Surgery for Acquired Cardiovascular Disease

Radial artery graft function is not affected by age

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Supplemental material is available online.

Objective: Extensive arterial grafting with the radial artery in elderly patients is still debated, because of the reduced life expectancy and the supposedly higher periprocedural morbidity caused by an accelerated atherosclerosis of arterial grafts in elderly patients, which might hamper functional results.

Methods: We reviewed our experience with patients undergoing radial artery myocardial revascularization (coronary artery bypass grafting) between January 2003 and December 2006, divided into 2 groups: elderly patients (≥70 years, group A) and young patients (≤60 years, group B). Hospital outcome and transit-time flowmetric maximum and mean flow, pulsatility index, and graft flow reserve were compared. Results were stratified by target vessel, surgical technique, and subgroups at risk.

Results: Hospital outcome, troponin I levels, and echocardiographic segmental kinetics were comparable in the 2 groups. Stratifying patients for target vessels, no differences in radial artery transit-time flowmetric results were recorded between the 2 groups either on-pump or off-pump, as free grafts or Y grafts, or in diabetic patients and hypertensive patients. Although graft flow reserve was significantly improved in all patients ($P < .05$ in the young and elderly groups, regardless of the target vessel, the surgical technique, and the comorbidities), graft flow reserve of radial artery grafts was comparable between elderly and young patients.

Conclusions: Radial artery coronary artery bypass grafting showed similar transit-time flowmetric functional results in elderly and young patients, regardless of the target vessel, the use or avoidance of cardiopulmonary bypass, the construction of proximal anastomoses, and the presence of comorbidities. These data explain the reported better results of arterial revascularization in the elderly and suggest an increase in extensive radial artery grafting in the last decades of life.

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The recent demonstration of improved survival in patients undergoing arterial revascularization has led surgeons to increasingly use arterial grafts other than internal thoracic arteries to completely revascularize the heart.[1] Of these, the radial artery (RA) is the most frequently used arterial conduit worldwide.[2] However, saphenous vein grafts (SVGs) continue to be used extensively and are often considered the conduit of choice.[3,4]

Moreover, with the exponential growth of the geriatric population referred for coronary artery bypass grafting (CABG), it is not surprising that the SVG continues to be the backbone of daily coronary revascularization.[3,4] It is in fact the second

Abbreviations and Acronyms

EF	= ejection fraction
GFR	= graft flow reserve
IABP	= intra-aortic balloon pump
LITA	= left internal thoracic artery
OPCABG	= off-pump coronary artery bypass grafting
PI	= pulsatility index
RA	= radial artery
SVG	= saphenous vein graft
TTF	= transit-time flowmetry
WMSI	= wall motion score index

most frequently used conduit in both Society of Thoracic Surgeons National and EuroSCORE Databases.[3,4] Furthermore, reluctance to use arterial grafts in elderly patients is based on concerns about long-term survival of this cohort of patients and on the concept that the extensive use of arterial grafts might be associated with an increased morbidity and mortality caused by excessive surgical invasiveness, prolonged operative time, and higher risk for arterial spasm with acute onset of ischemia.[5] Despite the recent demonstration by Wildhirt and colleagues[6] that RA grafts demonstrated good angiographic, morphometric, and basic flowmetric (mean flow and resistance index) results in aged patients, a detailed functional flowmetric behavior of these grafts has not been reported nor has the flowmetry stratified by the grafted vessel and surgical technique. In particular, graft flow reserve (GFR) has not been studied in this high-risk population.[6] On the other hand, other authors confirmed RA graft safety in the young,[7] others pointed out the critical role of a high-grade angiographic coronary stenosis regardless of age,[8] and still others, on the other hand, reported a higher rate of occlusion in RA grafts compared with that of SVGs.[9] Finally, recent studies pointed out that the prevalence of preexisting atherosclerotic lesions and calcification in the RA may hamper their functional short-term and long-term results, favoring arterial spasm, thus suggesting the avoidance of extensive arterial grafting in some high-risk categories, such as elderly, diabetic, and hypertensive patients.[10] Therefore, the acceptance of extensive arterial revascularization in elderly patients is still questioned; studies focusing on this topic are still scarce, and to date, it is not clear whether age per se might be an exclusion criterion for RA grafting.

Moreover, surgeons have recently discovered the possibility for an intraoperative functional assessment of the quality of their CABGs with the aid of the transit-time flowmetry (TTF), the intraoperative results of which predict graft patency at angiographic follow-up.[11] Again, the literature lacks studies comparing intraoperative TTF findings of arterial grafts in elderly patients.

Therefore, it was the aim of the present study to systematically review our experience with the TTF method in elderly (>70 years) and young (<60 years) patients undergoing myocardial revascularization with RA grafts during the last 4 years at a single academic institution, stratifying results by target vessel, surgical technique used (on-pump and off-pump CABG and free graft or Y-graft), and associated risk factors (diabetes and hypertension).

Materials and Methods

The present study evaluates clinical and flowmetric results of a prospective series of elderly patients (>70 years, group A) undergoing RA CABG during isolated myocardial revascularization, performed either off-pump (OPCABG) or on-pump and either as free grafts or with a Y-graft construction, during the last 4 years at a single academic institution. The elderly patients were compared with a cohort of young patients (<60 years, group B) undergoing arterial CABG during the same time period. Patients aged 60 to 70 years were excluded from the study to better differentiate elderly from young patients, so as to obtain a significant difference in the mean age of the 2 groups analyzed.

The study protocol was approved by the institution's ethical committee/institutional review board, and informed consent was obtained from each patient. Sixty-five consecutive elderly patients and 53 consecutive young patients undergoing first-time elective CABG between January 2003 and December 2006 with RA grafts were enrolled in the study.

Thirty-six (55.4%) patients belonging to group A had diabetes, and 37 (56.9%) had hypertension. When young patients were considered, there were 37 (69.8%) diabetic and 28 (52.8%) hypertensive patients.

