Ανδρέας Συνετός
Α Καρδιολογική Κλινική Πανεπιστημίου Αθηνών

Οπτική Συνεκτική Τομογραφία
• No conflict of interest
Balance Research/Clinical
Need for Intravascular Imaging

Intravascular Imaging: From sound to light

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

OCT
Far superior resolution (10x), but limited penetration (<2mm)
## OCT vs IVUS vs VH vs IVMRI

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

Imaging Wire 0.014" Through PCI Balloon

Figure 1

Clinical Application of OCT

1991

2002 2004

Intracoronary Imaging

Imaging Wire 0.019"
"Occlusive Method"

Regar et al. Eur Heart J 2004 (Abstract)
Clinical Application of OCT

1991

Intracoronary Imaging

2002  2004  2007

Imaging Wire 0.019"
"Non-Occlusive Method"
Selective Guide Catheter Engagement

Prati et al. Circ J 2008
Clinical Application of OCT

1991


Intercoronary Imaging

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

Barlis et al., EuroInterv.2009

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

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

Takarada et al, CCI 2009
Ανάλυση εικόνων OCT

• Ενταση σήματος (intensity)
• Απόσβεση σήματος (attenuation)
• Ορια ιστου
Intimal thickening

A Area: 4.31mm^2
B Length: 2.33mm
C Area: 7.48mm^2
D Length: 3.05mm
Lipid Pool

Sensitivity: 90-95% Specificity: 90-98%
Kawasaki et al., JACC 2006;48:81-88

Yabushita et al, Circulation. 2002;106:1640-1645
High attenuation

1st Department of Cardiology, University of Athens
Calcific depositions

Sensitivity: 95-100%, Specificity: 97-100%
Kawasaki et al., JACC 48;2006:81-88

n=357 segments

Yabushita et al, Circulation. 2002;106:1640-1645
Low attenuation

1st Department of Cardiology. University of Athens
Rupture
Thrombus
Based on the intensity attenuation

White Thrombus

Red Thrombus

Sensitivity: 90%
Specificity: 92%
for identifying the type of thrombus
(Cut-off value 250 \( \mu \text{m} \))

Kume et al, Am J Cardiol 2006;97:1713–1717
Macrophage Content

Sensitivity: 100% Specificity: 100% for caps >10% CD68 (raw)
Sensitivity: 70% Specificity: 75% for caps >10% CD68 (log 10)

OCT measurements of macrophage density were independent of fibrous cap thickness
Intraplaque Hemorrhage (?)
Neovascularization (?)
Well apposed with neointima coverage    Well apposed with no neointima coverage    Mallaposed
Evaluation of stent coverage by OCT -- ODESSA

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
Haziness...
...Dissection & Thrombus

Toutouzas, Synetos ... Stefanadis, Clin Cardiol 2007
Recanalized Thrombus
IVUS: απεικόνιση θρόμβου

Chromaflo™ Imaging

Φυσιολογικός αυλός

Θρόμβος
Stent thrombosis

Heart 2012;98:1213e1220. doi:10.1136/heatjnl-2012-302183
Stent thrombosis, restenosis or underexpansion?
Inferior STEMI

Toutouzas, Synetos, Stefanadis Int J Cardiol. 2011 Oct 20;152(2)
OCT evaluation of the LCx

Toutouzas, Synetos, Stefanadis Int J Cardiol. 2011 Oct 20;152(2)
OCT-Based Diagnosis and Management of STEMI Associated With Intact Fibrous Cap

Francesco Prati, MD, Ph.D.*,† Shiro Uemura, MD, Ph.D.,‡ Geraud Souteyrand, MD, Ph.D.,§ Remu Virmani, MD,‖ Pascal Mottreff, MD, Ph.D.,§ Luca Di Vito, MD, Ph.D.,*‡ Giuseppe Biondi-Zoccai, MD, Ph.D.,¶ Jonathan Halperin, MD,,# Valentin Fuster, MD, Ph.D.,## Yukio Ozaki, MD, Ph.D.,†† Jagat Narula, MD, Ph.D,#

Rome, Italy; Nara, Toyosake, Japan; Clermont-Ferrand, France; New York, New York; Gaithersburg, Maryland; and Madrid, Spain

31 patients presenting with STEMI and FD-OCT assessment of plaque erosion after aspiration thrombectomy.

