European Journal of Cardio-thoracic Surgery 15 (1999) 240–246

EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY

Intraoperative flow measurements in gastroepiploic grafts using pulsed Doppler[1]

Yves Louagie*, Michel Buche, Philippe Eucher, Jean-Claude Schoevaerdts

University Clinics of Mont-Godinne, Université Catholique De Louvain, Yvoir, Belgium

Received 23 September 1998; received in revised form 3 November 1998; accepted 10 November 1998

Abstract

Objective: The patency of a pedicled right gastroepiploic artery (RGEA) graft can be compromised by intraoperative twists, kinks or spasms. Therefore, a systematic flow assessment was made in RGEA grafts and was compared with similar measurements made in other types of bypass conduits. **Methods**: Intraoperative pulsed Doppler flowmeter measurements obtained in a series of 556 consecutive patients undergoing at least one coronary bypass grafting onto the right coronary system were studied. Eighty-five RGEA grafts were compared with 1427 bypass grafts implanted in the same group of patients and consisted of the following conduits: 442 left internal mammary (LIMA), 149 right internal mammary (RIMA), 831 greater saphenous vein (GSV) and five inferior epigastric (EPIG) grafts. Sequential grafts were excluded from the analysis. **Results**: Flow measurements and Doppler waveforms were abnormal and required graft repositioning, and the addition of a distal graft or intragraft papaverine injection (only in GSVs) in 29 cases (2.0% of all grafts). These graft corrections were necessary in 5.9% RGEAs, 3.4% LIMAs, 2.0% RIMAs, and 0.7% GSVs ($P < 0.001$). The relative risk for graft correction was eight times higher for RGEAs than for GSVs ($P = 0.002$). Flow increased from 8 ± 2 to 54 ± 5 ml/min ($P < 0.0001$). Flow data were significantly influenced by the type of run-off bed ($P < 0.001$), the measurements obtained in grafts implanted onto the right coronary artery and the left anterior descending artery being superior. Flows in RGEAs, however, were comparable with values obtained in other grafts implanted onto the same recipient coronary artery. **Conclusions**: A significantly higher incidence of graft malpositioning caused inadequate flows in RGEAs. However, normal flow values could be restored simply by assigning a better graft orientation under pulsed Doppler flowmeter control. Overall flow capacity of the RGEA did not differ from values obtained in other arterial and venous grafts implanted onto the same recipient arteries.

Keywords: Coronary-artery-bypass-methods; Thoracic-arteries-transplantation; Ultrasonography; Doppler

1. Introduction

The role of the right gastroepiploic artery (RGEA) has become fundamental in the revascularization of the posterior left ventricular wall. However, immediate flow adequacy of these grafts has been questioned since it can be compromised by intraoperative twists, kinks or spasms. Indeed, cases of postoperative ischaemia related to RGEA malfunction have been detected by intraoperative blood flow measurement [1]. In vivo studies have confirmed that the RGEA is more reactive to ergometrine, nitrates, and mechanical stimuli than internal mammary artery grafts [2,3]. This explains why a significant 'learning curve' is necessary to obtain adequate long-term patency rates [4].

The present study is based on data resulting from a systematic intraoperative flow control of bypass grafts. The aims of the analysis were to evaluate the incidence and mechanism of RGEA malfunction in comparison with other grafts, and secondly, to assess the flow potential of RGEA grafts and their run-off beds in comparison with other grafts and run-off beds.

* Corresponding author. Tel.: +32-081-423-151; fax: +32-081-423-158; e-mail: louagie@chir.ucl.ac.be

[1] Presented at the 12th Annual Meeting of the European Association for Cardio-thoracic Surgery, Brussels, Belgium, September 20–23, 1998.

1010-7940/99/$ - see front matter
PII: S1010-7940(99)00011-1

2. Patients and methods

A consecutive series of 556 patients (411 male and 145 female) undergoing a procedure of bypass grafting, including a graft onto the right coronary system (right coronary artery, posterior descending artery or posterior lateral branch), forms the basis of this study. Mean age was 65.4 ± 0.4 years. A total of 1512 termino-lateral anastomoses were made and included 442 left internal mammary (LIMA), 149 right internal mammary (RIMA), 831 greater saphenous vein (GSV), 85 RGEA and five inferior epigastric (EPIG) grafts. Sixty-two RGEA grafts were implanted onto the posterior descending artery, 15 onto the right coronary artery, seven onto the postero-lateral branch, and one onto the second marginal branch of the circumflex artery. To facilitate interpretation of the data, sequential bypass grafts were excluded from the analysis.

