Review Article

Circulatory Support Devices in Acute Heart Failure: Which and When?

Deborah de Sá Pereira Belfort,[1] *Rafael Cavalcanti Tourinho Dantas,*[1] *Silvia Moreira Ayub-Ferreira*[1]

Instituto do Coração do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo,[1] *São Paulo, SP – Brazil*

Introduction

Acute heart failure (AHF), which is the syndrome where there is a rapid or gradual worsening of chronic or new heart failure (HF), is one of the main causes of emergency department visits, and it is the leading cause responsible for non-elective hospitalizations in patients over 65 years of age, with an elevated readmission rate at 1 year.[1] In-hospital mortality due to AHF is 3% to 4% in international registries, reaching 12.6% in the Brazilian BREATHE registry.[2] When we analyze the most severe spectrum of AHF, which is cardiogenic shock (CS), in-hospital mortality varies from 32% to 58%, even in international registries.[3,4]

The path to reducing the elevated morbidity and mortality of AHF and CS involves quick and accurate identification and diagnosis, recognition and treatment of decompensating factors, assessment of severity and associated comorbidities, and quick and appropriate implementation of specific therapies to restore multiple organ perfusion.[5]

In the majority of cases, specific CS therapy initially comprises use of inotropes and vasodilators or vasopressors.[4] Nonetheless, in refractory cases or cases that are already more severe, it is necessary to use short-term mechanical circulatory support (MCS) devices. When indicated early, short-term MCS is related to hemodynamic benefits through increased cardiac output, leading to recovery of vital organ perfusion, decreased myocardial oxygen consumption and cardiac work, and increased coronary perfusion. Depending on the device, it can also lead to a decrease in ventricular filling pressures, reducing pulmonary congestion.[6]

The use of short-term MCS has grown worldwide in recent years, but the literature still lacks evidence to support its use, and the indication and choice of different devices is defined on an individual basis and in discussion by multidisciplinary teams. In Brazil, their availability is still low, and their use is limited to large centers.[5]

The objective of this review is to highlight the indications, contraindications, and main particularities of each percutaneous or surgical device, with clinical and hemodynamic data that can assist in the choice of each one and corroborate their use in AHF.

Keywords

Cardiogenic Shock; Mechanical Circulatory Support; Ventricular Assist Devices; Acute Heart Failure

Mailing Address: Silvia Moreira Ayub Ferreira •
Instituto do Coração do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo - Avenida Dr. Eneas Carvalho de Aguiar, 44. Postal Code 05403-000, Cerqueira Cesar, São Paulo, SP - Brazil
E-mail: silvia.ayub@fm.usp.br
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Device types

Numerous MCS device options are available on the market for the treatment of AHF and, when indicated, short- and/or medium-term devices are initially used. To facilitate the understanding of their role in CS, we can further subdivide them into categories according to type of implant and type of support (Table 1).[6]

Short-term MCS devices can also be allocated with the objective of implantation in the following situations:[5,7]

a. Bridge to transplantation: patients who are transplant candidates have high mortality on the waiting list, and the devices can be used for clinical stabilization until transplantation;

b. Bridge to long-term MCS devices: short-term MCS devices can be used for clinical stabilization before implantation of a long-term MCS device;

c. Bridge to decision: patients in critical CS who require rapid intervention for clinical stabilization, with subsequent evaluation for the next strategy (transplant, long-term MCS, recovery, or palliative care);

d. Bridge to recovery: short-term MCS devices can be used in etiologies of CS that allow recovery of ventricular function, such as acute myocardial infarction, myocarditis, and post-cardiotomy shock.

General indications and contraindications

Ventricular assist devices are classically used in CS for acute conditions, such as after acute myocardial infarction or myocarditis, or for chronic HF in an acute context, but their use goes beyond these indications, as follows:[5,7]

a. Complications of acute myocardial infarction (example: post-infarction intraventricular communication, acute mitral insufficiency)

b. Acute rejection after heart transplantation

c. Right ventricular (RV) failure after heart transplantation

d. Primary graft dysfunction after heart transplantation

e. RV failure after implantation of a long-term ventricular assist device

f. Difficult separation from cardiopulmonary bypass after heart surgery

g. Refractory ventricular arrhythmia

h. Prophylaxis before high-risk angioplasties

i. Prophylaxis before complex ventricular tachycardia ablations

Table 1 – Types of short/medium-term mechanical circulatory support devices divided by type of support and form of implantation

Short-term circulatory support devices	Percutaneous	Surgical
Left ventricle	Intra-aortic balloon pump (femoral or axillary) Impella 2.5 (LV-Ao) Impella CP (LV-Ao) TandemHeart (LA-Ao)	Impella 5.0 Impella LD (direct arteriotomy of the ascending aorta) Impella 5.5 LV CentriMag (LV apex)
Right ventricle	Impella RP (RV-PA) TandemHeart (RA-PA) ProtekDuo cannula with centrifugal pump (RA-PA)	RV CentriMag (RV or RA-PA)
Biventricular	Peripheral VA ECMO Impella CP or 2.5 + Impella RP Impella CP or 2.5 + TandemHeart ProtekDuo with centrifugal pump	Central VA ECMO Biventricular CentriMag

