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Elective Stenting of Unprotected Left Main Coronary Artery Stenosis

Effect of Debulking Before Stenting and Intravascular Ultrasound Guidance

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OBJECTIVES We sought to evaluate: 1) the long-term outcomes of 127 selected patients receiving unprotected left main coronary artery (LMCA) stenting; and 2) the impact of the debulking procedure before stenting and intravascular ultrasound (IVUS) guidance on their clinical outcomes.

BACKGROUND The long-term safety of stenting of unprotected LMCA stenoses has not been established yet.

METHODS A total of 127 consecutive patients with unprotected LMCA stenosis and normal left ventricular function were treated by elective stenting. The long-term outcomes were evaluated between two groups: IVUS guidance (n = 77) vs. angiographic guidance (n = 50); and debulking plus stenting (debulking/stenting; n = 40) vs. stenting only (n = 87).

RESULTS Angiographic restenosis was documented in 19 (19%) of 100 patients. The lumen diameter after stenting was significantly larger in IVUS-guided group (p = 0.003). The angiographic restenosis rate was significantly lower in the debulking/stenting group (8.3% vs. 25%, p = 0.034). The reference artery size was the only independent predictor of angiographic restenosis. During follow-up (25.5 ± 16.7 months), there were four deaths, but no nonfatal myocardial infarctions occurred. The survival rate was 97.0 ± 1.7% at two years.

CONCLUSIONS These data suggest that stenting of unprotected LMCA stenosis might be associated with a favorable long-term outcome in selected patients. Guidance with IVUS may optimize the immediate results, and debulking before stenting seems to be effective in reducing the restenosis rate. However, we need a large-scale, randomized study. (J Am Coll Cardiol 2001; 38:1054–60) © 2001 by the American College of Cardiology

Since the first report of balloon angioplasty, percutaneous intervention has been investigated for the treatment of unprotected left main coronary artery (LMCA) stenosis (1–12). Unfortunately, the initial experiences of patients undergoing unprotected LMCA interventions were discouraging because of high procedural complications and early mortality (2,9). However, recent progress in technique and equipment, including development of newly designed stents and use of intravascular ultrasound (IVUS) imaging, a debulking procedure and effective antiplatelet agents, has brought unprotected LMCA stenosis to the forefront of interventional cardiology, making it an inviting target for percutaneous intervention. The purposes of this study were: 1) to evaluate the long-term results of the first 127 patients with normal left ventricular function who received unprotected LMCA stenting; and 2) to evaluate the impact of the debulking procedure before stenting and IVUS guidance on their clinical outcomes.

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METHODS

Study patients. From November 1995 to April 2000, 127 consecutive patients with unprotected LMCA stenosis and normal left ventricular function were treated with elective stenting at our institution. The inclusion criteria were symptomatic LMCA disease or documented myocardial ischemia and angiographic evidence of ≥50% diameter stenosis of the LMCA. The exclusion criteria included a contraindication to antiplatelet or anticoagulation therapy and left ventricular dysfunction (ejection fraction <40%). The patients' informed, written consent was obtained, in accordance with the rules of the Institutional Ethics Committee, which approved the study.

Stenting procedure. The stenting procedures were described previously and briefly as follows (11). Several stents were used, depending on the length and location of the lesion: 1) slotted-tube stents were primarily used for ostial or body lesions of the LMCA; and 2) slotted-tube stents or coil stents, or their combination, were used for distal bifurcation lesions. For example, for an angled lesion in the distal LMCA and proximal portion of the left circumflex artery, a stent was placed from the LMCA into the left circumflex artery, and then another tube stent was placed in the proximal portion of the left anterior descending coronary artery (LAD) through the struts of the stent.

The use of IVUS was the operator's decision. Stenting

Abbreviations and Acronyms

CABG = coronary artery bypass graft surgery
CI = confidence interval
CSA = cross-sectional area
EEM = external elastic membrane
IVUS = intravascular ultrasound
LAD = left anterior descending coronary artery
LMCA = left main coronary artery
MLD = minimal lumen diameter
OR = odds ratio
QCA = quantitative coronary angiography

with IVUS guidance was performed in 77 patients. The IVUS criteria of stent optimization were as follows: 1) complete stent-to-vessel wall apposition; 2) adequate stent expansion (i.e., lumen cross-sectional area [CSA] of the target lesion ≥90% of the distal reference lumen CSA); and 3) full lesion coverage (13).

