Chronic compensatory increase in ulnar flow and accelerated atherosclerosis after radial artery removal for coronary artery bypass

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Background: Only scant information is available on the chronic consequences of radial artery removal for coronary artery bypass surgery on forearm circulation.

Methods: Twenty-five patients submitted to radial artery removal for coronary artery bypass were submitted to serial Doppler echocardiographic evaluation of the flow and morphology of the forearm arteries.

Results: The peak systolic velocity of the ulnar artery of the operated side was significantly higher than that of the control site. The intimal-medial thickness of the ulnar artery was always significantly higher on the operated side, and this difference reached statistical significance at 10 years' follow-up. There was a significantly higher prevalence of atherosclerotic plaques in the ulnar artery of the operated versus control arm (7/25 vs 0/25, $P = .03$).

Conclusion: Radial artery removal for coronary artery bypass surgery leads to a chronic increase in ulnar flow accompanied by increased intimal-medial thickness and accelerated atherosclerotic disease. These findings might have potentially important implications for surgical indications and patient management.

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The radial artery (RA) is gaining increasing popularity as an alternative arterial conduit for surgical myocardial revascularization, and several groups have reported excellent clinical and angiographic midterm to long-term results with this conduit.^{1,2} However, removal of the RA cuts forearm blood supply in half, leaving it completely dependent on the collateral circulation from the ulnar artery (UA).

Although acute ischemic forearm complications caused by insufficient ulnar flow have been minimized with the adoption of various methods of preoperative assessment of the adequacy of UA compensation,³⁻⁶ only scant information is available on the long-term consequences of RA removal on the forearm circulation,⁷ and no data on the effect of the long-term flow increase on the UA have to date been reported.

This study examines the midterm to long-term modifications of UA flow and structure in a series of 25 nonconsecutive patients at a mean interval of 10 years after RA removal for coronary artery bypass grafting.

TABLE 1. Main preoperative and intraoperative features of the patients

Variable	Value
Male/female ratio	16/9
Mean age (y)	58.4 ± 5.3
Cardiac risk factors	
Diabetes	5
Smoking	9
Dyslipidemia	6
Hypertension	5
Previous myocardial infarction	11
Mean ejection fraction	0.65 ± 0.18
Target RA vessel	
Obtuse marginal	13
Diagonal	4
Posterior descending	8

RA, Radial artery.

Patients and Methods

Patient Population

Our institutional experience with the use of the RA as a coronary artery bypass conduit started in 1993; a detailed description of the operative technique used in the operation, perioperative management, follow-up methods, and midterm to long-term clinical and angiographic results has been previously published.^{1,6-10}

Bilateral RA harvesting was never performed in our series, and the artery was always harvested from the nondominant arm.⁸

This study includes the first 25 nonconsecutive patients who have reached the 10-year follow-up point at the time of enrollment and agreed to forearm examination. All these patients had already undergone a similar study protocol 5 years after the operation, and detailed results of that study have been published.⁷ The main clinical data of these cases are depicted in Table 1.

Doppler Echocardiographic Evaluation

Doppler echocardiographic evaluation was performed according to a previously described method.^{6,7} The peak systolic velocity, end-diastolic velocity, resistance index, time average mean velocity (in meters per second), and the diameter and intimal-medial thickness (IMT) of the brachial artery and the UA and RA on the nonoperated arm were calculated. The time average mean velocity was defined as the area between the line traced on the Doppler wave and the baseline, and represents the mean velocity corrected for the duration of the velocity curve, as electronically calculated by the computer, by tracing the area of the curve.

Echogenic foci in the arterial wall with posterior acoustic shadowing were recorded as calcification. Those without posterior acoustic shadowing were recorded as atherosclerotic plaques. Stenosis was defined as a focal increase in peak systolic velocity compared with that seen in the proximal arterial segment.

Statistical Analysis

Data are expressed as means ± 1 standard deviation. For statistical analysis, the paired and unpaired *t* test was used.

