The Prognosis of Patients with Coronary Artery Disease After Coronary Bypass Operations

Time-Related Progress of 532 Patients with Disabling Angina Pectoris


SUMMARY

The clinical progress of 532 patients who were treated for ischemic heart disease by coronary bypass grafting during a five-year period was studied. All patients had at least 50% luminal narrowing of one or more major coronary arteries determined by preoperative coronary arteriography and relatively stable and disabling (New York Heart Association Functional Class III and IV) angina pectoris. During the total observation period there were 35 deaths: 18 early and 17 late. The over-all 4-year survival rate by life-table methods was 89%, and it differed among patients with one-vessel involvement (96%), two-vessel involvement (89%), and three-vessel involvement (84%), but not significantly so. The patency rate of bypass grafts determined in 191 patients at a mean time of six months postoperatively was 76%. Functional class I and II status was 93% during the first year and was 75% during the fourth year after operation in observed survivors.

Additional Indexing Words:
Aortocoronary bypass Follow-up studies

The role of coronary artery bypass surgery in the management of atherosclerotic heart disease urgently requires, but presently lacks, precise definition. Although many reports indicate that operation can be conducted with a relatively low mortality and is accompanied by excellent short-term relief of symptoms, little information is available on the subsequent course of surgical patients or, for purposes of comparison, on the course of patients treated by alternative methods. The needed insight may be provided by prospective, randomized studies of treatment but, unfortunately, these studies are not yet available.

Meanwhile, much useful information can be obtained from a detailed retrospective analysis of experience. This method, despite its inherent limitations, has been applied successfully in assessing the results of cardiovascular surgery in many forms of congenital and acquired heart disease.1-11 Admittedly, the assessment of coronary artery surgery is more difficult because the underlying disease tends to progress after treatment, and because angina pectoris, one of the prime functional expressions of the disease, tends to be highly personal and subjective in nature. In addition, surgical techniques and results vary widely, and surgical patients are not uniform in either extent of disease or irreversible impairment of ventricular function. Yet, when a defined subset of patients is considered, as in the following study, both the benefits and risks of coronary artery surgery become more clearly evident.

We relate herein our total experience in treating atherosclerotic heart disease in patients with relatively stable, disabling angina pectoris. Revascularization of obstructed coronary arteries was performed exclusively by means of venous bypass grafts. An analysis of the postoperative and time-related late mortality, the postoperative graft patency, and the time-related functional state of patients forms the basis of this report.

Patients and Methods
Five hundred thirty-two patients with disabling angina
pectoris (NYHA Functional Class III and IV) received aorta-
to-coronary artery vein bypass grafts (214 single, 260 dou-
ble, 58 triple) at the University of Oregon Medical School,
St. Vincent, and Portland Veterans Administration Hospitals
from December 1968, to July 1973. Specifically excluded
from analysis were other surgical patients characterized as
follows: patients with unstable and accelerated angina;
patients with coexisting valvular heart disease; patients with
angina who also had dyspnea, orthopnea, and fluid retention
and who were receiving both digitalis and diuretics for con-
trol of these symptoms; and patients with documented re-
cent acute myocardial infarction at the time of operation.
The study group contained 471 men (mean age 51.7 years)
and 61 women (mean age 53.7 years).

Preoperative coronary arteriography was obtained in all
cases. Most patients had both cinearteriograms and cut-film
selective left and right coronary arteriograms in several pro-
jections. Obstructions in the right, left main, left anterior
descending, and circumflex arteries were graded as percent
of lumen narrowing. For this analysis a 50% or greater
reduction of luminal diameter was considered significant
disease because a 50% reduction of luminal diameter cor-
responds to a 75% reduction of cross-sectional area and
produces a reduction in blood flow.13,14 Left main disease
was considered as double-vessel involvement irrespective
of the state of distal branches. On this basis 113 patients had
single-vessel involvement, 216 patients had double-vessel
involvement and 203 patients had triple-vessel involvement.
Postoperative coronary arteriography with assessment of
graft patency was performed in 191 patients at a mean time of
6.0 months after operation.

