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Abstract

Forty patients underwent coronary revascularization using bilateral internal thoracic artery (ITA) grafts between 1988 and 1992. A total of 111 coronary grafts were performed, or an average of 2.8 grafts per patient. Each patient received bilateral ITA grafts, and in 20 patients an additional 29 grafts were constructed with 18 autologous veins and 11 gastroepiploic arteries. The right ITA was grafted as a free graft in 20 patients. The ITA graft patency rate was 96 per cent (67/70) at the time of hospital discharge. The operative morbidity included 3 reoperations for bleeding, 1 perioperative myocardial infarction, 1 renal failure, 2 postcardiotomy shock, and 1 colon perforation. Two hospital deaths occurred; one due to colon perforation and the other due to postcardiotomy cardiogenic shock. One patient died of cerebral infarction 6 month after the operation. Thirty-four patients were in New York Heart Association functional class I, 2 were in class II and 1 was in class III. Cardiac function evaluated by echocardiography and scintigraphy showed significant improvement postoperatively. These data suggest that the use of bilateral ITA grafts is associated with an acceptable mortality and increases the versatility of arterial grafting.

KEYWORDS: coronary artery bypass graft, bilateral ITA grafts

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Mid-Term Results of Bilateral Internal Thoracic Artery Grafting

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Forty patients underwent coronary revascularization using bilateral internal thoracic artery (ITA) grafts between 1988 and 1992. A total of 111 coronary grafts were performed, or an average of 2.8 grafts per patient. Each patient received bilateral ITA grafts, and in 20 patients an addtional 29 grafts were constructed with 18 autologous veins and 11 gastroepiploic arteries. The right ITA was grafted as a free graft in 20 patients. The ITA graft patency rate was 96 per cent (67/70) at the time of hospital discharge. The operative morbidity included 3 reoperations for bleeding, 1 perioperative myocardial infarction, 1 renal failure, 2 postcardiotomy shock, and 1 colon perforation. Two hospital deaths occurred; one due to colon perforation and the other due to postcardiotomy cardiogenic shock. One patient died of cerebral infarction 6 month after the operation. Thirty-four patients were in New York Heart Association functional class I, 2 were in class II and 1 was in class III. Cardiac function evaluatd by echocardiography and scintigraphy showed significant improvement postoperatively. These data suggest that the use of bilateral ITA grafts is associated with an acceptable mortality and increases the versatility of arterial grafting.

Key words : **coronary artery bypass graft, bilateral ITA grafts**

Internal thoracic artery (ITA) grafts display a better patency rate than saphenous vein grafts because of the lower incidence of atherosclerosis (1). This significantly improves long-term survival and reduces the incidence of late cardiac events (2). In an attempt to further improve the results of myocardial revascularization, bilateral ITA grafts have been used to bypass multiple vessels with this conduit (3, 4). Bilateral ITA grafting has been our intinal choice of operation for patients requiring multivessel revascularization. A review of all patients undergoing revascularization with bilateral ITA grafts at the Okayama University Hospital during the period from 1988 to 1992 was undertaken to document the mid-term results of that procedure. These data were also compared with the results in patients with single ITA grafts and saphenous vein grafts.

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Subjects and Methods

During the period from May 1985 to September 1992, 75 patients underwent coronary artery bypass grafting. Among them, 10 patients received saphenous vein grafts without the use of ITA grafts, 25 patients received a single ITA graft with or without saphenous vein grafts, and 40 patients received bilateral ITA grafts. Of the 40 patients who underwent bilateral ITA grafting, 37 were men and 3 women, aged from 48 to 70 years, with a mean age of 60 years. Thirty-one patients had stable angina, 7 had unstable angina, and 2 had asymptomatic coronary heart disease. The coronary risk factors included diabetes mellitus in 10 patients, hypertension in 11, hyperlipidemia in 2, prior myocardial infarction in 27, and renal failure in 1. Preoperative angiography demonstrated single-vessel disease in 3 patients, double-vessel disease in 11, triple-vessel disease in 18 and left main coronary artery stenosis in 8. Two patients had mitral valve regurgitation and 2 had abdominal aortic aneurysms (Table 1). One patient was in New York Heart Association (NYHA) functional Class I, 11 in Class II, 20 in

