

Comparison of Radial Artery and Saphenous Vein Composite Y Grafts during Off-pump Coronary Artery Bypass

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Background: The safety and efficacy of arterial composite grafts for total arterial revascularization have been demonstrated. The saphenous vein (SV) is a widely used graft because of its accessibility, sufficient length, and ease of manipulation. Our aim was to compare mid-term outcomes of saphenous vein Y-grafts with radial artery Y-grafts joined by anastomosis to the left internal thoracic artery. **Materials and Methods:** Records of off-pump coronary artery bypass grafting with composite Y-grafts based on the left internal thoracic artery technique in 552 patients were analyzed retrospectively. After propensity score matching, 79 radial arterial (RA) composite grafts (RA group) and 79 saphenous vein composite grafts (SV group) were compared. The duration of mean follow-up was 24.6 ± 14.6 months (range, 1 to 55 months). **Results:** There were no differences in surgical mortality, all-cause mortality, or morbidity among the groups. Rates of 4-year survival were 91.7% and 96.3% in the RA and SV groups, respectively ($p=0.519$). The coronary reintervention-free survival rate and freedom from major adverse cardiovascular or cerebrovascular events were similar in the two groups ($p=0.685$, $p=0.564$). **Conclusion:** Construction of composite Y-grafts using the radial artery or saphenous vein showed similar mid-term results. Long-term follow-up and randomized trials will be needed to confirm our present conclusions.

Key words: 1. Coronary artery bypass
2. Radial artery
3. Saphenous vein
4. Mammary arteries

INTRODUCTION

The choice of conduit for coronary artery bypass grafting has always been an issue important to cardiac surgeons who perform coronary artery bypass graft (CABG) surgery. The use of a left internal thoracic artery (LITA) graft has become the 'gold standard' following the Cleveland Clinic group report that an internal thoracic artery (ITA) graft to the left anterior descending (LAD) artery was better than a vein graft

with regard to survival and preventing ischemic events [1]. The excellent outcomes associated with ITA graft have led several groups to pursue arterial composite grafts for total arterial revascularization based on the ITA graft as the preferred approach [2-5].

There have been only a few studies, of small sample sizes, reporting the results of CABG using the saphenous vein (SV) as a composite graft, and this vein composite graft is still controversial [6-9]. However, the SV has remained the most

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Table 1. Preoperative characteristics and risk factors of the study patients

| Variable | Entire study group (n=554) | | | Propensity-matched pairs (n=158) | | |
|------------------------------------|----------------------------|-----------|---------|----------------------------------|-----------|---------|
| | RA group | SV group | p-value | RA group | SV group | p-value |
| Patients (n) | 458 | 94 | | 79 | 79 | |
| Age | 64.2±9.4 | 69.9±6.7 | <0.001 | 69.6±5.7 | 69.7±6.4 | 0.954 |
| Female | 111 (24.2) | 29 (30.9) | 0.179 | 28 (35.4) | 25 (31.6) | 0.613 |
| Body mass index | 24.8±3.3 | 23.7±2.5 | 0.002 | 24.3±2.9 | 24.0±2.6 | 0.446 |
| Diabetes mellitus | 174 (38) | 53 (56.4) | 0.001 | 43 (54.4) | 43 (54.4) | 1.000 |
| Dyslipidemia | 168 (36.7) | 34 (36.2) | 0.925 | 25 (31.6) | 27 (34.2) | 0.735 |
| Chronic renal failure | 35 (7.6) | 14 (14.9) | 0.024 | 10 (12.7) | 12 (15.2) | 0.646 |
| Hypertension | 325 (71.0) | 78 (83.0) | 0.017 | 67 (84.8) | 65 (82.3) | 0.668 |
| Chronic lung disease | 7 (1.5) | 4 (4.3) | 0.051 | 2 (2.5) | 3 (3.8) | 0.649 |
| Old cerebrovascular accident | 46 (10.0) | 19 (20.2) | 0.005 | 17 (21.5) | 15 (19.0) | 0.692 |
| PAOD | 29 (6.3) | 11 (11.7) | 0.067 | 7 (8.9) | 8 (10.1) | 0.786 |
| PTCA | 88 (19.2) | 18 (19.1) | 0.988 | 16 (20.3) | 15 (19.0) | 0.841 |
| NSTEMI/UA | 225 (49.1) | 53 (56.4) | 0.200 | 43 (54.4) | 44 (55.7) | 0.873 |
| IABP | 1 (0.2) | 2 (2.1) | 0.022 | 0 (0) | 0 (0) | 1.000 |
| Inotrope | 4 (0.9) | 4 (4.3) | 0.013 | 4 (5.1) | 2 (2.5) | 0.405 |
| Atrial fibrillation | 9 (2.0) | 8 (8.5) | 0.001 | 7 (8.9) | 4 (5.1) | 0.348 |
| NYHA ≥3 | 46 (10.0) | 23 (24.5) | <0.001 | 13 (16.5) | 16 (20.3) | 0.538 |
| left main disease | 112 (24.5) | 21 (22.3) | 0.816 | 16 (20.3) | 17 (21.5) | 0.845 |
| Left ventricular ejection fraction | 57.1±14.2 | 52.9±13.8 | 0.009 | 54.5±15.7 | 54.5±13.0 | 0.991 |
| Mitral regurgitation >2 | 10 (2.2) | 4 (4.3) | 0.245 | 2 (2.5) | 4 (5.1) | 0.405 |

