NEW APPROACH TO PATENCY AND FLOW ASSESSMENT AFTER LEFT INTERNAL THORACIC ARTERY HYPOPERFUSION SYNDROME WITH ADDITIONAL SAPHENOUS VEIN GRAFT TO THE LEFT ANTERIOR DESCENDING ARTERY WITH PHASE-CONTRAST MAGNETIC RESONANCE ANGIOGRAPHY

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Objective: Perioperative and early postoperative flow reduction of a left internal thoracic artery conduit is a rare complication of myocardial revascularization and may lead to the potentially fatal left internal thoracic artery hypoperfusion syndrome. It has been advocated that an additional vein graft be placed to the distal left anterior descending artery to provide sufficient myocardial perfusion. Some evidence exists, however, that this high-flow vein might lead to competing or even backward flow through the internal thoracic artery. **Methods:** In the past 2 years, 21 patients received an additional vein graft to the distal left anterior descending artery for left internal thoracic artery hypoperfusion syndrome. Nineteen of these patients were available for magnetic resonance imaging. Early (<6 months) and late (>12 months) postoperative flow measurements, both in the left internal thoracic artery and in the saphenous vein grafts, were performed by means of conventional and a segmented k-space phase-contrast magnetic resonance angiography technique. **Results:** Early magnetic resonance examinations indicated that all conduits had adapted to the coronary flow type with predominant diastolic perfusion. Patency rate both at the early and at the late study was 100%. No concurrent flow, flow reversal, or steal phenomena were observed. Mean flow rates were 49.2 ml/min for the left internal thoracic artery and 72.6 ml/min for the saphenous vein graft. **Conclusion:** On the basis of the flow data obtained with magnetic resonance angiography, the use of an additional saphenous vein graft as the treatment of choice in left internal thoracic artery hypoperfusion syndrome does not lead to occlusion of the artery. Conduit flow adaptation to the diastolic predominance occurs in the first 6 months after operation. (J Thorac Cardiovasc Surg 1997;114:428-33)

The internal thoracic artery (LITA) has become the conduit of choice for myocardial revascularization, since it has been proved that early mortality and morbidity are low.¹⁻³ The long-term patency rates of LITA grafts are superior to those of saphenous vein bypass grafts, and late atherosclerotic lesions rarely

occur in these vessels.⁴⁻⁶ Perioperative or early postoperative malperfusion of the LITA is a rare complication of coronary artery bypass grafting and may lead to the potentially fatal LITA hypoperfusion syndrome, which is caused by an acute imbalance between myocardial demand and nutritional support through the LITA.⁷⁻¹⁰ The cause of this syndrome may be inadequate flow caused by spasm, steal phenomena, small size of the LITA, and caliper mismatch between the LITA and recipient coronary vessel in the presence of a technically satisfactory anastomosis or by large myocardial flow demand in a severely hypertrophied ventricle. Careless preparation of the LITA is especially likely to lead to arterial spasm. It has been advocated that an additional vein graft be placed to the distal left anterior descending artery (LAD) to provide sufficient myocardial perfusion and to prevent a myocardial

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infarction.¹¹ Some evidence exists, however, that this high-flow vein might lead to concurrent or even backward LITA flow.¹²⁻¹⁵ This study was undertaken to determine early and late postoperative flow rates in the LITA and in the additional saphenous vein grafts to the LAD.

Patients and methods

In a series of 1163 consecutive isolated myocardial revascularizations performed between 1994 and 1995, we identified 21 patients (1.8%) receiving an additional vein graft to the distal LAD for LITA hypoperfusion syndrome. LITA grafts are used in 92% of our patients. The standard way of preparing LITA grafts included wide opening of the left pleural cavity and mobilization of the LITA within a pedicle of 2 cm of the endothoracic fascia by low-powered electrocautery. The pedicle was immersed in a 1% papaverine solution and not touched further until implantation. Cardiopulmonary bypass was conducted under moderate hypothermia, and revascularization was performed during a single period of cardioplegic arrest. LITA anastomoses were performed only when flow through the LITA was found to be adequate. The anastomoses were sutured with 7-0 polypropylene and tested with a 1.5 to 2 mm probe. The 21 patients in this series had perioperative or early postoperative symptoms (within in first postoperative 24 hours) such as hemodynamic collapse, acute increase in pulmonary pressure, electrocardiographic changes compatible with anterolateral ischemia, and decreased contractility in the region supplied. In these cases an additional saphenous vein graft was interposed between the ascending aorta and the distal LAD during a short period of ventricular fibrillation. During revision, an arteriotomy was made in the LAD distal to the site of the LITA anastomosis, and a 1.5 mm probe was advanced retrogradely into the proximal coronary vessel and across the anastomosis into the LITA. All patients survived this additional procedure.

