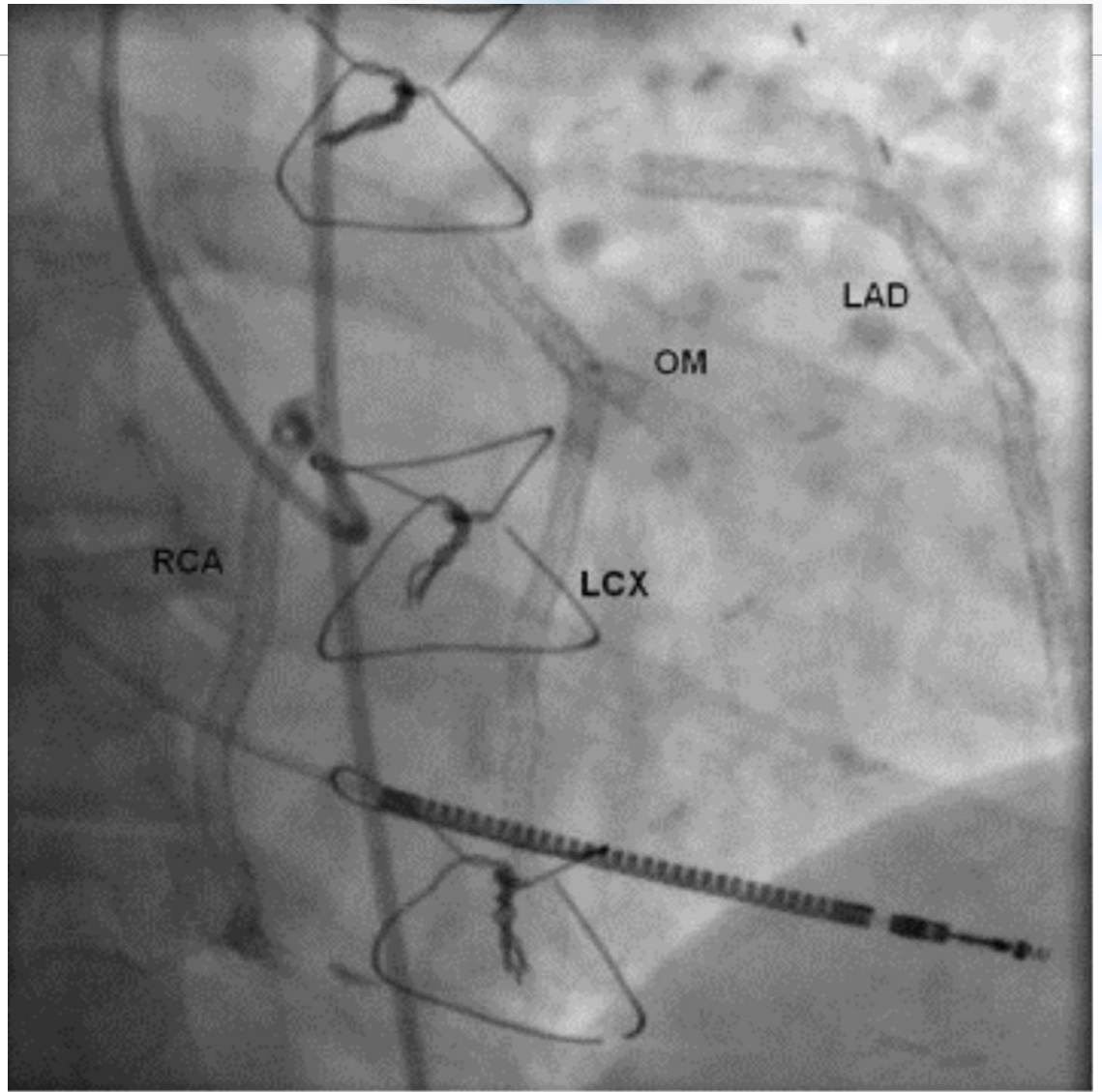
The Future of intravascular imaging : Is there light or sound at the end of the tunnel? Hybrid Imaging

Jung Ho Heo MD, PhD

Kosin University Hospital
Busan, Korea

From: A Heart With 67 Stents

J Am Coll Cardiol. 2010;56(19):1605-1605. doi:10.1016/j.jacc.2010.02.077

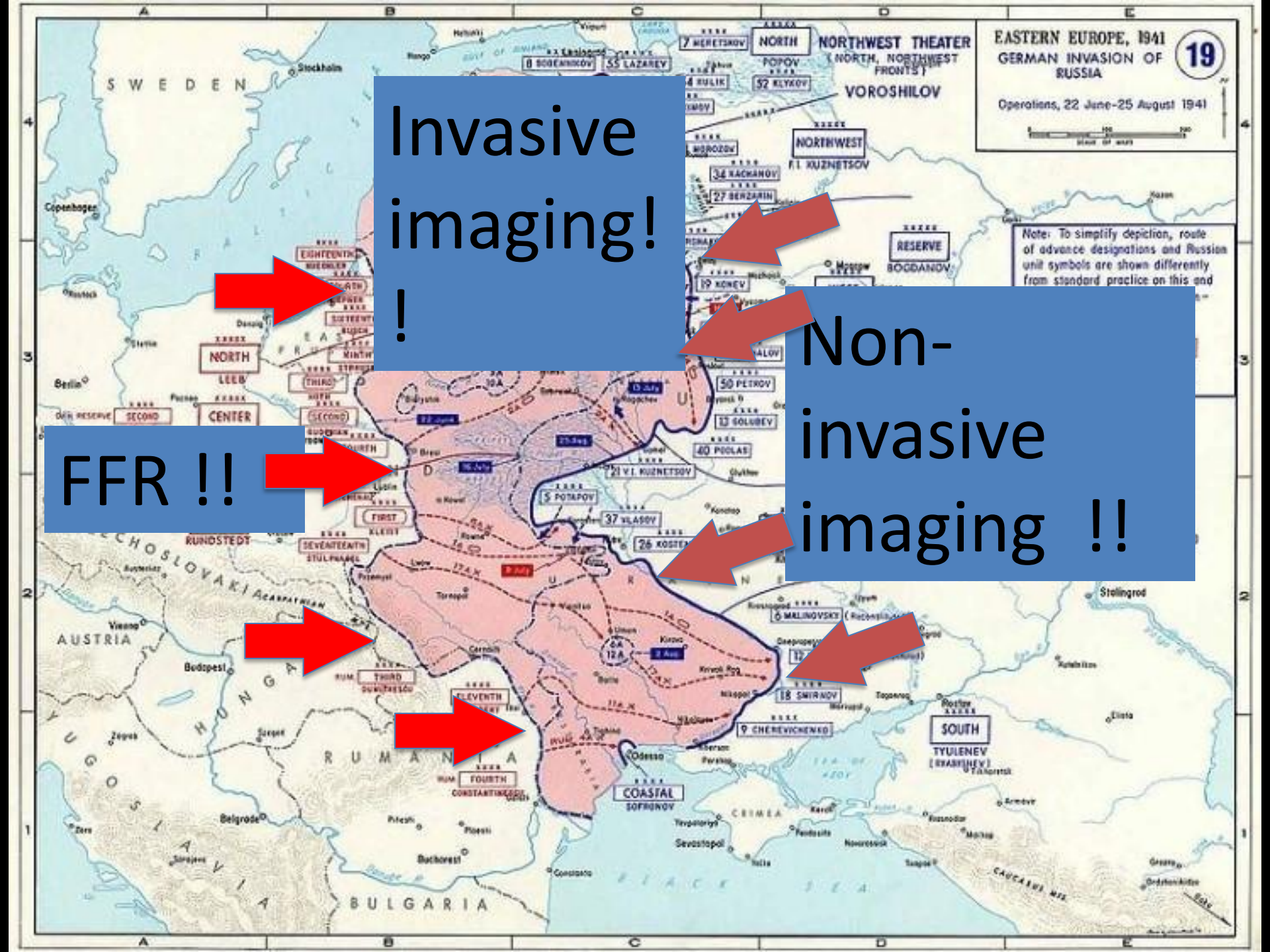


To improve cardiovascular outcomes

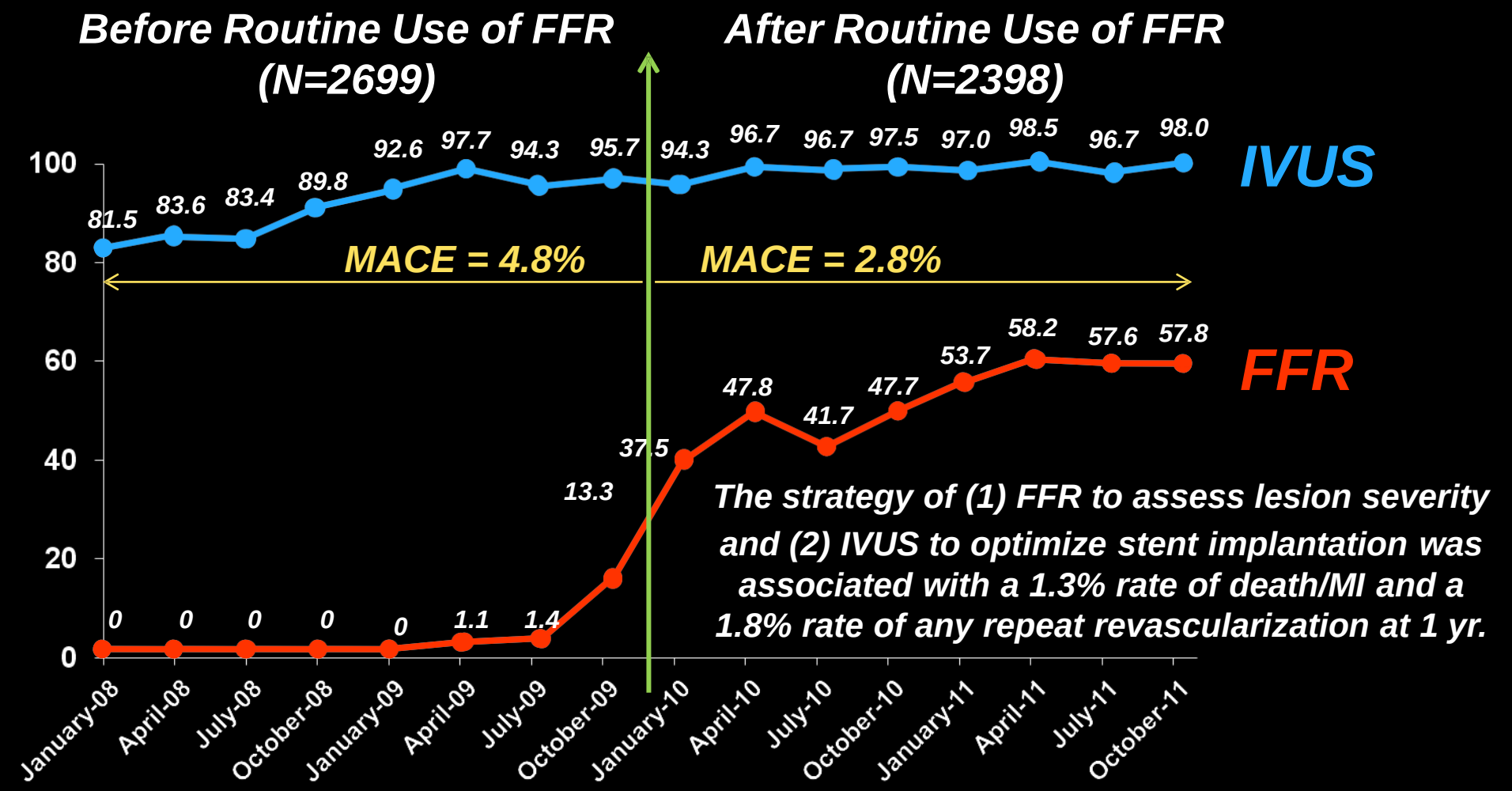
Progress of coronary stent technology

Antithrombotic therapy

The use of novel diagnostic approaches


Invasive imaging!
!
FFR !!
Non-invasive imaging !!
EASTERN EUROPE, 1941
GERMAN INVASION OF RUSSIA
19
Operations, 22 June-25 August 1941
NORTHWEST THEATER
(NORTH, NORTHWEST FRONTS)
VOROSHILOV
NORTHWEST
F.I. KUZNETSOV
NORTH
LEEB
CENTER
SOUTH
TYULENEV
COASTAL
SOFRONOV
RESERVE
BOGDANOV
RUNDSTEDT
SWEDEN
AUSTRIA
HUNGARY
RUMANIA
BULGARIA
YUGOSLAVIA
CZECHOSLOVAKIA
Stockholm
Copenhagen
Berlin
Budapest
Belgrade
Bucharest
Odessa
Sevastopol
Stalingrad
CRIMEA
BLACK SEA
CAUCASUS MTS.

Between January 2008 and December 2011, 5097 pts underwent PCI at Asan Medical Center, Seoul, Korea and were followed for 1 year.



The strategy of (1) FFR to assess lesion severity and (2) IVUS to optimize stent implantation was associated with a 1.3% rate of death/MI and a 1.8% rate of any repeat revascularization at 1 yr.

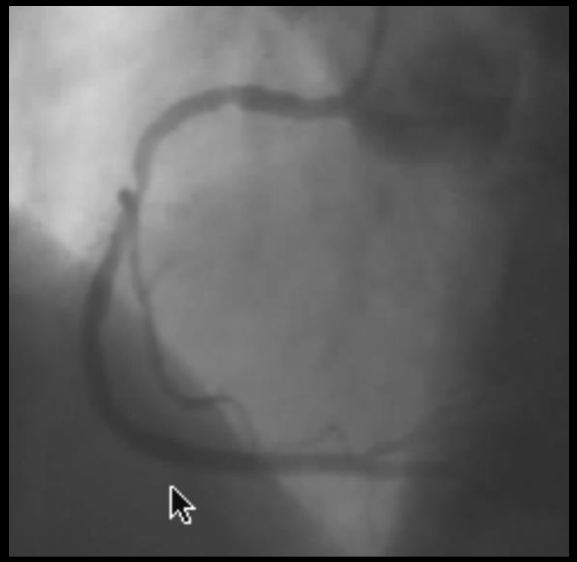
Park et al. Eur Heart J, in press

Tools in the Cath Lab: Physiology, Anatomy, and Biology

FFR

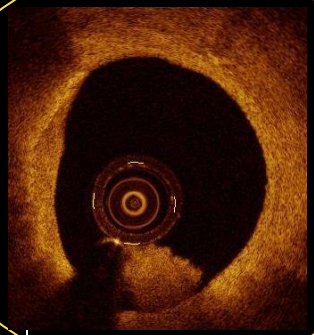
IVUS

CFR

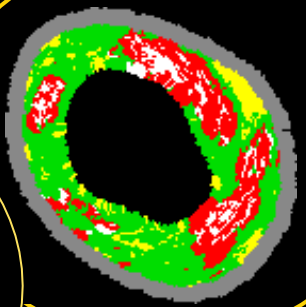


Endothelial Fx
Vasospasm

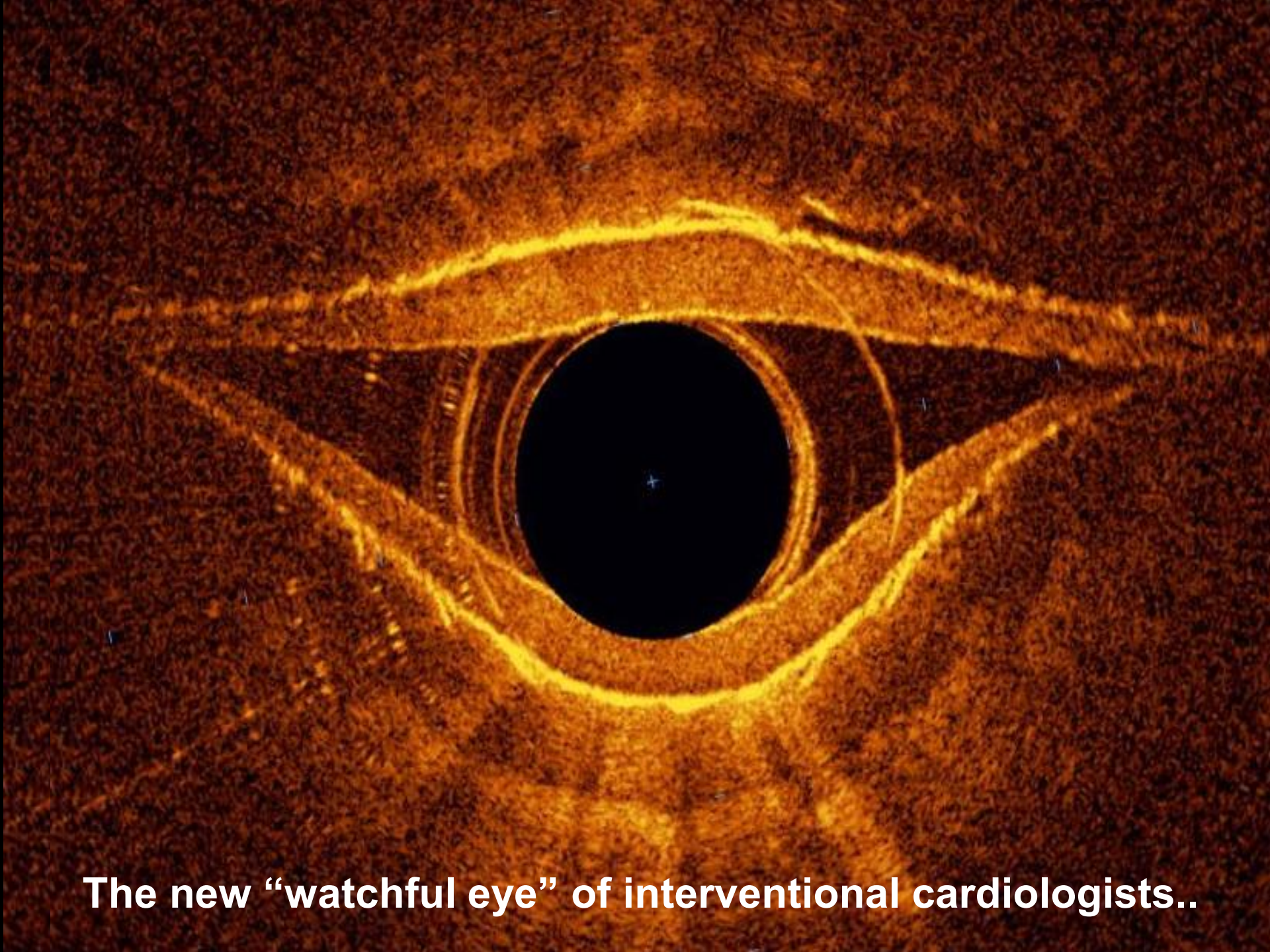
NIR



OCT

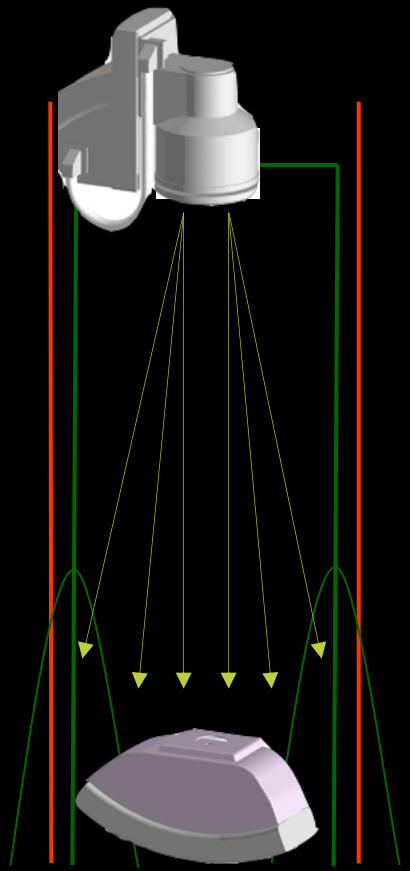


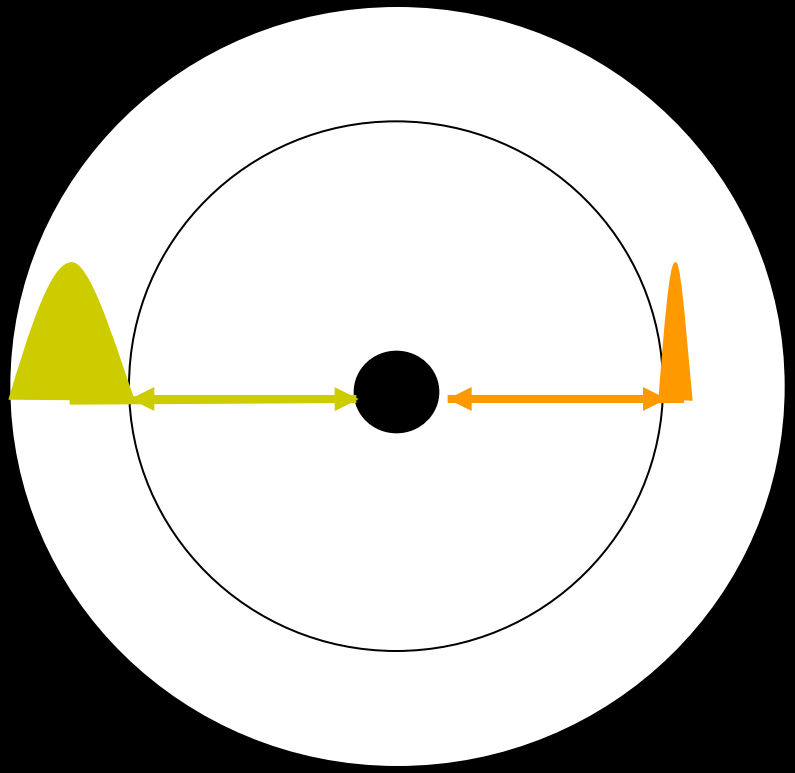
VH-IVUS


The new “watchful eye” of interventional cardiologists..

