Endoscopic Radial Artery Harvesting may be the Procedure of Choice for Coronary Artery Bypass Grafting

Gunjik Kim; Youngkyun Jeong; Yongkeun Cho*; Jongtae Lee; Joonyong Cho

Background This study assessed the neurologic and cosmetic outcome of the endoscopic radial artery harvesting (ERH) technique in coronary artery bypass grafting (CABG).

Methods and Results The study group comprised 257 consecutive patients who underwent CABG between January 2001 and August 2005 at Kyungpook National University Hospital. The first 157 patients (open group) underwent conventional open harvesting of the radial artery and the second 100 (endoscopic group) had endoscopic harvesting. The severity of both the motor and sensory symptoms, as well as the cosmetic results, was evaluated immediately and at least 6 months after surgery. In the open group, 29 patients experienced neuralgia along the distribution of the lateral antebrachial cutaneous nerve, but none in the endoscopic group patients experienced any sensory abnormalities ($p < 0.05$). However, neuralgia along the distribution of the superficial radial nerve was similarly observed in both groups. No one in either group complained of any motor symptoms. The patients in the endoscopic group were also satisfied with the cosmetic results.

Conclusions ERH resulted in less neurologic complications of the hand and forearm, and outstanding aesthetics. ERH may be the procedure of choice for radial artery harvesting. (Circ J 2007; 71: 1511–1515)

Key Words: Coronary artery bypass graft; Endoscopic harvesting; Radial artery

The use of the radial artery for coronary artery bypass grafting (CABG) was first performed by Carpentier et al in 1971,¹ but patency of those grafts was very poor and subsequently the radial artery was abandoned as a conduit for CABG.^{2,3} Since 1989 when Acar first described a number of patients returning for angiography with patent radial artery grafts and no evidence of graft disease,⁴ the radial artery has been revived as a conduit for CABG, together with the introduction of antispasmodic agents and better harvesting techniques. Since then the advantages of the radial artery as a conduit for myocardial revascularization have become widely accepted, with a better patency rate than that of the saphenous vein.^{5–11}

The conventional open techniques described by Reyes et al have been utilized for radial artery harvesting;¹² they are associated with some neurologic complications such as numbness or paresthesias of the hand or hypersensitivity of the forearm scar.^{13–15} In addition, many patients, especially women, are dissatisfied with the appearance of the scar.

It has already been shown that endoscopic vessel harvesting of the saphenous vein is safe and results in minimal morbidity,¹⁶ and our previous experience with endoscopic vessel harvesting has suggested that endoscopic radial artery harvesting (ERH) may decrease the incidence of the neurologic and wound complications compared with the open harvest technique. For these reasons we adopted an ERH technique for CABG procedures from May 2003 in an attempt to substantially reduce forearm scarring and

possibly reduce the incidence of neurologic complications. This report describes our initial ERH experience and the short-term clinical outcomes compared with a group of patients undergoing the open harvesting technique.

Methods

Patients

Since April 2000 we have been using the radial artery as the second arterial graft of choice after the internal mammary artery. From April 2000 to July 2005, 380 patients underwent primary CABG at Kyungpook National University Hospital and of them, 299 had the non-dominant radial artery harvested as a second arterial conduit for coronary revascularization. Between April 2000 and April 2003, we used the conventional open harvesting technique described by Reyes et al;¹² and from May 2003 we changed to the ERH technique¹⁷ utilizing the VasoView System® (Guidant Corporation, Santa Clara, CA, USA). Among 272 patients undergoing primary CABG using the radial artery between January 2001 and July 2005, we excluded 11 who died within 6 months after CABG and another 4 patients who were lost to follow-up, from whom data could not be reliably obtained. Finally, 257 patients were included in this study. The first 157 patients underwent open harvesting of the radial artery and the second 100 patients underwent ERH. The study protocol was approved by the institutional ethics committee and written informed consent was given by each patient.