The debulking procedure with directional atherectomy before stenting, in 40 lesions, was generally performed during the late study period. Optimal atherectomy and adjunct balloon angioplasty were performed in all 40 lesions until the residual diameter stenosis was <10% by visual estimation. Neither an intra-aortic balloon pump nor abciximab was used as preventive therapy. All patients, except for the first 14 patients who took aspirin plus coumadin, received aspirin (200 mg/day, indefinitely) and ticlopidine (250 mg twice a day for one month) at least 48 h before stenting.

Protocol and analysis of IVUS imaging. Pre-intervention (n = 56) and post-intervention (n = 77) IVUS images were obtained after intracoronary administration of 0.2 mg nitroglycerin, using a commercial IVUS system (SciMed/Boston Scientific, San Jose, California) and motorized pullback (at 0.5 mm/s). The external elastic membrane (EEM), lumen and plaque plus media (=EEM-lumen) CSAs were measured using computerized planimetry, according to validated and published protocols (13–15). After the intervention, the lesion site was image-sliced with the smallest lumen CSA. The distal reference segment had the most visually normal cross sections within 10 mm distal to the lesion.

Quantitative coronary angiographic (QCA) analysis. Coronary angiography was performed after intracoronary administration of 0.2 mg nitroglycerin. The coronary angiographic results were analyzed by two independent angiographers. Using an on-line QCA system (ANCOR version 2.0, Siemens, Solna, Sweden), the percent diameter stenosis and minimal lumen diameter (MLD) were measured before and after the intervention and at follow-up, from diastolic frames in single, matched view showing the smallest lumen diameter. Angiographic restenosis was defined as diameter stenosis ≥50% at follow-up.

Follow-up. All patients were evaluated clinically during an office visit and/or by a telephone interview at one, two, three and six months, and then every four months after the intervention. Repeat coronary angiography was requested routinely at six months, or earlier if clinically indicated.

Definitions. Procedural success was defined as <30% residual diameter stenosis by QCA, with no major procedural or in-hospital complications, such as death, Q-wave myocardial infarction and emergency coronary artery bypass graft surgery (CABG). A major cardiac event was defined as the occurrence of cardiac death, nonfatal myocardial infarction or target lesion revascularization during follow-up. Deaths were classified as either cardiac or noncardiac. Deaths that could not be classified were considered as cardiac-related.

Statistics. Data are expressed as the mean value ± SD for continuous variables and frequencies for categorical variables. Survival and event-free survival distributions were estimated according to the Kaplan-Meier method. Logistic regression analysis was performed on all variables to identify the predictors of angiographic restenosis, and variables with a p value <0.2 by univariate analysis were entered into the multivariate analysis. Statistical significance was defined as $p < 0.05$.

RESULTS

Baseline clinical characteristics. The baseline clinical characteristics of the patients are shown in Table 1. There were no statistically significant differences between the two groups. The patients' mean age was 55.4 ± 10.4 years old, and 65% of them presented with unstable angina. Left ventricular ejection fraction in five patients with acute myocardial infarction was >40%. Twenty-one patients had coronary artery disease in the right coronary artery (n = 8) and LAD (n = 13)

Procedural results and in-hospital complications. Fifty-nine lesions were located in the ostium of the LMCA, 19 lesions in the body and 49 lesions in the distal portion. The lesion length was 4.2 ± 1.5 mm for ostial lesions and 12.4 ± 3.6 mm for lesions in the body and distal portions. A total of 156 stents was deployed in 127 patients. Ninety percent (141/156) of the stents were tubular, and the remaining 10% (15/156) were coil-type stents. The procedural success rate was 99.2%, and 20 patients (16%) underwent a percutaneous intervention in another major coronary segment. There were no procedure-related deaths. However, one patient had stent thrombosis (0.8%) that occurred three days after the intervention without IVUS guidance. He was 67 years old and had a history of diabetes mellitus, a small reference artery size (2.3 mm) and diffuse involvement of both the LMCA and LAD; he sustained a Q-wave acute myocardial infarction, but was successfully treated with CABG. The causes of stent thrombosis in this patient remain uncertain. In the remaining patients, the in-hospital clinical outcomes were uneventful.

