Journal of the American College of Cardiology
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Published by Elsevier Inc.

Vol. 54, No. 2, 2009
ISSN 0735-1097/09/$36.00
doi:10.1016/j.jacc.2009.03.042

Serial Intravascular Ultrasound Analysis of the Main and Side Branches in Bifurcation Lesions Treated With the T-Stenting Technique

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Objectives This study sought to investigate the mechanism of restenosis and the predictive value of post-procedural minimum stent area (MSA) in the side branch (SB) after coronary bifurcation stenting.

Background The mechanism of restenosis, especially at the SB ostium, has not been fully elucidated.

Methods This study examined 73 bifurcation lesions with post-procedural and 9-month follow-up intravascular ultrasound images for both main vessel (MV) and SB. All lesions were treated with drug-eluting stents using the T-stenting technique. Analysis included 5 distinct locations: MV proximal stent, MV middle area, MV distal stent, SB ostium (<5 mm distal to the neocarina), and SB distal stent.

Results Stent expansion was significantly less in the SB than in the MV (87.1 ± 20.4% vs. 97.0 ± 29.1%, $p = 0.007$). The SB ostium was the most frequent site of post-procedural MSA. At the SB ostium, follow-up minimum lumen area (MLA) correlated with post-procedural MSA ($r = 0.81$, $p < 0.001$). The percentage of neointimal area was higher at the SB ostium than at the MV proximal, MV distal, and SB distal stent (23.8 ± 18.9% vs. 13.3 ± 17.3%, 15.4 ± 20.5%, and 12.5 ± 17.2%, $p < 0.001$). The optimal threshold of post-procedural MSA to predict follow-up MLA ≥4 mm^2 at the SB ostium was 4.83 mm^2, yielding an area under the curve of 0.88 (95% confidence interval: 0.80 to 0.95).

Conclusions Our data suggest that inadequate post-procedural MSA with increased neointimal hyperplasia may cause the SB ostium to be the most frequent site of restenosis after percutaneous coronary intervention on bifurcation lesions. (J Am Coll Cardiol 2009;54:110–7) © 2009 by the American College of Cardiology Foundation

Bifurcation lesion percutaneous coronary intervention (PCI) has a higher rate of restenosis than PCI for nonbifurcation lesions even in the drug-eluting stents (DES) era (1–3). In bifurcation lesions, restenosis occurs predominantly at the ostium of the side branch (SB). However, the reason that the SB ostium is the most frequent site of restenosis is not fully understood. The post-procedural minimum stent area (MSA) is shown to be an independent predictor of restenosis after PCI with DES in nonbifurcation lesions (4). Although stent underexpansion is common at the SB ostium (5), there are few data on the association between MSA after PCI and restenosis in bifurcation lesions. Increased neointimal hyperplasia or chronic stent recoil cannot be excluded as the causes of restenosis in bifurcation lesions.

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Manuscript received November 13, 2008; revised manuscript received March 4, 2009, accepted March 10, 2009.

The goal of this study was to investigate the mechanism of restenosis after coronary bifurcation stenting and the predictive value of post-procedural MSA in the SB. For this purpose, we performed serial intravascular ultrasound (IVUS) studies in both main branches and SB immediately after PCI and at angiographic follow-up.

Methods

Study population. The inclusion criteria were: 1) an elective coronary stenting with DES for a bifurcation lesion; 2) main vessel (MV) reference diameter (RD) ≥3.0 mm and SB RD ≥2.3 mm by visual estimation; and 3) DES in both MV and SB. Patients with hemodynamic instability or those undergoing primary PCI were excluded.

Between March 2005 and February 2007, 106 native bifurcation lesions in 105 patients were treated successfully by T-stenting and small-protrusion technique under IVUS guidance (Fig. 1). Post-intervention IVUS for the SB was

available in 94 lesions. Among these, angiographic follow-up was performed for 84 lesions in 83 patients (median 272 days, interquartile range 263 to 281 days after procedure) and follow-up IVUS for the SB was available in 73 lesions of 72 patients. Ten patients with available post-procedural IVUS data did not undergo a follow-up coronary angiogram; 1 patient died because of angiographically documented acute stent thrombosis, 1 patient died suddenly 38 days after the procedure, and renal failure developed in 1 patient during follow-up. The other 7 patients who refused a follow-up coronary angiogram had no adverse clinical events. At the follow-up coronary angiogram, the IVUS catheter could not pass because of tight stenosis at the SB ostium in 1 lesion. The IVUS study was not attempted in 7 lesions: 1 because of in-stent restenosis involving the MV and the SB simultaneously, 1 because of diffuse in-stent restenosis in the MV, and 5 for no definite cause. Among 3 lesions with lost or inadequate images for systemic IVUS analysis, angiographic restenosis at the SB ostium was not found. The institutional review board of Samsung Medical Center approved this study, and all subjects gave their informed consent to participation.

