The Radial Artery: Which Place in Coronary Operation?

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Previous long-term studies have shown unsatisfactory patency of saphenous vein grafts, compared with internal mammary artery grafts. Recently, the use of the radial artery as a coronary artery bypass graft has enjoyed a revival, on the basis of the belief that it will help improving long-term results of coronary operations. The recent report of encouraging 5-year patency rates, supports its continued use as a bypass graft. In this paper, we review the current knowledge about the radial artery as a bypass graft, with special emphasis on the clinical results.

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There is increasing interest for the use of the radial artery (RA) as a coronary bypass graft. This is due to the well-documented long-term failure of greater saphenous vein conduits, which is the main cause of reoperation, and is even more common than the progression of native coronary disease [1]. On the other hand, the excellent results obtained with the left internal thoracic artery anastomosed to the left anterior descending coronary artery, which is patent in more than 90% of cases 10 years after operation [2], have added strength to the concept of arterial revascularization, reducing the number of patients presenting for reoperation. As the frequency of patients with already harvested or unavailable saphenous vein grafts has increased, alternative arterial conduits have been sought, and the RA is rapidly regaining popularity because of its length, diameter, and encouraging midterm results [3, 4]. The aim of this paper is to review the data about RA as a coronary bypass graft.

Historical Note

The use of the RA as a graft for coronary revascularization was first introduced in 1975 by Carpentier and associates [5], but at that time, the experience was disappointing because of the high rate of graft failure [6, 7]. This failure was probably due both to the unavailability of antispasmodic drugs, and to the harvest techniques since the role of the preservation of the endothelial function during harvest was unknown at that time [8].

The use of the RA as coronary graft was proposed again in 1992 by Acar and colleagues [9], after the casual finding that some of the grafts implanted in 1972 were still patent 15 years later. Encouraging early patency rates were obtained during this new era, and were ascribed to an improved harvesting technique, together with the use of calcium channel blockers or other vasodilators to prevent perioperative spasm of the graft [10–12]. These reports led many other groups to reassess the role of this conduit in coronary bypass procedures.

Anatomy, Suitability for Harvest, and Pathology of the RA

The RA arises from the brachial artery bifurcation, below the elbow, at the radial tuberosity, and is the more direct continuation of the brachial artery. The other branch of the brachial artery bifurcation, the ulnar artery, which is usually of greater size, takes off at almost a right angle from the parent vessel.

The proximal RA courses underneath the muscle belly of the brachioradialis muscle, and then progressively leaves the lower surface of the muscle, running beneath the antebrachial fascia, between the brachioradialis muscle and the flexor carpi radialis muscle or the flexor carpi radialis tendon. In this area, care has to be taken to spare the lateral antebrachial cutaneous nerve, a branch of muscolocutaneous nerve which lies over the belly of the brachioradial muscle, to avoid postoperative paresthesias to the radial aspect of the volar forearm [13].

The intermediate portion of the RA lies close to the superficial branch of the radial nerve, which lies under the brachioradialis muscle. This nerve must be spared in order to avoid postoperative paresthesias to the thumb and the dorsum of the hand [13]. Near the wrist, the RA becomes superficial, lying anterior to the radius and pronator quadratus muscle, between the tendons of the brachoradialis and the flexor carp radialis muscles.

