Original Article

Early Angiographic Results of Multivessel Off-Pump Coronary Artery Bypass Grafting

Mimiko Tabata, MD, Hiroshi Niinami, MD, PhD, Yuji Suda, MD, Akihito Sasaki, MD, Masato Yamamoto, MD, Ryota Asano, MD, Masahiro Ikeda, MD, and Yasuo Takeuchi, MD

Objectives: Recently off-pump coronary artery bypass grafting (CABG) is being widely used for coronary revascularization. However, there is some evidence that off-pump surgery increases the risk of recurrent angina and the need for reintervention, suggesting poor graft quality or incomplete revascularization. We describe our experience to demonstrate the feasibility of multiple coronary revascularization in off-pump CABG (OPCAB).

Patients and Methods: From January 2002 to March 2003, 168 patients underwent OPCAB at our institute. In 16 of them, 6 to 9 vessels were revascularized in each patient. There were 14 males and 2 females with a mean age of 66 years (47 to 74 years). All patients had triple-vessel disease. Ten patients received *in situ* arterial grafts only which were harvested with the skeletonization technique using an ultrasonic scalpel. We used the Starfish® heart positioner to expose lateral, posterior, and inferior walls of the heart with minimal hemodynamic compromise.

Results: All patients were discharged from the hospital without any serious complications. Postoperative angiography was performed in 87.5% within 1 month after operation. The patency rate was 96.6%.

Conclusion: These results indicate that complete revascularization can be achieved in OPCAB in patients with diffuse coronary arterial disease. Complete revascularization with *in situ* arterial conduits only is technically feasible and yields a high early graft patency, even in the off-pump situation. (Ann Thorac Cardiovasc Surg 2006; 12: 174–8)

Key words: multivessel, off-pump coronary artery bypass grafting, *in situ* arterial graft

Introduction

Recently, off-pump coronary artery bypass grafting (CABG) is being widely used for coronary artery revascularization, and now comprises approximately 50% of all coronary artery bypass surgery being done in Japan. However, there is some evidence that off-pump surgery increases the risk of recurrent angina and the need for reintervention, suggesting poor graft quality or incomplete revascularization. We describe our experience to demonstrate the feasibility of multiple coronary revascularization in off-pump CABG (OPCAB).

Patients and Methods

From January 2002 to March 2003, 168 patients underwent isolated CABG without cardiopulmonary bypass at our institute. In 16 of them, 6 to 9 vessels were revascularized in each patient. Six vessels were revascularized in 11 patients, 7 vessels in 2 patients, 8 vessels in 2 patients,

From Department of Cadiovascular Surgery, Tokyo Women's Medical University Medical Center East, Tokyo, Japan

Received October 27, 2005; accepted for publication December 5, 2005.

Address reprint requests to Mimiko Tabata, MD: Department of Cadiovascular Surgery, Tokyo Women's Medical University Medical Center East, 2-1-10 Nisiogu, Arakawa-ku, Tokyo 116-8567, Japan.

Table 1. Number of patients

No. of grafts	No. of patients
1	24
2	35
3	27
4	42
5	24
6	11
7	2
8	2
9	1
Total	168

Table 2. Preoperative data (n=16)

Age (years)	66.0±7.2 (47-74)
Gender (M/F)	14/2
Hypertension	10
Diabetes mellitus	8 (Insulin treated 4)
Hyperlipidemia	7
Renal dysfunction	7 (Hemodialysis 3)
Previous cerebrovascular accident	5
Previous myocardial infarction	10
Left ventricular ejection fraction	50.9±9.6 (35-65)%

Table 3. Conduit arrangements

LITA+RITA+RGEA	10 (6-9)
LITA+RITA+RA (I-composite)+RGEA	1 (6)
LITA+RA (Y-composite)+RITA	1 (6)
LITA+RITA+RA (I-composite)	1 (6)
LITA+RGEA+RA	1 (6)
LITA+RITA+SVG	1 (6)
LITA+SVG	1 (6)

LITA, left internal thoracic artery; RITA, right internal thoracic artery; RGEA, right gastroepiploic artery; RA, radial artery; SVG, saphenous vein graft.

and 9 vessels in 1 patient (Table 1).

