The Inferior Epigastric Artery: An Alternative Arterial Conduit for Coronary Artery Bypass Surgery

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For many years, the saphenous vein (SV) has been the preferred graft over the internal thoracic artery (ITA) for coronary artery bypass (CAB) surgery. In the early 1980s, a change in favor of the ITA occurred when Grondin et al showed that both early and late patency rates of the pedicled left ITA (LITA) anastomosed to the left anterior descending (LAD) artery were much higher than those of a SV grafted in similar circumstances. The impact of these improved patency rates on the clinical outcome of the patients undergoing CAB surgery was well established by Loop et al. They showed that the patients who had received a single LITA to the LAD had not only a higher late survival rate but also less cardiac events than those who had received only SV grafts. These findings have stimulated surgeons to bypass more coronary arteries with arterial grafts by using both ITAs more extensively or even other arteries that could have the same patency rates as the ITA or at least better patency rates than the SV. The inferior epigastric artery (IEA) is one of these arteries.

Anatomy

The IEA originates from the medial side of the distal part of the iliac artery, approximately behind the inguinal ligament just opposite to the deep circumflex iliac artery. At first it follows the medial side of the deep inguinal ring, passing around the ductus deferens in the man or around the round ligament in the woman. Afterwards, it ascends obliquely and medially towards the umbilicus.

On this course, the IEA lies on the transversalis fascia as far as the arcuate line. Thereafter, it runs between the rectus muscle and its posterior sheath up to the umbilicus where it divides into several thin branches that form intramuscular anastomoses with the terminal branches of the superior epigastric artery. There is usually no difference between the right and left IEAs. Each IEA is accompanied by two satellite veins that drain either separately or via a venous confluent into the external iliac vein.

The proximal IEA gives off usually three branches. These are the external spermatic artery, the pubic branch artery, and the anastomotic branch to the obturator artery, or, in some patients, the obturator artery itself.

In 1989, an angiographic study was conducted in this investigator's institution to assess the suitability of the IEA for CAB grafting. A selective opacification of the right IEA (RIEA) was performed in 100 consecutive patients undergoing a cardiac catheterization for coronary artery disease. A comparative selective opacification of the LITA was also performed in 98 of those patients.

No atherosclerotic lesion of either the RIEA or the LITA was shown in any of the patients. Ninety-six of the 100 RIEAs were considered to be suitable for CAB grafting, whereas four were obviously too short or too narrow for grafting any coronary artery.

A quantitative angiography was obtained in 20 of the 94 patients having an IEA, which was considered to be adequate for CAB grafting. The average length of the RIEA from its iliac origin to its distal bifurcation was 13.1 ± 1.3 cm, and its diameter at 5 cm from its ostium was 2.4 ± 0.4 mm.

In comparison, all of the 98 LITAs were considered to be suitable for CAB grafting, and using similar landmarks, their average length and diameter were 20.3 ± 1.9 cm and 2.8 ± 0.4 mm, respectively. Later we learned that, despite a perfectly smooth aspect on the preoperative angiogram, some IEAs had to be shortened because of the peroperative evidence of atherosclerotic disease involving their proximal part close to the iliac artery. On the other hand, we must also mention that, by combining an angiographic selection and an extensive dissection of the IEAs from their origin to their termination, we have been able to harvest IEA grafts whose lengths were up to 19 cm.

Indications for CAB Grafting With the IEA

In 1988, the first patient who received an IEA as a CAB graft at this investigator's institution had no more SV available. She suffered from a three-vessel disease. The IEA was used for bypassing the right coronary artery (RCA) while both pedicled ITAs were directed to the LAD and circumflex (Cx) arteries.

Since this first operation, our policy is still to direct the IEA preferably to the RCA. The distal diameter of the IEA is, in our opinion, the main criterion by which to assess the suitability of the IEA for CAB grafting. We are convinced that the IEA should only be used in circumstances in which a preoperative angiogram has shown that the size of the IEA and the target coronary
artery are well matched, especially in circumstances in which it had been planned to use the IEA for bypassing a moderate (50%) stenosis of the RCA. The distal diameter of the IEA must exceed the diameter of the residual lumen of the coronary artery at the level of the stenosis to be bypassed. Should it be otherwise, we believe that the long-term patency rate of the IEA will be compromised by the competitive flow through the native coronary artery.

