Difference of Tissue Characteristics Between Early and Very Late Restenosis Lesions After Bare-Metal Stent Implantation
An Optical Coherence Tomography Study

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Background—Although in-stent restenosis (ISR) after bare-metal stent (BMS) implantation peaks in the early phase, very late (VL) ISR occasionally is observed beyond a few years after BMS implantation. To date, this mechanism has not been fully clarified.

Methods and Results—we compared the morphological characteristics of VL-ISR (>5 years, without restenosis within the first year) (n=43) to those of early (E) ISR (within the first year) (n=39) using optical coherence tomography (OCT). Qualitative restenotic tissue analysis included assessment of tissue structure (homogeneous or heterogeneous), presence of microvessels, disrupted intima with cavity, and intraluminal material and was performed at every 1-mm slice of the entire stent. The proportions of cross-sections with heterogeneous intima in the entire stent was significantly higher in the VL-ISR group compared to the E-ISR group (60.5±28.5% versus 5.8±11.5%, P<0.0001), with heterogeneous intima being more frequently observed at the minimum lumen area site in the VL-ISR group (90.7% versus 17.9%, P<0.0001). Disrupted intima with cavity and intraluminal material also were observed more frequently in the VL-ISR group for the entire stent (18.6% versus 0%, 20.9% versus 2.6%, P<0.03) as well as at the minimum lumen area site (13.9% versus 0%, 16.2% versus 0%, P<0.03).

Conclusions—The morphological characteristics of restenotic tissue in VL-ISR were different from those in E-ISR and similar to atherosclerotic plaque. In BMS, progression of the atherosclerotic process within neointima after stent implantation may be associated with VL-ISR. (Circ Cardiovasc Interv. 2011;4:232-238.)

Key Words: optical coherence tomography stents restenosis

Although drug-eluting stents are widely used for the treatment of patients with coronary artery disease, bare-metal stents (BMS) are still useful in some situations, such as acute coronary syndrome or contraindication to prolonged antiplatelet therapy. The most critical problem of BMS is restenosis mainly caused by neointimal hyperplasia, which peaks in the early phase (6 to 12 months) after stent implantation. However, very late restenosis of BMS occasionally is observed beyond 4 to 5 years.1 The mechanism and characteristics of late luminal narrowing have not been fully understood.

Clinical Perspective on p 238
Optical coherence tomography (OCT) is a novel intravascular imaging modality that can produce in vivo high-resolution images of the coronary artery, providing new insights into the characteristics of atherosclerotic plaques2-5 and stent restenotic tissue structure.6 To gain insight into the mechanisms of very late restenosis, we evaluated the presence of numerous morphological characteristics as visualized with OCT and compared these images between cases with early (<1 year) and very late (>5 years) restenotic lesions of BMS.

Methods
Study Design and Population
In this observational study design, in-stent restenosis (ISR) was defined as >50% of diameter stenosis within the stent segment. Early ISR (E-ISR) was defined as the first ISR observed within 1 year after stent implantation, whereas very late ISR (VL-ISR) was defined as the first ISR observed >5 years after stent implantation and not detected within the first year after implantation. Short-term
follow-up angiography (within 1 year) was performed because of (1) the scheduled follow-up of the implanted stent or (2) evidence of myocardial ischemia. Long-term follow-up angiography (>5 years) was performed because of (1) the scheduled follow-up of another treated segment or (2) evidence of myocardial ischemia. A prospective protocol was approved by the institutional review board to perform an OCT study in all patients with ISR on coronary angiography provided that the patients met the eligibility criteria as well as gave written informed consent.

Inclusion criteria were (1) E-ISR or VL-ISR of a BMS as seen on angiography and (2) patient amenability for OCT study. Exclusion criteria were (1) left main coronary artery disease, (2) totally occluded lesion, (3) bifurcation stenting lesion, (4) bypass graft lesion, (5) hybrid stenting lesion with drug-eluting stent, (6) cardiogenic shock, (7) left ventricular ejection fraction <50%, (8) serum creatinine level >2 mg/dL, and (9) ST-segment elevation myocardial infarction. After diagnostic cardiac catheterization, patients who met the eligibility criteria were invited to participate in the study.

