

## Complete Revascularization in Patients with Severe Left Ventricular Dysfunction

Hiroyuki Nishi, MD, Satoru Miyamoto, MD, Shuichiro Takanashi, MD,  
Hirokazu Minamimura, MD, Takumi Ishikawa, MD, and Yoshihiro Shimizu, MD

**Objective:** This study evaluates whether patients with coronary artery disease and severely depressed left ventricular ejection fraction (LVEF) benefit from complete revascularization by multivessel coronary artery bypass.

**Methods:** From April 1994 to May 2002, 42 patients who underwent coronary artery bypass grafting (CABG) at our institution had impaired left ventricular (LV) function [an ejection fraction (EF) of 30% or less]. The average preoperative LVEF was 23.8%. The mean number of grafts was 4.6. Complete revascularization by multivessel bypass grafting was the goal for all patients.

**Results:** Thirty days mortality was 0 and hospital mortality was 2.4%. The mean graft patency rate for 35 (83%) patients at one month was 98.8%. The mean postoperative LVEF improved significantly, from 23.8% to 35.2% ( $p < 0.05$ ), and the New York Heart Association (NYHA) classification was improved in most patients. The Kaplan-Meier estimate of survival at 5 years was 83.1%, and that of the cardiac event-free rate at 5 years was 77.5%.

**Conclusion:** For patients with poor LV function, complete surgical revascularization by multivessel bypass grafting can be performed safely, with satisfactory hospital mortality and long-term results. (*Ann Thorac Cardiovasc Surg* 2003; 9: 111–6)

**Key words:** complete revascularization, left ventricular (LV) dysfunction, coronary artery bypass grafting (CABG)

### Introduction

With recent advances in surgical technique and intraoperative myocardial protection, along with certain comparative advantages, coronary artery bypass grafting (CABG) is often considered an effective option for patients with severe left ventricular (LV) dysfunction.<sup>1-4</sup> It is often looked at favorably also because the results of medical therapy are often unsatisfactory,<sup>5</sup> and cardiac transplantation is limited because of the small number of donor organs.<sup>6</sup> These limitations, in conjunction with recent studies that report a lowering of mortality for coro-

nary revascularization,<sup>1-4,7</sup> make the latter a more important therapeutic option in patients with severely depressed ventricular function.

Nevertheless, CABG in patients with reduced LV function remains a surgical challenge. For example, hospital mortality associated with LV dysfunction cases is still higher than that for normal LV function cases.<sup>3,8,9</sup> In an attempt to improve the outcome for this set of patients, we have undertaken aggressive complete revascularization for poor LV function, in the expectation that this approach will activate the hibernating myocardium.<sup>10</sup> To quantify the efficacy of complete revascularization as practiced at our institution, we conducted a retrospective study.

### Patients and Methods

Between April 1994 and May 2002, 893 patients underwent CABG at our institution. Of these, 42 patients with an ejection fraction (EF) of less than 30%, as determined

*From Department of Cardiovascular Surgery, Osaka City General Hospital, Osaka, Japan*

Received October 18, 2002; accepted for publication November 24, 2002.

Address reprint requests to Hiroyuki Nishi, MD: Department of Cardiovascular Surgery, Osaka City General Hospital, 2-13-22 Miyakojimahondori, Miyakojima-ku, Osaka 534-0021, Japan.

**Table 1. Preoperative clinical variables**

Age (y)		66.0±9.3 (43-82)
Sex (male/female)		27/15
NYHA classification	II	26 (62%)
	III	9 (21%)
	IV	7 (17%)
Timing	Elective	30 (71%)
	Urgent	12 (29%)
Hypertension		25 (60%)
Diabetes mellitus		30 (71%)
Old MI		38 (90%)
History of CHF		32 (76%)
Preoperative IABP		2 (5%)
Dialysis		2 (5%)
Primary indication for operation		
	Heart failure	31 (74%)
	Angina	11 (26%)

NYHA, New York Heart Association; MI, myocardial infarction; IABP, intra-aortic balloon pumping; CHF, congestive heart failure.

by cineangiography, constituted the study group. Excluded from this series were 11 patients who underwent LV plasty or mitral annuloplasty and 5 patients with acute myocardial infarction (MI).