Exclusion criteria were additional cardiac or vascular surgical procedures and severe systemic comorbidities (dialysis, hepatic failure, cancer, and autoimmune disease).

Surgical Intervention

The RA was always harvested in a pedicled fashion. The RA was evaluated in all cases with the modified (percentage of arterial oxygen saturation) Allen test, the results of which were considered negative when hand vascularization became normal in less than 6 seconds and percentage of arterial oxygen saturation was recovered in the same time. The graft was harvested only from the nondominant forearm in all cases. Low-current electrocautery was used for the subcutaneous tissue and the deep fascia in the proximal half of the incision, with the distal deep fascia incised with scissors. The subsequent dissection continued with a harmonic scalpel (Ethicon Endo-Surgery, Cincinnati, Ohio) by using the hook blade and the variable mode at moderate intensity. RA branches that bled during or after transection, as well as the major collateral branches, were controlled with small clips. All RAs underwent gentle palpation before transection, and no cases of macroscopic calcification, atherosclerotic plaques, or both were detected. Topical vasodilators were not used during RA harvest at any time. After harvest, the RAs were placed in 100 mL of NaCl 0.9% with 50 mg of diltiazem, 30 mEq of papaverine buffered with 30 mEq of $NaHCO_3$, and 5000 IU of heparin until their use as grafts. All the RAs harvested were used as conduits. RA pedicles were always secured with 2 epicardial stitches using 6-0 polypropylene sutures on both sides after completion of distal anastomoses. RAs were proximally anastomosed to the left internal thoracic artery (LITA) in the Y-graft construction and to the ascending aorta in all other cases. In particular, 15 (23.1%) patients in group A and 18 (34.0%) patients in group B underwent Y-graft construction because of diffuse aortic atherosclerosis, calcifications, or both. When the aorta was the RA blood source, the proximal anastomosis was performed with aortic side clamping by using 6-0 polypropylene sutures before distal anastomoses in OPCABG and after crossclamp removal in conventional CABG during cardiopulmonary bypass. Obtuse marginal branches, the right coronary territory, or the diagonals were the targets of RA grafts. Distal anastomoses were performed with 8-0 polypropylene stitches. The only criterion adopted to RA grafting was the presence of a critical coronary lesion (≥80%) proximal to the anastomotic site. Intravenous or oral vasodilators, except for enoximone infusion, were never used after RA grafting.

Of 65 elderly patients enrolled, 21 (32.3%) underwent OPCABG, whereas 19 (35.8%) of 53 young patients received off-pump CABG operations.

Flowmetric Analysis and GFR

Assessment of each graft was performed during stable hemodynamic conditions, with a mean arterial pressure ranging between 65 and 75 mm Hg in both groups generally 30 minutes after protamine administration. Flowmetry of the grafts was performed with a transit-time flowmeter (HT313; Transonic Systems, Inc, Ithaca, NY). Different probe sizes (2, 2.5, or 3 mm) were available to avoid distortion or compression of the graft. Skeletonization of a small segment of the RA, LITA, and right internal thoracic artery was necessary to reduce the quantity of tissue interposed between the vessel and the probe. Maximum, mean, and minimum flows; flow curve; and pulsatility index (PI) were obtained directly from the flowmeter. The curves were always coupled with the electrocardiographic tracing to correctly differentiate the systolic from the diastolic flow. TTF measurements were interpreted as suggested by Di Giammarco and associates.[12] The maximum, minimum, and mean flow were reported in milliliters per minute, and PI was reported as an absolute number. Data from arterial conduits were recorded and compared between the 2 groups. In the Y-graft subgroup TTF results were collected at the level of the proximal RA graft segment.

It is institutional policy to insert an intra-aortic balloon pump (IABP) preoperatively, before anesthetic induction, in patients with unstable angina despite maximal intravenous nitrates with associated poor left ventricular ejection fraction (EF) with or without very critical left main coronary stenoses to improve myocardial protection before the completion of myocardial revascularization. According to the previous demonstration that IABP recruits GFR during assistance,[13] mean flow and PI were recorded in all patients undergoing preoperative intra-aortic balloon pumping, both during IABP support and during temporary cessation, so as to evaluate GFR. In particular, 32 elderly (49.2% of group A) and 29 young (54.7% of group B) patients underwent preoperative IABP and were therefore the objective of GFR study. GFR was calculated from the mean flow assessed during 1:1 IABP support divided by mean flow at baseline (IABP off).[14]

Postoperative Care, Biochemical Analysis, and Echocardiographic Results

According to an institutional policy, inotropes were started immediately after aortic crossclamp removal with enoximone at a dosage of 5 $\mu g \cdot kg^{-1} \cdot min^{-1}$.[14] Inotropic support was defined as low dose when enoximone was administered at a dosage lower than or equal to 5 $\mu g \cdot kg^{-1} \cdot min^{-1}$, medium dose when enoximone was used at a dosage of between 6 and 10 $\mu g \cdot kg^{-1} \cdot min^{-1}$ or dobutamine was added at a dosage of between 5 and 10 $\mu g \cdot kg^{-1} \cdot min^{-1}$, and high dose when enoximone or dobutamine infusion was greater than 10 $\mu g \cdot kg^{-1} \cdot min^{-1}$ or epinephrine at any dose was added.

Determinations of blood concentrations of cardiac troponin I and myoglobin were conducted preoperatively before anesthetic induction and postoperatively at 12, 24, 48, and 72 hours.

Echocardiographic scans were performed with a transthoracic Acuson Sequoia C256 system (Acuson Corp, Mountain View, Calif) with probe 3V2C and always by the same 2 physicians in a blind manner at the time of hospital admission and before discharge. Left ventricular EF and wall motion score index (WMSI) were recorded.

