Use of Internal Thoracic Artery T-Grafts for Complete Arterial Revascularization

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The internal thoracic artery (ITA) is one of the arteries that is least likely to develop obstructive atherosclerosis. A near-perfect internal elastic membrane restricts diffusion of formed elements from the lumen into the vessel wall and of mesenchymal or muscle cells from the media into the intima. The ITA is the most ideal bypass graft because it is capable of supplying sufficient blood to the ischemic myocardium during rest and exercise; it tends to remain free of obstruction from spasm, intimal hyperplasia, and obstructive atherosclerosis for the remainder of the patient’s life. Also, the ITA is accessible from a median sternotomy incision and will not be in the way if sternal reentry is required.

Vineberg was the first person to revascularize the myocardium with the ITA by implanting it into the myocardium. Demikhov directly anastomosed the ITA to the left anterior descending coronary artery (LAD) in 1953. Goetz et al performed the first direct coronary artery bypass reported in the literature when he anastomosed the right ITA to the right coronary artery (RCA).

To achieve our goal of completely revascularizing the entire heart with only the ITA, we began by attaching one ITA to the other as a T graft or as a tandem/sequential graft. The technique of connecting one ITA to the other was introduced by Mills and later popularized by Sauvage et al. This method brings the origin of the right internal thoracic artery (RITA) 10 to 15 cm closer to the circumflex and RCA branches than if the RITA was left attached or was anastomosed to the ascending aorta, and it makes it possible for the ITAs to reach the posterior branches of the circumflex and RCA in nearly every patient. Other distinct advantages of this procedure are that the most important coronary artery, the LADCA, is always bypassed with the bypass conduit with the greatest patency, the left internal thoracic artery (LITA), a graft is not sewn into the aorta, and leg incisions are eliminated.

Most patients are good candidates for complete revascularization with ITA grafts. This operation has been performed in patients whose ages ranged from 20 to 90 years old and in patients undergoing their second or third coronary bypass procedure. If the ITA is dissected, injured, and cannot be repaired or if it is severely atherosclerotic, it is not acceptable for grafting. We do not recommend dissecting the ITA in patients who have superior vena caval obstruction or coarctation of the aorta with increased collateral circulation. If the left ventricle is enlarged, sometimes the ITAs will not reach all the posterior vessels, and other graft material will also have to be used.

SURGICAL TECHNIQUE

Meticulous, precise technique is essential to the success of this procedure. We use 6X power magnification for all aspects of the operation. The major complications of this procedure, namely hypoperfusion, wound failure, and phrenic nerve injury, are almost always caused by errors in operative technique.
A median sternotomy incision is always used. The skin and fat are incised to the bone with a sharp knife and only the bleeding sites are cauterized. It is important to cut the sternum in the midline to preserve its vascularity and to have equal widths of bone on each side to offer the greatest strength at closure. The middle of the sternum is usually bisected by the decussation of the pectoral and rectus muscles. We do not use bone wax, and pieces of fat from the patient can be pressed into the marrow to control the bleeding from the bone.

We have used both the pedicle and the skeletonized techniques for mobilizing the ITAs. The possible disadvantage of removing a large pedicle is that many of the ITA collateral branches are injured and the early (3 weeks) blood supply to the sternum is reduced and healing is delayed. Although the skeletonized method better preserves these collateral branches, we have seen many more hematomas in the adventitia of these ITAs and are concerned that some of these areas could produce scarring and later obstruction of the ITAs. The lower pole of the sternum and xiphoid area are the most prone to insufficient perfusion and sternal nonhealing. Sparing the musculophrenic artery offers increased blood flow to this area; therefore, this vessel is left intact. We have combined the advantages of the pedicle and the skeletonized methods of ITA dissection in an attempt to prevent injury to the ITA and to improve perfusion to the lower sternum and xiphoid area.

