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Asymptomatic Cardiac Ischemia Pilot (ACIP) Study: Effects of Coronary Angioplasty and Coronary Artery Bypass Graft Surgery on Recurrent Angina and Ischemia*

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Objectives. **The Asymptomatic Cardiac Ischemia Pilot (ACIP) study showed that revascularization is more effective than medical therapy in suppressing cardiac ischemia at 12 weeks. This report compares the relative efficacy of coronary angioplasty or coronary artery bypass graft surgery in suppressing ambulatory electrocardiographic (ECG) and treadmill exercise cardiac ischemia between 2 and 3 months after revascularization in the ACIP study.**

Background. **Previous studies have shown that coronary angioplasty and bypass surgery relieve angina early after the procedure in a high proportion of selected patients. However, alleviation of ischemia on the ambulatory ECG and treadmill exercise test have not been adequately studied prospectively after revascularization.**

Methods. **In patients randomly assigned to revascularization in the ACIP study, the choice of coronary angioplasty or bypass surgery was made by the clinical unit staff and the patient.**

Results. **Patients assigned to bypass surgery (n = 78) had more severe coronary disease (p = 0.001) and more ischemic episodes (p = 0.01) at baseline than those assigned to angioplasty (n = 92). Ambulatory ECG ischemia was no longer present 8 weeks after revascularization (12 weeks after enrollment) in 70% of the bypass surgery group versus 46% of the angioplasty group (p = 0.002). ST segment depression on the exercise ECG was no longer present in 46% of the bypass surgery group versus 23% of the angioplasty group (p = 0.005). Total exercise time in minutes on the treadmill exercise test increased by 2.4 min after bypass surgery and by 1.4 min after angioplasty (p = 0.02). Only 10% of the bypass surgery group versus 32% of the angioplasty group still reported angina in the 4 weeks before the 12-week visit (p = 0.001).**

Conclusions. **Angina and ambulatory ECG ischemia are relieved in a high proportion of patients early after revascularization. However, ischemia can still be induced on the treadmill exercise test, albeit at higher levels of exercise, in many patients. Bypass surgery was superior to coronary angioplasty in suppressing cardiac ischemia despite the finding that patients who underwent bypass surgery had more severe coronary artery disease.**

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Silent myocardial ischemia is frequent in patients with documented coronary artery disease. Approximately 33% of asymptomatic patients and 50% of patients with angina have episodes of silent ischemia during ambulatory electrocardiographic (ECG) monitoring (1–3). In symptomatic patients with episodes of ambulatory ischemia, silent ischemic episodes outnumber the painful episodes by at least three to one. There is also recent evidence that asymptomatic myocardial ischemia detected by ambulatory ECG monitoring or exercise testing is associated with an adverse prognosis (4–8). Both medical therapy with beta-adrenergic blocking agents, calcium antagonists and long-acting nitrates and myocardial revascularization have been shown to suppress silent myocardial ischemia in a substantial number of patients (9,10). However, whether ischemia suppression improves prognosis in these patients remains to be demonstrated and can be achieved only within the framework of large controlled clinical trials.

The Asymptomatic Cardiac Ischemia Pilot (ACIP) study (11) showed that myocardial revascularization by means of coronary angioplasty or coronary artery bypass graft surgery was significantly more effective than either angina-guided or angina plus ischemia–guided medical strategy in the alleviation of silent myocardial ischemia. In patients randomized to undergo revascularization, the choice of the procedure was left

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to the patient and treating physician on the basis of coronary anatomy and other practical considerations. Although the ACIP design does not provide a randomized comparison of the effects of these procedures, the comparisons of observations made in patients according to procedure selected are of interest. This report compares the relative efficacy and safety of coronary angioplasty and coronary artery bypass graft surgery in the treatment of myocardial ischemia detected by ambulatory ECG monitoring and by treadmill exercise testing 2 to 3 months after revascularization in the ACIP study.

Methods

Study design. Details of the ACIP study design have been described previously (12,13). Briefly, the study was initiated to compare the safety and efficacy of three randomly assigned strategies to suppress ischemia and to assess the feasibility of a larger trial comparing the effects of treatment on prognosis. The three treatment strategies included 1) angina-guided medical strategy with titration of medication to relieve symptoms; 2) ischemia-guided medical strategy with titration of medication to eliminate both angina and ambulatory ECG ischemia; and 3) revascularization of all important stenoses in major coronary arteries.

