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Skeletonized Radial Artery Grafting: One-Year Patency Rate

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ABSTRACT

Background: The skeletonized radial artery harvesting technique has routinely been used in our institute. Its clinical outcome is acceptable; however, the graft patency rate at 1 year has not been reported.

Methods: Between July 1, 2003, and October 31, 2002, 50 consecutive patients underwent isolated coronary artery bypass using skeletonized radial artery grafts in our hospital. There were no hospital deaths or perioperative myocardial infarctions. All patients completed follow-up by November 2003. Twenty of these patients (18 asymptomatic volunteers and 2 symptomatic patients) underwent coronary angiography at 1 year, and the results were analyzed.

Results: At a mean (±SD) follow-up period of 1.2 ± 0.2 years, there were no deaths. Two patients developed angina due to graft occlusion (1 in the radial artery and another in the gastroepiploic artery). Twenty-one radial artery grafts and 36 distal anastomoses with radial artery grafts were evaluated by angiography at 1 year (0.9 ± 0.1 years). There was 1 radial artery graft occlusion affecting 1 distal anastomosis, giving a perfect graft patency rate of 95.2% (20/21) and a perfect anastomosis patency rate of 97.2% (35/36). The patient with the occluded radial artery graft had a history of peripheral vascular disease and diabetes. There were no graft stenoses or string signs.

Conclusion: At our limited follow-up, the results of using skeletonized radial artery grafts are excellent. Extensive skeletonization will not affect the graft patency rate or early graft spasm. Careful examinations of the radial artery grafts in patients with a history of peripheral artery disease and diabetes are mandated.

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INTRODUCTION

Skeletonized radial artery harvesting has been used for coronary artery bypass since mid 2000 [Amano 2002]. Skeletonized harvesting is different from classic pedicled harvesting in that it removes the satellite veins and surrounding tissue along with the main trunk of the radial artery. This method may optimize the response to intraluminal vasodilator injection and may decrease the incidence of graft spasm. Previously, we showed better early angiographic results with skeletonized radial artery grafts than with pedicled grafts [Amano 2002], as well as good clinical follow-up results [Hirose 2003]. However, clinical use of the skeletonized radial artery has been limited to certain institutions, probably because of the lack of angiographic follow-up studies. In our institution, skeletonized harvesting of the radial artery graft has been performed routinely, and pedicle harvesting has not been done since we moved to the current facility in July 2002. Here we report 1-year angiographic follow-up data for these skeletonized radial artery grafts.

METHODS

Patients

The perioperative data of the patients who underwent isolated primary coronary artery bypass grafting (CABG) at Juntendo University Hospital were prospectively entered into a structured database. The authors moved into the current facility in July 2002, and these data were collected since that date. Between July 2002 and November 2002, 75 consecutive isolated primary CABG procedures were performed. Of these operations, the radial artery was used in 50 patients (66.7%), and all of the radial arteries were harvested in a skeletonized manner. The patient characteristics are shown in the Table. No patients were excluded from this study.

Technique of Radial Artery Harvesting

Radial artery harvest was avoided in patients with renal dysfunction and in patients with a positive result in the Allen test.

Demographic Data of Patents Who Underwent Radial Artery Bypass followed by Angiographic Study 1 Year after Surgery*

