

## **Overview of Ventricular Assist Devices**

Susan Sample RN, MSN, CRNP  
Director of Nursing  
Lancaster General Hospital  
Lancaster PA

Objectives:

1. Describe the clinical indications for VAD therapy.
2. Compare and contrast pulsatile and axial flow VADs.
3. List three risk factors for development of post-operative infection.

Each year thousands of end-stage heart failure patients are dying due to lack of donor hearts available for transplant or to non-eligibility for transplant. Medical therapy has greatly improved over the last decade; however, there is no cure for heart failure. This continues to be an ongoing problem in our society as our population ages and our donor organs are scarce. Ventricular assist device (VAD) therapy may be a potential treatment alternative for those who have run out of medical options.

The historical indication for mechanical circulatory or VAD support has been as a bridge to transplant. In recent years the indications have expanded to include both support to recovery and destination therapy. Destination therapy is emerging as a popular option for patients who are not eligible for transplant, but who are looking for alternative options to prolong their life. The clinical indications for VAD therapy include one or more of the following: post cardiectomy failure, acute myocardial infarction, acute decompensated heart failure, myocarditis, uncontrollable ventricular arrhythmias and high risk cardiac operations. VADs can provide a safe and effective treatment for many of these disease states as either a short-term or a long-term therapy option.

This complex surgical procedure can provide ventricular support to the left ventricle with a left ventricular assist device (LVAD) which is the most common form of cardiac support. There are also devices that support the right ventricle with a right ventricular assist device (RVAD) and devices that support both sides of the heart (biventricular assist device [BiVAD]). Most patients can be maintained successfully with LVAD therapy alone; however those who have significant right ventricular failure or global cardiac dysfunction may require the additional support of an RVAD. The indications for biventricular support include renal failure, hepatic failure, acute respiratory distress syndrome (ARDS), uncontrolled arrhythmias, right ventricular or septal infarction, prolonged shock or multisystem organ failure.

#### Types of VADs

VADs may be pulsatile or non-pulsatile. The pulsatile pumps are the first generation of VADs and the ones that have the most extensive patient use. These pumps can be either pneumatic, run by air, or mechanical in nature. These pumps fill with blood and pump into the patient circulation through valves--much like the natural heart. These pumps may include the Thoratec Corporation's Heartmate XVE™ and Thoratec Percutaneous or Implantable VAD™, World Heart Corporation's Novacor LVAS™ and Abiomed's BVS 5000™ or AB 5000™.

The current focus with VAD therapy is the newer second generation technology which uses rotary or axial flow pumps. Although they are not approved yet by the FDA, they are showing promise in current human clinical trials. These are relatively small pumps that are implantable into the thorax and produce a low-pulsatile flow. They are small enough to be effective for a wide variety of body sizes, however they are powerful

enough to produce up to 10 liters of blood flow. These pumps include Thoratec Corporation's Heartmate II device™, Jarvic 2000™ and the MicroMed DeBakey VAD™. The third generation devices currently being developed are miniature centrifugal devices with a magnetically levitated bearing-less motor which extends pump life. An example of a third generation device is the Thoratec Corporation's Heartmate III LVAS™.

### Patient Selection

When selecting patients for VAD therapy, there are many variables that influence the outcome of the surgery. These pre-operative variables include: patient's age, promptness of implantation, degree of completed myocardial infarction, renal function, liver function, pulmonary status, neurological status, presence of malignancy and active infection. Patient selection can be the most difficult part of the implantation process. A VAD is indicated for NYHA Class IV heart failure patients; however, it is best to not wait until the patient exhibiting symptoms of end organ failure and cachexia. These late heart failure symptoms tend to be predictors of poor post-operative outcomes. Unfortunately, there is no standard approved screening system that exists for mechanical circulatory support. The hope for the future is for screening tools to evolve into a universal and comprehensive guide that will maximize the benefits of this therapy.

### Nursing Care

The peri-operative care of these patients is very complex. Prior to the surgical procedure it is important to prepare the patient and the family for what to expect from the device, how long the recovery period will be and the potential complications that can arise. Once the patient leaves the operating room, the team of nurses and physicians are

challenged to manage these patients in the intensive care unit. Some of the potential complications following VAD implantation are bleeding, infection, right heart failure (if the right side is not supported), pulmonary hypertension, systemic hypotension and arrhythmias.