From its more distal portion, the RA has many

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branches, which anastomose with similar branches of the ulnar artery, providing the vascularization of the hand: (1) the carpal palmar branch anastomoses with a similar branch of the ulnar artery [14]; (2) the superficial palmar branch, together with the main trunk of the ulnar artery, forms the superficial palmar arch, which gives four common digital palmar arteries that bifurcate in proper digital palmar arteries. This arch has a dominant ulnar supply and a small radial end that may be absent in some cases [14]; (3) the dorsal carpal branch, with a similar ulnar branch, forms the dorsal carpal arch, and from this arch, the dorsal metacarpal arteries that anastomose with the deep palmar arch and the corresponding palmar metacarpal arteries arise by perforating branches. Subsequently the dorsal metacarpal arteries bifurcate in the dorsal digital arteries [14]; and (4) the termination of the RA itself anastomoses with the deep palmar branch of the ulnar artery to form the deep palmar arch. This arch has a dominant radial supply, and is slightly more proximal than the superficial arch, lying just beyond the basis of the metacarpals. From its convexity arise the palmar metacarpal arteries that anastomose with the corresponding common digital palmar arteries (superficial arch), and with dorsal metacarpal arteries (dorsal carpal arch) [14].

The rich intercommunication among the branches of the deep, superficial, and dorsal carpal arches allows the vascularization of the hand, in case of RA harvest at the forearm. Various reports on surgical management of forearm vascular trauma suggest that one functional artery, distal to the elbow, is enough for limb viability and vascular function [15, 16].

In fact, the harvest of the RA, which usually begins proximally after the radial recurrent branch, and terminates distally before the origin of the superficial palmar branch, in order to preserve as much collateral circulation as possible [17], is rarely a cause of hand ischemia. This is because the numerous anastomoses between the superficial and deep palmar arches, and dorsal carpal arch, can supplement small or missing branches of the others.

Only the absence, hypoplasia, or atrophy of the ulnar artery, which are rare findings [14, 18], contraindicate RA harvest, even if in these cases, a persistent median or a common interosseous or anterior interosseous artery may supplement or replace the ulnar artery, and may originate the palmar superficial arch or the digital arteries.

It is however, mandatory to assess the adequacy of the ulnar collateral circulation to the hand, before RA harvest. The up-to-date methods employed, include the Allen test [19] and modifications [20, 21], static and dynamic Doppler testing [22], direct digit pressure measurement during RA compression [23], and oxymetric plethysmography, together with the computation of a perfusion index [24]. Concerns with the adequacy of forearm collateral circulation, raised by the preoperative testing method, have excluded RA harvest unilaterally in 5% [12] to 11.6% [20], and bilaterally in 5% [20] to 6.4% [24] of patients who are candidates for RA harvest.

In addition, sometimes the Allen test can be falsely normal, due to the presence of a high origin of the superficial palmar branch, or of an anomalous anterior interosseous artery. In these cases, it is cautious to perform an intraoperative Allen test, with the occlusion of these branches before ligating them [25].

Another anatomical feature, which must be considered when harvesting the RA, is that in about 15% of extremities, the RA may show a high origin, between the axilla and the elbow [18]. In these cases, RA course in the forearm can be more superficial, between the forearm muscles or in the subcutaneous tissue [14], and there is the chance of damage to the median nerve, which in case of origin of the RA directly from the axillary artery, can be immediately deep to the RA in the cubital fossa [18].

With regard to the anatomopathological features, the average RA length suitable for bypass varies between 18 and 22 cm, and its inner diameter varies between 2 and 3 mm [26–28]. The RA is a thick-walled muscular artery. The intima has one layer of endothelial cells beneath, where multiple layers of subendothelial cells, and small amount of myocytes, are present. The internal elastica lamina has multiple fenestrations, and the media is constituted by many leiomyocytes, elastic and collagen fibers, fibroblasts, and rare macrophages. The external elastic lamina is less individualized than the internal lamina. Some evidence suggests that the vasa vasorum, nerves, and lymphatic vessels are confined to the adventitia, and do not join the medial layer within the structure of the adventitia [29], while others describe vasa vasorum penetration into RA media. This may theoretically cause some degree of hypoxia after the RA harvest [30].

With respect to the internal thoracic artery, the RA is a greater in size, has a thicker wall, and a higher density of muscle cells with the same amount of elastic tissue in its media [27]. Moreover, in the RA, the myocytes are organized in to multiple tight layers, while in the internal thoracic artery, the muscle cells are less organized and irregular in shape, and this, together with the wider thickness of the media, may at least in part explain the propensity of the RA to spasm [29].

