

# Surgical implant techniques of left ventricular assist devices: an overview of acute and durable devices

Bryan A. Whitson

Department of Surgery, Division of Cardiac Surgery, Ohio State University Medical Center, Columbus, OH 43210, USA

Correspondence to: Bryan A. Whitson, MD, PhD, FACS. Assistant Professor of Surgery; Director, End-Stage Cardiopulmonary Failure Program; Co-Director, COPPER Laboratory. Department of Surgery, Division of Cardiac Surgery, Ohio State University Medical Center, N-816 Doan Hall, 410 W. 10th Avenue, Columbus, OH 43210, USA. Email: bryan.whitson@osumc.edu.

**Abstract:** Left ventricular support for the failing heart has evolved to include short-term and long-term devices. These devices are implanted percutaneously and surgically. This manuscript provides a general overview of the contemporary, typically practiced, implant techniques with additional insight on minimally invasive approaches.

**Keywords:** Left ventricular assist device (LVAD); implant technique

Submitted Oct 19, 2015. Accepted for publication Nov 12, 2015.

doi: 10.3978/j.issn.2072-1439.2015.11.53

View this article at: <http://dx.doi.org/10.3978/j.issn.2072-1439.2015.11.53>

## Introduction

The use of mechanical circulatory support (MCS) has increased as the technology and our surgical implant techniques have improved and evolved. Today, there are several options for both acute (short-term) and durable (long-term) MCS to support the failing ventricle. The etiology of the failing ventricle is broad. It may occur as an isolated issue, such as in the case of acute coronary syndromes, as an acute pathology that may recover, as in a post-partum cardiomyopathy, or as part of an acute on chronic decompensated heart failure picture. The variability of each patient, their comorbidities, and potential long-term implications of the initiation (or lack of initiation) of MCS must be carefully considered and demand a thoughtful evaluation. These technologies may be a bridge to recovery (1), a bridge to decision, a bridge to durable support, bridge to transplant (2), or destination therapy. This article will discuss the generally accepted surgical implantation techniques for either durable, or long-term MSC. Short-term, acute MCS will be briefly mentioned.

## Acute or short-term left ventricular assist devices (LVADs)

### *Percutaneous implants*

Percutaneous implant techniques consists of an intra-aortic balloon pump (IABP), the Abiomed Impella 2.5, 5.0, and CP devices, the Thoratec PHP (currently undergoing clinical trials) and the CardiacAssist Tandem Heart.

The IABP was first described in 1962 (3) and then used clinically in 1968 (4) and is the predicate device for which all other pumps are based. The IABP is easy to place at the bedside or with fluoroscopy and allows for improved coronary perfusion and afterload reduction. It has the potential to be placed via the femoral or axillary artery, either directly or through a conduit graft.

The Abiomed Impella 2.5 and CP devices (Abiomed Inc., Danvers, MA, USA) are truly percutaneous left heart pumps. The device is placed percutaneously via the femoral artery and has the micro-axial blood pump sit across the aortic valve (positioned under fluoroscopy). The variable speed can be adjusted via a console (5). The Impella 5.0

device has the potential of 5 liters of flow/minute (6,7) though it needs to be placed through a conduit sewn to the femoral or iliac artery (6-8).

The Cardiac Assist, Inc. TandemHeart (Pittsburgh, PA, USA) is a percutaneously inserted drainage and outflow catheter with an extracorporeal blood pump. The device is placed under fluoroscopy via the femoral vein with a trans-septal puncture into the left atrium and across the left ventricular outflow tract (9-14). Its use has some advantages on providing antegrade flow and left ventricular unloading.

### ***Surgically implanted LVADs***

Surgically implanted blood pumps provide flow beyond what the micro-axial pumps or IABP are able to provide. They are more invasive and similarly more secure. They consist of the pulsatile pumps [e.g., Abiomed BVS5000 or Thoratec PVAD (Paracorporeal Ventricular Assist Device)] and centrifugal pumps (e.g., Thoratec Centrimag, Medtronic Bio-Medicus Bio-Pump, or Maquet Rotaflow). The BVS5000 is pneumatically controlled (15-17) as is the PVAD. The centrifugal pumps are magnetically levitated (5,18,19) or fixed upon an axle (20,21).

When used in the left ventricular configuration as a ventricular assist device (VAD), there is a common outflow insertion, the ascending aorta. The outflow cannula can be either an adaptation of a standard aortic cannula used for cardiopulmonary bypass or a cannula with a conduit graft attached that is sewn to the ascending aorta. The inflow drainage to the surgically implanted left VAD (LVAD) comes from either the pulmonary vein [typically the right superior pulmonary vein is used (RSPV)] or the left ventricular apex.