A total of 558 patients were enrolled from October 23, 1991 to February 1, 1993. Entry criteria included angiographic evidence of coronary artery disease with stenoses suitable for revascularization, an abnormal stress test and at least one episode of asymptomatic 1-mm ST segment depression for at least 1 min on a 48-h ambulatory ECG.

The primary end point of the study was the effect of therapy on cardiac ischemia as detected by the 48-h ambulatory ECG at the 12-week visit. Other end points included other measurements related to ischemia from the 48-h ambulatory ECG, ACIP protocol treadmill exercise test and clinical outcomes.

Revascularization strategy. To be eligible for the ACIP study, all patients had to be suitable for revascularization by either coronary angioplasty or coronary artery bypass graft surgery. They were randomly assigned either to a revascularization strategy or to one of the two medical treatment strategies. Patients assigned to the revascularization strategy were to undergo either coronary angioplasty or bypass surgery within 4 weeks (6 weeks if staged angioplasty was performed) of the randomization visit.

The goal was to achieve revascularization of all important stenoses in major coronary arteries. The choice of coronary angioplasty or bypass surgery was made by the physician and patient and was based on the results of coronary angiography usually performed within 2 months of revascularization. In general, bypass surgery was considered for patients with multivessel disease and coronary angioplasty for patients with single- or multivessel disease when the important lesions in major coronary arteries were suitable for angioplasty.

Bypass surgery. Angiographic characteristics making bypass surgery preferable were diffuse coronary disease with lesions >20 mm in length, excessive tortuosity or angulation of the involved artery, occluded arteries, inability to protect major side branches and lesions located so that abrupt vessel closure would result in high risk of cardiogenic shock (14).

Angioplasty. The patient was considered suitable for angioplasty if the lesions satisfied previously established guidelines (15,16). The immediate outcome of the intervention was classified as successful by the clinical unit staff if all attempted stenoses in major coronary arteries were reduced to <50% lumen diameter as measured by electronic calipers and the patient was free of procedure-related complications, such as death, myocardial infarction or emergency coronary artery bypass graft surgery. Anatomic success was defined by the Angiography Core Laboratory as a postangioplasty stenosis <50% for any or all lesions attempted.

Medical therapy after revascularization was based on local clinical practice. The patient's management of angina after revascularization was changed to the ACIP regimen (atenolol/nifedipine or diltiazem/isosorbide dinitrate), either assigned randomly or chosen by the clinical investigator (11–13).

Follow-up at 12-week visit. All follow-up investigations were done ~12 weeks (84 to 182 days) after enrollment (i.e., ~8 weeks after revascularization). They included a 48-h ambulatory ECG, ACIP treadmill exercise test, evaluation of anginal status and documentation of clinical outcomes for patients who died, had myocardial infarction or underwent repeat revascularization.

At week 12, vital status and documentation of clinical events (myocardial infarction or repeat revascularization) were obtained for all 558 patients; however, anginal status could not be assessed in 1 bypass surgery group patient. The ambulatory ECG results were not available at week 12 for eight angioplasty group patients (three refused; two were unwilling or unable to report within the time window; two experienced technical problems; and one had a cardiac contraindication) and four bypass surgery group patients (one refused; and three had postoperative contraindications). The ACIP treadmill exercise test was not performed or was not interpretable at week 12 in eight angioplasty group patients (three refused; one had an alternate stress test at qualifying visit; one was unwilling or unable to report within the time window; two had cardiac contraindications; and one had an uninterpretable test) and seven bypass surgery group patients (one refused; three had uninterpretable tests; and three had cardiac or physical contraindications).

Statistical methods. Statistical analyses of categorical data were performed using the Fisher exact test or chi-square test, and analyses of continuous data were performed using the Student *t* test. The Wilcoxon rank-sum statistic was used for testing the distributions of ambulatory ECG episodes. The percent of patients with ischemic ST segment depression during the initial 10 min of the exercise test was estimated using the Kaplan–Meier method (17); patients who did not complete 10 min of exercise for reasons other than ST segment depression were censored without the event at the time the test was stopped. This analytic method was also used to estimate the time to onset of ≥1-mm ST segment depression.

