Cardiogenic shock code 2023. Expert document for a multidisciplinary organization that allows quality care

Código shock cardiogénico 2023. Documento de expertos para una organización multidisciplinaria que permita una atención de calidad

Manuel Martínez-Sellés[a,b,c,d], Francisco José Hernández-Pérez[e], Aitor Uribarri[f], Luis Martín Villén[g], Luis Zapata[h], Joaquín J. Alonso[c,i], Ignacio J. Amat-Santos[j], Albert Ariza-Solé[k], José A. Barrabés[b,f], José María Barrio[l], Ángela Canteli[m], Marta Alonso-Fernández-Gatta[b,n], Miguel J. Corbí Pascual[o], Domingo Díaz[p], María G. Crespo-Leiro[b,q], Jose María de la Torre-Hernández[m], Carlos Ferrera[r], Martín J. García González[s], Jorge García-Carreño[a,b], Luis García-Guereta[t], Antonio García Quintana[u], Pablo Jorge Pérez[s], José R. González-Juanatey[b,v], Esteban López de Sá[w], Pedro Luis Sánchez[b,n], María Monteagudo[x], Nora Palomo López[g], Guillermo Reyes[x], Fernando Rosell[y], Miguel Antonio Solla Buceta[z], Javier Segovia-Cubero[b,e], Alessandro Sionis Green[b,aa], Alexander Stepanenko[j], Diego Iglesias Álvarez[b,v], Ana Viana Tejedor[d,r], Roberto Voces[ab], María Paz Fuset Cabanes[ac], José Ricardo Gimeno Costa[ad], José Díaz[ae], Francisco Fernández-Avilés[a,b,d]

[a] Servicio de Cardiología, Hospital General Universitario Gregorio Marañón, Madrid, Spain
[b] Centro de Investigación Biomédica en Red Enfermedades Cardiovasculares (CIBERCV), Spain
[c] Universidad Europea, Madrid, Spain
[d] Universidad Complutense, Madrid, Spain
[e] Servicio de Cardiología, Hospital Universitario Puerta de Hierro-Majadahonda, Majadahonda, Madrid, Spain
[f] Servicio de Cardiología, Hospital Universitario Vall d'Hebron, Universidad Autónoma de Barcelona, Barcelona, Spain
[g] Unidad de Gestión Clínica de Cuidados Intensivos, Hospital Universitario Virgen del Rocío, Sevilla, Spain
[h] Servicio de Medicina Intensiva, Hospital de la Santa Creu i Sant Pau, Universidad Autónoma de Barcelona, Barcelona, Spain
[i] Servicio Cardiología, Hospital Universitario de Getafe, Getafe, Madrid, Spain
[j] Servicio de Cardiología, Hospital Clínico Universitario de Valladolid, Valladolid, Spain

[k] *Unidad de Cuidados Intensivos Cardiológicos, Servicio de Cardiología, Hospital Universitario de Bellvitge, L'Hospitalet de Llobregat, Barcelona, Spain*
[l] *Sección de Anestesia Cardiaca-Unidad de Cuidados Posquirúrgicos Cardiacos, Servicio de Anestesiología, Hospital General Universitario Gregorio Marañón, CIBERES, Madrid, Spain*
[m] *Servicio de Cardiología, Hospital Universitario Marqués de Valdecilla, Santander, Cantabria, Spain*
[n] *Servicio de Cardiología, Hospital Clínico Universitario de Salamanca, Salamanca, Spain*
[o] *Unidad de Cuidados Intensivos Cardiológicos, Servicio de Cardiología, Hospital General de Albacete, Albacete, Spain*
[p] *Servicio de Cuidados Intensivos, Hospital Universitario Infanta Leonor, Madrid, Spain*
[q] *Servicio de Cardiología, Complexo Hospitalario Universitario A Coruña, Universidad de A Coruña (UDC), A Coruña, Spain*
[r] *Unidad de Cuidados Agudos Cardiológicos, Instituto Cardiovascular, Hospital Clínico San Carlos, Madrid, Spain*
[s] *Unidad de Cuidados Intensivos Cardiológicos, Servicio de Cardiología, Hospital Universitario de Canarias, Santa Cruz de Tenerife, Spain*
[t] *Servicio de Cardiología Pediátrica, Hospital Universitario La Paz, Madrid, Spain*
[u] *Servicio de Cardiología, Hospital Universitario de Gran Canaria Doctor Negrín, Las Palmas de Gran Canaria, Spain*
[v] *Servicio de Cardiología y Unidad Coronaria, Hospital Clínico Universitario de Santiago de Compostela, Santiago de Compostela, A Coruña, Spain*
[w] *Servicio de Cardiología, Hospital Universitario La Paz, Madrid, Spain*
[x] *Servicio de Cirugía Cardiaca, Hospital Universitario de La Princesa, Universidad Autónoma de Madrid, Madrid, Spain*
[y] *Servicio de Emergencias Sanitarias (061), La Rioja Salud, La Rioja, Spain*
[z] *Servicio de Medicina Intensiva, Complejo Hospitalario Universitario A Coruña (CHUAC), Instituto de Investigación Biomédica de A Coruña (INIBIC), A Coruña, Spain*
[aa] *Unidad de Cuidados Agudos Cardiológicos, Servicio de Cardiología, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain*
[ab] *Grupo ECMO, Hospital Universitario de Cruces, Bilbao, Vizcaya, Spain*
[ac] *Servicio de Medicina Intensiva, Hospital Universitario de Bellvitge, Servicio de Emergencias Sanitarias de Cataluña, L'Hospitalet de Llobregat, Barcelona, Spain*
[ad] *Servicio de Medicina Intensiva, Hospital Universitario y Politécnico La Fe, Valencia, Spain*
[ae] *Servicio de Cardiología, Hospital Universitario Virgen del Rocío, Sevilla, Spain*

Corresponding author. E-mail address: mmselles@secardiologia.es (M. Martínez-Sellés).

Abstract

Despite the efforts made to improve the care of cardiogenic shock (CS) patients, including the development of mechanical circulatory support (MCS), the prognosis of these patients continues to be poor. In this context, CS code initiatives arise, based on providing adequate, rapid, and quality care to these patients. In this multidisciplinary document we try to justify the need to implement the SC code, defining its structure/organization, activation criteria, patient flow according to care level, and quality indicators. Our specific purposes are: *a)* to present the peculiarities of this condition and the lessons of infarction code and previous experiences in CS; *b)* to detail the structure of the teams, their logistics and the bases for the management of these patients, the choice of the type of MCS, and the moment of its implantation, and *c)* to address challenges to SC code implementation, including the uniqueness of the pediatric SC code. There is an urgent need to develop protocolized, multidisciplinary, and centralized care in hospitals with a large volume and experience that will minimize inequity in access to the MCS and improve the survival of these patients. Only institutional and structural support from the different administrations will allow optimizing care for CS.

