Dynamic assessment of a composite arterial Y-graft achieving complete myocardial revascularization: transthoracic echo-Doppler correlates with myocardial scintigraphy

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Key words:
Coronary artery bypass graft; Echo-Doppler; Exercise test; Myocardial scintigraphy.

Background. **Composite arterial grafts are presently being used ever more frequently in coronary bypass surgery. We assessed the composite radial artery and *in situ* left internal thoracic artery Y-graft by means of transthoracic echo-Doppler and myocardial perfusion scintigraphy (MPS).**

Methods. **In 53 patients who underwent complete myocardial revascularization using only this composite arterial graft, good transthoracic echographic images and pulsed Doppler signals of the Y-graft main stem were obtained at rest and early after standard exercise; the echographic parameters were measured. Stress/rest MPS was the gold standard for residual myocardial ischemia. The patients with negative MPS were divided into groups according to the number of coronary vessels grafted and their history of preoperative myocardial infarction.**

Results. **The diastolic-to-systolic ratio of the peak velocities and velocity-time integrals both at rest and after stress, and the stress-to-rest ratio of the diastolic peak velocities and diastolic velocity-time integrals in the negative MPS patients were significantly greater than in the 6 positive MPS patients. However, the restricted number of positive MPS cases limits the power of this statistical analysis. The stress-to-rest ratio of the diastolic velocity-time integrals in the patients with three grafted coronary vessels (median 2.3) and in those without preoperative myocardial infarction (median 2.1) were respectively greater than in the patients with two vessels grafted (median 1.7, $p < 0.0001$) and those with preoperative myocardial infarction (median 1.8, $p = 0.0048$).**

Conclusions. **Dynamic assessment with transthoracic echo-Doppler of a composite arterial graft including the *in situ* left internal thoracic artery correlates with MPS. In patients with negative MPS, transthoracic echo-Doppler correlates with the myocardial demand.**

(Ital Heart J 2005; 6 (4): 328-334)

Received November 24, 2004; revision received January 10, 2005; accepted January 12, 2005.

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Introduction

At present, the use of composite arterial grafts in coronary bypass surgery is becoming ever more widespread. Their use may overcome the limited availability of arterial conduits for performing total arterial myocardial revascularization and also allows for a gain in conduit length whilst minimizing manipulation of the ascending aorta[1-3]. The *in situ* left internal thoracic artery (LITA) in Y- or T-configurations with another arterial conduit has been utilized with good clinical results[3-5]. However, it is still controversial whether the main stem of the *in situ* LITA of composite Y- or T-grafts can adequately supply the whole stenotic coronary artery tree both at rest and under stress[6-9].

So far, the *in situ* LITA has been reliably evaluated by means of transthoracic echo-Doppler (TTED)[10-24]. These evaluations were compared with intraoperative ultrasound transit-time flowmeter results[21], or post-operatively tested with arteriography[10-13,15,17,18,20], exercise testing[14], and myocardial perfusion scintigraphy (MPS)[20].

The aim of this prospective study was to determine whether there was any correlation between the TTED and MPS outcomes regarding the dynamic evaluation of the main stem of the composite radial artery (RA) and the *in situ* LITA Y-graft.

Methods

Study patients. Between January and April 2003, 60 consecutive patients with two- or three-vessel disease underwent coronary artery bypass grafting at our Department. Complete myocardial revascularization was always achieved using only the composite RA and *in situ* LITA Y-graft. Emergency surgical priority (according to the Society of Thoracic Surgeons classification[25]), a positive Allen test of the non-dominant arm, angiographic stenosis of the LITA or left subclavian artery, and severe chronic obstructive pulmonary disease (forced expiratory volume in 1 s < 40% of the predicted values for age) were the only four exclusion criteria we chose to adopt in the present study. No limitations as to age, left ventricular ejection fraction, the site of a preoperative myocardial infarction, severity of critical coronary artery stenoses, renal function, metabolic diseases, or predicted operative risk (according to the European system for cardiac operative risk evaluation[26]) were used; no further exclusion criteria regarding the surgical priority or respiratory function were accepted.

The patients' personal data, preoperative clinical status and cardiac function (Table I) as well as the operative variables (Table II) and postoperative outcome were prospectively recorded and analyzed. All the patients were discharged home in good conditions after an 8- to 10-day stay in hospital. Only one patient presented with a major perioperative complication (myocardial infarction).