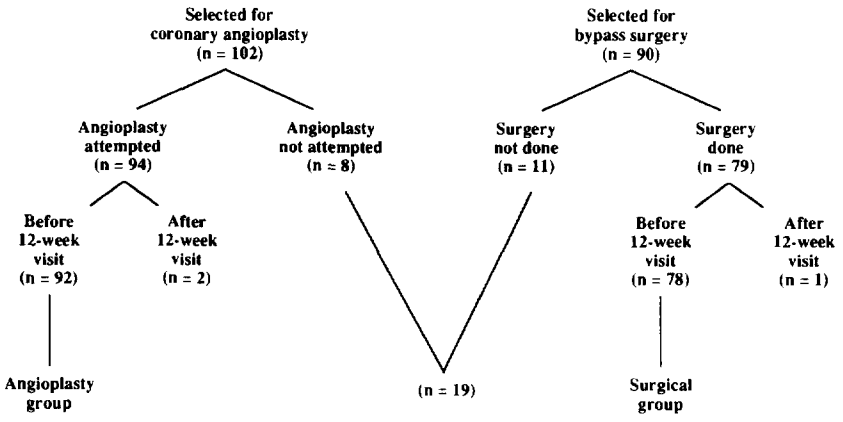

Figure 1. Schematic showing treatment actually received in 192 patients randomly assigned to revascularization in the ACIP study.

To take account of the many hypotheses tested in the ACIP study, in secondary analyses p = 0.01 was regarded as showing some evidence against the null hypothesis, and p = 0.001 was regarded as strong evidence.

All data processed in the clinical coordinating center as of January 18, 1995 were included in these analyses.

Results

Patients. Data reported here are for 558 patients (all 60 patients from one clinical unit have been excluded, as reported by Conti et al. [18]). Of the 192 patients randomly assigned to revascularization in the ACIP study, coronary angioplasty was judged to be the most appropriate procedure in 102 patients and bypass surgery in 90. However, after random assignment to revascularization, 8 patients assigned to coronary angioplasty and 11 to bypass surgery did not undergo the procedure because of subsequent patient or physician refusal. Coronary angioplasty was attempted in 94 patients (49%) and bypass surgery in 79 (41%); 19 patients (10%) did not undergo any revascularization procedure. Three patients (two in the angioplasty group, one in the bypass surgery group) underwent their procedures after the 12-week visit and were excluded from the analysis. Thus, this report is based on 92 patients in whom coronary angioplasty was attempted and 78 patients in whom bypass surgery was performed (Fig. 1).

The median number of days from study entry to angioplasty was 18 and to bypass surgery 32.

Baseline characteristics. The baseline characteristics of the coronary angioplasty and bypass surgery groups are shown in Table 1. Patients undergoing bypass surgery had more angina (p = 0.001) and more multivessel disease (p = 0.001) than those treated with angioplasty.

Ischemia on the qualifying 48-h ambulatory ECG was also more frequent in patients selected for bypass surgery than coronary angioplasty. Five or more ischemic episodes on the 48-h ambulatory ECG were recorded in 56% of the bypass surgery group versus 32% of the angioplasty group (comparison of distribution, p = 0.006). The median number of ischemic episodes/48 h was five in the bypass surgery group versus three in the angioplasty group (p < 0.001) (Table 2).

The qualifying ACIP treadmill exercise test was interpretable in 91 patients undergoing coronary angioplasty and in 77 undergoing bypass surgery (Table 3). The percent of patients with ≥1-mm ST segment depression was similar in both groups (98% for bypass surgery vs. 95% for coronary angioplasty). However, exercise-induced angina was significantly more frequent in the bypass surgery group than in the coronary angioplasty group (80% vs. 49%) (p < 0.001) (Table 3).

Ambulatory ECG results at 12-week visit. The number of patients who were free of ischemia on the 48-h ambulatory ECG or events (death, myocardial infarction, coronary angioplasty or bypass surgery) at the 12-week visit was different in the two groups (Table 2). Overall, 70% of patients after bypass surgery versus 46% after coronary angioplasty were free of

Table 1. Baseline Characteristics

	PTCA (n = 92)		CABG (n = 78)		
	No.	%	No.	%	p Value
Age ≥60 yr	55	60	43	55	
Male gender	72	78	66	85	
Angina present	54	59	67	86	0.001
Prior MI	36	39	36	46	
Diabetes	16	17	10	13	
Hypertension	36	39	31	40	
Current smoker	11	12	9	12	
Ever smoked	53	58	41	53	
Prior PTCA	20	22	9	12	
Prior CABG	4	4	5	6	
No. of arteries with stenosis ≥50%					
1	35	38	11	14	
2	42	46	32	41	
3	15	16	35	45	< 0.001
Ejection fraction					
<35%	2	2	1	1	
35–49%	4	5	12	16	
≥50%	77	93	61	82	
Not available	9		4		

Only p < 0.10 is reported. Data presented are number and percent of patients. CABG = coronary artery bypass graft surgery; MI = myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty.

