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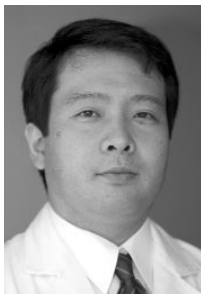
Early Adaptation of the Left Internal Thoracic Artery as a Blood Source of Y-Composite Radial Artery Grafts in Off-Pump Coronary Artery Bypass Grafting



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ABSTRACT

Objective: Y-composite grafting with the radial artery (RA) is often used in off-pump coronary artery bypass grafting (OPCAB). However, the early flow reserve of the left internal thoracic artery (LITA) as a blood source of the Y-composite RA graft has not been delineated.

Methods: The size of the LITA was examined angiographically in 42 patients who underwent OPCAB using LITA and Y-composite RA grafting between June 2000 and February 2002. In these patients, the LITA was used as a blood source of the Y-composite RA graft. The mean patient age ± SD was 67 ± 8 years. The average number of distal anastomoses was 3.2 ± 0.7. Total coronary revascularization was carried out in 34 patients with only LITA and Y-composite RA grafting. RA grafting was used for revascularization of the circumflex artery alone in 5 patients, for the right coronary artery system (RCS) alone in 6 patients, and for both the circumflex and the RCS in 23 patients. The average number of distal anastomoses using the RA was 1.9 ± 0.7. Flow measurements of the proximal LITA were achieved intraoperatively with a transit-time flowmeter. The diameters of the LITA before and after the operation were measured angiographically. Intraoperative flow volume was correlated with the ratio of the LITA diameters before and after the operation.

Results: The mean flow rate of the LITA was 61 ± 35 mL/min (range, 9-196 mL/min). The mean diameters of the LITA before and after the operation were 1.97 ± 0.36 mm and 2.74 ± 0.60 mm, respectively. The mean ratio of the LITA diameter after the operation to that before the operation was 1.43 ± 0.27. The intraoperative flow volume was positively correlated with the ratio of LITA diameters (r = 0.414; P = .006).

Conclusion: These results demonstrate the early adaptation of the LITA as a blood source of the Y-composite RA graft in OPCAB and the rationale for using the LITA as a single blood source for total coronary artery revascularization.

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INTRODUCTION

Off-pump coronary artery bypass grafting (OPCAB) has become an established method of coronary revascularization, and the advantages of OPCAB over conventional coronary artery bypass grafting (CABG) with cardiopulmonary bypass have been reported [Nader 1999, Arom 2000, Diegeler 2000, Matata 2000]. On the other hand, composite grafting with the radial artery (RA) anastomosed to the side of an in situ internal thoracic artery (ITA) has gained popularity as an alternative graft. The advantage of the composite graft is the efficient use of the arterial conduit by placing the point of inflow closer to the point of the target coronary vessel without manipulating the aorta. Consequently, OPCAB using the combination of one or both ITAs in situ in grafts and composite grafts enables realization of total arterial coronary revascularization (TACR) for treating multivessel disease by the "aorta no-touch" technique. However, hypoperfusion syndrome is suspected in a composite graft with a single blood source.

Intraoperative flow measurement using the transit-time flowmeter has become an established method of assessing anastomotic quality in CABG. Until now, it has been the most common intraoperative means of assessment because of the method's advantage of being independent of vessel diameter, hematocrit level, and angle of insertion [Louagie 1994, Canver 1994, Jaber 1998, Walpoth 1998, D'Ancona 2000, Shin 2001]. On the other hand, coronary angiograms are the gold standard for the quantitative evaluation of coronary arteries and grafts [Calafiore 1995, Elbeery 1998, Poirier 1999, Ömeroglu 2000]. The objective of this study was to assess the early adaptation of the left ITA (LITA) as a blood source for Y-composite RA grafts in OPCAB by means of intraoperative flow measurements and quantitative angiographic assessment of the LITA.

