COR ET VASA 57 (2015) e70–e74

Available online at www.sciencedirect.com

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journal homepage: http://www.elsevier.com/locate/crvasa

Original research article – *Special issue: Cardiovascular Surgery*

# Minimally invasive implantation of left ventricular assist device HeartWare HVAD

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ARTICLE INFO

*Article history:*
Received 9 February 2015
Accepted 19 February 2015
Available online 18 March 2015

*Keywords:*
Left ventricular assist device
HeartWare
Minimally invasive implantation

ABSTRACT

*Introduction:* Long-term left ventricular assist devices are nowadays part of standard therapy for patients in terminal phase of heart failure. Lower invasiveness of implantation might have the potential to enhance results of these high risk patients. The aim of this study is to introduce our minimally invasive approach to the implantation of left ventricular assist device of the latest generation HeartWare ventricle assist device (HVAD) and our initial experience with this method.

*Methods:* In our department we implanted HVAD between November 2013 and November 2014 in 8 patients as a bridge to heart transplantation. All patients were male with average age 59.5 ± 6.4 years. Basic diseases were dilated cardiomyopathy in 6 patients (75%), ischemic cardiomyopathy in 2 patients (25%). The mean value of left ventricular ejection fraction was 10 ± 3.6%, right ventricular ejection fraction was 35 ± 5.6%. Access to the left ventricular apex was reached by left-sided thoracotomy of approximately 8 cm. To access the ascending aorta we used upper J ministernotomy.

*Results:* Minimally invasive implantation was successfully done in all patients. In one patient closure of foramen ovale was simultaneously performed. Most patients (75%) were extubated on the first postoperative day. In one case, a failure of the right ventricle occurred with the need for temporary right-sided circulatory support device Centrimag. No patient died, four patients have successfully undergone heart transplantation, other are followed on an outpatient basis.

*Conclusion:* Minimally invasive implantation of left ventricular assist device HeartWare HVAD is safely feasible. After a very good initial experience with this technique it has become the method of choice in our department.



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http://dx.doi.org/10.1016/j.crvasa.2015.02.011

## Introduction

Implantation of left ventricular assist device (LVAD) as a bridge to heart transplantation nowadays represents part of standard therapy for the group of critically ill patients in the Czech Republic [1,2]. Guidelines of European Society of Cardiology recommend LVAD implantation in patients awaiting heart transplantation to improve their symptoms and to prevent readmission due to worsened heart failure (Class I/B recommendation) [3].

Standard medial sternotomy is the most frequent approach for LVAD implantation worldwide. Substitution of full sternotomy with smaller incisions may lead to the same effects as other minimally invasive cardiac surgery, i.e. to reduce blood loss, number of blood transfusions, infections, time of mechanical ventilation, length of ICU stay and total time of hospitalization [4,5]. These approaches are particularly beneficial for polymorbid and elderly patients [6]. A further positive factor of great significance is that the minimally invasive approach does not disrupt the integrity of pericardium, and thus we can avoid the negative impact of pericardium opening on the function of the right ventricle [7–9]. This approach left the sternum largely intact and outflow graft of LVAD is covered by pericardium, which considerably simplifies subsequent heart transplantation.

HeartWare VAD (HVAD) represents the latest LVAD generation of substantially smaller dimensions comparing to preceding systems, which enables completely intrapericardial implantation (see Fig. 1).

To perform minimally invasive HVAD implantation we apply incisions which have been commonly used in our department to perform other operations. Thus, we managed to eliminate the potential effect of learning curves. We use left-sided minithoracotomy to perform transapical transcatheter aortic valve implantation. The upper partial J ministernotomy is used for minimally invasive aortic valve replacement.

**Fig. 1 – Miniaturized centrifugal pump HeartWare with integrated inflow cannula.**

## Material and methods

### *Group of patients*

In our department, the implantation of mechanical circulatory support has been carried out since 2009; we have performed 57 operations in total. Since February 2013, we have implanted HVAD as a bridge to heart transplantation in 11 patients in total, 8 of whom, who are the subject to this study, underwent the minimally invasive approach. All patients were male, the median age of the patients was 59.5 ± 6.4 years. Six patients suffered from dilated cardiomyopathy (75%), ischemic cardiomyopathy was the primary disease in 2 patients (25%). The mean left ventricular ejection fraction was 10 ± 3.6%, right ventricular ejection fraction was 35 ± 5.6%, diastolic diameter of the right ventricle (RV) was 42 ± 5.2 mm. TAPSE (tricuspid annular plane systolic excursion) was 17 ± 3.5 mm. Other diseases included diabetes in 4 patients (50%), chronic obstructive pulmonary disease in 4 patients (50%), chronic renal insufficiency in 2 patients (25%), hepatopathy in 3 patients (37.5%).

