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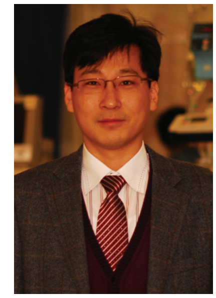
Complete Revascularization Using a Patent Left Internal Thoracic Artery and Variable Arterial Grafts in Multivessel Coronary Reoperation



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ABSTRACT

Background: Arterial grafting and complete revascularization are important requirements of coronary surgery to achieve optimum long-term results. In cases involving coronary artery bypass grafting reoperation (redo-CABG), it is sometimes difficult to satisfy these requirements because of the limited availability of grafts. In this study, we constructed composite and sequential grafting with a minimal number of new arterial grafts and a patent left internal thoracic artery (LITA), which sometimes is encountered in preoperative angiography, and we analyzed the results of redo-CABG.

Methods: Between January 2005 and October 2008, 29 patients underwent redo-CABG. Ten patients who had a patent LITA graft in situ were reviewed retrospectively. We performed conventional CABG in 8 patients and on-pump beating-heart CABG in 2 patients. The new arterial grafts for the composite grafts included 7 LITAs and 3 radial arteries. The types of composite grafts included 7 Y grafts, 1 K graft, 1 X graft, and 1 double-Y graft. Overall, we performed 28 distal anastomoses (mean per patient, 2.8 ± 0.7), of which 18 anastomoses were supplied from a patent LITA (mean, 1.8 ± 0.4).

Results: No hospital deaths occurred, and perioperative complications included injury to a LITA, low cardiac output, delirium, and postoperative bleeding in 1 patient each. The mean duration of follow-up was 23.6 ± 16.8 months (range, 2-46 months). There was 1 late death and no recurrent angina during the follow-up period. Follow-up coronary images obtained for 7 patients showed that all of the anastomoses were patent.

Conclusion: Composite and sequential grafting with new arterial grafts and a patent LITA is a safe and effective alternative in patients with multivessel disease undergoing redo-CABG.

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INTRODUCTION

Coronary artery bypass grafting (CABG) has been an established treatment for ischemic heart disease. Grafting strategies have evolved from the use of saphenous vein grafts to the use of arterial grafts, which show better patency rates and better long-term results. Of these arterial grafts, the left internal thoracic artery (LITA) has been demonstrated to have a superior graft-patency rate and has provided excellent clinical results, and grafts of the LITA to the left anterior descending artery (LAD) have shown a very high late patency rate [Loop 1986; Cameron 1996]. Recently, total arterial revascularization has been achieved with the use of variable arterial grafts in the expectation of better long-term patency [Calafiore 1994; Tatoulis 1999]. In addition, arterial composite grafts constructed with sequential grafting techniques can increase the number of distal coronary anastomoses with a limited number of grafts while avoiding proximal aortic anastomoses [Fukui 2005]. Because atherosclerosis progresses with age, however, CABG is not curative, and many patients will eventually become candidates for a CABG reoperation (redo-CABG) [Yamamuro 2000].

Complete revascularization is an important goal of CABG for optimal long-term results [Bell 1992; Jones 1996; Scott 2000; Synnergren 2008]; however, the limited number of available grafts may interfere with this goal because of the previous use of multiple grafts and increasing peripheral vascular atherosclerosis with age.

In the setting of a planned redo-CABG in a patient with multivessel disease, physicians sometimes encounter a patent in situ LITA in preoperative angiography evaluations because this vessel has a relatively long-term patency. In such situations, we have constructed composite grafts that use a new arterial free graft and a patent in situ LITA as an inflow in patients with multivessel disease to save the length of the graft to a distal target vessel and maximize the number of distal coronary anastomoses. In this study, we retrospectively reviewed the results of our strategy for redo-CABG.

