PREDICTORS OF OPERATIVE RISK FOR CORONARY BYPASS OPERATIONS IN PATIENTS WITH LEFT VENTRICULAR DYSFUNCTION

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Objectives: The prevalence of ventricular dysfunction in patients undergoing coronary operations, as well as the prevalence of other risk factors in these patients, has been increasing. We identified the predictors of mortality and morbidity in patients with ventricular dysfunction to permit more accurate evaluation of risk and to direct future strategies to improve outcomes. **Methods:** Demographic, intraoperative, and outcome data were collected prospectively on 20,614 patients undergoing isolated coronary operations at our institution from 1982-1997. Multivariable regression analyses were used to identify the independent predictors of mortality and low-output syndrome. **Results:** Moderate ventricular dysfunction (ejection fraction, 20%-40%) was noted in 4107 (19.9%) patients, and severe dysfunction (ejection fraction, <20%) was noted in 680 (3.3%) patients. Patients with worse ventricular function had an increasing prevalence of other risk factors with time. Mortality decreased between the 1982-1986 and 1987-1991 cohorts but did not decrease further. Low-output syndrome was less common in the 1992-1997 cohort than in previous years. The predictors of mortality were ventricular dysfunction, age, reoperation, year of operation, urgency, female sex, and left main stenosis. Low-output syndrome was predicted by ventricular dysfunction, reoperation, year of operation, female sex, urgency, extensive coronary disease, age, left main stenosis, and symptom class. **Conclusions:** Despite the increasing prevalence and risk profile of patients with ventricular dysfunction, mortality rates and incidence of low-output syndrome declined with time. Patients with severe dysfunction were at greatest risk when facing reoperation or urgent operation. Earlier intervention and more aggressive preoperative optimization may improve outcomes in these high-risk patients. (J Thorac Cardiovasc Surg 1999;118:1006-13)

Operative morbidity and mortality rates during coronary bypass surgery have decreased substantially during the past 2 decades. The overall mortality rate of patients undergoing coronary bypass operations at our institution fell from 4.0% in 1982 to 2.2% in 1997.

However, certain high-risk subgroups of patients remain at elevated risk of complications and death despite progressive advances in perioperative care and myocardial protection.¹ We have previously identified left ventricular (LV) dysfunction as one of the most significant independent predictors of operative mortality² and low-output syndrome³ during coronary bypass operations. We have noted both an increasing prevalence of patients presenting with preoperative LV dysfunction and an increasing profile of comorbidity and other risk factors within this subgroup. We therefore attempted to identify the independent predictors of operative mortality and morbidity in patients with moderate or severe LV dysfunction to permit more accurate evaluation of risk in these patients and to direct the development of novel strategies to improve outcomes.

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Table I. Number of patients by year of operation and LVEF

	1982-1986	1987-1991	1992-1997	All years
LVEF > 40%	4582 (78.5%)	4554 (76.8%)	6465 (75.0%)	15,601
LVEF 20%-40%	1072 (18.4%)	1162 (19.6%)	1873 (21.7%)	4107
LVEF < 20%	186 (3.2%)	216 (3.6%)	278 (3.2%)	680
All patients	5840	5932	8616	20,388

Table II. Demographic details of 20,388 patients by LVEF

	LVEF > 40%	LVEF 20%-40%	LVEF < 20%	P value
Age (y)	60.3 ± 9.7	61.2 ± 9.7	60.2 ± 9.6	<.0001
Sex (% male)	78.9	83.8	86.2	<.0001
NYHA class (% I/II/III/IV)	2.6/17.7/39.8/39.9	2.3/11.5/36.7/49.5	1.6/8.4/31.5/58.5	<.0001
No. of diseased vessels (% 1/2/3)	6.4/23.5/70.1	2.1/17.6/80.3	2.2/16.7/81.1	<.0001
Left main stenosis (%)	16.4	15.8	20.4	.01
Reoperative surgery (%)	5.2	8.7	7.5	<.0001
Preoperative MI <30 days (%)	19.2	33.2	35.9	<.0001
Preoperative IABP (%)	2.7	4.6	8.1	<.0001
Urgency (% elective/ urgent/emergency)	69.1/16.9/14.0	62.9/19.7/17.4	60.4/17.4/22.2	<.0001

MI, Myocardial infarction.

