Coronary Artery Bypass With Only In Situ Bilateral Internal Thoracic Arteries and Right Gastroepiploic Artery

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Background—With the rapid advance of catheter intervention, the direction taken by surgeons is not only to make conventional CABG less invasive but also to pursue better long-term results by using more arterial conduits.

Methods and Results—Between July 1989 and April 2000, 239 patients (218 men, 21 women) with a mean age of 59.7 (range 39 to 79) years underwent CABG with exclusive use of both internal thoracic arteries (ITAs) and the right gastroepiploic artery (RGEA). ITA grafts were harvested by using the skeletonization technique. Most patients (96%) had either triple-vessel or left main disease. Fifty percent of the patients were diabetic, and 16 were being treated with insulin. The left ventricular ejection fraction was ≤40% in 46 patients (19%). Eleven patients (5%) had chronic renal failure and were on hemodialysis. Follow-up was completed in 235 patients (98%). Postoperative follow-up averaged 43 (range 1 to 129) months. Sequential grafting was performed in 64 patients, and the mean number of anastomoses was 3.3. One patient (0.4%) died of mediastinitis on the 53rd postoperative day. Graft patency was confirmed angiographically in 230 patients (96%) 2 to 3 weeks after surgery. The patency rate was 97.1% for the left ITA, 99.6% for the right ITA, and 95.5% for the RGEA. Five-year actuarial survival rate was 92.9%, and the cardiac death-free rate was 97.8%.

Conclusions—Complete arterial grafting with both ITAs and RGEA was associated with minimal operative risk, a high early graft patency rate, and excellent long-term results. (Circulation. 2001;104[suppl I]:I-76-I-80.)

Key Words: bypass ■ surgery ■ revascularization ■ arteries

The most important advantage of CABG over PTCA is its significantly better long-term results. To achieve this goal, we should aim for complete arterial revascularization by using the theoretically best conduits, which are the in situ arterial conduits, such as the left and right internal thoracic arteries (ITAs) and right gastroepiploic artery (RGEA). To expand the use of arterial grafts for CABG, some surgeons make use of free arterial grafts, such as the radial artery, or they use the composite graft technique with the original in situ arterial grafts, such as the left and right ITAs and RGEA, as free grafts. However, we believe that the use of in situ arterial grafts as they are is the best strategy. The objective of the present study was to evaluate the early and long-term results of CABG with only 3 in situ arterial conduits.

Methods

Between July 1989 and April 2000, 1627 patients underwent isolated CABG. Among them, 239 patients (15%) underwent CABG with exclusive use of all 3 in situ arterial conduits: the left ITA, the right ITA, and RGEA. This corresponds to 38% of the 637 patients who underwent revascularization of all 3 vessels. The proportions of patients treated with this strategy are shown in Figure 1; the proportions are expressed as a percentage of the total number of patients who had isolated CABG per year. Patients who received additional saphenous vein grafts (n=581) or free arterial grafts (n=108) were excluded from the present study. During the same period, 531 patients underwent complete multiple arterial grafting with the use of ≥1 in situ arterial conduit to make the most of the sequential bypass technique. Of the 239 patients studied, there were 218 men and 21 women. The ages ranged from 39 to 79 years, with a mean of 59.7 years. There were 19 emergency operations and 5 repeat operations.

Follow-up was conducted annually in June with the use of a standardized protocol. The rate of completion of postoperative follow-up was 98% (235 of 239 patients), and the period averaged 43 months, ranging from 1 to 128 months. Among 4 patients who were lost to follow-up, 3 were foreigners who returned to their own nations 1, 2, and 3 years after CABG. One Japanese patient was lost to follow-up 2 years after CABG. These 4 patients were censored at the date when they were lost to follow-up during calculation of actuarial results by the Kaplan-Meier method.

