

# Artificial Heart Left Ventricular Assist Devices (LVADs) : A Bridge-to-Recovery —The Novel LVAD III-intrathoracic small blood pump with atriostomy drainage for combination therapies—

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## Ventricular Assist Device Therapy to Heal Chronic Failing Heart

Congestive heart failure is the leading cause of death in the industrialized world. The primary objective of the left ventricular assist device (LVAD) bridge-to-myocardial recovery is the regeneration of functional myocardial tissues and the reversal of myocyte dysfunction. The nontransplant candidates—approximately 5 million patients in the United States—tend to be older with more medical comorbidity than the bridge-to-transplant patients.

Instead of the cumbersome units clinically used today (HeartMate, Novacor, and Thoratec), better LVAD designs are mandatory. The new generation of pulsatile LVADs should be smaller, safer, and more reliable. And these new LVADs should be implanted much earlier than the present-day units during the course of advanced heart failure, before the final stage D of irreversible profound circulatory perturbations.

Mechanical circulatory assistance has become a common method of stabilizing patients with profound refractory heart failure as a “bridge-to-transplantation.” The amount of information gathered since our laboratory study and early clinical applications of circulatory devices at Baylor University College of Medicine, in Houston—more than 40 years ago—has been of tremendous benefit.

The LVAD system was created there in 1961 and 1962 by Domingo Liotta and Michael E. DeBakey.<sup>1,2</sup> Today, the implantation of LVADs is a well-established clinical procedure as (1) a bridge for cardiac transplantation and (2) a bridge for myocardial recovery.

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## First Clinical Application with an Intrathoracic Pump

On the evening of July 19, 1963, Liotta and E. Stanley Crawford implanted the first clinical LVAD at The Methodist Hospital, in Houston, bypassing the left ventricle (LV) from the left atrium (LA) to the descending thoracic aorta (DTA).

The pneumatic-powered intrathoracic pump implanted through a left thoracotomy was regulated to bypass with 1,800 to 2,500 mL of blood/min.

The pulmonary edema cleared. However, the anuria persisted. After 4 days of mechanical support, the pump was discontinued.

The patient, comatose before LVAD support, remained in that condition and died.<sup>3</sup>

In October 1966, DeBakey and Liotta implanted an LVAD from the LA to the left axillary artery. After mechanical circulatory support for 10 days, the patient recovered, thus becoming the first successful user of LVAD for postcardiotomy shock.

## First Clinical Implantation of a Total Artificial Heart

On the afternoon of April 4, 1969, Denton A. Cooley and Liotta replaced a dying man's heart with an orthotopic mechanical heart at Texas Heart Institute, also in Houston.<sup>4</sup>

After 64 hours, the pneumatic-powered heart was removed and replaced by a donor heart. Thirty-two hours after transplantation, the patient died of what was later proved to be an acute pulmonary infection caused by fungi that had extended to both lungs.

## A Strategy to Optimize Myocardial Recovery<sup>5</sup>

Five approaches support using the LVAD system as a tool to heal the heart:

### 1. Pump inflow

The inflow pump connection from the apex of the LV is clinically used today with all of the commercially available devices. The geometry of the blood path of pump inflow must undoubtedly be reconsidered. The power of contraction and relaxation that the LV exerts over its major axis of rotation (from apex to base) is severely affected.<sup>6</sup> *Any further loss of the LV power of contraction, of course, can be catastrophic in a patient attempting myocardial recovery.*

### 2. Partial unloading of the LV

The *partial unloading*, employing the LA as the pump inflow connection (atrial prosthesis), is of great simplicity. It is managed as follows: (a) We allow the native heart to eject from 1.8 to 2 L/min. (b) We regulate the LVAD output from 4 to 4.5 L/min. The total patient circulatory volume is 6 to 6.5 L/min.

### 3. ECG-synchronized LVAD

An electrocardiogram (ECG)-synchronized LVAD offers an additional prospect of reversing profound heart failure.

### 4. Avoidance of left atrial and left ventricular cannulation

Cannulation of a heart chamber in the *LVAD bridge-to-myocardial recovery* should be forbidden. It is the source of severe complications that may include an impingement of the pump inflow connector with intraventricular structures when the LV apex is entered, or a collapse of the LA with an intra-atrial connector and be the source of thromboembolic complications.

### 5. Development of the atrial prosthesis

A 25 mm glutaraldehyde-treated porcine-valved aortic root is directly sutured to the 25 mm atriotomy at the *epicardial side of the atrial wall* with an interrupted suture technique. The pledgeted sutures run from outside the atrial wall (visceral pericardium) to the endocardium, folding over it to contact the cuff of the valved aortic root when the sutures are tied; the pledgets remain at the atrium external surface. The 25 mm diameter atriotomy has a surface area of 4.6 cm<sup>2</sup> and is the elective size used in most situations. The 30 mm diameter has a surface area of 7 cm<sup>2</sup>. All blood-contacting surfaces, except the blood-pumping chamber, incorporate biological tissues. Both inflow and outflow blood paths contain a porcine-valved aortic root (full

aortic root) and 4 cm of the ascending aorta as an anatomical unit.

The design of the left ventricular assist system (LVAS) Novel-III geometry of blood flow places an imaginary vaultlike line from the LA, passing at the cardiac incisure between the lingula and the lower lobe, reaching the fifth intercostal space, and continuing around the lower lobe to be sutured to the upper DTA.

### Novel LVAS Driver System

The third generation of pneumatic LVAD-driver systems has been developed.<sup>7</sup> The drive unit is an air-driven pulsatile system. The driving parameters can be programmed and manually preset. The new system incorporates two small stand-alone pneumatic units, and each has its own motor compressor, electropneumatic valves, and electronic control. A timer keeps one pneumatic system activated and the other one inactivated. It alternates this function every 15 min. The purpose of the duplication is to increase the service life of the compressors and to prevent overheating, component fatigue, and malfunctioning of the components. If one system fails, an alarm will warn about the problem, and the other system will continue indefinitely.

The atriotomy method may be successfully employed with current commercial available pulsatile systems, including continuous blood flow pumps.

### Future Directions

Novel LVAD-III may also serve as a platform from which other promising therapies, such as specific pharmacological regimens or gene- or cell-based therapies, may be administered to reverse heart failure.<sup>8,9</sup> Transplantation is not a solution to the heart failure epidemic.

The association of  $\beta$  blockers and the synchronized ECG Novel LVAS can alter the global heart failure milieu. Chronic heart failure diminishes stroke volume with chamber geometry remodeling toward a more spherical state that causes mitral regurgitation, which leads to perfusion abnormalities in systemic central organs and peripheral circulation. Indeed, mechanical chronic cardiocirculatory assist device sustenance can change the final course of the patient's illness in chronic heart failure in New York Heart Association (NYHA) functional class IV.

For the past four decades, perseverance to care for

the assistance of extremely ill patients has been remarkable. The investigators in the assisted circulatory research field always encouraged themselves under the old maxim, “Heaven kindly gave our blood a moral flow.”

On December 5, 2006, Cooley wrote, “The Liotta-Cooley artificial heart was selected to be displayed prominently in the new Smithsonian Treasures of American History, establishing it as a worthy contribution to human history.”<sup>10)</sup>

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