v. 5, n. 26, 2025

International Journal of Health Science

Acceptance date: 17/07/2025

MANAGEMENT OF CARDIOGENIC SHOCK: THERAPEUTIC STRATEGIES

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Abstract: Cardiogenic shock (CS) is one of the most critical syndromes in cardiovascular medicine, characterized by acute circulatory failure and high mortality, especially after acute myocardial infarction. This article carries out a narrative review of recent literature, focusing on the main pharmacological and mechanical therapeutic strategies applied in the management of CHF. Norepinephrine remains the vasopressor of choice, while the association with dobutamine can be useful in patients with severe ventricular dysfunction. Circulatory support devices such as ECMO-VA and Impella have been used in refractory cases, although with significant risks. Percutaneous revascularization of the culprit lesion remains the only intervention with a proven impact on clinical outcomes. The implementation of multidisciplinary teams and structured protocols has shown an improvement in survival, especially in specialized centers. Finally, the need for an individualized approach, based on clinical phenotype, biomarker stratification and advances such as artificial intelligence, is highlighted in order to overcome the persistent challenges in the management of CHD and reduce its high morbidity and mortality.

INTRODUCTION

Cardiogenic shock (CS) is a serious medical emergency resulting from acute failure of myocardial contractile function, leading to sustained tissue hypoperfusion, persistent hypotension and often multiple organ dysfunction. Despite the advances made in cardiology in recent decades, CHD remains one of the main causes of hospital mortality, especially in patients affected by acute myocardial infarction (AMI), with rates varying between 40% and 50% (Crispino et al., 2025; Thiele et al., 2021).

The clinical profile of CHD is hemodynamically complex and multifactorial, requiring early diagnosis, assertive therapeutic inter-

ventions and immediate circulatory support. The use of inotropic agents, vasoactive drugs and mechanical circulatory assistance devices are widely used strategies, although not always backed by robust evidence. Early revascularization, especially in cases of post-AMI CHD, represents the only intervention with efficacy proven by randomized clinical trials to date. (Thiele et al., 2021) Despite this, many aspects of therapy remain dependent on expert consensus, given the scarcity of clinical studies with sufficient statistical power to definitively guide medical conduct. (Crispino et al., 2025)

The treatment of CHD, therefore, remains a considerable clinical challenge, with results that are still unsatisfactory, even in centers of excellence. The lack of standardized protocols , the phenotypic variability of the syndrome and the critical time between the onset of symptoms and the institution of adequate support contribute to the unfavorable outcomes. Emerging data from international registries suggest that the implementation of structured approaches, based on therapeutic algorithms, continuous hemodynamic assessment and multidisciplinary teams, can significantly improve the clinical evolution of these patients (Tehrani et al., 2020).

Given this scenario, a critical analysis of the available therapies and the strategies adopted in care practice becomes imperative, with a view to building a more efficient and well-founded therapeutic structure. This review aims to discuss the main pathophysiological and clinical aspects of cardiogenic shock, evaluate the evidence related to pharmacological and mechanical interventions and propose practical guidelines based on current best practices and the consensus of the specialized literature.

METHODOLOGY

The aim of this study is to gather and discuss the latest evidence on therapeutic strategies applied in the management of cardiogenic shock, based on current contributions from the scientific literature. To carry out the research, a structured search was conducted in the PubMed database, including publications from the last five years. The selection of studies was based on a combination of the descriptors: "Cardiogenic Shock", "Treatment" and "Diagnosis", in order to ensure the comprehensiveness and relevance of the results obtained.

Articles available in their entirety that directly or indirectly addressed the diagnosis and treatment of cardiogenic shock were included. Publications in different languages were accepted, as long as they were accessible, methodologically consistent and scientifically relevant to the proposed topic. Original studies, narrative reviews and update articles were considered eligible. Duplicate publications, studies outside the scope of the study and articles unavailable on the PubMed database were excluded.

RESULTS AND DISCUSSION

Analysis of the current literature on the management of CHD reveals that early invasive hemodynamic monitoring, especially with the use of a pulmonary artery catheter (PAC), is associated with better identification of the patient's hemodynamic phenotype. This approach has shown potential to guide pharmacological therapies and device interventions in a more personalized way, and has been proposed as a new standard of care in the initial management of CHD. (Tehrani et al., 2020)

Recent studies highlight the usefulness of biomarker-based prognostic scores, such as the CLIP score - which includes cystatin C, lactate, interleukin-6 and NT-proBNP - which have shown superiority over traditional clinical models for risk stratification in CHD, providing an objective tool for clinical decision support (Thiele et al, 2021).