Infection is still the most common complication after VAD implantation. Patients should receive IV antibiotic prophylaxis for 24-48 hours post-operatively. In addition, patients should be monitored closely for signs and symptoms of infection. It is vital to diagnose and treat infections early. Infection of the implanted pump or VAD exit sites can spread rapidly and be fatal if left untreated. Risk factors for developing post-operative infection include: prolonged hospitalization, prolonged intubation, indwelling catheters or invasive monitoring lines, pre-operative infection and co-morbid conditions. The co-morbidities that can increase infection risk are diabetes, malnutrition, multiple blood transfusions, multi-system organ failure and immunosuppression. Maintenance of a dry, sterile and occlusive dressing over the VAD exit sites is imperative. Of the utmost importance is a VAD immobilization binder to reduce the movement of any percutaneous leads or cannulae. Immobilization decreases movement, thereby increasing healing time and promoting good tissue growth around the exit sites. Other factors such as personal hygiene, oral care and comprehensive nutrition teaching are also helpful in the healing process.

There are some key principles to keep in mind when dealing caring for a patient with a VAD. It is important to differentiate between the mechanical function of the VAD and the physiological presentation of the patient. For example, the patient's heart rate on the ECG monitor will not match the patient's pulse. The pulse rate will be the beat rate

of the VAD; therefore, the pulse and ECG are asynchronous. In addition, the pulsatile VAD will pump slower with hypovolemia and increase speed as the volume status increases. Pulsatile VADs are volume driven and respond with rate adjustments to changes in preload or volume status.

The days and weeks preceding patient discharge should focus on rehabilitation. Physical therapy regimens should be designed to maximize the physical condition of the VAD supported patient. Daily and weekly therapy goals should be reviewed with the patient and family. Physical activity and good nutrition are essential to the rehabilitation process and a successful transition to home.

The hospital discharge and patient teaching is complex. Discharge planning should take place early in the post-operative course. Family and social support systems should be included in all aspects of the discharge planning and patient education process. Before discharge, patients and their caregivers need to learn how to change the VAD dressing, maintain the VAD equipment and troubleshoot VAD alarms. This process can take weeks to master depending on the learning capability of the patient and can be a daunting task. It is critical that patients receive both verbal, written and hands on teaching experiences. The patients will initially follow-up frequently in the office as an outpatient after discharge and over time can be more independent at home.

In conclusion, the future seems bright with the advances that we have seen in ventricular assist therapy. Ongoing clinical trials on smaller and more durable devices seem promising for future advances in heart failure management. The hope is to provide patients with safe and effective alternatives to improve their quality and quantity of life.

## **Right Ventricular Failure After Left Ventricular Assist System Implantation**

Nancy Scroggins, RN, MSN, CNS, CC, ACNP, CCRN  
St. Luke's Episcopal Hospital/ Texas Heart Institute, Houston Texas

Michelle L. Edwards RN, MSN, FNP, ACNP  
St. Luke's Episcopal Hospital/ Texas Heart Institute, Houston Texas

### Objectives:

- Describe the benefits of left ventricular assist systems (LVASs).
- Identify potential complications of LVAS implantation.
- Identify causes of right ventricular failure (RVF) post LVAS implantation.
- Discuss strategies for early recognition and optimal management of RVF.

### Introduction

Approximately 5 million people in the United States suffer from heart failure (HF). Despite advances in the medical management of HF and the substantial health care resources used to treat these patients, HF remains a major cause of morbidity and mortality, with a 5-year mortality rate of 50%. Treatment options approved by the Food and Drug Administration (FDA) for refractory end-stage HF are limited; these include cardiac transplantation and ventricular assist system (VAS) therapies used as either a bridge to transplantation or as destination therapy.<sup>1,2</sup>

According to United Network for Organ Sharing, there are approximately 3000 patients currently waiting for a donor heart.<sup>3</sup> As of March 2006, 324 patients received a donor heart in 2006. These statistics emphasize the shortage of available donor hearts for transplantation. Ventricular assist systems show promise as an alternative therapy for refractory HF, and are being implanted at many centers in the United States.

