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Coronary Angioplasty Versus Repeat Coronary Artery Bypass Grafting for Patients With Previous Bypass Surgery

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Objectives. **We attempted to determine the relative risks and benefits of percutaneous transluminal coronary angioplasty (PTCA) and repeat coronary artery bypass grafting (re-CABG) in patients with previous coronary bypass surgery (CABG).**

Background. **Due to an expanding population of patients with surgically treated coronary artery disease and the natural progression of atherosclerosis, an increasing number of patients with previous CABG require repeat revascularization procedures. Although there are randomized comparative data for CABG versus medical therapy and, more recently, versus PTCA, these studies have excluded patients with previous CABG.**

Methods. **We retrospectively analyzed data from 632 patients with previous CABG who required either elective re-CABG (n = 164) or PTCA (n = 468) at a single center during 1987 through 1988. The PTCA and re-CABG groups were similar with respect to gender (83% vs. 85% male), age >70 years (21% vs. 23%), mean left ventricular ejection fraction (46% vs. 48%), presence of class III or IV angina (70% vs. 63%) and three-vessel coronary artery disease (77% vs. 74%).**

Results. **Complete revascularization was achieved in 38% of patients with PTCA and 92% of those with re-CABG ($p < 0.0001$). The in-hospital complication rates were significantly lower in the PTCA group: death (0.3% vs. 7.3%, $p < 0.0001$) and Q wave myocardial infarction (MI) (0.9% vs. 6.1%, $p < 0.0001$). Actuarial survival was equivalent at 1 year (PTCA 95% vs. re-CABG 91%) and 6 years (PTCA 74% vs. re-CABG 73%) of follow-up ($p = 0.32$). Both procedures resulted in equivalent event-free survival (freedom from death or Q wave MI) and relief of angina; however, the need for repeat percutaneous or surgical revascularization, or both, by 6 years was significantly higher in the PTCA group (PTCA 64% vs. re-CABG 8%, $p < 0.0001$). Multivariate analysis identified age >70 years, left ventricular ejection fraction <40%, unstable angina, number of diseased vessels and diabetes mellitus as independent correlates of mortality for the entire group.**

Conclusions. **In this nonrandomized series of patients with previous CABG requiring revascularization, an initial stategy of either PTCA or re-CABG resulted in equivalent overall survival, event-free survival and relief of angina. PTCA offers lower procedural morbidity and mortality risks, although it is associated with less complete revascularization and a greater need for subsequent revascularization procedures.**

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The number of patients with previous coronary artery bypass grafting (CABG) requiring repeat revascularization procedures is steadily increasing (1). Consequently, clinicians increasingly face the challenge of recommending a percutaneous or repeat surgical approach to revascularization. Comparative randomized data are available for CABG versus medical therapy (2–4) and, more recently, for CABG versus percutaneous transluminal coronary angioplasty (PTCA) (5–9). However, patients with previous CABG have generally been excluded from these studies, and thus the relative efficacies of PTCA and repeat CABG (re-CABG) in patients with previous CABG are uncertain. This information is important for clinical decision making because re-CABG has been associated with greater morbidity and mortality than initial CABG (10,11). In contrast, PTCA in patients with previous CABG has been associated with procedural mortality rates comparable to those of PTCA in patients without prior CABG (12,13) despite the technical challenges presented by older grafts with complex atherosclerotic disease (14).

The purpose of this study was to determine the relative risks and benefits of PTCA versus re-CABG in patients with previous CABG.

