Serial angiographic follow-up of grafts one year and five years after coronary artery bypass surgery

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Abstract

Objective: We studied retrospectively the patency of grafts after coronary artery bypass grafting (CABG) using serial angiographies performed one year and five years after surgery. Methods: One hundred and nine patients who had available coronary angiographies at both one year and five years after CABG were included. Morphologic changes of anastomotic sites and grafts were traced in the same group of patients using the FitzGibbon grading system. Results: The arterial graft patency rate (FitzGibbon grade A + B) was significantly higher than the saphenous vein grafts at both one year (98.0% vs 82.4%, \( p < 0.001 \)) and five years (90.7% vs 80.2%, \( p = 0.006 \)) after surgery, respectively. The arterial graft patency rate was superior to vein grafts in the left anterior descending coronary artery territory at both one year (97.5% vs 82.0%, \( p = 0.001 \)) and five years (90.9% vs 78.0%, \( p = 0.042 \)) postoperatively. Other territories showed similar patency rates between arterial and vein grafts. The vein graft patency rate at five years postoperatively was lowest in the right coronary territory when compared with other territories. When the patency pattern was compared between postoperative years 1 and 5, the proportion of FitzGibbon grade B grafts increased significantly in the vein grafts (3.1% vs 7.5%, \( p = 0.002 \)), while that of arterial grafts remained stable (8.6% vs 7.3%, \( p = 0.774 \)). When the graft patency at postoperative year 5 was compared between patients with recurrent angina and those without, the patients with recurrent angina showed a higher proportion of FitzGibbon grade B grafts (19.2% vs 4.8% in arterial grafts, \( p = 0.023 \); 20.5% vs 4.8% in vein grafts, \( p = 0.003 \)) and lower grade A grafts (65.4% vs 86.4% in arterial grafts, \( p = 0.019 \); 43.6% vs 78.2% in vein grafts, \( p < 0.001 \)), and a lower vein graft patency rate (64.1% vs 83.0%, \( p = 0.014 \)). Conclusions: The arterial graft patency rate was significantly higher than that of saphenous vein grafts, especially in the left anterior descending coronary artery territory, at one year and five years postoperatively. The decreased patency rate of the vein grafts, along with insulin-dependent diabetes mellitus, were associated with angina recurrence.

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Keywords: Coronary artery bypass grafting (CABG); Angiography; Ischemic heart disease

1. Introduction

Several studies have investigated the patency rates of grafts after coronary artery bypass grafting (CABG) and shown that arterial grafts have superior patency than vein grafts [1—4]. However, most of these studies were cross-sectional investigations performed at a defined point in time after CABG. The aims of this study were (1) to compare the patency of arterial and saphenous vein grafts in patients who had received coronary angiography at both one year and five years after CABG, (2) to evaluate the graft patency rates based on target territories, and (3) to elucidate the predictors for angina recurrence.

2. Patients and methods

2.1. Patients

Of the 197 patients who underwent isolated conventional CABG between January 1995 and December 1997, 109 (55.3%) patients who received both one year and five years follow-up coronary angiographies were included for evaluation of the patentiste sites and patency of the grafts. Patients who required concomitant cardiac operations, who had early (<30 days) or late (>30 days) mortality after CABG, or who did not receive both follow-up coronary angiographies were excluded from this study. Written, informed consent was obtained from each participating patient, and Institutional Review Board approval was provided. The patients were 78 males and 31 females with a mean age of 59 ± 9 years at the time of surgery.
In 64 patients, and left main coronary artery disease with or without peripheral coronary artery disease in 21 patients. Eighty-three patients (76%) had unstable angina, 32 patients (29%) had diabetes mellitus, and 9 patients (8%) were older than 70 years (Table 1).

All the operations were performed by a single surgeon (K.-B.K.).

