Arterial conduits for myocardial revascularization: single-institutional results

Marco Lanfranconi, Jan G. Grandjean*, Massimo A. Mariani*, Piet W. Boonstra*

Division of Cardiac Surgery "A. De Gasperis", Niguarda Ca' Granda Hospital, Milan, Italy,
**Thoraxcenter, University Hospital, Groningen, The Netherlands*

Key words:
Coronary artery bypass; Coronary artery disease; Gastroepiploic artery; Inferior epigastric artery; Internal mammary artery; Radial artery.

Background. **Bilateral internal mammary artery (IMA) grafting is associated with an improved long-term survival, low rates of recurrence of angina and late myocardial infarction. This suggested the usefulness of a complete arterial revascularization in patients with three-vessel disease using IMAs in conjunction with other arterial conduits.**

Methods. **Between September 1989 and September 1999, 1052 patients underwent myocardial revascularization with the use of the gastroepiploic artery and one or two IMAs. Among them 561 patients with three-vessel disease underwent myocardial revascularization with the use of the gastroepiploic artery and both the IMAs. In this report the operative results up to hospital discharge obtained in the first 500 patients were considered. In total 1850 anastomoses were performed using 1500 arterial grafts; a mean number of 3.7 anastomoses per patient and 1.2 anastomoses per graft were performed.**

Results. **Twelve patients (2.4%) died during hospitalization. Perioperative myocardial infarction developed in 12 patients (2.4%). Twenty patients (4%) required temporary support with intra-aortic balloon pump. Repeat thoracotomy for bleeding was required in 33 patients (6.6%). Four patients (0.8%) developed mediastinitis and 4 (0.8%) aseptic sternal dehiscence. Gastrointestinal bleeding occurred in 3 patients (0.6%) and was treated conservatively, cerebrovascular accidents in 4 (0.8%), and abdominal wound herniation in 5 (1%).**

Conclusions. **According to our experience, systematic total arterial revascularization is feasible with a low complication rate and may contribute to the improvement of long-term outcome.**

(Ital Heart J 2000; 1 (9): 621-627)

Received April 14, 2000; revision received June 5, 2000; accepted July 14, 2000.

Address:

Jan G. Grandjean, MD, PhD

Dipartimento
Cardio-Toracico
Università degli Studi
Ospedale Cisanello
Via Paradisa, 2
56124 Pisa
E-mail:
j.gradjean@ao-pisa.toscana.it

Introduction

Since the early 1980s, the internal mammary artery (IMA) used as a coronary bypass graft, has proven to be superior to saphenous vein grafts as for long-term angiographic patency. Moreover, several clinical studies have demonstrated an improved long-term survival, a decreased incidence of cardiac events and a low need for repeated revascularization in patients receiving an IMA and especially the left IMA (LIMA) anastomosed to the left anterior descending coronary artery (LAD)[1-3]. In order to further improve long-term outcome of patients undergoing coronary surgery, it seemed reasonable to use also the right IMA (RIMA) as a bypass graft. Although single LIMA and bilateral IMA grafting strategies date to the same period, many investigations failed to prove a clear clinical advantage from the use of both IMAs[4-8]. This initial uncertainty was probably due to the non-homogeneity in the selection of patients receiving bilateral versus single IMA grafts and the need of at least a 10-year long follow-up to detect significant differences.

In a recent study Sergeant et al.[9] reported a 50% reduction in the incidence of myocardial infarction by arterial revascularization. However, the interpretation of these findings is not straightforward because the study covered a long period of time during which the institutional policy about arterial grafting changed.

A more recent study of the Cleveland Clinic group[10] has demonstrated the advantage of bilateral IMA grafting. In their study, the authors demonstrated that bilateral IMA grafting compared to single IMA grafting was an independent predictor of lower rates of recurrence of angina, late myocardial infarction and any cardiac events, including the need for repeated revascularization.

Thus complete arterial revascularization in patients with three-vessel disease became an attractive technique, and several surgical strategies using IMAs, alone or in conjunction with other arterial conduits, such as the right gastroepiploic artery (GEA), the radial artery or the inferior epigastric artery (IEA), were developed.

