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The application of mechanical circulatory support in special conditions

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Special conditions, though not typically associated with cardiovascular distress, may be considered for treatment with temporary mechanical circulatory support (tMCS) devices. Such non-classical examples of cardiovascular compromise include trauma, sepsis, and peri-partum cardiomyopathy, among others, and may require urgent treatment with a tMCS device for haemodynamic stabilization and tentatively saving the patient's life. In this section, examples of the use of tMCS in several special circumstances are presented to garner awareness for such conditions, which have previously been overlooked or even considered contraindications, and highlight the benefit of tMCS devices during treatment of these patients and the need for more research into these circumstances.

Introduction

Acute coronary syndrome and acute decompensated heart failure are the leading causes of cardiogenic shock (CS) admissions.[1] However, a growing number of *special conditions*, both primarily cardiac and non-cardiac, have also been identified as contributors to CS and often necessitate temporary mechanical circulatory support (tMCS). While these conditions are individually rare, they collectively account for a significant proportion of CS admissions (*Figure 1*). The management of these special conditions necessitates a multi-disciplinary approach, as their unique pathophysiologic characteristics add complexity to the clinical picture and require tailored expertise across multiple specialities. The application of tMCS in these patients must be carefully considered, as the decision-making process is influenced by the delicate inter-play of the underlying condition's specific features, haemodynamic instability, and potential contraindications. This document aims to provide pragmatic guidance on the application of tMCS in selected special conditions that extend beyond traditional aetiologies of CS. These include

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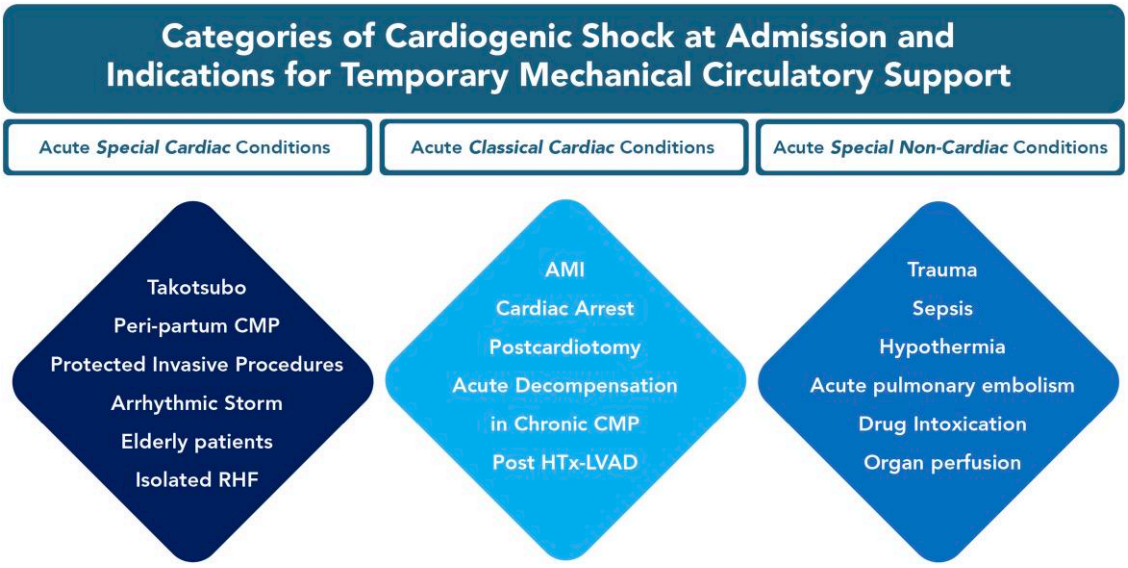

Figure 1 Categories of cardiogenic shock at admission and indications for temporary mechanical circulatory support. AMI, acute myocardial infarction; CMP, cardiomyopathy; HTx, heart transplant; LVAD, left ventricular assist device; RHF, right heart failure; sepsis, sepsis-associated cardiomyopathy.

Takotsubo cardiomyopathy, peri-partum cardiomyopathy (PPCM), and isolated right heart failure (RHF), which represent primarily cardiac triggers. Additionally, systemic or non-cardiac contributors such as sepsis, hypothermia, trauma, and drug or chemical intoxication are explored, as they underscore the expanding role of tMCS in managing multi-factorial causes of CS. Specific challenges, such as treating elderly patients with CS or managing arrhythmic storms, are also addressed to highlight evolving indications of tMCS. By examining these unique clinical scenarios, we aim to provide a comprehensive overview of current best practices and stimulate further research into these complex and increasingly recognized conditions.

