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Sternal Wound Infections in Patients After Coronary Artery Bypass Grafting Using Bilateral Skeletonized Internal Mammary Arteries

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Objectives
This study evaluated the risks of sternal wound infections in patients undergoing myocardial revascularization using bilateral skeletonized internal mammary arteries (IMAs).

Background
The skeletonized IMA is longer than the pedicled one, thus providing the cardiac surgeon with increased versatility for arterial myocardial revascularization without the use of vein grafts. It is isolated from the chest wall gently with scissors and silver clips, and no cauterization is employed. Preservation of collateral blood supply to the sternum and avoidance of thermal injury enable more rapid healing and decrease the risk of sternal wound infection.

Methods
From April 1996 to August 1997, 545 patients underwent arterial myocardial revascularization using bilateral skeletonized IMAs. The right gastroepiploic artery was used in 100 patients (18%). The average age of the patients was 65 years; 431 (79%) were men and 114 (21%) were women; 179 (33%) were older than 70 years of age; 166 (30%) were diabetics. The average number of grafts was 3.2 per patient.

Results
The 30-day operative mortality rate was 2% (n = 11). There were six perioperative infarcts (1.1%) and six strokes (1.1%); 9 patients had sternal infection (1.7%) and 15 (2.8%) had superficial infection. Risk factors for sternal infection were chronic obstructive pulmonary disease and emergency operation. Superficial sternal wound infections were more common in women and in patients with chronic obstructive pulmonary disease, renal failure, or peripheral vascular disease. The 1-year actuarial survival rate was 97%. Two of the six late deaths were not cardiac-related. Late dehiscence occurred in three patients (0.6%). The death rate (early and late) of patients with any sternal complication was higher than that of patients without those complications (33% *vs.* 2.7%).

Conclusions
Routine arterial myocardial revascularization using bilateral skeletonized IMAs is safe, and postoperative morbidity and mortality rates are low, even in elderly patients and those with diabetes. Chronic obstructive pulmonary disease and emergency operations were found to be associated with an increased risk of sternal infections, and the authors recommend avoiding the use of bilateral skeletonized IMAs in patients with these preoperative risk factors.

Routine use of the internal mammary artery (IMA) in coronary artery bypass grafting (CABG) began in the 1980s, when the IMA was proven to be less likely to become obstructed than the saphenous vein. In a prospective study by Barner et al,[1] the 5-year patency rate was 88% for the IMA *versus* 74% for the saphenous vein. After 10 years, the figures were 83% and 41%, respectively. In 1986, Loop et al[2] reported that >90% of IMA grafts to the left anterior descending artery were patent 10 years after the surgery. This improved patency rate was associated with a better survival rate than that found in patients who received vein grafts alone.[1]

In most centers, the IMA is isolated from the chest wall as a pedicle, together with the vein, muscle, fat, and accom-