On the other hand, our indications for IEA grafting are no longer restricted to patients who have no SV available. At present, most of the patients undergoing CAB grafting with the IEA at our institution are young patients with a three-vessel disease who also receive a LITA to the LAD and a right ITA (RITA) to the Cx; this is performed as a means to achieve a complete arterial myocardial revascularization.

**SURGICAL TECHNIQUE**

A selective opacification of the RIEA in situ, and, if needed, of the left IEA also, is routinely performed before surgery to assess its suitability as a CAB graft, as shown in this preoperative angiogram. The metallic ring encircles the umbilicus. The IEA is harvested only when its length and size are adequate, not only to reach, but also to match the coronary artery that is to be bypassed. In our experience, almost all IEAs, when used from the ascending aorta, have sufficient length to bypass any segment of the RCA proximally to the crux. However, only IEAs in which terminal bifurcation really occurs at the level of the umbilicus are long enough to reach the posterior descending artery (PDA). Longer IEAs may even be needed for grafting the postero-lateral branch (PLB) of the RCA, especially when the left ventricle is dilated.
Several techniques can be used to bypass the distal branches of the RCA with shorter IEA grafts. Selective opacification of an RIEA in situ shows a good-sized obturator artery originating from the proximal IEA.

The anastomotic branch to the obturator artery, when adequately sized, can provide an additional length of about 3 to 4 cm to the IEA. Note the use of metal clips of different sizes to secure the collateral branches originating from each side of the graft. However, the most effective technique to broaden the span of a short IEA is to anastomose it proximally onto another conduit, either on an ITA graft, a SV graft, or even a contralateral IEA graft, in either an end-to-side or end-to-end fashion.
Postoperative angiograms at (A) 10 days, (B) 12 months, and (C) 5 years of the same IEA graft extended with the obturator artery. The composite conduit has sufficient length to reach the distal RCA near the crux.
It has been the institution's practice to approach the IEA through a paramedian infraumbilical incision. The skin and the subcutaneous tissue are incised vertically along the lateral border of the rectus muscle, about 4 cm laterally to the midline from the level of the umbilicus to the infraumbilical abdominal crease. In our early experience, we extended this incision down and laterally towards the femoral vessels in a hockey-stick fashion to have better access to the proximal IEA. We now avoid this extended incision because of an increased risk of difficulties in the healing of the wound because of local swelling, especially in obese patients.

The anterior sheath of the rectus muscle is opened in the same way as in Fig 5 and the rectus muscle is retracted medially using Faraboeuf retractors. The IEA can easily be identified in the preperitoneal fat pad. The IEA is mobilized with its two satellite veins and with the surrounding fat. Its collateral branches are carefully identified, ligated with clips, and divided at some distance from the IEA itself, as is also performed for ITA harvesting. The use of clips of different sizes to secure the collateral branches originating from each side of the IEA provides a simple means to avoid the risk of twisting the IEA after explantation. Using a combination of sharp and blunt dissection, the IEA is extensively mobilized from its iliac origin to its distal bifurcation. The distal branches of the IEA are usually too narrow to be used for CAB grafting. However, when large enough, they can be dissected for using the IEA as a natural Y graft. After dissection, the IEA is forcefully sprayed with a solution of papaverine (40 mg/100 mL) and wrapped with gauze patches soaked with the same solution. The IEA is only explanted after total heparinization (3 mg heparin/kg body weight). The proximal end of the IEA is then opened longitudinally for about 5 mm and intubated with a 2-mm olive-tipped cannula (DLP, Inc, Grand Rapids, MI). The IEA is flushed with a solution of warm blood of the patient added with papaverine (40 mg/1200 mL) and dipyridamole (20 mg/100 mL) without distal clamping. Afterwards, the IEA is preserved in this medium at room temperature until it is grafted. Harvesting of the IEA takes about 15 minutes, but can be performed simultaneously with ITA harvesting. The abdominal wound is packed with gauze patches during cardiopulmonary bypass. At the end of the operation, after administration of protamine, it is closed anatomically with continuous polyglycolic continuous suture solution (Dexon, Davis, and Geck, Benelux, Belgium). One aspirating drain is placed under the rectus muscle and another is placed in the subcutaneous space. They can usually be removed within 48 hours.
The distal anastomoses of the IEA to the coronary arteries are performed before the proximal anastomoses to the aorta, during a single period of aortic crossclamping after anterograde and retrograde infusion of cold potassium crystalloid cardioplegia. The coronary arteriotomies are about 5 mm in length. The distal end of the IEA is opened longitudinally to slightly exceed the length of the coronary arteriotomy. The anastomoses to the RCA are constructed longitudinally.