Statistical Analysis

Statistical analysis was performed by using the SPSS program for Windows (version 10.1; SPSS, Inc, Chicago, Ill). Continuous variables are presented as means ± standard deviation, and categoric variables are presented as either absolute numbers or percentages. Data were checked for normality before statistical analysis. Normally distributed continuous variables were compared by using the unpaired *t* test, whereas the Mann–Whitney *U* test was used for those variables that were not normally distributed. Categoric variables were analyzed with either the χ^2 test or Fisher exact test.

Results

The 2 groups demonstrated comparable demographic data, except for age and EuroSCORE (Table E1). Intraoperative data are also shown in Table E1.

Hospital mortality was comparable between the 2 groups: 1 (1.9%) patient belonging to group B died from stroke, whereas 2 (3.1%) patients belonging to group A ($P = .577$) died during hospitalization, 1 for low-output cardiac state after perioperative myocardial infarction and another from multiorgan failure after pneumonia. No differences were recorded between the 2 groups either in terms of postoperative acute myocardial infarction (group A: 2/65 [3.1%] vs group B: 0/53; $P = .301$) or need for postoperative IABP (group A: 4/65 [6.2%] vs group B: 3/53 [5.7%]; $P = .613$). No IABP-related complications were registered during the period of assistance, except for a temporary limb ischemia that completely recovered after IABP withdrawal.

Similar proportions of patients in the 2 groups required medium doses of inotropes (group A: 14/65 [21.5%] vs

ACD

Table 1. TTF results of on-pump and off-pump RA CABG stratified by target vessel

Operation	Graft type	TTF results	Group A (elderly)	Group B (young)	*P* value
CPB-CABG	LITA-LAD (44 in group A vs 34 in group B)	Maximum flow	52.7 ± 27.5	64.6 ± 31.5	.429
		Mean flow	26.5 ± 17.7	31.7 ± 23.2	.427
		PI	1.51 ± 0.80	1.40 ± 0.82	.610
		DAP	47.2 ± 4.9	47.9 ± 4.8	.193
	RA-OM (27 in group A vs 14 in group B)	Maximum flow	78.9 ± 34.2	73.1 ± 33.3	.656
		Mean flow	40.9 ± 21.7	42.3 ± 19.2	.505
		PI	1.25 ± 0.73	1.29 ± 0.38	.152
		DAP	48.1 ± 4.4	47.5 ± 4.4	.505
	RA-RX (9 in group A vs 13 in group B)	Maximum flow	63.7 ± 41.8	62.0 ± 28.6	.568
		Mean flow	30.3 ± 20.8	28.7 ± 15.7	.507
		PI	1.77 ± 0.94	1.98 ± 1.22	.183
		DAP	47.3 ± 3.1	48.7 ± 3.4	.145
	RA-DIAG (8 in group A vs 7 in group B)	Maximum flow	50.6 ± 32.8	53.8 ± 35.2	.601
		Mean flow	29.4 ± 17.6	27.9 ± 15.1	.476
		PI	1.45 ± 1.08	1.38 ± 0.78	.652
		DAP	45.5 ± 3.0	46.5 ± 2.6	.333
OPCABG	LITA-LAD (20 in group A vs 19 in group B)	Maximum flow	42.2 ± 18.3	45.3 ± 19.7	.756
		Mean flow	23.7 ± 14.3	23.9 ± 15.1	.810
		PI	1.39 ± 0.67	1.33 ± 0.77	.701
		DAP	46.6 ± 3.5	46.4 ± 3.1	.802
	RA-OM (6 in group A vs 7 in group B)	Maximum flow	72.1 ± 55.8	69.4 ± 48.7	.391
		Mean flow	34.3 ± 26.5	38.3 ± 21.9	.431
		PI	1.39 ± 0.52	1.31 ± 0.58	.725
		DAP	46.6 ± 3.7	46.7 ± 3.8	.861
	RA-RX (10 in group A vs 7 in group B)	Maximum flow	62.9 ± 30.8	59.6 ± 34.7	.833
		Mean flow	39.9 ± 22.1	34.4 ± 21.5	.659
		PI	2.36 ± 1.20	2.20 ± 1.32	.273
		DAP	44.4 ± 3.6	44.5 ± 2.4	.941
	RA-DIAG (5 in group A vs 5 in group B)	Maximum flow	46.1 ± 27.3	51.1 ± 24.7	.756
		Mean flow	24.7 ± 17.3	25.9 ± 18.1	.810
		PI	1.69 ± 0.77	1.73 ± 0.82	.701
		DAP	43.0 ± 1.6	42.7 ± 1.9	.670

TTF, Transit-time flowmetry; *RA*, radial artery; *CABG*, coronary artery bypass grafting; *CPB–CABG*, on-pump myocardial revascularization; *LITA*, left internal thoracic artery; *LAD*, left anterior descending artery; PI, pulsatility index; *DAP*, diastolic arterial pressure; *OM*, obtuse marginals; *RX*, right coronary territory; *DIAG*, diagonals; *OPCABG*, off-pump myocardial revascularization.

group B: 15/53 [28.3%]; $P = .263$), as well as high doses of inotropes (group A: 3/65 [4.6%] vs group B: 5/53 [9.4%]; $P = .252$). No differences were recorded between the 2 groups either in perioperative troponin I or myoglobin concentrations (Table E2). Similarly, intensive therapy unit stay (group A: 2.39 ± 1.26 days vs group B: 1.81 ± 1.05 days; $P = .069$) and hospital stay (group A: 7.47 ± 3.42 days vs group B: 6.56 ± 1.75 days; $P = .067$) proved to be similar.