T-stenting technique: T-stenting and small protrusion. Before the procedure, aspirin 300 mg and clopidogrel 300 to 600 mg were loaded if patients were not taking these drugs. Intravenous heparin was administered to maintain an activated clotting time longer than 300 s. Administration of glycoprotein IIb/IIIa inhibitors was at the operator's discretion. All coronary lesions were treated with T-stenting and small-protrusion technique (6). After stenting of the MV, rewiring of the SB and kissing balloon inflation were performed if diameter stenosis was ≥50% at the SB ostium. If the residual stenosis was ≥50% or major dissection was observed after kissing balloon stenting, SB stenting was performed. The SB stent was pulled back slightly into the MV to fully cover the ostium of SB. Before final kissing balloon stenting, the balloon was dilated at as high a pressure as possible in both the MV and the SB sequentially to obtain an adequate MSA for each vessel. Then, final kissing balloon stenting was performed at moderate pressure. Representative post-procedural IVUS images are shown in Figure 2. Either sirolimus-eluting stents or paclitaxel-eluting stents were used, but the same type of DES was implanted in the MV and SB. After the procedure, aspirin (100 to 200 mg daily) was given indefinitely and clopidogrel (75 mg daily) was administered for at least 1 year.

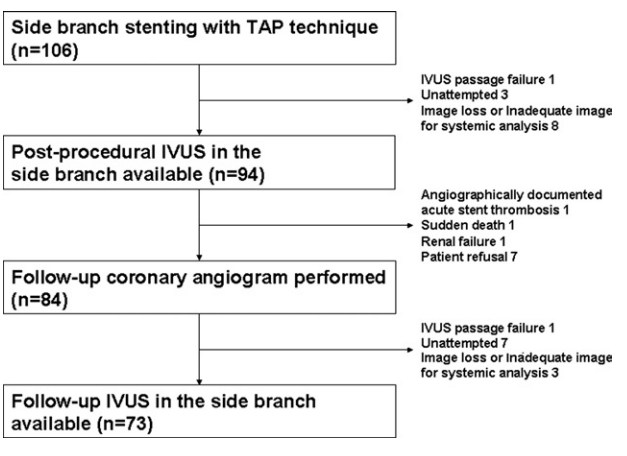

Figure 1 Patient Flow Chart

IVUS = intravascular ultrasound; TAP = T-stenting and small-protrusion.

Abbreviations and Acronyms

DES = drug-eluting stent(s)
IVUS = intravascular ultrasound
MLA = minimum luminal area
MLD = minimum luminal diameter
MSA = minimum stent area
MV = main vessel
PCI = percutaneous coronary intervention
QCA = quantitative coronary angiography
RD = reference diameter
SB = side branch

Quantitative coronary angiography (QCA). Baseline, post-intervention, and follow-up coronary angiographies were analyzed by 2 experienced technicians using an online QCA system (Integris H3000, Philips, Hamburg, Germany). The minimum luminal diameter (MLD) and RD before, immediately after the procedure, and at follow-up were measured in matched views. For the MV, the RD was the average of the proximal and distal reference lumen diameters. For the SB, the RD was the distal reference lumen diameter. Diameter stenosis was calculated by: $100 \times (RD - MLD)/RD$. Angiographic restenosis was defined as a diameter stenosis of ≥50% at follow-up.

IVUS imaging and analysis. The IVUS examinations were performed on the MV and the SB in a standard fashion (7). All IVUS images were obtained using a commercially available system (Boston Scientific Corporation/Cardiovascular Imaging System, San Jose, California) consisting of a rotating 40-MHz transducer within a 3.2-F imaging sheath. Before each IVUS run, 200 μg nitroglycerin was injected into the coronary artery. The catheter was advanced approximately 10 mm beyond the lesion, and imaging was performed from there to approximately 10 mm proximal to the lesion whenever possible. The transducer was pulled back automatically at a speed of 0.5 mm/s. Ultrasound studies were recorded on a 1/2-inch high-resolution s-VHS tape and were digitalized later (before November 2005) or recorded digitally (after November 2005) for offline analysis.

