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Percutaneous Transluminal Angioplasty in Patients With Multivessel Coronary Disease: How Important Is Complete Revascularization for Cardiac Event-Free Survival?

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The relative influences of revascularization status and baseline characteristics on long-term outcome were examined in 867 patients with multivessel coronary disease who had undergone successful coronary angioplasty. These patients represented 83% of a total of 1,039 patients in whom angioplasty had been attempted with an in-hospital mortality and infarction rate of 2.5% and 4.8%, respectively. Emergency coronary bypass surgery was needed in 4.9%. Of the 867 patients, 41% (group 1) were considered to have complete revascularization and 59% (group 2) to have incomplete revascularization. Univariate analysis revealed major differences between these two groups with patients in group 2 characterized by advanced age, more severe angina, a greater likelihood of previous coronary surgery and infarction, more extensive disease and poorer left ventricular function.

Over a mean follow-up period of 26 months, the probability of event-free survival was significantly lower for group 2 only with respect to the need for coronary artery surgery ($p = 0.004$) and occurrence of severe angina ($p = 0.04$). The difference in mortality was of borderline significance ($p = 0.051$) and there were no significant differences between groups 1 and 2 in either the incidence of myocardial infarction or the need for repeat angioplasty.

Multivariate analysis identified independent baseline predictors of late cardiac events that were then used to adjust the probabilities of event-free survival. This adjustment effectively removed any significant influence of completeness of revascularization on event-free survival for any of the above end points including the combination of death, myocardial infarction and need for coronary artery surgery. Therefore, late outcome in these patients is not significantly influenced by revascularization status but depends more on baseline patient characteristics.

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Percutaneous transluminal coronary angioplasty has rapidly emerged as an effective therapeutic option in patients with coronary artery disease; its use in patients with multivessel disease has resulted in high initial success rates and a low incidence of complications (1–9). The long-term efficacy of coronary angioplasty in these patients with multivessel disease remains controversial (10,11) and is now the subject of several randomized trials. In particular, the consequence of incomplete revascularization has become an important issue. Previous studies of patients with multivessel disease in whom revascularization with either angioplasty (2,4,12,13) or surgery (14–17) was incomplete have generally, but not always (18), shown poorer symptomatic outcome and survival compared with findings in patients in whom complete revascularization was achieved.

Complete revascularization with coronary angioplasty may not be achieved in patients with multivessel disease for a variety of reasons including the presence of an old total occlusion or lesions either unsuitable or technically difficult to dilate. The long-term outcome in these patients may be influenced by these and other related variables in addition to the degree of revascularization achieved. A report from the initial National Heart, Lung, and Blood Institute Percutaneous Transluminal Coronary Angioplasty registry data demonstrated that differences in long-term outcome between completely and incompletely revascularized patients with multivessel disease could be explained largely by differences in baseline patient characteristics (19).

The purposes of this study were to 1) analyze the effect of

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completeness of revascularization on the long-term clinical status and need for subsequent intervention in a large group of patients with multivessel disease who underwent successful coronary angioplasty, 2) compare baseline characteristics of patients with complete and those with incomplete revascularization, and 3) determine whether these baseline characteristics might influence clinical outcome independently from revascularization status.

Methods

Total patient population. Between September 1979 and April 1988, 1,039 patients with multivessel disease underwent coronary angioplasty at the Mayo Clinic. The mean age of the 1,039 patients was 62 ± 11 years, with 25% aged >70 years; there were 762 men (73%). The vast majority of patients had unstable angina (781 patients, 75%) and 95 patients (9%) were treated within 24 h of an acute myocardial infarction. The mean ejection fraction obtained from ventriculograms in 893 patients was 59 ± 13%; 199 patients (23%) had a rest ejection fraction ≤50%.

Patient selection. Eight hundred sixty-seven (83%) of these procedures were successful and these patients form the basis of this report. All patients had a minimum of 6 months' follow-up. Patient selection criteria were based on the presence of symptomatic myocardial ischemia poorly responsive to medical therapy and suitable coronary anatomy for dilation. Sixty-seven patients (7.7%) underwent dilation within 24 h of an acute myocardial infarction but no patient in this group had received concomitant thrombolytic therapy.

Coronary stenoses with luminal diameter narrowing ≥70% were considered suitable for dilation if they were located in the proximal, mid or distal left anterior descending and right coronary arteries, the first or second diagonal branches (if ≥1.5 mm in diameter), the proximal or distal circumflex artery or the first and second obtuse marginal branches. Angioplasty was performed only if the area of myocardium supplied by that vessel was considered to be viable, that is, if the area had at least some retained wall motion at the time of left ventricular or radionuclide angiography. The severity of coronary stenoses was visually assessed by two observers using orthogonal views.

