Beating Heart Revascularization Using Only Bilateral Internal Thoracic Arteries for Triple-Vessel Disease: Early Angiographic Findings

(#2003-2995)

Kiick Sung, MD, Young Tak Lee, MD, Kay-Hyun Park, MD, Tae-Gook Jun, MD, Pyo Won Park, MD, Ji-Hyuk Yang, MD

Department of Thoracic and Cardiovascular Surgery of Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

ABSTRACT

Background: Early postoperative coronary angiography was performed to establish the feasibility of treating patients with triple-vessel disease by performing completely arterial revascularization on the beating heart using only bilateral internal thoracic arteries (ITAs).

Methods: Between March 2001 and February 2003, 113 patients with triple-vessel disease (age, 62.0 ± 8.6 years) underwent beating heart revascularization using only the bilateral ITAs. Left ventricular ejection fractions ranged from 23% to 78% (mean, 51.3% ± 15.1%). The incidence of diabetes mellitus was 46%. Early postoperative coronary artery angiographic follow-up was performed since May 2002 in the last 59 sequential patients.

Results: There were no operative deaths. Perioperative myocardial infarction and postoperative low cardiac output occurred in only 1 patient each. The mean number of distal anastomoses was 3.9 ± 0.7 per patient. The patency rates were 100% for the left ITA and 98.1% for the right. Competitive flow patterns were present in 25 distal anastomosis sites (10.5%). A multivariate analysis showed that the degree of stenosis (<75%), the extent of focal stenosis of the native coronary artery, and the intraoperative transit-time flow rate (<10 mL/min) were the statistically significant risk factors for competitive flow.

Conclusion: This surgical strategy is feasible, is safe, and yields good early angiographic outcomes, even following beating heart revascularization. However, in less significant lesions competitive flow patterns were relatively prevalent, so this technique might be reserved until it is proven to provide good long-term patency and function.

Presented at the 9th Annual CTT Meeting 2003, Miami Beach, Florida, USA, March 19-22, 2003.

Address correspondence and reprint requests to: Young Tak Lee, MD, Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 50 Ilwon-Dong, Kangnam-Ku, Seoul, 135-280, Korea; 82-2-3410-3480; fax: 82-2-3410-0089 (e-mail: ytlee55@yahoo.co.kr).

INTRODUCTION

The internal thoracic artery (ITA) is considered the conduit of choice for myocardial revascularization because it provides superior long-term patency and survival compared with the saphenous vein graft (SVG) [Cameron 1986]. Moreover, the use of bilateral ITAs (BITAs) for revascularization is superior to using the left ITA and SVGs [Lytle 1999]. Many cardiac surgeons have attempted to achieve complete arterial revascularization using alternative arterial conduits, including the gastroepiploic, radial, and inferior epigastric arteries. However, these conduits differ histologically from the ITA [van Son 1993, He 1999], and the long-term patencies of these grafts are not established.

Tector et al first attempted to bypass as many coronary arteries as possible by using BITAs as T grafts or end-to-end extensions in patients with triple-vessel disease [Tector 1989]. This strategy has shown acceptable early and late mortality rates and good reintervention-free rates [Wendler 2000, Tector 2001]. However, this surgery has been performed under conditions of cardiopulmonary bypass (CPB) and cardioplegic arrest. We have performed it on the beating heart to treat triple-vessel disease by using a Y-graft extension as far as possible without manipulating the aorta, in the hope of decreasing the risk of cerebrovascular accidents and improving postoperative recovery [Ascione 1999, Diegeler 2000]. However, the feasibility of carrying out beating heart revascularization solely with BITAs for triple-vessel disease is not known, so we performed immediate postoperative angiograms to study the outcomes.

MATERIALS AND METHODS

Patients

From March 2001 to February 2003, 452 patients underwent coronary arterial revascularization by one surgeon (Y.L.) at Samsung Medical Center, Seoul, Korea. There were 244 patients with triple-vessel disease. Of these patients, BITAs were used in 216 (89%). BITAs only were used in 129 patients (53%), and beating heart revascularization with a Y-graft extension was performed in 113 of these patients. The patients' clinical characteristics are summarized in Table 1.