A program of non-invasive dynamic assessment by means of TTED of the composite arterial Y-graft at about 8 months following surgery was devised and performed. All patients were also submitted to MPS in order to determine the presence of any residual myocardial ischemia. A selective arteriography of the Y-graft was performed in the patients with a positive MPS. The patients with a negative MPS were divided into groups according to the number of coronary vessels bypassed, and the presence of preoperative myocardial infarction.

The institutional review committee approved the study. Each patient entering the study gave his informed consent with particular emphasis on the type of surgery and postoperative evaluation. The procedures followed were in accordance with institutional guidelines.

Table I. Preoperative clinical data of the study patients.

No. patients	60
Age (years)	64.9 ± 10.1
Females	10 (17%)
Diabetes mellitus	7 (12%)
Moderate COPD (FEV_1 > 40% of the predicted values for age)	5 (8%)
NYHA functional class IV	8 (13%)
CCS angina class 4	21 (35%)
Previous MI	14 (23%)
Left main coronary artery disease	12 (20%)
Three-vessel disease	33 (55%)
Previous PCI	6 (10%)
Previous CABG	4 (7%)
LVEF < 40%	7 (12%)
Urgent surgical priority*	6 (10%)
EuroSCORE > 6 (high-risk patients)	5 (8%)

CABG = coronary artery bypass grafting; COPD = chronic obstructive pulmonary disease; FEV_1 = forced expiratory volume in 1 s; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PCI = percutaneous coronary intervention. * according to the Society of Thoracic Surgeons classification.

Table II. Operative variables.

Aortic cross-clamping time (min)	58.3 ± 19.7
CPB time (min)	71.1 ± 24.4
Operative time (min)	238.5 ± 57.6
No. coronary anastomoses per patient	4.3 (range 2-6)
No. LITA anastomoses to the LAD	96
No. RA anastomoses to the Cx	125
No. RA anastomoses to the RCA	37

CPB = cardiopulmonary bypass; Cx = circumflex coronary artery; LAD = left anterior descending coronary artery; LITA = left internal thoracic artery; RA = radial artery; RCA = right coronary artery.

Operative procedure. Following a standard median sternotomy incision, the *in situ* LITA was dissected until completely skeletonized. The RA was harvested as a pedicled conduit from the non-dominant arm simultaneously to the LITA dissection. A warm diluted papaverine hydrochloride solution was applied onto the LITA and RA throughout the dissection, and gently injected into the two conduits early before distal end clip occlusion. The RA was maintained *in situ* until the end-to-side Y-anastomosis with the *in situ* LITA had to be performed. Cardiopulmonary bypass was then instituted. Myocardial protection was achieved with intermittent antegrade and retrograde cold crystalloid cardioplegia, and topical cooling. Mild systemic hypothermia was employed.

The LITA and RA branches of the Y-graft were respectively used for the left anterior descending and the circumflex and right coronary arteries. Every anastomosis was performed using an 8-0 polypropylene running suture.

Dynamic assessment with transthoracic echo-Doppler of the Y-graft. At about 8 months (range 6-9 months) following cardiac surgery, good transthoracic echographic images and pulsed Doppler signals of the Y-graft main stem were obtained at rest and early after standard exercise in 53 patients (88%).

TTED assessment was performed using a computed instrument (Vivid 3 Expert, GE Medical Systems, Solingen, Germany) equipped with 5.0 and 7.5 MHz linear array transducers, both at rest and early after a treadmill exercise test for 15 min on a flat surface at 5 km/hour. The systolic and diastolic blood pressures and heart rate were measured, and the double product was calculated before and after exercise. The scanner head was placed in the left supraclavicular space with the patient in the supine position. The main stem of the Y-graft was localized by means of low non-directional color flow mapping, and the diameter was measured at

B-mode. The intraluminal flow signals were obtained using the pulsed Doppler method: the sampling volume was located within the vessel lumen, with the ultrasound beam maintained as parallel as possible to the long axis of the main stem. The diastolic (DPV) and systolic peak velocities (SPV), the diastolic (DVTI) and systolic velocity-time integrals (SVTI), the diastolic-to-systolic ratio of the peak velocities (DPV/SPV) and velocity-time integrals (DVTI/SVTI), both at rest and after stress, as well as the stress-to-rest ratio of the diastolic peak velocities (DPVs/DPVr) and diastolic velocity-time integrals (DVTIs/DVTIr) were the evaluated echographic parameters. The DPV, SPV, DVTI, and SVTI were determined on the basis of the shape of the Doppler signal curve, the peak velocity being the highest point of the Doppler wave, and the velocity-time integral the area between the line traced on the Doppler wave and the base line.

