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A PROFILE OF CANDIDATES FOR REPEAT MYOCARDIAL REVASCULARIZATION: IMPLICATIONS FOR SELECTION OF TREATMENT

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Objectives: It is not known whether the results of randomized trials comparing coronary artery bypass grafting to percutaneous transluminal coronary angioplasty for initial revascularization apply to repeat revascularization in patients with prior bypass grafts. We studied the differences between the patients with prior bypass grafts referred for surgery or angioplasty to identify the clinical and angiographic characteristics that correlated best with either choice and to find clues that might aid in selecting one treatment over the other. **Methods:** Between 1992 and 1994, 870 patients underwent first isolated reoperation and 793 patients underwent first balloon angioplasty after a previous operation. A jeopardy score (0 to 8 points) was derived for each patient on the basis of the relative size of the ischemic territory. Clinical and angiographic data were analyzed for association with the revascularization strategy. **Results:** The following characteristics were more prevalent in the reoperation group: male sex, diabetes, hypertension, valvular disease, normocholesterolemia, and severe left ventricular systolic dysfunction; fewer functioning venous and arterial grafts; and a higher jeopardy score ($p < 0.01$ for all) than in the angioplasty group. A higher jeopardy score, diabetes, and a lower number of functioning arterial or venous grafts were strong, independent predictors of referral for reoperation ($p < 0.01$ for all). In-hospital death and Q-wave infarction ($p < 0.01$ for both) were more frequent in the reoperation group. **Conclusions:** Reoperation was the revascularization procedure of choice when larger regions of myocardium were in jeopardy. Angioplasty was more

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frequently chosen in the presence of a patent arterial graft to the left anterior descending coronary artery or multiple functioning bypass grafts. Reoperation was associated with a higher risk of in-hospital complications than angioplasty. (J Thorac Cardiovasc Surg 1997;114:153-61)

Although coronary artery bypass grafting (CABG) and percutaneous transluminal coronary angioplasty (PTCA) are effective treatments for primary coronary revascularization, both treatments are associated with increased risk and reduced efficacy in patients with prior bypass operations. CABG provides excellent symptomatic relief for patients with ischemic heart disease, and it provides better survival results than does medical therapy in patients with extensive coronary disease and left ventricular dysfunction.¹ However, the progression of atherosclerosis in native vessels and the development of obstructive lesions in saphenous vein bypass conduits diminishes the efficacy of revascularization over time, resulting in cardiac events and the need for repeat revascularization. It is estimated that only approximately half of venous bypass grafts remain functional 10 years after the operation² and that up to 31% of surviving patients require repeat revascularization within 15 years after the initial operation.³

Eight recently completed randomized trials⁴⁻¹¹ compared the effectiveness of PTCA and CABG for primary revascularization in patients eligible for both strategies. Death and myocardial infarction rates were equivalent for both therapies during follow-up periods of 1 to 5 years. However, it is not known whether these results are applicable to patients with previous CABG.

Compared with patients having primary CABG, those undergoing reoperation face a greater risk of mortality and morbidity, experience less relief of angina, and have a lower 10-year survival.³ On the other hand, the utility of PTCA for aged saphenous vein graft lesions is limited by a higher restenosis rate than that encountered in the treatment of native coronary arteries, despite a technical success rate greater than 90%.¹²

The clinical dilemma posed by the patient with prior CABG and recurrent ischemic symptoms is the choice between achieving more comprehensive and durable revascularization with repeat CABG, at an increased immediate risk, and obtaining a less complete and durable revascularization, at a lower procedural risk. We hypothesized that these patients are triaged to PTCA or reoperation on the basis of

differences in baseline demographic characteristics, angiographic features, and procedural risk. We then set out to identify the factors that best correlated with the choice of revascularization procedure in patients with prior CABG.