Quantitative Coronary Angiography
Offline quantitative coronary angiography (QCA) was conducted using the view that revealed the highest degree of stenosis. Severity of coronary stenosis was measured using the Cardiovascular Measurement System (MEDIS Medical Imaging System; Leiden, The Netherlands). For every patient, angiograms were analyzed at the time of OCT examination. Lesion length, reference diameter, minimal luminal diameter, and percent diameter stenosis were calculated by a single operator who was blinded to clinical characteristics. Analysis of angiographic frames was performed in the end-diastolic stage. Angiographic restenotic lesion type was classified as follows: focal restenosis, <10 mm in length (A) [articulation or gap (LA), margin (IB), focal body (IC), multifocal (ID)], or diffuse intrastent restenosis (B), >10 mm in length [intrastent (II), proliferative (III)].

OCT Imaging
After completion of coronary angiography and before any intervention, patients were evaluated with OCT. OCT imaging was performed using the M2 OCT system (LightLab Imaging; Westford, MA) and Helios occlusion balloon catheter (LightLab Imaging) method. The occlusion balloon catheter was advanced proximal to the implanted stent under the guidance of a 0.014-in angioplasty wire, and the guidewire was then exchanged with the OCT imaging wire, which was then positioned distal to the stent. During image acquisition, lactated Ringer solution was continuously flushed through the inner lumen of the occlusion catheter at a rate of 0.5 to 1.0 mL/s by power injector, and the balloon was inflated to 0.4 to 0.8 atmospheres until blood flow was fully occluded. Motorized pullback OCT imaging was performed at a rate of 1.0 mm/s throughout the stent. Images were acquired at 15.6 frames/s and digitally archived.

OCT Quantitative and Qualitative Analysis
OCT analysis was performed using LightLab Imaging proprietary software. Both qualitative and quantitative analyses of OCT images were performed by experienced analysts who were blinded to clinical and angiographic lesion characteristics. The analyses, including lumen and stent areas or morphological appearance, were performed at 1-mm longitudinal steps throughout the pullback from distal stent edge to proximal stent edge. At every frame, the lumen and stent were manually traced, and neointimal hyperplasia area (sten-t area − lumen area) was calculated. Percent neointimal hyperplasia area also was calculated [(neointimal hyperplasia area/stent area)×100]. To evaluate the morphological appearance of restenotic tissue, the pattern of restenotic tissue structure in cross-sectional images at every 1-mm interval was categorized as (1) homogeneous intima where restenotic tissue has uniform optical properties and does not show focal variations in backscattering pattern, (2) heterogeneous intima: restenotic tissue has uniform optical properties and does not show focal variations in backscattering pattern (Figure 1A) or (2) heterogeneous intima with marked signal attenuation with diffuse border (Figure 1B) or poor-signal region with sharp
border (Figure 1C) were present. In addition, we evaluated the presence of neovascularization (defined as small vesicular or tubular structures differentiated from any side branches with diameter <200 μm), and the location of the microvessels was classified into persistent or intraintima (Figure 1D and 1E). The proportions of cross-sections with these described qualitative findings with respect to the total number of analyzed cross-sections were reported. Moreover, we evaluated the presence of (1) disrupted intima (discontinuity of lumen border) with visible cavity (Figure 1F) and (2) intraluminal materials (protruding mass into the lumen and dimension >250 μm). Intraluminal materials were categorized by the presence of shadowing (Figure 1G and 1H).

When the reading of the qualitative analysis by 2 observers differed, a consensus was reached and used in the final decision. To test the interobserver variability of the qualitative OCT analysis, a total of 100 cross-sections within the restenotic lesions from 10 patients by 10 cross-sections each were selected and analyzed independently by 2 observers not involved in the primary data analysis. One of the observers repeated the analysis 1 week later to assess the intraobserver variability.

**Histopathologic Examination**

In a VL-ISR case, histopathologic examination was performed on the restenotic tissue retrieved by directional coronary atherectomy. Tissue samples were immersion fixed in 10% neutral-buffered formalin, processed for paraffin embedding, and sliced into 4-μm sections every 0.5 mm. A hematoxylin- and azan-stained slide was used for manual counting of the cellularity of these specimens, and an isolated operator blinded to the OCT data acquisition performed the analysis. In addition, immunocytochemistry was performed on adjacent slides with the following antibodies: anti-smooth muscle actin to identify smooth muscle cells and anti-CD68 to identify macrophages.