The indication for surgery was congestive heart failure with reversible ischemia (31 patients) or unstable or postinfarction angina (11 patients). We evaluated reversible ischemia by thallium-201 scintigraphy, cineangiography and echocardiography. Complete revascularization was the goal in all cases and we performed bypass grafting to all graftable vessels in which the myocardium was viable. Bypass grafting was targeted at all major branches, the left anterior descending artery (LAD), the diagonal branches (Dx), the obtuse marginal branch (OM), the posterolateral branch (PL), and the posterior descending artery (PD). We defined complete revascularization as bypass grafting to all these major branches which had stenosis. The left internal thoracic artery (LITA) was used in all cases. For the diffusely diseased or calcified coronary artery, we performed a coronary endarterectomy and on-lay patch anastomosis for all lesions. Even if graftable vessels by simple bypass grafting method could not be detected, we performed bypass grafting using these techniques.

Twenty-seven patients were men and 15 were women. They ranged in age from 43 to 82 years (mean, 66.0±9.3 years). As determined according to the New York Heart Association (NYHA) classification just before surgery, 26 patients were in class II, 9 in class III,

**Table 2. Catheterization data**

Diseased vessels		
	2	2 (5%)
	3	40 (95%)
Left main		6 (14%)
LVEF (%)		23.8±4.5 (13-30)
LVEDVI (mL/m <sup>2</sup> )		132±39
LVESVI (mL/m <sup>2</sup> )		100±31
Cardiac index (L/m <sup>2</sup> )		2.6±0.6
LVEDP (mmHg)		19.2±7.0

LVEF, left ventricular ejection fraction; LVEDVI, left ventricular end-diastolic volume index; LVESVI, left ventricular end-systolic volume index; LVEDP, left ventricular end-diastolic pressure.

and 7 in class IV. There was a history of known old myocardial infarction in 38 patients (90%). Thirty-two patients (76%) had had congestive heart failure. Thirty (71%) had diabetes mellitus, and 25 (60%) had hypertension. The operation was designated elective (30 patients) or urgent (12 patients); there were no emergent operations. Two patients (5%) had an intra-aortic balloon pumping (IABP) in place. Two patients had two-vessel disease and 40 had triple-vessel disease. Six patients had disease in the left main trunk. The values for the preoperative clinical variables are given in Table 1.

Catheterization data are shown in Table 2. The preoperative EF was calculated from single ventricular angiography by the modified Simpson method. The mean EF was 23.8±4.5% (range, 13% to 30%). The mean left ventricular end-diastolic volume index (LVEDVI) was 132±79 mL/m<sup>2</sup> and the mean left ventricular end-systolic volume index (LVESVI) was 100±31 mL/m<sup>2</sup>. The mean cardiac index (CI) was 2.6±0.6 L/m<sup>2</sup> and the mean left ventricular end-diastolic pressure (LVEDP) was 19.2±7.0 mmHg.

A standard operative technique for CABG was used on all 42 patients: standard cardiopulmonary bypass, moderate hypothermia, and cold crystalloid cardioplegia. The LV was vented through the right superior pulmonary vein. Combined intermittent antegrade and retrograde cardioplegia via the coronary sinus was used on all patients.

All data in the text and tables are presented as the mean±SD. Patient characteristics and outcomes were compared by using t tests for continuous variables. The late survival was evaluated by using Kaplan-Meier analysis. The StatView (StatView 4.5, Abacus Concepts, Cupertino, CA) program was used for statistical analysis.

**Table 3. Intraoperative variables and operative results**

Number of grafts	4.6±1.3
2	2
3	6
4	11
5	15
6	3
7	5
Number of arterial grafts	1.6±0.9 (1-5)
Operation time (min)	366±86 (205-545)
Pump time (min)	167±42 (75-277)
Cross-clamp time (min)	120±32 (41-195)
Use of LITA	42 (100%)
Endarterectomy	13 (31%)
On-lay anastomosis	20 (48%)
Early patency of grafts	98.8% (LITA: 100%)
Hospital mortality	1 (2.4%)
Perioperative MI	1 (2.4%)
Postoperative IABP	2 (excluding preoperative IABP)
Stroke	3 (major: 1, minor: 2)
Reoperation for bleeding	0
Sternal wound infection	1 (2.4%)

LITA, left internal thoracic artery; MI, myocardial infarction; IABP, intra-aortic balloon pumping.

