Coronary Artery Bypass Grafting in Severe Left Ventricular Dysfunction: Excellent Survival With Improved Ejection Fraction and Functional State

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Objectives. The present study evaluated our experience with coronary artery bypass grafting in patients with severe left ventricular dysfunction.

Background. Despite the ominous prognosis of advanced ischemic cardiomyopathy, coronary artery bypass grafting in this setting remains controversial because of concerns over operative risk and lack of functional or survival benefit.

Methods. We analyzed the data of 83 consecutive patients (69 men, 14 women, aged 42 to 83 years [mean 66.8]) with a left ventricular ejection fraction ≤30% who underwent isolated coronary artery bypass grafting (without aneurysmectomy, valve replacement or other open heart procedures) performed by one surgeon during a 6-year period. The ejection fraction ranged from 10% to 30% (mean 24.6%). Preoperatively, 49% of patients had angina, 52% had congestive heart failure (17% with pulmonary edema) and 30% manifested significant ventricular arrhythmia. The mean number of grafts was 2.7/patient. The internal mammary artery was used in 82% of grafts to the left anterior descending coronary artery. The intraaortic balloon pump was required therapeutically (for angina or pump failure) in 19% of patients and was prophylactically placed preoperatively in another 43% of patients.

Results. The hospital mortality rate was 8.4% (7 of 83). The mortality rate was 3.3% (2 of 61) in those patients who did not require admission to an intensive care unit immediately before operation. Canadian Cardiovascular Society angina class improved postoperatively by 1.9 categories and New York Heart Association congestive heart failure class by 1 category. Left ventricular ejection fraction (assessed postoperatively in 68 of 76 hospital survivors) improved from 24.6% preoperatively to 33.2% postoperatively (36% increase) (p < 0.001). At 1 and 3 years, respectively, all-cause survival was 87% and 80% and freedom from cardiac death was 89.8% and 84.5%.

Conclusions. In patients with coronary artery disease and advanced ventricular dysfunction: 1) coronary artery bypass grafting can be performed relatively safely, 2) good medium-term survival is attained, 3) improvement in left ventricular function can be documented objectively after bypass grafting, 4) quality of life is improved (as reflected by improvement in anginal and congestive heart failure status), and 5) the internal mammary artery can safely be used as a conduit. The use of coronary artery bypass grafting is encouraged for this group of patients and may provide a viable alternative to transplantation in selected patients.

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patients with an ejection fraction <25% in one study [10]. In some studies [10], patients undergoing mechanical corrections such as valve replacement or aneurysmectomy in addition to bypass grafting were not excluded from analysis, although clearly the pathophysiology and mechanisms of surgical benefit are different in these patients. In some prior reports [10], no assessment of symptomatic state after grafting was included, with emphasis only on survival.

For these reasons, the value of isolated coronary artery bypass grafting for patients with advanced left ventricular dysfunction and severe coronary artery disease is not clear. This report is intended to address this issue by determining the operative risk, long-term survival and symptomatic state in patients with advanced left ventricular dysfunction undergoing coronary revascularization.

The last 6 years of isolated coronary artery bypass grafting performed at our institution in patients with advanced left ventricular dysfunction is reviewed and both operative and long-term survival and symptomatic state after bypass grafting are reported. For the purposes of this study, advanced left ventricular dysfunction is defined as ejection fraction ≤30%. The review is confined to the consecutive patients undergoing operation by one surgeon using a single, standard operative technique. For the purposes of this study, advanced left ventricular dysfunction is defined as ejection fraction ≤30%. The review is confined to the consecutive patients undergoing operation by one surgeon using a single, standard operative technique. In view of the recent recognition of “stunned” and “hibernating” myocardium [12], a comparison of left ventricular performance before and after revascularization is reported.

### Methods

#### Study patients

The study group consisted of 83 consecutive patients with an ejection fraction ≤30% undergoing coronary artery bypass grafting (without other open heart procedures) by one surgeon (J.A.E.) between January 1986 and June 1992. Patients undergoing concomitant valve replacement or left ventricular aneurysmectomy were excluded from analysis. Age ranged from 42 to 83 years (mean 66.8). There were 69 men and 14 women (Table 1).

