

Effective Illustration of Decommissioning of Left Ventricular Assist Device after Bridge-to-Recovery by Hybrid Minimally-Invasive Tactic: Anesthesia Substances

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Received date: December 21, 2016; Accepted date: February 02, 2017; Published date: February 08, 2017

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Abstract

We report successful decommissioning of HeartWare left ventricular assist device (LVAD) (HVAD, HeartWare Inc., Framingham, MA) leaving the pump in situ by hybrid percutaneous approach. In this case, the indication for mechanical assist device separation was myocardial recovery, which occurred following 19 months of LVAD support.

Anesthetic goals include maintenance of sinus rhythm, avoidance of myocardial depression and increase in systemic vascular resistance (SVR), with optimal blood pressure control, normothermia, and judicious fluid management. Intraoperative assessment of suitability to wean using transesophageal echocardiography (TEE) and continuous cardiac output monitoring with pulmonary artery catheter must be expedient as no anticoagulation is given. This case report demonstrates the feasibility of separating a patient from a LVAD without the need for a major re-operative intervention.

Keywords: Anaesthesia; LVAD decommissioning

Introduction

Ventricular assist devices are mechanical circulatory assist devices-divided into pulsatile or continuous flow, which may be centrifugal or pulsatile pumps. The HeartWare[®] LVAD is an implantable continuous flow centrifugal pump that is designed to provide flows up to 10 L/min in a compact device which is lightweight and portable. It is FDA approved as a bridge to transplant. In the seventh Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) report, only 1% of the 1357 patients with continuous flow left ventricular assist devices (CFLVADs) that were implanted with the bridge-to-transplant (BTT) strategy had sufficient myocardial recovery to allow explant of the LVAD at 12 months [1-4].

Very few surgical techniques have been described to separate the patient from the LVAD once recovery has occurred. Majority are managed by explantation of the LVAD on cardiopulmonary bypass (CPB), with ischemic or fibrillatory arrest [5]. To avoid CPB, new and different minimally invasive techniques have become widespread, and it has also brought innovations in anaesthesia management [6]. This report describes a method of decommissioning of the LVAD for myocardial recovery by percutaneous approach by way of outflow graft ligation and driveline excision while leaving the pump and nearly all of its components in situ. This technique has the advantage of avoiding sternotomy and cardiopulmonary bypass.

Report

We describe the anaesthetic management in a 49 year patient with idiopathic dilated cardiomyopathy who was on LVAD support for 19 months coming for percutaneous decommissioning after complete myocardial recovery. IRB approval was obtained

This gentleman had a history of hypertension and idiopathic dilated cardiomyopathy with severely impaired left ventricular ejection fraction (LVEF) 16% and multiple admissions for congestive cardiac failure had received a HeartWare left ventricular assist device (HVAD, HeartWare Inc, Framingham, MA) as a bridge to transplant. However, he subsequently had significant recovery of myocardial function after 19 months, and decision was made for percutaneous transfemoral occlusion of the HVAD outflow graft with HVAD driveline removal.

He was electively admitted for trial of LVAD weaning and tolerated reduction in pump speed from baseline of 2600 revolutions per minute (RPM) with our institution's weaning protocol for myocardial recovery. Transthoracic echocardiography (TTE) showed normal left ventricle (LV) size and systolic function, LVEF 55 to 60% with no regional wall motion abnormality when pump speed was reduced to 1800 RPM.

The procedure was performed in a hybrid operating room under fluoroscopic guidance. Monitoring included 5 lead ECG, pulse oximetry, left radial arterial line, central venous catheter, continuous cardiac output measurement with pulmonary artery (PA) catheter, bispectral index (BIS) monitor, temperature and urine output monitoring. External defibrillation pads were applied, with confirmation of capture pre-induction.

Preoperative parameters were as follows: BP 103/65, HR 57 bpm, oxygen saturation 97% on room air. Anaesthesia induction was balanced with midazolam 2.5 mg, fentanyl 100 mcg, etomidate 14 mg and rocuronium 50 mg after preoxygenation. He was intubated uneventfully with Portex ETT #8.5 and commenced on mechanical ventilation. Anaesthesia was maintained with sevoflurane in air/oxygen mixture. Antibiotic prophylaxis with IV cefazolin 2 g was followed as per our institution's recommendation. He was positioned supine with both arms tucked in by side, care taken to ensure proper padding and protection of peripheries.