Postoperative predischarge echocardiography demonstrated a comparable recovery in the 2 groups of either left ventricular EF (group A—preoperative EF: 42.4% ± 8.6% vs postoperative EF: 49.8% ± 7.8%; statistical probability within group: $P < .01$; group B—preoperative EF: 41.4% ± 9.1% vs postoperative EF: 50.6% ± 7.3%; statistical probability within group: $P < .01$; statistical probability between groups: $P = .250$) and WMSI (group A—preoperative WMSI: 1.48 ± 0.32 vs postoperative WMSI: 1.26 ± 1.09; statistical probability within group: $P < .01$; group B—preoperative WMSI: 1.51 ± 0.34 vs postoperative WMSI: 1.24 ± 1.06; statistical probability within group: $P < .01$; statistical probability between groups: $P = .213$).

When hand complications caused by RA harvesting were considered, 5 (7.7%) patients belonging to group A and 3 (5.7%, $P = .477$) patients belonging to group B had temporary (3 days to 2.4 months) postoperative paresthesia. One (1.5%) patient in group A had postoperative deep forearm infection requiring surgical debridment of the wound and chronic antibiotic therapy; however, the patient fully recovered, and the wound completely closed after 3.6 months.

In no cases did RA grafts demonstrate unsatisfactory results, but all RAs showed good TTF values.

When TTF values stratified by the target vessel were considered, elderly patients undergoing RA grafting dem-

Table 2. TTF results (mean flow and PI) of RA grafts during 1:1 IABP assistance according to grafted vessel in on-pump and off-pump CABG

Operation	Graft type	TTF results	Group A	Group B	P value*		P value†
CPB-CABG	RA-OM (10 in group A vs 7 in group B)	Mean flow	64.2 ± 25.4	62.6 ± 21.3	Group A	.001	.446
					Group B	.001	
		PI	2.05 ± 1.23	2.10 ± 1.18	Group A	.04	.359
					Group B	.03	
	RA-RX (6 in group A vs 7 in group B)	Mean flow	57.2 ± 21.6	51.3 ± 21.1	Group A	.001	.417
					Group B	.001	
		PI	2.37 ± 1.38	2.49 ± 1.51	Group A	.005	.773
					Group B	.009	
	RA-DIAG (5 in group A vs 5 in group B)	Mean flow	44.2 ± 19.3	45.7 ± 16.8	Group A	.002	.598
					Group B	.003	
		PI	2.77 ± 1.58	2.45 ± 1.29	Group A	.001	.206
					Group B	.003	
OPCABG	RA-OM (5 in group A vs 4 in group B)	Mean flow	54.1 ± 26.4	49.9 ± 18.0	Group A	.008	.542
					Group B	.007	
		P.I.	2.67 ± 1.11	2.62 ± 1.26	Group A	.02	.577
					Group B	.02	
	RA-RX (3 in group A vs 3 in group B)	Mean flow	49.5 ± 22.8	48.5 ± 20.7	Group A	.010	.187
					Group B	.009	
		PI	2.57 ± 1.62	2.53 ± 1.55	Group A	.05	.078
					Group B	.02	
	RA-DIAG (3 in group A vs 3 in group B)	Mean flow	34.6 ± 7.4	35.2 ± 10.0	Group A	.03	.293
					Group B	.04	
		PI	2.58 ± 0.75	2.63 ± 1.16	Group A	.05	.597
					Group B	.05	

TTF, Transit-time flowmetry; *PI*, pulsatility index; *IABP*, intra-aortic balloon pump; *CABG*, coronary artery bypass grafting; *CPB–CABG*, on-pump myocardial revascularization; *RA*, radial artery; *OM*, obtuse marginals; *RX*, right coronary territory; *DIAG*, diagonals; *OPCABG*, off-pump myocardial revascularization. *1:1 IABP versus baseline (IABP off). †Elderly versus young patients.

onstrated comparable results with young patients, either for on-pump CABG or OPCABG (Table 1).

Furthermore, to rule out differences in GFR between elderly and young patients, of 61 patients (32 elderly and 29 young patients) undergoing preoperative IABP insertion, intraoperative TTF analysis with either 1:1 IABP or temporary cessation was performed. IABP support of 1:1 recruited GFR in all these patients, and no differences were detectable in graft mean flow and PI between the 2 groups, either in on-pump or off-pump CABG (Table 2). Similar GFR was detected either in off-pump or on-pump CABG (Figure 1).

When subgroups at higher risk for atherosclerotic involvement of RA grafts were analyzed, again no differences were recorded between old and young diabetic and hypertensive patients in mean flow (Figure E1) and PI (Figure E2). Again, GFR proved similar in RA grafts of young and old diabetic patients (Figure 2, *A*), as well as young and old hypertensive patients (Figure 2, *B*).

Finally, although no Y-grafts were done on diagonal branches, no statistical differences were found between elderly and young patients when the RA was used in a Y fashion to revascularize obtuse marginal branches or the right coronary territory, either in mean flows, PIs, or GFRs (Table 3).

Discussion

Numerous advances in operative techniques and perioperative care have resulted in an increasing number of patients in the seventh or eighth decade of life being referred for CABG.[15] It therefore becomes increasingly important to determine which operative techniques enhance perioperative and long-term survival and quality of life. Moreover, despite the higher intraoperative and postoperative risks in elderly patients, studies have demonstrated a survival advantage both in the short and long term for surgical therapy in these patients.[16,17]

It is well known that the LITA, because of its superior patency rate, is the conduit of choice for CABG in all published series of the literature. When arterial grafts other than the LITA (first of all the RA) are considered, the demonstrated advantages on short-term and long-term prognosis in young patients are questioned in elderly patients. In particular, the literature is still in conflict on this topic. Some authors have clearly demonstrated that the RA is a

