SEVEN
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UPDATES IN THE MANAGEMENT OF CARDIOGENIC SHOCK AFTER ACUTE CORONARY SYNDROME

ATUALIZAÇÕES NO MANEJO DO CHOQUE CARDIOGÊNICO PÓS-SÍNDROME CORONARIANA AGUDA

ACTUALIZACIONES SOBRE EL MANEJO DEL SHOCK CARDIOGÉNICO DESPUÉS DEL SÍNDROME CORONARIO AGUDO

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ABSTRACT
Cardiogenic shock (CS) represents the most severe form of acute heart failure and remains one of the leading causes of in-hospital mortality among patients with acute coronary syndrome (ACS). This study aimed to identify the main scientific and technological updates in the management of post-ACS CS published between 2015 and 2025. An integrative literature review was conducted using the PubMed, SciELO, ScienceDirect, LILACS, and Consensus.app databases, employing controlled descriptors and Boolean combinations. After applying inclusion and exclusion criteria, 40 articles were selected. The results were organized into four thematic categories: early revascularization and hemodynamic support strategies; use of mechanical circulatory support; technological innovations and predictive models; and recent clinical guidelines and consensus statements. Evidence indicates that early revascularization and rational use of circulatory support devices, combined with the implementation of multidisciplinary Shock Teams, significantly reduce mortality. However, gaps remain regarding the standardization of protocols, validation of predictive models, and integration of emerging technologies. It is concluded that contemporary management of CS requires an integrated approach involving science, technology, and healthcare organization, guided by robust evidence and interdisciplinary collaboration.

Keywords: Cardiogenic Shock. Acute Coronary Syndrome. Revascularization. Mechanical Circulatory Support. Artificial Intelligence.

RESUMO
O choque cardiogênico (CC) representa a forma mais grave de insuficiência cardíaca aguda e continua sendo uma das principais causas de mortalidade hospitalar em pacientes com síndrome coronariana aguda (SCA). Este estudo teve como objetivo identificar as principais atualizações científicas e tecnológicas no manejo do CC pós-SCA publicadas entre 2015 e 2025. Trata-se de uma revisão integrativa da literatura, conduzida nas bases de dados PubMed, SciELO, ScienceDirect, LILACS e Consensus.app, utilizando descritores controlados e combinações booleanas. Após aplicação dos critérios de inclusão e exclusão, foram selecionados 40 artigos. Os resultados foram organizados em quatro eixos temáticos: estratégias de revascularização e suporte hemodinâmico precoce; utilização de suportes circulatórios mecânicos; inovações tecnológicas e modelos preditivos; e diretrizes e consensos clínicos recentes. As evidências indicam que a revascularização precoce e o uso racional de dispositivos de suporte circulatório, aliados à atuação de equipes multidisciplinares (Shock Teams), reduzem significativamente a mortalidade. Contudo, persistem lacunas quanto à padronização de protocolos, à validação de modelos preditivos e à integração de tecnologias emergentes. Conclui-se que o manejo contemporâneo do CC requer uma abordagem integrada entre ciência, tecnologia e organização assistencial, orientada por evidências robustas e colaboração interdisciplinar.

Palavras-chave: Choque Cardiogênico. Síndrome Coronariana Aguda. Revascularização. Suporte Circulatório Mecânico. Inteligência Artificial.

RESUMEN
El shock cardiogénico (SC) representa la forma más grave de insuficiencia cardíaca aguda y sigue siendo una de las principales causas de mortalidad hospitalaria en pacientes con síndrome coronario agudo (SCA). Este estudio tuvo como objetivo identificar las principales actualizaciones científicas y tecnológicas en el manejo del SC post-SCA publicadas entre 2015 y 2025. Se trata de una revisión bibliográfica integradora, realizada en las bases de

datos PubMed, SciELO, ScienceDirect, LILACS y Consensus.app, utilizando descriptores controlados y combinaciones booleanas. Tras aplicar los criterios de inclusión y exclusión, se seleccionaron 40 artículos. Los resultados se organizaron en cuatro áreas temáticas: estrategias de revascularización y soporte hemodinámico temprano; uso de soporte circulatorio mecánico; innovaciones tecnológicas y modelos predictivos; y guías clínicas y consensos recientes. La evidencia indica que la revascularización temprana y el uso racional de dispositivos de soporte circulatorio, combinados con el trabajo de equipos multidisciplinarios (Equipos de Shock), reducen significativamente la mortalidad. Sin embargo, persisten brechas en la estandarización de protocolos, la validación de modelos predictivos y la integración de tecnologías emergentes. Se concluye que el manejo contemporáneo del shock cardíaco requiere un enfoque integrado entre la ciencia, la tecnología y la organización sanitaria, basado en evidencia sólida y colaboración interdisciplinaria.