Methods

Patients. All patients who had first isolated repeat CABG at the Cleveland Clinic Foundation between January 1992 and December 1994 were identified through the Cardiovascular Information Registry. This registry contains prospectively collected data, including demographic characteristics, coexistent chronic disease, coronary risk factors, qualitative angiographic findings (including the presence and patency of bypass grafts from previous operations), echocardiographic assessments of coexistent valvular disease, surgical details (conduits used and anastomoses performed), and in-hospital outcome (death and morbidity). We excluded patients ($n = 105$) who either had PTCA before the second operation or had a concomitant valvular or other cardiac procedure during the second operation.

All patients with symptomatic coronary atherosclerosis who had one prior CABG and who were referred for a first percutaneous coronary intervention between November 1992 and December 1994 were identified through the Cardiology Interventional Database at the same institution. This database contains prospectively collected data on demographic characteristics, coronary risk factors, qualitative and quantitative angiography before and after intervention, and in-hospital outcome (death and myocardial infarction). Patients unsuitable for surgical revascularization ($n = 23$) were excluded.

Definitions. The coronary risk profile encompassed the following: hypertension (blood pressure $> 140/90$ mm Hg or antihypertensive therapy), hypercholesterolemia (total cholesterol level > 5.2 mmol/L or cholesterol-lowering therapy), diabetes mellitus necessitating therapy (oral hypoglycemic agents or insulin), family history of premature symptomatic coronary artery disease (myocardial infarction or revascularization in male relatives younger than age 45 years or in female relatives younger than age 55 years), and smoking within 1 year of the procedure.

PTCA, as used here, refers to any percutaneous coronary intervention in which balloon angioplasty or newer devices, such as atherectomy or intravascular stents, were used.

PTCA success was defined as reducing the diameter of the stenosis to less than 50%, as determined by hand-held calipers, in all attempted lesions, in conjunction with Thrombolysis in Myocardial Infarction (TIMI) flow grade III. In the PTCA group, postprocedural myocardial infarction was defined as a peak creatine kinase MB fraction

Table I. Computation of the jeopardy score for characterizing the area of myocardium with impaired circulation (modified from Califf and associates¹⁴)

Arterial system supplying myocardial territory	Score	Comments
Right	2	Maximum score for right coronary system, including branches
Posterior descending	1	
Posterior ventricular	1	
Right ventricular	1	
Left main trunk	1	Applies only in patients in the PTCA group with open LAD grafts and jeopardized diagonal branches
Left anterior descending	3	Maximum left anterior descending system score, including branches. All grafts were considered to be placed in the midportion of the vessel.
Proximal, midportion	2	
Distal	1	
Diagonal branches	1	
Left circumflex	3	Maximum left circumflex system score, including branches
Proximal	2	
Midportion	1	
Obtuse marginal (each)	1	

greater than 30 $\mu\text{g/ml}$ (normal range: 0 to 5 $\mu\text{g/L}$), with or without new significant Q waves (≥ 0.04 second or $> 1/4$ of the R-wave amplitude in at least two contiguous leads). In the CABG group, myocardial infarction was defined as new significant Q waves or loss of R-wave amplitude and a creatine kinase MB fraction greater than 10% of an elevated total creatine kinase level. Creatine kinase measurements were obtained routinely in all patients after the revascularization procedure.

Angiographic and echocardiographic data. When the diameter of the stenosis, as assessed visually, was greater than 60%, native and graft lesions were classified as causing ischemia. Left ventricular systolic function was graded visually, according to the estimated ejection fraction, as normal ($>60\%$ ejection fraction), mildly impaired (50% to 60% ejection fraction), moderately impaired (30% to 49% ejection fraction), or severely impaired ($<30\%$ ejection fraction). Clinically important valvular disease was defined as any defect resulting in grade 3 (moderate) or 4 (severe) on a scale of 1 to 4.¹³

Jeopardy score. The jeopardy score is a modification of the score described by Califf and associates.¹⁴ It is based on the proportion of myocardium supplied by native coronary arteries or bypass grafts with flow-limiting stenoses, without accounting for lesion structure (Table I). The maximum score, 8 points, indicates patients with the largest burden of ischemia. We assumed that all revascularization procedures were applied to viable myocardium.

