OCT; Comparative Imaging Results with IVUS, VH and Angioscopy

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**Comparison among coronary imaging techniques**

<table>
<thead>
<tr>
<th></th>
<th>OCT</th>
<th>IVUS</th>
<th>MRI</th>
<th>CAG</th>
<th>Angioscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>10 – 15</td>
<td>80 – 120</td>
<td>80 – 300</td>
<td>100-200</td>
<td>&lt;200</td>
</tr>
<tr>
<td>Probe Size</td>
<td>140</td>
<td>700</td>
<td>1000</td>
<td>N/A</td>
<td>800</td>
</tr>
<tr>
<td>Contact</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ionizing Radiation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Other</td>
<td>Tissue Characterization</td>
<td>N/A</td>
<td>N/A</td>
<td>Flow Only</td>
<td>Surface Only</td>
</tr>
</tbody>
</table>

Advantages of OCT are its high resolution and accuracy of tissue characterization.
Intracoronary Imaging
Comparison among OCT, IVUS, VH & Angioscopy

- Tissue characterization: comparison with histology
- Vulnerable plaque identification
- Stent follow-up
Fibrous plaque

- Signal rich
- Diffuse border
- Attenuation

Wakayama Medical University
Fibrous plaque
Fibrocalcific plaque

Signal poor
Sharp border
Calcified plaque

Superficial calcified nodule
Fibro-lipidic plaque

Signal poor
Diffuse border
Fibrofatty plaque
Red & white thrombus

Red thrombus

White thrombus

Mixed thrombus

Protrusion mass with shadow

Protrusion mass without shadow

Protrusion mass with & without shadow

Kume T, Akasaka T, et al. (Am J Cardiol 97:1713-1717, 2006)

Kubo T, Akasaka T, et al. (J Am Coll Cardiol 50:933-939, 2007)
Thrombus

OCT

CAS

IVUS
Accuracy of intra-coronary OCT for differentiation between red and white thrombus

<table>
<thead>
<tr>
<th>OCT</th>
<th>Angioscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red thrombus</td>
</tr>
<tr>
<td>Intensity half distance &lt;250μm</td>
<td>18</td>
</tr>
<tr>
<td>Intensity half distance ≥250μm</td>
<td>1</td>
</tr>
</tbody>
</table>

Sensitivity = 95%
Specificity = 88%
Positive predictive value = 86%
Negative predictive value = 95%
Intracoronary Imaging
Comparison among OCT, IVUS & Angioscopy

- Tissue characterization: comparison with histology
- Vulnerable plaque identification
- Stent follow-up
Study Design

Oral aspirin (162 mg) and intravenous heparin (100 U/kg) were administered before PCI.

Cardiac catheterization was performed by the femoral approach, using a 7F sheath and catheters.

- **Thrombectomy** *(Export catheter ® Medtronic Japan)*
  - TIMI grade III
    - **IVUS** *(Atlantis SR Pro® 2.5F, 40-MHz; Boston Scientific, Natick, MA, USA)*
    - **CAS** *(Angioscope MC-800E and the optic fiber AS-003, Nihon Kohden)*
    - **OCT** *(ImageWire®; LightLab Imaging, Westford, MA, USA)*
Inferior AMI (71y.o. Male)
Inferior-AMI (71y.o., M)  Plaque Rupture

- Ruptured Fibrous Cap
- Fibrous Cap Thickness = 40μm
- TL : True Lumen
- UL : Ulceration

(71y.o., M)
Anteroseptal AMI (80y.o., M)