One surgeon (Y.L.), using identical techniques performed all procedures. The RGEA was dissected from the greater gastric curvature using hemoclips, brought anterior to the stomach and liver and directed through a diaphragmatic hole towards the inferior aspect of the heart. Prior to the initiation of cardiopulmonary bypass (CPB), a 2-ml shot of undiluted papaverine chlorhydrate was injected at 37°C into the distal end of the RGEA without mechanical dilatation, using an olive-tipped (1 mm) metal needle (DLP, Grand Rapids, MI, N° 31001). In order to obtain an adequate diameter, excess length was discarded and the grafts were kept as short as possible. The RGEA was anastomosed in antegrade fashion with the heel of the graft placed on the proximal end of the arteriotomy. No attempt was made to attach an internal mammary (IMA) or RGEA pedicle to the epicardium. Indeed, we observed in our early cases, anastomotic kinks caused by incorrectly placed fixation stitches. Proximal venous anastomoses were made during rewarming with the application of a tangential aortic clamp.

Flow was measured with an 8 MHz pulsed-wave Doppler ultrasound flowmeter (OPDOP 130; Scimed, Bristol, UK). Recording sites were in the proximal vein graft segment and the mid portion of the IMA pedicle. Sharp dissection was not necessary to measure flow of the IMA, as the cuff could easily be applied around the artery in an area where it protrudes from the anterior aspect of the musculofascial pedicle. Regarding the RGEA, the surrounding fat was incised and the measurements made at a level situated 3 cm distal from the origin of the gastroduodenal artery, where the graft crosses the anterior aspect of the liver. The measurements were obtained by constraining the vessel in an acrylic cuff whose two halves were clipped around it. The ultrasound pencil probe was slotted into the clip and acoustically coupled to the vessel by a small amount of sterile gel. A detailed description of the method used has been published previously [5]. The technique has been validated by comparing the Doppler measurements with flow measurements obtained in IMAs by the electromagnetic flowmeter ($r = 0.97$) and with in vitro timed-volume collection performed in saphenous veins ($r = 0.97$) [5]. Furthermore, according to Matre, the transit time flowmeter showed excellent agreement with the Doppler ultrasound method for both in vitro and in vivo studies performed on saphenous vein grafts [6].

The parameters measured by the pulsed Doppler were flow (ml/min), velocity (cm/s), and internal diameter (mm) of the vessel. Total resistance of the graft and coronary bed was calculated from mean radial artery pressure divided by mean flow and was expressed in peripheral resistance units (PRU). A pulsatility index was calculated to describe the shape of the curves. It is a dimensionless variable, independent of probe-to-vessel angle. This variable was defined as follows: $PI = (F_{max} - F_{min})/F_{mean}$, where F_{max} is the maximum frequency, F_{min} is the minimum frequency, and F_{mean} is the mean frequency. The measurements were made after weaning from cardiopulmonary bypass.

Values are presented as mean ± standard error of the mean. Data were compared by the two-sample *t*-test (paired or unpaired), χ^2 test or Fisher's exact test, one-way analysis of variance and post hoc Scheffé tests.

3. Results

3.1. Inadequate flows and their correction

Flow measurements and Doppler waveforms were abnormal and required graft repositioning, the addition of a distal graft or intragraft papaverine injection (only in GSVs) in 29 cases (2.0% of all grafts). These graft corrections were necessary in 5.9% RGEAs (5/85), 3.4% LIMAs (15/442), 2.0% RIMAs (3/149), and 0.7% GSVs (6/831). Corrections of RGEA grafts were necessary in three out of the 62 grafts implanted onto the PDA (4.8%) and in two out of the 15 grafts implanted onto the RCA (13.3%) (NS). If we exempt the five cases, where a high run-off bed resistance unrelated to the graft itself was seen, there was only one instance of twist among 831 (0.1%) GSV grafts. Interestingly, these cases of malfunctioning grafts that were identified early, were not associated with electrocardiographic ischaemic abnormalities or significant cardiac dysfunction. A description of the abnormalities detected and their concordant correction is detailed in Table 1. The need for graft correction was significantly higher (relative risk = 8.15) for RGEAs than for GSVs ($P = 0.002$). An example of the Doppler waveform and flow-derived data observed in a RGEA pedicle twist at the anastomosis is shown in Fig. 1. Flow measured in the malfunctioning grafts averaged 8 ± 2 ml/min and flow measured in the same graft after correction or in a new graft implanted distally, reached 54 ± 5 ml/min ($P < 0.0001$, paired *t*-test). Flow data are plotted in Fig. 2 and a detailed haemodynamic outcome is described in Table 2.

