Mending broken hearts with LVADS

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HEART FAILURE AFFECTS over 5 million Americans, and nearly 550,000 new cases are diagnosed each year. Ten of every 1,000 patients over 65 will suffer heart failure. One of every eight death certificates list heart failure as the cause. Alarmingly, 80% of men and 70% of women younger than 65 years old diagnosed with heart failure will die as a result of the condition within 8 years. In 2006, more than 1 million patients had the diagnosis of heart failure noted as one of their health conditions. This large patient population places significant financial strain on the healthcare system. Direct and indirect costs associated with heart failure led to about $37.2 billion in costs in 2009.

Left ventricular assist devices (LVADs) can improve survival and quality of life in patients with end-stage heart failure. Patients who require heart transplantation but who have a poor predicted survival to transplant can undergo LVAD implantation as a bridge to transplantation. At the time of transplant, the native heart and LVAD are removed and replaced by the donor organ. About 2,200 cardiac transplantations are performed annually in the United States. Many more patients could benefit, but transplantation is limited due to a lack of donor organs.

An LVAD may also be placed in a patient in cardiogenic shock and be removed after the shock has resolved. This indication is termed bridge to recovery. Patients with precardiotomy cardiogenic shock or those in postcardiotomy cardiogenic shock may benefit from LVAD placement until the heart has recovered enough function that support is no longer required.

An LVAD also can be used as destination therapy, an indication that’s been growing in prevalence due to the success shown in the Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure Trial. Patients with LVADs as destination therapy typically have end-stage heart failure and poor predictive survival. These patients are also ineligible for transplantation, usually due to advanced age, significant comorbidities, or psychosocial issues contraindicating transplant. Patients undergo LVAD implantation and live the rest of their lives with the device permanently in place.

Of the many LVADs available today, device selection primarily depends on the indication. For instance, the surgeon or interventionalist may choose a short-term, percutaneous device for a patient thought to be implanted as a bridge to recovery. These devices can be placed through peripheral blood vessels, similar to the placement of a central line. A sternotomy isn’t required for implant or explant and the procedure can be performed outside the OR in emergent situations.

Long-term LVADs are traditionally implanted through a median sternotomy with the use of cardiopulmonary bypass (CPB), although newer devices and greater experience have allowed some devices to be placed through a thoracotomy.

First-generation LVADs are pulsatile devices that mimic the native heart’s natural pulse. These devices pump in beats-per-minute with a set stroke volume unique to each device. The device generates a flow, or VAD cardiac output, in L/minute. Newer generation devices provide continuous flow through axial or centrifugal motions. The device dynamics differ because the pump doesn’t create a systole or diastole. Volume that enters the LVAD is circulated continuously.

Patient management differs slightly depending on whether LVAD flow is pulsatile or continuous. This article focuses on the postoperative management of long-term LVAD patients (both pulsatile- and continuous-flow devices), illustrating key aspects of both inpatient and outpatient management so you can provide optimum patient care.
Preoperative assessment
Perhaps the greatest factor affecting postoperative success and survival is the preoperative assessment. The typical LVAD candidate should have a New York Heart Association class III or IV or American College of Cardiology/American Heart Association Stage C or D heart failure symptoms, an ejection fraction less than 25%, significant functional limitation for at least 90 days despite the use of maximal medical therapy, functional limitations with a cardiopulmonary exercise test with a peak oxygen consumption value less than 14 mL/kg/minute, or be inotrope-dependent. These factors support the need for a long-term versus a short-term device.

Patient risk factors that need further assessment before LVAD placement include chronic kidney disease, coagulopathy, liver dysfunction, malnutrition, right ventricular (RV) dysfunction, and significant pulmonary dysfunction. Identifying these risk factors will help healthcare providers address potential issues to optimize patient health before surgery. Preoperative optimization will help postoperative recovery.

Postoperative management
Postoperative patient management requires an understanding of LVAD function and how it relates to patient care. This includes how the LVAD may affect hemodynamics, optimizing preload and reducing afterload, assessing end-organ perfusion, and using echocardiography to assess LVAD performance.

