

# Ενδοστεφανιαία απεικόνιση: Την χρειαζόμαστε;

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Μιχαήλ Παπαφακλής

Επεμβατικός Καρδιολόγος, Πανεπιστημιακό Νοσοκομείο Ιωαννίνων

# Τρόποι ενδοστεφανιαίας απεικόνισης

- IntraVascular UltraSound (IVUS)
- Optical Coherence Tomography (OCT)
- Άλλες τεχνικές

# Ενδοστεφανιαία απεικόνιση

- Έρευνα
  - Γνώση – Κατανόηση Παθοφυσιολογικών φαινομένων και μηχανισμών
  - Σημασία Κλινικής Χρήσης
- Κλινική χρήση

# IVUS

- Ερευνα (διαχρονικά)
  - Κατανόηση μηχανισμών επαναστένωσης
  - Τρόπος τοποθέτησης stent
  - Επιδράσεις φαρμάκων στην διαδικασία της αθηροσκλήρυνσης (surrogate marker)

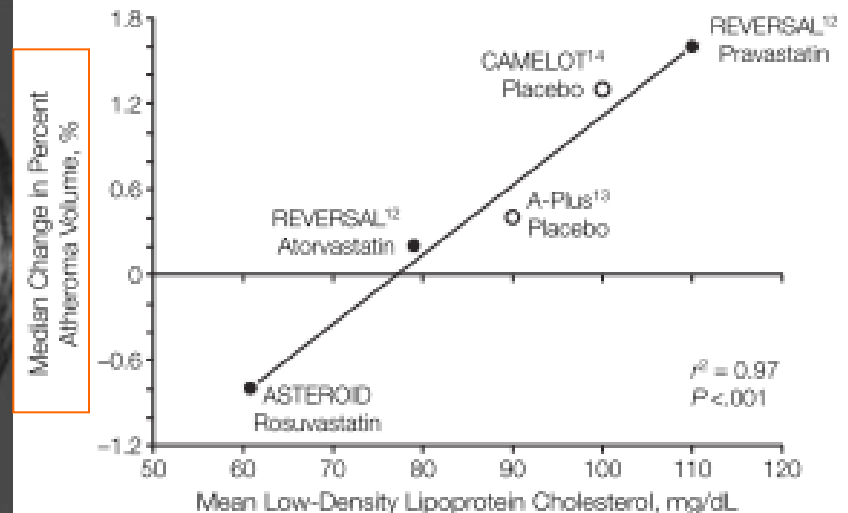
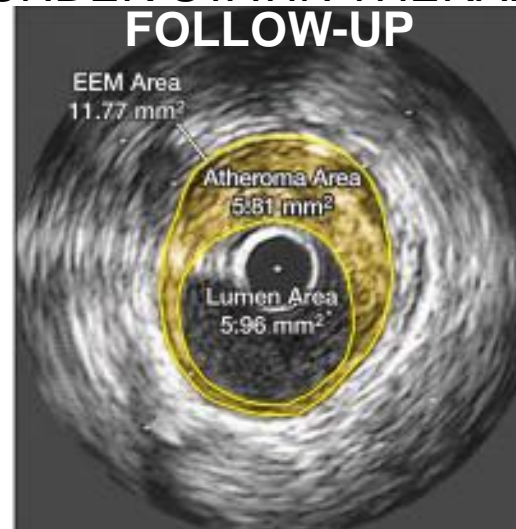
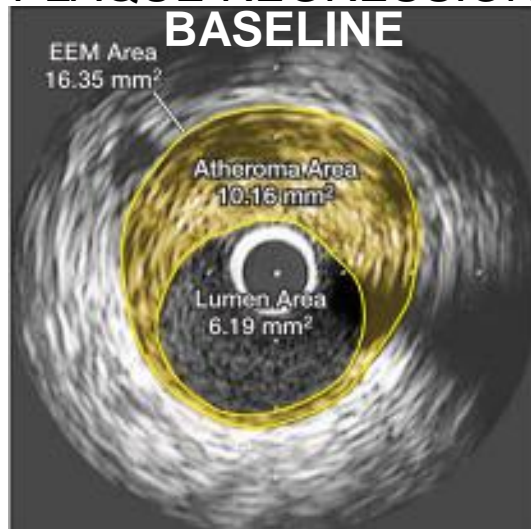
# Intravascular Ultrasound Research Utility

## Application of Intravascular Ultrasound to Characterize Coronary Artery Disease and Assess the Progression or Regression of Atherosclerosis

Nissen SE. Am J Cardiol 2002

## And to Assess the Effect of Treatment

### PLAQUE REGRESSION UNDER STATIN THERAPY



Nissen SE, et al. JAMA 2006

# Associations between genetic variation, atherosclerosis phenotypes and plaque vulnerability as determined by IVUS

Figure 3. Manhattan plots: potential association between multiple genomic locations and vulnerable plaque.

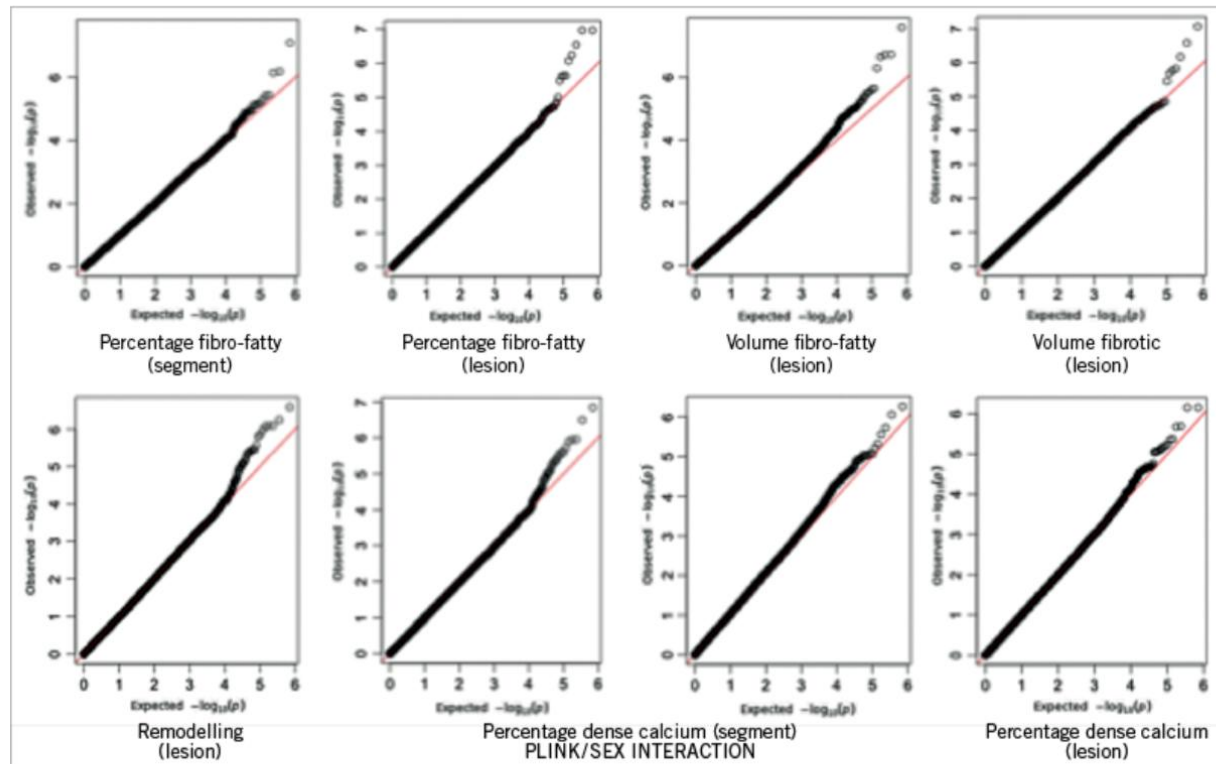


Figure 4. QQ-plots: potential association between multiple genomic locations and vulnerable plaque.

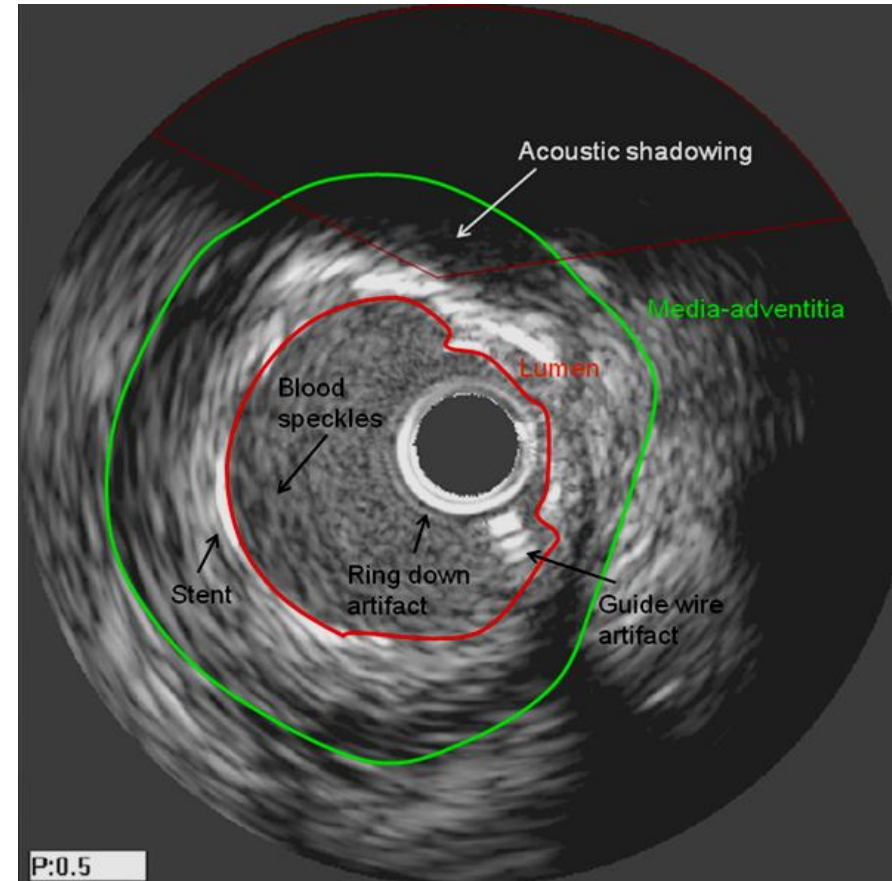
# Intravascular Ultrasound

The acquired cross-sectional images allow:

- ✓ Identification of the lumen, stent and vessel wall
- ✓ Quantification of their dimensions and **plaque volume**
- ✓ Classification of the plaque type

Relatively low resolution - limited capability in:

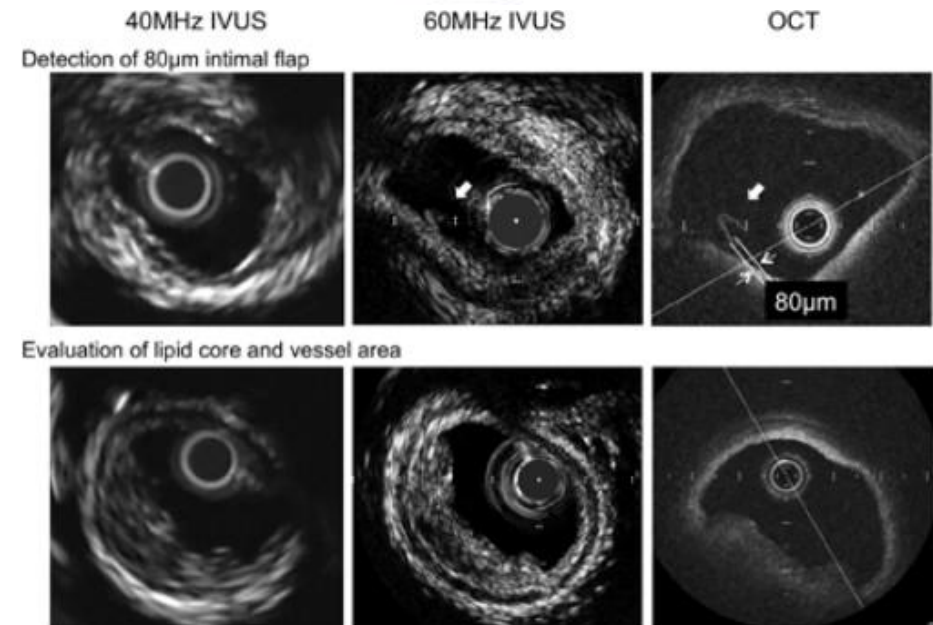
- Detecting plaque erosion, rupture and the presence of thrombus
- Unable to see microstructures related to increased vulnerability



Mintz et al. J Am Coll Cardiol. 2001  
Mintz et al. EuroIntervention 2011

# High-Definition IVUS

- **Image clarity – Fine plaque details**
  - **60MHz transducer**
  - State-of-the-art signal processing
  - **High Axial resolution (<math><40\mu\text{m}</math>)**
  - Minimized image noise
  - Preserved depth of penetration
  - **Pullback options up to 10 mm/s**
- Sep 2015: First patient case (by Dr. P.Terstein)





# IVUS

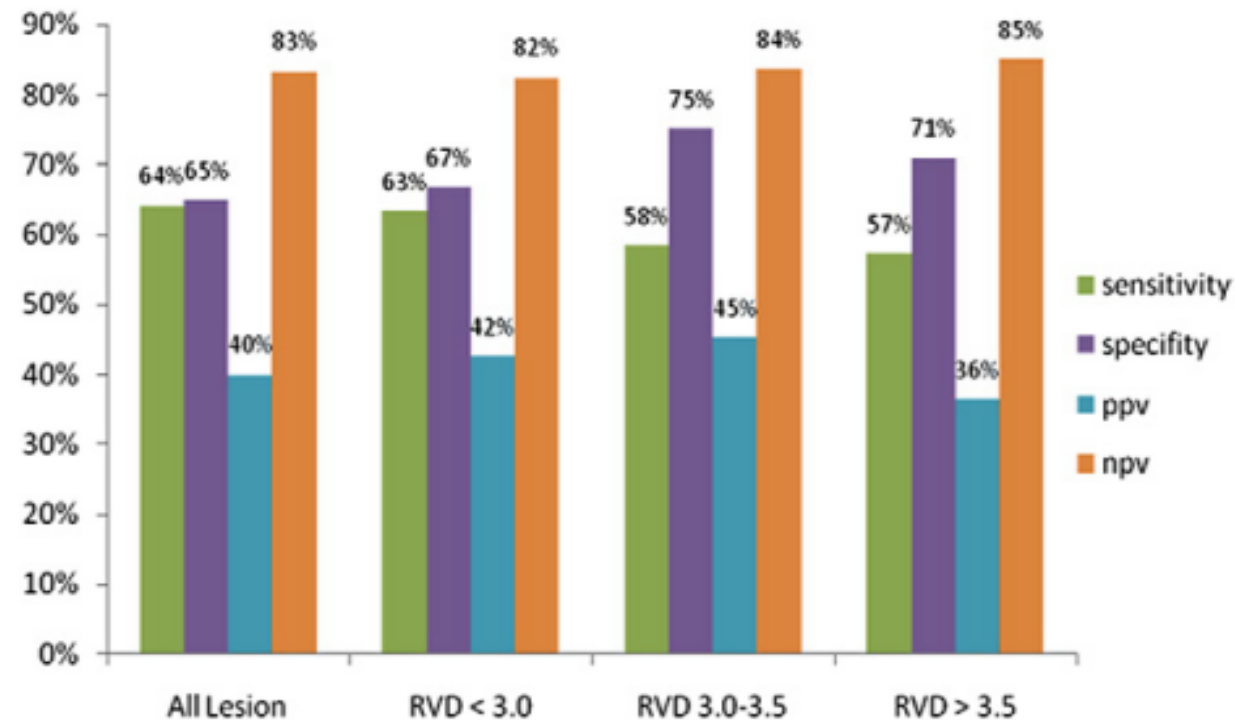
- Κλινική χρήση 2018
  - Διάγνωση
    - Νόσος στελέχους
    - Εκτίμηση βαρύτητας, αγγειογραφικά οριακών στενώσεων
  - Επεμβατική Θεραπεία
    - Αγγειοπλαστική στελέχους
    - Αγγειοπλαστική επιπλεγμένων βλαβών (ο ρόλος του ασβεστίου)
    - Εκτίμηση αποτελέσματος PCI (post stenting) σε επιπλεγμένες βλάβες
    - Αγγειοπλαστική χρονίων αποφράξεων
      - Βλάβη με μη σαφή συνέχεια του αγγείου (blunt entry shape)
      - Θέση οδηγού σύρματος (αληθής vs ψευδής αυλός)
      - Διάμετρος αγγείου (απόφαση με μέγεθος stent)

# Intravascular Ultrasound

## Diagnosis of Functionally Significant Lesions

### FIRST: Fractional Flow Reserve and Intravascular Ultrasound Relationship Study

**FIRST:**  
a multinational,  
multicenter,  
prospective registry  
of a large patient  
cohort with  
intermediate  
coronary stenosis  
(350 patients; 367  
intermediate  
lesions)



### Diagnostic Accuracy of IVUS MLA in the Prediction of Functionally Significant Stenosis Overall and by RVD

# Guidelines – IVUS for LM assessment

## ESC/EACTS 2018

### Recommendations on functional testing and intravascular imaging for lesion assessment

Recommendations	Class <sup>a</sup>	Level <sup>b</sup>
When evidence of ischaemia is not available, FFR or iwFR are recommended to assess the haemodynamic relevance of intermediate-grade stenosis. <sup>15,17,18,39</sup>	I	A
FFR-guided PCI should be considered in patients with multivessel disease undergoing PCI. <sup>29,31</sup>	IIa	B
IVUS should be considered to assess the severity of unprotected left main lesions. <sup>35–37</sup>	IIa	B

© ESC 2018

FFR = fractional flow reserve; iwFR = instantaneous wave-free ratio; IVUS = intravascular ultrasound; PCI = percutaneous coronary intervention.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

## AHA/ACC/SCAI 2011



### 5.4.2. IVUS: Recommendations

#### Class IIa

1. IVUS is reasonable for the assessment of angiographically indeterminate left main CAD.<sup>489–491</sup>  
(Level of Evidence: B)

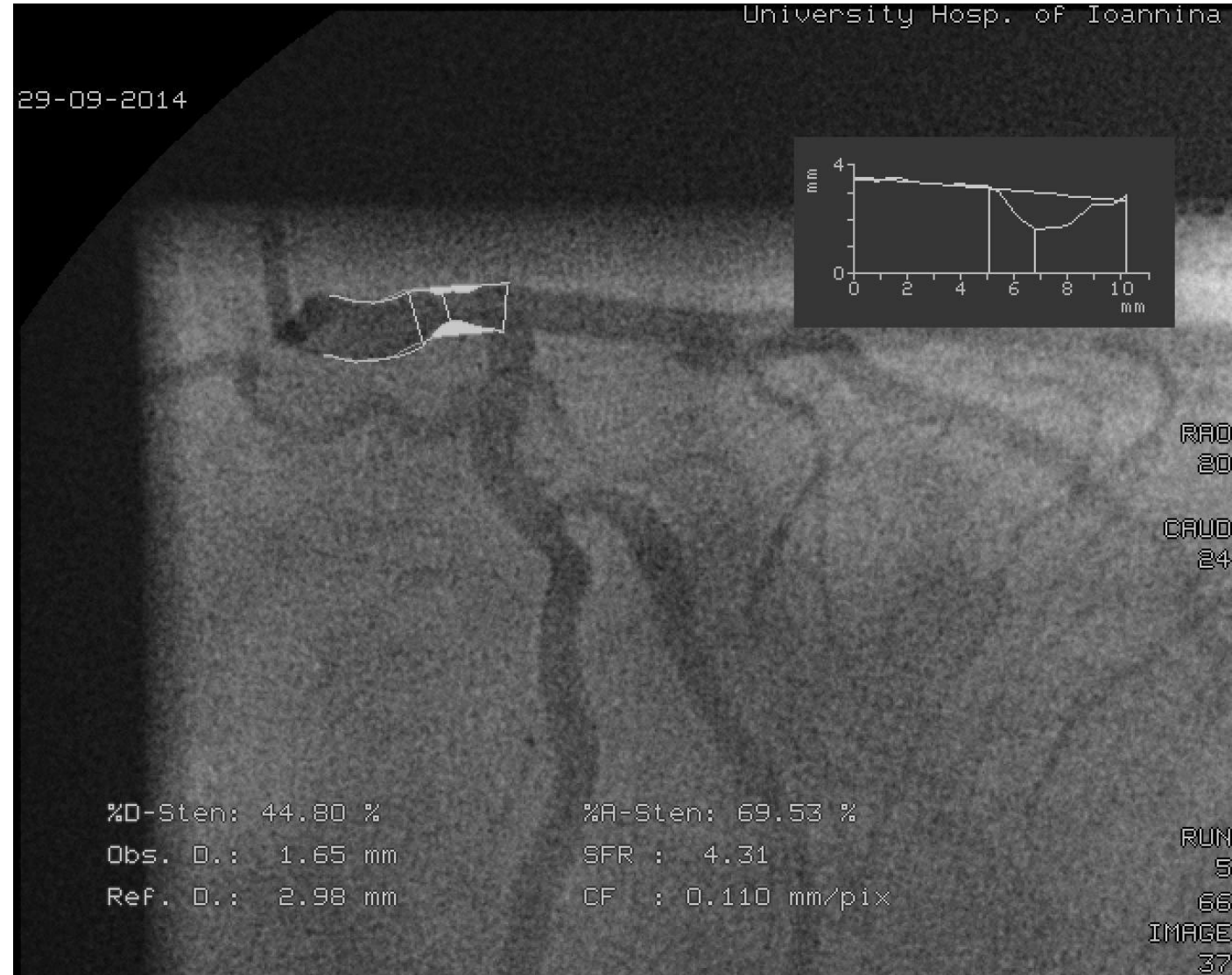
*LM is the one coronary territory that IVUS may be as good (or even better?) as FFR for assessing hemodynamic significance*