	All Patients with Radial Bypass (n = 50)	Angiographically Studied Patients (n = 20)	*P*
Clinical characteristics			
Age, y	65 ± 9.3 (47-80)	66.6 ± 8.2 (54-79)	.48
Age >75 y, n	11 (22.0%)	6 (30.0%)	.48
Female sex, n	10 (20.0%)	2 (10.0%)	.31
Cardiac profile, n			
Unstable angina	9 (18.0%)	5 (25.0%)	.50
Acute myocardial infarction	3 (6.0%)	0 (0.0%)	.26
Poor ejection function (<40%)	5 (10.0%)	0 (0.0%)	.14
Atrial fibrillation	1 (2.0%)	0 (0.0%)	.52
Redo surgery	2 (4.0%)	1 (5.0%)	.85
Urgent or emergent surgery	9 (18.0%)	6 (30.0%)	.26
Angiographic profile, n			
Left main disease	17 (34.0%)	5 (25.0%)	.46
No. of diseased vessels	2.5 ± 0.6 (2-3)	2.7 ± 0.5 (2-3)	.15
3-Vessel disease	46 (92.0%)	19 (95.0%)	.65
Coronary risk factors, n			
Hypertension	33 (66.0%)	13 (65.0%)	.93
Diabetes	21 (42.0%)	6 (30.0%)	.35
Insulin user	4 (8.0%)	2 (10.0%)	.78
Hyperlipidemia	27 (54.0%)	10 (50.0%)	.76
Smoking	26 (52.0%)	13 (65.0%)	.32
Obesity	17 (34.0%)	6 (30.0%)	.74
Family history	10 (20.0%)	3 (15.0%)	.62
Comorbidity, n			
Peripheral vascular disease	4 (8.0%)	2 (10.0%)	.78
Cerebral vascular accident	12 (24.0%)	3 (15.0%)	.40
Calcified ascending aorta	11 (22.0%)	5 (25.0%)	.78
No. of distal anastomoses	3.9 ± 1.0 (2-5)	4.0 ± 0.9 (2-5)	.68
Graft conduits, n			
Left internal mammary artery	47 (94.0%)	19 (95.0%)	.87
Right internal mammary artery	11 (22.0%)	3 (15.0%)	.51
Radial artery	50 (100.0%)	20 (100.0%)	NS
Gastroepiploic artery	28 (56.0%)	13 (65.0%)	.48
Saphenous vein	8 (16.0%)	3 (15.0%)	.91
Intubation time, h	6.9 ± 3.2 (0-12)	6.8 ± 3.0 (1-92)	.90
Intensive care unit stay, d	2.9 ± 2.2 (1-10)	2.5 ± 2.1 (1-17)	.48
Postoperative stay, d	17.4 ± 21.5 (4-121)	12.0 ± 3.6 (5-107)	.09
Major complications (patients), n			
Congestive heart failure	1 (2.0%)	1 (5.0%)	.49
Postoperative myocardial infarction	0	0	NS
Respiratory failure	0	0	NS
Pneumonia	1 (2.0%)	0	.52
Severe arrhythmia	0	0	NS
Cerebral vascular accident	0	0	NS
Reexploration for bleeding	0	0	NS
Postoperative hemodialysis	0	0	NS
Mediastinitis	2 (4.0%)	0	.36
Others	0	0	NS
In-hospital death	0	0	NS

*Data are presented as the mean ± SD (range) where appropriate. There were no significant differences between the 2 groups by the Student *t* test or the Mann-Whitney *U* test for continuous variables or by the chi-square test (Fisher exact test if n < 5) for categorical variables, as appropriate. NS indicates not significant.

The radial artery was primarily harvested from the nondominant arm. The details of skeletonization have been reported in our previous publications [Amano 2002, Hirose 2003]. Briefly, the fascia covering the radial artery and satellite veins was sharply opened with a Metzenbaum. The space between the satellite veins and the radial artery was then dissected with the ultrasonic scalpel (Harmonic Scalpel; Ethicon Endo-Surgery, Cincinnati, OH, USA). The side branches were transected by applying the ultrasonic scalpel. Removal of the adventitia was completed with microscissors. Before transection of the proximal end, diluted warm milrinone (0.5 mg/mL) was injected from the distal end, and the graft was manually dilated while mild, gentle hydrostatic pressure was applied to the graft.

Coronary Artery Bypass Grafting

Off-pump CABG is our preferred method for isolated CABG. During the study period, off-pump CABG was performed in 93.3% (70/75) of isolated CABG procedures. All of the patients with radial artery bypass in this series (n = 50) successfully completed off-pump CABG. The proximal anastomosis of the radial artery graft was made to the ascending aorta or to the internal mammary artery (IMA) to create a composite Y graft if the ascending aorta was calcified. For prophylaxis of perioperative vasospasm, a calcium channel blocker such as diltiazem or nicorandil was started shortly after the induction of general anesthesia and continued for at least a year with oral maintenance doses.

There were no incidences of radial artery dissection or injury during harvesting. The mean (±SD) number of distal anastomoses of the radial artery was 1.8 ± 0.7. A composite Y graft was made with an IMA in 12 cases (24.0%). In addition to the radial artery, various other conduits were used, and the mean number of distal anastomoses was 3.9 ± 1.0. Eighty-seven distal anastomoses were made with the radial artery graft. The bypass targets of the radial artery were the left anterior descending artery in 1 patient (1.5%), the diagonal artery in 24 patients (27.6%), the circumflex artery in 50 patients (57.5%), and the right coronary artery in 12 patients (13.8%). The degree of the proximal stenosis of the radial artery targets was greater than 75% (severe stenosis) in 44 patients (50.6%) and equal to or less than 75% (mild stenosis) in 43 patients (49.4%).