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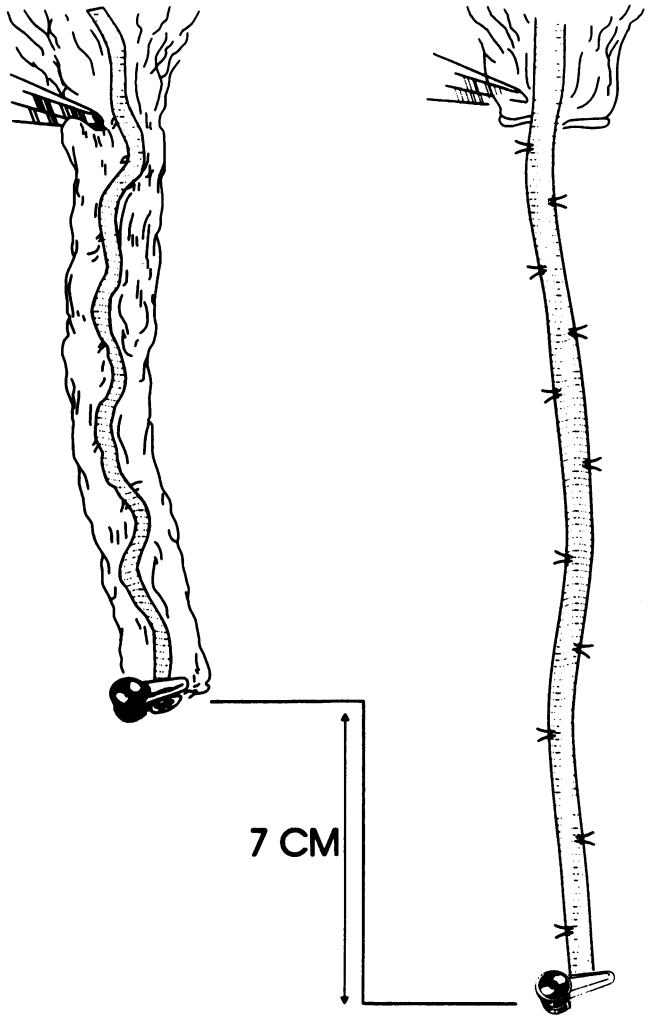

Figure 1. Pedicled internal mammary artery (left) and skeletonized internal mammary artery (right).

panying endothoracic fascia. Harvesting is relatively quick (10 to 20 minutes) because cautery is used to separate the pedicle from the chest wall. However, cauterization damages the blood supply to the sternum; this in turn impedes sternal healing and exposes the sternum to the risk of early dehiscence and infection, particularly in procedures in which both IMAs are used.[3–6] This risk is even higher in elderly patients and patients with diabetes.[6–9]

A surgical technique was recently developed whereby the IMA is dissected as a skeletonized vessel.[10,11] The skeletonized artery is isolated gently with scissors and silver clips without the use of cauterization. One advantage is that the dissected artery is particularly long (Fig. 1), and its spontaneous blood flow is greater than that in a pedicled IMA, allowing the use of both IMAs as grafts to all necessary coronary vessels. No addition of vein grafts is required in most cases.[12] Another advantage of using skeletonized IMAs is the preservation of collateral blood supply to the sternum, enabling more rapid healing and decreasing the risk of infection.[13]

As of May 1996, we decided to adopt this bilateral skeletonized IMA technique as the exclusive method for myocardial revascularization in our department. In this report, we describe our clinical experience in a series of 545 consecutive patients who underwent CABG using bilateral skeletonized IMAs. Because sternal complications and wound infections are the main concern when using bilateral IMAs, we evaluated these complications with the above technique and tried to define preoperative risk factors for their occurrence.

PATIENTS AND METHODS

From April 1996 to August 1997, 545 patients had undergone CABG using bilateral skeletonized IMAs. Table 1 lists their characteristics. The average age was 64 years; 179 (33%) were older than 70 years. One hundred sixty-six (30%) had diabetes. The IMAs were dissected as skeletonized arteries[11] before heparin administration to decrease the risk of damage and hematoma formation in the region of the side branches during dissection.

Operations were performed with cardiopulmonary bypass. The myocardial preservation technique consisted of intermittent warm cardioplegia (30° to 32°C).[14] In 100 patients (18%), the right gastroepiploic artery was used as a third arterial conduit to bypass the posterior descending branch of the right coronary artery.[15] In 322 patients (60%), a composite graft was prepared before connection to cardiopulmonary bypass (Fig. 2). Most of the composite grafts included end-to-side anastomosis of a free right IMA on an *in situ* left IMA. The extra length obtained by the skeletonization technique enabled us to graft the left anterior descending artery with the right IMA (the "cross" technique, Fig. 3).

