Vascular adaptation of the internal thoracic artery graft early and late after bypass surgery

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Objective: Flow mismatch between the supplying artery and the myocardial perfusion region has been observed in patients with internal thoracic artery grafts. Thus coronary flow changes of arterial (internal thoracic artery grafts) and saphenous (saphenous vein grafts) bypass grafts were studied early and late after coronary artery bypass grafting.

Methods: Thirty patients undergoing elective bypass surgery (internal thoracic artery and saphenous vein grafts) were studied intraoperatively and (17 patients) 3 to 10 months postoperatively. Coronary flow was measured intraoperatively with the transit-time Doppler scanning technique. Postoperatively, flow velocity and coronary flow reserve were determined with the Doppler flow wire technique. Quantitative angiographic analysis was used to determine vessel size for calculation of absolute flow.

Results: Intraoperatively, internal thoracic artery graft flow was significantly lower than saphenous vein graft flow (31 $\pm$ 8 vs 58 $\pm$ 29 mL/min, $P < .01$). Postoperatively, internal thoracic artery graft flow increased significantly to 42 $\pm$ 24 mL/min at 3 months and to 56 $\pm$ 30 mL/min ($P < .02$ vs intraoperative value) at 10 months, respectively. However, saphenous vein graft flow remained unchanged over time (58 $\pm$ 29 to 50 $\pm$ 27 mL/min at 3 months and 46 $\pm$ 27 mL/min at 10 months). Coronary flow reserve was abnormally low intraoperatively in the internal thoracic artery (1.3 $\pm$ 0.3) and saphenous vein (1.6 $\pm$ 0.5) grafts but increased significantly to normal values in both types of graft at follow-up.

Conclusions: Bypass flow of the internal thoracic artery graft is significantly reduced intraoperatively when compared with that of the saphenous vein graft. However, 3 and 10 months after the operation, flow of the internal thoracic artery graft increases significantly and is similar to saphenous vein graft flow. This finding can be explained by an early flow mismatch of the native internal thoracic artery in the presence of a large perfusion territory. During follow-up, there is vascular remodeling of the internal thoracic artery, probably because of endothelium-mediated mechanisms.

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Coronary artery bypass grafting (CABG) has been associated with excellent clinical results with regard to outcome and long-term follow-up.[1] However, clinical results have been shown to be different for saphenous vein grafts (SVGs) and internal thoracic artery (ITA) grafts.[2,3] The type of bypass graft is crucial for clinical outcome because veins and arteries have a completely different behavior with regard to early adaptation to the requirements of the myocardium and long-term patency.[4]

Arterial revascularization with the ITA as the bypass graft has shown excellent long-term results,[5] despite the fact that early hypoperfusion can occur and can cause ischemia and contractile dysfunction.[6,7] SVGs demonstrated favorable early results, although patency rates are typically lower in venous than in arterial grafts. Degenerative changes and abnormal vessel wall remodeling are enhanced in vein grafts, as well as increased platelet–vessel wall interactions, and can lead to early bypass failure.[2,8-10]

The purpose of this study was to assess early vascular adaptation of arterial and venous bypass grafts and to determine vascular remodeling of these grafts during the first year of follow-up.

Abbreviations and Acronyms

CABG = coronary artery bypass grafting
CFR = coronary flow reserve
EDHF = endothelium-derived hyperpolarizing factor
ITA = internal thoracic artery
LAD = left anterior descending coronary artery
LV = left ventricular
NO = nitric oxide
SVG = saphenous vein graft