The territory supplied by the right coronary artery was assigned a maximum score of 2 points, corresponding to the two terminal branches of this artery. Grafts to the distal right coronary artery were assigned points according to the patency status of the distal branches. The territory of the left anterior descending coronary artery, including the myocardium supplied by the diagonal branches, was assigned a maximum score of 3 points. We assumed that all bypasses to the left anterior descending coronary artery were placed in the midportion of the vessel. The territory

Table II. Baseline characteristics of 1663 patients with a history of isolated CABG undergoing repeat revascularization with CABG or PTCA

Variable	CABG (n = 870)	PTCA (n = 793)	p Value
Age	64 $\pm$ 8	65 $\pm$ 9	0.19
Men	85	77	0.01
Hypertension	66	56	0.01
Diabetes mellitus	48	28	0.01
Hypercholesterolemia (>200 mg/dl)	31	46	0.01
Interval from first CABG	10.6 $\pm$ 4.4	7.7 $\pm$ 5.4	0.01
Functional grafts per patient	1.0 $\pm$ 0.3	1.6 $\pm$ 0.5	0.01
Patent ITA graft to LAD	41	55	0.01
Jeopardy score	3.6 $\pm$ 1.3	1.9 $\pm$ 0.9	0.01
Severe LV dysfunction	40	28	0.01
Important valvular disease	11	3	0.01

Data presented as mean $\pm$ standard deviation or as percent. ITA, Internal thoracic artery graft; LAD, left anterior descending coronary artery; LV, left ventricular.

of the left circumflex artery, including the contribution of the obtuse marginal branches, was assigned a maximum score of 3 points. Because most distal anastomoses in this system do not involve the left circumflex artery trunk per se, all bypass grafts to this system were categorized as supplying the area of an obtuse marginal branch.

Data management and statistical analysis. After abstraction from the original registries, the two populations were consolidated in one database. Continuous variables were compared with the Wilcoxon rank-sum test and categorical values were compared with the χ^2 test or Fisher's exact test. Multivariate logistic regression modeling was performed to detect any independent association between the method of repeat revascularization and clin-

Fig. 1. Distribution of jeopardy scores in the reoperation (white bars) and angioplasty (black bars) groups.

Table III. Distribution of saphenous vein grafts by degree of stenosis and graft location in 1663 patients before repeat revascularization with CABG* or PTCA

Artery	<60% stenosis		60%-99% stenosis		Occluded	
	CABG (%)	PTCA (%)	CABG (%)	PTCA (%)	CABG (%)	PTCA (%)
Right coronary artery	26	44	20	18	52	38
Left anterior descending artery	30	63	29	11	41	26
Left circumflex artery	22	46	25	20	53	34
<i>p</i> Value	<0.001, all arteries		>0.2, all arteries		<0.001, all arteries	

Data presented as percentage of total grafts per artery.

*Based on graft patency data in 798 patients (91.7%).

ical and angiographic variables. A 0.05 level of significance was used for all tests, and two-tailed comparisons were employed. All analyses were performed with the SAS software package (version 6.08).¹⁵

Results

Study population. The 870 consecutive patients who underwent isolated second CABG during the study form the reoperation (CABG) group. The

PTCA group consisted of 793 consecutive patients with a first percutaneous intervention after an initial CABG operation. In 502 patients (63%) having PTCA, the treated vessels included only native coronary arteries; in the other 291 patients (37%), at least one graft was treated.

