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Clinical Results of Coronary Revascularization in Left Ventricular Dysfunction

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Background In the present study 15 years of experience with surgical coronary artery bypass grafting (CABG) in patients with left ventricular (LV) dysfunction were retrospectively analyzed.
Methods and Results Between August 1990 and May 2005, a total of 120 patients with severe LV dysfunction (LV ejection fraction (EF) ≤30%) caused by coronary artery disease underwent CABG (mean age 60.3 years, 94 males) Among the 120 patients, 102 had 3-vessel or left main disease. Mean LVEF was 23.5%, and 75% of patients were New York Heart Association functional class III or IV. CABG was performed in all patients with a mean of 2.9 distal grafts/patient. There were 13 hospital deaths (11%). Mean LVEF improved to 32% postoperatively, and further improved to 39% at a mean follow-up of 57.6 months ($p<0.05$). During the follow-up period, 2 cardiac-related deaths occurred. Kaplan-Meier survival rates at 1, 5 and 10 years were 87.7%, 80.9%, and 44.4%, respectively, and respective freedom from cardiac-related event rates were 96.5%, 90.3% and 63.5%.
Conclusions CABG in patients with severe LV dysfunction provides optimal survival with an improved EF and functional state, and may provide a good alternative to transplantation in selected patients. (*Circ J* 2007; **71:** 1862 – 1866)

Key Words: Coronary artery bypass grafting; Coronary artery disease; Ventricular function

Severe left ventricular (LV) dysfunction caused by coronary artery disease generally has a poor prognosis, even with optimal medical management, although surgical revascularization is thought to be the best option. Myocardial revascularization in patients with severe LV dysfunction prevents further myocardial damage, preserves the remaining myocardium and induces the recovery of systolic function in ischemic LV myocardial segments. However, in patients with severe LV dysfunction caused by extensive ischemic heart disease, surgical mortality and morbidity are still high and long-term survival is unsatisfactory in most reports.

In this study, we evaluated the safety and efficacy of coronary revascularization in 120 consecutive patients with severe LV dysfunction (ejection fraction (EF) <30%).

Methods

Patients' Characteristics

We retrospectively reviewed the medical and surgical records of 120 consecutive patients with severe LV dysfunction (LVEF ≤30%) caused by coronary artery disease who underwent coronary revascularization at Yonsei University College of Medicine, Cardiovascular Center, between August 1990 and May 2005. The mean age at the time of surgery was 60.3±7.3 years (range, 37–75 years; 94 men, 26 women). Preoperative diagnoses included acute myocardial infarction (MI) in 23 patients, unstable angina in 15, stable angina in 8, and old MI with unstable angina in 74 patients. Among the 120 patients, 102 (85%) had 3-vessel or left main disease. For all patients, the operative indications were congestive heart failure (CHF) manifesting as pulmonary edema and/or angina. The severity of the patients' CHF and angina were graded by New York Heart Association (NYHA) and Canadian Cardiovascular Society (CCS) classifications, respectively. The mean measured LV end-diastolic pressure was 26.7±8.7 mmHg (range 12–50 mmHg). Emergency (without delay) coronary artery bypass grafting (CABG) was performed in 12 patients (10%), and urgent (≤24 h from diagnosis) CABG was performed in 16 patients (13%).

Two-dimensional Doppler echocardiography was performed preoperatively, 1–2 weeks after CABG, and again during the follow-up period. Two-dimensional echocardiographic investigations included measurements of LV end-diastolic diameter (EDd), LV end-systolic diameter (ESd), and LVEF. Preoperative mean LVEF was 23.5±4.2% (range 12–30%). A preoperative nuclear study was performed in 52 patients (43%).

For all patients, preoperative and postoperative variables were investigated by reviewing the clinical chart and surgical records, and follow-up was conducted by telephone interview and review of outpatient records.

Definitions

The number of diseased vessels was defined as the number of the 3 major coronary perfusion territories affected. Perioperative insertion of an intra-aortic balloon pump (IABP) was defined as a procedure for improving hemodynamics in the presence of cardiogenic shock. Postoperative cerebrovascular accident (CVA) was defined as a focal or global neurological deficit confirmed by a neurologist.

