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Midterm Results of Routine Bilateral Internal Thoracic Artery Grafting

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ABSTRACT

Background: Skeletonized dissection of the internal thoracic artery (ITA) decreases the occurrence of sternal devascularization, thus decreasing the risk of postoperative sternal complications in patients undergoing bilateral ITA grafting.

Methods: From April 1996 to July 1999, 1000 consecutive patients underwent bilateral skeletonized ITA grafting. Of the 770 male and 230 female patients, 420 were older than 70 years, and 312 had diabetes.

Results: Operative mortality was 3.3%. Follow-up (40-78 months) revealed 79 late deaths, and the Kaplan-Meier 6-year survival rate was 88%. Cox regression analysis revealed increased overall mortality (early and late) in patients with preoperative congestive heart failure (risk ratio [RR], 2.13; 95% confidence interval [CI], 1.31-3.45), in patients with peripheral vascular disease (RR, 5.52; 95% CI, 3.31-9.19), and in patients older than 70 years (RR, 2.18; 95% CI, 1.37-3.47). Early postoperative morbidity included sternal infection (2.2%), cerebrovascular accident (1.6%), and perioperative myocardial infarction (1%). Multiple regression analysis showed repeat operation (odds ratio [OR], 7.5; 95% CI, 1.77-31.6) and chronic obstructive pulmonary disease (OR, 3.6; 95% CI, 1.27-10.75) to be independent predictors of sternal infection. During follow-up, angina returned in 95 patients, 24 of whom required reintervention (20 cases of percutaneous balloon angioplasty and 4 reoperations). Postoperative coronary angiography performed in 87 patients revealed an ITA patency rate of 91%.

Conclusions: Bilateral skeletonized ITA grafting is associated with satisfactory early and midterm results. We do not recommend the use of this surgical technique in patients with chronic obstructive pulmonary disease.

INTRODUCTION

The use of the left internal thoracic artery (ITA) as a bypass graft has been shown to result in a better early patency rate and improved survival in all patients, including elderly patients [Galbut 1993], but most published series have failed to show an additional survival benefit with the use of bilateral ITA grafts [Lytle 1992, Leavitt 1997].

The lack of survival benefits and the technical complexity of performing complete arterial revascularization with bilateral ITAs are the probable causes of the relative lack of popularity of this technique. The Society of Thoracic Surgery database includes 153,000 coronary artery bypass graft (CABG) operations performed in the United States and Canada, only 4% of which involved the use of bilateral ITAs [Loop 1998].

In contrast to most previously published reports, three important large-scale studies have shown that long-term survival with bilateral ITA grafting is better than that with single ITA. Lytle et al reported that the 10- and 15-year survival rates of bilateral ITA patients were 84% and 67%, respectively, compared with 79% and 64% for patients with single ITA ($P < .001$). Reoperative and angina-free survival, as well as freedom from additional revascularization procedures, was significantly higher in the bilateral ITA subset [Lytle 1998]. In another study performed by Buxton et al [Buxton 1998], the 10-year actuarial survival rate of bilateral ITA patients was 86% ± 3%, compared with 71% ± 5% for a single ITA ($P < .001$). In that report, the use of bilateral ITAs improved the rate of freedom from late myocardial infarction and reoperations. The third report by Schmidt et al demonstrated that the survival benefit with bilateral ITA operations is achieved by grafting the ITA conduits to coronary arteries supplying the left ventricle rather than to the right coronary system [Schmidt 1997].

In all of the above series, extensive arterial grafting with bilateral ITAs was used preferentially in a selected group of young male, nonobese, and nondiabetic patients [Schmidt 1997, Buxton 1998, Lytle 1998].

Studies reporting results of bilateral ITA grafting contain preselected patients operated on over a relatively long period [Cunningham 1992, Schmidt 1997, Lytle 1998]. Most patients were preselected for this procedure according to their life expectancy, and few of the patients older than 70 years were offered the option of bilateral ITA grafting. Unlike these earlier reports, we describe in our report results in a nonselected group of patients. Complete arterial grafting with bilateral ITAs was the preferred method of myocardial revascularization for patients of all ages during the 40-month study period. Bilateral ITA grafting was performed in 71% of the patients referred for CABG during this time period, and 42% of them were 70 years of age or older.