**IVUS**



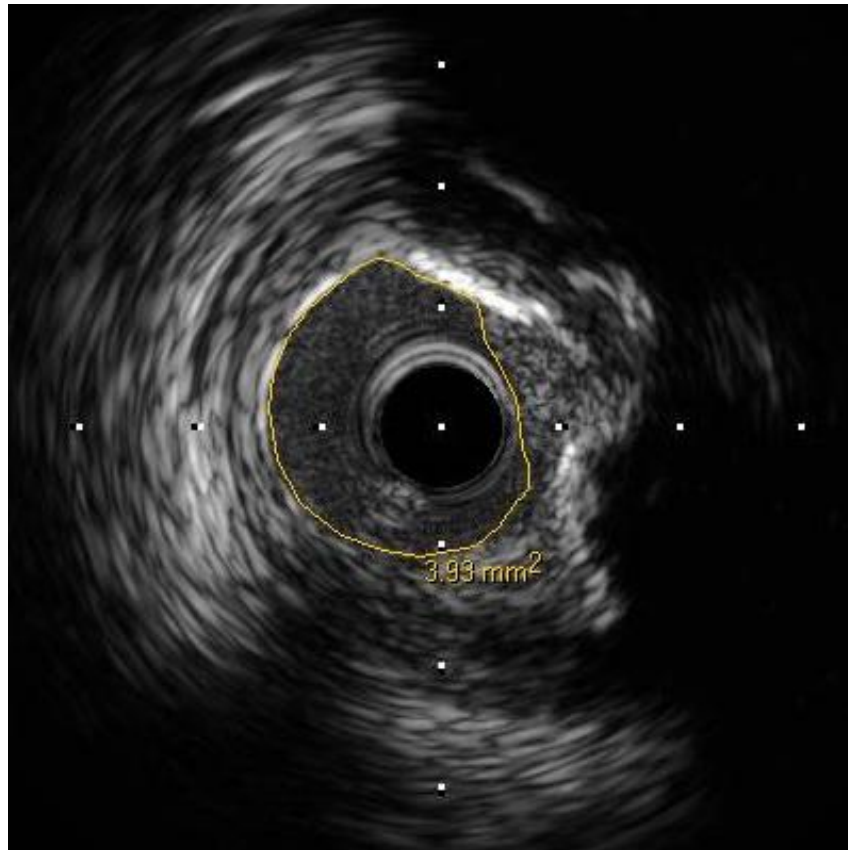
**FFR**

# Patient Case – QCA LM lesion

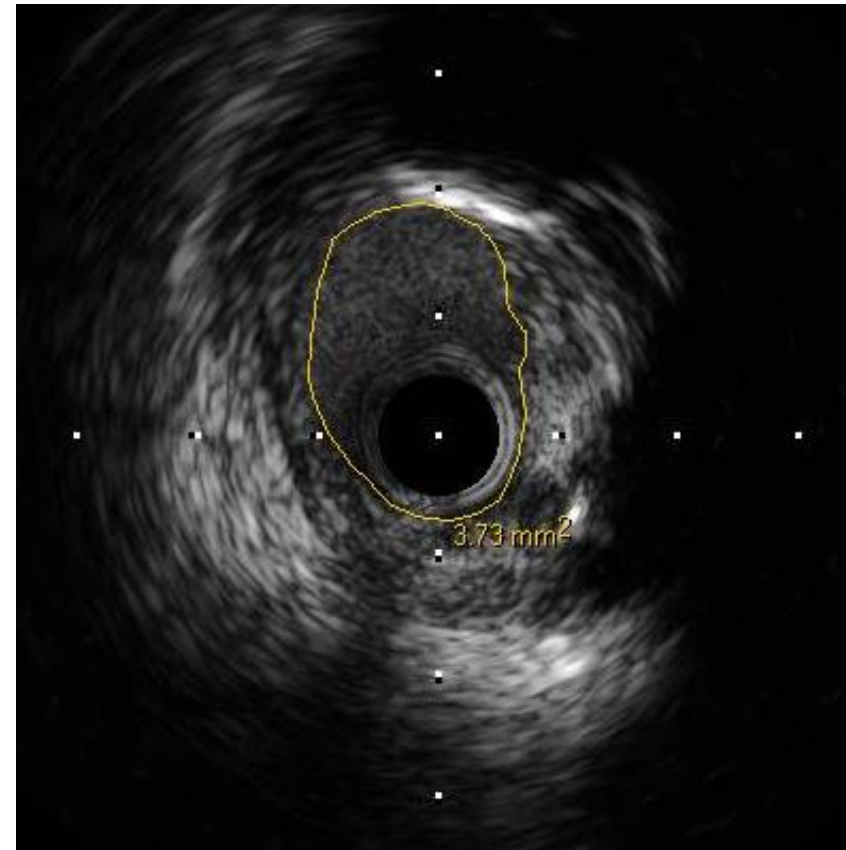


# Patient Case – IVUS LM MLA

IVUS LM MLA: 3.9 mm<sup>2</sup>  
*LAD-LM pullback*



IVUS LM MLA: 3.7 mm<sup>2</sup>  
*LCx-LM pullback*



# Impact of Intravascular Ultrasound Guidance on Long-Term Mortality in Stenting for Unprotected Left Main Coronary Artery Stenosis

Seung-Jung Park, MD, PhD\*; Young-Hak Kim, MD, PhD\*; Duk-Woo Park, MD, PhD;  
Seung-Whan Lee, MD, PhD; Won-Jang Kim, MD, PhD; Jon Suh, MD; Sung-Cheol Yun, PhD;  
Cheol Whan Lee, MD, PhD; Myeong-Ki Hong, MD, PhD; Jae-Hwan Lee, MD, PhD;  
Seong-Wook Park, MD, PhD; for the MAIN-COMPARE Investigators

**Background**—Although intravascular ultrasound (IVUS) guidance has been useful in stenting for unprotected left main coronary artery stenosis, its impact on long-term mortality is still unclear.

**Methods and Results**—In the MAIN-COMPARE registry, patients with unprotected left main coronary artery stenosis in a hemodynamically stable condition underwent elective stenting under the guidance of IVUS (756 patients) or conventional angiography (219 patients). Patients with acute myocardial infarction were excluded. The 3-year outcomes between the 2 groups were primarily compared using propensity-score matching in the entire and separate populations according to stent type. In 201 matched pairs of the overall population, there was a tendency of lower risk of 3-year mortality with IVUS guidance compared with angiography guidance (6.0% versus 13.6%, log-rank  $P=0.063$ ; hazard ratio, 0.54; 95% CI, 0.28 to 1.03; Cox-model  $P=0.061$ ). In particular, in 145 matched pairs of patients receiving drug-eluting stent, the 3-year incidence of mortality was lower with IVUS guidance as compared with angiography guidance (4.7% versus 16.0%, log-rank  $P=0.048$ ; hazard ratio, 0.39; 95% CI, 0.15 to 1.02; Cox model  $P=0.055$ ). In contrast, the use of IVUS guidance did not reduce the risk of mortality in 47 matched pairs of patients receiving bare-metal stent (8.6% versus 10.8%, log-rank  $P=0.35$ ; hazard ratio, 0.59; 95% CI, 0.18 to 1.91; Cox model  $P=0.38$ ). The risk of myocardial infarction or target vessel revascularization was not associated with the use of IVUS guidance.

**Conclusions**—Elective stenting with IVUS guidance, especially in the placement of drug-eluting stent, may reduce the long-term mortality rate for unprotected left main coronary artery stenosis when compared with conventional angiography guidance. (*Circ Cardiovasc Intervent.* 2009;2:167-177.)

# IVUS guidelines – PCI guidance - LM

ESC/EACTS 2018

## Recommendations on intravascular imaging for procedural optimization

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

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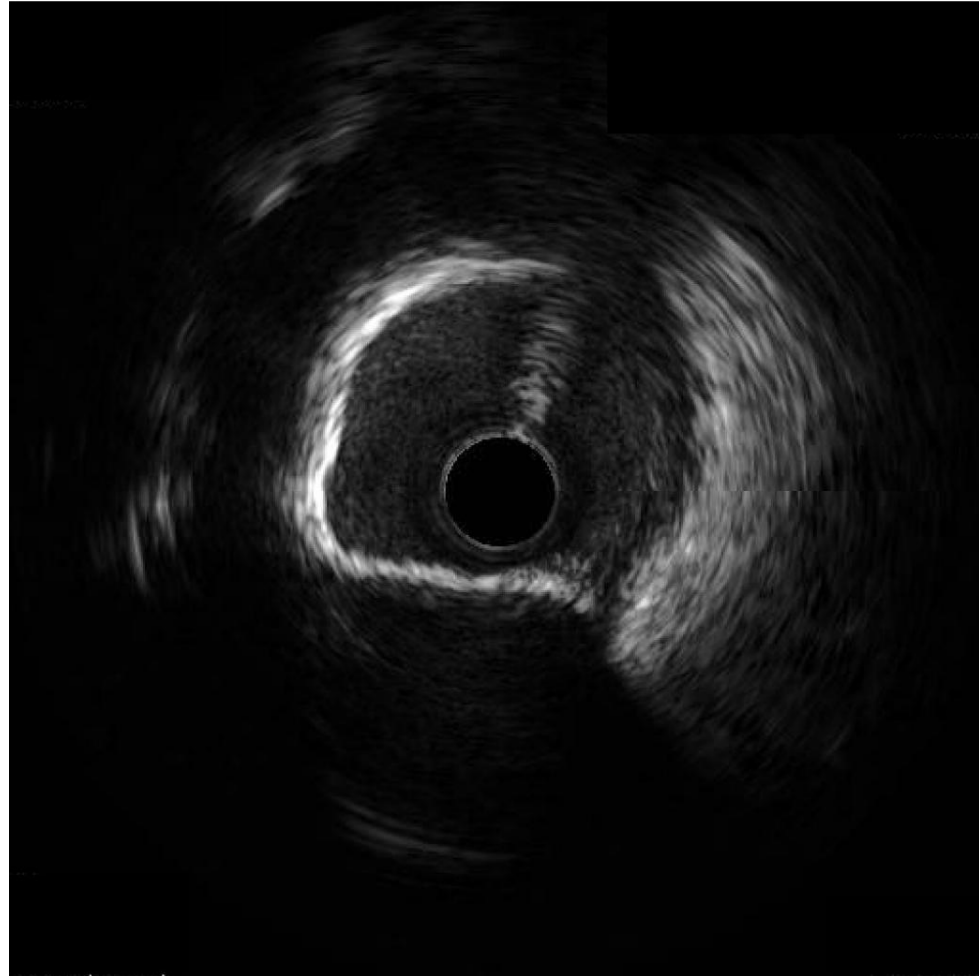
IVUS = intravascular ultrasound; OCT = optical coherence tomography.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

