

## Capítulo 12

# Artificial Intelligence in the Control, Diagnosis and Treatment of Heart Failure

ELDEVAN SANTOS DE SANTANA <sup>1</sup>

NÁRIMA SENA ARAUJO <sup>2</sup>

MANUELA ZAMBAM GASPERIN CARBONERA <sup>3</sup>

MATEUS JOSÉ TEIXEIRA CASTRO ALENCAR <sup>4</sup>

ORLANDO ALBERTO DOS SANTOS NICOLLS <sup>5</sup>

RAFAEL DUARTE SIGOLO ROBERTO <sup>6</sup>

LEIANNY HANNA FRAGA CARRIJO <sup>7</sup>

NICOLE LIMA COELHO <sup>8</sup>

LUIZA RAQUEL FERNANDES SILVA BUCSKY <sup>9</sup>

<sup>1</sup> Discente - Universidad Nacional de Rosario (UNR)

<sup>2</sup> Discente - Universidad Abierta Interamericana (UAI)

<sup>3</sup> Discente - Universidade Positivo (UP)

<sup>4</sup> Discente - Universidade Federal de Juiz de Fora (UFJF)

<sup>5</sup> Discente - Centro Universitário São Camilo (CUSC)

<sup>6</sup> Discente - Universidade Municipal de São Caetano do Sul (USCS)

<sup>7</sup> Discente - Centro Universitário de Caratinga (UNEC)

<sup>8</sup> Discente - Faculdade de Medicina Nova Esperança (FAMEME)

<sup>9</sup> Discente - Universidade Iguazu - (UNIG)

*Keywords: Artificial Intelligence; Chronic Heart Failure; Diagnosis; Treatment.*

## INTRODUCTION

Heart failure (HF) is a condition with high prevalence and a significant impact on global health, associated with elevated rates of mortality, morbidity, and costs. It is a complex syndrome whose pathophysiology involves marked hemodynamic alterations—such as reduced cardiac output and systemic congestion—demanding increasingly precise diagnostic and therapeutic approaches (CHEUNG-PASITPORN et al., 2024).

In this context, artificial intelligence (AI) has emerged as a promising tool for enhancing care in patients with HF. Through techniques such as machine learning, deep learning, supervised and unsupervised algorithms, reinforcement learning, and neural networks, AI enables the processing of large volumes of clinical, laboratory, and imaging data, facilitating early disease detection, outcome prediction, and treatment personalization (CHEUNG-PASITPORN et al., 2024; SINGH et al., 2025).

The integration of AI with blood biomarkers has allowed for greater precision in risk stratification and therapy individualization in HF patients, contributing to more effective clinical decisions and slowing disease progression. Moreover, the concept of interoception—the body’s ability to perceive and interpret internal signals such as heart rate and respiration—has proven relevant in the cardiovascular

context. Interoceptive alterations can negatively impact prognosis, and AI can assist in understanding and monitoring these physiological mechanisms (SUN et al., 2023; SINGH et al., 2025).

Among the practical applications of AI are imaging processing techniques applied to exams such as echocardiography, cardiac magnetic resonance, and computed tomography, which allow for more accurate structural and functional heart analyses. Additionally, the use of remote monitoring tools, automated analysis of complementary exams, and large-scale language models (LLMs), such as clinical chatbots, has expanded AI’s applicability in the outpatient and home management of HF patients (REICH & MEDER, 2023).

Heart failure remains one of the leading causes of morbidity and mortality worldwide, affecting more than 60 million people and placing a substantial burden on healthcare systems (KHAN et al., 2023). Despite recent therapeutic advances, traditional strategies still face limitations, such as late detection and challenges in accurately stratifying patient risk. AI emerges as a strategic ally by integrating clinical, genetic, and imaging data, promoting more personalized and effective care (CHEUNG-PASITPORN et al., 2024).

Therefore, this chapter is justified by the need to understand how AI technologies can be

integrated into HF management, aiming to enhance diagnostic accuracy, reduce clinical complications, and promote treatment individualization. Given the increasing digitalization of healthcare and the complexity of medical data, it is essential to discuss the opportunities, ethical challenges, and limitations related to the implementation of these technologies in the HF context (REICH & MEDER, 2023; KHAN et al., 2023).

### Challenges and Future of AI in Heart Failure

Supervised learning techniques — such as artificial neural networks (ANNs) and support vector machines (SVMs) — have proven effective in analyzing electrocardiograms, while unsupervised approaches have enabled the clustering of patients with similar clinical characteristics, facilitating risk stratification and therapeutic planning (SUN et al., 2023; LI et al., 2022). In the context of myocardial recovery, machine learning algorithms applied to patients with reduced ejection fraction or those supported by left ventricular assist devices (LVADs) have demonstrated the ability to predict clinical outcomes with areas under the curve (AUC) exceeding 0.85 (LANG et al., 2024).

However, despite these advances, the incorporation of AI into clinical practice faces

significant challenges. The quality and diversity of the data used to train models are critical to their accuracy and generalizability. Incomplete, biased, or unrepresentative data undermine algorithm performance and can perpetuate disparities — such as those based on race or socioeconomic status (LANG et al., 2024). The low interpretability of models, especially deep neural networks, also hinders their acceptance by healthcare professionals (AMIN et al., 2021).

Moreover, unresolved ethical and regulatory issues remain — among them data privacy protection, legal liability in the event of errors, and the need for methodological standardization. To overcome these limitations, measures have been suggested such as building diverse databases, employing explainable models, training clinical teams, adopting metrics familiar to healthcare providers, and establishing clear data governance guidelines (LANG et al., 2024).

