Natural History of Stent Edge Dissection, Tissue Protrusion and Incomplete Stent Apposition Detectable Only on Optical Coherence Tomography After Stent Implantation – Preliminary Observation –

Teruyoshi Kume, MD; Hiroyuki Okura, MD; Yoshinori Miyamoto, MD; Ryotaro Yamada, MD; Ken Saito, MD; Tomoko Tamada, MD; Terumasa Koyama, MD; Yoji Neishi, MD; Akihiro Hayashida, MD; Takahiro Kawamoto, MD; Kiyoshi Yoshida, MD

**Background:** The clinical impact of stent edge dissection, tissue protrusion, and incomplete stent apposition (ISA) after stent implantation, detectable only on optical coherence tomography (OCT), is still unknown because the natural course has not been investigated.

**Methods and Results:** All consecutive patients with angina pectoris in whom both intravascular ultrasound (IVUS) and OCT were performed immediately after stenting and at follow-up were included in the present study. The natural history of OCT-detected stent edge dissection, tissue protrusion, and ISA during follow-up was investigated. A total of 36 patients with 39 lesions was analyzed. At baseline, OCT showed 12 stent edge dissections, 25 tissue protrusions, and 8 ISAs, whereas IVUS demonstrated 6 stent edge dissections, 5 tissue protrusions, and 3 ISAs. All IVUS findings were clearly visualized on OCT. The maximum length of dissection flap and depth of ISA visualized on OCT were significantly shorter than those visualized on IVUS. Maximum length of tissue protrusion tended to be smaller on OCT than on IVUS. At follow-up (median 188 days), all findings noted on OCT were healed or resolved without any restenosis or thrombus formation.

**Conclusions:** Acute findings after stenting, such as edge dissection, tissue protrusion, and ISA, detectable only on OCT, tended to be smaller than those seen on both OCT and IVUS. The majority of OCT-detected acute findings resolved completely at follow-up. *(Circ J 2012; 76: 698–703)*

**Key Words:** Intravascular ultrasound; Optical coherence tomography; Stent

Stent thrombosis is a critical complication associated with either bare metal stent (BMS) or drug-eluting stent (DES) implantation. A previous study using intravascular ultrasound (IVUS) showed that significant stent edge dissection and tissue protrusion were more frequently detected in patients with early stent thrombosis. In addition, another retrospective IVUS registry reported that incomplete stent apposition (ISA) was frequently identified in patients with subsequent stent thrombosis, although the clinical impact of ISA is still in dispute. These findings, possibly associated with early stent thrombosis, have been assessed using IVUS. Recently, optical coherence tomography (OCT), which has a 10-fold higher resolution than IVUS, has been developed as a new intravascular imaging modality to assess stent morphology and vessel response after stent implantation in the catheterization laboratory. OCT could provide more detailed information on acute findings, such as stent edge dissection, tissue protrusion, and ISA immediately after stent implantation than IVUS. Therefore, it is not uncommon that OCT visualizes these unfavorable findings in segments in which angiography or IVUS have not indicated any evidence of abnormal findings. The clinical impact of these small unfavorable findings detected only on OCT, however, is still unknown, because their natural course has not been investigated. The aim of the present study was therefore to evaluate the natural history of the acute unfavorable findings detected only by OCT after stent implantation.

**Methods**

Patients with angina pectoris in whom both IVUS and OCT were performed immediately after stent implantation and at
Natural History of Acute OCT Findings

**Table 1. Baseline Clinical Characteristics**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>67.4±10.3</td>
</tr>
<tr>
<td>Male</td>
<td>27 (75.0)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>30 (83.3)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>23 (63.9)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>20 (55.6)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>14 (38.9)</td>
</tr>
<tr>
<td>Dialysis dependent</td>
<td>3 (8.3)</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>6 (16.7)</td>
</tr>
</tbody>
</table>

Data given as mean±SD or n (%).

