

Ventricular Assist Devices as a Bridge to Heart Transplant and Destination Therapy

By Anirudh Penumaka

Pioneering work by cardiac surgeons in the 20th century led to the development of surgical techniques that are used today to repair congenital heart defects, bypass blocked arteries, replace heart

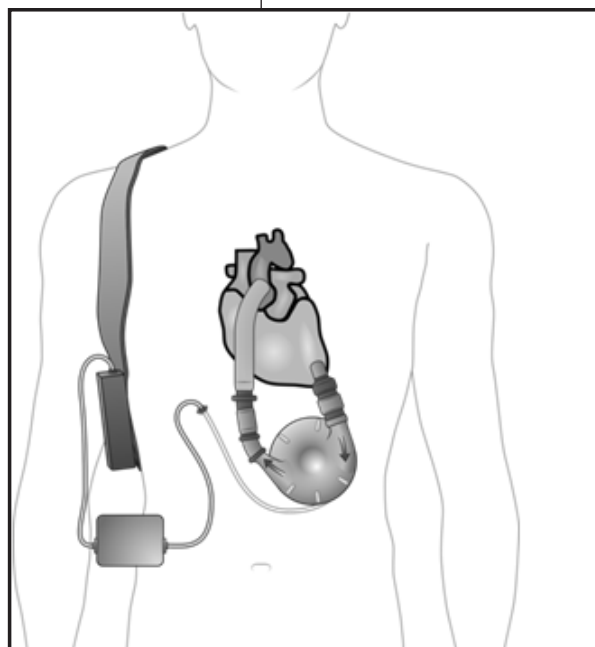
valves, and transplant the heart itself. Today, it is estimated that 6 million adults in the United States suffer from heart failure, and the prevalence of this disease is rapidly growing in the developing world (1). Heart disease can arise from a variety of factors, including heart attack due to the narrowing or obstruction of coronary arteries supplying the heart, failure

of heart valves to effectively control the flow of blood, and hypertension, defined as chronically elevated blood pressure. Initial treatment of heart disease involves drug therapy to lower blood pressure and decrease the risk of future complications, but acute heart failure requires intervention to maintain heart function. In 2007, it was estimated that approximately 200,000 people in the United States over the age of 45 have severe heart failure that cannot be medically managed (2). The ability to regenerate heart muscle following injury through the use of cardiac progenitor/stem cells or replacement with a permanent artificial heart remains some years away; however, ventricular assist devices (VAD) hold enormous potential both as bridges to heart transplantation and as long term treatments for heart failure.

As the central element of the circulatory system, heart muscle is responsible for pumping blood to supply organs throughout the body with oxygen. Heart failure can affect both of the pumping chambers of the heart, the left and right ventricles, result-

ing in an insufficient amount of blood flow. The left ventricle pumps oxygenated blood from the lungs to the rest of the body; therefore, left ventricular assist devices (LVAD) can compensate for the decreased cardiac output by supporting the left ventricle. LVADs remove blood through the apex of the left ventricle and pump the blood to the ascending aorta, from where blood can perfuse other organs. VADs are electrically powered through a subcutaneous lead from an external device controller and power source. The first widely used VADs, pulsatile flow ventricular assist devices, mimic the contractile rhythm of the heart, but they are relatively large and are mechanically viable for a limited period of time. The use of VADs as a permanent “destination therapy” to sustain heart function when a patient is not eligible for heart transplant, is an important application of this technology that was first approved in 2001 (3). The Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure (REMATCH) trial conducted from 1999 to 2001 revealed a very significant increase in survival at one year (52% versus 25%) and two years (23% versus 8%) compared to patients who received “optimal medical therapy” (4). Although the authors report that implantation with the pulsatile flow LVAD was associated with considerable morbidity/mortality, as well as initial decrease in the quality of life, this study demonstrated the principle that LVADs could improve survival. Device related effects such as malfunction also played an important role, so the development of smaller and more reliable devices could improve clinical outcomes (4, 5).

Newer continuous flow devices are smaller and have longer life spans because of the simpler design of the pump. While pulsatile flow LVADs required a larger space in the body, continuous flow LVADs are small enough to be implanted in women and young adults with heart failure. A large multi-center trial reported in 2009 randomly assigned patients to receive a continuous flow LVAD or pulsatile flow LVAD. Among other considerations, patients in this clinical trial did not respond to medication to manage heart failure and had a left ventricular ejection fraction, measured as the percentage of blood pumped from the left ventricle per heartbeat, of less than 25%, while healthy individuals normally have 50% – 70% left ventricular ejection fractions. 46%



▲ **Figure 1.** Implanted pulsatile flow ventricular assist device and external device controller.

of patients with continuous flow LVADs either survived at least two years or received heart transplant, compared to 11% of patients who received a pulsatile flow LVAD. In addition, a higher fraction of pulsatile flow devices required replacement or explantation following infection or mechanical malfunction (6). Measured by both quality of life and survival, continuous flow devices were shown to be more effective. Subsequent evaluation for two years demonstrated a statistically significant improvement in patients who had received the continuous flow LVAD (6). Some of the significant areas of concern with LVADs are the risk of infection due to the extensive surgical operation to implant the device, as well as the formation of blood clots that may cause neurological damage following stroke. However, the frequency of stroke was reported by Pullicino et al. to be approximately equal in patients with heart failure who did not receive an LVAD (7).