The patient is heparinized to conserve blood. We use a Morris sternal retractor (Codman, Randolph, MA) and spring the left table of the sternum and chest wall upwards and to the left to improve exposure of the LITA. When dissecting the RITA, we spring the right chest up and to the right in a similar fashion. We use monopolar cautery at a very low amperage and cover most of the blade, except the tip, with a piece of plastic tubing to prevent injury to the ITA. The dissection begins at the sixth intercostal space near the bifurcation of the ITA into the superior epigastric and musculophrenic branches. If injury to the ITA occurs, it will most frequently occur at the beginning of the dissection and there is usually enough length to reach the vessels to be bypassed. We proceed proximally by bluntly separating the ITA and a small pedicle from the chest wall, cauterizing only the arterial and venous branches. By not placing unnecessary tension on the pedicle, the branches can be transected closer to the ITA without injuring the vessel. The endothoracic fascia is cut with the cautery. When approaching the thoracic inlet, the surgeon must be careful not to injure the subclavian vein or the phrenic nerve. Also, all intercostal arteries should be cauterized to eliminate a steel postoperatively. The phrenic nerve is most often injured on the left side where the slit is made in the pericardium to allow the LITA to enter the surface of the heart over the LAD, and on the right side where the nerve lies close to the RITA proximal to the point where the internal thoracic vein proceeds medially to the superior vena cava. We skeletonize the RITA from this point to where it is detached at the thoracic inlet. The RITA is secured with four hemoclips proximally and then is transected.
2 The ITA grafts are prepared by incising the endothoracic fascia down to the adventitia. Aside from adding additional length to the ITA, this procedure makes it easier to construct the side-to-side (SS) anastomoses. The ITA is inspected for injury, dissection, and pulse.

3 Ten milliliters of a dilute 1:30 papaverine saline solution is gently infused over a 30-second period into the lumen of the ITA. If the ITA is an attached graft, the proximal portion near the thoracic inlet is clamped with a bulldog clamp. When the ITA is a free graft, the papaverine saline solution is injected into the proximal end and the distal end is occluded. The pulse and flow increase dramatically after infusion of the papaverine saline solution. Papaverine inhibits phosphodiesterase and increases cyclic guanosine monophosphate, which induces relaxation of vascular smooth muscle cells. We prefer to infuse the papaverine saline solution instead of topically spraying it because the ITA does not have vaso vasorum and the blood supply of the intima and media comes from inside the lumen.

4 The RITA is anastomosed to the LITA as a T graft or, in some instances, as a tandem/sequential graft. When the proximal left subclavian artery is obstructed, the LITA is anastomosed to the RITA. The tandem/sequential attachment is preferred in situations in which the LAD is a very large vessel and requires maximum flow. Sometimes, when the left ventricle is dilated and enlarged, attaching the ITAs in tandem is the only way that the ITAs will reach all the coronaries that need to be bypassed.

To construct the T graft, the arteriotomy in the LITA is made at the level of the left atrial appendage or more distal, and it should always be proximal to the site of the LITA-LAD connection. The proximal RITA is transversely cut and a 2 to 3 mm slit is made in the posterior wall.
5 The proximal end of the RITA is anastomosed to the side of the LITA perpendicularly. Sewing the ITAs at right angles conserves valuable proximal length. The anterior wall of the anastomosis is sewn with a continuous 8-0 monofilament suture.

. . . and then the LITA is lifted out of the mediastinum and the posterior wall is completed. When suturing the ITAs, it is important to have the tip of the needle enter the arteries perpendicularly, which allows the surgeon to sew closer to the edge of the artery, making the anastomosis larger. Also, this technique prevents tearing the artery or separating its layers. The pedicles are attached to prevent tension on the anastomosis. If the ITAs were skeletonized, the adventitia of the RITA is sutured to the epicardium. The bulldog clamp is released and the pulse and flow is checked in each limb of the graft. If they are insufficient, the anastomosis should be redone.

7 To construct the tandem/sequential graft, the distal end of the LITA is transected above the bifurcation of the ITA into the musculophrenic and superior epigastric branches and the flow is measured. The right lateral side of the artery is slit 2 or 3 mm to make its circumference similar to the proximal RITA. A continuous 8-0 monofilament suture is used to construct the anastomosis. The clamp is released and pulse and flow are measured. Flow in the distal RITA should be at least 80 mL/min and an adequate pulse should be present. If they are lacking, the anastomosis should be reconstructed. The pedicle of the RITA is attached to the LITA to prevent tension at the anastomotic site.
The ascending aorta is cannulated and a two-staged cannula is placed into the right atrium for venous drainage to the heart-lung machine. A 13-gauge needle is inserted into the ascending aorta for infusion of antegrade cardioplegia and for venting of the ascending aorta. A catheter with a self-inflating balloon is introduced into the coronary sinus for infusion of retrograde cardioplegia. Warm substrate-enriched blood cardioplegia is used followed by cold-blood cardioplegia, as described by Buckberg. Cold maintenance blood cardioplegia is infused antegrade and retrograde every 20 minutes. After completion of the last anastomosis, warm-blood substrate-enriched cardioplegia is administered and then the aortic clamp is removed. The use of retrograde cardioplegia is beneficial for sufficient myocardial protection because, unlike saphenous vein graft procedures, none of the bypasses are attached to the ascending aorta in this technique. Thus, they cannot be perfused antegrade until the aortic clamp and the bulldog clamp on the LITA are removed.
The placement of the distal anastomosis is similar in each patient when using the T graft or the tandem/sequential graft techniques. When the T graft is constructed, the LADCA and the diagonal (the anterior branches of the heart) are bypassed with the LITA. The circumflex marginal branches, the right coronary artery branches, and sometimes a lateral diagonal artery are bypassed with the RITA. When using the tandem/sequential technique, the LAD and diagonal are anastomosed to the LITA and the RCA and circumflex branches are bypassed with the RITA. The first SS anastomosis is constructed to the most proximal artery that is to be bypassed and the end-to-side (ES) anastomosis is constructed to the most distal artery that is to be grafted.