Takotsubo cardiomyopathy

Takotsubo syndrome (TTS), also known as stress cardiomyopathy, is a rare cardiovascular disease that is characterized by transient and reversible systolic dysfunction of the left ventricle (LV), typically presenting with a distinctive apical ballooning appearance of this ventricle on imaging.[2] Although the exact pathophysiological mechanism of TTS remains to be elucidated, catecholamine surge plays an essential role, which is why it is often referred to as stress-induced cardiomyopathy. Currently, there are no universally accepted guidelines for the diagnosis and management of TTS.

Cardiogenic shock complicates TTS in ~10–15% of cases, usually within the first 72 hours (h) of admission, and often requires urgent pharmacologic- or tMCS-guided haemodynamic support.[2] Importantly, inotropic agents and/or vasopressors are contraindicated in TTS as they may exacerbate the catecholamine-driven pathology, worsening the patient's clinical status and prognosis.[2] Unlike with other causes of CS where haemodynamic stabilization with inotropes is standard, treatment with tMCS should be considered significantly earlier in patients with TTS to support recovery.[2,3]

Data from The International Takotsubo Registry, the largest TTS database in the world, reveal that in-hospital mortality is significantly higher in patients with CS (23.5%) compared with those without CS (2.3%, $P < 0.001$).[4] However, patients who received tMCS for Takotsubo cardiomyopathy complicated by CS had reduced mortality rates compared with those who did not receive tMCS.[5] Another retrospective registry that includes 10 US and European centres identified 16 patients with TTS-CS supported with an Impella.[6] In this study, the majority of these patients (81.3%) survived with a mean duration of Impella support of 1.9 ± 1.0 days and with improved LV ejection fraction (LVEF) compared with baseline.[6]

More recently, a systematic literature review analysed 93 publications involving a total of 124 patients with TTS where tMCS was used for treatment of TTS complicated by CS.[3] Among these cases, patients were most commonly supported with veno-arterial extracorporeal membrane oxygenation (VA-ECMO, 50%), an Impella micro-axial flow pump (mAFP, 35.5%), or an intra-aortic balloon pump (IABP, 10.5%) and demonstrated an overall survival rate of 86.3%.[3] Interestingly, the authors noted that recovery time was lower in patients treated with an Impella device.[3]

In summary, the use of tMCS for treatment of TTS-related CS is becoming more common, with a particular rise in the use of VA-ECMO and Impella. Given TTS primarily affects the LV, Impella can be considered as first-line tMCS. Intra-aortic balloon pump, on the other hand, should be avoided in cases with severe LV outflow tract obstruction due to its potential to worsen haemodynamics.[7] While retrospective data support these treatments, prospective studies are needed to further evaluate the safety and efficacy of different tMCS devices, determine optimal timing, and refine tMCS strategies in special patient populations, like those impacted by TTS.[6]

Temporary mechanical circulatory support devices in elderly patients: more than just age

In the European Union, the elderly population (defined as individuals aged ≥65 years) currently accounts for 21.3% of

the total population, representing ~95.6 million people.[8] This proportion is projected to rise to 32.5% by 2100.[8] As the population ages, so does the number of people considered for tMCS devices. However, managing this population presents unique challenges due to the heterogeneity of prognostically significant variables among elderly patients, which complicates assessments on the impact of age alone on the outcomes of individuals treated with tMCS devices. As such, we have reviewed the recent literature on the outcomes of elderly patients treated with tMCS devices.

Extracorporeal membrane oxygenation in elderly patients

The adoption and accessibility of ECMO have expanded significantly in recent years, enabling its expanded use in high-risk patient groups, including those who were previously considered unsuitable candidates for support.[9-11] However, there is currently no universally accepted criteria for ECMO use in elderly patients, and limited guidance exists regarding its contraindications.[12] Moreover, it remains unclear which populations will potentially benefit the most from this resource-intensive support modality.[10] As a result, ECMO utilization varies widely based on the underlying disorder requiring support and the nuances of the modality utilized. For example, short-term cardiopulmonary support may be used for post-cardiotomy failure, while longer term respiratory support is employed for conditions like viral pneumonia and respiratory disorders.[13] It remains to be determined whether age should be a primary selection criterion to guide the decision to initiate ECMO or to withhold tMCS support.[14] Recent publications continue to present a mixed picture but suggest that the consideration for short-term cardiopulmonary support is distinct from long-term respiratory support.[10,15,16]