The purpose of this report is to analyze early and midterm (up to 78 months) results of a series of 1000 consecutive patients operated on with bilateral skeletonized ITAs.

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Table 1. Patient Characteristics and Overall (Early and Late) Mortality (n = 112)*

Factor	Prevalence (N = 1000), n	Mortality with Factor, n (%)	Mortality without Factor, n (%)	*P*
Age ≥70 y	420	66 (15.8)	46 (7.9)	<.001
Female sex	230	27 (11.7)	85 (11)	NS
Left main stenosis	317	39 (12.3)	73 (10.8)	NS
Acute MI <1 wk	267	40 (15)	72 (9.8)	NS
PTCA	115	14 (12.2)	98 (11.1)	NS
Ejection fraction ≤35%	155	29 (18.7)	83 (9.9)	.056
CHF	168	42 (25)	70 (8.4)	<.001
Preoperative IABP	36	10 (27.8)	102 (10.6)	.066
Diabetes	312	43 (13.8)	69 (10.1)	NS
PVD	65	26 (40)	85 (9)	<.001
Chronic renal failure	77	12 (15.6)	100 (10.9)	NS
Severe COPD	83	17 (20.5)	95 (10.4)	.010
Emergency surgery	136	22 (16.2)	90 (10.4)	NS
Repeat CABG	24	4 (16.7)	108 (11.1)	NS
Surgical technique (composite)	648	80 (12.3)	32 (9.1)	NS
Use of GEA	231	22 (9.5)	90 (11.7)	NS
Use of SVG	158	20 (12.7)	92 (10.9)	NS

*MI indicates myocardial infarction; NS, nonsignificant; PTCA, percutaneous transluminal balloon angioplasty; CHF, congestive heart failure; IABP, intra-aortic balloon counterpulsation; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; CABG, coronary artery bypass grafting; GEA, gastroepiploic artery; SVG, saphenous vein graft.

MATERIALS AND METHODS

Between May 1996 and July 1999, 1000 consecutive patients underwent CABG by means of bilateral skeletonized ITA grafting. The patient group comprised 71% of the 1408 patients who underwent CABG surgery during this period in the Tel Aviv Sourasky Medical Center.

The patients' preoperative and operative characteristics are presented in Table 1. The ITAs were dissected as skeletonized arteries [Gurevitch 2000] before heparin administration to decrease the risk of damage and hematoma formation in the region of the side branches during dissection. The technique of skeletonized ITA dissection was performed routinely and daily in our operating rooms, and cautery, which might cause direct or indirect thermal injury, was not used.

The incidence of injury to the ITAs was extremely low and occurred mainly in the learning curve period.

Operations were performed with cardiopulmonary bypass. The myocardial preservation technique involved intermittent warm cardioplegia (30°C-32°C) [Calafiore 1995].

We prefer the use of the bilateral ITA as in situ grafts for myocardial revascularization. The two ITAs, in combination with the right gastroepiploic artery (GEA) or a saphenous vein graft (SVG) gave us three sources of blood supply. We believe that more blood sources are associated with an improved long-term outcome. The cross arrangement (Figure 1) is based on the assumption that the patency rates of the right ITA on the left anterior descending coronary artery (LAD) is similar to that of the left ITA on the LAD. To improve the probability of late survival, the surgeon should make every effort to use both ITA grafts for the left system [Schmidt 1997]. In 231 patients, the right GEA was used as a third arterial conduit to bypass the posterior descending branch of the right coronary artery (Figure 2). In only 158 patients was the right coronary system grafted with an SVG.

We do not use the cross technique in patients who have a short right ITA, a very long ascending aorta, an enlarged right ventricle, a too distal or unpredictable LAD anastomotic

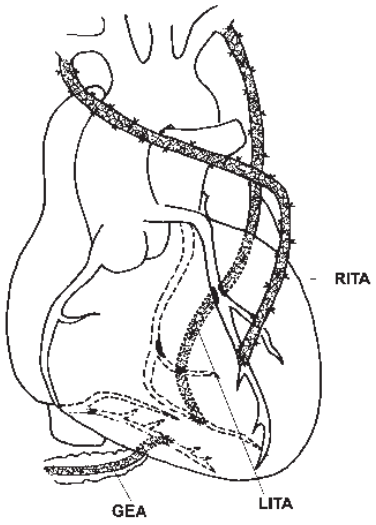

Figure 1. The cross arrangement: in situ right internal thoracic artery (RITA) to the left anterior descending coronary artery and the left ITA (LITA) to the circumflex marginal artery. GEA indicates gastroepiploic artery.