The baseline characteristics of the two groups are given in Table II. The mean age was similar between the CABG and PTCA groups. Compared with the

PTCA group, the surgical cohort had a higher proportion of male, diabetic, and hypertensive patients. In general, the interval between revascularizations was longer in the CABG group (10.6 ± 4.4 vs 7.7 ± 5.4 years, respectively, $p < 0.01$). The incidence of severe left ventricular systolic dysfunction and important valvular disease in the CABG group significantly exceeded that of the PTCA group.

Jeopardy scores. The distributions of the jeopardy scores in the CABG and PTCA groups are shown in Fig. 1. The mean ($\pm$ standard deviation) score was significantly higher in the CABG than in the PTCA group (3.62 ± 1.3 vs 1.88 ± 0.9 , $p < 0.01$). Patients with and without treated diabetes mellitus had similar jeopardy scores in the PTCA group (1.85 ± 0.93 vs 1.89 ± 0.85 , $p = 0.49$) and in the CABG group (3.60 ± 1.23 vs 3.65 ± 1.29 , $p = 0.38$).

In the PTCA cohort, the jeopardy score for the 502 patients who underwent native coronary artery PTCA (1.89 ± 0.8) was not significantly different from that of the 291 patients with graft PTCA (1.87 ± 1.0 , $p = 0.72$). Patients with and without at least moderate left ventricular systolic dysfunction had identical mean jeopardy scores (1.88 ± 0.9 in both groups, $p = 0.96$). In contrast, patients with successful PTCA ($n = 692$) had a lower mean jeopardy score than those ($n = 101$) with failed or partially successful PTCA (1.84 ± 0.9 vs 2.1 ± 0.9 , $p = 0.006$).

Characteristics of first CABG conduits. The distribution of patent, diseased, and occluded saphenous vein grafts to the various native coronary arteries before the index procedure captured in this study is shown in Table III. Patients in the CABG group had a significantly lower proportion of functional (diameter stenosis $< 60\%$) saphenous vein grafts than those in the PTCA group. Similarly, 41% and 55% of patients in the CABG and PTCA groups, respectively, had functional internal thoracic artery grafts to the left anterior descending coronary artery ($p < 0.001$). Overall, the patients in the CABG group (data on graft patency were not available for 72 patients [8.3%]) had 1.0 ± 0.3 functional grafts, whereas those receiving PTCA had 1.6 ± 0.5 patent grafts ($p < 0.01$), despite a similar number of grafts placed at the initial CABG (2.9 ± 1.0 in both groups, $p = 0.48$).

Determinants of revascularization method. The method of repeat revascularization was modeled with the variables of age, gender, coronary risk profile, presence of severe left ventricular systolic

Table IV. Results of multiple logistic regression analysis for predicting the choice of CABG or PTCA

Variable	Odds ratio	95% CI	p Value
Jeopardy score	3.8*	3.2-4.5	0.001
Diabetes mellitus	2.9	2.0-4.2	0.001
Valvular disease	2.9	1.4-6.2	0.006
Functional ITA graft to LAD	0.6	0.4-0.8	0.002
Number of functional grafts	0.6†	0.5-0.7	0.001

Jeopardy score, diabetes, and valvular disease were associated with referral to CABG, and functional internal thoracic artery grafts and total number of functional grafts were associated with referral to PTCA. *CI*, Confidence interval; *ITA*, internal thoracic artery; *LAD*, left anterior descending coronary artery.

*For 1 point increment.

†For 1 additional functional graft.

dysfunction, presence of clinically important valvular disease, jeopardy score, a functional arterial graft to the left anterior descending coronary artery, and the number of functional grafts (Table IV).

A higher jeopardy score was directly, independently, and strongly associated with repeat CABG, rather than with PTCA. The odds of undergoing repeat CABG increased 3.8-fold (95% confidence interval 3.2 to 4.5) for each 1 point increase in score (Table IV). The other variables significantly associated with repeat CABG rather than PTCA were the presence of diabetes and important valvular heart disease. In contrast, a functional internal thoracic artery graft to the left anterior descending coronary artery and a higher number of functional grafts were more likely to be associated with PTCA rather than repeat CABG ($p < 0.002$ for both). Age, gender, hypertension, and severe left ventricular systolic dysfunction were not significantly associated with the method of repeat revascularization in this model.