MATERIALS AND METHODS

Between January 2005 and October 2008, 1658 patients underwent CABG, and 29 patients (1.7%) underwent

Table 1. Patient Characteristics and Operative Methods*

Patient No.	Age, y	Sex	Patent Target	New Graft for CG	Type of CG	New Target of CG	Additional Bypass	CPB Time, min	ACC Time, min
1	66	F	Dx	RA	Y	LAD	GEA-PDA	63	—
2†	58	M	PDA	RA	Y	OM	GEA-LAD	137	83
3‡	68	M	—	RA	Y	OM	Free RITA-LAD	125	95
4	73	F	LAD	RITA	K	Dx, OM	GEA-PDA	138	71
5	54	M	LAD	RITA	Y	OM1, OM2	GEA-PDA	116	80
6	51	M	Dx	RITA	X	LAD, OM	GEA-PDA-OM	111	84
7	61	M	LAD	RITA	dY	Dx, OM, PL	—	109	78
8	74	M	LAD	RITA	Y	OM1, OM2, PL, PDA	—	98	—
9	58	M	LAD	RITA	Y	OM	GEA-PDA, GEA-RITA-PL	107	84
10	62	M	LAD	RITA	Y	OM	SVG-PL	127	87

*CG indicates composite graft; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; Dx, diagonal branch; RA, radial artery; Y, Y composite graft; LAD, left anterior descending artery; GEA, gastroepiploic artery; PDA, posterior descending artery; OM, obtuse marginal branch; RITA, right internal thoracic artery; K, K composite graft; X, X composite graft; dY, double-Y composite graft; PL, posterolateral branch; SVG, saphenous vein graft.

†Patient 2 had a patent LITA-RITA-PDA anastomosis and an occluded LITA-LAD anastomosis according to a preoperative angiography examination after the primary coronary artery bypass grafting was performed with an in situ LITA-LAD anastomosis and a RITA-PDA anastomosis (the RITA was connected to the LITA in a Y configuration; Figure 4A).

‡Patient 3 had a totally occluded in situ LITA-LAD anastomosis, but the proximal LITA segment was visualized to be patent in a preoperative angiography procedure. The proximal segment of the LITA was reused as an inflow for a Y graft (Figure 4B).

reoperation. Of the 29 redo-CABG patients, 10 (0.6%) had a patent in situ LITA during the operation, and we reviewed these cases retrospectively. Generally, our inclusion criteria for reoperation were as follows: (1) stenotic vein grafts that supply the LAD artery or large areas of the myocardium, (2) multivessel disease with abnormal left ventricular dysfunction, and (3) severe symptoms (chest pain, dyspnea, or exercise intolerance) combined with an ischemia-producing pathology with an inadequate coronary anatomy for percutaneous intervention, even if patients had a patent graft. The operative indications for the 10 patients with a patent LITA included severe symptoms with inadequate anatomy in 4 patients, left ventricular dysfunction with an LAD lesion or LAD graft failure in 3 patients, left ventricular dysfunction with symptoms in 2 patients, and failure of a graft to the LAD in 1 patient. The mean (±SD) patient age was 62.5 ± 7.7 years (range, 51-74 years), and the majority of the patients were men (80%; n = 8). The mean left ventricle ejection fraction was 52.3% ± 10.3% (range, 35%-67%), and the echocardiograms indicated no significant mitral regurgitation. All procedures were elective. Four patients (40%) presented with hypertension, 3 patients had diabetes, 1 patient had renal insufficiency (defined by a preoperative serum creatinine concentration >2.2 mg/dL), and 1 patient had severe left ventricle dysfunction (defined by a left ventricle ejection fraction ≤35%). The quality of the distal anastomoses from a patent in situ LITA was graded according to the Fitzgibbon classification system in preoperative angiography [Fitzgibbon 1996], as follows: grade A in 9 patients and grade X in 1 patient who had patency of the proximal LITA segment. Of the 9 grade A patients, distal target vessels included the LAD in 6 patients, the diagonal branch in 2 patients, and the posterior descending artery (PDA) in 1 patient who had only a patent LITA–right internal thoracic artery (RITA)–PDA anastomosis after the primary CABG had been performed with an in situ LITA-LAD anastomosis and a RITA-PDA anastomosis as a Y graft connected to the LITA. The Table summarizes the characteristics and operative methods for the patients.

