Bilateral internal mammary artery for multi-territory myocardial revascularization: long-term follow-up of pedicled versus skeletonized conduits†

Michele Di Mauroa,b, Angela L. Iacoc, Angelo Acitelli, Gabriele D’Ambrosiob, Laura Filipponib, Elisa Salustri, Chiara De Lucaa, Silvio Romanoa, Maria Pencob and Antonio M. Calafiore*•

a Department of Adult Cardiac Surgery, Prince Sultan Cardiac Center, Riyadh, Kingdom of Saudi Arabia
b Department of Cardiology, University of L’Aquila, L’Aquila, Italy

* Corresponding author. Department of Adult Cardiac Surgery, Prince Sultan Cardiac Center, Riyadh, Kingdom of Saudi Arabia. Tel: +966-566-299948; fax: +966-1-4760543; e-mail: am.calafiore@gmail.com (A.M. Calafiore).

Abstract

OBJECTIVES: The aim of this study was to evaluate 17-year actual clinical outcomes of patients undergoing coronary artery bypass graft (CABG) using skeletonized versus pedicled bilateral internal mammary arteries (BIMAs).

METHODS: From September 1991 to June 1996, 548 consecutive patients underwent CABG for multivessel disease using BIMA. After propensity matching, 350 patients were enrolled: 175 patients with skeletonized BIMA (Group S) and 175 with pedicled BIMA (Group P). The two groups were adequately comparable. Composite end-point: deaths, new revascularization and new myocardial infarctions were defined as ‘events’.

RESULTS: Group S provided a higher rate of total arterial myocardial revascularization (94.3 vs 82.9%, P = 0.001) with a higher average number of arterial anastomoses (3.1 ± 0.8 vs 2.7 ± 0.8, P < 0.001) and BIMA anastomoses (2.5 ± 0.3 vs 2.1 ± 0.3, P < 0.001). In Group S, the incidence of sequential grafts was higher (37.7 vs 17.7%, P < 0.001). The rate of sternal wound healing problems was lower (1.7 vs 7.4%, P = 0.003) with a higher average number of arterial anastomoses (3.1 ± 0.8 vs 2.7 ± 0.8, P < 0.001) and BIMA anastomoses (2.5 ± 0.3 vs 2.1 ± 0.3, P < 0.001). In Group S, the incidence of sequential grafts was higher (37.7 vs 17.7%, P < 0.001). The rate of sternal wound healing problems was lower (1.7 vs 7.4%, P = 0.003). Thirty-day mortality and morbidity were similar. The median survival time of survivors was 17.8 years (min–max = 17.0–21.5); 17.3 (17.0–18.0) in Group S vs 19.1 (18.1–21.5) in Group P, P < 0.001. Seventeen-year actual outcomes were better in Group S: deaths (8.7 vs 27.9%, P < 0.001), cardiac deaths (4.7 vs 13.4%, P = 0.005), cardiac events (10.5 vs 22.1%, P = 0.003), new revascularization (2.9 vs 8.7%, P = 0.021) and events (15.1 vs 36.1%, P < 0.001).

CONCLUSIONS: Skeletonization of BIMA allows one to achieve a higher rate of arterial grafting and better outcome if compared with pedicled BIMA.

Keywords: Bilateral mammary artery • Pedicled mammary artery • Skeletonization

INTRODUCTION

The internal mammary artery is widely considered the graft of first choice, mainly for the territory of the left anterior descending artery, in patients undergoing coronary artery bypass grafting [1]. Since 1990, several studies have supported the superiority of a bilateral internal mammary artery (BIMA) over a single internal mammary artery (SIMA) [2–4], both in terms of survival and quality of life, in particular when BIMA was used to revascularize the left coronary system [5, 6]. However, BIMA utilization still remains low [7], mainly due to longer harvesting time and to a higher incidence of deep sternal wound problems, especially in some subgroups such as diabetic, obese or patients with chronic obstructive pulmonary disease [8]. There is general agreement that skeletonized BIMA harvesting is able to reduce significantly the incidence of deep sternal wound problems, especially in high-risk subsets [9–11]. However, there is a debate about whether skeletonized BIMA might have long-term results similar to pedicled BIMA.