In 2 patients with a robust neck it was impossible to identify the main stem even at rest, and in another patient it was impossible to re-visualize the main stem after stress. In 3 patients the pulsed Doppler signals were unreliable because the angle between the ultrasound beam and the long axis of the main stem was > 30° and hence the velocity obtained was an underestimation of the true velocity. Finally, in one patient with perioperative myocardial infarction and a Doppler waveform with a very small diastolic peak followed by a larger systolic component, the stress test was prudentially not attempted at all; arteriography confirmed stenosis at the Y-anastomosis.

Every TTED examination was recorded on VHS videotape for separate off-line analysis by two experienced observers who were unaware of the MPS results.

Myocardial perfusion scintigraphic evaluation. For the 53 patients with satisfactory dynamic assessment at TTED of the Y-graft main stem, 99mTc-sestamibi MPS, with the single-photon emission computed tomographic approach, and according to the 2-day stress/rest protocol, was chosen to determine the presence of any residual myocardial ischemia[27]. MPS was always performed within 7 days of the echographic evaluation in each patient, and was considered positive for myocardial ischemia if any reversible filling defect was identified on the stress and resting images. The Bruce exercise protocol was used for exercise testing; it was considered positive for myocardial ischemia in the presence of a horizontal or downsloping ST-segment depression of at least 0.1 mV at 80 ms after the J-point in two adjacent leads of a continuously recorded 12-lead electrocardiogram. The patient was considered as having reached peak exercise when he achieved 90% of the predicted maximal heart rate.

Statistical analysis. Variables are expressed as mean ± SD, percentage or median. The Mann-Whitney test was used to compare the TTED parameters. Statistical significance was assumed for a p value < 0.05. The power of the test ($1 - \beta$) was calculated with α set to 0.05. The sensitivity and specificity for myocardial ischemia of the considered TTED parameters were calculated using standard formulas, with MPS as the gold standard. The medians of each parameter were chosen as threshold values. Box-and-whisker plots were used to show the distributional characteristics of the TTED parameters, and to show any correlations with the MPS results.

The highest inter- and intraobserver variability allowed for the echographic measurements was 3%.

Statistical analysis was performed using the MINITAB release statistical software (MINITAB Inc., State College, PA, USA).

Results

Out of all the 53 patients with satisfactory dynamic assessment at TTED of the Y-graft, 6 (11%) patients had a positive MPS. Postoperative coronary arteriography confirmed the presence of a stenotic Y-graft (at the RA-to-coronary artery anastomotic site) only in 2 patients.

Diagnosis of residual myocardial ischemia: correlation between transthoracic echo-Doppler parameters and myocardial perfusion scintigraphic results. The inter- and intraobserver variability for the echo-Doppler measurements were respectively 2.4 and 2.2%.

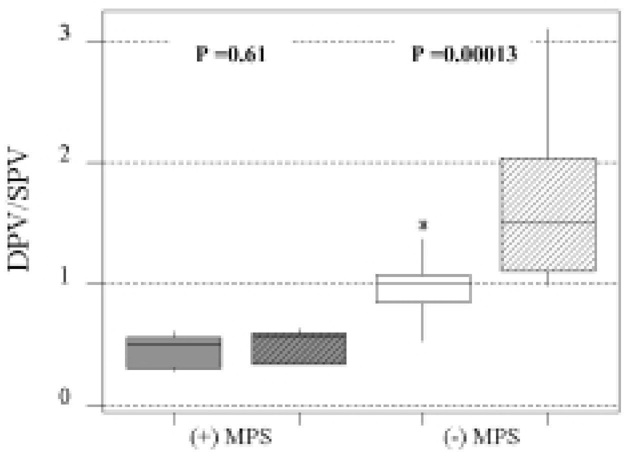
At rest, while there were no statistically significant differences regarding the evaluated systolic echo-Doppler parameters (SPV and SVTI) between the positive MPS patients and the 47 patients with a negative MPS, the diastolic echo-Doppler parameters (DPV and DVTI) as well as the DPV/SPV and DVTI/SVTI ratios were significantly lower in the positive MPS patients. After stress, these differences (and the diastolic-to-systolic ratios) between the two groups of patients were still more evident (Table III, Figs. 1A and 1B). The DPVs/DPVr and DVTIs/DVTIr were severely impaired in the positive MPS patients, and significantly lower with respect to the negative MPS patients (Table III, Fig. 1C). Stress also increased the sensitivity for residual myocardial ischemia of a DVTI/ SVTI ratio < 1.9 to 100%. However, the specificity for residual ischemia of every TTED parameter was low because of the threshold values adopted (Table IV).