Stenting with IVUS guidance. The quantitative angiographic data and procedural results for the IVUS-guided vs.

Table 1. Baseline Clinical Characteristics of Patients

	IVUS Guidance (n = 77)	Angiographic Guidance (n = 50)	p Value	Debulking Plus Stenting (n = 40)	Stenting Only (n = 87)	p Value
Age (yrs)	54.7 ± 9.9	56.7 ± 10.9	0.289	56.1 ± 9.9	55.1 ± 10.6	0.606
Males	52 (68%)	35 (70%)	0.463	28 (70%)	59 (68%)	0.488
Hypertension	14 (18%)	10 (20%)	0.486	7 (18%)	17 (20%)	0.496
Diabetes mellitus	11 (14%)	9 (18%)	0.374	7 (18%)	13 (15%)	0.449
Hypercholesterolemia*	24 (31%)	14 (28%)	0.430	12 (30%)	26 (30%)	0.573
Cigarette smoking	30 (39%)	18 (36%)	0.442	15 (38%)	33 (38%)	0.562
Clinical presentation			0.557			0.849
Stable angina	27 (35%)	13 (26%)		13 (33%)	27 (31%)	
Unstable angina	47 (61%)	35 (70%)		26 (65%)	56 (64%)	
Acute MI	3 (4%)	2 (4%)		1 (3%)	4 (5%)	
No. of diseased vessels			0.611			0.488
Two	72 (94%)	47 (94%)		37 (92%)	82 (94%)	
Three	5 (6%)	3 (6%)		3 (8%)	5 (6%)	

*Hypercholesterolemia > 240 mg/dl. Data are presented as the mean value ± SD or number (%) of patients or vessels.
IVUS = intravascular ultrasound; MI = myocardial infarction.

angiography-guided LMCA stenting groups are presented in Table 2. The debulking procedure before stenting was more frequently performed in the IVUS-guided stenting group (p = 0.019). The treatment strategies changed from the debulking/stenting group to the stenting-only group because of severe calcification >90° after IVUS evaluation in four patients. The lumen diameter after stenting was significantly larger in the IVUS-guided group (p = 0.003). Pre-intervention IVUS was performed in 22 of 40 LMCA ostial lesions. Negative remodeling (defined as EEM CSA of the lesion site less than that of the distal reference segment) was documented in 20 (91%) of 22 lesions. According to IVUS criteria of stent optimization, additional balloon angioplasty was performed in 15 (19.5%) of 77 lesions. As a consequence, the post-intervention stent CSA increased from 10.7 ± 2.8 to 13.0 ± 4.0 mm^2 after additional balloon angioplasty. There was no significant difference in the angiographic restenosis rate between the IVUS-guided vs. angiography-guided LMCA stenting groups.

Debulking plus stenting. The quantitative angiographic data and procedural results for the debulking/stenting and stenting-only groups are presented in Table 2. The IVUS data for the two groups are shown in Table 3. Compared with the stenting-only group, the debulking/stenting group have a significantly lower rate of angiographic restenosis (8.3% vs. 25.0%, p = 0.034) and target lesion revascularization (5.4% [2/37] vs. 18.8% [13/69], p = 0.049). A comparison of serial IVUS images before the intervention and after directional atherectomy at the same pre-intervention lesion site was performed in 24 of 30 lesions with directional atherectomy plus stenting. The plaque