Table 1. Clinical Characteristics of 113 Patients Who Had Triple-Vessel Disease and Underwent Beating Heart Revascularization

Age (mean ± SD), y	62.0 ± 8.6
Age >70 y, n	21 (19%)
Sex (male/female), n	82/31
Diabetes, n	52 (46%)
Creatinine >2.0 mg/dL, n	10 (9%)
Previous intervention, n	17 (15%)
Previous cerebrovascular accident, n	15 (13%)
Previous myocardial infarction, n	45 (40%)
Myocardial infarction ≤4 wk, n	25 (22%)
Ejection fraction <35%, n	13 (12%)
Emergency operation, n	5 (4%)
Unstable angina, n	59 (52%)
Left main disease, n	24 (21%)

Surgical Technique

ITAs were prepared by skeletonization. After the grafts were prepared, they were sprayed with diluted papaverine solution and the distal ends were closed with Hemoclips (Weck Closure Systems, Research Triangle Park, NC, USA). After the coronary arteries were inspected, the proximal end of the right ITA was anastomosed to the side of the left ITA with a continuous running suture. The length of the right ITA of several patients was measured after harvesting (Figure 1). The left ITA was then anastomosed to the left anterior descending artery (LAD) and its branches, and the right ITA was sequentially anastomosed to the left circumflex (LCx) and the right coronary artery (RCA) system. All anastomoses were performed with either the Medtronic Octopus (Medtronic, Minneapolis, MN, USA) or the Axius (Guidant, Santa Clara, CA, USA) off-pump system. If the patient had cardiomegaly and unstable hemodynamics during the distal anastomosis, an on-pump coronary artery bypass graft (CABG) was performed. The quality of the anastomosis sites was checked by routinely recording postoperative transit-time flow rates with a Transonic HT207 flowmeter (Transonic Systems, Ithaca, NY, USA).

Coronary Angiography

Informed consent was obtained from the last 59 consecutive patients, and follow-up angiography was performed before patient discharge to check the anastomosis sites and the quality of the grafts. Both native coronary arteriography and left internal thoracic arteriography were performed in all patients. We reviewed all the postoperative angiography results, and the percentage of native coronary artery stenosis was determined from the cardiologist's reports.

Statistics

All data are expressed as the mean ± standard deviation. The risk factor for competitive flow was evaluated by performing univariate and multivariate logistic regression analyses with the following variables: region of the distal anastomosis (LAD, LCx, RCA); number of distal anastomoses per region; type of