Operative Technique

The redo sternotomy was carefully made with an oscillating saw. After the heart was dissected away from the sternum, the right atrium and aorta were exposed, starting at the diaphragmatic surface of the heart for cannulation. Adhesions in the pericardial space were divided sharply with scissors. If adhesions of the LITA graft were severe, cardiopulmonary bypass (CPB) was instituted to accomplish separation of the LITA graft from adjacent organs. The decompression with CPB and the use of a heart positioner and stabilizer (Starfish and Octopus; Medtronic, Minneapolis, MN, USA) were helpful for further dissection of target vessels and a patent LITA. The dissection of a patent LITA was sufficient to mobilize the heart without tension. After the relationship between a patent in situ LITA and target vessels was identified, arterial composite grafts were constructed by joining them together. Thus, a patent in situ LITA provided the blood inflow to the other artery. An intracoronary shunt

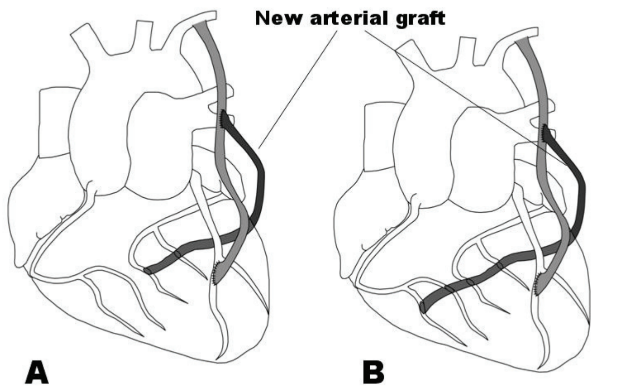

Figure 1. New arterial graft was anastomosed to the patent in situ left internal thoracic artery (LITA), which had previously been anastomosed to the left anterior descending artery (LAD). A, The graft was anastomosed to the LITA in a Y configuration, and the distal end was anastomosed to the circumflex territory (n = 3). B, New graft was anastomosed to the LITA in a Y configuration and sequentially anastomosed to the circumflex territory and the right coronary artery territory (n = 1).

(ClearView; Medtronic) was sometimes used to maintain the flow of a patent LITA during construction of a composite graft. Our basic procedure for reoperation was on-pump beating-heart CABG, except in some situations. The criteria for the conversion to conventional CABG included the following: (1) the presence of a small vessel size (<1.0 mm); (2) the presence of diffuse coronary calcifications; and (3) difficulty in identifying target vessels, including deep-seated coronary arteries, an intramyocardial course, or epicardial scarring. When used, our protocols for myocardial protection consisted of a combination of antegrade and retrograde cardioplegia with temporary occlusion of the LITA graft to achieve myocardial arrest, followed by intermittent maintenance of retrograde cardioplegia and a last warm shot with blood-based cardioplegic solution at a ratio of 4:1 (blood to crystalloid solution). The distal anastomosis to the coronary artery was done by continuous suturing with single 8-0 polypropylene suture using a parachute technique. Weaning from bypass followed the usual pattern. Before decannulation was completed, graft flow tracing data were obtained intraoperatively with a transit-time flowmeter (VeriQ system; Medi-Stim, Oslo, Norway) during the hemodynamic-stabilization period to demonstrate that the distal LITA and new grafts were patent.

Operative Data

We performed conventional CABG in 8 patients and on-pump beating-heart CABG in 2 patients. The grafts included 8 RITAs, 6 right gastroepiploic arteries, 3 radial arteries, and 1 saphenous vein. The arterial grafts for the composite grafts included 7 RITAs and 3 radial arteries. The types of composite grafts included the following: Y graft, 7 (70%); K graft, 1 (10%); X graft, 1 (10%); and double-Y graft, 1 (10%); see Figures 1-4. Overall, we made 28 distal anastomoses (mean number per patient, 2.8 ± 0.7; range, 2-4), of which 18 anastomoses were supplied from patent in situ LITAs (mean number per patient, 1.8 ± 0.4; range, 1-4). The mean durations of aortic cross-clamping (n = 8) and CPB (n = 10) were 83 minutes (range, 71-95 minutes) and 113 minutes (range, 63-138 minutes), respectively.

