

How to do it: tips and tricks of minimal-invasive HVAD[®] implantation – the lateral approach

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Introduction

Chronic end-stage heart failure (CHF) is a major healthcare problem with rapidly growing incidences in Europe and the United States (1). With decreasing cardiac transplant rates worldwide, alternative treatment methods become increasingly important. The role and application of mechanical circulatory support (MCS) devices such as left ventricular assist devices (LVADs) for the therapy of CHF has increased worldwide (2-5). Novel technologies and surgical experience have played a key role in VAD-related successes. The most significant improvement in LVADs has been their essential miniaturization, which allows their implantation with less invasive surgical procedures (2-4,6-10). It is already known that minimally invasive surgical (MIS) procedures result in reduced wound size, ameliorated blood loss, shorter hospitalization duration, and improved cost-effectiveness. The reduction in post-operative complications has contributed to improved survival rates. This has led to considerably improved long-term outcomes over time (6,7,9-12). With further miniaturization of LVADs, the application of MIS techniques for implantations is likely to increase, giving rise to the need for well-established surgical approaches. The start of the development of the MIS-LVAD implantation technique for the HVAD as well as for other devices was worldwide first performed at Hannover Medical School in 2011 (2). The publication of this novel technique is the mark of a clinical paradigm shift in the therapy of patients with permanent ventricular assist devices. The implantation technique includes an upper hemi-sternotomy combined

with anterior-lateral thoracotomy and is developed to reduce complication rates (trauma size, postoperative blood loss, right heart failure), thereby allowing earlier recovery and better survival. Several modifications of this approach have been described for LVAD implantation (2,6,7,13-15). HVAD implantation with this technique is acknowledged worldwide as a procedure to treat left ventricular failure (2,6). The HeartWare ventricular assist device or HVAD (Medtronic, Minnesota, MN, USA) is a miniaturized, continuous-flow, centrifugal, implantable VAD (16). The inflow is in the apex of the left ventricle and the outflow on the aorta ascendens, while the pump is operated by a percutaneous driveline. The current article describes the technical aspects and characteristic features of less invasive HVAD implantation in detail.

Surgical technique

The less invasive approach for HVAD implantation was developed at the Hannover Medical School, Germany in 2011 (2). Sometimes referred to as the “Hannover technique” this technique was introduced by Schmitto *et al.*, and it is a combination of an upper mini-sternotomy and a left-sided anterolateral mini-thoracotomy (2).

At the start of the procedure, general anesthesia and single-lumen endotracheal intubations are performed, followed by an upper J hemisternotomy into the right second-to- third intercostal space (*Figure 1*). By obviating a total sternotomy the pericardium stays primarily unopened (only opened near the ascending aorta) in turn leading to

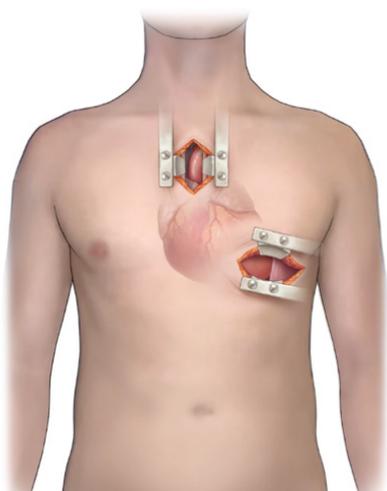


Figure 1 Minimally invasive placement of the HeartWare ventricular assist device by anastomosis aorta ascendens through left anterolateral thoracotomy.

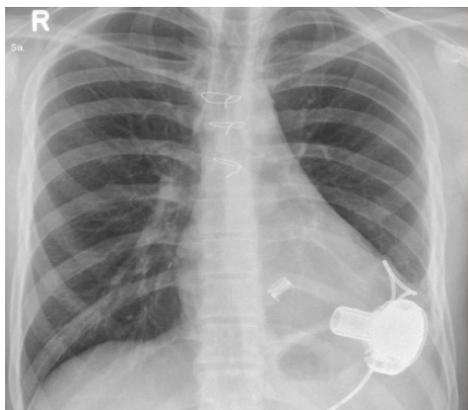


Figure 2 Postoperative X-ray with *in situ* LVAD. LVAD, left ventricular assist device.

additional right ventricular stabilization along with avoidance of right ventricular dilation during operation, in particular during the onset of the LVAD implantation. Thus, the right ventricular function remains passively sustained (2).

Thereafter, transthoracic echocardiography is performed for assessing the LV-apex. An anterior left 7–9 cm mini-thoracotomy through the fifth intercostal space is performed to access the apex cordis. A transesophageal echocardiography is performed while poking the apex to find the right place for the epicardial sewing ring of the HVAD onto the left ventricle. Soft tissue and Tuffier retractors are used to secure incisions. The HVAD-sewing-ring is positioned on the apex