Pulmonary artery (PA) catheter insertion in right IJV was performed under ultrasound guidance after induction, and continuous cardiac output monitoring after *in vivo* calibration performed. Initial PA pressure 40/23 mmHg, CCI 3.3, CCO 5.6. The initial venous blood gas performed via PA catheter for calibration: pH 7.3, Calcium: 1.24, Glucose: 8.4, Hb: 11.2, K+: 3.6, NA+: 141, SAT: 77.

Transesophageal echocardiography (TEE) probe was placed post induction. Intraoperative TEE findings: LVEF 45 to 50% with normal right ventricular (RV) size and systolic function. Normal valves with no aortic regurgitation, trivial mitral and tricuspid regurgitation. LVAD inlet cannula seen at apex and points towards the mitral valve. Outflow graft seen coursing along the anterior aspect of the right ventricle anastomosing into the proximal ascending aorta. LVAD outlet cannula flow velocity 1 m/s, with retrograde flow seen in diastole. The LVAD pump speed was reduced progressively to 2200 rpm then 2000 rpm with improvement in LVEF to 50 to 55%. Mitral regurgitation remained trivial.

IV noradrenaline started at 0.03 mcg/kg/min and IV adrenaline infusion at 0.02 mcg/kg/min shortly after induction due to hypotension with fall in mean arterial pressure to 50-60 attributed to fall in systemic vascular resistance (SVR) and bradycardia. IV adrenaline infusion increased to maximum of 0.05 mcg/kg/min, as heart rate was low (rate 40-45 bpm). IV ephedrine 6 mg and atropine 0.6 mg was also given to increase heart rate to baseline of 50 to 60 bpm.

Surgical approach was via bilateral femoral artery puncture with 6 French sheath, and subsequent guiding catheter placement. After placement of catheter through outflow graft, a fall in CCI was noted: PCWP 30 PAP 48/25 CVP 18 CCI 1.9 CCO 3.8. LVAD was weaned to 1800 RPM, with satisfactory TEE and PA haemodynamics - PA 42/22, PCWP 25, CCI 3.3, and CCO 6.7. There was no occurrence of intraoperative arrhythmias during weaning or withdrawal of LVAD support.

Consensus agreement was reached that LVAD support be withdrawn in view of satisfactory TEE and PA haemodynamics with reduction in pump speed. LVAD was switched off and simultaneously, a 14 mm vascular plug (Amplatzer vascular plug II; St Jude Medical, Inc., St Paul, MN) was first deployed near the pump head at the proximal end of graft (Figure 1).

The first vascular plug deployment is done simultaneously as LVAD support is stopped to reduce risk of vascular plug migration due to retrograde flow as pump is switched off. The second vascular plug (16 mm) was then deployed in distal end of the outflow graft (Figure 2).

Immediate angiography showed minimal flow down the graft, which indicates that thrombosis of outflow graft has occurred. At the end of operation: PCWP 21, PA 47/25, CCI 2.2, and CCO 4.4. Both noradrenaline and adrenaline infusions were weaned to 0.02mcg/kg/min by the end of procedure. Post procedure TEE demonstrated flow cessation in outflow graft on doppler interrogation, and visually estimated LVEF was 55 to 60%.

At the end of procedure, analgesia included IV fentanyl 50 mcg and local infiltration of bupivacaine 0.5% 10 ml to bilateral groin. He was reversed with IV neostigmine 2.5 mg and atropine 0.6 mg, extubated awake and breathing well spontaneously. He was sent to ICU for monitoring overnight and discharged the following day to the general ward.

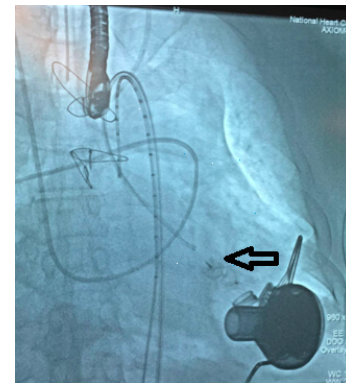


Figure 1: Fluoroscopic image captured during deployment of the first Amplatzer vascular plug II (indicated by an arrow) within the proximal portion of the HVAD outflow graft.

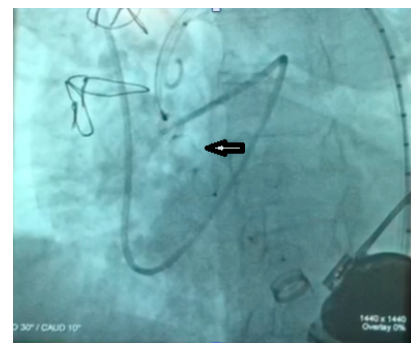


Figure 2: Fluoroscopic image captured during deployment of the second Amplatzer vascular plug II (indicated by an arrow) at the distal portion of the HVAD outflow graft near the aorta.

