Harvesting: Tip and Pitfalls

14

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Abstract

Currently, the main graft materials used for coronary artery bypass grafting are the internal thoracic artery, radial artery, gastroepiploic artery, and saphenous vein. In this section, the characteristics of each graft and its harvesting, as well as essence of ultrasonic complete skeletonization, are described.

Keywords

Graft • Internal thoracic artery • Skeletonization

14.1 Internal Thoracic Artery

14.1.1 Characteristics of Internal Thoracic Artery

Each internal thoracic artery (ITA) is an elastic vessel (vessel with elastic tissues in the tunica media) with a lower frequency of arteriosclerosis and 2–3 mm vascular diameter which diverges from the subclavian artery and travels downward on the dorsal edges of the sternum. The vascular diameter is equivalent to the coronary diameter. Obviously, the advantages of the ITA are long-term graft patency and improved life prognosis. Among currently available grafts, the ITA is by far the best material. Furthermore, harvesting of the ITA by ultrasonic complete skeletonization (UCS) has the advantages regarding handling during surgery. The effective graft length is approximately 5 cm (30 %) longer than the ITA from pedicle harvesting. In addition, free flow of more than 100 mL/min can be obtained in many cases. The free flow increases by approximately 40 % in comparison to the ITA from pedicle harvesting. In terms of length, enough length for grafting of in situ anastomosis can be provided with UCS. With the left skeletonized ITA, all regions of the left anterior descending artery and circumflex branch can be available.

The expanded use of the right ITA with UCS has surpassed the application of pedicle harvesting. With right skeletonized ITA, most regions of the anterior descending artery and the circumflex branch, except for the end branch of the circumflex artery, can be used for in situ anastomosis. Furthermore, the bilateral ITA with UCS is not only adequately feasible for left main coronary artery disease in terms of blood flow, but it is capable of frequent use for sequential bypass, as well. In addition, the diameter of the skeletonized ITA allows easy anastomosis that leads to its feasibility in an off-pump coronary artery anastomosis in particular.

It is difficult to identify the disadvantages of the ITA. However, pedicle harvesting of the right ITA limits the coronary artery region during in situ anastomosis, which indicates less efficiency than the left ITA. Furthermore, since there are strong concerns about the development of mediastinitis caused by the use of bilateral ITA in high-risk groups including diabetic patients, the disadvantages on the use of the right ITA have been widely recognized. Consequently, the use of which is limited to special cases. However, the limited region for anastomosis and the risk of development of mediastinitis, which are indicated as disadvantages of the right

ITA, are almost solved by the application of UCS. Currently, the right ITA can be safely and easily used as long as harvested by UCS.

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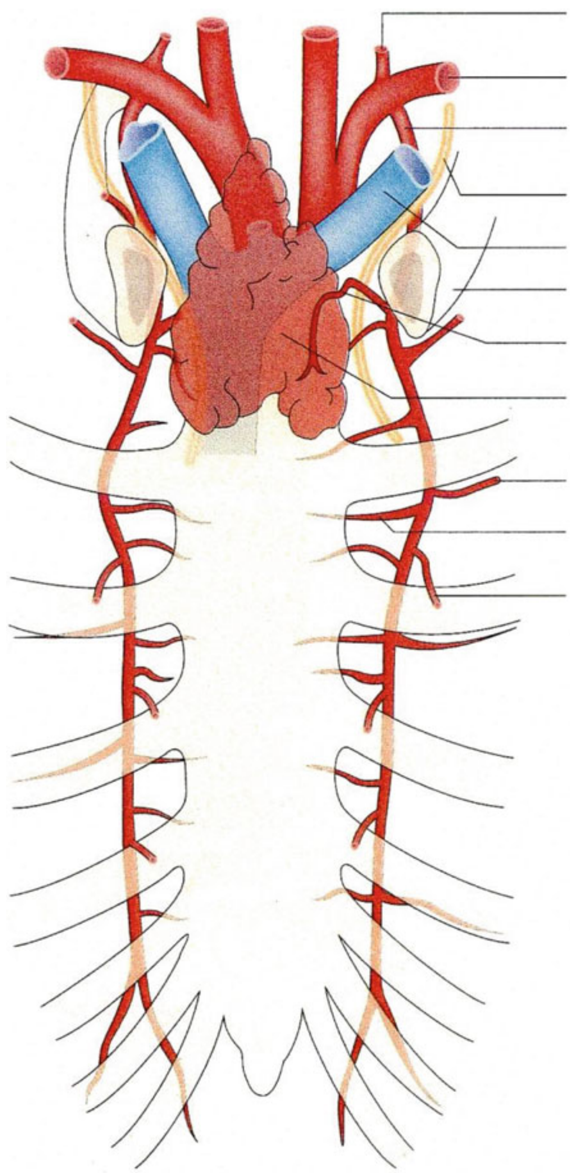

Fig. 14.1 Anatomy of internal thoracic artery

14.1.2 Anatomy of Internal Thoracic Artery (Fig. 14.1)

The ITA, opposite to the origin of the vertebral artery from the subclavian artery, diverges in almost a straight line vertically downward. The ITA courses with the phrenic nerve and then reaches the upper edge of the first rib. At this level, the ITA crosses the phrenic nerve and descends along with two accompanying veins in the space between the intercostal muscle and endothoracic fascia and rib in the posterior surface of the anterior chest wall approximately 1 cm distal to the sternal edge. However, the two accompanying veins merge at the cephalic site from the first intercostal space, and the single vein usually runs distally from the ITA. The brachiocephalic vein extends to the cephalic and lateral sites from the upper edge of the first rib. This vein is located between the medial side (laterally) and the anterior side (frontally) of the ITA. On the other side, since the transversus thoracis muscle often develops in the caudal site from the level of the fourth intercostal space and the fifth rib, the continuity of the transversus thoracis muscle makes the endothoracic fascia unclear. The ITA divides into the superior epigastric artery and musculophrenic artery at the level of the sixth rib and intercostal space.

