Analysis by Early Angiography of Right Internal Thoracic Artery Grafting Via the Transverse Sinus

Predictors of Graft Failure

Masashi Ura, MD; Ryuzo Sakata, MD; Yoshihiro Nakayama, MD; Yoshio Arai, MD; Shuichi Oshima, MD; Katsuo Noda, MD

Background—There has been debate regarding whether technically demanding right internal thoracic artery (RITA) grafting via the transverse sinus can be extensively applied to patients in high-risk groups, such as patients with a small body size, elderly patients, and woman with relatively smaller coronary artery and internal thoracic artery (ITA) diameters.

Methods and Results—Of the 1456 patients who underwent isolated coronary artery bypass grafting between January 1989 and December 1998 at Kumamoto Central Hospital, 393 patients (mean age, 62.4±9.0 years) with the RITA anastomosed to the major branches of the circumflex artery were studied. Left ITA grafting was performed in 384 patients, and in 369, the in situ left ITA was anastomosed to the left anterior descending coronary artery using standard methods. Early postoperative angiography was performed in 381 patients. The RITA was occluded in 4 patients, and string-like artery and significant stenosis were present in 11 and 7 patients, respectively; RITA graft patency was thus 94.1%. Of the preoperative variables and angiographic data, simple and multiple logistic regression analyses identified decreased severity of native stenosis, diffuse sclerosis of native vessels, and residual side branches of the ITA as independent predictors of nonfunctional grafts. The method of ITA grafting did not influence the patency of the graft.

Conclusions—The excellent patency rate demonstrated by this study, the largest angiographic study to date of RITA grafting via the transverse sinus, indicates that this technique can provide reliable revascularization of the left ventricle and that it has the potential to be applied to a wide variety of patients with diseased circumflex arteries. (Circulation. 2000;101:640-646.)

Key Words: mammary arteries ■ coronary artery bypass ■ vascular patency

Right internal thoracic artery (RITA) grafting via the transverse sinus has been demonstrated to be an important method of achieving extensive arterial revascularization of the left ventricle; in the standard technique, the left internal thoracic artery (LITA) is grafted to the left anterior descending coronary artery (LAD).1–7 RITA grafting shows good long-term and short-term patency.2–5 In this anastomotic technique, a long length of the internal thoracic artery (ITA) is required, which necessitates including the narrower, terminal portion of the ITA. This fact suggests that this technically demanding method could be extensively applied to patients in high-risk groups, such as those with small body sizes, elderly patients, and woman, who tend to have a smaller coronary artery and ITA.8–14 Although small body size and female sex have been recognized as major contributors to increased risk when undergoing coronary artery bypass grafting, little is known about the independent influence of body size and sex on RITA grafting via the transverse sinus to the circumflex artery and diagonal artery (previous studies have not demonstrated any influence of body size, older age, or sex on the outcome of RITA grafting via the transverse sinus). Thus, the purpose of this study was to determine the independent influence of body size and sex on the patency rate of the ITA and the operative outcomes in patients with RITA grafting via the transverse sinus.

Methods

Of the 1456 patients who underwent coronary artery bypass grafting (CABG) between January 1989 and December 1998 at Kumamoto Central Hospital (these included 1370 cases of isolated CABG), 393 patients with the RITA anastomosed to the major branches of the circumflex or diagonal arteries were studied. This procedure was approved by the Ethics Committee and the Internal Review Board of Kumamoto Central Hospital. In the operative technique used, the RITA was routed via the transverse sinus. There was a steady increase in the use of this method and in multiple arterial grafting, especially in patients with isolated CABG, during the study period as
we gained experience (Figure). These procedures were initially performed only in selected patients, but they were gradually extended for use in high-risk patients. Although we have made some changes in the selection criteria for the use of these procedures, our most recent exclusion criteria for bilateral ITA (BITA) harvest include the following: severe, chronic obstructive pulmonary disease; subclavian arterial stenosis (restriction of ITA flow); radiation therapy to the chest wall; and emergency surgery. Old age in itself was not considered a contraindication for BITA harvest. However, if the patient was >75 years old, the decision to harvest the ITA bilaterally was made on an individual basis.

During 1998, 109 RITA grafts via the transverse sinus (63.4%) were performed in the 172 patients undergoing isolated CABG. Of the 393 total patients studied, 310 were men and 83 were women; they had a mean age of 62.4 ± 9.0 years (range, 13 to 78 years). Patient characteristics are summarized in Table 1.