Methods

Until the middle 1980s at the Groningen University Hospital (The Netherlands) the graft of choice was the saphenous vein. As soon as the superiority of the IMA over venous graft was demonstrated, we changed our policy introducing initially the LIMA in conjunction with venous grafts, then both IMAs and GEA or radial artery. The trend of increasing use of arterial grafts is shown in figure 1.

The grafting strategy is oriented toward total arterial revascularization to reduce as much as possible the use of venous grafts.

As for the choice of the grafts the policy is to use, whenever possible, *in situ* grafts to avoid the need for proximal anastomosis. Due to this reason the GEA is the graft of choice to revascularize the inferior cardiac wall.

The use of arterial grafts was tailored to each patient according to biological age and life expectancy. We considered every patient < 65 years, regardless of the number of diseased coronary vessels, suitable for total arterial revascularization. In patients > 65 years we used the LIMA combined with a vein graft but we did not consider old age as an absolute contraindication to complete arterial grafting.

Apart from age, diabetes mellitus, severe obesity, chronic obstructive pulmonary disease, previous abdominal surgery, availability of venous grafts in old patients were considered. The presence of these factors, alone or in combination, represented a contraindication to utilize certain arterial conduits. The presence of chronic obstructive pulmonary disease, insulin-dependent diabetes mellitus, often associated with severe obesity, was considered as a risk factor for sternal dehiscence and therefore a contraindication to bilateral mammary artery harvesting. Previous upper abdominal surgery was considered a contraindication for the use of GEA and a positive Allen test a contraindication to radial artery harvesting. The presence of varicose veins was an indication to total arterial grafting also in old patients.

Patients. Between September 1989 and September 1999, out of total 8882 patients undergoing coronary surgery, 1052 patients underwent myocardial revascularization with the use of the GEA and 1 or 2 IMAs. Among them 561 patients with three-vessel disease underwent myocardial revascularization with the use of the GEA and both the IMAs. For our purpose the data regarding the first 500 patients were analyzed.

Patient characteristics are summarized in table I.

Surgical technique. All the operations were performed through median sternotomy. Internal thoracic arteries (ITAs) were harvested with both accompanying veins and surrounding by means of electrocautery. The harvesting began as cranially as possible and proceeded distally by bluntly separating the pedicle from the chest wall, cauterizing the arterial and venous branches. The endothoracic fascia was cut with the cautery. The dissection was completed from the thoracic inlet to the superior epigastric and musculophrenic branches. Each ITA was dilated by intraluminal administration of diluted papaverine and subsequently occluded distally with a small vascular clamp. The LIMA entered the pericardium through