Correlation between the transthoracic echo-Doppler parameters and myocardial demand. The DVTIs/DVTIr in the patients with three coronary vessels grafted and in those without preoperative myocardial infarction (higher expected myocardial demand) were respectively significantly greater than in the patients with two vessels grafted and in those with preoperative myocardial infarction (lower expected myocardial demand). The DPVs/DPVr in the patients without

Table III. Correlation between the transthoracic echo-Doppler parameters and the results of myocardial perfusion scintigraphy (MPS).

Echo-Doppler parameter	(+) MPS patients (n=6, 11%)	(-) MPS-patients (n=47, 89%)	p (n=53)	1 - β (n=53)
DPV/SPV				
At rest	0.5	1.0	< 0.0001	0.26
After stress	0.6	1.5	< 0.0001	0.21
DVTI/SVTI				
At rest	0.7	1.5	0.0079	0.67
After stress	0.6	2.0	0.0002	0.27
DPVs/DPVr	1.1	2.3	< 0.0001	0.21
DVTIs/DVTIr	1.2	2.0	0.0002	0.31

DPVs/DPVr = the stress-to-rest ratio of the diastolic peak velocities; DPV/SPV = the diastolic-to-systolic ratio of the peak velocities; DVTIs/DVTIr = the stress-to-rest ratio of the diastolic velocity-time integrals; DVTI/SVTI = the diastolic-to-systolic ratio of the velocity-time integrals.



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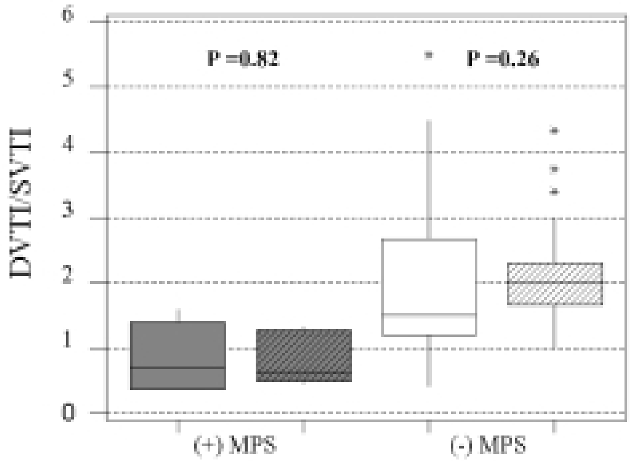

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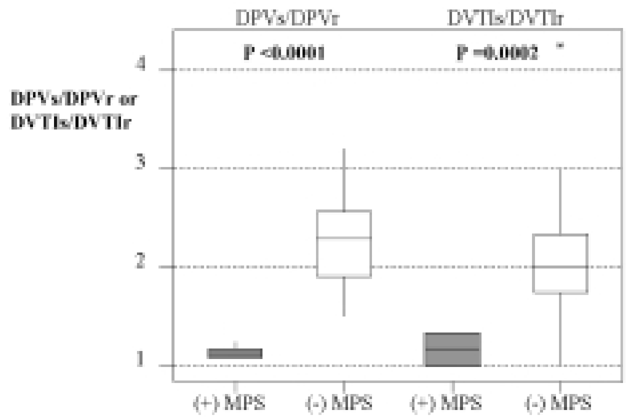

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Figure 1. *Distributional characteristics of the diastolic-to-systolic ratio of the peak velocities (DPV/SPV)* (A) *and velocity-time integrals (DVTI/SVTI)* (B), *both at rest and after stress, as well as of the stress-to-rest ratio of the diastolic peak velocities (DPVs/DPVr) and diastolic velocity-time integrals (DVTIs/DVTIr)* (C) *in the 53 patients with good transthoracic echographic images and pulsed Doppler signals of the Y-graft main stem. The echo-Doppler data are correlated with those obtained using 99mTc-sestamibi myocardial perfusion scintigraphy (MPS). The data are shown using box-and-whisker plots. The bottom of the box is at the first quartile (Q1) and the top is at the third quartile (Q3). The line drawn across the box is the median. The lower whisker is the vertical line extending from the bottom of the box to the lowest value within the lower limit, i.e. Q1 - 1.5 • (Q3 - Q1); the upper whisker extends from the top of the box to the highest value within the upper limit, i.e. Q3 + 1.5 • (Q3 - Q1). The* asterisk *denotes the outlier, i.e. any point outside the lower and upper limits. The gray boxes represent the values of the echo-Doppler parameters of the patients with a MPS positive for residual myocardial ischemia [(+) MPS]; the white boxes those of the patients with a MPS negative for residual myocardial ischemia [(-) MPS]. Boxes with a right slant fill type show the values after stress.*

Table IV. Sensitivity and specificity of the transthoracic echo-Doppler parameters for ischemia.

