Left Ventricular Assist Devices, Kidney Disease, and Dialysis

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Left ventricular assist devices (LVADs) improve survival in patients with advanced heart failure. As LVAD use increases, so do the number of patients with LVADs who also have kidney disease. However, there are only sparse data on how best to care for these patients. This review provides an overview of LVAD principles and indications, including blood pressure assessment and criteria for receipt of both destination and bridge to transplantation LVADs. Following LVAD implantation, kidney function may improve in the short term, particularly if cardiorenal physiology was present; in the longer term, data remain limited. Individuals with glomerular filtration rates chronically < 30 mL/min/1.73 m^2, including those treated with maintenance dialysis, are generally ineligible for destination LVADs. However, select patients with advanced chronic kidney disease can be considered for LVADs as a bridge to heart or heart-kidney transplantation. Patients who develop acute kidney injury and require dialysis following LVAD implantation have high mortality rates. Although thrice-weekly hemodialysis is the most common modality for patients with LVADs, peritoneal dialysis and home hemodialysis are additional options. Peritoneal dialysis in particular may be associated with lower risk for bloodstream infection and fewer hemodynamic shifts. For those treated with hemodialysis, arteriovenous fistulas can successfully be used for vascular access. Many questions remain, including optimal anemia management and refinement of hemodialysis protocols for patients with an LVAD, and further research is needed in this field.

Complete author and article information provided before references.

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Case Presentation: *A 35-year-old woman with long-standing type 1 diabetes mellitus resulting in kidney failure and nonischemic cardiomyopathy with a left ventricular ejection fraction of 10% was initially treated with peritoneal dialysis (PD), but was transitioned to in-center hemodialysis (HD) therapy for abdominal bloating symptoms and insufficient ultrafiltration. Following the transition to HD therapy, her heart failure symptoms worsened and she required initiation of an inotrope infusion for stage D systolic heart failure. She underwent surgical implantation of a HeartWare left ventricular assist device (LVAD) as a bridge to heart-kidney transplantation. She was maintained on HD therapy via a tunneled central venous catheter. After approximately 6 months of thrice-weekly in-center HD therapy complicated by fatigue, she and her family trained for frequent home HD using the NxStage system. She received frequent home HD for approximately 2 years after LVAD placement, until she underwent combined heart-kidney transplantation. Unfortunately, her posttransplantation course was complicated by vasoplegia, sternal wound infection, and delayed kidney graft function, and she died several months after transplantation.*

Introduction

Heart failure and kidney disease are common comorbid conditions. Cardiorenal syndrome may cause kidney disease, whereas common conditions such as hypertension and diabetes predispose to both heart failure and chronic kidney disease (CKD).[1,2] Importantly, kidney failure and heart failure often potentiate each other. As heart failure worsens, patients may become dependent on inotropes to augment cardiac output and diuresis, and with further progression, may require mechanical circulatory support to survive.[3] In the short term, treatment options may include an intra-aortic balloon pump, an intravascular microaxial ventricular assist device (such as the Impella), or, in extreme cases, extracorporeal membrane oxygenation, whereas medium- and longer-term options may include an LVAD, heart transplant, or in the setting of advanced kidney disease, combined heart-kidney transplant.

Heart transplantation is the gold-standard intervention for end-stage heart failure, but is not always an option, either due to organ unavailability or patients being temporarily or permanently ineligible for heart transplantation. In this situation, an LVAD, either as a temporizing measure while awaiting transplantation or as a destination therapy for the rest of a patient's life, can be life saving. LVAD use is increasing, as is the number of patients with LVADs who have concurrent kidney disease. Few data exist for providing kidney care to patients with LVADs, with critical gaps on dialysis access, dialysis modality, and management of comorbid conditions such as anemia. This review summarizes current knowledge and treatment strategies for patients with LVADs and kidney disease.

In Practice is a focused review providing in-depth guidance on a clinical topic that nephrologists commonly encounter. Using clinical vignettes, these articles illustrate a complex problem for which optimal diagnostic and/or therapeutic approaches are uncertain.

