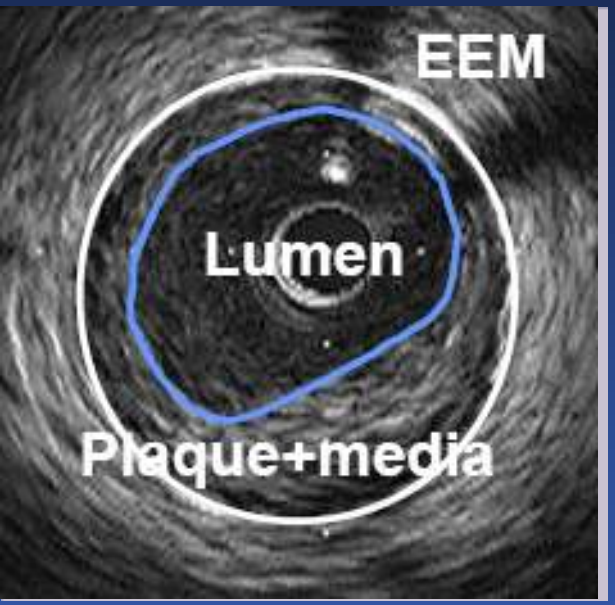
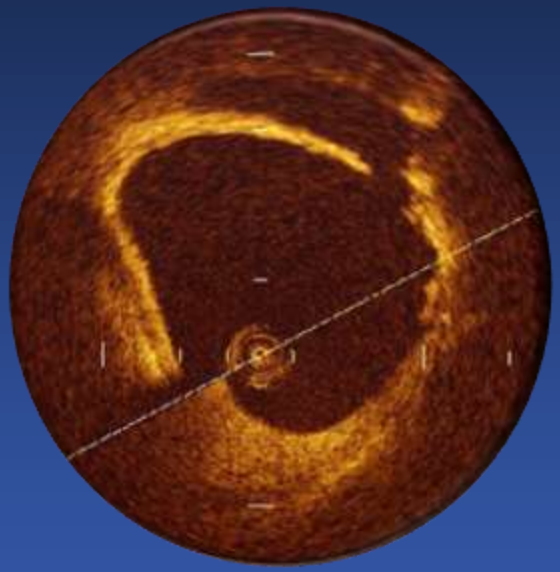
Intracoronary imaging techniques: Intracoronary ultrasonography, Optical coherence Tomography



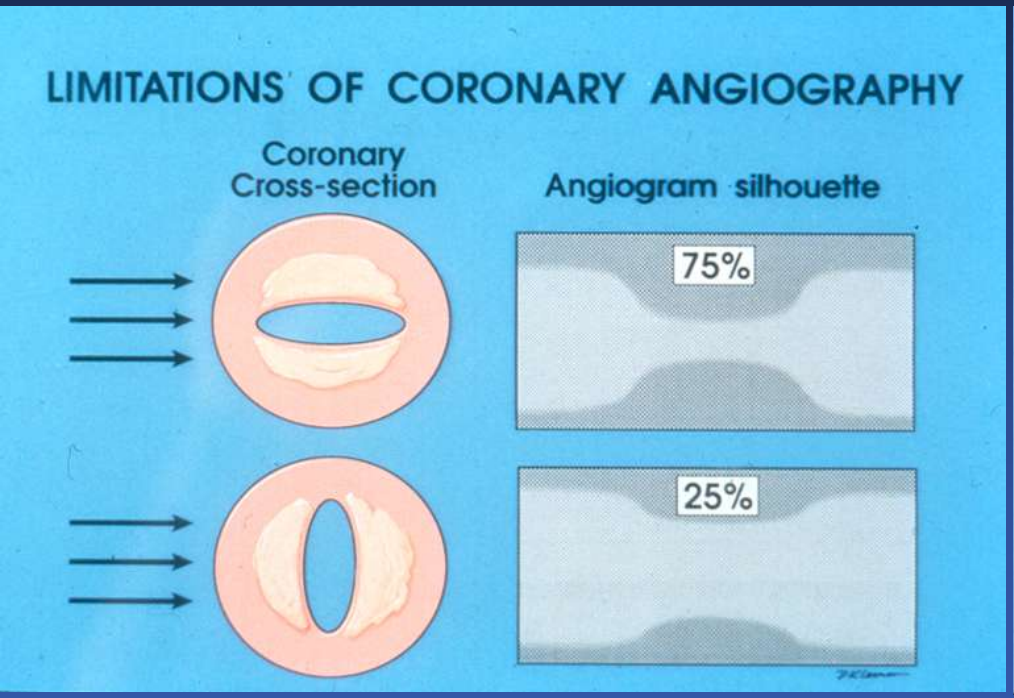


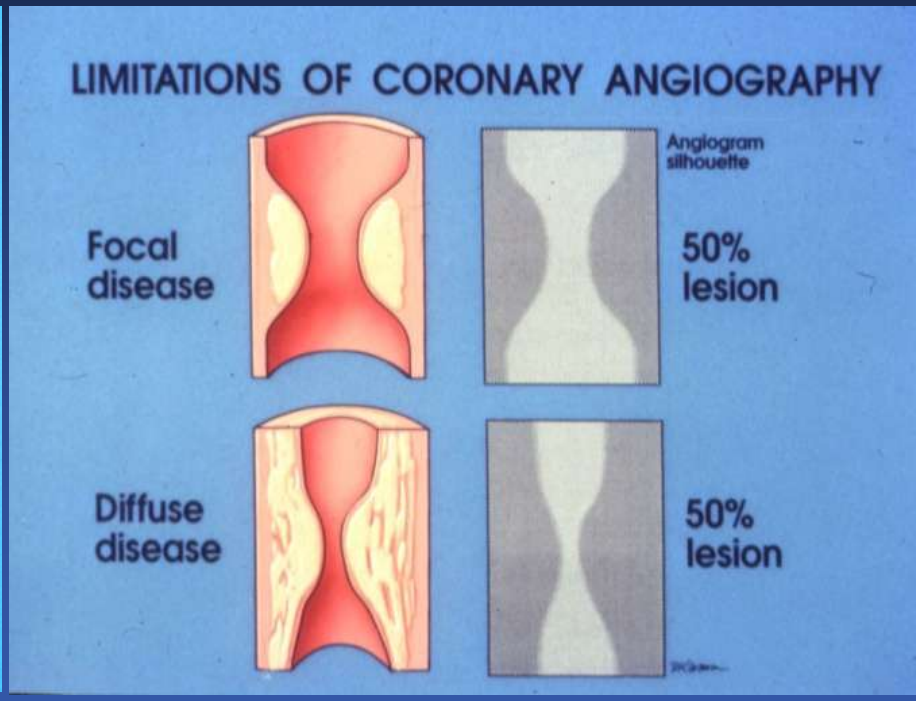
Andreas Synetos

First Department of Cardiology

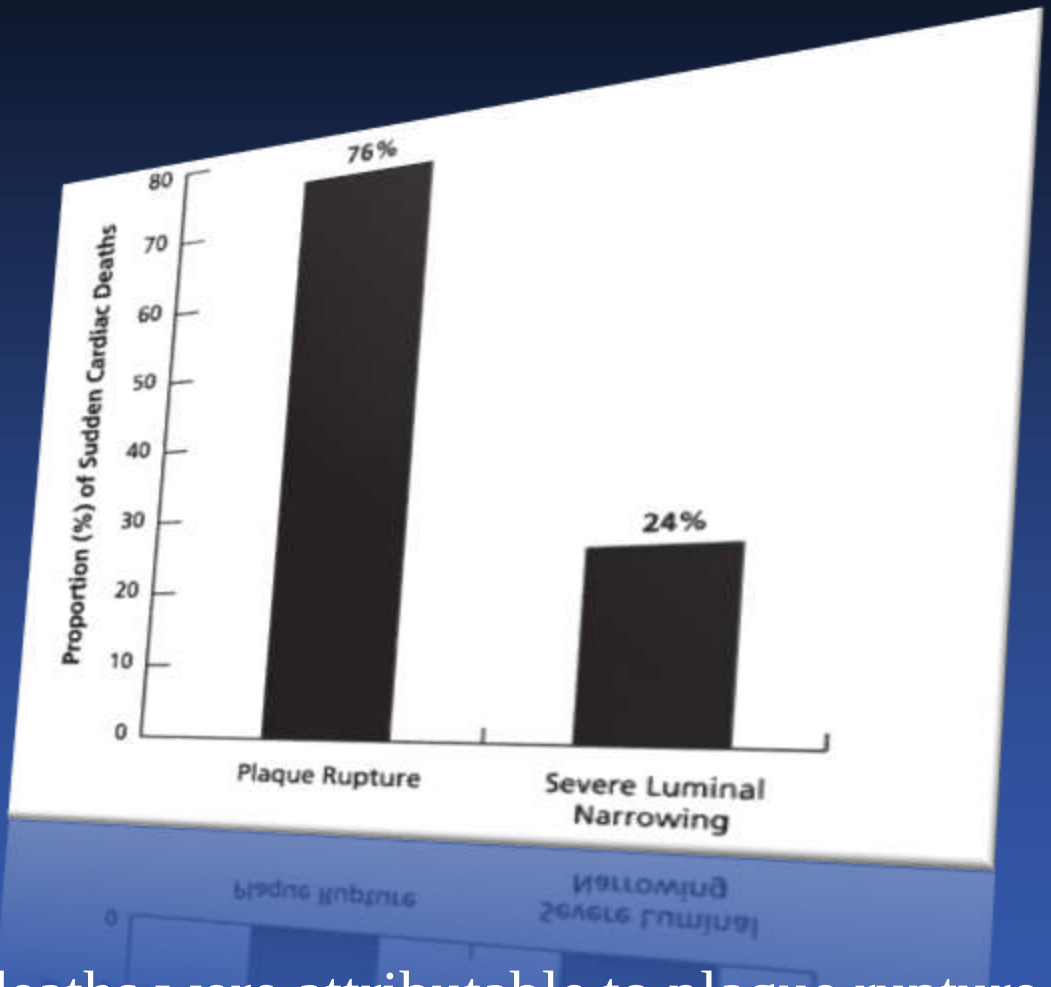
University of Athens

Περιορισμοί αγγειογραφίας





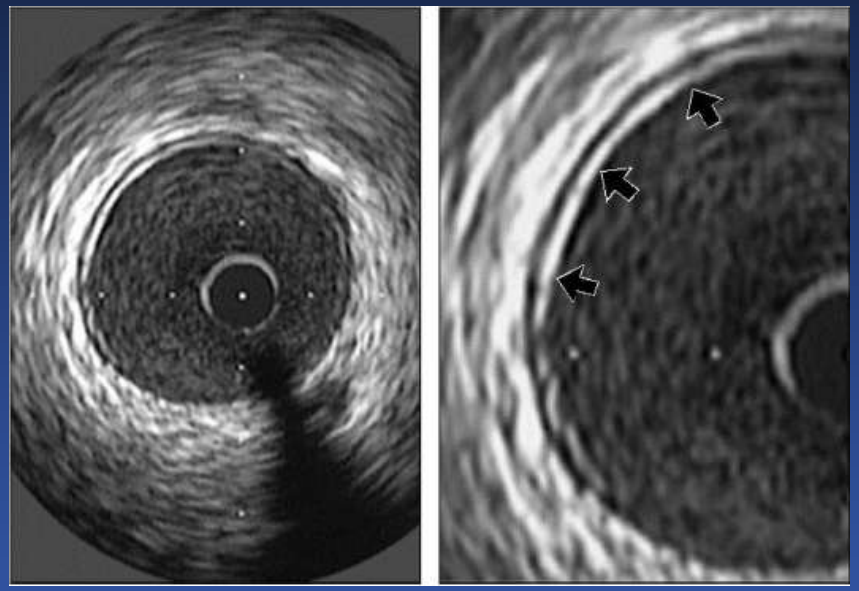
Plaque rupture impact



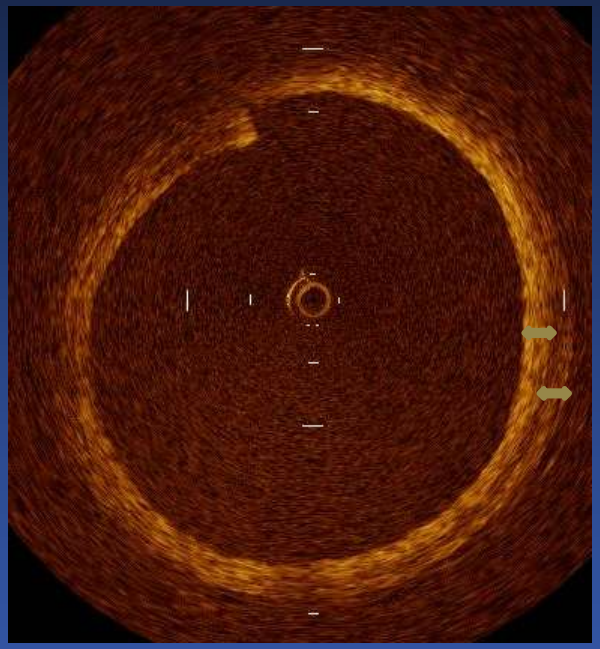
76% of sudden deaths were attributable to plaque rupture, and only 24% of MIs were associated with severe luminal narrowing.

Falk E, …,Fuster V. Coronary plaque disruption. Circulation 1995;92:657– 671

Intravascular Imaging: From sound to light



IVUS was the gold standard for evaluation of lumen dimensions and plaque morphology



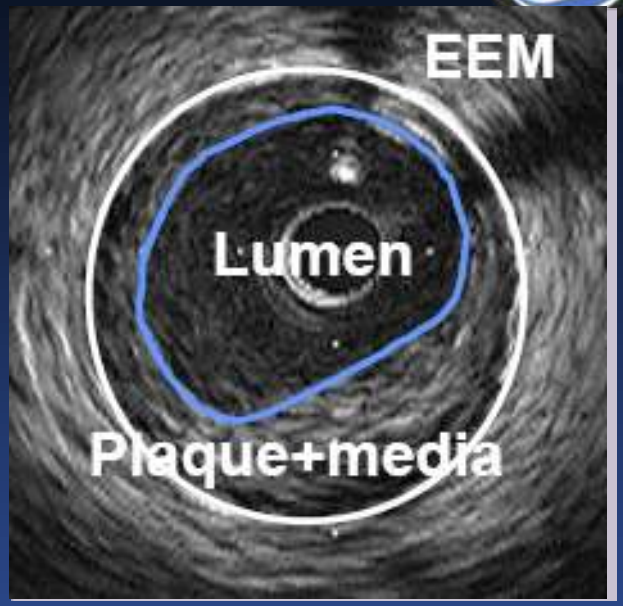
Yet the advent of OCT has provided us with another useful tool with far superior resolution (10x), but limited penetration (<2mm)

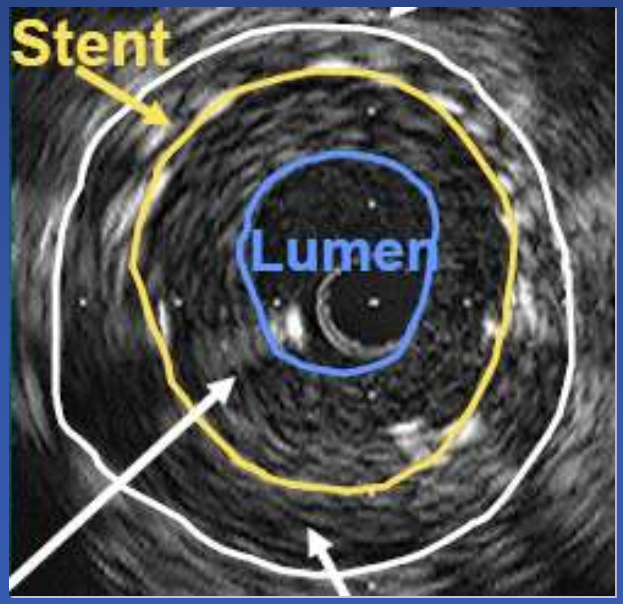
Εφαρμογές ενδοαγγειακής απεικόνισης

- Αξιολόγηση σημαντικότητας βλάβης
- Καθοδήγηση της αγγειοπλαστικής (πριν από το stent)
- Εκτίμηση του αποτελέσματος της αγγειοπλαστικής
- Αξιολόγηση επιπλοκών μετά από το stent
- Θρόμβωση & επαναστένωση του stent
- Σύγκριση μεθόδων
- Εκτίμηση σύστασης πλάκας

IVUS: μετρήσεις

- **Ολική αρτηριακή επιφάνεια** (Total arterial CSA)
- **Επιφάνεια αυλού** (Lumen CSA)
- **Μέγιστη & ελάχιστη διάμετρος αυλού**
- **% Στένωση επιφάνειας αυλού**
- **Μήκος βλάβης**
- **Επιφάνεια πλάκας & μέσου χιτώνα**
  = Ολική αρτηριακή επιφάνεια - Επιφάνεια αυλού (σε βλάβη χωρίς stent)
  = Ολική αρτηριακή επιφάνεια - Επιφάνεια stent(σε βλάβη με stent)
- **Δείκτης αναδιαμόρφωσης (remodeling index):**
  = Επιφάνεια αυλού (σε βλάβη) / Επιφάνεια αυλού (σε υγιές τμήμα)
- Σε stent: **επιφάνεια stent, μέγιστη & ελάχιστη διάμετρος stent**
- **Επιφάνεια υπερπλασίας έσω χιτώνα** = Επιφάνεια stent - Επιφάνεια αυλού



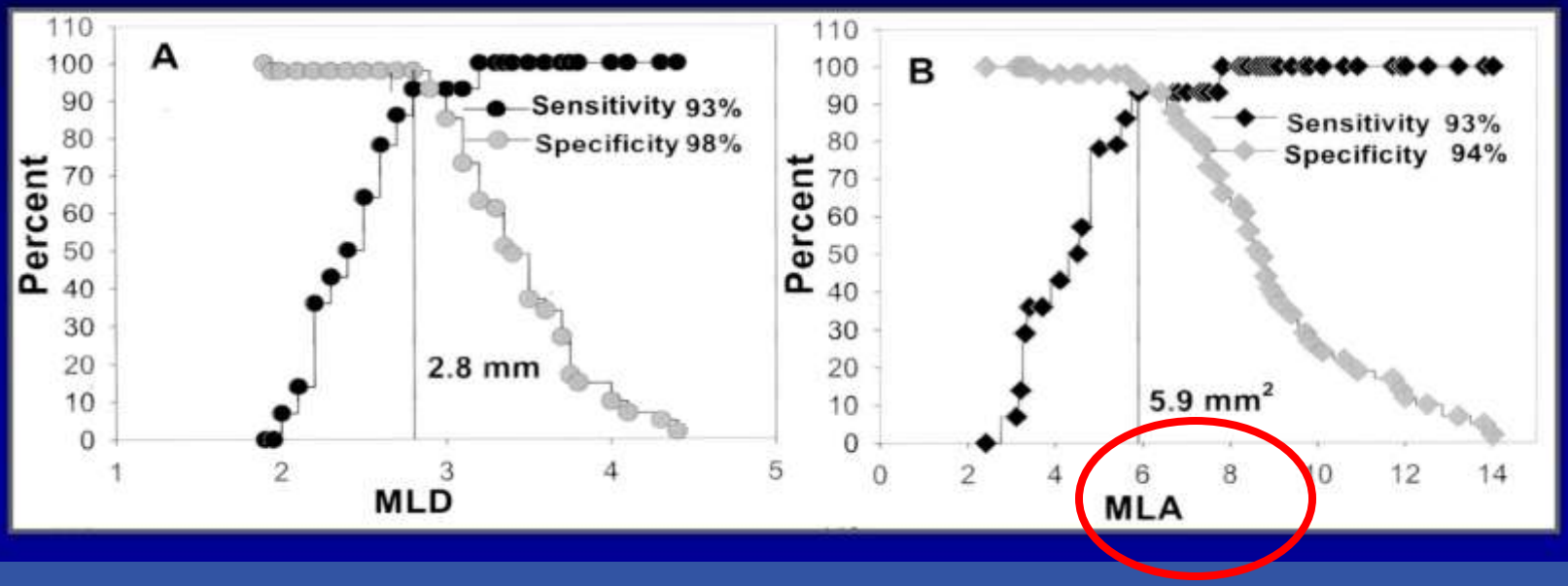


IVUS: Ορισμός «σημαντικής» στένωσης

- % ελάττωση διαμέτρου > 70%
- % ελάττωση επιφανείας > 50%
- MLA < 4 mm^2 (εγγύς LAD, LCX, RCA)
  < 6 mm^2 (στέλεχος)
- Ελάχιστη διάμετρος < 1.8 mm (εγγύς LAD, LCX, RCA)
  < 2.9 mm (στέλεχος)

Παράμετροι IVUS που προβλέπουν FFR<0.75 σε νόσο στελέχους

55 patients with ambiguous left main disease

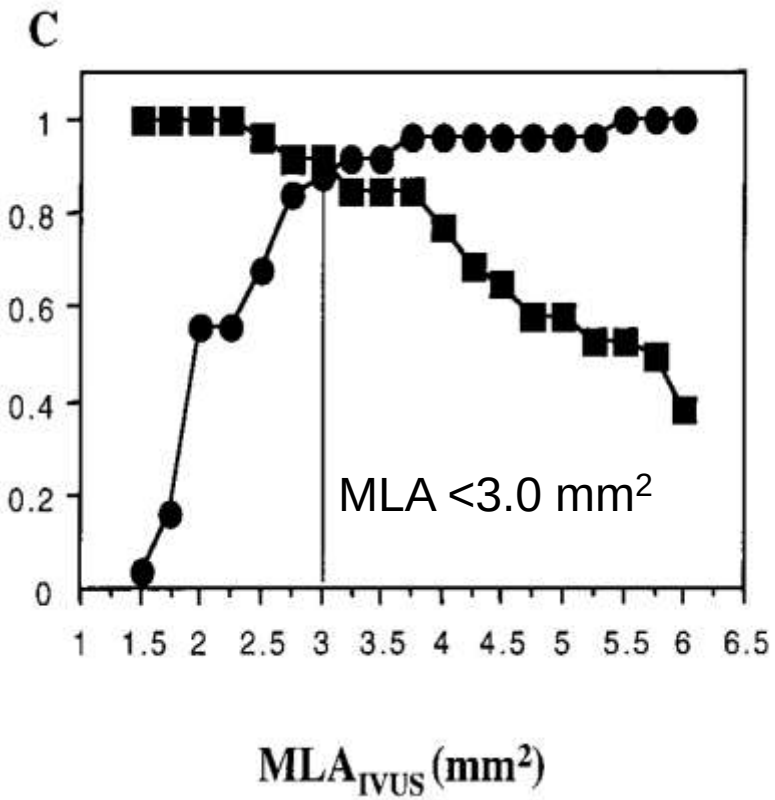


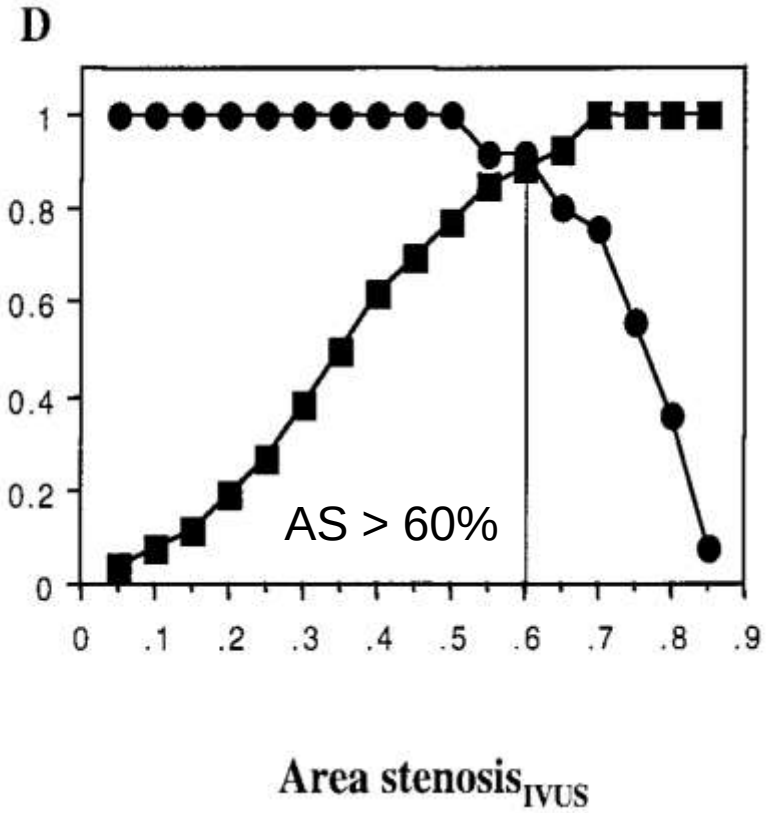
Jasti et al. Circulation 2004;110:2831-6

Non LM- Minimum Lumen Area (MLA) and Area Stenosis (AS) vs. FFR

(83% sensitivity, 92.3 % specificity)

(92% sensitivity, 88.5 % specificity)

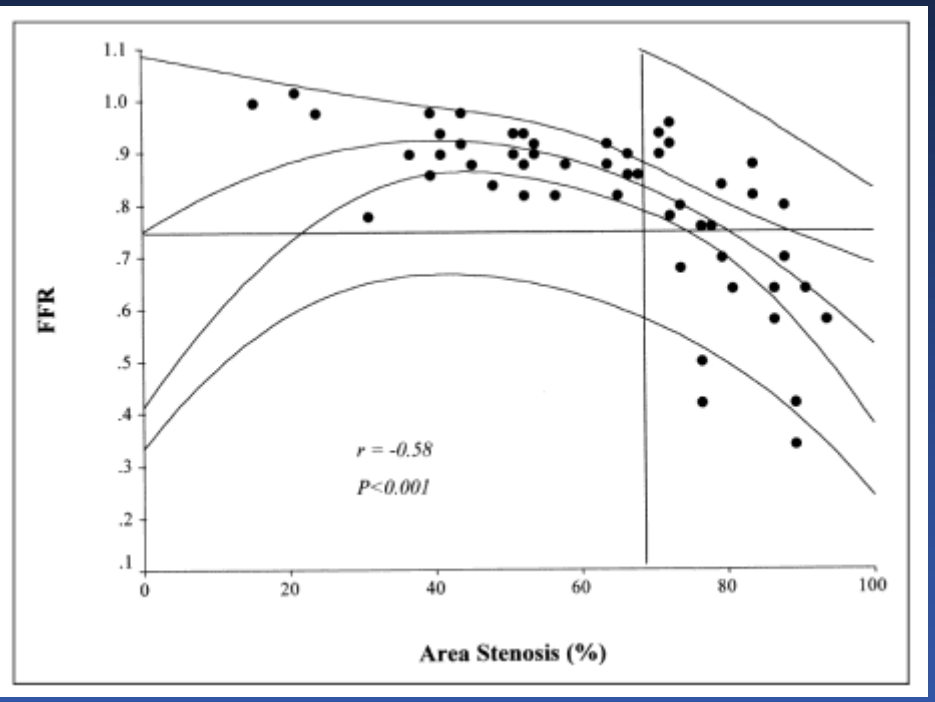




Circulation 1999;100;250-255

Non LM- IVUS vs. FFR

53 lesions, 43 patients



Area Stenosis >70%
(sensitivity 100%, specificity 68%)

MLA≤4.0
(sensitivity 92%, specificity 56%)

(Am J Cardiol 2001;87:136–141)

Εφαρμογές ενδοαγγειακής απεικόνισης

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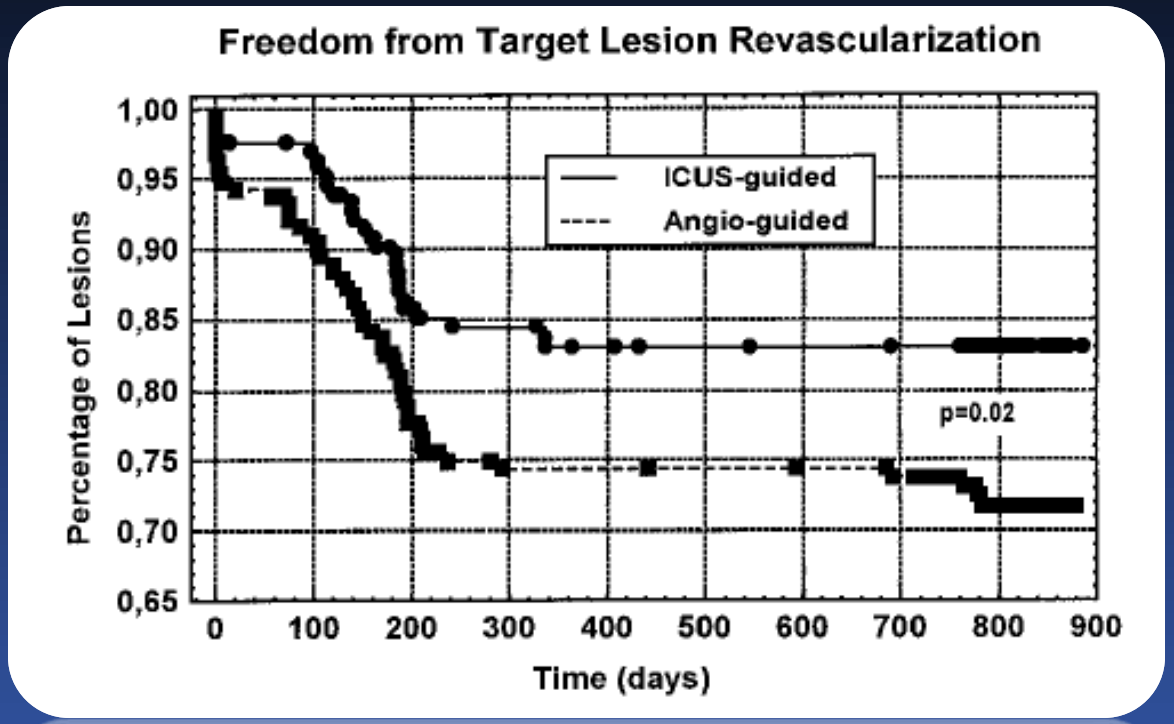
- Αξιολόγηση επιπλοκών μετά από το stent
- Θρόμβωση & επαναστένωση του stent
- Σύγκριση OCT-IVUS
- Εκτίμηση σύστασης πλάκας

RCT

SIPS trial

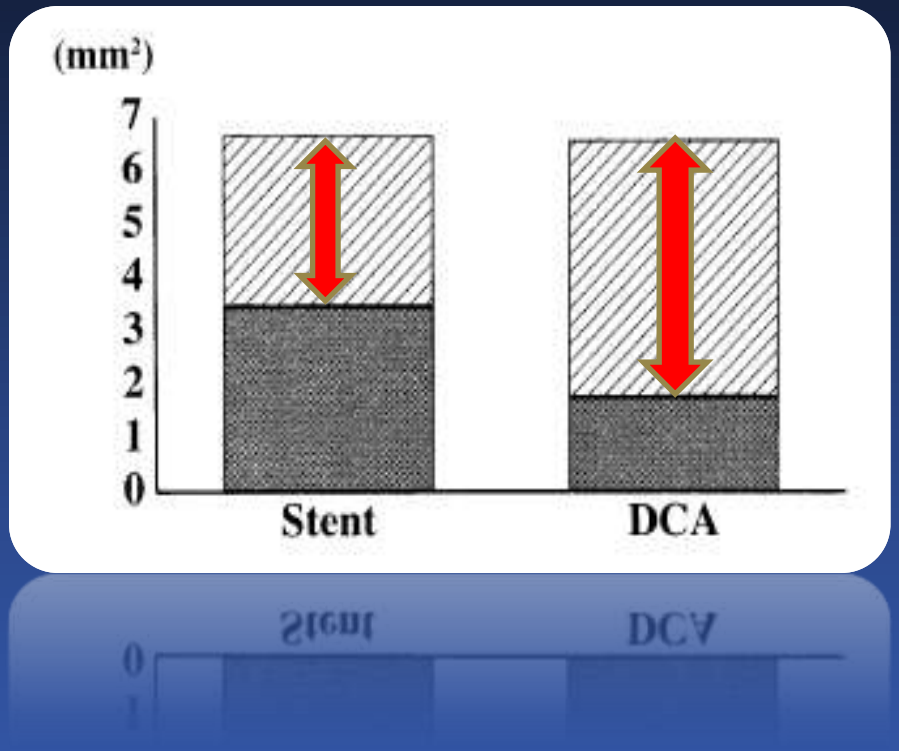


n=269
p=0,02

Although there was no significant difference in MLD at 6 months, clinical follow-up at 2 years showed a significant decrease in clinically driven TLR in the IVUS group compared with the angiography group (17% vs. 29%, p=0.02).

Frey AW et al, Circulation 2000;102;2497-2502

IVUS utilization for DCA

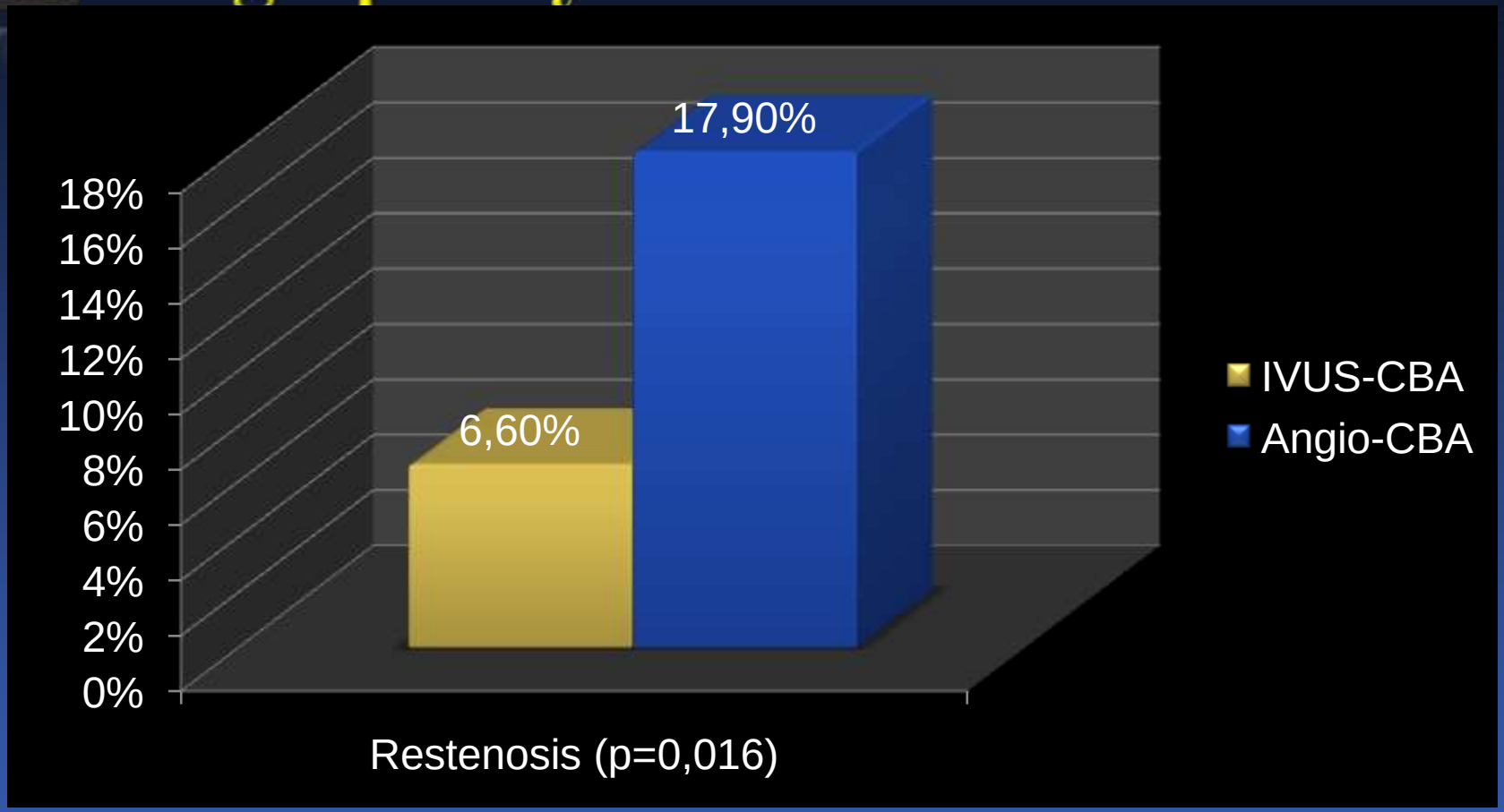


Striped bars :
plaque reduction
Gray bars :
vessel expansion.

