EARLY POSTOPERATIVE ANGIOGRAPHIC ASSESSMENT OF RADIAL ARTERY GRAFTS USED FOR CORONARY ARTERY BYPASS GRAFTING

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Despite a revival of interest in using the radial artery as an alternative conduit for myocardial revascularization, little angiographic documentation of early postoperative results has been presented, particularly in North America. Accordingly, 60 of 150 patients who underwent coronary artery bypass with radial arteries from November 1993 to July 1995 have had postoperative cardiac catheterization at our institution. The patency rate of the radial artery grafts was 95.7% (90 of 94 grafts patent) with an average internal diameter of 2.51 mm. Four radial artery grafts showed diffuse narrowing. The patency rate of the internal thoracic artery grafts was 100% with an average internal diameter of 2.25 mm. Three of 62 grafts demonstrated diffuse narrowing. Two of 24 (7.7%) saphenous vein grafts were occluded; the average internal diameter was 3.23 mm. The internal thoracic artery, the radial artery, and saphenous vein grafts were, respectively, 7.5%, 19.5%, and 53.3% larger than the anastomosed native coronary arteries. Graft-dependent flow was found in 81.1% of the radial artery grafts. ***Conclusion:*** **The results of this study demonstrate that the short-term patency rate of radial artery grafts is excellent. (J Thorac Cardiovasc Surg 1996;111:1208-12)**

The internal thoracic artery (ITA) provides excellent long-term patency rates when used as a coronary artery bypass graft (CABG).[1, 2] Because the long-term results with the ITA are superior to those obtained with saphenous vein grafts (SVGs),[3-5] recent attention has focused on determining appropriate alternative arterial grafts, including the inferior epigastric artery,[6] gastroepiploic artery,[7, 8] and radial artery.[9-11] Literature from the current surgical era describing postoperative angiographic studies after use of the radial artery in CABG is limited.[9-11] Routine use of radial artery conduits for CABG began in our institution in November 1993. This article reports our preliminary results of early postoperative angiographic findings in 60 of 150 patients who received radial artery bypass conduits.

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Patients and methods

Routine use of the radial artery as a conduit for CABG began at our institution in November 1993; bilateral harvesting began in May 1994 (institutional review board approval, June 1993, No. 1199304107). All patients referred for CABG to a single surgeon (R.B.) were evaluated for eligibility and safety of radial artery harvest. All patients signed informed consent forms before the operation. A total of 150 patients through July 1995 enrolled in the program. A total of 484 distal anastomoses were performed, with 241 distal anastomoses fashioned with the radial artery graft for the 150 patients. The technique used to harvest and prepare the radial artery for CABG was described by Reyes, Frame, and Brodman.[12] The ascending aorta was used for the proximal anastomoses except when a radial artery segment was used as a Y graft to either another radial artery or the left ITA.

At the time of enrollment into the protocol, all patients were informed of the postoperative follow-up procedures. Some patients were excluded from postoperative cardiac catheterization because of medical reasons (including prior adverse reaction to catheterization, severe peripheral arterial disease, or prior cerebral vascular accidents). Other patients refused to consent to the catheterization. Thus postoperative cardiac catheterization was performed

Table I. *Preoperative clinical characteristics from November 1993 to July 1994*

Patient characteristics	*No*	*Percent*
Total	60	100.0
Gender		
Male	48	80.0
Female	12	20.0
Age (yr)	57.6 ± 9.4	
Preoperative clinical findings		
Coronary artery disease		
Single vessel disease	2	3.3
Double vessel disease	26	43.3
Triple vessel disease	32	53.3
Diabetes mellitus	22	43.3
Type I	9	40.9
Type II	13	59.1
Diet controlled	3	23.1
Oral agents	9	69.2
Unknown	1	7.7
Hypertension	35	58.3
Family history of CAD	35	58.3
Smoking history	38	63.3
Hypercholesterolemia	35	58.3

CAD, Coronary artery disease.

in 60 patients a mean of 11.6 ± 7.8 weeks after the operation (range 1 day to 38 weeks). All patients were pretreated with nitroglycerin (1/150 gr sublingually) and nifedipine (10 mg sublingually; Procardia, Pratt Pharmaceuticals, New York, N.Y.) 30 minutes before the start of cardiac catheterization. Preoperative clinical characteristics of the 60 patients are shown in Table I. Table II indicates the coronary arteries grafted; an average of 3.1 distal anastomoses was performed (range 2 to 5). A total of 182 grafts (94 radial artery grafts, 62 ITA grafts, and 26 SVGs) from 60 patients were reviewed and constitute this report.