Resumen

Pese a los esfuerzos realizados para mejorar la atención al *shock* cardiogénico (SC), incluyendo el desarrollo de dispositivos de asistencia circulatoria mecánica (ACM), su pronóstico continúa siendo desfavorable. En este contexto surgen iniciativas de código SC, basadas en proporcionar una asistencia rápida y de calidad a estos pacientes. Este documento multidisciplinario trata de justificar la necesidad de implantar el código SC, definiendo su estructura/organización, criterios de activación, flujo de pacientes según nivel asistencial e indicadores de calidad. Sus propósitos concretos son: *a)* presentar las peculiaridades de esta enfermedad y el aprendizaje del código infarto y de experiencias previas en SC; *b)* detallar las bases para el abordaje de estos pacientes, la estructura de los equipos, su logística, la elección del tipo de ACM y el momento de su implante, y *c)* abordar los desafíos para la implantación del código SC, como la singularidad del código SC pediátrico. Urge desarrollar una asistencia protocolizada, multidisciplinaria y centralizada en hospitales con gran volumen y experiencia que permita minimizar la inequidad en el acceso a la ACM y mejorar la supervivencia de estos enfermos. Solo el apoyo institucional y estructural de las distintas administraciones permitirá optimizar la atención al SC.

Keywords

Cardiogenic shock; Logistics; Multidisciplinary organization; Quality of care

Palabras clave

Shock cardiogénico; Logística; Organización multidisciplinaria; Atención de calidad

Abbreviations

CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation; HF, heart failure; MCS, mechanical circulatory support

INTRODUCTION

This document is endorsed by: the Scientific Associations of the Spanish Society of Cardiology (Interventional Cardiology, Heart Failure, Ischemic Heart Disease, and Acute Cardiovascular Care), the Spanish Society of Pediatric Cardiology and Congenital Heart Disease, the Spanish Society of Anesthesiology, Critical Care and Pain Therapy, the Spanish Society of Cardiovascular and Endovascular Surgery, the Spanish Society of Intensive and Critical Care Medicine and Coronary Units, the Spanish Society of Emergency Medicine, and the Spanish Association of Perfusionists.

Cardiogenic shock (CS) is the most severe form of heart failure, and the 30-day mortality of patients who receive appropriate treatment is between 30% and 50%.[1] CS is caused by severe cardiac dysfunction that leads to tissue hypoperfusion and cell hypoxia.[2,3,4] As with any time-dependent process, it can be reversible if the trigger is identified and controlled and measures taken to restore sufficient cardiocirculatory support to maintain optimal systemic perfusion.

The variable effectiveness of treatment can be explained by the different causes, clinical presentation and phenotypes, comorbidities, and the difficulty in identifying reliable risk factors.[5] Regarding the etiology, the cardiac dysfunction that leads to CS can be caused by an acute cardiac insult (as in acute coronary syndrome or myocarditis) or decompensation of chronic heart failure (HF).

In 2019, the Society for Cardiovascular Angiography and Intervention (SCAI) established 5 stages: A (at risk of CS), B (beginning CS), C (classic CS), D (deteriorating CS), and E (extremis), easily identifiable based on physical examination, biochemical markers (lactate and degree of metabolic acidosis/base deficit), and hemodynamic parameters,[6] and with prognostic implications (mortality reaches 70%-80% in stage E).[7] In 2022, some aspects of this were updated, such as cardiac arrest including only those with impaired neurological status, better precision of clinical parameters, and emphasis of the dynamic transition between stages.[7] Validation studies support its clinical applicability.[4]

Successful management of CS is based on the early identification and treatment of the underlying cause, accurate staging, hemodynamic/respiratory stabilization, and the management of multiorgan failure. The aim of this document is to set out the fundamentals to improve management of CS in Spain with protocols that enable quality care adapted to the characteristics of each hospital and each patient. An overview is provided in the executive summary in annex 1 of the supplementary data.

STRUCTURE OF THE CARDIOGENIC SHOCK CODE CARE SYSTEMS AND TEAMS

Multiple registry publications have reported experiences and good clinical outcomes with multidisciplinary teams in the setting of a CS code.[8,9,10,11] The appropriate care of these patients requires organization of health care services: a “hub and spoke” model of care network has been proposed, in which treatment can be delivered according to the patient's needs, in a timely manner, and in the most suitable center. [2,5,7,12] Some of the learning points from the infarct code may be useful when designing this care structure (annex 2 of the supplementary data). As shown by previous local experiences in Spain (annex 3 of the supplementary data) and other countries (annex 4 of the supplementary data), the geographical situation and the health care resources of each hospital and health care area should be considered, and the most appropriate treatment should be initiated at the first center, or, if that is not possible, the patient should be referred rapidly to another hospital with expedited transfer.

It is essential to designate referral centers in high-volume hospitals, with clearly defined protocols, at the center of a regional system organized by levels of care (table 1 and figure 1).[13] The characteristics of the hospitals according to their level of care are described in table 2. Although the most common situation will be that patients who trigger a CS code are identified in the hospital setting, the early identification of those in stages A or B can allow a decision to be made on whether they should be sent directly to a level 2 or 1 center. Either way, level 3 centers play a key role, as the assessment by a critical care specialist in this identifying center (an intensivist, or emergency medicine physician) can avoid treatment delay with early activation of the CS code if the patient deteriorates or does not respond well to the initial treatment. Level 2 centers should have the capacity to implant short-term mechanical circulatory support (MCS) devices. These centers can play a very important role in receiving patients in CS and implanting extracorporeal membrane oxygenation (ECMO). Lastly, level 1 centers (and some level 2 centers with the required structure) should have multidisciplinary teams, whose aims, members, and functions are shown in table 3. The definition of care levels is no simple task. A key factor in level 1 centers is having extensive experience in the use of various MCS devices. In addition, the evidence supports the need for these patients to be managed by specialists with experience and competencies in the care of critically ill cardiovascular patients.[14,15,16] These specialists are also essential to a coordinated approach that allows the rapid evaluation of the patient and activation of the CS code.[17,18] Recently, the term “shock doc” has been proposed for specialists with experience in cardiological critical care who are responsible for coordinating decisions and interventions.[17]

TRANSPORT BETWEEN CENTERS

The organization of the CS system needs to include transfers to level 1 centers, MCS implantation in level 2 centers and implantation in level 3 centers by mobile teams from level 1 or 2 (figure 2). Table 4 presents the composition of the mobile teams who must adapt to the regional situations and be available 24 hours a day, 7 days a week, with direct telephone contact with the level 2 and 3 hospitals. It is especially important that the cannulating physician is highly experienced in the vascular approach. With the creation of these teams, which can travel to other centers and implant a circulatory support device, mainly ECMO, a survival benefit has been demonstrated in these patients.[19,20] The means of transport recommended for distances < 400 km is by road, and plane is recommended for distances > 600 km (table 5). In the case of island transport, the decision should be individualized depending on the distance to be traveled and the weather conditions. Complications may arise in any transfer (table 6).