Materials and Methods

Thirty patients undergoing elective bypass grafting were included in the present cohort study (Figure 1). Seventeen patients had intraoperative measurements and were catheterized early (3 months, n = 8) or late (10 months, n = 9) after surgical intervention for follow-up measurements (group A). Furthermore, 13 matched patients with additional intraoperative hyperemic flow measurements of the ITA for calculation of coronary flow reserve (CFR) but without follow-up measurements were included (group B). The study protocol was approved by the local ethics committee, and all patients provided written informed consent. Patient characteristics are summarized in Table 1. The mean age was 63 ± 9 years, 10% were women, and 90% were men. Body mass index was 29 ± 5 kg/m^2. The mean left ventricular (LV) ejection fraction was 63% ± 9%. Twenty-five patients had multiple-vessel disease, and 5 patients had single-vessel disease. Thirteen patients had previous myocardial infarctions. Medication after bypass surgery consisted of aspirin in 94%, β-blockers in 82%, and inhibitors of the renin angiotensin system in 53%. Only 6% received calcium antagonists postoperatively. Cardiovascular risk factors included a history of hypertension in 63%, dyslipidemia in 67%, and a family history of coronary artery disease in 37%. Obesity and diabetes mellitus were present in 26% and 17% of cases, respectively. Hemodynamic and angiographic data are summarized in Table 2. LV ejection fraction was determined by means of LV angiography. Coronary artery diameter was determined by using quantitative coronary angiography with preoperative biplane coronary angiograms. Stenosis diameter was assessed for the ITA graft and SVG target vessels by using the Philips Integra System.

Bypass Surgery

General anesthesia was performed with fentanyl, midazolam, and isoflurane. Cardiopulmonary bypass with mild-to-moderate hypothermia was used. Mean cardiopulmonary bypass time was 58 ± 25 minutes, and aortic crossclamp time was 36 ± 15 minutes.

Twenty-six patients received an ITA graft to the left anterior descending coronary artery (LAD), and all patients received 1 or 2 SVGs to the diagonal and marginal branches or to the right coronary artery. Overall, 76 grafts were implanted, namely 26 ITA grafts and 50 SVGs. The mean number of distal anastomosis was 2.53 ± 1.23. All ITA grafts were carefully harvested as a pedicled graft.[11]

Determination of Perfusion Territory

The perfusion territory was determined from preoperative coronary angiograms. The method has been validated by Seiler and colleagues.[12]

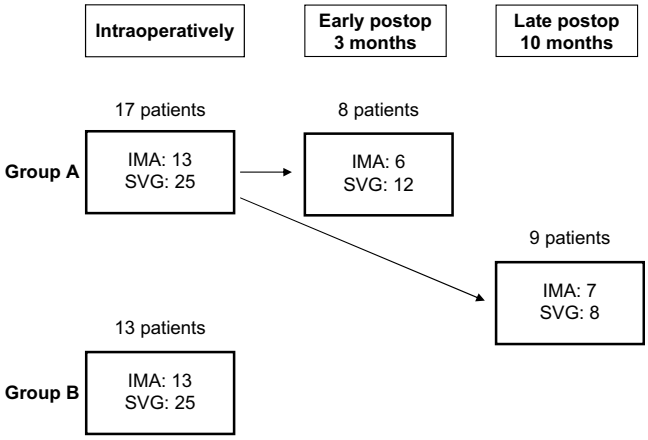

Figure 1. Study protocol. The total number of patients is 30. Group A contains 17 patients. Eight patients of group A have been studied after 3 months and 9 patients after 10 months of follow-up. Group B contains 13 patients studied intraoperatively. *ITA*, Internal thoracic artery; *SVG*, saphenous vein graft.

The perfusion territory was calculated from the fractional length of the coronary segments distal to the culprit lesion in relation to the total LV coronary length. This ratio was multiplied by LV muscle mass.

Intraoperative Flow Measurements

Doppler flow measurements of ITA grafts and SVGs were obtained 5 to 10 minutes after cessation of cardiopulmonary bypass, and no

TABLE 1. Preoperative patient characteristics

	All patients (n = 30)
Male/female sex (n)	27/3
Age (y)	63 ± 9
Body mass index (kg/m^2)	29 ± 5
LV ejection fraction (%)	63 ± 9
Perfusion territory (g)	
ITA region	75 ± 32
SVG region	71 ± 27
Cardiovascular risk factors	
History of hypertension	63%
Dyslipidemia	67%
Family history of CAD	37%
Smoking	67%
Obesity	26%
Diabetes mellitus	17%
Medication (postoperatively)	
Aspirin	94%
β-Blockers	82%
ACI/ARB	53%
Calcium antagonists	6%

ITA, Internal thoracic artery; *SVG*, saphenous vein graft; *CAD*, coronary artery disease; *ACI*, angiotensin-converting enzyme inhibitors; *ARB*, angiotensin II receptor blockers.