Hence, the aim of the present retrospective study is to evaluate the very long-term results of skeletonized versus pedicled BIMA.

MATERIALS AND METHODS

From September 1991 to June 1996, 548 consecutive patients, who had undergone coronary artery bypass grafting for multivessel disease using BIMA grafting, were divided in two groups according to harvesting technique: Group S (skeletonized, n = 274) and Group P (pedicled, n = 274). After propensity matching, 350 patients (175 per group) were enrolled in the study (Table 1).
Surgical technique

Patients were anaesthetized as previously described [9]. The ‘pedicled IMA’ was harvested together with the surrounding veins, muscle and the fascia. Cautery was always used and the side branches were clipped. When the IMA was harvested the ‘skeletonized’ surgical technique was the following. After having dissected the reflection of the mediastinal pleura from the endo-troacic fascia, the mammary artery and both satellite veins are visualized. The fascia is incised medially to the medial mammary vein for the resection of the mediastinal pleura from the endotho-racic cult, it can be ligated. The pleuro-pericardial space is then dis- 
itute and the end-to-end anastomoses has already been reported [9]. To avoid any distortion of the graft, it is necessary only to put the mammary over the heart. The internal pressure will force the graft to always maintain the right orientation.

After heparinization, the IMAs, independently of the harvesting technique used, were distally clipped, injected with 10 ml of diluted papaverine (1 mg/ml) and allowed to pharmacologically dilate. When a composite graft was constructed, the proximal anastomosis of the free arterial graft to the IMA was performed before starting cardiopulmonary bypass.

Follow-up

All the patients were clinically followed up: the most recent information was obtained by calling up the patient or the referring cardiologists. Follow-up was 100% complete and ended in March 2013.

Statistics and end-points

Results are expressed as the mean (±standard deviation) or median value. Categorical variables were reported as counts and percentages. Differences between the two groups were evaluated by means of an independent t-test or Mann–Whitney U-test (continuous variables) and χ² test (categorical variables). A saturated propensity score model was built by having ‘BIMA skeletonized’ as the treatment. A 1 : 1 sample matching was performed. The list of variables included in the model is reported in Fig. 1. To validate the matching, a dotplot of standardized mean differences before and after matching is shown in Fig. 1. A standardized mean difference equal to or lower than 10% was considered as the threshold for a good balance. Appendix A reported the initial data set. For all tests, a P-value <0.05 was considered significant. The SPSS 20 software (SPSS, Inc., Chicago, IL, USA) was used; an integration with R-software 2.1 was used to automatically obtain a good sample matching. The primary end-point was to demonstrate the superiority of skeletonized over pedicled BIMA regarding 17-year actual outcomes: death, cardiac deaths (myocardial infarction, sudden death, heart failure and ventricular arrhythmias), cardiac events (cardiac death, non-fatal myocardial infarction, new revascularization), new revascularization and events (death, non-fatal myocardial infarction, new revascularization). The secondary end-point was to demonstrate the reduction of deep sternal wound problems with skeletonization.
Long-term results

The median survival time of survivors was 17.8 years (min–max = 17.0–21.5); 17.3 (17.0–18.0) in Group S vs 19.1 (18.1–21.5) in Group P, \( P < 0.001 \). Seventeen-year outcomes of 344 survivors after first postoperative month are summarized in Fig. 2. The number of deaths were 69 (19.7%); of them, 34 (9.7%) died due to cardiac causes. Events occurred in 94 (26.9%); 59 (16.9%) of them were cardiac events. New revascularization was needed in 20 cases (5.7%). The odds ratios for late outcome are plotted in Fig. 3.

DISCUSSION

When BIMAs are harvested as skeletonized instead of as pedicled conduits, there is a significant reduction in the incidence of postoperative pain and wound sternal problems, either mechanical or infective [9–11]. A recent meta-analysis of 32 studies [13] reported a sternal wound infection incidence rate ranging from 1.2 to 8.4% when BIMAs were harvested as a pedicled conduit and from 0.5 to 2.4% in the case of skeletonization. Comparing single IMA grafting with BIMA, the authors found that the sternal wound infection incidence was significantly higher when BIMAs were harvested pedicled and similar when BIMAs were harvested skeletonized.