Methods

Patients. This study was a retrospective analysis of 632 consecutive patients with previous CABG who underwent elective re-CABG (n = 164) or PTCA (n = 468) between January 1, 1987 and December 31, 1988. All percutaneous and

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Abbreviations and Acronyms

CABG	=	coronary artery bypass grafting
CCS	=	Canadian Cardiovascular Society
ECG	=	electrocardiogram
MI	=	myocardial infarction
PTCA	=	percutaneous transluminal coronary angioplasty
re-CABG	=	repeat coronary artery bypass grafting

repeat surgical revascularization procedures were performed at the Mid America Heart Institute of Saint Luke's Hospital in Kansas City, Missouri. Patients presenting with acute myocardial infarction (MI) as manifested by chest pain and electrocardiographic (ECG) evidence of ST segment elevation were excluded, as were all emergency re-CABG procedures. The groups were matched for 1) gender; 2) age >70 years; 3) left ventricular systolic function (as measured by ejection fraction); 4) three-vessel native coronary artery disease; 5) Canadian Cardiovascular Society (CCS) functional class III or IV angina.

Definitions. Q wave MI was defined as ECG appearance of new Q waves supported by creatine kinase MB fraction enzyme elevation. In-hospital death was defined as all-cause mortality during the index hospital stay. Baseline left ventricular ejection fraction was documented by ventriculography at cardiac catheterization, transthoracic echocardiography or rest radionuclide ventriculography. Significant stenosis was defined as any lesion in a major epicardial coronary artery or branch vessel (≥2.0 mm in diameter) that by visual angiographic assessment demonstrated ≥50% narrowing of lumen diameter. Three-vessel native coronary artery disease was defined as significant stenosis in each of the three major epicardial coronary arteries or their corresponding branch vessels. PTCA procedural success was defined as <50% residual stenosis in all lesions attempted without the occurrence of a major complication (death, Q-wave MI, emergency CABG). Incomplete revascularization was defined as the presence of any lesion with ≥50% lumen diameter stenosis in a major epicardial coronary artery or branch (≥2.0 mm in diameter) whose dilation either was not attempted or was unsuccessful during PTCA procedure, or was not bypassed during CABG or re-CABG. In the multivariate analysis, unstable angina was defined as CCS class IV symptoms.

Coronary angioplasty procedure. PTCA was performed by previously described standard techniques (15). Complete revascularization through dilation of all angiographically significant stenoses during a single procedure was attempted whenever possible. Patients were pretreated with aspirin, 325 mg. At the beginning of the procedure an intravenous bolus injection of 10,000 U of heparin was given, followed by a bolus of 5,000 U/h of elapsed time during the procedure. Intravenous diazepam and morphine sulfate were administered as needed for sedation. Aspirin, 325 mg daily, was continued indefinitely after the procedure.

CABG. Patients underwent CABG with standard techniques using anterograde or retrograde, or both, cold cardioplegia in accordance with surgeon preference. Whenever possible, the left internal mammary artery graft was utilized to bypass the left anterior descending coronary artery. Reversed saphenous vein graft segments were generally used to bypass diseased vessels in the left circumflex or right coronary artery systems. Patients were discharged on a regimen of aspirin, 325 mg daily.

Follow-up. Prospective long-term follow-up data were obtained from mailed questionnaires, telephone interviews and subsequent office visits. This information was recorded in a computer data base and updated on a systematic, periodic basis. Follow-up data were available for 95.4% of the patients. The mean ± duration of the follow-up period was 48 ± 21 months.

Statistical analysis. Demographic, clinical and angiographic data were compared by using the Student *t* test, chi-square test or Fisher exact test where appropriate. All reported p values were two-tailed. Long-term actuarial survival tables were constructed on an intention-to-treat basis with use of the Kaplan-Meier method. Late results were compared by using univariate actuarial (life-table) and multiple regression Cox proportional hazards analyses. Variables entered in the Cox regression equation included age >70 years, gender, left ventricular ejection fraction <40%, number of diseased vessels, diabetes mellitus, history of previous MI, presentation with unstable angina, presence of left anterior descending coronary artery disease, use of the left internal mammary artery, extent of revascularization, graft age at reoperation, re-CABG and PTCA.

