Journal of the American College of Cardiology
© 2005 by the American College of Cardiology Foundation
Published by Elsevier Inc.

Vol. 45, No. 3, 2005
ISSN 0735-1097/05/$30.00
doi:10.1016/j.jacc.2004.10.039

Interventional Cardiology

Sirolimus-Eluting Stent Implantation for Unprotected Left Main Coronary Artery Stenosis

Comparison With Bare Metal Stent Implantation

Seung-Jung Park, MD, PHD,* Young-Hak Kim, MD,* Bong-Ki Lee, MD,* Seung-Whan Lee, MD,* Cheol Whan Lee, MD, PHD,* Myeong-Ki Hong, MD, PHD,* Jae-Joong Kim, MD, PHD,* Gary S. Mintz, MD,† Seong-Wook Park, MD, PHD*

Seoul, Korea; and New York, New York

OBJECTIVES This study was designed to compare the clinical and angiographic outcomes of sirolimus-eluting stent (SES) and bare metal stent (BMS) implantation for unprotected left main coronary artery (LMCA) stenosis.

BACKGROUND The safety and effectiveness of SES implantation for unprotected LMCA stenosis have not been ascertained.

METHODS Elective SES implantation for de novo unprotected LMCA stenosis was performed in 102 consecutive patients with preserved left ventricular function from March 2003 to March 2004. Data from this group were compared to those from 121 patients treated with BMS during the preceding two years.

RESULTS Compared to the BMS group, the SES group received more direct stenting, had fewer debulking atherectomies, had a greater number of stents, had more segments stented, and underwent more bifurcation stenting. The procedural success rate was 100% for both groups. There were no incidents of death, stent thrombosis, Q-wave myocardial infarction (MI), or emergent bypass surgery during hospitalization in either group. Despite less acute gain (2.06 ± 0.56 mm vs. 2.73 ± 0.73 mm, $p < 0.001$) in the SES group, SES patients showed a lower late lumen loss (0.05 ± 0.57 mm vs. 1.27 ± 0.90 mm, $p < 0.001$) and a lower six-month angiographic restenosis rate (7.0% vs. 30.3%, $p < 0.001$) versus the BMS group. At 12 months, the rate of freedom from death, MI, and target lesion revascularization was 98.0 ± 1.4% in the SES group and 81.4 ± 3.7% in the BMS group ($p = 0.0003$).

CONCLUSIONS Sirolimus-eluting stent implantation for unprotected LMCA stenosis appears safe with regard to acute and midterm complications and is more effective in preventing restenosis compared to BMS implantation. (J Am Coll Cardiol 2005;45:351–6) © 2005 by the American College of Cardiology Foundation

Several studies have demonstrated the safety and feasibility of unprotected left main coronary artery (LMCA) intervention using bare metal stents (BMS) (1–8). In-stent restenosis is the main limit to the long-term efficacy of coronary stenting and may be associated with increased long-term mortality of unprotected LMCA intervention (5).

The sirolimus-eluting stent (SES) (Cypher, Cordis, Johnson and Johnson Corp, Miami, Florida) markedly decreases in-stent restenosis in elective patients with relatively simple coronary lesions (9,10). Recent reports from the RESEARCH registry suggest that SES implantation for LMCA stenosis may lead to favorable clinical outcomes by decreasing restenosis (11,12). However, these studies were limited by their small numbers of patients, heterogeneity of inclusion criteria, and low rates of angiographic follow-up.

The present study reports the clinical and angiographic outcomes following elective SES implantation and compares these outcomes with those of BMS implantation in a large number of patients with unprotected LMCA stenoses.

METHODS

Study population. From March 2003 to March 2004, 102 consecutive patients with de novo unprotected LMCA stenoses underwent elective SES stenting (SES group). The control group consisted of 121 consecutive patients treated with BMS implantation for unprotected LMCA stenoses during the preceding two years (BMS group). The inclusion criteria were symptomatic LMCA disease or documented myocardial ischemia and angiographic evidence of ≥50% diameter stenosis of the LMCA suitable for stent placement. The LMCA was considered unprotected if there were no patent coronary artery bypass grafts to the left anterior descending artery or left circumflex artery (LCX). Patients with a contraindication for antiplatelet or anticoagulation therapy, or left ventricular dysfunction (ejection fraction ≤40%), were excluded. Informed written consent was ob-

From the *Department of Medicine, University of Ulsan College of Medicine, Asan Medical Center, Seoul, Korea; and the †Cardiovascular Research Foundation, New York, New York. This study was partly supported by the Cardiovascular Research Foundation, Seoul, Korea.