**Statistical Analysis**

Categorical variables are expressed as numbers and percentages. Continuous variables are expressed as mean±SD. Comparisons between groups were performed with 2-tailed Student t test for continuous variables and with χ² or Fisher exact test for categorical variables. The reproducibility of qualitative variables was assessed with κ test. A P<0.05 was considered statistically significant. All statistical analyses were performed using SPSS (SPSS Inc; Chicago, IL) software.

**Results**

Between June 2008 and August 2010, 6264 patients underwent follow-up coronary angiography after percutaneous coronary intervention in which follow-up coronary angiography after BMS implantation was performed for 1045 patients. Of these patients, 159 had ISR, and 92 meeting the eligibility criteria for this study underwent OCT (VL-ISR, 50 patients; E-ISR, 42 patients). However, 7 patients in the VL-ISR group and 3 in the E-ISR group were excluded because of poor OCT images. Finally, 43 lesions in 43 patients with VL-ISR and 39 lesions in 39 patients with E-ISR were enrolled.

**Clinical Characteristics**

Clinical characteristics of the study population are listed in Table 1. There were no significant differences between the 2 groups. Asymptomatic patients were included in both groups (VL-ISR, 17 patients; E-ISR, 21 patients; P=0.19). The follow-up coronary angiography for the asymptomatic patients in the VL-ISR group was performed because of the scheduled follow-up of another treated segment, whereas that in the E-ISR group was because of scheduled follow-up of the target lesions. In VL-ISR patients, 28 had other lesions treated before final coronary angiography.

**QCA Analysis**

QCA findings revealed no significant differences in any parameters and restenotic pattern between the 2 groups (Table 2). In addition, no patients in either group presented with angiographic evidence of thrombus.

In the VL-ISR group, QCA findings within the first year after stent implantation were as follows: lesion length, 8.3±8.1 mm; reference diameter, 2.9±0.5 mm; minimum lumen diameter, 2.3±0.6 mm; and percent diameter stenosis, 22.8±11.2%. As expected, minimum lumen diameter was reduced from 2.3±0.6 mm to 1.1±0.4 mm, and percent diameter stenosis was increased from 22.8±11.2% to 60.4±10.4% at very late follow-up (P<0.001).

**OCT Analysis**

The results of OCT quantitative and qualitative analysis in the entire stent are shown in Table 3. In quantitative analysis,
Table 2. Quantitative Coronary Angiography Analysis

<table>
<thead>
<tr>
<th></th>
<th>VL-ISR (n=43)</th>
<th>E-ISR (n=39)</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Length, mm</td>
<td>13.1±8.2</td>
<td>12.3±5.8</td>
<td>0.61</td>
</tr>
<tr>
<td>Reference lumen diameter, mm</td>
<td>2.7±0.6</td>
<td>2.5±0.5</td>
<td>0.13</td>
</tr>
<tr>
<td>Minimal lumen diameter, mm</td>
<td>1.1±0.4</td>
<td>1.2±0.4</td>
<td>0.26</td>
</tr>
<tr>
<td>Diameter stenosis, %</td>
<td>60.4±10.4</td>
<td>59.6±9.9</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Restenotic pattern
- Focal: 26 (60.5) vs 21 (53.8) vs 0.37
- Articulation or gap (IA): 0 (0) vs 0 (0) vs >0.99
- Margin (IB): 7 (16.3) vs 5 (12.8) vs 0.76
- Focal body (IC): 16 (37.2) vs 15 (38.5) vs 0.84
- Multifocal (ID): 3 (7.0) vs 1 (2.6) vs 0.62
- Diffuse: 17 (39.5) vs 18 (46.2) vs 0.37
- Intrastent (II): 12 (27.9) vs 12 (30.8) vs 0.78
- Proliferative (III): 5 (11.6) vs 6 (15.4) vs 0.75

Data are presented as mean±SD or n (%). E-ISR indicates early in-stent restenosis; VL-ISR, very late in-stent restenosis.