Table III. Intraoperative details of 20,388 patients by LVEF

	LVEF > 40%	LVEF 20%-40%	LVEF < 20%	P value
No. of grafts (% 1/2/3/4)	3.1/13.1/35.7/37.7	1.4/10.1/35.3/42.5	2.4/11.3/34.6/43.4	
No. of grafts (% 5/6/7)	9.9/0.4/0.01	9.9/0.7/0.07	8.2/0.2/0.0	<.0001
LITA (% 1982-1997)	69.3	65.1	54.0	<.0001
LITA (% 1992-1997, 8614 patients)	89.1	83.2	73.0	<.0001
CPB time (min)	86.3 ± 30.7	91.7 ± 28.5	99.6 ± 35.2	<.0001
Crossclamp time (min)	56.9 ± 20.3	59.7 ± 18.6	60.2 ± 19.4	<.0001

CPB, Cardiopulmonary bypass.

Methods

Data source. Demographic, anatomic, intraoperative, and in-hospital outcome data were collected prospectively and entered into a computerized database on all patients undergoing cardiac surgery at our institution (The Toronto Hospital, formerly the Toronto General and Toronto Western Hospitals). From this database, the records of all patients undergoing isolated coronary artery bypass grafting between January 1, 1982, and December 31, 1997, were retrieved for analysis.

Core fields collected in our database since its inception in 1982 included age, sex, LV grade (based on LV ejection fraction [LVEF]: grade 1, LVEF >60%; grade 2, LVEF 40%-60%; grade 3, LVEF 20%-39%; and grade 4, LVEF < 20%), previous coronary artery bypass operations, urgency of the

operation (elective; semiurgent, indicating surgery during the same admission as cardiac catheterization or a cardiac event; or emergency, indicating surgery within 12 hours of cardiac catheterization or a cardiac event), number of coronary arteries with significant stenoses, left main stenosis of greater than 50%, severity of angina, and New York Heart Association (NYHA) functional class. LVEF was determined semiquantitatively by contrast ventriculography. Echocardiography and nuclear ventriculography were carried out in a minority of patients, and when these additional data were available, the greatest value for LVEF obtained was used for subsequent analysis. In the minority of patients in whom these estimates differed, this was generally caused by performance of one study within 1 to 3 days after a myocardial infarction, resulting in overestimation of LV dysfunction, with a subsequent

Fig 1. The prevalence of operative risk factors in 20,614 patients undergoing isolated coronary artery bypass grafting over 3 time periods (1982-1986, 1987-1991, and 1992-1997). Patient age and symptom class increased significantly with more recent year of operation, as did the prevalence of left main coronary artery stenosis and the requirement for an urgent or emergency operation. *LM*, Left main; *Non-elective*, Requiring urgent or emergency surgery.

study showing partial recovery of contractility. In these cases the later study (always resulting in a higher estimated LVEF) was used for analysis. Core data were complete on 20,388 (98.9%) of 20,614 patients.

Analysis. Data were collected and managed in dBASE IV datasets and analyzed with SAS and BMDP/DYN LR statistical analysis software (SAS Institute, Inc, Cary, NC; BMDP Software, Los Angeles, Calif). Univariate analysis of categorical data was carried out by using χ^2 analysis or the Fisher exact test. Univariate analysis of continuous variables was carried out by using the Student *t* test. Variables that had a univariate *P* value of less than .25 or those of known biologic importance but failing to meet the critical α level were submitted for consideration to logistic regression analysis by using stepwise selection. Multivariable logistic regression methods were used to calculate risk-adjusted mortality rates and factor-adjusted odds ratios. Model discrimination was evaluated by the area under the receiver-operator characteristic curve, and calibration was assessed with the Hosmer-Lemeshow goodness-of-fit statistic. For goodness-of-fit, the null hypothesis is that the model fits the data. Therefore a nonsignificant *P* value is desired because *P* values of less than .05 would indicate a poor fit between predicted and observed results.