Palabras clave: Shock Cardiogénico. Síndrome Coronario Agudo. Revascularización. Asistencia Circulatoria Mecánica. Inteligencia Artificial.

1 INTRODUCTION

Cardiogenic shock (CHD) is the most severe form of acute heart failure and represents the leading cause of in-hospital mortality among patients with acute coronary syndrome (ACS), even after significant advances in reperfusion treatment and intensive support. It is estimated that between 5% and 10% of patients with acute myocardial infarction (AMI) develop CHD, with mortality rates ranging from 40% to 50%, even in specialized centers (SADOWSKI; JANION-SADOWSKA, 2017; SAMSKY et al., 2021). The rapid hemodynamic deterioration and multiorgan dysfunction resulting from persistent hypoperfusion constitute a medical emergency that requires early diagnosis and immediate therapeutic approach (THIELE et al., 2015).

In recent decades, the management of cardiogenic shock has undergone substantial transformations, driven by the development of new circulatory support technologies and the consolidation of early revascularization strategies. Immediate revascularization of the culprit artery, through percutaneous coronary intervention (PCI), remains the main approach supported by randomized clinical trials, being associated with a significant reduction in mortality compared to early multivascular revascularization, as demonstrated in the CULPRIT-SHOCK study (SAMSKY et al., 2021). Still, mortality remains high, which reinforces the need for combined approaches and standardized protocols.

The use of mechanical circulatory support devices (MCS), such as intra-aortic balloon (IABP), Impella, and veno-arterial extracorporeal membrane oxygenation (ECMO-VA), has gained prominence in the management of refractory CC. Although clinical evidence shows significant hemodynamic benefits, the impacts on survival are still controversial and depend on the appropriate selection of patients and the experience of the multidisciplinary team (EHRENBERGER et al., 2023; HORIMOTO et al., 2023). The "Shock Team" concept, which advocates a multidisciplinary approach involving interventional cardiologists, intensivists, and cardiovascular surgeons, has proven effective in optimizing response time and rational choice of mechanical supports (ZEYMER et al., 2020).

At the same time, technological advances and predictive methods have been incorporated into clinical practice. Machine learning-based models, such as the STOP SHOCK score, have demonstrated high accuracy in predicting patients at high risk of developing cardiogenic shock during hospitalization for ACS (BÖHM et al., 2025). These models allow for early preventive interventions and better risk stratification, contributing to personalized therapeutic decisions and better allocation of resources.

Despite the significant advances observed in the last decade, **there are still important gaps in the literature regarding the standardization of therapeutic conducts, the definition of clinical criteria for the use of mechanical support, and the integration of new technologies in care practice**. Thus, **the present study aims to analyze the main scientific and technological updates in the management of cardiogenic shock after acute coronary syndrome**, based on **an integrative review of the literature published between 2015 and 2025 in the PubMed, Scielo, and ScienceDirect databases**, highlighting the most recent strategies for revascularization, circulatory support, and risk prediction.

2 METHODOLOGY

The present study is characterized as an **integrative literature review**, a method that allows the synthesis and analysis of previous research results, providing a broad, critical and systematized view of the current state of scientific knowledge on a given topic (MENDES; SCOTT; GALVÃO, 2008). This type of review is appropriate for integrating evidence from experimental and non-experimental studies, allowing the combination of theoretical and empirical results in an organized and interpretative manner.

The review was conducted between September and November 2025, following the six methodological steps described by Souza, Silva, and Carvalho (2010): identification of the theme and formulation of the research question; definition of inclusion and exclusion criteria; choice of databases and descriptors; selection and analysis of studies; categorization of findings; and presentation of the integrative synthesis. The guiding question established to guide the study was: *"What are the main scientific and technological updates in the management of cardiogenic shock after acute coronary syndrome published in the last ten years?"*

Articles published between January 2015 and November 2025, available in full text and written in Portuguese, English, or Spanish, were included. Eligible studies addressed the clinical, pharmacological, hemodynamic, or technological management of cardiogenic shock due to acute coronary syndrome (ACS). Abstracts from congresses, editorials, theses, dissertations, non-peer-reviewed protocols, as well as studies related to shocks of other etiologies (septic, anaphylactic, or neurogenic) and duplicate articles among the databases consulted were excluded.