Values are presented as mean±standard deviation or number (%).

RA, radial artery; SV, saphenous vein; PAOD, peripheral artery occlusive disease; PTCA, percutaneous transluminal coronary angioplasty; NSTEMI, non-ST elevation myocardial infarction; UA, unstable angina; NYHA, New York Heart Association.

widely used graft because of its accessibility, sufficient length, and ease of use. For patients with a diffusely atherosclerotic ascending aorta, SV composite Y-grafts may be necessary, particularly when there is some contraindication to the use of radial arterial (RA) grafts and LITA target vessels (mainly LAD artery) and severe (>70%) stenosis.

The goal of this study was to compare the clinical outcomes in two off-pump coronary artery bypass (OPCAB) groups that received either a pedicled RA composite graft or an SV composite graft to the LITA.

MATERIALS AND METHODS

1) Patient characteristics

Among the 1,181 patients who underwent isolated CABG at the Severance Cardiovascular Center of Yonsei University Health System in Korea between January 2008 and July 2012, OPCAB was performed in 1,158 cases (98.1%). Among those, 552 patients (47.7%) who underwent elective

OPCAB using composite Y-grafts anastomosed to the LITA entered this study. Patients undergoing an emergency operation or LITA anastomosis to target coronary vessels other than the LAD were excluded. Also, patients who required multiple composite Y-grafts (double or triple Y-graft) or extension of a graft were also excluded from this study. A pedicled RA (n=458) or SV (n=94) graft was joined by anastomosis to the side of the LITA to construct a composite Y-graft. Propensity-score matching was used to balance the distribution of baseline risk factors between the patients receiving RA versus SV composite grafts. From those results, 79 cases were selected for inclusion in the RA group and 79 in the SV group. The characteristics of the study population before and after propensity matching analysis are summarized in Table 1.

2) Grafting strategy

The use of RA versus SV composite grafting was not random; rather, it was decided according to the surgeon's prefer-

ence, the patient's underlying condition, presence and degree of stenosis, and size of the target vessel. RA was a preferred composite Y-graft whenever possible for revascularization. However, in cases of atherosclerotic change in the RA graft, a positive Allen's test, or severe peripheral artery occlusive disease, or particularly when there was severe (>70%) stenosis of the LITA target vessels (mainly the LAD artery), an SV graft was used. We usually harvested the SV from the calf instead of the thigh to secure a vessel with small caliber to reduce flow steal and size discrepancy. Because the average pedicled RA graft length was 18 to 20 cm, a third graft was needed in some patients with three-vessel coronary disease. We usually used the SV as a third graft, as it is long enough to revascularize all the diseased territories when used as a free graft proximally anastomosed to the ascending aorta.

