The First Decade of Aortocoronary Bypass Grafting, 1967–1977
A Review

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SUMMARY Despite a decade of experience with aortocoronary bypass grafting embracing 300,000 or more operations, indications for its use remain controversial. The controversy persists because of a lack of adequate controls with which to compare the clinical course of operated patients; only 1248 have been reported who have been studied in a carefully controlled and random manner.

Benefit has been claimed frequently by comparing the course of patients treated surgically with medically treated patients followed the decade before. Such comparisons are not valid in view of the well documented changes in the natural history of coronary artery disease that have been occurring during the last decade.

Despite a low operative mortality and rate of graft closure, available data in the literature do not indicate that initial symptomatic improvement necessarily persists, or that myocardial infarctions, arrhythmias, or congestive heart failure will be prevented, or that life will be prolonged in the vast majority of operated patients.

"It is much easier to write upon a disease than upon a remedy. The former is in the hands of nature and a faithful observer with an eye to tolerable judgment can not fail to delineate a likeness; the latter will ever be subject to the whim, the inaccuracy and the blunder of man."

William Withering*
An Account of the Foxglove
1758

THE FIRST REPORTED saphenous vein aortocoronary bypass operation was performed in The Methodist Hospital, Houston, Texas, in 1964. The event was reported nine years later by Garrett et al. The patient is still alive and doing well. Three years later, May 1967, Favaloro at the Cleveland Clinic performed the second such operation. Over the next three years he and his associates gained sufficient experience to report the feasibility of performing the operation on large numbers of patients with a low operative mortality and a high incidence of relief of pain. The operation was quickly adopted by others and by 1970 considerable experience had been gained in a number of centers. Thus, in 1977, the understanding of the therapeutic effectiveness of aortocoronary bypass grafting (ACBG) is based on a decade of experience.

It is uncertain how many patients have received ACBG during the last decade. From May 9, 1967 through December 31, 1975, 10,744 patients underwent various types of graft procedures in the Cleveland Clinic; between 1968 and 1974 more than 4,000 patients were operated at St. Luke's and the V.A. Hospital in Milwaukee; Cooley and colleagues at the Texas Heart Institute in Houston performed 4,522 ACBGs from October 1969 through December 1974. Based on the responses to a questionnaire from 400 experienced cardiovascular surgeons in this country, Miller et al. estimated that over 100,000 ACBGs were performed in the United States during the past decade.

*After ten years of experience with the use of aortocoronary bypass grafting (ACBG) in the treatment of ischemic heart disease (IHD), it was thought timely to assess what is known and what is not known about the procedure. In preparing this review, it became apparent that despite the passage of 300 years since William Withering's provocative comment, much of the literature regarding ACBG as a "remedy" for IHD has been "subject to whim, inaccuracy and blunder."

From January 1967 through April 1977 approximately 450 articles have been cataloged in the Cumulative Index Medicus under the classification of "Coronary Artery Disease-Surgery." It was therefore difficult not to include over 200 references . . . some are merely biased anecdotes based on few critical observations . . . others are reports of carefully designed studies that utilized the full range of appropriate laboratory techniques available at the time. Both types of reports have been included in this review for it appeared that not infrequently the poorly designed studies have been more accepted as proven guidelines for therapy of large numbers of patients and the more carefully carried out and critical studies have been ignored.

This manuscript may appear to be more detailed than usual. However, it was thought that sufficient detail should be included to permit the reader to identify "whims, inaccuracies and blunders," as well as carefully collected "hard data." As a result, it is hoped that the physician could better make intelligent decisions about the use of this procedure as a "remedy" in the management of his patients.
performed in the United States by 1974; possibly 30,000 to 40,000 were performed in 1974 and approximately 54,000 in 1975.8 Braunwald9 estimated that during 1976 over 60,000 ACBGs were carried out in the United States; possibly 80,000 to 100,000 ACBGs were done in 1977.

With such an extensive experience extending over a decade, and involving over 400,000 patients, it would seem reasonable to expect that most of the questions and uncertainties regarding the procedure would have been answered. But the thoughtful observer must realize that there is still much that is not known about the effectiveness of ACBG when compared to the currently available nonoperative management of coronary artery disease (CAD) in the individual patient.10-17 This concern was succinctly articulated by Kirkl1n10 in the George C. Griffith Lecture in 1974: “Clearly we all have much to do to clarify the effectiveness of medical and surgical therapy in this disease. Therein lies our dilemma but also our challenge and our opportunity.” The purpose of this review is to determine how well we have met this challenge.

After assessing the effectiveness of ACBG in 1976, Braunwald1 warned that “there is a growing uneasiness that by simple common consent, rather than by rational analysis of data, we may be adopting for general use a form of treatment that has yet to prove itself.” This uneasiness is shared not only by internists but by some surgeons as well.8,11

Despite Effler’s18 criticism of the health planners concern over the economics of so widely used a procedure, cost must be considered... at least until the effectiveness of the procedure in the various subsets of patients with ischemic heart disease (IHD) is defined. The related expenses and costs of the operation are between $10,000 and $15,000; approximately a quarter or more is for the surgeon’s fee and one-eighth or more is for the cardiologist’s fee. If 60,000 procedures were done in 1976 in this country, the total cost for ACBG in 1977 may well have approached one billion dollars. This is over two and a half times the total budget of the National Heart, Lung and Blood Institute.

Potential Role of ACBG

CAD begins in early childhood; when established, it progresses at a variable and unpredictable tempo until death. For the major part of its natural history, the process is asymptomatic. During this period the anatomic presence of CAD can be demonstrated only by coronary arteriography or postmortem examination. At various times during the variable course of the disease, CAD may become IHD. This diagnosis, IHD, is established by the development of recognizable symptoms, occasionally signs and/or diagnostic changes on the electrocardiogram, either at rest or in response to stress.

In some centers, the simple diagnosis of anatomically demonstrable CAD by coronary arteriography, even if in a completely asymptomatic patient, is considered an indication for surgery.4-7,16,17 On the other hand, most clinicians believe that if ACBG is to be useful, it will be in the management or prevention of the clinical manifestations of IHD. These include: 1) myocardial infarction; 2) serious arrhythmias or conduction abnormalities; 3) congestive heart failure; 4) premature death, either a) sudden or b) non-sudden; 5) pain of myocardial ischemia.

What data are available after ten years of experience that justify the use of ACBG as a “remedy”19 for any and/or all of these clinical manifestations of IHD?

Prevention of Myocardial Infarction

In Patients with Stable Angina Pectoris

Three studies,19-22 involving 807 randomized patients with stable angina pectoris, were designed to evaluate the effectiveness of ACBG in comparison to currently accepted medical therapy. All patients had selective coronary arteriography before randomization. A reduction of the diameter4 of a major coronary artery of 70% was considered significant in the first study and a reduction of the luminal diameter of such a vessel by 50% was considered significant in the other two. Patients with significant obstruction of the left main coronary artery were excluded from each study. All patients were followed for a mean of 30 months or longer. Additional details from each study are included in Table 1.

1) Mathur, Guinn and associates19,20 randomized 116 patients with stable angina pectoris at the Houston V.A. Hospital to medical or surgical treatment.† The patients randomized for ACBG were all operated by one surgeon. Follow-up of these patients continues.

2) Thirteen V.A. Hospitals are currently continuing to follow those patients surviving from an initial group of 596 patients with stable angina pectoris. These patients were followed for a minimum of 21 months; 290 patients were followed for 36 months. No comment regarding the incidence of myocardial infarction was made by the authors.

3) Kloster et al.21 recently completed a randomized study of 95 patients with stable angina initiated at the University of Oregon Health Science Center in 1972. The incidence of acute myocardial infarction in these three studies was essentially the same regardless of whether the patient had an ACBG or not. Although more surgical patients at the Houston V.A. Hospital had acute myocardial infarctions than those treated medically, the difference is not statistically significant (Table 1).

The authors know of no other randomized studies carried out in this country which have evaluated either the effectiveness of ACBG in preventing subsequent myocardial infarctions in patients with stable angina pectoris or other po-

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*Precision and/or consistency must be exercised in defining the degree of obstruction of a coronary vessel. Two terms are commonly used: 1) reduction of the diameter of the vessel by a certain percent, or 2) reduction or obstruction of the lumen of the vessel and thus the cross-sectional area by a certain percent. A 50% reduction of the diameter of the vessel (and it should be viewed in two planes) is equal to approximately a 75% reduction in the cross-sectional area of the vessel. Flow is not reduced significantly until the diameter is narrowed approximately 50% (i.e., the cross-sectional area is reduced by 75%). The Ad Hoc Committee of the American Heart Association for Grading Coronary Artery Disease has adopted the diameter reduction method.19

†It is inaccurate to refer to the treatment of IHD as being either medical or surgical. Even the most enthusiastic supporter of ACBG would recommend nitroglycerin and beta blockers, if indicated, in addition to recommending ACBG; even the most conservative cardiologist would recommend ACBG to an occasional patient with incapacitating angina. Thus, in practice, most clinicians do or should add ACBG to a fairly rigid medical program. Recognizing these considerations, we will, for the sake of brevity, refer to the “medical versus the surgical management of IHD.”
tential benefits of the procedure. The NHLBI is currently sponsoring a multicenter randomized study of patients with stable angina treated with ACBG. This study is referred to as the Coronary Artery Surgical Trial (CAST). It is anticipated that between 800 and 1,000 patients will be recruited by January 1978 and that they will be followed for five years.

Two additional studies are worth considering (table 1). Arnow and Stemmer reported in 1975 the two year follow-up of a group of 40 patients receiving strict therapy for severe angina pectoris. The patients were divided into two comparable groups of 20 patients; one group received ACBG. To be included in the study, a major coronary vessel had to be demonstrated to have "> 70% luminal narrowing." Kouchoukos et al. collected 53 patients with stable angina in the same hospital between June 1966 and February 1973; these patients were demonstrated to have > 75% narrowing of the intraluminal diameter of the proximal portion of the left anterior descending coronary artery with < 50% stenosis of the intraluminal diameter of the other vessels and with normal or minimally impaired left ventricular contraction. Twenty-four nonrandomized patients were treated medically for 24 months; 29 patients treated surgically were followed for a mean of 37 months. Many of these patients were collected early in the study and had less advantage of newer therapeutic programs than was true once the surgical program in the institution was established in July of 1969. Neither of these studies reported that ACBG exerted a positive effect against the development of an acute myocardial infarction.

A number of other reports could be cited in which it was implied or stated that an ACBG did reduce the incidence of acute myocardial infarction. Such studies, however, suffer from a lack of adequate control. A representative example was published by Ullyot et al. They followed 200 consecutive patients for an average of 27 months after ACBG. There was an incidence of perioperative infarction of 8.5% and a total incidence of myocardial infarction of 14%. According to the authors, the incidence of myocardial infarction after surgery is low.

### Table 1. Incidence of Myocardial Infarction and Death

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of study</th>
<th>Length of follow-up</th>
<th>Total</th>
<th>Number of patients</th>
<th>Number of infarcts</th>
<th>Number of deaths</th>
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<td></td>
<td>Medical only</td>
<td>Therapy with ACBG</td>
<td>Medical only</td>
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<td>Stable Angina Pectoris</td>
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<tr>
<td>Guinn20</td>
<td>R</td>
<td>34 months (mean)</td>
<td>116</td>
<td>60</td>
<td>56</td>
<td>11 (18%)</td>
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<tr>
<td>VA Coop21</td>
<td>R</td>
<td>36 months (mean)</td>
<td>596</td>
<td>310</td>
<td>286</td>
<td>No Difference</td>
</tr>
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<td>Kloster22</td>
<td>R</td>
<td>30 months (mean)</td>
<td>95</td>
<td>46</td>
<td>49</td>
<td>4 (9%)</td>
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<tr>
<td>Aronow24</td>
<td>M</td>
<td>24 months</td>
<td>40</td>
<td>20</td>
<td>20</td>
<td>2 (10%)</td>
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<td>Kouchoukos25</td>
<td>C</td>
<td>med. 37 mos. surg. 21 mos. (mean)</td>
<td>53</td>
<td>24</td>
<td>29</td>
<td>1 (4%)</td>
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<td>NHLBI27</td>
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<td>24 months (mean)</td>
<td>288</td>
<td>147</td>
<td>141</td>
<td>32 (22%)</td>
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<td>Selden28</td>
<td>R</td>
<td>4 months</td>
<td>40</td>
<td>19</td>
<td>21</td>
<td>2 (10%)</td>
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<tr>
<td>Hultgren29</td>
<td>C</td>
<td>23 months (mean)</td>
<td>118</td>
<td>66*</td>
<td>52</td>
<td>11 (17%)</td>
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<tr>
<td>Left Main Coronary Artery Stenosis</td>
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<tr>
<td>Takaro30</td>
<td>R</td>
<td>30 months (mean)</td>
<td>113</td>
<td>53</td>
<td>60</td>
<td>10 (19%)</td>
</tr>
</tbody>
</table>

*Angiography was performed in only 41%.
Abbreviations: R = randomised patient control group; M = matched patient control group; C = comparable patient control group in same hospital.

In Patients with Unstable Angina Pectoris

Two studies embraced 328 patients with unstable angina randomized to medical or surgical management. The NHLBI National Cooperative Unstable Angina Study includes nine institutions that have randomized 288 patients with > 70% narrowing of a major coronary artery. The patients have been followed for a mean of 24 months. In addition, Selden et al. at the Portland V.A. Hospital for four months followed 40 randomized patients selected from all admitted between May 1972 and May 1975 with new or accelerated angina pectoris. Neither of these studies demonstrated that ACBG exerted a protective influence against the development of acute myocardial infarction in patients with unstable angina.

