SHORT-TERM MECHANICAL CIRCULATORY SUPPORT

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Summary

Heart failure continues to be an ever-growing public health concern. The continued aging of the population has contributed to the increasing incidence and prevalence of heart failure. Mechanical circulatory support is used to treat patients with advanced heart failure. A mechanical pump is surgically implanted to provide pulsatile or non-pulsatile flow of blood to supplement or replace the blood flow generated by the native heart. The main purpose of a mechanical circulatory support is to unload the failing heart and help maintain forward cardiac output and vital organ perfusion. A big variety of devices exists: from the percutaneous and short-term support, which can be used in the operating room or the cath-lab and afterwards in the intensive or coronary care units, to the internal and long-term devices, which can be used as a bridge-to-recovery or cardiac transplant, or as definitive therapy in patients with contraindication to cardiac transplant. This treatment involves not only the cardiac surgeons, but also the cardiologists, anaesthesiologists, intensivists and perfusionists. Appropriate patient selection represents the critical determinant of successful outcomes with the VAD therapy. The predictive risk stratification is extremely important for achieving the minimal peri-operative mortality rate. As VAD technology progresses, the collaboration of multidisciplinary teams composed of engineers, scientists, physicians, and nurses will continue to refine the technology and improve patient care and operation outcomes. Advances in device design will allow for an easier implantation and create smaller, more efficient, durable, and reliable units.

Key words: ventricular assist device; heart failure; mechanical circulatory support

Heart failure continues to be an ever-growing public health concern. The continued aging of the population has contributed to the increasing incidence and prevalence of heart failure [1]. Mechanical circulatory support is used to treat patients with advanced heart failure. A mechanical pump is surgically implanted to provide pulsatile or non-pulsatile flow of blood to supplement or replace the blood flow generated by the native heart. Types of circulatory support pumps include pneumatic

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and electromagnetic pumps. Rotary pumps are also available. Investigators and the medical device industry have been pursuing the development of mechanical cardiac support for more than four decades. Mechanical circulatory support has significantly evolved over the last years. It is now a real and useful therapeutic option not only for the treatment of cardiogenic shock, but also for advanced chronic heart failure, and even preventively in high-risk cases of percutaneous coronary intervention and cardiac surgery. The main purpose of a mechanical circulatory support is to unload the failing heart and help maintain forward cardiac output and vital organ perfusion. Originally introduced as a temporary bridge-to-recovery and then as a bridge-to-transplantation, the mechanical circulatory support has evolved into permanent or "destination" therapy for a growing number of patients with refractory heart failure [2]. A big variety of devices exists: from the percutaneous and short-term support, which can be used in the operating room or the cath-lab and afterwards in the intensive or coronary care units, to the internal and long-term devices, which can be used as a bridge-to-recovery or cardiac transplant, or as definitive therapy in patients with contraindication to cardiac transplant. This treatment involves not only the cardiac surgeons, but also the cardiologists, anaesthesiologists, intensivists and perfusionists. Indications for device support continue to evolve from day to day. Patients considered for mechanical circulatory support are not able to sustain adequate systemic oxygen delivery to maintain normal end-organ function despite maximal medical therapy. Haemodynamic criteria for device implantation include: systolic blood pressure lower than 80 mm Hg; mean arterial pressure lower than 65 mm Hg; cardiac index lower than 2.0 L/min/m^2; pulmonary capillary wedge pressure higher than 20 mm Hg; and systemic vascular resistance over 2,100 dynes-sec/cm [3]. The decision to implement mechanical circulatory support must be made with consideration to the ultimate goal of therapy. Mechanical circulatory support always represents a kind of a bridge (bridge-to-: decision, recovery, transplant, conventional treatment, death; or, finally, bridge-to-nowhere). As mentioned above, indications for mechanical support are continuously evolving, and herein we present some of them.

1. Cardiogenic shock associated with acute myocardial infarction (AMI) complicates clinical presentation of 6 to 20 % of patients suffering from AMI, and is reported with a mortality rate between 70-80 % [4].

2. Postcardiotomy cardiogenic shock is experienced by 2 to 6 % of patients undergoing coronary or valvular cardiac procedures [5]. Special consideration should be given to patients with severely impaired ventricular function undergoing high-risk cardiac procedures. Transplant evaluation should be initiated pre-operatively, and the procedure should be performed with an LVAD „back-up".

3. Chronic cardiac failure. In this subgroup of patients, short-term mechanical support can be instituted as a bridge-to-transplantation. The normalisation of haemodynamics and the maintenance of the end-organ function decrease post-transplant mortality [6].