Results

The data of 632 consecutive patients requiring repeat revascularization procedures after previous CABG were reviewed. During the index hospital admission, 468 patients underwent 643 PTCA procedures, and elective re-CABG was performed in 164 patients. These procedures represented 26% (468 of 1,803) of all PTCA procedures and 16% (164 of 1,033) of all CABG operations performed at our institution during this time period. The demographic and clinical characteristics of the two clinical groups are described in Table 1. The mean age was similar, and there was no significant difference in the percent of patients >70 years of age in either group (PTCA 21% vs. re-CABG 23%, p = 0.78). The gender mix was equivalent in the two patient groups, and the majority of patients were male. Advanced anginal symptoms were commonly present at the time of the procedure; however, a significantly greater number of patients with CCS functional class IV symptoms were treated with PTCA versus re-CABG (45.8% vs. 26.2%, p < 0.0001). Nearly 75% of the patients in both groups had three-vessel native coronary artery disease, and ~20% of patients in both groups had diabetes mellitus.

The mean left ventricular ejection fractions were similar between the groups, despite the significantly greater proportion of PTCA-treated patients with a history of previous MI (56.0% vs. 41.5%, p < 0.0001). The mean graft age in both

Table 1. Baseline Patient Demographics and Clinical Characteristics

	PTCA Group (n = 468)	Re-CABG Group (n = 164)	p Value
Mean age (yr)	62.3 ± 9.0	63.6 ± 8.6	0.1
Age >70 yr	21.2%	22.6%	0.78
Male	82.7%	84.8%	0.63
CCS angina class III or IV	69.7%	63.4%	0.15
CCS angina class IV	45.8%	26.2%	<0.0001
Mean LVEF	45.8 ± 23.7%	48.2 ± 14.5%	0.3
3-vessel CAD	76.5%	73.8%	0.74
Prior MI	56.0%	41.5%	<0.0001
Diabetes mellitus	19.4%	21.3%	0.65
Mean graft age (mo)	79.7 ± 51.6	106.8 ± 48.2	<0.0001

Data presented are mean value ± SD or percent of patient group. CAD = coronary artery disease; CCS = Canadian Cardiovascular Society; LVEF = left ventricular ejection fraction; MI = myocardial infarction; n = number of patients; PTCA = percutaneous transluminal coronary angioplasty; Re-CABG = repeat coronary artery bypass grafting.

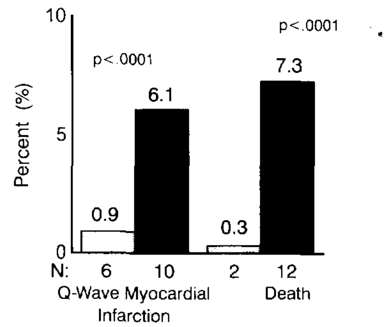

Figure 1. Number (N) and percent of major in-hospital events in patients with previous CABG treated with PTCA or re-CABG. Rates of both Q wave MI and death were significantly lower ($p < 0.0001$) in the patients treated with PTCA. **Striped bars** = PTCA; **solid bars** = re-CABG.

groups was >7 years, although patients who underwent re-CABG had significantly older grafts than those in the PTCA group (106.8 ± 48.2 vs. 79.7 ± 51.6 months, $p < 0.0001$).

Procedural results. *PTCA.* Patients with significant stenoses of the left main coronary artery (both protected and unprotected) or left main equivalent disease were not excluded from the PTCA group, and their lesions represent 2.9% (40 of 1,376) of the lesions dilated. Saphenous vein graft lesions represented 19% (262 of 1,376) of the lesions dilated and the native circulation represented 81% (1,114 of 1,376). The mean number of lesions dilated per patient was 2.9 ± 1.8. The procedural success rate was 94.9%.

Re-CABG. The left internal mammary artery was used for 58.5% (96 of 164) of re-CABG procedures. The mean number of new grafts placed and new distal anastomoses constructed was 2.2 ± 0.75 and 3.1 ± 1.2, respectively.

In-hospital complications. Major in-hospital complications occurred more frequently in the re-CABG group (Fig. 1). Death during the initial hospital stay occurred in 2 patients treated with PTCA (0.3%) versus 12 (7.3%) of those with who underwent re-CABG ($p < 0.0001$). Q wave MI was also significantly more frequent in the re-CABG group (6.1% vs. 0.9%, $p < 0.0001$).

