Graft patency and completeness of revascularization in minimally invasive multivessel coronary artery bypass surgery

Lufeng Zhang[1], Yuanhao Fu[1], Yicheng Gong[1], Hong Zhao[1], Song WU[1], Hang Yang[1], Zhe Zhang[1], and Yunpeng Ling[1]

[1]Peking University Third Hospital

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Abstract

Objectives: Graft patency and completeness of revascularization were analyzed in patients who underwent off-pump minimally invasive coronary artery bypass grafting via left small thoracotomy. Methods: We retrospectively reviewed the invasive angiography findings and clinical data of 186 consecutive patients who underwent off-pump minimally invasive coronary artery bypass grafting via left small thoracotomy. The left internal thoracic artery and saphenous vein were used to bypass two or more of three coronary artery systems: the left anterior descending artery, left circumflex artery, or right coronary artery. Before hospital discharge, invasive angiography was performed to assess graft patency and completeness of revascularization. Clinical variables during hospitalization and follow-up were collected and analyzed. Results: All 186 patients successfully underwent off-pump minimally invasive coronary artery bypass grafting without conversion to sternotomy or assistance of cardiopulmonary bypass. The mean graft number was 2.81 per patient (range, 2–5), and the total number of grafts was 522. The in-hospital mortality rate was 1.6% (3/186). A total of 181 of 186 (97.3%) patients underwent postoperative invasive angiography. Among the 510 grafts assessed by angiography, the total graft patency rate was 96.3% (491/510) [98.3% (171/174) for left internal thoracic artery grafts and 95.2% (318/334) for saphenous vein grafts]. The rate of complete revascularization was 98.8% (510/516) of the total grafts in 180 of 186 (96.8%) patients. Conclusions: Minimally invasive coronary artery bypass grafting using left internal thoracic artery and saphenous vein grafts provides acceptable graft patency and completeness of revascularization for patients with multivessel disease.

Abbreviations:

A.o Ascending aorta

BMI Body mass index

CABG Coronary artery bypass grafting

COPD Chronic obstructive pulmonary disease

CR Completeness of revascularization

CT Computed tomography

DES Drug eluting stent

EF Ejection fraction

IABP Intra-aortic balloon pump

ICR Incomplete revascularization

ICU Intensive care unit

LAD Left anterior descending artery

LITA Left internal thoracic artery

LCX Left circumflex artery

LM Left main artery

LVEDD Left ventricular end-diastolic dimension

MACCE Major adverse cardiovascular and cerebral events

MI Myocardium infarction

MICS CABG Minimally invasive coronary surgery-coronary artery bypass grafting

OPCAB Off pump coronary artery bypass

PCI Percutaneous coronary intervention

RA Radial artery

RBC Red blood cell

RCA Right coronary artery

SV Saphenous vein

Introduction

For several decades, coronary artery bypass grafting (CABG) has been considered the gold standard treatment for coronary disease[1,2]. CABG has good outcomes [3]because of complete revascularization (CR) and good graft patency. Off-pump CABG (OPCAB) was shown in a randomized trial[4] and retrospective analysis [5] to have the same advantages as on-pump CABG while avoiding the morbidities associated with blood–machine interactions. However, these approaches are potentially associated with surgical invasiveness involving the sternum and wound complications. In the era of minimally invasive surgery, patients prefer durable outcomes and less invasiveness, which help them to recover their normal activity. Minimally invasive coronary surgery–CABG (MICS CABG) via left anterior thoracotomy is reportedly a less invasive and sternum-sparing approach for multivessel or left main artery disease [6-9]. Unlike CABG via sternotomy, which has been studied for many years with convincing data showing its effectiveness and reproducibility, fewer objective data are available for MICS CABG, especially angiographic data regarding the graft patency and CR rates [10-12].

In MICS CABG, limited space for visualization and heart manipulation adds technical difficulty when constructing anastomoses to the lateral or post-inferior epicardial vessels [13]. This might be associated with impaired graft patency and incomplete revascularization (ICR). After adopting OPCAB and minimally invasive direct CABG as routine practice for surgical revascularization, we transformed our practice to MICS CABG for multivessel and left main artery disease. Our preliminary experience made it possible to revascularize target vessels with a left internal thoracic artery (LITA) and sequential saphenous vein (SV) graft via minimal thoracotomy. In the present study, we analyzed a series of 186 consecutive patients who underwent MICS CABG with a focus on the postoperative graft patency and CR rates.

