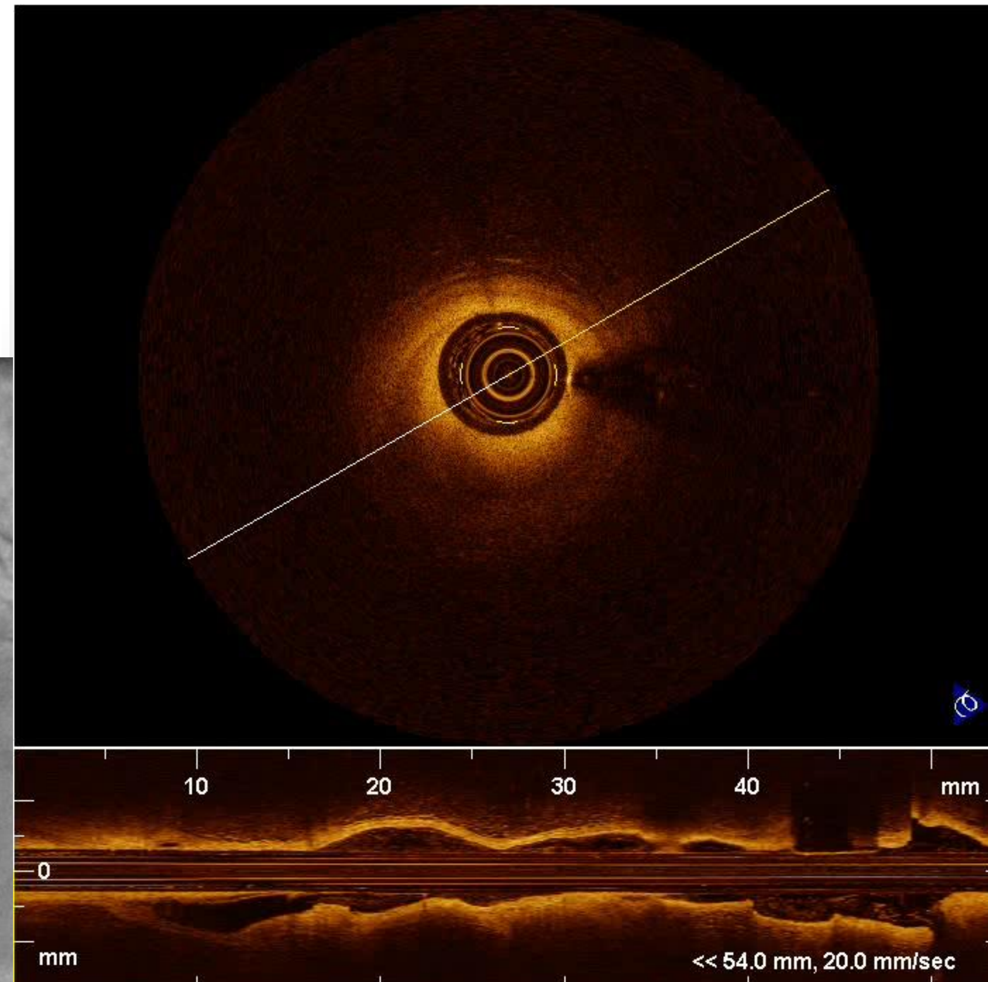


- Measure echo time delay of reflected light waves
- One pixel → 5 x 19 um
- One axial line → 1024 pixels
- One frame → 500 axial lines
- *Optical resolution → 15 axial, 20 to 40 um transverse*





Pullback – image generation



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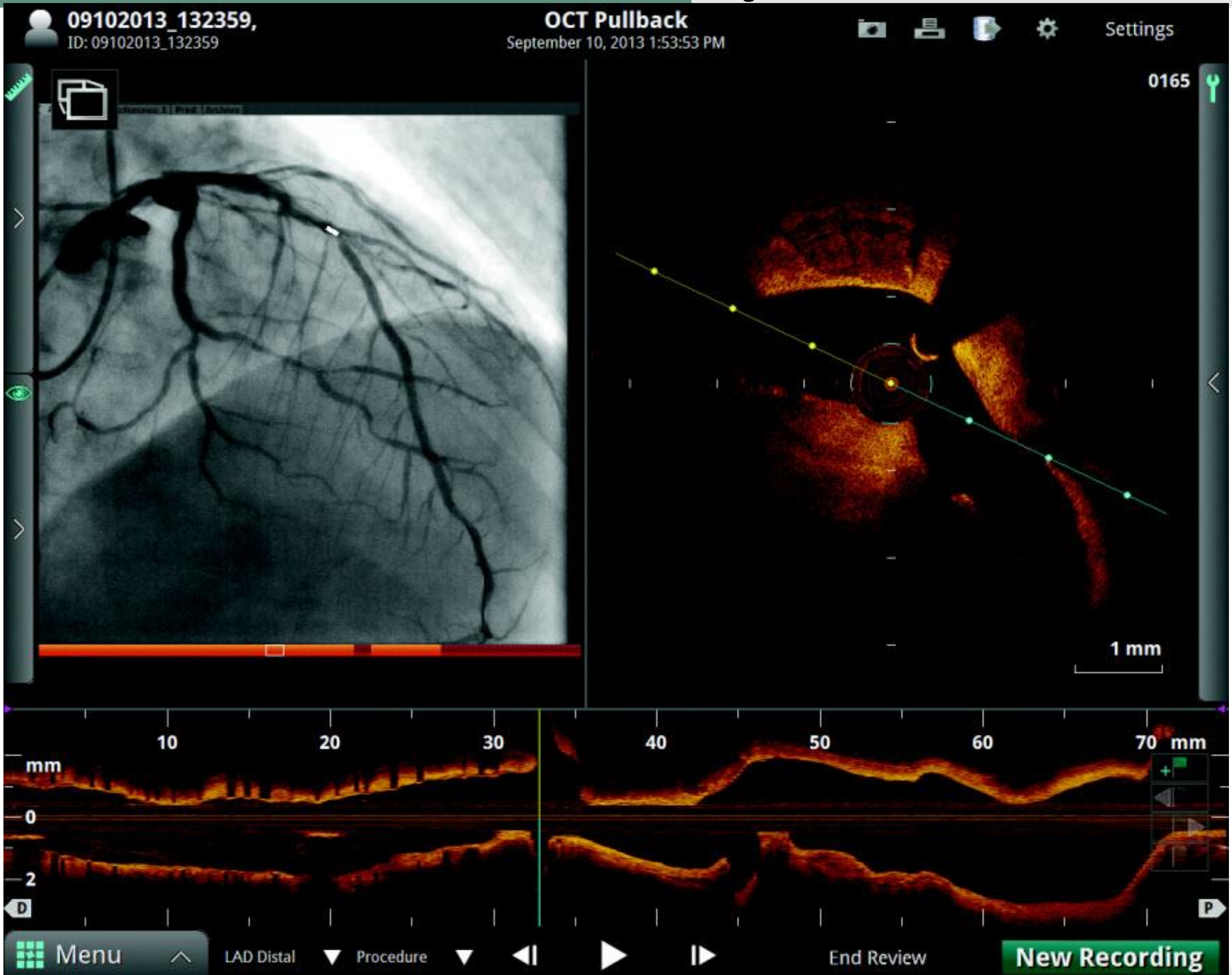

