Five-Year Angiographic Patency of Radial Artery Bypass Grafts

James Cameron, MD; Shailendra Trivedi, MD; Gregory Stafford, MD; J. H. Nicholas Bett, MD

Background—Little information exists regarding mid-term and long-term patency of radial artery grafts.

Methods and Results—We performed restudy coronary angiography at 5.2±0.4 years after surgery on 50 asymptomatic patients who had undergone coronary artery bypass graft surgery, using at least 1 radial artery graft, to determine both graft patency and presence of narrowing. We examined preoperative clinical or angiographic variables that might predict graft occlusion. Radial artery graft patency was 89%, with 91% of grafts free of narrowing. Preoperative New York Heart Association anginal class ≤2, target vessel proximal stenosis ≤70%, and small target vessel supply territory were predictive of graft occlusion.

Conclusion—At 5 years after surgery, radial artery grafts have disease-free patency rates that are similar to other graft types. (Circulation. 2004;110[suppl II]:II-23–II-26.)

Key Words: revascularization ■ surgery ■ bypass ■ grafting

Complete or near-complete revascularization with arterial bypass grafts has been promoted to improve long-term outcome of patients undergoing coronary artery bypass surgery. Long-term disease-free patency rates of 85% to 95% of the internal mammary artery bypass graft1–3 have encouraged use of other arterial conduits, including radial artery grafts.4–6 Several studies of the use of radial artery bypass grafts have documented excellent clinical results and satisfactory short-term and mid-term patency rates at restudy angiography.7–17 One long-term angiographic study has demonstrated disease-free patency of 88%.18 In this study, we report angiographic patency rates of radial artery bypass grafts at 5 years after bypass graft surgery.

Methods

Study Population

After approval by the Prince Charles Hospital Ethics Committee, 50 asymptomatic patients, from a cohort of the initial 300 patients who underwent coronary artery bypass graft surgery using at least 1 radial artery graft as conduit at our institution from 1994 to 1997, were contacted and agreed to undergo elective restudy coronary angiography. Patients from the cohort of 300 patients were not invited for restudy if they lived >150 km from the center; had undergone recent restudy coronary angiography at our institution; had declined restudy for angiography; or were not recommended for restudy by the referring cardiologist. The preoperative clinical and angiographic details for the 50 patients are noted in Table 1. Retrospective review of the patient records for the 300 patients was made. Review of preoperative coronary angiograms for the 50 study patients was performed and, in particular, target vessel proximal stenosis, target vessel diameter, and size of supply territory were noted. Target vessel proximal stenosis was determined by caliper measurement of the narrowed segment diameter compared with the adjacent normal segment diameter, expressed as a percentage. Target vessel diameter was determined from the preoperative angiogram in millimeters or, in the case of the vessel being poorly filled at angiography, from an assessment of vessel diameter at surgery. An empiric descriptor of supply territory was used according to target vessel as follows: small territory, left anterior descending coronary artery; left circumflex marginal or codominant right coronary artery as target vessel; moderate territory, sequential grafts to either left anterior descending coronary artery or left circumflex coronary artery and one other vessel; left anterior descending coronary artery with mid vessel stenosis or dominant right coronary arteries as target vessel; and large territory, proximal left anterior descending, dominant left circumflex or large dominant right coronary arteries as target vessel.