Table 1 Preoperative clinical and angiographic characteristics

Number of patients	40
Sex (F/M)	3/37
Age (years, mean)	48-70 (60)
Risk factors	
Hypertension	11
Diabetes mellitus	10
Hyperlipidemia	2
Previous myocardial infarction	27
Renal failure	1
Diseased vessels	
Single vessel	3
Double vessel	11
Triple vessel	18
Left main trunk	8
Concurrent diseases	
Mitral regurgitation	2
Abdominal aortic aneurysm	2

Class III, and 8 in Class IV.

The ITA and accompanying vein were dissected as a pedicle from the ITA subcalvian source proximally to its bifurcation. For *in situ* grafts, the origin of the ITA from the subclavian artery was left intact. The distal end of the ITA was then divided proximal to its major bifurcation and anastomosed to the coronary artery. If the *in situ* graft was not long enough to reach the coronary artery, the ITA was also divided proximally and used as a free aortocoronary graft. The ITA-coronary anastomosis was constructed with a continuous suture of 8-0 prolene. The proximal anastomosis of the aortocoronary free ITA graft was constructed with a continuous suture of 7-0 prolene after excising a small segment of the aortic wall by using a 4-mm aortic punch. All operations were conducted using cardiopulmonary bypass and moderate systemic hypothermia. Cold potassium crystalloid cardioplegia was employed in 9 patients and antegrade/retrograde cold blood cardioplegia (5) was used in 31 patients.

Cardiac function before and after surgery was evaluated by echocardiography and scintigraphy. Results are expressed as mean $\pm$ SD. The sigsificance of differences was determined by Student's t-test. A p-value of less than 0.05 was considered significant.

Results

Forty patients received bilateral ITA grafts. These patients received a total of 111 coronary grafts, or an average of 2.8 grafts per patient. Besides the ITA grafts, 29 other grafts were constructed with 18 autologous veins and 11 right gastroepiploic arteries. The ITA grafts and corresponding recipient arteries are listed in Table 2. Twenty-six LITAs were grafted to the left anterior descending (LAD) coronary artery, 3 LITAs to the diagonal artery, and 13 LITAs to the circumflex artery (including 2 LITA sequential grafts to the LAD and the diagonal artery). Eleven RITAs were grafted to the LAD, 8 RITAs to the diagonal artery, 8 RITAs to the circumflex artery, and 13 RITAs to the right coronary artery. A free right ITA was used for the right coronary artery in 7 patients, the circumflex artery in 8 patients, and the diagonal artery in 5 patints.

Two patients died postoperatively. One patient died of colon perforation 14 days after surgery. He had a history of abdominal aortic aneurysm which had been treated with a vascular prosthesis. Another patient died of postcardiotomy cardiogenic shock. Three patients required reoperation for postoperative bleeding, one developed perioperative inferior myocardial infarction, one exprienced postcardiotomy cardiogenic shock but was saved by using a left ventricular assist device, and one developed renal failure necessitating dialysis. One patient died of cerebral infarction 6 months after surgery. Thirty-five patients underwent angiography one month after surgery. The patency rate of ITA grafts was 96 % (67/70). The saphenous vein was 80 % (12/15), and right gastroepiploic artery was 100 % (8/8).

Cardiac function was evaluated before and after surgery by echocardiography in 12 patients (Fig. 1). The left ventricular diastlic dimension (LVDd) decreased from 55.3 ± 5.4 mm to 48.8 ± 9.0 mm ($p < 0.005$), and the left ventricular systolic dimension (LVDs) decreased from 39.9 ± 9.2 mm to 35.9 ± 10.0 mm ($p < 0.005$). The fractional shortening (FS) decreased from 29.2 ± 10.4 % to

Table 2 Coronary arteries grafted and types of coduits in 40 patients

Type of coduit	Recipient artery	Number of conduit
LITA	LAD	26
	Diagonal	3
	CX	13
RITA	LAD	11
	Diagonal	8
	CX	8
	RCA	13
Right gastroepiploic artery		11
Saphenous vein		18
Total		111 (mean 2.8)[a]

LITA: left internal thoracic artery, RITA: right internal thoracic artery, LAD: left anterior descending artery, CX: Circumflex artery, RCA: right coronary artery. *a:* An average of 2.8 conduits per patient.