Echo-Doppler parameter	Sensitivity (%)	Specificity (%)
DPV/SPV at rest < 1.0	100	66
DPV/SPV after stress < 1.3	100	57
DVTI/SVTI at rest < 1.5	83	61
DVTI/SVTI after stress < 1.9	100	66
DPVs/DPVr < 2.1	100	64
DVTIs/DVTIr < 2.0	100	57

DPVs/DPVr = the stress-to-rest ratio of the diastolic peak velocities; DPV/SPV = the diastolic-to-systolic ratio of the peak velocities; DVTIs/DVTIr = the stress-to-rest ratio of the diastolic velocity-time integrals; DVTI/SVTI = the diastolic-to-systolic ratio of the velocity-time integrals.

preoperative myocardial infarction was significantly greater than in those with preoperative myocardial infarction (Table V, Fig. 2).

Discussion

Coronary arteriography is the choice method to confirm graft patency and the correct localization of anastomoses, to exclude any stenosis throughout the graft or distal coronary artery, as well as to determine the adequacy of the peripheral run-off of the grafted coronary vessel. Arteriography is essentially a morphologic but non-functional diagnostic tool. Optimal measurements of coronary artery and coronary graft blood flows are obtained using Doppler guide wire, which is presently the gold standard for the assessment of the coronary flow reserve in conscious humans[7]. However, both coronary arteriography and flow wire determinations are invasive and expensive. Moreover, since they imply selective catheterization of the target vessel, these examinations may induce spasm of the catheterized artery, so causing a catastrophic event if the target artery is the main stem of a composite arterial graft achieving complete myocardial revascularization. Recent studies have shown that non-invasive assessment with TTED of *in situ* LITA graft blood flow is feasible and reliable[10-24]. Thanks to TTED, it is possible to perform a complete (morphological and functional) evaluation of the explored coronary graft.

The aim of this prospective study was to determine whether TTED and MPS, with regard to the dynamic evaluation of the main stem of the composite RA and *in situ* LITA Y-graft achieving complete revascularization, were correlated.

Our choice of exclusion criteria derives from the need for a standard population of patients with coronary artery disease, and good arterial conduits to construct good composite Y-grafts. We chose 99mTc-sestamibi MPS as the gold standard for residual myocardial ischemia because it is effective in predicting subsequent cardiac events after coronary artery bypass grafting and hence determining the need for coronary arteriography even in asymptomatic patients[28]. All the patients were assessed after 6 to 9 months following surgery. They underwent the same surgical management and were prescribed the same therapeutic regimen. Nuclear investigation was always performed early after TTED to rule out any clinical change between the two evaluations. The plan of performing a complete myocardial revascularization of the whole stenotic coronary artery tree using only the composite arterial Y-graft was completed for every study patient. The average number of coronary bypasses per patient and of coronary bypasses with the RA branch of the Y-graft per patient was high.

Our rate (88%) of satisfactory ultrasonic visualizations and evaluations of the main stem Y-grafts is in agreement with what reported in the literature[10-24]. Since TTED assessments after exercise were performed in polypneic and stressed patients, we believe that this is a very good result. The cause of failure in the patient whose main stem was not visible after stress was probably linked to hyperventilation follow-

Table V. Correlation, in the negative myocardial perfusion scintigraphy patients, between the transthoracic echo-Doppler parameters and the number of coronary vessels bypassed with the Y-graft, and the occurrence of preoperative myocardial infarction (MI).

Echocardiographic parameter	2 vessels grafted (n=20, 43%)	3 vessels grafted (n=27, 57%)	p (n=47)	Preoperative MI (n=14, 30%)	No MI (n=33, 70%)	p (n=47)
DPV/SPV						
At rest	1.0	1.0	0.96	1.0	1.0	0.68
After stress	1.3	1.5	0.79	1.2	1.6	0.62
DVTI/SVTI						
At rest	1.5	1.5	0.77	1.5	2.0	0.74
After stress	1.9	2.0	0.41	1.9	2.0	0.26
DPVs/DPVr	2.0	2.4	0.058	1.8	2.3	0.035
DVTIs/DVTIr	1.7	2.3	< 0.0001	1.8	2.1	0.0048

DPVs/DPVr = the stress-to-rest ratio of the diastolic peak velocities; DPV/SPV = the diastolic-to-systolic ratio of the peak velocities; DVTIs/DVTIr = the stress-to-rest ratio of the diastolic velocity-time integrals; DVTI/SVTI = the diastolic-to-systolic ratio of the velocity-time integrals.