# IVUS – Identify heavy calcification

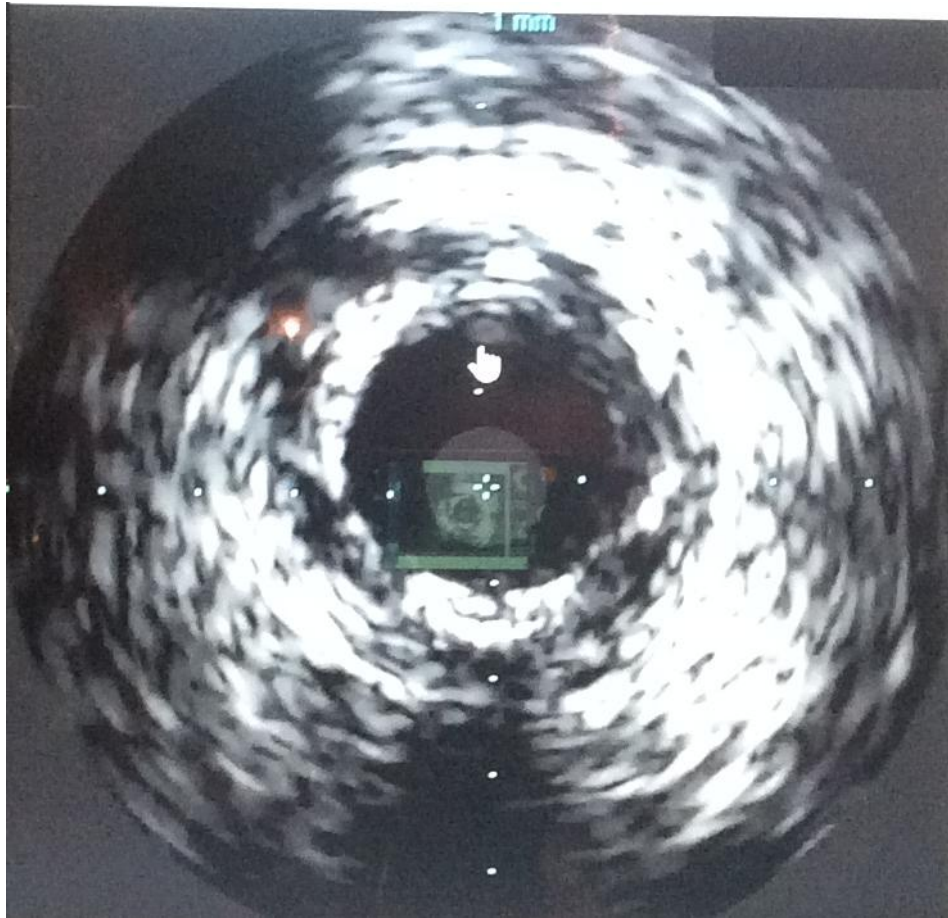
Importance for  
PCI guidance  
(use of  
Rotablation?)





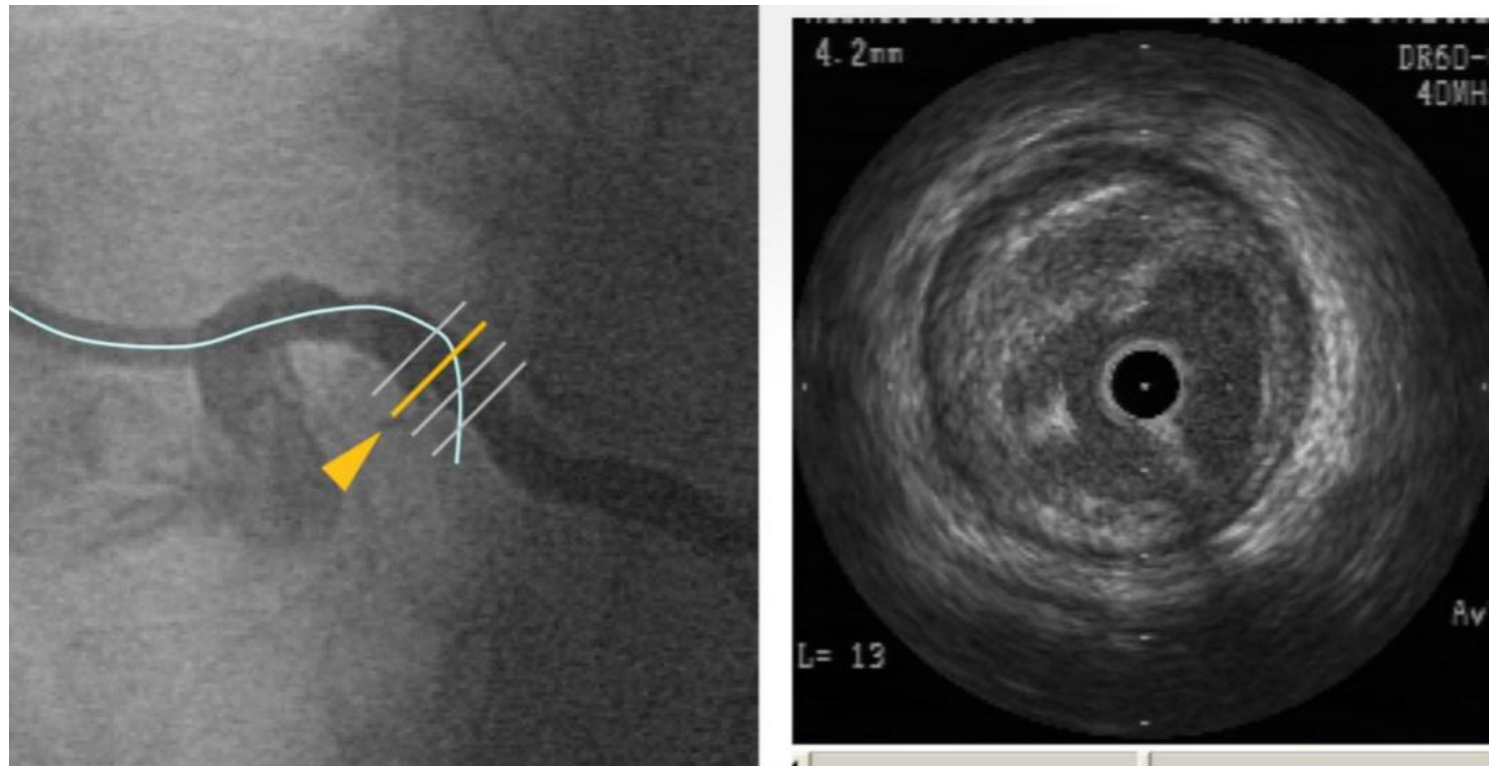
# IVUS in stent restenosis

- Constricted stent



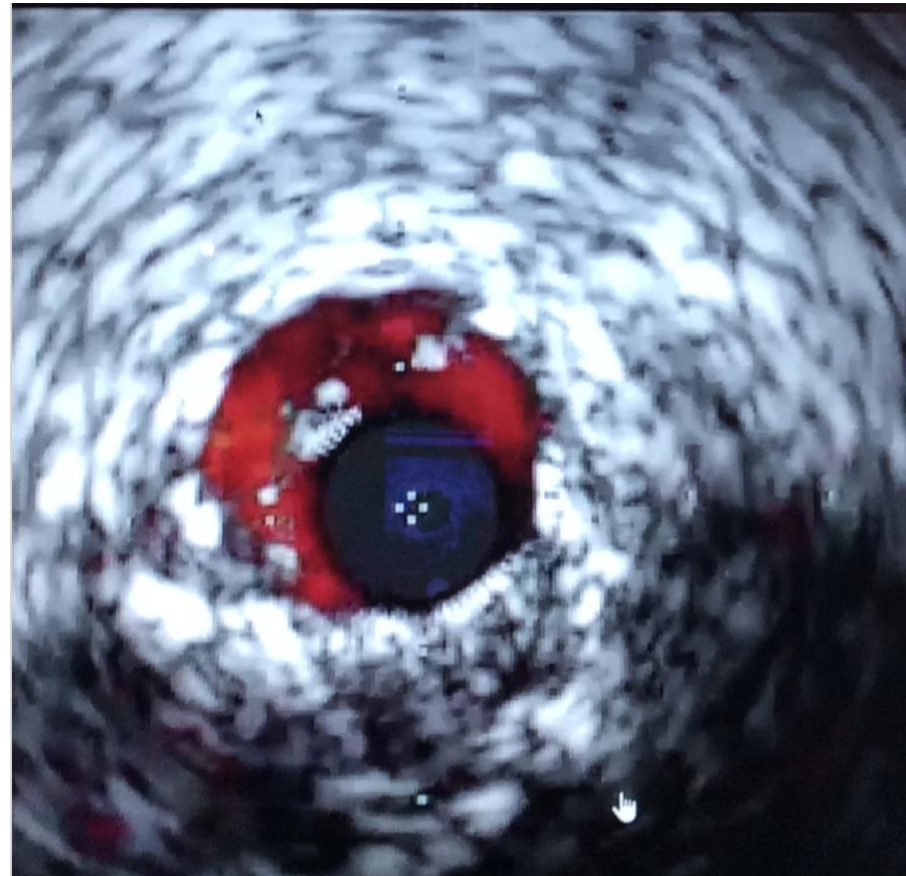
# CTO angioplasty

- Identification of proximal cap



# CTO angioplasty

- Stent underexpansion



# CTO angioplasty

- Guide wire: true vs false lumen



# OCT

- Ερευνα 2018
  - Γνώση Παθοφυσιολογικών φαινομένων
  - Σημασία Κλινικής Χρήσης

# Intravascular Optical Coherence Tomography: *An Ultra-High Resolution Imaging Modality*

## INTRAVASCULAR DIAGNOSTICS

Modality	Resolution	Penetration	Cap	Lipid	Inflam	Ca
OCT	10 um	poor	+++	+++	+	++
Spectroscopy	-	poor	-	+++	-	-
IVUS	100 um	good	+	+	-	+++
Angioscopy	100 um	poor	+	++	-	-
Thermography	500 um	poor	-	-	+++	-
IV MR	160 um	good	+	++	++	++