Table 2. Results of Ambulatory Electrocardiography

	Qualifying Visit			Week 12 Visit		
	PTCA	CABG	p Value	PTCA	CABG	p Value
AECG results available	92	78		84	74	
No. of ischemic episodes						
0	—	—		39 (46)	52 (70)	
1	20 (22)	7 (9)		11 (13)	7 (10)	
2	23 (25)	10 (13)		8 (9)	4 (5)	
3	9 (10)	10 (13)		6 (7)	0 (0)	
4	11 (12)	7 (9)		2 (2)	1 (1)	
≥5	29 (32)	44 (56)	0.006	12 (14)	9 (12)	
Event (see Table 6)	—	—		7 (8)	1 (1)	0.02
25th percentile	2	3		0	0	
Median	3	5	<0.001	0	0	
75th percentile	5	8		2	1	
Total AECG ischemic time (min)						
25th percentile	9	12		0	0	
Median	21	28		0	0	
75th percentile	52	63		15	4	
Heart rate (beats/min)	74.0 ± 9.8	74.6 ± 10.4		70.2 ± 10.4	79.3 ± 12.1	< 0.001
Maximal heart rate (beats/min)	130.5 ± 16.1	130.0 ± 18.5		121.5 ± 16.1	130.5 ± 20.3	0.002
Maximal ST segment depression	2.0 ± 0.9	2.2 ± 1.2		0.9 ± 1.1	0.5 ± 0.8	0.003
× Total ischemic time	76.5 ± 104.1	95.1 ± 139.5		29.3 ± 73.2	16.4 ± 38.7	

Only $p < 0.10$ is reported. Data presented are number (%) of patients or mean value ± SD. AECG = ambulatory electrocardiographic; other abbreviations as in Table 1.

ambulatory ischemia or events at the 12-week visit ($p = 0.002$) (Fig. 2).

Treadmill exercise test results at 12-week visit. ST segment depression ≥1 mm was no longer present in 46% of patients after bypass surgery versus 23% after angioplasty ($p = 0.005$) (Table 3). Exercise-induced angina was no longer present at the 12-week visit in 90% of the bypass surgery group versus 70% of the angioplasty group ($p = 0.01$) (Fig. 3). In patients who performed the ACIP treadmill test at both qualifying and 12-week visits, total exercise time increased by 2.4 min after bypass surgery and by 1.4 min after angioplasty ($p = 0.02$); time to 1-mm ST segment depression increased by 3.7 min after bypass surgery and by 1.7 min after angioplasty. The number of abnormal exercise ECG leads at the 12-week visit was 1.7 in the surgery group versus 3.1 in the angioplasty group ($p < 0.001$). Maximal ST depression at the 12-week visit was 0.9 mm after bypass surgery versus 1.7 mm after angioplasty ($p < 0.001$). The sum of ST segment depression at the 12-week visit was 3.6 mm after bypass surgery versus 7.0 mm after angioplasty ($p < 0.001$).

Angina status at 12-week visit. *Stable angina,* defined as any angina during the past 4 weeks, was present at the 12-week

Table 3. Treadmill Exercise Test Results

	Qualifying Visit			Week 12 Visit		
	PTCA	CABG	p Value	PTCA	CABG	p Value
ETT data interpretable	91	77		84	71	
≥1-mm ST segment depression*	84 (95)	72 (98)		56 (77)	31 (54)	0.005
Exercise-induced angina*	33 (49)	51 (80)	< 0.001	21 (30)	6 (10)	0.01
Total exercise time (min)	7.2 ± 3.2	6.3 ± 2.9		8.6 ± 3.4	8.5 ± 3.6	
% of age-predicted maximal heart rate	86.5 ± 11.3	81.2 ± 12.0	0.009	85.4 ± 13.5	93.1 ± 12.0	< 0.001
Time to 1-mm ST depression (min [mean ±SE])†	4.8 ± 0.3	3.9 ± 0.2		6.5 ± 0.3	7.6 ± 0.3	
No. of exercise ECG leads with abnormal findings	4.4 ± 1.8	4.4 ± 2.0		3.1 ± 2.4	1.7 ± 2.2	< 0.001
Maximal ST segment depression	2.4 ± 0.9	2.6 ± 1.3		1.7 ± 1.3	0.9 ± 1.1	< 0.001
Sum of ST segment depression in leads with abnormal findings	9.5 ± 4.7	10.4 ± 5.8		7.0 ± 5.8	3.6 ± 4.4	< 0.001
Maximal heart rate (beats/min)	137.5 ± 17.9	128.7 ± 17.9	0.002	135.9 ± 21.4	147.7 ± 18.9	< 0.001
Maximal systolic blood pressure (mm Hg)	177.2 ± 27.5	169.1 ± 24.7		177.8 ± 24.3	179.5 ± 27.3	

