Coronary Artery Bypass Surgery with Radial Artery
-Early Results-

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=Abstract=

요골동맥을 이용한 관상동맥우회술
-조기성적-

나 찬 영 · 이 영 탁 · 박 국 양 · 이 해 영 · 김 욱 성 · 박 철 현 · 홍 민 수 · 심 재 천
권 오 춘 · 김 웅 한 · 정 철 현 · 정 윤 섭 · 한 재 진 · 라 명 훈
박 영 관 · 홍 승 록 · 정 일 상 · 박 중 원 · 정 도 현

The radial artery as a graft for myocardial revascularization was introduced by Carpentier in the early 1970s. Mid-term results were unfortunately discouraging, and the clinical experience with this graft was interrupted. At the end of the 1980s, these authors reproposed the same arterial conduit with more satisfying results, because of improved technique and pharmacological management of the graft. Between October 1994 and July 1995, 36 patients underwent myocardial revascularization with a radial artery graft in Sejong General Hospital. Left internal mammary artery was concomitantly used as a pedicled graft in 34 patients. Fifteen patients(42%) had a complete arterial graft revascularization. A total of 123 distal anastomoses were performed(average 3.4 per patient), including 36 left internal mammary artery grafts(two sequential in 2 patients), and 23 saphenous vein grafts. The remaining 64 distal anastomoses were performed with radial artery grafts(mean 1.8 per patient). The radial arteries were anastomosed to the circumflex(n=38), diagonal(n=18), right coronary(n=6), and left anterior descending coronary artery(n=2). The percentage of radial artery graft anastomoses(64) to the total anastomoses(123) was 52%. The radial artery was used as a single graft in 10 patients, as a sequential graft in 25 patients, and two grafts in 1 patient. Twenty patients underwent associated procedures : coronary endarterectomy(14), coronary artery patch angioplasty(4), mitral valve repair(1), and repair of ventricular septal rupture(1). One patient died of low cardiac output syndrome and the others had no perioperative myocardial infarction. There are no ischemic and functional complications in the arm or hand after removal of the radial artery. Only 1 patient required reexploration of the arm, for the hematoma evacuation, and 2 patients complained transient thumb dysesthesia of the side of the havested arm. This dysesthesia improved within one month. Postoperative angiographic controls were obtained in 11 patients(31%) postoperative 79 to 210 days (mean 126 days). The patency rate were as follows : left internal mammary artery(100%), saphenous vein (100%), and radial artery(95%). We concluded that the radial artery is useful alternative graft, but long term clinical and angiographic studies are required to dertermine whether wider application is warranted.

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Key words: 1. Coronary artery bypass grafting
2. Radial artery

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INTRODUCTION

In the 1971, the radial artery (RA) was introduced as an alternative conduit for coronary artery bypass surgery grafting (CABG). Graft occlusion secondary to spasm from traumatic harvesting and preparation in addition to complications of cripping hand ischemia led to abandonment of this artery as a coronary artery graft by mid 1970s.

The introduction of calcium channel blockers, minimally traumatic dissection, and gentle hydrostatic graft dilatation, and the unexcepted observation that some RA grafts originally thought to be occluded are fully patent 15 years after occlusion, encouraged Acar & associates to review the use of the RA in CABG.

Surgical indications

In the great majority of cases, RA was used instead of a saphenous vein (SV) graft. It was used in patients with diabetes mellitus (n=8), obesity (n=9), and severe pulmonary dysfunction (n=2), aged greater than 70 (n=2), and urgent/emergency operation (n=4) or relative contraindication in order to avoid use of bilateral internal mammary artery (IMA). It was also used in reoperations. We prefer to use RA in territories with occlusion or severe stenosis, to ensure maximal flow through the graft.

MATERIAL and METHODS

Patient Population

Between October 1994 and July 1995, total 69 coronanary artery bypass grafting were performed in our institute. Among of these, 36 patients underwent myocardial revascularization using a RA graft (Table 1). Their mean age was 58 years (ranged, 38 to 79 years). There were 21 male and 15 female. Eleven patients (30%) presented two-vessel disease, 22 patients (60%) presented three-vessel disease, 5 patients presented left main lesions (isolated left main lesion was 3 patients), and 2 redo-CABG patients were included.

