Functional Recovery After Coronary Artery Bypass Grafting in Patients With Severe Left Ventricular Dysfunction and Preserved Myocardial Viability in the Left Anterior Descending Arterial Territory as Assessed by Thallium-201 Myocardial Perfusion Imaging

Taishiro Chikamori, MD; Kunihiko Hirose, MD*; Tomio Hamada, MD; Nobuhiko Hitomi, MD; Hiroaki Kitaoka, MD; Toshikazu Yabe, MD; Takashi Furuno, MD; Hiromi Seo, MD; Toshiyuki Yamashiro, MD*; Yoshinori Doi, MD

To evaluate the functional recovery after coronary bypass surgery in patients with severe left ventricular (LV) dysfunction, 100 consecutive patients with viable myocardium in the territory supplied by the left anterior descending artery (LAD) underwent coronary bypass grafting. In addition, cardiac catheterization and single-photon emission computed tomography (SPECT) perfusion imaging with thallium-201 were repeated 1-year postoperatively. Although 12 patients with severe LV dysfunction were preoperatively in a worse New York Heart Association functional class (3.1±0.7 vs 2.4±0.8; p<0.01), had a higher incidence of heart failure (10/12 vs 14/88; p<0.001) and had a worse LVEF (29±5 vs 61±14%; p<0.001) compared with 88 patients without severe LV dysfunction, the operative mortality was similar in the 2 groups (1/12 vs 2/88; p=NS). The postoperative NYHA functional class in the patients with severe LV dysfunction was similar to that in the patients without such dysfunction (1.6±0.7 vs 1.3±0.6; p=NS). In addition, the 1-year postoperative study revealed a significant improvement in the thallium defect score in both the LAD territory (1.7±1.2 to 0.7±1.0, p=0.01) and all the territories (5.2±2.2 to 3.2±1.9, p=0.002) in patients with severe LV dysfunction, whereas no improvement in defect score was found in either of these territories in those without severe LV dysfunction (LAD: 0.6±1.4 to 0.4±1.2, p=NS; All: 1.9±2.2 to 1.8±2.0, p=NS). Furthermore, a marked 1-year postoperative improvement (15–24%; 95% confidence interval) in LVEF (29±5 to 48±10%, p<0.001) was demonstrated in patients with severe LV dysfunction, but not in those without such dysfunction (60±13 to 61±11%, p=NS). These results indicate that myocardial viability in the LAD territory, as demonstrated by thallium-201 SPECT perfusion imaging, predicts a significant improvement in functional class and LVEF of at least 10% or more after coronary artery bypass grafting in patients with severe LV dysfunction. (Jpn Circ J 1999; 63: 752–758)

Key Words: Coronary artery bypass grafting; Left ventricular function; Myocardial viability; Thallium-201 myocardial imaging

Methods

Study Patients

One hundred consecutive patients, all who demonstrated of having myocardial viability in the LAD territory and who undergone CAGB (66 men, 34 women, aged 42–85 years [mean, 66]) were studied retrospectively. Previous myocardial infarction and CAGB had occurred in 66 and 3 patients, respectively. Left main coronary artery disease was found in 31 patients, 3-vessel disease in 44, 2-vessel disease in 23, and 1-vessel disease in 2. Written informed consent was obtained from all of the patients.

Echocardiography

Echocardiograms were performed using a Toshiba SSH-65A (Tokyo, Japan) or an Aloka SSD-710 (Tokyo, Japan) with 2.5–3.75 MHz transducers. A complete M-mode and 2-dimensional study were performed and recorded on video tape for subsequent analysis. LV segmental wall motion abnormality and systolic wall thick-
Thallium-201 Single-Photon Emission Computed Tomography

