Minimally Invasive Thoracic Left Ventricular Assist Device Implantation; Case Series Demonstrating an Integrated Multidisciplinary Strategy

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Objectives: **The present report describes the authors' initial experience with implantation of the Heartware left ventricular assist devices (HeartWare Inc., Framingham, MA). via a minimally invasive surgical approach without cardiopulmonary bypass. A detailed overview of the anesthesiologist's role during the procedure, characteristics of the patient population, and short-term clinical outcomes are provided, and the clinical considerations that influence the decision to implant this device via an off-pump minimally invasive approach are outlined.**

Design: **Retrospective medical record review.**

Setting: **University hospital.**

Participants: **Thirteen patients with advanced heart failure deemed candidates for off-pump minimally invasive left ventricular Heartware implantation as a bridge to heart transplantation.**

Interventions: **The Heartware left ventricular assist device was implanted in all 13 patients via a minimally invasive approach.**

Measurements and Main Results: **One patient required unplanned cardiopulmonary bypass to control bleeding around the left ventricular outflow cannula. The average operating room time was 249.8 minutes ± 46.2 minutes. Six of 13 patients required no intraoperative red blood cell transfusions. Seven patients were extubated within 12 hours after surgery. Two patients required reintubation within 48 hours. No patients required reoperation for bleeding. Average intensive care unit and hospital lengths of stay were 7.2 ± 3.9 days and 13.4 ± 3.6 days, respectively. There were no in-hospital deaths.**

Conclusions: **Minimally invasive off-pump left ventricular Heartware implantation is an emerging alternative to placement by midline sternotomy. The authors speculate, based on their limited experience, that an off-pump thoracic strategy may be a desirable option for some patients and that clinical outcomes may be non-inferior to placement by midline sternotomy with cardiopulmonary bypass.**

KEY WORDS: cardiac surgery, left ventricular assist device placement via thoracotomy, intensive care management, Heartware LVAD (HVAD)

The Heartware ventricular assist device (HVAD) is a centrifugal pump approved to bridge patients with advanced heart failure to heart transplantation.[1–3] It is smaller than many other ventricular assist devices, allowing for pericardial implantation and exhibiting a lower profile in the mediastinum. Innovative minimally invasive surgical HVAD implantation techniques have been developed.[4–7] In addition, the HVAD can be implanted in the left ventricle without cardiopulmonary bypass via a minimally invasive approach. Some patients who have had a previous midline sternotomy and deemed too high risk for standard left ventricular assist device implantation may benefit from left ventricular minimally invasive off-pump HVAD (LV MIOP HVAD) implantation. The authors' initial experience with LV MIOP HVAD implantation, along with perioperative outcomes of interest, are reported.

METHODS

The LV MIOP HVAD implantation procedure will be described. The patient is brought into the operating room. If present, the sensing function of the patient's automated implanted cardioverter-defibrillator is suspended with a magnet. A device programmer is kept in the operating room, because reprogramming the pacemaker settings usually is required during the operation. An arterial pressure monitoring catheter is placed, and general anesthesia is induced. A single-lumen endotracheal tube, central venous introducer, pulmonary artery catheter, and transesophageal echocardiography (TEE) probe are placed in the patient. A TEE exam is performed. The surgeon and anesthesiologist review the TEE exam findings, as well as previously obtained computerized tomography and peripheral ultrasound studies, to determine if LV MIOP HVAD placement is appropriate. Table 1 lists the issues that influence the decision to proceed with LV MIOP HVAD implantation.

After the decision to proceed with LV MIOP HVAD implantation has been made, the anesthesiologist uses a transthoracic ultrasound probe to identify and mark the left ventricular apex that is typically at the 5th or 6th intercostal space. Surgical exposure includes a j-shaped hemisternotomy at the 3rd intercostal space, an anterolateral thoracotomy at the ventricular apex, and exposure of the femoral vessels in the event that cardiopulmonary bypass is needed. The ascending aorta is inspected with an epiaortic ultrasound to definitively exclude pathology (calcification, aneurysms, plaques, dissections) that precludes placement of the HVAD inflow graft. Attention is turned to the left ventricular apex. The surgeon places a spinal needle in the left ventricular apex, and the anesthesiologist uses TEE to identify its location. This information is used by the surgeon to guide the optimal placement of the HVAD outflow cannula.