Both strategies provided an identical acute luminal gain, but the plaque reduction ratio was significantly greater in the IVUS-guided DCA arm (46.7% vs 71.6%, p-=0.0014).

Tsuchikane E et al, J Am Coll Cardiol 1999;34:1050 –7

IVUS effect on cutting balloon angioplasty – REDUCE III trial

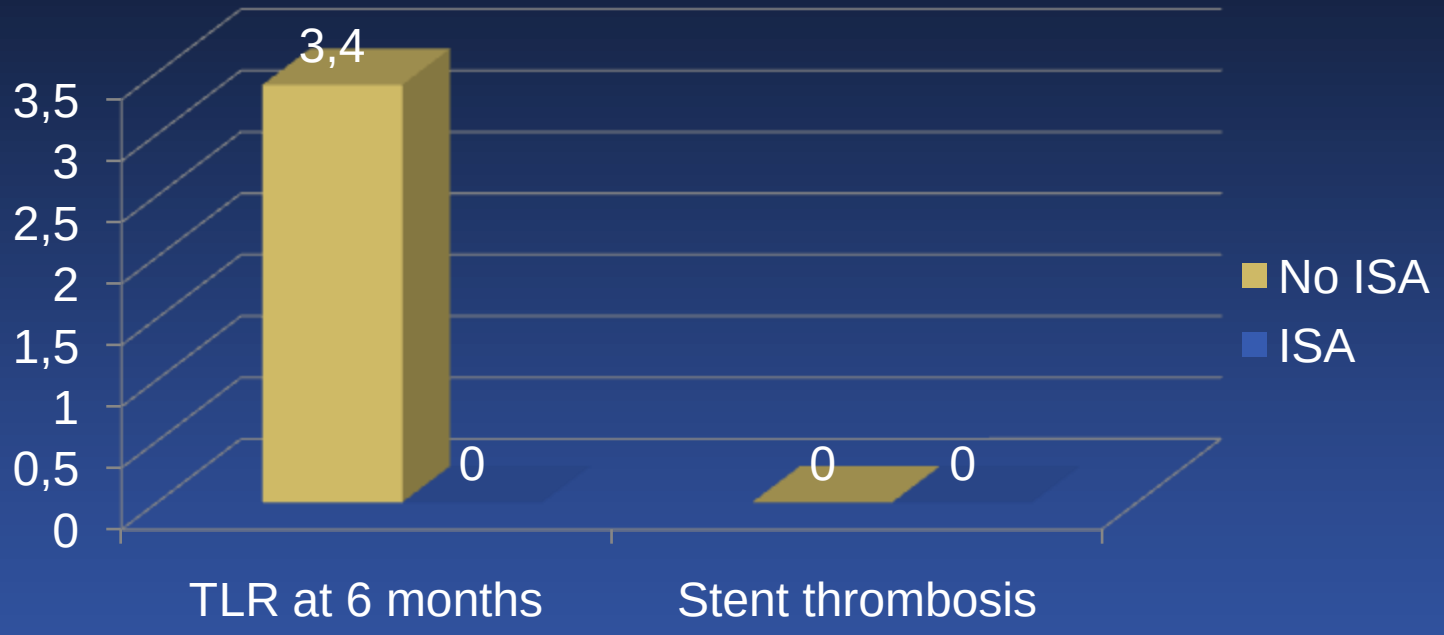


IVUS-guided CBA-BMS strategy results in low restenosis rates (6.6%) comparable to those achieved in recent DES studies.

Ozaki Y et al, Circ J 2007; 71: 1–8

RCT

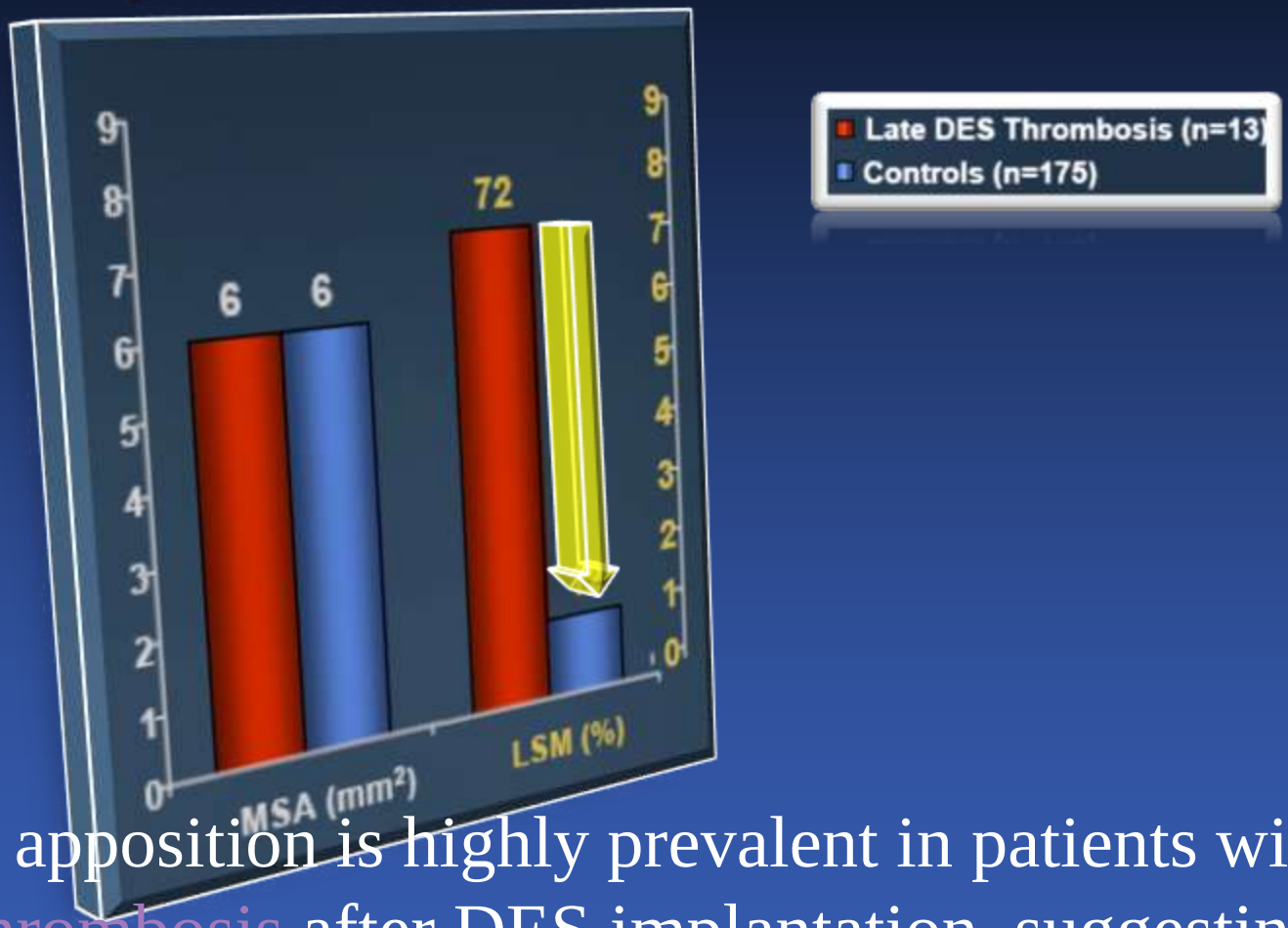
Effect of incomplete apposition : thrombosis



Incomplete stent apposition after DES *does not increase* stent thrombosis or restenosis, but…

Tanabe K et al, Circulation. 2005 Feb 22; 111:900-905 (TAXUS II Trial)

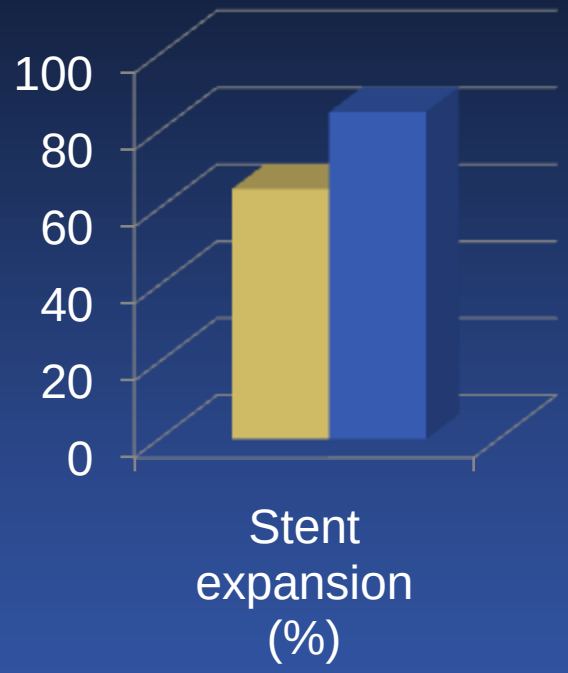
Effect of incomplete apposition : very late thrombosis



Incomplete stent apposition is highly prevalent in patients with very late stent thrombosis after DES implantation, suggesting a role in the pathogenesis of this adverse event.

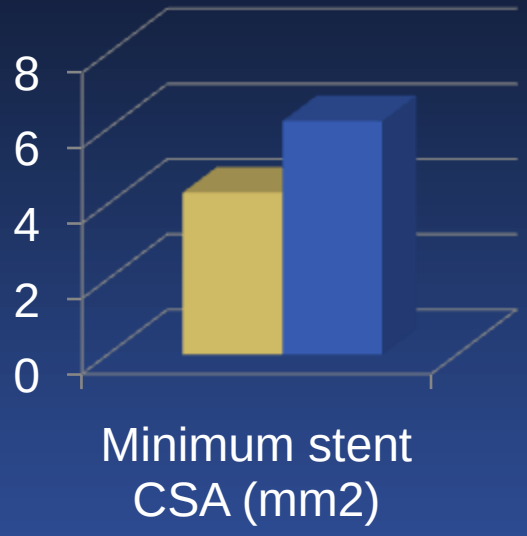
Cook S et al, Circulation 2007;115:2426-34

Effect of underexpansion
(inadequate stent dimensions)



p= 0,03

Thrombosis
Control



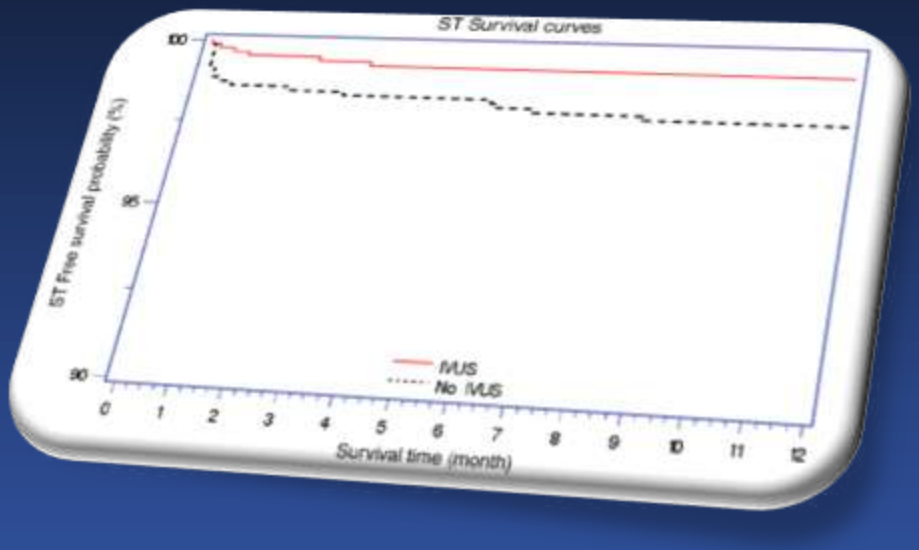
p= 0,02

Thrombosis
Control

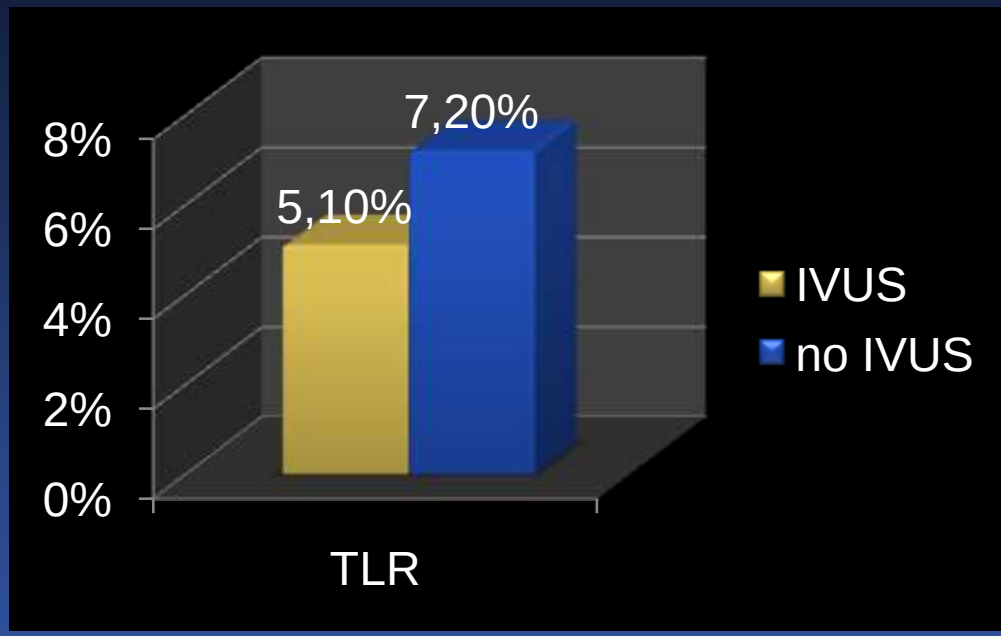
Stent under-expansion and residual reference segment stenosis are associated with an increased risk of stent thrombosis after successful drug-eluting stent implantation.

Fugii, K, et al, J Am Coll Cardiol. 2005 Apr 5;45(7):995-8

IVUS guided DES implantation



p=0,014



p=0,07

IVUS guidance during DES implantation has the potential to influence treatment strategy and reduce both DES thrombosis and the need for repeat revascularization.

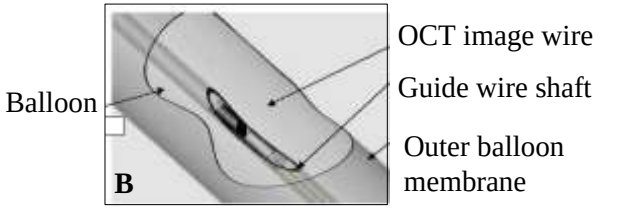
Probal R,….,Waksman R, Eur Heart J 2008;29:1851–1857

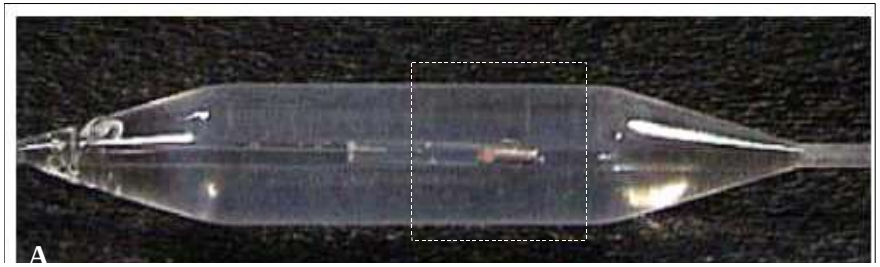
Clinical Application of OCT

Intracoronary Imaging

1991 **2002**

Imaging Wire 0.014" Through PCI Balloon





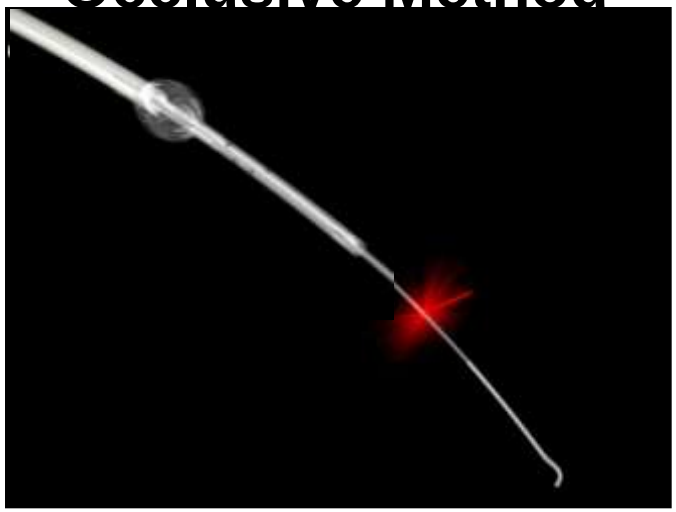
Regar et al. Am J Cardiol 2002 (Abstract), Regar et al. Heart 2006; Regar E, van Leeuwen AMGJ, Serruys PW (Eds): Optical coherence tomography in cardiovascular research. London: Informa Healthcare. 2007.

Clinical Application of OCT

Intracoronary Imaging

1991 **2002** **2004**

Imaging Wire 0.019"
"Occlusive Method"

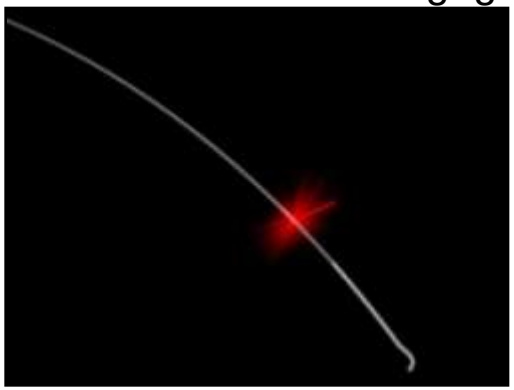


Regar et al. Eur Heart J 2004 (Abstract)
Regar E, van Leeuwen AMGJ, Serruys PW (Eds): Optical coherence tomography in cardiovascular research. London: Informa Healthcare. 2007.

Clinical Application of OCT

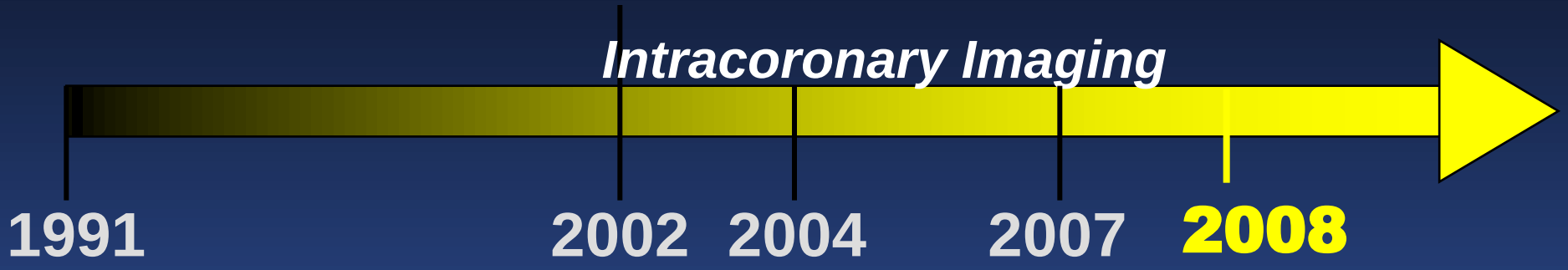
Imaging Wire 0.019"
“Non-Occlusive Method“

Selective Guide Catheter Engagement



Prati et al. Circ J 2008

Clinical Application of OCT



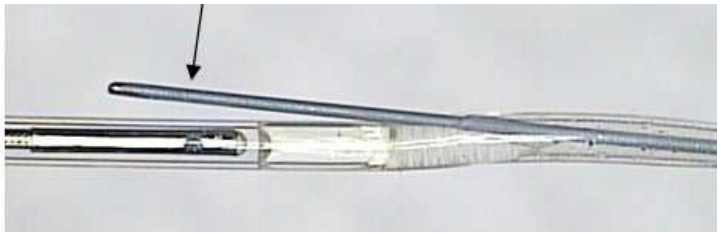
2nd Generation OCT

Fourier Domain OCT

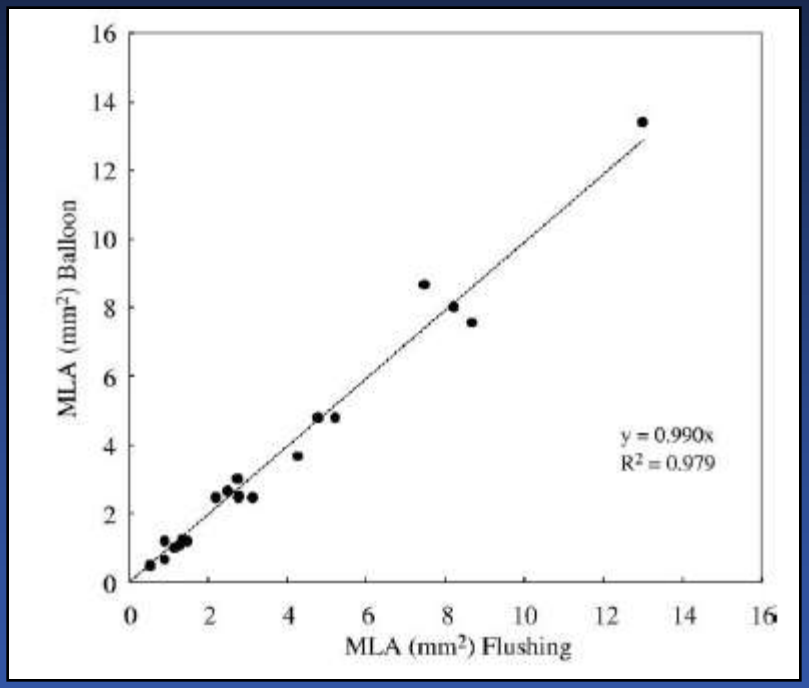
(OFDI/Frequency/Spectral Domain/Swept Source)

Monorail Imaging Catheter

Non-Occlusive



Occlusive vs non-occlusive technique



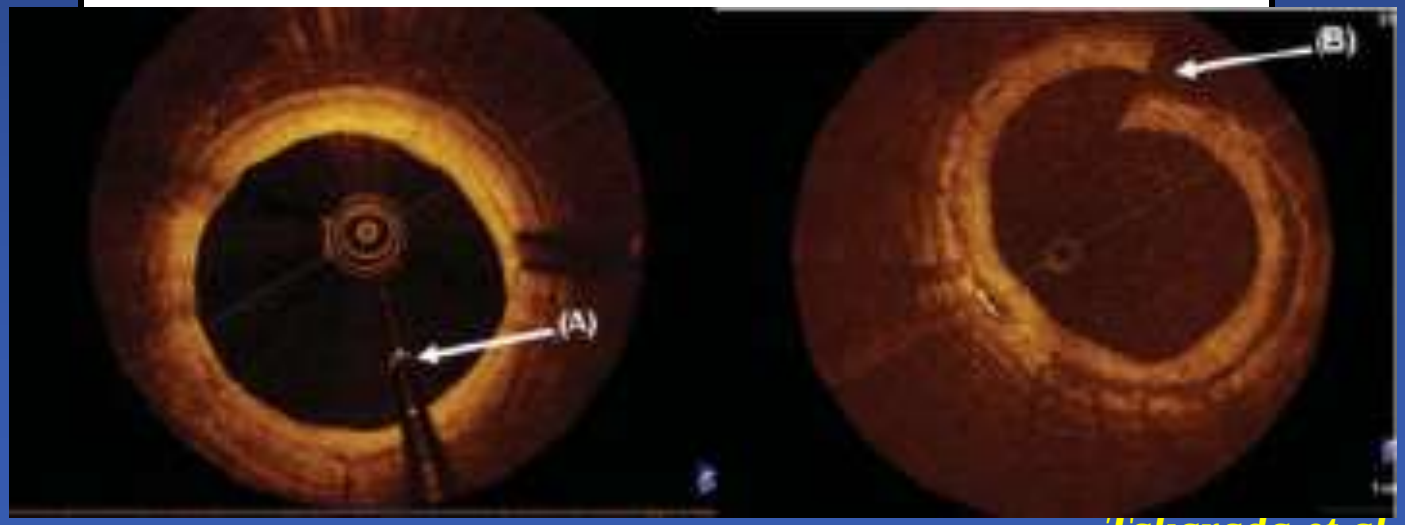
Kataiwa et al., IJC.2009

	All (n=468)	Occlusive technique (n=256)	Non-occlusive technique (n=212)	p-value
Self-limiting events				
Chest pain	223 (47.6)	179 (69.9)	44 (20.8)	<0.001
Widening QRS/ST depression	192 (41.0)	139 (54.3)	53 (25)	<0.001
ST elevation	21 (4.5)	17 (6.6)	4 (1.9)	0.01
Sinus bradycardia	14 (3.0)	11 (4.3)	3 (1.4)	0.07
Sinus tachycardia	10 (2.1)	7 (2.7)	3 (1.4)	0.33
Atrioventricular block	2 (0.4)	2 (0.8)	0	0.19

Barlis et al., EuroInterv.2009

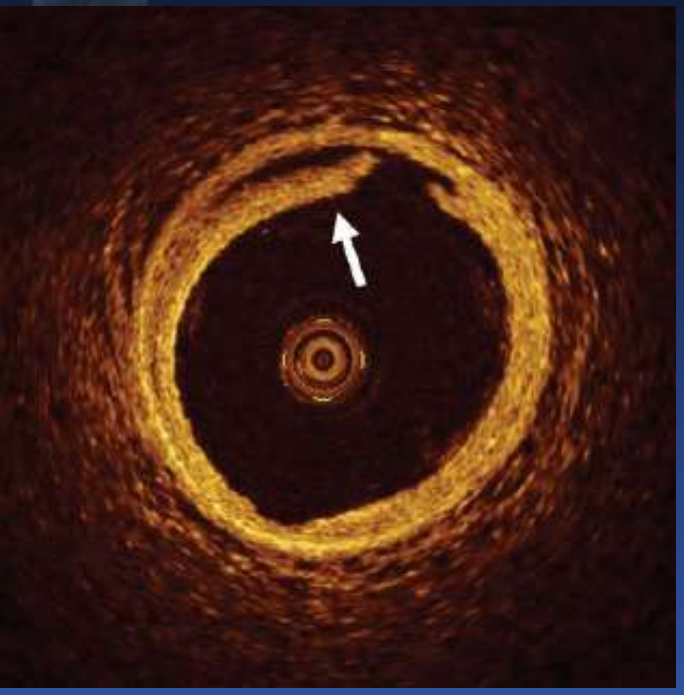
OCT vs OFDI

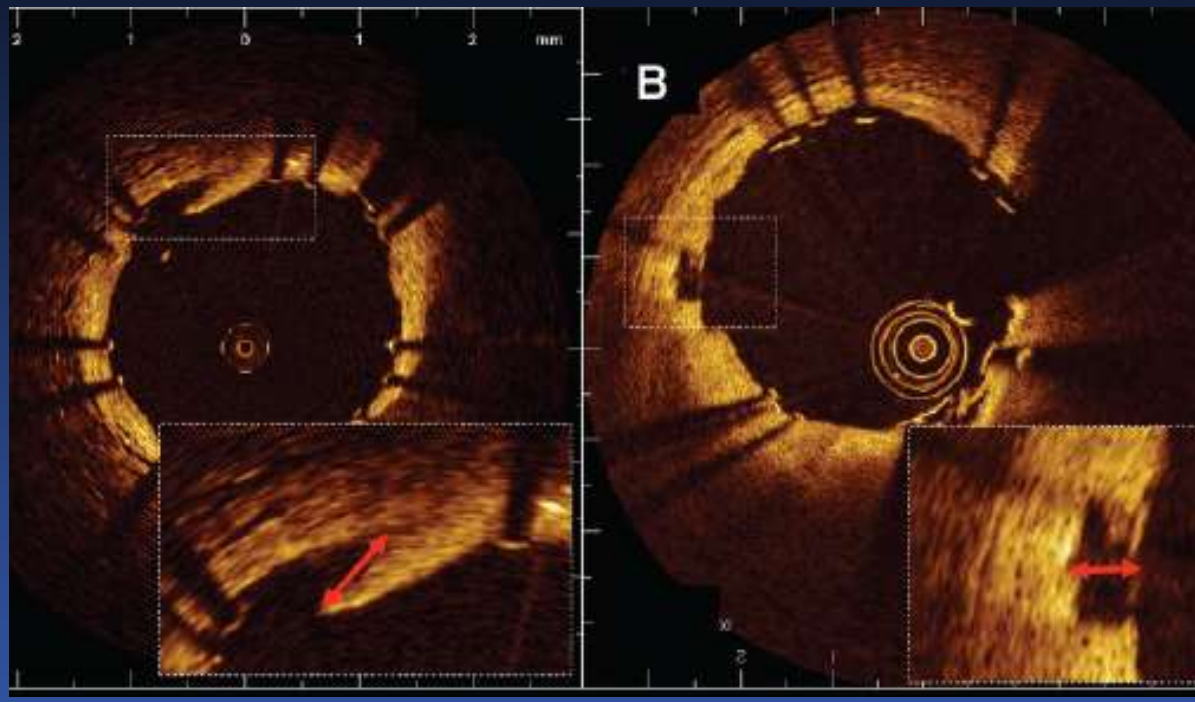
Parameters	FD-OCT	TD-OCT	*P*
Image analysis segment: *n*	518	520	
Clear image segment: *n* (%)	515 (99.4)	420 (80.8)	<0.01
Mean time from setup to completion of the procedure (min.)	5.1 ± 1.7	16 ± 3.8	<0.01
Sew-up artifact: *n* (%)	14 (2.7)	88 (16.9)	<0.01
Complications (number of procedure)			
Couplet or more	0	2	0.16
ST-elevation	0	6	0.010
Bradycardia	0	4	0.083
Chest oppression or pain	1	14	<0.01



Takarada et al, CCI 2009

Dissection





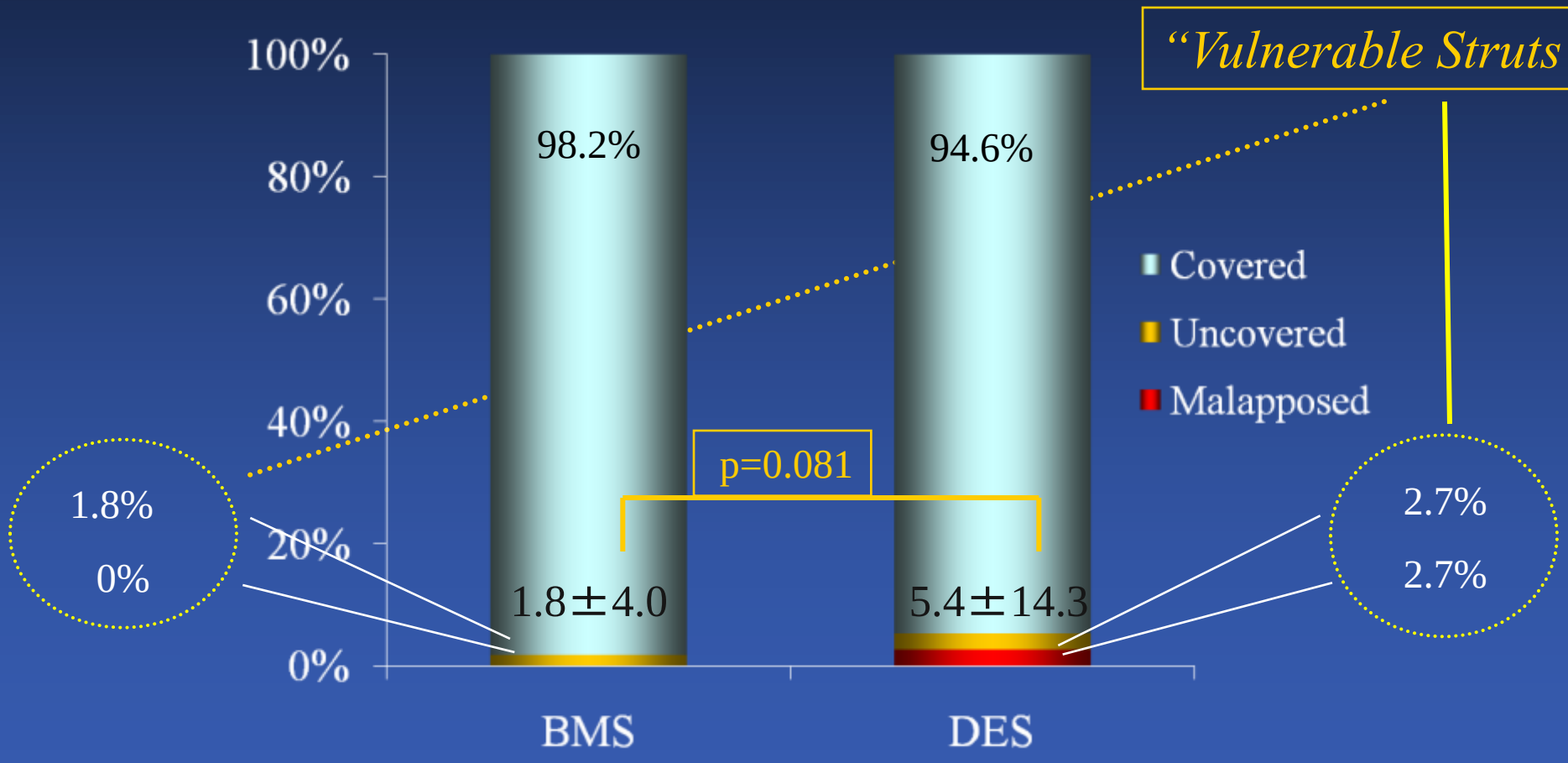
Edge dissection

Intra-stent dissection

IVUS-detected edge dissection has been associated with restenosis and must be treated, however there are no data about OCT-detected dissections

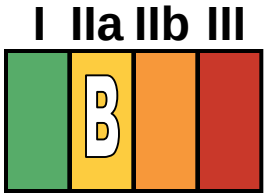
Gonzalo N et al, Heart Dec 2009

Evaluation of stent coverage by OCT ODESSA (6m fu)

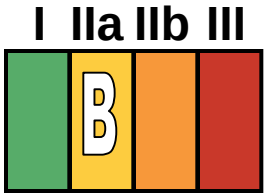


Guagliumi et al., JACC Cardiovasc Interv. 2010 May;3(5):531-9.

Intravascular Ultrasound

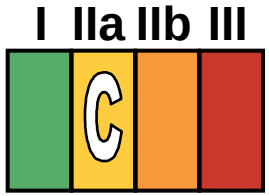


IVUS is reasonable for the assessment of angiographically indeterminate left main CAD.

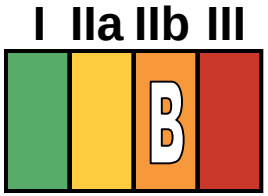


IVUS and coronary angiography are reasonable 4 to 6 weeks and 1 year after transplantation to exclude donor CAD, to detect rapidly progressive cardiac allograft vasculopathy, and to provide prognostic information.

Intravascular Ultrasound (cont.)



IVUS is reasonable to determine the mechanism of stent restenosis.



IVUS may be reasonable for the assessment of non-left main coronary arteries with angiographically intermediate coronary stenoses (50% to 70% diameter stenosis).

Fractional Flow Reserve

FFR is reasonable to assess angiographic intermediate coronary lesions (50% to 70% diameter stenosis) and can be useful in guiding revascularization decisions in patients with SIHD.

