Risk factors for operative mortality and sternal wound infection in bilateral internal mammary artery grafting

To investigate risk factors for operative mortality and sternal infection in patients undergoing bilateral internal mammary artery grafting, we analyzed the data of 199 patients who underwent this procedure from January 1986 through June 1992. These patients were also compared with those who underwent only saphenous vein grafting (1664 cases) and those who underwent unilateral internal mammary artery grafting (3359 cases) during the same time frame. The operative mortality was 3.52 % (7/199) in the patients having bilateral internal mammary artery grafting, 2.71 % (91/3359) in those having unilateral internal mammary artery grafting, and 8.53 % (142/1664) in the patients having saphenous vein grafting ($p < 0.0001$). The occurrence rate of sternal infections was 2.45 % (5/199) for bilateral internal mammary artery grafting, 1.32 % (13/1664) for saphenous vein grafting, and 1.19 % (20/3359) for unilateral internal mammary artery grafting ($p = 0.27$). The univariate analysis revealed that age, history of congestive heart failure, emergency operation, ejection fraction, and aortic crossclamp time were significantly correlated with operative mortality and that obesity was correlated with sternal wound infection. Stepwise multiple logistic regression identified that old age (≥ 70 years) ($p < 0.0001$), long perfusion time ($p < 0.0001$), and emergency operation ($p = 0.0004$) are risk factors for operative mortality and that obesity ($p = 0.0009$) is the only significant risk factor for sternal wound infection. We conclude that bilateral internal mammary artery grafting does not increase operative mortality in properly selected patients. However, this procedure should be carefully chosen in elderly (≥ 70 years) patients and for emergency operation. Obese patients have a high risk for sternal infection after bilateral internal mammary artery grafting. (*J THORAC CARDIOVASC SURG* 1994;107:196-202)

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The internal mammary artery (IMA) has been widely used as a coronary artery bypass conduit because of its superior long-term patency rates.¹⁻⁴ Both single and bilateral IMAs have been used in coronary artery bypass grafting with or without saphenous vein conduits. The extensive use of IMA grafting, including bilateral IMA

grafting,⁵⁻¹¹ sequential anastomoses,¹² and free grafts,¹³ is based on the superior graft patency of this conduit and on the fact that the IMA improves long-term survival, decreases the rate of reoperation, and improves reoperation-free survival and cardiac morbidity in multiple coronary artery disease. The extensive use of bilateral IMA grafting has been believed to further enhance the advantages of the IMA graft. However, one of the controversial questions is whether the extensive use of the IMA, as in bilateral IMA grafting, increases operative mortality or morbidity. Although a study by Cosgrove and associates¹⁴ suggested that bilateral IMA grafting does not increase surgical mortality, they indicated that the technique increases operative morbidity by an increase in the mean transfusion requirement. Other studies have also demonstrated that bilateral IMA grafting increases the likelihood of perioperative myocardial infarction¹⁵ and, in

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particular, sternal infection.^{7, 16-19} Furthermore, risk factors for operative mortality in bilateral IMA grafting have not yet been determined and little information is available for the predictive risk factors in sternal infection after the operation. This study was designed to determine if bilateral IMA grafting increases operative risk and the likelihood of sternal infection and to identify predictive risk factors for operative mortality and sternal infection.

Patients and methods

From January 1986 through June 1992, 5222 patients underwent coronary artery bypass grafting. Patients who had valve operations combined with coronary artery bypass grafting were excluded. The computerized cardiac surgery registry provided the basis for this study. Among these patients, 199 underwent bilateral IMA grafting, 3359 patients underwent unilateral IMA grafting, and 1664 patients underwent saphenous vein grafting. Both patients having bilateral and those having unilateral IMA grafting may have had saphenous vein grafting as a part of their bypass grafts as well. The present study is composed of two parts.