Once the patient is on cardiopulmonary bypass, the coronary artery sites that are to be bypassed are identified. If the T graft is used, it is attached to the epicardium adjacent to the LAD, allowing the proximal portion of the pedicle to lie near the phrenic nerve. This makes it easier to measure the proper graft length of the RITA to the first SS anastomosis. Arteries tend to run a meandering course and it is essential to allow enough length between anastomoses. We prefer that the anastomosis lie parallel to the coronary artery that is to be bypassed because we feel it is more hemodynamically suitable than if the anastomosis is perpendicular.

An 8 to 10 mm coronary arteriotomy, and a slightly longer opening in the ITA, is made when constructing the SS anastomosis. All ITA arteriotomies are fashioned on the posterior surface of the vessel.
With the ITA suspended, a continuous 8-0 monofilament suture is started at the toe or heel of the anastomosis and is continued around the opposite toe or heel. The other end of the suture is used to complete the anastomosis. The needle entry sites should enter perpendicular to the ITA and coronary artery, allowing the surgeon to stay as close as possible to the edge of the artery and preventing narrowing of the anastomosis and reduction in blood flow into the coronary artery. It is imperative to include the adventitia in each stitch. If the arterial layers are separated, they can be sewn together while performing the anastomosis. The ITA pedicle is attached to the epicardium above and below the anastomosis to prevent kinking or torsion of the anastomosis.

After all the SS anastomoses are performed, the last anastomosis to be performed is ES. An 8 to 10 mm arteriotomy is made in the coronary artery and a slit is cut in the end of the ITA, which is slightly longer. The anastomosis is created with continuous 8-0 monofilament suture beginning at the heel or toe and progressing to the opposite end. The pedicle is sutured to the epicardium on each side of the anastomosis.
The average number of grafts per patient is 4.4 and as many as eight ITA to coronary anastomoses have been performed in a single patient.

Bilateral ITA dissection has been estimated to reduce sternal blood supply by 46%. Development of collateral circulation returns the blood supply of the sternum to normal in 1 month. Early wound healing is suppressed and sternal dehiscence is more prone to occur, which leads to wound infection, particularly in obese diabetic women. We strongly believe that placing 12 single stainless-steel wires into the sternum offers maximum support to the sternum during the time that sternal blood flow is compromised and collateral circulation is developing. Because of less tension on each individual wire, the chance of sternal dehiscence is markedly reduced during the delayed healing phase. Use of this type of closure has reduced the incidence of deep sternal wound infection in patients who have bilateral ITA dissection to the level seen in patients who have had none or one ITA harvested.

We have reported 486 patients with T grafts. The operative survival was 2.3%. The major complications that pertain to this operation include phrenic nerve injury, hypoperfusion, and sternal dehiscence leading to wound infection. These problems can be avoided by using proper operative techniques. Being careful not to injure the phrenic nerve when slitting the pericardium on the left side and skeletonizing the RITA above the point at which the internal thoracic vein passes medially to enter the superior vena cava will nearly always prevent injuries to this nerve. Precision in constructing ITA to ITA and ITA to coronary anastomoses and attaching the ITA pedicle to the epicardium appropriately will avoid hypoperfusion of the bypassed coronary arteries. Opening the sternum in the midline and tightly closing the sternum with 12 interrupted stainless-steel wires will reduce the incidence of deep sternal wound
infection to levels that occur when the ITAs are not harvested.

The T-graft anastomotic angle is 90°; this conserves the length of the graft and makes it easier to align the ITA with the first SS anastomosis. High-frequency pulsed Doppler ultrasound monitoring of experimental rat carotid artery to carotid artery anastomosis constructed at 45° and 90° showed no significant difference in flow to the grafted segment of artery at 30 minutes and 2 hours. 13

Complete revascularization with ITA grafts allows each coronary artery to be bypassed with the most ideal conduit. The LAD, the most important coronary artery, is always bypassed with the graft with the highest patency, the LITA. No grafts are sewn into the ascending aorta and leg incisions are avoided. If a second operation is ever necessary, the ITAs are distanced from the reentry site.

REFERENCES


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