Anastomoses to the PDA and to the PLB of the RCA are constructed in a diamond shaped fashion. The anastomoses are performed with 8/0 polypropylene running sutures using the parachute technique. After completion of the distal anastomosis, the suture line is checked for bleeding. A perfect alignment of clips of the same size on each side of the IEA at this stage of the procedure is a good indication that the IEA has not been twisted during grafting. The pedicle is then attached to the epicardium with a few stitches.
Proximal anastomoses between the IEA and the ascending aorta are performed after removal of the aortic crossclamp. A side-biting clamp is positioned on the ascending aorta. A round opening is made with a 4.5-mm aortic punch in the anterior aspect of the aorta to the right of the midline. (A) Direct aortoepigastric anastomoses are performed when the aortic wall is pliable and the IEA is well sized. Interposition of (B) a short SV tube or (C) a SV patch between the IEA and the aorta can facilitate the construction of the proximal anastomoses when the IEA is of small size or when the aortic wall is of abnormal thickness. (D) As an alternative, the hood of a SV graft can be used to attach the IEA.
These postoperative angiograms, at 10 days and 1 year, show satisfactory results with direct suture of the IEA to the aorta.
When the IEA is clearly too short to reach the coronary artery to be bypassed from the aorta or when it is evident that clamping the aorta will be hazardous, the IEA can be proximally attached to a pedicled ITA (either the RITA or LITA in an end-to-side or end-to-end fashion). The preferred technique in these circumstances has been to attach the IEA to the pedicled RITA.\(^8\) The RITA is transected just above its bifurcation. Its distal end is opened longitudinally for about 5 mm. The proximal IEA is opened in a similar fashion. The two arteries are anastomosed together in an end-to-end fashion with a 8/0 continuous suture. Their pedicles are similarly attached together with a few stitches and the composite conduit is passed through the transverse sinus. The RITA has usually enough length to bypass the proximal branches of the Cx artery and the IEA can easily reach all the distal branches of the Cx or the RCA, as shown previously in Fig 8.
Postoperative angiograms at 10 days and 14 months postoperatively; the IEA graft is anastomosed end-to-end to the pedicled RITA. The composite conduit is passed through the transverse sinus (see Fig 7). The RITA is anastomosed to the Cx artery, and the IEA is anastomosed to the posterod lateral (PL) branch of the RCA.
Postoperative angiogram at 10 days and 10 months; the IEA is attached between an IEA in a end-to-end fashion to a pedicled LITA. The LITA is anastomosed to the LAD, and the IEA is anastomosed to the RCA.

### COMMENTS

#### Results

Between December 1988 and September 1993, this investigator placed 157 IEA grafts in 157 consecutive patients. One third of these patients had no suitable SV available. All of the 157 IEA grafts were harvested through paramedian infraumbilical incisions. Eighty percent of the IEA grafts were directed to the RCA system and 95% were proximally anastomosed to the ascending aorta.