Most patients were considered potential candidates for coronary bypass surgery. The decision to revascularize patients with angioplasty rather than with surgical means was generally made by the attending physician in consultation with the angioplasty personnel and surgeon. Patients were not considered for angioplasty if there was significant left main coronary artery disease unprotected by bypass grafts, multiple chronic total occlusions or severe diffuse disease in the vessels to be treated. However, some patients who were treated with angioplasty in one or more vessel segments had additional disease that was either diffuse or distal, or present in vessels considered too small for either angioplasty or surgery. In some patients the decision to treat with angioplasty rather than surgery was based on the presence of concomitant severe medical disease, a history of prior coronary bypass surgery or the perceived surgical and anesthetic risks.

Technique. The technique of coronary angioplasty has been previously described (20,21). If identified, the culprit lesion was dilated first. Determination of the culprit lesion was based on the correlation of electrocardiographic (ECG), regional ventricular function and coronary angiographic findings. If dilation of this lesion was successful, then dilation of other significant stenoses was attempted depending on the condition of the patient and the preference of the operator and referring cardiologist. However, attempts to dilate other lesions were not usually made if dilation of the culprit lesion had failed. Most patients in whom angioplasty failed underwent coronary artery surgery.

Definitions. *Multivessel disease.* Multivessel disease was defined as ≥70% stenosis in one major coronary artery with ≥50% stenosis in one or more other major coronary arteries. Two and three vessel disease referred to the number of lesions, as defined earlier, present in the distribution of the left anterior descending, left circumflex and right coronary arteries.

Successful angioplasty. Successful angioplasty was defined as a ≥40% reduction of the luminal diameter of at least one stenosis without complications requiring coronary artery surgery before hospital discharge.

Completeness of revascularization. Complete revascularization (group 1) was defined as successful dilation of all stenoses ≥70%. Incomplete revascularization (group 2) was defined as successful dilation of one or more stenoses but with one or more residual stenoses ≥70%.

Restenosis. Restenosis on the follow-up angiogram was defined as a ≥30% increase in luminal stenosis over the immediate postangioplasty residual stenosis.

Follow-up. Follow-up was maintained in all patients at 6 months and then at yearly intervals after their initial procedure, but data are presented only for those 867 patients with successful angioplasty. The follow-up protocol consisted of examining the case records of patients followed up at this institution and interviewing all patients by telephone. Documentation of follow-up events was sought from physicians if the event occurred outside this institution. Angina was classified according to the Canadian Heart Association (22), and severe angina refers to class III or IV. The subsequent need for coronary artery surgery or repeat coronary angioplasty was recorded. Myocardial infarction during follow-up was assessed from patient records of their home physician or the admitting hospital, or both, and was considered to have occurred when two or more of the three following criteria

were met: 1) new Q waves present on ECG (Minnesota code); 2) serum creatine kinase elevation to three times normal or positive MB isoenzyme, and 3) prolonged chest pain requiring hospitalization.

End points during follow-up. Death, myocardial infarction, severe angina (class III or IV) and the need for revascularization with angioplasty or coronary artery bypass surgery were used as the significant end points. Event-free survival defined by these end points was compared in groups 1 and 2. Individual end points were compared, as well as the combined end points of death, myocardial infarction and coronary artery surgery.

Follow-up angiography. Follow-up angiography was not routine and was generally performed only if the referring physician was concerned about recurrent symptoms suggestive of myocardial ischemia.

Statistical analysis. Continuous data are expressed as mean values ± 1 SD. The significance of differences in baseline characteristics between the two groups was determined using chi-square analysis for discrete variables and rank sum testing for continuous data. Event-free survival was computed with the Kaplan-Meier method for all follow-up events from the date of the initial angioplasty and a comparison made between groups 1 and 2 with the log-rank statistic to determine the significance of observed differences.

Multivariate analysis with backward stepwise Cox regression was used to examine 23 clinical, hemodynamic and angiographic baseline variables (Table 1) to determine whether any prognostic factors independently influenced outcome in terms of all follow-up events for the group of 867 patients. Data on ejection fraction were unavailable for 117 patients, usually because ventriculography had not been performed at the time of diagnostic angiography; to avoid excluding these patients from the analysis, each of these patients was assigned an ejection fraction value obtained by computing the mean value of the remaining patients. However, these data were also categorized in the model as a separate variable ("ejection fraction not obtained"). Once the final variables had been identified in the model, completeness of revascularization was entered as a variable. By adjusting for the variables identified at the $p = 0.10$ level in this model, adjusted survival curves comparing outcomes were computed for complete and incomplete revascularization. A similar analysis was performed after excluding patients without ejection fraction data. All significance testing was determined using an alpha of 0.05.

