Using Transesophageal Echocardiography (TEE) to Detect VAD Complications

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At the conclusion of this lecture, the participant should be able to:

1. Review the echocardiographic assessment of patients following VAD placement.
2. Describe how echocardiography can assist in the management of hemodynamic compromise in the VAD patient.
3. Discuss the use of two-dimensional and Doppler echocardiography in differentiating normal from abnormal function of a newly implanted VAD.

Echocardiographic assessment following LVAD implantation is imperative, as complications can arise. Left ventricular assist devices (LVADs), have emerged as a feasible option for improving quality of life and survival in patients with end-stage heart failure. The most common indications include bridge to transplant (BTT), destination therapy (DT) and bridge to recovery (BTR). Echocardiography is an important imaging modality used not only in the diagnosis of heart failure, but in the intraoperative implantation and management of LVADs. Echocardiographers must develop a systematic approach to echocardiographic assessment, including post-implantation assessment.

Post-Implantation Exam

The key components in this evaluation are assessment of proper cannula positioning within the cardiac chambers, determination of adequate flows within the cannula using Doppler imaging, obtaining adequate chamber decompression and excluding the presence of air within the circuit. All intraoperative echocardiographers are familiar with de-airing the heart prior to separation from CPB. In VAD patients, however, this takes on a new level of importance and usually takes significantly longer. LVADs can generate negative intraventricular pressure. As a result of this phenomenon, it is possible to
entrain extracardiac air; particularly if the RV is not delivering enough pre-load. If air enters the RCA, compromising RV function and exacerbating the lack of LV pre-load.

**Cannula Positioning**

The inflow cannula of an LVAD is usually well-imaged with TEE. Proper apical placement of the inflow cannula should be directly beneath the mitral valve and not abut any of the LV walls. Wall impingement can compromise pump function by obstructing blood flow. Most surgeons will specifically direct the cannula away from the interventricular septum to minimize RV dysfunction. Color flow Doppler within the inflow cannula should demonstrate laminar flow. Velocities within the cannula can be measured using CW Doppler, and are typically in the range of 1-2 m/s.(6)

The outflow cannula of an LVAD consists of a length of graft material anastomosed to the proximal ascending aorta. While not as well visualized as the inflow cannula, Doppler interrogation of outflow velocities will also typically be in the 1-2 m/s range. Higher velocities immediately post-implantation should raise concern of graft kinking. CT is the modality most commonly used to evaluate outflow cannula function in the post-operative period.

**Hemodynamics post implantation**

Besides checking LVAD cannula position, the immediate post-implantation examination should be used for the monitoring of volume status and RV function. Inadequate filling of the pump results in a “suction event,” whereby the LV collapses around the inflow cannula. Below is an example of a suction event.

*Suction event; adapted from (4)*
The two main causes of “suction events” in the immediate post-CPB period are hypovolemia and severe RV failure. A fluctuating interatrial septum, a collapsible IVC, and relatively small RV and LV chambers indicate hypovolemia. Alternatively, a dilated, hypocontractile RV, leftward bowing of the interventricular septum, and increasing amounts of tricuspid regurgitation all point toward worsening RV failure. Because the LV’s increased output creates more venous return to the RV, the use of inotropes is common following LVAD placement. Extended periods of right heart support (2-3 weeks), including use of temporary RVADs, occurs in 10-20% of LVAD implantations.(7)

Doppler Imaging

Following assessment of satisfactory cannula anatomic positioning, Doppler imaging (including color and spectral Doppler) is used to determine adequate flows into and out of the cannula. Color Doppler imaging is used to assess appropriate flow into and out of a cannula, as well as determine whether any part of the cannula is obstructed. Continuous wave Doppler can then be used if the ultrasound beam can be aligned with the flow. The type of signal obtained (for both color and spectral Doppler) is dependent upon which type of VAD device is inserted. A pulsatile device will result in an intermittent flow profile (usually asynchronous with the ECG rhythm), while a continuous flow pump will provide a lower velocity continuous signal. However, there may be a degree of pulsatility to the continuous flow outflow signal due to variation in filling if there is native heart contraction as well.

There is a scarcity of data that has been published regarding normal reference ranges for VAD cannula Doppler flow assessment. Obtaining baseline hemodynamic data can help in the serial evaluation of cannula flow. The actual velocities obtained can vary depending upon the cannula diameter, preload, afterload and contribution of native cardiac function. Inflow velocities into a VAD cannula are usually below around 2 meters/second (11). Velocities above this usually indicate pathology within or around the inflow cannula, such as partial obstruction with a thrombus or impingement from a surrounding structure such as a papillary muscle or atrial wall.

Doppler imaging of the outflow cannula is also important. It enables assessment of satisfactory flow out of the VAD. Due to the higher velocities present, continuous wave spectral Doppler is often needed to interrogate these flows. Again the normal velocities can vary depending upon the type of pump used and the loading conditions. Outflow from a continuous flow device has a continuous flow pattern with a flow velocity of usually less than 2 meters/second (11). Outflows from a pulsatile pump can be higher, with velocities up to 4 meters/second (11). However, outflow velocities of 2
meters/second are normal for the Heartmate VE or Heartmate XVE. The outflow velocities were lower in those patients who had inflow valve regurgitation (12). Higher flows than this usually indicate obstruction within the outflow cannula, usually by a thrombus. Additionally, external compression or kinking of the cannula can also cause an increased velocity detected on spectral Doppler imaging.
References


