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Immediate Results and Late Outcomes After Stent Implantation in Saphenous Vein Graft Lesions: The Multicenter U.S. Palmaz-Schatz Stent Experience

S. CHIU WONG, MD, FACC, DONALD S. BAIM, MD, FACC,* RICHARD A. SCHATZ, MD, FACC,†
PAUL S. TEIRSTEIN, MD, FACC,† SPENCER B. KING III, MD, FACC,‡
R. CHARLES CURRY, JR., MD, FACC,§ RICHARD R. HEUSER, MD, FACC,‖
STEPHEN G. ELLIS, MD, FACC,¶ MICHAEL W. CLEMAN, MD, FACC,#
PAUL OVERLIE, MD, FACC,** JOHN W. HIRSHFELD, MD, FACC,††
CRAIG M. WALKER, MD, FACC,‡‡ FRANK LITVACK, MD, FACC,§§ DAVID FISH, MD, FACC,‖‖
JEFFREY A. BRINKER, MD, FACC,¶¶ MAURICE BUCHBINDER, MD, FACC,##
SHELDON GOLDBERG, MD, FACC,*** YA CHIEN CHUANG, PHD,
MARTIN B. LEON, MD, FACC, FOR THE PALMAZ-SCHATZ STENT STUDY GROUP

Objectives. **This study reports the multicenter registry experience evaluating the safety and efficacy of the Palmaz-Schatz stent in the treatment of saphenous vein graft disease.**

Background. **Saphenous vein graft angioplasty is associated with frequent periprocedural complications and a high frequency of restenosis. Stent implantation has been shown to reduce restenosis, with improved long-term outcomes in the treatment of native coronary artery disease. Preliminary experience with stent placement in the treatment of saphenous vein graft lesions has been favorable.**

Methods. **Twenty U.S. investigator sites enrolled a total of 589 symptomatic patients (624 lesions) for treatment of focal vein graft stenoses between January 1990 and April 1992. Follow-up angiography was performed at 6 months, and the clinical course of all study patients was prospectively collected at regular intervals for up to 12 months.**

Results. **Stent delivery was successful in 98.8% of cases, and the procedural success rate was 97.1%. The lesion diameter stenosis decreased from 82 ± 12% (mean ± SD) before to 6.6 ± 10.2% after treatment. Major in-hospital complications occurred in 17 patients (2.9%); stent thrombosis was found in 8 (1.4%); and major vascular or bleeding complications were noted in 83 (14.3%). Six-month angiographic follow-up revealed an overall restenosis rate (≥50% diameter stenosis) of 29.7%. Multivariate logistic regression analysis indicated that 1) restenotic lesions, 2) smaller reference vessel size, 3) history of diabetes mellitus, and 4) higher percent poststent diameter stenosis were independent predictors of restenosis. The 12-month actuarial event-free survival was 76.3%.**

Conclusions. **Stent implantation in patients with focal saphenous vein graft lesions can be achieved with a high rate of procedural success, acceptable major complications, reduced angiographic restenosis and favorable late clinical outcome compared with historical balloon angioplasty control series. The rigorous anticoagulation regimen after stent placement results in more frequent vascular and other bleeding complications. Future randomized studies comparing standard balloon angioplasty with stent implantation are warranted to properly assess the full impact of stent placement in the treatment of saphenous vein graft lesions.**

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From the Department of Internal Medicine (Division of Cardiology), Washington Hospital Center, Washington, D.C.; *Beth Israel Hospital, Boston, Massachusetts; †Scripps Clinic and Research Foundation, La Jolla, California; ‡Emory University School of Medicine, Atlanta, Georgia; §Florida Heart Group, Orlando, Florida; ‖Arizona Heart Institute, Phoenix, Arizona; ¶Cleveland Clinic Foundation, Cleveland, Ohio; #Yale University Medical School, New Haven, Connecticut; **Cardiology Associates of Lubbock, Lubbock, Texas; ††Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania; ‡‡Houma Heart Clinic, Houma, Louisiana; §§Cedars-Sinai Medical Center, Los Angeles, California; ‖‖St. Luke's Episcopal Hospital, Houston, Texas; ¶¶John Hopkins Hospital, Baltimore, Maryland; ##University of California at San Diego, San Diego, California; ***Thomas Jefferson University Hospital, Philadelphia, Pennsylvania. This study was supported by a grant from the Johnson & Johnson Interventional Systems, a Johnson & Johnson Company, Warren, New Jersey and from the Cardiology Research Foundation, Washington, D.C. Drs. Leon and Goldberg are paid consultants of Johnson & Johnson Interventional Systems; Dr. Schatz has a royalty agreement with Johnson & Johnson.

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Address for correspondence: Dr. Martin B. Leon, Washington Hospital Center, Suite 4B-1, 110 Irving Street NW, Washington, D.C. 20010.

