European Heart Journal Supplements (2025) **27** (Supplement 4), iv39–iv46
The Heart of the Matter
https://doi.org/10.1093/eurheartjsupp/suaf002

ESC
European Society
of Cardiology

The role of temporary mechanical circulatory support in heart failure

Christophe Vandenbriele [1,2,3], Letizia F. Bertoldi[4], Francesco Bruno [2,5], Assad Haneya[6], Alexander Nap[7], Evgenij Potapov[8], Felix Schoenrath[8], Daniel Zimpfer [9], and Federico Pappalardo [10]*

[1]Cardiovascular Center Aalst, OLV Hospital, 9300 Aalst, Belgium; [2]Royal Brompton and Harefield Hospital NHS Foundation Trust, London UB9 6JH, UK; [3]Department of Cancer and Surgery, Imperial College London, Du Cane Road, London W12 0NN, UK; [4]Cardio Center, IRCCS Humanitas Clinical and Research Center, 20029 Rozzano, MI, Italy; [5]Cardiovascular and Thoracic Department, Città della Salute e della Scienza di Torino, 10126 Turin, Italy; [6]Cardiothoracic Surgery, Heart Centre Trier, Barmherzige Brüder Trier Hospital, 54292 Trier, Germany; [7]Department of Cardiology Heart Center, VU University Medical Center Amsterdam, 1081 HV Amsterdam, The Netherlands; [8]Department of Cardiovascular Surgery, Deutsches Herzzentrum der Charité Campus Virchow-Klinikum, 13353 Berlin, Germany; [9]Department of Cardiac Surgery, Medical University Vienna, Währinger Gürtel 18-20, 1090 Vienna, Austria; and [10]Kore University, Enna and Centro Cuore GB Morgagni, 94100 Catania, Italy

KEYWORDS
Acute heart failure;
Cardiogenic shock;
Mechanical circulatory support devices;
Multi-disciplinary care models;
Heart Team

Heart failure (HF) remains a leading cause of morbidity and mortality worldwide, with acute HF (AHF) or cardiogenic shock requiring rapid intervention to prevent fatal outcomes. Advances in temporary mechanical circulatory support (tMCS) devices have revolutionized the management of advanced HF, offering temporary, durable, and individualized support options. This manuscript reviews the pathophysiology and clinical presentation of AHF, the role of multi-disciplinary Heart Teams, and the growing importance of structured care networks in managing complex cases of HF. We explore the strategic deployment of tMCS in acute settings, device options, implications for patient outcomes, and current challenges in the field. This manuscript emphasizes the importance of team-based approaches and underscores the potential of tMCS devices in stabilizing patient haemodynamics, bridging to recovery or definitive therapy, and improving survival in patients facing high-risk HF.

Introduction

The spectrum of heart failure (HF) ranges from chronic, manageable conditions to acute, life-threatening cases, demanding rapid and precise treatment strategies to improve patient outcomes. However, HF management has evolved substantially with technology advancements, most notably the introduction of temporary mechanical circulatory support (tMCS) devices. Selecting the appropriate tMCS device and optimizing treatment is complex, requiring expertise and multi-disciplinary collaboration. This manuscript will explore the pathophysiology and clinical presentation of HF, the role of Heart Teams, the application of tMCS in diverse clinical scenarios, and future directions in HF care. Emphasis will be placed on the importance of comprehensive,

*Corresponding author. Tel: +39 095 7026111, Fax: +39 095 7026111, Email: fedepappa@me.com

team-based strategies and advanced technologies in improving patient outcomes.[1-3]

Pathophysiology and clinical presentation of acute heart failure

Acute HF (AHF) is defined as either new-onset or worsening symptoms and signs of HF that require emergency therapeutic interventions. The European Society of Cardiology (ESC) HF guidelines categorize this highly heterogeneous syndrome according to clinical presentation into four major groups, which may overlap:[1]

(1) Acute decompensated HF (ADHF) is the most common profile, accounting for 50–70% of hospital admissions[4] and is associated with lower in-hospital mortality compared with *de novo* AHF.[5]
(2) Acute pulmonary oedema is characterized by pulmonary congestion with dyspnoea and respiratory failure.
(3) Isolated right ventricular failure is marked by increased right atrial pressure and peripheral congestion; reduced systemic cardiac output (CO) may occur if ventricular interdependence is present.
(4) Cardiogenic shock (CS) is defined as primary (severe) cardiac dysfunction resulting in an imbalance between tissue perfusion and tissue oxygen requirements. The underlying cardiac dysfunction may be acute, such as in myocardial infarction or myocarditis, or progressive, as seen in ADHF due to the progression of advanced HF or precipitant factors. The Society for Cardiovascular Angiography and Intervention (SCAI) classification categorizes CS severity into five stages (A–E), ranging from 'at risk' to 'extreme' CS.[6] The association between SCAI stages and mortality has been well established, and early, standardized recognition of CS severity can improve clinical outcomes for this deadly condition.[7]

For the remainder of this manuscript, we will focus on the role of the Heart Team and tMCS management specifically in the setting of AHF patients.