3) Surgical technique

OPCAB was performed as previously described [10]. General endotracheal anesthesia with continuous Swan-Ganz catheter monitoring, transesophageal echocardiography, and arterial pressure monitoring was used. All of the operations were performed by the off-pump method via a full sternotomy incision. The LITA was used in all of the patients, and the RA, SV, right ITA, or right gastroepiploic artery was used if necessary. Harvest of the LITA was performed by a semi-skeletonized method using very low voltage unipolar electrocautery. Heparin with papaverine was used to avoid vasospasm of the LITA. At the same time, the RA or SV was harvested by using an open technique. The RA or SV was exposed by a longitudinal incision and then all of the visible side branches were ligated. The SV was isolated, together with a pedicle of surrounding fatty tissue (no-touch technique). After removal, the excised SV or RA tissue was stored in heparinized blood, and a calcium channel blocker (diltiazem) was used to prevent spasm of the RA during the operation. Heparin was given at a dose of 100 U/kg to achieve a target activated clotting time of at least 300 seconds during the operation. For cardiac stabilization and displacement, we used an Octopus tissue stabilizer and Starfish heart positioner (Medtronic, Minneapolis, MN, USA) during construction of the anastomosis. An intracoronary shunt was mainly used for the LAD anastomosis, and the proximal snaring technique with a silicone

elastomer was used for anastomosis of other left coronary artery system vessels. For right coronary anastomosis, an intracoronary shunt was usually used for the main right coronary artery (RCA), and the proximal snaring technique was used for the posterior descending or posterolateral artery. To remove blood from the sites of arteriotomy, a combination of a carbon dioxide blower and irrigation with warm saline was used. Before the sternum was closed, the LITA graft was wrapped in thymic tissue to prevent injury during reoperation.

4) Data collection

Preoperative and perioperative data were collected retrospectively from the cardiac research databases at the Severance Cardiovascular Center of Yonsei University Health System in Korea. Follow-up data were obtained by reviewing hospital charts, telephone interviews, and searching the National Death Index. The collection of mid-term outcomes was complete in 90.1% of the patients. The mean follow-up duration was 24.6 ± 14.6 months (range, 1 to 55 months).

5) Mid-term outcome assessment

Mid-term outcomes were assessed by all-cause mortality, reintervention, major adverse cardiac and cerebrovascular events (MACCEs), and morbidity. MACCEs were defined as any of the following: death from any cause, nonfatal myocardial infarction, reintervention, or stroke. Myocardial infarction was defined as new onset of wall motion abnormality, creatine kinase MB isoenzyme elevation with appearance of new Q waves, or ST segment elevation of more than 2 mm on electrocardiogram. Reintervention was defined as percutaneous coronary intervention after surgery or redo coronary bypass surgery.

6) Statistical analysis

For analysis of characteristics between the unmatched groups, continuous variables were compared using the t-test, and categorical variables were compared using the χ^2 or Fisher's exact test. To correct for the effect of non-randomization and selection bias in this retrospective study, propensity score matching analysis was done. To produce propensity scores, we used logistic regression analysis of various preoperative variables. To analyze the differences between the

Table 2. Number of distal anastomoses

| | Entire study group (n=552) | | | Propensity-matched pairs (n=158) | | |
|--------------------------------------|----------------------------|-----------|---------|----------------------------------|-----------|---------|
| | RA group | SV group | p-value | RA group | SV group | p-value |
| Patients (n) | 458 | 94 | | 79 | 79 | |
| Total distal anastomoses per patient | 3.23±0.76 | 3.17±0.63 | 0.061 | 3.10±0.69 | 3.16±0.65 | 0.556 |
| Composite graft distal anastomoses | 1.97±0.71 | 1.97±0.71 | 0.987 | 1.97±0.68 | 1.97±0.70 | 1.000 |
| Free graft distal anastomoses | 0.28±0.60 | 0.21±0.51 | 0.328 | 0.14±0.42 | 0.20±0.49 | 0.401 |
| LAD territory | 1.36±0.51 | 1.31±0.46 | 0.323 | 1.34±0.20 | 1.27±0.45 | 0.276 |
| LCX territory | 1.01±0.60 | 1.03±0.50 | 0.751 | 0.95±0.62 | 1.01±0.52 | 0.479 |
| RCA territory | 0.91±1.26 | 0.81±0.51 | 0.460 | 0.78±0.52 | 0.87±0.49 | 0.310 |

Values are presented as mean±standard deviation.