Discussion

LVAD support carries the risks of bleeding, in particular gastrointestinal bleeding, driveline infection, pump thrombosis, stroke and ventricular arrhythmias [7]. There have been encouraging safety and survival outcomes after LVAD explantation following recovery of native heart function. A systematic review by Phan et al. [8] looking at ventricular recovery and pump explantation in LVAD patients showed that post-weaning freedom from heart failure (HF) recurrence reached 81.3%, with subset analysis demonstrating that patients explanted from a continuous flow LVAD versus pulsatile LVAD had a lower rate of HF recurrence (6.6 vs. 28.3%, $p=0.03$) and LVAD reimplantation (7.5 vs. 37%, $p=0.001$).

LVAD explantation after myocardial recovery can be enormously gruelling and challenging, the foremost reason being dense mediastinal adhesions and the peril of surgical trauma during the dissection. This may cause extensive damage to the recovered heart. Furthermore, a full sternotomy and cardiopulmonary bypass can produce major bleeding, necessitating more blood and blood products, which may possibly affect the pulmonary vascular resistance and negatively impact the right ventricular function. With newer generation devices and advances in minimally invasive techniques for LVAD explantation,

such that relatively virgin territory is used, cardiopulmonary bypass may be avoided [9-11], and the attendant risks are minimized.

Also, despite the low rate of HF recurrence of 6.6% after explantation of a continuous flow LVAD device [8], such as the Heartware HVAD LVAD, there remains the possibility of subsequent deterioration of myocardial function after LVAD explantation, which may require device reimplantation and eventual heart transplant. There has been conflicting data with regards to prior sternotomy on outcomes after heart transplant, as technical complexity of operation is likely to increase with repeated surgeries. Schulze et al. [12] showed that >2 prior sternotomies were associated with poor survival after heart transplant. However, Gaffey et al. did a retrospective review of over 250 cases of heart transplant at his institution and found that implantation of an LVAD as a bridge to transplantation or prior sternotomy does not adversely impact allograft function, hospital length of stay, or long-term outcomes after orthotopic heart transplant [13]. In any case, it is prudent to avoid sternotomy where possible.

There are few surgical choices to separate the patient from the VAD. The classic procedure involves a redo sternotomy with the complete explantation of the device and its components. The risks of this redo-sternotomy for this approach have been mentioned above. With the newer, smaller-sized LVADs, explants can be performed by merely detaching the pump through a subcostal incision, occluding the ventriculotomy with a plug (i.e., Cohn plug), and oversewing the outflow graft. These less invasive approaches allowing complete explantation of the device still require establishment of peripheral CPB with the need to arrest or fibrillate the heart [14-16]. There have been only few isolated reports of exclusion of the device by hybrid technique [17].

A technique for percutaneous decommissioning of LVAD support is therefore ideal. Firstly, the surgical approach is clearly less invasive when compared with a full sternotomy or even minimally invasive techniques e.g. left anterior thoracotomy and subxiphoid incisions, cardiopulmonary bypass, reduces surgical complexity and risk, and minimizes blood loss and need for blood product replacement. Secondly, the pericardium remains mainly closed, controlling to further stabilize the right ventricular function, including avoidance of right ventricular dilatation. In addition, retained LVAD graft material has also been shown to be well tolerated [11]. Still, this technique is limited by poor visual control of cardiac pump function.

There is the possibility of the following two worries:

First, there is a risk of embolization from the VAD as it thromboses after interruption of blood flow. The probability of this embolization after ligation in a patient without graft thrombosis is theoretically minimal, as the pressure from the ventricle and aorta immobilizes the thrombus within the retained pump/components [16,18]. The intraoperative anticoagulation strategy to prevent this is administration of 5000 units of heparin prior to ligation of the graft. Another technique that may limit embolic events is ligation of the inflow graft instead of the outflow graft to discontinue LVAD. Also, the application of an Amplatzer occluder device may reduce the risk of embolization while achieving interruption of flow through the VAD. The Amplatzer vascular plug II has a multi-layered, multiple-lobed mesh design for rapid embolization, and multiple points of contact with the outflow graft wall to allow secure positioning in a high-flow conduit. In addition, it allows repositioning if required. The second risk is that of VAD-associated infections. The incidence of this is similar to that with other implantable surgical prostheses.

