The Long-Term Follow-Up of Patients Undergoing Saphenous Vein Bypass Surgery

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SUMMARY
The results of the first 400 consecutive patients (335 males, 65 females; mean age 52 years) having saphenous vein-coronary artery graft surgery at Stanford between October 1968 and January 1972 were reviewed. Through patient or physician contact, 100% follow-up period was achieved in the 375 patients surviving surgery. The mean follow-up period was 9.9 months, with the range 2 to 40 months. The operative mortality was 6.5%; patients having this surgery electively had a 0.8% mortality. The major cause of operative mortality was myocardial infarction (9 patients) and congestive heart failure and cardiogenic shock (10 patients). Predominant postoperative morbidity was due to pulmonary emboli (17 patients) and intrathoracic hemorrhage requiring thoracotomy (11 patients). The use of anticoagulants in the early postoperative period has reduced the incidence of pulmonary emboli. Angina was completely relieved in 79% (295 patients), 237 of whom had returned to full time employment. However, another 12% either were unchanged from their preoperative symptomatic state or incurred major late complications. This group includes 15 patients (3.9%) who had late deaths from cardiovascular causes. Another 23 patients had late, nonfatal myocardial infarctions. Using as a data base the degree of preoperative congestive heart failure, the extent of electrocardiographic changes and the presence of mitral regurgitation, a prognostic preoperative clinical risk-benefit guideline has been developed for use in any patient undergoing saphenous vein coronary artery graft surgery.

Additional Indexing Words:
Multivariable analysis Coronary artery disease Congestive heart failure
Angina pectoris Myocardial infarction

While aorto-coronary saphenous vein bypass surgery has been documented to relieve angina pectoris, 1-3 the long-term effects, as evaluated by patient survival, have yet to be determined. Only the long-term results of a double-blind, randomized study employing this operative procedure versus standard medical therapy will ultimately clarify its impact as treatment for ischemic heart disease. 4 As an interim measure, we have critically analyzed the results of the first 400 aorto-coronary saphenous vein bypass procedures performed at Stanford University Hospital. Several statistical approaches have been utilized to evaluate patient survival and symptomatic results. Also, a statistical technique has been devised which potentially permits the prediction of a favorable or unfavorable surgical outcome for any specific patient, based on the use of three preoperative variables. Thus, the results of this study may be useful as a guide to the clinician as he selects patients with a complicated clinical course for the operation.

Materials and Methods
The first 400 consecutive patients undergoing saphenous vein coronary artery bypass surgery at the Stanford University Hospital between October 1968 and January 1972 have been studied. Three hundred and thirty five of these patients were male, and 65 were female. The mean age was 52 years, with the range being 26 to 79 years. The patient's medical record was reviewed, and the 18 preoperative variables listed in...
Table 1