Harvesting technique

The Allen test as well as Doppler studies of the forearm were routinely performed before RA harvesting. The left forearm was chosen in right-handed individuals, left handed patient was excluded. The left forearm was exposed and, during the harvesting of left
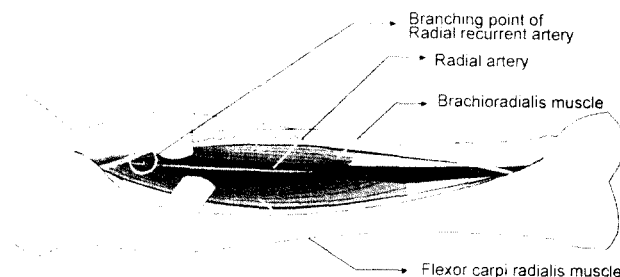

Fig. 1. Anatomy of the radial artery harvesting

Table 1. Demographic Data

· Sex (male/female)	21/15
· Age (years)	39~79 (mean 58)
· Two-vessel disease	11
· Three-vessel disease	22
· Left main lesion	5 (isolated-3)
· Redo-CABG	2
· No saphenous vein	15 (42%)

IMA, a skin incision was made, beginning from the wrist and extended to the elbow.

The antebrachial fascia was divided (Fig. 1) and the RA was dissected from the level of pulse groove to its proximal segment lying underneath the muscle belly of the brachioradialis reaching the humeral bifurcation, this muscle was retracted without division. The RA was removed together with its pedicle including two satellite veins and the surrounding fat tissue. The RA has numerous collateral branches, particulary in its distal portion, which were occluded using surgical clips. After total mobilization, the RA was wrapped with sponges soaked with papaverine and kept circulating. The branches of the RA were divided with scissors between hemostatic clips; electrocautery was not used, to prevent thermal injury to the artery. This is important because patency of a arterial graft may be jeopardized by using the electrocautery. A small atraumatic vascular clamp was applied temporarily to occluded the RA in its middle segment. A palpable pulse or even a visible pulsation distal to the vascular clamp was considered a reliable indication of adequate collateral blood flow provided by the ulnar artery. After the RA removal, hydrostatic dilatation was undertaken at a gentle pressure using a solution of pa-

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Table 2. Number of distal anastomosed vessel

· LIMA	36(29%)
· RA	64(52%)
· SV	23(19%)
Total	123

LIMA : left internal mammary artery   RA : radial artery
SV : saphenous vein

Table 3. Targets of RA graft(64)

· LAD	2
· DX	18
· OM	38
· RCA	6

LAD : left anterior descending artery   Dx : diagonal branch
OM : obtuse marginal branch   RCA : right coronary artery

paverine(1mg/1ml of saline), until a regular aspect of the graft to totally free of segmental spasm. To avoid intimal trauma, no metaltic probes or dilators were used. The RA was put in a bowel containing a papaverine solution(1mg/ml of saline). After hemostasis was verified carefully, the arm incision was closed. The antebrachial fascia was not closed, to prevent a compartment syndrome. After the arm incision was closed and elastic bandages were applied, the arm was repositioned parallel to the patient's body. The time required to harvest the RA graft ranged 30 to 40 minutes. However, total operating time was not prolonged because the RA was harvestied during IMA and SV preparation. The mean length of RA was 18. 5cm(ranged from 16 to 23cm) and the mean internal diameter 3.2mm(ranged from 2.5 to 3.5mm). One patient was excluded for a negative Allen test.

Perioperative medical management

A calcium antagonist, diltiagem was administrated through intravenous route and continued until the first postoperative day, at the rate of 4mg/hr. , then the diltiazem was given orally(180mg/day). Aspirin also was administrated(300mg/day), starting on the first postoperative day. To minimize the risk of infection or hematoma, no intravenous lines were placed in the donor arm until discharge from the hospital.

Cariopulmonary bypass and Cardioplegia.

Cardiopulmonary bypass was instituted with a single two stage right atrial cannula, an ascending aortic perfusion cannula and ascending aortic cardioplegic cannula/vent line. Retrograde cardio-

plegic cannula(self-inflating or mannual balloon) was inserted in the coronary sinus through right atrium with a blind technique. Standard cardiopulmonary bypass management included membrane oxygenator, arterial line filter, nonpulsatile flows of 2.4L/min. per m², mean arterial pressure great than 50 mmHg, moderate hemodilution(hematocrit 20% to 25%). Systemic temperature is dropped to 30℃ to 33℃. Initially antegrade warm/cold blood cardioplegia(20ml/Kg) was perfused, and subsequently retrograde cold/warm continuous blood cardioplegia was used. Retrograde cardioplegic perfusion pressure was allowed from 20 to 60mmHg. During distal anastomosis, we used intermittent cardio-plegic interruption(less than 10 minutes) or air jet(3~5L/min) to obtain-ed the clear the surgical field.

