Predictors of Early Outcome After Coronary Artery Surgery in Patients with Severe Left Ventricular Dysfunction

Naresh Trehan, Surendra Nath Khanna, Yugal Mishra, Vijay Kohli, Yatin Mehta, Manisha Mishra, and Sanjay Mittal

Escorts Heart Institute and Research Centre, Okhla Road, New Delhi 110025, India

Abstract ***Background:*** **The surgical survival in patients with severe myocardial dysfunction is critically dependent on the selection of patients. The present study was undertaken to identify the prognostic factors in such patients.** ***Methods:*** **We analyzed the data of 176 consecutive patients (161 men, 15 women), aged 29 to 88 years (mean 58.43), with a left ventricular ejection fraction (LVEF) <30% who underwent isolated coronary artery bypass grafting. The LVEF ranged from 15% to 30% (mean 27.18%). Preoperatively, 33% had angina, 19.9% had recent myocardial infarction, and 21.6% had congestive heart failure. The mean number of grafts was 2.5/patient. The intra-aortic balloon was used prophylactically in 20.5% of patients and therapeutically in 4.0% of patients.** ***Results:*** **The hospital mortality was 2.3%. The complications occurred as follows: perioperative myocardial infarction in two (1.1%), intractable ventricular arrhythmias in two (1.1%), prolonged ventilation in four (2.3%) and peritoneal dialysis in 1 (0.6%). The mean ICU and hospital stay were 2.46 $\pm$ 0.76 and 7.57 $\pm$ 2.24 days, respectively. The predictors of survival on univariate analysis were New York Heart Association (NYHA) class ($x2 = 14.458$, $p < 0.001$), recent myocardial infarction ($x2 = 5.852$, $p = 0.016$), congestive heart failure (CHF) ($x2 = 5.526$, $p = 0.019$), and left ventricular end-systolic volume index (LVESVI) ($x2 = 25.833$, $p < 0.001$). However, on multivariate analysis, left ventricular end-systolic volume index was the only independent left ventricular function measurement predictive of survival ($x2 = 10.228$, $p = 0.001$).** ***Conclusion:*** **Left ventricular end-systolic volume index is the most important predictor of survival after coronary artery bypass surgery in patients with severe myocardial dysfunction.** *(J Card Surg 2003;18:101-106)*

The prevalence of ventricular dysfunction in patients undergoing coronary artery bypass grafting, as well as the prevalence of other risk factors in these patients, has been increasing. However, with progress in surgical techniques and overall patient management, surgery has become quite safe in patients with severe left ventricular (LV) dysfunction. Surgical revascularization offers the best short-term as well as long-term survival and better relief from symptoms in such patients,[1] yet the individual results are sometimes unpredictable. The present study was undertaken with the aim to identify the predictors of poor outcome after coronary artery bypass surgery (CABG).

Presented at "Left Ventricular Volume Reduction for Dilated Cardiomyopathy," September 20-22, 2001, Rome, Italy.

Address for correspondence: Dr. Surendra Nath Khanna, Escorts Heart Institute and Research Centre, Okhla Road, New Delhi 110025, India. Fax: 6825013; e-mail: surendrank@hotmail.com

MATERIAL AND METHODS

Out of the 20638 coronary artery bypass surgeries performed at our faculty from January 1989

to May 2001, 2577 (12.47%) patients had left ventricular ejection fraction (LVEF) <30%. The present prospective study comprised 176 patients (161 males, 15 females) with an ejection fraction <30% undergoing coronary artery bypass surgery by one surgeon between January 2001 and May 2001. Age ranged from 29 to 88 years (mean 58.43). Patients undergoing concomitant valve surgery, left ventricular aneurysmectomy, post infarction ventricular septal defect (VSD), and redo-surgery were excluded from the present study. The LVEF ranged from 15% to 30% (mean = 22.18%) (Table 1).