Quantitative IVUS analysis was performed using computerized planimetry (echoPlaque, Indec System, Mountain View, California) by 2 experienced observers following the criteria of the American College of Cardiology Clinical Expert Consensus Document on IVUS (8). The cross-sectional areas of the lumen, stent, and the external elastic membrane were measured. In the MV, the proximal and distal references were analyzed, whereas only the distal reference was analyzed in the SB. The reference sites were

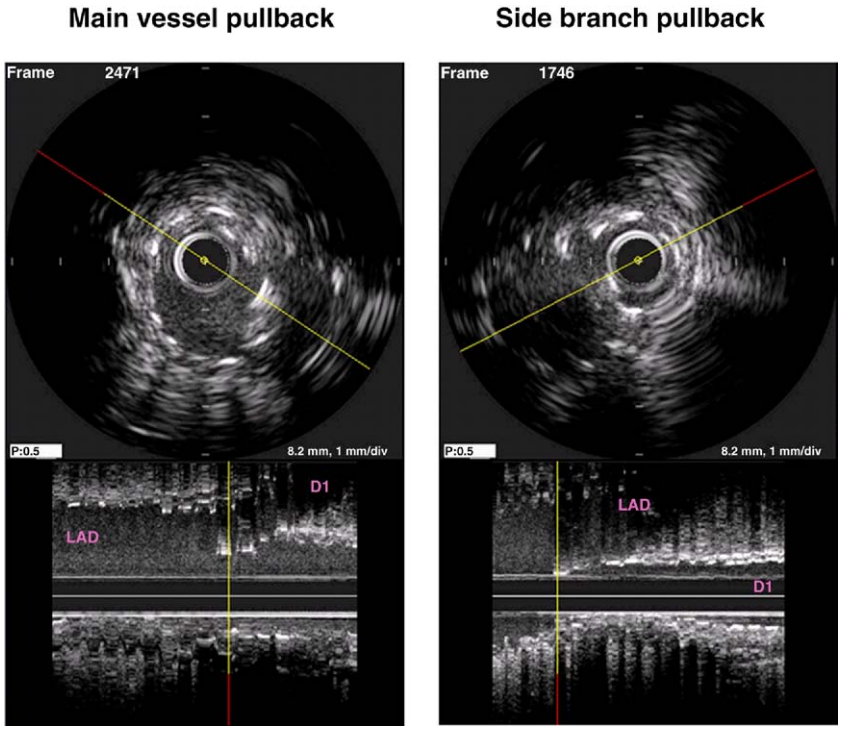

Figure 2 Representative Images of Post-Procedural Intravascular Ultrasound

The neocarina was observed, and the side branch (SB) stent was slightly pulled back into the main vessel. The SB ostium was fully covered, and stents were well apposed against the vessel wall. D1 = first diagonal branch; LAD = left anterior descending artery.

chosen as the image slices with the least amount of plaque within 10 mm proximal and distal to the lesions. Stent expansion was defined as MSA divided by distal reference lumen area. Percentage of neointimal area was calculated as: 100 × (stent area − lumen area)/stent area. Based on previous studies, adequate minimum luminal area (MLA) at follow-up was defined as ≥4 mm^2 (9). Bifurcation lesions were divided into 5 segments for analysis based on the previously used method with modification (Fig. 3) (5):

- MV proximal stent: between the proximal stent edge of the MV and the most proximal part of the neocarina area
- MV middle area: between the most proximal part of the neocarina and <5 mm distal to the neocarina in the MV stent
- MV distal stent: ≥5 mm distal to the neocarina in the MV stent
- SB ostium: <5 mm distal to the neocarina in the SB stent
- SB distal stent: ≥5 mm distal to the neocarina in the SB stent

Statistical analysis. Data are expressed as mean ± SD or frequencies. Continuous variables were analyzed using the paired *t* test and categorical variables using a Pearson chi-square or Fisher exact test. Statistical comparisons among 3 or more parameters were performed by the Friedman test and post hoc analysis with the least significant difference test using ranks for multiple comparisons. The p values are 2-tailed, and $p < 0.05$ was considered significant. All analyses were performed with the Statistical Analysis Software package (SAS version 9.1, SAS Institute, Cary, North Carolina).