4. Myocarditis is characterised by an unpredictable clinical course, and short-term mechanical circulatory support (especially biventricular support due to biventricular disease involvement) presents the chance for a bridge-to-recovery.

Of note, there are some reports of device implantation in patients suffering from ventricular arrhythmias refractory to medical therapy [7].

Appropriate patient selection represents the critical determinant of successful outcomes with the VAD therapy. The predictive risk stratification is extremely important for achieving the minimal peri-operative mortality rate. Aiming the optimal risk/benefit ratio, some reports have sought to identify the predictives of risks and benefits [8]. The timing of intervention is an important determinant of the clinical outcomes. For example, the optimisation of patient status with diuresis; the correction of coagulation abnormalities; the pulmonary rehabilitation; and the implementation of intra-aortic balloon pump may be useful. It is obligatory to control systemic sepsis or bacteraemia, due to a high risk of device contamination. On the other hand, the mentioned treatments and procedures may lead to unnecessary postponements, which may further lead to a marked increase in mortality [9-10]. Contraindications for device implantation, such as irreversible end-organ damage and unrecoverable neurologic injury, have to be considered as well.

THE COMPONENTS OF THE MECHANICAL CIRCULATORY SUPPORT

Ventricular assist devices (VAD) used in the outpatient setting are implanted devices placed through a median sternotomy typically during cardiopulmonary bypass. VAD is connected to the heart by an inflow cannula that decompresses the ventricular cavity and an outflow cannula that returns blood to either the ascending aorta or the main pulmonary artery. The pumping chamber of the VAD is implanted sub-diaphragmatically to a pre-peritoneal or intra-abdominal position, or it may be situated in a para-corporeal position outside the body. Smaller devices are being developed for thoracic implantation, some with outflow to the descending aorta.

THE PHYSIOLOGY OF VADS

VADs support the failing heart by unloading the ventricle and generating the flow to the systemic and / or pulmonary circulation. This creates parallel pumping

chambers that compete for the same venous return (pre-load), and face the arterial resistance (after-load) of their respective pulmonary and systemic vascular beds. Under optimal conditions, the native ventricle is a passive conduit, through which the mechanical pump fills throughout the cardiac cycle, and the decompressed ventricle should contribute little to the systemic cardiac output. If a ventricular stroke volume is generated, and the aortic / pulmonic valve leaflets are seen to open on echocardiography, either the return of the native ventricular function or an inadequate decompression of the native ventricle and device dysfunction should be suspected. Isolated right ventricular dysfunction, requiring insertion of a right ventricular assist device (RVAD) to support the failing ventricle, is a rare event. Cases have been reported postcardiotomy after an acute myocardial infarction, coronary artery bypass grafting, and valvular surgery. More commonly, an RVAD may be inserted around the time a left ventricular assist device (LVAD) to provide biventricular assistance is placed. Unlike a single VAD, biventricular mechanical devices create a complex system with two independent pumps, one of them right-sided and the other one left-sided. The left atrial venous return is normally greater than the right atrial pre-load, because of the bronchial circulation; overall, the left-sided output (LVAD plus native left ventricle) must always be greater than the right-sided output (RVAD plus native right ventricle), or else, pulmonary oedema may develop. In addition to navigating complex biventricular cannula insertion anatomy, native right and left ventricular function may also recover at different rates.

CHANGES IN THE VENTRICULAR FUNCTION AFTER IMPLANTATION

The histological and biochemical signs of recovery of mechanically supported myocardial tissue are an issue of inquiry. Although a VAD's main purpose is to assume the pumping function of the heart, the reduction in myocardial stretch after the VAD decompression may lead to a recovery process referred to as reverse ventricular remodelling [11]. Improvement in intrinsic myocyte function may occur due to alterations in abnormal gene expression; changes in collagen content; regression of cellular hypertrophy; and reduction in myocytolysis and inflammatory cytokines [12-15]. Although such changes may occur, most patients do not fully recover and are ineligible for explantation [16]. To help promote reverse remodelling, efforts are underway to assess the use of disease-altering pharmacological regimens in VAD patients. At the present time, all patients who appear to be bridge-to-recovery candidates are restarted on neuro-hormonal antagonists, which are then up-titrated to published guidelines as tolerated. In 2006, Birks et al. reported on the successful re-

versal of remodelling in selected VAD patients with non-ischemic cardiomyopathy treated with clenbuterol [17].