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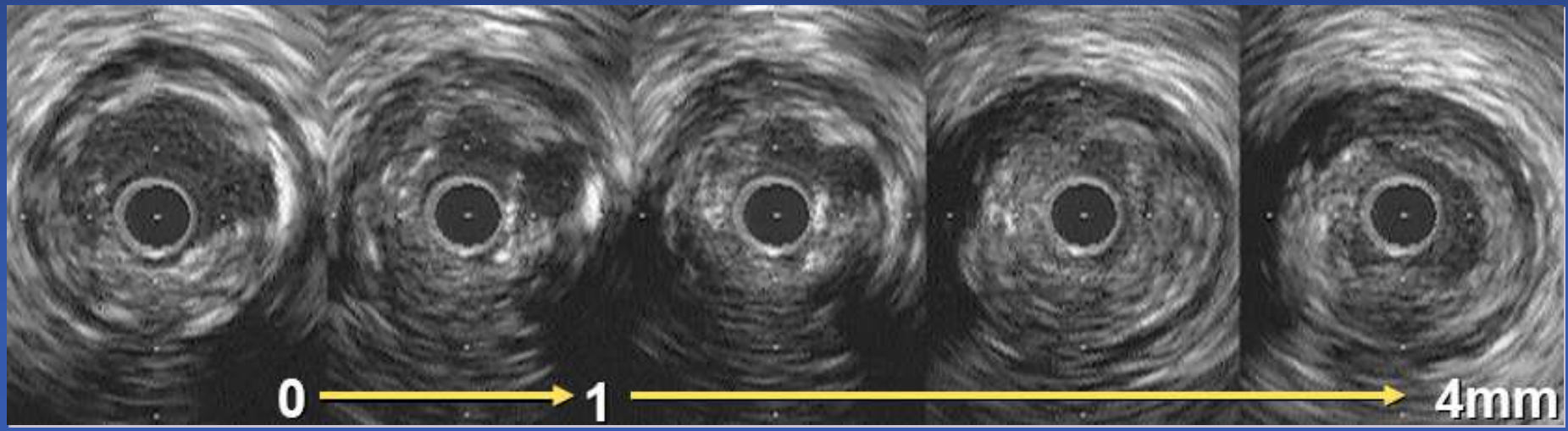
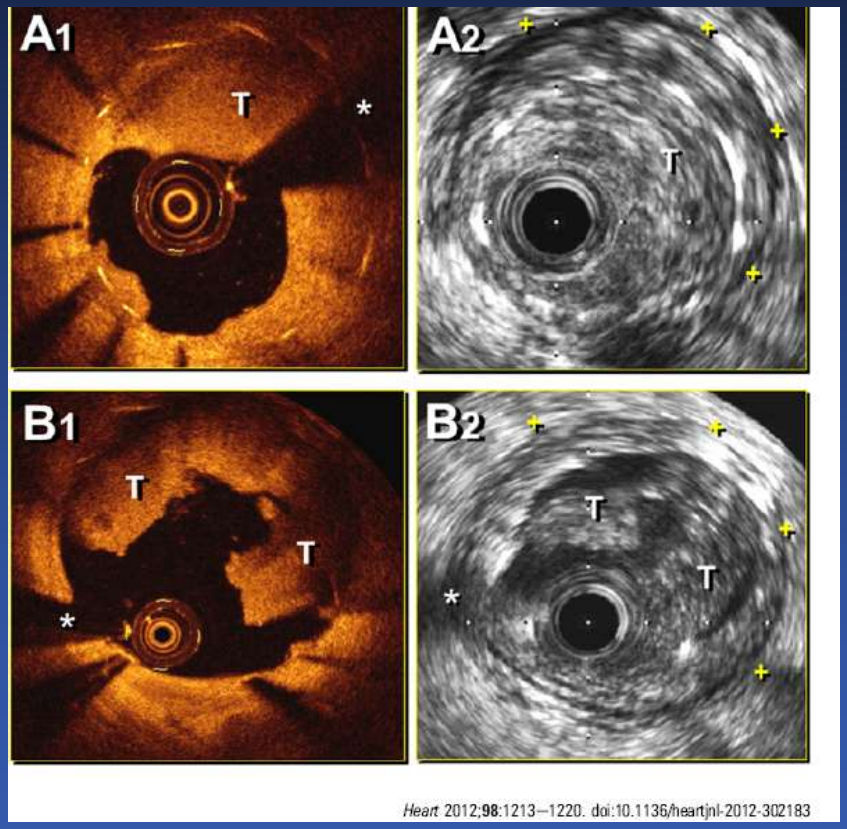
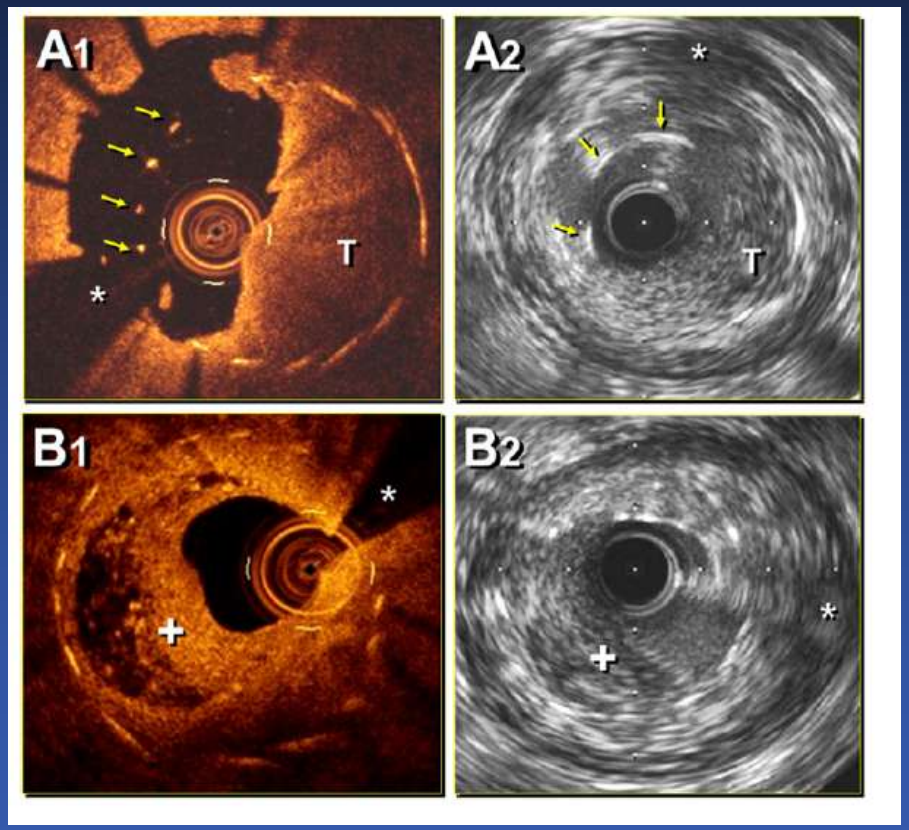
- Εκτίμηση του αποτελέσματος της αγγειοπλαστικής
- Αξιολόγηση επιπλοκών μετά από το stent
- **Θρόμβωση & επαναστένωση του stent**
- Σύγκριση OCT-IVUS
- Εκτίμηση σύστασης πλάκας

IVUS: απεικόνιση θρόμβου



Stent thrombosis



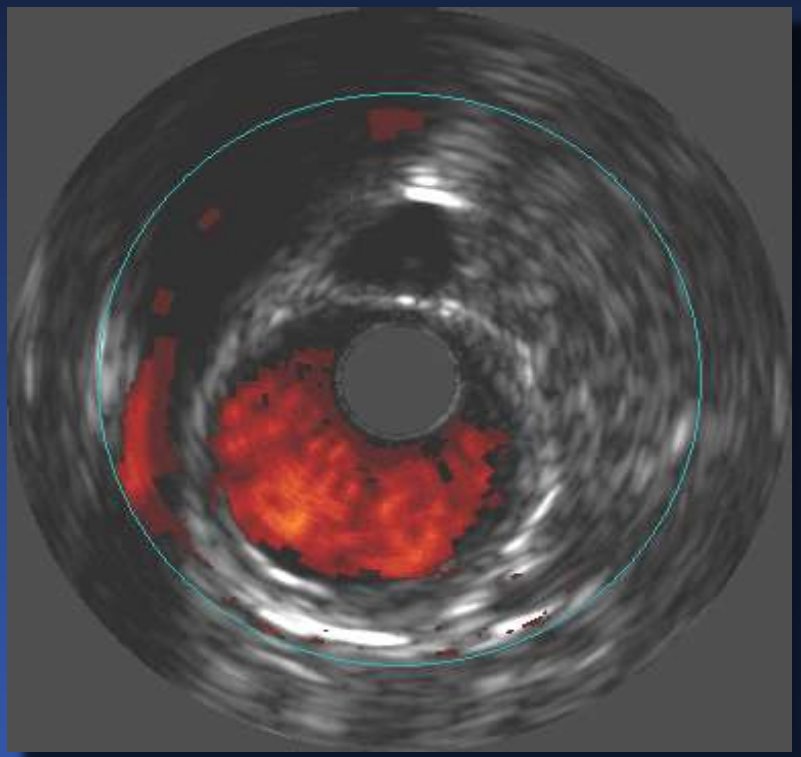


Heart 2012;98:1213–1220. doi:10.1136/heartjnl-2012-302183

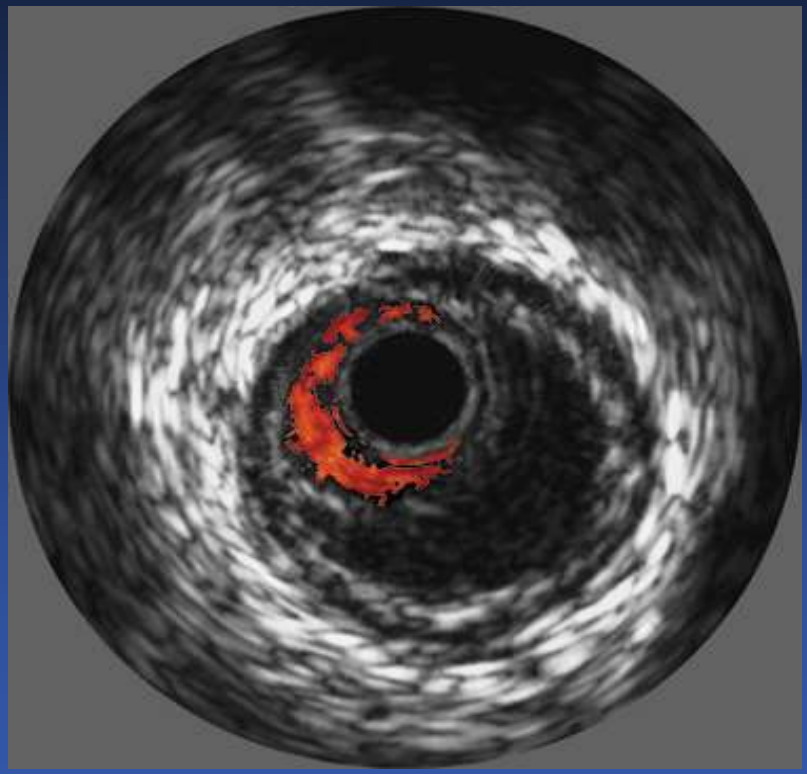
Heart 2012;98:1213e1220. doi:10.1136/heartjnl-2012-302183

IVUS: απεικόνιση θρόμβου

Chromaflo™ Imaging

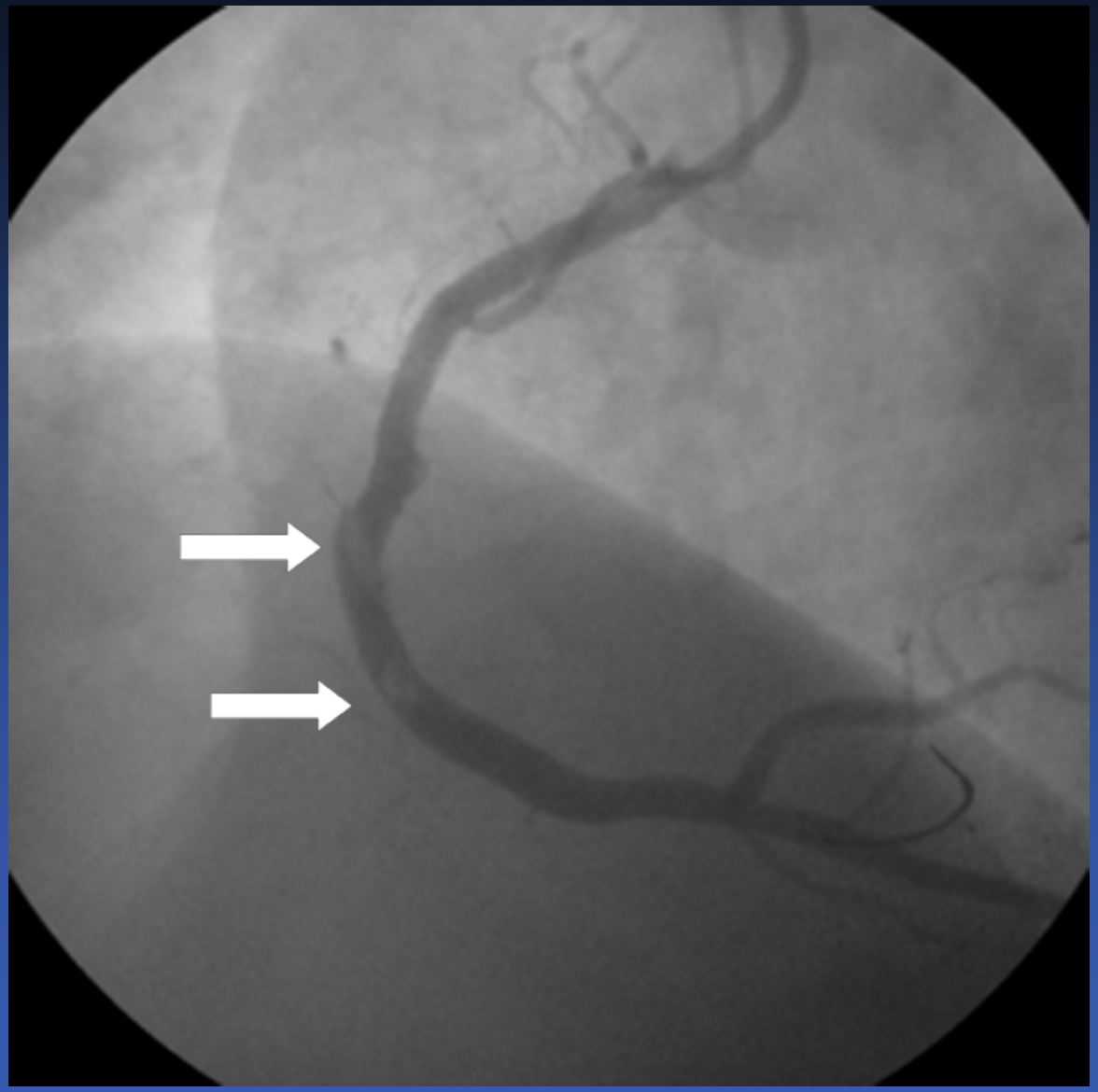


Φυσιολογικός αυλός



Θρόμβος

Haziness…



Toutouzas, Synetos …Stefanadis Clin Cardiol 2007

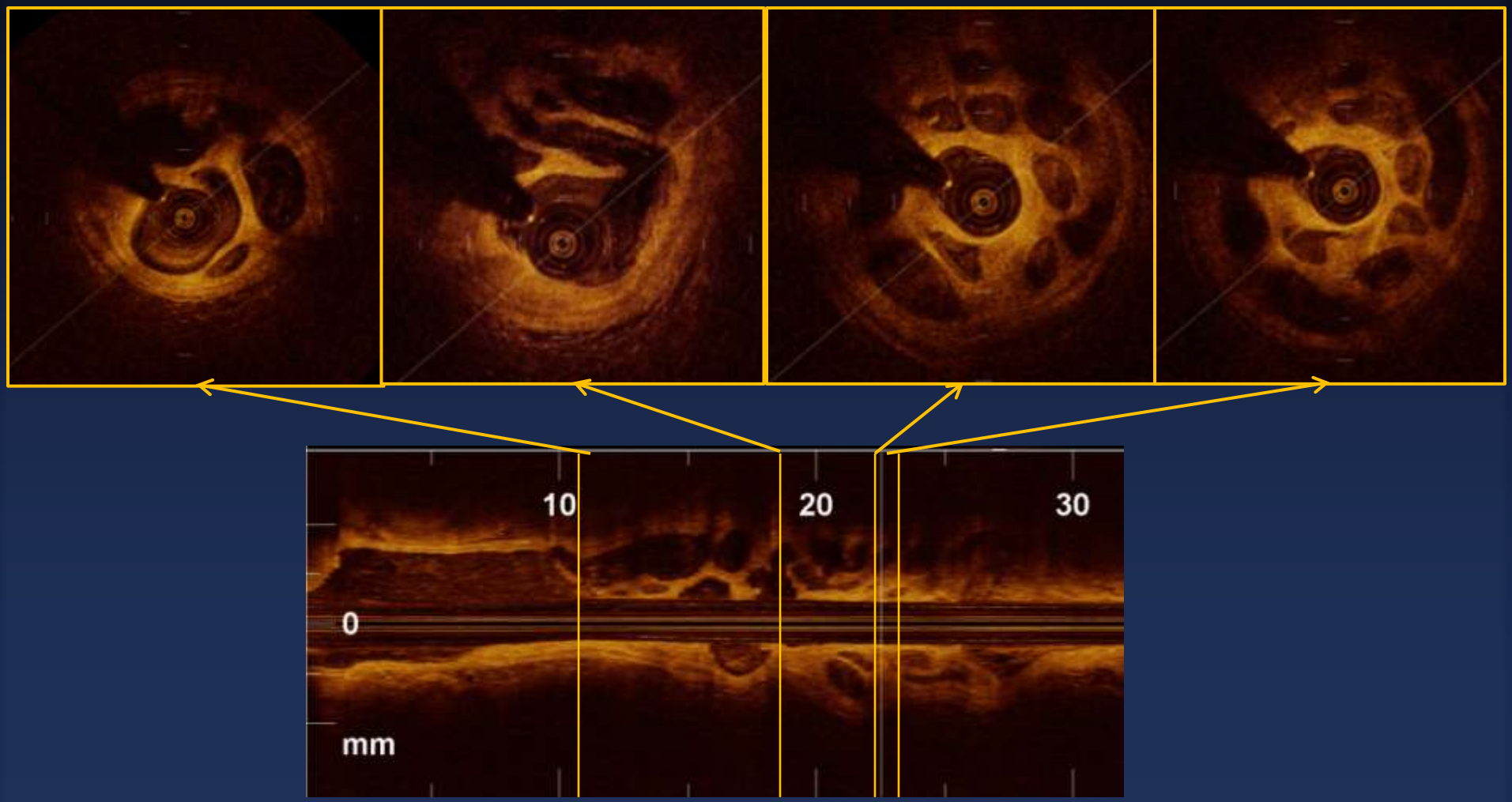
…Dissection & Thrombus

Toutouzas , Synetos …Stefanadis, Clin Cardiol 2007

Evaluation of haziness

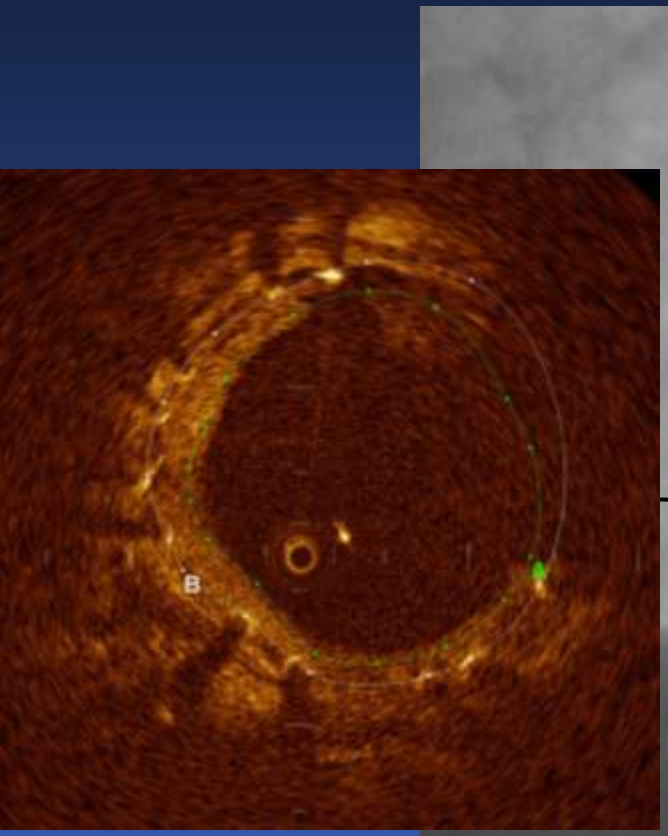
Toutouzas , Karanasos, Synetos…Stefanadis Eurointervention 2012

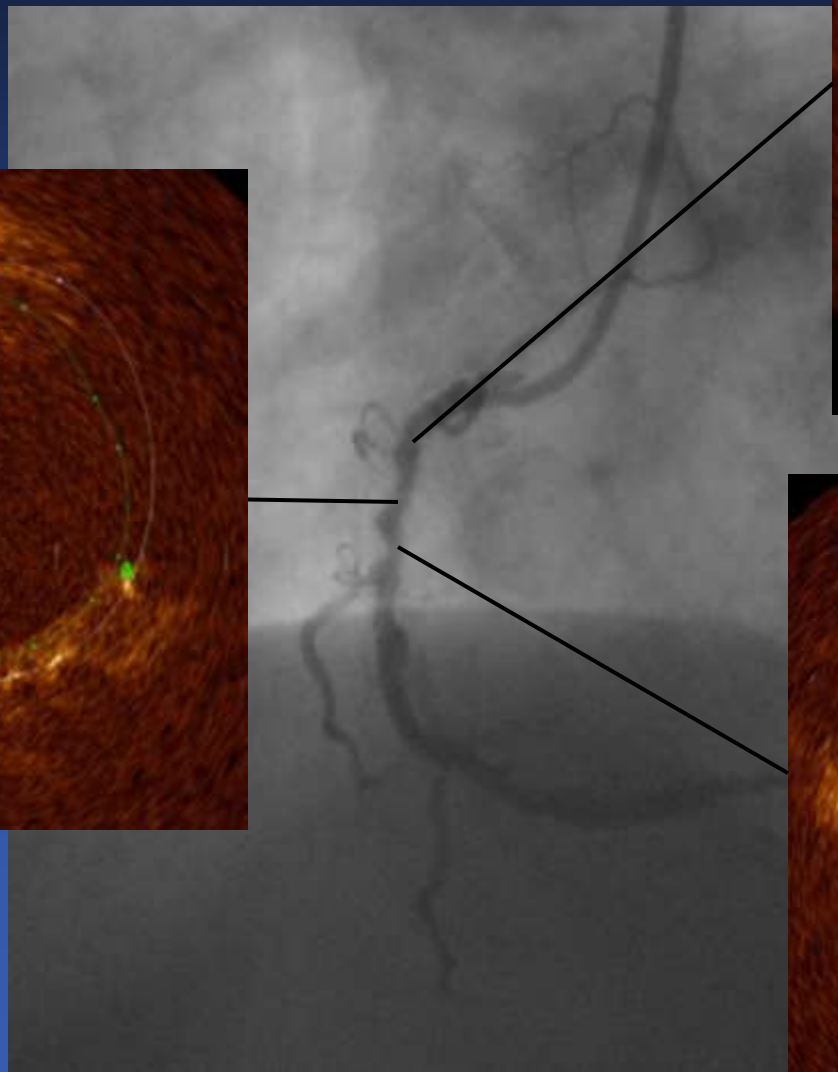
Recanalized Thrombus

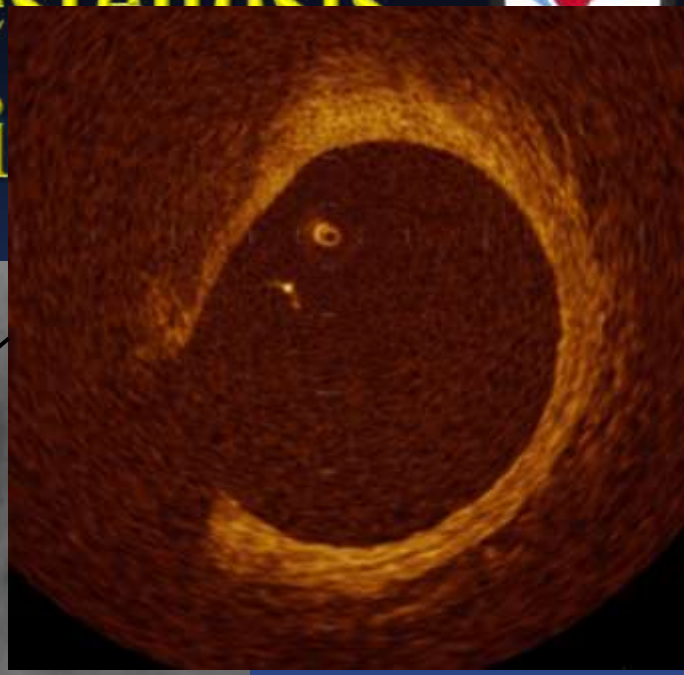


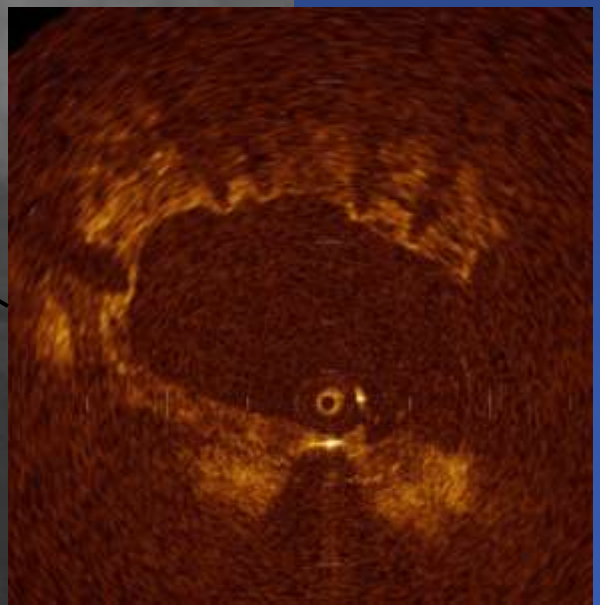
Toutouzas , Karanasos, Synetos…Stefanadis Eurointervention . in press

Stent thrombosis, re
or underexpansi

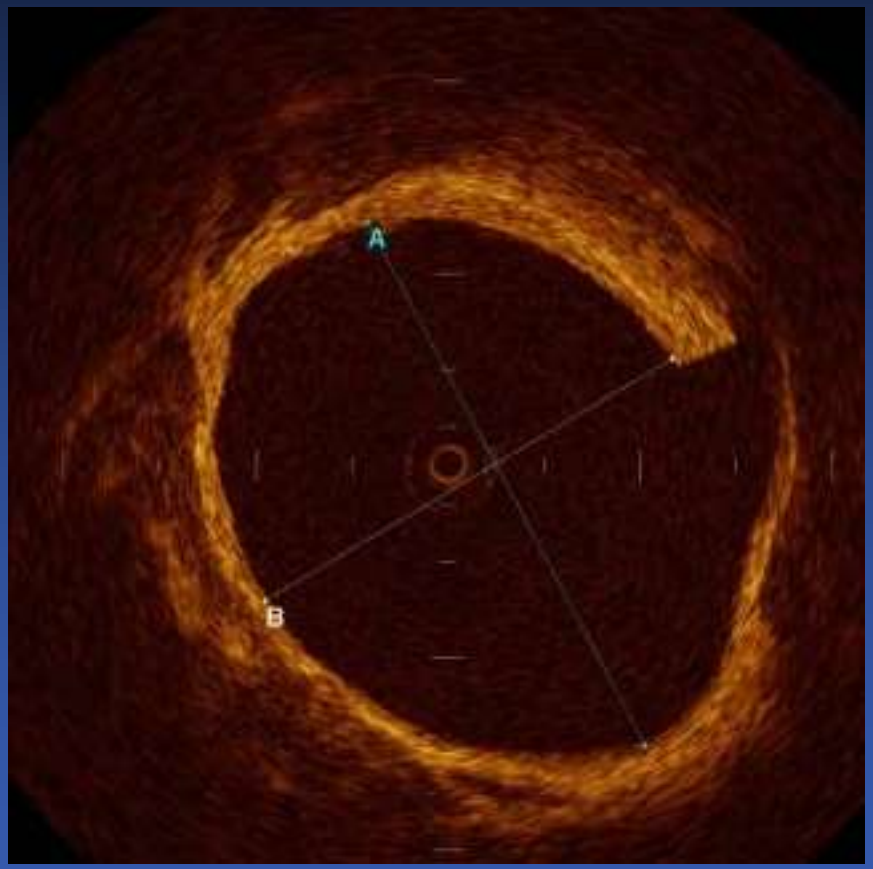




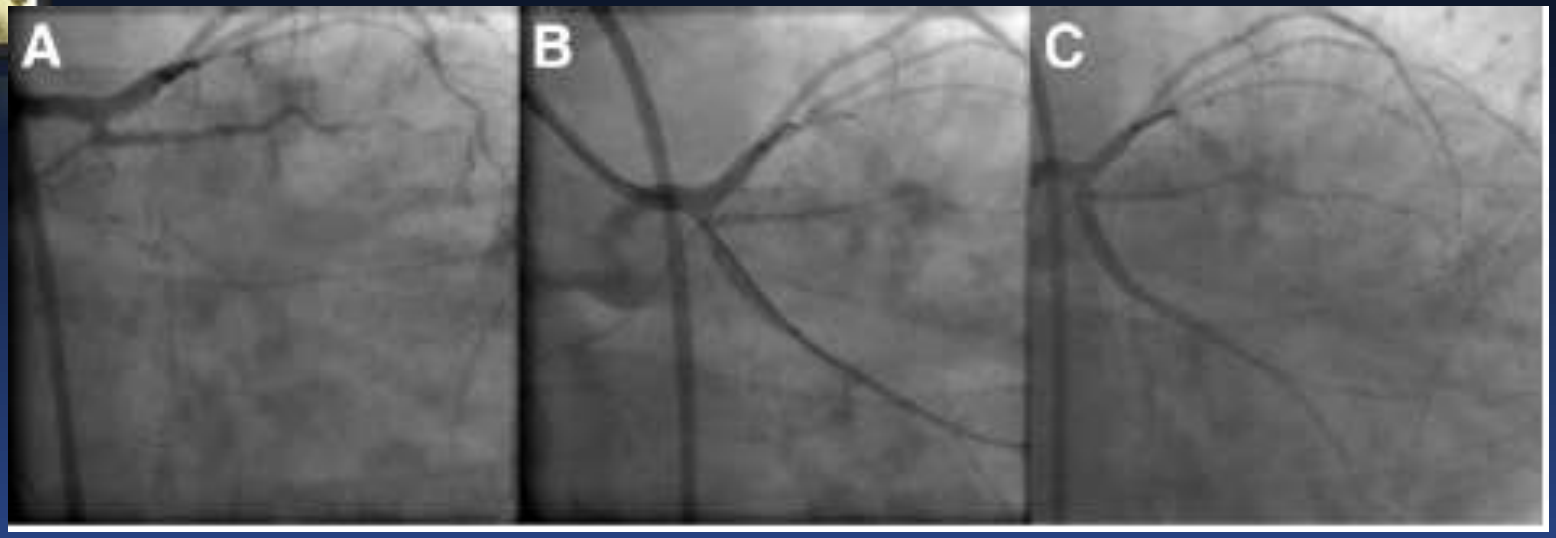


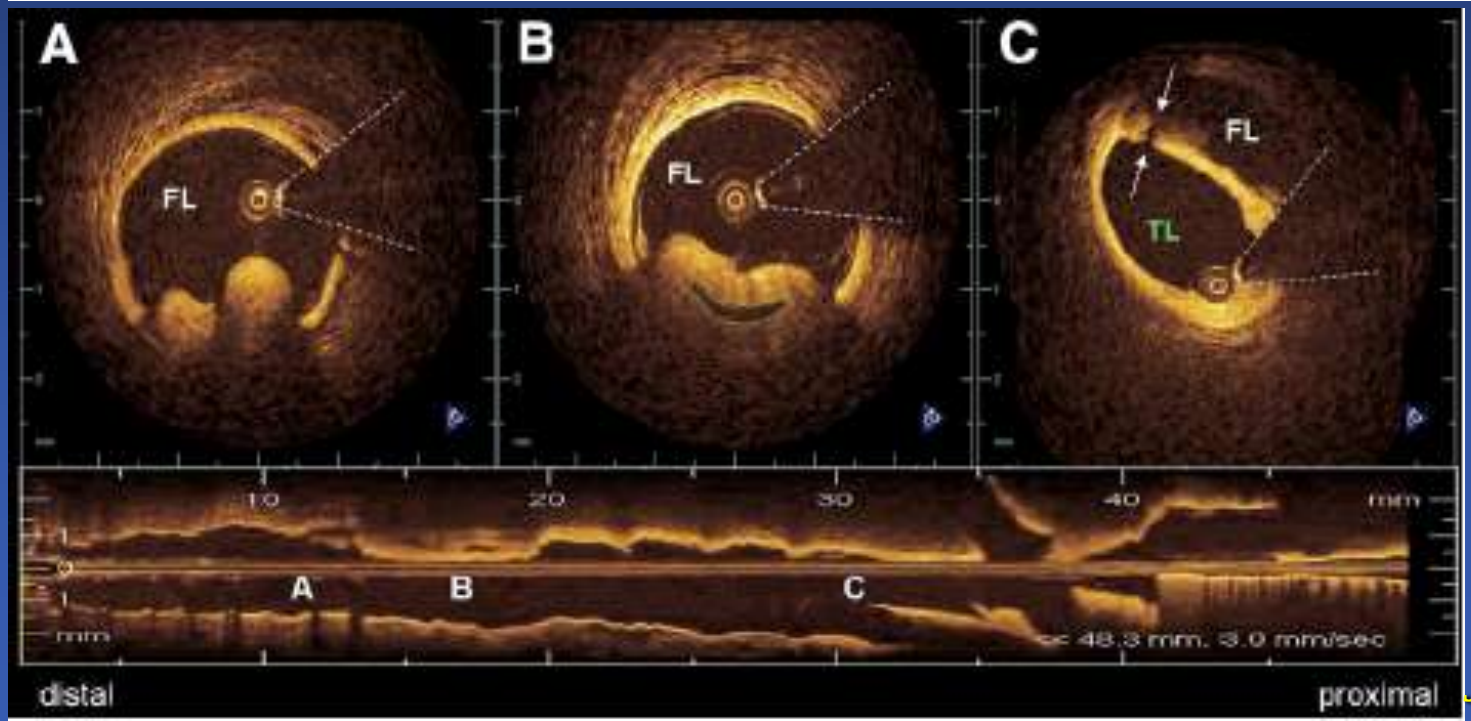


Calcified plaque – decision for rotablator?



