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Mechanical circulatory support for end-stage heart failure☆

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ABSTRACT

Mechanical circulatory assistance has become a frequent therapeutic option for patients with advanced heart failure. For patients with acute cardiogenic shock and impaired organ function, short-term assistance with venoarterial extracorporeal membrane oxygenation is the leading therapeutic option. It enables a "bridge to decision-making" i.e. withdrawal of the device after myocardial recovery or after recognition of therapeutic futility, or as a bridge-to-transplantation or to long-term mechanical support. For Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) class 2–6 patients, implantation of a long-term ventricular assist-device (VAD) should be considered before progression to multiple organ failure if heart transplantation is not a first-line option. Most patients receive a miniaturized axial or centrifugal fully implantable left VAD as a bridge-to-transplantation or as "destination therapy" in this setting.

1. Introduction

Despite major advances in pharmacologic therapies for heart failure with left ventricular pump dysfunction, the number of hospitalizations for decompensated heart failure is increasing with most patients ultimately dying of disease complications. Heart transplantation remains the only treatment providing substantial individual benefit for patients with advanced disease, but <3000 organ donors are available worldwide per year, limiting its overall impact. Therefore, alternative approaches such as mechanical circulatory support have been the subject of intense research over recent decades [1–4].

The development of mechanical circulatory devices parallel that of cardiac surgery and cardiac transplantation. The first clinical implantation of a pneumatically-driven ventricular assist-device (VAD) was performed by De Bakey in 1966. Since then, collaborative efforts between scientists, engineers and clinicians have resulted in major improvements in the design, biocompatibility and performance of these machines [5,6]. Traditional indications or strategies for mechanical circulatory support included bridge-to-bridge, in which a first device is used as a bridge to another long-term machine, bridge-to-recovery of heart function, bridge-to-transplantation and destination therapy [7].

2. Short-Term Indications for Mechanical Support

2.1. *Rescuing the "Crash and Burn" Patient and Bridging Others to Recovery*

Short-term mechanical circulatory support devices are indicated in patients with medical conditions (acute myocardial infarction, myocarditis, intoxication with cardiotoxic drugs,

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end-stage dilated cardiomyopathy), post-cardiotomy or post-transplantation acute cardiogenic shock [8–13]. Most of these "crash and burn" patients receive a device as salvage therapy after having already developed signs of multiple organ failure. In these situations, mechanical assistance is used as a bridge to decision-making if the patient survives the first days to reach the "decision-making" point. In patients with potentially reversible cardiac failure (e.g. myocarditis, myocardial stunning post-myocardial infarction), a short-term device may also be used as a bridge to recovery [8].

2.2. *Devices Used as First-Line and Short-Term Cardiac Support Systems*

Devices inserted in such situations are catheter- or cannula-based pumps. In the last decade, venoarterial extracorporeal membrane oxygenation (VA-ECMO) has become the first-line therapy in the setting of acute cardiogenic shock. It provides both respiratory and cardiac support, is easy to insert, even at the bedside, provides stable flow rates, and is associated with less organ failure after implantation compared to large biventricular assist-devices that require open-heart surgery [8,9]. Several considerations must be taken into account before instituting ECMO. First, the device should be inserted before the patient has developed multiple organ failure or myocardial failure has led to refractory cardiac arrest, since these conditions are associated with significantly poorer outcomes [9,10,13]. Second, highly unstable patients may benefit from urgent on-site ECMO initiation by a rapid resuscitation team able to operate a portable and quick-to-prime ECMO circuit before transportation to the ECMO referral center [11]. Third, cardiac failure and other organ injuries should be deemed reversible and the patient's underlying condition should not contraindicate a bridge to a more permanent device or to transplantation. Fourth, management of patients on ECMO for refractory cardiogenic shock is complex and should be conducted in experienced medical–surgical centers [14]. ECMO can also be configured using central cannulation where right atrium, ascending aorta and sometimes left atrium or left ventricle are directly cannulated [15]. This configuration is used first-line with post-cardiotomy or post-transplantation cardiogenic shock, or if peripheral ECMO has failed to deliver adequate flow or is complicated by severe pulmonary edema.