The group of patients studied included 10 dialysis patients (2.5%) and 99 patients (25.2%) with diabetes mellitus (13 required insulin treatment, 39 were on oral drug therapy, and 47 were on diet control). In the 14 patients with severe atherosclerosis of the ascending aorta, BITA grafting was performed during hypothermic ventricular fibrillation.

Data Definitions
A perioperative myocardial infarction was documented if a new Q wave appeared on the ECG or if creatine kinase MB levels rose beyond 100 IU/L. Mediastinitis was defined as infection involving the mediastinal area, with sternal instability and positive organism culture.

Only permanent or reversible focal complications, such as reversible ischemic neurological deficit or transient ischemic attacks, were categorized as strokes. Confusion, agitation, dementia, disorientation, or psychosis were categorized as strokes only if new focal neurological signs were also present.

The residual side branches of the ITA were defined as large if their size was at least half the diameter of the ITA and as small if their size was less than half.

Operative Procedures
The operative technique used was similar to that described in our previous reports. After dissection, the ITA pedicle was wrapped with papaverine-soaked gauze (200 mg/50 mL of saline solution). No intraluminal papaverine injections were given.

As shown in Table 2, the technique of in situ RITA grafting via the transverse sinus was most commonly used to revascularize the posterolateral wall; LITA grafting was used to revascularize the anterolateral wall of the left ventricle. The RITA was directed to the most important branches of the circumflex artery with good drainage. LITA grafting was performed in 384 patients; in 369 (81%), the in situ LITA was anastomosed to the LAD using standard methods. Supplementary saphenous vein grafts were used in most patients. The mean number of distal anastomoses was 3.7 ± 1.0 (range, 2 to 6). Concomitant procedures included mitral annuloplasty (4 patients), left ventricular aneurysmectomy (5 patients), mitral annuloplasty and tricuspid annuloplasty (1 patient), tricuspid annuloplasty alone (1 patient), and mitral valve replacement and left ventricular aneurysmectomy (1 patient).

Preoperative and Postoperative Angiography
All patients underwent preoperative angiography. The size of the perfusion areas of each of the major branches (target vessels) was
TABLE 1. Preoperative Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean ± SD or N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, y (range)</td>
<td>62.4 ± 9.0 (13–78)</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
</tr>
<tr>
<td>&lt;50 y</td>
<td>36</td>
</tr>
<tr>
<td>50–59 y</td>
<td>90</td>
</tr>
<tr>
<td>60–69 y</td>
<td>181</td>
</tr>
<tr>
<td>70–74 y</td>
<td>75</td>
</tr>
<tr>
<td>≥75 y</td>
<td>11</td>
</tr>
<tr>
<td>Sex, male:female</td>
<td>310:83</td>
</tr>
<tr>
<td>Hypertension</td>
<td>219 (55.7%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>99 (25.2%)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>140 (35.6%)</td>
</tr>
<tr>
<td>Chronic renal failure (dialysis)</td>
<td>10 (2.5%)</td>
</tr>
<tr>
<td>No. of diseased vessels</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>64</td>
</tr>
<tr>
<td>3</td>
<td>185</td>
</tr>
<tr>
<td>LMT</td>
<td>23</td>
</tr>
<tr>
<td>LMT + 1</td>
<td>11</td>
</tr>
<tr>
<td>LMT + 2</td>
<td>45</td>
</tr>
<tr>
<td>LMT + 3</td>
<td>65</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>181 (46.1%)</td>
</tr>
<tr>
<td>EF&lt;40</td>
<td>16 (4.1%)</td>
</tr>
</tbody>
</table>

LMT indicates left main trunk disease; and EF, ejection fraction.

qualitatively graded by independent observers from 1 to 4 (tiny, small, medium, or large, respectively). The dominance of the left coronary artery system was also qualitatively graded from 1 to 3 (small, balanced, or large, respectively).

To evaluate the early patency rate, postoperative angiography was performed 2 to 3 weeks after surgery. All ITA grafts were evaluated for occlusion, the development of string sign, or the presence of significant stenosis (flow limitation or >50% stenosis of the vessel diameter at any point along the body of the graft or at any anastomoses). For purposes of analysis, occluded grafts and grafts showing string sign without a definite technical failure (anastomotic stenosis) were considered nonfunctional.

All angiographic data were reviewed by independent observers (S.O. and K.N.) who were unaware of the operative outcomes.