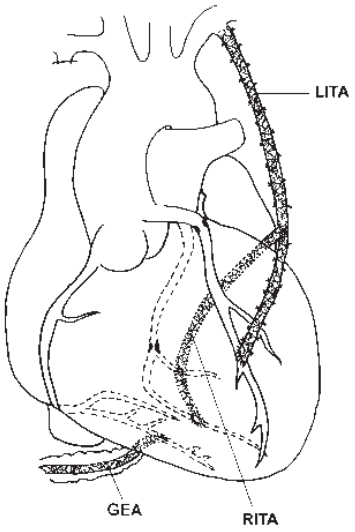

Figure 2. Composite T graft. LITA indicates left internal thoracic artery; RITA, right internal thoracic artery; GEA, gastroepiploic artery.

site, or a high probability of future reoperations (for example, combined aortic valve replacement and CABG). In most of these cases (648 patients), we used the composite arterial grafting technique.

The composite graft can be prepared before patient connection to cardiopulmonary bypass. Most of the composite grafts included end-to-side anastomosis of the free right ITA on an in situ left ITA (Figure 2). To date, injury to the ITA requiring a revision of the original operative plan has occurred in less than 5% of our patients, and in most cases, the operation could still be based on both ITAs.

If injury is caused to the proximal right ITA, the operation can still be based on constructing a composite graft, in which the right ITA is anastomosed end-to-side to the in situ left ITA as a free graft. The operative plan is changed in these cases only when our original plan was to use the cross technique.

If the proximal left ITA is injured, a reverse composite graft can be constructed, in which the free left ITA is connected end-to-side to the in situ right ITA. This arrangement of a free left ITA on an in situ right ITA can also be used when the spontaneous free flow of the left ITA is inadequate.

Our current preference is to use the small composite Y graft for the LAD diagonal artery when we do not need grafts to the circumflex system. In cases that require grafts to the circumflex system, the left ITA is anastomosed to the LAD, and the diagonal is one of the vessels supplied by the free right ITA (sequential grafting).

To decrease the risk of spasm of the arterial grafts, we treat all of our patients with high-dose intravenous infusion of isosorbide dinitrate (Isoket; 4-20 mg/h) during the first 24 to 48 hours postoperatively [Sofer 1999]. Systolic blood pressure was maintained above 100 to 120 mm Hg. From the second postoperative day, the patients whose GEA was used were treated with calcium channel blockers (diltiazem; 90-180 mg/day administered orally) for at least 3 months.

Statistical Analysis

Data are expressed as the mean ± standard deviation or as a proportion. The χ^2 test and 2-sample *t* tests were used to compare discrete and continuous variables, respectively. Multivariate logistic regression analysis was used to predict early mortality, sternal infection, and return angina by various risk factors. The odds ratio (OR) and the 95% confidence interval (CI) are given. The Cox proportional hazard model was used to evaluate the influence of preoperative variables on late and overall mortality. Postoperative survival is expressed by the Kaplan-Meier method. All analyses were performed by means of SPSS 9.0 software (SPSS, Chicago, IL, USA).

RESULTS

The 1000 study patients received 2 to 6 grafts (mean, 3.1) each. The average cardiopulmonary bypass time was 78 ± 27 minutes, and the aortic cross-clamping time was 65 ± 21 minutes. The operative mortality rate (30 days postoperatively) was 3.3% (33 of 1000 patients). An increased mortality rate was noted in emergency patients, in patients supported preoperatively with intra-aortic balloon counterpulsation (IABP), in patients with congestive heart failure, peripheral vascular disease, or an ejection fraction <35%, and in patients operated on within the first 7 days of acute myocardial infarction (Table 2). After adjustment for other demographic, clinical, and surgical predictors of outcome, only preoperative peripheral vascular disease (OR, 2.88; 95% CI, 1.09-7.64), and congestive heart failure (OR, 3.65; 95% CI 1.68-7.98)

Table 2. Bilateral Internal Thoracic Artery Grafting and Early Mortality (n = 30)*

Factor	Prevalence (N = 1000), n	Early Mortality with Factor, n (%)	Early Mortality without Factor, n (%)	*P*
CHF	168	14 (8.2)	19 (2.2)	<.001
Acute MI	267	16 (6)	17 (2.3)	.006
IABP	36	5 (13.8)	27 (2.8)	.001
EF <35%	155	11 (7.1)	22 (2.6)	.006
Emergency	136	9 (6.6)	24 (2.7)	.007
PVD	65	6 (9.2)	27 (2.9)	.007

*CHF indicates congestive heart failure; MI, myocardial infarction; IABP, intra-aortic balloon counterpulsation; EF, ejection fraction; PVD, peripheral vascular disease.

