ANGINA RELIEF

Historically, patients subjected to a variety of indirect surgical procedures for angina relief experienced little benefit except for a short-term placebo effect. Direct coronary artery surgery by vein or internal mammary artery grafting is the first procedure to produce consistent, predictable, and prolonged relief of angina. Conclusive evidence for increased myocardial perfusion through bypass grafts exists from a number of techniques including electromagnetic flow-probe measurements, xenon flow studies, exercise stress testing with or without radionuclide studies, evaluation of myocardial lactate production, and the correlation of postoperative graft patency with symptom improvement and exercise stress testing. Today, randomized prospective studies of medical versus surgical treatment have shown that bypass surgery is superior to medical management for alleviating or improving angina.137

Many controlled studies were organized when coronary artery surgery was in a developmental phase, and many comparative studies were flawed by poor surgical results, selection of good risk medical and surgical groups, and a high crossover rate from medical to surgical treatment. Nevertheless, data from four randomized prospective studies of chronic angina (Table 4) show significantly more improvement in functional class after surgical therapy as well as a higher rate of uneventful course, fewer symptoms during sexual activity, and less use of anti-anginal medication.

King and Hurst138 have separated patient characteristics likely to correlate with angina relief postoperatively and another set of patient variables that adversely influence angina relief (Table 5). Angina that reappears within the first six months is usually due to an unsuccessful operation. Recurrence of angina in the

Table 5—Postoperative Angina Relief

<table>
<thead>
<tr>
<th>Patient Characteristics Influencing Postoperative Angina Relief</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Typical angina relieved by rest and nitrates</td>
</tr>
<tr>
<td>(2) Attacks of ischemic pain or objective evidence of ischemia by electrocardiographic and/or radionuclide stress imaging</td>
</tr>
<tr>
<td>(3) Focal high-grade proximal obstructions in vessels 2 mm or larger, especially with well-preserved left ventricular function</td>
</tr>
<tr>
<td>(4) Complete revascularization</td>
</tr>
<tr>
<td>(5) Psychological motivation to improve</td>
</tr>
<tr>
<td>(6) Current or recent employment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient Characteristics Negatively Influencing Postoperative Angina Relief</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Atypical or pain probably not angina</td>
</tr>
<tr>
<td>(2) No objective evidence of ischemia</td>
</tr>
<tr>
<td>(3) One-vessel disease supplying a small area of myocardium</td>
</tr>
<tr>
<td>(4) Chronic poor left ventricular function, especially with chronic congestive heart failure</td>
</tr>
<tr>
<td>(5) Obstructed vessels perfusing noncontractile myocardial segments</td>
</tr>
<tr>
<td>(6) Anatomically small or diffusely atherosclerotic vessels with poor arterial runoff</td>
</tr>
<tr>
<td>(7) No motivation to improve</td>
</tr>
<tr>
<td>(8) Disability claims are being processed</td>
</tr>
</tbody>
</table>

*From King SB, Hurst JW.138

*From The Cleveland Clinic Foundation, Cleveland. Part I appeared in the November issue of Chest. Reprint requests: Dr. Loop, Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland 44106

Table 4—Incidence of Various Clinical Features in Patients Treated Medically and Surgically

<table>
<thead>
<tr>
<th>Features</th>
<th>Medical Therapy (percent)</th>
<th>Surgical Therapy (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved: Asymptomatic</td>
<td>0.9†</td>
<td>33-55</td>
</tr>
<tr>
<td>Better</td>
<td>48-52</td>
<td>76-90</td>
</tr>
<tr>
<td>Worse</td>
<td>3-21</td>
<td>5-6</td>
</tr>
<tr>
<td>Angina at rest</td>
<td>45-55</td>
<td>18-20</td>
</tr>
<tr>
<td>Uneventful course up to 7 years</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Symptoms during sexual activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Angina</td>
<td>45</td>
<td>16</td>
</tr>
<tr>
<td>Therapy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitroglycerine</td>
<td>59-67</td>
<td>21-27</td>
</tr>
<tr>
<td>Propranolol</td>
<td>60-75</td>
<td>7-20</td>
</tr>
</tbody>
</table>

*Data from four prospective randomized studies of chronic angina from Rahimtoola SH.137
†All differences between medical and surgical patients were statistically significant.
§In the European Coronary Surgery Study, 14 percent of medical patients became asymptomatic. However, many of the asymptomatic patients in the medically treated group received therapy.

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first year is significantly more common in women and after incomplete revascularization, but thereafter, recurrence does not differ by gender or other variables. Our experience is similar in that angina relief five and ten years postoperatively was less in women than in men. At ten years postoperatively, 56 percent of women were angina-free in comparison with 66 percent of men.  
In one long-term follow-up study, angina reappeared in 20 percent of patients during the first postoperative year and in 3 percent of patients per year up to ten years. Angina was milder than preoperatively in 66 percent. In another report, patients who were asymptomatic one year postoperatively experienced angina recurrence at a rate of approximately 4 percent per year over the next six years. Changes in a graft or in a coronary artery were noted in 64 percent of patients who had clinical deterioration but in only 18 percent of those who did not experience recurring angina. As mentioned previously, severe progressive atherosclerosis in coronary arteries tends to occur proximal to the vein graft, and there is a low frequency of distal lesions beyond the distal anastomosis in passing years. In one correlation with angiography, graft closure was observed in 22 percent of patients with recurring symptoms but in only 4 percent of those without angina. This gradual decay in angina relief is attributed largely to new obstructive changes in the vein grafts or coronary arteries. A Finnish randomized study of medical and surgical therapy included 45 surgical patients who were evaluated annually by exercise testing during a five-year follow-up. Serial angiography at three weeks, one year, and five years found a 15 percent graft attrition rate at five years. The surgical group had a sustained improvement in exercise tolerance up to five years, although beta-blocking drugs increased in usage so that by five years, two-thirds of these patients were receiving drug therapy. Improvement was confined to those who had received complete revascularization.

Table 6—Ten-Year Survival After Coronary Artery Surgery

<table>
<thead>
<tr>
<th>Patients</th>
<th>Series Year</th>
<th>10-Year Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baylor College of Medicine</td>
<td>500</td>
<td>1968-1971</td>
</tr>
<tr>
<td>Cleveland Clinic</td>
<td>2,000</td>
<td>1971-1972</td>
</tr>
<tr>
<td>Texas Heart Institute</td>
<td>22,284</td>
<td>1970-1981</td>
</tr>
<tr>
<td>Salt Lake City</td>
<td>761</td>
<td>1969-1980</td>
</tr>
<tr>
<td>Houston VA</td>
<td>56</td>
<td>1972-1974</td>
</tr>
</tbody>
</table>

*Estimated from one-, two-, and three-vessel subsets. †Cardiac deaths only.

diastolic blood pressures) among those with no angina at four years and those with recurrence. In most reports, complete angina relief is achieved in 60 percent to 75 percent of patients five years postoperatively. Few papers have addressed angina relief at ten years, but approximately half of these patients are angina-free at this interval.