Preoperative Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age at time of operation</td>
<td></td>
</tr>
<tr>
<td>2. Sex</td>
<td></td>
</tr>
<tr>
<td>3. Number of bypass grafts placed</td>
<td></td>
</tr>
<tr>
<td>4. Duration of cardiopulmonary bypass during operation</td>
<td></td>
</tr>
<tr>
<td>5. Preoperative NYHA classification</td>
<td></td>
</tr>
<tr>
<td>6. Years of known heart disease</td>
<td></td>
</tr>
<tr>
<td>7. Degree of angina pectoris clinically [0–4]</td>
<td></td>
</tr>
<tr>
<td>0 = no angina</td>
<td></td>
</tr>
<tr>
<td>1 = mild, noncapacitating angina pectoris</td>
<td></td>
</tr>
<tr>
<td>2 = moderate angina pectoris</td>
<td></td>
</tr>
<tr>
<td>3 = severe angina pectoris with rest, or nocturnally</td>
<td></td>
</tr>
<tr>
<td>4 = unstable angina pectoris or acute infarction</td>
<td></td>
</tr>
<tr>
<td>8. Number of prior myocardial infarctions</td>
<td></td>
</tr>
<tr>
<td>9. Sum of years since all prior myocardial infarctions</td>
<td></td>
</tr>
<tr>
<td>10. Months since last myocardial infarction</td>
<td></td>
</tr>
<tr>
<td>11. Degree of congestive heart failure clinically [0–4]</td>
<td></td>
</tr>
<tr>
<td>0 = no CHF (LVEDP &lt; 12 mm Hg)</td>
<td></td>
</tr>
<tr>
<td>1 = mild untreated DOE or PND (LVEDP 12–20 mm Hg)</td>
<td></td>
</tr>
<tr>
<td>2 = moderate DOE controlled on medication (LVEDP 12–20 mm Hg)</td>
<td></td>
</tr>
<tr>
<td>3 = severe DOE refractory to therapy (LVEDP &gt; 20 mm Hg)</td>
<td></td>
</tr>
<tr>
<td>4 = acute pulmonary edema (LVEDP &gt; 20 mm Hg)</td>
<td></td>
</tr>
<tr>
<td>12. Degree of clinical shock preoperatively [0–4]</td>
<td></td>
</tr>
<tr>
<td>0 = blood pressure &gt; 120/X</td>
<td></td>
</tr>
<tr>
<td>1 = blood pressure &lt; 100/X with minimal therapy</td>
<td></td>
</tr>
<tr>
<td>2 = blood pressure &lt; 100/X with intensive therapy</td>
<td></td>
</tr>
<tr>
<td>3 = blood pressure &lt; 100/X with adequate perfusion but oliguria</td>
<td></td>
</tr>
<tr>
<td>4 = inadequate perfusion and oliguria refractory to therapy</td>
<td></td>
</tr>
<tr>
<td>13. Number of associated diseased valves judged clinically and/or at catheterization</td>
<td></td>
</tr>
<tr>
<td>14. Extent of electrocardiographic abnormality [0–4]</td>
<td></td>
</tr>
<tr>
<td>0 = normal ECG</td>
<td></td>
</tr>
<tr>
<td>1 = normal ECG, positive (2 mm depression)</td>
<td></td>
</tr>
<tr>
<td>2 = ECG showing prior infarction, bundle branch block, axis deviation, LVH, or nonspecific ST-T changes</td>
<td></td>
</tr>
<tr>
<td>3 = changes in #2, plus acute ischemic ST-T wave changes</td>
<td></td>
</tr>
<tr>
<td>4 = acute myocardial infarction, high degree atioventricular block or ventricular tachyarrhythmias</td>
<td></td>
</tr>
<tr>
<td>15. Number of vessels diseased at angiography (&gt;70% occlusion)</td>
<td></td>
</tr>
<tr>
<td>16. Extent of left ventricular dysfunction by ventriculogram [0–4]</td>
<td></td>
</tr>
<tr>
<td>0 = normal function</td>
<td></td>
</tr>
<tr>
<td>1 = minimal asynergy</td>
<td></td>
</tr>
<tr>
<td>2 = localized segmental contractile abnormalities</td>
<td></td>
</tr>
<tr>
<td>3 = generalized areas of akinesis</td>
<td></td>
</tr>
<tr>
<td>4 = paradoxical motion of portion of left ventricle during systole</td>
<td></td>
</tr>
<tr>
<td>17. Degree of mitral regurgitation by left ventricular angiogram [0–4]</td>
<td></td>
</tr>
</tbody>
</table>

18. Number of associated clinical risk factors (including hypertension, positive family history of heart disease, smoking history, history of a well defined lipid abnormality, presence of diabetes mellitus)

*Catheterization data employed when available.

Abbreviations: NYHA = New York Heart Association; CHF = congestive heart failure; DOE = dyspnea on exertion; PND = paroxysmal nocturnal dyspnea; LVEDP = left ventricular end-diastolic pressure; LVH = left ventricular hypertrophy.

Table 1 was recorded. Data forms for evaluating the postoperative response were sent to each patient's referring physician. The nine postoperative variables considered are listed in Table 2. In those patients for whom physician evaluation was not possible, the patient was contacted directly by telephone and an assessment made of his current clinical status. In this manner, it was possible to obtain follow-up data on all 400 of the patients in the study group.

Operative Technique

The operative technique utilized in this series of 400 patients has been essentially the same. Moderate hypothermia (30–33°C) and electrical fibrillation of the heart have been employed; local hypothermia using 4°C normal saline instilled into the pericardial well has been used in selected circumstances. Aortic cross-clamping has been minimized. Perfusion flow rates have been between 2,000 and 3,000 cc/min. The average pump time for the entire group was 115 min, ranging from 60 to 240 min. Preoperatively and postoperatively, patients were treated with broad spectrum antibiotics. Since March 1971 the patients have received oral anticoagulants for six weeks postoperatively, unless there were some contraindications.