Our previously described operative technique,16 which in-
cluded cardiopulmonary bypass with moderate hemodilu-
tion and mild hypothermia (32°C), was applied throughout
the study with a few major changes as experience was
 gained. Beginning in 1972 distal anastomoses were per-
formed with the aorta cross-clamped and the heart
fibrillating; regular use of a left ventricular venting catheter
was abandoned. Proximal anastomoses were performed with
a partially occluding aortic clamp in the beating heart. Dur-
ing the first two years of this experience few vessels with 50-
65% obstruction were grafted, and during the first three
years diseased circumflex arteries were not grafted unless
they appeared to provide the sole vascular supply to the
posterior wall of the heart. Subsequently, all major vessels of
50% or greater obstruction have been grafted whenever
feasible.

Follow-up data from the patients were collected by per-
sonal physicians, by the authors, and by questionnaires and
telephone interviews during each year of the study. The
clinical results were determined from these data using the
functional classification system (FC) of the New York Heart
Association.18 Essentially, patients in FC I had no angina
and patients in FC II had mild angina. FC III and IV pa-
tients with moderate to severe angina were combined in
the analysis because of small numbers after operation and
because either category was considered a treatment failure.
The Chi square method was used to test the statistical
significance of differences in FC between various subsets of
patients. A difference was considered not significant if the
probability that it arose by chance was 5% or more.

Yearly survival rates, standard errors, and survival curves
were determined for the entire group and various subsets by
actuarial methods.17,18 Differences in survival rates were
tested by determining a z score and requiring a value of 1.96
in the table of standardized normal distribution for
significance at the 5% level. The z score was calculated ac-


dc = \sqrt{SE_a^2 + SE_b^2}

where \( P_a \) and \( P_b \) is the difference, and \( SE_a \) and \( SE_b \) are the


It was considered not significant if the probability
that it arose by chance was 5% or more.

Yearly survival rates, standard errors, and survival curves
were determined for the entire group and various subsets by
actuarial methods.17,18 Differences in survival rates were

determined from the formula:

\[
Z = \frac{P_a - P_b}{\sqrt{SE_a^2 + SE_b^2}}
\]

where \( P_a - P_b \) is the difference, and \( SE_a \) and \( SE_b \) are the corre-
sponding standard errors, in cumulative yearly survival rate
for any two groups a and b.

At the closing date of the study, December 15, 1973, a
total of 38 patients had been lost to follow-up at various
times after operation while the current status of 494 patients
(93%) was known.

Results

Mortality

There were 18 postoperative deaths (prior to hospital
discharge or within 30 days of operation), an
operative mortality rate of 3.4%. A comparison of
operative deaths and numbers treated each year (fig. 1)
showed much improvement in operative mortality,
from 12% in the first year to 1.5% in the last year, and
a steady increase in caseload. There were 17 late
deaths from 5 weeks to 46 months after operation.

The causes of postoperative and late mortality are
listed in table 1. A myocardial infarction that occurred
during operation was the chief cause of postoperative
mortality. By contrast, acute myocardial infarction
could not be documented among the 13 late cardiac
deaths. Since postmortem examinations were not ob-
tained in the seven patients who died suddenly, it was
not possible to confirm whether they had sustained
fatal infarctions before reaching the hospital.

The time-related progress of the entire population
was determined from a life table (table 2) and survival
curve (fig. 2). The one-year mortality rate, which in-
cluded all operative deaths, was 5.6%. The mortality

Figure 1

Histogram showing the yearly operative experience in 332 patients.
The operative mortality rate fell during each year while the number of
patients treated increased.
Causes of Postoperative Four-Year Mortality (calculated on a patient number of patients determined from life group artery (40 right cumflex) was operative one major artery (40 right plus left anterior descending, 33 left anterior descending plus circumflex, and 23 right plus circumflex) was present in 216 patients (table 4). All major obstructions were bypassed in 149 patients who received double grafts while one obstructed artery was not bypassed in 67 patients who received single grafts. The operative mortality rate was 2.8% and the four-year survival rate was 88.7%. These values were, respectively, higher and lower than the corresponding values for patients with single vessel involvement, although the differences were not statistically significant.