SURVIVAL AFTER SURGICAL TREATMENT

Coronary artery surgery has shown a sustained benefit in terms of fewer cardiac events, decreased symptoms, and generally a better quality of life up to ten postoperative years. In addition, there is strong evidence that survival is improved from multivessel disease categories including left main coronary artery disease for the first five and ten postoperative years. Table 6 lists published ten-year survival and Table 7 lists five-year survival after coronary bypass surgery. For women in our series, the operative mortality is slightly higher, vein graft patency significantly lower.

Table 7—Five-Year Survival After Coronary Artery Surgery

<table>
<thead>
<tr>
<th>Patients</th>
<th>Series Year</th>
<th>5-Year (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleveland Clinic Foundation</td>
<td>741</td>
<td>1967-1970</td>
</tr>
<tr>
<td>Baylor College of Medicine</td>
<td>1,144</td>
<td>1969-1971</td>
</tr>
<tr>
<td>Hospital of the Good Samaritan, Los Angeles</td>
<td>1,532</td>
<td>1969-1974</td>
</tr>
<tr>
<td>Salt Lake City</td>
<td>761</td>
<td>1969-1980</td>
</tr>
<tr>
<td>St. Louis University</td>
<td>1,733</td>
<td>1970-1977</td>
</tr>
<tr>
<td>Texas Heart Institute</td>
<td>22,284</td>
<td>1970-1981</td>
</tr>
<tr>
<td>St. Louis Park and Hennepin County Medical Centers, Minneapolis</td>
<td>304</td>
<td>1971-1978</td>
</tr>
<tr>
<td>VA Cooperative</td>
<td>332</td>
<td>1972-1974</td>
</tr>
<tr>
<td>Hines VA, Loyola University</td>
<td>71</td>
<td>1968-1974</td>
</tr>
<tr>
<td>Seattle Heart Watch</td>
<td>1,880</td>
<td>1968-1974</td>
</tr>
<tr>
<td>Cleveland Clinic Foundation</td>
<td>5,000</td>
<td>1973-1977</td>
</tr>
<tr>
<td>Buffalo General Hospital</td>
<td>1,051</td>
<td>1973-1977</td>
</tr>
<tr>
<td>Emory University</td>
<td>3,433</td>
<td>1973-1979</td>
</tr>
<tr>
<td>European Coronary Surgery Study Group</td>
<td>368</td>
<td>1973-1976</td>
</tr>
</tbody>
</table>

*Cardiac deaths only. †1973-1977 first 1,000 patients operated on each year. ‡Men with mild-moderate angina and good left ventricular function.
and internal mammary artery graft patency is similar. Women had less relief of angina at five and ten years postoperatively, but mortality at five and ten years is virtually identical.\(^{63}\)

The final report of the European Coronary Surgery Study Group\(^{10}\) reviewed the course of 768 men with mild-to-moderate angina and good left ventricular function (ejection fraction < 0.50 excluded) who were randomized to medical and surgical treatment. Medical patients were retained in their treatment group whether or not they eventually had surgery, and surgical candidates who either refused surgery or died before operation were kept in their randomly allocated treatment group. Thus, 27 percent of medical patients had coronary artery surgery but were kept in the group followed for medical treatment. Of the surgical patients, 7 percent did not undergo operation. Nonetheless, survival was improved significantly for patients with three-vessel disease and for those with stenosis of the proximal third of the anterior descending artery constituting a component of either two- or three-vessel disease. The five-year survival for the entire study group was 92.4 percent for surgery and 83.6 percent for medical treatment, which was highly significant. Patients with left main disease showed an 85.7 percent survival compared with 67.9 percent for medically treated patients; however, the small numbers (28 and 31) made it insignificant. Angina was decreased significantly more in the surgical patients than in the medical group. Quoting the authors, "The time honored advice of medical care until symptoms deteriorate to an unacceptable level is proved invalid... surgery was the treatment of choice even when angina pectoris responded adequately to medical management."

The most important factors which determine late survival are age at operation, preoperative left ventricular function, and the quality of the surgical result, namely, perioperative morbidity and mortality, graft patency, and completeness of revascularization.\(^{147}\) Whereas clinical risk factors are useful in predicting coronary events in the general population, they lose much of their predictive value in a population with proven coronary heart disease. Findings of the Seattle Heart Watch indicate that the coronary patient most likely to enjoy improved longevity is older than 48 years, has two- or three-vessel disease with an ejection fraction greater than 30 percent, and has no history of congestive heart failure. The number of diseased vessels has minimal influence on intermediate term survival; however, the number of residual lesions (atherosclerosis) in ungrafted vessels is an important late predictor of survival.\(^{148}\) Hammermeister et al\(^{148}\) found that the number of vessels involved preoperatively was a predictable variable in survival of medically treated patients but not for the surgical cohort, ie, the extent of coronary artery disease was no longer a risk factor after surgery for the first five years. In contrast, we find that patients with one-vessel disease fare better than those with three-vessel disease five and ten years postoperatively.\(^{65}\)

At one end of the spectrum, the dangerous left main lesion group appears more heterogeneous than previously assumed. For most patients in this subset, surgery improves survival. In our first 300 left main patients\(^{100}\) operated on from 1967 through 1973, women had a higher prevalence of left ostial lesions than men. However, the majority of left main lesions occur at the bifurcation. The operative mortality was 4 percent, but the risk has dropped to approximately 1 percent or lower today. In our early left main experience (1967 to 1972), five-year and ten-year survivals were 88 percent and 68 percent, respectively. Survival was significantly higher in patients with preoperative normal left ventricular function and in those who achieved complete revascularization. Our results were confirmed by a recent CASS report of left main coronary disease patients who were operated on from 1974 to 1979.\(^{103}\)

Their pooled operative mortality was 4 percent and three-year survival was 88 percent for surgical patients versus 63 percent for those treated medically. Their trends in improvement and survival did not reach significance in women. Left dominant circulation carried a high operative mortality (10 percent). However, in their experience, coronary artery surgery improved survival in all age categories studied, but surgery did not improve survival for patients with nondominant right or balanced circulations or for those with severe right coronary artery disease with normal left ventricular function.

Five-year survival of 1,086 patients aged 65 years or older was reported from the CASS registry.\(^{108}\) The cumulative five-year survival was 83 percent, which includes an operative mortality of 5 percent and is significantly less than the 91 percent experienced by patients younger than 65 years of age. Five-year survival was 84 percent for those aged 65 to 69 years, 80 percent for patients aged 70 to 74 years, and 70 percent for patients aged 75 years or older. Left ventricular function significantly influenced five-year survival; patients with ejection fractions of less than 35 percent had a 47 percent five-year survival and an incremental rise in ejection fraction correlated with increased survival up to 88 percent in those with an ejection fraction of more than 50 percent. Associated medical disease adversely influenced five-year survival. The attrition rate was significantly greater in those with hypertension. Survival for older patients with few or no associated medical diseases was similar to that for patients younger than 65 years of age.

