Case Reports

Nonidentical Continuous-Flow Devices For Biventricular Support

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Although biventricular heart failure has been successfully managed with dual continuous-flow ventricular assist devices, the long-term use of 2 mechanically dissimilar pumps has traditionally been discouraged. We present the case of a 52-year-old man whose treatment with a HeartMate II left ventricular assist device was complicated by right ventricular failure, necessitating the implantation of a long-term right ventricular assist device. A HeartWare left ventricular assist device was placed along the right ventricular base to avoid interference with the HeartMate II housing. The patient was discharged from the hospital after routine postoperative care and dual-device training. This case shows that, despite logistical complexities, nonidentical continuous-flow device pairings can successfully provide long-term biventricular support. **(Tex Heart Inst J 2017;44(2):141-3)**

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The success of continuous-flow (CF) left ventricular assist devices (LVADs) has revolutionized the surgical management of end-stage heart failure. However, studies have shown that up to 10% of LVAD candidates need biventricular support.[1] In the absence of a long-awaited CF total artificial heart, some patients with biventricular failure have received long-term support from dual, identical CF pumps.[2] Here, we present a case in which 2 separate devices—a left-sided HeartMate II® LVAD (Thoratec Corporation; Pleasanton, Calif) and a right-sided HeartWare® HVAD (HeartWare International, Inc., part of Medtronic, Inc.; Framingham, Mass)—were used simultaneously in the successful long-term treatment of a patient with biventricular heart failure.

Case Report

A 52-year-old man with a long-standing history of ischemic cardiomyopathy was referred to our institution when his condition precipitously declined despite the administration of home milrinone therapy. The patient's clinical history was further complicated by chronic renal insufficiency (baseline creatinine level, 2–2.5 mg/dL) and the placement of a mechanical aortic valve (St. Jude Medical, Inc., part of Abbott Laboratories; St. Paul, Minn) 17 years earlier. Echocardiographic results showed that the patient had a left ventricular (LV) ejection fraction of <0.20, an LV end-diastolic dimension of 5.9 cm, and normal right ventricular (RV) size and function. Subsequent test results indicated that the patient had a pulmonary capillary wedge pressure of 21 mmHg, a pulmonary vascular resistance of 5.2 Wood units, and a cardiac index of 1.47 L/min/m^2.

After stabilizing the patient by administering multiple inotropic infusions, we implanted a HeartMate II LVAD, positioning the device along the diaphragmatic surface of the LV. To decrease the risk of thromboembolic complications, we used a felt plug "sandwich" technique to close the patient's mechanical aortic valve.[3] The patient had evidence of severe RV dysfunction, and after multiple failed attempts to wean him from cardiopulmonary bypass, we placed a temporary CentriMag® device (Abbott Laboratories; Abbott Park, Ill) to provide right-sided support, by cannulating the right atrium and pulmonary artery. During the subsequent 48 hours, no improvement was seen in the patient's RV functional dynamics, so we decided to implant a right-sided pump in anticipation of the need for long-term RV support. We chose a HeartWare HVAD to enable positioning of the device along the acute margin of the RV and to minimize the geometric complexity of accommodating a second HeartMate II pump housing. Transdiaphragmatic placement of the left-sided pump—standard

practice at our institution—also facilitated this arrangement (Fig. 1). To avoid interference with the path of the LVAD conduit and to minimize the danger of disrupting flow upon sternal re-entry, the outflow conduit of the HeartWare device was directed posterolaterally for anastomosis with the pulmonary artery trunk (Fig. 2). The chest was closed, the pump speeds were optimized with echocardiography, and the patient was removed from ventilator support 5 days later.

The patient's postoperative course was uneventful. He was placed on a warfarin anticoagulation regimen (goal international normalized ratio, 2–3) and physical therapy. He also received comprehensive dual-device training so he could master setting each pump's unique controller and corresponding power supply. Because of his severe preoperative renal dysfunction, the patient also needed long-term postoperative dialysis. He was discharged from the hospital 7 weeks postoperatively and was monitored as an outpatient after more than 10 months of biventricular support. More than 2 years postoperatively, he had experienced no device-related complications.

Discussion

Continuous-flow LVADs are increasingly used in the management of end-stage heart disease. However, the application of CF technology in the treatment of biventricular failure remains relatively unknown. In 2004, surgeons from our institution were the first to describe the emergency use of 2 CF devices—dual Jarvik 2000® pumps (Jarvik Heart, Inc.; New York, New York)—for biventricular support.[4] Since then, several institutions have successfully used biventricular CF devices to provide short- and long-term support to patients.[2,5] The HeartWare HVAD has been used in most of these cases, presumably because of the advantages provided by its relatively small profile and intrapericardial pump position.