Despite increased operator expertise and technical improvements in angioplasty equipment during the past decade, conventional balloon angioplasty of saphenous vein graft lesions is still limited by frequent restenosis (especially in the ostium and shaft portion of vein grafts) and substantial periprocedural complications, particularly in older vein grafts with unfavorable morphologic features (1–17). Moreover, repeat bypass surgery is associated with increased mortality and less effective symptom relief than the initial operation (4,9,18–21). This finding has prompted an intense effort to develop alternative transcatheter modalities to improve both short- and long-term outcomes after treatment of saphenous vein graft lesions (22–26).

Two randomized multicenter studies (27,28) have recently shown that the Palmaz-Schatz stent reduces restenosis fre-

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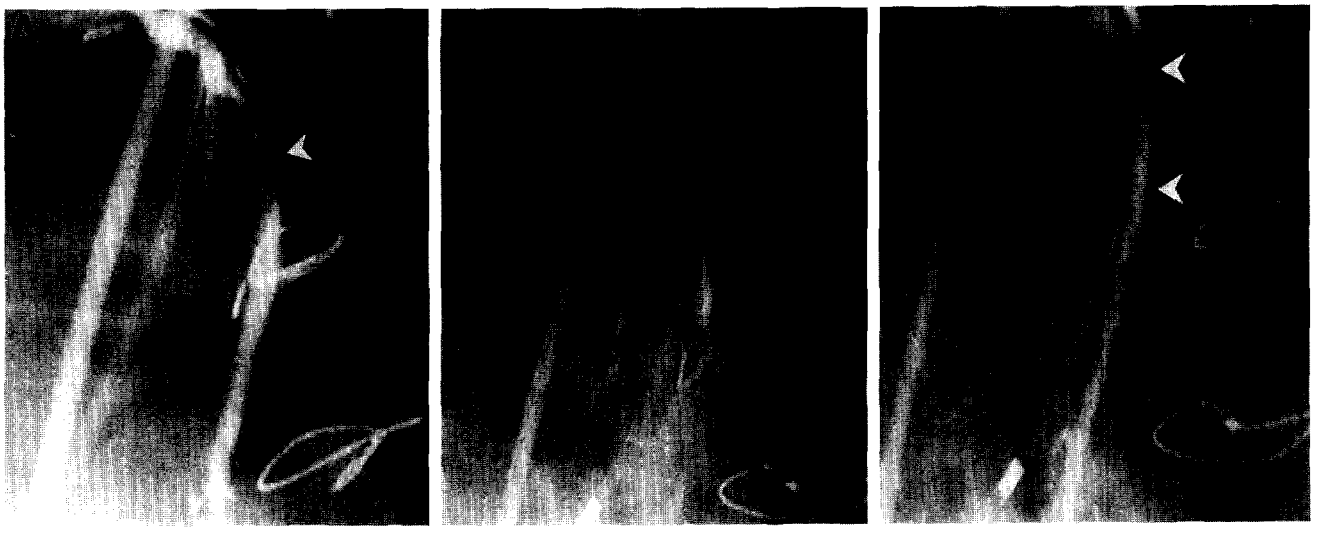

Figure 1. A, Pretreatment lesion **(arrowhead). B,** Stent delivery system crosses the lesion with stent deployed and balloon inflation. **C,** Poststent angiogram reveals smooth lumen with proximal "step-up" and distal "step-down" appearance **(arrowheads).**

quency in new lesions in native coronary arteries compared with balloon angioplasty. Preliminary reports (29,30) have also revealed that stents may be advantageous for the treatment of saphenous vein graft lesions. The present study reports the procedural results, complications and late clinical outcomes from the Johnson & Johnson Interventional Systems multicenter registry of patients who underwent Palmaz-Schatz stent implantation for saphenous vein graft lesions.

Methods

Patients. Five hundred eighty-nine consecutive patients were enrolled prospectively from January 1990 to April 1992. The clinical outcome in a subset of 69 patients from a single institution has been reported previously (26). All 20 U.S. investigator sites (see Appendix) participating in the Food and Drug Administration-approved saphenous vein graft stent protocol are included in this report. Inclusion criteria included patients with symptomatic coronary artery disease or documented ischemia by exercise stress testing or thallium scintigraphy and angiographic evidence of focal (<15 mm in length) vein graft stenosis (>70% diameter stenosis) in the shaft portion of aortocoronary saphenous vein grafts (3 to 5 mm in diameter) with good inflow and distal runoff into the native circulation. Investigators were advised to avoid true aorto-ostial lesions, distal anastomotic site lesions, diffuse disease (requiring multiple overlapping stents), vein grafts with unsuitable reference size (<3 or >5 mm) and angiographic evidence of significant thrombus at the target site. Patients with evolving myocardial infarction (within 7 days) or contraindications to vigorous anticoagulation were excluded.

Stent design and implantation technique. In all patients, the Palmaz-Schatz coronary stent delivery system (Johnson & Johnson Interventional Systems) was utilized. Details of stent design and the technique of stent deployment have been described previously (31). Briefly, the Palmaz-Schatz coronary stent is 15 mm in axial length, with two 7-mm segments connected by a central 1-mm articulating bridge. The stent is premounted on a delivery balloon and is enclosed within a 5F retractable sheath. The lesion is crossed with a 0.014-in. (0.036-cm) guide wire, and predilation is performed, usually with an undersized balloon catheter. Next, the stent delivery system is advanced across the predilated lesion site, the sheath is retracted exposing the stent balloon system, and deployment is accomplished with a single inflation to nominal pressure. Postdilation may be performed with larger (or noncompliant) balloon catheters to maximize the final lumen dimensions at the operator's discretion. After stent implantation, the angiogram usually reveals a smooth lumen surface at the stent site with a "step-up" and "step-down" appearance at the proximal and distal junctures of the vessel/stent interface, respectively (Fig. 1).

