Graft Planning

12

Tomoaki Suzuki and Tohru Asai

Abstract

With the development of the OPCAB technique, the current trend in CABG is toward in situ arterial reconstruction because of the benefit of the aorta no-touch technique and the better long-term clinical outcomes (Endo M, Nishida H, Tomizawa Y, Kasanuki H, Circulation 104:2164–2170, 2001). An arterial graft produces better late graft patency and better long-term patient outcomes than vein graft. Now we have three reliable in situ arteries (both internal thoracic arteries (ITA) and right gastroepiploic artery (GEA)) and one free graft (radial artery). As we all know, the use of the ITA is associated with low rates of mortality and reintervention. Furthermore, some recent reports demonstrate that bilateral internal thoracic artery grafting to the left anterior descending and circumflex coronary arteries offers the best long-term survival and lowest rates of reintervention (Rizzoli G, Schiavon L, Bellini P, Eur J Cardiathorac Surg 22:781–786, 2002; Taggart DP, D'Amico R, Altman DG, Lancet 358:870–875, 2001; Lytle BW, Blackstone EH, Loop FD et al., J Thorac Cardiovasc Surg 117:855–872. 1999). In the decade since Buxton and coworkers (Buxton BF, Komeda M, Fuller JA, Gordon I, Circulation 98:II-1–II-6, 1998) and Lytle and coworkers (Lytle BW, Blackstone EH, Loop FD et al., J Thorac Cardiovasc Surg 117:855–872. 1999) revealed the long-term efficacy of bilateral ITA grafting, it has been gaining acceptance among surgeons, and there is no doubt that it affords the best long-term outcome. CABG with grafting of the bilateral ITAs to the left coronary system and additionally the GEA to the distal RCA has been reported to provide good long-term outcome (Chavanon O, Durand M, Hacini R et al., Ann Thorac Surg 73:499–504, 2002; Tavilla G, Kappetein AP, Braum J, Gopie J, Tjien ATJ, Dion RAE, Ann Thorac Surg 77:794–799, 2004; Suzuki T, Asai T, Matsubayashi K et al., Ann Thorac Surg 91:1159–1164, 2011).

For high-quality OPCAB, the skeletonization technique is now essential that makes the arterial graft into optimum condition. Skeletonization has many advantages, such as avoidance of early spasm, easy identification of potential bleeding, quality of the vessel, functionally lengthened and larger graft with maximum flow, ease in performing sequential anastomosis, and preservation of sternal blood flow and venous drainage.

In this chapter, I discuss the optimal grafting model using multiple arterial conduits.

Keywords

Aorta no-touch • Composite graft • In situ graft

T. Suzuki (✉) • T. Asai (✉)
Division of Cardiovascular Surgery, Department of Surgery,
Shiga University of Medical Science, Ootsu, Japan
e-mail: suzukit@belle.shiga-med.ac.jp;
toruasai@belle.shigamed.ac.jp

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12.1 Arterial Graft Planning Using ITA, GEA, and RA

12.1.1 Internal Thoracic Artery

The ITA is the most reliable conduit. Its patency is better than 90 % at 15 years, and its use has been proven to prolong patient survival. The ITA is an elastic artery with a thin intima and a well-formed internal elastic membrane. The media is formed by a combination of elastic lamellae and smooth muscle cells. Vasa vasorum are seen in the adventitia but there are few in the media. The ITAs produced endothelium-derived relaxing factor and prostacyclin which contribute to the high patency and excellent function as grafts. The incidence of atherosclerosis in ITAs is lower than the SVG after used for CABG. The ITA is a very delicate vessel that can be injured easily. Skeletonization has gained acceptance among surgeons for harvesting the ITA because of the advantage of preservation sternal blood flow, creating increased effective length and the free flow of the ITAs in anastomoses. Higami [9] and associates firstly described ultrasonic ITA skeletonization and revealed its technical feasibility and advantage. They showed that the skeletonized ITA averaged 4 cm longer than the pedicled conduit, and the free flow rate is greater than 100 mL/min, which is at least 20 % higher than of the pedicled ITA. In my experience, the ultrasonic scalpel improves technical ease, shortens the harvesting time, and increases the effective length and free flow of the ITAs. Now standard surgeons should master the ultrasonic skeletonization technique for the effective use of ITAs in OPCAB surgery.