There are three main branches of the ITA, which diverge into three different directions: (1) the sternal branch which courses to the median side (dorsum of the sternum), (2) the perforating branch which penetrates through the sternal edge, and (3) the anterior intercostal branch which courses laterally. They exit according to the number of the rib. These are the ones which must be dissected in branch trimming. Additionally, one or two branches (thymic branch and rami mediastinales) which course to the mediastinum at the upper ITA (near the first rib and first intercostal space), except the branches which supply the thoracic wall, should be dissected carefully. A relatively thick branch, which is divided superiorly and laterally from the first rib, can sometimes be seen. Trimming this branch allows the course of the ITA to be more linear, and this contributes to the extension of the effective length.

14.1.3 Internal Thoracic Artery Conventional Harvest Technique

A median sternotomy was performed. After dissecting the reflection of the mediastinal pleura from the endothoracic fascia, the ITA and both satellite veins were visualized. The endothoracic fascia was longitudinally incised several millimeters medial to one of the satellite veins using electrocautery. The incision extended along the most of the length of the vessel down to the sixth intercostal space. Retraction of the pedicle visualizes the accompanying vessels and the ITA itself. With the pedicle gently retracted downward and with gentle blunt dissection, the perforating and anterior intercostal arteries are occluded with small metal clips and divided with electrocautery close to the chest wall to avoid damaging the ITA. The pedicle is dissected up to the level of the second or first rib. With variable relation of phrenic nerve with ITA, careful dissection is needed on either side to avoid phrenic nerve injury causing paralysis of the diaphragm which results in delayed postoperative recovery. All the branches of ITA must be clipped to ensure a long-term patency. Inadequate harvest of ITA can result in steal of blood.

14.1.4 Skeletonization of the Internal Thoracic Artery with an Ultrasonic Scalpel

The right and left internal thoracic arteries possess suitable properties (quality and diameter) for grafting. Long-term graft patency of the bilateral ITA is also better. However, the conventional pedicle harvesting of bilateral ITA is now applied less commonly because of concerns about not only the length and blood flow but also the development of mediastinitis caused by a decline in blood flow to the sternum.

In contrast, ultrasonic complete skeletonization (UCS), the procedure invented by the author in 1998, [1–3] is a useful and safe graft harvest technique which alters our view on the use of ITA. The UCS can make in situ grafting using bilateral ITA easier (Fig. 14.2). In this section, the essence on ITA harvesting by UCS is described in detail.

Prior to harvesting, the endothoracic fascia is exposed by dissecting the pleura from the dorsum of the sternum. The endothoracic fascia around the third rib, approximately one centimeter near the median from the course of the ITA, is incised. An endothoracic fascia incision must be made near the median (in an upside visual field) from the internal thoracic vein, which travels with the ITA. It prevents not only unnecessary venous injury but also the knack of effective ITA dissection (Fig. 14.3). The internal thoracic vein can be visualized by a quick touch of the loose adipose and connective tissues with an ultrasonic scalpel (Harmonic Scalpel DH105; Ethicon). "Quick touch" is named for the safe and quick removal procedure of the tissues surrounding the ITA by using a cavitation phenomenon that an ultrasonic scalpel creates. The key points to use the "Quick touch" are as follows: within 0.2 s. of ITA contact time and no several contacts of the same area. When the internal thoracic vein can be clearly and proximally visualized, it should be pulled away to the superior visual field by using the Quick touch. In harvesting of the ITA, it is important for the UCS to separate the vein from the beginning of the procedure and not to cause bleeding.

The basics of ITA exposure are as follows. First is to use the "Quick touch" technique only to the superior region of the visualized ITA. Next is to leave untouched the area inferior to the ITA, that is, the margin connected to the endothoracic fascia. Final point is to rotate the ITA toward and inferiorly by pulling down the fascia. In branch dissection, start with the "Melting cut" of the sternal branch, which is visualized frontally, by grasping the endothoracic fascia with forceps using the left hand and pulling it toward and inferiorly. "Melting cut" is named for the procedure of protein coagulation of the branches by the Harmonic Scalpel. First, it is crucial to keep the probe tip of the Harmonic Scalpel 1 mm away from the main trunk and make a three-dimensional right angle, that is, to square up the main trunk, branch, and probe. Next, rotate the ITA proximally at an angle of 90° by pulling the endothoracic fascia inferior distally. Use the "Melting cut" procedure to the perforating branch visualized in front. Furthermore, rotate the artery at an angle of 90° to use the "Melting cut" procedure to the "anterior-coastal branch" in the frontal visual field. Finally, detach the ITA from the endothoracic fascia. Complete skeletonization of the region is done. In many cases, it is adequate that the distal end of the ITA is stripped up to the bifurcation of the superior epigastric artery and musculophrenic artery. The ITA of distal bifurcation has clearly different macroscopical and histological characteristics. Thus, it is not suitable as a regular graft.