At the lower risk end, our patients with one-vessel disease showed a 96 percent five-year survival (1973 to 1977 cohorts) and an 82 percent ten-year survival (1971
and 1972 cohorts). Lytle et al reviewed a consecutive series of patients who had received a left internal mammary artery graft for single-vessel anterior descending disease and a matched group who had received a saphenous vein graft. Of these 200 patients, 98 percent were alive at five years and only 1 percent died of cardiac causes. These five-year survival figures are significantly higher than the range of one-vessel disease five-year survival from matched and prospective, randomized medical treatment series. When surgery was compared with medical management in the Duke University one-vessel disease series, there was no significant difference in survival. Angina relief in NYHA Class 3 and 4 single-vessel patients was sustained more frequently in surgical patients despite more severe preoperative chest pain and the inclusion of more women in the surgical group. A matched medical-surgical experience from Seattle compiled from 1969 through 1974 includes a five-year follow-up of mildly symptomatic patients. The authors concluded that surgical therapy favorably influences survival in subsets of asymptomatic and minimally symptomatic patients in categories of two- and three-vessel disease patients with ejection fractions of 31 percent to 50 percent. Patients with normal left ventricular ejection fractions (>51 percent) had an excellent prognosis regardless of treatment. In an updated analysis, survival after surgical therapy was improved for the whole group of coronary artery disease patients and held true for asymptomatic and mildly symptomatic patients as well as for those with more severe symptoms. The greatest benefit was seen primarily in patients with three-vessel disease and normal and moderately abnormal left ventricular function. The forthcoming CASS prospective, randomized comparison of medical and surgical treatment of patients with no angina or mild angina, is eagerly awaited.

Of all the variables predictive of five-year survival, left ventricular function is conceded to be the most important. Poor left ventricular function is generally regarded as an ejection fraction of 30 percent to 35 percent or less. Early surgical reports recounted mixed results in this subset but the preponderance of reports weighed against surgical treatment for poor left ventricular function. More recently, in the Stanford University experience, the operative mortality was 9 percent between 1972 and 1978, and the five-year survival of comparable surgically and medically treated subgroups with poor left ventricular function was 66 percent and 18 percent, respectively. Patients with poor left ventricular function with predominant angina and little or no congestive heart failure fare better than those with congestive heart failure alone. The severity of preoperative congestive heart failure is the strongest determinant of survival in this subset. An alternative therapy would be cardiac transplantation, but fewer than 20 percent of patients referred for transplantation are actually accepted and nearly 20 percent of those accepted die before a donor becomes available. In a series of 188 patients from Emory University with a mean ejection fraction of 0.35, two-thirds had ejection fractions of 0.35 or less and were operated on between 1973 and 1977. Intraaortic balloon pump usage was 9 percent but the low operative mortality (2.1 percent) was attributed to better myocardial protection and other technical factors discussed previously. Yet, some form of inotropic agent was required in 20 percent of patients. The two-year survival was approximately 90 percent, and angina relief occurred in 77 percent. These series have survival rates significantly higher than any comparable group of medically treated patients.

Symptom relief and longevity depend on the extent or completeness of revascularization. The term complete revascularization is defined as grafts performed to all major coronary arteries (>1 mm in diameter) that have an estimated 50 percent (70 percent in some series) or greater narrowing in lumen diameter documented by preoperative coronary arteriography. Others prefer to use the term obstructed arteries that supply viable myocardium. Bear in mind that these definitions of completeness have nothing to do with the angiographic result, ie, graft patency; it is simply a term for optimal revascularization based on the preoperative arteriographic findings. There is a significant difference in angina relief in complete versus incompletely revascularized patients even when all grafts are patent. At approximately one year, 87 percent of those completely revascularized with all grafts patent were angina-free in comparison with 42 percent of incompletely revascularized patients with all grafts patent. Recently, Jones et al reviewed 1,238 completely revascularized three-vessel disease patients who had an 88.5 percent five-year survival in comparison with 83.5 percent for incomplete revascularization. Also, the completely revascularized patients had a higher rate of postoperative employment and 70 percent were angina-free compared with 58 percent of the incompletely revascularized group. In virtually all five- and ten-year longevity analyses, patients completely revascularized had significantly higher survival.

Diabetics have quantitatively and qualitatively more coronary artery disease than nondiabetics and show higher perioperative morbidity and mortality and lower long-term survival than nondiabetics. In one of the largest recent surveys, 250 diet/oral medicated diabetics and 162 insulin-dependent diabetics showed these characteristics: a greater percentage of women among diabetics, more tobacco usage, more hypertension, and left ventricular hypertrophy. However, dura-
tion of angina, unstable angina, family history of coronary heart disease, and history of previous myocardial infarction were comparable among diabetics and nondiabetics. Because of diffuse disease, diabetic patients received a significantly greater number of bypass grafts. Operative mortality over the 12-year period was 5.0 percent for diabetics versus 2.5 percent for nondiabetics. Survival rates for oral/diet and insulin-treated diabetics were 80 percent and 77 percent at five years, and 59 percent and 64 percent at ten years, respectively. This information corroborates the report of Johnson et al who concluded that controlled diabetes is no contraindication to bypass surgery.

Among the CASS registry surgical patients, 1,340 underwent coronary artery surgery in 1978, and their incidence of perioperative Q-wave infarction was 4.6 percent. The hospital mortality was 9.7 percent in those with new Q waves versus 1 percent in patients without new Q waves. The three-year follow-up showed a lower survival of 85 percent for perioperative infarct patients compared with 95 percent for those who did not have new infarction; however, the major influence on mortality occurred before hospital discharge. Hospital readmission for chest pain, myocardial infarction, or congestive heart failure was similar for both groups. A stepwise discriminant analysis could not identify the commonly measured preoperative and angiographic variables predictive of perioperative myocardial infarction. Another report also concluded that other than coronary collateral vessels, which were seen less frequently in the group that experienced perioperative infarction, there were no baseline or operative characteristics which could predict the occurrence of a perioperative infarction. In retrospect, we know that myocardial protection, ie, anoxic arrest vs cardioplegia, affects the incidence of perioperative myocardial infarction significantly. Of patients with perioperative infarction, 76 percent survived five years compared with 90 percent of those with no perioperative infarction. Even when operative deaths were excluded, perioperative infarction was predictive of impaired survival. In contrast, a third report found that late postoperative status, ie, relief of angina, dyspnea, level of physical activity, and use of cardiac medications was no different in perioperative infarction patients; nor was survival. Perioperative infarction is associated with a higher operative mortality; however, in contrast to very early reports, our analysis of perioperative infarction patients discharged from the hospital (1971 to 1973) showed a five-year survival of 94 percent. This finding has been confirmed by others. Except for the few patients who die from ischemia/infarction intraoperatively, or in the early course (many of whom were emergency cases), perioperative infarction today is infrequent and generally involves a small area of myocardium which probably has a minor effect on longevity.

The onset of better intraoperative myocardial protection has meant a gradually declining surgical intraaortic balloon pump usage. Of 197 patients who had a balloon pump inserted in conjunction with coronary artery surgery, 73 percent were discharged from the hospital. Delayed use of the balloon pump, ie, more than 24 hours postoperatively, was associated with a higher mortality. Results were equal for women and men. Interestingly, in the first 18 months after discharge, the clinical results in these former balloon patients were essentially the same as in those who did not require balloon support. For hospital survivors, the two-year cardiac actuarial survival was 96 percent.