In addition, the formation of multidisciplinary "shock teams" made up of interventional cardiologists, intensivists and cardiovascular surgeons has been associated with better outcomes in large centers (Thiele et al., 2021).

With regard to revascularization, the CULPRIT-SHOCK study showed that the strategy of angioplasty of only the culprit lesion resulted in lower 30-day mortality and less need for renal replacement therapy compared to the immediate multivessel approach, supporting the current recommendation of limited revascularization followed by staged revascularization (Thiele et al., 2021).

In addition, recent guidelines reinforce that the time until revascularization is a critical determinant of prognosis. A delay of more than 120 minutes is associated with worse outcomes, and PCI should preferably be performed in centers with more than 24 hours. (Thiele et al, 2021)

Vasoactive therapies remain central to the pharmacological support of patients with CHD, with norepinephrine standing out as the first-line vasopressor agent. Comparative studies have indicated that, compared to dopamine and epinephrine, norepinephrine is associated with a lower incidence of arrhythmias and lower mortality, especially in refractory CHD (THIELE et al., 2020). Dobutamine, although widely used, has a class IIb/C recommendation, given the lack of robust evidence on its effects on mortality. The combination of dobutamine with norepinephrine has been considered safe and potentially beneficial, particularly in patients with severe systolic dysfunction and organ hypoperfusion (Crispino et al., 2025).

However, more recent meta-analyses reveal conflicting findings. Such as the fact that the review by Crispino et al (2025) highlighted, that despite the widespread use of norepinephrine as a first-line vasopressor, studies such as SOAP II showed conflicting findings as to its superiority. Epinephrine was associated with a higher incidence of refractory shock and hyperlactatemia, which limits its use as initial monotherapy in patients with CHD (Crispino et al., 2025).

Still on the subject of inotropic support, agents such as milrinone and levosimendan have shown theoretical advantages, especially in patients on beta-blockers, as they act through pathways independent of adrenergic receptors. However, clinical data remains limited, restricting their use to specific situations (Tehrani et al., 2020).

In the network meta-analysis presented by Crispino et al. (2025), levosimendan showed a better hemodynamic profile and greater potential benefit in patients with less severe shock, compared to dobutamine. However, the authors point out that the evidence is still of low quality and caution is needed when interpreting these results (Crispino et at., 2025)

Moderate/severe bleeding is common in cardiogenic shock, ranging from 20 to 90% depending on the definition used. The CULPRIT-SHOCK trial evaluated the incidence of bleeding in patients with AMI and cardiogenic shock, showing that 21.5% had at least one bleeding event within 30 days (Thiele et al., 2021).

In patients with bleeding, clinical trials have shown that a restrictive transfusion regimen (i.e. less frequent transfusions) can improve clinical outcomes. Strategies in intensive care units (ICUs) generally adopt the practice of not correcting hemoglobin levels in patients with values above 7 g/dL (4.3 mmol/l), unless there is a bleeding problem (Thiele et al., 2021).

Intravascular volume management in the ICU is based on initial volume challenges, except in the presence of obvious signs of congestion, which is supported by a class I recommendation. The use of therapeutic hypothermia in post-cardiac arrest CHD patients has shown no significant benefit, and studies

such as SHOCK-COOL have even pointed to possible deleterious effects on lactate clearance (Thiele et al., 2021).

A recent analysis of the Japanese JROA-DHF cohort by Ken Kato et al.(2024) found that the sex of the patient can influence outcomes in relation to cardiogenic shock. Men had lower in-hospital and one-year mortality rates, as well as more frequent use of invasive strategies such as PCI and intra-aortic balloon. However, the authors draw attention to a possible disparity in clinical management, with underuse of invasive strategies in women, which may partially explain the higher mortality observed in this group. In addition, the burden of comorbidities, such as diabetes and renal failure, is also higher in women, negatively influencing prognosis.