The role of the Heart Team in heart failure management

The complexity of HF management—including CS, AHF, and chronic HF—necessitates an inter-disciplinary approach and structured care networks. The Heart Team is a collaborative and multi-disciplinary local group that plays a pivotal role in the decision-making process for HF patients at every stage of the disease. Team composition should vary depending on the phase and aetiology of the HF case at hand. Unlike other teams in cardiovascular medicine, HF nurses and cardiologists play a central role throughout the entire disease trajectory. The coming sections will explore the Heart Team's role in managing patients with AHF, with an emphasis on the importance of networks and referral structures and a focus on tMCS and its impact on clinical outcomes, decision-making, and patient care.

For decades, cancer care and solid organ transplantation programmes in tertiary centres have employed inter-professional and multi-disciplinary teams to deliver highly individualized treatment protocols, driven by the need to integrate multiple specialists and professions. The concept of the Heart Team originated from the Synergy between Percutaneous Coronary Intervention (PCI) with Taxus and Cardiac Surgery (SYNTAX) trial, which compared myocardial revascularization strategies for coronary artery disease.[8] In general, the Heart Team approach can be defined by four core pillars:

(1) Collaborative decision-making: Integration of diverse expertise allows for more accurate diagnoses and individually tailored treatment plans.
(2) Coordinated care: Seamless communication among team members ensures timely and effective interventions.
(3) Patient-centred approach: Involving patients and their families in the decision-making process enhances satisfaction and adherence to treatment plans.
(4) Evidence-based management: Leveraging the latest guidelines and research optimizes clinical practice and improves patient outcomes.

While HF teams are frequently discussed in position papers, no widely accepted standard for Heart Team composition currently exists. The distinction between core and extended team members is somewhat arbitrary. However structured, an effective Heart Team requires a comprehensive range of expertise to address complex disease scenarios, and adaptability to meet unique patient needs. Unlike other specialized teams, such as those focused on valvular heart disease or revascularization, HF teams support their patients throughout their lifelong HF trajectory. These teams represent the highest level of expertise within their respective centres and prioritize a holistic, patient-centred approach, integrating input from a wide range of professionals to address both clinical and social dimensions of care. At each stage of HF and during key decision-making processes, additional specialists such as cardiac surgeons, electrophysiologists, interventional cardiologists, intensivists, social workers, pharmacists, dietitians, psychologists, and palliative care physicians are added to the Heart Team. The roles of these team members vary depending on the clinical setting (ambulatory vs. hospital), specific patient needs, social factors, and local expertise.

Acute heart failure and cardiogenic shock networks

In AHF and CS, rapid, accurate diagnosis and haemodynamic stabilization—with or without tMCS—are crucial for achieving optimal outcomes. As treatment options grow increasingly complex and resource intensive, HF networks have become essential in delivering effective, resource-efficient care. Both the International Society for Heart and Lung Transplantation (ISHLT) and the Heart Failure Association (HFA) of the ESC propose a tiered structure for CS care that incorporates inter-centre mobile services.[9,10] Level 1 centres are local centres able to diagnose and stabilize patients with CS, but lack PCI capabilities, requiring referrals for cases of acute myocardial infarction (AMI) CS and more complex CS scenarios. Level 2 centres have PCI capabilities and are equipped to treat most patients with CS. Given the ageing population, the incidence of

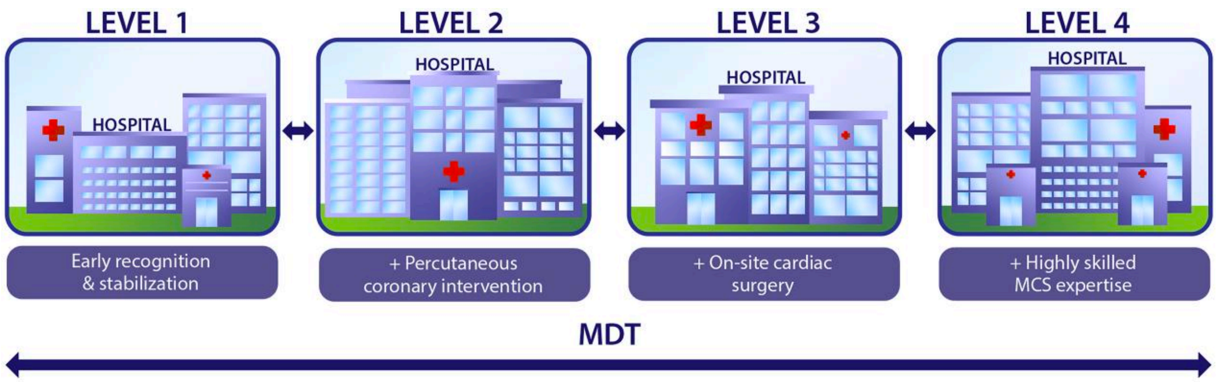

Figure 1 Acute heart failure and cardiogenic shock networks. The implementation of multi-disciplinary teams in managing patient care requires a coordinated effort and potential transfer among the different hospital levels (1-4).

AMI CS has declined, while cases of acute-on-chronic HF are increasingly prevalent.[11] The HFA defines supra-regional hub centres as centres with cardiac intensive care units (ICUs), specialized CS teams, and treatment protocols; dedicated CS nursing and ICU staff; and on-site cardiac surgery. These hubs enable both escalation of care in high-risk patients with shock and de-escalation for patients transitioning to destination therapies such as long-term mechanical circulatory support (MCS) or transplantation. Finally, ISHLT-defined Level 3 centres include on-site cardiac surgery but lack specialized HF surgery programmes (e.g. durable MCS and transplantation), while Level 4 centres provide these advanced services.[10] This structured approach allows for seamless escalation and de-escalation of treatment, optimizing patient management at every stage and ensuring access to specialized care for complex cases across a network of centres (*Figure 1*).

