A COMPARISON OF ANGIOPLASTY WITH MEDICAL THERAPY IN THE TREATMENT OF SINGLE-VESSEL CORONARY ARTERY DISEASE

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Abstract *Background.* Despite the widespread use of percutaneous transluminal coronary angioplasty (PTCA), only a few prospective trials have assessed its efficacy. We compared the effects of PTCA with those of medical therapy on angina and exercise tolerance in patients with stable single-vessel coronary artery disease.

Methods. Patients with 70 to 99 percent stenosis of one epicardial coronary artery and with exercise-induced myocardial ischemia were randomly assigned either to undergo PTCA or to receive medical therapy and were evaluated monthly. The patients assigned to PTCA were urged to have repeat angioplasty if their symptoms suggested restenosis. After six months, all the patients had repeat exercise testing and coronary angiography.

Results. A total of 107 patients were randomly assigned to medical therapy and 105 to PTCA. PTCA was clinically successful in 80 of the 100 patients who actually had the procedure, with an initial reduction in mean percent stenosis from 76 to 36 percent. Two patients in the PTCA group required emergency coronary-artery bypass surgery. By six months after the procedure, 16 patients had had repeat PTCA. Myocardial infarction occurred in five patients assigned to PTCA and in three patients assigned to medical therapy. At six months 64 percent of the patients in the PTCA group (61 of 96) were free of angina, as compared with 46 percent of the medically treated patients (47 of 102; $P<0.01$). The patients in the PTCA group were able to increase their total duration of exercise more than the medical patients (2.1 vs. 0.5 minutes, $P<0.0001$) and were able to exercise longer without angina on treadmill testing ($P<0.01$).

Conclusions. For patients with single-vessel coronary artery disease, PTCA offers earlier and more complete relief of angina than medical therapy and is associated with better performance on the exercise test. However, PTCA initially costs more than medical treatment and is associated with a higher frequency of complications. (N Engl J Med 1992;326:10-6.)

PERCUTANEOUS transluminal coronary angioplasty (PTCA) is an increasingly popular treatment for coronary-artery stenosis. An estimated 200,000 procedures were performed in the United States and another 100,000 in Europe during 1990.[1] The growth in the use of PTCA has been based on its perceived benefits as compared with medical or surgical treatment, yet these benefits have not been demonstrated by a randomized clinical trial, despite repeated recommendations for such a study.[2-7] Specifically, the question of whether PTCA offers any advantage over drug therapy in patients with single-vessel coronary artery disease and stable angina has remained unanswered.

The Coronary Artery Surgery Study (CASS) demonstrated that coronary-artery bypass surgery reduced neither mortality nor subsequent myocardial infarctions in patients with stable single-vessel disease.[8] Since PTCA is unlikely to be more effective than bypass surgery in reducing mortality or infarction in this patient population, its potential benefits are more readily measured in terms of symptomatic and functional outcomes. We report on our comparison of the results of angioplasty with those of medical therapy after six months, the initial follow-up period designated by the protocol.

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*Investigators who participated in the ACME (Angioplasty Compared to Medicine) study are listed in the Appendix.

METHODS

Patient Selection

We screened all patients referred for coronary angiography at eight participating Veterans Affairs centers between May 1987 and May 1990. The research protocol was approved by the institutional review board of each center. In order to be enrolled in the study, patients had to satisfy clinical, angiographic, and exercise-test criteria. The clinical requirement was any of the following: stable angina pectoris, a strikingly positive exercise-tolerance test (ST-segment depression $\geq$3 mm), or a myocardial infarction within the past three months. The angiographic requirement was stenosis of 70 to 99 percent of the diameter, assessed visually, in the proximal two thirds of one major epicardial coronary artery or similar serial stenoses limited to the proximal two thirds of the same artery or its branches. The qualifying stenoses were termed "index lesions." The exercise-test requirement was a horizontal or down-sloping ST-segment depression $\geq$1.0 mm in one or more leads measured 80 msec after the J point that occurred during or after treadmill exercise testing. Patients with no ST-segment depression who had angina during the test could also be included if there was evidence on thallium scanning of a defect in the area corresponding to the index lesion that "filled in" during the period after the exercise test.

