Propensity matched analysis of bilateral internal mammary artery versus single left internal mammary artery grafting at 17-year follow-up: validation of a contemporary surgical experience†

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Abstract

OBJECTIVES: Bilateral internal mammary arteries (BIMA) remains widely underutilized in coronary artery bypass grafting (CABG). Although prior research has demonstrated a long-term benefit of the use of BIMA over left internal mammary artery (LIMA)-only, validation of these results is lacking in a contemporary surgical experience. We compared complications and survival at 17-year follow-up in a large series of consecutive CABG patients from a single institution that underwent BIMA grafting with a propensity-matched group where LIMA only was used.

METHODS: Propensity scores representing the estimated probabilities of patients receiving either BIMA or LIMA alone were developed based on 22 observed baseline covariates in a logistic regression model with procedure group as the dependent variable. The nearest-neighbour-matching algorithm with Greedy 5-1 Digit Matching was used to produce two patient cohorts of 928 patients each balanced for baseline factors. We compared 30-day morbidity and mortality, as well as long-term survival at 5-year intervals up to 17-year follow-up.

RESULTS: In-hospital and 30-day mortality was 0.8% for the BIMA group and 1.1% for the LIMA-saphenous vein grafting (SVG). No significant difference was found in complications, mortality and/or length-of-stay between these two groups. Off-pump was done in 48.9% of BIMA cases and 51.3% of LIMA cases. Regardless of the types of grafts used, on-pump patients were more likely to have postoperative permanent strokes and longer postoperative lengths of stay. Use of the BIMA over LIMA-only had a statistically significant impact conferring a 10% survival advantage at 10-year and 18% at 15-year follow-up. The Kaplan–Meier survival curves comparing off-/on-pump BIMA and off-/on-pump LIMA-SVG patients demonstrated a 22% survival advantage for off-pump BIMA patients when compared with on-pump LIMA-SVG patients at 15-year follow-up.

CONCLUSIONS: Perioperative complications do not increase with the use of BIMAs. Long-term survival is optimized with off-pump CABG and BIMA grafting. The low morbidity and mortality rates in this series are likely due to the continuous evolution of technology and the adoption of less invasive options for CABG patients. A more widespread use of BIMAs in CABG patients would continue to improve the overall excellent short- and long-term results of this operation.

Keywords: Coronary artery bypass • Mammary arteries • Off-pump

INTRODUCTION

The use of bilateral internal mammary arteries (BIMA) grafting has been documented to be advantageous over left internal mammary artery (LIMA) grafting [1–5]. Although some surgeons still question its overall effectiveness in coronary artery bypass grafting (CABG) surgery, BIMA grafting has been shown to significantly improve clinical outcomes [1] and increase long-term survival, even in patients with chronic kidney disease [2] and diabetes [3] and those who are 70 years of age or less [4, 5]. In-hospital and 30-day mortality rates for LIMA patients have also been reported to be 1.5–2.7 times higher than that of BIMA patients [2, 4]. However, the increased risk of sternal wound infections (SWIs) that has been associated with BIMA grafting remains unresolved. Some studies cite no increase in the risk of SWIs with BIMA grafting [6, 7], while others report an increased incidence of SWIs particularly in diabetic patients [8, 9]. Despite the risks involved, BIMA grafting appears to be highly effective at...
improving short- and long-term survival. Unfortunately, BIMA grafting is used sparingly and remains widely underutilized, accounting for only 4% of CABG procedures in the USA [10].

The objective of this study was to compare the perioperative risks, complications, outcomes, in-hospital (up to 30 days) and long-term survival in a large series of consecutively isolated CABG patients who underwent BIMA grafting versus LIMA grafting between 1994 and 2010. Data from two propensity-matched groups of patients selected from this contemporary experience were analysed.

MATERIALS AND METHODS

Patient population

This study included patients who had isolated CABG procedures that utilized internal mammary artery (IMA) grafting performed at The Valley Heart and Vascular Institute between January 1994 and December 2010. Data were collected prospectively using standard elements and definitions from the Society of Thoracic Surgeons (STS) database. The database was approved by the Institutional Review Board (IRB), and informed consent was waived for this study.