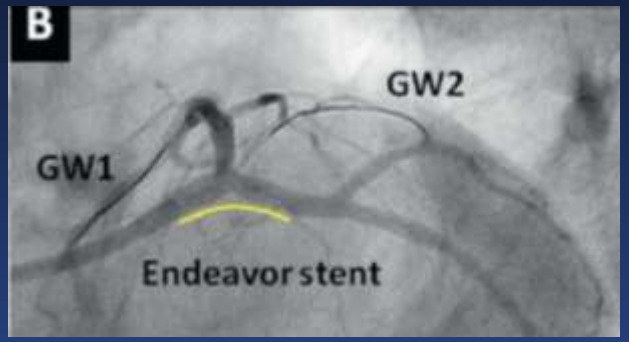
CTO guidance





Schulz et al, JACC interv 2009

3D OCT for bifurcation guidance

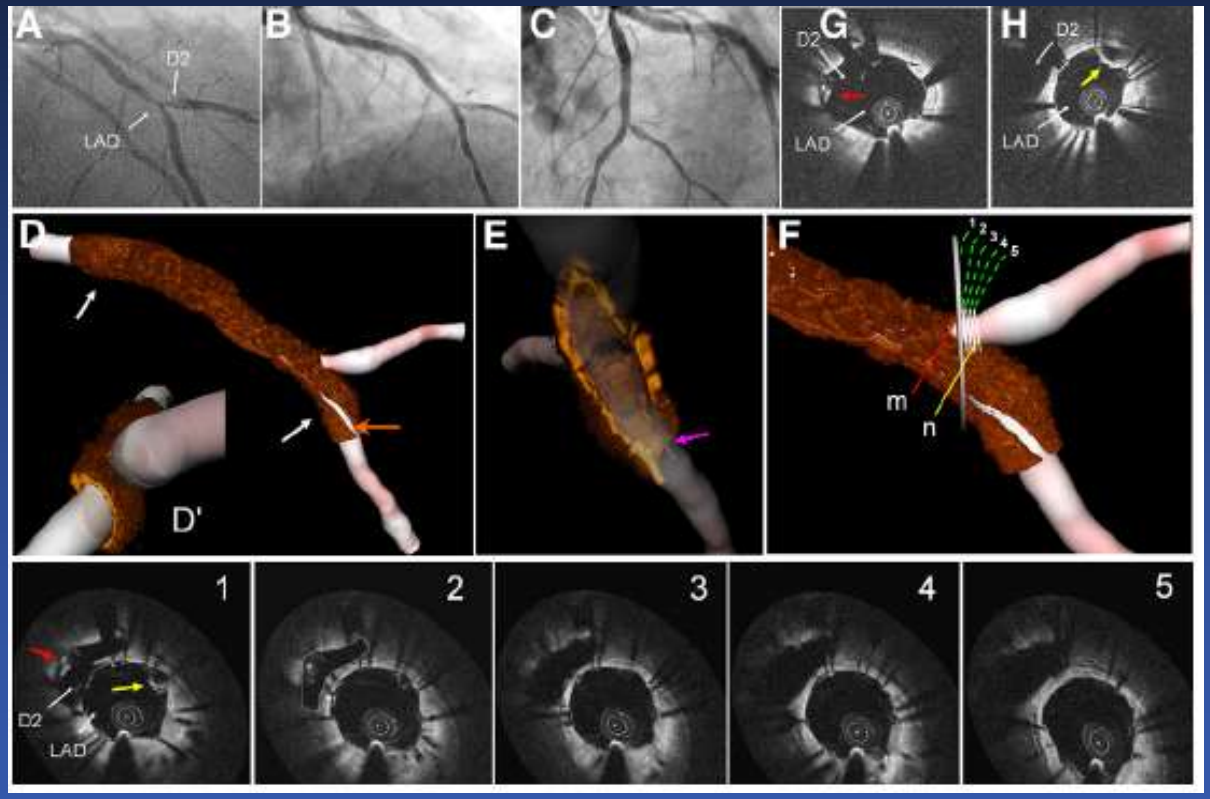


3D OCT after guidewire recross

3D OCT after kissing balloon post dilation

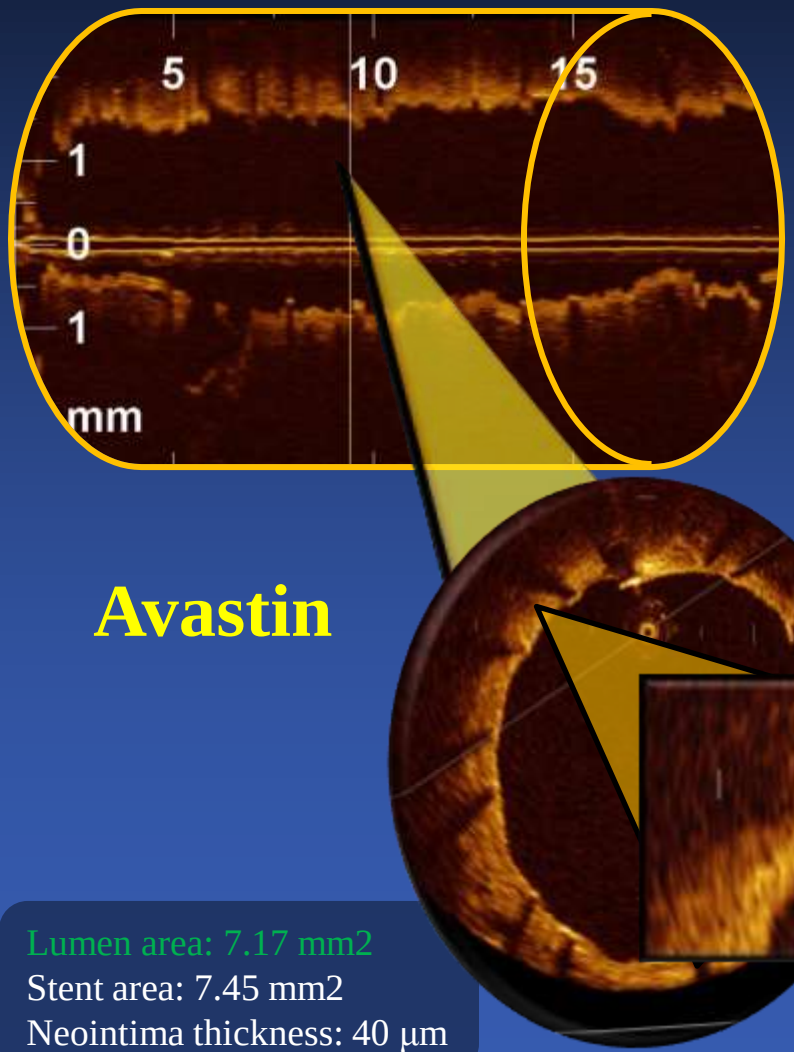
Okamura et al, Eurointervention 13 Oct 2011

First Presentation of 3-Dimensional Reconstruction and Centerline-Guided Assessment of Coronary Bifurcation by Fusion of X-Ray Angiography and Optical Coherence Tomography



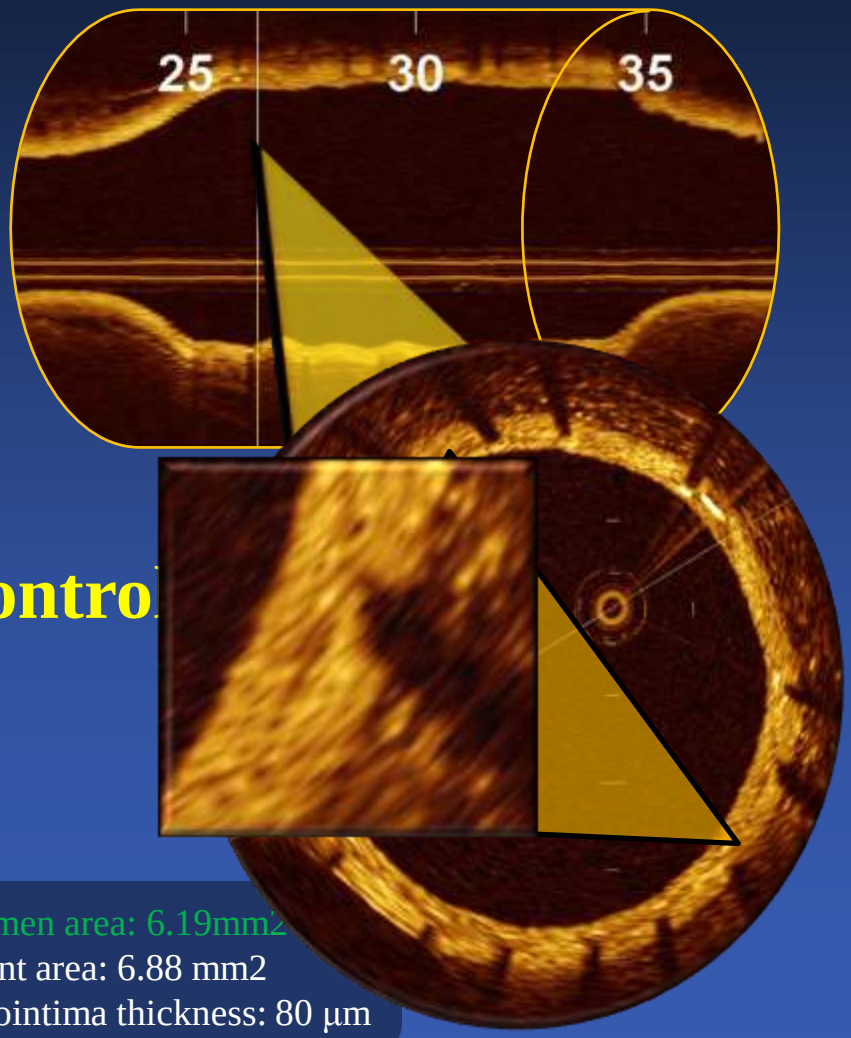
Tu *et al.* J ACC: CARDIOVASCULAR INTERVENTIONS, VOL. 5, NO. 8, 2012 AUGUST 2012:884–5

OCT images
28 day follow-up



Avastin

Lumen area: 7.17 mm2
Stent area: 7.45 mm2
Neointima thickness: 40 μm

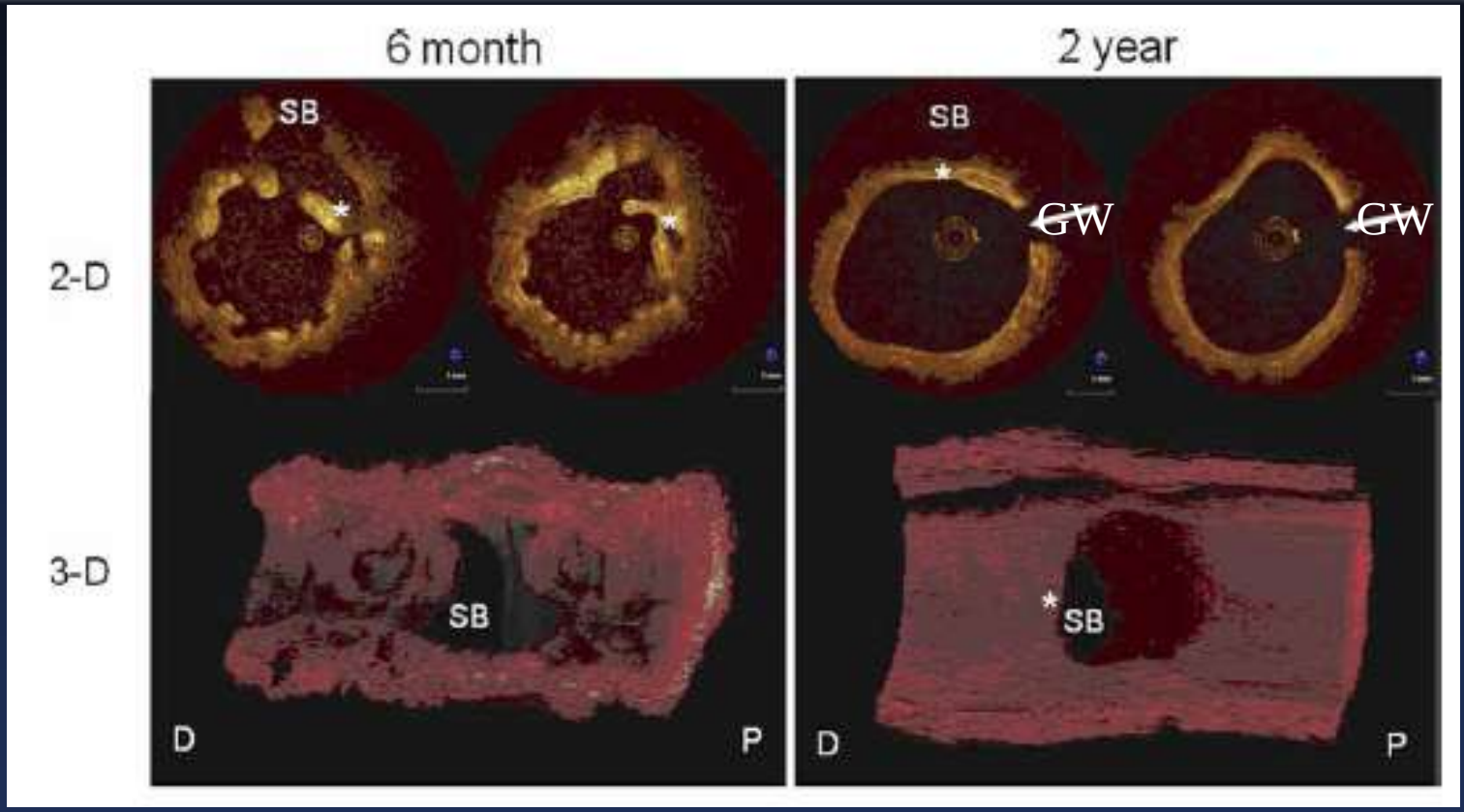


Contro

Lumen area: 6.19mm2
Stent area: 6.88 mm2
Neointima thickness: 80 μm

Toutouzas ..Synetos..Stefanadis AHA 2009

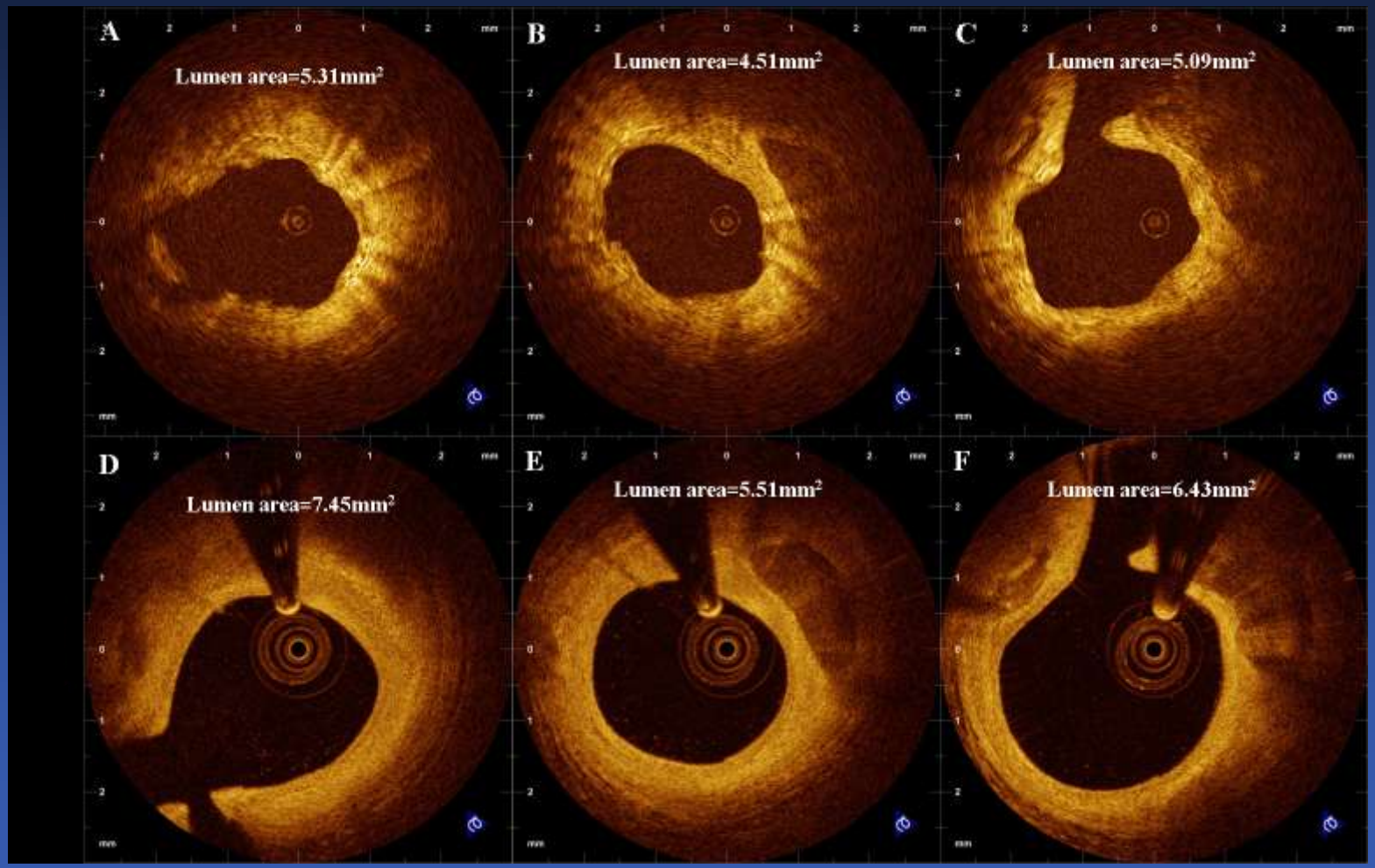
ABSORB: Evaluation of degradation of bioabsorbable stents



Struts in front of a SB were covered by neointimal tissue at 6 months. At 2 years, the neointimal tissue further extended to form a membranous structure bridging over the orifice (*, neointimal bridge).

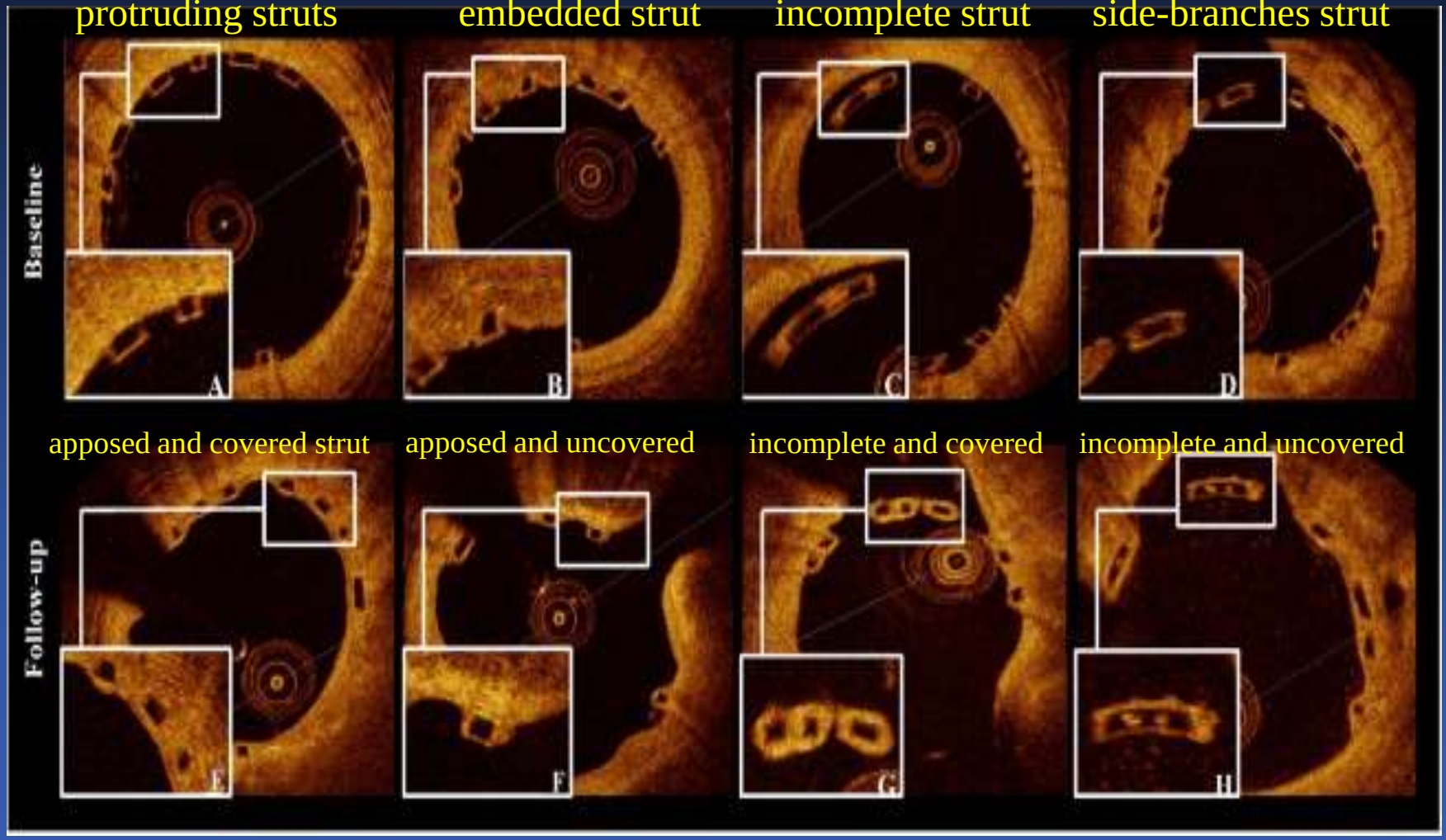
Okamura et al., J. Am. Coll. Cardiol. Intv 2010;3;836-844

Long-term follow-up of BVS



Karanasos A et al., Circulation 2012

Malapposed and Uncovered Struts of the Everolimus-Eluting Bioresorbable Scaffold With OCT



Gomez-Lara et al, JACC interv, 2011

European Heart Journal Advance Access published May 31, 2012

European Heart Journal
doi:10.1093/eurheartj/ehs095

CURRENT OPINION

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], Pascale Motreff[17], Fernando Alfonso[18], Kostas Toutouzas[19], Nieves Gonzalo[20], Corrado 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

Εφαρμογές ενδοαγγειακής απεικόνισης

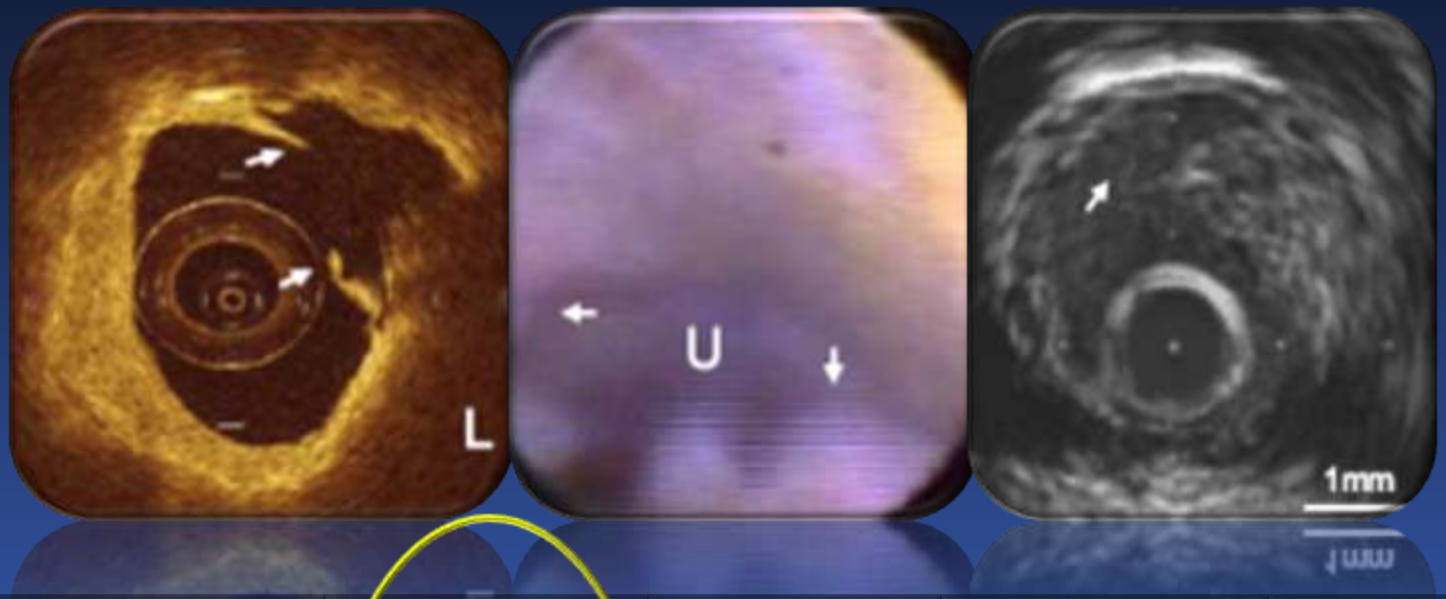
- Αξιολόγηση σημαντικότητας βλάβης
- Καθοδήγηση της αγγειοπλαστικής (πριν από το stent)
- Εκτίμηση του αποτελέσματος της αγγειοπλαστικής
- Αξιολόγηση επιπλοκών μετά από το stent
- Θρόμβωση & επαναστένωση του stent
- Σύγκριση OCT-IVUS
- Εκτίμηση σύστασης πλάκας

OCT vs IVUS vs VH vs IVMRI

	GS IVUS	IVUS RFD	OCT	IV MR
Axial resolution (μm)	100-150	100-150	10-20	200
Probe size (mm)	1.1	1.1	0.4	1.8
Penetration depth	4-8 mm	4-8 mm	1.5-2 mm	200 μm
Vessel occlusion	No	No	No/Yes	Yes
Morphological information	Yes	Yes	Yes	No
Lipid identification	+	+++	++	+++
Thin cap detection	+	+	+++	-
Remodelling	+++	+++	+	-
Inflammation	-	-	+	-

Gonzalo et al, IJC 2008

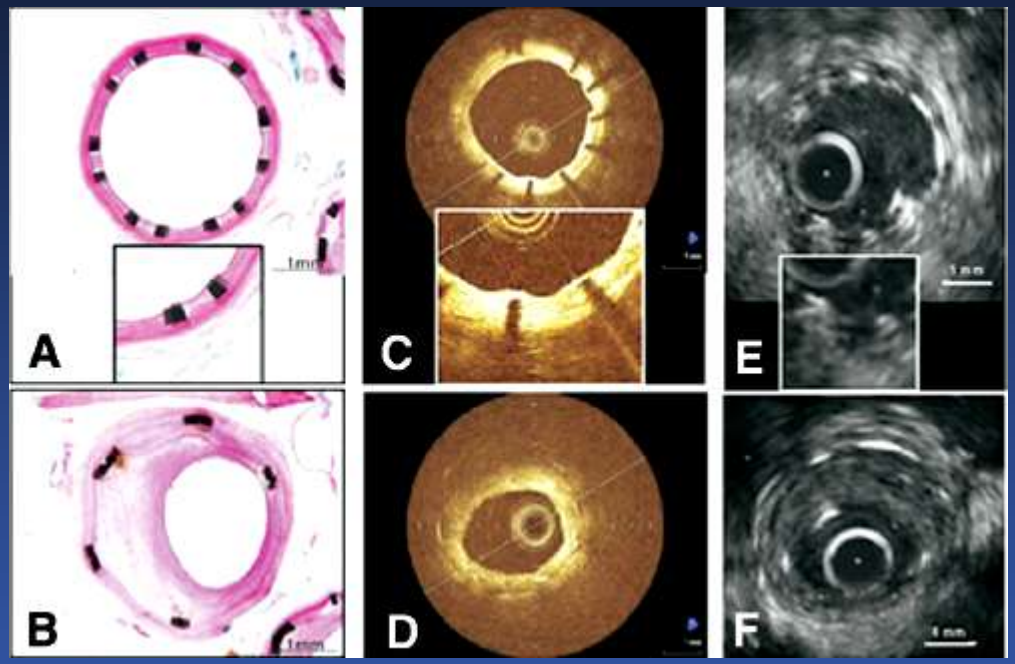
OCT vs CAS vs IVUS

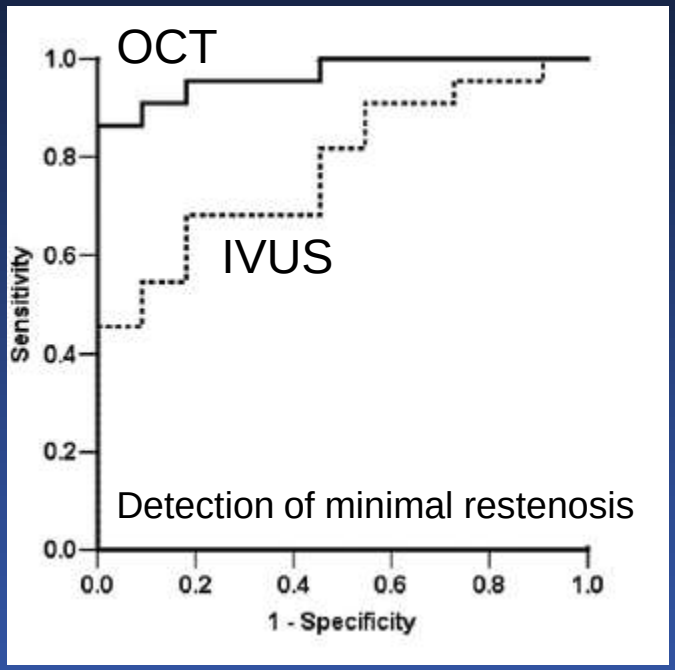


Finding	OCT (n=30)	CAS (n=30)	IVUS (n=30)	p
Rupture	22 (73%)	14 (47%)	12 (40%)	0,021
Erosion	7 (23%)	1 (3%)	0	0,003
Thrombus	30 (100%)	30 (100%)	10 (33%)	<0,001

Kubo et al, JACC 2007

IVUS vs OCT for evaluation of restenosis

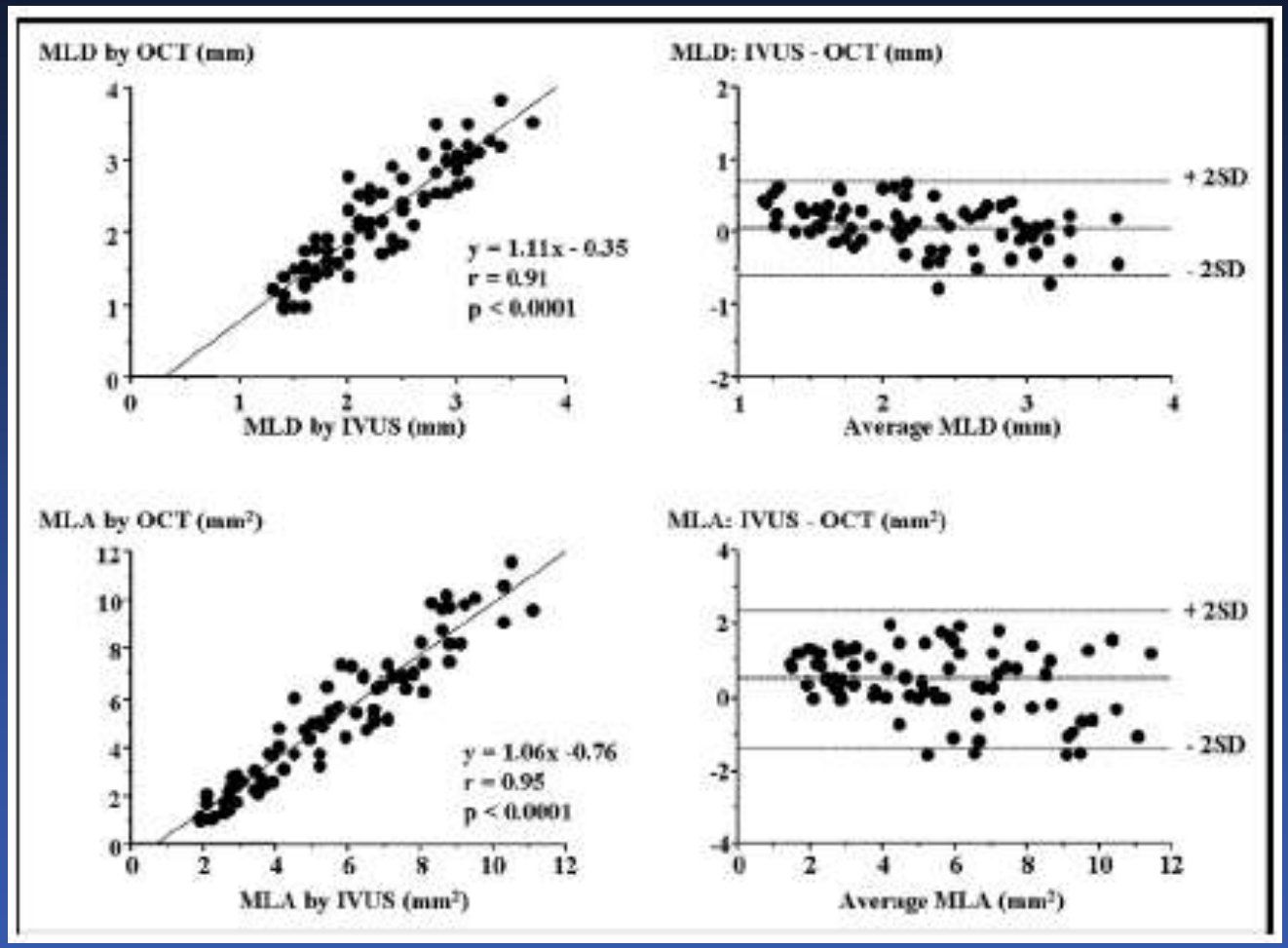




Stents, n = 11	Histology	OCT	IVUS
Lumen area	4.52 ± 0.61	4.74 ± 0.69	5.21 ± 0.84
Stent area	5.78 ± 0.93	6.01 ± 1.01	6.19 ± 1.27
ISN area	1.26 ± 0.46	1.27 ± 0.57	0.98 ± 0.69
% area stenosis	21.4 ± 5.2	20.3 ± 7.0	14.7 ± 8.6

Suzuki et al., JACC intv 2008

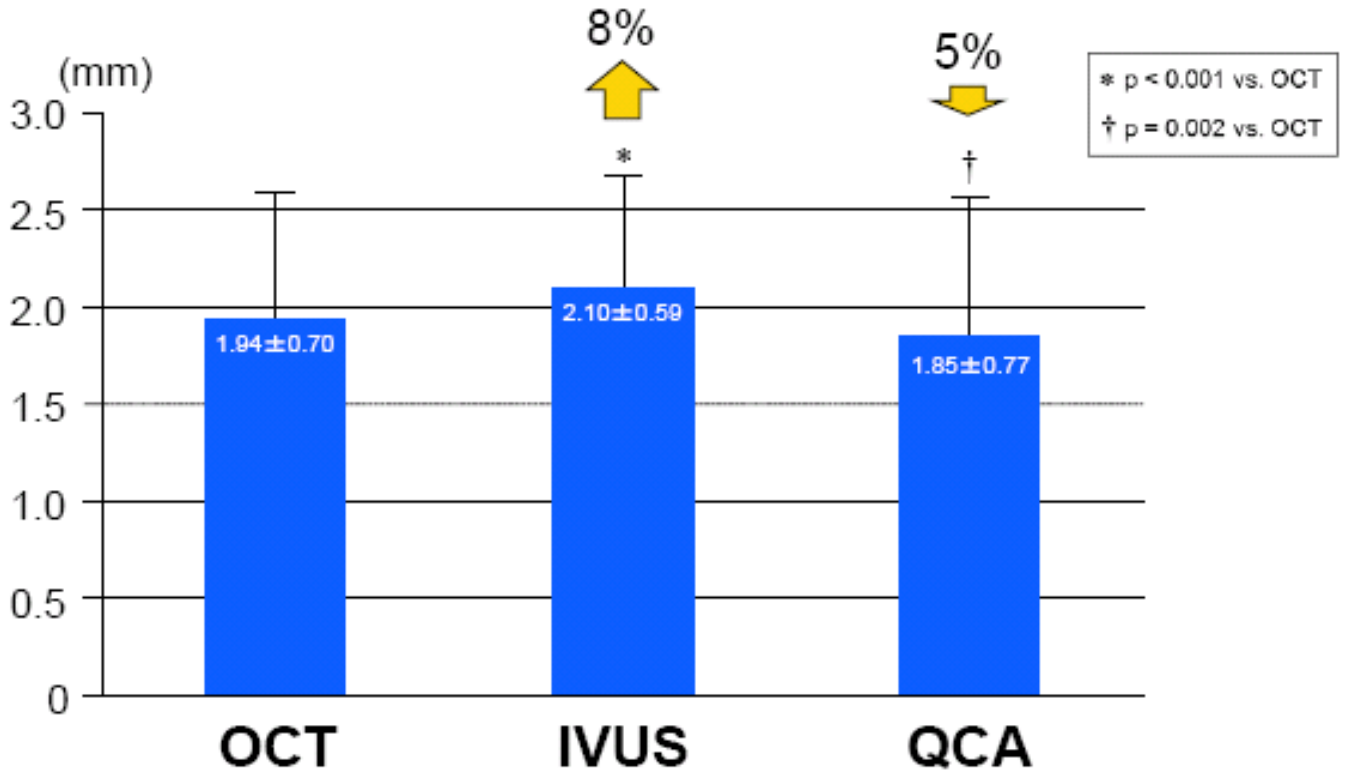
Area-length measurements
OCT vs IVUS



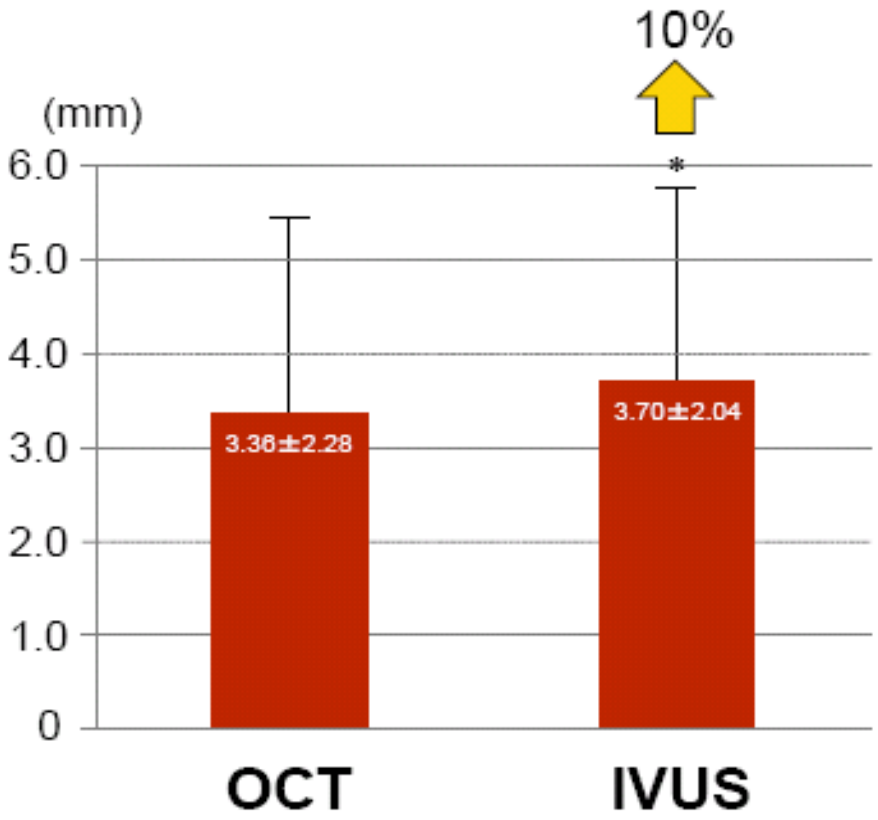
IVUS measurements are greater than those of OCT. (Resolution? – Dotter effect?)