Patients and Methods

From 24 November 2016 to 23 December 2019, 186 patients who had been diagnosed with multivessel or left main coronary artery disease by coronary angiography were referred for surgical revascularization. After preoperative examination and exclusion of other cardiovascular abnormalities, elective MICS CABG via small left thoracotomy was performed by surgeons who had passed the steep learning curve of this procedure. This study was approved by the ethics committee of Peking University Third Hospital.

Contraindications for this procedure included an unstable preoperative hemodynamic status, severe pulmonary dysfunction, severe obesity, thoracic cavity deformity, and porcelain ascending aorta (A.o) calcification as indicated by computed tomography (CT). The patients' preoperative characteristics are listed in Table 1.

The preoperative antiplatelet regimen was administration of 100 mg of oral aspirin per day from admission to the day before the operation. In patients who had undergone percutaneous coronary intervention (PCI) <1 year preoperatively while the stent remained patent, a dual antiplatelet regimen of 100 mg of aspirin and 75 mg of clopidogrel per day was adopted until the day before the operation.

An individualized surgical plan for revascularization was established preoperatively according to each patient's variables and coronary anatomy. All 186 patients were intent to achieve complete myocardial revascularization with the use of two grafts to bypass two or more of three coronary systems: the left anterior descending artery (LAD), left circumflex artery (LCX), and right coronary artery (RCA).

The patient was placed in the supine position with a soft pad under the left scapula, which elevated the left chest by 10 cm. The patient was then intubated with a double-lumen endotracheal tube. An external defibrillator pad was placed for emergency defibrillation. A Swan-Ganz catheter was placed via the right internal jugular vein into the pulmonary artery for intraoperative hemodynamic monitoring. After draping, a 7- to 8-cm-long incision, two-thirds lateral to the left middle clavicle line, was made via the fifth intercostal space after establishing single-lung ventilation. The chest wall was lifted with a retraction system, and the LITA was carefully identified and harvested in a pedicled manner under direct vision from the innominate vein superiorly to its bifurcation or trifurcation inferiorly. The thymus and pericardial fat tissue were dissected and removed with cautery for exposure of the A.o before pericardiotomy. Heparin (1 mg/kg) was administered to achieve an activated clotting time of >250 seconds. Heparin was supplemented at 30-minute intervals to keep the activated clotting time at >250 seconds. After pericardiotomy, the target vessel was identified and exposed. At the same time, an endoscopic or open procedure to harvest the SV was performed by the surgical staff. The SV was prepared in heparinized solution after ligation of its branches.

An apical suction device was used to position the heart, and the target vessel was then stabilized with a vacuum-assisted Octopus Nuvo epicardial stabilizer (Medtronic, Minneapolis, MN, USA). After arteriotomy, an intracoronary shunt was routinely inserted into the vessel to minimize acute ischemia. Handsewn distal anastomosis was accomplished with a running 7-0 or 8-0 Prolene suture (Ethicon, Inc., Somerville, NJ, USA). The routine revascularization strategy was the LITA to LAD first, then proximal anastomosis to the A.o with the SV or radial artery (RA), followed by sequential grafting with a single SV or RA graft [14] to bypass the trunk or branch of the LAD, LCX, or RCA.

Placement of traction sutures on the right pericardium lateral to the A.o, together with insertion of a moist sponge between the right pericardium and A.o, pushed the A.o leftward and facilitated exposure of the proximal A.o. The proximal anastomosis was performed using 6-0 running propylene suture (Ethicon, Inc.) with the aid of a long-shaft side clamp to connect the SV with the A.o. The presence of an eggshell A.o that had not been visible in the preoperative CT scan excluded the possibility of proximal A.o anastomosis. In such cases, the SV graft was anastomosed to the left axillary artery via a horizontal incision placed 1 cm under the clavicle, then passed through the first intercostal space as a sequential graft to bypass the target vessels. Epicardial coronary arteries with a caliber of >1.5 mm and proximal stenosis of >70% were grafted intraoperatively. In two patients, the left RA was used because of shortage of the SV. The distribution of the grafts and target vessels are listed in Table 2.