### *HeartWare HVAD*

The system of implantable left ventricular assist device HVAD consists of a miniaturized centrifugal pump with integrated inflow cannula and outflow graft, external control unit and an external source of energy (2 batteries, power supply) (see Fig. 2). The pump is attached to the left ventricular apex

**Fig. 2 – HeartWare HVAD.**

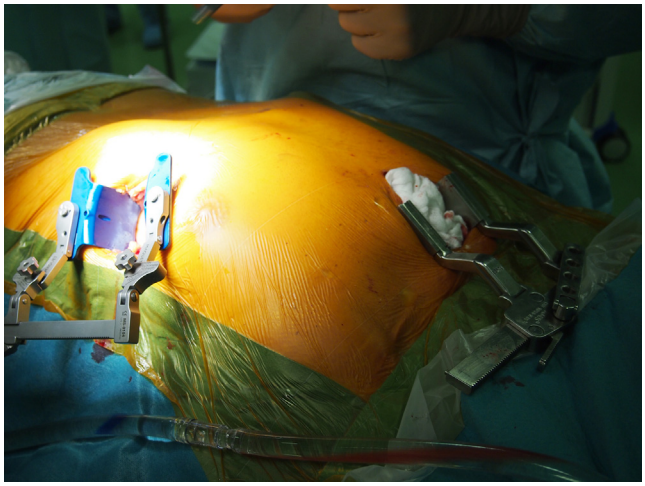

**Fig. 3 – Surgical approach: left-sided minithoracotomy and upper ministernotomy.**

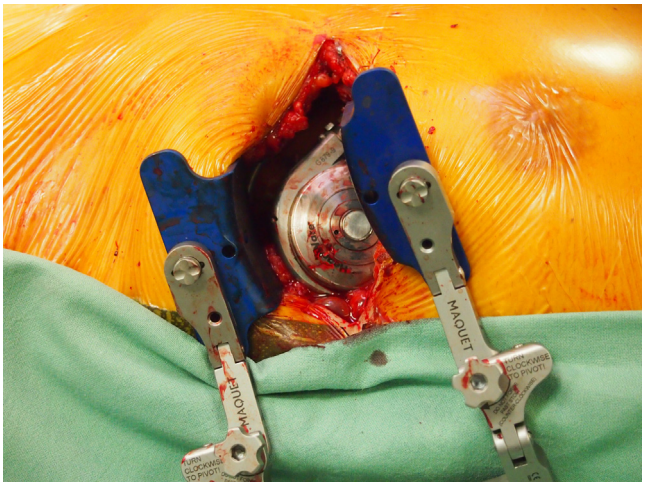


**Fig. 5 – Implanted HeartWare HVAD.**

via the implantation ring. The end of the outflow graft is anastomosed to the side of ascending aorta.

*Implantation*

The left ventricular apex is reached by left-side thoracotomy of approximately 8 cm in the fourth or fifth intercostal space. For precise detection of left ventricular (LV) apex the transthoracic echocardiography was used immediately before operation. Simultaneously J-shaped upper ministernotomy was performed. The sternum from was opened from the jugulum to the 3rd or 4th intercostal space to the right (see Fig. 3). After the pericardium is opened above both the apex and the aorta, the cannulation and extracorporeal circulation take place. Arterial cannula is inserted into the ascending aorta. Venous cannula is inserted via the femoral vein in the right groin into the right atrium. By means of transesophageal echocardiography we determine by pressure of the finger on LV apex an ideal place for the pump implantation. In the proper spot the implantation ring is sutured to myocardium (Fig. 4).

