MEDICAL CARE COSTS AND QUALITY OF LIFE AFTER RANDOMIZATION TO CORONARY ANGIOPLASTY OR CORONARY BYPASS SURGERY

MARK A. HLATKY, M.D., WILLIAM J. ROGERS, M.D., IAIN JOHNSTONE, PH.D., DEREK BOOTHROYD, M.S., MARIA MORI BROOKS, PH.D., BERTRAM PITT, M.D., GUY REEDER, M.D., THOMAS RYAN, M.D., HUGH SMITH, M.D., PATRICK WHITLOW, M.D., ROBERT WIENS, M.D., AND DANIEL B. MARK, M.D., M.P.H., FOR THE BYPASS ANGIOPLASTY REVASCULARIZATION INVESTIGATION (BARI) INVESTIGATORS

ABSTRACT

Background Randomized trials comparing coronary angioplasty with bypass surgery in patients with multivessel coronary disease have shown no significant differences in overall rates of death and myocardial infarction. We compared quality of life, employment, and medical care costs during five years of follow-up among patients treated with angioplasty or bypass surgery.

Methods A total of 934 of the 1829 patients enrolled in the randomized Bypass Angioplasty Revascularization Investigation participated in this study. Detailed data on quality of life were collected annually, and economic data were collected quarterly.

Results During the first three years of follow-up, functional-status scores on the Duke Activity Status Index, which measures the ability to perform common activities of daily living, improved more in patients assigned to surgery than in those assigned to angioplasty ($P<0.05$). Other measures of quality of life improved equally in both groups throughout the follow-up period. Patients in the angioplasty group returned to work five weeks sooner than did patients in the surgery group ($P<0.001$). The initial mean cost of angioplasty was 65 percent that of surgery ($21,113 vs. $32,347, $P<0.001$), but after five years the total medical cost of angioplasty was 95 percent that of surgery ($56,225 vs. $58,889), a difference of $2,664 ($P=0.047$). The five-year cost of angioplasty was significantly lower than that of surgery among patients with two-vessel disease ($52,930 vs. $58,498, $P<0.05$), but not among patients with three-vessel disease ($60,918 vs. $59,430). After five years of follow-up, surgery had an overall cost-effectiveness ratio of $26,117 per year of life added, but unacceptable ratios of $100,000 or more per year of life added could not be excluded ($P=0.13$). Surgery appeared particularly cost effective in treating patients with diabetes because of their significantly improved survival.

Conclusions In patients with multivessel coronary disease, coronary-artery bypass surgery is associated with a better quality of life for three years than coronary angioplasty, after the initial morbidity caused by the procedure. Coronary angioplasty has a lower five-year cost than bypass surgery only in patients with two-vessel coronary disease. (N Engl J Med 1997;336:92-9.)

PERCUTANEOUS transluminal coronary angioplasty was introduced by Grüntzig et al.[1] in 1977 as a less invasive alternative to coronary-artery bypass surgery. Several randomized clinical trials of angioplasty and bypass surgery have compared the clinical outcomes of these procedures.[2-7] The Bypass Angioplasty Revascularization Investigation (BARI) was a large trial of angioplasty and bypass surgery[8]; the results of five years of follow-up have been reported.[9] Although survival among patients with diabetes improved significantly after bypass surgery, overall rates of survival and survival free of Q-wave myocardial infarction after randomization to angioplasty or bypass surgery did not differ significantly in the BARI study,[9] in any of the other randomized trials,[2-7] or in quantitative overviews.[10,11] The effect of angioplasty and bypass surgery on quality of life and medical costs should therefore also play an important part in the choice between these two techniques of revascularization.

We began the Study of Economics and Quality of Life in 1988 as a prospective substudy of the randomized BARI trial, seeking to compare long-term functional status, quality of life, employment, and costs after angioplasty and bypass surgery.