PATIENTS AND METHODS

Between June 2000 and February 2002, 42 nonrandomly selected patients underwent OPCAB using a combination of

Table 1. Demographic and Clinical Profile of Patients (n = 42)

Age (range), y	67.3 ± 7.7 (48-79)
Male/female, n	31/11
Coronary disease, n	
Left main	13
Triple-vessel	26
Double-vessel	2
Single-vessel	1
Unstable angina, n	11

in situ LITA and Y-composite RA grafts at the National Cardiovascular Center and gave informed consent for an angiographic evaluation during the immediate postoperative period. Two patients underwent urgent OPCAB for unstable angina pectoris, and one underwent emergent OPCAB for acute myocardial infarction. The study group comprised 31 men and 11 women with a mean age of 67.3 ± 7.7 years (range, 48-79 years) (Table 1). One patient had undergone previous CABG. This study was approved by the Institutional Review Board of the National Cardiovascular Center.

Preparation of the Conduits

The dissection technique for the LITA was a conventional semiskeletonized method. The RA was harvested with an ultrasonic dissection technique. The ITA and RA were wrapped in a sponge soaked with a solution of papaverine hydrochloride. The spasm of the RA was released by gently injecting a mixture of blood and papaverine hydrochloride solution into the lumen. The length of the RA ranged from 16 to 22 cm (mean, 18 cm). After the administration of heparin (1.0-1.5 mg/kg), the LITA and the RA were divided. The LITA was used as an in situ graft to the left anterior descending artery (LAD). The RA was used only for a composite graft. The RA was connected to the side of the LITA as a Y-composite graft. Since December 2000, the RA has been anastomosed with the LITA in a side-to-side fashion to avoid kinking. All arterial anastomoses were performed with a continuous suture of 7-0 polypropylene (Prolene; Ethicon, Somerville, NJ, USA) and a parachute technique.

Surgical Technique

A standard median sternotomy was used in all patients. The pericardium was opened, and deep pericardial retraction sutures were placed. After the construction of the Y-composite graft, the coronary arteries were anastomosed in the order of the LAD, the diagonal, the obtuse marginal, and the posterolateral to posterior descending arterial branches. Proper positioning and stabilization of the heart were obtained with pericardial sutures, surgical sponges, and the Octopus III stabilizer (Medtronic, Minneapolis, MN, USA) with steep Trendelenburg positioning and rotation of the operative table toward the surgeon. Transesophageal echocardiography and left atrial pressure monitoring were performed to check mitral and tricuspid regurgitations caused by extensive left and right ventricular geometric change and right ventricular outflow obstruction due to change in right ventricular geometry. Proximal compression of the target vessel was accomplished transiently with Retract-O-Tape (Quest Medical, Allen, TX, USA) traction without encircling. Neither preconditioning nor distal occlusion was performed. The control of heart rate and blood pressure was obtained with diltiazem and norepinephrine. After coronary arteriotomy, the operative field was kept free from blood with a carbon dioxide blower (Visuflo, Edwards Lifesciences, Irvine, CA, USA) and an internal shunt (Anastaflo, Edwards Lifesciences; ClearView, Medtronic).

Transit-Time Flow Measurement

Flowmetry of the LITA was performed with a transit-time flowmeter (CardioMed flowmeter; Medi-Stim, Oslo, Norway) just before chest closure with the patient in a stable hemodynamic condition. The transit-time flowmeter probe was fitted around the LITA just above the connection of the RA. Skeletonization of a small segment of the LITA was necessary to reduce the quantity of tissue between the probe and the vessel. Although mean flow values were expressed in milliliters per minute, they were always interpreted with the diastolic filling pattern of the flow curve.