Variant angina patients with fixed occlusive coronary artery disease, defined as >70 percent narrowing in diameter, achieve results from revascularization which appear no different from the clinical benefit reported for other subsets.

When survival is considered alone, a significant number of ischemic events may be overlooked. When 1,214 symptomatic, medically treated patients with coronary artery disease catheterized at Duke University between 1969 and 1978 were followed seven years, nonfatal infarction accounted for approximately one third of the initial cardiac events after catheterization; however, in patients with one- or two-vessel disease and normal ventricular function, nonfatal infarction accounted for as much as two-thirds of the initial events. Ventricular function was an important predictor of survival, but the number of diseased vessels was an important predictor of ischemic events. Also, progressive pain increased the incidence of fatal and nonfatal events in all categories of ventricular function in patients with three-vessel disease. The shape of event rate curves indicates that progressive angina exerts most of its effect in the 12 months or so after catheterization. The probability of surviving an ischemic event is strongly influenced by the quality of left ventricular function and the presence of left main coronary artery disease.

Surgery favorably alters the number of cardiac events in the first five postoperative years. In a matched-pair cohort of medical and surgical patients from the Seattle Heart Watch, the clinical courses of 287 patients were surveyed and a 26 percent reduction was found in cardiovascular hospitalizations in the surgically treated patients, largely because of a reduction in the hospital rate for myocardial infarction, which was 1.1 percent a year in surgically treated patients versus 2.6 percent a year in medically treated patients after a mean follow-up of six years. They found that 14 percent of medically treated patients and 5 percent of surgically treated patients had been hospitalized at least once for myocardial infarction within five years. This surgical group was compiled
between 1968 and 1974 and consisted predominantly of one- and two-vessel disease. When perioperative infarction was considered, the overall infarction rate between the two forms of therapy became insignificant. In the comparative analysis of Mason et al., both the incidence and fatal outcome of subsequent acute myocardial infarction in patients with stable angina were lower after surgical treatment. The late postoperative annual incidences of total (2.1 percent) and fatal (0.6 percent) infarctions were significantly lower than with medical therapy which achieved total (5.9 percent) and fatal (3.5 percent) annualized infarction rates. Later, reported annualized late infarction after surgery has been even lower (1.5 percent per year).  

Patients with severe coronary atherosclerosis pose a variable but potentially high risk for myocardial infarction during any major operation. From the reports of McCollum, Edwards, and Crawford and their colleagues, it appears that myocardial revascularization may offer protection against myocardial infarction during subsequent operations. In the largest series to date, Crawford et al. followed the course of 358 patients who had undergone coronary artery bypass surgery and 484 subsequent major operations, predominantly vascular surgery. Two-thirds of these operations were performed within two years of the bypass operation, and the operative mortality was 1 percent, with no deaths of cardiac origin. Only 3 percent of these patients who had undergone coronary artery surgery before a major noncardiac operation died of myocardial infarction during the three-year follow-up. 

The effect of coronary bypass surgery on the incidence of sudden cardiac death is favorable in the first three to five years of follow-up. Seattle investigators, comparing three different categories of ejection fraction in patients with one-, two-, and three-vessel disease, found that significantly fewer surgical than medical patients in each subgroup died suddenly. Similarly, another study of two- and three-vessel disease patients showed that 6 percent of surgical patients died suddenly (mean 39 months) in contrast to 24 percent of comparable medically treated patients, which was highly significant.  

Little information exists about the role of coronary artery surgery in survivors of prehospital cardiac arrest. One report examined the effect of myocardial revascularization on inducible ventricular arrhythmias. After symptomatic electrophysiologic investigation both before and after surgery in a group of 17 patients, these investigators concluded that myocardial revascularization may improve an abnormal electrophysiologic finding, but the effect of surgical revascularization is unpredictable in suppressing inducible ventricular arrhythmias. Left ventricular scar formation did not necessarily underlie inducible ventricular arrhythmias. In most of their patients with spontaneous ventricular ectopic activity, the arrhythmias persisted after coronary artery surgery. However, even when the scarred myocardium is left in situ, surgical revascularization may have a role in suppressing lethal ventricular arrhythmias either alone or in conjunction with antiarrhythmic drugs. Unfortunately, it was not possible to select these patients from preoperative angiographic information alone. Both preoperative and postoperative electrophysiologic studies were recommended as part of the evaluation and treatment of patients known to be at high risk for sudden cardiac death. Other investigators have reached similar conclusions, ie, coronary bypass grafting frequently improves exercise capacity but it does not decrease the frequency or severity of exercise-induced or resting ventricular arrhythmias consistently. 

**RETURN TO WORK**

Reports on employment after coronary artery surgery are diverse, with return to work ranging from 17 percent to 92 percent. The problem appears to be more socioeconomic than medical. In the first five postoperative years, approximately 90 percent of patients who undergo coronary bypass surgery are improved and yet only half return to work. Determinants of return to work are present before surgery. Most studies show that preoperative employment and clinical status postoperatively followed by age are the strongest predictors of return to work. Patients under 55 were more likely to return to work than those over that age. Other preoperative traits that affect return to work are summarized in Table 8. In addition, preoperative self-evaluations by the patients correlated very strongly with preoperative work status. In two large surveys of employment status, a substantial number of patients gave physician advice as a reason for not working postoperatively. To complicate matters, there is a persistent view among many employers, unions, and workers that coronary artery surgery patients are disabled. Receiving disability compensation correlates with unemployment and lower income level among men preoperatively and postoperatively. Participation

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employed preoperatively</td>
<td>Unemployed preoperatively</td>
</tr>
<tr>
<td>Age &lt;55</td>
<td>Age &gt;55</td>
</tr>
<tr>
<td>High income</td>
<td>Low income</td>
</tr>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Self-employed</td>
<td>Blue-collar</td>
</tr>
<tr>
<td>White-collar</td>
<td>Presence of cardiac symptoms</td>
</tr>
<tr>
<td>College education</td>
<td>Number of chronic medical problems</td>
</tr>
<tr>
<td>Relief of symptoms</td>
<td>Physician advice</td>
</tr>
<tr>
<td>Good LV performance</td>
<td>Receipt of disability compensation</td>
</tr>
</tbody>
</table>

This information was partially abstracted from Stanton, Barnes, Oberman, and their associates.
in an outpatient rehabilitation program increased the number of men returning to work who had been employed before surgery. In a report about employment after peripheral vascular surgery, only 3 percent of patients who had been receiving disability benefits for vascular disease prior to vascular reconstruction returned to work. In that group, there was no correlation between age or success of operation.

Oberman reminds us that indirect health care costs are almost four times the direct cost of managing coronary heart disease. In the United States, lost income, lower productivity, disability, insurance expenses, and workmen's compensation account for costs exceeding $20 billion annually, whereas only $5.5 billion is spent directly on the medical care of coronary heart disease. The pool of physically able people of working age who have undergone coronary artery surgery and are not gainfully employed is substantial and growing rapidly.