• Optimal hemodynamics. The goal of VAD therapy is to improve end-organ perfusion and resolve the shock state, if applicable. LVAD flows should be titrated to obtain optimal hemodynamics for each patient based on traditional measures of cardiac index (CI) and mean arterial pressure (MAP). Optimal hemodynamic parameters are a central venous pressure (CVP) of 10 to 20 mm Hg, systolic BP of 100 to 140 mm Hg (pulsatile-flow devices), MAP of 60 to 90 mm Hg (continuous-flow devices), CI of 2.2 L/minute/m² or greater, and urine output greater than 1 mL/kg/hour.

• Preload and afterload. LVAD flow is a function of preload and afterload. An LVAD is dependent on preload and sensitive to afterload. The greater the volume presented to the device, the greater the amount of flow it can generate. Reasons for decreased preload may be due to hypovolemia related to third-spacing, bleeding, tamponade, lack of vascular tone, inflow cannula positioning leading to decreased drainage from the left ventricle (LV) into the device, or RV dysfunction. By diagnosing and treating the cause of a decrease in preload, you can help optimize LVAD performance.

Conversely, the LVAD won’t be able to effectively pump against the increased resistance created by increased afterload. This increased systemic vascular resistance means that flow through the LVAD will decrease. Administer afterload-reducing agents or wean vasoconstrictive agents as tolerated and prescribed to help increase LVAD flow.

• End-organ perfusion. Both pulsatile and continuous-flow LVADs can lead to a decrease in pulmonary capillary wedge pressure (PCWP), increased CI, and help maintain or improve renal and hepatic function.

Pulmonary function may be affected by the congestion seen in heart failure patients. Increasing forward flow through the use of an LVAD will help relieve congestion, decrease shortness of breath, and ultimately improve functional capacity. During LVAD implantation, assess for a patent foramen ovale (PFO), which may be present in up to 25% of the general population. Under normal intracardiac pressures, blood doesn’t cross the PFO due to higher left-sided than right-sided pressures. By unloading the LV with an LVAD, the pressure difference changes, resulting in a decrease in left-sided pressure. This lets deoxygenated blood cross the PFO and circulate peripherally. Diagnosis can be made intraoperatively with the use of a transesophageal echocardiogram (TEE) and the injection of agitated 0.9% sodium chloride solution. Bubbles seen in the LV after injection of the 0.9% sodium chloride solution indicate the presence of a PFO that requires closure. If assessment doesn’t occur in the OR, consider the presence of a PFO if your patient has hypoxia despite adequate LVAD flows and a clear chest X-ray.

Renal dysfunction is common in patients with cardiogenic shock and advanced heart failure. Rising renal function studies often indicate poor cardiac perfusion of all organs. Many of these patients require ultrafiltration or aggressive diuresis before LVAD implantation to relieve volume overload. Assessing renal function studies along with urine output postoperatively will help guide LVAD performance. The increased CI created with the help of the LVAD should lead to greater renal perfusion. In the initial postoperative period, a patient who was in cardiogenic shock preoperatively may have oliguria or anuria. Optimizing fluid status and providing a greater preload to the LVAD will increase organ perfusion and normalize renal function.

Many patients have gastrointestinal (GI) issues after cardiac surgery. Patients with LVADs may experience GI abnormalities due to the presence of the device—for example, elevated bilirubin levels due to hemolysis caused by the device. A VAD can create negative pressure,
or a vacuum, that’s used to fill the device. In patients with low preload or turbulent blood flow, this vacuum can lead to a shearing of blood vessels, creating hemolysis.\(^9\) Maintaining adequate preload and ensuring the proper alignment of the infl ow cannula at the time of surgery will help reduce the potential for hemolysis. Liver function studies may be elevated preoperatively due to cardiogenic shock or a persistent low-flow state as seen in end-stage heart failure. These levels should begin to normalize shortly after LVAD implantation.\(^9\)