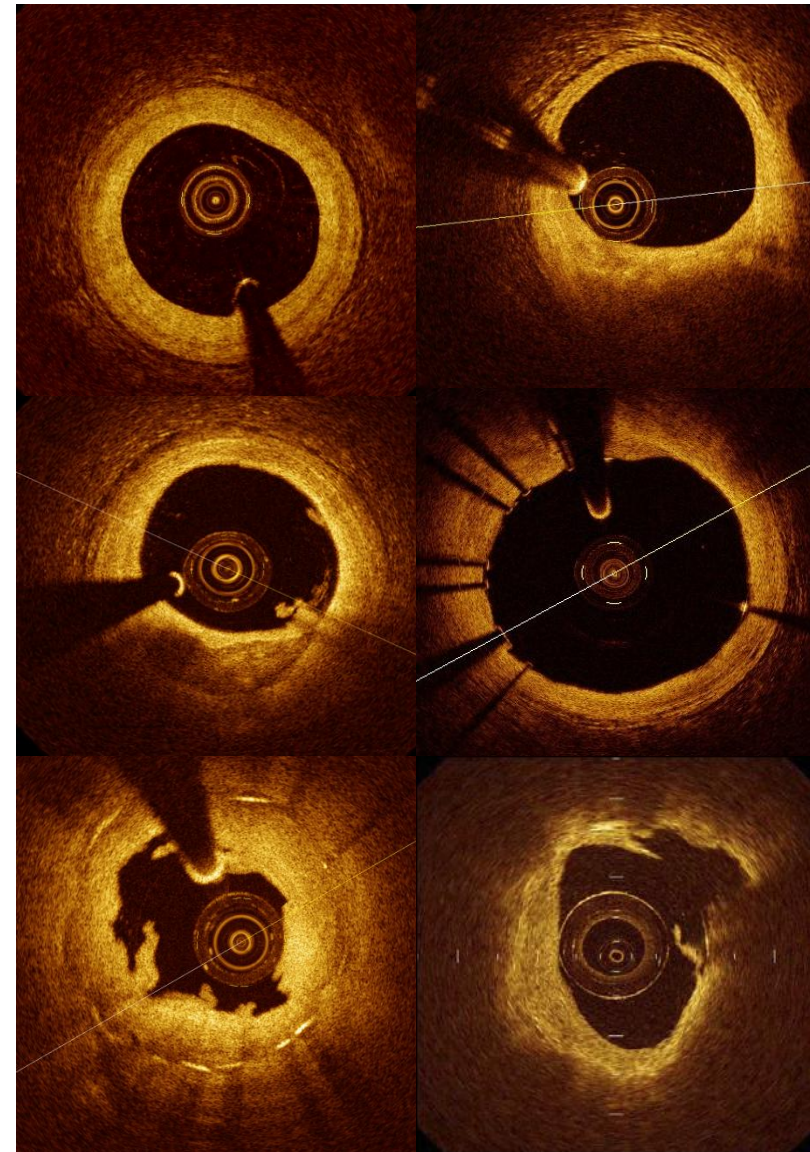
# Optical Coherence Tomography

The acquired cross-sectional images allow:

- ✓ Imaging of micro-features related to plaque vulnerability (Cap Thk, Lipid pool)
- ✓ Evaluation of stent endothelialization
- ✓ Classification of the plaque type
- ✓ Identification of plaque rupture/thrombus

Limitations of this modality are:

- Poor penetration which often does not allow imaging of the entire vessel wall
- Cannot “see” behind lipid tissue
- Unable to discriminate deeply embedded lipid-rich from calcific tissue



# OCT

- Κλινική χρήση 2018
  - Διάγνωση
    - Εκτίμηση βαρύτητας, ιστολογίας και παθοφυσιολογίας οριακών στενώσεων κυρίως σε οξεία στεφανιαία σύνδρομα
  - Επεμβατική Θεραπεία
    - Αγγειοπλαστική επιπλεγμένων βλαβών
    - Εκτίμηση αποτελέσματος PCI
    - Αγγειοπλαστική διχασμού αγγείων
      - Απόφαση για provisional stenting vs both vessels stenting με βάση το OCT
      - Τοποθέτηση οδηγού σύρματος διαμέσου των struts



# OCT-guided PCI

## ➤ **CLI-OPCI Study:**

The use of OCT may improve clinical outcomes of patients undergoing PCI

## ➤ **CLI-OPCI II Study:**

Suboptimal stent deployment defined according to specific quantitative OCT criteria was associated with an increased risk of MACE during follow-up

## ➤ **TOTAL Trial - Substudy:**

OCT-guided primary PCI for STEMI was associated with a larger final in-stent minimum lumen diameter

<b>CLI-OPCI Study</b>	<b>Angiographic guidance group (n=335)</b>	<b>Angiographic plus OCT guidance group (n=335)</b>	<b>p-value</b>
<b>In-hospital events</b>			
Cardiac death	3 (0.9%)	2 (0.6%)	1.0
Non-fatal myocardial infarction	22 (6.5%)	13 (3.9%)	0.118
<b>Events at 1-year follow-up</b>			
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

Prati F et al. EuroIntervention 2012  
 Prati F et al. J Am Coll Cardiol Img 2015  
 Sheth TN, Circ CV Interv 2016

# Guidelines: OCT Imaging

## ESC/EACTS 2018

### Recommendations on intravascular imaging for procedural optimization

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

©ESC 2018

IVUS = intravascular ultrasound; OCT = optical coherence tomography.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

## SCAI 2013 Consensus

### 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.

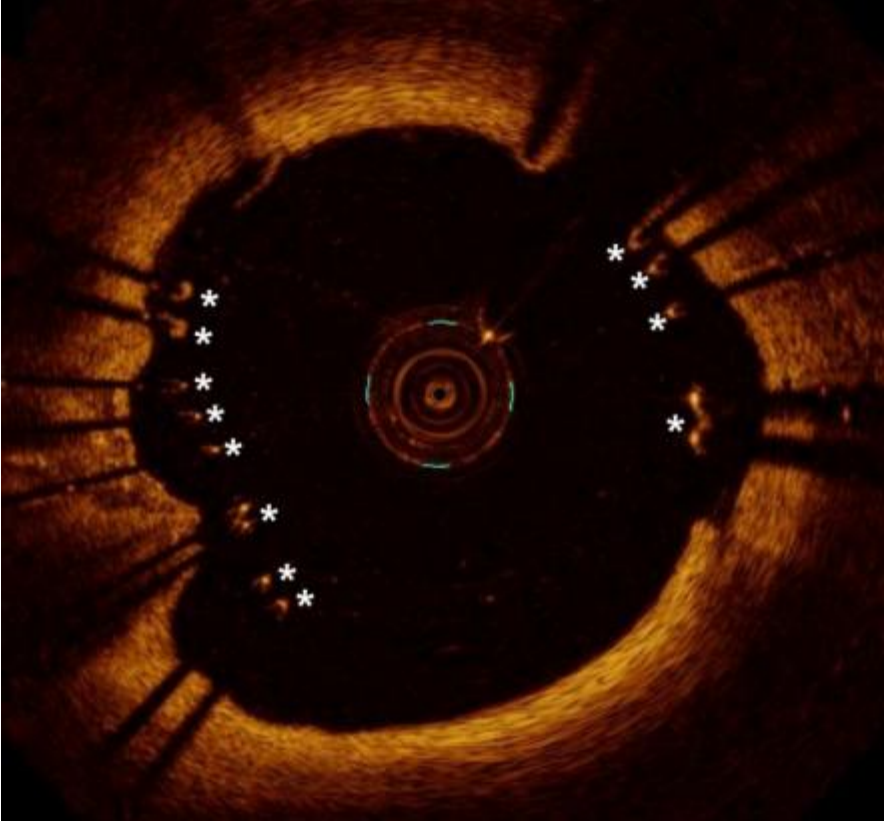
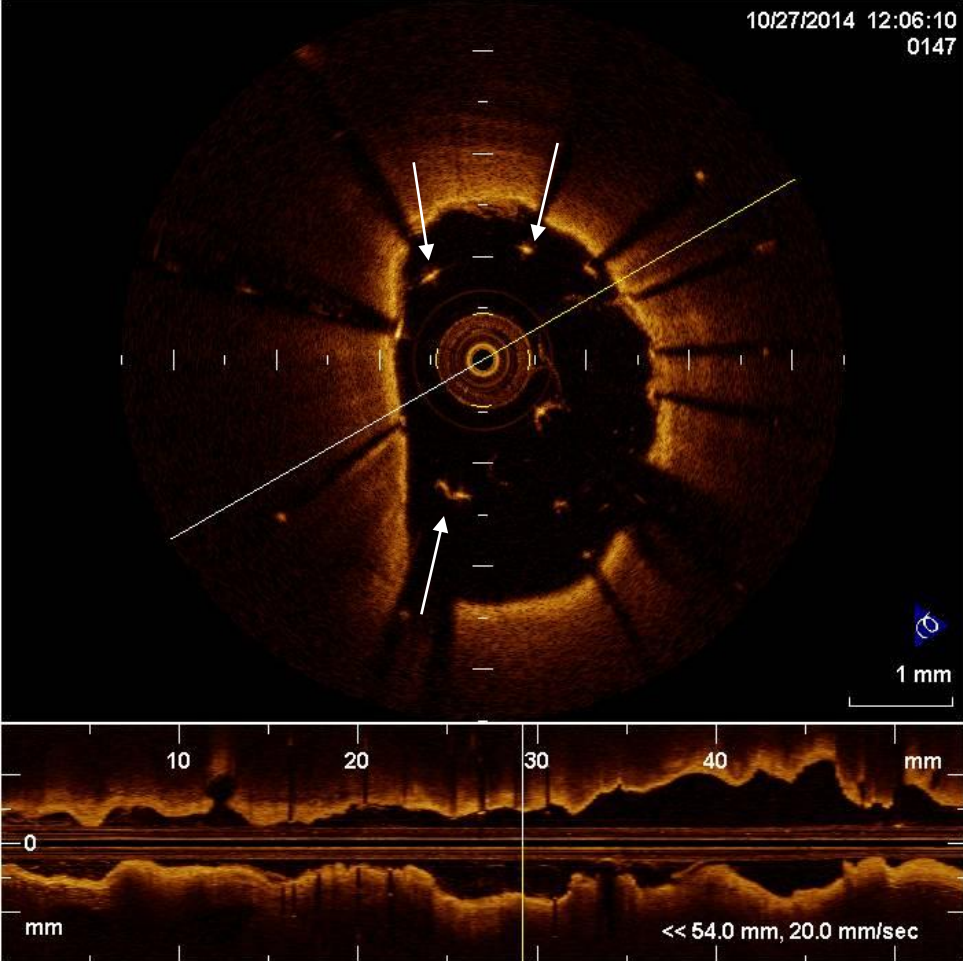
Lotfi A, et al. Catheter Cardiovasc Interv 2013

Neumann FJ, et al. Eur Heart J 2018

# PCI guidance by OCT

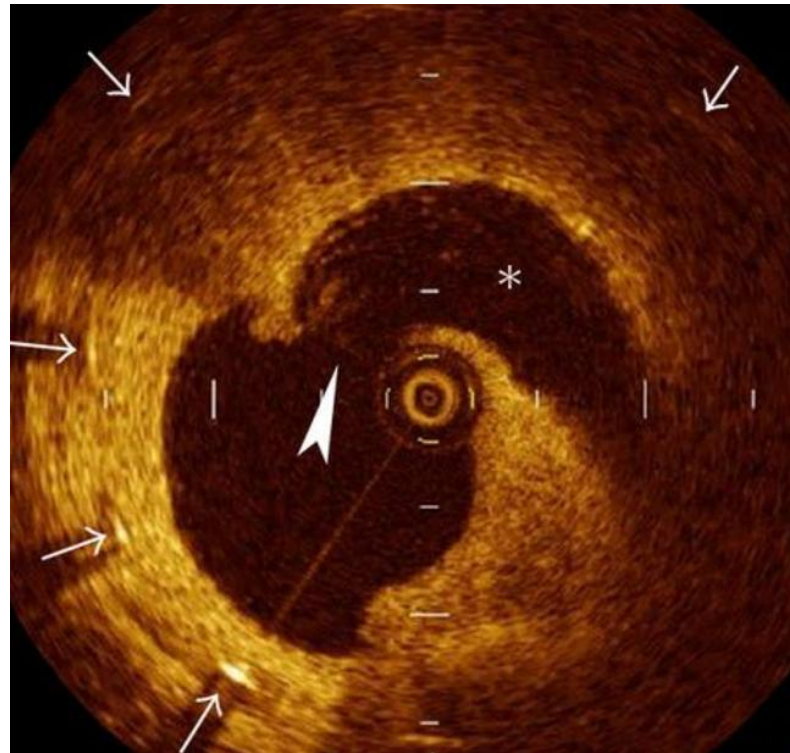
## Identification of severe malapposition (multiple struts)