Nineteen of the 21 patients (male/female = 12/7, mean age 64.3 years) were available for magnetic resonance (MR) imaging. In two patients the examination could not be performed because of implanted pacemakers. Early (<6 months) and late (>12 months) postoperative flow measurements both in the LITA and in the saphenous vein grafts were performed with a 1.5-tesla MR imager (Signa Advantage; GE Medical Systems, Milwaukee, Wis.). Fat-suppressed segmented k-space breath-held 5 mm thick slices were acquired in the axial and oblique sagittal planes to identify the proximal vein graft and the LITA conduit. Subsequently, both cine phase-contrast imaging and segmented k-space cine phase-contrast imaging were acquired perpendicular to the conduit to be studied (Fig. 1, *a* to *c*). The imaging parameters for cine phase-contrast imaging were as follows: field-of-view 24 cm; image matrix 256×256 , rendering an in-plane resolution of 0.9×0.9 mm; flip angle 45 degrees; 2 NEX; TR/TE 32/8 msec; slice 5 mm; 16 phases.* The imaging

*NEX = Number of excitations; TR = relaxation time; TE = excitation time.

Fig. 1. Fast-gradient echo MR images and corresponding diagrams describing the technique used for bypass localization. **a**, Coronal localizer sequence with orthogonal visualization of the LITA (LIMA) and venous graft. **b**, Oblique sagittal plane corresponding to line A-B with cross section through venous graft. **c**, Oblique sagittal plane corresponding to line C-D with visualization of the LITA-LAD anastomosis. PA, Pulmonary artery.

Fig. 2. MR phase-contrast flow measurement in a venous graft. *Upper left*, Gradient echo image with indicated region of interest (F1). *Upper right*, Graphic depiction of flow rate (ml/min) during an RR interval. The calculated mean flow rate in this example was 36.5 ml/min, and mean systolic peak velocity was 12.6 cm/sec.

parameters for segmented k-space phase-contrast imaging were as follows: field-of-view 22×11 cm; image matrix 256×96 , rendering an in-plane resolution of 0.8×1.15 mm; flip angle 25 degrees; TR/TE 19.8/11.6 msec. The velocity encoding value was 120 cm/sec. Each cardiac cycle provided a temporal resolution of approximately 87 msec using 4 k-lines per cycle with subsequent 7 to 14 phase and magnitude images per heartbeat. Flow rates were measured by means of standard software equipment with an operator-defined region of interest method (mean region of interest 19 mm^2 , Fig. 2).

Results

Preoperative selective angiography of both ITAs is routinely performed at the end of every coronary angiography at our institution. No anomalies of the LITA or significant branches were observed in our patient group. In addition, no evident correlation between preoperative angiographic findings and development of LITA malperfusion could be observed. Visual assessment of the internal thoracic artery (ITA) was done in terms of adequacy of

pulse, size, injury, and arteriosclerosis. The caliber of the graft was estimated to be adequate (2 to 4 mm) in all patients. Strong evidence for ITA spasm was observed in four patients. In these patients, an intraoperative continuous low dose of nifedipine (5 to $10 \mu\text{g/min}$) was administered systemically. Early postoperative (<8 weeks) coronary angiography was performed in all 21 patients, showing widely patent LITA grafts and a patent additional saphenous vein graft to the distal LAD. At the time of the MR imaging all patients were in New York Heart Association class I or II.

In all patients, the venous and arterial grafts could be identified by MR imaging and flow could be measured as well. Early MR studies (<6 months after the operation) indicated that all conduits had adapted to the coronary flow type with predominant diastolic perfusion. Patency rate both at the early and at the late study (>12 months after the operation) was 100%. No concurrent flow, flow reversal, or steal phenomena

Fig. 3. Comparison of early and late postoperative flow rates in arterial and venous coronary grafts.

were observed. Mean flow rates were 49.2 ml/min for the saphenous vein graft and 72.6 ml/min for the LITA (at 3 months 49.4 ml/min and at 1 year 44.3 ml/min for the saphenous vein graft; at 3 months 70.9 ml/min and at 1 year 66.4 ml/min for the LITA) (Fig. 3).