Intravenous lidocaine and magnesium are administered routinely before left ventricular sewing ring placement to minimize arrhythmias that frequently are encountered. After the sewing ring is sutured to the left ventricular apex, the anesthesiologist and surgeon perform a carefully choreographed sequence of events. Heparin (300 units/kg) is administered to achieve a target activated coagulation time greater than 400 seconds. It is critical that the patient be heparinized adequately for cardiopulmonary bypass should it be needed emergently. The patient's pacemaker, if present, is reprogrammed to a heart rate <50

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1053-0770/2601-0001$36.00/0

http://dx.doi.org/10.1053/j.jvca.2014.11.007

Table 1. Clinical Considerations That Influence the Decision to Implant a Left Ventricular HVAD Without Cardiopulmonary Bypass

Comorbidity	Off-Pump HVAD Clinical Considerations
Aortic valve disease	Greater-than-moderate aortic regurgitation is an indication for midline sternotomy and on-pump HVAD placement
Previous mechanical aortic valve replacement	Requires midline sternotomy and on-pump HVAD placement
Tricuspid valve disease	Tricuspid valve disease requiring surgical intervention is an indication for midline sternotomy and on-pump HVAD placement
Mitral valve stenosis	Mitral valve stenosis requiring surgical intervention is an indication for midline sternotomy and on-pump HVAD placement
Atrial shunting	Small atrial shunts amenable to percutaneous occlusion devices may be observed following off-pump HVAD placement. Large shunts not amenable to percutaneous occlusion devices may require midline sternotomy and on-pump HVAD placement.
Presence of left ventricular thrombus	Requires on-pump HVAD placement to better visualize the left ventricular apex
Aortic disease	Severe ascending aorta calcification, aortic dissections, or aneurysms are contraindications to off-pump HVAD placement.
Peripheral vascular disease	The presence of femoral vessels that are inadequate for cardiopulmonary bypass cannulation is an indication for midline sternotomy and on-pump HVAD placement.

Abbreviation: HVAD, Heartware ventricular assist device.

beats per minute. Adenosine is administered, creating brief periods of asystole. The brief period of cardiac immobility makes placement of the left ventricular outflow cannula less technically challenging. Further, the brief asystole reduces blood loss during left ventricular outflow cannula placement. The surgeon then allows a few blood ejections out of the outflow cannula, through the HVAD, and out the inflow graft to expel air from the left ventricle and HVAD. TEE is used to confirm adequate deairing of the left ventricle. The pacemaker rate is increased. Finally, the inflow graft is anastomosed to the ascending aorta, final deairing is performed, and the HVAD is turned on. TEE is used to assess cardiac response to the HVAD and flows are adjusted as the surgeon and anesthesiologist deem appropriate. Vigilant TEE cardiac surveillance is required to identify right ventricular failure and/or left ventricular "suck-down" events. Protamine is administered and the incisions are closed.

All study data were extracted from the institutional review board-approved ventricular assist device registry. Average and standard deviations of continuous variables were calculated with Microsoft Excel 2011.

RESULTS

Over a 13-month period, 13 patients were deemed candidates to undergo LV MIOP HVAD implantation for bridge to heart transplantation. Preoperative patient characteristics and hemodynamic profiles are listed in Table 2 and Table 3, respectively. Three patients had a previous sternotomy. Twelve patients underwent successful LV MIOP HVAD implantation. One patient required unplanned cardiopulmonary bypass to control bleeding around the left ventricular outflow cannula.

No patients required reoperation for bleeding. Seventy-one percent of patients were extubated within 12 hours of intensive care unit admission. One patient was extubated before leaving the operating room. Fourteen percent of patients required reintubation and bi-level positive airway pressure was required in 41% of patients. All patients recovered and were discharged from the hospital. One patient died of intractable and symptomatic ventricular fibrillation 31 days after surgery in an outside rehabilitation facility. Three patients underwent heart

Table 2. Preoperative Patient Characteristics Before Planned Off-Pump Minimally Invasive Left Ventricular HVAD Implantation

Patient	Type of Heart Failure	Sex	Age	BMI	EF%	Kormos	Creatinine
1	Ischemic	male	62.2	24	17.5	0.27	1.27
2	Ischemic	male	61.8	30.8	20	0.58	1.24
3	Ischemic	male	57.9	30.8	22.5	0.48	2.46
4	Non-Ischemic	male	63.6	34.7	25	0.72	6.85
5	Non-Ischemic	female	64.8	30.4	15	0.428	0.81
6	Ischemic	male	66.6	31.6	12.5	0.59	1.62
7	Ischemic	male	67	21.59	17.5	0.58	1.06
8	Ischemic	male	63.6	29.3	25	0.6	1.39
9	Ischemic	male	45	30.8	12.5	0.71	1.01
10	Non-Ischemic	female	38	26.3	22.5	0.384	0.86
11	Non-Ischemic	male	30.4	37.9	12.5	0.9	0.95
12	Non-Ischemic	female	40.7	22.9	7.5	0.421	1.2
13	Non-Ischemic	male	65	26.3	22.5	NA	1.71
AVERAGE			55.8	29	17.8	0.55	1.72
STD			12.6	4.7	5.6	0.17	1.6

Abbreviations: BMI, body mass index; EF, ejection fraction; HVAD, Heartware ventricular assist device STD, standard deviation.