TABLE 1
Patients Profile (n = 176)

Variable	No. (%)
Age (years)	29-88
Mean	56 ± 7.4
Males	161 (91.5%)
NYHA	
Class II	32 (18.2%)
Class III/IV	144 (81.8%)
DM	61 (34.7%)
Hypertension	59 (33.5%)
Smoking	55 (31.3%)
Obesity (Quetelet index >30 kg/m^2)	55 (31.3%)
Recent MI	35 (19.9%)
H/O TIA	17 (9.7%)
COPD	25 (14.2%)
CHF	38 (21.6%)
Emergency surgery	16 (9.1%)
Urgent surgery	32 (18.2%)
IABP	
Preoperative	36 (20.5%)
Postoperative	7 (4.0%)
LVEF	
<15%	2 (1.1%)
15%-20%	12 (6.8%)
20%-25%	59 (33.5%)
25%-30%	103 (58.5%)
Vessel Disease	
LM	40 (22.7%)
SVD	7 (4.0%)
DVD	30 (17%)
TVD	139 (79%)
Stress thallium viable area	
Small	5 (2.8%)
Large	127 (72.2%)
Moderate	44 (25%)
Preoperative arrhythmia	22 (12.5%)
Postoperative arrhythmia	19 (10.8%)

NYHA = New York Heart Association; DM = diabetes mellitus; MI = myocardial infarction; H/O TIA = history of transient ischemic attack; COPD = chronic obstructive pulmonary disease; CHF = congestive heart failure; IABP = intra-aortic balloon pump; LVEF = left ventricular ejection fraction; LM = left main; SVD = single vessel disease; DVD = double vessel disease; TVD = triple vessel disease.

Seventeen patients (9.7%) received one graft, 28.4% received two grafts, 60.2% received three grafts, and 1.7% received four grafts. The mean number of grafts per patient was 2.5.

Left internal mammary artery was used to graft left anterior descending artery in 166 patients (94.3%). Prophylactic intra-aortic balloon was used in 14.2% of the patients in view of low cardiac output and high pulmonary artery pressures and in 6.3% of patients because of unstable angina and ECG changes refractory to medical therapy. Postoperative intra-aortic balloon was used in 7 (4%) patients who were in low cardiac output state.

The mean left ventricular end-systolic index was 81.53 ± 9.43 mL/m2; mean left ventricular enddiastolic index was 111.59 ± 11.54 mL/m2; mean left ventricular end diastolic pressure was 15.7 ± 5.43 mmHg; mean pulmonary artery systolic pressure was 38.44 ± 9.26 mmHg.

Congestive heart failure was present in 21.6% of the patients, 118 patients (67%) had angina, and 35 (19.9%) had recent myocardial infarction.

Operative technique

All patients underwent coronary artery bypass grafting by one surgeon. One hundred seventy (96.5%) were operated on beating heart using Octopus device and intraluminal shunt, four (2.4%) patients were done on cardiopulmonary bypass because on lifting the heart there was hemodynamic instability, and two (1.1%) patients were done on aortic cross-clamp because of the unstable hemodynamic status in conjunction with small size and unsatisfactory anatomy of the coronary arteries. The proximal anastomosis on the left side was performed first and then the distal anastomosis. The proximal anastomosis was performed using side-biting clamp, selecting the "soft" spots and taking special care to control the pressure while applying it, particularly when the ascending aorta was found to have atheromas on transesophageal echocardiography.