Value of optimising post-dilation of the stent



# PCI guidance by OCT

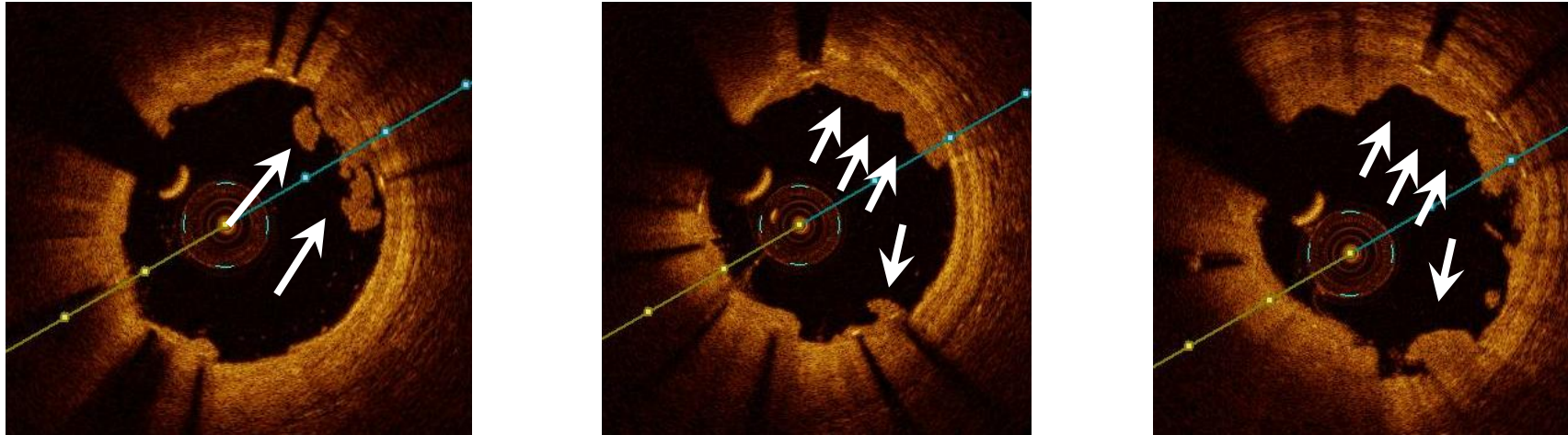
- Intermediate lesions in ACS: stent or not stent



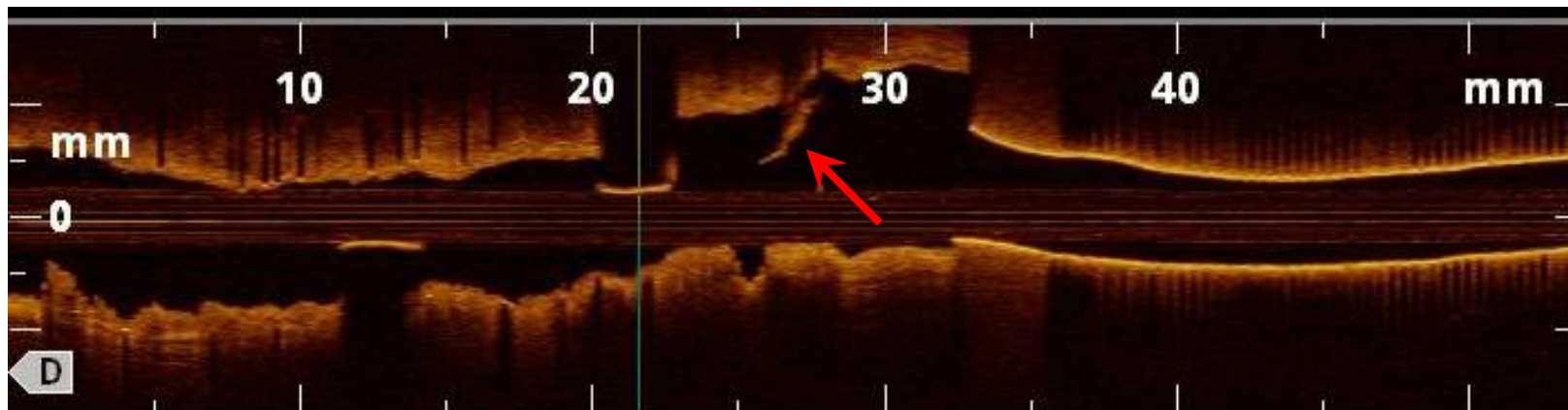
# OCT Imaging

## In-stent Thrombus and Identification of Intimal Flaps

Thrombus material in a stent implanted 4 days ago (Stent Thrombosis)



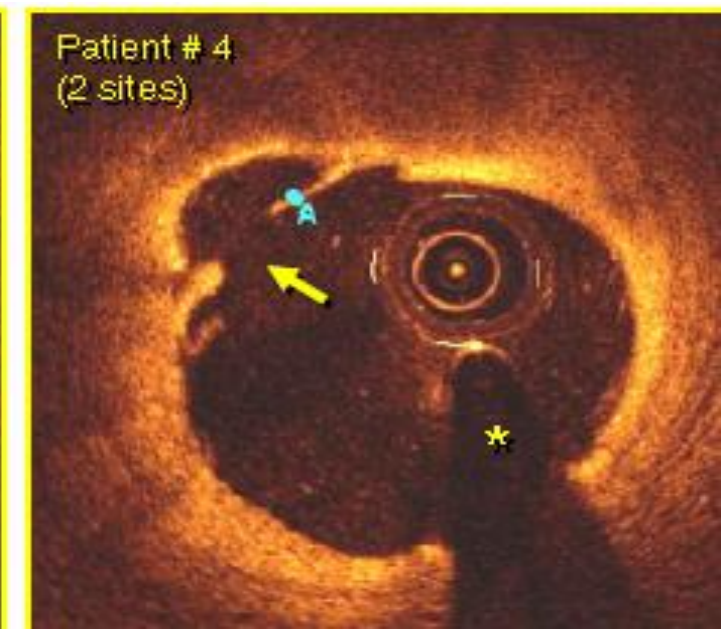
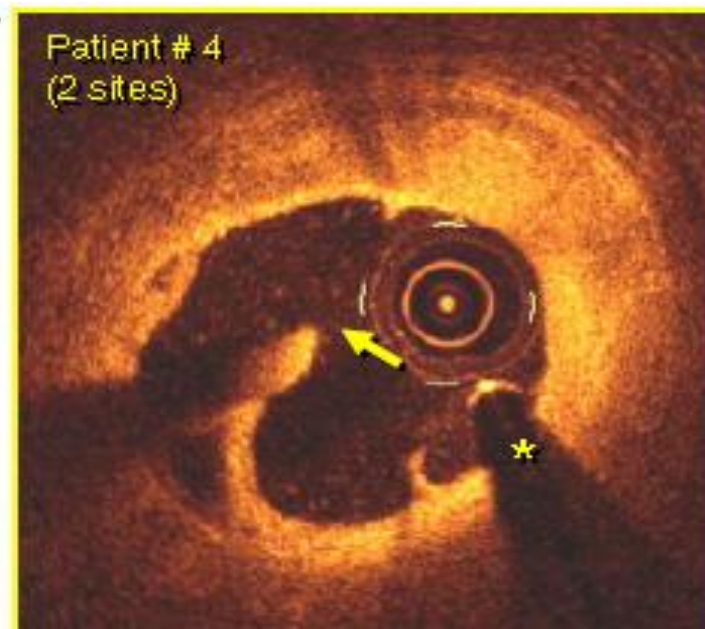
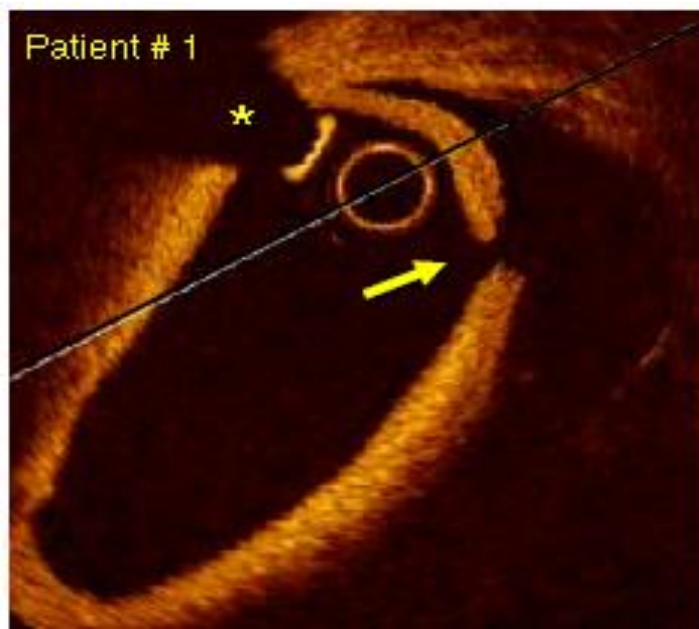
Intimal flap within 5 mm proximal to the stent edge

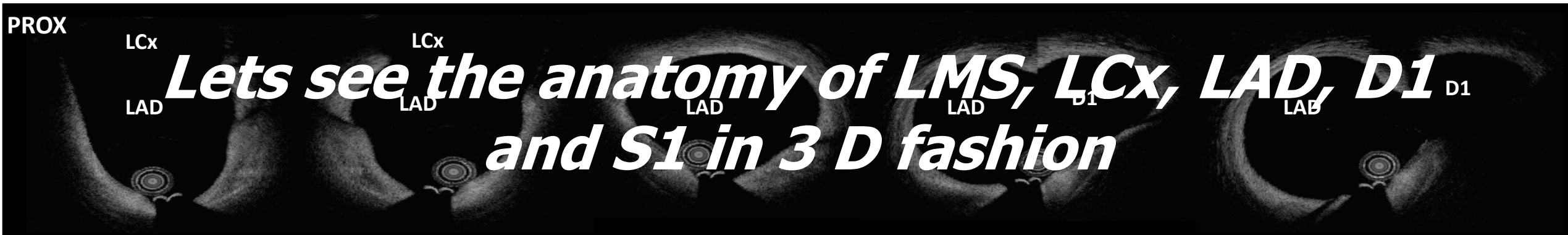


**MINI-FOCUS ISSUE: OPTICAL COHERENCE TOMOGRAPHY**

## **Diagnosis of Spontaneous Coronary Artery Dissection by Optical Coherence Tomography**

Fernando Alfonso, MD, PHD, Manuel Paulo, MD, Nieves Gonzalo, MD, PHD, Jaime Dutary, MD, Pilar Jimenez-Quevedo, MD, PHD, Vera Lennie, MD, Javier Escaned, MD, PHD, Camino Bañuelos, MD, Rosana Hernandez, MD, PHD, Carlos Macaya, MD, PHD