METHODS

Study Design

The methods[8,12-15] and major findings[9,16] of the BARI trial have been reported previously. In brief, patients were eligible for that trial if they had angina or objective evidence of myocardial ischemia severe enough to warrant coronary revascularization, stenosis of 50 percent or more in two or more coronary vessels, technical suitability for both angioplasty and bypass surgery, and no prior coronary revascularization procedure.[8]

From the Stanford University School of Medicine, Stanford, Calif. (M.A.H., I.J., D.B.); the University of Alabama Medical Center, Birmingham (W.J.R.); the University of Pittsburgh Graduate School of Public Health, Pittsburgh (M.M.B.); the University of Michigan School of Medicine, Ann Arbor (B.P.); the Mayo Clinic, Rochester, Minn. (G.R., H.S.); Boston University School of Medicine, Boston (T.R.); the Cleveland Clinic Foundation, Cleveland (P.W.); St. Louis University School of Medicine, St. Louis (R.W.); and Duke University School of Medicine, Durham, N.C. (D.B.M.). Address reprint requests to Dr. Hlatky at Stanford University School of Medicine, HRP Redwood Bldg., Rm. 150, Stanford, CA 94305-5092.

Other authors were Allan D. Rosen, M.S., and Katherine Detre, M.D., Dr.P.H. (University of Pittsburgh Graduate School of Public Health), and Robert L. Frye, M.D. (Mayo Clinic).

We conducted the present study at 7 of the 18 clinical sites that participated in the BARI trial.[17] Functional status and quality of life were assessed at study entry and annually during follow-up. Use of health care services and employment status were documented every three months throughout follow-up.[17]

Functional status was measured with the Duke Activity Status Index, a 12-item scale with total scores ranging from 0 to 58.2 (with higher scores indicating better functional status) that evaluates the ability to perform common activities of daily living.[18,19] Emotional health was measured with the RAND Mental Health Inventory, a five-item scale with total scores ranging from 0 to 100 (with higher scores indicating better mental health) that assesses anxiety, depression, and positive affect.[20-23] The employment status of the patients was ascertained quarterly, including the average number of hours they worked each week and the amount of time they lost from work because of ill health or any other reason.

The quarterly documentation of the patients' use of medical services included all hospitalizations (regardless of length or diagnosis), visits to physicians and other health care providers (studied in 10 categories), and outpatient cardiac tests and procedures. Hospital bills were obtained for all discharges occurring on or after the date of randomization, including those at hospitals not participating in this study as well as participating sites. Charges from each hospital department (such as radiology or electrocardiography) were converted to costs by multiplying the charges by the department-specific ratio of costs to charges as found in each hospital's Medicare cost report.[24] When data on charges were unavailable (for 452 admissions to Veterans Affairs hospitals and 61 of the 3270 admissions to other hospitals), the 1995 Medicare reimbursement for the diagnosis-related group (DRG) specific to the patient's diagnosis was used. Physicians' charges were obtained from the participating hospitals, and Medicare rates of reimbursement to physicians were assigned to office visits. Costs for cardiac medications were calculated on the basis of the average wholesale prices in the 1995 Red Book. All costs were adjusted to 1995 dollars with the Consumer Price Index.[25] To correct for the lower value of dollars spent in the future as compared with the value of those spent in the present, costs for follow-up treatment were discounted at a rate of 3 percent per year after the date of randomization.[26,27]

Statistical Analysis

The changes from base line in annual quality-of-life scores were compared on an intention-to-treat basis by the Wilcoxon rank-sum test. Only the patients surviving at each follow-up visit were included in the quality-of-life analyses. Base-line predictors of improvement in the quality of life were analyzed by multiple linear regression.

Data on costs were totaled quarterly through June 5, 1995, and cumulative costs were compared by the Wilcoxon rank-sum test. The time course of the accumulation of costs during the follow-up period was described by an adaptation of the life-table method[28] in which successive quarterly mean costs were cumulatively totaled, with the surviving patients included through the time of last contact and the deceased patients included with the actual costs of their care through their dates of death and then with no additional cost until their last potential follow-up as of June 5, 1995. Variability in cost was assessed by a permutation test. Base-line predictors of cost were assessed by linear regression, with the logarithm of the four-year cumulative cost used as the dependent variable. The effect on cost of an interaction between the number of diseased vessels and the assigned treatment was the only prespecified subject of a subgroup analysis in this study.