2.2. Operation

Conventional CABG was performed with single-stage venous cannula drainage, moderate systemic hypothermia, and antegrade or retrograde cold-blood cardioplegic solution. The patients were heparinized with an initial dose of heparin (3 mg/kg) and periodically supplemented with additional doses to maintain an activated clotting time of >480 s. At the end of the procedure, 1 mg of protamine per each milligram of heparin was given.

2.3. Postoperative follow-up

All the patients received aspirin (300 mg/day) postoperatively and follow-up examinations at three-month intervals after discharge. Follow-up coronary angiographies were performed at one year (14 ± 4 months) and five years (64 ± 9 months) after CABG. Patients received one year and five years follow-up coronary angiographies regardless of any angina symptoms, but angiographies were not performed in patients with renal dysfunction or in patients who refused the procedure. Follow-up coronary angiography included four-plane selective coronary and bypass graft angiography. One physician initially reviewed all the coronary angiograms and consensus was reached after review.

2.4. Grading of anastomoses

All of the anastomoses were reviewed and graded as described by FitzGibbon and associates [5] as follows. Grade A was defined as an excellent graft with unimpaired run-off. Grade B was defined as a graft displaying stenosis that reduced the caliber of the proximal or distal anastomosis or trunk to <50%, or a graft that was functionally impaired by new stenosis equivalent to >50% of the impairment before the operation, which was proximal or distal, as relevant to the anastomosis site. Grade O was defined as occlusion. The grade for the entire graft was determined by the lowest of the three site grades.

2.5. Statistical analysis

Statistical analysis was performed with the Statistical Analysis System software package (version 11.0; SAS Institute, Cary, NC, USA). The patency rates of the arterial and vein grafts were compared using the $\chi^2$-test. The graft patency rate and the proportion of FitzGibbon grade B grafts between the one-year and five-year coronary angiographies were compared using the $\chi^2$-test with McNemar examination. The freedom from graft occlusion during the follow-up period was calculated using the Kaplan–Meier survival curve, and the factors affecting graft occlusion were analyzed using the Cox proportional hazard model. The factors affecting angina recurrence were analyzed using the simple logistic regression analysis.

All results are expressed as mean ± standard deviation; a $p$ value < 0.05 was considered significant.

3. Results

The average number of distal anastomoses per patient was 3.5 ± 1.1. Of the 378 distal anastomoses performed, internal thoracic arteries (ITA) were used in 144 (38.1%), radial arteries were used in 7 (1.9%), and saphenous veins were used in 227 (60.1%). Bilateral ITAs were used in 21 of 109 (19.3%) patients. The sequential anastomotic technique was performed in 42 of 151 (27.8%) distal arterial grafts and in 77 of 227 (33.9%) saphenous vein grafts.

3.1. Patency of grafts at one year and five years postoperatively (Table 2)

The one-year patency rate (FitzGibbon grade A + B) was 98.0% for arterial graft (including 100%, 7/7 for radial arteries) which was superior to the one-year patency rate of 82.4% for saphenous vein grafts ($p < 0.001$). The grade A patency rate was 89.4% for arterial grafts (including 85.7%, 6/7 for radial arteries), which was also higher than the grade A patency rate of 79.3% for saphenous vein grafts ($p = 0.011$). The proportion of FitzGibbon grade B grafts was higher in the

<table>
<thead>
<tr>
<th>FitzGibbon grade</th>
<th>Arterial graft (%)</th>
<th>Vein graft (%)</th>
<th>$p$</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>One-year 135/151 (89.4)</td>
<td>180/227 (79.3)</td>
<td>0.011</td>
</tr>
<tr>
<td>B</td>
<td>One-year 126/151 (83.4)</td>
<td>165/227 (72.7)</td>
<td>0.018</td>
</tr>
<tr>
<td>C</td>
<td>One-year 11/151 (7.3)</td>
<td>17/227 (7.5)</td>
<td>1.000</td>
</tr>
<tr>
<td>D</td>
<td>One-year 3/151 (2.0)</td>
<td>40/227 (17.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>E</td>
<td>One-year 14/151 (9.3)</td>
<td>45/227 (19.8)</td>
<td>0.006</td>
</tr>
<tr>
<td>Patency (A + B)</td>
<td>One-year 148/151 (98.0)</td>
<td>187/227 (82.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Five-year 137/151 (90.7)</td>
<td>182/227 (80.2)</td>
<td>0.006</td>
<td></td>
</tr>
</tbody>
</table>
arterial graft group than in the vein graft group (8.6% vs 3.1%, \( p = 0.032 \)).