Group 1) 12 pts with subcritically occlusive plaque treated with dual antiplatelet therapy without percutaneous revascularization
Group 2) 19 pts treated with angioplasty and stenting
OCT-Based Diagnosis and Management of STEMI Associated With Intact Fibrous Cap

Francesco Prati, MD, PhD,*,† Shiro Uemura, MD, PhD,‡ Geraud Souteyrand, MD, PhD,§ Renu Virmani, MD,‖ Pascal Motreff, MD, PhD,§ Luca Di Vito, MD, PhD,† Giuseppe Biondi-Zoccai, MD, PhD,†‡ Jonathan Halperin, MD,# Valentin Fuster, MD, PhD,## Yukio Ozaki, MD, PhD,†† Jagat Narula, MD, PhD#

Rome, Italy; Nara, Toyoake, Japan; Clermont-Ferrand, France; New York, New York; Gaithersburg, Maryland; and Madrid, Spain

At a median follow-up of 753 days, all patients were asymptomatic, regardless of 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.
Expert review document part 2: methodology, terminology and clinical applications of optical coherence tomography for the assessment of interventional procedures

Francesco Prati¹,²*, Giulio Guagliumi³, Gary S. Mintz⁴, Marco Costa⁵, Evelyn Regar⁶,⁷, Takashi Akasaka⁸, Peter Barlis⁹, Guillermo J. Tearney¹⁰,¹¹, Ilk-Kyung Jang¹², Elosia Arbustini¹³, Hiram G. Bezerra⁵, Yukio Ozaki¹⁴, Nico Bruining⁶,⁷, Darius Dudek¹⁵, Maria Radu⁶,⁷, Andrejs Erglis¹⁶, Pascale Motreff¹⁷, Fernando Alfonso¹⁸, Costas Toutouzas¹⁹, Nieves Gonzalo²⁰, Corrado Tamburino²¹, Tom Adriaenssens²², Fausto Pinto²³, Patrick W.J. Serruys⁶,⁷, and Carlo Di Mario²⁴,²⁵, for the Expert’s OCT Review Document
Malapposed and Uncovered Struts of the Everolimus-Eluting Bioresorbable Scaffold With OCT

Gomez-Lara et al, JACC interv, 2011
3D OCT
Αξιολόγηση σημαντικότητας βλάβης

Εκτίμηση σύστασης πλάκας

Καθοδήγηση της αγγειοπλαστικής (πριν από το stent)

Εκτίμηση του αποτελέσματος της αγγειοπλαστικής

Σύγκριση μεθόδων

Θρόμβωση & επαναστένωση του stent

Αξιολόγηση επιπλοκών μετά από το stent
Area-length measurements
OCT-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 area (MLA) between OCT and IVUS measurement

* p < 0.001 vs. OCT
Difference of minimum lumen diameter (MLD) among OCT, IVUS and QCA measurement

<table>
<thead>
<tr>
<th></th>
<th>OCT</th>
<th>IVUS</th>
<th>QCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLD (mm)</td>
<td>1.94±0.70</td>
<td>2.10±0.59</td>
<td>1.85±0.77</td>
</tr>
</tbody>
</table>

8%  
*p < 0.001 vs. OCT
† p = 0.002 vs. OCT
**OCT vs IVUS guided PCI**

**Angio Guidance**
- Is the lumen border at reference detectable?
  - Is the vessel border at reference detectable?
    - The largest lumen with PB<50%
      - Stent length = length between both reference
        - Stent size = mean lumen diameter of reference

**Randomization**
- 70 de novo Lesions
  - OCT guided (n=35)
    - Pre-OCT
      - OCT guided PCI
        - Final-OCT
          - Final documented IVUS
  - IVUS guided (n=35)
    - Pre-IVUS
      - IVUS guided PCI
        - Final-IVUS
          - Final documented OCT

_Habara et al, Circ Interv; 2012;5_
IVUS guided showed bigger stent area.

<table>
<thead>
<tr>
<th></th>
<th>OCT n=35</th>
<th>IVUS n=35</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balloon Diameter (mm)</td>
<td>3.4±0.6</td>
<td>3.2±0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Balloon Pressure (atm)</td>
<td>13.5±3.4</td>
<td>16.1±4.7</td>
<td>0.03</td>
</tr>
<tr>
<td>QCA RVD (mm)</td>
<td>3.0±0.5</td>
<td>3.0±0.5</td>
<td>0.56</td>
</tr>
<tr>
<td>QCA MLD (mm)</td>
<td>2.8±0.5</td>
<td>2.9±0.4</td>
<td>0.22</td>
</tr>
<tr>
<td>IVUS Reference Area (mm²)</td>
<td>9.2±3.3</td>
<td>9.1±3.1</td>
<td>0.98</td>
</tr>
<tr>
<td>IVUS MSA (mm²)</td>
<td>6.1±2.2</td>
<td>7.1±2.1</td>
<td>0.04</td>
</tr>
<tr>
<td>OCT MSA (mm²)</td>
<td>5.7±2.1</td>
<td>6.9±2.4</td>
<td>0.03</td>
</tr>
<tr>
<td>OCT Stent malapposition (%)</td>
<td>0.4±0.7</td>
<td>0.6±0.8</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Habara et al, Circ Interv; 2012; 5
### OCT vs CAS vs IVUS