Continuous-flow LVADs may cause arteriovenous malformations leading to GI bleeding, which could be due to a decrease in pulsatile blood flow. This lack of pulsatility can also lead to an acquired von Willebrand condition contributing to GI bleeding. Reducing the pump speed to allow more pulsatility and discontinuing anticoagulation, either temporarily or permanently, has been shown to decrease or eliminate the bleeding.\(^6\)

Neurologic complications can be the most devastating risk of LVAD therapy. Due to the large surface area of artificial material that the blood contacts, there is a potential for thrombus formation. Anticoagulation can be accomplished using aspirin, warfarin, or other antiplatelet therapies. Patient presentation preoperatively and intraoperative management may also affect postoperative neurologic status. A low-flow state as experienced in cardiogenic shock can lead to poor cerebral perfusion affecting neurologic status postoperatively. Rapid diagnosis and treatment of hypoxia or an embolic event can minimize neurologic dysfunction.

**Echocardiography**

Echocardiography has always played an important role in the management of patients with LVADs, but with the growing use of continuous-flow devices, its role is expanding. Intraoperative TEE has traditionally been used to assess LVAD cannula placement with pulsatile devices. Echocardiography can also be used to assess for cannula migration and cannula obstruction due to thrombus or positioning against a wall of the heart. The risk of complete unloading of the LV with a pulsatile device is limited due to the LVAD diastolic filling phase. With continuous-flow devices, the LVAD is constantly unloading the LV without a diastolic phase. Minimal changes in preload or pump speed can dramatically affect LV dynamics. Because of this, echocardiography is used when manipulating device settings.\(^6,12\) Some institutions have created protocols to consistently assess LVAD settings using echocardiography in the inpatient and outpatient settings.\(^6\)

Routine echocardiography should include assessment of RV function, cannula position in the LV, aortic valve opening in continuous-flow devices, the presence of mitral regurgitation, and an estimation of PCWP. This information can assess LVAD effectiveness and become the basis for pump speed changes in continuous-flow devices.

**Complications**

Any cardiac surgical procedure may result in bleeding complications (especially with the use of anticoagulation), RV dysfunction, dysrhythmias, and infection. This section describes the significance of these complications in relation to LVAD therapy.

- **Bleeding and anticoagulation.** Most LVADs are implanted with the use of CPB, which can contribute to clotting factor dysfunction and depletion and increase the patient’s risk of postoperative bleeding. Patients who are hypothermic following surgery are also prone to bleeding. Proper rewarming in the OR and in the ICU will help return a patient to normothermia, reducing the risk of bleeding.

Patients with advanced heart failure may have coagulopathies. Due to cardiogenic shock or long-term end-stage heart dysfunction, patients may have some level of liver dysfunction leading to a decreased ability to produce the appropriate clotting factors. Assess the patient’s need for transfusion of whole blood or fresh frozen plasma, or administration of medications that reverse bleeding, depending on the nature of the coagulopathy.

Bleeding can also lead to cardiac tamponade. Diagnosing tamponade early through hemodynamic changes, low LVAD flows, chest X-ray, or echocardiography can lead to prompt treatment and reoptimization of LVAD function.

One of the best ways to prevent bleeding and tamponade is meticulous surgical care. Taking time to ensure that all possible areas of bleeding have been addressed before closing the chest will decrease the possibility of the patient needing to return to the OR to treat bleeding from surgical sites.

Anticoagulation should be started early in the postoperative period to prevent a thromboembolic event. Generally, once postoperative bleeding has subsided (chest tube output less than 1 mL/kg/hour, normalized coagulation studies), anticoagulation is initiated. This may be in the form of heparin, warfarin, or argatroban (for patients at risk for heparin-induced thrombocytopenia). Activated partial thromboplastin time is maintained between 60 and 80 seconds, with a goal international normalized ratio (INR) of 2 to 2.5. Special consideration
should be given to patients at risk for hypercoagulability. Testing for heparin-induced antibodies, protein C and protein S deficiencies, and antithrombin III deficiencies may help diagnose this condition. If a patient is identified as hypercoagulable, an anticoagulation regimen consisting of heparin, argatroban, aspirin, warfarin, clopidogrel, or dipyridamole may need to be initiated sooner than normal.3 Drug combinations vary based on the device used, the preference of the surgeon or cardiologist for I.V. anticoagulation, and the patient’s clinical condition.