A scintigraphic study was performed in 83 patients within 1 month prior to CABG. In the remaining 17 patients, the scintigraphic study could not be performed due to clinical instability and/or the necessity for emergency surgery. Single-photon emission computed tomography (SPECT) perfusion imaging with thallium-201 (201Tl) was performed in 74 patients ≥15 h after the cessation of cardioactive medication, with infusion of 0.568 mg/kg of dipyridamole13 and walking ‘on the spot’ for 3 min. Then 3 mCi (111 MBq) of 201Tl chloride was injected during walking, and imaging was begun within 5 min of its administration. In the remaining 9 patients, rest-redistribution SPECT perfusion imaging with 201Tl was performed. A digital gamma camera with 3 detectors (Toshiba GCA-9300A/HG) was rotated over a 360-degree arc. Seventy-two images were obtained for 30 s in each 5-degree interval and were stored in a computer for subsequent analysis. Identical redistribution images were acquired 3 h later. For image reconstruction, preprocessing was performed with a Butterworth filter, with a cut-off frequency of 0.15 cycle/pixel, then filtered back projections were obtained with a Ramp filter. No attenuation or scatter correction was used. The findings were interpreted by 2 observers who were unaware of the results of coronary angiography. With the help of bull’s-eye polar coordinate maps, defects were classified as reversible or fixed according to the conventional method.14 In addition, perfusion defects were scored as described previously: 0= no perfusion defect, 1= mild perfusion defect, 2= moderate perfusion defect and 3= severe perfusion defect (Fig 1). The thallium defect score was the sum of the points attributed to each of 8 segments in the redistribution images. Thallium reversibility score was the sum of the points in the initial image subtracted by that in the redistribution image. For the calculation of the thallium defect and reversibility scores, the LAD territory was assessed on the combination of coronary anatomy with clinical information, including the history of myocardial infarction, electrocardiograms and the systolic motion and thickening of the anterior-anteroseptal segments seen on echocardiographic studies.

Coronary Bypass Surgery

The surgical indication was based on clinical or viability information, or both, provided that myocardial viability in the LAD territory was demonstrated by the method mentioned before. Coronary bypass surgery was performed using standard techniques with complete revascularization if technically and anatomically feasible.

Follow-up

Follow-up included monthly evaluation by a cardiologist at Kochi Medical School. Medications at the time of discharge after CABG were nitrates in 97 patients, calcium-channel blockers in 85, ß-blockers in 7, digitalis in 48, diuretics in 55 and antiarrhythmic drugs in 5. One-year follow-up was completed in all of the patients, and 73 patients agreed with and gave written informed consent to a 1-year postoperative evaluation including 201Tl SPECT perfusion imaging and cardiac catheterization.

Statistical Analysis

Results are expressed as mean±1 SD. Student’s t test was used to compare the means of the continuous variables, and contingency tables were analyzed using a chi-squared test. A paired t test was used to compare the changes of
each test variables before and after CABG. The computations were performed using the SPSS-PC+ computer program (version 7.5; SPSS, Chicago, ILL, USA).

Results

Baseline Characteristics

Twelve patients with severe LV dysfunction were in a worse New York Heart Association functional class and had a higher incidence of heart failure, demonstrated with chest roentgenogram, and a worse LVEF compared with 88 patients without severe LV dysfunction, whereas age, gender and extent of coronary artery disease were similar in the 2 groups (Table 1).

Results of Coronary Bypass Surgery

Emergency operation was undertaken in 15 patients. All patients received bypass grafting to the LAD. Surgical results, including the number of bypass grafts, the use of an internal thoracic artery graft, extracorporeal circulation time and cross-clamp time, were similar between patients with and without severe LV dysfunction, except for a higher necessity for intra-aortic balloon pumping in those with severe LV dysfunction (Table 2). Three patients died in the perioperative period; 1 with severe LV dysfunction and 2 without. Two of the 3 patients needed emergency reoperation 8 and 11 years, respectively, after the initial operation. The remaining patient died of low output syndrome due to right ventricular dysfunction.

Pre- and Postoperative Functional Class

New York Heart Association functional class significantly improved soon after CABG in patients with and without severe LV dysfunction (3.1±0.7 to 1.6±0.7, p<0.001; 2.4±0.8 to 1.3±0.6, p<0.001, respectively). The functional class was similar in the 2 groups soon after the operation and at the 1-year postoperative follow-up (1.6±0.7 vs 1.3±0.6, p=NS; 1.2±0.4 vs 1.2±0.5, p=NS, respectively) (Fig 2). No patient with severe LV dysfunction showed congestive heart failure documented by chest roentgenogram after CABG. The improvement in functional class in patients without severe LV dysfunction was due predomi-
Fig 3. Pre- and 1-year postoperative thallium defect score in the left anterior descending coronary artery (LAD) territory and all the territories. LV, left ventricle.