The incremental cost effectiveness of bypass surgery as compared with angioplasty was calculated as follows:

$$\frac{\text{cost}_{\text{surgery}}(t) - \text{cost}_{\text{angioplasty}}(t)}{\text{life-years}_{\text{surgery}}(t) - \text{life-years}_{\text{angioplasty}}(t)},$$

with cost (t) representing the cumulative medical cost up to a specified time (t) during follow-up, and life-years (t) representing the area under the survival curve up to that time. In accordance with standard methods of cost-effectiveness analysis,[26,27] an annual discount rate of 3 percent was applied to both follow-up costs and life-years. The precision of the ratio of costs to the effectiveness of treatment was assessed by the bootstrap method[29,30]: the patients in the angioplasty and bypass-surgery groups were each resampled with replacement 1000 times, and five-year survival, five-year costs, and the resulting cost-effectiveness ratio were recalculated in each bootstrap sample.

RESULTS

A total of 1829 patients were randomized in the BARI trial, 952 of them (52 percent) at the seven sites participating in the present study. Nine hundred thirty-four patients (98 percent) agreed to participate in this study, with 465 assigned to angioplasty and 469 assigned to bypass surgery. The mean follow-up period was 5.5 years; there were 5 years or more of follow-up for 67 percent of patients and 4 years or more of follow-up for 95 percent. The clinical characteristics and quality-of-life measures of the patients at entry into the study were generally well balanced

TABLE 1. CHARACTERISTICS OF THE PATIENTS RANDOMLY ASSIGNED TO ANGIOPLASTY OR BYPASS SURGERY.

CHARACTERISTIC	ANGIOPLASTY (N=465)	BYPASS SURGERY (N=469)
Age (yr)		
Mean	62.5	61.4
Median	63.6	62.4
Male sex (%)	72	71
Medical history (%)		
Diabetes mellitus	20	24
Hypertension	52	54
Smoking, past 12 mo	34	34
Prior myocardial infarction	57	55
Chronic heart failure	4	4
Unstable angina	65	64
Angina on exertion, past 3 mo	57	58
Three-vessel disease	41	42
Ejection fraction <50%	26	22
Quality-of-life scores		
Duke Activity Status Index		
Mean	21.6	20.0
Median	18.0	15.2
Mental Health Inventory		
Mean	72.7	73.0
Median	76.0	76.0
Employed (%)	40	46
Event rates at 5 yr (%)		
Death*	14	11
Death or Q-wave myocardial infarction*	21	22
Second or subsequent revascularizations	57	10
Angina among surviving patients (%)		
At 1 yr	26	11
At 3 yr	23	16
At 5 yr	18	14

*Values shown are Kaplan–Meier estimates.

between the angioplasty and bypass-surgery groups (Table 1). Event rates during follow-up were similar to those in the overall trial,[9,16] with the patients in the angioplasty group having a slightly higher mortality rate ($P=0.54$), significantly more second or subsequent revascularizations ($P<0.001$), and significantly more angina after one year ($P=0.001$) and three years ($P=0.01$) of follow-up (Table 1).

The functional status of all the patients in the study, as assessed by the Duke Activity Status Index, improved by 5.7 units ($P<0.001$) after one year. The improvement in functional status among the patients undergoing bypass surgery was significantly greater than that among those undergoing angioplasty after one year (7.0 vs. 4.4 units, $P=0.02$), two years (5.5 vs. 3.0 units, $P=0.02$), and three years (5.6 vs. 3.2 units, $P=0.04$) of follow-up, but the difference was not significant after four (4.3 vs. 2.6 units, $P=0.17$) or five (3.6 vs. 2.0 units, $P=0.26$) years (Fig. 1).

Emotional health, as measured by the RAND Mental Health Inventory, also improved significantly after coronary revascularization (mean change in all patients after one year, 1.8 units; $P<0.001$), with no significant difference between the groups throughout follow-up.

