Coronary Artery Bypass Grafting Using the Radial Artery
Clinical Outcomes, Patency, and Need for Reintervention

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Background—Radial artery (RA) grafts are an attractive second arterial conduit after the left internal thoracic artery (LITA) for coronary artery bypass graft (CABG) surgery. However, long-term outcomes and the need for subsequent reintervention have not been defined.

Methods and Results—We performed a retrospective cohort study of our single institution’s 16-year experience with 1851 consecutive patients (average age, 58 years; 82% men, 36% diabetic) undergoing primary, isolated CABG with the LITA, RA, and saphenous vein as needed. Average grafts per patient were 3.8, with 2.4 arterial grafts per patient. Survival was determined using the Social Security Death Index. Grafts were nonpatent if they had a >50% stenosis, a string sign, or were occluded. Five patients (0.3%) died in hospital and 0.8% had a myocardial infarction, 1.1% a stroke, and 0.6% renal failure. Kaplan-Meier—estimated 1-, 5-, 10-, and 15-year survival was 99%, 96%, 89%, and 75%, respectively.

Of the cohort, 278 symptomatic patients underwent cardiac catheterization at our institution an average of 5.0±3.8 years (range, 0.1–12 years) after CABG. Overall RA (n=420 grafts) patency was 82% and SV (n=364 grafts) patency, 47% (P<0.0001). LITA (n=287 grafts including 9 sequential grafts) patency was 85% and right internal thoracic artery (n=15 grafts) patency was 80% (P=0.6). RA patency was not different from LITA patency (P=0.3). Overall freedom from catheterization, percutaneous coronary intervention, and CABG was 85%, 97%, and 99%, respectively.

Conclusions—RA grafting is a highly effective revascularization strategy providing excellent short and long-term outcomes with very low rates of reintervention. RA patency is similar to LITA patency and is much better than SV patency. RA grafting should be more widely utilized in patients undergoing CABG. (Circulation. 2012;126[suppl 1]:S170–S175.)

Key Words: CABG ■ coronary disease ■ radial artery grafting ■ bypass surgery

The radial artery (RA) is an attractive second arterial conduit after the left internal thoracic artery (LITA) for coronary artery bypass grafting (CABG). The superiority of LITA to left anterior descending coronary artery (LAD) grafting is well established,1 and the use of the LITA graft is now a quality indicator. The next best arterial conduit is less clear.2,3 Bilateral internal thoracic artery (BITA) grafting using the LITA and the right internal thoracic artery (RITA) has clearly documented survival advantages,4–7 yet this grafting strategy is used in only 4% of all CABG patients as noted in the Society of Thoracic Surgeons (STS) database. Concerns regarding infection, dehiscence, bleeding, and ease of use have limited the widespread adoption of RITA grafting. The RA potentially offers the survival advantage of arterial grafting8,9 without these concerns. The RA can be endoscopically harvested simultaneously with the LITA, easily reaches all territories of the heart, and is an excellent size match to the coronary arteries.10

Persistent concerns regarding RA spasm and patency, however, have limited RA grafting during CABG. The vast majority of the literature11–15 shows excellent patency rates in protocol-driven studies and in symptomatic patients. Reported RA patency rates range from 83% to 98% patency at 1 to 7 years after CABG. However, 2 single-center studies16,17 recorded far lower RA patency. These reports, potential spasm, and concern with RA size matching to target coronary artery have resulted in only 9% of CABG patients in the STS database receiving an RA graft.9 Thus, RA grafting during CABG appears to be underutilized.

We have reviewed our 16-year experience in 1851 consecutive patients undergoing isolated CABG, using the RA after the LITA to LAD graft to better define the outcomes, long-term survival, patency, and need for reintervention after RA grafting.