"B-Mode" cross-sectional view

"L-Mode" longitudinal view

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

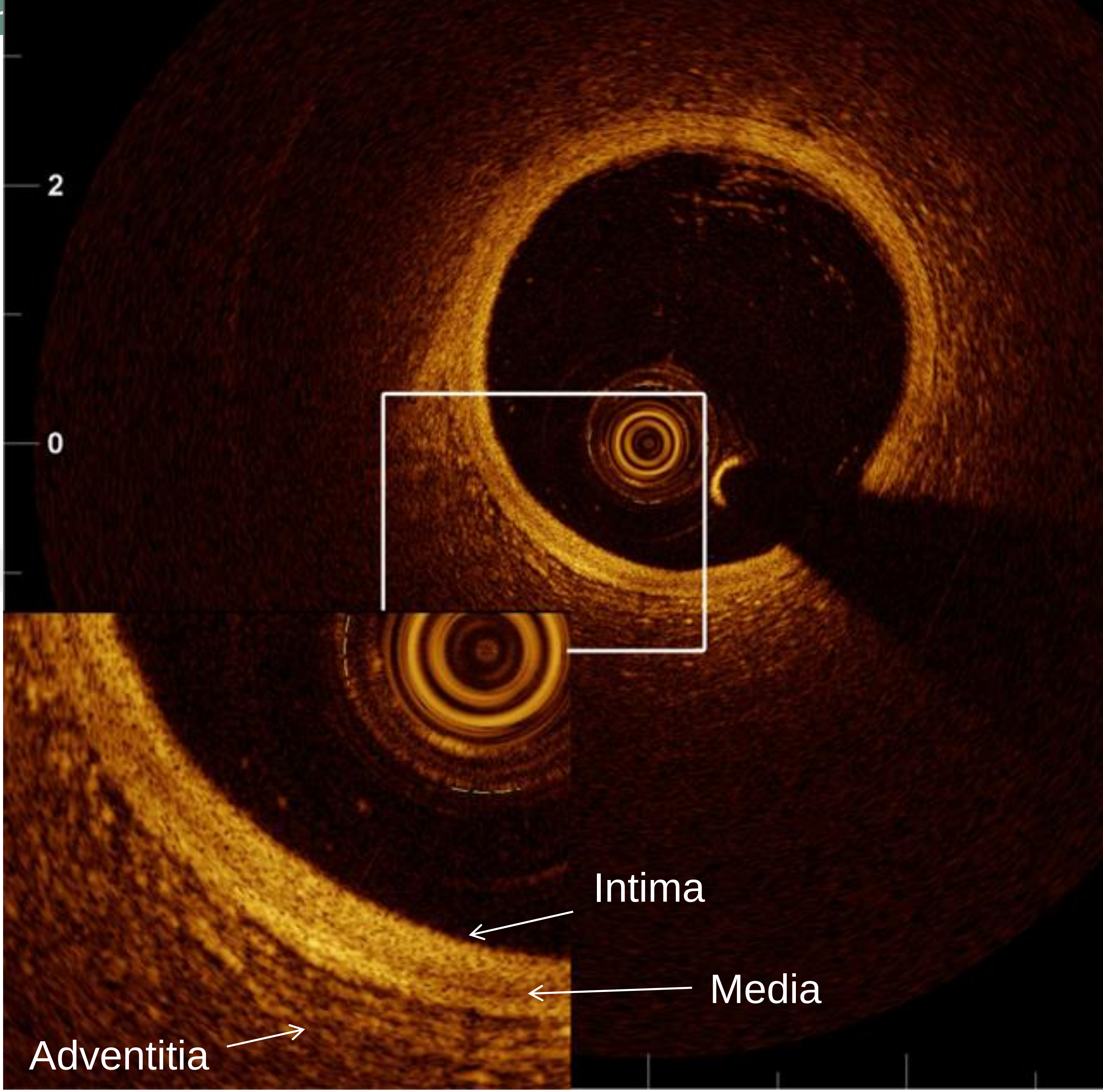

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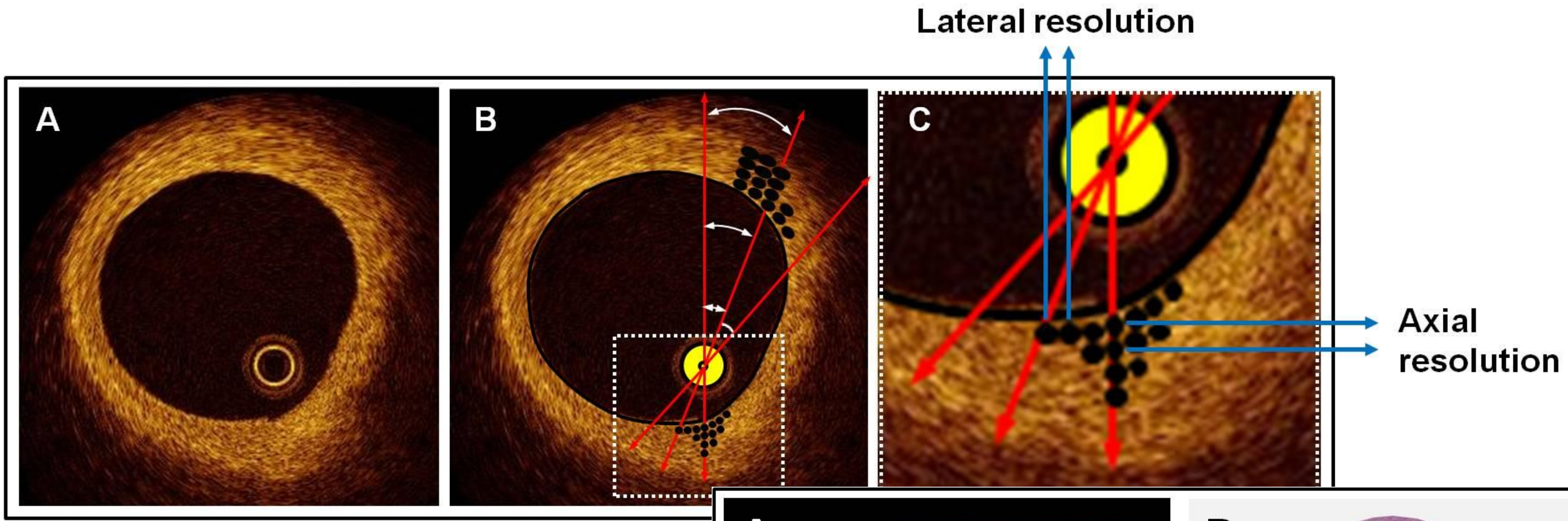
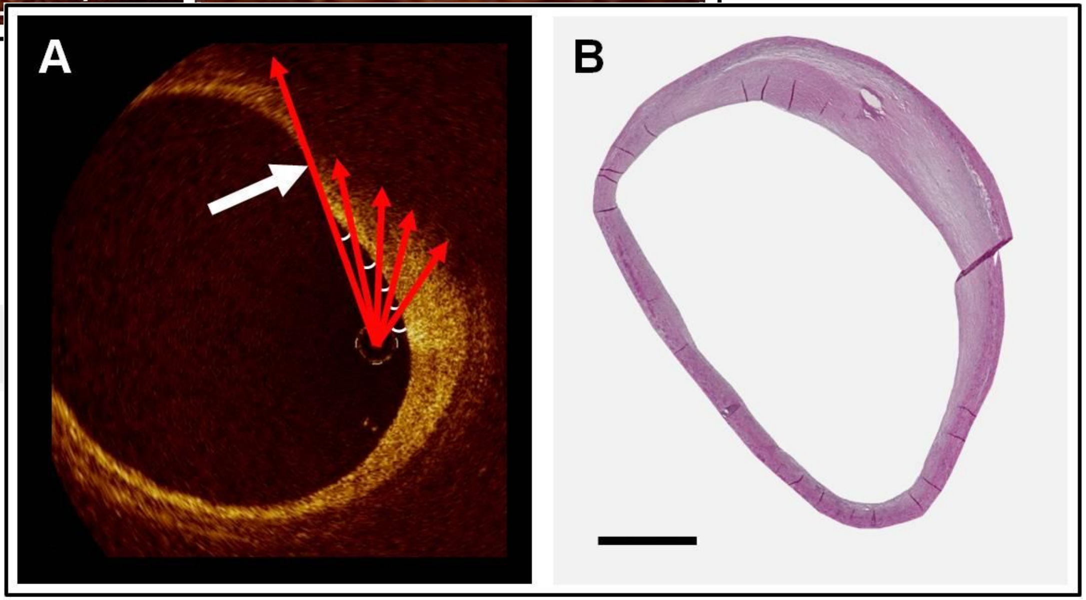
Image: pitfalls and potential artefacts



Tangential signal drop-out



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Today – 2017: 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

OPINION
doi:10.1093/eurheartj/ehs095

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], ...e Motreff[17], Fernando Alfonso[18], Kostas Toutouzas[19], Nieves Gonzalo[20], ...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

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doi:10.1016/j.jacc.2011.09.07...

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

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Neil J. Weissman, MD, Giora Weisz, MD
Boston, Massachusetts; Rotterdam, the Netherlands; and Wakayama, Japan

EHJ 2010 & 2012

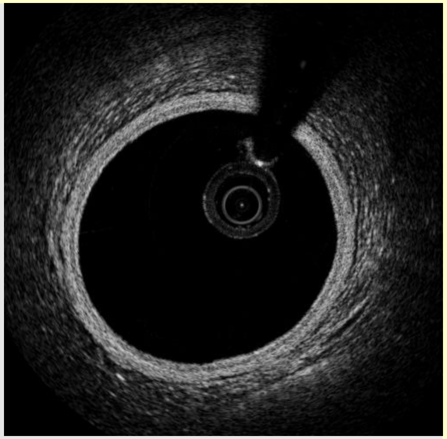
J Am Coll Cardiol. 2012

Optical Coherence Tomography (OCT)

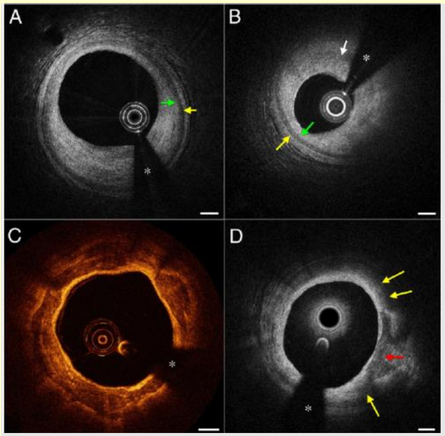
Today – 2017: Reliable Diagnostic Tool !

High Evidence Level

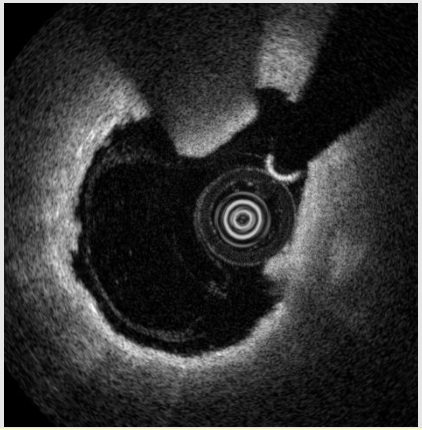
Normal vessel wall



Atherosclerosis



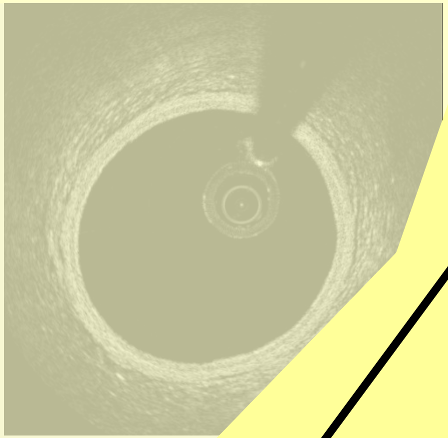
Thrombus



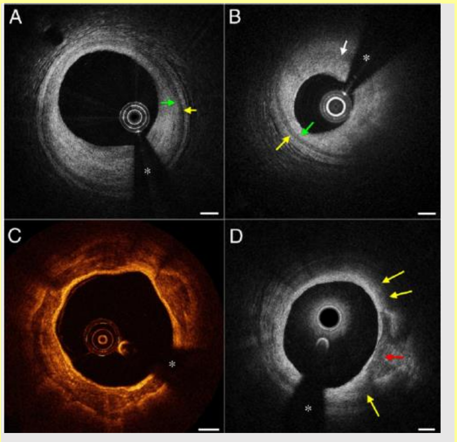
J Am Coll Cardiol. 2012

High Evidence Level

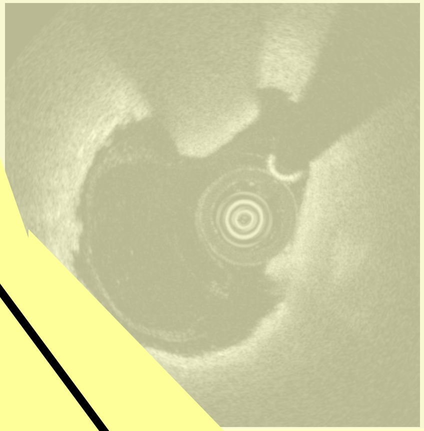
Normal vessel wall



Atherosclerosis



Thrombus



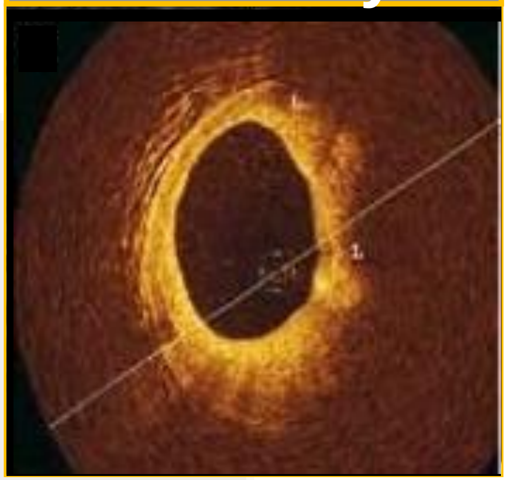
Fibrous Fibrocalcific Lipid pool Fibrous cap Rupture

