Keynote Lecture Series

Different surgical strategies for implantation of continuous-flow VADs—Experience from Deutsches Herzzentrum Berlin

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Objective: This manuscript summarizes our surgical experience with the implantation of recent continuous-flow left ventricular assist devices (LVADs), with special emphasis on the HeartWare HVAD pump.

Methods: The HeartWare HVAD is, in our experience currently implanted in four different techniques: (I) "Classical" LVAD implantation with heart-lung machine and median sternotomy; (II) "Minimally-invasive" implantation without sternotomy and without heart-lung machine; (III) "Lateral implantation" to the descending aorta; (IV) Using two continuous-flow LVADs for implantable biventricular support.

Results: Five-hundred and four HeartWare HVADs have been implanted using the described techniques in our institution up to now.

Conclusions: The HeartWare HVAD is a versatile device. It has been found to be eminently suited to these four different modes of implantation.

Keywords: Heart failure; ventricular assist devices (VADs); cardiac surgery

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Introduction

This manuscript summarizes major aspects of our surgical experience with the implantation of recent continuous-flow left ventricular (LV) assist devices (LVADs), with special emphasis on the HeartWare HVAD pump. The HeartWare HVAD is, in our experience, currently the most versatile pump available (1). We use the HeartWare HVAD for standard LVAD implantations, minimally invasive implants, lateral implantations (to descending aorta) as well as for implantable continuous-flow biventricular support.

Classical LVAD implantation with heart-lung machine and median sternotomy

During a classical implant operation with median sternotomy and use of a heart-lung machine (HLM), the LVAD implantation is a three-step procedure which involves:

(I) Connection between LV and inflow cannula;
(II) Tunneling of the driveline;
(III) Anastomosis of the outflow cannula to the ascending aorta.

In implantations with median sternotomy, we prefer to use a HLM with classical right atrial and ascending aortic cannulation. Major reasons for using the HLM are two-fold. Firstly, trabeculae can cross the blood path to the inflow cannula and thereby later be the origin of thrombus formation; and secondly, mandatory intraoperative inspection for intraventricular thrombi is not possible without HLM.

To insert the apical cannula, we open the LV anterior wall one thumb-width from its apex and one thumb-width from the left anterior descending artery (LAD). The apical connection ring is then attached with 12 3-0 prolene sutures supported with medium-sized Teflon felts. The stitches go deep into the myocardium without reaching the intraventricular cavity. Deep stiches are especially important in patients with fresh anterior myocardial infarction. Apical coring should result in a perfectly circular harmonic hole.

The second step involves tunneling the driveline.

Driveline infections are one of the most frequent and serious complications after LVAD implantation. Therefore, maximum attention is paid at keeping the driveline sterile until it is brought into the patient's body.

The exit site of the driveline is mostly in the right lower quadrant of the abdominal wall, about three fingers higher than the right spina iliaca. As the tunnel itself should be as long as possible, in small patients we prefer a two-step tunneling approach with the first step directed at the right lateral aspect of the patient. The second step tunnels to the definitive driveline exit site. A long Maier forceps, which is routinely used to place mediastinal tubes, can safely be used after connecting the tip of the driveline to a chest tube, which be done without any sutures or ligatures.

With this tunneling technique, we have been able to prevent any damage to the abdominal organs during more than 400 HVAD and 250 HeartMate II implantations.

The second step tunnels the driveline to the definitive exit site. The velour-covered part of the driveline should be positioned completely inside the tunnel, as better healing results of the exit sites are achieved when the skin is crossed with the silicon or plastic covered part.

The last step after tunneling of the driveline is anastomosis of the LVAD outflow graft to the side-clamped ascending aorta. For this anastomosis, we use a 4-0 or 5-0 running prolene suture.

The HeartWare HVAD is the only pump where non-optimal selection of the outflow graft length can be easily corrected by rotating the pump. The graft can be stretched or released after opening the screw on the apical ring and rotating the pump anti-clockwise (if it is too long) or clockwise (if it is under tension). This maneuver prevents graft kinking or tension on the aortic anastomosis.

Weaning from HLM after LVAD implantation is a well-standardized procedure at our center. Finally, we immobilize the driveline to ensure proper wound healing.

"Minimally-invasive" implantation without sternotomy and without HLM

Recently, the HeartWare HVAD pump has been implanted in a minimally invasive fashion by different groups. We regard our implantations as "minimally invasive" only when we operate without sternotomy and without using the HLM.