Table 1. Patient Variables Used in the Multivariate Analysis Model for Prediction of Late Cardiac Events

Clinical characteristics
Age
Gender
Angina class (Canadian Heart Association class I–IV)
Unstable angina
New onset angina
Previous coronary artery bypass surgery
Previous myocardial infarction
History of cardiac failure
Smoking history
Diabetes
Hypertension
Hypercholesterolemia (serum cholesterol >250 mg/dl)
Family history of coronary artery disease
Angioplasty within 24 h of acute myocardial infarction
Angiographic characteristics
Number of diseased vessels
Maximal stenosis in any vessel
Total occlusion
Proximal left anterior descending stenosis ≥50%
Left main stenosis ≥50%
Eccentric lesion at angioplasty site
Calcium present in lesion
Hemodynamic characteristics
Ejection fraction (from ventriculography) (%)
Ejection fraction not obtained

Results

Initial results. Angioplasty was successfully performed in 867 (83%) of the 1,039 patients with multivessel disease. Success rates in patients with two and three vessel disease were similar: 84% and 83%, respectively. There were 26 in-hospital deaths (2.5%) within the entire group of 1,039 patients, with a 30 day mortality rate of 3.0%. After excluding patients in whom angioplasty was performed within 24 h of acute infarction, the in-hospital mortality rate was 1.7%. Emergency bypass surgery was required in 4.9% of all patients and 4.8% had an in-hospital myocardial infarction (46 Q wave and 4 non-Q wave infarction). Of the 172 patients with unsuccessful angioplasty, 128 had coronary artery surgery performed during their hospital stay, and the remainder of the survivors were continued on medical therapy.

Revascularization status. Complete revascularization was achieved in 356 (41%) of the 867 patients with successful angioplasty (group 1). Five hundred eleven patients (59%), despite successful angioplasty in at least one vessel, had residual stenosis ≥70% in at least one other vessel and were thus considered to have incomplete revascularization (group 2). Complete revascularization was achieved in 51% of 540 patients with two vessel disease compared with 25% of 327 patients with three vessel disease ($p < 0.001$).

The most common reasons for not achieving complete revascularization were that, after successful dilation of one or more vessels, no attempt was made to dilate another vessel with a stenosis of 70% to 99% (52.4% of the 511 patients with incomplete revascularization) or to dilate a chronic total occlusion (22.6% of these patients), or both (17.9%). Failed attempts at dilation of a vessel lesion contributed, in part, to an additional 4.3% of these patients not

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Table 2. Baseline Clinical, Hemodynamic and Angiographic Data of 867 Patients Who Underwent Successful Angioplasty and Who Are Compared According to Revascularization Status

	Revascularization Status		
	Complete (group 1) (n = 356)	Incomplete (group 2) (n = 511)	p Value
Clinical variables			
Mean age (yr)	60 ± 11	63 ± 12	0.001
Male gender	268 (75)	375 (75)	NS
History of diabetes	46 (13)	67 (13)	NS
History of hypertension	148 (42)	272 (53)	0.001
Current smoker	98 (28)	110 (22)	0.04
Family history of CAD	84 (24)	115 (23)	NS
Serum cholesterol >250 mg/dl	101 (28)	158 (31)	NS
Angina (CHA class III or IV)	258 (72)	403 (79)	0.03
Unstable angina	263 (74)	391 (77)	NS
Angina of recent onset	155 (44)	176 (34)	0.007
Mean duration of angina (mo.)	25	46	<0.001
Prior CABG	28 (8)	109 (21)	<0.001
Prior infarction	122 (34)	264 (52)	<0.001
History of cardiac failure	19 (5)	62 (12)	0.001
PTCA within 24 h of acute infarction	15 (4)	52 (10)	0.001
Hemodynamic variable			
Ejection fraction (mean ± SD) (%)	62 ± 12	58 ± 13	<0.001
Angiographic variables			
Two vessel disease	275 (77)	265 (52)	<0.001
Three vessel disease	81 (23)	246 (48)	<0.001
Mean maximal stenosis in any vessel (%)	92	96	<0.001
Mean preangioplasty stenosis of lesion (%)	86	89	<0.001
Total occlusion present	43 (12)	280 (55)	<0.001

Numbers in parentheses are percents. CABG = coronary artery bypass grafting; CAD =coronary artery disease; CHA = Canadian Heart Association; PTCA = percutaneous transluminal coronary angioplasty.

achieving revascularization. Only 2.8% of patients were incompletely revascularized solely because of failed dilation.

