Survival 15 to 20 Years After Coronary Bypass Surgery for Angina

SHAHBUDIN H. RAHIMTOOLA, MB, FRCP, FACC,* CINDY L. FESSLER, BS,
GARY L. GRUNKEMEIER, PhD, ALBERT STARR, MD, FACC
Portland, Oregon

Objectives. The aim of this study was to determine the 15- to
20-year outcome of coronary bypass surgery in patients with
angina.

Background. Coronary bypass surgery has been performed for
>20 years; we need to know the expected outcome of a very
long-term follow-up.

Methods. Using actuarial techniques, we determined the out-
come of coronary bypass surgery performed for chronic stable
and unstable angina in 7,529 patients from 1969 to 1988.

Results. The 5-, 10-, 15-, and 20-year survival rates (mean ±
SE) were 88 ± 1, 73 ± 1, 53 ± 1 and 38 ± 3%, respectively, for
the whole group. Compared with patients operated on in 1974 to
1988 (n = 7,026), patients operated in 1969 to 1973 (n = 503)
were younger and had less coronary artery disease but had a
higher operative mortality rate and a shorter long-term survival
time; 15- and 20-year survival of the 1969 to 1973 cohort was 47 ±
2% and 33 ± 5%, respectively. The 1974 to 1988 cohort of
patients had a 2.1% operative mortality rate and a 10- and
15-year survival probability of 74 ± 1% and 55 ± 2%, respec-
tively. For 2,128 patients with "normal" left ventricular function,
the 10- and 15-year survival probability was 82 ± 1% and 64 ±
3%, respectively, and for 2,413 patients with "abnormal" left
ventricular function, it was 66 ± 1% and 47 ± 3%, respectively
(p < 0.0001); for men it was 74 ± 1% and 56 ± 2%, respectively,
and for women, 70 ± 2% and 52 ± 5%, respectively, p < 0.05.
The actuarial percentages of reoperation and myocardial infar-
cion at 15 years were 33 ± 2% and 26 ± 2%, respectively; these
values did not differ significantly between men and women. There
was a significant (p < 0.001) difference between men and women
in angina status; 81% of the men versus 74% of the women had
no angina or mild angina at the most recent follow-up study.

Conclusions. Coronary bypass surgery is an effective form of
therapy for angina (for 15 to 20 years) in both men and women.
(J Am Coll Cardiol 1993;21:151-7)

Coronary bypass surgery has been performed for >20 years
and has been shown to relieve angina and myocardial
ischemia more effectively than medical therapy in patients
with chronic stable and unstable angina (1-3). It has also
been shown to prolong life at the 5-year and 10-year
follow-up periods in selected subgroups of patients (4-8).
Most long-term follow-up studies have provided data up to
10 years postoperatively (4-11). However, Lawrie and co-
workers (12) recently presented the 20-year results of pa-
tients operated on between 1968 and 1975. We have previ-
ously documented that results of surgery up to 4 years of
follow-up study were worse in those operated on in 1969 to
1973 than in those operated on in 1974 to 1979 (13).

The purpose of this study was to analyze the results of
coronary bypass surgery at a single institution over a very
long term to 1) obtain 15- to 20-year follow-up data; 2) assess
whether the long-term results of surgery performed in 1974
and later were better than those of surgery performed in 1969
to 1973, and 3) evaluate the long-term survival and functional
results of those operated on from 1974 to 1988 because these
data might be more applicable to the expected results in
patients operated on in the more recent era of coronary
bypass surgery.

Methods

From January 1969 through December 1988, isolated
coronary bypass surgery was performed in 9,128 patients at
the Heart Institute, St. Vincent Hospital Medical Center.
There were 256 operative deaths (that is, within 30 days of
operation, including death after discharge or later than 30
days if a direct result of the operation) for an operative
mortality rate of 2.8%. Of the 9,128 patients, 7,529 under-
go coronary bypass surgery primarily for angina and were
classified as having chronic stable or unstable angina accord-
ing to criteria established in 1979 (9). These patients with
angina are described in this report.