Manuscript received July 27, 2004; revised manuscript received September 27, 2004, accepted October 4, 2004.

JACC Vol. 45, No. 3, 2005
February 1, 2005:351–6

Abbreviations and Acronyms

BMS = bare metal stent
CSA = cross-sectional area
EEM = external elastic membrane
IVUS = intravascular ultrasound
LCX = left circumflex artery
LMCA = left main coronary artery
MACE = major adverse cardiac event
MI = myocardial infarction
QCA = quantitative coronary angiography
SES = sirolimus-eluting stent

tained from patients in accordance with the Declaration of Helsinki.

Stenting procedure. In general, LMCA intervention was performed as previously described (13). Predilation was routinely performed for BMS implantations, whereas the SES group underwent predilation only in selected cases with very tight stenoses in order to minimize balloon injury to the arterial wall. Most lesions at the ostium or shaft without involvement of the bifurcation were treated with a single stent. Bifurcation lesions were treated using one of the four following stenting strategies at the operator's discretion: stenting across the LCX ostium, kissing stenting, T stenting, or the Crush technique. The techniques of stenting across the LCX ostium, kissing stenting, and T stenting were performed as previously described (6). In the BMS group, bifurcation stenting such as kissing stenting or T stenting was rarely used because our previous study showed these complex stenting techniques did not result in superior outcomes compared to simple stenting techniques (6). The Crush technique is a relatively new bifurcation stenting technique involving drug-eluting stents for bifurcation coronary lesions (14). Final kissing balloon dilation was performed in cases with suboptimal results at the LCX ostium after bifurcation treatment and in most Crush technique cases (n = 10). Stenting across the LCX ostium was frequently adopted in patients with normal or diminutive (≤2.5 mm) LCX, whereas complex techniques such as kissing stenting, T stenting, and Crush technique were used in cases of a diseased LCX.

The use of intravascular ultrasound (IVUS) was strongly encouraged to achieve optimal stent placement. In the BMS group, debulking atherectomy before stenting was performed to decrease plaque burden in suitable cases. In contrast, in the SES group debulking atherectomy was used in only three cases to facilitate stent delivery to the target lesions. An intra-aortic balloon pump was used in selected cases for hemodynamic support. Postdilation with balloons larger than the nominal stent size was performed in cases of suboptimal stent expansion according to IVUS examination. Use of glycoprotein IIb/IIIa inhibitors was restricted because of the limited reimbursement in this country, and their use was left to the operator's discretion. Until May 2003, the available SES size was ≤3.0 mm, and 16 patients received this size. All patients received aspirin (200 mg/day) indefinitely and a loading dose of 300 mg clopidogrel, followed by 75 mg daily in a single dose for six months in the SES group and for one month in the BMS group. In addition, 200 mg cilostazol was administered as a loading dose, followed by 100 mg twice daily for one month in the SES group (15). A loading dose of clopidogrel or cilostazol was administered within 24 h before the procedure. Combined use of cilostazol after SES implantation was based on our unpublished findings, which showed a superior clinical outcome when using triple antiplatelet combination compared to double conventional combination therapy after stenting for complex coronary lesions.

Quantitative coronary angiography (QCA) analysis. Coronary angiography was performed after administering 0.2 mg intracoronary nitroglycerin. Coronary angiographic results were analyzed by two experienced angiographers not involved in the stenting procedures. Using the guiding catheter for magnification calibration and an online QCA system (ANCOR V2.0, Siemens, Solna, Sweden), minimal lumen diameter, percent diameter stenosis, and reference vessel diameter were measured before and after intervention and at follow-up from diastolic frames in single, matched views showing the smallest lumen diameter. The diameters of normal segments proximal and distal to the treated area were averaged to determine the reference diameter. In ostial and bifurcation lesions, adjacent normal segments were used as a reference. The acute gain was calculated as the difference between the minimal lumen diameter before and after the procedure. The late loss was defined as the difference in minimal lumen diameter after the procedure and at follow-up.