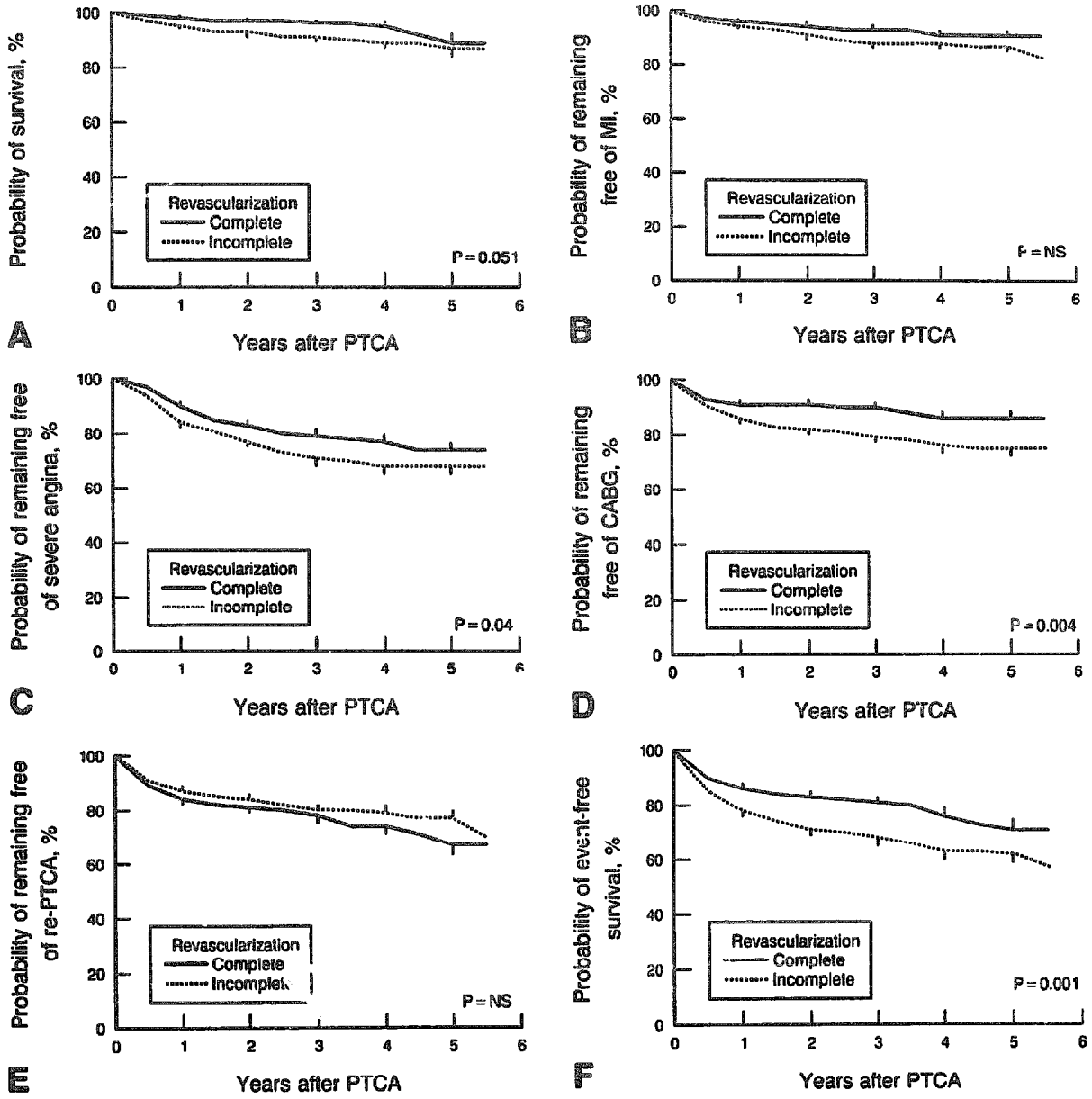
Baseline characteristics. The distribution of clinical, hemodynamic and angiographic baseline variables for the two groups of patients is shown in Table 2. The two groups were similar with respect to gender ratio and most coronary risk factors but there were significant and important differences noted in many other characteristics. The presence of class III or IV angina was higher in patients in group 2, and they were also more likely than patients in group 1 to have had prior infarction or coronary artery surgery and to have a history of cardiac failure. In addition, 4% of patients in group 1 had angioplasty within 24 h of acute infarction compared with 10% in group 2 ($p < 0.001$) and the ejection fraction at baseline was also significantly lower in patients in group 2 compared with group 1. Significantly more patients in group 2 than in group 1 had three vessel disease.