To decrease the risk of spasm of the arterial grafts, all patients received an intravenous infusion of high-dose isosorbide dinitrate (Isoket) (4 to 20 mg/hour) during the first 24 to 48 hours after surgery.[16] Systolic blood pressure was maintained at more than 100 to 120 mmHg. From the second postoperative day, patients were given oral calcium channel blockers (diltiazem 90 to 180 mg/day) for ≥3 months.

Statistical Analysis

Data are expressed as mean ± standard deviation or proportions. The chi square test and two-sample t tests were used to compare discrete and continuous variables, respectively. Multivariate logistic regression analysis was used to predict unfavorable outcome events by various risk factors. Odds ratio (OR) and 95% confidence intervals (CI) are given. Postoperative survival is expressed using the Kaplan–Meier method. All analyses were performed using SPSS 7.5 software.

Table 1. UNIVARIATE ANALYSIS FOR STERNAL INFECTIONS

			Sternal Infections (9/545)					Overall Wound Infections (24/545)				
Risk Factor	n	%*	n1	%†	n2	%‡	P	n1	%†	n2	%‡	P
Age ≥70 years	179	33	3	1.7	6	1.6	NS	11	6.1	13	3.6	NS
Age ≥65	284	52	4	1.4	5	1.9	NS	15	5.3	9	3.5	NS
Female gender	114	21	3	2.6	6	1.4	NS	12	10.5	12	2.8	<0.001
Left main stenosis	168	31	2	1.2	7	1.8	NS	7	4.0	17	4.5	NS
Acute MI (<1 week)	167	31	2	1.2	7	1.9	NS	4	2.4	20	5.3	NS
Old MI	195	36	4	2.1	5	1.4	NS	8	4.1	16	4.6	NS
Complicated PTCA	43	8	1	2.3	8	1.6	NS	2	4.7	22	4.4	NS
EF ≤35%	116	21	3	2.6	6	1.4	NS	6	5.2	18	4.2	NS
Congestive heart failure	75	14	1	1.3	8	1.7	NS	4	5.3	20	4.3	NS
Preop. (IABP)	9	1.7	0	0	9	1.7	NS	0	0	24	4.5	NS
Diabetes mellitus	166	30	4	2.4	5	1.3	NS	8	4.8	16	4.2	NS
Diabetes mellitus > 65 y	85	16	1	1.2	8	1.7	NS	2	2.4	22	48	NS
Hypertension	258	47	6	2.3	3	1	NS	16	6.2	8	2.8	NS
PVD	34	6.2	1	2.9	8	1.6	NS	4	11.8	20	3.9	<0.03
Chronic renal failure	40	7.3	1	2.5	8	1.6	NS	6	15	18	3.6	<0.002
Severe COPD	53	10	5	9.4	4	0.8	<0.001	7	13.2	17	3.5	<0.005
Emergency CABG surgery	66	12	3	4.5	6	1.3	<0.005	4	6.1	20	4.2	NS
Repeat CABG	16	2.9	0	0	9	1.7	NS	0	0	24	4.5	NS
Surgical technique: *in situ*	28	5	1	3.6	8	1.5	NS	1	3.6	21	4.4	NS
Surgical technique: cross	185	35	3	1.6	6	1.7	NS	6	3.2	18	5	NS
Surgical technique: composite	322	60	5	1.6	4	1.8	NS	17	5.3	7	3.7	NS
Sequential grafts	381	70	6	1.5	3	1.7	NS	15	3.9	9	5.4	NS
Use of GEA	100	18	0	0	9	2	NS	3	3	21	4.7	NS
Use of vein	71	13	0	0	9	1.9	NS	2	2.8	22	4.6	NS

* Percent evaluated for the entire study group (n/545)
† Percent of n1 out of n.
‡ Percent of n2 out of 545−n.
MI, myocardial infarction; IABP, intraaortic balloon pump; PVD, peripheral vessel disease; PTCA, percutaneous transluminal coronary angioplasty; EF, ejection fraction; COPD, chronic obstructive pulmonary disease; GEA, gastroepiploic artery; n, no. of patients with risk factor; n1, no. of complications in patients with this risk factor; n2, no. of complications in patients without this risk factor.