12.1.2 How to Use Both ITAs

Some recent reports demonstrate that bilateral internal thoracic artery grafting to the left anterior descending and circumflex coronary arteries offers the best long-term survival and lowest rates of reintervention. The clinical evidence level of long-term effect of using bilateral ITAs has elevated recently. If the patient requires reconstruction of both the LAD and CX area, the left and right ITAs should be used routinely in combination together.

It is unknown what grafting model of both ITAs is the most effective. Cardiovascular surgeons should discuss the best grafting model of both ITAs. Two common combinations of the ITA placement include (1) the right ITA (RITA) to the LAD across the midline with the LITA to the CX and (2) the RITA to the CX through the transverse sinus with the LITA to the LAD. Several reports showed that the early clinical results, graft patency rate, and technical difficulty were similar in both combinations. The LAD reconstruction is most important in CABG that should be anastomosed individually by one ITA. We prefer the RITA to the LAD and the LITA to the CX combination because we often experience a case that requires the CX-CX sequential grafting (Fig. 12.1). It is not difficult to perform CX-CX sequential grafting using skeletonized left ITA. As they say, the RITA is too short to graft to the LAD; however, it occurs mainly in pedicled RITA. The skeletonized RITA with ultrasonic scalpel is long enough to reach to the distal LAD (Fig. 12.2). We have experienced in only 2 % of cases that the skeletonized RITA is too short to achieve the LAD.

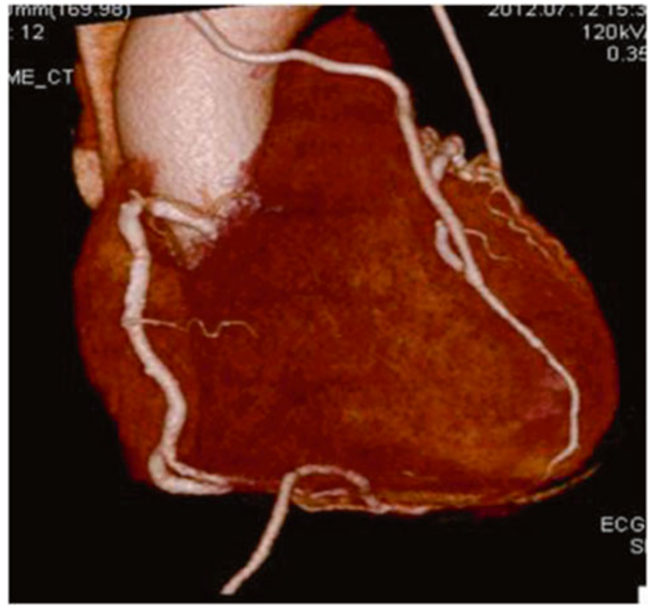

Fig. 12.1 Three in situ arterial grafts: left IMA, right IMA, and right GEA

Some study showed good results of composite Y- or T-graft of the free RITA connected to the in situ LITA. A composite graft can increase the number of anastomoses and may cause damage to the donor artery and undesirable distribution of graft flow to the larger area. Although the results of composite graft are acceptable, almost all reports showed better patency rate and long-term outcomes of the in situ graft than the composite graft. Thus, the ITAs should be used as the in situ graft whenever technically possible.

12.1.3 Right Gastroepiploic Artery

The history of using the right gastroepiploic artery (GEA) in coronary revascularization started in the 1960s, when Bailey reported the Vineberg implantation of the GEA into the posterior area of the heart. Since direct coronary artery bypass procedures became the standard revascularization method, the GEA to coronary artery anastomosis has been reported by Pym [10] and Suma [11] in 1987.

The GEA is the main branch of the gastroduodenal artery which arises from the right hepatic artery. After the GEA gives off branches to the pancreas, duodenum, and the pylorus, it runs along the greater curvature of the stomach. In contrast to the IMA, the GEA has fewer elastic lamellae in its media and is classified as a muscular artery [12].