<table>
<thead>
<tr>
<th>Finding</th>
<th>OCT (n=30)</th>
<th>CAS (n=30)</th>
<th>IVUS (n=30)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rupture</td>
<td>22 (73%)</td>
<td>14 (47%)</td>
<td>12 (40%)</td>
<td>0,021</td>
</tr>
<tr>
<td>Erosion</td>
<td>7 (23%)</td>
<td>1 (3%)</td>
<td>0</td>
<td>0,003</td>
</tr>
<tr>
<td>Thrombus</td>
<td>30 (100%)</td>
<td>30 (100%)</td>
<td>10 (33%)</td>
<td>&lt;0,001</td>
</tr>
</tbody>
</table>

Kubo et al, JACC 2007
IVUS vs OCT for evaluation of restenosis

Detection of minimal restenosis

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

Suzuki et al., JACC intv 2008
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

- Increased Plaque size
  - Positive remodeling
- Increased Necrotic core
  - ~34% of plaque area
  - ~3.8 mm² & ~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

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

<table>
<thead>
<tr>
<th>Correlates</th>
<th>Hazard Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictors of patient-level events†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulin-requiring diabetes</td>
<td>3.32 (1.43–7.72)</td>
<td>0.005</td>
</tr>
<tr>
<td>Previous percutaneous coronary intervention</td>
<td>2.03 (1.15–3.59)</td>
<td>0.02</td>
</tr>
<tr>
<td>Predictors of events at individual lesion sites‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plaque burden ≥70%</td>
<td>5.03 (2.51–10.11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Thin-cap fibroatheroma</td>
<td>3.35 (1.77–6.36)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MLA ≤4.0 mm²</td>
<td>3.21 (1.61–6.42)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Μελέτη PROSPECT: VH-TCFA ως προγνωστικός δείκτης σε επίπεδο βλάβης
Overestimation of fibroatheroma incidence by OCT and underestimation by VH compared to histology.

Addition of VH to OCT imaging helped to properly classify an extra 8% of plaques.

Goderie et al, Int J Cardiovasc Imaging April 2010
Vulnerable plaque characteristics are associated with thrombolysis failure

Residual thrombus burden one day after fibrinolysis was greater in rupture compared to erosion in patients with successful fibrinolysis for STEMI.

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

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

*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

Non-culprit lipid-rich plaque with thick cap
Napkin ring – significant lesion
Red thrombus
MLS - white thrombus
Plaque rupture
TCFA

Toutouzas..Synetos..Stefanadis, Heart July 2010
Neoatherosclerosis is frequent and more common among symptomatic patients. Importantly, neointimal rupture is associated with ACS late after stent implantation.

Specific morphological characteristics, such as cap thickness and macrophage infiltration are associated with rupture of neoatherosclerotic plaques.
Thermal Heterogeneity Within Human Atherosclerotic Coronary Arteries Detected In Vivo: A New Method of Detection by Application of a Special Thermography Catheter

Christodoulos Stefanadis, Leonidas Diamantopoulos, Charalambos Vlachopoulos, Eleftherios Tsiamis, John Dernellis, Konstantinos Toutouzas, Elli Stefanadi and Pavlos Toutouzas

Circulation 1999;99:1965-1971

Stefanadis et al. Circulation 1999
Correlation Between Morphologic Characteristics and Local Temperature Differences in Culprit Lesions of Patients With Symptomatic Coronary Artery Disease

**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 $\Delta T$ and $R_i$

Remodeling index ($R_i$) is positively correlated with the difference between atherosclerotic plaque temperature and background temperature ($\Delta T$) ($p < 0.01; r = 0.59$).

Figure 5  $\Delta T$ in Nonruptured and Ruptured Plaques

The presence of ruptured plaque is associated with increased $\Delta T$ 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 $\Delta T$. Abbreviations as in Figures 1 and 2.
OCT - Thermography

ΔΤ=0.03 °C

Cap thickness 100 μm

Toutouzas, Synetos, … Stefanadis ACC 2009
Microwave Radiometry: Comparison of OCT-detected atheromatosis with thermal heterogeneity

$\Delta T = 0.8^\circ C$

Toutouzas, Synetos... Stefanadis., ESC 2010
Experimental study

Measurements with MR are correlated with measurements with IVT

$R = 0.61$, $p < 0.001$

Toutouzas...Syntos...Stefanadis, Atherosclerosis 2010
Best cutoff point for small vessels was

1.62 mm² for OCT and 2.36 mm² for IVUS.
Optical coherence tomography criteria for defining functional severity of intermediate lesions: a comparative study with FFR.