Heart transplant remains a critical standard of care for end-stage heart failure; yet, there is a significant shortage of organs which must be carefully matched between the donor and recipient. Heart transplant, first performed by Christiaan Bernard in 1967, became widely used only when methods to control immune system rejection of the transplanted organ were developed. It is estimated that 3000 viable donor hearts are available for transplant each year, meaning that many of the 100,000 patients eligible for transplant will not survive the waiting period before a heart transplant is performed (8). VADs as “a bridge to heart transplant” means that mechanical support will maintain heart function until the patient receives a heart transplant. The Heartmate II LVAD study measured the benefits of the continuous flow devices as a bridge to heart transplant in patients requiring heart transplant due to end stage heart failure. 75% of patients implanted with the device survived for at least 6-months due to the LVAD, subsequent heart transplant, or recovery of cardiac function. Although this bridge to transplant approach performed well in most patients, there were also serious complications in others, including significant bleeding following surgery, sepsis, or a systemic inflammatory response, stroke, and organ failure. The authors report 70% survival for patients who had received an LVAD; therefore, based on this initial proof of principle, continuous flow LVADs appear to be viable approach to extend life in patients awaiting heart transplant (9). Another interesting observation was that LVADs, while supporting the heart, may decrease work load to allow the heart to recover from previous injury (10). A study published in 2006 reported that the combined use of Left Ventricular Assist Device (LVAD) and drug therapy can promote “myocardial recovery,” extending the period before a patient requires a heart transplant (11). Although the sample size of patients was relatively small, the majority of these patients showed consistent improvements in myocardial function and

tolerance to exercise over four years. In other words, the use of the mechanical LVAD and drugs achieved “sustained reversal of heart failure” by counteracting ventricular remodeling (changes to the structure of ventricle) and reducing ventricular hypertrophy, enlargement of ventricle (11).

Even though they may have initially been envisaged as a short term measure for patients recommended for heart transplant, ventricular assist devices have proven to be effective also as destination therapies for patients suffering from end stage heart failure. The REMATCH trial demonstrated the life extending capacity of VADs, and the recent Heartmate II study established the improved function of continuous flow VADs compared to the older pulsatile flow VADs. Ventricular assist devices seem to be remarkably effective in treating intricate, multifaceted heart conditions; they will continue to evolve to address both medical realities and patients’ qualities of life. **H**

—Anirudh Penumaka '12 is a Chemical and Physical Biology concentrator in Adams House.

1. Center for Disease Control and Prevention. January 25, 2010. <<http://www.cdc.gov/heartdisease/statistics.htm>>. Accessed November 10, 2010.
2. Baughman, L. Kenneth, and Jarcho, A. John. Bridge to Life — Cardiac Mechanical Support. *New England Journal of Medicine*. 2007. 357: 846-849.
3. Parides MK, Moskowitz AJ, Ascheim DD, Rose EA, Gelijns AC. Progress versus precision: challenges in clinical trial design for left ventricular assist devices. *Ann Thorac Surg*. 2006. 82: 1140-1146.
4. Rose, A. Eric, et al. Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure (REMATCH) Study Group. Long-Term Use of a Left Ventricular Assist Device for End-Stage Heart Failure. *New England Journal of Medicine*. 2001. 345:1435-1443.
5. Lietz, K., et al. Outcomes of left ventricular assist device implantation as destination therapy in the post-REMATCH era: implications for patient selection. *Circulation*. 2007. 116(5):497-505.
6. Miller, W. Leslie, et al. Use of a Continuous-Flow Device in Patients Awaiting Heart Transplantation. *New England Journal of Medicine*. 2007. 357:885-896.
7. Pullicino PM, Halperin JL, Thompson JL. Stroke in patients with heart failure and reduced left ventricular ejection fraction. *Neurology*. 2000. 54:288-294.
8. Stevenson LW, Rose EA. Left ventricular assist devices: bridges to transplantation, recovery, and destination for whom? *Circulation*. 2003. 108:3059-3063.
9. Miller, W. Leslie, et al. Use of a Continuous-Flow Device in Patients Awaiting Heart Transplantation. *New England Journal of Medicine*. 2007. 357:885-896.
10. Mancini D, Burkhoff D. Mechanical device-based methods of managing and treating heart failure. *Circulation*. 2005. 112:438-448.
11. Birks, J. Emma, et al. Left Ventricular Assist Device and Drug Therapy for the Reversal of Heart Failure. *New England Journal of Medicine*. 2006. 355:1873-1884.