Mechanical Circulatory Support Devices in the Older Adults

Bhoumesh Patel, MD[a,*], Robert P. Davis, MD[b], Siavosh Saatee, MD[c]

KEYWORDS

• Mechanical circulatory support • Cardiogenic shock • Older adults • Geriatrics • Frailty

KEY POINTS

- Because mechanical circulatory support (MCS) continues to advance with improving outcomes, older adults patients previously not considered for MCS are now being supported.
- All MCS devices, to varying degrees, restore systemic circulation, improve oxygen delivery, reduce ventricular distension, thereby reducing wall stress, stroke work, and myocardial oxygen consumption.
- Extracorporeal membrane oxygenation should be considered earlier in the clinical course of the disease and initiated without a delay before prolonged hypoperfusion leads to a significant degree of metabolic derangement.
- Palliative care physician should be consulted throughout the course MCS therapy, from decision-making period, preimplantation, through the duration of MCS therapy.
- Age itself should not preclude patients from being candidates for MCS.

INTRODUCTION

Mechanical circulatory support (MCS) era began in 1953 with the development of cardiopulmonary bypass to facilitate open-heart surgery.[1] Past few decades have seen substantial progress in MCS, and it has expanded the treatment options for patients. Currently available MCS devices can be implanted percutaneously or surgically. They can also be configured to support the left, right, or both ventricles, offering varying levels of circulatory support.[2] Because the field continues to advance and

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[a] Division of Cardiac Anesthesiology, Department of Anesthesiology, Yale School of Medicine, 333 Cedar Street, P.O. Box 208051, New Haven, CT 06520-8051, USA; [b] Division of Cardiac Surgery, Department of Surgery, Yale School of Medicine, 333 Cedar Street, P.O. Box 208051, New Haven, CT 06520-8051, USA; [c] Department of Anesthesiology, Feinberg School of Medicine, 251 East Huron St., F5-704, Chicago, IL 60611, USA
* Correspondence author.
E-mail address: bhoumesh.patel@yale.edu

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resuscitation protocols are being refined, patients previously not considered for MCS are now being supported. An older adults patient is defined as having a chronological age of 65 years or older. However, there is no clear medical or biological evidence to support this definition. Many of the older adults patients, especially those aged younger than 75 years, are still robust and active. During the last century, life expectancy has increased, and population ageing is a global phenomenon. In the United States, for example, this increased from 47.3 years at birth in 1900 to 78.7 years in 2010.[3] According to the latest population estimates and projections from UN Department of Economic and Social Affairs's Population Division, 1 in 6 people in the world will be aged older than 65 years by 2050, up from 1 in 11 in 2019.[4] In many regions, the population aged 65 years will double by 2050, whereas global life expectancy beyond 65 years will increase by 19 years.[4] Currently, there are no published guidelines for the use of MCS in the older adults. The purpose of our review is to provide anesthesiologists caring for older adults patients with an overview of commonly use MCS and discuss fundamental principles of these devices, physiological effect, older adults specific factors when considering MCS.

Mechanical Circulatory Support Devices and Hemodynamic Effects

MCS devices can broadly be classified based on duration of support into temporary or durable devices. Patients with durable devices can be discharged from the hospital. Temporary MCS devices can be placed percutaneously or surgically but patient on these cannot leave the hospital. In addition, these devices can be used in various configurations, alone or in combination with each other to support either right, left, or both ventricles.

Mechanical circulatory support devices for right ventricular failure

Right ventricular failure remains a major cause of morbidity and mortality.[5] MCS devices for the RV are an important tool in the management of cardiogenic shock due to RV failure with the ability to rapidly stabilize patients and restore perfusion. The most used devices are the intra-aortic balloon pump (IABP), the Impella RP (AbioMed, Danvers, MA), the TandemHeart (LivaNova, London, England, UK), and venoarterial extracorporeal membrane oxygenation (VA-ECMO; **Fig. 1**).

Mechanical circulatory support devices for left ventricular failure

Left ventricular mechanical support devices can be broadly classified based on the hemodynamic circuit as (A) left ventricle (LV) to aorta assist devices, namely, the IABP and the Impella; (B) left atrium (LA) to systemic artery, namely, the Tandem Heart; and (C) the right atrium (RA) to systemic artery, namely, venoarterial extracorporeal membrane oxygenation (VA-ECMO; **Fig. 2**).