In-hospital outcome. The patients in the PTCA group had angioplasty at 1.6 ± 0.9 sites, whereas the patients undergoing CABG had a mean of 2.9 ± 1.0 distal anastomoses. Both these values compare favorably with the preintervention jeopardy scores of 1.88 ± 0.9 and 3.62 ± 1.3 , respectively. The main events after revascularization are summarized in Fig. 2. Forty-two patients (4.8%) died after repeat CABG, compared with four (0.5%) after PTCA ($p < 0.001$). Q-wave myocardial infarctions occurred in 11 (1.4%) patients in the PTCA and in 32 (3.7%, $p = 0.005$) patients in the CABG group. An additional 66 (8.3%) patients undergoing PTCA had non-Q-wave infarctions; the rate of this event could not be determined in the patients having CABG. The incidence of any myocardial infarction was not

Fig. 2. In-hospital death and Q-wave infarction (MI) in the reoperation (white bars) and angioplasty (black bars) groups.

significantly higher in patients who had graft PTCA than in those who had native-vessel PTCA: 12.0% (35/291 patients) and 8.4% (42/502 patients), respectively ($p = 0.13$). In 101 (12.7%) patients undergoing PTCA, the procedure failed or was only partially successful, and three (0.4%) patients required emergency CABG. Thirty (3.4%) patients undergoing reoperation needed reexploration for bleeding. Neurologic and respiratory complications (prolonged intubation, infection, tracheostomy) were noted in 2.1% and 13.8% of the CABG cohort, respectively.

Discussion

This large series of consecutive patients who previously underwent CABG and again became candidates for revascularization yielded considerable insight into the determinants for the choice of the revascularization strategy. By using a simple scoring system to estimate the extent of myocardium at risk, we found that the patients referred for repeat CABG had a much larger proportion of

myocardium that could be revascularized than did patients referred for PTCA. In-hospital mortality and Q-wave myocardial infarction were significantly more common after repeat CABG than after PTCA.

In two thirds of the PTCA group, progression of native coronary atherosclerosis was implicated in causing new symptoms. The greater incidence of progressive coronary atherosclerosis rather than vein graft disease in this group resulted in a shorter interval between revascularization episodes than for the CABG group. The combination of baseline characteristics, coronary risk factors, and graft patency in a multivariate regression model further underscored the independent association of a higher jeopardy score, diabetes, and coexisting valvular disease with referral to CABG for revascularization. A patent arterial graft to the left anterior descending coronary artery and a higher number of functional grafts were directly linked to PTCA as a revascularization strategy. Interestingly, age, gender, and severe left ventricular systolic dysfunction were not statistically related to either method of revascularization.

Repeat revascularization series. Surgical revascularization in patients with previous CABG is technically more challenging and is associated with a higher incidence of morbidity than the initial intervention. Three series^{3, 16, 17} confirmed the emergence of vein graft atherosclerosis as the main indication for reoperation.

We reviewed CABG reoperations over a 20-year period (1967 to 1987) and provided in-hospital outcome and 10-year survivals.³ The annual hospital mortality for 2509 consecutive patients fluctuated between 2% and 5%. Over time, the candidates for reoperation became older and the interval between operations lengthened (10 years in the most recent cohort). In the intervening years, one third of patients lost previously normal left ventricular function. During the same period, however, advances in operative technique provided new advantages. Improved myocardial protection during surgery is credited with reducing by half the perioperative Q-wave infarction rate, bringing it to 4%. Improved graft patency was achieved with the increasing use of internal thoracic artery grafts in patients undergoing reoperation, reaching a prevalence of 67%. Simultaneously, the increased prevalence of older patients and important left main coronary artery narrowing adversely influenced long-term survival. Characteristics associated with improved survival included age younger than 65 years and the following preoperative variables: no comorbidity, mild angina, no significant left main coronary artery disease, good left ventricular function, and placement of an internal thoracic artery graft to the anterior descending coronary artery in the first or second operation. The overall 10-year survival and event-free survival were 69% and 41%, respectively.