The GEA provides at least 20 cm of useable length which can reach all areas of the heart. Skeletonization using ultrasonic scalpel makes the GEA longer and wider, so that it can be anastomosed at a more proximal position than the pedicled GEA. In 1998, the use of skeletonized GEA has been reported for coronary bypass conduit [13]. However, the skeletonization technique is cumbersome and time-consuming with ordinary methods using electrocautery, scissors, and hemoclips. In 2001, we developed a simple and safe technique for harvesting skeletonized GEA using an ultrasonic scalpel (Harmonic Scalpel, Ethicon Endo-Surgery, Cincinnati, Ohio) [14]. The size of the skeletonized GEA has surprised us since we have been using the technique described above. It has ranged from 2.5 to 6.5 mm in internal diameter at the site of the distal anastomosis (Fig. 12.3). This is quite different from the size of conventionally prepared GEA with surrounding tissues, which was reported to be 1.25–2.5 mm in earlier work. The difference implies that skeletonization may play an important role in dilating GEA maximally. I believe it is most important that we prepare each GEA conduit at its maximal dilatation prior to anastomosis. What we have found since we started the skeletonization technique is that the first appearance of GEA does not predict the potential size of the artery. The vascular tonus of GEA can vary significantly during an operation. Care should be taken not to underestimate the size of GEA at the beginning of operation. In no case the GEA was too narrow for use after the proper skeletonization technique. The suitable targets of the in situ GEA are the distal right coronary artery or the distal circumflex artery. It is very feasible to perform sequential grafting using skeletonized GEA for its sufficient length and diameter.

The early functional patency rate of the skeletonized GEA is reported to be better than that of the nonskeletonized GEA. Kim and coworkers [15] evaluated the early and 1-year postoperative results of grafting the skeletonized GEA to the

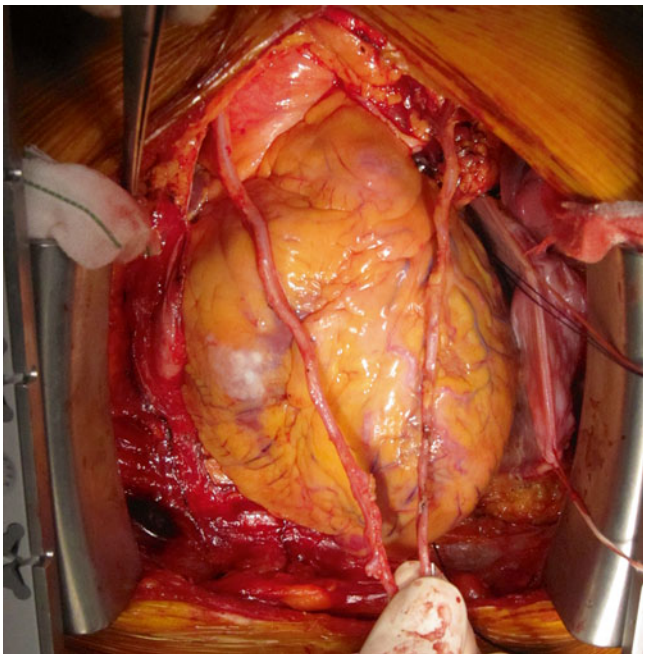

Fig. 12.2 Two mammary arteries: the skeletonized RIMA is long enough to reach the distal LAD