While research on CS networks is limited, a recent study examined the outcomes of patients treated within a CS network model.[12] This model centralizes care in specialized centres with expertise in managing CS, using standardized protocols across local treatment sites. In this study, which included 1 hub centre and 34 affiliated spoke centres, 55% of all patients initially presented to spoke hospitals. Although spoke centres more frequently used inotropes and intra-aortic balloon pumps (IABPs), the hub centre employed right heart catheters and advanced tMCS, such as micro-axial flow pumps and extracorporeal life support (ECLS), more often. Importantly, no significant differences in risk-adjusted 30-day mortality or major adverse events were detected between hub and spoke centres. Thus, with ongoing education, training, and quality improvement initiatives within a network, we can yield similar outcomes in patients with CS across varied clinical settings.[12] Key components include early identification and triage, rapid transfer to specialized centres, and the timely use of advanced tMCS. Moreover, authors highlighted that collaboration among healthcare providers across different levels of care is essential for timely, effective treatment. Thus, establishing regional networks further facilitates efficient patient transfer to specialized centres, ensuring timely access to high-level care.

Current literature on CS teams (CSTs) suggests notable improvements in outcomes for patients with CS,[13] despite the absence of prospective randomized evidence. Studies indicate that CSTs improve survival rates and reduce complications compared with traditional, non-standardized approaches.[14] Hospitals implementing CSTs report reductions in in-hospital mortality rates, renal replacement therapy requirements, and mechanical ventilation, in addition to improvements in rapid decision-making and consistency of evidence-based practices.[14,15] However, variations persist in CST staffing, care processes, structure, activation methods, and available resources.[16]

Despite clear guideline recommendations, care is often delayed or inadequately addressed for patients with AHF or CS. Earlier integration of palliative care into treatment plans, focusing on symptom management, quality of life, and psychosocial support alongside traditional HF therapies, is essential in contemporary HF programmes.[17,18] Advances in personalized care, driven by predictive analytics and patient-centred technologies (e.g. artificial intelligence, remote monitoring and telemedicine), offer opportunities for more tailored palliative interventions that align with patient preferences and disease progression.

Treatment options and decision-making in acute heart failure management

AHF and CS are life-threatening conditions that require urgent and phased management approaches:

(1) Urgent phase: Immediately after medical contact, respiratory failure and/or CS must be recognized and treated to achieve haemodynamic stability and symptom relief. This is achieved by pharmacological, ventilatory, and/or tMCS support. Timely intervention in this phase is essential to interrupt the rapidly progressing downwards spiral of haemodynamic failure.
(2) Immediate phase: This phase occurs within the first 60–120 min after first medical contact and the aetiology of AHF/CS and/or the precipitating event must be identified and, if possible, treated with tailored interventions. Potential aetiologies include acute coronary syndrome (ACS), hypertensive emergencies, arrhythmias, acute mechanical causes (e.g. acute valve regurgitation or acute pulmonary embolism),

infections (e.g. myocarditis), and tamponade. The specific treatment path varies based on the underlying cause and severity of haemodynamic failure:[10,19]

- *Congestion:* For patients with pulmonary congestion and respiratory failure, oxygen therapy (Class IC) and non-invasive mechanical ventilation (NIMV, Class IIaB) or oral intubation if NIMV fails (Class IC) are recommended. Concomitantly, afterload reduction and loop diuretics (Class IC), or diuretic combinations in resistant cases (Class IIaB), are advised to relieve both pulmonary and peripheral congestion.
- *Hypoperfusion:* For patients presenting with CS, ESC guidelines recommend inotropic agents (Class IIbC) and short-term MCS as first-line therapy, serving as a bridge to recovery, decision-making, or longer-term heart replacement options (Class IIaC). Although inotropes are commonly administered as frontline therapy for CS, early and short-term MCS is strongly advised to avoid the cardiotoxic effects associated with high-dose inotropes or vasopressors.[20,21]

In patients with advanced or end-stage HF, a time-sensitive multi-disciplinary team approach is critical for devising an appropriate tMCS plan and establishing comprehensive long-term management (*Figure 2*). When haemodynamic instability persists or worsens in CS despite fluid challenges, maximal oxygen therapy, and inotropic or vasopressor support, tMCS is often employed to address circulatory failure. In cases of acute decompensation, tMCS devices typically serve as a bridge-to-decision, providing a critical time window to evaluate the patient's recovery potential and plan the appropriate next steps. If patient recovery does not occur with tMCS, more durable solutions such as left ventricular assisted devices (LVAD) or transplantation may be pursued as either bridge-to-transplantation or as destination therapy for non-candidates. Given the increasing reliance on these devices, especially amid heart donor shortages, research efforts have progressively shifted towards optimizing tMCS.