Table 2 lists the primary cause of in-hospital death for all patients who failed to survive the revascularization procedure. The mean saphenous vein graft age of the two patients with PTCA who died was 12.5 years. One of these patients died during dilation of an unprotected left main coronary artery stenosis. The mean left ventricular ejection fraction and graft age of the 12 patients with re-CABG who died was 41.0 ± 12% and 9.4 ± 3.5 years, respectively. In the re-CABG group, 50% (6 of 12) of the deaths occurred in the operating room or within 24 h of the procedure. The majority of these deaths were associated with inadequate restoration of myocardial function despite maximal mechanical and pharmacologic support and an apparently technically successful procedure. An additional three patients were classified as having a late cardiac death (>24 h after the procedure), and three patients died from complications of sepsis after a long stay in the intensive care unit. Thirty-three percent (4 of 12) of the deaths in the re-CABG group occurred in patients with advanced class IV symptoms at the time of their procedure.

Long-term follow-up. Overall actuarial survival was equivalent with both PTCA and re-CABG at 1 year (95% vs. 91%) and 6 years (74% vs. 73%) of follow-up ($p = 0.32$) (Fig. 2). There was no significant difference in angina class between the two groups at a mean follow-up interval of 4 years; angina status in both groups was better than that immediately before the procedure (Table 3).

Although both groups demonstrated equivalent relief of angina, patients treated with PTCA achieved significantly less complete revascularization (PTCA 38% vs. re-CABG 92%, $p < 0.0001$) and required more additional revascularization procedures (PTCA or re-CABG, or both) over the ensuing 6-year follow-up period (Fig. 3). Of the PTCA-treated patients, 46% (214 of 468) underwent repeat angioplasty, 16% (74 of 468) ultimately required CABG and 9% (40 of 468) had both procedures. In the re-CABG group, 6 patients (3.7%) required subsequent PTCA, and only 2.4% (4 of 164) underwent a second re-CABG. There was no significant difference in event-free survival (freedom from death or Q wave MI) between the PTCA and re-CABG groups (Fig. 4). The follow-up analyses of both groups were performed in both a censored and an uncensored fashion. No statistically significant differences were noted between the two analyses in regard to the major long-term clinical end points of death, event-free survival and need for repeat revascularization.

Multivariate analysis using Cox proportional hazards methodology identified age >70 years, left ventricular ejection fraction <40%, unstable angina, number of diseased vessels and diabetes as independent correlates of overall mortality (Fig. 5).

Table 2. Clinical Characteristics of Patients Who Died in the Hospital

Pt No.	Age (yr)/Gender	LVEF	CCS Angina Class	Graft Age (yr)	Primary Cause of Death	Time of Death
PTCA						
1	63/M	N/A	III	13	Cardiac	In lab
2	58/M	N/A	III	12	Cardiac	PP day 1
Mean	60.5			12.5		
Re-CABG						
1	59/F	61%	II	15	Cardiac	<24 h PP
2	65/M	45%	III	7	Cardiac	In OR
3	80/F	60%	IV	9	Cardiac	In OR
4	57/M	41%	III	15	Cardiac	In OR
5	75/M	52%	III	6	Cardiac	In OR
6	67/F	35%	III	9	Sepsis syndrome	PO day 42
7	63/M	25%	III	4	Cardiac	PO day 2
8	67/M	45%	III	12	Cardiac	PO day 6
9	67/M	35%	IV	9	Cardiac	<24 h PP
10	65/M	25%	IV	11	Cardiac	PO day 18
11	72/M	38%	IV	6	Sepsis syndrome	PO day 33
12	77/M	30%	III	10	Sepsis syndrome	PO day 22
Mean ± SD	67.8	41.0%		9.4		
	7.0	12.2%		3.5		

F = female; lab = catheterization laboratory; M = male; N/A = not available; OR = operating room; PO = postoperative; PP = post procedure; Pt = patient; other abbreviations as in Table 1.