RA, radial artery; SV, saphenous vein; LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery.

matched groups, means were compared using a paired Student's t-test, and frequencies were analyzed by McNemar's test. Overall survival, MACCEs, and coronary reintervention-free survival rate curves were estimated by the Kaplan-Meier method. Differences between curves were compared using the log-rank test. In all statistical tests, statistical significance was defined as a two-tailed p-value of less than 0.05. Statistical analysis was performed with IBM SPSS ver. 19.0 (IBM Co., Armonk, NY, USA). All of the results in the paper are expressed as mean±standard deviation, and a probability value less than 0.05 was considered statistically significant.

RESULTS

1) Patient characteristics

After propensity score matching, the demographics of the RA and SV groups were found to be similar with respect to age, gender (proportion of females), body mass index, diabetes mellitus, dyslipidemia, chronic renal failure, hypertension, chronic lung disease, previous history of stroke, peripheral arterial occlusive disease, prior percutaneous coronary intervention, non-ST elevation myocardial infarction/unstable angina, intra-aortic balloon pump, inotropic agents, atrial fibrillation, New York Heart Association functional class, left main coronary artery disease, echocardiographic left ventricular ejection fraction, and higher than grade two mitral regurgitation. From these covariates, a propensity score was calculated for each patient. Each patient in the RA group was matched 1:1 with a patient in the SV group. From this

matching analysis, 79 patients in each group were selected for final analysis. The baseline characteristics of the RA and SV groups are shown in Table 1.

2) Surgical data

The average number of distal anastomoses per patient was similar in the RA and SV groups (3.10±0.69 vs. 3.16±0.65; p=0.556). The average number of distal anastomoses per Y-graft (1.97±0.68 vs. 1.97±0.70; p=1.000) and the average number of distal anastomoses per patient using a free graft proximally anastomosed to the ascending aorta (0.14±0.42 vs. 0.20±0.49; 0.401) did not differ between the two groups. When the coronary arteries were classified according to the LAD, left circumflex artery, and RCA regions, the number of distal anastomoses per region did not differ between the two groups (Table 2).

3) Surgical and mid-term clinical results

The surgical mortality was 1.27% (1/79) in the RA group, and this value was not significantly different than 0% in the SV group. There were no significant differences in the incidence of postoperative morbidities, such as MACCEs, stroke, myocardial infarction, coronary reintervention, mediastinitis, atrial fibrillation, low cardiac output syndrome, wound problems, respiratory complications, peripheral vascular complications, or acute renal failure (Table 3). Two late mortalities occurred, one in the RA group (cancer-related death) and the other in the SV group (sudden death of unknown origin). The 4-year survival rates were 91.7% and