Table 2. Baseline Angiographic Characteristics and Procedural Results of Lesions

	IVUS Guidance (n = 77)	Angiographic Guidance (n = 50)	p Value	Debulking Plus Stenting (n = 40)	Stenting Only (n = 87)	p Value
Lesion site			0.103			0.003
Os	40 (52%)	19 (38%)		11 (28%)	48 (55%)	
Body	13 (17%)	6 (12%)		5 (12%)	14 (16%)	
Bifurcation	24 (31%)	25 (50%)		24 (60%)	25 (29%)	
Debulking before stenting	30 (39%)	10 (20%)	0.019	30 (75%)	47 (54%)	0.019
Lesion morphology			0.816			0.714
A	11 (14%)	5 (10%)		6 (15%)	10 (12%)	
B1	26 (34%)	15 (30%)		11 (28%)	30 (35%)	
B2	27 (35%)	20 (40%)		14 (35%)	33 (38%)	
C	13 (17%)	10 (20%)		9 (22%)	14 (16%)	
Reference vessel diameter (mm)	4.0 ± 0.7	4.0 ± 0.6	0.463	4.0 ± 0.6	4.0 ± 0.7	0.547
Minimal lumen diameter (mm)						
Before intervention	1.2 ± 0.5	1.0 ± 0.5	0.020	1.1 ± 0.4	1.1 ± 0.5	0.896
After intervention	4.2 ± 0.6	4.0 ± 0.6	0.003	4.2 ± 0.7	4.0 ± 0.6	0.177
Follow-up	2.7 ± 1.0	2.7 ± 1.0	0.976	2.8 ± 1.0	2.7 ± 1.1	0.699
Pressure (atm)	15.1 ± 2.6	15.3 ± 2.8	0.327	15.0 ± 3.1	15.4 ± 2.5	0.284
Angiographic follow-up (%)	59/63 (94%)	41/43 (95%)	0.532	36/37 (97%)	64/69 (93%)	0.314
Angiographic restenosis rate (%)	11/59 (18.6%)	8/41 (19.5%)	0.556	3/36 (8.3%)	16/64 (25%)	0.034

Data are presented as the number (%) of lesions or the mean value ± SD.
IVUS = intravascular ultrasound.

Table 3. Intravascular Ultrasound Results for Debulking Plus Stenting and Stenting-Only Groups

	Debulking Plus Stenting	Stenting Only	p Value
Before intervention (n = 56)	n = 24	n = 32	
Distal reference segment			
Lumen MLD	3.1 ± 0.8	3.1 ± 0.5	0.975
Lumen CSA	9.4 ± 3.5	9.7 ± 3.2	0.768
EEM CSA	19.6 ± 6.1	18.3 ± 5.0	0.389
Lesion segment			
Lumen MLD	1.7 ± 0.3	1.8 ± 0.3	0.375
Lumen CSA	2.8 ± 1.3	2.9 ± 0.9	0.674
EEM CSA	18.2 ± 6.8	17.9 ± 6.2	0.495
After intervention (n = 77)	n = 30	n = 47	
Distal reference segment			
Lumen MLD	3.6 ± 0.5	3.4 ± 0.5	0.248
Lumen CSA	11.9 ± 2.9	11.0 ± 3.1	0.249
EEM CSA	20.3 ± 5.0	18.9 ± 5.0	0.242
Lesion segment			
Lumen MLD	3.7 ± 0.5	3.5 ± 0.5	0.159
Lumen CSA	12.9 ± 2.8	12.1 ± 3.4	0.231

Data are presented as the mean value ± SD.
CSA = cross-sectional area; EEM = external elastic membrane; MLD = minimal lumen diameter.

burden decreased from 86% to 55%, and the lumen CSA increased from 2.6 ± 0.9 to 8.9 ± 2.0 mm^2 after directional atherectomy. The plaque plus media CSA decreased from 19.9 ± 6.5 to 12.1 ± 5.6 mm^2—a 30% reduction.

Predictors of angiographic restenosis. Angiographic follow-up data were obtained for 100 of the 106 eligible patients (follow-up rate of 94%), and restenosis (≥50% diameter stenosis) was documented in 19 (19%) of these 100 patients. Table 4 shows the univariate predictors of angiographic restenosis. However, the reference artery size (odds ratio [OR] 0.39, 95% confidence interval [CI] 0.17 to 0.87, p = 0.021), by angiographic analysis, was the only significant predictor of angiographic restenosis on multivariate analysis. The angiographic restenosis rate was statistically different at the cut-off level of 3.6 mm for the reference artery size: 13% (9/68) for a reference artery size >3.6 mm vs. 31% (10/32) for ≤3.6 mm (p = 0.032). The angiographic restenosis rate was 13% (1/8) in the debulking/stenting group versus 40% (8/20) in the stenting-only group for a reference vessel size ≤3.5 mm (p = 0.159), and 7% (2/28) in the debulking/stenting group versus 18% (8/44) in the stenting-only group for a reference vessel size >3.5 mm (p = 0.187). Likewise, the pre-intervention distal reference lumen dimension (OR 0.65, 95% CI 0.44 to 0.97, p = 0.033) was an independent predictor of angiographic restenosis by IVUS analysis.