There were 14 males and 2 females with a mean age of 66 years (47 to 74 years). All patients had triple-vessel disease. Eight patients were diabetic, and 4 were being treated with insulin. Seven patients had renal dysfunction, and 3 were on hemodialysis. The left ventricular ejection fraction ranged from 35 to 65% (Table 2).

Surgical technique

All operations were performed through a median sternotomy. *In situ* arterial conduits were harvested with the complete skeletonization technique using an ultrasonic scalpel (Ethicon Endo-Surgery, Inc., Somerville, NJ). After heparinization, all arterial conduits were divided. A deep pericardial suture was placed in the posterior pericardium, between the left atrial appendage and the apex. Traction on this suture elevated and rotated the heart to the right and exposed the left anterior descending (LAD) and the diagonal branches.[1)] A Starfish® heart positioner (Medtronic, Inc., Minneapolis, MN) was used to expose the lateral, posterior, and inferior walls of the heart, and an Octopus stabilizer (Medtronic, Inc., Minneapolis, MN) was used to immobilize and present the anastomotic site. The patients were placed in the Trendelenberg position and rotated to the right to assist in coronary artery exposure and prevent hemodynamic instability during construction of the distal anastomoses. The coronary arteries were occluded proximally using a snare with a 4-0 polypropylene suture before the anastomosis (Note 1). Intracoronary shunts were not used routinely; indications for their use included poor visibility, ST-segment changes, and hemodynamic instability. Anastomosis was performed in a side-to-side fashion with 8-0 polypropylene continuous sutures in the internal thoracic arteries (ITAs) and the right gastroepiploic artery (RGEA).

Results

Ten patients received only *in situ* bilateral ITAs and RGEA. The radial artery (RA) was used in 4 patients and the saphenous vein graft (SVG) in 2 patients (Table 3).

The target coronary vessels and anastomosed conduits are shown in Table 4. The left ITA (LITA) was most commonly anastomosed to the left circumflex (LCX) artery region, the right ITA (RITA) to the LAD artery region, and the RGEA to the distal portion of the right coronary artery (RCA).

Sequential grafting was performed with the LITA in 14 patients, the RITA in 6 patients, and the RGEA in 10 patients. Triple sequential grafting was performed with the LITA in 9 patients, the RITA in 1 patient, and the RGEA in 2 patients. One patient underwent quadruple sequential grafting with the LITA (Table 5).

No patient was converted to on-pump surgery. No patients suffered from wound problems. All patients recovered from the surgery and were discharged from the hospital without any serious complications. Postoperative angiography was performed in 14 patients (87.5%) within 1 month after operation. The patency rate was 96.6% (Table 6).

Table 4. Target coronary artery

	LAD	D	LCX	RCA
LITA, n	3	10	29	–
RITA, n	12	7	–	–
RGEA, n	–	–	1	23

LAD, left anterior descending artery; D, diagonal branch; LCX, left circumflex artery; RCA, right coronary artery; LITA, left internal thoracic artery; n, number of times used for anastomosis; RITA, right internal thoracic artery; RGEA, right gastroepiploic artery.

Table 5. Sequential grafting

	Double	Triple	Quadruple
LITA, n	4	9	1
RITA, n	5	1	–
RGEA, n	8	2	–

LITA, left internal thoracic artery; n, number of patients; RITA, right internal thoracic artery; RGEA, right gastroepiploic artery.

Table 6. Postoperative data (n=16)

Switch to cardiopulmonary bypass	0%
Post operative CK-MB (mean±SD)	20.3±10.7 IU/L
Transfusion	12 (75.0%)
ICU stay	2.0±1.1 days
Hospital mortality	0%
Myocardial infarction	1 (6.3%)
Patency rate	96.6%
LITA	100.0%
RITA	100.0%
RGEA	100.0%
RA	75.0%
SVG	100.0%

SD, standard deviation; ICU, intensive care unit; LITA, left internal thoracic artery; RITA, right internal thoracic artery; RGEA, right gastroepiploic artery; RA, radial artery; SVG, saphenous vein graft.