Statistical methods

All values are reported as the mean ± standard deviation. The analysis of significance for the risk factors was evaluated using the x2 statistics for all

TABLE 2
Hemodynamic Parameters

Parameters	Values
LVESV	78-132 mL (105.56 ± 13.14)
LVESVI	60-110 mL/m^2 (81.53 ± 9.43)
LVEDV	122-240 mL (156.53 ± 19.94)
LVEDVI	90-168 mL/m^2 (111.59 ± 11.54)
LVEDP	8-40 mmHg (15.7 ± 5.43)
PASP	24-68 mmHg (35.66 ± 9.26)
PADP	8-40 mmHg (13.36 ± 6.01)
CI	1.8-2.8 l.min/m^2 (2.56 ± 0.60)

LVESV = left ventricular end-systolic volume; LVESVI = left ventricular end-systolic volume index; LVEDV = left ventricular end-diastolic volume; LVEDVI = left ventricular end-diastolic volume index; LVEDP = left ventricular end-diastolic pressure; PASP = pulmonary artery systolic pressure; PADP = pulmonary artery diastolic pressure; CI = cardiac index.

countable data. The null hypothesis was rejected when the p-value was less than 0.05. Multiple logistic regression analysis was used to determine the predictors of early survival. The variables in the predictors set were identified by a forward conditional process, such that the p-value associated with the introduction of additional variables was greater than 0.10.

Results

The hospital mortality was 2.3%. One patient who underwent emergency coronary artery bypass grafting had crashed in cardiac catheterization laboratory and was taken for emergency CABG and died due to low cardiac output. Two patients died of intractable ventricular arrhythmias that were present even preoperatively. One patient who required prolonged ventilation, and who also was in chronic renal failure preoperatively, developed septicemia and multiorgan failure and later died (Table 3).

Twelve patients required inotropic support, which was gradually weaned off. Two patients had perioperative myocardial infarction and were taken back to operation theater, and in one, a vein graft to a large obtuse marginal was blocked, and was revised, and the patient recovered subsequently. In the other patient, all grafts were normal. Four (2.3%) patients required re-exploration while blood and/or blood products were required in 25 (14.2%) patients. Two (1.1%) patients required prolonged ventilation, and tracheostomy had to be done.Transient ischemic attacks occurred in one patient. Blood urea and serum creatinine levels were high in four patients and gradually normalized. Superficial wound infection occurred in five (2.8%) patients and deep wound infection in four (2.3%) patients. The mean ICU stay was 2.46 days (±0.76) and the mean hospital stay 7.57 days (±2.24).

TABLE 3
Results

Parameters	No. (%)
Perioperative MI	2 (1.1%)
Intractable ventricular arrhythmia	2 (1.1%)
Blood used	25 (14.2%)
Re-exploration	4 (2.3%)
Delayed ventilation	2 (1.1%)
Respiratory complications	
Tracheostomy	4 (2.3%)
Minitracheostomy	2 (1.1%)
CNS	
TIA	1 (0.6%)
Renal	
Transient ↑ in urea/creatinine	4 (2.3%)
Renal failure	1 (0.6%)
Wound infection	
Superficial	5 (2.8%)
Deep	2 (1.15%)
ICU stay	
Range: 1-6 Days	Mean: 2.46 ± 0.76
Hospital Stay	
Range: 4-16 Days	Mean: 7.57 ± 2.24

MI = myocardial infarction; CNS = central nervous system; TIA = transient ischemic attack.

The predictors of survival on univariate analysis were New York Heart Association (NYHA) class ($x2 = 14.458$, $p < 0.001$), recent myocardial infarction ($x2 = 5.852$, $p = 0.016$), congestive heart failure ($x2 = 5.526$, $p = 0.019$), left ventricular end-systolic volume index ($x2 = 25.833$, $p < 0.001$), and pulmonary artery systolic pressures ($x2 = 36.613$, $p < 0.001$) at the time of surgery (Table 4). However, on multivariate analysis, left ventricular end-systolic index was the only independent left ventricular function measurement predictive of survival ($x2 = 10.228$, $p = 0.001$) (Table 5).