Weintraub and colleagues¹⁶ recently analyzed the Emory University experience with reoperation in 2030 patients. In-hospital mortality was 5.7% in elective reoperations, and Q-wave infarctions were noted in 5.6%. Increased age, emergency surgery, and depressed left ventricular function were significant predictors of adverse outcome. One year after reoperation, 22% of patients had died, had had a myocardial infarction, or had had another revascularization procedure. Twelve years after reoperation, 54% of the patients were alive, and 84% had had a myocardial infarction or repeat revascularization.

Akins and coworkers¹⁷ reviewed the reoperation experience at Massachusetts General Hospital from 1977 through 1992, reporting 5.3% mortality and 6.2% myocardial infarction rates in 750 patients.

The efficacy of PTCA is also affected by a previous CABG operation. Lesions in saphenous vein grafts present a particular challenge because of the presence of concentric, diffuse atheromata and a tendency for distal embolization.¹⁸ These characteristics result in somewhat lower procedural success rates (75% to 97%, mean 88%) than in native coronary angioplasty,¹⁹ despite the use of newer devices with debulking capability.²⁰⁻²² Nevertheless, the proportion of patients dying (0% to 5%, mean 0.7%) or having a myocardial infarction (0% to 9%, mean 3.4%) remains consistently low under these conditions. The high rate of restenosis after PTCA for late saphenous vein bypass narrowing is the principal deterrent to its more widespread use. Angiographic restenosis rates of 45% to 60% are commonly reported, reflecting mostly the experience with balloon angioplasty and directional atherectomy.¹² The outcome of PTCA in native coronary arteries after previous CABG appears to be equivalent to the results of angioplasty in patients without a previous CABG. The exception is failed angioplasty complicated by ongoing ischemia or hemodynamic instability, for which emergency reoperation is highly hazardous.²³

Randomized primary revascularization trials. A metaanalysis of eight randomized trials comparing PTCA with CABG for primary revascularization found substantial similarity of outcome across the published studies.²⁴ The two revascularization strategies yielded the same prognosis for survival and subsequent myocardial infarction. In an average 3-year follow-up, the two strategies differed significantly in their requirements for repeat revascularization: 33.7% for those initially assigned to PTCA and 3.3% for those assigned to CABG. Not included is the report of the Bypass Angioplasty Revascularization Investigation (BARI), which found marked differences in the diabetes subset, favoring CABG.²⁵ Overall, 30% of all patients undergoing PTCA in the BARI received CABG during the first 5 years of follow-up.

The aforementioned deficiencies of repeat revascularization ushered in the search for alternative strategies. In the field of coronary bypass surgery, improved methods of myocardial protection and increased use of arterial bypass grafts have improved survival and freedom from cardiac events. As for angioplasty, the advent of new interventional devices, especially stents,²⁶ and the development of novel adjunctive antiplatelet agents²⁷ have improved the immediate procedural outcome and reduced the need for repeat revascularization.

Limitations. Besides the inherent limitations of retrospective analyses and lack of documentation of the decision-making process, the lack of systematic, functional evaluation of myocardium at risk diminishes the validity of the jeopardy score used in this study. Moreover, we do not have detailed angiographic descriptions of the lesion location in bypass grafts, which may have influenced the choice of revascularization. It is possible that a referral bias favoring angioplasty existed in patients with patent internal thoracic artery grafts, such that bypass surgery was not even considered in these patients, even though technically feasible. Yet the data presented are pertinent to the practice of cardiovascular medicine outside randomized totals and provide a unique attempt to determine the patient characteristics relevant to treatment selection.