Evaluation of temporal trends. Rather than constructing a complex model to assess the temporal trends in prevalence, risk profiles, and outcomes, we used a simpler approach

based on risk stratification and contingency tables. To examine the effect of time on patient risk profiles and outcomes, patients were divided into 3 groups based on the year of operation (1982-1986, 1987-1991, and 1992-1997). Contingency table analysis was then used to examine changes in the prevalence of LV dysfunction, risk factors, and operative mortality over time and among the 3 risk groups.

Results

Demographics

Prevalence of LV dysfunction. A total of 15,601 patients had no or only mild LV dysfunction (LVEF > 40% for 75.7% of all patients), whereas 4107 (19.9%) patients had moderate dysfunction (LVEF 20%-40%), and 680 (3.3%) patients had severe dysfunction (LVEF < 20%). The number of patients, categorized by LVEF and by year of operation, is shown in Table I. The proportion of patients presenting with an LVEF of 20% to 40% increased from 18.4% in 1982-1986 to 21.7% in 1992-1997, but the proportion of patients with an LVEF of less than 20% remained constant.

Additional risk factors in patients with LV dysfunction. Demographic details, grouped by degree of LV dysfunction, are listed in Table II. Patients with worse LV function were more likely to be male and to have more extensive coronary disease or left main coronary artery stenosis. The acuity of patients with worse LV function was greater, with higher NYHA symptom class and a greater likelihood of requiring an urgent or emergency operation. The prevalence of preoperative intra-aortic balloon pump (IABP) support was greatest in patients with severe ventricular dysfunction. These patients were therefore more likely to require an urgent or emergency operation.

Increasing risk profile of patients with LV dysfunction. In more recent years, patients with LVEF of less than 20% were older and more symptomatic (Fig 1). They were also more likely to have left main stenosis (*P* = .01) and to require an urgent or emergency operation, although the trend to more urgent operation did not reach statistical significance.

Patients with an LVEF of 20% to 40% demonstrated a similar statistically significant increase in patient age, symptom class, left main stenosis, and need for urgent or emergency operation. In addition, in this subgroup there was also an increasing number of female patients (1982-1986, 13.9%; 1987-1991, 15.7%; and 1992-1997, 17.8%; *P* = .02) and a greater prevalence of reoperative surgery (1982-1986, 6.2%; 1987-1991, 9.6%; and 1992-1997, 9.6%; *P* = .003).

Intraoperative data. Intraoperative details, grouped by degree of LV dysfunction, are listed in Table III.

Fig 2. Operative mortality rate and incidence of postoperative low-output syndrome, as determined by preoperative LVEF. Mortality rate was low in patients with no or minimal ventricular dysfunction but doubled when LVEF was 20% to 40% and was more than quadrupled in patients with LVEFs of less than 20%. Low-output syndrome was uncommon in patients with no or minimal ventricular dysfunction but was twice as common when LVEFs were 20% to 40% and 3 times as common in patients with LVEFs of less than 20%.

Although overall use of the left internal thoracic artery (LITA) increased with year of operation (1982-1986, 36.0%; 1987-1991, 70.6%; and 1992-1997, 87.3%; $P < .0001$), patients with worse LV function were less likely to receive an internal thoracic artery (ITA) graft in any year.

Most patients received 3 or 4 bypass grafts. The duration of cardiopulmonary bypass was greater in patients with worse ventricular function (Table III). The duration of aortic crossclamping was similar between groups, ranging from approximately 57 to 60 minutes.

In earlier years, systemic perfusion was carried out at moderate hypothermia (1982-1986: 25°C-29°C for 96% and 30°C-35°C for 4% of patients) but our routine is now to use only mild hypothermia (1992-1997: 25°C-29°C for 9%, 30°C-35°C for 82%, and 36°C-37°C for 9% of patients; $P < .0001$ vs 1982-1986). The degree of systemic hypothermia was not different, however, between LVEF groups. Antegrade cold blood cardioplegia was used for myocardial protection in 91% to 95% of patients over the 3 time periods; the technique

Fig 3. Operative mortality rates, as determined by preoperative LVEF, over 3 time periods (1982-1986, 1987-1991, and 1992-1997). Mortality decreased from the 1982-1986 cohort to the 1987-1991 cohort in all LVEF groups, but the reduction was most marked in patients with LVEFs of less than 40%. No further reduction in mortality rate was noted from the 1987-1991 cohort to the 1992-1997 cohort.

of cardioplegia was not different between LVEF groups.