LA-Ao: left atrium-aorta; LV: left ventricle; LV-Ao: left ventricle-aorta; RA-PA: right atrium-pulmonary artery; RV: right ventricle; RV-PA right ventricle-pulmonary artery; VA ECMO: venoarterial extracorporeal membrane oxygenation. Table adapted from Telukuntla et al.[6]

j. Prophylaxis before high-risk percutaneous procedures in patients with valvular heart disease

The following clinical situations must be evaluated before implanting a short-term MCS device, as they are contraindications to the use of some devices:[4,5]

a. Patients in palliative care

b. Aortic insufficiency or mechanical aortic prosthesis

c. Aortic aneurysm and/or dissection

d. Severe peripheral arterial or aortic disease

e. Intracavitary thrombus

f. Severe coagulopathy

g. Uncontrolled sepsis

We have presented a general scenario regarding short-term MCS devices, but each device has specific particularities and contraindications that assist in their selection, depending on the patient and the situation in question. We will detail each of them in the following section.

Percutaneous circulatory support devices

Percutaneous MCS devices are less invasive, and they usually have shorter durability, from days to weeks (Table 2).[6] Among the available short-term percutaneous devices, the following stand out: intra-aortic balloon pump (IABP), TandemHeart™, and Impella™ for left ventricular (LV) support; peripheral extracorporeal membrane oxygenation (ECMO) for biventricular support; and ImpellaRP and ProtekDuo™ for RV support (Figure 1).

a. Intra-aortic balloon pump

IABP is the most widely used short-term MCS device in Brazil. It was introduced in 1968, and its design has remained the same since then. It is a helium-inflated balloon positioned in the descending thoracic aorta, distal to the left subclavian artery and proximal to the emergence of the renal arteries. The preference for helium is due to the fact that it has low viscosity, allowing rapid inflation and deflation of the balloon, in addition to being harmless in case of rupture. The balloon is synchronized to the cardiac cycle. Inflation occurs during diastole, increasing coronary perfusion, and deflation occurs during systole, reducing peripheral vascular resistance and increasing cardiac output, in addition to decreasing cardiac work.[7]

The gain in cardiac output with the use of IABP depends on some factors, and it ranges from 0.5 to 1 L/min. Aortic compliance is inversely proportional to the diastolic gain of the balloon, so that young patients or patients in distributive shock who have low peripheral vascular resistance tend to have less gain. Tachycardia also leads to worsening of IABP performance, as the cardiac cycle time becomes too short for adequate balloon cycling. IABP is also ineffective in pulseless rhythms such as ventricular fibrillation or asystole.[9]

Insertion is usually percutaneous via the femoral artery, with the help of a guidewire and 8.5 to 9.0 Fr introducer, in a simple manner at the bedside. The position of the IABP is confirmed through a chest X-ray, in which the tip of the balloon is observed at the level of the carina, meaning that this device can be used in critical patients who cannot be transported. More recently, access via the axillary or subclavian artery has been used, mainly in patients with the prospect of a long period of support to allow greater mobilization or in cases of difficult femoral access, whether due to severe peripheral arterial disease or obesity making femoral access difficult. The size of the balloon depends on the patient's height: 34 mL in patients from 1.52 to 1.63 m and 40 mL in patients > 1.64 m.[7] The 50 mL balloon is rarely available in Brazil, even though it is preferable for patients > 1.83 m tall.

The main contraindication to the use of IABP is the presence of aortic insufficiency. Aortic disease or severe peripheral arterial disease are relative contraindications. Possible complications of IABP are limb ischemia ipsilateral to the access, organ ischemia, bleeding at the insertion site, atheroembolic events that may even lead to ischemic stroke, worsening of renal function in case of malpositioning of the IABP, and thrombocytopenia due to consumption.[7,9]

Despite its current widespread use, the literature does not demonstrate benefits in the context of CS after acute myocardial infarction. The IABP SHOCK II (Intra-Aortic

Table 2 – Main short-term percutaneous MCS devices

	IABP	ECMO	TandemHeart	Impella CP
Mechanism	Pneumatic	Centrifugal	Centrifugal	Axial
Cannula	7-9 Fr	21-25 Fr Inflow; 15-19 Fr Outflow	21 Fr Inflow; 15-17 Fr Outflow	14 Fr
Insertion technique	Descending aorta via femoral artery	Inflow: right atrium via femoral vein; Outflow: descending aorta via femoral artery	Inflow: left atrium via femoral vein and transseptal puncture; Outflow: femoral artery	Retrograde insertion in the left ventricle via femoral artery
Hemodynamic support	0.5 L/min	> 4.5 L/min	4 L/min	3.7 L/min
Implant time	+	++	++++	++
Risk of limb ischemia	+	+++	+++	++
Anticoagulation	+	+++	+++	+
Hemolysis	+	++	++	++
Complexity of management	+	+++	++++	++

ECMO: extracorporeal membrane oxygenation; Fr: French; IABP: intra-aortic balloon pump; MCS: mechanical circulatory support.