## STATE-OF-THE-ART PAPER

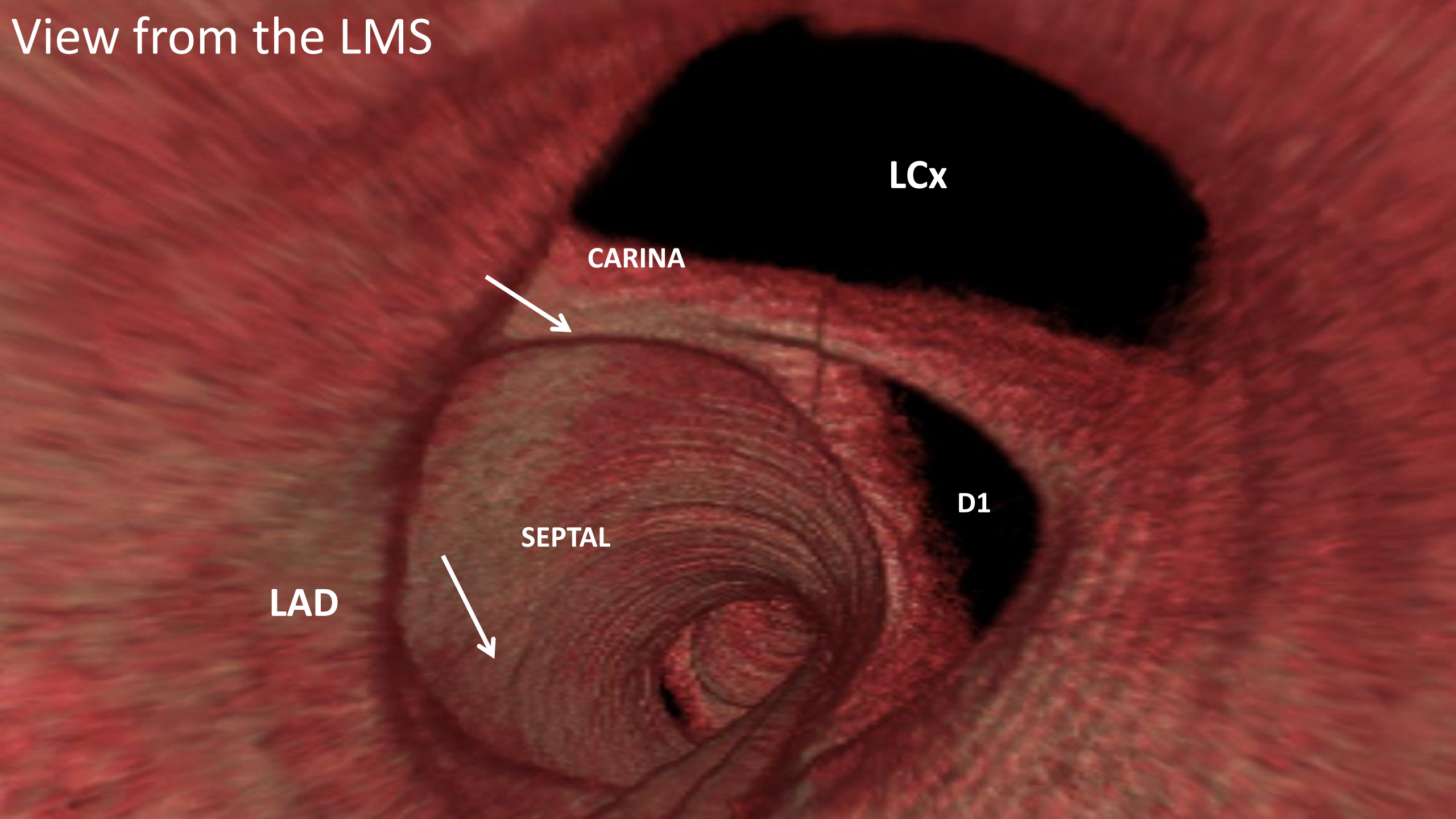
Is the evaluation of coronary anatomy better?  
Is it useful?

# New Insights Into the Coronary Artery Bifurcation

Hypothesis-Generating Concepts Utilizing 3-Dimensional  
Optical Frequency Domain Imaging

Vasim Farooq, MBChB, Patrick W. Serruys, MD, PhD, Jung Ho Heo, MD,  
Bill D. Gogas, MD, Takayuki Okamura, MD, PhD, Josep Gomez-Lara, MD,  
Salvatore Brugaletta, MD, Hector M. Garcia-Garcia, MD, MSc, PhD,  
Robert Jan van Geuns MD, PhD

# View from the LMS



LCx

CARINA

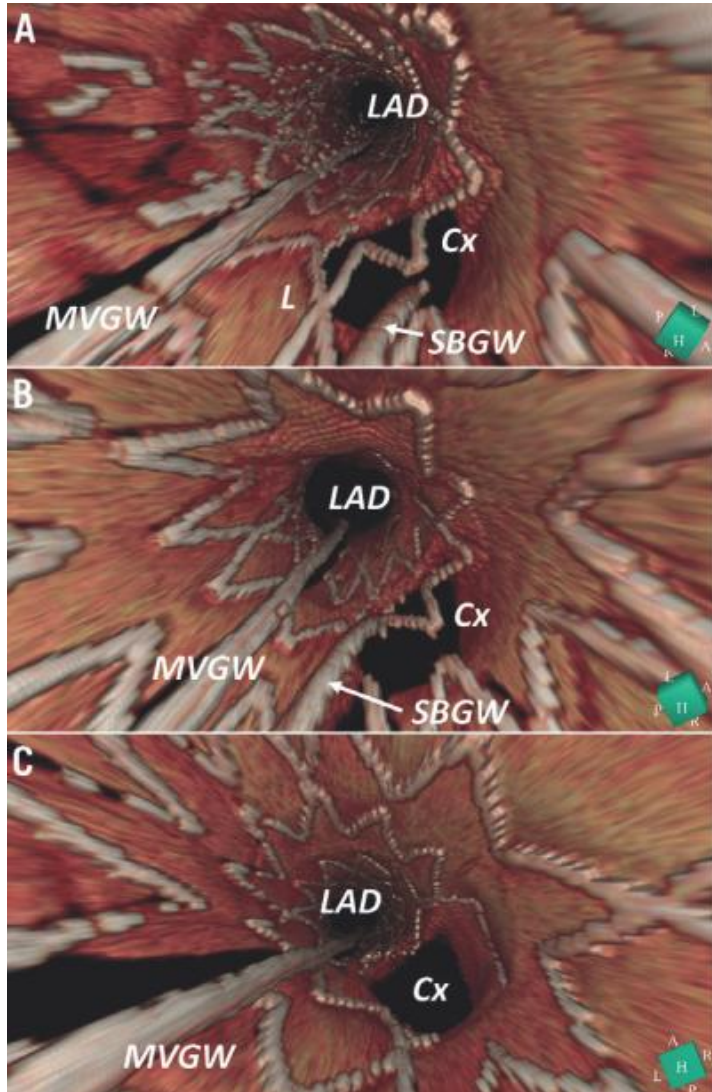
D1

SEPTAL

LAD



# 3D OCT guidance in Bifurcational Stenting



Changing the recrossing position according to three-dimensional optical coherence tomography findings

A) First attempt at rewiring (proximal cell)

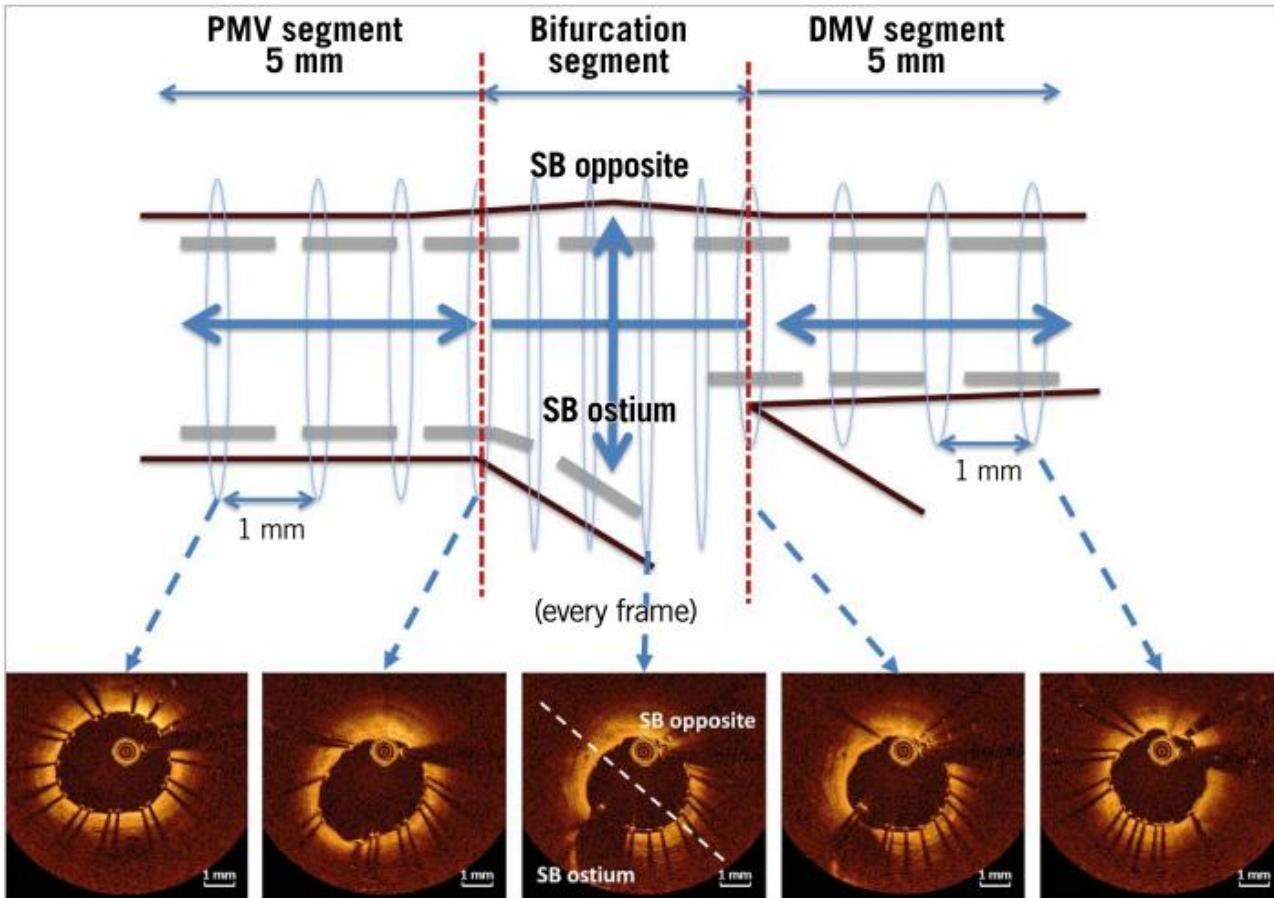
B) Second attempt at rewiring (distal cell)


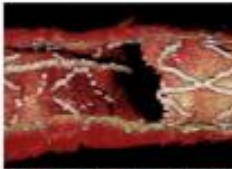
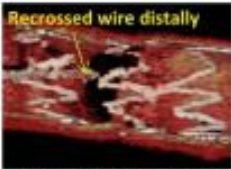
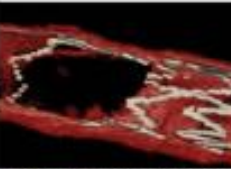




C) After final kissing balloon inflation

L: link; MVGW: main vessel guidewire; SBGW: side branch guidewire

# 3D OCT guidance in Bifurcational Stenting

The **guidewire recrossing point** and the location of a stent link at the SB orifice had an influence on the **incomplete stent apposition**. Kissing balloon dilatation with optimal conditions under 3D-OCT guidance may reduce side branch restenosis.