In a unique experience, (the probable upper limit of work rehabilitation), 80 percent of surgical patients returned to work, and duration of work was not influenced by preoperative disability. The total postoperative income of those returning to work generated nearly four times their total cost of care and even those who underwent reoperation generated a postoperative aggregate income 2.7 times their hospital and physician charges and disability payments. A successful reoperation may be cost-effective, but in most reports, reoperations negatively influence return to work. Most studies that have focused on the cost effectiveness of coronary artery surgery have shown that money earned from employment postoperatively greatly exceeds the cost of operation.

Since fewer patients work postoperatively than before operation, the prevailing opinion is that coronary artery surgery results in a loss of workers. But Johnson et al point out that there is an expected loss of 3 percent to 5 percent per year for subjects of comparable age, sex, and race. In a series of approximately 1,600 patients, bypass surgery seemed to arrest the loss of workers for a few years. In the group aged 60 to 70, there was a clear loss, and for patients near retirement age, surgery accelerated the rate of retirement. These data tend to discount employers as a significant factor in not returning to work, and doctor's advice was cited by only 5 percent of patients as their main excuse for not working. What negatively influenced return to work was the most physical disability. Patients with good preoperative left ventricular function, successful bypass surgery, and complete relief of angina should not be advised to stop working.

The Montreal Heart Institute found that the percentage of return to work has increased from 69 percent in 1969 to 1972 surgical patients to 76 percent in years 1973 to 1978, and to 89 percent in years 1979 to 1980. Despite the cost of hospitalization for catheterization and uncomplicated surgery, which reaches nearly $20,000 (considerably higher in some areas of California, New York, and Florida), the net cost per quality-adjusted year of life is reasonably good and compares favorably with other accepted medical therapies such as the treatment of moderate diastolic hypertension. If more bypass patients could be returned to the work force, the rehabilitative aspect of the operation would be enhanced greatly and cost of the procedure reduced.

**Unstable Angina**

There is no consensus about the definition of unstable angina. It encompasses recent onset of angina, recent progressive angina, angina of a changing pattern either at rest or with effort, and possibly postinfarction angina. The National Cooperative Study (NCS) of unstable angina included the provision of no evidence of acute myocardial infarction and at least one episode of pain associated with reversible electrocardiographic evidence of ischemia. In a national conference on coronary bypass surgery, coronary arteriography was advised for all patients with unstable angina. Approximately 10 percent of these patients will have roentgenographically normal coronary arteries. Most clinicians advocate coronary artery surgery in patients with left main disease, three-vessel disease, refractory unstable angina, and when later recurring symptoms are not adequately controlled. In one-vessel patients, balloon angioplasty should be considered. Indications for surgical and medical therapy of unstable angina are listed below. Timing depends on both institution-related and patient-related factors.

**Indications for Surgical Treatment**

1. Electrocardiographic or myocardial imaging proof of ischemia despite control by medical therapy
2. Left main, three- and probably two-vessel disease, and in selected cases, proximal one-vessel disease jeopardizing a large muscle mass
3. Intracoronary balloon pump counterpulsation required for control of ischemia
4. Subsequent medically refractory angina and operable pathoanatomy

**Indications for Medical Treatment**

1. Pain well-controlled and coronary pathoanatomy confined to isolated right or circumflex artery, or limited two-vessel disease in which small amounts of myocardium are at risk
2. A balloon pump is required but coronary arteriography displays inoperable anatomy
3. When severe left ventricular dysfunction, advanced age, serious medical conditions or unwillingness to
undergo the procedure take precedence.

In our experience with unstable angina treated by emergency revascularization, 100 consecutive patients who met the National Cooperative Study criteria were reanalyzed. In this series, compiled before 1976, there was no organized "cooling-off period," and the interval between admission and emergency revascularization averaged one day. Operative mortality was 4 percent and survival at 42 months was 92 percent. Perioperative myocardial infarction was unacceptably high (18 percent) and indicates that the therapeutic approach for unstable angina should be aimed initially toward intensive medical treatment for stabilization of the patient.

The National Cooperative Study concluded the following: (1) medical treatment of unstable angina had improved by administration of propranolol and nitrates; (2) in almost all cases, the unstable angina patient could be stabilized in a coronary care unit preoperatively with low risk of infarct; (3) although clinical and angiographic features of high risk were not clearly identified, patients with three-vessel disease were more likely to require early revascularization than those with one-vessel disease; and (4) when revascularization is complete, surgical results were consistently acceptable. Since more than a third of the National Cooperative Study patients assigned to medical treatment have crossed over to surgical treatment, no meaningful longevity comparison can be drawn from the modes of therapy. In our experience, unstable angina superimposed on a history of chronic angina may be more resistant to medical management than angina of recent onset.

The majority of patients treated initially by medical means and who later require surgery because of persistent angina were later identified by discriminant analysis. Multiple vessel involvement, frequent angina, prolonged pain, heart failure, and hypertension point toward surgical treatment. The mean hospital charges (1972 to 1976) for the first two years were $6,226 ± $2,967 for persistent medical patients, $10,416 ± $2,146 for surgical patients, and $20,059 ± $10,748 for patients who cross over to surgical therapy. Late surgical crossovers generated total costs twice as high as original surgical costs and 3.5 times as high as persistent medical costs. The costs cited above are inpatient costs (hospital, pharmacy, and professional fees) for the first two years after randomization to one treatment group or the other.

The National Cooperative Study early results may be eclipsed by more recent reports. For example, Emory University surgeons report that unstable angina patients operated on from 1974 to 1980 had a perioperative infarction rate of 3.8 percent (NCS 17 percent), hospital mortality of 1.9 percent (NCS 3.0 percent), and a late myocardial infarction rate of 3 percent at 43 months versus NCS 13 percent at 30 months. The Emory data showed a 95 percent 42-month survival; the better results are attributed to advances in anesthesia and surgical technique and more complete revascularization.

Hultgren et al reviewed 104 surgical and 124 medical patients with unstable angina. In the surgical group, operative mortality was 2 percent, perioperative infarction 13 percent, late infarct rate 9 percent, and complete relief of angina 62 percent at a mean follow-up of 52 months. The perioperative infarction rate was gradually reduced to 3 percent over the course of the series and actuarial survival was 85 percent for the surgical group versus 65 percent for the non-crossover medical group. They conclude that surgical management of selected patients with unstable angina appears preferable to medical therapy in view of improved survival and greater symptom relief.

Unstable angina patients were divided into three clinical subgroups by Rahimtoola and co-workers who assessed results up to ten years in 1,282 patients treated by coronary bypass surgery from 1970 to 1982. Operative mortality for these unstable patients was 1.8 percent which was lower than the mortality of their overall coronary artery surgery experience. Patients in the three clinical categories, angina at rest, angina after recovery from acute myocardial infarction, and progressive angina of recent onset, fared equally well, both early and late, despite worse preoperative left ventricular function among those with postinfarction angina. Five- and ten-year survivals were 92 percent and 83 percent, respectively. Reoperation occurred at a rate of 1 percent to 2 percent per year.