J Am Coll Cardiol. 2012

2. Assess Plaque Composition

Fibrous

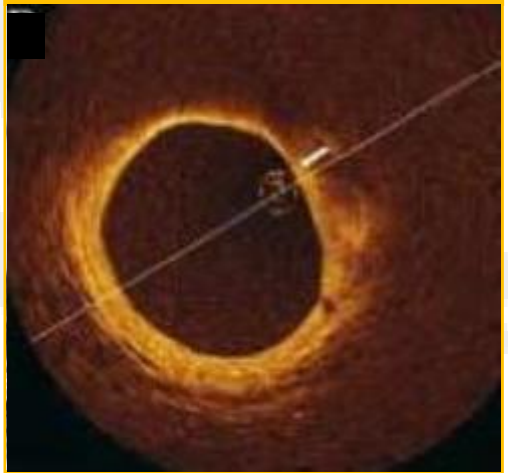
Fibro-Fatty



Calcific

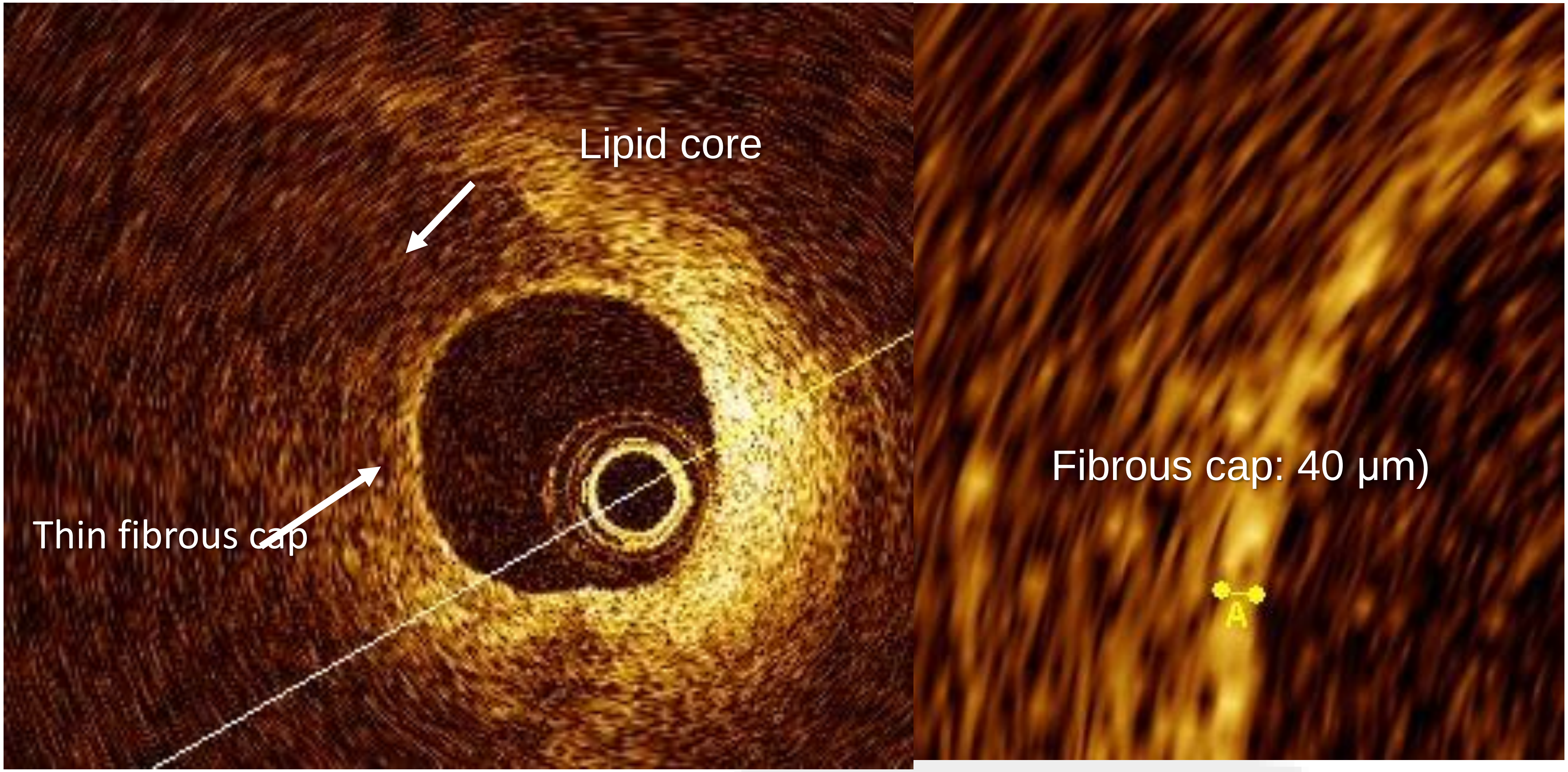
Rotablator

Necrotic Core



- Cutting Balloon
- High Pressure

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



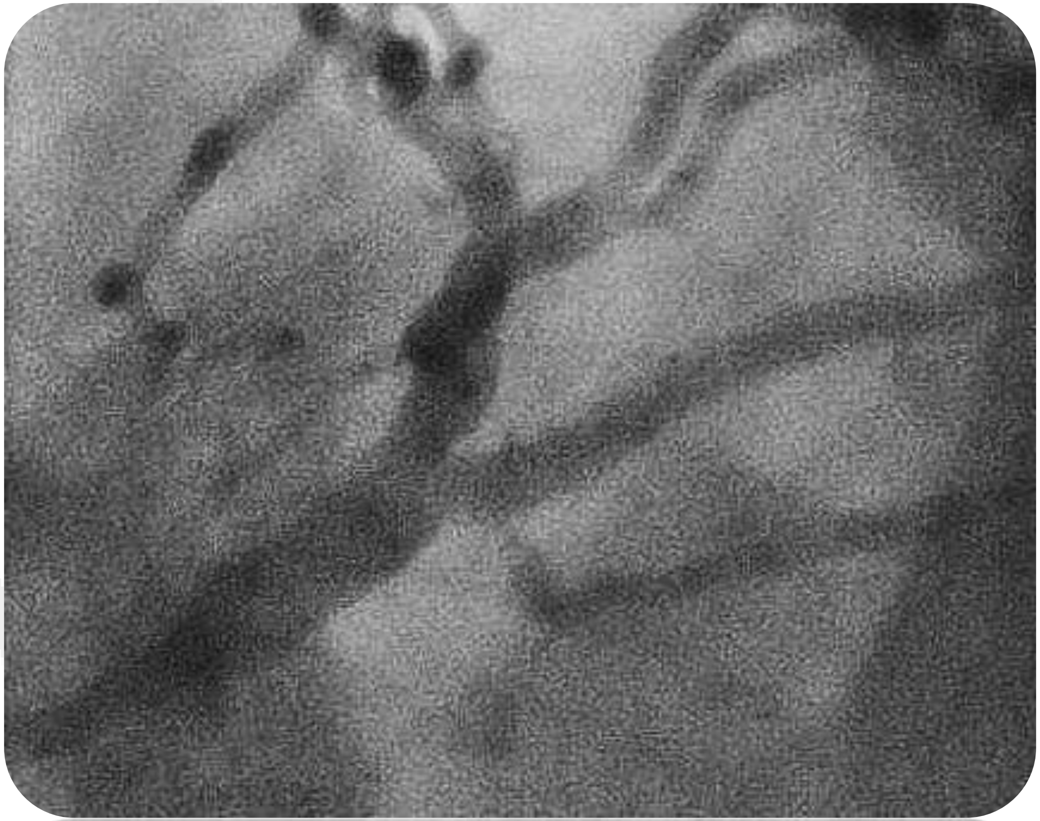
TCFA: lipid-rich atheroma with thin (< 65 μm) fibrous cap

Optical Coherence Tomography (OCT)

Today – 2017: Reliable Diagnostic Tool !

OCT is superior to angiography in LM

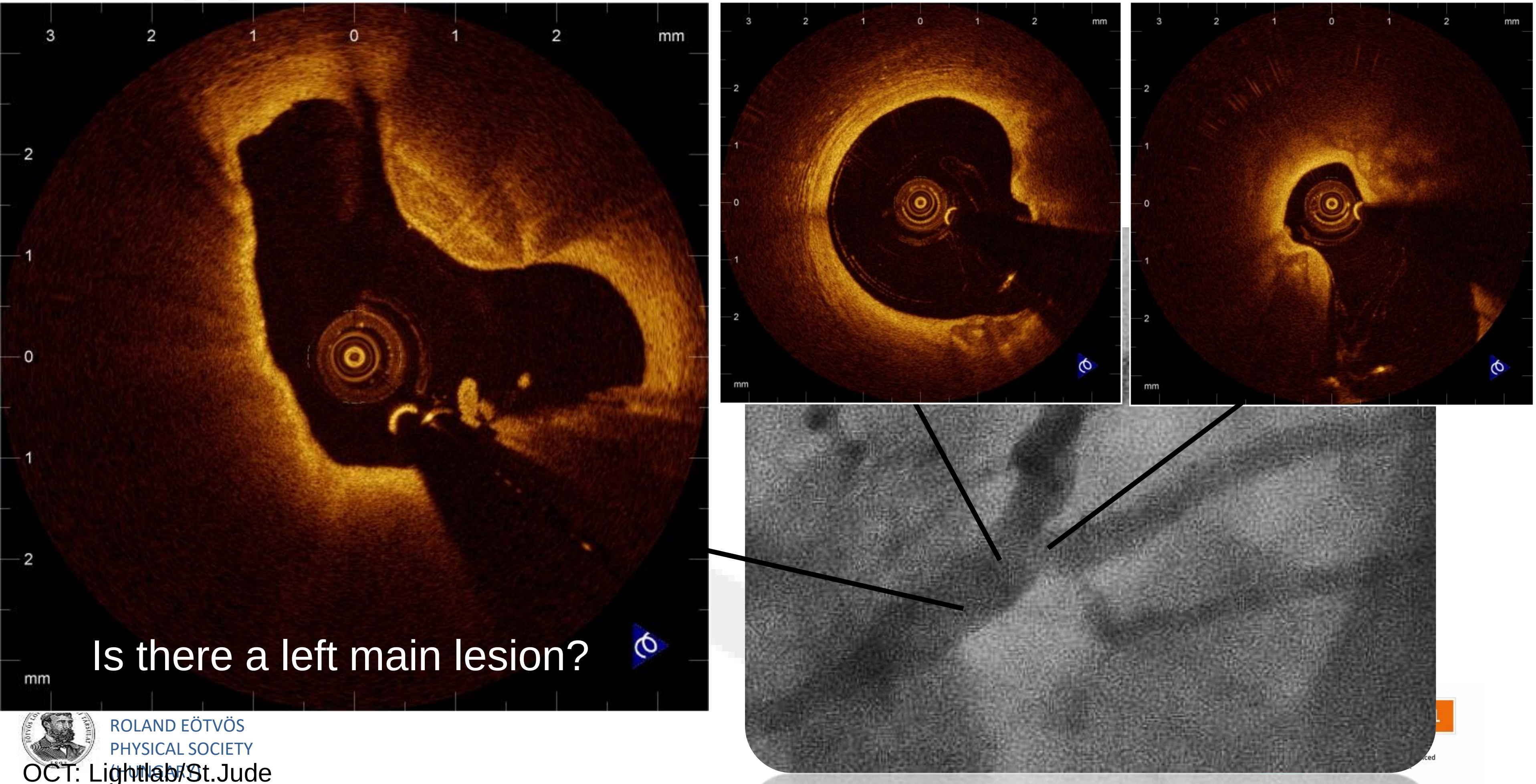
Is there a left main lesion?



OCT: Lightlab/St.Jude

Today – 2017: Reliable Diagnostic Tool !

OCT is superior to angiography in LM



OCT: Lightlab/St.Jude

Today – 2017: Reliable Diagnostic Tool !

OCT is superior to angiography

Left Main stem lesions
Complex lesions

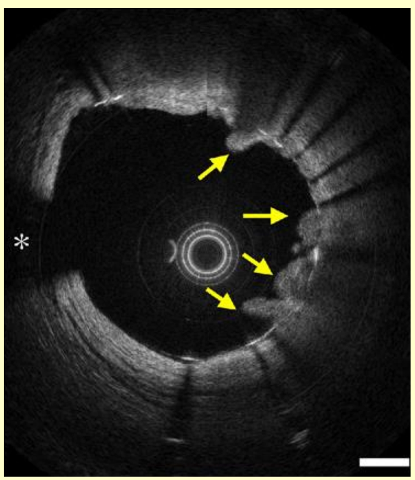
OCT is prognostic in stenting

Periprocedual complications
Clinical outcome ?

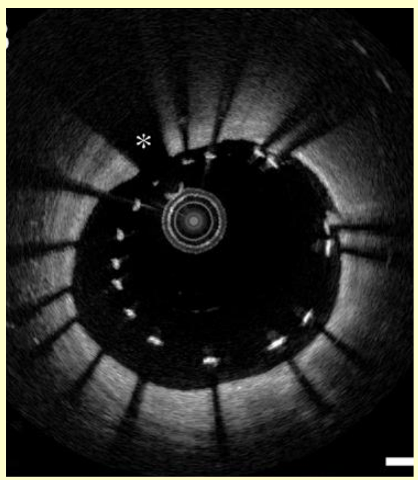
Today – 2017: Guidance in PCI (after stenting)

High Evidence Level

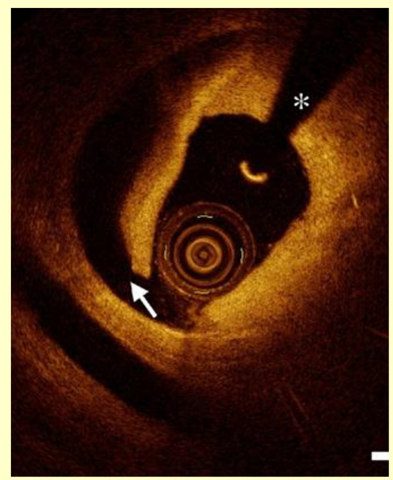
Prolapse



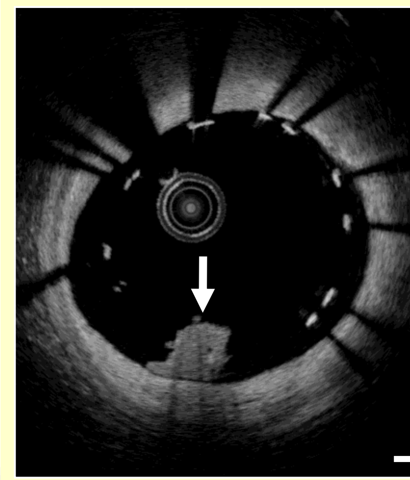
Apposition Malapposition



Dissection



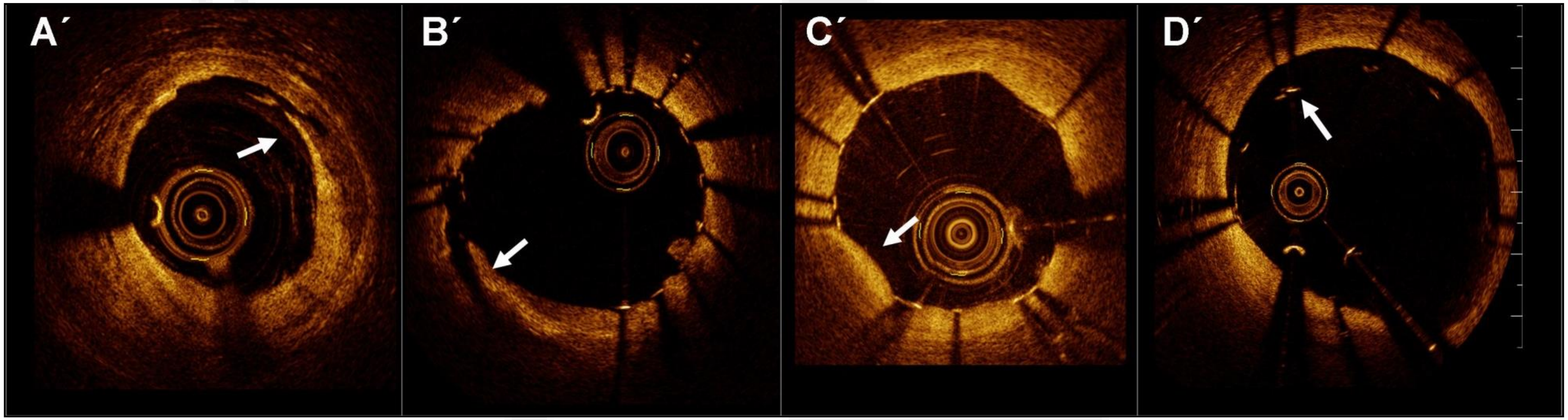
Thrombus



J Am Coll Cardiol. 2012

Today – 2017: Guidance in PCI (after stenting)

Suboptimal acute stent result is frequent and missed by angiography



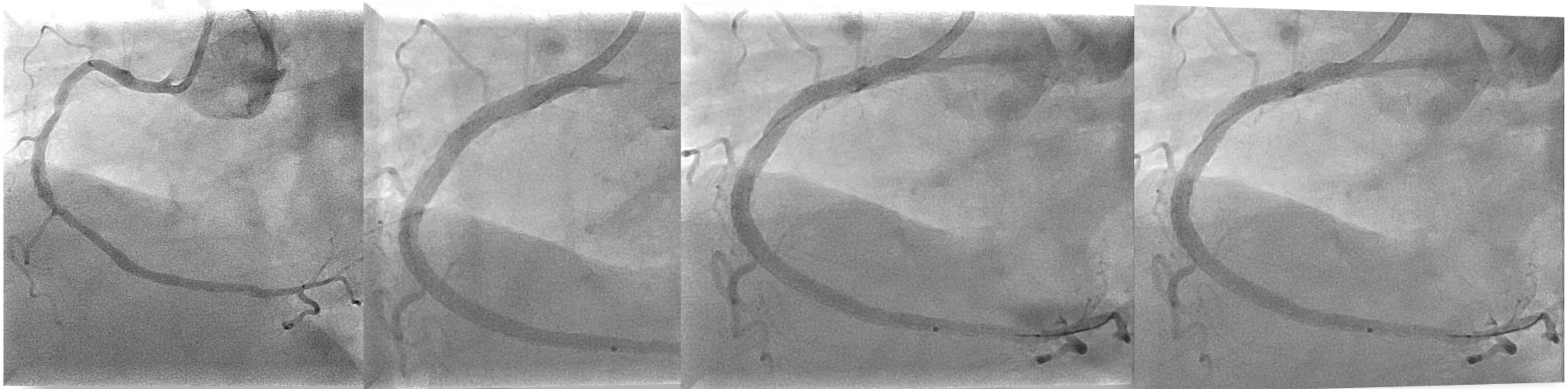
Edge dissection	Intra-stent dissection	Tissue prolapse	Strut malapposition
26.0%	87.5%	97.5%	65.5%