Outcomes

Operative mortality rates. The overall operative mortality rate increased with greater LV dysfunction ($P < .0001$; Fig 2). Mortality decreased between the 1982-1986 and 1987-1991 cohorts in all LVEF groups but did not decrease further in the 1992-1997 cohort (Fig 3).

Myocardial infarction. The rate of perioperative myocardial infarction was not different between LVEF groups (LVEF > 40%, 3.8%; LVEF 20-40%, 4.0%; and LVEF < 20%, 4.9%; $P = .4$).

Low-output syndrome. Postoperative low cardiac output syndrome (the requirement for inotropic or IABP support to maintain a cardiac index of greater than 2.0 $L \cdot \min^{-1} \cdot m^{-2}$ despite optimization of heart rate, preload, and afterload) was significantly greater in patients with LV dysfunction ($P < .0001$; Fig 2).

The rate of low-output syndrome fell between the 1987-1991 and 1992-1997 cohorts, but even in the latest cohort, low-output syndrome was still 4 times as common in patients with LVEFs of less than 20% as it was in patients with LVEFs of greater than 40% ($P < .0001$; Fig 4).

IABP support. Placement of an IABP preoperatively

Fig 4. The prevalence of postoperative low-output syndrome, as determined by preoperative LVEF, over 3 time periods (1982-1986, 1987-1991, and 1992-1997). Low-output syndrome decreased with time in all LVEF groups but only from the 1987-1991 cohort to the 1992-1997 cohort.

Table IV. Multivariable predictors of operative mortality in all 20,614 patients

Variable	Regression coefficient	OR	95% CI
Constant	-0.9659 ± 0.911		
Age	0.0464 ± 0.005	1.048	1.037-1.058
LV grade	0.5385 ± 0.051	1.713	1.550-1.894
NYHA class	0.3301 ± 0.078	1.391	1.193-1.622
Reoperative surgery	1.0538 ± 0.128	2.869	2.234-3.683
Urgency	0.4340 ± 0.074	1.543	1.334-1.786
Year of operation	-0.0997 ± 0.010	0.905	0.887-0.924
Female sex	0.5601 ± 0.099	1.751	1.441-2.127
Left main stenosis	0.4737 ± 0.105	1.606	1.309-1.971

The area under the receiver-operator characteristic curve was 0.754. The Hosmer-Lemeshow goodness-of-fit *P* value was .375.

LV grade: 1, LVEF > 60%; 2, LVEF 40%-60%; 3, LVEF 20%-40%; 4, LVEF < 20%. *Urgency:* 0, Elective; 1, same hospitalization; 2, within 12 hours of a cardiac catheterization or cardiac event (eg, myocardial infarction and unstable angina). *Year of operation:* 1982-1997. *OR,* Odds ratio; *CI,* confidence interval.

in the coronary care unit for refractory angina or cardiogenic shock was required more often in patients with LV dysfunction (LVEF > 40%, 2.7%; LVEF 20%-40%, 4.6%; and LVEF < 20%, 8.1%; *P* < .0001). Surgeons were also more likely to place an IABP *prophylactically* in the operating room before commencement of the surgical procedure to provide perioperative support in patients with poor ventricular function

Table V. Multivariable predictors of low-output syndrome in all 20,614 patients

Variable	Regression coefficient	OR	95% CI
Constant	0.7957 ± 0.511		
Age	0.0246 ± 0.003	1.025	1.109-1.031
LV grade	0.4469 ± 0.030	1.563	1.475-1.657
NYHA class	0.0949 ± 0.040	1.100	1.017-1.189
Reoperative surgery	1.1951 ± 0.078	3.304	2.838-3.846
Urgency	0.4214 ± 0.046	1.524	1.393-1.668
Year of operation	-0.0884 ± 0.006	0.915	0.905-0.926
Female sex	0.7325 ± 0.058	2.080	1.858-2.330
Left main stenosis	0.2311 ± 0.064	1.260	1.111-1.429
Extent of coronary artery disease	0.3394 ± 0.051	1.404	1.270-1.552

The area under the receiver-operator characteristic curve was 0.719. The Hosmer-Lemeshow goodness-of-fit *P* value was .673.