Finally, it has been reported that the RA has a low prevalence of atherosclerosis [31]. However, comparative studies among arterial conduits used in myocardial revascularization have shown that the RA has a slightly higher degree of atherosclerosis than the internal thoracic artery, which also seems to be more resistant to the development of atherosclerosis, in the presence of vascular disease risk factors [29, 32, 33]. This slightly higher propensity of the RA to atherosclerosis usually does not impair RA flow, because of its relatively large diameter. Moreover, the RA is more subject to the chance of previous iatrogenous vascular trauma. The inability to use the RA because of severe calcification of this artery, or chronic dissection of the RA from prior cannulation, is a relatively rare event, occuring in only about 1% to 2% of candidates for RA harvest [34].

Table 1. Antispasmodic Drug Regimens for Radial Artery Graft Operation

Drug	Loading Dose	Maintenance Dose	Reference
Diltiazem	0.15 to 0.25 mg/kg	1 μg/kg/min, until able to take oral medications	[9]
	0.10 to 0.15 mg/kg	0.25 to 0.50 μg/kg/min, until able to take oral medications	[24]
		4 mg/hour after aorta unclamping, until the 1st postoperative day	[12]
Milrinone	25 μg/kg after aorta unclamping	0.2 μg/kg/min, until extubation	[25]
Nifedipine		10 mg every 6 hours sublingually for 24 hours, then 30 mg orally	[41]
Nitroglycerin		0.5 to 1.0 μg/kg/min for 24 hours	[34]

Biology and Spasm of the RA

It is well-known that the biological features of the grafts, usually employed in coronary operation, may affect their long-term performance, in particular the endothelial function, which may sensibly affect the patency rate [8].

Early reports emphasized the high propensity of the RA to spasm [35], even though this phenomenon has also been reported in other arterial grafts, and the real incidence in the various conduits is still debated [36, 37]. Spasm has also been described in greater saphenous veins as well [38]. There are different hypotheses regarding the mechanisms underlying arterial graft and RA spasm, varying from endothelial trauma related to harvest [39], impaired vasomotor function due to coexistent systemic disease [39], and differing arterial graft endothelial function properties [40]. The advent of less traumatic RA harvesting techniques has significantly reduced the chance of endothelial trauma to this graft. It is commonly agreed upon that RA harvest must be performed with gentle mobilization of the RA, with light tractions, minimal touch, and minimal diathermy. Mechanical or hydrostatical dilation of the graft should be avoided, and the RA should only be flushed with a mixture of heparinized blood and papaverine [13, 24, 25].

The propensity of the RA to spasm has greatly been reduced using both topically and systemically different categories of vasodilators, including calcium channel blockers [9, 13, 41], papaverine [42], the phosphodiesterase inhibitor milrinone [25], and drug mixtures such as verapamil and nitroglycerin [43], or verapamil and papaverine [28]. Recent experimental evidence suggests that diltiazem and verapamil may have little effect in preventing both receptor-dependent and receptor-independent RA contractions, while organic nitrates and nifedipine seem to be more effective in inhibiting and reversing RA contractions [44]. Table 1 reports some of the intravenous antispasmodic drug administration protocols currently adopted.

It has recently been shown that adenoviral-mediated gene transfer, causing overexpression of nitric oxide synthase in human RAs, can minimize RA vasospasm through the inhibition of both voltage-dependent and receptor-dependent pathways [44], suggesting a possible future clinical application of gene therapy in the prevention of RA spasm.

Concern still exists however, for the theoretical possibility of RA spasm, and for that reason various studies have focused on the biological properties of this conduit in order to investigate the basis of this phenomenon.