**Table 2. Procedural Characteristics**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Target vessel</td>
<td>LAD/LCX/RCA</td>
</tr>
<tr>
<td></td>
<td>17 (43.6)/9 (23.1)/13 (33.3)</td>
</tr>
<tr>
<td>Stents per lesion</td>
<td>1.2±0.5</td>
</tr>
<tr>
<td>Total stent length (mm)</td>
<td>23.6±12.0</td>
</tr>
<tr>
<td>Mean stent diameter (mm)</td>
<td>3.1±0.5</td>
</tr>
</tbody>
</table>

Data given as mean±SD or n (%).
LAD, left anterior descending artery; LCX, left circumflex; RCA, right coronary artery.

**Table 3. Quantitative OCT Analysis**

<table>
<thead>
<tr>
<th></th>
<th>OCT-detected</th>
<th>IVUS-detected</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stent edge dissection</td>
<td>6 (15.4)</td>
<td>6 (15.4)</td>
<td></td>
</tr>
<tr>
<td>Maximum flap length (mm)</td>
<td>0.67±0.34</td>
<td>1.55±0.63</td>
<td>0.013</td>
</tr>
<tr>
<td>Tissue protrusion</td>
<td>20 (51.3)</td>
<td>5 (12.8)</td>
<td></td>
</tr>
<tr>
<td>Maximum protrusion length (mm)</td>
<td>0.60±0.21</td>
<td>1.02±0.54</td>
<td>0.165</td>
</tr>
<tr>
<td>Incomplete stent apposition</td>
<td>5 (12.8)</td>
<td>3 (7.7)</td>
<td></td>
</tr>
<tr>
<td>Maximum area (mm²)</td>
<td>0.58±0.21</td>
<td>1.48±0.74</td>
<td>0.165</td>
</tr>
<tr>
<td>Maximum depth (mm)</td>
<td>0.32±0.07</td>
<td>0.58±0.20</td>
<td>0.029</td>
</tr>
</tbody>
</table>

Data given as mean±SD or n (%).

**Figure 1.** Serial qualitative optical coherence tomography (OCT) and intravascular ultrasound (IVUS) after stent implantation. All OCT findings were healed or had resolved at follow-up. IVUS findings had also disappeared at follow-up, except for 1 lesion with stent edge dissection.
follow-up were included in the present study. Patients with acute myocardial infarction, a left main coronary artery lesion, and chronic total occlusion were excluded. Stent implantation was performed using current conventional techniques. The interventional strategy was left to the discretion of the operator. After stent implantation, all patients received dual antiplatelet therapy. This study was in accordance with the Declaration of Helsinki with regard to investigations in humans, and written informed consent was obtained from all patients before cardiac catheterization.

Intravascular Imaging and Analysis

IVUS was performed after intracoronary nitroglycerin (0.2 mg) was given. A 40-MHz IVUS catheter (Atlantis Pro, Boston Scientific, MA, USA) was placed distal (>10 mm) to the stented lesion and pulled back to the ostial junction using a motorized catheter pullback system set at 0.5 mm/s. After completion of IVUS, OCT was performed using the M2 OCT imaging system (LightLab Imaging, Westford, MA, USA) using a motorized pullback system.

Qualitative and quantitative OCT assessment of stent edge dissection, tissue protrusion, and ISA were performed. Stent edge dissection was defined as a disruption of the vessel luminal surface in the stent edges (5 mm proximal and distal) with visible flap. Maximum flap length of stent edge dissection was measured. Tissue protrusion was defined as protrusion of tissue between stent struts extending inside a circular arc connecting adjacent struts on OCT images. ISA was identified as a clear separation between at least one stent strut and the vessel wall and was defined as a distance between the center...
reflection of the strut and the vessel wall of greater than the actual stent thickness +20 μm on OCT images.14–18 Maximum area and depth of ISA were measured. Qualitative IVUS analysis was also performed to detect stent edge dissection, tissue protrusion, and ISA. On IVUS images, ISA was identified as ≥1 struts clearly separated from the vessel wall with evidence of blood speckles behind the strut. Quantitative IVUS assessment of vessel, peri-stent plaque, stent, lumen area in lesions with stent edge dissection, tissue protrusion, and ISA was done using PC-based software (echo-Plaque™, Indec Systems, Santa Clara, CA, USA). Peri-stent plaque area was calculated as vessel minus stent area. These IVUS measurements were repeated at follow-up coronary angiography. Neointimal area was calculated as stent minus lumen area, and % neointimal area was defined as neointimal area divided by stent area. Late lumen area loss was defined as lumen area at follow-up minus lumen area at baseline.

