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EDITORIAL COMMENT

Ramping Up Evidence-Based Ventricular Assist Device Care*

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Over the past several decades, mechanical circulatory support has become an increasingly important treatment for patients with advanced heart failure. Initial proof-of-concept trials focused on reducing the mortality of critically ill patients in cardiogenic shock. Although the ultimate goal of mechanically assisted circulation was always long-term support as an alternative to cardiac transplantation, uncertainties about the durability of device performance and adverse events led to its early use in transplant candidates to provide a "bail-out" strategy in the event of device malfunction.

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With additional experience and technological advances, large-scale clinical trials have demonstrated the efficacy of ventricular assist device (VAD) in prolonging survival, improving quality of life, and maintaining end-organ function (1,2). In particular, development of smaller continuous flow VADs that operate silently and are powered electrically have invigorated clinicians and patients alike as demonstrated by the rapid uptake in device implantation in the United States (3). In addition, clinical trials and registry results have fueled enthusiasm to examine VAD therapy in heart failure patients who are not as critically ill as those previously studied.

Clinicians caring for the growing VAD population are constantly reminded of important knowledge gaps that remain in patient management. A glaring example is the lack of consensus regarding the most effective approach to set the device speed, a key determinant of flow provided by the pump. Typically, the speed is set in the operating room and subsequently adjusted on the basis of integration of hemodynamic parameters, device information, and reduction of left ventricular size determined by echocardiography. The optimal device speed results in maximal "unloading" of the failing left ventricle without reducing cavity size to the point that the myocardium is in contact with left ventricular inflow cannula. Within physiologic limits, there should be a relatively linear relationship between VAD speed and left ventricular dimension; in a normally functioning VAD, higher speeds should reduce left ventricle size.

In this issue of the *Journal,* Uriel et al. (4) from Columbia University present their approach for determining the optimal speed of a continuous flow left ventricular assist device (LVAD) using a "ramp" study. They describe a retrospective review of 39 patients who underwent ramp testing, a procedure in which the LVAD speed is reduced to provide a low level of support followed by progressive increases in device speed while simultaneously assessing blood pressure, left ventricular size, frequency of aortic valve opening, severity of mitral regurgitation and aortic insufficiency, and right ventricular systolic pressure. The clinical goal was to obtain maximal reduction in left ventricular size with intermittent aortic valve opening and maintenance of a mean arterial blood pressure of at least 65 mm Hg. Using this systematic approach, the authors demonstrate that 60% of patients undergoing routine ramp studies for speed optimization had adjustments made to the LVAD settings.

Uriel et al. (4) also used ramp testing to provide additional objective information regarding device performance in patients with suspected VAD thrombosis. Development of thrombus on an internal component of the VAD can be a devastating event resulting in device malfunction, stroke, and death. The clinical presentation of device thrombosis is commonly hemolysis with maintenance of adequate circulatory support, although cases of device malfunction and hemodynamic compromise have been reported (5). The Columbia investigators performed ramp testing in 17 patients with suspected device thrombosis and showed that failure to reduce left ventricular dimensions with increasing VAD speed was diagnostic of pump dysfunction. In their series, all 9 patients whose device was explanted after a ramp study suggestive of device malfunction had either thrombus in the pump or disconnection of a component of the outflow graft.

Several important caveats regarding this study require consideration. First, it is not clear that the minor adjustments in VAD speed described in this paper are linked to favorable patient outcomes. Larger scale trials examining the optimal strategies for device management are needed. Further, it should be acknowledged that mechanical circulatory support is a dynamic treatment with clinical triggers that should prompt re-evaluation of device speed. Second, ramp studies were highly predictive of LVAD thrombosis in patients whose clinical presentation was already suggestive of the condition. Perhaps the routine use of the ramp study to detect device malfunction at an earlier time point would allow preemptive treatment that would obviate the need for dramatic surgical intervention. Finally, the role of the ramp study requires additional validation before broad adoption and incorporation

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in VAD management guidelines. Uriel et al. (4) have provided a detailed description of the protocol to facilitate replication.

As mechanical circulatory support continues its maturation as a therapy, development and validation of objective management approaches like the ramp study are needed. In addition, many other VAD-specific observations require investigation, for example, the excessive hemorrhagic stroke risk of VAD-treated women (6), the development of small bowel arteriovenous malformations (7), the relatively high incidence of de novo aortic insufficiency in continuous flow VAD patients (8), and the residual challenge of right-side heart failure after LVAD placement. The therapy has moved beyond justifying its role as an important adjunct in the treatment of advanced heart failure. It is now time to focus on improving care processes, understanding and reducing adverse events, and demonstrating cost effectiveness.

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REFERENCES

1. Rose EA, Gelijns AC, Moskowitz AJ, et al. Long-term use of a left ventricular assist device for end-stage heart failure. N Engl J Med 2001;345:1435–43.
2. Slaughter MS, Rogers JG, Milano CA, et al. Advanced heart failure treated with continuous flow left ventricular assist device. N Engl J Med 2009;361:2241–51.
3. Kirklin JK, Naftel DC, Kormos RL, et al. The fourth INTERMACS annual report: 4,000 implants and counting. J Heart Lung Transplant 2012;31:117–26.
4. Uriel N, Morrison KA, Garan AR, et al. Development of a novel echocardiographic ramp test for speed optimization and diagnosis of device thrombosis in continuous-flow left ventricular assist devices: the Columbia Ramp Study. J Am Coll Cardiol 2012;60:1764–75.
5. Bashir J, Cheung A, Kaan A, et al. Thrombosis and failure of a HeartMate II device in the absence of alarms. J Heart Lung Transplant 2011;30:1197–9.
6. Bogaev RC, Pamboukian SV, Moore SA, et al. Comparison of outcomes in women versus men using a continuous-flow left ventricular assist device as a bridge to transplantation. J Heart Lung Transplant 2011;30:515–22.
7. Suarez J, Patel CB, Felker GM. Mechanisms of bleeding and approach to patients with axial-flow left ventricular assist devices. Circ Heart Fail 2011;4:779–84.
8. Cowger J, Pagani FD, Haft JW, at al. The development of aortic insufficiency in left ventricular assist device-supported patients. Circ Heart Fail 2010;3:668–74.

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