6 LVAD Surgical Implant Technique: Infradiaphragmatic Approach

Jeffrey A. Morgan and O.H. Frazier

Introduction

The evolution of mechanical circulatory support (MCS) systems from early-generation volume-displacement pumps to smaller and more durable continuous-flow (CF) devices has dramatically reduced mortality rates and device-related complications. The advantages afforded by CF left ventricular assist devices (LVADs) have led to their widespread application in the treatment of severe heart failure. However, the perpetuation of implantation strategies developed in an era of pulsatile MCS makes some patients vulnerable to complications unique to CF physiology and design.

Proper orientation of the inlet cannula is an essential component of overall device function. Ideally, the mouth of the cannula should rest within the center of the left ventricular (LV) cavity, thus being free of potentially obstructive surfaces and oriented toward the mitral valve orifice. Traditionally, the pump inlet was inserted through the LV apex to take advantage of the longest measured span within the ventricle.

Surgeons at our institution have developed a method for implanting the HeartMate II along the diaphragmatic surface of the heart [1–3]. Although this method is a significant departure from traditional implantation techniques, it has proved valuable in both eliminating the need for a preperitoneal pump pocket and establishing a geometrically advantageous pump alignment.

Methods

A vertical midline incision is made, incorporating a 6-cm subxiphoid extension. Via a standard median sternotomy, the pericardium is opened both in the midline and along the length of the diaphragm. The anterior border of the diaphragm is then incised from the midline to the apex of the heart, providing access to the peritoneal cavity.

After systemic heparinization and initiation of cardiopulmonary bypass (CPB), the LV apex is brought out of the chest and controlled with a suction stabilizer device. The ventricular coring site is then identified approximately one third of the distance from the apex to the base of the heart (thus, anterior to the origin of the papillary muscles). The

J.A. Morgan, M.D. (✉)
Division of Cardiothoracic Transplantation, Texas Heart Institute at Baylor St. Luke's Medical Center, Baylor College of Medicine, Houston, TX, USA

Center for Cardiac Support, Texas Heart Institute at Baylor St. Luke's Medical Center, Baylor College of Medicine, Houston, TX, USA
e-mail: Jeffrey.Morgan@bcm.edu

O.H. Frazier, M.D.
Mechanical Circulatory Support and Cardiac Transplantation, Texas Heart Institute at Baylor St. Luke's Medical Center, Baylor College of Medicine, Houston, TX, USA
e-mail: ofrazier@bcm.edu; lschwenke@texasheart.org

J.A. Morgan et al. (eds.), *Mechanical Circulatory Support for Advanced Heart Failure*,
https://doi.org/10.1007/978-3-319-65364-8_6

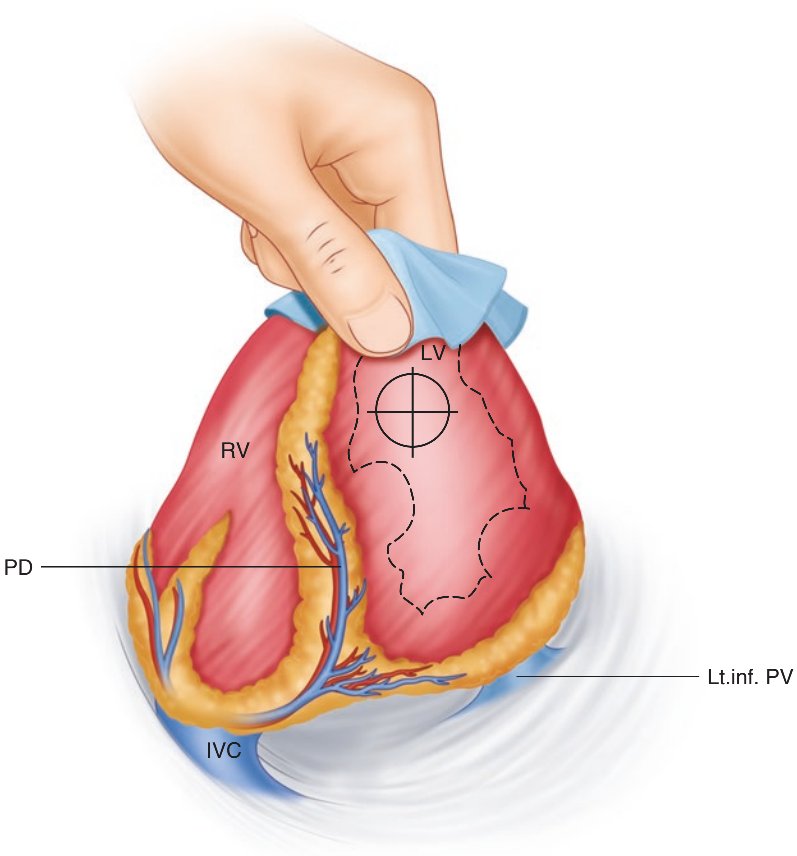

Fig. 6.1 The left ventricular (LV) apex is reflected in a cephalad direction to expose the diaphragmatic surface of the heart. The LV cavity is outlined by the *dotted line*, and the enclosed crosshair depicts "Frazier's point," the optimal location for transdiaphragmatic insertion of the inlet cannula (Modified from Gregoric ID et al. [6])

medial edge of the sewing ring is placed 0.5–1.0 cm lateral to the posterior descending artery to ensure a parallel orientation with respect to the short axis of the left ventricle (Fig. 6.1). The ventriculotomy is performed with a circular coring knife, taking care to stay parallel to the septum and to follow posteriorly in the direction of the mitral valve. The ventricular cavity must then be digitally explored and inspected for evidence of thrombus or obstructive trabeculae.