*Kaplan–Meier life-table analysis used to calculate percent of patients with specified event during first 10 min of exercise; occurrences after 10 min or during recovery are not counted. †Kaplan–Meier life-table analysis used to estimate mean time to event during first 10 min of exercise; occurrences after 10 min or during recovery are not counted. If event rates are <50%, mean and median values are not available. Only $p < 0.10$ is reported. Data presented are number (%) of patients or mean value ± SD, unless otherwise indicated. ECG = electrocardiogram; ETT = treadmill exercise test; other abbreviations as in Table 1.

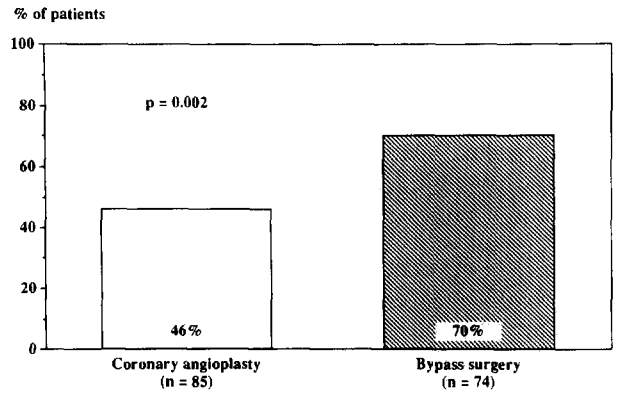

Figure 2. Patients without ischemia on the ambulatory electrocardiogram or events at 12 weeks. Ambulatory cardiac ischemia was suppressed in 46% of patients after coronary angioplasty versus 70% of patients after coronary artery bypass graft surgery (p = 0.002).

visit in 32% of patients after angioplasty but in only 10% of patients after bypass surgery (p = 0.001) (Table 4, Fig. 4). Angina was mild to moderate (Canadian Cardiovascular Society class I or II) in all but one patient in the coronary angioplasty group. No patient experienced unstable angina before the 12-week visit.

Adjunctive medical therapy at 12-week visit. The percent of patients who were taking study medication (background or open label to relieve angina at the 12-week visit) was 49% after angioplasty and 10% after bypass surgery. The percent of patients taking one drug was 36% and 10%, respectively. The percent of patients taking two drugs was 13% and 0%, respectively.

Revascularization strategy and outcome. Coronary angioplasty was performed in 86 of the 92 patients in whom it was attempted (Table 5). It was not performed in six patients because of inability to cross the lesion. By clinical unit assessment, the procedure was successful in 76 patients (83%). Angiography core laboratory assessment of anatomic success was 82% when defined as postangioplasty stenosis <50% for any lesion attempted and 78% for all lesions attempted. One lesion was dilated in 73% of patients, two in 23% and three in 4%. One vessel was dilated in 89% of patients and two vessels in 11%. Core laboratory assessment of complete revascularization, defined as all significant stenoses reduced to <50% diameter stenosis, was achieved in 29 patients (32%).

Bypass surgery was performed before the 12-week visit in 78 patients. The mean number of grafts placed was three. The number of bypass grafts matched or exceeded that of diseased major coronary arteries in 74 (95%) of the 78 patients. Internal thoracic artery grafts were used in 66 patients (85%). Fifty-five patients had one and 11 patients had two internal thoracic artery grafts. One patient had another arterial graft.

Within 24 h of coronary angioplasty, there were three events in two patients (nonfatal myocardial infarction and bypass surgery in one, emergency bypass surgery in the other). There were no deaths and no myocardial infarctions in the 24 h after bypass surgery. Five patients had other complications (stroke followed by recovery with no residual neurologic impairment in one, reoperation for bleeding in four).