Today, a variety of tMCS options are available, spanning devices that provide modest to substantial circulatory support. The IABP offers modest CO support of ∼0.5–1 L/min. Micro-axial flow pumps (e.g. Impella, Abiomed) can significantly augment CO (up to 3.5–5.5 L/min) depending on the model.[7,10,22,23] Another key tMCS option for refractory HF is veno-arterial extracorporeal membrane oxygenation (VA-ECMO). Veno-arterial ECMO is particularly useful in biventricular HF, post-cardiac arrest, and/or when both circulatory and oxygenation support are required. When combined with an Impella device (ECMELLA), VA-ECMO support is provided while mitigating the potentially harmful afterload increase associated with peripheral ECLS devices. Other short-term temporary ventricular assist devices that utilize centrifugal pump technology include the percutaneous TandemHeart and the surgically implanted CentriMag.[24,25]

The choice of a tMCS device should typically follow an algorithm that considers patient clinical status, anatomy, time constraints, underlying disease, oxygenation, and cardiac arrest.[26] After haemodynamic stabilization and aetiology treatment, the patient should be considered for weaning from the tMCS device if pharmacological guideline-directed medical therapy can be initiated and up-titrated before device weaning. Though weaning from tMCS devices is complex and currently lacks standardized protocols, long-term devices may be indicated if weaning fails.

Temporary mechanical circulatory support in specific clinical scenarios

The management of CS entails, as previously mentioned, haemodynamic stabilization and the identification of the underlying aetiology that caused the shock. With the rapid advancements of tMCS devices, they are increasingly used not just to facilitate percutaneous techniques or improve their procedural success rates (by extending time through stabilization) but also to potentially avoid cardiac surgeries altogether. Here, we explore a few scenarios where tMCS-guided interventions have shown promise.

Left-sided Impella in mitral valve transcatheter edge-to-edge repair

Moderate to severe mitral regurgitation (MR) in patients with HF with reduced ejection fraction (HFrEF) is independently associated with a higher risk of adverse events compared with those without significant MR.[27] Over recent years, transcatheter edge-to-edge repair (TEER) has emerged as a viable therapeutic option, reducing HF hospitalizations and mortality rates in patients with HFrEF and MR.[28,29] However, patients with CS or those on inotropic support were typically excluded from these trials, and performing the procedure on critically ill patients remains high-risk. In cases of myocardial infarction, acute MR may even precipitate CS, leaving these patients ineligible for surgery due to high-risk and poor prognosis.[30]

Existing data on Impella-assisted TEER are largely limited to case reports and series, suggesting short-term success with Impella as either an adjunct or bridge to TEER in patients with shock and severe MR.[31-33] In these case series, the procedure appeared to be feasible, safe, and effective. Impella offers several benefits in selected high-risk mitral TEER, including pre-procedural support to mitigate end-organ damage, intra-procedural stabilization during complications (e.g. clip entanglement, clip dislodgement, or ventricular arrhythmias), and ventricular unloading to optimize outcomes in cases of advanced left ventricular dilation.[31,33] Finally, prolonged Impella support (hours or days after the procedure) could minimize the risk of afterload mismatch after TEER, which is common in patients with advanced HF.[34] Although not durable, left-sided Impella support may be effective for high-risk TEER, offering haemodynamic assistance before, during, and post-procedure. However, larger studies are needed to confirm the efficacy of Impella support in TEER.

Left-sided Impella support in ventricular tachycardia ablation

During ventricular tachycardia (VT) ablation procedures, acute haemodynamic decompensation occurs in 10–15% of patients, leading to both short- and long-term adverse outcomes.[35] Patients at the highest risk for haemodynamic decompensation are those with