Mechanical Circulatory Support Devices Physiology and Hemodynamic Effects

All MCS devices, to varying degrees, restore systemic circulation, improve oxygen delivery, reduce ventricular distension, thereby reducing wall stress, stroke work, and myocardial oxygen consumption.[2,6,7] However, the specific features such as circuit configurations, flow rates, and characteristics of the pump (eg, axial, or centrifugal flow) result in different overall cardiac and systemic hemodynamic effects.[6–8] In addition, baseline volume status, myocardial function, and systemic vascular resistance determines the response of a given patient to a specific MCS device. Therefore, it is of utmost importance to differentiate between the primary hemodynamic effects of a device and the net hemodynamic changes observed.

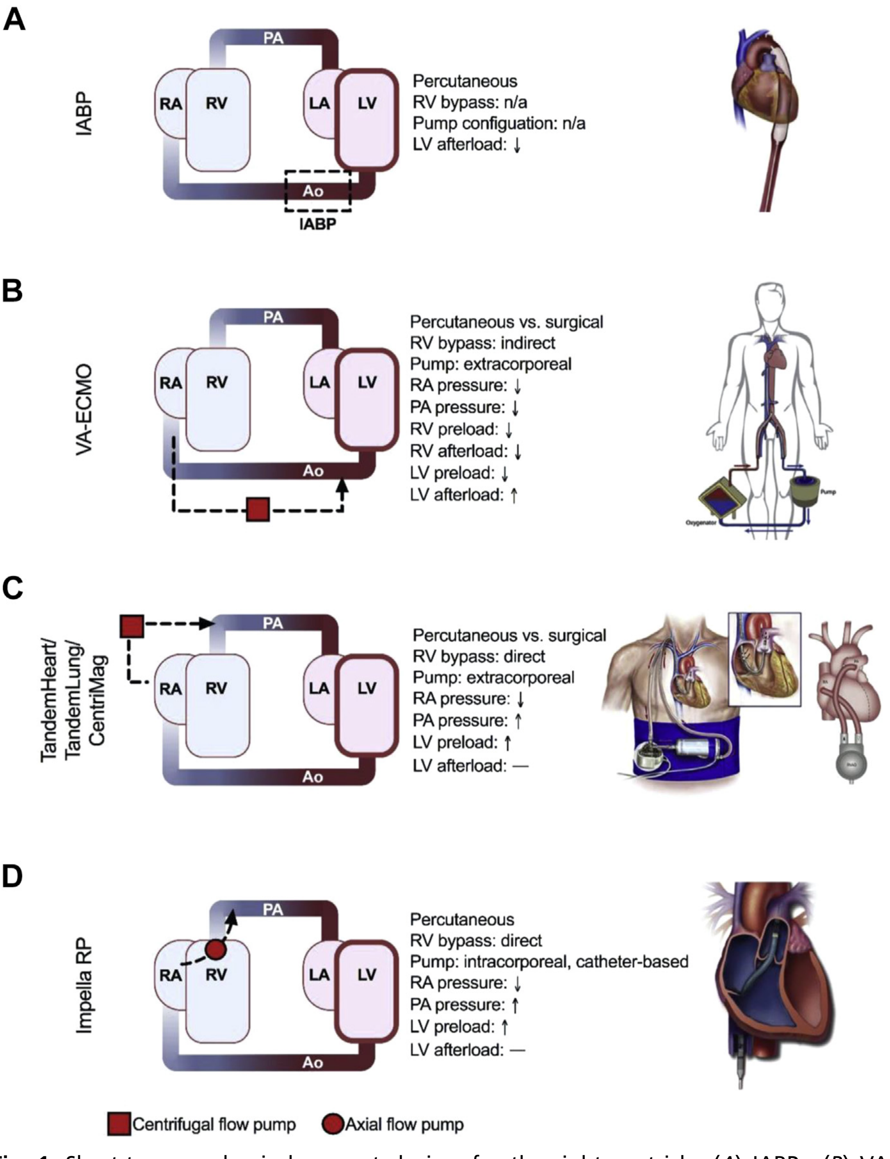

Fig. 1. Short-term mechanical support devices for the right ventricle. (*A*) IABPs; (*B*) VA-ECMO; (*C*) TandemHeart, TandemLung, and CentriMag devices; and (*D*) Impella RP. (Created with BioRender.com.)

