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● *Technical Note*

LEFT VENTRICULAR ASSIST DEVICES: PHYSIOLOGIC ASSESSMENT USING ECHOCARDIOGRAPHY FOR MANAGEMENT AND OPTIMIZATION

Farouk Mookadam,* Christopher B. Kendall,* Raymond K. Wong,† Anantharam Kalya,* Tahlil Warsame,* Francisco A. Arabia,† Joan Lusk,* Sherif Moustafa,* Eric Steidley,* Nishath Quader,* and Krishnaswamy Chandrasekaran*

* Division of Cardiovascular Diseases; and † Division of Cardiothoracic Surgery, Mayo Clinic Arizona, Scottsdale, AZ, USA

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Abstract—Left ventricular assist devices (LVAD) are being deployed increasingly in patients with severe left ventricular dysfunction and medically refractory congestive heart failure of any etiology. The United States Food and Drug Administration (FDA) recently approved the use of the Thoratec Heartmate II (Thoratec Corporation, Pleasanton, CA, USA) for outpatient use. Echocardiography is fundamental during each stage of patient management, pre-LVAD placement, during LVAD placement, for postoperative LVAD optimization and long-term follow-up. We present a pragmatic and systematic echocardiographic approach that serves as a guide for the management of left ventricular assist devices. (E-mail: mookadam.farouk@mayo.edu) © **2012 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **2-dimensional echocardiography, Congestive heart failure, Left ventricular assist devices, LVAD physiology and optimization.**

INTRODUCTION

Left ventricular assist devices (LVAD) are becoming increasingly important as a therapeutic intervention for appropriately selected individuals with advanced heart failure recalcitrant to medical therapy. Not all patients are eligible for transplantation and some of those who are candidates for cardiac transplant need immediate hemodynamic support beyond inotropes, without which, death or serious morbidity may supervene. The limitations to cardiac transplantation for both donor and recipient, coupled with technologic advancements have resulted in broader application of the LVAD, both as a bridge to transplantation (BTT) and as destination therapy (DT) (Jessup and Brozena 2003; Rose et al. 2001). LVAD "standbys" also provide the option for immediate and intermediate-term support in the high-risk post-cardiac surgical patient. Oftentimes, this support can be extended for longer periods of time when BTT or DT is later prescribed (Miller et al. 2007; Rose et al. 2001). Current second and third generation LVAD technology use continuous axial flow pumps with fewer moving parts and is much smaller in size. As a result, long-term durability has improved and availability has been expanded to a larger group of patients.

Transthoracic echocardiography (TTE), transesophageal echocardiography (TEE) and, less commonly, epicardial echocardiography (EE) can all be used in the management of LVAD patients before, during and after deployment of the assist device. With TEE and EE, visualization of cardiac anatomy can be superior and thus especially useful in guiding the cardiac surgeon during LVAD placement. It should be emphasized that for the preoperative evaluation and postextubation day-to-day optimization, fluid and hemodynamic assessment, TTE can provide much of the needed information if a technically directed approach is used for patient management.

Overview of ventricular assist devices

Two main types of ventricular assist devices (VADs) are in use currently, pulsatile and continuous (axial) flow mechanical assist devices. First generation VADs provide pulsatile flow from blood pumps that are either extracorporeal or implanted within an abdominal pocket. Second generation VADs use axial flow impellers that provide continuous pump flow and dispenses with the need for

Address correspondence to: Dr. Farouk Mookadam, Division of Cardiovascular Diseases, Mayo Clinic, 13400 East Shea Boulevard, Scottsdale, AZ 85259 USA. E-mail: mookadam.farouk@mayo.edu

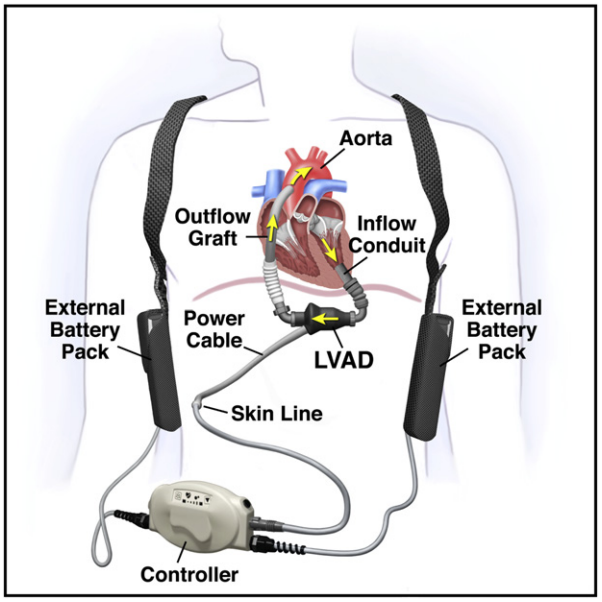

Fig. 1. New generation left ventricular assist device.

