SPECIAL ARTICLE

Some Reflections on the Coronary Bypass Operation

By William W. L. Glenn, M.D.

SUMMARY

A promising new operation—coronary bypass—has been developed for the treatment of coronary heart disease. However, because of the nature of the underlying disease and the minute size of the vessels to be anastomosed, its long-range prospects are in doubt. At this point in time there is no evidence that the operation either prevents infarction or prolongs life, and great caution is urged in applying it, reserving it for those who have life-threatening coronary artery disease, are clearly recalcitrant to optimum medical management, and have apparently normal coronary vessels distal to the point of stenosis.

There is an urgent need for a better definition of the indications for operation in patients with coronary artery disease based on a study of the natural history of this condition. Prophylactic operation for patients with a compromised coronary circulation with or without angina must await long-term results of therapeutic operation.

In view of the extraordinary interest in the current surgical operation for coronary atherosclerosis, and the great expansion of our medical facilities and training programs to which we would be committed by enthusiastic endorsement of this operation, I believe the time is propitious for an airing of the situation. I feel obligated to present to you evidence that suggests a cautious approach to this operation, while at the same time I acknowledge its successful application to certain patients with life-threatening myocardial ischemia.

It is of course not possible to determine precisely the number of patients with coronary heart disease in the United States at this moment, but let us look at some figures. Though grossly approximate at best, they do reveal the magnitude of the case load. In 1967 heart and blood vessel diseases accounted for 54.1% of the deaths in the United States, or just over a million deaths. Coronary heart disease (CHD) accounted for 57.2% of these, or 573,153 deaths (Code 420 International Classification of Disease, 7th revision), the highest rate in the world probably, except for Finland's. According to figures from 1962 (the common reference point in Keys' study), in the 40–59 age group, where at least two thirds of CHD is found, 33.9–42.3% of deaths in white males were due to the disease (fig. 1). Of the United States sample of 2571 railroad men aged 40–59 years, 25 in the sample, or 1% (a surprisingly smaller percentage than in samples from some of the other countries in this study), had angina pectoris when entered into the study. Thus, based on the number of white males aged 40–59 years in 1962, which was 18.5 million, there must have been at least 185,000 individuals in this age, sex, and race group with angina in the United States.

A rough idea of the incidence of new cases of angina in adult males can be estimated...
U.S. WHITE MEN, 1962 DATA  
CAUSES OF DEATHS IN 5 YEARS  
FROM STARTING AGES SHOWN

<table>
<thead>
<tr>
<th>Ages 40-44</th>
<th>45</th>
<th>11.8</th>
<th>33.9</th>
<th>54</th>
<th>19.1</th>
<th>19.4</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ages 45-49</td>
<td>5.7</td>
<td>12.5</td>
<td>38.8</td>
<td>53</td>
<td>12.8</td>
<td>19.0</td>
<td>100%</td>
</tr>
<tr>
<td>Ages 50-54</td>
<td>6.6</td>
<td>13.4</td>
<td>411</td>
<td>53</td>
<td>8.9</td>
<td>18.8</td>
<td>100%</td>
</tr>
<tr>
<td>Ages 55-59</td>
<td>6.8</td>
<td>13.2</td>
<td>42.3</td>
<td>51</td>
<td>6.2</td>
<td>19.5</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Figure 1**

Distribution by cause of death of U.S. white men of specified starting age. Calculated from U.S. vital statistics for 1962.\(^2\) (Reproduced by permission.)

from the Framingham study reported by Kannel and Feinleib.\(^3\) Of 2283 males who were aged 30–59 years when they entered the study, 181 or 7.9% developed angina for the first time during a 14-year follow-up period. In 1990, when this study began, the population in this same sex and age group was 29.5 million; applying the 7.9% and dividing the total by 14 (the years of the study) we get an incidence of approximately 167,000 new cases in males per year. During the same period there were 122 females, of 2844 who entered the study, who developed angina during the 14-year follow-up period. The average annual incidence of angina as the presenting complaint is shown in figure 2.

The true incidence of coronary artery atherosclerosis can only be obtained from a study of autopsy material. Schlesinger and Zoll, using injection of the coronary system to demonstrate possible obstruction, found an incidence of obstruction of 23.5% in males aged 40–59 years.\(^4\) It is not at all uncommon to find more than one coronary vessel partially or completely occluded. The opinion of the group having the largest experience in coronary angiography is that the “overwhelming majority of patients studied with selective angiography demonstrate a diffuse pattern of

**Figure 2**

Smoothed average annual incidence of angina pectoris as a presenting complaint in men and women, aged 33–69 years: Framingham study, 14-year follow-up.\(^3\) (Reproduced by permission.)