Preoperative left ventricular ejection fraction was determined by contrast angiography in 38 patients and by equilibrium radionuclide angiography in 45 (Fig. 1). Mean ejection fraction was 24.6%. The lowest ejection fraction was 10% and the highest 30%. Postoperative ejection fraction was determined in all cases by equilibrium radionuclide angiography. A regression equation was used to normalize preoperative contrast angiographic ejection fraction (EF) to equilibrium radionuclide angiography (ERNA) scan equivalents [13]. This equation is as follows: ERNA EF = 0.86 × ventriculographic EF + 2.9. In the low range of ejection fractions in this study, this formula changes the absolute value of the ejection fraction between the two methods by ≤1.8%.

Six (7.5%) of 83 patients had a single coronary artery bypass graft. 26 (31.3%) had two grafts, 42 (50%) had three grafts. 8 (9.6%) had four grafts and 1 (1.2%) had five grafts. The mean number of grafts per patient was 2.7. Twenty-one patients (25%) underwent simultaneous placement of the hardware for the automatic implantable cardioverter-defibrillator because of an associated history of serious ventricular arrhythmia. Sixty-three (76%) of 83 patients had an internal mammary artery graft placed to the left anterior descending coronary artery. Of the 77 patients who required a graft to this artery, 63 (82%) had an internal mammary artery graft. One patient had a sequential internal mammary artery graft to two coronary arteries using the left internal mammary artery. Sixteen patients (19%) had an intraaortic balloon pump in place for therapeutic reasons (angina or low output state) at the time of operation. In 36 patients (43%), the intraaortic balloon pump was placed preoperatively to facilitate anesthesia and operation and to protect the patient perioperatively.

#### Table 1. Clinical Characteristics of the 83 Study Patients

| Age (yr) | 42 to 83; average 66.8 |
| Male/Female | 69/14 |
| Ejection fraction (%) | 10 to 30; mean 24.2 |
| Grafts/patient (mean) | 2.7 |
| Prior MI | 62 (75) |
| Associated AICD | 21 (25) |
| IABP | |
| Therapeutic | 16 (19) |
| Prophylactic | 36 (43) |
| Indications for surgery | |
| Heart failure | 43 (52) |
| Pulmonary edema | 14 (17) |
| Angina | 41 (49) |
| Arrhythmia | 21 (25) |

Unless otherwise indicated, values are expressed as number (%). AICD = automatic implantable cardioverter-defibrillator; IABP = intraaortic balloon pump; MI = myocardial infarction.

Figure 1. Frequency distribution graph of ejection fraction (EF). More than 50% of the patients had an ejection fraction ≤25%. The ejection fraction in the seven patients who died in the hospital were 13%, 18%, 20% (three patients), 26 and 30%, respectively.

![Graph of ejection fraction distribution](image-url)
Indications for surgery were as follows. Forty-three patients (52%) had congestive heart failure, which was manifested as pulmonary edema in 14 patients (17%). Forty-one patients (49%) had angina. Twenty-one patients (25%) re-exhibited as pulmonary edema in 14 patients (17%). Forty-one patients (52%) had congestive heart failure, which was manifested as pulmonary edema in 14 patients (17%).

Operative technique. All patients underwent coronary artery bypass grafting by a single surgeon using a standard operative technique. Single cannulation of the right atrium was carried out with a two-stage venous cannula. The left ventricle was vented to gravity through the right superior pulmonary vein. Myocardial preservation was performed by means of systemic hypothermia (26° to 28°C), topical hypothermia with iced saline solution and cold crystalloid cardioplegic solution administered into the ascending aorta before each graft. Distal anastomoses were performed first during a single period of aortic occlusion, with proximal anastomoses performed subsequently under side-biting control of the ascending aorta.

Follow-up. Follow-up data were obtained from office charts, hospital charts and interviews with the primary physicians or the patient, or both. Complete follow-up data were available in 80 (96%) of 83 patients. Anginal status was tabulated according to Canadian Cardiovascular Society criteria and heart failure status by New York Heart Association criteria.

Data analysis. Survival curves were drawn on an actuarial basis using the Kaplan-Meier technique. Survival curves were compared by the Wilcoxon test. The statistical significance of differences was determined using the unpaired t test (comparisons between patients with and without an automatic implantable cardioverter-defibrillator) and the paired t test (comparison of pre- and postoperative ejection fraction) (Primer of Biostatistics: The Program, Version 3.0, McGraw-Hill).