For a minimally invasive HeartWare HVAD implantation, we perform two thoracotomy incisions—one in the sixth left intercostal space above the LV apex and one in the third right intercostal space close to the sternum. We access the ascending aorta through the first incision, and the LV apex through the second incision.

This strategy is optimal for a patient in whom HLM and median sternotomy would pose a significant risk for postoperative morbidity. Two surgeons operate simultaneously, thereby decreasing the operation time. A maximally 10 cm long incision exposes the LV apex. The apical ring is connected on the beating heart in our standard technique. The driveline is tunneled and connected to the controller. After completion of the anastomosis between the outflow graft and the ascending aorta, the graft is tunneled intrapericardially to the apical incision. Care has to be taken not to twist or to kink the graft. The graft is then covered with the bend relief and finally connected to the pump housing.

After apical coring has been performed, the pump is immediately inserted into the LV. To diminish blood loss during this phase, rapid pacing can be applied or adenosine administered. After final de-airing, the LVAD can be started.

"Lateral implantation" to the descending aorta

As long as 15 years ago, our group started implanting LVADs with the outflow graft connected to the descending aorta. With implantation through a left lateral thoracotomy, this technique avoids a resternotomy after previous cardiac operations. This operative approach is ideal for patients with a history of complex cardiac operations, such as several open bypass grafts, where a redo-sternotomy would bear a significant risk of damage to the grafts or other cardiac structures.

There are two disadvantages of the lateral approach: (I) a left lateral thoracotomy is more painful than a sternotomy; and (II) the surgeon has only limited access to the right side of the heart if temporary right ventricular assist device (RVAD) support is required.

This technique works with several devices. Our center has used this approach for implantation of the Jarvik 2000, Berlin Heart Incor, HeartMate II, Micromed DeBakey HA5, and HeartWare HVAD.

Use of a double lumen tube is optimal for temporary single-lung ventilation. The patients are placed in a 45° right decubitus position, with the left arm fixated over the head. We use HLM with cannulation of the femoral artery and vein. We recommend completely dividing the ligamentum pulmonale. This enables a direct path for the outflow graft

from the apical aspect to the descending aorta without any interference between the graft and the left lung.

Using two continuous-flow LVADs for implantable biventricular support

Whereas the proportion of patients who need biventricular support has decreased over the past 20 years, 10-20% of VAD candidates still cannot be treated with an LVAD alone or an LVAD combined with a temporary RVAD and later RVAD explantation after right ventricular (RV) recovery. Conventional biventricular systems are large and noisy, and offer limited quality of life.

When a HeartWare HVAD pump is intended for biventricular assistance, three issues have to be addressed: the design of the HVAD is calculated for use in systemic circulation; the inflow cannula of the HVAD is too long for an average RV; and the optimal anatomical site for the connection of the right pump to the right heart has to be determined (2).

When an HVAD is implanted into the pulmonary circulation, even in patients with normal pulmonary resistance and the lowest adjustable pump speed, the flow would be too high and may cause severe pulmonary edema. Our solution is to reduce the outflow graft diameter of the right pump, thereby increasing the afterload to the right pump to "normal" levels. This can easily be done by side-clamping and narrowing of the graft with a suture (6-0 prolene). The goal is a harmonious reduction of the diameter which does not cause severe turbulence within the graft. Use of titanium clips instead of a suture gives the surgeon more flexibility, as single clips can be released or added even on a running BiVAD system. In this way the afterload can be optimized until the right pump can be run with normal pump speed, e.g., between 2,200 and 2,800 rpm. This procedure leads to perfect overlap of the working fields of the left and right HVAD pump (3).

A reduction of the effective length of the inflow cannula can be achieved by the addition of two sewing rings which come with Excor cannulas or the Berlin Heart Incor LVAD. Two of the rings are attached to the original HeartWare apex ring using BioGlue.

The free RV wall (point of maximum distance from the RV free wall to the septum) seems to be an optimal area to attach the right HVAD pump.

Our first HeartWare BVAD patient is still alive—five years after the operation.

In patients with a small chest, the inferior RV wall or the right atrium may be the better implantation site, as the right pump could be pressed into the RV after sternal closure in very slim patients (4).

Conclusions

The HeartWare HVAD is a versatile device. It has been found to be eminently suited to these four different modes of implantation.

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