Boodhwani et al. [11] demonstrated a 17% increase in sternal perfusion with skeletonized IMA compared with the controlateral pedicled one. This effect was particularly evident and notable in some high-risk subgroups such as diabetic [9, 10] and elderly patients [14]. In the present series, the incidence of sternal wound healing problems was significantly lower in the skeletonized BIMA group (\( P = 0.010 \)).

Besides the reduction of sternal wound problems, no differences were found in the literature between the two techniques of BIMA harvesting concerning early mortality [9, 15]. However, a recent meta-analysis [16] stratified the mortality into two populations: low risk and high risk (diabetic and elderly), finding skeletonized BIMA superior to pedicled in a high-risk population (\( P = 0.043 \)), very likely due to a high incidence of deep sternal wound complications and respiratory failures.

Another concern is whether the harvesting technique might influence early and late patency. In a previous study [9], our group reported similar early (<30 days, 98.2% in the skeletonized group vs 97.5% in the pedicled group) and mid-term (16 months, 96.8 vs 94.3%) patency. No differences were found also by others [17, 18]. In the present study, no angiographic results were provided because, in addition to poor compliance of patients, often in good health, to undergo invasive procedures, the exponential increase in invasive procedures in the last decade has considerably reduced the space for angiographic controls in asymptomatic patients.

Long-term results of pedicled BIMA have been available since the 1990s. Galbut et al. [19] reported a 15-year survival rate of 60% using pedicled BIMA, while it was even higher in other studies, ranging from 67 [3] to 70% [2]. A more recent experience with pedicled BIMA reported a 15-year survival rate of 79% [20], which is in line with our results. On the other hand, very long-term survival of skeletonized BIMA has still not been reported. Endo et al. [21] reported a 7-year survival rate of 88.7% using skeletonization in 443 BIMAs.

Hence, to our best knowledge, the present study is the first comparative study addressing long-term actual clinical outcome of skeletonized harvesting of BIMA versus pedicled harvesting.
The main finding of this study is that BIMA skeletonization provides better actual results to those obtained by the use of pedicled BIMA, reducing sternal morbidity.

There are several anatomical and physiological reasons supporting these results.

Skeletonized BIMAs have a larger calibre [22, 23]. Takami and Ina [22] measured the three diameters of the IMA by means of postoperative angiography, demonstrating that skeletonized IMA had larger diameter proximal to the anastomoses (1.77 ± 0.28 vs 1.57 ± 0.28 mm, \(P = 0.022\)).

Skeletonized IMA grafts have a higher flow capacity than do pedicle grafts [22, 23], perhaps due to the resulting periarterial sympathectomy. Moreover, increased blood flow produces endothelium-dependent vasodilatation [24].

Skeletonization increases significantly the length of the IMA graft [9, 11, 15]. In a previous study [9], we demonstrated that the skeletonized IMA was longer both in the baseline condition (17.77 ± 1.76 cm, \(P < 0.01\)) and 10 min after intraluminal papaverine injection (20.1 ± 1.64 cm, \(P < 0.001\)), with an increase of 13.9% in skeletonized IMA and of 1.7% in pedicled IMA. The greater length of the conduit allows the surgeon to perform a higher number of anastomoses per patients, increasing the incidence of sequential grafting, as reported in the present study. Dion et al. [25] demonstrated that long-term patency of sequential IMA is excellent (96.1%), similar to that of single IMA grafting (93.1%). Thus, very likely, the main strength of skeletonized BIMA is the higher rate of total arterial revascularization mostly achieved by BIMA sequential grafting; this reduced the rate of new revascularization, either surgical or interventional; and moreover, it reduced the occurrence of cardiac deaths and events.

Limitations and strength of the study

The main limitation of the study is its retrospective nature, which is partially overcome by applying propensity matching. The size of the two groups is, furthermore, relatively small and clinical outcomes are not supported by an angiographic visualization of the state of the anastomoses. Another limitation is the fact that both groups are different, one group being more a historical control, even if the risk characteristics of patients were quite similar throughout the period included in the study (first part of 1990). On the other side, when BIMA was indicated, all patients were operated on consecutively (all comers, Group P first, followed by Group S) using the same surgical strategy and the same indications. An important strength of this study is the length of the follow-up, all patients being operated on during the 1990s.