The five-year patency rate (FitzGibbon grade A + B) was 90.7% for arterial grafts (including 100%, 7/7 for the radial arteries), which was higher than the 80.2% rate for saphenous vein grafts (\( p = 0.006 \)). The grade A patency rate was 83.4% for arterial grafts (including 85.7%, 6/7 for radial arteries), which was also higher than the grade A patency rate of 72.7% for saphenous vein grafts (\( p = 0.018 \)). The proportion of grade B grafts was similar in both arterial and vein grafts at five years postoperatively (7.3% vs 7.5%, \( p = 1.000 \)).

### 3.2. Graft patency rates (Table 2)

The arterial graft patency rate decreased significantly from one year to five years after surgery (98.0% to 97.5%, \( p = 0.001 \)) while the vein graft patency rate remained stable (82.4% to 80.2%, \( p = 0.063 \)). However, the proportion of grafts with FitzGibbon grade B increased in vein grafts (3.1% to 7.5%, \( p = 0.002 \)) while grade B arterial grafts (8.6% to 7.3%, \( p = 0.774 \)) remained stable between one year and five years.

### 3.3. Comparison of graft patency rates according to target territories (Table 3)

We defined target territories as the left anterior descending coronary artery (LAD) territory, which includes the LAD or diagonal branches; the left circumflex coronary artery (LCX) territory, which includes the ramus intermedius or obtuse marginal branches; and the right coronary artery (RCA) territory, which includes the RCA, posterior descending artery, or posterolateral branch. Most of the arterial grafts were used in the LAD or LCX territories. In the LAD territory, the patency rate of vein grafts was inferior to arterial grafts at both one and five years after surgery. The vein graft patency rate was also similar in all territories at one year; but it was lowest in the RCA territory at five years after surgery (73.5%, 61/83) when compared with other territories (78.0% in LAD territory, \( p = 0.680 \); 87.2% in LCX territory, \( p = 0.023 \)).

### 3.4. Effect of grafting techniques on graft patency rate

Arterial sequential anastomoses were made in 42 (27.8%) of the 151 distal anastomoses. The patency rate of the sequential anastomoses at one year and five years was 97.6% (41/42) and 90.5% (38/42), respectively. There were no differences in patency of arterial sequential grafting compared with individual grafting (98.2%, 107/109 at one year, \( p = 1.000 \); and 90.8%, 99/109 at five years, \( p = 1.000 \)). The patency rates of sequentially grafted veins were also similar to those of individual grafts (87.0%, 67/77 vs 80.0%, 120/150 at one year, \( p = 0.204 \); 84.4%, 65/77 vs 78.0%, 117/150 at five years, \( p = 0.294 \)).

In 46 of 151 (30.5%) distal anastomoses using arterial grafts, proximal inflow was supplied by an arterial Y-composite graft. Composite vein grafts for proximal inflow were used in 6 of 227 distal anastomoses. The patency rates of the distal anastomoses in the composite graft groups were similar to those of non-composite graft groups at both one year and five years after surgery.