By 84 days, only one patient had had an event (myocardial infarction) in the bypass surgery group, whereas seven had

Table 4. Angina Status at 12-Week Visit

	PTCA [no. (%) of pts]	CABG [no. (%) of pts]	p Value
Angina data available	92	77	
Canadian Cardiovascular Society classification			
None	63 (69)	69 (90)	
I	14 (15)	4 (5)	
II	14 (15)	4 (5)	
III	1 (1)	0 (0)	
IV	0 (0)	0 (0)	0.01

Only p < 0.10 is reported. pts = patients; other abbreviations as in Table 1.

Figure 3. Patients without ischemia or angina on the ACIP treadmill exercise test at the 12-week visit (~8 weeks after revascularization). At the 12-week visit, ≥1 mm ST segment depression was no longer present in 23% of patients after coronary angioplasty versus 46% after bypass surgery (p = 0.005). Exercise-induced angina was absent in 70% of patients after coronary angioplasty versus 90% after bypass surgery (p = 0.01).

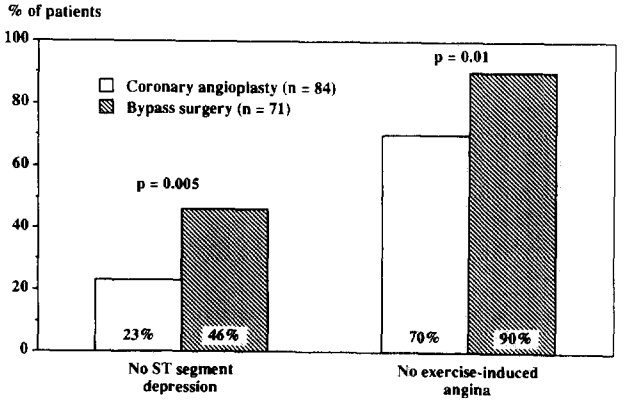

Figure 4. Patients without angina at the 12-week visit. Angina in the 4-week period before the 12-week visit was absent in 68% of patients after coronary angioplasty versus 90% after bypass surgery (p = 0.001).

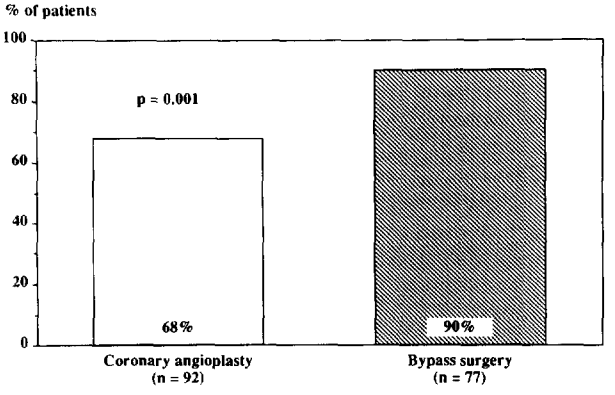

Table 5. Outcome After Coronary Angioplasty

	PTCA (n = 92)	
	No.	%
Performed	86	
Attempted but not performed because of inability to cross lesion	6	
Outcome (clinical unit assessment)		
Successful	76	83
Not successful (includes attempts)	16	17
No. of lesions dilated (angiography core laboratory review)		
1	67	73
2	21	23
3	4	4
Anatomic success		
Any lesion attempted	75	82
All lesions attempted	72	78

Data presented are number and percent of patients. PTCA = percutaneous transluminal coronary angioplasty.

events (myocardial infarction in three, repeat angioplasty in two, bypass surgery in four) in the coronary angioplasty group (Table 6). Repeat coronary angioplasty after the index procedure was performed because of unstable angina after abrupt vessel closure in one patient and because of severe ischemia on the treadmill exercise test in another. The reasons for nonprotocol coronary artery bypass graft surgery included failed coronary angioplasty in four patients and unstable angina in one.

Discussion

Rationale for assessing revascularization by treatment received. The results of the ACIP study showed that myocardial revascularization was superior to medical therapy in reducing ischemia on the 48-h ambulatory ECG at the 12-week visit (11). The percent of patients who were ischemia free was similar for both angina-guided and angina plus ischemia–guided medical strategies, but more patients in the revascularization strategy were ischemia free on the 12-week ambulatory ECG than in the other two groups. The treadmill exercise test results at the 12-week visit were concordant with those of ambulatory ECG monitoring. All three treatment strategies improved exercise tolerance and reduced exercise-induced angina and exercise-induced ECG evidence of ischemia. The results of the two medical strategies were comparable, and the revascularization strategy was more effective than either medical strategy in increasing total exercise time and decreasing the percent of patients with exercise-induced angina and ST segment depression (11).