Surgical Technique

All patients underwent elective surgery using cardiopulmonary bypass and cardioplegic arrest. The left internal mammary artery graft was used in most patients as a pedicle graft to the left anterior descending coronary artery (42 of 51 anastomoses); the right internal mammary artery graft, either as a pedicle or free graft, and radial artery grafts were used in most patients to the right coronary or left circumflex arteries; and venous grafts were used to complete the revascularization. A mean of 3.3 (range 1 to 6) distal anastomoses were performed per patient, comprising 62 radial grafts, 51 left internal mammary artery grafts, and 36 venous and 18 right internal mammary artery graft anastomoses. The left radial was harvested in 48 patients and the right radial in 3 patients; only 1 patient had both radial arteries harvested. Radial artery graft anastomoses by vessel were: right coronary 31 (50%); left circumflex 23 (37%); left anterior descending coronary artery 7 (11%); and left anterior descending 1 (2%). In 9 patients, the radial was used as a sequential graft, including 6 sequential grafts to the right coronary artery and 3 sequential grafts to the left circumflex coronary artery distributions. In 2 patients the radial was divided into 2 pieces and used to provide 2 separate grafts. Of the 53 radial graft proximal anastomoses, 51 radial grafts had the proximal anastomosis onto the aorta; 1 graft used the left internal mammary artery graft and 1 graft used the saphenous vein graft to the right coronary artery as the proximal anastomosis.

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Calcium channel blocking drugs were used perioperatively in 37 of 50 patients (74%) of patients, including diltiazem in 29, amlodipine in 4, verapamil in 3, and nifedipine in 1. After discharge postprocedure, the maintenance of these agents was left to the discretion of the primary care physician. At the time of restudy, 13 patients (26%) reported using these agents, including diltiazem in 8, amlodipine in 4, and felodipine in 1.

**Coronary Angiography Restudy**

After informed consent was obtained, coronary artery studies were performed via the femoral route including selective graft cannulation and left ventriculography. Radial artery graft occlusion was defined by either complete occlusion or presence of the “string sign.” Grafts were examined for the presence of narrowing, which was defined as mild (≤50%), moderate (50% to 70%), or severe (>70%) diameter narrowing.

**Statistical Analysis**

Demographic results are expressed as mean±SD. The nonparametric Mann–Whitney U test, Pearson χ² test, and χ² test with Yates correction were used to compare continuous and categorical variables, respectively.

**Results**

No difference was noted between the 50 study patients and the 250 nonstudy patients from the total cohort of 300 patients when baseline clinical characteristics, including age, gender, New York Heart Association anginal class before surgery, and left ventricular function, were compared.

Coronary angiography restudies were performed at 5.2±0.4 years (range, 4.5 to 6.6 years) after bypass graft surgery. Of 62 radial artery graft distal anastomoses, 7 were occluded or filled poorly (“string sign”), leaving 55 patent (89%). Table 2 notes the patency rates for all graft types. We examined patent graft sections for presence of narrowing. Of these, 50 of 55 (91%) patent grafts had no narrowing, whereas 5 of 55 (9%) had mild narrowing. None of the patent grafts had moderate or severe narrowing.

**TABLE 1. Preoperative Characteristics of 50 Study Patients**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>NYHA anginal class</td>
<td>3</td>
</tr>
<tr>
<td>Previous CABG surgery</td>
<td></td>
</tr>
<tr>
<td>Perioperative calcium blocker</td>
<td></td>
</tr>
<tr>
<td>LV ejection fraction</td>
<td></td>
</tr>
<tr>
<td>Target vessel location</td>
<td></td>
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<tr>
<td>Target vessel proximal stenosis</td>
<td></td>
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<tr>
<td>Target vessel diameter size</td>
<td></td>
</tr>
<tr>
<td>Target vessel supply territory</td>
<td></td>
</tr>
</tbody>
</table>

NS indicates not significant (P>0.05); NYHA, New York Heart Association; CABG, coronary artery bypass graft; perioperative, any perioperative use of calcium channel blocking drugs up to discharge.

In addition to the 50 study patients, we identified a group of 21 patients who had restudy coronary angiography to investigate recurrent chest pain within the first 5 years after surgery (average time of restudy 2.7 years; range, 2 months to 5 years) and found a patency rate of 21/24 radial graft anastomoses (88%), with no disease in 19/21 (90%), mild disease in 1/21 (5%), and severe disease in 1/21 (5%) patent grafts.

Results of correlation of clinical and angiographic variables with graft patency for the 50 study patients demonstrated New York Heart Association class ≤2 (P=0.03), target vessel proximal stenosis ≤70% (P=0.01), and small target vessel territory (P=0.001) correlated with graft occlusion (Table 3).