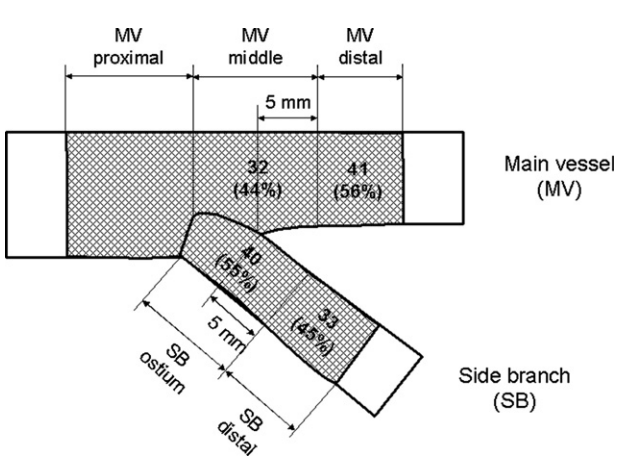

Figure 3 Schematic Diagram of Intravascular Ultrasound Analysis

Schematic diagram of intravascular ultrasound analysis and location of post-procedural minimum stent area in the main vessel (MV) and the side branch (SB).

Results

Patient characteristics. Baseline characteristics are presented in Table 1. The left anterior descending artery lesions were most common. Two-thirds of the lesions were true bifurcations. Sirolimus-eluting stents were used predominantly, and final kissing balloon stenting was performed in all lesions.

Angiographic and procedural data. Angiographic and procedural data are shown in Table 2. The RD was smaller and lesions were significantly shorter in the SB than in the MV. The post-procedural stent MLD was significantly smaller in the SB than in the MV. At follow-up, stent MLD was significantly smaller in the SB than in the MV, but the percent diameter stenosis was similar. Late loss was not significantly different between the MV and SB. Angiographic restenosis was noted in 6 lesions (8.2%) in the MV and in 9 lesions (12.3%) in the SB: 6 lesions were focal restenosis at the SB ostium, 2 lesions were diffuse restenosis involving the SB ostium, and 1 lesion occurred in the SB distal stent. The total restenosis rate per bifurcation lesion (restenosis of either the MV, the SB, or both) was 17.8% (13 of 73 lesions). Target lesion revascularization was performed in 5 lesions (6.8%).

IVUS data. The IVUS showed that the distal reference cross-sectional area and post-procedural MSA were smaller in the SB than the MV (Table 3). Stent expansion was significantly less in the SB than in the MV. Incomplete apposition was found in the MV middle area in 3 cases (2 cases at the neocarina and 1 case distal to the neocarina) and in the SB ostium in 3 cases after the procedure. The length of protruding stents was 2.7 ± 1.4 mm. In 6 cases (8.2%), the SB ostium was not fully covered. Of these, the angle between the main branch and SB was <60° in 5 cases. However, the uncovered length was very short (1 to 2 struts) in 5 cases and <3 mm even in the worst case. In the MV, the post-procedural MSA differed significantly according to location ($p < 0.001$). The MSA was largest in the MV proximal stent and smallest in the MV distal stent. Considering the whole MV, the MV distal stent was the most

Table 1 Baseline Characteristics*

Age (yrs)	62 ± 9
Male	52 (71)
Hypertension	41 (56)
Diabetes	16 (22)
Dyslipidemia	11 (15)
Current smoking	13 (18)
Prior myocardial infarction	4 (6)
Acute coronary syndrome	28 (38)
Site of bifurcation	
Distal left main stem	31 (42)
Left anterior descending/diagonal	34 (47)
Left circumflex/obtuse marginal	6 (8)
Right coronary/posterior descending	2 (3)
Type of bifurcation according to Medina classification	
1,1,1	36 (49)
1,1,0	10 (14)
1,0,1	3 (4)
1,0,0	5 (7)
0,1,1	10 (14)
0,1,0	6 (8)
0,0,1	3 (4)
True bifurcation†	49 (67)
Angle between main and side branch (°)	58 ± 22
Stents used	
Sirolimus-eluting stent	57 (78)
Paclitaxel-eluting stent	16 (22)
Final kissing balloon	73 (100)

Values are expressed as n (%) or mean ± SD. *n = 73 lesions in 72 patients. †Medina classification (1,1,1), (1,0,1), or (0,1,1).