The effect of the three treatment strategies in the ACIP study was analyzed according to treatment assignment. Thus, all patients randomly assigned to revascularization were included in the analysis. Even though analysis of the revascularization by treatment received was not specified in the ACIP protocol, and therefore the conclusions of this post hoc analysis are less definitive than those of the main ACIP results, further analysis of patients assigned to revascularization strategy according to treatment received is of interest.

1) As observed in previous trials involving myocardial revascularization (19), not all patients who were assigned to revascularization in the ACIP study underwent coronary angioplasty or bypass surgery. A total of 19 patients did not undergo any revascularization procedure because of patient or physician refusal or preference or for other logistic reasons, and 3 patients underwent the procedure after the 12-week follow-up visit. This high noncompliance rate is probably not unusual in patients who, although they had severe coronary artery disease, had few or no symptoms. These 22 patients were receiving medical therapy when the 12-week 48-h ambulatory ECG, ACIP protocol treadmill exercise test and clinical outcome data were analyzed.

2) To our knowledge, the relative efficacy and safety of coronary angioplasty and bypass surgery in relieving cardiac ischemia in patients with severe coronary artery disease has not previously been assessed prospectively. Bypass surgery is expected to be more effective than coronary angioplasty in patients with multivessel disease, mainly because it usually results in more complete revascularization. Revascularization may be incomplete after coronary angioplasty in patients with multivessel coronary artery disease: One or more significant lesions may not be successfully dilated; complete revascularization may be intended but not attempted because of proce-

Table 6. Events and Procedures by 84 Days

	PTCA (n = 92)		CABG (n = 78)		
Event or Procedure	No.	%	No.	%	p Value
Death	0	0	0	0	
MI	3	3	1	1	
Death or MI	3	3	1	1	
PTCA	2	2	0	0	
CABG	4	4	0	0	
PTCA or CABG	6	7	0	0	0.03
Any of above	7	8	1	1	

Only $p < 0.10$ is reported. Data presented are number and percent of patients. MI = myocardial infarction; other abbreviations as in Table 1.

dural complications. However, in most cases, incomplete revascularization is part of a preferred coronary angioplasty strategy, and it can be anticipated before the procedure. Complete revascularization may not be planned for clinical reasons, which include, among others, unstable angina, recent myocardial infarction, severe left ventricular dysfunction and other urgent/emergent problems arising during coronary angioplasty. Complete correction may not be possible in patients with chronic total occlusions or adverse stenosis morphology or may not be planned in patients with less than severe coronary narrowing (20).

3) Restenosis of one or more lesions occurs frequently between 1 and 4 months after coronary angioplasty and contributes to recurrence of ischemia in patients with single- and multivessel disease.

Relative efficacy and safety of coronary angioplasty and bypass surgery. Previous studies (21–25) have shown that cardiac ischemia on the ambulatory ECG or the treadmill exercise test, or both, is frequently abolished after revascularization by either coronary angioplasty or coronary artery bypass graft surgery. However, the relative efficacy and safety of each procedure in suppressing cardiac ischemia have not been adequately studied. Moreover, it has not yet been clearly established whether ischemia suppression is dependent on completeness of revascularization (21,24) and whether ischemia suppression after myocardial revascularization influences long-term prognosis (22–24).

Among patients randomly assigned to revascularization in the ACIP study, those in whom coronary artery bypass graft surgery was selected and performed were higher risk patients than those undergoing coronary angioplasty. They had more angina, and more had a history of previous myocardial infarction, more severe coronary artery disease and left ventricular dysfunction. They also had evidence of more ischemia on the prerandomization 48-h ambulatory ECG and lower exercise tolerance and more ischemia on the baseline ACIP treadmill test. The ACIP results showed that despite these differences in baseline characteristics, a much higher percent of patients were ischemia free on the 48-h ambulatory ECG at the 12-week visit (~8 weeks after revascularization) after bypass surgery than after coronary angioplasty. Overall, 70% of patients were ischemia free after bypass surgery compared with 46% after coronary angioplasty. Bypass surgery was by far the most effective treatment in reducing myocardial ischemia in the ACIP study. Coronary angioplasty was not significantly better than medical therapy alone, where ~40% of patients were ischemia free on the 48-h ambulatory ECG at the 12-week visit (11).

Angina pectoris within the past 4 weeks was relieved in 90% of patients after bypass surgery, whereas it was relieved in 68% after coronary angioplasty. These clinical benefits are in agreement with the relative efficacy of each revascularization procedure on suppression of ambulatory ECG ischemia in this study. They are also consistent with previous reports on clinical effectiveness of these interventions (26,27).