Balloon Pump in Cardiogenic Shock II) Trial was the main randomized study evaluating the use of IABP in CS after acute myocardial infarction with early myocardial revascularization in 600 patients, and it showed no difference in mortality between groups at 30 days or in long-term follow-up.[10] A possible explanation is the fact that the impact of IABP on cardiac output is small and, in many cases, insufficient for CS after acute myocardial infarction.

In CS related to chronic cardiomyopathy, the literature lacks studies. In a Brazilian study carried out at the Heart Institute (HCFMUSP), 223 patients with chronic cardiomyopathy and an average ejection fraction of 24% underwent IABP implantation in the context of CS.[11] Compared to pre-implantation values, there was an improvement in central venous saturation, a drop in lactate, less need for vasopressors, and greater tolerance to the use of nitroprusside after IABP implantation, suggesting hemodynamic improvement after the intervention. Although there is little evidence, the IABP is an accessible device that is easy to implant and manage, and it can promote hemodynamic improvement in selected cases; it is thus used as the first choice for CS in Brazil.

b. Peripheral ECMO

Venoarterial extracorporeal membrane oxygenation (VA ECMO) is a device that can be implanted percutaneously or surgically, and it provides circulatory and respiratory support. Percutaneous VA ECMO is composed of a cannula that drains blood from the right atrium by insertion into the femoral vein, a centrifugal pump, and an oxygenation membrane, as well as a cannula inserted in the common femoral artery that directs the flow to the aorta in a retrograde manner. It can provide output of more than 4.5 L/min and pulmonary support, making peripheral VA ECMO widely used in cases of very hemodynamically unstable patients and even in cardiorespiratory arrest due to the rapid percutaneous insertion of cannulas at the bedside and the fact that it provides biventricular support.[7,12] Currently, it is the only modality available for percutaneous RV support in Brazil.

Although it restores systemic perfusion, due to retrograde flow in the aorta, peripheral VA ECMO leads to an increase in LV afterload, causing distension of the LV with significant pulmonary congestion, and making ventricular recovery difficult in reversible causes of CS.[13] Patients with acute causes of CS, such as acute myocardial infarction and myocarditis, are at greater risk of LV distension since the LV, in these cases, tends to be less compliant, and the mitral valve is usually competent. Patients with chronic HF in CS, on the other hand, have distended LV and mitral insufficiency, and they tend to have less distension, at the expense of a higher incidence of pulmonary edema. In addition to the consequences already mentioned, non-opening of the aortic valve with very elevated afterload leads to stasis and thrombus formation above the aortic valve and within the LV, increasing the risk of embolic events.[14] In these cases of LV distension, left chamber decompression strategies lead to improvement in pulmonary congestion and appear to increase the chances of weaning from support and reduced mortality when performed in less than 12 hours, according to a recent meta-analysis.[15] The use of inotropes and vasodilators, reduced ECMO flow, additional procedures such as the associated use of IABP or Impella, atrial septostomy, and cannula implantation at the tip of the left ventricle are possible strategies for LV decompression.[5,7,15]

Aortic insufficiency and aortic dissection contraindicate the use of ECMO, as do situations that impede adequate systemic anticoagulation and severe peripheral arterial occlusive disease making peripheral cannulation impossible.[7] Complications of ECMO are common to other devices that use vascular access, such as limb ischemia ipsilateral to the insertion of the cannula, and larger the lumen, the more frequent it is. A strategy that minimizes this complication is the retrograde insertion of a distal perfusion cannula (5 to 8 Fr) into the superficial femoral or posterior tibial artery. Other possible complications are major bleeding including intracranial hemorrhage, consumptive coagulopathy, hemolysis, thromboembolic events, and circuit infection.[16] Another specific complication of VA ECMO is Harlequin syndrome, which occurs when the patient begins to recover ventricular function, but pulmonary