Randomization and Treatment

After written informed consent was obtained, patients were admitted to the hospital; all antianginal medication was discontinued for at least 24 hours before a base-line exercise-tolerance test that included thallium scintigraphy. If this test showed ischemia, the patient was randomly assigned to one of two treatment groups (PTCA or medical therapy) by means of a permuted-block scheme.[9] After randomization, all patients received 325 mg of aspirin per day.

The patients assigned to medical therapy were treated according to a stepped-care approach designed to eliminate angina. The "steps" included oral isosorbide dinitrate with sublingual prophylactic and therapeutic nitroglycerin, beta-blocking agents, calcium-channel–blocking agents, or a combination of these drugs.

The patients assigned to PTCA underwent the procedure within three days of randomization. They received a calcium-channel

blocker before and for one month after the procedure, heparin at the beginning of the procedure, and nitroglycerin during it and for 12 hours thereafter. The technical details of the procedure were left up to the investigator who performed the angioplasty.

Follow-up

After discharge, all patients were seen monthly. Patients in the medical-therapy group had their dosage of antianginal drugs increased, as needed, to the maximal tolerated dose. If symptoms persisted or recurred, the patients assigned to PTCA were encouraged to have a repeat coronary angiogram and angioplasty, if necessary, so that the use of PTCA in this trial would approximate its use in clinical practice.

Six months after randomization (or at least three months after repeat PTCA), each patient was admitted to the hospital for repeat exercise testing and coronary angiography. The patients assigned to medical therapy performed the exercise test while receiving their optimal drug regimen. Those assigned to PTCA performed the exercise test after their antianginal medications (if any) had been discontinued for at least 24 hours, since the goal was to assess the efficacy of PTCA alone (without adjunctive medical therapy) in relieving symptoms.

End Points

The primary end points in this study were the changes in exercise tolerance between the base-line and follow-up exercise tests, the frequency of angina attacks, and the use of nitroglycerin between the base line and the final month of the study. The measures of exercise tolerance we evaluated were the total duration of exercise, the length of time to the onset of angina, the length of time to the onset of 1-mm ST-segment depression, the maximal ST-segment depression, and the maximal product of the heart rate and the systolic blood pressure. The principal secondary end point was the change in the degree of stenosis in the originally identified index lesions. Other end points included the change in the score on a standard self-administered questionnaire designed to measure psychological well-being[10] and employment status. All cardiac events, procedures, and hospital admissions were recorded.

Statistical Analysis

We calculated the sample size necessary to achieve 95 percent statistical power at the $P = 0.05$ level. The accrual goal was based on earlier reports of the effects of either medical therapy or PTCA on the total duration of exercise[11,12] and the frequency of angina.[13,14] In order to detect a 1-minute advantage in total duration of exercise for PTCA over medical therapy (with a maximal variance of 3.7 minutes), we needed to enroll 96 patients in each treatment group. If we assumed that 50 percent of the medically treated patients and 75 percent of the patients treated with PTCA would have improvement in their symptoms, 95 patients would be required in each cohort. Assuming a 10 percent loss to follow-up, we set a goal of 200 patients for the study.

The two groups were compared by the chi-square test or Fisher's exact test for discrete variables and the t-test or the Wilcoxon rank-sum test for continuous variables.[15] The lengths of time to the onset of angina and to ST-segment depression in the treadmill exercise test were estimated by the Kaplan–Meier method.[16] Proportional-hazards models were used to adjust the six-month comparison for base-line performance by including the patient's base-line value for length of time to the event of interest.[17] The treatment effect was tested with the log-rank statistic.[18] All analyses were performed according to intention to treat. All reported P values are two-sided and compare the treatment groups, unless otherwise specified. The progress of the study was reviewed twice a year by an independent data-monitoring board.

Testing Procedures and Analysis

At each center, the investigator's readings of exercise electrocardiograms, thallium scintigrams, and coronary arteriograms were used to determine whether the inclusion criteria had been met. Blinded analyses of the exercise studies, coronary arteriograms,[19] and serum lipid levels were performed at central laboratories and are reported here.

