Aortic Valve Replacement
Combined with Myocardial Revascularization

Late Clinical Results and Survival
of Surgically-Treated Aortic Valve Patients
with and without Coronary Artery Disease

FLOYD D. LOOP, M.D., DANIEL F. PHILLIPS, M.D., MOHAN ROY, M.D.,
PAUL C. TAYLOR, M.D., LAurence K. GROVES, M.D.,
AND DONALD B. EFFLER, M.D.

SUMMARY From 1967 through 1973, 80 consecutive patients underwent simultaneous aortic valve replacement (AVR) and coronary bypass grafting. Fourteen (18%) experienced no angina pectoris and had no history or electrocardiographic evidence of coronary atherosclerosis. Seven of these 14 had severe multiple vessel disease. All operations were performed under normothermic conditions without coronary perfusion. Seven patients (9%) died during operation. Intraoperative myocardial infarction was documented in eight (10%).

THE FREQUENT FINDING of coronary atherosclerosis in adults with aortic valve disease has influenced the practice of coronary arteriography in the preoperative examination. Patients with aortic stenosis (AS) who experienced angina pectoris have a prevalence of 58% severe coronary obstruction(s) reported by Lewis and Creus1 and 64% reported by Hancock2 in series documented by arteriography. Those without angina and/or patients with aortic regurgitation (AR) have a lower prevalence of associated coronary artery stenosis.

Atherosclerotic heart disease may severely jeopardize the prognosis after valve replacement. To offset this risk, with proper angiographic indications, bypass grafts have been combined with all forms of valve repair or replacement. Aortic valve replacement performed simultaneously with direct myocardial revascularization is the subject of this report. In reviewing the Cleveland Clinic experience, we emphasize clinical results and long-term survival, and discuss factors which potentially influence valvular and coronary artery operations.

Clinical Experience

From November 1967 through December 1973, aortic valve replacement (AVR) combined with coronary artery surgery was performed in 80 consecutive patients (76 men and 4 women) aged 44 to 70 years (mean, 57 years). The yearly distribution of operations was 1967, 2; 1968, 1; 1969, 2; 1970, 12; 1971, 19; 1972, 19; 1973, 25.

The American Heart Association reporting system for grading coronary artery disease6 was used to describe clinical and angiographic findings. Angina pectoris was defined as 1) exertional pain related to effort and relieved within 5 min by rest or coronary vasodilators; 2) rest pain is considered a) pain at rest when not in bed, b) nocturnal pain (angina decubitus), 3) unstable angina, or 4) atypical pain considered cardiac in origin. Of 66 patients with angina pectoris, the pain was classified (AHA functional classification) as mild in 30, moderate in 17, and severe in 19. A diagnosis of congestive heart failure (CHF) was accepted when the history revealed dyspnea at rest, orthopnea, paroxysmal
nocturnal dyspnea, or episodes of acute pulmonary edema. Congestive heart failure occurred in 46 patients and was considered mild in 25, moderate in 19, and severe in two. A history of syncope was elicited in nine patients and one patient had experienced subacute bacterial endocarditis previously.

Fourteen of 80 patients (18%) had no angina, no history of a coronary event, and no evidence of abnormal Q waves on the electrocardiogram (ECG) (fig. 1). Ten patients (13%) had ECG documentation of a previous myocardial infarction.

The predominant valve dysfunction derived from the cardiac catheterization report and the surgeon’s operative note was AS in 54 patients, AR in 13, and mixed stenosis and regurgitation in 13. In the 54 with AS, 19 bicuspid degenerative valves were documented. In nine patients, the valve anatomy could not be ascertained from the catheterization findings and was not adequately recorded in the operative note.

In each patient, coronary arteriography showed an estimated 70% or greater obstruction in one or more of the major coronary vessels. Thirty-six (45%) had single vessel disease, 21 (26%) double vessel disease, and 23 (29%) triple vessel disease. Of 36 with single vessel disease, the right coronary artery was involved in 21. Two of 19 bicuspid valves were associated with dominant left coronary arteries and two had a balanced distribution. Table 1 records the extent of coronary atherosclerosis corresponding to the valve lesion. Left ventricular contraction appeared normal in 26 of 80 patients (33%). As estimated subjectively, left ventricular segment motion was reduced in 22 patients (28%). All areas of localized impairment corresponded to the distribution of a severely stenotic or totally occluded coronary artery. A generalized reduction of contraction involving two or more ventricular segments was noted in 32 patients (40%). In the series of 80 patients, left ventricular end-diastolic pressure ranged from 6 to 50 mm Hg (mean 22 mm Hg). Of 67 patients with either AS or mixed pathology, the transvalvular systolic gradient ranged from 35 to 175 mm Hg (mean 73 mm Hg). Other hemodynamic parameters were measured in too few patients to provide meaningful data.