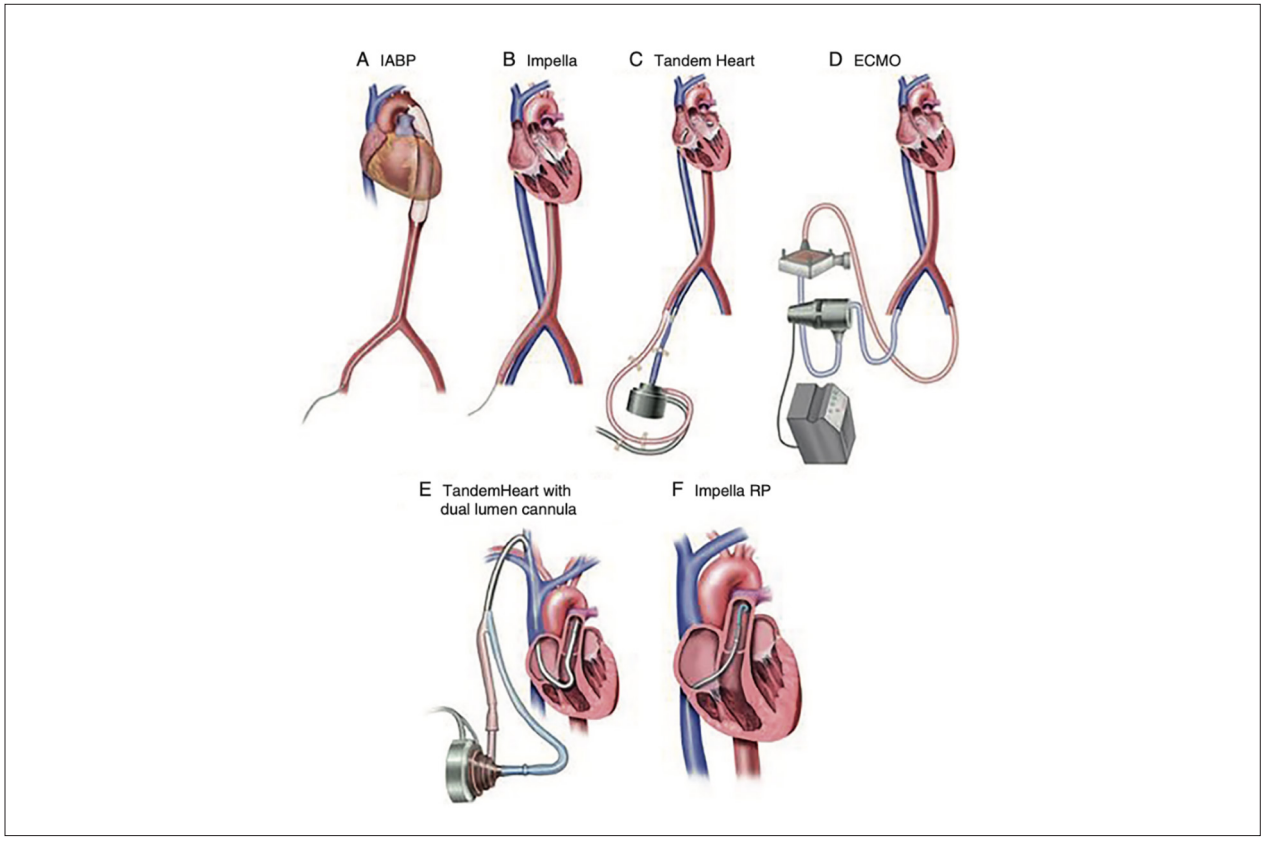

Figure 1 – *Temporary percutaneous mechanical circulatory support for the management of cardiogenic shock. The top row highlights the most used devices for left circulatory support: (A) intra-aortic balloon pump (IABP), (B) Impella, (C) TandemHeart, and (D) extracorporeal membrane oxygenation (ECMO). The bottom row exhibits the devices used for right circulatory support: (E) ProtekDuo TandemHeart and (F) Impella RP. (Reprinted with permission from Mandawat e Rao.[8])*

impairment remains significant, causing the blood leaving the aortic valve to be hypoxemic and irrigate the first branches of the aorta: brachiocephalic trunk, left carotid, and up to the left subclavian. This leads to segmental hypoxemia in the upper limbs and central nervous system and can have neurological consequences depending on the degree of hypoxemia.[17]

Although the indication for VA ECMO is well established in clinical practice as a bridge to recovery and decision-making, the literature does not show a mortality benefit with routine use of this strategy. Published in 2022, the ECMO-CS was a randomized study comparing VA ECMO in rapidly deteriorating CS versus routine care.[18] The study analyzed 117 patients, 58 for immediate VA ECMO and 59 for the control group. There was no difference between groups in the primary composite outcome of death, cardiopulmonary resuscitation, or placement of another support device within 30 days, but 39% of patients in the control group underwent non-immediate ECMO support. Mortality at 30 days was 47.5% in the control group and 50% in the intervention group. In 2023, the ECLS-SHOCK Trial was published, including only patients with post-infarction CS. It also showed no benefit in mortality comparing 208 patients in the control group with 209 patients in the VA ECMO group, with 30-day mortality of 47.8% versus 48%, respectively; moreover, there was more bleeding in the intervention group than in the control group.[19]

Both studies do not support routine use of VA ECMO in CS, making individualized patient assessment necessary to identify the optimal moment to provide circulatory assistance, when the patient does not yet have irreversible organ dysfunction and when the implantation of the support will not be futile.

c. Impella™ 2.5 and Impella™ CP

The Impella is an axial flow rotary pump inserted through the aortic valve via femoral artery access, which aspirates blood from the LV to the aortic root. It provides LV decompression and better coronary perfusion and reduces myocardial oxygen consumption.[5,7,20] In addition to being used in the context of CS, it is also used as support for procedures with a high risk of hemodynamic instability, such as angioplasty of the left coronary artery trunk and ventricular tachycardia ablation. It does not depend on myocardial contractility or the cardiac cycle.