A total of 6313 patients with isolated CABG were available for inclusion in this study. Of these, 1459 procedures (23.1%) were performed using BIMA grafting and 4854 (76.9%) with LIMA-saphenous vein grafting (SVG). All available LIMA-SVG patients who had not undergone valvular or previous CABG surgeries were included. Patients undergoing procedures that involved the use of radial arteries as conduits and where bypass was performed on only one coronary artery were excluded. Preliminary comparisons of demographic and preoperative comorbidities are presented in Table 1.

Since the BIMA and LIMA-SVG groups were significantly different on a majority of the baseline characteristics, propensity-matching was used to provide a more balanced comparison between the groups. Baseline characteristics of the propensity-matched groups are presented in Table 2. The groups were well-balanced on all characteristics except age and body mass index (BMI), which were found to be significantly higher in the LIMA-SVG group (Table 2).

The overall goals of this study were to: (i) examine in-hospital and 30-day operative morbidity and (ii) compare long-term survival by assessing all-cause mortality. In-hospital and 30-day operative mortality outcomes were documented in the STS database and included in the analyses. Long-term mortality was ascertained by searching demographic information for each database and included in the analyses. Long-term operative mortality outcomes were documented in the STS database.

Surgical technique

Each patient underwent off-pump or on-pump CABG at the discretion of the surgeon, using either the BIMA or LIMA-SVG as the conduit(s) of choice. Mammary arteries were not skeletonized as it was not a routine practice at our institution. Of the total 928 propensity-matched BIMA patients, 454 (48.9%) procedures were performed without cardiopulmonary bypass (off-pump) and 474 (51.1%) with cardiopulmonary bypass (on-pump). Likewise, 476 (51.3%) LIMA-SVG patients underwent off-pump CABG, while 452 (48.7%) underwent on-pump CABG. Various factors factored in when deciding whether off-pump or on-pump CABG approach should be used, including difficulty level, characteristics of the aorta, target sizes, haemodynamic stability and tolerance to cardiac mobilization. The final decision was left entirely to the surgeon and evolved as more experience

### Table 1: Baseline characteristics of all 6313 isolated coronary bypass graft surgery patients comparing use of BIMA and LIMA-SVG

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>BIMA N (%)</th>
<th>LIMA-SVG N (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD)</td>
<td>58.6 ± 9</td>
<td>69.1 ± 10</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI (mean ± SD)</td>
<td>27.8 ± 4</td>
<td>28.3 ± 5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>1358 (93.1)</td>
<td>3306 (68.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of smoking</td>
<td>922 (63.2)</td>
<td>3010 (62.0)</td>
<td>0.41</td>
</tr>
<tr>
<td>History of diabetes mellitus</td>
<td>100 (6.9)</td>
<td>1881 (38.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of renal failure</td>
<td>14 (1.0)</td>
<td>316 (6.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Elevated cholesterol</td>
<td>996 (68.3)</td>
<td>3081 (63.5)</td>
<td>0.01</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>910 (62.4)</td>
<td>3667 (75.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td>632 (43.3)</td>
<td>2446 (50.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Prior cerebrovascular accident</td>
<td>36 (2.5)</td>
<td>363 (7.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of atherosclerotic disease</td>
<td>44 (3.0)</td>
<td>482 (9.9)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of peripheral vascular disease</td>
<td>102 (7.0)</td>
<td>712 (14.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>18 (1.2)</td>
<td>251 (5.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of arrhythmias</td>
<td>80 (5.5)</td>
<td>536 (11.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Haematocrit</td>
<td>41 (3.4)</td>
<td>385 (5.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Left main disease</td>
<td>474 (32.5)</td>
<td>1659 (34.2)</td>
<td>0.23</td>
</tr>
<tr>
<td>Triple vessel disease</td>
<td>1240 (85.0)</td>
<td>3998 (82.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Left ventricular ejection fraction</td>
<td>52 ± 11</td>
<td>49 ± 13</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

### Table 2: Baseline characteristics of 928 propensity-matched isolated coronary artery bypass patients comparing use of BIMA and LIMA-SVG