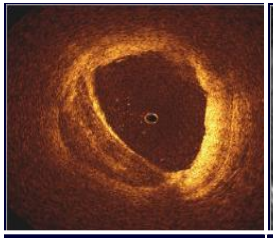
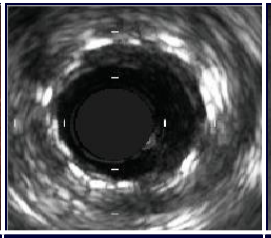
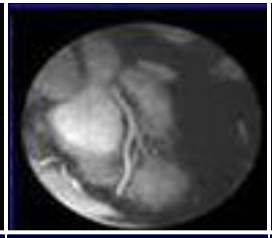
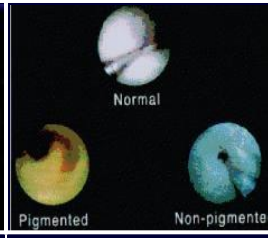
Intravascular Imaging

QCA	IVUS	OCT
	Axial Resolution: **150 -200μm** Lat. Resolution: **150-300 μm**	Axial Resolution: **12 -18μm** Lat. Resolution: **20-90 μm**





OCT vs Other Imaging Modalities

	OCT	IVUS	CA	MSCT	MRI	Angioscopy
						
Resolution (µm)	5-20	80-150	200	300	300	200
Time aspect I	Real-time	Real-time	Real-time			Real-time
Time aspect II	2-50 sec	20-50 sec				30 sec
Type of scan source	IR-light	Ultrasound	X-Ray	X-Ray	Magnetic res	Visible light
Imaging target	Layer	Layer	Bloodflow	Density	Density	Surface

Some people think that…

JACC: CARDIOVASCULAR IMAGING

PUBLISHED BY ELSEVIER INC.

EDITORIAL COMMENT

The Vulnerable Plaque "Hypothesis"

Promise, but Little Progress*

Steven E. Nissen, MD

Cleveland, Ohio

A PubMed search using the terms "vulnerable plaque" or "high-risk" plaque yields >2,000 references to journal articles published over the past 20 years. Indeed, few concepts in cardiovascular medicine have achieved such intense scientific interest over such a long duration. During this 20-year period, many diagnostic techniques designed to "detect" vulnerable plaques have come and gone. In each case, a flurry of promising "findings" has been followed by a sobering reality check. These include thermography, spectroscopy, palpography, virtual histology, optical coherence tomography, and many more (1–5). A large number of startup companies with "breakthrough" approaches have come and gone, nearly all leaving investors with empty pockets, but no progress. What has gone wrong?

[redacted]

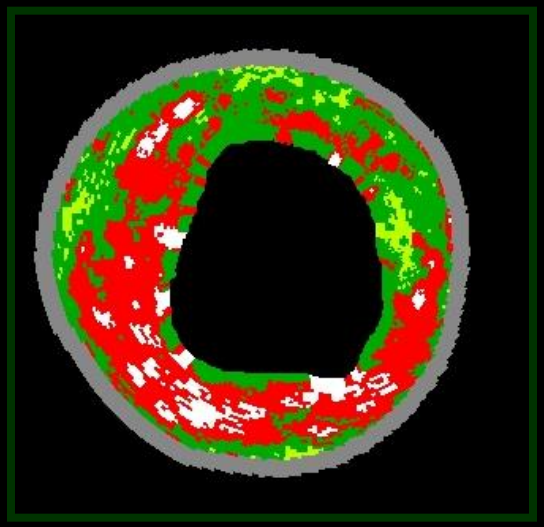
It is time to face reality. Much of the contemporary concept of vulnerable plaque is fundamentally flawed or overly simplistic, and most approaches to detection are poorly conceived. [redacted]

The NEW ENGLAND JOURNAL of MEDICINE

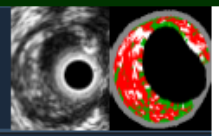
ORIGINAL ARTICLE

A Prospective Natural-History Study of Coronary Atherosclerosis

Gregg W. Stone, M.D., Akiko Maehara, M.D., Alexandra J. Lansky, M.D., Bernard de Bruyne, M.D., Ecaterina Cristea, M.D., Gary S. Mintz, M.D., Roxana Mehran, M.D., John McPherson, M.D., Naim Farhat, M.D., Steven P. Marso, M.D., Helen Parise, Sc.D., Barry Templin, M.B.A., Roseann White, M.A., Zhen Zhang, Ph.D., and Patrick W. Serruys, M.D., Ph.D., for the PROSPECT Investigators*



PROSPECT: Multivariable Correlates of Non Culprit Lesion Related Events



Independent predictors of lesion level events by logistic regression analysis

Variable	OR [95% CI]	P value
PB_{MLA} ≥70%	4.99 [2.54, 9.79]	<0.0001
VH-TCFA	3.00 [1.68, 5.37]	0.0002
MLA ≤4.0 mm^2	2.77 [1.32, 5.81]	0.007
Lesion length ≥11.6 mm	1.97 [0.94, 4.16]	0.07
EEM_{MLA} <14.3 mm^2	1.30 [0.62, 2.75]	0.49

Variables entered into the model: Minimal luminal area (MLA); plaque burden at the MLA (PB_{MLA}); external elastic membrane at the MLA (EEM_{MLA}) <median; lesion length ≥ median (mm); VH-TCFA.

N Engl J Med 2011; 364:226-235

Lesson learnt…

A quarter of century later, IVUS… is a IIB C guideline recommendation for LM. That's all…

ESC/EACTS GUIDELINES

ESC guidelines for myocardial revascularization: Recommendations for specific percutaneous coronary intervention devices and pharmacotherapy

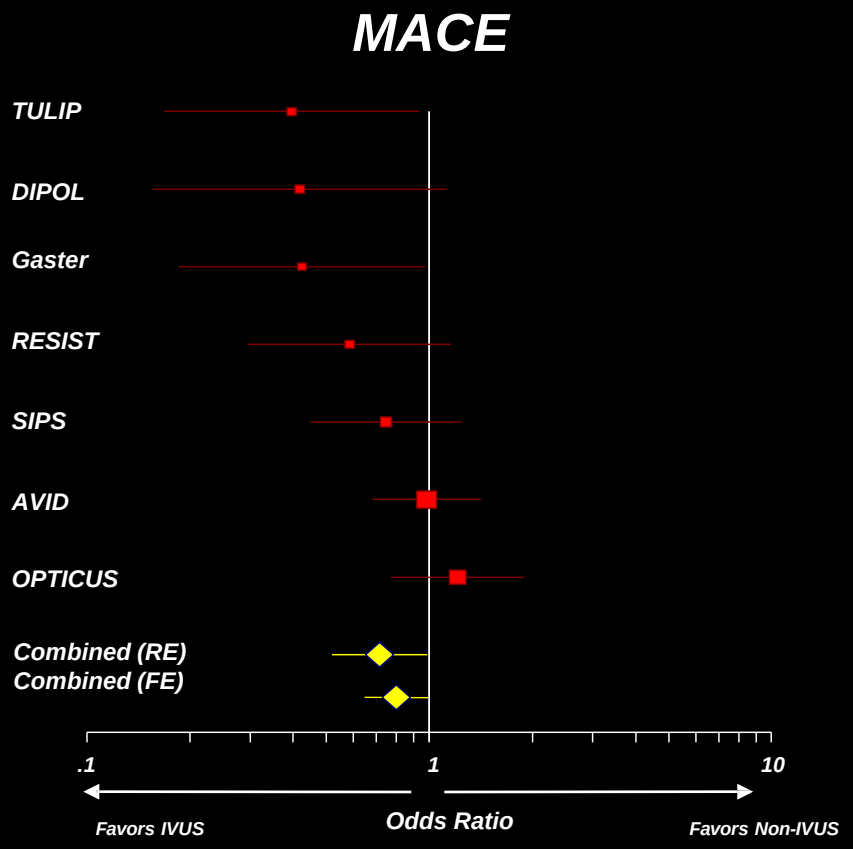
IVUS-guided stent implantation may be considered for unprotected left main PCI.	**IIB C**

Class IIb	*Usefulness/efficacy is less well established by evidence/opinion.*
Level of evidence C	Consensus of opinion of the experts and/or small studies, retrospective studies, registries.

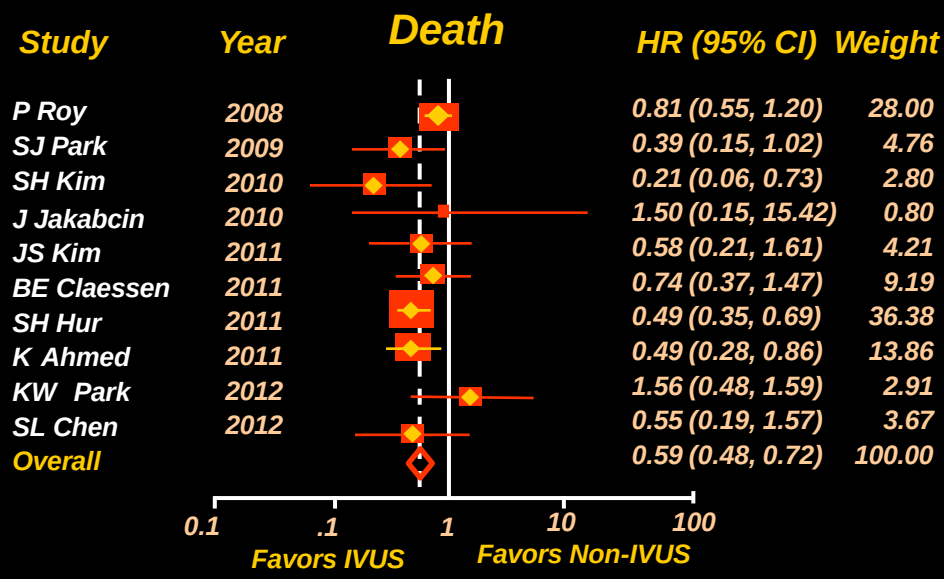
Meta-analysis of Randomized Trials of IVUS vs Angiographic Guided BMS implantation (n=2193 pts)

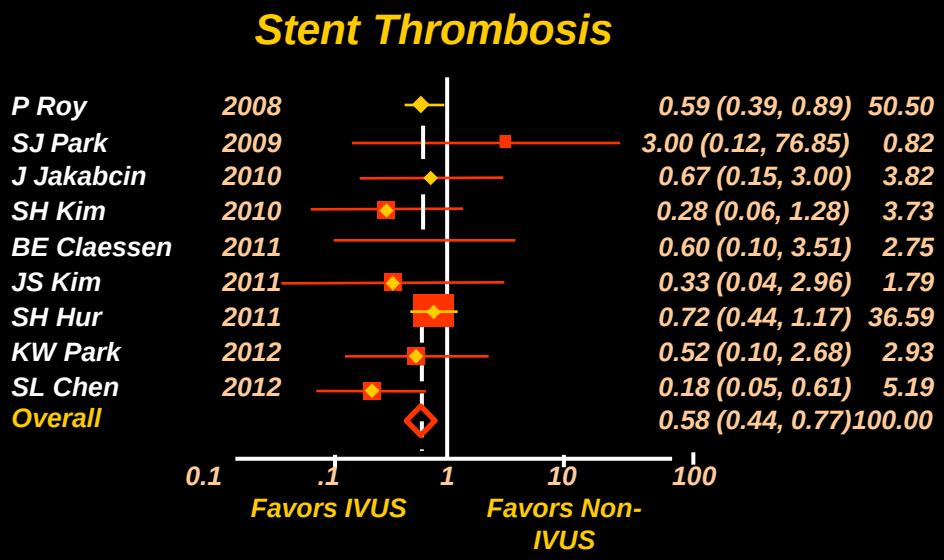
IVUS guidance was associated with significantly lower rate of

- *Angiographic restenosis (22.2% vs. 28.9%; OR 0.64, p=0.02)*
- *Repeat revascularization (12.6% vs. 18.4%; OR 0.66, p=0.004)*
- *Overall MACE (19.1% vs. 23.1%; OR 0.69, p=0.03)*
- *But no significant effect on MI (p=0.51) or mortality (p=0.18).*
- *ST was not reported*



Parise et al. Am J Cardiol. 2011;107:374-82





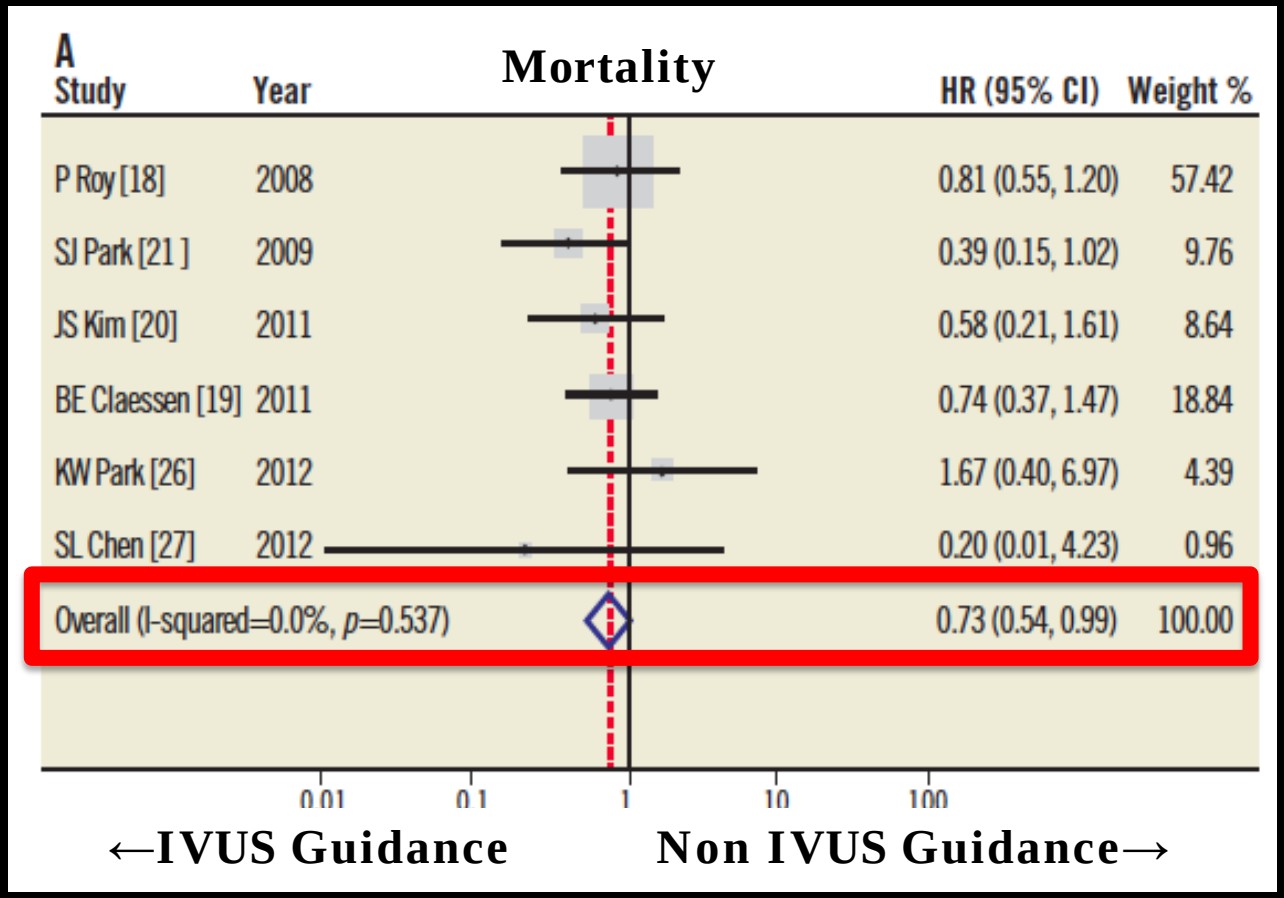
Meta-Analysis of 11 Studies (n=19,619 patients)

Compared with angiography-guidance, IVUS-guided DES implantation was associated with a reduced incidence of

- *Death (HR: 0.59, 95% CI: 0.48-0.73, p<0.001)*
- *Stent thrombosis (HR: 0.58, 95% CI: 0.44-0.77, p<0.0001)*
- *Major adverse cardiac events (HR: 0.87, 95% CI: 0.78-0.96, p=0.008)*

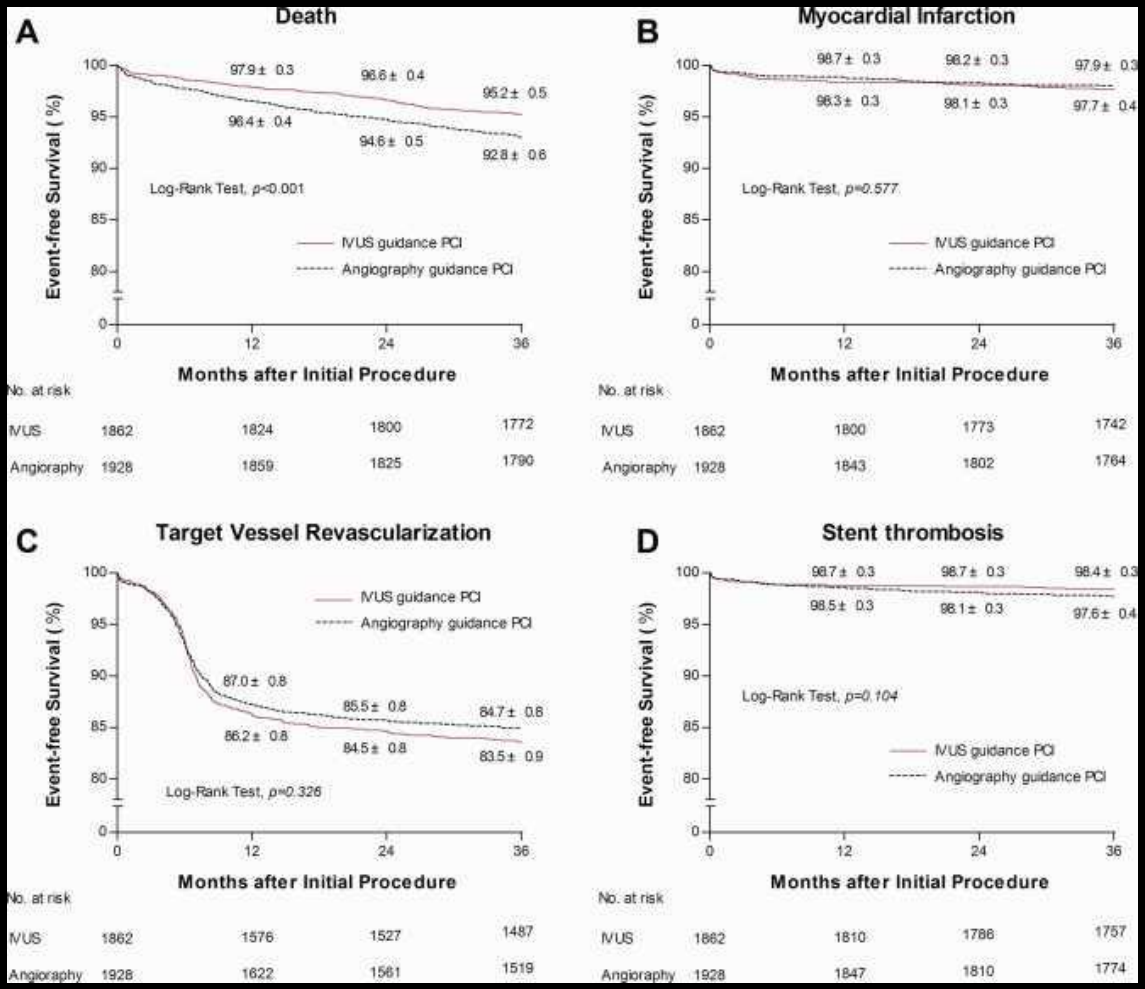
Zhang et al. Eurointervention 2012;8:855-65

In the meta-analysis of 19,619 patients, mortality was significantly reduced by 27%...