Conclusion

Among 1663 consecutive candidates for repeat revascularization, patients with larger areas of ischemic myocardium, diabetes, and moderate valvular dysfunction were considerably more likely to undergo repeat CABG than PTCA. A patent internal thoracic artery graft to the left anterior descending coronary artery and a higher number of functional grafts were more often associated with referral to PTCA than to CABG. Poor left ventricular systolic function, advanced age, and other baseline characteristics were not associated with preferential use of either strategy. Periprocedural death and myocardial infarction were more common after repeat CABG. These observations reinforce the need for a randomized trial of secondary revascularization to resolve the clinical dilemma posed by patients with progressive native coronary and vein graft atherosclerosis.

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REFERENCES

1. Yusuf S, Zucker D, Peduzzi P, Fisher LD, Takaro T, Kennedy JW, et al. Effect of coronary artery bypass graft surgery on survival: overview of 10-year results from randomised trials by the Coronary Artery Bypass Graft Surgery Trialists Collaboration. *Lancet* 1994;344:563-70.
2. Lytle BW, Loop FD, Cosgrove DM, Ratliff NB, Easley K, Taylor PC. Long-term (5 to 12 years) serial studies of internal mammary artery and saphenous vein coronary bypass grafts. *J Thorac Cardiovasc Surg* 1985;89:248-58.
3. Loop FD, Lytle BW, Cosgrove DM, Woods EL, Stewart RW, Golding LAR, et al. Reoperation for coronary atherosclerosis: changing practice in 2509 consecutive patients. *Ann Surg* 1990;212:378-86.
4. RITA Trial Participants. Coronary angioplasty versus coronary artery bypass surgery: The Randomized Intervention Treatment of Angina (RITA) trial. *Lancet* 1993;341:573-80.
5. Rodriguez A, Bouillon F, Perez-Balino L, Paviotti C, Liprandi MIS, Palacios IF, on behalf of the ERACI Group. Argentine randomized trial of percutaneous transluminal coronary angioplasty versus coronary artery bypass surgery in multivessel disease (ERACI): in-hospital results and 1-year follow-up. *J Am Coll Cardiol* 1993;22:1060-7.
6. Hamm CW, Reimers J, Ischinger T, Rupprecht HJ, Berger J, Bleifeld W. German Angioplasty Bypass Surgery Investigation (GABI): a randomized study of coronary angioplasty compared with bypass surgery in patients with symptomatic multivessel coronary disease. *N Engl J Med* 1994;331:1037-43.
7. CABRI Trial Participants. First-year results of CABRI (Coronary Angioplasty vs Bypass Revascularization Investigation). *Lancet* 1995;346:1179-84.
8. King SB III, Lembo NJ, Weintraub WS, Kosinski AS, Barnhardt XS, Kutner MH, et al. Emory Angioplasty versus Surgery Trial (EAST): a randomized trial comparing coronary angioplasty with coronary bypass surgery. *N Engl J Med* 1994;331:1044-50.
9. Puel J, Karouny E, Marco F, Arsoun B, Galinier M, Elbaz M, et al. Angioplasty versus surgery in multivessel disease: immediate results and in-hospital outcome in a randomized prospective study [abstract]. *Circulation* 1992;86(Suppl):I372.
10. Hueb WA, Bellotti G, de Oliveira SA, Ade S, de Albuquerque CP, Jatene AD, et al. The Medicine, Angioplasty or Surgery Study (MASS): A prospective randomized trial for single proximal left anterior descending artery stenosis. *J Am Coll Cardiol* 1995;26:1600-5.
11. Goy JJ, Eeckhout E, Burnand B, Vogt P, Stauffer JC, Hurni M, et al. Coronary angioplasty versus left internal mammary grafting for isolated proximal left anterior descending artery stenosis. *Lancet* 1994;343:1449-53.
12. De Feyter PJ, van Suylen RJ, de Jaegere PP, Topol EJ, Serruys PW. Balloon angioplasty for the treatment of lesions in saphenous vein bypass grafts. *J Am Coll Cardiol* 1993;21:1539-49.
13. Stewart WJ, Currie PJ, Salcedo EE, Lytle BW, Gill CG, Schiavone WA, et al. Intraoperative Doppler color flow mapping for decision-making in valve repair for mitral regurgitation: technique and results in 100 patients. *Circulation* 1990;81:556-66.
14. Califf RM, Phillips RH III, Hindman MC, Mark DB, Lec KL, Behar VS, et al. Prognostic value of a coronary artery jeopardy score. *J Am Coll Cardiol* 1985;5:1055-63.
15. SAS Institute. SAS/STAT User's Guide, volume 2, version 6, 4th ed. Cary [NC]: SAS Institute; 1990.
16. Weintraub WS, Jones EL, Craver JM, Grosswald R, Guyton RA. In-hospital and long-term outcome after reoperative coronary artery bypass surgery. *Circulation* 1995;92(Suppl):II50-7.
17. Akins CW, Buckley MJ, Daggett WM, Hilgenberg AD, Vlahakes GJ, Torchiana DF, et al. Reoperative coronary grafting: changing profiles, operative indications, techniques, and results. *Ann Thorac Surg* 1994;58:359-64.
18. Kalan JM, Roberts WC. Morphologic findings in saphenous veins used as coronary arterial bypass conduits for longer