MEASURES OF THE PROCESS

Naturally, the first gauge is the very existence of regional multidisciplinary CS care programs (CS code). It is also very important to record the in-hospital mortality rate for CS (patients who died from CS/all patients admitted with CS) and the percentage of patients with CS secondary to an acute coronary syndrome who undergo emergency coronary angiography (< 120 minutes). This provides information on the integration between the infarct code network and the CS network. Lastly, the percentage of MCS devices that are registered in the national registry of circulatory and respiratory support devices in Spain (the RENACER Registry) should be recorded. As this is a compulsory registry, it should be 100%.

It is also important to record measures that help prevent CS, primarily those recommended in the infarct code. It is estimated that 1 in every 5 deaths from CS could have been avoided with a time from first medical contact to primary angioplasty within the recommended 90 minutes.[21] In recent decades, the proportion of cases of CS due to ACS has decreased.[5]

MECHANICAL CIRCULATORY SUPPORT: TIMING OF IMPLANTATION AND CHOICE OF DEVICE

The types of short-term MCS used in Spain and their contraindications are described in annex 5 of the supplementary data. The current lack of evidence from randomized trials of a benefit from the different MCS systems means that the scientific societies' recommendations on their indications, the timing of implantation, and the type of device are relatively loose,[22] leaving considerable leeway up to the experience of each team. One of the more difficult decisions in the treatment of CS is the timing of MCS implantation and the choice of device. The concept of door-to-treatment time has gained relevance in recent years. Several registries have shown that the more severe the CS at the time of device implantation, the lower the probability of survival.[23] Current evidence indicates that timely MCS implantation has a strong effect on prognosis.[11,24,25] MCS is particularly indicated, unless futile, in refractory CS (stages D and E). In stages B and C without respiratory failure/hypoxia, a detailed echocardiographic and hemodynamic assessment should be carried out to determine the need for MCS and type of device depending on ventricular function and degree of congestion. In stage C with hypoxemia and in stages D and E, MCS with ECMO combined with intra-aortic balloon counterpulsation or Impella (Abiomed, USA) should be considered.

In the context of patients with CS secondary to acute myocardial infarction, the current recommendations are for MCS implantation prior to revascularization.[11,24,25] This approach is associated with a reduced infarct size.[26] The results from the Detroit Cardiogenic Shock Initiative suggest something similar, although that study evaluated survival.[11] Recently, a meta-analysis including 6700 patients confirmed that mechanical support with Impella prior to angioplasty drastically reduced 30-day mortality.[27] This strategy is being validated by the DanGer shock trial, which is currently in the enrolment phase.[28] However, the use of ECMO in this situation is less clear, as it can increase left ventricular afterload and oxygen consumption. From the pathophysiological perspective, it is not the ideal support for CS in the initial phase, but progression to a more severe phase of CS means not only pump failure but circulatory and multiorgan failure, in which the high flows that ECMO can deliver, along with a left ventricular unloading device, can play an important role. We are also awaiting the publication of the clinical trials currently underway with ECMO in this context: ExtraCorporeal Life Support in patients with acute myocardial infarction complicated by cardiogenic shock (ECLS-shock),[29] EURO-Shock,[30] and Assessment of ECMO in Acute Myocardial Infarction Cardiogenic Shock (ANCHOR-NCT04184635).

The choice of device in CS not caused by acute myocardial infarction is more complex. The etiology of the clinical presentation and the severity are fundamental to this decision (SCAI classification, biventricular involvement, respiratory status). Assessment of right ventricular function is of great importance.[31] In patients with preserved right ventricular function, balloon counterpulsation or an Impella can be enough to provide adequate support in some cases, while ECMO is the device of choice if there is biventricular dysfunction or associated respiratory failure (figure 3).[32] The outcomes of ECMO appear to improve with the addition of a left ventricular unloading device,[33] although the usefulness of ECMO plus Impella remains to be confirmed in the ongoing clinical trial

Randomized trial of Early LV VEnting using impella CP for Recovery in patients with cardiogenic Shock managed with VA-ECMO (REVERSE)[34]. For patients with isolated right ventricular dysfunction, there are percutaneous continuous flow systems dedicated to right ventricular unloading. One unresolved question is the choice between a counterpulsation balloon and the other percutaneous left ventricular unloading devices. Although the percutaneous unloading devices provide a much superior flow to the counterpulsation balloon, their clinical superiority has not yet been demonstrated, and some studies have described a higher incidence of complications with these devices, either alone[35] or combined with venoarterial ECMO.[33]

Cardiorespiratory arrest is a special situation, which obviously carries a different prognosis and treatment protocol. In this emergency situation, there is often not enough information and it is reasonable to use MCS as a bridge to decision-making once the care team has all the necessary information.