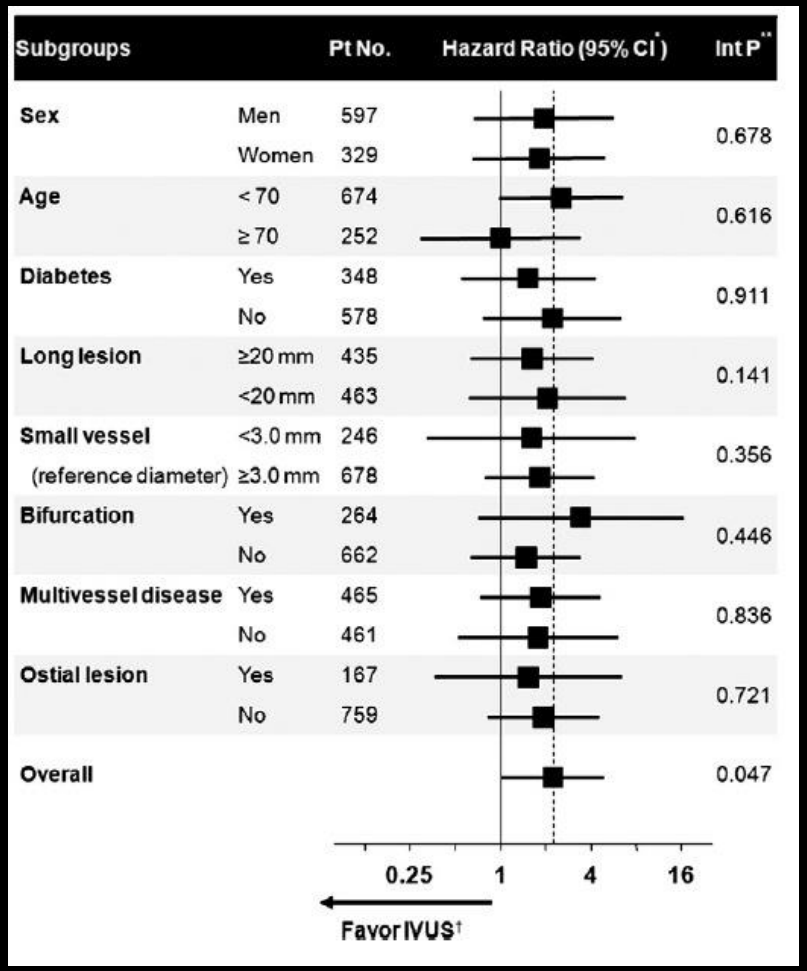
Zhang et al. EuroIntervention

Impact of Intravascular Ultrasound-Guided Percutaneous Coronary Intervention on Long-Term Clinical Outcomes in a Real World Population



Hur et al. CCI 2013

Impact of intravascular ultrasound guidance in routine percutaneous coronaryintervention for conventional lesions: data from the EXCELLENT trial



Park et al. IJC 2012

ADAPT-DES

Assessment of **D**ual **A**nti**P**latelet **T**herapy with **D**rug-**E**luting **S**tents

8,575 pts prospectively enrolled

No clinical or anatomic exclusion criteria

Succesful and uncomplicated PCI with ≥1 non-investigational DES

↓

Pre-specified IVUS vs no IVUS substudy

↙ ↘

IVUS: 3349 pts

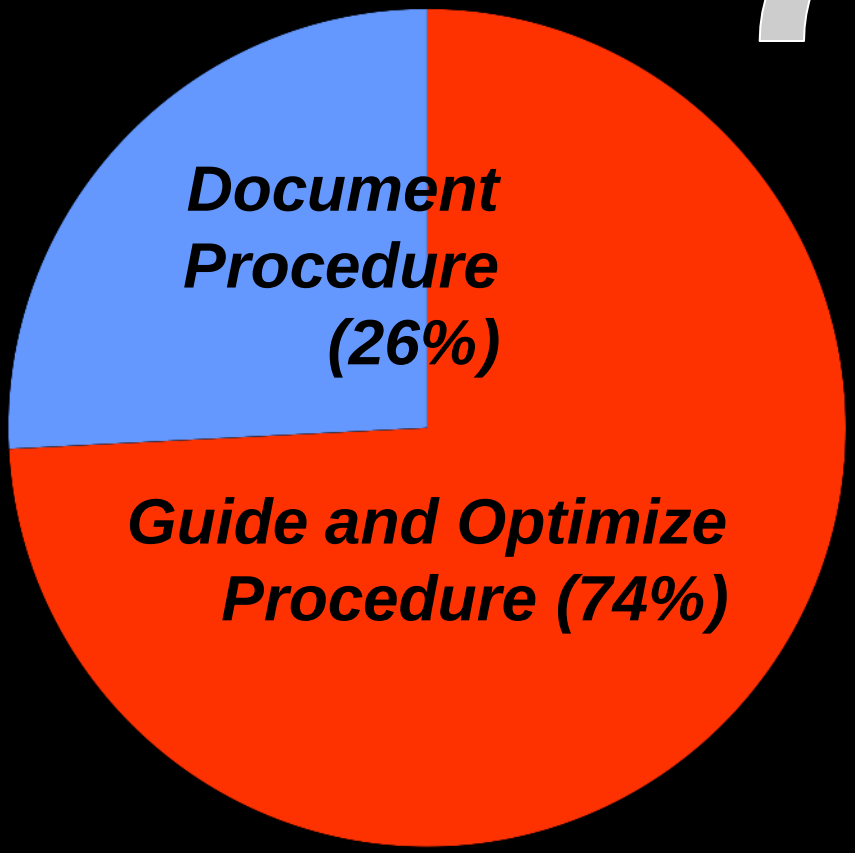
No IVUS: 5234 pts

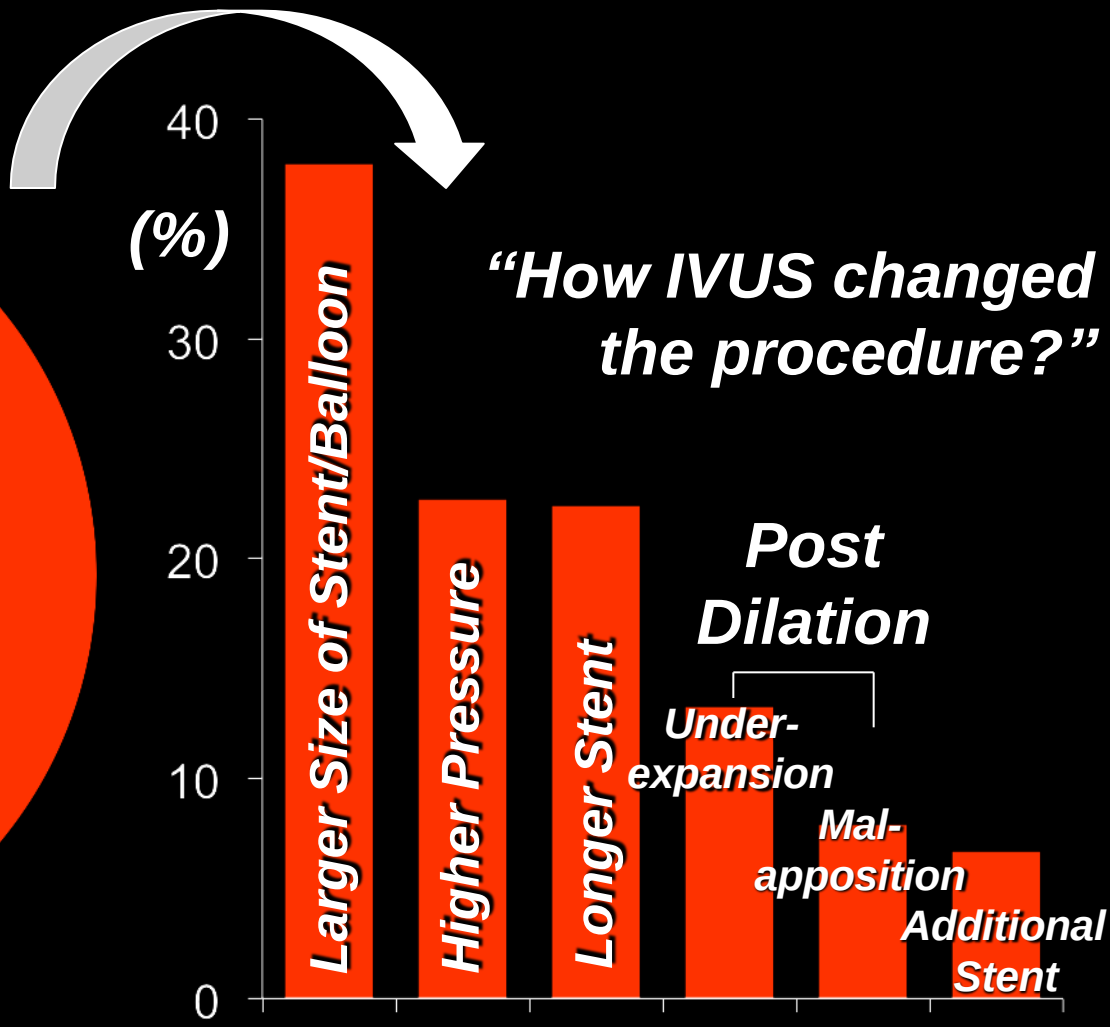
↓ ↓

Clinical FU at 30 days, 1 year, 2 years

Witzenbichler, et al. Circulation, Nov 2013

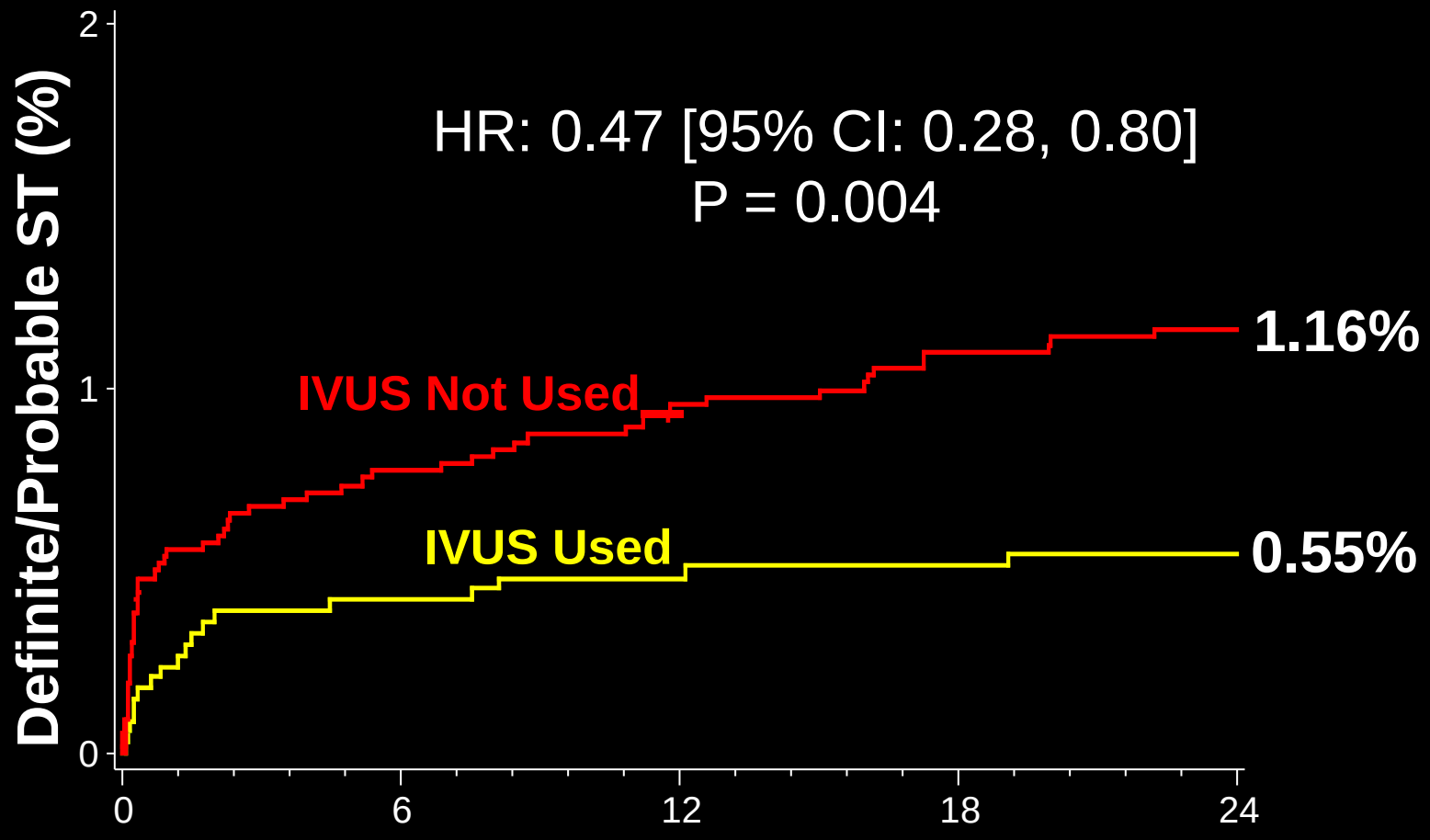
Reason for IVUS Use





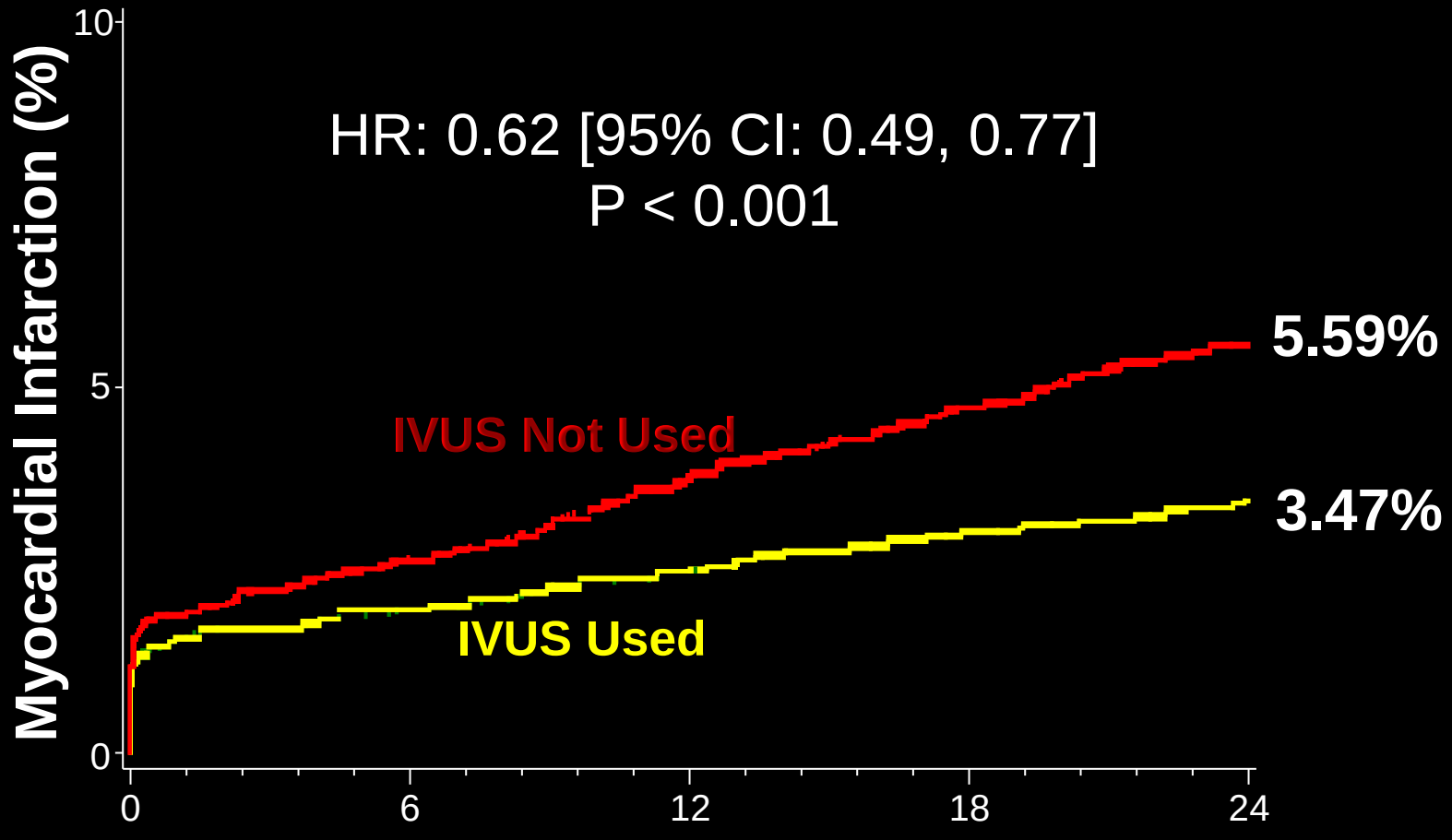
Witzenbichler, et al. Circulation Nov 2013

IVUS Use and Definite/Probable ST Within 2 Years



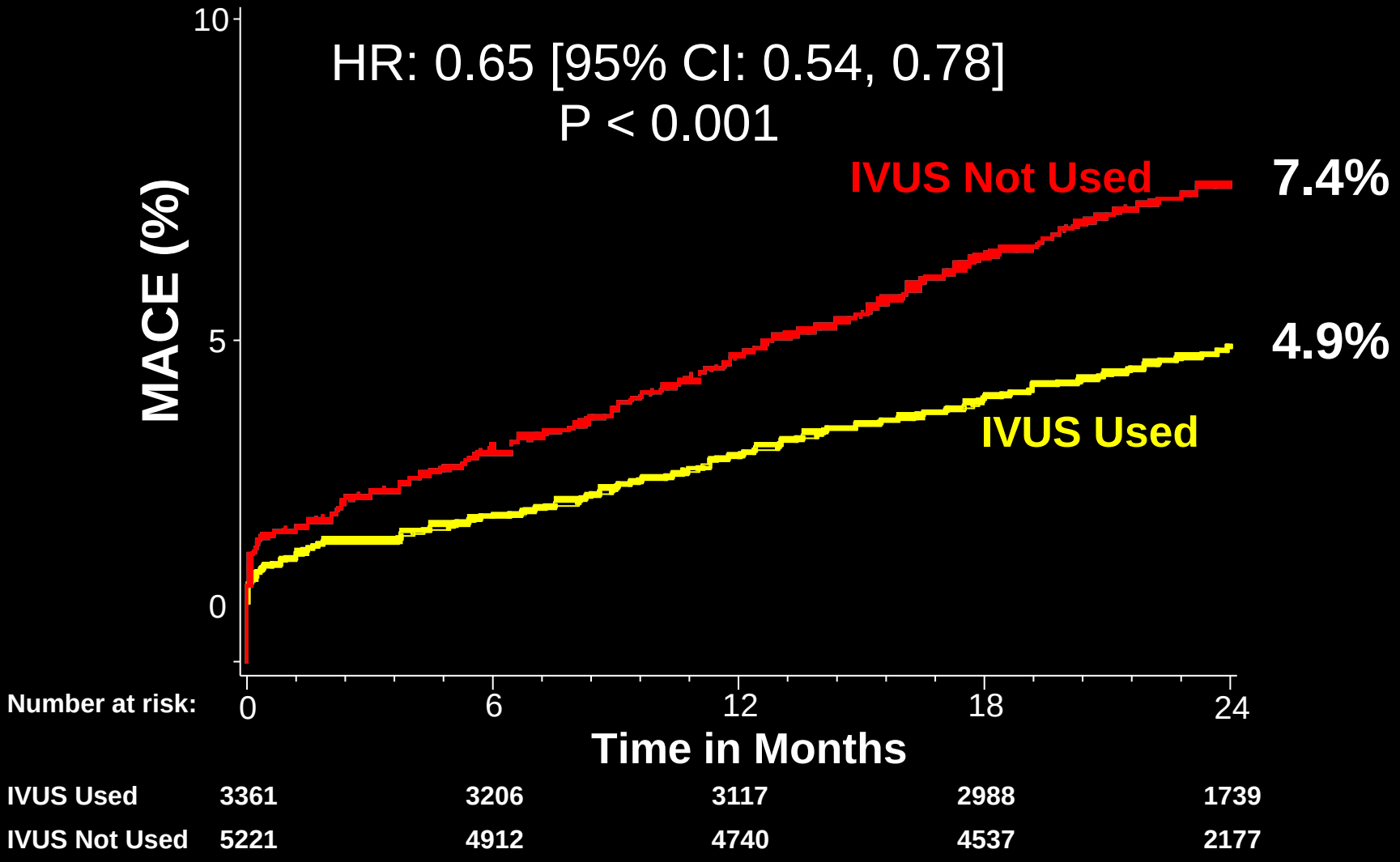
Number at risk:					
IVUS Used	3361	3260	3182	3065	1791
IVUS Not Used	5221	5019	4886	4713	2279