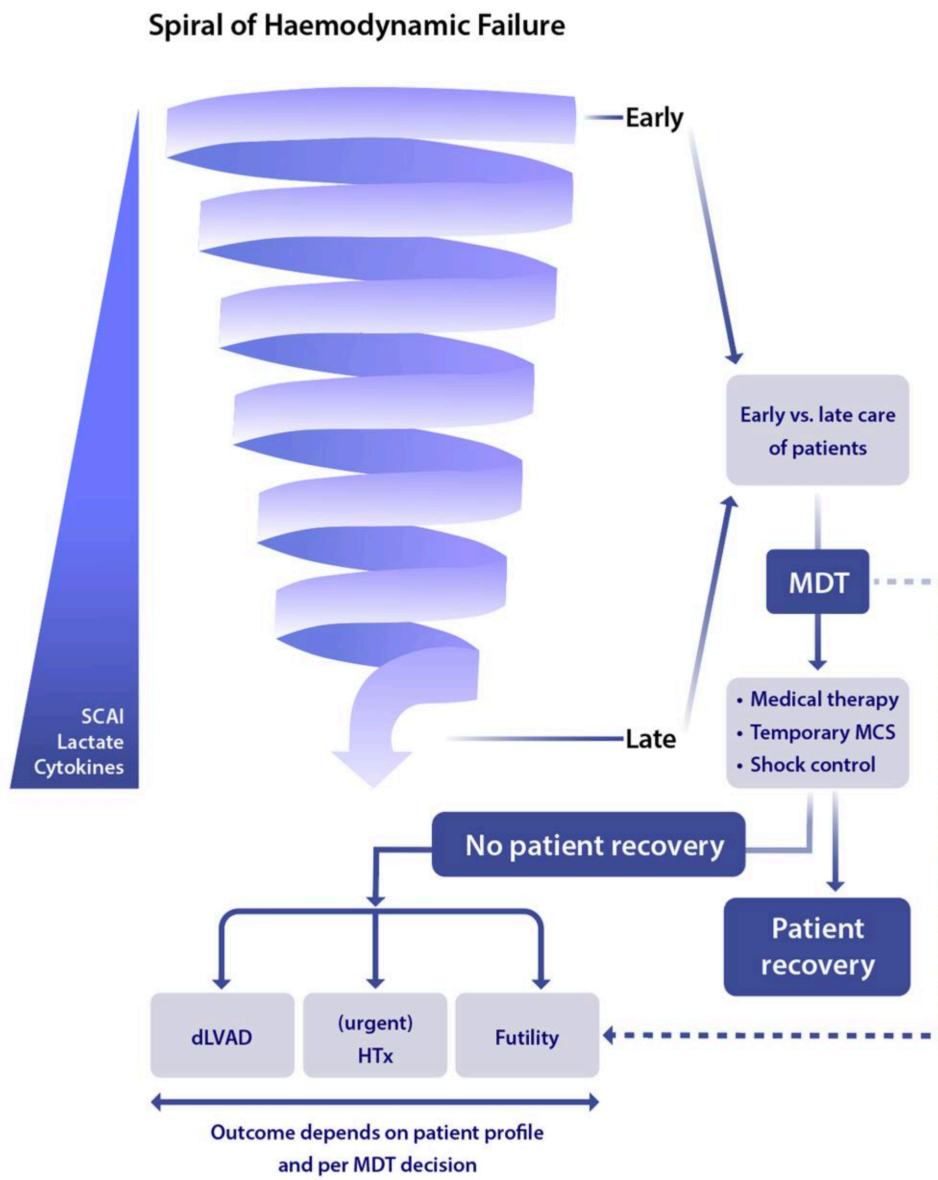

Figure 2 Cardiogenic shock management. The key in cardiogenic shock management is early recognition and management of these critically ill patients. As the downward spiral continues, the cardiogenic shock Society for Cardiovascular Angiography and Intervention (SCAI) level will increase, the systemic inflammatory reaction syndrome (SIRS) will increase (cytokine rush), and the biomarkers of ischaemia (lactate) will rise. The multi-disciplinary team is central in this decision process. Depending on the patient's profile, the underlying aetiology and timing of presentation (early vs. late), the multi-disciplinary team will decide on a patient- and disease-tailored treatment approach. The same multi-disciplinary team will have the task to decide early—ideally before therapy is started—to which bridge-to-group the patient belongs once weaning from drug and/or mechanical circulatory support proves unsuccessful (long-term mechanical support vs. heart transplant vs. futility). MDT, multi-disciplinary team; MCS, mechanical circulatory support; dLVAD, durable left ventricular assisted device; HTx, heart transplantation.

severely reduced left ventricular ejection fraction and underlying ischaemic heart disease. In such cases, tMCS devices may be employed to prevent haemodynamic instability (Class of recommendation IIa) and enable mapping and ablation of unstable VTs (Class of recommendation IIb).[36] Haemodynamic instability can significantly reduce procedural success as it prevents prolonged activation and comprehensive entrainment mapping, or makes multiple cardioversions during substrate mapping.[37] Impella support may also be beneficial in patients experiencing CS caused by electric storm, providing stabilization and a bridge to VT ablation with improved haemodynamic parameters and reduced reliance on potentially pro-arrhythmogenic pharmacological support.[35] However, robust evidence supporting the benefits of MCS in VT ablation procedures is limited, and literature thus far reports conflicting results.

Impella in 'protected' coronary artery bypass surgery

The use of right- or left-sided Impella pumps before or during coronary artery bypass surgery (CABG) surgery has been increasing worldwide, with outcomes documented in small registries, case reports, and case series. A registry analysis from the USA evaluated over 5000 patients with AMI CS undergoing CABG, including 129 patients who received Impella insertion before surgery.[38] In this high-risk group, adverse outcomes were significantly lower compared with similar patients who required intra- or post-operative tMCS, such as VA-ECMO, suggesting a possible benefit of pre-CABG Impella implantation in very high-risk patients. Beyond the CS setting, several reports highlight the prophylactic use of Impella CP or 5.0/5.5 in high-risk cardiac surgery patients, similar to their use in high-risk PCI.[39,40] In the surgical setting, these devices support high-risk patients undergoing off-pump CABG by minimizing cardiovascular instability during heart positioning for coronary anastomoses or by enabling off-pump instead of on-pump CABG in patients with severely reduced left ventricular ejection fraction, who cannot tolerate prolonged extracorporeal circulation. Impella 5.0/5.5 devices can provide a flow up to 5.5 L/min, thus offering full haemodynamic support to the left heart during these procedures.[41] Further evidence is needed to assess the role of MCS and Impella in this specialized field of protected surgery and to evaluate the possible benefit of peri-surgical unloading on both short- and long-term outcomes.

Mechanical circulatory support as a bridge-to-LVAD/transplant/futility

When patients lack potential for recovery or repetitively fail weaning, options include considering durable MCS devices, such as LVADs, or transitioning to cessation of care if deemed futile. In the latter case, early involvement of a palliative care team is essential to support the patient, family, and clinical team. Durable LVADs were originally developed as bridge-to-transplantation devices but have since proven beneficial as destination therapy for patients deemed ineligible for transplantation.