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>BIMA N (%)</th>
<th>LIMA-SVG N (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD)</td>
<td>60.9 ± 9</td>
<td>62.1 ± 9</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>BMI (mean ± SD)</td>
<td>27.6 ± 4</td>
<td>28.9 ± 5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>828 (92.9)</td>
<td>829 (89.3)</td>
<td>0.94</td>
</tr>
<tr>
<td>History of smoking</td>
<td>598 (64.4)</td>
<td>635 (68.4)</td>
<td>0.07</td>
</tr>
<tr>
<td>History of diabetes mellitus</td>
<td>100 (10.8)</td>
<td>101 (10.9)</td>
<td>0.94</td>
</tr>
<tr>
<td>History of renal failure</td>
<td>13 (1.4)</td>
<td>17 (1.8)</td>
<td>0.48</td>
</tr>
<tr>
<td>Elevated cholesterol</td>
<td>625 (67.3)</td>
<td>605 (65.2)</td>
<td>0.34</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>631 (68.0)</td>
<td>641 (69.1)</td>
<td>0.62</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td>416 (44.8)</td>
<td>420 (45.3)</td>
<td>0.85</td>
</tr>
<tr>
<td>Prior cerebrovascular accident</td>
<td>35 (1.9)</td>
<td>23 (1.2)</td>
<td>0.11</td>
</tr>
<tr>
<td>History of cardiovascular disease</td>
<td>39 (2.1)</td>
<td>29 (1.6)</td>
<td>0.22</td>
</tr>
<tr>
<td>History of peripheral vascular disease</td>
<td>84 (4.5)</td>
<td>92 (5.0)</td>
<td>0.53</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>17 (1.8)</td>
<td>20 (2.1)</td>
<td>0.96</td>
</tr>
<tr>
<td>History of arrhythmias</td>
<td>56 (3.0)</td>
<td>69 (3.7)</td>
<td>0.23</td>
</tr>
<tr>
<td>Haematocrit</td>
<td>41.1 ± 4</td>
<td>40.8 ± 5</td>
<td>0.74</td>
</tr>
<tr>
<td>Left main disease</td>
<td>304 (32.8)</td>
<td>295 (31.8)</td>
<td>0.66</td>
</tr>
<tr>
<td>Triple vessel disease</td>
<td>752 (81.0)</td>
<td>761 (82.0)</td>
<td>0.86</td>
</tr>
<tr>
<td>Left ventricular ejection fraction</td>
<td>52 ± 11</td>
<td>51 ± 12</td>
<td>0.09</td>
</tr>
</tbody>
</table>
was gathered with the off-pump platform. These data are not included in our analysis, since they were not documented for most of the patients in the series.

Off-pump cases were performed using a commercially available stabilizing device. Due to the fact that at least four different surgeons performed these procedures throughout the 17 years, there were some minor variations in surgical technique. There were nonuniform criteria for grafting sequences. Proximal anastomosis was performed using a partial occlusion clamp, and intracoronary shunts were used occasionally. For extremely calcified aortas, the ‘no-touch technique’ was applied.

Traditional cardiopulmonary bypass (on-pump) procedures were performed with the following standard techniques: central cannulation, roller pumps, membrane oxygenators, appropriate filters, antegrade and retrograde cardioplegia, and mild hypothermia at 30–34°C.

Data analysis

Data were prospectively collected and stored in a database certified by the Society of Thoracic Surgeons. Continuous data are displayed as means with standard deviation. Categorical data are expressed as proportions. Univariate statistical tests for continuous data included tests of mean differences using the Student’s t-test. Categorical variables were analysed using the Chi-squared test. Survival was analysed using Kaplan–Meier survival curves. Multivariate analysis of long-term outcomes was analysed using Cox proportional hazards regression modelling, including in-hospital clinical and procedural variables as factors in the model. Propensity-matching was used to provide a more valid comparison between the groups. Propensity scores representing the estimated probabilities of patients receiving either BIMA or LIMA-SVG alone were developed based on 22 observed baseline covariates in a logistic regression model with procedure group as the dependent variable (All variables in Table 2 plus surgical acuity, pump status, arteries bypassed and use of intra-aortic balloon pump from Table 3 were used to construct the propensity model). The nearest-neighbour-matching algorithm with Greedy 5·1 Digit Matching was employed to find as many 1:1 matches between the surgical approaches based on the propensity scores to produce two balanced patient cohorts. A value of $P < 0.05$ was used to determine the statistical significance of all tests used. Analyses were performed using the SPSS statistical software package version 18.0 (IBM/SPSS Inc., Chicago, IL).

