



Off-pump coronary artery bypass grafting using a bilateral internal mammary artery Y graft

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Abstract

Objective To evaluate the outcome of off-pump coronary artery bypass grafting (OPCABG) using a bilateral internal mammary artery (BIMA) Y configuration graft to achieve total arterial myocardial revascularization. **Methods** From October 2002 to December 2008, 208 patients (196 males and 12 females) underwent OPCABG using a BIMA Y configuration graft. The average age of the patients was 56.5 ± 11.3 years, with an age range of 33–78 years. A total of 167 (80.2%) cases had triple-vessel disease. Left main stem disease was found in 33 (15.9%) cases, and double-vessel disease was found in 8 (3.9%) cases. The semi-skeletonization technique was used to harvest the two internal mammary arteries (IMAs), and then the free right internal mammary artery was connected end-to-side to the left internal mammary artery (LIMA) *in situ* to complete the Y configuration graft. Off-pump and sequential anastomosis methods were used to perform coronary artery bypass surgery in all patients. Graft patency was assessed intra-operatively with the HT311 transit time flowmeter. **Results** A total of 728 distal anastomoses were performed in 208 patients, with the average being 3.5 ± 1.3 per person. No one died or experienced recurrent angina within 30 days after the operation. **Conclusions** OPCABG using the BIMA Y graft was safe and effective to achieve total arterial revascularization. This method avoids surgical operation on the ascending aorta and other incisions.

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Keywords: Bilateral internal mammary arteries; Coronary artery bypass grafting; Internal mammary artery; Off-pump

1 Introduction

A Y graft is a graft formed from the following: the left internal mammary artery (LIMA) connected to the left anterior descending (LAD) artery and the free right internal mammary artery (RIMA) is connected to the LIMA and to a marginal artery of the left circumflex artery (LCX). Since the internal mammary artery (IMA) conduit for coronary artery bypass grafting (CABG) has better long-term results than saphenous vein grafts (SVGs),^[1] the LIMA graft is considered the best graft for bypassing the LAD coronary artery.^[2–4] Use of the RIMA, in place of the LIMA, may also produce the same results.^[5–7] Thus, Barn & Barnett^[8], Tector *et al.*,^[9] and Barr *et al.*^[10] proposed that the Y or T graft procedure should be carried out by anastomosing the proximal end of the free RIMA to the side of the attached

LIMA. This procedure provides additional length to reach a distal coronary artery branch, such as the posterior descending branch of the right coronary artery or the posterior branch of the left ventricle.

Kamathi *et al.*^[11] and Chocron *et al.*^[12] first reported their experiences with off-pump coronary artery bypass grafting (OPCABG) three decades ago. This technique then became more popular than CABG with cardiopulmonary bypass (CPB) because it was not associated with many complications.

We used bilateral internal mammary artery (BIMA) Y graft with OPCABG for the selected patients, and wanted to test whether it is an appropriate selection for CABG. It may entail the following benefits: total arterial revascularization, no interaction with the aorta thus avoiding cerebral apoplexy, no significant scarring, and fewer complications associated with major organs.

In this paper, we summarize our recent experience with off-pump coronary artery bypass surgery using a BIMA Y graft in China. The detailed report follows.

2 Methods

2.1 Clinical data

From October 2002 to December 2008, the Sixth surgery Department of Anzhen Hospital completed 208 (196 male

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and 12 female patients) CABG surgeries using a BIMA Y configuration graft to achieve total arterial myocardial revascularization. During these procedures, we considered the following three conditions: (1) were BIMA angiograph data available; (2) did the patient not suffer from serious peripheral artery disease; and (3) personal willingness. We should explain that most patients underwent CABG with LIMA + SVG in our department, and 5.84% of patients received the BIMA Y graft. Patients were included in different operation groups. Since different results would be obtained from different operation methods and from different surgeons performing the operations, comparisons between LIMA + SVG and BIMA Y grafts were not made.

