

## Impact of pump status and conduit choice in coronary artery bypass: A 15-year follow-up study in 1412 propensity-matched patients

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**Objective:** Previous studies have demonstrated that bilateral internal mammary artery (BIMA) grafts lead to superior outcomes compared with single internal mammary artery grafts. This study examines whether cardiopulmonary bypass affects conduit-dependent outcomes of coronary artery bypass grafting (CABG) surgery.

**Methods:** From 1994 to 2013, a total of 6666 patients underwent isolated CABG surgery at our institution. Of these procedures, 3548 (53.2%) were performed off pump. A BIMA–saphenous vein graft (SVG) was used in 1544, and 5122 had left internal mammary artery–SVGs. These 2 conduit groups differed significantly in baseline characteristics. Propensity matching based on 22 preoperative variables and using a nearest-neighbor matching algorithm was used to make balanced cohorts, resulting in 2 groups of 1006. To account for the influence of pump status on conduit selection, a second propensity score was developed for pump use. These cases were matched to create 4 patient cohorts of 353 patients each (a total of 1412), balanced for both conduit use and pump status. Late mortality was determined using the Social Security Death Index.

**Results:** No difference was found in survival between patients receiving BIMA-SVGs on or off pump (78.9% vs 79.1%). BIMA-SVGs outperformed the left internal mammary artery–SVGs regardless of whether the procedure was performed off pump (73.9%) or on pump (69.9%).

**Conclusions:** This study demonstrates that the use of cardiopulmonary bypass does not significantly affect the long-term outcomes in these patients as long as full revascularization is achieved. In addition, these results are consistent with prior research showing that the use of BIMAs produces better outcomes than use of a single internal mammary artery when performing CABG. (*J Thorac Cardiovasc Surg* 2015;149:1027-33)

See related article on pages 1034-5.

Supplemental material is available online.

Coronary artery bypass grafting (CABG) remains the most common cardiac surgery in the United States. However, the question of whether to perform this procedure with cardiopulmonary bypass (on pump) or without (off pump) has been contested recently. In the past 4 years, several large randomized trials have been aimed at elucidating the

optimal surgical strategy for CABG, including the following: Randomized On/Off Bypass (ROOBY); CABG Off or On Pump Revascularization Study (CORONARY); German Off-Pump Coronary Artery Bypass Grafting in Elderly Patients (GOECABE); Danish On-Pump Versus Off-Pump Randomization Study (DOORS); and Best Bypass Surgery Trial (BBS).<sup>1-5</sup> However, these trials have shown mixed results.

In 2012, Møller and colleagues<sup>6</sup> performed a meta-analysis of randomized controlled trials comparing on-pump and off-pump CABG.<sup>6</sup> The meta-analysis of 47 studies found that off-pump CABG carried a 37% lower risk for 30-day mortality.<sup>6</sup> Conversely, the same meta-analysis,<sup>6</sup> based on 27 studies that reported >30-day mortality, demonstrated that patients undergoing off-pump CABG had a 34% higher risk for mortality. However, Zhang and colleagues<sup>7</sup> recently performed a meta-analysis that includes trials (GOECABE and CORONARY) published after the analysis by Møller and colleagues,<sup>6</sup> and demonstrated no significant difference in 1-year survival after on-pump versus off-pump CABG.

The long-term effects of pump status have been investigated recently by Kim and colleagues,<sup>8</sup> who report that off-pump CABG patients had both a significantly higher risk of death and a lower number of target vessels bypassed. These results are complemented by the recent meta-analysis

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**Abbreviations and Acronyms**

BIMA	= bilateral internal mammary artery
MI	= body mass index
CABG	= coronary artery bypass grafting
LIMA	= left internal mammary artery
STS	= Society of Thoracic Surgeons
SVG	= saphenous vein graft

by Takagi and colleagues,<sup>9</sup> which demonstrates a significant 7% increase in long-term mortality, decreased number of grafts and degree of revascularization in off-pump compared with on-pump CABG. These studies emphasize the current concern with off-pump CABG—that the increased technical difficulty will lead to fewer distal grafts and therefore incomplete revascularization.

