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ANGIOGRAPHIC RESULTS OF OFF-PUMP SKELETONIZED RADIAL ARTERY GRAFTING

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The summary: Background: To improve the patency rate of radial artery grafts, we have been using A skeletonized harvesting technique since 09/01/2000. Our early reports confirmed better graft patency of skeletonized radial graft compared to conventional pedicled grafts. Off-pump coronary artery bypass has been increasing in our institution. Here, we present our angiographic and clinical follow-up data on skeletonized radial artery grafting, exclusively among those who underwent off-pump bypass.

Methods: Between September, 2000 and July, 2002, a total of 247 patients underwent isolated off-pump coronary artery bypass using skeletonized radial artery graft, excluding T-grafting. Of these, 152 (61.5%) underwent postoperative angiography, and their perioperative, early angiographic, and follow-up results were analyzed.

Results: There was no hospital death and 5 incidences of postoperative myocardial infarction. None were related to radial artery bypass. Early angiographic control revealed that the stenosis-free graft patency rate of radial artery anastomoses (233/242, 97.9%) was not significantly different from other conduits (the left internal mammary artery 100%, right internal mammary artery 90.2%, gastroepiploic artery 98.4%, and saphenous vein 100%). Follow-up was completed all hospital survivors with a mean follow-up of 1.0 ± 0.4 years. There were no cardiac deaths, myocardial infarction, or angina recurrence.

Conclusion: The angiographical patency of the skeletonized radial artery graft performed under off-pump technique was excellent. Although cardiac events were not observed so far, follow-up mid-term angiographies will be necessary to confirm our clinical outcome data.

Key Words: coronary artery bypass, radial artery, skeletonization, off-pump, angiography

Introduction

The radial artery has been widely utilized in coronary artery bypass grafting (CABG). Since Acar reported a series of the radial artery grafting in 1992 [1], meticulously gentle handling of the radial artery, with light traction, minimal touch to the artery, and minimal use of electrocautery has been emphasized [2]. Trauma to the radial artery graft was believed to play a role in the process of vasospasm and to negatively influence the early graft patency; thus, harvesting of the radial artery as a pedicle was recommended. The pharmacologic characteristics of the radial artery, especially its local production of nitric oxide [3], are known to be similar to the IMA [4]. Thus, the radial artery has been considered to have the potential to behave as an arterial conduit with as a good graft patency rate as the IMA. However, the reported graft patency rate of the radial artery is considerable lower than the IMA; 80% at 5 years for the radial artery [5], versus 95% at 5 years of the IMA grafts.

Skeletonized harvesting has been used in IMA harvesting and it has provided a long graft length and a large caliber graft. The vasodilators used for prophylaxis of vasospasm, such as papaverine, milrinone, or nitrates are known to act on the media of the arterial wall, but not on the adventitia [6]. Skeletonized harvesting, a method of removing all adventitia from the main trunk of the artery, is theoretically reasonable to maximize the effects of the anti-vasospasm agents. In our institution, skeletonized techniques have been applied to the harvesting of the radial artery since September 2000 [7]. The skeletonized radial artery appears to behave as a large caliber, high-flow, valveless conduit, and its initial results were excellent [8]. We have abandoned the pedicle harvesting of the radial artery, and skeletonized harvesting has become our routine.

Off-pump coronary artery bypass grafting (CABG) is known to be less invasive and to provide earlier recovery than on-pump CABG [9]. A combination of off-pump CABG and arterial bypass may optimize patient’s recovery and postoperative long-term results.

We report here prospectively collected and analyzed angiographic and clinical data of patients who underwent off-pump CABG using skeletonized radial artery conduits.

Methods

Patients: The perioperative and remote data of patients who underwent isolated off-pump coronary artery bypass at Shin-Tokyo Hospital Group (Shin-Tokyo Hospital, Kobari General Hospital) were prospectively put into a structured database. Patients with T-grafting using the IMA or gastroepiploic artery as an in-flow were excluded because it is difficult to interpreter if the T-graft failure is due to an inflow or outflow problem.

