

POSTOPERATIVE MANAGEMENT OF LVAD PATIENTS: **THE ROLE OF ECHOCARDIOGRAPHY**

Case Study:
Elisabeth Hospital Essen
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Further. Together

CASE STUDY: ELISABETH HOSPITAL ESSEN; ESSEN, GERMANY

CASE AT-A-GLANCE

Gender: Male
Age: 60 years old
Diagnoses: Nonischemic cardiomyopathy (NICM), NYHA Class IV
Comorbidities: COPD II, Chronic Kidney Disease
Treatment Approach: HVAD™ for BTT
Treatment Facility: Elisabeth Hospital Essen; Essen, Germany

CASE HISTORY

As previously discussed in 'HeartWare Case Study: LVAD Therapy, The Role of Echocardiography', a 60-year-old male patient with advanced NYHA Class IV heart failure (HF) secondary to a NICM was referred by our institution to an implanting center for HVAD implant as a bridge to heart transplantation. The patient was then transferred back to our institution following successful implant for follow-up care.

His preoperative echocardiography (ECHO) had shown severely impaired left ventricular (LV) function (EF 10%) with LV dilation (LVEDD 72mm), moderate mitral regurgitation (MR), moderate tricuspid regurgitation (TR), dilated RA and RV, moderately impaired RV function (FAC 26%, TAPSE 12mm, S' 10 cm/s, TEI Index 1), as well as signs of pulmonary hypertension.

SHORT-TERM FOLLOW UP

In the postoperative setting, ECHO is used to confirm the correct position of the LVAD pump, volume management, and assist with trouble shooting in the setting of hemodynamic instability. Correct LVAD position has been defined as the inflow cannula being parallel with the intraventricular septum, directed towards the mitral valve¹.

In the setting of hemodynamic instability, our institution follows the diagnostic algorithm outlined in Figure 1.

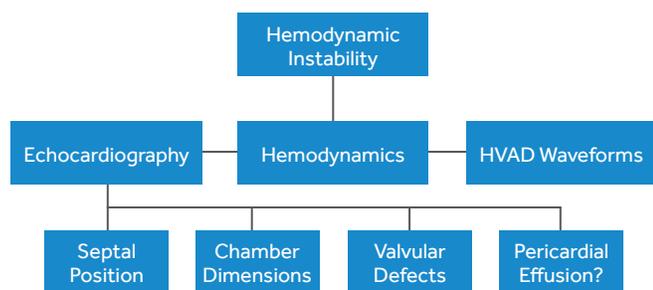


Figure 1: Diagnostic algorithm in the setting of hemodynamic instability in the postoperative setting

In this case, the patient had an uncomplicated postoperative course until the third day when he required increasing catecholamines. His HVAD System waveform displayed low pulsatility without signs of suction and an ECHO revealed collapsed left-sided chambers with the intraventricular septum shifted leftward, indicating hypovolemia. The patient was treated with a temporary decrease in HVAD speed as well as optimizing his volume status and his symptoms improved quickly. In this setting

of hemodynamic instability and reduced pulsatility of the HVAD waveform, there are several clinical scenarios that can be excluded, such as tamponade and right heart failure, utilizing ECHO. The following table (Table 1) sums up the differential diagnostic algorithm used by our institution for major complications in the postoperative setting.

Hemodynamics	Avg HVAD Flow	ECHO	Diagnosis
↓ Filling Pressures	↓	↓ LVEDD ↓ RVEDD IVS neutral / leftward	Hypovolemia
↑ CVP ↓ LV filling pressure	↓	↑ RVEDD / RA ↓ LVEDD IVS leftward	RHF
Equalizing left and right heart pressures	↓	General / local compression Pulmonary Edema IVS leftward	Tamponade
↑ LV Filling Pressure ↑ Ao pulse pressure	↑	↑ LVEDD IVS central / rightward AR	Aortic Regurgitation
↑ Filling Pressures	↓	↑ LVEDD IVS rightward AV opening (possible) MR (possible)	Occlusion
↑ Filling Pressures	↑	↑ LVEDD IVS rightward AV opening (possible) MR (possible)	Thrombus
↑ LV Filling Pressure ↑ Ao Pulse Pressure	↓	↑ LVEDD IVS rightward AV opening (possible) MR (possible)	Low Set RPMs

Table 1. Differential Diagnosis for major complications with HVAD patients in the postoperative setting. LVEDD: left ventricular end-diastolic diameter, RVEDD: right ventricular end-diastolic diameter, IVS: intraventricular septum, AV: aortic valve, MR: mitral regurgitation