Outcomes from the Extracorporeal Life Support Organization (ELSO) registry offer valuable insights into the outcomes of elderly patients supported with ECMO. Among 1035 patients receiving ECMO support for COVID-19-related respiratory failure across 213 centres in 36 countries between 16 January 2020 and 1 May 2020, the cumulative in-hospital mortality 90 days post-ECMO initiation was 37.4%.[17] Within this cohort, increasing age was associated with a higher risk of in-hospital mortality compared with patients aged 16–39. Moreover, when stratified for decade of life, this was progressive with a mortality hazard ratio of 1.76 (1.23–2.52) for patients aged 50–59 and 3.07 (1.58–5.95) for those over 70.[17] Similarly, in a retrospective 4-year single-site study of 243 patients where 75% of patients received VA-ECMO support and 25% received veno-venous ECMO (VV-ECMO) support, increasing age was also found to be a strong independent predictor of outcome.[15] Modelling in this study demonstrated a 2.8% increase in the odds of in-hospital mortality for each year of life.[15,16] The relationship between age and mortality with age stratifications of <45, 45–54, 55–64, and ≥65 years over 4 years in patients supported with VV-ECMO has also been examined. In this study, a progressive and incremental increase in mortality was demonstrated with each advancing age cohort. A low survival rate of 16.7% was reported for patients over the age of 65 years compared with 77.8% for those aged under 65 years.[18]

Further data from the ELSO registry spanning 22 years examined outcomes for 5408 patients receiving VA-ECMO for refractory CS.[19] While the overall in-hospital survival rate was 41.4% in all adult patients, this fell to 30.5% for patients aged over 70. This survival impairment remained statistically significant when controlling for confounding variables. However, given the high overall mortality of this adult cohort, the authors noted that the ~10% increase in mortality among the >70-year-old patients should not be a strict contraindication.[19]

In summary, ECMO is a supportive, non-curative modality, with outcomes closely tied to the reversibility of the underlying condition and the anticipated time course of recovery. Although advanced age is clearly associated with worse outcomes, it should not be used as the sole determinant when deciding if ECMO support is an appropriate treatment option. The heterogeneity in age cut-offs used to define 'elderly' across studies limits direct comparisons across studies. Furthermore, it remains unclear whether poor outcomes are primarily driven by age alone or by the cumulative effects of secondary conditions often seen in older patients.[20] A more granular approach, incorporating biological age, frailty, and comorbidities, may help refine patient selection criteria and optimize resource utilization in this population.

Intra-aortic balloon pump and micro-axial flow pump support in elderly patients

Age consistently emerges as a powerful independent predictor of mortality in patients with CS, including those supported with IABP and mAFP.[21,22] The IABP-SHOCK II trial identified age ≥73 years as a significant predictor of higher 30-day mortality, as reflected in the development of the IABP-SHOCK II scoring system, a 6-item risk stratification tool.[21] Similarly, a large cohort study of patients with IABP found that an age ≥75 years was also predictive of complications, further underscoring the prognostic impact of advanced age.[23] Recently, a dedicated sub-analysis of the DanGer shock trial found no benefit (and possibly harm) from mAFP support in patients aged ≥77 years with acute myocardial infarction–related CS (AMI-CS).[24] These findings highlight the importance of cautious patient selection in this vulnerable population.

Although no definitive age thresholds can be provided, an age of at least 75 years should prompt individualized treatment and case-by-case decision-making as to whether a patient should receive tMCS support. Furthermore, considerations should include the limited or, more likely, absent eligibility for heart replacement therapy and the frequent presence of frailty in this patient population.

Peri-partum cardiomyopathy and shock

Peri-partum cardiomyopathy is a serious pregnancy-associated condition indicated by LV dysfunction and heart failure that can be life-threatening.[25] The exact causes of PPCM are unclear, but it has been associated with viral myocarditis, nutritional deficiencies, autoimmunity, microchimerism, and haemodynamic instability.[25,26] The use of tMCS for refractory CS in PPCM is rare but increasing,

Table 1 Summary of typical haemodynamic findings according to right heart failure profile