Yamaguchi et al., Am J Cardiol 2008;101:562–567

Difference of minimum lumen diameter (MLD) among OCT, IVUS and QCA measurement



Difference of minimum lumen area (MLA) between OCT and IVUS measurement



* p < 0.001 vs. OCT

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Vol. 59, No. 12, 2012
ISSN 0735-1097/$36.00
doi:10.1016/j.jacc.2011.09.078

MINI-FOCUS ISSUE: OPTICAL COHERENCE TOMOGRAPHY

Morphometric Assessment of Coronary Stenosis Relevance With Optical Coherence Tomography

A Comparison With Fractional Flow Reserve and Intravascular Ultrasound

Nieve Gonzalo, MD, PhD, Javier Escaned, MD, PhD, Fernando Alfonso, MD, PhD,

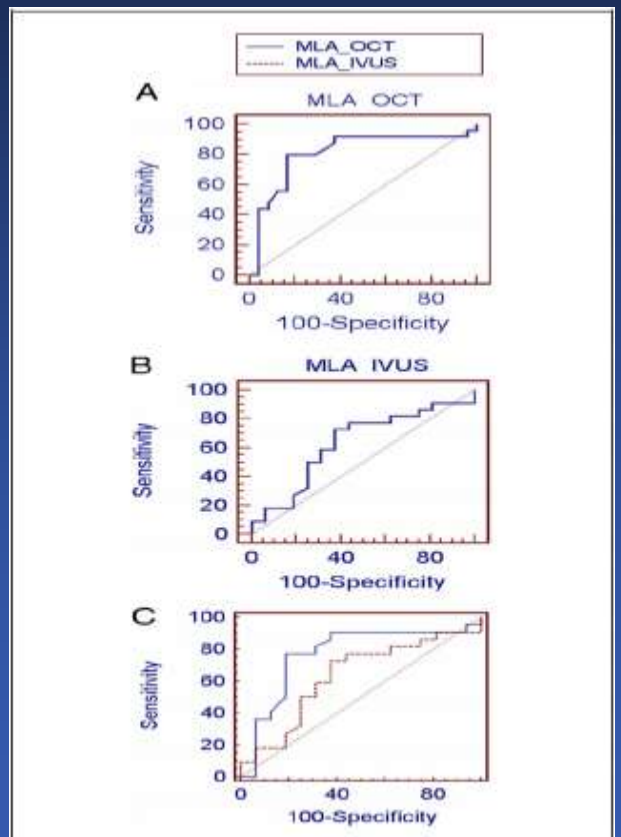


Figure 7 Vessels <3 mm

Receiver operating characteristic curves for (A) OCT- and (B) IVUS-derived MLA to predict FFR ≤0.80 in vessels with a reference diameter <3 mm. (C) Comparison of ROC curves for OCT- and IVUS-derived MLA to predict FFR ≤0.80 in vessels with a reference diameter <3 mm. Abbreviations as in Figure 2.

- Best cutoff point for small vessels was
- 1.62 mm2 for OCT and 2.36 mm2 for IVUS.

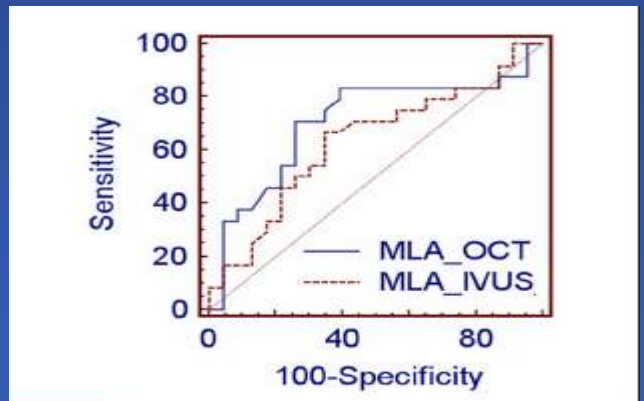
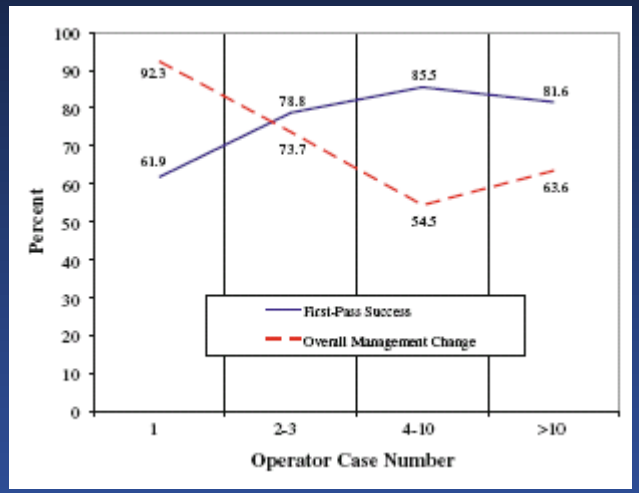


Figure 6 Comparison of OCT and IVUS

Comparison of receiver-operating characteristic curve for OCT- and IVUS-derived MLA to predict FFR ≤0.80. Abbreviations as in Figure 2.

Clinical application

176 consecutive interventional procedures



FD-OCT is safe, can successfully be incorporated into routine practice, and alters procedural strategy in a high proportion of patients undergoing PCI

Prospective, single center initiative planned for 100 % FD-OCT utilization in all patients undergoing coronary interventions during a 60-day period

1. Intention to perform PCI,
2. planned site of intervention,
3. number of stents, length and diameter of each stent,
4. pre- and postdilation
5. balloon diameter and length

Stefano et al Int J Cardiovasc Imaging, DOI 10.1007/s10554-012-0135-02012

Clinical application

Table 4 Impact of FD-OCT on Management

*Pre-intervention (n = 33 *)*	
Operator predictions	
Predicted number of stents (n/target vessel)	1.24 ± 0.66
Predicted length of stents (mm)	28.64 ± 18.9
Predicted stent diameter (mm)	2.98 ± 0.34
Predicted post-dilation diameter (mm)	3.21 ± 0.39
Procedure characteristics guided by FD-OCT	
Actual number of stents (n/target vessel)	1.24 ± 0.56
Actual length of stents (mm)	29.52 ± 15.8
Actual stent diameter (mm)	2.96 ± 0.36
Actual post-dilation diameter (mm)	3.20 ± 0.48
Maximal post-dilation pressure (atm)	18.00 ± 3.74
Management changes based on successful FD-OCT	
Change in number of stents	6.1 (2)
Greater	3.0 (1)
Less	3.0 (1)
Change in stent length based on lesion length	48.5 (16)
Longer	30.3 (10)
<10 mm	21.2 (7)
11–20 mm	6.1 (2)
>20 mm	3.0 (1)
Shorter	18.2 (6)
<10 mm	15.2 (5)
11–20 mm	– (0)
>20 mm	3.0 (1)
Change in stent length based on presence of TCFA	9.1 (3)
Change in stent diameter	27.3 (9)
Larger	9.1 (3)
<0.50 mm	– (0)
≥0.50 mm	9.1 (3)
Smaller	18.2 (6)
<0.50 mm	12.1 (4)
≥0.50 mm	6.1 (2)
Change in post-dilation diameter	63.7 (21)
Larger	30.3 (10)
<0.50 mm	15.2 (5)
≥0.50 mm	15.2 (5)
Smaller	33.3 (11)
<0.50 mm	27.3 (9)
≥0.50 mm	6.1 (2)
Any management change based on FD-OCT	81.8 (27)

There were no FD-OCT procedural related cardiac adverse events and success was obtained in 85.7 %

Success on the first pullback occurred in 80.3 % overall (61.9 % in the initial operator experience and 85.5 % after the third procedure).

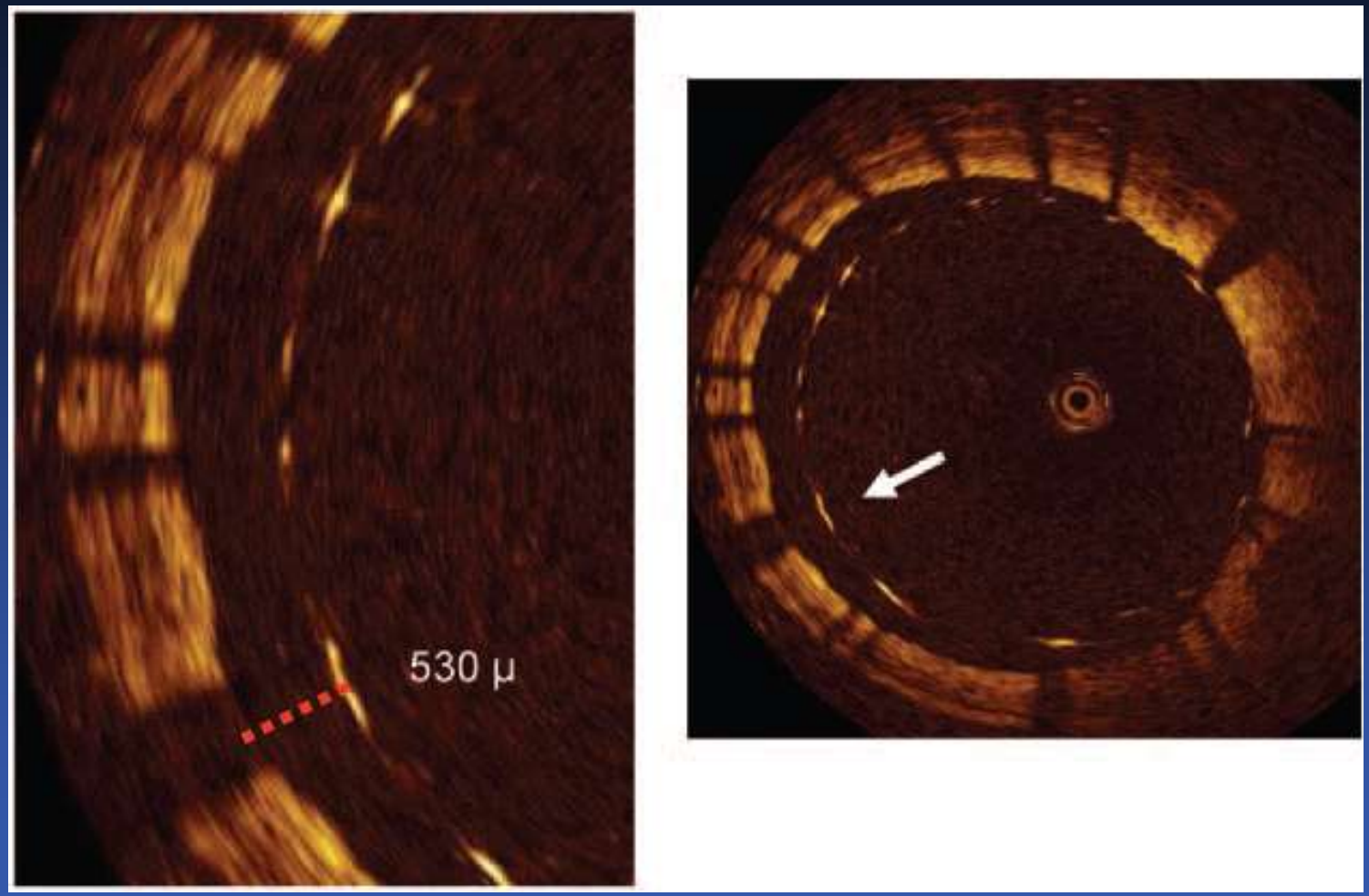
FD-OCT impact on management was 81.8 % pre-PCI and 54.8 % post-PCI.

Stent malapposition was detected in 39.2 % (89.4 % underwent further intervention) and edge dissection in 32.5 % (21.1 % treated with stent).

FD-OCT success and management impact were similar in ACS and non-ACS patients (82.1 vs. 81.1 %, p = 1.000, and 62.5 vs. 65.1 %, p = 0.854, respectively).

Stefano et al Int J Cardiovasc Imaging, 2012

OCT guided revascularization



Stent struts malapposition

Prati F., et al., Eur Heart J Oct 2012

OCT guided revascularization

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

Prati et al.Euro**Intervention 2012;8:823-829**

Εφαρμογές ενδοαγγειακής απεικόνισης

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- Θρόμβωση & επαναστένωση του stent
- Σύγκριση OCT-IVUS
- Εκτίμηση σύστασης πλάκας

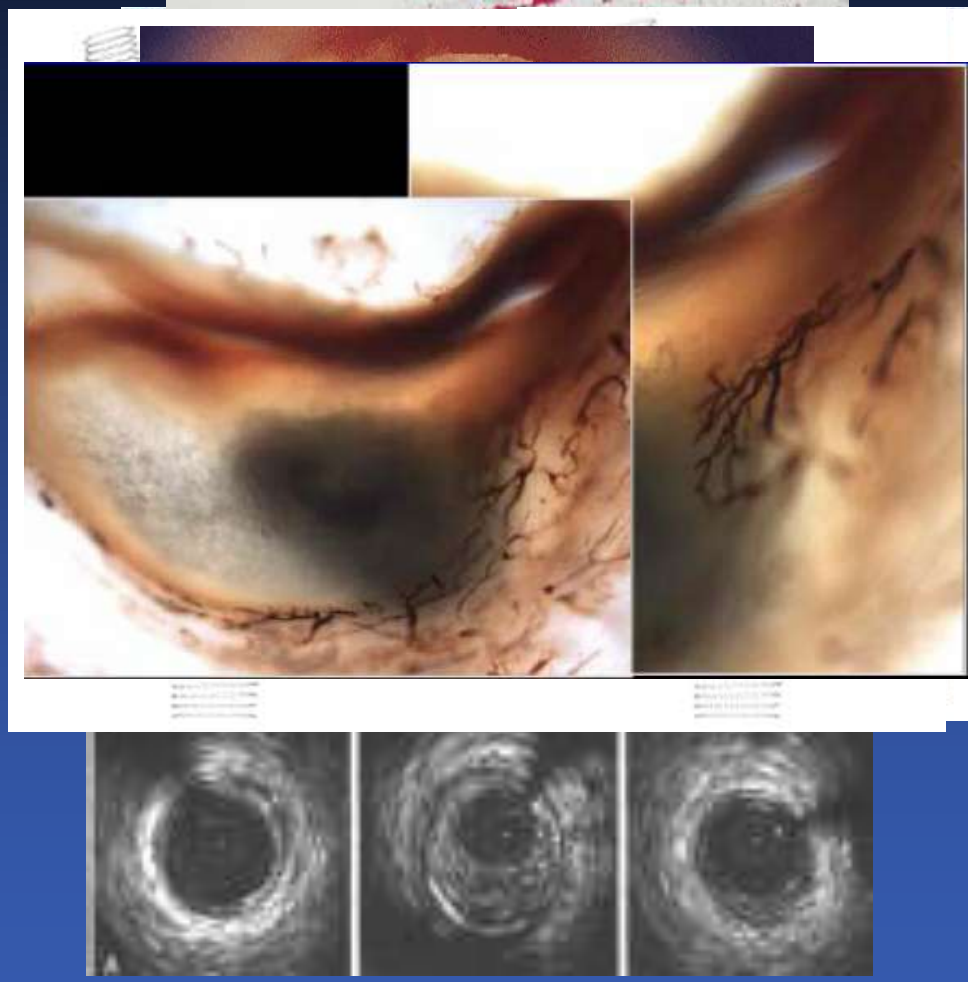
Vulnerable Plaque Components

- Fibrous Cap Thickness< 65 μm
- Large Necrotic Core
- Inflammation
- Positive Remodelling

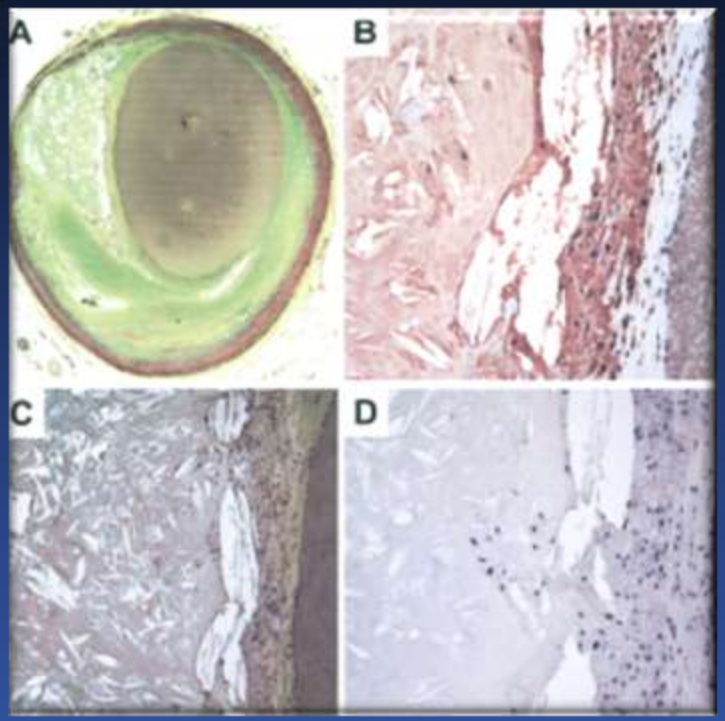
VP Meeting, Eur Heart J 2004.
Schaar, Stefanadis et al

- Reduced shear stress
- Intravascular Hemorrhage
- Neovascularization

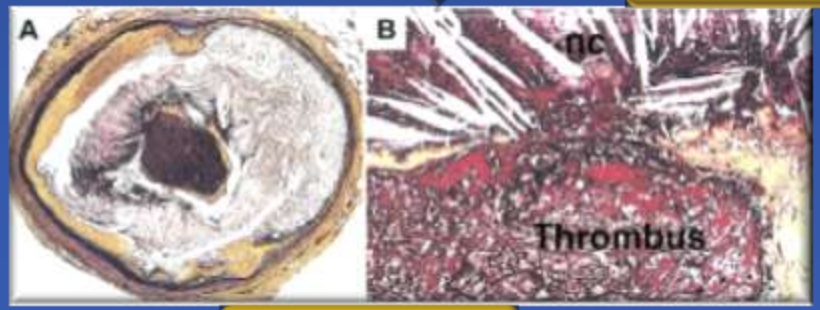
VP Meeting, P. Serruys, A. Colombo, C. Stefanadis, S. Casscells, J. Schaar, 2007



Vulnerable Plaque Components



Rupture



Thrombosis

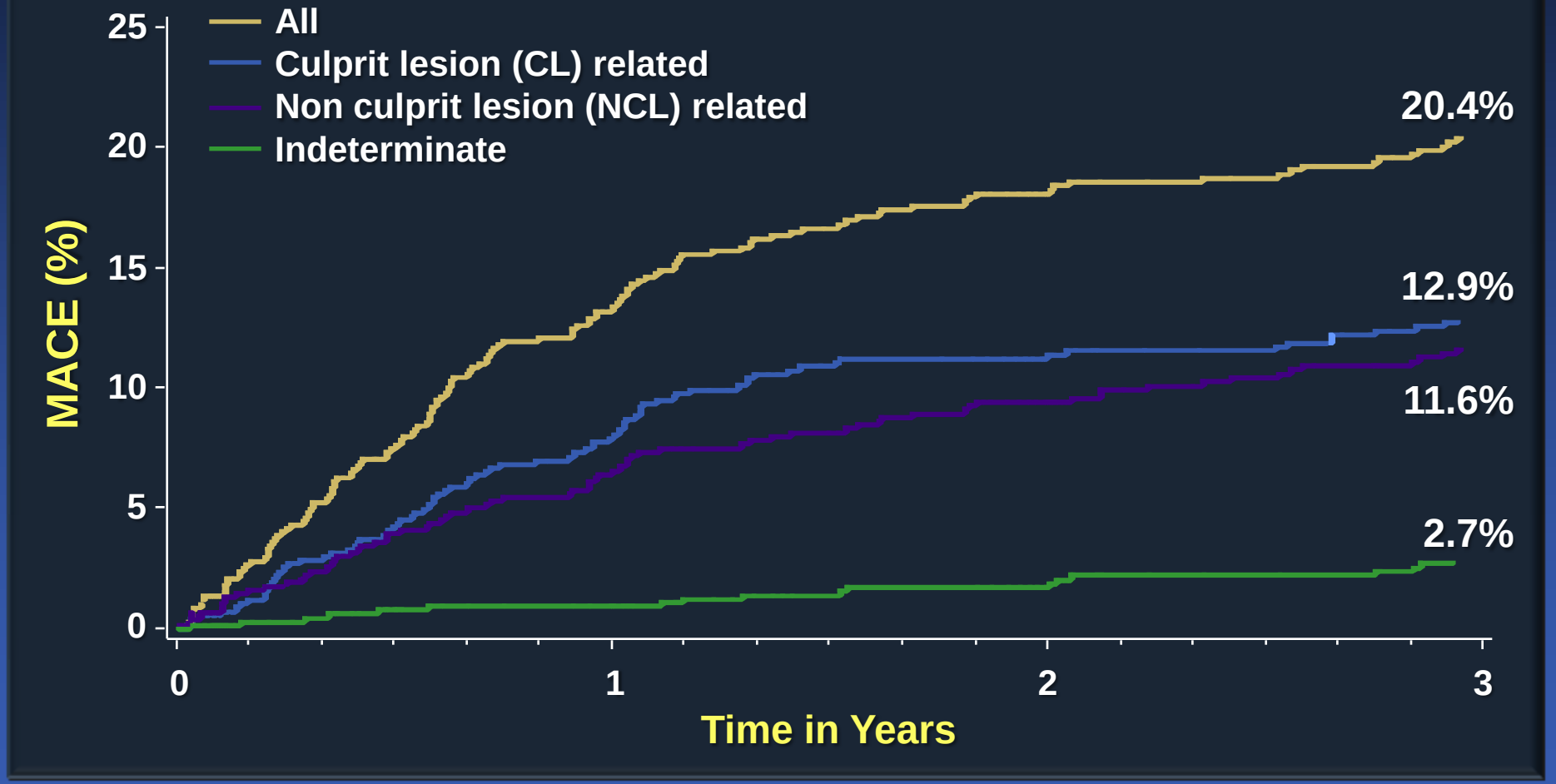
- **Increased Plaque size**
  - *Positive remodeling*
- **Increased Necrotic core**
  - ~34% of plaque area
  - ~3.8 mm^2 & ~9 mm long
- **Fibrous cap**
  - Reduced Thickness, *~23 μm (95% <65 μm)*
  - Increased Macrophage Density, *~26% of cap*
  - *Reduced Smooth Muscle Cells*
- **Increased Angiogenesis**
  - Intraplaque hemorrhage
- **Perivascular inflammation**
- **Reduced Calcification & *Spotty***

Detected by OCT

Virmani R, et al., JACC 2006;47:C13–8

PROSPECT trial:

The significance of evaluation of non-culprit lesions



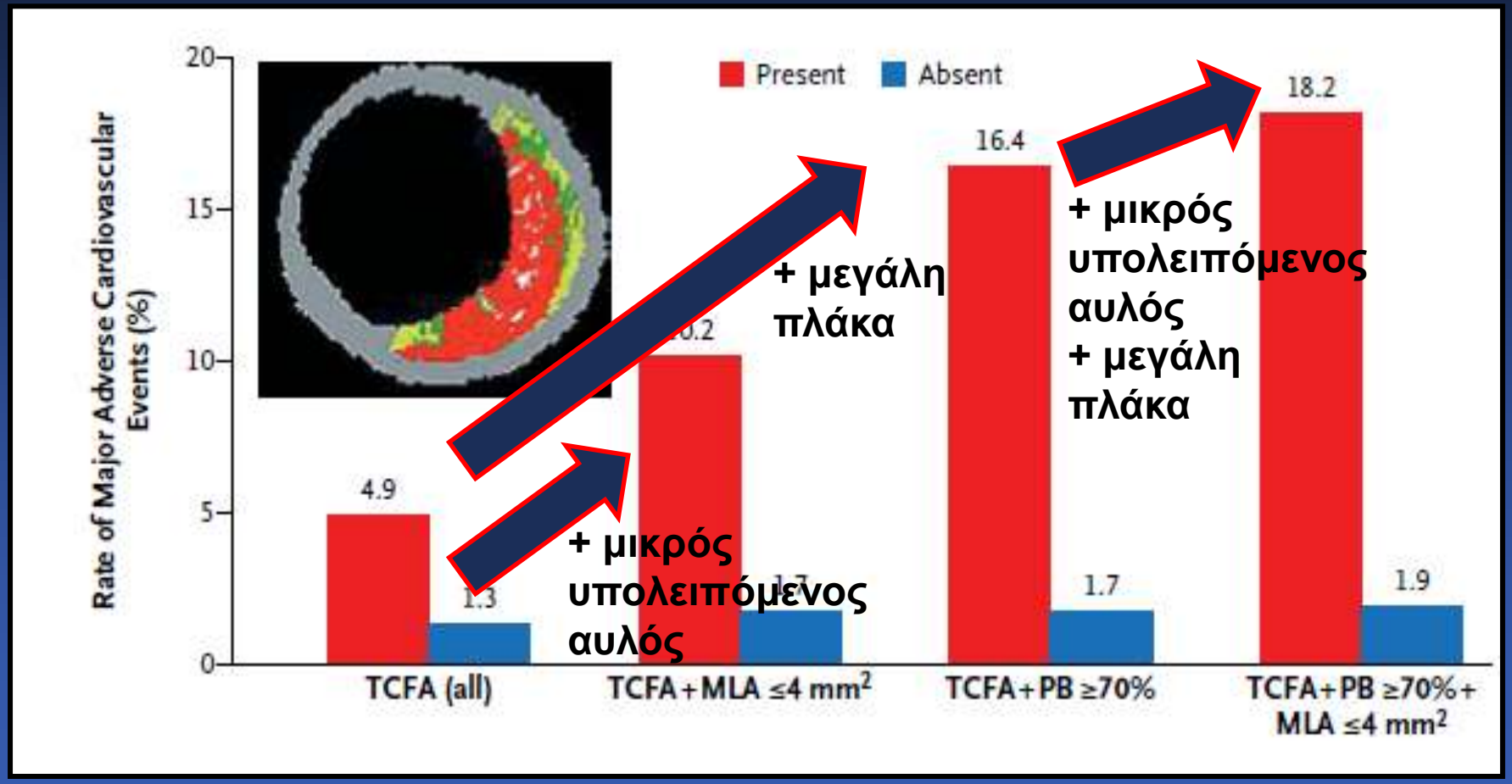
Stone GW et al., N Engl J Med 2011;364:226-35.

PROSPECT: Independent predictors of patient and lesion level events by logistic regression analysis

Correlates	Hazard Ratio (95% CI)	P Value
Predictors of patient-level events†		
Insulin-requiring diabetes	3.32 (1.43–7.72)	0.005
Previous percutaneous coronary intervention	2.03 (1.15–3.59)	0.02
Predictors of events at individual lesion sites‡		
Plaque burden ≥70%	5.03 (2.51–10.11)	<0.001
Thin-cap fibroatheroma	3.35 (1.77–6.36)	<0.001
MLA ≤4.0 mm^2	3.21 (1.61–6.42)	0.001

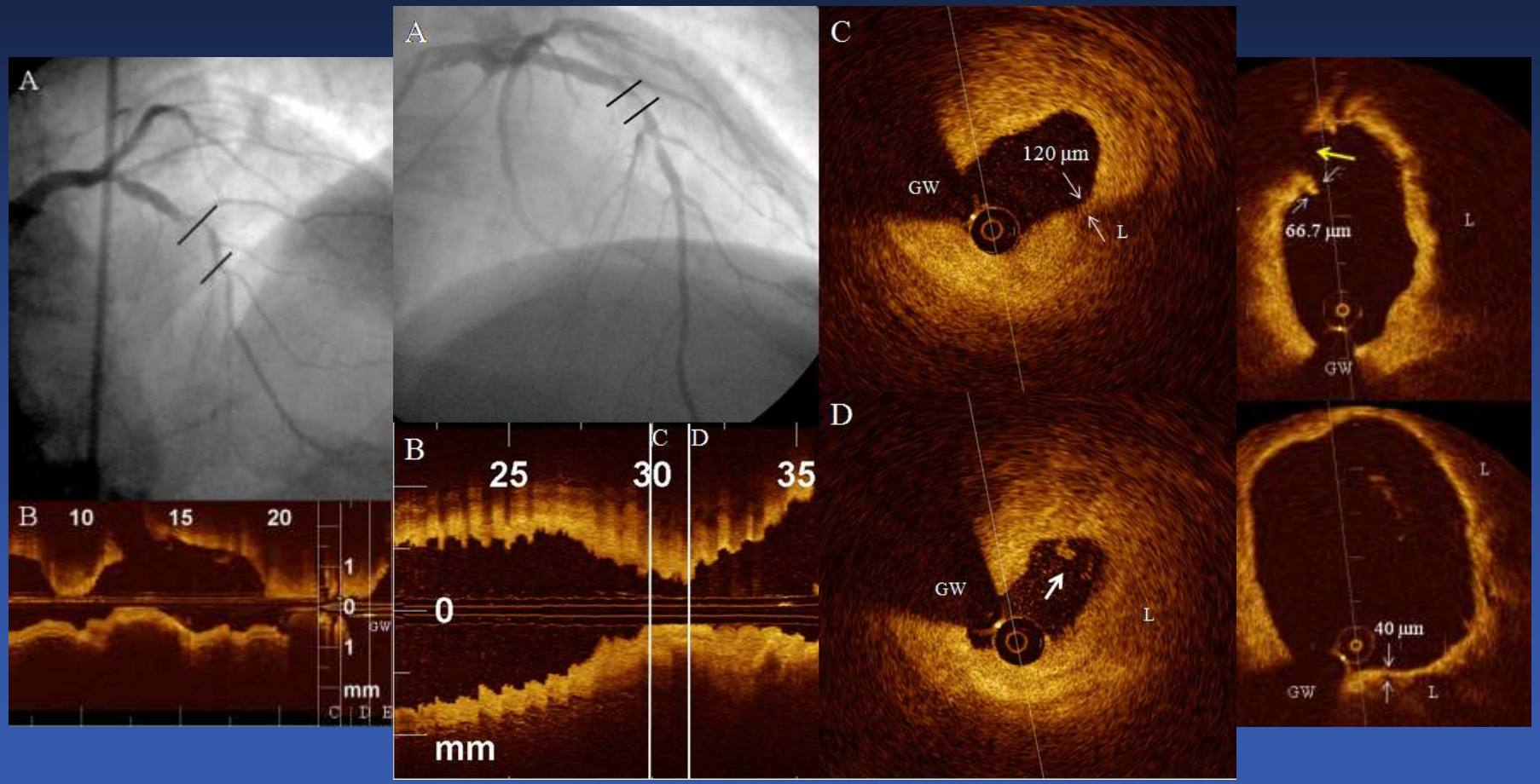
Stone GW et al., N Engl J Med 2011;364:226-35.

Μελέτη PROSPECT: VH-TCFA ως προγνωστικός δείκτης σε επίπεδο βλάβης



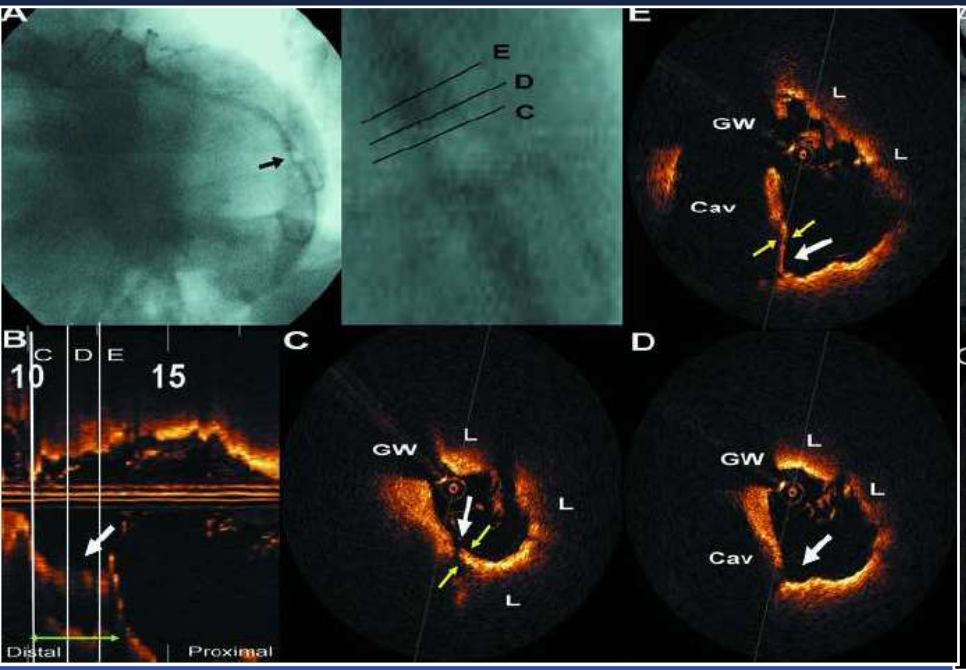
Stone GW et al., N Engl J Med 2011;364:226-35.

