Robotic Total Arterial Off-Pump Coronary Artery Bypass Grafting: Seven-Year Single-Center Experience and Long-Term Follow-Up of Graft Patency

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Background. **Coronary artery bypass grafting (CABG) is the gold-standard treatment for coronary artery disease, but the long-term benefits of robotic CABG remain unclear.**

Methods. **Between January 2007 and November 2014, 240 consecutive patients (187 male and 53 female, average age 59 years) underwent robotic off-pump CABG with the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA) in our center. Totally endoscopic coronary artery bypass (TECAB) (n = 100) or mini-thoracotomy coronary artery bypass (MINICAB) (n = 140) grafting was performed with skeletonized internal mammary arteries (IMA). Patients were followed up and graft patency was assessed every 6 months by coronary angiography or 64-multi-slide computed tomographic angiography.**

Results. **All cases were completed without conversion to median sternotomy or cardiopulmonary bypass. A total of 237 single IMA grafts (98.3%) and 4 bilateral IMA grafts (1.7%) were used. No operative mortality was observed. Hybrid revascularization of non-left anterior descending vessels was performed in 24 patients (10%). No death, stroke, or myocardial infarction occurred in the follow-up of 41.1 ± 12.9 months. All grafts were patent before discharge. The IMA graft patency was 97.1% in TECAB and 96.4 % in MINICAB over 3 years (up to 91 months) postoperatively.**

Conclusions. **Robotic off-pump CABG using IMA grafts is a safe and effective procedure in selected patients. The long-term outcome and patency of IMA grafts are excellent.**

(Ann Thorac Surg 2015;■:■–■)

Coronary artery bypass grafting (CABG) is the current gold-standard treatment for severe coronary artery disease and it reduces the risks of re-intervention and benefits the long-term survival of patients with multi-vessel and left main stem disease [1, 2]. Recent advances, such as arterial grafting and off-pump techniques, further improve the surgical outcome as arterial grafts significantly reduce the rate of graft failure and improve survival in the long term [3] while the off-pump CABG is shown to reduce the risks of mortality and complications relevant to aortic manipulation and cardiopulmonary bypass (CPB) [2, 4–6].

Robotic CABG is a minimally invasive alternative for patients who had single or multi-vessel disease. Both left and right internal mammary arteries (IMAs) could be harvested on the same side of a patient [7]. Recent reports showed that robotic CABG had comparable short-term results to conventional CABG and a lower re-intervention rate compared with percutaneous coronary intervention (PCI) [8, 9]. However, report on the long-term outcome and the graft patency after robotic CABG was limited [10]. We started to perform robotic off-pump CABG from 2007. Single or bilateral IMA was used for single or double-vessel disease with totally endoscopic coronary artery bypass (TECAB) or mini-thoracotomy coronary artery bypass (MINICAB), with staged hybrid revascularization strategy used for multi-vessel disease [11]. In this study, we aimed to demonstrate the surgical outcome of arterial revascularization in robotic off-pump CABG and the long-term graft patency.

Material and Methods

Preoperative Data

A total of 240 consecutive patients underwent robotic off-pump CABG with informed consent approved by the Institutional Review Board, including 100 TECAB (84 male and 16 female) and 140 MINICAB (103 male and 37 female). The eligible candidates included patients with single-vessel disease in the left anterior descending (LAD) artery or proximal right coronary artery (RCA) and multi-vessel disease in which LAD was involved while the non-LAD disease was amenable to PCI. Before surgery, patients with localized lesion, total or subtotal occluded vessels were primarily selected for TECAB

Accepted for publication April 15, 2015.