Angina was defined in the standard manner. We included
two clinical subgroups in the category of patients with
unstable angina (9): 1) patients with pain at rest, and
2) patients with pain of recent onset. The rationale for
including these clinical subgroups, their definition, medical
treatment received, definition of "abnormal" left ventricular
function and surgical techniques have been described in
detail previously (9); some of these data will be summarized

*Present address and address for correspondence: Shahbudin H. Rahim-
tools, MD, Griffith Center, Division of Cardiology, University of Southern
California, 2025 Zonal Avenue, Los Angeles, California 90033.

©1993 by the American College of Cardiology
0735-1097/93/0600-00
here. However, patients who had angina soon after myocardial infarction are excluded because they were recently described in detail elsewhere (14).

Patients with anginal pain at rest had pain that was severe enough to warrant admission to the coronary care unit. They invariably had at least one documented episode of pain that was accompanied by transient electrocardiographic (ECG) changes; acute myocardial infarction was excluded (9). Pain of recent onset that was progressive was considered to be present when anginal pain had started during the month before operation or the pattern of angina changed suddenly in that month and was of increasing severity, duration or frequency despite medical treatment (9). Left ventricular function was considered abnormal if left ventricular end-diastolic pressure was ≥15 mm Hg or if left ventricular wall motion was assessed as abnormal on subjective analysis of the left ventriculogram (9).

In the last 5 years, a progressively determined effort was made to use the internal mammary artery as the conduit for the graft whenever it was feasible to do so. A revascularization index was calculated (9) as the ratio of the number of vessels grafted to the number of obstructed arteries identified on coronary arteriography or by surgical examination. Coronary arteries with a reduction in lumen diameter of ≥50% were considered to be obstructed; this reduction corresponds to a reduction of ≥75% in the cross-sectional area of the arterial lumen.

Data were entered into a computer and, if there was a concern about the data, the original data were reviewed. Many angiograms were not available for review at the time of data entry into the computer, primarily because they had been returned to the referring cardiologist; thus, details could not be confirmed (9). Therefore, when the patients were classified on the basis of the number of vessels involved, the number of patients did not equal the total number of patients operated on. In a small number of patients, the left ventricular angiograms could not be evaluated primarily because of an arrhythmia that occurred during the ventriculographic study. Therefore, the sum of the patients with "normal" or "abnormal" function does not equal the total number of patients (9).

Follow-up questionnaires were sent annually to the patients. More intense follow-up study with questionnaires, review of hospital records and telephone interviews with patients, family or physicians was provided as needed. Diagnosis of myocardial infarction after hospital discharge was made by review of hospital records if patients gave a history of myocardial infarction or of hospital admission. Standard historical, ECG and enzymatic criteria were used in making this diagnosis. Current follow-up study (January 1990 to March 1991) was complete for 89% of all patients: 89%, 87%, 90% and 90% for patients operated on during 1969 to 1973, 1974 to 1978, 1979 to 1983 and 1984 to 1988, respectively. In addition, data from previous follow-up contacts were usually available for the other 11% of patients as well, that is, those in whom follow-up was not available in the period from January 1990 to March 1991.

**Table 1. Age and Gender Distribution and Frequency of Risk Factors in Various Time Intervals**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr) 60.7 ± 9.9</td>
<td>53.7 ± 8.3</td>
<td>61.1 ± 9.9</td>
</tr>
<tr>
<td>Age group (yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤65</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>66 to 69</td>
<td>58</td>
<td>75</td>
</tr>
<tr>
<td>≥70</td>
<td>29</td>
<td>9</td>
</tr>
<tr>
<td>Men</td>
<td>78</td>
<td>85</td>
</tr>
<tr>
<td>Diabetes</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Systemic hypertension</td>
<td>42</td>
<td>24</td>
</tr>
<tr>
<td>Family history of CAD</td>
<td>44</td>
<td>50</td>
</tr>
<tr>
<td>Smoking Currently</td>
<td>30</td>
<td>44</td>
</tr>
<tr>
<td>Previously</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td>41</td>
<td>46</td>
</tr>
</tbody>
</table>

*Early cohort versus late cohort. Values are presented as mean ± SD or percent of cohort. CAD = coronary artery disease.

**Statistical Methods.** Survival probabilities and standard errors were estimated by the life-table method (15). Actuarial curves were compared with the Lee-Desu statistic (16). Chi-square statistics were used to compare categoric variables and analysis of variance for continuous variables. Two-tailed tests were used, and a p value > 0.05 was not considered statistically significant.

