The Role of Artificial Intelligence and 3D Printing in Advancing the Diagnosis and Treatment of Cardiomyopathies

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Central Illustration: **The Role of Artificial Intelligence and 3D Printing in Advancing the Diagnosis and Treatment of Cardiomyopathies**

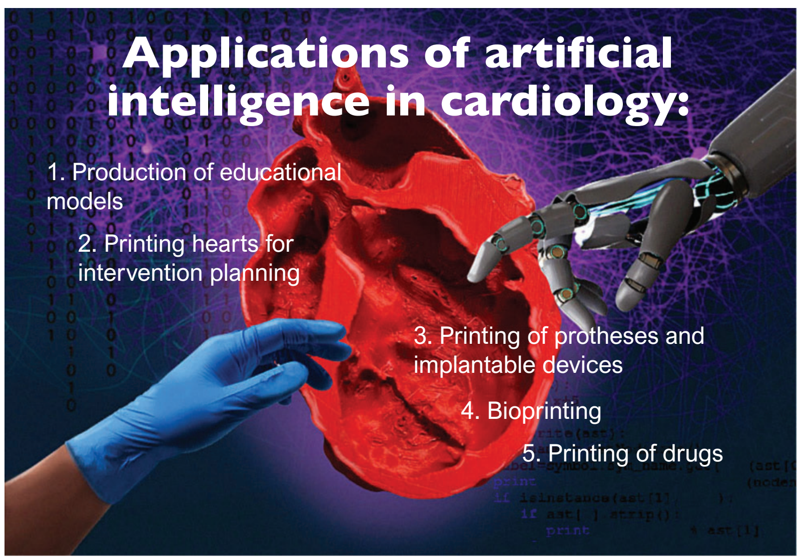

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Illustration demonstrating the key applications of artificial intelligence in cardiology.

"It is not the strongest of the species that survives, nor the most intelligent, but the most responsive to change."
Charles Darwin

Cardiology has witnessed a true revolution with significant advances in recent years, highlighting cutting-edge technologies such as Artificial Intelligence (AI) and 3D printing. These technologies have the potential to make the diagnosis and treatment of cardiomyopathies more accurate, offering innovative and personalized solutions for patients with these conditions.[1,2] AI is a product of the combination of sophisticated mathematical models and computing, essential for developing complex algorithms capable of simulating human intelligence activities.[3] In the health field, it is worth noting that there are multiple processes involved, and, in practice, these models allow for tasks such as learning, rationalization, understanding, and comprehension of abstract concepts whose effects culminate in criticism.[4] A practical consequence of this panorama is a new vision that traditional tools such as electrocardiograms and echocardiograms gain an expanded dimension as they can bring hidden "clinical pearls" of great value, although invisible to the naked eye. It can allow for an expansion of diagnostic and prognostic evaluation capabilities, as well as promote early intervention and treatment.

Keywords

Artificial intelligence, 3D printing, Machine learning, Cardiomyopathy

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The use of AI has the potential to revolutionize cardiology by providing new tools and possibilities for doctors, such as the ability to process a large amount of patient information to increase the predictability of risks associated with cardiomyopathies, contributing to more accurate and personalized diagnoses. AI models used for these purposes will need to receive various types of information, such as 2D and 3D images, videos, time series data, numerical data, medical reports, and medical records, thus improving decision-making and prognosis.[4-6] In addition, AI can also reduce the number of transactional activities performed by doctors, increasing their availability for more relevant and valuable activities to patients. Among the potential applications of this type are AI assistants that can take notes during a consultation, record the conversation and create the medical record, and even intervene in the process by suggesting important questions to ask based on the main diagnostic hypotheses.[7] The central illustration shows some potential applications of AI in clinical cardiology practice, including the promise of treating heart failure by transplanting a 3D bioprinted patient-specific cardiac patch to the myocardium.[8]

It is very important to highlight the value that data generated by wearable devices can add to the monitoring of chronic conditions, providing information that can contribute to risk management and monitoring. The use of AI models in these cases can contribute in different ways, both individually to the patient and the at-risk population, including notifying the patient about the need and urgency of seeking healthcare, notifying the healthcare team monitoring the case about possible complications, constructing personalized histories with the evaluation of the evolution of a specific condition, epidemiological surveillance, and better resource management in public health.