Distal Anastomosis

Using cardioplegic arrest(antegrade or retrograde, cold or warm blood), all distal anastomoses were performed using 7-0 or 8-0 polypropylene suture. A total of 123 distal anastomoses were performed(average 3.4 per patient), including 36 left IMA grafts, 23 SV grafts(Table 2). The remaining 64 distal anastomoses were performed with RA grafts(mean 1.8 per patient). The target vessels of the RA graft are left anterior descending artery(n=2), diagonal branches(n=18), obtuse marginal branches(n=38), and right coronary artery(n=6)(Table 3). 15 patients(42%) had a complete arterial graft revascularization(from 2 to 5 distal anastomoses). The arterial graft anastomosis(n=100) to the total anastomosis(n=123) was 81 percent. The RA was used as a single graft in 10 patient, as a sequential graft in 25 patients(two sequential graft in 22 patients, and three sequential graft in 3 patients), and two grafts in 1 patient. The most frequent targets were the obtuse marginal branches of the circumflex artery.

Proximal anastomoses

Using cardioplegic arrest, the proximal anasto-moses were performed, after excision of a fragment of aortic wall using continous 6-0 or 5-0 polypropylene suture.

Combined procedures

Twenty patients underwent combined procedures (Table 4) : coronary endarterectomy(n=14), coronary artery patch angioplasty(n=4), repair of mitral valve (n=1), and repair of postmyocardial infarction ventricular septal defect(n=1). The sites of the coronary endarterectomy are the distal right coronary artery in

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Table 4. Combined procedures

· RCA patch angioplasty	3
· LAD patch angioplasty	1
· MVP	1
· VSR repair	1

MVP : mitral valvuloplasty   VSR : ventricular septal rupture
RCA : right coronary artery   LAD : left anterior descending artery

Table 5. Endarterectomy (14)

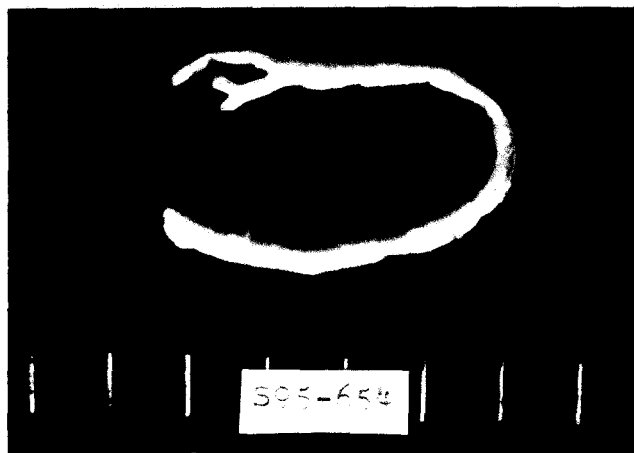|	
· d-RCA	8
· PDA	2
· OM	2
· LAD	1
· DX	1

d-RCA : distal right coronary artery   PDA : posterior descending artery
OM : obtuse marginal branch   AD : left anterior descending artery
Dx : diagonal branch

Fig. 2. Atheroma from the right coronary artery endarterectomy.

8 patients (Fig. 2), posterior descending artery and obtuse marginal branch in 2 patients, and left anterior descending artery and diagonal branch in 1 patient respectively (Table 5). The sites of coronary artery patch angioplasty are distal right coronary artery in 3 patients and left anterior descending artery in 1 patient (the IMA or SV graft were anaastomosed on the patch in 3 patients in the other patient, patch angioplasty was performed only). The mitral valve repair was done using Carpentier ring in a patient with rheumatic mitral stenoinsufficiency patient.

Fig. 3. Postoperative coronary angiogram of a sequential radial artery graft anastomosed to a diagonal branch and to an obtuse marginal branch.

RESULTS

Clinical results

There were no ischemic or functional complications in the arm or hand after removal of the RA. Only 1 patient required re-exploration of the arm, for hematoma evacuation and 2 patients complained thumb dysesthesia on the side of RA harvested arm. Perioperative complications show at table 6. One 64 years old female patient died(mortality in this series 2. 7%) of low cardiac output. The preoperative diagnosis was three-vessel disease and ventricular septal rupture due to acute myocardial infarction. She was assisted by intraaortic balloon pump preoperatively. Postoperatively, left ventricular assist by device(centrifugal biopump) and intraaortic balloon pump were used due to low cardiac output. She died at the second postoperative day due to low cardiac output syndrome and cerebral damage.