Statistical Methods

Data are presented as means with 95% confidence intervals. Simple (univariate) and multiple (multivariate) logistic regression analyses were performed to determine the predictors of nonfunctional ITA among the preoperative variables (sex, body surface area [BSA], age, hypertension, diabetes, hyperlipidemia, chronic renal failure, previous myocardial infarction, and ejection fraction) and the angiographic data (laterality of ITA, site of ITA grafting, the perfusion area of ITA, major side branches of the ITA, the size [dominance of] of the left coronary artery system, and degree of native coronary artery stenosis). P<0.05 was considered significant. For comparison purposes, only cases with the ITA anastomosed singly to the recipient artery were analyzed. All analyses were performed using commercial statistical software (SAS version 6.12).

Results

Operative Results

Three hospital deaths occurred (0.76%). One occurred in a 65-year-old man who seemed to be doing well; he died from liver failure due to sudden hepatic artery embolization 3 days after the operation. Emergent angiography revealed a patent ITA and an occluded hepatic artery. This patient had undergone revascularization during hypothermic ventricular fibrillation due to extensive atherosclerosis of the ascending aorta. Embolization from the diseased aorta was suspected to be the cause. One death occurred in a 69-year-old woman with a history of bronchial asthma. On the 49th postoperative day, a local anesthetic used during the treatment of a leg wound induced a severe asthmatic attack, necessitating ventilator support, which was subsequently complicated by pneumonia. She died of septic shock 61 days after the operation. In this patient, the early postoperative angiography performed before deterioration revealed that all grafts, including ITAs, were patent. The remaining patient, a 70-year-old man who suffered a stroke and mediastinitis, died postoperatively of sepsis. In this patient, no evidence suggested ischemia of the left ventricle or hypoperfusion syndrome in his postoperative course.

Postoperative intra-aortic balloon pumping was required in 4 patients (1.0%). A perioperative myocardial infarction occurred in 22 patients (5.5%). There were 14 re-explorations for bleeding (3.6%), but none was related to the RITA graft. The other noncardiac operative complications included mediastinitis (6 patients; 1.5%), prolonged (>48 hours) ventilation (19 patients; 4.8%), and cerebrovascular accident (16 patients; 4.1%).

Angiographic Examinations

Early postoperative angiography was performed in 381 patients (96.9%) 2 to 3 weeks after surgery. This study was not performed in 12 patients due to severe atherosclerosis of the ascending aorta in 6, chronic renal failure in 3, and postoperative cerebrovascular accidents in 3. The study failed to evaluate the RITA grafts in 8 patients and the LITA grafts in 3 patients. In these patients, complete opacification of the ITA grafts was not performed because of the difficulty of selective engagement into the grafts. Although these ITA grafts were determined to be nonoccluded by means of semiselective angiography and retrograde flow from the

TABLE 2. ITA Destination

<table>
<thead>
<tr>
<th>Obstructed Marginal Branch or Intermediate Branch</th>
<th>Posterior Artery</th>
<th>Posterior Diagonal Artery</th>
<th>Postero-Lateral Descending LAD</th>
<th>LAD</th>
<th>Diagonal LAD (Sequential)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RITA</td>
<td>213</td>
<td>167</td>
<td>11</td>
<td>2</td>
<td>0</td>
<td>393</td>
</tr>
<tr>
<td>LITA</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>355 (FG 4)</td>
<td>19 (FG 1)</td>
</tr>
</tbody>
</table>

FG indicates free graft.
native coronary artery, these data were excluded from the analysis. Thus, complete data for angiography of the ITA was obtained for RITA grafts in 373 patients and for LITA grafts in 355 patients. The RITA graft was occluded in 4 patients (1.1%), and string-like artery and significant stenosis were present in 11 (2.9%) and 7 (1.9%) patients, respectively; thus, the patency of RITA grafts was 94.1%. Six LITA grafts (1.7%) were occluded, and string-like artery and significant stenosis were present in 3 patients each (0.85%), which gave a patency rate of 97.2% for LITA grafts. No significant differences existed in patency rates between the LITA and RITA grafts.

Among the patients who did not undergo angiography (including 1 patient who died postoperatively) and those in whom adequate data were not obtained, no evidence existed that suggested ischemia of the left ventricle occurred in either the postoperative clinical course or stress tests.

Predictors of Graft Failure
Both simple and multiple logistic regression analysis identified decreased severity of native stenosis, diffuse sclerosis of native vessels, and residual side branches of ITA as independent predictors of nonfunctional grafts (Tables 3 through 5). The method of ITA grafting (laterality of RITA or LITA), BSA, sex, or location of distal anastomoses did not influence the patency of the graft.

