

## Surgical Experience with Bilateral Internal Thoracic Artery Grafts

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**ABSTRACT.** Forty-two patients underwent coronary revascularization using bilateral internal thoracic artery (ITA) grafts between 1988 and 1993. A total of 116 coronary grafts were performed, or an average of 2.8 grafts per patient. Each patient received bilateral ITA grafts, and in 21 patients an additional 30 grafts were constructed with 18 autologous veins and 12 right gastroepiploic arteries. The right ITA was grafted as a free graft in 21 patients. The ITA graft patency was 94 per cent (68/72) at the time of hospital discharge. The operative morbidity included three reoperations for bleeding, one perioperative myocardial infarction, one renal failure, two postcardiotomy shock, and one 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 six months after the operation. Another patient died suddenly at home 10 months after surgery. Thirty-two patients were in New York Heart Association functional class I, five were in class II and one was in class III. Cardiac functions assessed by echocardiography and scintigraphy showed significant improvement postoperatively. The actuarial survival was 91 per cent at five years for patients with bilateral ITA grafts. 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

The internal thoracic artery (ITA) provides better early and long-term patency than do venous conduits.<sup>1)</sup> Patients receiving one ITA graft to the left anterior descending artery enjoy increased longevity and greater freedom from reoperation and late cardiac events.<sup>2)</sup> The excellent long-term patency of the ITA suggests that the improved patient longevity associated with one ITA graft might be extended if two grafts were used in patients with multivessel coronary artery disease requiring revascularization. Several reported surgical experiences have used bilateral ITA grafting in an effort to extend the use of this preferred conduit.<sup>3-5)</sup> Bilateral ITA grafting has been our initial choice of operation for patients requiring multivessel revascularization. A review of all patients undergoing revascularization with bilateral ITA grafts during the period from 1988 to 1993 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 only.

### PATIENTS AND METHODS

During the period from June 1981 to May 1993, 101 patients underwent coronary artery bypass grafting at the Okayama University Hospital. Among them, 32 patients received saphenous vein grafts without the use of ITA grafts, 27 patients received a single ITA graft with or without saphenous vein grafts, and 42 patients received bilateral ITA grafts. Of the above 42 patients who underwent bilateral ITA grafting, 39 were men and 3 were women, with a mean age of 59 years old, ranging from 47 to 70 years old. Thirty-three patients had stable angina, seven unstable angina, and two asymptomatic coronary heart disease. The coronary risk factors included hypertension in 11 patients, diabetes mellitus in 11, hyperlipidemia in 4, previous myocardial infarction in 28, and renal failure in 1. Preoperative angiography demonstrated single-vessel disease in 3 patients, double-vessel disease in 12, triple-vessel disease in 19 and left main coronary artery stenosis in 8. Two patients had mitral valve regurgitation and 2 had abdominal aortic aneurysm (Table 1). One patient was in New York Heart Association (NYHA) functional class I, 12 were in class II, 21 were in class III, and 8 were in class IV.

TABLE 1. Preoperative clinical and angiographic characteristics

No. of Patient	42
Gender (male)	39
Age	47-70 (59.6)
Risk Factors	
hypertension	11
diabetes mellitus	11
hyperlipidemia	4
previous myocardial infarction	28
renal failure	1
Diseased Vessels	
single vessel	3
double vessel	12
triple vessel	19
left main trunk	8
Concurrent Diseases	
mitral regurgitation	2
abdominal aortic aneurysm	2

(Feb. 1988~May 1993)

The ITA and accompanying vein were dissected as a pedicle from the ITA subclavian 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<sup>6)</sup> was used in 33 patients.

Cardiac function before and after surgery was evaluated by echocardiography and scintigraphy. Results were expressed as mean  $\pm$  standard deviation of the mean. The significance of differences between the mean values of measurements for different groups was determined by Student's *t* test. A *p*-value of less than 0.05 was considered significant. Patients were followed up by telephone or letter. Patient survival was assessed by actuarial analysis according to the method of Kaplan and Meier.<sup>7)</sup> Differences between actuarial curves were determined using the generalized Wilcoxon analysis and Kaplan and Meier analysis.