For patients with severe biventricular failure, total artificial heart technologies are early-stage solutions for when other long-term MCS options are insufficient. Their use, however, remains limited due to procedural complexity, high complication rates, costs, and the need for specialized surgical expertise. Notable examples of such devices include the Aeson (CARMAT) and the BiVACOR device.[42,43]

Heart transplantation remains the definitive treatment for patients dependent on MCS devices or inotropes, but it is constrained by the critical shortage of donor hearts. Recent observational data suggest that mid-term survival rates for patients receiving hearts from donors after circulatory death (DCD) are comparable with those from brain-dead donors, offering a promising avenue to address the organ shortage.[44,45] However, these findings are limited by a lack of long-term follow-up and higher rates of loss to follow-up among DCD recipients. Patient preferences also play a significant role in the decision to accept DCD hearts. In the future, other solutions such as xenotransplantation or bioengineered organs may become available to help alleviate this organ shortage crisis.

Conclusions

This review highlights the transformative potential of tMCS devices in addressing the acute and complex needs of HF, particularly in cases involving CS. It also underscores the role of multi-disciplinary Heart Teams in tailoring interventions, optimizing decision-making, and improving survival outcomes by leveraging the benefits of tMCS devices. Despite the clear impact of the Heart Team and advancing medical technologies, future research is required to develop standardized device protocols and ensure equitable access to specialized care within HF networks.

Acknowledgements

This manuscript is one of nine manuscripts published as a Supplement to address Mechanical Circulatory Support in Special Settings and the importance of the Heart Team Approach. JetPub Scientific Communications, LLC, provided editorial assistance to the authors during preparation of this manuscript.

Funding

This paper was published as part of a supplement financially supported by Abiomed Europe GmbH.

Conflict of interest: L.F.B. has received speaker fees from Abiomed. A.H. has received honoraria for presentations. A.N. has received support for the present manuscript from Abiomed and grants and contracts from Abiomed. F.P. has received consulting fees and honoraria from Abiomed; participation on a data safety monitoring board or advisory board from Carmat. E.P. has received support for the present manuscript and participation on a Data Safety Monitoring Board or Advisory Board from Abiomed; grants or contracts, consulting fees, payment or honoraria, and support for attending meetings and/or travel from Abbott, Abiomed, Medtronic, and Recovery therapeutics. F.S. has received payment for presentations from Abiomed, the other institutional grants from Novartis and Abbott, the non-financial support from Medtronic, and institutional fees (speaker honoraria) from Novartis and Bayer outside of submitted work. C.V. has received speaking fees, travel fees, consulting fees, and support for attending meetings and/or travel; a participation on an Advisory Board from Abiomed. D.Z. has received grants or contracts, consulting fees, and payment or honoraria for lectures from Edwards, Gigax Stiftung, Abiomed, Medtronic, Corzym, and Berlin Heart. F.B. has nothing to disclose.

Data availability

No new data were generated or analysed in support of this research.

References

1. McDonagh TA, Metra M, Adamo M, Gardner RS, Baumbach A, Böhm M, *et al*. 2021 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure. *Eur Heart J* 2021;**42**:3599–3726.
2. Crespo-Leiro MG, Metra M, Lund LH, Milicic D, Costanzo MR, Filippatos G, *et al*. Advanced heart failure: a position statement of the Heart Failure Association of the European Society of Cardiology. *Eur J Heart Fail* 2018;**20**:1505–1535.
3. Stevenson LW, Pagani FD, Young JB, Jessup M, Miller L, Kormos RL, *et al*. INTERMACS profiles of advanced heart failure: the current picture. *J Heart Lung Transplant* 2009;**28**:535–541.
4. Chioncel O, Mebazaa A, Harjola V-P, Coats AJ, Piepoli MF, Crespo-Leiro MG, *et al*. Clinical phenotypes and outcome of patients hospitalized