- than 1 year: necropsy analysis of 53 patients, 123 saphenous veins, and 1865 five-millimeter segments of veins. *Am Heart J* 1990;119:1164-84.
19. Douglas JS. Percutaneous intervention in patients with prior coronary bypass surgery. In: Topol EJ, editor. *Textbook of interventional cardiology*. Philadelphia: WB Saunders; 1994. p. 339-54.
 20. Litvack F, Eigler N, Margolis J, Rothbaum D, Bresnahan JF, Dolmes D, et al., for the ELCA investigators. Percutaneous excimer laser coronary angioplasty: results in the first consecutive 3,000 patients. *J Am Coll Cardiol* 1994;23:323-9.
 21. Meany TB, Leon MB, Kramer BL, Margolis JR, Matthews RV, Whitlow PL, et al. Transluminal extraction catheter for the treatment of diseased saphenous vein grafts: a multicenter experience. *Cathet Cardiovasc Diagn* 1995;34:112-20.
 22. Hinohara T, Robertson GC, Selmon MR, Vetter JW, Rowe MH, Braden LJ, et al. Restenosis after directional coronary atherectomy. *J Am Coll Cardiol* 1992;20:623-32.
 23. Boylan MJ, Lytle BW, Taylor PC, Loop FD, Proudfit W, Borsch JA, et al. Have PTCA failures requiring emergent bypass operation changed? *Ann Thorac Surg* 1995;59:23-6.
 24. Pocock SJ, Henderson RA, Rickards AF, Hampton JR, King SB III, Hareem CW, et al. Meta-analysis of randomised trials comparing coronary angioplasty with bypass surgery. *Lancet* 1995;346:1184-9.
 25. The Bypass Angioplasty Revascularization Investigation (BARI) Investigators. Comparison of coronary bypass surgery with angioplasty in patients with multivessel disease. *N Engl J Med* 1996;335:217-25.
 26. Wong SC, Baim DS, Schatz RA, Teirstein PS, King SB III, Curry CR Jr, et al, for the Palmaz-Schatz Stent Study Group. Immediate results and late outcomes after stent implantation in saphenous vein graft lesions: the multicenter US Palmaz-Schatz stent experience. *J Am Coll Cardiol* 1995;26:704-12.
 27. The EPIC Investigators. Use of a monoclonal antibody directed against the platelet glycoprotein IIb/IIIa receptor in high-risk coronary angioplasty. *N Engl J Med* 1994;330:956-61.