Ventricular Assist Devices

Ventricular Assist Device Principles

An LVAD is a mechanical pump that is inserted into the body to augment cardiac output. LVADs work in parallel with the native failing heart to mechanically unload the left ventricle by pumping blood directly from the left ventricle to the aorta. The LVAD inflow cannula is implanted through the apex of the left ventricle and draws blood from the left ventricular cavity into the pump. For the current generation of continuous-flow LVADs, the LVAD pump lies either in the pericardial space or below the diaphragm in a preperitoneal pocket. A flexible outflow cannula connects the pump to the ascending aorta, pushing blood into the systemic circulation. A driveline cable connects the internal pump to an external controller and power source (Fig 1).[4-6]

There currently are 2 main types of continuous-flow LVAD technology in current use. The HeartMate II is an axial flow pump design, while the HeartWare HVAD and HeartMate III pumps use centrifugal flow with levitating magnetic discs. In contrast, earlier generation LVADs such as the HeartMate XVE used pulsatile flow, were large and noisy, and had limited mechanical durability. The current generation of continuous-flow devices are not only smaller and quieter, but also are associated with improved survival, decreased pump failure, and lower infection rates compared with the original pulsatile-flow LVADs.[7-9] Patients with continuous-flow devices require anticoagulation to prevent pump thrombosis; the typical target international normalized ratio with warfarin in this setting is 2 to 3, and most centers also use an antiplatelet agent. Blood pressure typically is assessed using a Doppler device and ideally is maintained in the 70– to 85–mm Hg range; pressures > 90 mm Hg have been associated with increased risk for stroke and pump thrombosis.[10,11]

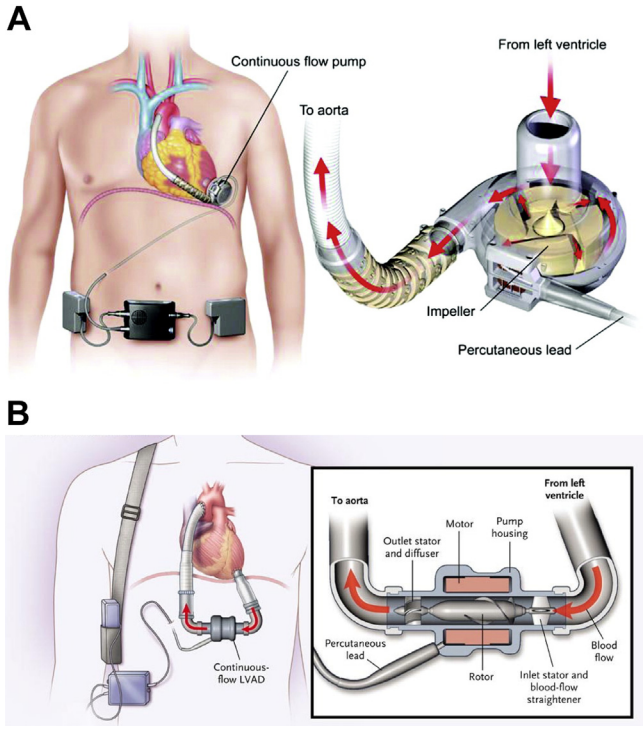

Figure 1. Schematic diagram of left ventricular assist devices (LVADs). (A) An exploded view of the HeartWare Ventricular Assist Device, a centrifugal flow device (reproduced with permission of the copyright holder [American Health Association] from Aaronson et al[25]). (B) The HeartMate II device, a continuous-flow device with axial flow, and its location in the body (reproduced with permission of the copyright holder [Massachusetts Medical Society] from Slaughter et al[7]).

Ventricular Assist Device Alarms

The high-power alarm signals following an increase in pump power in an attempt to maintain adequate flows within the LVAD and may herald a pump thrombosis. Low-flow alarms may occur with hypovolemia, sepsis, hemorrhage, right-sided cardiac failure, tamponade, or obstruction at either the inflow or outflow cannula. Suction events may occur when blood flow into the inflow cannula is insufficient to meet pump speed, causing the inflow cannula to pull against the interventricular septum. The most common cause of suction events is hypovolemia, and these events typically are treated by volume administration.[12,13] "Red heart alarms" occur during critically low flows, pump stoppage, and/or loss of all power sources. Other alarms can indicate driveline, controller, or battery faults.

Ventricular Assist Device Complications

As displayed in Box 1, current LVAD technology remains limited by several key complications. LVAD pump thrombosis can present as hemolysis of varying severity depending on the extent of thrombosis and potentially with LVAD failure or occasionally with an embolic stroke or transient ischemic attack.[14] Lactate dehydrogenase is used as a biomarker to indicate hemolysis secondary to pump thrombosis, with a level 2.5 times the upper limit of normal considered diagnostic.[15] Medical management of LVAD thrombosis may have 6-month mortality as high as 50%; accordingly, early surgical intervention is often recommended.[16] Gastrointestinal bleeding affects as many as 15% to 40% of LVAD recipients, with recurrent bleeding affecting up to 40% of these patients.[17-19] Neurologic events associated with LVAD support include intracerebral

Box 1. Potential Serious LVAD Complications

- Pump thrombosis and hemolysis
- Gastrointestinal bleeding
- Intracerebral hemorrhage
- Stroke or transient ischemic attack
- Driveline site and pump infections
- Right-sided cardiac failure

Abbreviation: LVAD, left ventricular assist device.