Section A-Research paper

MECHANICAL CIRCULATORY SUPPORT: A REVIEW

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Abstract

The therapy of individuals with progressive heart failure has changed as a result of "*Mechanical Circulatory Support* (MCS)". MCS offers patients who are not transplant candidates long-term care, a temporary bridge to heart transplantation, and treatment for patients with acute heart failure. The goal of this review article is to give a thorough summary of MCS as it is right now. It covers the history, evolution, and types of devices available for support, as well as the indications for MCS and patient selection criteria. The article also discusses the implantation and management of devices, including potential complications, and summarizes the outcomes of MCS, including survival rates and quality of life. The review concludes by highlighting the future of MCS and its potential impact on patient care. Overall, this review article offers medical professionals a useful tool for treating patients with severe heart failure. It is crucial for healthcare professionals to comprehend the indications and alternatives offered for mechanical circulatory support (MCS) given the rising number of individuals in need of it. By providing a comprehensive overview of the current state of MCS, this article aims to improve patient care and outcomes for those with advanced heart failure.

Keywords: Mechanical circulatory support, heart failure, heart transplantation, Right ventricular failure, INTERMACS

Introduction to MCS

"*Mechanical circulatory support* (MCS)" is a therapy that has revolutionized the management of patients with advanced heart failure. For patients who have tried everything else, including medicinal management, cardiac resynchronization therapy, or implantable cardioverter-defibrillators, it offers a temporary or long-term answer. The purpose of MCS devices is to support or take over the role of the heart, ensuring hemodynamic stability and

enhancing symptoms and survival rates (1). The history of MCS dates back to the 1950s when the first external cardiac pacemakers were developed to treat bradycardia (2).
There are several types of MCS devices available. The clinical condition of the patient, the underlying cause of heart failure, and the anticipated length of support all factor into the device selection. The implantation and management of MCS devices require a multidisciplinary team approach, involving cardiac surgeons, cardiologists, intensivists, and specialized nurses (1).

History and Evolution of MCS Devices

MCS devices have come a long way since their inception. The history of MCS dates back to the 1950s when the first external cardiac pacemakers were developed to treat bradycardia. In the 1960s, the first "*Ventricular Assist Devices* (VADs)" were introduced, followed by the first implantable pacemakers. By the 1980s, the first total artificial heart was inserted in a patient, and in 1994, the first "*Left Ventricular Assist Device* (LVAD)" was permitted by the USFDA for use as a bridge to heart transplantation (3).
Over the years, the technology and devices for MCS have advanced significantly, improving patient outcomes and quality of life. The devices have become smaller, more durable, and more efficient. The introduction of continuous-flow devices has revolutionized MCS, offering a much longer lifespan and fewer complications than the earlier pulsatile-flow devices (3). The history and evolution of MCS devices have been marked by significant advancements in technology, design, and clinical application.

Types of MCS Devices

There are several types of MCS devices available, each with its unique features and clinical indications.
The most common MCS device is the VAD, which can be used as a bridge to transplantation, a bridge to recovery, or destination therapy in patients who are not eligible for heart transplantation (5). VADs can be classified into two types: continuous-flow and pulsatile-flow. Pulsatile-flow VADs mimic the natural pulse of the heart, whereas continuous-flow VADs provide a constant flow of blood without a pulse. Continuous-flow VADs are more commonly used due to their smaller size, longer lifespan, and lower complication rates (6).
Another type of MCS device is the "*Intra-Aortic Balloon Pump* (IABP)", which is a temporary device that can improve coronary blood flow and decrease afterload in patients with high-risk percutaneous coronary intervention, cardiogenic shock, or acute myocardial infarction (7).
"*Total artificial hearts* (TAHs)" are also available as a treatment option for end-stage heart failure. TAHs replace the patient's entire heart and are used as a bridge to transplantation (8). However, TAHs are associated with a higher risk of complications and mortality compared to VADs (9). "*Extracorporeal membrane oxygenation* (ECMO)" is another MCS device used in patients with acute respiratory or cardiac failure. ECMO involves the insertion of a catheter into the patient's vein or artery to circulate blood through an external circuit for gas exchange (4). In conclusion, there are several types of MCS devices available, each with its unique

features and clinical indications. Based on the patient's clinical condition and underlying cause of heart failure, the best device should be selected for them.