Involvement of all three major coronary arteries was found in 203 patients (table 5). All obstructions were bypassed in 58 patients who received three grafts while one obstructed artery was not bypassed in 111

Table 1

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postoperative</td>
<td></td>
</tr>
<tr>
<td>Failure to come off bypass</td>
<td>5</td>
</tr>
<tr>
<td>Myocardial infarction and low output</td>
<td>11</td>
</tr>
<tr>
<td>Stroke</td>
<td>1</td>
</tr>
<tr>
<td>Brain damage after hemorrhage</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
</tr>
<tr>
<td>Late</td>
<td></td>
</tr>
<tr>
<td>Sudden and unexplained</td>
<td>7</td>
</tr>
<tr>
<td>Arhythmia</td>
<td>4</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>2</td>
</tr>
<tr>
<td>Noncardia*</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
</tr>
</tbody>
</table>

*Pedestrian trauma, stroke, lung malignancy, stomach malignancy.

rate (calculated by the yearly survival proportion) declined to 1.4% during the second year and to 0.7% during the third year after operation and then increased to 3.9% during the fourth year. There was no mortality during the fifth year and, therefore, the four- and five-year survival rates were identical (89%). However, since the five-year survival rate was based on a relatively small number of patients at risk, the four-year survival rate, based on a sufficiently large number of patients to insure reliability, was used for purposes of comparison.

The progress of patients having one, two, or three major arteries with 50% or more obstruction was determined from life tables and survival curves for each group (fig. 3). Involvement of only one major artery (40 right, 71 left anterior descending, and 2 circumflex) was present in 113 patients (table 3). Only one operative death occurred in this group (0.9% mortality) and the four-year survival rate was 95.7%.

Table 2

Modified Life Table: 532 Patients with Angina and Coronary Artery Disease

<table>
<thead>
<tr>
<th>Interval (months postoperative)</th>
<th>No. entering alive Nk</th>
<th>Deaths dk</th>
<th>Lost to follow-up lk</th>
<th>Removed (reoperation) rk</th>
<th>Surviving incomplete interval sk</th>
<th>Interval survival proportion p_k</th>
<th>Cumulative survival rate P_k</th>
<th>Standard error s_e_k</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>(N_k) 532</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.966</td>
<td>0.966</td>
<td>0.008</td>
</tr>
<tr>
<td>2–12</td>
<td>(N_k) 514</td>
<td>10</td>
<td>4</td>
<td>3</td>
<td>124</td>
<td>0.978</td>
<td>0.944</td>
<td>0.010</td>
</tr>
<tr>
<td>13–24</td>
<td>(N_k) 373</td>
<td>4</td>
<td>12</td>
<td>3</td>
<td>142</td>
<td>0.986</td>
<td>0.931</td>
<td>0.012</td>
</tr>
<tr>
<td>25–36</td>
<td>(N_k) 212</td>
<td>1</td>
<td>16</td>
<td>2</td>
<td>108</td>
<td>0.993</td>
<td>0.925</td>
<td>0.013</td>
</tr>
<tr>
<td>37–48</td>
<td>(N_k) 85</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>62</td>
<td>0.961</td>
<td>0.889</td>
<td>0.028</td>
</tr>
<tr>
<td>49–60</td>
<td>(N_k) 17</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>15</td>
<td>1.000</td>
<td>0.889</td>
<td>0.028</td>
</tr>
</tbody>
</table>

*N_k is the number entering study; for k > 1, N_k = N_k-1 - (d_k-1 + l_k-1 + r_k-1 + s_k-1).

†p_k = 1 - dk

‡p_k = p_1 × p_2 × p_3 × ... × p_k expressed as percent.

§s_e_k = p_k \sum (N_k - \frac{1}{2} (s_k + l_k + r_k) - d_k)
survival after three-vessel involvement with patients arteries were not bypassed in 34 patients who received one graft. The operative mortality rate for patients with three-vessel involvement was 5.4%. This was significantly greater ($P < 0.05$) than the operative mortality rate for patients with one-vessel involvement but not for patients with two-vessel involvement. The four-year survival rate for patients with three-vessel involvement was 84.4%, not significantly different from the four-year estimates for patients with either one- or two-vessel involvement.