Intra-aortic balloon pump

IABP augments pulsatile blood flow by inflating during diastole, increasing mean aortic pressure, thereby improving coronary perfusion. Balloon deflation during systole reduces LV afterload, left ventricular end-diastolic pressure (LVEDP), right ventricular afterload, and myocardial oxygen demand.[7,9] Overall, it increases LV stroke volume, systemic mean arterial pressure, reduces left ventricular diastolic volume and pressure, and increases coronary perfusion pressure.[10] However, IABP does not directly

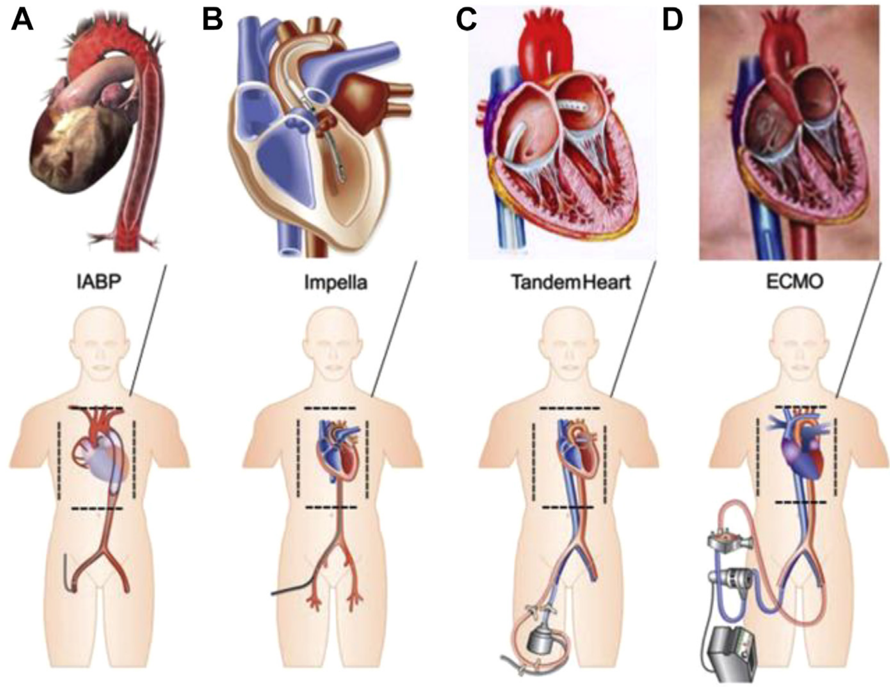

Fig. 2. Short-term mechanical support devices for the LV. (*A*) IABPs, (*B*) Impella, (*C*) TandemHeart, and (*D*) VA-ECMO. (*From* [Brown JL, Estep JD. Temporary Percutaneous Mechanical Circulatory Support in Advanced Heart Failure. Heart Fail Clin. 2016 Jul;12(3):385–98]; with permission.)

improve flow, with typically causing only a modest increase in cardiac output of ≅ 0.5 L/min.[9,10] Hence, IABP largely is regarded as a means of augmenting coronary and systemic perfusion pressure and reducing LV dilation and pulmonary congestion, rather than an effective form of MCS (see **Fig. 1**).

Impella

The Impella devices (Abiomed, Danvers, MA) are continuous microaxial flow pumps. Blood is pumped directly from the LV, independent of the phase of the cardiac cycle, resulting in the loss of the normal isovolumic periods. As a result, the pressure volume loop changes from its normal trapezoidal shape to a triangular shape.[2] It unloads the LV directly, leading to a decrease in the LVEDP and decreasing myocardial oxygen consumption.[2] By diverting blood into the aorta, it increases forward flow improving the systemic mean arterial blood pressure (**Fig. 3**). These pumps provide cardiac output augmentation ranging from 2.5 L/min up to 6 L/min.