For left circulatory assistance, it is available in 4 models: the 2.5, with percutaneous implantation in the femoral artery, which provides up to 2.5 L/min of output; the CP, also percutaneous, which provides up to 3.8 L/min of flow; the 5.0, which is surgically implanted via the femoral or axillary artery and allows a flow rate of up to 5 L/min; and the 5.5, which is also surgically implanted, allowing cardiac output

of up to 6.2 L/min. The Impella 2.5 and CP are approved for use for up to 4 days, and the Impella 5.0 and 5.5 for up to 10 and 14 days, respectively; therefore, they are not the devices of choice for situations in which the expected support time is longer.[20] The appropriate positioning of the Impella is achieved in hemodynamics with the aid of fluoroscopy or transesophageal echocardiography, positioning it so that the inflow orifice is far enough from the ventricular wall to avoid suction and also 3.5 to 4 cm from the aortic valve, to avoid damaging the leaflets. Due to its position inside the LV and through the aortic valve, its use is contraindicated in the presence of a thrombus in the LV, important aortic stenosis, moderate to important aortic insufficiency, aortic dissection, and mechanical aortic prosthesis; additionally, there is a relative contraindication in the presence of peripheral arterial occlusive disease with vascular access < 6 mm, prior ischemia in the limb, and infection at the insertion site.[7]

Possible complications of using Impella include hemolysis, limb ischemia, or bleeding, especially if used for a prolonged period of time, worsening of RV dysfunction leading to failure, and, more rarely, heart perforation, device fracture, aortic valve damage, and ischemic stroke.[21]

Despite the hemodynamic benefit, there is currently no evidence in the literature showing clinical benefit for the use of Impella. The ISAR-Shock trial$_{22}$ showed a gain in cardiac output and hemodynamic improvement with the use of Impella 2.5 in CS compared to IABP, but without mortality benefit, and another randomized study with 48 patients showed a similar clinical outcome.[23] A meta-analysis encompassing these 2 randomized studies and 5 observational studies showed, in addition to similar survival, a greater risk of bleeding, hemolysis, and limb complications with Impella compared to IABP.[24] In Brazil, its use is limited mainly due to cost, making it available in few centers.

d. TandemHeart™

The TandemHeart™ is a percutaneous implant device that involves an entry cannula, positioned in the left atrium via femoral vein puncture, with insertion through the vena cava arriving in the right atrium, where transseptal puncture is performed, guided by fluoroscopy and/or transesophageal echocardiography. The flow is directed to a centrifugal pump; through an outlet cannula positioned in the femoral artery, it is directed to the aorta and generates a flow rate of up to 4 L/min. It leads to a reduction in left atrial and pulmonary pressure and improves output, but can increase LV afterload due to retrograde flow in the aorta, which can lead to LV distension, preventing the TandemHeart from offering a myocardial protective effect, similar to peripheral VA ECMO.[25]

Similar to other devices, contraindications to TandemHeart implantation are severe peripheral arterial occlusive disease, interatrial thrombus, and aortic insufficiency. Defects in the interventricular septum can, in theory, evolve into a right-to-left shunt using this device. Unlike Impella, LV thrombus or aortic stenosis are not contraindications in this case. Complications common to other devices that use vascular access may occur: vascular injury, bleeding, and limb ischemia. Due to transseptal puncture, cardiac tamponade is a possible complication. Hemolysis is uncommon, but it may occur.[7,25]

Compared to IABP, observational studies have shown better hemodynamic performance, but with no difference in mortality and a higher incidence of complications such as bleeding and ischemia of the lower limbs.[25] There is also greater difficulty in implanting the device, as it involves transseptal puncture. The TandemHeart is not available in Brazil.

e. Impella RP™

The Impella RP model provides RV assistance, aspirating blood from the inferior vena cava to the pulmonary artery, and it can be used in situations such as primary RV failure or RV failure after implantation of a long-term device. It provides flow of up to 4 L/min. The RECOVER RIGHT study showed that the use of this device in patients with RV failure after implantation of a left ventricular assist device, after cardiotomy, and after infarction was easy to manage, with cohort survival of 73% at 30 days and 62% at 180 days.[26] It is contraindicated in patients with RV thrombus, tricuspid or pulmonary stenosis or regurgitation, or the presence of right-sided mechanical prostheses.

Possible complications are those related to venipuncture such as venous dissection; perforation of the femoral, iliac, or cava vein; and malpositioning of the device with suction phenomena. Chest radiography must be performed daily to monitor the position of the device, and, in case of changes in the flow or curve of the pump, a transesophageal echocardiogram must be performed to confirm the positioning.[7] It is currently not available in Brazil.

f. TandemHeart ProtekDuo™

This more recent device allows right ventricular support, with the advantage, in relation to the Impella RP, of making early patient mobilization possible. It is inserted percutaneously into the right internal jugular vein, allowing blood to be aspirated from the right atrium, passed through a TandemHeart system pump and returned to the pulmonary artery. It is indicated in cases of RV failure following the implantation of a long-term support device, and it has the advantage of simple removal without the need for an additional surgical procedure.[27] Possible complications include bleeding at the puncture site, venous perforation, and others related to venous access. As with any right assist device, pulmonary congestion should be monitored due to increased RV output. Also similar to the Impella RP, it is contraindicated in patients with RV thrombus, tricuspid or pulmonary stenosis or regurgitation, or the presence of right-sided mechanical prostheses.[7] It is not yet available in Brazil.