Table 1. Baseline Clinical Characteristics

	SES	BMS	p Value
Patients	102	121	
Age, yrs	60.3 ± 11.1	57.6 ± 11.9	0.084
Men	76 (74.5)	87 (71.9)	0.762
Cardiac risk factors			
Hypertension	48 (47.1)	44 (36.4)	0.103
Diabetes mellitus	29 (28.4)	26 (21.5)	0.231
Hypercholesterolemia (total cholesterol ≥200 mg/dl)	18 (17.6)	27 (22.3)	0.387
Current smoking	28 (27.5)	36 (29.8)	0.705
Previous percutaneous coronary intervention	13 (12.7)	9 (7.4)	0.185
Clinical manifestation			0.234
Stable angina	41 (40.2)	39 (32.2)	
Unstable angina	51 (50.0)	74 (61.2)	
Myocardial infarction within 2 weeks	10 (9.8)	8 (6.6)	
Multivessel involvement (≥2 vessels)	59 (58.4)	13 (10.7)	<0.001
Left ventricular ejection fraction, %	60.4 ± 8.4	61.8 ± 6.8	0.152

Values represent number (%) or mean ± 1SD.
BMS = bare metal stent; SES = sirolimus-eluting stent.

Table 2. Quantitative Angiographic Characteristics

	SES	BMS	p Value
Lesions	102	121	
Lesion location			<0.001
Ostium	4 (23.5)	58 (48.3)	
Shaft	6 (5.9)	11 (9.2)	
Bifurcation	72 (70.6)	51 (42.5)	
Reference vessel diameter, mm	3.46 ± 0.65	3.98 ± 0.69	<0.001
Lesion length, mm	20.9 ± 15.5	10.9 ± 5.3	<0.001
Minimal lumen diameter, mm			
Baseline	1.31 ± 0.57	1.35 ± 0.58	0.552
Final	3.36 ± 0.47	4.08 ± 0.57	<0.001
Follow-up	3.25 ± 0.53	2.78 ± 1.11	<0.001
Diameter stenosis, %			
Baseline	62.0 ± 14.5	65.7 ± 14.8	0.066
Final	0.8 ± 15	−3.3 ± 11.8	0.027
Follow-up	10.1 ± 15.3	30.0 ± 25.9	<0.001
Acute gain, mm	2.06 ± 0.56	2.73 ± 0.73	<0.001
Late loss, mm	0.05 ± 0.57	1.27 ± 0.90	<0.001
Restenosis			
Follow-up angiography	86 (84.3)	99 (81.8)	0.874
Overall	6 (7.0)	30 (30.3)	<0.001
Main vessel	2 (2.3)	26 (26.3)	<0.001
Ostial circumflex artery	4 (4.7)	13 (13.1)	0.072

Values represent number (%) or mean ± 1 SD.
Abbreviations as in Table 1.

Quantitative IVUS analysis. Preintervention and postintervention IVUS images were obtained after administering 0.2 mg intracoronary 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) and lumen cross-sectional areas (CSA) were measured using computerized planimetry, according to validated and published protocols (16–18). The plaque burden (%) was measured as: 100 × (EEM CSA − lumen CSA)/EEM CSA. After intervention, the lesion site was the image slice with the smallest lumen CSA.

Follow-up. All patients were evaluated clinically by office visits or telephone interviews at one, three, and six months, and then every four months after stenting. Repeat coronary angiography was routinely performed six months after stenting or earlier if clinically indicated by symptoms or documentation of myocardial ischemia.

Definition. Procedural success was defined as a Thrombolysis In Myocardial Infarction flow grade 3 and <30% residual diameter stenosis by QCA, without major procedural or in-hospital complications such as death, Q-wave myocardial infarction (MI), or emergent bypass surgery. A major adverse cardiac event (MACE) was defined as the occurrence of cardiac death, nonfatal MI, and target lesion revascularization during the follow-up period. Deaths that could not be classified were considered cardiac-related. Angiographic restenosis was defined as a diameter stenosis of ≥50% at the target site or the major side branches, such as the left anterior descending artery or the LCX. An untreated diminutive LCX with a diameter stenosis of ≥50% after the procedure and at follow-up was not considered restenosed.

Statistical analysis. Data are expressed as mean ± 1 SD for continuous variables and as frequencies for categorical variables. Differences between groups were assessed using chi-square statistics for categorical variables and Student *t* test for continuous variables. Clinical outcomes after one year were compared because the two groups were treated at different times. Major adverse cardiac event-free survival distributions were estimated according to the Kaplan-Meier method. The log-rank test was used to compare MACE-free survival between the two groups. A value $p < 0.05$ was considered to represent a significant difference. Statistical analysis was performed using commercially available software (SPSS 11 for windows, SPSS Inc., Chicago, Illinois).