Next, the Silastic inflow cuff is secured in the standard fashion, using 12 pledgeted, full-thickness horizontal mattress sutures placed circumferentially around the coring site. Hemostasis around the inflow cannula is bolstered by using a large-caliber monofilament suture to place a full-thickness purse-string stitch through the pledgeted ring.

After a diaphragmatic myotomy has been created to correspond to the selected coring site, the inlet cannula is then guided through the diaphragm, inserted within the Silastic ring, and secured in place with two ratcheting cable ties. Proper orientation of the device is achieved by first pulling the pump housing into the abdomen until the heart lies flush with the diaphragm and then positioning the outflow graft to course above the left lobe of the liver. Our preference is to wrap the body of the pump in available omentum to protect the bowel from erosive injury.

The outflow graft then is measured and bevel cut with enough length to allow a gentle curve toward the right side of the chest without excessive redundancy. The outflow anastomosis is then performed in a standard end-to-side fashion with the aid of a partial occluding clamp along the ascending aorta. After externalization of the driveline, the system is thoroughly de-aired by using a 19-gauge needle placed at the highest point of the outflow graft. Cardiopulmonary bypass flows are gradually decreased, the heart is allowed to fill, and the pump is started at its lowest setting (6000 rpm). The patient is weaned from CPB, which is eventually terminated with the aid of transesophageal echocardiographic guidance to allow optimization of LVAD speeds, chamber size, interventricular septal position, and right ventricular function.

Once proper function and orientation are verified, protamine is administered, the CPB cannulas are removed, and drains are placed in the mediastinum and pleural spaces. The bare portion of the outflow graft is covered with a 20-mm-diameter ringed Gore-Tex graft (Gore Medical, Newark, DE) to prevent kinking and damage during future sternal reentry. The defect in the diaphragm is partially reapproximated, and the sternum and soft tissues are closed in the standard fashion.

Discussion

Early in the development of MCS, inflow cannulation was performed through the LV apex to accommodate lengthy inlet-cannula designs. Although inlet conduits were eventually shortened in response to excessive inflow-graft occlusion seen in experimental testing, device implantation techniques changed little over time [4]. As a result, apical cannulation became standard practice after widespread adoption of the HeartMate XVE LVAD (Thoratec Corp.). Although care had to be taken at the time of implantation to avoid mechanical inlet obstruction, few complications arose from this orientation because of the obligatory preservation of a ventricular reservoir with pulsatile devices. Familiarity with this implantation technique resulted in its subsequent application to CF LVADs——a practice bolstered by the inclusion of an inlet cannula identical to that of the HeartMate XVE in the design of the HeartMate II. However, the unique physiology associated with CF technology necessitates consideration of specific anatomic and mechanical challenges associated with the use of these pumps.

Inlet placement along the diaphragmatic surface of the heart was first reported nearly 10 years ago, when surgeons from our institution described a subcostal approach for implanting the Jarvik 2000 pump (Jarvik Heart Inc., New York, NY) [5]. Although used sparingly, the procedure revealed both the feasibility and potential advantage of an alternative cannulation site for LVAD implantation. The HeartWare HVAD (HeartWare Inc., Framingham, MA) was developed in the Texas Heart Institute laboratories during the mid-1990s and was specifically designed to fit within the pericardial space. Whereas a familiarity with apical positioning led surgeons to prefer this method in early clinical trials, diaphragmatic implantation of the HVAD and HM3, as previously described elsewhere, is also performed at our institution [6].

Disclosures None of the authors has any commercial conflicts of interest.

References

1. El-Sayed Ahmed MM, Aftab M, Singh SK, Mallidi HR, Frazier OH. Left ventricular assist device outflow graft: alternative sites. Ann Cardiothorac Surg. 2014;3:541–5.
2. Riebandt J, Sandner S, Mahr S, et al. Minimally invasive thoratec Heartmate II implantation in the setting of severe thoracic aortic calcification. Ann Thorac Surg. 2013;96:1094–6.
3. Umakanthan R, Haglund NA, Stulak JM, et al. Left thoracotomy HeartWare implantation with outflow graft anastomosis to the descending aorta: a simplified bridge for patients with multiple previous sternotomies. ASAIO J. 2013;59:664–7.
4. Pool GE, Parnis SM, Creager GJ, et al. Evaluation of occlusive inlet pannus formation: comparison of conduit designs. Trans Am Soc Artif Intern Organs. 1985;31:408–10.
5. Frazier OH, Gregoric ID, Cohn WE. Initial experience with non-thoracic, extraperitoneal, off-pump insertion of the Jarvik 2000 heart in patients with previous median sternotomy. J Heart Lung Transplant. 2006;25:499–503.
6. Gregoric ID, Cohn WE, Frazier OH. Diaphragmatic implantation of the HeartWare ventricular assist device. J Heart Lung Transplant. 2011;30:467–70.