Reoperations

Eight patients had reoperation for coronary bypass grafting at intervals of four to 30 months after the initial operation. The surgical indication in each instance was the reappearance of FC III or IV angina associated with angiographic evidence of occlusion of one or more grafts and favorable coronary artery anatomy. There were no operative or late deaths in this group. These patients were withdrawn from the population at risk in the interval of their reoperation for survival analysis (table 2). In the analysis of clinical results, they were classified as treatment failures (FC III and IV) in intervals of occurrence and subsequently excluded after reoperation.

Graft Patency

The status of bypass grafts was determined in 191 patients at a mean time of 6.0 months after operation by selective angiography. Of the 303 grafts, 229 were found to be patent (76%). All grafts were patent in 132 patients (69%), both patent and occluded grafts were found in 34 patients (18%), and only 25 patients (13%) had no patent grafts.

The above figures were not based on a random selection of patients for angiography and were biased against patients with good surgical results. Chi-square

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**Table 3**

*Modified Life Table*: 113 Patients with Single Vessel Involvement

<table>
<thead>
<tr>
<th>Months postoperative</th>
<th>Nk</th>
<th>dk</th>
<th>tk</th>
<th>rk</th>
<th>sk</th>
<th>p(k)</th>
<th>P(k)</th>
<th>n(k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>113</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.991</td>
<td>0.991</td>
<td>0.009</td>
</tr>
<tr>
<td>2–12</td>
<td>112</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td>0.980</td>
<td>0.971</td>
<td>0.016</td>
</tr>
<tr>
<td>13–24</td>
<td>86</td>
<td>1</td>
<td>1</td>
<td>29</td>
<td>0.986</td>
<td>0.957</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>25–36</td>
<td>53</td>
<td>0</td>
<td>6</td>
<td>22</td>
<td>1.000</td>
<td>0.957</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>37–48</td>
<td>25</td>
<td>0</td>
<td>1</td>
<td>19</td>
<td>1.000</td>
<td>0.957</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>49–60</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>1.000</td>
<td>0.957</td>
<td>0.021</td>
<td></td>
</tr>
</tbody>
</table>

*Symbols and calculations as in table 2.

**Table 4**

*Modified Life Table*: 216 Patients with Double Vessel Involvement

<table>
<thead>
<tr>
<th>Months postoperative</th>
<th>Nk</th>
<th>dk</th>
<th>tk</th>
<th>rk</th>
<th>sk</th>
<th>p(k)</th>
<th>P(k)</th>
<th>n(k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>216</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.972</td>
<td>0.972</td>
<td>0.011</td>
</tr>
<tr>
<td>2–12</td>
<td>210</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>41</td>
<td>0.984</td>
<td>0.956</td>
<td>0.014</td>
</tr>
<tr>
<td>13–24</td>
<td>165</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>58</td>
<td>0.985</td>
<td>0.942</td>
<td>0.017</td>
</tr>
<tr>
<td>25–36</td>
<td>99</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>56</td>
<td>0.985</td>
<td>0.928</td>
<td>0.022</td>
</tr>
<tr>
<td>37–48</td>
<td>35</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>23</td>
<td>0.956</td>
<td>0.887</td>
<td>0.045</td>
</tr>
<tr>
<td>49–60</td>
<td>9</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>1.000</td>
<td>0.887</td>
<td>0.045</td>
</tr>
</tbody>
</table>

*Symbols and calculations as in table 2.
analysis of patients who had and had not undergone restudy, grouped according to functional class (table 6), indicated a highly significant difference \((P < 0.001)\) with fewer patients restudied in FC I and more in FC III and IV than could be expected by chance alone. This came about because of difficulty in inducing patients whose symptoms were dramatically improved by operation (and their personal physicians) to accept restudy. This difficulty was seldom encountered in unimproved patients. Postoperative functional class was also found to be significantly related \((P < 0.001)\) to graft occlusion with more FC III and IV patients than expected by chance having all grafts occluded (table 6). Thus the 76% graft patency rate in the restudy sample was probably lower than in the entire population because disproportionate numbers of FC III and IV patients were restudied and because these patients tended to have occluded grafts.