Discussion
As a complement to the routine use of LITA to LAD grafting, we used in situ RITA grafting via the transverse sinus for the revascularization of circumflex and diagonal arteries. This technique showed encouraging early and late angiographic results, which were similar to those reported by Puig et al in 1984 and Buche et al in 1995. In this anastomotic technique, a long length of the ITA is required, which necessitates the use of the terminal, smaller portion of the ITA. This technically demanding method may, thus, have the potential for extensive application in patients in certain subgroups previously considered to be placed at high risk by this technique, such as patients with a small body size, elderly patients, and woman, who have relatively small coronary artery and ITA diameters.

Although our previous study demonstrated the excellent early patency rate of RITA grafting, only 21 women were among the 116 patients studied. Nishida et al reported the effects of smaller physical size on complex arterial grafting in CABG. They noted that the 1-month patency rate of arterial grafts was not significantly different between the groups (98.7% versus 96.7%; P = 0.16), but that of venous grafts was significantly lower in groups with a smaller physical size (88.9% versus 97.7%; P = 0.045). Although their study included 264 RITA grafts and 34 women among the 445 patients who underwent CABG with ≥2 distal anastomoses, the site and method of anastomosis were not described. Small body size and female sex have been recognized as major contributors to the increased risk of coronary artery bypass grafting; however, little is known about the independent influence of body size and sex on RITA grafting via the transverse sinus to the circumflex and diagonal arteries.

Several studies have drawn attention to the technical difficulty of arterial grafting in women and patients with a small body size. O’Connor et al reported that a small mid-LAD diameter was associated with a substantially increased risk of in-hospital mortality resulting from CABG. Although body size is correlated with mid-LAD diameter, women have smaller coronary arteries than men, even after compensating for differences in body size. O’Connor et al also noted that their smaller coronary arteries explained the higher perioperative mortality associated with CABG in women and smaller people.

Christakis et al noted that after adjusting for preoperative risk variables and body size, sex remained a significant predictor of both operative mortality and low-output syndrome. Grandjean et al reported that incremental risk factors for the occlusion of the gastroepiploic artery were pump time (operative complexity) and female sex. However, in our study, neither sex nor body size were predictors of graft failure.

In our experience, by creating the shortest route for the ITA and harvesting the ITA as proximally as possible, an RITA

### TABLE 3. Angiographic Results

<table>
<thead>
<tr>
<th>Graft</th>
<th>Destination</th>
<th>Patent</th>
<th>String/Stenosis</th>
<th>Occluded</th>
<th>Patency Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>RITA</td>
<td>Obtuse marginal artery</td>
<td>189</td>
<td>5/4</td>
<td>4</td>
<td>93.6</td>
</tr>
<tr>
<td></td>
<td>Posteriolateral artery</td>
<td>150</td>
<td>6/2</td>
<td>0</td>
<td>94.9</td>
</tr>
<tr>
<td></td>
<td>Diagonal artery</td>
<td>10</td>
<td>0/1</td>
<td>0</td>
<td>90.9</td>
</tr>
<tr>
<td></td>
<td>Posteriodescending artery</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>351</td>
<td>11/7</td>
<td>4</td>
<td>94.1</td>
</tr>
<tr>
<td>LITA</td>
<td>LAD</td>
<td>319</td>
<td>3/3</td>
<td>4</td>
<td>97.0</td>
</tr>
<tr>
<td></td>
<td>D-LAD</td>
<td>15</td>
<td>0</td>
<td>2</td>
<td>88.2</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>343</td>
<td>3/3</td>
<td>6</td>
<td>97.2</td>
</tr>
</tbody>
</table>

Data are from only in situ ITAs. D indicates diagonal artery.

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with an acceptable diameter can be anastomosed to the target coronary artery, even in high-risk groups, such as women, smaller people, and elderly patients. In fact, as shown in the Figure, there has been a steady increase, with the accumulation of experience, in the use of this method in CABG patients.

Kurlansky et al\(^{16}\) reported the largest series to date of 327 bilateral internal mammary artery grafts in women, and they concluded that bilateral internal mammary artery grafting can be achieved with low hospital mortality and morbidity rates. They noted that 11 of 327 patients (3.4\%) suffered postoperative in-hospital cardiac arrest, which suggested that the relatively higher incidence of this complication seemed to be related to a technical factor rather than sex. Their study covered a wide variety of ITA grafting methods, including 107 cases of the RITA grafted to the right coronary artery system in the 331 RITA grafts. Dietl et al\(^{17}\) reported an increased rate of RITA graft failure when it was used to bypass the right coronary and posterior descending arteries; they attributed this problem to spasm of the distal end of the RITA graft and tension on the graft.