After neutralization of heparin with protamine, the pericardium was closed. An indwelling catheter was inserted percutaneously and passed underneath the pleura under direct visualization to block the intercostal nerves and thus allow for continuous injection of analgesics postoperatively. A #28 left chest drainage tube was inserted via the sixth intercostal space lateral to the incision. The patients were extubated in the intensive care unit and received an oral dual antiplatelet regimen of daily aspirin (100 mg) and clopidogrel (75 mg). The standard regimen after hospital discharge was lifelong continuation of the aspirin and [?]1-year continuation of the clopidogrel.

The patients underwent invasive coronary artery and graft angiography via the left RA or femoral artery before hospital discharge. The postoperative angiograms were reviewed by three coronary surgeons. Each graft was viewed in at least two orthogonal planes and scored on the worst appearance of the graft. Graft assessment was standardized by the FitzGibbon gradation as the presence of stenosis at either the proximal/distal anastomosis or trunk of the graft: grade A, perfectly patent; grade B, patent with stenosis reducing the caliber to <50% of the target coronary artery; and grade O, occluded graft. Grade A and B grafts were deemed patent. The CR rate was the ratio of the number of grafts constructed intraoperatively to the number of grafts intended to be constructed. Complementary PCI was performed with a drug-eluting stent if indicated.

The patients were followed up via the WeChat app by a single physician assistant after discharge. Major adverse cardiovascular and cerebral events (MACCE) and all causes of death were recorded.

Statistical analyses

Descriptive, continuous variables are presented as mean and standard deviation, median and range; categorical variables are presented as frequencies and percentages.

Results

In total, 186 patients successfully underwent elective MICS CABG. The mean number of grafts per patient was 2.81 (range, 2–5). Overall, 522 grafts were constructed. No patient required conversion to sternotomy or extracorporeal circulation support intraoperatively. Three of 186 (1.6%) patients required intraoperative support by an intra-aortic balloon pump (IABP) because of ischemia, arrhythmia, or hemodynamic instability. Postoperatively, eight (4.3%) patients underwent re-exploration. Additionally, three (1.6) patients underwent insertion of an IABP for postoperative hemodynamic support. The postoperative mortality rate was 1.6% (3/186). The cause of death was postoperative myocardial infarction in two patients and stroke in one patient. The postoperative variables are listed in Table 3.

A total of 181 patients underwent postoperative angiography before discharge. The reasons why the remaining five patients did not undergo angiography are listed in Table 4. The postoperative graft angiography showed that the overall patency rate was 96.3% (491/510). Further analysis of graft patency showed that the patency rate of the LITA was 98.3% (171/174), that of the SV was 95.2% (318/334), and that of the RA was 100% (2/2). The subgroup analysis results of the graft patency rate in the three different systems of the coronary artery and/or its branches are shown in Table 5.

A total of 96.8% (180/186) of patients achieved complete coronary revascularization. One of the six patients with ICR developed postoperative bradycardia and hypotension. This patient underwent emergency invasive angiography with the support of an IABP and recovered after treatment of a tight stenosis at the orifice of the RCA with a drug-eluting stent. The CR rate was 97.3% (181/186) after complementary PCI. The main cause of ICR was underestimation of stenosis on the preoperative angiogram.

Calculated by graft, the revascularization rate was 98.9% (522/528) before and 99.1% (523/528) after complementary PCI.

In total, 179 of 183 (97.8%) patients were closely followed up for a mean of 18 ± 10.2 months (range, 4–41 months). During follow-up, one patient experienced sudden death and another died of stomach cancer at 1 and 36 months after discharge, respectively. Five of 183 (2.7%) patients developed postoperative major adverse cardiovascular and cerebral events (4 strokes and 1 repeat PCI for native coronary artery restenosis). Finally, 182 of 183 (99.5%) patients survived without symptoms of myocardial ischemia.