In addition, in six RGEA grafts, initial flow was <20 ml/min in the absence of any obvious anomaly. In five of these

Table 1
Anomalies detected by pulsed Doppler assessment and their correction

Anomaly	Correction	Grafts			
		LIMA (n = 442)	RIMA (n = 149)	RGEA (n = 85)	GSV (n = 831)
Kink	Reposition	6	2	2	–
Twist	Untwisting	1	–	3	1
Dissection	Distal grafting	3	–	–	–
Small calibre	Distal grafting	2	–	–	–
Constriction	String section	2	–	–	–
Compression by aorta	Reposition	–	1	–	–
Subclavian stenosis	Free grafting	1	–	–	–
High resistance of run-off bed	Papaverine injection	–	–	–	5
Total (%)		15 (3.4)	3 (2.0)	5 (5.9)	6 (0.7)

LIMA, left internal mammary artery; RIMA, right internal mammary artery; RGEA, right gastroepiploic artery; GSV, greater saphenous vein.

cases, the flow that averaged 9.8 ± 1.7 ml/min (range 5.0–14.0 ml/min) at the initial measurement, increased spontaneously to 44.2 ± 6.5 ml/min (range 26.0–64.0 ml/min). This situation can be explained by spasms at the anastomosis, high peripheral resistance, or both. In the sixth case, an initial flow of 13 cc/min dropped further to 5 cc/min. This was the only instance where RGEA occlusion could be suspected. Since no direct manipulation was performed, these cases were not included in the flow correction data. There was no untoward effect related to the use of dual beam Doppler.

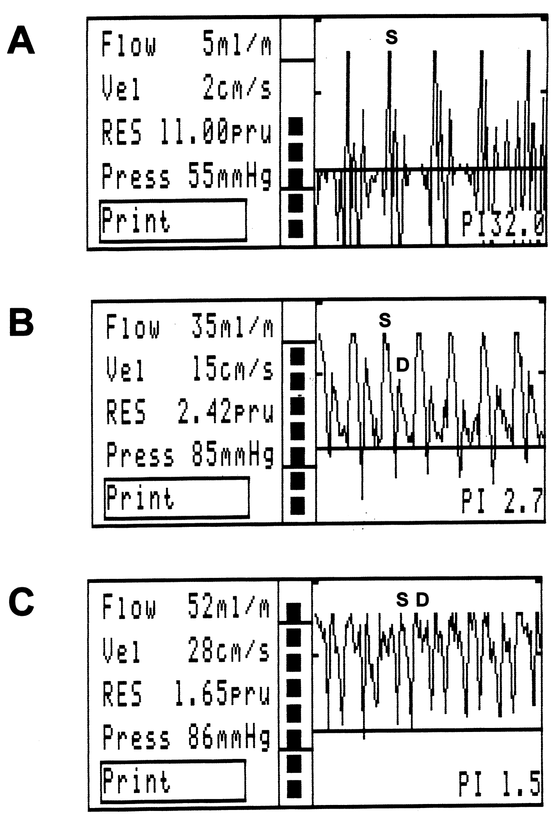

Fig. 1. (A) Doppler waveform and flow-derived data observed in a case of right gastroepiploic artery twisting at the anastomotic site. The waveform configuration is characterized by phasic flow patterns in systole (S) oscillating around the zero line. Flow and velocity (Vel) are low, resistance (RES) and pulsatility index (PI) are markedly increased. (B) Correction of malpositioning resulted in an immediate increase in systolic velocity (S) and the appearance of a positive diastolic flow (D). (C) At the end of the procedure, further normalization of systolic and diastolic waveforms was obtained.

3.2. Overall flow data

When flow data are ranked according to the nature of the bypass graft, the highest flow values are obtained in RIMA and LIMA grafts (Fig. 3). These results were significantly higher than in GSVs using the Scheffé multiple comparison. However, flows measured in RGEA grafts did not differ from flows measured in the other conduits.

Flow data were markedly influenced by the type of run-off bed ($P < 0.001$) since flow measurements obtained in grafts implanted onto the right coronary artery and the left anterior descending artery were significantly higher than in conduits grafted onto the second and third obtuse marginals, diagonals and posterior descending arteries (Fig. 4). Vessels grafted onto the first obtuse marginals showed intermediate flow values and did not differ from the other categories.

Finally, flow volumes analyzed according to both the nature of the graft and the type of recipient coronary artery did not differ (Fig. 5). Specifically, flows measured in

Table 2
Influence of graft corrections on haemodynamic outcome

	Before correction	After correction	P-value
Flow (ml/min)	7.8 ± 1.7	53.8 ± 5.4	<0.0001
Velocity (cm/s)	4.3 ± 0.7	18.0 ± 1.7	<0.0001
Resistance (PRU)	12.2 ± 1.6	2.7 ± 0.8	<0.0001
Pulsatility Index	15.8 ± 4.0	2.7 ± 0.4	0.0052
Radial blood pressure (mmHg)	72 ± 2	74 ± 2	NS

PRU, peripheral resistance units.