The bibliographic search was carried out in the **PubMed/MEDLINE**, **SciELO, ScienceDirect** and **LILACS databases**, selected for their scope and relevance in the health area. To increase the international representativeness and timeliness of the findings, publications available on the **Consensus.app** platform and in high-impact journals, such as *JAMA, European Heart Journal*, *Frontiers in Medicine,* and *Clinical Cardiology, were also* consulted. The searches were carried out between **September 10 and November 5, 2025**.

The search strategy used controlled descriptors from the vocabularies **DeCS (Health Sciences Descriptors)** and **MeSH (Medical Subject Headings),** combined with Boolean operators, according to the expression: ("cardiogenic shock" OR "cardiogenic shock management") AND ("acute coronary syndrome" OR "myocardial infarction") AND ("mechanical circulatory support" OR "ECMO" OR "Impella" OR "IABP" OR "revascularization" OR "guidelines"). Filters were applied to limit the results to publications from the last ten years, prioritizing full-access, peer-reviewed studies with direct relevance to the research question.

The screening of the studies was conducted independently by two reviewers, by reading the titles and abstracts, followed by the full evaluation of the selected texts. The differences were resolved by consensus. In total, **248 articles were initially identified**, of which **65 were excluded due to duplication** and **143 for not meeting the inclusion criteria**. There were **40 studies included in the final sample**, which were analyzed qualitatively and grouped by thematic affinity. This process followed the **PRISMA model adapted** for integrative reviews, ensuring transparency and traceability in the selection of evidence.

The information extracted from each study included: author, year, journal, country, type of design, sample size, interventions evaluated, main results, and conclusions. The data were organized and tabulated in Microsoft **Excel®** spreadsheets, while the sorting and management of references were performed with the aid of the **Zotero® software**, which allowed the identification of duplicates and the consistency of the bibliographic database was maintained.

The methodological quality of the studies was independently assessed by the reviewers, using an adaptation of the criteria of the **Critical Appraisal Skills Programme (CASP)** and the **STROBE** (Strengthening the Reporting of Observational Studies in Epidemiology) recommendations. This evaluation considered the clarity of the objectives, the

coherence between method and results, internal validity, and clinical applicability of the conclusions.

After critical analysis, the studies were organized into four **main thematic categories**: (1) revascularization strategies and early hemodynamic support; (2) use of mechanical circulatory supports (IABP, Impella, ECMO-VA); (3) technological innovations and predictive models based on machine learning (such as the STOP SHOCK score); and (4) recent guidelines and clinical consensus on the management of cardiogenic shock. The synthesis of the results was conducted in a **narrative and comparative** way, emphasizing advances, controversies and knowledge gaps.

Regarding the ethical aspects, as this is a research based on secondary data, with public access and without direct involvement of human beings, **it was not necessary to submit it to the Research Ethics Committee**, as provided for in **Resolution No. 510, of April 7, 2016**, of the **National Health Council** (BRASIL, 2016).

As **methodological limitations**, it is recognized that the search was restricted to four main databases and to open access articles, which may have excluded relevant studies published in restricted access journals. In addition, no quantitative meta-analysis was performed, since the objective of this review was essentially descriptive and integrative, aimed at identifying and critically discussing the main scientific updates on the management of cardiogenic shock after acute coronary syndrome.

3 RESULTS AND DISCUSSION

3.1 REVASCULARIZATION STRATEGIES AND EARLY HEMODYNAMIC SUPPORT

Early coronary revascularization is recognized as the **therapeutic pillar in the management of cardiogenic shock (CHD) after acute coronary syndrome (ACS),** as it rapidly restores coronary flow and limits the extent of myocardial damage. The **CULPRIT-SHOCK randomized controlled trial**, level of evidence A, demonstrated that **percutaneous coronary intervention (PCI) restricted to the culprit artery** in the acute event reduces 30-day mortality and the need for dialysis, compared to immediate multivascular revascularization (SAMSKY et al., 2021). These results were reinforced by reviews conducted by **Thiele et al. (2015)** and **De Luca et al. (2015),** which consolidate early reperfusion as a priority strategy for hemodynamic stabilization and preservation of ventricular function.

Despite this recommendation, there are **divergences in the literature** regarding the ideal extent of revascularization. Observational studies indicate that **complete PCI in later stages**, after hemodynamic stabilization, can reduce ischemia recurrence and the need for new interventions, which suggests that the decision should be individualized according to coronary anatomy, shock severity, and clinical condition.

Invasive **hemodynamic monitoring** plays an essential role in therapeutic optimization. The use of pulmonary artery catheters and continuous monitoring of parameters such as **cardiac index, pulmonary capillary pressure, and central venous saturation** allow adjusting the use of inotropes and vasopressors, minimizing complications such as arrhythmias and increased myocardial oxygen consumption (ZEYMER et al., 2020).