## Results

The mean operative time was 366±86 minutes (205-545 minutes), the mean cardiopulmonary bypass time was 167±42 minutes (75-277 minutes), and the mean aortic cross-clamp time was 120±32 minutes (41-195 minutes). Two of the 42 patients had two coronary grafts, 6 had three, 11 had four, 15 had five, 3 had six, and 5 had seven. The mean number of grafts per patient was 4.6±1.3, and that of arterial grafts was 1.6±0.9. Endarterectomy was performed in 13 patients and on-lay patch anastomosis in 20. Endarterectomy of the LAD was done in 6 patients, that of the PD in 7, that of the OM in 2, and that of the Dx in 1. The mean patency rate determined by postoperative coronary angiography 1 month after operation was 98.8%, and that of LITA was 100%. The mean patency rate of endarterectomy or on-lay patch anastomosis was 97% (Table 3).

Two patients disregarding 2 preoperative cases had an IABP in place for therapeutic reasons at the time of operation. One patient sustained MI perioperatively according to the criteria used at our hospital; creatine kinase, myocardial band fraction >100 IU/L. There were 3 cerebrovascular complications (major: 1, minor: 2), and 1 patient required reoperation for infection. No patient died during the operation and 1 patient died due to mediastini-

tis 2 months after surgery. Follow-up ranged from 1 to 94 months (mean, 32±26 months). Seven patients died sometime after discharge; 3 from cardiac events (heart failure and MI), and 4 for unknown reasons. Figure 1 shows the Kaplan-Meier estimated survival rate: the 5-year rate was 83.1%. Five patients were readmitted because of congestive heart failure. Figure 2 shows the Kaplan-Meier estimated cardiac event-free rate; the 5-year rate was 77.5%.

Thirty-five patients (83%) underwent follow-up cineangiography studies to determine the EF. The mean EF, on average determined 1 month after CABG, increased significantly; from 23.8±4.5% to 35.3±8.5% (range, 21% to 52%). For 8 patients the EF remained essentially unchanged (within 5 EF points of the preoperative value); it improved significantly in the other 27 patients. The maximum improvement was 29 EF units. The mean LVEDVI and LVESVI also improved, but not significantly.

Figure 3 compares preoperative and postoperative symptom status for heart failure in the study group. The mean NYHA classification improved from 2.6±0.7 preoperatively to 1.1±0.3 postoperatively. Thirty-eight patients were improved to NYHA class I.

## Discussion

Patients with poor LV function caused by coronary artery disease increasingly have a third treatment option; myocardial revascularization. Cardiac transplantation is very effective, but limited by donor availability,<sup>6,11</sup> and medical treatment of such patients is associated with poor results.<sup>5</sup> As many studies have shown, such patients respond better to myocardial revascularization than to medical treatment alone.<sup>5,12,13</sup> Furthermore, with recent advances in surgical technique and myocardial protection during revascularization, studies have reported good initial and mid-term results.<sup>1-4</sup> Thus, apart from a heart transplant, CABG for severe LV dysfunction may offer these patients their only chance for significant improvement. However, despite recent reports that CABG for poor LV function showed low hospital mortality,<sup>1-4</sup> the rate is still higher than that of cases with normal LV function.<sup>3,14</sup> Hence, despite the significant advances, CABG in patients with reduced LV function remains a surgical challenge.