RESULTS

Patient and lesion characteristics. The baseline clinical and angiographic characteristics of patients are shown in Tables 1 and 2. Compared to the BMS group, the SES group had more multivessel involvement (58.4% vs. 10.7%, $p < 0.001$), more bifurcation lesions (70.6% vs. 42.5%, $p < 0.001$), a smaller reference diameter (3.46 ± 0.65 mm vs. 3.98 ± 0.69 mm, $p < 0.001$), and a longer lesion length (20.9 ± 15.5 mm vs. 10.9 ± 5.3 mm, $p < 0.001$).

Procedural results. Procedural characteristics are summarized in Table 3. Compared to the BMS group, the SES

Table 3. Procedural Characteristics

	SES	BMS	p Value
Patients	102	121	
Intervention of other coronary lesions	43 (42.2)	42 (34.7)	0.254
Direct stenting	46 (45.1)	21 (17.4)	<0.001
Debulking coronary atherectomy	3 (2.9)	40 (33.1)	<0.001
Use of glycoprotein IIb/IIIa inhibitors	8 (7.8)	6 (5.0)	0.376
Use of additional high-pressure balloons	60 (58.8)	24 (19.8)	<0.001
Guidance of intravascular ultrasound	88 (86.3)	91 (75.2)	0.039
Support of intra-aortic balloon pump	5 (4.9)	5 (4.1)	0.782
Stents per patient	2.1 ± 1.0	1.6 ± 0.7	<0.001
Stents per lesion	1.6 ± 0.9	1.1 ± 0.4	<0.001
Contiguous stent length, mm	26.6 ± 18.1	13.3 ± 5.5	<0.001
Maximal balloon size, mm	3.90 ± 0.44	4.39 ± 0.55	<0.001
Balloon-to-artery ratio	1.1 ± 0.3	1.1 ± 0.2	0.290
Maximal inflation pressure, atm	18.5 ± 2.8	14.0 ± 2.6	<0.001
Treatment strategy for bifurcation lesions			<0.001
Stenting across left circumflex artery	43 (59.7)	42 (82.4)	
Kissing stenting	17 (23.6)	1 (2.0)	
T stenting	1 (1.4)	8 (15.7)	
Crush technique	11 (15.3)	0	

Values represent number (%) or mean ± 1 SD.
Abbreviations as in Table 1.

Table 4. Intravascular Ultrasound Measurements at the Lesion Segment

	SES	BMS	p Value
Before procedure			
Lumen CSA, mm^2	3.24 ± 1.33	2.86 ± 1.08	0.095
EEM CSA, mm^2	18.95 ± 5.06	17.73 ± 6.65	0.285
Plaque burden, %	82.4 ± 7.0	81.5 ± 9.7	0.605
After procedure			
Lumen CSA, mm^2	9.62 ± 2.57	12.41 ± 3.20	<0.001
EEM CSA, mm^2	20.02 ± 5.29	21.38 ± 5.41	0.708
Plaque burden, %	53.7 ± 7.9	41.2 ± 10.2	<0.001

Values represent mean ± 1 SD.
CSA = cross-sectional area; EEM = external elastic membrane; other abbreviations as in Table 1.

group received more direct stenting, fewer debulking atherectomies, had more stents implanted, and had more segments stented. In addition, IVUS guidance and additional high-pressure balloons were used more frequently in the SES group compared to the BMS group. Extreme overdilation with a balloon ≥1 mm larger than the nominal stent size was performed in 18 SES patients and four BMS patients ($p < 0.001$). Bifurcation stenting, including kissing stenting, T stenting, or Crush technique of bifurcation LMCA lesions, was performed in 40.3% of the SES group and in 17.6% of the BMS group ($p = 0.010$).

The procedural success rate was 100% in both groups. Periprocedural creatine kinase-MB elevation ≥3 times normal developed in seven SES patients (6.9%) and in 10 BMS patients (8.3%) ($p = 0.69$). There were no incidents of death, stent thrombosis, Q-wave MI, or emergent bypass surgery during hospitalization in either group. Quantitative angiographic and IVUS results after the procedures are shown in Tables 2 and 4. We found that the QCA minimal lumen diameter (4.08 ± 0.57 mm vs. 3.36 ± 0.47mm, $p < 0.001$) and IVUS lesion lumen CSA (12.41 ± 3.20 mm^2 vs. 9.62 ± 2.57 mm^2, $p < 0.001$) after procedure were larger owing to greater acute lumen gain (2.73 ± 0.73 mm vs. 2.06 ± 0.56 mm, $p < 0.001$) in the BMS group compared to the SES group.