In general, **PCI directed to the culprit artery**, associated with **early hemodynamic evaluation guided by objective parameters**, constitutes the basis of contemporary management of post-ACS CC and remains the main strategy associated with reducing hospital mortality.

3.2 MECHANICAL CIRCULATORY SUPPORTS

Over the past two decades, the introduction of **mechanical circulatory support (MCS) devices** has substantially modified the management of refractory cardiogenic shock (CHD), offering temporary alternatives to severe ventricular dysfunction. Among the main devices used are **the intra-aortic balloon (IABP),** the **Impella®,** and **veno-arterial extracorporeal membrane oxygenation (ECMO-VA).**

IABP, widely used since the 1980s, had its efficacy questioned after the **IABP-SHOCK II** study, which demonstrated no significant benefit in mortality compared to conventional treatment, resulting in the **reclassification of its recommendation** for selective use (THIELE et al., 2015). On the other hand, the **Impella®**, a percutaneous left ventricular assist device, showed significant hemodynamic benefits by reducing afterload and optimizing cardiac output, although without a consistent impact on long-term survival.

ECMO-VA has stood out in cases of refractory CHD, especially when implemented early and in centers with trained multiprofessional staff. The study by **Ehrenberger et al. (2023)** showed a significant improvement in hemodynamic stability and systemic perfusion in patients undergoing ECMO-VA during acute myocardial infarction. Similarly, **Horimoto et al. (2023)** reported successful cases in the combined use of **ECMO and Impella**, a configuration

called *ECPELLA*, capable of offering temporary biventricular support and optimizing myocardial recovery.

Despite these technological advances, **the reduction in overall mortality associated with SCM remains controversial**. Multicenter reviews indicate that clinical benefit is strongly dependent on **time of onset, careful patient selection, and institutional experience** (ZEYMER et al., 2020). In addition, the rates of vascular complications, hemorrhages, and infections associated with prolonged use still limit its universal applicability.

In summary, MCS represent an **essential therapeutic resource in the management of refractory CC**, but their use should be based on structured protocols, with well-defined criteria for indication, monitoring, and discontinuation, in order to maximize the benefits and reduce associated risks.

3.3 TECHNOLOGICAL INNOVATIONS AND PREDICTIVE MODELS

The advancement of digital technology and data science has played an increasing role in intensive cardiology, especially in the **management of cardiogenic shock (CHD),** by enabling greater diagnostic accuracy and individualized risk stratification. In recent years, models based on **machine learning and** artificial intelligence (AI) have been applied to predict the occurrence of CHD in hospitalized patients with acute coronary syndrome (ACS) and assist in clinical decision-making.

The **STOP SHOCK model**, developed by **Böhm et al. (2025),** showed high accuracy (c-statistic = 0.84) in predicting the development of WC in patients hospitalized for ACS, using routine clinical variables such as serum lactate levels, troponin, and renal function. In addition, the study by **Abu Ghosh et al. (2023)** showed that patients who develop CHD during hospitalization have significantly higher mortality than those admitted already in shock, reinforcing the relevance of **early detection of hemodynamic deterioration** and continuous surveillance of clinical parameters.

Despite the promising results, **the practical application of these models still faces important challenges**. Most studies have a retrospective design and samples from high-complexity centers, which limits external **validation and generalization of algorithms**. In addition, there are concerns about selection bias and interoperability of hospital data systems, especially in low- and middle-income countries where technological infrastructure is more constrained.

Still, the progressive incorporation of AI-based predictive tools represents a consolidated trend in modern cardiovascular medicine. These resources have the potential to **complement traditional therapeutic strategies**, offering clinical decision support, optimization of response time, and early identification of patients at risk of cardiogenic shock, as long as they are applied critically and validated in different contexts.

3.4 RECENT CLINICAL GUIDELINES AND CONSENSUS

International guidelines play a fundamental role in standardizing the management of cardiogenic shock (CHD) after acute coronary syndrome (ACS), consolidating evidence and guiding conducts based on best practices. The most recent updates published by the **European Society of Cardiology (ESC)** and the **American Heart Association (AHA)** emphasize the need for a **structured multidisciplinary approach**, through the formation of specialized teams called *Shock Teams*. These teams, composed of interventional cardiologists, intensivists, cardiovascular surgeons, and perfusionists, aim to optimize response time, patient selection, and decision on the use of mechanical circulatory support (ZEYMER et al., 2020; SAMSKY et al., 2021).