## RESULTS

Forty-two patients received bilateral ITA grafts. These patients received a total of 116 coronary grafts, or an average of 2.8 grafts per patient. Besides the ITA grafts, 30 other grafts were constructed with 18 autologous veins and 12 right gastroepiploic arteries. The ITA graft and corresponding recipient arteries are listed in Table 2. Twenty-seven left ITAs (LITAs) were grafted to the left anterior descending (LAD) coronary artery, 3 LITAs to the diagonal artery, and 14 LITAs to the circumflex artery (including 2 LITA sequential grafts to the LAD and the diagonal artery). Twelve right ITAs (RITAs) were grafted to the LAD, 8 RITAs to the diagonal artery, 9 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 seven patients, the circumflex artery in nine patients, and the diagonal artery in five patients.

TABLE 2. Coronary arteries grafted and type of conduits

LITA	[	LAD	27
		Diagonal	3
		CX	14
RITA	[	LAD	12
		Diagonal	8
		CX	9
		RCA	13
Right gastroepiploic artery		12	
Saphenous vein		18	
Total		116 (mean, 2.8)	
		(Feb. 1988~May 1993)	

LITA, left internal thoracic artery; RITA, right internal thoracic artery; LAD, left anterior descending artery; CX, circumflex artery; RCA, right coronary artery

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 experienced postcardiotomy cardiogenic shock but was saved by using a left ventricular assist device, and one developed renal failure necessitating dialysis. Two patients died during the follow-up period. One patient died of cerebral infarction six months after surgery. Another patient died suddenly at home 10 months after the operation. Thirty-seven patients underwent angiography one month after surgery. The patency rate of the ITA grafts was 94.6% (70/74) and those of the saphenous vein and right gastroepiploic artery were 73% (11/15) and 100% (9/9), respectively.

Cardiac function was evaluated before and after surgery by echocardiography in 16 patients (Fig. 1). The left ventricular diastolic dimension (LVDd) decreased from  $56.4 \pm 5.2$  mm to  $50.5 \pm 8.8$  mm ( $p < 0.01$ ), while the left ventricular systolic dimension (LVDs) decreased from  $40.8 \pm 9.8$  mm to  $37.7 \pm 10$  mm ( $p < 0.01$ ). The fractional shortening (FS) decreased from  $29.8 \pm 10.4\%$

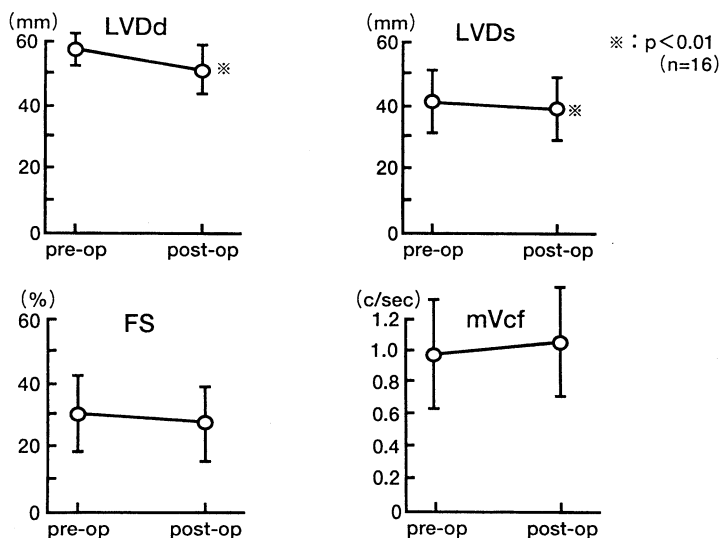


Fig. 1. Pre- and postoperative cardiac functions as determined by echocardiography. LVDd, left ventricular diastolic dimension; LVDs, left ventricular systolic dimension; FS, fractional shortening; mVcf, mean velocity of circumferential fiber shortening