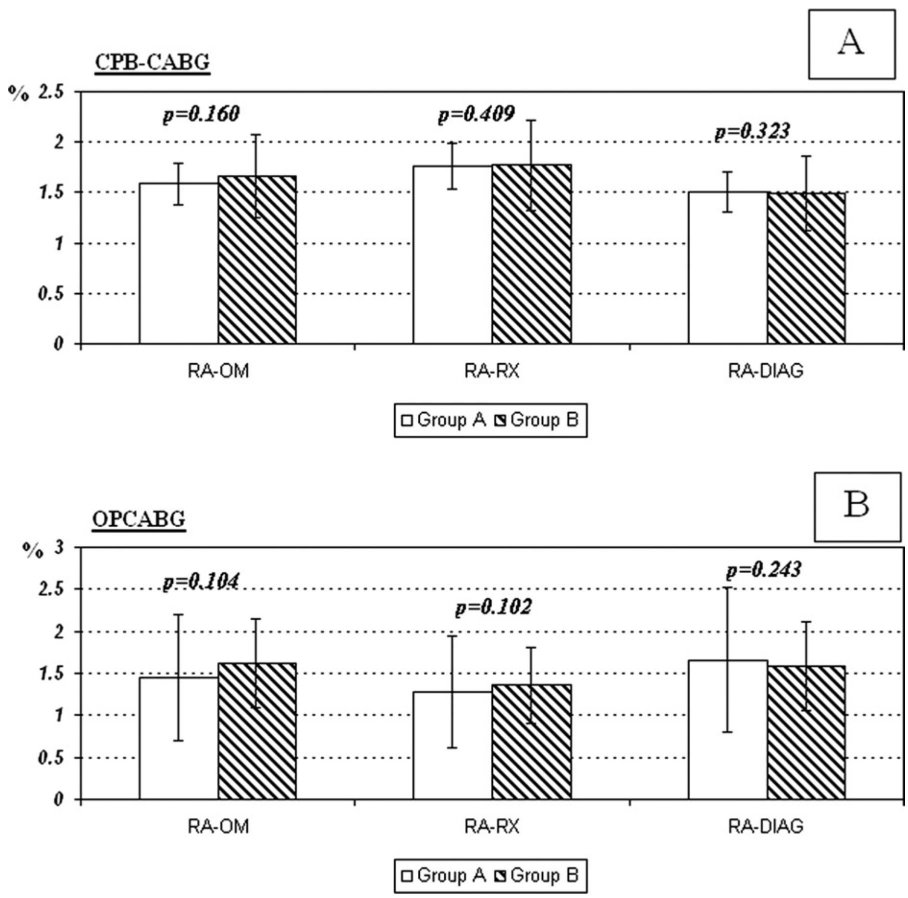

Figure 1. Graft flow reserve stratified by surgical technique (cardiopulmonary bypass, A; off-pump CABG, B) and grafted vessel. ***CPB*, Cardiopulmonary bypass; *CABG*, coronary artery bypass grafting; *RA*, radial artery; *OM*, obtuse marginal branches; *RX*, right coronary territory; *DIAG*, diagonals.**

preferred target for atherosclerotic lesions,[6,10,18] therefore suggesting care in its use as a conduit for CABG[10]; others have excluded age per se as a contraindication[6]; others reported a higher occlusion rate in RA grafts compared with SVGs regardless of age[9]; and finally, some authors have excluded atherosclerotic lesions as having a potential to affect graft patency and endothelial function and suggest that RA grafting is appropriate in advanced decades.[18] Moreover, it has to be considered that all these studies focused on the histopatholgic and morphometric analysis of the arterial conduits rather than their in vivo (ie, after completion of CABG) functional behavior. The recent introduction in the routine surgical practice of TTF has given surgeons the ability to analyze intraoperatively the results of their practice and to detect early graft failure or malfunction. Accordingly, no RA graft failures were encountered intraoperatively in our series.

Recent studies have demonstrated that arterial revascularization improves the outcome of patients undergoing CABG, regardless of the type of arterial conduit used.[1,19,20] A number of authors have also reported satisfactory results with arterial grafts in elderly patients. Muneretto and colleagues[20] demonstrated that the use of full arterial revascularization in elderly patients did not increase postoperative complications, exhibiting a better clinical outcome in the midterm follow-up in terms of both freedom from angina and acute myocardial infarction.[20] Borger and associates[21] further showed comparable results in terms of cardiac morbidity and mortality in patients undergoing LITA plus RA grafting and those with bilateral internal thoracic artery grafting, with a significant prevalence of the RA over the right internal thoracic artery in elderly patients. Again, these studies focused on midterm and long-term results of arterial CABG in elderly patients but did not report the intraoperative functional results of arterial CABG. In particular, a recent study by Wildhirt and colleagues[6] demonstrated good angiographic, morphometric, and basic flowmetric (mean flow and resistance index) results of RA grafts in aged patients. However, the authors did not analyze in detail the functional flowmetric behavior of these grafts nor stratified flowmetry by grafted vessel and surgical technique used (eg, on-pump vs off-pump CABG and free grafts vs Y-grafts), and in particular, they did not study GFR in this high-risk population. This is of particular relevance, considering that TTF has been proved to be predictive of graft patency[11] and that GFR is crucial in determining graft patency.[22]