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Table 1 Preop. Patient Characteristics

	No. of patients (%)
Age, years	*60.3±7.3 (range, 37–75)*
Gender	
Male	*94 (78)*
Female	*26 (22)*
Preop. MI-related Cx	
Ischemic MR (G≥2)	*29 (24)*
LV aneurysm	*24 (20)*
Post MI-VSD	*1 (1)*
Cardiogenic shock	*8 (7)*
Preop. IABP	*8 (7)*
Preop. heart failure symptoms	*90 (75)*
Preop. pulmonary edema	*35 (29)*
Preop. angina	
LVEDd (mm)	*64.5±8.1*
LVESd (mm)	*54.7±7.6*
LVEF (%)	*23.5±4.2*

Preop., preoperative; MI, myocardial infarction; Cx, complication; MR, mitral regurgitation; LV, left ventricle; VSD, ventricular septal defect; IABP, intra-aortic balloon pump; EDd, end-diastolic dimension; ESd, end-systolic dimension; EF, ejection fraction.

Table 2 Preop. Risk Factors

Risk factor	*No. of patients (%)*
Diabetes mellitus	*68 (57)*
Hypertension	*70 (58)*
Smoking	*63 (53)*
Obesity	*19 (16)*
Family history	*9 (8)*
Hyperlipidemia	*20 (17)*
COPD	*24 (20)*
CVA	*16 (13)*
CRF	*25 (21)*
ESRD	*7 (6)*
S/p CABG	*1 (1)*
S/p PTCA	*28 (23)*
Valvular heart disease	*2 (1)*
Aortic disease	*4 (3)*
Peripheral vascular disease	*24 (20)*

COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; CRF, chronic renal failure; ESRD, end-stage renal disease; S/p, post status; CABG, coronary artery bypass grafting; PTCA, percutaneous transluminal coronary angioplasty. Other abbreviation see in Table 1.

Perioperative MI was defined as echocardiographic findings of a newly developed Q wave or ST segment elevation, or a postoperative serum creatinine kinase MB isoenzyme level greater than 100 IU/L. Low cardiac output syndrome was defined as cardiac index measured through Swan-Ganz catheter of less than $2.5 L \cdot min^{-1} \cdot m^{-2}$. A cardiac event was defined as recurrent angina, MI, or CHF that required hospitalization more than once during the follow-up period.

Surgical Procedures

All patients underwent CABG, either on or off pump, via a full sternotomy. Patients who underwent conventional CABG (n=97) were cooled down to 32–34°C and were administered either antegrade or both antegrade and retrograde cold blood to elicit cardioplegic arrest following the administration of routine anesthesia and the institution of cardiopulmonary bypass in the usual manner. Off-pump CABG (n=23) was performed according to the surgeons' preference. The target vessels were stabilized with a tissue stabilizer and heparin was administered. The artery was then occluded with a shunt occluder followed by completion of the end-to-side anastomosis.

Concomitant operative procedures included LV aneurysmectomy in 24 patients, mitral annuloplasty in 6 patients, mitral valve replacement in 2 patients, aortic valve replacement in 2 patients, and the repair of a post-infarct ventricular septal defect (VSD) in 1 patient. The concomitant mitral valve procedures were performed in patients with significant mitral regurgitation (≥grade III). In this institution, the indications for surgical ventricular restoration (SVR) include symptomatic ischemic cardiomyopathy where medical treatment failed to control symptoms of CHF, angina, thromboembolism, or ventricular tachyarrhythmia, and asymptomatic patients with LVEF <35%, LVESVI ≥60 ml/m^2 or in patients undergoing CABG. Therefore, we performed concomitant SVR in all patients during CABG. In patients with acute MI, because of the possibility of reperfusion injury we performed CABG after 1 week if the patient's symptoms were controllable with medical treatment, and the patient was hemodynamically stable.

Statistical Analysis

All data were retrospectively collected, and statistical data, as well as the values of continuous variables in the text and tables, are expressed as mean ± standard deviation. Comparison of means was conducted using Student's t-test. Survival curves were constructed using the Kaplan-Meier method. A p-value <0.05 was considered to be statistically significant. The statistical package used was SPSS version 11 (version 11; SPSS Inc, Chicago, IL, USA).

Results

Of the 120 patients, 6 (5%) had a single coronary graft, 33 had 2 grafts (27%), 50 had 3 grafts (42%), 26 had 4 grafts (22%) and 5 had 5 grafts (4%). The mean number of distal grafts per patient was 2.9 (range: 1–5 grafts/patient). Eight patients (7%) had preoperative IABP in place because of cardiogenic shock. Preoperative clinical characteristics, as well as preoperative MI-related complications and risk factors, are described in Tables 1 and 2. Ninety-seven patients (81%) had a history of known MI at the time of the surgery.