to  $25.8 \pm 7\%$ . The mean velocity of circumferential fiber shortening (mVcf) increased from  $0.96 \pm 0.35$  c/sec to  $1.05 \pm 0.34$  c/sec. Multiple-gated equilibrium cardiac blood pool scintigraphy was performed during exercise in 17 patients. The left ventricular ejection fraction (LVEF) determined by this technique and the percent change of LVEF from rest to exercise ( $\% \Delta \text{EF}$ ) are shown in Fig. 2. Before surgery, the rest and exercise LVEF values were  $50.3 \pm 12.6\%$  and  $46.0 \pm 12.8\%$ , respectively ( $p < 0.05$ ). After surgery, they were  $49.3 \pm 14.5\%$  and

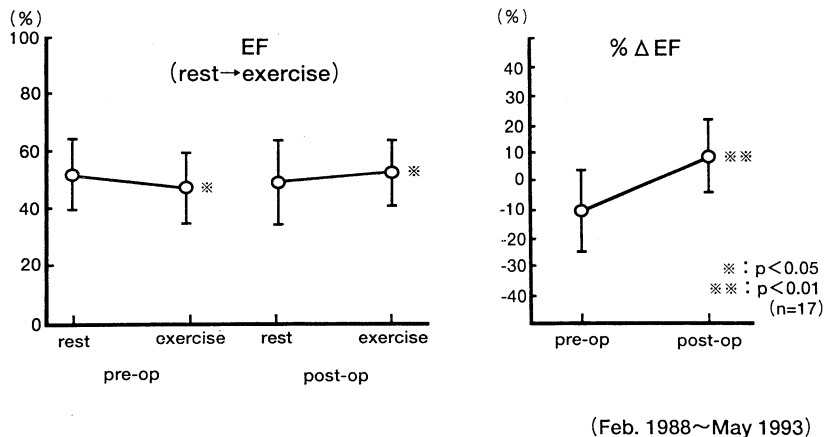


Fig. 2. Pre- and postoperative left ventricular ejection fractions as determined by scintigraphy. EF, ejection fraction

52.4±11.8%, respectively (p<0.05). The percent changes of LVEF were -9.6±14% before surgery and 9.5±13.1% after surgery (p<0.01). The right ventricular ejection fraction (RVEF) determined by the same technique and the percent change of RVEF from rest to exercise (%ΔEF) were shown in Fig. 3. Before surgery, the rest and exercise RVEF were 39.7±7.4% and 34.2±7.8%, respectively (p<0.01). After surgery, they were 40.4±10.6% and 40.0±8.8%, respectively. The percent changes of RVEF were -13.0±15.2% before surgery and -2.0±17.4% after surgery (p<0.05).

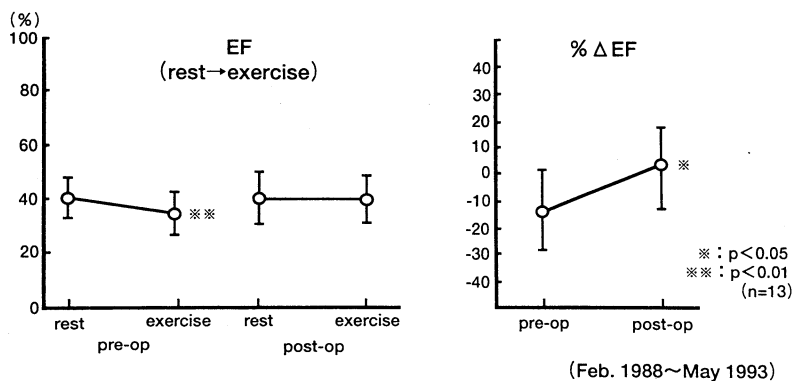


Fig. 3. Pre- and postoperative right ventricular ejection fractions as determined by scintigraphy. EF, ejection fraction