Surgically implanted circulatory support devices

Although they have greater durability and a better long-term safety profile when compared to percutaneous implant devices, surgically implanted devices are more invasive, requiring a surgical procedure with anesthesia and prior programming for admission, which limits their use in cases of rescue of patients with frank CS and INTERMACS classification

1. The most available short/intermediate-term surgical MCS devices are Impella 5.0™, Impella LD™, Impella 5.5™, central VA ECMO, and CentriMag™.[5,7]

a. Impella 5.0, Impella LD, and Impella 5.5 (Abiomed)

The general description of Impella has already been provided in the topic of percutaneous devices. The difference between the two that will be covered here is the greater magnitude of flow it can provide and the method of insertion. It also has a better safety profile against vascular complications and the capacity to be used for a longer period.[6]

The Impella 5.0 requires a surgical cut in the right femoral artery; however, if removal is not expected in the short term, it is recommended that the insertion be made through the axillary artery, using a 23 Fr introducer. This device has the capacity to provide a flow of up to 5 L/min, with an approved duration of use of 10 days.[7]

The Impella LD differs from the 5.0 in that the insertion method is performed surgically in the ascending aorta, with direct passage through the aortic valve and placement in the LV. Compared to the former, it has the disadvantage of requiring a sternotomy. For this reason, it is generally used in cases of pump failure with difficulty weaning from extracorporeal circulation, with the advantage of reducing vascular complications and having a lower risk of thromboembolic events.[7]

Recently, the use of Impella 5.5 was approved by the United States Food and Drug Administration for use in CS. It can be inserted either directly through the ascending aorta or through the axillary artery, with a duration of up to 14 days. Its benefit over the other two is due to the provision of a greater flow of up to 6 L/min, as the device is thinner and shorter, which facilitates insertion through the vessels, and because it has a SmartAssist. This system provides information about cardiac output, end-diastolic pressure, and LV pressure. These data facilitate device configuration and weaning, optimizing the chance of recovery of the native heart. Furthermore, the sensors present in the SmartAssist provide a more precise location of the pump's position, allowing more effective monitoring and replacement at the bedside. This position, as previously stated, is directly related to proper functioning of the device.[6,7]

The indications, contraindications, and complications of the various Impellas for surgical insertion are similar to those for percutaneous insertion, and the choice should be based on the profile of the patient being treated, mainly taking into account the magnitude of flow the patient needs, the support time, and the possibility of peripheral vascular access. In Brazil, none of these types of Impella are available for use.

b. Central venoarterial ECMO

Central VA ECMO, unlike peripheral VA ECMO, requires admission to a surgical center; except in cases where cannulation of the axillary artery occurs, sternotomy is necessary for its placement. The most common use is in post-cardiotomy shock, taking advantage of the surgical procedure itself, but it is an interesting alternative for upgrading peripheral VA ECMO in situations where it is insufficient in organic perfusion, when there is lower limb ischemia due to peripheral arterial complications caused by the device, and/or when there is pulmonary volume overload due to increased LV afterload.[7]

The preferred sites for central VA ECMO cannulation are the right atrium, where the inflow cannula is inserted, and the ascending aorta for the outflow cannula. The size of the cannulas should be determined by the size of the patient and the desired cardiac output, generally between 18 and 24 Fr in the aorta and 28 and 36 Fr in the right atrium, and good fixation must be performed to avoid bleeding as much as possible. Although the chest is generally kept open with occlusive dressing, closure of the chest is associated with a higher extubation success rate, ease of patient mobilization, and lower risk of infection.[5,7]

It presents characteristics similar to peripheral VA ECMO with a flow that varies from 4 to 6 L/min and a capacity for biventricular and respiratory hemodynamic support, due to the presence of an oxygenation membrane. It presents the advantages of having an unlimited and anterograde flow through the device, without increasing LV afterload, absence of complications in peripheral arteries, and the ability to insert a LV decompression device. However, it has disadvantages, such as the fact that it requires surgical insertion, increasing the risk of the procedure for already patients who are already critical, greater risk of infection, especially if the chest is open, and potential aortic dissection and embolic ischemic events.[6]

Central VA ECMO is the most widely available surgical short-term MCS device for AHF in Brazil.[5]

c. CentriMag™

The CentriMag™ device is surgically inserted via median or lateral sternotomy for acute circulatory support, and it can be used for up to 30 days as RV, LV, or biventricular extracorporeal support. Its use as a cardiopulmonary circuit is also possible for a period of up to 6 hours.[28]