Pawlowski T, Prati F, Kulawik T, Ficarra E, Bil J, Gil R.

Author information
Department of Invasive Cardiology, Central Clinical Hospital of the Ministry of Interior, Warsaw, Poland, pawtom@gmail.com.

Abstract
Fractional flow reserve (FFR) is the gold standard in the assessment of severity of the coronary stenosis. The aim of the study was to compare optical coherence tomography (OCT) obtained intermediate coronary lesions lumen areas measurements with FFR assessments, with the goal to develop an OCT threshold to identify significant coronary stenosis. 48 patients (mean age 65 ± 10 years) was enrolled for the study. Within this population, 71 intermediate coronary lesions were investigated using both FFR and OCT. High dose bolus of Adenosine (120 μg) was used to obtain coronary hyperemia. OCT imaging was performed using non-occlusive technique to assess minimal lumen area (MLA) and diameter. The OCT cut-off value that showed the best correlation with the FFR cut-off of 0.80 was the MLA less than 2.05 mm² (accuracy 87%, sensitivity 75%, specificity 90%, p < 0.001). The study did not disclose any relationship between FFR value and the lesion length. Vessel size influenced the OCT cut-off values, with greater values being found in presence of arteries with a reference diameter greater than 3.0 mm. OCT derived minimal lumen area might be complementary to FFR measurement in identifying ischemia related lesions. Further studies are warranted to assess threshold values in relation to vessel size and location.
GUIDING NEW THERAPIES

1. EXPERIMENTAL

2. CLINICAL
Inhibition of calcification by zolendronic acid

Toutouzas, Synetos, Benetos, Stefanadis ACC2014
Ανίχνευση θερμικής ετερογένειας σε αθηρωματικές αορτές κουνελιών

Toutouzas..Synetos..Stefanadis., Atherosclerosis 215 (2011) 82–89
OCT images
28 day follow-up

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

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

Stefanadis et al, AHA 2009
PET NaF combined with OCT for the evaluation of VP
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
Shear Stress Map of the Reconstructed RCA

First Department of Cardiology, University of Athens
Aristotle University of Thessaloniki
Harvard Medical School
Clinical validation of an algorithm for rapid and accurate automated segmentation of intracoronary optical coherence tomography image
Μελέτη PREDICTION: Συσχέτιση shear stress με μελλοντικά συμβάματα

Το χαμηλό shear stress ήταν ανεξάρτητος προγνωστικός παράγοντας για εξέλιξη βλάβης

Hybrid IVUS-OCT catheters

Li et al, Catheter CardiovascInterv 2012
Miniature integrated (OCT) (IVUS) probe, with 1.5-mm-long rigid part and 0.9-mm outer diameter,
5.4.2 IVUS: Recommendations
CLASS IIa
1. IVUS is reasonable for the assessment of angiographically indeterminant left main CAD. (Level of Evidence: B)
2. IVUS and coronary angiography are reasonable 4 to 6 weeks and 1 year after cardiac transplantation to exclude donor CAD, detect rapidly progressive cardiac allograft vasculopathy, and provide prognostic information. (Level of Evidence: B)
3. IVUS is reasonable to determine the mechanism of stent restenosis. (Level of Evidence: C)

CLASS IIb
1. IVUS may be reasonable for the assessment of non-left main coronary arteries with angiographically intermediate coronary stenosis (50% to 70% diameter stenosis). (Level of Evidence: B)
2. IVUS may be considered for guidance of coronary stent implantation, particularly in cases of left main coronary artery stenting. (Level of Evidence: B)
3. IVUS may be reasonable to determine the mechanism of stent thrombosis. (Level of Evidence: C)

CLASS III: NO BENEFIT
1. IVUS for routine lesion assessment is not recommended when revascularization with PCI or CABG is not being contemplated. (Level of Evidence: C)

5.4.3 Optical Coherence Tomography
The appropriate role for optical coherence tomography in routine clinical-decision making has not been established.
# SCAI CONSESUS

Recommendations for Use of FFR, IVUS, and OCT

<table>
<thead>
<tr>
<th><strong>IVUS</strong></th>
<th>Can determine optimal stent deployment and the size of the vessel undergoing stent implantation, ensuring proper fit.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Could appraise the significance of LM stenosis and assess whether or not revascularization is warranted.</td>
</tr>
<tr>
<td><strong>OCT</strong></td>
<td>Could determine optimal stent deployment with improved resolution compared with IVUS.</td>
</tr>
</tbody>
</table>