In summary, AI has the potential to revolutionize cardiology, particularly in the management of heart failure. From early detection to continuous monitoring and the discovery of new therapies, the advances observed thus far point to a promising future. Nevertheless, it is essential that these technologies be implemented ethically, safely, rigorously validated, and equitably—ensuring that their benefits are

fully realized by all populations (WEYMANN et al., 2023).

### **Fundamentals and Clinical Applications of AI in Heart Failure**

The application of artificial intelligence (AI) in cardiovascular medicine — especially in the management of heart failure (HF) — has gained prominence in recent decades, driven by the growing demand for more effective diagnostic, therapeutic, and monitoring solutions. Given that non-communicable chronic diseases, particularly heart conditions such as HF, rank among the leading causes of morbidity and mortality in Brazil and worldwide, the integration of AI into healthcare systems represents a paradigm shift in clinical practice (FARAH et al., 2021; SOARES et al., 2024).

HF, characterized by the heart's inability to maintain adequate cardiac output without pathologically elevated intracavitary pressures, affects more than 64 million people globally, with prevalence rising due to population aging (MICHELHAUGH & JANUZZI et al., 2022).

In this context, AI emerges as a promising tool for early diagnosis, risk stratification, remote monitoring, and clinical decision support. Machine learning models have demonstrated superior performance over traditional methods in identifying asymptomatic left ventricular dysfunction, interpreting echocardiograms, and predicting response to cardiac resynchronization therapy (CRT) (SOUZA FILHO et al., 2020; SUN et al., 2023; NAZAR et al., 2023).

When integrated with AI, clinical decision support systems (CDSSs) have expanded the potential of personalized medicine. The use of algorithms such as XGBoost and LightGBM has proven capable of anticipating critical events—such as cardiac arrest—up to six hours in advance, outperforming previous approaches in accuracy, sensitivity, and specificity (KIM et al., 2023). Furthermore, AI applied to the analysis of electronic medical records (EMRs) and omics data has enabled the discovery of novel biomarkers and more precise stratification of HF subtypes, facilitating targeted therapeutic approaches and individualized prognoses (MICHELHAUGH & JANUZZI et al., 2022).

**REFERENCES**

- AMIN, H. *et al.* Future Perspective of Heart Failure Care: Benefits and Bottlenecks of Artificial Intelligence and eHealth. *Future Cardiology*, v. 17, n. 6, p. 917–921, 2021.
- CHEUNG PASITPORN, W. *et al.* Inteligência Artificial em Insuficiência Cardíaca e Lesão Renal Aguda: Conceitos Emergentes e Dimensões Controversas. *Cardiorenal Medicine*, 14(1):147–159, 2024.
- FARAH, Y. *et al.* Inteligência artificial no diagnóstico e detecção de insuficiência cardíaca: passado, presente e futuro. *22(4)*, 1095–1113, 2021.
- KHAN, MS, Arshad, MS, Greene, SJ, Van Spall, HGC, Pandey, A., Vemulapalli, S., Perakslis, E. e Butler, J. (2023), Inteligência artificial e insuficiência cardíaca: uma revisão de última geração. *Eur J Heart Fail*, 25: 1507-1525.
- KIM, Y. K. *et al.* Modelo de Alerta de Inteligência Artificial Explicável Usando uma Abordagem de Conjunto para Previsão de Parada Cardíaca Hospitalar: Estudo de Coorte Retrospectivo. *Journal of Medical Internet Research*, 25:e48244, 2023.
- LANG, F. M. *et al.* Papel da Inteligência Artificial e do Aprendizado de Máquina para Criar Preditores, Melhorar a Compreensão Molecular e Implementar Programas Propósitos para a Recuperação Miocárdica. *20(4)*:76-87, 2024.
- LI, J. *et al.* Prevendo a Mortalidade em Pacientes com Insuficiência Cardíaca Usando um Modelo de Aprendizado de Máquina Interpretável: Estudo de Coorte Retrospectivo. *Journal of Medical Internet Research*, 24(8):e38082, 2022.
- MICHELHAUGH, S. A.; JANUZZI, J. L. Using Artificial Intelligence to Better Predict and Develop Biomarkers. *Heart Failure Clinics*, 18(2):275-285, 2022.
- NAZAR, W. *et al.* Modelos de inteligência artificial na previsão de resposta à terapia de ressincronização cardíaca: uma revisão sistemática, 2023.
- REICH, C.; MEDER, B. O Coração e a Inteligência Artificial - Como Podemos Melhorar a Medicina Sem Causar Danos. Epub 9 de junho, 2023.
- SINGH, M. *et al.* Interocepção, saúde cardíaca e insuficiência cardíaca: O potencial para diagnóstico e tratamento orientados por inteligência artificial (IA). *Physiological Reports*, 13(1):e70146, 2025.
- SOARES, Felipe Leal *et al.* Perfil epidemiológico das internações por Insuficiência Cardíaca no Brasil entre 2019 e 2023. *Brazilian Journal of Implantology and Health Sciences*, v. 6, n. 4, p. 887-896, 2024.
- SOUZA FILHO, Erito Marques de *et al.* Inteligência artificial em cardiologia: conceitos, ferramentas e desafios—“quem corre é o cavalo, você precisa ser o jóquei”. *Arquivos Brasileiros de Cardiologia*, v. 114, n. 4, p. 718-725, 2020.
- SUN, X. *et al.* Artificial intelligence in cardiovascular diseases: diagnostic and therapeutic perspectives. *European Journal of Medical Research*, v. 28, n. 1, p. 242, 2023.
- WEYMANN, A. *et al.* Músculos artificiais e dispositivos robóticos macios para o tratamento da insuficiência cardíaca em estágio terminal. *Advanced Materials*, 35(19):e2207390, 2023.