Follow-up and late cardiac events. All patients had ≥6 months' follow-up (mean 26 months) with a mean duration of 27 months (range 97) for patients in group 1 and of 25 months (range 85) for patients in group 2. The probability of event-free survival for all follow-up cardiac events is shown in Figure 1. The probability of survival was only slightly better in patients in group 1 versus group 2 (Fig. 1A) ($p = 0.051$). No significant difference in occurrence of myocardial infarction was observed between the two groups (Fig. 1B). However, patients in group 2, had a significantly ($p = 0.04$) greater occurrence of severe angina (Fig. 1C). These patients also had a significantly ($p = 0.004$) greater need for subsequent coronary artery bypass surgery (Fig. 1D) compared with patients in group 1, but the need for repeat angioplasty was similar (Fig. 1E). However, the combined probability for cardiac event-free survival for any one event, death, myocardial infarction or need for coronary artery surgery, was higher for patients in group 2 compared with group 1 ($p = 0.001$, Fig. 1F).

Factors related to adverse long-term outcome. Multivariate analysis identified several important baseline characteristics that influenced long-term outcome (Table 3). Once these variables had been identified and revascularization status included in the model, there was no significant predictive value of completeness of revascularization for any cardiac event either alone or in combination. Adjustment of the probabilities for all long-term events, with the baseline variables identified (at the $p < 0.10$ level) for each individual event in the multivariate analysis model showed that the differences between patients with complete and those with incomplete revascularization were very much diminished (Fig. 2). The small and statistically insignificant differences between completely and incompletely revascularized patients, noted previously in Figure 1, for death, myocardial infarction and repeat angioplasty, become even smaller after this adjustment (Fig. 2A, 2B and 2E). In addition, the significant differences previously noted between these patients in the occurrence of severe angina, the need for subsequent coronary artery surgery and the combined events of death, myocardial infarction and need for surgery are reduced significantly after accounting for baseline differences (Fig. 2C, 2D and 2F).

The Cox model was also used to identify predictive variables for the preceding end points after excluding the 117 patients in whom no ejection fraction was available. Only minor differences from those identified in Table 3 were found and, importantly, the additional variable of "completeness of revascularization" remained relatively unimportant for all these events: death ($p = 0.2228$), myocardial infarction ($p = 0.0866$), coronary artery bypass surgery ($p = 0.0951$), severe angina ($p = 0.6112$), repeat angioplasty ($p = 0.2523$) and for death, infarction or coronary surgery ($p = 0.0857$).

Restenosis. Within 1 year of angioplasty (mean 4.9 months), 362 patients (42%) underwent repeat coronary



angiography. Among 159 patients in group 1, 93 (58.5%) had restenosis documented in at least one dilated coronary segment compared with 102 (50%) of 203 patients in group 2 ($p = 0.12$).

Figure 1. Actuarial event-free survival curves comparing patients with complete revascularization (group 1) with those with incomplete revascularization (group 2) in terms of freedom from death (A), myocardial infarction (MI) (B), severe angina (C), need for coronary artery bypass surgery (CABG) (D), need for repeat angioplasty (re-PTCA) (E), and the combined events of death, myocardial infarction and coronary artery bypass surgery (F).

Discussion

Coronary angioplasty is being performed with increasing frequency in patients with multivessel disease. The role of coronary angioplasty versus coronary artery bypass surgery in this patient population remains undefined, although several randomized studies comparing the two are currently in progress. Until the results with extended follow-up of such trials are known, careful analysis of follow-up data of patients with multivessel disease who have undergone angioplasty should continue to provide valuable information. In particular, the influence of completeness of revascularization must be considered. Comparisons among reported series of patients are made difficult by varying definitions of

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Table 3. Major Baseline Variables in 867 Patients Independently Predictive of Late Cardiac Events Before and After Considering Revascularization Status