Two-year clinical outcomes. All patients have completed at least one month of clinical follow-up (mean 25.5 ± 16.7 months, range 1.0 to 54.9). Four patients died during the follow-up period (mean 12.0 ± 10.7 months). One died of an extensive myocardial infarction after elective CABG for treatment of restenosis (at 3.5 months); one died of sepsis (at 12.6 months); and the other two died of cancer (at 5 and 27 months). There were no nonfatal myocardial infarctions during the follow-up period. A total of 15 patients underwent repeat revascularization of the recurrent LMCA stenosis after stenting: 9 patients had a repeat percutaneous intervention (rotablation with balloon in 8 and rotablation with radiation therapy in 1) and 6 patients had CABG. The

Table 4. Univariate Predictors of Angiographic Restenosis

	Total	Restenosis	No Restenosis	OR (95% CI)	p Value
Angiography	n = 100	n = 19	n = 81		
Ref. MLD (mm)	4.0 ± 0.7	3.7 ± 0.6	4.1 ± 0.7	0.39 (0.17–0.87)	0.021
Pre-intervention MLD (mm)	1.1 ± 0.5	1.1 ± 0.5	1.1 ± 0.5	1.80 (0.63–5.18)	0.275
Final MLD (mm)	4.2 ± 0.6	3.9 ± 0.5	4.2 ± 0.6	0.46 (0.19–1.07)	0.072
Pressure (atm)	15.2 ± 2.7	15.1 ± 2.4	15.3 ± 2.9	0.94 (0.78–1.12)	0.480
Debulking (n)	36	3	33	0.27 (0.07–1.01)	0.052
Pre-intervention IVUS	n = 43	n = 9	n = 34		
Distal ref. segment					
Lumen MLD	3.1 ± 0.6	2.7 ± 0.3	3.2 ± 0.6	0.11 (0.02–0.80)	0.029
Lumen CSA	9.3 ± 3.3	7.0 ± 1.4	9.9 ± 3.5	0.66 (0.45–0.97)	0.037
EEM CSA	18.2 ± 5.4	15.3 ± 3.7	18.9 ± 5.5	0.86 (0.73–1.02)	0.077
Lesion segment					
Lumen MLD	1.7 ± 0.3	1.7 ± 0.2	1.7 ± 0.3	0.92 (0.08–10.54)	0.949
Lumen CSA	2.9 ± 1.1	2.8 ± 0.7	2.9 ± 1.2	0.88 (0.43–1.81)	0.724
EEM CSA	16.5 ± 6.6	16.1 ± 6.5	16.6 ± 6.7	0.99 (0.88–1.11)	0.839
Post-intervention IVUS	n = 59	n = 11	n = 48		
Distal ref. segment					
Lumen MLD	3.5 ± 0.5	3.3 ± 0.5	3.5 ± 0.5	0.53 (0.15–1.85)	0.319
Lumen CSA	11.1 ± 2.8	10.0 ± 2.7	11.4 ± 2.8	0.84 (0.67–1.06)	0.138
EEM CSA	19.1 ± 5.1	17.4 ± 5.2	19.5 ± 5.0	0.92 (0.80–1.05)	0.192
Lesion segment					
Lumen MLD	3.6 ± 0.5	3.4 ± 0.3	3.6 ± 0.5	0.41 (0.11–1.59)	0.198
Lumen CSA	12.1 ± 3.0	10.8 ± 1.8	12.4 ± 3.2	0.82 (0.65–1.04)	0.103

Data are presented as the mean value ± SD.
Ref. = reference vessel; other abbreviations as in Table 3.

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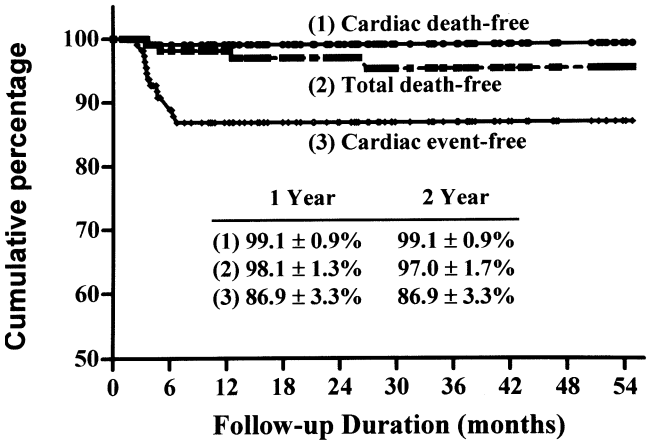