Part I. Patients having bilateral IMA grafting were compared with those having unilateral IMA or saphenous vein grafting. The preoperative, intraoperative, and postoperative variables and the operative mortality or morbidity in patients having bilateral IMA grafting were compared with those in the patients having saphenous vein grafting or in the patients having unilateral IMA grafting. The clinical characteristics were recorded by cardiologists. The criterion of obesity was based on the body mass index. Body mass index was calculated by dividing measured body weight in kilograms by the height in meters squared. A body mass index greater than 27.5 kg/m² (>120% of "normal" body mass index) was considered to indicate obesity.²⁰

Part II. In the patients having bilateral IMA grafting (199 cases), the correlation between preoperative, intraoperative, and postoperative variables and operative mortality or sternal infection was tested by univariate analysis. After univariate analysis, logistic regression was used to further test significant variables in a multivariate situation.

Indications for bilateral IMA grafting. In general, a second IMA graft was primarily preferred for younger patients with good ventricular function. A right IMA would be grafted to the mid or distal RCA or, alternatively, a second IMA graft would be placed on a large obtuse marginal artery. Use of the distal branch of the IMA was avoided if possible.

Catheterization data. All patients underwent preoperative catheterization of the left side of the heart and coronary angiography. Patients were grouped into categories of single, double, or triple vessel disease. Significant coronary artery disease was defined as 70% stenosis or more in any view of the right, left anterior descending, or left circumflex artery or their major branches. Left main artery disease was defined as 50% stenosis or more. Left ventricular ejection fraction was calculated according to left ventriculography.

Operative technique. A similar operative technique was used throughout this experience. After the sternotomy, the left IMA was mobilized from the chest wall. A Favaloro or similar retractor was used for IMA pedicle dissection. Low-voltage electrocoagulation was used to avoid thermal damage to the

IMA. The IMA was mobilized from its origin to the distal end close to the bifurcation. The IMA pedicle was then wrapped with a gauze swab immersed in papaverine solution. The right IMA was then mobilized by a similar technique. After heparinization, the IMAs were divided distally and free flow was examined. The decision of which IMA or saphenous vein graft to be used for which diseased coronary artery was based on the individual surgeon's preference. Coronary anastomosis was performed with continuous 8-0 Prolene suture (Ethicon, Inc., Somerville, N.J.) with the aid of magnification. The core temperature was lowered to 28° C. Myocardial protection was achieved by antegrade or retrograde (or both) infusion of cardioplegic solution and topical cooling. The proximal anastomosis was performed with the aid of cardiopulmonary bypass if vein grafts were needed in addition to the bilateral IMA grafts. The sternum was closed with interrupted 18-gauge stainless steel wires. The fascial tissue and subcutaneous tissue were closed with running absorbable suture and the skin was closed with continuous subcuticular suture.

Statistical analysis. Univariate testing of variables was performed with χ^2 analysis or Fisher's exact test on discrete variable comparisons. Unpaired *t* test or one-way analysis of variance was used on continuous variable comparisons. These univariate analyses were performed separately for operative mortality and occurrence of sternal infection. Stepwise multiple logistic regression analysis was then used to further test significant variables in a multivariate situation.²¹⁻²³ Any variables that had trends associated with operative mortality or with sternal infection ($p < 0.3$) were included in stepwise multiple logistic regression analysis. The logistic regression was also performed separately for operative mortality and sternal infection. Univariate analysis and logistic regression were performed with the SAS Program (SAS Institute, Inc., Cary, N.C.). A *p* value of less than 0.05 was considered significant.