Event	Predictive Variable	Revascularization Status Included in Regression Model: No (p value)	Revascularization Status Included in Regression Model: Yes (p value)
Death	Incomplete revascularization	—	0.3636
	History of cardiac failure	0.0003	0.0004
	Advanced age	0.0112	0.0130
	Hypertension	0.0394	0.0516
	Male gender	0.0517	0.0483
Myocardial infarction	Incomplete revascularization	—	0.0812
	PTCA performed within 24 h of acute infarction	0.0773	0.1079
	Maximal lesion stenosis less severe*	0.0853	0.0221
CABG	Incomplete revascularization	—	0.0873
	PTCA performed within 24 h of acute infarction	0.0033	0.0052
	Prior CABG	0.0091	0.0149
	Diabetes	0.0199	0.0223
	Ejection fraction obtained†	0.0230	0.0239
Severe angina (CHA class III or IV)	Incomplete revascularization	—	0.6491
	Prior CABG	<0.0001	<0.0001
	Advanced CHA class angina	<0.0001	<0.0001
	Advanced age	0.0098	0.0108
	Angina not of recent onset	0.0293	0.0313
	Serum cholesterol >250 mg/dl	0.0343	0.0371
Repeat PTCA	Incomplete revascularization	—	0.2798
	Unstable angina	0.0078	0.0064
	Ejection fraction obtained†	0.0374	0.0445
	Younger age	0.0437	0.0537
Death/myocardial infarction/CABG	Incomplete revascularization	—	0.1040
	PTCA performed within 24 h of acute infarction	0.0002	0.0002
	Diabetes	0.0179	0.0213
	Calcium in lesion	0.0186	0.0139
	Chronic total occlusion	0.0433	0.1845
	Lower ejection fraction	0.0491	0.0613

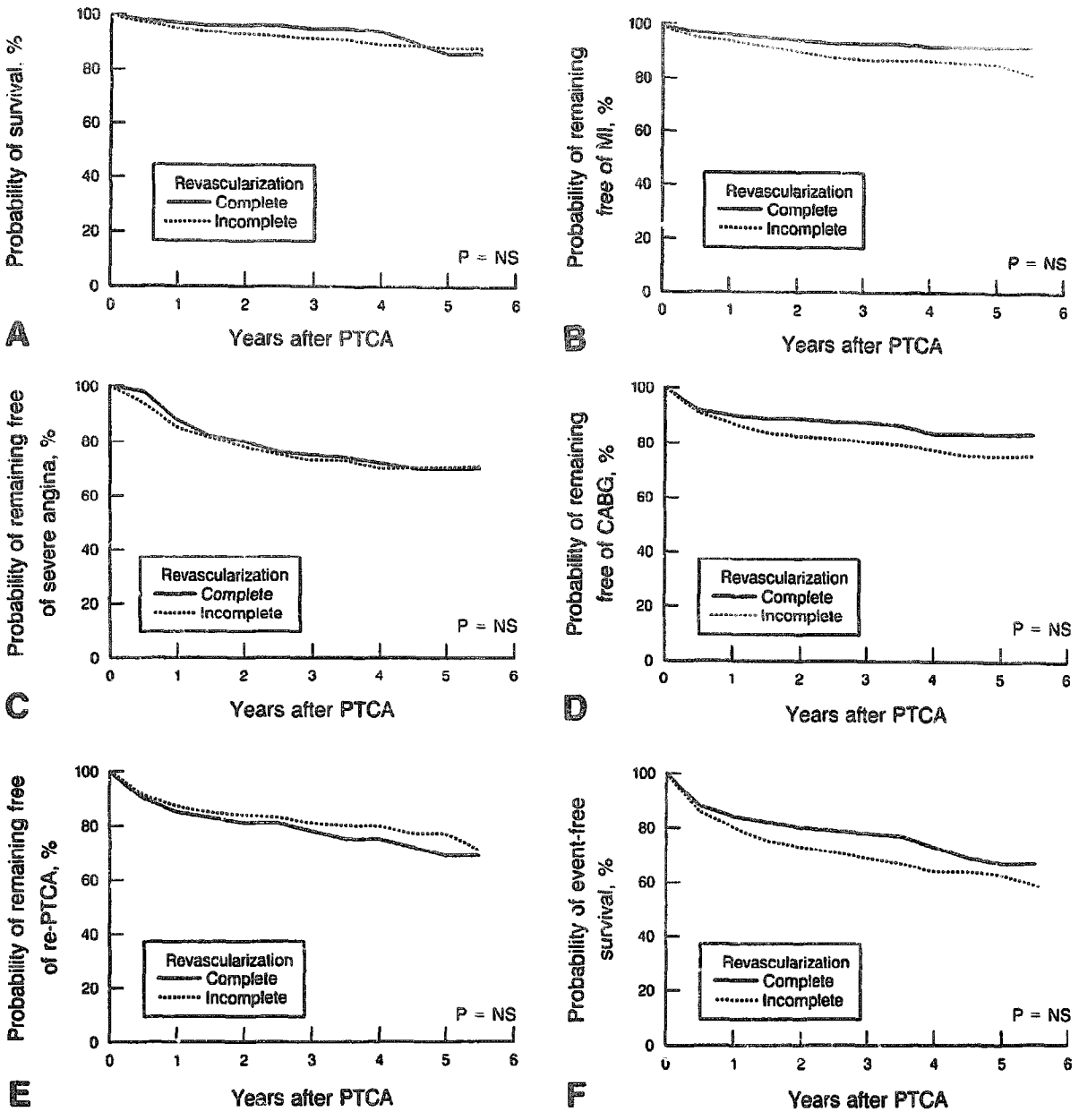
*Maximal lesion severity refers to the most severe stenosis observed in any vessel and was considered as a continuous variable from 70% to 100%; † patients who underwent ventriculography from which an ejection fraction was calculated (see text). Abbreviations as in Table 2.