**Results**

**Preoperative Findings**

The age and gender distribution and frequency of various risk factors for the three patient cohorts (the total group operated on in 1969 to 1988 and those operated on in 1969 to 1973 or in 1974 to 1988) are shown in Table 1. Type of angina, previous coronary bypass surgery, extent of coronary artery disease, left ventricular function, number of grafts and revascularization index for the three groups are shown in Table 2.

**Results at 20 Years**

**Total patient cohort (1969 to 1988).** For the total cohort of 7,529 patients, the operative mortality rate was 2.4%. The 20-year survival probability (mean ± SE) was 38 ± 3% (Tables 3 and 4; Fig. 1). The mortality rate averaged 3.2%/year; in the 1st 10 years it averaged 2.7%/year and in years 11 to 20 it averaged 3.5%/year.

**Early patient cohort (1969 to 1973).** The operative mortality rate was 7.0% and the 20-year survival probability was
33 ± 3%; these rates were worse than those for the total cohort of patients. Early (1969 to 1973) versus late (1974 to 1988) patient cohorts. The operative mortality and late survival probability (5-, 10-, and 15-year survival) for the 1974 to 1988, 1979 to 1983 and 1984 to 1988 cohorts were similar (Tables 3 and 4) and thus are combined into a single cohort 1974 to 1988.

The operative mortality rate for the 1974 to 1988 cohort of patients was 2.1% (vs. 7.0% for the 1969 to 1973 cohort, p < 0.0001). The reduction in operative mortality rate and improved 15-year survival probability occurred despite the fact that in the period 1974 to 1988, as compared with the period 1969 to 1973, the patients were older (61.1 ± 9.9 vs. 53.7 ± 8.3 years, p < 0.0001) and had a higher incidence of disease involving three or more vessels or left main coronary artery (67% vs. 42%, p < 0.0001) (Tables 1 and 2).

Late patient cohort (1974 to 1988). Operative mortality. One hundred forty-seven of the 7,026 patients in the late cohort died within 1 month of operation for an overall operative mortality rate of 2.1%. Operative mortality for patients in various subgroups characterized by extent of coronary artery disease, left ventricular function, gender, age and type of angina is shown in Table 5.

Actuarial survival. The long-term survival data, including operative mortality, for all patients in the late cohort are shown in Figure 2. The survival data for patients classified by left ventricular function, gender and age are shown in Figures 3, 4 and 5, respectively. Survival probabilities in various subgroups of patients by extent of coronary artery disease, left ventricular function, gender, age and type of angina are shown in detail in Table 6.

Reoperation, late myocardial infarction and angina status. The incidence of reoperation and of late myocardial infarction is shown in Figures 6 and 7. The reoperation

Table 2. Distribution of Various Characteristics During the Different Time Periods

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Angina</td>
<td>74</td>
<td>83</td>
<td>74</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Unstable</td>
<td>26</td>
<td>17</td>
<td>26</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Prior coronary bypass surgery</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>&lt; 0.03</td>
</tr>
<tr>
<td>Coronary arteries with disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>21</td>
<td>12</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>37</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>≥3</td>
<td>33</td>
<td>35</td>
<td>35</td>
<td>NS</td>
</tr>
<tr>
<td>Left main artery</td>
<td>12</td>
<td>7</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>LV end-diastolic pressure</td>
<td>21</td>
<td>31</td>
<td>21</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>LV wall motion abnormalities</td>
<td></td>
<td></td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>LV function</td>
<td>47</td>
<td>45</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>53</td>
<td>55</td>
<td>53</td>
<td>NS</td>
</tr>
<tr>
<td>Abnormal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td></td>
<td>14</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>45</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>≥3</td>
<td>54</td>
<td>16</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Revascularization index</td>
<td>0.91</td>
<td>0.84</td>
<td>0.92</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

*Early cohort vs. late cohort. Data are presented as percent of cohort or as an index. LV = left ventricular.