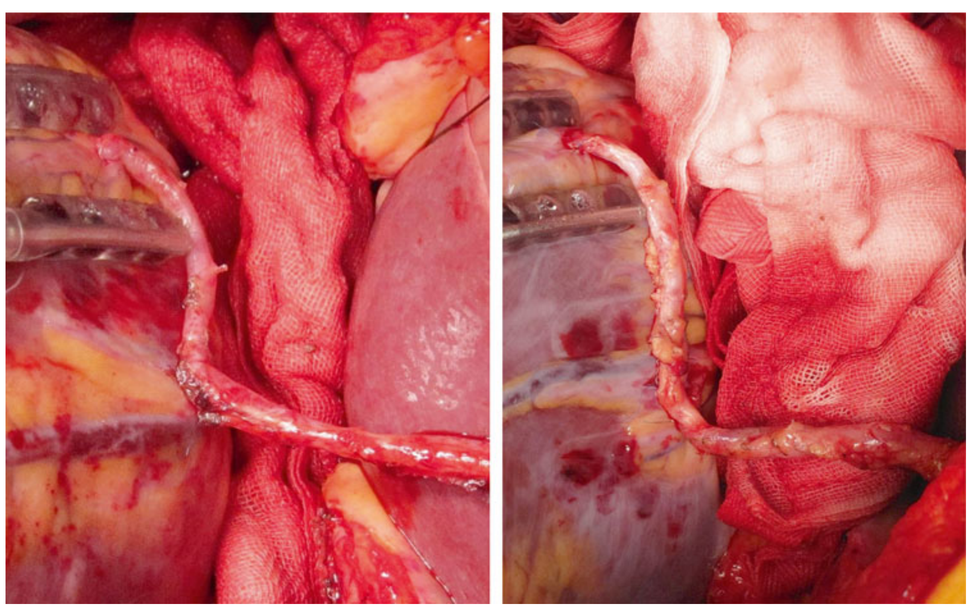

Fig. 12.3 Skeletonized GEA has sufficient length and adequate large diameter that make easy sequential grafting

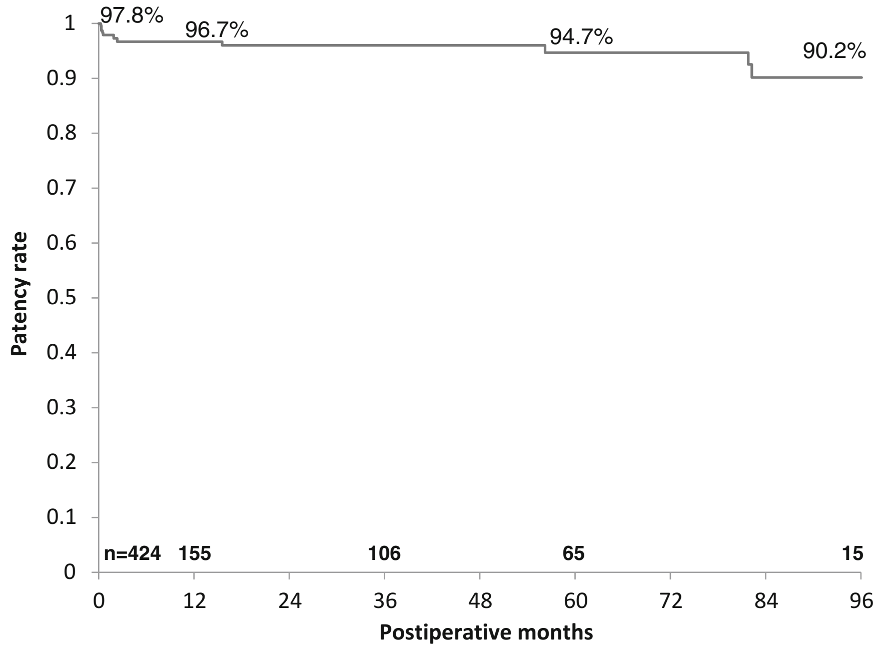

Fig. 12.4 Cumulative patency rate of the GEA graft by the Kaplan-Meier method

RCA and found an excellent early patency rate of 98.3 % and 1-year patency rate of 92.0 %.

There are little in the literature of mid- and long-term patency rate of the GEA. Suma and coworkers [12] reported their 20 years' experience of using GEA graft that the cumulative patency rate of the GEA was 97.1 % at 1 month, 92.3 % at 1 year, 85.5 % at 5 years, and 66.5 % at 10 years, respectively. Of them, in 172 skeletonized GEA graft with 233 distal anastomoses, the patency rate at 1 and 4 years after surgery was 92.9 % and 86.4 %, respectively. Ali and colleague [16] focused and evaluated the skeletonized GEA patency rate collecting the data from 11 clinical papers. Overall patency rates were 97.7 % within three months, 92.4 % at a mean of ~1 year, 91.5 % at a mean of 2 year, and 86.4 % at 4 years. In 2013, we presented our single-center report that the cumulative patency rate of the skeletonized GEA was 97.8 % at 30 days, 96.7 % at one year, 96.0 % at 3 years, 94.7 % at 5 years, and 90.2 % at 8 years after surgery that is superior to that for pedicled GEA or saphenous vein graft [17] (Fig. 12.4). It can be said that skeletonized GEA is a reliable conduit and assumes a large role in all arterial OPCAB strategy. However, the GEA has not necessarily gained acceptance among cardiovascular surgeons worldwide. Reasons for its less frequent use include concerns about insufficient flow capacity and vasospasm, the need to open the abdomen, and competitive flow causing graft failure. We need to open the abdomen when using the GEA; however, the skin incision extends only 3–4 cm. It is well known that flow competition may occur when the GEA is anastomosed to coronary artery with low-grade stenosis. As a general rule, we use the GEA only when the coronary artery stenosis is severe. We think that late graft occlusion may occur in association with flow competition. In our study, we discovered through multivariate analysis that low-grade target vessel stenosis was a strong risk factor for late GEA occlusion. We therefore recommend again that the GEA should in principle be used for more severe stenosis (>75 %).