Gonzalo N et al., Heart 2009

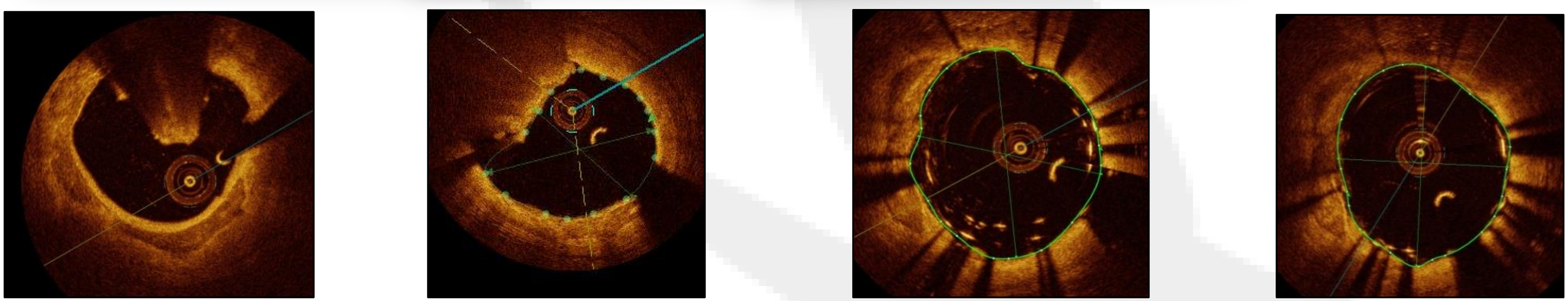
OCT: Lightlab/StJUDE

Today – 2017: Guidance in PCI (after stenting)

Suboptimal acute stent result is frequent and missed by angiography



pre 3 stents 4 stents final

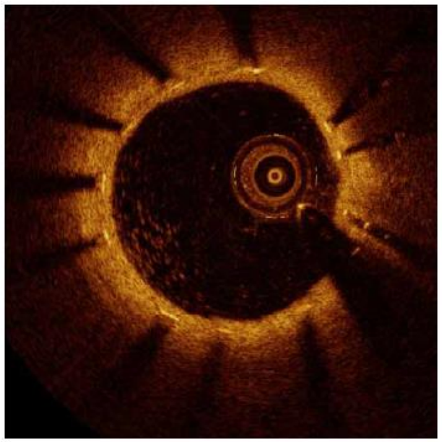


thrombus gap malapposition optimal

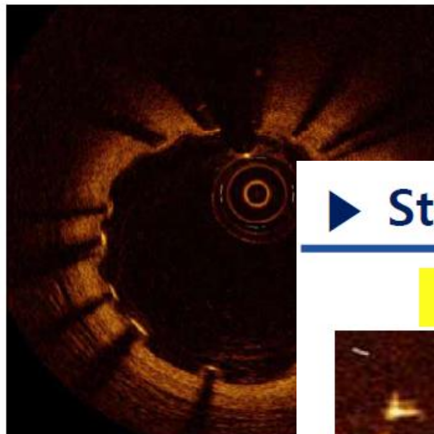
OCT: Lightlab/StJUDE

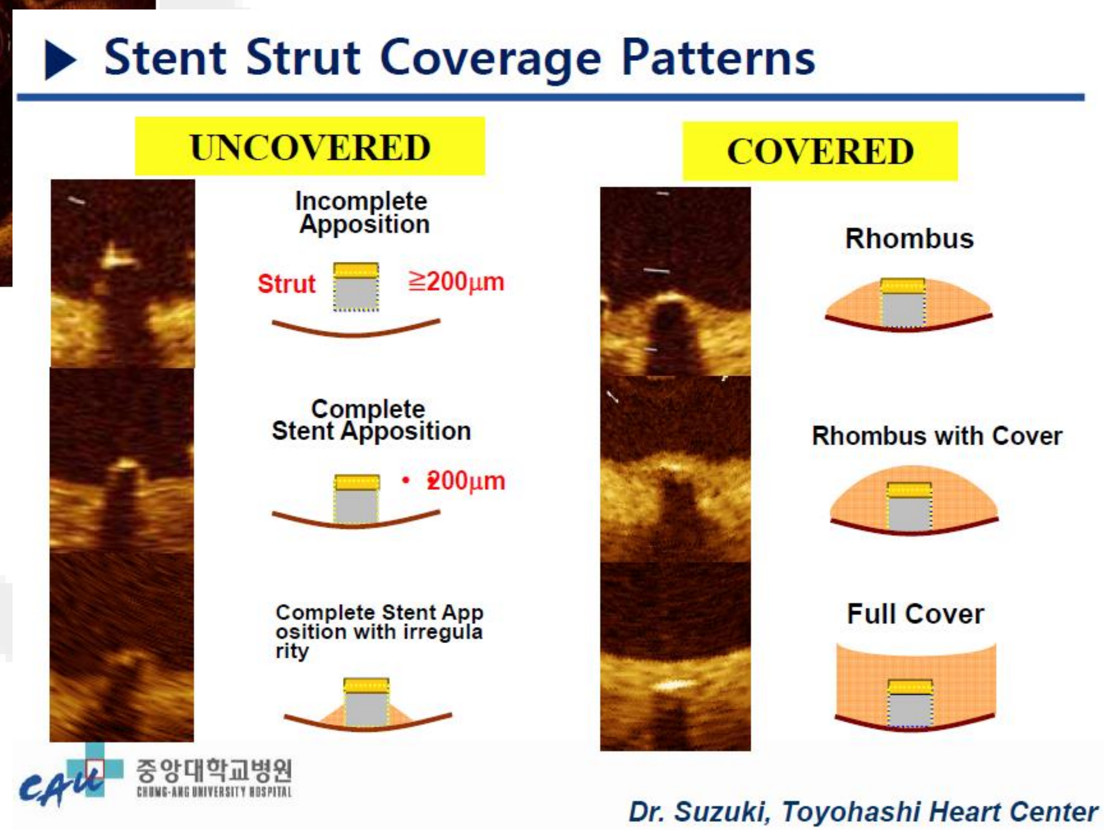
Today – 2017: Guidance in PCI (long after stenting)

Coverd stent



Uncoverd stent





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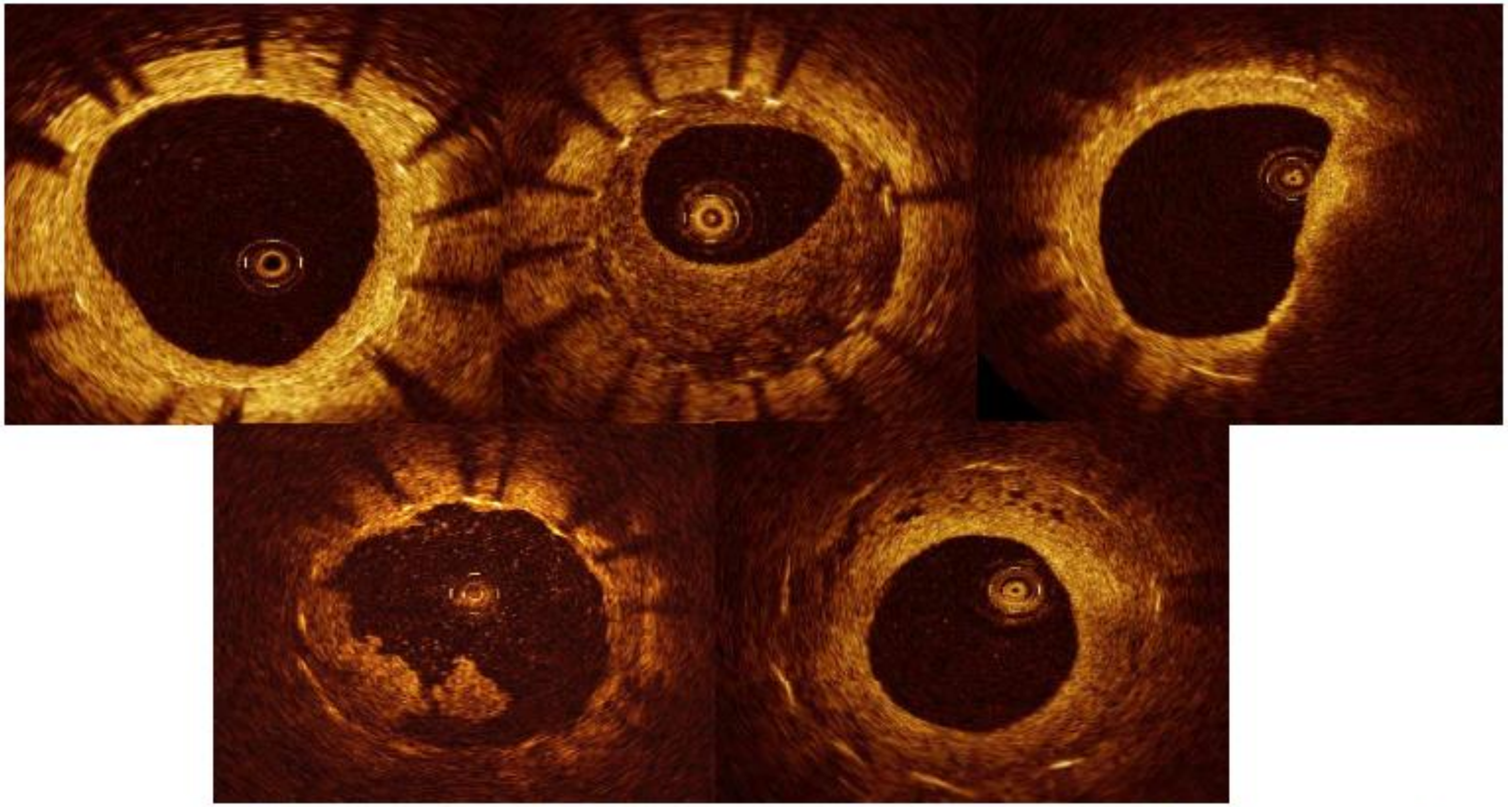
Today – 2017: Guidance in PCI (long after stenting)

▶ 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 – 2017: 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

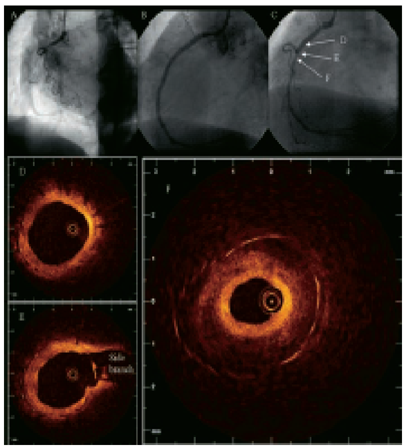
EuroIntervention

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

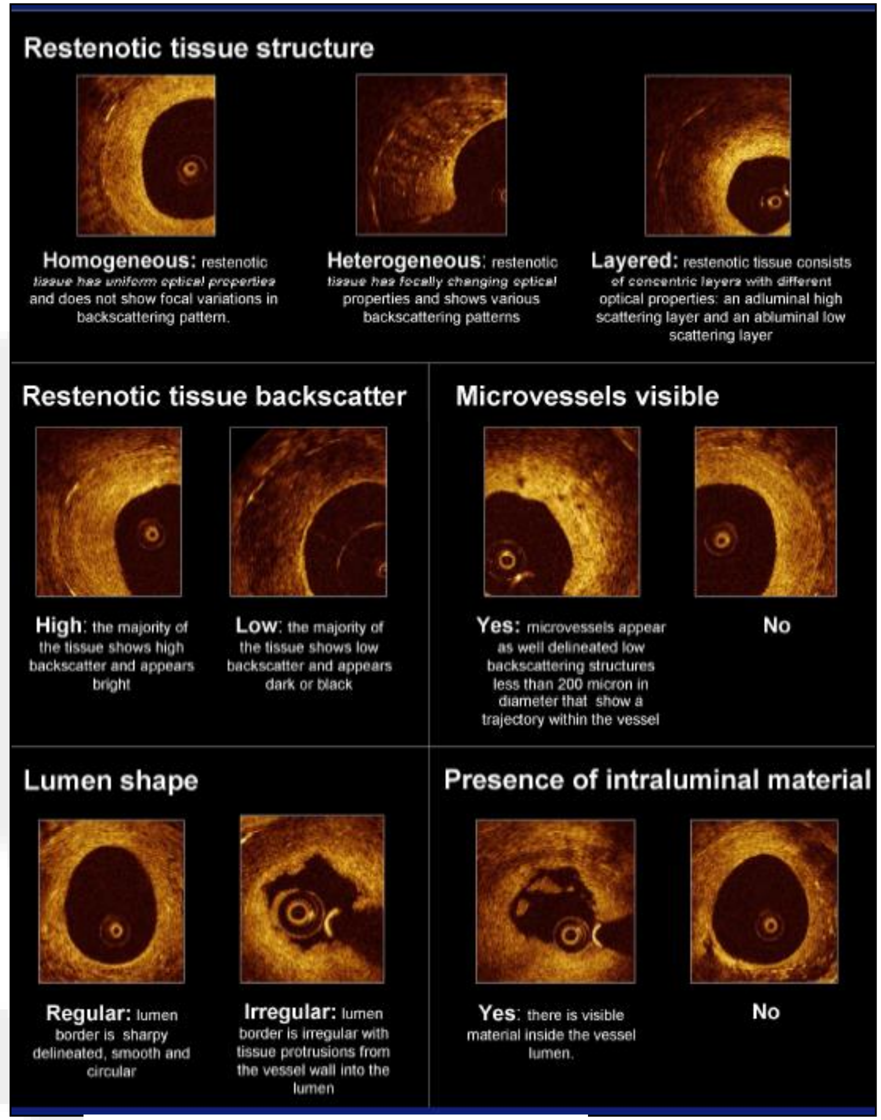
Thoraxcenter, Erasmus Medical Center, Rotterdam, The Netherlands.