In the proximal side, particularly in the proximal part of first to second intercostal spaces where the endothoracic fascia becomes unclear, harvesting is slightly different. First, the ITA is stripped bluntly using Tuppels by pushing it up from the pleural side to the sternal side, and then the course of the ITA is confirmed. After trimming the branches toward the mediastinal side, the branches toward the thoracic wall

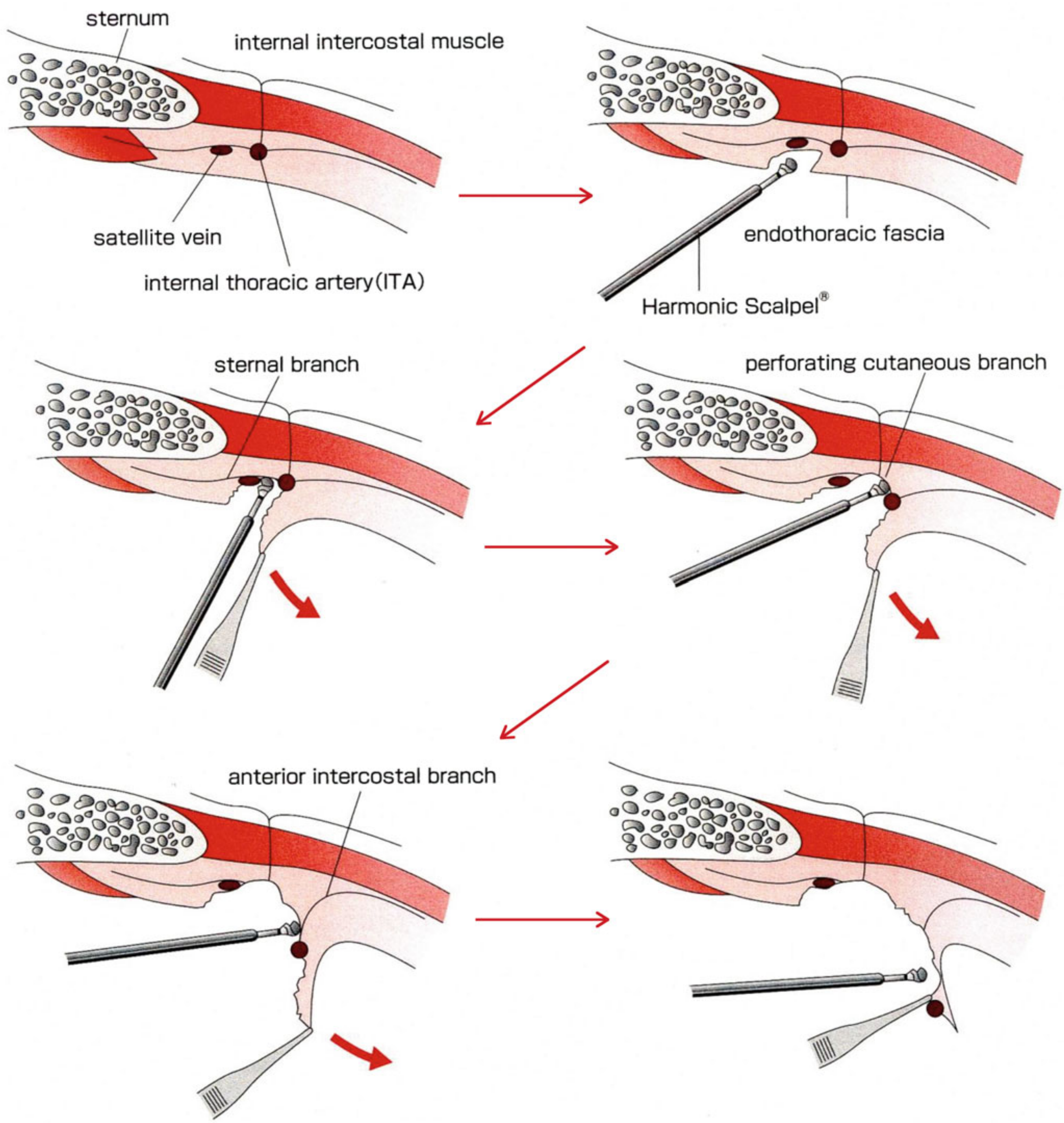

Fig. 14.2 Ultrasonic complete skeletonization of the internal thoracic artery

are trimmed with the Melting cut by rotating the ITA from the proximal visual field to the mediastinal side. Finally, the phrenic nerve is confirmed and stripped up to the site of the intersection with the ITA. At this time, it is crucial to use an ultrasonic scalpel from the viewpoint of avoiding injury to the phrenic nerve after visualizing the courses of the ITA and phrenic nerve.