Hultgren et al. recently reported a comparison of the medical versus the surgical treatment of unstable angina in a prospective nonrandomized study of 118 patients admitted to one hospital from 1970 to 1975. Twenty-seven of the 66 patients treated medically did not have coronary arteriography. A number of other limitations to this study were cited by the authors. Nevertheless, there was no significant difference in the occurrence of an acute myocardial infarction in the medical group when compared with the surgical group. Hultgren concluded that the "surgical management of unstable angina cannot be justified on the basis of prevention of myocardial infarction because of the high incidence of perioperative infarction despite a low operative mortality."
been reported. These studies, however, were retrospective and did not have a temporally comparable control population. Opinions expressed in these publications vary as to the benefit of ACBG in preventing myocardial infarction. Three examples have been selected as representative of the extremes of the expressed opinions. The Stanford group, concluded, after evaluating 81 patients, that although "bypass surgery appears to be effective in relieving pain of patients with unstable angina ... the incidence of myocardial infarction in surgically treated patients is comparable to that in medically treated patients." On the other hand, the Oregon group, after evaluating 55 consecutive patients, concluded that "for high-risk patients with unstable angina and operable disease, direct myocardial revascularization on an urgent basis is an effective therapy in terms of early and late survival, frequency of myocardial infarction, and relief of anginal pain." Despite a perioperative infarction rate of 11%, the group at the Texas Heart Institute reported that "surgical intervention can improve the poor prognosis of patients with preinfarction angina and appears to be superior to medical treatment."

Although there is no uniform consensus as to the protection of patients with unstable angina from a subsequent myocardial infarction, it is generally agreed that ACBG, if undertaken in patients with unstable angina, should not be carried out as an emergency procedure. Urgency, interfering with the time required to rule out an acute myocardial infarction, is usually not indicated in patients with unstable angina pectoris; a not insignificant number of patients who may already have infarcted may be propelled to surgery that carries a prohibitively high morbidity and mortality.

The difference in operative mortality between patients with unstable angina and stable angina (reported to be increased as much as three times) disappears when patients with unstable angina are stabilized before initiating diagnostic and surgical procedures.

In Patients with Variant Angina or Prinzmetal Angina Pectoris

Available data regarding the role of ACBG in preventing myocardial infarction in patients with variant angina are scant and conflicting. This may be due to the possibility that the pattern of coronary blood flow following ACBG varies in patients in whom spasm is the major pathophysiologic alteration compared to patients who have significant fixed stenosis and lesser degrees of spasm.

Gaasch et al. analyzed the effect of ACBG in 24 patients managed personally or collected from the literature. They concluded that if spasm played the major role in the pathophysiology, the results of surgery were inferior to those generally obtained in patients with classical angina pectoris. Five of 24 patients developed myocardial infarction despite ACBG. These observations were supported by those of MacAlpin who warned that ACBG was a "last resort type of surgical therapy and the chances of relief of symptoms when surgery is limited to bypass grafting are not great in the absence of interoperative myocardial infarction."

None of Endo et al.'s nine patients with variant angina and discrete coronary artery stenosis treated with ACBG developed a myocardial infarction during an undefined follow-up period. However, these investigators stated that the improvement was not permanent in any patient. Shubrooks and colleagues at Massachusetts General Hospital were more optimistic about the surgical treatment of Prinzmetal's variant, especially when there is > 70% fixed obstruction in the proximal coronary vessels. Fifteen of 17 patients received ACBG; there was one perioperative death. The 14 survivors were free of pain for an average of 17 months follow-up. Only one patient was reported to have had a perioperative myocardial infarction.

In Patients with Left Main Coronary Artery Stenosis

Obstruction of the left main coronary artery constitutes a unique management problem; it obviously cannot be considered a "one vessel" lesion. It is said to occur in 8% of all patients with stable angina pectoris and 11.5% of patients with unstable angina admitted to a tertiary care referral center. There is reason to believe that the lesion is much less common in the total population of patients with IHD. Isolated stenosis of the left main coronary artery is a rare condition; it was found in 0.9% of 113 patients with left main disease in the V.A. Cooperative Randomized Study. The more discriminatingly patients are screened for the presence of IHD prior to coronary arteriography, the higher the proportion will be of patients with significant lesions of the left main coronary artery.

Takaro et al. recently reported the 30 month follow-up of these 113 patients in the V.A. Cooperative Study of Stable Angina; the patients had a reduction of the luminal diameter of the left main artery by 50% in two views (table 1). There was no difference in the incidence of myocardial infarction in these patients treated medically or surgically. Eight of the ten myocardial infarctions in the ACBG group were perioperative.

Most clinicians, but not all, have concluded that ACBG will improve the clinical course of patients with left main coronary artery stenosis; it thereby might be assumed that ACBG will prevent myocardial infarction. No data to support this assumption could be found in the literature. Contrary to common opinion, Cohen et al. reported that the occurrence of a myocardial infarction in patients with left main coronary stenosis is uncommon despite a large amount of jeopardized myocardium.

Sung et al. followed 30 patients with 50% or greater obstruction of the left main coronary artery; 19 of the patients had surgery, 11 did not. They concluded that "the mortality is extremely high in those with poor distal vasculature technically unsuitable for surgery. On the other hand, the mortality is relatively low in patients who have technically bypassable lesions whether treated surgically or medically. Surgery does appear, however, to be more effective in providing symptomatic and clinical improvement.... It appears doubtful that angiographic evidence of left main coronary obstruction alone justifies surgical therapy."

It would appear that the severity of the clinical course including the occurrence of myocardial infarctions in patients in this subset depends on 1) whether the right coronary artery is dominant, and if so, 2) the extent of the disease in the distal vessels of the left system and the extent of collateral flow from the right coronary, and 3) the contractility of the ventricle. In addition, the clinical course may depend on the length of the left main coronary artery and the number of diagonal branches.
In Patients with Evolving Myocardial Infarction

The authors know of no randomized study that has evaluated the role of ACBG in patients with an evolving myocardial infarction. Most clinicians avoid surgery in patients with myocardial necrosis. Experimental data indicate that increasing blood flow after several hours of occlusion is not beneficial; in fact, it may lead to myocardial hemorrhage and extension of the infarct.66

Dawson and colleagues23 emphasized that there was an increased risk associated with ACBG in patients with a recent myocardial infarction. Based on experience with 1,700 patients, they reported a 38% mortality with surgery within the first seven days after an acute myocardial infarction; a 16% mortality when the infarction occurred eight to 30 days before surgery and a 5.8% mortality when the infarction was 31 to 60 days old. It has generally been accepted that, if possible, major surgery should be postponed for one, preferably three, months after an acute myocardial infarction.

Nevertheless, some surgeons have recommended ACBG for selected patients with bypassable lesions despite evidence of myocardial necrosis. Keon and associates47 after experience with 15 patients prior to 1973, recommended ACBG for patients with a complicated myocardial infarction; increasing the blood flow was thought to salvage myocardium in the underperfused marginal zone where muscle cells remain viable but have very depressed contractility. Eleven patients survived. The authors concluded that "controlled prospective studies are required to elucidate the timing and indications for operation." There is no evidence that such a study has been carried out.

Berg et al.,46 in 1975, also considered an acute myocardial infarction to be a surgical emergency. They operated on 96 patients with evidence of an evolving myocardial infarction with a mortality at one year of 6.3%. This was compared by the authors to a "30% mortality" reported in non-randomized patients treated medically. The average preoperative serum glutamic oxaloacetic transaminase, known not to be specific for myocardial necrosis, was 59.0 U (upper limits of normal was 24 U); postoperatively it was 180.5 U. Follow-up through 46 months revealed only one late death, four months postoperatively. No comment was made about subsequent myocardial infarctions, but 85 of 96 patients were said to be living and well. Berg concluded that "most patients with acute myocardial infarction are best treated by emergency coronary bypass surgery."

A word of caution, however, was sounded by Bologna et al.63 in 1976. After studying 25 patients with a diagnosis of acute myocardial infarction, operated two to eight hours after the onset of symptoms, they concluded that the maximum period of ischemia for re-establishment of coronary blood flow should be less than four hours; furthermore, even though the operative mortality was comparatively small (8%), ACBG "at the present time is not acceptable as definitive therapy for an evolving, uncomplicated acute myocardial infarction." It would appear that most surgeons today ascribe to this opinion.

Perioperative Myocardial Infarction

Perioperative myocardial infarctions diagnosed by the development of new Q waves have been reported to occur in from 1.3% to 40% of patients receiving ACBG.10, 12-14, 24, 49-66 Kouchoukos et al.15 reported that 15 (10%) of 151 consecutive patients, evaluated with serial ECGs and serum enzyme analysis, developed Q waves diagnostic of an intraoperative myocardial infarction. There were an additional 34 patients (22%) who had only ST-segment changes, suggesting significant myocardial injury possibly due to subendocardial infarction.

Approximately 80% of the patients studied by Oldham and co-workers60 had evidence of intraoperative myocardial injury detected by analysis of plasma for serum creatine phosphokinase (CPK) activity. MB-CPK is almost invariably elevated after coronary bypass surgery;68 it is also elevated following noncardiac thoracic surgery, but not abdominal surgery.68 However, when the MB-CPK exceeds 470 U/L and persists for more than 30 hours postoperatively, a myocardial infarction should be suspected.67 Other investigators have found that the reversal of the normal LDH1:LDH2 ratio correlates well with myocardial necrosis.69

It has been implied that surgically induced infarcts are reasonably well tolerated,65, 68 this may not be so. Several studies have shown that patients who develop an infarct in relation to ACBG have an immediate postoperative mortality from 12% to 64%.52, 64, 66 For example, Cannom and associates52 at Stanford, reported nine deaths among 14 (64%) patients with perioperative infarcts.

A number of investigators60, 64, 66 have reported that in approximately three-fourths of the patients who develop new Q waves perioperatively, the postoperative angiographic studies, when compared to preoperative studies, reveal either a new total occlusion of the corresponding coronary artery, or decreased wall motion of the corresponding myocardial segment, or both. A decline in ejection fraction has been demonstrated in association with such changes in contractility.66 Similar changes have been reported in a high incidence of patients with probable perioperative myocardial infarctions, as well as patients who developed perioperative and transitory ECG changes.64

Perioperative infarctions appear to have a significant effect on the long term prognosis of the patient. Schrank et al.64 reported that typical changes of perioperative myocardial infarction were seen in 40% of the postoperative ECGs and 46% of the VCGs of 35 consecutive patients who survived elective ACBG. Those patients with evidence of perioperative infarction had the highest incidence of late death, and clinical evidence of myocardial damage and reinfarction at the time of evaluation one year post ACBG. There was no difference in NYHA functional classification, congestive heart failure or presentation of angina pectoris in patients with or without an infarction.

Based on personal experience and a review of the literature, Mundth and Auten64 concluded that a 10% to 15% incidence of postoperative myocardial infarction can be expected from elective ACBG. They further stated that "although some patients may be benefited in terms of relief of angina by postoperative infarction, the occurrence of an infarction probably has a definitely adverse effect on the long term functional results and longevity."

After a careful study of 71 patients, Achuff et al.66 concluded that "there are no grounds for undertaking coronary bypass surgery if the objective of operation is to prevent
myocardial infarction or enhance left ventricular function. The demonstration of new occlusive changes in the intrinsic coronary circulation, the frequent occurrence of perioperative myocardial damage and lack of improvement or deterioration in ventricular function all preclude operating on patients with mild angina or no symptoms at all.

Ulliyot et al. reported 22% (20/91) of all Q waves, either Q waves present preoperatively or those that developed perioperatively, disappeared or became nondiagnostic of a myocardial infarction before the patient was discharged from the hospital. It was suggested that the disappearance of Q waves “lends support to the notion that myocardial infarction occurring in the context of ACBG may be different from those occurring spontaneously.” The disappearance of Q waves postoperatively, both those present preoperatively and those developing perioperatively, might be due to increased perfusion of the myocardium.

This concept is not in concert with what is known about ECG changes accompanying myocardial infarctions. Q waves have been reported without evidence of an infarction, or at least a transmural myocardial infarction. However, much better documented is the return of the ECG to normal after a definite infarction. In the recently completed cooperative study of the effects of lipid lowering agents in 8,341 subjects with a previous myocardial infarction, 80% of the subjects had a Q or QS pattern in the initial qualifying ECG; only 43% retained such diagnostic findings in the baseline examination. The interval from the last infarction to entry into the study varied from a few months to more than 120 months (median 22.9 months). In some cases a new infarction, electrically opposite to the previous one, may result in a cancellation of the opposing electrical forces and a disappearance of the Q wave.

It is well documented that large nontransmural subendocardial infarctions can occur without the development of new Q waves. Such infarctions, which may be extensive, but not at any site transmural, may be manifested on the ECG by a loss of R wave voltage and/or ST and T wave changes. They are not necessarily “mild infarctions.” There is essentially no difference in the hospital or short term mortality of patients with transmural and nontransmural myocardial infarctions.

Bulkley and Hutchins studied the postmortem hearts of 53 patients who died within one month of ACBG. Operation-related necrosis was present in 46 (87%) of the hearts; 18 had a transmural infarction. Only four of these 18 infarcts appeared to be due to the graft or intrinsic occlusion of the recipient coronary artery. The other 14 infarcts reflected prolonged myocardial ischemia in the distribution of a critically stenosed coronary artery not intimately related to the revascularization procedure.