The hospital mortality rate was 2.5% (four patients). One patient died from an acute tamponade caused by a subtotal disruption of a direct aortoepigastric anastomosis. Another patient died from ventricular fibrillation secondary to an anteroseptal myocardial infarction; the two other patients died from low cardiac output.

These last three patients had several risk factors, including more than 70 years of age (1 patient), urgent operation (2 patients), and poor left ventricular function (2 patients). Two of them were undergoing a reoperation. All of them had no more suitable SV available. The IEA graft was anastomosed to the RCA system in all four patients, and in none of the patients was death caused by an inadequate IEA graft flow. No ischemia of the abdominal wall was observed, but six patients required drainage of an abdominal wound collection. Two of these patients developed an incisional hernia later on.
One hundred thirty-five patients (85%) consented to an early angiographic restudy within 2 weeks postoperatively. One hundred thirty-two of the 135 IEA grafts (97.7%) were patent. One hundred twenty IEA grafts (88%) had a perfect angiographic appearance, whereas 12 showed either significant anastomotic stenoses (≥70%) or focal irregularities (≤50%). Forty-eight patients underwent a second angiographic restudy between 6 and 12 months after the operation (average, 8.5 months); 44 IEA grafts (91.7%) were patent. Thirty-six (75%) perfectly matched the receiving coronary artery, whereas 8 were diffusely narrowed. Twenty-nine patients were restudied from 13 to 43 months postoperatively (average, 25 months). Twenty-eight IEA grafts (96%) were patent. Twenty-five (86%) were widely open, whereas three showed a diffuse narrowing.

In total, 61 (79%) of the 77 IEA grafts restudied between 6 and 43 months after the operation were widely open and perfectly matched the receiving coronary artery. Five patients underwent a third angiographic restudy up to 5 years after the operation. It must be pointed out that 96% of the IEA grafts were patent at the time of the second restudy. Five patients underwent a third angiographic restudy up to 5 years after the operation were widely open, whereas three showed a diffuse narrowing.

In total, 61 (79%) of the 77 IEA grafts restudied between 6 and 43 months after the operation were widely open and perfectly matched the receiving coronary artery. Five patients underwent a third angiographic restudy up to 5 years after the operation (average, 39 months). All had widely patent IEA grafts. It must be pointed out that 8 of the 11 IEA grafts that became narrowed were used to bypass RCAs that showed mild stenosis at the time of restudy. On the contrary, 37 of 40 IEAs grafted onto coronary arteries that were occluded at the time of operation were widely patent at the time of the second restudy.

Conclusions

The IEA is a newcomer in the field of CAB surgery, and still needs to stand the test of time before its place among the other CAB grafts can be established. However, on the basis of our experience, we can conclude that:

1. Harvesting of IEA grafts is easy (in the way we describe in this article).
2. Most of the IEA grafts have sufficient length to bypass coronary arteries that are closer to the aorta (especially the RCA proximally to the crux), and by constructing their proximal anastomoses onto the pedicled RITA, it is even possible to use shorter IEA grafts for grafting the distal branches of the RCA. However, IEA grafts whose caliber is insufficient to match the coronary artery to be bypassed should not be used. A preoperative opacification of the IEAs in situ is a very reliable technique to measure their length and size to determine the operative strategy to follow.
3. CAB grafting with the IEA does not seem to increase the operative mortality.
4. The incidence of parietal complications related to IEA harvesting is relatively low. The use of shorter incisions and a routine aspirating drainage of both the preperitoneal space and the subcutaneous tissue in the postoperative period might reduce the parietal morbidity. However, patients undergoing bilateral ITA and IEA harvesting are probably at a higher risk for parietal complications.
5. The midterm patency rate of the IEA grafts is lower than those of the pedicled ITA grafts, but is still similar to the patency rates of free ITA grafts used in similar circumstances.
6. The fact that the patency rate of the IEA grafts seems to stabilize after the first postoperative year could indicate that IEA grafts will have the same long-term durability as the ITA grafts. Construction of the proximal anastomoses of the IEA grafts onto pedicled ITA may reduce the early attrition rate of IEA grafts.

REFERENCES