Each center used the same treadmill-exercise electrocardiographic systems (CASE 12, Marquette Electronics, Milwaukee). The exercise tests were maximal, symptom-limited studies beginning at 5 percent elevation and 1.7 mph and followed the modified Bruce protocol.[20] Twelve-lead recordings were made during the last 10 seconds of each minute of exercise and during each of the first 3 to 5 minutes of recovery.

Follow-up coronary angiograms similar to the base-line studies were obtained in all patients. Lesions were analyzed by an observer who used electronic calipers and who was blinded to the patient's treatment group and the timing of each angiogram.

Myocardial infarction was defined as the appearance of new Q waves on the electrocardiogram or an increase in the serum creatine kinase level above normal limits in combination with typical clinical signs. The major complications of catheterization that we studied were death, cerebrovascular accident, myocardial infarction, ventricular fibrillation, bleeding requiring transfusion, and arterial occlusion requiring surgical repair.

The questionnaire that measured psychological well-being contained 22 questions, the responses to which were scored from 0 (most negative) to 5 (most positive). The answers were summed to yield an overall score (maximum, 110). The mean scores for this test in community studies with large samples have ranged from 76 to 83.[10] Subscores were reported for anxiety, depressed mood, general health, positive well-being, self-control, and vitality.

Results

Screening, Randomization, and Base-Line Characteristics of Patients

The participating centers screened 9573 patients over a period of 37 months. Of these, 96 percent did not satisfy the clinical or angiographic requirements for enrollment (Table 1). Of the 371 remaining patients, 212 (57 percent) were randomly assigned: 105 to PTCA and 107 to medical therapy. The base-line characteristics of the two treatment groups were similar (Table 2).

Outcomes

Of 105 patients assigned to PTCA, 100 actually underwent the procedure (Table 3). In two cases the patients refused the procedure; in another the participating investigator refused to perform the procedure because on further review the patient was deemed unsuitable for PTCA; in a fourth the pressure gradient across the lesion was trivial, so no dilation was considered necessary; and in the fifth patient the lesion had disappeared since the qualifying angiogram was obtained. More than one lesion was dilated (either serial lesions or lesions in coronary-artery branches) in 16 patients. Eighty-two procedures were angiographically successful (as indicated by >20 percent decrease in percent stenosis of all lesions in which dilation was attempted) and 80 were clinically successful (the total with angiographic success, no myocardial infarction, and no need for emergency surgery). Two patients underwent emergency bypass surgery. Four patients had an acute myocardial infarction (one Q-wave and three non–Q-wave infarctions) as a result of the initial procedure; in one of these cases infarction accompanied emergency bypass surgery. There were no deaths

in the PTCA group at any time. During follow-up, 19 repeat PTCA procedures were performed in 16 patients: 18 for restenosis and 1 as a second attempt after initial failure. Five additional patients required bypass surgery, and one more patient had a myocardial infarction. At the six-month clinic visit, significantly fewer patients in the PTCA group than in the medical-therapy group were taking antianginal agents (Table 3).

Of 107 patients assigned to medical therapy, none had bypass surgery, but 11 underwent PTCA (1 of the 11 had two repeat procedures). Three patients had myocardial infarctions during follow-up, and one died as a result of a PTCA procedure he insisted on having despite random assignment to medical therapy and a lack of progression of symptoms.

No major complications were associated with diagnostic catheterization, and no adverse outcomes were caused by exercise testing.

Change in Exercise Performance and Angina Status

Paired exercise tests were performed at base line and six months after randomization by 199 of the 212 patients (94 percent). Thirteen patients (seven in the medical-therapy group and six in the PTCA group) did not have a six-month exercise study. One had died, eight withdrew from the study, three had had surgery (one a hip replacement and two coronary-artery bypass), and one had had a stroke and could not exercise. The mean length of time from randomization to follow-up exercise testing was 209 days for medically treated patients and 212 days for patients in the PTCA group.