Lofti et al. - Catheterization and Cardiovascular Interventions 00:00–00 (2013)
Micro OCT

Liu et al, Nat Med 2011 17(8)
OCT images
28 day follow-up

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

Control
Lumen area: 6.19 mm²
Stent area: 6.88 mm²
Neointima thickness: 80 μm
Εφαρμογές IVUS-OCT

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- Αξιολόγηση επιπλοκών μετά από το stent
- Θρόμβωση & επαναστένωση του stent
- Σύγκριση OCT-IVUS
- Εκτίμηση σύστασης πλάκας
Economic evaluation of fractional flow reserve-guided percutaneous coronary intervention in patients with multivessel disease. FAME

Table 1. Mean Costs at 1 Year

<table>
<thead>
<tr>
<th></th>
<th>FFR</th>
<th>Angiography</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index Procedure and Hospitalization</td>
<td>$13,182 ± 9,667</td>
<td>$14,878 ± 9,509</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Overall</td>
<td>$14,315 ± 11,109</td>
<td>$16,700 ± 11,868</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>
• FFR reproducibility data from the landmark Deferral Versus Performance of PTCA in Patients Without Documented Ischemia (DEFER) trial was analyzed

• Two repeated FFR measurements in the same lesion, 10 min apart

• Outside the [0.75 to 0.85] FFR range, measurement certainty of a single FFR result is >95%

• However, closer to its cut-off, certainty falls to less than 80% within 0.77 to 0.83, reaching a nadir of 50% around 0.8

Pedraco et al., JACC Cardiovasc Interv. 2013 Mar;6(3):222
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.
Περιορισμοί αγγειογραφίας

LIMITATIONS OF CORONARY ANGIOGRAPHY

Coronary Cross-section

Angiogram silhouette

75%

25%

LIMITATIONS OF CORONARY ANGIOGRAPHY

Focal disease

50% lesion

Diffuse disease

50% lesion
% ελάττωση διαμέτρου > 70%

% ελάττωση επιφανείας > 50%

MLA < 4 mm² (εγγύς LAD, LCX, RCA)
< 6 mm² (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

MLD

Percent

Sensitivity 93%
Specificity 98%

2.8 mm

MLA

Percent

Sensitivity 93%
Specificity 94%

5.9 mm²

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

(83% sensitivity, 92.3 % specificity)

(92% sensitivity, 88.5 % specificity)

MLA < 3.0 mm$^2$

AS > 60%

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 IVUS-OCT

- Αξιολόγηση σημαντικότητας βλάβης
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- Θρόμβωση & επαναστένωση του stent
- Σύγκριση OCT-IVUS
- Εκτίμηση σύστασης πλάκας
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
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
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)
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)

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

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

Clinical Application of OCT

Intracoronary Imaging

1991

2002

Imaging Wire 0.014"
Through PCI Balloon

Regar E, van Leeuwen AMGJ, Serruys PW (Eds): Optical coherence tomography in
Clinical Application of OCT

1991

2002

2004

Intracoronary Imaging

Imaging Wire 0.019"
"Occlusive Method"

Regar et al. Eur Heart J 2004 (Abstract)
Clinical Application of OCT

Intracoronary Imaging


Imaging Wire 0.019"
“Non-Occlusive Method“
Selective Guide Catheter Engagement

Prati et al. Circ J 2008
Clinical Application of OCT

- **1991**: Intracoronary Imaging
- **2002**: 2nd Generation OCT (OFDI/Frequency/Spectral Domain/Swept Source)
- **2004**: Monorail Imaging Catheter
- **2007**: Non-Occlusive Clinical Application of OCT
- **2008**:
Occlusive vs non-occlusive technique

**Kataiwa et al., IJC.2009**

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

**Barlis et al., EuroInterv.2009**

\[ y = 0.990x \]
\[ R^2 = 0.979 \]
### OCT vs OFDI

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

_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

1.8% 98.2%

94.6%

1.8 ± 4.0 5.4 ± 14.3

p=0.081

"Vulnerable Struts"

Guagliumi et al., TCT 2008
OCT images
28 day follow-up

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

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

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Neointima thickness: 80 μm

Toutouzas ..Synetos..Stefanadis AHA 2009
Κλινικές εφαρμογές του IVUS-OCT

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

Chromaflo™ Imaging

Φυσιολογικός αυλός

Θρόμβος
Stent thrombosis, restenosis or underexpansion?
Haziness...
Dissection & Thrombus