↑ Erosion (Ulceration)
↑ Thrombus
### Comparison of plaque Images in AMI

**(OCT vs. CAS vs. IVUS) n=30**


<table>
<thead>
<tr>
<th></th>
<th>OCT</th>
<th>*CAS</th>
<th>**IVUS</th>
<th>*p</th>
<th>**p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaque Rupture (%)</td>
<td>73</td>
<td>47</td>
<td>40</td>
<td>0.035</td>
<td>0.009</td>
</tr>
<tr>
<td>Ulceration (erosion) (%)</td>
<td>23</td>
<td>3</td>
<td>0</td>
<td>0.022</td>
<td>0.005</td>
</tr>
<tr>
<td>Thrombus (%)</td>
<td>100</td>
<td>100</td>
<td>33</td>
<td>1.000</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Red thrombus (%)</td>
<td>100</td>
<td>90</td>
<td>-</td>
<td>0.076</td>
<td>-</td>
</tr>
<tr>
<td>White thrombus (%)</td>
<td>100</td>
<td>93</td>
<td>-</td>
<td>0.150</td>
<td>-</td>
</tr>
<tr>
<td>TCFA (≤65μm) (%)</td>
<td>83</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fibrous cap thickness (μm)</td>
<td>49±21</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LRP (Lipid Arch&gt;180°) (%)</td>
<td>83</td>
<td>-</td>
<td>67</td>
<td>-</td>
<td>NS</td>
</tr>
</tbody>
</table>

TCFA; Thin Cap Fibro-Atheroma, LRP; Lipid Rich Plaque
Thin-cap fibroatheroma (TCFA)

Possibility to identify TCFA has been demonstrated by several pilot studies.
Corresponding Images of OCT and Angioscopy

Angioscopy vs OCT

Plaque color vs lipid size

Plaque color vs fibrous cap thickness

**IVUS-derived TCFA**


- Percent atheroma volume = \((\text{EEM area} - \text{Lumen area})/\text{EEM area} \times 100 \geq 40\%\)
- Nectrotic core \( \geq 10\%\)
- Without evident overlying fibrous tissue
VH-IVUS vs OCT

Figure 2

Concordant

Without evident overlying fibrous tissue

Discordant

Without evident overlying fibrous tissue

With evident overlying fibrous tissue
## Concordance & discordance between VH-IVUS and OCT in the assessment of TCFA

<table>
<thead>
<tr>
<th>IVUS-VH Diagnosis</th>
<th>OCT Diagnosis</th>
<th>TCFA (n=11)</th>
<th>Not TCFA (n=36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VH-TCFA (n=31)</td>
<td></td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>Not VH-TCFA (n=16)</td>
<td></td>
<td>2</td>
<td>14</td>
</tr>
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</table>

Discordance between VH-IVUS & OCT has been described by Sawada T, et al. (Eur Heart J 29:1136-1146, 2008)
OCT assessment of non-culprit lesion (47y.o. male)

Baseline

9 month later

<table>
<thead>
<tr>
<th>Metric</th>
<th>Baseline</th>
<th>9 month later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumen Area</td>
<td>6.1 mm²</td>
<td>8.0 mm²</td>
</tr>
<tr>
<td>EEL Area</td>
<td>12.3 mm²</td>
<td>14.4 mm²</td>
</tr>
<tr>
<td>Plaque Area</td>
<td>6.2 mm²</td>
<td>6.4 mm²</td>
</tr>
<tr>
<td>%plaque burden</td>
<td>50%</td>
<td>44%</td>
</tr>
<tr>
<td>FI Green Area</td>
<td>2.1 mm²</td>
<td>2.5 mm²</td>
</tr>
<tr>
<td>FF Light green Area</td>
<td>0.4 mm²</td>
<td>0.3 mm²</td>
</tr>
<tr>
<td>DC White Area</td>
<td>0.1 mm²</td>
<td>0.1 mm²</td>
</tr>
<tr>
<td>NC Red area</td>
<td>0.6 mm²</td>
<td>0.1 mm²</td>
</tr>
<tr>
<td>%plaque burden</td>
<td>50%</td>
<td>44%</td>
</tr>
<tr>
<td>FI Green Area</td>
<td>68%</td>
<td>84%</td>
</tr>
<tr>
<td>FF Light green Area</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>DC White Area</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td>NC Red area</td>
<td>18%</td>
<td>4%</td>
</tr>
</tbody>
</table>

### Changes of plaque characteristics by statin


<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Follow-up</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statin group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibrous cap thickness (μm)</td>
<td>114±83</td>
<td>162±75</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Lipid arc (degrees)</td>
<td>132±37</td>
<td>116±23</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Non-statin group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibrous cap thickness (μm)</td>
<td>117±78</td>
<td>129±54</td>
<td>ns</td>
</tr>
<tr>
<td>Lipid arc (degrees)</td>
<td>129±37</td>
<td>128±28</td>
<td>ns</td>
</tr>
</tbody>
</table>
The correlation between the lipid profile and the % change of fibrous-cap thickness (FCT) and total atheroma volume (TAV).