Discussion

MICS CABG has been proven to be a reliable and reproducible alternative to conventional CABG [6]. Convincing data show that MICS CABG provides the benefits of a low transfusion rate, short length of hospital stay, and rapid recovery to normal activity[7,12]. Graft patency and CR are predictive of the short- and long-term outcomes of patients who undergo coronary revascularization. Most previous studies used 64- or 256-slice CT angiography as a noninvasive approach, which showed reliable and convincing results [12,15]. In our preliminary study using CT evaluation (data not shown), the trunk of the graft was well constructed while the distal anastomosis was less precise for assessment than transcatheter angiography, especially when the FitzGibbon grade was B (impaired anastomosis but patent graft). Despite its high invasiveness, selective coronary and graft angiography via insertion of a catheter into the orifice of the target vessel was a precise approach for assessment of the coronary artery or graft.

Invasive postoperative angiography has proven the effectiveness and superior long-term outcome of CABG versus PCI, which is attributed to the high CR rate and good graft patency. Some studies did not involve invasive angiography, mostly because the patients were reluctant to undergo an invasive intervention. Patients who were not evaluated were usually asymptomatic; thus, the graft patency rate might have been underestimated. Furthermore, early postoperative silent occlusion of the graft makes the real graft patency rate more unpredictable[16].

In our institution, postoperative invasive angiography is routinely performed for every patient who undergoes surgical revascularization without a contraindication for quality control. Complementary PCI is performed to revise either a problematic graft or native coronary vessel.

Notably, although interventionists are trained to be skillful in native coronary angiography, not all of them are familiar with LITA and SV/RA graft angiography. It is sometimes necessary to switch to a femoral approach for selective angiography of the proximal anastomosis in the anterior wall of the A.o. The exact location of the proximal anastomosis might be anywhere in the anterior wall of the A.o. An excessive exposure time and contrast use makes this challenging. The most likely location of the proximal anastomosis performed with a side-biter during MICS CABG is the anterior wall of the A.o just at the level of the tracheal carina, which can be easily identified by X-ray fluoroscopy in the catheter laboratory. Selective angiography of the LITA can be performed via the left RA or femoral artery. The patients in the present study underwent successful coronary and graft inspection with the above-described method.

ICR induces postoperative angina, may jeopardize the late outcome, and usually necessitates repeat revascularization. The technical difficulty of off-pump heart manipulation and the limited exposure for target vessel anastomosis in MICS CABG add to the difficulty of accomplishing CR. The clinical volume of surgical coronary revascularization was 500 to 600 cases (half OPCAB and half sternum-sparing cases) per year in our center. Before we adopted MICS CABG in our clinical practice, we had performed more than 800 minimally invasive direct CABG procedures for treatment of isolated LAD lesions or in combination with PCI procedures for treatment of multivessel disease. We adopted the "Nambiar technique" [10] when starting MICS CABG with the bilateral internal thoracic arteries and performed this procedure in about 50 cases. Once we had become comfortable with handsewn proximal anastomosis using a side clamp, we routinely performed the "proximal first" sequential graft [17] after LITA-to-LAD anastomosis. This strategy provides the greatest possible blood supply to the myocardium during manipulation of the heart, minimizing the possibility of intraoperative hemodynamic instability.

Total arterial revascularization provides good short- and long-term graft patency and is superior to venous grafting. We have widely performed MICS CABG with deployment of the bilateral internal thoracic arteries and RA, and we plan to provide our data in the near future.

The causes of ICR include an invisible target vessel, hemodynamic instability precluding positioning of the heart, and underestimation of the target vessel caliber. One patient underwent complementary PCI for CR of the myocardium. The CR rate in this group of patients undergoing MICS CABG was not inferior to that of patients undergoing OPCAB or on-pump CABG in other studies [18,19]. This finding proves that MICS CABG can attain a good CR rate similiar to that attained by conventional procedures.

Conclusion

MICS CABG using LITA and SV grafts provides good graft patency and CR rates for patients with multi-vessel disease.

Limitations:

First, this study only showed short term in-hospital angiographic result, which is more related to surgical technique during operation. Data regarding mid- and long-term angiographic result will provide more information. Second, this is a retrospective study of clinical outcome, graft patency and CR in patients underwent MICS CABG. Prospective, randomized analysis of MICS CABG comparing with conventional CABG would be more convincing.

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