Table 1:
Preoperative patient demographics.

n	152			
Clinical characteristics				
Age	66.3	±	8.8	(42-89)
Age over 75		31		20.4%
Female sex		42		27.6%
Cardiac profile				
Unstable angina		38		25.0%
Acute myocardial infarction		5		3.3%
Previous myocardial infarction		87		57.2%
History of congestive heart failure		16		10.5%
Poor ejection function (<40%)		16		10.5%
Atrial fibrillation		7		4.6%
Redo surgery		3		2.0%
Emergency surgery		13		8.6%
Angiographic profile				
Left main disease		33		21.7%
Number of diseased vessels	2.7	±	0.5	(1-3)
Three vessel disease		113		74.3%
Coronary risk factors				
Hypertension		108		71.1%
Diabetes		80		52.6%
Insulin user		21		13.8%
Hyperlipidemia		77		50.7%
Smoking		52		34.2%
Obesity		9		5.9%
Family history		21		13.8%
Comorbidity				
Peripheral vascular disease		10		6.6%
Cerebral vascular accident		21		13.8%
Chronic pulmonary obstructive disease		10		6.6%
Calcified ascending aorta		8		5.3%
Renal dysfunction (serum creatinine >1.5 mg/dl)		3		2.0%
Hemodialysis		0		0.0%
Euro score	3.5	±	2.2	(0-10)

Between September 1, 2000 and July 31, 2002, a total of 247 consecutive patients who underwent off-pump CABG using the skeletonized radial artery bypass met the above criteria. Among them For quality control, postoperative angiography was recommended for all patients who had skeletonized radial artery grafting. Of these, 152 patients (61.5%) agreed to a postoperative angiogram and their perioperative results and follow-up data were analyzed. The patients' preoperative demographics are shown in Table 1.

Technique for radial artery harvesting: Radial artery harvesting was avoided in patients with renal dysfunction (serum creatinine > 1.8 mg/dl) or patients with a positive Allen test. The radial artery was primarily harvested from the non-dominant arm, except for bilateral harvesting.

A longitudinal skin incision was made from 2 cm proximal to the wrist crease to 2 cm distal to the antecubital fossa, following the medial border of the brachioradialis muscle. The fascia bridging between the forearm muscles was divided with an electrocautery. Then, the thin layer of fascia covering the anterior surface of the radial artery and satellite veins was longitudinally opened using a metzenbaum. The space between the satellite veins and the radial artery was then dissected using an ultrasonic scalpel (Harmonic Scalpel, Ethicon Endo-Surgery, Cincinnati, OH). Lysis of adhesions, occasionally observed at the catheterization site, was also performed with the ultrasonic scalpel. Control of the side branches was done by applying the back side of the dissecting hook initially, but it was later switched to clamping the side branch with coagulating shears. Electrocautery was not used after uncovering the fascia, avoiding thermal injury to the main trunk. Diluted papaverine was occasionally sprayed onto the graft. Further complete removal of the adventitia was carried out using micro-scissors. After transection of the distal end, a cannula was positioned, and diluted warm milrinone (0.5mg/ml) was injected though the cannula while the proximal end was temporally occluded. Mild gentle pressure was applied to optimize dilatation of the graft, and the proximal end was transected. The harvested graft was flushed with warm milrinone solution again and preserved in it until use. No drains were left in the radial artery harvesting site.

CABG: The selection of off-pump CABG was individualized [10]. The patients with poor left ventricular function, mild mitral regurgitation, and pre-existing atrial fibrillation preferably underwent on-pump CABG. Patients with calcified coronary arteries, small (diameter less than 1.5 mm), or intramyocardial coronary arteries were also underwent on-pump CABG. The remanding isolated CABG were performed under off-pump CABG via midline sternotomy. Exposure of the target coronary artery was performed using retropericardial sutures, and use of a suction-type coronary stabilizer (Octopus-2 or 3 coronary stabilizer, Medtronic, Minneapolis, MN) [11]. A carbon oxide gas blower was used to facilitate anastomosis by providing a blood-free operating field. Intracoronary shunt was used for high flow coronary artery, or the patients who developed ischemia during the snaring of the target artery. Distal coronary anastomoses were made using 8-0 polypropylene sutures (Figure 1). Proximal free-graft anastomosis to the ascending aorta was performed using 6-0 polypropylene sutures with a side-biting clamp applied to the ascending aorta.

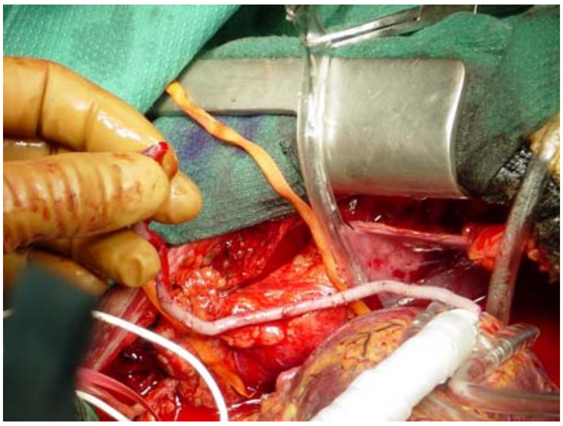

Figure 1: Skeletonized radial artery bypass grafting under the off-pump beating-heart.