IVUS Use and MI Within 2 Years

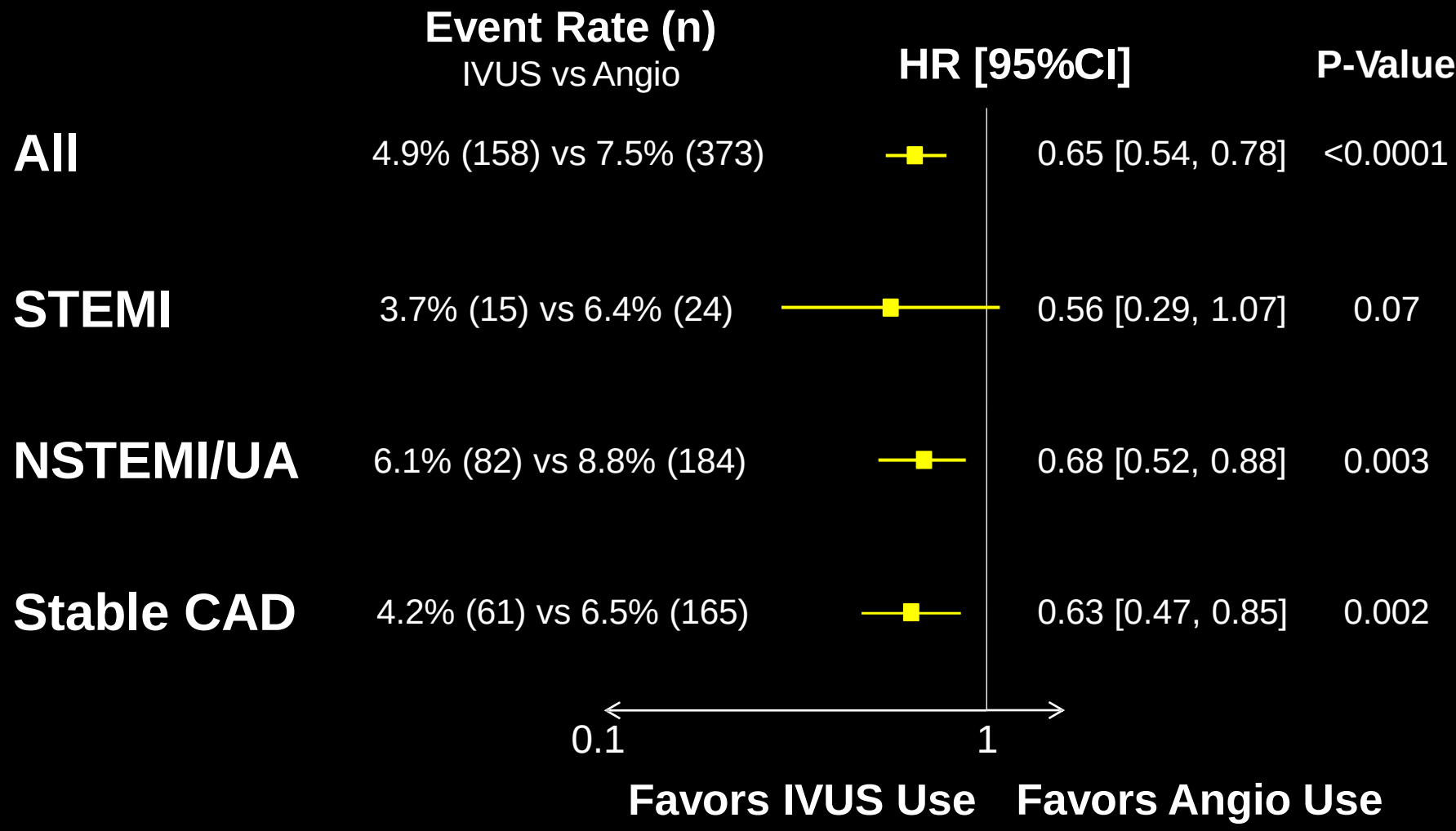


Number at risk:					
IVUS Used	3361	3209	3120	2991	1739
IVUS Not Used	5221	4916	4744	4541	2179

IVUS Use and MACE (Definite/Probable ST, Cardiac Death, MI) Within 2 Years



Association of IVUS Use with MACE (Definite/Probable ST, Cardiac Death, MI) in Relation to Index Presentation



Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

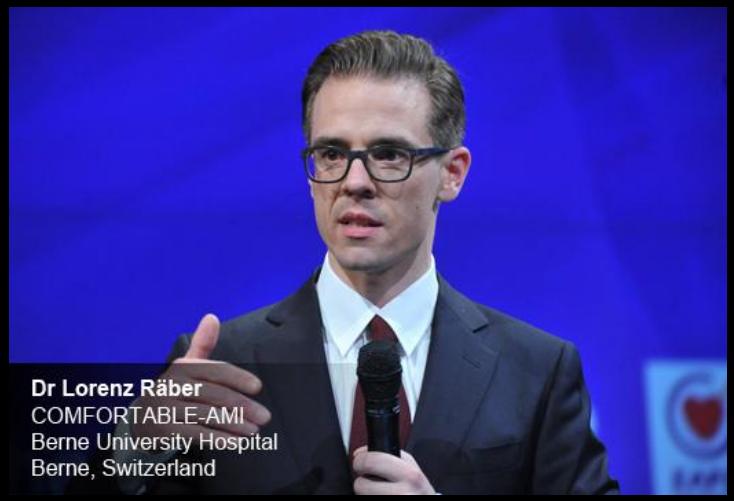
American Heart Association®

IVUS-Guided Percutaneous Coronary Interventions: An Ongoing Odyssey?

Lorenz Räber and Stephan Windecker

Circulation. published online November 26, 2013;
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0009-7322. Online ISSN: 1524-4539



Lesson learnt…

Optical coherence tomography☆

E. Regar[a] J.A. Schaar[a] E. Mont[b] R. Virmani[b] P.W. Serruys[a,*]

Received 16 December 2003; accepted 17 December 2003

CARDIOVASCULAR RADIATION MEDICINE

"Intravascular OCT allows for accurate assessment of vessel structures close to the luminal side. Clinical application is feasible. To date, however, the clinical relevance of OCT findings in coronary arteries is unclear and further validation of OCT imaging is mandatory."

A decade later, OCT is still "a valuable research tool". That's all…

ESC guidelines for myocardial revascularization: Recommendations for specific percutaneous coronary intervention devices and pharmacotherapy

ESC/EACTS GUIDELINES

"Optical coherence tomography (OCT) is a light-based modality of intravascular imaging with higher spatial resolution than IVUS (15 vs. 100 μm). Its penetration is lower than IVUS but it provides detailed imaging of the endoluminal borders. At present, OCT is a valuable research tool."

Journal of the American College of Cardiology

Published by Elsevier Inc.

EDITORIAL COMMENT

Intracoronary Optical Coherence Tomography

Are We Getting Too Close to the Light?*

Stephen J. Nicholls, MBBS, PhD,†
Rishi Puri, MBBS‡

Adelaide, Australia; and Cleveland, Ohio

Greek mythology of Icarus

Lesson learnt…
Although some evidences are emerging…

Angiography alone versus angiography plus optical coherence tomography to guide decision-making during percutaneous coronary intervention: the Centro per la Lotta contro l'Infarto-Optimisation of Percutaneous Coronary Intervention (CLI-OPCI) study

In the analysis of 335 matched pair (670 patients), mortality was significantly reduced by 52% …

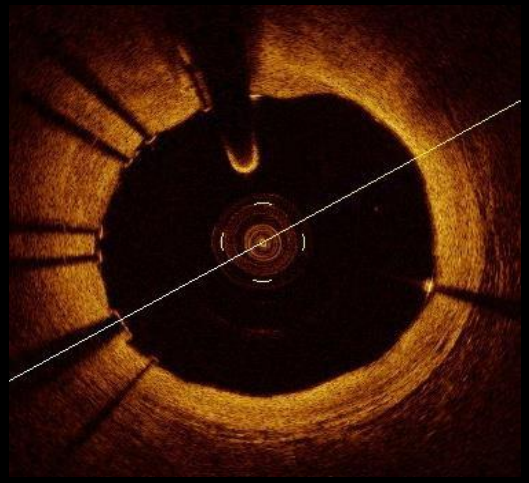


Table 4. Clinical results.

	Angiographic guidance group (n=335)	Angiographic plus OCT guidance group (n=335)	*p*-value
In-hospital events			
Cardiac death	3 (0.9%)	2 (0.6%)	1.0
Non-fatal myocardial infarction	22 (6.5%)	13 (3.9%)	0.118
Events at 1-year follow-up			
Death	23 (6.9%)	11 (3.3%)	0.035
Cardiac death	15 (4.5%)	4 (1.2%)	0.010
Myocardial infarction	29 (8.7%)	18 (5.4%)	0.096
Target lesion repeat revascularisation	11 (3.3%)	11 (3.3%)	1.0
Definite stent thrombosis	2 (0.6%)	1 (0.3%)	1.0
Cardiac death or myocardial infarction	43 (13.0%)	22 (6.6%)	0.006
Cardiac death, myocardial infarction, or repeat revascularisation	50 (15.1%)	32 (9.6%)	0.034

Safety and Feasibility of FD-OCT Imaging

Imola F et al. *EuroIntervention* 2010;6:575-81

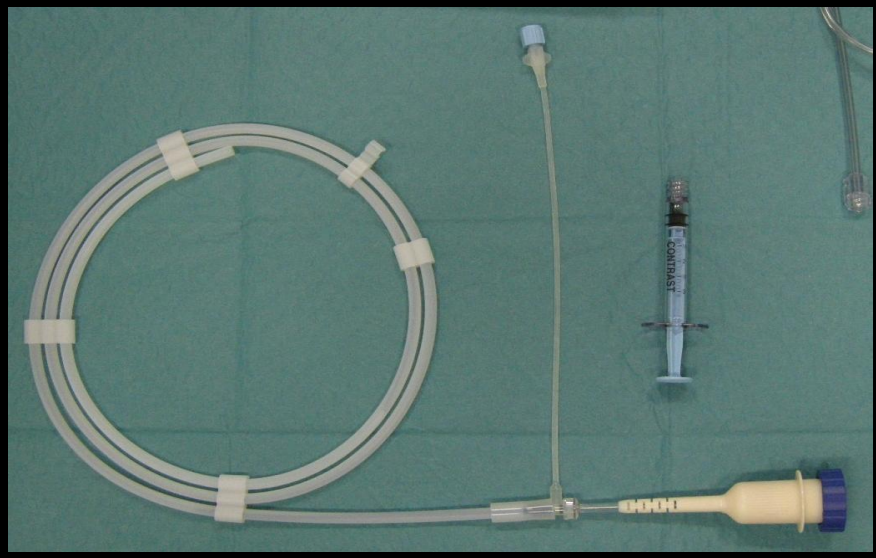
Success **99%**

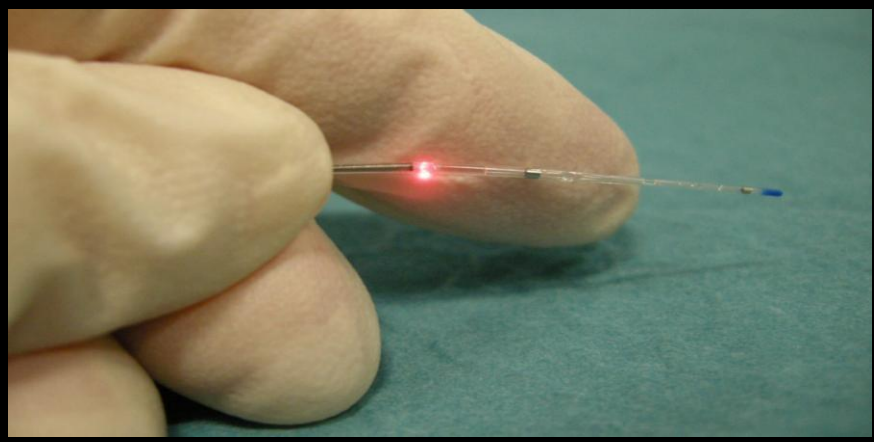
Duration **2.1±0.5 mi**

Contrast **49±19 ml**

VT/VF **0%**

MACE **0%**





OCT for Intracoronary Imaging

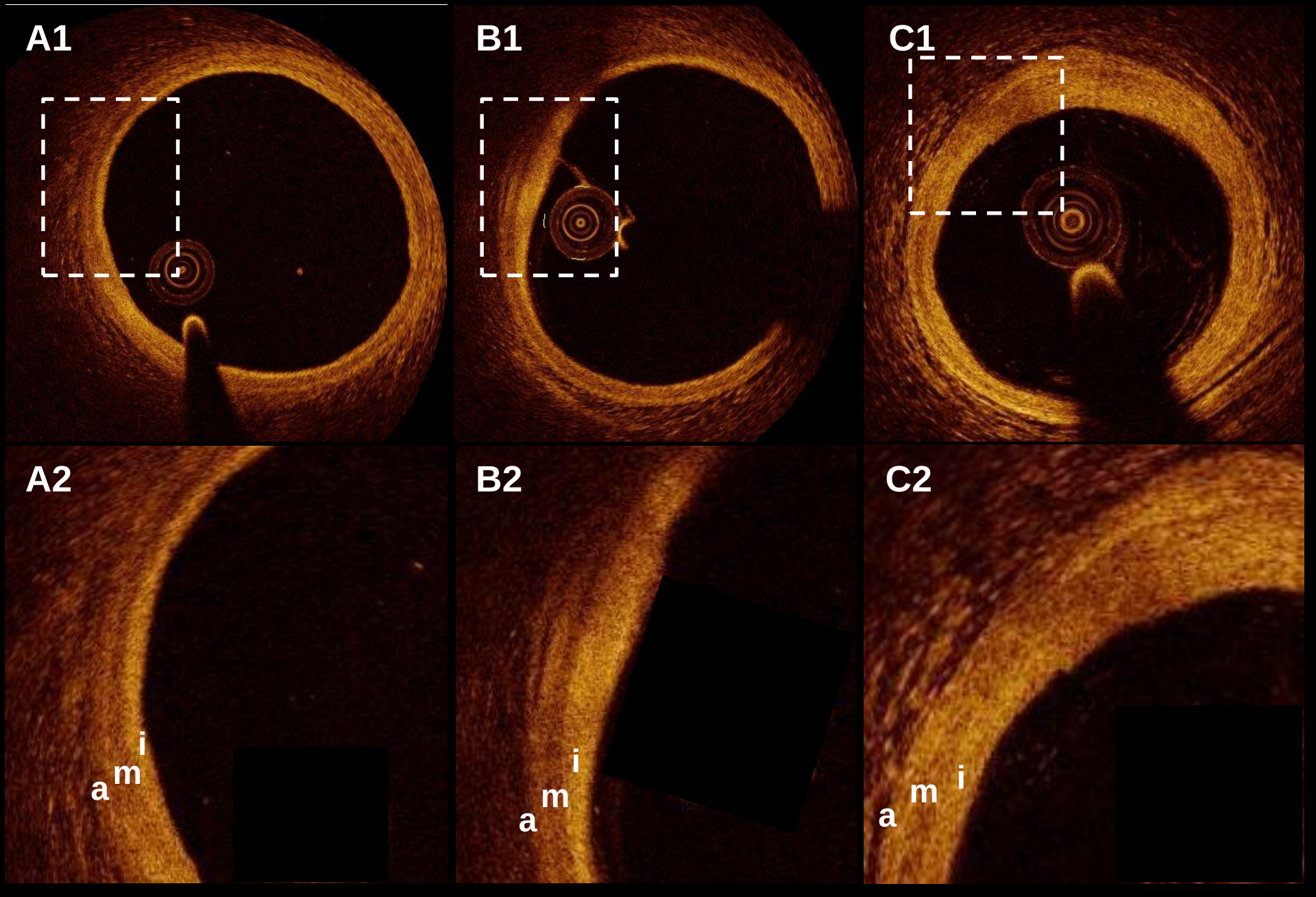
Atherosclerosis

- Normal Vessel Wall
- Different Plaque Types
- Plaque Progression
- Plaque Rupture

Stent Evaluation

- Neointimal Hyperplasia
- Pattern of Restenosis
- Strut Coverage and Apposition
- Stent thrombosis

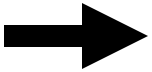
Tunica Intima



Value of Combined Assessment Grayscale IVUS, IVUS-VH and OCT

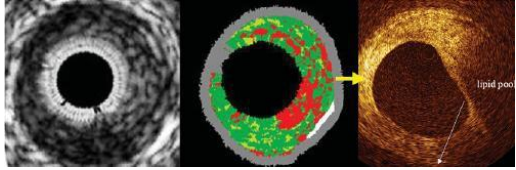
Vulnerable Plaque characteristics

	OCT	IVUS-VH
Fibrous cap thickness	●	●
Detailed surface morphology	●	●
Visualization of entire plaques	●	●
Plaque composition	●	●
Differentiation lipid vs calcium	●	●

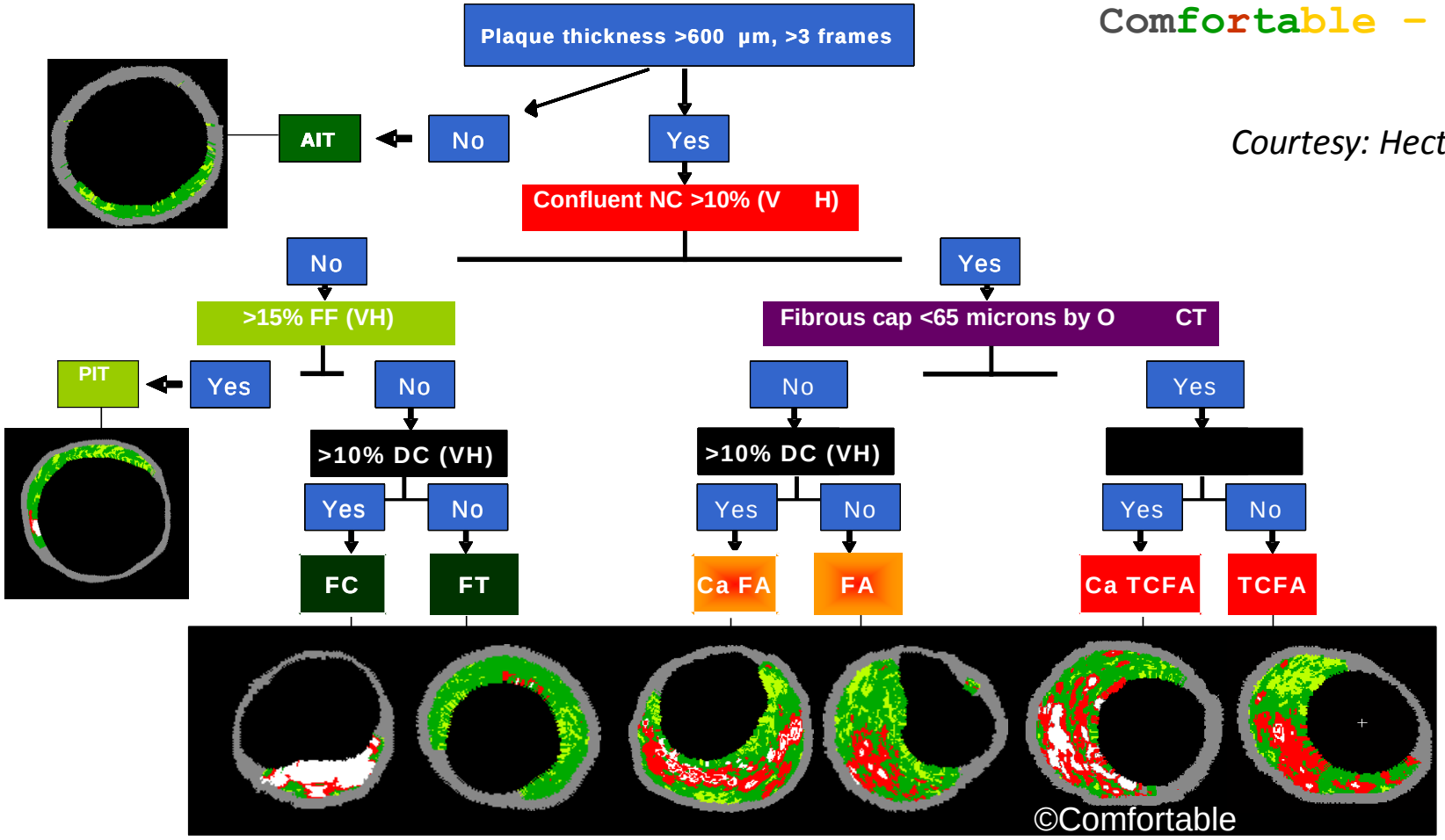


Thin cap fibroma-atheroma TCFA Detection Algorithm ?