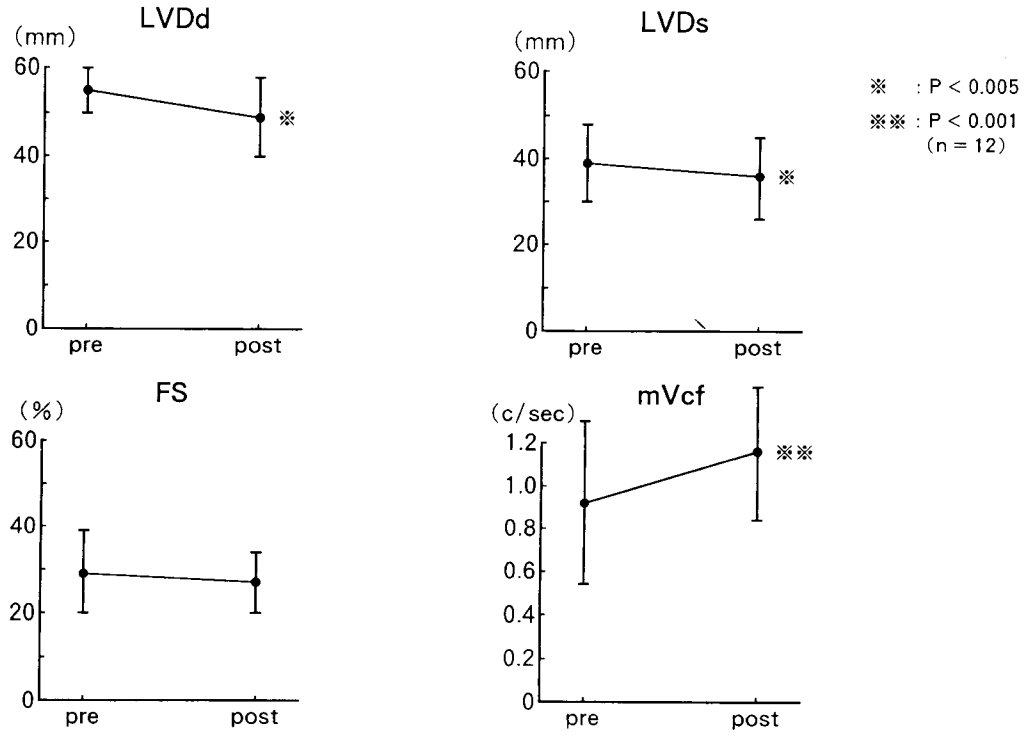

Fig. 1 Pre-operative and post-operative cardiac functions as determined by echocardiography. LVDd: left ventricular diastolic dimension, LVDs: left ventricular systolic dimension, FS:: fractional shortening, mVcf: mean velocity of circumferential fiber shortening.