Figure 1. Cumulative probability of survival free of cardiac death (**1**), total death (**2**) and major cardiac events (**3**).

remaining four patients with asymptomatic, noncritical restenosis were treated with medication. However, no patients required a percutaneous intervention of a nontarget vessel during the follow-up period. Actuarial survival and major cardiac event-free survival rates are shown in Figure 1. The survival rates were 98.1 ± 1.3% and 97.0 ± 1.7% at one and two years, respectively. The cumulative probabilities of major cardiac event-free survival were 86.9 ± 3.3% and 86.9 ± 3.3% at one and two years, respectively, with no late target lesion revascularization (>6 months).

DISCUSSION

The major findings of this study are: 1) stenting of unprotected LMCA stenosis may be safe, with a high procedural success rate in selected patients with normal left ventricular function; 2) the overall long-term survival and major cardiac event-free survival rates were good; 3) IVUS guidance may help to achieve excellent initial outcomes; 4) the debulking procedure before stenting appears to result in lower restenosis rates; and 5) the reference artery size was an independent predictor of angiographic restenosis. These findings may provide some new insights into the approach for percutaneous intervention of unprotected LMCA stenosis.

Patient selection. The initial report from the Unprotected Left Main Trunk Intervention Multicenter Assessment (ULTIMA) registry still demonstrated relatively high subacute cardiac mortality in this heterogeneous group of patients. Many of these patients were at high risk or ineligible for CABG, and a low left ventricular ejection fraction was inversely related to the event rate (9,16). Therefore, in the current study, only patients who had a left ventricular ejection fraction ≥40% were included. Consequently, good long-term clinical outcomes could be expected.

Guidance with IVUS. In some cases of LMCA disease, it is often difficult to evaluate the actual size of the LMCA by angiography (17). In particular, in cases of ostial lesions with a certain degree of negative remodeling, the treatment strategy should be changed from debulking with stenting to stenting only. Therefore, IVUS before stenting provides useful information and good procedural outcomes. The post-stenting MLD was significantly larger in the IVUS-guided group in this study. However, the angiographic restenosis rate was not different between the IVUS-guided and angiography-guided procedures (Table 2). This finding may be partly explained by the fact that the reference vessel size in the current study was large (4.0 mm), and the post-stenting MLD was also large (4.0 mm), even in the angiography-guided group. A post-stenting MLD of 4.0 mm should be large enough to maintain the final MLD, without angiographic restenosis at follow-up.

Debulking before stenting. Aggressive debulking with directional atherectomy before stenting may reduce the residual plaque burden and subsequently the restenosis, as well (18,19). The degree of debulking using directional atherectomy in this study was comparable to that in other reports (19–21). On univariate analysis, debulking before stenting resulted in a significant reduction in angiographic restenosis. However, the benefit of debulking atherectomy was not found to be significant on multivariate analysis. In our study, the reference vessel size of the LMCA varied from 2.3 to 5.8 mm, and 57% of patients who had a follow-up angiogram had large reference vessels (>4.0 mm). The most likely explanation is that the degree of debulking might be relatively insufficient in such large vessels because of the limited device size. In large vessels, we could achieve a large MLD after stent deployment by using only high-pressure balloon dilation without debulking. Therefore, the effect of debulking seemed to be less in these vessels. Although there was no statistical significance, the benefit of debulking may be more crucial in vessels that are relatively small (<3.6 mm in this study). Regardless, it is notable that the debulking/stenting group had a lower restenosis rate, even though the reference diameter, final MLD by QCA analysis and final lumen dimensions by IVUS were similar to those in the stenting-only group. This suggests that the plaque, itself, may contribute to the restenosis process and supports the promise that debulking plus stenting may reduce restenosis.

Angiographic restenosis. Although there was a trend toward lower restenosis rates in the debulking group and univariate analysis demonstrated a large post-stenting MLD (Table 4), the reference artery size was the only independent predictor of angiographic restenosis on multivariate analysis in this study. In the debulking/stenting group, the angiographic restenosis rate was significantly lower. However, there were more patients with borderline diameter stenosis (40% to 50%) at follow-up angiography in the debulking/stenting group. Therefore, the follow-up MLD did not achieve statistical significance in the debulking/stenting group.