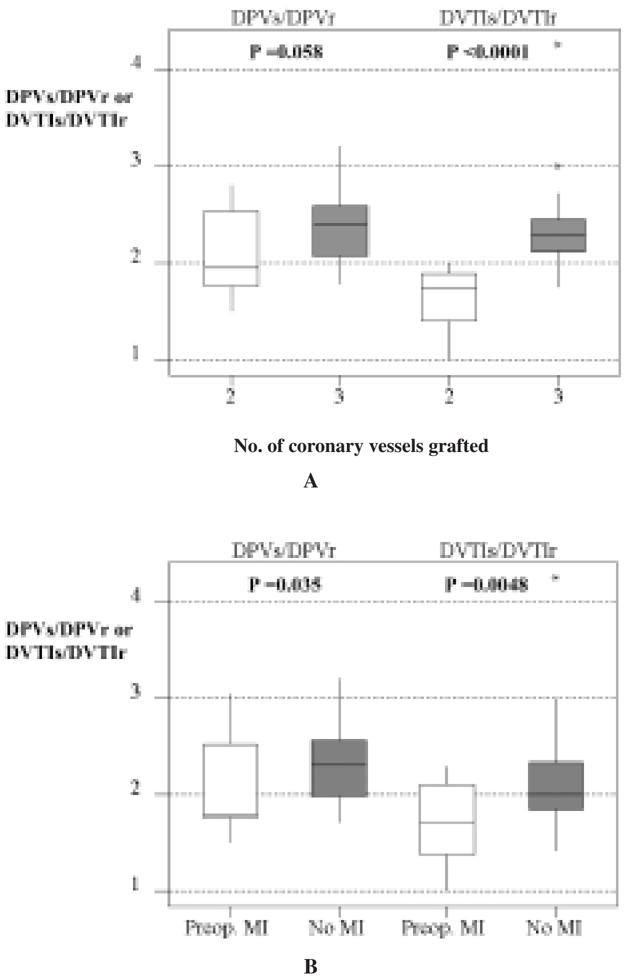

Figure 2. *Distributional characteristics of the stress-to-rest ratio of the diastolic peak velocities (DPVs/DPVr) and diastolic velocity-time integrals (DVTIs/DVTIr) in the 47 negative MPS patients, according to two empiric determinants of the myocardial demand: the number (2 or 3) of coronary vessels bypassed with the Y-graft* (A)*, and the occurrence of preoperative myocardial infarction (MI)* (B). *The white boxes represent the values of the echo-Doppler parameters of the patients with two grafted coronary vessels (n = 20) or preoperative MI (n = 14); the gray boxes those of the patients with three grafted coronary vessels (n = 17) or without MI (n = 13).*

ing muscular exercise: the exuberant activation of the accessory respiratory muscles, e.g. the (left) anterior scalenus muscle, reduced the acoustic window for TTED evaluation; indeed, the main stem was re-visualized when the patient had recovered from stress but the vasodilation induced by the physiological stimulus had by then reverted. Any issue delaying the TTED interrogation after stress jeopardizes complete dynamic assessment of the Y-graft.

There were 4 patients with positive MPS but angiographic patency of the Y-graft. A 34-year-old woman with a history of combined familial hypercholesterolemia and insulin-dependent diabetes mellitus had confirmed diffuse and peripheral coronary artery disease. The 2 patients with two grafted vessels and a nuclear stress test positive for inferior or inferolateral myocardial ischemia had only one RA anastomosis and neither occlusion nor subocclusive stenosis of the proximal right coronary artery; perhaps, in the presence of a small coronary flow reserve and in the absence of both good coronary run-off and proximal protective stenosis, stress caused a crisis in the RA branch of the Y-graft of these patients (a kind of steal phenomenon to the LITA branch). Finally, failure of the main stem to adequately perfuse the three stenotic coronary vessels was a plausible explanation in the patient with extensive myocardial ischemia. There was a very good correlation between the TTED assessment of the Y-graft main stem and the MPS results in diagnosing residual myocardial ischemia. There was a good correlation between the DVTIs/DVTIr ratio and the expected myocardial demand.

The composite RA and *in situ* LITA Y-graft of this study achieved complete myocardial revascularization; thus any artifacts due to the presence of other coronary grafts were eliminated. All the patients were evaluated at midterm follow-up to remove any time-dependent variability as regards to the growth potential of the graft[7,21,24,29]. The results were compared with those obtained using a very sensitive diagnostic tool such as the 2-day stress/rest 99mTc-sestamibi MPS.

