Trends in isolated coronary artery bypass grafting over the last decade

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Abstract

OBJECTIVES: The purpose of this study was to assess the impact on hospital mortality and morbidity of extensive myocardial revascularization, using arterial grafts in patients undergoing isolated coronary artery bypass grafting (CABG).

METHODS: Our prospective perioperative database was used to define two groups of patients who underwent isolated CABG with cardiopulmonary bypass, based on the years in which the operation was performed: Group A (2000–2003; 898 patients) and Group B (2009–2012; 1249 patients). The baseline and operative characteristics and outcomes were compared.

RESULTS: Several significant changes in perioperative variables were observed. Group B included higher percentages of patients aged over 80 years (+58.1%), with diabetes (+32.0%) and with a history of percutaneous coronary intervention (+24.9%). The mean EuroSCORE II was significantly increased from 2.5 ± 4.4% in Group A to 3.2 ± 5.7% in Group B (P = 0.001). The mean number of distal anastomoses was significantly increased over time (total: 2.6 ± 0.8 vs 3.1 ± 1.0, P < 0.0001 and with arterial grafts: 1.6 ± 0.8 vs 2.6 ± 0.9, P = 0.017). In-hospital mortality was low and did not significantly differ between Groups A and B (1.3 vs 2.4%; P = 0.08). Significant increases of new-onset atrial fibrillation (11.7 vs 21.9%, P = 0.017) and deep sternal infection (0.2 vs 1.1%, P = 0.017) were observed in Group B, compared with Group A. In multivariate analysis, extensive use of arterial grafts was not a risk factor of hospital mortality or sternal morbidity.

CONCLUSIONS: Despite the increasing risk profiles of patients undergoing CABG, extensive myocardial revascularization using arterial grafts is associated with good early results.

Keywords: Coronary artery disease • Coronary artery bypass grafts • Coronary artery bypass grafting, arterial grafts • Outcomes

INTRODUCTION

Percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG) are two efficient treatments for coronary artery diseases (CADs) that involve significant coronary artery stenoses [1, 2]. Several studies have been published during the last decade, which compare PCI with CABG for myocardial revascularization in a spectrum of CAD patients. In response to these studies, new guidelines on myocardial revascularization have recently been published [2]. CABG revascularization strategies have been shown to produce better results (death, rates of complete revascularization, myocardial infarction (MI), repeat revascularization, quality of life and cost-effectiveness) than PCI for patients with multivessel CAD, left main disease with a SYNTAX score ≥23, diabetes, left ventricular dysfunction and chronic kidney disease [2]. Recent studies have shown that among patients with multivessel CAD, CABG was associated with lower long-term rates of major cardiovascular events than PCI, using new-generation drug-eluting stents [3, 4].

Over the last two decades, a considerable body of evidence has accumulated regarding the long-term benefits of CABG using arterial grafts [e.g. on the left internal thoracic artery (LITA), right ITA (RITA), gastroepiploic artery and radial artery] than using venous grafts. These benefits show improvements in long-term survival and risk reductions for MI, recurrent angina, the need for repeat revascularization and progression of native CADs in grafted vessels with arterial grafts [2, 5–9]. Despite these results, arterial grafts other than the LITA remain poorly utilized in patients undergoing isolated CABG [1, 10, 11].

In response to these results, during the last decade, we have progressively switched our myocardial revascularization strategy in patients undergoing CABG to a strategy of extensively using arterial grafts. The impact of this new strategy on early outcomes has been poorly described, especially in patients who may have during the same period an evolution of their preoperative characteristics. Furthermore, the evolution of patients undergoing isolated CABG has typically been reported from registries with few collected variables [10, 12, 13]. The purpose of this study was to assess the hospital mortality and morbidity associated with the use of an extensive myocardial revascularization strategy, using arterial grafts in patients undergoing...
isolated CABG with cardiopulmonary bypass (CPB) during the past decade.