Angiographic Evaluation

Coronary and graft angiography was performed at 10 to 21 days (mean, 14 days) after OPCAB. After the selective injection of 0.25 mg nitroglycerin into each ostium of the coronary arteries and the LITA, a contrast medium was injected manually for each projection with a 5F catheter. LITA diameter was measured with a computer-assisted method [Lesperance 1996] using the Cardiovascular Measurement System (QCA-CMS, version 4.1; Medis, Leiden, The Netherlands). An automatic edge-detection program determined the LITA contours by assessing the brightness along the scan lines perpendicular to the centerlines of the vessel. The vessel diameters (in millimeters) were measured by calibration with a 5F catheter. The preoperative diameter of the LITA was measured in right anterior oblique view. The place of connection to the RA graft to be measured depended on the distance from the bifurcation (7.6 ± 1.1 cm), which was measured at the time of the operation. The diameter of the LITA after the operation was measured just above the connection of the RA in left anterior oblique view (Figure 1).

Data Collection

Follow-up data were collected prospectively from the database of the National Cardiovascular Center. All cardiac and noncardiac events were recorded in detail.

Statistical Analysis

Data were analyzed with the Student *t* test in the case of 2 groups for discontinuous variables. Comparisons of the characteristics in the 4 groups were performed with a nonparametric analysis of variance followed by a posthoc Bonferroni test for continuous and ordinal variables. Data were expressed as the mean ± standard deviation. Relationships between variables were assessed by linear regression. Differences were considered statistically significant when the *P* value was less than .05.