Findings that were visualized only on OCT were defined as OCT findings. In contrast, findings that could be documented on IVUS were defined as IVUS findings. We examined the natural history of acute findings during the follow-up period.

**Statistical Analysis**

Data are presented as mean±SD for continuous variables and as frequency (%) for categorical variables. In general, Student’s t-test was used to compare continuous variables, and the chi-square test or Fisher’s exact test was used to compare categorical variables. Statistical analysis was performed with SPSS version 17.0 for Windows (SPSS, Chicago, IL, USA), and P<0.05 was considered to be statistically significant.

**Results**

A total of 36 patients with 39 lesions treated with sirolimus-eluting stents (n=5) or paclitaxel-eluting stents (n=26) or BMS (n=8) was analyzed (27 men; mean age, 67.4±10.3 years). Of these 36 patients, serial IVUS and OCT were performed due to target-vessel revascularization in 5 patients, and non-target vessel revascularization in 2 patients. In the rest of the patients, serial IVUS and OCT were performed as the usual follow-up. Baseline clinical, and procedural characteristics are listed in Table 3. At baseline, OCT showed 12 stent edge dissections, 25 tissue protrusions, and 8 ISAs, whereas IVUS demonstrated 6 stent edge dissections, 5 tissue protrusions, and 3 ISAs. All IVUS findings were clearly visualized on OCT. As a result, findings seen only on OCT consisted of 6 stent edge dissections, 20 tissue protrusions, and 5 ISAs at baseline.

**Serial OCT Assessment of OCT vs. IVUS Findings**

At baseline, the maximum length of dissection flap and maximum depth of ISA on OCT were significantly shorter than those visualized on IVUS (Table 3). Other findings, such as maximum length of tissue protrusion and maximum area of ISA tended to be smaller on OCT than on IVUS. At follow-up (median 188 days; range, 98–461 days), all findings noted on OCT were healed or resolved (Figure 1). In contrast, an IVUS-detected stent edge dissection was persistent at follow-up. At follow-up, there was no visible material inside the vessel lumen, such as thrombosis within the stented lesion in this study. Representative OCT and IVUS images are given in Figure 2.

**Serial IVUS Assessment of Vessel Response on OCT vs. IVUS**

Serial quantitative IVUS assessment of vessel response on OCT vs. IVUS is given in Table 4. Vessel and plaque area did not change in all lesions during the follow-up period. Lumen area in lesions with OCT-detected tissue protrusion was significantly decreased due to neointimal proliferation at follow-up. Similarly, lumen area in lesions with IVUS-detected tissue protrusion tended to decrease at follow-up. Late lumen area loss tended to be greater in lesions with IVUS-detected than in those with OCT-detected tissue protrusion (2.18±1.74 mm² vs.
1.05±1.79 mm², P=0.189). Four (10%) of 39 lesions (3 paclitaxel-eluting stents and 1 BMS) demonstrated angiographic restenosis (% stenosis >50%). Of these 4 restenosis lesions, 2 lesions treated with paclitaxel-eluting stent showed stent edge dissection and tissue protrusion visualized only on OCT at baseline. No lesion with acute OCT findings, however, was directly related to the restenosis site at follow-up. The other 2 restenosis lesions, which included 1 BMS lesion, did not show any acute findings at baseline.

**Discussion**

The main findings of the present study are as follows: (1) OCT could detect more stent edge dissections, tissue protrusions, and ISAs after stent implantation than IVUS; (2) at baseline, OCT findings tended to be smaller than IVUS findings; and (3) at follow-up, all findings noted only on OCT were healed or resolved without any restenosis or thrombus formation. To the best of our knowledge, this is the first report to assess the time course significance of acute findings detectable only on OCT after stent implantation.