PARTICULAR FEATURES OF THE PEDIATRIC CARDIOGENIC SHOCK PROTOCOL

The most common causes of pediatric CS are acute or fulminant myocarditis, decompensated complex congenital heart disease or cardiomyopathy, and myocardial failure after heart surgery, and the most common age of presentation is < 1 year.[36] The incidence of HF in patients younger than 18 years is estimated at 1 to 7/100 000 and the estimated annual incidence of hospital admission is 14 to 18/100 000.[37] Mortality (7%-26%) exceeds 30% when there is associated kidney or liver failure and reaches 50% if ECMO is required.[37] CS is treated in pediatric intensive care units that have a pediatric cardiologist. Although Spain has 16 pediatric heart surgery units, not all the autonomous communities have one. If we consider the low incidence of CS and the complexity of its treatment, it seems reasonable to establish common criteria and expedited referral mechanisms to these referral centers. Treatment of pediatric CS often requires MCS.[38] The usual short-term MCS in pediatrics is ECMO, and its use, although initially limited to 2 to 3 weeks, has recently been successfully extended to 3 months.[39] However, most pediatric hospitals do not have the human and technical resources for ECMO implantation, so there is a need for multidisciplinary teams, comprising surgeons, intensivists, and perfusionists, who can implant on site and transfer the patient to a specialized unit.[40] The need for MCS in patients with congenital heart disease is mainly in cases of CS after extracorporeal circulation that need urgent ECMO as a bridge to recovery. Patients with congenital heart disease that has not been surgically repaired are also candidates for MCS, especially univentricular disease with severe decompensation as a bridge to surgery or transplant.[39] 6Sixty percent of patients requiring MCS have treatment-refractory myocarditis or cardiomyopathy. Short-term MCS is useful as a bridge to recovery or as a bridge to a long-term MCS, but is limited as a bridge to transplant, as the median wait time for emergency transplant is longer than 3 months.[41] In Spain, both pulsatile paracorporeal devices (Berlin Heart EXCOR, Berlin-Heart AG, Germany) and continuous paracorporeal devices (Thoratec PediVAS/CentriMag, Thoratec, USA; Maquet Rotaflow, Maquet, Germany) are used as a bridge to heart transplant[42] (table 7). The international experience has grown enormously in recent years and includes intracorporeal continuous flow systems for patients of a suitable size, generally older than 12 years and with a weight > 40 kg (HeartMate 3, Abbott Labs, USA; Heartware, HeartWare Inc., USA, although Heartware is not currently available).[43] Support platforms have been developed that have helped improve outcomes and reduce thrombotic complications.[44] Currently, 40% of patients younger than 18 years survive to transplant with an MCS device.[41] Survival is similar for patients who undergo this electively or as an emergency with long-term ventricular assistance, but is lower for patients on ECMO, those younger than 1 year, and patients with congenital heart disease.[41] The special characteristics of children with CS require treatment in special pediatric HF and transplant units.

CHALLENGES IN THE IMPLEMENTATION OF THE CARDIOGENIC SHOCK CODE

The CS code represents an organizational challenge for hospitals and between-hospital transport systems. This is an inherent part of structuring a new care circuit that involves changes in patient flow, with an expected increase in demand in some centers and reduced demand in others. One of the main obstacles in the proper, successful implementation of the CS code is the individual interests of the various people and hospitals involved. Implementation of the CS code can face several barriers: among them, that hospitals not selected to house the multidisciplinary coordination team may not understand the decision, in addition to a lack of financial resources for establishing the mobile teams. It is therefore absolutely essential that all those involved work for the common good and collaborate actively in developing the protocol and reach consensus on the criteria for transfer. The availability of material resources and staffing are also essential for the success of such an initiative. Centers anticipating increased patient flow must have the option to increase bed availability (especially in critical care units dedicated to these patients) and the availability of staff, both medical and specialized nursing, depending on the requirements. In addition, the budget for devices and procedures required in this clinical context must be considered. Another crucial aspect for the proper functioning of this type of circuit is to have a robust interhospital transport system. In the case of the CS code it is essential, as treatment times are crucial and the staff in charge of the transfers must have a high level of training and specialization. Hiring and ongoing training of staff, with special emphasis on clinical simulation,[45] are essential factors for the success of the program, and much more so if the plan is for remote implantation of MCS devices by the interhospital transfer system staff. Another potential limiting factor is saturation of critical care units in the referral centers. Patients with CS who survive the first few hours have long hospital stays, with a high incidence of complications and need for invasive procedures.[46] As occurred with the infarct code in some autonomous communities, certain measures can be implemented to avoid saturation of high-complexity referral centers, such as a consensus on certain conditions for returning patients to lower-complexity hospitals if they reach a certain level of stability, especially if it is decided that they are not candidates for advanced treatment. Similarly, decisions on appropriate level of treatment must be made with the involvement of the multidisciplinary team to avoid futile interventions and unnecessary stays in patients with multiple complications and poor short-term prognosis, a common situation in this context. Lastly, in irreversible situations where support measures are ineffective, we must consider the option of organ or tissue donation.

CONCLUSIONS

Despite advances in MCS devices, the prognosis of CS has a wide margin for improvement. This is largely due to the fragmentation of care, nonuniformity of management, and a non–protocol-based approach. Numerous observational registries support the establishment of a centralized, integrative, multidisciplinary CS code. The CS code is feasible and can improve survival in these patients, allowing early diagnosis and prompt MCS implantation, with appropriate revascularization strategies and timing. Institutional support is essential for the success of this initiative.

FUNDING

This article did not receive funding and the authors have not received any payment for their participation.

AUTHORS' CONTRIBUTIONS

All the authors have contributed substantial intellectual content and have approved the final text of the main document and the appendices. J. Díaz and F. Fernández-Avilés contributed equally to this article.

CONFLICTS OF INTEREST

J.M. de la Torre-Hernández: consultancy honoraria from Medtronic, Boston Science, Abbott; payment or honoraria for conferences, presentations, speaker workshops, writing manuscripts and educational events from Medtronic, Abbott, Boston Science; support to attend meetings and/or travel from Biotronik, Abbott; participation in a supervisory board on data security and in an advisory board from Medtronic and Philips. A. Sionis Green: honoraria for consulting/conferences/presentations from Amgen, Daiichi-Sankyo, Novartis, Sanofi, and Servier. J.M. Barrio: honoraria for conferences/presentations from Edwards Lifesciences. A. Uribarri: honoraria for consulting/conferences/presentations from Abbott. M. Monteagudo: honoraria as consultant for Abiomed. The other authors have no conflicts of interest.

Appendix A. APPENDIX. SUPPLEMENTARY DATA

Supplementary data associated with this article can be found in the online version, at https://doi.org/10.1016/j.rec.2022.10.014s

REFERENCES

1. Hernández-Pérez FJ, Álvarez-Avelló JM, Forteza A, et al. Initial outcomes of aultidisciplinary network for the care of patients with cardiogenic shock. *Rev Esp Cardiol*. 2021;74:33–43.
2. McDonagh TA, Metra M, Adamo M, et al. ESC Scientific Document Group. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. *Eur Heart J*. 2021;42:3599–3726.
3. Cecconi M, De Backer D, Antonelli M, et al. Consensus on circulatory shock and hemodynamic monitoring. Task Force of the European Society of Intensive Care Medicine. *Intensive Care Med*. 2014;40:1795–1815.
4. Kapur NK, Kanwar M, Sinha SS, et al. Criteria for defining stages of cardiogenic shock severity. *J Am Coll Cardiol*. 2022;80:185–198.
5. Chioncel O, Parissis J, Mebazaa A, 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.
6. Baran DA, Grines CL, Bailey S, 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. Naidu SS, Baran DA, Jentzer JC, 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.
8. Taleb I, Koliopoulou AG, Tandar A, et al. Shock team approach in refractory cardiogenic shock requiring short-term mechanical circulatory support: a proof of concept. *Circulation*. 2019;140:98–100.
9. Tehrani BN, Truesdell AG, Psotka MA, et al. A standardized and comprehensive approach to the management of cardiogenic shock. *JACC Heart Fail*. 2020;8:879–891.