Results

Surgical outcome. No patient died at operation. Nineteen (23%) of 83 patients required pharmacologic inotropic support in the operating room (usually low doses). Eleven of these patients were already receiving such support when brought to the operating room. There were seven in-hospital deaths (8.4%). Five of the seven deaths were in patients who had manifested cardiogenic shock from myocardial infarction earlier during the same hospital admission. Death occurred on postoperative days 1, 4, 5, 6, 10, 11 and 14, respectively. The cause of death was arrhythmia in two patients, pump failure in two, cerebrovascular accident in one, intestinal infarction in one and multiple organ failure in one. One of the two patients dying from pump failure died of end-stage right heart failure associated with antecedent fixed high pulmonary vascular resistance.

No patient sustained a Q wave myocardial infarction or subendocardial myocardial infarction by criteria used at our hospital (creatine kinase, MB fraction [CK-MB] product >90 IU/liter).

Among the 36 patients who had an intraaortic balloon pump placed prophylactically, 1 had a vascular complication requiring an operative thrombectomy. Among the 16 patients who had an intraaortic balloon pump placed therapeutically, 2 had vascular complications; 1 patient lost a limb because of ischemia and the other required removal of the balloon pump because of limb ischemia.

Follow-up. The duration of follow-up ranged from 1 to 62 months (mean 22). During this period, nine patients died outside the hospital at 2, 5, 8, 28, 29, 38, 44 and 59 months, respectively. The cause of death was cardiac in four (sudden death or heart failure) and noncardiac in five (cerebrovascular accident, renal failure, diabetes, cancer) (Fig. 2). In-hospital deaths are included in computing the survival curve. Among all patients undergoing surgery, survival was 87% at 1 year, 87% at 2 years and 80% at 3 years. The standard errors are indicated at the follow-up points. Fifty-two patients attained a 1-year, 35 a 2-year and 17 a 3-year follow-up survival time.

Cardiac survival (freedom from death due to a cardiac cause) was 89.8% at 1 year, 89.8% at 2 years and 84.5% at 3 years. (This tabulation includes all perioperative deaths as cardiac and excludes only those late deaths clearly due to noncardiac causes.)

The 21 patients who underwent placement of the hardware for an automatic implantable cardioverter-defibrillator did not differ significantly in long-term survival (p = 0.82) or...
in general characteristics from the 63 patients who did not have this device implanted (0 women, 16.8% men, p = 0.17; mean age 68.4 and 65.3 years, respectively, p = 0.291; preoperative ejection fraction: 23.9% and 24.2%, respectively, p = 0.742).

Figure 3 compares the survival rate for the 21 patients with an ejection fraction of 10% to 20% with that for the 62 patients with an ejection fraction of 21% to 30%. Although the survival curve for the lower ejection fraction group demonstrates a higher early mortality rate, the curve is flat, so that at 3 years there is no statistically significant difference between the survival curves (p = 0.11, Wilcoxon test).

Figures 4 and 5 compare the preoperative and postoperative symptomatic state. Follow-up data are recorded for all patients alive and available for follow-up study at the completion of data analysis. Patients with previous angina had marked improvement: Nearly all were asymptomatic or minimally symptomatic. Mean angina class (among patients with angina) improved from 3.2 preoperatively to 1.3 postoperatively. Improvement in congestive heart failure status was realized as well, with the majority of patients in class I or II after operation. Mean congestive heart failure class (among patients with congestive heart failure) improved from 2.8 preoperatively to 1.8 postoperatively.

Figure 6 presents the pre- and postoperative ejection fraction data. Sixty-eight (89.5%) of the 76 hospital survivors underwent follow-up equilibrium radionuclide angiography studies after operation. Ejection fraction was determined at a mean of 6.2 months from coronary artery bypass grafting (range 7 days to 39 months). Mean ejection fraction increased substantially from 24.6% to 33.2% (p < 0.001). Only five patients showed a decrease of >4 ejection fraction percentage points, with the remainder showing no change (21 patients with an ejection fraction within 4 ejection fraction points of that before operation) or improving (42 patients). The maximal improvement was 29 ejection fraction units (from 30% to 59%).

Comparison of results between the 22 critically ill patients...
in the intensive care unit immediately before operation and the 61 patients not in the intensive care unit revealed the following: The hospital mortality rate was higher in patients in the intensive care unit (22.7% [5 of 22] vs. 3.3% [2 of 61]) (p = 0.004 by t-test). Improvement in ejection fraction after coronary artery bypass grafting did not differ significantly between patients in or not in the intensive care unit preoperatively (6.5% vs. 8.9%, p = 0.40 by t test). Long-term survival also did not differ between the two groups (81% and 79%, respectively, at 3 years, p = 0.36 by Wilcoxon test).