Table 1. Principal Reasons for the Exclusion of Potential Subjects.*

Reason for Exclusion	No.	Percent
Clinical (n = 4497)		
Previous CABG	1647	36.6
Unstable angina	839	18.7
Previous PTCA	832	18.5
No inclusion criteria	574	12.8
Unable to perform ETT	458	10.0
Other illness	121	2.7
Female sex	109	2.4
Participation in another trial	108	2.4
Unable to return monthly	106	2.4
Negative ETT	62	1.4
Other†	127	2.8
Angiographic (n = 4705)		
Triple-vessel disease	1769	37.6
All lesions <70% stenosed	1381	29.4
Lesions not suitable for PTCA	868	18.4
Disease of left main coronary artery	327	7.0
Valvular disease	312	6.6
Ejection fraction <30%	276	5.9
Double-vessel disease	135	2.9
Angiogram >45 days old	34	0.7
SVD (total occlusion)	20	0.4

*Some patients had more than one reason for exclusion. CABG denotes coronary-artery bypass graft, ETT exercise-tolerance test, and SVD single-vessel disease.

†"Other" reasons were as follows: patient was incompetent to give informed consent (n = 53); patient had an absolute requirement for beta-blocker therapy (n = 30); medical therapy had already failed (n = 34); and patient had aspirin intolerance (n = 10).

Table 2. Base-Line Characteristics of Patients According to Treatment Group.*

Characteristic	Medical Therapy (N = 107)	PTCA (N = 105)
Clinical		
Age (yr)	63	62
Previous infarction (%)	28	33
Hypertension (%)	53	52
Diabetes (%)	19	17
Heart failure (%)	1	2
Current smoker (%)	33	29
Employed (%)	29	42
Blood pressure — systolic/diastolic (mm Hg)	137/82	134/79
Angina-free for past 30 days (%)	8	9
Psychological–well-being score	72.0	72.7
Laboratory		
Total cholesterol (mmol/liter)†	5.98±0.10	5.93±0.13
High-density lipoproteins (mmol/liter)†	0.98±0.02	0.93±0.10
Triglycerides (mmol/liter)‡	2.35±0.15	2.26±0.12
Angiographic		
Mean percent stenosis		
All lesions	77	76
Right coronary artery (no.)	80 (34)	79 (42)
Left anterior descending coronary artery (no.)	78 (38)	77 (41)
Left circumflex coronary artery (no.)	75 (32)	70 (21)
Ejection fraction	65.1±1.3	64.9±1.1
Exercise test		
Total duration (min)	8.8±2.8	8.9±3.1
Time to onset of angina (min)	5.7±2.7	5.6±2.6
Time to 1-mm ST-segment depression (min)	5.3±2.7	5.0±2.6
Maximal ST-segment depression (mm)	2.0±0.9	1.8±1.0
Maximal HR–BP ($\times 10^{-3}$)	24.3±5.8	25.0±5.4

*Plus–minus values are means ±SD. HR–BP denotes the product of the heart rate and the systolic blood pressure.

†To convert cholesterol values to milligrams per deciliter, multiply by 38.6.

‡To convert triglyceride values to milligrams per deciliter, multiply by 188.4.

Both groups of patients had an increase in the total duration of exercise (Table 3). The medical-therapy group had a mean increase of 0.5 minute over their base-line values and the PTCA group an increase of 2.1 minutes ($P<0.0001$). In the medical-therapy group the maximal heart rate–blood pressure product decreased by 2800 units, whereas it increased by 1800 in the PTCA group ($P<0.0001$).

The remaining exercise-test outcomes were based on fewer observations, because many participants had no angina or electrocardiographic evidence of ischemia after treatment. Therefore, angina was analyzed in terms of the duration of angina-free exercise on the treadmill test (Fig. 1). At base line the duration curves did not differ between the groups