Table 3. Comparison of clinical results

| Variable | Entire study group (n=552) | | | Propensity-matched pairs (n=158) | | |
|------------------------|----------------------------|------------|---------|----------------------------------|-----------|---------|
| | RA group | SV group | p-value | RA group | SV group | p-value |
| Patients (n) | 458 | 94 | | 79 | 79 | |
| Early mortality | 1 (0.2) | 0 (0) | 0.650 | 1 (1.3) | 0 (0) | 0.313 |
| Myocardial infarction | 3 (0.7) | 1 (1.1) | 0.672 | 1 (1.3) | 1 (1.3) | 1.000 |
| Infection | 5 (1.1) | 6 (6.4) | 0.001 | 2 (2.5) | 3 (3.8) | 0.649 |
| Stroke | 6 (3.8) | 1 (1.1) | 0.846 | 1 (1.3) | 1 (1.3) | 1.000 |
| Pulmonary complication | 25 (5.5) | 8 (8.5) | 0.258 | 5 (6.3) | 7 (8.9) | 0.548 |
| Acute renal failure | 25 (5.5) | 7 (7.4) | 0.452 | 8 (10.1) | 5 (6.3) | 0.385 |
| Vascular complication | 3 (0.7) | 2 (2.1) | 0.170 | 0 (0) | 1 (1.3) | 0.316 |
| Atrial fibrillation | 87 (19.0) | 22 (23.4) | 0.328 | 16 (20.3) | 19 (24.1) | 0.565 |
| Wound complication | 28 (6.1) | 3 (3.2) | 0.262 | 7 (8.9) | 2 (2.5) | 0.086 |
| LCOS | 66 (14.4) | 13 (13.8) | 0.877 | 14 (17.7) | 8 (10.1) | 0.168 |
| Ventilator time (hr) | 23.2±48.5 | 41.6±132.5 | 0.021 | 30.2±78.5 | 29.2±51.0 | 0.925 |
| Late mortality | 7 (1.5) | 4 (4.3) | 0.086 | 1 (1.3) | 1 (1.3) | 1.000 |
| MACCEs | 26 (5.7) | 8 (8.5) | 0.301 | 6 (7.6) | 4 (5.1) | 0.513 |
| Reintervention | 11 (2.4) | 1 (1.1) | 0.418 | 2 (2.5) | 1 (1.3) | 0.560 |

Values are presented as number (%) or mean±standard deviation.

RA, radial artery; SV, saphenous vein; LCOS, low cardiac output syndrome; MACCEs, major adverse cardiac and cerebrovascular events.

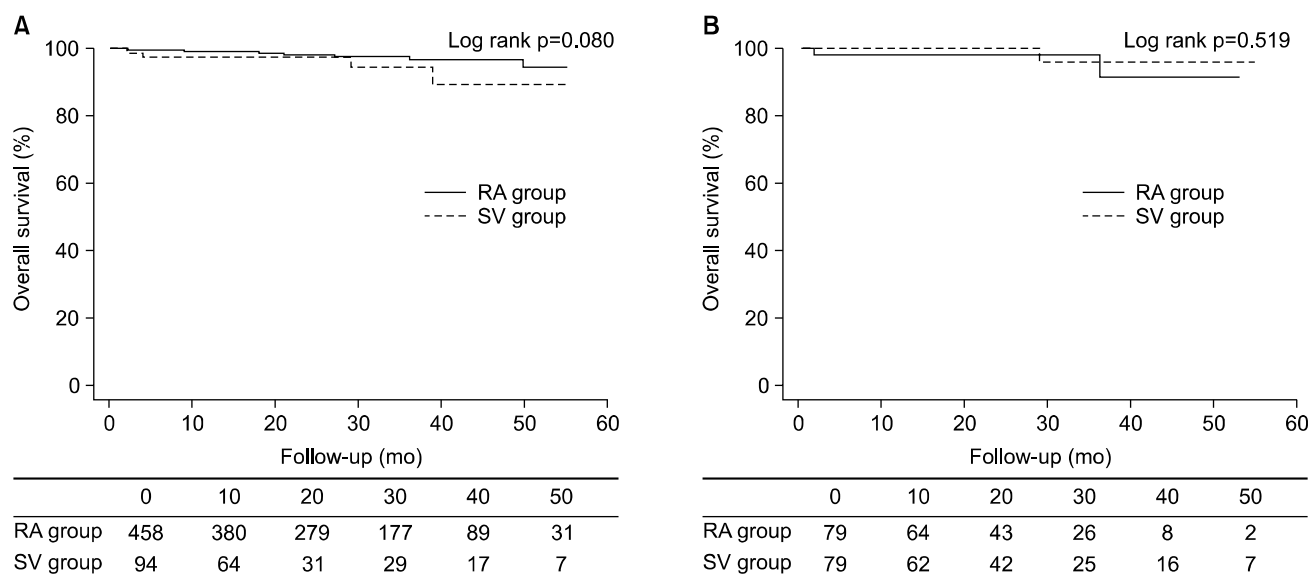


Fig. 1. Overall survival rate comparing radial artery (RA) group and saphenous vein (SV) group in (A) entire study groups (B) matched groups.