Fig 4. Pre- and 1-year postoperative thallium reversible score in the left anterior descending coronary artery (LAD) and all the territories. LV, left ventricle.

nanty to the abolition of angina. Late deaths occurred in 4 patients: refractory heart failure in 1 and malignancies in 3. Therefore, 93 patients were alive at the 1-year postoperative follow-up, and 73 of those agreed to the 1-year postoperative studies.

Pre- and Postoperative Scintigraphic Studies

Ten of the 12 patients with severe LV dysfunction, and
62 of the 88 patients without, completed both the pre- and postoperative scintigraphic studies. Although the thallium defect score before CABG was worse in both the LAD territory and all the territories as a whole in the patients with severe LV dysfunction than in those without dysfunction (1.7±1.2 vs 0.6±1.4, p<0.02; 5.2±2.2 vs 1.9±2.2, p<0.001, respectively), significant improvements in the score were observed in both territories at the 1-year postoperative follow-up in patients with severe LV dysfunction (1.7±1.2 to 0.7±1.0, p=0.01; 5.2±2.2 to 3.2±1.9, p=0.002, respectively) (Fig 3). In the territories of the left circumflex and right coronary arteries, the thallium defect score also improved after CABG in these patients (3.4±2.1 to 2.4±2.2, p<0.05). In patients without such dysfunction, however, no improvement in defect score was found in either of the territories (0.6±1.4 to 0.4±1.2, p=NS; 1.9±2.2 to 1.7±2.0, p=NS, respectively). The thallium reversibility score, however, improved in both territories in patients with and without severe LV dysfunction (Fig 4).

**Pre- and Postoperative Cardiac Function (Fig 5)**

Coronary arteriograms at the 1-year postoperative follow-up revealed a patent bypass graft to the LAD in all patients studied. A marked 1-year postoperative improvement (15–24%; 95% confidence interval (CI)) in LVEF (29±5 to 48±10%, p<0.001) was demonstrated in 10 patients with severe LV dysfunction, all of whom had undergone a scintigraphic study before CABG. A typical case is shown in Fig 6. In contrast, no significant postoperative change (60±13 to 61±11%, p=NS) was observed in those without severe LV dysfunction.

![Graph showing pre- and 1-year postoperative LV ejection fraction (EF) in patients with and without LV dysfunction after excluding those with perioperative myocardial infarction.](image)

**Fig 5.** Pre- and 1-year postoperative LV ejection fraction (EF) in patients with and without LV dysfunction after excluding those with perioperative myocardial infarction. LV, left ventricle.

![Images showing pre-operative and 1-year post-operative cardiac function](image)

**Fig 6.** A 67-year-old woman with severe left main trunk and 3-vessel coronary artery disease with depressed cardiac function. One year after successful coronary artery bypass grafting, short-axis thallium tomograms show improved myocardial perfusion in association with reduced left ventricular end-diastolic volume (LVEDV) and increased ejection fraction (EF). D1, first diagonal branch; LAD, left anterior descending coronary artery.
Discussion

The results of the present study demonstrate that myocardial viability in the LAD territory, as detected by 201Tl SPECT perfusion imaging, in patients with severe LV dysfunction (LVEF ≤35%) predicted a low surgical risk and a significant postoperative improvement in the LVEF of at least 10% or more. Recent studies with noninvasive assessments such as SPECT, positron emission tomography and low-dose dobutamine stress echocardiography have reported successful prediction of recovery in LV function after coronary revascularization. Using segmental systems, most of those studies focused on regional LV function, not on global LV function, which is more relevant in the clinical setting. In the present study, done in patients with severe LV dysfunction, a significant recovery in global LV function, documented by an increase in the LVEF of 15–24% (95% CI), was demonstrated in association with marked improvement in heart failure symptoms and NYHA functional class. The repeat study at 1-year postoperative demonstrated a patent bypass graft to the LAD in all of the patients studied, which is the dominant vessel responsible for preserving ventricular function. Although the procedural and prognostic significance of CABG to the LAD was stressed recently, the present study also emphasizes the impact of a bypass graft to this coronary artery upon a marked recovery in global LV function in patients with severe LV dysfunction.