Anticoagulation regimen. Both aspirin (325 mg orally, four times daily) and dipyridamole (75 mg orally, three times daily) were started 24 to 48 h before the procedure. Two hours before stent deployment, an intravenous dextran 40 infusion was initiated at 100 ml/h and reduced to 50 ml/h thereafter until sheath removal and reinstitution of heparin infusion (usual dextran dose 1 liter). Activated clotting time was maintained for >300 s during the procedure with an initial heparin bolus (10,000 to 15,000 U) and subsequent heparin boluses as needed. After stent implantation, activated clotting time was monitored closely, and the introducer sheath was removed when the activated clotting time was <170 s. Six hours after access site hemostasis, heparin was reinstituted, and the infusion rate was titrated to keep partial thromboplastin time at 50 to 70 s. Coumadin was administered on the day of procedure (10 to 15 mg), with daily dose adjustment to achieve a prothrombin time of 16 to 18 s, at which time the heparin infusion was stopped. After discharge, coumadin (to keep

prothrombin time 16 to 18 s) and dipyridamole were continued for 1 month, and aspirin was continued indefinitely.

Poststent clinical follow-up. Patients were evaluated clinically by office visit or telephone contact at 1 and 2 weeks and 1-, 2-, 3-, 6-, 9- and 12-month intervals. Exercise thallium scintigraphy was usually performed at 1 month after stent placement and at 4 to 6 months during follow-up. Repeat angiography was performed at ~6 months after stent placement or earlier if clinically indicated. Clinical outcomes and follow-up events were recorded at each investigator site, and uniform case report forms were forwarded to the Johnson & Johnson Interventional Systems registry. Complete (100%) chart auditing for all patients was carried out by Johnson & Johnson Interventional Systems personnel to ensure accuracy of data collection.

Angiographic analysis. Qualitative and quantitative angiographic findings were obtained from data collected in case report forms at each investigator site. Qualitative morphologic data was acquired by careful visual analysis. Quantitative measurements were obtained with the guiding catheter as a reference for calibration. At each investigator site, either computer-assisted edge detection algorithms or hand-held electronic calipers were used to obtain the baseline, poststent implantation (after adjunct balloon angioplasty) and follow-up angiographic results in two or more views after intragraft nitroglycerin administration. Reference vessel (mean of proximal and distal to the lesion site) and treatment site minimal lumen diameters were used to derive percent diameter stenosis.

Definitions. *Successful stent delivery* = complete passage of the stent across the target lesion with expansion of the stent; *procedural success* = successful stent implantation with <50% final stent minimal lumen diameter and no major in-hospital complications (death, Q wave myocardial infarction, urgent bypass surgery); *high surgical risk* = patients with severe or multiple comorbid conditions (e.g., renal insufficiency, pulmonary disease) or poor left ventricular function (ejection fraction <40%), or both; *acute thrombotic closure* = angiographic evidence of thrombosis at the stent site within 24 h of the procedure; *subacute thrombotic closure* = angiographic evidence of thrombosis at the stent site >24 h after the procedure; *restenosis* = ≥50% diameter stenosis on follow-up angiography.

Statistical analysis. Categoric variables were expressed as percent frequencies and continuous variables as mean value ± SD. Chi-square analysis or the Fisher exact test was used for comparison between groups for categoric variables, and the Student *t* test was used for normally distributed continuous variables. The Mann-Whitney *U* test was used to compare nongaussian distributed continuous variables. Predictors of restenosis were determined by univariate and multivariate logistic regression analysis. A variable with p value <0.2 in the univariate analysis would be entered into the multivariate stepwise logistic regression model. Out-of-hospital event-free survival analysis was performed using the Kaplan-Meier method, and three different event-free survival curves were generated: 1) freedom from death; 2) freedom from death and nonfatal Q wave myocardial infarction; 3) freedom from death, nonfatal Q wave myocardial infarction, coronary bypass surgery and percutaneous transluminal coronary angioplasty. A p value <0.05 was considered significant. All analyses were performed using BMDP statistical software.

Table 1. Demographic Data for 582 Study Patients

Age (yr)	66 ± 9
Male gender	84
Previous angioplasty of target lesion	39
1	20
2	13
>2	6
SVG age (yr)	8.9 ± 4.2
SVG location	
LAD	31
Cx/obtuse marginal	30
RCA	21
Other	18
Hypertension	57
Diabetes	28
Cholesterol >200 mg/dl	73
History of CHF	22
History of smoking	73
Unstable angina	72
Angina status (CCS)	
0	3
I	2
II	8
III	22
IV	65
LV ejection fraction (%)	50 ± 14
High surgical risk	49

Data presented are mean value ± SD or percent of patients. CCS = Canadian Cardiovascular Society; CHF = congestive heart failure; Cx (LAD, RCA) = circumflex (left anterior descending, right) coronary artery; LV = left ventricular; SVG = saphenous vein graft.