RESULTS

Mortality and Morbidity Rates

The early (perioperative) mortality rate was 2% (n = 11). The causes of early death were perioperative myocardial infarction (n = 4), sudden death (n = 2), pulmonary emboli (n = 1), stroke (n = 1), bleeding (n = 1), deep sternal wound infection (n = 1), and ventricular arrhythmia (n = 1). Perioperative complications included stroke in six patients (1.1%), myocardial infarction in six patients (1.1%), and bleeding in six patients (1.1%).

The late postoperative mortality rate at 14 months of follow-up was 1.5% (n = 8). The causes of late death were sternal wound infection (mediastinitis) (n = 3), sudden death (n = 1), gastrointestinal bleeding (n = 1), lung abscess (n = 1), pneumonia (n = 1), and abdominal aneurysm (n = 1). The 1-year actuarial survival rate was 97%. Ninety-seven percent of the surviving patients were angina-free at the latest follow-up.

Sternal Wound Complications

The wound complications included superficial sternal wound infection (n = 15, 2.8%), deep sternal infection (n = 9, 1.7%), and late dehiscence (n = 3, 0.6%). Severe sternal complications were defined as the sum of deep infection and late dehiscence requiring resternotomy or sternectomy (n = 12, 2.2%). Severe sternal complications were found to be associated with a higher total mortality rate (early and late). The total mortality rate in patients with sternal complications was 33% (n = 4) *versus* 2.7% in patients without sternal complications ($p < 0.05$).

Univariate analysis (see Table 1) demonstrated that severe chronic obstructive pulmonary disease, emergency operation, and the mean number of grafts per patient (2.8 in patients with sternal infection *vs.* 3.3 in those without sternal infection, $p < 0.05$) were associated with an increased risk of sternal infection. However, after adjustment for all other demographic, clinical, and surgical predictors, chronic obstructive pulmonary disease (OR 13.0, 95% CI 3.3 to 50.8) and emergency operation (OR 3.8, 95%, CI 0.9 to

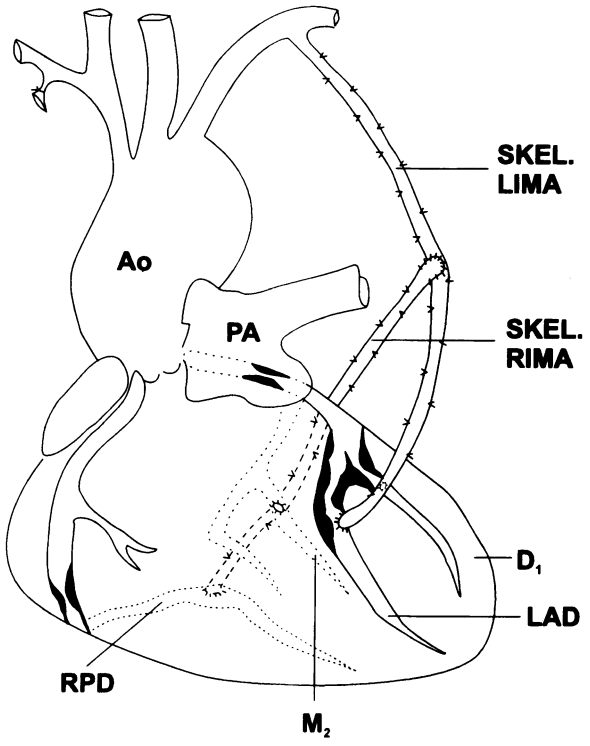

Figure 2. Composite graft. A free right internal mammary artery (RIMA) (to marginal circumflex and posterior descending branches) is anastomosed end-to-side to an *in situ* left internal mammary artery (LIMA) (to the left anterior descending artery). D_1, diagonal; LAD, left anterior descending; M_2, marginal; RPD, right posterior descending; SKEL, skeletonized.