Table 3. OCT Analysis of Entire Stent and at Minimum Lumen Area Site

<table>
<thead>
<tr>
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<th>VL-ISR (n=43)</th>
<th>E-ISR (n=39)</th>
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<tbody>
<tr>
<td>Analysis of entire stent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean no. observed cross-sections</td>
<td>18.7±8.3</td>
<td>16.2±5.4</td>
<td>0.11</td>
</tr>
<tr>
<td>Quantitative analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean lumen area, mm²</td>
<td>3.8±1.3</td>
<td>4.7±2.4</td>
<td>0.06</td>
</tr>
<tr>
<td>Mean stent area, mm²</td>
<td>9.0±2.5</td>
<td>10.0±3.4</td>
<td>0.15</td>
</tr>
<tr>
<td>Mean neointimal hyperplasia area, mm²</td>
<td>5.4±1.5</td>
<td>5.3±1.9</td>
<td>0.78</td>
</tr>
<tr>
<td>Mean neointimal hyperplasia area, %</td>
<td>58.6±10.3</td>
<td>55.6±13.4</td>
<td>0.28</td>
</tr>
<tr>
<td>Qualitative analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homogeneous intima, %*</td>
<td>39.5±28.5</td>
<td>94.2±11.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Heterogeneous intima, %*</td>
<td>60.5±28.5</td>
<td>5.8±11.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Microvessels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent, %</td>
<td>25.6±18.6</td>
<td>6.8±8.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Intraintima, %</td>
<td>13.1±12.8</td>
<td>0±0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Disrupted intima with visible cavity</td>
<td>8 (18.6)</td>
<td>0 (0)</td>
<td>0.006</td>
</tr>
<tr>
<td>Intraluminal material</td>
<td>9 (20.9)</td>
<td>1 (2.6)</td>
<td>0.02</td>
</tr>
<tr>
<td>With shadowing</td>
<td>7 (16.2)</td>
<td>0 (0)</td>
<td>0.01</td>
</tr>
<tr>
<td>Without shadowing</td>
<td>2 (4.7)</td>
<td>1 (2.6)</td>
<td>&gt;0.99</td>
</tr>
</tbody>
</table>

Analysis at minimum lumen area site

<table>
<thead>
<tr>
<th></th>
<th>VL-ISR (n=43)</th>
<th>E-ISR (n=39)</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Quantitative analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum lumen area, mm²</td>
<td>1.9±1.1</td>
<td>2.2±0.9</td>
<td>0.17</td>
</tr>
<tr>
<td>Stent area, mm²</td>
<td>9.1±2.2</td>
<td>10.1±2.9</td>
<td>0.11</td>
</tr>
<tr>
<td>Neointimal hyperplasia area, mm²</td>
<td>7.2±2.2</td>
<td>7.9±2.4</td>
<td>0.23</td>
</tr>
<tr>
<td>Mean neointimal hyperplasia area, %</td>
<td>79.0±10.0</td>
<td>77.6±7.1</td>
<td>0.46</td>
</tr>
<tr>
<td>Qualitative analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homogeneous intima</td>
<td>4 (9.3)</td>
<td>32 (82.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Heterogeneous intima</td>
<td>39 (90.7)</td>
<td>7 (17.9)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Microvessels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent</td>
<td>11 (25.6)</td>
<td>5 (12.8)</td>
<td>0.17</td>
</tr>
<tr>
<td>Intraintima</td>
<td>7 (16.3)</td>
<td>0 (0)</td>
<td>0.01</td>
</tr>
<tr>
<td>Disrupted intima with visible cavity</td>
<td>6 (13.9)</td>
<td>0 (0)</td>
<td>0.03</td>
</tr>
<tr>
<td>Intraluminal material</td>
<td>7 (16.2)</td>
<td>0 (0)</td>
<td>0.01</td>
</tr>
<tr>
<td>With shadowing</td>
<td>6 (14.0)</td>
<td>0 (0)</td>
<td>0.03</td>
</tr>
<tr>
<td>Without shadowing</td>
<td>1 (2.3)</td>
<td>0 (0)</td>
<td>&gt;0.99</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD or n (%). E-ISR indicates early in-stent restenosis; VL-ISR, very late in-stent restenosis.

Reproducibility of Qualitative OCT Analysis

Interobserver/intraobserver variability (κ values) for the qualitative OCT assessment was as follows: 0.87/0.88 for restenotic tissue structure (homogeneous versus heterogeneous intima), 0.81/0.89 for disrupted intima with visible cavity, 0.87/0.91 for intraluminal material, 0.85/0.86 for persistent microvessels, and 0.86/0.86 for intraintima microvessels.