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0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2015.04.054

Acronyms and Abbreviations

(B/L/R/S)IMA	=	(bilateral/left/right/single) internal mammary artery
BMI	=	body mass index
BSA	=	body surface area
CABG	=	coronary artery bypass grafting
CTA	=	64-multi-slide CT angiography
DES	=	drug eluting stent
LCX	=	left circumflex branch
LVEDD	=	left ventricular end-diastolic diameter
LVEF	=	left ventricular ejection fraction
LVP	=	left ventricular posterior branch
MIDCAB	=	minimally invasive direct coronary artery bypass
MINICAB	=	mini-thoracotomy coronary artery bypass
OM	=	obtuse marginal branch
PCI	=	percutaneous coronary intervention
RCA	=	right coronary artery
TECAB	=	totally endoscopic coronary artery bypass

while patients who had diffuse calcified disease, poor runoff, or myocardial bridging were scheduled for MINICAB. Importantly, the surgical plan was subject to change after the target vessel was examined intraoperatively. The contraindications included the past history of left lung surgery, dense pleural adhesion, severe chronic obstructive pulmonary disease, hemodynamic instability, and moderate to severe left ventricular dysfunction or dilation. The patients' preoperative data are shown in Table 1. All cases were operated by the same console surgeon (C.G.) with the same patient-side assistants.

Anesthesia and Preparation

The patient was positioned supine and anesthetized as previously described [5]. The single right lung was ventilated with double-lumen intubation. Three 0.8 to 1.0-cm incisions were made in the third, fifth, and seventh intercostal spaces that located about 3cm lateral to the mid-clavicular line on the left chest wall. After deflation of the left lung, the pleural cavity was insufflated with carbon dioxide to achieve a pressure of 6 to 8 mm Hg. The surgical cart was docked to the right side of the patient and a 30-degree angle upward camera and micro-instruments were inserted through the ports.

Internal Mammary Artery Harvesting

The internal mammary artery (IMA) was harvested in a skeletonized manner as described before [12]. Before harvesting, the entire course of the left (L)IMA was carefully inspected. The LIMA was detached from the chest wall by using blunt dissection and short bursts with a low power monopolar cautery (Fig 1). If more than 1 graft was required, the right (R)IMA was harvested before the LIMA and the right pleural cavity and RIMA were accessed after dissection of the anterior mediastinum. The distal end of the harvested IMA was left attached to the chest wall to prevent it from hanging over the pericardium.

TECAB Procedure

After IMA harvest, the pericardium was cut open and the target vessel was exposed. The pericardium over the apex of the left ventricle was left intact to prevent herniation of the heart. An endoscopic heart stabilizer with an irrigator was applied to the anastomosing site of the target vessel through a subxiphoid incision. After heparinization, the distal IMA was cut obliquely with a small toe left attached to the distal vessel. Five S18-U clips (Medtronic, Minneapolis, MN) were put from outside in on the offside rim of the distal end of the IMA. Then the distal end was detached from the chest wall and secured to the epicardial fat to maintain its location and orientation. After the target vessel was dissected and occluded proximally and distally with Saddle Loops (Quest Medical, Allen, TX), an incision was made in the middle. The IMA graft was parachuted onto the coronary artery. Then 3 more U-clips were put on the nearside to complete the anastomosis (Fig 2). After the Saddle Loop occluders were removed, the anastomosis was checked to secure hemostasis. The blood flow in the grafts was measured after protamine was administered. All instruments were removed from the ports and a chest drain was placed before all wounds were closed.

MINICAB Procedure

As in TECAB, the skeletonized IMA was harvested and the distal end was attached to the pericardium with a ligated clip before the pericardium was opened. Then, a 4 to 6 cm incision was made in the fourth intercostal space and a retractor was applied to expose the target vessels. The heart was stabilized and the IMA grafts were anastomosed to the target vessels by using continuous 7-0 Prolene sutures (Ethicon, Somerville, NJ).

Assessment of Arterial Graft Patency and Follow-Up

The blood flow and pulsatility index of the arterial grafts were measured by a Medistim VeriQC flowmeter (Oslo, Norway) after all anastomoses were completed. Coronary arteriography or 64-multi-slice computed tomography angiography (CTA) was performed to evaluate the graft patency before the patients were discharged. Aspirin and clopidogrel were commenced on day 1 postoperatively and recommended for life-time use in all patients. After discharge, the patients were contacted regularly through telephone and were invited to attend the outpatient clinic every 6 months. During the follow-up, the incidences of mortality, stroke, myocardial infarction, re-intervention of the target vessels, and hybrid coronary stent placement were noted. The graft patency was assessed by coronary angiography or CTA and classified as follows: Grade A, fully patent; grade B, stenosis reducing caliber of the graft to less than 50%; grade O greater than 50% lumen stenosis or occluded graft [13–15].