## Time-Related Functional Class

The functional class of survivors was determined for each yearly interval after operation so that results for similar intervals of follow-up could be combined. The population was then further divided according to year of operation so that any change in results as experience was gained might become apparent. Table 7 lists patients by functional class, calendar year of operation, and interval after operation, and provides cumulative functional class totals for each yearly interval of follow-up. Figure 4 represents the same data converted to percent and displayed by histogram.

Most patients remained improved in FC I and II after operation \((75\% \text{ at four years, table 7})\). However, there was a highly significant difference in functional class with time \((P < 0.001)\) as asymptomatic patients (FC I) decreased in number while unimproved patients (FC III and IV) increased. In part, this was caused by generally poorer results during the early years of the study (fig. 4) and persistence of these results into the longer follow-up intervals. Thus, when the results in the yearly cohorts were compared during the first year after operation (table 7), there was a significant difference \((P < 0.01)\) with proportionately more FC I patients in the recent years and more FC III and IV patients in the earlier years of experience with the vein graft operation.

The improved results in recent years were associated with more complete revascularization of obstructed arteries (fig. 5). Beginning in 1972, non-dominant circumflex arteries and obstructions of 50-65% in all vessels were regularly grafted. This resulted in an increased proportion of diseased vessels receiving grafts (74% in 1971, 81% in 1972, and 91% in 1973), despite a concomitant increase in the proportion of obstructed arteries/arteries at risk during the same period. Overall, 1596 coronary arteries were at risk in the population, 1136 (71%) were found to be 50% or more obstructed, and 908 diseased arteries (80%) were bypassed by grafts.

## Discussion

The treatment of ischemic heart disease can be analyzed in terms of the achievement of many desirable goals. These goals include extending the duration and quality of life, lessening or eliminating

### Table 5

<table>
<thead>
<tr>
<th>Months postoperative</th>
<th>Nk</th>
<th>dk</th>
<th>lk</th>
<th>rk</th>
<th>ak</th>
<th>pk</th>
<th>Pk</th>
<th>sepk</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>203</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.946</td>
<td>0.946</td>
<td>0.016</td>
</tr>
<tr>
<td>2-12</td>
<td>192</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>63</td>
<td>0.969</td>
<td>0.917</td>
<td>0.020</td>
</tr>
<tr>
<td>13-24</td>
<td>122</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>55</td>
<td>0.989</td>
<td>0.907</td>
<td>0.022</td>
</tr>
<tr>
<td>25-36</td>
<td>60</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>30</td>
<td>1.000</td>
<td>0.907</td>
<td>0.022</td>
</tr>
<tr>
<td>37-48</td>
<td>25</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>0.931</td>
<td>0.844</td>
<td>0.064</td>
</tr>
<tr>
<td>49-60</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1.000</td>
<td>0.844</td>
<td>0.064</td>
</tr>
</tbody>
</table>

*Symbols and calculations as in table 2.

### Table 6

**NYHA Functional Classification of Patients* During First Year after Operation According to Postoperative Angiographic Status**

<table>
<thead>
<tr>
<th>Functional classification</th>
<th>I</th>
<th>II</th>
<th>III &amp; IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients studied</td>
<td>65</td>
<td>63</td>
<td>4</td>
</tr>
<tr>
<td>All grafts patent</td>
<td>18</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Both patent and occluded</td>
<td>5</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>All grafts occluded</td>
<td>88</td>
<td>83</td>
<td>20</td>
</tr>
<tr>
<td>Total patients studied</td>
<td>199</td>
<td>95</td>
<td>15</td>
</tr>
</tbody>
</table>

*Deaths and losses to follow-up are excluded and removals for cause (reoperations) are tallied as treatment failures (FC III & IV).
angina, improving or stabilizing ventricular function and exercise capacity, and preventing arrhythmias, myocardial infarction, and sudden death. This study is confined to a description of the outcome of surgical treatment in two areas, time-related survival and symptomatic state. The study patients probably resemble the majority who currently undergo bypass surgery in this country in that they have incapacitating but relatively stable angina accompanied by arteriographic demonstrations of major coronary artery obstructions.