One means of improving the outcome in low EF cases is better intraoperative myocardial protection. Some studies indicate that blood cardioplegia is superior<sup>8</sup> and that retrograde coronary sinus cardioplegia may provide a more uniform myocardial protection in patients with se-

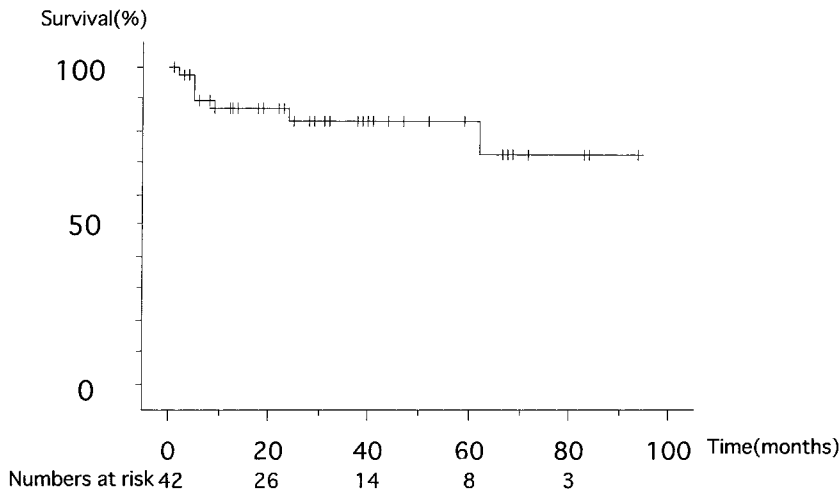


Fig. 1. Actuarial survival for study group.

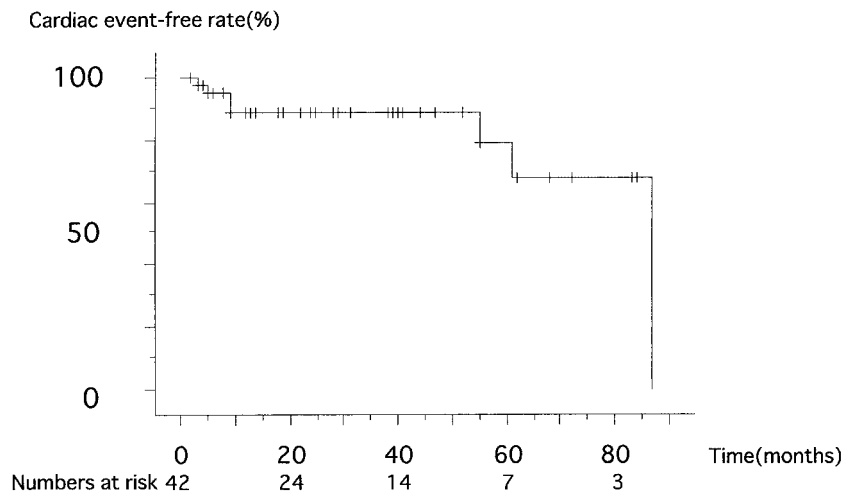


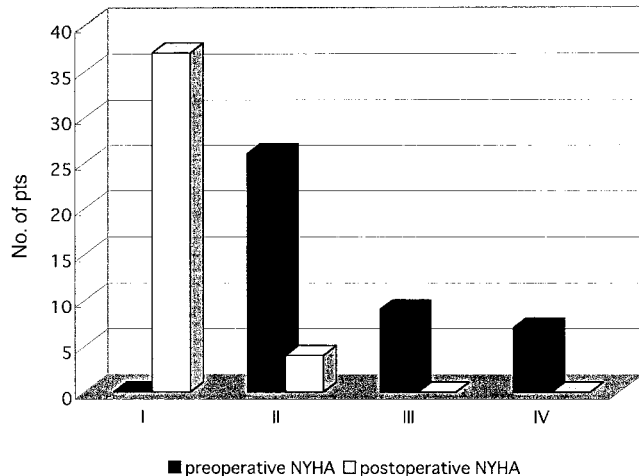
Fig. 2. Freedom from cardiac events for study group.

were multivessel disease.<sup>15)</sup> Furthermore, it has recently been shown that off-pump CABG can be performed safely even in patients with low EF.<sup>16)</sup> CABG without cardiac arrest may be a good method for improving the outcome of severe LV dysfunction, but it limits the number of distal anastomoses and its long-term results are still unknown. That is the reason we selected not to use this methodology. On the other hand, one study showed that complete revascularization in patients with three-vessel disease appeared to provide the greatest benefit to those with LV dysfunction.<sup>17)</sup>

Further, the new understanding that abnormal LV function may not necessarily represent irreversible myocardial necrosis, but instead severe but reversible myocardial ischemia (“hibernating myocardium”) puts complete revascularization in a new, favorable light.<sup>10,18)</sup> It is possible that in patients with an EF that is on the lower end of the scale, the beneficial effect of complete

revascularization results from the improvement in myocardial perfusion made possible by evoking latent viable portions of the myocardium.