Data were processed and analyzed with the SPSS statistical program, version 12.0 (SPSS, Chicago, IL, USA). Continuous variables are expressed as the mean ± SD.

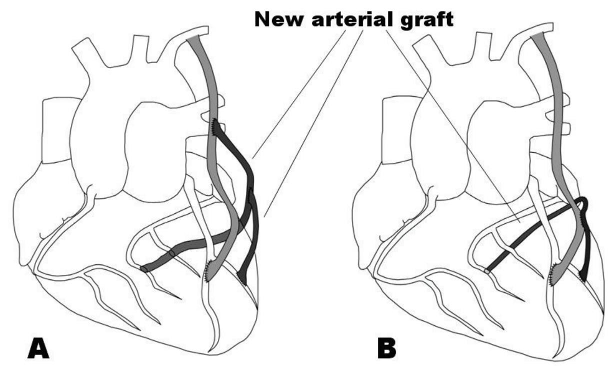

Figure 2. New arterial graft was anastomosed to the patent in situ left internal thoracic artery (LITA), which had previously been anastomosed to the left anterior descending artery (LAD). A, New arterial graft was anastomosed to the LITA in a Y configuration, and the distal end was anastomosed to the obtuse marginal branch of the circumflex artery. A residual segment of new arterial graft was anastomosed to a proximal segment of new arterial graft in a Y configuration, and the distal end was anastomosed to the diagonal branch (n = 1). B, New arterial graft was anastomosed to the LITA in a K configuration, and both ends were anastomosed to the diagonal branch and the obtuse marginal branch of the circumflex artery (n = 1).

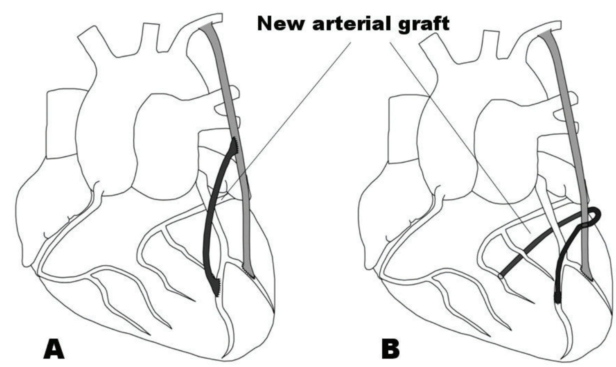

Figure 3. New arterial graft was anastomosed to the patent in situ left internal thoracic artery (LITA), which had previously been anastomosed to the diagonal branch. A, New graft was anastomosed to the LITA in a Y configuration, and the other end was anastomosed to the left anterior descending artery (LAD) (n = 1). B, New arterial graft was anastomosed to the LITA in an X configuration (side-to-side), and both ends were anastomosed to the LAD and the obtuse marginal branch of the circumflex artery (n = 1).

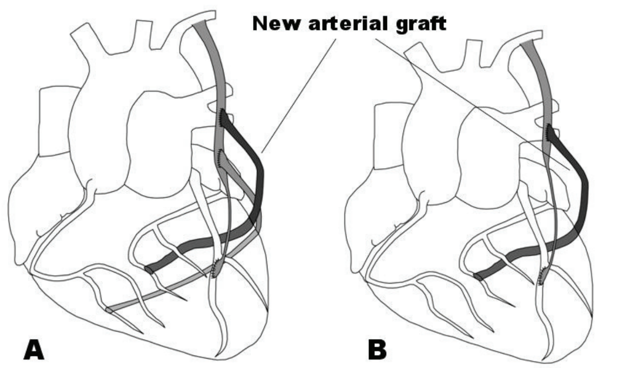

Figure 4. A, New arterial graft was anastomosed to the patent in situ left internal thoracic artery (LITA), which had previously been anastomosed to the left anterior descending artery (LAD). The primary coronary artery bypass grafting was performed with an in situ LITA-to-LAD anastomosis and anastomosis of the right internal thoracic artery (RITA) to the posterior descending coronary artery (PDA), with the RITA connected to the LITA in a Y configuration. A preoperative angiography evaluation demonstrated that the distal segment of the LITA-to-LAD anastomosis was totally occluded and that only the LITA-RITA-PDA anastomosis was patent. B, At the coronary reoperation, the in situ LITA-to-LAD anastomosis was totally occluded, but the proximal LITA segment was visualized to be patent in a preoperative angiography examination. New arterial graft was anastomosed to the proximal segment of the LITA, which was reused as an inflow for a Y composite graft.