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 mm²; stent area 9.0 mm²) 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

HUNGARIAN BIOPHYSICAL SOCIETY

ROLAND EÖTVÖS PHYSICAL SOCIETY (HUNGARY)

Optical Coherence Tomography (OCT)

Today – 2017: 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*

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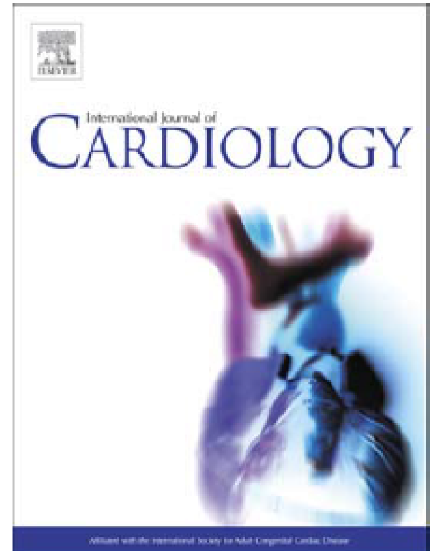
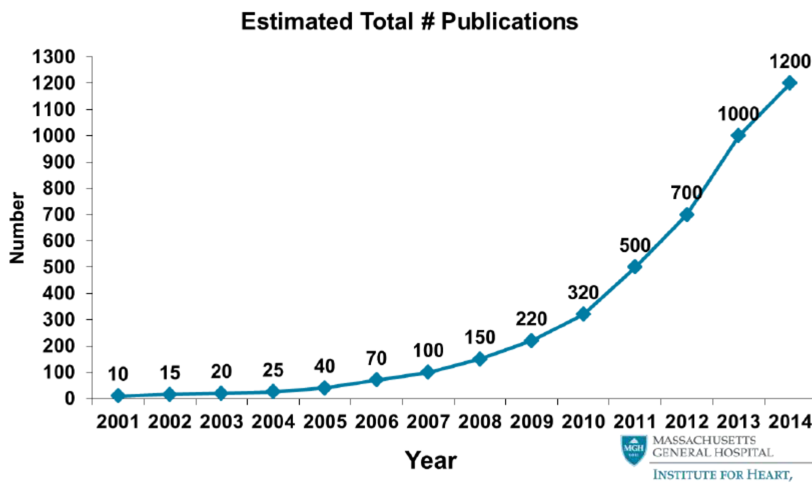
Accepted date: 5 July 2014



Intra-Coronary OCT Publications



MASSACHUSETTS GENERAL HOSPITAL
INSTITUTE FOR HEART,

HUNGARIAN BIOPHYSICAL SOCIETY

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Clinical data

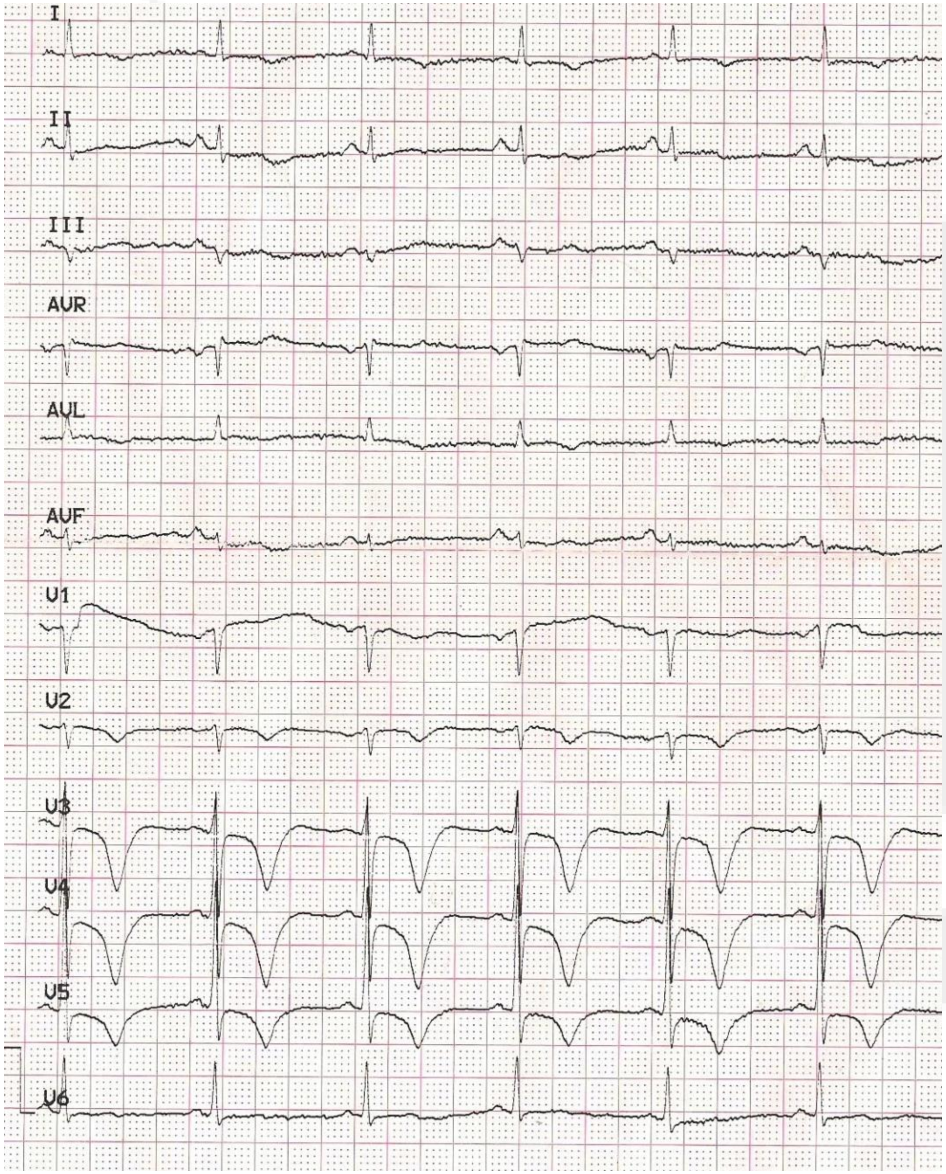
80-year-old male

Risk factors:
-hypertension
-smoker

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

One-week history of unstable angina (CCS4)

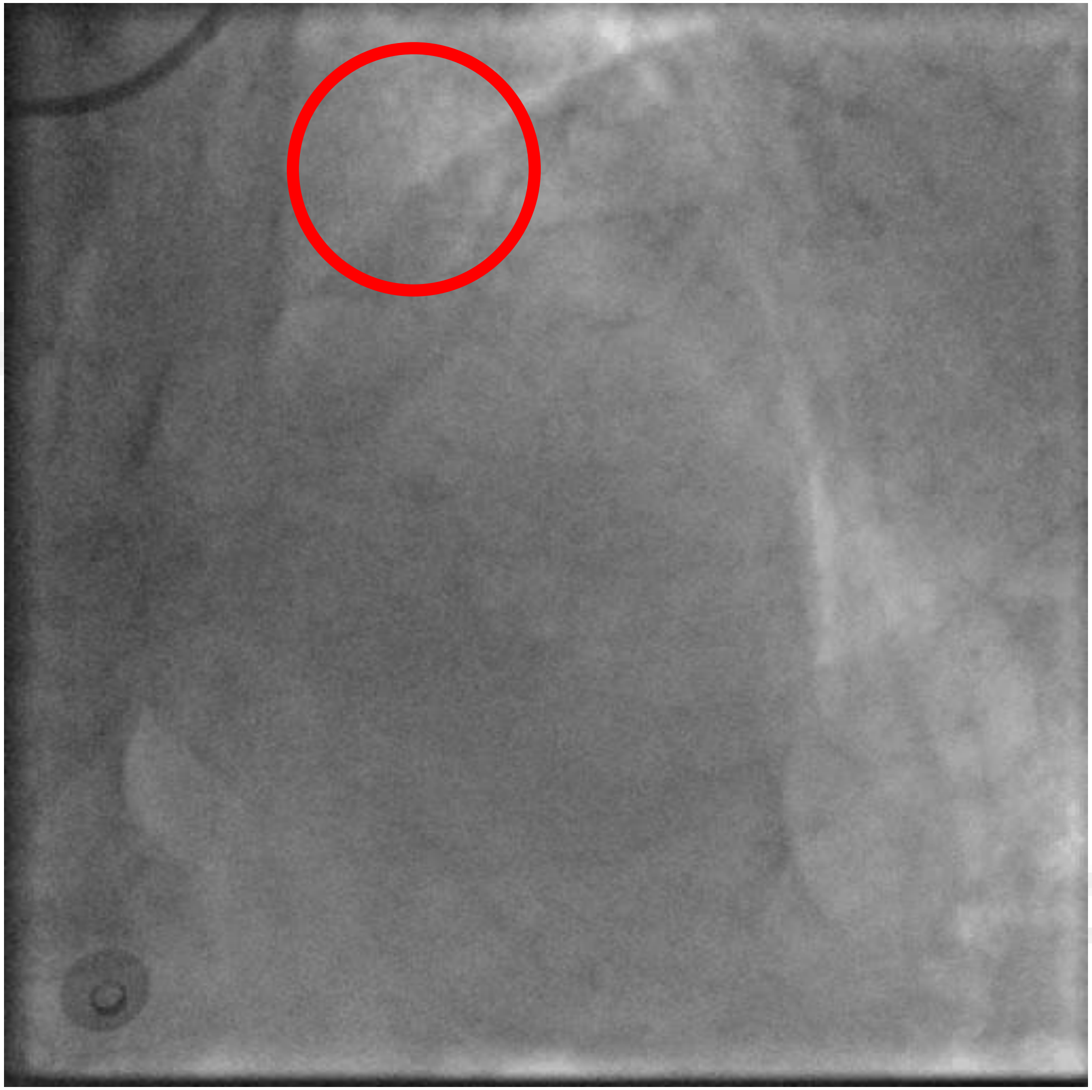
On admission



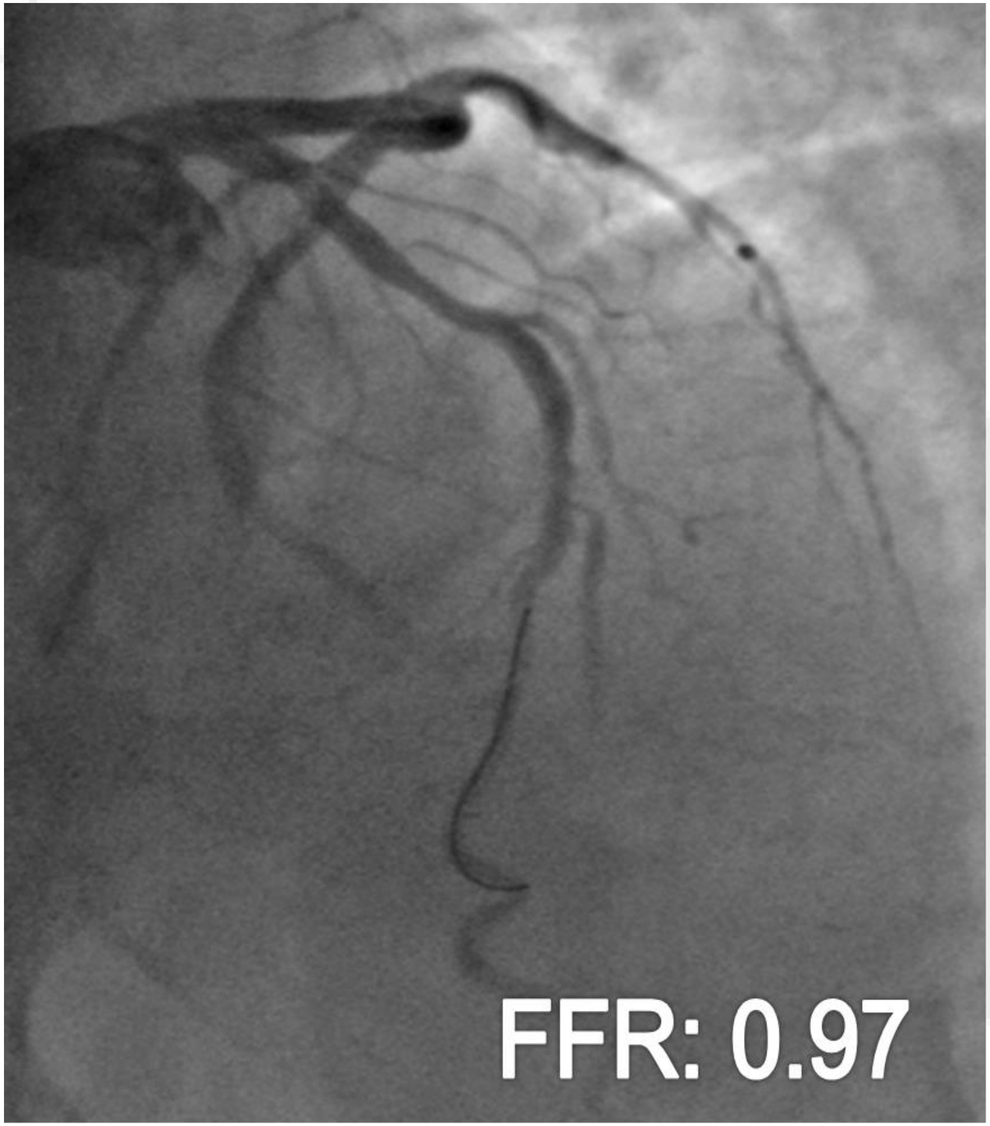
Baseline ECG on admission:

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

Diagnostic Cardiac Catheterization



FFR measurement

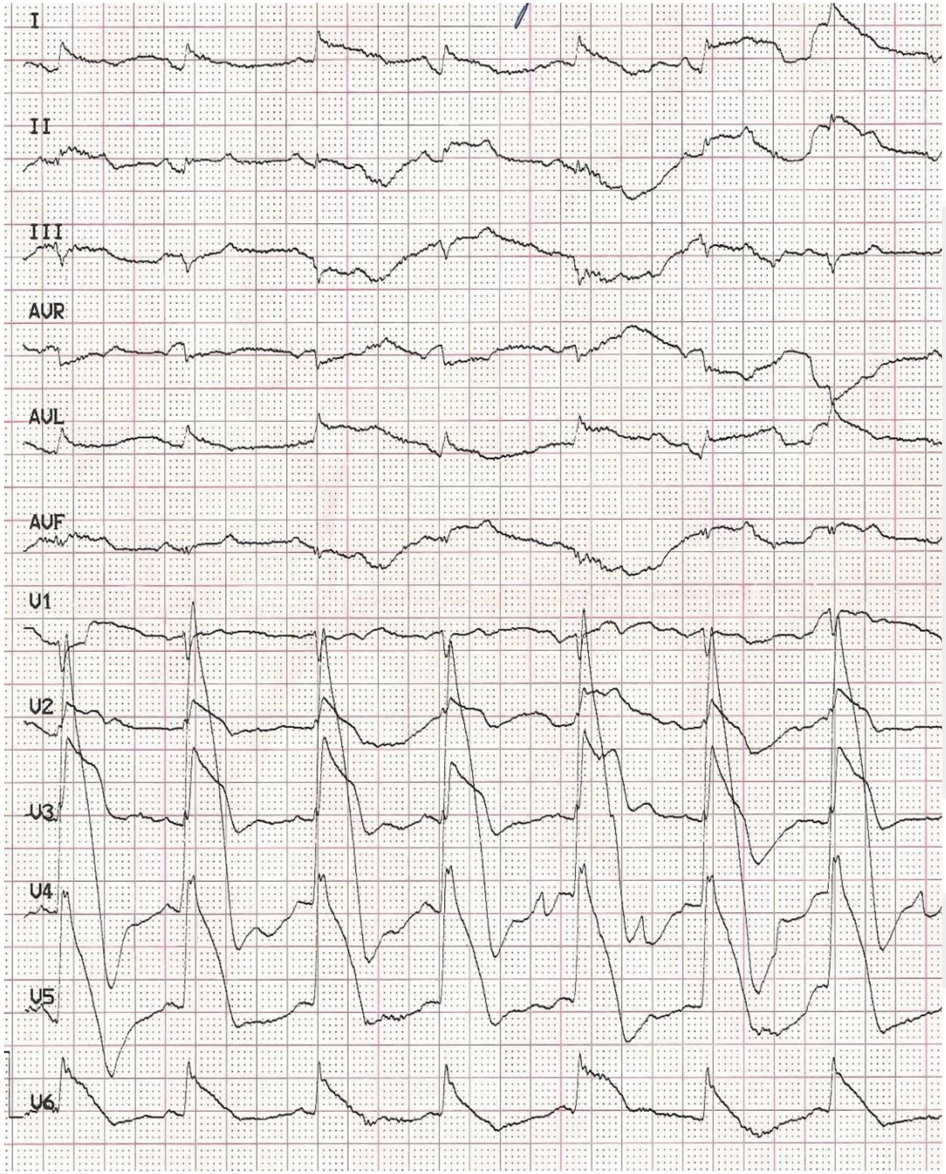


200 ug NTG +
240ug adenosine

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

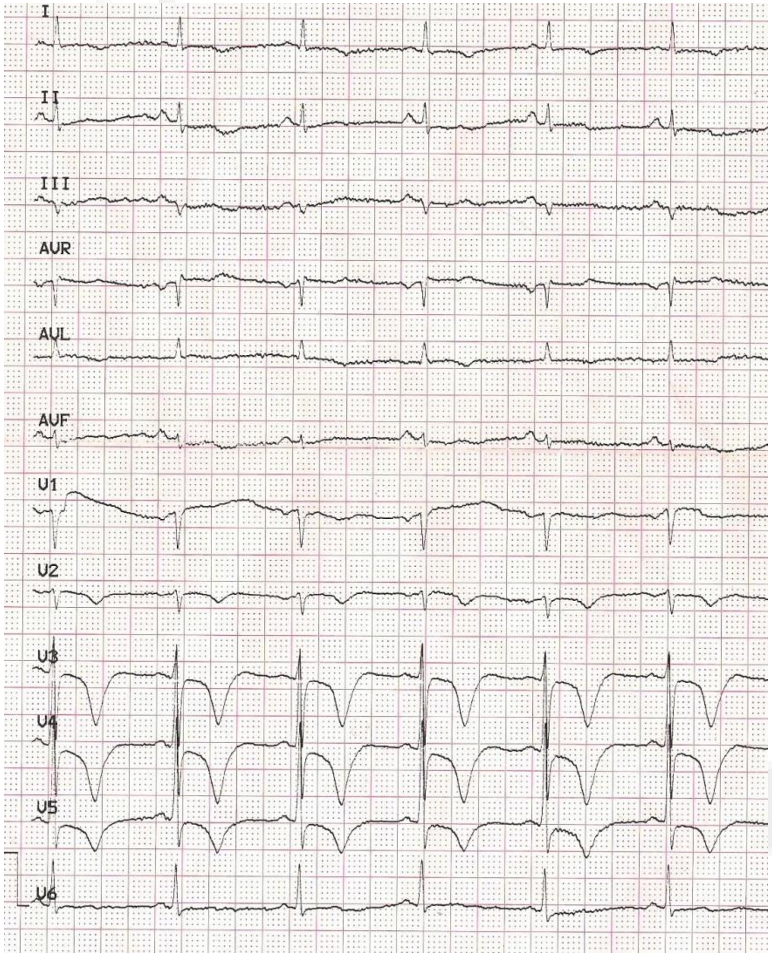
- ASA 1x100mg
- Clopidogrel 1x75mg
- LMWH 2x0.6ml s.c.
- Ramipril 1x2.5mg
- Rosuvastatin 1x20mg
- ~~Nebivolol 1x5mg~~