There are advantages and disadvantages of each drainage approach. For the RSPV approach, the implant is rather quick and expeditious. The patient typically does not need cardiopulmonary bypass and the dissection can be limited. The downside is that the cannula can be positional and the left ventricle may not be decompressed as well as one would like. For the drainage via the ventricular apex, a cannula needs to be sewn to the LV apex. This can have problems for hemostasis, cannula position, migration, and often will mandate cardiopulmonary bypass, in the acutely decompensating patient.

### **Durable or long-term LVADs**

Durable LVADs are currently on their third generation of pump implants. The second and third generation pumps

are continuous flow, instead of pulsatile flow. At the current time, the common axial pumps are: Thoratec HeartMate II (Pleasanton, CA, USA), HeartWare MVAD (Framingham, MA, USA), ReliantHeart HeartAssist5 (Houston, TX, USA), Jarvik 2000 FlowMaker (New York, NY, USA) and Incor Berlin Heart (Berlin, Germany). The common centrifugal pumps are the HeartWare HVAD (Framingham, MA, USA), the Thoratec HeartMate III (Pleasanton, CA, USA), and DuraHeart LVAS (Terumo, Tokyo, Japan). The HeartMate II and HVAD are the largest implanting pumps (22,23). The durable LVADs have been associated with hemolysis, pump thrombosis, and neurologic events (24). Refinement of surgical implant technique and the shared care of these patients is likely to improve outcomes in these ill patients (25). As one might expect, the failing heart can be in the need of concomitant procedures. These varied techniques are beyond the scope of this review (26,27).

### ***General techniques and considerations***

The most accepted approach to durable LVAD technique involves the implantation being performed on cardiopulmonary bypass with the heart beating. These implants have been performed with aortic cross clamp, cardioplegia and a non-beating heart as well as without the use of cardiopulmonary bypass with fibrillatory arrest (28,29).

The securing of the inflow cannula to the LV apex can be performed in two fashions, similar variations of the required steps—cut then sew or sew then cut. In the cut then sew approach, the LV apex is cored. Both approaches are performed after appropriate anticoagulation. The inflow graft is then secured to the LV apex with either running or interrupted suture with or without pledgetted sutures, depending on the implanters' preference and the quality of the heart muscle integrity. For the sew then cut approach, the inflow graft is secured to the LV apex, again with the suture and technique of choice, then the LV apex is cored. After both steps are complete and any papillary muscle or LV wall is removed from the inflow, the pump is attached to the inflow-sewing ring and secured in the approach appropriate to the pump (e.g., suture or tie with the HeartMate II, set screw with HVAD, or clip with HeartMate III).

The outflow graft is attached to the aorta. This is typically attached to the ascending aorta just distal to the sinotubular junction on the greater curvature. The attachment can often be performed with a partial occlusion

clamp, after appropriate anticoagulation. The outflow graft is sewn after an aortotomy is made sharply with a small gauge (4-0 or 5-0) non-absorbable monofilament suture. The suture often benefits from tightening with nerve hooks prior to tying.

In the patient with a highly calcified ascending aorta, or in those undergoing alternative, less invasive implant approaches, the outflow graft can be connected to the descending thoracic aorta, in an approach akin to an apical-aortic conduit. The centrifugal pumps appear to be more flexible for alternative implant strategies.

Drivelines that provide pump power, control, and communication are typically tunneled to the mid-clavicular line 2–3 finger breaths below the costal margin. The dermis is re-approximated and the driveline secured with monofilament suture that is to remain until maximal ingrowth into the driveline coating (typically velour).

With increasing frequency, alternative implant techniques are being undertaken. These implant techniques can be in order to minimize the surgical stress or because of a hostile mediastinum in the patient with multiple surgical procedures. These approaches can be an implant that is performed via a left thoracotomy alone or with a left thoracotomy coupled with a counter incision on the right parasternal area and a right anterior thoracotomy or hemi-median-sternotomy with tunneling of the outflow conduit (29–32). The approaches will undoubtedly become more commonplace as the pump profile becomes smaller and more efficient.

### Special considerations

Postoperative anticoagulation should be initiated as soon as is clinically safe. In the percutaneous blood pumps, systemic anticoagulation is required and this is often performed with heparin to maintain a partial thromboplastin time (PTT) of 50–56 seconds (33–35) or ACT above 250 seconds. In the durable LVAD population, a PTT of 60–80 is often used (24,36,37) with the initiation of coumadin for long-term anticoagulation early.

The pump pocket and the securing of the inflow cannula so as not to induce obstruction of the inflow is becoming increasingly realized as a significant contributor to the long term function of the LVADS. Whether the pump is in an intra-pericardial pump, external to the pericardium or partially inside, the pump needs to sit freely with axial alignment of the inflow cannula with the mitral valve and LV cavity.