We can more clearly determine the difference in the restenosis rate according to the reference vessel size, because our data included various reference vessel sizes, from 2.3 to 5.8 mm. The predictor of the reference vessel size, as shown

in our study, may subsume the significance of those factors (post-stenting MLD, minimal lumen CSA) that have been identified previously (22–25). Based on our current analysis, the angiographic restenosis rate was statistically higher in the group with a reference vessel size <3.6 mm. This cut-off level of 3.6 mm in vessel size is an arbitrary lower threshold. Although 31% restenosis rate in those vessels might be slightly higher than that for non-LMCA stenting, it is still acceptable.

Long-term clinical outcomes. In the present study, the cumulative survival rate was 97.0 ± 1.7%, and the cardiac event-free survival rate was 86.9 ± 3.3% at two years (Fig. 1); these figures are consistent with those reported in a low-risk group of patients (12).

One-year mortality after CABG for a low-risk group similar to that identified in this study was 5.7% (26). The mortality rate in our series over two-year follow-up was 3.1%, which is acceptable.

For patients with restenosis, CABG was recommended first. However, 9 (47%) of 19 patients with restenosis received repeat angioplasty using rotational atherectomy. In the case of a long main shaft, radiation therapy was performed after rotational atherectomy. After a repeat intervention, only one of them developed restenosis, 17 months after the procedure. The patient had a history of diabetes mellitus with insulin treatment. The angiographic findings of patients with a second episode of restenosis showed new disease progression in the LAD and a diffuse pattern of in-stent restenosis of the LMCA. Therefore, he underwent elective CABG. The remaining eight patients who had a repeat intervention were free of symptoms during two years of follow-up.

After six months, there were no cardiac deaths or target lesion revascularizations, indicating that the long-term clinical course may be excellent after unprotected LMCA stenting in selected patients with normal left ventricular function. This result is consistent with previously published data showing that the restenotic process after stenting is time-limited and that little progression occurs beyond six months (27,28).

Study limitations. First, our findings may not be applicable to the entire range of unprotected LMCA stenoses, because only selected patients were included. Second, this study dealt with a relatively small number of debulking procedures, and our results may not be conclusive for evaluation of the role of debulking atherectomy before stenting. Third, the risks and benefits of unprotected LMCA stenting were not compared with those of CABG.

Conclusions. Stenting of unprotected LMCA stenosis has no serious procedure-related complications, and overall, long-term clinical outcomes appear to be excellent. The IVUS-guided procedure should be used to assess unusual lesion morphology and to optimize the immediate results, and debulking before stenting seems to be effective in reducing the restenosis rate. Stenting of unprotected LMCA stenosis may be a promising alternative to CABG in selected patient subsets with normal left ventricular function. However, a randomized clinical trial should be performed to validate its impact.