At the same time, multicentric reviews, such as those by **De Luca et al. (2015)** and **Sadowski and Janion-Sadowska (2017),** demonstrate that, despite the advancement of invasive therapies and support devices, **in-hospital mortality of SC remains between 40% and 50%.** This persistence of unfavorable results shows that **organizational and structural factors**, such as door-to-balloon time, availability of intensive support, and interprofessional coordination, have a decisive impact on clinical outcomes, often comparable to the effectiveness of technical interventions.

There are still **divergences among international guidelines** regarding the ideal time to start mechanical support and the choice of the most appropriate devices for each patient profile. While the ESC recommends the early use of circulatory support in cases of persistent hemodynamic instability, the AHA takes a more conservative approach, prioritizing pharmacological stabilization before the installation of high-cost devices. These differences reflect variations in infrastructure, cost, and technological access among health systems.

In addition, in low- and middle-income countries, the full implementation of the recommendations faces **economic, logistical and training barriers**, requiring local adaptations. Recent Latin American studies have highlighted the importance of developing **standardized institutional protocols** that integrate international guidelines with the reality

of regional services, ensuring equity and efficiency in the care of patients with cardiogenic shock.

In summary, the current clinical guidelines and consensuses reinforce the need **for organization in care networks**, **coordinated multiprofessional action,** and **the adoption of institutional protocols** as central elements to improve the prognosis of post-ACS CC, consolidating the role of evidence-based medicine as a structuring axis of care practices.

3.5 GENERAL SYNTHESIS, LIMITATIONS AND FUTURE PROSPECTS

The integrative analysis of the evidence published between 2015 and 2025 allowed us to identify significant advances in the management of **cardiogenic shock (CHD) after acute coronary syndrome (ACS),** distributed in four main axes: **early revascularization strategies**, **use of mechanical circulatory supports**, **incorporation of predictive technologies based on artificial intelligence,** and **standardization of guidelines and specialized multiprofessional teams**. Taken together, these elements reflect a transition in the care of the patient in CC from predominantly reactive approaches to **integrated, technological, and coordinated strategies**.

Despite the advances observed, **substantial limitations in the available evidence** persist. Most of the studies included have an observational design, heterogeneity of samples, and lack of standardization in diagnostic and prognostic criteria, making it difficult to directly compare results. In addition, few **randomized controlled trials (RCTs)** have systematically evaluated the comparative impact between mechanical support devices, revascularization protocols, and AI-based decision models.

Another relevant aspect refers to the **disparity of infrastructure and technological resources** between different regions, which limits the universal applicability of many international recommendations. The scarcity of centers capable of using ECMO and Impella, as well as the lack of integration between clinical information systems, still represent relevant challenges for the implementation of modern care strategies in middle- and low-income countries.

Considering these gaps, future investigations should prioritize **multicenter and randomized studies**, aimed at the external validation of predictive models, the **comparison between circulatory support modalities,** and the **evaluation of integrated protocols based on specialized multidisciplinary teams (Shock Teams).** The incorporation of **big**

data, **machine learning,** and **telemonitoring** methodologies can strengthen predictive capacity and expand the clinical applicability of evidence.

In summary, the literature of the last decade demonstrates that progress in the management of SC post-ACS depends on the **convergence between technological innovation, care standardization, and collaborative research**. The consolidation of a systemic and evidence-based approach is the most promising way to reduce mortality and improve the outcomes of patients affected by this critical condition.

4 CONCLUSION

The present study aimed to **identify the main scientific and technological updates in the management of cardiogenic shock (CHD) after acute coronary syndrome (ACS)** published in the last decade. The integrative analysis showed significant advances related to **early revascularization**, the rational use of **mechanical circulatory supports (MCS),** and the incorporation of **predictive technologies based on artificial intelligence**, which have been improving diagnostic accuracy and clinical decision support.

The **international guidelines** of the European Society of Cardiology (ESC) and the American Heart Association (AHA) highlight the importance of a **structured multidisciplinary approach**, through *Shock Teams*, in addition to the **standardization of institutional protocols** and integration between reference centers. Despite the progress, **limitations in the available evidence persist**, marked by the predominance of observational studies, methodological heterogeneity, and restrictions on external validation.

It is concluded that the improvement of the management of post-ACS CC requires **integration between science, technology and care organization**, supported by evidence-based practices and interdisciplinary collaboration. The strengthening of **multicenter research** and the **adaptation of guidelines to regional realities** are essential steps to reduce mortality and optimize the clinical outcomes of these patients.

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