In the present study, it was noted that for patients with left ventricular end-systolic volumes (LVESV) of >100 mL versus <100 mL, the risk ratio for mortality was 1.12 (confidence interval, 1.00 to 1.28), and for patients with end-systolic

TABLE 4
Univariate Analysis

Variables	Score	Significance
Age	1.330	.249
Sex	.170	.680
NYHA	14.458	.000
Diabetes mellitus	.345	.557
Hypertension	.273	.601
Obesity	1.371	.242
Recent MI	5.852	.016
Transient Ischemic Attack	.896	.344
COPD	.020	.888
Congestive heart failure	5.526	.019
IABP	23.154	.000
Ejection fraction	10.216	.001
LVESV	20.404	.000
LVESVI	25.833	.000
LVEDV	20.153	.000
LVEDVI	12.248	.000
LVEDP	20.329	.000
Left main	1.041	.307
PASP	36.613	.000
PADP	10.265	.001
Cardiac index	2.212	.001

NYHA = New York Heart Association; MI = myocardial infarction; COPD = chronic obstructive pulmonary disease; IABP = intra-aortic balloon pump; LVESV = left ventricular end-systolic volume; LVESVI = left ventricular end-systolic volume index; LVEDV = left ventricular end-diastolic volume; LVEDVI = left ventricular end-diastolic volume index; LVEDP = left ventricular end-diastolic pressure; PASP = pulmonary artery systolic pressure; PADP = pulmonary artery diastolic pressure.

volumes of >135 mL compared to <135 mL, the risk ratio was 1.58 (confidence interval, 1.16 to 2.10).

DISCUSSIONS AND CONCLUSION

The natural history in patients with severe LV dysfunction is dismal, and so are the results with medical treatment.[2] Surgery is the most beneficial modality and is the cornerstone in management of such patients. Five-year survival of patients with normal LV functions, when treated medically, is 89%; it is 70% for "moderate LV dysfunction," and it drops to 38% in severe LV dysfunction.[1] The Coronary Artery Study group[1] and the multicenter Veterans Administration cooperative randomized trial of unstable angina showed greatest survival benefit and better relief from symptoms, as well as quality of life, in patients with impaired left ventricular function treated surgically.[3]

TABLE 5
Multivariate Analysis of Prognostic Factors for Survival after CABG

	WALD x 2	p > x 2
LVESVI	10.228	.001

LVESVI = left ventricular end-systolic volume index.

However, the surgical survival is critically dependent on the selection of patients in whom severe angina is the predominant symptom, indicating the presence of ischemic but potentially viable myocardium, and the exclusion of patients presenting solely with congestive heart failure (CHF) secondary to irreversible myocardial fibrosis.[4]

The presence of viable myocardium was detected on preoperative rest-injection thallium-201 scintigraphy. Imaging of myocardial glucose metabolism using (18F) fluorodeoxyglucose (FDG) with positron emission tomography (PET) is also used for identification of tissue viability in patients with advanced coronary artery disease. The role of coronary revascularization, therefore, is to preserve the remaining myocardium, and to recruit the hibernating myocardium. In the present study, none of the patients with large viable areas on stress thallium died.

In the literature, the mortality for patients with severe LV dysfunction ranges from 1.8% to 8%.[5-7] The mortality was 2.3% in the present study. All four patients who died had high pulmonary artery systolic pressures (>55 mmHg), which decreased with inodilators and insertion of intra-aortic balloon, and their LVESV was more than 100 mL. In the present study, as well in the one reported by Elefteriades et al.,[8] the majority of the in-hospital deaths occurred in patients manifesting with post infarction cardiogenic shock at admission. On the contrary, when the patients presented in stable hemodynamic condition, the risk of CABG was very low.[8]

The functional status of the left ventricle is the main predictor of prognosis in patients with coronary artery disease.[9] However, LVEF alone is not appropriate for evaluating LV dysfunction. We found LVESVI to be the most important predictor of postoperative outcome. Since regression analysis was performed with a small number of incidents, it should be interpreted as indicative.

Hamer et al.[9] noted left ventricular end-systolic volume as the most important predictor of postoperative outcome after surgery and, therefore, emphasised the importance of prevention of left ventricular dilatation. The left ventricular end-systolic volume measures ventricular dilatation related to infarct expansion, stretching of myocardial scar, and ventricular remodeling in response to ventricular wall stress. Remodeling is accompanied by changes in the diastolic properties of the left ventricle and a cavity shape change with the apex becoming more spherical. Remodeling continues for some months after infarction, and possibly after CABG.