Indications for MCS

The indications for MCS have evolved over the past few decades, and the use of MCS has expanded beyond just bridging to transplantation. The appropriate use of MCS devices is essential for optimizing outcomes in these patients.

Bridge to Transplantation

The most typical sign is this. Patients with end-stage heart failure who are awaiting a suitable donor heart can receive assistance from MCS devices. Improved survival rates and a decline in post-transplant morbidity and death have been linked to the use of MCS as a stopgap measure before transplantation (4). The clinical condition of the patient, the amount of time that support is needed, and the experience and knowledge of the center all play a role in the MCS device selection. Long-term support is typically best provided by continuous-flow VADs, whereas short-term support is best provided by pulsatile-flow VADs (10).

Bridge to Recovery

Patients with acute heart failure who are anticipated to regain their native cardiac function with temporary support can also employ MCS devices as a bridge to recovery. Improved survival rates and a drop in the frequency of negative events have been linked to the use of MCS as a bridge to recovery (5). Depending on the underlying cause of heart failure and the patient's reaction to therapy, the length of time that support is needed for recovery varies. For patients who are anticipated to recover within days to weeks, short-term support with a VAD or an IABP is preferred (11).

Destination Therapy

For patients with end-stage heart failure who are ineligible for heart transplantation, destination treatment refers to the use of MCS devices as a long-term therapy option. Destination therapy has been linked to higher rates of survival and higher levels of life satisfaction (12). The clinical condition of the patient, as well as the knowledge and experience of the center, will determine which MCS device is used for destination therapy. Due to their reduced size, longer longevity, and lower complication rates, continuous-flow VADs are typically chosen for destination therapy (2).

Bridge to Decision

In patients with acute heart failure who need time to decide on the best care plan, MCS devices can also be utilized as a bridge to decision. Improved survival rates and an increase in the percentage of patients receiving the right treatment have been linked to the use of MCS as a bridge to decision (13). Depending on the underlying cause of heart failure and the difficulty of the management decisions that must be made, different amounts of support must be provided during a bridging period before a decision is made.

Bridge to Candidacy

In patients with end-stage heart failure who are initially ineligible for heart transplantation but who might become eligible with proper medical therapy or an improvement in their clinical status, MCS devices can also be utilized as a bridge to candidacy. Improvements in survival rates and an increase in the proportion of patients who are transplant-eligible have been linked to the use of MCS as a bridge to candidacy (14). Depending on the underlying cause of heart failure and the anticipated response to therapy, the length of support needed for a bridge to eligibility varies.

Bridge to Recovery and Bridge to Decision

When the diagnosis of MCS is unclear, the device may be utilized both as a bridge to recovery and as a bridge to a decision. Improvements in survival rates and an increase in the proportion of patients who receive appropriate care have been linked to the use of MCS as a bridge to recovery and a bridge to decision-making (15).

In conclusion, the indications for MCS have expanded beyond just bridging to transplantation, and the appropriate use of MCS devices is essential for optimizing outcomes in these patients.

Patient Selection for MCS

The patient selection for MCS is critical to ensuring optimal outcomes. The clinical status, comorbidities, and anticipated therapeutic response of the patient should all be carefully considered before the decision to implant an MCS device is made.

Identifying patients with severe heart failure despite receiving the best medical care is the first step in the patient selection process for MCS. A helpful tool for determining the severity of heart failure and forecasting results after MCS is the "INTERMACS (Interagency Registry for Mechanically Assisted Circulatory Support)" profile. The best candidates for MCS are patients with an INTERMACS profile of 1 or 2, which indicates severe symptoms and a significant mortality risk (16,17).

In addition to the INTERMACS profile, other factors that should be considered when selecting patients for MCS include age, comorbidities, and the presence of other organ dysfunction. Advanced age and significant comorbidities, such as renal or hepatic dysfunction, may increase the risk of adverse events following MCS (18,19). Therefore, careful consideration of the patient's overall health status is essential when selecting patients for MCS.

Patients who are candidates for MCS should also be evaluated for potential contraindications to therapy. Absolute contraindications to MCS include active infection, irreversible multiorgan dysfunction, and advanced neurological impairment (5). Relative contraindications include advanced pulmonary disease, significant peripheral vascular disease, and severe obesity (5). Patients with significant psychiatric or cognitive impairment may also be poor candidates for MCS due to the complex nature of the therapy and the need for ongoing management.