Table 3. Outcomes of Treatment According to Treatment Group.*

Outcome Variable	Medical Therapy		PTCA		P Value
	no.	*%*	*no.*	*%*	
Therapy received					
No. randomized	107	100	105	100	
Revascularization procedure					
PTCA	11	10	100†	96	—
Repeat PTCA‡	1	9	16	16	—
Coronary bypass surgery	0	0	7	7	<0.01
Use of antianginal medications at 6 mo					
Total	102	95	96	91	0.25
Oral nitrates	53	50	25	24	<0.01
Topical nitrates	10	9	3	3	0.05
Calcium-channel blocker	76	71	37	35	<0.01
Beta-adrenergic blocker	53	50	31	30	<0.01
Aspirin	97	91	89	85	0.19
Dipyridamole	3	3	3	3	1.00
	no.	*change*	*no.*	*change*	
Primary end points at 6 mo					
Exercise-test criteria					
Total duration of exercise (min)	100	+0.5±2.2§	99	+2.1±3.1¶	<0.0001
Maximal HR–BP ($\times 10^{-3}$)	100	−2.8±5.8¶	99	+1.8±6.0§	<0.0001
Time to onset of angina (min)	37	+0.8±3.8¶	24	+2.6±4.1¶	<0.01
Time to onset of 1-mm ST-segment depression (min)	37	+1.1±2.7§	43	+2.2±4.4¶	0.26
Maximal ST-segment depression (mm)	37	−0.3±1.1	43	−0.1±1.2	0.36
	no.	*value*	*no.*	*value*	
Clinical criteria					
Angina pectoris					
Mean change in episodes/mo	98	−7±22¶	94	−15±39¶	0.06
Percent angina-free in 6th mo	102	46¶	96	64¶	<0.01
Nitroglycerin use					
Mean change in tablets/mo	97	−5±25§	94	−9±30¶	0.25
Adverse outcomes					
Myocardial infarction	3		5		0.50
Death	1		0		1.0

*Plus–minus values are means ±SD. P values are for the comparison between the treatment groups. HR–BP denotes the product of the heart rate and the systolic blood pressure.

†In the group assigned to PTCA, two patients declined to undergo the procedure; one patient's physician refused to have the patient undergo it; in one case the pressure gradient across the index lesion was minimal; and in one case the index lesion disappeared between the time of angiography and of PTCA.

‡One patient in the medical-therapy group had two repeat PTCA procedures, and three patients in the PTCA group had two repeat procedures.

§$P<0.05$ for the comparison with the base-line value.

¶$P<0.01$ for the comparison with the base-line value.

(P = 0.47); approximately 50 percent of each group had angina after six minutes. By six months after randomization each group had improved, as indicated by a shift of the curves upward and to the right ($P<0.0001$ for the PTCA group; $P<0.0001$ for the medical-therapy group). Moreover, the curve for the PTCA group indicated more improvement than that for the medical-therapy group (P = 0.01), reflecting longer angina-free exercise by patients treated with PTCA.

Patients assigned to PTCA had a mean decrease of 15 episodes of angina per month, as compared with 7 fewer episodes per month for those assigned to medical therapy (P = 0.06) (Table 3). Moreover, a greater proportion of the PTCA group was free of angina at six months (61 of 96 vs. 47 of 102, P = 0.01). For the PTCA group, most of this relief was evident at the first monthly clinic visit; the medical-therapy group improved gradually during the six months of treatment (Fig. 2). Nitroglycerin consumption also decreased after treatment; the difference between the groups was not statistically significant (Table 3).

Change in Index Lesions

We analyzed 100 pairs of lesions (base line vs. six months) in patients in the medical-therapy group and 104 pairs in those assigned to PTCA. In the medical-therapy group, the mean percent stenosis of the index lesions decreased from 77 percent at base line to 75 percent at follow-up (P = 0.86). The mean percent stenosis of the index lesions in the PTCA group decreased from 76 percent at base line to 36 percent immediately after dilation, then increased to 54 percent at follow-up ($P<0.001$).

A similar proportion of both groups had evidence of progression to ≥70 percent stenosis in other vessels on the six-month coronary arteriogram (10 of 98 patients in the medical-therapy group and 7 of 94 patients in the PTCA group, P = 0.50).

Other End Points

The overall psychological–well-being score improved by 8.6 for patients in the PTCA group and 2.4 for patients in the medical-therapy group (P = 0.03) from base-line values of 72.7 and 72.0, respectively. An advantage for PTCA over medical therapy ($P\leq 0.05$) was evident in the subscores for general health and vitality. Employment (at base line, 42 percent in the PTCA group and 29 percent in the medical-therapy group) was not substantially changed at follow-up (43 percent and 29 percent, respectively). The number of hospital days was greater for patients in the PTCA group (total, 400 days; for cardiac disorders, 324 days) than for those assigned to medical therapy (total 252 days; for cardiac disorders, 191 days). The patients in the medical-therapy group spent more days in the intensive care unit (129 days vs. 68 days).