Circulation, Volume XLV, April 1972
coronary arteriosclerosis.5 If one can assume that the incidence remained the same over the years and we apply this percentage figure to the white male population in the 40–59 age group in 1969, that is, approximately 22 million, we have to accept the fact that it is possible that there are now in the U. S. over 5 million males aged 40 through 59 years with an obstructed coronary artery—truly a disease of epidemic proportions!

The prognosis of angina treated medically has been the subject of much discussion for many years. There are a large number of studies, and many are meritorious. The simple one reported by White and associates in 1943, with 497 carefully followed patients, gives an accurate prognosis as well as a fairly optimistic one.6 With the recent improvement in coronary care arising from the establishment of the coronary care unit, even their results might improve. In the much larger series of nearly 7000 angina patients reported by Block and associates, the figures which were calculated by the actuarial method clearly demonstrate the shortened life of the average patient with angina compared to the normal control in the same age group (fig. 3).7 Evidence is accumulating that some patients with angina have a far better prognosis than others. Females with angina live longer and are less likely to develop infarction than males with angina.3 Also, patients with angina who have a normal electrocardiogram and normal blood pressure have a better prognosis than those with an abnormal electrocardiogram or with hypertension.8

The history of revascularization of the myocardium includes many operations. Apart from those designed to relieve angina simply by interrupting the different sympathetic pathways or stimulating the carotid sinus nerves, the operations can be divided into

### Figure 3

The prognosis of angina pectoris calculated by the actuarial method.7 (Reproduced by permission.)

*Normal population*
*Females*
*Males*
*Total series*

<table>
<thead>
<tr>
<th>Years after clinic diagnosis of angina pectoris</th>
<th>Percent survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
</tr>
</tbody>
</table>
those that sought to increase blood flow through development and expansion of the extracardiac vessels and those that sought to deliver a new direct arterial supply to the myocardium (fig. 4).

All these operations reached clinical application and received temporary acclaim for their relief of angina. There could be no disputing the claim, though it was clearly recognized that relief was sometimes psychogenic. This was proved in the case of the internal mammary artery ligation operation: a similar relief of angina was obtained from a sham operation.\(^\text{10}\) Obviously, relief of angina cannot be relied upon as evidence of successful myocardial revascularization. Prior to the introduction of the direct coronary artery anastomosis, two operations gained fairly wide clinical application: myocardial abrasion, developed by Beck, and mammary artery implantation, developed by Vineberg. There are many reports of success from these two operations (table 1), and claims and counterclaims have been made regarding their

<table>
<thead>
<tr>
<th>Operation</th>
<th>No.</th>
<th>Operative mortality (%)</th>
<th>Symptomatic improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal mammary artery implant*</td>
<td>675</td>
<td>5.6</td>
<td>79.1</td>
</tr>
<tr>
<td>Epicardial abrasion†</td>
<td>347</td>
<td>6.0</td>
<td>94</td>
</tr>
</tbody>
</table>

*5-year experience.\(^\text{12}\)
†4-year experience.\(^\text{11}\)

value. Only recently one group reported "agreement between reversion to normal lactate metabolism, angiographic patency and clinical improvement following internal mammary artery implantation."\(^\text{13}\) Other investigators were able to show a statistically significant higher number of myocardial infarcts in a control group of unoperated patients than in patients who had undergone internal mammary artery implants.\(^\text{14}\) On the other hand, another investigator found that in six patients implanted 2–5 years earlier, and showing on

Figure 4

*Surgical methods proposed for revascularization of the heart.\(^\text{9}\) (Reproduced by permission.)

*Circulation, Volume XLV, April 1972
CORONARY BYPASS OPERATION

angiography good filling of the coronary arteries, the rate of flow through the internal mammary arteries was an average of only 10.7 cc/min with no alteration in the electrocardiogram when the artery was occluded.\textsuperscript{15} From a clinical analysis of 118 patients who had an implant, they found that it did not make much difference whether the implant was occluded or patent.

Obviously the worth of any procedure designed to add blood to an ischemic myocardium will be proved by an unequivocal demonstration of reduction or elimination of myocardial infarction and the prolongation of life to approach or equal that experienced by individuals without coronary artery disease.

So far no operation to revascularize the heart has consistently met these requirements.

The operation of direct arterial anastomosis to the coronary arteries was first proposed as a clinical procedure by Murray in 1954.\textsuperscript{16} He had performed experiments on animals using several technics and concluded “the best results were obtained using a free graft of carotid artery, bringing it off the aorta in such a position that it was easily and directly brought to the coronary vessels.”