There were 13 early deaths (11%), and 8 (7%) of those were cardiac-related (intractable heart failure in 5, and ventricular arrhythmia in 3); 5 patients (4%) died of non-cardiac causes (mediastinitis in 1, acute renal failure in 1, sepsis in 2, and upper gastrointestinal bleeding in 1). Among the cardiac-related deaths, 1 patient with prior renal transplantation, who was taking long-term corticosteroid therapy, died during surgery because of cardiopulmonary bypass weaning failure caused by severe LV dysfunction and low cardiac output. Another death involved a patient who had a post-MI VSD and was taken to the operating room in cardiac arrest, where cardiopulmonary bypass was instituted emergently. When analyzing the early mortality according to the period, most of the early mortalities occurred among patients who underwent the operation before 2000 (11/56), and only 2 patients died among the 64 who underwent operation after 2000 (19% vs 3%).

Postoperative IABP support was required in 15 patients. In 7 patients, IABP was inserted during cardiopulmonary bypass weaning, because of unstable hemodynamics, and

Table 3 Intraoperative and Postop. Data

Variables	*No. of patients*
Surgical time (min)	*347.9±76.2*
ACC time (min)	*104.8±29.6*
CPB time (min)	*149.5±39.0*
No. of distal anastomoses/patient	*2.92±0.93*
Intubation time (h)	*34.3±52.4*
ICU length of stay (days)	*4.8±4.4*
Hospital length of stay (days)	*18.9±14.2*
Postop. LVEF (%)	*32.8±8.6*
Postop. LVEDd (mm)	*60.4±6.9*
Postop. LVESd (mm)	*49.9±7.5*
Complications	
LCO syndrome	*18 (15)*
ARF	*8 (7)*
Arrhythmia	*8 (7)*
CVA	*3 (2)*
Reop. for bleeding	*6 (5)*
Wound infection	*2 (2)*
Postop. MI	*2 (2)*

ACC, aortic cross-clamping; CPB, cardiopulmonary bypass; ICU, intensive care unit; Postop., postoperative; LCO, low cardiac output; ARF, acute renal failure; Reop., reoperation. Other abbreviations see in Tables 1,2.

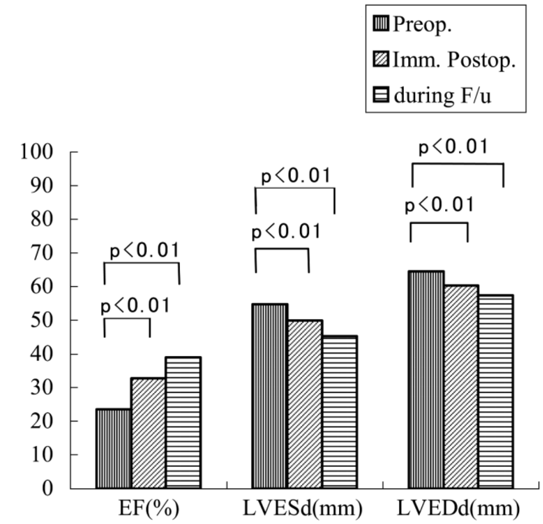

Fig 1. Changes in left ventricular ejection fraction (EF) and systolic and diastolic diameters after revascularization. LVESd, left ventricular end-systolic diameter; LVEDd, left ventricular end-diastolic diameter; Preop., preoperative; Imm. Postop., immediate postoperative period; F/u, follow-up.

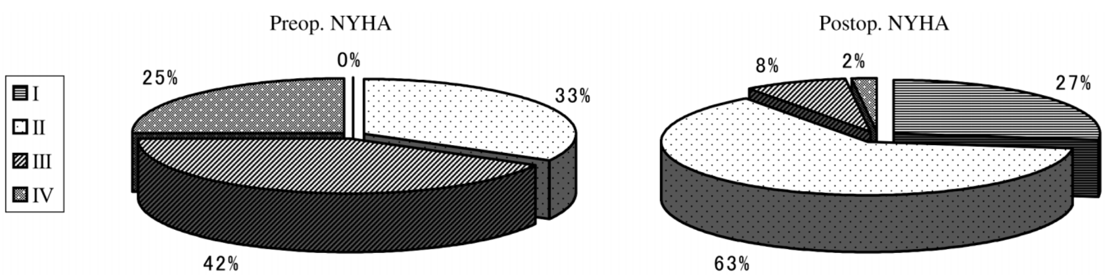

Fig 2. Change in New York Heart Association (NYHA) functional class after coronary revascularization. Preop., preoperative; Postop., postoperative.