PATIENTS AND METHODS

Study population

This study was designed to assess trends in patients undergoing isolated CABG with CPB. For all consecutive patients who underwent surgery in our department, preoperative, intraoperative and postoperative data were systematically and prospectively collected in a database (ASTRE, Access, Microsoft®). The Institutional Review Board approved the study procedures. The inclusion criteria consisted of patients aged ≥18 years who underwent an isolated CABG procedure with CPB. Patients were divided into two groups based on the year that the operation was performed: between 1 January 2000 and 31 December 2003 (Group A, 898 patients) and between 1 January 2009 and 31 December 2012 (Group B, 1249 patients; +39.1% compared with Group A). This study design was established regarding the fact that from the year 2004, all the surgeons have adopted progressively the strategy of extensive myocardial revascularization, using arterial grafts for patients undergoing CABG, which is our current strategy since 2009 with no limitations regarding the patient age or comorbidities.

Definition of study end-points

The primary study end-point was hospital mortality, defined as death during the same hospitalization as the surgery or within 30 days of the surgery. The secondary end-point was hospital morbidity.

Statistical analysis

The data are presented as the means ± standard deviations (SDs) or frequencies and percentages. Differences between the categorical variables were analysed using Fisher’s exact tests, depending on the expected values. Differences between continuous variables were analysed using Student’s t-test or the Mann–Whitney test, depending on whether the data exhibited a Gaussian distribution. When differences between two groups were significant, the percentage relative risk was calculated as 100 × (B – A)/A, where A and B are the percentages of patients experiencing the end-points in Groups A and B, respectively.

Receiver-operating characteristic curve (ROC) analysis was performed to estimate the discriminatory ability of the EuroSCORE I (logistic) and EuroSCORE II to predict hospital mortality.

Potential risk factors for hospital mortality and sternal morbidity in Groups A and B were first tested using a univariate analysis (see Supplementary Tables 1–4). Only the variables with a P-value <0.150, and not already included in the EuroSCORE II for the hospital mortality, were used in a multivariate logistic regression analysis (with a backward, stepwise method based on the likelihood ratio test). The odds ratios and their corresponding 95% confidence intervals are reported in addition to their associated P-values.

The statistical computations were performed using SPSS (SPSS®, version 22.0, Chicago, IL, USA).

RESULTS

Preoperative characteristics

The preoperative characteristics are reported in Table 1. Compared with Group A, we observed a significant increase in the proportion of patients with an age of ≥80 years (+58.1%), a high body mass index (BMI, +2.1%), hypertension (+15.3%), dyslipidaemia (+12.6%), diabetes (+32.0%), a history of cerebral vascular disease (+79.4%), extracardiac arteriopathy (+20.0%), PCI (+24.8%), permanent atrial fibrillation (AF) (+86.9%) and New-York Heart Association (NYHA) ≥Class III dyspnoea (+76.7%) in Group B. Significant decreases were observed over time in Group B regarding previous cardiac surgeries (−45.2%), histories of MI (−38.4%), recent MI (−27.1%), prior heart failure (−39.1%) and Canadian Classification Society (CCS) Class IV angina (−37.4%) compared with Group A. Furthermore, antiplatelet therapy significantly increased over time (+30.8%). In Group B, patients were more frequently undergoing optimal medical therapy [statins (+166.5%), β-blockers (+14.6%) and angiotensin-converting enzyme inhibitors (+33.8%)].

Significant increases in glomerular filtration rates (GFRs, regardless of the severity of renal impairment) were observed over time.

The catheterization characteristics revealed no significant changes. The mean left ventricular ejection fraction did not significantly change over time, whereas the percentage of the different degrees of left ventricular dysfunction used for EuroSCORE I and EuroSCORE II assessments decreased during the study period. Regarding the systolic pulmonary artery pressure, significant increases in the different degrees of pulmonary hypertension were observed in the EuroSCORE I and EuroSCORE II assessments over time.