Results

Part I. With the exception of New York Heart Association functional class, patients who underwent bilateral IMA grafting were better operative candidates than the other patients. They were younger (54.78 ± 0.79 years old) than patients undergoing unilateral IMA (59.20 ± 0.17 years old, $p < 0.01$) or saphenous vein grafting (65.65 ± 0.27 years old, $p < 0.001$). Fewer patients undergoing bilateral IMA grafting (12.56%) were older than 70 years ($p < 0.001$), were female (11.56%, $p < 0.05$), were obese (12.06%, $p < 0.01$), were diabetic (14.07%, $p < 0.05$), or were hypertensive (45.96%, $p < 0.05$) than in the other two groups. Also, fewer patients undergoing bilateral IMA grafting had previous myocardial infarction ($p < 0.001$) or congestive heart failure (CHF) ($p < 0.01$) than patients undergoing saphenous vein grafting. Preoperative catheterization demonstrated that there was a significant difference in number of vessels diseased among the three groups, but the percentage of the patients undergoing bilateral IMA grafting who had triple vessel disease was not different from that of the other two groups ($p > 0.05$). Similarly, there was no difference in the patients who had left main

Table I. Univariate analysis for operative mortality in patients having bilateral IMA grafting

Variable	Mortality (%)	p value
Age		
Survival (54.15 ± 0.77 yr)	192/199 (96.48)	0.0016
Death (72.13 ± 3.40 yr)	7/199 (3.52)	
Age ≥ 70 yr		
Yes	6/24 (25.0)	0.00001
No	1/175 (0.57)	
History of congestive heart failure		
Yes	4/15 (26.67)	0.0006
No	3/182 (1.65)	
Emergency operation		
Yes	2/5 (40.0)	0.01
No	5/194 (2.58)	
Ejection fraction		
Survival (0.55 ± 0.01)	175/181	0.0007
Death (0.41 ± 0.07)	6/181	
Aortic crossclamp time (min)		
Survival (60.35 ± 1.23)	192	0.03
Death (74.57 ± 8.59)	7	
Intraaortic balloon pumping		
Yes	5/12 (41.67)	<0.0001
No	2/187 (1.07)	
Ventilation >2 days		
Yes	2/9 (22.22)	0.03
No	5/188 (2.66)	
Postoperative low cardiac output		
Yes	3/5 (60.0)	0.0003
No	4/194 (2.06)	
Blood transfusion		
Yes	7/103 (6.8)	0.009
No	0/96 (0)	

coronary artery disease among the three groups ($p > 0.05$). From the catheterization data, patients undergoing bilateral IMA grafting had better left ventricular function assessed by the left ventricular ejection fraction than patients undergoing saphenous vein grafting ($p < 0.05$), but there was no difference between the patients having bilateral and those having unilateral IMA grafting ($p > 0.05$).

In regard to the operative characteristics among the three groups, fewer patients undergoing bilateral IMA grafting than saphenous vein grafting underwent emergency operation (2.51% compared with 15.47%, $p < 0.001$). There were fewer patients (6.03%) in the group having bilateral IMA grafting who required intraaortic balloon pumping than in the saphenous vein grafting group (19.59%, $p < 0.001$). Fewer patients in the bilateral IMA grafting group (2.51%) required reoperation for bleeding than in the saphenous vein grafting group (5.59%), but this difference did not reach statistical significance ($p = 0.066$). On the other hand, the patients having bilateral IMA grafting had a longer aor-

tic crossclamp time than either of the other two patient groups ($p < 0.01$), and more patients undergoing bilateral IMA grafting (46.73%) required more than three bypass grafts than did the saphenous vein grafting group (32.57%, $p < 0.001$). From this study, no significant difference could be detected for the prevalence of perioperative myocardial infarction ($p = 0.051$), perioperative stroke ($p = 0.06$), or postoperative pneumonia ($p = 0.26$).

Operative mortality in the patients undergoing bilateral IMA grafting was 3.52%, significantly lower than that (8.53%, $p < 0.05$) in the patients undergoing saphenous vein grafting but not significantly different from that of the patients undergoing unilateral IMA grafting (2.71%). Sternal infection in the patients having bilateral IMA grafting was slightly more prevalent (2.51%) than that in those having unilateral IMA grafting (1.19%) or saphenous vein grafting (1.32%), but the differences were not statistically significant ($p = 0.27$).