Methods

Patients

We performed a retrospective cohort study of our single institution’s 16-year experience with 1851 consecutive patients who underwent...
isolated, primary CABG from January 1995 to January 2011. All patients received a LITA to the LAD graft and at least 1 RA graft. SV grafts were used as needed. Our primary indications early in our series for RA use was an age less than 65 years or unavailable or unsuitable SV conduits, accounting for our use of RA grafts in elderly patients. Over the past several years, we have liberalized our age limit to 80 years and have increased our utilization of RA grafting from our initial rate of 33% to our current rate of 75%. We have limited the use of RA grafting to target vessels with >70% stenosis, primarily based on the work of Tatsoulis et al and our own experience. Selecting the best conduit for each target vessel was based on the patient’s age, overall health, the quality of the conduit, the size and runoff of the target vessel, and the degree of native coronary artery stenosis. RA conduits were used primarily to graft the circumflex and/or diagonal territories, whereas SV grafts were used mostly for the right coronary artery territory. Recently, we have increased our use of bilateral RA grafting to include grafting the posterior descending artery. Contraindications to RA use were hemodialysis or chronic renal disease due to the possible need for hemodialysis access, peripheral vascular or Raynaud disease, and recent radial artery catheterization.

The Division of Cardiac Surgery at the Beth Israel Medical Center maintains a prospectively collected database on all patients undergoing cardiac surgery as part of the New York State, Department of Health, Cardiac Surgery Reporting System. All data are reported to the State and also are maintained in a separate database using ACCESS. This study was approved by the institutional review board, which waived the need for written informed consent.

Surgical and RA Harvesting Technique
CABG was performed on-pump, using cold blood cardiopulmonary arrest. Distal and proximal anastomoses were performed during a single period of aortic cross-clamping. The RA grafts were used as aortoconary bypasses. Proximal anastomosis to another RA, SV, or, very rarely, LITA, was used only when lack of RA length or aortic disease precluded direct aortic anastomosis. Off-pump procedures were performed in 1.0% of all patients because of an unclampable or heavily diseased ascending aorta. Endoscopic RA harvesting using the harmonic scalpel has been used exclusively since 2000, with no conversions to an open technique. Diltiazem is administered by intravenous infusion after induction of anesthesia and continued until the first postoperative day, when oral nitrates or diltiazem are substituted, and continued wherever possible for at least 6 months. We have seen only 1 case of intraoperative or perioperative RA spasm that required the addition of a SV graft to the obtuse marginal branch. In contrast, we have had several episodes of LITA spasm requiring the addition of a SV graft.

Intraoperative Allen test and pulse oximetry were used to confirm adequate collateral blood flow to the hand. Less than 2% of screened RA was not harvested. No postoperative hand ischemia has been detected. A rare harvested RA had to be discarded because of unsuspected intraluminal calcific disease. After removal, the radial artery was cannulated at the proximal end and placed in a solution of diltiazem.

Statistical Methods
Statistical analysis was performed with the SAS system v9.2 (SAS Institute, Cary, NC). Continuous variables are expressed as mean and standard deviation. Categorical variables are expressed as percentages. All-cause mortality was obtained using the Social Security Death Index, which was searched in January and February 2011. Overall survival was estimated by Kaplan-Meier survival method. The Cox proportional hazards regression model was used to determine independent predictors of survival. Modeling was done using backward elimination. Variables with probability values <0.05 were retained in the final model. Hazard ratios and 95% confidence intervals are presented. Statistical analysis of graft patency was performed using the STATA system v12.1 (StataCorp LP, College Station, TX). The primary end point was graft failure, defined as graft occlusion or a ≥50% stenosis. The Cox proportional hazard model was used to assess differences in the hazard ratio between groups defined by graft type. Because patients contributed 1 or more grafts to the analysis, robust standard errors, and confidence limits for the hazard ratios were achieved by adjusting for 772 patient clusters within the data. Estimated freedom from events (CABG, percutaneous coronary intervention [PCI], and recatheterization) was calculated by means of the Kaplan-Meier method.