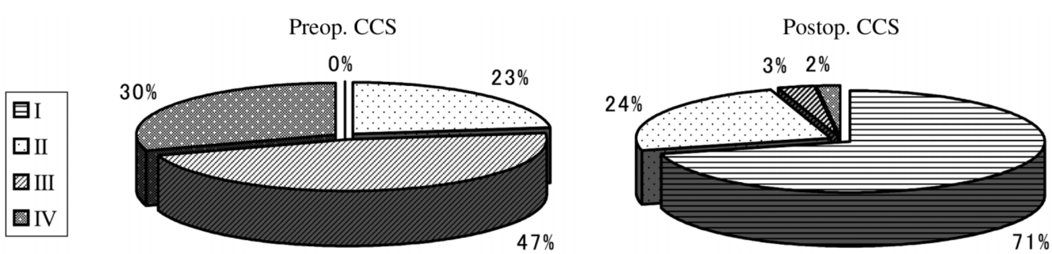

Fig 3. Change in Canadian Cardiovascular Society (CCS) angina class following coronary revascularization. Preop., preoperative; Postop., postoperative.

in 1 patient it was required postoperatively for low cardiac output syndrome with hemodynamic collapse. Of the 8 patients who required IABP preoperatively, only 1 could be weaned off it after the operation. Early postoperative complications included low cardiac output syndrome in 18 patients, acute renal failure requiring dialysis in 8 patients, re-exploration for bleeding in 6 patients, CVA in 3 patients, perioperative MI in 2 patients, and deep wound infection in 2 patients (Table 3). Postoperative inotropic support was required in 84% (101/120) of patients for a mean duration of 3.8±3.9 days. Other intraoperative and postoperative data are described in Table 3.

Mean LVEF values, as measured postoperatively and during the follow-up period, significantly improved from 23.5±4.2% to 32.8±8.6% ($p<0.01$) early after operation, and to 39.0±13.7% ($p<0.01$) late during follow-up period. Mean LVESd and LVEDd significantly decreased gradually (Fig 1). The mean preoperative NYHA functional class improved from 2.9 preoperatively to 1.8 postoperatively ($p<0.01$). The mean CCS angina class also improved from 3.1 preoperatively to 1.3 postoperatively ($p<0.01$) (Figs 2,3, respectively).

Among the 107 patients who survived, 92 (86%) were followed for a mean duration of 57.6±36.1 months (range

10–175 months). Only 1 patient required redo-CABG because of stenosis of the left internal mammary artery graft anastomosed to the left anterior descending artery. Eleven patients underwent follow-up coronary angiography for recurrent angina, and 2 patients required PTCA. During follow-up, there were 2 cardiac-related deaths (1 heart failure, 1 MI), and 4 non-cardiac related deaths (2 CVA, 1 pneumonia, and 1 cancer; Table 4). Kaplan Meier survival rates at 1, 5, and 10 years were 87.7%, 80.9%, and 44.4%, respectively, and freedom from cardiac related event rates at 1, 5, and 10 years were 96.5%, 90.3% and 63.5%.

Discussion

Although the current modes of medical therapy are rapidly evolving, patients with coronary artery disease associated with severe LV dysfunction have a poor prognosis even with optimal medical management.[1–3] In the past decades, it has been suggested that patients with both ischemic cardiomyopathy and significant LV dilatation and dysfunction have a poor outcome and should instead undergo orthotopic heart transplantation. Unfortunately, that is significantly limited by the need for lifelong immunosuppression and the shortage of donor organs.[4] In addition to the lack of donor availability, heart transplantation has been restricted to those without comorbid medical conditions and relatively restricted to those younger than 65 years of age. Because patients with coronary artery disease and LV dysfunction often have medical comorbidity, it is necessary to find alternatives to supplement medical treatment. Large randomized clinical trials have proven that revascularization in patients with LV dysfunction can result in improved long-term survival rates, up to 25% higher.[5,6] Many other groups have reported improvements in survival, ventricular function, and functional status after coronary revascularization in patients with severe LV dysfunction.[7–10]