All surviving patients(n=35) were followed up a period ranging from 2 to 12 months(mean 7 months). All are alive and free of symptoms, no functional disturbances related to RA were reported.

Control angiograms

Postoperative angiographic controls were obtained in 11 patients(31%) at ranged 79 to 210 days(mean 126 day). The patency rate by angiography was 100% patent in IMA and SV, and 95% patent in RA(Fig. 3). The occluded RA graft was anastomosed sequen-

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tially in diagonal and obtuse marginal branch. The obstruction was found in the diagonal branch, but obtuse marginal branch was well visualized and then we suspected the technical error of butterfly phenomenon in the sequential anastomosis.

DISCUSSIONS

The initial experience with the RA resulted in a high failure rate, which was attributed to a combination of spasm and intimal hyperplasia[1~3]. The propensity to spasm of RA is related to the microscopic structure of this vessel. The RA is a muscular artery with a thick wall whose media contains a high density of leiomyocytes[4]. The RA has a muscular tunica media and many fenestrations in the internal elastica lumina: nutrient vessels are limited to the adventitia. This can explain why the RA may undergo spasm and intimal hyperplasia, which cause early graft failure[4]. In many institute[5~7], left forearm was choosen in the right handed individuals, and the right forearm in the left handed patients. We have choosen only the left forearm in right handed patients, and left handed patient was excluded because of the time waste during the right forearm and left IMA preparation. Before RA harvesting, evaluation of the palmar collateral circulation is very important. We used an Allen test and Doppler study of the forearm, but not used angiography of forearm. S. E. Fremes et al[8] used digital phlethysmography to check palmar collaterals. Digital plethysmography with the radial artery compression may objective determine palmar collaterals. We excluded 1 patient due to negative Allen test and doppler examination. Patients with a history of vasculitis or Raynaud's syndrome were excluded. In severe diabetis mellitus patients, the RA was judged to be unsuitable for a graft because of nonobstructive medial calcification[6]. Also, the RA may not be an appropriate conduit in the case of severe chronic renal failure likely to require hemodialysis through a radial arterio-venous fistula. The RA gives off many small perforating branches[6]. Most of these branches come off the dorsal aspect of the RA. In the proximal half the RA course in the forearm, the segment covered by the brachioradialis muscle, there are an average of the 4.2 branches(range, 0 to 10). In the distal half of the RA course, the portion of that lies directly under skin and fascia,(9.6 branches on average with a range of 4 to 14) exit the main trunk of the vessel. From a purely surgical standpoint, the RA is an excellent conduit for coronary bypass because 1) it is an arterial graft used to systemic pressure regimen, 2) its diameter, slightly greater than the IMA, correspends perfectly to the diameter of most coronary arteries, 3) the quality of its wall(thick and resistant) offers very good technical conditions for coronary and aortic anastomosis, and 4) its length allows it to reach all target vessels on the surface of the heart and can be performed using two segments of the same RA. The IMA is the best conduit currently available for coronary artery grafting, with a patency rate of 85% to 95% after 10 years[9~11].

Patency rate of the right gastroepiploic artery (RGEA), when used as a pedicled graft, with approximately 95% to 97% patency after 2 to 5 years[12, 13]. The improved patency rates if the IMA and RGEA grafts also may be explained by the increased capacity of the arterial endothelium to secrete prostacylin and endothelial derived relaxing factor, which are potent vasodilaters and inhibitors of platelet aggregation[14, 15].

Free arterial grafts also may fail because of spasm[16, 17]. Two possible explains are an increased reaction to norepinephrine, as a consequense of total denervation of the vasa vasorum[16], and a total disruption of the vasa vasorum at both ends[18]. Early failure of the RA graft has been attributed to generalized intimal hyperplasia[19]. To minimize these problems, Acar and associates[4] recommended following modifications in the harvesting techniques: the RA artery should be dissected en bloc, together with its pedicle, including the two satellite veins and the surround fat tissue, to preserve the vasa vasorum as much as possible. They also advocate avoiding intraluminal dilatation, to prevent intimal trauma, and the routine administration of calcium-channel blockers during and after operation, to prevent spasm. But, C. A. Dietl et al[7] experienced several patients who were bradycardia or hypotension, which may be caused or aggravated by calcium channel blocker(diltiazem). So they reduced the dosage to one-half and added low dose inotropic support if needed, also used tempoary atrial pacing wire to increase heart rate. The infusion dosage of calcium channel blocker during and immediate postoperative period is some different among the institute(1μg/kg/min. in Acar[5], loading dose 0.05mg/Kg, and followed by 0.15 to 0.2μg/kg/min. in A. T. Reyes[6], 3 to 5mg/hr. in C. A. Dietl[7], 4mg/hr. in A. M. Calafiore[20]. The target vessels for RA grafting is preferly in territories with occluded or severe obstructive vessels to ensure maximal flow through the graft. The target