Surgeons have not necessarily achieved great understanding of the potential ability of the GEA that has been undervalued. We think that the GEA will play a critical role in an area of OPCAB procedure with in situ all arterial grafting and surgeons should discuss and grasp the detail of the potential power of the GEA.

12.1.4 Radial Artery

The radial artery is frequently used as second graft of choice after the ITAs in CABG. Carpentier [18] et al. firstly reported the use of radial artery in CABG; however, it was soon abandoned because of disappointing early angiographic outcomes. After improvement of harvesting technique, management of pharmacologic dilatation, and the use of postoperative calcium channel blocker, the radial artery was reviewed according to encouraging reports in the 1990s.

The radial artery is a very convenient conduit that has several advantages including the ease of harvesting, sufficient length for grafting to almost any coronary artery territory, and suitable caliber for matching coronary artery. The radial artery is the muscular artery and has more spastic character than other arterial conduits. To prevent the spasm of the radial artery, intravenous nitrates or calcium channel blockers should be used intraoperatively as well as postoperatively until the patient can take oral medications. The endothelium of the radial artery plays an important role for preventing vasospasm. To preserve the endothelial function, the surgeon should take caution not to inflict excessive manipulation on the radial artery and not to mechanically dilate it during harvesting.

The radial artery is often used as composite graft connected to the ITA in end-to-side fashion. Effort to achieve aorta no-touch strategy in OPCAB procedure has led to the increased use of the RA as a composite bypass graft. Although the patency rate of radial artery composite graft is acceptable, almost all studies showed the superiority of direct aortocoronary bypass to composite graft. Therefore, when the RA composite grafting is performed, careful consideration of undesirable distribution of the blood flow due to unbalanced vascular area is needed.

The early (~12 months) patency rate of the radial artery is very favorable that is expected more than 90 %. Recently, the long-term (5years~) patency rate has been reported to be between 70 and 98 %. The patency differences of the radial artery are more significantly influenced by target coronary territory and target vessel stenosis than other conduits. It is said that if the proximal stenosis is 90 % or more, radial artery patency between ITA-RA composite graft and direct aortocoronary bypass was similar. Therefore, when the proximal native stenosis is milder, the radial artery should be used as direct aortocoronary anastomosis.

In the current circumstance of aorta no-touch OPCAB, the radial artery is a supplemental conduit used in cases which the bilateral ITAs are not available or complete reconstruction of left side coronary area cannot be achieved with bilateral ITAs alone.

12.1.5 Saphenous Vein Graft

The saphenous vein is the most popular and easily handled for graft to the RCA or the CX, and the relevant long-term clinical outcome, flow capacity, patency, and long-term complications are well known. As the advantage of the arterial conduit has become evident, the use of the SVGs has decreased. Now, in an aorta no-touch arterial OPCAB era, the SVGs are used in limited cases, including nonavailable GEA, RCA target with milder proximal stenosis, hemodialysis or renal failure patient in that the RA should not be used, and emergency with hemodynamic instability. The reasons for less use of the SVGs are as follows: wound complication such as edema, cellulitis, and delayed healing causing patients' discomfort; need for aorta manipulation during proximal anastomosis; and so-called graft disease that worsens long-term outcome. The SVG may developed intimal hyperplasia in early phase within 1 year, furthermore, atherosclerotic change in long term (>5years) that related to graft occlusion more frequently than arterial conduits. The patency rate of the SVG may increasingly deteriorate with time, as we know, that is 50–60 % at 10 years after CABG. Endoscopic vein harvesting technique has been developed for the purpose to reduce the clinical complications including wound infection, leg edema, pain, and prolonged hospital stay. Although the endoscopic vein harvesting technique has been widely spread among surgeon, the clinical result is disappointing. Lopes et al. reported the clinical outcome comparing endoscopic harvesting to open harvesting and concluded that endoscopic vein-graft harvesting is independently associated with vein-graft failure and adverse clinical outcomes. Thus, the endoscopic vein harvesting technique should be used only in selected patient. The damage of the endothelium of the SVGs often leads to platelet aggregation that causes intimal hyperplasia resulting to graft occlusion. Recently, no-touch technique of the SVG harvesting is recommended that provides a pedicled graft. It preserves normal intact adventitia, vasa vasorum, medial blood flow, and endothelial function. The perivascular fat protects the vein against arterial hemodynamics and kinking result in preventing future atherosclerosis. Early SVG failure is associated with distention-induced endothelial denudation. Superior long-term patency rate of pedicled SVG is demonstrated in recent review. In either approach of endoscopic or open harvesting, a careful handling of the SVG during harvesting is important not to damage the endothelium.