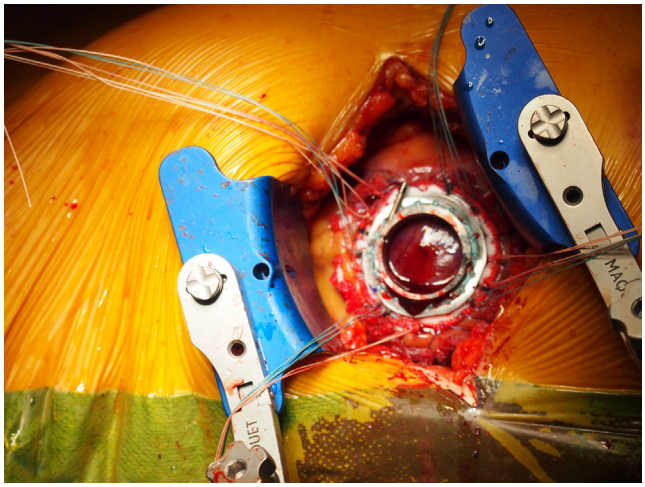

**Fig. 4 – Implantation ring sutured to left ventricular apex.**

Cardiopulmonary bypass is set off. Further steps are as follows: opening of the left ventricle by a cylindrical knife, left ventricular cavity inspection and connection of the pump (Fig. 5). The outflow graft is pulled intrapericardially and its end is sutured to the side of ascending aorta (Fig. 6). When de-airing of the system is completed, the support gradually starts up. We always make the effort to close the pericardium by direct suture. Alternatively HVAD is overlapped by CorMatrix membrane.

## Results

Minimally invasive implantation was successful in all patients. In one patient closure of foramen ovale was simultaneously performed. Most of the patients (75%) were extubated on the first postoperative day. Reoperation due to post-operative bleeding was necessary in two patients. In one case a feared failure of right ventricle occurred with the need for temporary right-sided mechanical supports with

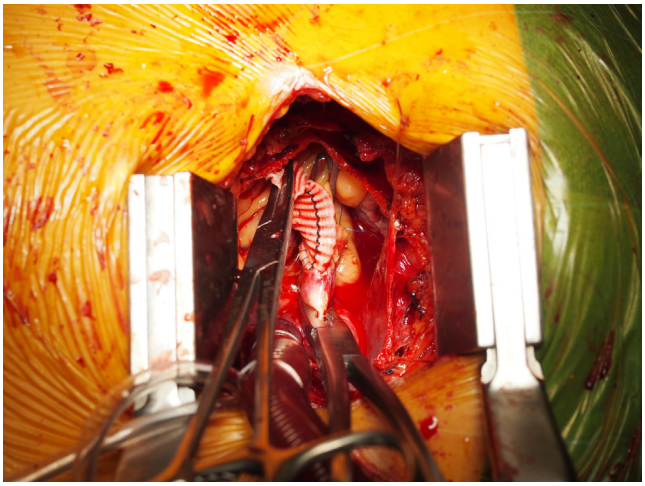

**Fig. 6 – Anastomosis of the outflow graft to the side of ascending aorta.**

| Table 1 – Results ($n$ = 8). | |
|---|---|
| Cardiopulmonary bypass (min) | 63.5 ± 25.4 |
| Erythrocytes (transf. units) | 2.5 ± 6.1 |
| Thrombocytes (transf. units) | 2 ± 2.8 |
| Frozen plasma (transf. units) | 6.5 ± 8.5 |
| Mechanical ventilation (days) | 1 ± 2.95 |
| ICU stay (days) | 11.5 ± 5.29 |
| Hospital admission (days) | 26 ± 7.30 |
| Bleeding with the need of reoperation | 1 (12.5%) |
| RV mechanical support | 1 (12.5%) |
| Cerebrovascular accident | 0 (0%) |
| Mortality | 0 (0%) |

Quantitative figures are given as a median value and standard deviation.

Centrimag device whose cannulas were inserted percutaneously. No patient from our group died. Four patients have already successfully undergone heart transplantation. Detailed results are given in Table 1.

## Discussion

The use of a long-term LVAD has significantly expanded the treatment options of patients in terminal stage of heart failure. LVAD implantation is however still burdened with significant perioperative and post-operative morbidity and mortality. Among the complications the most feared are: right ventricular failure, bleeding and complications connected with long-term mechanical ventilation.

Perioperative failure of the right ventricle is connected with high rate of early morbidity and mortality and its prediction still remains difficult [10]. Our method of approaching the left ventricular apex through the left-minithoracotomy maintains the integrity of pericardium above the RV, thereby significantly reducing the risk of the RV dilatation [7–9]. In comparison to the traditional approach, the manipulation of the heart is minimized, which reduces the risk of arrhythmias [8]. Both of these factors contribute the lower frequency of RV failure. Thus only one significant postoperative RV failure necessitating 19 days of temporary RV support occurred in our group of patients.

The described approach significantly reduces surgical trauma and thus, there is no need for greater mediastinal dissection. Our group was too small to enable a comparison with the classical approach, nevertheless we can confirm the tendency to lower blood loss described by other authors [8,9,11].

Prolonged mechanical ventilation is a factor that has a very strong relation to mortality in cardiac surgery [12]. Minimally invasive implantation maintains the continuity at the bottom of the thoracic cage and the diaphragm is also not affected during the operation. It contributes to the possibility to extubate most patients (75%) during the first postoperative day, which is, in case of LVAD implantation, a very encouraging result.

