

Chapter 6

Artificial Intelligence and Control in the Cardiac Pacemakers

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ABSTRACT

The incorporation of AI in cardiology provides advantageous viewpoints for improving accuracy by diminishing the error rate and raising efficiency in different cardiovascular clinical procedures. Overall, the aim is to diagnose complex pathologies, anticipate complications, and decrease diagnostic times as well as medical errors. Arrhythmia is one of the primary cardiovascular illnesses that involve a sizeable number of people in the world. For real-time patient heart rate control, the most extensively utilised implantable device in the cardiovascular system is the cardiac pacemaker. Certain pathologies need the implantation of cardiac pacemakers to restore the cardiac rhythm. Efficient and robust control of cardiac pacemakers is fundamental for supplying life-saving control action to handle heart rate in dynamic conditions. Thus, the development of new pacemaker-based heart stimulation techniques has an essential role in the evolution of this field. The chapter tackles the control techniques and the implementation of AI in this context and their further challenges.

INTRODUCTION

Artificial intelligence (AI) is having an impact on many research fields, including the medical, wherein there exist considerable applications of AI that have accomplished significant progress such as data analysis and therapeutic decision-making, among others. The incorporation of AI in cardiology provides advantageous viewpoints for improving accuracy by diminishing the error rate and raising efficiency in different cardiovascular clinical procedures. AI techniques aid physicians in perfecting their corresponding skills, systematizing procedures and selecting the best surgical practices. Overall,

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the aim is to diagnose complex pathologies, anticipate complications, and decrease diagnostic times as well as medical errors.

Cardiology maintains a top position among all specialties where AI has set up its place via clinical applications. World Health Organization has pointed out that the principal cause of death globally is cardiovascular disease, being around a third of annual deaths. AI possesses the potential to open the doors through personalized procedures to each patient. Therefore, incorporating AI into medical practice helps its clinical activity. AI techniques have demonstrated their capacity to improve progress in the management of heart failure, valvular heart diseases, congenital heart diseases, etc. The human factor remains essential in the medical procedure, with physicians finally determining where to use and how to interpret the data derived by AI, however; it helps in the partial elimination of human error by diminishing human involvement, correcting clinician errors, etc, which is an advantage of AI in healthcare (Stamate et al., 2024).

A healthy state shows some grade of stochastic variability in physiologic variables, for example, heart rate. This variability is an estimation of complexity that goes with healthy systems and has been proposed as liable, for their more prominent adaptability and functionality associated with pathologic systems. If this variability is lost, the complexity that accompanies cardiovascular disease and critical illness is also lost. This is correlated to a raised mortality rate after acute myocardial infarction, sepsis, etc. Heart rate variability is contemplated as a risk marker in critical illness, especially in heart failure and severe sepsis. Besides, it is an indirect estimator of autonomic modulation of heart rate. Neuro-autonomic uncoupling or decreased baroreflex sensitivity has been related to diminished heart rate variability discovered in critically ill patients (Papaioannou et al., 2013).

Myocardial electrical activity and the heart's normal combined electrical running are connected to the growth of activity potentials in individual cardiac cells. A cardiac pacemaker consists of a pulse initiator that boards the battery, electronics and the lines that link to the myocardium to supply a depolarizing pulse and detect intrinsic cardiac stimulation. Current cardiac pacemakers contain units for helping patients with other diseases like heart failure, which occurs when the heart does not pump as strongly as it should (Agarwal and Shinde, 2022).

Cardiac pacemaking is a tricky phenomenon that is being studied still. The exploratory studies, numerical modelling has been employed to obtain mechanical insights in this field. Numerical modelling is an essential tool of contemporary science. In numerous cases, modelling is the only achievable approach to correctly explain experimental data characterizing a complex biological system. Numerical modelling expands testing horizons to further experimental data, yielding novel mechanistic understandings. Cardiac impulse initiation, the basic biological phenomenon essential for heart function and life, has been frequently studied by numerical modelling and experimental procedures (Maltsev et al., 2014).

Implantable medical devices have produced considerable assistance in diagnosis, treatment and clinical monitoring. A growing number of intelligent automatic devices are used in clinical practice to enhance the patient's health disease (Li et al., 2019). Cardiovascular implantable electronic devices are employed widely for treating diseases such as bradycardia and heart failure, among others. The complex physical dynamics of patients generate different challenges to device development and validation. This issue can be faced using a closed-loop device-heart model framework that can reach an elevated system test range (Ai et al., 2020).

Efficient and robust control of cardiac pacemakers is fundamental for supplying life-saving control action to handle heart rate in dynamic conditions. Control engineering has allowed the implementation of diverse systems has evolved into a reality. For real-time patient heart rate control, the main implantable

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