12.2 Aorta No-Touch Technique with All Arterial Grafting

12.2.1 An Advantage of Aorta No-Touch Technique

The incidence of stroke in patients undergoing routine CABG is reported to be 1–3 %, most commonly as a result of ascending aortic embolic phenomena. Various studies have proven embolic showers using transcranial Doppler during cannulation, clamping, or declamping maneuvers and especially in association with the release of the aortic cross-clamp. The best strategy to reduce stroke risk appears to be to completely avoid handling the aorta, the so-called aorta no-touch technique. An effort to reduce stroke during CABG has led to widespread use of aorta no-touch strategy with off-pump technique. The main indication for no-touch aorta OPCAB operation is patients who have a severely atherosclerotic or porcelain ascending aorta.

Kapetanakis and associates [19] reported that stroke rate with on-pump CABG was 1.5 times (2.2 % versus 1.6 %) that with off-pump CABG with partial aortic clamping and three times (2.2 % versus 0.8 %) that in the no-touch aorta OPCAB group. Kim and associates [20] reported a lower incidence of perioperative stroke with the no-touch aorta

OPCAB technique, but similar stroke rates between OPCAB with aortic manipulation and conventional on-pump CABG. Misfeld and coworkers [21] presented that 81 of 5,779 (1.4 %) patients in the OPCAB group with aortic manipulation had strokes, compared with 29 of 5,619 (0.5 %) patients in the aortic no-touch group. Lev-Ran and coworkers [22] reported one neurologic event among 429 consecutive patients (0.2 %) in the no-touch OPCAB group, which compared favorably with a stroke rate of 2.2 % observed in the side-clamp OPCAB group. On the other hand, complete avoidance of aortic manipulation preserves the aortic fat pad containing neurogenic tissue and thereby may avoid an autonomic imbalance and further decrease the incidence of atrial fibrillation. Kim and coworkers [23] demonstrated that OPCAB with complete avoidance of aortic manipulation significantly reduced the incidence of postoperative atrial fibrillation compared with conventional CABG (11.4 % versus 21.1 %).

Even though the no-touch technique may be the best clinical practice, it may not always be applicable for every patient and is not routinely applied in many centers. Despite all above evidence in favor of no-touch technique, the real world does still include saphenous vein grafting with proximal anastomosis in patients with multivessel disease.

It is known that the cause of neurologic complication in 3 % of patients undergoing CABG who have strokes is multifactorial and thus may not be avoided by reducing the manipulation of the aorta alone. It needs to be addressed whether there is a relationship between the degree and type of aortic manipulation during OPCAB procedures and subsequent stroke.

At any rate, there is almost no doubt that aorta no-touch technique has several advantages to prevent an embolic complication associated to diseased ascending aorta. Surgeon should keep making an effort to refine their skill and master the aorta no-touch technique to reduce an extra preventable embolic event.