Results
Patient Outcomes
Table 1 summarizes the prospectively collected preoperative risk factors, the operative data, and the postoperative mortality and complications for all RA patients. Briefly, our patient’s average age was 58 years, with a range of 33 years to 88 years. Eighty-two percent of our patients were male and 36% were diabetic. The vast majority of patients had triple-vessel disease, and the average number of grafts per patient was 3.8, with an average of 2.4 arterial grafts per patient. Of the group, 38% received more than 2 arterial grafts, accomplished by the use of bilateral RA grafting in 119 patients (9.7%), sequential RA grafting in 152 patients (8.2%), RA Y-grafting in 170 patients (9.1%), and the use of BITA grafting in 119 patients (6.5%). Average cross-clamp time was 72 minutes, which included both distal and proximal anastomoses.

A total of 5 patients died in-hospital or within 30 days of surgery, for an operative mortality rate of 0.3%. Complication rates were low. Postoperative myocardial infarctions occurred in 15 patients: 10 in the LAD (LITA), 3 in the circumflex (RA), and 2 in the right coronary (SV) distributions. Stroke, sternal infection, and renal failure rates were all around 1%. Prolonged intubation (>72 hours) was required in 1.8% of patients. Four patients (0.2%) had a postoperative RA harvest site infection requiring readmission to the hospital for successful treatment. No patients had postoperative hand ischemia.

Long-term follow-up averaged 8.1±6 years (range, 0.1–16 years; median, 8.3 years). There was a total of 211 postdischarge deaths (11.4% of cohort). Kaplan-Meier estimated 1-, 5-, 10-, and 15-year survival is shown in Figure 1 along with the numbers of patients at risk. Long-term survival at 10 years was 89%.

Predictors of survival using Cox regression modeling are shown in Table 2. Older age and decreased left ventricular function were strong predictors of increased mortality as well as associated cerebral, aortic, and peripheral vascular disease, diabetes, hypertension, heart failure, and chronic lung disease.

Radial Artery Patency
Of the total cohort of 1851 RA patients, 278 patients (15%) had symptom-driven cardiac catheterization at our institution 0.1 to 12 years after CABG. The mean time to catheterization was 5.0±3.8 years, with a median time of 4.6 years. Table 3 shows the angiographic patency per distal anastomosis for all conduits. A total of 1081 grafts (287 LITA, 15 RITA, 420 RA, and 364 SV) were evaluated in 278 patients (3.9 grafts per patient, 2.6 arterial grafts per patient). The overall LITA, RITA, and RA patency was 85%, 80%, and 82%, respectively. The RA occlusion rate was 16% (65 RA grafts), which included 7% with string signs (29 RA grafts) and 9% with complete occlusion (37 RA grafts).
Table 1. Patient Characteristics and Outcomes

| Variable                  | All-cause mortality | Mean age, y | Male | BMI | Hispanic | Grafs per patient | White | Black | Other | Mean EF | Transmural MI | Stroke | Carotid disease | Femoral PVD | Hemodynamics unstable | Current CHF | COPD | Ascending aortic disease | Diabetes mellitus | Creatinine >2.5 mg/dL | Hypertension | Coronary vessel disease | Arterial grafts per patient | Mean cross-clamp | Mean perfusion | Priority | Operative mortality | Permanent stroke | Perioperative MI | Sternal wound infection | Septicemia | Reoperation for bleeding | Respiratory failure | Renal failure |
|---------------------------|---------------------|-------------|------|-----|----------|------------------|-------|-------|-------|---------|---------------|--------|----------------------|------------|------------------------|------------|--------|----------------------|------------------|-----------------------|-------------|----------------------|---------------------|----------------|--------------------------|----------------|-----------------------|
|                           | 216 (11.7%)         | 58, SD=8.6  | 1518 | 29.0| 407 (22%)| 3.8 (2–6)        | 1270 | 196   | 385   | 48%     | 561 (30.3%)  | 93 (5.02%)| 98 (5.30%)           | 102 (5.5%)  | 19 (1.0%)             | 67 (3.6%)   | 315 (17%)            | 68 (3.7%)  | 661 (35.7%)         | 18 (0.9%)  | 1209 (65.3%)          | 1610 (87.0%)| 189 (10.2%)         | 52 (2.8%)  | 537 (29.0%)           | 2.4 (2–4), 685>2 ART grafts | 72 min, SD 24 min | 95 min, SD 32 min |
|                           |                     |             |      |     |          |                  |       |       |       |         |               |        |                      |            |                       |            |       |                      |                  |                      |             |                     |                     |               |                          |                |                      |                      |             |

BMI indicates body mass index; EF, ejection fraction; MI, myocardial infarction; PVD, peripheral vascular disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ART, arterial; BITA, bilateral internal thoracic artery; BRA, bilateral radial artery; SEQ, sequential; and RA, radial artery.