**Discussion**

Results of studies of patients who have undergone coronary artery bypass graft surgery using the internal mammary artery graft have indicated improved survival for these patients compared with patients who have undergone surgery using saphenous vein grafts. This improved outcome relates to excellent long-term disease-free angiographic patency rates of 85% to 95% of the internal mammary artery graft compared with reported saphenous vein graft patency rates of 45% to 77%. These findings have prompted interest in use of other artery conduits with the aim to provide patients undergoing coronary bypass surgery with complete arterial revascularization.

Several studies have now reported excellent clinical results using a strategy using one or both internal mammary artery grafts and one or both radial artery grafts in an attempt to provide complete or near-complete arterial revascularization. Coronary angiographic studies, which have been performed in the early and medium-term postsurgical period, have demonstrated patency rates for the radial artery graft of 83% to 100%. One long-term study has indicated an angiographic patency rate of 88%, which is comparable to the results for internal mammary artery grafts.

We determined angiographic patency in a group of asymptomatic patients, who were selected largely by their availability to attend for restudy, and found a patency rate of 89%.

**TABLE 2. Patency Rates for Distal Anastomoses for Bypass Grafts for the 50 Study Patients by Graft Type**

<table>
<thead>
<tr>
<th>Graft Type</th>
<th>N Anastomoses</th>
<th>N Patent</th>
<th>% Patent</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIMA</td>
<td>51</td>
<td>51</td>
<td>100</td>
</tr>
<tr>
<td>RIMA</td>
<td>18</td>
<td>17</td>
<td>94</td>
</tr>
<tr>
<td>SVG</td>
<td>36</td>
<td>33</td>
<td>92</td>
</tr>
<tr>
<td>RADIAL</td>
<td>62</td>
<td>55</td>
<td>89</td>
</tr>
</tbody>
</table>

LIMA indicates left internal mammary artery; RIMA, right internal mammary artery; SVG, saphenous vein.

**TABLE 3. Correlation of Clinical and Angiographic Characteristics With Radial Graft Patency**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Gender</td>
<td>NS</td>
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<td>LV ejection fraction</td>
<td>NS</td>
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<tr>
<td>Target vessel location</td>
<td>NS</td>
</tr>
<tr>
<td>Target vessel proximal stenosis</td>
<td>0.01</td>
</tr>
<tr>
<td>Target vessel diameter size</td>
<td>NS</td>
</tr>
<tr>
<td>Target vessel supply territory</td>
<td>0.001</td>
</tr>
</tbody>
</table>

NS indicates not significant (P>0.05); NYHA, New York Heart Association; CABG, coronary artery bypass graft; perioperative, any perioperative use of calcium channel blocking drugs up to discharge.
Patients were all ≈5 years postbypass graft surgery. Patients who demonstrated poor flow, the so-called string sign, were included in the “occlusion” group, although anecdotal reports have indicated that in some of these grafts, the poor flow may relate to a less severe target vessel proximal stenosis, or diffuse spasm, and that these grafts may function satisfactorily, in instances in which the target vessel proximal stenosis becomes more severe or progresses to occlusion. The patency rate demonstrated in our study is similar to reported patency rates for the internal mammary artery graft.1-3 In our study, patency rates for left internal mammary graft, which were applied to the left anterior descending coronary artery in 42/51 anastomoses (82%), were high at 100% and comparable between right internal mammary graft (94%) and saphenous vein (92%) and radial artery graft (89%). Our study is too small to detect a statistically significant difference between these graft types, although the differences may be of clinical importance. The generally high patency rate for all grafts in this study may reflect, to some extent, the asymptomatic state of this patient group. The reasons for the high patency rates of saphenous grafts in this series are speculative but might include factors such as improved protection from atherosclerotic change with improved lipid control from more widespread use of statin agents. However, in a group of 21 patients who underwent restudy for clinical reasons, the patency rate of radial artery grafts was similar to that found in our study group at 88%, with a similar disease-free state in patent radial artery graft segments. We therefore believe that the patency rate of 89% of radial artery grafts in our study group may be a true reflection of patency rates for the group as a whole. Further, the clinical characteristics of the study group of 50 patients were similar to those of the 250 in the nonstudy group from the total group of 300 patients, suggesting no major selection bias for the study group.