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vessels in our series are distributed left anterior descending artery(n=2), diagonal branches(n=18), obtuse marginal branches(n=38), and right coronary artery and posterior descending artery branches(n=6). Also we have grafted borderline distal artery(1-1.5mm) and endarterectomized vessel and severe left main stenosis(exceeding 90%). A. M. Calafiore et al.[20] and S. E. Fremes et al[8] reported that the RA proximal anastomosis to the IMA. The RA was anastomosed proximally to the IMA, as a branch(end to side, Y-graft) or as a prolongation(end to end). In our institute, this technique was not used, but all RA proximal anastomosis placed on the ascending aorta.

The short term and mid-term results of RA graft are excellent. There are 100% patent at 3 weeks and 93.5% patent at 9.2 months in C. Acar's series[5], 100% patent at 7 to 30 days, and 94.1% patent at 14 months in C. M. Calafione's report[20]. Our short term result(mean 4 months) is 95% patency rate in the RA conduit, but 100% patent in the left IMA and SV graft. Since 1989, C. Acar et al.[7] routinely used the RA in CABG in 324 patients and carefully followed the patients receiving an RA graft over the past 5 years. They concluded that the RA had remained an excellent graft and, after the pedicled IMA, was now the arterial conduit of choice in their surgical practice.

We conclude that the RA is useful for patients with inadequate venous conduit. Long term clinical and angiographic studies are required to determine whether wider application is warranted.

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=국문초록=

요골동맥을 이용한 관상동맥우회술은 1970년대초 처음 도입되었으나 요골동맥 연축(spasm)에 의한 이식편의 부전으로 사용이 중지되었으나, 1980년대 후반 칼슘 길항제등 새로운 연축 방지제의 개발과 요골동맥 채취방법(harvesting technique)의 개선으로 다시 사용하게 되었다.

저자들은 1994년 10월부터 1995년 7월까지 총 36례에서 요골동맥 자유이식편을 이용하여 관상동맥우회술을 시행하였다. 이들중 34례에서 좌측 내흉동맥을 동시에 사용하였으며 15례(42%)에서는 모든 이식편을 동맥이식편으로 사용하였다. 총 123개의 원위부 문합중(환자당 평균 3.4개) 좌측 내흉동맥을 사용한 문합이 36개, 복재정맥을 이용한 문합이 23개였으며 나머지 64개의 원위부 문합은 요골동맥을 사용하였고(환자당 평균 1.8개), 요골동맥을 이용한 문합이 전체문합수의 52%를 차지하였다. 요골동맥이식편의 원위부 문합장소는 좌측회선지(circumflex artery)가 38개, 사선지(diagonal artery)가 18개, 우측 관상동맥이 6개, 좌전하행지(left anterior descending artery)가 2개로 분포하였다. 요골동맥을 하나의 이식편으로 사용한 경우가 10례, 순차적문합으로 사용한 경우가 25례 및 두개의 이식편으로 나누어 사용한 경우가 1례였다. 관상동맥우회술과 동반된 수술로는 관상동맥 내막절제술이 14례, 관상동맥 포편성형술(patch angioplasy)이 4례, 승모판막 재건술이 1례, 심근경색후 심실중격파열 봉합술이 1례였다. 수술후 합병증으로는 요골동맥을 채취한 측의 엄지손가락 감각이상이 2례, 술후 출혈이 1례, 저심박출증으로 좌심실보조장치 1례등이 있었으며 이중 좌심실보조장치를 시행한 1례에서 사망하였다. 조기추적 관상동맥 조영술은 생존한 35례중 11례(31%)에서 수술후 79일에서 210일(평균 126일)에 시행하여 좌측 내흉동맥 및 복재정맥은 100%, 요골동맥은 95%의 개방률을 보였다. 생존한 환자 모두에서 협심증의 재발은 없었다. 결론적으로 본 연구에서는 아직 증례의 부족과 짧은 추적기간으로 요골동맥 이식편의 우월성을 입증할 수 없으나 단기적으로 만족할만한 것으로 향후 더 많은 경험의 축적과 장기적인 추적이 요할 것으로 사료된다.