The goal of anticoagulation is to prevent thrombus formation while avoiding hemorrhage. INR and activated partial thromboplastin time levels should be individualized for each patient, taking into account the patient’s anticoagulation history, initial presentation before implantation, and the LVAD implanted. New data suggest lowering the goal INR to 1.5 to 2.5 for long-term continuous-flow LVAD patients, because of the low rate of thrombus and the risk of hemorrhage.13 Consult the surgeon and cardiologist to establish an anticoagulation goal.

• RV dysfunction. In a patient with an LVAD, the heart becomes dependent on the RV to function properly enough to provide an adequate preload to the LVAD. Preoperative testing should include evaluation of the RV. Placement of an LVAD leads to the unloading of the LV, but pulling volume rapidly out of the LV into the LVAD can cause a shifting of the interventricular septum. Shifting of the septum can lead to residual RV dysfunction.12 Adjusting either the vacuum the LVAD uses to pull volume from the LV or the speed of a continuous-flow device will help alleviate the septal shift and improve RV function. With continuous-flow devices, LVAD speed adjustments are usually performed with echocardiogram assessment to assure there is no septal shifting with optimal LV unloading.12

In the initial postoperative period, a patient may experience fluid shifting or may receive volume in the form of blood or blood products, which leads to an increase in the CVP. If the RV isn’t healthy enough to handle this increase in intravascular volume, LVAD flows will begin to suffer. Treatment of RV dysfunction may include initiation of inotropic therapy, such as milrinone or dobutamine, use of pulmonary vasodilators to decrease RV afterload, ultrafiltration or hemodialysis to remove excess volume, or, in extreme cases, placement of an RV assist device. In patients with biventricular heart failure, LVAD therapy alone is contraindicated. In the event of biventricular failure, the patient may be eligible for biventricular assist device (BiVAD) support. In this case, an RVAD and an LVAD are used to support both ventricles. Some devices can be used in either the RVAD or LVAD position; others can only be used to support either the RV or LV. If a patient who receives an LVAD-only device needs additional RV support, a separate RVAD can be used for short-term or long-term support.

• Dysrhythmia. Ventricular tachycardia or atrial fibrillation may lead to a decrease in LVAD flows, but unlike an intra-aortic balloon pump, an LVAD isn’t triggered by the heart’s native rhythm, and continues to pump volume despite the rhythm. Flows may be lower because of the effects the dysrhythmia has on preload. If the unsupported RV is affected by the dysrhythmia and unable to deliver volume effectively to the LVAD, flows will decrease. Diagnosing the dysrhythmia and treating it effectively will ultimately improve LVAD flows. Dysrhythmia treatment may include medications to control the rhythm, pacing to override the dysrhythmia, or electrical cardioversion or defibrillation. Some LVADs require manipulation before a shock is delivered; other devices have been built to withstand these procedures. Follow the LVAD manufacturer’s instructions for defibrillation or cardioversion.

Continuous-flow devices can create a suction condition that causes the walls of the LV to collapse when there is little or no volume in the LV. This suction event can be arrhythmogenic. To treat it, administer fluid to decrease the LVAD speed and increase preload.6

• Infection. Preventing infection, a major cause of morbidity and mortality, is one of the main goals of long-term LVAD therapy.14 Infection can occur at the percutaneous line site, within the pocket created for the LVAD to rest, or within the device itself (VAD endocarditis). Preoperative and postoperative antibiotic regimens should be established to prevent infection. Infections starting at the percutaneous site may lead to pocket infections and ultimately device infection. VAD endocarditis is the most serious of these infections and may require replacing the device or urgent cardiac transplantation.14 Meticulous surgical care during device implantation and attention to the percutaneous line postoperatively are important measures in infection prevention.14