Discussion

The main findings of this study were that (1) the qualitative OCT findings of BMS restenosis tissue between VL-ISR and E-ISR are significantly different, (2) the heterogeneous OCT images of restenotic tissue were more frequently observed in the VL-ISR group, and (3) the OCT homogeneous pattern of restenotic tissue was more frequently observed in E-ISR. ISR remains a major limitation of coronary stenting with BMS. Pathological studies have suggested that reendothelialization occurs with variable deposition of the neointima within the vessel wall.
lumen, and intimal hyperplasia peaks in the early phase (6 to 12 months) after deployment of a BMS.\textsuperscript{11} The stented lesion has been believed to stabilize after the early restenosis phase. Choussat et al\textsuperscript{12} reported clinical stability of the stented site at 8 to 10 years after coronary stenting. However, Kimura et al\textsuperscript{1} demonstrated that late luminal renarrowing occurred beyond 4 years after BMS implantation in a serial coronary angiography study. They reported a triphasic long-term luminal response after BMS implantation as follows: early restenosis phase (≤6 months), an intermediate-term regression phase (6 months to 3 years), and a late renarrowing phase (>4 years).\textsuperscript{1}

To date, neither the mechanisms nor the characteristics of late

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure2}
\caption{A case of very late in-stent restenosis. Optical coherence tomography (OCT) images and histological findings in a symptomatic patient with a GFX stent (3.5×25 mm). Follow-up coronary angiography 9 months (A) and 8 years (B) after index percutaneous coronary intervention demonstrated no restenosis. The line indicates the implanted stent. Follow-up coronary angiography 10 years (C) after stent implantation. D through F, OCT images (D1, E1, and F1, cross-sectional images of site D, E, and F in C before directional coronary atherectomy; D2, E2, and F2, images after directional coronary atherectomy). OCT images at minimum lumen area site (E1) showed remarkable intimal growth inside the stent, which demonstrated a heterogeneous appearance (*) and irregular surface (white arrow) at the minimum lumen area site. At the proximal site, heterogeneous intima (*) also was observed (F1). Furthermore, intraluminal material suggesting thrombus (white arrows) was detected at the distal site (D1). Directional coronary atherectomy was performed, and restenotic tissue was retrieved from site E and F. Arrows in E2 and F2 indicate retrieval site. G through J, Histopathologic findings of the restenotic tissue from site E or F (G, azan magnification ×20; H, smooth muscle actin magnification ×30; I, CD68 magnification ×30; J, hematoxylin-eosin, magnification ×40) (bars=0.20 mm). Tissue was composed of collagen fiber in which cholesterol crystals (black arrow), foaming macrophages, and smooth muscle cells were observed consistent with the signal poor area with diffuse border (lipid-laden intima) on the OCT image.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure3}
\caption{A case of early in-stent restenosis. Optical coherence tomography findings in a symptomatic patient with 1 Vision stent (3.0×18 mm). A, Follow-up coronary angiography 9 months after index percutaneous coronary intervention demonstrated in-stent restenosis. The line indicates the implanted stent. B through D, The optical coherence tomography images showed typical bare metal stent restenotic tissue. The images demonstrated homogeneous and high backscatter and regular surface appearance as typical neointima. Although a peristrut heterogeneous pattern also was observed, the neointima was predominantly homogeneous.}
\end{figure}
luminal narrowing have been fully understood. Novel means of interrogating the tissue causing stent restenosis would be of great interest to improve our understanding about the mechanisms and impact of this clinical entity. Therefore, the current study was designed to compare the lesion characteristics between VL-ISR and E-ISR using OCT.