Ventricular assist systems have been shown to reverse ventricular remodeling and end organ(s) insufficiency, and improve patient's quality of life and New York Heart Association Class symptoms. In addition, VAS therapy can increase left ventricular chamber compliance, reduce myocardial damage, and reduce plasma concentrations of renin, angiotensin II, epinephrine, norepinephrine, vasopressin, interleukin-6 and interleukin – 8.<sup>4</sup> Examples of long-term devices include the Heartmate® XVE, Thoratec®, and Jarvik 2000 pumps. The Heartmate® XVE is the only device approved for both bridge to transplantation and destination therapy. While the Jarvik 2000 pump has shown great promise, its use remains investigational. Pump selection is based on degree of support (partial versus nearly complete left ventricular support), invasiveness of the device, patient mobility, patient size and anatomy, and indication.

#### Potential Complications Post-Left Ventricular Assist System Implant

There are potential complications that can occur post-implant. These include right ventricular failure (RVF), low cardiac output with decreased organ perfusion, infection, bleeding diatheses and disseminated intravascular coagulopathy, thromboembolic events, hemolysis, and pump failure. Right ventricular failure is a potential complication that occurs in approximately 30% of patients who receive an LVAS. In order to minimize the occurrence of RVF after LVAS implant, patient selection is extremely important. Patients who are at high risk pre-operatively for post-implant RVF include those with pulmonary hypertension and those with underlying biventricular failure.

#### Causes of Right Ventricular Failure

One cause of RVF is peri-operative bleeding or hemorrhage and the subsequent need for large volumes of blood product replacement. As a result of blood product transfusion, increased complement activation causes a significant increase in pulmonary vascular resistance (PVR). Pre-existing pulmonary hypertension with a transpulmonary gradient (TPG)  $>15$  mmHg (mean pulmonary artery pressure – pulmonary capillary wedge pressure) can lead to RVF after LVAS implant.

Acidosis ( $\text{pH} < 7.35$ ) can also lead to RVF. Clinical manifestations include hyperpnea (deep, pauseless breathing), decreased myocardial contractility, arrhythmias, hypotension, and pulmonary edema. Decreased contractility, arrhythmias, and pulmonary edema can also directly contribute to RVF.

Last, RV volume overload can cause RVF. This can be secondary to decreased pump flow or systemic volume overload.

#### Assessment of Right Ventricular Insufficiency

Careful attention to RV function post-implant is important. Physical examination, hemodynamic monitoring, pump flow monitoring, and echocardiography are useful tools to assist in diagnosing RV insufficiency and anticipating RV dysfunction such that corrective measures can be made. On physical examination, signs of RV insufficiency include peripheral or abdominal edema, positive jugular venous distension, positive hepatojugular reflex, and a systolic murmur of tricuspid regurgitation. Hemodynamic changes reflecting RV insufficiency includes right atrial pressures  $>20$  mmHg, left atrial pressures  $< 10$  mmHg (low flow), a pump index  $< 1.8$  L/min/m<sup>2</sup>, and a TPG  $> 15$  mmHg.

Echocardiography can be a useful tool to provide a relatively quick, non-invasive insight to RV function. An echocardiogram will reveal tricuspid regurgitation and a decreased RV ejection fraction. In addition, septal bowing may be seen.

#### Treatment of Right Ventricular Failure

Treatment strategies for RV insufficiency include close volume management to avoid systemic overload and subsequent elevated RV filling pressures. If diuresis is unsuccessful or insufficient in lowering filling pressures, intravenous nesiritide can be utilized.<sup>5</sup> Nesiritide is an exogenous brain natriuretic peptide that has both diuretic and natriuretic effects. If RV overload is secondary to pump flow, adjustments to the pump may be made such as increasing rotations per minute or rate (depending on the type of pump implanted).