Another form of unstable angina is linked to balloon angioplasty. Signs pointing to potential ischemic injury during balloon angioplasty are: (1) absence of visible collaterals; (2) low pressure distal to the stenosis; and (3) pain and ST-segment changes when the balloon is inflated. Two patient categories for emergency revascularization are reported as follows: (1) visible arterial injury resulting in ischemic pain, and (2) acute ischemic pain in the absence of electrocardiographic changes but with extensive myocardium in jeopardy. Although balloon angioplasty is beyond the scope of this surgical review, the NHLBI Percutaneous Transluminal Coronary Angioplasty (PTCA) Registry reported the first 1,500 cases contributed from 73 centers between September 1977 and April 1981. The PTCA was successful in 60 percent of attempts; mortality was 1 percent; complications resulted in 21 percent, the most frequent of which were prolonged angina in 8 percent, myocardial infarction in 5 percent, coronary occlusion in 5 percent, and emergency coronary bypass surgery in 7 percent. The most common observation at surgery was dissection of an atheromatous plaque by the dilatation catheter, or subepicardial...
hemorrhage.\textsuperscript{801}

**Myocardial Infarction**

Approximately 1.5 million myocardial infarctions are recorded in the United States annually; 20 percent to 25 percent of patients may die before reaching the hospital, another 12 percent to 20 percent die in the hospital, and postmyocardial infarction survivors face a 4 percent to 5 percent annual mortality. In a survey of 63 acute care hospitals in Boston, the in-hospital mortality rate from acute myocardial infarction did not change in any age group from 1973 to 1979.\textsuperscript{802} Because myocardial infarction death rates were decreasing significantly during the 1970s at a time when in-hospital mortality from myocardial infarction remained constant, the percentage of myocardial infarction deaths occurring in the Boston hospitals actually increased from 30 percent in 1973 to 1974 to about 40 percent in 1975 to 1979. These data indicate that a greater number of myocardial infarction patients are reaching the hospital. This finding also means that improvements in the in-hospital care of acute myocardial infarction patients is not a major explanation for the decreasing nationwide mortality trend.

A report from the Health Insurance Plan of greater New York compared men who had survived their first myocardial infarction in the 1960s with myocardial infarction survivors in the 1970s (men aged 55 to 64).\textsuperscript{803} They found no evidence that long-term prognosis (4.5 years) from the 1970s differed from that of the 1960s and concluded that the decline in mortality from coronary heart disease must be restricted to the acute stage of myocardial infarction. A metropolitan Baltimore hospital study found lower in-hospital fatality rates among coronary care unit patients in the 1970s compared with the 1960s, but no significant differences were found in long-term prognosis for patients discharged in 1971 compared with those discharged during 1966 and 1967.\textsuperscript{804}

The presence or absence of Q waves in the surface ECG does not distinguish between transmural and subendocardial infarcts.\textsuperscript{805} Nevertheless, this differentiation has persisted in the literature. Early mortality is higher with transmural infarction than with subendocardial infarction, but nearly half of those with subendocardial infarction will suffer infarct extension an average of ten days after the initial event.\textsuperscript{806} Why non-Q wave infarcts should encounter a graver prognosis is unknown. Subendocardial infarction is generally regarded as an unstable entity and may be followed by a high rate of early transmural myocardial infarction. These patients should be considered as candidates for coronary arteriography.\textsuperscript{807} The mortality for patients with persistent angina after infarction may be 50 percent or higher.\textsuperscript{808,809} Approximately one third of patients with uncomplicated myocardial infarctions develop a 1mm or more ST-segment depression during stress testing. These patients will suffer an annual mortality of almost 20 percent. In contrast, patients with negative exercise stress tests have a first-year mortality of less than 3 percent. Clinically overt left ventricular failure identifies a high risk subgroup encompassing nearly 30 percent of the total. These patients comprise approximately half of the patients who will die during the first year after discharge. Safety of exercise testing and cardiac catheterization after myocardial infarction has been established.\textsuperscript{800,810}

The prevalence of multivessel disease in first-time myocardial infarction patients ranges from 55 percent to 75 percent. As mentioned earlier, the prevalence of multivessel disease after inferior myocardial infarction may be higher than after anterior myocardial infarction. Other investigators have shown no difference in the extent of coronary artery disease between survivors of anterior and inferior myocardial infarction. Sanz et al\textsuperscript{811} studied 255 men by coronary angiography one month after myocardial infarction and followed them for 34 months. They found that ejection fraction and quantity of jeopardized myocardium were the best predictors of survival. When the left ventricular ejection fraction was greater than 50 percent, prognosis over the ensuing three years was excellent and independent of coronary anatomy. An ejection fraction of 20 percent indicated a poor prognosis and three-vessel disease in conjunction with an ejection fraction between 20 percent to 50 percent represented intermediate risk. The longest life expectancy was observed among patients with a normal ejection fraction regardless of the number of arteries involved. The number of coronary artery surgery candidates gleaned from this study was 14 percent of all patients surviving myocardial infarction.

Earlier postmortem reports indicated that coronary occlusion (thrombosis) increases with time after myocardial infarction. More recently, DeWood et al\textsuperscript{812} challenged this conclusion by a careful arteriographic study in acute myocardial infarction patients. They found signs of total coronary occlusion in 87 percent of patients studied within the first four hours after onset of symptoms; however, this figure decreased to 65 percent among patients catheterized 12 to 24 hours after onset of symptoms. These findings indicate that coronary spasm or thrombosis formation with subsequent recanalization or both may occur in the evolution of transmural myocardial infarction. Patients in cardiogenic shock were more apt to have total occlusion throughout the 24 hours of infarction. Maseri et al\textsuperscript{813} have shown that coronary spasm may occur before thrombosis.

\textsuperscript{748} Progress in Surgical Treatment of Coronary Atherosclerosis (Floyd D. Loop)
INTERVENTIONS FOR ACUTE MYOCARDIAL INFARCTION

Rentrop,214 Ganz,215 Reduto216 and their colleagues were among the first to inject streptokinase selectively into acutely obstructed coronary arteries within a few hours after onset of infarction and report improvement in left ventricular ejection fraction and hemodynamics. Thrombolytic therapy has generated great interest; however, it is expensive, time consuming, and not without risk. First reports indicate an early success rate of approximately 75 percent. One must keep in perspective that spontaneous recanalization occurs in 35 percent to 40 percent. On the negative side, bleeding problems are infrequent but worrisome, and thrombosis recurs in approximately 20 percent despite adequate anticoagulation. In editorials relating to thrombolysis and acute myocardial infarction, Swan217 and Sobel and Bergmann218 caution that the early application of thrombolytic therapy in evolving myocardial infarction frequently results in a benign hospital course, but one cannot conclude that this intervention alone results in satisfactory outcome. The long-term effects of intracoronary thrombolysis on symptoms, incidence of reinfarction, risk of lethal arrhythmia, and survival are speculative. Early clinical reports showed either significantly better survival after streptokinase compared with controls or a trend in that direction. Newer clinical trials are underway.

In thrombolytic therapy (unlike balloon angioplasty), there is lower correlation between experience and results. Infusion may be done selectively into the specific coronary artery or achieved by ostial perfusion. Neither method appears superior to the other. Results of thrombolytic therapy in circumflex occlusion are worse when compared with anterior descending or right coronary artery thrombolysis.219 The data are preliminary, but earlier infusion of streptokinase (<3-4 hours after onset of symptoms) may produce better results than later usage. Patients who are not recanalized by thrombolytic agents may exhibit a higher mortality. After successful thrombolysis, an anticoagulant is administered to prevent reocclusion, but this may be delayed until after fibrinogen values have recovered.