The mean age of the patients was 61.1 ± 8.7 years and 33.5% were female. Among the 257 patients, the following risk factors were noted: hypertension in 46.7%, diabetes mellitus in 42.8%, hyperlipidemia in 42.4%, and smoking in 48.6%. A left ventricular ejection fraction $< 30\%$ occurred in 7.4% of the patients. The clinical characteristics of the patients are detailed in Table 1.

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Departments of Thoracic and Cardiovascular Surgery, *Internal Medicine, Kyungpook National University, Daegu, Korea
Mailing address: Joonyong Cho, MD, Department of Thoracic and Cardiovascular Surgery, Kyungpook National University Hospital, 50 Samduck 2-Ga, Chung-Ku, Daegu 700-721, Korea. E-mail: jycho@knu.ac.kr

Table 1 Clinical Characteristics of the Patients

	Open group (n=157)	Endoscopic group (n=100)	p value
Female	34.4%	33.0%	0.786
Age (years)	59.8±8.8	63.3±8.2	0.001
Angina			
Stable	25 (15.9%)	13 (13.0%)	0.591
Unstable	88 (56.1%)	46 (46.0%)	0.160
Myocardial infarction	44 (28.0%)	41 (41.0%)	0.041
Ejection fraction	50.5±9.2%	48.5±10.8%	0.112
Risk factors			
Diabetes mellitus	62 (39.5%)	48 (48.0%)	0.197
Hypertension	72 (45.9%)	48 (48.0%)	0.798
Hyperlipidemia	72 (45.9%)	37 (37.0%)	0.196
Smoking	75 (47.8%)	50 (50.0%)	0.798

Table 2 Operative Data

	Open group (n=157)	Endoscopic group (n=100)	p value
On-pump CABG	147 (93.6%)	99 (99.0%)	0.055
Cardiopulmonary bypass time (min)	107.8±32.5	87.3±23.2	<0.001
Aortic cross-clamping time (min)	61.6±20.4	58.3±17.2	0.187
Total operative time (min)	319.9±63.0	324.7±47.5	0.518
Distal anastomoses/patient	3.2±0.9	4.0±0.8	<0.001
Combined procedure			
Valvular procedure	8 (5.1%)	7 (7.0%)	
Postinfarct ventricular septal defect closure	0	1 (1.0%)	
Site of the radial artery anastomosis			
Obtuse marginal branch of the circumflex artery	121 (77.1%)	69 (69.0%)	0.189
Posterior descending artery of the right coronary artery	15 (9.6%)	7 (7.0%)	0.648
Diagonal branch of the left anterior descending artery	14 (8.9%)	7 (7.0%)	0.647
≥2 anastomosis	7 (4.4%)	17 (17.0%)	0.002

CABG, coronary artery bypass grafting.

ERH Technique

All patients underwent a modified Allen's test with the use of a pulse oximeter placed on the thumb. Ten seconds was chosen as the upper limit for hyperemic reperfusion of the tips of the thumb and index fingers after the release of the compression on the ulnar artery. Doppler ultrasonography was occasionally used for the detection of any evidence of atherosclerosis. The radial artery in the non-dominant arm was exclusively used. Contraindications to radial artery use were an abnormal Allen's test and prior trauma or surgery to the relevant forearm.

A conventional radial artery harvest was primarily performed according to the method described by Reyes et al.¹² The radial artery was harvested as a pedicle with the accompanying veins and fat using sharp dissection and metal clipping.

ERH was performed as described by Connolly et al.¹⁷ All radial arteries were obtained by a specially trained physician assistant who routinely performed both saphenous vein and radial artery harvesting. In all cases we used the VasoView System® (Guidant Corporation). A 2–3 cm longitudinal skin incision was made from approximately 1 cm cephalad to the radial styloid prominence. Dissection was performed to the anterior aspect of the radial artery and veins and isolated from the superficial fascia and connective tissue under direct vision. This dissection was extended 3–4 cm proximally to create a space for the later insertion of a blunt tip trocar (BTT) port. Sodium heparin (5,000 units) was administered via a central intravenous catheter.