DEVICE SELECTION

The anticipated treatment endpoint must be considered when choosing a specific device. In this article, short-term mechanical support devices are described. These include counter-pulsation and centrifugal, axial, and pneumatic pumps. These devices, which are easily implemented, aim at providing either a short-term bridge-to-recovery or a short-term bridge-to-more permanent assistance or transplant as destination therapy.

Intraaorticsed pre-operatively as an adjunct to high-risk percutaneous interventions or coronary artery bypass grafting. Contraindications for IABP use are aortic insufficiency, aortic dissection and severe aortic and peripheral vascular atherosclerosis. The latter concerns the pre-operative use; it is however possible to insert the balloon via the ascending aorta during surgery.

The iVAC 3L™ is a mid-range minimal heart circulatory assist device that effectively generates up to three litres per minute. The iVAC 3L™ off balloon pump (IABP), first described in 1968 [18], is the most common form of short-term mechanical circulatory assistance. Couner-pulsation, provided by balloon inflation within the descending thoracic aorta during diastole with deflation at the onset of systole. The result is reduction in myocardial work through after-load reduction, and improvement in myocardial oxygen supply through the augmentation of diastolic blood pressure and coronary perfusion pressure [19]. IABP counter-pulsation timing is performed from the ECG or the arterial waveform. IABP counter-pulsation is used today in a variety of clinical settings, including the cardiogenic shock associated with myocardial infarction; the postcardiotomy shock; the mechanical complications of infarction, such as acute mitral regurgitation and ventricular septal defect; the post-infarction angina; and for the treatment of ventricular arrhythmias in the setting of ongoing ischemia. IABP has also been u ers critical haemodynamic support in the case of left ventricular failure, or during high-risk revascularisation procedures with potential postcardiotomy weaning complications, as a cost-effective bridge- to-decision or bridge-to-bridge solution. The use of device ensures a fast and cost-effective implementation, due to a universally adaptable design that fully integrates with any standard IABP console. Patients have faster post-operative mobility with subclavian or axillary artery access. With the increase in more complex and higher risk cases, the incidence of postcardiotomy failure has now begun to rise. Currently, about 6 % of patients develop postcardiotomy ventricular failure. The iVAC 3L™ is indicated

for OPCAB procedures (recovery support); postcardiotomy weaning complications; cases of cardiogenic shock; acute myocardial infarction. At 3 l/m, the iVAC 3L™ does the job when an IABP is insufficient for the demand, and a higher-cost and more complicated LVAD may not be warranted. The iVAC 3L™ provides the cardiologist and cardiac surgeon with additional life saving options, and opens previously not available procedural possibilities. The use of this device unloads the left ventricle and increases circulatory blood flow; reduces the myocardial workload allowing the heart to rest and heal; potentially avoids the need for inotropes during CPB weaning; lowers the anticoagulation requirements; increases the coronary artery and end-organ perfusion; and finally, lowers the risk of haemodynamic deterioration. The iVAC 3L™ incorporates a patented rotating two-way valve, which is connected to an extracorporeal dual chamber membrane housing via a 21 Fr. lumen catheter. It can be used with any standard IABP driver unit and does not require dedicated hardware. When the heart is in the systolic phase, the blood flows from the ventricle through the catheter tip and is aspirated into the membrane housing. During the diastolic phase, the membrane pushes the blood back through the catheter, subsequently opening the valve and delivering the blood to the aorta through the side outflow port. The device directly unloads the heart by active aspiration from the left ventricle and simultaneously creates a pulsatile flow in the ascending aorta. The use of this device provides many advantages, such as: the aortic blood-flow increase; the mean arterial blood pressure improvement; the myocardial perfusion increase; the after-load reducement; the end systolic LV volume reducement; and the myocardial demand decrease by reducing the cardiac work.

Centrifugal pumps have been used both for intra-operative cardiopulmonary bypass and as a means of providing right, left, or biventricular mechanical circulatory support. They have following advantages: wide availability, the ease of use, and relative low cost when compared to other devices. Disadvantages include the need for systemic anticoagulation with resultant bleeding complications. The progressive development of interstitial oedema secondary to capillary leak and the inability to ambulate and rehabilitate these patients limit this technology to short-term support. Some of the most commonly used pumps are the Biomedicus Biopump (Medtronic Bio-Medicus, Inc., Eden Prairie, Minn); the Sarns centrifugal pump (3-M Health Care, Ann Arbor, Mich); and the St. Jude Lifestream centrifugal pump (St. Jude Medical, Inc., St. Paul, Minn).