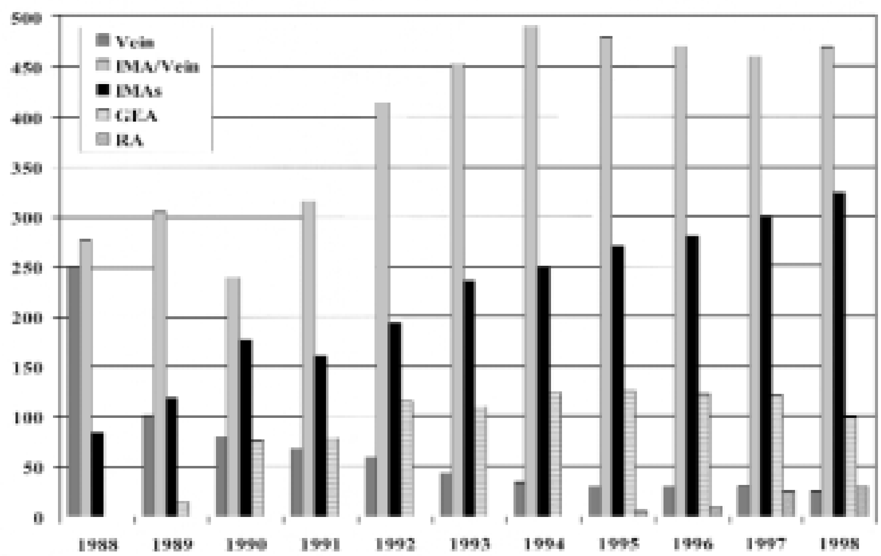

Figure 1. *Time trends of the use of arterial grafts in coronary artery surgery at the University Hospital of Groningen (The Netherlands) from 1988 to 1998. Vein = coronary artery bypass graft with venous grafts only; IMA/Vein = coronary artery bypass graft with one internal mammary artery and venous grafts; IMAs = coronary artery bypass graft with one or two internal mammary arteries; GEA = coronary artery bypass graft with one or two internal mammary arteries and the gastroepiploic artery; RA = coronary artery bypass graft with one or two internal mammary arteries and the radial artery. In the groups IMAs, GEA and RA only arterial grafts were employed.*

Table I. Patient characteristics.

	No. patients	%
Chronic stable angina	340	68
Unstable angina	160	32
Previous AMI	274	54.9
Previous > 1 AMI	39	7.8
Left main stenosis > 50%	59	11.8
Previous CABG	36	7.2
Previous PTCA	75	15
Insulin-dependent diabetes	55	11
Hypercholesterolemia	340	68
Previous cholecystectomy	12	2.4

CABG = coronary artery bypass graft; AMI = acute myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty.

a fenestration in the pericardium properly made exactly in front of its division from the subclavian artery; this fashion avoids every tension of the pedicle due to the left lung physiological movement even in patients with pathologically increased lung volume. The RIMA enters the pericardium directly from right to left over the aorta if grafted to the LAD system or through the transverse sinus if grafted to the left circumflex coronary artery system.

The technique of the GEA dissection is the same as previously described[11].

The coronary anastomoses were made with running 8-0 or 7-0 polypropylene sutures. The pedicles of the grafts were fixed to the epicardium by means of two sutures (5-0 or 6-0 polypropylene) to avoid kinking of the grafts.

These patients were operated with a standard cardiopulmonary bypass procedure technique as described elsewhere[12].

Statistical analysis. All data were collected prospectively in a customized database (SPSS Inc., Chicago, IL, USA) used for patients undergoing coronary surgery with the use of the GEA. All continuous variables are expressed as mean ± SD. All discrete variables are expressed as percentage.

Results

The LIMA has been used to graft the LAD system in 373 patients (74.6%) and the left circumflex coronary artery system in 127 patients (25.4%) respectively. The RIMA has been used to graft the left circumflex coronary branches in 373 patients and the LAD system in 127 patients, respectively. The GEA has always been used to graft the branches of the diaphragmatic aspect of the heart. In total 1850 anastomoses were performed using 1500 arterial grafts; a mean number of 3.7 anastomoses per patient and 1.2 anastomoses per graft were performed. Using the LIMA 248 single and 252 sequential anastomoses were performed. With the RIMA 457 single anastomoses and 43 sequential anastomoses were performed. With the GEA 487 single anastomoses and 13 sequential anastomoses were performed (Table II).

Table II. Number of anastomoses (mean 3.7 per patient, range 3-8, total 1850).

	LIMA	RIMA	GEA
1	248	457	487
2	233	42	13
3	18	1	
4	1		

GEA = gastroepiploic artery; LIMA = left internal mammary artery; RIMA = right internal mammary artery.

Twelve patients (2.4%) died during hospitalization. One of them had had a previous coronary artery bypass graft operation. Eight patients died of low output syndrome, 1 patient had massive cerebral embolism, 1 patient died of a massive myocardial infarction from an extensive atheromatous aorta, 1 patient died of multiorgan failure 45 days after the operation and the grafts were found patent at autopsy, 1 patient died of gastric perforation due to a splenic artery occlusion (*postmortem* diagnosis).

Ten patients (2%) underwent coronary artery bypass graft operation combined with another cardiac procedure. Three patients had aortic valve replacement, 1 patient had mitral valvuloplasty, 1 patient had aortic valve replacement and mitral valvuloplasty, 5 patients had left ventricular aneurysmectomy.