Postoperative Results

There were no hospital deaths, but 4 major complications did occur, including mediastinitis in 2 cases (4.0%), pneumonia in 1 case (2.0%), and congestive heart failure in 1 case (2.0%). There were no perioperative myocardial infarctions. There were no instances of postoperative bleeding, harvesting site infection, or neurologic deficit of the hand. All patients were discharged from the hospital without undergoing postoperative angiography.

Follow-up

Hospital survivors were followed at our outpatient clinic or by private physicians. All cardiac events were recorded prospectively. The follow-up results were compiled at the end of November 2003. Instances of myocardial infarction, recurrence of angina, arrhythmia requiring hospitalization, congestive heart failure requiring hospitalization, coronary reintervention (percutaneous transluminal coronary angioplasty or redo CABG), and sudden death were counted as cardiac events.

Angiographic Study

Patients with cardiac symptoms were mandated for angiographic study, and the study was repeated 1 year after surgery (n = 2). Other asymptomatic patients were asked if they desired to participate in the angiographic study 1 year after surgery, and 18 patients consented. The perioperative characteristics of the patients who underwent angiography (n = 20) are shown in the Table. The demographics of the patients who underwent angiography were not significantly different from those of the overall series of radial artery bypass patients.

The quality of the anastomoses was graded according to the Fitzgibbon classification [Fitzgibbon 1996]. Briefly, grade A stands for perfect graft patency, grade B for graft stenosis >50%, and grade O for occlusion. String sign, which is defined as severe and extensive narrowing of the whole body of the graft [Acar 1992], was classified as a grade B anastomosis.

Statistics

Descriptive statistics were completed. Results are expressed as appropriate as the mean ± SD or as a number with the percentage. A 90% confidence level was calculated when necessary.

RESULTS

Clinical Follow-up Results

Postoperative follow-up was completed for all patients with a mean follow-up period of 1.2 ± 0.2 years. There were no deaths during the follow-up, but 2 patients (4.0%) developed angina due to graft occlusions. No other cardiac events were observed during this follow-up.

One patient developed angina related to occlusion of the radial artery graft. This patient was a 75-year-old man with unstable angina, uncontrolled diabetes, peripheral vascular disease without palpable pulses on the legs, aortic calcification, and a fragile sternum who underwent urgent CABG with the left IMA (LIMA), a radial artery, and the gastroepiploic artery. During surgery, the radial artery demonstrated some atherosclerotic changes in the mid portion of the graft; however, it was used for bypass because of a lack of other available graft material. The use of the bilateral IMA was not considered in this particular patient because of the presence of diabetes and a fragile sternum, and the saphenous vein was not used because of the risk of leg wound infection due to the presence of diabetes and peripheral vascular disease. The radial artery was proximally anastomosed with the LIMA to make a composite graft because of the aortic calcification and was distally anastomosed to the circumflex artery, which had 90% proxymal stenosis. Postoperative recovery for the patient was uneventful; however, he developed angina 7 months after surgery. An angiographic examination demonstrated total occlusion of the radial artery graft, although the other grafts were patent. The patient successfully underwent catheter intervention to the circumflex artery.

Another symptomatic patient had an occluded gastroepiploic artery that had been bypassed to the right coronary artery. This occlusion was also treated with catheter intervention to the right coronary artery.

Angiographic Study

Angiographic examinations were performed 0.9 ± 0.1 years after surgery, and 21 radial artery grafts and 36 distal anastomoses were evaluated. All grafts were patent except for those of the above-described patients (occlusion in the radial artery in 1 patient and in the gastroepiploic artery in the other) and another patient who had an asymptomatic graft occlusion in the LIMA. The graft patency rate of the radial artery was 95.2% (20/21), and the anastomosis patency rate was 97.2% (35/36; 90% confidence interval: 88.5%-99.4%). Distal anastomosis patency rates were 95.5% (21/22) in the LIMA, 100% (3/3) in the right IMA, 93.3% (14/15) in the gastroepiploic artery, and 100% (3/3) in the saphenous vein. There were no instances of graft spasm or graft stenosis in any grafts.