OCT images and quantifies intracoronary structures in great detail with very high resolution. The typical OCT image has an axial resolution of 10 to 20 μm and a lateral resolution of 20 μm, which is 10 times higher than that of intravascular ultrasonography and 20 to 30 times higher than that of multislice CT, MRI, and angiography. Experiments correlating excised coronary and aortic specimens with histology have demonstrated that OCT is capable of displaying the resolution of microstructural features of atherosclerotic plaques, despite low-intensity area possibly corresponds not only to intrinsic limitations in the qualitative analysis of restenotic tissue. OCT has intrinsic limitations in the qualitative analysis of restenotic tissue. Low-intensity area possibly corresponds not only to lipidic components, but also to myxomatous extracellular matrix. In addition, signal intensity is influenced by the intraluminal position of the OCT imaging wire or relatively low-penetration power of the light source through thick restenotic tissue. Thus, these intrinsic limitations of OCT should be taken into account when interpreting the present results.

Neoangiogenesis also is closely associated with plaque progression and may play a role in plaque hemorrhage. Increased neovascularization also has been observed at the site of intimal hyperplasia in models of arterial stenting and angioplasty. In the present study, intraintima microvessels were more frequently observed in the VL-ISR group. According to these results, intraintimal microvessels might play an important role in the progression of atherosclerosis in the neointima. However, the diagnostic accuracy of identifying neovascularization is uncertain, and there is a possibility that extremely small microvessels (<10 μm) could not be identified. Thus, this could be one of the important limitations of the present study.

Takano et al also reported on the neointimal characteristics of BMS in the extended late phase and found atherosclerosis and intimal neovascularization. Their study did not include ISR patients in an early phase group (0/20), and 62% of ISR patients were in a late-phase group (13/21, P<0.001). However, the current study exclusively included patients with ISR and compared the restenotic tissue between very late phase (n=43) and early phase (n=39). In addition, both cross-sectional images at the MLA site and at every 1-mm slice of the entire stented segments were analyzed. Therefore, our study was designed to better clarify the difference in restenotic tissue characterization between these 2 groups. Takano et al reported that normal neointima proliferated homogeneously, and lipid-laden intima were not observed in the early phase; however, the present study results showed heterogeneous intima observed in 7 (17.9%) patients at the MLA site in E-ISR. The findings of Takano et al may be affected by differences in patient characteristics (0% ISR in early phase versus 60% ISR in late phase). The results of the current study showed that atherosclerotic changes of intima presented not only at the MLA sites, but also at the non-MLA sites, suggesting that a pan-coronary process of atherosclerotic changes may be associated with lumen narrowing of BMS at the very late phase.

Limitations

OCT has intrinsic limitations in the qualitative analysis of restenotic tissue. First, histological data should be required to validate the sensitivity and specificity of OCT findings of restenotic tissue, including components and microvessels. In addition, these limitations highlight the need for improved quantitative methods for tissue intensity or backscatter assessment to facilitate accuracy and reduce observer variability. Second, our findings are based on observations in a relatively small number of patients. The third limitation relates to the different kinds of implanted stents between the groups because the initial procedure and stent implantation dates were different among these patients. Finally, VL-ISR cannot be classified as accurately as E-ISR in that the moment of atherosclerotic progression and lesion appearance could not be the same as the moment of angiographic assessment in...
VL-ISR. The sample included several asymptomatic patients at the time of follow-up angiography.

Conclusions

The OCT morphological characteristics of restenotic tissue in VL-ISR corresponded predominantly to a heterogeneous pattern and were different from that in E-ISR (homogeneous pattern), yet they were similar to an atherosclerotic plaque of the coronary artery. The cause of VL-ISR of BMS might be associated with the atherosclerotic progression of neointimal proliferation of the stent.

Acknowledgments

We thank Leigh Childs, Donald Bohannon, and Heidi N. Bonneau, RN, MS, CCA, for their assistance and important contributions.

Disclosures

None.

References


CLINICAL PERSPECTIVE

Recent reports have demonstrated that late restenosis occasionally was observed several years after bare-metal stent implantation. However, the mechanisms of this late luminal narrowing have not been clarified. Optical coherence tomography, a high-resolution intravascular imaging modality, can serve as a useful adjunct to visualize microscopic structures of the coronary artery. We compared optical coherence tomography findings between very late and early restenotic tissue after bare-metal stent implantation. Very late in-stent restenosis lesions demonstrated predominantly a heterogeneous pattern, whereas restenotic tissue in very late in-stent restenosis lesions is predominantly homogeneous. These findings suggest different mechanisms between very late and early restenosis after bare-metal stent implantation. Very late in-stent restenosis of bare-metal stents may be a manifestation of atherosclerotic disease progression.
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