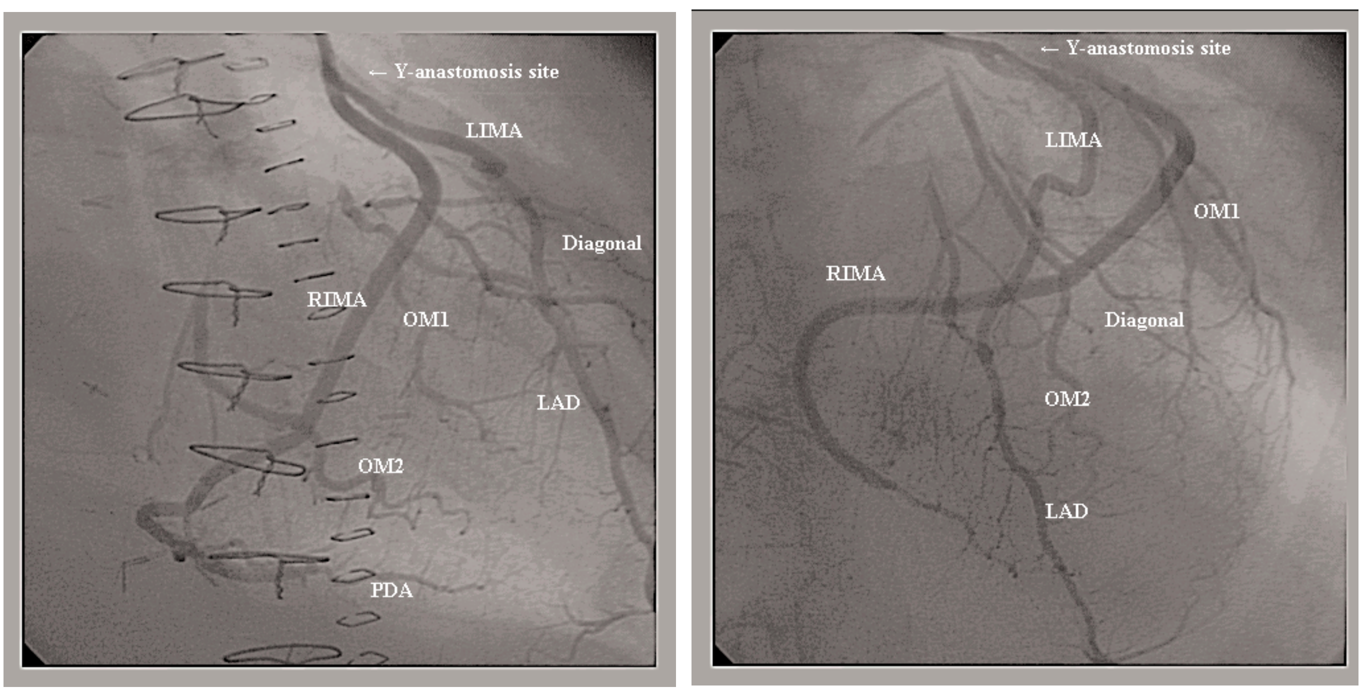

Figure 1. All of the distal anastomosis sites were patent in early postoperative selective angiograms of the proximal left internal thoracic artery in the same patient. The left internal thoracic artery (LIMA) was anastomosed sequentially to the diagonal and left anterior descending (LAD) arteries. The right internal thoracic artery (RIMA) was anastomosed sequentially to the first and second obtuse marginal branches (OM1 and OM2) and the posterior descending artery (PDA) of the right coronary artery. All the anastomoses were performed with the off-pump technique.