Another treatment option to prevent RVF is early treatment with inhaled nitric oxide (NO) post-operatively<sup>6</sup>. This therapy provides pulmonary vasculature vasodilation and decreased pulmonary vascular resistance. Nitric oxide is an endothelium-derived relaxing factor and a selective pulmonary vasodilator. Although rare, NO toxicity may result either from the formation of methemoglobin or from the direct effects of NO and its oxidized derivatives (principally NO<sub>2</sub>) on alveolar and vascular tissue.

Methemoglobin (metHgb) levels should be monitored to maintain a metHgb < 0.15 g/dL.

Another treatment option is the use of inhaled iloprost, which is an exogenous form of prostaglandin. Prostaglandin is known to cause vasodilation and prevent thrombus formation. Inhaled iloprost dilates pulmonary vasculature and decreases PVR. There are no clear FDA indications for the use of nesiritide, inhaled NO

or iloprost to prevent RV failure after LVAS implant. Clinical use of these agents is guided by small studies performed at experienced centers and by practical expertise.

Treatment of metabolic or respiratory acidosis is necessary to maintain a pH of 7.40. Respiratory acidosis can be treated by adjusting mechanical ventilation parameters such as increasing ventilatory rate or tidal volume. Metabolic acidosis can also be treated with intravenous sodium bicarbonate.

Other treatment strategies to prevent RVF include optimization of cardiac electrical activity with transvenous or epicardial pacing, for bradycardia or junctional heart rhythms; limiting the number of blood product transfusions as appropriate; and maintaining LVAS pump index  $>2.2 \text{ L/min/m}^2$  with a reasonably low right atrial pressure. The pump index can be assisted with intravenous inotropic agents such as dobutamine or milrinone.

Refractory RVF may require surgical intervention with a RVAS. Peri-operative morbidity and mortality substantially increases when biventricular support is required. Risk for infection, renal and liver failure, and the incidence of adult respiratory distress syndrome are also increased.

### Summary

Patients with NYHA Class IV symptoms refractory to optimized medical therapy fall into American Heart Association/American College of Cardiology treatment stage D. Selected patients may benefit from more invasive therapies such a VAS, either as bridge to transplant or destination therapy with the Heartmate® XVE. Symptom and functional class improvement may be dramatic. However, there are significant risks associated with such an extensive, invasive surgical procedure. Proper patient selection is clearly the key

to limiting post-implant complications, such as RVF<sup>7</sup>. Close assessment of signs and symptoms of RV insufficiency; identification of clinical, pathophysiologic, or mechanical causes of RVF; and prompt treatment of identified causes, can prevent the development of RVF.

Authors' Acknowledgement: Reynolds Delgado, MD

#### References

<sup>1</sup> Hirsch, DJ, Cooper Jr JR. Cardiac failure and left ventricular assist devices. *Anesthesia Clin N Am*, 2003, 21:625-638.

<sup>2</sup> Yager, JE, Felker GM. Left ventricular assist devices as destination therapy for end-stage heart failure. *Am Heart J*, 2004, 148:252-253.

<sup>3</sup> Transplant statistics. 3/28/2006. United Network for Organ Donation (UNOS). [www.unos.org](http://www.unos.org)

<sup>4</sup> Weiskopf RB, Nicolosi AC, Pael PS. Perioperative considerations in the patient with a left ventricular assist device. *Anesthesiology*, 2003, 98(2):10-18.

<sup>5</sup> Delgado III RM, Radovancevic B, Vrtovec B, Radavancevic R, Thomas CD, Kar B, Frazier OH. Perioperative use of nesiritide in heart failure patients undergoing implantation of left ventricular assist device. *Journal of Cardiac Failure*, 2003, 9(5-Suppl):S111.

<sup>6</sup> Hare JM, Shernan SK, Body SC et al. Influence of inhaled nitric oxide on system flow and ventricular filling pressure in patients receiving mechanical circulatory assistance. *Circulation*, 1997, 95(9):2250-2253.

<sup>7</sup> Ochiai, Y, McCarthy, PM, Smedira NG, et al. Predictors of severe right ventricular failure after implantable left ventricular assist device insertion: analysis of 245 patients. *Circulation*, 2002, 106(12 Suppl1), I198-I202.