10. Lee F, Hutson JH, Boodhwani M, et al. Multidisciplinary code shock team in cardiogenic shock: a Canadian centre experience. *CJC Open*. 2020;2:249–257.
11. Basir MB, Kapur NK, Patel K, et al. National Cardiogenic Shock Initiative Investigators. Improved outcomes associated with the use of shock protocols: updates from the National Cardiogenic Shock Initiative. *Catheter Cardiovasc Interv*. 2019;93:1173–1183.
12. Crespo-Leiro MG, Metra M, Lund LH, 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.
13. Bonnefoy-Cudraz E, Bueno H, Casella G, et al. Acute Cardiovascular Care Association position paper on intensive cardiovascular care units: an update on their definition, structure, organisation and function. *Eur Heart J Acute Cardiovascular Care*. 2018;7:80–95.
14. Sánchez-Salado JC, Burgos V, Ariza-Solé A, et al. Trends in cardiogenic shock management and prognostic impact of type of treating center. *Rev Esp Cardiol*. 2020;73:546–553.
15. Na SJ, Chung CR, Jeon K, et al. Association between presence of a cardiac intensivist and mortality in an adult cardiac care unit. *J Am Coll Cardiol*. 2016;68:2637–2648.
16. Kapoor K, Verceles AC, Netzer G, et al. A collaborative cardiologist-intensivist management model improves cardiac intensive care unit outcomes. *J Am Coll Cardiol*. 2017;70:1422-1423. Erratum in. *J Am Coll Cardiol*. 2017;70:2737–2738.
17. Rab T. Shock Teams'' and ''Shock Docs''. *J Am Coll Cardiol*. 2019;73:1670–1672.
18. Doll JA, Ohman EM, Patel MR, et al. A team-based approach to patients in cardiogenic shock. *Catheter Cardiovasc Interv*. 2016;88:424–433.
19. Uribarri A, Cruz-González I, Dalmau MJ, Rubia-Martín MC, Ochoa M, Sánchez PL. Interhospital transfer in patients on ECMO support. An essential tool for a critical care network *Rev Esp Cardiol*. 2017;70:1147–1149.
20. Argudo E, Hernández-Tejedor A, Belda Hofheinz S, et al. Spanish Society of Intensive and Critical Care Medicine and Coronary Units (SEMICYUC) and the Spanish Society of Pediatric Intensive Care (SECIP) consensus recommendations for ECMO transport. *Med Intensiva (Engl Ed)*. 2022;46:446–454.
21. Moghaddam N, van Diepen S, So D, Lawler PR, Fordyce CB. Cardiogenic shock teams and centres: a contemporary review of multidisciplinary care for cardiogenic shock. *ESC Heart Fail.* 2021;8:988–998.

22. Henry TD, Tomey MI, Tamis-Holland JE, et al. Invasive management of acute myocardial infarction complicated by cardiogenic shock: a scientific statement from the American Heart Association. *Circulation*. 2021;143:815–829.
23. Hanson ID, Tagami T, Mando R, et al. National Cardiogenic Shock Investigators. SCAI shock classification in acute myocardial infarction: Insights from the National Cardiogenic Shock Initiative. *Catheter Cardiovasc Interv*. 2020;96:1137–1142.
24. Miyashita S, Banlengchit R, Marbach JA, et al. Left ventricular unloading before percutaneous coronary intervention is associated with improved survival in patients with acute myocardial infarction complicated by cardiogenic shock: a systematic review and meta-analysis. *Cardiovasc Revasc Med*. 2022;39:28–35.
25. Lee HH, Kim HC, Ahn CM, et al. Association between timing of extracorporeal membrane oxygenation and clinical outcomes in refractory cardiogenic shock. *JACC Cardiovasc Interv*. 2021;14:1109–1119.
26. Esposito ML, Zhang Y, Qiao X, et al. Left ventricular unloading before reperfusión promotes functional recovery after acute myocardial infarction. *J Am Coll Cardiol*. 2018;72:501–514.
27. Archilletti F, Giuliani L, Dangas GD, et al. Timing of mechanical circulatory support during primary angioplasty in acute myocardial infarction and cardiogenic shock: Systematic review and meta-analysis. *Catheter Cardiovasc Interv*. 2022;99:998–1005.
28. Udesen NJ, Moller JE, Lindholm MG, et al. Rationale and design of DanGer shock: Danish-German cardiogenic shock trial. *Am Heart J*. 2019;214:60–68.
29. Thiele H, Freund A, Gimenez MR, et al. Extracorporeal life support in patients with acute myocardial infarction complicated by cardiogenic shock—Design and rationale of the ECLS-SHOCK trial. *Am Heart J*. 2021;234:1–11.
30. Banning AS, Adriaenssens T, Berry C, et al. Veno-arterial extracorporeal membrane oxygenation (ECMO) in patients with cardiogenic shock: rationale and design of the randomised, multicentre, open-label EURO SHOCK trial. *EuroIntervention*. 2021;16:e1227–e1236.
31. Combes A, Price S, Slutsky AS, Brodie D. Temporary circulatory support for cardiogenic shock. *Lancet*. 2020;396:199–212.
32. Furer A, Wessler J, Burkhoff D. Hemodynamics of cardiogenic shock. *Interv Cardiol Clin*. 2017;6:359–371.
33. Grandin EW, Nunez JI, Willar B, et al. Mechanical left ventricular unloading in patients undergoing venoarterial extracorporeal membrane oxygenation. *J Am Coll Cardiol*. 2022;79:1239–1250.