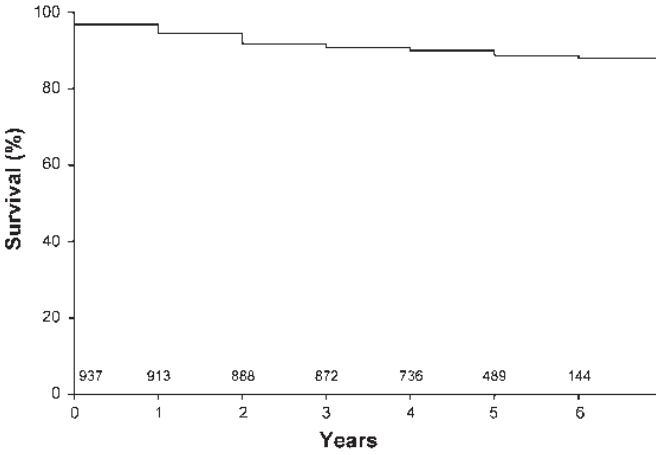

Figure 3. Kaplan-Meier survival curve.

emerged as independent risk factors for early mortality. Postoperative morbidity included 10 cases (1%) of perioperative myocardial infarction, 16 patients (1.6%) who experienced stroke, and 22 patients (22%) who sustained sternal wound infection. Sixteen patients (1.6%) experienced postoperative bleeding that required reopening of the chest.

The only significant risk factors for sternal infection were chronic obstructive pulmonary disease (OR, 3.66; 95% CI, 1.25-10.74) and repeat operations (OR, 7.48; 95% CI, 1.7-31.6).

Follow-up data between 40 months and 78 months postoperatively were available for 938 (97%) of the 967 surviving patients. There were 79 late deaths, and the 6-year actuarial survival rate (Kaplan-Meier) was 88% (Figure 3). There were 10 cases (1%) of late myocardial infarction, and 95 patients (9.5%) reported a return of angina. An increased rate of angina return was noted in patients with peripheral vascular disease (OR, 3.04; 95% CI, 1.6-5.77) and in patients younger than 70 years (OR, 2.03; 95% CI, 1.27-3.33). Eighty-seven patients underwent cardiac catheterization during the follow-up period, 78 because of chest pain, and 9 patients consented to elective catheterization within the framework of our learning to use the composite graft. Of the 176 distal ITA anastomoses, 160 (91%) were patent. There were 15 occluded ITAs (11 with string sign). Reinterventions included 4 repeat operations and 20 percutaneous transluminal balloon angioplasties and stents.

Analysis of both early and late mortality (Table 1) showed the following risk factors to be independent predictors of overall mortality: peripheral vascular disease (risk ratio [RR], 5.52; 95% CI, 3.31-9.2), congestive heart failure (RR, 2.13; 95% CI, 1.31-3.45), and age >70 years (RR, 2.1; 95% CI, 1.37-3.47). Similar findings were observed when late mortality was analyzed separately.

DISCUSSION

The current conventional and most commonly used operative procedure for myocardial revascularization in patients of all ages involves using one ITA together with one or more SVGs [Lytle 1992, Leavitt 1997]. The major surgical objective is to supply the LAD with an ITA to improve the patient's chances of survival [Barner 1985, Loop 1986].

Because SVG failure is a major drawback of CABG [Lytle 1992], surgical techniques that involve the minimal use of SVGs have been attempted. In most centers, the ITA is isolated from the chest wall as a pedicle, together with the vein, muscle, fat, and accompanying endothoracic fascia [Barner 1985, Loop 1986, Lytle 1998]. Harvesting is relatively quick, because cautery is used to separate the pedicle from the chest wall. However, cauterization damages the blood supply to the sternum, and this damage in turn impedes sternal healing and exposes the sternum to the risks of early dehiscence and infection in operations involving both ITAs. The risk of sternal infection is particularly high in patients with a preoperatively limited sternal blood supply, such as elderly patients and patients with diabetes [Carrier 1992, He 1994].