In our experience, although the number of female patients in this study was relatively small (n = 83), none required the postoperative use of intra-aortic balloon pumping and, despite a hospital mortality rate of 1.3\%, no sternal infections developed. Although no definite conclusions could be drawn due to a lack of angiographic data in Kurlansky et al’s study\(^{16}\) and the relatively small number of women in our study, the excellent patency of RITA in the posterolateral wall of the left ventricle may explain the comparatively good results in the woman in our series.

Large ITA side branches have been suspected of causing a diversion of blood away from the myocardium, but no cause-and-effect relationship has ever been established.\(^ {18}\) In our series, the residual side branches of the ITA were identified by multivariate analysis as independent predictors of nonfunctional grafts. Although a residual side branch of the ITA may result from a nonfunctional graft,
we think that with this method of RITA grafting, harvesting the ITA as proximally as possible is mandatory to gain the maximum length of graft and prevent any tension on the RITA.

Several authors have reported significantly lower patency in RITA grafts compared with LITA grafts when the vessel bypassed was not the left anterior descending artery.\(^1,10\) However, in our study, once other variables related to graft patency were compensated for, the laterality of the RITA or LITA and the location of distal anastomoses were not predictors of graft failure. Several studies have reported higher operative mortality and an increased rate of graft failure in patients undergoing RITA grafting. He et al\(^1,11\) reported that operative mortality was significantly higher in patients undergoing RITA grafting (21.62%; 8 of 37) than in patients undergoing only LITA grafting (6.53%; 31 of 475; \(P<0.004\)). They speculated that the higher operative mortality in elderly patients with RITA could be due to the fact that an extensive length of artery is usually required to reach the posterior descending artery or that the branches of the left coronary artery increase the risk of spasm. When the RITA is used to bypass the right coronary artery, especially segment 3, the dilatation and motion of the right atrium may apply tension to the graft, promoting graft failure. When anastomosed to the circumflex artery, however, once anastomosis is complete at the site of the RITA graft, the course of the graft seems to be smooth due to a lack of exposure to tension or excessive motion.

Other variables associated with graft failure in this study included decreased severity of native stenosis and diffuse sclerosis of the native vessels. Manninen et al\(^20\) noted that the frequency of string sign correlated with a decreased severity of stenosis. The results of our multivariate analysis may be partly due to categorizing grafts showing string sign as nonfunctional. In our institution, RITA grafting was sometimes performed on a mildly stenotic circumflex artery when the LITA was anastomosed to a LAD with severe lesions. Although the patency rate of the RITA was comparable to that of the LITA, a better patency rate would be expected when anastomosing the RITA to a circumflex artery with good drainage despite severe lesions.

**Study Limitations**

Because of the retrospective nature of this study and a lack of data, the recipient coronary artery diameters were not included in our analysis. However, previous studies demonstrated that coronary artery diameter is related to both sex and measures of body size.\(^10\) Thus, we think that including variables such as sex, BSA, and age will add to the existing evidence regarding the universal feasibility of RITA grafting.

In this study group, angiography was not performed for various reasons in 12 patients, including 1 patient that died in the hospital. Also, the study failed to evaluate the RITA graft in 8 patients and the LITA graft in 3. Because it is impossible to include patients with no or inadequate angiographic data in the analysis and because it is also impossible to extrapolate the results of patients with data to patients with no data, the final analysis was based on the angiographic data of patients in whom complete opacification of ITA grafts was feasible. For RITA grafting, despite the 393 patients entered in the study, data from only 373 patients were obtained. Considering the relatively small number of patients who were not included in the analysis (5.1%) and the lack of clinical data suggesting ischemia of the left ventricle or indirect demonstration of patent grafts in these patients, we think that the results of our final analysis using this method reflect the results of the entire patient body.

**Conclusions**

Multivariate analysis revealed that routing the RITA via the transverse sinus (laterality of RITA or LITA and location of distal anastomosis) was not a predictor of graft failure once other variables related to graft patency were compensated for. The excellent patency rate demonstrated by this, the largest angiographic study to date of RITA grafting via the transverse sinus, indicates that this technique could provide reliable revascularization of the left ventricle; it seems to have the potential for application to a wide variety of patients with diseased circumflex arteries.

**References**


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