Discussion

There is evidence that compared with on-pump surgery, off-pump surgery may decrease the incidence of myocardial injury, renal damage, pulmonary complications, and injury to the brain. Previous randomized studies have shown a shorter length of stay, a reduced use of transfusion products, and a lower frequency of atrial fibrillation in patients who underwent OPCAB.[2-4] On the other hand, there is some evidence that off-pump surgery increases the risk of recurrent angina and the need for reintervention, suggesting poor graft quality or incomplete revascularization.[5]

We have aimed for complete arterial revascularization with the OPCAB technique for patients who received isolated CABG since January 2001. OPCAB has not been completely accepted because of a lack of long-term results and technical difficulties in grafting the lateral wall.[6] Accessing the vessels, particularly on the lateral and inferior walls of the heart, can sometimes be challenging while the heart is beating, especially in hearts with an impaired and severely dilated left ventricle. Recently, technological advances that have improved methods of coronary artery stabilization and exposure have allowed access to all coronary arteries and complete revascularization. The Starfish® heart positioner was designed to achieve optimal exposure of the lateral and inferior walls of the heart with minimal hemodynamic compromise. Now sequential grafting can be performed safely in patients with a severely impaired and dilated left ventricle while the hemodynamic status remains unchanged.[7]

We have tried to maximize the patency rate of CABGs by extending the use of *in situ* ITA and GEA grafts (Note 2). The patency rate of the RA graft in this study was 75%. Two cases of RA malfunction occurred in patients in whom the artery was anastomosed to the coronary arteries with nonocclusive stenoses. The factor that clearly influenced RA patency was the severity of stenosis of the target coronary vessel.[8]

Excellent long-term results have been demonstrated for both the ITA and RGEA grafts (Note 2) in conventional CABG.[9,10] We believe that complete arterial revascularization with only *in situ* arterial conduits is associated with better long-term results also in the off-pump situation. The bilateral ITAs were taken down as *in situ* grafts using the skeletonization technique. We have attempted to expand the use of the ITA to achieve more extensive and complete revascularization. The ITA can be anastomosed sequentially in a retrograde or a diamond fashion. Finally, its distal branches can be anastomosed separately to two different coronary arteries in a "Y" fashion. The ITA divides at the level of the fifth or sixth intercostal space into the superior epigastric and musculophrenic branches. Both branches were dissected for a distance of 2 to 3 cm. If the terminal branches of the ITA are large and long enough for grafting, they can be used to construct a natural "Y" anastomosis to the coronary arteries (Figs. 1-3). However, this type of anastomosis is techni-

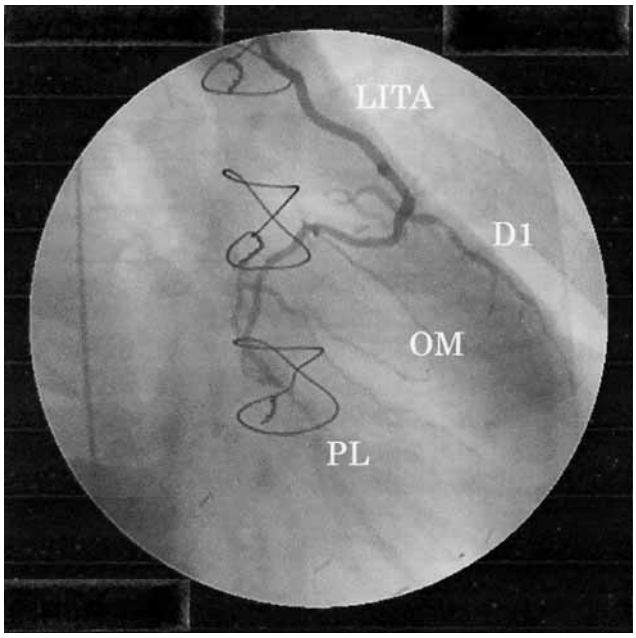

Fig. 1. The left internal thoracic artery (LITA) is anastomosed to the first diagonal branch (D1), obtuse marginal branch (OM), and posterolateral branch (PL) in a diamond and a retrograde fashion.