LV grade: 1, LVEF > 60%; 2, LVEF 40%-60%; 3, LVEF 20%-40%; 4, LVEF < 20%. *Urgency:* 0, Elective; 1, same hospitalization; 2, within 12 hours of a cardiac catheterization or cardiac event (eg, myocardial infarction and unstable angina). *Year of operation:* 1982-1997. *Extent of coronary artery disease:* Number of diseased vessels (0, 1, 2, or 3). *OR,* Odds ratio; *CI,* confidence interval.

(LVEF > 40%, 0.9%; LVEF 20%-40%, 1.7%; and LVEF < 20%, 9.3%; *P* < .0001). Postoperative placement of an IABP (whether in the operating room at the conclusion of the surgical procedure or in the intensive care unit) for hemodynamic support was also related to the degree of ventricular dysfunction (LVEF > 40%, 3.8%; LVEF 20%-40%, 8.5%; and LVEF < 20%, 13.8%; *P* < .0001).

Other outcomes. Perioperative cerebrovascular accidents were more common with greater LV impairment (LVEF > 40%, 1.4%; LVEF 20%-40%, 2.5%; and LVEF < 20%, 3.8%; *P* < .0001). Deep sternal infections were also more common in patients with greater LV dysfunction (LVEF > 40%, 1.9%; LVEF 20%-40%, 3.1%; and LVEF < 20%, 3.2%; *P* < .0001). In general, deep sternal infection rates have fallen with time; in 1997, only 0.7% of patients undergoing coronary artery bypass grafting developed sternal osteomyelitis.

Predictors of operative mortality and low-output syndrome

Independent predictors of operative mortality by LVEF. Preoperative patient variables that were univariate predictors of operative mortality and variables of known biologic importance not meeting the critical α level were entered into a multivariable regression model for the entire patient cohort. The independent predictors of mortality were greater LV dysfunction, increased age, reoperative surgery, earlier year of operation, urgent surgery, female sex, and left main stenosis (Table IV).

In patients with LVEFs of 20% to 40%, the independent predictors of mortality were reoperative surgery (χ^2 , 38.09; $P < .0001$), earlier year of operation (χ^2 , 26.81; $P < .0001$), female sex (χ^2 , 17.72; $P < .0001$), urgent surgery (χ^2 , 15.48; $P = .0004$), and increased age (χ^2 , 13.15; $P = .001$).

For the smallest group of patients, with the greatest LV impairment (LVEF < 20%), the only significant independent predictors were urgent surgery (χ^2 , 16.43; $P = .0003$) and reoperative surgery (χ^2 , 5.38; $P = .02$).

Independent predictors of low-output syndrome by LVEF. Preoperative patient variables that were predictive of postoperative low cardiac output syndrome in the entire patient cohort are listed in Table V.

In patients with LVEFs of 20% to 40%, the independent predictors of low-output syndrome were reoperative surgery (χ^2 , 87.63; $P < .0001$), earlier year of operation (χ^2 , 55.29; $P < .0001$), female sex (χ^2 , 54.18; $P < .0001$), urgent surgery (χ^2 , 33.11; $P < .0001$), more extensive coronary disease (χ^2 , 14.18; $P = .0008$), increased age (χ^2 , 11.61; $P = .003$), and NYHA class (χ^2 , 8.34; $P = .04$).

In patients with LVEFs of less than 20%, the predictors of low-output syndrome were urgent surgery (χ^2 , 16.62; $P = .0002$), left main stenosis (χ^2 , 8.06; $P = .004$), earlier year of operation (χ^2 , 7.95; $P = .02$), and reoperative surgery (χ^2 , 5.22; $P = .02$).