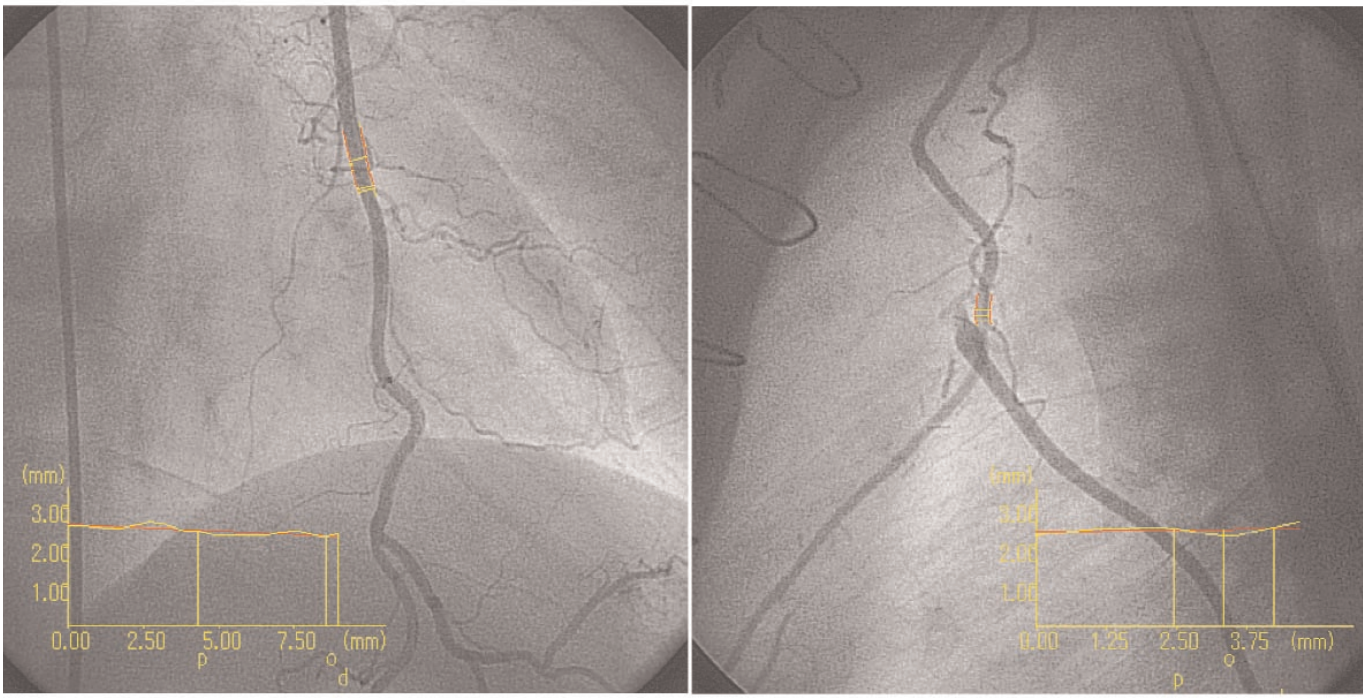

Figure 1. Quantitative angiographic evaluation of the left internal thoracic artery before (left) and after (right) the operation.

RESULTS

Clinical Results

The average number of distal anastomoses was 3.2 ± 0.7. The postoperative angiography results showed a graft patency rate of 98.5% (133 of 135), with an ITA-to-LAD patency of 100%. Additional grafting with the LITA and Y-composite RA graft was required for coronary revascularization in 10 patients (Table 2). RA grafting was used for revascularization of the diagonal branch alone in 5 patients, the circumflex artery alone in 9 patients, the right coronary artery system alone in 6 patients, and both the circumflex artery and the right coronary system in 22 patients (Figure 2, Table 3). The average number of distal anastomoses using the RA was 1.9 ± 0.7. The graft patency rate was 98.7%. There were no hospital or late deaths during the follow-up period. No neurologic complications or strokes occurred in the early postoperative period, and there was no reexploration for bleeding or mediastinitis. Perioperative myocardial infarction (creatine kinase–MB >50 U/L) occurred in 2 patients.

Intraoperative Flow Measurement and Quantitative Angiographic Evaluation

The mean flow rate of the LITAs was 61 ± 35 mL/min (range, 9-196 mL/min). There were no significant differences between revascularized areas.

There was a significant difference in the mean diameters of the LITAs before and after the operation (1.97 ± 0.36 mm and 2.74 ± 0.60 mm, respectively; $P < .0001$). The mean ratio of the LITA diameters (postoperative/preoperative) was 1.43 ± 0.27. There were no significant differences between revascularized areas (Table 4). Intraoperative flow volume, however, was positively correlated with the ratio of LITA diameters ($r = 0.414$; $P = .006$) (Figure 3).

DISCUSSION

The excellent results obtained with OPCAB using an in situ ITA have led to the significant development of techniques to extend the use of TACR. TACR without cardiopulmonary bypass for treating multivessel disease is a goal of cardiac surgeons. However, the bilateral use of the ITAs has not been sufficient for complete myocardial revascularization because of the length of the conduits, even if a skeletonized technique is applied for harvesting [Kramer 2000]. Harvesting multiple arterial conduits may not only prolong the operation time but also increase the risk of wound infection [He 1994, Borger 1998]. As an arterial conduit, the RA has several advantages [Acar 1992, Calafiore 2002]. It can be harvested simultaneously and easily with the LITA and with low mor-

Table 2. Results*

Distal anastomoses, n	3.2 ± 0.7
Graft patency	98.5% (133/135)
LITA and RA Y-composite graft alone, n	32
Additional grafts, n	
In situ RITA and RA composite graft	5
In situ RITA	4
Saphenous vein graft	1

*LITA indicates left internal thoracic artery; RA, radial artery; RITA, right internal thoracic artery.