It has been shown that the endothelial function of the RA, as it releases endothelium-derived relaxing factors in response to endogenous and exogenous agents, is similar to that of other arteries. Significant basal and stimulated nitric oxide release have been reported in vivo [45], as well as maximal relaxation of the RA after acetylcholine administration [46]. Some comparative studies have shown that both endothelium-dependent and endothelium-independent vasorelaxation were similar to that of the internal thoracic artery [47], and that sensitivity to vasoconstricting agents like norepinephrine and serotonin was also similar [36].

On the other hand, it has been shown that, despite similar endothelial function, the RA can develop significantly higher maximal contractile force to vasoconstricting agents such as norepinephrine, serotonin, endothelin-I, and angiotensin II [36, 47], or to depolarizing agents such as potassium, with respect to the internal thoracic artery. This can be explained by the more muscular nature of this graft, which has a considerably thicker media, with respect to internal thoracic, gastroepiploic, and epigastric arteries, which are the usual conduits for arterial myocardial revascularization [29].

From the aforementioned data, it is suggested that the differences between the RA and internal thoracic artery are mainly related to histological features, and in particular, to the muscle cell population of the media and intima. This may affect the contractile properties of the graft, while the endothelial function seems to be very similar to that of the internal thoracic artery, and could be the basis for a more than satisfactory long-term patency. Because of these features, modulation of the RA graft with antispasmodic drugs of the RA graft contractile properties seems to be mandatory, especially in the early perioperative period, in order to avoid perioperative spasm, and possible failure of the graft.

Review of Recent Clinical Experience Concerning the Use of the RA as a Bypass Graft

We have reviewed recent use of the RA as coronary artery bypass graft by analyzing papers published in Medline-indexed journals between 1992 and 1998, in order to summarize current knowledge of conduit, with

Table 2. Anastomotic Sites of Radial Artery Graft

Year	Author	Patients	RA Grafts[a]	Distal Anastomoses[b]	LAD	CX	RCA
1992	Acar [9]	104	122 (1, 2)	122 (1, 2)	36 (29.5%)	59 (48.4%)	27 (22.1%)
1993	Acar [55]	158	189 (1, 2)	189 (1, 2)	49 (25.9%)	93 (49.2%)	47 (24.9%)
1993	Hoffman [56]	46	46 (1, 0)	46 (1, 0)	11 (23.9%)	22 (47.8%)	13 (28.3%)
1995	Calafiore [12]	?	161 (1, 1)	188 (1, 3)	32 (25.0%)	122 (64.9%)	34 (10.1%)
1995	Calafiore [53]	148	152 (1, 0)	184 (1, 2)	32 (17.4%)	113 (61.4%)	39 (21.2%)
1995	Dietl [42]	165	166 (1, 0)	226 (1, 4)	32 (14.2%)	178 (78.8%)	16 (7.0%)
1995	Fremes [28]	50	51 (1, 0)	51 (1, 0)	5 (9.8%)	34 (66.7%)	12 (23.5%)
1996	Brodman [24]	175	226 (1, 3)	264 (1, 5)	49 (18.6%)	146 (55.3%)	69 (26.1%)
1996	Brodman [51]	197	261 (1, 3)	311 (1, 6)	55 (17.7%)	169 (54.3%)	87 (28.0%)
1996	Chen [10]	60	94 (1, 6)	94 (1, 6)	28 (29.8%)	45 (47.9%)	21 (22.3%)
1996	Da Costa [40]	83	84 (1, 0)	99 (1, 2)	32 (32.3%)	47 (47.5%)	20 (20.2%)
1996	Manasse [52]	109	110 (1, 0)	121 (1, 1)	22 (18.2%)	74 (61.2%)	25 (20.6%)
1998	Acar [4]	102	122 (1, 2)	NA	NA (20.0%)	NA (51.0%)	NA (29.0%)
1998	Possati [3]	68	74 (1, 1)	74 (1, 1)	11 (14.9%)	43 (58.1%)	20 (27.0%)
1998	Tatoulis [34]	261	522 (2, 0)	594 (2, 3)	50 (8.4%)	281 (47.3%)	263 (44.3%)

[a] Average number of RA grafts per patient in parentheses. [b] Average number of distal anastomoses with the RA graft in parentheses.
CX = circumflex artery; LAD = left anterior descending artery; NA = not available; RA = radial artery; RCA = right coronary artery.

special emphasis on surgical strategies and postoperative results [3, 4, 9–12, 17, 20, 24, 25, 28, 34, 41, 42, 48–57].