Postoperative angiograms were analyzed by means of the methods described by Nakao and Kawaue[8] in their study of the gastroepiploic artery. Calipers were used to measure the graft diameters of the angiographic images projected directly onto the Tagarno screen (Tagarno-35 AX, Horsens, Denmark). The measurements were compared with the measured diameters of the angiographic catheters (sizes 6F, 7F, and 8F). Because the actual diameter of each catheter was known, the ratio of the measured catheter diameter to the actual catheter diameter was used to calculate the diameter of each graft.

Each catheter was measured at a site 4 cm from the distal tip. Each free graft (radial artery and SVG) was measured in three sites divided equally along the entire length of the graft (Fig. 1). The ITA pedicled grafts were measured at three locations near their anastomotic sites. Native coronary arteries were measured approximately 1 cm distal to the anastomoses. The measurements for each graft and coronary artery were calculated, averaged, and recorded generally for the right anterior oblique and the left anterior oblique angiographic views. The values from these two views were then averaged and recorded as the actual diameters of the vessels. All measurements were taken at the beginning of the QRS complex.

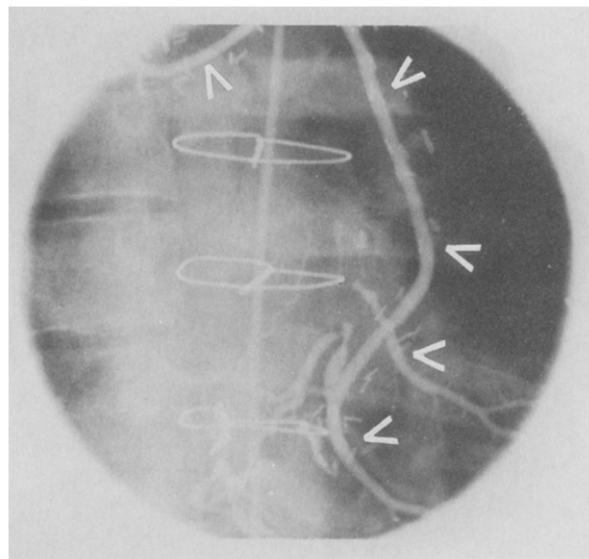

Fig. 1. Postoperative angiogram of free radial artery graft to two obtuse marginal arteries. *Arrows* indicate where measurements were taken.

Table II. *Anastomotic sites of the radial artery graft*

Site	*No. of anastomoses*
LCA	73
LAD	5
D_1	13
D_2	9
D_3	1
OM_1	29
OM_2	13
OM_3	2
OM_4	1
RCA	21
Main	12
PDA	7
PLVB	2

LCA, Left coronary artery; *LAD,* left anterior descending artery; D_1, first diagonal artery branch; D_2, second diagonal; D_3, third diagonal; OM_1, first branch of obtuse marginal artery; OM_2, second branch of obtuse marginal; OM_3, third branch of obtuse marginal; OM_4, fourth branch of obtuse marginal; *RCA,* right coronary artery; *PDA,* posterior descending artery; *PLVB,* posterior left ventricular branch.

The graft/native coronary artery size discrepancy ratio (SDR) was calculated as follows:

$$\text{SDR} = \frac{(\text{Graft size} - \text{Native artery size})}{\text{Native artery size}} \times 100\%$$

Therefore, a *positive* size discrepancy ratio indicates a graft *larger* than the anastomosed native coronary artery, whereas a *negative* ratio indicates a graft *smaller* than the native artery.

The flow characteristics of the grafts were divided into three categories: graft-dependent flow, graft–native artery

Table III. *Graft size distribution*

Size range (mm)	No. of grafts in range					
	RA		*ITA*		*SVG*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
0.00-1.00	2	0	0	0	0	0
1.01-1.50	2	0	2	1	0	0
1.51-2.00	5	3	8	4	1	0
2.01-2.50	28	5	26	7	0	0
2.51-3.00	24	9	12	0	4	1
3.01-3.50	7	0	1	0	10	1
3.51-4.00	2	2	1	0	6	0
4.01-4.50	1	0	0	0	1	0
Occluded	2	2	0	0	2	0
Total	73	21	50	12	24	2

RA, Radial artery; *ITA,* internal thoracic artery; *SVG,* saphenous vein graft.

Table IV. *Flow characteristics*

Flow type	*RA*		*ITA*		*SVG*	
	No	*%*	*No*	*%*	*No*	*%*
Graft dependent	73	77.3	38	61.3	22	84.6
Graft-native balanced	13	13.8	21	33.9	2	7.7
Native dependent	4	4.3	3	4.8	0	0
Total	90	95.7	62	100	24	92.3

RA, Radial artery; *ITA,* internal thoracic artery; *SVG,* saphenous vein graft.

balanced flow, and native artery–dependent flow.[8] The grafts that had narrowed (having a diameter less than 1.50 mm) or that had focal stenosis were noted as *imperfect grafts*. Occluded grafts were also noted.