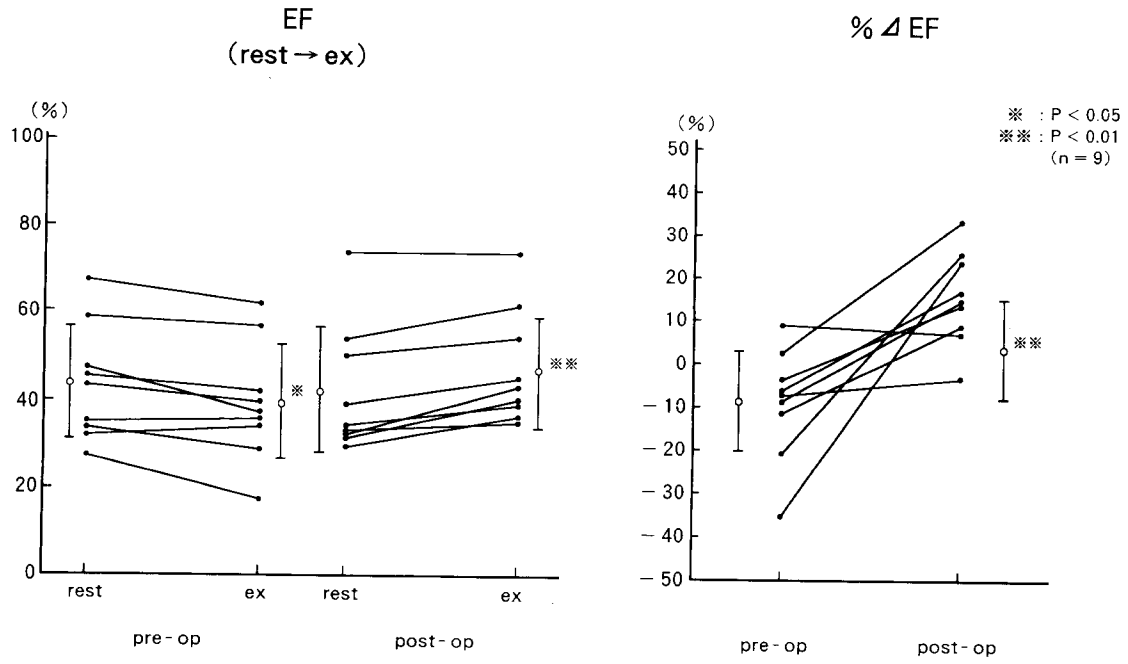

Fig. 2 Pre-operative and post-operative cardiac functions as determined by scintigraphy. EF: ejection fraction, ex: exercise.

27.5 ± 7.1 %. The mean velocity of circumferential fiber shortening (mVcf) increased from 0.92 ± 0.37 c/sec to 1.16 ± 0.33 c/sec ($p < 0.001$). Multiple-gated equilibrium cardiac blood pool scintigraphy was performed during exercise in 9 patients. The left ventricular ejection fraction (EF) determined by this technique and the percent change of EF from rest to exercise (% △ EF) are shown in Fig 2. Before surgery, the resting EF value was 43.3 ± 13.4 % and exercise EF value was 39.4 ± 13.5 % ($p < 0.05$). After surgery they were 41.8 ± 14.7 % and 47.5 ± 13.0 %, respectively ($p < 0.01$). The percent changes of EF were −9.4 ± 12.8 % before surgery and 3.2 ± 11.6 % after surgery ($p < 0.01$).

Follow-up of all 38 survivors who underwent bilateral ITA grafting continued to September 1992, with a mean follow-up period of 26.9 moths (range: 1 to 55 months). Thirty-four patients were in NYHA class I, 2 in class II and one in class III in September 1992. Patient survival was assessed by actuarial analysis according to the method of Kaplan and Meier (6). For comparison, 25 patients who received single ITA graft and 10 patents who received saphenous vein grafts were also followed up (Table 3). The survival data for the three groups were shown in Fig. 3. At 4 years, survival was 93 % for patients with bilateral ITA grafts. Survival rates for patients with single ITA grafts were 83 % at 4 years and 70 % at 7 years. Survival rates for patients with saphenous vein graafts were 80 % at 4 years and 80 % at 7 years. At 4 years, the survival data showed no significant differences among the three groups.

Table 3 Clinical profile of patients with grafts using bilateral ITA, single ITA or saphenous vein

	Bilateral ITA	Single ITA	Saphenous vein
Number of patient	40	25	10
Age (years, mean)	48-70(60)	46-74(60)	54-76(65)
Sex (F/M)	3/37	4/21	6/4
Grafts per patient	2.8	1.8	1.6

ITA: internal thoracic artery.

