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Ventricular reconditioning and pump explantation in patients supported by continuous-flow left ventricular assist devices

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ventricular unloading;
ventricular recovery;
ventricular reconditioning

BACKGROUND: The potential for myocardial reconditioning and device explantation after long-term continuous-flow left ventricular assist device (LVAD) support presents an opportunity to delay or avoid transplantation in select patients.

METHODS: Thirty of 657 patients with end-stage heart failure supported with continuous-flow LVADs were assessed for device explantation. Each patient underwent an individualized process of weaning focused on principles of ventricular unloading, gradual reconditioning, and transition to medical therapy.

RESULTS: After varying reconditioning periods, 27 patients (16 men, 11 women; age, 39 ± 12 years) underwent LVAD explant, and 3 patients (2 men, 1 woman; age, 22 ± 6 years) were evaluated for explantation but could not be weaned. The duration of LVAD support was 533 ± 424 days (range, 42–1,937 days) for the explant cohort and 1,097 ± 424 days (range, 643–1,483) for the non-explant cohort. The LV end-diastolic dimension, LV ejection fraction, systolic pulmonary artery pressure, cardiac output, and cardiac index in the explant cohort were significantly improved at explantation (all, $p < 0.05$). Two late deaths occurred after LVAD explantation despite satisfactory native cardiac function, and 1 patient required resumption of LVAD support 2.7 years after device removal. The remaining explant patients remain in New York Heart Association classes I to II with medical management alone (mean survival post-explant, 1,172 ± 948 days). The 3 candidates who could not be weaned ultimately underwent transplantation.

CONCLUSIONS: The potential for recovery of native LV function after long-term continuous-flow LVAD support should encourage a more aggressive approach to ventricular reconditioning with the goal of device explantation and a return to medical management, particularly in young patients with dilated cardiomyopathy.

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Technologic advancements in the field of mechanical circulatory support and the relative scarcity of donor organs have resulted in the adoption of left ventricular assist devices (LVADs)—once relegated to the periphery of medical therapy—as important tools in the treatment of end-stage heart failure. Used as a bridge to transplantation (BTT) or destination therapy (DT), these pumps have improved the quality of life and overall survival of patients

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when all other therapeutic options have been exhausted.[1–3] However, the risks associated with LVAD therapy are far from negligible. The use of mechanical circulatory support brings an increased risk of infection, stroke, and device malfunction, whereas cardiac transplantation requires life-long immunosuppression and is limited by the lifespan that can be expected of the donor graft.

Studies from our institution[4–7] and others[8–11] have reported an improvement in a number of anatomic, physiologic, histologic, and sub-cellular markers of native heart function after prolonged periods of mechanical circulatory support. In light of this potential to improve native LV function,[4,6,12–14] we have sought to demonstrate the ability to bridge selected LVAD patients to a return to medical therapy. In this way, pump explantation could minimize the risk of complications associated with long-term LVAD support and delay (or avoid) transplantation, especially in younger patients who are otherwise unlikely to experience an acceptable post-operative life expectancy.[15]

Thirty patients at our institution were identified as potential candidates for ventricular reconditioning. All patients were in end-stage heart failure, were being supported by continuous-flow LVADS, and expressed a desire to be weaned from the device. Our goal in these patients was a return to medical management through a process of device weaning that allowed for pump explantation after a satisfactory improvement in ventricular function. In this report we describe a large cohort of patients undergoing continuous-flow LVAD explantation for improved ventricular function.

Methods

The Texas Heart Institute Institutional Review Board approved this study, and written informed consent was obtained from the patients or an authorized representative.

Patient selection

Between August 2006 and January 2014, 30 non-consecutive patients supported by continuous-flow LVADs at our institution were evaluated as candidates for pump explantation. All patients selected for this study were outpatients in New York Heart Association (NYHA) Functional Class I who did not require inotropic support before the device-weaning strategy was implemented. Inclusion in the study cohort was determined at the discretion of a multidisciplinary review committee and not as part of a protocol, with a particular emphasis placed on the patient's age, echocardiographic data, and overall clinical condition. Patients had to meet the heart failure criteria necessary to be added to the waiting list for transplant, including an LV ejection fraction (LVEF) of less than 20%. Younger patients were preferentially selected, because it was felt that they faced a disproportionate level of exposure to the complications associated with long-term LVAD support and were statistically unlikely to realize a normal lifespan after transplantation. Some of the patients in our 30-case series asked to be weaned from the device rather than undergo heart transplantation. All patients were required to demonstrate an understanding of the risks and benefits of a weaning protocol and to provide explicit interest in the pursuit of an explantation strategy.

During the same period at our institution, continuous-flow LVADs were implanted in 657 patients. However, no attempt was made to pursue a strategy of ventricular remodeling, pump weaning, or device explantation to those outside the study cohort.

Before LVAD implantation, each patient had been diagnosed with severe, chronic, end-stage heart failure (NYHA Functional Class IV), despite optimal medical therapy, and did not have clinical or histologic evidence of acute myocarditis. Twenty-eight of the enrolled patients were supported by the HeartMate II (Thoratec Corp, Pleasanton, CA), and 2 patients were supported by the HeartWare HVAD (HeartWare International, Framington, MA).

Hemodynamic and echocardiographic data

Hemodynamic and echocardiographic data were recorded before LVAD implantation, throughout the period of mechanical support and weaning, after explantation or transplantation, and at all subsequent follow-up visits. Variables documented included LV end-diastolic dimension (LVEDD), LVEF, aortic valve opening time, systolic pulmonary artery pressure (SysPAP), pulmonary capillary wedge pressure (PCWP), cardiac output (CO), cardiac index (CI), septal thickness, and posterior wall thickness.

Post-operative management

After LVAD implantation, the patients underwent standard post-operative intensive care management, including early extubation, titration of inotropic medications, individualized anti-coagulation therapy, and intensive physical therapy. All patients were treated with optimal medical therapy for heart failure (β-blockers, angiotensin-converting enzyme inhibitors, digitalis, and diuretics), which were initiated at the earliest clinically appropriate post-operative opportunity.[16] After assurance of hemodynamic stability, clearance by the physical therapy service, and comprehensive inpatient device training, patients were discharged home with close outpatient follow-up.

LVAD weaning

After an initial post-operative recovery period (typically 3–6 months), the patients were evaluated monthly as outpatients to assess suitability for the initiation of a ventricular reconditioning protocol. This assessment was facilitated by echocardiographic testing performed at regular intervals to quantitate native LV function. The initial phase of our weaning protocol was characterized by a period of ventricular unloading. The goal of this process was to reduce the LVEDD to the upper limits of normal and to correct or minimize mitral regurgitation, a condition secondary to dilated cardiomyopathy, by increasing the rpm of the device and thereby offloading the volume retained within the LV. Initially, these conditions were met only when the aortic valve remained closed throughout the cardiac cycle, allowing the pump to operate in series with the native ventricle. To avoid a resultant excessive increase in blood pressure and, we believe, the attendant risk of hypertensive-hemorrhagic stroke, the afterload was pharmacologically reduced to maximal clinically tolerated levels, typically with peripheral Doppler pressures maintained below 100 mm Hg and ideally in the 70 to 90 mm Hg range.

When a patient was clinically stable with appropriately controlled blood pressure, the device speed was briefly reduced to 6,000 rpm, and the aortic valve opening time was measured by echocardiography. This transient reduction in pump speed did not require any change in the anti-coagulation management, and