Part II

Univariate analysis. To determine the risk factors correlated to operative mortality and sternal infection in patients undergoing bilateral IMA grafting, we performed univariate analysis separately for 27 preoperative and perioperative variables (see appendix). Table I lists the significant variables for operative mortality. The average age of operative survivors (54.15 ± 0.77 years) was younger than that of patients who died (72.13 ± 3.40 years, $p < 0.01$), and the mortality was significantly higher in elderly (≥ 70 years) patients ($p = 0.0016$). Other factors related to operative mortality were history of CHF, emergency operation, left ventricular ejection fraction, aortic crossclamp time, intraaortic balloon pumping, prolonged postoperative mechanical ventilation (>2 days), postoperative low cardiac output, and blood transfusion. Univariate analysis was also performed for the correlation between sternal infection and perioperative variables. Of the 27 variables, only obesity was significantly correlated with sternal infection ($p = 0.0029$). Other variables did not reach statistical significance although the prevalence of sternal infection was higher for female patients (2/19 for women versus 3/180 for men, $p = 0.07$, Fisher's exact test).

Multivariate analysis. In patients undergoing bilateral IMA grafting, stepwise multiple logistic regression analysis was performed separately for operative mortality and sternal infection. Sixteen preoperative or intraoperative variables were included in the regression model for the operative mortality. These variables were chosen because they were significant in the univariate analysis (age, age ≥ 70 years, history of CHF, ejection fraction, aortic crossclamp time, blood transfusion, and emergen-

Table II. Stepwise multiple logistic regression for operative mortality

Variables	Score χ^2	p value
Age $\geq$ 70 years	37.11	0.0001
Perfusion time	20.44	0.0001
Emergency operation	12.62	0.0004
Smoking history	3.63	0.0569
History of congestive heart failure	4.04	0.044

cy operation) or their trend associated with the operative mortality by univariate analysis ($p < 0.3$, smoking history, diabetes, and perfusion time). Sex, hypercholesterolemia, hypertension, left main artery disease, perioperative myocardial infarction, and number of vessels diseased were also included in the regression model. The logistic regression demonstrated that old age (≥ 70 years), long perfusion time, and emergency operation were significantly associated with increased operative mortality (Table II).

For sternal infection, 10 variables were included in the stepwise multiple logistic regression analysis. Sex, body mass index, obesity, and diabetes were included because of their significance or trends ($p < 0.3$) found with univariate analysis. Old age (≥ 70 years), reoperation for bleeding, perioperative low cardiac output, requirement of blood transfusion, ventilation longer than 2 days, and emergency operation were also included because of possible association with sternal infection according to the literature.^{16, 18, 24, 25} The logistic regression demonstrated that in this multivariate model obesity was the only factor associated with sternal infection (Table III).

Discussion

Some important conclusions may be drawn from this study. First, in properly selected patients neither the operative mortality nor the sternal infection rates for bilateral IMA grafting are higher than those in patients having saphenous vein grafting or unilateral IMA grafting. In contrast, the operative mortality was lower in the patients undergoing bilateral IMA than in those undergoing saphenous vein grafting. Second, this study revealed the risk factors for operative mortality in patients having bilateral IMA grafting—old age, long cardiopulmonary bypass time, and emergency operation. Third, according to this study, the risk factor for sternal infection in patients having bilateral IMA grafting is obesity.