Table 3. Operative Mortality Over 20 Years and in Various Time Periods

<table>
<thead>
<tr>
<th>Year of Operation</th>
<th>Patients (no.)</th>
<th>Operative Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>1969 to 1988</td>
<td>2,529</td>
<td>182</td>
</tr>
<tr>
<td>1969 to 1973</td>
<td>350</td>
<td>35</td>
</tr>
<tr>
<td>1974 to 1988</td>
<td>7,026</td>
<td>147</td>
</tr>
<tr>
<td>1974 to 1978</td>
<td>1,881</td>
<td>53</td>
</tr>
<tr>
<td>1979 to 1983</td>
<td>2,437</td>
<td>45</td>
</tr>
<tr>
<td>1984 to 1988</td>
<td>2,708</td>
<td>49</td>
</tr>
</tbody>
</table>

*p < 0.0001 between 1969 to 1973 versus total 1974 to 1988 group and each subgroup.
and myocardial infarction rates averaged 0.6%/year and 1.2%/year for 
postoperative years 1 through 5; 2.5%/year and 3.0%/year for 
postoperative years 6 through 10; and 3.5%/year and 2.0%/year for 
postoperative years 11 through

Figure 2. Late cohort. Actuarial survival of all patients operated on 
from 1974 to 1988. Abbreviations as in Figure 1.

and myocardial infarction rates averaged 0.6%/year and 1.2%/year for 
postoperative years 1 through 5; 2.5%/year and 3.0%/year for 
postoperative years 6 through 10; and 3.5%/year and 2.0%/year for 
postoperative years 11 through

Figure 2. Late cohort. Actuarial survival of all patients operated on 
from 1974 to 1988. Abbreviations as in Figure 1.

15, respectively. The incidence of reoperation at 10 years for 
men and women was 16 ± 1 and 18 ± 2%, and at 15 years it 
was 34 ± 2 and 31 ± 4%, respectively (p = 0.1). The 
incidence of myocardial infarction for men and women at 10 
years was 16.1% and 16.2%, and at 15 years it was 26 ± 2 
and 26 ± 4%, respectively (p = 0.6).

At the end of the follow-up period, 58% of patients were 
totally asymptomatic, and 22% were minimally symptomatic; 15% had angina with ordinary exertion, and 6% were 
disabled by angina that occurred with mild exertion. There 
was a significant difference (p < 0.001) between men and 
women in angina status: 66% of men were in New York Heart 
Association functional class I, 21% in class II, 13% in class III 
and 5% in class IV, compared with 48% of women in class I, 26% in class II, 15% in class III and 8% in class IV.

Discussion

Our data show that 1) the overall 20-year survival probability 
after coronary bypass surgery is 38%; 2) those operated 
on in 1969 to 1973 (early cohort) had a 15- and 20-year 
survival probability of 47% and 33%, respectively; 3) the

Figure 4. Late cohort. Actuarial survival by gender for patients 
operated on from 1974 to 1988. Abbreviations as in Figure 1.
7,026 patients operated on in 1974 to 1988 (late cohort) had an operative mortality rate of 2.1% and a 15-year survival probability of 55%. In the follow-up years 1 to 5, 6 to 10 and 11 to 15, the annual reoperation rate was 0.6%, 2.5%, and 3.5%, respectively, and that of myocardial infarction was 1.2%, 2.0%, and 2.0%, respectively. Those with abnormal left ventricular function, more vessels with disease and older age had a lower 15-year survival probability; and 4) women, when compared with men, had a higher operative mortality (2.8 vs. 1.9%), lower 15-year survival probability (52 vs. 56%) and a lower incidence of non-mild angina (74 vs. 81%). However, the incidence at 15 years of reoperation (31% and 34%) and of myocardial infarction (26% and 26%) was similar.

There are no 20-year data in a comparable group of patients treated medically with which to compare the present results. The large randomized trials of coronary bypass surgery have provided very useful data (3,6–8). However, several problems (4,17,18) and, in particular, the large number of patients who have crossed over from the medical to the surgical group at 10 years (3,4–8,17,19) make the comparison of surgical and medical treatment difficult. Thus, data >10 years after surgery will probably be obtained only from good, large data bases.

In our study during the 20-year period, operative mortality initially was higher, and in the last 10 years it was ≤2%. As with valve surgery (19), operative mortality with coronary bypass surgery is related to overall operative expertise, health care delivery factors and patient-related factors. The high operative mortality in the 1st 5 years of this study was probably related to the learning phase of this procedure. Over the next 15 years, despite the patients' older age and

---

**Figure 5.** Late cohort. Actuarial survival by age group for patients operated on from 1974 to 1988. Abbreviations as in Figure 1.