After dissection of the ITA, a gauze soaked in warm papaverine hydrochloride 10 % is applied on the stripped ITA. This can solve adequately the spasm caused by irritation from the pull or rotation with forceps during ITA harvesting. After systemic heparinization, the bifurcation of the last peripheral branch is dissected, and then free flow is confirmed. The final free flow of ITA is usually more than

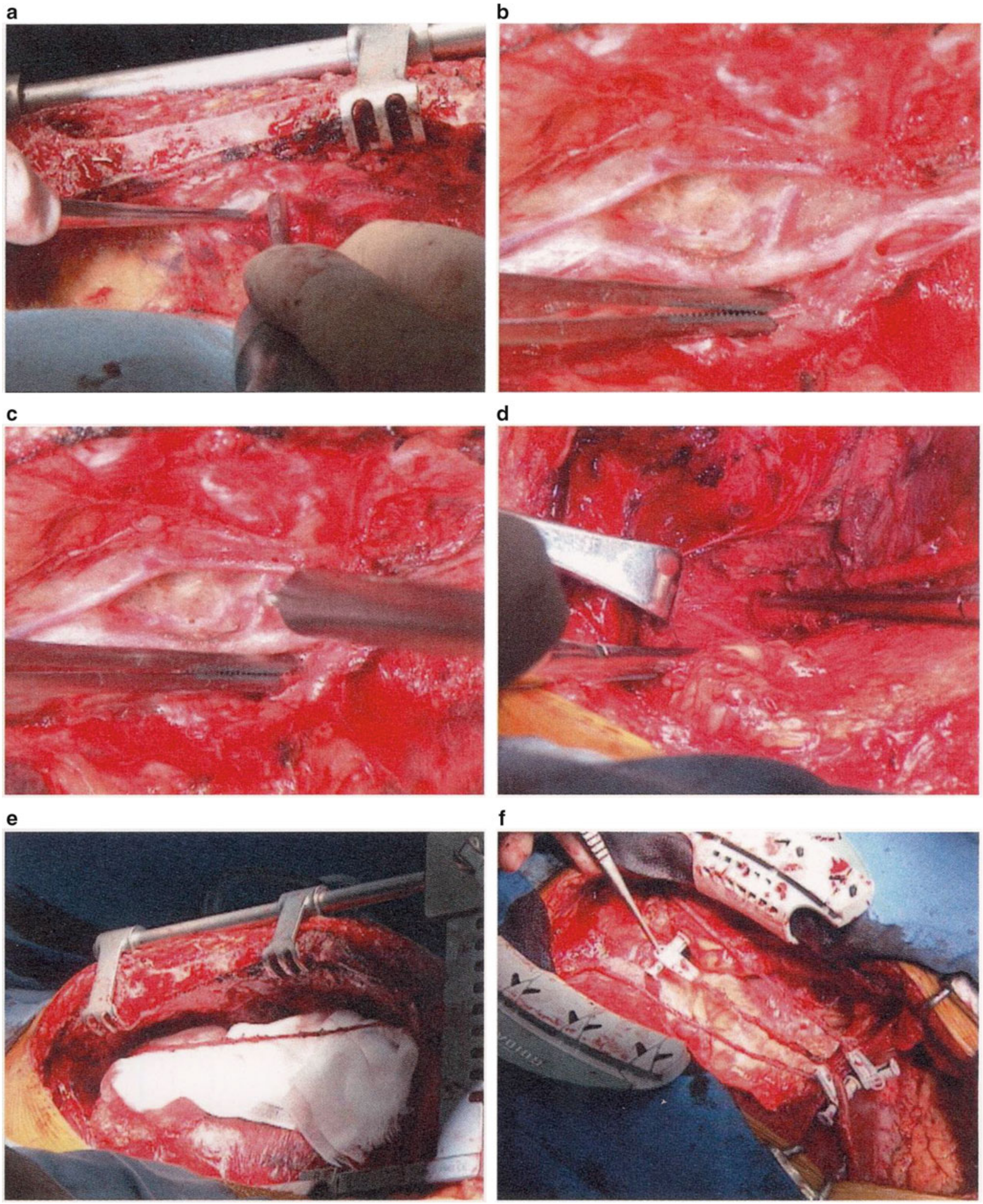

Fig. 14.3 Intraoperative view of ultrasonic complete skeletonization of the internal thoracic artery

100 ml/min. In the event that the free flow is less than 50 mL/min, ITA damage should be considered. The main causes of ITA damage are local hematoma because of branch-out, lumen pressure because of intimal dissection, and thermal damage to the media and adventitia from defect or failure of the Quick touch.

The left ITA harvested in such a way enables in situ anastomosis for the anterior descending artery region and the entire course of the circumflex branch, while the right ITA enables in situ anastomosis for most regions of the left anterior descending artery and circumflex branch.

14.2 Radial Artery

14.2.1 Characteristics of Radial Artery

The radial artery (RA) is relatively a muscular artery which lies in the forearm. Its vascular diameter is 3–4 mm which is slightly thicker than that of the ITA. The use of RA graft has been inadequate because of the occurrence of spasm. In 1992, it was reported that the use of calcium channel blocker prevented spasm. Since then, attention has been drawn to the RA as a friendly conduit for coronary grafting. When Allen's test (test to confirm discontinuity with the ulnar artery) reveals a patent RA, bilateral RA is available. Usually, the nondominant forearm is selected. Currently, the RA is often harvested by the skeletonization technique with an ultrasonic scalpel. An adequate graft length (approximately 20 cm) can be obtained. For long-term graft patency, the RA is said to be better but not superior to the ITA.