In early experience with bilateral IMA grafting, Barner⁷ indicated that the technique increased the risk of operative mortality (8% versus 5% after saphenous vein grafting) and mediastinal infection (4% versus 1% after

Table III. Stepwise multiple logistic regression for sternal infection

Variables	Score χ^2	p Value
Logistic procedure—variables		
Sex	5.5073	0.0189*
Age $\geq$ 70 years	0.7369	0.3907
Body mass index	3.4308	0.0640
Diabetes	2.8521	0.0913
Obesity	8.8526	0.0029
Reoperation for bleeding	0.1322	0.7162
Postoperative low cardiac output	0.1322	0.7162
Blood transfusion	0.2840	0.5941
Ventilation $\geq$ 2 days	0.2429	0.6221
Emergency operation	0.1322	0.7162
Summary of stepwise procedure—entered variables		
Obesity	8.8526	0.0029

* $p = 0.07$ by Fisher's exact test.

saphenous vein grafting). This possibility has become a concern for many surgeons. Later reports have confirmed these early observations of either operative mortality or sternal infection.¹⁶⁻¹⁹ In contrast, others have reported that bilateral IMA grafting does not increase operative mortality.^{5, 6, 14, 15} However, even in these reports, bilateral IMA grafting has been demonstrated to increase operative morbidity such as perioperative myocardial infarction¹⁵ and requirement for blood transfusion.¹⁴ Therefore, in the present study, we compared operative mortality and sternal infection in patients having bilateral IMA grafting with those in patients having saphenous vein or unilateral IMA grafting. Our study demonstrated that there was no difference in the operative mortality (3.52%) between the patients having bilateral or unilateral IMA grafting (2.71%) and that it was significantly lower among the patients having bilateral IMA grafting than among those having saphenous vein grafting (8.53%, $p < 0.05$). However, in this series, the patients having bilateral IMA grafting were selected for this particular procedure. In general, more of them were young and male and fewer patients in this subset were obese, diabetic, or hypertensive. Also, fewer patients having bilateral IMA grafting had a history of myocardial infarction or CHF and fewer underwent emergency operation. These characteristics reflect that in our series the patients having bilateral IMA grafting were carefully selected because the procedure was thought to be related to a longer operative time and an increased operative risk. Therefore, unlike other studies in which patients having bilateral IMA grafting were matched with those having saphenous vein grafting or unilateral IMA grafting by similar preoperative characteristics,¹⁴ we cannot simply conclude

that bilateral IMA grafting does not increase operative mortality. However, at least we can conclude that in properly selected patients bilateral IMA grafting can be performed with a lower operative mortality than saphenous vein grafting. This information is valuable in surgical practice because others also select their patients for bilateral IMA grafting.¹⁵ On the other hand, in our series, patients having bilateral IMA grafting required more grafts (46.73% patients required more than three grafts versus 32.5% having saphenous vein grafting, $p < 0.001$) and longer aortic crossclamp time (60.85 minutes versus 52.73 minutes for unilateral IMA grafting and 46.45 for saphenous vein grafting, $p < 0.01$), which are generally factors increasing operative mortality. These features combined with a lower mortality among patients having bilateral IMA grafting may reflect the superiority of this procedure to saphenous vein grafting.

Despite the fact that the operative mortality and morbidity of bilateral IMA grafting have attracted the attention of many investigators, the risk factors for operative mortality in patients having this procedure have not been well studied yet. Obviously, the knowledge of the risk factors for mortality in these patients will help surgeons to select proper patients for bilateral IMA grafting and to pay special attention to the patients with high risk factors for this procedure if it is contemplated. Therefore, in our study, one of the major aims was to analyze the risk factors for the patients having bilateral IMA grafting. Univariate analysis has revealed that the risk factors associated with operative mortality were age, old age (≥ 70 years), history of CHF, emergency operation, depressed left ventricular ejection fraction, aortic cross-clamp time, intraaortic balloon pumping, prolonged postoperative mechanical ventilation (> 2 days), postoperative low cardiac output, and blood transfusion. The logistic regression analysis has revealed that old age (≥ 70 years) is one of the most important predictors for operative mortality in patients having bilateral IMA grafting. In our experience, the operative mortality in patients older than 70 years was as high as 25% (6/24). In contrast, in the patients younger than 70 years who underwent bilateral IMA grafting, the operative mortality was only 0.57%. This finding strongly suggests that bilateral IMA grafting should be used with extreme caution in patients older than 70 years. Emergency operation is another predictor for operative mortality in patients having bilateral IMA grafting. In this study, two of five (40%) patients died after emergency bilateral IMA grafting whereas only 2.58% (5/195) of patients died after elective bilateral IMA grafting. Among five patients who underwent emergency bilateral IMA grafting, three had had unsuc-