Operative characteristics

The operative characteristics are reported in Table 2. The mean number of distal anastomoses significantly increased by 19.2% in Group B relative to Group A. The proportion of patients with four or more distal anastomoses significantly increased from 12.0% in 2000–2003 to 32.5% in 2009–2012 (+170.8%, P < 0.0001). The ratio of the mean number of distal anastomoses with arterial grafts to the total number of distal anastomoses increased from 61.5% in Group A to 83.8% in Group B (P < 0.0001), whereas the ratio of the mean number of distal anastomoses with venous grafts to the total number of distal anastomoses decreased from 38.5% in Group A to 16.2% in Group B (P < 0.0001). The use of the LITA remained constant, whereas the use of the RITA and BITA significantly increased throughout the study period (+143.1%, P < 0.0001 and +150.1%, P < 0.0001, respectively). The third choice for an arterial graft was the gastroepiploic artery, which showed constant use rates. The use of sequential and Y arterial grafting for distal anastomoses was significantly increased during recent years (+226.8 and +65.3%, respectively, P < 0.0001).

Significant increases were observed in the CPB and cross-clamp times in Group B compared with Group A (P < 0.0001). In recent years, myocardial protection was mainly performed by intermittent antegrade and retrograde cardioplegia. The use of warm blood cardioplegia decreased from 41.8% in 2000–2003 to 24.0% in 2009–2012.
Hospital mortality

The hospital mortality rates were 1.3% in 2000–2003 and 2.4% in 2009–2012, with no significant difference between the two time periods (P = 0.08; Table 3). Between 2000–2003 and 2009–2012, significant increases of 35.4 and 28.0% occurred in the mortality predicted by the EuroSCORE I and EuroSCORE II, respectively (Table 1). In Groups A and B, the expected-to-observed hospital mortality ratios for the EuroSCORE I were 2.3 and 1.7, whereas these ratios for the EuroSCORE II were 1.9 and 1.3, respectively. Using ROC analyses, the area under the curve (AUC) values for the EuroSCORE I were 0.749 (95% confidence interval: 0.549–0.950; P = 0.01) and 0.829 (95% confidence interval: 0.752–0.906; P = 0.03) in Groups A and B, respectively. Regarding the mortality predicted by the EuroSCORE II, the AUC values were 0.874 (95% confidence interval: 0.797–0.951; P < 0.0001) and 0.768 (95% confidence interval: 0.682–0.853; P = 0.04) in Groups A and B, respectively.

Among the preoperative and operative variables, multivariate analysis demonstrated that EuroSCORE II (odds ratio (OR) = 1.06,
Table 3:  End-points