Table 2. Predictors of Mortality Over 15 Years After CABG Using the Radial Artery

<table>
<thead>
<tr>
<th>Variable</th>
<th>HR Lower Bound (95%)</th>
<th>HR Upper Bound (95%)</th>
<th>Wald $\chi^2$</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, per y</td>
<td>1.06</td>
<td>1.04</td>
<td>1.08</td>
<td>39.35</td>
</tr>
<tr>
<td>PVD</td>
<td>2.22</td>
<td>1.50</td>
<td>3.29</td>
<td>15.83</td>
</tr>
<tr>
<td>EF, per 1%</td>
<td>0.98</td>
<td>0.97</td>
<td>0.99</td>
<td>11.99</td>
</tr>
<tr>
<td>DM</td>
<td>1.57</td>
<td>1.18</td>
<td>2.09</td>
<td>9.47</td>
</tr>
<tr>
<td>Stroke</td>
<td>1.95</td>
<td>1.20</td>
<td>3.17</td>
<td>7.15</td>
</tr>
<tr>
<td>CHF</td>
<td>1.91</td>
<td>1.11</td>
<td>3.28</td>
<td>5.48</td>
</tr>
<tr>
<td>HTN</td>
<td>1.47</td>
<td>1.06</td>
<td>2.02</td>
<td>5.40</td>
</tr>
<tr>
<td>COPD</td>
<td>1.37</td>
<td>1.01</td>
<td>1.86</td>
<td>4.11</td>
</tr>
<tr>
<td>CA aorta</td>
<td>1.85</td>
<td>1.07</td>
<td>3.16</td>
<td>4.89</td>
</tr>
</tbody>
</table>

HR indicates hazard ratio; PVD, peripheral vascular disease; EF, ejection fraction; DM, diabetes mellitus; CABG, coronary artery bypass grafting; CHF, chronic heart failure; HTN, hypertension; COPD, chronic obstructive pulmonary disease; and CA aorta, calcified aorta.

Table 4 shows the LITA, RA, and SV patency by territory grafted. Only 22 RA grafts were placed to the right coronary artery territory, with an 82% patency. SV patency to lateral wall targets was only 36%, partially reflecting the bias of using the RA to bypass larger target vessels with better runoff on the lateral wall. We thus examined SV patency by territory grafted in a separate and parallel cohort of 494 symptomatic patients (17.5% of 2821 patients undergoing CABG with LITA and only SV grafts) over the same 16-year interval.

Table 5 shows that overall SV patency was 60% (706/1169 grafts) and SV lateral wall patency was 63% (341/545 grafts) in this concurrent group of patients receiving LITA and only SV grafts. This improved SV patency is probably due to SV grafts being used to bypass the second or third best targets rather than SV grafts being used to bypass third- or fourth-order target vessels, as in the RA patients.

Figure 2A shows the cumulative incidence of graft failure, and Figure 2B shows the patency for LITA, RA, and SV grafts. SV patency is indicated for the 278 LITA/RA/SV patients (SV [RA] group) and the 494 LITA/SV-only patients...
findings and numerous other reports8-12,14,18,19 clearly support the expanded use of RA grafting during CABG.

Our operative mortality and myocardial infarction and stroke rates (0.3%, 0.8%, and 1.2%, respectively) are very low and consistent with other reports8,11,18 in patients undergoing CABG using the RA. Our 10-year survival of 89% is very similar to other reported 10-year survivals (ranging from 81% to 89%) using BITA grafting in a similar age population.1-4,7 There are no previous reports of long-term (>10 years) survival after CABG using the RA. Our 10-year survival compares favorably to these previous reports of long-term survival using BITA grafting.

