A novel procedure for imaging acute coronary syndrome lesions using frequency-domain optical coherence tomography

Yuji Yamaguchi¹, BE; Eisuke Kagawa²*, MD; Masaya Kato², MD, PhD; Shota Sasaki², MD, PhD; Yoshinori Nakano², MD; Yusuke Ochiumi², MD; Yu Takiguchi², MD; Yasuo Arakawa¹; Ai Ishimaru¹; Akira Ueda¹; Keigo Dote², MD, PhD

¹. Department of Clinical Engineering, Hiroshima City Asa Hospital, Hiroshima, Japan; ². Department of Cardiology, Hiroshima City Asa Hospital, Hiroshima, Japan

This paper also includes accompanying supplementary data published online at: http://www.pcronline.com/eurointervention/67th_issue/166

Description

Next-generation OCT (frequency-domain optical coherence tomography, FD-OCT) facilitates high-speed pullbacks during image acquisition without necessitating transient balloon occlusion of the coronary artery¹⁻³. However, a more robust catheter is necessary to facilitate high-speed pullbacks during FD-OCT. The profile diameter of the FD-OCT catheter is larger than that of the previous generation time-domain OCT (TD-OCT) imaging wire. A larger FD-OCT catheter could occlude severely stenotic lesions, causing insufficient distal contrast flushing. Subsequently, this causes insufficient blood clearance, resulting in poor OCT imaging.

We investigated visualisation challenges of FD-OCT in the presence of severely stenotic lesions in an ex vivo model and developed a new procedure to obtain clear images using FD-OCT (Figure 1 and Figure 2).

Technical specifications

The FD-OCT system (ILUMIEN™; St. Jude Medical, Inc., St. Paul, MN, USA) is composed of an intravascular OCT catheter (Dragonfly™; St. Jude Medical), an imaging engine, a probe interface unit, and a computer console, which also contains a data acquisition board. A 2.7 Fr Dragonfly catheter was delivered as a monorail rapid-exchange catheter over a 0.014-inch coronary guidewire through a 6 Fr guide catheter. After catheter placement, a cardiovascular injection pump was used to deliver the contrast medium at a rate of 20 mm/sec. Our protocol allowed imaging of approximately 5 cm of the coronary segment over a period of 3.5 sec with 14 ml of the contrast medium¹⁻³.

Indications for use

This new procedure should be used for FD-OCT imaging of severe stenosis in which the conventional procedure would fail to yield images.

Tips and tricks for use

After passing a guidewire through the target lesion, we confirmed that the Dragonfly catheter could pass through the lesion without problems. Once this was confirmed, the Dragonfly catheter was retracted to a position proximal to the target lesion. The pullback trigger of the FD-OCT system was set to manual, the system mode switched to live view and pullback enabled.

Once the system settings were prepared, the contrast medium was injected into the target coronary artery (left coronary artery: flow rate 4 ml/sec, volume 14 ml; right coronary artery: flow rate 3 ml/sec, volume 12 ml) as per the manufacturer’s instructions. The Dragonfly catheter was passed through the target lesion and, as soon as positioning was complete, pullback was initiated. When pullback was complete, contrast flush was discontinued and the Dragonfly catheter retracted into the guide catheter.

Preclinical experience

We successfully acquired clear images using the new procedure in our ex vivo model. It was difficult to acquire clear images using the conventional procedure (Figure 1 and Figure 2).

*Corresponding author: Department of Cardiology, Hiroshima City Asa Hospital, 2-1-1, Kabeminami, Asakita-ku, Hiroshima, 731-0293, Japan. E-mail: ekagawa007@gmail.com

© Europa Digital & Publishing 2013. All rights reserved.
Clinical experience

In our hospital, OCT was used in ACS patients primarily to observe the culprit lesion.

We performed FD-OCT in 109 patients (of whom 92 exhibited ACS) between December 2011 and September 2012. OCT imaging was attempted in 116 patients, but the catheter could not cross the lesion in seven. These seven patients were not included in the analysis.

In patients with TIMI 0-1 coronary flow after guidewire crossing, we attempted to obtain TIMI 2 flow. However, if this manoeuvre failed to guarantee an adequate anterograde coronary flow, direct thrombus aspiration was performed before imaging. The conventional procedure failed to acquire clear images in 19 patients. We performed the new procedure in 20 patients (17 with ACS, two with stable angina pectoris and one with stent restenosis) (Table 1).

This group comprised 19 patients in whom the conventional procedure failed to acquire clear images and one patient who was used for image comparison.

We successfully acquired clear images in 17 patients using the new procedure (Figure 3, Moving image 1 - Moving image 3). In the three remaining patients, because of inadequate blood clearance distal to the lesion, OCT signal attenuation due to blood flow was observed.