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REFERENCES

1. Gruntzig A. Transluminal dilation of coronary-artery senosis. Lancet 1978;1:263.
2. O'Keefe JH, Jr., Hartzler GO, Rutherford BD, et al. Left main coronary angioplasty: early and late results of 127 acute and elective procedures. Am J Cardiol 1989;64:144–7.
3. Eldar M, Schulhoff RN, Hertz I, et al. Results of percutaneous transluminal coronary angioplasty of the left main coronary artery. Am J Cardiol 1991;68:255–6.
4. Lopez JJ, Ho KK, Stoler RC, Cohen DJ, et al. Percutaneous treatment of protected and unprotected left main coronary stenoses with new devices: immediate angiographic results and intermediate-term follow-up. J Am Coll Cardiol 1997;29:345–52.
5. Laham RJ, Carrozza JP, Baim DS. Treatment of unprotected left main stenoses with Palmaz-Schatz stenting. Cathet Cardiovasc Diagn 1996;37:77–80.
6. Macaya C, Alfonso F, Iniguez A, et al. Stenting for elastic recoil during coronary angioplasty of the left main coronary artery. Am J Cardiol 1992;70:105–7.
7. Sathe S, Sebastian M, Vohra J, Valentine P. Bailout stenting for left main coronary artery occlusion following diagnostic angiography. Cathet Cardiovasc Diagn 1994;31:70–2.
8. Garcia-Robles JA, Garcia E, Rico M, et al. Emergency coronary stenting for acute occlusive dissection of the left main coronary artery. Cathet Cardiovasc Diagn 1993;30:227–9.
9. Ellis SG, Tamai H, Nobuyoshi M, et al. Contemporary percutaneous treatment of unprotected left main stenoses: initial results from a multicenter registry analysis 1994–1996. Circulation 1997;96:3867–72.
10. Laruelle CJJ, Brueren GBR, Ernst AMPG, et al. Stenting of unprotected left main coronary artery stenoses: early and late results. Heart 1998;79:148–52.
11. Park SJ, Park SW, Hong MK, et al. Stenting of unprotected left main coronary artery stenoses: immediate and late outcomes. J Am Coll Cardiol 1998;31:37–42.
12. Silvestri M, Baragan P, Sainous J, et al. Unprotected left main coronary artery stenting: immediate and medium-term outcomes of 140 elective procedures. J Am Coll Cardiol 2000;35:1543–50.
13. Hong MK, Park SW, Lee CW, et al. Intravascular ultrasound findings in stenting of unprotected left main coronary artery stenosis. Am J Cardiol 1998;82:670–3.
14. Tobis JM, Mallery J, Mahon D, et al. Intravascular ultrasound imaging of human coronary arteries in vivo: analysis of tissue characteristics with comparison to in vivo histologic specimens. Circulation 1991;83:913–26.
15. Nishimura RA, Edwards WD, Warnes CA, et al. Intravascular ultrasound imaging: in vitro validation and pathologic correlation. J Am Coll Cardiol 1990;16:145–54.
16. Bergelson BA, Tommaso CL. Left main coronary artery disease: assessment, diagnosis and therapy. Am Heart J 1995;129:350–9.

17. Hermiller JB, Buller CE, Tenaglia AN, et al. Unrecognized left main coronary artery disease in patients undergoing interventional procedures. Am J Cardiol 1993;71:173–6.
18. Prati F, Di Mario C, Moussa I, et al. In-stent neointimal proliferation correlates with the amount of residual plaque burden outside the stent: an intravascular ultrasound study. Circulation 1999;99:1011–4.
19. Moussa I, Moses J, Mario CD, et al. Stenting after Optimal Lesion Debulking (SOLD) registry: angographic and clinical outcomes. Circulation 1998;98:1604–9.
20. Tsuchikane E, Sumitsuji S, Awata N, et al. Final results of the STent versus directional coronary Atherectomy Randomized Trial (START). J Am Coll Cardiol 1999;34:1050–7.
21. Simonton CA, Leon MB, Baim DS, et al. Optimal directional coronary atherectomy: Final results of the Optimal Atherectomy Restenosis Study (OARS). Circulation 1998;97:332–9.
22. Hoffmann R, Mintz GS, Pichard AD, et al. Intimal hyperplasia thickness at follow-up is independent of stent size: a serial intravascular ultrasound study. Am J Cardiol 1998;82:1168–72.
23. Hoffmann R, Mintz GS, Mehran R, et al. Intravascular ultrasound predictors of angiographic restenosis in lesions treated with Palmaz-Schatz stents. J Am Coll Cardiol 1998;31:43–9.
24. Kasaoka S, Tobis JM, Akiyama T, et al. Angiographic and intravascular ultrasound predictors of in-stent restenosis. J Am Coll Cardiol 1998;32:1630–5.
25. Hong MK, Mintz GS, Hong MK, et al. Intravascular ultrasound predictors of target lesion revascularization after stenting of protected left main coronary artery stenoses. Am J Cardiol 1999;83:175–9.
26. Ellis SG, Hill CM, Lytle BW. Spectrum of surgical risk for left main coronary stenosis: benchmark for potentially competing percutaneous therapies. Am Heart J 1998;135:335–8.
27. Kimura T, Yokoi N, Nakagawa Y, et al. Three-year follow-up after implantation of metallic coronary-artery stents. N Engl J Med 1996; 334:561–6.
28. Asakura M, Ueda Y, Nanto S, et al. Remodeling of in-stent neointima, which became thinner and transparent over 3 years. Circulation 1998;97:2003–6.