### 3.5. Fate of FitzGibbon grade B grafts

There were 13 FitzGibbon grade B arterial grafts at one year postoperatively. Eleven of the grafts were found to be slender and the other two showed anastomotic stenosis. Seven of 13 became occluded while six remained grade B at five years postoperatively. Six of the seven occluded arterial

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Table 3

Comparisons of graft patency rates according to target lesions

<table>
<thead>
<tr>
<th>Target</th>
<th>Time</th>
<th>Arterial graft (%)</th>
<th>Vein graft (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ITA (%) RA (%)</td>
<td></td>
</tr>
<tr>
<td>LAD territory</td>
<td>One-year</td>
<td>118/121 (97.5)</td>
<td>41/50 (82.0)</td>
</tr>
<tr>
<td></td>
<td>Five-year</td>
<td>117/120 (97.5)</td>
<td>39/50 (78.0)</td>
</tr>
<tr>
<td>LCX territory</td>
<td>One-year</td>
<td>21/24 (100)</td>
<td>82/94 (87.2)</td>
</tr>
<tr>
<td></td>
<td>Five-year</td>
<td>21/24 (87.5)</td>
<td>82/94 (87.2)</td>
</tr>
<tr>
<td>RCA territory</td>
<td>One-year</td>
<td>3/3 (100)</td>
<td>64/83 (77.1)</td>
</tr>
<tr>
<td></td>
<td>Five-year</td>
<td>3/3 (100)</td>
<td>61/83 (73.5)</td>
</tr>
</tbody>
</table>

LAD: left anterior descending coronary artery; LCX: left circumflex coronary artery; RCA: right coronary artery.

\( a \) LAD territory: left anterior descending artery and diagonal branches.

\( b \) LCX territory: ramus intermedius and obtuse marginal branches.

\( c \) RCA territory: right coronary artery, posterior descending coronary artery and posterolateral branches.

\( p = 0.023 \) when compared with LCX territory.
grafs (grade O) were associated with moderate stenosis (<80%) of the native vessel. Four newly occluded arterial grafts at five years postoperatively were all associated with moderate stenosis of the native vessel.

There were seven FitzGibbon grade B vein grafts at one year postoperatively. All seven demonstrated segmental narrowing in the trunk of the vein grafts. All seven remained as grade B grafts at five years postoperatively; however, two of them required percutaneous interventions because of recurrent angina. Five newly occluded vein grafts at five years postoperatively were grade A grafts at one year postoperatively.

3.6. Freedom from graft occlusion

Freedom from arterial graft occlusion at one year, three years, and five years postoperatively were 99.1%, 96.2%, and 94.8%, respectively. Freedom from SVG occlusion at one year, three years, and five years postoperatively were 90.3%, 65.6%, and 64.3%, respectively. Cox proportional hazard model failed to define any risk factors for graft occlusion in both arterial and vein grafts.

3.7. Recurrence of angina and graft patency (Table 4)

During the follow-up period, 20 patients experienced the recurrence of angina. When graft patency was compared between patients with recurrent angina and those without, the main differences were higher FitzGibbon grade B grafts (19.2% vs 4.8% in arterial grafts, p = 0.023; 20.5% vs 4.8% in vein grafts, p = 0.003) and lower grade A grafts (65.4% vs 86.4% in arterial grafts, p = 0.019; 43.6% vs 78.2% in vein grafts, p < 0.001), and a lower vein graft patency rate (64.1% vs 83.0%, p = 0.014). Of the 20 patients with recurrent angina, 5 underwent percutaneous interventions (two for new native lesions, two for vein graft lesions, and one for LAD with occluded ITA). One patient without recurrent angina underwent percutaneous intervention for a progressed native coronary lesion. When the predictors for angina recurrence were analyzed, multivariate analysis identified insulin-dependent diabetes mellitus as the only predictor for angina recurrence (odds ratio: 14.278, p = 0.007) among the patient variables.

4. Discussion

This study demonstrated four main findings. First, the patency rates were significantly higher in arterial grafts than in vein grafts at both one year and five years after CABG. Second, the benefit of using arterial grafts was most prominent in the LAD territory at one year and five years after surgery. Third, the decreased patency rate of the vein grafts, along with insulin-dependent diabetes mellitus, were associated with angina recurrence. Fourth, most of the decrease in patency of arterial grafts was associated with moderate stenosis of the native coronary artery and most of the decrease in patency of vein grafts was associated with graft disease itself.