The Vasoview Conical Dissection Cannula with a pre-

loaded BTT port was inserted into the previously dissected area. Anterior advancement of the cannula was performed over the adjacent veins next to the radial artery, allowing for the insertion of the BTT port. The BTT port was inserted and the balloon was inflated to the minimum amount necessary to establish an appropriate seal. CO₂ was infused to pressurize the tunnel to approximately 10 mmHg and not to exceed 15 mmHg. An anterior and posterior dissection was performed over the adjacent vein, with careful dissection of the side branches to a degree allowing for the passage of the cannula. The Vasoview Uniport Plus Dissection Cannula without a Conical Tip with Bipolar Scissors was inserted into the pre-dissected tunnel. A branch division was carried out in the same manner as the established harvesting techniques of the saphenous vein,¹⁶ using bipolar cautery. Confirmation of complete branch division was performed by advancing the vessel cradle along the length of the artery.

Under endoscopic guidance the desired area for the distal ligation was established by external manipulation and a 5-mm puncture was made with a surgical blade. A small clamp was inserted into the tunnel under endoscopic guidance and the radial artery was clamped. The clamped artery was extracted through the puncture and the suture was tied. After removal of the radial artery, ligation at the wrist area under direct vision was performed. The radial artery was cannulated at the proximal end and flushed with papaverine solution. The radial artery was examined closely, and all branches were ligated prior to the use as an arterial conduit with metal clips. Ten to fifteen metal clips and 2–3 additional sutures with 7–0 monofilament were usually used

Table 3 Radial Artery Harvesting-Related Complications

	Open group (n=157)	Endoscopic group (n=100)	p value
Hematoma	5 (3.2%)	1 (1.0%)	0.409
Hand ischemia	0	0	1.0
Wound infection	2 (1.3%)	0	0.523
Injury to the radial artery conduit	0	0	1.0

Table 4 Neurologic Complications After Radial Artery Harvesting

Site of neuralgia (innervation)	Open group (n=157)	Endoscopic group (n=100)	p value
Follow-up (months)	60.0±8.6	33.0±7.8	0.000
Lateral aspect of the forearm (lateral antebrachial cutaneous nerve)	29	0	0.000
Improved*	17	0	
Unchanged*	12	0	
Area of the anatomic "snuff box" (superficial radial nerve)	35	27	0.455
Improved*	28	22	
Unchanged*	7	5	

*Severity of the sensory symptoms was evaluated both immediately and at least 6 months after CABG.

Abbreviation see in Table 2.

per radial artery. Suturing with monofilament was used exclusively in cases of inadequate hemostasis using the metal clips.

Intravenous diltiazem was also used as prophylaxis against spasm, usually up to 24 h according to the surgeon's preference. Oral diltiazem was administered postoperatively, usually up to 3 months after discharge.

Data Collection and Statistical Analysis

All patients were contacted by telephone, and in the outpatient clinic, and asked whether they had experienced any sensory or motor symptoms, wound complications or functional impairment of the forearm or hand immediately and at least 6 months after CABG. Cosmetic results were subjectively assessed by a 5-point scale. A score of 1 reflected a poor result and a score of 5 reflected an excellent result. Continuous variables are reported as the mean±standard deviation and range. Statistical analyses were performed using the Student t-test and chi-square test. The Mann-Whitney test was used to analyze the difference in the scores between the groups. A p-value of less than 0.05 was considered significant. All statistical analyses were performed using SPSS 12.0 software (SPSS Inc, Chicago, IL, USA).

Results

Operative and Postoperative Results

On-pump CABG was performed in most cases (open group: 93.6%, endoscopic group: 99.0%), and off-pump CABG was rarely performed. In 93.8% of the cases (n=241) the procedure was confined to coronary revascularization; 15 patients underwent an associated valvular procedure, and 1 had a postinfarct ventricular septal defect closure. Cardiopulmonary bypass times were shorter, and the average number of anastomoses per patient was higher in the endoscopic group than in the open group ($p<0.001$). However, there were no significant differences between the groups with respect to the aortic cross-clamping times and total operative times (Table 2).