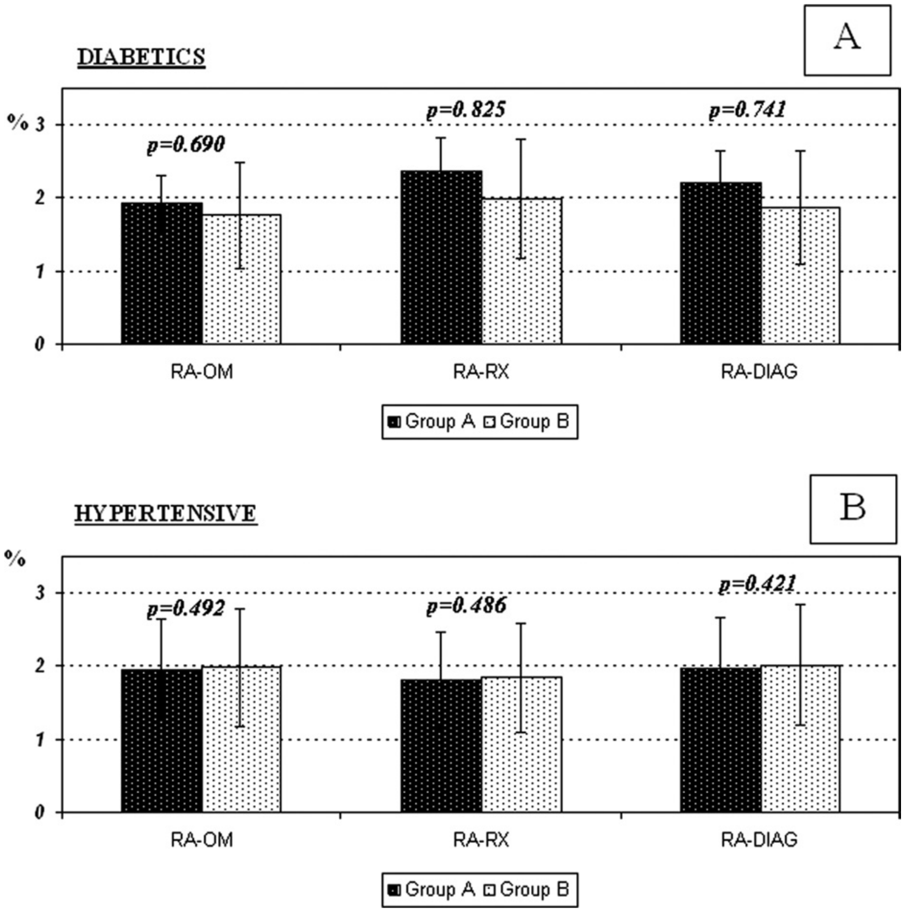

Figure 2. Graft flow reserve stratified by grafted vessel in diabetic (A) and hypertensive (B) patients. *RA*, Radial artery; *OM*, obtuse marginal branches; *RX*, right coronary territory; *DIAG*, diagonals.

Therefore, the literature lacks studies reporting detailed TTF results of arterial conduits, especially when the last decades of life are considered. We reported here not only the maximum and mean flows of these arterial conduits, but also the PI and, most importantly, GFR, predictive of short-term graft function,[11,12] demonstrating comparable results

Table 3. TTF results (mean flow, PI, and GFR during 1:1 IABP assistance) of RA Y-grafts according to grafted vessel and surgical technique (on-pump and off-pump CABG)

Operation	Graft type	TTF results	Group A (15 patients)	Group B (18 patients)	*P* value
CPB–CABG	RA–OM (3 in group A vs 4 in group B)	Mean Flow	38.7 ± 18.3	40.9 ± 21.2	.741
		PI	1.64 ± 0.92	1.70 ± 0.87	.267
		GFR	1.68 ± 0.33	1.67 ± 0.25	.498
	RA–RX (3 in group A vs 3 in group B)	Mean flow	34.6 ± 25.4	39.1 ± 18.8	.690
		PI	1.50 ± 0.87	1.62 ± 0.75	.374
		GFR	1.52 ± 0.51	1.60 ± 0.44	.105
OPCABG	RA–OM (4 in group A vs 6 in group B)	Mean flow	26.7 ± 19.2	31.0 ± 15.6	.825
		PI	1.83 ± 1.02	1.76 ± 0.78	.173
		GFR	1.55 ± 0.40	1.67 ± 0.37	.089
	RA–RX (5 in group A vs 5 in group B)	Mean flow	31.2 ± 22.7	33.8 ± 14.2	.581
		PI	1.48 ± 0.85	1.55 ± 0.74	.220
		GFR	1.65 ± 0.38	1.62 ± 0.29	.131

TTF, Transit-time flowmetry; *PI*, pulsatility index; *GFR*, graft flow reserve; *IABP*, intra-aortic balloon pump; *CABG*, coronary artery bypass grafting; *CPB–CABG*, on-pump myocardial revascularization; *RA*, radial artery; *OM*, obtuse marginals; *RX*: right coronary territory; *OPCABG*, off-pump myocardial revascularization.

in young and elderly patients regardless of the type of target vessel, the surgical technique used (on-pump and off-pump CABG), or the grafting fashion (free graft or Y-graft). Accordingly, perioperative enzymatic leakage and a predischarge echocardiographic finding of a comparable left ventricular functional recovery similarly demonstrated the safety and efficacy of the procedure.

Moreover, according to the demonstration that IABP recruits GFR during assistance,[13] we were able to detect in the subset of patients undergoing preoperative IABP insertion a significant improvement of graft flows and PIs in both elderly and young patients without finding differences when comparing the 2 groups. These comparable GFRs further confirm that arterial grafts in elderly patients show in vivo the same functional behavior as do those in young patients, and because of the predictive value of TTF on angiographic graft patency,[23] this might explain the better results of arterial grafting compared with traditional LITA plus saphenous vein grafting in elderly patients reported by other authors.[1,19-21] Therefore, the potential for GFR evaluation is another tool to be kept in mind in patients undergoing IABP assistance, because it can further explore the accuracy of the anastomosis and the quality of the graft. We now routinely assess flowmetric values during IABP assistance and, compared with those values obtained during temporary IABP discontinuance, when issues on the quality of the surgical result are argued.

Furthermore, a poorer graft quality and anastomotic accuracy caused by a technically more demanding procedure and the learning curve recently have been suggested in OPCABG,[24] with incidence of technical abnormalities of the distal anastomoses as high as 9.9%.[25] Although we have previously reported comparable TTF results in our experience between off-pump and on-pump CABG operations,[14] we confirm here similar findings when isolated RA grafting is considered, further demonstrating that arterial conduits in elderly patients behave as those in young patients, regardless of the surgical technique used.