OCT/IVUS VH TCFA Detection Algorithm

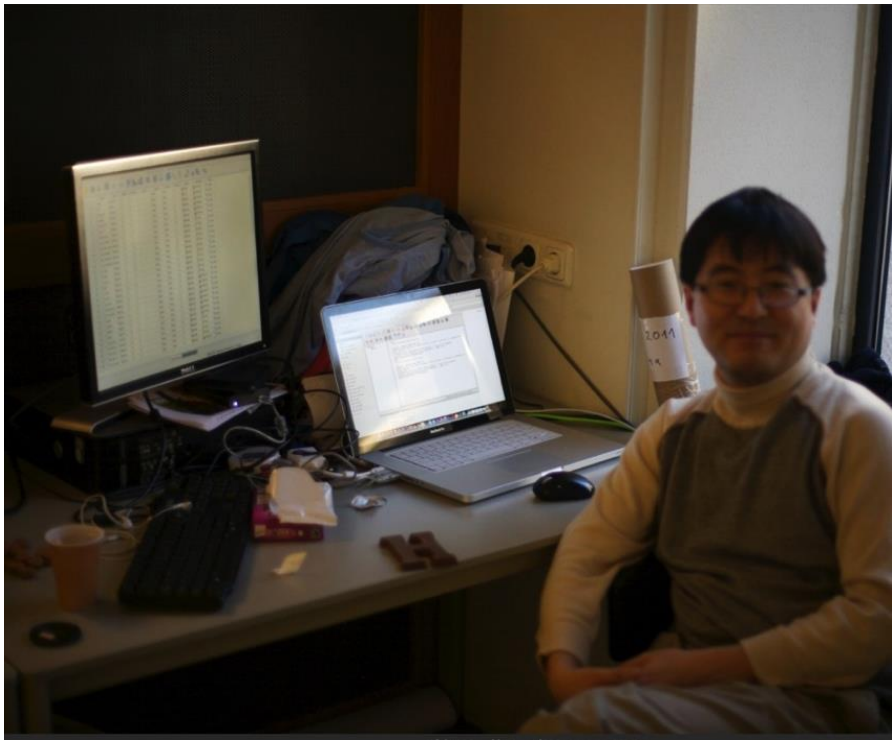


Comfortable – IBIS 4

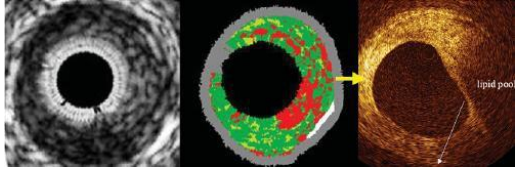


Courtesy: Hector Garcia

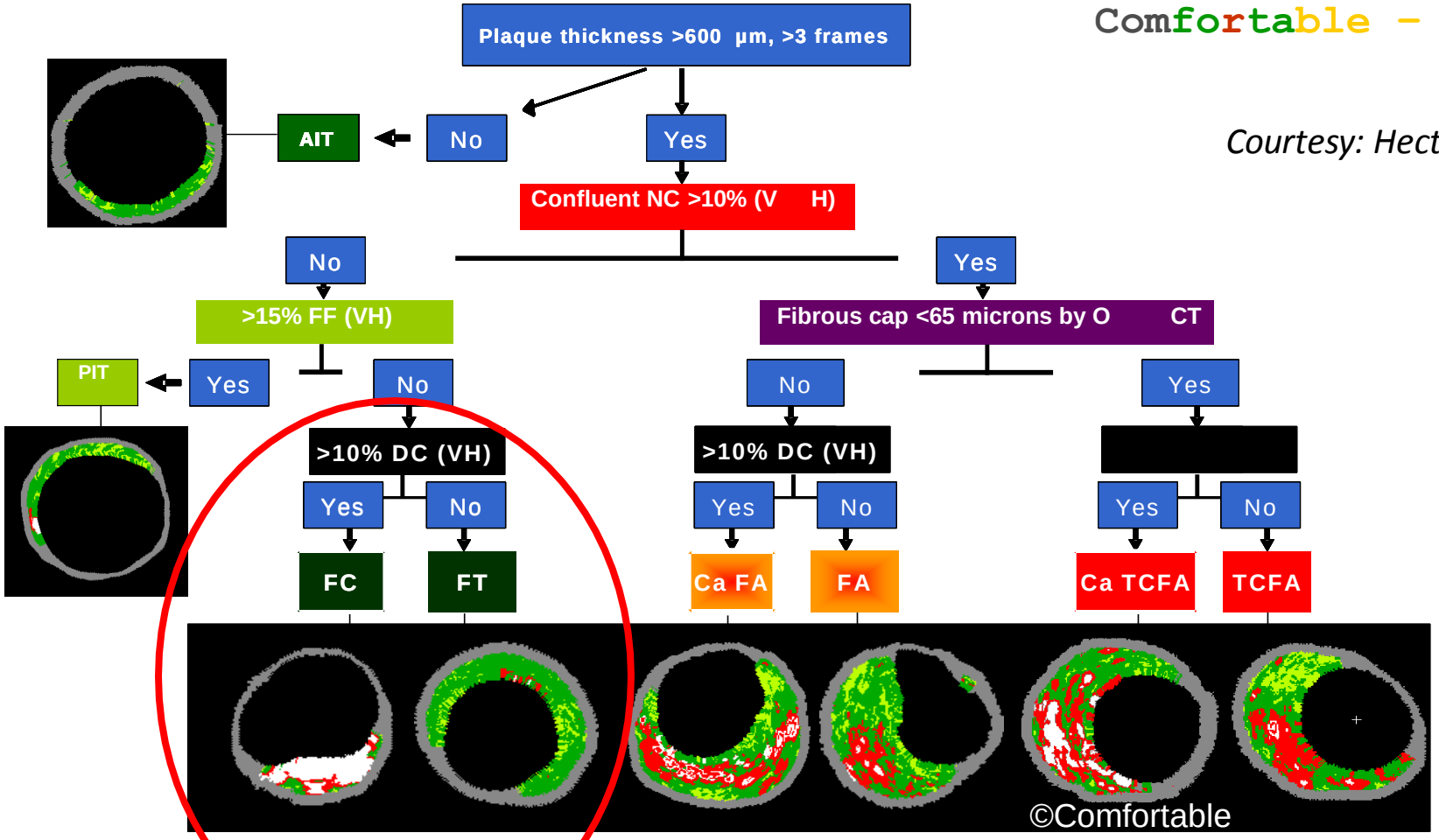
AIT	= adaptive intimal thickening	FT	= fibrotic
NC	= necrotic core	Ca FA	= calcium fibroatheroma
FF	= fibrofatty	FA	= fibroatheroma
DC	= dense calcium	Ca TCFA	= ca-thin-cap-fibroatheroma
FC	= fibrocalcic	TCFA	= thin-cap-fibroatheroma



OCT/IVUS VH TCFA Detection Algorithm



Comfortable – IBIS 4

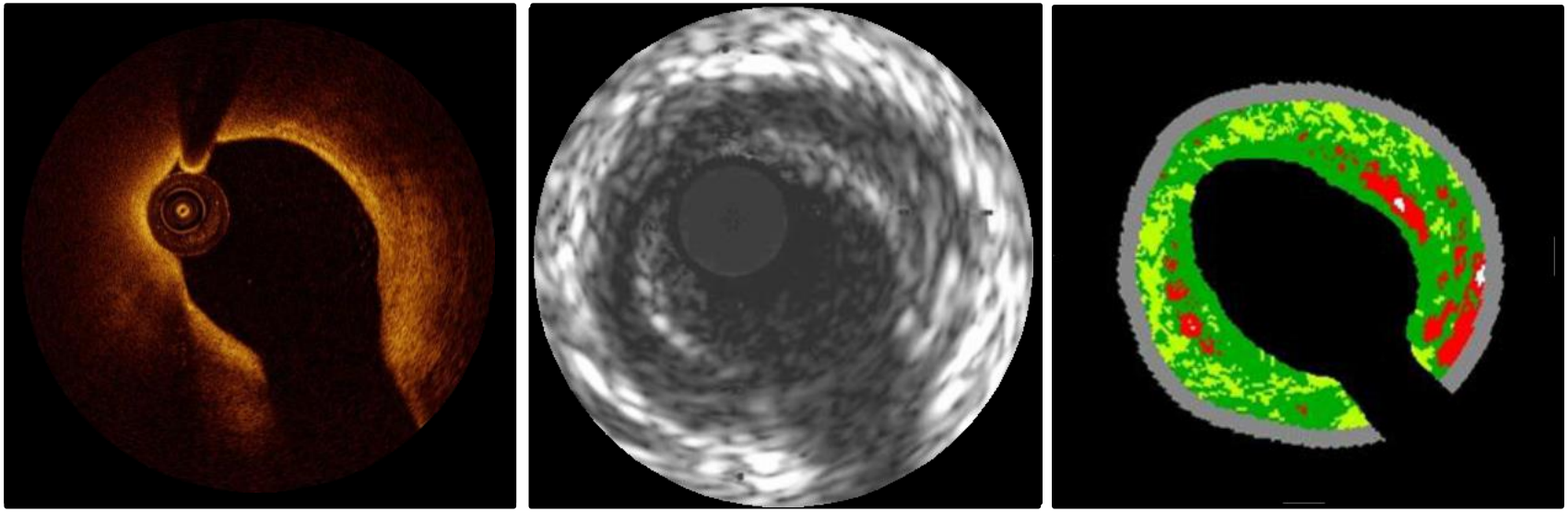


Courtesy: Hector Garcia

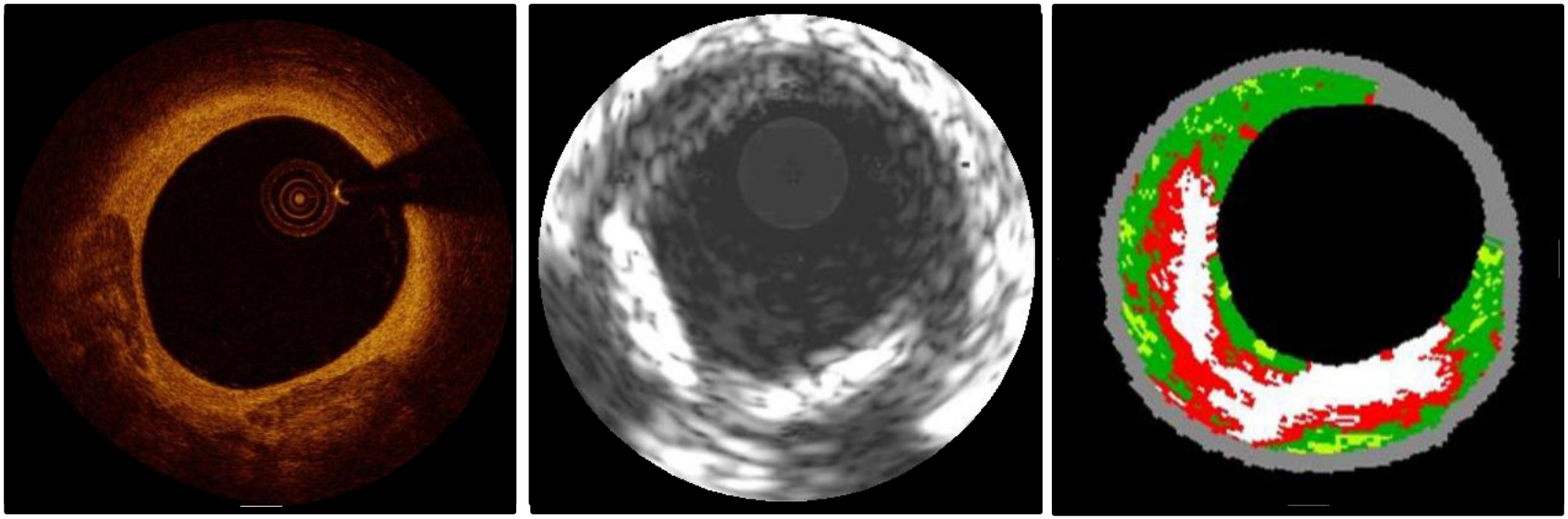
AIT = adaptive intimal thickening
NC = necrotic core
FF = fibrofatty
DC = dense calcium
FC = fibrocalcic

FT = fibrotic
Ca FA = calcium fibroatheroma
FA = fibroatheroma
Ca TCFA = ca-thin-cap-fibroatheroma
TCFA = thin-cap-fibroatheroma

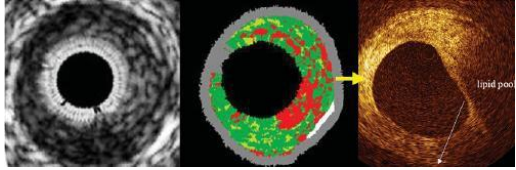
Fibrous plaque



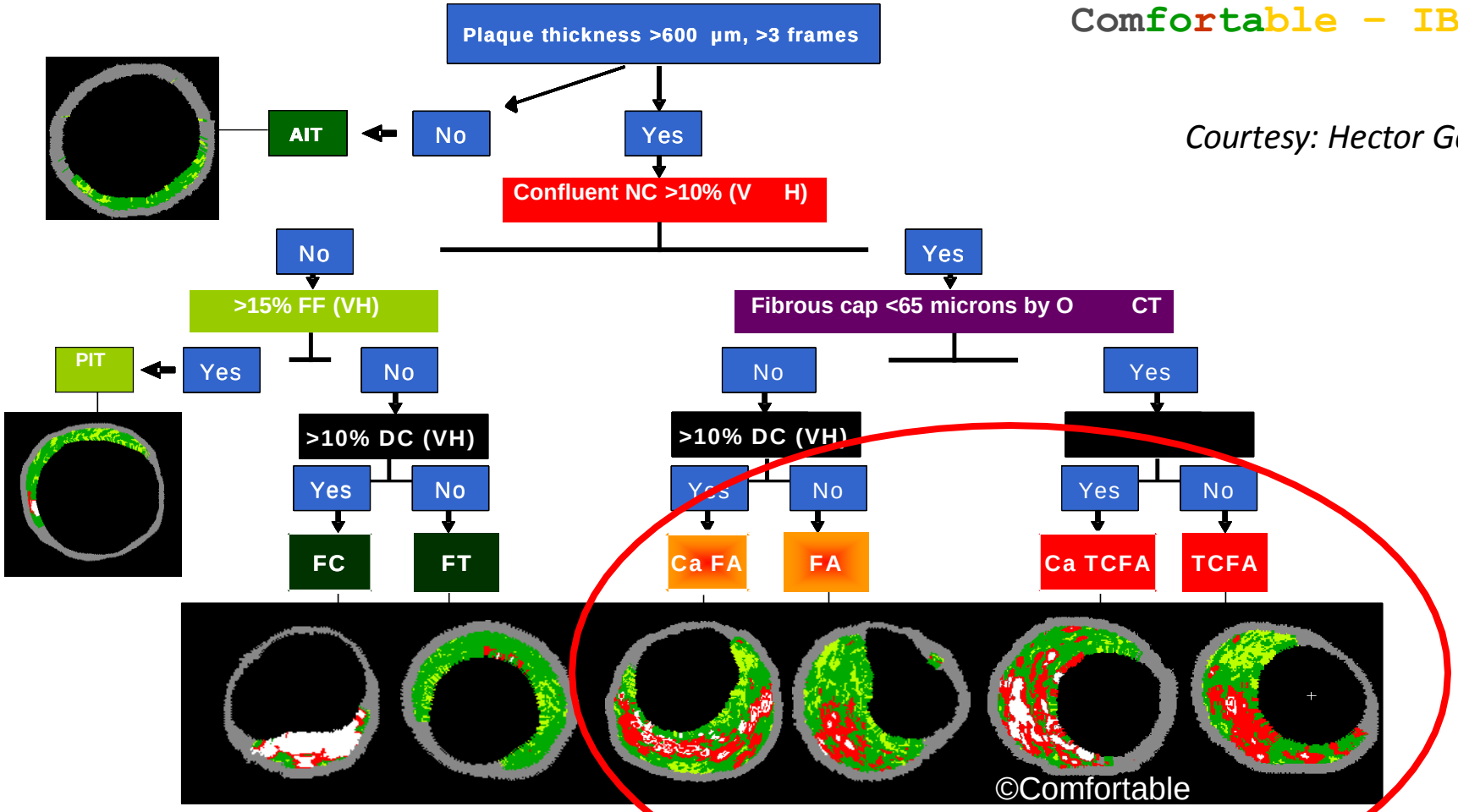
Fibrocalcific plaque



OCT/IVUS VH TCFA Detection Algorithm – Hector Garcia



Comfortable – IBIS 4

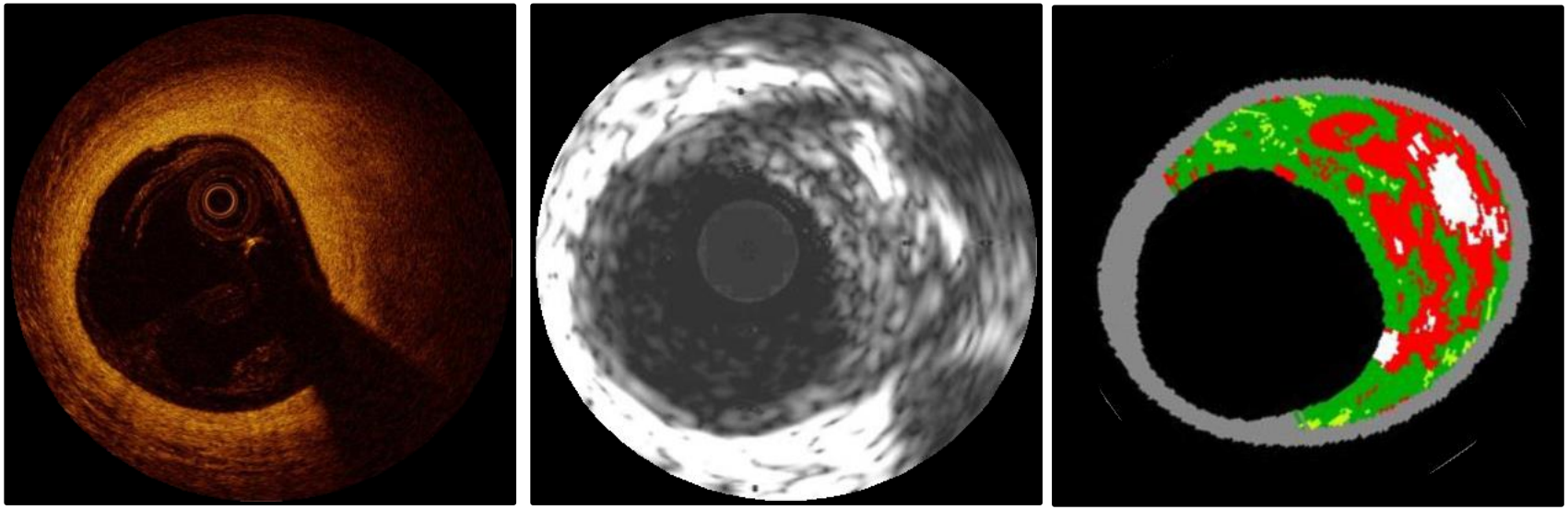


Courtesy: Hector Garcia

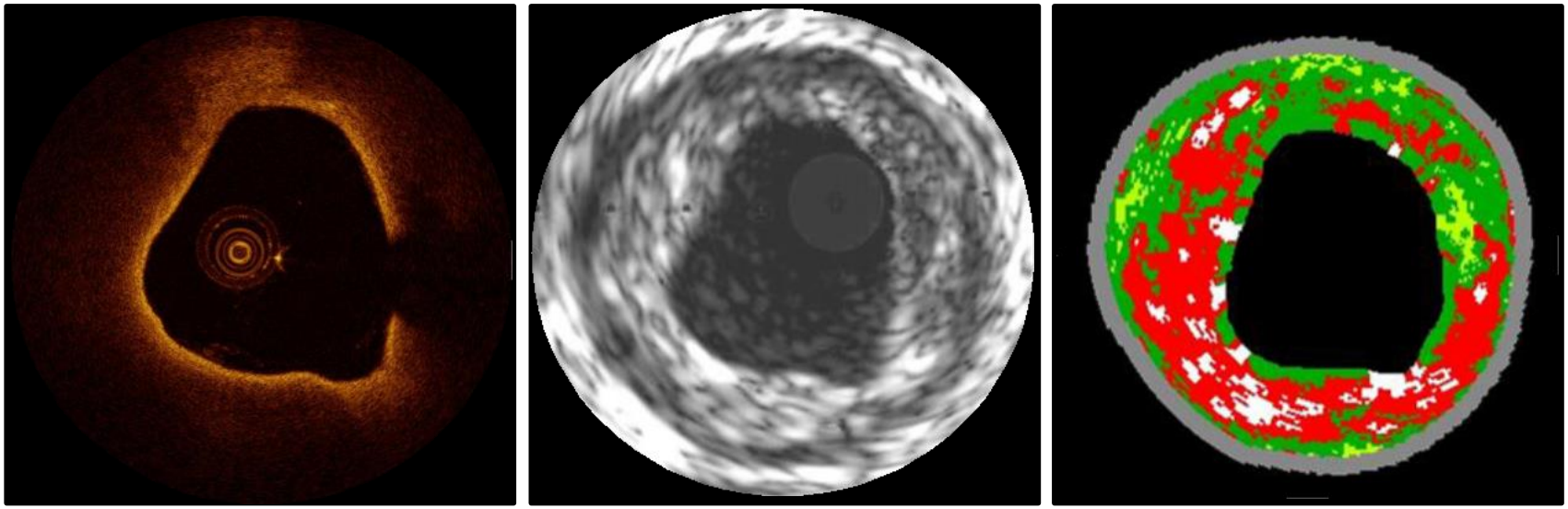
AIT = adaptive intimal thickening
NC = necrotic core
FF = fibrofatty
DC = dense calcium
FC = fibrocalcic

FT = fibrotic
Ca FA = calcium fibroatheroma
FA = fibroatheroma
Ca TCFA = ca-thin-cap-fibroatheroma
TCFA = thin-cap-fibroatheroma

Thick Cap Fibroatheroma



Thin Cap Fibroatheroma (TCFA)



Broad Inclusion Criteria:
Age ≥ 18 years
ECG and Chest pain
Primary PCI within 24 hours

Screening of all incoming STEMI patients

Recanalisation, aspiration, intra- and extracoronary blood sampling

Imaging Candidate if
-Hemodynamic stable
-Creatinine Clearance >50ml/min
-Age <90
-OCT/IVUS feasible
-No stent at the site of infarct lesion

Comfortable AMI IBIS 4 n=1100

1:1 R

DES-Biomatrix N=500

BMS-Gazelle N=500

IBIS 4 n=100

R 1:1

DES-Biomatrix N=50

BMS-Gazelle N=50

3-vessel IVUS and OCT at baseline

Rosuvastatin 40mg

30 day telephone (n=1100)