The anaesthesia considerations involve the following aspects: Repeat cardiac surgery, associated co-morbidities of cardiac surgical patients, ability and knowledge of use and interpret results of various invasive intraoperative monitoring techniques, difficulty in providing effective cardiopulmonary resuscitation and defibrillation in previous cardiac surgery, working in hybrid theatre occupied with radiological and other equipments limiting the working space and need for emergency reopening or instituting peripheral cardiopulmonary bypass in an event of disaster. Anaesthetic aims intraoperatively are to maintain normovolemia and sinus rhythm, avoid myocardial depression and increase in SVR. Blood pressure control is important and avoidance of hypotension or hypertension equally necessary. Noradrenaline infusion may be utilized to maintain SVR, to maintain MAP within the target range of 70 to 80 mmHg to optimise cardiac support.

Intraoperative TEE is an important monitoring tool. TEE is not only useful to assess LV and RV function, LVAD inlet cannula and outflow graft flow, but is also used to confirm absence of LV clot prior to LVAD decommissioning. As the LVAD pump speed is reduced, TEE allows real time assessment of biventricular function and helps in determining suitability to be weaned, along with PA haemodynamics. After the device is switched off and vascular plug deployed, TEE is also useful for assessing LV and RV function, estimation of RVSP and PASP and identify tamponade collection if it occurs.

Temperature monitoring is important and the aim is to maintain normothermia, as hypothermia not only has an impact on intraoperative arrhythmias and cardiovascular morbidity, but also increases blood loss with need for transfusion, and increases the risk of postoperative infection. Pre warming, the use of forced air warming blanket and a heated humidifier are measures that can be taken to avoid hypothermia, as under body warming blanket would interfere with intraoperative fluoroscopic imaging.

Surgical stimulus is minimal for this procedure, and intravenous fentanyl boluses intraoperatively, with local anaesthetic infiltration to the femoral access sites and site of driveline removal at the end of the procedure, provide adequate analgesia. As with any procedure involving angiography and use of contrast, we should ensure that the patient is adequately hydrated with intraoperative urine output monitoring to reduce the risk of contrast induced nephropathy [19].

The combined expertise and effective collaboration of a multi-disciplinary team is necessary for the success of this percutaneous approach to LVAD decommissioning. It is important for the entire team to be engaged and maintain active communication throughout the procedure. Every member needs to be aware of their role and provide accurate, appropriate and timely feedback.

A special point to note is that no anticoagulation is provided intraoperatively, which is contrary to endovascular procedures where ACT is checked and kept above 250. This is because the aim was for thrombosis of the outflow graft. The assessment as to the suitability for weaning from LVAD support should therefore be expedient and should the patient be deemed unsuitable, anticoagulation must be provided to avoid pump thrombosis.

The procedure was performed in a hybrid operating room, with a view for open cardiac surgery in the event of emergency. It is possible that with better assessment and clearer identification of patients who have recovered sufficient myocardial function to be suitable for LVAD weaning, and increasing familiarity with percutaneous technique for occlusion of LVAD outflow graft, this procedure may be performed in a remote location in the cardiac catheterization laboratory. A single

stage catheter based embolization and deactivation of a HeartMate II LVAD [20], as well as a two-step procedure with percutaneous HVAD LVAD withdrawal in a cardiac catheterization laboratory, followed by subcutaneous burial of the disconnected and divided drive line the next day in the operating room [21] has both been described. The issues with remote anaesthesia would apply with presence of unfamiliar environment with limited space, unfamiliar equipment and limited access to skilled assistant.

Conclusion

In conclusion, we describe the case of successful LVAD decommissioning via percutaneous trans-femoral occlusion of the HeartWare HVAD LVAD outflow graft with Amplatzer vascular plug with HVAD driveline removal, in a 49 year old patient with idiopathic dilated cardiomyopathy who had myocardial recovery. It is safe, effective technique obviating the need for cardiopulmonary bypass. Left ventricle myocardium remains undamaged, minimising the risk of haemodynamic compromise with no early or late risk of thromboembolic complications. The durability of remission of heart failure will hopefully become clearer as more protocols and techniques are developed to address myocardial recovery in patients on VAD therapy. The explantation of a centrifugal pump by minimally invasive surgical approach is technically much easier compared with a full sternotomy. Surgeons performing such minimal procedures should be well experienced in the standard approach and diligent in evaluating their results to ensure the highest quality of ventricular assist device surgery. Anaesthesia providers should be cognizant of the various anaesthetic issues involved in this procedure.

Acknowledgement

Published with institutional IRB approval obtained. We thank the National Heart Centre's VAD team for their dedicated care to all patients requiring VADs.

Competing Interests

No external funding and no competing interests declared.

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