14.2.2 Preoperative Evaluation for RA Harvesting

A patient's dominant arm during interview is confirmed. Currently, transradial artery catheterization is often performed. Consequently, it is essential to confirm history of catheterization and the site. RA postharvest complication is the development of symptoms of hand ischemia because of incomplete arch and low formation of the ulnar artery. The reported frequency of low formation of the arch is 6–34 %. No reduction in blood flow from the ulnar artery to the hand is confirmed with the Allen's test. Also, a modified Allen's test for confirmation of blood flow from the arcade to the thumb is routinely conducted by suppression of the peripheral adjacent artery with the use of Doppler blood flowmetry. RA graft has a higher frequency of arteriosclerosis than that of ITA. Thus, tomography and Doppler ultrasonography are useful for evaluation of the RA aspects, such as arterial calcification and coarctation. When skeletonization is performed during surgery, evaluation with Doppler ultrasonography is not required.

The contraindications of RA harvesting are as follows: positive Allen's test results, patients with over 1.5 mg/dL of serum creatinine who are candidates for future dialysis, cases of connective tissue disease presenting with Raynaud phenomenon, and vascular trauma on the antebrachial region or vasculitis.

14.2.3 Anatomy of Radial Artery

The radial artery is the continuation of the brachial artery. It runs between the brachioradialis muscle and flexor carpi radialis in the lateral two-thirds of the forearm. In the distal one-third region of the forearm, the radial artery travels to the wrist, which is surrounded by the fascia sheath. In the proximal two-thirds of the forearm, the lateral cutaneous nerve of the forearm lies above the brachioradialis muscle. The radial nerve divides into the superficial branch and posterior interosseous nerve. The latter passes deeper and laterally than that of the RA, while the superficial branch passes along the lateral site of the RA and travels to the wrist. It is reported that sensory nerve damage can develop because of injury and edema of the lateral cutaneous nerve of the forearm and superficial branch of the radial nerve in 2.6–15.2 %. Thus, care should be taken during skin incision and dissection.

14.2.4 RA Harvest Technique (Fig. 14.4)

For skin incision, two landmark points are plotted parallel to the arterial pulsation at 1–2 cm proximal to the wrist and at 2–3 cm distal to the elbow joint. Incision is done directly above the RA slightly or proximal to the ulnar site in order to avoid edema and sensory damage to the lateral cutaneous nerve of the forearm. Next, the RA beneath the fascia sheath, 3 cm proximal to the wrist, is exposed. The fatty tissues and fascia that course along with the right and left accompanying veins are proximally dissected with an electrocautery. Then, after proximal exposure of the RA, it is adequately visualized with a retractor as it enters the muscles, and the fascial sheath overlying the RA is dissected with an electrosurgical generator. The entire course of the RA and the accompanying veins are exposed with surgical scissors. In order to separate the artery and veins, the fibrous capsule overlying the artery is dissected with surgical scissors and then incised. Since more branches of the veins lie near the elbow joint, the veins are ligated if needed to adequately expose the artery. After adequate exposure of the area directly above the artery, incision of the RA is started with the use of Harmonic Scalpel. A hook-type Harmonic Scalpel is used with output level set at 2. Basically, this maneuver is the same as that of the ITA. Dissection of each branch is sequentially performed with gentle rotation of the RA. Each branch is incised more