Discussion

Saphenous vein grafts used as arterial conduits show fracturing of the internal elastic lamina and can further develop intimal hyperplasia that leads to early graft closure. Lytle reported that early vein graft stenoses are usuary caused by intimal fibroplasia and late vein graft stenoses by vein graft atherosclerosis (7). He also stated that late vein graft stenosis is far more clinically dangerous than either early vein graft stenosis or native vessel coronary artery disease. Late stenoses in saphenous vein grafts to the left anterior descending coronary artery portend a high rate of death and cardiac events and constitute an indication for reoperation.

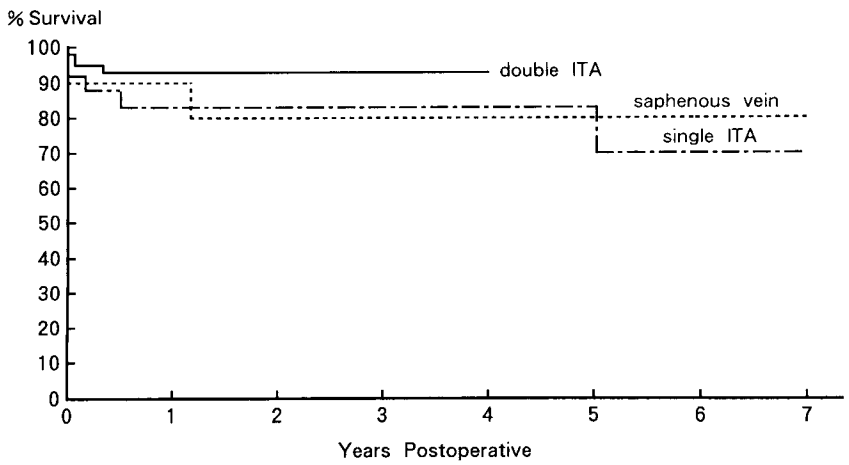

Fig 3 Survival rates of patients receiving saphenous veim, single ITA or bilateral ITA grafts. ITA: internal thoracic artery.

ITA grafts rarely develop atherosclerosis and display a late patency rate in the 90th percentile up to 12 years postoperatively (8). The ITA is particularly resistant to intimal hyperplasia because the internal elastic lamina perfectly formed at an early age and does not fracture with the passage of time, a mechnism suggested by Sims (9) to be an etiologic factor in the development of atherosclerosis. Recent work has suggested that vasoactive mediators within the ITA wall may protect this vessel against the development of atherosclerosis. Chaikouni (10) observed that prostacyclin, a potent vasodilator and inhibitor of platelet aggregation, is produced by endothelial cells of the human ITA at a higher level than is observed in the saphenous vein. In addition to these basic studies, clinical results have supported the superioity of the ITA as a conduit. ITA rather than vein grafts to the anterior descending coronary artery significantly improve long-term survival, decrease the occurrence of myocardial infarction, decrease the need for reoperation, and improve cumulative event-free survival (2).

With a view to further improving the results of myocardial revascularization, numerous methods of extending the use of ITA grafts have been suggested, including augmentation of their length by multiple transection of the fascia in the ITA pedicle (11) and the construction of sequential grafts (12). Others have suggested the use of free ITA grafts by constructing an anastomosis with the aorta (13), the use of both ITAs (3, 4), and careful choice of the shortest route from ITA origin to the recipient artery (14). Barner (15) reported on the results of double internal mammary-coronary bypass in 100 patients in 1974, and Geha (16) used crossed double internal mammary-coronary artery grafts in 36 patients with excellent functional results. Galbut (4) has shown that patients with bilateral ITA grafts have a better survival rate and a higher event-free survival rate than patients given other types of grafts. The actuarial survival was 80 % at 10 years and 60 % at 15 years. Recently, Fiore (17) has reported that the 15-year actuarial survival rate was significantly higher for patients with double ITA grafts than for patients with single ITA grafts (74 % *versus* 59 %). The improvement in actuarial survival and freedom from myocardial infarction observed in patients with bilateral ITA grafts were particularly marked in the longer follow-up period. This would suggest that the continued patency of both ITA grafts confers greater protection from death and myocardial infarction beyond 10 years, when the rate of loss of saphenous vein grafts increases. Only by the examination of late survival these subtle differences will become apparent. According to our follow-up data, at 4 years, survival rates for patients with bilateral ITA grafts, single ITA graft and saphenous veins grafts were 93 %, 83 % and 80 %, respectively. Initial survival for patients with bilateral ITA grafts was superior to that for patients with single ITA graft or saphenous vein grafts, but these differences were not statistically significant.