Further testing and evaluation are required once a patient has been identified as a possible candidate for MCS in order to establish the best device type and the anticipated length of support. Lab tests, imaging studies, functional tests, and a thorough physical examination should all be part of a thorough evaluation (20). To evaluate the patient's hemodynamic status and choose the proper level of assistance, cardiac catheterization and hemodynamic monitoring may also be required (21).

The clinical condition of the patient, the anticipated length of support, and the experience and knowledge of the center all play a role in the MCS device selection. The three most common types of MCS devices are intra-aortic balloon pumps (IABPs), ventricular assist devices (VADs), and total artificial hearts (TAHs) (15). IABPs, the most widely used type of MCS, are recommended for people who have just suffered a myocardial infarction or are experiencing cardiogenic shock (22). In individuals who are not transplant candidates, VADs can be utilized as a stopgap measure or as a final treatment (23). Patients with end-stage heart failure who are not transplant candidates should receive TAHs (7).

Management of MCS devices should be done in specialized facilities with experience controlling these complex devices as it demands specific knowledge. To avoid issues and achieve the best results, patients who receive MCS need to be continuously monitored and managed (24). Bleeding, infection, thromboembolic incidents, device malfunction, and right ventricular failure are all complications related to MCS (25). As a result, careful monitoring and continued treatment are crucial for obtaining the best results after MCS.

Implantation and Management of MCS Devices

Implantation

TAHs and LVADs are typically implanted via sternotomy, although less invasive techniques such as subxiphoid or thoracotomy approaches have also been used (11). The implantation process involves connecting the device to the heart and blood vessels to ensure proper blood flow (27). Intraoperative transesophageal echocardiography is commonly used to assess the function of the device and to identify any potential complications (28).

Postoperative Management

Following implantation, patients require intensive care and close monitoring to ensure optimal device function and to prevent complications. Hemodynamic monitoring, including the use of pulmonary artery catheters and continuous cardiac output monitoring, is necessary to guide management and prevent adverse events (15).

Anticoagulation therapy is also critical to prevent device thrombosis and stroke. Warfarin is typically used, with a target "*International Normalized Ratio* (INR)" of 2.0-3.0 (29). However, newer anticoagulation agents such as direct thrombin inhibitors and factor Xa inhibitors are being studied as potential alternatives (30).

Device malfunction or failure can occur and may require urgent intervention, such as pump exchange or TAH replacement. Early identification of device malfunction is crucial, and patients should be instructed on the signs and symptoms of device malfunction, such as changes in pump speed, power, or flow (31).

Long-term Management

Long-term management of MCS devices involves routine follow-up appointments with a multidisciplinary team approach, involving cardiac surgeons, cardiologists, intensivists, and specialized nurses (32). Patients require frequent device checks, including device interrogation, echocardiography, and laboratory tests (33). Patients must also maintain close communication with their healthcare providers and report any changes in symptoms or device function promptly.

Advanced heart failure care has been transformed by MCS devices, which offer patients who are ineligible for transplant a bridge to transplant or long-term support. Implantation and management of these devices require a multidisciplinary approach and close monitoring to ensure optimal outcomes and prevent complications.

Complications Associated with MCS Devices

Despite their potential benefits, MCS devices are associated with various complications that require careful management to optimize outcomes.

Bleeding is one of the most frequent side effects linked to MCS devices, and it might happen because anticoagulant medication is required to avoid thrombosis in the device. Bleeding can come from a variety of locations, including the gastrointestinal system, intracranial, and surgical sites, and can range in severity from minor to life-threatening. To balance the risk of bleeding with the requirement for anticoagulant medication, regular monitoring of coagulation status is required (15).

Another significant complication of MCS devices is infection, which can occur at the device site or systemically. Infection can lead to device malfunction, sepsis, and endocarditis. In addition, the use of long-term antibiotics to treat infections can lead to the development of antibiotic-resistant strains of bacteria (29).

Device malfunction is another potential complication associated with MCS devices, which can result in thrombosis or device failure. Thrombosis can occur due to a combination of factors, including blood stasis and altered coagulation status. Regular monitoring of device function and anticoagulation status is necessary to prevent and manage device malfunction (20).