Four patients (0.8%) needed a venous graft in the perioperative period due to the presence of ischemic electrocardiographic changes, 3 on the right coronary artery system and 1 on the left circumflex coronary artery system.

Perioperative myocardial infarction was recorded in 12 patients (2.4%) on the basis of electrocardiographic changes and/or increased specific enzyme levels. Twenty patients (4.0%) were temporarily supported with intra-aortic balloon pump in the early postoperative hours. Repeat thoracotomy for persistent bleeding was necessary in 33 patients (6.6%). Mediastinitis was recorded in 4 patients (0.8%) and other 4 patients (0.8%) needed sternal refixation due to aseptic sternal dehiscence. Gastrointestinal bleeding was recorded in 3 patients (0.6%) and was treated conservatively. Cerebrovascular accidents occurred in 4 patients (0.8%). Abdominal wound herniation was recorded in 5 patients (0.9%). Twelve patients (2.2%) needed to stay in the Intensive Care Unit for > 3 days (Table III).

Table III. Morbidity.

	No. patients	%
Perioperative AMI	12	2.4
IABP	20	4.0
Repeat thoracotomy	33	6.6
Mediastinitis	4	0.8
Sternum re-fixation	4	0.8
Gastrointestinal bleeding	3	0.6
CVA	4	0.8
Abdominal wound hernia	5	0.9
ICU stay > 3 days	12	2.2

AMI = acute myocardial infarction; CVA = cerebrovascular accidents; IABP = intra-aortic balloon pump; ICU = intensive care unit.

Discussion

In this report we presented the operative results up to hospital discharge in a consecutive series of the first 500 patients with three-vesssel disease completely revascularized by arterial conduits (LIMA, RIMA, GEA) between 1989 and 1999. Out of a total of 1052 patients over the same period of time, they represent 47.5% of the total number of patients who underwent coronary surgery over the same period of time at our Institution. The perioperative and in-hospital complications were low and apparently not related to any of the preoperative risk factors.

In our choice of grafting strategies with arterial conduits we were guided by a number of considerations.

Intrinsic properties of the arterial conduits. Unlike the IMA, the GEA, as well as the radial artery and the IEA, are prevalently muscular arteries[13] according to the morphology of the media (elastic, elasto-muscular, or muscular). This fact leads to important technical considerations. Flow adaptation after the operation is immediate, therefore if the grafted vessel has only a moderate stenosis and/or high coronary resistances (distal stenosis with poor “run-off”), a low flow pattern is present and it can cause a “string-sign” reduction up to the total occlusion of the conduit. As a consequence, these arterial conduits are preferably used onto severely stenosed or occluded coronary arteries, in order to have a high flow pattern and to avoid the “string-sign” or the occlusion of the graft due to the adverse flow pattern.

It is known that functional changes occur in the vein grafts such as intimal hyperplasia and loss of the endothelium capability of producing substances like nitric oxide. These functional changes are the base for vein graft failure[14,15]. Furthermore, nitric oxide plays an important role in promoting the regulation of the vascular tone, thus providing a non-thrombogenic luminal surface and inhibiting vascular smooth muscle cell proliferation. These morphologic and physiologic aspects have been investigated in arterial graft conduits. IMA and GEA showed to have histological, morphologic and functional similarities[16].

In vivo studies have also demonstrated that mammary artery grafts have a better vasodilative reserve after surgery than vein grafts[17,18]. Mammary artery grafts show a preserved relaxation, both to endothelium-dependent and endothelium-independent stimuli, thus indicating the preservation of the functional integrity of the artery[19,20].

Furthermore, although the media is different in the two conduits, being elasto-muscular in the IMA and muscular in the GEA, they both show only minimal intimal hyperplasia 2 years after implantation[21]. Different from the IMA and GEA, the IEA has a mean luminal diameter that is significantly smaller and presents substantial intimal hyperplasia in its proximal part[22]. As a consequence, the use of the IEA as a graft conduit must be carefully evaluated in clinical practice.