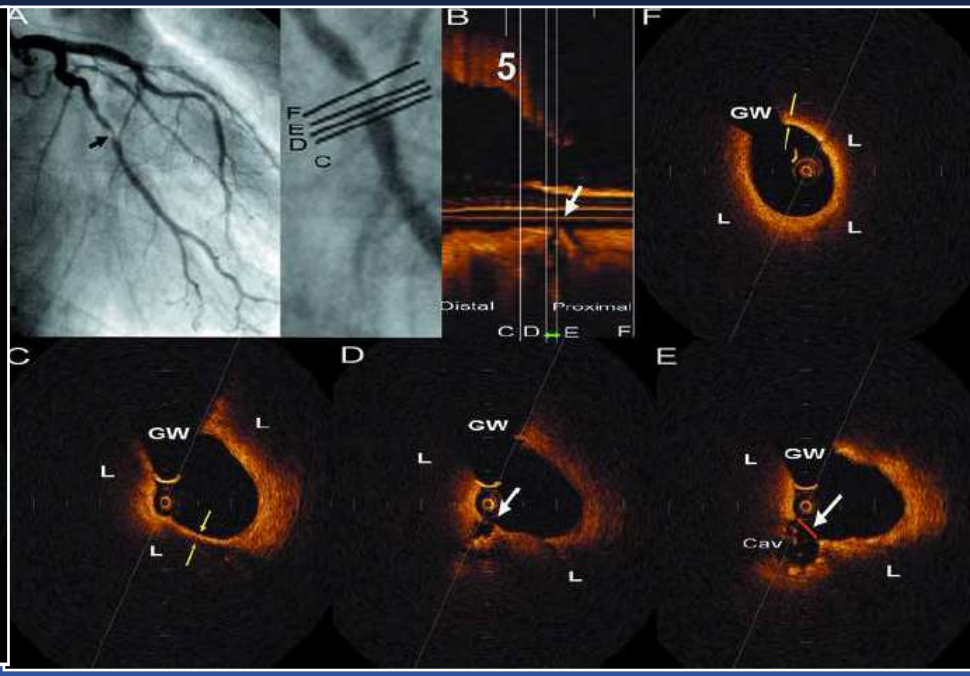
Vulnerable plaque characteristics are associated with thrombolysis failure



Toutouzas K, Tsiamis E, Karanasos A, Drakopoulou M, Synetos A, Tsioufis C, Tousoulis D, Davlouros P, Alexopoulos D, Bouki K, Apostolou T, Stefanadis C. JACC Cardiovasc Interv. 2010 May;3(5):507-14

Difference in rupture between STEMI & NSTEMI





STEMI NSTEMI

STEMI patients have greater rupture length and greater length of missing fibrous cap than NSTEMI patients

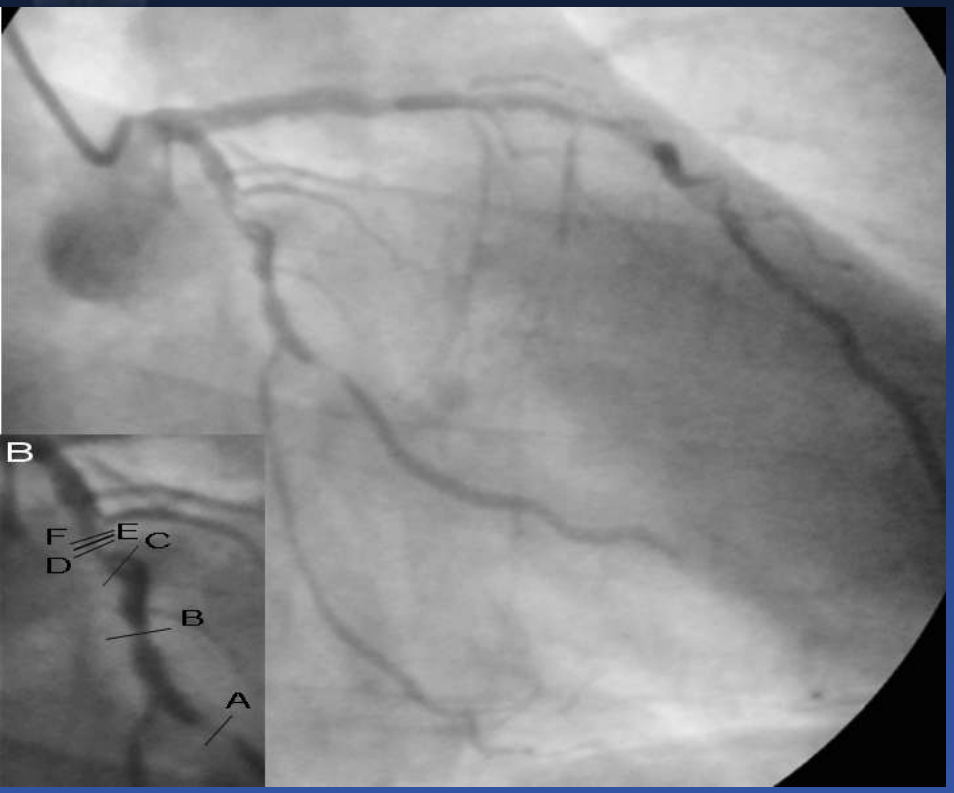
Toutouzas.. Synetos…Stefanadis, Am Heart J 2011 Jun; 161:1192-9

Rupture location in ACS

Rupture Characteristics	
Rupture Length(mm)	2.27±1.70
Location of rupture	
Distal to the MLS	14(36.8)
MLS	14(36.8)
Proximal to the MLS	10(26.3)
Distance from MLS(mm)	2.01±2.10
Cross Sectional Area(mm2)	4.12±2.68
Minimal Cap Thickness(μm)	59±21μm
Rupture at cap shoulder	26(68.4)
Length of missing fibrous cap(mm)	0.53±0.27

Toutouzas, Karanasos,Synetos…Stefanadis, Am Heart J 2011 Jun; 161:1192-9

OCT imaging in ACS

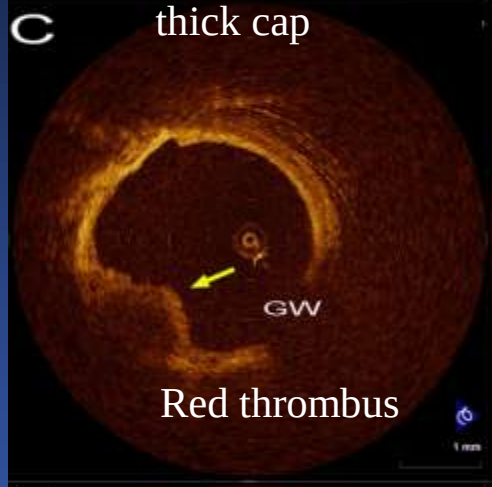


Evaluation of culprit lesion in ACS revealed multiple morphologies

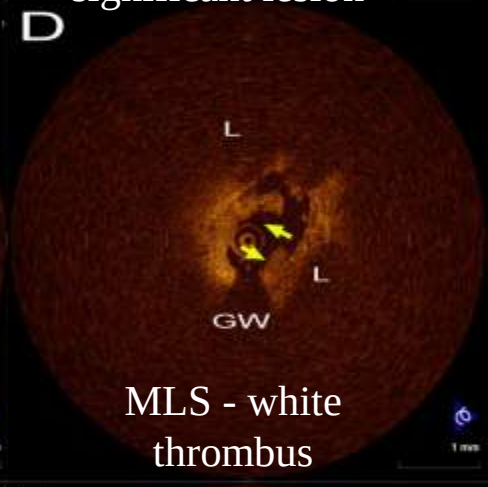
Toutouzas..Synetos..Stefanadis, Heart July 2010

Non-culprit lipid-rich plaque with thick cap

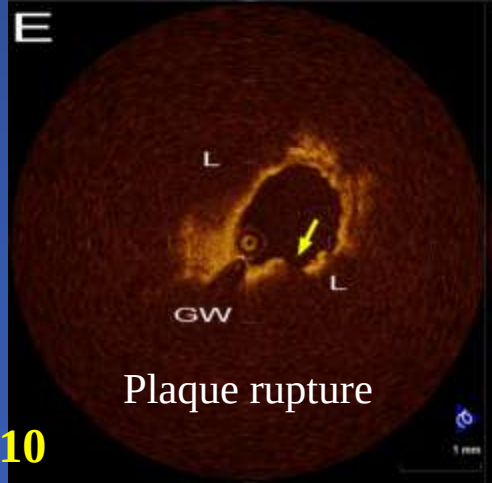
Napkin ring – significant lesion



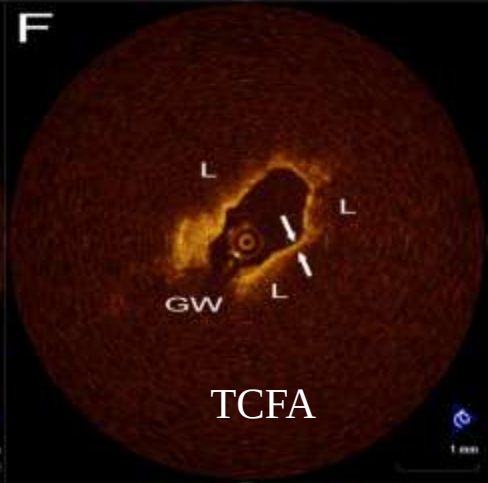
Red thrombus



MLS - white thrombus



Plaque rupture



TCFA

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ISSN 0735-1097/07/$32.00
doi:10.1016/j.jacc.2007.03.026

Correlation Between Morphologic Characteristics and Local Temperature Differences in Culprit Lesions of Patients With Symptomatic Coronary Artery Disease

Konstantinos Toutouzas, MD, Andreas Synetos, MD, Elli Stefanadi, MD, Sophia Vaina, MD, Virginia Markou, MD, Manolis Vavuranakis, MD, FACC, Eleftherios Tsiamis, MD, Dimitrios Tousoulis, MD, FACC, Christodoulos Stefanadis, MD, FACC

Athens, Greece

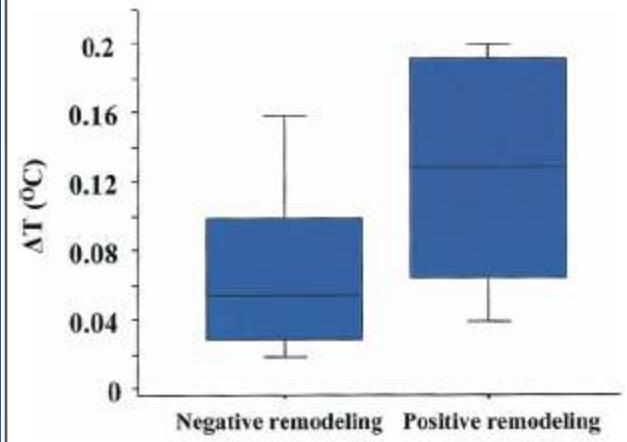


Figure 1 ΔT in Lesions With Negative and Positive Remodeling

Difference between atherosclerotic plaque temperature and background temperature (ΔT) in patients with negative remodeling and those with positive remodeling. The bottom of each box represents the first quartile, the top of the box represents the third quartile, and the line in the box represents the median value of ΔT.

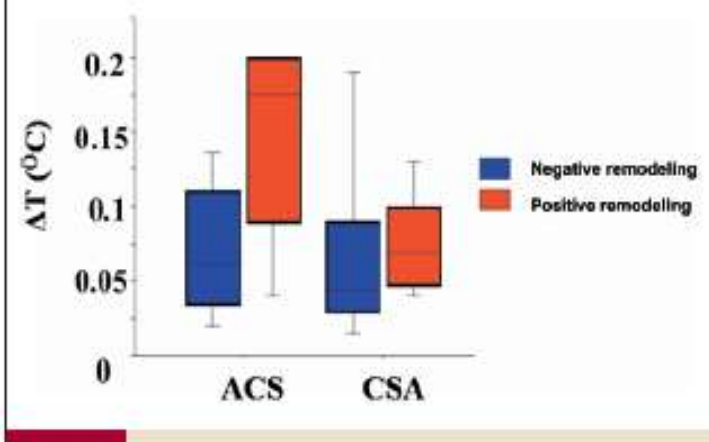


Figure 3 Temperature Measurements Stratified by Clinical Syndrome and Remodeling Index

The ΔT stratified by clinical syndrome and remodeling index. The bottom of each box represents the first quartile; the top of the box represents the third quartile, and the line in the box represents the median value of ΔT. Abbreviations as in Figure 1.

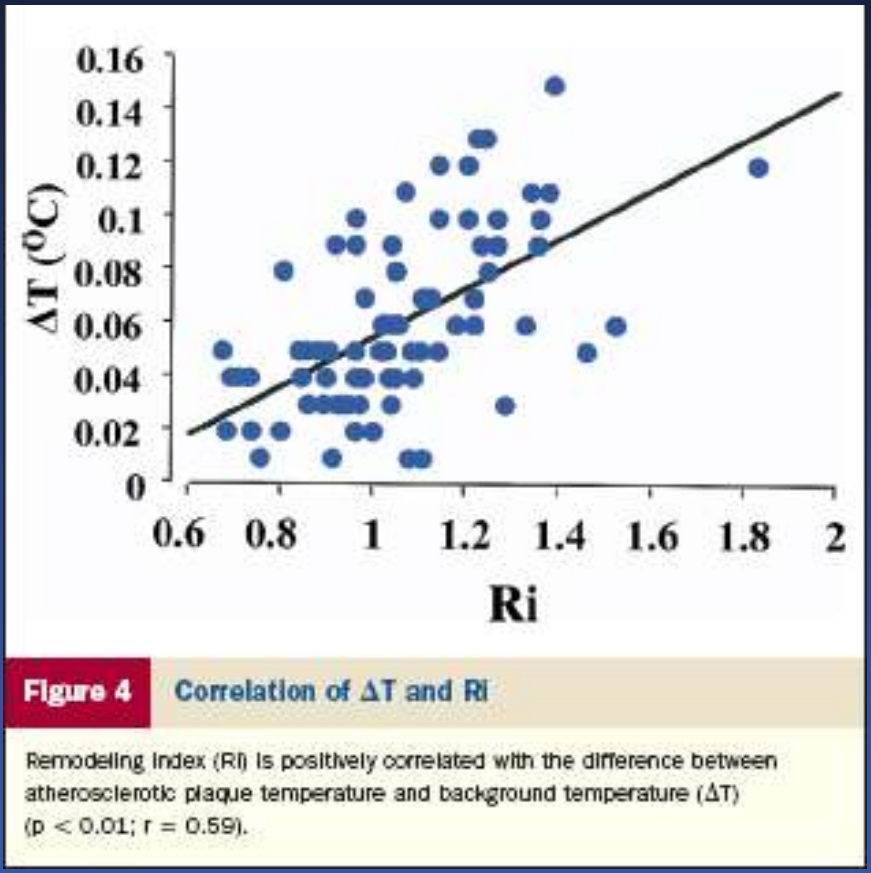


Figure 4 Correlation of ΔT and Ri

Remodeling Index (RI) is positively correlated with the difference between atherosclerotic plaque temperature and background temperature (ΔT) ($p < 0.01$; $r = 0.59$).

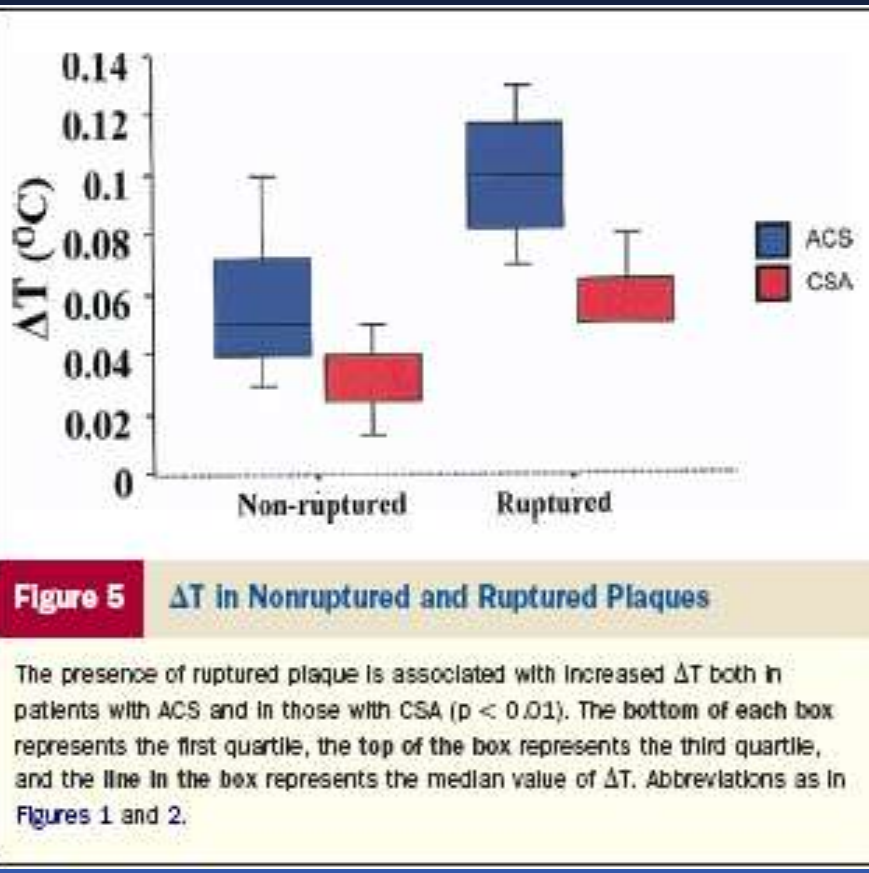
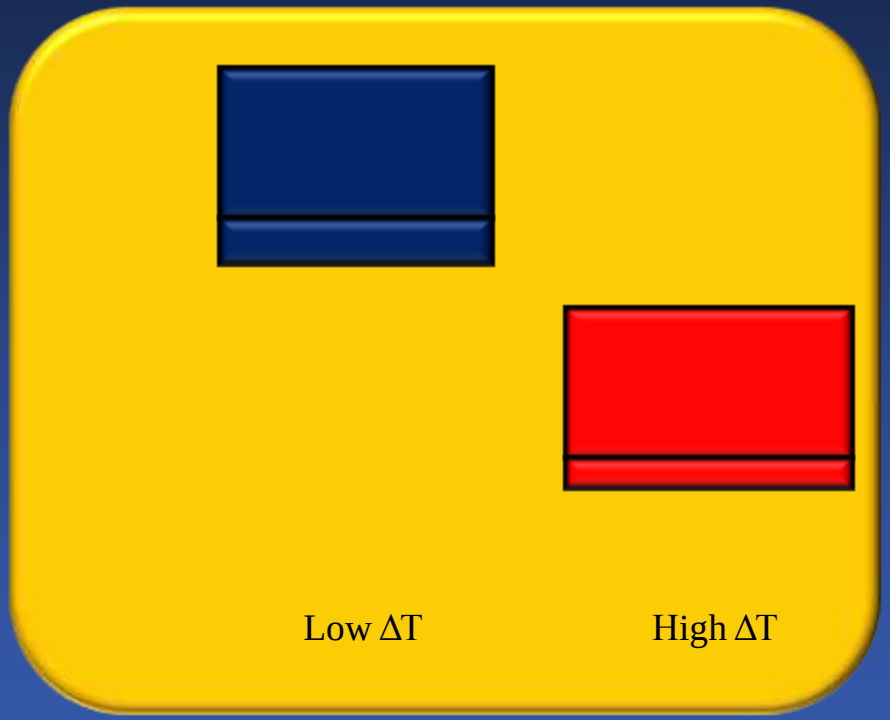


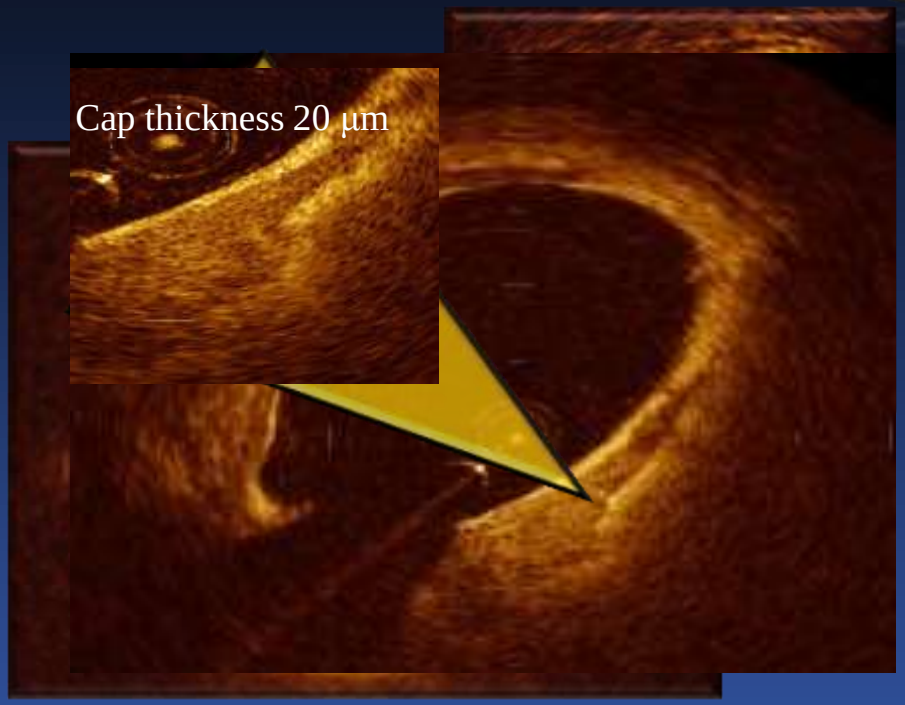
Figure 5 ΔT in Nonruptured and Ruptured Plaques

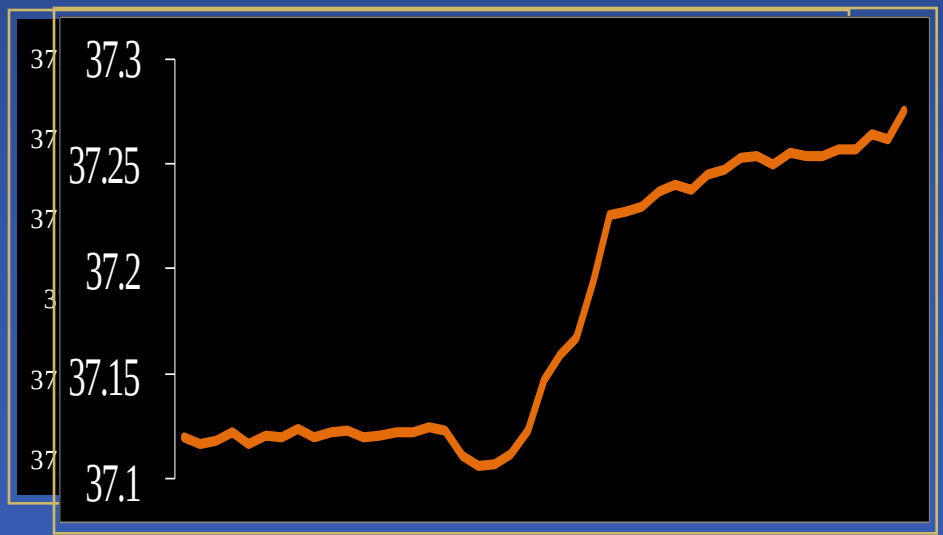
The presence of ruptured plaque is associated with increased ΔT both in patients with ACS and in those with CSA ($p < 0.01$). The bottom of each box represents the first quartile, the top of the box represents the third quartile, and the line in the box represents the median value of ΔT. Abbreviations as in Figures 1 and 2.

Toutouzas , Synetos…Stefanadis ,JACC Vol. 49, No. 23, 2007

OCT - Thermography



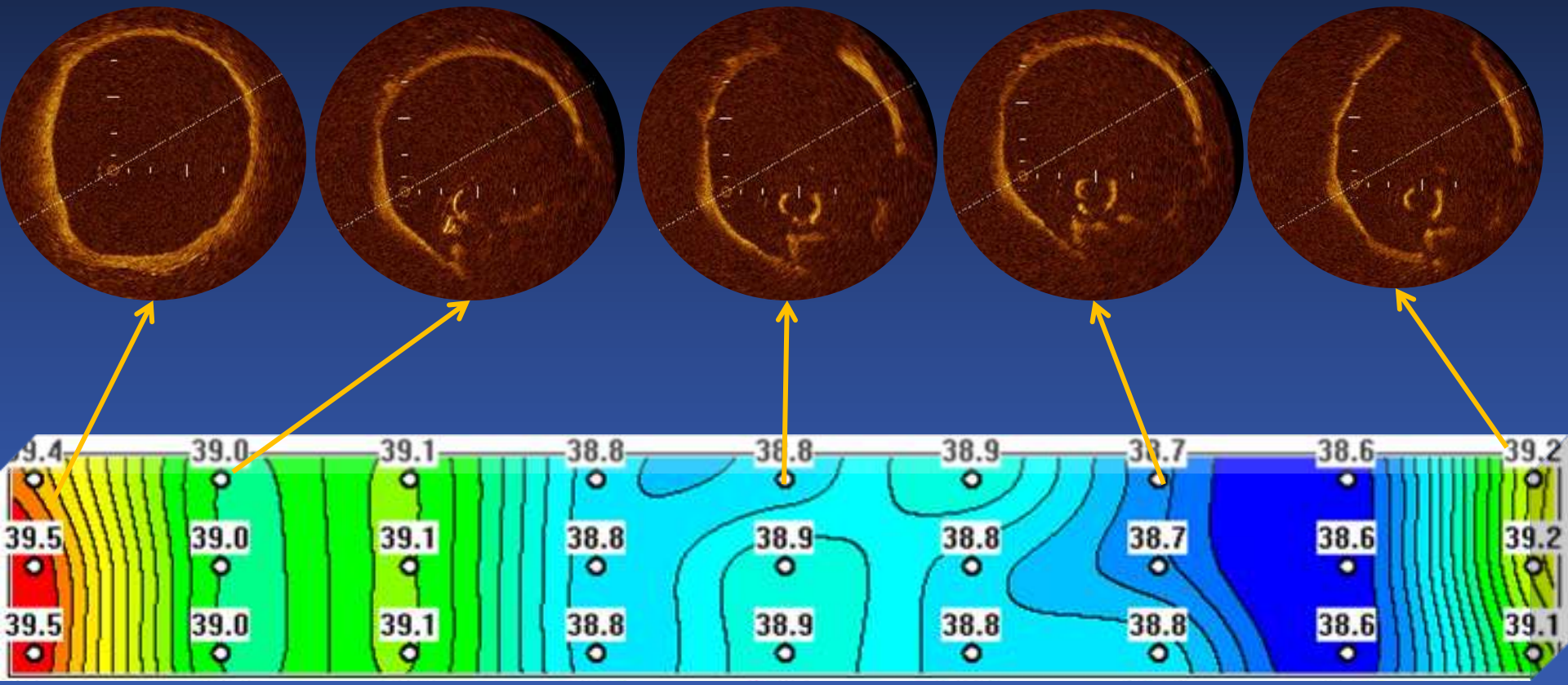




Toutouzas , Synetos , … Stefanadis ACC 2009

Microwave Radiometry:

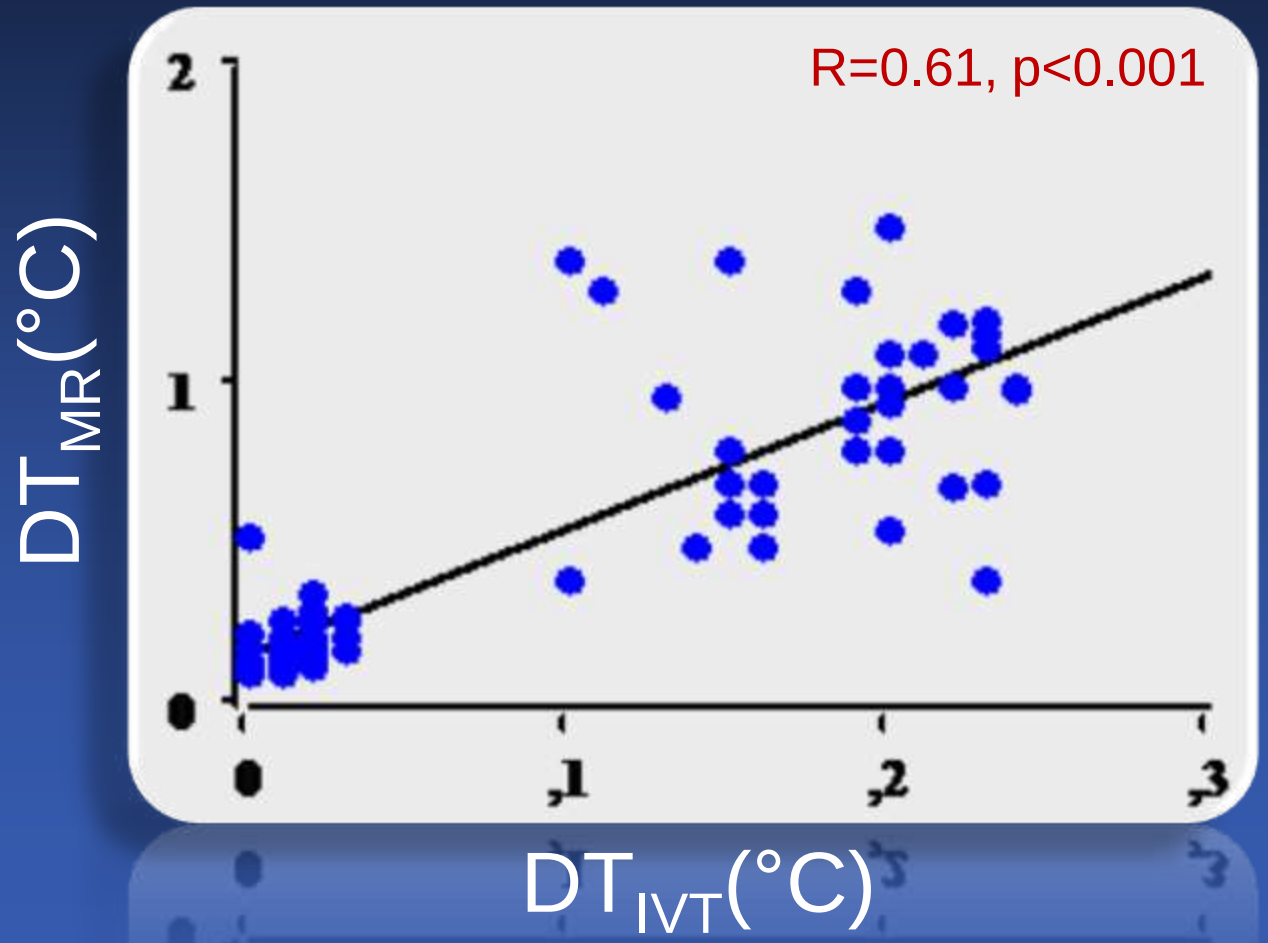
Comparison of OCT-detected atheromatosis with thermal heterogeinity



$\Delta T = 0.8^{o}C$

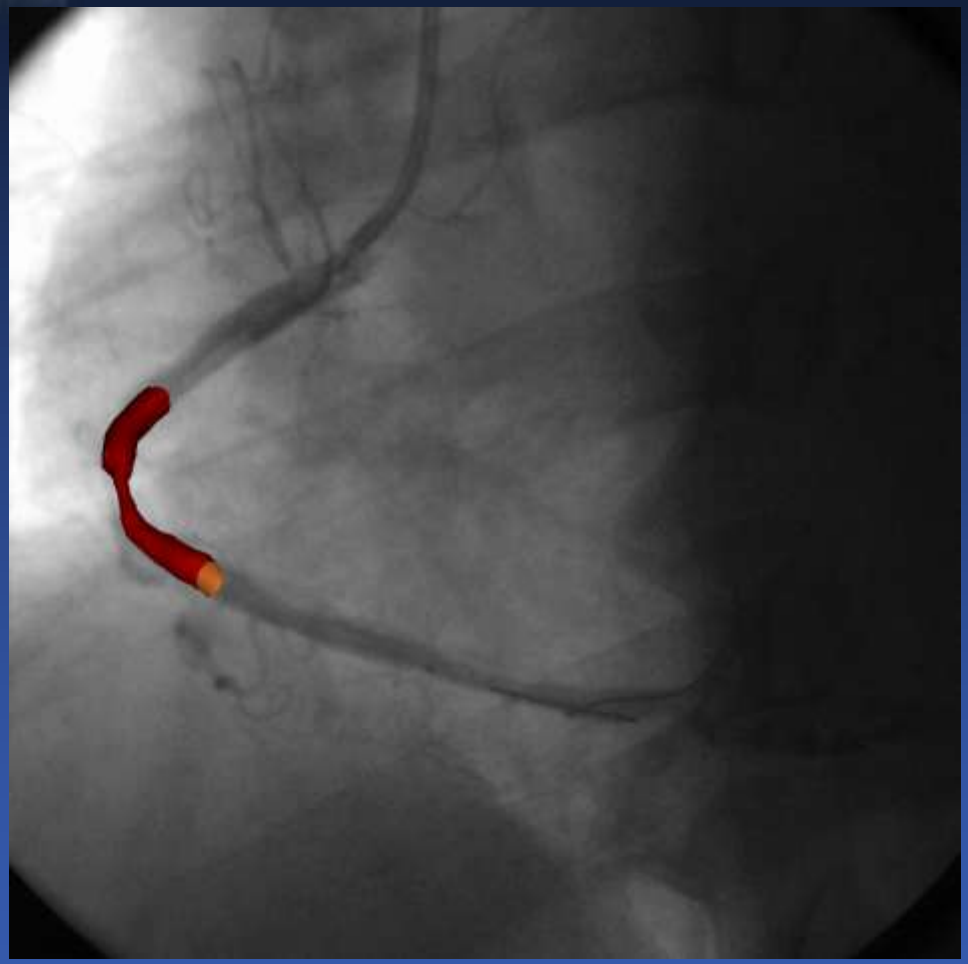
Toutouzas, Synetos…Stefanadis., ESC 2010

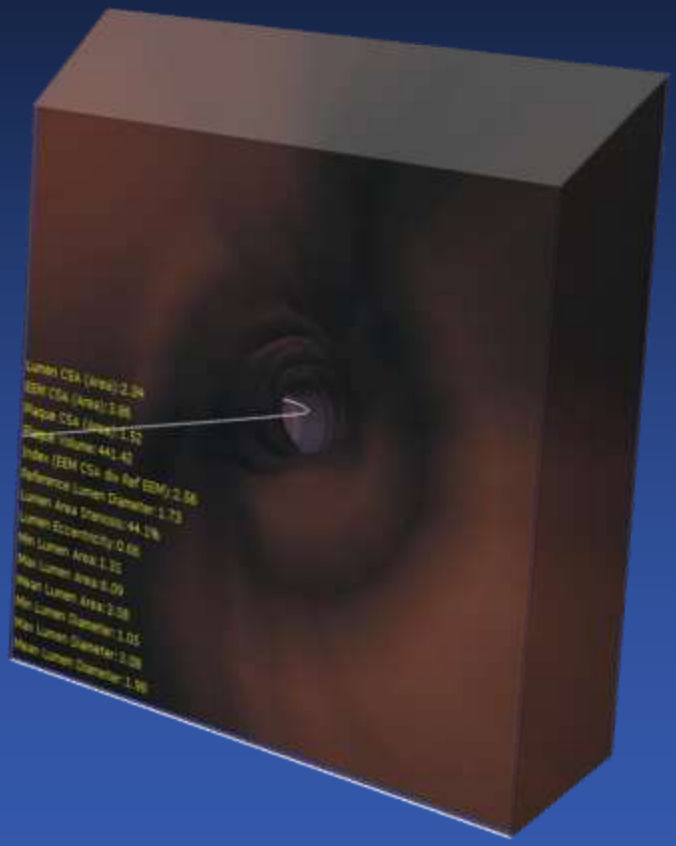
Measurements with MR are corellated with measurements with IVT



Toutouzas…Synetos..Stefanadis ,Atherosclerosis 2010

3D OCT – Shear Stress





Development of an algorithm that can provide us with automated measurements and provide us with the 3d structure of the vessel allowing the measurement of ESS

First Dept. of Cardiology, Athens Medical School

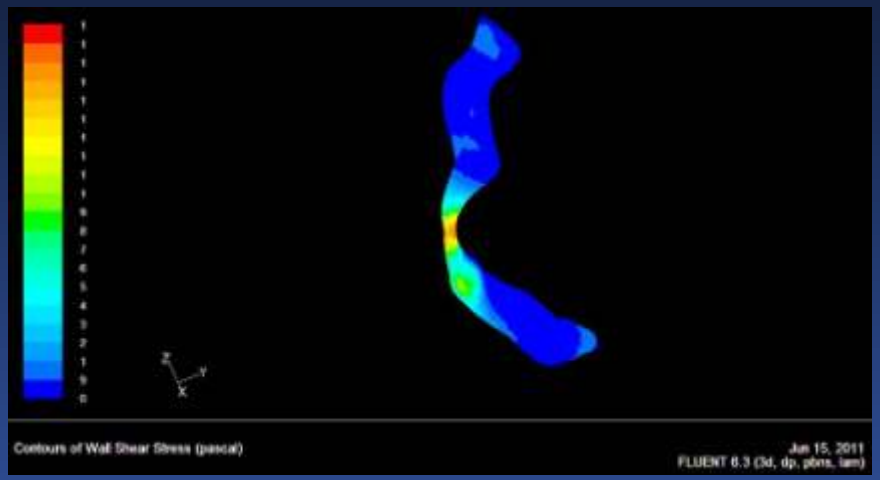
3D OCT

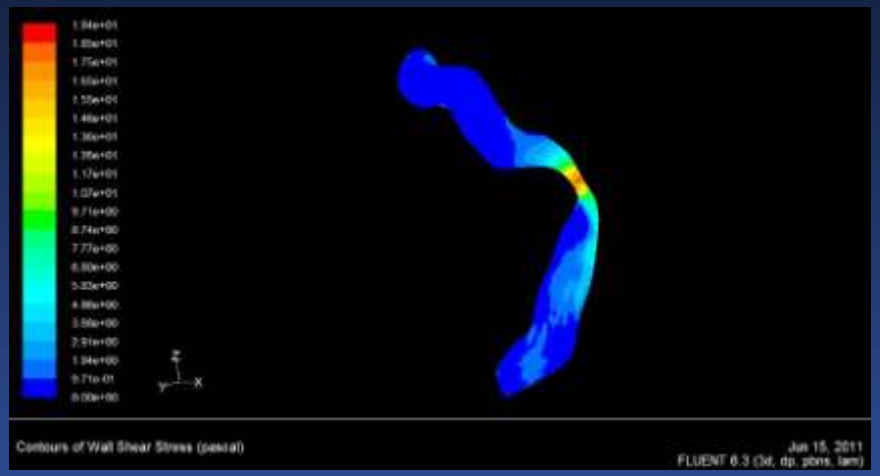
Fusion of Angiography and OCT

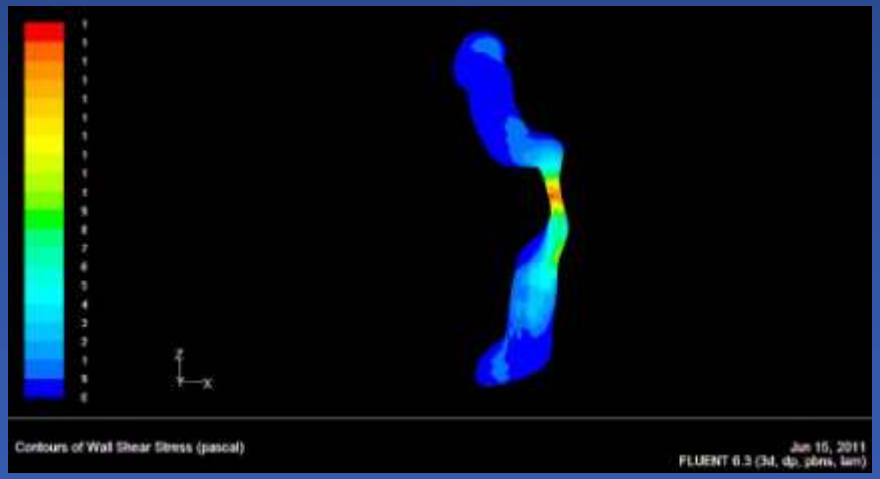
3D Reconstructed RCA

Toutouzas K, Synetos A, Chatzizisis Y, , Stefanadis C
First Department of Cardiology, University of Athens
First Cardiology Department, University of Thessaloniki
University of Chicago, Medical School