Follow-up results. Six-month angiographic follow-up was performed on 86 SES patients (84.3%) and 99 BMS patients (81.8%). The QCA results at follow-up are shown in Table 2. Late lumen loss (0.05 ± 0.57 mm vs. 1.27 ± 0.90 mm, $p < 0.001$) and the overall angiographic restenosis rate (7.0% vs. 30.3%, $p < 0.001$) were significantly lower in the SES group than the BMS group. In the SES group, all restenoses occurred in patients with bifurcation LMCA lesions, with two in the main vessels and four at the ostial LCX (Table 5).

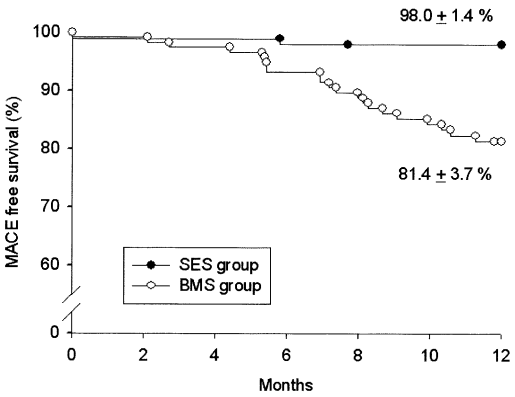

Figure 1. Kaplan-Meier curves for one-year MACE-free survival in patients treated with sirolimus-eluting stents (SES group) and bare metal stents (BMS group). A statistically significant difference was observed between the two groups ($p = 0.0003$). MACE = major adverse cardiac events including death, myocardial infarction, and target lesion revascularization.

Clinical follow-up information was collected on all patients in the two groups. The mean clinical follow-up duration was 11.7 ± 3.4 months in the SES group and 30.3 ± 13.7 months in the BMS group. At one-year follow-up, there were no deaths or acute MIs in either group. Target lesion revascularization at one year was performed in two SES patients (2.0%) and 21 BMS patients (17.4%) ($p < 0.001$). Information about patients with target lesion revascularization is shown in Table 5. In the SES group, four patients with restenoses at the LCX ostium did not undergo target lesion revascularization as there were no ischemic symptoms. At 12 months, the MACE-free survival rate was 98.0 ± 1.4% in the SES group and 81.4 ± 3.7% in the BMS group ($p = 0.0003$) (Fig. 1).

DISCUSSION

The present study found that SES implantation for patients with unprotected LMCA lesions and normal left ventricular function was safe, was associated with a low procedure-related complication rate, and was followed by no episodes of death or stent thrombosis. This is similar to BMS implantation. In addition, despite more complex patient and

Table 5. Patients With Angiographic Restenosis

Age, Gender	Lesion Location	Stenting Strategy	Location of Restenosis	Target Lesion Revascularization
62, M	Bifurcation	Kissing stenting	Proximal edge of stents	Repeat kissing stenting
65, F	Bifurcation	Kissing stenting	Stented segment	Bypass surgery
54, M	Bifurcation	Stenting across the LCX	LCX ostium	None
65, M	Bifurcation	Crush technique	LCX ostium	None
54, M	Bifurcation	Crush technique	LCX ostium	None
73, M	Bifurcation	Kissing stenting	LCX ostium	None

LCX = left circumflex artery.

lesion characteristics, the target lesion revascularization rate of 2.0% and the restenosis rate of 7.0% in the SES group were less than after BMS implantation, indicating that SES is more effective in preventing in-stent restenosis compared to BMS.

There are few reports regarding implantation of drug-eluting stents for LMCA stenosis. Two papers from the RESEARCH registry reported favorable results of SES implantation in LMCA stenoses (11,12). However, those studies involved small populations, included emergent interventions or protected LMCA stenoses, and had limited angiographic follow-up. In contrast, the present study included a large number of elective patients with unprotected LMCA stenoses. In addition, this study compared outcomes of SES with contemporary BMS implantation.