The *in situ* left ITA is used for grafts to the anterior descending and diagonal branches of the left coronary artery. However, its length and the course of the lateral coronary arteries limit the use of the left ITA to these vessels on the lateral wall of the ventricle. In addition, use of the *in situ* right ITA is limited by its length to the upper right coronary artery. These technical problems related to the length and site of the vessels can be overcome by removing the ITA and using it as an aortocoronary graft (13). In our series, 20/40 right ITA (RITA) grafts had to be free grafts, even though we first attempted multiple transections of the fascia in the ITA pedicle. The free ITA graft is useful for two reasons (13). First, its use may permit the surgeon to avoid crossing the midline, a procedure which can jeopardize the use of the RITA at reoperation. Second, the use of a free graft provides additional length for reaching a distal anastomosis. Loop (13) has reported an excellent patency rate using free ITA grafts. Thirty-two of 35 (91 %) free grafts followed for more than 18 months postoperatively were open and 24/26 (92 %) restudied beyond 60 months were patent. Late studies of free ITA grafts have shown no evidence of graft atherosclerosis. These findings have expanded the indications for ITA grafts and have permitted the greater part of the left ventricular myocardium to be revascularized using two arterial conduits.

Criticisms of bilateral ITA grafting include the facts that graft preparation is technically demanding, can prolong the operating time, and may possibly increase bleeding, wound infection, and respiratory complications. Depending on the period studied, wound infection is 1 % -3 % higher in bilateral ITA graft patients and is related more to diabetes and age than to other factors. The authors concluded that bilateral ITA grafting did not increase surgical mortality and only increased surgical morbidity by slightly increasing transfusion requirements (18). Another report has stated that obesity, diabetes, bilateral ITA grafting, and the need for prolonged mechanical ventilation were associated with a significantly

higher incidence of sternal infection (19).

In our series, we experienced two operative deaths. One patient died of colon perforation, but this was not directly related to the surgical technique. Another patient died of postcardiotomy cardiogenic shock. This patient with three-vessel disease had a history of anterior myocardial infarction, had poor left ventricular function (ejection fraction, 26.1 %)and received 5 coronary artery bypass grafts. In terms of cardiac function, this patient should not have been a candidate for bilateral ITA grafting. We also encountered one case of perioperative inferior myocardial infarction, which had minimal effect on postoperative cardiac function, and three cases of postperative bleeding. These complications can be minimized through increased surgical experience and shortened operating time. We have not experienced sternal infection in this series. To avoid this serious complication, we close the sternum as tightly as possible using 7 or more stainless steel wires.

We have used right gastroepiploic artery as an *in situ* graft for the right posterior descending artery in 10 patients and for the circumflex artery in one case. Postoperative angiography revealed all grafts to be patent (8/8). Lytle reported that right gastroepiploic artery segments from 18 patients could not be distinguished histologically from ITA segments, and that no evidence of atherosclerosis was found (20). He reported that early graft patency had been excellent and concluded that the histologic similarity between the right gastroepiploic artery and ITA suggested favorable long-term results.

In conclusion, coronary artery bypass grafting using bilateral ITA grafts can be performed with mininal surgical mortality and morbidity, and that the application of this procedure facilitates complete revascularization with arterial grafts. Nevertheless, the high-risk patient with renal dysfunction, previous surgical intervention or poor left ventricular function should not be a candidate for bilateral ITA grafting.

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