Clinical Variables

Table 1 lists the 18 preoperative variables considered; standard definitions were employed unless commented upon. Certain of the postoperative variables presented in Table 2 deserve further comment. The assessment of the degree of angina and the degree of congestive heart failure was the same as that used in the preoperative evaluation already defined in Table 1.

Table 2

Postoperative Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Alive or dead</td>
<td></td>
</tr>
<tr>
<td>2. Date of follow-up* or death</td>
<td></td>
</tr>
<tr>
<td>3. Months to follow-up* or death</td>
<td></td>
</tr>
<tr>
<td>4. NYHA classification at follow-up [I–IV]</td>
<td></td>
</tr>
<tr>
<td>5. Degree of angina pectoris clinically [0–4]</td>
<td></td>
</tr>
<tr>
<td>6. Degree of congestive heart failure clinically [0–4]</td>
<td></td>
</tr>
<tr>
<td>7. Number of postoperative myocardial infarctions</td>
<td></td>
</tr>
<tr>
<td>8. Months postoperatively when myocardial infarction(s) occurred</td>
<td></td>
</tr>
<tr>
<td>9. Overall outcome [1–6]</td>
<td></td>
</tr>
</tbody>
</table>

*All follow-up times are from the date of initial operation.
The overall outcome (table 2) broadens the analysis of symptomatic outcome, as the relief of angina is not the sole consideration. Also, overall outcome is used for later statistical analysis. This was scored on a one through six basis. A score of one represented an excellent clinical result, with the patient experiencing no angina and returning to full time work and/or physical activity; a score of two was considered to be a good clinical result, with the patient experiencing no angina. A score of three represented a fair result, with diminished angina, still requiring some therapy for its control, and no postoperative myocardial infarction. A score of four represented either no change in the patient's angina status or a postoperative myocardial infarction; a score of five represented a poor operative result, with either a late cardiovascular death, an increase in the anginal syndrome itself, or an increase in the degree of congestive heart failure; a score of six represented an operative death.

The Kaplan-Meier actuarial method was used to estimate the survival experience of the various patient groups. The best variables for predicting outcome were selected by stepwise regression analysis, using the overall outcome index (1 through 6) as the dependent variable. In the step-wise regression procedure the best predicting variable is chosen by the criterion of least squares. A second best variable is to be combined with the best variable is then chosen by the least square criterion and this process is repeated until additional reductions in the sum of the squares become negligible. Utilizing the best predictor variable, and dichotomizing the outcome index to "good" (1 through 3) and "bad" (4 through 6), the Duncan-Walker multiple logistic method was used to develop a rule for computing the probability of a good outcome. Calculations were made on the Stanford IBM 360/50 computer utilizing a standard statistical program developed by the biostatistics group for the ACME computer facility.

Table 3

Symptomatic Presentation (400 patients—406 operations)

<table>
<thead>
<tr>
<th>Classifications</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Mean of classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYHA classification (angina)</td>
<td>31</td>
<td>82</td>
<td>144</td>
<td>149</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Degree of angina (authors' classification)</td>
<td>15</td>
<td>49</td>
<td>109</td>
<td>166</td>
<td>67</td>
<td>2.5</td>
</tr>
<tr>
<td>Degree of CHF</td>
<td>186</td>
<td>98</td>
<td>83</td>
<td>18</td>
<td>21</td>
<td>1.0</td>
</tr>
<tr>
<td>Degree of shock</td>
<td>382</td>
<td>12</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>Number of risk factors (400 patients)</td>
<td>57</td>
<td>126</td>
<td>131</td>
<td>70</td>
<td>16</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Abbreviations: CHF = congestive heart failure; NYHA = New York Heart Association.

Results

Table 3 summarizes the symptomatic presentation of the 400 patients included in this study. The majority of patients had angina pectoris which was the primary indication for saphenous vein bypass surgery. Most patients were in the New York Heart Association (NYHA) class III or IV for angina pectoris. Approximately half of the patients were in some degree of congestive heart failure as defined by us.