Toutouzas, Syntes ... Stefanadis, Clin Cardiol 2007
Evaluation of haziness

Toutouzas, Karanasos, Synetos...Stefanadis  Eurointervention. in press
Recanalized Thrombus

Toutouzas, Karanasos, Synetos... Stefanadis  Eurointervention. in press
Calcified plaque – decision for rotablator?
CTO guidance

Schulz et al, JACC inter 2009
3D OCT for bifurcation guidance

- 3D OCT after guidewire recross
- 3D OCT after kissing balloon post dilatation

Okamura et al, Eurointervention 13 Oct 2011
Κλινικές εφαρμογές του IVUS-OCT

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- Εκτίμηση σύστασης πλάκας
# OCT vs CAS vs IVUS

<table>
<thead>
<tr>
<th>Finding</th>
<th>OCT (n=30)</th>
<th>CAS (n=30)</th>
<th>IVUS (n=30)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rupture</td>
<td>22 (73%)</td>
<td>14 (47%)</td>
<td>12 (40%)</td>
<td>0.021</td>
</tr>
<tr>
<td>Erosion</td>
<td>7 (23%)</td>
<td>1 (3%)</td>
<td>0</td>
<td>0.003</td>
</tr>
<tr>
<td>Thrombus</td>
<td>30 (100%)</td>
<td>30 (100%)</td>
<td>10 (33%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Kubo et al, JACC 2007
IVUS vs OCT for evaluation of restenosis

Detection of minimal restenosis

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

Suzuki et al., JACC intv 2008
OCT – IVUS VH

Total 126 lesions

- IVUS-derived TCFA (48.4%)
- OCT Derived TCFA (28.6%)
- Definite TCFA (22.2%)
- Non-thin-cap IVUS-derived TCFA (26.2%)
- Non-NCCL OCT-derived TCFA 6.3%

Κλινικές εφαρμογές του IVUS-OCT

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- 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

Vulnerable Plaque Components

- **Increased Plaque size**
  - **Positive remodeling**

- **Increased Necrotic core**
  - ~34% of plaque area
  - ~3.8 mm² & ~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*
Vulnerable plaque characteristics are associated with thrombolysis failure

Difference in rupture between 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 Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rupture Length (mm)</td>
<td>2.27±1.70</td>
</tr>
<tr>
<td>Location of rupture</td>
<td></td>
</tr>
<tr>
<td>Distal to the MLS</td>
<td>14(36.8)</td>
</tr>
<tr>
<td>MLS</td>
<td>14(36.8)</td>
</tr>
<tr>
<td>Proximal to the MLS</td>
<td>10(26.3)</td>
</tr>
<tr>
<td>Distance from MLS (mm)</td>
<td>2.01±2.10</td>
</tr>
<tr>
<td>Cross Sectional Area (mm²)</td>
<td>4.12±2.68</td>
</tr>
<tr>
<td>Minimal Cap Thickness (μm)</td>
<td>59±21μm</td>
</tr>
<tr>
<td>Rupture at cap shoulder</td>
<td>26(68.4)</td>
</tr>
<tr>
<td>Length of missing fibrous cap (mm)</td>
<td>0.53±0.27</td>
</tr>
</tbody>
</table>

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

- Non-culprit lipid-rich plaque with thick cap
- Napkin ring – significant lesion
- Red thrombus
- MLS - white thrombus
- Plaque rupture
- TCFA

Toutouzas..Synetos..Stefanadis, Heart July 2010
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
Thermal Heterogeneity Within Human Atherosclerotic Coronary Arteries Detected In Vivo: A New Method of Detection by Application of a Special Thermography Catheter

Christodoulos Stefanadis, Leonidas Diamantopoulos, Charalambos Vlachopoulos, Eletherios Tsiamis, John Dernellis, Konstantinos Toutouzas, Elli Stefanadi and Pavlos Toutouzas

Circulation 1999;99:1965-1971

Stefanadis et al. Circulation 1999
Correlation Between Morphologic Characteristics and Local Temperature Differences in Culprit Lesions of Patients With Symptomatic Coronary Artery Disease

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Athens, Greece

Figure 1: \( \Delta T \) in Lesions With Negative and Positive Remodeling

Difference between atherosclerotic plaque temperature and background temperature (\( \Delta T \)) 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 \( \Delta T \).

Figure 3: Temperature Measurements Stratified by Clinical Syndrome and Remodeling Index

The \( \Delta T \) 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 \( \Delta T \). Abbreviations as in Figure 1.
Figure 4: Correlation of $\Delta T$ and $R_i$

Remodeling index ($R_i$) is positively correlated with the difference between atherosclerotic plaque temperature and background temperature ($\Delta T$) ($p < 0.01; r = 0.59$).