CONCLUSIONS

In the absence of long-term comparison of BIMA patency between the two types of harvesting, the present retrospective comparative study demonstrated a significant superiority of skeletonized over pedicled BIMA, both in terms of survival and event-free survival. The only 'macroscopical' evidence that could be addressed to explain this superiority is the higher rate of grafting achieved with BIMA when skeletonization was used.

Conflict of interest: none declared.

REFERENCES


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[18] Dr F. Riess (Hamburg, Germany): I can give a short comment on bilateral skeletonized mammary artery and patency control by re-angiography. We have performed more than 6000 complete arterial revascularizations during the last 15 years using bilateral mammary artery in the T-raft technique and we have postoperative re-angiography in about 10% of these patients showing fantastic patency rates. About 95% of all bypasses were patent within a follow-up period up to 13 years. So we are very convinced that the concept of bilateral skeletonized mammary artery and patency control in the T-raft technique with sequential anastomoses is excellent.

APPENDIX. CONFERENCE DISCUSSION

Dr A. Hatemi (Istanbul, Turkey): I would like to begin by mentioning one important issue: the lack of control angiograms that unfortunately conforts all coronary surgeons in our time. It is indeed difficult to convince a patient without any complaint to accept such a procedure, but I wanted to emphasize this issue because I believe that the clinical outcome or survival might not be the correct parameters to compare the fate of the arterial graft types used. The problem could possibly be overcome with the help of multi-slice CT coronary angiography. Would you comment on that.

Dr Di Mauro: Yes, sure. You are right. But today it is very difficult to find any space in the cath lab to obtain a control, especially in an asymptomatic patient. And most of our patients had no positive provocative test or angina, so it’s very difficult to convince them to undergo angiograms which is an invasive assessment method. Then if we convince the patient, we have no space in the cath lab, so the problem remains. Probably you are right. Now I’m working with a cardiologist who performs CT scans and so probably in the future we will superimpose controls using the high-risk subgroups. But we should or might also agree that the longer harvesting time for the IMA is becoming even longer when a resident is in charge of that harvest, which is very often in the case in university hospitals like yours. And if a skeletonization request is added, which I believe is a more demanding technique necessitating higher levels of concentration, patience and expertise, this can sometimes make the situation a bit more complex for the resident.

On the other hand, manipulation difficulties with the skeletonized graft can also be an important issue for the first assistant. For this reason, in our institution we didn’t insist on full skeletonization for IMA harvest, and partial skeletonization is our standard. With this technique we were able to overcome all of these problems and without any sacrifices in our arterial anastomosis numbers, patency rates, et cetera.

I believe the utmost advantage of the skeletonized IMA graft lies in the ease of visualization and evaluation of its quality and full length, which is not possible with a classically pedicled IMA graft. I would therefore assume that the superiority of skeletonized IMAs shown in your paper may well be attributed to overlapped traumas that may easily be hidden in a crowded pedicled IMA pack. Would you agree?

Dr Di Mauro: One of the reasons could surely be that we can look at the entire course of the mammary and so we can check everything. And if we were not convinced about using the mammary, we changed. With the pedicle you cannot do this.

Regarding the semi-skeletonization, as I said before, I started my residency with the concept that we must harvest the internal mammary in a skeletonized fashion. Initially, we took a few minutes to take some pieces of mammary and then progressed to taking all of the mammary in no more than 15 minutes. We also have other advantages with skeletonization: we avoid opening the pleura and so we have a good chance of the patient being discharged from the ICU very quickly, without any respiratory issues or chest pain. However, semi-skeletonization could also be a good alternative to pedicled IMAs.

Dr F. Riess: I agree. The difference between pedicled and skeletonized IMAs is in the anatomy of the mammary artery. A skeletonized IMA can be harvested with a single incision in the chest and the pedicle is preserved. In contrast, a pedicled IMA requires multiple incisions and the pedicle is not preserved.

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