The magnitude of the increase in the LVEF of 15–24% was greater when compared with that of 7–12% in previous studies of patients with myocardial viability. No major difference was observed in patient selection between previous studies and ours because the extent of coronary artery disease and the severity of LV dysfunction were similar. The timing of surgery after the viability assessment in patients with hibernating myocardium may influence the magnitude of the recovery in LV function. Coronary bypass surgery was performed within 1 month of the viability assessment in the present study, so performing a more-delayed bypass operation may lose the patient the opportunity for LV function to recover due to the progressive structural degeneration with enhanced fibrosis. The time difference between the CABG and the postoperative study is another explanation. Postoperative catheterization was performed 1 week to 6 months after CABG in the previous studies whereas a repeat study was done at 1-year postoperative in the present study. The greater improvement in LV function observed in our study is due partly to this time difference because recovery in LV function after coronary revascularization is a progressive phenomenon. In addition to the postoperative assessment of global LV function, repeat SPECT perfusion imaging, which was seldom addressed in previous studies, was also evaluated by us. The scintigraphic evaluation revealed a significant improvement not only in the reversibility score, but also in the defect score in patients with severe LV dysfunction, whereas an improvement was found only in reversibility score in those without such dysfunction. Thus, the recovery in NYHA functional class after CABG in patients without severe LV dysfunction is due to the improvement in myocardial ischemia and angina-related symptoms. In contrast, in patients with severe LV dysfunction, LV functional and symptomatic recovery after coronary revascularization may result not only from the improvement in myocardial ischemia, but also from that of the cell membrane integrity. This result also implies that myocardial perfusion imaging with 201Tl has a potential possibility to underestimate myocardial viability in the infarcted area before CABG.

For the identification of those patients with LV dysfunction and myocardial viability who will benefit from coronary revascularization, many noninvasive methods claim their superiority. These methods are grouped as either stimulants of inotropic reserve, of which low-dose dobutamine stress echocardiography is most widely used, or radioactive tracers, which are used in SPECT or positron emission tomography. Even head-to-head comparison studies between the former and the latter were conducted recently. In contrast, the method presented in the present study used 201Tl SPECT perfusion imaging, which is most frequently used in institutions and with which most clinicians have more experience. Moreover, visual analysis of the SPECT imaging is simple and does not restrict the viability information to a particular specialist. Thus, not only cardiologists specialized in myocardial viability assessment, but also surgeons, can have easy access to this important clinical information. Although a recent report suggested that many patients with severe LV dysfunction were not evaluated by a test assessing viability before undergoing coronary bypass surgery, the development of simple and low-cost methods to obtain viability information will facilitate the application of viability assessment to these patients for whom such screening should be mandatory. Obviously, in some patients in whom the myocardial viability is questionable or falls into a borderline zone, high-cost sophisticated methods, such as quantitative analysis of SPECT perfusion imaging or positron emission tomography, may be necessary.

Study Limitations

Because the present study is retrospective in its nature, a randomized control group was not included. To scientifically assess the effect of CABG to the LAD on functional recovery in patients with LV dysfunction, a control group in whom bypass surgery is done without grafting to the LAD is necessary. However, to perform bypass surgery in patients with a LVEF of ≤35% without grafting to the LAD, which is graftable and supplies the viable myocardium, can not be justified ethically. In addition, CABG not only to the LAD, but also to other 2 coronary arteries may have a beneficial effect on LV functional recovery. To answer this question, another study design with or without grafting to the left circumflex and/or right coronary artery is necessary. However, to provide a control group on whom CABG is performed without grafting to the left circumflex or right coronary artery despite its necessity may pose an ethical problem. At the present time, although the scientific feasibility remains to be determined, the fact that a considerable number of patients undergoing CABG can be identified as having myocardial viability using the visually assessed SPECT method may give an important clinical guideline as to low operative risk and a significant postoperative improvement in LVEF, as demonstrated in the present study.
References
17. Kaul S: There may be more to myocardial viability than meets the eye! Circulation 1995; 92: 2790–2793