ECMO weaning is considered when there has been partial or full cardiac recovery, or as a bridge to transplantation or VAD implantation because of absence of LV functional recovery [16]. ECMO can also be simply withdrawn in cases of therapeutic futility (severe brain lesions, end-stage multiple organ failure or absence of myocardial recovery in the context of a definitive contraindication to transplantation or VAD implantation). Long-term survival after VA-ECMO is 70–80% after myocarditis or cardiotoxic drug poisoning, 40–50% after myocardial infarction and 15–25% when the device was used to rescue refractory cardiac arrest [9,10,13,16–18]. Survivors reported a preserved quality of life, despite some limitations in physical activities and social functioning in previous series [9,10,13].

Complications are frequently observed under veno-arterial ECMO. They include local hemorrhage (10–20%), pulmonary edema due the increased afterload of the left ventricle (10–15%), cannulation site infection (10–15%), limb ischemia (5–10%), ischemic or hemorrhagic stroke (5%) [9,10,13,19,20].

Other short term devices used in this setting are the Impella® (ABIOMED, Danvers, MA) that is a catheter-based axial flow pump with a propeller at the tip of the catheter which is positioned retrogradely across the aortic valve into the left ventricle. The Impella directly vents the left ventricle and provides more physiologic support than VA-ECMO, which increases LV afterload [21–23]. The TandemHeart® (TandemLife, Pittsburgh, PA) is a percutaneous ventricular assist-device consisting of an extracorporeal centrifugal continuous flow pump that drains blood from the left atrium via a cannula introduced trans-septally through the femoral vein. Blood is then pumped back to the femoral artery at a flow rate of up to 3.5 L/min [8,24]. Compared to VA-ECMO, these systems are more expensive and are not adapted to support patients with severe biventricular failure.

3. Long-Term Indications for Mechanical Support

3.1. *Patient Selection and Indications*

In the large Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) registry, indications for VAD implantation at the time of surgery were bridge to transplantation (53%), destination therapy (46%) and bridge to recovery (<1%) [7]. Before surgery, patients should undergo thorough clinical and psychosocial evaluation, specifically assessment of severity of cardiac failure, co-existing life-limiting or psychiatric illnesses and evaluation of the surgery-associated risk. The INTERMACS severity classification (Table 1) is commonly used to classify the different degrees of clinical severity of patients with New York Heart Association class III-IV symptoms, and helps to define the appropriate timing for device insertion [7]. The most common indications for left ventricular assist device (LVAD) placement are cardiogenic shock (INTERMACS level 1, 15%), worsening of symptoms in inotrope-dependent patients (INTERMACS level 2, 35%), stable but truly inotrope-dependent patients (INTERMACS level 3, 30%) and patients with resting symptoms (INTERMACS level 4, 15%). However, as previously stressed, the most severe patients (INTERMACS level 1) may benefit from insertion of a first-line device such as ECMO and later be bridged to a long term cardiac-assist machine after clinical and hemodynamic stabilization. For INTERMACS class 2 patients, an increase in inotrope dose, use of vasopressors or signs of end-stage organ failure should indicate urgent device placement. Stable but truly inotrope-dependent patients (INTERMACS level 3) are those who might derive the greatest benefit from heart transplantation or VAD insertion. At this stage of the disease, VAD insertion may be elective, especially for patients expected to have a long waiting time on the transplantation list. VAD implantation in INTERMACS class 5–7 patients is still controversial and depends on the evolution of the disease, its impact on the patient's functional status and quality of life. Newest generation devices, which are better tolerated and have fewer complications, may significantly increase the number of patients implanted at that stage. (See Table 2.)