Table 4 summarizes the clinical and angiographic studies which allowed an assessment of the extent of coronary artery disease in the patient population. Sixty-three percent of this population had incurred a prior myocardial infarction. Only 53 of the entire 400 patients had normal 12-lead and treadmill electrocardiograms. The vast majority of the patients had either two or three vessel disease, as assessed at coronary arteriography, with only 81 of 400 having single vessel disease. A total of 70 patients had mitral valvular disease as assessed by

Table 4

Extent of Coronary Artery Disease (400 patients—406 operations)

<table>
<thead>
<tr>
<th>Classifications</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Mean of classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of heart disease</td>
<td>0</td>
<td>119</td>
<td>54</td>
<td>37</td>
<td>23</td>
<td>39</td>
<td>19</td>
<td>115</td>
</tr>
<tr>
<td>Number of prior MI's</td>
<td>150</td>
<td>155</td>
<td>62</td>
<td>28</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sum of years since prior MI's</td>
<td>150</td>
<td>75</td>
<td>38</td>
<td>20</td>
<td>12</td>
<td>17</td>
<td>13</td>
<td>81</td>
</tr>
<tr>
<td>Months since last MI</td>
<td>150</td>
<td>14</td>
<td>8</td>
<td>7</td>
<td>20</td>
<td>5</td>
<td>12</td>
<td>190</td>
</tr>
<tr>
<td>Extent of ECG abnormality</td>
<td>53</td>
<td>90</td>
<td>161</td>
<td>74</td>
<td>28</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Disease vessels at arteriography</td>
<td>1</td>
<td>81</td>
<td>172</td>
<td>152</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Associated diseased valves</td>
<td>336</td>
<td>64</td>
<td>6</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>LV dysfunction at ventriculography</td>
<td>237</td>
<td>31</td>
<td>41</td>
<td>52</td>
<td>45</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Mitral regurgitation</td>
<td>354</td>
<td>22</td>
<td>24</td>
<td>2</td>
<td>4</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Abbreviations: MI = myocardial infarction; ECG = electrocardiographic; LV = left ventricular.
left ventriculography, and 160 of the 400 patients demonstrated some measure of left ventricular dysfunction on ventriculogram. It is of note that of the patients having left ventricular dysfunction, 45, or approximately 10% of the population, had marked abnormalities, with some paradoxical motion of a portion of the left ventricle being noted.

The 400 patients in this series had a total of 406 saphenous vein bypass operations, implying that six patients necessitated re-operation after discharge from the hospital. Of the 400 patients, 375 survived operation, for an overall operative mortality of 6.2%. It is clear that the operative mortality was related to the preoperative NYHA classification of functional capacity, as shown in Table 5. In NYHA classes I and II, the total of 113 patients had no operative deaths. Those patients in class IV, of whom there were 149, experienced 21 operative deaths, which accounted for 84% of the surgical mortality (operative mortality was considered if the patient died within 24 hours of the initial operation).

The patient with angina pectoris undergoing an elective saphenous vein bypass procedure had a different prognosis from the patient who came to surgery with either class IV angina, fulminating congestive heart failure, severe cardiogenic shock, or severe electrocardiographic changes as outlined. For example, if patients with these latter clinical findings are excluded, as well as those patients who had associated surgical procedures such as valve replacement or ventricular resection, 249 patients remain, of whom two died, giving an operative mortality of 0.8% in this population of favorable candidates. If the 29 patients having class IV congestive heart failure are excluded from the overall series, there were 11 operative deaths in the total series, yielding a surgical mortality of 2.9%. We have previously reported our experience with those patients presenting with "pre-infarction angina," where we have experienced an operative mortality of 10.7% in 67 patients.7

The operative procedures performed in the 406 operations are summarized in Table 6. Two hundred and forty-two patients had multiple grafts; more grafts were placed as experience with the procedure increased. A simultaneous aortic or mitral valve replacement did not significantly affect the operative mortality in this group of patients. Table 7 summarizes which grafts were placed. The number of coronary endarterectomies performed has diminished in the past 18 months, as an increased incidence of intraoperative myocardial infarction and late arterial occlusion has been documented.

The causes of the 25 operative deaths are listed in Table 8; the most common causes were "pump failure" (ten patients) and myocardial infarction (nine patients).