The Levitronix CentriMag short-term LVAS comprises a single-use centrifugal pump, a motor, and a primary drive console. Compared to other devices, the Levitronix LVAS is unique insofar that it is designed to operate with no mechanical bearings or seals. This is possible since the motor magnetically levitates the impeller,

achieving rotation with no friction or wear. The Levitronix CentriMag is a continuous-flow, centrifugal-type rotary blood pump that is placed outside the body (extracorporeally). The pump housing and the rotor are made of medical-grade polycarbonate, designed for single use. The only moving component within the pump is the impeller, which is magnetically levitated and rotated in a contact-free manner. The centrifugal pump design permits the rotation of the impeller at lower speeds, while still achieving the desired flow rates. The pump can rotate at the speeds from 1,500 rpm to 5,500 rpm, and can provide the flow rates of up to 9.9 litres per minute. The Levitronix pump causes very little damage to the blood, as it contains no bearings or seals – components known to cause haemolysis and promote thrombus formation. Moreover, the pump does not contain any flexing sacs, diaphragms, or valves, minimising thereby the risk of component failure and device-related adverse effects.

The extracorporeal membrane oxygenation (ECMO) utilises a centrifugal pump in combination with a membrane oxygenator to provide complete cardiopulmonary support in the setting of circulatory and respiratory failure. The successful use of ECMO in the paediatric population has been well described [20]. The outcome of ECMO for the treatment of cardiac failure in the adult population is more limited.

The TandemHeart percutaneous VAD (CardiacAssist, Inc., Pittsburgh, Penn) utilises a centrifugal pump that pumps blood from the left atrium to one or both femoral arteries. The left atrial catheter is placed percutaneously via a trans-septal puncture [21].

The Impella Recover device (Impella CardioSystems AG, Aachen, Germany) is a miniature axial flow pump designed for short-term right, left, or biventricular support. The device is able to generate flows of up to 4 to 5 L/min at the rotational speeds of between 28,000 and 32,000 rpm. The device has the advantage of being easily implanted and having minimal requirement for anticoagulation. The device can be placed percutaneously and positioned with echocardiographic guidance [22].

The Abiomed BVS 5000i (Abiomed Cardiovascular, Inc., Danvers, Mass) is a device for acute postcardiotomy failure. It is a dual-chambered, pneumatically driven extracorporeal pump, designed for short-term cardiac support. The dual chamber polyurethane blood sacs fill passively, with pneumatically driven ejection. The configuration mimics that of the native atria and ventricles. The device is capable of generating a pulsatile flow of up to 6 L/min. The ease of implantation, operation, weaning, cost-effectiveness, and widespread availability have made it one of the most commonly used devices in the setting of acute cardiac failure. The indications for its use have expanded beyond the postcardiotomy setting, to include the cardiogenic shock associated with acute infarction; myocarditis; and temporary right ventricular support in association with long-term LVAD implantation.

The MAQUET Heart Lung Support (HLS) system including CARDIOHELP and the disposable HLS Set and HLS Cannulae is a very light and small life support system. The portable system provides extracorporeal life support (ECLS), to replace or support the patient's circulation and respiration, the so-called cardiopulmonary support. The device is light enough to be carried by one person, and compact enough to be transported in a helicopter or vehicle. With its disposables, its integrated sensors and its software versions, the CARDIOHELP life support system opens up new possibilities for patients requiring veno-venous ECLS or veno-arterial ECLS, as well as for CO_2 removal and the use of minimal extracorporeal circulation (MECC). Vessel access is needed to link the extracorporeal life support (ECLS) system to the patient. Special HLS Cannulae can be gently percutaneously inserted into appropriate veins and arteries for cardiac support and/or respiratory assistance. Some authors reported in observational study that extracorporeal cardiopulmonary resuscitation (CPR) has a short-term and long-term survival benefit over patients with conventional CPR in patients with in-hospital cardiac arrest of cardiac origin [23].

The AB5000 Circulatory Support System provides temporary support for one or both sides of the natural heart in circumstances where the heart has failed, giving the patient's heart an opportunity to rest and potentially recover. The AB5000 Ventricle is vacuum-assisted technology with clear housing to allow clinicians a view into the device. It uses the same cannula as the previously described BVS 5000 Blood Pumps, allowing for a seamless transition of devices without requiring any additional surgical procedure. Unlike other ventricular assist systems that can require multiple drivers for a single patient, patients on the AB5000 Ventricle require only a single console – regardless of their condition. The AB5000 Console is designed to allow patients to leave their hospital rooms and walk within the hospital and on hospital grounds. Multiple studies have shown that patient ambulation, or walking, assists the recovery process greatly. The ease of use and the transport capability of the AB5000 System make it an important option for both regional and local cardiac centres, and enable a patient to be transported to a more advanced cardiac centre if necessary.