Figure 5: $\Delta T$ in Nonruptured and Ruptured Plaques

The presence of ruptured plaque is associated with increased $\Delta T$ 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 $\Delta T$. Abbreviations as in Figures 1 and 2.
OCT - Thermography

ΔΤ = 0.03 °C

Cap thickness 100 μm

Toutouzas, Synetos, … Stefanadis ACC 2009
Microwave Radiometry:
Comparison of OCT-detected atheromatosis with thermal heterogeneity

$\Delta T = 0.8^\circ C$

Toutouzas, Synetos… Stefanadis., ESC 2010
Experimental study

Measurements with MR are correlated with measurements with IVT

$DT_{MR}(°C)$ vs. $DT_{IVT}(°C)$

$R=0.61$, $p<0.001$

Toutouzas .. Synetos .. Stefanadis, Atherosclerosis 2011
PROSPECT trial:
The significance of evaluation of non-culprit lesions

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

<table>
<thead>
<tr>
<th>Correlates</th>
<th>Hazard Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predictors of patient-level events†</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulin-requiring diabetes</td>
<td>3.32 (1.43–7.72)</td>
<td>0.005</td>
</tr>
<tr>
<td>Previous percutaneous coronary intervention</td>
<td>2.03 (1.15–3.59)</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Predictors of events at individual lesion sites‡</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plaque burden ≥70%</td>
<td>5.03 (2.51–10.11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Thin-cap fibroatheroma</td>
<td>3.35 (1.77–6.36)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MLA ≤4.0 mm²</td>
<td>3.21 (1.61–6.42)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Ενάλωτη πλάκα

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

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

<table>
<thead>
<tr>
<th>Predictor at Baseline</th>
<th>Odds Ratio (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaque Burden &gt; 60% (at Throat)</td>
<td>5.26 (2.04-13.57)</td>
<td>0.001</td>
</tr>
<tr>
<td>Low ESS (distal to Throat)</td>
<td>2.64 (1.11-6.26)</td>
<td>0.028</td>
</tr>
</tbody>
</table>
Volumetric assessment of TCFA

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

Ενσωμάτωση απεικονιστικών τεχνικών OCT-IVUS
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
Feasibility of new imaging modalities from radial and ulnar arteries

- IVUS, FFR, OCT, Rotablator
- Can be used during catheterization from the radial, ulnar arteries

- 6-French hydrophilic arterial sheath was initially introduced (Radifocus®, Terumo Medical Co, NJ, USA) and subsequently exchanged with a 7.5F sheathless guide catheter (ASAHI Sheathless Eaucath PTCA Guiding Catheter, Vascular Perspectives Ltd., UK)

Deftereos, Giannopoulos…. Stefanadis, Int J Cardiol. 2011 Jun 16;149(3):398-400
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.

- 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.
The Natural History of Lipid Plaques: Longitudinal Observation at Baseline, 6 Months, and 12 Months Using Optical Coherence Tomography and Intravascular Ultrasound

A total of 77 (82.8%) lipid plaques and 16 (17.2%) fibrous plaques were identified at non-culprit sites in 47 patients. All 47 patients underwent OCT and IVUS at three time points: baseline, 6 months, and 12 months.

With reduction of LDL, fibrous cap became thicker, lipid content became smaller, and macrophage became less frequent over a period of 12 months. The change in fibrous cap thickness occurred before lipid volume decreased. Despite stabilization of lipid plaques, plaque burden measured by IVUS did not change during the examined period.
Anatomic features that lead to the development of culprit lesions causing ACS after plaque rupture.

- 102 plaque ruptures by using OCT and compared lesion morphologies between symptomatic plaque rupture in unstable angina pectoris (UAP; n=67) and silent plaque rupture in stable angina pectoris (SAP; n=35).

- Maximal ruptured cavity area was significantly greater in UAP compared with SAP (1.57 ± 0.54 mm² vs. 1.30 ± 0.72 mm², p=0.032).

- Lumen area at rupture site (3.00 ± 0.86 mm² vs. 3.45 ± 1.18 mm², p=0.030).

- MLA (2.69 ± 0.80 mm² vs. 3.12 ± 1.14 mm², p=0.029) was significantly smaller in UAP compared with SAP.

- The frequency of lipid-rich plaque (84% vs. 63%, p=0.019) and intracoronary thrombus (94% vs. 3%, p<0.001) was significantly higher in UAP compared with SAP.

Thirty mini pigs were divided into bare metal stent (BMS) group (n=15), SES group (n=15) and SES+atorvastatin pretreatment (SES+ator) group (50mg atorvastatin 12h before PCI and 20mg/day until sacrifice [n=15]). All animals were given BMS or SES implantation and optical coherence tomography (OCT) examination immediately after PCI, and at 7-day, 14-day and 28-day after stent implantation.