A significant number of patients incurred postoperative complications. Fifty eight patients, or 14.2% of the entire series, experienced major morbidity as summarized in Table 9. The leading cause of postoperative morbidity was pulmonary embolization, which occurred in 17 patients. The occurrence of this complication has been reduced significantly since institution of routine postoperative anticoagulation. In this series, patients taken back to the operating room for re-exploration experienced no added mortality. Bleeding was usually traced to extra-cardiac sources. Of note is the fact that there were five patients who experienced documented nonfatal myocardial infarctions within the hospital prior to their discharge. These were remarkably benign clinically. In

<table>
<thead>
<tr>
<th><strong>Table 6</strong></th>
<th>Operative Procedure on 400 Patients (406 Operations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single graft</td>
<td>164</td>
</tr>
<tr>
<td>Double graft</td>
<td>205</td>
</tr>
<tr>
<td>Triple graft</td>
<td>33</td>
</tr>
<tr>
<td>Quadruple graft</td>
<td>4</td>
</tr>
<tr>
<td>Aneurysmectomy</td>
<td>25</td>
</tr>
<tr>
<td>Aortic valve replacement</td>
<td>18</td>
</tr>
<tr>
<td>Mitral valve replacement</td>
<td>6</td>
</tr>
<tr>
<td>AVR and MVR</td>
<td>1</td>
</tr>
<tr>
<td>Associated procedures</td>
<td>41</td>
</tr>
</tbody>
</table>

Abbreviations: AVR = aortic valve replacement; MVR = mitral valve replacement.

<table>
<thead>
<tr>
<th><strong>Table 7</strong></th>
<th>Type of Graft Placed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right coronary artery</td>
<td>262 (98 with EA)</td>
</tr>
<tr>
<td>Left main coronary artery</td>
<td>8</td>
</tr>
<tr>
<td>Left anterior descending</td>
<td>326 (5 with EA)</td>
</tr>
<tr>
<td>Left circumflex or marginal branch</td>
<td>93 (2 with EA)</td>
</tr>
</tbody>
</table>

Abbreviations: EA = endarterectomy.

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Table 8

<table>
<thead>
<tr>
<th>Cause of Operative Death—25 Patients (6.15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postoperative pump failure</td>
</tr>
<tr>
<td>Myocardial infarction</td>
</tr>
<tr>
<td>Disseminated intravascular coagulation</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
</tr>
<tr>
<td>Cerebral vascular accident</td>
</tr>
<tr>
<td>Ruptured ventricular suture line</td>
</tr>
<tr>
<td>Preoperative myocardial infarction</td>
</tr>
</tbody>
</table>

those cases in which early angiographic studies were performed, infarction was usually associated with occlusion of one of the saphenous vein grafts.

Of the 375 patients surviving surgery, follow-up has been obtained in 100% of the cases. The mean follow-up time is 9.9 months, with a standard deviation of 5.9 months. The range of follow-up is from a minimum of two months to a maximum of 40 months.

The postoperative clinical outcome for the 375 surviving patients is summarized in table 10. Two hundred and ninety five of these patients (79%) are entirely angina-free (fig. 1). Of these, 237 have returned to full time work and/or full physical activity. If, in terms of overall outcome, scores of one, two and three are considered a clinical improvement in the patient's functional status, then 300 of the 375 patients being discharged from the hospital, or 88%, derived benefit from the procedure itself.

The remaining 12% were considered to have derived no benefit from the procedure, having either no change or an increase in their anginal status, incurring a late myocardial infarction, or dying of a cardiovascular event. There were 15 late cardiovascular deaths which have been analyzed. Nine of these were thought to be due to congestive heart failure, two to acute myocardial infarction, and four occurred suddenly, presumably due to associated arrhythmia. In addition, there have been 23 late nonfatal myocardial infarctions which constitute 6% of those surviving the operation.

When the survival experience of the total group was analyzed actuarially by the method of Kaplan and Meier, 30 day survival was calculated at 93.4% and the one year survival was calculated at 88.5%. There have been no deaths among patients surviving more than one year postoperation. The longest follow-up was 40 months, and the total follow-up after the first year involved 94 patients, or 438 person-months (36% person-years) of experience.