It has been noted in the literature that ventricular dilatation sets in to compensate for low EF and there is no upper limit to ventricular dilatation as long as there is no critical pulmonary hypertension.[10] However, when pulmonary hypertension occurs with LV dilatation, it should be considered a contraindication to CABG. Dreyfus et al.[10] found emergency surgery to be a high risk factor, probably because there is LV failure without ventricular dilatation. We found that left ventricular end-systolic volumes >100 mL, in association with high pulmonary artery systolic pressures >55 mmHg, have bad prognosis, as do high pulmonary artery (PA) pressures with small ventricular volumes, as with acute infarcts taken for emergency surgery.

Angiotensin-converting enzyme (ACE) inhibitors have been shown to attenuate ventricular remodeling.[9] In the Survival and Ventricular Enlargement (SAVE) trial and studies of left ventricular dysfunction (SOLVD) trial there was a significantly lower mortality in patients with left ventricular dysfunction who were treated with ACE inhibitors than in the placebo group.[9] The remodeling process can be slowed or even reversed by ACE inhibitors.

Few authors have noted LV end-diastolic diameter (LVEDD) to be an important prognostic indicator,[11] while others observed that LV end-diastolic volume[10] or LV end-systolic volume[9] is such an indicator. Louie et al.[11] found LVEDD to be an important prognostic indicator for successful revascularization. They observed that LVEDD of successfully revascularized patients was 68 ± 3 mm versus 81 ± 4 mm for patients who failed revascularization.

The factors affecting the prognosis in such patients include previous myocardial infarction,[12] age at the time of surgery,[13] and severity of coronary artery disease.[12,13] In addition, female gender,[13] diabetes mellitus,[13] hypertension,[12,13] diuretic therapy,[14] smoking,[8] dyslipidemia,[15] chronic obstructive pulmonary disease,[9] and other concomitant diseases[13] have also been implicated in adversely affecting the prognosis after surgery in such patients.

Concerns have been raised regarding CABG in patients with CHF. The incidence of CHF in patients with LVEF <30% in different studies has been 10% to 26%.[1] Franciosa[16] reported better survival after surgery as compared to medical therapy in patients with CHF. In the present series, CHF was present in 21.6% patients, and we observed good short-term results as well as amelioration of symptoms after CABG, as has been reported in the literature.[11]

The use of intra-aortic balloon preoperatively is very important in patients with severe left ventricular dysfunction. It improves the myocardial performance and protects the heart against perioperative myocardial damage to the already jeopardized myocardium. In the present study, we found use of IABP to be of paramount importance in stabilizing the patient, lowering the pulmonary artery pressures, and improving the hemodynamic status of the patient. Dietl et al.[17] and Christenson et al.[18] noted that patients with LVEF <25%, in whom an IABP was placed preoperatively, had lower 30-day mortality rates, shorter hospital stays, and lower hospital charges than patients without IABP support. Similarily, Cimochowski et al.[6] reported a remarkably low mortality rate of 1.8% in patients with LVEF between 10% and 34% with liberal use of IABP and mechanical support strategies. Although, there exists a definite risk of underlying complications, its use seems to be justifiable in patients with severe left ventricular dysfunction.

In an attempt to redefine the therapeutic indication, Louie et al.[11] noted that left-ventricular end-diastolic diameter < 70 mm and positron emission tomography demonstrating reversible myocardial ischemia may accurately predict successful coronary revascularization, and operative mortality, and three-year survival is comparable to that after transplantation.

Malignant arrhythmia is a significant risk factor, and it can be overcome either by taking the patient

for cardiac transplantation or by use of automatic implantable cardioverter defibrillator in conjunction with CABG.[10]

For patients with severe ischemic cardiomyopathy, coronary revascularization may be performed in select patients with low operative mortality. The best predictor seems to be left ventricular end-systolic volume index.