The CentriMag system consists of a console, centrifugal pump, flow cannula, and motor. There is a floating rotor that levitates by magnetic forces, reducing friction, wear, and heat production from the device's rotation, thus reducing the risk of mechanical failure and hemocompatibility events (thrombosis, bleeding, and hemolysis) due to the device. The flow generated by the device can reach 10 L/min. The speed responsible for generating this flow is adjusted by turning a button, making it quick and easy to couple the device with the patient's scenario, promoting increased flow in cases of circulatory shock and reduced flow during device weaning.[6]

CentriMag is surgically placed using techniques similar to other cardiopulmonary bypass cannulations, and its versatility in connecting various types of cannulas facilitates the insertion procedure, with flexible configuration of support. In case of LV support, the inflow cannula is placed in the left atrium or at the apex of the LV, and the outflow cannula is placed in the ascending aorta. In case of RV support, the inflow cannula is inserted into the right atrium or RV, and the outflow cannula is placed in the pulmonary artery, directly or through the anastomosis of a vascular graft. Biventricular assistance is performed with a combination of both configurations

mentioned (Figure 2). The versatility of the device also allows the insertion of an oxygenator into the circuit in cases that require pulmonary support. The evolution of insertion techniques with minithoracotomy, or even minimally invasive without sternotomy, and use of peripheral arterial grafts, such as axillary artery, jugular vein, and femoral, reduces the risk of complications of device placement.[28]

The main indications for this device are both AHF that evolves to CS in diverse etiologies (post-acute myocardial infarction, chronic decompensated HF, myocarditis) and CS after cardiac surgical procedures, such as RV failure after heart transplantation, primary graft dysfunction, post-cardiotomy shock, and RV shock after long-term MCS implantation for LV assistance. Although the risk of thromboembolic phenomena is reduced with CentriMag, due to its mode of functioning, the use of anticoagulants is still indicated. Maintaining a device flow above 4 L/min reduces the risk of thrombosis.[6,7]

There is little evidence on the use of CentriMag in CS. Most studies are small and/or non-randomized, and the outcomes differ depending on the etiology of the shock. The largest, a cohort study that included 143 patients, had a mean duration of use of 14 days (ranging from 8 to 26 days), with 30-day and 1-year mortality of 69% and 49%, respectively.[29] In another smaller study on use of the device in 12 patients with post-cardiotomy shock, 8 of them survived until long-term MCS device implantation; 2 achieved complete recovery, and 2 died.

The presence of device complications seems to be directly related to the duration of use. It is not uncommon for patients with the device to experience bleeding, neurological events such as ischemic and hemorrhagic stroke, atrial and ventricular arrhythmias, infection, and respiratory and renal failure. Nonetheless, few cases of pump failure and hemolysis have been observed, even with prolonged use. There are no major contraindications to the use of CentriMag, but some examples are the presence of coagulopathy and/or severe bleeding when the use of an anticoagulant is not possible, and patients in palliative care, with no prospect of improvement and/or advanced treatment, such as heart transplantation or long-term MCS devices.[6,7]

Patient selection: given the options, which device is preferable?

Device selection for each patient is based on an analysis of different factors such as INTERMACS profile (Table 3), use strategy, additional cardiac output required, presence of isolated or biventricular LV or RV dysfunction, presence of contraindications, and availability. Ideally, the device choice should be based on invasive hemodynamic assessment with a pulmonary artery catheter.

Patients in INTERMACS 1, that is, critical CS, should be prioritized for bedside devices that provide rapid assistance. In general, percutaneous implant devices are preferable for this situation, with the objective of metabolic rescue and subsequent assessment of multisystemic viability that will be able to guide future interventions.[4,6,31] In this scenario, when the shock is predominantly in the LV, the first option may be IABP, as it has greater availability, low cost, and low implant complexity; on the other hand, it offers low additional cardiac output and is, in many cases, insufficient to provide adequate perfusion. In these cases, it is necessary to escalate support to a device that provides greater output, the most available being peripheral VA ECMO. In emergency cases before or during cardiorespiratory arrest, peripheral VA ECMO is the device of choice.

Patients in INTERMACS 2, that is, worsening organ functions despite inotropes, may be considered for other percutaneous devices (if available) that require transfer to the hemodynamic sector, such as Impella 2.5, Impella CP, or TandemHeart in LV shock and Impella RP and ProtekDuo in RV shock. In cases of biventricular dysfunction, the combination of two devices is possible,[30] as mentioned in Table 1, but there are important cost limitations and greater complexity of management, with VA ECMO being preferable in most cases.