**Table 6.** Late Survival Probabilities for the Late (1974 to 1988) Cohort Expressed as Percentages (mean ± SE)

<table>
<thead>
<tr>
<th>Survival (%)</th>
<th>5 Years</th>
<th>10 Years</th>
<th>15 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>88 ± 1</td>
<td>74 ± 1</td>
<td>55 ± 2</td>
</tr>
<tr>
<td>1-vessel CAD</td>
<td>93 ± 1</td>
<td>82 ± 2</td>
<td>67 ± 5*</td>
</tr>
<tr>
<td>2-vessel CAD</td>
<td>92 ± 1</td>
<td>79 ± 2</td>
<td>63 ± 4*</td>
</tr>
<tr>
<td>≥3-vessel CAD</td>
<td>87 ± 1</td>
<td>70 ± 1</td>
<td>49 ± 3*</td>
</tr>
<tr>
<td>Left main CAD</td>
<td>85 ± 2</td>
<td>71 ± 3</td>
<td>53 ± 5*</td>
</tr>
</tbody>
</table>

**Survival t9M**

<table>
<thead>
<tr>
<th>Survival (%)</th>
<th>10 to 15</th>
<th>20 to 25</th>
<th>25 to 30</th>
<th>30 to 35</th>
<th>35 to 40</th>
<th>40 to 45</th>
<th>45 to 50</th>
<th>50 to 55</th>
<th>55 to 60</th>
<th>60 to 65</th>
<th>65 to 70</th>
<th>70 to 75</th>
<th>75 to 80</th>
<th>80 to 85</th>
<th>85 to 90</th>
<th>90 to 95</th>
<th>95 to 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>44 ± 2</td>
<td>39 ± 2</td>
<td>35 ± 2</td>
<td>32 ± 2</td>
<td>29 ± 2</td>
<td>26 ± 2</td>
<td>23 ± 2</td>
<td>20 ± 2</td>
<td>17 ± 2</td>
<td>14 ± 2</td>
<td>11 ± 2</td>
<td>8 ± 2</td>
<td>5 ± 2</td>
<td>2 ± 2</td>
<td>1 ± 2</td>
<td>0 ± 2</td>
<td>0 ± 2</td>
</tr>
<tr>
<td>1-vessel CAD</td>
<td>54 ± 2</td>
<td>49 ± 2</td>
<td>44 ± 2</td>
<td>40 ± 2</td>
<td>36 ± 2</td>
<td>32 ± 2</td>
<td>29 ± 2</td>
<td>26 ± 2</td>
<td>23 ± 2</td>
<td>20 ± 2</td>
<td>17 ± 2</td>
<td>14 ± 2</td>
<td>11 ± 2</td>
<td>8 ± 2</td>
<td>5 ± 2</td>
<td>2 ± 2</td>
<td>1 ± 2</td>
</tr>
<tr>
<td>2-vessel CAD</td>
<td>52 ± 2</td>
<td>47 ± 2</td>
<td>42 ± 2</td>
<td>38 ± 2</td>
<td>34 ± 2</td>
<td>30 ± 2</td>
<td>26 ± 2</td>
<td>23 ± 2</td>
<td>20 ± 2</td>
<td>17 ± 2</td>
<td>14 ± 2</td>
<td>11 ± 2</td>
<td>8 ± 2</td>
<td>5 ± 2</td>
<td>2 ± 2</td>
<td>1 ± 2</td>
<td></td>
</tr>
<tr>
<td>≥3-vessel CAD</td>
<td>49 ± 2</td>
<td>44 ± 2</td>
<td>39 ± 2</td>
<td>35 ± 2</td>
<td>31 ± 2</td>
<td>28 ± 2</td>
<td>25 ± 2</td>
<td>22 ± 2</td>
<td>19 ± 2</td>
<td>16 ± 2</td>
<td>13 ± 2</td>
<td>10 ± 2</td>
<td>7 ± 2</td>
<td>4 ± 2</td>
<td>2 ± 2</td>
<td>1 ± 2</td>
<td></td>
</tr>
<tr>
<td>Left main CAD</td>
<td>46 ± 2</td>
<td>41 ± 2</td>
<td>36 ± 2</td>
<td>32 ± 2</td>
<td>28 ± 2</td>
<td>24 ± 2</td>
<td>20 ± 2</td>
<td>17 ± 2</td>
<td>14 ± 2</td>
<td>11 ± 2</td>
<td>8 ± 2</td>
<td>5 ± 2</td>
<td>2 ± 2</td>
<td>1 ± 2</td>
<td>0 ± 2</td>
<td>0 ± 2</td>
<td></td>
</tr>
</tbody>
</table>