Cardiac events and repeat revascularization procedures through 12 weeks were more frequent after angioplasty than after bypass surgery. Only one surgical patient had an event before 12 weeks compared with seven angioplasty patients.

Suppression of ambulatory and exercise-induced ischemia follow-up results differed in the ACIP study. After bypass surgery, ambulatory ECG ST segment depression persisted at 12 weeks in only 30% of patients, whereas exercise-induced ST segment depression persisted in 54%. Likewise, after coronary angioplasty, ambulatory ECG ST segment depression was present at 12 weeks in 54% of patients, whereas exercise-induced ST segment depression was present in 77%. However, exercise-induced ischemia occurred at a higher work load after revascularization. Patients were able to exercise an average of 3.7 min longer after bypass surgery and an average of 1.7 min longer after angioplasty before onset of ST segment depression. Nevertheless, these results suggest that some degree of residual ischemia persists in many patients after revascularization and that even after coronary artery bypass graft surgery, restoration of blood supply may be incomplete.

Influence of completeness of revascularization. The ACIP protocol was not designed to assess completeness of revascularization after either coronary angioplasty or bypass surgery. Multivessel disease was present in 86% of patients undergoing bypass surgery. The average number of grafts in these patients was three, and the number of grafts matched or exceeded the number of diseased major coronary arteries in 95% of patients. In addition, 85% of patients received one or more internal thoracic artery grafts.

Multivessel disease was present in 62% of patients undergoing coronary angioplasty. The procedure was successful; that is, all attempted stenoses in the major coronary arteries were reduced to <50% diameter without procedure-related complications in 83% of patients. However, angioplasty of only one lesion was attempted in 73% of patients and only one vessel in 89%. Complete revascularization was achieved in only 32% of the patients. These procedures were performed at major academic centers with the specific goal of achieving revascularization of all important stenoses in major coronary arteries. Thus, it can be assumed that this outcome is representative of current clinical practice. Comparison with data in published reports of coronary angioplasty in patients with multivessel disease supports this assumption (20).

Recent trials comparing coronary angioplasty and bypass surgery. Four prospective randomized trials comparing the relative efficacy and safety of coronary angioplasty and bypass surgery in patients with symptomatic coronary artery disease have been published recently (28–31). There are major differences in patient selection and study design between the ACIP study and these recent trials. In the ACIP study, the patients had to be suitable for revascularization by only one procedure, although they were randomly assigned to revascularization, and the choice of the revascularization procedure was made by the clinical site physician and patient on the basis of coronary anatomy and other clinical considerations. In the other studies, the patients had to be suitable for equivalent revascularization with either

angioplasty or bypass surgery, and they were randomly assigned to one or the other procedure. Thus, the anatomic characteristics were different, and the patients in these other studies may be viewed as having anatomic characteristics present only in the subset of ACIP patients who would be suitable for equivalent revascularization by either procedure. These anatomic differences resulted in the finding that complete or optimal revascularization was more consistently attempted and achieved after angioplasty in these studies than in the ACIP study. Finally, the primary end points of these studies were clinical events at 1 to 3 years after revascularization, whereas the primary end point of the ACIP study was suppression of ambulatory ischemia at 3 months.

These studies suggested that, as a rule, both coronary angioplasty and bypass surgery resulted in a similar clinical outcome, including similar mortality and myocardial infarction 1 to 3 years after enrollment. However, nonprotocol repeat revascularization was fourfold to tenfold more frequent after coronary angioplasty than after bypass surgery. When this higher frequency of nonprotocol revascularization after angioplasty was taken into account, angina was relieved in most cases with both procedures, and, in the Emory Angioplasty versus Surgery Trial (31), residual ischemia on the thallium-201 perfusion scan was similar at 3 years in both treatment groups. If one assumes that nonprotocol repeat revascularization was a marker for persistent ischemia after the index revascularization in these studies, their results are concordant with those of the ACIP study. Whether clinical events are also less frequent after bypass surgery than after angioplasty, when the ACIP revascularization strategy, which is more in line with the usual clinical practice, is followed is not known. The effect of the revascularization practice used in the ACIP study on 1-year clinical outcome should be available shortly and will be of considerable interest. However, the full answer to the question of frequency of postrevascularization clinical events will require a larger long-term prognosis study using the ACIP protocol.

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