By incorporating radionuclide imaging of the heart and myocardial specific enzyme changes with electrocardiographic surveillance, the incidence of perioperative myocardial infarction has been found to be considerably greater than when diagnosed solely by Q wave changes. Righeti and his associates at San Diego studied by electrocardiography, MB-CPK and 99mTc pyrophosphate scintigrams 41 consecutive patients who received ACBG. They required for the diagnosis of a perioperative infarction that there be 1) persistent Q waves and either an elevated MB-CPK level or a positive 99mTc pyrophosphate scan; or 2) ischemic ST-T wave changes as well as both an elevated MB-CPK and a positive 99mTc pyrophosphate scan. Based only on Q wave changes, the incidence of perioperative myocardial infarction was 15%; based on the combined criteria the incidence was 27%. The development of a perioperative infarction did not appear to be correlated with the performance of an endarterectomy, the number of diseased vessels, or the number of grafts performed. There was a correlation, however, with the duration of the cross-clamp time.

Other investigators have also found that a comparison of postoperative 99mTc (Sn) labelled pyrophosphate scintigrams with preoperative studies revealed evidence of myocardial necrosis more frequently than observed by ECG changes alone.

There is evidence that attention to the details of the surgical technique can significantly reduce the incidence of perioperative myocardial infarction. The group at Southwestern reduced the incidence of perioperative myocardial infarction, documented by the development of new Q waves in 12% and by positive 99mTc (Sn) pyrophosphate scintigrams in 31% to 7% and 14%, respectively, after changing certain operative procedures including initiating the use of magnifying lenses.

Other groups have reported a decrease in the incidence of perioperative myocardial infarction of similar magnitude or more by introducing the technique of aortic cross clamping and profound regional hypothermia, venting the atrium rather than the ventricle or abandoning electrical fibrillation of the heart.

Serious Arrhythmias and Conduction Abnormalities

Despite initial enthusiasm for the use of ACBG in the treatment of recurrent arrhythmias, most investigators now believe that the procedure has limited value for this purpose.

Guinn and Mathur did not find a difference in the incidence of arrhythmias in the previously described randomized study of 116 patients with stable angina. The authors of the other randomized studies have not reported data concerning arrhythmias.

Tilkian et al. analyzed the incidence of arrhythmias in a total of 84 patients followed for one year at the Palo Alto V. A. Hospital. Forty-two were randomized to surgery and 42 to medicine. The incidence of ventricular arrhythmia appearing during treadmill testing was determined at the beginning of the study and one year later. Significant changes in the frequency or severity of the exercise induced ventricular arrhythmia was not demonstrated following ACBG. In fact, high grade ventricular arrhythmias occurred occasionally after successful ACBG. Patients with all grafts patent had the greatest improvement in exercise capacity and achieved higher heart rates with less evidence of myocardial ischemia; however, this same subgroup of patients showed a tendency to more frequent and higher grades of arrhythmias.

There have been occasional reports, mostly anecdotal, of recurrent arrhythmias responding to “or being controlled by” ACBG in conjunction with the resection of a discrete ventricular aneurysm. These reports, however, have not had adequate controls or have consisted of a small number of patients who have been followed for a short period of
time. Ricks et al. recently reviewed the experience at Stanford of 21 patients with refractory arrhythmias who received ACBG with or without resection of a ventricular aneurysm. They concluded that surgery carried out during the relatively unstable postmyocardial infarction period was associated with a high early mortality; in more stable patients, the mortality was "modest" and the early results gratifying. However, late failures occurred and all survivors demonstrated resistant ventricular ectopic activity. Additional studies have recently been reported that suggest that ACBG may reduce the incidence of sudden death in patients with IHD. These studies will be discussed in a subsequent section.

Prinzmetal's variant form of angina pectoris is associated with a high frequency of arrhythmias. As indicated previously, most investigators have not found that ACBG alters favorably the course of the disease. Only two reports comment specifically on the effect of ACBG on the incidence of arrhythmias in such patients. The positive benefits reported by Shubrooks et al. have already been cited. Nordstrom et al. described two patients with variant angina and recurrent tachycardia who, for one and two and a half years after surgery, respectively, had no further arrhythmias.

It is now recognized that re-entry is the common mechanism for the development and the perpetuation of ventricular tachycardia. Re-entry pathways do not involve large areas of muscle. They are not macro-reentry pathways, but rather micro-reentry pathways. Location of such pathways requires careful use of complex electrophysiologic mapping techniques not available in most medical centers. Resection and/or reperfusion of a re-entry pathway in most centers would be a "hit or miss affair."

Conduction abnormalities are a common development in patients with IHD. However, no report was found in the literature of a study designed to demonstrate that ACBG improved abnormal conduction of the myocardium. Lambert et al., in 1971, reported that second or third degree heart block, complete heart block or recurrent bouts of ventricular tachycardia due to obstructive disease of the anterior coronary artery or left main coronary artery were emergency situations. They concluded that "from this report we established that the number of patients who will live and have ventricular function can be improved from (a survival rate of) 20% to 80%."

Prevention or Treatment of Congestive Heart Failure

It is well known that the development of congestive heart failure adversely affects the prognosis of IHD. However, since that oft quoted study by Paul was published, considerable knowledge has been gained about fluid and electrolyte problems and the use of time honored drugs such as digitalis and nitroglycerin. Additional new drugs and families of drugs, useful in the management of congestive heart failure, have been developed. New concepts such as preload and afterload reduction have added new perspectives to the treatment of congestive heart failure. It is, therefore, not surprising that even after ten years of experience the role of ACBG in the treatment of congestive heart failure in patients with IHD is controversial.

Morris et al. was one of the first groups to enthusiastically support the use of ACBG in the treatment of patients with congestive heart failure. They reported a series of 161 patients with a total hospital mortality of 8.7% despite "almost no exclusion of very ill or bad risk patients as operative candidates." Twenty-five percent of the patients had both angina and congestive heart failure. An elevation of the end-diastolic pressure was present in 48.2%; it was greater than 20 mm Hg in 13.5%. Nearly one-quarter of the patients who had noncontractile areas or areas of paradoxical contraction of the left ventricle; six patients had large left ventricular aneurysms requiring resection. Eighty-two of the patients who had congestive heart failure prior to ACBG improved, 9% were unchanged and 9% were worse at an unpaired follow-up period. Morris considered that the only relevant contraindication to ACBG was a recent myocardial infarction. He further stated in 1970 that "only time and actuarial studies will provide undisputed proof of the efficacy of the distal coronary bypass."

The enthusiasm for the use of ACBG in the treatment of congestive heart failure secondary to IHD was shared by several other groups. Chatterjee et al. demonstrated, in studies 14 days after surgery, that severely depressed left ventricular function from profound myocardial ischemia due to high grade proximal occlusive lesions of the left coronary artery or its branches was returned to normal if there was a normal restoration of blood supply to ischemic myocardium by ACBG. Rees et al. reported that ventricular function was demonstrated to be improved significantly when patients were studied three months after surgery if the operation was technically successful. If the operation was technically unsuccessful, ventricular function was found to have deteriorated markedly. Success was based on the anatomic location of the coronary artery disease in relation to the patency and location of the vein graft. Mundth et al. reported their experience with 40 patients with IHD and severe congestive heart failure; 11 had a ventricular aneurysm; 26 of these had significant angina pectoris. Follow-up ranged from three months to three years. Clinical assessment of the results of surgery was based on the classification of symptomatic improvement and functional status, evidence of change in heart size and resolution of clinical findings of cardiac failure. There were 31 survivors; 80% had good to excellent clinical results. Significant improvement of left ventricular function was demonstrated by cardiac catheterization within one year of surgery in five patients. It was postulated that myocardial perfusion improved promptly after ACBG and resulted in improved contractility of previously ischemic myocardium.

Spencer et al. also reported favorable results from the use of ACBG, together with resection of a ventricular scar or aneurysm. Thirty-seven percent of 40 patients did not survive surgery; 20% were said to have a good result, 33% a fair result and 10% a poor result. Improvement was correlated with the presence of angina pectoris in association with congestive heart failure. Cardiac catheterization six to 10 months postoperatively in ten patients who had congestive heart failure without significant angina demonstrated no improvement in myocardial contractility or reduction of the elevated left ventricular pressure. The authors concluded that advanced congestive heart failure without angina secondary to diffuse hypokinesis probably should be considered inoperable.
The concept of ACBG being a major addition to the management of many patients with congestive heart failure was not supported by all investigators. Solignac et al. operated on 11 patients with congestive heart failure due to severe IHD that was intractable to medical therapy. Although the operative mortality was acceptable for such ill patients (2/11), the overall survival for three years was only 36%. The authors concluded that the mortality curve for the patients receiving ACBG was the same as for patients treated medically and that ACBG is not helpful in cases of intractable congestive heart failure because the severe diffuse left ventricular asynergy which is invariably present is seldom reversible and is so extensive that segmental resection of the ventricular wall is of doubtful value.

Kouchoukos et al. also supported a more conservative approach by reporting their experience with nine patients with congestive failure with large noncontracting segments secondary to occlusion of the left anterior descending coronary artery. The operative mortality resulting from myocardial excision and ACBG was 33%; four additional patients who received surgery died within four months. Neither of the two survivors showed improvement in the level of activity or symptoms. Despite symptomatic improvement and disappearance of ST-segment changes, even with increased stress following ACBG, left ventricular function did not consistently improve. With increasing reports of poor long term results, despite a surprisingly low operative mortality for such critically ill patients, only a few reports supporting the use of ACBG in patients with congestive heart failure have appeared.

Prevention of Premature Death

Does ACBG prevent premature death, either sudden or nonsudden?

Again, a review of currently available literature indicates a considerable difference of opinion. A total of 250,000 to 300,000 patients in the United States have had an ACBG through the summer of 1977. Yet fewer than 1,300 patients in this country have been studied and randomized into groups receiving or not receiving ACBG and followed for a period approaching three years. The need for a large randomized study to answer questions regarding ACBG has been emphasized by many. Others have considered a truly randomized study unattainable, impractical or unnecessary.

In the absence of a randomized control, what group or groups of patients have frequently been used as controls to evaluate survival after ACBG? (See figs. 1 and 2). There are five:

1A) Friesinger et al. in 1970, reported the mortality from IHD in relation to the extent of atherosclerotic involvement determined angiographically in 224 patients followed for two to nine years (fig. 3). This group was selected from 350 patients who were studied by coronary angiography from 1960 to 1967. One hundred twenty-six patients were excluded because they had unsatisfactory studies, evidence of primary myocardial or valvular disease or because they received a coronary vascular surgical procedure. (There were 40 patients excluded for this latter reason.) One hundred twenty-one of the 224 patients were considered not to have CAD. The authors stated that "while this study was in progress, most patients who had unequivocal manifestations of ischemic heart disease did not have angiographic studies performed since it was felt un-

*Rosati et al. recently analyzed the suitability of these studies as controls for evaluating ACBG.

![Figure 1. The survival of patients who underwent ACBG at the Texas Heart Institute from 1960 through 1974 is compared to patients seen at the Cleveland Clinic from January 1963 through July 1965 and followed up to 54 months without ACBG (112). (Published with permission of the authors.)](http://circ.ahajournals.org/)

![Figure 2. Comparison of four large series of non-operated patients (Cleveland, Hopkins, Queens, Duke) with four operated series of patients. These are not randomized or even matched groups, nor were the operated and nonoperated patients, with one exception, followed at the same time and place. (Published with permission of the authors.)](http://circ.ahajournals.org/)
necessary and would not facilitate management. Therefore, such patients with obvious ischemic heart disease were not included in this study. Patients with severe disease involving at least two coronary arteries, determined by a point system developed for the purpose of standardizing the interpretation of coronary arteriograms, had an annual mortality of 10%. Those with mild disease had an annual attrition rate of only 1%.

1B) Humphries et al. 115 in 1974, extended the follow-up of the above patients for five to 12 years (fig. 3). The group with mild disease had no significant mortality. The groups with moderate IHD experienced accelerated deterioration between the sixth and ninth years; the total mortality was about 50%. By ten years, 50% of the patients with severe atherosclerosis had died.

2) In 1973, Bruschke et al. 112 reported the five year survival of 590 nonsurgical patients studied angiographically at the Cleveland Clinic from January 1963 through July 1965. A 50% or greater obstruction of a coronary vessel was considered significant. The 590 patients were consecutively studied except for 17 patients lost to follow-up and an unspecified number of patients in whom surgery was performed. The authors stated that when the coronary arteriography was performed implantation of a single internal mammary artery was by far the most common type of coronary surgery. Due to selection for surgery of a relatively high proportion of patients with single vessel disease and normal left ventricular function, a relatively high proportion of poor risk patients from the arteriographic standpoint was left in the medical group. The mortality was highest during the first year of the study apparently because of the large number of high risk patients unacceptable for surgery. The five year mortality for the entire group was 34.4%; for one, two, three vessel and left main coronary disease it was 14.6%, 37.8%, 53.8%, and 56.8%, respectively. The prognosis appeared to be worsened by certain combinations of disease, for example, with occlusion of the right and a subtotal occlusion of the left anterior descending coronary artery, the five year mortality was 74%. Furthermore, it was demonstrated that the mortality was increased in patients with poorly contracting ventricles.

3) The Cleveland Clinic experience 113 was further analyzed restricting the criteria for significant lesions to 80 to 100% occlusions and including patients studied from 1960 through 1965. Thus, this study began before the above and apparently included those cases in the earlier reported study that met the more rigid criteria. Four hundred sixty-nine patients were followed for six to 11 years. As a result larger subsets of patients could be analyzed. One hundred twenty-eight patients had single vessel disease defined as 80 to 100% occlusion of one major vessel and < 50% occlusion of the other two. The rate of dying over six years was 20%, or about 3.3% per year. One hundred twenty-one patients with triple vessel disease had a six year mortality of 63% or approximately 10.5% per year. The annual mortality for patients with involvement of the right coronary artery was 2.3%; for the left anterior descending 4.0% and circumflex 4.2% (fig. 4).
4) Oberman et al.114 studied 301 patients between 1965 and 1970 and followed them for four years (mean 22 months). Fifty-five of these patients underwent some form of surgery, two were lost to follow up and one died immediately after study. Thus, the study population consisted of 246 patients with > 50% obstruction of the lumen of one or more major coronary arteries. Patients with one vessel disease had a mortality of 1% per year, two vessel disease 13% and three vessel disease 15%.