Compared with BMS group, SES significantly delayed neointimal coverage and impaired endothelium function from the result of OCT, histology and SEM.

However, the ratio of uncovered struts and sections with more than 30% uncovered struts in SES+ator group was significantly decreased at 7-day (31.3±5.7% vs. 56.8±5.7%, p<0.01; 45.7±11.8% vs. 84.9±4.3%, p<0.01, respectively) and 14-day (24.8±4.3% vs. 45.3±2.8%, p<0.01; 29.0±7.5% vs. 61.0±9.8, p<0.01, respectively) compared with the ration in SES group.

Wang et al, ACC 2012
Cost Effectiveness
IVUS COST EFFECTIVENESS

- 108 pts
- Stable angina
- Prosp/rand
- IVUS guided vs conventional PCI
- Individual accumulated cost
- Cumulative cost effectiveness

Heart 2003;89:1043–1049
IVUS COST EFFECTIVENESS

Table 4: Occurrence of major adverse cardiac events (MACE) during follow up

<table>
<thead>
<tr>
<th>MACE</th>
<th>CAG guided group (n=54)</th>
<th>IVUS guided group (n=54)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeat PCI (%)</td>
<td>61</td>
<td>31</td>
<td>0.004</td>
</tr>
<tr>
<td>CABG (%)</td>
<td>17</td>
<td>11</td>
<td>NS</td>
</tr>
<tr>
<td>Q wave AMI (%)</td>
<td>0</td>
<td>2</td>
<td>NS</td>
</tr>
<tr>
<td>Death (%)</td>
<td>4</td>
<td>0</td>
<td>NS</td>
</tr>
</tbody>
</table>

Heart 2003;89:1043–1049
IVUS COST EFFECTIVENESS 2

N= 269 /365 lesions
Rand/ prospective

Conventional PCI/ IVUS guided PCI

Am J Cardiol 2003;91:143–147
### TABLE 2 In-hospital and Follow-up Cost (in United States dollars per patient)

<table>
<thead>
<tr>
<th></th>
<th>IVUS</th>
<th>ANGIO</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-hospital costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedural personnel and capital equipment</td>
<td>1,242 ± 624</td>
<td>1,091 ± 616</td>
<td>0.05</td>
</tr>
<tr>
<td>Disposable equipment</td>
<td>2,400 ± 1,207</td>
<td>1,592 ± 1,040</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Inpatient care</td>
<td>1,464 ± 832</td>
<td>1,731 ± 1,208</td>
<td>0.04</td>
</tr>
<tr>
<td>In-hospital TVR</td>
<td>140 ± 629</td>
<td>362 ± 1,495</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Total in-hospital costs</strong></td>
<td>5,245 ± 2,256</td>
<td>4,776 ± 2,961</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Hospitalizations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient care</td>
<td>2,287 ± 2,222</td>
<td>2,527 ± 3,199</td>
<td>0.48</td>
</tr>
<tr>
<td>Coronary angiography</td>
<td>.575 ± 594</td>
<td>.580 ± 521</td>
<td>0.94</td>
</tr>
<tr>
<td>Percutaneous intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel and capital equipment</td>
<td>465 ± 942</td>
<td>593 ± 1,149</td>
<td>0.32</td>
</tr>
<tr>
<td>Disposable equipment</td>
<td>599 ± 1,221</td>
<td>707 ± 1,506</td>
<td>0.53</td>
</tr>
<tr>
<td>Bypass grafting*</td>
<td>723 ± 3,498</td>
<td>946 ± 3,971</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Total hospitalization costs</strong></td>
<td>4,648 ± 5,686</td>
<td>5,353 ± 7,658</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Total hospitalization costs adjusted</strong>††</td>
<td>4,004 ± 5,621</td>
<td>4,766 ± 7,317</td>
<td>0.35</td>
</tr>
<tr>
<td>Medication†</td>
<td>1,352 ± 619</td>
<td>1,288 ± 658</td>
<td>0.42</td>
</tr>
<tr>
<td>Indirect costs†</td>
<td>5,346 ± 2,759</td>
<td>5,273 ± 2,971</td>
<td>0.84</td>
</tr>
<tr>
<td><strong>Total costs</strong>†</td>
<td>15,947 ± 8,545</td>
<td>16,103 ± 9,954</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Including cost for periprocedural inpatient care.
†Adjusted for the cost effect of follow-up angiography.
‡Discounted by 3%/year (net of inflation).

Abbreviation as in Table 1.
### Table 4. Clinical results.

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