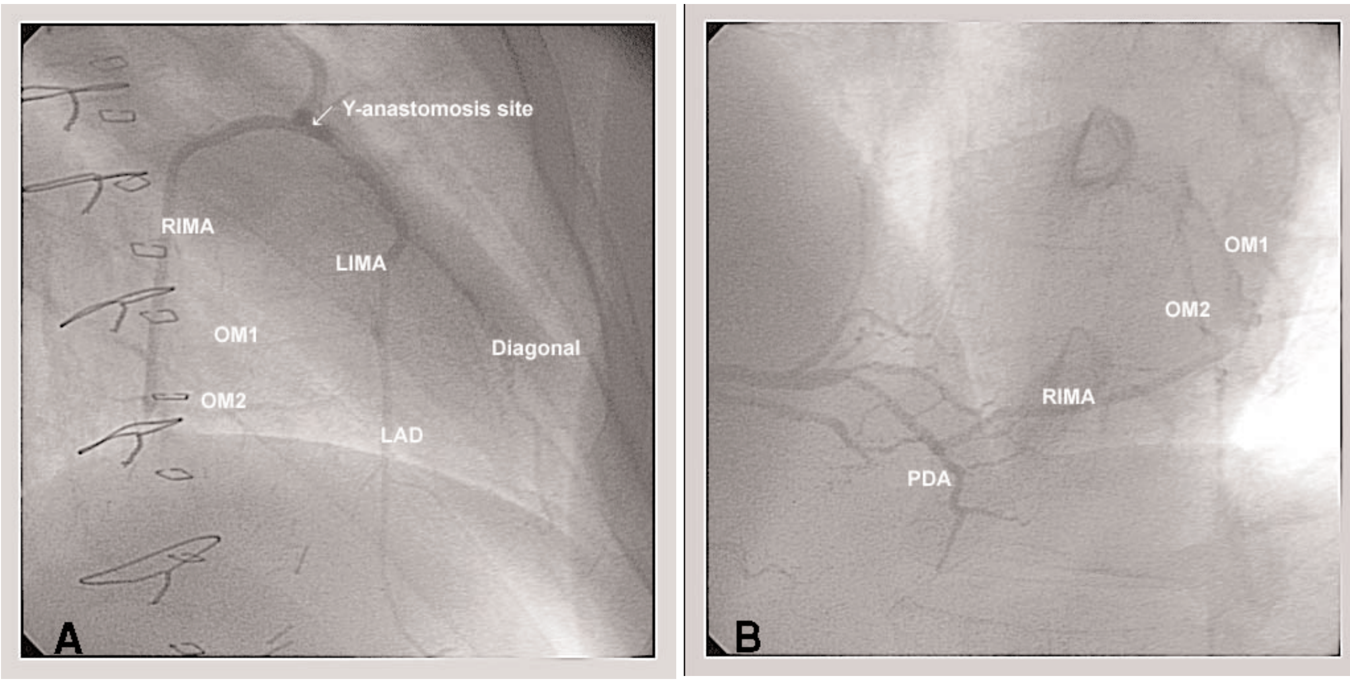

Figure 2. Competitive flow was shown in early postoperative selective angiography of the proximal left internal thoracic artery (LIMA) (A) and right coronary artery (B). Flow from the right internal thoracic artery (RIMA) to the posterior descending artery (PDA) was not shown. However, retrograde filling of the RIMA was seen in right coronary arteriography. Intercoronary shunting from the PDA through the RIMA to the first and second obtuse marginal branches (OM1, OM2) was also demonstrated.

graft (left ITA, right ITA); number of distal anastomoses per graft; size of the coronary artery (less than 1.5 mm or 1.5 mm and greater); degree of native coronary artery stenosis (less than 75% or 75% and greater); extent of native coronary artery stenosis (focal, diffuse); shape of the distal anastomosis site (perpendicular, parallel); location of the distal anastomosis (side-to-side, end-to-side); and measurement of the transit-time flow rate (less than 10 mL/min or 10 mL/min and greater). A *P* value of less than .05 was considered statistically significant.

RESULTS

Clinical Results

Off-pump CABG (OPCAB) was performed on 103 patients, and on-pump CABG was performed on 10 patients. The total number of distal anastomoses was 3.9 ± 0.7 (range, 3-6). There were no operative or postoperative in-hospital deaths. No patient needed new intra-aortic balloon pump support postoperatively. Perioperative myocardial infarction occurred in 1 patient who underwent an emergency operation because of LAD dissection during the intervention. Low cardiac output occurred in 1 patient, and long (>48 hours) ventilatory support was needed in the same patient, who had a lower ejection fraction (approximately 30%) and a restrictive pattern of diastolic dysfunction preoperatively and who experienced short ventricular tachycardia postoperatively. No patients required reoperation for bleeding. Deep sternal wound infections occurred in 2 patients but were managed successfully with omental flap transposition. Transient cognitive dysfunction occurred in 3 patients, but no new cerebrovascular accidents occurred. No patient needed new hemodialysis or hemofiltration therapy postoperatively.

Angiographic Results

Early postoperative angiography was performed in the last 59 consecutive patients (52%) before discharge at 5.8 ± 1.0 days (range, 4-8 days) after the operation. No patients complained of recurrent angina symptoms. OPCAB was performed in 56 patients, and on-pump CABG was performed in 3 patients. The total number of distal anastomoses performed in these patients was 237, and the mean number of distal anastomoses was 4.0 ± 0.7. Two hundred thirty-four (99%) of these sites proved patent (Figure 1). All 75 distal anastomoses (100%) of the left ITA were patent, as were 156 (98%) of the 159 distal anastomoses of the right ITA. All of the occluded sites were anastomoses of the right ITA to the posterior descending coronary artery branch of the dominant RCA.