2.2 Surgical technique

All patients received general anesthesia under a standardized protocol of the median sternotomy. The semi-skeletonization method of the BIMA harvesting technique was employed.^[9] IMA exposure was achieved with a sternal retractor (Puluo, CN2735936, Beijing, China), and the IMA was dissected via electrocautery and hemoclips from the chest wall along with a narrow pedicle of surrounding tissue. The LIMA was harvested first and dissected from the origin to the distal region of bifurcation. The RIMA was then dissected in a similar manner. After heparinization, the RIMA was removed as a free graft. The LIMA was divided at the last bifurcation. The endothoracic fascia of the BIMAs was then resected with scissors or electrocautery. The IMA pedicle was left with accompanying veins and little fat. Both arteries were placed onto a thick pad of gauze. An oblique one centimeter incision was made in the LIMA, and the proximal end of the RIMA was anastomosed with a continuous 8-0 polypropylene suture. The anastomosis location was under the level of the pulmonary annulus. The BIMA was comprised of a Y configuration graft, with the LIMA serving as the short limb of the Y graft and the RIMA serving as the long branch. The length of the RIMA made it possible to graft as far as the lateral circumflex or posterior descending arteries.

2.3 Off-pump technique

All off-pump coronary artery bypass surgeries were performed by the same surgeon. The patients were heparinized with an initial dose of 1.5 mg/kg of heparin and periodically received supplemental doses to maintain an activated clotting time of ≥ 300 s. Anesthesia management, including volume loading and placing the patient in the Trendelenburg position, was controlled by hemodynamic derangement during displacement or manipulation of the heart. To reduce the amplitude of ventricular wall movement, a compression-type mechanical stabilizer (Chase; Chase Medical Company) or

suction-type mechanical stabilizer (Octopus; Medtronic, Minneapolis, MN, USA) was used. To obtain a bloodless operative field, the small bulldog clamp temporarily occluded the coronary flow, and a warm saline solution flush was used. The most critical vessel, the LAD branch in almost all patients, was first revascularized with the LIMA in an end-to-side fashion to provide a backup to the less critical area. Sequential anastomoses of the diagonal and circumflex branches were then performed in a side-to-side perpendicular (diamond) fashion using the RIMA. The posterior descending or distal right coronary artery graft was performed last using the distal end of the RIMA as an end-to-side anastomosis in parallel. All anastomoses were performed with a single continuous 7-0 polypropylene suture under $\times 2.5$ magnification. After the anastomoses were completed, the flow of the Y graft was measured with the HT311 transit time flowmeter (USA Transonic Systems Inc.). Graft patency was assessed using flow curves, mean flow, and pulsatility index (PI). A left extrapericardial fat pad was secured to anterior percardiotomy, and the sternum was closed with eight wires.

Cardiac enzyme analyses and electrocardiograms were performed on all patients immediately post-operatively and at one, two and six days. A surgical review was done one month post-operatively, and routine follow-up was maintained by cardiologists.

2.4 Statistical analysis

The variables are expressed as the mean \pm SD. The baseline characteristics and outcomes were compared using χ^2 analysis for categorical data and Student's *t*-test for continuous variables. Differences were considered significant only when $P < 0.05$.

3 RESULTS

The age range of the patients was 33–78 years, with the average age being 56.5 ± 11.3 years. Of the 208 patients, 15 (7.2%) patients were over 70 years of age. Triple-vessel lesions were present in 167 (80.2%) patients, left main trunk lesions in 33 (15.9%) patients, and double-vessel disease in eight (3.9%) patients. The data and basic information are given in Table 1. At the same time, there were 3561 patients who finished CABG, including 3,280 with OPCAB.

A total of 728 distal anastomoses were made in all 208 patients, with an average of 3.5 ± 1.3 bypasses performed for each patient. No one received supplemental vein graft. The flow of the Y graft was measured intra-operatively, which showed that all anastomoses were patent. The mean flow in the main stem of the LIMA was 62.8 ± 14.3 mL/min, with the PI being 2.9 ± 1.8 . The mean flow of the distal LIMA graft was 32.3 ± 11.1 mL/min, with the PI being 3.2 ± 1.7 .

Table 1. Patients' general data.

Variable	n (%)
Gender	208 (100)
Male	196 (94.2)
Female	12 (5.8)
Age*	56.5 ± 11.3
Hypertension	73 (35.1)
DM	53 (25.5)
Hyperlipidemia	49 (23.6)
Smokers	87 (41.8)
OMI	80 (38.5)
COPD	11 (5.3)
Stroke	44 (21.2)
PCI	36 (17.3)
Renal insufficiency (Cr > 2.5 mg/dL)	7 (3.4)
Triple-vessel disease	167 (80.2)
Double-vessel disease	33 (15.9)
Left main disease	8 (3.9)
NYHA class*	2.1 ± 1.1 (1–4)
CCSA class*	2.3 ± 1.3 (0–4)
Ejection Fraction (EF) *	
Mean value of EF	0.51 ± 0.08 (0.30–0.76)
EF < 0.4	37 (17.8)

*Data are presented as mean ± SD (range). CCSA: Canadian cardiovascular society angina; COPD: chronic obstructive pulmonary disease; DM: diabetes mellitus; EF: ejection fraction; NYHA: New York Heart Association; OMI: old myocardial infarction; PCI: percutaneous coronary intervention.