12 month visit or telephone

3-vessel IVUS and OCT at 13 months

2 year telephone

Final 5 year telephone

Principal Investigators
Lorenz Räber
Hector Garcia Garcia
Stephan Windecker

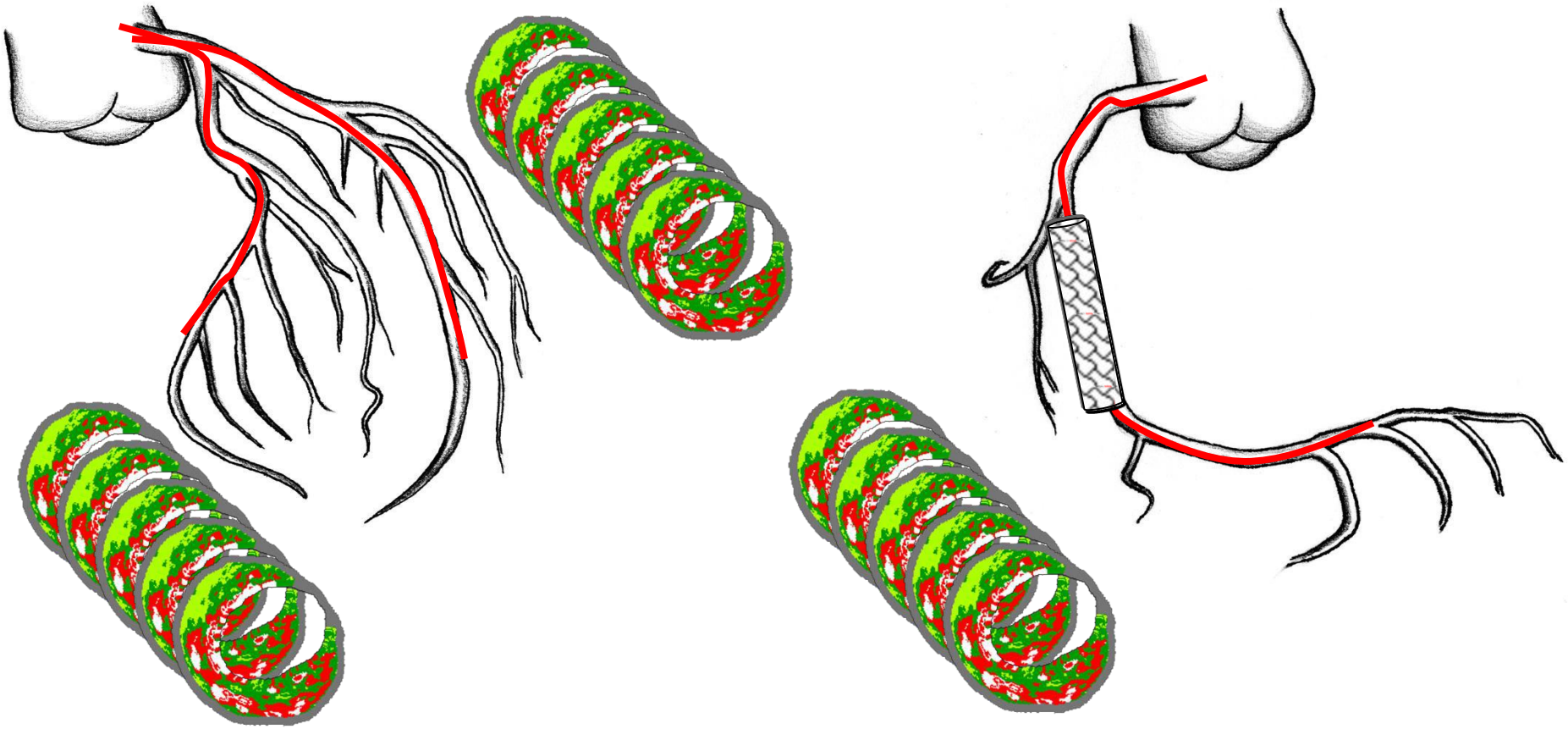
Participating sites
Bern (60)
Copenhagen (21)
Geneva (13)
Lugano (6)
Zurich (3)

Comfortable – IBIS 4 study

3 vessel imaging using IVUS Virtual Histology:

- Culprit vessel: Post-treatment imaging of the stented segment and distal segment

- Non-culprit vessel: >40 mm of proximal coronary artery



Comfortable – IBIS 4 study

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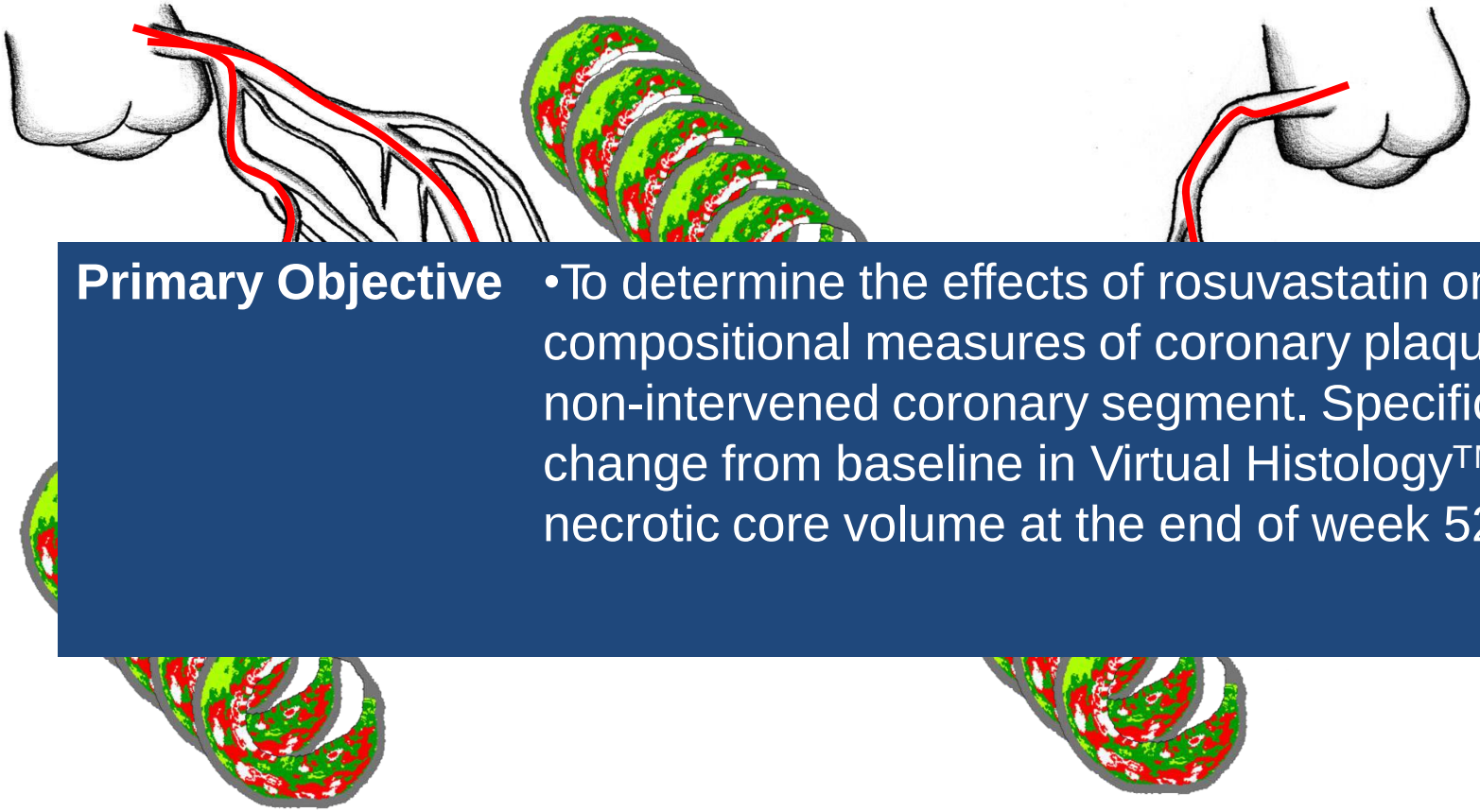


Primary Objective

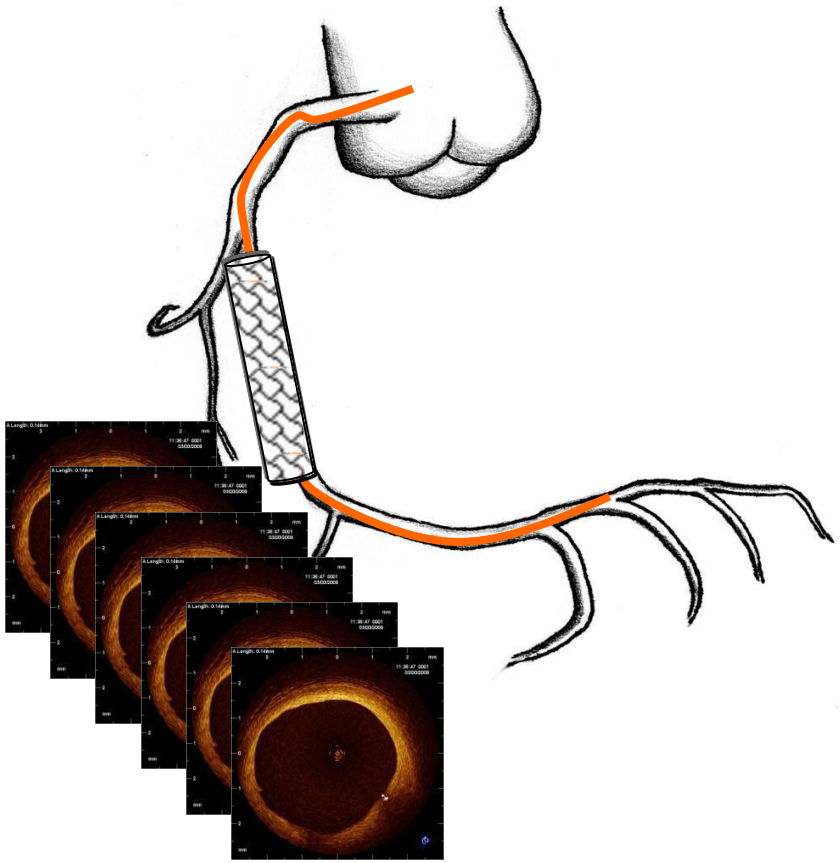
•To determine the effects of rosuvastatin on compositional measures of coronary plaque in a non-intervened coronary segment. Specifically, the change from baseline in Virtual Histology™ necrotic core volume at the end of week 52.

Comfortable – IBIS 4 study

3 vessel imaging using OCT:

- Culprit vessel: Post-treatment imaging of the stented segment and distal segment

- Non-culprit vessel: >40 mm of proximal coronary artery

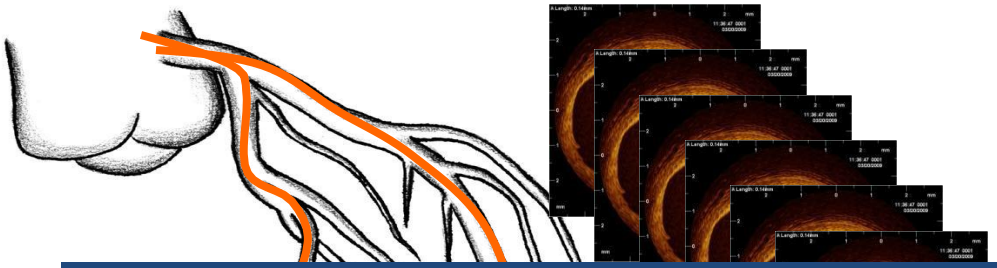


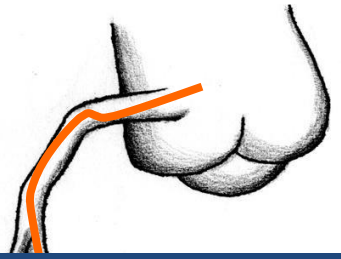
Comfortable – IBIS 4 study

3 vessel imaging using OCT:

- Culprit vessel: Post-treatment imaging of the stented segment and distal segment

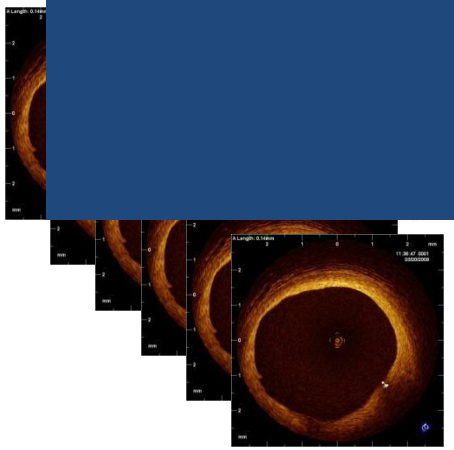
- Non-culprit vessel: >40 mm of proximal coronary artery

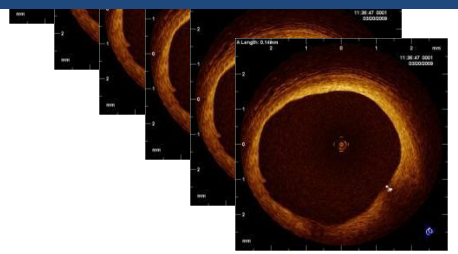


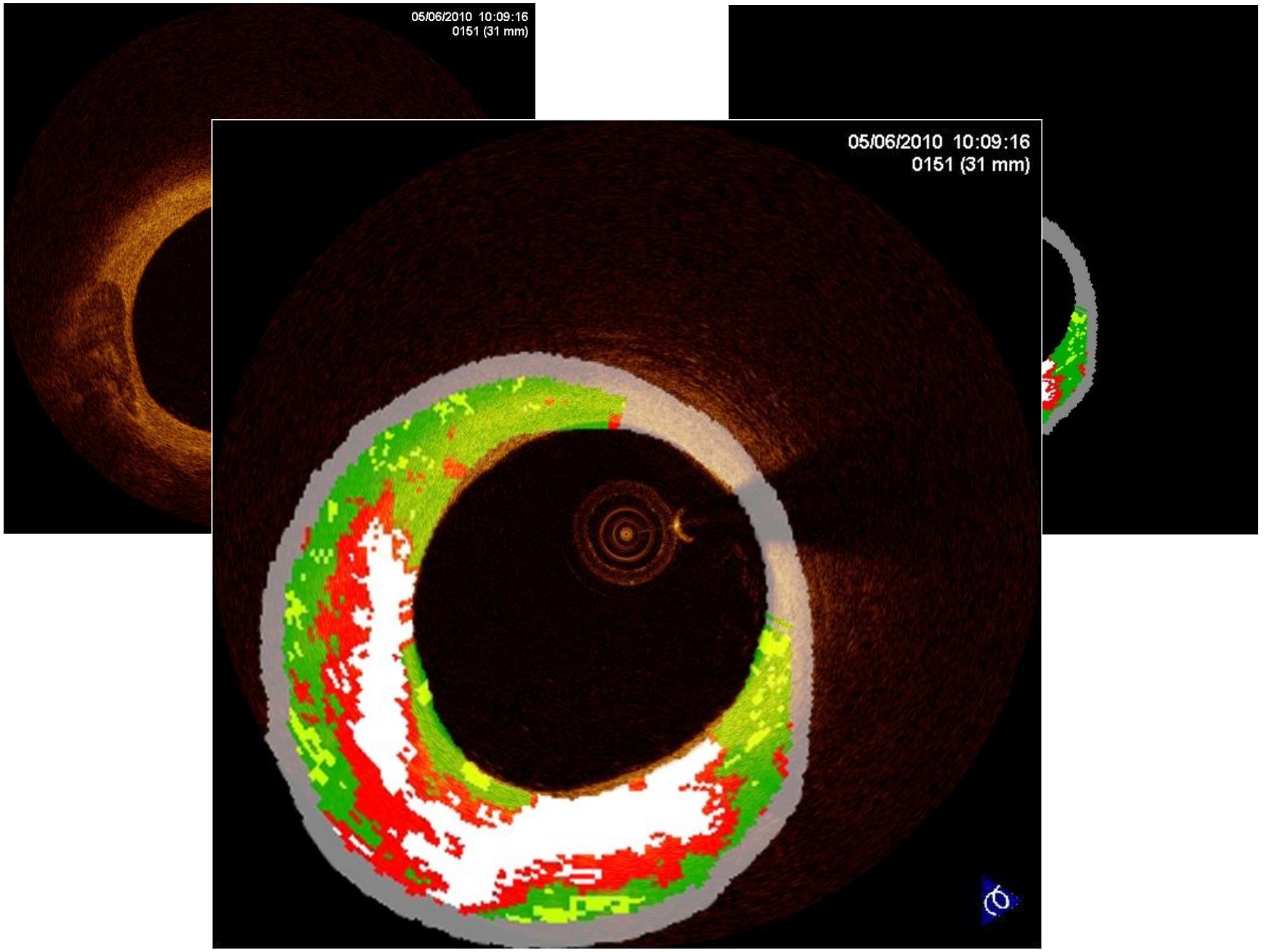


Secondary Objective

•To determine the effects of rosuvastatin on fibrous cap thickness of coronary plaque in a non-intervened coronary segment. Specifically, the change from baseline in OCT cap thickness at the end of week 52.



