American Journal of Emergency Medicine xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Ventricular assist device in the emergency department: Evaluation and management considerations

William Brady, MD [a,*], Sabrina Weigand, MD [a], James Bergin, MD [b]

[a] Department of Emergency Medicine, University of Virginia School of Medicine, Charlottesville, VA 22908, United States
[b] Department of Medicine, University of Virginia School of Medicine, Charlottesville, VA 22908, United States

ARTICLE INFO

Article history:
Received 28 February 2018
Received in revised form 18 April 2018
Accepted 20 April 2018
Available online xxxx

Keywords:
LVAD
Left ventricular assist device
Heart failure

ABSTRACT

Ventricular assist devices (VAD) are being used at increasing rates in patients with severe, end-stage heart failure. Specific indications include VAD placement as a bridge to cardiac function recovery, a bridge to cardiac transplantation, or destination therapy (long-term support for patients ineligible for transplant). The assessment and management of the VAD patient is rather complex, requiring a basic knowledge of device structure and function. This article reviews the basic structure and function, discusses the approach to the VAD patient in the ED, and reviews the more common presentations and complications encountered in these technology-complex patients who are critically ill at baseline.

Contents

1. Introduction

Heart failure continues to be a significant cause of mortality in the United States. According to the American Heart Association, the prevalence of heart failure has increased from 5.7 million in 2013 to 6.5 million cases in 2017 [1]. Despite advances in medical treatment, heart failure contributed to 1 out of every 9 deaths in 2009 [2]. Mortality from advanced heart failure is potentially decreased by ventricular assist devices (VAD) as compared to medical management alone [3]. VADs, once only used as either a bridge to cardiac transplant or overall improvement in cardiac function, are increasing in prevalence at a rapid rate since their approval for use as destination therapy [4]; destination therapy is defined as the use of a VAD as the primary therapy in a patient with severe heart failure who is not a candidate for transplantation or other definitive therapy – in other words, it is offered to patients as a final means of prolonging life in the setting of end-stage heart failure. Thus, the three categories of indication for VAD placement include the following:

- bridge to cardiac transplant;
- bridge to recovery in potentially reversible cardiac pathology; and
- destination therapy, long-term support for patients ineligible for transplant.

According to INTERMACS (Interagency Registry for Mechanically Assisted Circulatory Support), there have been 22,866 mechanical

* Corresponding author.
E-mail address: wb4z@virginia.edu. (W. Brady).

https://doi.org/10.1016/j.ajem.2018.04.047
0735-6757/

circulatory support devices placed between 2006 and 2016, with a current pace of over 2500 devices implanted per year [5]. With this number of patient's receiving VADs, it is likely many will present outside of tertiary medical centers, in essence VAD centers; therefore, all emergency practitioners should be competent with management and stabilization of the VAD patient until they can be transferred to a VAD center.

2. Ventricular assist device components and function

VADs function by receiving blood from the failing ventricle and, with the aid of a mechanic pump, augment cardiac output. In their simplest terms, the VAD consists of the internal pump, an external power source, and a control unit. Placement is indicated in patients with a New York Heart Association Class IIIb - IV heart failure that is worsening despite optimized medical management [4]. Of course, consideration of the ultimate goal is also made, whether it be a bridge to cardiac transplantation, a period of cardiac function support during recovery, or destination therapy in a patient with no other recourse.

Since the placement of the first pneumatically driven ventricular assist devices in 1966, multiple advancements have been made to these devices [6]. First generation VADs had inlet and outlet valves and created a pulsatile flow; these devices, however, were large and cumbersome – they were not portable in any real sense. These devices gave way to the development of second and third generation VADs that provide a decrease in size while offering an improvement in function. While VADs can be placed in either a right, left or biventricular configuration, the most frequently encountered are left ventricular assist devices (LVAD).

The pumps employed in VADs can be divided into two primary categories, either pulsatile or continuous-flow. A pulsatile pump mimics the natural pulsatile flow of the heart while the continuous flow device produces a steady perfusion state. Continuous-flow devices account for the vast majority (in excess of 90%) of implanted VADs [5]; this type of device is both more compact smaller and more durable than pulsatile VADs.