Finally, rescue therapy with percutaneous mitral valve repair (PMVr) in patients with CHD and significant mitral regurgitation has been shown to be feasible and safe, with a success rate of over 85% and a positive impact on hospital and 90-day survival (Thiele et al., 2021).

The use of the Impella device, a minimally invasive mechanical circulatory assist device, especially in early strategies before PCI, has been associated with higher survival rates in registries such as USpella and the Detroit Cardiogenic Shock Initiative. However, randomized clinical trials still present contradictory data and may have an increased risk of complications such as severe bleeding (Dhruva et al., 2020; Schrage et al., 2019).

VA-ECMO is considered in patients with refractory CHD. However, there must be rigorous selection for its indication, as its indiscriminate use can lead to left ventricular overload, thromboembolic complications and bleeding. Studies such as ECMO-CS and ECLS-SHOCK are evaluating its effectiveness in hard outcomes such as mortality (Thiele et al., 2021).

The ECMELLA strategy, which uses ECMO-VA and Impella simultaneously, has been described as effective in reducing LV load, reducing filling pressure and preventing pulmonary congestion, and may be beneficial in the context of biventricular failure (Russo et al., 2019; Kowalewski et al., 2020).

The management of cardiogenic shock remains a complex clinical challenge, with a high mortality rate despite therapeutic advances in recent decades. Early implementation of strategies based on invasive hemodynamic assessment, such as the use of the pulmonary artery catheter, offers an opportunity to personalize treatment according to the patient's clinical profile, contributing to more effective interventions and potentially better outcomes. (Tehrani et al., 2020)

As far as pharmacological support is concerned, vasopressors and inotropic agents still represent the backbone of acute treatment, although their efficacy must be weighed against the risks associated with increased oxygen consumption and the induction of arrhythmias. Norepinephrine has emerged as the agent of choice for restoring perfusion in patients with CHD, with a safety profile superior to dopamine and epinephrine, as evidenced in studies such as SOAP II and OPTIMA-CC. (Thiele et al., 2021) Dobutamine, although widely used, lacks definitive evidence to support its use as an isolated therapy. Its role seems to be better defined in association with norepinephrine, especially in patients with severe left ventricular dysfunction (Crispino et al., 2025).

The choice between inotropic drugs must be individualized. In patients with chronic use of beta-blockers, the choice of milrinone or levosimendan may be more appropriate, given their independence from beta-adrenergic receptors. However, the scarcity of large-scale studies limits the generalization of these agents as a therapeutic standard. (Tehrani et al., 2020) In addition, the use of any vasoactive

International Journal of Health Science ISSN 2764-0159 DOI https://doi.org/10.22533/at.ed.15952625140713

agent should obey the principle of the lowest effective dose, for the shortest time necessary, always carefully monitoring signs of ischemia and organ dysfunction.

It is important to note that inotropes and vasopressors are administered to shocked patients who have poor tissue perfusion but adequate blood volume. Even though they are administered frequently, they can cause increased ischemia due to vasoconstriction and the need for greater oxygen supply to the heart muscle.(Thiele et al., 2021)

Therapeutic strategies also include mechanical circulatory support, since most of the time the administration of drugs alone is not enough to stabilize the patient hemodynamically. Among the devices used for circulatory support are: intra-aortic balloon pumping, IMPELLA ECP and extracorporeal membrane oxygenation (ECMO).(Ken kato et al., 2024)

In the Ken Kato et al. study, in 20% of patients with cardiogenic shock and Takotsubo Syndrome who received IABP, its use was unsatisfactory, as there was no reduction in deaths. On the other hand, in another study using IMPELLA, 13 out of 16 patients, or 81.3%, survived until hospital discharge, and all 16 showed a good improvement in LV systolic function.

In patients with cardiogenic shock and AMI, the use of IABP and IMPELLA were not effective, and the use of IMPELLA compared to IABP had higher hospital mortality, bleeding and strokes (Thiele et al., 2021).

Other elements of management, such as initial volume control and support in specialized intensive care units, are essential to optimize hemodynamic stabilization and prevent complications such as multiple organ dysfunction syndrome. (Thiele et al., 2021) The absence of a clearly established target for mean arterial pressure (MAP) in patients with CHD reflects yet another gap in the available evidence. Recent studies suggest that higher MAP targets could reduce myocardial injury, but these hypotheses still await confirmation in randomized clinical trials.