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0151 (31 mm)
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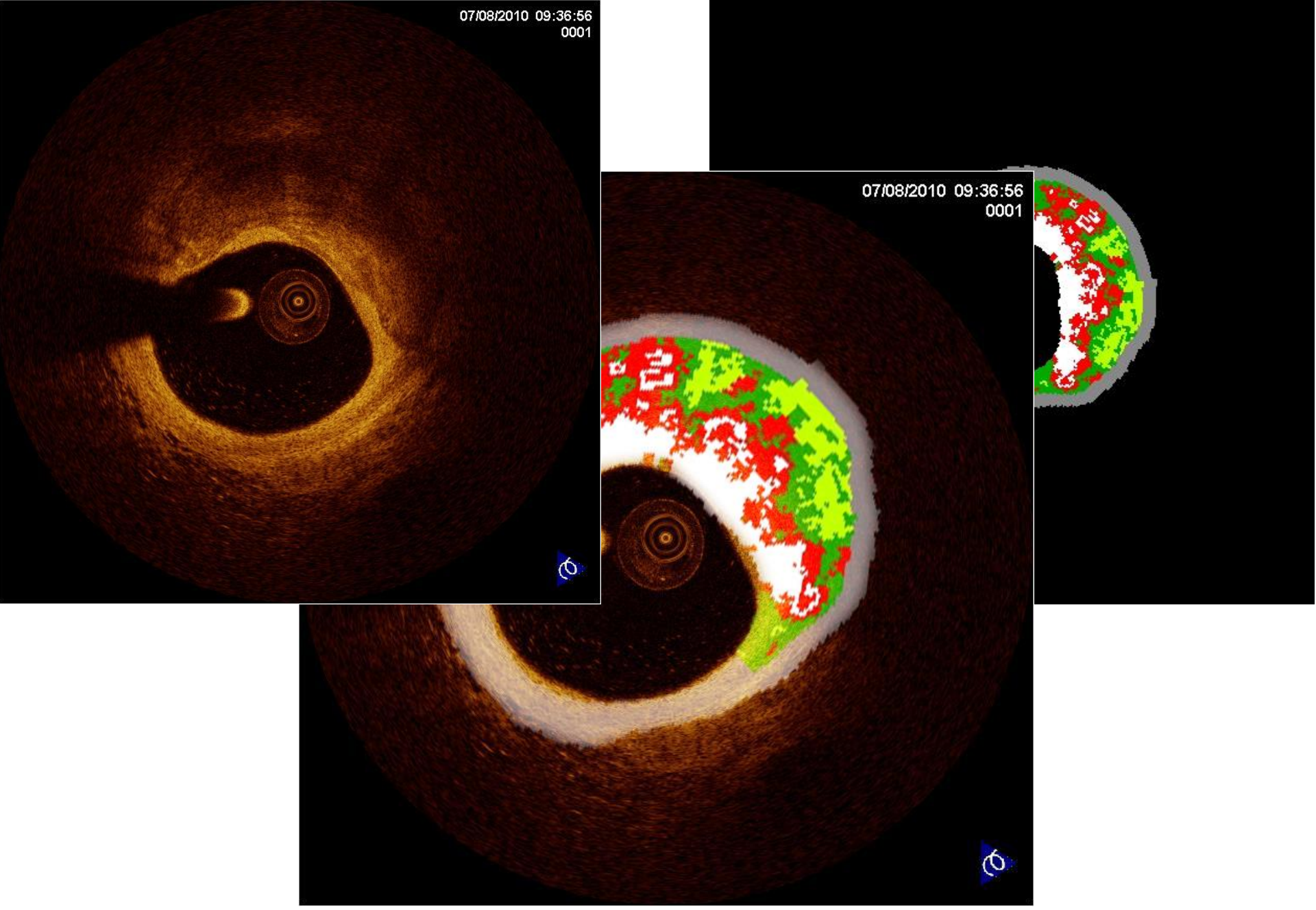
0151 (31 mm)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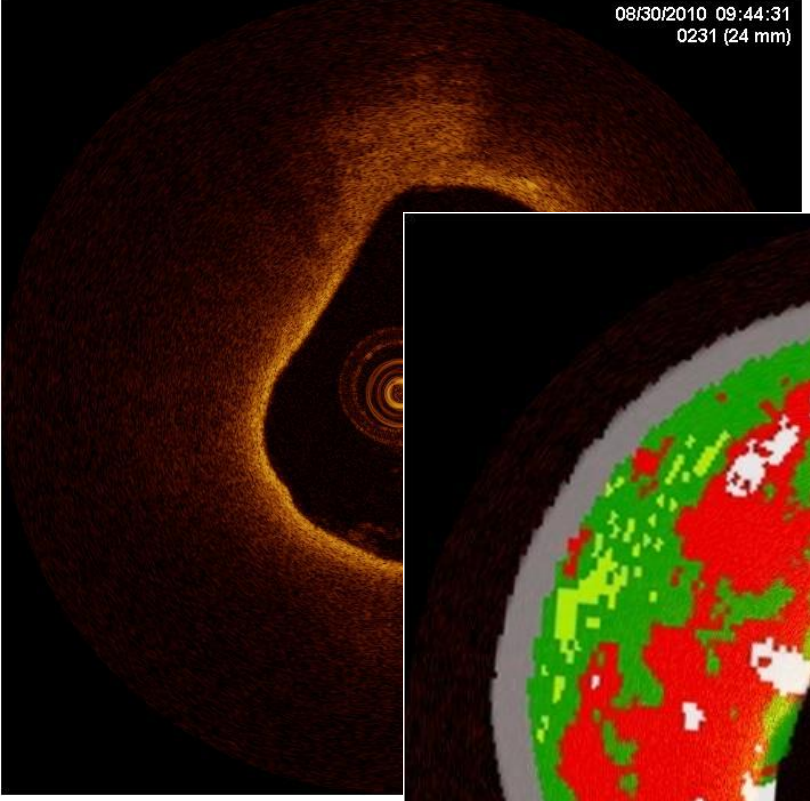
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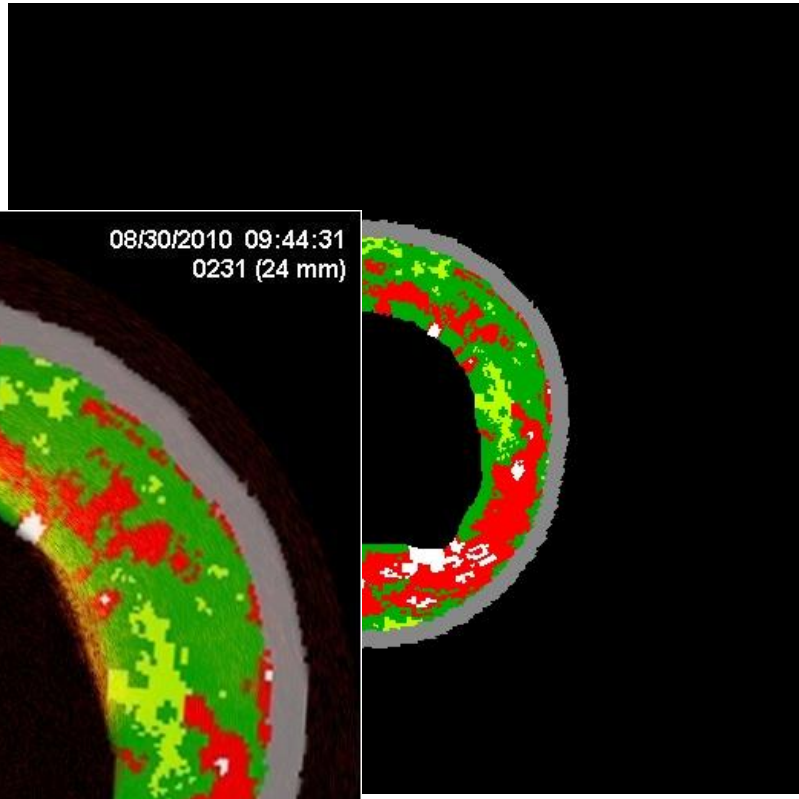
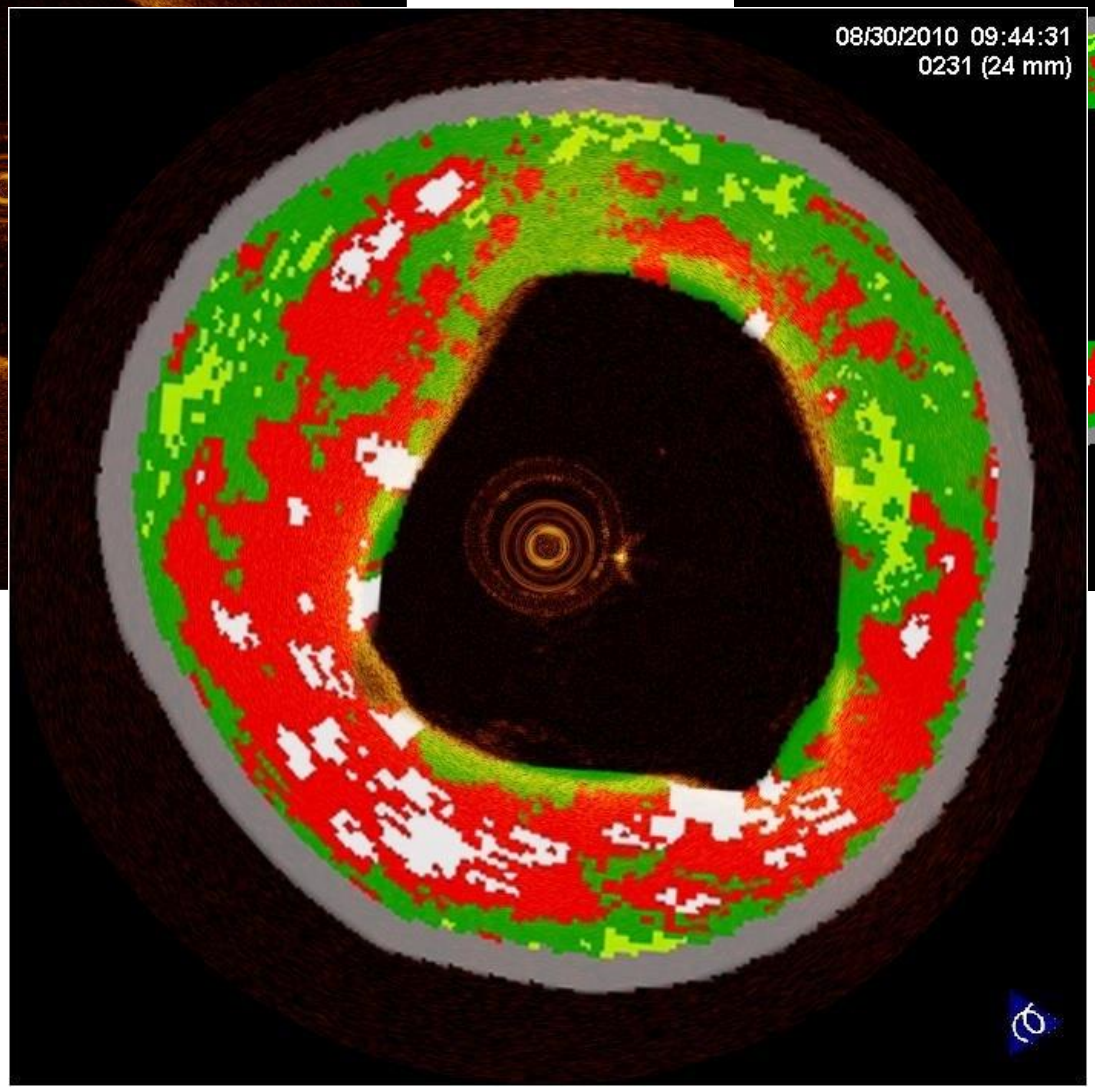
0231 (24 mm)




08/30/2010 09:44:31
0231 (24 mm)

Stent underexpansion

Geographical miss

(Minor) findings not seen on IVUS

Malapposition

Tissue protrusion

Edge dissections

What are the intravascular imaging modalities in interventional cardiology: current and future technologies

Current

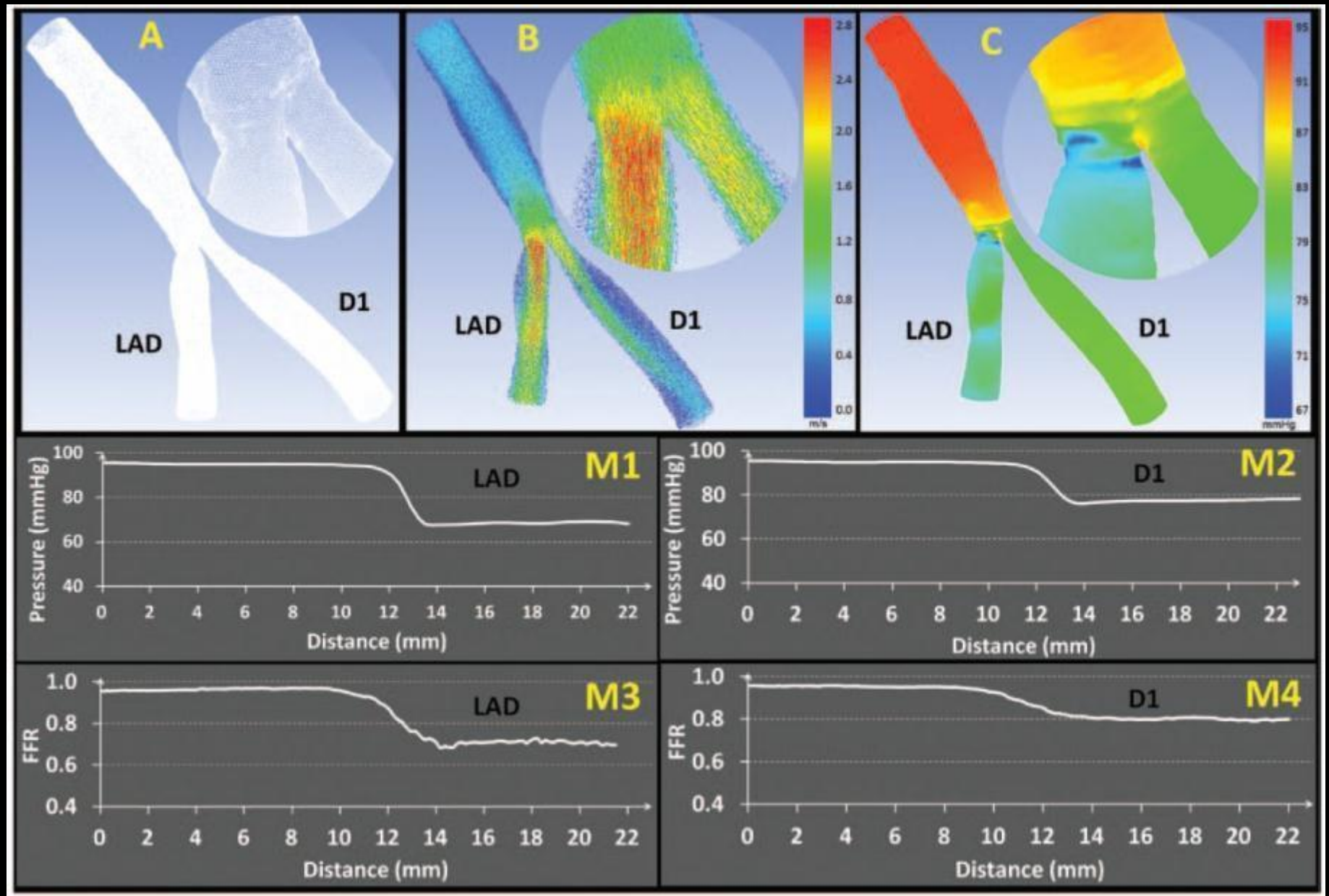
- Intravascular ultrasound (IVUS)
  - Grey Scale (20, 40, 45 Mhz)
  - Radiofrequency backscattering (Virtual histology, Palpography, Integrated backscatter IVUS and iMAP)
- Optical coherence tomography
  - 2D (100, 160, 180 frames/sec)
  - 3D (offline/ on line)
  - Hemodynamic parameter derived from 3D imaging
- NIR infrared spectroscopy
- Combined IVUS and NIRS (FDA approved)

Future

- Intravascular ultrasound (IVUS)
  - High-frequency
  - Focused acoustic tomography (FACT)
- Intravascular imaging combined with interventional devices
- Optical coherence tomography
  - 3D OCT with tissue characterization
  - Micro OCT
  - Super fast OCT (100mm/s)
- Hybrid intravascular imaging
  - OCT + NIR
  - OCT + IVUS
  - IVUS + TRFS
  - IVUS + IVPA

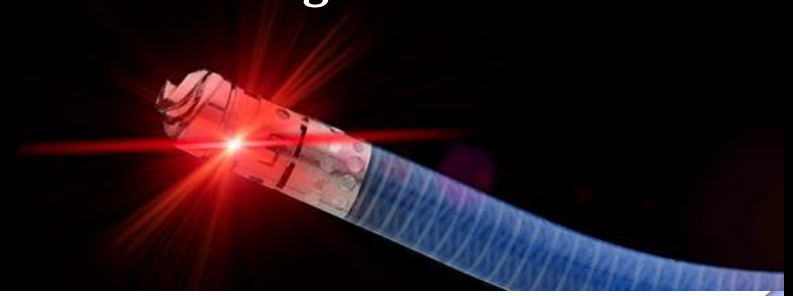
#current technology: Hemodynamic parameter derived from 3D imaging

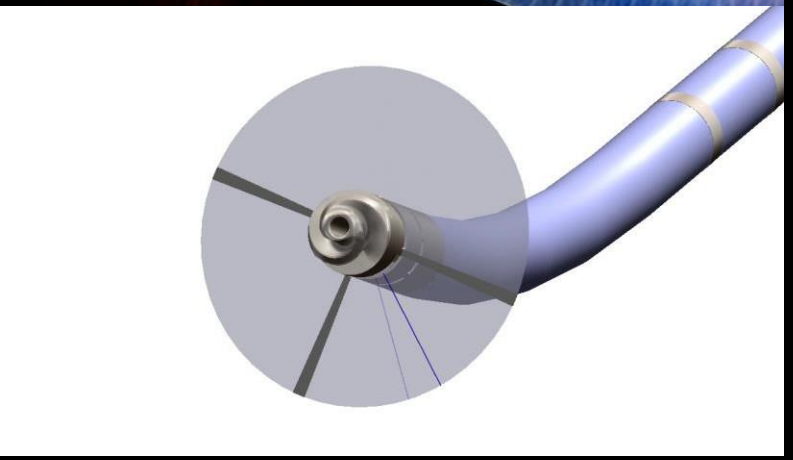
Fusion of 3D-QCA and OCT



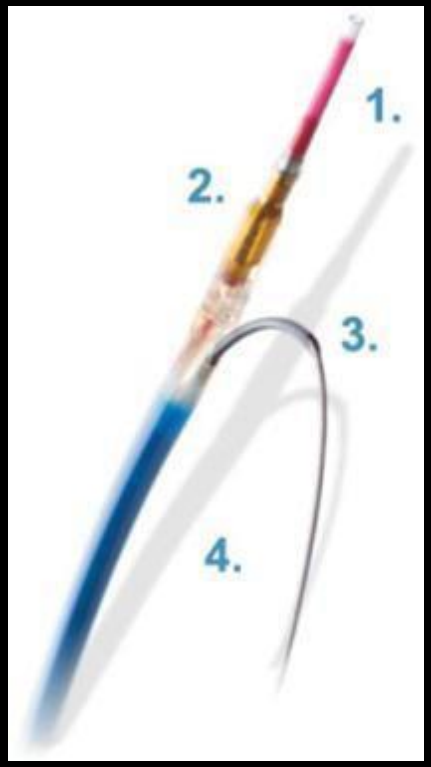
#Future technology: Intravascular imaging combined with interventional devices