The proportion of patients who were initially employed and who continued to work either full time or part time declined to 83 percent after six months, to 73 percent after one year, to 57 percent after three years, and to 45 percent after five years, with no significant differences between the groups. The patients in the angioplasty group returned to work significantly earlier after randomization than those in the bypass-surgery group (median, 6 vs. 11 weeks; $P<0.001$), but after their return the number of hours spent on the job did not differ significantly between the groups.

The initial cost of coronary revascularization was significantly lower in the angioplasty group than in the bypass-surgery group ($P<0.001$), with mean hospital costs and physicians' fees of $21,113 as compared with $32,347 (Table 2). The difference of $11,234 in the initial cost (a 35 percent difference) narrowed progressively over the next three years, but the cost of angioplasty remained significantly lower than that of bypass surgery throughout follow-up (Fig. 2). The total cost after five years of follow-up was $2,664 less (5 percent lower) in the angioplasty group than in the bypass-surgery group ($56,225 vs. $58,889, $P=0.047$). The higher cost of subsequent hospitalizations and cardiac medications accounted for most of the increase in cost during follow-up in the angioplasty group (Table 2). The variation in cost was significantly greater among the patients assigned to angioplasty than among those assigned to bypass surgery (Fig. 2) after one and three years ($P<0.001$ for both), but not after five years ($P=0.15$).

Predictors of Outcome

The improvement in scores on the Duke Activity Status Index and the RAND Mental Health Inventory varied significantly according to the patients'

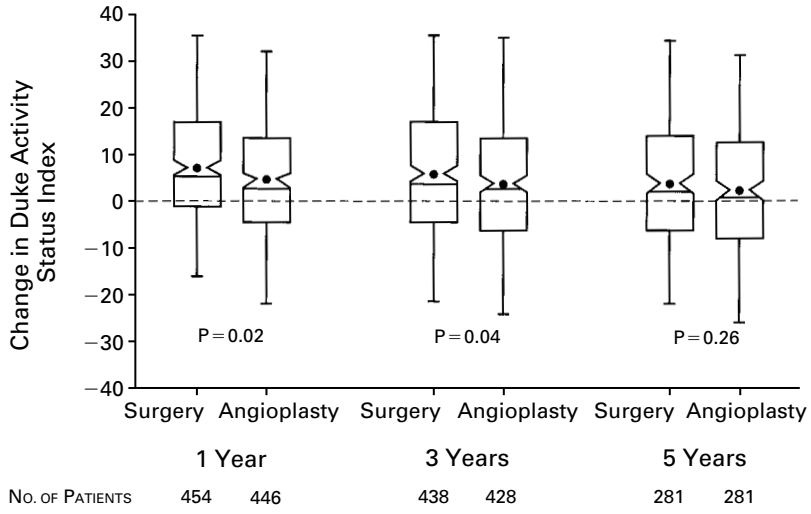

Figure 1. Changes in Scores on the Duke Activity Status Index from Base Line to the Annual Follow-up Evaluations in Patients Randomly Assigned to Bypass Surgery or Angioplasty.

The "whiskers" at the top and bottom of each box indicate the 95th and 5th percentiles of the distribution, respectively; the top and bottom of each box, the 75th and 25th percentiles; and the line through the box, the median (the 50th percentile). The solid circle in the box indicates the mean, and the notches in the sides of the box indicate ±2 SE.

clinical characteristics at entry into the study (Table 3). Patients who had heart failure at entry improved substantially less in physical function, and men improved more than women in both physical and emotional function. Older patients improved significantly less than younger patients in physical function, but improved significantly more in emotional function. The degree of improvement in physical function was similar among patients with and without diabetes after one year, but there was significantly less improvement among the diabetic patients by four years. There were no significant interactions between base-line variables and group assignments with respect to either the Duke Activity Status Index or the RAND Mental Health Inventory.

Four-year cumulative costs were significantly higher in patients with heart failure (29 percent higher, $P<0.001$), patients with diabetes (21 percent higher, $P=0.001$), and patients with more coexisting conditions (10 percent higher per unit of the Charlson comorbidity index,[31] $P<0.001$), after adjustment for clinical site ($P<0.001$) and the length of hospitalization before randomization ($P<0.001$). The number of diseased vessels was the only base-line clinical factor that had a significant interaction with the group assignment with respect to four-year cumulative costs ($P<0.001$). The lowest cost was among patients in the angioplasty group who had two-vessel disease; in the remaining patients, costs were 17 to 22 percent higher.