Table 2 Angiographic and Procedural Data

	Main Vessel	Side Branch	p Value
Angiographic data			
Pre-procedural			
Reference diameter (mm)	3.03 ± 0.75	2.49 ± 0.67	<0.001
MLD (mm)	1.01 ± 0.81	1.17 ± 0.60	0.10
Diameter stenosis (%)	66.7 ± 25.3	51.0 ± 29.5	<0.001
Lesion length (mm)	14.25 ± 7.95	5.77 ± 5.01	<0.001
Post-procedural			
Stent MLD (mm)	2.85 ± 0.60	2.46 ± 0.57	<0.001
At follow-up			
Reference diameter (mm)	3.20 ± 0.71	2.56 ± 0.59	<0.001
Stent MLD (mm)	2.39 ± 0.71	1.91 ± 0.63	<0.001
Stent diameter stenosis (%)	24.8 ± 20.5	24.7 ± 20.4	0.96
Late loss	0.45 ± 0.72	0.53 ± 0.75	0.35
Procedural data			
Stent diameter (mm)	3.33 ± 0.29	3.01 ± 0.39	<0.001
Stent length (mm)	27.04 ± 5.61	20.41 ± 6.71	<0.001
Maximum pressure (atm)	15.4 ± 2.9	15.3 ± 2.7	0.81

Values are expressed as mean ± SD.
MLD = minimum luminal diameter.

Table 3 Intravascular Ultrasound Data

	Main Vessel	Side Branch	p Value
Post-procedural			
Proximal reference lumen CSA (mm^2)	13.1 ± 5.2	—	—
Distal reference lumen CSA (mm^2)	6.5 ± 2.3	5.5 ± 2.4	0.002
MSA (mm^2)	6.1 ± 1.9	4.7 ± 1.8	<0.001
MV proximal	10.0 ± 3.3	—	—
MV middle/SB ostium	6.8 ± 1.8	5.0 ± 1.8	<0.001
Distal	6.3 ± 2.1	5.0 ± 2.1	<0.001
Stent expansion* (%)	97.0 ± 29.1	87.1 ± 20.4	0.007
At follow-up (mm^2)			
Proximal reference lumen CSA	12.2 ± 4.9	—	—
Distal reference lumen CSA	6.9 ± 2.5	5.9 ± 2.3	0.002
MLA (mm^2)	5.3 ± 1.8	4.1 ± 1.7	<0.001
MV proximal	9.0 ± 3.3	—	—
MV middle/SB ostium	6.0 ± 1.9	4.4 ± 1.8	<0.001
Distal	5.7 ± 2.3	4.7 ± 2.2	0.001
Stent area at the MLA site	6.7 ± 2.0	5.1 ± 1.9	<0.001

Values are expressed as mean ± SD. *Defined as MSA divided by distal reference lumen area.
CSA = cross-sectional area; MLA = minimum lumen area; MSA = minimum stent area; MV = main vessel; SB = side branch.

frequent site of post-procedural MSA (Fig. 3). Post-procedural MSA was similar between the ostium and distal stent in the SB. However, considering the whole SB, the post-procedural MSA was found more frequently at the SB ostium than the SB distal stent (Fig. 3). When both the MV and the SB were considered, MSA was found in the SB in 79% of cases, and the SB ostium was the most frequent site of post-procedural MSA (42%) despite a length of only around 5 mm.

At follow-up, MLA was significantly smaller in the SB than in the MV (Table 3). In the MV, MLA differed significantly according to the location ($p < 0.001$). In the SB, MLA at the ostium had a tendency to be smaller than distal MLA ($p = 0.06$). Although MLA of the MV was ≥4 mm^2 in 56 lesions (77%), MLA of the SB was ≥4 mm^2 in only 26 lesions (36%). Chronic stent recoil was not observed: stent area at the MLA site was not significantly different from post-procedural MSA. When we focused on the SB ostium and the MV middle area, there was a significant correlation between post-procedural MSA and MLA at follow-up in the corresponding segments (Fig. 4). The percentage of neointimal area was significantly higher in the SB ostium compared with the MV proximal, MV distal, and SB distal stent (23.8 ± 18.9% vs. 13.3 ± 17.3%, 15.4 ± 20.5%, and 12.5 ± 17.2%, respectively, $p < 0.001$) (Fig. 5). The MV middle area showed a significantly higher percentage of neointimal area (19.7 ± 15.8%) than the MV proximal, MV distal, and SB distal stent as well. There was no significant difference in the percentage of neointimal area among the MV proximal, MV distal, and SB distal stent.