Study limitations. The restricted number of positive MPS patients strongly limits the statistical power of this study. Neither intravascular Doppler guide wire nor quantitative arteriography were used to validate our TTED parameter values. Because at our Institution economic and ethical reasons limit postoperative coronary arteriography in asymptomatic patients, this procedure was performed only in the positive MPS patients and in the patient who presented with perioperative myocardial infarction. Our echo-Doppler measurements were obtained neither after pharmacologically-induced maximal hyperemic blood flow (with adenosine, dipyridamole, or dobutamine) nor during atrial pacing[9], but after peak muscular exercise. The vasodilation induced by physiological stimuli does not appear to be as complete as that induced pharmacologically[30]. Moreover, we did not assess simple grafts bypassing one coronary artery but composite grafts sustaining up to three coronary artery vessels. However, this appears to be a limitation of the study: we were interested in the values of the echo-Doppler parameters as they were related to the results of MPS, the number of coronary arteries bypassed with the Y-graft, and the occurrence of preoperative myocardial infarction, but not in the absolute values; after maximal hyperemia the differences in the values might be even more striking. We did not consider the impact of the severity of coronary stenosis on the coronary blood flow reserve. Last but not least, the determinants of myocardial demand we used are arbitrary and debatable, but simple and intuitive[6,7,21-23].

In conclusion, composite arterial Y-grafts including the *in situ* LITA minimize manipulation of the ascending aorta and should be able to sustain the whole stenotic coronary artery tree, even during peak muscular exercise stress. It is also possible to perform, by means of TTED, a complete dynamic assessment of the main stem. This dynamic assessment with TTED correlates with MPS. In patients with negative MPS, TTED correlates with the myocardial demand. The wide application of TTED of the LITA may reduce the need of nuclear imaging for the follow-up evaluation of patients.