TABLE 2. MEAN USE OF RESOURCES AND COSTS IN THE ANGIOPLASTY AND BYPASS-SURGERY GROUPS OVER THE FIVE-YEAR FOLLOW-UP PERIOD.*

VARIABLE	ANGIOPLASTY	BYPASS SURGERY	RATIO (ANGIOPLASTY: BYPASS SURGERY)
Initial procedure			
No. of admissions	1.17	1.24	0.94
No. of days in hospital	9.03	13.25	0.68
Costs ($)	14,415	21,534	0.67
Charges ($)	23,183	35,710	0.65
Physicians' fees ($)	6,698	10,813	0.62
Follow-up			
Hospital			
No. of admissions	3.10	2.68	1.12
No. of days	20.06	18.31	1.10
Costs ($)	21,743	16,129	1.30
Charges ($)	34,443	24,547	1.40
Physicians' fees ($)	5,696	3,400	1.68
Outpatient visits			
To physician (no.)	32.3	32.9	0.98
To other provider (no.)	19.2	16.3	1.18
Outpatient fees ($)	1,656	1,617	1.02
Medications			
All drugs taken (no.)	4.13	3.97	1.04
Costs of cardiac drugs ($)†	4,948	3,670	1.35
Outpatient testing			
Exercise tests (no.)	3.31	2.95	1.12
All tests (no.)	4.32	3.98	1.08
Costs ($)	803	700	1.15
Nursing home			
% of patients admitted	2.6	3.2	0.81
Costs ($)	265	1,027	0.26
All health care costs ($)	56,225	58,889	0.95

*Costs are expressed in 1995 U.S. dollars and are discounted at 3 percent per year after the date of randomization.

†Cardiac medications include beta-blocking drugs, calcium-channel blockers, nitrates, diuretics, digoxin, angiotension-converting–enzyme inhibitors, and cholesterol-lowering drugs.

Cost-Effectiveness Analyses

Over the five years of follow-up, the patients assigned to bypass surgery incurred higher overall costs (by $2,664) than those assigned to angioplasty, but they also had slightly better average survival rates (0.10 life-year), leading to an overall cost-effectiveness ratio of $26,117 per year of life added. The cost-effectiveness ratio for bypass surgery became considerably more favorable over the course of follow-up: $478,609 per year of life added at one year, $97,032 at two years, $37,876 at three years, $29,740 at four years, and $26,117 at five years.

The cost-effectiveness ratio at five years for bypass surgery as compared with angioplasty was relatively imprecise when assessed by the bootstrap method. There was a 71 percent probability that the ratio would be $50,000 or less per added year of life, but a 13 percent probability that it would exceed $100,000 per added year.

Five-year analyses of cost effectiveness were performed separately in the patients with two-vessel disease and those with three-vessel disease and in the patients with and without diabetes, because of the significant interaction between these factors and study-group assignment with respect to either cost or survival (Table 4). In patients with two-vessel disease, surgery had a cost-effectiveness ratio of $60,057 per year of life added, whereas among patients with three-vessel disease there was a trend toward lower cost and better survival with surgery (Table 4). Among the patients with diabetes, surgery led to lower costs and longer life expectancy than did angioplasty, whereas among the remaining patients surgery had higher costs and an equal life expectancy (Table 4). Post hoc analysis suggested that angioplasty was associated with a higher cost than surgery only among patients with diabetes and three-vessel disease (Table 4), but this trend was not statistically significant because of the small size of the subgroups.

DISCUSSION

We found that coronary bypass surgery improved physical function more than angioplasty during the first three years of follow-up. The five-year cumulative cost of angioplasty was 5 percent lower than that of surgery. Angioplasty was significantly less expensive only among patients with two-vessel disease;

among patients with three-vessel disease, the five-year costs of the two procedures were similar.