LONG-TERM FOLLOW UP

After discharge from our center, follow up TTE is performed, at a minimum, every 4 weeks for the first 3 months post-implant and then every 3 months thereafter. The TTE includes the PLAX, PSAX, apical 4CH, 5CH, 2CH as well as the subcostal and suprasternal view. Outflow graft visualization can sometimes be evaluated via the right-parasternal view. Due to the location of the inflow cannula in the LV apex, standard views may not be feasible and an individual approach, utilizing non-standard views, may be necessary². Besides the TTE data, VAD type, pump speed, power, and flow should be documented. Detailed documentation of the examination, including deviations from the standard approach, is essential for reliable long-term follow up. Further evaluation with TEE or other modalities such as cardiac CT may be necessary in the setting of abnormalities.



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Assessment of the LV

A standardized evaluation of left heart dimensions per international recommendations⁴ along with position of the interventricular septum in serial examinations for comparison to previous measurement is essential. Parasternal long axis is the best and most reproducible way to assess left ventricular diameter⁵. In our experience, serial measurements of LVEDD as well as EPSS (E-point septal separation) are important markers for sufficient unloading of the LV⁵. Our patient presented a slight reduction in LVEDD (66mm) as a marker for sufficient unloading of the LV. Generally, a decrease in LVEDD of approximately 15% within the 3 months after implantation is normal⁵. Detection of left ventricular ejection fraction is not valid in LVAD patients due to non-physiologic filling although a value can be considered as a surrogate for worsening LV function or LV recovery^{1,5}. In patients with a poor apical window, alternate methods such as FAC or LV fractional shortening may be applicable to quantify LV function⁵.

Assessment of the RV

As described in the preoperative case study, a detailed right heart evaluation using RIMP, TAPSE, S', and fractional area change (FAC) is recommended. A decrease of the FAC by 10% relative to the preoperative assessment is highly indicative of RHF¹. To quantify tricuspid regurgitation, qualitative as well as quantitative approaches are feasible. VC is a common, semi quantitative parameter for further assessment, particularly to distinguish between moderate and severe TR³. The ratio of the TR jet area and the right atrial (RA) area is another quantitative approach¹. Estimation of systolic pulmonary pressure as described in the preoperative case completes evaluation of the right heart.

In our patient, the right heart remained dilated and was unchanged from the preoperative assessment: RVED 58mm, RA 24cm², RV/LV-Index 0.88. Further dilation relative to the preoperative evaluation may be considered an early warning sign.

Aortic Valve

Aortic valve (AV) opening in patients with LVADs depends on multiple factors such as pump speed and intrinsic LV function. The best way of assessing AV opening is by using slow M-Mode sweep and categorizing it into opening every beat, opening intermittently, or closed throughout the cardiac cycle. In a fast M-Mode sweep, the duration of AV-opening should be documented. An increase in duration may indicate increased intrinsic LV function, LV overload, or device malfunction⁵. Newly onset, greater than mild AR is seen in 11% of patients after 6 months of VAD therapy with general worsening over time with 51% incidence after 18 months⁶. Whenever feasible, quantitative assessment using proximal isovelocity surface area (PISA) is also recommended¹. If PISA and pressure half time (PHT) are not feasible due to continuous flow and lack of aortic valve opening, an aggregate assessment using the following parameters is recommended: duration of aortic regurgitation (AR), AR jet/LVOT ratio, vena contracta, and LV dimensions. A quantitative approach is also available⁵.

Our patient showed a permanent closure of the valve with trace continuous AR despite adjusting the pump speed. Vena contracta measured 1 mm. Table 2 shows reference values for aortic regurgitation as well as other common valvular defects per international recommendations³.

Mitral Valve

In the case of secondary mitral regurgitation, unloading the LV after VAD implant will result in an improvement of valvular function and is of less concern in the postoperative setting. Insufficient unloading of the LV or primary MR may result in MR while on LVAD support and can result in worsening right heart function.