ERH-Related Results

All 257 radial arteries were harvested successfully without significant dissections or intimal injury. All had adequate distal flow and were grossly acceptable. We have not experienced radial artery failure as a conduit for bypass. No patients required conversion to the open technique from the ERH technique. The obtuse marginal branch of the circumflex artery was the most common anastomotic site in 82.4% of the patients, followed by the posterior descending artery of the right coronary artery in 8.6%, diagonal branch of the left anterior descending artery in 8.2% and left anterior descending artery in 0.8%. In 24 patients the radial artery was used to graft more than 1 distal target (Table 2).

None of the patients in either group had ischemic or functional complications of the hand or forearm. In the open vs endoscopic group, 5 vs 1 localized hematoma occurred, which were drained through the previous incision without sequelae (Table 3). The following neurologic complications occurred. In the open group, 29 patients complained of a tingling or burning sensation in the forearm, corresponding to injury to the lateral antebrachial cutaneous nerve but no patients in the endoscopic group complained of any forearm numbness or paresthesia, functional limitation of the hand, or wound problems ($p<0.05$). In contrast, sensory symptoms along the distribution of the superficial radial nerve (the volar and dorsal part of the first 2 fingers) were similar between the 2 groups (35 patients in the open group, 27 patients in the endoscopic group). In the open group, 28 of the 35 (80%) patients said their symptoms had resolved within 4 weeks postoperatively, and 7 (20%) reported that the symptoms had not changed since their onset. In the endoscopic group, 21 of the 27 (78%) patients said their initial symptoms had resolved completely within 2–4 weeks, 5 (19%) reported that the symptoms had not changed since their onset, and 1 (4%) patient reported that the sensory symptoms had become worse during the follow-up period (Table 4). The average cosmetic grading was significantly higher in the endoscopic group than in the open group (endoscopic group: 4.1 ± 0.4 , open group: 2.7 ± 0.8 , $p<0.000$). Almost all the patients in the endoscopic group were satisfied with the small incisional scar, as com-

Fig 1. Postoperative scars are small after endoscopic radial artery harvesting and the distal one can be covered by the band of a wrist-watch.

pared with the long forearm incision used for the open technique (Fig 1).

Graft Patency Assessed by Multidetector Computed Tomography (MDCT) and Coronary Angiography (CAG)

Although we did not routinely inspect the patency of the grafted radial arteries in all the patients in both groups, 18 patients in the open group and 76 in the endoscopic group underwent scanning with 16-channel MDCT after the CABG and the short-term patency rate was 94.4% and 97.4%, respectively ($p=0.476$) (Table 5). Conventional invasive CAG was also performed in 23 patients in the open group and 8 in the endoscopic group who had chest discomfort or pain during follow-up. Radial artery segments to anastomoses were completely occluded in 2 cases and another case in the open group had string sign with inadequate distal flow. However, all radial artery grafts in the endoscopic group showed good distal flow with no significant stenosis ($p=0.550$).

Discussion

The radial artery was used as a conduit for CABG by Carpentier et al in the early 1970s,¹ but the lower than expected rate of patency discouraged its use in CABG procedures. Two decades later, the use of the radial artery in CABG procedures was again proposed by Acar et al,⁴ who reported that a number of the radial artery grafts that had been thought to be occluded were found to be patent. Thus,

they used the radial artery again, with improved results, and their results revolutionized the world's view of the radial artery as an arterial conduit for CABG. Since then many groups have reported excellent radial artery graft patency rates compared with saphenous vein grafts^{6,18} and the radial artery has become an increasingly popular arterial conduit for coronary artery revascularization. However, the conventional open harvesting technique is associated with several complications. In addition to the hypertrophic scar, functional impairment and wound infections of the forearm and hands, the most frequently occurring complications are neurologic. The reported incidences of neurologic symptoms vary widely in the literature, from 12% to 68%^{9,13–15,19}. Not surprisingly, sensory symptoms in the hand and forearm, mild limitations of hand activity, wound hypersensitivity and patient dissatisfaction have not been uncommon. Compared with the conventional harvesting technique, the ERH method results in significantly fewer major and minor long-term residual sensory symptoms, and the incidence of neurologic complications reported in the literature has ranged from 1% to 8.7%.^{17,20,21}