RESULTS

There was no statistically significant difference in terms of surgical acuity between the BIMA and LIMA-SVG patients; slightly more than half of each group underwent urgent CABG (Table 3). About half of the propensity-matched cases from each group (48.9% for BIMA and 51.3% for LIMA-SVG) were conducted off-pump, but there was no significant difference between the two groups. The only significant difference in surgery status between the two groups was in the number of arteries bypassed. The BIMA group had a slightly higher number of bypassed arteries when compared with the LIMA-SVG group (3.6 versus 3.4; $P < 0.0001$). STS-predicted mortality rates were similar for both the BIMA and LIMA-SVG groups (1.1 versus 1.2% respectively; $P = 0.14$).

In-hospital and 30-day mortality was similar between the BIMA and LIMA-SVG groups, 0.8 versus 1.1%, respectively; $P = 0.47$ (Table 3). Overall, there was no significant difference between perioperative complications and post-surgery length of stay. However, more BIMA patients required blood transfusions than LIMA-SVG patients (35.8 versus 31.5%; $P = 0.05$).

Average follow-up time for the cohorts was 9.0 ± 5 years. The use of the BIMA resulted in an overall long-term survival advantage for CABG patients when compared with those who had the LIMA-SVG utilized (Fig. 1). Initial long-term survival at 1 year for

![Figure 1: Kaplan–Meier survival curves comparing propensity-matched BIMA and LIMA-SVG patients ($P < 0.0001$).](https://academic.oup.com/ejcts/article-abstract/41/4/770/645681)
both groups was very high (99%). Differences in survival were first observed at around 3 years, resulting in a 5% survival advantage for BIMA patients at 5 years (96 versus 91%). By 10 years, the long-term survival advantage increased to 10% (89 versus 79%) and was most pronounced at 15 years, conferring a survival advantage of 18% (79 versus 61%) for BIMA patients over LIMA-SVG patients.

Since age and BMI were statistically significantly different between BIMA and LIMA-SVG patients after propensity adjustment, a Cox proportional hazards regression analysis was used to determine the independent association of these factors with long-term survival. This analysis demonstrated that after controlling for the effects of patient age and BMI, patients receiving a LIMA-SVG procedure were almost one and a half times more likely to die compared with the BIMA patients (Hazard ratio (HR) = 1.485 [1.191–1.852, 95% confidence interval (CI)]; see Table 4).

Given the improved outcomes and mortality reported for patients undergoing CABG, the use of cardiopulmonary bypass (off pump versus on pump) was analysed. Observed in-hospital and 30-day mortality was not significantly different among off-/on-pump BIMA and off-/on-pump LIMA-SVG patients, although the STS-predicted mortality rate for on-pump LIMA-SVG patients was significantly higher than the other three subgroups (Table 5). However, on-pump patients had a higher prevalence of post-operative permanent stroke (1.1% for on-pump BIMA and 1.1% for on-pump LIMA-SVG; P = 0.02). On average, on-pump patients stayed in the hospital for almost 8 days, compared with 6 days for off-pump patients (P < 0.0001).

**DISCUSSION**

This retrospective study found that CABG patients who underwent BIMA grafting had significantly better long-term survival when compared with propensity-matched patients who underwent LIMA-SVG grafting. A significant survival advantage for BIMA patients was found throughout the 17-year follow-up period. This difference continued to diverge between the groups and became most pronounced at 15 years. Long-term survival rates at each time interval for these two patient groups were higher than those reported in other studies [2, 5, 10–12]. Thirty-day mortality rates for both groups were lower than STS-predicted rates and those cited in other similar studies [1, 4, 5, 10, 11]. Fewer in-hospital and 30-day deaths occurred in the BIMA group when compared with the LIMA-SVG.
The number of arteries bypassed for both the LIMA and BIMA groups were higher than the national STS average, which can be explained by increased efforts of surgeons to achieve a more complete revascularization in the patients undergoing BIMA grafting, who are typically younger [13]. Interestingly, a higher number of BIMA patients needed blood transfusions than LIMA patients, which is in concordance with prior published reports [14, 15] and is likely related to a more extensive dissection necessary for the harvesting of both IMAs.