The design of the current study was such that BMS patients were treated between March 2001 and March 2003 in the pre-SES era, whereas SES patients were treated in the subsequent period between March 2003 and March 2004. Although the study was conducted over a relatively short period (three years), the two groups showed significant differences in terms of clinical characteristics and underwent different stenting strategies. Patients undergoing SES implantation were treated with a less restrictive interventional approach, similar to the RESEARCH registry (19). Sirolimus-eluting stent patients showed more complex baseline clinical characteristics than BMS patients, which led to an expectation of greater procedural and long-term complications (20). The SES patients included more multivessel disease, more bifurcation lesions, and longer lesion lengths. This difference in preoperative characteristics between the two groups was due to our expectation that the remarkable benefits of SES observed in the RAVEL and the SIRIUS trials might extend to more complex lesions (9,10,19). The stenting strategy was also different for the BMS procedure compared to the SES procedure. To avoid arterial trauma outside the stented segment, direct stenting without predilation followed by postdilation with an additional balloon were performed more frequently in SES patients compared to BMS patients (21).

There is a favorable initial outcome after LMCA intervention using BMS in low-risk patients (1–3,5,7). However, in-stent restenosis after BMS implantation is the most important reason for bypass surgery as the first choice for treating LMCA stenosis. In-stent restenosis in these patients not only influences long-term survival, but may also make repeat intervention so difficult that surgery is required (5). Despite endeavors to decrease in-stent restenosis after LMCA intervention using BMS, such as using aggressive debulking atherectomy, the restenosis rate remains at 20% to 30% (1,5,8). In the present study, BMS implantation with more use of debulking atherectomy achieved larger lumen gain than SES implantation (2). However, SES was associated with less angiographic restenosis and less target lesion revascularization compared to BMS. These results indicate that SES implantation may be very effective in suppressing intimal growth even in complex LMCA lesions and may lead to an excellent long-term clinical outcome.

A recent study reported that LMCA stenting using a 3.0 mm SES resulted in a relatively high target lesion revascularization rate (18.7%), suggesting that a 3.0 mm stent might not achieve adequate or homogenous drug delivery in large vessels such as the LMCA (22). In the present study, 16 SES patients received stents of ≤3.0 mm, and 18% of total patients underwent IVUS-guided extreme overdilation with a balloon ≥1 mm larger than the nominal stent size (23). However, restenosis in the main LMCA vessel occurred in only 2.0% of SES patients. Thus, LMCA SES implantation appears to be a highly efficient treatment, even when stents larger than 3.5 mm are not available.

Bifurcation LMCA lesions are considered inappropriate for percutaneous intervention owing to the technical difficulties of stenting and the possible narrowing of the large side branches (left anterior descending artery or LCX) after stenting. The first clinical randomized study using SES for bifurcation coronary lesions showed a very low restenosis rate in the main vessel compared with historical controls (24). However, the study did not reveal a benefit of side branch SES over balloon angioplasty in terms of side branch patency. In the present study, the higher overall restenosis rate in bifurcation lesions (6/61 patients, 9.8%) compared to proximal lesions (0 of 25 patients, 0%) after SES implantation indicates that treatment of bifurcation lesions remains challenging even in the era of drug-eluting stents (14,24,25). However, the present results showing very low restenosis rates in the main vessel and a very low frequency of target lesion revascularization indicate that the LMCA bifurcation may become an inviting target for percutaneous intervention with SES.

It is pertinent to note that the findings are based on a relatively short-term, single-center observational study. Furthermore, the number of study patients was too small to generalize our results to all patients with LMCA lesions. However, the present study provides important new information regarding the safety and effectiveness of SES implantation for unprotected LMCA stenosis. These data encourage the undertaking of a large, long-term, multicenter randomized study to compare SES implantation and bypass surgery for unprotected LMCA stenosis.

Reprint requests and correspondence: Dr. Seung-Jung Park, Department of Medicine, University of Ulsan College of Medicine, Asan Medical Center, 388-1 Poongnap-dong, Songpa-gu, Seoul 138-736, Korea. E-mail: sjpark@amc.seoul.kr.

REFERENCES

1. Silvestri M, Barragan P, Sainsous 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.
2. Park SJ, Hong MK, Lee CW, et al. Elective stenting of unprotected left main coronary artery stenosis: effect of debulking before stenting and intravascular ultrasound guidance. J Am Coll Cardiol 2001;38:1054–60.