It is believed that the apparent improvements in LVEF, long-term survival, and quality of life following coronary revascularization are related to postoperative myocyte recruitment. Restoration of perfusion resuscitates dormant, viable myocardium and serves to protect the previously functioning portions of the ventricle from further ischemic insults, arrhythmias, and infarction.[4] The most important factor for successful surgical recovery may be the viability of revascularized myocardium.[11–14] Therefore, preoperative investigations should include transthoracic echocardiography to grossly evaluate ventricular function, and nuclear studies or dobutamine stress echocardiography to identify the reversibility of myocardial ischemia. In addition, coronary angiography is needed to define the affected territory. However, for patients with unstable angina, many institutions will proceed directly to coronary angiography. In this study, nuclear studies were performed in only 43% (52/120) of patients because most patients were unstable, and we assumed that the symptoms of angina indicated the presence of viable myocardium.

Ventricular arrhythmias are a common cause of sudden death in patients with reduced ventricular function, and even after successful revascularization, the risk of arrhythmia remains high. In this study, postoperative ventricular arrhythmia occurred in 8 patients (7%), 3 of whom died because of intractable ventricular tachycardia or fibrillation, and the other 5 were treated with antiarrhythmic medication or an implantable cardioverter-defibrillator. Therefore, postoperative maximal medical treatment, including antiarrhythmic drugs, should be considered in these patients.

Table 4 Causes of Postop. Mortality

	No. of patients (n=120)
Early	*13 (11%)*
Cardiac related	*8 (7%)*
CHF	*5*
Arrhythmia	*3*
Non-cardiac related	*5 (4%)*
Sepsis	*2*
ARF	*1*
Mediastinitis	*1*
UGI bleeding	*1*
Late	*6 (6%)*
Cardiac related	*2*
Chronic CHF	*1*
MI	*1*
Non-cardiac related	*4*
CVA	*2*
Malignancy	*1*
Pneumonia	*1*

CHF, congestive heart failure; UGI, upper gastrointestinal. Other abbreviations see in Tables 1–3.

Recent studies demonstrate that the hospital mortality of these patients ranges from 3% to 12%.[4,7,8,10,15] In our study the hospital mortality was 11%, and only 7% of deaths were cardiac-related, which compares well with most studies. Most of the hospital deaths occurred in the earlier period (early 1990s), and after 2000 only 2 hospital deaths occurred. These improved outcomes are attributed to advances in myocardial management, surgical techniques, including off-pump techniques, and perioperative intensive care, as well as routine use of intraoperative echocardiography to monitor cardiac contractility during the operation, and postoperatively helps in the choice of inotropics. The long-term survival rates following coronary revascularization in these patients are modest. Our study indicated that approximately 80% and 45% of patients were alive 5 and 10 years after surgery, respectively. Other studies have reported 5-year survival rates between 60% and 80%,[4,8,9] and 10-year survival rates of approximately 50%. Although the 10-year survival rate is only 40–50%, it is important to note that most of these patients are severely ill with advanced heart failure and it is unlikely that they would have achieved such long-term survival had they been treated with medical treatment alone. In addition, many other studies, including the present one, demonstrate improved LVEF, functional status, and quality of life, as well as decreased ventricular size, even in long-term follow-up, for patients treated with CABG, which implies reverse remodeling of the failing heart.[9,13,16–18]

Study Limitations

Similar to other reports on the same topic, the principal limitation of this study is that it was based on retrospective evaluation of patient charts. In order to prove the usefulness of a surgical procedure, a study should be prospective, controlled and randomized. Another limitation is that a myocardial viability study was only performed in approximately 43% of the patients. Because myocardial viability is such an important factor in successful revascularization, failure to capture this data may have resulted in bias. During the study period, because many of the patients were unstable, hospital policy required that a viability study only be performed when myocardial ischemia was difficult to identify by electrocardiography alone. However, because a viability test is important for predicting long-term prognosis in these patients, we now routinely perform dobutamine stress test echocardiography, and cardiac magnetic resonance imaging in elective cases.

In conclusion, patients with ischemic cardiomyopathy and LV dysfunction treated with CABG showed an improvement in LV systolic function, symptoms of angina and heart failure, and had acceptable medium-term survival with significant reduction in LV chamber size. Coronary revascularization in patients with severe LV dysfunction provides optimal survival with improved EF and functional state, and may provide a good alternative to transplantation in selected patients. However, larger, controlled and prospective studies must be performed to more effectively evaluate those patients that may benefit from coronary revascularization.

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