To minimize the risk of infection, remove and replace all preoperative invasive lines if necessary. This should be done either immediately postoperatively if possible, or if infection is suspected. Antibiotic treatment should be initiated in cases of leukocytosis and fever. Wound, blood, urine, and sputum cultures should be obtained to identify the source of infection. Most VAD infections are due to Gram-positive organisms. Gram-negative infections are also commonly seen in VAD...
therapy and result in a greater risk of mortality when compared with Gram-positive infections. The highest risk of mortality results from fungemia.15 Until the culprit organism is identified, implement broad-spectrum antibiotic coverage. Early endotracheal extubation and meticulous wound care around the percutaneous line also will help prevent infection.14 Hospital personnel, patients, and their families should know sterile techniques for dressing the wound. This process is continued as long as the LVAD is in place. Take care to avoid manipulating the percutaneous line, especially once it’s begun to heal. Teach patients not to place stress on the line, which will disrupt the skin surrounding the wound, leading to a potential infection. Also teach patients to use abdominal binders or other stabilization devices to limit accidental manipulation of the line. Explain to patients and families how to recognize signs and symptoms of infection and tell them to report these findings immediately.

Pulsatile-flow devices are generally larger devices with large percutaneous exit lines. Continuous-flow devices are generally smaller and have a smaller percutaneous line. The smaller line is beneficial for infection prevention.11

Rehabilitation
Rehabilitation of the patient with an LVAD requires attention to nutrition and focuses on increasing activity. Work in collaboration with multiple disciplines to optimize patient health and recovery from surgery.

- Nutrition. Cardiac cachexia is often present in patients with advanced heart failure.14,16 As appropriate, administer tube feedings, parenteral infusions, or nutritional supplements to improve patient nutritional status. Enteral feeding is the preferred option.16 Frequent assessment of albumin and prealbumin levels will help direct feedings and supplementation to achieve nutrition goals.

Proper nutrition also plays an important role in wound healing. Starting enteral or parenteral feedings in the initial postoperative period is essential to optimize nutrition. Due to LVAD placement in a preperitoneal pocket in the left upper quadrant, the device itself may put pressure on the stomach causing the patient to feel full.16 Smaller, more frequent meals are encouraged once the patient is tolerating oral intake.

- Activity. Patient activity should be increased as soon as tolerated following LVAD implantation. Activity may include range of motion exercises, getting out of bed into a chair, or ambulating with assistance. Physical therapists and occupational therapists are important members of the treatment team. A physical and occupational therapist will work with patients to identify strategies to make transitioning into the home environment easier.

Discharge preparation and outpatient management
Outpatient management of the LVAD patient is evolving as the number of LVAD patients, particularly the destination therapy population, continues to grow. As LVAD therapy becomes more of an accepted treatment option, and as the awareness of its benefits increases in the healthcare community, the number of patients referred for treatment will likely continue to rise.

Before discharge, patients and family members must be able to demonstrate competency with device management and troubleshooting. Teach the patient about the components of the LVAD (batteries, primary console, and monitor) and how to recognize and address any malfunctions in device performance.

The referring physician and primary care provider will be notified that the patient has received LVAD therapy. Local emergency medical services (EMS) and the local ED are also notified in case the patient presents in an emergency scenario. The key device and physical exam information is also communicated to EMS personnel. Aside from medical personnel, local utility companies also should be notified. Because LVADs rely on electricity, through either charged batteries or direct connection to an outlet, the patient should be placed on a priority status in the event of a disruption in utility services.

During routine clinic visits, the patient’s anticoagulant medication or heart failure medications may need to be adjusted. In patients with continuous-flow LVADs, echocardiography plays a key role in managing their devices.

An evolving treatment option
Long-term LVAD therapy for patients with advanced heart failure can lead to a significant improvement in patient lifestyle. As this therapy becomes more accepted and recognized, nurses will become involved with LVAD patient care. These patients require lifelong care, not only for the LVAD but for other ailments as well. Understanding the function of the LVAD, how it can affect a physical exam, and key aspects to help the LVAD function optimally will help you provide quality patient care.

References


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