Discussion

Angina improved significantly in both groups in this trial; however, greater relief of angina was observed among patients who received PTCA than

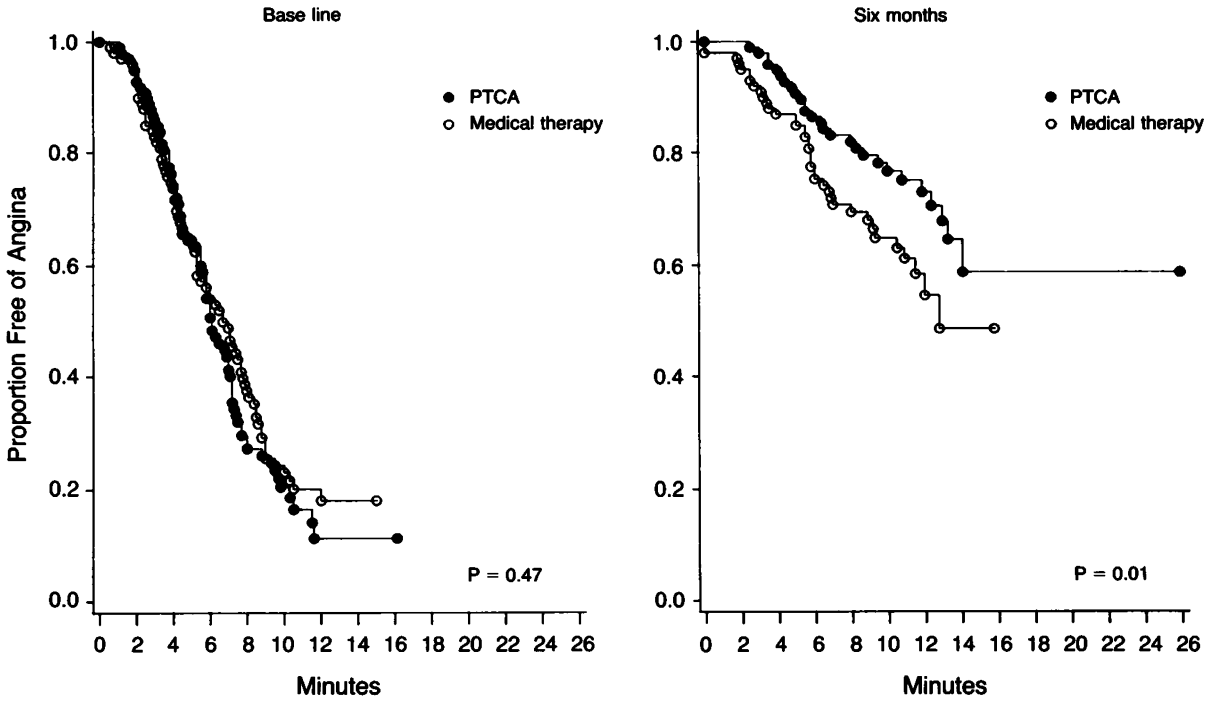

Figure 1. Duration of Angina-free Exercise on the Treadmill.

The proportion of patients who were free of angina is plotted on the vertical axis, and the length of time to the onset of angina on the horizontal axis. Data were censored at the patients' total exercise time if they did not have angina during the test. The left panel shows the treatment groups at base line, and the right panel shows the groups six months after randomization.

among those who received only medical therapy. Twice as many of the PTCA group were free of angina one month after treatment; at six months, 64 percent of the PTCA group and 46 percent of the medical-therapy group were free of angina. Moreover, patients in the PTCA group had a greater decrease in the frequency of angina attacks and a greater improvement in psychological well-being as measured by the questionnaire.