	Any RHF	
Flow/power indexes	CI [(SV × HR)/BSA] <2.2 L/min/m^2 CPO [(CO × MAP)/451] <0.53 W CPI [(CI × MAP)/451] <0.32 W/m^2 CPO-RAP [CO × (MAP−RAP)/451 <0.66 W CPI-RAP [CI × (MAP −RAP)/451] <0.28 W/m^2	
	Isolated RHF	Combined LHF and Predominant RHF
Congestion indexes	RAP ≥12 mmHg PAWP <18 mmHg RAP/PAWP >0.63 (HF) RAP/PAWP >0.86 (AMI-CS) Low sPAP/dPAP/mPAP	RAP ≥12 mmHg PAWP ≥18 mmHg RAP/PAWP ≥0.63 (HF) RAP/PAWP ≥0.86 (AMI-CS) High sPAP/dPAP/mPAP
Afterload indexes	PAE (SV/sPAP) >0.85 mmHg/mL High PAC [(sPAP-dPAP)/SV]	PAE (SV/sPAP) ≤0.85 mmHg/mL Low PAC [(sPAP-dPAP)/SV]
Adaptation indexes	PAPi <0.90 (AMI-CS) PAPi <1.85 (ADHF)	PAPi variable (depending on PAP values and RV adaptation)

ADHF, acute decompensated heart failure; AMI-CS, acute myocardial infarction with cardiogenic shock; BSA, body surface area; CI, cardiac index; CO, cardiac output; CPI, cardiac power index; CPO, cardiac power output; d, diastolic; HF, heart failure; HR, heart rate; LHF, left HF; m, mean; MAP, mean arterial pressure; PAC, pulmonary artery compliance; PAE, pulmonary artery elastance; PAP, pulmonary artery pressures; PAPi, pulmonary artery pulsatility index (PAPi); PAWP, pulmonary artery wedge pressure; RAP, right atrial pressure; RHF, right HF; RV, right ventricular; s, systolic; SV, stroke volume; W, watts.

with reports often demonstrating favourable outcomes. While treatment with IABP or Impella for PPCM has been described in several case studies,[27,28] no robust data about indication or device selection are currently available.[21,22] Peripartum cardiomyopathy is predominantly associated with severe LV dysfunction, often requiring prolonged tMCS support due to the extended recovery period. Interestingly, survival rates for patients with PPCM receiving tMCS are higher compared with other patient populations, emphasizing the potential benefit of early and effective intervention. However, complications, such as bleeding, are a significant concern, particularly in patients supported with ECMO, where bleeding incidence ranges from 30 to 60%.[29] Minimizing these complications is crucial to achieving favourable outcomes.

Emerging data support the early use of mAFP (e.g. Impella) for PPCM-related CS. A small, single-centre case series reported better outcomes when tMCS was implemented early compared with delayed implantation.[25,30] These findings suggest that timely intervention may improve recovery trajectories and reduce morbidity.

Moving forward, large repositories such as the EURObservational Research Program international PPCM registry can provide valuable opportunities to data mine, deepen our understanding of PPCM, and refine treatment protocols. Timely recognition of PPCM, paired with multi-disciplinary management, is critical to ensuring optimal maternal and foetal outcomes in severe PPCM cases.

Isolated right heart failure

Up to 50% of CS cases involve biventricular dysfunction, with left heart failure (LHF) being the most common cause of RHF, often referred to as secondary RHF.[18] However, CS may also be sustained by isolated RHF in ~8% of cases.[31] The most common clinical triggers of isolated RHF in adults include acute right ventricular (RV) myocardial infarction (MI, ~50% of acute inferior MI), acute pulmonary embolism (PE), acute myocarditis, cardiac surgery, severe pulmonary hypertension, severe long-lasting or acute tricuspid valve regurgitation, chronic constrictive pericarditis, and acute respiratory distress syndrome (ARDS).

The RV is exquisitely sensitive to afterload,[32] inter-ventricular septum geometry and systolic function,[33] inter-ventricular dependence within the pericardial sac,[33] and coronary perfusion.[34] In the case of RHF, derangements in all of these factors may interact and often coexist. Isolated RHF can be subtle and, if LV output is preserved, may lack the classic clinical signs of LHF shock. At the same time, backward splanchnic congestion may be a late finding, and early clinical hints may only include tachycardia, normal-to-low blood pressure, and jugular congestion. Therefore, high clinical suspicion supported by diagnostic tools such as echocardiography and right heart catheterization is essential for early recognition. Haemodynamically, isolated RHF is characterized by low global flow and power indexes [cardiac output (CO) and cardiac power output] and high right atrial pressure (RAP). Isolated/predominant RV failure (RVF) is then characterized by low pulmonary artery wedge pressure (PAWP), low pulmonary artery pressures (PAPs), low pulmonary artery pulsatility index (PAPi), and an RAP/PAWP >0.63. Importantly, PAPi may be variable in secondary RHF. These indexes might also implicate a different response to MCS (*Table 1*).[35,36]