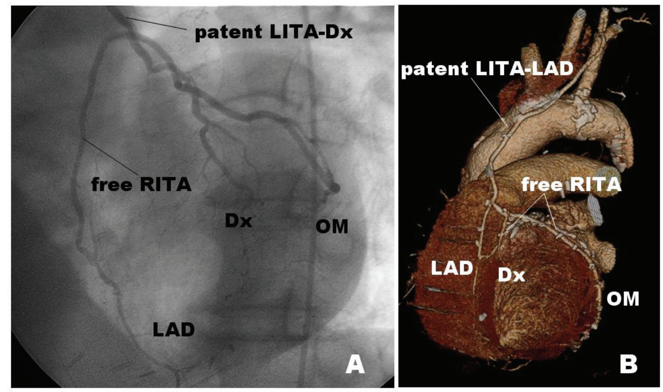

Figure 5. A, Angiography imaging after injection of contrast medium into the in situ left internal thoracic artery (LITA) (left anterior oblique view). The free right internal thoracic artery (RITA) was sequentially grafted to the left anterior descending artery (LAD) and the obtuse marginal branch (OM) after connecting to the patent in situ LITA in an X configuration, which was anastomosed to the diagonal branch (Dx). B, A 3-dimensional image of the heart and coronary arteries reconstructed from a computed tomography angiographic scan. The free RITA was grafted to the OM after connecting to the patent in situ LITA in a Y configuration, which was anastomosed to the LAD. A distal resected RITA was reused to connect the proximal RITA to the Dx as a small graft in a Y configuration.

RESULTS

All 10 patients were discharged from the hospital in excellent condition. There were no perioperative myocardial infarctions, strokes, or major wound problems. The perioperative complications included an injury to a patent LITA during intrapericardial dissection in 1 patient (a resection of the injured portion was performed as a beveled shape, and a direct anastomosis was made in an end-to-end configuration), low cardiac output owing to hypoperfusion in 1 patient, delirium requiring medication in 1 patient, and postoperative bleeding requiring surgical revision in 1 patient. The mean follow-up duration was 23.6 ± 16.8 months (range, 2-46 months). During the follow-up there was 1 late death and no patients with recurrent angina. A coronary angiography or coronary computed tomography examination performed in 7 patients showed that all of the anastomoses in these patients were patent (Figure 5). Two of the patients had their examinations performed in the hospital. The other 5 patients had their imaging examination performed in the outpatient department, and the mean time between the operation and imaging study in these patients was 16.2 ± 16.5 months (range, 1.5-41.7 months).

DISCUSSION

CABG is a well-established method for treating multivessel coronary artery disease. Saphenous vein grafts have shown poor patency rates and have failed to improve long-term morbidity [Fitzgibbon 1996]. The recent wide acceptance of the use of arterial grafts for myocardial revascularization is based on the clinical advantage of the use of the LITA as a bypass conduit [Loop 1986; Cameron 1996]. Many retrospective studies have supported the safety and effectiveness of arterial grafting [Calafiore 1994; Tatoulis 1999; Sato 2000; Quigley 2001]. In our opinion, this concept should be applied to redo-CABG to possibly improve long-term patency.