of the heart in a ‘no-touch-technique’ without heparin and the screw position is directed in parallel to the skin incision. Afterwards the ring is implanted using Teflon pledgeted sutures along with a 4-0 running Prolene suture. After sewing the HVAD-ring the ring along with the sutures are secured with biological glues such as Purastat glue, fibrin glue or even synthetic glues like BioGlue. Then, after assurance of 100% hemostasis at the LV apex, injection of i.v. heparin is followed by waiting for an appropriate activated clotting time (ACT). Cardiopulmonary bypass is then performed with arterial cannulation of the distal aorta ascendens and venous cannulation of the femoral vein or 2-stage cannulation of the RA, if there is enough space. After careful inspection of the left ventricular cavity to harvest potential thrombus formation or intraventricular trabecularization which might induce inflow disturbances, the HVAD pump is inserted through the HVAD ring, over the apex cordis, onto the left ventricle and the outflow graft is used to de-air and vent the left ventricle using the extracorporeal circulation (ECC)-succer. Afterwards, the ligature used to fasten the outflow vascular graft is clamped to the forceps and tunneled to the upper sternotomy site intra-pericardially. A side clamp is then set to the anterior section of the ascending aorta. An angled cut is made on the outflow graft and aortic anastomosis is implemented at the aorta ascendens with continuous 4-0 Prolene sutures through the mini-sternotomy. The driveline is set first in an umbilical direction in the rectus muscle sheath and then subcutaneously to the right or left upper abdominal quadrant. This approach has been shown to increase the subcutaneous driveline course, leading to lower risks of driveline infections (17).

After the LVAD is de-aired and the absence of bubbles in the left ventricle is confirmed by transesophageal echocardiography, the pump is switched on *in situ*. The pump speed should be incrementally amplified while weaning the patient from the cardiopulmonary bypass with stable vital signs, no RV-failure signs and adequate AV-opening. An average pump flow-rate of 4.5 to 5±1 liters is typically achieved when the left pump is operating at 2,700±200 rpm. After closure of the two small wounds, the patient is relocated to the ICU where the first X-ray is performed (Figure 2).

Discussion and outlook

Conventional LVAD implantation is synonymous with large incisions, high complication rates, and overall poor outcomes, but the establishment of MIS procedures is

Table 1 Advantages and disadvantages of minimally invasive HVAD implantation

Advantages	Disadvantages
Less trauma	Technical hurdles
Less bleeding	Reduced visual access
Less right heart failure	Challenging estimation of length of the outflow graft
Better outcome	Concomitant procedures
Reduced complications	Missing comparative studies
Fewer inflow cannula malpositions	Fairly new
Shorter ECC time	
Shorter OR time	
Shorter ICU time	
Shorter Respirator time	
Shorter length of hospital stays	
Economic benefits	
Less adhesions	
Facilitates cardiac transplantation	
Better survival	

revolutionizing the entire field (18). MIS for LVAD is not only technically feasible but also becoming the standard procedure of choice in VAD centres worldwide. Rapid development and miniaturization of next-generation devices, have significantly improved outcomes (2,19-21). The novel HVAD pump design is well suited for an MIS approach because of its small size. MIS-HVAD implantation by upper J hemisternotomy combined with anterolateral mini-thoracotomy entails several benefits (*Table 1*). This procedure is also feasible for other LVADs such as the HeartMate 3 (22).

Firstly, MIS procedures are associated with smaller incisions, less pain and bleeding, reduced reliance on transfusion products and anticoagulation drugs, shorter hospital stays and ultimately results in lower treatment costs (2,11,12). Secondly, the reduced incision sizes due to the hemisternotomy enable targeted access to the areas required for cannulation and the anterolateral mini-thoracotomy exposes the apex cordis without the need for cardiac displacement, which is a prerequisite for midline sternotomy. As is already known, in severe heart failure patients have poor tolerance for any form of cardiac manipulation. Thirdly, access is ultimately required for only two thoracic regions: the apex of the heart and the

ascending aorta. Among all of the less invasive LVAD implant techniques described in literature, those two thoracic regions are separated into isolated incisions and surgical tasks. Thus, two surgeons can simultaneously expose the apex and the ascending aorta, thereby lowering the surgical operation time with improved postoperative outcome. Fourthly, despite recommendations from other reports on HVAD positioning on the LV diaphragmatic surface, our team has demonstrated that the pump placement with our new MIS technique leads to further optimized and stabilized inflow cannula placement through the anterolateral approach to the apex cordis (8,16). This technique prevents inflow obstruction and endocardial contact, hence reducing the risks of arrhythmias. Finally, this approach also reduces risks of developing right heart failure. The pericardium stays mainly unopened, enabling additional stabilization of right ventricular function including avoidance of right ventricular dilation during surgery, especially when the pump is switched on upon implantation (2).

There are some existing limitations of this technique which include the following: (I) the minimized surgical approach can be more technically challenging than a complete sternotomy; (II) accurate assessment of the outflow

graft length can be more difficult than the conventional procedure; (III) limited visual confirmation of cardiac contractile function, particularly of the right ventricle and (IV) concomitant procedures such as valve replacement are technically more challenging or infeasible using the MIS approach (e.g., concomitant CABG procedure). Additionally, as opposed to other cardiothoracic procedures (such as coronary revascularizations or valve surgery), MIS-LVAD implantation is a fairly recent development. There is a dearth of comparative studies presenting middle-term or long-term results. Therefore, such minimized VAD-implantations should only be performed at centres with highly skilled cardiac surgeons with experience in other types of cardiac surgery who can diligently evaluate surgical results to enable the optimal quality of LVAD implantations.

In conclusion, HVAD implantation with this MIS approach is not only technically feasible but also associated with several advantages and will become the gold standard in the near future.

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Footnote

Conflicts of Interest: JD Schmitto and G Dogan are consultants of Medtronic. Other authors have no conflicts of interest to declare.

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