Tandem heart system

The TandemHeart is a percutaneous device (Cardiac Assist, Inc; Pittsburgh, PA) is an extracorporeal LA to femoral artery bypass continuous flow centrifugal pump that can provide support of up to 4 L/min. Overall hemodynamic affect include increased cardiac output and unloading of the LV, resulting in a decrease in pulmonary artery occlusion pressure, pulmonary artery pressure, and reduced myocardial workload, and oxygen demand.[2,11] It requires adequate RV function to maintain left atrial volume. However, in the setting of worsening RV failure, it can be converted to an ECMO circuit

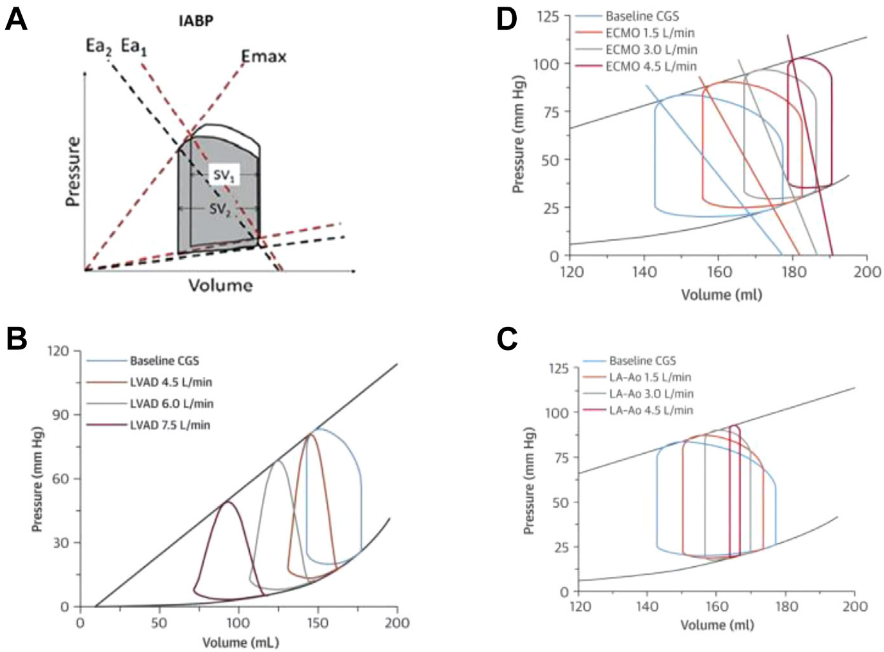

Fig. 3. Hemodynamics effect on pressure-volume loops. (*A*) IABP reduces peak LV systolic and diastolic pressures and increases LV stroke volume. (*B*) Pressure–volume loop with LV to aorta assist device such as the Impella, the LVEDP decreases and there is an increased uncoupling of the aortic and peak left ventricular pressure generation. (*C*) Pressure–volume loops with left atrial-to-aortic (LA-Ao) pumping such as Tandem Heart, showing reducing end-diastolic pressures, increasing end-systolic volume, and decreasing LV stroke volume. (*D*) Pressure–volume loop with VA-ECMO. Increasing flow is associated with an increase in the LVEDP, a decrease in LV stroke volume, and an increase in the effective arterial elastance. (*Adapted from* [Burkhoff D, Sayer G, Doshi D et al. Hemodynamic of Mechanical Circulatory Support. JACC, 2015 Dec;66(23):2663-2674; with permission and Rihal CS, Naidu SS, Givertz MM et al 2015 SCAI/ACC/HFSA/STS Clinical Expert Consensus Statement on the Use of Percutaneous Mechanical Circulatory Support Devices in Cardiovascular Care. JACC 2015 May 19;65(19):e7-e26)]; with permission.)

by repositioning the inflow cannula back across the interatrial septum into the RA and adding a membrane oxygenator to the circuit to provide complete cardiopulmonary support.

Extracorporeal membrane oxygenation

There are 2 types of extracorporeal support: the venovenous ECMO (VV-ECMO) that is used solely for pulmonary support and the VA-ECMO that provides total cardiopulmonary and biventricular support. The overall hemodynamic effect of VA-ECMO is increased global systemic perfusion and mean arterial pressure.[2] However, it causes increased LV afterload with subsequent increase in LVEDP and pulmonary capillary wedge pressure and decreased LV stroke volume.[2] This may lead to deleterious consequences and may exacerbate LV ischemia unless the LV is unloaded. LV can be decompressed with various strategies that include percutaneous options such as IABP, Impella, or atrial septostomy; surgical options such as direct LV apical or left atrial cannulation; or medical management that includes increasing inotropic support and vasodilation.[12]