The medical management of RHF is summarized in *Figure 2*. Mechanical circulatory support is tailored to the specific clinical setting, and effective management requires identification of the primary mechanism

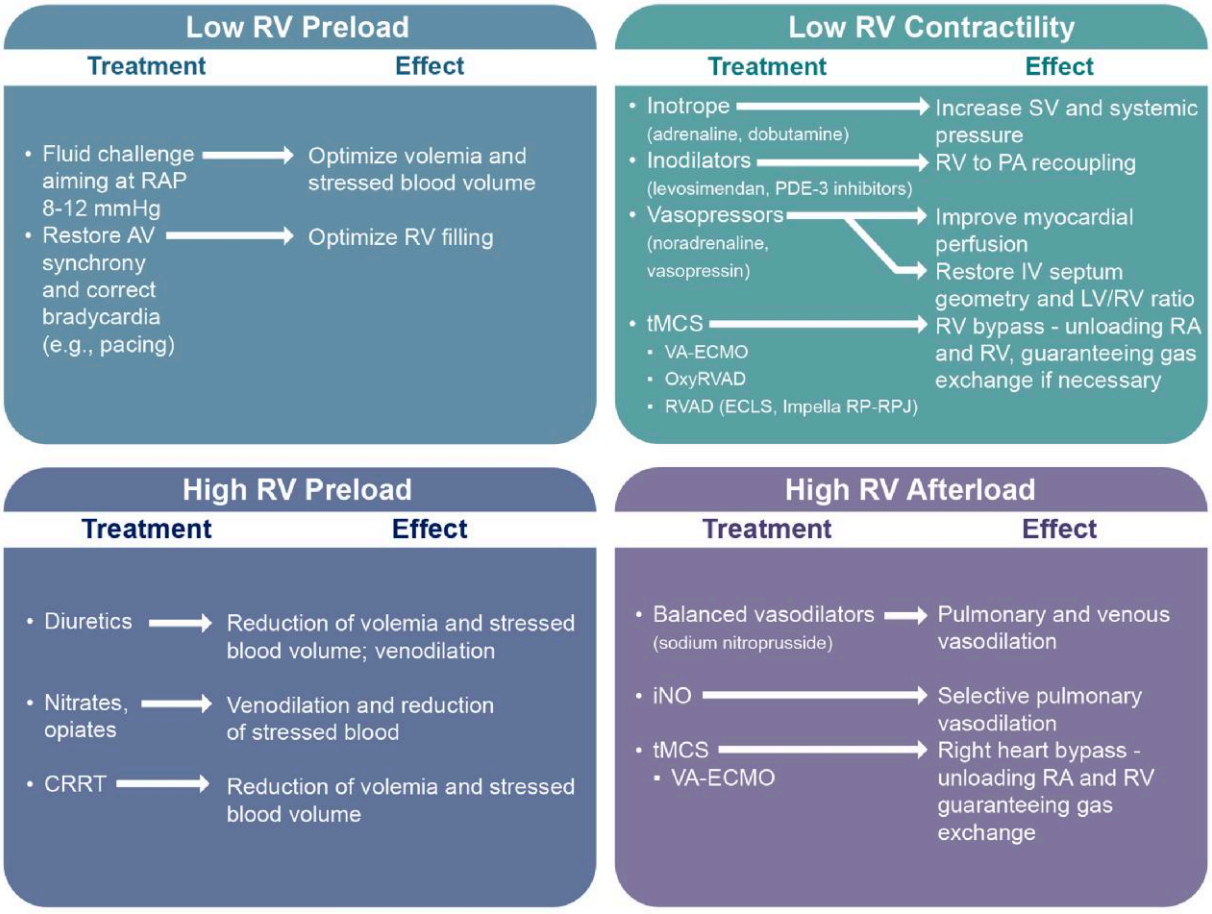

Figure 2 Summary of medical treatment options for right heart failure. AV, atrioventricular; CRRT, continuous renal replacement therapy; ECLS, extracorporeal life support; iNO, inhaled nitric oxide; IV, inter-ventricular; LV, left ventricular; OxyRVAD, oxygenated right ventricular assist device; PA, pulmonary artery; PDE-3, phosphodiesterase-3; RA, right atrium; RAP, right atrial pressure; RHF, right heart failure; RV, right ventricular; RVAD, RV assist device; SV, stroke volume; tMCS, temporary mechanical circulatory support; VA-ECMO, veno-arterial extracorporeal membrane oxygenation.