We believe that complete CABG obtains its effects by preserving functional muscle against future infarction and recruiting hibernating muscle.<sup>18)</sup> This recruitment leads to the objective improvement in EF and the amelioration of congestive heart failure (CHF). The protection against subsequent ischemic events results in enhanced long-term survival. Therefore, even though CABG requires a long cardiac arrest time, we performed CABG for all viable areas and performed as many distal anastomoses as possible to improve the surgical outcome of severe LV dysfunction. If standard bypass grafting was impossible because a coronary artery was diffusely diseased, we performed bypass grafting by using endarterectomy and onlay patch anastomosis.<sup>19)</sup> As a result, the mean number of grafts per patient was  $4.6 \pm 1.3$  and that of arterial grafts



**Fig. 3.** Preoperative and postoperative symptom status for congestive heart failure [New York Heart Association (NYHA) classification] in operative survivors showing number of patients in each group.

was  $1.6 \pm 0.9$ , and aggressive endarterectomy of the LAD was performed in 6 cases to obtain or approximate complete revascularization. Our results, obtained in a small sized institute—0% of 30 days mortality and 2.4% of hospital mortality, and a 5-year estimated survival rate of 83.1%—compare favorably not only with those from recent larger severe LV dysfunction series (1.7% to 24% of hospital mortality and a 72% to 77% of 5-year survival rate<sup>1-4,7</sup>), but also with those for normal LV function.<sup>14</sup> In addition, the results from these 35 cases demonstrate that improvement in NYHA classification and postoperative EF can be achieved with complete revascularization in most patients with poor LV function. The quality of life in these patients with low EF is improved, and we believe that improved postoperative EF is necessary for a good long-term result.

Some recent studies have reported unfavorable patient characteristics in patients with CABG for low EF cases, for example, advanced age, female gender, ventricular irritability,<sup>8,20</sup> and severity of coronary artery disease. Mickleborough and colleagues<sup>1</sup> reported that the outcome in patients with severe LV dysfunction and whose vessels were poorly visualized was significantly lower than in those whose vessels were well visualized. Furthermore, Langenburg and colleagues<sup>21</sup> have recommended that patients with poor LV function and poor visualization of distal vessels are not good candidates for revascularization. From our point of view, however, if there is viable myocardium, we think that revas-

cularization is needed whether or not there is poor visualization of distal vessels. Because complete revascularization was more effective in low EF cases than in normal EF cases,<sup>17</sup> we aggressively did endarterectomy in 13 patients with poorly visualized distal vessels, and LAD endarterectomy in 6 of the 13 patients. The result was low operative mortality in our series.

It should be emphasized that this study was not a randomized study comparing complete versus incomplete coronary revascularization among surgical patients and as such is subject to the limitations of any retrospective analysis. Nonetheless, we have demonstrated that surgical complete revascularization by multivessel bypass grafting can be performed safely, with satisfactory hospital mortality and long-term results, for patients with poor LV function.