for acute heart failure: the ESC Heart Failure Long-Term Registry. *Eur J Heart Fail* 2017;**19**:1242–1254.
5. Nieminen MS, Brutsaert D, Dickstein K, Drexler H, Follath F, Harjola V-P, *et al*. EuroHeart Failure Survey II (EHFS II): a survey on hospitalized acute heart failure patients: description of population. *Eur Heart J* 2006;**27**:2725–2736.
6. Baran DA, Grines CL, Bailey S, Burkhoff D, Hall SA, Henry TD, *et al*. SCAI clinical expert consensus statement on the classification of cardiogenic shock: this document was endorsed by the American College of Cardiology (ACC), the American Heart Association (AHA), the Society of Critical Care Medicine (SCCM), and the Society of Thoracic Surgeons (STS) in April 2019. *Catheter Cardiovasc Interv* 2019;**94**:29–37.
7. Kapur NK, Kanwar M, Sinha SS, Thayer KL, Garan A, Hernandez-Montfort J, *et al*. Criteria for defining stages of cardiogenic shock severity. *J Am Coll Cardiol* 2022;**80**:185–198.
8. Serruys PW, Morice M-C, Kappetein AP, Colombo A, Holmes DR, Mack MJ, *et al*. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. *N Engl J Med* 2009;**360**:961–972.
9. Chioncel O, Parissis J, Mebazaa A, Thiele H, Desch S, Bauersachs J, *et al*. Epidemiology, pathophysiology and contemporary management of cardiogenic shock—a position statement from the Heart Failure Association of the European Society of Cardiology. *Eur J Heart Fail* 2020;**22**:1315–1341.
10. Kanwar MK, Billia F, Randhawa V, Cowger JA, Barnett CM, Chih S, *et al*. Heart failure related cardiogenic shock: an ISHLT consensus conference content summary. *J Heart Lung Transplant* 2024;**43**: 189–203.
11. Bhatt AS, Berg DD, Bohula EA, Alviar CL, Baird-Zars VM, Barnett CF, *et al*. De novo vs acute-on-chronic presentations of heart failure-related cardiogenic shock: insights from the critical care cardiology trials network registry. *J Card Fail* 2021;**27**:1073–1081.
12. Tehrani BN, Sherwood MW, Rosner C, Truesdell AG, Ben Lee S, Damluji AA, *et al*. A standardized and regionalized network of care for cardiogenic shock. *JACC Heart Fail* 2022;**10**:768–781.
13. Tehrani BN, Truesdell AG, Psotka MA, Rosner C, Singh R, Sinha SS, *et al*. A standardized and comprehensive approach to the management of cardiogenic shock. *JACC Heart Fail* 2020;**8**:879–891.
14. Papolos AI, Kenigsberg BB, Berg DD, Alviar CL, Bohula E, Burke JA, *et al*. Management and outcomes of cardiogenic shock in cardiac ICUs with versus without shock teams. *J Am Coll Cardiol* 2021;**78**: 1309–1317.
15. Basir MB, Schreiber T, Dixon S, Alaswad K, Patel K, Almany S, *et al*. Feasibility of early mechanical circulatory support in acute myocardial infarction complicated by cardiogenic shock: the Detroit cardiogenic shock initiative. *Catheter Cardiovasc Interv* 2018;**91**: 454–461.
16. Senman B, Jentzer JC, Barnett CF, Bartos JA, Berg DD, Chih S, *et al*. Need for a cardiogenic shock team collaborative—promoting a team-based model of care to improve outcomes and identify best practices. *J Am Heart Assoc* 2024;**13**:e031979.
17. Writing Committee; Maddox TM, Januzzi JL Jr, Allen LA, Breathett K, Butler J, *et al*. 2021 update to the 2017 ACC expert consensus decision pathway for optimization of heart failure treatment: answers to 10 pivotal issues about heart failure with reduced ejection fraction: a report of the American College of Cardiology solution set oversight committee. *J Am Coll Cardiol* 2021;**77**:772–810.
18. Feder S, Iannone L, Lendvai D, Zhan Y, Akgün K, Ersek M *et al*. Clinician insights into effective components, delivery characteristics and implementation strategies of ambulatory palliative care for people with heart failure: a qualitative analysis. *J Card Fail* 2024;**24**:1–10.
19. Møller JE, Sionis A, Aissaoui N, Ariza A, Bělohlávek J, De Backer D, *et al*. Step by step daily management of short-term mechanical circulatory support for cardiogenic shock in adults in the intensive cardiac care unit: a clinical consensus statement of the Association for Acute CardioVascular Care of the European Society of Cardiology SC, the European Society of Intensive Care Medicine, the European branch of the Extracorporeal Life Support Organization, and the European Association for Cardio-Thoracic Surgery. *Eur Heart J Acute Cardiovasc Care* 2023;**12**:475–485.
20. Ostadal P, Rokyta R, Karasek J, Kruger A, Vondrakova D, Janotka M, *et al*. Extracorporeal membrane oxygenation in the therapy of cardiogenic shock: results of the ECMO-CS randomized clinical trial. *Circulation* 2023;**147**:454–464.
21. Banning AS, Sabaté M, Orban M, Gracey J, López-Sobrino T, Massberg S, *et al*. Venoarterial extracorporeal membrane oxygenation or standard care in patients with cardiogenic shock complicating acute myocardial infarction: the multicentre, randomised EURO SHOCK trial. *EuroIntervention* 2023;**19**:482–492.
22. Waksman R, Pahuja M, Van Diepen S, Proudfoot AG, Morrow D, Spitzer E, *et al*. Standardized definitions for cardiogenic shock research and mechanical circulatory support devices: scientific expert panel from the Shock Academic Research Consortium (SHARC). *Circulation* 2023; **148**:1113–1126.
23. Naidu SS, Baran DA, Jentzer JC, Hollenberg SM, van Diepen S, Basir MB, *et al*. SCAI SHOCK stage classification expert consensus update: a review and incorporation of validation studies: this statement was endorsed by the American College of Cardiology (ACC), American College of Emergency Physicians (ACEP), American Heart Association (AHA), European Society of Cardiology (ESC) Association for Acute Cardiovascular Care (ACVC), International Society for Heart and Lung Transplantation (ISHLT), Society of Critical Care Medicine (SCCM), and Society of Thoracic Surgeons (STS) in December 2021. *J Am Coll Cardiol* 2022;**79**:933–946.
24. Salter BS, Gross CR, Weiner MM, Dukkipati SR, Serrao GW, Moss N, *et al*. Temporary mechanical circulatory support devices: practical considerations for all stakeholders. *Nat Rev Cardiol* 2023;**20**:263–277.
25. Atti V, Narayanan MA, Patel B, Balla S, Siddique A, Lundgren S, *et al*. A comprehensive review of mechanical circulatory support devices. *Heart Int* 2022;**16**:37–48.
26. Balthazar T, Vandenbriele C, Verbrugge FH, Den Uil C, Engström A, Janssens S, *et al*. Managing patients with short-term mechanical circulatory support: JACC review topic of the week. *J Am Coll Cardiol* 2021;**77**:1243–1256.
27. Rossi A, Dini FL, Faggiano P, Agricola E, Cicoira M, Frattini S, *et al*. Independent prognostic value of functional mitral regurgitation in patients with heart failure. A quantitative analysis of 1256 patients with ischaemic and non-ischaemic dilated cardiomyopathy. *Heart* 2011;**97**:1675–1680.
28. Stone GW, Lindenfeld J, Abraham WT, Kar S, Lim DS, Mishell JM, *et al*. Transcatheter mitral-valve repair in patients with heart failure. *N Engl J Med* 2018;**379**:2307–2318.
29. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, *et al*. 2021 ESC/EACTS guidelines for the management of valvular heart disease. *Eur Heart J* 2022;**43**:561–632.
30. Thompson CR, Buller CE, Sleeper LA, Antonelli TA, Webb JG, Jaber WA, *et al*. Cardiogenic shock due to acute severe mitral regurgitation complicating acute myocardial infarction: a report from the SHOCK trial registry. Should we use emergently revascularize occluded coronaries in cardiogenic shock? *J Am Coll Cardiol* 2000;**36**:1104–1109.
31. Muraca I, Pennesi M, Carrabba N, Scudiero F, Migliorini A, Marchionni N, *et al*. Percutaneous left ventricular advanced support for ‘protected’ complex high-risk transcatheter mitral valve repair: a case series. *Eur Heart J Case Rep* 2020;**4**:1–7.
32. Vandenbriele C, Balthazar T, Wilson J, Adriaenssens T, Davies S, Droogne W, *et al*. Left Impella®-device as bridge from cardiogenic shock with acute, severe mitral regurgitation to MitraClip®-procedure: a new option for critically ill patients. *Eur Heart J Acute Cardiovasc Care* 2021;**10**:415–421.
33. Tanaka S, Imamura T, Narang N, Fukuo A, Nakamura M, Fukuda N, *et al*. Case series of transcatherter edge-to-edge repair using MitraClip™ system with Impella® mechanical circulatory support. *Eur Heart J Case Rep* 2022;**6**:ytac370.
34. Melisurgo G, Ajello S, Pappalardo F, Guidotti A, Agricola E, Kawaguchi M, *et al*. Afterload mismatch after MitraClip insertion for functional mitral regurgitation. *Am J Cardiol* 2014;**113**:1844–1850.
35. Turagam MK, Vuddanda V, Atkins D, Santangeli P, Frankel DS, Tung R, *et al*. Hemodynamic support in ventricular tachycardia ablation: an international VT ablation center collaborative group study. *JACC Clin Electrophysiol* 2017;**3**:1534–1543.
36. Cronin EM, Bogun FM, Maury P, Chen M, Namboodiri N, Aguinaga L, *et al*. 2019 HRS/EHRA/APHRS/LAHRS expert consensus statement on catheter ablation of ventricular arrhythmias. *Europace* 2019;**21**: 1143–1144.
37. Mariani MV, Pierucci N, Cipollone P, Vignaroli W, Piro A, Compagnucci P, *et al*. Mechanical circulatory support systems in the management of