3. Black A Jr., Cortina R, Bossi I, Choussat R, Fajadet J, Marco J. Unprotected left main coronary artery stenting: correlates of midterm survival and impact of patient selection. J Am Coll Cardiol 2001;37: 832–8.
4. Tan WA, Tamai H, Park SJ, et al. Long-term clinical outcomes after unprotected left main trunk percutaneous revascularization in 279 patients. Circulation 2001;104:1609–14.
5. Takagi T, Stankovic G, Finci L, et al. Results and long-term predictors of adverse clinical events after elective percutaneous interventions on unprotected left main coronary artery. Circulation 2002; 106:698–702.
6. Park SJ, Lee CW, Kim YH, et al. Technical feasibility, safety, and clinical outcome of stenting of unprotected left main coronary artery bifurcation narrowing. Am J Cardiol 2002;90:374–8.
7. Park SJ, Park SW, Hong MK, et al. Long-term (three-year) outcomes after stenting of unprotected left main coronary artery stenosis in patients with normal left ventricular function. Am J Cardiol 2003;91:12–6.
8. Hu FB, Tamai H, Kosuga K, et al. Intravascular ultrasound-guided directional coronary atherectomy for unprotected left main coronary stenoses with distal bifurcation involvement. Am J Cardiol 2003;92: 936–40.
9. Morice MC, Serruys PW, Sousa JE, et al. A randomized comparison of a sirolimus-eluting stent with a standard stent for coronary revascularization. N Engl J Med 2002;346:1773–80.
10. Moses JW, Leon MB, Popma JJ, et al. Sirolimus-eluting stents versus standard stents in patients with stenosis in a native coronary artery. N Engl J Med 2003;349:1315–23.
11. Arampatzis CA, Lemos PA, Tanabe K, et al. Effectiveness of sirolimus-eluting stent for treatment of left main coronary artery disease. Am J Cardiol 2003;92:327–9.
12. Arampatzis CA, Hoye A, Saia F, et al. Elective sirolimus-eluting stent implantation for left main coronary artery disease: six-month angiographic follow-up and 1-year clinical outcome. Cathet Cardiovasc Interv 2004;62:292–6.
13. Park SJ, Park SW, Hong MK, Cheong SS, Lee CW, Kim JJ. Stenting of unprotected left main coronary artery stenoses: immediate and late outcomes. J Am Coll Cardiol 1998;31:37–42.
14. Colombo A, Orlic D, Corvaja N, et al. Modified T-stenting technique with crushing for bifurcation lesions: immediate results and 30-day outcome. Cathet Cardiovasc Interv 2003;60:145–51.
15. Park SW, Hong MK, Moon DH, et al. Treatment of diffuse in-stent restenosis with rotational atherectomy followed by radiation therapy with a rhenium-188-mercaptoacetyltriglycine-filled balloon. J Am Coll Cardiol 2001;38:631–7.
16. 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.
17. 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.
18. 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.
19. Lemos PA, Serruys PW, van Domburg RT, et al. Unrestricted utilization of sirolimus-eluting stents compared with BMS implantation in the "real world": the Rapamycin-Eluting Stent Evaluated At Rotterdam Cardiology Hospital (RESEARCH) registry. Circulation 2004;109:190–5.
20. Rajagopal V, Rockson SG. Coronary restenosis: a review of mechanisms and management. Am J Med 2003;115:547–53.
21. Sousa JE, Serruys PW, Costa MA. New frontiers in cardiology: drug-eluting stents: part II. Circulation 2003;107:2383–9.
22. Chieffo A, Airoldi F, Michev I, et al. Early and mid-term results of Cypher stents in unprotected left main (abstr). J Am Coll Cardiol 2004;43 Suppl:21A.
23. Saia F, Lemos PA, Arampatzis CA, et al. Clinical and angiographic outcomes after overdilatation of undersized sirolimus-eluting stents with largely oversized balloons: an observational study. Cathet Cardiovasc Interv 2004;61:455–60.
24. Colombo A, Moses JW, Morice MC, et al. Randomized study to evaluate sirolimus-eluting stents implanted at coronary bifurcation lesions. Circulation 2004;109:1244–9.
25. Tanabe K, Hoye A, Lemos PA, et al. Restenosis rates following bifurcation stenting with sirolimus-eluting stents for de novo narrowings. Am J Cardiol 2004;94:115–8.