Many other factors, including conduit choice, contribute to the long-term success of CABG. Retrospective studies have demonstrated that use of bilateral internal mammary arteries (BIMAs) is associated with significantly improved clinical outcomes and long-term survival, even in patients who have diabetes, chronic kidney disease, or are below 70 years of age.<sup>10-15</sup> The use of BIMAs has also been shown to reduce the negative effects of gender on short- and long-term outcomes.<sup>16</sup>

We recently published a retrospective comparison of long-term outcomes in 1856 propensity-matched patients receiving either BIMA–saphenous vein grafts (SVGs) or left internal mammary artery (LIMA)–SVGs.<sup>17</sup> In that study, an 18% survival benefit was found in BIMA-SVG patients at 15 years. These results are representative of the current state of BIMA research: retrospective, yet robust, analyses that support the long-term benefit of BIMA use.<sup>14</sup> Despite this evidence, BIMAs are used in only 4% of cases in the United States, and 12% in Europe.<sup>12,18</sup> The current American College of Cardiology Foundation/American Heart Association Guidelines for CABG reflect the lack of randomized clinical trials addressing the matter, as they label the use of BIMAs as a class IIa recommendation with a B level of evidence.<sup>19</sup> The Arterial Revascularisation Trial<sup>13</sup> is looking at this subject, and this work will not be completed until 2018. At 1 year, Taggart and colleagues<sup>13</sup> found that short-term morbidity and mortality were comparable, regardless of whether the BIMA or single internal mammary artery approach was used.

Given the recent focus on the long-term outcomes of on-pump and off-pump CABG, we investigated whether the advantages of using BIMAs were influenced positively or negatively by the use of cardiopulmonary bypass. In the current study, we analyze the effects of pump status and conduit choice on the long-term outcomes of CABG in

1412 patients who were propensity matched for both conduit use and pump status.

**METHODS****Patient Demographics**

From 1994 to 2013, a total of 6666 patients underwent isolated CABG. Of these procedures, 3548 (53.2%) were performed off pump. Patients received either BIMA-SVGs (n = 1544; 23.2%) or LIMA-SVGs (n = 5122; 76.8%). Patient demographics were prospectively collected at the time of surgery using a Society of Thoracic Surgeons (STS)–certified database, approved by the hospital institutional review board, which gave a waiver of consent for the purposes of this research.

Comparison of the 1544 BIMA-SVG and 5122 LIMA-SVG patients showed many statistically significant differences in preoperative characteristics between the 2 groups. To correct for these differences, and to evaluate the interrelationship between conduit selection and pump status, propensity matching was utilized in 2 stages. Using a logistic regression model, the probability of a patient receiving BIMA grafts was developed based on 22 baseline covariates: gender, age, body mass index (BMI), diabetes, history of smoking and current smoking status, hypertension, history of cerebrovascular disease, number of diseased coronary vessels, peripheral vascular disease, presence of heart failure New York Heart Association class IV, history of stroke, chronic lung disease, myocardial infarction history, renal failure, left main disease, left ventricular ejection fraction, creatinine, cardiogenic shock presentation, prior cardiac surgery, and urgency status. The resulting propensity scores were used to identify as many 1:1 matches as possible between BIMA-SVG and LIMA-SVG patients, using the nearest-neighbor matching algorithm with greedy 5-1 digit matching. This process produced a balanced cohort of 1006 BIMA-SVG and 1006 LIMA-SVG patients (Table E1).

The STS risk-adjusted in-hospital mortality rate was similar in the 2 groups. These 2012 patients were further divided into 4 groups based on pump use (BIMA-SVG: 492 off pump, 514 on pump; LIMA-SVG: 492 off pump, 514 on pump). Statistically significant differences among these 4 groups were found on many baseline characteristics, including age, BMI, left ventricular ejection fraction, diabetes, history of renal failure, history of heart failure or presence of heart failure New York Heart Association class IV, and STS-predicted risk of in-hospital mortality. A propensity score for pump use was calculated for these patients. Matching produced 4 equal-size groups that were comparable on baseline characteristics (Table E2). The STS risk-adjusted mortality rate was similar among the groups. The 30-day and long-term outcomes were compared from the 4 groups from these 1412 patients (353 in each group).

**Statistical Analyses**

Categorical and continuous data are reported as proportions, and means with SDs, respectively. Categorical variables were analyzed using  $\chi^2$  analysis. Continuous data were analyzed using the Student *t* test, or ANOVA for multiple-group comparisons. Late mortality was determined using the Social Security Death Index. Kaplan-Meier survival curves were used to present long-term data, and the log-rank test was used to compare long-term survival among the conduit and pump groups. Cox proportional hazards regression modeling was used as a multivariate analysis to compare the long-term outcomes in the 1412 patients representing the 4 propensity-matched groups. This model included patient baseline characteristics used in the propensity matching, and procedural variables (perioperative placement of the intra-aortic balloon pump, blood transfusion required, number of grafts placed). To control for the year when surgery was performed, a variable corresponding to the era of the surgery was constructed with 3 levels, representing the early (2000 and before), middle (2001 to 2005), and late (2006 to present) surgical experience.

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