Eighty-one prosthetic valves were inserted in 80 patients. The operations were performed under normothermic conditions without coronary perfusion during valve replacement. Cutter-Smeloff prostheses were inserted in 40 patients, Starr-Edwards cloth-covered valves in 33 (two were 2310 and 31 were 2320), Lillehei-Kaster in six, and Bjork-Shiley in two patients.

**Results**

Of the 80 patients (table 1) who underwent simultaneous AVR and myocardial revascularization, seven (9%) died either during the operative procedure or within the first 30 days (table 2). Four of 58 single graft (7%), two of 18 double graft (11%), and one of four triple graft patients (25%) died in the early period. Postmortem examinations were performed in six of seven patients. Causes of early death were left ventricular failure, three patients; documented myocardial infarction, two; stroke, one; mesenteric embolus, one. Intraoperative myocardial infarction, evidenced by elevated cardiac enzymes and new Q waves, was documented in eight patients (10%), two of whom were operative deaths. Three of the six who survived after a documented intraoperative myocardial infarction later died at 8 months (CHF), 11 months (myocardial infarction), and 30 months (sudden death).

Of the 73 patients who survived the operative procedure, 58 were maintained on oral anticoagulants continuously. To date, nine patients have experienced symptoms consistent with nonfatal thromboembolism from 3 weeks to 30 months postoperatively. Five patients who had received Cutter-Smeloff prostheses sustained transient neurologic deficits (three hemiparesis, one aphasia, one transient ischemic attack). Four of these five patients were taking dicumarol at the time of the presumed embolic event. Three patients with Starr-Edwards valves experienced quadrantanopia, syncope, and memory loss, and hemiparesis respectively. Two of these three were receiving anticoagulants at the time of the event. One patient with a Lillehei-Kaster valve did not receive anticoagulants and became hemiparetic 3 weeks postoperatively.

Eighteen patients (23%) died in the late postoperative period between 4 and 55 months postoperatively (mean 16 months). Nine died suddenly from unexplained but probable cardiac causes, two died suddenly after documented arrhythmias, and other causes of death included myocardial

**Table 1. Aortic Valve Pathology and Extent of Coronary Artery Disease**

<table>
<thead>
<tr>
<th>Valve Dysfunction</th>
<th>Coronary vessels obstructed</th>
<th>No.</th>
<th>Single</th>
<th>Double</th>
<th>Triple</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS</td>
<td>54</td>
<td>24</td>
<td>14</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>AR</td>
<td>13</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AS and AR</td>
<td>13</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
<td>36 (45%)</td>
<td>21 (26%)</td>
<td>23 (29%)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: AS = aortic stenosis; AR = aortic regurgitation.
infarction (2), stroke (1), CHF (2), and bacterial endocarditis was responsible for two valve replacements in one patient, and postoperative paravalvular leakage and recurrent infection contributed to his death. One died presumably from a ruptured abdominal aneurysm.

Follow-up for the 55 surviving patients ranged from 21 to 90 months (mean 35 months). Angina was relieved completely in 39 of 44 (89%) survivors who had experienced ischemic chest pain preoperatively. Congestive heart failure was improved or alleviated in 27 of 30 survivors (90%). Eight survivors who had preoperative syncope have had no recurrent symptoms. Longevity calculated by the life-table method shows an 81% survival at 12 months, 76% at 24 months, 67% at 36 months, and 65% at 42 months. This series is compared with longevity of 300 patients who underwent isolated AVR at The Cleveland Clinic Foundation from 1968 through 1970. The latter group of patients had undergone preoperative cine coronary arteriography and had either normal coronary arteries or minor obstruction(s) (< estimated 50%). A 65% 42-month survival for the 80 combined AVR and graft patients is lower than the 76% survival of the 300 (noncoronary) AVR series but the difference does not reach statistical significance. The survival curves are illustrated in figure 2.

Angiography

Twenty-five patients underwent postoperative coronary arteriography after a 2- to 27-month interval (mean 12 months). Thirteen of 14 right coronary artery grafts, seven of nine circumflex, ten of ten anterior descending, and one diagonal graft were open for a patency rate of 91%. Included are two internal mammary artery grafts to the anterior descending coronary artery, both patent. Of the 25 patients studied, normal left ventricular contraction was observed in 18, localized impairment in four, and diffuse generalized impairment in three. Specifically, of the 12 who had normal contraction preoperatively, nine were normal postoperatively and three showed new segmental impairment. Five of six who had reduced segmental motion preoperatively demonstrated improved contraction or a return to normal function, and the sixth is unchanged. Of seven with generalized left ventricular impairment of at least moderate degree preoperatively, four have normal contraction postoperatively, and three have unchanged diffuse impairment.