Venovenous extracorporeal membrane oxygenation outcomes in the older adults. Acute respiratory distress syndrome (ARDS) is a life-threatening form of respiratory failure, characterized by acute inflammatory lung injury that results in increased capillary permeability and pulmonary edema.[13] Management of ARDS is largely focused on supportive management, lung-protective ventilation, prone positioning, and minimizing iatrogenic forms of lung injury with ECMO as a salvage therapy in selected patients.[14–16] Appropriate patient selection remains the most important aspect and several outcome prediction scoring systems have been developed, such as the ECMOnet score, the PRESERVE score, and the respiratory ecmo survival prediction (RESP) score.[17–19] Data on the use of VV-ECMO in the older adults are limited and are mostly from retrospective studies. A study by Mendiratta and colleagues focused on patients aged older than 65 years supported with ECMO between 1990 and May 2013 found a significant increase in the number of older adults patients receiving ECMO, with more than two-thirds of cases performed after 2010. In-hospital survival for older adults was 41%, compared with 55% for all other adults.[20] Deatrick and colleagues evaluated survival to hospital discharge for patients on VV-ECMO by age stratification. They examined the relationship between age and mortality with age stratifications of less than 45, 45 to 54, 55 to 64, and more than 65 years. They found age is an independent predictor of survival to discharge and beginning at age 45 years, in-hospital mortality increases incrementally. Survival to hospital discharge for those aged younger than 45 years was 84.6%, for those aged 45 years or older was significantly lower (67.0%; $P = .009$), as was survival for those aged 55 years (57.1%; $P = .001$) and patients aged 65 years or older (16.7%; $P = .003$).[21] Similarly, Barbaro and colleagues found increasing age was associated with a higher risk of in-hospital mortality when compared with patients aged 16 to 39 years. Whenever stratified for decade of life, this was progressive with a mortality hazard ratio of 1.76 (1.23–2.52) for those aged 50 to 59 years and as high as 3.07 (1.58–5.95) in patients aged older than 70 years.[22] Pranikoff and colleagues[23] found that survival was inversely correlated with the number of days of mechanical ventilation before ECMO. In that study, the predicted mortality rate was 50% after 5 days of mechanical ventilation.[23] Above data suggest that the older age alone should not be a contraindication and indicate that the initiation of ECMO support in older adults patients with respiratory failure should be considered and undertaken early in the clinical course without a delay before prolonged hypoxemia leads to a significant degree of metabolic derangement.

ST-elevation Myocardial Infarction and Mechanical Support

Percutaneous coronary intervention (PCI) remains to be the standard management of ST-elevation myocardial infarction (STEMI); however, there is lack of proper perfusion in about a third of patients after catheterization.[24] Moreover, there is evidence to suggest association with pre-PCI LV mechanical unloading with myocardial protection and augmented myocardial recovery.[25] LV unloading minimizes the reperfusion injury by decreasing the myocardial oxygen requirement, thus limiting ischemic/infarct size.[24,25] (**Fig. 4**) Increasing body of data suggest that pre-PCI LV mechanical unloading is associated with an improved survival.[26] Patients aged 75 years and older with STEMI are at higher risk to present in cardiogenic shock.[24] Other causes such as post-cardiotomy cardiogenic shock, myocarditis, stress-induced cardiomyopathy, pulmonary embolization, and even a mixed picture of sepsis, bleeding, can manifest as cardiogenic shock and should be carefully distinguished. When shock persists, despite preload and afterload optimization, the need for more cardiac output is needed to avoid or recover from multiorgan failure. Temporary MCS should be initiated as soon as possible to stabilize the patient and avoid further deterioration from