Quality of Life

A major goal of coronary revascularization is to relieve symptoms of myocardial ischemia. Bypass surgery[32-34] and angioplasty[35] both reduce angina and exercise-induced myocardial ischemia better than medical therapy. In the BARI trial as well as in other randomized trials,[10,11] a larger proportion of patients assigned to bypass surgery had no angina for the first three years of follow-up. In accordance with the greater relief from angina noted early after bypass surgery, functional status as assessed by scores on the Duke Activity Status Index improved more during the first three years in the patients assigned to bypass surgery. The increased scores on the Duke Activity Status Index after one year in the bypass-surgery group as compared with the angioplasty group were clinically meaningful: an increase of 2.7 units, for example, was the equivalent of being able to do light work around the house or walk for a block or two on level ground as compared with being unable to perform these activities.[18] The improvement in physical function expected after angioplasty and bypass surgery varies substantially among patients, however, so clinical recommendations should be tailored to the condition of the individual patient.

Employment

Since angioplasty is less invasive than bypass surgery and is associated with a shorter convalescence, it was hoped that patients undergoing angioplasty would be more likely to maintain their employment. Our findings confirm that these patients returned to work faster, as reported in nonrandomized studies,[36] but after the first three months the proportion of patients employed and the number of hours they spent on the job were equivalent in the angioplasty group and the bypass-surgery group. Relief from angina and improved functional status do not appear sufficient to preserve long-term employment among patients with coronary disease.[37]

Medical Costs

Angioplasty has lower initial costs than bypass surgery,[38-40] but because of restenosis the costs are increased over one year of follow-up.[41] In this study, the cost of the initial revascularization was 35 percent ($11,234) lower in the angioplasty group than in the bypass-surgery group, but the patients undergoing angioplasty incurred considerably higher costs for hospitalization and medications during follow-up, so that the long-term cost advantage was reduced to 5 percent ($2,664) after five years. Nevertheless, the mean cumulative cost of angioplasty remained significantly lower throughout follow-up. Further

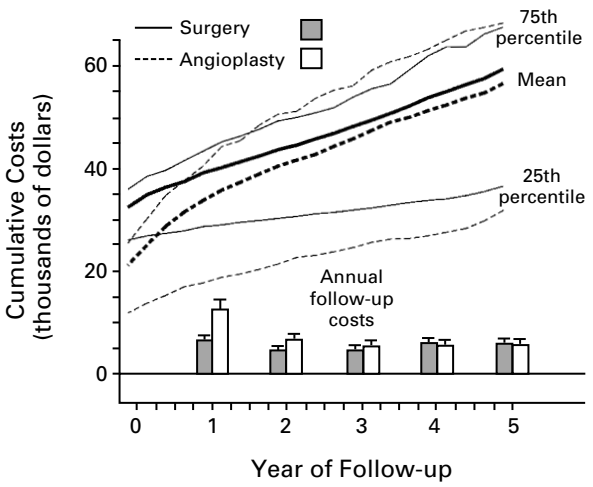

Figure 2. Cumulative Costs at Quarterly Intervals during Follow-up of Patients Randomly Assigned to Bypass Surgery or Angioplasty.

The thick curves indicate mean cumulative costs calculated by a modification of the life-table method. The lighter curves at the top indicate the 75th percentile of the cumulative cost, and the lighter curves at the bottom the 25th percentile, among the patients remaining in the follow-up cohort. The bars at the bottom of the figure indicate the mean (+2 SE) follow-up costs accrued in the previous year among patients followed throughout that year.

TABLE 3. MULTIVARIABLE PREDICTORS OF IMPROVEMENT IN QUALITY-OF-LIFE SCORES.