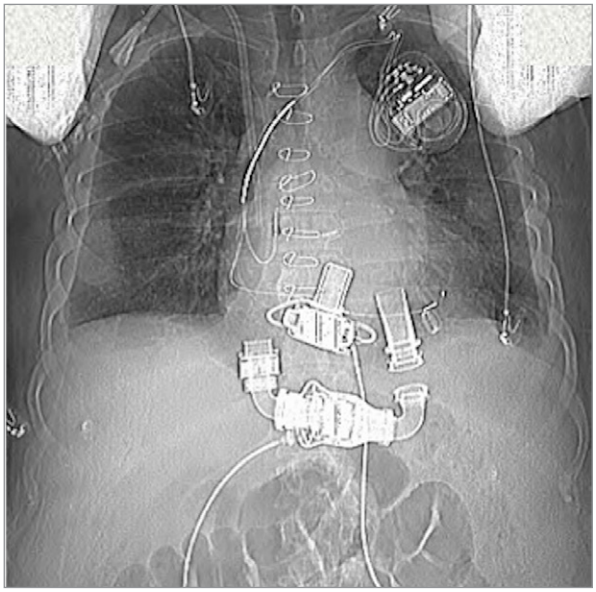

Fig. 1 *Chest topogram shows biventricular device placement. Transdiaphragmatic inferoapical implantation of the HeartMate II enabled positioning of the HeartWare ventricular assist device along the acute margin of the right ventricle.*

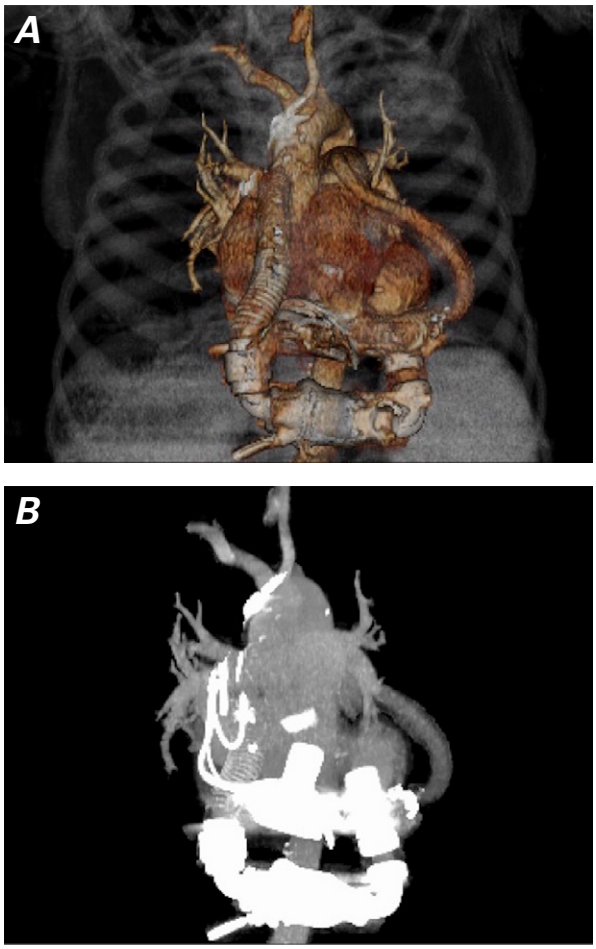

Fig. 2 *Chest computed tomogram (3-dimensional reconstruction) **A**) without and **B**) with abstraction shows biventricular pump alignment and outflow-graft configuration.*

The simultaneous use of 2 nonidentical pumps has traditionally been discouraged because of the perceived complexity of accommodating disparate design elements, flow dynamics, and external components. Although some operational aspects of this arrangement are challenging, using different devices in our patient did not affect the performance of the biventricular CF system. Flow through a CF pump is regulated by the speed of the rotor and the pressure difference across the device. As a result, a continuous-flow LVAD operating at a constant speed produces variable flows that correspond to the volume of blood delivered to the inlet. This principle of automaticity also applies to the management of CF pumps in series; the right-sided pump,

in the setting of low-pressure pulmonary circulation, produces substantial flow variability with changes in ventricular preload. In our experience, the management of a biventricular system is best accomplished by identifying a right-sided pump speed that enables venous offloading without causing pulmonary edema and by actively titrating the left-sided pump to compensate for physiologic variations.

Because of the intimate and complex flow relationship between mechanically dissimilar pumps in series, another major concern has been the potential effects of intrinsic differences in baseline flow characteristics and pump speeds. For example, the axial-flow HeartMate II can operate between 8,000 and 14,000 rpm, whereas the speed of the continuous-flow HeartWare HVAD ranges from 2,400 to 3,800 rpm. Despite the incongruity between the 2 pump displays in our patient, we observed no physiologically significant problems attributable to dissimilar flow dynamics. However, the asymmetric device arrangement did create some logistical problems. The need for 2 controllers and 4 batteries is a long-recognized shortcoming of biventricular device therapy, and having to accommodate redundant, dissimilar equipment not only limits the use of pumps from different manufacturers, but also necessitates the patient's undergoing rigorous training on both devices. Nevertheless, the long-term success of the heterogeneous pump arrangement described in this case study is noteworthy.

Preoperatively, we did not anticipate our patient's experiencing long-term RV failure. Accordingly, the decision to implant a right-sided pump was born of necessity rather than design. Our preferred approach to long-term biventricular support is to use the SynCardia® total artificial heart (SynCardia Systems, LLC; Tucson, Ariz), as opposed to a combined LVAD and RVAD support system. However, when our patient's RV function deteriorated during LVAD implantation, using 2 different systems proved to be feasible.

It is worth noting that biventricular support with identical HeartMate II devices, although possible, is geometrically undesirable because of the difficulty of aligning the opposing pump housings.[6] In contrast, intrapericardial placement of a HeartWare HVAD for RV support avoids interference with the outflow path of the left-sided pump. Thus, despite the logistical complexities in their management, nonidentical CF device pairings can provide successful long-term biventricular support.

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