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<tr>
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<tr>
<td><strong>Primary end-point</strong></td>
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<tr>
<td>Hospital mortality</td>
<td>12 (1.3)</td>
<td>30 (2.4)</td>
<td>0.079</td>
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<tr>
<td><strong>Secondary end-points</strong></td>
<td></td>
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<tr>
<td>Cardiac morbidity</td>
<td>169 (18.8)</td>
<td>336 (26.9)</td>
<td>&lt;0.0001</td>
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<td>New-onset atrial fibrillation</td>
<td>105 (11.7)</td>
<td>273 (21.9)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Acute myocardial infarction</td>
<td>22 (2.4)</td>
<td>13 (1.0)</td>
<td>0.011</td>
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<tr>
<td>Troponin I peak (µg/L)</td>
<td>10.2 ± 35.2</td>
<td>14.8 ± 72.8</td>
<td>0.169</td>
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<tr>
<td>Operative or postoperative</td>
<td>86 (9.6)</td>
<td>80 (6.4)</td>
<td>0.007</td>
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<td>ECMO</td>
<td></td>
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<tr>
<td>Operative or postoperative</td>
<td>1 (0.1)</td>
<td>13 (1.0)</td>
<td>0.011</td>
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<tr>
<td>Stroke</td>
<td>14 (1.6)</td>
<td>17 (1.4)</td>
<td>0.055</td>
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<td>Transient stroke</td>
<td>5 (0.6)</td>
<td>7 (0.6)</td>
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<tr>
<td>Permanent stroke</td>
<td>9 (1.0)</td>
<td>10 (0.8)</td>
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<tr>
<td>Pulmonary morbidity</td>
<td>55 (6.1)</td>
<td>104 (8.3)</td>
<td>0.055</td>
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<tr>
<td>Pneumothorax</td>
<td>10 (1.1)</td>
<td>34 (2.7)</td>
<td>0.009</td>
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<tr>
<td>Acute respiratory distress</td>
<td>21 (2.3)</td>
<td>37 (3.0)</td>
<td>0.159</td>
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<tr>
<td>Syndrome</td>
<td></td>
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<tr>
<td>Pleural effusion</td>
<td>26 (2.9)</td>
<td>37 (3.0)</td>
<td>0.928</td>
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<td>Renal function</td>
<td></td>
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<tr>
<td>GFR MDRD on the first POD (mL/min/1.73 m²)</td>
<td>70.2 ± 25.6</td>
<td>81.4 ± 31.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>GFR MDRD at discharge (mL/min/1.73 m²)</td>
<td>73.6 ± 21.7</td>
<td>88.0 ± 29.7</td>
<td>&lt;0.0001</td>
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<tr>
<td>RRT</td>
<td>4 (0.4)</td>
<td>27 (2.2)</td>
<td>0.001</td>
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<tr>
<td>Creatinine level increased by 2-fold</td>
<td>24 (2.7)</td>
<td>94 (7.5)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Sternal morbidity</td>
<td>13 (1.4)</td>
<td>43 (3.4)</td>
<td>0.004</td>
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<tr>
<td>Superficial sternal wound infection</td>
<td>5 (0.6)</td>
<td>16 (1.3)</td>
<td>0.098</td>
</tr>
<tr>
<td>Sternal dehiscence requiring reoperation</td>
<td>6 (0.7)</td>
<td>13 (1.0)</td>
<td>0.118</td>
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<tr>
<td>Deep sternal infection</td>
<td>2 (0.2)</td>
<td>14 (1.1)</td>
<td>0.017</td>
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<tr>
<td>Reoperation on leg after vein-graft harvesting</td>
<td>9 (1.0)</td>
<td>5 (0.4)</td>
<td>0.087</td>
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<tr>
<td>RBC transfusion</td>
<td>487 (54.2)</td>
<td>853 (68.3)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Reoperation due to bleeding</td>
<td>14 (1.6)</td>
<td>26 (2.1)</td>
<td>0.167</td>
</tr>
<tr>
<td>Length of ICU stay (days)</td>
<td>2.7 ± 2.6</td>
<td>3.4 ± 5.4</td>
<td>0.001</td>
</tr>
<tr>
<td>Length of ICU stay ≤ 2 days</td>
<td>597 (66.5)</td>
<td>844 (67.8)</td>
<td>0.266</td>
</tr>
<tr>
<td>Length of hospital stay (days)</td>
<td>8.2 ± 4.2</td>
<td>9.0 ± 6.9</td>
<td>0.003</td>
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</table>

Values with plus and minus signs represent the means ± SD; others represent no. (%). P-values refer to the 2000–2003 group versus the 2009–2012 group (in bold if significant [P < 0.05]). IABP: intra-aortic balloon pump; ECMO: extracorporeal membrane oxygenation; GFR: glomerular filtration rate determined with the Modification of Diet in Renal Disease (MDRD) study equation; POD: postoperative day; RRT: renal replacement therapy; superficial sternal wound infection, involving the skin and subcutaneous tissue but not the sternum; sternal dehiscence requiring reoperation, no positive culture and no treatment with antibiotics; deep sternal infection, infection involving the sternum and/or the mediastinum requiring reoperation and treatment with antibiotics; RBC: red blood cells; ICU: intensive care unit.