Discussion

In our experience LV dysfunction has been the most significant independent predictor of operative mortality and postoperative low-output syndrome. In the 16-year time span from 1982-1997, we noted an increasing prevalence of moderate-to-severe LV dysfunction in patients referred for coronary artery bypass grafting. This increase may have been due to the widespread application of thrombolysis, increasing the number of patients surviving acute myocardial infarctions to require revascularization, and of angioplasty, which may delay surgical revascularization until coronary atherosclerosis is more extensive and ventricular dysfunction is more severe. The risk profile of patients referred for coronary bypass surgery has increased with time,¹ and this trend has been particularly marked in patients with preoperative ventricular dysfunction. In the later years of this series, patients with LVEFs of less than 40% were older, more symptomatic, more likely to have left main stenosis, and more likely to require urgent or reoperative surgery. All of these factors have also been identified as independent predictors of operative mortality,² low-output syndrome,³ or both.

The operative mortality rate decreased in all patients

between the 1982-1986 and 1987-1991 cohorts, and the decline was most marked in patients with LVEFs of less than 40%. However, no further reduction in the mortality rate was noted from the 1987-1991 cohort to the 1992-1997 cohort. During this most recent decade, incremental improvements in perioperative patient management were offset by the increasing risk profile of patients with LVEFs of less than 40%, resulting in stable overall mortality rates. Estefanous and colleagues⁴ have reported a comparison of 2 cohorts of patients undergoing coronary artery bypass grafting (1986-1988 vs 1993-1994) from the Cleveland Clinic and also noted an increasing risk profile with time. The gross mortality rate was greater in the more recent cohort, but the risk-adjusted mortality rate was unchanged. Smaller single-institution series have reported variable results in patients with moderate-to-severe ventricular dysfunction; Baumgartner and colleagues⁵ reported an overall mortality rate of 8% in 61 patients with LVEFs of less than 25% undergoing coronary artery bypass grafting, and Elefrierades and colleagues⁶ had a mortality rate of 5.2% in 135 patients with LVEFs of less than 30%. Mickleborough and colleagues⁷ reported a mortality rate of only 3.8% in 79 patients with severe LV dysfunction (mean LVEF 18%). These results were attributed in part to careful myocardial temperature mapping with cold cardioplegia to maintain myocardial protection.

Earlier year of operation was an independent predictor of both operative mortality and postoperative low-output syndrome in patients with LVEFs of 20% to 40%. Year of operation did not predict outcomes in patients with LVEFs of less than 20%, but this may have been due to the much smaller number of patients in this group. This time-related improvement may have been due to progressive advances in anesthetic technique, myocardial protection, and postoperative intensive care. Most surgeons at our institution have used intermittent cold antegrade blood cardioplegia as a standard technique of myocardial protection for coronary artery bypass grafting, adding retrograde cardioplegia for specific anatomic indications or for ongoing myocardial ischemia. Tepid (29°C)⁸ or warm (37°C)^{9,10} blood cardioplegia was used in a minority of patients and only since 1990, and the effect of cardioplegia temperature on operative outcomes is therefore difficult to determine in this cohort. However, a terminal *hot shot* of warm blood cardioplegia before crossclamp removal was universally adopted by our surgeons in 1987-1988 after a randomized clinical trial demonstrated improved perioperative myocardial metabolism and function with this technique.¹¹ This consistent change

to our institutional strategy of myocardial protection may have contributed to the overall improvement in results noted with time and particularly to the decrease in the prevalence of low-output syndrome from the 1987-1991 cohort to the 1992-1997 group. However, because the adoption of the hot shot was so directly related to year of operation, it was not possible to separate the effects of these 2 factors in our analyses.