96.3% in the RA and SV groups, respectively ($p=0.519$) (Fig. 1). Three patients underwent coronary reintervention during follow-up. Coronary reintervention-free survival rates at 4 years were 94.4% and 98.7% in the RA and SV groups, respectively ($p=0.685$) (Fig. 2). Freedom from MACCEs at 4

years was also similar in the two groups ($p=0.564$) (Fig. 3).

4) Early patency rates

Early postoperative coronary computed tomography angiography (CTA) was performed before discharge (4 to 7 days af-

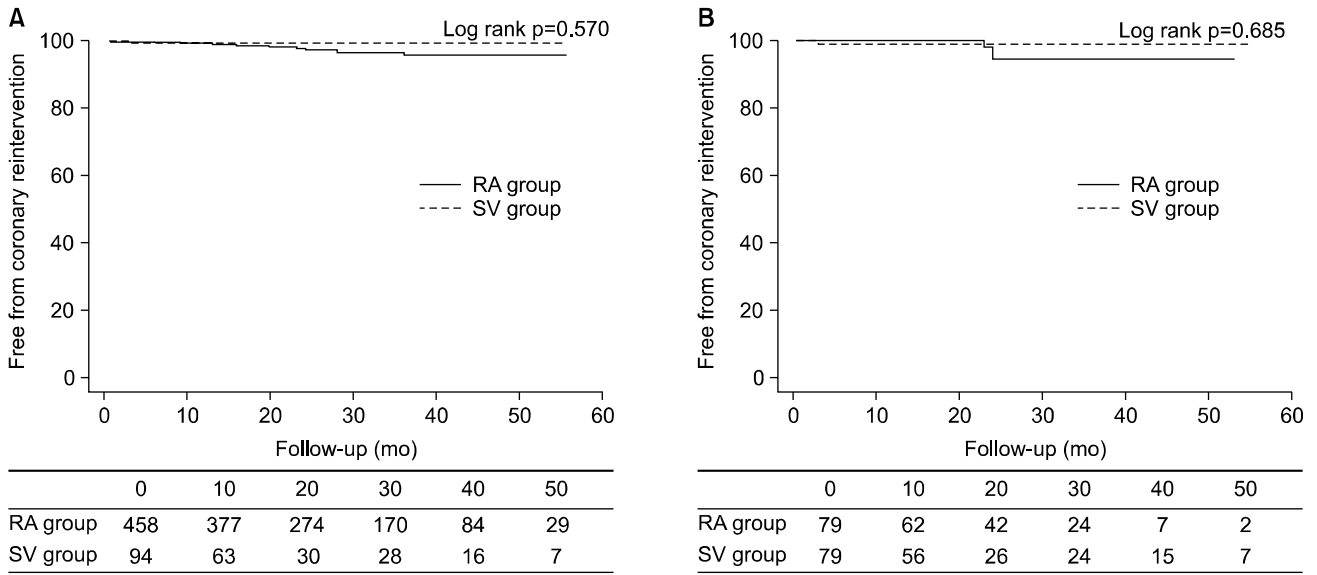


Fig. 2. Coronary reintervention-free survival rate comparing radial artery (RA) group and saphenous vein (SV) groups in (A) entire study groups (B) matched groups.