References

1. Muneretto C, Bisleri G, Negri A, et al. Left internal thoracic artery-radial artery composite grafts as the technique of choice for myocardial revascularization in elderly patients: a prospective randomized evaluation. J Thorac Cardiovasc Surg 2004; 127: 179-84.
2. Kobayashi J, Tagusari O, Bando K, et al. Total arterial off-pump coronary revascularization with only internal thoracic artery and composite radial artery grafts. Heart Surg Forum 2002; 6: 30-7.
3. Pevni D, Kramer A, Paz Y, et al. Composite arterial grafting with double skeletonized internal thoracic arteries. Eur J Cardiothorac Surg 2001; 20: 299-304.
4. Muneretto C, Bisleri G, Negri A, et al. Total artery myocardial revascularization with composite grafts improves results of coronary surgery in elderly: a prospective randomized comparison with conventional coronary artery bypass surgery. Circulation 2003; 108 (Suppl 2): II29-II33.
5. Wendler O, Hennen B, Demertzis S, et al. Complete arterial revascularization in multivessel coronary artery disease with 2 conduits (skeletonized grafts and T grafts). Circulation 2000; 102 (Suppl 3): III79-III83.
6. Royse AG, Royse CF, Groves KL, Bus B, Yu G. Blood flow in composite arterial grafts and effect of native coronary flow. Ann Thorac Surg 1999; 68: 1619-22.
7. Markwirth T, Hennen B, Scheller B, Schafers HJ, Wendler O. Flow wire measurements after complete arterial coronary revascularization with T-grafts. Ann Thorac Surg 2001; 71: 788-93.
8. Sakaguchi G, Tadamura E, Ohnaka M, Tambara K, Nishimura K, Komeda M. Composite arterial Y graft has less coronary flow reserve than independent grafts. Ann Thorac Surg 2002; 74: 493-6.
9. Lemma M, Mangini A, Gelpi G, et al. Effects of heart rate on phasic Y-graft blood flow and flow reserve in patients with complete arterial myocardial revascularization: an intravascular Doppler catheter study. Eur J Cardiothorac Surg 2003; 24: 81-5.
10. Hirata N, Asaoka N, Amemiya A, Hatsuoka S, Ueno T, Kosakai Y. Noninvasive evaluation of internal thoracic artery and left anterior descending coronary artery anastomotic sites using transthoracic Doppler echocardiography: comparison with coronary arteriography. J Thorac Cardiovasc Surg 2003; 126: 1080-6.
11. De Simone L, Caso P, Severino S, et al. Noninvasive assessment of left and right internal mammary artery graft patency using transthoracic color Doppler echocardiography. Ital Heart J 2003; 4: 173-8.
12. Lisboa LA, Dallan LA, De Figueiredo LF, et al. A prospective comparison of Doppler echocardiography and postoperative angiography in the assessment of left internal thoracic artery graft in 72 patients submitted to minimally invasive direct coronary artery bypass. Heart Surg Forum 2002; 5 (Suppl 4): S362-S377.
13. El-Masry MM, Salama MM, Darwish AZ, Abd El-Aziz O. Assessment of left internal mammary artery graft patency by transthoracic Doppler echocardiography. Clin Cardiol 2002; 25: 511-6.
14. Catalyurek H, Karabay O, Silistreli E, Acikel U. Transthoracic color Doppler ultrasonography in the evaluation of internal thoracic artery bypass graft patency. J Int Med Res 2001; 29: 503-7.
15. Chirillo F, Bruni A, Balestra G, et al. Assessment of internal mammary artery and saphenous vein graft patency and flow reserve using transthoracic Doppler echocardiography. Heart 2001; 86: 424-31.
16. Arruda AM, Pellikka PA, Mahoney DW, Joseph A Jr, Mathias W Jr, Seward JB. Transthoracic Doppler echocardiographic comparison of left internal mammary grafts to left anterior descending coronary artery with ungrafted right internal mammary arteries in patients with and without myocardial ischemia by dobutamine stress echocardiography. Am J Cardiol 2000; 86: 919-22.
17. Fukata Y, Horike K, Fujimoto E, Shimoe Y, Kanbara T. Evaluation of the internal thoracic arterial graft patency by the transthoracic Doppler method under continuous intravenous infusion of adenosine triphosphate disodium. Ann Thorac Cardiovasc Surg 1999; 5: 310-20.
18. Katz WE, Zenati M, Mandarino WA, Cohen HA, Gorcsan J 3rd. Assessment of the left internal mammary artery graft patency and flow reserve after minimally invasive direct coronary artery bypass. Am J Cardiol 1999; 84: 795-801.
19. Moreno R, Garcia-Fernandez MA, Moreno M, et al. The Doppler color detection of internal mammary artery anastomoses and a functional assessment of their patency. Rev Esp Cardiol 1999; 52: 253-8.
20. Gaudino M, Serricchio M, Tondi P, et al. Non-invasive evaluation of mammary artery flow reserve and adequacy to increased myocardial oxygen demand. Eur J Cardiothorac Surg 1998; 13: 404-9.
21. Takemura H, Kawasuji M, Sakakibara N, Teodoriya T, Ushijima T, Watanabe Y. Internal thoracic artery graft function during exercise assessment by transthoracic Doppler echography. Ann Thorac Surg 1996; 61: 914-9.
22. Takemura H, Kawasuji M, Sakakibara N, et al. Quantitative hemodynamic assessment of internal thoracic artery grafts using transthoracic duplex imaging. Nippon Kyobu Geka Gakkai Zasshi 1994; 42: 2171-7.
23. Goto Y, Atsumi H, Kadowaki K, et al. Noninvasive assessment of left internal thoracic artery graft patency using transthoracic echocardiography. Nippon Kyobu Geka Gakkai Zasshi 1993; 41: 2013-8.
24. van Son JA, Skotnicki SH, Peters MB, Pijls NH, Noyez L, van Asten WN. Noninvasive hemodynamic assessment of the internal mammary artery in myocardial revascularization. Ann Thorac Surg 1993; 55: 404-9.
25. Shroyer AL, Grover FL, Edwards FH. 1995 Coronary Artery Bypass Risk Model: The Society of Thoracic Surgeons Adult Cardiac National Database. Ann Thorac Surg 1998; 65: 879-84.
26. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R, and the EuroSCORE Study Group. European System for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg 1999; 16: 9-13.
27. Berman DS, Kiat H, Maddahi J. The new 99mTc myocardial perfusion imaging agents: 99mTc-sestamibi and 99mTc-teboroxime. Circulation 1991; 84 (Suppl): I7-I21.
28. Zellweger MJ, Lewin HC, Lai S, et al. When to stress patients after coronary artery bypass surgery? Risk stratification in patients early and late post-CABG using stress myocardial perfusion SPECT: implications of appropriate clinical strategies. J Am Coll Cardiol 2001; 37: 144-52.
29. Nakayama Y, Sakata R, Ura M. Growth potential of the left internal thoracic artery grafts: analysis of angiographic findings. Ann Thorac Surg 2001; 71: 142-7.
30. Barnard RJ, Duncan HW, Livesay JJ, Bucberg GD. Coronary vasodilator reserve and flow distribution during near-maximal exercise in dogs. J Appl Physiol 1977; 43: 988-92.