Shear Stress Map of the Reconstructed RCA



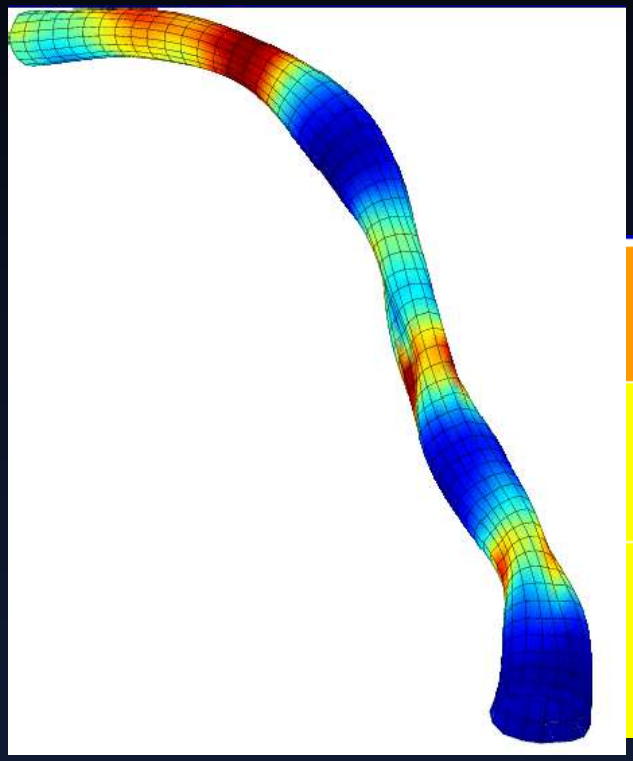


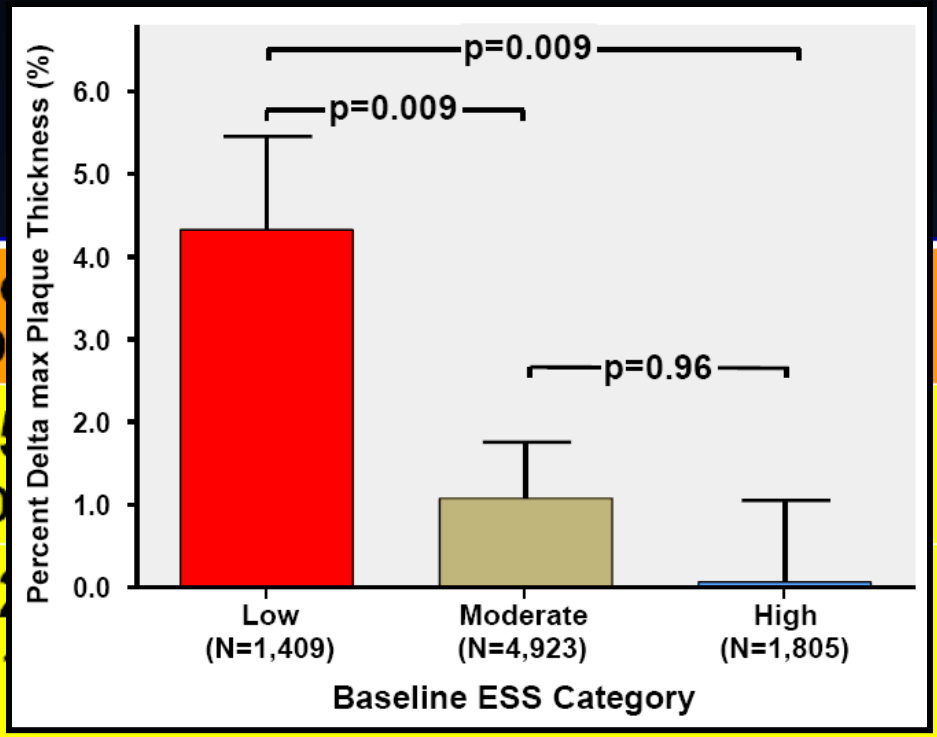


Toutouzas K, Synetos A, Chatzizisis Y, Stefanadis C
First Department of Cardiology, University of Athens
First Cardiology Department, University of Thessaloniki
University of Chicago, Medical School

Μελέτη PREDICTION:

Συσχέτιση shear stress με μελλοντικά συμβάματα

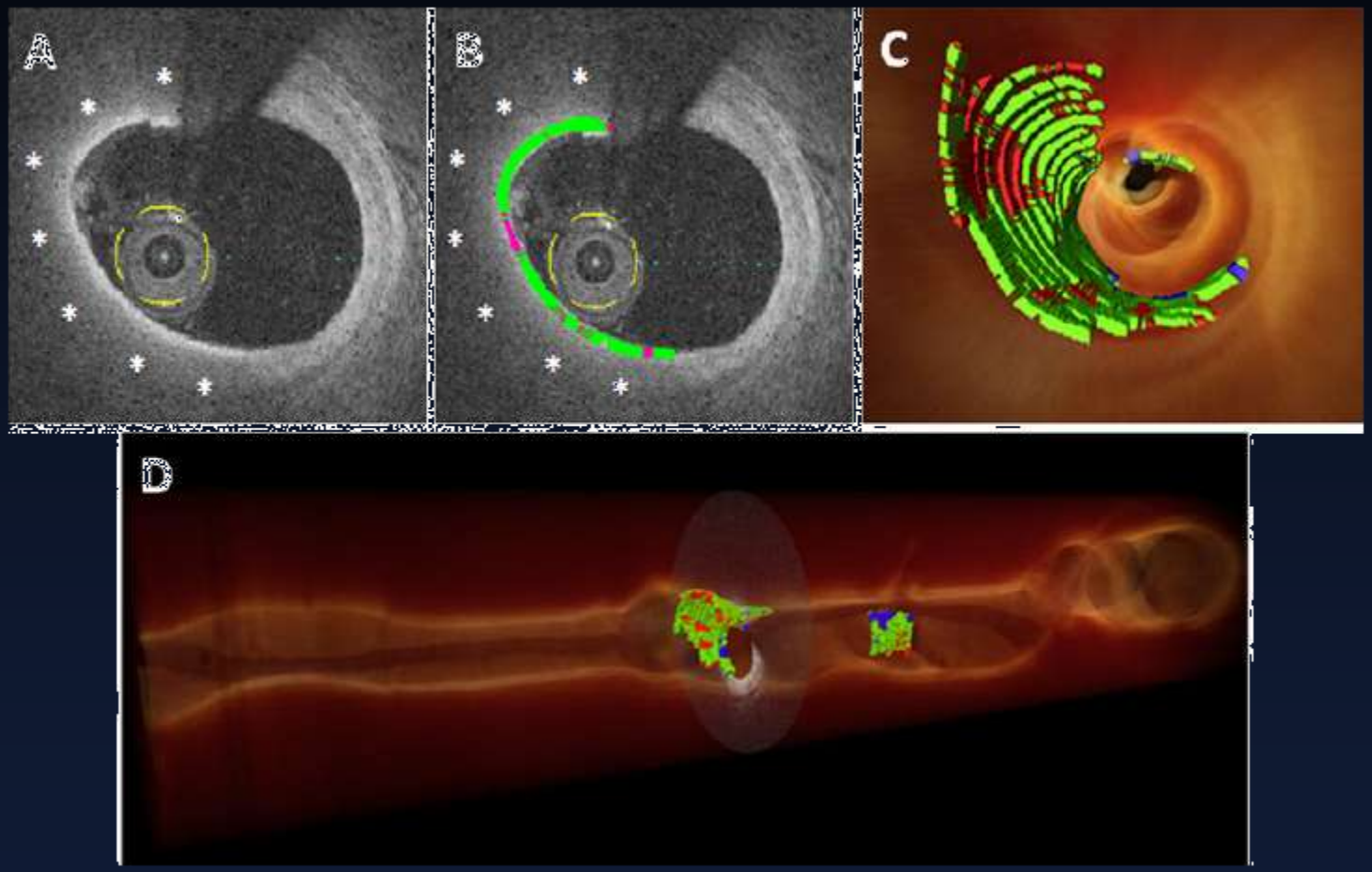




Το χαμηλό shear stress ήταν ανεξάρτητος προγνωστικός παράγοντας για εξέλιξη βλάβης

Stone P, TCT 2010

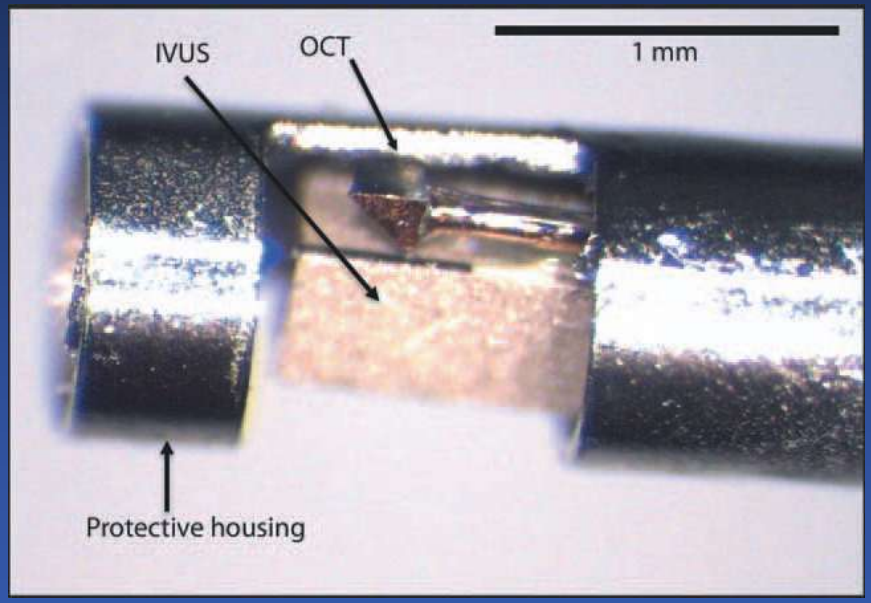
Volumetric assessment of TCFA

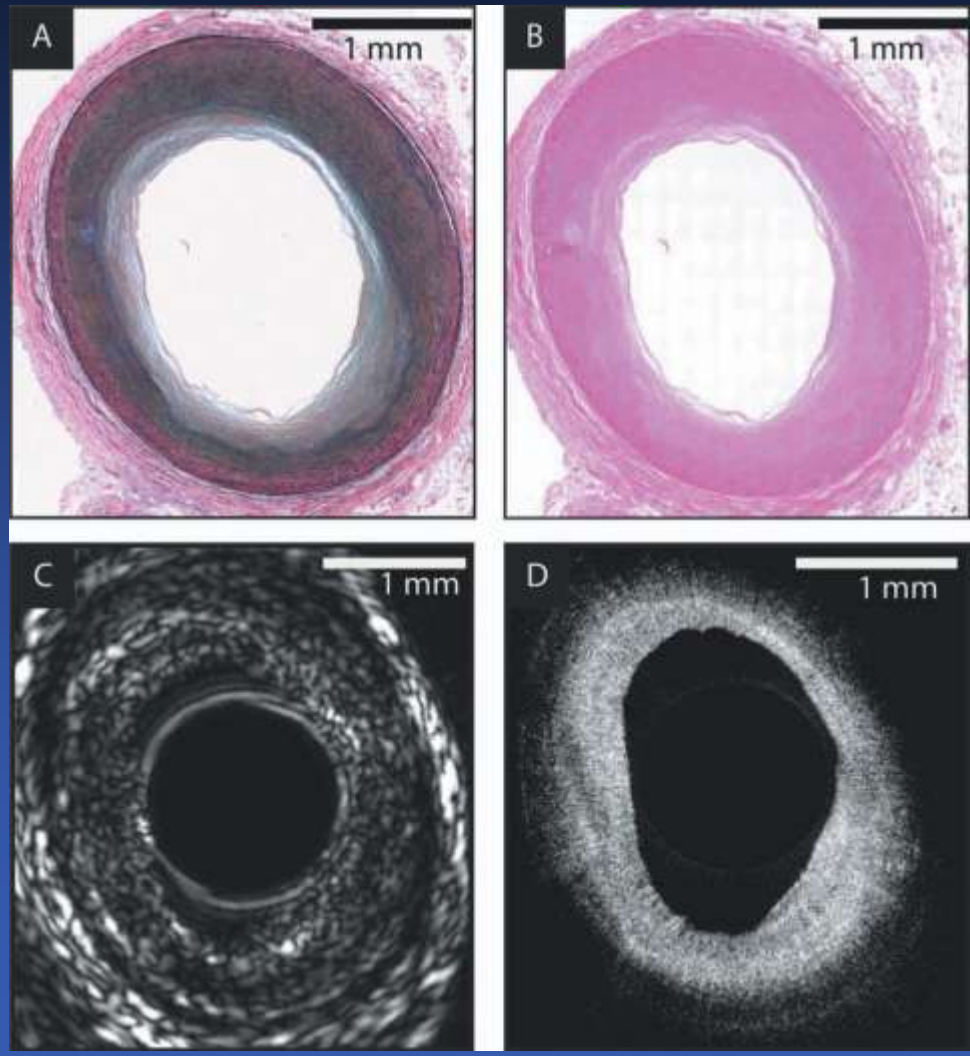


3D reconstruction for measurement of the area of the thin fibrous cap

Chamie D et al, Curr Cardiovasc Imaging Rep (2011) 4:276–283

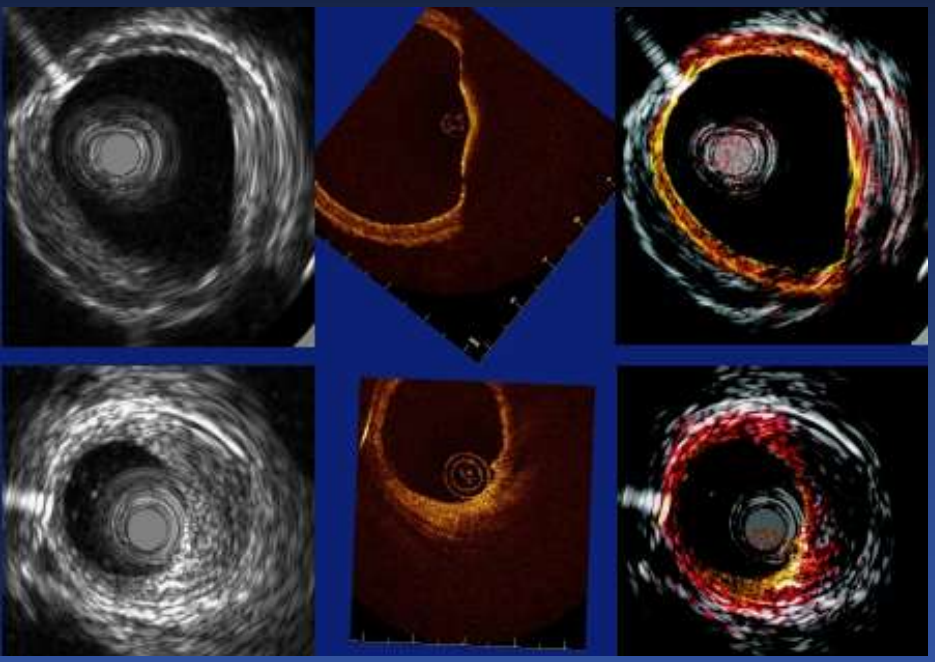
Hybrid IVUS-OCT catheters

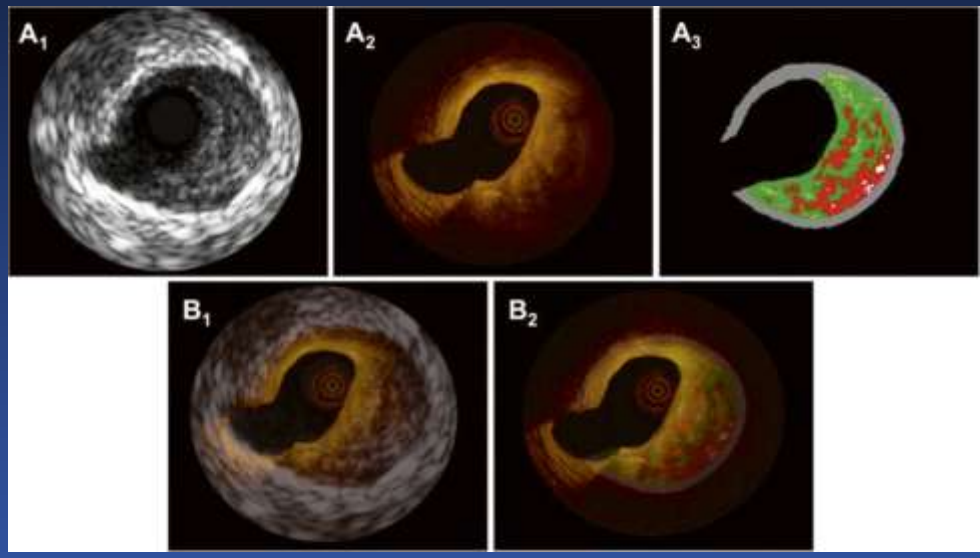




Li et al, Catheter CardiovascInterv 2012

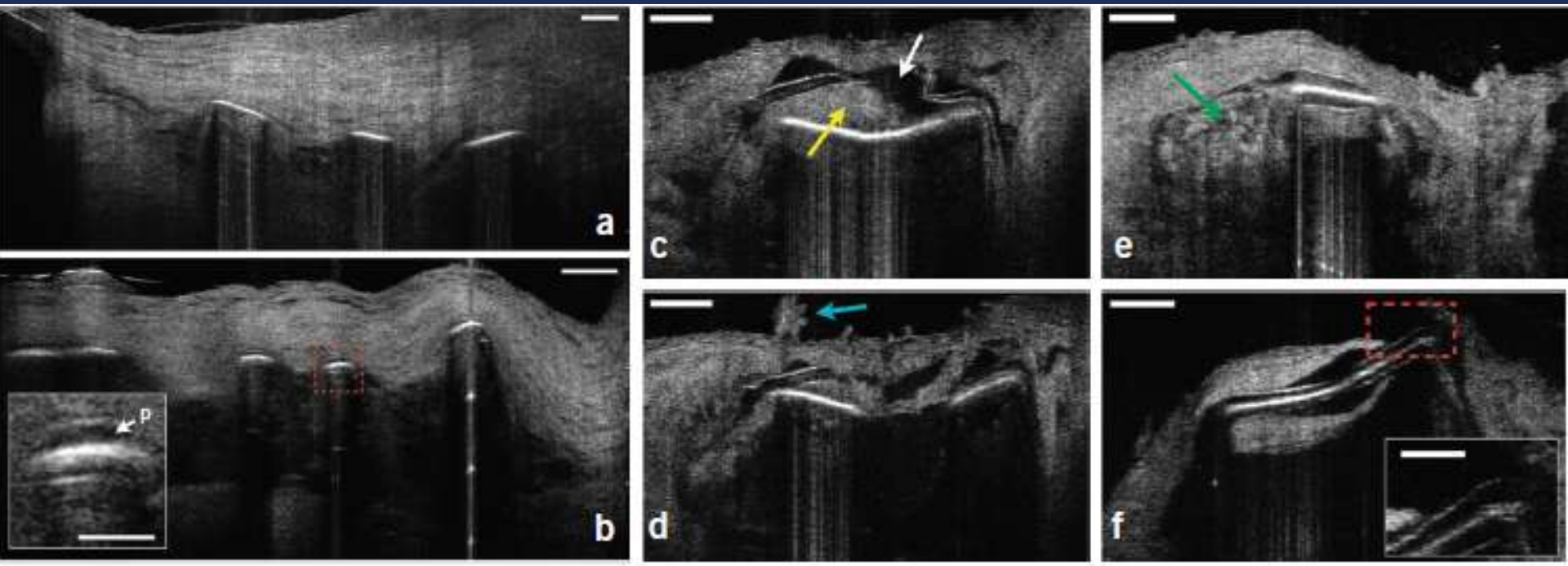
Ενσωμάτωση απεικονιστικών τεχνικών)





Raber et al, Eurointervention 2012

Micro OCT



Liu et al, Nat Med 2011 17(8)

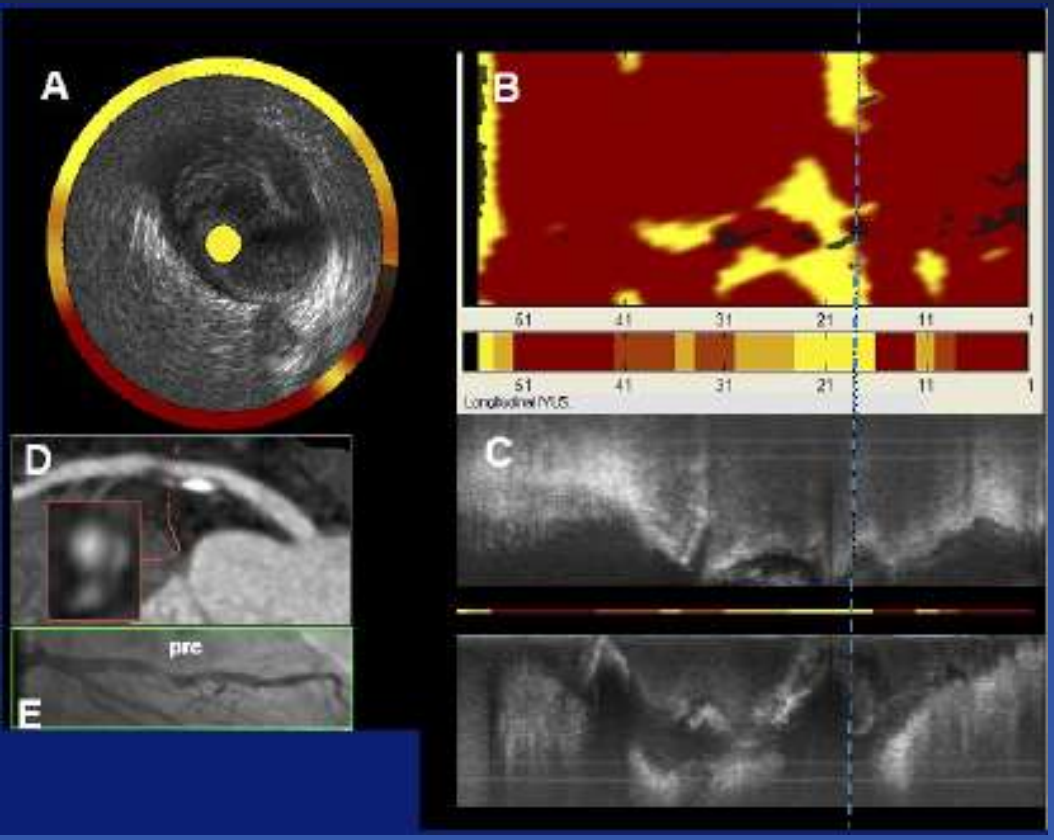
CONCLUSIONS

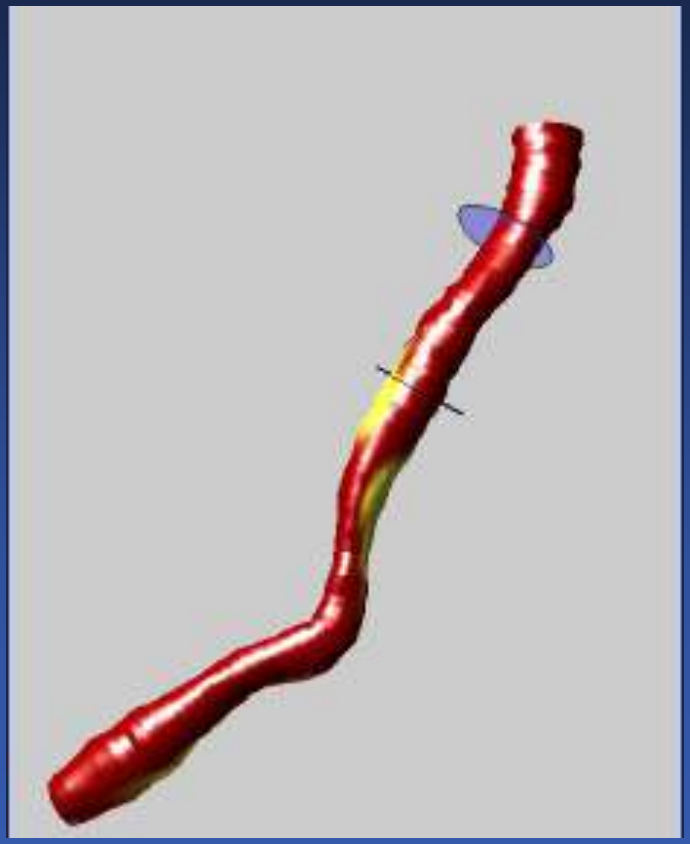
- OCT and IVUS are nowadays considered as important modalities for the evaluation of the morphological characteristics of a coronary plaque, for the guidance of the PCI, and for the assessment of its result
- Both OCT and IVUS are important tools for the understanding of the natural history of coronary artery disease and the evaluation of the VP

CONCLUSIONS /2

- The combination of methods that assess the morphological and functional characteristics of the plaque may be the future solution for the full understanding the pathophysiology of acute coronary events

Συνδυασμός NIR και IVUS – Τρισδιάστατη αναπαράσταση αγγείου

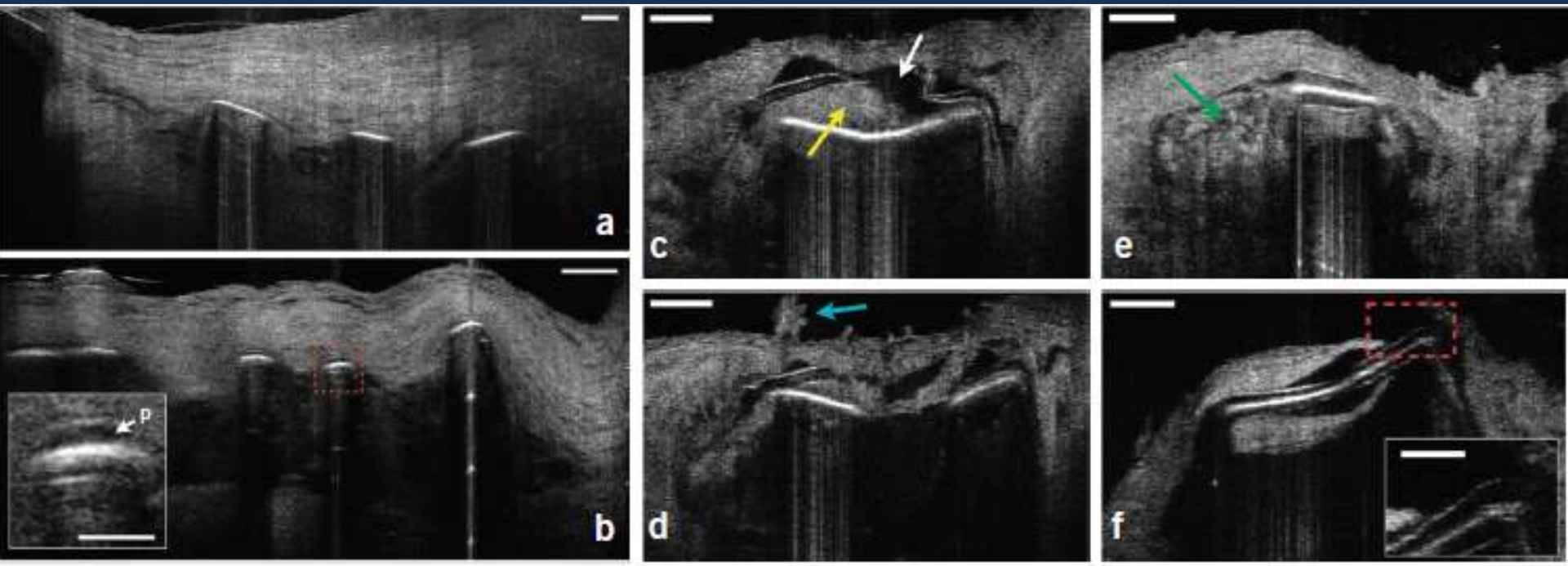




Schultz et al, JACC 2010

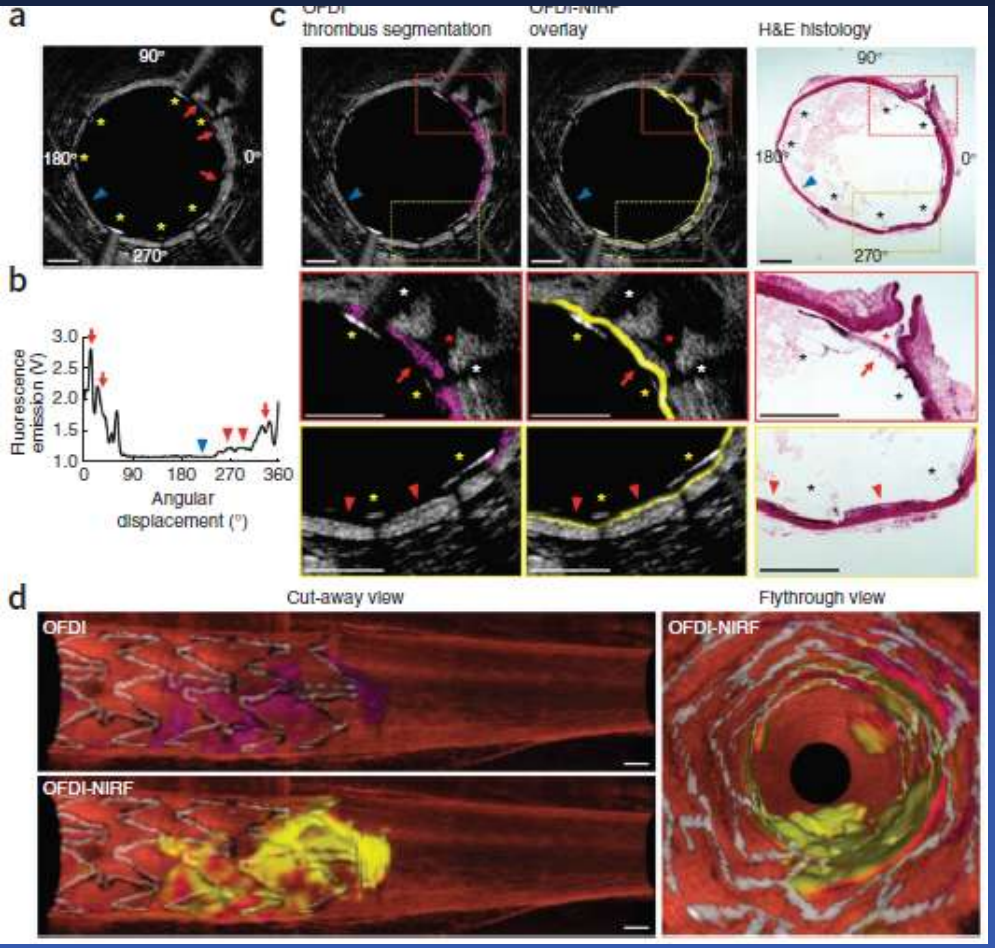
Wentzel et al, Circ Cardiovasc Imaging. 2010 Nov 1;3(6):e6-7

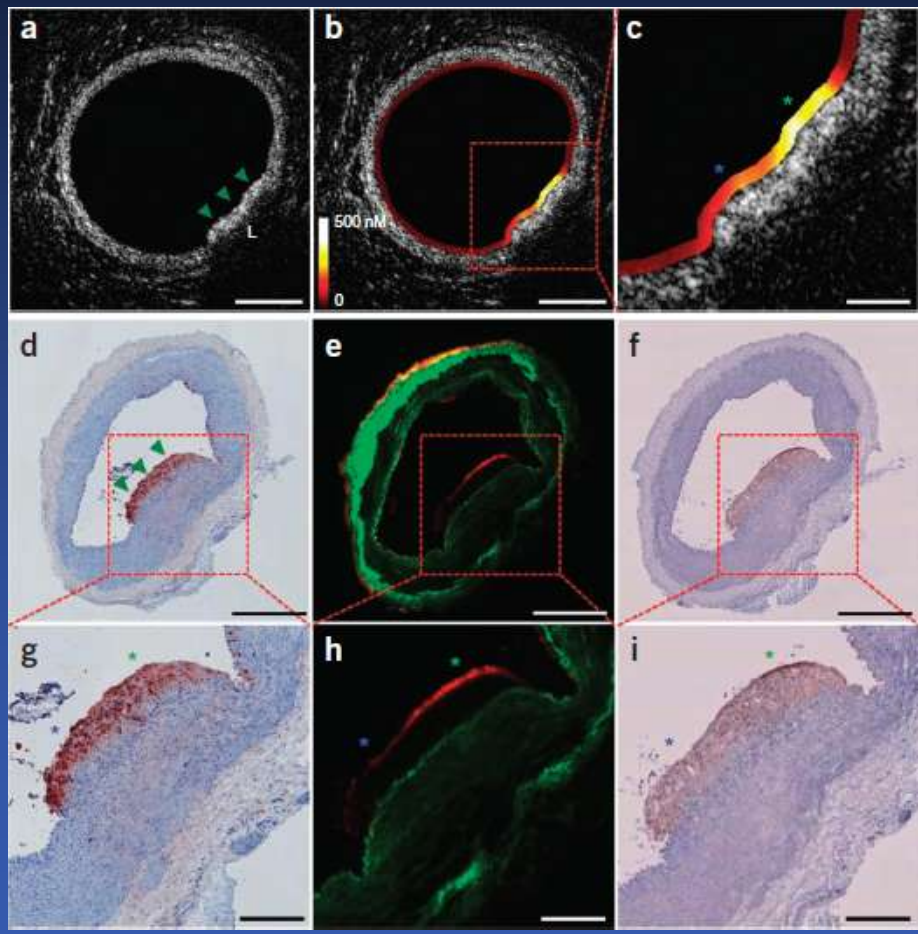
Micro OCT



Liu et al, Nat Med 2011 17(8)

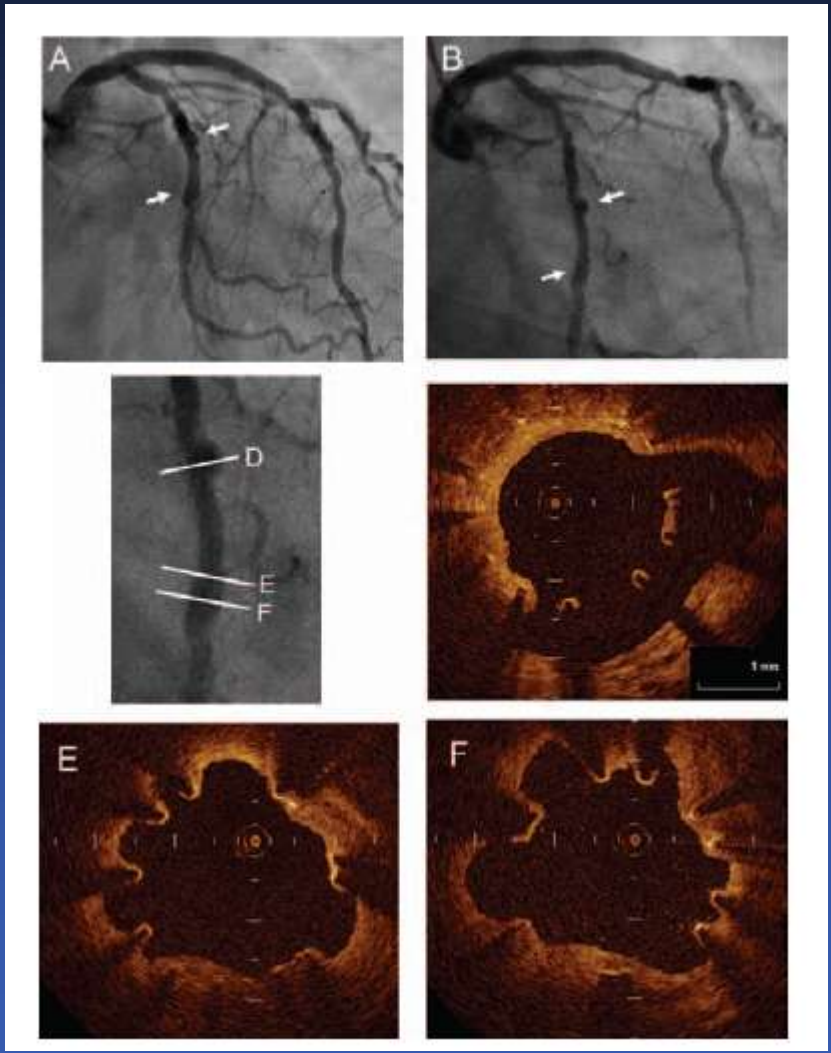
OCT - NIRF





Yoo et al, Nat Med 2011 17(12)

Peri-stent contrast staining (PSS).