95% confidence interval (CI) = 1.01–1.12; P = 0.011), preoperative haemoglobin level (OR = 0.58, 95% CI = 0.39–0.89; P = 0.006) and CPB time (OR = 1.02, 95% CI = 1.00–1.03; P = 0.011) were the risk factors of hospital mortality in Group A. In Group B, these risk factors were BMI (OR = 0.89, 95% CI = 0.80–0.99; P = 0.04), persistent AF (OR = 4.12, 95% CI = 1.28–13.17; P = 0.017), EuroSCORE II (OR = 1.07, 95% CI = 1.04–1.10; P < 0.0001) and CPB time (OR = 1.01, 95% CI = 1.00–1.02; P = 0.008).

Secondary end-points

The secondary end-points are reported in Table 3. The incidence of cardiac morbidity significantly increased over time, primarily due to an 87.1% increase of new-onset AF. Between 2000–2003 and 2009–2012, relative reductions of 58.3 and 33.3% in the risk of postoperative acute MIs and the use of intra-aortic balloon pumps were observed, respectively. Peak postoperative troponin I levels remained constant during the study. The need for mechanical support with extracorporeal membrane oxygenation was significantly increased in Group B compared with Group A.

The incidence rates of postoperative transient ischaemic attacks or stroke were low and did not significantly differ between the two groups. Regarding pulmonary morbidity, no differences were observed in the overall rates between the two groups, whereas the rate of pneumothorax requiring drainage increased during the study period. The preoperative GFR difference observed between the two groups remained present on the first postoperative day (POD) and at discharge, but a greater proportion of patients in Group B had acute kidney injuries during the postoperative course as demonstrated by the need of renal replacement therapy and/or a 2-fold increase in creatinine levels.

More patients in Group B than in Group A had sternal morbidities, with 1.1% deep sternal infections in Group B versus 0.2% in Group A (P = 0.017). Among the preoperative and operative variables, multivariate analysis demonstrated that BMI (OR = 1.10, 95% CI = 1.05–1.16; P = 0.001) was the risk factor of sternal morbidity in Group A. In Group B, the risk factors of sternal morbidity were BMI (OR = 1.10, 95% CI = 1.05–1.16; P < 0.0001) and severe kidney failure (OR = 3.61, 95% CI = 1.58–8.23; P = 0.002).

Over time, red blood cell (RBC) transfusion significantly increased. No differences were observed regarding the need for reoperation due to bleeding between the two groups.

The lengths of intensive care unit and hospital stays were significantly longer in Group B than in Group A, whereas the proportion of patients with a length of intensive care unit ≤ 2 days was similar in the two groups.

DISCUSSION

In our experience, the switch to the extensive use of a myocardial revascularization strategy using arterial grafts was associated with low hospital mortality despite the increased risk profiles of patients undergoing isolated CABG with CPB.

The overall hospital mortality of isolated CABG has been reported to range from 1 to 3% in elective surgery to 42.6% in the presence of acute MI associated with cardiogenic shock [1,2,14]. In our study, the hospital mortality slightly but not significantly increased from 1.3 to 2.4% over time, whereas the predicted 30-day mortality assessed by the EuroSCORE II increased significantly to 3.2% in recent years. Bardissi et al. reported a significant decrease in the observed mortality to 1.9% in 2009. However, this study was limited to isolated primary CABG, and the predicted mortality established by the STS score remained constant at 2.3% during the study period [10]. Two other studies observed slight but nonsignificant decreases in the observed mortality, ranging from 1.8 to 2.2% in more recent years, with no significant changes regarding risk factors [12,13]. Our study reveals that changes to several preoperative variables have occurred during the past decade. Several of these variables are independent predictors of short-term mortality after cardiac surgery used to calculate the
EuroSCORE II [15]. We have observed that the EuroSCORE II was more accurate for predicting in-hospital mortality than the EuroSCORE I. This result was supported by the observation of Biancari et al. [16]. Furthermore, the EuroSCORE II was an independent predictor of hospital mortality in our study. Finally, we observed a 2-fold increase in preoperative AF, which is an independent predictor of postoperative mortality after CABG [17]. This observation was confirmed in our study in Group B.