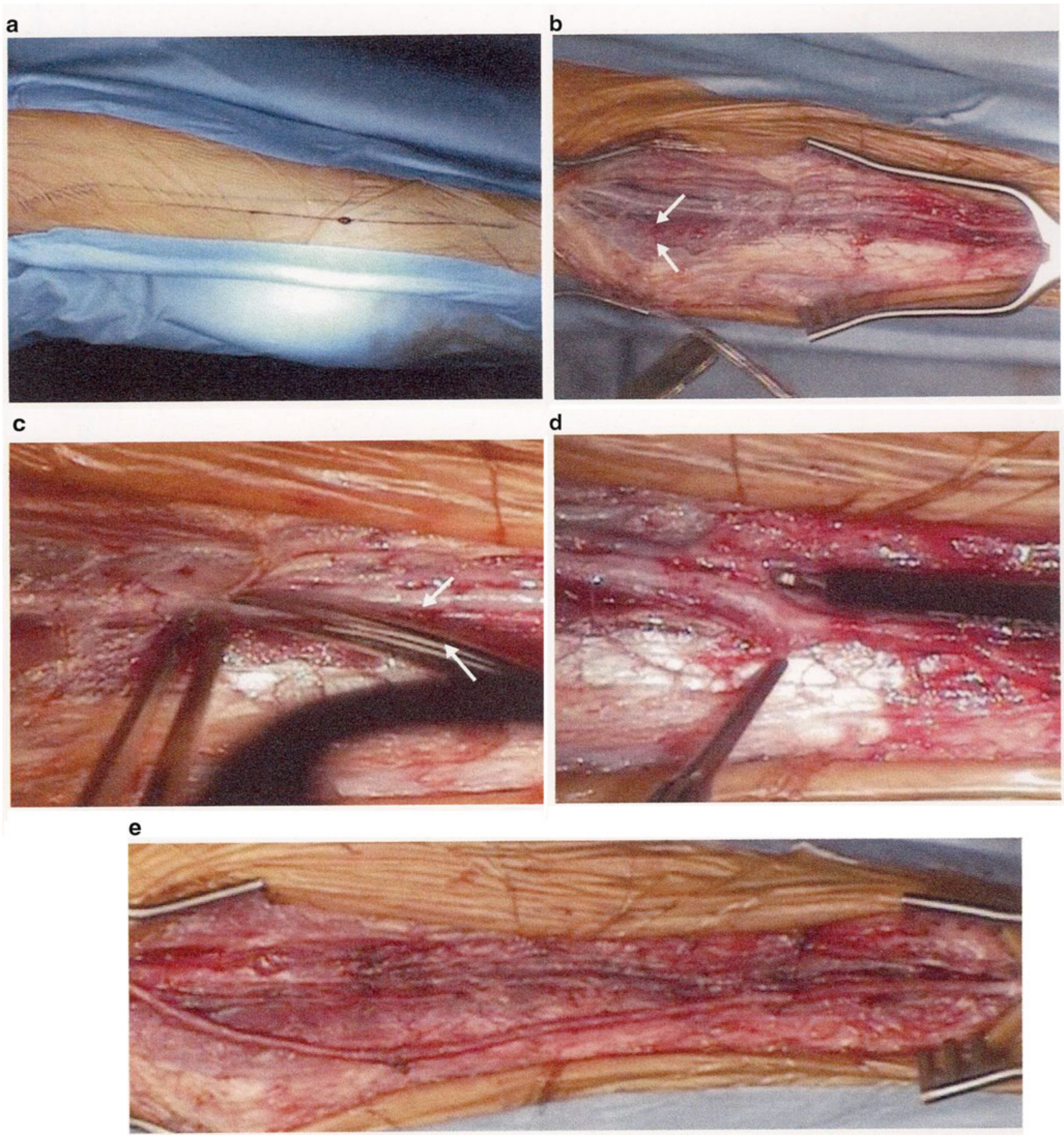

Fig. 14.4 Intraoperative view of ultrasonic complete skeletonization of the radial artery

than 1 mm distal to the main trunk, and the procedure is accomplished with the Melting cut in order not to pull the branches out. The length of the RA harvested by UCS is approximately 20–23 cm in male adults. The blood flow from the proximal site is secured. It is necessary to finally confirm if the ulnar artery and arcade are patent. A blunt needle, such as a vessel cannula, is inserted from the proximal site of the harvested RA, and the RA is hydrostatically dilated by VG solution to remove spasm. Until the time that the harvested RA will be used, it is soaked in the warm VG solution. An in vitro test revealed that "VG solution," which contains verapamil and nitroglycerin, has a superior vasorelaxant property and protective effect on the intimal layer. It demonstrates the most effective result among various vasoconstrictors (Table 14.1). After hemostasis is confirmed, only the deep fascia and skin are closed after sump drain is placed.

14.3 Gastroepiploic Artery

14.3.1 Characteristics of Gastroepiploic Artery

The gastroepiploic artery (GEA) originates from the gastroduodenal branch of the celiac artery. The GEA courses with the gastroepiploic vein 1–2 cm away from the greater curvature of the stomach (Fig. 14.5). The vascular diameter of the GEA is about the same as that of the ITA. The GEA, however, is a muscular artery which is composed of smooth muscle cells within the tunica media different from the ITA. The use of the GEA for coronary artery bypass grafting was reported to be beneficial in 1987. Since then, it has been often used as an in situ graft. However, there are concerns that long-term graft patency rate is inferior to that of the ITA, and there is competition to the blood flow with the coronary artery when stenosis rate is poor. Since the development of the skeletonization technique with the Harmonic Scalpel in order to overcome these disadvantages, the width, length, and blood flow of the GEA graft have been significantly improved. Although the GEA as an in situ graft is valuable second to the bilateral ITA graft, long-term graft patency and blood flow competition remain as its disadvantages. Basically, it is wise not to use the GEA for grafting of the left anterior descending coronary artery (LAD, Cx).

Table 14.1

VG solution	
Verapamil	5 mg
Nitroglycerin	1 mg
Heparin	500 units
8.4 % NaHCO3	1 mL
Saline	100 mL (pH 7.4)

14.3.2 GEA Harvest Technique (Fig. 14.6)

The skeletonization of the GEA is different from that of the ITA. The GEA is located in the free peritoneal cavity, and the trimming of the side branches is not suitable for the hook-type Harmonic Scalpel. Good use of the scissors-type Harmonic Scalpel for GEA skeletonization allows satisfactory results. First, pinpoint exposure of the right GEA is made from the attachment site of the greater omentum at the greater curvature of the stomach. Vessel tape is looped. Similarly, the GEA is dissected and exposed every 3–4 cm. Vessel tape is looped at each dissection site. A total of 6–7 sites are taped. Two neighboring vessel loops are lifted up. First, the fatty tissue above the GEA is completely incised with the Harmonic Scalpel without causing any damage to the GEA. This procedure is performed between vessel loops to completely expose the upper portion of the GEA. The side branches of the GEA together with the lateral fatty tissues are allowed to hang as a bundle below the GEA. Then, they are clipped and dissected with the Harmonic Scalpel 1 mm