REFERENCES

1. Alderman DL, Fisher LD, Litwin P, et al: Results of coronary artery surgery in patients with poor left ventricular function (CASS). Circulation 1983;68:785-795.
2. Harris PJ, Harrel FE, Lee KL, et al: Survival in medically treated coronary artery disease. Circulation 1979;60:1259.
3. Participants of VA cooperative study of unstable angina: Comparison of medical and surgical treatment for patients with unstable angina and poor left ventricular function (abstract). Abstracts of the 60th Scientific Sessions, American Heart Association, Anaheim Convention Center, Nov. 16-19, 1987. Circulation 1987;76 (Suppl IV):IV-351.
4. Coles JG, Del Campo C, Ahmed SN, et al: Improved long-term survival following myocardial revascularization in patients with severe left ventricular dysfunction. J Thorac Cardiovasc Surg 1981;81:846-850.
5. Baumgartner FJ, Omari BO, Goldberg S, et al: Coronary artery bypass grafting in patients with profound ventricular dysfunction. Tex Heart Inst J 1998;25:125-129.
6. Cimochowski GE, Harostock MD, Foldes PJ: Minimal operative mortality in patients undergoing coronary artery bypass with significant left ventricular dysfunction by maximization of metabolic and mechanical support. J Thor Cardiovasc Surg 1997;113:655-666.
7. Yau TM, Fedak PWM, Weisel RD, et al: Predictors of operative risk for coronary bypass operations in patients with left ventricular dysfunction. J Thorac Cardiovasc Surg 1999;118:1006-1013.
8. Elefteriades JA, Tolis G, Levi E, et al: Coronary artery bypass grafting in severe left ventricular dysfunction: Excellent survival with improved ejection fraction and functional state. J Am Coll Cardiol 1993;22:1411-1417.
9. Hamer AW, Takayama M, Abraham KA, et al: End-systolic volume and long-term survival after coronary artery bypass graft surgery in patients with impaired left ventricular function. Circulation 1994;90:2899-2904.
10. Dreyfus GD, Duboc D, Blasco A: Myocardial viability assessment in ischemic cardiomyopathy: Benefits of coronary revascularization. Ann Thorac Surg 1994;57:1402-8.
11. Louie HW, Laks H, Milgalter E: Ischemic cardiomyopathy: Criteria for coronary revascularization and cardiac transplantation. Circulation 1991;84 (Suppl 3):290-295.
12. Cosgrove DM, Loop FD, Lytle BW, et al: Determinants of ten-year survival after primary myocardial revascularization. Ann Surg 1985;202;480-488.
13. Smith LR, Harrell FE Jr, Rankin JS, et al: Determinants of early versus late cardiac death in patients undergoing coronary artery bypass graft surgery. Circulation 1991;84 (Suppl 111):111-245–111-253.
14. Lawrie GM, Morris GC, Baron A, et al: Determinants of survival 10 to 14 years after coronary bypass: Analysis of preoperative variables in 1448 patients. Ann Thorac Surg 1987;44:180-185.
15. Cosgrove DM, Loop FD, Lytle BW, et al: Primary myocardial revascularization: trends in surgical mortality. J Thorac Cardiovasc Surg 1984;88:673-684.
16. Franciosa J. Why patients with heart failure die: Hemodynamic and functional determinants of survival. Circulation 1987;75 (Suppl IV):IV-1-IV-3.
17. Dietl CA, Berkheimer MD, Woods EL, et al: Efficacy and cost-effectiveness of preoperative IABP in patients with ejection fraction of 0.25 or less. Ann Thorac Surg 1996;62:401-409.
18. Christenson JT, Simonet F, Badel P, et al: Evaluation of preoperative intra-aortic balloon pump support in high risk coronary patients. Eur J Cardiothorac Surg 1997;11:1097-1103.