Atherectomy with OCT Avinger Ocelot

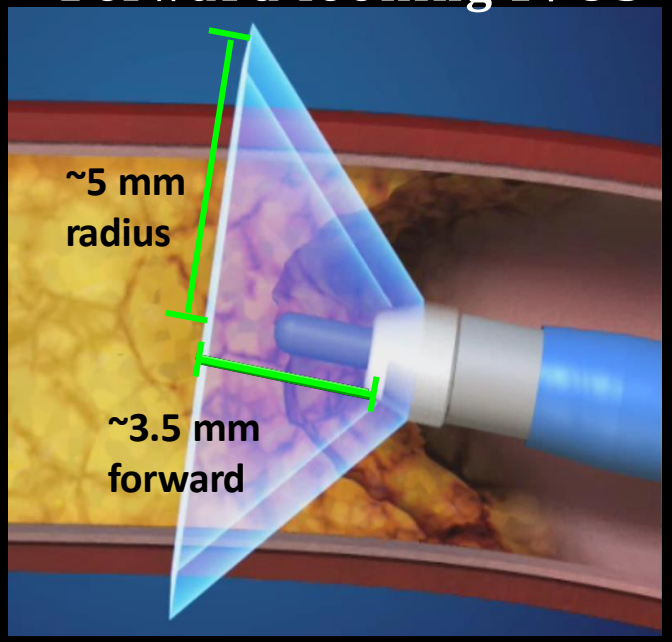


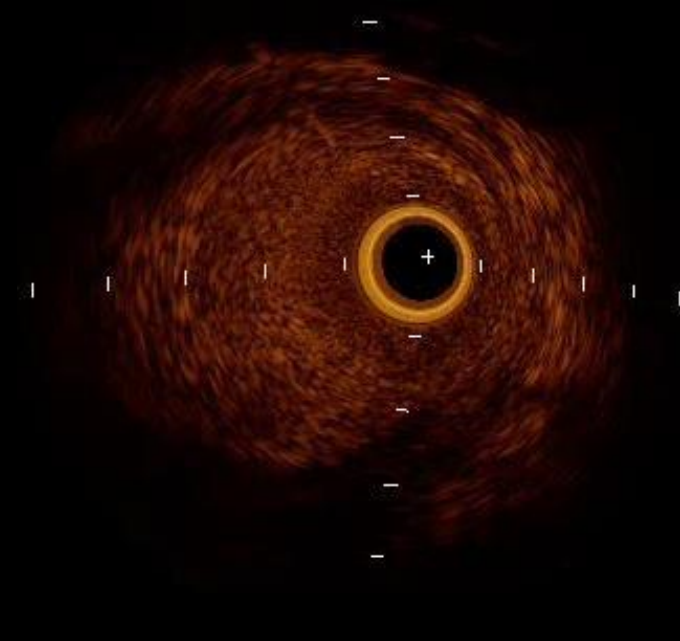


IVUS guided subintimal reentry device



Forward looking IVUS





Artery wall

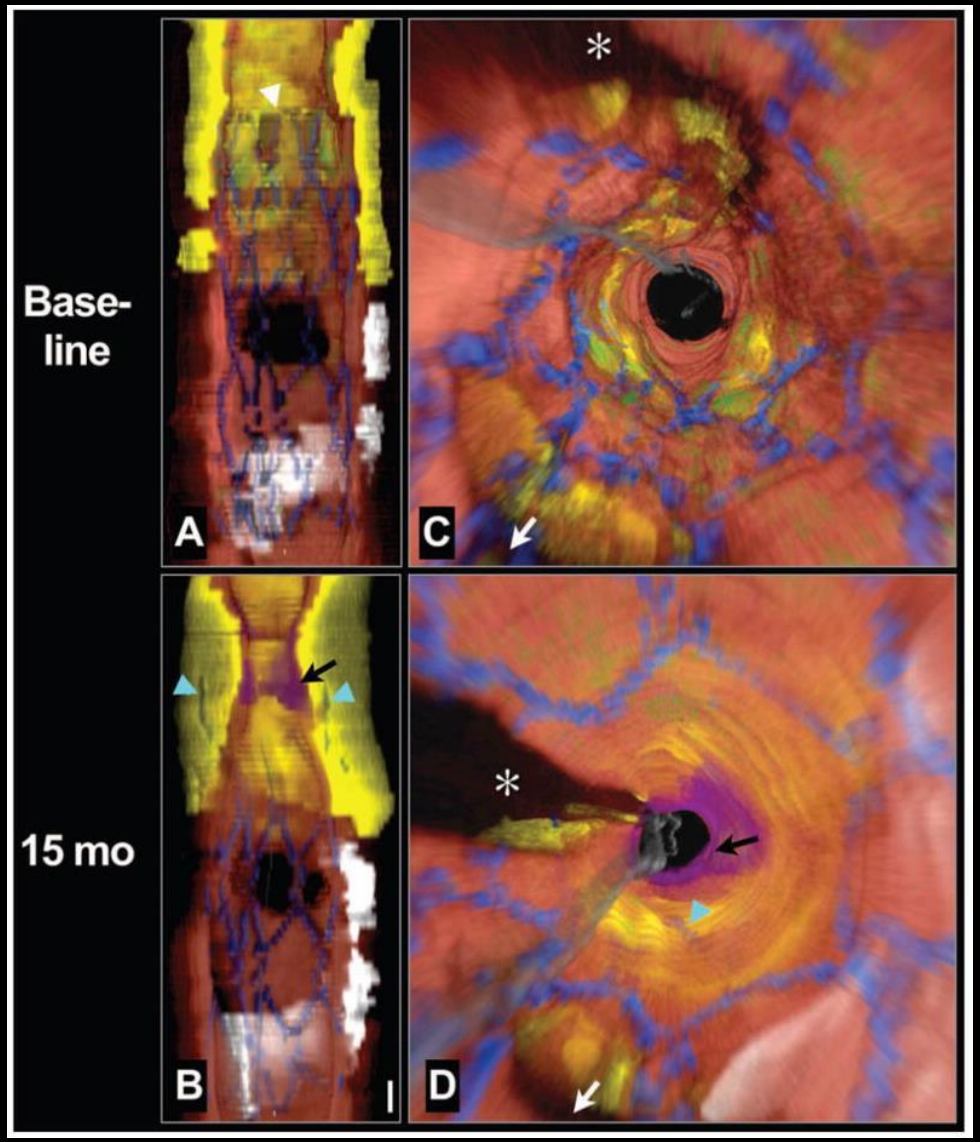
Lipid

Calcium

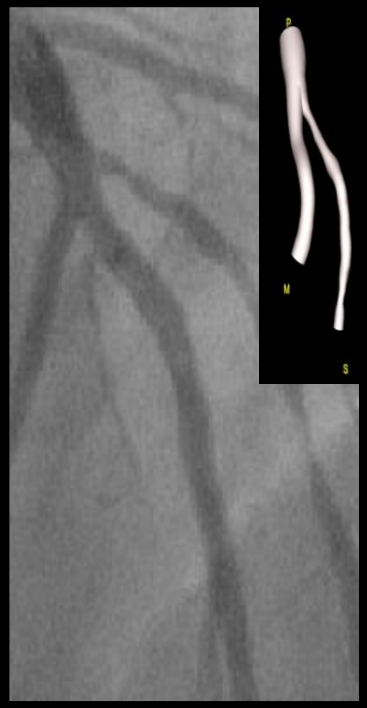
Macrophages

Stent

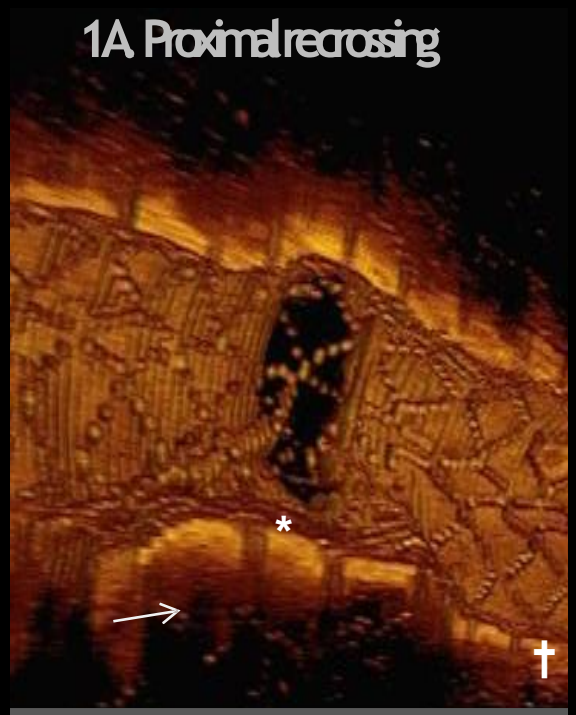
Guidewire

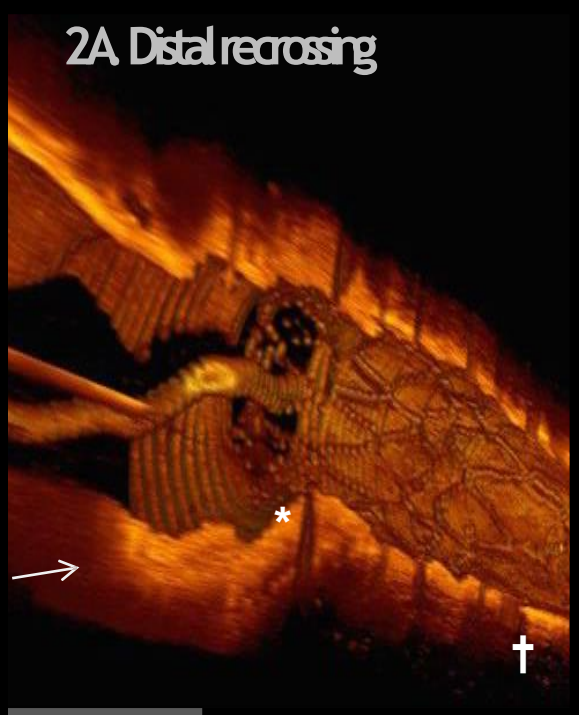


MGH Courtesy of Prof. Tearney



P
M
S


1A. Proximal recrossing
*
†


2A. Distal recrossing
*
†

P
M
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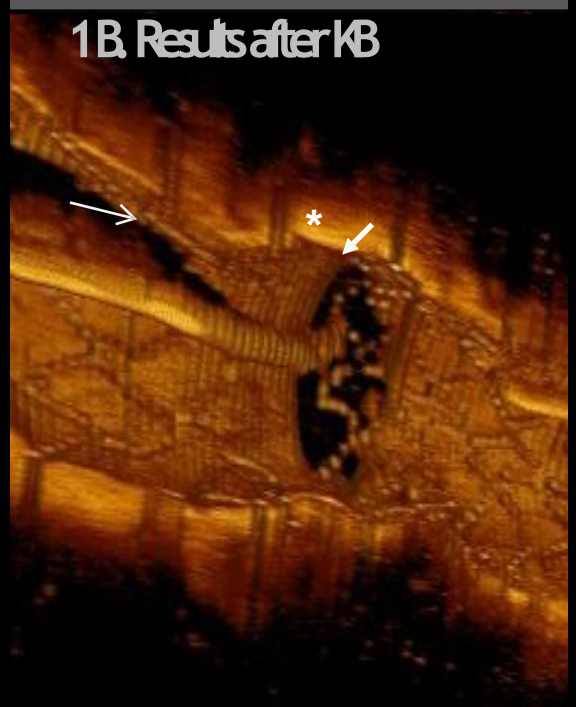
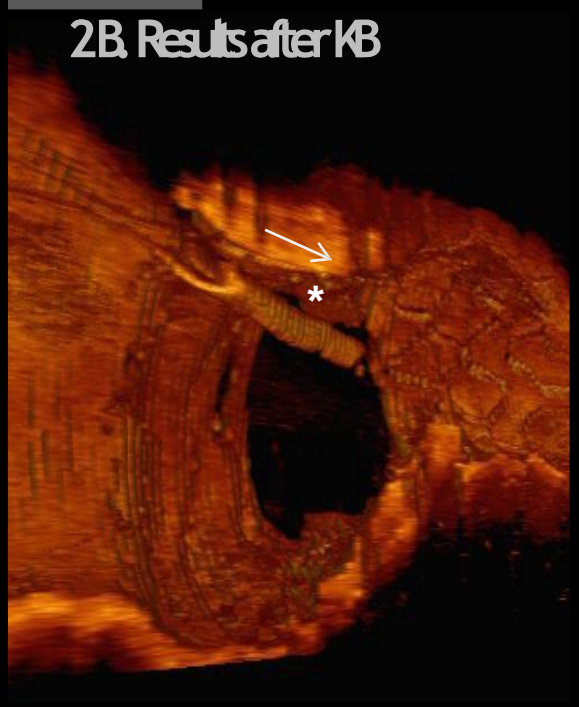
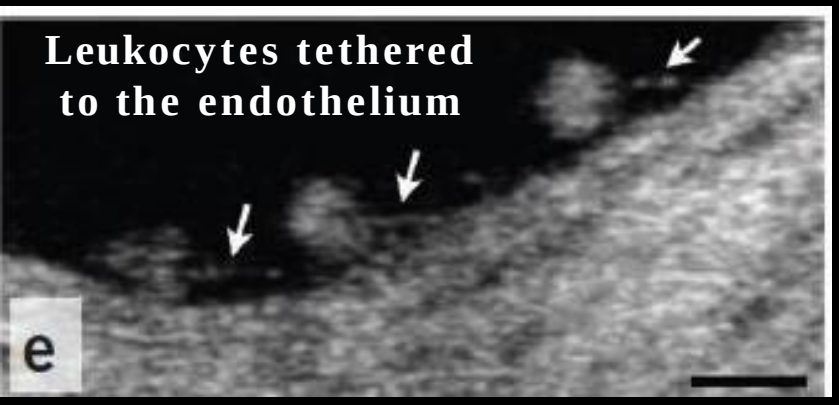

1B. Results after KB
*

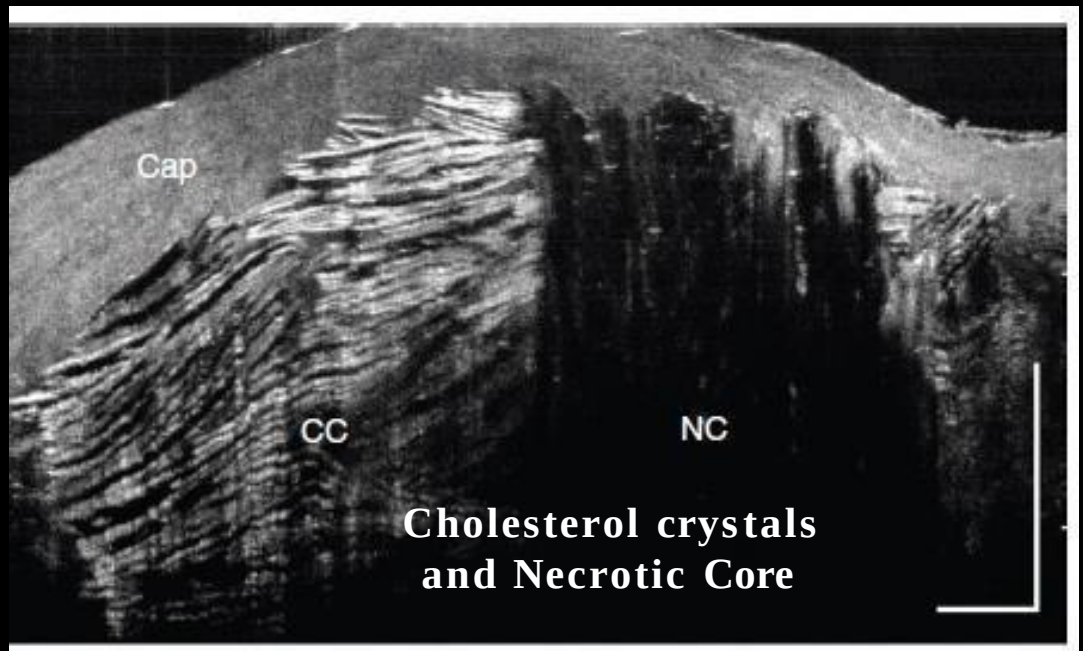

2B. Results after KB
*

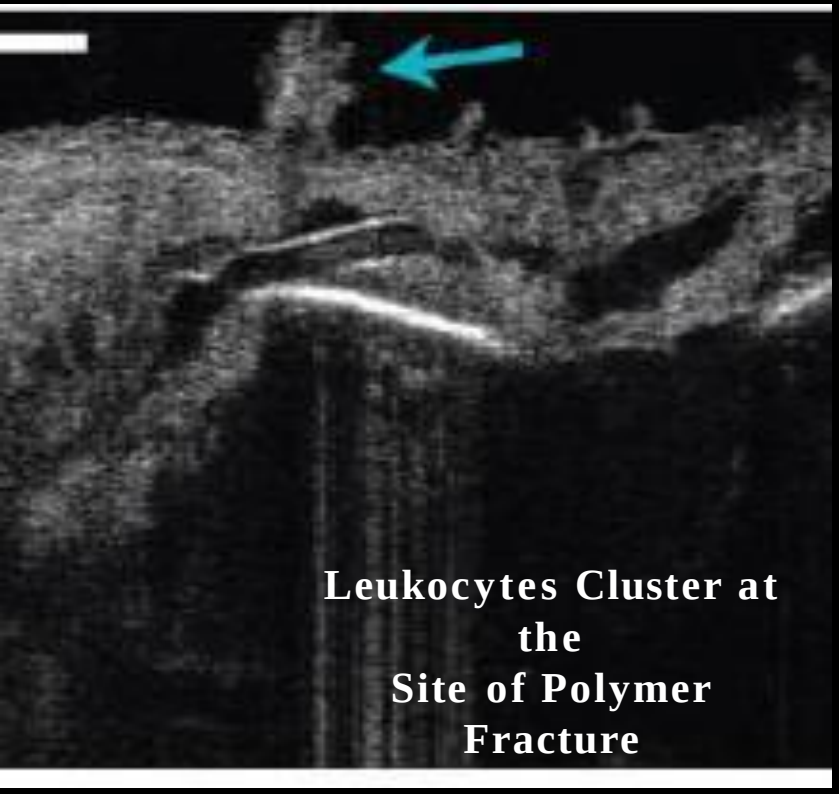

P
R
H
L
A

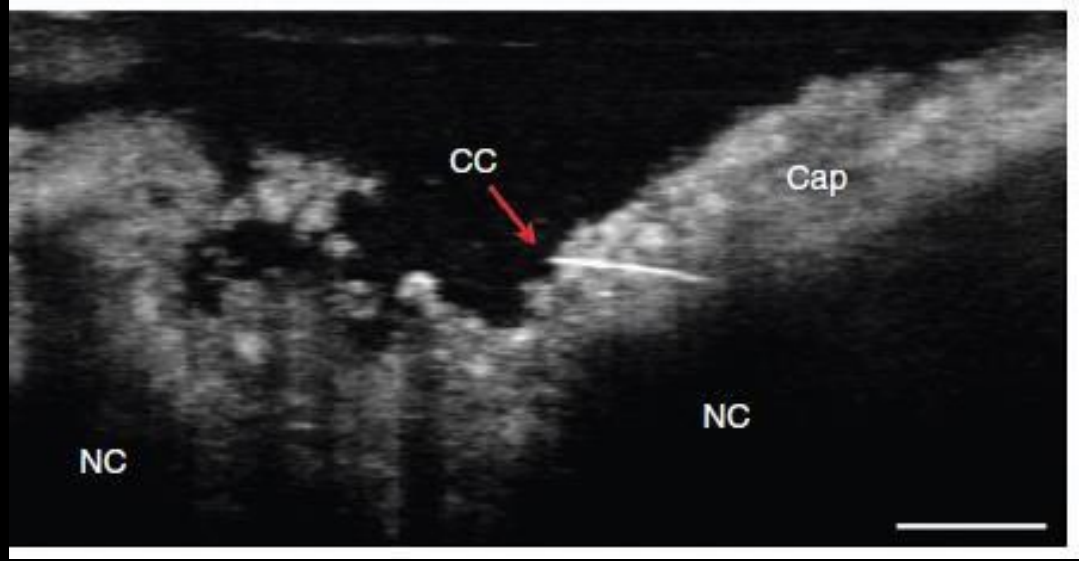

R
P
A
H
L

Micro OCT


Leukocytes tethered
to the endothelium
e


Cap
CC
NC
Cholesterol crystals
and Necrotic Core


Leukocytes Cluster at
the
Site of Polymer
Fracture


CC
Cap
NC
NC

Journal of the American College of Cardiology
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Published by Elsevier Inc.

Vol. 61, No. 13, 2013
ISSN 0735-1097/$36.00
http://dx.doi.org/10.1016/j.jacc.2012.10.057

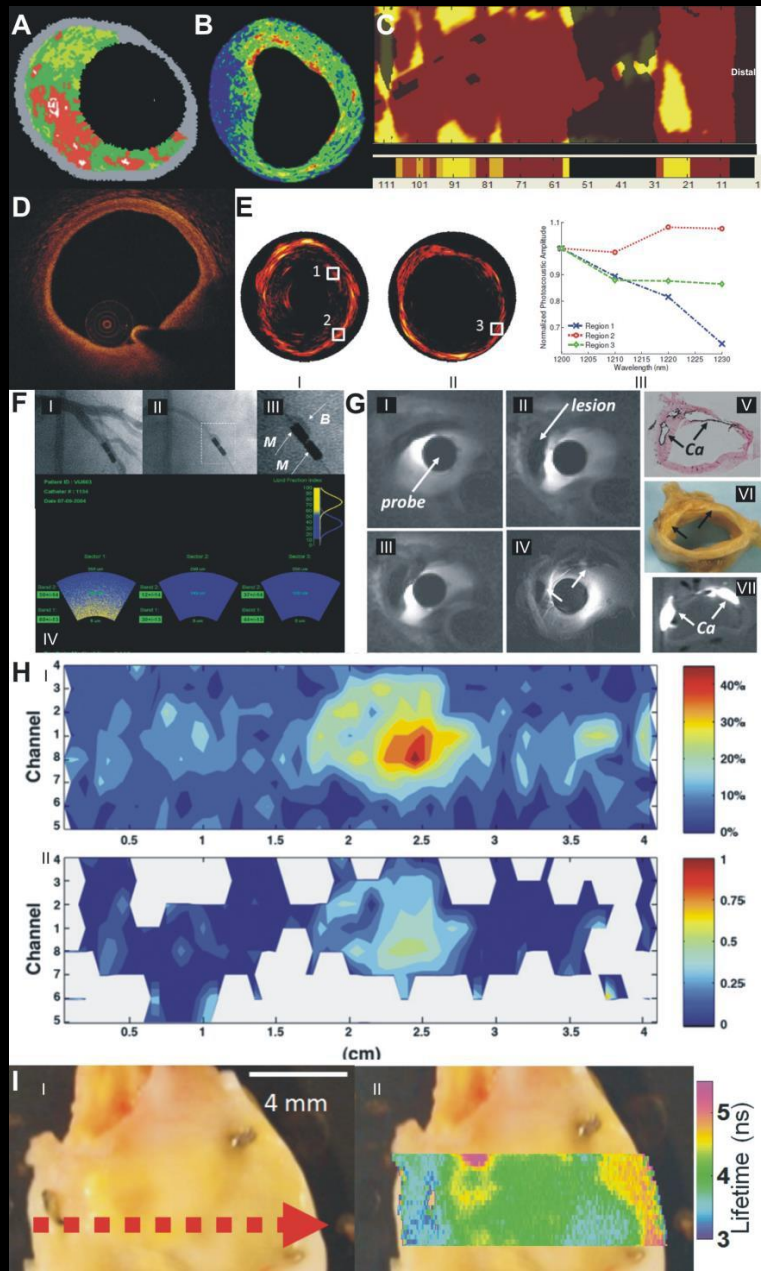
STATE-OF-THE-ART PAPER

Hybrid Intravascular Imaging

Current Applications and Prospective Potential in the Study of Coronary Atherosclerosis

Christos V. Bourantas, MD, PHD,* Hector M. Garcia-Garcia, MD, PHD,* Katerina K. Naka, MD,† Antonios Sakellarios, BSC,‡ Lambros Athanasiou, BSC,‡ Dimitrios I. Fotiadis, PHD,‡ Lampros K. Michalis, MD,† Patrick W. Serruys, MD, PHD*

Rotterdam, the Netherlands; and Ioannina, Greece



- Intravascular imaging allowed us for the first time to study in vivo plaque morphology and atherosclerotic evolution
- Today numerous invasive modalities are available: integrated backscatter analysis (IB)-IVUS, VH-IVUS, NIRS, OCT, IVPA, IV-MRI spectroscopy, IV-MRI, Raman spectroscopy and time resolved fluorescence spectroscopic (TRFS) that permit imaging of the plaque
- IB-IVUS, VH-IVUS, NIRS, OCT and CTCA have been used in clinical studies and allowed detection of plaque features related with future adverse events

Catheterization and Cardiovascular Interventions 00:00–00 (2013)

Original Studies

Expert Consensus Statement on the Use of Fractional Flow Reserve, Intravascular Ultrasound, and Optical Coherence Tomography: A Consensus Statement of the Society of Cardiovascular Angiography and Interventions

Amir Lotfi,[1] MD, FSCAI, Allen Jeremias,[2] MD, FSCAI, William F. Fearon,[3] MD, FSCAI, Marc D. Feldman,[4] MD, FSCAI, Roxana Mehran,[5] MD, John C. Messenger,[6] MD, FSCAI, Cindy L. Grines,[7] MD, FSCAI, Larry S. Dean,[8] MD, FSCAI, Morton J. Kern,[9] MD, FSCAI, and Lloyd W. Klein,[10*] MD, FSCAI

Key words: fractional flow reserve; imaging; intravascular ultrasound; imaging; optical coherence tomography; interventional devices/innovation

Intravascular ultrasound (IVUS).

Definitely Beneficial.

IVUS is an accurate method for determining optimal stent deployment (complete stent expansion and apposition and lack of edge dissection or other complications after implantation), and the size of the vessel undergoing stent implantation.

Probably Beneficial.

IVUS can be used to appraise the significance of LMCA stenosis and, employing a cutoff MLA¼6 mm2 , assess whether revascularization is warranted.

Possibly Beneficial.

IVUS can be useful for the assessment of plaque morphology.

No Proven Value/Should be Discouraged.

IVUS measurements for determination of non-LMCA lesion severity should not be relied upon, in the absence of additional functional evidence, for recommending revascularization.

Optical Coherence Tomography (OCT).

Probably Beneficial.

Determination of optimal stent deployment (sizing, apposition, and lack of edge dissection), with improved resolution compared with IVUS.

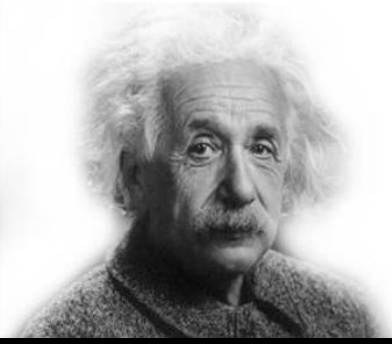
Possibly Beneficial.

OCT can be useful for the assessment of plaque morphology.

No Proven Value/Should be Discouraged.

OCT should not be performed to determine stenosis functional significance.

THE TRUE SIGN OF INTELLIGENCE IS NOT KNOWLEDGE BUT IMAGINATION.



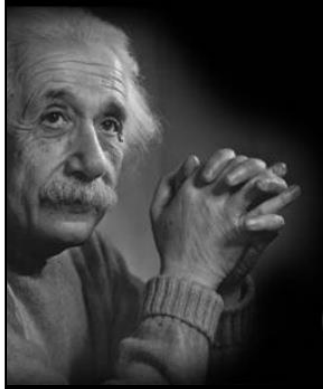
Albert Einstein

German Theoretical-Physicist

(1879-1955)

QuoteHD.com

I NEVER THINK OF THE FUTURE - IT COMES SOON ENOUGH.



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(1879-1955)

QuoteHD.com