underlying RHF (e.g. myocardial failure, its aetiologies, or increased afterload) and assessment of the presence and severity of concomitant respiratory failure. Several devices are available to provide haemodynamic support, including Impella RP or RP-J, veno-pulmonary (V-P) artery extracorporeal life support (ECLS) with or without an oxygenator [V-P RV assist device (RVAD)], and VA-ECMO. These devices provide haemodynamic support by temporarily taking over the heart's pumping function and allowing the ventricle to recover or by facilitating the transition to a more permanent solution, such as a durable ventricular assist device (VAD) or heart transplant. The choice between these devices depends on the severity of RVF, the underlying cause, and the patient's overall condition and age. For instance, patients with isolated RVF may benefit from Impella RP/RP-J, V-P RVAD, or ECMO, while those with biventricular failure may require more complex strategies, such as combining ECMO with IABP or using a BiVAD system.

In cases of isolated RHF due to acute myocardial injury induced by RV MI, post-cardiotomy shock, or RV myocarditis, mAFP such as the Impella RP/RP-J may be beneficial.[37] The Impella RP can deliver up to 4.0 L/min of blood flow from the inferior vena cava to the pulmonary artery (PA) trunk, thus unloading the RV. The RECOVER-RIGHT trial demonstrated its efficacy in patients with MI or post-cardiotomy shock, meeting criteria such as persistent CS with a cardiac index (CI) of <2.2 L/min/m^2 despite >1 inotrope/vasopressor, RAP >15 mmHg, RAP/PAWP >0.63, and echocardiographic evidence of RV dysfunction or dilation. Right heart failure due to primary myocardial failure usually exhibits high central venous pressure and low pulmonary pressure due to antegrade failure.[38]

For RHF with obstructive shock in the context of acute PE, rapid pharmacologic and/or mechanical reperfusion combined with vasoactive support is critical. In cases of refractory cardiac arrest (CA) due to acute PE, VA-ECMO should be used in conjunction with mechanical reperfusion techniques to prevent patient death,[39] although in clinical practice this varies widely.[40] Shared decision-making among the intensive care unit (ICU) cardiologist, interventional cardiologist, and attending physician is warranted to determine the best treatment options while assessing the overall bleeding risk of the patient.

Acute respiratory distress syndrome is another significant contributor to RHF, with rates of RV dilation and failure during ARDS as high as 21–37% and

associated with higher mortality.[41-43] Veno-venous extracorporeal membrane oxygenation provides full respiratory support and may provide some degree of RV unloading due to the secondary beneficial effect of airway plateau pressure reduction, mitigation of hypoxic PA vasoconstriction, reduction of hypercarbia, and respiratory acidosis.[44,45] Additionally, trans-jugular single-lumen with double cannulas or dual-lumen single cannulas (e.g. ProtekDuo, LivaNova), which bypass the RV from the right atrium to the PA, can directly unload the RV and serve as combined RV respiratory support when paired with an oxygenator.[46,47] Such devices have been employed in a wide array of conditions including RV infarction, ARDS, PE, and post-cardiotomy RHF. Owing to this pronounced unloading effect, preliminary evidence suggests reduction in non-cardiac end-organ failure rates and lower mortality in ARDS patients.[47-50] Furthermore, percutaneous jugular cannulas also enable patient mobilization during support, while surgically implanted cannulas remain a viable option for post-cardiotomy-isolated RHF.

Arrhythmic storm

Arrhythmic storm, characterized by recurrent or sustained ventricular arrhythmias (VA) leading to CS or acute CA, is the most common indication for tMCS. Ventricular arrhythmia can arise from a variety of aetiologies, including active myocardial ischaemia, myocardial reperfusion, myocardial overload, and hyper-adrenergic tone.[51] The consideration for tMCS typically arises when there is an imminent life threat after initial stabilization measures have failed. While first-line pharmacologic therapies are detailed elsewhere,[51] it is important to emphasize that sedation and mechanical ventilation are the mainstay of drug-refractory VA management. For patients with refractory CA or high VA burden, VA-ECMO remains the option of choice as it ensures end-organ perfusion despite poor or absent CO.[52] Additionally, VA-ECMO provides a stable platform for performing percutaneous ablation procedures in patients with rapid or unstable VA.[53,54]

Intense VA burden may also be present in the case of ongoing myocardial ischaemia, especially in cases of ST-elevation MI-related CS. In such cases, prompt primary percutaneous intervention combined with Impella CP support has been shown to improve survival outcomes.[55] In patients supported by mAFP, the onset of VA should prompt immediate confirmation of appropriate pump position, since mechanical contact with cardiac structures may trigger VA.[56] While supraventricular arrhythmias (SVA) may be better tolerated than VA, persistent SVA can adversely affect the function of tMCS devices. Continuous-flow mAFP devices are particularly sensitive to pre-load conditions. Loss of atrial contribution due to atrial fibrillation, junctional rhythm, or atrioventricular dissociation may lead to insufficient pre-load, suction alarms, and persistent aortic valve closure.