Free grafts and *in situ* grafts. The intrinsic properties of the above-mentioned arterial conduits are not the sole determinants of graft patency. An important aspect is whether they are used as *in situ* or as free grafts. The patency rate of the arterial conduits used as free grafts is lower than that of *in situ* grafts. The exposure of a free graft to the high shear stress at the site of the anastomosis on the ascending aorta may lead to rapid development of intimal hyperplasia. Moreover, from a technical standpoint, a free graft obviously needs an adjunctive anastomosis which may constitute a potential procedural risk for human error. For these reasons it is advisable to use arterial grafts *in situ* or, if not possible, to avoid anastomising them to the ascending aorta and prefer composite graft anastomosis[23,24].

Right coronary artery system. The results of arterial grafting of the right coronary artery system are less satisfying in comparison to the left coronary system. Anatomical and technical problems can explain these results. Different from the left coronary system, the anatomical configuration of the right coronary artery system is inconsistent. The segment before the take off of the posterior descending coronary artery, is theoretically the most appropriate anatomical site to anastomose a graft conduit, especially for the *in situ* RIMA. However, it is common to find a significant atherosclerotic process in this anatomical site extending over time toward the mid right coronary artery and the proximal part of the posterior descending branch. Furthermore, the right coronary artery diameter is usually much larger than the RIMA diameter. Due to these reasons, a RIMA anastomosed in this site could be at high risk for occlusion. On the other hand, the diameter of the distal part of the posterior descending artery can be excessively small for a more distal grafting. Furthermore, if *in situ* RIMA is the chosen conduit, stretching of the artery[25] often occurs when grafting the distal posterior descending artery and this adds further technical risks.

Internal mammary arteries. Several techniques have been developed both for *in situ*, free and sequential mammary grafting. Routing the RIMA through the transverse sinus has also been advised for revascularizing coronary arteries with *in situ* IMA grafting. A different approach introduced by Tector et al.[23] consists in using the RIMA anastomosed to the LIMA in a T-shaped anastomosis. This allows the IMAs to reach the posterior branches of the circumflex coronary artery and the right coronary artery nearly in every patient.

The common IMA grafting strategy is to anastomose the grafts to "the best myocardium"[26], using the LIMA for the LAD and diagonal artery area, and the RIMA for the remaining most important graftable vessel. Circumflex coronary branches should be preferred as a target for RIMA grafting because the patency rate of the RIMA anastomosed to the distal right coronary artery and its branches is not satisfying[27]. On the other hand, the left-sided bilateral IMAs showed excellent results[28]. In fact, the use of left-sided bilateral IMAs enables to revascularize the coronary arteries supplying the majority of the left ventricular myocardium. This is best accomplished with *in situ* grafts using the LIMA and the RIMA. There are two possibilities: in the first the LIMA is used to graft the LAD system and the RIMA is used for the left circumflex coronary artery system; this is possible by routing the RIMA through the transverse sinus. The second possibility is to use the LIMA to graft the left circumflex coronary artery system and to use the RIMA to graft the LAD system. In this case the RIMA crosses the midline over the aorta and the pulmonary artery. Using this option the RIMA pedicle should be protected covering it with the anterior mediastinal fatty tissue before the sternal closure. That is generally sufficient to protect the RIMA in the case of chest re-entering through median sternotomy.

Right gastroepiploic artery. The GEA has been used in clinical practice since the late 1980s[29] and satisfactory mid- and long-term results are reported. At the University Hospital of Groningen (The Netherlands), the combination of the GEA with the IMAs is the treatment of choice to achieve total arterial revascularization in patients with three-vessel disease[11]. The advantage of the GEA is to be an *in situ* graft, similar to the IMA in relation to size, flow, length, pharmacological responses, and low susceptibility to atherosclerosis[30-32]. The preferred targets for the GEA are particularly the distal branches of the right coronary artery because they are less involved in the atherosclerotic process compared to the right coronary artery itself.