No increase in perioperative complications was found when BIMA grafting was used. This finding serves to assuage surgeons’ concerns that BIMA grafting increases the risk for complications, such as SWIs, postoperative MIs, and postoperative stroke. In fact, BIMA grafting has been shown to yield similar or lower rates of SWIs when compared with other grafting procedures [6]. Additionally, skeletonization of the IMAs during harvesting has been shown to minimize the likelihood of SWIs [16], particularly in diabetic patients [17, 18]. In our study, we did not control for this variable as most surgeons involved in this study did not routinely skeletonize either mammary artery.

Although this is not the first retrospective study examining short- and long-term mortality and complications between BIMA and LIMA-SVG patients, our study represents one of the largest retrospective propensity-matched studies in terms of size of patient population and length of follow-up. It is, however, the largest study examining these differences in a contemporary series of patients. Similar studies analysed patients who underwent procedures from 1971 to 1995, whereas our experience extends from 1994 to 2010 [1, 10, 12]. Our contemporary series of patients underwent CABG procedures more recently, where technology, surgical techniques, and other procedural factors are likely more advanced and refined than they were in the 1970s and 1980s.

Our results demonstrated a significant interplay between conduit selection and pump status. The increased use of off-pump CABG procedures has been shown to result in overall lower stroke rates and stroke-related mortalities in the published literature [19, 20]. This finding has been confirmed in our series, in addition to lower postoperative lengths of stay. In addition, we found that the use of BIMA in conjunction with off-pump surgery resulted in a statistically significant improvement in long-term survival. This confirms that conduit selection and pump status provide an independent and unique additive benefit, which was confirmed by the multivariate Cox proportional hazards regression model comparing off-pump BIMA with on-pump LIMA-SVG. This fact was further supported by the Kaplan-Meier analysis comparing on-pump BIMA versus on-pump LIMA-SVG.

The differential survival advantage conferred by the use of BIMA over LIMA in our study, particularly at 15 years, was greater than that reported in other studies [1, 5, 10, 12]. Our findings add to the growing literature that asserts the superiority of BIMA over LIMA use, particularly in terms of improved short- and long-term mortality with no significant increase in perioperative complications for CABG patients, despite the increased operative time, technical skill and demands of the procedure.

It has been reported that IMAs have atheroprotective effects through increased synthesis of potent vasodilators like nitric oxide and decreased production of vasoconstrictors such as endothelin-1 and angiotensin-II [21]. Moreover, IMAs have also been found to transmit their atheroprotective properties and increased collateral circulation to recipient vessels thereby preserving myocardial viability and improving overall post-CABG outcomes [21]. These factors may have contributed to the survival advantage observed in our cohort that received BIMA.

Translational studies have also been conducted to analyse the different aspects between the IMAs and other conduits, such as the radial artery and saphenous vein. Differential gene expression, protein levels and histological features have been found that explain the superiority of IMA as a CABG conduit, including decreased blood coagulation via increased tissue plasminogen activator and reduced tissue factor levels, anti-atherosclerotic properties via decreased LOX-1 receptor expression, and regulated cell growth via decreased platelet-derived growth factor (PDGF) and MAP Kinase levels [22-24].

Along with proven superior clinical outcomes in numerous large published series, the exceptional inherent biological features of IMA combined with new surgical approaches to coronary bypass grafting should help increase the overall use of BIMAs in coronary revascularization. Our study confirms that a more widespread use of both IMAs may provide superior outcomes and better long-term survival after coronary revascularization without an increase in immediate complications.

### Limitations

Follow-up data were conducted using the social security death index (SSDI). Although mortality information for the majority of
patients was found using this database, there were a small number of patients with incorrect social security numbers or other erroneous information. It is possible that records in the SSDI have not yet been updated for patients who recently expired. However, given the relatively large sample size in this study, it is unlikely that these limitations would substantially alter the results, and any errors would most likely be equally distributed across the groups. Furthermore, cause of death was not reported as this information was not available in the SSDI.

With regard to the patients who had a stroke as a complication of CABG, we do not provide any information about the characteristics of the ascending aorta as the routine use of intraoperative transoesophageal echocardiogram (TEE) was not standardized throughout the study period and therefore this information is not available for all patients.