Hypothermia and drug intoxication

Acute intoxication with pharmacological or non-pharmacological substances can lead to severe haemodynamic instability or collapse, including CA. Such collapse often triggers the deterioration of other organ systems, including respiratory depression, kidney and liver failure, and acid–base disorders. Metabolic alterations and toxin accumulation within fat tissue may further impair cardiac function, exacerbating toxicity. Similarly, hypothermia, defined by a core temperature below 35°C, is another potential cause of CS.[57] Hypothermia can occur in cold environmental conditions but may also present secondary to intoxication or trauma. Patients presenting with intoxication and/or hypothermia are initially managed by emergency department personnel in collaboration with intensive care specialists. However, patients with cardiac failure are referred to the Heart Team for evaluation. Immediate management includes addressing symptoms of intoxication and administering specific antidotes when available, aiming to prevent vital organ failure. While these measures are usually effective, they may not suffice in the case of life-threatening overdoses that lead to cardiovascular collapse.

The implementation of tMCS, particularly ECMO, has become increasingly common over the last decade to treat severe CS and acute lung failure.[58] Among the total number of ECMO cases performed every year, the number of ECMO implemented due to intoxication appears small and is mainly limited to case reports and data from registries.[59,60] The use of Impella to treat specific cases of pharmacological intoxication causing torsades de pointes[61] and CS[62] is also reported. A recent systematic literature review that included 145 studies and 539 patients documented that the most frequent indications to tMCS in these settings are CA (48%) and refractory CS (37%), where VA-ECMO is the most commonly employed tMCS device.[63] The most frequent drugs observed in these cases are cardiovascular drugs, psychotropic medications, and other hazardous chemicals. Overdose patients tend to be younger than the standard ECMO population.[64] Concomitant dialysis, hemadsorption, or plasmapheresis is also frequently employed to remove the chemical entities that are responsible for the intoxication.

In cases of intoxication, a Heart Team's decision to use ECMO is based on the need to provide cardiac and/or respiratory support to the patient, with a bridge-to-elimination or bridge-to-antidote strategy.[63] Therefore, the possible interaction of the extracorporeal circuit and toxin removal measures must be kept in mind, and a consultancy with toxicologists is advised. For example, intravenous lipid emulsion administration to bind drugs during ECMO or dialysis is associated with life-threatening complications, including clotting of the circuits.[64,65]

The use of tMCS in intoxicated patients provides an effective means of increasing survival, with a 69% hospital survival rate for patients treated with VA-ECMO and 51% for extracorporeal cardiopulmonary resuscitation patients.[63] Encouraging survival rates in cases of hypothermia and intoxication can be attributed to factors such as young age, cause of cardiopulmonary collapse (other than a pathology of cardiac origin), reversible cause of shock, and absence of structural heart disease. These factors should be taken into account by the Heart Team when deciding whether to implement tMCS in these patients. In hypothermic patients, survival rates and neurological outcomes are

better than for normothermic patients with asystolic CA. For this reason, hypothermic patients with a core temperature <30°C, systolic blood pressure <90 mmHg, VA, or CA should be referred to an ECLS centre if possible.[66] Following haemodynamic stabilization with ECLS, the primary treatment for hypothermia is rewarming, which should be performed with ongoing ECMO support.[66] Effective rewarming strategies must also account for severe coagulopathy and slow metabolism, both of which increase the risk of haemorrhage. Once the acute phase of intoxication or hypothermia has resolved, tMCS weaning can begin.