The use of therapeutic hypothermia in the context of post-cardiac arrest CHD is still a controversial area. The lack of clear clinical benefit and data suggesting a worsening of lactate clearance reinforce the need for caution when indicating this strategy (Thiele et al., 2021).

Finally, structural interventions, such as percutaneous mitral valve repair, are emerging as viable alternatives for patients with significant mitral regurgitation associated with refractory CHD. The positive results observed in multicenter cohorts suggest that these therapies can reduce mortality and improve prognosis in selected subgroups, although more studies are needed to define their role in the overall therapeutic algorithm.

Taken together, these observations reinforce the need for a multidisciplinary treatment model, based on continuous assessment, a personalized approach and integration between pharmacological therapies, circulatory support and structural interventions. The consolidation of evidence-based protocols and the development of robust clinical trials are imperative if we are to make progress in standardizing management and reducing the mortality associated with cardiogenic shock.

Given the high complexity of cardiogenic shock, it is becoming increasingly clear that the management of this condition requires not only up-to-date knowledge of the available therapies, but also a well-structured care organization. Specialized centers, with prepared teams and well-defined protocols, show better results, especially when they are able to offer advanced support quickly and in a coordinated manner. The creation of "shock teams", made up of professionals from different areas, allows for a more assertive and individualized approach, increasing patients' chances of recovery. In addition, modern risk stratification tools, such as the **SCAI (Society for Cardio-**

vascular Angiography and Interventions) classification, have been important in categorizing patients into different stages of severity (from A to E), facilitating more precise and safer clinical decisions.

Future prospects for the treatment of cardiogenic shock are focused on optimizing current therapies and developing more innovative and personalized approaches. The continued study of the neurobiological and molecular mechanisms underlying cardiogenic shock is critical for the identification of specific phenotypes and genotypes and may allow for the implementation of more specific interventions (JUNG et al., 2024). The inclusion of new biomarkers, artificial intelligence and machine learning is highly promising for increasing diagnostic accuracy, predicting patient trajectories and enhancing more personalized management (JUNG et al., 2024). The development of targeted, age-specific and phenotype-guided treatment strategies reflects the realization that a simple approach is insufficient in the most heterogeneous disease (LÜSEBRINK et al., 2024ç LAGHLAM et al., 2024). In addition, efforts to improve the accessibility and effectiveness of multidisciplinary cardiogenic shock teams and specialized care centers continue to ensure the implementation of more timely and appropriate treatments (SINHA et al., 2025). The ultimate goal will be the elimination of cardiogenic shock as a syndrome and the adoption of even more specific and personalized interventions in the quest for precision and a more significant reduction in the sudden and persistent mortality and morbidity of cardiogenic shock.

In view of the risks associated with the treatment of cardiogenic shock, it is important to know the specific cause in order to optimize treatment and improve the prognosis of these patients.

CONCLUSION

The management of cardiogenic shock continues to be one of the greatest challenges in cardiovascular intensive care medicine, with mortality rates still high, despite therapeutic and technological advances. It is essential that management is individualized, guided by invasive hemodynamic monitoring, biomarker stratification and careful clinical assessment, in order to optimize patient prognosis.

Early revascularization of the culprit lesion remains the only intervention with proven efficacy in randomized clinical trials, and the time until its completion is a critical survival factor. At the same time, the rational and evidence--based choice of vasopressors and inotropic agents, with preference for norepinephrine and possible association with dobutamine, is essential to restore tissue perfusion. However, it is important to consider the risks of arrhythmias and adverse metabolic effects.

The use of mechanical circulatory support has been consolidated as a rescue therapy in refractory cases, although it requires experienced centers and careful patient selection. Combined strategies, such as ECMELLA, have also gained ground, especially in the context of biventricular failure.

In addition, disparities in management between the sexes, evidenced by large cohorts, reinforce the need for standardization of procedures and equitable access to more complex therapies. The work of multidisciplinary teams specializing in shock, combined with evidence-based protocols, is a promising approach for reducing mortality and promoting better clinical outcomes.

Thus, the consolidation of integrated strategies, combining pharmacotherapy, coronary intervention, mechanical support and structured care organization, represents the most promising way to tackle the impact of cardiogenic shock in the coming years.

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