Radial artery. The radial artery was employed in the very early era of coronary artery bypass surgery by Carpentier et al.[33], but it was later abandoned after early reports of poor angiographic patency[34]. In the last few years the interest in this graft was renewed thanks to the findings of open radial artery grafts in some patients of the early Carpentier's experience, after more than 15 years of follow-up[35]. Other authors also reported satisfactory mid-term results with this graft[24,36]. In particular, Possati et al.[37] found that the radial artery propensity to serotonin-induced spasm was shown to markedly decrease at mid-term follow-up (5 years after the operation). This group also found that the late patency rate of the radial artery was not influenced by the continued use of calcium-channel antagonists, whereas the severity of atherosclerosis in the grafted vessel markedly influenced the postoperative results.

Main advantages of the radial artery are its diameter, which is slightly wider than that of the IMA, and the possibility of harvesting this graft at the same time as the IMAs. The radial artery can satisfactorily be used for a length of at least 18-20 cm. Initially, the radial artery was used as a free graft with a proximal anastomosis to the ascending aorta. Currently it is mainly used as a T graft[23] anastomosed to the LIMA. Target vessels for the radial artery are the circumflex coronary artery and its branches, as well as the right coronary artery and its distal branches.

Inferior epigastric artery. The use of the IEA was initially introduced in the 1980s[38,39] as a free graft anastomosed to the ascending aorta generating disappointing results[40]. The distal size of the IEA is quite small (about 1-1.2 mm) and the proximal anastomosis on the ascending aorta could be technically demanding, because of the discrepancy between the small diameter of the IEA and the thickness of the aortic wall. Different surgical approaches using this arterial conduit have been reported with encouraging results. Calafiore et al.[24] promoted the use of the IEA mainly for lengthening other *in situ* arterial conduits and avoiding, whenever possible, to perform a proximal anastomosis on the ascending aorta. Other authors preferred to use the IEA for the right coronary artery system and to anastomose it proximally to the ascending aorta[41]. Surgical indications for this graft are limited to those cases in which other conduits are either not available or technically unfeasible.

In conclusion, the combination of bilateral IMA grafting with the GEA allows for a complete arterial revascularization in all patients with multivessel disease, with a low rate of perioperative complications. These results, and in particular freedom from angina pectoris, are better than those of studies in which vein grafts, single IMA or double IMA grafts alone were used. This is also supported by the previous clinical experience of the Groningen University Hospital[42,43]. As a consequence, more surgeons are today prone to achieve total arterial revascularization in the effort to improve long-term results. The use of the radial artery may extend the chance of a complete arterial revascularization in patients with contraindications to bilateral IMA grafting as for the use of the GEA. According to our experience, the mid-term results of total arterial revascularization are supporting this choice, in order to give the patients the best chance of long-term results. This means not only an improvement in life expectancy and quality of life but also a consistent reduction in time of hospitalization and need for repeated revascularization at follow-up. All those facts together translate themselves into a better use of health care resources, which is currently the main drive of modern medicine.

Moreover, the striking progress of current interventional cardiology and the consistent investment in basic research are now reducing worldwide the impact of surgical treatment of coronary artery disease. Therefore, the role of coronary surgery will be strictly related to the success of long-term results which are mainly related to the quality of graft material.

According to this clinical evidence and this trend, it is expected that total arterial revascularization will maintain the weight of the surgical treatment of coronary artery disease by guaranteeing a stable improvement in long-term results.