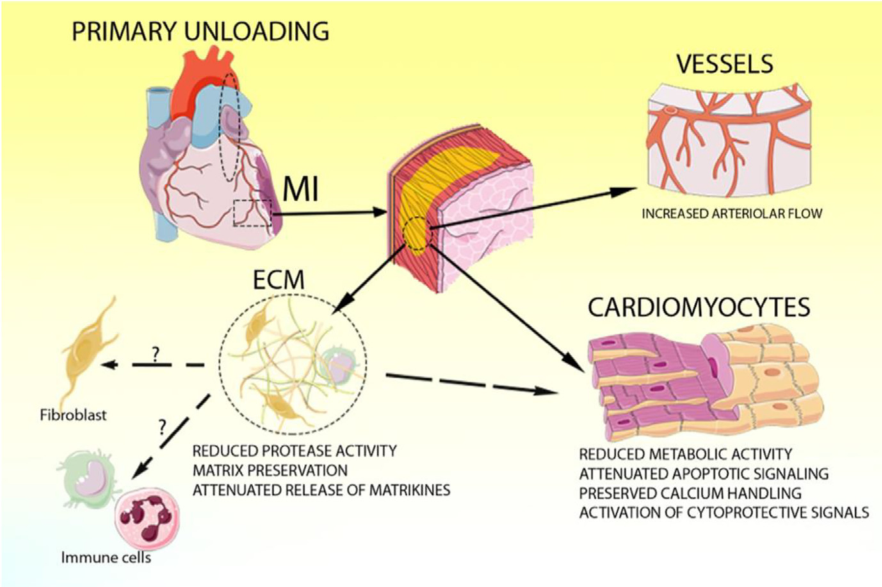

Fig. 4. Cellular mechanisms remediating the proposed protective effects of primary unloading in the infarcted heart. (*Source*: Hanna A, Frangogiannis NG. The cell biological basis for primary unloading in acute myocardial infarction. Int J Cardiol. 2019 Oct 15;293:45–47.)

the initial insult. Moreover, it will create a window of opportunity for further thorough clinical assessment.

Older Adults Specific Considerations

Frailty

Frailty does not have a universally acceptable definition but has been generally defined as a condition that results from increased vulnerability to stressors. It has been reported to have affected up to 60% of patients with advanced heart failure and had been associated with increased mortality, prolonged length of stay, and prolonged time on the ventilator and time to hospital discharge in heart failure patients.[27,28]

Frailty evaluation involves the measurement of various deficits ranging from physical to cognitive and psychosocial aspects of patients. Some basic screening measures such as slow chair rise, slow gait and poor ambulation that highlights the need for assistance to complete basic daily tasks have been shown to independently increase the risks of perioperative mortality by 2 to 4 times, compared with nonfrail patients in cardiac procedures.[28]

Sarcopenia is defined as the age-related decline in skeletal muscle mass and strength and is the cornerstone of the frailty syndrome.[29] It is an objective variable (usually less than 2 standard deviation muscle mass of a healthy normal in men and women) is aimed to replace some subjective general measures such as weight loss and body mass index. Various imaging modalities have been proposed to measure sarcopenia.[30,31] Modalities such as dual x-ray absorptiometry scans, computed tomography (CT) scans, MRI, or bioimpedance testing are usually needed but CT imaging has been the one used and validated widely in cardiac surgeries, specially left ventricular assist device (LVAD) operations.[31,32]

Neurologic

Considering the higher risk of cognitive dysfunction, postoperative delirium, and the presence of other comorbidities such as dementia, unrecognized stroke, and cerebrovascular disease; a comprehensive examination seems to be necessary but a proper imaging (CT or MRI), including carotid and vertebral Doppler studies are all recommended by International Society for Heart and Lung Transplantation guidelines.[33]

Psychosocial considerations

Frail patients, especially those with advanced age have more neurological, psychosocial, and musculoskeletal comorbidities. That can impair their ability for understanding and communicating their desired goal of care and reasonable quality of life, postoperatively. Diminished cognitive and sensory ability in advanced age specially when combined with limited social support will create huge challenge to understand the burden of disease and care, medically and surgically. Patients in acute heart failure and cardiogenic shock are specially at higher risk of neurological derangements and have less time available for a long-term, proper decision-making communication and education. Temporary MCS provides a significant window of opportunities to evaluate and improve the neurological function while discussing the potential long-term durable MCS candidacy.[34] Being in state of shock, most patients and their families choose an aggressive approach that maximize their chances of survival and therefore would agree with any offered procedure at the time. However, factors such as depression and acceptance of their illness can result in significant dissatisfaction, usually 6 months after initiating LVAD education.[35]

Pulmonary

Although pulmonary function test (PFT) is not mandatory preoperatively for patients undergoing MCS device procedure, advanced age has been associated with higher risk of chronic lung disease, especially in the presence of previous history of smoking, and therefore, PFT can be an additional helpful prognostic tool in this patient population.[34,36] Presence of cardiogenic pulmonary edema may produce unreliable results especially in the setting of acute heart failure and therefore the test is not very helpful.