In general antibiotics consist of aggressive gram-positive

coverage, gram-negative coverage, and antifungals for 48–72 hours after chest closure. Some centers routinely employ leaving the chest open post LVAD to follow bleeding and to not impart added stress that could continue to right ventricular failure.

Right ventricular support is absolutely critical. There are no good long-term options for durable right ventricular assist device (RVAD). Maximizing RV performance by appropriately adjusting the LVAD speed so as to not completely decompress the LV, shift the septum and uncouple the interventricular dependence is a nuanced management. IABP can augment coronary perfusion to aid in RV function. Additionally a “chemical” RVAD is often employed. This can consist of appropriate RV pacing rate (>90 BPM), milrinone, dobutamine, modest doses of epinephrine, inhaled epoprostenol and/or inhaled nitric oxide. A vigilant management style to follow the central venous and pulmonary artery pressures is needed so as to not volume overload the right ventricle—often these patients have concomitant right ventricular failure or pulmonary hypertension.

As with all surgical patients that are able, early ambulation, physical therapy and occupational therapy are critical to an expeditious perioperative recovery, both for the acute and durable LVAD patients.

### Summary

MCS has seen and is seeing an evolution of our LVAD technology and our surgical technique. The devices and indications for acute MCS are ever evolving. Similarly, as our durable pumps become more miniaturized and require less power, their utilization with increase and surgical implantation trauma with decrease. The selection of the pump, patient, and implant technique for acute and durable MCS will remain a critical part of the surgeons’ care and decision-making process as these technologies utilization increases.

### Acknowledgements

None.

### Footnote

*Conflicts of Interest:* The author has no conflicts of interest to declare.

## References

- Whitson BA, D'Cunha J, Knutsen AC, et al. Levitronix ventricular assist devices as a bridge to recovery after profound biventricular heart failure associated with pulmonary aspergillosis. *J Heart Lung Transplant* 2007;26:345-9.
- Morgan JA, John R, Rao V, et al. Bridging to transplant with the HeartMate left ventricular assist device: The Columbia Presbyterian 12-year experience. *J Thorac Cardiovasc Surg* 2004;127:1309-16.
- Moulopoulos SD, Topaz S, Kolff WJ. Diastolic balloon pumping (with carbon dioxide) in the aorta--a mechanical assistance to the failing circulation. *Am Heart J* 1962;63:669-75.
- Kantrowitz A, Tjonneland S, Freed PS, et al. Initial clinical experience with intraaortic balloon pumping in cardiogenic shock. *JAMA* 1968;203:113-8.
- Ziemba EA, John R. Mechanical circulatory support for bridge to decision: which device and when to decide. *J Card Surg* 2010;25:425-33.
- Samoukovic G, Rosu C, Giannetti N, et al. The Impella LP 5.0 as a bridge to long-term circulatory support. *Interact Cardiovasc Thorac Surg* 2009;8:682-3.
- Siegenthaler MP, Brehm K, Strecker T, et al. The Impella Recover microaxial left ventricular assist device reduces mortality for postcardiotomy failure: a three-center experience. *J Thorac Cardiovasc Surg* 2004;127:812-22.
- Samoukovic G, Al-Atassi T, Rosu C, et al. Successful treatment of heart failure due to acute transplant rejection with the Impella LP 5.0. *Ann Thorac Surg* 2009;88:271-3.
- Bruckner BA, Jacob LP, Gregoric ID, et al. Clinical experience with the TandemHeart percutaneous ventricular assist device as a bridge to cardiac transplantation. *Tex Heart Inst J* 2008;35:447-50.
- Cheng JM, den Uil CA, Hoeks SE, et al. Percutaneous left ventricular assist devices vs. intra-aortic balloon pump counterpulsation for treatment of cardiogenic shock: a meta-analysis of controlled trials. *Eur Heart J* 2009;30:2102-8.
- Gregoric ID, Jacob LP, La Francesca S, et al. The TandemHeart as a bridge to a long-term axial-flow left ventricular assist device (bridge to bridge). *Tex Heart Inst J* 2008;35:125-9.
- Reverdin S, Gregoric ID, Kar B, et al. Bridge to transplantation with the TandemHeart: bending the indications in a chronic aortic dissection patient with postcardiotomy shock. *Tex Heart Inst J* 2008;35:340-1.
- Vranckx P, Meliga E, De Jaegere PP, et al. The TandemHeart, percutaneous transseptal left ventricular assist device: a safeguard in high-risk percutaneous coronary interventions. The six-year Rotterdam experience. *EuroIntervention* 2008;4:331-7.
- Windecker S. Percutaneous left ventricular assist devices for treatment of patients with cardiogenic shock. *Curr Opin Crit Care* 2007;13:521-7.
- Luo XJ, Hu SS, Sun HS, et al. Clinical application of BVS5000 left ventricular assist device in heart failure patients. *Chin Med J (Engl)* 2008;121:877-80.
- Samuels LE, Holmes EC, Thomas MP, et al. Management of acute cardiac failure with mechanical assist: experience with the ABIOMED BVS 5000. *Ann Thorac Surg* 2001;71:S67-72; discussion S82-5.
- Wassenberg PA. The Abiomed BVS 5000 biventricular support system. *Perfusion* 2000;15:369-71.
- John R, Liao K, Lietz K, et al. Experience with the Levitronix CentriMag circulatory support system as a bridge to decision in patients with refractory acute cardiogenic shock and multisystem organ failure. *J Thorac Cardiovasc Surg* 2007;134:351-8.
- John R, Long JW, Massey HT, et al. Outcomes of a multicenter trial of the Levitronix CentriMag ventricular assist system for short-term circulatory support. *J Thorac Cardiovasc Surg* 2011;141:932-9.
- Mert M, Akcevin A, Yildiz CE, et al. Postoperative mechanical circulatory support with Biomedicus centrifugal pump. *Asian Cardiovasc Thorac Ann* 2005;13:38-41.
- Noon GP, Ball JW Jr, Papaconstantinou HT. Clinical experience with BioMedicus centrifugal ventricular support in 172 patients. *Artif Organs* 1995;19:756-60.
- Mallidi HR, Anand J, Cohn WE. State of the art of mechanical circulatory support. *Tex Heart Inst J* 2014;41:115-20.
- Garbade J, Bittner HB, Barten MJ, et al. Current trends in implantable left ventricular assist devices. *Cardiol Res Pract* 2011;2011:290561.
- Whitson BA, Eckman P, Kamdar F, et al. Hemolysis, pump thrombus, and neurologic events in continuous-flow left ventricular assist device recipients. *Ann Thorac Surg* 2014;97:2097-103.
- Kiernan MS, Joseph SM, Katz JN, et al. Sharing the care of mechanical circulatory support: collaborative efforts of patients/caregivers, shared-care sites, and left ventricular assist device implanting centers. *Circ Heart Fail* 2015;8:629-35.
- Jaik N, Higgins RS, Whitson BA. Simultaneous procedures