A surgical technique was recently developed in which the ITA is dissected as a skeletonized vessel [Cunningham 1992, Parish 1992]. The skeletonized artery is isolated gently with scissors and silver clips without the use of cauterization. Skeletonized ITA dissection leaves the vein, the muscle, and the accompanying tissue in place. The advantages are that the dissected ITA is longer and its spontaneous blood flow is greater than that of the pedicled ITA [Loop 1986], allowing the use of both ITAs as grafts to all necessary coronary vessels.

Harvesting the ITA as a skeletonized artery preserves the collateral blood supply to the sternum, enabling more rapid healing and a low risk of infection [Sauvage 1986]. In a previous study describing our experience with 545 patients, we showed that the use of skeletonized bilateral ITAs was not associated with an increased risk of sternal infection [Sofer 1999] while chronic obstructive pulmonary disease and emergency operation were found to be associated with an increased risk of infection. In addition, we did not find an increased occurrence of deep sternal infection in diabetic patients compared with nondiabetic patients [Sofer 1999, Matsa 2001, Pevni 2001]. Our current report is based on 1000 consecutive patients who underwent CABG with the use of skeletonized bilateral ITAs. The rate of deep sternal wound infection was relatively low (2.2%) and comparable with that of patients undergoing CABG with a single ITA. Multivariable analysis demonstrated severe chronic obstructive pulmonary disease and repeat operation to be associated with an increased risk of sternal infection, whereas diabetes, sex, and old age were not found to be significant predictors. Similarly, we did not find an increased occurrence of sternal infection in patients with the insulin-dependent type of diabetes mellitus.

A new observation of the present study was the surprisingly high incidence of deep sternal wound infections in patients undergoing repeat operation. This finding may be associated with a decreased blood supply to the healing zone of a sternum undergoing resternotomy, but no definitive explanation has been found.

Our study clearly defines two subgroups of patients with increased operative and overall (early and late) mortality. Patients with peripheral vascular disease and congestive heart failure are probably those with a diffuse and advanced form of atherosclerotic involvement of the heart and peripheral

vessels. This finding may partly explain the unfavorable early and late results.

An age older than 70 years was not a risk factor for 30-day mortality in our study; however, it was associated with a decreased late survival rate. The use of bilateral ITAs in the elderly is controversial. He et al reported an operative mortality of 24% in elderly patients (≥70 years) who underwent bilateral ITA grafting [He 1994]. Moreover, the use of bilateral ITAs in the older patients described in their report was found to be a major risk factor for operative mortality because the mortality rate for patients receiving one ITA was only 6.8% ($P < .007$). It is important to note that the ITA described in their report was used as a pedicled conduit, and, as the authors stated, the fact that only 4% of the patients were grafted with bilateral ITAs may explain the higher operative mortality and increased use of postoperative IABP (16.2% versus 5.9%; $P < .015$).

In a study by Lytle et al [Lytle 1998], the number of patients older than 60 years operated on with bilateral ITAs was relatively small; however, bilateral ITA grafting improved the survival rate of this subset of older patients compared with patients older than 60 years with a single ITA graft.

The only large series (1467 patients) comparing bilateral with single ITA grafting in the elderly population was reported by Galbut et al [Galbut 1993]. In this study, patients with bilateral ITAs had lower hospital mortality rates (3.1%), compared with 6.4% for patients with a single ITA, and the late survival rate (mean, 43 months) was better as well (69.7% versus 60.7%).

Despite the low risk of sternal infection and early mortality, patients older than 70 years in our study have an increased risk of late mortality, and the use of bilateral ITAs for these patients is still controversial. In conclusion, this study shows that left-sided arterial revascularization with skeletonized bilateral ITAs is safe. Morbidity is low even in old or diabetic patients, and midterm survival is good. This technique may be used routinely in most patients referred for CABG. The midterm results for this cohort showed that chronic obstructive pulmonary disease and repeat operations are associated with an increased risk of sternal infection, and we do not advocate the use of this procedure in these subgroups of patients.

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