Finally, the use of the RA has been questioned in subgroups of patients undergoing CABG with risk factors for an accelerated atherosclerosis, such as diabetes and hypertension. Previous studies have reported conflicting results regarding the adverse effect of diabetes on surgical outcomes after arterial CABG, despite the equivocal data resulting from significant differences in the extent of coronary artery disease, adequacy of diabetic control, strategy of conduit selection, and surgical techniques between the studies.[26] According to the recent evidence of comparable early and mid-term results, including graft patency, of arterial grafting in diabetic and nondiabetic patients,[26] our TTF results demonstrated that the in vivo functional properties of these grafts are comparable with those of young patients with the same risk factors. Our data also confirm those by Lorusso and coworkers,[27] showing a significant impairment of the endothelium-dependent vasorelaxation and intimal degeneration of SVGs in diabetic patients not detected in LITA grafts, as well as those of Wendler and associates,[28] who demonstrated comparable in vitro vasoreactivity of LITA and RA grafts in diabetic and nondiabetic patients.

In conclusion, our data show that arterial grafts in the last decades demonstrate the same in vivo functional results as do those in the younger decades, together with a comparable recruitable GFR regardless of the type of arterial conduit, the type of target vessel, and the type of surgical technique used. All these data might explain the reported better results of arterial revascularization in the last decades of life in previously published series, opening the way to routine RA grafting and furthermore avoiding aortic manipulation with the Y-graft technique, allowing early ambulation, and allowing minimally invasive approaches with good clinical and cosmetic results in the growing number of elderly patients nowadays referred to CABG.

The main limitation of the study is related to the relatively small sample size of patients enrolled in the study. This is a result of the single-center design of the study itself, which, on the other hand, guarantees uniformity of the surgical technique and perioperative management of the population throughout the time period considered.

Another limitation is the absence of a systematic angiographic control in the 2 groups. Certainly, when graft function is considered, angiography is still the gold standard method to detect patency; however, it was the aim of the study to detect the acute behavior of arterial grafts in elderly patients compared with young patients, according to the recent demonstration of a good correlation between TTF results and angiographic patency rate. Moreover, a systematic angiographic control, in the absence of angina, raises ethical issues in performing repeat contrast medium injection in the elderly, according to their physiologically reduced glomerular filtration rate. Finally, it has to be considered that a great majority of elderly patients referred for CABG had acute coronary syndromes. Therefore, it is the main interest of the surgeon to save the life of the patient, perhaps with arterial revascularization, which carries the potential for a long-term patency rate.

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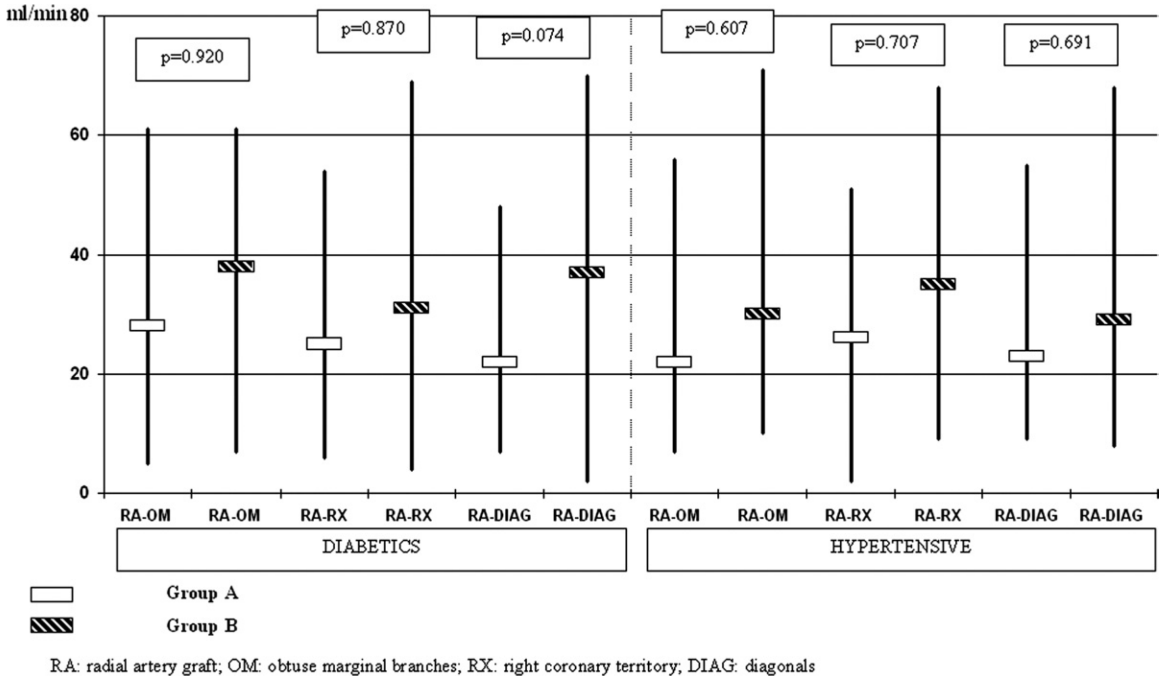

Figure E1. Transit-time flowmetry mean flows in diabetic and hypertensive patients stratified by grafted vessel. *RA*, Radial artery; *OM*, obtuse marginal branches; *RX*, right coronary territory; *DIAG*, diagonals.