Nisoldipin 2x10mg

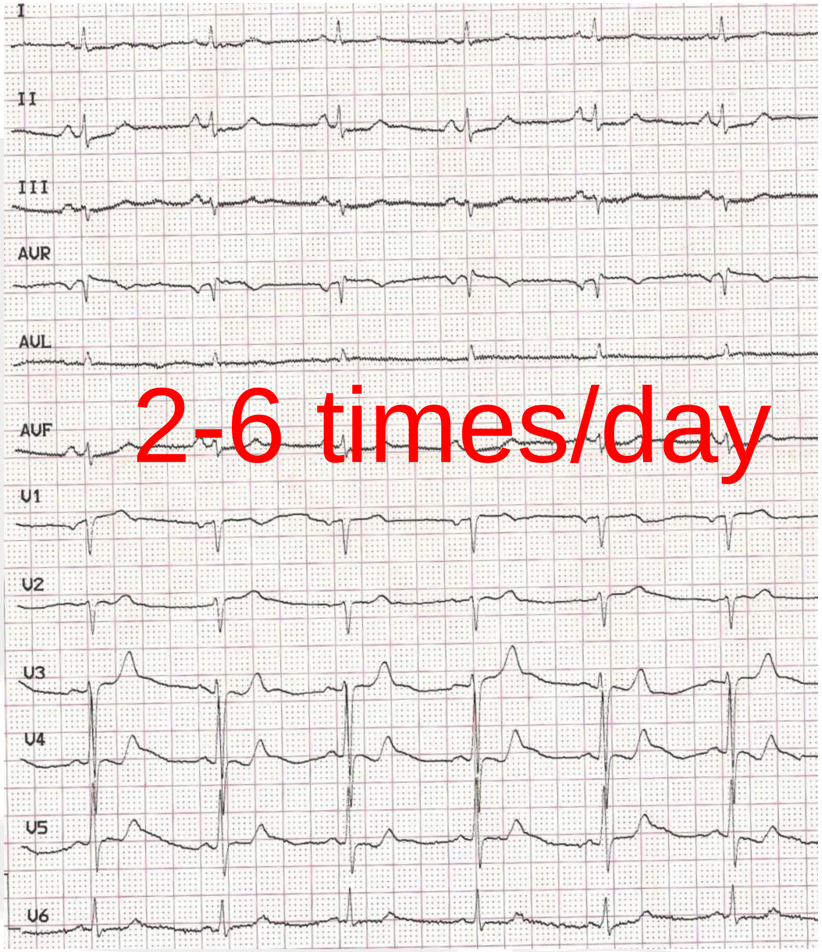
+

Iv NTG

Despite medical therapy

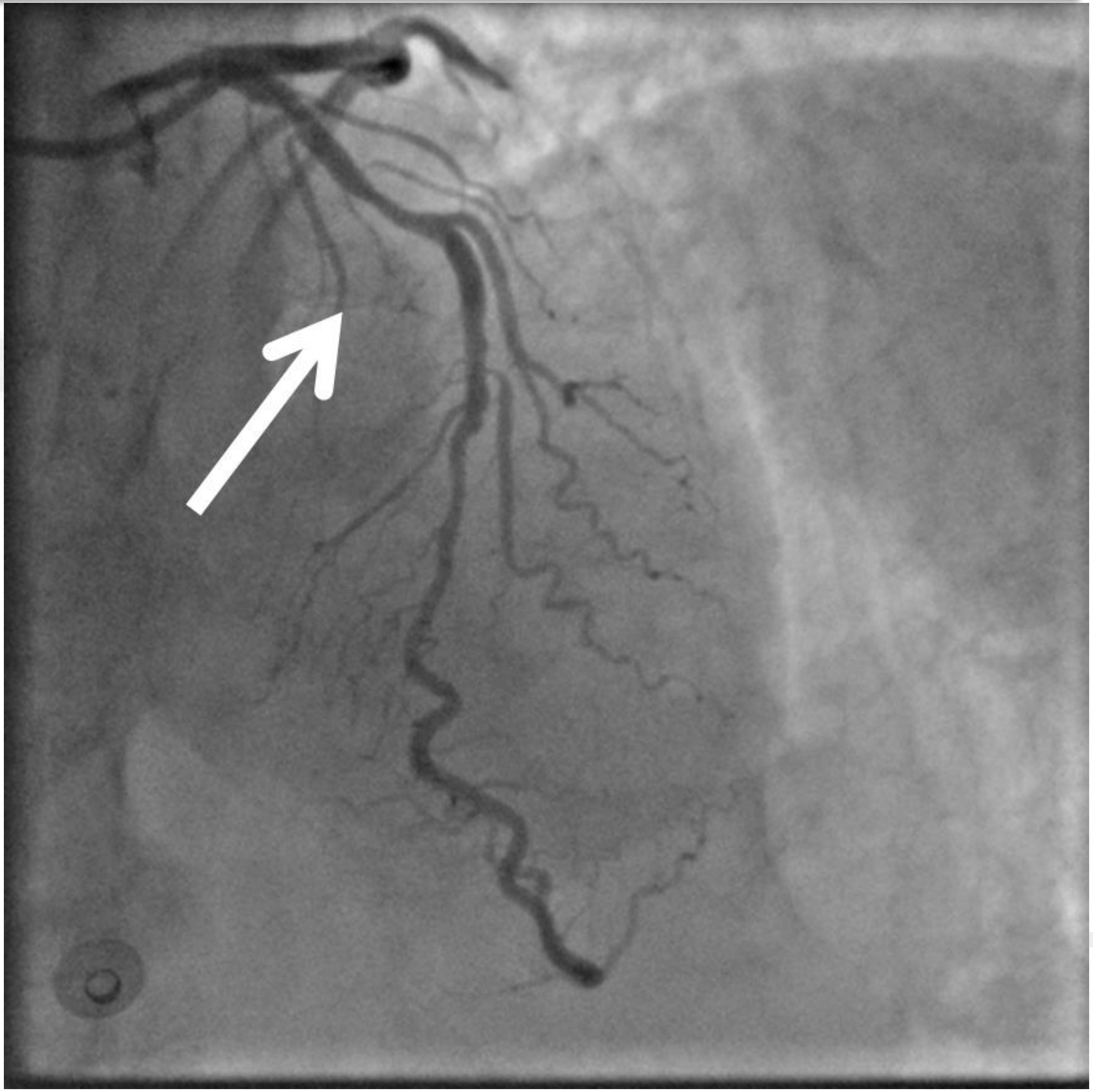


No angina

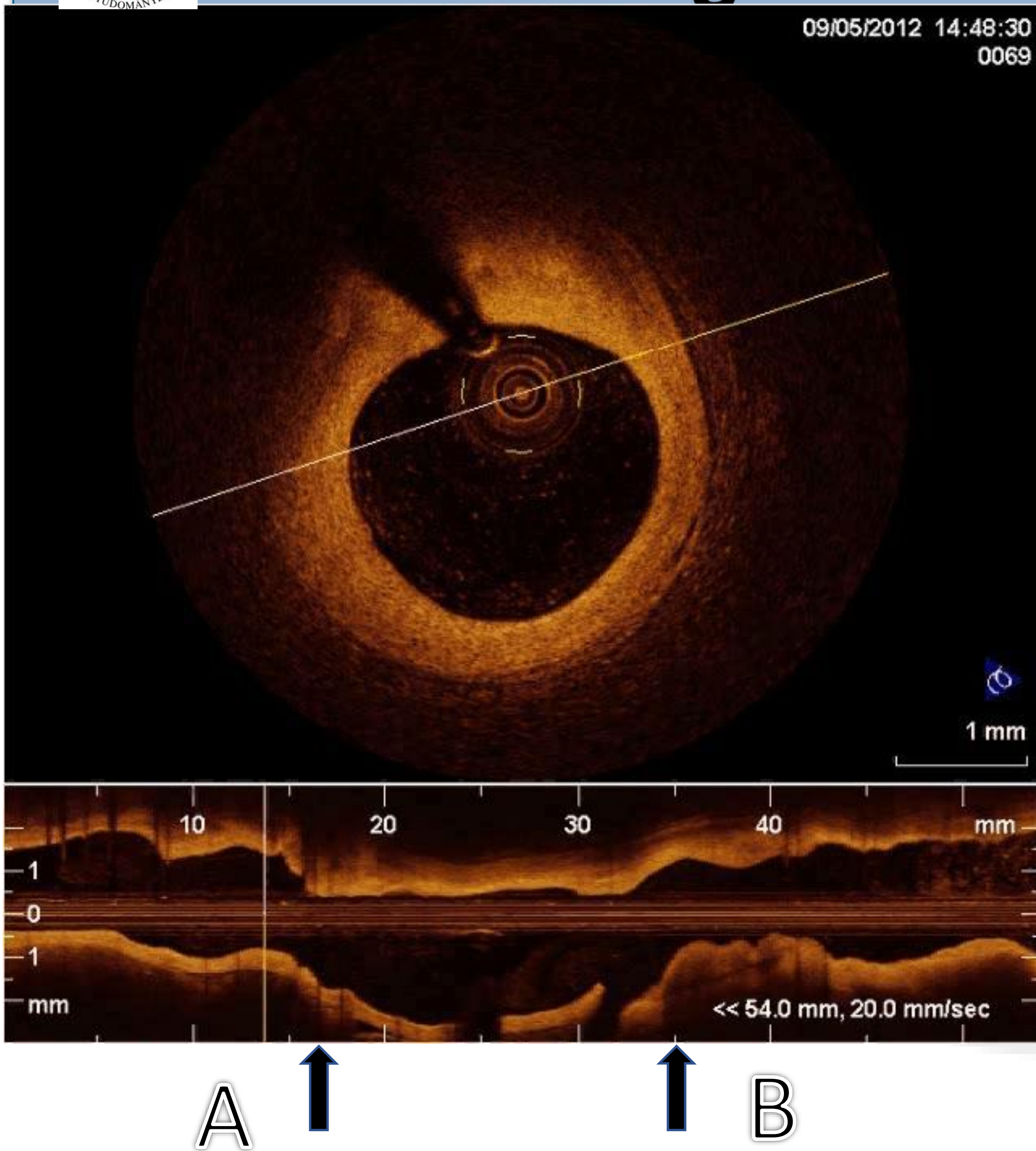


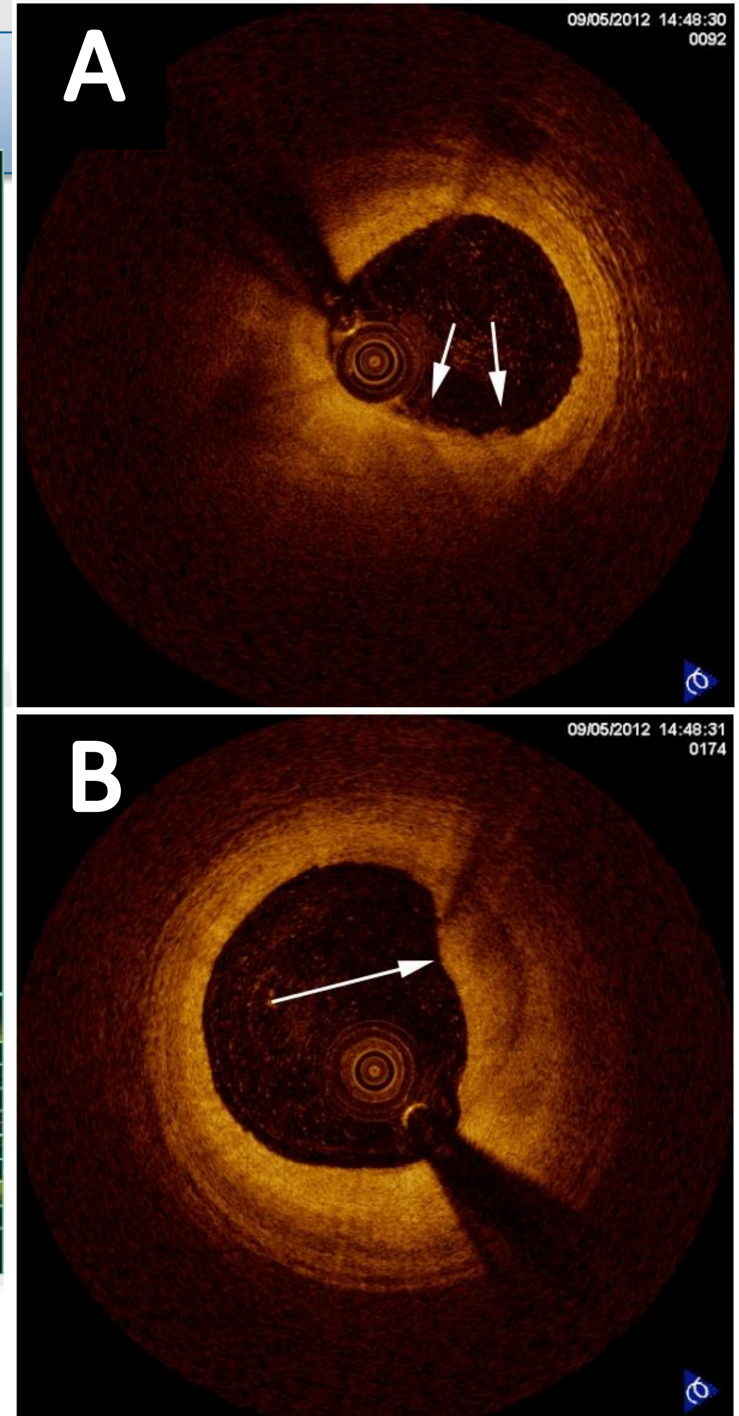
Angina

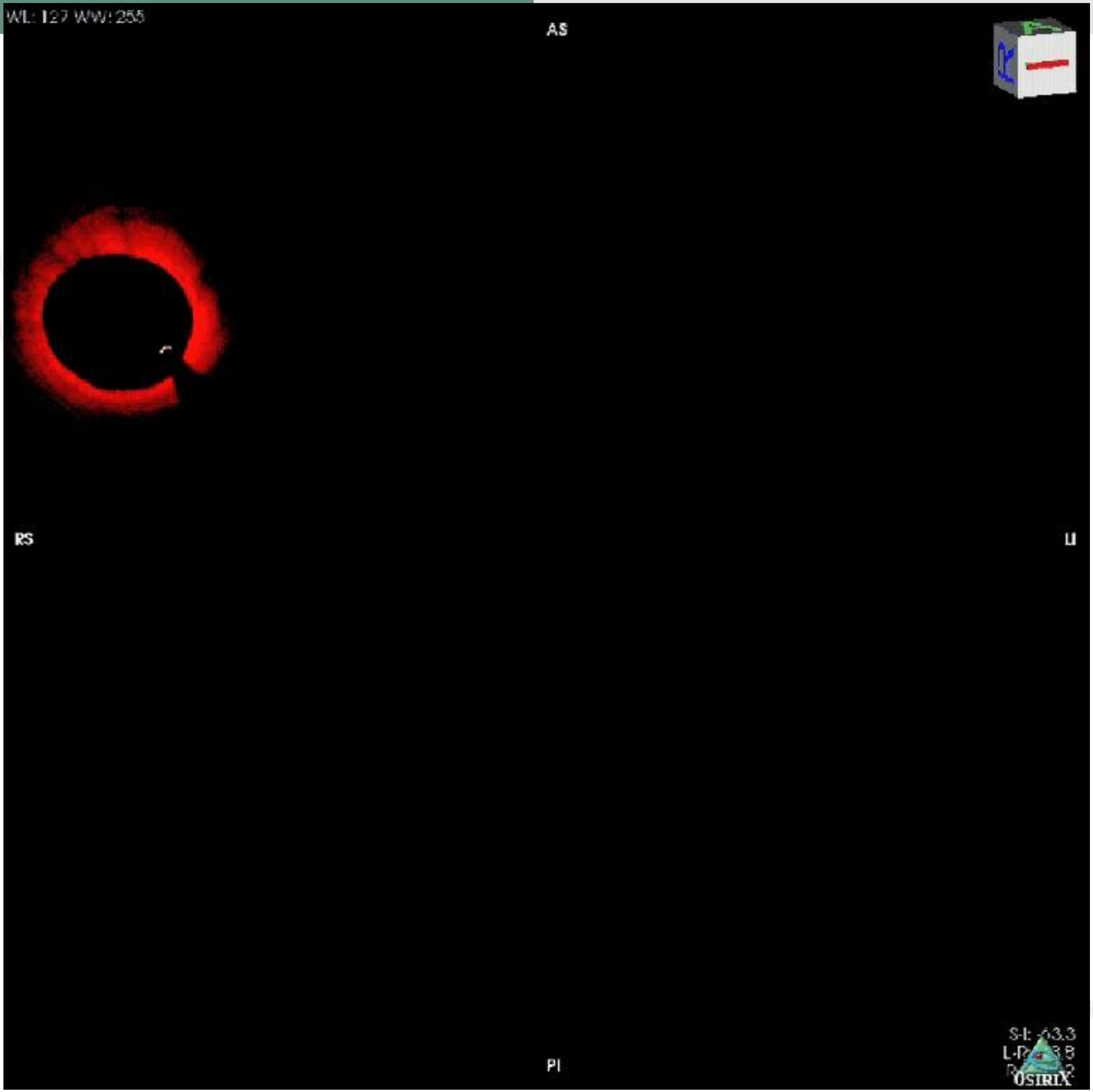
Repeated Cardiac Catheterization



OCT Interrogation






WL: 127 WW: 255
AS
RS
LI
PI
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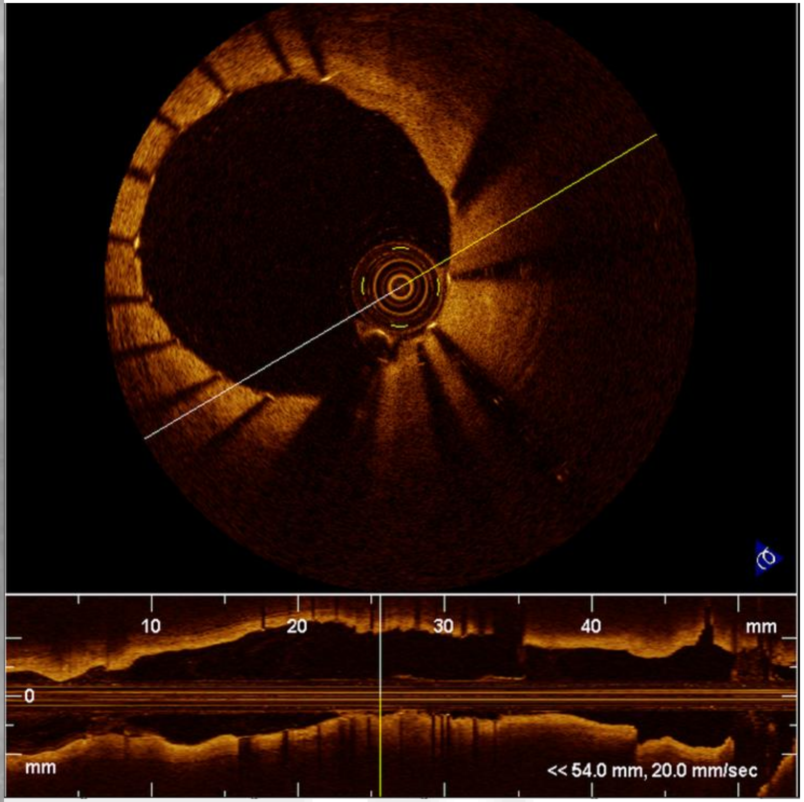