Competitive flow patterns (Figure 2) were observed in 25 distal anastomosis sites (10.5%). Univariate analysis indicated that the major risk factors were the region of anastomosis, the presence of a right ITA graft, more distal anastomoses per graft, less than 75% stenosis, the presence of focal lesions, an end-to-side anastomosis site, and a less than 10 mL/min transit-time flow rate (Table 2). However, multivariate analysis indicated that only 3 of these variables proved statistically significant as risk factors: less than 75% stenosis, focal stenosis of the native coronary artery, and a less than 10 mL/min transit-time flow rate (Table 2).

Table 2. Risk Factors for Competitive Flow Pattern Analyzed with Univariate and Multivariate Logistic Regression*

Variables	Univariate *P*	Multivariate *P*
Territory (LAD, LCx, RCA)	.002	.946
No. of anastomoses/territory	.105	.407
Type of graft (LITA, RITA)	.012	.989
No. of anastomoses/graft	.016	.341
Coronary artery size (<1.5 mm)	.435	.223
Degree of coronary artery stenosis (<75%)	.000	.002
Extent of coronary artery stenosis (focal, diffuse)	.000	.002
Shape of anastomosis site (perpendicular, parallel)	.008	.415
Location of anastomosis site (end-to-side, side-to-side)	.763	.676
Transit-time flow rate <10 mL/min	.000	.023

*LAD indicates left anterior descending coronary artery; LCx, left circumflex coronary artery; RCA, right coronary artery; LITA, left internal thoracic artery; RITA, right internal thoracic artery.

DISCUSSION

The long-term patency of the ITA graft compared with that of the SVG is well known [Cameron 1986]. Other arterial grafts have been used in the hope of showing similar long-term results, but they have not been satisfactory [Moran 2001, Hirose 2002]. The unsatisfactory results with these other conduits may be related to the varying histologic characteristics of the arteries [van Son 1993, He 1999]. Some surgeons have used BITA grafts and have demonstrated that patients who received "ideal" BITA grafts had decreased risks of death, need for reoperation, and angioplasty [Lytle 1999]. Others have used BITAs alone in patients with multivessel disease and have demonstrated good surgical results [Tector 1989, Wendler 2000, Tector 2001]. We have used this technique on most triple-vessel disease patients without the need for inducing cardioplegic arrest, and CPB was not necessary in most patients unless they had unstable hemodynamics and cardiomegaly.

Performing this surgical strategy requires sequential grafting and Y- or T-graft extension. The angiographic results of sequential grafting have shown good results, even in patients receiving OPCAB [Al-Ruzzeh 2002]. Coronary angiography showed a good patency rate of 99% in this series. Sequential grafting sites showed no occlusion, and all 3 occluded distal anastomosis sites were the distal ends of the right ITA to the posterior descending artery. After finishing each anastomosis, we measured the transit time by flowmetry and checked the distal ITA graft flow visually, with the aim of decreasing the occlusion rates of sequential grafting. Such Y- or T-graft anastomoses may have a potential disadvantage in that coronary bypass flow is dependent on a single source of flow in the proximal left ITA. Thus, postoperative hypoperfusion and catastrophic events may occur if distal demands exceed the available blood supply [Jones 1989, Carrel 1995]. The authors who pioneered this surgical strategy said that they had not observed this phenomenon [Tector 1989, Wendler 2000, Tector 2001]. There is evidence that the ITA adapts to myocardial blood demand by enlarging [Kitamura 1992, Seki 1992, Nakayama 2001] so that it can accommodate higher flow requirements; therefore, the flow reserve of the ITA is influenced by the status of native coronary arteries [Wendler 1999, Markwirth 2001]. Sakaguchi et al reported that the myocardial blood flow of arterial composite Y grafts measured with positron emission tomography is less than that of independent grafts [Sakaguchi 2002]. However, these investigators used types of arterial conduits that are liable to spasm. Thus, it is not valid to compare in situ BITA grafts with left ITA plus other arterial grafts. Moreover, these authors harvested the left ITA by using skeletonization techniques and anastomosed it to the LAD region with a Y-graft group, but they did not describe the harvesting technique for the other grafts. In addition, they only measured the myocardial blood flow within 2 weeks after the operation. Spyrou et al reported that the coronary vasodilator reserve improves only slowly after coronary bypass grafting, possibly because of persistent microvascular dysfunction [Spyrou 2000]. Peripheral factors of the myocardial vascular bed or myocardial stunning during the immediate postoperative period could be the cause. Markwirth et al reported similar results, even though they did not observe any hypoperfusion syndrome clinically [Markwirth 2001]. The procedures described in these reports all used CPB combined with cardioplegic arrest. If we understood the exact effects of the OPCAB technique on microvascular dysfunction, we could discuss this point further. Until we do, it is not appropriate to apply these previous results to our OPCAB patients. Interestingly, some of our patients with triple-vessel disease (not presented here) who underwent bypass under CPB support needed an additional SVG.