Results

Demographics. The average vein graft age was 8.9 ± 4.2 years, and 86.7% were >4 years old. Fifteen saphenous vein grafts were treated for total occlusions. There was a high incidence of unstable angina (72%), and 87% of the cohort had Canadian Cardiovascular Society class III or IV angina. The majority of patients had preserved left ventricular function. However, nearly half of the patients (49%) were deemed by the operators as a high surgical risk (Table 1).

Delivery success. Successful stent deployment was accomplished in 582 patients (98.8%), of whom 13 had at least one failed attempt before subsequent success. In seven patients stent delivery was unsuccessful, and six stents (from six patients) were retrieved without complications. In one patient, two stents were deployed proximal to the target site, and one stent embolized in the peripheral circulation.

Of the 582 patients with successful stent deployment, 481 (82.7%) received a single stent, 64 (11.0%) received multiple single nonoverlapping stents for separate discrete lesions, 34

(5.8%) had tandem overlapping stents, and 3 (0.5%) had both single and tandem overlapping stents in the same vein graft.

Angiographic findings. The majority of lesions treated (61%) were new, but recurrent restenosis (two or more episodes) was present in 19% of lesions. The average reference vessel diameter was 3.5 ± 0.6 mm. The majority of lesions treated were focal (mean lesion length 7.6 ± 4.9 mm). The percent diameter stenosis at the lesion site decreased from 82 ± 12% before treatment to 6.6 ± 10.2% after stent implantation. Only one patient had ≥50% residual diameter stenosis after stent placement at the lesion site. Similarly, the minimal lumen diameter increased from 0.7 ± 0.5 mm before treatment to 3.4 ± 0.6 mm after stent placement. In one patient, poststent dilation with a 5.0-mm balloon catheter resulted in vein graft rupture and cardiac tamponade. Angiographic evidence of thrombus at the target site did not differ before (7.5%) or after (7.9%) stent implantation. Angiographic thrombus at baseline in 46 patients was eliminated in 21 after stent placement. However, 24 patients developed new angiographic evidence of thrombus after stent implantation. Neither the presence of thrombus at the target site nor the use of intragraft thrombolytic agents influenced deployment success or immediate angiographic results after stent implantation. Angiographic dissection that was evident at baseline in 43 patients (7.1%) was obliterated in 36 (84%) after stent placement. An additional eight patients developed new angiographic evidence of dissection after stent placement, resulting in a total of 15 patients (2.4%) with angiographic dissection noted after stent placement.

Complications. *Death.* Of the 582 patients with successful stent placement, major in-hospital hierarchic complications included death in 10 (1.7%), nonfatal Q wave myocardial infarction in 2 (0.3%) and urgent coronary bypass surgery in 5 (0.9%). Overall major in-hospital complications (hierarchic analyses) occurred in 17 patients (2.9%). The overall procedural success rate was 97.1%. Of the 10 in-hospital deaths, 2 were due to postprocedural cardiogenic shock, 2 to multiorgan system failure, 2 to sudden ventricular arrhythmias 6 and 9 days after the procedure, 2 to sepsis and 2 to retroperitoneal hemorrhage.

Myocardial infarction. Non–Q wave myocardial infarction occurred in 28 patients (4.8%). Acute stent thrombosis occurred in two patients and subacute stent thrombosis in six others (a total of 1.4%) after stent placement (mean time to stent thrombosis 5 days). Six events occurred in the hospital, and two occurred after hospital discharge, both at 11 days after the procedure. In six of the eight patients with stent thrombosis, the stent site was at the "aorto-ostial junction." Although intragraft thrombolysis was given in six patients after stent thrombosis, urgent coronary angioplasty was required to restore flow in all occluded grafts. No patient died after stent thrombosis; three patients were later referred for elective bypass surgery, and five patients had an acute myocardial infarction (two Q wave, three non–Q wave).

Procedural. Angiographic evidence of significant distal embolization was seen in 11 patients (1.9%). Although the risk of embolization was unrelated to prestent angiographic evidence of thrombus, poststent angiographic evidence of thrombus increased the risk of embolization from 1.2% to 8.2% ($p = 0.007$).

Two procedure-related cerebral vascular accidents occurred in the cohort; both were caused by guiding catheter–induced aortic plaque embolization during stent implantation. Clinical sequelae from these two episodes included partial third nerve palsy in one patient, and complete neurologic recovery in the other patient. No hemorrhagic cerebral vascular accidents were temporally associated with the procedure or subsequent systemic anticoagulation.

Bleeding. The intense anticoagulation regimen (aspirin, persantine, coumadin, dextran and heparin) required during and after stent placement resulted in frequent bleeding complications (14.3% [83 patients]), including access site hematomas (5.5%), vascular events (7.1%) and gastrointestinal or urinary tract bleeding episodes (1.7%). Treatment of bleeding complications included transfusion in 6.3% of patients and surgical intervention (with or without transfusion) in an additional 8.0%.