Qualitative measurements assessed in this study included visibility of the lumen border at the minimum lumen site and visibility of the length of the observation site. The visibility of the lumen border by OCT was classified into three grades: (1) good (entire circumference visible), (2) fair (>75% of circumference visible), and (3) poor (<75% of circumference visible) (Figure 4). These grades ignore the wire artefact. The length of these grades was also measured. The prevalence of good/fair grade images was determined by dividing the length of good/fair images by the total length of observation (excluding guiding catheter) (Table 1). There was no significant difference in the length of clear image between the conventional (n=77, 34.5±11.0 mm) and the new procedure (n=20, 33.4±12.8 mm; Student’s t-test, p=0.64). The difference between the control group (good or fair=29 [70%], poor=12) and post-adoption of the new procedure (good or fair=65 [95%], poor=3) was not statistically significant (chi-square test, p=0.001).

Patient 7 (Table 1) exhibited grade 3 Rentrop collateral flow, and we could not acquire clear images using the conventional procedure.

Finally, no complications such as acute vessel occlusion, dissection, significant arrhythmias or vasospasm along the entire procedure-related artery were associated with this new procedure.

Discussion

Our new FD-OCT procedure acquired clear images of severely stenotic lesions, something which is difficult using the conventional procedure. The conventional procedure failed to acquire clear images because the catheter itself occludes the coronary artery when traversing a severe stenosis, preventing the contrast medium from flushing out the blood for clear imaging.
Table 1. Patient characteristics of the study population using optical coherence tomography with the new procedure.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>Target vessel</th>
<th>Thrombus aspiration</th>
<th>TIMI grade</th>
<th>Rentrop grade</th>
<th>Image quality of MLA</th>
<th>Image quality of length</th>
<th>Contrast medium for OCT (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>81</td>
<td>Male</td>
<td>Non-STEMI</td>
<td>LAD</td>
<td>–</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>27.5/49.7</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
<td>Female</td>
<td>UAP</td>
<td>RCA</td>
<td>–</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>32.7/54.0</td>
<td>61</td>
</tr>
<tr>
<td>3</td>
<td>58</td>
<td>Female</td>
<td>UAP</td>
<td>LAD</td>
<td>–</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>22.7/48.4</td>
<td>47</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>Female</td>
<td>SAP</td>
<td>LCX</td>
<td>–</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>29.2/54.0</td>
<td>54</td>
</tr>
<tr>
<td>5</td>
<td>71</td>
<td>Male</td>
<td>STEMI</td>
<td>RCA</td>
<td>+</td>
<td>2</td>
<td>2</td>
<td>Good/Good</td>
<td>22.2/22.2</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>79</td>
<td>Female</td>
<td>STEMI</td>
<td>LAD</td>
<td>+</td>
<td>2</td>
<td>0</td>
<td>Poor/Good</td>
<td>54.0/54.0</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>77</td>
<td>Male</td>
<td>STEMI</td>
<td>LAD</td>
<td>+</td>
<td>2</td>
<td>3</td>
<td>Poor/Good</td>
<td>28.0/43.8</td>
<td>64</td>
</tr>
<tr>
<td>8</td>
<td>79</td>
<td>Male</td>
<td>STEMI</td>
<td>RCA</td>
<td>+</td>
<td>2</td>
<td>0</td>
<td>Poor/Good</td>
<td>45.8/54.0</td>
<td>85</td>
</tr>
<tr>
<td>9</td>
<td>80</td>
<td>Male</td>
<td>STEMI</td>
<td>LAD</td>
<td>+</td>
<td>1</td>
<td>1</td>
<td>Poor/Good</td>
<td>22.3/36.5</td>
<td>61</td>
</tr>
<tr>
<td>10</td>
<td>74</td>
<td>Male</td>
<td>STEMI</td>
<td>RCA</td>
<td>+</td>
<td>1</td>
<td>2</td>
<td>Poor/Good</td>
<td>13.9/33.6</td>
<td>41</td>
</tr>
<tr>
<td>11</td>
<td>84</td>
<td>Male</td>
<td>SAP</td>
<td>RCA</td>
<td>–</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>15.8/26.4</td>
<td>60</td>
</tr>
<tr>
<td>12</td>
<td>59</td>
<td>Male</td>
<td>Non-STEMI</td>
<td>LCX</td>
<td>+</td>
<td>3</td>
<td>0</td>
<td>Poor/Poor</td>
<td>32.3/47.9</td>
<td>67</td>
</tr>
<tr>
<td>13</td>
<td>67</td>
<td>Male</td>
<td>Stent restenosis</td>
<td>RCA</td>
<td>–</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>44.5/44.5</td>
<td>100</td>
</tr>
<tr>
<td>14</td>
<td>74</td>
<td>Male</td>
<td>Non-STEMI</td>
<td>LAD</td>
<td>–</td>
<td>2</td>
<td>0</td>
<td>Poor/Good</td>
<td>25.8/44.7</td>
<td>58</td>
</tr>
<tr>
<td>15</td>
<td>54</td>
<td>Male</td>
<td>UAP</td>
<td>RCA</td>
<td>–</td>
<td>2</td>
<td>0</td>
<td>Poor/Good</td>
<td>54.0/54.0</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>69</td>
<td>Female</td>
<td>Non-STEMI</td>
<td>RCA</td>
<td>+</td>
<td>3</td>
<td>1</td>
<td>Poor/Good</td>
<td>25.4/30.3</td>
<td>84</td>
</tr>
<tr>
<td>17</td>
<td>71</td>
<td>Male</td>
<td>STEMI</td>
<td>RCA</td>
<td>–</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>54.0/54.0</td>
<td>100</td>
</tr>
<tr>
<td>18</td>
<td>66</td>
<td>Male</td>
<td>Non-STEMI</td>
<td>LCX</td>
<td>+</td>
<td>3</td>
<td>1</td>
<td>Poor/Poor</td>
<td>30.7/33.6</td>
<td>91</td>
</tr>
<tr>
<td>19</td>
<td>81</td>
<td>Male</td>
<td>STEMI</td>
<td>RCA</td>
<td>+</td>
<td>3</td>
<td>1</td>
<td>Poor/Poor</td>
<td>38.7/54.0</td>
<td>72</td>
</tr>
<tr>
<td>20</td>
<td>70</td>
<td>Male</td>
<td>STEMI</td>
<td>RCA</td>
<td>+</td>
<td>3</td>
<td>0</td>
<td>Poor/Good</td>
<td>54.0/54.0</td>
<td>100</td>
</tr>
</tbody>
</table>

