Mechanical support of the heart

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Learning objectives

After reading this article, you should be able to:

- summarize the indications for mechanical support
- classify ventricular assist devices into three types
- list the main specific anaesthetic concerns associated with ventricular assist device implantation

Abstract

Mechanical support of the heart can be offered to patients who are refractory to pharmacological treatment, therapy for coronary or valvular disease or resynchronization therapy. Ventricular assist devices enable end-organ perfusion in the setting of heart failure. This can be temporary (as a bridge to recovery or transplantation) or permanent (destination therapy). Devices can be extracorporeal or implanted, and generated flows can be pulsatile or non-pulsatile. Implantation usually requires sternotomy with or without cardiopulmonary bypass, but percutaneous devices exist. Cardiostable anaesthesia with inotropic support is vital. Problems include bleeding versus thrombosis, right heart failure and late infections. Transoesophageal echocardiography can be used to detect potential right-to-left atrial shunts, aortic regurgitation and cannula malposition, and to monitor filling and right ventricular function after implantation. In the future, total implantability of the devices, including the power source, is likely to occur. Eventually, they are likely to become a widespread alternative to transplantation.

Keywords Bridge to transplantation; destination therapy; heart failure; mechanical support; ventricular assist devices

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Introduction

Heart failure is implicated in approximately 20% of all hospital admissions among people older than 65. It has multiple causes, including ischaemic heart disease, non-ischemic cardiomyopathy, valvular heart disease and congenital heart disease. Cardiac transplantation is the gold standard treatment for heart failure in patients with New York Heart Association class IV symptoms, but few donor organs are available. Mechanical support of the heart can be offered to patients who are refractory to pharmacological treatment, therapy for coronary or valvular disease or resynchronization therapy.

The earliest forms of mechanical cardiac support were cardiopulmonary bypass, introduced in 1953 and used for cardiopulmonary support during cardiac surgery, and intra-aortic balloon counter pulsation (IABP), introduced in 1962 and used for temporary partial haemodynamic support and to improve coronary perfusion. The first left ventricular assist device (LVAD) was implanted by Cooley in 1969.

Ventricular assist devices (VADs) enable end-organ perfusion in the setting of heart failure. VADs can be used as a 'bridge to recovery' to support patients after myocardial infarction and for those with non-ischaemic cardiomyopathy or those who cannot be weaned from cardiopulmonary bypass. VADs are frequently used to allow patients to survive and improve their overall condition while they wait for heart transplantation (bridge to transplant; BTT). Destination therapy (as an alternative to transplantation) is of growing importance and is expected to be increasingly so in the future. Successful unloading of the failing heart reduces wall tension and myocardial oxygen demand through reinstatement of the Frank–Starling properties. This occurs through effective recruitment of myocardial muscle elements and offloading the isovolumetric phase of contraction. Subsequently, it may favorably alter the myocardial remodelling pathway, called 'reverse remodelling', eventually even resulting in explantation.

Devices

VADs are available as extracorporeal and implantable types. The available devices can be classified into three types: centrifugal pumps, volume-displacement pumps and axial-flow pumps.

Extracorporeal devices

The most commonly used are centrifugal pumps that produce non-pulsatile flows of up to 8 l/min. These are used for temporary left, right or biventricular support either as a bridge to decision in moribund patients, for patients with postcardiotomy heart failure, for temporary right ventricular support, or for post transplant allograft failure. They can be used with an oxygenator for extracorporeal membrane oxygenation. Heparin is required during use. The Levitronix VAD is an example of a centrifugal pump. Extracorporeal pulsatile pumps include an inflow valve (bioprosthetic or mechanical), which allows unidirectional flow into the device and prevents regurgitation during mechanical systole, and an outflow valve to prevent regurgitation during mechanical relaxation. The Thoratec biventricular assist device (Thoratec Corp., Pleasanton, CA, USA) is an example of an extracorporeal pulsatile pumps. They require long-term anticoagulation with warfarin with or without aspirin.

Total artificial hearts

Total artificial hearts are generally volume-displacement devices, generating pulsatile flow through the filling and compression of an internal chamber with air. During implantation of such a

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device, the patient's own left and right ventricles are removed and the device is inserted in the same anatomical location as the heart. Examples of total artificial hearts include the CardioWest device (SynCardia Systems, Tucson, USA) and the AbioCor (Abiomed, Danvers, Massachusetts, USA).

Implantable devices

These are the mainstay of current devices and are designed for longer term use. They are smaller pumps, allowing patients to have better mobility and quality of life. They generally have lower infection rates, although they still require a power source through a percutaneous driveline, which can be a source of infection.