Results

Seventy-four radial artery grafts were used to bypass a single coronary artery; 12 were used as sequential grafts for two coronary arteries, and a segment of radial artery was sewn to the side of either the left ITA or the radial artery graft as a Y graft in eight of the patients who underwent recatheterization. Thirty-five of the 60 patients in the study received only arterial grafts. Bilateral radial artery grafts were harvested and used in 13 of the 60 patients.

The average internal diameter of the 94 radial artery grafts evaluated was 2.51 mm (range 0.73 to 4.02 mm), with a 95.7% patency rate (90 patent/94 grafts); four radial artery grafts were occluded. Four imperfect radial artery grafts had diffuse narrowing with inner diameters ranging 0.73 to 1.30 mm. Sixty-two ITA grafts had an average inner diameter of 2.25 mm (range 1.19 to 3.90 mm), and all were patent. There were three imperfect ITA grafts showing diffuse narrowing, with inner diameters ranging from 1.19 to 1.40 mm. Twenty-six SVGs had an average inner diameter of 3.23 mm (range 1.90 to 4.13 mm), with 92.3% (24 patent/26 grafts) being patent. Table III displays the number of grafts falling within the various size ranges. No significant difference in the size of the radial artery grafts of the male and female patients was found ($p = 0.37$).

The size discrepancy ratio between graft and native artery was +19.5% for the radial artery grafts, +7.5% for the ITA grafts, and +53.3% for the SVGs ($p < 0.001$). Table IV summarizes the flow characteristics of the grafts. The SVGs demonstrated the highest percentage of graft-dependent flow, followed by the radial artery grafts ($p < 0.001$). The ITA grafts had the highest percentage of balanced flow. Analysis also demonstrated that in one SVG anastomosed to the second diagonal artery, the SVG generated retrograde flow in the adjacent ITA graft anastomosed to the left anterior descending artery.

Discussion

With the advent of improved harvesting techniques, use of postoperative aspirin, and the introduction of calcium channel blockers, interest in the use of the radial artery for CABG has been revived.[9] In 1989, Acar and colleagues[9] reported a 94% patency rate in radial artery grafts at 9 months after the operation. Calafiore and associates[10] and Dietl and Benoit[11] showed similarly encouraging results. In our series, we report a 95.7% patency rate in the 94 radial artery grafts evaluated. Eighty-six of the 94 radial artery grafts (91.5%) were *perfect grafts* with

no evidence of stenosis, narrowing, or spasm. These grafts had smooth lumina with excellent flow.

Our radial artery harvesting technique[12] (a modification of the technique outlined by Acar and coworkers[9]) includes using an intravenous calcium channel blocker, diltiazem hydrochloride (Marion Merrill Dow, Inc., Kansas City, Mo.), for the first day after the operation, followed by long-term oral administration. Intraoperatively, gentle hydrostatic dilation with a solution of blood and papaverine[12] was used primarily to check for bleeding from the side branches before the radial artery was grafted to the recipient vessel. Dietl and Benoit,[11] who used radial artery grafts in 165 patients, also used a similar hydrostatic dilation technique plus the administration of a calcium channel blocking agent. In both studies, the early graft failure pattern seen in the 1970s, which led to discontinuation of use of the radial artery for CABG, was avoided.

Flow analysis revealed that 81.1% of the radial artery grafts (73/90 grafts) exhibited graft-dependent flow ($p < 0.001$), whereas only 4.4% (4/90 grafts) exhibited native artery–dependent flow. Interestingly, two of the four grafts with native artery–dependent flow characteristics showed diffuse narrowing, which suggests that competitive flow from the native artery may have produced the narrowing. Grafts with native artery–dependent or balanced flow should become graft dependent with time if graft supply capability remains the same or improves over time, because coronary disease is progressive and further proximal native artery/balanced flow should diminish. Therefore it is possible that the luminal size of the narrowed *imperfect grafts* may increase with time.

Four radial artery grafts were occluded in this study. The occlusions may have been caused by any one or a combination of the following factors: technical problems, competitive flow, or other unknown causes. A 5- to 10-year follow-up study of these patients may help elucidate the cause of the occlusions.

The advantages of using the radial artery in myocardial revascularization are numerous. The radial artery is larger than the ITA but smaller and better matched to the size of anastomosed coronary artery than the SVG, as shown angiographically in this study. Multiple distal anastomoses are technically easy to perform, and early patency of these anastomoses is excellent. We harvested an average of 18.5 ± 2.85 cm of radial artery (range 7 to 24 cm), which allowed us to reach any coronary artery, as well as to perform the proximal anastomosis directly to the aorta.

Conclusions

The ITA is still the preferred graft for CABG. We used the radial artery graft to supplement the ITA as another arterial bypass graft. Early angiographic results with the radial artery demonstrate excellent patency rates and flows. A follow-up study of 5- to 10-year angiographic findings of radial artery grafts constructed by means of the methods and results described here will aid in prognosticating the long-term patency of this graft.

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