**Abnormal LV function**

<table>
<thead>
<tr>
<th>Survival (%)</th>
<th>5 Years</th>
<th>10 Years</th>
<th>15 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>84 ± 1</td>
<td>71 ± 4</td>
<td>59 ± 6</td>
</tr>
<tr>
<td>1-vessel CAD</td>
<td>89 ± 3</td>
<td>72 ± 3</td>
<td>54 ± 6</td>
</tr>
<tr>
<td>2-vessel CAD</td>
<td>89 ± 2</td>
<td>72 ± 3</td>
<td>54 ± 6</td>
</tr>
<tr>
<td>≥3-vessel CAD</td>
<td>82 ± 1</td>
<td>64 ± 2</td>
<td>42 ± 4</td>
</tr>
<tr>
<td>Left main CAD</td>
<td>82 ± 3</td>
<td>65 ± 4</td>
<td>50 ± 6</td>
</tr>
</tbody>
</table>

**Gender**

<table>
<thead>
<tr>
<th>Survival (%)</th>
<th>5 Years</th>
<th>10 Years</th>
<th>15 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>89 ± 1</td>
<td>74 ± 1</td>
<td>56 ± 2</td>
</tr>
<tr>
<td>Female</td>
<td>87 ± 1</td>
<td>70 ± 2</td>
<td>52 ± 5</td>
</tr>
</tbody>
</table>

**Age group (yrs)**

<table>
<thead>
<tr>
<th>Survival (%)</th>
<th>5 Years</th>
<th>10 Years</th>
<th>15 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤45</td>
<td>92 ± 2</td>
<td>83 ± 3</td>
<td>56 ± 9</td>
</tr>
<tr>
<td>46 to 54</td>
<td>94 ± 1</td>
<td>84 ± 1</td>
<td>69 ± 3</td>
</tr>
<tr>
<td>55 to 64</td>
<td>91 ± 1</td>
<td>75 ± 1</td>
<td>57 ± 3</td>
</tr>
<tr>
<td>65 to 74</td>
<td>84 ± 1</td>
<td>64 ± 2</td>
<td>40 ± 5</td>
</tr>
<tr>
<td>≥75</td>
<td>71 ± 3</td>
<td>41 ± 5</td>
<td>#</td>
</tr>
</tbody>
</table>

**Angina**

<table>
<thead>
<tr>
<th>Survival (%)</th>
<th>5 Years</th>
<th>10 Years</th>
<th>15 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable</td>
<td>88 ± 1</td>
<td>73 ± 1</td>
<td>55 ± 2</td>
</tr>
<tr>
<td>Unstable</td>
<td>88 ± 1</td>
<td>75 ± 2</td>
<td>59 ± 4</td>
</tr>
</tbody>
</table>

*p < 0.0001 for increasing number of vessels with disease. *p < 0.0001 for abnormal versus normal left ventricular function. #1± 14 years. *p < 0.0001 for increasing number of vessels with disease. *p < 0.05 for men versus women. #Too few patients at risk. LV = left ventricular.
greater number of vessels with disease in the patients, operative mortality decreased in the hands of a relatively constant, experienced and homogeneous group of surgeons. Nevertheless, patients with abnormal left ventricular function, more vessels with severe disease, women and older patients had a higher operative mortality rate (Table 5).

The present report extends our early report (13), which had shown that the short-term survival probability of patients operated on in the “learning phase” (early cohort, 1969 to 1973) was worse than for those in the late cohort (1974 to 1978). Patients in the early cohort had a poorer long-term survival rate than patients in the total cohort or in the late cohort. Even in the late cohort, the 15-year survival probability was related to patient-related factors; those with abnormal left ventricular function and those with a greater number of diseased vessels had a worse 15-year survival probability than those without. Previously, we and others (10,11) had demonstrated a worse survival probability for patients ≥65 years old than for younger patients and this observation was also demonstrated in the present study. We have previously shown (11) that the lower 10-year survival probability of those ≥65 years old can be partly explained by the expected lower survival probability of the older patient.