Trauma

Major trauma-associated haemodynamic instability poses a global health risk with a high rate of mortality, particularly in young adults.[67] Trauma patients often present with multiple injury-related complications such as a high risk of bleeding, traumatic brain injury, coagulopathy, and contraindication to anticoagulation, among others, that can render them unsuitable for tMCS. Despite the lack of formal guidelines or robust evidence, ECMO (either VA-ECMO or VV-ECMO) has been used in trauma settings to manage refractory cardiac and/or respiratory failure, which are often the primary drivers of mortality in patients who survive the initial injury and reach the hospital.[68] When deciding whether to start VV- or VA-ECMO in a trauma patient, the Heart Team must carefully weigh haemodynamic and metabolic factors to stabilize the patient while preserving neurological function after CA. Another critical consideration is the role of tMCS in supporting the patient through further therapeutic steps, such as definitive haemostatic surgery or damage control surgery. Decisions to implement tMCS must involve the entire trauma care team to ensure alignment and co-ordination of care.

The application of tMCS beyond ECMO in trauma patients remains limited due to a lack of supporting data and clinical experience. This highlights the urgent need for clinical studies to explore the potential utility of other tMCS devices in trauma-related critical care.

Sepsis

Septic cardiomyopathy (SCM) is a common complication of septic shock first described in 1984,[69] with an incidence of 20–60% during the first few days of ICU admission.[70] Septic cardiomyopathy is characterized by a reversible impairment of intrinsic cardiac contractility that typically normalizes within 7–10 days.[71] Although the exact pathophysiology is not fully understood, myocardial dysfunction is thought to result from inflammatory cytokines, mitochondrial dysfunction, and direct functional and structural myocardial injury.[71,72] While the initial definition of SCM focused on LV systolic dysfunction, it is now recognized that both ventricles can be affected. Importantly, SCM is associated with a mortality two to three times higher than that seen in septic shock without myocardial involvement,[70] highlighting the need for improved therapeutic approaches to address this condition.[70]

In standard clinical practice, SCM is regularly overlooked due to the heavy focus on stroke volume (SV) or CO in the haemodynamic monitoring of septic shock, parameters that are typically increased in septic shock due to vasodilatory shock with decreased afterload.[71,72] As a result, normal values for SV or CO do not necessarily reflect preserved cardiac contractility. Thus, patients with SCM should be referred to the Heart Team within a cardiac ICU setting for specialized management. Treatment of SCM begins with prompt and targeted antibiotic therapy, co-ordinated with infectious disease specialists, along with surgical removal of the infectious focus to address infection origin, decrease pathogen-associated molecular patterns, and control hyper-activation of the inflammatory cascade.[73] Management of SCM focuses on supportive care aimed at optimizing haemodynamics and ensuring adequate tissue perfusion, including early and goal-directed fluid resuscitation, vasopressors, and inotropic therapy.[73] In contrast to the evidence of tMCS use in the paediatric population affected by SCM,[74] the role of tMCS and device choice is less documented in adults.[75] As such, the discussion of tMCS use in cases of septic shock remains controversial and is based on retrospective, observational studies and expert opinions rather than on data from robust studies. The current literature mainly reports on the use of VA-ECMO.[76-78]

In a retrospective, multicentre, international cohort study with propensity score matching including a total of 212 patients, the use of ECMO was associated with significantly improved survival.[76] In a more recently published meta-analysis including 14 observational studies with 468 patients, survival was 62% in patients with LVEF <20%, but only 32% in patients with normal cardiac function, supporting that only patients with primary cardiac dysfunction rather than vasodilatory shock might benefit from tMCS in sepsis.[77] The use of tMCS other than ECMO for treating SCM, such as IABP or mAFP, is currently only reported in single case reports. Notably, in a recent retrospective analysis exploring the use of tMCS for sepsis-related CS, only the use of IABP and pVADs was associated with a lower risk of in-hospital mortality.[78]

The decision to implement tMCS during SCM should be driven by the presence of cardiac failure. Moreover, isolated vasodilatory septic shock without significant myocardial dysfunction is not an indication for tMCS.[78]

Myocarditis, a condition where myocardial tissue is the primary site of infection or inflammation, deserves its own separate discussion. Cardiac dysfunction in myocarditis may be severe and prolonged, with unfavourable tissue remodelling due to intra-cardiac inflammation. Historically, VA-ECMO has been widely adopted in patients with myocarditis presenting with CS.[79] In particular, evidence is accumulating that shows LV unloading via an mAFP is a valuable treatment for patients with fulminant myocarditis and CS, and histo-pathological proof of myocardial healing due to prolonged mAFP has been reported.[80] Patients with myocarditis typically come to the attention of the Heart Team soon after hospitalization due to primary cardiac involvement. Impella-driven unloading in myocarditis cases is widely considered one of the therapeutic mechanisms with the greatest potential to promote native heart recovery, although robust evidence in this setting is lacking.[80-82]

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