The receiver-operator characteristic curve identified that the optimal cutoff value of post-procedural MSA at the SB ostium to predict adequate follow-up MLA in the SB was 4.83 mm^2, yielding an area under the curve of 0.88 (95% confidence interval: 0.80 to 0.95) (Fig. 6). The positive predictive value with this cutoff point was 70%. However, there was no significant difference in the rate of focal restenosis at the SB ostium between bifurcation lesions with post-procedural MSA at the SB ostium ≥4.83 mm^2 ($n = 33$) and those with post-procedural MSA at the SB ostium <4.83 mm^2 ($n = 40$) (9.1% vs. 7.5%, $p = 0.81$). The target lesion revascularization rate was also similar in both groups (6.1% vs. 7.5%, $p = 0.99$).

The optimal cutoff value of post-procedural MSA at the MV middle area to predict adequate follow-up MLA in the MV was 6.14 mm^2, yielding an area under the curve of 0.81 (95% confidence interval: 0.64 to 0.99). The positive predictive value with this cutoff point was 91%.

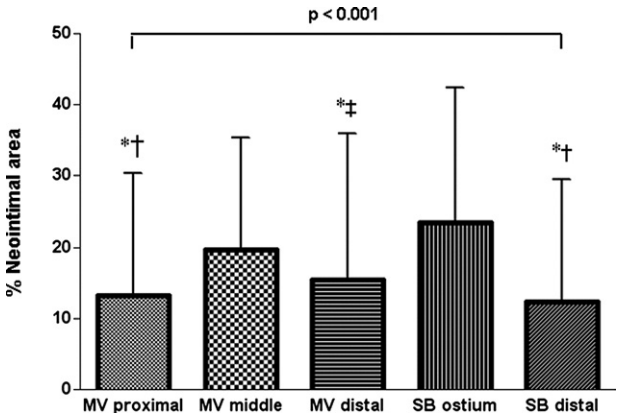

Figure 5 Percentage of Neointimal Hyperplasia

Percentage of neointimal hyperplasia (100 × neointimal area/stent area) according to each segment. *$p < 0.001$ versus the SD ostium; †$p < 0.01$ versus the MV middle area; ‡$p < 0.05$ versus the MV middle area. Abbreviations as in Figure 3.

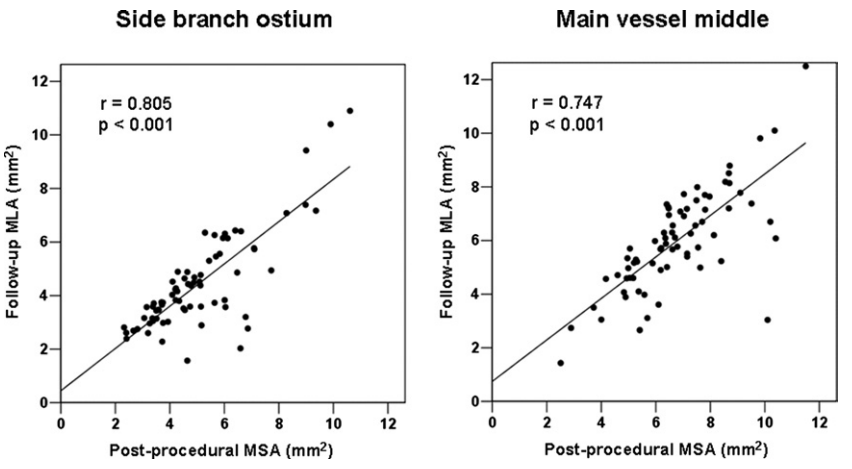

Figure 4 Correlation Between Post-Procedural MSA and Follow-Up MLA

Correlation between post-procedural minimum stent area (MSA) and follow-up minimum luminal area (MLA) at the side branch ostium and the main vessel middle area.