Mitral regurgitation			
	I°	II°	III°
Vena contracts (mm)	< 3	4 - 7	> 7 (biplan > 8)
LA Volume	Normal	<36ml/m ² / <30cm ²	>36ml/m ²
EORA (cm ²)	< 0,20	0,20 - 0,39	> 0,40
R Vol (ml)	< 30	30 - 59	> 60
S/D (PV)	> 1	< 1	< 1/ reversal
Mitral stenosis			
	I°	II°	III°
MVA (cm ²)	> 1.5	1.0 - 1.5	< 1.0
Pmean (mmHg)	< 5	5 - 10	> 10
sPAP (mmHg)	< 30	30 - 50	> 50
Aortic regurgitation			
	I°	II°	III°
Vena contracts (mm)	< 3	3 - 5	≥ 6
Jet width (% LVOT)	< 25	> 25	> 65
PHT (ms)	> 500	200 - 500	≤ 200
EORA (mm ²)	< 10	10 - 29	≥ 30
RV Vol (ml)	< 30	30 - 59	≥ 60
Aortic stenosis			
	I°	II°	III°
Vmax (m/s)	> 2.5	3.0 - 4.0	≥ 4.0
AVA (cm ²)	> 1.5	1.0 - 1.5	< 1.0
Pmean (mmHg)	> 10	20 - 40	≥ 40
Tricuspid regurgitation			
	I°	II°	III°
Vena contracts (mm)		< 7	≥ 7
Hepatic veins	S-dominant	S-blunting	Reversal
PISA (mm)	< 5	6 - 9	> 9
EROA (cm ²) / R-Vol (ml)			> 0,4/ >45

Table 2. Shows reference values for valvular defects (non-LVAD patients)

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Inflow and Outflow Conduits

The position of the inflow cannula can be best assessed the parasternal long-axis and apical 4CH views. The cannula should parallel the ventricular septum and point towards the mitral valve. Correct alignment of the cannula is important to avoid obstruction of the inlet by the ventricular walls which can lead to ventricular suction and arrhythmias. Color flow and spectral Doppler may be feasible to assess flow but it can be difficult due to artifact.

Visualization of the outflow cannula can be challenging and is highly dependent on the surgical approach and there is a lot of interindividual variability. An atypical, usually high parasternal long axis view or right parasternal view are two possible ways to demonstrate and assess end-to-side anastomosis of the outflow graft and the ascending aorta.

TEE Assessment

TEE evaluation in LVAD patients is necessary whenever echocardiographic findings in TTE suggest abnormalities such as suspicion for clots, new valvular defects, and shunts. In patients with poor acoustic window a transesophageal approach may also be considered.

Conclusion

The patient in this case has been on HVAD support for 8 months now. Within this period, echocardiographic findings have remained unchanged. So far, he hasn't shown signs of RHF and, as mentioned, his parameters have remained stable over time. AR hasn't worsened even though the aortic valve still doesn't open at all. Routine follow-up examinations are still scheduled every 3 months.

References

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Brief Statement: HeartWare™ HVAD™ System

Indications

The HeartWare™ Ventricular Assist System is indicated for use as a bridge to cardiac transplantation in patients who are at risk of death from refractory end-stage left ventricular heart failure. The HeartWare System is designed for in-hospital and out-of-hospital settings, including transportation via fixed wing aircraft or helicopter.

Contraindications

The HeartWare System is contraindicated in patients who cannot tolerate anticoagulation therapy.

Warnings/Precautions

Proper usage and maintenance of the HVAD™ System is critical for the functioning of the device. Never disconnect from two power sources at the same time (batteries or power adapters) since this will stop the pump, which could lead to serious injury or death. At least one power source must be connected at all times. Always keep a spare controller and fully charged spare batteries available at all times in case of an emergency. Do not expose batteries to excessive shock or vibration since this may affect battery operation. Do not grasp the driveline cable as this may damage the driveline. Do not pull, kink or twist the driveline or the power cables, as these actions may damage the driveline. Special care should be taken not to twist the driveline including while sitting, getting out of bed, adjusting the controller or power sources, or when using the shower bag. Do not disconnect the driveline from the controller or the pump will stop. If this happens, reconnect the driveline to the controller as soon as possible to restart the pump.

Potential Complications

Implantation of a Ventricular Assist Device (VAD) is an invasive procedure requiring general anesthesia, a median sternotomy, a ventilator and cardiopulmonary bypass. There are numerous risks associated with this surgical procedure and the therapy including but not limited to, death, stroke, device malfunction, peripheral and device-related thromboembolic events, bleeding, infection, hemolysis and sepsis.

Refer to the "Instructions for Use" for detailed information regarding the implant procedure, indications, contraindications, warnings, precautions and potential adverse events prior to using this device. The IFU can be found at www.heartware.com/clinicians/instructions-use.

Caution: Federal law (USA) restricts these devices to sale by or on the order of a physician.