The step-wise regression analyses showed that preoperative variables can be of some use in selecting those patients who will derive benefit from surgery. The best preoperative variables for predicting overall outcome were congestive heart failure, degree of shock, degree of electrocardiographic changes, degree of mitral regurgitation, age, and NYHA preoperative class (table 11). Note that these six variables account for 30% of the variation in surgical outcome. When the surgical deaths are

Table 9

| Significant Postoperative Morbidity—58 Patients (14.2%) | |
|--------------------------------------------------------|
| Pulmonary emboli                                        | 17 |
| Re-exploration for bleeding                             | 11 |
| Myocardial infarction                                   | 5  |
| Hepatitis                                               | 5  |
| Cerebral vascular accident                              | 4  |
| Sepsis with acute tubular necrosis                      | 4  |
| Congestive heart failure                                | 3  |
| Pneumonia                                               | 3  |
| 3rd A-V block with pacemaker                            | 3  |
| Blood reactions                                         | 2  |
| Iliofemoral thrombosis                                  | 1  |
omitted from the analysis, and only the outcome of those surviving surgery is considered, the best variables for prediction, in order of predictive value, were congestive heart failure, left ventricular dysfunction, age, degree of mitral regurgitation, NYHA preoperative class, and number of prior myocardial infarctions (table 12). Note that when surgical deaths are removed, the six best predictive variables account for 16% of the variation remaining.

Since it was thought that the group of patients of primary interest was the one in which the patients received grafts alone, without valve replacement or aneurysmectomy, stepwise prediction for this group was carried out. The variables that were of greatest predictive worth for this group were congestive heart failure, electrocardiographic changes, mitral regurgitation, shock, age, and NYHA preoperative class (table 13).

The predictive power of the best preoperative variables is shown most clearly by using the Duncan-Walker method to calculate a multiple logistic function that gives the probability of a good outcome (scores one through three) for each patient. For example, disregarding patients receiving valve replacement and having aneurysmectomy, and using the three best preoperative variables (congestive heart failure, electrocardiographic changes, and mitral regurgitation), the best fitting multiple logistic function was:

\[
\text{Probability (Success) } = \frac{1}{1 + e^{-A - B_1X_1 - B_2X_2 - B_3X_3}}
\]

Where: \(A = 3.06\)

\(B_1 = 0.48\)

\(B_2 = 0.45\)

\(B_3 = 0.62\)

\(X_1 = \text{degree of congestive heart failure}\)

\(X_2 = \text{degree of electrocardiographic change}\)

\(X_3 = \text{degree of mitral regurgitation}\)

Considering a 0.7 probability of success as an adequate threshold for a predicted good result, figure 2 shows that good, although not absolute, predictability of outcome can be achieved if these variables are used.

**Table 10**

<table>
<thead>
<tr>
<th>Classifications</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean of classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYHA classification (angina)</td>
<td>—</td>
<td>243</td>
<td>91</td>
<td>35</td>
<td>0</td>
<td>—</td>
<td>1.05</td>
</tr>
<tr>
<td>Degree of CHF</td>
<td>314</td>
<td>29</td>
<td>20</td>
<td>17</td>
<td>5</td>
<td>—</td>
<td>0.4</td>
</tr>
<tr>
<td>Total results*</td>
<td>—</td>
<td>237</td>
<td>58</td>
<td>35</td>
<td>30</td>
<td>15</td>
<td>1.7</td>
</tr>
</tbody>
</table>

*As defined by overall outcome (see Methods section).

Abbreviations: CHF = congestive heart failure; NYHA = New York Heart Association.

**Table 11**

Results of Step-Wise Regression for All Patients*

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable selected</th>
<th>Residual sum of squares†</th>
<th>Percent reduction in sum of squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>—</td>
<td>947</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Congestive heart failure</td>
<td>740</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Degree of shock</td>
<td>710</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>Degree of ECG changes</td>
<td>694</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>Degree of mitral regurgitation</td>
<td>684</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>Age</td>
<td>673</td>
<td>29</td>
</tr>
<tr>
<td>6</td>
<td>NYHA preoperative class</td>
<td>665</td>
<td>30</td>
</tr>
</tbody>
</table>

*Using overall outcome [1 - 6] as the dependent variable, and the 18 preoperative variables in table 1 as the predictor variables.