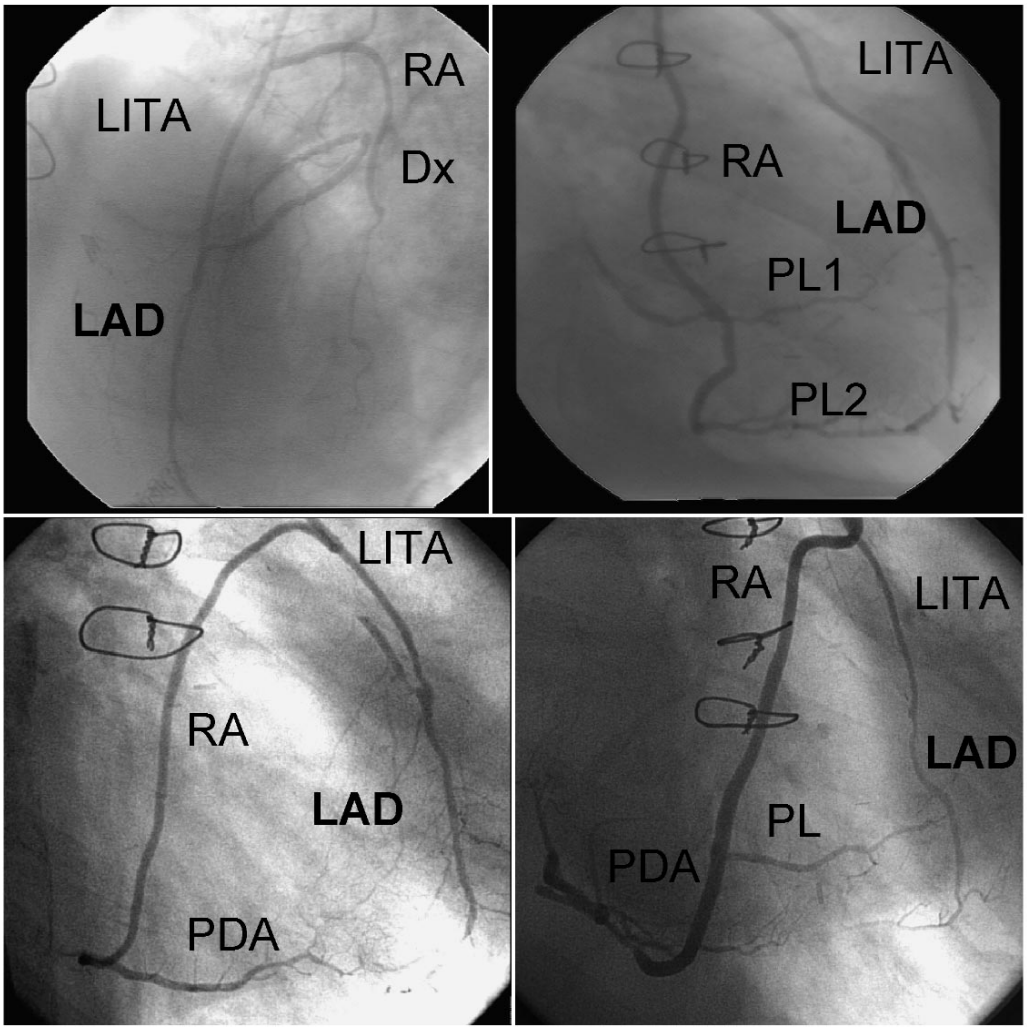

Figure 2. Postoperative angiography of a radial arterial (RA) Y-composite graft. Revascularization of the left anterior descending artery (LAD) and diagonal branch (Dx) in 5 patients (upper left), the LAD and circumflex artery in 9 patients (upper right), the LAD and right coronary artery system in 6 patients (lower left), and the entire coronary system in 22 patients (lower right). LITA indicates left internal thoracic artery; Dx, diagonal branch; PL1 and PL2, posterolateral branches 1 and 2; PDA, posterior descending artery.

bidity. The RA has a constant diameter and a length sufficient to reach almost all of the coronary branches when it is used as a composite graft anastomosed to the side of in situ LITA. Handling of the RA is easy, even with a beating heart. As a result, a combination of an in situ LITA and an RA composite graft enables the realization of TACR for treating multivessel coronary disease while the heart is beating. In addition, a composite graft anastomosed to the side of an in situ LITA avoids the high wall stress and turbulence directly from the ascending aorta that can result in fibrous intimal hyperplasia [Calafiore 1994]. On the other hand, one of the major disadvantages is the single blood supply from the ITA for the entire coronary system [Speziale 2000, Maniar 2002]. However, hypoperfusion syndrome occurred in none of our patients, even though the entire coronary system was supplied only by the single blood source of the LITA in 52% of the patients in the present series. Additionally, we have demonstrated the early adaptation of LITA as a blood source for Y-composite RA grafts in OPCAB by means of intraoperative flow measurements and quantitative angiographic assessment