Although the patency rate (based on immediate postoperative coronary angiography) was relatively high in our patients, approximately 10% of distal anastomosis sites showed competitive flow patterns. Although there is controversy regarding competitive blood flow in the ITA and long-term patency [Lust 1994, Carrel 1995, Kawasuji 1996, Shimizu 2000], we decided to avoid those sites in which the native coronary artery showed less than 75% and focal stenosis, especially in the main RCA with a dominant distal branch. However, some investigators have demonstrated a reopening of the obstructed ITA during the progression of coronary artery disease [Kitamura 1992, Seki 1992]. In the present study, the anastomosis technique and the number of distal anastomoses per graft or territory were not statistically significant risk factors. If the native coronary artery showed significant stenosis, sequential multiple grafting with 2 grafts, especially BITAs, may be possible without showing competitive flow patterns (Figure 1). However, our angiography was performed during the resting state, and we do not know the flow pattern during exercise. It is known that competitive flow patterns at rest disappear during hyperemic states such as exercise [Akasaka 1998]. Thus, if the coronary flow reserve of the left ITA is sufficient, competitive flow patterns may disappear or diminish. This possibility requires further study.

We frequently observed intercoronary shunt flow in the grafts that showed competitive flow patterns (Figure 2). We think this intercoronary shunting may have some benefit. If a proximal Y-anastomosis site or another more proximal anastomosis site is occluded, such intercoronary shunts may deliver blood to more distally located branches of the LCx or RCA, providing a persistent long-term flow through the graft. To confirm this shunting, we will perform angiographic follow-ups 1 or 2 years later.

Our angiography was performed on a relatively small number of patients during the immediate postoperative period. To determine the exact flow dynamics requires additional functional study, and more patients and long-term follow-up angiograms are required to establish confidence in this strategy.

In conclusion, the surgical strategy of using of BITAs alone in patients with triple-vessel disease may be feasible, be safe, and yield good early angiographic outcomes, even in patients receiving beating heart CABGs. Multiple sequential grafting with 2 BITA grafts may be possible without showing competitive flow if the native coronary artery has a significant stenotic lesion. However, competitive flow patterns are more prevalent in patients with less significant coronary artery disease, and it may be necessary to evaluate long-term angiographic follow-ups and to do additional functional studies in such patients.

REFERENCES

Akasaka T, Yoshida K, Hozumi T, et al. 1998. Flow dynamics of angiographically no-flow patent internal mammary artery grafts. J Am Coll Cardiol 31:1049-56.

Al-Ruzzeh S, George S, Bustami M, et al. 2002. The early clinical and angiographic outcome of sequential coronary artery bypass grafting with the off-pump technique. J Thorac Cardiovasc Surg 123:525-30.

Ascione R, Lloyd CT, Gomes WJ, Caputo M, Bryan AJ, Angelini GD. 1999. Beating versus arrested heart revascularization: evaluation of myocardial function in a prospective randomized study. Eur J Cardiothorac Surg 15:685-90.

Cameron A, Kemp HG Jr, Green GE. 1986. Bypass surgery with the internal mammary artery graft: 15 year follow-up. Circulation 74:III-30-6.

Carrel T, Kujawski T, Zund G, et al. 1995. The internal mammary artery malperfusion syndrome: incidence, treatment and angiographic verification. Eur J Cardiothorac Surg 9:190-7.