Preparation of the ITA

We have consistently used the skeletonization technique in the dissection of the ITA since 1970. After longitudinally opening the endothoracic fascia over the ITA, the surrounding adipose tissue is thoroughly removed with the use of an ultrasound surgical aspirator. All individual side branches are ligated at their origin near the ITA with 7-0 nylon sutures, and the parietal side of the side branches is controlled with hemoclips before transection. After skeletonization is completed, the ITA is sprayed with papaverine solution (8 mg/dL in...
saline) and wrapped in a sponge saturated with the same papaverine solution. Skeletonization technique of the ITA takes 40 minutes on average. The incidence of injury during skeletonization that forced us to use ITA as a free graft or nonuse was 0.7%.

Preparation of the RGEA
The RGEA is isolated from the stomach by ligation of individual branches and surrounding adipose tissues with 4-0 nylon or 3-0 nylon. Hemoclips and staples are not used during dissection. Surrounding adipose tissue is segmentally ligated with 4-0 nylon (stomach side) or 3-0 nylon (omentum side). The distal 2 to 3 cm of the RGEA is thoroughly skeletonized with fine scissors, and all tiny side branches are ligated with 7-0 nylon.

Before the anastomosis is constructed, dilute papaverine solution (0.8 mg/dL in saline) is injected through the cut end. To prevent intimal damage, we use a flexible 30-cm 3F neonatal nutrition tube with a tapered blunt tip (Toray Medical Corp). Anastomosis is performed in an end-to-side fashion with an 8-0 nylon continuous suture in the left ITA. The RGEA is anastomosed in an antegrade and end-to-side fashion with a 7-0 polypropylene running suture. The RGEA grafts are always brought anterior to the stomach and liver.

Results
Patient Characteristics
Baseline patient characteristics are shown in Table 1. The body surface area was \( \approx 1.60 \text{ m}^2 \) in 49 patients (21%). The smallest body surface area was 1.34 m². Ninety-six percent of patients had either left main disease (38 patients [16%]) or triple-vessel disease (191 patients [80%]). The left ventricular ejection fraction was \( \approx 40\% \) in 46 patients (19%).

Operation
Individual grafting with all 3 in situ arterial conduits was performed in 175 patients (73%), and sequential grafting was performed in 64 patients (27%): the left ITA in 49 patients, the RGEA in 13 patients, the left LTA and REGA in 1 patient, and the right and left ITA and REGA in 1 patient. One patient underwent triple sequential grafting with both ITAs and RGEA. The number of distal anastomoses ranged from 3 to 6, with a mean of 3.30 per patient. Concomitant endarterectomy was carried out in 23 patients (10%). The target vessels of endarterectomy were the distal portion of the right coronary artery in all patients.

The graft placement of each in situ arterial graft is summarized in Table 2. The left ITA was most commonly anastomosed to the left circumflex region and then to the diagonal and left anterior descending artery. The right ITA was most commonly anastomosed to the left anterior descending artery. The RGEA was most often anastomosed to the distal portion of the right coronary artery. The distal portion of the right coronary artery includes all the branches, such as the posterior descending artery, atrioventricular branches, and posterolateral branches.

Thus, the most common combination in graft placement of the 3 in situ arterial grafts was the right ITA to the left anterior descending artery, the left ITA to the circumflex artery, and the RGEA to the right coronary artery. This combination was adopted in 175 patients (73%). The next most common combination was sequential grafting of the left ITA to the diagonal and left anterior descending artery, the right ITA to the circumflex artery through the transverse sinus, and the RGEA to the right coronary artery in 20 patients (8%).

### Table 1. Baseline Patient Characteristics

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CCS indicates Canadian Cardiovascular Society; NYHA, New York Heart Association.