Operative Strategies

The current indication in the use of the RA as a coronary graft is to supplement the internal thoracic artery in achieving complete arterial coronary revascularization [24], and, for that reason, the usual targets for this conduit are the right and circumflex arteries, and their branches (Table 2). Less frequently, the RA is used to revascularize some diagonal branches or the ramus intermedius. Finally, only when the mammary arteries are not suitable, the RA is anastomosed to the left anterior descending coronary artery [3, 4, 24, 34].

The majority of groups perform the RA harvest only on the nondominant upper limb, usually the left allowing simultaneous harvest of the RA and of the left internal thoracic artery [3, 9, 52]. Other authors, however, show no reluctance to also harvest the RA from the dominant upper limb [17, 20], and some groups have already described routine bilateral harvest of the RA [24, 34].

Sometimes a RA of adequate length can be divided into two segments, in order to obtain two separate grafts [9, 20, 24], or it can be used to perform multiple distal anastomoses in a sequential fashion [11, 50].

There is still some debate on how to locate the proximal anastomosis of the RA, even if, in most cases, the majority of the groups prefer to anastomose the RA to the ascending aorta [9, 11, 34, 42, 52]. There is a consistent group of surgeons who suggest that the optimal method for proximal anastomosis is to perform a composite arterial graft with the RA coming off the left internal thoracic artery [12, 17, 50, 53, 54]. However, as reported patency rates are similar in both cases, it is suggested that performing proximal anastomosis on the ascending aorta should be the preferred method, because it is less technically demanding with respect to composite arterial grafting. In some selected cases, the RA can also be proximally anastomosed to a saphenous vein graft [12, 28, 53, 54], to the right internal thoracic artery [12, 17, 53, 54], to another radial artery graft [34], to the innominate artery [52], or to another coronary artery, as a coronary to coronary bypass graft [58, 59].

Early Results

Early average patency rate (within 6 months), and perfect patency rate of the RA are 98.1% (627 of 639) and 90.8% (474 of 522), respectively (Table 3).

The use of the RA in coronary operation does not seem to increase the rate of main postoperative complications, as reported in Table 4. Briefly, myocardial infarction rates in the published series vary between 0% [17, 20] and 4.0%

Table 3. Early Patency Rates of the Radial Artery Graft

Year	Author	RA Grafts Assessed	Patent RA Grafts	Perfectly Patent RA Grafts
1992	Acar [9]	56	56 (100%)	50 (89.3%)
1993	Acar [55]	73	73 (100%)	67 (91.8%)
1993	Hoffman [56]	46	46 (100%)	42 (91.3%)
1994	Calafiore [54]	26	26 (100%)	26 (100%)
1995	Calafiore [12]	76	75 (98.7%)	NA
1995	Calafiore [53]	41	41 (100%)	NA
1996	Barner [17]	13	10 (76.9%)	10 (76.9%)
1996	Brodman [24]	89	87 (97.8%)	86 (96.6%)
1996	Chen [10]	94	90 (95.7%)	86 (95.5%)
1996	Da Costa [40]	61	59 (96.7%)	53 (86.9%)
1996	Manasse [52]	18	18 (100%)	11 (61.1%)
1997	Weinschelbaum [50]	46	46 (100%)	43 (93.5%)

NA = not available; RA = radial artery.