5) Burgraf and Parker126 reported in 1975 the fate of 266 patients with angiographically documented significant stenosis of coronary arteries followed at Queen's Hospital for one to ten years. This study was initiated in 1964; apparently only 34 patients were followed after 1970. The patients were selected from a larger group of patients of whom 231 underwent coronary artery revascularization procedures. Seven patients had stenosis of the left main coronary artery and were analyzed separately. Thus, there remained 259 patients for the final analysis. Eight percent of the patients with single vessel disease, 35% with double vessel disease and 45% with triple vessel disease died during the first five years of follow-up.

These five studies include less than 1,750 patients. (Apparently some of the same patients were reported in both studies from the Cleveland Clinic.115, 116) Each of these studies was initiated in the early or mid 1960s and apparently only a few patients in any of the studies were followed after 1970. Therefore, many of these patients were referred to one of these four medical centers at a time when little was being done for IHD in most medical centers in this country. It would seem reasonable to assume that the subjects were selected for the most part from the more symptomatic subsets of the population at large. In all but study #1 symptomatic patients without demonstrable CAD were excluded. It is possible that the population was further biased when patients were withdrawn for surgery at each institution.119 Thus, a relatively high risk population would remain in the group being followed.

One additional report which has served as a control for published studies should be cited. In 1974, Reeves et al.126 combined the study of Oberman114 with that of Friesinger129 and three additional studies: 1) a report by Moberg et al.,117 which analyzed the clinical course of 200 patients at the Cleveland Clinic who had 80 to 100% occlusive lesions of the proximal coronary tree who were followed for seven years; 2) a report by Lichtlen and Moccetti126 of Zurich which evaluated 231 patients followed for a period of nine to 80 months; 3) a report by Slagle and associates at Duke126 that described the six to 30 month follow up of 94 patients.

These last three studies were published only in brief abstract form. Although Reeves' study is often quoted, few details about more than one-half of the combined 995 patients are known. All patients were studied angiographically, apparently in the 1960s. It is known that Moberg et al.117 considered an obstruction of > 80% to be significant; it is unknown what criteria were used for the other studies. Nevertheless, as a result of the pooled heterogeneous data, Reeves126 reported that 265 patients with one vessel disease (which vessel was not stated) had an annual mortality of 2.2%; 220 patients with two vessel disease had an annual mortality of 6.8%, whereas 220 patients with three vessel disease had an annual mortality of 11.4%.

Are the data reported in these six studies satisfactory to be used as a control for evaluating the effectiveness of ACBG in the early and mid years of the 1970s?

The peak incidence of death from IHD in the United States occurred in 1963127 (table 2). From 1950 to 1963 the mortality from IHD increased 19%. From 1963 to 1973 the age-specific death for subjects with IHD declined for the ages 35 to 74 years by 18.4% (figs. 5 and 6). The decline for persons more than 75 years of age was 5%. Hospital admission for purposes of treating heart attacks in persons 45 to 64 years of age declined 16% between 1968 and 1971.128 The total number of cardiovascular deaths, after being well over the million mark for several years, fell below that level in 1975 despite the increase in the number of adults in the population at risk of a fatal cardiovascular event;129 the life expectancy for the average male in the United States increased between 1971 and 1974 by one year.130 This sizable decline in mortality rates for IHD has been associated with substantial declines in mortality rates, not only from cardiovascular causes, but also from all causes as well.131 The decline of "all causes" mortality rates strongly supports the conclusion that the decrease reported in IHD mortality rates is real and not spurious.132

Data supporting this trend have been collected from a number of divergent areas. The Metropolitan Life Insurance Company reported133 a modest 7% to 9% reduction in the incidence of death from IHD in its policy holders from 1962 to 1968; from 1969 to 1974 the reduction in the incidence of death in males was 19%, the reduction in females was 12%. Rogers and Blendon,134 in discussing the changing American health scene, emphasized that the decline in the death rate from IHD appears to be accelerating.

The Bureau of Census in the Center for National Statistics reported in 1975 that the death rate declined to 8.9 per thousand population. Deaths from coronary artery disease declined 2.9% for that year alone.124 Australia also observed a similar decline135 as did a select population in East Finland. There has been no increase in ACBGs in Australia to account for this decline.128

Other observations that the natural history of coronary artery disease is changing come from a comparison of the pathologic findings of casualties of the Korean and Vietnam conflicts. Enos et al.129 found some degree of atherosclerosis in the coronary arteries of 73% of 300 U.S. casualties killed in the Korean conflict in the early 1950s. Fifteen percent had over 50% luminal narrowing as judged by gross examination of the coronary arteries. Eighteen years later McNamara et al.130 examined 105 U.S. soldiers killed in the

**Table 2. Age-specific Death Rate from Ischemic Heart Disease (Per 100,000 Population in the United States*)**

<table>
<thead>
<tr>
<th>Year</th>
<th>35-44</th>
<th>45-54</th>
<th>55-64</th>
<th>65-74</th>
<th>75-84</th>
<th>≥ 85</th>
</tr>
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<tr>
<td>1958</td>
<td>58.0</td>
<td>232.2</td>
<td>658.4</td>
<td>1,628.8</td>
<td>3,364.8</td>
<td>7,009.3</td>
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<tr>
<td>1959</td>
<td>57.6</td>
<td>252.7</td>
<td>665.3</td>
<td>1,642.6</td>
<td>3,359.2</td>
<td>7,321.0</td>
</tr>
<tr>
<td>1960</td>
<td>57.7</td>
<td>258.0</td>
<td>665.5</td>
<td>1,551.7</td>
<td>3,434.8</td>
<td>7,256.5</td>
</tr>
<tr>
<td>1961</td>
<td>57.9</td>
<td>235.2</td>
<td>649.4</td>
<td>1,541.4</td>
<td>3,360.6</td>
<td>7,383.3</td>
</tr>
<tr>
<td>1962</td>
<td>58.7</td>
<td>238.4</td>
<td>660.4</td>
<td>1,586.7</td>
<td>3,449.2</td>
<td>7,922.2</td>
</tr>
<tr>
<td>1963</td>
<td>61.0</td>
<td>240.3</td>
<td>668.4</td>
<td>1,619.1</td>
<td>3,485.6</td>
<td>8,165.6</td>
</tr>
<tr>
<td>1964</td>
<td>61.0</td>
<td>235.8</td>
<td>660.3</td>
<td>1,586.7</td>
<td>3,388.6</td>
<td>7,885.7</td>
</tr>
<tr>
<td>1965</td>
<td>60.9</td>
<td>236.6</td>
<td>657.4</td>
<td>1,580.9</td>
<td>3,422.0</td>
<td>8,088.2</td>
</tr>
<tr>
<td>1966</td>
<td>59.6</td>
<td>206.4</td>
<td>661.4</td>
<td>1,609.0</td>
<td>3,413.6</td>
<td>8,037.7</td>
</tr>
<tr>
<td>1967</td>
<td>60.1</td>
<td>201.4</td>
<td>645.0</td>
<td>1,568.8</td>
<td>3,292.4</td>
<td>7,941.8</td>
</tr>
<tr>
<td>1968</td>
<td>59.6</td>
<td>218.8</td>
<td>624.1</td>
<td>1,552.2</td>
<td>3,441.7</td>
<td>8,496.7</td>
</tr>
<tr>
<td>1969</td>
<td>55.4</td>
<td>219.3</td>
<td>668.4</td>
<td>1,580.3</td>
<td>3,267.8</td>
<td>8,400.2</td>
</tr>
</tbody>
</table>

Vietnam conflict; only 45% had any evidence of atherosclerosis. Only 5% of this group had gross evidence of severe coronary atherosclerosis. No soldier had postmortem angiographic evidence of severe coronary narrowing and in only one case was any degree of stenosis observed. Both series were comprised of young male combat troops, killed in action, with a mean age of 22.1 years and an identical age range. The only difference was that they were separated in time by 18 years. McNamara et al. discussed the possible technical difficulties that could account for some of the observed differences in the extent of CHD. They finally concluded that “if one assumes that the two groups of patients are similar then the decrease in atherosclerosis in young males of this age is really quite significant (P < 0.01).”

Clearly, several trends have been proceeding in parallel over the last decade or more. The medical management of IHD has changed significantly with the introduction of new modes of medical management including coronary care units, lidocaine, propranolol, potent diuretics such as furosemide, life support systems, etc. The public also has become aware of risk factors such as smoking, hypertension, diet and physical activity. Much professional and community effort has been exerted to reduce these factors.

Thus, the individuals comprising studies of patients in the early and mid 1960s were selected from a population at large that had a significantly higher death rate from IHD than does the population in the 1970s from which patients are selected for ACBG. Such studies of the natural history of CAD as those cited above defined certain aspects of the natural history of the disease in the early and mid sixties. But do they define the natural history of the disease in 1977?

In view of these considerations, what can be said about the role of ACBG in preventing premature death from IHD?

The three randomized studies evaluating the role of ACBG in the treatment of stable angina and the two randomized studies of unstable angina have already been described in the section on myocardial infarction. It should be recalled that patients with stenosis of the left main coronary artery were excluded from those studies. There is no statistical evidence that ACBG prolonged the life of the patients with stable or unstable angina over what was observed in the randomized control group in any of those five studies. The same is true for the two nonrandomized but somewhat controlled studies previously described (table 1).

Hultgren”s study of unstable angina, also described in the previous section, indicated that life was prolonged by ACBG in unstable angina but the study was not adequately controlled. Hultgren pointed out that the study was not a prospective, randomized evaluation. The surgical group had a slightly greater incidence of stable angina, angina of recent onset and prior myocardial infarction. That group also had a smaller number of patients with single vessel disease; 59% of the medical patients did not have coronary arteriography. Hultgren concluded that “although our study has demonstrated an improvement in survival with surgical treatment, a longer follow-up evaluation of a larger number of patients will be necessary to evaluate this question thoroughly.” (The mean follow-up of these patients was only 23 months.)

Data from the one randomized study of left main coronary artery disease lend support to the premise that life expectancy in patients with this serious lesion may be prolonged by ACBG at least through 30 months. At 36 months the number of survivors in both groups was so small that the difference became statistically insignificant (fig. 7, table 1). It should be noted, however, that the operative mortality for the first two years of the study, which included 20 patients, was 25%; for the last three years it was 7% (45 patients). Thus, it is reasonable to believe that with increased operative experience and an expected lower operative mortality, the benefits of surgery in preventing premature death in properly selected patients in this subset could be even more significant.
A number of other less well controlled studies support the concept that life is prolonged by ACBG in properly selected patients with this lesion. Yet not all investigators believe that all patients with left main disease will benefit from ACBG by living longer. Sung et al., after following 30 patients with >50% obstruction of the left main coronary artery, concluded that "it is doubtful that angiographic evidence of left main coronary obstruction alone justifies surgical therapy." Demots et al., concluded from their experience with 58 patients that improved survival with surgery was not statistically significant. Battock et al., as a result of a study of 21 patients that even though the overall mortality is greater in unoperated patients with left main coronary artery disease, the long term follow-up and surgical results are not sufficient to justify prophylactic operation.

Because of the difficulty in conducting randomized studies, McNeer et al. utilized a different approach to determine if ACBG prolonged life. A computer program was developed at the Duke Medical Center that permitted the storage of pertinent historical data as well as data referable to physical findings, laboratory observations and therapeutic programs of individual patients; 110 items of information were stored. In 1974 they reported the results of a follow-up of 781 consecutively evaluated patients with coronary artery disease; 402 were treated medically and 379 surgically. There was a significant difference between the groups of patients in only a few of the parameters. After two years, the survival rate was the same in the medical (83%) and in the surgical (85%) group; the four year survival was 78% and 82%, respectively. At four years, however, the non-operated group was older and had an excess of patients with ECG evidence of LVH, three vessel disease, distal vessel disease, abnormal left ventricular contraction patterns and elevated left ventricular end-diastolic pressure. One subgroup of patients with A-VO$_2$ difference of <5.5 vol %, an abnormally contracting left ventricle and three vessels significantly involved appeared initially to benefit from surgery. Continued follow-up of these and additional patients, however, has failed to confirm the initial encouraging results. At four years 79% of the surgical group was alive compared to 74% for the nonoperated group. It would appear that the combination of total occlusion of the right coronary artery and subtotal occlusion (>70%) of the left anterior descending artery may be improved by ACBG. The three year survival after ACBG was 88% versus 68% for the control.

Based on this type of observation, the Duke group concluded that "ACBG does not prolong life in comparison to medical management over a span of two to five years. There may be certain higher risk patients whose lives may be prolonged by aorto-coronary bypass surgery but more patients and prolonged follow-up are needed to answer the question."

Using the same computer matching technique, the Duke group evaluated the difference in survival rates between complete and incomplete revascularization in 392 consecutive patients. Complete revascularization was defined as having been accomplished if all major arteries with a 70% or greater occlusion received a bypass graft. Incomplete revascularization resulted when an artery with such a stenosis did not receive a graft. There were 186 completely revascularized patients and 206 incompletely revascularized patients. These two groups were compared over a 24 month period. There was no difference in survival or relief of pain that could be correlated with the completeness of the revascularization procedure.

Is there evidence that ACBG will reduce the incidence of sudden death, if not the total incidence of premature death, from IHD?