Discussion

The continual refinement of medical and surgical therapies for coronary artery disease has contributed to a significant reduction in cardiovascular morbidity and mortality in recent decades (16). In turn, a greater number of patients who have undergone previous CABG now present with clinical syndromes requiring consideration of repeat revascularization (17). The decision to pursue re-CABG or revascularization with PTCA is often difficult, and few comparative data are available to guide the clinician with this recommendation (18).

Clinical background. The importance of this issue is underscored by the well established increased morbidity and mortality associated with re-CABG (10,11,19,20). Procedural mortality, ventricular arrhythmias, excessive bleeding, prolonged ventilatory support, intraaortic balloon pump insertion and perioperative myocardial infarction are all more prevalent after re-CABG than after the initial CABG (10,11). In addition, patients undergoing re-CABG have been reported to have decreased long-term survival and to experience significantly greater recurrent angina than those undergoing initial CABG (11). Factors responsible for the higher likelihood of adverse outcomes with re-CABG are numerous and reflect both the greater technical challenges presented by a reoperation, as well as the frequent presence of high risk clinical features such as left main coronary artery disease, advanced age, class III or IV anginal symptoms, left ventricular dysfunction and other comorbid illnesses (21). Even at institutions with extensive experience in re-CABG, the risk of in-hospital death and nonfatal Q wave MI is triple that of the initial operation (21,22).

Given the inherent risks of re-CABG, PTCA has been used as an alternative revascularization approach. A compilation of reported data on >2,000 patients who underwent saphenous

Figure 2. Overall survival (including in-hospital mortality) in patients with previous CABG treated with PTCA or re-CABG. There was no significant difference in overall actuarial survival between the two groups (p = 0.32). N = number of patients.

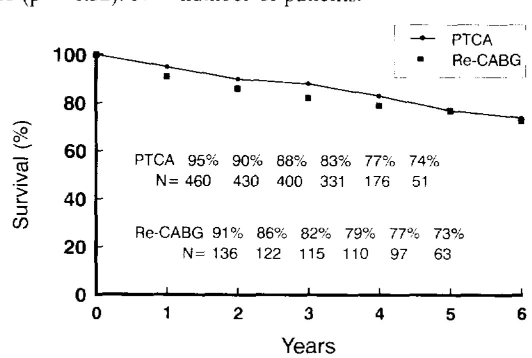

Table 3. Baseline and Follow-Up Symptomatic Status

CCS Angina Class	Preprocedure Baseline: PTCA (n = 468)	Preprocedure Baseline: Re-CABG (n = 164)	Follow-Up Interval (mean 4 yr): PTCA (n = 372)*	Follow-Up Interval (mean 4 yr): Re-CABG (n = 99)
0/I	12%	9%	51%	62%
II	18%	28%	26%	18%
III	24%	37%	10%	11%
IV	46%†	26%	13%	9%

*p = 0.3 at follow-up for entire group (PTCA vs. Re-CABG). †p < 0.0001 at baseline (PTCA vs. Re-CABG). Abbreviations as in Table 1.

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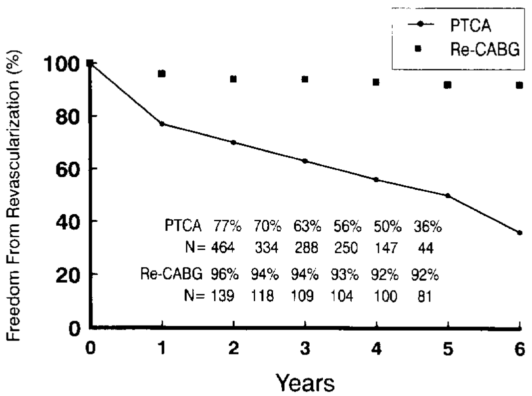