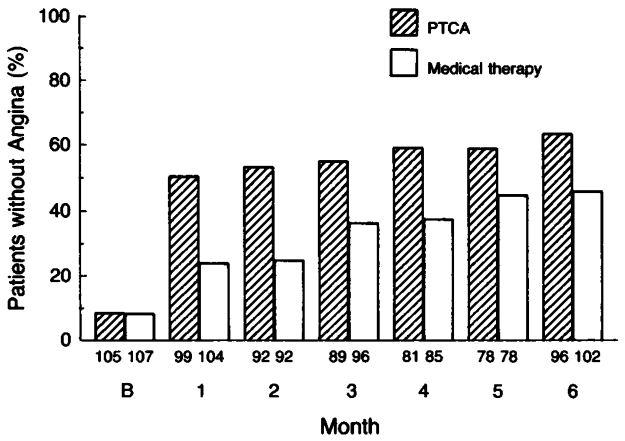

Figure 2. Percent of Patients Who Were Free of Angina Each Month after Randomization.

The horizontal axis shows the month before randomization (base line [B]) and clinic visits at months 1 through 6 for each treatment group. The numbers below the bars indicate the numbers of patients who were evaluated.

These clinical observations were verified by performance on the treadmill exercise test. The total exercise time, the maximal heart rate–blood pressure product, and the maximal duration of angina-free exercise increased significantly more among patients treated with PTCA. Underlying these outcomes was a substantial reduction in the percent stenosis of the index lesions. Nevertheless, ischemic ST-segment depression was still evident in many patients treated with PTCA (Table 3), suggesting that PTCA does not eliminate coronary lesions but reduces luminal encroachment, enabling patients to tolerate higher levels of exercise and, by inference, greater myocardial oxygen demand.

Our study examined PTCA not as a one-time procedure but as a treatment strategy. Because the use of repeat dilation was encouraged in the PTCA group, this study simulated the current clinical practice of treating restenosis with repeat dilation. Our intention was to compare the best results obtainable with PTCA or with medical therapy without combining the two. The discontinuation of all antianginal medication before the base-line exercise test allowed us to compare PTCA and medical therapy in equivalent contexts, using each patient as his own control. This procedure

maximized the opportunity to compare the outcome of a multiple-drug antianginal regimen with that of PTCA alone, since in the PTCA group antianginal medications were discontinued before the six-month exercise test. Clinical practitioners would not hesitate to use these two therapies in combination to enable a patient to be free of angina. Thus, the differences we observed between treatment groups might have been even greater if the use of medical therapy had been allowed in the PTCA group during the six-month exercise-tolerance test.

Our study population was carefully selected, comprising only 4 percent of all patients who underwent coronary angiography in the participating laboratories. Since common reasons for exclusion were multivessel coronary-artery disease, previous coronary-artery surgery or PTCA, and ongoing unstable angina, the conclusions from this study should not be generalized beyond clinically stable patients with subtotal stenosis of a single coronary artery.

The medical therapy and PTCA techniques used in this trial represent state-of-the-art treatments in 1987 through 1990. The success and safety of our procedures compare favorably with data from the National Heart, Lung, and Blood Institute's PTCA registry for 1985 through 1986, in which two or more lesions were dilated in 22 percent of 839 patients undergoing PTCA for single-vessel disease, the initial angiographic success rate was 87 percent, the clinical success rate was 84 percent, emergency bypass surgery was required in 3.5 percent, and death occurred in 0.2 percent.[21,22] Angiographic outcomes were assessed by local personnel who participated in the registry, whereas our results were based on caliper measurements made by blinded observers at the central laboratory. Currently, PTCA is used more aggressively in multivessel disease than it was during our study, to treat either all lesions or "culprit" lesions, as well as in clinical conditions such as ongoing unstable angina and acute myocardial infarction.[21,23-26] Our results cannot be extrapolated to these situations.

The outcomes for patients in our study who were treated with drug therapy or PTCA are similar to the outcomes of patients treated by either drug therapy or surgery in the randomized Coronary Artery Surgery Study (CASS).[27] The portion of PTCA-treated patients in our study who were free of angina increased from 9 percent at base line to 64 percent at six months; in the CASS, by comparison, the surgically treated group with single-vessel disease had an increase from 20 percent of patients free of angina at base line to 55 percent at one year. Nearly twice as many medically treated patients were free of angina in our study at six months (46 percent) as in the CASS at one year (25 percent). The increase in the total duration of treadmill exercise at six months was similar in our study (medical therapy, 30 seconds; PTCA, 126 seconds) and in the CASS group as a whole (medical therapy, 50 seconds; bypass surgery, 120 seconds).