POST-OPERATIVE MANAGEMENT AND COMPLICATIONS

In the immediate peri-operative period, proper device function and meticulous post-operative care must be ensured in order to maintain adequate end-organ perfusion. Antibiotic prophylaxis begins pre-operatively, and is usually continued for 48 to 72 hours post-operatively. 24 to 36 hours after implantation, systemic anticoagulation with heparin and warfarin is initiated. Patients should be weaned

from mechanical ventilatory support as soon as feasible. Diuretics are administered early in the post-operative course, since many of these patients are in a chronic volume-overloaded state. Peri-operative renal insufficiency is usually managed with the early institution of continuous veno-venous haemofiltration for the optimisation of fluid balance. Since the publication of the landmark REMATCH (Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure) trial in 2001, refinement in devices and the adoption of best practice management techniques have improved the short- and long-term patient care [24,25]. Peri-operative complications include haemorrhage; right ventricular failure; sepsis; air embolism; and kinking of conduits. The most common late complications are mechanical device failure, neurological events, and infection [2,26,27].

Herein, we describe some of the most common complications:

Mediastinal bleeding following left ventricular assist device implantation is relatively common and may be related to systemic anticoagulation or the potentially acquired von Willebrand disease [28]. The predisposing factors include hepatic congestion and dysfunction related to chronic heart failure; compromised nutritional status; the use of pre-operative anticoagulation; extensive surgical dissection; re-operative procedures; prolonged cardiopulmonary bypass; and coagulopathy secondary to interactions between the circulating blood elements and the artificial device surfaces [29]. Of note late bleeding and tamponade can occur due to the requirement of systemic anticoagulation.

Sepsis due to infection is the leading cause of death in patients receiving ventricular assist devices[2]. Infections in LVAD patients can affect different components of the device and can vary in severity. Patients can also develop infectious complications at sites remote from the device such as in the respiratory, gastrointestinal, or genitourinary tracts, as well as from indwelling intravenous and central lines. Other patient factors, which may increase the susceptibility to infection, include generalised debilitation and malnutrition, diabetes, renal failure, and immunologic derangements associated with T-cell death seen after device implantation [30]. VAD infections can occur at any time, but most frequently, they occur between 2 weeks and 2 months after the implantation. Bacteria that are able to form biofilm, such as Staphylococcus, Pseudomonas, or Enterococcus, predominantly cause device-related infections. The frequent use of broad-spectrum antibiotics increase susceptibility for fungal infections, which are associated with the highest risk of death [31].

Implanted mechanical devices are susceptible to thromboembolic events due to their unique properties. The foreign surfaces of VADs can activate the immune system, platelets, and the coagulation cascade. In addition, the blood-contact surfaces

of VADs, along with the turbulent blood flow, increase the risk of shear stress on the blood and thrombi formation. Intracranial haemorrhage, syncope, seizure, brain abscesses, and encephalopathy have all been reported. These data mostly originate from the bridge-to-transplantation experience, and may not apply to destination therapy patients, who are generally older, and have more comorbidities and longer implantation periods. Not all devices have the same neurological event rate, and design modifications incorporated in the newer generation of VADs, including the use of novel biologic materials, textured coatings, and a single moving part, are believed to reduce the risk of thrombus formation. All device patients are maintained on aspirin, mainly for its anti-inflammatory effect, and most devices require anticoagulation with heparin and warfarin. The vigilant control of anticoagulation parameters is necessary to balance the risk of thrombus formation with the threat of late mediastinal bleeding.

Approximately 20 % of patients undergoing left ventricular assist device placement will suffer from post-operative right heart failure [32]. Predicting which patients will manifest right-sided failure can be difficult. The post-operative right ventricular failure has a significant effect on the clinical outcomes, leading to increased length of stay in the intensive care unit; increased 30-day mortality following the LVAD implantation; and a lower bridge-to-transplantation rate. Clinically, the onset of the right ventricular failure can be sudden, and may occur at the onset of an LVAD device initiation. The blood product transfusion has been shown to have adverse effects on pulmonary vascular resistance [33]. The use of aprotinin has been shown to decrease the blood loss, the incidence of the right VAD implantation, and the peri-operative mortality in patients undergoing LVAD placement [34].