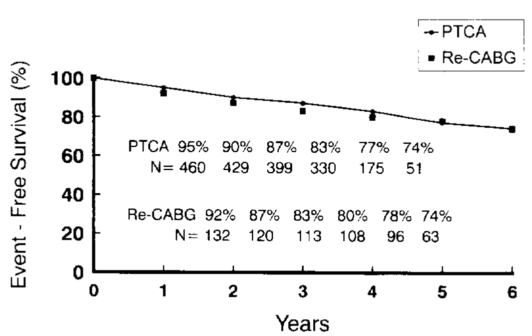
Figure 3. Actuarial analysis of revascularization durability. In patients with previous CABG, an initial treatment strategy of PTCA rather than re-CABG resulted in a significantly greater need for repeat revascularization (PTCA or CABG, or both) at 6 years of follow-up (PTCA 64% vs. re-CABG 8%, $p < 0.0001$). N = number of patients.

vein graft PTCA from 1979 to 1992 (23) revealed an overall procedural success rate of 90%, with a 0 to 2.5% rate of Q wave MI, a 0.3% to 5.0% incidence rate of emergency CABG and an overall mortality rate of 0.8%. Although in many cases these were selected patients with anatomic features favorable for PTCA, the results are comparable to those of more recent data for native artery PTCA (24) showing procedural success rates >90% and major complication rates (death, Q wave MI, emergency CABG) <4.0%.

Clinical trials. To date, available published data from randomized trials of PTCA versus CABG describe results for patients with multivessel coronary artery disease and no prior bypass surgery (5–8). Although these trials have provided, and continue to provide, valuable clinical information, their application to patients with previous CABG is limited because such patients were systematically excluded from enrollment.

Major procedural complications. The 7.3% in-hospital mortality rate for re-CABG is comparable to mortality rates reported from other experienced centers during this time period (1,10,11,21,22,25–30), and it may partly reflect the severity of atherosclerotic heart disease in the surgical cohort.

Figure 4. Event-free survival from hospital discharge in patients with previous CABG treated with PTCA or re-CABG. There was no significant difference in the freedom from death or Q wave MI between the two groups over the 6-year follow-up period ($p = 0.54$). N = number of patients.



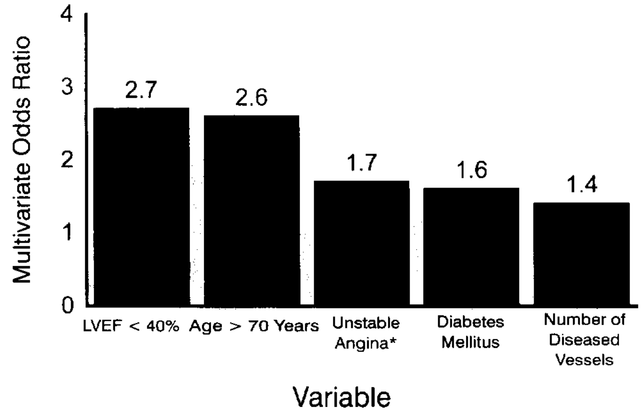


Figure 5. Multivariate correlates of long-term mortality in patients with previous CABG treated with PTCA or re-CABG. With use of the Cox proportional hazards model, five independent predictors of long-term mortality were identified for the entire group (632 patients). Additional variables entered that did not correlate with long-term mortality were gender, history of prior MI, incomplete revascularization, left anterior descending coronary artery disease, graft age, use of the internal mammary artery at reoperation, PTCA and re-CABG. *CCS class IV angina symptoms. LVEF = left ventricular ejection fraction.

At the time of reoperation, ~25% of the surgical patients had functional class IV angina, which has been associated with increased rates of perioperative mortality and Q wave MI compared with those associated with elective CABG in patients with stable angina pectoris (31–34). In addition, the mean interval to reoperation was 9.4 years in the patients with re-CABG who died, and the majority of these patients had angiographic evidence of extensive atherosclerosis. This extended time frame is prognostically important; Salomon et al. (11) reported a procedural mortality rate of 5.8% (18 of 312) in patients with a reoperative interval of 1 to 10 years compared with a rate of 17.6% (13 of 74) for those whose interval between procedures was >10 years.