As a result of a three to four year follow-up of patients being monitored by the Seattle Heart Watch program, Hammermeister et al. reported that patients with two vessels with >70% proximal stenosis and normally or moderately impaired ventricular function, and possibly those with three vessels so involved, had improved survival after ACBG due to a decrease in sudden death when compared to patients in the Seattle Heart Watch group who did not have ACBG (1.8 to 10.9). An unknown number of patients with obstruction of the left main coronary artery were considered in this study to have two vessel disease. The authors were careful to point out that the medically treated patients, in contrast to those receiving ACBG, had a lower functional class, more extensive ventricular contraction abnormalities, a larger end-diastolic volume and fewer distal vessels feasible for grafting. Furthermore, 36 patients (58%) were excluded from the surgical group for "procedural" death; three patients (7%) were excluded for this cause from the medical group. This was obviously not a randomized study.

Vismara et al. recently reported their experience with ACBG in reducing the incidence of sudden death. Sudden death was defined as occurring within six hours of the onset of symptoms attributable to unexpected arrhythmia. Two
hundred and sixty-four patients with > 75% luminal narrowing of two or three major coronary arteries that were studied from 1970 to 1973 were divided into two groups: group one included 112 patients treated medically and group two 172 patients treated surgically. Both groups were reduced by excluding patients: from group one, eight patients were excluded who died from congestive heart failure and eight who died from noncardiac causes. From group two, five patients who died as a result of surgery for ACBG, five patients who died from congestive heart failure and four from noncardiac causes were also excluded. In addition, 17 surgical patients were excluded from the surgical group because they were found to have an LVED pressure below 7 mm Hg. All medical patients had an LVED pressure above that level. Furthermore, it would seem that the medical patients were followed from the day of catheterization, the surgical patients from the day of the surgery which occurred within one month postcatheterization. There were thus 96 patients treated medically and 121 patients treated surgically who were followed prospectively for an average of 39 months. After these exclusions, the total groups were said to be comparable. There were 12 patients in the surgical group with disease of the left main coronary artery and six in the medical group. It is clear that these patients were not randomized. Seven of 121 surgical patients (6%) died suddenly, whereas 23 of 96 (24%) of the medically treated patients died suddenly.

Both of these last two studies report suggestive evidence that ACBG prolongs survival in patients with multivessel disease by decreasing the incidence of sudden death, possibly by preventing unexpected fatal arrhythmias. Yet it should be emphasized that in no randomized study evaluating patients with stable or unstable angina have similar results been reported.

**Is there evidence that ACBG will modify the course of patients who have experienced an episode of unexpected cardiac arrest and have been successfully resuscitated?**

Cobb et al. reported that resuscitated patients who have evidence of a transmural myocardial infarction had no mortality during the first 16 months and 14% by two years; in patients who did not have evidence of myocardial necrosis, the mortality was 36% and 47%. They found that 17 of 23 patients who had coronary arteriograms had operable lesions. Myerburg et al. found that 11 of 13 resuscitated patients without evidence of necrosis had operable lesions; eight of these had ACBG. The patients had survived eight to 32 months at the time of the report. However, it is of interest that these same investigators recently reported the results of a long term arrhythmia detection program for similar patients without operable anatomy. Sixteen patients, appearing clinically similar to those bypassed, were carefully followed for one to 12 months (average seven months). The patients were maintained on a carefully controlled, high dose, membrane-active, antiarrhythmic drug program with blood level monitoring. There was good adherence. There was only one death in 122 patient months, or 1.0% per year. Therefore, these investigators reported a striking improvement in survival in patients who had been successfully resuscitated from ventricular fibrillation, when compared with a historic control population collected in their own institution, when the patients either received ACBG or were managed by intensive antiarrhythmic medication and surveillance.

That malignant ventricular arrhythmias may be prevented by compulsive nonsurgical management was further supported by a study by Lown and Graboys. They studied 43 consecutive patients with such arrhythmias. These patients, who were not catheterized, were divided in a nonrandomized manner into two groups. Group one consisted of 26 patients subjected to a carefully controlled and tailored antiarrhythmic program and group two consisted of 17 patients who received a standard antiarrhythmic program based on clinical factors and therapeutic blood drug concentrations. Twenty-four of 26 patients in group one (92%) demonstrated control of arrhythmias and were alive at a mean of 17 months compared to a survival of 7 (41%) of group two followed for a mean of 14.8 months. It is noteworthy that these authors reported that six of the patients had a cardiac operation. Of three who had an aneurysmectomy, two did not benefit and one had a remission of arrhythmia for nearly two years and then died suddenly. Three patients had ACBG; the arrhythmia was not affected in two and made worse in one.

**Relief of Pain of Myocardial Ischemia**

It is generally accepted that following ACBG symptoms are relieved and the quality of life is improved for a time in up to 90% of the patients; at least 75% of the patients are initially completely free of symptoms. This widely held impression is strongly supported by the previously described randomized studies of patients with stable angina, unstable angina, and left main stem coronary artery disease. The symptomatic improvement is so marked that the patient frequently requires less medication after surgery than before. For example, Mathur and Quinn found that for an average of 24 months after surgery nitrates were used by 18% of patients who received an ACBG and 96% of those who did not; propranolol was prescribed for 8% of the operated and 72% of the nonoperated patients. Other investigators have reported similar observations.

Relief of pain is usually correlated with graft patency, although there are exceptions. Benchimol et al. described 32 patients from a large series of subjects undergoing routine postoperative evaluation of ACBG; 20 of these patients had one graft totally occluded, 12 had all grafts totally occluded. Yet all patients had persistent subjective improvement manifest by significant diminution or complete disappearance of angina. Kouchoukos et al. reported that there was complete relief of angina in 39% of 18 patients in whom all grafts were occluded. This success compares with 63% relief of angina in 69 patients with all grafts patent.

It is of interest, however, that in the study by McNeer et al. designed to investigate the benefits of complete versus incomplete revascularization, no correlation was found between the completeness of the revascularization and the relief of pain.

Achuff et al. concluded after studying 71 unselected patients for a mean interval of 6.1 months postoperatively that the relief of angina in 18 of the patients was due totally or in part to the development of a myocardial infarction. These investigators concluded, "the potentially harmful effects of surgery, including even myocardial infarction, may
be outweighed by the relief of angina experienced by patients who are severely incapacitated and have not responded satisfactorily to an intensive medical regimen."

The initial highly satisfactory symptomatic improvement observed immediately after surgery is not always lasting. Adam et al.\(^\text{14}\) found an attrition of good results from a level of 82% in the postoperative interval of six to 18 months to 76% at 18 to 24 months and 69% at 24 to 43 months. Kloster\(^\text{29}\) reported a highly significant difference in the functional classification, six months after surgery, between groups receiving and not receiving ACBG; by two years, there was no longer a significant difference between the two groups. Between the initial evaluation of the Stanford series\(^\text{34}\) at a mean of nine months postoperatively (range 2 to 40 months) and after a mean of 30 months (range 6 to 72 months) 13% of patients showed further clinical improvement, 47% were unchanged, but 40% deteriorated further with respect to chest pain. These investigators concluded that the initial symptomatic benefits may not be maintained in late follow-up studies owing to progression of underlying vascular disease. This concern was supported by observations of Anderson et al.\(^\text{41}\) Ninety-three percent of 532 patients were considered to be functional class I and class II status during the first year after ACBG; the fourth year after operation only 75% had such a classification. Thus, there appears to be a tendency for gradual clinical deterioration after the initial very gratifying results attributable to ACBG; the level of clinical improvement following ACBG appears to be influenced by the length of the follow-up after surgery.

Not infrequently, patients who are referred for ACBG are said to be refractory to optimal medical management; there is reason to believe that in many instances patients have been referred for ACBG before there has been great effort by the physician to control the symptoms by means of medications of proven value, or modification of life style.\(^\text{43}\) In this regard Reeves et al.\(^\text{144}\) stated: "if only those patients who were truly refractory to medical management were referred for surgery, the number of patients operated on for this disease would decrease dramatically."

It should be noted that the control medical groups in the randomized studies reported by Mathur et al.\(^\text{18}\) and Kloster et al.\(^\text{29}\) as well as the study by Aronow et al.\(^\text{24}\) (table 1), all improved symptomatically and functionally during the course of the study. Thus, intensive medical therapy can frequently be successful and make surgery, initially being considered to improve the quality of life, unnecessary.

Most observers, including the authors, believe that the regular relief of pain following ACBG results from an increased coronary perfusion and abolition of areas of ischemia. It is possible that other mechanisms may be operative in individual patients.

Several explanations have been proposed as mechanisms by which the pain of ischemic heart disease could be relieved by surgical procedures, including ACBG: 1) increased blood flow beyond points of significant obstruction, thus abolishing ischemic myocardium; 2) denervation of ischemic areas by surgical manipulation of the vessels and/or epicardium; 3) production of a recognized perioperative infarction turning ischemic muscle into scar, or the progression of the disease in the native circulation causing obstruction to blood flow to ischemic areas and resulting in one or more small infarcts not demonstrated by the ECG; 4) nonspecific placebo effects of surgery similar to those that were frequently observed to accompany the less direct surgical procedures in the past.

Soloff\(^\text{46}\) observed that the symptomatic relief of ischemic pain that followed a variety of surgical procedures was frequently correlated with deterioration of myocardial function. "There frequently appears to be an antagonism between cardiac pain and congestive failure."

In 1916 a surgical sympathectomy was reported to have been performed for the purpose of relieving the pain of angina pectoris.\(^\text{16}\) This was the first of a variety of procedures carried out over the next 50 years; these years can properly be designated as the era of indirect efforts of revascularizing the heart. Many of the physicians who were a part of those 50 years learned that many patients, in fact the majority with pain from IHD, did improve dramatically after a variety of operations upon the heart. Most cardiologists and surgeons actively engaged in the field today were not involved with caring for patients during that era.

One of the pioneers of efforts to indirectly revascularize the heart was Claude Beck. In the early 1930s\(^\text{147}\) he proposed relieving ischemic pain by improving myocardial perfusion by encouraging vascular growth into the myocardium from the pericardium. Stimulation of such a process was attempted by mechanically abrading the epicardium and pericardium and then instilling a variety of irritants into the pericardial space, or making pedicles of pectoralis muscle, omentum, spleen, stomach and/or jejunum and attaching these to the bloody epicardium. Fell,\(^\text{148}\) in a detailed evaluation of 37 patients operated on by Beck, reported that there were 14 postoperative deaths (37.8%) and an additional nine late deaths over a six year period. Fourteen (60.9%) of the survivors received excellent clinical results from the operation. Obviously, none of the patients were studied by coronary arteriography.

This concept was extended by Harken et al.\(^\text{149, 150}\) who developed and evaluated "an operation, consisting of de-epicardialization, poudrage and pneumopathy." Discussing this and other "protective measures," Harken\(^\text{150}\) intentionally or unintentionally suggested the placebo effect of such procedures. He stated that "with surprising regularity the human subjects have been relieved of pain almost immediately, long before new vessels could have grown in."

This approach was followed in 1955\(^\text{151}\) by bilateral ligation of internal mammary arteries. Cobb et al.\(^\text{152}\) and later Dimond et al.\(^\text{153}\) promptly discredited the use of this procedure. Cobb et al.\(^\text{152}\) in a double blind randomized study, were unable to show any difference in results following bilateral ligation of the internal mammary artery versus a sham procedure. They concluded that "the value of the usual clinical evaluation of any form of surgical therapy designed to relieve the symptoms of angina pectoris is considered highly speculative." Dimond et al.\(^\text{153}\) after evaluating 18 patients in the same double blind manner, also emphasized the placebo effect of surgery for coronary artery disease. They realized that "the frightened, poorly informed man with angina, winding himself tighter and tighter, sensitizing himself to every twinge of chest discomfort, who then comes into the environment of a great medical center and a positive, powerful personality and sees and hears the
results to be anticipated from the suggested therapy is not the same total patient who leaves the institution with the trademark scar."

The placebo effects of surgery in the treatment of pain were studied rather extensively by Beecher. He concluded, "there is evidence in surgery, as in other fields, that the enthusiast gets results which are better than those of the skeptic. There are data to indicate that one can, and surgeons must, test their new procedures when value judgments are involved, so as to eliminate the effect of bias in their conclusions. The short life cycle (two years in this country from enthusiastic acceptance to discredit) of the treatment of angina pectoris by internal mammary artery ligation demonstrates how swiftly the proper design of a study can answer difficult questions about the value of such a procedure."

About the mid century, Vineberg described the procedure of implanting the freely bleeding internal mammary artery into the left ventricular myocardium. After many modifications and varying degrees of enthusiasm for the procedure, Sewell reported that over 89% of nearly 300 graft implants produced a myocardial blush following injection of contrast media into the orifice of the internal mammary artery. Evidence gradually accumulated as the procedure was carried out with increasing frequency in many centers throughout the world that the Vineberg procedure, despite symptomatic improvement in up to 80% of patients, had little effect in augmenting myocardial oxygenation or on the clinical course of IHD.

The era of indirect efforts to revascularize the human heart came to an end in 1957 when Bailey introduced the era of operating directly on the coronary arteries with a report of the first successful coronary endarterectomy. The era of operating directly on coronary arteries became more firmly established two years later when Sones described the technique of selective coronary arteriography. Five years later the first ACBG was performed.