ventricular arrhythmias: a contemporary overview. *J Clin Med* 2024;**13**:1746.
38. Acharya D, Gulack BC, Loyaga-Rendon RY, Davies JE, He X, Brennan JM, *et al*. Clinical characteristics and outcomes of patients with myocardial infarction and cardiogenic shock undergoing coronary artery bypass surgery: data from the Society of Thoracic Surgeons National Database. *Ann Thorac Surg* 2016;**101**:558–566.
39. Benke K, Korça E, Boltjes A, Stengl R, Hofmann B, Matin M, *et al*. Preventive Impella® support in high-risk patients undergoing cardiac surgery. *J Clin Med* 2022;**11**:5404.
40. Upadhyaya VD, Campbell S, Douedi S, Patel I, Asgarian KT, Saybolt MD, *et al*. Use of Impella CP device in off-pump coronary artery bypass graft surgery. *Int Heart J* 2021;**62**:175–177.
41. Katahira S, Sugimura Y, Mehdiani A, Assmann A, Rellecke P, Tudorache I, *et al*. Coronary artery bypass grafting under sole Impella 5.0 support for patients with severely depressed left ventricular function. *J Artif Organs* 2022;**25**:158–162.
42. Huenges K, Panholzer B, Cremer J, Haneya A. Case report-CARMAT: the first experience with the Aeson bioprosthetic total artificial heart as a bridge to transplantation in a case of post-infarction ventricular septal rupture. *Front Cardiovasc Med* 2023;**10**:1211365.
43. Shah AM. First successful implant of BiVACOR's total artificial heart. *Artif Organs* 2024;**48**:1075–1076.
44. Ahmed HF, Kulshrestha K, Kennedy JT, Gomez-Guzman A, Greenberg JW, Hossain MM, *et al*. Donation after circulatory death significantly reduces waitlist times while not changing post-heart transplant outcomes: a united network for organ sharing analysis. *J Heart Lung Transplant* 2024;**43**:461–470.
45. Louca J, Öchsner M, Shah A, Hoffman J, Vilchez FG, Garrido I, *et al*. The international experience of in-situ recovery of the DCD heart: a multicentre retrospective observational study. *EClinicalMedicine* 2023;**58**:101887.