†This is the sum of squared deviation of the actual values of the dependent variable from the predicted values based on the variables selected at the step and the preceding steps. At step zero the grand mean is used for prediction.

**Table 12**

Results of Step-Wise Regression for All Patients Surviving Surgery*

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable selected</th>
<th>Residual sum of squares†</th>
<th>Percent reduction in sum of squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>—</td>
<td>527</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Congestive heart failure</td>
<td>480</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Left ventricular dysfunction</td>
<td>470</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Age</td>
<td>462</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Degree of mitral regurgitation</td>
<td>455</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>NYHA preoperative class</td>
<td>448</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Number of prior myocardial infarctions</td>
<td>444</td>
<td>16</td>
</tr>
</tbody>
</table>

*Using overall outcome [1 - 5] as the dependent variable, and the 18 preoperative variables in table 1 as the predictor variables.

†This is the sum of squared deviation of the actual values of the dependent variable from the predicted values based on the variables selected at the step and the preceding steps. At step zero the grand mean is used for prediction.
Table 13

Results of Step-Wise Regression for All Patients Except Those Receiving Valve Repair or Aneurysmectomy

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable selected</th>
<th>Residual sum of squares†</th>
<th>Percent reduction in sum of squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>—</td>
<td>653</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Congestive heart failure</td>
<td>550</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Degree of ECG changes</td>
<td>521</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Degree of mitral regurgitation</td>
<td>502</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>Degree of shock</td>
<td>491</td>
<td>25</td>
</tr>
<tr>
<td>5</td>
<td>Age</td>
<td>485</td>
<td>26</td>
</tr>
<tr>
<td>6</td>
<td>NYHA preoperative class</td>
<td>481</td>
<td>26</td>
</tr>
</tbody>
</table>

*Using overall outcome [1 - 6] as the dependent variable and the 18 preoperative variables of table 1 as the predictor variables.
†This is the sum of squared deviation of the actual values of the dependent variable from the predicted values based on the variables selected at the step and the preceding steps. At step zero the grand mean is used for prediction.

Three variables alone are considered. Note that 92% of Group B (predicted "good result") patients did well; on the other hand, only 57% of the Group A (predicted "poor result") patients actually enjoyed a good result. Most predictive discrepancies occurred for patients with probability in the mid-range from zero to one. Patients with probability close to zero almost uniformly failed to enjoy surgical success, while those with very high probability were assured a favorable outcome.

Discussion

The application of direct coronary artery bypass surgery has been the most recent of many surgical approaches to the problem of occlusive coronary disease in the patient with angina pectoris. In the few years that this procedure has been performed on large groups of patients, strong advocates for its efficacy have emerged, as well as a group of careful clinicians who urge caution lest this procedure become accepted as standard therapy before its benefits are proven.

As more surgical groups begin to assemble their postoperative results of aorto-coronary surgery, large series are now becoming available, enabling comparison of the effectiveness of the procedure. Prior work substantiated by this review has shown the procedure to relieve angina in the vast majority of cases, although a distinct minority of patients, varying from 10 to 15% between groups, derives no benefit or incurs late cardiovascular complications. Recent work from this institution has

![Figure 2](http://example.com/figure2.png)

**Figure 2**

Using three preoperative variables, congestive heart failure, electrocardiographic changes, and the degree of mitral regurgitation, the Duncan-Walker method of calculating a multiple logistic function was employed to calculate the probability of any patient receiving a good surgical result. Note that separation to the 0.7 level was possible for 92% of those having a good result from surgery (includes those patients having saphenous vein bypass surgery without associated procedures). Abbreviations: CHF = congestive heart failure; MR = mitral regurgitation; EKG = electrocardiographic.
related surgical success, as determined by relief of angina, to late graft patency. The current study, while corroborating the effectiveness of the procedure as a treatment for angina pectoris, employs statistical methods that potentially permit initial comment on two prior unknowns: the long-term survival of patients undergoing the procedure, and the selection of preoperative parameters which may predict a good or bad overall result.