The continuous-flow device uses a pump with either centrifugal or axial flow. Both types of continuous-flow device have a central rotor containing permanent magnets. Controlled electric currents running through coils contained in the pump housing cause the rotors to spin. In the centrifugal pump, the rotors accelerate the blood circumferentially, producing flow toward the outer rim of the pump (figure); in the axial flow pump, the rotors are cylindrical with blades that are helical, causing the blood to be accelerated along the axis of the rotors (figure). Physiologically, the continuous-flow pump produces perfusion which is unlike “natural” blood flow; perfusion occurs in a non-physiologic manner and yet provides the more favorable circulatory support for organ system function – as compared to the pulsatile pump.

Components of the VAD include the following (Fig. 1A): inflow cannula, pumping chamber, outflow cannula, percutaneous driveline, controller, and power source. As noted, the VAD can be placed in either the right or left ventricle. For illustrative purposes, we will assume placement in the left ventricle, thus an LVAD. The inflow cannula, placed within the left ventricle, pulls blood from the ventricular cavity into the LVAD pump. The pumping chamber is located at the apex of the left ventricle for the HeartMateIII and HeartWare devices, or in the sudiaphragmatic space for the HeartMateII device, and houses the impeller, a frictionless rotor which rotates at speeds of approximately 3000 rpm (HeartWare), 5000 rpm (HeartMateIII) and 9000 rpm (HeartMateII); these types of pumps can generate blood flows up to 10 l per minute. The outflow cannula carries blood from the pumping chamber to the ascending aorta. The percutaneous driveline provides a conduit for the various wires which connect the system controller to the pump; the driveline is tunneled subcutaneously from the pump, exits the skin in the epigastric area, and connects to the controller. The controller performs a number of important functions, including power regulation, LVAD system monitoring, alarm status, battery life, and data download. The controller panel of a has a number of important functions and symbols; an example of the controller panel of a HeartMateIII is shown in Fig. 1B. The batteries are, of course, the power supply; current units carry two rechargeable batteries.

LVADs offer a variety of unique challenges for emergency providers. Herein, we discus some of the most common and life-threatening presentations and offer a basic approach to treatment in the most common continuous flow devices (i.e., HeartMateII, HeartMateIII, HeartWare VAD).

3. Initial evaluation of the VAD patient

The initial assessment of the patient, including interpretation of vital signs and the physical examination, differs significantly from non-VAD individual, though still needs to be accomplished in a systematic and

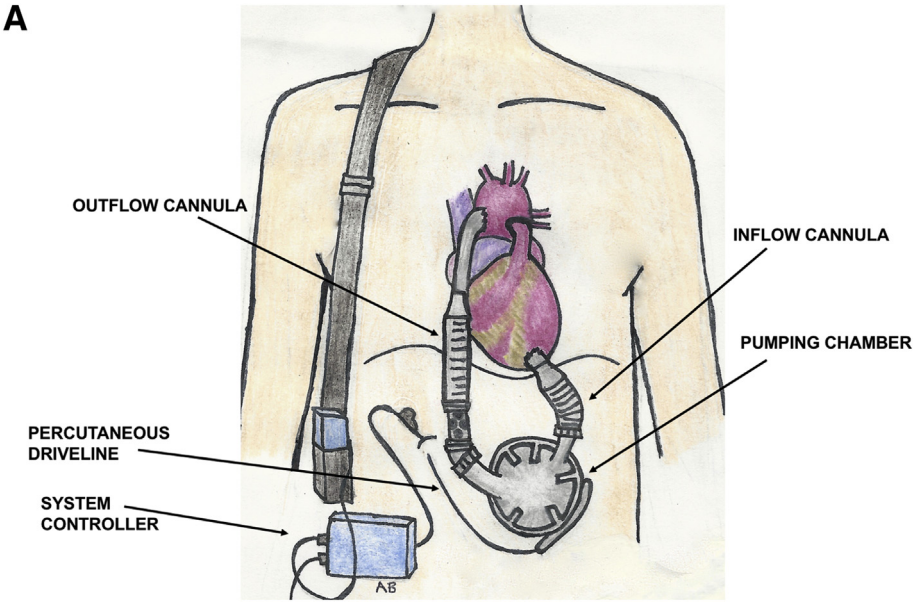

Fig. 1A. Ventricular assist device diagram, demonstrating the various components of the system.

Please cite this article as: Brady W, et al, Ventricular assist device in the emergency department: Evaluation and management considerations, American Journal of Emergency Medicine (2018), https://doi.org/10.1016/j.ajem.2018.04.047