"*Right ventricular failure* (RVF)" is another common complication associated with MCS devices. RVF can occur due to multiple factors, including device malposition, pulmonary hypertension, and RV dysfunction at the time of device implantation. Early detection and management of RVF are essential to prevent adverse outcomes (31).

Some other potential complications include:

Stroke: MCS devices can increase the risk of stroke due to the potential for thrombus formation or embolism. Regular monitoring of device function and anticoagulation status is necessary to prevent and manage stroke (34).

Device-related thrombosis: Thrombosis can occur within the device itself, leading to device malfunction and potentially life-threatening complications. Management may involve anticoagulation therapy, thrombolysis, or device exchange (35).

Hemolysis: Mechanical forces generated by the device can cause hemolysis, which can lead to anemia and other complications. Regular monitoring of hemoglobin levels and markers of hemolysis is necessary to prevent and manage this complication (36).
Aortic insufficiency: MCS devices can lead to aortic insufficiency, which can occur due to regurgitation of blood from the aorta into the left ventricle. Regular monitoring of aortic valve function is necessary to prevent and manage this complication (37).

Outcomes of MCS

Because of improvements in technology and patient care, MCS results have dramatically improved in recent years. The survival rates of individuals who received MCS have been published in several studies. According to a retrospective study by John et al. (2020), patients who got MCS as a bridge to transplantation had survival rates of 73% at one year and 62% at three years (38). The survival rates of patients undergoing MCS as destination therapy were 67% at one year and 42% after three years, according to a different study by Smith et al. (2019) (39).
MCS has also been demonstrated to enhance patients' quality of life. Patients who underwent MCS as a bridge to transplantation showed a considerable increase in their functional status and quality of life, according to a study by Chen et al. (2018). In a similar vein, Lee et al.'s study from 2021 found that patients who received MCS as destination therapy saw a significant improvement in both their physical and mental wellbeing (40).
MCS also has a positive impact on healthcare costs. A study by Ambardekar et al. (2019) found that the total healthcare costs for patients receiving MCS decreased significantly after implantation compared to before implantation (41). The study reported that the median total healthcare cost per patient decreased from $257,557 to $137,105.

Future of MCS

The way that heart failure is treated has changed dramatically thanks to the use of mechanical circulatory support devices. For patients who are unable to have a heart transplant or who are waiting for one, these devices have emerged as a crucial option. But there are a lot of interesting new advancements in the works in the realm of mechanical circulatory support. One area of innovation in mechanical circulatory support is the use of artificial intelligence (AI) algorithms to optimize device performance. According to a study by Hafez et al., AI algorithms can help predict device malfunction and improve patient outcomes (42). These algorithms use data from sensors embedded in the device to monitor device function and detect potential problems before they become serious. By analyzing this data, AI algorithms can provide real-time feedback to clinicians and allow for more efficient and personalized care.
Another promising development in mechanical circulatory support is the use of 3D printing to create customized devices. According to a study by Liu et al., 3D printing technology can be used to produce patient-specific ventricular assist devices (43). These devices are designed to fit the unique anatomy of each patient, which can improve device performance and reduce

the risk of complications. 3D printing also allows for rapid prototyping and testing of new device designs, which can accelerate the development of new technologies.

In addition to these technological advancements, there is also a growing focus on improving the patient experience with mechanical circulatory support. One way to achieve this is through the use of wearable devices that can monitor patients' vital signs and provide real-time feedback to clinicians. According to a study by Lam et al., wearable devices can improve patient outcomes by allowing for earlier detection of complications and more timely intervention (44). Overall, the future of mechanical circulatory support looks bright, with ongoing advancements in technology and a growing focus on patient-centered care. As these developments continue to unfold, it is important for clinicians and researchers to collaborate in order to ensure that patients receive the best possible care.

Conclusion

The indications for MCS have expanded over time and now include bridge-to-transplantation, bridge-to-recovery, and destination therapy. Patient selection for MCS is based on several factors, including the severity of heart failure, comorbidities, age, and the patient's preferences (1). The MCS has become an essential therapy for patients with advanced heart failure, providing a bridge to transplantation or long-term support. The development and evolution of MCS devices have improved patient outcomes and expanded the indications for use. As the demand for MCS continues to increase, further research and technological advancements are needed to improve patient outcomes and quality of life.

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