Restenosis. Follow-up angiograms were obtained in 357 patients (66% of those eligible) at a mean follow-up duration of 5.9 ± 2.2 months. In these patients, mean minimal lumen diameter and percent diameter stenosis at follow-up were 2.3 ± 1.3 mm and 35 ± 36%, respectively. Compared with patients with angiographic follow-up, those without angiographic follow-up were older (65 vs. 68 years, $p < 0.001$) had less frequent previous coronary angioplasty (41% vs. 33%, $p = 0.053$) and had a lower frequency of class III or IV angina at follow-up (20.5% vs. 8.2%, $p = 0.007$). Moreover, target vessel revascularization (coronary angioplasty or repeat coronary artery bypass surgery at the stent site) was strikingly lower in patients without (0.5%) than with angiographic follow-up (20.7%, $p < 0.001$).

The overall restenosis frequency (≥50% diameter stenosis) was 29.7% (Fig. 2). Restenosis was significantly lower in patients with new (18.3%) versus restenotic lesions (46.1%, $p < 0.0001$) and in patients with larger (≥3 mm) (26.0%) versus smaller (<3 mm) vein grafts (47.5%, $p < 0.001$). Post hoc analysis comparing new and restenotic lesions in larger versus smaller vein grafts revealed a wide range of restenosis rates; patients with new lesions with a reference vessel diameter ≥3 mm (185 patients) had a restenosis frequency of 15.1%; those with restenotic lesions with a reference vessel diameter <3 mm (27 patients) had a restenosis frequency of 63.0%.

Univariate logistic regression analysis (Table 2) indicated that predictors of in-stent restenosis included 1) previous coronary angioplasty at the stent site (odds ratio [OR] 3.83, $p < 0.001$); 2) reference vessel diameter (OR 0.53, $p < 0.001$); 3) poststent minimal lumen diameter (OR 0.57, $p < 0.01$); 4) high density lipoprotein (HDL) cholesterol (OR 0.96, $p < 0.01$); 5) poststent dissection (OR 10.1, $p < 0.01$); 6) diabetes mellitus (OR 1.76, $p < 0.05$); and 7) baseline minimal lumen diameter (OR 0.49, $p < 0.05$). Other angiographic factors, such as lesion

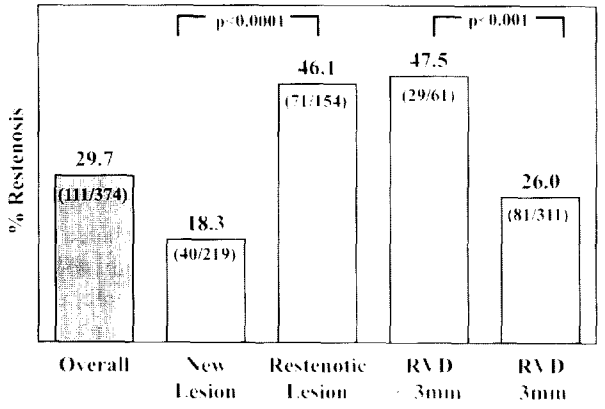

Figure 2. Restenosis frequency for the entire cohort and various subgroups. RVD = reference vessel diameter.

length (OR 1.62, p = 0.06) and final percent diameter stenosis (OR 1.22, p = 0.07) were marginally associated with restenosis. Importantly, vein graft age, history of unstable angina and multiple stents were not predictive of subsequent restenosis.

Multivariate logistic regression analysis (Table 2), identified four variables as independent predictors for restenosis: 1) previous coronary angioplasty at the stent site (OR 3.50, $p < 0.001$); 2) reference vessel diameter (OR 0.53, $p < 0.01$); 3) history of diabetes mellitus (OR 1.78, $p < 0.05$); and 4) final percent diameter stenosis (OR 1.30, $p < 0.05$).

Follow-up clinical events. Clinical follow-up was obtained for all patients and averaged 8.1 ± 4.0 months. Significant improvement in anginal symptoms after stent placement was observed, before stent placement only 5% of patients had mild or no symptoms (angina class 0 or 1), and 87% had severe symptoms (angina class III or IV); however, after stent placement 74% of patients had mild symptoms, and only 16% had severe symptoms at follow-up. The overall hierarchic incidence of major out-of-hospital clinical events (death, Q wave myocardial infarction and coronary bypass surgery) was 19.1% during the follow-up period (Table 3). Of the postdischarge 28 deaths, only 5 were definitely stent related. One patient died of progressive congestive heart failure 5.4 months after stent placement (1 month after stent occlusion); one died 7.3 months after stent placement because of myocardial infarction with cardiogenic shock after stent restenosis; one died suddenly 2 days after coronary angioplasty for stent site restenosis; and two died of complications after bypass surgery for stent restenosis. In the remaining 23 patients, death was associated with intercurrent medical illnesses and was probably not related to stent implantation: 3 patients died of cerebral vascular accident, 2 of pulmonary infection, 2 as result of myocardial infarction that did not involve the stent site; 5 of progressive heart failure with a patent stent site; and the remaining 11 patients of either sudden death or unknown causes. Four patients had a cerebrovascular accident during the follow-up period, three of whom were not taking coumadin at the time of the neurologic event, and the fourth was taking coumadin 9 months after stent placement for chronic atrial fibrillation. Event-free survival for the entire cohort was 82.9% at 6 months (459 patients), 78.8% at 9 months (376 patients) and 76.3% (321 patients) during the first year after stent placement (Fig. 3). Most of of the major events after stent placement involved target vessel revascularization: 5.4% of