Although our findings suggest similar outcomes using the RA or BITA, the choice of the second best arterial bypass graft is not resolved.2 Hayward and the Radial Artery Patency and Clinical Outcome (RAPCO) Investigators20 found equivalent 5-year outcomes in patients randomly assigned a RA or a RITA to the next largest target artery after the LAD. Others found similar21 or no different22 short-term outcomes when comparing the RA to the RITA. In contrast, Ruttmann et al17 found that the RITA was superior to the RA in a propensity-matched, retrospective analysis. However, they reported unusually high operative mortality and myocardial infarction and stroke rates of 1.8%, 3.6%, and 3.6%, respectively, in their 277 RA patients. Their findings suggest selection bias rather than the use of a RA was the cause of the observed inferior RA results compared with BITA patients. Long-term results of the randomized, controlled RAPCO trial20 will help clarify the RITA versus RA debate.

We found that RA patency (82%) is similar to LITA patency (85%) in 278 symptomatic patients undergoing catheterization at our institution an average of 5 years after CABG. Multiple previous protocol and symptom-driven catheterization studies18-20 have shown RA patency to be in the 89% to 98% range 1 to 7 years after CABG. We also found that RA patency is better than SV patency (Figure 2 and Table 6), which probably accounts for the excellent long-term survival of patients undergoing CABG using the RA. This confirms our previous propensity-matched study in patients undergoing CABG using LITA-RA versus CABG using LITA and only SV.9 We previously found improved long-term survival in the LITA-RA group that was probably due to the observed RA patency rate of 81%. However, we had patency data on only 151 RA patients with 192 RA grafts. In our current study, we found an RA patency rate of 82% in 278 patients with 420 RA grafts. This confirms our previous RA patency findings and further supports RA grafting during CABG.

Discussion
Our 16-year experience with CABG using the RA in 1851 patients is one of the largest reported series. We found excellent short- and long-term survival and found that RA patency is similar to LITA patency and better than SV patency. Rates of reintervention are very low after CABG using the RA. Our

### Table 3. Angiographic Results in 278 Symptomatic Patients With 1086 Grafts

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD/diagonal</td>
<td>251/287 (85)</td>
<td>12/15 (80)</td>
<td>345/420 (82)</td>
<td>171/364 (47)</td>
</tr>
<tr>
<td>Circumflex</td>
<td>22/8 (82)</td>
<td>1/7 (14)</td>
<td>10/2 (50)</td>
<td>52/1 (14)</td>
</tr>
</tbody>
</table>

LITA indicates left internal thoracic artery; RITA, right internal thoracic artery; RA, radial artery; and SV, saphenous vein.

### Table 4. Left Internal Thoracic Artery, Radial Artery, and Saphenous Vein Patency by Territory Grafted in 278 Symptomatic CABG/RA/SV Patients

<table>
<thead>
<tr>
<th>Coronary Territory</th>
<th>LITA %</th>
<th>RA %</th>
<th>SV %</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD/diagonal</td>
<td>85</td>
<td>74/86</td>
<td>86</td>
</tr>
<tr>
<td>Circumflex</td>
<td>0</td>
<td>253/312</td>
<td>81</td>
</tr>
<tr>
<td>RCA</td>
<td>0</td>
<td>18/22</td>
<td>82</td>
</tr>
<tr>
<td>Total</td>
<td>251/287</td>
<td>345/420</td>
<td>82</td>
</tr>
</tbody>
</table>

CABG indicates coronary artery bypass grafting; RA, radial artery; SV, saphenous vein; LITA, left internal thoracic artery; LAD, left anterior descending artery; and RCA, right coronary artery.

(SV [SV] group). Table 6 shows that the use of LITA (hazard ratio [HR] 0.27) and RA (HR 0.34) is significantly protective from graft failure compared with the reference category SV (SV). Patency of SV (RA) (HR 1.25) grafts was also statistically less than SV (SV) grafts (P = 0.021). LITA and RA grafts have similar patency, and each has better patency than both SV (SV) and SV (RA) grafts.