The lower graft patency rate of the saphenous vein than with the ITA has prompted surgeons to use arterial grafts in CABG to improve the long-term outcome of myocardial revascularization. However, the saphenous vein is still being utilized frequently as a graft in CABG. In addition to immediate postoperative graft failure caused by thrombosis, the long-term patency of the saphenous vein graft can be affected by fibro-intimal hyperplasia during the first year after surgery [6] and by atherosclerosis beyond the fifth postoperative year [7,8]. In contrast to most of the previous studies investigating the patency of grafts by cross-sectional study at a specific time point, we performed coronary angiography in all of the 109 patients at both one year and five years after CABG to trace the changes of the anastomoses and grafts in the same patient population.

The ITA has demonstrated higher intermediate and late patency rates than saphenous vein grafts and has a >90% patency rate five years after CABG [2,9,10]. The present study demonstrated that both the overall (grade A + B) and grade A patency rates were significantly higher in the arterial grafts than in the saphenous vein grafts at one year and five years after surgery. However, the patency rate of arterial grafts decreased significantly between one year and five years after surgery [9]. Although previous studies [12,13] demonstrated a greater benefit of using arterial grafts in the LCX and RCA territories were comparable with those of arterial grafts until five years after surgery. However, the patency rates of arterial grafts were superior to vein grafts in the LAD territory at both time points (97.5% vs 82.0% at one-year, p = 0.001; 90.9% vs 78.0% at five-year, p = 0.042). Excellent arterial graft patency rates regardless of target territories in the present study correlated with previous studies [12,13]. Although previous studies [14,15] demonstrated a lower patency rate of RITA in the RCA territory, we did not observe the finding in our small number of arterial grafts in the RCA territory.

The patency of sequential vein grafting has been demonstrated to be superior to individual grafting if the most distally located anastomosis had good quality and

<table>
<thead>
<tr>
<th>Graft</th>
<th>Grade</th>
<th>Patency (%)</th>
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<tbody>
<tr>
<td>Arterial</td>
<td>A</td>
<td>17/26 (65.4)</td>
</tr>
<tr>
<td></td>
<td>A + B</td>
<td>22/26 (84.6)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>5/26 (19.2)</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>4/26 (15.4)</td>
</tr>
<tr>
<td></td>
<td>A + B</td>
<td>25/39 (64.1)</td>
</tr>
<tr>
<td>Vein</td>
<td>A</td>
<td>17/39 (43.6)</td>
</tr>
<tr>
<td></td>
<td>A + B</td>
<td>22/39 (56.4)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>8/39 (20.5)</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>14/39 (35.9)</td>
</tr>
<tr>
<td></td>
<td>A + B</td>
<td>25/39 (64.1)</td>
</tr>
</tbody>
</table>

Table 4
Graft patency at five years postoperatively in patients with recurrent angina

During the follow-up period, 20 patients experienced the recurrence of angina. When graft patency was compared between patients with recurrent angina and those without, the main differences were higher FitzGibbon grade B grafts (19.2% vs 4.8% in arterial grafts, p = 0.023; 20.5% vs 4.8% in vein grafts, p = 0.003) and lower grade A grafts (65.4% vs 86.4% in arterial grafts, p = 0.019; 43.6% vs 78.2% in vein grafts, p < 0.001), and a lower vein graft patency rate (64.1% vs 83.0%, p = 0.014). Of the 20 patients with recurrent angina, 5 underwent percutaneous interventions (two for new native lesions, two for vein graft lesions, and one for LAD with occluded ITA). One patient without recurrent angina underwent percutaneous intervention for a progressed native coronary lesion. When the predictors for angina recurrence were analyzed, multivariate analysis identified insulin-dependent diabetes mellitus as the only predictor for angina recurrence (odds ratio: 14.278, p = 0.007) among the patient variables.