Discussion

Surgical revascularization of the myocardium has evolved into an extremely safe, predictable, and life-prolonging procedure.¹⁶ The ITA has been shown to be the conduit with the greatest longevity among those currently available for coronary artery bypass grafting.¹⁻³ Unlike saphenous vein grafts, failures of LITA grafts are seldom due to atherosclerotic changes or intimal graft hyperplasia but rather are thought to be due to technical problems with the graft. Furthermore, immediate blood flow through this arterial graft is generally less than through a saphenous vein graft. The LITA malperfusion syndrome is the clinical entity reported to result from inadequate flow through this arterial graft.⁷

This study was designed to examine the patency and flow rates in LITA grafts and additional saphenous vein grafts when both vessels were anastomosed to the same coronary artery, the LAD. Some evidence has been offered that the additional high-

flow vein grafted distal to the LITA might lead to concurrent flow reversal or even backward LITA flow.^{14, 15}

ITA malperfusion syndrome is caused by an acute imbalance between myocardial demand and nutritional support through the ITA. The mechanism of this syndrome during and after coronary surgery has not yet been fully elucidated, but this syndrome requires early diagnosis and immediate aggressive treatment, and this may be crucial for the survival of the patient. The cause may be inadequate flow resulting from spasm, steal phenomena, small size of the LITA, and caliber mismatch between the LITA and recipient coronary vessel in the presence of a technically satisfactory anastomosis.¹⁷ An additional saphenous vein graft to the distal LAD, grafted distal to the LITA implantation site, has been recognized as an effective approach to prevent further ischemia. In our series, postoperative coronary angiography demonstrated patency of both the arterial and saphenous vein graft in all patients and no technical error could be proved. However, the flow in the LITA graft is of special interest. Flow in the saphenous vein graft is higher than in the ITA, and a concurrent or even backward LITA flow may be reasonable. The long-term patency rate of the LITA grafts is superior to that of saphenous vein grafts, and late atherosclerotic lesions rarely occur in these

vessels. It is evident that the LITA graft stays patent, and concurrent or even backward flow may lead to graft occlusion. On the basis of flow data obtained with MR angiography, the use of an additional saphenous vein graft as the treatment of choice in LITA hypoperfusion syndrome does not lead to concurrent flow, flow reversal, or steal phenomena. In the event of concurrent or even backward flow late in the postoperative period, resulting in narrowing and ultimate failure of the graft, a thoracoscopic clipping or a catheter occlusion of the additional saphenous vein graft may be discussed. Recent results from animal experiments have indicated that competitive flow from a fully patent native artery did not stop LITA graft flow and does not cause ITA shriveling.^{12, 18} The authors are suggesting that ITA grafts are dynamic and may remain patent despite significant residual flow in the native vessel.¹⁸ In addition, Kitamura,¹⁹ Feld,²⁰ and their associates report that ITA grafts may continuously maintain anatomic patency even under no-flow situations, just like nonfunctional collateral vessels, and may function properly later as a graft when the native coronary flow decreases. Others²¹ are reporting cases in which an ITA graft was found to be nonfunctional in the early postoperative period, with the possibility of competitive flow as the cause of the temporary closure of the graft. In contrast, other authors¹³ believe that competitive flow does not cause vessel or graft occlusion if the anastomosis is technically satisfactory. Flemma and coworkers²² reported a clinical experiment in which they inserted an LITA graft into the hood of a coronary artery saphenous vein bypass graft, with continued patency of both conduits.

In addition, if proximal subclavian artery disease coexists or develops in a patient who had myocardial revascularization with an in situ LITA, myocardial ischemia can occur. For this reason, a careful evaluation and postoperative follow-up of the subclavian arteries, even by simple comparison of bilateral arm blood pressure, should help to reduce the prevalence of this syndrome. In these cases carotid-subclavian bypass grafting appears to be the treatment of choice.²³

The use of an additional saphenous vein graft as the treatment of choice in LITA hypoperfusion syndrome does not lead to LITA occlusion or to concurrent flow, flow reversal, or steal phenomena. Conduit flow adaptation to the diastolic predominance occurs within the first 6 months after the operation. On the basis of our data, we recommend

the use of an additional saphenous vein graft to the distal LAD in patients with LITA hypoperfusion syndrome.

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