In the late follow-up, five patients who had undergone postoperative angiography died, but no death could be related to the catheterization procedure. Intervals between operation and cause of death were as follows: 8 months, bacterial endocarditis; 14 months, sudden death-arrhythmia; 31 months, myocardial infarction; 31 months, sudden death-arrhythmia; 55 months, myocardial infarction. Of these patients who later died, four of five had shown improvement in LV contraction and reduction in left ventricular and diastolic pressure. Six grafts were open and two closed. Only one showed obvious deterioration in left ventricular contraction compared to the preoperative study.

### Discussion

Whether coronary arteriography should be performed in all adult AVR candidates is still debated, but recent findings suggest that arteriography should accompany preoperative catheterization. Our data reveal that 18% of patients with no history of angina pectoris or ECG evidence of coronary disease had severe coronary artery obstruction documented by preoperative arteriography (fig. 1). The mean age of our patients without angina was not appreciably different from those with angina (57 vs 58 years). These data differ sharply with the data of Bonchek et al., who reviewed 178 cases of aortic valve disease in patients over age 40. In their experience all patients with critical coronary artery obstruction had angina pectoris, which led them to conclude that severe coronary atherosclerosis in conjunction with aortic valve disease is always associated with angina. Lacey and colleagues found a 22% incidence of coronary atherosclerosis in 201 patients with all varieties of valvular heart
disease, and 18 of the 45 patients (40%) with severe coronary atherosclerosis had no history of angina pectoris. Evaluation of risk factors, ECG, and consideration of the valvular pathology did not help distinguish these patients. On the basis of our experience, the absence of angina is not a reliable guide to the presence or extent of coronary atherosclerosis in adult patients with all forms of aortic valve dysfunction.

A number of reports about combined valve and coronary artery operations indicate that the dual pathology and technical magnitude of simultaneous procedures increase the early death rate. In these series, operative mortality has ranged from 4% to 54%. Our operative mortality of 9% is three times higher than that of our isolated AVR patients who did not have coronary atherosclerosis. Similarly, our 10% perioperative infarction rate was more than twice that found in our isolated series. The Stanford experience was quite similar; mortality 14% in combined vs 0% in isolated AVR, and infarction incidence 11% in combined vs 0% in isolated AVR.

Thus far, the reported methods of myocardial preservation and sequence of grafting do not show one technique to be clearly superior to another. Berger at al. found no significant difference in the incidence of perioperative myocardial infarction between patients having coronary perfusion and those with hypothermic anoxic arrest which did not exceed 50 min. Their overall perioperative infarction rate was 23% using these techniques. Hypothermia with or without coronary perfusion was utilized by Rossiter et al. who reported a 21% infarction rate. Normothermia without coronary perfusion was utilized exclusively in our series. Theoretically, this technique offers less protection; however, our frequency of myocardial damage is comparable to the above reports. Perhaps the relatively short period of anoxic arrest for valve insertion (mean 39 minutes) offsets the theoretic disadvantages of normothermia.

Patients with AR sustained an overall long-term mortality of 54% (7 of 13) which compared to 31% in AS patients (17 of 54) \( P < 0.07 \) and mixed pathology 8% (1 of 13). It is unlikely that technical factors increased the risk, since valve replacement for AR is frequently less difficult due to the absence of a calcified anulus. In this subgroup of 13 AR patients, eight (62%) showed evidence of CHF, not substantially different from the AS patients (29/54 [54%]) or those with mixed pathology (9/13 [69%]). Cardiomegaly was found in ten of 13 AR patients, but the risk related to cardiac size \textit{per se} was not statistically significant when analyzed for all groups of valve pathology. Heart size determined from the chest roentgenogram averaged 27% above normal for AR patients, which was not substantially different from the 16% above normal found in the AS and mixed categories. In other large series, however, preoperative heart size has been implicated as an independent variable of high risk in AVR. In a report on a large aortic valve series, massive cardiomegaly and AR were implicated in poor long-term survival. So the reason for higher surgical risk in the AR subgroup is not clearly elucidated but may depend on interrelated factors such as heart size, pre-existing myocardial damage, and extent of coronary atherosclerosis.

Preliminary clinical and angiographic information indicates that many patients can be successfully rehabilitated by the combination of AVR and bypass grafts. After a mean follow-up period of 35 months, 49 of the 55 survivors are fully active. Angina was relieved completely in 39 of 44 (89%), and of those survivors who had preoperative symptoms of CHF, 27 of 30 (90%) have shown significant improvement. After an average interval of 12 months, 31 of 34 (91%) bypass grafts are patent.

Although seven internal mammary artery grafts were performed, and the two that were restudied were patent, we no longer use internal mammary grafts in patients with large coronary arteries and an increased left ventricular mass. Under these circumstances, flow requirements are considerably elevated and frequently exceed the peak of 150 ml/min delivered normally by the IMA.