Our experience with the ERH supports the previous reports and confirms that the endoscopic technique is safe and effective for reducing the morbidity commonly associated with the open harvesting technique. The patients who underwent the ERH technique had significantly fewer neurologic complications along the distribution of the lateral antebrachial cutaneous nerve. In the open group, 29 patients complained of postoperative forearm neuralgia, corresponding to injury to the lateral antebrachial cutaneous nerve, and subjective forearm paresthesia continued at 6 months, but no patients in the endoscopic group complained of forearm numbness or paresthesia. The decrease in the neurologic complications observed in the ERH group could have been attributed to the lack of contusions or damage to the lateral antebrachial cutaneous nerve. Because the lateral antebrachial cutaneous nerve provides the sensation to the lateral anterior aspect of the forearm and traverses the top of the brachioradialis muscle fascial sheath, we did not encounter any nerve injury or related neurologic symptoms with the ERH technique. In the open harvesting technique, the lateral antebrachial cutaneous nerve can be damaged from excessive traction, dissection, or suturing during wound closure. The ERH virtually eliminated any injury to the lateral antebrachial cutaneous nerve, which is frequently injured during the open harvesting technique.

However, we experienced a significantly higher incidence of superficial radial nerve related neurologic symptoms, even with the ERH technique, which may have been related to the use of the BTT port balloon, because the incidence of neurologic symptoms in this study was higher than in other reports.^{17,20,21} Because the superficial radial nerve provides sensation to the volar and dorsal area of the first 2 fingers and runs laterally to the radial artery in the distal forearm, it may be injured during dissection in the

Table 5 Radial Artery Graft Patency Assessed by MDCT

	Open group (n=18)	Endoscopic group (n=76)	p value
Radial artery	17 (94.4%)	74 (97.4%)	0.476
Left IMA	17 (94.4%)	76 (100%)	0.191
Saphenous vein	16 (88.9%)	62 (82.7%)	0.727

MDCT, multidetector computed tomography; IMA, internal mammary artery.

distal forearm and wrist. Damage to the superficial radial nerve continues to be a problem for both the open and ERH techniques. In the endoscopic group, we suspect that the reason for the superficial radial nerve injury was compression on that nerve by the BTT port. However, we have been experiencing somewhat less incidence and severity of superficial radial nerve related neuralgia with the ERH technique, attributable to minimal inflation of the BTT port balloon, as we gain more experience with the ERH technique. Further developments in endoscopic instruments, such as an arm-specific device with a smaller BTT port balloon, may further decrease the neurologic complications related to the superficial radial nerve.

Undoubtedly, the cosmetic results in the endoscopic group were clearly superior to those in the open group. Because the incision was smaller than that used in the open harvesting technique, the patients in the endoscopic group were very satisfied with the forearm scar.

Because MDCT has been available in our institution only since 2003, we began using the ERH technique before being able to use MDCT to assess the rate of patency of radial artery grafts. However, in the present study the patency assessed by MDCT or conventional CAG was similar between the 2 groups. Future investigations comparing the long-term patency rate for ERH compared with the conventional open technique will be needed.

Study Limitations

The major limitations are that we measured self-reported neurologic symptoms, which was not objective testing performed by neurologists, and this was a retrospective study with a clear and intentional selection bias.

Conclusion

Our results suggest that the ERH technique leads to a significant reduction in the neurologic complications of the forearm, corresponding to the distribution of the lateral antebrachial cutaneous nerve, and, in particular, has improved cosmetic results as compared with the open radial artery harvesting technique.

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