cessful percutaneous transluminal coronary angioplasty and only one of them survived the operation. Prolonged operative time for mobilization of bilateral IMA grafts, as well as for anastomosis, may account for the increased mortality. Therefore, we suggest that in emergency situations bilateral IMA grafting should be used cautiously if at all. Prolonged cardiopulmonary bypass time, implying complexity of the operation and reduced cardiac function, is another risk factor that also implies the importance of improvement of operating technique. As demonstrated in this study, patients having bilateral IMA grafting had longer aortic crossclamp times and more patients in this subset required blood transfusions.

Sternal infection is another major concern in bilateral IMA grafting. In an early theoretical anatomic study, Arnold²⁶ proposed that complete mobilization of bilateral IMAs should be avoided because the IMA is the only supplying artery that provides blood to the sternum so that after complete mobilization of bilateral IMAs the sternum becomes avascular. This hypothesis was later supported by a functional study measuring sternal blood flow.²⁷ Clinical observations supported this hypothesis because sternal infection was more prevalent after bilateral IMA grafting in a number of clinical reports. In general, many factors have been considered to be associated with sternal infection—female gender, obesity, diabetes, length of hospital stay before operation, current smoking, prolonged mechanical ventilation, low cardiac output, and other postoperative factors.^{19, 24, 25, 27-31} Despite these observations, whether bilateral IMA grafting increases risk of sternal infection is still controversial. Others^{15, 28} have reported that bilateral IMA grafting does not significantly increase the risk of sternal infection. The present study also failed to demonstrate a significantly higher prevalence of sternal infection associated with bilateral IMA grafting. However, it is still worthwhile to identify risk factors for sternal infection, because in our series this significant postoperative complication was encountered in 2.51% of patients having bilateral IMA grafting. In the present study, 10 variables were included in the logistic regression model and the analysis has revealed that among these factors obesity is the only factor significantly associated with sternal infection after bilateral IMA grafting. As shown from this study, sternal osteomyelitis developed in 12.5% of obese patients in comparison with only 1.14% of nonobese patients. This analysis strongly suggests that the risks of bilateral IMA grafting should be carefully assessed in obese patients. Others¹⁹ have suggested that diabetes is a risk factor for sternal infection in patients having bilateral IMA grafting. In the present study, although this morbidity was

higher in patients with diabetes (7.14%) than in those without diabetes (1.75%), the difference did not reach statistical significance ($p = 0.15$).

In conclusion, the present study demonstrates that bilateral IMA grafting can be performed in properly selected patients with multiple coronary disease, particularly in patients younger than 70 years old and as an elective procedure with low operative risk. This study also demonstrates that sternal infection is not significantly more prevalent in patients having bilateral IMA grafting than in those having saphenous vein or unilateral IMA grafting and that the only risk factor for sternal infection after bilateral IMA grafting is obesity.

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Appendix: Variables examined for univariate analysis for operative mortality and sternal infection in patients having bilateral IMA grafting

Sex
Age
Age 70 years or older
Smoking history
Family history of coronary artery disease
Diabetes
Obesity
Hypercholesterolemia
Hypertension

History of myocardial infarction
History of congestive heart failure
New York Heart Association functional class
Number of vessels diseased
Disease of left main coronary artery
Emergency operation
Ejection fraction
Aortic crossclamp time
Perfusion time
Number of coronary artery bypass grafts
Graft to left anterior descending coronary artery
Route of cardioplegia
Intraaortic balloon pumping
Ventilation for more than 2 days
Reoperation for bleeding
Perioperative myocardial infarction
Postoperative low cardiac output
Blood transfusion