## References

1. Mickleborough LL, Carson S, Tamariz M, Ivanov J. Results of revascularization in patients with severe left ventricular dysfunction. *J Thorac Cardiovasc Surg* 2000; **119**: 550–7.
2. Kaul TK, Agnihotri AK, Fields BL, Riggins LS, Wyatt DA, Jones CR. Coronary artery bypass grafting in patients with an ejection fraction of twenty percent or less. *J Thorac Cardiovasc Surg* 1996; **111**: 1001–12.
3. Milano CA, White WD, Smith LR, et al. Coronary artery bypass grafting in patients with severely depressed ventricular function. *Ann Thorac Surg* 1993; **56**: 483–93.
4. Elefteriades JA, Morales DLS, Gradel C, Tollis G Jr, Levi E, Zaret BL. Results of coronary artery bypass grafting by a single surgeon in patients with left ventricular ejection fractions < or =30%. *Am J Cardiol* 1997; **79**: 1573–8.
5. Luchi RJ, Scott SM, Deupree RH, et al. Comparison of medical and surgical treatment for unstable angina pectoris: results of a Veterans Administration Cooperative Study. *N Engl J Med* 1987; **316**: 977–84.
6. Evans RW, Maier AM. Outcome of patients referred for cardiac transplantation. *J Am Coll Cardiol* 1986; **8**: 1312–7.
7. Chan RKM, Raman J, Lee KJ, et al. Prediction of outcome after revascularization in patients with poor left ventricular function. *Ann Thorac Surg* 1996; **61**: 1428–34.
8. Christakis GT, Weisel RD, Fremes SE, et al. Coronary artery bypass grafting in patients with poor ventricular function. *J Thorac Cardiovasc Surg* 1992; **103**: 1083–92.
9. Zubieta P, Kay JH, Mendez AM. Myocardial revascularization for the patients with drastic impairment of function of the left ventricle. *J Thorac*

- Cardiovasc Surg* 1977; **73**: 84–6.
10. Ferrari R, La Canna G, Giubbini R, et al. Left ventricular dysfunction due to stunning and hibernation in patients. *Cardiovasc Drugs Ther* 1994; **8**: 371–80.
  11. Kaye MP. The Registry of the International Society for Heart and Lung Transplantation: ninth official report–1992. *J Heart Lung Transplant* 1992; **11**: 599–606.
  12. Figott JD, Kouchoukos NT, Oberman A, Cutter GR. Late results of surgical and medical therapy for patients with coronary artery disease and depressed left ventricular function. *J Am Coll Cardiol* 1985; **5**: 1036–45.
  13. The Veterans Administrative Coronary Artery Bypass Surgery Cooperative Study Group. Eleven-year survival in the Veterans Administration randomized trial of coronary bypass surgery for stable angina. *N Engl J Med* 1984; **311**: 1333–9.
  14. Hannan EL, Kumar D, Racz M, Sui AL, Chassin MR. New York State's Cardiac Surgery Reporting System: four years later. *Ann Thorac Surg* 1994; **58**: 1852–7.
  15. Misale BD, Krukenkamp IB, Lazer ZP, Levitsky S. Retrograde is superior to antegrade continuous warm cardioplegia for acute cardiac ischemia. *Circulation* 1992; **86** (Suppl II): 393–7.
  16. Arom KV, Flavin TF, Emery RW, Kshetry VR, Petersen RJ, Janey PA. Is low ejection fraction safe for off-pump coronary bypass operation? *Ann Thorac Surg* 2000; **70**: 1021–5.
  17. Bell MR, Gersh BJ, Schaff HV, et al. Effect of completeness of revascularization on long-term outcome of patients with three-vessel disease undergoing coronary artery bypass surgery. A report from the Coronary Artery Surgery Study (CASS) Registry. *Circulation* 1992; **86**: 446–57.
  18. Braunwald E, Kloner RA. The stunned myocardium: prolonged, post-ischemic ventricular dysfunction. *Circulation* 1982; **66**: 1146–9.
  19. Bara JA, Bezon E, Mondine P, Resk A, Gilard M, Boshart J. Coronary artery reconstruction for extensive coronary disease: 108 patients and two year follow-up. *Ann Thorac Surg* 2000; **70**: 1541–5.
  20. Jones EL, Craver JM, Kaplan JA, et al. Criteria for operability and reduction of surgical mortality in patients with severe left ventricular ischemia and dysfunction. *Ann Thorac Surg* 1978; **25**: 413–24.
  21. Langenburg SE, Buchaman SA, Blackbourne LH, et al. Predicting survival after coronary revascularization for ischemic cardiomyopathy. *Ann Thorac Surg* 1995; **60**: 1193–7.