**Patency of the Grafts**

After a decade of experience with ACBG, it is reported that up to three-fourths of the grafts examined at intervals up to five years after surgery are patent. Lawrie et al. studied 281 patients with 492 grafts zero to 75 months postoperatively. Graft patency was 92% (55/60) of the grafts examined during the first month; 81% (113/140) of grafts examined during the 13th to 24th month; and 84% (60/79) during the 37th to the 75th month. Intimal proliferation appeared to develop promptly so that the intima soon became twice the thickness of the media (grade II proliferation). However, there was little evidence that the proliferation advanced beyond the initial changes. These changes resulted in an angiographically demonstrable uniform reduction in the diameter of the graft lumen by 30% to 50%. Lawrie et al. suggested that surgeons use for the graft veins with a lumen initially larger than the recipient artery anticipating that the diameter of the vein would rapidly decrease.

When graft occlusion occurred it was usually early and was thought to be due to thrombosis. Late graft occlusion was found to be uncommon. Further intimal proliferation did not appear to occur.

This study, like most others evaluating graft patency, did not include consecutive patients; therefore, it did not follow an experimental design to look at the same patient, and thus the same grafts, over time. The study did not take into account patients who had died and might have had a high incidence of graft occlusion. On the other hand, patients who had symptoms were probably more willing to be studied and might have a higher incidence of occluded grafts than the less symptomatic patients who declined a postoperative study; such patients would lead to an overestimation of the incidence of graft occlusion.

Other investigators have reported comparable patency but usually for shorter periods of observation.

Efforts were made by Grondin et al. to partially correct the deficiencies of the experimental design cited above. They obtained serial angiographic studies two weeks, one year and three years after operation in 60 patients that were obtained from 106 consecutive patients with ACBG. The reasons for exclusions from the study were death, patient refusal or demonstration that the grafts were occluded at the previous study. The graft occlusion rate was 11.3% in those patients studied within two weeks of surgery; 20.4% at one year. Of 108 grafts studied at the end of one year, 22 (20.4%) were occluded. At the end of three years there were an additional four of 79 grafts occluded in 60 patients (5.1%). Most grafts displayed a significant reduction in caliber within one year; none developed further reduction in caliber during the next two years of observation.

There has been a direct correlation of early patency with the graft flow rate measured at the time of surgery. The state of the distal vascular bed may be the single most important determinant of the long term vein graft patency. ACBGs to the left anterior descending artery, which usually provides greater runoff, have patency rates in asymptomatic patients comparable to those reported with internal mammary artery grafts. Grafts attached to the right and circumflex coronary arteries have lower patency rates. This increased incidence of occlusion could be due to the greater possibility of the longer grafts kinking when attached to more posteriorly and/or distally located vessels.

Walker and his colleagues at Milwaukee analyzed 540 patients collected in a nonrandomized manner from a group of over 4,000 patients operated between 1968 and 1974. This group appeared to include a disproportionate number of patients who failed to improve, experienced new angina, or had had new surgical procedures or modifications of existing procedures that required investigation. The studies were grouped into three periods after surgery: zero to six months, seven to 12 months, and 13 to 24 months. They found a patency rate of 75% to 78% for the three periods of study. They concluded that closure of the individual vein graft in a patient is an independent and random event during the first two postoperative years. Closure was said to be independent of the patency status of the remaining grafts in an individual patient. Factors affecting postoperative vein graft patency are specific for each graft. These include the diameter of the recipient vessel and distal arterial runoff. Factors that affect similarly all grafts in a patient, such as ventricular function, serum cholesterol level and blood pressure, may have little
or no effect on patency of individual vein grafts during the first two years. These conclusions appear rather sweeping in view of the heterogeneous nature of the sample study. Nevertheless the authors184 suggest that the observations might be useful "to plan strategy for preoperative and postoperative patient management and a decision as to the number of grafts to use." It would appear that the conclusions should be validated under more controlled circumstances before put to such use.

This theory of independence of grafts as regards closure is not supported by other observations. It was demonstrated by McLoughlin and associates169 that the patency of grafts might influence not only the fate of collaterals from grafted vessels to nongrafted vessels but also collaterals originating from and supplying nongrafted vessels. It has been suggested that revascularization of one vessel alters the location of the "watershed area" between the grafted and nongrafted vessels thus decreasing the flow requirements in the nongrafted vessel.170

These observations were extended by Apstein et al.,171 who reported that the risk of graft occlusion when the early and late follow-up studies are considered together was much higher for those patients with abnormal preoperative ventricular function. Furthermore, he and others172 reported that studies of progression of disease in the native circulation revealed that the process and graft patency are intimately related. Both progression of the disease and occlusion of a graft can contribute to deterioration of ventricular function.

That graft occlusion contributes to deterioration of ventricular function was demonstrated by Shepherd et al.172 They compared the myocardial function of ten patients with 15 patent grafts with that of 12 patients with 15 of 22 grafts occluded one week to nine months postoperatively (average time 5 months). All patients improved symptomatically regardless of graft patency. However, in the occluded group, left ventricular and end-diastolic pressure increased and stroke volume index, ejection fraction and left ventricular stroke work index fell significantly. Of 28 segments supplied by patent grafts, contractility improved in six and deteriorated in nine. Of 22 segments supplied by occluded grafts, none improved and eight deteriorated. In no instance was depressed contractility restored to normal after ACBG.

Many of these new occlusive changes occurring in the native circulation were noted to begin or terminate at the bypass-graft-to-coronary-artery-anastomotic-site. Griffith et al.,172 after careful morphologic studies of 95 grafts concluded that occlusive changes may occur more commonly postoperatively in coronary arteries with small internal diameters, arteries with plaques that have required endarterectomy, or those in which the graft-artery anastomosis was made across a major branch point of the coronary artery. The importance of this observation is appreciated by realizing that not only are more patients with more extensive distal plaques undergoing bypass surgery, but also that the current surgical objective is complete revascularization. This includes bypassing small coronary branches if there is significant proximal narrowing. Both features contribute to the development of progression of the disease in the native circulation.

There is evidence to suggest that the patency rate may be improved if the disease in the native circulation progresses to total occlusion in the proximal segment of the recipient artery.173 It is apparent that occlusion of the native circulation proximal to the anastomotic site possesses a greater potential hazard when it occurs in the left anterior descending coronary artery than when it occurs in the right coronary artery. The patency rate of grafts to the left anterior descending coronary is greater than to the circumflex and right coronary arteries.181

Whether atherosclerosis will involve the vein grafts with greater frequency remains to be seen. Lawrie et al.161 did not report atherosclerotic changes in vein grafts that they studied. But Barboriak et al.174 had previously reported unequivocal atherosclerotic changes in the vein grafts of six of eight patients who survived an ACBG for six to 61 months. No such lesions were found at necropsy in 25 patients who survived the operation less than six months. Farry et al.175 recently added a report of fully developed atherosclerosis in a bypass graft of a 49-year-old man four years after implantation.

With passage of time, more lesions in the vein grafts are being observed. Barboriak et al.176 reported that two patients with vein grafts for 37 and 59 months showed extensive mural changes characteristic of degeneration and loss of normal morphologic features of the intima and cellular accumulation of lipids. Lie et al.177 studied the vein grafts from 41 normolipoproteinemic and 14 hyperlipoproteinemic patients. When examined 13 to 75 months after surgery two of 14 subjects with normal lipids and seven of nine patients with hyperlipoproteinemia had evidence of atherosclerosis.

As indicated, the initial fears that the vein graft might be the site of intimal proliferation have proven unwarranted. Because of these fears and other reasons, the internal mammary artery has been used for direct anastomosis by several surgeons,178-181 who maintain that there is a closer approximation of the lumen of the internal mammary artery with that of the coronary artery. This procedure also is useful when operating on a patient who has had extensive disease of the venous system of the lower extremities. A potential hazard in using this vessel is that its origin and/or course may be compromised by an atherosclerotic plaque and thus have a reduced flow. This hazard could be obviated by preoperative arteriography. The procedure requires more technical experience and time to perform in order to achieve a high patency rate.181 Therefore, it is not overly popular with surgeons.

Acceleration of the Atherosclerotic Process in the Native Circulation

The original observation by Aldridge and Trimble182 that ACBG contributes to an acceleration of the occlusive process in the native circulation has been confirmed by numerous investigators.12,14,169,170,173,182-197 However, there is no agreement as to the significance of this progression or its pattern. The group at Hopkins analyzed their own data186 and those reported188 by six other institutions169,184,185,187,189,190 in 663 arteries to which were attached patent bypass grafts, there were 264 (40%) new total occlusions; 281 arteries to which were attached grafts that had occluded had 119 new total occlusions (42%). Seven hundred and twenty-six arteries without grafts were examined; there were only 43
new occlusions (6%). Eighty-five percent of the new occlusions of grafted arteries in which the graft remained patent were proximal to the graft. Therefore, it was considered unlikely that the new occlusions represented natural progression of the disease process (table 3).

One of the studies included in the Johns Hopkins report is of particular note. Maurer and colleagues at Alabama studied 121 unselected patients by a second angiogram an average of 11.7 months after surgery. They found that new total occlusions, new obstructive lesions, and progression of pre-existing lesions were five times more frequent in grafted than in nongrafted arteries with comparable initial disease. New and progressive lesions were encountered with the same frequency in arteries with patent as with occluded grafts. Occlusion occurred more frequently in segments proximal to than those distal to the graft. Arteries with moderate (< 75%) and severe (75% to 99%) stenosis had similar progression rates. Only 2% of segments of ungrafted arteries showed new total occlusion, as compared to 60% of grafted arteries. Maurer et al. stated that the incidence of new total occlusions is approximately 16 times greater in grafted than in nongrafted previously normal segments. The total rate of progression is 3.5 times greater in such grafted segments. In previously diseased segments new total occlusions are seven times more frequent, and the progression rate three times greater in grafted segments irrespective of the degree of the disease. Progression was four times greater at the site of lesions that were at least 50% stenosed at the time of the initial observation. These investigators concluded that "when the total number of segments and branches visualized in grafted and non-grafted vessels at the first and second examination is determined it is clear that significantly less of the coronary arterial bed is visualized in vessels which have been grafted than in vessels which are not."

Frick et al. studied 77 patients a mean of three weeks after bypass surgery and again a mean of 13 months after surgery to assess changes in the native circulation. Two hundred-fourteen arteries were bypassed. Progression of the disease was found in 2.9% of 208 nongrafted arteries at the time of the second study. In arteries that were normal before operation, the rate of progression was 0.7%; in those with luminal obstruction, 7.6%. The authors indicated that the low incidence of progression of nongrafted arteries may reflect their surgical approach. They sought to obtain as complete a revascularization as possible and had often provided bypass grafts to small arteries such as the left diagonal, left obtuse marginal, and right ventricular branches. Consequently, most of the nongrafted arteries were essentially normal at the completion of surgery. Progression of the disease occurred proximal to 24.2% of the graft insertions and progressed to total occlusion in almost 50%; it occurred with equal frequency in association with patent as with occluded grafts. Progression of the disease distal to the graft insertion occurred in only two of 85 arteries examined but did not progress to total occlusion. The overall rate of progression of disease in distal segments was similar to that observed in nongrafted arteries.

It is noteworthy that Mathur et al., in the oft quoted randomized study of stable angina, failed to find "any striking difference in the progression of the disease" between operated (18%) and nonoperated patients (11%) when studied a median of 24 months postoperatively. They suggested that possibly the other reported series had overestimated the process by studying only those patients who volunteered for study because of symptoms.

This possibility was supported by Ben-Zvi et al. They studied 69 consecutive patients an average of ten months post ACBG; there was progression of disease in only 17% of the grafted vessels and 6% of the nongrafted vessels. In contrast, these same investigators observed progression of the disease after 27 months in 56% of 16 randomly selected symptomatic patients treated medically. The investigators emphasized that the two groups were not comparable in that they were studied at different points in time, the surgical group had fewer nonoperated vessels in which disease could be observed to develop, and being a consecutive series the surgical group included both symptomatic and asymptomatic patients. They found that progression of disease was associated with deterioration of left ventricular function, while absence of progression was associated with stable function. They concluded that inappropriate conclusions about the progression of the disease might be drawn if only symptomatic patients were studied.

After ACBG, flow in collateral vessels has been observed to remain unchanged, to disappear or to reverse direction. The resulting flow pattern appears to depend on the presence or absence of myocardial ischemia, changes in the pressure gradient or progression of disease in the native circulation resulting in obstruction of collateral vessels. Intracoronary collaterals have been observed to disappear more frequently when associated with arteries receiving flow from patent grafts and to persist when the graft is occluded.

In a study specifically designed to evaluate collateral blood flow patterns, See et al. studied 63 consecutive patients with more than 75% stenosis of major coronary vessels two weeks post ACBG. One hundred and eighty-six collateral channels were demonstrated preoperatively in 48 patients; postoperatively 45% of these collateral channels were no longer present. In 40% the direction of flow was unchanged, while in 15% the direction of flow was reversed.

Since graft patency is the desired long term feature of ACBG, it is paradoxical that this characteristic seems to play a role in the development of an undesired result. This observation prompted Rees to investigate the "watershed" phenomenon as a factor facilitating bypass vein occlusion. He found that 87% of grafts were patent if they were inserted distally to a previously occluded coronary artery. If the vessel was not occluded, only 62% of the grafts were patent. He speculated, without recommending, that ligation of the coronary artery proximal to the anastomosis might therefore result in the highest patency rate.