Intravenous streptokinase has two advantages in that application can be performed earlier, and less equipment and personnel are required. Coronary arteries have been opened successfully in one hour in approximately half the cases by this technique; bleeding complications may be more frequent and early experience indicates that intravenous administration overall may be less efficacious.220 Angioplasty and/or bypass surgery may have a role in this therapy, but hard data are lacking. Coronary artery surgery has been performed after streptokinase infusion for persistent stenosis, intermittent coronary spasm, or unstable angina. In one comprehensive German experience, thrombolytic therapy with streptokinase was successful in 86 percent, but the reocclusion rate was high and the best early and long-term results were achieved in 17 patients who underwent coronary bypass grafting within three days after thrombolysis.221 There was no operative mortality, and bleeding was insignificant. Some believe that surgery should be delayed a few days to allow the myocardium time to resynthesize its energy-rich phosphates before the heart is subjected to additional ischemic injury.222 Among 20 such patients, no untoward bleeding was reported, and there were no early deaths. The concept that ischemia stuns the myocardium for prolonged periods is not clearly elucidated, but numerous experimental and clinical observations have verified that previously ischemic myocardium may remain depressed for days.223 Thus, assessment of the efficacy of thrombolytic therapy with or without balloon angioplasty or coronary bypass surgery should be delayed for at least two weeks after the intervention.

Thrombolytic therapy in 1983 may be summarized as follows:219,224 (1) intracoronary thrombolysis appears superior in thrombolytic effect to intravenous thrombolytic therapy during the early phase of acute myocardial infarction; (2) the two- to four-hour window may be important—early thrombolytic therapy is necessary to achieve greater myocardial salvage; (3) the risk of early reocclusion after successful thrombolysis may be high; (4) early bypass surgery after successful thrombolysis may be necessary to assure prolongation of the successful result; (5) patients not suitable for early bypass surgery and those with one-vessel disease may derive benefit from balloon angioplasty; (6) late bypass surgery is reserved for selected symptomatic patients with noncritical residual stenosis and for those with signs of extensive transmural infarction despite successful thrombolysis.

Success of emergency myocardial revascularization for evolving myocardial infarction depends largely on the timing of the operation.225,226 This year, the Spokane experience with surgical reperfusion during acute myocardial infarction has been extensively reevaluated.227 Patients were divided into transmural and nontransmural myocardial infarction groups. Surgical mortality was 5.2 percent for transmural and 3.1 percent for nontransmural infarcts. Anterior and inferior transmural infarction carried the same mortality. Their experience indicates that early reperfusion for both transmural and nontransmural myocardial infarction is associated with low short-term and long-term mortality. This is especially true when reperfusion is applied early in the time course. On the other hand, their data do not support the concept that all patients benefit from surgical revascularization during the first
24 hours of acute myocardial infarction. They were troubled by the relatively high early mortality in patients with triple-vessel disease (9 percent) in the transmural infarction group as well as in patients treated six hours after onset of symptoms. The transmural group appeared to benefit only if restoration of blood flow was achieved within a few hours of onset. They emphasized that today only early arrivals are considered candidates for surgical reperfusion. Patients with anterior myocardial infarction are treated more aggressively and are more likely to undergo surgery than those with infarctions involving other sites. The presence or absence of multivessel disease supplying an infarcted area may also play a role in the decision-making process. The presence of collaterals and whether or not the patient has continued pain are also taken into consideration.

Postinfarction angina is an indication for coronary arteriography. Myocardial revascularization should be undertaken urgently when the angiogram reveals surgically favorable pathoanatomy. Jones et al\textsuperscript{220} reported no hospital deaths with surgical treatment, but noted more perioperative complications within patients operated on for persistent or recurrent pain in the first week of an acute myocardial infarction. These authors emphasize that surgery is performed principally for chest pain after infarction, not for evolving myocardial infarction or for power failure. After that interval, coronary artery surgery was accomplished with the same morbidity as an elective operation.

Approximately 350,000 sudden deaths occur annually in the United States. Sudden cardiac death has been defined in various ways, but a practical description is unexpected cardiac death occurring without symptoms or with symptoms of less than an hour's duration.\textsuperscript{220} The hypothesis that most episodes of ventricular fibrillation result from acute myocardial ischemia is reasonable but not well documented. Approximately three-fourths of the victims of sudden death examined at autopsy are found to have advanced coronary artery disease.\textsuperscript{220} Few communities have duplicated the Seattle experience. In Seattle, the response time of the Seattle fire department from dispatch to arrival of the first unit averages 2.9 minutes and Medic units arrive on the scene approximately 4 minutes later. When bystanders initiated cardiopulmonary resuscitation, the percentage of patients who survived and returned home with little or no neurologic deficit was twice that of patients in whom resuscitation was not begun until arrival of the fire department personnel. In a nine-year period, there has been an increase in the rates of successful resuscitation and less than 2 percent of survivors have been lost to follow-up.

In the Seattle experience,\textsuperscript{221} approximately 30 percent of patients resuscitated during hospital ventricular fibrillation survived and were discharged. Patients at greatest risk are those in whom ventricular fibrillation has occurred without myocardial infarction.\textsuperscript{231} Their one-year recurrence rate was 22 percent compared with 2 percent in those with myocardial infarction evolving after sudden death resuscitation. Whether electrophysiologic testing is efficacious in these patients is unknown, but Ruskine et al\textsuperscript{224} demonstrated that programmed electrical stimulation could evoke ventricular arrhythmias in 25 of 31 survivors of out-of-hospital cardiac arrest. When these electrically induced arrhythmias could be suppressed in the laboratory by drug therapy, none died suddenly during a mean of 15 months, whereas three of six patients in whom suppression was unsuccessful died. Propranolol appears to reduce the incidence of sudden death in myocardial infarction patients in the early course but cannot be prescribed for many patients with moderate-to-severe left ventricular dysfunction. The role of other drugs has not been clearly elucidated, or they have been withdrawn because of side effects or else are unavailable in the United States. The results of coronary artery surgery in this sudden death subset are too preliminary to draw any conclusions; however, in one angiographic study in patients resuscitated from sudden cardiac death, over half had coronary pathoanatomy amenable to complete revascularization.\textsuperscript{223}

**Reoperation**

Early in the evolution of coronary bypass operations, reoperations were performed mainly for early graft closure or incomplete primary revascularization. Morbidity and mortality associated with reoperations were high initially because of technical inexperience, accidents, poor myocardial protection, prolonged oxygenator perfusion time, hemorrhage, and increased blood requirements. Results of reoperative coronary artery surgery have improved in the latter half of the 1970s because of greater operative experience, better myocardial protection, and blood conservation measures.\textsuperscript{224}

The referral patterns mentioned earlier, ie, less referral for single-vessel disease surgery, the advent of balloon angioplasty, and medical treatment for asymptomatic patients potentially checks the growth of coronary artery surgery. Nevertheless, from 150,000 to perhaps 200,000 bypass operations annually in the United States will ultimately generate an increasing number of reoperations regardless of complete revascularization or an increasing number of grafts per patient initially. Time brings progressive atherosclerosis in native vessels and graft conduits. Ten-year follow-ups indicate a reoperation rate of 6 percent to 17 percent.