34. Ibrahim M, Acker MA, Szeto W, et al. Proposal for a trial of early left ventricular venting during venoarterial extracorporeal membrane oxygenation for cardiogenic shock. *JTCVS Open*. 2021;8:393–400.
35. Miller PE, Bromfield SG, Ma Q, et al. Clinical outcomes and cost associated with an intravascular microaxial left ventricular assist device vs intra-aortic balloon pump in patients presenting with acute myocardial infarction complicated by cardiogenic shock. *JAMA Intern Med*. 2022;182:926–933.
36. Bronicki RA, Taylor M, Baden H. Critical heart failure and shock. *Pediatr Crit Care Med*. 2016;17:S124–S130.
37. Rossano JW, Kim JJ, Decker JA, et al. Prevalence, morbidity, and mortality of heart failure-related hospitalizations in children in the United States: a population-based study. *J Card Fail*. 2012;18:459–470.
38. Amhed H, Van der Pluym C. Medical management of pediatric heart failure. *Cardiovasc Diagn Ther*. 2021;11:323–335.
39. Lorts A, Eghtesady P, Mehegan M, et al. Outcomes of children supported with devices labeled as ‘‘temporary’’ or short term: A report from the Pediatric Interagency Registry for Mechanical Circulatory Support. *J Heart Lung Transplant*. 2018;37:54–60.
40. Bourgoin P, Aubert L, Joram N, et al. Frequency of extracorporeal membrane oxygenation support and outcomes after implementation of a structured PICU network in neonates and children: a prospective population-based study in the West of France. *Pediatr Crit Care Med*. 2021;22:e558–e570.
41. González-Vílchez F, Gómez-Bueno M, Almenar-Bonet L, et al. Spanish heart transplant registry. 33rd official report of the Heart failure Association of the Spanish Society of Cardiology *Rev Esp Cardiol*. 2022;75:923–932.
42. Rossano JW, VanderPluym CJ, Peng DM, et al. Pedimacs Investigators Fifth Annual Pediatric Interagency Registry for Mechanical Circulatory Support (Pedimacs) Report *Ann Thorac Surg*. 2021;112:1763–1774.
43. Friedland-Little JM, Joong A, Shugh SB, et al. Patient and device selection in pediatric MCS: a review of current consensus and unsettled questions. *Pediatr Cardiol.* 2022;43:1193–1204.
44. Murray JM, Miera O, Stiller B, et al. Lessons learned from managing antithrombotic therapy in children supported with pediatric ventricular assist devices. *ASAIO J*. 2022. http://dx.doi.org/10.1097/MAT.0000000000001782.
45. Castillo García J, Barrionuevo Sánchez MI, Sánchez-Salado JC, Molina Mazón CS, Arbó n Arqué D, Ariza-Solé A. Surprise evaluation of basic life support competencias in health

care personnel in the cardiology area of a tertiary hospital. *Rev Esp Cardiol*. 2022;75:349–351.

46. Collado E, Luiso D, Ariza-Solé A, et al. Hospitalization-related economic impact of patients with cardiogenic shock in a high-complexity reference centre. *Eur Heart J Acute Cardiovasc Care*. 2021;10:50–53.

Table 1. Characteristics of a hierarchical regional organization to enable the cardiogenic shock code

Categorized interhospital regional network
Consensus on selection criteria
Capacity for rapid contact between centers
Protocol-baswed indication for and type of mechanical circulatory support
Protocol-based transfers and transport between centers

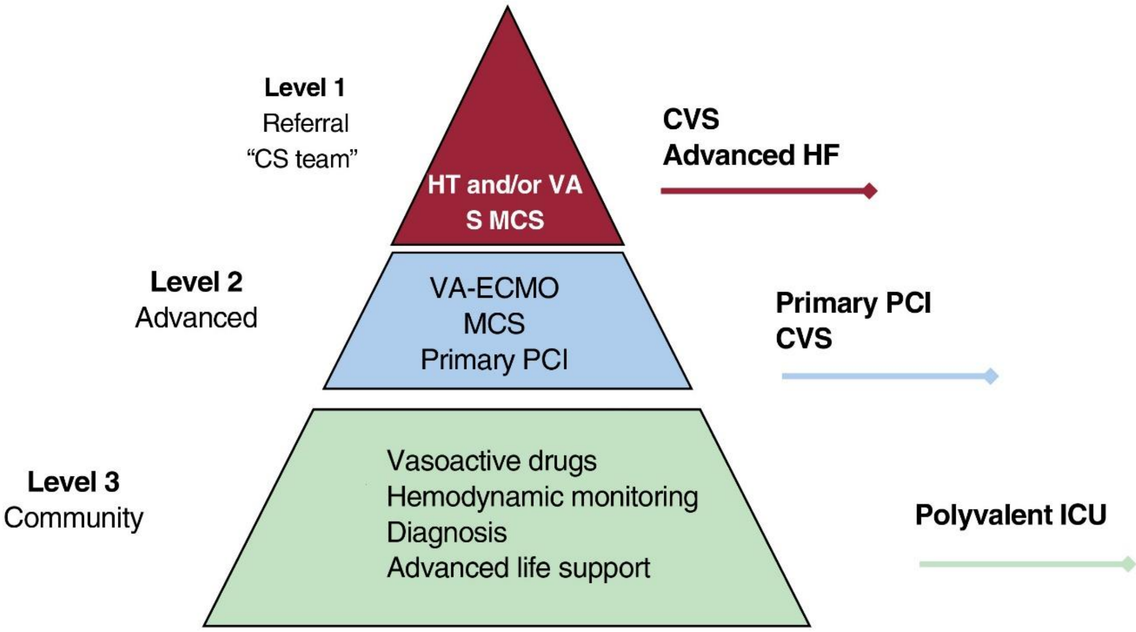

Figure 1. Central figure. Hospital levels of care for the treatment of cardiogenic shock. CS, cardiogenic shock; CVS, cardiovascular surgery; HF, heart failure; HT, heart transplant; ICU, intensive care unit; MCS, mechanical circulatory support; PCI, percutaneous coronary intervention; S, surgery; VA, mid/long-term ventricular assistance; VA-ECMO, venoarterial extracorporeal membrane oxygenation.

Table 2. Characteristics of the different levels of hospital involved in CS management

Level 3 or community (identification of CS): polyvalent ICU, with no cardiac surgery, primary angioplasty, or MCS
Level 2 or advanced (initial CS management): round-the-clock program of primary angioplasty and cardiac surgery. Capacity to implant short/mid-term MCS devices
Level 1 or advanced + long-term options (definitive CS treatment): multidisciplinary CS teams, extensive experience in percutaneous and surgical implantation of short-term MCS devices, accredited mid-/long-term MCS or HT programs

CS, cardiogenic shock; HT, heart transplant; ICU, intensive care unit; MCS, mechanical circulatory support.