12.2.2 Graft Arrangement for Complete Revascularization with Aortic No-Touch Technique

12.2.2.1. Composite Grafting

Left-sided bilateral ITA grafting can be regarded as the best surgical revascularization technique with respect to survival and freedom from adverse cardiovascular events such as late myocardial infarction, recurrent angina, and reintervention. The use of bilateral ITAs enables the performance of OPCAB operations without manipulation of the ascending aorta, as an in situ or Y-configuration. Several arrangements of bilateral ITA grafting have been proposed to achieve left anterior descending and circumflex arterial grafting. With the advent and increased popularity of the off-pump technique, many surgeons currently use the technique of arterial composite T- or Y-grafting with free right ITA or radial artery attached end to side to the left ITA. A commonly used arrangement is the composite T-graft, whereby free ITA grafts are attached proximally end to side to in situ ITA. Several studies [24–26] reported that the clinical and angiographic results of composite grafting were equivalent to those of individual grafting. Some other studies reported that composite grafting may be susceptible to the detrimental effect of flow competition with native coronary artery when used for a mildly stenosed target vessel. When all target vessels in triple-vessel disease were bypassed with a composite ITA graft, a major concern was that the single attached LITA would not be able to supply enough blood to the revascularized myocardium. Studies using transit-time Doppler techniques indicate that construction of composite arterial grafts results in a significant increase in flow through the left ITA. The amount of flow supplying each region depends on the severity of coronary stenosis and coronary vascular area. Composite arterial grafting causes splitting of internal thoracic artery flow to various myocardial regions. Conduit flow is largely affected by the native coronary flow. Nakajima and coworkers [27] presented angiographic study of 362 patients with composite T-graft in that competitive flow was found in 14.6 % of the composite grafts and occlusion occurred in 3.6 % of the patients. Sabik and colleagues [28] also reported that multivariate analysis identified the degree of preoperative proximal coronary stenosis to be an important predictor of ITA graft occlusion. Manabe et al. [29] showed that the angiographic outcomes of composite grafts were closely related to the severity of stenosis of the target coronary artery. In target vessels with mild stenosis, composite grafting resulted in a higher incidence of graft occlusion or string sign than individual grafting did. They found that composite grafting has been shown to be an independent predictor of graft occlusion or string sign in case of target vessels with mild stenosis; therefore, they do not recommend composite grafting in target vessels with mild stenosis. The precise mechanism of graft failure in composite grafts has not been completely clarified. Failure of ITA graft to LAD as a result of competitive flow deprives the patients of the main benefit they expected to gain from the operation that could have been achieved by using a simple in situ ITA. Lev-Ran and coworkers [24] reported that early results of bilateral ITA grafting with T-graft are comparable with those of in situ grafts; however, increased angina return and decreased midterm survival led them to recommend in situ grafting whenever technically possible. However, composite grafting plays a crucial role in these procedures, because it eliminates the need for proximal anastomosis to the ascending aorta and conserves extra lengths of an arterial graft for additional grafting. We therefore think that composite T- or Y-grafting with two ITAs should be employed for selected patients with severe stenosis in their LAD and marginal branches of the circumflex.

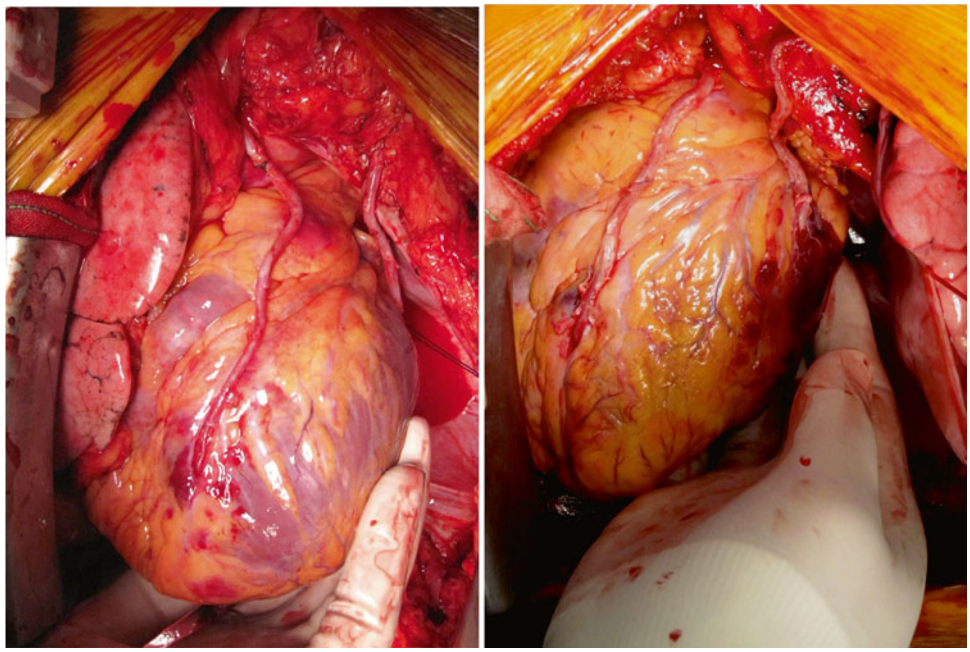

Fig. 12.5 Our favorable graft arrangements: in situ RITA anterior to the aorta to LAD and in situ LITA grafting to CX area