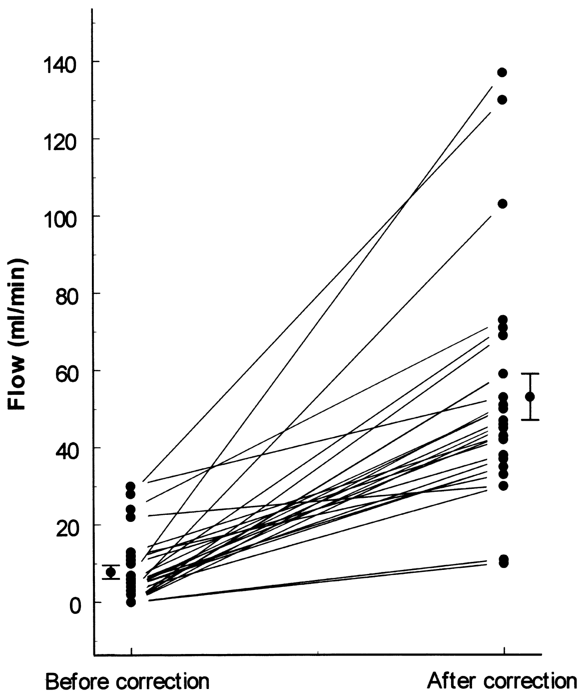

Fig. 2. Difference in flow volume before and after correction of graft malfunction.

RGEAs were comparable with values obtained in other grafts implanted onto the same recipient artery. Only RIMAs implanted onto obtuse marginals maintained higher flow values than GSVs. Flow measured in RGEA grafts implanted onto the right coronary artery averaged 59 ± 7 ml/min, for grafts implanted onto the posterior descending artery, the average was 60 ± 6 ml/min, and grafts supplying the obtuse marginals, averaged 52 ± 11 ml/min.

3.3. In-hospital outcome

There was no hospital death among the 85 patients undergoing a bypass using the RGEA. The only acute dysfunction of a bypass graft happened in a patient with severe chronic obstructive pulmonary disease, who had a sequential internal mammary bypass graft to the left anterior descending artery and the first diagonal branch, a RGEA graft to the posterior descending artery and a GSV to the first obtuse marginal branch. He suddenly developed cardiogenic shock 3 h after his admission to the intensive care unit. At immediate re-operation, the mechanism of ischaemia was twisting, induced by the compression of the sequential left internal mammary bypass by the over-inflated left lung. Additional saphenous vein grafts were completed and the patient survived, thanks to the temporary implantation of an extracorporeal membrane oxygenator. Intraaortic balloon counterpulsation was required to wean the patient from CPB in two cases. The only complication specific to the RGEA harvest was bleeding originating from an artery of the greater gastric curvature requiring re-exploration. The other complications affecting patients having RGEA grafts and ranked by their frequency were the following: atrial fibrillation (26%), bronchopneumonia (14%), need for prolonged ventilatory support (2%), gastric ulcer (2%), renal failure (1%), pneumothorax (1%) and pulmonary embolism (1%). There was no case of myocardial infarction related to the use of the RGEA.