In 1966 the bypass operation developed by Murray was applied clinically by Kahn (in discussion of Effler’s report),\textsuperscript{17} who placed a segment of saphenous vein between the aorta and coronary artery, and in 1968 by Green who sutured the internal mammary artery directly to the coronary artery.\textsuperscript{18} Goetz and associates in 1961 had reported a case in which they used a nonsuture anastomosis of the internal mammary to the coronary artery.\textsuperscript{19}

In the few years since its introduction, the bypass operation has been done hundreds, probably thousands, of times. With the better understanding of the nature and distribution of the pathologic lesions in the coronary arteries made possible by coronary angiography technics developed by Sones, multiple bypass grafts have become commonplace and are often made to revascularize as many areas of the myocardium as possible. It is obviously too early to pass judgment on the ability of this operation to meet the criteria of reduction in the infarction rate and the prolongation of life, but certain facts both pro and con have become apparent and we should look at these carefully.

There is no question that symptomatic relief follows a successful bypass operation: pain and electrocardiographic signs of ischemia on exercise usually disappear, and ventricular function improves, virtually assuring the operation’s acceptance, temporarily at least, by most physicians and their patients.

However, certain other factors counsel caution. It has been demonstrated many times that a patent anastomosis of a 1–2-mm vessel to another vessel can be attained, provided the technic is meticulous and the patient is heparinized at the time the anastomosis is made. We might look at the well-established operation of saphenous vein bypass in the thigh in attempting to predict the long-term success of the coronary operation. Though not strictly comparable, there are some common denominators. For example, the most important factors limiting the success of any bypass graft, including coronary bypass, are the extent of the involvement of the arteries with atherosclerosis (the “runoff”) and the size of the anastomosed vessels.\textsuperscript{17}

The recent report of Braddeley and co-workers\textsuperscript{20} on the saphenous vein bypass operation for the lower extremity is fairly representative of the experience in the field. There was a significant difference in patency rates depending on when after the operation the observation was made, and it was of interest to note that their 6-months’ postoperative figure of about 90% patency is similar to that reported today following the coronary bypass operation. However, where the “runoff” was only moderate or poor, presumably due to atherosclerosis, there was a dramatic fall in patency rates after a few years (table 2). Vessel size, also, had a marked influence on patency rate, it being distinctly lower when the distal artery was less than 5 mm in diameter.

Much concern was expressed initially over the fate of the saphenous vein graft when
interposed between the ascending aorta and the coronary artery. Perhaps more feared than thrombosis was aneurysm, but the latter has not been reported. On the other hand, thickening of the vein wall has been demonstrated in a number of cases, and it may prove to be a most serious complication. Carrel, in 1906, reported thickening of the wall of the vein interposed in the arterial system. The significance of this thickening as a cause of obstruction to blood flow was appreciated only after Vlodavar and Edwards showed, in six of eight long-term grafts, a lesion characterized by intimal thickening with avascular, highly cellular connective tissue, partially or completely obstructing the vein graft (figs. 5 and 6) and called by them intimal fibrous proliferation. The lesion has also been described by Johnson and co-workers and by others. Green thinks this lesion may account for the majority of obstructed vein grafts in his experience, 30% of which have closed (Green GE: Personal communication). In contrast he found in 145 internal mammary artery-coronary artery shunts done by him only two closures and one stenosis in the 3½ years since his first operation. Seventy of his patients have undergone postoperative angiography. Two thirds of these patients had at least one vein graft in addition to the mammary artery graft. It is of signal importance that the technic he used to do most of the vein graft anastomoses was precisely the same one he used to do the internal mammary artery anastomosis. It would appear from his experience that the saphenous vein is a less desirable bypass graft material than the internal mammary artery. It is interesting to recollect here that Murray, in 1954, advised the use of a free graft of carotid artery though he was well aware of vein grafts and had indeed placed the first vein graft clinically, in 1940 in a patient with a popliteal aneurysm. Perhaps a free autogenous artery graft, if such can be safely harvested, can be substituted for the saphenous vein.

Also, attention has recently been called to the possibility of total obstruction at an area of stenosis proximal to the point of anastomosis, precipitated by a stasis at the site of obstruction, due to the competition of flow through the normal channel and through the graft. Obviously, however, if the grafts should close after obstruction of the normal channel becomes complete, infarction may occur.

Table 2

<table>
<thead>
<tr>
<th>Runoff</th>
<th>Duration</th>
<th>No. patients</th>
<th>Percent grafts (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>6 months</td>
<td>85</td>
<td>89.4</td>
</tr>
<tr>
<td></td>
<td>4 years</td>
<td>38</td>
<td>73</td>
</tr>
<tr>
<td>Moderate</td>
<td>6 months</td>
<td>46</td>
<td>93.5</td>
</tr>
<tr>
<td></td>
<td>4 years</td>
<td>11</td>
<td>45.5</td>
</tr>
<tr>
<td>Poor</td>
<td>6 months</td>
<td>32</td>
<td>71.9</td>
</tr>
<tr>
<td></td>
<td>4 years</td>
<td>10</td>
<td>22.2</td>
</tr>
</tbody>
</table>

Figure 5

Coronary bypass operation: saphenous vein graft obstruction due to internal fibrosis proliferation. Graft in place for 3½ months.
Now let us look at the facilities to handle the bypass operation. In 1969, a questionnaire survey of 6600 hospitals in the United States was conducted by the American Hospital Association. Data received from 5200 of the hospitals and an estimate of the performance of those not responding revealed that 518 did at least one open or closed cardiac operation per year. Astonishingly, however, in 1969, 177 of these were doing less than 10 a year, and only 38 were doing more than 200 a year!