The four-year survival rate in this study was determined by actuarial methods to be 89%. However, this figure cannot be fairly compared with similar estimates in patients with angina who were treated non-operatively because the studies available for comparison contain different or unknown proportions of high and low risk patients. Two early survival studies of patients with angina, those of Richards et al.19 from the Massachusetts General Hospital and Block and coworkers20 from the Mayo Clinic, reported four-year survival rates of 75% and 63%, respectively. Since these survival rates were based on observations made prior to 1950, they may be taken as baseline estimates of the natural course of angina in hospitalized patients unmodiﬁed by present day diagnostic or therapeutic techniques. Several recent prospective studies of large groups in the general population have provided

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### Table 7

NYHA Functional Classification of Survivors* for Each Year after Operation

<table>
<thead>
<tr>
<th>Follow-up time</th>
<th>Year of operation</th>
<th>Functional class:</th>
<th>1st yr</th>
<th>2nd yr</th>
<th>3rd yr</th>
<th>4th yr</th>
<th>5th yr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>II &amp; IV</td>
<td>I</td>
<td>II &amp; IV</td>
<td>I</td>
<td>II &amp; IV</td>
</tr>
<tr>
<td>1973 (Jan.-June)</td>
<td>88</td>
<td>32</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1972</td>
<td>85</td>
<td>52</td>
<td>15</td>
<td>75</td>
<td>53</td>
<td>14</td>
<td></td>
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<td>3</td>
<td>58</td>
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<td>8</td>
<td>26</td>
<td>33</td>
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<tr>
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<td>9</td>
<td>10</td>
<td>3</td>
<td>7</td>
<td>10</td>
<td>5</td>
<td>7</td>
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<tr>
<td>Totals</td>
<td>287</td>
<td>178</td>
<td>35</td>
<td>166</td>
<td>147</td>
<td>44</td>
<td>81</td>
</tr>
<tr>
<td>% Total patients in interval</td>
<td>57</td>
<td>36</td>
<td>7</td>
<td>47</td>
<td>41</td>
<td>12</td>
<td>41</td>
</tr>
</tbody>
</table>

*Deaths and losses to follow-up are excluded in the interval of their occurrence.

Removals for cause (reoperations) are tallied as treatment failures (FC III & IV) in the intervals of occurrence and subsequently excluded.

---

**Figure 4**

Percent of patients in various functional classes with time. Before operation all are in FC III and IV. After operation most patients remain in FC I and II (75% of cumulative total at 3-4 years). The values are based on living and traced patients in each interval (deaths and losses to follow-up excluded). Reoperation patients were classed as treatment failures (FC III and IV) and excluded from later intervals.

**Figure 5**

The percent of involved (●) and treated (○) vessels for each year of the study is shown above. The proportion of involved vessels/vessels at risk increased in the study population with time because more patients with multiple vessel disease were treated. The proportion of involved vessels which were grafted increased substantially after 1971 because more complete revascularization of obstructed arteries was performed as a matter of policy.
follow-up of persons after the first appearance of angina and these data suggest a more favorable prognosis. Frank et al.\textsuperscript{23} reported 275 such individuals from the Health Insurance Plan of Greater New York with a 4.5 year survival estimate of 82\%, and Kannel and Feinlieb\textsuperscript{24} in the Framingham study showed four-year survival rate of 95\% for men with uncomplicated angina and 81\% for men with angina and previous myocardial infarction. A lower mortality rate might reasonably be expected among these patients who were community-based and not under treatment in a hospital. Also, it has been recognized for some time that patients with typical angina pectoris may have normal coronary arteries,\textsuperscript{23, 24, 25} the incidence of which may be as high as 19\%.\textsuperscript{26} Patients with typical angina pectoris and normal coronary arteries have a benign course\textsuperscript{26, 27} and their life expectancy is no different from the general population.\textsuperscript{28} Since coronary arteriography was not obtained in the studies previously mentioned,\textsuperscript{21, 22} it seems likely that some of the patients included did not have obstructive coronary artery disease and its generally unfavorable prognosis.