Only 15 preoperative thallium or sestamibi myocardial perfusion imaging studies had been performed at Yale-New Haven Hospital within 6 months of coronary artery bypass grafting. Ten studies were performed with stress testing (seven by treadmill and three with dipyridamole); five studies were performed only at rest. All patients showed fixed defects consistent with scar. Nine patients were also found to have areas of reversible defects consistent with viability or ischemia. After bypass grafting, absolute ejection fraction increased by 7.6% in the patients who showed reversibility and 11.5% in the patients who did not. This difference was not significant statistically (p = 0.48 by t test); however, the sample size does not provide sufficient power for analysis.

**Discussion**

Although coronary artery bypass grafting in the setting of a very low ejection fraction remains controversial (5–7,14–23), the present study strongly supports its application. A unifying concept behind our findings is that coronary artery bypass grafting preserves already functioning muscle against future infarction and recruits hibernating muscle (12). This recruitment leads to the objective improvement in ejection fraction and to the amelioration of congestive heart failure. The protection against infarction results in enhanced medium-term survival.

**Conclusions.** We emphasize the following specific conclusions to our study.

**Safety of operation.** The 8.4% hospital mortality rate indicates that even those patients with marked left ventricular compromise can undergo bypass surgery relatively safely. The majority of in-hospital deaths (five of seven) occurred in patients manifesting postinfarction cardiogenic shock at the time of operation or earlier during the same hospital admission. This implies that for patients in stable condition with severe ventricular dysfunction, coronary artery bypass grafting may be even safer than is reflected in the overall statistics.

**Long-term survival.** Long-term survival (87% at 1 year and 80% at 3 years) is excellent in the context of expected medical prognosis. These results include hospital deaths after coronary artery bypass grafting. The survival rate for patients discharged from the hospital is 96% at 1 year and 88% at 3 years. These results are consistent with the best results reported from recent work despite our relatively severe ejection fraction criterion of ≤30% (as opposed to the
studies of coronary artery bypass grafting in patients with a low ejection fraction, but often on an "as needed" basis intraoperatively when attempting to wean the patient from cardiopulmonary bypass. In contrast, selective prophylactic use (our selection was subjective, based on severity of depression of ventricular function and vulnerability of coronary supply) avoids the cardiac distension and oxygen debt incurred before the decision for ad hoc use at the time of attempted weaning from cardiopulmonary bypass. Postoperative inotropic support was required relatively infrequently (23% of cases in our study, supporting the view that the intraaortic balloon pump was of value. Avoidance of perioperative myocardial damage through use of the balloon pump may have been a factor allowing the emergence of the net improvement of ejection fraction seen in our patients. Complications from prophylactic balloon pump use were infrequent and manageable.

Twenty-one of our patients underwent associated placement of an automatic implantable cardioverter-defibrillator because of prior life-threatening ventricular tachycardia or ventricular fibrillation. Patients with severe arrhythmia were often excluded in prior investigations, most of which were done before the advent of the automatic implantable cardioverter-defibrillator. The presence of this device in a portion of our cohort may have contributed to long-term survival. Both the preoperative clinical states and subsequent outcome were comparable in those with and without automatic implantable cardioverter-defibrillator placement.

There is clearly an overlap between the patients included in the present report and those evaluated for heart transplantation for ischemic cardiomyopathy. The safety of operation, improvement in symptomatic state, objective improvement in left ventricular ejection fraction and good medium-term survival realized in the present series argue for consideration of coronary artery bypass grafting as an alternative to transplantation in selected patients.

In the present study, the postoperative equilibrium radionuclide angiographic evaluations were obtained at varying intervals after coronary artery bypass grafting. Consequently, physiologic factors that may have influenced the ejection fraction (such as blood pressure control and negative inotropic medications) were not controlled at the times of pre- and postoperative ejection fraction determinations. In early postoperative studies, stunning may still have been present. Despite these factors, the improvement in ejection fraction is both statistically meaningful and physiologically relevant. Further standardization and control of intervening factors in future studies may magnify even further the objective postoperative improvement in ventricular function in appropriately selected patients.

These patients were enlisted primarily without a detailed assessment of myocardial viability by means of perfusion scintigraphy with delayed thallium imaging or positron emission tomography (26–29). Such studies, which should be employed prospectively in the present era, could further enhance selection of patients for coronary artery bypass grafting in the setting of substantial ventricular dysfunction.

References
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