Reinterventions
Overall, 15% of the 1851 RA patients had cardiac catheterization, 3% had PCI, and <1% had CABG at our institution. Estimated Kaplan-Meier freedom from these events is shown in Figure 3. Eighty-nine interventions were performed in the 55 patients undergoing PCI; 28 PCIs were done on diseased (mostly anastomotic lesions) grafts, including 16 LITA, 2 RA, and 10 SV grafts; 61 PCIs were performed on native coronary artery vessels: 15 LADs (13 with graft failure and 2 with new native coronary artery disease), 26 circumflex arteries (12 with RA graft failure, 24 with SV graft failure and 4 with new native coronary artery disease), 15 right coronary arteries (2 with RA graft failure, 6 with SV graft failure and 9 with new native coronary artery disease), 5 diagonal branches of the LAD (1 with RA graft failure, 2 with SV graft failure, and 2 with new native coronary artery disease). Of the 47 PCIs performed on native coronary vessels because of conduit failure, 32 (68%) were done for SV failure and 15 (32%) were done for RA failure. There were 2 patients who had redo-CABG after initial PCI.

### Table 5. Saphenous Vein Patency by Territory Grafted in 494 Symptomatic CABG/Only SV Patients

<table>
<thead>
<tr>
<th>Coronary Territory</th>
<th>No. Patent</th>
<th>Patency, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD/diagonal</td>
<td>162/272</td>
<td>60</td>
</tr>
<tr>
<td>Circumflex</td>
<td>341/545</td>
<td>63</td>
</tr>
<tr>
<td>Right</td>
<td>203/352</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>706/1169</td>
<td>60</td>
</tr>
</tbody>
</table>

CABG indicates coronary artery bypass grafting; SV, saphenous vein; and LAD, left anterior descending artery.

Our operative mortality and myocardial infarction and stroke rates (0.3%, 0.8%, and 1.2%, respectively) are very low and consistent with other reports8,11,18 in patients undergoing CABG using the RA. Our 10-year survival of 89% is very similar to other reported 10-year survivals (ranging from 81% to 89%) using BITA grafting in a similar age population.1-4,7 There are no previous reports of long-term (>10 years) survival after CABG using the RA. Our 10-year survival compares favorably to these previous reports of long-term survival using BITA grafting.

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Reported SV patency rates vary considerably, and early failure rate can be quite high. Investigators have recently reported 11%, 20%, and 30% occlusion rates of SV grafts by 1 year. On the other hand, Hayward et al found an 87% SV patency at 5 years in their protocol-driven study, which is a very unusual and rarely reported patency rate. Indeed, Singh et al recently concluded that the incidence of SV graft failure remains high despite contemporary practice.

We found that SV grafts, when used as the primary conduit after the LITA, have better patency compared with SV used as needed after LITA/RA grafting, especially in the lateral wall targets (Tables 4 and 5 and Figure 2B). This difference probably reflects the preferential use of RA grafting to better target vessels leaving the SV for third- and fourth-order targets. This difference was statistically significant, with a hazard ratio for conduit failure of 1.25 ($P=0.021$) for SV (RA) grafts compared with the reference SV (SV) grafts (Table 6). A well-constructed, good-quality SV graft to a large target coronary artery may well have good early patency but is likely to have declining patency as vein graft atherosclerosis develops. This is confirmed by our finding that RA grafts have a strong and lasting protective effect (HR=0.34) from graft failure compared with SV (SV) grafts.

There are 2 studies in the literature showing poor RA patency. Khot et al reported a 51% patency at 18 months in 310 patients with 394 RA grafts. Only 1.1% of 27,211 patients undergoing cardiac catheterization performed at the Cleveland Clinic from 1996 to 2001 had an RA graft and formed the basis of this study. The total number of patients receiving an RA graft during this time interval is not specified; 22% of the studied RA patients had had previous CABG, and only 63% of RA patients received postoperative calcium channel blockers. Last, 25% of the 310 patients had a RITA graft, which suggests that the RA was used for less important target vessels. Ruttmann et al recently reported RA patency of 51% at 33 months after CABG and worse long-term survival in RA patients who were propensity-matched to BITA patients. However, their 277 RA patients had a very high perioperative complication rate and mortality that probably contributed to the observed decreased RA patency and survival. The significant limitations of these two reports, the vast majority of RA patency studies, and our findings support excellent RA patency that is probably similar to LITA patency.