During the 16 years from 1982-1997, overall use of the LITA as a bypass conduit increased markedly, but patients with worse ventricular function were less likely to receive an ITA graft regardless of the year of operation. Although the reason for not using an ITA graft was not recorded in our database, a number of concerns about the short-term limitations of ITA grafts may have made surgeons more likely to use venous conduits in these high-risk patients. These considerations may have included the time required for ITA harvesting in unstable patients, lower initial flow compared with vein grafts, the potential for spasm (particularly in patients likely to receive vasoactive inotropic agents), and the inability to deliver cardioplegic solution down a pedicled arterial graft. In addition, the relative benefit of use of the LITA on late mortality rate, myocardial infarction, and reintervention in the setting of severe ventricular dysfunction has not been well established. The reduced late survival associated with LV dysfunction, advanced age, and significant comorbidity in these patients may offset the survival advantage generally associated with LITA use. Selection bias may account for the lower operative mortality and morbidity rates associated with LITA use in some series. Baumgartner and colleagues⁵ have suggested that the indications for and results of its use in this subgroup of patients have been poorly documented and require further investigation. Despite these concerns, a number of recent studies have reported LITA use in 76% to 86% of patients with ventricular dysfunction, with excellent initial results.^{6,7} Other recent series quote its use in as few as 41% of patients.⁵ Canver and colleagues¹² reported a diminished survival benefit with use of the LITA conduit in patients with LV dysfunction. Early outcomes were not influenced by its use, and it was not established if use of the LITA in the setting of ventricular compromise was deleterious. Anderson and colleagues¹³ reported use of the LITA in 70% of patients with ventricular dysfunction presenting with chronic congestive heart failure and reported that its use enhanced late survival. Reports are conflicting, and the magnitude of benefit of the LITA in patients with severely depressed LVEFs remains to be definitively established.

In patients with severe LV impairment (LVEF < 20%), the need for urgent surgery or reoperative surgery were independent predictors of both operative mortality and low-output syndrome. Earlier surgical intervention in patients with progressive angina who are known to have significant ventricular dysfunction may reduce overall mortality rates and the prevalence of low-output syndrome because acute myocardial ischemia in patients requiring urgent revascularization increases operative risk. Alternatively, more aggressive intervention to treat ischemia and stabilize the patient preoperatively may also improve outcomes. Dietl and colleagues¹⁴ reported in a retrospective study that patients with LVEFs of less than 25% in whom an IABP was placed preoperatively had lower 30-day mortality rates, shorter hospital stays, and lower hospital charges than patients without preoperative IABP support. Christenson and colleagues¹⁵ reported that preoperative IABP support in high-risk patients undergoing coronary artery bypass grafting, 87% of whom had LVEFs of less than 40%, resulted in lower operative mortality rates, lower requirements for inotropic drugs, and shorter intensive care unit stays. Although the low but finite complication rate of IABP insertion may make elective placement of balloon pumps undesirable in the majority of patients requiring urgent coronary artery bypass grafting, it may be a reasonable option in patients with severe LV impairment. Cimochowski and colleagues¹⁶ reported that a combination of liberal use of IABP support in combination with a cocktail of metabolic and mechanical support strategies resulted in a remarkable 1.8% mortality rate in 111 patients with LVEFs of 10% to 34%.

In patients with the most severe LV dysfunction, often related to end-stage ischemic cardiomyopathy, cardiac transplantation may be considered. However, because of the continuing shortage of donor organs and the consequences of long-term immunosuppression, high-risk coronary artery bypass grafting may be considered for patients with adequate target vessels and evidence of reversible ischemia on viability studies. We, and other institutions, have used this strategy with reasonable outcomes in this select patient population.^{7,17} The presence of a large reversible thallium defect is associated with a greater likelihood of improvement in LVEF after revascularization. Chan and colleagues¹⁸ noted that a large reversible thallium defect predicted an improvement of 5% or more in LVEF after coronary artery bypass grafting, with an adjusted odds ratio of 15. Even a presentation with symptoms of congestive heart failure alone, without angina, does not necessarily indicate a fixed defect and

a higher risk of operation. Anderson and colleagues¹³ reported a series of 203 patients with chronic congestive heart failure but no angina and a mean LVEF of 34% in whom coronary artery bypass grafting was performed with a hospital mortality rate of 6.0% and a 5-year survival of 59%. In these patients transplantation may still be offered if clinical improvement does not occur with revascularization alone.

Our results suggest that although the risk of coronary artery bypass grafting is generally low, patients with significant ventricular dysfunction still face markedly elevated operative morbidity and mortality rates. Advances in operative technique, myocardial protection, and perioperative critical care have been offset by a steadily increasing risk profile of patients referred for surgical revascularization. In the presence of an LVEF of less than 20%, the requirement for reoperation or urgent operation poses a dramatically increased risk. Attention to myocardial protection, meticulous surgical technique, and perhaps routine preoperative IABP support are required to achieve optimal results in these high-risk patients.

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