16.5) were found to be the only independent predictors of deep infection.

Neither diabetes nor old age was found to be an independent predictor of infection: sternal wound infection developed in only 1 of the 85 patients with diabetes who were older than 65 years of age (see Table 1). The risk factors for overall wound infection (deep and superficial, n = 24) were chronic renal failure (OR 8.0, 95% CI 2.6 to 24.2), female gender (OR 5.4, 95% CI 2.2 to 13.3), chronic lung disease (OR 4.7, 95% CI 1.7 to 13.0), and peripheral vascular disease (OR 2, 95% CI 1.2 to 15). Potential risk factors for sternal complications, such as advanced age (older than 65 years), diabetes mellitus, repeat CABG, bypass time, and cross-clamp time, were not found to be statistically significant for sternal complications in this study.

DISCUSSION

The relation between the use of IMA and sternal wound infections was first reported by Grmoljez et al,[17] who showed a fivefold risk of mediastinitis in patients when one IMA was used. Their findings were supported by other authors, who showed an even greater risk of infection when using bilateral IMAs.[8,9,18,19] Kouchoukos et al[9] reported that the use of bilateral IMAs was associated with a greater risk of sternal infection (6.9%) than was the use of a unilateral IMA (1.9%) or a saphenous vein graft (1.3%, $p < 0.001$). The relative risk for patients with diabetes and bilateral IMAs was 5.00 (95% CI, 2.4 to 10.5) in the Cleveland Clinic experience with 6504 patients.[7]

Thus, although the use of bilateral IMAs for CABG is believed to provide better results with regard to patency and long-term survival, sternal wound infections continue to occur after IMA grafting, despite the use of aseptic procedures and broad-spectrum antibiotics, and they do so at rates of 1.6% to 8.5%.[8,9,18,19]

An important factor contributing to the development of wound complications is the impairment of blood supply to the sternum associated with IMA harvesting. Anatomic and physiologic studies have demonstrated that IMA dissection as a pedicle greatly decreases the blood supply to the ipsilateral side of the sternum.[3,20] In another report, chest wall blood flow was found to be significantly decreased after IMA mobilization as a pedicle; however, residual sternal blood flow was found to be significantly greater when using the skeletonizing technique for IMA harvesting.[21]

Our report summarizes the early experience with routine use of bilateral and skeletonized IMAs at the Tel Aviv Medical Center. The patients examined were typical for this urban population (a relatively older one), and this technique was used in most (71%) of the patients who underwent

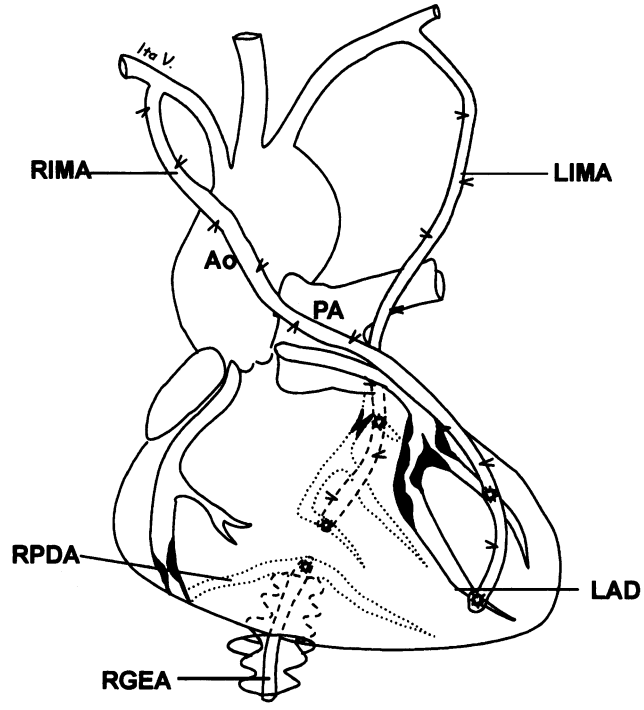

Figure 3. Left internal mammary artery (LIMA) anastomosis to marginal branches of the circumflex, right internal mammary artery (RIMA) to left anterior descending (LAD) ("cross"), and right gastroepiploic artery (RGEA) to the posterior descending coronary arteries. RPDA, right posterior descending artery.