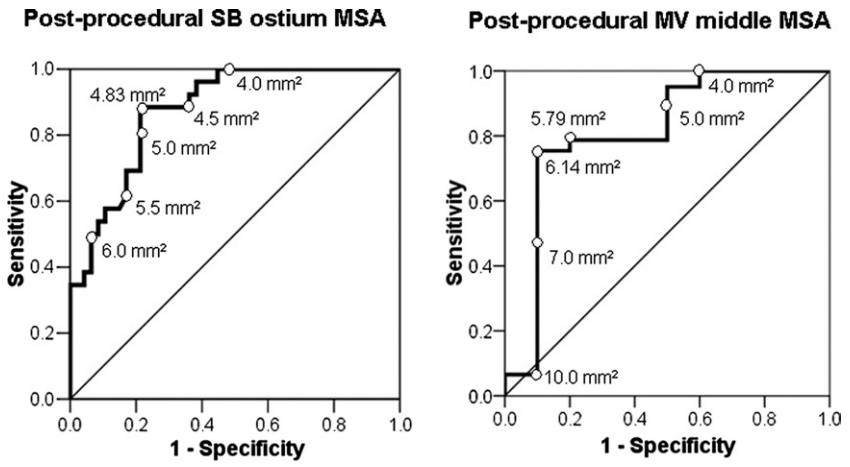

Figure 6 The Optimal Cutoff Value of Post-Procedural MSA

The receiver-operator characteristic curve showing the optimal cutoff value of post-procedural minimum stent area (MSA) at the SB ostium **(A)** and at the MV middle area **(B)** to predict adequate follow-up minimum luminal area. Abbreviations as in Figure 3.

Discussion

In the present study, we performed a serial IVUS study in both the main branches and SB of bifurcation lesions treated with 2 DES by T-stenting and the small-protrusion technique. The post-procedural MSA was smaller and stent expansion was significantly less in the SB than in the MV. The MLA at follow-up correlated significantly with the post-procedural MSA in both branches. The percentage of neointimal area is significantly higher in the SB ostium and MV middle area compared with other segments. To our knowledge, this is the first study to perform serial IVUS analysis on both branches immediately after procedure and at follow-up.

Restenosis rates after PCI on bifurcation lesions are still high, even with DES (1–3). However, the mechanism of restenosis and the reasons the SB ostium is the most frequent site of restenosis are not fully understood. A serial IVUS study showed that DES is very effective at reducing neointimal hyperplasia and, in turn, increased predictability of post-procedural MSA for stent long-term patency (10). Moreover, post-procedural MSA is an independent predictor of angiographic restenosis (4). Bifurcation lesions, however, were excluded in these studies. Therefore, the predictive value of post-procedural MSA in the SB and the optimum threshold to predict adequate follow-up MLA in the SB have not been known. The role of increased neointimal hyperplasia or chronic stent recoil for restenosis in bifurcation lesions has not been determined. To elucidate the mechanism of restenosis in bifurcation lesions, serial IVUS studies of both the MV and the SB are mandatory, as shown in the present study.

Mechanism of restenosis. Previous studies reported that most cases of restenosis occurred at the SB ostium (1,3). Costa et al. (5) performed an IVUS study on bifurcation lesions treated with the crush technique and showed that the majority of SB lesions had stent underexpansion and the smallest MSA was typically found at the SB ostium. Consistent with the previous study, post-procedural MSA was smaller and stent expansion was significantly less in the SB than in the MV in our study. The smallest MSA was found most frequently at the SB ostium. Moreover, MLA at follow-up significantly correlated with post-procedural MSA not only in the MV but also in the SB. Collectively, stent underexpansion or inadequate post-procedural MSA seems to contribute considerably to restenosis at the SB ostium.

Increased neointimal hyperplasia might explain the higher rate of restenosis in bifurcation lesions compared with nonbifurcation lesions. Angiographic late loss seemed to be greater in the SB than in the MV in previous studies on bifurcation lesions treated with DES (1). In the present study, we showed that neointimal hyperplasia was increased significantly at the SB ostium and MV middle area compared with other segments. Bifurcation sites are predisposed to early development of atherogenesis, and this may be related to variable shear forces produced by bifurcation (11). Bifurcation lesions showed marked intimal hyperplasia (12). Even after stenting, there is a possibility that neointimal hyperplasia increases in bifurcation lesions because of low shear stress. Although the MV middle area showed significantly increased neointimal hyperplasia compared with other segments as the SB ostium did, the difference in post-procedural MSA between the MV middle area and the SB ostium may explain why restenosis selectively involved the SB ostium.