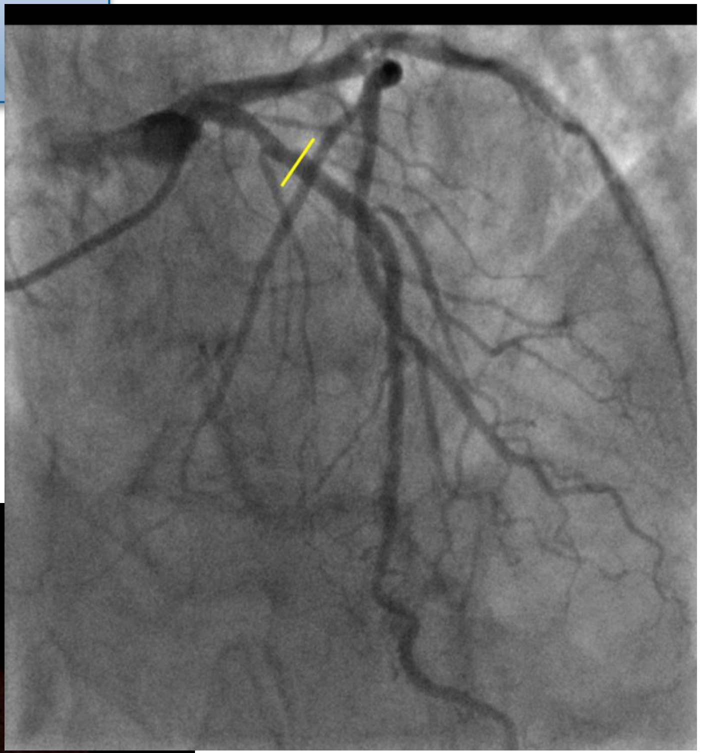
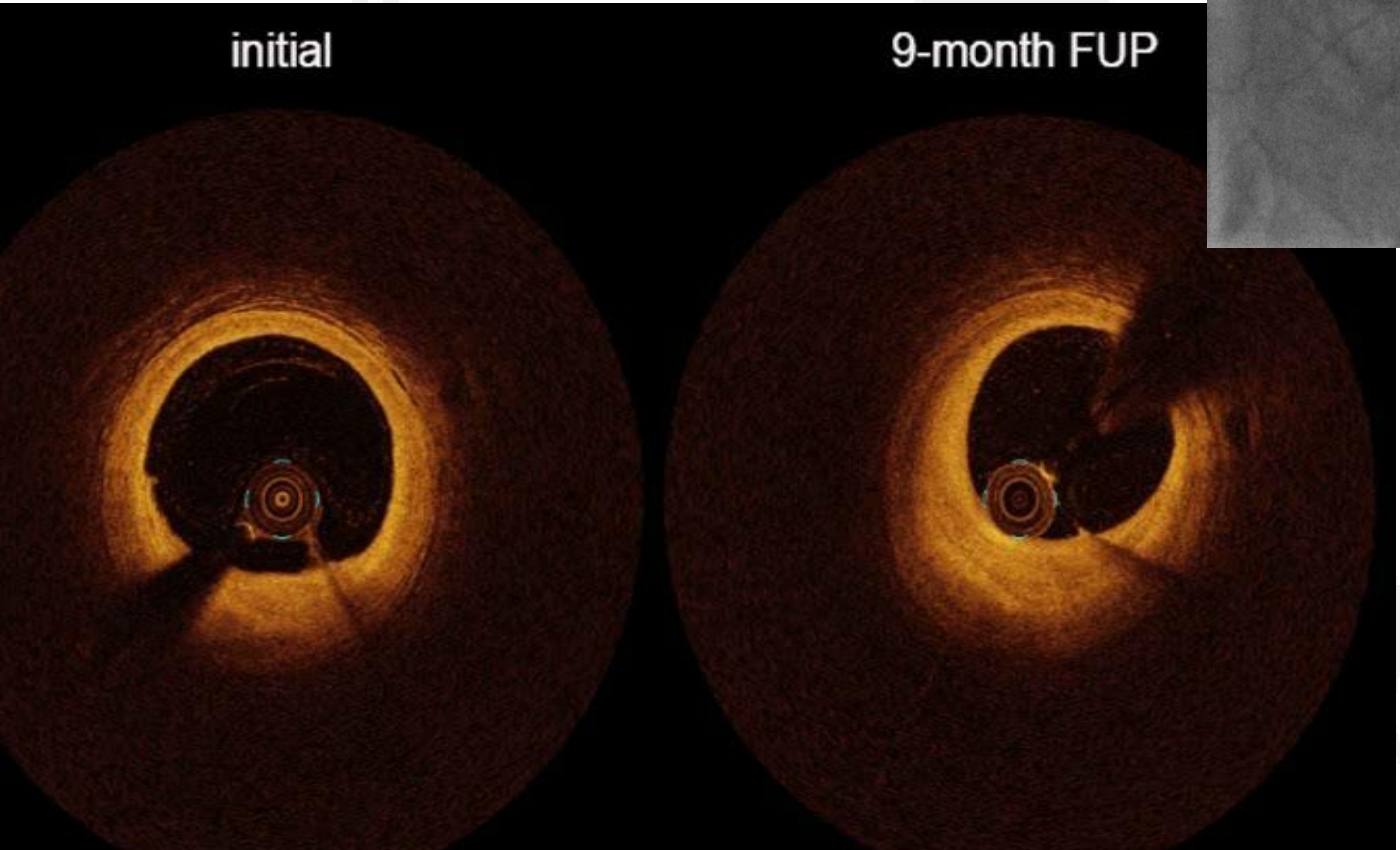
Interventional Management

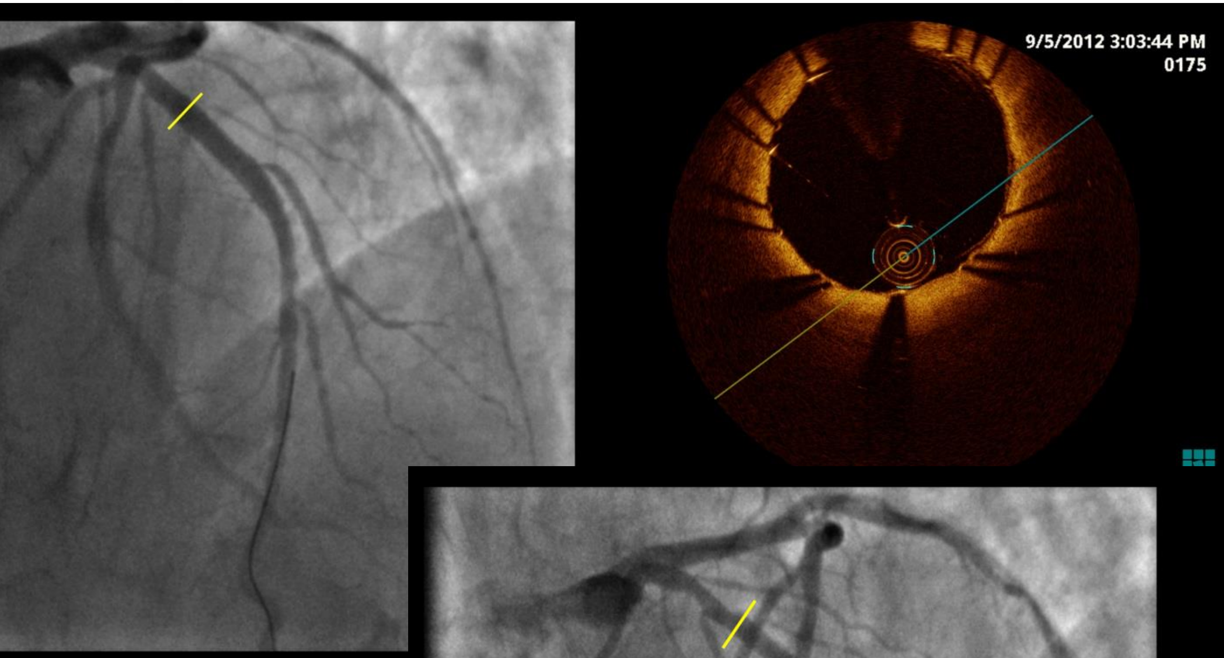


ine-month follow-up

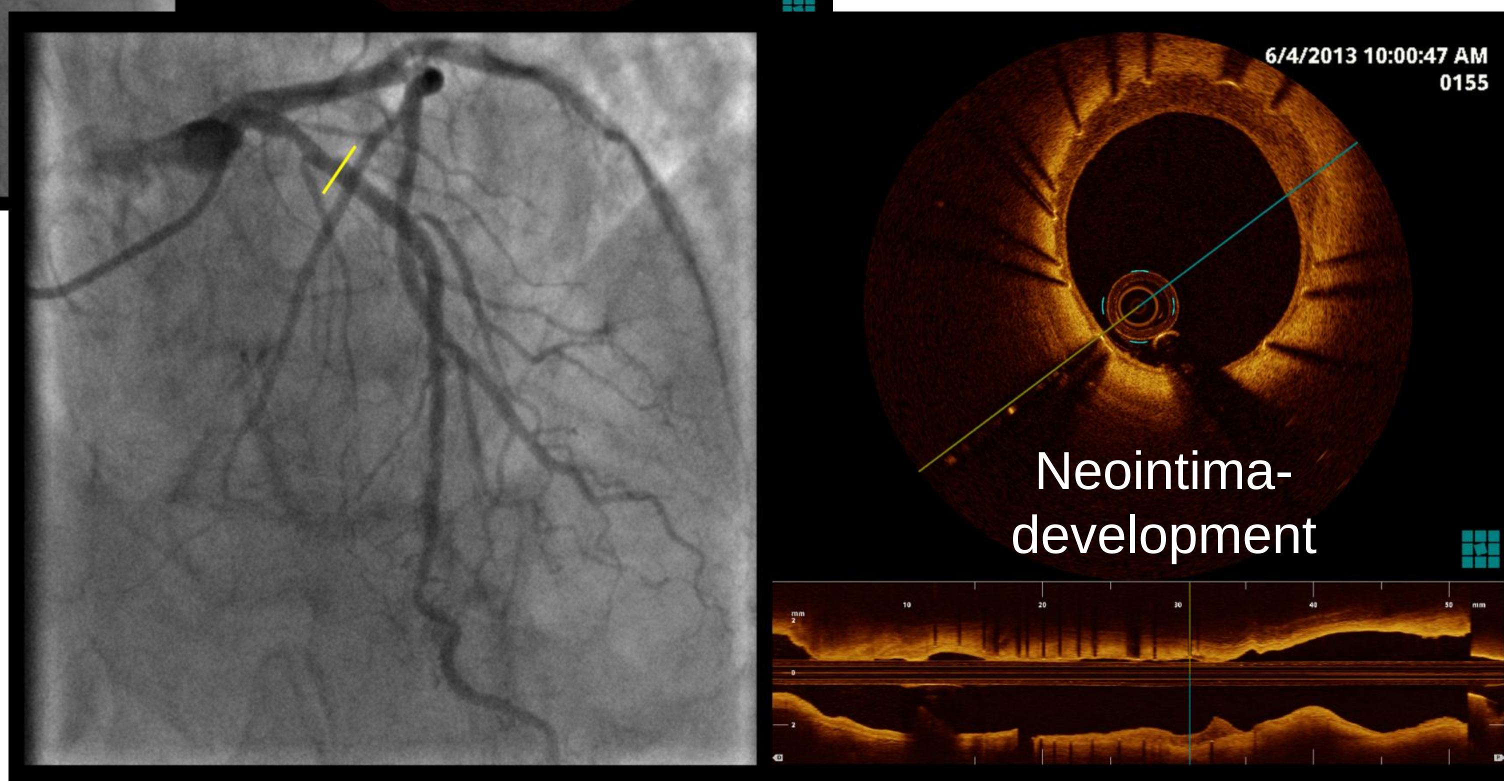
Patient is free of angina



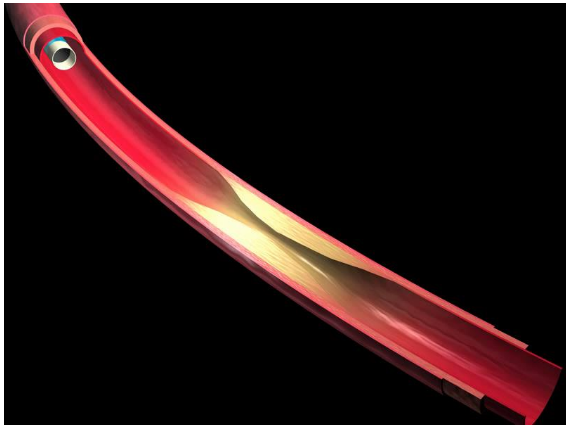




Neo-atherosclerosis ?



Optical Coherence Tomography (OCT) in coronary arteries



Today – 2017: 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!