Table 4. Perioperative Complications of Radial Artery Grafting

Year	Author	Patients	In-hospital Death	AMI	Low-Output Syndrome	Reexploration for Bleeding	Minor Hand Complications
1992	Acar et al [9]	104	1 (0.9%)	2 (1.9%)	5 (4.8%)	0 (0%)	8 (7.6%)
1993	Acar et al [55]	158	2 (1.3%)	3 (1.8%)	10 (6.3%)	NA	11 (7.0%)
1995	Calafiore et al [53]	148	2 (1.4%)	3 (2.0%)	3 (2.0%)	2 (1.4%)	1 (0.7%)
1995	Dietl and Benoit [42]	165	5 (3.0%)	9 (5.5%)	NA	NA	3 (1.8%)
1995	Fremes et al [28]	50	0 (0%)	0 (0%)	3 (6.5%)	3 (1.8%)	0 (0%)
1996	Barner and Johnson [17]	172	0 (0%)	5 (2.9%)	6 (3.4%)	2 (1.2%)	NA
1996	Barner [20]	377	0 (0.0%)	9 (2.4%)	5 (1.3%)	5 (1.3%)	11 (3.0%)
1996	Brodman et al [24]	175	3 (1.7%)	2 (1.1%)	NA	NA	7 (4.2%)
1996	Da Costa et al [11]	83	4 (4.8%)	3 (3.6%)	6 (7.2%)	2 (2.4%)	3 (3.6%)
1996	Manasse et al [52]	109	2 (1.9%)	4 (3.6%)	0 (0%)	2 (1.9%)	5 (4.7%)
1997	Buxton et al [25]	757	6 (0.9%)	6 (0.9%)	7 (0.9%)	NA	0 (0%)
1997	Gurevitch et al [49]	33	1 (3.0%)	1 (3.0%)	1 (3.0%)	0 (0%)	0 (0%)
1997	Shapira et al [61]	138	0 (0%)	0 (0%)	1 (0.7%)	0 (0%)	6 (4.0%)
1997	Weinschelbaum et al [50]	164	3 (1.8%)	3 (1.8%)	4 (2.4%)	NA	32 (19.6%)
1998	Sudhakar et al [48]	200	2 (1.0%)	8 (4.0%)	NA	NA	6 (3.0%)
1998	Tatoulis et al [34]	261	2 (0.8%)	2 (0.8%)	NA	1 (0.4%)	4 (1.6%)

AMI = acute myocardial infarction; NA = not available.

[48] to 5.5% [42], and myocardial infarction has been reported in the territory of the RA graft in no more of one third of these cases. The rates of in-hospital mortality reported in the series, using the RA are within the usual range for primary coronary operation, ranging between 0.8% [34] and 3.0% [42, 49] to 4.8% [11].

A recent paper from the University of Toronto has analyzed the outcomes in patients who underwent coronary artery bypass grafting between 1989 and 1996 at their institution. They retrospectively compared 2333 patients who underwent operation with the use of 1 arterial graft (internal thoracic artery), with patients who, during the same time period, received bilateral internal thoracic arteries (n = 378) or left internal thoracic artery plus the RA (n = 171), documenting, within the limits of a retrospective nonrandomized study, that the use of two arterial grafts is associated with lower mortality and morbidity rates. Moreover, when assessing the outcomes of the two patient groups, receiving two arterial grafts (bilateral mammary grafts versus left internal thoracic artery plus RA), there was no difference in perioperative mortality or cardiac morbidity rates, despite an higher risk factor incidence in patients receiving a RA graft as a second arterial graft. Finally, patients who received the RA graft had a lower incidence of sternal wound infection, and a trend toward reduced transfusion requirements compared with patients who underwent operation with the use of bilateral thoracic arteries [41].