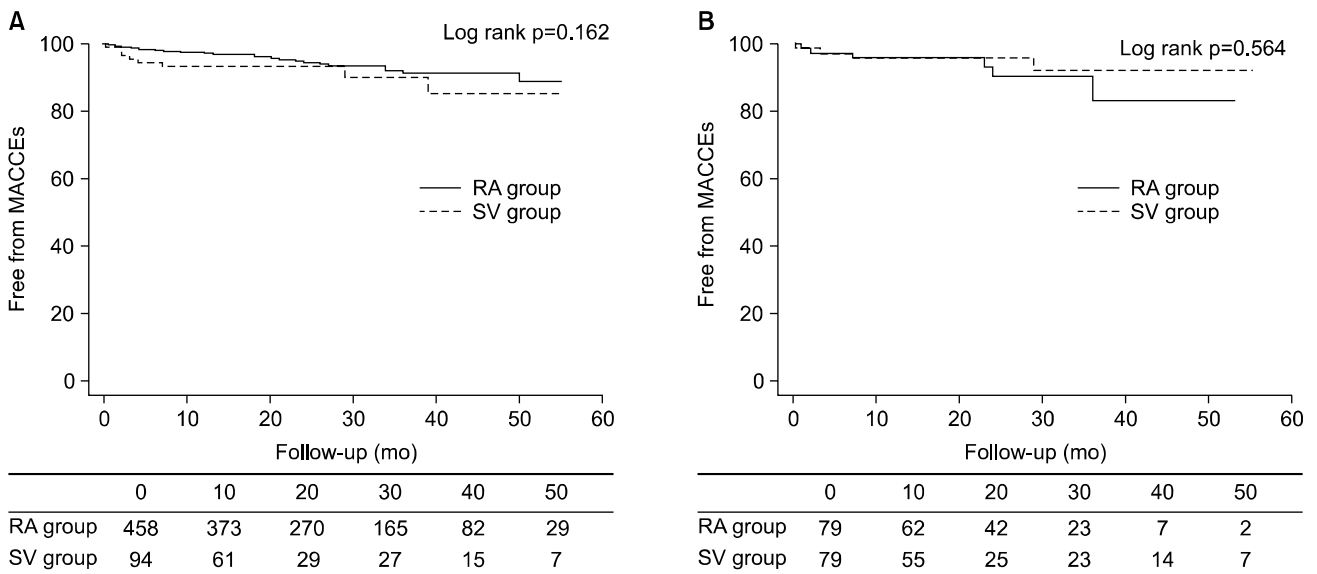


Fig. 3. MACCEs-free survival rate comparing radial artery (RA) group and saphenous vein (SV) group in (A) entire study groups (B) matched groups. MACCEs, major adverse cardiac and cerebrovascular events.

ter the operation) in 65.9% (364 of 552) of the patients (318 of 458 in the RA group; 46 of 94 in the SV group) regardless of the patient’s anginal symptoms. Patients who died, refused CTA evaluation, had limited financial resources, or had renal function impairment were excluded from CTA follow-up. Early postoperative coronary CTA demonstrated a

100% patency rate in both groups (Table 4).

DISCUSSION

The present study revealed two main findings. First, the mid-term clinical results were similar for RA and SV compo-

Table 4. Comparison of early angio computed tomography patency rates

| | Entire study group (n=364) | | | Propensity-matched pairs (n=87) | | |
|--|----------------------------|-----------------|---------|---------------------------------|-----------------|---------|
| | RA group (n=318) | SV group (n=46) | p-value | RA group (n=48) | SV group (n=39) | p-value |
| Overall patency | 1,025/1,030 (99.5) | 149/149 (100) | 0.446 | 151/151 (100) | 126/126 (100) | 1.000 |
| <i>In situ</i> left internal thoracic artery | 315/318 (99.1) | 46/46 (100) | 0.589 | 48/48 (100) | 39/39 (100) | 1.000 |
| Y-composite | 611/613 (99.7) | 92/92 (100) | 0.698 | 97/97 (100) | 78/78 (100) | 1.000 |
| Free graft | 103/103 (100) | 12/12 (100) | 1.000 | 7/7 (100) | 10/10 (100) | 1.000 |

Values are presented as number (%).

RA, radial artery; SV, saphenous vein.

site Y-grafts anastomosed to the LITA. Second, the early postoperative coronary CTA patency rates of the SV and RA groups were similar.