In a review of our first 1,000 isolated coronary artery reoperation cases, we documented some distinct
trends in angiographic indications for reoperation. Risk factors in reoperation candidates differ little from those in patients facing their first coronary artery operation with the exception that diabetics (on insulin treatment) make up 19 percent of reoperation patients compared with 9 percent of primary revascularization patients. The prevalence of reoperations for graft failure rose from 26 percent during 1969 to 1976 to 40 percent during 1981 to 1982, presumably because of late closures between five and ten years after the first operation. In contrast, progressive atherosclerosis in the coronary circulation declined as an indication for reoperation from 62 percent in 1969 to 1976 to 23 percent in 1981 to 1982; this is attributed to more complete revascularization during the first procedure.

Reoperative mortality in The Cleveland Clinic experience has declined from 5 percent to 2 percent, and major perioperative morbidity has decreased significantly when the early years are compared with the later experience. The number of grafts per patient in our reoperations has increased from 1.4 to 2.3, and complete revascularization has increased from 65 percent to 76 percent. Intraoperative atheromatous embolization from the aorta, the coronary arteries and from atherosclerotic vein grafts has been described. This complication is potentially lethal and warrants early ligation of atherosclerotic vein grafts during reoperation, especially in those who show retained antegrade flow. A new graft should be used for replacement rather than relying on an interposed graft across the atherosclerotic lesion.

After a mean of 29 months, our graft patency was 81 percent in 153 patients restudied after reoperation, which is essentially the same as the result after the first operation. The internal mammary artery graft enjoys a 96 percent patency rate compared to 78 percent for saphenous vein grafts. Graft patency to vessels previously involved with graft failure and graft patency to vessels previously not grafted were the same as the overall postreoperative patency. Clinical benefit in terms of symptom relief is less impressive after reoperation in comparison with angina relief after the first operation. Although 60 percent to 70 percent of patients are completely relieved of angina after the first operation, only 50 percent were angina-free five years after reoperation, a finding attributed to more diffuse atherosclerosis and left ventricular asynergy. After five full years of follow-up, survival for our first 750 reoperation patients was 89 percent, a figure not too different from the five-year longevity after primary coronary artery surgery. As expected, survival is influenced by extent of disease and left ventricular performance before reoperation and by completeness of revascularization. Five-year survival was not affected by angiographic indication for reoperation, ie, graft closure, progressive atherosclerosis, or both.

**Rehabilitation After Bypass Surgery**

Coronary atherosclerosis is an ongoing process, and any patient who undergoes coronary artery surgery, albeit successful, faces lifelong medical treatment and follow-up. Coronary artery surgery is not curative but can provide excellent palliation and relative protection from ischemic events in the intermediate term and possibly the long term. Rehabilitation begins preoperatively with the discussion of potential benefits and expectations of the operation. Preoperative education classes cover basic operative details including objectives of the intensive care unit. Early mobilization, breathing exercises, and ambulation are outlined. In the hospital postoperatively, patients may experience unusual discomfort, anxiety, mood swings, or sleeplessness which generally respond to appropriate sedation and reassurance. A postoperative education session between the fifth and seventh day explains low level exercise methods to prevent limb venostasis, the value of continued breathing exercises, proper rest, and resumption of sexual activity. Individual counseling is necessary for medications and to answer questions specifically about the operation.

In straightforward uncomplicated cases, discharge frequently occurs on the seventh postoperative day. Patients should be cautioned that they may feel unusually fatigued the first week at home, and their activity should resemble that of the last few days in the hospital. As strength and confidence are gained, walking is an excellent exercise with incremental increases in pace and distance. Patients who live far away from the referral center are encouraged to see their doctor within the first week or two of returning home. Otherwise, a six-week check-up is sufficient for uncomplicated patients. Early recurrence of angina pectoris, new evidence of congestive heart failure, and new arrhythmias must be investigated, preferably prior to discharge. A failed operation is infrequent today, but these complications must be pursued and corrected when feasible. If nothing further can be accomplished, explicit recommendations should be communicated about energy-saving activity, supervised rehabilitation, and close medical follow-up. Many of these points have been amplified eloquently in the new edition of a textbook on rehabilitation of the coronary patient edited by Wenger and Hellerstein. Return to work was dealt with in a separate section.

Modifications of risk factors have not correlated well with disease prevention, but some modification may alter the probability of its recurrence or progression. These risk factors include: (1) elevated plasma cholesterol and triglycerides, (2) hypertension, (3) smoking, (4) diabetes mellitus, and (5) obesity. Hypertension, smoking, and obesity enhance myocardial oxygen consumption which may promote myocardial ischemia.
in the presence of coronary insufficiency. It is difficult to prove that lowering plasma cholesterol by diet or other means will stop progression, cause regression of coronary atherosclerosis, or reduce coronary events.\(^{230}\)

Diabetes is an independent disease, and the combination of diabetes and coronary heart disease does not necessarily reflect a cause-and-effect relationship; diabetes may promote atherosclerosis, but its management is warranted for other obvious reasons.

Many patients will benefit from an organized cardiac rehabilitation program. It has been well documented that exercise training results in improved aerobic capacity in cardiac (including postbypass) patients.\(^{240}\) These programs provide structure and supervision for patients who find it hard to become physically fit and to eat prudently. Many patients enjoy the activity and the camaraderie with other patients and staff. The safety of monitored outpatient\(^{240}\) and inpatient\(^{240}\) exercise rehabilitation for coronary artery surgery patients has been documented. For those who wish to begin more strenuous activity, such as jogging or playing tennis, we recommend an exercise stress test before engaging in this exercise. These findings give the patient and his physician confidence that the operation has been successful and that strenuous activity is safe. Encouragement from family and friends, participation in a coronary club or similar educational program, and support from fellow workers improve motivation to return to work. The physician must deemphasize invalidism and urge the patient to continue his occupation whenever possible.

We encourage our patients to take an exercise stress test annually. When symptoms or exercise testing indicate recurrent ischemia, another coronary arteriogram may be indicated. Progressive coronary atherosclerosis and graft atherosclerosis will have affected many bypass patients during the five to ten year interval, and until digital subtraction angiography is refined to visualize underlying disease and bypass graft status, repeat coronary angiography is the most accurate method of reassessment.

Author's Note

The literature on coronary artery surgery is too comprehensive for a collective review. In trying to avoid the large volume of contradictory data, this survey concentrates on results derived from the late 1970s and early 1980s. There are thousands of papers on the surgical treatment of coronary atherosclerosis and it has not been possible to include more than a small fraction of them. Many of the important references cited herein represent the consensus or current understanding of the subject. Many good papers are conspicuously absent simply because of space and depth; no reference has been intentionally overlooked for any reason. Dissenting points of view are represented wherever possible.

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