For the prophylaxis of perioperative vasospasm, a calcium channel blocker such as diltiazem or nicorandil was started after the induction of general anesthesia, and then continued for at least a year with oral maintenance doses. Intravenous milrinone was not routinely used.

Angiographic control: Postoperative angiographic control was obtained within 3 months of surgery if the patients agreed to the procedure. A postoperative angiogram was routinely performed via a trans-brachial approach (proximally to the stump of the radial artery), except for patients requiring images of the bilateral IMAs. The quality of the anastomosis was graded according to Fitzgibbon's classification [12]. Briefly, grade A stands for perfect graft patency, grade B for graft stenosis >50%, and grade O for occlusion. String signs, which are defined as a severe and extensive narrowing of the whole body of the graft [1], was classified as grade B anastomosis. If the patient remained angina-free, a repeat coronary angiogram was not routinely performed.

Data collection: Postoperative data were prospectively collected. Outpatient follow-up was completed by the end of September 2003. Remote myocardial infarction, angina, arrhythmia requiring hospitalization, congestive heart failure requiring hospitalization, coronary re-intervention, and sudden death were counted as cardiac events. Results are expressed as mean ± standard deviation.

Results

Operative results: Operative data are shown in Table 2. Bilateral radial arteries were used in 2 patients, and the rest of the patients' radial arteries were harvested from the non-dominant arm alone. There were no incidences of radial artery dissection or injury during graft harvesting. The mean number of distal anastomoses of the radial artery was 1.57 ± 0.94. In addition to the radial artery, various other conduits were used, and the mean number of distal anastomoses was 3.9 ± 1.1.

Table 2:

Surgical results

n	152			
Number of distal anastomosis	3.9	±	1.1	(2-8)
Bilateral internal mammary artery	80			52.6%
Total arterial revascularization	135			88.8%
Radial sequential bypass	56			36.8%
Radial composite graft	25			16.4%
Coronary anastomosis time/vessel	11.4	±	2.3	(7-21)
Operation time (minutes)	307.3	±	64.4	(175-525)
Blood transfusion	31			20.4%
Left internal mammary artery	151			99.3%
Right internal mammary artery	81			53.3%
Radial artery	152			100.0%
Gastroepiploic artery	55			36.2%
Inferior epigastric artery	1			0.7%
Saphenous vein	17			11.2%

Table 3:

Postoperative outcomes

n	152			
Intubation (hours)	9.4	±	7.0	(1-65)
ICU stay (days)	2.1	±	1	(1-9)
Postop stay (days)	12.3	±	5.1	(4-51)
Major complication (patients)				
Congestive heart failure	2			1.3%
Postoperative myocardial infarction	4			2.6%
Respiratory failure	1			1.5%
Pneumonia	0			0.0%
Severe arrhythmia	0			0.0%
Cerebral vascular accident	1			0.7%
Re-exploration for bleeding	1			0.7%
Postoperative hemodialysis	0			0.0%
Mediastinitis	2			1.3%
Inhospital Death	0			0.0%

In-hospital results: The postoperative course is displayed in Table 3. There was no hospital death. There were 5 incidences of postoperative myocardial infarction, but none of them were related to radial artery bypass, confirmed by angiography No postoperative bleeding from the radial graft occurred. One patient developed an arm wound infection which was treated with antibiotics. No postoperative hematoma was observed.

Remote results: Postoperative follow-up was completed in all patients (1.0 ± 0.4 years. During the follow-up, there were no cardiac deaths, myocardial infarction, or angina recurrence. There was 1 non-cardiac death during this follow-up.

Table 4:
Remote results.

Number of patients followed	215/215 (100%)
Follow up period (years)	1.6 ± 0.4
Total outpatient cardiac events	9 (4.2%)
Angina	1
PTCA	5
Congestive heart failure	2
Arrhythmia	1
Sudden death	0
Others	0
Distant death	1 (0.5%)
Cardiac death	0
Non-cardiac death	1

Angiographic study: A total of 242 distal anastomoses were evaluated by early angiography. Angiography revealed 5 radial artery anastomosis occlusions (2.1%). String signs were observed in 2 patients (3 anastomosis) and anastomosis stenoses were observed in an additional 1 distal anastomoses. The early radial artery patency rate (grade A and B) and perfect patency rate (grade A only) were 97.9% and 96.3%, respectively. The graft patency rates of the other graft conduits are shown in Table 4. There were no statistical differences in terms of occlusion or stenosis between the conduits by chi-squire tests.