%TA\text{V} and %LDL/HDL were positively correlated (p<0.01, r = 0.42). %FCT and %CRP were inversely correlated (p<0.01, r = -0.44).

(Takarada S, et al. JACC Interv. 2010, in press)
Changes of plaque, media & lumen area

PIT  VH-TCFA  ThCFA  Fibrotic  Fibrocalcific

Coronary lesion morphology by VH-IVUS

Intracoronary Imaging
Comparison among OCT, IVUS & Angioscopy

- Tissue characterization: comparison with histology
- Vulnerable plaque identification
- Stent follow-up
ACS; 69 y.o. M  #6 Cypher 3.5 x 18 mm  Post PCI
Stent malapposition

Tissue protrusion

Incomplete stent apposition

Stent edge dissection
Vascular response after stent implantation between unstable and stable AP

24 unstable and 31 stable AP patients were examined by OCT to evaluate lesion morphologies after stent implantation.

Conclusion: The inadequate lesion morphologies after stenting were observed more frequently in unstable AP patients.

Kubo T, et al, JACC Img. 2008 1:475–484
OCT and IVUS images of stented lesions

Malapposition  Tissue protrusion  Thrombi  Dissection

Kubo T, et al, JACC Img. 2008 1:475–484
Conclusion: OCT can provide more detailed morphological information after stenting than IVUS.

Kubo T, et al, JACC Img. 2008 1:475–484
Classification of strut condition

- Wellapposed with neointima
- Wellapposed without neointima
- Malapposed with neointima
- Malapposed without neointima
- Side branch orifice with neointimal coverage
- Side branch orifice without neointimal coverage
Post-stent follow up
Distribution of the neointima thickness on SES strut (6 months f/u)

34 pts, 6840 stent strut cross sections


Neointima thickness is under IVUS resolution in more than 70% pts.

64% beyond IVUS resolution

Neointimal thickness (μm)
An SES (Cypher, 3.5x23 mm) implanted proximally in the LAD

Stent struts bulged into the lumen and, although covered, were transparently visible

Changes in neointimal coverage grades from the first to the third follow-up in 28 stents

Stent struts condition
- Fully visible similar to soon after implantation
- Embedded by the neointima, but still visible translucently
- Bulged into the lumen, although covered, transparently visible
- Fully embedded and not visible

Asymptomatic instent thrombus by CAS

SES : 33% BMS : 8%

SES : 19% PES : 43%

Takano et al. Eur Heart J 2006; 27: 2189-2195

Instent thrombus

DES

BMS

Distal to DES
Instent thrombus by OCT

Prevalence of in-stent thrombus (%)

<table>
<thead>
<tr>
<th>Device</th>
<th>Prevalence</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SES</td>
<td>27%</td>
<td>0.60</td>
</tr>
<tr>
<td>PES</td>
<td>43%</td>
<td>0.63</td>
</tr>
<tr>
<td>BMS</td>
<td>13%</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Conclusions

- OCT can identify lipid-rich plaques & differentiate the plaque types more sensitively compared with IVUS.

- OCT can demonstrate rupture or ulceration of fibrous cap with higher detection rate than that of IVUS or CAS.

- OCT could detect intracoronary thrombus almost exclusively which was confirmed by CAS.

- OCT may demonstrate the results of PCIs precisely, including mal-appositions, tissue (or thrombus) protrusion, and edge dissection immediately after the procedure and thin neo-intima formation and small thrombus within stents late after DES.
Representative case of plaque stabilization: 66yo, male

Primary PCI

Total atheroma volume = 63 mm³

9-months follow-up

Total atheroma volume = 61 mm³

Fibrous-cap thickness = 90 μm

Fibrous-cap thickness = 310 μm

(Takarada S, et al. JACC Interv. 2010, in press)