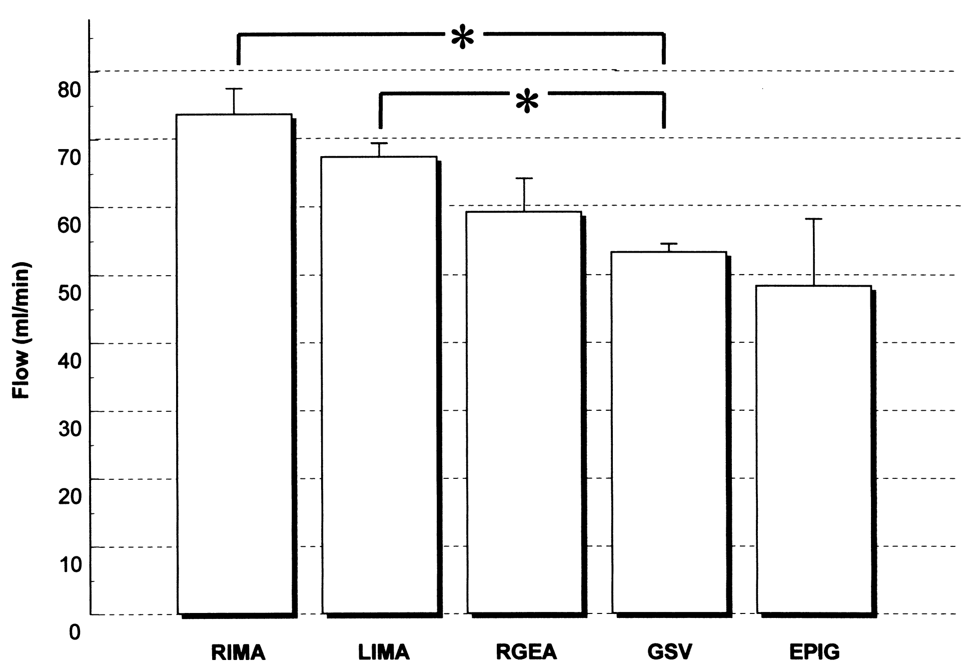

Fig. 3. Average flow volume data ranked according to the nature of the bypass graft. *$P < 0.001$ by post hoc Scheffé test. RIMA, right internal mammary artery; LIMA, left internal mammary artery; RGEA, right gastroepiploic artery; GSV, greater saphenous vein; EPIG, inferior epigastric artery.

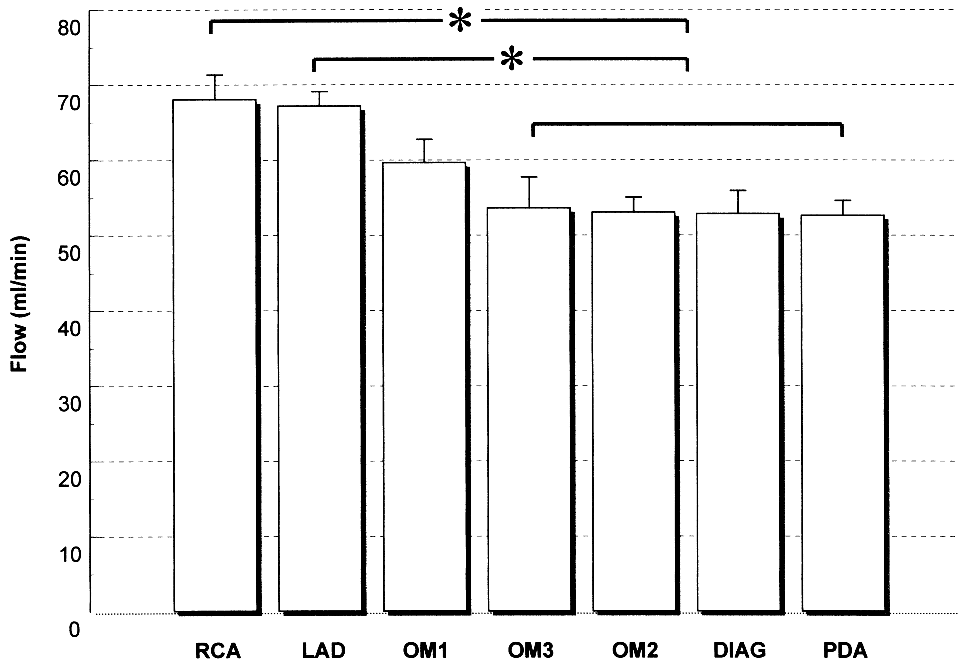

Fig. 4. Average flow volume data ranked according to the nature of the recipient artery. *$P < 0.001$ by post hoc Scheffé test. RCA, right coronary artery; LAD, left anterior descending artery; OM1, 2 and 3, obtuse marginal artery 1, 2 and 3; DIAG, diagonal branch; PDA, posterior descending artery.

4. Discussion

Although the RGEA is a pediculated arterial graft, its patency rate has always been inferior to IMA grafts. Indeed, mid-term angiographic patency rates ranged from 82 to 88% for RGEA grafts and from 90 to 98% for LIMA grafts [7,8]. Actually, early permeability is already lower for RGEA grafts, ranging from 80 to 92% [7,9,10]. Only Suma [11] has obtained better results with an early patency rate reaching 94%. This is not surprising since this author is known to perform intraoperative Doppler evaluation of his grafts [12,13]. Moreover, according to Suma, graft patency seems not to deteriorate later in the process, since late patency remains at 94% [11]. Likewise, Voutilainen [7] reported early patent RGEA grafts in 80% of his patients and a 5 year patency of 82%. Thus, early detection and