Survival in these patients with aortic valve and coronary artery disease has been compared with a series of 300 patients who by angiography did not show severe coronary atherosclerosis and underwent isolated AVR (fig. 2). These latter patients operated on at the Cleveland Clinic include those who received bulb valve prostheses. Sixty-five percent of our combined AVR and revascularization patients were alive compared to a noncoronary isolated aortic valve survival of 76% at 42 months. The late follow-up of these aortic valve groups is relatively short; however, in the initial experience with simultaneous valve and coronary operations, mortality is higher and the actuarial curves indicate that severe coronary atherosclerosis may adversely affect longevity, despite bypass grafting.

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Detection of Perioperative Myocardial Damage after Coronary Artery Bypass Graft Surgery

ALBERTO RIGHETTI, M.D., MICHAEL H. CRAWFORD, M.D., ROBERT A. O’ROURKE, M.D., THORDUR HARDARSON, M.D., HEINZ SCHELBERT, M.D., PAT O. DAILY, M.D., MARLENE DELUCA, PH.D., WILLIAM ASHBURN, M.D., AND JOHN ROSS, JR., M.D.

SUMMARY In order to evaluate methods for detecting perioperative myocardial damage we studied 41 patients before and serially following coronary artery bypass graft surgery utilizing the 12-lead ECG, serum MB-CPK measurements, and 99mTc pyrophosphate myocardial scans. Six of the 41 patients (15%) developed persistent new Q waves after surgery. Six other patients demonstrated ischemic ST-T wave changes that persisted for 48 hours or more. Mean total MB-CPK released was highest for the group with new Q waves [1598 ± 545 (SE) I.U./L · hr] as compared to the group with ischemic ST-T wave changes [708 ± 65 I.U./L · hr] or the group with no ECG changes [262 ± 47 I.U./L · hr]. Ten patients (24%) had positive postoperative pyrophosphate scans consistent with myocardial infarction. The three techniques were compared in these 41 patients utilizing 465 I.U./L · hr as the upper limit of normal MB-CPK released after uncomplicated coronary bypass surgery (no ECG changes, negative scan). Five patients with ischemic ECG changes had a positive scan and high MB-CPK; six patients with no ECG changes had high MB-CPK but a negative scan; and one patient with high MB-CPK and new Q wave had a negative scan. We conclude 1) new Q waves on ECG underestimate the incidence of myocardial damage after coronary artery surgery; 2) MB-CPK alone overestimates the incidence of infarction; and 3) a combination of the three techniques is the best means for detecting myocardial damage after coronary artery bypass graft surgery.

MYOCARDIAL INFARCTION following coronary artery bypass graft surgery is usually associated with increased mortality and morbidity,1,4 but definite figures on its incidence have been difficult to obtain because of problems in making a reliable diagnosis. The incidence of electrocardiographic (ECG) and vectorcardiographic findings consistent with postoperative myocardial infarction has ranged from 6 to over 40% in various series.4,8 However, problems with the interpretation of the postoperative ECG limit its usefulness.5 Various serum enzymes have been used in an attempt to detect myocardial damage after coronary artery surgery. Unfortunately, the serum concentrations of CPK, GOT and LDH are all elevated postoperatively due to skeletal muscle trauma, and the degree of elevation of these serum enzymes is not a reliable indicator of myocardial infarction.7

The heart specific or MB-isoenzyme of CPK may be more useful for the detection of infarction after coronary bypass surgery.9 In addition, myocardial infarction imaging with such agents as technetium-99m labeled pyrophosphate has been advocated for the detection of acute myocardial infarction.9 For these reasons, we designed a protocol to evaluate the relative usefulness of the electrocardiogram, MB-CPK serum levels, and pyrophosphate scanning for the detection of myocardial damage early after coronary artery bypass graft surgery.

Methods

The study population consisted of 41 patients who underwent elective saphenous vein bypass grafting as an isolated procedure for symptomatic coronary artery disease. There were 34 males and seven females with a mean age of 56 years (range 37 to 74). The operative technique utilized was essentially the same for every patient with the exception that 11 patients had a right coronary artery mechanical endarterectomy in addition to bypass grafting of this vessel. Moderate hypothermia (30 to 33°C) and electrical fibrillation and defibrillation of the heart were used. In each case aortic cross-clamping was performed for short periods during the procedure and direct perfusion of the coronary arteries was not performed. Venting was accomplished through a pulmonary vein unless there was a definite left ventricular scar through which the drain could be placed.

A standard 12-lead electrocardiogram was obtained in each patient the day prior to surgery, immediately following
Aortic valve replacement combined with myocardial revascularization. Late clinical results and survival of surgically-treated aortic valve patients with and without coronary artery disease.

F D Loop, D F Phillips, M Roy, P C Taylor, L K Groves and D B Effler

doi: 10.1161/01.CIR.55.1.169

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1977 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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