We chose to measure our primary end points six months after randomization for several reasons. Six months is long enough for most episodes of restenosis to occur and be treated by redilation if necessary.[28,29] In patients who do not have restenosis by six months, it is unlikely to develop later.[30-32] How the differences reported here will be sustained remains to be seen. An additional three-year follow-up study aimed at answering this question is now in progress.

The use of medical resources, as measured by the cumulative total of cardiac procedures and the number of hospital days at six months, was higher among patients assigned to PTCA than among medically treated patients, making PTCA the more costly treatment initially. Ultimate costs depend on the outcome of further follow-up studies and the cost of long-term drug therapy.

PTCA treatment involved a small immediate risk of acute myocardial infarction, acute coronary occlusion leading to bypass surgery, and a later need for redilation to treat restenosis. Although the incidence of these events was within accepted norms, our findings underscore the risks of angioplasty. Since survival is not improved by revascularization surgery in patients with single-vessel disease, the value of PTCA in terms of the relief of symptoms, improved exercise tolerance, and a reduced need for antianginal medication must be weighed against the inherent risks and greater initial costs of the procedure. Thus, if PTCA and medical therapy are equally acceptable to the patient and the physician, our data indicate that for clinically stable patients with a subtotal obstruction in one major coronary artery, PTCA will initially be more successful in relieving angina and increasing exercise tolerance.

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Appendix: Participating Veterans Affairs Centers and Investigators

The participants in the Veterans Affairs ACME study were as follows: *Participating Institutions and Investigators: Ann Arbor Veterans Affairs Medical Center, Mich.* — E.R. Bates, J.K. Mickelson, P. Verlee, G. Harris, and S. Sample; *Durham Veterans Affairs Medical Center, N.C.* — K. Morris, F.R. Cobb, R. Piatt, and S. Abel; *Lexington Veterans Affairs Medical Center, Lexington, Ky.* — D.C. Booth, A.N. DeMaria, S. McConnell, and P. Frazier; *Memphis Veterans Affairs Medical Center, Tenn.* — K.B. Ramanathan, D.M. Mirvis, R. Thomas, and G. Frulla; *Palo Alto Veterans Affairs Medical Center, Calif.* — J.C. Giacomini, H.J. Gordon, D. Rood, and J. Hines; *Richmond Veterans Affairs Medical Center, Va.* — J.McB. Hodgson, M.D. Cohen, J. Stroney, G. Vetrovec, L. Fox, and K. Manor; *Wadsworth Veterans Affairs Medical Center, Los Angeles* — M.A. Josephson, R. Beyer, K. Nademanee, B.N. Singh, and K. Coyle; *West Roxbury, Mass.* — D.A. Pietro, W.E. Strauss, P. Flood, and S. Schwartz; *Data Monitoring Board* — L. Cohen, D.O. Williams, and R. Hardy; *Executive*

Committee — A.F. Parisi, E.D. Folland, and P. Hartigan; *West Haven Coordinating Center* — D. Collins (chief), P. Hartigan, S. Bottino, J. Derrico, and V. Latvis; *Central Laboratories: Computer Angiography Review* — University of Maryland Hospital, R. Vogel and G. Beauman; *Caliper Angiography Review* — E.D. Folland, D. Morris, and T. Fortin; *Thallium Scintigraphic Laboratory* — Massachusetts General Hospital, C. Boucher and M. McCarthy; *Central Lipid Laboratory* — Lexington Veterans Affairs Medical Center, P. Oeltgen; *Central Electrocardiographic and ETT Analysis Laboratory* — A.F. Parisi T. Fortin, D. Morris, and M. Nassise; *Planning Committee:* A. Parisi (study cochairman), E. Folland (study cochairman), P. Block, D. Booth, A. DeMaria, K. Detre, C. Fye, J. Giacomini, P. Hartigan, S. Khuri, M. Murphy, and W. Stason; *Human Rights Committee:* J. Messore, J. Evans, B. Kathe, V. Marenna, J. Niederman, and W. Pritchett.

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