Table 3. Aims of the multidisciplinary cardiogenic shock team, its members and their roles in MCS assessment and choice

	Aims
	Ensure rapid diagnosis
	Identify the specific phenotype
	Assign the appropriate level of care
	Make decisions on interventions and MCS
	Recognize futility and adopt palliative measures
	Identify candidates for clinical trials
Members	**Roles**
Physicians and nurses from the hospital emergency departments and out-of-hospital emergency medical services	First contact with the patient if not already admitted
	Risk stratification and initial management
	Decision on receiving hospital
	Transfers between hospitals with level 1 or 2 support
Intensivist/critical care cardiologist/anesthesiologist/cardiovascular surgeon and critical care nurses	Coordinate the process
	Identification, stratification, and diagnosis
	Medical treatment
	Invasive hemodynamic monitoring
	Monitoring, planning and early decision on MCS
	Postintervention and postoperative monitoring
	Neurological assessment
	Rehabilitation and nutrition

Table 3. Aims of the multidisciplinary cardiogenic shock team, its members and their roles in MCS assessment and choice

	Appropriate therapeutic/palliative measures End-of-life care/donation
Cardiologist specialized in heart failure and transplantation	Medical treatment Long-term MCS decision Indications and contraindications for heart transplant
Interventional cardiologist and interventional nursing staff	Coronary or structural intervention Decision on early MCS implantation Percutaneous implantation of short-term MCS
Surgical block/cardiac and/or vascular surgeon, anesthesiologist, perfusionist, and surgical nurses	Surgical implantation of short- and mid-term MCS Heart transplant/long-term MCS Monitoring of MCS device during its implantation, exchange, or transfer

MCS, mechanical circulatory support.

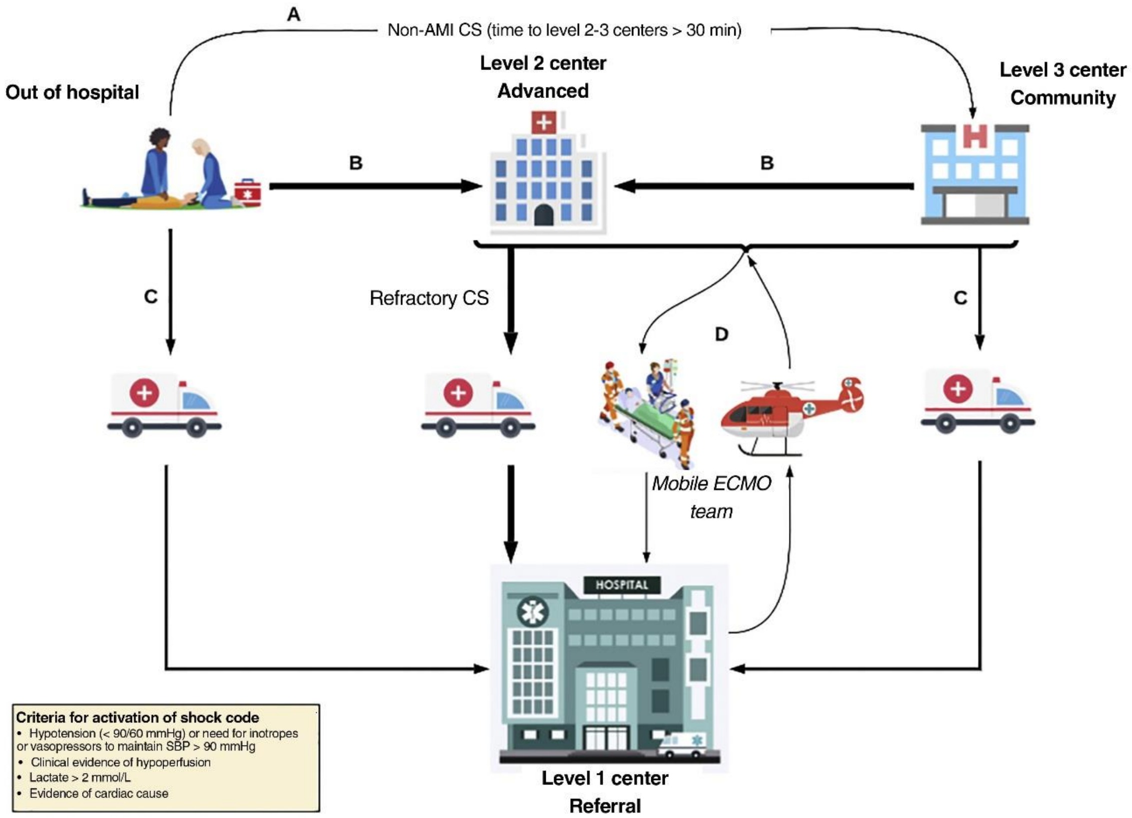

Figure 2. Patient flow in the cardiogenic shock care network. A: to ensure early stabilization of a patient with CS not caused by acute myocardial infarction (AMI) diagnosed out of hospital, the patient may be transported to the closest level 3 center if transfer to a level 1 or 2 center is in excess of 30 minutes longer than to the level 3 center. B: patients with CS diagnosed out of hospital or who are in a level 3 center should be transferred to a level 1 or 2 center depending on the transfer times, especially in the context of acute coronary syndrome. C: patients with CS diagnosed out of hospital or in a level 3 center can be transferred to a level 1 center if they are expected to require complex care. D: activation of the ECMO team; deployment of a mobile unit from the level 1 center to its different referring centers (levels 2 and 3) if implantation of complex mechanical circulatory support is needed to ensure a safe transfer. CS, cardiogenic shock; ECMO: extracorporeal membrane oxygenation; SBP, systolic blood pressure.

Table 4. Mobile ECMO team, profiles, and roles

Team member	Profile	Roles
Team leader	Cardiologist/intensivist/anesthesiologist/cardiovascular surgeon, experienced in ECMO	Leader
		Coordination of the team
		Medical treatment of the patient
		Collaborate on cannulation procedure
Cannulating physician	Interventional cardiologist/cardiovascular surgeon/critical care specialist*	Cannulation
		Secure cannulas
ECMO specialist	Cardiologist/intensivist/anesthesiologist experienced in ECMO. Perfusion nurses or critical care nurses trained in ECMO	ECMO flushing
		Initiate treatment
		Ensure device is functioning correctly
		Monitor clotting/blood gases
Critical care nurses	Nurses experienced in critically ill patients	Prepare material (checklist)
		Support during cannulation/instrumentation
		Support nursing staff during transport

ECMO, extracorporeal membrane oxygenation.

*In centers without an interventional cardiologist or cardiovascular surgeon.