Progression of the disease in the native circulation has

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**Table 3. Native Circulation Studies**

<table>
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<tr>
<th>Bypass graft status</th>
<th>Arteries examined</th>
<th>New total occlusion</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>663</td>
<td>264</td>
<td>40†</td>
</tr>
<tr>
<td>Closed</td>
<td>281</td>
<td>110</td>
<td>42</td>
</tr>
<tr>
<td>None</td>
<td>726</td>
<td>43</td>
<td>6</td>
</tr>
</tbody>
</table>

*The seven institutions included in this study are Johns Hopkins, Montreal Heart, Oregon, New York University, Alabama, Peter Bent Brigham.*

180% in proximal segment.
been considered insignificant by many clinicians. However, Apstein et al. demonstrated that proximal occlusion of the native vessel can have a deleterious effect on myocardial function. They studied 14 patients four to nine months after surgery and compared the ventricular function to that existing before surgery. Ten of the 14 patients had occluded at least one graft or failed to fill the proximal segment of the native grafted coronary artery; four of 14 had a persistence of patency of both of the grafts and the proximal segment of the grafted artery. Patients without graft or arterial occlusion maintained ventricular performance at preoperative levels. The subgroup with occlusion of the graft or recipient artery showed a significant decrease in left ventricular ejection fraction and the mean rate of circumferential fiber shortening ($P < 0.01$ and $P < 0.05$, respectively).

Similar evidence that progression of the disease in the native circulation results in deterioration of left ventricular function was strikingly demonstrated by Brundage et al. They studied 30 patients preoperatively and an average of five months postoperatively. Deterioration of left ventricular function was consistently demonstrated in patients who sustained a perioperative infarction or had one or more grafts occluded. These investigators found that the most important predictor of the state of postoperative ventricular function was the condition of the native circulation at the time of restudy. Nineteen of 30 patients demonstrated either progression of a preoperative occlusion or the development of a new occlusion in the native circulation postoperatively. The majority of these changes consisted of progression to total occlusion of a lesion proximal to a patent graft. Such patients as a group showed very significant depression in the postoperative ventricular function curves. On the other hand, if there was no change in the native circulation, the postoperative hemodynamic values were virtually identical to those observed in the preoperative study.

Such studies of graft patency and progression of disease in the native circulation are difficult to carry out accurately. The state of the disease in the native circulation could obviously best be demonstrated by injection of contrast media into the ostium of the coronary artery in question. In evaluating the extent of the disease process, care must be taken to reproduce the same geometry with regard to the relation of the patient and the X-ray tube in each study.

It is assumed that following insertion of the graft, if both the graft and the native vessel are patent, flow in the native vessel would be demonstrated as bidirectional (fig. 8A). If the proximal segment of the native vessel is occluded, the flow would be unidirectional and distal (fig. 8B); if the artery is occluded distal to the site of anastomosis, and an occlusion had not occurred proximally, the flow would be unidirectional and proximal (fig. 8C). It is now known that there are rare exceptions to these generalizations. Failure to opacify a channel does not prove that it is not patent and flow does not occur.

Roberts and Buya found in histologic studies of the extramural coronary arterial tree of 107 subjects who died of IHD certain patterns that are pertinent to the discussion of progression of the disease in the native circulation as a result of ACBG. In reviewing the pathologic changes, three coronaries were considered in each patient; the left main was considered separately. Regardless of whether the patient died suddenly or had transmural or subendocardial necrosis, 2.3-2.4 coronaries were narrowed >75%. The site of narrowing was variable. Maximal narrowing of the left anterior descending and left circumflex coronary arteries was usually within two centimeters of the bifurcation of the left main coronary artery; on the other hand, the proximal and mid-portions of the right coronary artery were not predisposed to greater degrees of luminal narrowing than was the distal portion.

The main function of the right coronary artery is to supply the posterior wall of the left ventricle by means of the posterior descending branches. These branches do not arise until the right coronary has traversed the atrioventricular sulcus for a distance of approximately 12 cm. On the other hand, the left coronary arteries begin to supply the left ventricle with oxygen approximately 2 cm from the origin. Therefore, progression of disease proximal to an ACBG close to the origin of the left coronary artery has a far more deleterious effect than at a similar site, or even much more distal site, in the right coronary artery.

Based on similar considerations Frick et al. concluded: "The longer the segment between the obstruction and the distal graft anastomosis, the greater is the amount of jeopar-
dized myocardium if disease progresses in arterial segments proximal to the graft. This is particularly pertinent in grafting the left anterior descending artery; it is less important to grafting the left circumflex and it is least important in grafting the right coronary.”

Finally, progression of the disease and possible occlusion of the graft may be due to placement of the graft in a less than ideal site. Spray et al. studied 37 grafts plus coronary artery systems at postmortem examination. Forty-four percent of the grafts were attached proximally rather than distally to a luminal narrowing >75%. In each case the lumen of the artery distal to the observed stenosis was relatively uncompromised.

The Role Of ACBG On Exercise Tolerance And Work Status

With the frequently reported significant symptomatic improvement following ACBG particularly in the relief of the pain of myocardial ischemia, it might be expected that an improvement in exercise tolerance would also occur. However, as has been indicated previously, there is not a parallel prolongation of life expectancy in patients with stable or unstable angina accompanying the symptomatic improvement. Nor has ventricular function consistently improved following ACBG. Furthermore, it has been suggested that the initial symptomatic improvement is not long-lasting in all patients.

Therefore, does ACBG improve exercise tolerance, and if so, can it be documented that the improvement is long-lasting?

Such data are obviously difficult to obtain. The multiplicity of factors, such as bed rest after surgery, perioperative myocardial damage and the patient's and physician's desires to improve, complicate all attempts to evaluate a form of treatment. Austen and Mundth stated that the patient is reluctant “after operation to reveal that he has persistent angina.”

In the previously described randomized studies of patients with stable angina conducted by Mathur et al. and Kloster et al., both found a significant improvement in exercise tolerance after ACBG when compared to a control population. As indicated, Mathur also reported that the control population experienced an improvement over their prestudy exercise tolerance indicating the benefits of intensive medical therapy. Atrial pacing showed an increased anginal threshold at the time of follow-up study in 70% of the surgical group; however, 48% of the medical group also enjoyed a similar improvement.

Kloster et al. reported a significant increase in maximum work load in the ACBG patients compared to the nonoperated patients after six months of follow-up. However, the mean maximum heart rate during pacing and the myocardial lactate extraction were significantly high in the ACBG group compared to the control group. These values were unchanged in the non-ACBG group.

The VA Cooperative Randomized Study of patients with stable angina, the NHLBI randomized study of patients with unstable angina, and the VA randomized study of left main coronary artery stenosis have not yet reported data regarding the effect of ACBG on exercise tolerance.

The small randomized study of unstable angina by Selden reported that at four months the ACBG group had a statistically significantly higher functional capacity than the control group; a higher exercise angina threshold, higher pacing angina threshold and myocardial lactate extraction during pacing when compared to the medically treated group. Angina limited or curtailed exercise in 14 of 17 patients treated medically compared with only three of 19 treated surgically.

Aronow et al. reported the results of observations of a small study of matched patients with stable angina (table 1). After two years, 50% of the medical group had no angina upon reaching their control exercise tolerance level or exceeding that level by 25%, whereas 76% of the surgical group were able to attain that level without angina.

A number of nonrandomized studies have emphasized the improvement in exercise tolerance after coronary artery bypass surgery. Several groups have shown that many patients fail to develop chest pain and ST-segment depression at a higher rate-pressure-product in comparison with preoperative exercise. It should be noted that Graboyes et al. have recently reported that significant depression of the ST segment of two millimeters or more was not reproducible on multiple testing; 20 of 34 subjects had at least one normal response and at least one with only a one millimeter ST-segment depression.

Barry et al. studied 38 patients before and one year after surgery and compared the results to 40 patients treated medically during the same period who were studied hemodynamically on two occasions separated by one year. Those patients who had a history of classical angina, a strongly positive exercise test, normal resting hemodynamics and a well preserved resting ejection fraction, but who had a marked rise preoperatively of the left ventricular filling pressure in response to exercise, were shown one year postoperatively to have benefited significantly from surgery. They concluded that “marked depression of resting ejection fraction or cardiac index associated with increased ventricular filling pressures in the patient with stable angina probably indicates the presence of significant irreversible myocardial damage, and decreased the chance of successful outcome of surgery. On the other hand evidence for ischemic dysfunction during stress with relatively normal resting function seems to predict a good outcome by objective functional criteria.”

Several studies have shown a good correlation between improved exercise tolerance and left ventricular function with patent grafts. However, Benchimol et al. reported improvement of functional capacity despite angiographically documented closure of grafts. As previously indicated, Shepherd et al. also found that deterioration of wall motion and ejection fraction was not uncommon in the presence of patent grafts with good distal runoff.

It should be noted that improvement in ventricular function during exercise following ACBG was duplicated without surgery in some patients by the administration of nitroglycerin. Kent et al. compared preoperative ECG gated Tc radionuclide scintigrams with those obtained two to four months postoperatively in 11 patients. The ejection fraction calculated with the patient at rest postoperatively was decreased with exercise in ten of the 11 patients by an average of 24%; postoperatively the ejection fraction increased with exercise in seven of 11 patients and was unchanged or decreased less than observed preoperatively in four. Twenty-one left ventricular segments
received an ACBG; 11 demonstrated improvement during exercise, eight of which became normal. It is noteworthy, however, that the same laboratory demonstrated that nitroglycerin had a similar effect on global and regional left ventricular function. Twenty patients with CAD (six of whom were asymptomatic) were studied in a similar manner before and after administration of nitroglycerin. Each of these patients, during the baseline studies, developed at least one new region of ventricular dysfunction during exercise; the left ventricular ejection fraction invariably decreased. However, following nitroglycerin the regions of dysfunction produced by exercise were absent or markedly diminished in 18 of the 20 patients and the ejection fraction during exercise was significantly improved.

The effect of surgery on work status of the patients is less dramatic than the relief of angina and improvement in exercise tolerance. Logue et al. observed that patients with a strong motivation to return to work because of economic considerations usually did so, whereas those with generous disability programs often retired after surgery. Although 90% of the patients observed at Emory had symptomatic improvement and relief of angina, only 50% returned to work. It was emphasized that the physician may influence the patient not to return to stressful working conditions, despite successful surgery.

Of 893 men in another study, who had an ACBG, 11% of those under the age of 55 years who were gainfully employed before surgery and 26% above that age retired. Of the remaining employed patients, 30% changed their occupational status postoperatively. Forty-nine percent took less physically demanding jobs; 40% took more physically demanding jobs. Based on the retirement practices of the population at large, the observed retirement rate was increased 7.5 times above that of the total population for those under 55 years of age and 11.3 times for those above that age. This frequency of retirement, however, was not higher than those observed in patients of both age groups who sustained a myocardial infarction.

Barnes et al. after evaluating the work status of 263 patients one year after ACBG, concluded that contrary to expectations, rehabilitation benefits as a result of ACBG appear to be few.

**Socioeconomic Considerations**

The public sector as well as the medical profession are concerned about the acceleration of the escalation of the cost of medical care. There are many causes, a detailed discussion of which is beyond the scope of this article.

Ross divided the factors responsible for this currently near billion dollar business into two groups. The first group includes general factors which apply to all of medicine, not just to cardiology and cardiac surgery. These factors embrace costs that result from the approach to medicine which might be termed "procedurism." Ross stated that "procedurism results in physicians doing more tests and procedures than are necessary for the diagnosis and treatment of the patient. . . . in procedurism is a product of 'defensive medicine' dictated by the current litigious climate. . . . there are other reasons . . . insurance companies pay for procedures and the physician derives more income per unit time from each patient encounter if procedures are done."

The second set of economic factors, Dr. Ross indicated, are specifically related to cardiology and cardiac surgery. "Hospitals are motivated to start cardiac surgical programs in order to keep the beds full and support expansion. . . . Accreditation boards tell the hospital that in order to justify the program, a certain minimum number of procedures must be done. Minimum standards were originated to protect patient safety by assuring that the volume of the procedures were sufficient to maintain requisite skill. Unfortunately, these standards have been perverted to generate a demand for service which equals or exceeds the minimum."

As indicated earlier, the cost of coronary bypass surgery and related therapeutic diagnostic supporting services in 1977 may well approach one billion dollars. This is over two and a half times the total budget of the National Heart, Lung and Blood Institute. This expense was accepted by Effler as being inevitable. Others have predicted that revascularization surgery will be one of the most common forms of major elective surgery performed on adults within the United States. Effler further stated that "the question is raised repeatedly as to whether our economy can accommodate itself to the enormous cost of surgically treated patients who have IHD. In the minds of many, bureaucrats and doctors included, providing health care automatically increases the medical cost. Ergo, the greater the volume of patients, the greater the burden on our society. This paradoxical thinking suggests that a sick patient is synonymous with economic liability even though the patient may go from invalidism to gainful activity."

A review of the literature does not support Effler's implications that ACBG is economically beneficial to society by returning large numbers of individuals "from invalidism to gainful activity." As previously indicated, Logue et al. found that although 90% of the patients observed at Emory had symptomatic improvement and relief of angina, only 50% returned to work. Rimm and associates found retirement after ACBG equal to that of patients who had sustained an acute myocardial infarction. The Alabama group concluded "that contrary to expectations, rehabilitation benefits as a result of ACBG appear to be few."

Not all cardiologists and surgeons share Effler's philosophy. Many have indicated a concern not only over the escalation of the numbers of procedures that are being done, but also the quality of the procedures. For example, Miller et al. in analyzing the responses to the previously cited questionnaire returned by 400 experienced cardiovascular surgeons in this country, stated that "we must establish what criteria are to be used to denote 'success.'" A review of the literature makes such a need apparent. The Ad Hoc Committee of the Council of the American Association of Thoracic Surgeons, on October 13, 1976, concluded, "the explosive, uncontrolled outgrowth of coronary artery operations in small community hospitals, as shown previously, has led to a lack of quality control, duplication of services and economic expenses." The committee proposed a system whereby hospital programs devoted to open heart surgery would be established after review by a committee of peers to determine the need for the services and the ability of the applicants to perform the services.