The safety and efficacy of composite grafts for total arterial myocardial revascularization have been demonstrated in terms of clinical outcomes, angiographic patency, and myocardial perfusion, although controversy still exists [2-5,11]. The expanded use of LITA in a Y configuration with another arterial conduit, such as an RA graft, which allows maximal arterial graft economy and sufficient length of the grafts, has been performed with excellent clinical results [12]. Indeed, this graft configuration allows the performance of complete myocardial revascularization with no more than two grafts. This method significantly increases the flow capacity of the *in situ* ITA [13]. In addition, it can avoid aortic manipulation and thereby reduces the risk of stroke during the operation. The incidence of postoperative stroke increases with increased levels of aortic manipulation. This is particularly true in elderly patients, considering the high prevalence of moderate to severe atherosclerotic aortic disease.

However, CABG using the SV as a composite graft anastomosed to *in situ* LITA represents an unusual type of procedure. Only a few studies conducted in a small number of patients have reported results of CABG using SV composite grafts, and this graft configuration is controversial [6-8,14]. The SV graft may be regarded as a major ITA collateral branch whose caliber is significantly larger than that of the main artery itself. Moreover, it is less reactive than all of the other arterial conduits and is likely to offer less resistance to flow. This situation can create the possibility of a significant flow diversion from the ITA to the SV. Flow steal is even enhanced when the ITA is anastomosed to a coronary

vessel with moderate (<70%) stenosis [15-18]. Gaudino et al. [6] studied 25 patients in whom a saphenous vein graft (SVG) was implanted into the LITA. They found that the short-term patency of a composite Y ITA-SVG was sub-optimal and markedly influenced by distal runoff and native flow competition. In fact, all cases of ITA malfunction were reported in the part of the ITA distal to the SVG anastomosis and in the patients in whom the composite SVG was anastomosed to the coronary arteries with less than 70% stenosis (p=0.02).

However, SVG is still the most widely used graft because of its accessibility, sufficient length, and ease of use. Hayward et al. [19] found no clinical benefit of RA over SV graft at 6 years of follow-up. Glineur et al. [9] evaluated the hemodynamic characteristics of 17 composite Y-grafts of the LITA with either the free right ITA or SVG bypassed to the circumflex territory 6 months after the operation. They found that composite Y-grafts with the SV or right ITA allow similar and adequate reperfusion of the left system, with minimal resistance to maximal flow and an even distribution of flow in both distal branches.

In the present study, RA was preferred for use as a composite Y-graft for the LITA whenever possible for revascularization. We performed CABG using the SV as a composite graft for the LITA only in case of patients with a diffusely atherosclerotic ascending aorta, particularly when there was some contraindication to the RA grafts and LITA target vessels (mainly LAD artery) with severe (>70%) stenosis. We also usually harvested the SV from the calf instead of the thigh to secure an SV with small caliber to reduce the flow steal and size discrepancy.

In the current study, we did not observe any disadvantage

of SV composite grafting relative to that with RA. However, our results are too limited to assert that the clinical results of SV grafting can actually be expected to be similar to those of RA grafting. Studies with longer follow-up may in fact encounter different results. However, this study at least leads to the conclusion that SV composite grafts are similar to RA composite grafts anastomosed to the LITA with respect to the 4-year survival rate and occurrence of MACCEs.

There are some limitations to this study. First, it is retrospective, non-randomized, and based on a single-center experience. Second, the data were obtained from two surgeons, so bias associated with the surgeons may play an important role in our findings. However, the surgeons were both highly experienced, mainly performed off-pump CABG, and used very similar methods for grafting, and this minimizes some of that bias. Third, our preferred strategy was total arterial revascularization, and the SV was used as an alternative graft when an RA graft was not available. This might have influenced the surgical results as a confounding variable, even though there were no differences in the demographic data after propensity score matching. Fourth, the number of patients and mortality and morbidity rates may not have been sufficient to achieve adequate outcomes after statistical analysis in order to conclusively decide the issue of the preferred graft vessel.

In conclusion, we observed that mid-term clinical results were similar between RA and SV composite Y-grafts anastomosed to the LITA. However, long-term clinical and angiographic data might be necessary to draw a definite conclusion regarding the safety and efficacy of SV composite grafts.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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