Abnormal angiographic coronary dilatation, <50% of the reference vessel, at the site of sirolimus-eluting stent implantation, suggesting contrast staining outside the stent struts

Peri-stent contrast staining appeared to be associated with subsequent target-lesion revascularization and very late stent thrombosis.

PSS might be closely associated with 2 different optical coherence tomography findings,
(multiple interstrut hollows) MIH
and incomplete stent apposition,
in lesions after sirolimus-eluting stent implantation.

Peri-stent contrast staining (PSS)

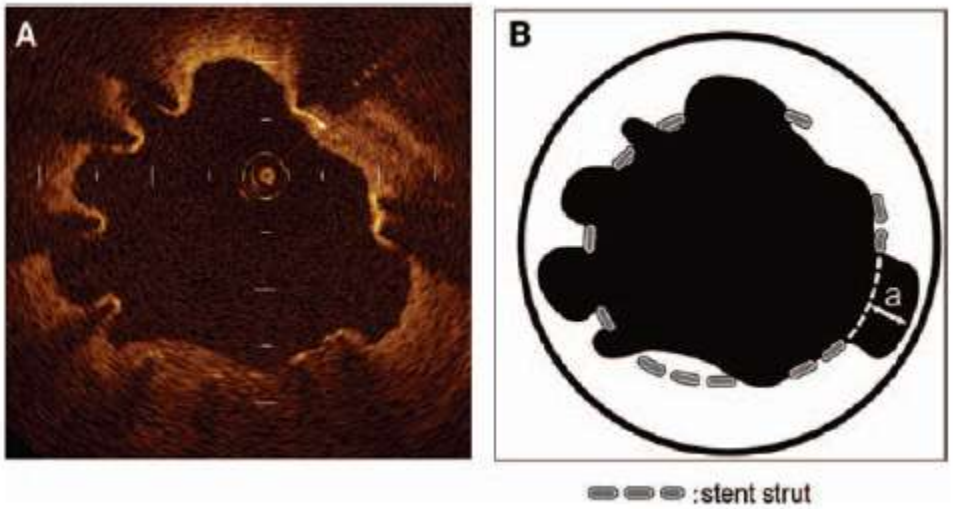
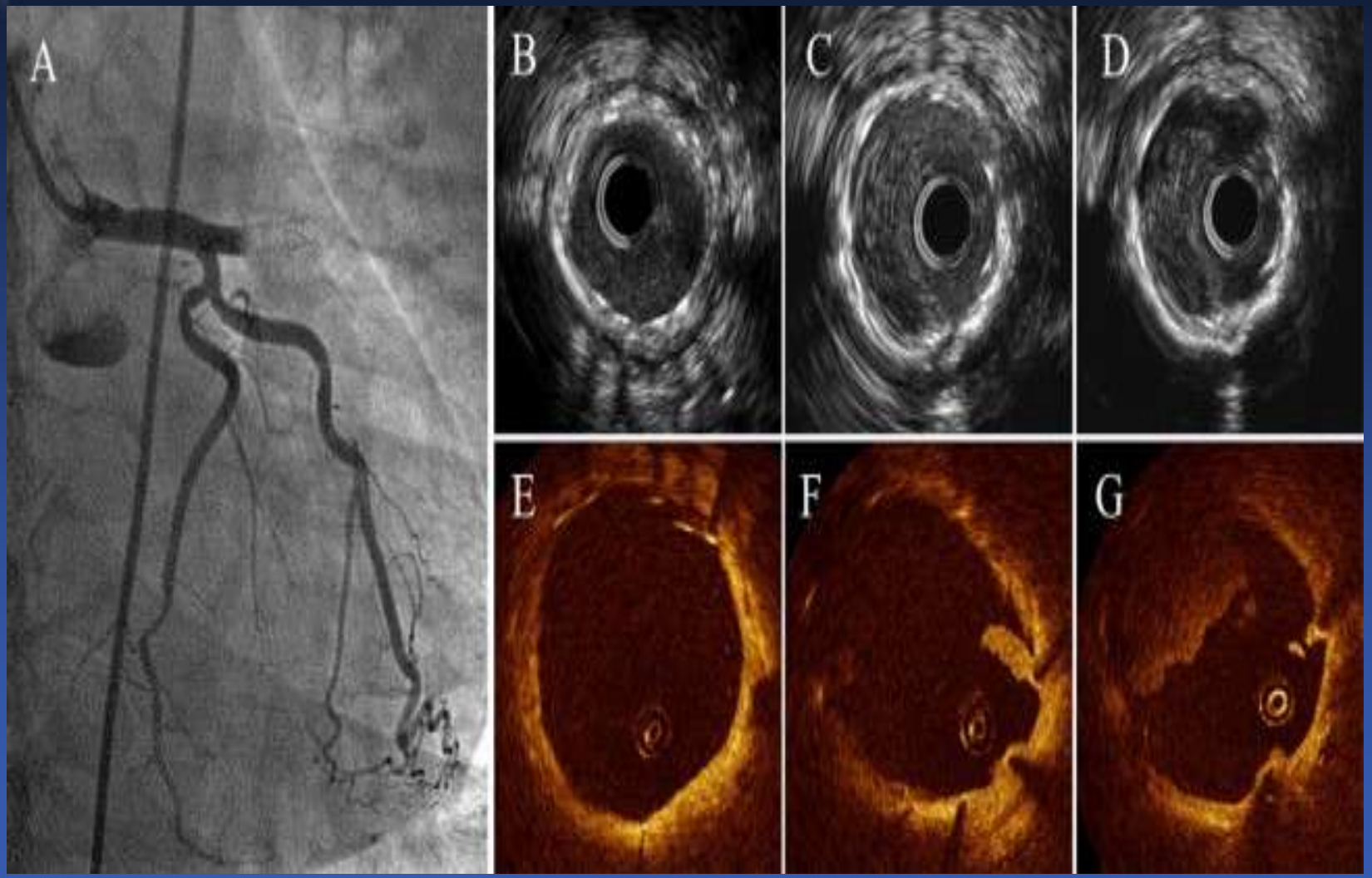


Figure 1. Representative case and schema of multiple interstruts hollows (MIH). **A**, Representative case of MIH. **B**, Schema of MIH. Hollows existed between and outside well-apposed stent struts. The maximum depth of the hollow (**A**) was >0.5 mm.

Circ Cardiovasc Interv. 2012;5:00-00.

Uncovered struts in pts with late stent thrombosis seen by OCT



Guagliumi et al, JACC interv, 2012

EuroPCR 2012

CLI-OPCI registry 1 yr results:

OCT guidance on top of angiography was associated with significant clinical benefits

	OCT (n = 335)	Angiography Alone (n = 335)	P Value
Death	3.3%	6.9%	0.035
Cardiac Death	1.2%	4.5%	0.010
MI	5.4%	8.7%	0.096
TLR	3.3%	3.3%	1.0
Definite Stent Thrombosis	0.3%	0.6%	0.624
Cardiac Death or MI	6.6%	13.0%	0.006
Cardiac Death, MI, or Repeat Revascularization	9.6%	15.1%	0.034

Prati et al

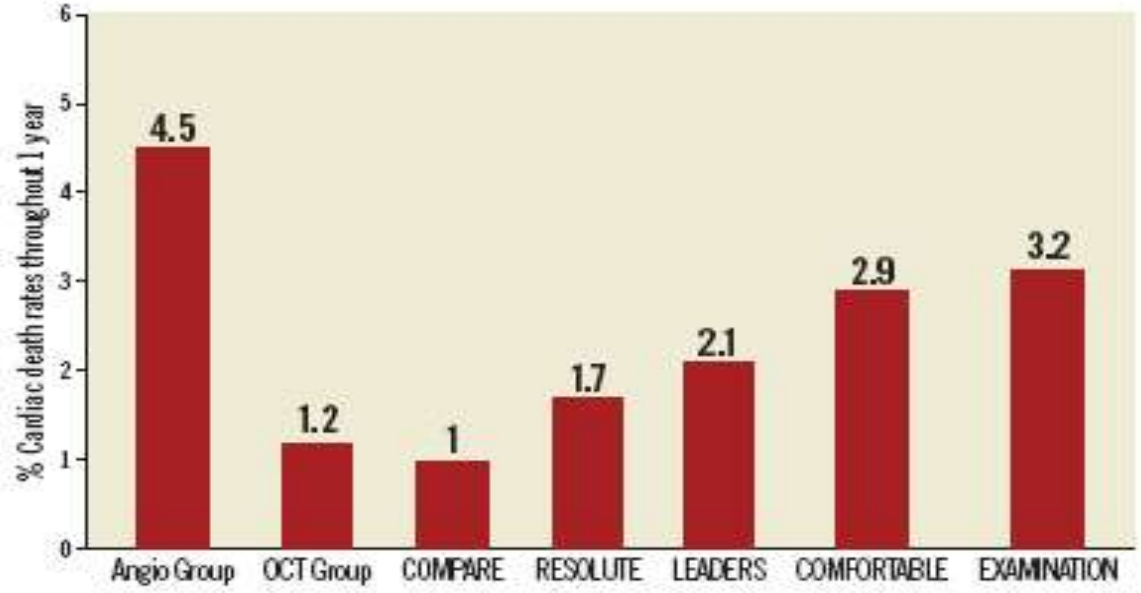


Figure 1. *Cardiac death rates in perspective. Cardiac death rates at one year follow-up as assessed in the study of Prati et al (angiography-guided and OCT-guided) are shown and compared to cardiac death rates observed in large scale stent trials including all-comers patients COMPARE (everolimus-eluting stent); RESOLUTE (everolimus-eluting stent); LEADERS (biolimus-eluting stent), and STEMI patients COMFORTABLE (biolimus-eluting stent) and EXAMINATION (everolimus-eluting stent).*

Pratti et al EuroIntervention. 2012, October [Epub ahead of print].

FAME TRIAL II

In patients with stable coronary artery disease for whom PCI was being considered, we assessed all stenoses by measuring FFR.

Patients in whom at least one stenosis was functionally significant (FFR, ≤0.80) were randomly assigned to FFR-guided PCI plus the best available medical therapy (PCI group) or the best available medical therapy alone (medical-therapy group).

Patients in whom all stenoses had an FFR of more than 0.80 were entered into a registry and received the best available medical therapy. The primary end point was a composite of death, myocardial infarction, or urgent revascularization.

Patients with stable coronary artery disease (CAD) in whom fractional flow reserve (FFR) identifies at least one "hemodynamically significant" stenosis face more than a 10-times-higher risk of urgent revascularization if they are initially treated with optimal medical therapy (OMT) rather than PCI.

N Engl J Med 2012; 367:991-1001DOI: 10.1056/NEJMoa1205361

Stent thrombosis

- 15 consecutive pts with ST undergoing combined IVUS/OCT

Table 3 Intravascular ultrasound findings

	Pre-intervention	Post-intervention
Total image length (mm)	47±17	52±22
Inflow/outflow disease	5/7	5/4
Reference segment lumen area (mm^2)	9.1±3.3	9.5±2.7*
Stent		
Minimal stent area (mm^2)	6.2±2.4	7.6±2.6***
Maximal stent area (mm^2)	10.1±2.7	10.9+2.2***
Minimal stent expansion (%)	69±14	79±14**
Severe underexpansion	10 (67%)	6 (40%)
MUSIC criteria	2 (13%)	6 (40%)
Maximal asymmetry	0.83±0.1	0.88±0.1
Thrombus	15 (100%)	12 (80%)
Maximal thrombus area (mm^2)	5.4±2.7	2.7±2.0***
Minimal residual lumen (mm^2)	1.9±0.9	6.1±2.1***
Obstruction largest thrombus (%)	58±18	22±11**
Maximal stent obstruction (%)	75.6±8.9	23.5±19.2***
Malapposition	6 (40%)	4 (27%)†
Maximal distance (mm)	0.72±0.3	0.5±0.3
Maximal area (mm^2)	1.9±0.7	1.3±0.6*
Length (mm)***	5.2±3.4	4.5±3.8*
Edge-dissections	2 (14%)	3 (20%)
Related side-branches	11 (73%)	11 (73%)

*p<0.1; **p<0.05; ***p<0.01.
†1 additional patient had malapposition in a newly implanted stent.

Table 4 Optical coherence tomography findings

	Pre-intervention	Post-intervention
Number of OCT runs	2.1±0.4	1.8±0.9
Total image length (mm)	36.7±8.3	36.1±10
Inflow/outflow disease	5/5	3/3
Reference segment lumen area (mm^2)	7.9±2.4	8.9±2.9
Stent		
Minimal stent area (mm^2)	4.7±2.1	6.8±2.9***
Maximal stent area (mm^2)	8.8±3.4	10.9±3.5***
Minimal stent expansion (%)	60±21	75±21**
Severe underexpansion	13 (87%)	6 (40%)
Maximal asymmetry	0.84±0.1	0.86±0.1
Thrombus	15 (100%)	15 (100%)
Red/White/Both	7/1/7	7/1/7
Shadowing Length (mm)	12.3±6	9.3±5***
Maximal thrombus area (mm^2)	4.7±2.5	2.4±1.6***
Minimal residual lumen (mm^2)	1.2±1.4	5.4±2.3***
Obstruction at largest thrombus (%)	63±25	24±13***
Maximal stent obstruction (%)	82±14	24±14***
Malapposition	6 (47%)	5 (33%)†
Maximal distance (mm)	0.97±0.4	0.56±0.4*
Maximal area (mm^2)	2.0±1.2	0.86±0.9*
Length (mm)	6.7±4.5	4.9±3.4*
Uncovered struts	9 (60%)	9 (60%)
Number per image	4.6±2.7	4.6±2.3
Maximal Arc (°)	72±100	69±101
Associated in-stent restenosis	5 (33%)	–
Neoatherogenesis/plaque rupture	4 (24%) 1	–
Edge dissections	3 (20)	8 (54%)
Related side-branches	12 (80)	12 (80)

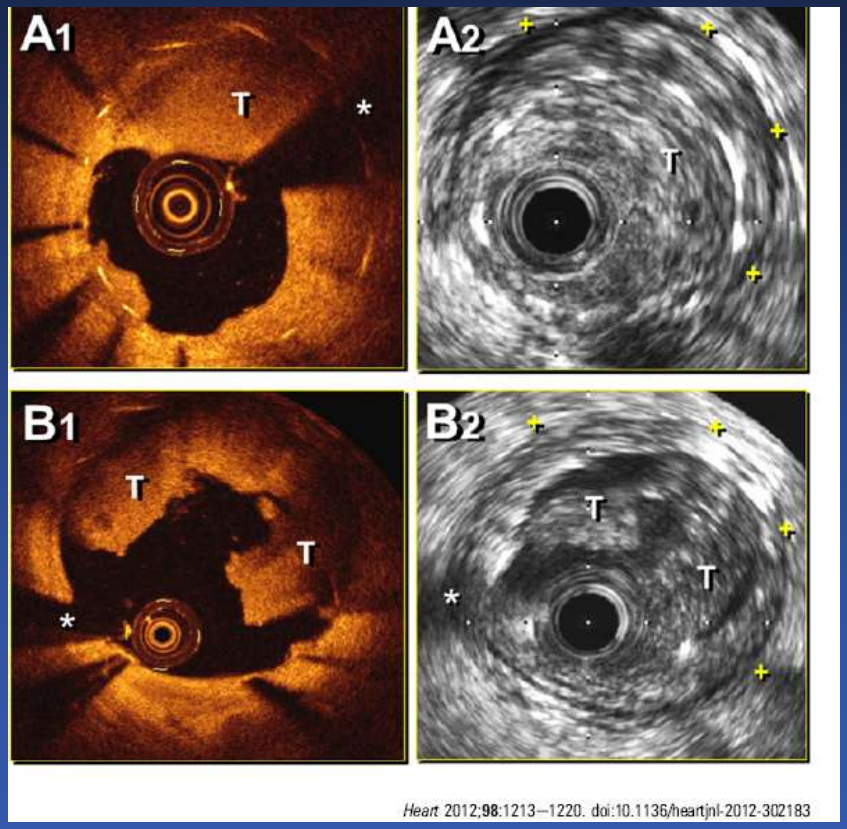
*p<0.1; **p<0.05; ***p<0.01.
†1 additional patient had malapposition in a newly implanted stent.
OCT, Optical coherence tomography.

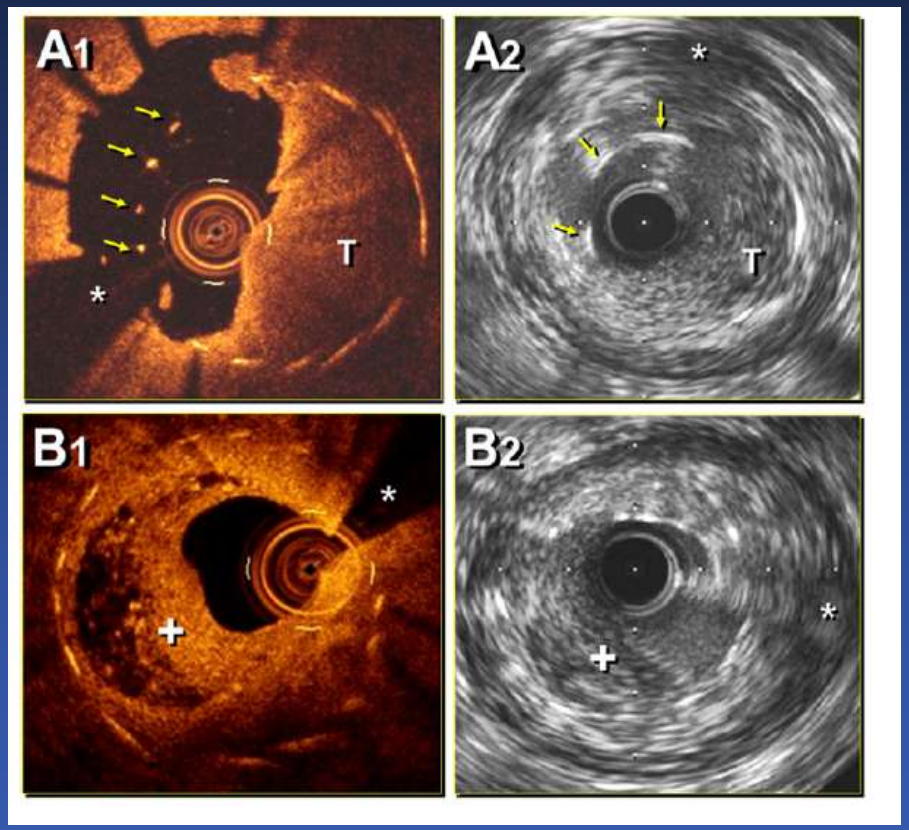
Before intervention, OCT visualised the responsible thrombus in all pts
Minimal stent area was 4.76±2.1 mm2 leading to severe stent underexpansion
malapposition (6pts)
nflow-outflow disease
uncovered struts (9pts) and associated in-stent restenosis (5pts)
was clearly recognised.

IVUS disclosed similar findings but achieved poorer visualisation of thrombuselumen interface and strut malapposition, and failed to recognise uncovered struts and associated neoatherosclerosis.

Heart 2012;98:1213e1220. doi:10.1136/heartjnl-2012-302183

Stent thrombosis





Heart 2012;98:1213–1220. doi:10.1136/heartjnl-2012-302183

Heart 2012;98:1213e1220. doi:10.1136/heartjnl-2012-302183

OCT – IVUS VH

Total 126 lesions

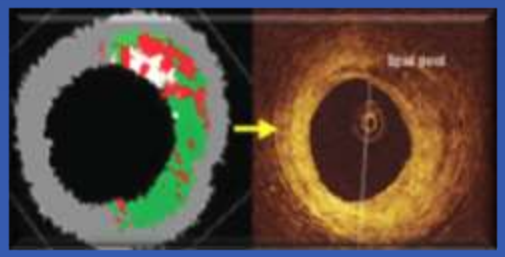
IVUS-derived TCFA (48.4%)

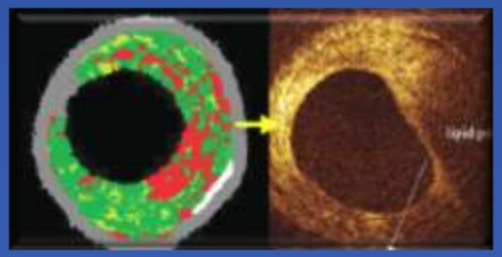
OCT Derived TCFA (28.6%)

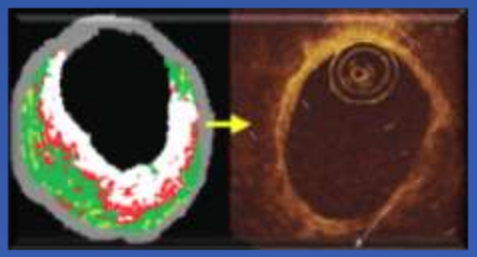
Non-thin-cap IVUS-derived TCFA (26.2%)

Definite TCFA (22.2%)

Non-NCCL OCT-derived TCFA 6.3%





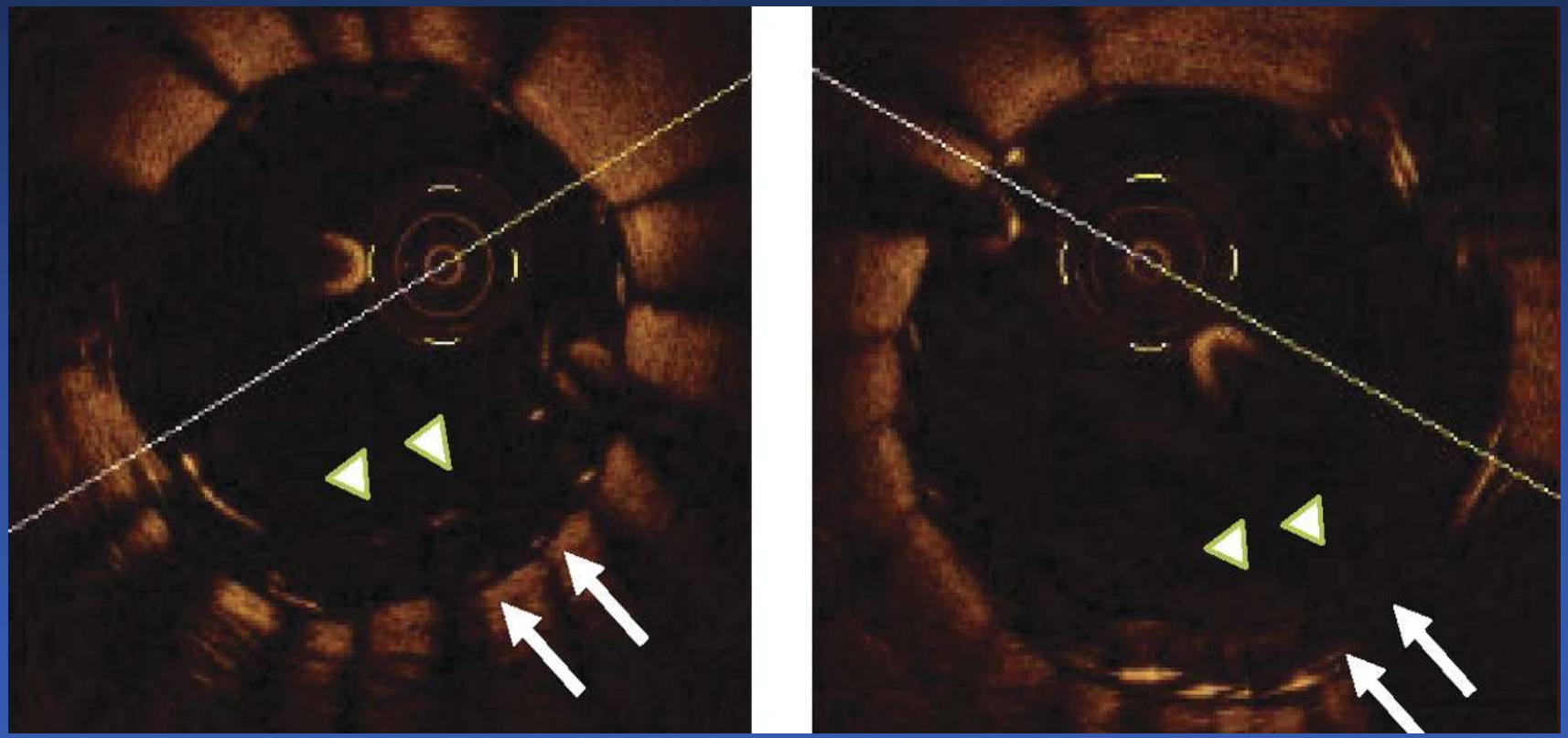


Sawada et al, EHJ (2008) 29, 1136–1146

OCT for detecting stent overlapping

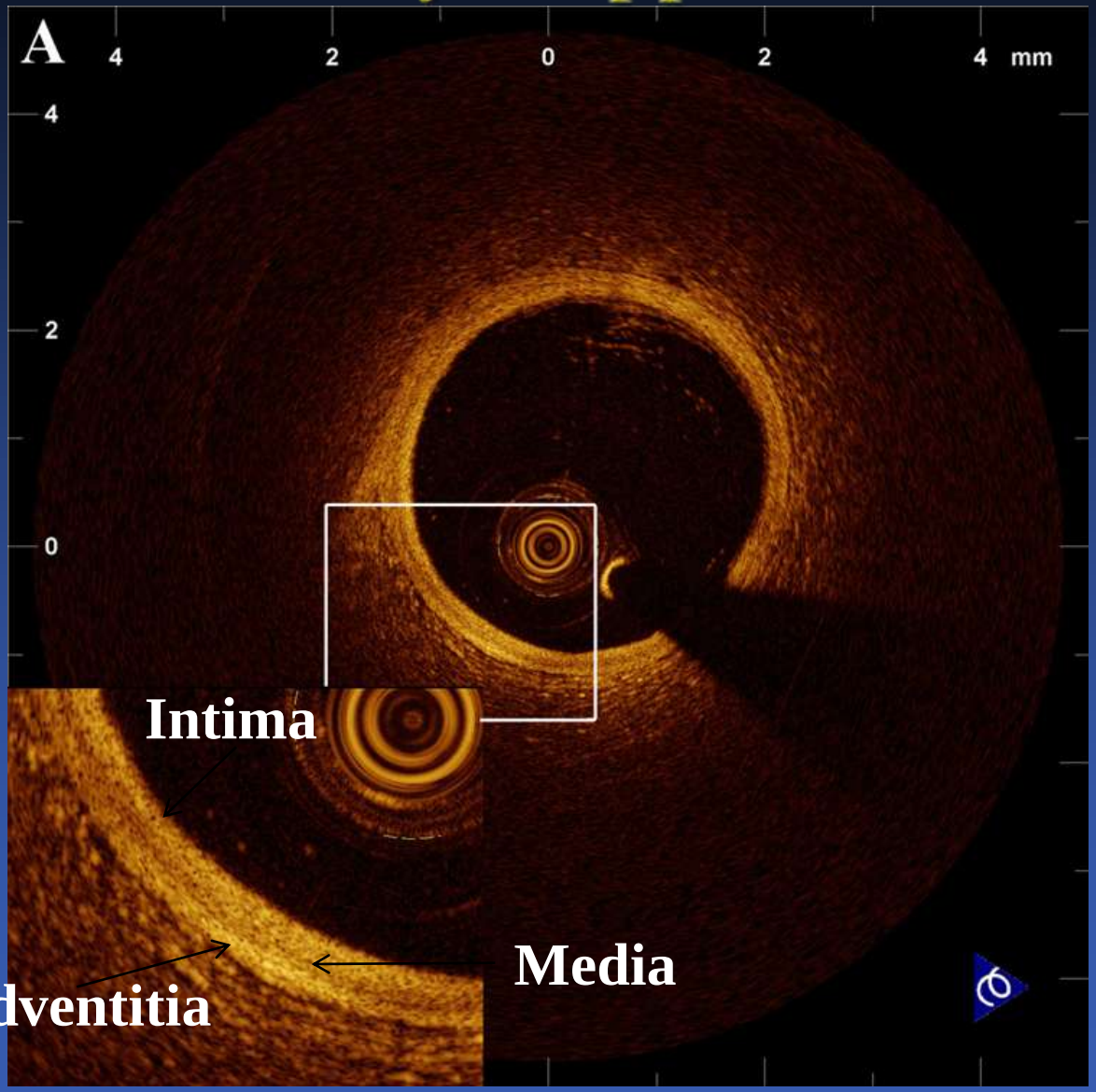
Stent overlapping in the left anterior descending artery

After additional high pressure inflation with a non-compliant oversized balloon shows a correction of the malapposition.



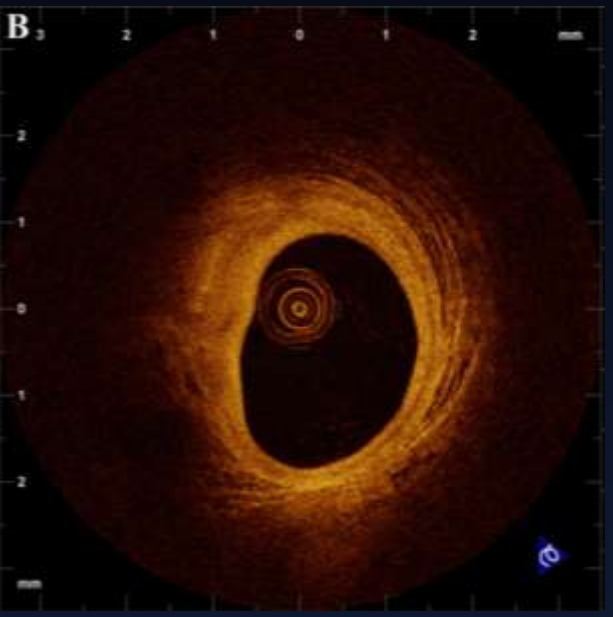
Prati… Toutouzas… DiMario, EHJ, 2012

Normal vessel morphology in vivo
Three-layer appearance

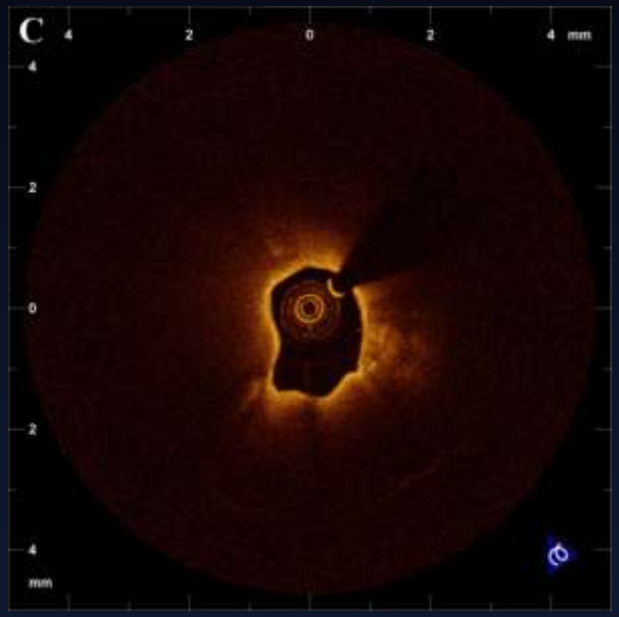


Karanasos et al, CurrCardiovascImag Rep 2012

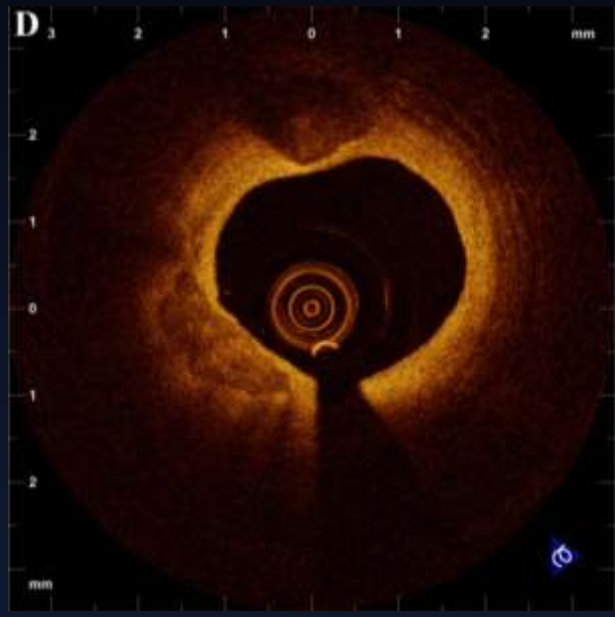
In vivo plaque morphologies



Fibrous plaque/
Intimal thickening



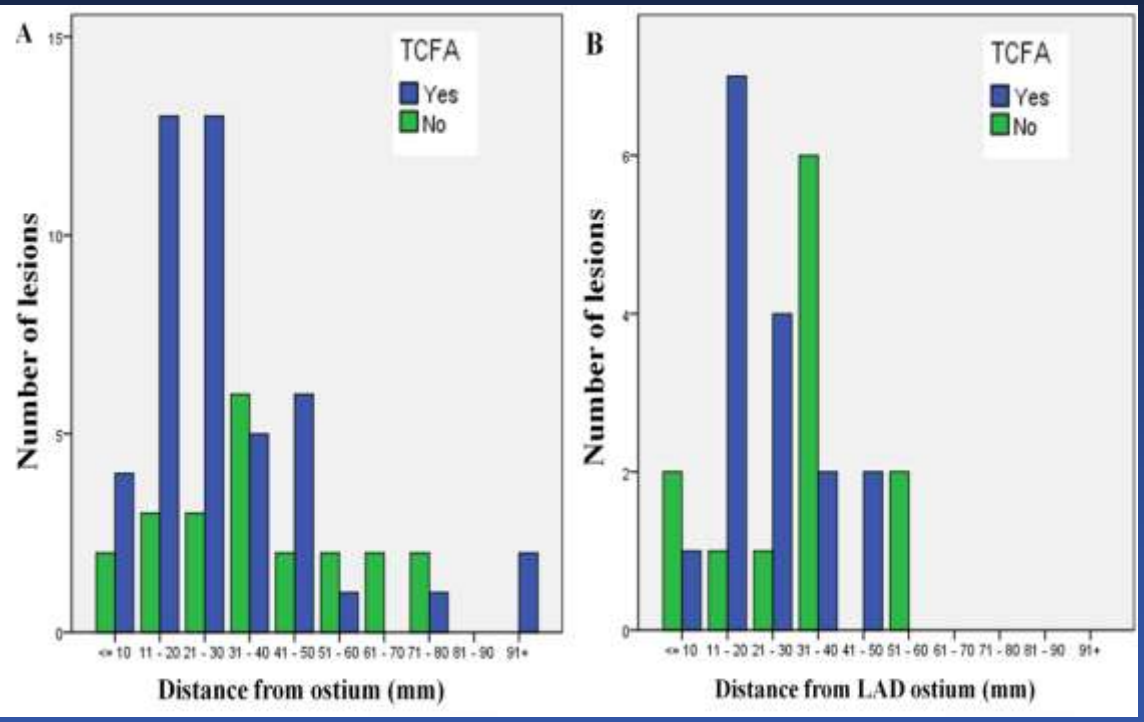
Lipid-rich plaque
NC fibroatheroma



Fibrocalcific plaque

Karanasos et al, CurrCardiovascImag Rep 2012

Optical Coherence Tomography Assessment of the Spatial Distribution of Culprit Ruptured Plaques and Thin-cap Fibroatheromas in Acute Coronary Syndrome



- 74 patients presenting with ACS that underwent OCT study of the culprit lesion..
- The distance from the ostium was lower for culprit ruptured plaques versus culprit non-ruptured plaques ($p<0.01$), particularly in the LAD and the LCx arteries.
- The majority of culprit ruptured plaques (68.9%) was located in the proximal 30mm of the coronary arteries.
- Distance from ostium≤30.54mm predicted plaque rupture with 71.1% sensitivity and 68.2% specificity.
- Culprit lesions in the proximal 30mm are associated with rupture ($p<0.05$), TCFA ($p<0.05$), and lower minimal cap thickness ($p<0.05$).

Toutouzas, Karanasos,Synetos…Stefanadis. Eurointervention 2012 in press