This appeared to be gross underutilization of the available facilities. The fact is that there were only about 31,000 cardiac operations of any type done in the United States in 1969 and this included about 5000 coronary revascularization procedures of one type or another.

Crocetti found earlier, in 1961, that there were actually 586 hospitals tooled up for cardiac surgery. Apparently 106 of these dropped out before the 1969 study, presumably for lack of business, which was no surprise since 305 wrote that they did fewer than 10 cardiac operations per year. It is obvious that to maintain their skill cardiac surgical teams must perform a certain minimum number of operations each week. The Surgery Study Committee of the Inter-Society Commission on Heart Disease Resources has recommended a minimum of four to six cardiac operations a week to be done by a team of two or three cardiac surgeons.

As for the supply of cardiac surgeons: Each year 150–175 new cardiothoracic surgeons are certified by the Board of Thoracic Surgery,
and just over 2,000 surgeons trained in cardiothoracic surgery have been certified in the past 15 years (Daniel RA, Sper L: Personal communication). Though many have probably done little or no cardiac surgery after completing their residency training because of a dearth of clinical material, there are probably enough trained cardiac surgeons to staff about 500 hospitals doing at least five cardiac operations per week.

Now let us suppose that all 586 hospitals with adequate facilities and staff were to do five cardiac operations per week—not an unreasonable load. Then a maximum of 150,000 operations per year could be done. This would be five times the number that was actually done in 1969.

The selection of patients for the bypass operation is not simple. It has been demonstrated that the operation can be accomplished technically and that most of the venous grafts and nearly all of the arterial grafts remain open for some time. Yet there is also evidence that some have closed and others are closing. We will not know for perhaps 4–5 years which patients have vessels favored to remain patent. Sabiston has listed eight criteria to be followed in the critique of this operation. I commend them to you.

If we believe there are close to half a million Americans with angina who might be referred for operation now and that new cases are occurring at the rate of more than 200,000 a year, it is obvious with the available facilities we cannot provide each with a bypass operation.

Nor should we. It is a tragic mistake in view of the experience with many earlier operations that received acclaim initially only to find limited use ultimately, and the not inconsiderable mortality and morbidity directly related to the operative procedure, particularly during the developmental phase, to advocate unqualified acceptance of this new operation for angina. In view, also, of the chronic progressive and diffuse nature of coronary atherosclerosis, the long-term benefit from any operation to improve the coronary circulation must be questioned. At this point in time the operation should be advised only in cases of definitely imminent infarction ("crescendo," "decubitus" angina), as the last resort in ventricular arrhythmia following myocardial infarction and, finally, in cases of frankly disabling angina recalcitrant to optimum medical care.

It should not take long to determine the proper place of this operation in the management of CHD. If after several years of carefully documented study using a large number of cases in several different clinics it becomes clear that the indications for operation should be broadened or that the operation is not maintaining its initial success, then an adjustment of the medical facilities would be required accordingly.

Finally, a plan to determine the number of cases of coronary heart disease suitable for the new coronary bypass operation must be made as soon as possible. To this end the Coronary Artery Surgery Committee of the Inter-Society Commission for Heart Disease Resources made the following recommendation to the Director of the National Heart and Lung Institute on October 1, 1971:

1. Examine the feasibility of conducting a retrospective study of the natural history of patients with coronary artery disease in relation to coronary arteriographic anatomy.
2. Examine the feasibility of conducting prospective studies of surgical treatment for coronary artery disease.

(The Coronary Artery Surgery Committee of the Inter-Society Commission for Heart Disease Resources is preparing guidelines for hospitals interested in coronary bypass surgery. Their report will be available soon.)

References

Circulation, Volume XLIV, April 1972
6. White PD, Bland EF, Miskall EW: The prognosis of angina pectoris: A long-term follow-up of 497 cases including a note of 75 additional cases of angina decubitus. JAMA 123: 801, 1943
10. Dimond EG, Kittle CF, Crockett JS: Comparison of internal mammary artery ligation and sham operation for angina pectoris. Amer J Cardiol 5: 483, 1960
27. Data provided by The Regional Medical Programs Service, based on a survey by the American Hospitals Association, 1970
Some Reflections on the Coronary Bypass Operation
WILLIAM W. L. GLENN

Circulation. 1972;45:869-877
doi: 10.1161/01.CIR.45.4.869

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1972 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/45/4/869

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/