BASE-LINE PREDICTOR	DUKE ACTIVITY STATUS INDEX		RAND MENTAL HEALTH INVENTORY	
	1 YR	4 YR	1 YR	4 YR
	coefficient*			
Bypass surgery	1.8†	0.7	0.1	0.9
Age (per 10 yr)	−1.1†	−1.2†	1.4‡	1.4†
Male sex	4.8‡	6.6§	1.1	3.5†
Education¶	3.0‡	3.1§	1.6†	2.0†
Married	2.3†	2.5†	0.0	0.8
Heart failure	−8.5‡	−4.7†	−1.3	−0.3
Diabetes mellitus	−1.7	−3.6‡	0.6	−0.3
Three-vessel disease	−1.6	−0.5	−0.6	0.8
Functional class‖	0.3	−0.1	0.1	−0.4

*Entries are the coefficients of a multivariable linear regression of the base-line predictors on the dependent quality-of-life variable (improvement in the Duke Activity Status Index or the RAND Mental Health Inventory). P values are for the comparison with 0 (the value obtained by the null hypothesis).

†$P<0.05$.

‡$P<0.01$.

§$P<0.001$.

¶The educational levels studied were as follows: less than high school, completion of high school, and some college.

‖The classes were those established by the Canadian Cardiovascular Society.

TABLE 4. COST AND LIFE EXPECTANCY OVER THE FIVE YEARS OF FOLLOW-UP, ACCORDING TO CLINICAL CHARACTERISTICS.

CHARACTERISTIC	PATIENTS		COST ($)		YEARS OF LIFE ADDED	
	SURGERY	ANGIOPLASTY	SURGERY	ANGIOPLASTY	SURGERY	ANGIOPLASTY
All patients	469	465	58,889	56,225*	4.4	4.3
No. of diseased vessels						
2	274	273	58,498	52,930*	4.4	4.3
3	195	192	59,430	60,918	4.4	4.3
Diabetes mellitus						
No	355	373	54,777	51,709	4.4	4.4
Yes	114	92	71,776	74,427	4.3	3.8†
Nondiabetics						
2-Vessel disease	215	218	55,129	51,039	4.4	4.4
3-Vessel disease	140	155	54,166	52,659	4.4	4.4
Diabetics						
2-Vessel disease	59	55	70,830	60,445	4.4	4.0†
3-Vessel disease	55	37	72,837	95,376	4.3	3.5†

*$P<0.05$ for the comparison with surgery by the Wilcoxon rank-sum test (for cumulative cost) and by the log-rank test (for survival), each through June 5, 1995.

†$P<0.01$ for the comparison with surgery.

follow-up will be needed to determine how failure of saphenous-vein grafts after bypass surgery and progression of disease in the native circulation affect cost and clinical outcome.

Our findings about the costs of angioplasty and bypass surgery confirm and extend the results of other randomized trials. The Randomized Intervention Treatment of Angina trial found that the two-year cumulative cost of angioplasty was 79 percent to 84 percent lower than the cost of bypass surgery.[42] The Argentine Randomized Trial of Percutaneous Transluminal Coronary Angioplasty versus Coronary Artery Bypass Surgery in Multivessel Disease found that the three-year cost of angioplasty was 57 percent less than that of bypass surgery.[43] The Emory Angioplasty versus Surgery Trial found that the three-year cost of angioplasty was 94 percent that of bypass surgery.[44] This study extends these observations in several ways. Most important, the five-year follow-up period is considerably longer than those of previous studies, allowing us to show that the steady increase in the cost of angioplasty as compared with bypass surgery halted after roughly three years of follow-up. In addition, our study included a more comprehensive accounting of costs than did previous studies; these costs included the costs of outpatient visits, cardiac medications, nursing home admissions, and all hospital admissions for any cause during follow-up.

