Assessment of plaque morphology by OCT in patients with ACS

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Unstable plaque

① Total occlusion
AMI
Sudden death

② Subtotal occlusion

③ Unstable AP

④ Stable plaque

⑤ Mural thrombus

⑥ Cholesterol lowering therapy

Identification of vulnerable plaque

- Plaque prone to rupture
  - Rupture (−)
  - Rupture (+)
    - Event (−)
    - Event (+)
      - UAP
      - AMI
      - Sudden cardiac death
        - in vivo
        - in vitro
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*)
Study Population

Inclusion criteria

**Acute Myocardial Infarction**
- continuous chest pain lasted > 30 minutes,
- arrival within 6 hours from the onset of chest pain
- ST elevation ≥ 0.1 mV in 2 or more contiguous leads
- culprit lesion with diameter stenosis ≥ 75%
- TIMI flow ≤ 2 identified by CAG

Exclusion criteria

- left bundle-branch block
- pacemaker rhythm
- a culprit lesion in the left main coronary artery
- history of prior MI
- cardiogenic shock
- unsuccessful reperfusion < TIMI III flow by thrombectomy
OCT system (LightLab Inc.)

Prototype

Commercially available system

Wakayama Medical University
Optical Coherence Tomography (OCT)

- Size of imaging core (0.4 mm)
- Microscopic resolution (10-20 $\mu$ m)
- Real time Imaging (15 frames/s)
Inferior-AMI (71y.o., M) Plaque Rupture

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

Wakayama Medical University
Ruptured Fibrous Caps

OCT  CAS  IVUS

Wakayama Medical University
Anteroseptal AMI (80y.o., M)
Anteroseptal AMI (80y.o., M)

↑ Erosion (Ulceration)

↑ Thrombus
Plaque Erosion

OCT

CAS

IVUS

1mm

1mm

Wakayama Medical University
Thickness of Fibrous Cap

Thickness of fibrous cap was 42 μm
Anteroseptal AMI (80y.o., M)

Fibrous cap thickness = 60 μm
Thickness of fibrous caps

Histology vs OCT

Inf-AMI (71y.o., M) Thrombus

Red Thrombus

Thrombectomy

Intensity Half Distance = 135 μm
Red thrombus
White thrombus
Differentiation between red and white thrombus


Peak intensity

- Red thrombus: 130 ± 18
- White thrombus: 145 ± 34

Intensity half distance

- Red thrombus: 183 ± 42
- White thrombus: 324 ± 50 *

*p = 0.0001
## Baseline characteristics

<table>
<thead>
<tr>
<th></th>
<th>Red thrombus (n=19)</th>
<th>White thrombus (n=24)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y*</td>
<td>69 ± 5</td>
<td>69 ± 7</td>
<td>0.99</td>
</tr>
<tr>
<td>Male sex</td>
<td>12 (62)</td>
<td>14 (59)</td>
<td>0.74</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>6 (34)</td>
<td>8 (33)</td>
<td>0.90</td>
</tr>
<tr>
<td>Hypertension</td>
<td>16 (85)</td>
<td>20 (83)</td>
<td>0.94</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>9 (46)</td>
<td>10 (40)</td>
<td>0.71</td>
</tr>
<tr>
<td>Culprit vessel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>9 (47)</td>
<td>11 (46)</td>
<td>0.92</td>
</tr>
<tr>
<td>LCx</td>
<td>2 (11)</td>
<td>3 (13)</td>
<td>0.84</td>
</tr>
<tr>
<td>RCA</td>
<td>8 (42)</td>
<td>10 (41)</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Values are given as n (%) or *mean ± SD.

LAD, left anterior descending coronary artery; LCx, left circumflex artery; RCA, right coronary artery.
Comparison of light intensity properties in OCT images between yellow and white plaques

**Peak intensity**

![Graph showing comparison of light intensity between red and white thrombus. The graph displays the peak intensity with error bars for both red and white thrombus. Red thrombus has a higher peak intensity compared to white thrombus.]
Comparison of light intensity properties in OCT images between yellow and white plaques

<table>
<thead>
<tr>
<th>Distance (µm)</th>
<th>Intensity half distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>

- **Red thrombus**
- **White thrombus**

* $p<0.001$
Accuracy of intra-coronary OCT for differentiation between red and white thrombus

<table>
<thead>
<tr>
<th>OCT</th>
<th>Angioscopy</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red thrombus</td>
<td>White thrombus</td>
<td></td>
</tr>
<tr>
<td>Intensity half distance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;250 μm</td>
<td>18</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>≥250 μm</td>
<td>1</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

Sensitivity = 95%
Specificity = 88%
Positive predictive value = 86%
Negative predictive value = 95%
## 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 (≤ 65 μm) (%)</td>
<td>85</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fibrous cap thickness (μm)</td>
<td>59±13</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LRP (Lipid Arch &gt; 120°) (%)</td>
<td>57</td>
<td>-</td>
<td>67</td>
<td>-</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Notes:**
- *CAS: comparison with OCT
- **IVUS: comparison with OCT
- *p: p < 0.05
- **p: p < 0.01
- NS: not significant

TCFA: Thin Cap Fibro-Atheroma, LRP: Lipid Rich Plaque
Comparison of plaque images among AMI, UAP & SAP

<table>
<thead>
<tr>
<th>Finding</th>
<th>AMI (n=30)</th>
<th>UAP (n=11)</th>
<th>SAP (n=63)</th>
<th>p - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaque rupture</td>
<td>22 (73) * #</td>
<td>3 (27) $</td>
<td>2 (3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Erosion</td>
<td>7 (23) #</td>
<td>4 (36) $</td>
<td>1 (2)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Thrombus</td>
<td>30 (100) * #</td>
<td>7 (64) $</td>
<td>3 (5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fibrous cap thickness (µm)</td>
<td>49 ± 21 * #</td>
<td>113 ± 64 $</td>
<td>305 ± 97</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>TCFA</td>
<td>25 (83) * #</td>
<td>4 (36) $</td>
<td>2 (3)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Values are given as n (%) or mean ± SD.

TCFA; thin-cap fibroatheroma
(lipid > 2 quadrants & fibrous cap thickness < 65 µm).

* p<0.05; AMI vs UAP, # p<0.001; AMI vs SAP, $ p<0.005; UAP vs SAP.
Summary

- OCT can identify lipid-rich plaques more sensitively compared with IVUS.

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

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

- OCT may have a potential to estimate macrophage accumulation within fibrous caps.
Conclusion

OCT may allow us to assess the pathophysiology of ACS by demonstrating *lipid-rich plaques*, *thin cap fibro-atheroma* with rupture or erosion, and *thrombi*, which are proposed by pathohistology, compared with IVUS and CAS.