One common goal of CABG has been complete revascularization. This goal has been based on logic, and past studies have generally shown that complete revascularization is associated with better long-term survival [Bell 1992; Jones 1996; Scott 2000; Synnergren 2008]. However, the fact that the limited number of available grafts may interfere with complete revascularization is another problem in multivessel redo-CABGs because of previous use of multiple grafts and the increase in peripheral vascular atherosclerosis with age. Many retrospective studies have found that the free arterial graft can be used as a branched or a lengthened conduit to the in situ arterial graft [Calafiore 1994; Tatoulis 1999; Sato 2000; Quigley 2001; Fukui 2005]. In redo-CABG, we believe that multivessel revascularizations can be achieved with a composite and sequential grafting technique that uses a limited number of arterial grafts. When a preoperative angiographic examination indicates the presence of a patent in situ LITA, only 1 arterial graft is needed to reach the distal circumflex artery or the right coronary artery (RCA) for complete revascularization. Other advantages of this approach are that it can avoid a side anastomosis to the aorta and save the length of the graft to a distal target vessel.

A possible weak point of composite and sequential grafting is that the flow is dependent on a single in situ LITA;

however, the preoperative angiogram has already demonstrated its integrity, thus suggesting that the LITA has already successfully passed all hurdles of graft failure and has in some way become biologically privileged, thus ensuring its long-term patency. In our patients, occlusion of the LITA was not observed during the follow-up period, and these results are compatible with our hypothesis.

Another possible weak point of our technique is the possibility of hypoperfusion, which results from a relative decrease in flow to the LAD, because the LAD flow can be diverted to the distal circumflex or right coronary arteries. Moreover, hypoperfusion may be accelerated if competitive flow develops after surgery. On the other hand, the old LITA graft may increase in size because of increased runoff. In our cases, we experienced low cardiac output owing to hypoperfusion in 1 patient, for whom 4 distal anastomoses were performed (2 obtuse marginal branches, 1 posterolateral branch, and 1 PDA) with a composite and sequential grafting technique in which a free RITA was connected to a patent in situ LITA (Figure 1B). One vein graft was added to the RCA territory on the second postoperative day, and the patient became stable. This case suggests that too many distal anastomoses from the patent LITA as an inflow or a bypass to the RCA territory from the patent LITA can be hazardous. In such cases, individual grafting to the RCA territory should be considered.

Although the presence of a patent LITA graft to the LAD decreases the morbidity and mortality of a redo-CABG [Lytle 1994; Velebit 1994; Christenson 1995], it also creates specific technical challenges at the time of redo-CABG. These challenges include myocardial protection and avoidance of injury to the LITA graft. In conventional CABG, cardiac arrest with a combination of antegrade and retrograde cardioplegia along with temporary occlusion of the LITA graft provides adequate myocardial protection in most cases. In on-pump beating-heart CABG, we usually use intracoronary shunts to minimize coronary ischemia during the construction of composite grafts and maintain the flow of the LITA during distal anastomoses. Dissection and control of the LITA graft can be challenging and hazardous, however, and some investigators have reported injury to the LITA graft in 5% to 40% of redo-CABGs, with related poor outcomes [Ivert 1988; Verkkala 1990; Elami 1994; Gillinov 1999]. When a patient with a patent LITA-to-LAD graft requires a redo-CABG through a median sternotomy, a carefully planned stepwise approach is essential. Evaluation with the aid of coronary catheterization and computed tomography is helpful to identify the relationship between the LITA graft and adjacent organs. If the LITA graft is adherent to the posterior sternal table or crosses the midline, we favor exposure of a femoral artery and vein to facilitate urgent institution of CPB in the event that injury to the LITA graft occurs. In our cases, we experienced injury to a patent LITA in 1 patient, who underwent resection of the injured portion as a beveled shape and a direct anastomosis in an end-to-end configuration.

In conclusion, composite and sequential grafting with new arterial grafts and a patent LITA is a safe and effective alternative in patients with multivessel disease undergoing redo-CABG; however, too many distal anastomoses from a patent LITA as an inflow or a bypass to the RCA territory from a patent LITA can be hazardous. In these cases, individual grafting to the RCA territory should be considered.

Study Limitations

The limitations of this clinical study are that the number of patients included in the study was small and that the length of clinical follow-up was only 23.6 months. Furthermore, this study was retrospective and observational in nature and was not randomized. Because there was no control group, we cannot conclude that the composite arterial and sequential grafting technique with a previously performed patent LITA graft is fully safe and effective in redo-CABG.

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