The 20-year survival probability of the early cohort was 33 ± 3% and that of the total cohort was 38 ± 3%. The 15-year survival probability of the late cohort was 55 ± 2% and was significantly better than the 47 ± 2% of the early cohort. This improvement may be expected to persist up to 20 years and may be more relevant to the expected survival of patients operated on in the more recent era.

The 20-year survival probability and outcome of the early (1969 to 1973) cohort is similar to that reported by Lawrie and co-workers (12) for their patients operated on between 1968 and 1975. Because of the “high” rate of graft occlusion up to 10 years after surgery (20) and progression of disease in the native coronary vessels, it had been believed that the results of coronary bypass surgery would markedly deteriorate after the 10-year follow-up period. This has happened but only to a limited extent. In our total cohort (1969 to 1988), the average annual mortality rate in the 11 to 20-year postoperative period was 3.5%/year and in the 1st 10 years it averaged 2.7%/year. Furthermore, the incidence of reoperation and of myocardial infarction increased after 10 years (Fig. 6 and 7). However, the probability of surviving 20 years after surgery is 38%, and most of the survivors had no angina or only minimal angina. The data of Lawrie et al. (12) are similar: at 20 years, 20% to 40% of patients were alive, depending on the extent of coronary disease, and 38% had had a reoperation. The higher mortality rate after 10 years can be partly explained by the late effects of preoperative left ventricular dysfunction and perioperative myocardial infarction; the aging of the patients; operative mortality associated with reoperation; occurrence of late myocardial infarction, and progression of coronary and graft vessel disease. However, the 15 to 20-year results are still very good for several reasons. It is likely that the high attrition rates of saphenous vein grafts up to 10 years postoperatively demonstrated in the early studies (19) were influenced by the learning phase of the procedure. Advances have included atraumatic harvesting of the vein, use of perioperative papaverine, avoidance of high distensing pressures, construction of proximal anastomoses first, greater use of the saphenous vein below the knee or of the short saphenous vein (20) and better techniques of myocardial protection, which would have favorably influenced the results of those operated in the mid- and late 1970s.

In the 1980s, use of antiplatelet drugs, which has improved graft patency rates (21,22), control of hyperlipidemia (23) and use of the internal mammary artery as a graft conduit (24) exerted a further beneficial effect on the results of surgery. Moreover, other studies showed a better graft patency rate than the early studies. For example, the data of Lawrie et al. (12) showed graft patency rates of 68% at 6 to 10 years and of 46% at 16 to 20 years. Furthermore, graft patency rate is highest for the important left anterior descending coronary artery and lowest for the left circumflex coronary artery (25), which would favorably influence a larger amount of myocardium at risk (26,27). In addition, one or two partially obstructed or nonobstructed patent grafts may be able to revascularize adequate amounts of myocardium either directly or through collateral channels (28), which would favorably influence survival and occurrence of late myocardial infarction or angina. Furthermore, the increasing incidence of reoperation would also improve long-term survival.

To summarize, the results of coronary bypass surgery up to 20 years later are better than the predictions based on early studies of graft occlusion for several reasons. 1) In those early studies the surgical techniques were probably not optimal and some of the patients studied may have been selected. 2) Increasing use has been made of the internal mammary artery as a graft conduit. 3) Postoperative management has improved. 4) Graft occlusion does not necessarily mean no myocardial blood flow. As long as some blood flow persists either through a partially occluded vessel or collateral vessels, or both, myocardial and cardiac function may be preserved. 5) Each coronary artery should not be assigned an equal degree of importance; thus, graft occlusions to different coronary arteries may have different clinical consequences. All of these are possible factors that have contributed to a good outcome up to 20 years after surgery. However, it needs to be emphasized that our patients did not undergo routine postoperative graft and coronary angiography either initially or sequentially.

Although women experienced a statistically significant higher operative mortality rate, lower long-term survival probability and less relief of angina than did men, the differences were small and probably not clinically meaningful. Therefore, one should not deny or restrict the use of coronary bypass surgery in women provided the usual
indications for surgery are present; thus one can avoid "the Yentl syndrome" (29).

References