References

1. Lytle BW, Loop FD, Cosgrove DM, Ratcliff NB, Easley K, Taylor PC. Long-term (5-12 years) serial studies of internal mammary artery and saphenous vein coronary bypass grafts. J Thorac Cardiovasc Surg 1985; 89: 248-58.
2. Loop FD, Lytle BW, Cosgrove DM, et al. Influence of the internal mammary artery graft on 10-year survival and other cardiac events. N Engl J Med 1986; 314: 1-6.
3. Cameron A, Davis KB, Green GE. Coronary bypass surgery with internal thoracic artery grafts. Effects on survival over a 15-year period. N Engl J Med 1996; 334: 216-9.
4. Sergeant P, Blackstone E, Meyns B. Validation and interdependence with patient-variables of the influence of procedural variables on early and late survival after CABG. KU Leuven Coronary Surgery Program. Eur J Cardiothorac Surg 1997; 12: 1-19.
5. Pick AW, Orzusalak TA, Anderson BJ, Schaff HV. Single versus bilateral internal mammary artery grafts: 10-year outcome analysis. Ann Thorac Surg 1997; 64: 599-605.
6. Fiore AC, Naunheim KS, Dean P, et al. Results of internal thoracic artery grafting over 15 years: single versus double grafts. Ann Thorac Surg 1990; 49: 202-9.
7. Galbut DL, Traad EA, Dorman MJ, et al. Twelve-year experience with bilateral internal mammary artery grafts. Ann Thorac Surg 1985; 53: 457-81.
8. Tector AJ, Kress DC, Downing FX, et al. Complete revascularization with internal thoracic artery grafts. Semin Thorac Cardiovasc Surg 1996; 8: 29-41.
9. Sergeant PT, Blackstone EH, Meyns BP. Does arterial revascularization decrease the risk of infarction after coronary artery bypass grafting? Ann Thorac Surg 1998; 66: 1-11.
10. Lytle BW, Blackstone EH, Loop FD, et al. Two internal thoracic artery grafts are better than one. J Thorac Cardiovasc Surg 1999; 117: 855-72.
11. Grandjean JG, Boonstra PW, den Heyer P, Ebels T. Arterial revascularization with the right gastroepiploic artery and internal mammary arteries in 300 patients. J Thorac Cardiovasc Surg 1994; 107: 1309-16.
12. Boonstra PW, van Imhoff GW, Eijsman L, et al. Reduced platelet activation and improved hemostasis after controlled cardiotomy suction during clinical membrane oxygenator perfusions. J Thorac Cardiovasc Surg 1985; 89: 900-6.
13. van Son JAM, Smedts F, Vincent JG, et al. Comparative anatomic studies of various arterial conduits for myocardial revascularization. J Thorac Cardiovasc Surg 1990; 99: 703-7.
14. Mills JL, Fujitani RM, Taylor SM. The characteristics and anatomic distribution of lesions that caused reversed vein graft failure: a five-year prospective study. J Vasc Surg 1993; 17: 195-206.
15. Davies MG, Hagen PO. The vascular endothelium. A new horizon. Ann Thorac Surg 1993; 218: 593-609.
16. Buikema JH, Grandjean JG, van der Broek S, et al. Differences in vasomotor control between human gastroepiploic and left internal mammary artery. Circulation 1992; 86: II205-II209.
17. Hanet C, Robert A, Wijns W. Vasomotor response to ergometrine and nitrates of saphenous vein grafts, internal mammary artery grafts, and grafted coronary arteries late after surgery. Circulation 1992; 86 (Suppl 2): 210-6.
18. Gurne O, Chenu P, Polidori C, et al. Functional evaluation of internal mammary artery bypass grafts in the early and late postoperative periods. J Am Coll Cardiol 1995; 25: 1120-8.
19. Werner GS, Wiegand V, Kreuzer H. Effect of acetylcholine on arterial and venous grafts and coronary arteries in patients with coronary artery disease. Eur Heart J 1990; 11: 127-37.
20. Hartmann A, Lahoda T, Burger W, Beyersdorf F, Schräder R, Satter P. Endothelium-dependent and endothelium-independent flow regulation in coronary vascular regions supplied by arterial and venous bypass grafts. Cardiology 1997; 88: 425-32.
21. van Son JAM, Falk V, Walther T, et al. Low-grade intimal hyperplasia in internal mammary and right gastroepiploic arteries as bypass grafts. Ann Thorac Surg 1997; 63: 706-8.
22. van Son JAM, Smedts FM, Yang CQ, et al. Morphometric study of the right gastroepiploic and inferior epigastric arteries. Ann Thorac Surg 1997; 63: 709-15.
23. Tector AJ, Amundsen S, Schmahl TM, et al. Total revascularization with T grafts. Ann Thorac Surg 1994; 57: 33-9.
24. Calafiore AM, Di Gianmarco G, Teodori G, et al. Radial artery and inferior epigastric artery in composite grafts: improved midterm angiographic results. Ann Thorac Surg 1995; 60: 517-24.
25. Mills N, Pigott J. Arterial conduits for coronary artery bypass. Operative Techniques in Cardiac and Thoracic Surgery 1996; 1: 172-84.
26. Rankin JS, Newman GE, Bashore TM. Clinical angiographic assessment of complex mammary artery bypass grafting. J Thorac Cardiovasc Surg 1986; 92: 832-46.
27. Dion R, Verhelst R, Rousseau M, et al. Sequential mammary artery grafting: clinical, functional and angiographic assessment 6 months postoperatively in 231 consecutive patients. J Thorac Cardiovasc Surg 1989; 98: 80-9.
28. Schmidt SE, Jones JW, Thornby JI, et al. Improved survival with multiple left-sided bilateral internal thoracic artery grafts. Ann Thorac Surg 1997; 64: 9-15.
29. Pym J, Brown PM, Charrette EJP, et al. Gastroepiploic-coronary anastomosis: a viable alternative bypass graft. J Thorac Cardiovasc Surg 1987; 94: 256-9.
30. Suma H, Fukumoto H, Takeuchi A. Coronary artery bypass grafting by utilizing in situ right gastroepiploic artery: implication for its use as a bypass graft. J Thorac Surg 1991; 102: 561-5.
31. Suma H, Wanibuchi Y, Furuta S, et al. Comparative study between the gastroepiploic and the internal thoracic artery as a coronary bypass graft: size, flow, patency, histology. Eur J Cardiothorac Surg 1991; 5: 244-7.
32. Suma H, Takanashi R. Arteriosclerosis of the gastroepiploic and thoracic arteries. Ann Thorac Surg 1990; 50: 413-6.
33. Carpentier A, Guermonprez JL, Delouche A, et al. The aorto-coronary radial artery bypass graft. Ann Thorac Surg 1973; 16: 111-21.

