Device Management and Flow Optimization on Left Ventricular Assist Device Support

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KEYWORDS

- Left ventricular assist device • Heart failure • Mechanical circulatory support
- Pump thrombosis • Device parameters • Ramp study

KEY POINTS

- It is critical to know the device parameters while managing a patient on left ventricular assist device (LVAD) support.
- The LVAD flow depends on interaction between the pump and the native heart and is determined by speed of the pump rotation, preload at the pump inlet, and afterload at the pump outlet.
- The LVAD flow is directly proportional to the device speed (increases at higher speed settings) and inversely proportional to the pressure differential, ΔP, between the inflow and outflow (decreases as ΔP increases).
- Abnormal LVAD flow and pulsatility patterns help recognize LVAD-specific complications.
- Systematic analysis of LVAD parameters and echocardiographic and hemodynamic assessment allow for personalized optimization of LVAD flow.

INTRODUCTION

Left ventricular assist devices (LVAD) improve longevity, functional capacity, and quality of life in patients with refractory, end-stage (stage D) systolic heart failure.[1–3] The original concept of pulsatile flow pumps has been replaced with continuous-flow designs that allowed for miniaturization of the pump sizes, less device-associated infections, and improved device durability.[4] With less mechanical pump failures, long-term LVAD therapy has become a well-accepted reality to support patients until the time of heart transplantation, or as destination therapy for those ineligible for transplantation. As of December 2016, 17,634 patients received US Food and Drug

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Administration–approved continuous-flow LVADs in the Unites States alone with many more implants performed worldwide.[5,6] Currently, 3 continuous-flow LVADs are commercially available for clinical use in the United States: (a) HeartMate-II (Abbott Laboratories, Abbott Park, IL, USA), (b) HVAD (HeartWare Inc, Framingham, MA, USA), and (c) HeartMate-III (Abbott Laboratories, Abbott Park, IL, USA). Most acute care facilities are likely to encounter patients supported with LVADs, and it is imperative that providers of critical care are familiar with the hemodynamic principles of LVAD operation to ensure appropriate care.

In this article, the authors discuss the following:

- Principles of flow optimization in LVAD patients;
- Understanding of normal LVAD physiology and device interaction with the heart;
- Interpretation of LVAD parameters and their application to clinical assessment and patient care.

PRINCIPLES OF LEFT VENTRICULAR ASSIST DEVICE FUNCTION AND NORMAL LEFT VENTRICULAR ASSIST DEVICE PHYSIOLOGY

Contemporary LVADs consist of 3 basic components: an inflow cannula that attaches to the left ventricular (LV) apex or in its proximity and draws blood from the LV chamber into the device, the impeller that moves the volume of blood forward in parallel with native cardiac output, and an outflow tract that returns blood back into the vascular system via the proximal aorta.

The LVAD flow depends on a complex interaction between the pump and the native heart and is determined by the following 3 major components:

1. Programmed speed of the pump rotation,
2. Preload, or pressure/volume of blood available at the pump inlet, and
3. Afterload, or pressure at the pump outlet.

The speed of the device is directly proportional to the pump flow, that is, given a constant preload and afterload, the flow will increase at higher and decrease at lower LVAD speeds. The pressure difference between the pump inlet and outlet, in the absence of obstruction within the inflow cannula or the outflow tract, is termed "head pressure" or "ΔP." The flow of blood through the LVAD is inversely proportional

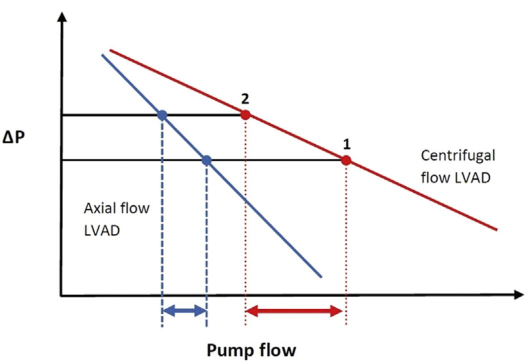

Fig. 1. Schematic representation of HQ curves of axial flow (*solid blue line*) and centrifugal flow (*solid red line*) LVADs, and impact of changing differential pressure ("ΔP") on the pump flow. As "ΔP" increases, the pump flow decreases (move from point 1 to point 2). The same change in "ΔP" will produce greater flow change in the centrifugal pump compared with the axial pump (*solid double-headed arrows*).