All 40 survivors who underwent bilateral ITA grafting were followed up to May 1993, with a mean follow-up period of 33.5 months (range: 5 to 63

months). Thirty-two patients were in NYHA class I, five in class II and one in class III in May 1993. Patient survival was assessed by actuarial analysis. For comparison, 27 patients who received single ITA graft and 32 patients who received saphenous vein grafts only were also followed up (Table 3). Three patients were lost to follow-up in the single ITA group and nine patients in the

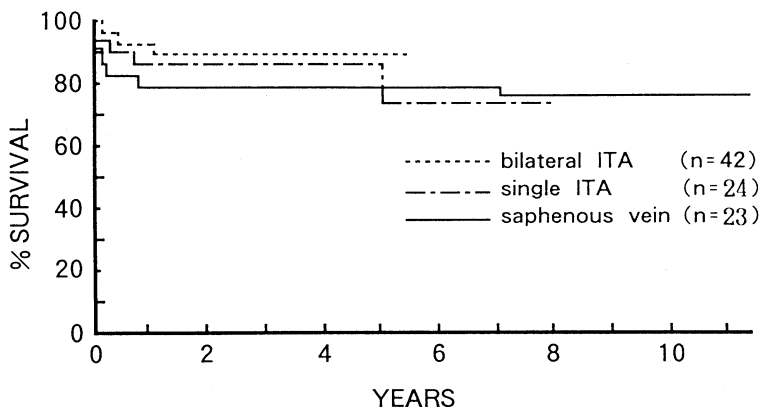
TABLE 3. Clinical profile of patients receiving bilateral ITA, single ITA or saphenous vein grafts

	Bilateral ITA	Single ITA	Saphenous Vein
No. of patient	42	27	32
Age	45-70 (59)	46-74 (60)	27-75 (58)
Gender (male)	39	21	21
Grafts per patient	2.8	1.9	2.0
Follow-up (month)	5-63 (33.5)	1-96 (40.1)	4-155 (91.6)
Operative death	2	2	3
Late death	2	3	5

(June 1981~May 1993)

ITA, internal thoracic artery; parentheses indicate mean values

saphenous vein group. The survival data for the three groups are shown in Fig. 4. At five years, survival was 91% for patients with bilateral ITA grafts. On the other hand, survival rates for patients with single ITA grafts were 84% at five years and 73% at eight years. Survival rates for patients with saphenous vein grafts only were 78% at five years and 74% at eight years. At five years, the survival data showed no significant differences among the three groups.



(June 1981~May 1993)

Fig. 4. Survival rates of patients receiving saphenous vein, single ITA or bilateral ITA grafts. 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 usually caused by intimal fibroplasia and late vein graft stenoses by vein graft atherosclerosis.<sup>8)</sup> He also stated that late stenoses in saphenous vein grafts to the left anterior descending coronary artery predict a high rate of death and cardiac events and are an indication for reoperation. Indeed, reoperation improves the survival of patients with late vein graft stenoses, particularly those with stenotic grafts to the left anterior descending coronary artery.<sup>9)</sup>

Internal thoracic artery (ITA) grafts rarely develop atherosclerosis and display a late patency rate in the 90th percentile up to 12 years postoperatively.<sup>10)</sup> The ITA is particularly resistant to intimal hyperplasia because the internal elastic lamina is perfectly formed at an early age and does not fracture with the passage of time.<sup>11)</sup> Recent work has suggested that vasoactive mediators within the ITA wall may protect this vessel against the development of atherosclerosis. Chaikouni 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.<sup>12)</sup> In addition to these basic studies, clinical results have supported the superiority 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.<sup>2)</sup>