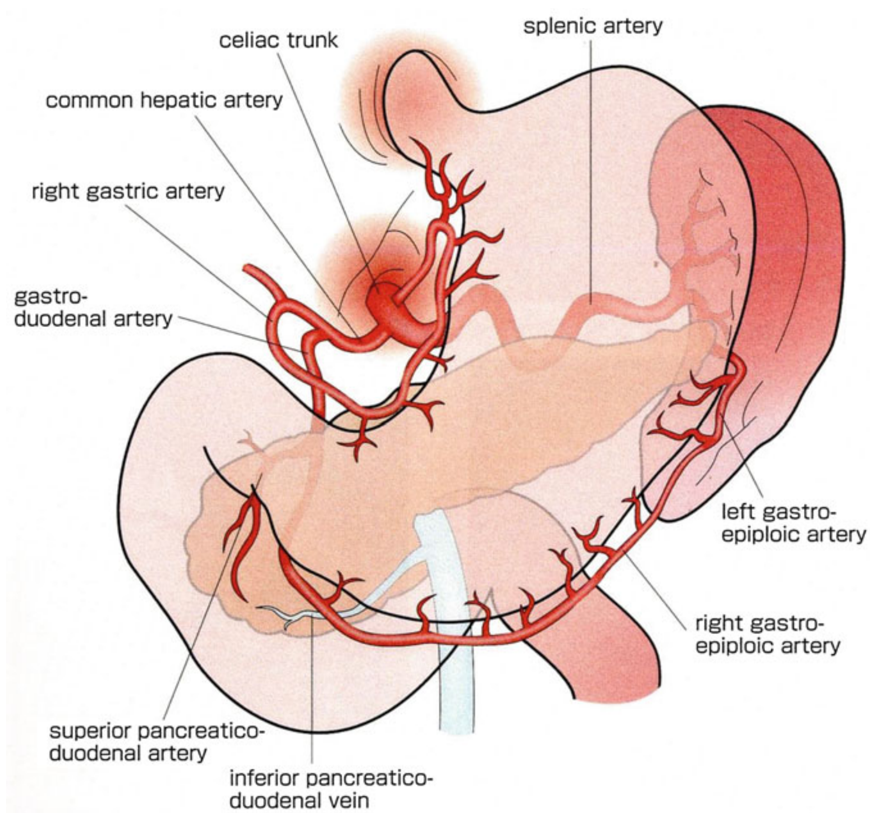

Fig. 14.5 Anatomy of gastro-epiploic artery

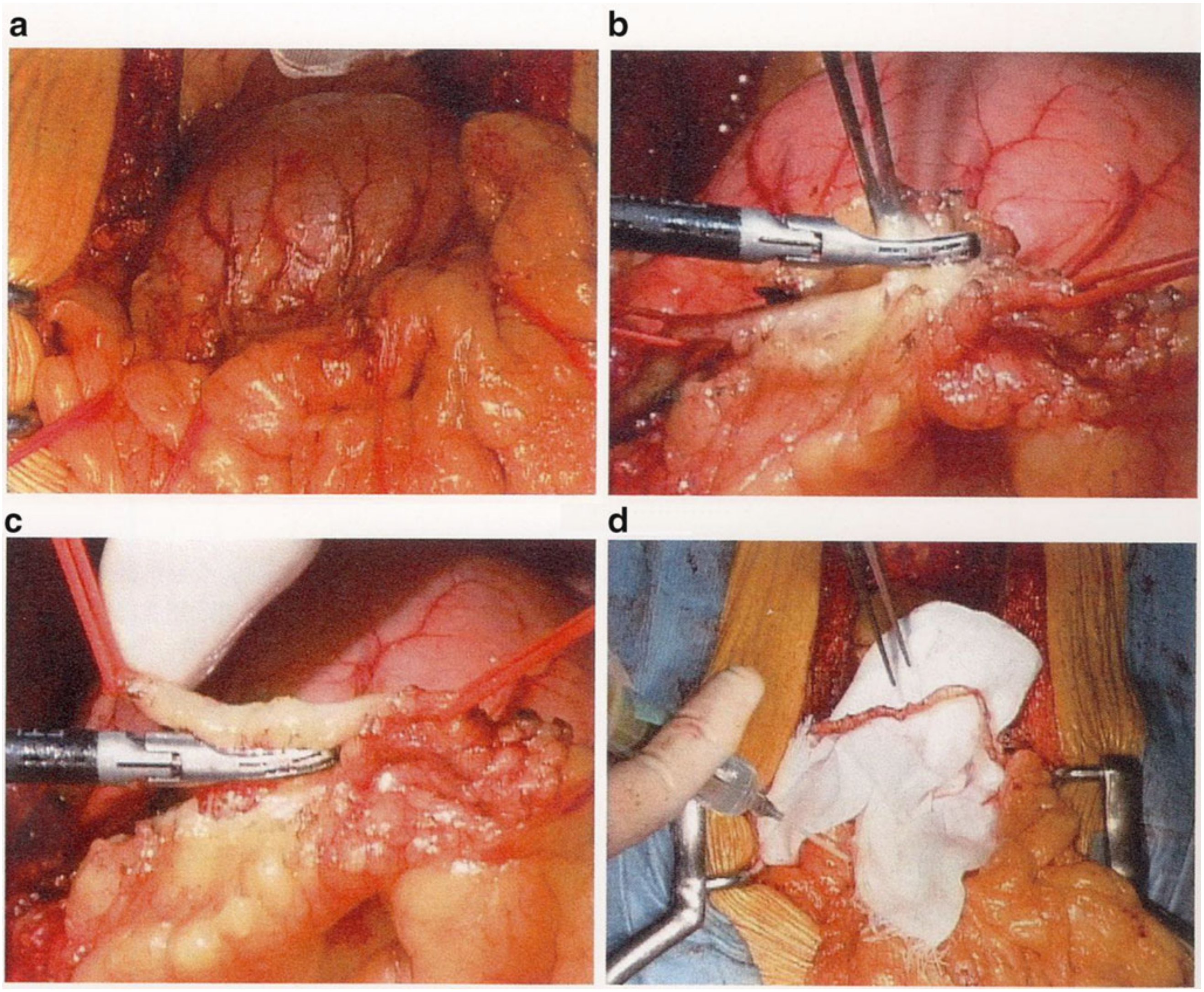

Fig. 14.6 Intraoperative view of ultrasonic complete skeletonization of the right gatro-epiploic artery

distal to the main trunk. In this case, it is important to dissect the branches by gently and slowly rotating the Harmonic Scalpel with the active side of the scissors-type Harmonic Scalpel distally from the main trunk in order to avoid thermal damage to the main trunk. This maneuver is repeated at each vessel loop to complete the skeletonization. At this time, the output level of the Harmonic Scalpel is set at 5. Bleeding due to inadequate coagulation is sometimes observed. As long as skeletonization is performed with the scissors-type Harmonic Scalpel, a longer period of time for coagulation with a lower output level can cause thermal damage to the GEA. This is why the scissors-type Harmonic Scalpel usually causes thermal damage within 2–3 cm laterally. Consequently, a shorter period of time for incision is desirable. After dissection of the GEA, it is covered with gauze soaked in warm papaverine hydrochloride 10 % solution. This solution can adequately relieve spasm caused by irritation from the traction of vessel loop during GEA harvesting.

14.4 Saphenous Vein

14.4.1 Characteristics of Saphenous Vein Graft

The saphenous vein graft (SVG) has had the longest history since Favaloro reported its use in 1968. Currently, the dependent use of SVG decreased sharply because the aorta no-touch technique for off-pump CABG is inevitable, in addition to poor long-term graft patency of SVG compared with arterial grafts. It is an indisputable fact that the SVG is useful in cases with short duration of operation, such as in an emergency surgery, and that the use of arterial graft is deficient under limited circumstances. In addition, current introduction of surgical instruments and appliances, including heart strings and vein enclosure in the aortic anastomosis, allows proximal anastomosis of the SVG, which can avoid partial occlusion of the aorta. They are easy to use in off-pump CABG.

14.4.2 Pre-evaluation for Saphenous Vein Harvesting

Past varix of the lower extremities, vein inflammation, deep thrombophlebitis, and lower extremity trauma and thermal burns are inquired during patient interview. The presence of any previous illness aforementioned is a contraindication to the use of the SVG. Unilateral varix of the lower extremity allows the use of the contralateral SVG. Consequently, preoperative inspection and palpation