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The lower graft patency rate of the saphenous vein than with the ITA has prompted surgeons to use arterial grafts in CABG to improve the long-term outcome of myocardial revascularization. However, the saphenous vein is still being utilized frequently as a graft in CABG. In addition to immediate postoperative graft failure caused by thrombosis, the long-term patency of the saphenous vein graft can be affected by fibro-intimal hyperplasia during the first year after surgery [6] and by atherosclerosis beyond the fifth postoperative year [7,8]. In contrast to most of the previous studies investigating the patency of grafts by cross-sectional study at a specific time point, we performed coronary angiography in all of the 109 patients at both one year and five years after CABG to trace the changes of the anastomoses and grafts in the same patient population.

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The patency of sequential vein grafting has been demonstrated to be superior to individual grafting if the most distally located anastomosis had good quality and
diameter [16]. In the present study, we failed to identify a difference between sequential and individual vein grafting at one year and five years after surgery. The excellent patency rate of arterial sequential anastomoses (97.6% at one year and 90.5% at five years) in the present study correlated with the previous reports [12,17].

Although the occlusion rate of saphenous vein grafts has been reported to be 2–2.5% per year between the first and fifth postoperative years [18], the patency of vein grafts remained stable in the present study (82.4% to 80.2%, p = 0.063). This study supports the idea that very little change occurs between one year and five years in the overall patency rate of saphenous vein grafts [19,20]. Instead, the proportion of FitzGibbon grade B grafts increased in vein grafts (3.1%, 7/227 to 7.5%, 17/227, p = 0.002) while the proportion of grade B arterial grafts (8.6%, 13/151 to 7.3%, 11/151, p = 0.774) remained stable during the four-year interval. Interestingly, most of the decreased patency of arterial grafts in the present study seemed to be associated with the status of the native coronary artery. Of the 11 occluded arterial grafts after one year, 10 (90.9%) were associated with moderate stenosis native disease (<80% stenosis). Only 1 of 11 occluded arterial grafts needed a percutaneous intervention in the native coronary artery because of angina recurrence. The decrease in vein graft patency was associated with disease in the graft itself, demonstrated by segmental narrowing in the vein graft trunks. Although all seven of the grade B vein grafts at one year remained as grade B, two needed percutaneous interventions because of progressive stenosis and recurrent angina at five years. The increase in the FitzGibbon grade B and grade O vein grafts and decrease in the grade A vein grafts were associated with angina recurrence in the present study. However, multivariate analysis failed to correlate the graft occlusion to angina recurrence. Only the insulin-dependent diabetes mellitus predicted the angina recurrence. Its deleterious effect on the progression of native coronary artery disease as well as grafts could be a possible explanation for this. When the predictors for angina recurrence were analyzed according to the patient variables, multivariate analysis identified insulin-dependent diabetes mellitus as the only predictor for angina recurrence (odds ratio: 14.278, p = 0.007).

There are limitations to the present study that must be recognized. First, the present study was not performed in a randomized manner with regard to the type of conduits and the target vessels because randomized controlled trials with regard to this type of study are often unrealistic and impractical. Second, this study had a relatively small sample size, which might be insufficient to compare the fate of grafts. Third, we might have overestimated the patency rates by selecting the patients who survived and had angiographies performed at one year and five years after surgery. Eight saphenous vein grafts (four in patients with inadequate left ITA flow, three in emergent cases, and one additional vein graft to the LAD in a patient with cardiopulmonary bypass weaning difficulty) were used to revascularize the LAD whereas nearly 100% of LAD grafts are arterial grafts in most current practice. These might serve as confounding variables. Fourth, the present study included a low risk group of patients with young age and good left ventricular function. Consequently, the conclusions of this study should be applied for those patients undergoing conventional CABG with comparable risks.

References