A significant proportion of patients undergoing the device placement experience a multi-system organ failure that carries a high mortality in patients. Patients undergoing the VAD implantation have a high incidence of comorbidities, and many manifest significant end-organ dysfunctions pre-operatively. Some may not recover the organ function following the device implantation. Other patients may manifest multi-system organ failure as the end result of complications related to device implantation. These include surgical trauma, prolonged cardiopulmonary bypass times, peri-operative bleeding, and sepsis.

Device failure is an ever-present concern in patients with mechanical circulatory assistance. Both cardiac catheterisation and transesophageal echocardiography have been described as useful tools for the diagnosis of device malfunction.

Immunologic effects and allosensitization are derived from the interaction between prosthetic device surfaces and circulating blood elements. A number of alterations are seen in the T-cell function. T cells in LVAD patients demonstrated an

increased susceptibility to activation-induced cell death. Another aspect of the immunologic disturbance that is seen is the B-cell hyper-reactivity. The overall clinical effect of these changes is two-fold. First, patients demonstrate progressive defects in cellular immunity, with a resultant increased risk of infection. Second, B-cell hyper-reactivity ultimately leads to allosensitization to human leukocyte antigens. Untreated allosensitization is associated with prolonged pre-transplant waiting times, as well as an increased risk of acute rejection. When sensitisation develops, immuno-modulation with intravenous immunoglobulin therapy in conjunction with cyclophosphamide has proven to be effective in reducing alloreactivity, and reducing the risk of acute rejection [35].

CONCLUSION

Mechanical circulatory support has emerged as an important therapeutic option in the treatment of both acute and chronic heart failure of various aetiologies. As VAD technology progresses, the collaboration of multidisciplinary teams composed of engineers, scientists, physicians, and nurses will continue to refine the technology and improve patient care and operation outcomes. Advances in device design will allow for an easier implantation and create smaller, more efficient, durable, and reliable units. Active areas of investigation include the effects of mechanical unloading on ventricular remodelling, as well as the potential use of device support in conjunction with other modalities, such as gene therapy; pharmacotherapy; and stem cell implantation to promote myocardial recovery.

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Sažetak

Kratkotrajna potpora cirkulaciji i izmjeni plinova u krvi

Zatajenje srca s porastom incidencije i prevalencije u sve starijoj populaciji polako postaje javno zdravstveni problem. Mehanička cirkulacijska potpora se koristi kao oblik liječenja u skupini bolesnika s uznapredovalim zatajenjem srca. Mehanička crpka se kirurški implantira kako bi osigurala, bilo pulsatilni, bilo nepulsatilni protok krvi koji služi kao supplement ili kao zamjena protoku krvi kojeg bi trebalo generirati srce. Glavni cilj i namjena mehaničke cirkulacijske potpore je volumno rasteretiti srce u terminalnom zatajenju i pomoći u održavanju protoka vitalnih organa održavajući minutni volumen. Prisutna je široka paleta uređaja: od onih koji se mogu perkutano implantirati, uređaja za kratkoročnu potporu koji se mogu koristiti u operacijskoj sali, u laboratoriju za kateterizaciju kao i u jedinici intenzivnog liječenja do potpuno implantibilnih uređaja za dugoročnu potporu. Uređaji mogu biti korišteni kao terapija premoštenja do oporavka ili do transplantacije srca ili, u pojedinim slučajevima, uređaji predstavljaju definitivnu terapiju, npr. kod bolesnika u kojih je kontraindicirana transplantacija. Ovaj oblik liječenja ne uključuje samo kardiokirurge, već i kardiologe, anesteziologe kao i perfuzioniste. Pravilna trijaža bolesnika predstavlja ključnu točku uspjeha u ishodu liječenja volesnika s mehaničkom cirkulacijskom potporom. Prijeoperacijska stratifikacija rizika je iznimno važna u minimaliziranju stope perioperacijsakog mortaliteta. Istovremeni tehnološki razvoj, kao i multidisciplinarna suradnja konstruktora uređaja, znanstvenika, liječnika i ostalog medicinskog osoblja dovest će do unaprijeđenja cjelokupnog procesa liječenja ove skupine bolesnika. Daljnji tehnološki razvoj ide u smjeru pojednostavljenja procesa implantacije, s manjim, efikasnijim, trajnijim i još više pouzdanijim uređajima.

Ključne riječi: mehanička cirkulacijska potpora; zatajenje srca