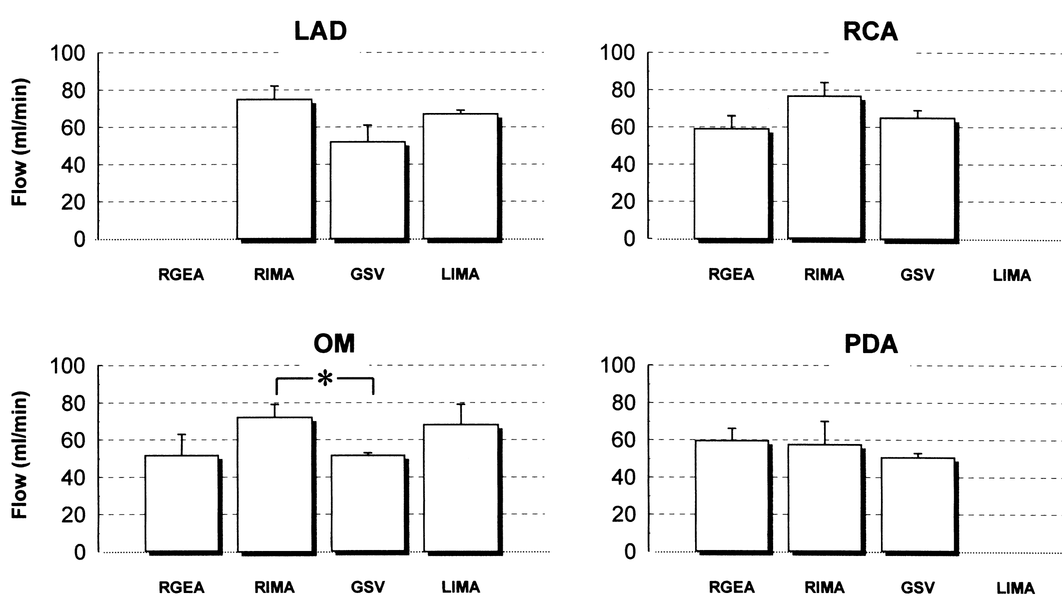

Fig. 5. Average flow volume data ranked according to the nature of the recipient artery (LAD, left anterior descending artery; RCA, right coronary artery; OM, obtuse marginal artery; PDA, posterior descending artery) and the nature of the graft (RGEA, right gastroepiploic artery; RIMA, right internal mammary artery; GSV, greater saphenous vein; LIMA, left internal mammary artery). *$P < 0.001$ by post hoc Scheffé test.

correction of technical errors is mandatory and should improve both early and late patency.

The main benefit of bypass graft flow assessment is the detection and correction of malfunctioning conduits. According to the literature, severe dysfunction of IMA grafts due to anastomotic occlusion or to malpositioning is detected intraoperatively in 3.0–6.2% of the grafts [14–16]. More precisely, an early graft dysfunction rate of 1% for vein grafts and 5.3% for IMA grafts could be demonstrated by intraoperative thermal coronary angiography [15]. Similar data were not available for RGEA grafts despite their well-known propensity to kink and twist. Thus, the main contribution of the present study is to demonstrate a dysfunction incidence in RGEA grafts reaching 6%, and contrasting with a very low dysfunction rate for GSV grafts. This is explained by the smaller size of the distal RGEA and by the difficulty of adequately checking the anastomotic area when the heart is relocated, the field being obstructed by the bulky fat pedicle. The detection of graft malfunction by Doppler sonometry was based on the association of low flow, low velocity and high resistance. In addition, the morphology of the Doppler signal was characterized by a systolo-diastolic high-pitch frequency curve oscillating around the zero line and producing an elevated pulsatility index, as shown in the example of Fig. 1. By contrast, the advent of a diastolic component and the gain in systolic constituent, characterized flow restoration. Of practical importance, these typical velocity modifications are monitored by acoustic control, which may help the surgeon considerably while he attempts to relocate the graft.

Pharmacological studies [17–19] and clinical observations [2,3,20,21] have demonstrated the increased tendency for spasm in RGEA grafts. Furthermore, Tavilla [1] reported two cases of ischaemia in patients having RGEA grafts, cases which required complementary saphenous grafts. Since no technical error at the RGEA anastomosis could be found, it was concluded that the blood flow supply of these RGEA grafts to the myocardial area of the target coronary artery arteries was inadequate. In the present study, spasms were suspected in five cases. This limited incidence of spasm may be related to the fact that undiluted papaverine was injected at body temperature in the RGEA grafts and that the grafts were kept as short as possible since larger and more proximal segments of the RGEA have less tendency for spasm, as stressed by Dietl [22]. In addition, spasm at the distal end of the RGEA is difficult to differentiate from increased run-off bed resistance. In both cases, no obvious anastomotic anomaly is detected and flow improves spontaneously within a few minutes. The phenomenon of increased run-off resistance was observed in five out of 831 GSV grafts and was alleviated by intragraft papaverine injection. The latter manipulation is obviously contraindicated in RGEA grafts.