Beyond 1 year after surgery (1.5 ± 0.1 year), 4 patients without symptoms volunteered for repeat angiography, which revealed no graft occlusion or stenoses.

Discussion

Skeletonized harvesting was not recommended in previous studies, most likely based on the initial graft failure report in 1973 [13]. Even after the introduction of skeletonized IMA harvesting using an ultrasonic scalpel, pedicle harvesting remained the "gold standard" in radial artery harvesting [14, 15]. ' Skeletonized radial harvesting using sharp scissors and clips was first reported in early 2001 [16], but it was criticized because of the possibility of trauma and vasospasm [17]. We published our initial data of skeletonized radial artery grafting in 2002 [7]. Our method of radial artery harvesting is quite different, even opposite, from the "gold standard": we open the covering fascia over the radial artery, separate the satellite veins, remove the adventitia, cannulate the graft, and inject an anti-vasospastic agent directly to the lumen. Skeletonization is achieved mainly by an ultrasonic scalpel without any bleeding complications. Our goals with skeletonization are to remove as much excessive adventitia as possible. Sometimes, the radial artery becomes spastic, but the spasm is easily released by injecting milrinone. A recent study, although it was done in the IMA, showed that skeletonization has little influence on nitric oxide synthase production or endothelial damage compared to pedicle harvesting [18]. Furthermore, vasospastic phenomena is mediated and processed in the endothelium and media, but not by the adventitia [18]. Thus, the removal of the adventitia may not effect to the vasospasm at all; it may even optimize dilation of the graft.

Completely vasospasm-free radial grafts have a large caliber size and deliver high-flow volume. Moran [19] and Calafiore [20] separately reported that the radial artery should be used for coronary arteries with lesions of 70% or more stenosis because a small caliber pedicled radial artery may not deliver enough volume to these mildly stenosed coronary arteries. These mild stenotic high-flow lesions should be bypassed with a large caliber conduit. The saphenous vein is an option as the high-flow conduit; however its patency rate is poor: 90% at the early postoperative period and 70% at 5 years [21]. However, the skeletonized radial graft is perfectly suitable for these mildly stenosed coronary arteries.

Previous reports demonstrated early radial artery stenosis occurred in the postoperative period in between 5-7% of anastomoses [5, 22]. A literature review found a radial artery early patency rate (grade A and B) of 98.1% and a perfect patency rate (grade A alone) of 90.8%, giving a potential radial artery stenosis rate of 7.3% [23]. Our angiographic results showed an early stenosis rate of 1.8% and an occlusion rate of 2.1%, which are competitive or even better than previous series. Only a small number of patients underwent repeat angiography, since most were symptom-free. Repeat angiography for asymptomatic patients is not easy and it could even be an ethical issue. In addition, our limited clinical follow-up data appear to be competitive with previous reports: 97.8% at 0.7 year [24], and 89.7% at 3 years [25].

Off-pump CABG has been proven to be less invasive, and provides earlier recovery than on-pump CABG. The creation of steady and hemodynamically stable operative field for distal anastomosis is the one of key points when performed multivessel off-pump CABG. We believe that local coronary stabilization, suction type of stabilizer, play a important role in off-pump CABG. The posterior wall of the heart, where the most frequent target vessel revascularized with the radial artery, used to be a contraindication of off-pump CABG because of difficulty of maintaining blood pressure. However, using the suction type of coronary stabilizer and retropericardial suspension, the anastomoses of the posterior wall can be completed without hemodynamics change under heart-beating condition. Complete revascularization under off-pump CABG is feasible. The contraindications of off-pump CABG are now limited to intramyocardial coronary arteries and severely calcified coronary arteries. An recent large study of off-pump CABG demonstrated a complete revascularization rate of 82% under on-pump and 69% under off-pump [26]; however, our complete revascularization rates (82.3%) were almost as high as that study of on-pump CABG. We believe that all graftable coronary arteries were bypassed adequately with arterial conduits.

Summary: The early results of off-pump skeletonized radial artery grafting were excellent, by using ultrasonic scalpel and appropriate anti-vasospastic maneuvers, although skeletonized radial artery harvesting had not previously been recommended. The benefits of skeletonization include easy reverse of vasospasm, a large caliber conduit, enough length to reach any coronary arteries from the ascending aorta, ease of handling without adventitia, and the nature of the arterial graft. To confirm our data several studies are necessary including: repeat angiography and histo-pharmacological studies of skeletonized arteries.

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