34. Fisk RL, Brooks CH, Callaghan JC, et al. Experience with the radial artery graft for coronary artery bypass. Ann Thorac Surg 1976; 21: 513-8.
35. Acar C, Jebara VA, Portoghese M, et al. Revival of radial artery for coronary artery bypass grafting. Ann Thorac Surg 1992; 54: 652-60.
36. Chen AH, Tastuya N, Brodman RF, et al. Early postoperative angiographic assessment of radial artery grafts used for coronary artery bypass grafting. J Thorac Cardiovasc Surg 1996; 111: 1208-12.
37. Possati G, Gaudino M, Alessandrini F, et al. Midterm clinical and angiographic results of radial artery grafts used for myocardial revascularization. J Thorac Cardiovasc Surg 1998; 116: 1015-21.
38. Puig LB, Ciongolli W, Cividanes GL, et al. Inferior epigastric artery as a free graft for myocardial revascularization. J Thorac Cardiovasc Surg 1990; 99: 251-5.
39. Buche M, Schoevaerdts JC, Chalant CH. Multiple-vessel coronary revascularization using both in situ mammary arteries and a free inferior epigastric artery. J Thorac Cardiovasc Surg 1990; 99: 754-5.
40. Perrault LP, Carrier M, Hebert Y, et al. Early experience with the inferior epigastric artery in coronary artery bypass grafting. J Thorac Cardiovasc Surg 1993; 106: 928-30.
41. Buche M, Schroeder E, Gurne O, et al. Coronary artery bypass grafting with the inferior epigastric artery: midterm clinical and angiographic results. J Thorac Cardiovasc Surg 1994; 109: 553-60.
42. Bergsma MT, Grandjean JG, Voors AA, et al. Low recurrence of angina pectoris after coronary artery bypass graft surgery with bilateral internal thoracic and right gastroepiploic arteries. Circulation 1998; 97: 2402-5.
43. Grandjean JG, Voors A, Boonstra PW, den Heyer P, Ebels T. Exclusive use of arterial grafts in coronary artery bypass operations for three-vessel disease: use of both thoracic arteries and the gastroepiploic artery in 256 consecutive patients. J Thorac Cardiovasc Surg 1996; 112: 935-42.