Because stenting reduces initial elastic recoil and limits negative arterial remodeling (13), chronic stent recoil can be a very rare cause of in-stent restenosis in nonbifurcation lesions. However, bifurcation lesions have a special geometry and may have external constrictive forces. The MV stents may chronically compress SB stents. Nonetheless, in our serial IVUS studies, stent area of the MLA site at follow-up was not

decreased compared with post-procedural MSA. Our data suggested that chronic stent recoil contributes minimally, if at all, to restenosis in bifurcation lesions.

Predictive value of post-procedural MSA. In this study, the optimal cutoff value of post-procedural MSA in the SB to predict adequate follow-up MLA in the SB ostium was 4.83 mm^2. In the IVUS substudy of the SIRIUS (Sirolimus-Eluting Stent Versus Standard Stents in Patients With Stenosis in Native Coronary Artery) trial, the optimal threshold of post-procedural MSA to predict adequate follow-up MLA was 4.5 mm^2 in the small coronary arteries (<2.8 mm as measured by QCA) of nonbifurcation lesions (10). Considering that the vessel size of the SB was about 2.5 mm in our study, the optimal cutoff value of post-procedural MSA to predict adequate follow-up MLA in the SB ostium seemed to be larger than that in nonbifurcation lesions. In addition, the positive predictive values with the cutoff point of 4.83 mm^2 were 70%, somewhat lower compared with the IVUS substudy of the SIRIUS trial. Increased neointimal hyperplasia in the SB may lower the predictability of post-procedural MSA.

Study strengths and limitations. Our study had some strengths. First of all, we performed serial IVUS studies of both the MV and the SB. All lesions were treated with the same technique: T-stenting and small-protrusion technique, which excluded confounding derived from a difference in stenting techniques. Furthermore, final kissing ballooning was performed in all lesions. Most follow-up coronary angiograms were uniformly performed at 9 months.

Differences between the previous study by Costa et al. (5) and ours should be pointed out. Above all, we performed a follow-up IVUS study, which had not been done in the previous study. As mentioned in the paper by Costa et al. (5), serial IVUS study of both branches at implantation and follow-up would be required to elucidate the mechanism of restenosis after PCI on bifurcation lesions. Moreover, our study included nearly 3 times as many patients as did the study by Costa et al. (5). Post-procedural IVUS findings showed some discordance between the 2 studies: the MSA of the SB was larger in our study compared with the Costa et al. (5) study, whereas it was the opposite regarding the MV; when only the MV was considered, the MSA was found in the crush area rather than the distal stent in the Costa et al. (5) study, but the MV distal stent was the most frequent site of post-procedural MSA in our study. The following differences may explain this discordance. First, the treatment strategy was different: crush technique versus provisional T-stenting. Second, although we divided bifurcation lesions into 5 segments for analysis based on the method used by Costa et al. (5), the definition of some segments in our study differed from that in the previous study.

There are several limitations to our study. First, our study did not have the power to make any conclusion on angiographic restenosis and revascularization because of the small number of events. Second, our results cannot be generalized to all bifurcation lesions because we studied only bifurcation lesions treated with 2 DES using T-stenting and small-protrusion technique. Third, follow-up coronary angiograms and IVUS studies were not performed on all lesions with available post-procedural MSA. Nevertheless, the follow-up angiogram rate was about 90% and the follow-up IVUS rate was about 80%, which was fairly high. Fourth, although we used T-stenting and small-protrusion technique for ensuring stent coverage at the SB ostium, the SB ostium was not fully covered in 6 cases. Incomplete stent coverage may contribute to restenosis at the SB ostium. It is important to fully cover the SB ostium with the stent to minimize this issue.

Conclusions

We performed serial IVUS studies in both the MV and the SB immediately after PCI and at 9-month follow-up to investigate the mechanism of restenosis after PCI on bifurcation lesions and the predictive value of post-procedural MSA at the SB ostium. In bifurcation lesions treated with 2 DES, follow-up MLA correlated significantly with post-procedural MSA, and neointimal hyperplasia was found to be increased at the SB ostium. Our data suggest that both inadequate post-procedural MSA and increased neointimal hyperplasia are the major mechanisms of an increased restenosis rate in the SB ostium.

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Key Words: coronary disease ■ bifurcation ■ restenosis ■ ultrasonic.