It is noteworthy that the risk factors, history and treatment of patients referred for CABG have changed. Risk factors of CADs, such as obesity, diabetes, dyslipidaemia and hypertension, have increased in recent years as observed in our and other studies [10, 12, 13]. The increased number of patients who underwent PCI before CABG may lead to several outcomes. Indeed, patients were more often undergoing antiplatelet therapy, which is an independent predictor of increased blood loss and RBC transfusion [18]. Furthermore, several studies have demonstrated that PCI before CABG is associated with higher postoperative mortality and incidence of long-term of death and MI [19]. In our study, patients referred for CABG were more often receiving optimal medical therapy before surgery in the more recent group. These results may explain the global improvement in left ventricular function observed during the past decade as well as the improvement of the GFR.

Most of our CABG procedures were performed in patients with multivessel diseases. CABG is the referent myocardial revascularization therapy for multivessel diseases and produces better long-term survival and lower risks of MI and repeat revascularization than PCI regardless of the type of stent utilized [2–4, 20, 21]. Nevertheless, it must be noted that nearly all of these studies poorly utilized arterial grafts, whereas multiarterial CABG with the BITA has been shown to have a clear long-term survival benefit and a lower risk of nonfatal events [6, 8, 9, 11, 20]. However, extensive myocardial revascularization with arterial grafts, such as the BITA, is associated with longer CPB and cross-clamp times due to the technical time required to perform sequential or Y arterial grafting with the ITA. Nonetheless, in our experience, a longer cross-clamp time did not affect the myocardial protection as assessed by the absence of a modified Troponin I peak and the lower incidence of acute MIs and use of postoperative intra-aortic balloon pumps over time. However, this longer operative time may have impacted several other outcomes. The incidence of postoperative AF significantly increased during the study period, but remained within the range of the most recent publications [22]. Aortic cross-clamp and CPB times have been demonstrated to be the risk factors of postoperative AF. Other studies have also identified that risk factors significantly increase with advanced age, obesity, hypertension and peripheral vascular disease [22]. Another concern regarding a longer CPB time is the risk of renal failure. The incidences of renal replacement therapy and 2-fold increases in creatinine levels were higher in the recent group. However, several independent predictors of renal failure were significantly increased during the same period (e.g. age, obesity, diabetes, hypertension, peripheral vascular disease, cerebrovascular disease and pulmonary hypertension) [23].

One major concern regarding the use of ITAs is the risk of deep sternal infection [24]. Despite a small but significant increased incidence of deep sternal infection, the rate of occurrence remains in the lower range of known incidence values [24]. However, in our multivariate analysis, neither the BITA used nor the mean number of distal anastomoses with arterial grafts was identified as the risk factor of sternal morbidity. The BMI was an independent predictor of sternal morbidity and increased over time in our study. This may explain the small but significant increased incidence of deep sternal infection. Furthermore, it must be noted that when the numbers of deep sternal infections and reoperations on legs after vein-graft harvesting were analysed, no significant difference remained between the two groups (1.2 vs 1.4%). Finally, another adverse outcome that could be attributed to BITA harvesting was a significant increase in pneumothorax.

Our study has several limitations. This study was an observational and single-centre investigation and therefore may have limited applicability to other centres. However, this study shows reduced variability in the studied clinical procedure. Another limitation was the small number of patients in this study. The absence of statistical significance to the observed difference in-hospital mortality might, therefore, be due to insufficient power. We were not able to perform long-term follow-ups to confirm the benefit of arterial grafts on survival.

In conclusion, the switch to extensive myocardial revascularization using both ITAs was associated with good early results despite the changing risk profiles of patients undergoing CABG over the last decade. The EuroSCORE II is a satisfactory risk model for predicting in-hospital mortality. Although it is time-consuming, technically challenging, and associated with the occurrence of marginally adverse events, the use of the BITA must not interfere with the decision-making process when choosing grafts for CABG due to the well-established long-term benefits of using both ITAs for myocardial revascularization.

**SUPPLEMENTARY MATERIAL**

Supplementary material is available at ICVTS online.

Conflict of interest: none declared.

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