Stent edge dissection could be caused by excessive vessel damage during stent implantation and is considered to be one of the major predictors of acute stent thrombosis. In contrast, previous IVUS studies have shown that non-flow-limiting edge dissections are not necessarily associated with an increase in acute stent thrombosis or the development of restenosis. Furthermore, some dissections may be associated with favorable vessel remodeling or vessel dilation after balloon angioplasty. In the present study, flap length on OCT-detected stent edge dissection was significantly shorter, and healing occurred without any thrombus formation or restenosis at follow-up. Thus, the clinical impact of minor stent edge dissections visible only on OCT seems to be minimal.

Tissue protrusion is usually minimal and a previous IVUS study showed that the majority of tissue protrusion disappeared at follow-up. A recent IVUS study, however, reported that significant tissue protrusion might be associated with early stent thrombosis because of limitation of coronary flow, and suggested that tissue protrusion must be factored into the assessment of the final result after stent implantation. In the present study, tissue protrusions detected on OCT tended to be smaller than those detected on IVUS, and all OCT-detected tissue protrusions disappeared and/or were replaced by neointima during follow-up. Mean lumen area in lesions with OCT-detected tissue protrusion at baseline was sufficiently greater than lumen area narrowed by significant tissue protrusion in the previous study (lumen area <4 cm). In contrast, lumen area loss in lesions with IVUS-detected tissue protrusion tended to be greater than in those with OCT-detected tissue protrusion. Therefore, it is possible that lesions with IVUS-detected tissue protrusion may be associated with restenosis as well as thrombosis.

ISA immediately after stent implantation is mostly technique dependent, and it can resolve or persist at follow-up. A retrospective IVUS registry suggested that ISA immediately after stent implantation is associated with subsequent stent thrombosis. That study, however, was done before high pressure balloon dilation was routinely used for stent expansion. Conversely, other investigators have reported that ISA immediately after stent implantation was not related to adverse clinical events. In contrast, IVUS studies have demonstrated that late acquired ISA could be observed following BMS with or without brachytherapy or following DES implantation, and could possibly be related to very late stent thrombosis.

Considering the low incidence of stent thrombosis, it is possible that the potential impact of ISA may have been underestimated in stent thrombosis. Although the clinical impact of ISA immediately after stent implantation is still under discussion, OCT-detected ISA tended to be smaller than IVUS-detected ISA, and all resolved at follow-up without any thrombus formation.

The number of study lesions was not large enough to perform separate analyses according to the type of implanted stent. Vessel healing, such as neointimal proliferation after stent implantation, was different even among different types of DES. This difference might affect the natural course of ISA development. In addition, IVUS-detected ISAs, which were bigger than those seen on OCT, were all resolved at follow-up in the present study. Therefore, the cut-off for depth or area of ISA that predicts persistent ISA at follow-up could not be determined in the current study. A further study including a large number and wider variety of lesions that could analyzed separately according to the type of stent is warranted, to more accurately evaluate the natural history of acute findings after stent implantation.

After implantation of coronary stent, acute findings, such as edge dissection, tissue protrusion, and ISA, were frequently observed on OCT, and the clinical importance of OCT-detected findings may be different to that of IVUS-detected findings. It is important to discriminate between findings with and without significant clinical impact after stent implantation on OCT.

**Study Limitations**

This study had several limitations. First, this study was a retrospective, observational study. There was no randomization and the intravascular imaging was performed at the operator’s discretion. This limitation prevents the reaching of definitive conclusions as to the natural history of acute findings.

Although acute findings detected on either IVUS or OCT were not related to any adverse cardiac events, these results may be biased by the fact that larger dissection, ISA or tissue protrusion was treated with additional balloon dilatation and/or stent implantation according to the operator’s decision.

**Conclusion**

Acute findings after stenting, such as edge dissection, tissue protrusion, and ISA, detectable only on OCT, tended to be smaller than those visualized on both OCT and IVUS. The majority of OCT-detected acute findings resolved completely at follow-up.

**References**