Other recent reports describe the survival experience of patients treated nonsurgically following angiographic documentation of coronary artery disease. Frieseiger et al.\textsuperscript{29} from the Johns Hopkins Hospital and Bruschke et al.\textsuperscript{30} from the Cleveland Clinic, have reported such groups which, although differing somewhat in numbers and mean age of patients and in methods of angiographic scoring of coronary lesions, are remarkably similar to one another in terms of the proportion of involved vessels and four-year survival rates. The four-year survival rate in the Johns Hopkins study was 75\% while in the Cleveland Clinic experience it was 69\%. Our analysis of these data show that the difference in rates is not statistically significant.

We have systematically excluded from our study patients with unstable angina, valvular heart disease, clinical congestive heart failure requiring therapy, and acute-phase myocardial infarction, and have thus obtained a relatively good-risk group. Both the Cleveland Clinic and the Johns Hopkins study either may have contained or did contain numbers of these high risk patients. Thus a comparison of survival between our surgical and their nonsurgical patients is probably not valid. Discrepancies between treatment groups, such as those noted above, are the reason why comparisons of retrospective analyses of treatment are so difficult. A wholly valid comparison is impossible because of biased and insufficient data and prospective randomized studies of surgical versus nonsurgical treatment are required to insure comparability of treatment groups.

The severity of coronary artery disease is an important factor in the prognosis of nonsurgical patients. For example, in the Johns Hopkins study prognosis was more accurately assessed by the severity of arteriographic changes than by clinical parameters. Moreover, Oberman and co-workers,\textsuperscript{31} reporting from the University of Alabama on the course of 148 nonsurgical patients with angiographically demonstrated 50\% or more obstruction of major coronary arteries, found by life-table estimate that while 95\% of patients with single vessel disease survived two years, only 70\% of those with multiple vessel disease survived as long. The Cleveland Clinic study also described striking differences in survival among nonsurgical patients with one-, two-, or three-vessel involvement. The survival experience of our surgical patients according to number of vessels involved is shown in figure 3. The differences in long term survival after operation for patients with one, two, or three vessels involved are small.

The excellent prognosis for survival in patients with single vessel disease has led some to question the need for surgical therapy in these individuals.\textsuperscript{31, 32} Surgical patients with single vessel disease in our study had an operative mortality rate of 0.9\% and a four-year survival rate of 96\%. Our study suggests that the role of surgical therapy in these patients should not be prematurely discounted because the prognosis of surgical patients compares favorably with that of nonsurgical patients, and because the severity of disabling angina was consistently reduced postoperatively.

There are obvious limitations in determining the benefits of surgery by noting a reduction in angina because of the highly subjective nature of this type of evaluation. However, up to now, the main purpose of surgery has been the relief of anginal pain. Previous reports from this\textsuperscript{19} and other institutions\textsuperscript{33, 34, 35} that approximately 90\% of patients experience a reduction in angina for more than a year after bypass grafting are further substantiated here. In addition, clinical improvement was found to be fairly durable: of the patients followed for at least four years, 75\% continued to remain in FC I and II. It seems likely that further improvement in late results will be noted in the future. The more complete revascularization performed in recent years has been associated with proportionately more early FC I results and fewer FC III and IV results. Thus, since the recent cohorts are improved over the earlier ones, the proportion of long term good results can be expected to increase with time.

Previous studies\textsuperscript{36, 37, 38} have demonstrated a close relationship between patent grafts and objective evidence of increased exercise capacity. In the present study, a highly significant relationship ($P < 0.001$)
was also found between graft patency and clinical result during the first year after operation. \textit{Graft patency rates}, like survival rates or clinical results, appear to be time-related. While the patency rates of grafts studied in the first postoperative month are usually 90\% or better,\textsuperscript{38-40} a further attrition of approximately 20\% during the first year after operation has been noted.\textsuperscript{41} Current information suggests, however, that there is little further attrition up to three years.\textsuperscript{43} The graft patency rate in this series was 76\% at a mean time of six months after operation. This figure is consistent with the above observations despite the inclusion of disporportionate numbers of patients with poor clinical results and occluded grafts in the restudy group. However, the slow accumulation of poor (FC III and IV) results with time also suggests that a further rapid attrition of patent grafts probably does not occur up to four years.

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