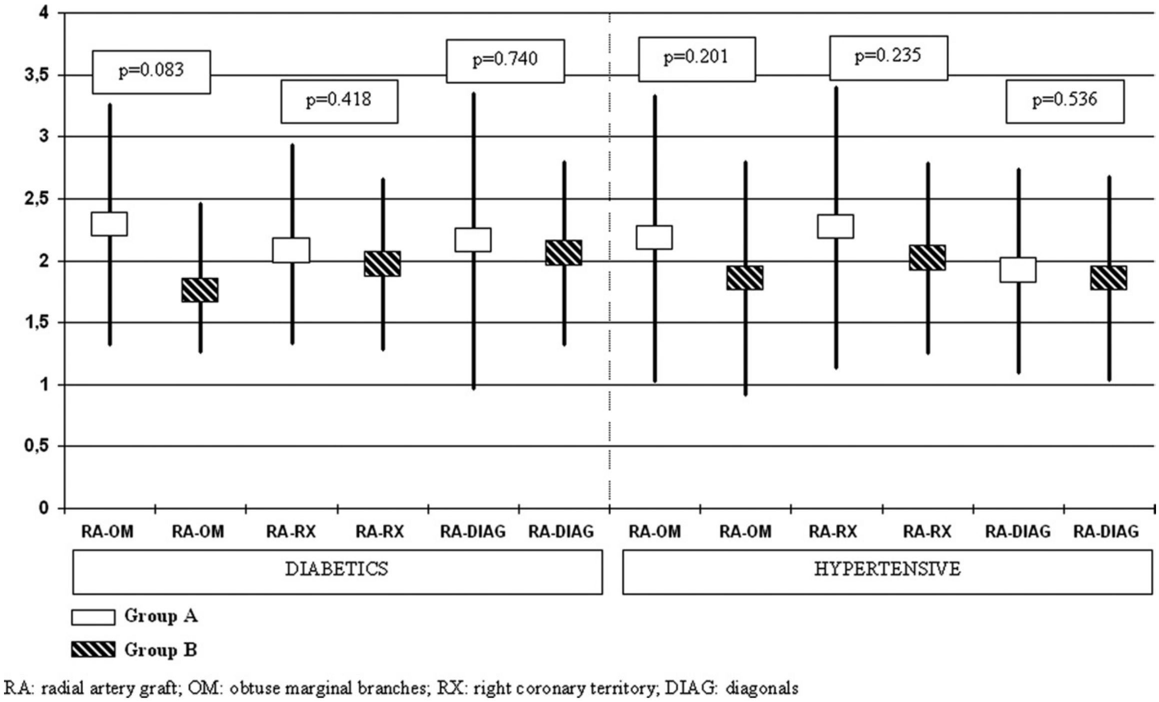

Figure E2. Transit-time flowmetry pulsatility indices in diabetic and hypertensive patients stratified by grafted vessel. *RA*, Radial artery; *OM*, obtuse marginal branches; *RX*, right coronary territory; *DIAG*, diagonals.

Table E1. Demographic and intraoperative data

	Group A (elderly), 65 patients	Group B (young), 53 patients	*P* value
Age (y)	76.7 ± 3.76	51.1 ± 8.42	.0001
Male sex	39 (60.0%)	33 (62.3%)	.476
EuroSCORE (mean ± SD)	5.32 ± 1.97	2.75 ± 1.60	.0001
Diabetes	36 (55.4%)	37 (69.8%)	.078
Hypertension	37 (56.9%)	28 (52.8%)	.398
Dyslipidemia	23 (35.4%)	21 (39.6%)	.388
Acute coronary syndrome	35 (53.8%)	34 (64.2%)	.268
AMI ≤4 wk	23 (35.4%)	25 (47.2%)	.134
Left main stem disease	43 (66.2%)	35 (66.0%)	.571
Preoperative IABP	32 (49.2%)	29 (54.7%)	.342
Preoperative EF <30%	8 (12.3%)	4 (7.5%)	.296
Preoperative EF 31%–49%	41 (63.1%)	38 (71.7%)	.214
Preoperative EF >50%	16 (24.6%)	11 (20.8%)	.393
LAD TIMI score	0.74 ± 0.55	0.72 ± 0.68	.408
CX TIMI score	1.03 ± 0.57	0.98 ± 0.69	.642
DIAG TIMI score	1.07 ± 0.58	1.13 ± 0.63	.395
RX TIMI score	0.84 ± 0.44	0.79 ± 0.67	.573
ACC time (min)	39.4 ± 14.8	38.8 ± 15.9	.842
CPB time (min)	67.1 ± 23.1	72.5 ± 24.9	.230
No. of anastomoses/patient	4.35 ± 0.78	4.26 ± 0.87	.778
LITA	64 (98.5%)	53 (100%)	.551
RITA	12 (18.5%)	13 (24.5%)	.282
Total arterial grafting	8 (12.3%)	11 (20.8%)	.161
Vein grafts/patient	2.41 ± 0.60	2.32 ± 0.72	.116

SD, Standard deviation; *AMI*, acute myocardial infarction; *IABP*, intra-aortic balloon pump; *EF*, left ventricular ejection fraction; *LAD*, left anterior descending artery; *TIMI*, Thrombolysis in Myocardial Infarction; *CX*, circumflex artery; *DIAG*, diagonals; *RX*, right coronary artery; *ACC*, aortic crossclamp; *CPB*, cardiopulmonary bypass; *LITA*, left internal thoracic artery; *RITA*, right internal thoracic artery.

Table E2. Perioperative troponin I and myoglobin leakage

		T0	T1	T2	T3	T4
Troponin I (μg/L)	Group A	0.038 ± 0.060	1.71 ± 1.34	1.72 ± 1.46	1.71 ± 2.24	1.38 ± 2.05
	Group B	0.029 ± 0.056	1.87 ± 0.83	1.80 ± 1.39	1.49 ± 1.73	1.04 ± 1.39
	P value	.369	.120	.107	.544	.060
Myoglobin (ng/mL)	Group A	76.8 ± 67.7	414.8 ± 356	298.8 ± 268.7	269.9 ± 202.1	169.5 ± 136.3
	Group B	72.2 ± 59.5	374.5 ± 345.2	293.6 ± 306.2	294.5 ± 308.5	223.3 ± 206.5
	P value	.561	.526	.628	.630	.102

T0, Preoperative value; *T1*, values at 12 hours postoperatively; *T2*, values at 24 hours postoperatively; *T3*, values at 48 hours postoperatively; *T4*, values at 72 hours postoperatively.