In our group LVAD implantation was indicated as a bridge to heart transplantation, which has been successfully performed in 4 patients. From a surgical point of view we appreciated the largely intact sternum, the outflow graft covered by pericardium and lower tendency to adhesions in the pericardial cavity which made subsequent cardiac transplantation much easier.

It is vital to mention the drawbacks of a minimally invasive approach. Direct access to the left ventricular apex might be technically demanding due to small thoracotomy. It has been proved to be beneficial when surgeon identifies the apex position by transthoracic echocardiography immediately prior to surgery. Upper ministernotomy brings limited access to the ascending aorta and consequent dealing with possible complications connected with anastomosis of outflow graft may be technically challenging as well. In comparison with the classical approach the inspection of the outflow graft course is more difficult, particularly when malrotation is concerned.

Each new surgical procedure carries the risk of learning curves. This phenomenon was meaningfully reduced in our situation, because both miniinvasive approaches are commonly used in our department to carry out other operations. Upper ministernotomy is regularly used for aortic valve replacement and left-minithoracotomy for transapical transcatheter aortic valve implantation.

## Conclusion

Minimally invasive implantation of HeartWare HVAD is safely feasible. After very good initial experience with this technique it has become the method of choice in our department.

## Conflict of interest

Authors declare no conflict of interest.

## Funding body

The work was supported by the European Fund for Regional Development – project FNUSA-ICRC (No. CZ.1.05/1.1.00/02.0123).

## Ethical statement

This study was done according to ethical standards of Centre for Cardiovascular Surgery and International Clinic Research Centre in Brno, Czech Republic.

## REFERENCES

[1] I. Netuka, J. Malý, O. Szárszoi, Mechanické srdeční podpory v terapii terminálního srdečního selhání, Cor et Vasa 50 (2008) 207–214.
[2] P. Fila, H. Bedáňová, V. Horváth, et al., Mechanické podpory a transplantace srdce v léčbě chronického srdečního selhání, Kardiologicka Revue Interni Medicina 16 (2014) 109–115.
[3] J.J. McMurray, S. Adamopoulos, S.D. Anker, et al., ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2012: The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012

of the European Society of Cardiology Developed in collaboration with the Heart Failure Association (HFA) of the ESC, European Heart Journal 33 (2012) 1787–1847.
[4] T. Mihaljevic, L.H. Cohn, D. Unic, et al., One thousand minimally invasive valve operations: early and late results, Annals of Surgery 240 (2004) 529–534 (discussion 34).
[5] L.H. Cohn, D.H. Adams, G.S. Couper, D.P. Bichell, Minimally invasive aortic valve replacement, Seminars in Thoracic and Cardiovascular Surgery 9 (1997) 331–336.
[6] E.A. Grossi, A.C. Galloway, G.H. Ribakove, et al., Minimally invasive port access surgery reduces operative morbidity for valve replacement in the elderly, Heart Surgery Forum 2 (1999) 212–215.
[7] B. Unsworth, R.P. Casula, A.A. Kyriacou, et al., The right ventricular annular velocity reduction caused by coronary artery bypass graft surgery occurs at the moment of pericardial incision, American Heart Journal 159 (2010) 314–322.
[8] J.D. Schmitto, U. Molitoris, A. Haverich, M. Strueber, Implantation of a centrifugal pump as a left ventricular assist device through a novel, minimized approach: upper hemisternotomy combined with anterolateral thoracotomy, Journal of Thoracic and Cardiovascular Surgery 143 (2012) 511–513.
[9] T. Haberl, J. Riebandt, S. Mahr, et al., Viennese approach to minimize the invasiveness of ventricular assist device implantation, European Journal of Cardio-Thoracic Surgery 46 (2014) 991–996. , http://dx.doi.org/10.1093/ejcts/ezu051.
[10] G. Gerosa, M. Gallo, V. Tarzia, et al., Less invasive surgical and perfusion technique for implantation of the Jarvik 2000 left ventricular assist device, Annals of Thoracic Surgery 96 (2013) 712–714.
[11] T. Bottio, J. Bejko, M. Gallo, et al., Less invasive implantation of HeartWare left ventricular assist device, Multimedia Manual of Cardiothoracic Surgery 11 (July) (2014), http://dx.doi.org/10.1093/mmcts/mmu008 (Print 2014).
[12] D.J. La Par, J.R. Gillen, I.K. Crosby, et al., Predictors of operative mortality in cardiac surgical patients with prolonged intensive care unit duration, Journal of the American College of Surgeons 216 (2013) 1116–1123.