multivessel disease, angioplasty success and completeness of revascularization.

Immediate outcome. The relatively high success rate for coronary angioplasty in patients with multivessel disease observed in this study is similar to those reported by others (1–9). The in-hospital mortality rate in our study was 2.5%, which is similar to the 2.8% rate reported by Deligonul et al. (2) in a similar study of 470 patients but comparatively higher than those reported in smaller patient series (1,5,7–9). However, many of the patients in our current series were considered high risk: 25% were ≥70 years old, 75% had unstable angina, 9% were treated within 24 h of acute myocardial infarction (exclusive of those receiving thrombolytic therapy) and 23% had an ejection fraction ≤50%. The in-hospital mortality rate was lower (1.7%) after excluding those patients in whom angioplasty was used for treatment of acute myocardial infarction.

Completeness of revascularization. *Surgical experience.* Completeness of revascularization appears to have an important influence on long-term outcome of patients with multivessel disease who have undergone coronary artery bypass surgery (14–17). The definitions of complete revascularization vary in these surgical series, but one conclusion drawn from these studies is that complete revascularization is associated with improved long-term survival and freedom from symptoms including late myocardial infarction. The mean follow-up time in these studies ranged from 16 to 46 months, but with a longer follow-up time the results may be different. For example, after a 10 year follow-up of patients with two and three vessel disease undergoing coronary surgery at the Mayo Clinic, Schaff et al. (23) observed no significant difference in survival based on revascularization status.

Detailed examination of the influence of baseline varia-



bles was not attempted in these series, although it appeared from the study of Tyras et al. (17) that abnormal left ventricular function affected survival in a manner similar to incomplete revascularization. The presence of a significant lesion distal to the graft insertion and the known high early occlusion rates of saphenous vein grafts (24,25) could also influence outcome, and these factors may have disparate effects on completely and incompletely revascularized patients.

Angioplasty experience. The issue of completeness of revascularization after successful angioplasty is of major interest because complete revascularization has not been achieved in the majority of patients with multivessel disease. Most studies (2,12,13,18,19) have reported rates of complete revascularization of <50%, although one study (4) reported a rate of 77%. In our study only 41% of successfully treated patients had complete revascularization. Patients with two vessel disease were more likely to have complete revascu-

Figure 2. Actuarial event-free survival curves comparing patients with complete revascularization (group 1) with those with incomplete revascularization (group 2) after adjusting for predictive baseline variables identified for each event by multivariate analysis. The adjusted curves represent event-free survival in terms of freedom from death (A), myocardial infarction (MI) (B), severe angina (C), need for coronary artery bypass surgery (CABG) (D), need for repeat angioplasty (re-PTCA) (E), and the combined events of death, myocardial infarction and coronary artery bypass surgery (F).

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larization (51%) than were those with three vessel disease (25%), a finding similar to those of two earlier smaller studies (2,12).

The most common reason for failure to achieve complete revascularization in our study was that, after successful angioplasty of one or more lesions, dilation of another significant lesion (or lesions) was not attempted. The second most frequent cause was the presence of an old total occlusion. A strategy of incomplete revascularization might be chosen after identification and treatment of a so-called culprit lesion alone, a priori avoidance of a technically difficult or unsuitable lesion or the operator's decision to abandon a long or complicated procedure when it is considered that the patient's safety and comfort will be compromised if dilation of additional lesions is attempted during the same procedure. For incomplete revascularization to result simply because of failed dilation of a second or subsequent lesion was distinctly uncommon among our patients. Thus, in most cases incomplete revascularization can be predicted before the procedure and thus can be considered a predetermined strategy in the majority of patients with multivessel disease. A similar observation has been made by Deligonul et al. (2).