The Stanford patient population shows a 30-day survival of 94%, reflecting the operative mortality, and a one year survival of 88.5%. To date there have been no deaths among patients surviving operation for more than one year, which is a remarkable finding, although the patients at risk after one year total only 94 in this series. The recent study by Oberman et al. of 246 patients with arteriographically documented, but nonoperated, coronary disease (values are extrapolated and calculated from figure 8 of their paper), and the results of the Framingham study of men with uncomplicated angina pectoris, have been used as groups with which to compare survival. While these studies do not provide absolute controls, it is interesting that the Stanford patients, considered only in terms of survival, showed improved survival over the Oberman group by 16 months, and over the Framingham group by 30 months (fig. 3). The sample size and very distinct group differences in terms of severity of disease exist between these groups, and thus do not permit direct comparison. However, there are no other objective data available for comparison at this time. Further follow-up of our group and comparison of patient groups in randomized control studies are clearly needed.

The step-wise regression analysis applied for all patients using the 18 preoperative parameters as predictors of overall success (table 12) demonstrates the importance of congestive heart failure as the dominant feature in determining subsequent result. This observation was expected from clinical judgment alone but now has statistical validation. Other investigators have suggested that preoperative congestive heart failure had adversely affected the overall symptomatic outcome of patients undergoing saphenous vein bypass surgery.

Using statistical methods similar to ours, Oberman et al. derived comparable results in their study of nonoperated patients with documented coronary artery disease. They found seven factors standing out as predictors of subsequent mortality in their nonoperated group; two of the first three most important variables were heart size and dyspnea on exertion, both clinical features of congestive heart failure. Thus, in both operated and nonoperated

![SURVIVAL IN MONTHS](image)

**Figure 3**

An actuarial plot compares, in months, the survival figures of the Stanford group to those patients in the Framingham study and the group of patients with documented but nonoperated coronary disease reported by Oberman. The Stanford patients showed improved survival over the Oberman group at 16 months, and over the Framingham group at 30 months.
patients, the dilated, chronically congested ventricle is the dominant cause of an unfavorable long-term clinical outcome.

In terms of predicting overall outcome, the presence of clinical shock emerged as the second most important variable (table 11). This is because 11 of the 25 patients dying at surgery were in some degree of preoperative clinical shock (5 in class III or IV—see Methods), which contributed to their mortality. Of the remaining 375 patients who survived the operation, only 12 were judged preoperatively to be clinically in shock; of these, only two were class III, with none in class IV. Thus, in describing variables which affect outcome for those surviving surgery (table 12) shock does not appear. Only congestive heart failure, degree of electrocardiographic changes, and mitral regurgitation had any significant impact on predicting overall outcome among those patients undergoing saphenous vein surgery without associated procedures (table 13).

Other clinical features expected to affect outcome, such as age, number of grafts placed, or duration of pump time, had little further impact in reducing the sum of the squares. While each value may be important in an individual patient and should be considered clinically, these observations emphasize the importance of determining the patient’s hemodynamic status preoperatively and suggests that the patient in congestive failure should receive critical clinical consideration preoperatively to determine whether the additional risks of surgery outweigh the potential benefits.

The attempt to quantitate the preoperative probability of successful surgical outcome using the Duncan-Walker method (fig. 2) showed that good predictability is possible to the 0.7 level. Sample size, perhaps the need for other preoperative variables, plus unpredictable technical factors at surgery make absolute predictability impossible. Yet, given an assessment of the variables we have chosen, it is potentially possible to predict statistically how well a patient can be expected to do within the limits outlined above. Clearly patients with a computed probability of success that is close to zero should be re-evaluated with sound clinical judgment with regard to overall indications for surgery. It is hoped that these approaches can be further developed as a help to the clinician as he looks for more objective measures to use in selecting patients for this operation.

Although not absolute, our data suggest that in the properly selected patient, symptomatic improvement for angina pectoris can be expected in the majority of patients. While patient follow-up data to date do not permit any definite statement regarding patient survival and the reduction of myocardial infarction, our results suggest that patient survival may be enhanced. Careful and serial follow-up of these patients is planned during the ensuing five years.

References


The Long-Term Follow-Up of Patients Undergoing Saphenous Vein Bypass Surgery

DAVID S. CANNOM, D. CRAIG MILLER, NORMAN E. SHUMWAY, THOMAS J. FOGARTY, PAT O. DAILY, MARIE HU, BYRON BROWN, JR. and DONALD C. HARRISON

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