LAD: left anterior descending; LCX: left circumflex; MLA: minimum lumen area; OCT: optical coherence tomography; RCA: right coronary artery; SAP: stable angina pectoris; STEMI: ST-elevation myocardial infarction; TIMI: Thrombolysis in Myocardial Infarction; UAP: unstable angina pectoris

In the case of patient 7 (Table 1), who exhibited grade 3 Rentrop collateral flow, imaging was clear using the new procedure. In this case, anterograde flow competed with retrograde flow. However, anterograde flow was overcome by retrograde flow when the Dragonfly catheter crossed the target lesion in accordance with the “Dotter effect”6.

Performing the new procedure requires specific techniques for both the Dragonfly catheter operator and the system console. Precise timing of contrast medium flushing and pullback initiation is crucial to achieve clear images. Practice with our ex vivo simulator allowed us to learn the steps that are key to the success of the new procedure and apply them smoothly in the clinical setting. These steps include prior confirmation that the catheter can cross the lesion, selection of a location for catheter placement and indication by the operator that the technician should initiate pullback as soon as the catheter has crossed the lesion.

In three patients in whom the new procedure failed, blood remained distal to the lesion despite the fact that the lesion itself was flushed (Table 1, patients 12, 18, & 19). We think these failures resulted from operators who had not practised with the ex vivo simulator and mismatched the start time and contrast medium flush settings. Further investigation allowed for the optimisation of the flush rate and the timing of contrast medium injection.

In addition to conventional flushing through the guiding catheter, another technique that uses simultaneous injection of contrast media through the distal port of the imaging catheter (gentle flushing) exists7. While this technique may yield acceptable images, using the narrow imaging catheter purge lumen in this manner creates pressure that distorts live OCT imaging and may introduce the risk of imaging core breakage while the optics are turning at high speeds. Both procedures offer effective alternatives when conventional flush is not an option; however, our technique may limit the time that the OCT catheter occludes the coronary artery.

There are two limitations of the new procedure. First, the Dragonfly catheter has to traverse the target lesion quickly. Hence, this procedure is unsuitable for complicated lesions. Second, as with the conventional procedure, the new procedure requires a contrast medium injection and carries the risk of contrast-induced nephropathy3,8,9. Low-molecular-weight dextran can be used instead of contrast medium, but this makes it difficult to visualise whether blood is adequately flushed3.
A novel FD-OCT imaging procedure

The new procedure effectively and safely obtained clear images in coronary arteries in which the conventional procedure failed to achieve successful visualisation.

Conflict of interest statement
The authors have no conflicts of interest to declare.

References


**Online data supplement**


Moving image 2. Coronary angiography of new procedure.

Moving image 3. Optical coherence tomography of new procedure.