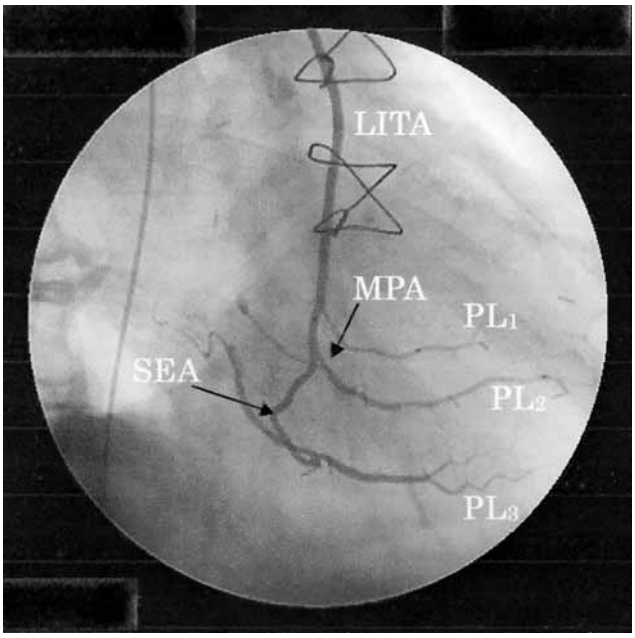

Fig. 2. The left internal thoracic artery (LITA) is anastomosed to the first posterolateral branch (PL_1) in a diamond fashion and the terminal branches of the LITA anastomosed seperately to second and third posterolateral branches (PL_2 and PL_3) in a "Y" fashion.
SEA, superior epigastric artery; MPA, musculophrenic artery.

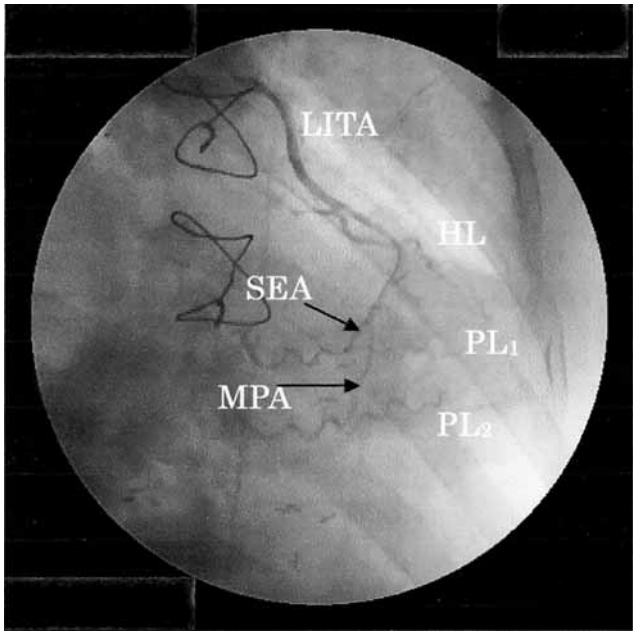

Fig. 3. The left internal thoracic artery (LITA) anastomosed to the highlateral branch (HL) and the terminal branches of the LITA anastomosed seperately to the first and second posterolateral branches (PL_1 and PL_2) in a "Y" fashion.
SEA, superior epigastric artery; MPA, musculophrenic artery.

cally more demanding than the standard ITA to LAD anastomosis. The "Y" branches are of smaller diameter. The vessel wall appeared thinner and more friable, and its layers seemed to separate more easily (Note 3). In addition, the coronary anatomy is not always suitable for the natural "Y" grafts to fit perfectly. This can lead to slight angulations and increased tension on the limbs of the "Y" grafts, which may contribute to the higher obstruction rate. Its use is limited by the small size of the "Y" branches, mild proximal stenosis, and the coronary anatomy.[11,12]

Generally, excellent results have been achieved with CABG; however, significant morbidity and mortality still exist. CPB requires full heparinization, induces a whole-body inflammatory response, and generates microemboli.[13,14] It also requires cannulation and cross-clamping of the ascending aorta, which may lead to atheromatous macroemboli.[15] Procedures without CPB are likely to prevent these unwanted effects. One of the advantages of off-pump revascularization is lower postoperative morbidity,[5] and the other advantage of applying the off-pump technique is that it might be easier to arrange the graft placement compared with conventional CABG.