Rates for subsequent interventions were very low in our patients. The need for reoperative CABG is rare not only as the result of better patency of arterial grafting but also as the result of improved percutaneous approaches to new or recurrent native vessel and graft disease. The LITA was the bypass graft most commonly requiring PCI, nearly always at the anastomosis. PCI was rarely done on an RA graft. Most of the

Table 6. Cox Proportional Hazard Model of Conduit Failure Stratified on Patient and Referenced on SV (SV) Grafts

<table>
<thead>
<tr>
<th>Conduit</th>
<th>HR</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
<th>$P$ Value</th>
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<tbody>
<tr>
<td>LITA</td>
<td>0.27</td>
<td>0.19</td>
<td>0.37</td>
<td>$&lt;$0.0001</td>
</tr>
<tr>
<td>RA</td>
<td>0.34</td>
<td>0.26</td>
<td>0.45</td>
<td>$&lt;$0.0001</td>
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<tr>
<td>SV (RA)</td>
<td>1.25</td>
<td>1.03</td>
<td>1.51</td>
<td>0.021</td>
</tr>
<tr>
<td>SV (SV)</td>
<td></td>
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SV indicates saphenous vein; HR, hazard ratio; CI, confidence interval; LITA, left internal thoracic artery; and RA, radial artery.

Figure 2. A, Cumulative incidence for graft failure. LITA indicates left internal thoracic artery; RA, radial artery; SV (RA), saphenous vein grafts used in patients revascularized with LITA+RA; SV (SV), saphenous vein grafts used in patients revascularized with LITA only. B, Graft patency from Cox modeling adjusting for patient clusters.

Figure 3. Kaplan-Meier–estimated freedom from reoperation, percutaneous coronary intervention (PCI), and recatheterization. CABG indicates coronary artery bypass graft.
PCIs done on the native coronary vessels were in territories supplied by SV grafts (68% of PCIs done for graft failure) versus RA grafts (32% of PCIs done for graft failure). There were fewer PCIs done for new disease in all territories, probably as the result of patients having an average of 3.8 grafts. Early graft failure was usually due to technical or competitive flow issues. In vessels with moderate disease (50% to 60% stenosis), RITA and RA grafts appear to be more likely to fail because of competitive flow.\(^\text{7,10,14}\) The ideal conduit for a circumflex or right coronary vessel with a 50% to 60% lesion appears to be an SV.

Our study has several limitations. Although this is a large cohort from a single surgical group with standardized approaches, patient selection for RA grafting was at the discretion of the surgeon and subject to bias. Available hospital data points were limited to those recorded for the New York State database. All-cause mortality was used to determine survival, and the specific cause of death and other cardiac events were not available. Selection of the target for the RA was heavily weighted toward the circumflex branches. We were able to capture only those patients who underwent coronary angiography for symptoms at our institution and thus certainly underestimated the frequency of interventions and perhaps overestimated graft patency. Compliance with our recommendations for postoperative nitrates, statins, and aspirin was not studied. Few RA grafts were used to bypass the right coronary artery and thus direct comparison of circumflex and right RA grafts are not valid. The mechanism of graft failure was not determined. Further analysis of the occluded grafts may help to differentiate the mode of failure—technical, anastomotic, intimal hyperplasia, competitive flow, or graft atherosclerosis.

CABG using the RA results in excellent short- and long-term survival. Freedom from recatheterization, PCI, and CABG is excellent. RA patency is similar to LITA patency and better than SV patency. We conclude that RA grafting should be more widely utilized in patients undergoing CABG.

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Disclosures

None.

References

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