The degree of stenosis in the proximal native coronary artery anastomosed with the radial artery among those who underwent angiography was severe (greater than 75% stenosis) in 20 anastomoses (55.6%, 20/36) and mild (stenosis equal to or less than 75%) in 16 anastomoses (44.4%, 16/36).

DISCUSSION

The classic technique for pedicled harvest of the radial artery emphasizes meticulously gentle handling of the conduit. With this classic harvesting technique, removal of the satellite veins or the surrounding tissue was not recommended, and manual dilatation of the graft with intraluminal injection was not advised either. Our methods completely contradict the recommendations of this pedicled harvesting technique. We open the fascia covering the radial artery, separate the satellite veins, remove the adventitia, cannulate the graft, inject an antivasospastic agent directly into the lumen, and manually expand the graft. However, the gold standard of radial artery harvesting was the pedicled harvest, and pedicled harvesting has been strongly recommended, even in recent publications [Psacioglu 1998, Ronan 2000]. This classic pedicled harvesting method may have been overemphasized since Acar et al. reported the revival of radial artery grafting in 1992 [Acar 1992].

The early failure rate of radial artery grafts reported in the 1970s (radial artery graft patency rate of 50% within 6 months after surgery) was due to the combinations of vasospasm and intimal hyperplasia [Fisk 1976]. The incidence of vasospasm of the radial artery graft was reported to be 5% to 10% despite modern antispastic care [Parolari 2000], and vasospasm has been considered to be due to the muscular nature of the artery. Minimal touching of the graft and no peeling of the adventitia had been recommended to avoid mechanical stimuli to the radial artery.

In fact, the media of the radial artery consists of a large number of leiomyocytes. Recently, nitric oxide synthase (NOS), the enzyme that induces endogenous nitric oxide, which acts against vasoconstriction and atherosclerosis, was found to be abundant in the intima and media of the radial artery [Gaudino 2003a]. On the other hand, NOS or leiomyocytes are rarely observed in the adventitia. Furthermore, the vasa vasorum, nerves, and lymphatic vessels are confined to the adventitia and do not join the medial layer [van Son 1990]. Thus, we speculated that removal of the adventitia might not have any effect on vasospasm. A study of the skeletonized arterial graft has demonstrated that skeletonization itself will not affect the biofunctional integrity of the graft [Ueda 2003].

Intimal hyperplasia may be a secondary phenomenon due to intimal damage, most likely because of heat injury from the improper use of electrocautery during harvesting. Unlike electrocautery, the ultrasonic scalpel used for skeletonization produces less heat when applied to the vessels [Manasse 1996]. The ultrasonic scalpel was first introduced in 1997 for endoscopic IMA harvesting [Ohtsuka 1997] and has become widely used in IMA harvesting under direct vision since 2000 [Higami 2000]. Study of IMA skeletonization has found that an ultrasonic scalpel causes less heat injury to the main trunk while achieving adequate hemostasis [Higami 2000, Gaudino 2003b]. Another study showed that the skeletonized IMA has a better response to vasodilators, and the caliber of the skeletonized IMA was found to be larger than that of the pedicled IMA [Choi 1996].

We essentially applied the technique used for IMA skeletonization to radial artery harvesting. In 2001, skeletonized radial artery harvesting using scissors and clips was introduced [Taggart 2001]; however, probably because of the technical difficulty of the hemostasis and the lack of follow-up results, this technique never became widely accepted as a procedure of choice and was even criticized as carrying a higher risk of vasospasm [Bizzarri 2002]. Skeletonization of the radial artery has become more common in Japan since the early angiographic results of skeletonized radial artery grafting using an ultrasonic scalpel were published in 2002 [Amano 2002]. We consider that the ultrasonic scalpel facilitates skeletonization more effectively and more quickly than the clip-and-scissors technique.