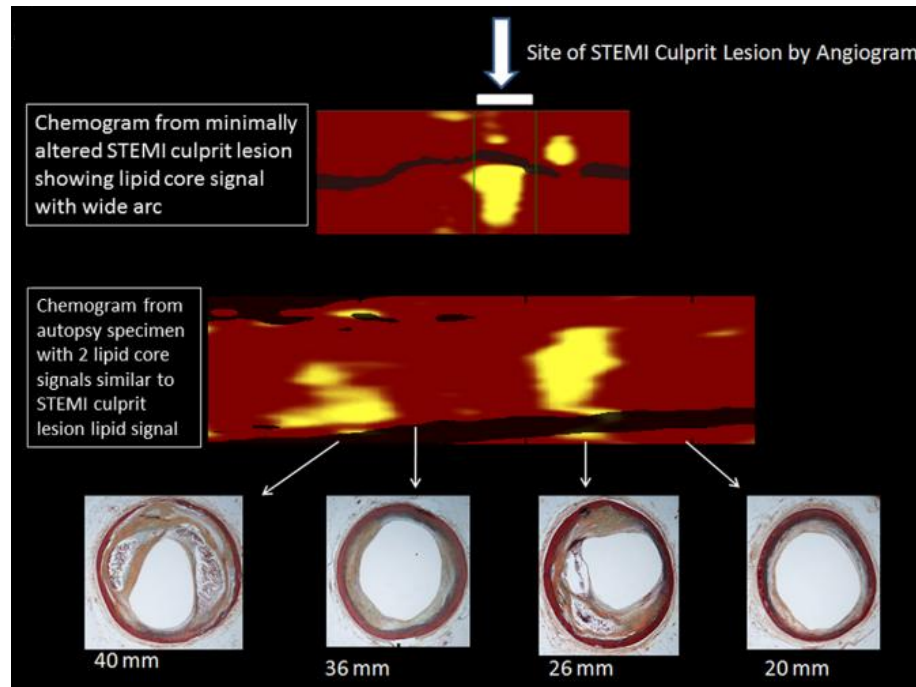
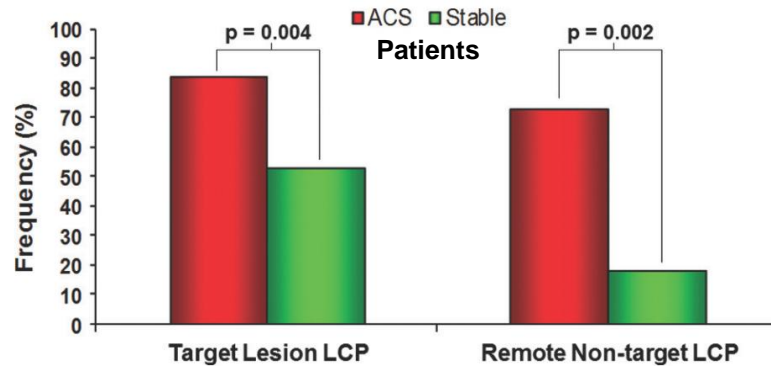


Recross position	Parallel type		Perpendicular type	
	Guidewire recrossing	After kissing ballooning	Guidewire recrossing	After kissing ballooning
Distal				
Proximal				

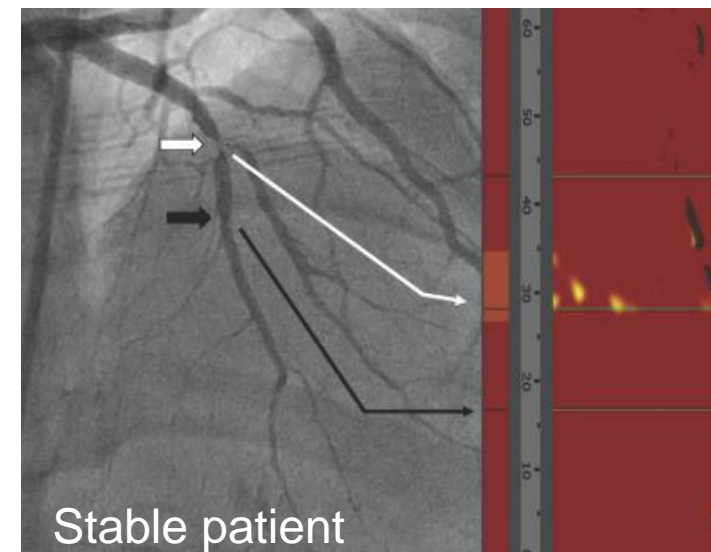
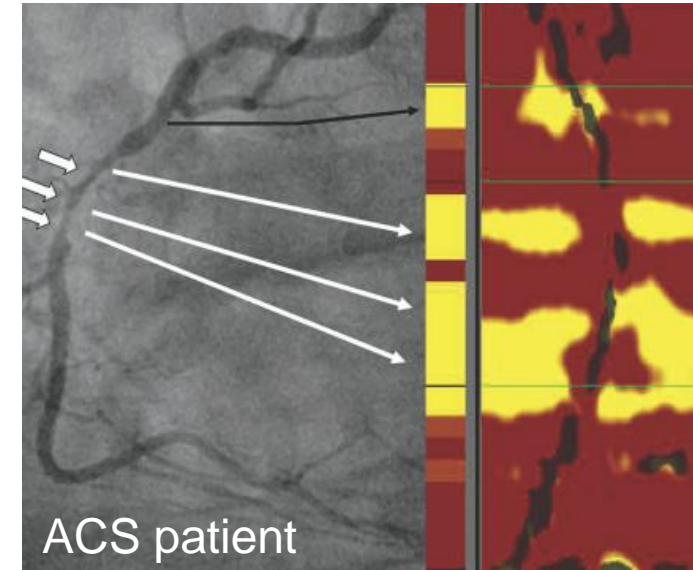
# Νεώτερες τεχνικές

- NIR spectroscopy
- Υβριδικοί καθετήρες

# NIRS: Clinical Correlation



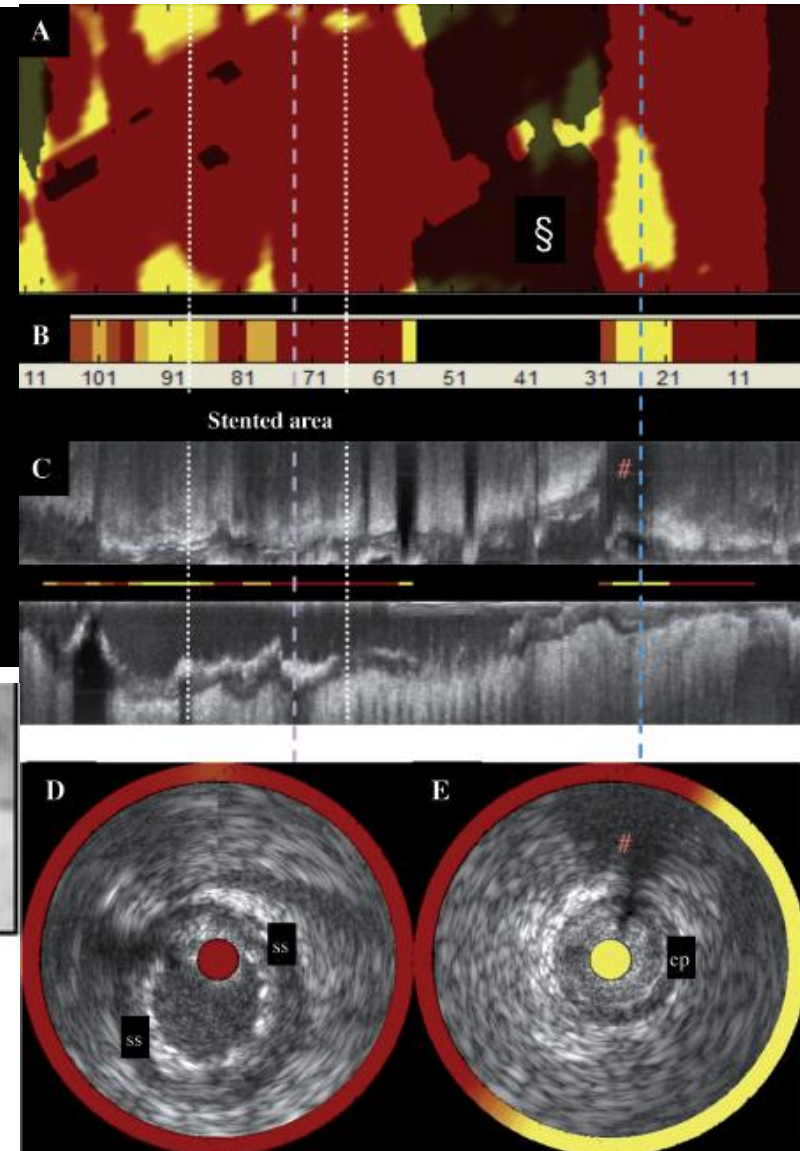
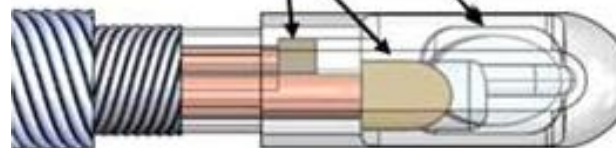
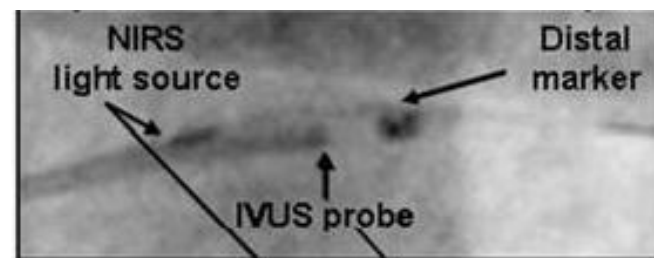
Madder et al. Circ Cardiovasc Interv 2012  
Madder et al. JACC Interv 2013



# Hybrid catheter – IVUS and NIRS

- Imaging is performed with the use of the TVC catheter that combines a NIRS light source and an IVUS probe
- The catheter allows overlay of the NIRS estimations onto the IVUS images
- Provides plaque anatomy and **lipid probability**

Garg et al. EuroIntervention 2010  
Schultz et al. JACC 2010



ΕΥΧΑΡΙΣΤΩ