Diegeler A, Hirsch R, Schneider F, et al. 2000. Neuromonitoring and neurocognitive outcome in off-pump versus conventional coronary bypass operation. Ann Thorac Surg 69:1162-6.

He G. 1999. Arterial grafts for coronary artery bypass grating: biological characteristics, functional classification, and clinical choice. Ann Thorac Surg 67:277-84.

Hirose H, Amano A, Takanashi S, Takahashi A. 2002. Coronary artery bypass grafting using the gastroepiploic artery in 1,000 patients. Ann Thorac Surg 73:1371-9.

Jones EL, Lattouf MO, Weintraub WS. 1989. Catastrophic consequences of internal mammary artery hypoperfusion. J Thorac Cardiovasc Surg 98:902-7.

Kawasuji M, Sakakibara N, Takemura H, Tedoriya T, Ushijima T, Watanabe Y. 1996. Is internal thoracic artery grafting suitable for a moderately stenotic coronary artery? J Thorac Cardiovasc Surg 112:253-9.

Kitamura S, Kawachi K, Seki T, Sawabata N, Morita R, Kawata T. 1992. Angiographic demonstration of no-flow anatomical patency of internal thoracic-coronary artery bypass grafts. Ann Thorac Surg 53:156-9.

Lust RM, Zeri RS, Spence PA, et al. 1994. Effect of chronic native flow competition on internal thoracic artery grafts. Ann Thorac Surg 57:45-50.

Lytle BW, Blackstone EH, Loop FD, et al. 1999. Two internal thoracic artery grafts are better than one. J Thorac Cardiovasc Surg 117:855-72.

Markwirth T, Hennen B, Scheller B, Schafers HJ, Wendler O. 2001. Flow wire measurements after complete arterial coronary revascularization with T-grafts. Ann Thorac Surg 71:788-93.

Moran SV, Baeza R, Guarda E, et al. 2001. Predictors of radial artery patency for coronary bypass operations. Ann Thorac Surg 72:1552-6.

Nakayama Y, Sakata R, Ura M. 2001. Growth potential of left internal thoracic artery grafts: analysis of angiographic findings. Ann Thorac Surg 71:142-7.

Sakaguchi G, Tadamura E, Ohnaka M, Tambara K, Nishimura K, Komeda M. 2002. Composite arterial Y graft has less coronary flow reserve than independent grafts. Ann Thorac Surg 74:493-6.

Seki T, Kitamura S, Kawachi K, et al. 1992. A quantitative study of postoperative luminal narrowing of the internal thoracic artery graft in coronary artery bypass surgery. J Thorac Cardiovasc Surg 104:1532-8.

Shimizu T, Hirayama T, Suesada H, Ikeda K, Ito S, Ishimaru S. 2000. Effect of flow competition on internal thoracic artery graft: postoperative velocimetric and angiographic study. J Thorac Cardiovasc Surg 120:459-65.

Spyrou N, Khan MA, Rosen SD, et al. 2000. Persistent but reversible coronary microvascular dysfunction after bypass grafting. Am J Physiol Heart Circ Physiol 279:H2634-40.

Tector A, McDonald ML, Kress DC, Canino VR, Heckel RC. 2001. Purely internal thoracic artery grafts: outcomes. Ann Thorac Surg 72:450-5.

Tector A, Schmahl T, Crouch J, Downey FX, Schmahl TM. 1989. Sequential free and Y internal thoracic artery grafts. Eur Heart J 10(suppl H):71-7.

van Son JAM, Smedts F, de Wilde PCM, et al. 1993. Histological study of the internal mammary artery with emphasis on its suitability as a coronary artery bypass graft. Ann Thorac Surg 55:106-13.

Wendler O, Hennen B, Demertzis S, et al. 2000. Complete arterial revascularization in multivessel coronary artery disease with 2 conduits (skeletonized grafts and T grafts). Circulation 102:III-79-83.

Wendler O, Hennen B, Markwirth T, et al. 1999. T grafts with the right internal thoracic artery to left internal thoracic artery versus the left internal thoracic artery and radial artery: flow dynamics in the internal thoracic artery main stem. J Thorac Cardiovasc Surg 118:841-8.