The mean flow of the proximal RIMA was 31.8 ± 8.5 mL/min, with the PI being 2.7 ± 1.5. At the same time, 29 (13.9%) patients received off-pump ventricular aneurysm plasty, and 21 (10.1%) cases underwent coronary artery endarterectomy. No perioperative deaths occurred.

A total of 35 (16.8%) patients did not undergo blood transfusion, four (1.9%) patients had peri-operative myocardial infarction, and two (1.0%) cases underwent Intra-Aortic Balloon Pump. Two (1.0%) patients received Continuous Renal Replacement Therapy (CRRT). Three (1.4%) cases needed reentry for bleeding. Six (2.9%) patients developed wound problems (including two diabetic patients). These included two (1.0%) patients with superficial wound infection, two patients with sternal dehiscence due to wire loosening, and two patients with sternal wound infection (including one diabetic patient). One (0.5%) case had a cerebral vascular accident. All patients were successfully discharged from the hospital.

All patients were free of angina at one month follow-up visit. Cardiology angiography was not performed because of

economic reasons and concern about iatrogenic injury of the LIMA. Only one patient died of a stroke, which occurred three months post-operatively. All others were still alive after a mean follow-up of 20.4 ± 4.3 months (6–69 months). No patient experienced a new case of myocardial infarction or severe angina. Six months post-operation, the mean left ventricular ejection fraction was 0.52 ± 0.11 compared to the pre-operative value of 0.51 ± 0.08 ($P = 0.13$). The average patient NYHA score was 2.0 ± 1.2 (post-operatively) versus 2.1 ± 1.1 (pre-operatively) ($P = 0.24$). The average patient CCSA score was 1.6 ± 1.1 (post-operatively) versus 2.3 ± 1.3 (pre-operatively) ($P = 0.00001$).

4 Discussion

In 1967, Kolessov^[1] first reported IMA in coronary artery anastomosis. Green *et al.*,^[2] Tector *et al.*,^[3] Mills & Bringaze,^[4] Loop *et al.*,^[5] and Dion *et al.*^[6] increased the versatility of the IMA by performing CABG. The lower patency of SVGs compared with IMA grafts informed many surgeons in the use of the arterial conduit for coronary bypass, especially the use of BIMAs.^[7,8] Tector *et al.*,^[9] Barra *et al.*,^[10] Kamath *et al.*,^[11] and Chocron *et al.*^[12] described sequential anastomoses, BIMA anastomoses, the free graft technique, and reimplantation of the RIMA as a free graft into the LIMA *in situ* to compose either a Y or T graft. Excellent late clinical results were reported by Tector *et al.*,^[9] Tatoulis *et al.*,^[13] and Lytle *et al.*^[14]

Among the various strategies to select the IMA as the ideal arterial graft, we used a single Y configuration graft with a free RIMA attached to the side of the LIMA *in situ*. Through this graft strategy, the LIMA could be anastomosed to the LAD, which was fundamental to CABG because of the graft's superior long-term patency. The other critical reason for using this graft strategy was to maximize the use of ideal arterial grafts, namely, BIMAs. Patients undergoing CABG with BIMAs have been well known to have long-term results that are superior to those found with only the LIMA.^[14,15] The RIMA was histologically identical to the LIMA and might even show similar long-term patency rates. The length of the semi-skeletonized RIMA in the Asian population is approximately 15–20 cm if harvested from the first rib to the bifurcation region. In most patients, the RIMA could reach the right coronary system without difficulty. Consequently, all of the triple-vessel diseases could be revascularized using BIMAs as the two ideal arterial grafts. This technique has been previously shown to be associated with good early clinical and angiographic results when performed without a cardiopulmonary bypass.^[16,17] Total arterial OPCABG using BIMA was associated with a very low incidence of in-hospital deaths, complications, or late outcomes compared to

the on-pump technique. In our study, the off-pump coronary artery bypass graft using the BIMA Y graft was safe and feasible for all patients. No patient was obliged to change off-pump to on-pump intra-operatively, especially those experiencing moderate or severe heart function (LVEF < 30%). No death occurred within 30 days post-operatively.