Hematologic consideration

Bleeding seems to be more frequent among frail and very old patients and plays an important role in the postprocedural phase of mechanical circulatory support.[37] Factors such as polypharmacy with drug–drug interaction, decreased renal/hepatic clearance, pharmacokinetic changes in the older adults, preexisting cerebrovascular condition and gastrointestinal bleeding and chronic anemia can all play a role in exacerbating bleeding, and it is important to pay more attention to anticoagulation aspect of MCS management in older adults and adopt a more individualized plan.

MALIGNANCIES

Advanced age is strongly associated with higher incidence of malignancies.[38] Patients with a history of recently treated or active cancer and a life expectancy of more than 2 years may be candidates for destination therapy if a multidisciplinary evaluation by oncologist, heart failure team, and patient and family will clear the postoperative path.

NUTRITIONAL STATUS

Malnutrition in the older adults is a challenging issue and is associated with increased mortality and morbidity, increased frailty, and reduced activities of daily living and quality of life in general.[39] Ability for a proper self-nourishment is a multifactorial issue affected by psychosocial status of the patient as well as mechanical considerations such as oral hygiene, partially or complete edentulous status, and poor gastrointestinal mucosal perfusion and nutrient absorption. Patients with evidence of severe malnutrition should have a proper dietary consultation, and their durable MCS should be postponed till their nutritional status is optimized. However, temporary MCS will allow to bridge this gap while waiting to improve the nutritional frailty.[34,39,40]

Palliative Care for the Older Adults on Mechanical Circulatory Support

MCS devices have been shown to improve functional status and quality of life as well as survival. However, complications remain common and can have a significant impact on quality of life and even survival.[41–43] Furthermore, patients on MCS may face unanticipated challenges and complications, with operative course, which is less predictable and more complicated to prognosticate. Particularly, end-of-life experience for both patients and their families could be very challenging.[44,45] Hence, the palliative care team should be consulted throughout the course from decision-making period, preimplantation, and for the duration of therapy. They can guide difficult communications to establish goals of care and provide support to patient and family depending on their individual needs. Given the high morbidity and mortality with MCS, collaboration with palliative care is encouraged by the International Society for Heart and Lung Transplantation guidelines for MCS and considered a class IIa recommendation.[33] The Centers for Medicare and Medicaid Services and the Joint Commission further requires that a palliative care specialist be a part of the core multidisciplinary MCS team.[46] Despite limited data on the efficacy of palliative care in patients with MCS, overall impressions of palliative care specialists are highly positive, with perceptions of improved patient and family experience and decreased burden on MCS team members.[47]

SUMMARY

Because MCS continues to advance with improving outcomes, careful patient selection among the older adults population will become increasingly important. Although mortality is higher in the older adults, carefully selected patients, MCS support can be valuable and lead to clinical recovery. The optimal use of MCS requires an individualized approach that is based on patient's comorbidities, the mechanism of a patient's disease, an understanding of the physiological effects of these devices, and the patient's potential clinical course. Age itself should not preclude patients from being candidates for MCS. Many institutions currently use arbitrarily selected age thresholds for MCS use, which precludes many older adults patients with minimal comorbidities from receiving MCS. The ability to select older adults patients who are most likely to benefit from MCS remains uncertain and warrants systematic study. Future studies will be needed to develop risk stratification tools to define those older adults patients for whom support is futile and those who will benefit the most from MCS.

CLINICS CARE POINTS

- Age is an independent risk factor for mortality in patients supported with MCS devices.
- Impella unloads the LV directly, leading to increase in cardiac output, a decrease in the LVEDP and decreasing myocardial oxygen consumption.

- VA-ECMO increases global systemic perfusion and mean arterial pressure, but it causes increased LV afterload, increase in LVEDP and pulmonary artery wedge pressure.
- Palliative care physician as a part of MCS team improves patient and family experience and decreases burden on MCS team members.

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DECLARATION OF INTERESTS

The authors declare no competing financial disclosure and conflict of interests.

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