12.2.2.2. In Situ Grafting

Arterial grafts are known to narrow diffusely or occlude when they are used in low-flow condition. However, even in vessels with a stenosis degree as low as 50 %, the patency rate of in situ ITA to LAD was over 90 %. This excellent patency of in situ ITA to LAD was long-lasting and remained high up to 15 years or more after surgery. Although the results of composite graft are acceptable, almost all reports showed better patency rate and long-term outcomes of the in situ graft than the composite graft. We prefer an in situ ITA grafting to composite grafting. Reduced patency rates for free RITA grafts have been demonstrated when these grafts are connected proximally to the aorta. The concerns of in situ right ITA grafting to LAD are insufficient length and proximity of the crossover right ITA to the sternum which could compromise a subsequent repeat sternotomy. Refinement in ITA-skeletonized harvesting technique increased graft length and improved distal free flow and may reduce postoperative sternal wound complication. If the length of the crossover right ITA is not sufficient to comfortably reach the desired anastomotic site on the LAD, we consider the T-graft arrangement. However, in our 225 OPCAB cases of recent 2 years, T-graft technique was implemented in only two cases (0.9 %). Thus, a skilled technique of skeletonization ITA harvesting can resolve the issue of the insufficient length of the RITA graft in almost all cases. The surgeon should master the skeletonization technique of the ITA harvesting with ultrasound scalpel. Grafting an in situ right ITA to the left coronary system can either be performed through the transverse sinus in a retroaortic course [30] or crossing over a route anterior to the aorta. Both techniques have particular disadvantages. Although a retroaortic course of an in situ RITA to the CX coronary artery (through the transverse sinus) has been advocated by some surgeons [30], this technique has several disadvantages such as technical difficulty, compression of the right ITA by the aorta, or the inability to control side-branch bleeding and to detect graft kinks because of out of direct vision. These disadvantages of the retroaortic course have limited its widespread use.

We prefer in situ RITA grafting anterior to the aorta because of technical ease and equivalent patency rate to in situ LITA grafting to the LAD (Fig. 12.5). A major concern over the anterior retrosternal RITA crossover route is the potential risk of damage to the artery during repeat sternotomy. We have made all kinds of efforts to prevent injury of the crossover RITA. The RITA is let into a tunnel of the right pericardium and directed leftward crossing the midline of the ascending aorta toward the LAD. Mediastinal fat was used to cover the RITA. Thus, a space is maintained between the crossover RITA and the posterior table of the sternum for future resternotomy. This maneuver allows free space on the aorta and provides a safety distance between the crossover ITA and sternum. In our previous experience with 7 patients undergoing resternotomy with a patent retrosternal RITA, no RITA was damaged. In all seven cases, the crossover RITA was easily dissected without injury, and the aortic cannulation site and clamping zone were safely maintained.

The use of sequential grafting is essential to achieve complete revascularization with only in situ arterial grafts. The two ITAs in combination with the right gastroepiploic artery provide three sources of blood supply. When OPCAB is planned with the aorta no-touch technique and using BITA grafts, the right coronary artery can be bypassed with an in situ right GEA or an extension of the composite ITA graft. The LAD should be reconstructed individually with one ITA (mainly with the right ITA). We often use the in situ left ITA as sequential graft for CX reconstruction. The left ITA may be allowed to use up to double sequential anastomoses, but difficult for three anastomoses. The skeletonized right GEA is very suitable for sequential grafting with sufficient length and diameter, even up to three or four sequential anastomoses.

In our consecutive 225 elective OPCAB cases of recent 2 years, over 90 % (203 cases) of them were performed using in situ all arterial grafting technique with aorta no-touch policy. We routinely use both ITA and right GEA as in situ graft and never use the radial artery. Thus, in almost all cases, complete revascularization can be achieved with in situ three arterial conduits (both ITAs and right GEA). We use the SVG in a particular case such as previous gastrectomy, RCA target with mild stenosis, or severe calcified right GEA.

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