Transit-time flowmetry has been widely accepted for use in intra-operative graft assessment because it is non-invasive, technically simple, reproducible, fast, and inexpensive.^[18–20] It provided important and accurate intra-operative information on the status and patency of each individual graft. The ideal PI value should be between one and five after completion of bypass grafts. Importantly, technical error in the anastomosis may increase the PI values.^[18] A problem was thought to be present when the mean flow of the graft was less than 15 mL/min. In our study, the mean flow of all the Y grafts was measured intra-operatively at the main stem, distal LIMA graft, and proximal RIMA. The ideal patent was confirmed, indicating that all the Y grafts were patent following the anastomosis.

Numerous studies have shown the use of both IMAs improves long-term survival relative to the use of the left internal thoracic artery or SVGs. However, the concern that diabetes may lead to an increased risk of deep sternal wound infection has limited the use of both IMAs in non-diabetic patients.^[14,15,21] Although the use of BIMA is considered a risk factor for sternal infection,^[22] this risk appears to be attenuated by skeletonized IMA mobilization.^[23] Tarrío *et al.*^[24] reported the largest group of patients (743 cases) who underwent OPCABG with the BIMA Y or T graft. They used the skeletonization technique to reduce the sternal complication. The rate of mediastinitis was 0.9% (7/743), which is similar to our study (1%, 2/208). In our series, we dissected the BIMA using the narrow pedicle IMA first and then resected the endothoracic fascia using the semi-skeletonization technique.^[25,26] Therefore, more muscle was left attached to the chest wall. This minimized sternal devascularization and possibly reduced the risk of deep sternal wound infection as well. In our study, six patients suffered from a wound event, including two who suffered from diabetes. Two also experienced infections. We did not find any differences with other CABG patients without the BIMA Y graft in our department. If the blood glucose level was controlled before the operation, if sternum fracture was avoided, and if the sternum was stably fixed during the operation, diabetic patients could obtain the same results as non-diabetic patients. Thus, diabetes should not prevent performance of the BIMA Y graft. For an experienced team, this technique could be easily performed in daily practice. It is not a time-consuming procedure, in fact, in our department it is similar to the conventional pedicle technique. It is true that there is a learning curve associated with performing the

technique and therefore, we believe that those who are new to the technique should finish 100 conventional CABGs before taking up the technique of performing the BIMA Y graft.

Total arterial revascularization with two arterial grafts can cause life-threatening hypoperfusion syndrome,^[27] since reperfusion of the entire myocardium depends on the proximal source of the left IMA. This scenario has led to the concern that flow reserve in the LIMA be sufficient to supply more than one coronary anastomosis. Several reports had concluded that the IMA T graft allowed complete myocardial revascularization with good perioperative results and that the flow reserve of the proximal LIMA was adequate for multiple coronary anastomoses.^[28] Clinically, we did not observe any hypoperfusion syndrome in our study, which is consistent with other surgeons who have performed this graft strategy.^[29,30] We performed CABG without CPB to reduce the occurrence of unstable hemodynamics and avoided using the distal IMA for anastomoses. Additionally, we paid special attention to treat the first intercostal artery of any patients experiencing hypertension. There was evidence that the coronary flow reserve could be improved several months after the operation,^[31,32] and that the IMA could adapt to the myocardial blood demand by compensatory dilatation.^[33,34] We did not measure the endpoint flow of the Y graft. The mean flow of the proximal RIMA does not provide enough evidence for good flow at the endpoint. Importantly, there is no clinical evidence for ischemia.

OPCABG combined with the aorta no-touch technique has been accepted as an effective procedure to avoid neurologic and aortic complications and to reduce operative risks. In our study, the incidence of stroke was 0.4% (1 of 208), which is similar to previous reports by Tarrío *et al.*^[25] (0.4%, 3 of 743) and Kim *et al.*^[35] (0.8%, 4 of 512).

In this study, we focus on the skill safety surrounding the BIMA Y graft since it is the first of its kind in China. In order to answer questions concerning the overall outcome in the population of China, this patient group should be followed long term and more patients should be enrolled in this study randomly.

In conclusion, the total arterial off-pump coronary bypass grafting using a BIMA Y graft could be successfully performed by skillful cardiac surgeons. It is associated with low in-hospital mortality and low complication rates. Using the BIMA Y graft achieves total arterial revascularization and avoids surgical operation on the ascending aorta and other incisions. The importance of coronary stabilizers, Chinese IM specific characteristics, and surgical skills need to be evaluated for this new technique, which appears to be quite promising for patients.

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