Table 3. Results: Revascularization Area with Radial Artery Composite Graft from the Left Internal Thoracic Artery*

	Patients	Distal Anastomoses
Diagonal branch, n	5	5
LCx, n	9	14
RCS, n	6	7
LCx and RCS, n	22	52
Total, n	42	78
Patency	98.7% (77/78)	

*LCx indicates left circumflex artery; RCS, right coronary artery system.

Table 4. Left Internal Thoracic Artery (ITA) Flow Rates and Diameters*

	Patients, n	Flow, mL/min	ITA Diameter, mm		P	Ratio†
			Preoperative	Postoperative		
Diagonal branch	5	55.6 ± 24.2	2.02 ± 0.34	2.77 ± 0.54	.014	1.38 ± 0.24
LCx	9	68.3 ± 56.6	1.98 ± 0.31	2.90 ± 0.42	.0006	1.50 ± 0.37
RCS	6	44.5 ± 14.3	1.90 ± 0.46	2.49 ± 0.71	.016	1.31 ± 0.23
LCx and RCS	22	61.3 ± 30.3	1.98 ± 0.47	2.84 ± 0.65	<.0001	1.44 ± 0.24
Total	42	59.7 ± 35.1	1.97 ± 0.36	2.74 ± 0.60	<.0001	1.43 ± 0.27

*Data are presented as the mean ± SD. LCx indicates left circumflex artery; RCS, right coronary artery system.
†Postoperative/preoperative diameter.

of the LITA, though no significant differences in flow volume and diameter ratio were found to exist between the revascularized areas. This result supports the concept mentioned by several other investigators [Weinschelbaum 1997, Royse 1999, Calafiore 1999, Quigley 2001] that the use of composite arterial conduit for a wide myocardial revascularization is safe. However, the adaptation demonstrated in this study was just for an early stage after surgery. Angiographic studies were performed at 10 to 21 days (mean, 14 days) after the operation and with the patient at rest. The present study does not provide information about the potential flow reserve of the LITA over the long term or when the patient is exercising. On the basis of these results, we have performed TACR using a combination of an in situ LITA and RA composite grafting for a select group of patients older than 65 years or who are at poor risk. Further investigation will be necessary to elucidate the potential flow reserve in patients over the long term or during exercise.

CONCLUSION

These results demonstrate the early adaptation of LITA as a blood source for Y-composite RA grafting in OPCAB and the rationale for using the LITA as a single blood source for total coronary revascularization.

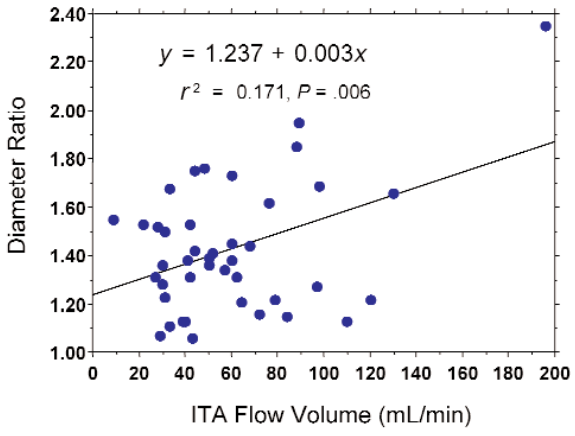

Figure 3. The correlation between flow volume of the left internal thoracic artery (ITA) and the diameter ratio of the left ITA.

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