Provided RGEA malfunctions are corrected, overall flow values in these conduits are equivalent to RIMA and GSV grafts implanted onto the same run-off bed. Flow measurements were made at resting flow and did not evaluate maximal flow reserve. The maximal recruitable flow capacity could be evaluated by pharmacological (adenosine injection) [23–25] or physiological (cardiac pacing) [24,26] stimulation. Reactive hyperhaemia can also be induced by a 20-s clamping of the bypass graft if the recipient coronary artery is occluded or severely stenosed proximally [27]. To our knowledge, maximal flow reserve of RGEA grafts has never been evaluated intraoperatively, although studies measuring the response of velocity in RGEA grafts under various physiological and pharmacological stimulations have been performed in postoperative patients [13,28].

We conclude from our study that RGEA graft malpositioning is of more concern than spasms. However, the former complication is readily detected by Doppler ultrasound and can be corrected at once. In this way, immediate patency can be improved by 6%. Finally, overall resting flow in RGEA grafts was equivalent to other grafts supplying the same run-off beds.

References

[1] Tavilla G, Jacobowitz JJ, Berreklouw E. Intraoperative blood flow measurement of the right gastroepiploic artery using pulsed Doppler echocardiography. Ann Thorac Surg 1997;64:426–431.

[2] Hanet C, Semaan C, Khoury G, Dion R, Robert A. Differences in vasoreactivity between gastroepiploic artery grafts late after bypass surgery and grafted coronary arteries. Circulation 1994;90:II155–II159.

[3] Suma H. Spasm of the gastroepiploic artery graft. Ann Thorac Surg 1990;49:166–170.

[4] 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;107:1309–1315.

[5] Louagie YAG, Haxhe JP, Jamart J, Buche M, Schoevaerdts JC. Intraoperative assessment of coronary artery bypass grafts using a pulsed Doppler flowmeter. Ann Thorac Surg 1994;58:742–749.

[6] Matre K, Birkeland S, Hessevik I, Segadal L. Comparison of transit-time and Doppler ultrasound methods for measurement of flow in aortocoronary bypass grafts during cardiac surgery. Thorac Cardiovasc Surg 1994;42:170–174.

[7] Voutilainen S, Verkkala K, Jarvinen A, Keto P. Angiographic 5-year follow-up study of right gastroepiploic artery grafts. Ann Thorac Surg 1996;62:501–505.

[8] Grandjean JG, Voors AA, 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;112:935–942.

[9] Perrault LP, Carrier M, Hebert Y, Hudon G, Cartier R, Leclerc Y, Pelletier LC. Clinical experience with the right gastroepiploic artery in coronary artery bypass grafting. Ann Thorac Surg 1993;56:1082–1084.

[10] Jegaden O, Eker A, Montagna P, Ossette J, Rossi R, Revel D, Saint PA, Itti R, Mikaeloff P. Technical aspects and late functional results of gastroepiploic bypass grafting (400 cases). Eur J Cardiothorac Surg 1995;9:575–580.

[11] Suma H, Amano A, Horii T, Kigawa I, Fukuda S, Wanibuchi Y. Gastroepiploic artery graft in 400 patients. Eur J Cardiothorac Surg 1996;10:6–10.