This retrospective study was conducted at a medium-sized, non-academic hospital that serves a rather large and affluent patient population. Due to its location in an affluent suburb outside of a major city, this hospital serves a generally wealthier group of patients who have the resources and knowledge to maintain healthier lifestyles. These attributes may have predisposed this institution to an overall different experience than that of a large academic or small community hospital. Nonetheless, the long follow-up time, large series of patients and statistical methods (e.g. propensity matching) included in this study were substantial enough to reduce sampling bias as much as possible without compromising the integrity of the study.

In conclusion, the low rates of morbidity and mortality in this series of patients are likely due to the constant evolution of technology and the adoption of less invasive options for CABG patients. A more widespread use of BIMAs for CABG would continue to improve the overall excellent short- and long-term results of this operation.

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Conflict of interest: none declared.

REFERENCES


APPENDIX. CONFERENCE DISCUSSION

Dr D.P. Taggart (Oxford, UK): If what you have shown us is correct, because this is one of the longest propensity-matched follow-ups that exists in the literature, then again, as Professor Buxton showed us, this is potentially very important.

But this is also the first time I have seen a paper on bilateral internal mammary arteries which showed no difference; there was absolutely no difference in deep sternal wound infection. There are two possibilities here, either you are doing something totally different from every other group who has ever achieved this, or, alternatively, in your propensity matching you must have excluded patients who did have deep sternal wound infections. So the obvious question I am going to ask you is, of the bilateral IMA grafts you have shown us here, what percentage is that of the total population who had bilateral IMA grafts?

Dr Grau: Of the total of 6,000 patients, around 1,800 of them had bilateral mammarys. From that total, we selected the group for propensity matching analysis. The overall risk of a sternal wound infection in that population was around 0.5%, so it was very low in the entire group even before our selection by propensity matching. This was shown in one of the first tables when I described the two populations; the risk of a sternal wound infection in the overall series of 6,000 cases was also very low.

But the truth of the matter is that there was no difference between bilateral mammarys and the use of a single mammary, understanding that the other 4,000 patients that were not included in the single mammary SVG were likely to be people who were sick or were older and who we couldn’t match by propensity matching analysis to the BIMA group. There was nobody younger.

Dr Grau: And has the rate of use of double mammary changed over time?

Dr Grau: Yes, it did change. In the 1990s, I would say 1996–1997, one of the surgeons led in the use of bilateral mammarys and everybody kind of followed track after that.

Dr Pagano: So there are two methodological issues that I think you need to address and recognise the potential limitations of your outstanding results. First of all, if you do a propensity score matching within a single unit, you are really tied down by confounding by indication. The second thing is that if you have four surgeons, you will have some variability in the outcomes, and that variability may be significant, and you should consider using surgeons as a random effect to account for that.

Dr Grau: Point well taken.


EDITORIAL COMMENT

Bilateral internal mammary arteries: a very important missing trick for coronary artery bypass grafting

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Keywords: Coronary artery bypass grafting • Bilateral • Internal mammary arteries

In the current issue of the journal, Grau et al. [1] described 17-year outcomes of a propensity-matched group of 928 patients with bilateral internal mammary arteries (BIMAs) and 928 with a left internal mammary artery (LIMA) and additional vein grafts as necessary. Their most important conclusion is a clinically important survival benefit with BIMAs at ~10% at 10 years and 18% at 15 years and further enhanced if performed as an off-pump procedure. If correct, this should encourage a change in clinical practice because currently fewer than 10% of patients in Europe and fewer than 5% in the USA receive BIMA grafts. So, two fundamental questions are: (i) are the conclusions supported by the data and (ii) are the conclusions consistent with other existing evidence?

Before answering these questions, some relevant background information is useful. The IMA story began in earnest over a quarter of a century ago when Loop et al. [2] from the Cleveland Clinic published their seminal paper reporting that an IMA graft to the left anterior descending coronary artery, in comparison to a saphenous vein graft, over a 10-year period significantly improved the survival accompanied by a reduction in the incidence of myocardial infarction, recurrent angina and the need for repeat intervention. In 2001, our own group published the first systematic review of BIMA versus SIMA in almost 15,000 patients and reported a hazard ratio of death at 0.81 in favour of BIMA patients [3]. Such observations were entirely consistent with several angiographic studies reporting superior angiographic patency of both IMAs in comparison to saphenous vein grafts when placed to the left-sided coronary vessels both early and late after surgery.

Although such evidence in favour of BIMA has been available for over a decade, their routine use in clinical practice as