- during left ventricular assist device implantation: is less always more? *Curr Heart Fail Rep* 2014;11:98-102.
27. Morgan JA, Tsiouris A, Nemeh HW, et al. Impact of concomitant cardiac procedures performed during implantation of long-term left ventricular assist devices. *J Heart Lung Transplant* 2013;32:1255-61.
  28. Sun BC, Firstenberg MS, Louis LB, et al. Placement of long-term implantable ventricular assist devices without the use of cardiopulmonary bypass. *J Heart Lung Transplant* 2008;27:718-21.
  29. Anyanwu AC. Technique for less invasive implantation of Heartmate II left ventricular assist device without median sternotomy. *Semin Thorac Cardiovasc Surg* 2011;23:241-4.
  30. Wagner CE, Bick JS, Kennedy J, et al. Minimally invasive thoracic left ventricular assist device implantation; case series demonstrating an integrated multidisciplinary strategy. *J Cardiothorac Vasc Anesth* 2015;29:271-4.
  31. Collart F, Feier H, Metras D, et al. A safe, alternative technique for off-pump left ventricular assist device implantation in high-risk reoperative cases. *Interact Cardiovasc Thorac Surg* 2004;3:286-8.
  32. Bottio T, Bejko J, Guariento A, et al. Bilateral mini-thoracotomy off-pump Jarvik 2000 implantation in regional asymmetric paravertebral analgesia. *J Cardiovasc Med (Hagerstown)* 2016;17:160-4.
  33. Desai NR, Bhatt DL. Evaluating percutaneous support for cardiogenic shock: data shock and sticker shock. *Eur Heart J* 2009;30:2073-5.
  34. Raess DH, Weber DM. Impella 2.5. *J Cardiovasc Transl Res* 2009;2:168-72.
  35. Valgimigli M, Steendijk P, Sianos G, et al. Left ventricular unloading and concomitant total cardiac output increase by the use of percutaneous Impella Recover LP 2.5 assist device during high-risk coronary intervention. *Catheter Cardiovasc Interv* 2005;65:263-7.
  36. Slaughter MS, Pagani FD, Rogers JG, et al. Clinical management of continuous-flow left ventricular assist devices in advanced heart failure. *J Heart Lung Transplant* 2010;29:S1-39.
  37. Görlinger K, Bergmann L, Dirkmann D. Coagulation management in patients undergoing mechanical circulatory support. *Best Pract Res Clin Anaesthesiol* 2012;26:179-98.

**Cite this article as:** Whitson BA. Surgical implant techniques of left ventricular assist devices: an overview of acute and durable devices. *J Thorac Dis* 2015;7(12):2097-2101. doi: 10.3978/j.issn.2072-1439.2015.11.53