The 6.1% surgical Q wave MI rate is comparable to previously reported rates (1,10,11,19,21,22,25–30) of 0.8% to 11.3% for re-CABG, in diverse patient groups. The significantly lower Q wave MI rate in the PTCA-treated patients, 0.9%, is consistent with data from two trials (6,7) in which PTCA was confined to native vessels: the recently published German Angioplasty Bypass Surgery Investigation (GABI) (6) (Q wave MI rate: PTCA 2.3% vs. CABG 8.1%, $p = 0.022$) and the Emory Angioplasty versus Surgery Trial (EAST) (Q wave MI rate: PTCA 3.0% vs. CABG 10.3%, $p = 0.004$) (7).

Long-term outcomes. During the follow-up period, overall and event-free (freedom from death or myocardial infarction) survival rates were similar in the PTCA and re-CABG groups. Angina class was similar in both groups at 4 years after the procedure; however, as mentioned, the patients with PTCA required significantly more procedures than did the patients with re-CABG to achieve equivalent symptom relief. These findings are similar to previously published randomized data comparing these two revascularization options in patients without previous CABG (5–8).

Limitations of the study. This study was a retrospective review of nonrandomized, prospectively collected data. The retrospective nature, <100% follow-up and potential for selection and referral bias may limit the application of these results to all patients who require repeat revascularization after an initially successful CABG procedure. Given the lack of a prospective, randomized comparison of these two techniques, the selection for re-CABG of patients with more extensive coronary disease and unfavorable anatomic features for percutaneous revascularization (i.e., diffuse native coronary atherosclerosis, degenerated saphenous vein graft disease, unprotected left main coronary artery stenoses, chronic total occlusions) may have potentially biased the results against re-CABG and contributed to the procedural mortality benefit seen with PTCA.

Although clinical follow-up was 6 years, this interval may not have been long enough to reveal true differences between these techniques. It is possible that a preferential survival benefit for one of the two techniques would have evolved over a longer study period. Ideally, prospective, randomized trials are needed to confirm retrospective, nonrandomized data; however, given the complexity of clinical decision making in patients after CABG, it may be unrealistic and economically prohibitive to properly complete such a study. In addition, with the passage of time, the performance of repeat revascularization procedures, often utilizing the alternative modality, dilutes the significance of the initial treatment stategy.

Continued technical changes have occurred in both the surgical and percutaneous revascularization techniques compared with the state-of-the-art at the time of the study. Increasing experience with re-CABG, improved myocardial preservation techniques and evolving technical strategies for revascularization have progressively reduced procedural morbidity and mortality (21,22,25,35). In addition, the increasing use of arterial bypass conduits may lessen the need for repeat revascularization procedures and favorably alter long-term survival.

Insufficient data are available to report on the economic impact of re-CABG and PTCA in patients with previous CABG. The recently published randomized trials comparing PTCA with CABG in patients with multivessel coronary artery disease suggest an early economic benefit for PTCA. However, this benefit is eroded over time because of the greatly increased need for repeat revascularization procedures in those patients treated with PTCA (5–8). It remains to be seen whether improved catheter designs, continued expansion of operator experience, synergistic application of new device technology, novel therapeutic strategies and use of adjunctive techniques such as intravascular ultrasound and intracoronary stent placement will improve immediate outcomes and potentially decrease the need for repeat revascularization procedures in a clinically and economically beneficial fashion (36–38).

Conclusions. In this nonrandomized series of patients with previous CABG requiring revascularization, an initial stategy of either PTCA or re-CABG resulted in equivalent overall survival, event-free survival and relief of angina. PTCA offers lower procedural morbidity and mortality risks, although it is associated with less complete initial revascularization and a greater need for subsequent revascularization procedures. This information, together with the specific clinical and anatomic features presented by the patient, should assist in the formulation of an individualized revascularization strategy that offers the greatest opportunity for immediate and long-term clinical benefit.

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