Table 3. Follow-Up Clinical Outcome (per patient)*

Clinical Event	No. (%) of Pts
Major event (hierarchic)	
Death	28 (4.9)
Nonfatal Q-wave MI	5 (0.9)
CABG (target lesion)	31 (5.4)
PTCA (target lesion)	45 (7.9)
No event	460 (80.9)
Nontarget vessel revascularization	
CABG	9 (1.6)
PTCA	9 (1.6)
Other event	
Non-Q wave MI	15 (2.6)
Cerebrovascular accident	4 (0.7)

*Average time of follow-up of 569 patients (601 lesions) 8.2 ± 3.9 months. CABG = coronary artery bypass surgery; MI = myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty; Pts = patients.

Table 2. Logistic Regression Analysis for Predictors of Restenosis

Variable	Total (n = 357)	No Restenosis (n = 248)	Restenosis (n = 109)	Univariate		Multivariate	
				OR	95% CI	OR	95% CI
HDL cholesterol*	39 ± 12	40 ± 13	36 ± 11	0.96†	0.94–0.99		
Diabetes (% of pts)	26	23	35	1.76‡	1.08–2.85	1.78‡	1.05–3.00
Poststent dissection (% of pts)	2.7	0.8	7.2	10.10†	2.10–48.60		
Previous PTCA (% of pts)	41.3	31.7	64.0	3.83§	2.40–6.11	3.50§	2.16–5.68
Reference vessel diameter (mm)*	3.54 ± 0.63	3.61 ± 0.63	3.37 ± 0.60	0.53§	0.36–0.77	0.53†	0.34–0.81
Final % diameter stenosis*	6 ± 10	6 ± 10	8 ± 11	1.22	0.98–1.52	1.30‡	1.01–1.66
Prestent MLD (mm)*	0.70 ± 0.46	0.74 ± 0.48	0.61 ± 0.39	0.49‡	0.28–0.85		
Final MLD (mm)	3.41 ± 0.62	3.47 ± 0.60	3.26 ± 0.64	0.57†	0.38–0.83		

*Mean value ± SD, odds ratio (OR), 95% confidence interval (CI) calculation and statistical comparison did not include missing data. †$p < 0.01$. ‡$p < 0.05$. §$p < 0.001$. ||Odds ratio and 95% confidence interval were based on per 10% increment for diameter stenosis. HDL = high density lipoprotein; MLD = minimal lumen diameter; PTCA = percutaneous transluminal coronary angioplasty; pts = patients.

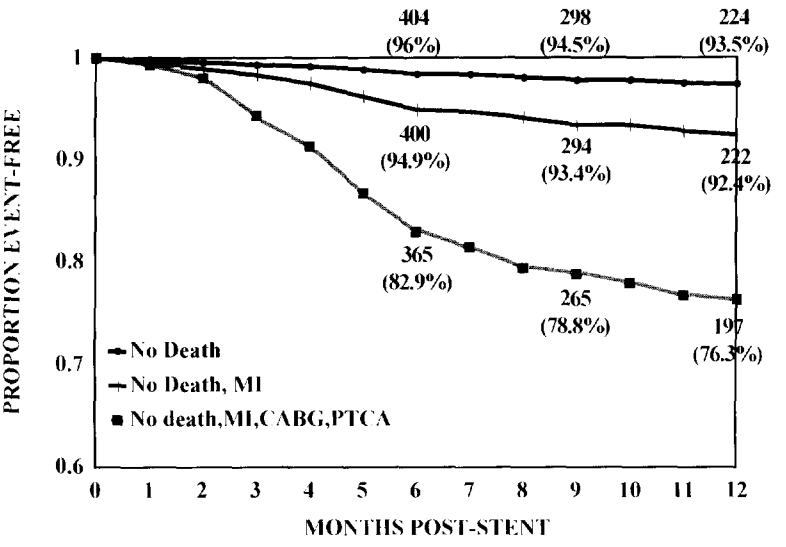

Figure 3. Twelve-month event-free survival curves: freedom from death; freedom from death and nonfatal Q wave myocardial infarction (MI); and freedom from death, myocardial infarction, bypass surgery (CABG) as well as repeat angioplasty of the target lesion (PTCA).

patients underwent bypass surgery and 7.9% repeat angioplasty.