[12] Takayama T, Suma H, Wanibuchi Y, Furuta S, Tohda E, Yamashita

S, Matsunaka T. Doppler miniprobe to measure arterial graft flow in coronary artery bypass grafting. Ann Thorac Surg 1991;52:322–324.
[13] Takayama T, Suma H, Wanibuchi Y, Tohda E, Matsunaka T, Yamashita S. Physiological and pharmacological responses of arterial graft flow after coronary artery bypass grafting measured with an implantable ultrasonic Doppler miniprobe. Circulation 1992;86: II217–II223.
[14] Bandyk DF, Galbraith TA, Haasler GB, Almassi GH. Blood flow velocity of internal mammary artery and saphenous vein grafts to the coronary arteries. J Surg Res 1988;44:342–351.
[15] Falk V, Walther T, Philippi A, Autschbach R, Krieger H, Dalichau H, Mohr FW. Thermal coronary angiography for intraoperative patency control of arterial and saphenous vein coronary artery bypass grafts: results in 370 patients. J Card Surg 1995;10:147–160.
[16] Mohr FW, Falk V, Philippi A, Autschbach R, Krieger H, Diegeler A, Dalichau H. Intraoperative assessment of internal mammary artery bypass graft patency by thermal coronary angiography. Cardiovasc Surg 1994;2:703–710.
[17] Dignan RJ, Yeh TJ, Dyke CM, Lee KF, Lutz HA, Ding M, Wechsler AS. Reactivity of gastroepiploic and internal mammary arteries. Relevance to coronary artery bypass grafting. J Thorac Cardiovasc Surg 1992;103:116–122.
[18] He GW, Yang CQ. Comparison among arterial grafts and coronary artery. An attempt at functional classification. J Thorac Cardiovasc Surg 1995;109:707–715.
[19] Yang Z, Siebenmann R, Studer M, Egloff L, Luscher TF. Similar endothelium-dependent relaxation, but enhanced contractility, of the right gastroepiploic artery as compared with the internal mammary artery. J Thorac Cardiovasc Surg 1992;104:459–464.
[20] Cate CM, Gitter R, Jett K. Spasm of the gastroepiploic artery used for coronary artery bypass grafting. Am J Cardiol 1996;77:1022–1023.
[21] Suma H, Wanibuchi Y, Furuta S, Takeuchi A. Does use of gastroepiploic artery graft increase surgical risk? J Thorac Cardiovasc Surg 1991;101:121–125.
[22] Dietl CA. Vascular reactivity of the gastroepiploic artery graft. J Thorac Cardiovasc Surg 1995;110:1568–1570.
[23] Luise R, Teodori G, Di GG, D'Annunzio E, Paloscia L, Barsotti A, Gallina S, Contini M, Vitolla G, Calafiore AM. Persistence of mammary artery branches and blood supply to the left anterior descending artery. Ann Thorac Surg 1997;63:1759–1764.
[24] Otaki M, Lust RM, Sun YS, Norton TO, Rock DT, Spence PA, Chitwood WJ. Experimental supplemental vein grafting and hypoperfusion syndrome. Ann Thorac Surg 1995;59:1423–1428.
[25] Otaki M, Lust RM, Sun YS, Norton TO, Chitwood WJ. Distal flow determinants in canine myocardium perfused through internal thoracic artery bypass grafts. Ann Thorac Surg 1995;59:829–834.
[26] Gurné O, Chenu P, Buche M, Jamart J, Louagie Y, Eucher P, Marchandise B, Schroeder E. Flow-mediated vasodilation during pacing of the free epigastric artery bypass graft early and late postoperatively. J Am Coll Cardiol 1996;27:415–420.
[27] Marcus M, Wright C, Doty D, Eastham C, Laughlin D, Krumm P, Fastenow C, Brody M. Measurements of coronary velocity and reactive hyperemia in the coronary circulation of humans. Circ Res 1981;49:877–891.
[28] Hanet C, Semaan C, Khoury G, Dion R, Robert A. Differences in vasoreactivity between gastroepiploic artery grafts late after bypass surgery and grafted coronary arteries. Circulation 1994;90:II155–II159.

Appendix A Conference discussion

•

Dr F. Mohr (*Leipzig, Germany*): Can you comment on your technique of anastomosis to the right coronary artery? Did you do it in the antegrade or the retrograde fashion, because it has an impact.

Dr Louagie: All the anastomoses were done in the antegrade fashion with the heal of the gastroepiploic artery on the proximal heal of the coronary artery. So there was no attempt to do it in the converse fashion.

Dr Mohr: How do you treat the gastroepiploic artery, in general?

Dr Louagie: In general, we prepare the dissection of the distal artery before starting cardiopulmonary bypass. We inject intraluminally undiluted pure papaverine warmed at body temperature. We complete the dissection of the distal end just before starting the anastomosis. Finally, we try to keep the artery as short as possible to have the largest part of the artery available for the anastomosis.

Dr R. Gutti (*Hyderabad, India*): Did you make any postoperative studies by Doppler studies in these patients to know if there are any flows, how are the flows postoperatively, compared preoperatively and postoperatively?

Dr Louagie: We did not realize systematic postoperative angiographies or Doppler studies in this series of 85 patients. However, I studied 100 patients who had to undergo a new angiography because of the reappearance of symptoms. They had undergone the same kind of intraoperative Doppler evaluation. In that specific and selected group, we had a 94% patency for arterial grafts, and a 98% patency for the left internal thoracic arteries. Regarding venous conduits, we found an 84% patency rate (unpublished data).

Dr B. Walpoth (*Bern, Switzerland*): It might be dangerous to quote that you have similar flow values according to the grafted region whether it was vein, IMA or gastroepiploic grafts. I think to support your conclusion, you have to measure the area at risk, because we find very different results when looking at the flow divided by the weight of myocardium at risk. For instance, we found that, the IMA grafts have much lesser flow than vein grafts. You base your assumption on a large number of measured grafts, but I think you must express it according to the territory at risk.

Dr Louagie: I agree with you that a large number cannot compensate for the absence of randomization of the territories at risk that were grafted. However, I made a study that is submitted for publication, where I compared 50 gastroepiploic artery grafts with a similar number of saphenous vein grafts implanted on the same territory at risk. Both groups were characterized by the same angiographic, macroscopic features, and quality of the artery upon opening at surgery. There was no flow difference between both groups. In addition, we studied velocity trends during closure of the chest during an average duration of 30 min and did not find significant differences between the gastroepiploic and saphenous vein grafts. We observed indeed differences in waveform shape, but not in flow.