Conclusion

Complete arterial revascularization can be achieved in OPCAB in patients with multiple coronary arterial disease without major morbidity. Complete arterial revascularization with the exclusive use of *in situ* arterial conduits is technically feasible and yields a high early graft patency, even in the off-pump situation.

References

1. Niinami H, Koyanagi H, Brady PW, Ross DE. The heart string: a simple, inexpensive exposure of the heart during coronary artery operations. *Ann Thorac Surg* 2000; **69**: 1280–1.
2. Khan NE, De Souza A, Mister R, et al. A randomized comparison of off-pump and on-pump multivessel coronary-artery bypass surgery. *N Engl J Med* 2004; **350**: 21–8.
3. van Dijk D, Nierich AP, Jansen EW, et al. Early outcome after off-pump versus on-pump coronary bypass surgery: results from a randomized study. *Circulation* 2001; **104**: 1761–6.
4. Mack MJ, Pfister A, Bachand D, et al. Comparison of coronary bypass surgery with and without cardiopulmonary bypass in patients with multivessel disease. *J Thorac Cardiovasc Surg* 2004; **127**: 167–73.
5. Sabik JF, Gillinov AM, Blackstone EH, et al. Does off-pump coronary surgery reduce morbidity and mortality? *J Thorac Cardiovasc Surg* 2002; **124**: 698–707.
6. Buffolo E, de Andrade CS, Branco JN, Teles CA, Aguiar LF, Gomes WJ. Coronary artery bypass grafting without cardiopulmonary bypass. *Ann Thorac Surg* 1996; **61**: 63–6.
7. Niinami H, Takeuchi Y, Ichikawa S, et al. Multivessel off-pump coronary aortic bypass grafting with an impaired and severely dilated left ventricle using the Starfish heart positioner. *Kyobu Geka* 2002; **55**: 773–7. (in Jpse.)
8. Possati G, Gaudino M, Prati F, et al. Long-term results of the radial artery used for myocardial revascularization. *Circulation* 2003; **108**: 1350–4.
9. Bergsma TM, Grandjean JG, Voors AA, Boonstra PW, den Heyer P, Ebels T. Low recurrence of angina pectoris after coronary artery bypass graft surgery with bilateral internal thoracic and right gastroepiploic arteries. *Circulation* 1998; **97**: 2402–5.
10. Nishida H, Tomizawa Y, Endo M, Koyanagi H, Kasanuki H. Coronary artery bypass with only in situ bilateral internal thoracic arteries and right gastroepiploic artery. *Circulation* 2001; **104** (12 Suppl 1): I76–80.
11. Morin JE, Hedderich G, Poirier NL, Sampalis J, Symes JF. Coronary artery bypass using internal mammary artery branches. *Ann Thorac Surg* 1992; **54**: 911–4.
12. Niinami H, Suda Y, Tabata M, Yamamoto M, Ikeda M, Takeuchi Y. Natural Y-grafting using internal thoracic artery branches for off-pump coronary artery bypass. *Kyobu Geka* 2004; **57**: 187–90. (in Jpse.)
13. Ascione R, Lloyd CT, Underwood MJ, Lotto AA, Pitsis AA, Angelini GD. Inflammatory response after coronary revascularization with or without cardiopulmonary bypass. *Ann Thorac Surg* 2000; **69**: 1198–204.
14. Diegeler A, Hirsch R, Schneider F, et al. Neuromonitoring and neurocognitive outcome in off-pump versus conventional coronary bypass operation. *Ann Thorac Surg* 2000; **69**: 1162–6.
15. Hartman GS, Yao FS, Bruefach M 3rd, et al. Severity of aortic atheromatous disease diagnosed by transesophageal echocardiography predicts stroke and other outcomes associated with coronary artery surgery: a prospective study. *Anesth Analg* 1996; **83**: 701–8.