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<sup>13)</sup> and the construction of sequential grafts.<sup>14)</sup> In addition, the use of free ITA grafts by constructing an anastomosis with the aorta<sup>15)</sup> and the use of both ITAs<sup>3-5)</sup> have been suggested. Barner reported on the results of double internal mammary-coronary bypass in 100 patients in 1974<sup>16)</sup> and Geha used crossed double internal mammary-coronary artery grafts in 36 patients with excellent functional results.<sup>17)</sup> Galbut 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.<sup>4)</sup> The actuarial survival was 80% at 10 years and 60% at 15 years. Fiore 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%).<sup>5)</sup> The improvement in actuarial survival and freedom from myocardial infarction observed in patients with bilateral ITA grafts were particularly marked in the late 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 is increasing. Only by the examination of late survival will these subtle differences become apparent. According to our follow-up data, at five years, survival rates for patients with bilateral ITA grafts, single ITA grafts and saphenous vein grafts only were 91%, 84% and 78%, respectively. The survival for patients with bilateral ITA grafts was superior to that for patients with single ITA grafts or saphenous vein grafts only, but these

differences were not statistically significant.

If the left ITA is used for the left anterior descending artery or the obtuse marginal artery, the in situ right ITA can be grafted to the left anterior descending artery, the diagonal artery, the high lateral branch of the circumflex artery or the right coronary artery. Grafting the in situ right ITA to the mid-right coronary artery may be suboptimal, since the progression of atherosclerosis at the right coronary artery bifurcation may lead to early graft closure. Thus, the right ITA often needs to be used as a free graft. The free ITA graft is useful for two reasons.<sup>15)</sup> First, its use may allow the surgeon to avoid crossing the midline, a procedure which can jeopardize the use of the right ITA at reoperation. Second, the use of a free graft provides additional length to reach a distal anastomosis. In our series, 21/42 right ITA grafts had to be free grafts, even though we first attempted multiple transections of the fascia in the ITA pedicle. Questions have arisen about the effect of compromising the vasa vasorum and the lymphatic drainage of the pedicle when the ITA is used as a free graft. Landymore reported that nourishment of the media may occur from the lumen and not via the vasa vasorum, which do not penetrate the adventitia in the ITA.<sup>18)</sup> Sims postulated that an internal elastic lamina without gross deficiencies tends to suppress major intimal thickening.<sup>11)</sup> The low incidence of ITA graft atherosclerosis is probably also related to vasoactive properties of the arterial wall that have a protective effect. For these reasons, use of the ITA as an aortocoronary graft does not compromise the long-term results. 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. Cosgrove has reported that wound infection is 1%-3% higher in bilateral ITA graft patients and that this is related to diabetes and age more than any other factors. He concluded that bilateral ITA grafting did not increase surgical mortality and only increased surgical morbidity by slightly increasing transfusion requirements.<sup>19)</sup> 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.<sup>20)</sup> In our series, we experienced two operative deaths. One patient died of colon perforation, but this was not directly related to the surgical technique used. 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 five coronary artery bypass grafts. From the viewpoint 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 a minimal effect on postoperative cardiac function, and three cases of postoperative bleeding. These complications can be minimized as surgical experience is increased and the operating time is shortened. As far as infection is concerned, we have not experienced sternal infection in this series.

We have used the right gastroepiploic artery as an in situ graft for the right posterior descending artery in 11 patients and for the circumflex artery in 1



patient. Postoperative angiography revealed all grafts to be patent (9/9). Lytle reported that histologically, right gastroepiploic artery segments from 18 patients could not be distinguished from ITA segments and that no evidence of atherosclerosis was found.<sup>21)</sup> He reported that early graft patency had been excellent and concluded that the histologic similarity between the right gastroepiploic artery and ITA suggests favorable long-term results. Suma reported mid-term results in 200 patients who received the right gastroepiploic artery. The graft patency was 95% (144/152) in the early postoperative period and 95% (38/40) in the late postoperative period. He concluded that the gastroepiploic artery is a suitable conduit for coronary artery bypass grafting in terms of low surgical risk, high patency rate, and excellent patient outcome.<sup>22)</sup>

We have now used bilateral ITA grafts for myocardial revascularization in 42 patients. The postoperative functional results were satisfactory in a short to mid-term follow-up period, and the patency rate of ITA grafts was also excellent. It is concluded that coronary artery bypass grafting using bilateral ITA grafts can be performed with minimal 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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