Concerns over the uncontrolled escalation of the number of ACBGs performed and the quality of the services have not only been voiced by physicians but by nonphysicians as well. Marcia Millman, a sociologist, articulated these con-
cerns in her recent book intended for lay readers, entitled *The Unkindest Cut: Life in the Backrooms of Medicine*. In one chapter she wrote that “coronary bypass surgery may be the most momentous innovation in contemporary American medicine. Some analysts have predicted on the basis of present trends that within ten years the operation could be a hundred billion dollar a year industry; it could dominate not only our health budget but a large part of our national resources.”

There can be little doubt that the medical profession must face realistically the cost factors that are associated with ACBG. There is a limit to the economic resources that can be devoted to health. The enormous expenditure of money for ACBG, at a time when changes in socioeconomic factors are resulting in a decline in the mortality from CAD in this country, could be justified if the benefits received by the patient, or by society in general, were of considerable magnitude.

**What is the magnitude of the cost/benefit ratio of ACBG?**

Currently available literature does not indicate that ACBG reliably reduces the occurrence of acute myocardial infarctions or predictably prevents the occurrence of serious arrhythmias, or consistently ameliorates congestive heart failure due to IHD. Except for relatively small subsets of patients with IHD, there is no conclusive evidence that ACBG prevents premature death. There is little doubt that pain is relieved for a time following ACBG in over 75% of the patients.4, 5, 12-14, 28, 52 This frequency exceeds the 60.9% relief of pain observed after the Beck procedure.148 Therefore, the known and demonstrated benefits derived from ACBG embrace primarily a high likelihood of improved quality of life, for a time, for those patients whose quality of life was impaired by uncontrolled or unpredictable pain of myocardial ischemia. For this benefit the patient must assume a small operative risk and the unknown possibility of graft occlusion and progression of disease in the native circulation. In addition there is a rather substantial cost of the procedure and related services without evidence that increased productivity can be anticipated. These benefits for many patients may be highly desirable and valuable, even if for a relatively short period of time. Physicians have the responsibility to counsel their patients as to whether these benefits justify the risk and the cost. But in counseling patients it should be realized that the Framingham study has recently reported that spontaneous remission of four or more years occurred in 30% of subjects with angina pectoris.217

Miller4 concluded the analysis of the previously mentioned questionnaire from cardiovascular surgeons rather philosophically and provocatively. “It is ironic that we are developing a complex, mass produced operation to treat a disease that is largely a product of society which has made such a procedure possible.” CAD and its sequela, IHD, are obviously not just a medical disease and a medical problem, but a socioeconomic challenge.

**Discussion and Conclusions**

After carefully reviewing in detail the literature that has been published during the first decade of the use of ACBG, it seems to the authors that the following conclusions may be drawn:

1. The operation, ACBG, is extremely popular in this country. It would appear that between 80,000 and 100,000 procedures were performed in this country in 1977. It is predicted that ACBG will soon become the most common elective surgical procedure performed on adults. The popularity of the procedure appears to result from the relatively low operative mortality, the frequency with which the pain of myocardial ischemia is relieved and the fear of the patient and his physician of sudden death, which is known to occur in up to one-half of the patients who die from coronary artery disease.

   It is surprising that the procedure was so widely adopted before it was shown that it prevented or reduced the incidence and/or postponed the occurrence of the other clinical manifestations of ischemic heart disease: myocardial infarction, arrhythmias, congestive heart failure, or premature death, either sudden or nonsudden (except possibly in small subsets of patients). For these reasons it is not surprising that despite enthusiasm for the widespread use of the procedure from many sectors, there are a few who have sounded a word of caution.10-17, 44-46, 49, 59, 119, 128, 131-133, 172, 213-217

   2. It is clear that the adverse effects of the procedure may be significant. For example:

   a) Perioperative myocardial infarctions are common, being demonstrated by the development of Q waves appearing on the ECG in from 1.2% to 40% of patients receiving ACBG10, 12-14, 22, 49-66, significant subendocardial injury, not demonstrated by Q wave changes but by enzyme elevations and/or radionuclide imaging changes, occurs in again as many patients.77-79 The development of a perioperative myocardial infarction has an adverse effect on the immediate and long term results of the therapy.30, 52, 53, 56, 61, 64, 66 Yet it is encouraging to note evidence that, as a result of attention to and modification of the details of the surgical technique, the incidence of perioperative myocardial infarction can be significantly reduced.79-83

   b) It appears that the implantation of an ACBG results in the acceleration of the rate of progression of the disease in the native circulation in large numbers of patients.12 14, 149, 170, 173, 182 185, 197 Progression of the disease, even if proximal to the insertion of a vein graft which remains patent, may have a detrimental effect on the integrity of the myocardium by the occlusion of significant collateral vessels; in addition accelerated progression of the disease, with or without specific changes in the collateral flow, appears to be associated with deterioration of left ventricular function.162, 171, 186

   That not all investigators agree as to the frequency of the occurrence of significant acceleration of the disease in the native circulation19, 188 suggests that the incidence may be related to patient selection, surgical techniques, or merely the selection of the patients for postoperative study. It has been suggested that predominantly symptomatic patients are studied postoperatively, which would exaggerate estimates of acceleration of the disease.188 However, the currently available literature indicates that ACBG does result in an acceleration of the disease in about 40% of grafted arteries. The process appears to be intimately related to the patency of the grafts.171-173

   c) Occlusion of the graft occurs in 36% or more of the grafts after three years; it seems to be associated with further deterioration of ventricular function and further progression of disease in the native circulation. Occlusion is
more likely to occur in grafts to the right or circumflex coronary arteries than to the anterior descending branch of the left coronary artery.

3. It is becoming apparent that the clinical improvement observed initially after surgery gradually deteriorates in some patients. The level of clinical improvement following ACBG may be influenced by the length of the follow-up after surgery. It is thought that the deterioration in good results is due to progression of the disease, and may, therefore, be preventable.

4. Despite the popularity that ACBG has enjoyed during its first decade, except for certain relatively small subsets of patients, there is no convincing evidence that the procedure prevents or postpones premature death.

Fewer than 1,300 patients in this country have been studied and randomized into groups that received and did not receive ACBG and were then followed for a period approaching three years.19-22, 27, 40 Only in the V.A. Cooperative study have patients who were symptomatic as a result of significant obstruction of the left main coronary artery been shown to enjoy a prolongation of life as a result of ACBG.

Efforts to determine that the procedure prolonged life by comparing the follow-up results with controlled data of the natural history of unoperated patients obtained from the literature has not been convincing. This is so because the series of patients used for controls were for the most part collected in the early and mid 1960s before ACBG was undertaken.109, 111-116 As experience has been gained with ACBG, in the 1970s there has been a striking decline in the mortality from coronary artery disease.120-130 This decline appears to result from the benefits of several trends that have been proceeding in parallel over the last decade or more. The general public has become aware of risk factors such as smoking, hypertension, diet, physical activity, etc.123, 126 Much professional and community effort has been exerted to reduce these risks. In addition the medical management of IHD has changed significantly with the introduction of new therapies including coronary care units, lidocaine, propranolol, potent diuretics such as furosemide, life support systems, etc.

Because of inadequate randomized studies to answer the questions regarding prolongation of life, the difficulty of carrying out such studies and the inadequate control population available in the literature, the Duke group has developed a computer program that has permitted the storage of pertinent historical data as well as data referable to physical findings, laboratory observations and therapeutic programs of individual patients; 110 items of information per patient were stored. Based on this type of approach, it was concluded that "ACBG does not prolong life in comparison to medical management over a span of two to five years. There may be certain high risk patients whose lives have been prolonged by the procedure, however." In addition to the possible prolongation of life in symptomatic patients due to significant stenosis of the left main coronary artery, this group found encouraging results in patients with total occlusion of the right coronary and a subtotal, but greater than 70% occlusion, of the left anterior descending coronary artery.

It is clear that patient selection is an important consideration in evaluating the results of a procedure. The better the risk for surgery, the less the need for the procedure.216

5. There has been a tendency among surgeons to attempt to completely revascularize the heart by attaching grafts to ever smaller vessels. Persistence of the patency of such grafts may not be as frequent as grafts to larger vessels. Patency appears to be related to the adequacy of runoff. It is unknown what effect occlusion of such small grafts has on myocardial function.

Despite the widespread acceptance of the concept of complete revascularization, there are no data to support the use of multiple grafts and attempts to bypass all major obstructions. It should be noted that using a computer matching technique, the Duke group could not demonstrate a difference in the relief of pain or survival by complete revascularization defined as bypassing all major arteries with a 70% or greater occlusion; an incomplete revascularization was accomplished when such a vessel(s) was not bypassed.133

6. Contrary to opinions expressed as a result of the early experience with ACBG18 the procedure has not contributed to a large number of patients with CAD returning to work or remaining gainfully employed. "Contrary to expectations, rehabilitation benefits, as a result of ACBG, appear to be few."214

7. The enthusiasm for ACBG has in some sectors been almost boundless. Such enthusiasm has usually appeared to have been motivated solely for the purpose of benefiting suffering patients. But at times, as the numbers of procedures increase and performance of the procedures becomes more mechanized, it becomes difficult not to wonder if there are not other goals such as self-aggrandizement, "keeping the beds full," or supporting further personal or institutional expansion.128 The enthusiastic claims for the procedure frequently appeared to exceed the benefits documented in the medical literature.

8. During this decade of experience with ACBG, it has become clear that the medical profession can no longer expect that the unfounded enthusiasm of a few will be kept "within the house." The "sunlight" or "open record" policy is not being applied just to government or political activities. Therefore, the medical profession must not be surprised to see itself portrayed to the public, as the result of the actions of a few, in books intended for the lay readership entitled The Unkindest Cut: Life in the Backrooms of Medicine.218

After considerable personal experience and a careful review of the available literature based on a decade of experience, it would appear that the following recommendations for the management of the individual patient may be made:

1. ACBG is most effective, if not the most effective therapy, for the relief of angina pectoris which is refractory to currently available medical management. The quality of life of patients with angina pectoris may be regularly improved. ACBG can be of real benefit in the management of such patients. There are at present no conclusive data in the literature to support the concept that ACBG is superior to adequate medical management to prevent or even ameliorate other signs and symptoms of IHD, such as myocardial infarction, arrhythmias and congestive heart failure. The procedure is therefore not recommended for these purposes.

2. With the exception of left main coronary artery disease49 and possibly other subsets of patients such as those with total occlusion of the right coronary artery and >70%
but less than total occlusion of the left anterior descending coronary artery,
there are inadequate data to justify the premise that ACBG prolongs life. The comments regarding
the two subsets of patients are based on small numbers of patients followed for relatively short periods of time. The
prudent physician, therefore, is advised to maintain an open mind even about these conclusions. However, at the present
time the physician may wish to tell patients with such lesions, who are symptomatic, that there is some evidence to
suggest that their life may be prolonged by ACBG.

The physician should also keep an open mind to the possibility that other subsets of patients may be indentified
that can expect to have an increased survival following ACBG.

3. There are at present no evidence to justify the use of ACBG in the asymptomatic patient, regardless of the lesions, in order to prevent the development of pain, a myocardial infarction, arrhythmias, congestive heart failure or premature death, either sudden or delayed. Therefore, the procedure should not be recommended for the asymptomatic patient.

5. There are considerable data indicating that the incidence of death from CAD is declining in this country and that this decline is due in part to a modification of "the life style." Therefore, the physician should strongly recommend that patients, whether candidates for ACBG or not, practice risk factor control and take other preventive measures.

Finally, it is apparent after ten years of experience with ACBG that there is still much that is unknown about the effectiveness of the therapy when compared to nonoperative management of CAD in the individual patient. Sir James MacKenzie said when discussing another therapy: "A great mass of observations has been accumulated but there has been divergence of opinion as to their interpretation. The divergence is an indication that there is something lacking in the knowledge of the subject. Seeing that the considerations of this subject have failed to bring an agreement, it may be assumed that the method of inquiry has been defective." Possibly this is currently the greatest challenge for the cardiovascular sector.

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Recurrent Sustained Ventricular Tachycardia

1. Mechanisms

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SUMMARY The mechanism of recurrent sustained ventricular tachycardia (VT) was evaluated in 21 patients. Re-entry as the mechanism for VT was suggested by a) the reproducible initiation (19) and termination (15) of the arrhythmia by programmed stimulation. The rate, ventricle of origin, and stimulation site determined the method of termination. One VPD was usually required with VT rates less than 175/min and/or ventricle of origin ipsilateral to the stimulation site, while two VPDs were usually required for VT with faster rates originating in a contralateral ventricle. The proximal His-Purkinje system (HPS) was not required for initiation or maintenance of VT. Evidence localizing the site of re-entry to a small portion of the ventricles included: a) ventricular capture by ventricular premature depolarizations (VPDs) or pacing (VP) without terminating VT (5), b) sinus capture following VPDs and/or supraventricular fusions without terminating VT (12), and c) atrial pacing normalizing the QRS and H-V intervals without terminating VT (5).

THE MECHANISM OF RECURRENT SUSTAINED VENTRICULAR TACHYCARDIA is not established. Recent investigations utilizing intracardiac stimulation and recording techniques to evaluate this arrhythmia have yielded conflicting results. Studies by Wellens" suggested that most recurrent ventricular tachycardias could be reproducibly initiated and/or terminated by programmed stimulation, implicating re-entry as the underlying mechanism. Furthermore, it has been postulated that the bundle branches can be an integral part of the re-entrant circuit. In contrast, a recent publication by Denes et al. suggested that most ventricular tachycardias could not be predictably induced or terminated.

The present study was undertaken to investigate the mechanism of chronic sustained ventricular tachycardia and the role of the bundle branches and ventricular myocardium in its initiation and maintenance.