The HeartMate XVE (Thoratec/St. Jude), a very effective pulsatile implantable pump, was available as a bridge to transplantation and approved for destination therapy. However, its short durability (1–2 years before requiring replacement) and high rate of complications restricted its widespread adoption in end-stage heart failure. There are now two types of continuous-flow pumps: axial and centrifugal. All pumps utilize an impeller to generate flow. The axial pumps include the HeartMate II (Thoratec/St. Jude) (Figure 1) and the Jarvik 2000 FlowMaker (Jarvik Heart, New York, NY, USA). The spinning of the impeller draws blood from the inflow orifice or cannula through the device to the outflow cannula. The HeartMate II is an axial-flow pump providing flows of 3–10 l/min between 8000 and 12,000 r.p.m. The device measures 4 cm in diameter and 6 cm in length and has a mass of 375 g. The centrifugal pumps include the Heartware (Heartware Inc., Miami, FL, USA) and the recently approved HeartMate 3 (St. Jude Medical Inc., USA) pumps. Heartware (Figure 2), is a centrifugal pump with only one moving part, the impeller, and no mechanical bearings. The impeller is suspended within the pump housing through a combination of passive magnets and a hydrodynamic thrust bearing. The inflow cannula is integrated with the device itself, which is implanted in the pericardial cavity and provides up to 10 litres flow/min.

The HeartMate 3 is the next generation, continuous flow centrifugal pump which recently received the Food and Drug Administration, USA approval in 2017 while it was approved in Europe in October 2015. This miniaturized device provides a wide blood flow access chamber, complete magnetic levitation system and artificial pulse generation to reduce blood stasis and friction. It also features a titanium microsphere-textured surface promoting blood-biomembrane interface for better in vivo compatibility. Similar to the HeartWare device, HeartMate 3 is implanted intrapericardially and the outflow cannula attached to the ascending aorta. It is capable of providing up to 10 litres flow/min within an operating speed range from 3000 to 9000 r.p.m.

Most VADs require cardiac surgery for implantation. New percutaneous devices exist. The smallest and least invasive is the Impella pump (Abiomed). It is inserted in the femoral artery and advanced retrogradely into the left ventricle. It aspirates blood from the left ventricle (LV) and expels it into the ascending aorta using a microaxial-flow pump located on the distal end of a catheter. Another percutaneous VAD is the TandemHeart (CardiacAssist), which is an extracorporeal centrifugal pump whose inflow catheter is placed percutaneously in the left atrium through a trans-septal approach and whose outflow cannula is placed in the femoral artery. Both devices require systemic anticoagulation to prevent device clotting.

Currently, most of the systems in clinical use are operated in a partial support mode, using a fixed speed mode. Continuous flow is well tolerated. Pulsatility, by virtue of aortic ejection, returns once the heart recovers some function. Before this, a pulsatile

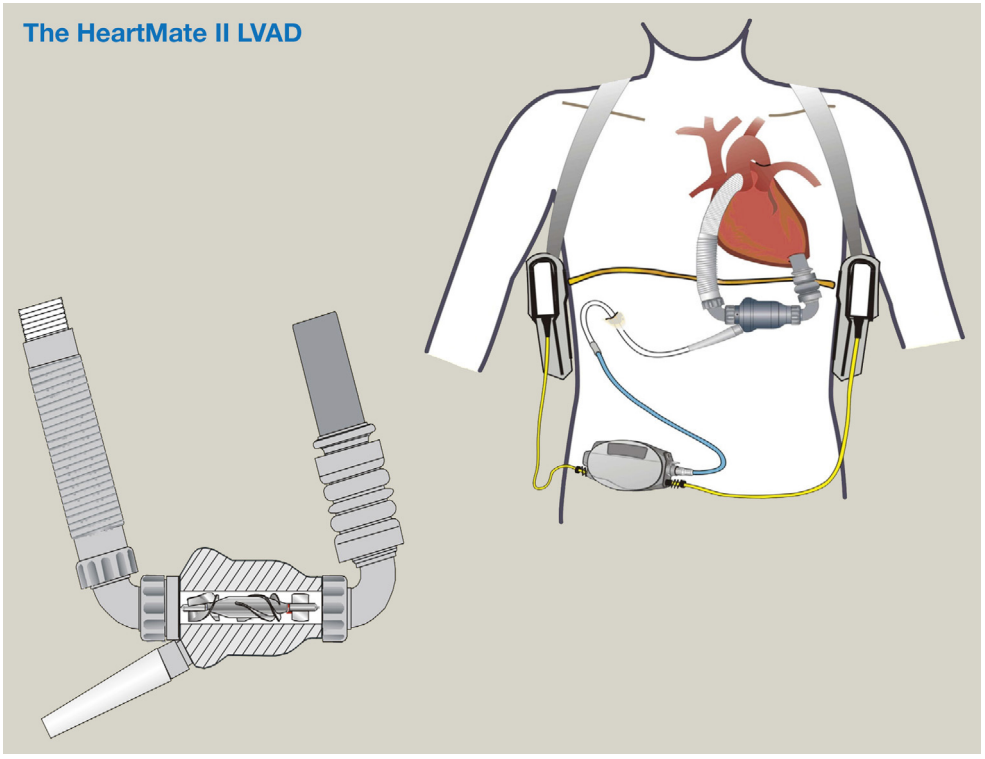

Figure 1

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