Cost Effectiveness

With the persistent concern about the cost of health care, a frequently asked question is whether a therapy provides enough value to the patient to justify its added cost. We found that the overall cost-effectiveness ratio for bypass surgery as compared with angioplasty after five years ($26,117) was in the range of the ratios for generally accepted therapies, such as renal dialysis ($30,000) and captopril treatment in patients with reduced ejection fractions after myocardial infarction ($28,400).[45] The cost-effectiveness ratio for bypass surgery should be interpreted cautiously, however, for several reasons. Estimates of cost effectiveness in this study were relatively imprecise, because of the considerable variation in long-term costs among patients and the relatively small difference in overall mortality at five years. The data are consistent with an acceptable overall cost-effectiveness ratio for bypass surgery (there is a 71 percent probability that this ratio would be $50,000 or less per year of life added), but the possibility of an unacceptable ratio cannot be ruled out (that is, there is a 13 percent probability that the ratio would be $100,000 or more per year of life added). Furthermore, the cost-effectiveness ratio for bypass surgery as compared with angioplasty changed substantially from early in the follow-up period ($478,609 after one year) to late in that period ($26,117 after five years). Longer follow-up of the cohort will be important for making the estimates of cost effectiveness more precise and for determining whether, on average, surgery is more or less cost effective beyond five years.

The cost-effectiveness ratio of a particular therapy may vary substantially according to the characteristics of patients, since the effectiveness of therapy or its cost, or both, may vary considerably among populations of patients.[45] Despite the relative uniformity of the patients enrolled in the BARI study, the cost-effectiveness ratios found in this study varied consid-

erably according to the clinical characteristics of the patients. Bypass surgery was quite cost effective in diabetic patients because of their significantly better survival, whereas the cost of angioplasty was lower than that of surgery in patients with two-vessel disease, but not in those with three-vessel disease. Multivariable analysis would provide an assessment of the relative importance of these and other factors (such as age, sex, and the presence or absence of congestive heart failure) with regard to cost effectiveness. Methods of performing such analyses of the complex relations inherent in a cost-effectiveness ratio have not yet been established, but the increasing availability of primary data on cost and outcome from clinical trials will undoubtedly spur their development.

Conclusions

We found that, on average, functional status was improved more with bypass surgery than with angioplasty in the first three years, whereas in other respects the quality of life was equivalent with either method of revascularization. The cost of angioplasty was initially $11,234 lower than that of bypass surgery (a 35 percent savings, $P<0.001$), but higher subsequent costs for hospitalization and medication reduced the savings to $2,664 at five years (a 5 percent savings, $P=0.047$). Balloon angioplasty has a significant cost advantage over bypass surgery in patients with two-vessel coronary disease, but the costs are similar in patients with three-vessel disease.

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APPENDIX

The following institutions and investigators participated in the Study of Economics and Quality of Life substudy of the BARI trial: **University of Alabama at Birmingham** — W. Rogers, W. Baxley, L. Dean, G. Roubin, G. Zorn, G. Duke, S. Brewer, W. Lowe, E. Charles, L. Carr, L. Maske, and A. McCarroll; **Boston University** — T. Ryan, M. Mazur, J. Brush, D. Faxon, and B. Hankin; **Cleveland Clinic Foundation** — P. Whitlow, M. Lincoff, E. Topol, K. Comella, B. Healy, A. Rogers, J. Tedrick, E. Griffin, L. Webster, and K. Schaffer; **Duke University** — D. Mark, R. Califf, D. Fortin, J. Grinnell, M.A. Sellers, L. Drew, V. Bass, D. Frid, E. Hampton, H. Gessner, L. Hicks, T. Daniels, E. Griffin, and B. Bacon; **Mayo Clinic** — G. Reeder, H. Smith, M. Mock, L. Pierre, F. Nobrega, and R. Vlietstra; **University of Michigan** — B. Pitt, M. Stock, K. McNeely, P. Fox, K. Burek, H.-L. Shu, L. Belzowski, J. Collins, and T. Johnson; **St. Louis University** — R. Wiens, B. Chaitman, C. Huffman, P. Thibodeau, and J. Fehl; **Coordinating Center** — K. Detre, S. Kelsey, K. Tyrell, M.M. Brooks, G. Hardison, A. Rosen, S. Crow, G. Harger, J. Bost, J. Melvin, and A. Steenkiste; **Central Laboratory** — M. Hlatky, I. Johnstone, D. Boothroyd, C. Winston, C. Kallmann, E. Steel, C. Bacon, K. Gelman, N. Clapp-Channing, C.-K. Kim, K. Lee, S. Wilson, R. Lynn, and A. Heaton; **Robert Wood Johnson Foundation** — L. Sandy and J. Cantor.

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