of the SVG are essential. If necessary, availability and patency of the SVG should be evaluated with an echography. If a vein graft after extension is less than 3 mm graft, the occurrence of early occlusion is likely high. Thus, it is recommended that the SVG should be harvested from the proximal thigh, not from the distal thigh. The following are the advantages of harvesting from the distal thigh: (1) less mismatch with the coronary artery, (2) thin subcutaneous tissue and less branching, and (3) better wound healing and less postoperative edema. On the other hand, the advantages of harvesting from the proximal thigh are as follows: (1) more elastic SVG and (2) larger caliber and better patency in cases when the proximal anastomotic devices are used.

14.4.3 SVG Harvest Technique

Currently, the endoscopic SVG harvest technique has been developed. In this section, the conventional harvest – skin incision – technique is described. The SVG in the distal thigh is harvested from the medial malleolar artery. The SVG in the proximal thigh is harvested from the groin one fingerbreadth medial and distal from the pulsation of the femoral artery. Both parts of the SVG are harvested toward the knee. It is recommended that skin incision should be performed in several batches in order to confirm the vein. If subcutaneous tissue is obliquely dissected due to misperception of the course of the SVG, this can lead to difficult harvesting, poor wound healing, and longer hospitalization. Parallel dissection of the connective tissue capsule above the SVG with surgical scissors will allow adequate length of the SVG to be exposed. During skin incision, it is essential not to touch the SVG by gripping the surrounding tissues with forceps. In the distal thigh, meticulous attention should be applied in order not to damage the saphenous nerve, which runs along the SVG. The side branches are trimmed. They are ligated with 4–0 silk suture. At this time, it is essential to gently and carefully dissect the adventitia of the branch sites in advance to avoid dissection of the surrounding tissues. Since ligation proximal to the branch site can cause SVG stenosis, more than 1 mm length of the branches should be ligated. The SVG is proximally and peripherally ligated and dissected to accomplish the harvesting. When hemostasis is confirmed particularly in the thigh, leakage of clear lymphatic fluid must be confirmed to prevent postoperative lymphatic fluid leakage. When the incision site is closed, a dead space is prevented.

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