unidirectional valves connected to the inflow/outflow cannula. Third and fourth generation devices employ centrifugal pumps that also provide continuous flow, with the latter generation sufficiently miniaturized that they can be positioned at the left ventricular apex (Scalia et al. 2000; Stainback et al. 2005).

Left VADs are positioned in parallel with the normal blood circulation from the left ventricle into the aorta and have several essential components (Fig. 1), which include:

(1) An inflow conduit from the LV apex to the VAD pump;
(2) Propulsion pump (LVAD) that moves the blood;
(3) An outflow graft conduit that returns blood to the aorta;
(4) An external controller which receives and processes information from the pump and returns information for pump operation. (Frazier et al. 2001; Horton et al. 2004; Tittle et al. 2002).

Role of echocardiography for management of patient with LVAD

Axial flow VADs are currently approved for outpatient use. Due to the portability of these devices and the agrarian nature of the patient, medical attention may be sought at a facility that may be less familiar with the echocardiographic examination or may be uncertain of which echocardiographic parameters to measure, or which morphologic features to observe for during echocardiographic interrogation of the device and related hemodynamics. Hence, a good understanding of cardiac anatomy and physiology is needed to understand normal VAD function and potential complications that can occur. The purpose of this overview is to systematically guide physicians and sonographers caring for patients with devices as a routine or when such a device may be encountered unexpectedly.

Table 1. Pre-left ventricular device insertion

(1) Examine LV systolic and diastolic function, and exclude ventricular thrombus.
(2) Examine RV size, systolic and diastolic function.
(3) Assess aortic valve for stenosis and regurgitation.
(4) Examine ascending, descending and abdominal aorta for dissection and atherosclerosis.
(5) Examine mitral valve function, regurgitation and rule out mitral valve stenosis.
(6) Examine tricuspid valve annular size and regurgitation.
(7) Exclude cardiac abnormalities that could lead to right to left shunting post-LVAD placement: PFO, ASD or iatrogenic atrial shunt.
(8) Assess for ventricular scar and aneurysm with ischemic cardiomyopathy.
(9) Assess pulmonary valve regurgitation.
(10) Assess for pulmonary hypertension, increased pulmonary vascular resistance and pulmonary embolism.
(11) Examine pericardial space for effusion or adhesions if prior cardiac surgery or history of pericarditis with constrictive physiology.

LVAD = left ventricular assist device; RV = right ventricle; LV = left ventricle; PFO = patent foramen ovale; ASD = atrial septal defect.

Preoperative echocardiography

A comprehensive transthoracic echocardiogram (TTE) for LVAD candidates should include standard two-dimensional (2-D) and Doppler interrogation per guidelines (Table 1).

Important findings, which may influence hemodynamic status and encumber device function, should be evaluated before the patient arrives in the operating suite: Left ventricular (LV) thrombus; aortic valve function, rule out stenosis and greater than mild regurgitation; atrial septal shunt; ascending aorta pathology; atrial septal shunt; and mitral inflow stenosis.

If LV thrombus is suspected, the use of ultrasound contrast agent can aid in LV opacification for visualization of thrombus size and location.

The aortic valve (AoV) should be evaluated for significant stenosis and insufficiency. If greater than mild AoV regurgitation is present, the surgeon may suture repair the AoV cusps to prevent increased recirculation of pump flow (Rao et al. 2001)

The potential site for the outflow cannula should be interrogated closely. Transthoracic echocardiography can be used to assess the size and appearance of the aorta. The aortic arch can be visualized from the suprasternal view; descending thoracic limited views and abdominal aorta limited views should be assessed for dissection, aneurysm, atherosclerosis or any potential pathology, which could compromise outflow cannula function, or interfere with the cross clamp procedure.

Patent foramen ovale (PFO) is common in the adult population (Hagen et al. 1984). The presence of an atrial septal defect (ASD) or patent foramen ovale (PFO) should