Discussion

The present report summarizes the U.S. Palmaz-Schatz stent experience in 589 consecutive patients with 624 vein graft lesions. The study cohort represents a relatively homogeneous group of patients with focal lesions in the shaft segment of saphenous vein grafts with a reference vessel diameter between 3 and 5 mm. Hence, these results should not be extrapolated to patients with vein grafts with diffuse disease, marked degeneration with intraluminal thrombus, aorto-ostial lesions, or distal anastomotic site lesions or patients with nonelective stent placement. Both delivery (98.9%) and procedural (97.1%) success rates were high, and immediate stent-related complications, except for vascular and bleeding events, were infrequent. The immediate angiographic findings were strikingly predictable, despite treatment of older (~9 years) saphenous vein grafts, resulting in smooth in-stent lumen contours and a marked increase in minimal lumen diameter and a reduction in percent diameter stenosis at the stent site.

Follow-up results. Follow-up angiography was performed in 66% of eligible patients, and the overall restenosis rate was 29.7%. New lesions had a significantly lower frequency of restenosis (18.3%) than lesions with previous angioplasty (46.1%, $p < 0.0001$), and patients with a larger (≥3 mm) reference vessel diameter had a substantially lower rate of restenosis than those with a smaller (<3 mm) reference vessel diameter (26.0% vs. 47.5%, $p < 0.001$). Previous angioplasty of the target lesions, size of reference vessel diameter, history of diabetes and final percent diameter stenosis were independent predictors for subsequent restenosis.

Complications. Early and late major complications were acceptable given the aged patient cohort and frequent associated conditions (~50% of patients), rendering them at high risk for repeat surgical revascularization. Importantly, many late morbid events were associated with intercurrent medical illnesses and not the stent procedure itself. The incidence of acute (two patients) and subacute (six patients) thrombosis in saphenous vein graft lesions treated with elective stents was surprisingly low (1.4%) compared with that for native coronary artery stents (27,28,32). The reason for this difference is unclear but may be related to the larger vein graft size or an intrinsic lower thrombogenic propensity of arterialized venous conduits. Although intragraft thrombolysis was given in six of the eight patients with stent thrombosis, urgent coronary angioplasty was required to restore flow in all eight. Six of the stent thrombosis sites were in the aorto-ostial location. Univariate analysis revealed that higher poststent percent diameter stenosis ($p < 0.0001$), lower final stent diameter ($p < 0.007$) and thrombus after stent placement ($p < 0.02$) were correlated with subsequent stent thrombosis. Although stent thrombosis frequency was low, bleeding complications associated with the intensive poststent systemic anticoagulation were frequent, with >14% of patients requiring transfusion or surgical treatment for vascular or bleeding complications.

Stent implantation versus balloon angioplasty. Compared with previous historical series examining the efficacy of balloon angioplasty in patients with saphenous vein graft disease (1–17), stent implantation results in a greater improvement in immediate angiographic results and more predictable outcomes than conventional coronary angioplasty (15). In a recently concluded multicenter randomized trial (33) comparing balloon angioplasty with directional atherectomy in patients with focal new saphenous vein graft lesions, the immediate and late angiographic results from the coronary angioplasty cohort (156 patients) were significantly different from saphenous vein graft stent outcomes in the current study. Thus, the final percent diameter stenosis (38%) and restenosis frequency (51%) for coronary angioplasty in that trial were substantially greater than saphenous vein graft stent results, providing further evidence of the incremental benefit of stents compared with coronary angioplasty in saphenous vein graft

Table 4. Summary of Clinical Outcomes After Stent Placement in Saphenous Vein Grafts

Stent Type (ref. no.)	No. of Lesions	Procedural Success (%)	Stent Thrombosis (%)	Complications (%)		Angiographic Restenosis (% [follow-up time, mo])	Event-Free Survival (% [follow-up time, mo])
				Death/Q-MI/ CABG	Bleeding		
Palmaz–Schatz							
Coronary (26)	84	99	0	0/0/0	5	25 [6]	74 [24]
Coronary and biliary							
(36)	239	95	1.7	1.3/0.9/0.4	27	NR	75 [6]
(37)	200	98	0.6	0.5/0/0	23	17 [7]	57 [24]
Wallstent							
(29)	13	100	0	0/0/0	15	20 [7]	70 [7]
(30)	145	NR	7	NR	NR	39 [7]	37 [20]
Wiktor (38)	101*	90	2	1/3/1	NR	NR	NR†

*No. of patients. †Included 6% death, 2% myocardial infarction, 2% coronary artery bypass surgery (CABG) and 8% coronary angioplasty. NR = not reported; Q-MI = Q-wave myocardial infarction.

lesions. Another potential benefit of stent therapy over balloon angioplasty in older saphenous vein graft lesions is an apparent lower embolization frequency (1.9%). Perhaps this is due to the less aggressive predilation strategy with brief inflations using undersized balloons, which minimizes vessel wall trauma and may help to reduce the incidence of plaque fragmentation and embolization. Alternatively, the obvious scaffolding effect of the stent itself may prevent plaque rupture and dislodgment.