Whether the current rates of complete revascularization in multivessel disease can be improved with the use of newer technology is not known. For example, attempts to restore patency to old total occlusions with current technology have met with success rates of only about 50% (26–31) with early reocclusion rates as high as 57% (4). However, the effect of restored patency of these lesions on long-term outcome remains undefined.

Influence of baseline variables on follow-up events. At first this study appears to confirm the findings of others (2,4,12,13) that incomplete revascularization results in lower event-free survival compared with complete revascularization. However, this was only true with respect to the need for coronary artery bypass surgery and the risk of developing severe angina. The probability of survival was marginally better for patients with complete revascularization, but this did not quite reach statistical significance. The long-term probability of myocardial infarction and of repeat angioplasty was similar for both groups.

However, the definition of completeness of revascularization in all these studies was arbitrary and the patients analyzed were not randomly assigned to a specific treatment group. In the present study notable differences in the baseline characteristics of the two groups were identified. Patients in whom complete revascularization was not achieved were more likely to be older and to have more severe disease (as evidenced by worse angina, longer duration of symptoms, higher incidence of three vessel disease and slightly greater lesion stenosis severity). They were also more likely to have had a prior infarction and coronary artery bypass surgery and have abnormal left ventricular function (with a history of cardiac failure and a lower ejection fraction).

Multivariate analysis identified a number of these and other variables as predictors of adverse long-term outcome that were independent of revascularization status. Indeed, once these variables had been taken into account, the degree of revascularization was not strongly predictive of any long-term cardiac event, and adjusted event-free survival curves demonstrated that any differences in outcome between patients with complete and incomplete revascularization could be largely explained by differences in baseline characteristics.

Reeder et al. (19), in his review of 286 patients with multivessel disease from the initial National Heart, Lung, and Blood Institute Percutaneous Transluminal Coronary Angioplasty registry who had undergone successful angioplasty, also found significant baseline differences between patients with complete and incomplete revascularization, with the latter group of patients being older, with more severe angina, lower ejection fraction, a history of prior infarction and more eccentric lesions. After adjusting for these variables, no differences were found in the risks of death, myocardial infarction or presence of angina between the two groups. Although the need for coronary artery surgery was greater for patients with incomplete revascularization, their lower risk for having repeat angioplasty resulted in an overall similar risk of requiring a second revascularization procedure.

Limitations of the study. Despite careful analysis of all data, this study suffers from the limitations of any retrospective study. Nevertheless, we believe that with the careful prospective collection of data and the large population of patients it provides meaningful information regarding patients with multivessel disease and initially successful angioplasty. Our definition of completeness of revascularization is arbitrary and based only on angiographic criteria. The limitations in the accuracy of visual estimation alone of coronary lesions and, more importantly, the inability to determine the physiologic significance of such lesions have been emphasized previously (32,33).

The multivariate analysis and adjusted event-free survival curves utilized a computed mean ejection fraction for patients in whom this variable was missing. This presumption was made because it was considered more important not to exclude such a large number of patients from the analysis. However, even when the analyses were repeated after exclusion of these patients, the lack of a major impact of revascularization status on event-free survival was still evident. Finally, our adjusted event-free survival curves were based on a statistical model and, as such, should be considered hypothetical; use of different statistical models in different patient populations may produce alternative results.

Revascularization status may also be muted by resteno-

sis. Although <50% of the patients underwent follow-up angiography, no significant difference in the rate of restenosis per patient was noted between the patients with complete or incomplete revascularization. Our relatively high rate of restenosis probably reflects a bias from a selected group of patients returning for follow-up angiography, but similar rates have been reported from other series of patients undergoing multilesion angioplasty (8,34). Whether the consequences of restenosis are different between patients with complete versus those with incomplete revascularization is still not clear.

Conclusions. These results emphasize that complete revascularization with coronary angioplasty in patients with multivessel disease is achievable in <50% of all patients and generally appears predictable before the procedure. There will probably be major baseline differences between patients with complete versus incomplete revascularization, and thus, conclusions about long-term outcome based solely on revascularization status may be misleading. Whether or not complete revascularization offers substantial long-term benefit over incomplete revascularization can only be satisfactorily answered with a prospective randomized study. Finally, further efforts are required to lower the in-hospital mortality rate in patients with multivessel disease undergoing angioplasty, as well as to better prevent restenosis.

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