Complications related to RA harvest are usually very low, and postoperative acute hand ischemia after RA harvest is a rare event whichever method is used for the assessment of collateral circulation. In fact, most of the previous reports could not document a postoperative case of hand ischemia, and only 1 case of acute hand ischemia, due to congenital absence of the ulnar artery, has been described after harvest of the RA [60], to our knowledge.

In this surgical series, no cases of compartment syndrome were reported, and only 1 case of upper limb motor loss, due to surgical lesion of a forearm peripheral nerve, was reported [34]. The incidence of dysesthesias of the forearm and the hand, the most frequent upper limb complications, was under 10% [11, 17, 24, 48, 52] and, in most cases, these sensitive symptoms disappeared completely within days or weeks. The occurrence of forearm surgical wound infection was a rare event [42], as well as the development of forearm hematoma, which happened in less than 4% of patients [34, 42, 48, 50].

Follow-up Studies

The average angiographic RA graft patency rates at midterm (6 to 36 months) were 93.3% (280 of 300) for overall patency rates, and 78.8% (186 of 233) for perfect patency rates (Table 5). Encouraging 5-year RA patency rates RA have recently been reported by two different

Table 5. Midterm Angiographic Studies of the Radial Artery Graft

Year	Author	RA Grafts Assessed	Patent RA Grafts	Perfectly Patent RA Grafts
1992	Acar et al [9]	31	29 (93.5%)	28 (90.3%)
1993	Acar et al [55]	46	42 (91.3%)	41 (89.1%)
1994	Calafiore et al [54]	17	16 (94.1%)	16 (94.1%)
1995	Calafiore et al [12]	35	33 (94.3%)	NA
1995	Calafiore et al [53]	32	30 (93.7%)	NA
1996	Da Costa et al [11]	12	12 (100%)	12 (100%)
1996	Manasse et al [52]	57	55 (96.5%)	37 (64.9%)
1998	Possati et al [3]	48	42 (87.5%)	32 (66.7%)
1998	Sudhakar et al [48]	6	6 (100%)	6 (100%)
1998	Tatoulis et al [34]	16	15 (93.7%)	14 (87.5%)

NA = not available; RA = radial artery.

groups, with overall patency rates of 84.4% [4] and 91.9% [3], respectively, and perfect patency rates of 82.8% [4] and 87.1% [3], respectively. Interestingly, both groups report that in a small percentage of cases, the midterm control showed a perfect angiographic result, whereas at short-term, a narrowing of the same RA graft was detected.

Finally, Possati and colleagues report that a Doppler study of the vascularization of the forearm, performed 5 years after operation, can document that removal of the RA could be completely compensated for by an anastomotic network of the ulnar artery in all patients. The only complication related to RA harvest, which was present at 5 years follow-up, was the presence of a very slight paresthesias to the hand in one fourth of patients, while three fourths of patients were completely asymptomatic [3].

Comment

The favorable results summarized in this review indicate that the RA can be used successfully in coronary operation, and is rapidly becoming the second choice for arterial grafting, after the internal thoracic artery, because of ease in dissection and handling and because of minor harvesting complications, which do not hinder forearm blood flow.

The collateral flow to the hand which is almost constantly furnished by the ulnar artery through the palmar arches, and the low incidence of atherosclerosis on the native vessel, support RA grafting within a large spectrum of age. Correct preoperative assessment of the adequacy of the ulnar collateral circulation is critical in avoiding ischemic complications to the forearm and the hand.

The use of the RA can help to expand complete arterial myocardial revascularizations, and moreover, its morphometric features allow it to reach virtually any coronary artery, to perform multiple distal anastomoses in sequential fashion, and sometimes to obtain two separate grafts by dividing one RA of adequate length. It has also been shown that it is possible to construct composite arterial conduits by proximally anastomosing the RA to the internal thoracic arteries.

The recent evidence regarding 5-years patency rates, supports the use of the RA as the second arterial graft, after the internal thoracic arteries, and we can expect that in future years further data will add strength to the use of the RA graft.

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