Clinical results. The clinical results in our current series compare favorably with other reports using different stent designs, including the Wallstent and the Wiktor stent (26,29,30,34–38). Although patient inclusion criteria and stent designs varied in those reports, angiographic and clinical outcomes were strikingly consistent (Table 4), with high procedural success (>90%), acceptable stent thrombosis (generally <2%) and infrequent major procedure-related complications (≤5%). Furthermore, angiographic restenosis rates (17% to 39%) and the 1-year event rate (~24%) were encouragingly low. At present, late follow-up (>1 year) in patients with stent placement in saphenous vein grafts has not been available and warrants further investigation.

Study limitations. The selection of focal lesions in the shaft portion of saphenous vein grafts with relatively large reference vessel diameters in this registry report may introduce biases favoring lower acute complications, reduced restenosis frequency and fewer late clinical events. Furthermore, only 66% of the eligible patients had angiographic follow-up, resulting in considerable uncertainty concerning the "true" incidence of restenosis. However, careful analysis of the patient cohort not undergoing follow-up angiography indicates that these patients had a higher frequency of new lesions, lower incidence of major clinical events and reduced angina class during the follow-up period. Thus, the true restenosis frequency may be lower than stated in the present report. The average interval for angiographic follow-up was 5.9 ± 2.2 months and the mean clinical follow-up time was 8.1 ± 4.0 months. It is certainly possible that, as with coronary angioplasty, the time course of in-stent restenosis for vein graft lesions is more delayed than that observed in native coronary vessels, and a longer follow-up period may be needed to define the incidence of "late" restenosis (15). In the absence of a randomized trial, it would be difficult to conclude that stent implantation definitively reduces restenosis frequency. However, compared with historical balloon angioplasty series (1–15), the overall restenosis rate of 29.7% and restenosis frequency of 15.1% in new lesions with a reference vessel diameter of ≥3 mm would seem to be an improvement. These favorable results were confirmed by quantitative angiographic core laboratory analysis of a consecutive subset (198 patients) from the current multicenter registry wherein the overall restenosis rate was 34% and 22% in new lesions (34). The concordant improvement in patient anginal status and a 76.3% 1-year event-free survival rate are similarly encouraging. At present, there is an ongoing multicenter randomized trial in de novo saphenous vein graft lesions comparing the early and late outcomes after Palmaz-Schatz stents with those after conventional coronary angioplasty therapy.

These results of elective Palmaz-Schatz stent implantation in focal shaft vein graft lesions cannot be extrapolated to more complex lesion morphologies or urgent placement of stents for abrupt or threatened abrupt closure. Moreover, a conservative anticoagulation strategy was utilized for all patients, which was associated with infrequent stent thrombosis but common vascular and bleeding events. Pilot studies have been completed, and future randomized trials are being proposed to determine whether stent placement in a cohort of patients with simple and complex lesion morphologies may be accomplished with similar results and reduced complications in the absence of postprocedural heparin or coumadin (39).

Conclusions. The present report clearly demonstrates that Palmaz-Schatz stent implantation in the shaft portion of aortocoronary saphenous vein grafts can be achieved with high deployment and procedural success, excellent angiographic results, acceptable complications and lower than expected restenosis and follow-up clinical event rates, even in this cohort of patients with older (8.9 ± 4.2 years) vein grafts, compared with previously reported balloon angioplasty series (1–15). Subacute stent thrombosis was a rare event (1.4%) and did not

contribute to mortality, but bleeding complications, especially at the arteriotomy access site, remained problematic. Future randomized studies comparing standard balloon angioplasty with stent implantation are warranted to properly assess the full impact of stent placement in the treatment of saphenous vein graft lesions.

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Appendix

Participating Centers and Principal Investigators

Beth Israel Hospital, Boston, Massachusetts: Donald Baim; **John Hopkins Hospital, Baltimore, Maryland**: Jeffrey Brinker; **Yale University Medical School, New Haven, Connecticut**: Michael W. Clemen; **Florida Heart Group, Orlando, Florida**: R. Charles Curry, Jr.; **Cleveland Clinic Foundation, Cleveland, Ohio**: Stephen Ellis; **University of Michigan, Ann Arbor, Michigan**: Stephen Ellis; **St. Luke's Episcopal Hospital, Houston, Texas**: R. David Fish; **Cardiovascular Consultants, Inc., Kansas City, Missouri**: Lee V. Giorgi; **Thomas Jefferson University Hospital, Philadelphia, Pennsylvania**: Sheldon Goldberg; **Arizona Heart Institute, Phoenix, Arizona**: Richard Heuser, Richard A. Schatz; **Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania**: John Hirshfeld; **Emory University Hospital, Atlanta, Georgia**: Spencer King; **Washington Hospital Center, Washington, DC**: Martin B. Leon; **Cedars-Sinai Medical Center, Los Angeles, California**: Frank Litvack; **Cardiology Associates of Lubbock, Lubbock, Texas**: Paul Overlie; **Scripps Clinic and Research Foundation, La Jolla, California**: Richard Schatz, Paul Teirstein; **University of Texas Medical School, Houston, Texas**: Richard Smalling; **Medical College of Virginia, Richmond, Virginia**: George Vetrovec; **Houma Heart Clinic, Houma, Louisiana**: Craig M. Walker; **Summit Madison Medical Group, Seattle, Washington**: Jeffrey Werner.

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