### Table 2. Graft Placement

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<th>DB</th>
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<td>32</td>
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<td>RGEA, n</td>
<td>3</td>
<td>2</td>
<td>16</td>
<td>237</td>
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LAD indicates left anterior descending artery; DB, diagonal branch; LCX, left circumflex artery; RCA, right coronary artery; LITA, left ITA; RITA, right ITA; RGEA, right gastroepiploic artery; and n, number of times used for anastomosis.
Early Results
One patient died of mediastinitis on the 53rd postoperative day. The remaining 238 patients were discharged from the hospital, and the in-hospital mortality was 0.4%. One other patient developed mediastinitis, and 4 other patients developed superficial presternal wound infections; all recovered subsequently. Perioperative myocardial infarction, defined by the development of a new Q wave and a peak aspartate aminotransferase level of ≥200 IU/L, occurred in 5 patients. Graft patency was confirmed angiographically in 230 patients (96%) 2 to 3 weeks after surgery. The patency rate was 97.1% (269 of 277) in the left ITA, 99.6% (230 of 231) in the right ITA, and 95.5% (234 of 245) in the RGEA. The patency was 100% (23 of 23) in cases of RGEA to right coronary artery with endarterectomy and 96.0% (194 of 202) in cases without endarterectomy. The difference is not significant. The patency rate for each coronary artery was 99.1% (227 of 229) in the left anterior descending artery, 96.6% (57 of 59) in the diagonal branch, 96.5% (220 of 228) in the left circumflex artery, and 96.6% (229 of 237) in the right coronary artery.

Late Results
During the follow-up period, 9 patients died of noncardiac causes (1.0% per patient-year), 1 patient died of cardiac cause (0.1% per patient-year), and 3 patients died of sudden death (0.3% per patient-year). Although 3 patients developed myocardial infarction (0.3% per patient-year), no patients underwent another CABG.

Figure 2 shows the actuarial survival curve calculated by the Kaplan-Meier method. The 5-year actuarial survival rate including in-hospital and noncardiac deaths was 92.9%. The 5-year cardiac death–free rate including sudden death was 97.8% (Figure 3). The 5-year angina-free cardiac survival rate was 89.0% (Figure 4).

Discussion
With the rapid advance of catheter intervention techniques such as PTCA, rotablator, and coronary stenting, one direction for surgeons to follow is to make conventional CABG less invasive. This approach has led to an enthusiastic effort toward minimally invasive direct coronary artery bypass or multiple off-pump CABG. However, reports have indicated that less invasive CABG is associated with low quality in terms of lower number of in situ arterial conduits used and a lower graft patency rate.1–3 Another direction for surgeons to take is to pursue better long-term results, which is the most significant advantage of CABG over catheter intervention. This approach has led to a trend for a gradual but steady transition to the use of more arterial grafts instead of saphenous vein grafts.

We always aim at complete arterial grafting with the exclusive use of the theoretically best conduits, ie, the in situ arterial conduits, whenever possible anatomically. Anatomic consideration includes the relationship between the target coronary artery and the reach of each in situ arterial conduit and the relationship between the degree of the proximal stenosis and the size of the in situ arterial conduits. The only limiting factors are too small a graft size, too mild a proximal stenosis, or the impossibility of proper design of graft placement.

The presence of diabetes mellitus, advanced age, or left ventricular dysfunction is not thought to be a contraindication for this approach. Although several authors have pointed out that the use of bilateral internal thoracic arteries increases the chance of postoperative mediastinitis,4 we believe that the incidence of wound infection can be minimized by various preventative measures to preserve the viability of the presternal soft tissues and sternum. These measures include the use of pinpoint electrocautery on presternal soft tissues5,6 and skeletonization of the internal thoracic arteries.7–9 Generally, the long-term prognosis of the diabetic patients has been said to be significantly worse after CABG or PTCA because of the diffuse involvement of coronary artery disease with a poor runoff. Therefore, we should extensively use in situ arterial conduits to obtain better long-term patency of grafts, with
careful perioperative management. Similarly, older patients, especially female patients, have generally very small coronary arteries in proportion to their small body size and require in situ arterial grafts even to obtain satisfactory early patency. In patients with left ventricular dysfunction, the flow rate in the graft tends to be small in proportion to the low cardiac output and requires in situ arterial grafts.

In the past 3 years, almost two thirds of the patients underwent multiple CABG with only in situ arterial grafts. The radial artery has been used as the fourth graft next to the 3 in situ arterial conduits and has replaced the role of saphenous vein grafts, but its use has remained at <25% of the patients.