CABG in our institution over a short period of time (16 months). The only contraindications for the use of IMA grafts were emergency operations with hemodynamic instability requiring rapid connection to a cardiopulmonary bypass. The immediate operative results are comparable to those described in procedures in which one IMA was used.[22] Our report conferred significant clinical approval of the basic assumption concerning the skeletonized IMA technique: that it probably causes less damage to the sternal blood flow,[3,5,21] and therefore the rates of sternal infections and complications are in the lower range of those reported by others.

Apart from the surgical technique, other risk factors such as chronic obstructive pulmonary disease, diabetes mellitus, and low cardiac output have been implicated in the development of sternal infection and complications.[23,24] However, we found only chronic lung disease and emergency operations to be major risk factors for deep sternal infection. Explanations for the latter findings in patients with chronic lung disease might include high suture-line pressure or collagen abnormalities described in smokers.[25]

Diabetes mellitus is generally considered to be a major risk factor for sternal complications, especially when bilateral IMA grafting is used. The risk in these circumstances was estimated to be fivefold that in other patients.[26] We found no evidence of this relation in patients who received bilateral skeletonized IMAs. Our results are even more definitive, considering the fact that 30.5% of our patients had diabetes mellitus. In only 1 of our 85 patients with diabetes who were older than 65 years (1.2%) did sternal infection develop. This is clearly compatible with the findings of Bical et al,[27] who observed no wound complications in 63 patients with diabetes who underwent bilateral skeletonized IMA grafting.

Stahle et al[28] found that female sex was an independent risk factor for sternal complications in patients undergoing CABG. In our series, overall infection rates (deep and superficial) were higher in women. These rates proved to be consistent using both univariate and multivariate statistical tests, but the physiologic explanation for this finding is yet undetermined. The drop in tissue blood flow can also explain the increased risk of superficial wound infection observed in the current report in patients with peripheral vascular disease and in women with large breasts. The blood supply to the fat tissue is further compromised by the decreased blood flow from the IMA collaterals to the pectoralis muscles and to the breasts.[29] We found no significant correlation between sternal complications and age, hyperlipidemia, grafting technique, redo surgery, acute or old myocardial infarction, hypertension, congestive heart failure, and the duration of extracorporeal circulation.

In summary, routine use of bilateral skeletonized IMAs seems to be safe in patients undergoing CABG, not only in terms of morbidity and mortality rates but also in terms of sternal complications and infections. However, in patients with chronic lung disease, the risk of sternal infection is still unacceptably high; for them we advocate the use of a single IMA plus saphenous vein grafts instead of bilateral IMAs. This approach is our considered opinion, given that we did not demonstrate any decrease in sternal complications in patients with chronic lung disease who underwent the more conventional IMA plus saphenous vein graft CABG operations.

Despite the increased rate of superficial infections in women and in patients with peripheral vascular disease or chronic renal failure, we do not think this relatively minor complication justifies abandoning the use of double skeletonized IMAs in these subgroups of patients. The avoidance of cautery when opening the skin, or the use of special bandaging techniques to avoid breast pressure on the suture line might decrease the occurrence of this complication. Because superficial infection can also occur in a leg incision, we do not believe that using saphenous vein grafts will decrease the rate of morbidity in these subgroups of patients. Therefore, unlike our recommendation for patients with chronic lung disease, we do not recommend the use of single IMA and vein grafting for women and for patients with peripheral vascular disease or chronic renal failure.

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