We examined for narrowing in the radial grafts that were patent and found mild, or ≤50%, narrowing in 9% of sections, and 91% sections were free of narrowing. The latter grafts typically had a smooth-walled appearance with prompt flow, similar in appearance to that of the patent internal mammary artery grafts. The cause for the narrowing in the radial artery grafts is unclear and perhaps may be determined by intracoronary ultrasound. One group has reported results of intracoronary ultrasound in 5 patients and “confirmed the presence of limited atherosclerotic deposits and revealed moderate plaque burden at the site of maximal angiographic narrowing” in 1 patient with angiographic narrowing.18 In the other 4 patients, with perfectly patent grafts, only minimal intimal narrowing was noted. The site of narrowing, which we noted, was typically anastomotic rather than being placed in the body of the graft, raising the possibility of reactive intimal fibroplasia as the cause, rather than atherosclerotic narrowing.

In our review of clinical and angiographic predictors of graft patency, we found lower New York Heart Association anginal class to be the only clinical predictor of patency, presumably on the basis that these patients may have less severe or extensive disease. We did consider the question of graft patency according to calcium channel blocker usage. We believe the retrospective nature of the data makes it difficult to provide a meaningful answer to this question. We found that 74% of patients received these drugs perioperatively but did not find a correlation with graft patency for use of these drugs in the perioperative period. In addition, use of these drugs after discharge was inconsistent, and many of these agents had been discontinued by the time of restudy when only 26% of patients were using these medications.

A history of previous bypass surgery did not predict graft occlusion. Although the numbers in our study were small, we believe this to be an important observation, because patients who undergo redo surgery are part of an expanding group. Many of these patients may be candidates for use of radial artery grafts, particularly when there has been failure of previous saphenous veins grafts, or when available conduits are limited. In a large series of 352 patients undergoing redo surgery using radial artery grafts, Tatoulis et al demonstrated an advantage for patients undergoing redo surgery, including radial artery grafts as conduit. The authors noted no difference in mortality and improved morbidity in the radial graft group, with reduced deep sternal wound and harvest site infections, compared with a group undergoing redo surgery in which radial grafts were not used.11 If long-term patency and clinical efficacy of the radial artery graft is confirmed, the radial artery graft may offer improved outcome for this group of patients.

Similarly to that of other authors,8,9 our study found less severe target vessel proximal stenosis correlated with graft occlusion. Further, we found that smaller target vessel supply territory predicted graft occlusion. For this assessment, we used an empiric descriptor for supply territory size. Our descriptor, although simple and having the virtue of being readily applied clinically, has not been validated and may be criticized as being related to vessel location, rather than being related to absolute territory supply size. Our analysis did not show any difference for patency according to the target vessel location; however, this analysis is questionable given a clear surgical strategy in our study to select either the right or left circumflex coronary artery as the target vessel. In addition, because of the small study sample size, the validity of these predictors may be questioned and correlation in further studies would be desirable.

In conclusion, our study indicates patency rates for radial artery grafts at 5 years after surgery that are similar to patency rates of other graft types, including internal mammary artery grafts, with the majority of patent radial grafts being free of narrowing. At 5 years, our angiographic study does not establish the long-term efficacy of the radial artery graft and does not predict long-term outcome for patients undergoing coronary artery bypass surgery using the radial artery graft. However, the long-term patency of other arterial bypass grafts suggests that the radial artery graft has the potential to remain patent and disease-free for long-term periods after surgery, and thus may contribute to improved outcome after coronary artery bypass surgery. Further long-term angiographic studies, at and beyond 10 years, will be required to clearly establish the role of this graft.

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References
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