Surgically implanted devices are preferable in patients who are already undergoing cardiac surgery for another reason, such as in situations of post-cardiotomy shock, post-heart

Table 3 – INTERMACS classification for severity of heart failure

Level	Description	Hemodynamic status	Time for intervention
1	Critical cardiogenic shock	Persistent hypotension despite the use of inotropes and IABP, with critical organic hypoperfusion (“crash and burn”)	Hours
2	Progressive decline despite inotrope use	Progressive decline in organ function, water retention, and nutrition despite the use of inotropes in optimized doses	Days
3	Stable with inotrope	Stable on moderate inotrope doses, but failure to wean	Elective, in weeks to months
4	Symptoms at rest	Water retention and frequent decompensation, despite tolerating weaning from inotrope	Elective, in weeks to months
5	Exertion intolerant	Severe exertion intolerance, presence of congestion, comfortable at rest	Varying urgency, depending on nutrition and organic function
6	Exertion limited	Moderate limitation to exertion, less congestion	Varying urgency, depending on nutrition and organic function
7	NYHA FC III	Hemodynamic stability without signs of hypervolemia	Not indicated

FC: functional class; IABP: intra-aortic balloon pump; NYHA: New York Heart Association.Adapted from Diretriz de Assistência Circulatória Mecânica da Sociedade Brasileira de Cardiologia.[5]

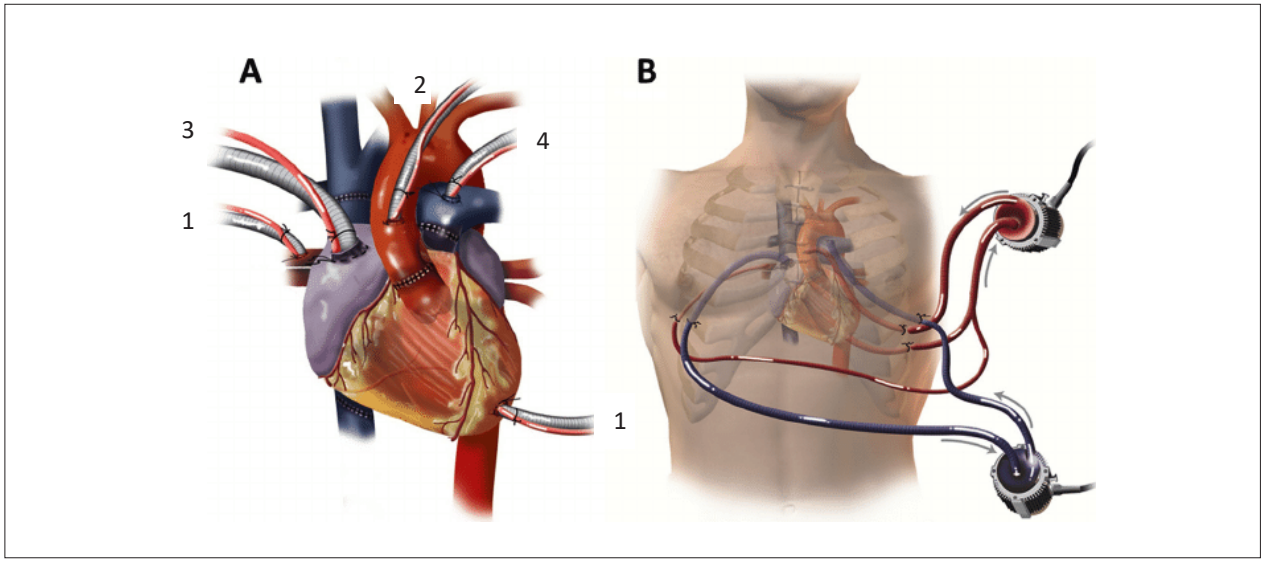

Figure 2 – *(A) Cannulation of a biventricular CentriMag: with inflow cannulas in the left atrium and left ventricle [1] and in the right atrium [2] and outflow cannula in the aorta [3] and pulmonary artery [4]. (B) CentriMag cannulas seen from the outside connected to the pump, removed from the chest in this figure via intercostal and subcostal incisions. Image reproduced from Kaczorowski et al.*[30]

transplantation primary graft dysfunction, and RV shock after long-term device implantation. They can also be considered in patients who present any unwanted complication of a percutaneously implanted device, for example, LV distension and pulmonary congestion in peripheral ECMO and TandemHeart, and in cases of severe peripheral vascular disease, provided that the patient has the clinical conditions to be transported and undergo a more invasive surgical procedure.

Eventually, patients in less complex centers should be transferred to a center capable of heart transplantation and advanced therapy for short- and long-term ventricular support.[4,31] Clinical stabilization with the implantation of temporary circulatory support devices before transfer can increase the safety of transporting these critical patients, and it should be discussed with the center that will receive the patient.

Final messages

CS continues to be a condition with high morbidity and mortality despite advances in technology, and the routine use of short-term devices in CS has not yet shown an increase in survival in the literature. However, carefully evaluated and selected cases may benefit from short-term MCS, and further studies are needed to support the use of short-term MCS devices in this context.

Author Contributions

Conception and design of the research: Belfort DSP, Dantas RCT, Ayub-Ferreira SM; Acquisition of data: Belfort DSP, Dantas RCT, Ayub-Ferreira SM; Analysis and interpretation of the data and Writing of the manuscript: Belfort DSP, Dantas RCT; Critical revision of the manuscript for content: Ayub-Ferreira SM.

Potential conflict of interest

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This article does not contain any studies with human participants or animals performed by any of the authors.

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