Table 5. Means of transport for transfer of patients with cardiogenic shock and mechanical circulatory support/ECMO

	Ambulance	Helicopter	Plane
Distance for reasonable time	≤ 400 km	≤ 650 km	Any distance
Noise	Relatively quiet	Very noisy	Noisy
Cost	++	+++	++++
Weight limits	No limit	Depends on the aircraft and the weather conditions	Variable, depending on the aircraft and the conditions
Space for staff and equipment	Sufficient (4-5 members)	Limited (3-5 members)	Variable (≥ 4 members)
Setup logistics, securing equipment, and ECMO circuit/patient	Relatively simple	Relatively simple	Variable depending on the equipment and the aircraft
Logistics on arrival	Additional transport not required	Hospital heliport or airport. Additional transport may be required	Requires suitable airport Additional transport required
Effect of weather	++	++++	+++

ECMO, extracorporeal membrane oxygenation.

All vehicles must have *a)* a power supply suitable for ECMO and all other equipment for the duration of transport; *b)* climate control; *c)* reliable oxygen supply (in addition to transport cylinders); *d)* an aspiration system; *e)* compressed air; *f)* adequate lighting; and *e)* adequate space for the necessary staff and equipment.

Table 6. Complications related to transport of patients on mechanical circulatory support and strategies to minimize them

Complications	
Patient-related	Accidental extubation
	Low level of sedation
	Hypovolemia
	Recirculation
	Arterial ischemia
	Bleeding
Staff-related	Forgetting equipment
	Lack of staffing
	Communication errors
Equipment-related	Circuit thrombosis
	Cannula movement
	Defective materials
	Electrical failure/battery failure
Transport-related	Malfunction of power source
	Logistical errors
	Traffic
	Unsuitable ambulance
Environment-related	Weather conditions
	Decompression
	Freezing of venous access
	Hypothermia
Strategies to minimize	Clear, accurate, detailed communication of information between all those involved
	Ensure the safety of the professionals and that they are familiar with procedures
	Official referral protocol between hospitals
	Regular team training, with simulation if possible
	Checklists
	Portable ultrasound with cardiac and vascular probes

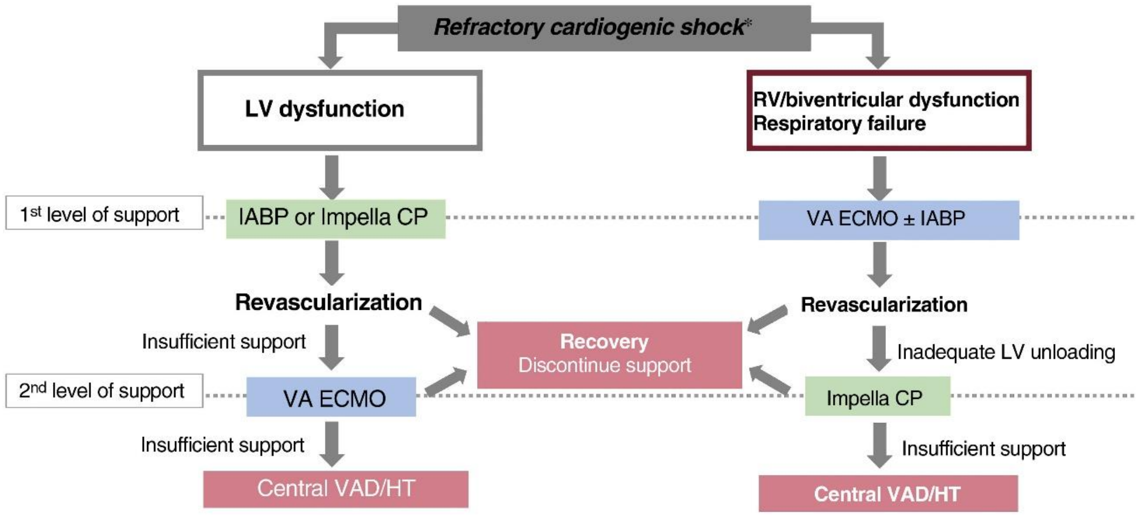

Figure 3. Patient selection and choice of device for patients with cardiogenic shock (CS). HT, heart transplant; IABP, intra-aortic counterpulsation balloon pump; LV, left ventricle; RV, right ventricle; VA, venoarterial; VAD, ventricular assist device.

*SBP < 90 mmHg for more than 30 min or inotropes to get SBP > 90 mmHg, signs of pulmonary congestion and poor perfusion and at least one of the following: altered mental state, cold clammy skin, oliguria< 30 mL/h or arterial lactate > 2.0 mmol/L. Refractory CS is CS despite vasopressors/inotropes and appropriate volume replacement.

Table 7. Pediatric mechanical circulatory support devices

Device	Venoarterial ECMO	Continuous flow paracorporeal support	Pulsatile flow paracorporeal support	Continuous flow intracorporal support	Total artificial heart
General points					
Experience	A lot	Moderate	Abundant	Little	Anecdotal
Duration of support	Short (2-3 weeks)	Medium (3-6 weeks)	Long (months)	Months/Years	Months/Years
Patient mobilization	No	Occasionally	Yes	Yes	Yes
Technical details					
Blood flow	Continuous	Continuous	Pulsatile	Continuous	Pulsatile
Respiratory support	Yes	No (possible)	No	No	No
Circulatory support	Biventricular	Univentricular or biventricular	Univentricular or biventricular	Univentricular or biventricular	Biventricular
Cannulation	Vascular	Cardiac	Cardiac	Intracardiac	Heart replacement
Ventricular unloading	Incomplete	Almost complete	Complete	Complete	Complete
Anticoagulation	Yes	Yes	Yes	Yes	Yes
Antiplatelet therapy	No	Yes	Yes	Yes	Yes
Indications	Bridge to recovery Bridge to decision Bridge to support	Bridge to transplant Bridge to recovery (late)	Bridge to transplant	Bridge to transplant Bridge to destination	Bridge to destination Bridge to transplant
Devices	Various	Thoratec PediVAS	Berlin Heart EXCOR (Berlin-Heart AG; Germany)	HeartMate3 (Abbott Labs, USA)	SynCardia (Syncardia Systems, USA)

Table 7. Pediatric mechanical circulatory support devices

Device	Venoarterial ECMO	Continuous flow paracorporeal support	Pulsatile flow paracorporeal support	Continuous flow intracorporal support	Total artificial heart
		Thoratec CentriMag (Thoratec, USA) Maquet Rotaflow (Maquet, Germany)		Heartware (withdrawn) (HeartWare Inc, USA)	

ECMO, extracorporeal membrane oxygenation.