Graft patency reported for the radial artery graft has almost always been inferior to that of the IMA [Parolari 2000]. Review of the radial artery bypass by Parolari et al demonstrated a patency rate (Fitzgibbon criteria A plus B) within 6 months of 98.1% and a perfect patency rate (Fitzgibbon criterion A only) of 90.8%. Midterm (0.5-3 years) patency and perfect patency rates were 93.3% and 78.8%, respectively [Parolari 2000]. Compared with the IMA patency rate (greater than 90% at 10 years) and the saphenous vein patency rate (approximately 50% at 10 years) [Reardon 1997], the radial artery patency rate was somewhere between the rates of IMA and saphenous vein grafts. The reason an arterial graft fails is reported to be due to poor runoff because of a small coronary artery, severe distal atherosclerosis, and/or lack of viable myocardium or due to competitive flow [Barner 2002]. Competitive flow from the native coronary artery may decrease graft flow, making the arterial graft atrophic and resulting in a narrowing of the caliber size (remodeling of the arterial conduit); then, the arterial graft eventually becomes occluded [Barner 2002]. Moran et al [2001] and Calafiore et al [1995] separately reported that the radial artery should not be used for a coronary artery with stenotic lesions of 70% or less, because a small-caliber pedicled radial artery might not deliver enough volume to the distal coronary artery. In these high-flow and mildly stenosed coronary arteries, we used to use a saphenous vein graft and accepted the poor long-term patency results. However, these coronary vessels are now revascularized with a skeletonized radial artery graft without compromising their graft patency rates, because a skeletonized radial artery graft can provide a large caliber and a great flow capacity. Our observations suggested that the skeletonized radial artery graft would remain patent, even when it is anastomosed to a mildly stenosed coronary artery.

After the removal of satellite veins and surrounding tissue, the radial artery is easily expanded with an intraluminal injection of the vasodilator. If the ultrasonic scalpel is applied to the main trunk to remove adhesions or if the side branches are transected very close to the main trunk, vasospasm of the radial artery graft may occur. However, we have learned from our experiences that these vasospasms are reversible with an intraluminal injection of a vasodilator and with manual dilatation of the graft. The vasospasm-released radial artery can be a large-caliber valveless arterial conduit, allowing the radial artery to be anastomosed to a mildly stenosed high-flow coronary artery. In the current study, the radial artery was anastomosed to a coronary artery with mild proximal stenosis in almost half of the patients; however, no angiographic evidence of compromise to the radial artery graft was observed.

Another benefit of skeletonization is graft length. Because of the frequent application of transradial catheterization, the distal part of the radial artery may be sclerosed or adhered [Kamiya 2003]. Although we routinely did not measure the length of the radial artery graft, we have learned that skeletonization gives us a few more centimeters of graft length than the classic pedicled graft. This extra length allows us to discard the distal part of the radial artery where sclerosis is frequently observed.

The patient with early occlusion of the radial artery graft had several risk factors for atherosclerosis disease. Focal calcification of the radial artery has been reported in 5% of patients who undergo CABG [Buxton 1997]. The risk factors for atherosclerosis of the radial artery graft are reported to be diabetes and peripheral vascular disease [Kaufer 1997]. The radial artery graft from patients with these risk factors should be examined carefully, and the affected segment should be discarded. If alternative grafts are available, the radial artery should not be used in this patient group. Graft patency of the atherosclerotic radial artery would be suboptimal no matter what kinds of harvesting techniques are used.

The clinical follow-up study results after skeletonized radial artery harvesting are known to be excellent [Hirose 2003]. Angina was suppressed adequately. However, the present study is the first to report angiographic data obtained 1 year after surgery. The current findings of graft patency rate at 1 year are equivalent to those of the IMA. Furthermore, our results support the conclusion that the skeletonized radial artery graft will remain patent even when it is used for revascularization of a mildly stenosed coronary artery.

Our study was limited to a relatively small sample size at a single center. Angiographic study was performed only in patients who consented to the procedure; obviously, this study is not randomized. Unlike the initial results in the 1970s that showed radial artery graft failure, the patients who underwent skeletonized radial artery grafting remained asymptomatic. It would be difficult to obtain consent from asymptomatic patients to participate in the postoperative angiographic study. We were unable to perform a comparison study of skeletonized and pedicled artery bypass patients, because the radial artery was harvested in a skeletonized manner in all patients without exclusion. We are not planning to do a comparison study because we consider skeletonized grafting more beneficial to patients than pedicled grafting. It might be interesting to conduct such a study to confirm the superiority of skeletonized radial artery grafting; however, the ethics committee of our department rejected such a study. We also did not perform any early postoperative angiographic studies because early angiographic results were obvious [Hirose 2003] and because no patients developed postoperative myocardial infarction in this series. Our observation period was limited to only 1 year; however, it would be interesting to follow-up long-term patency results because saphenous vein disease is known to become significant a few years after surgery.

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