TABLE 2. Ten-year Doppler echocardiographic results

	Control arm	Operated arm	P value
Brachial artery			
PSV (m/s)	0.60 ± 0.14	0.69 ± 0.18	.13
EDV (m/s)	0.02 ± 0.02	0.02 ± 0.04	.62
TAMV (m/s)	0.12 ± 0.05	0.13 ± 0.06	.62
RI	0.98 ± 0.04	0.97 ± 0.05	.80
IMT (mm)	0.53 ± 0.12	0.54 ± 0.16	.89
Diameter (mm)	4.72 ± 0.50	4.48 ± 0.66	.27
Radial artery			
PSV (m/s)	0.55 ± 0.21	—	—
EDV (m/s)	0.05 ± 0.06	—	—
TAMV (m/s)	0.14 ± 0.09	—	—
RI	0.92 ± 0.09	—	—
IMT (mm)	0.46 ± 0.12	—	—
Diameter (mm)	2.46 ± 0.38	—	—
Ulnar artery			
PSV (m/s)	0.45 ± 0.14	0.77 ± 0.31	.001
EDV (m/s)	0.03 ± 0.04	0.07 ± 0.07	.11
TAMV (m/s)	0.11 ± 0.06	0.21 ± 0.11	.004
RI	0.92 ± 0.09	0.92 ± 0.08	.94
IMT (mm)	0.43 ± 0.11	0.57 ± 0.22	.02
Diameter (mm)	2.25 ± 0.58	2.40 ± 0.53	.47

Values are presented as means ± standard deviation. PSV, Peak systolic velocity; EDV, end-diastolic velocity; TAMV, time average mean velocity; IMT, intimal-medial thickness; RI, resistance index [(PSV – EDV)/PSV].

Results

No patient reported having forearm ischemic symptoms at any time during the follow-up.

Detailed results of the Doppler echocardiographic examination are summarized in Table 2. The peak systolic velocity of the UA of the operated side was higher than that of the control arm, testifying to the ulnar compensation to RA removal. The IMT of the UA was always significantly higher on the operated side, and this difference reached statistical significance at 10 years' follow-up (Table 2 and Figure 1). Moreover, there was a significantly higher prevalence of atherosclerotic plaques in the UA of the operated versus control arm (7/25 vs 0/25, *P* = .03; Figure 2), whereas no difference in atherosclerotic involvement was found between the brachial arteries of the 2 sides (2/25 vs 1/25, *P* = .97).

Discussion

The reintroduction of the RA in coronary artery surgery in the early 1990s was accompanied by major theoretical concerns related to both the intrinsic characteristics of this artery and the consequences of RA removal on the forearm blood supply.^{11,12}

Actually, the good clinical and angiographic results reported have ruled out the perplexities related to the long-term durability of this conduit,^{1,2} and the immediate consequences of RA harvesting on the forearm blood supply and the methods to minimize the incidence of acute hand is-

Figure 1. Variations of IMT with time in the operated versus control arm.

chemia have been clearly established.³⁻⁶ However, to date, only limited information is available on the long-term modifications of the forearm vasculature and circulation after RA harvesting.

After RA removal, the forearm blood supply becomes totally dependent on the UA. This compensation leads to the significant increase in flow of the UA of the operated site that is evident from the early postoperative period and, according to our data, remains unchanged at 5 and 10 years of follow-up.⁷

Surprisingly, we found that in the years after surgical intervention, the IMT of the UA of the operated arm become progressively higher than that of the control side (Table 2). This difference was already evident at midterm follow-up and increased until reaching significance in the successive years (Figure 1).

Although it is not possible to exclude that the increase in IMT is the result of a remodeling of the arterial wall of the UA in response to the chronic flow increase without any

detrimental consequences, the alarmingly high incidence of overt atherosclerosis reported in the UAs of the operated side seems to deny this favorable hypothesis and to suggest that the UA of the operated arm is more susceptible to the development of atherosclerosis compared with the nonoperated site (Table 2). This observation is concordant with the reported value of IMT as a marker of early atherosclerosis in other vascular districts.¹³⁻¹⁵

These findings remain to be confirmed in the longer term and in studies with larger sample sizes but open a new and alarming perspective on the possible chronic ischemic consequences of RA removal on the forearm circulation.

For the moment, our data must be kept in mind when selecting the appropriate arterial conduits for surgical myocardial revascularization and have particular relevance in young patients with a long life expectancy (to whom total arterial coronary revascularization is most often offered).

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Figure 2. Atherosclerotic plaques in the UA of the operated arm 10 years after surgical intervention.

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