To expand the use of arterial grafts for CABG, some surgeons use free arterial grafts, such as the radial artery or the inferior epigastric artery. Other surgeons use a composite graft technique with the use of the original in situ arterial grafts, such as the ITAs and RGEA, as free grafts. In situ arterial conduits are living conduits and are advantageous in terms of no need for proximal anastomoses to the frequently diseased ascending aorta. Use of an original in situ arterial graft as a free graft to make a composite graft has several disadvantages. First, it increases the number of anastomoses and can cause damage to the most important left ITA graft to the left anterior descending artery as a donor artery of the composite graft. We should avoid the burden on the left ITA. Second, a composite graft can cause undesirable distribution of graft flow to the larger side conduits, such as the radial artery, and cause thinning sign of the most important ITA graft to the left anterior descending artery. Instead of a composite graft, we prefer the sequential bypass technique to increase the number of distal anastomoses, and the composite graft technique with free arterial conduits has not been adopted. We should avoid the use of composite grafts supplying a wide area, such as the anterior wall and posterior wall.

As for the placement of the internal thoracic arteries, we prefer the combination of the right ITA to the left anterior descending and the left ITA to the left circumflex artery over the combination of the right ITA to the left circumflex artery and the left ITA to the left anterior descending artery. We routinely cover the right ITA to the left anterior descending artery by reapproximating the predivided thymus tissue in preparation for possible repeat CABG. We believe that repeat median sternotomy itself can be performed safely with this preventive measure. In fact, the chance of repeat CABG is very low if the right ITA to the left anterior descending artery graft is patent, and no patient required repeat CABG in our series. Although Ueyama et al reported that the in situ right ITA can reach the posterolateral branch of the left circumflex artery through the transverse sinus, we believe that, not infrequently, the in situ right ITA is too short to reach the posterolateral wall of the left ventricle, even with exclusive use of the skeletonization technique to elongate the distance of reach. However, we use the right ITA to the obtuse marginal branch of the left circumflex artery when we plan to perform sequential left ITA grafting to the diagonal branch and left anterior descending artery. The right ITA was also brought to the circumflex artery if it could reach the target vessel, in which case we felt that it was mandatory to use the proximal large site of the left ITA for the revascularization of the left anterior descending artery.

Skeletonization technique of the ITA is a key technique for complete arterial grafting. Although skeletonization of the ITA is time-consuming and technically demanding, it has various the following advantages: (1) less devascularization of sternum and presternal soft tissues and low incidence of mediastinitis, (2) low incidence of opening of the pleural cavity, (3) longer extension and availability of the more proximal portion of the ITA, leading to greater diameter at the site of arteriotomy for anastomoses, and (4) ease of sequential bypass grafting.

The RGEA is most commonly used for revascularization of the distal part of the right coronary artery. We believe that the RGEA is the best conduit for the revascularization of these small distal right coronary arteries because the patency rate of the saphenous vein graft to such arteries to which the right ITA cannot reach is thought to be unsatisfactory because of low graft flow. However, we do not use an RGEA with a small or usual size (diameter <2.0 mm) for revascularization of a dominant right coronary artery if the proximal stenosis is <90%. In such situations, we have recently used the radial artery instead of the saphenous vein, unless the patient had severe renal dysfunction. The reason for this strategy is that the RGEA is a more distal tributary of the aorta than is either ITA, and we have frequently experienced dominant flow from the proximal part of the native right coronary artery toward the RGEA and distal right coronary artery in the case of mild proximal stenosis. To ensure the size of the RGEA before surgery, we routinely check the size of the RGEA angiographically during diagnostic coronary angiography if the patient seems to be a possible candidate for CABG, because the size of the RGEA does not correlate with the body size at all.

Bergman et al also demonstrated excellent results in 256 CABG patients with complete arterial grafting with the use of bilateral ITAs and RGEA. Their early and long-term results were equivalent to our results. Extensive use of in situ arterial conduits does not increase the operative risk and improves the long-term results.

In conclusion, complete arterial grafting with both ITAs and RGEA was associated with minimal operative risk, high early graft patency rate, and excellent long-term results.

References
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