In this future scenario, it is important to consider how medical information should be made available to these AI applications in an environment with increasingly restrictive regulations regarding data protection. The data should belong entirely to the patients, with any decision regarding availability and access management resting with them. Integrating data in a standardized, secure, and encrypted manner is a potential path for the scalability of AI models, and the development of innovative ecosystems that foster the development of these solutions is also necessary. One technology with the potential to address some of these problems is blockchain technology due to its ability to generate secure, encrypted, and immutable records, as well as the possibility of being used with a decentralized consensus architecture, which would eliminate the need for large, centralized institutions to possess this data.[9]

Lee et al. developed a deep-learning model for the diagnostic screening of patients with peripartum cardiomyopathy.[10] They used electrocardiographic and transthoracic echocardiogram images from 122,733 patients, including 58,530 women, to train the model and make internal validation - obtained from two general hospitals. Lee and colleagues performed external validation using data from 271 patients from a third hospital. The results showed an area under the receiver operating characteristic curve (AUROC) of 0.877, a sensitivity of 0.877, and a negative predictive value of 0.975. On the other hand, Siontis and colleagues used electrocardiographic data to train a convolutional neural network for screening hypertrophic cardiomyopathy in children and adolescents (300 with the disease and 18,439 controls). The results were impressive (AUROC: 0.98; sensitivity: 92% and specificity 95%).[11] It is worth noting the importance of validating the results in different clinical contexts, the relevance of expanding the database, and ensuring that it is of good quality (healthy).

On the other hand, it is also possible to use AI models for integrated analysis of large amounts of imaging data, such as cardiac magnetic resonance and echocardiograms, electrocardiograms, clinical-laboratory data from consultations, wearable data, omic data, etc., also identifying patterns that may not be discernible to human evaluation. It can also help in the early and accurate diagnosis and treatment of cardiomyopathies, even in subclinical phases. As a result, we can expect to improve patients' quality of life and reduce healthcare costs.[3]

AI has shown promise in developing advanced models of cardiac simulation, allowing for detailed computational models of a specific patient's heart anatomy and function. These models can be used to simulate the behavior of the heart in different conditions, such as cardiomyopathies, and test the effectiveness of different treatment approaches before applying them to patients. It can reduce the risk and cost of invasive procedures such as cardiac surgeries and optimize treatment for each patient. In addition, 3D printing allows the creation of precise and personalized 3D models of a patient's heart based on imaging exams such as computed tomography. These models can be used to plan and practice complex procedures, such as heart valve replacement - resulting in a more precise and minimally invasive approach. It also is helpful to create personalized cardiac prostheses and circulatory support devices, allowing for innovative and tailored solutions for patients with cardiomyopathies. Kim et al., for instance, described a novel method of creating a resectable myocardial model for mock myectomy using a hybrid approach of 3D printing and silicone molding. The study involved generating 3D models of three patients with apical hypertrophic cardiomyopathy (ApHCM) and comparing the myocardial thickness and left ventricular (LV) myocardial mass and cavity volumes between the model images and cardiac CT images. During the mock surgery, the surgeon could determine an ideal site for the incision and the optimal extent of myocardial resection. The results showed that the 3D model would help analyze the extension of surgery and planning surgery guided by a rehearsal platform for ApHCM.[12] Zhang et al. presented a case of 3D printing technology combined with assisted Da Vinci robotic surgery on surgical treatment for hypertrophic obstructive cardiomyopathy. They considered it a safe surgical and relatively effective option for patients with the disease. They highlighted several advancements that have been achieved, such as minimal invasion, complete lesion resection, procedural stability, and accurate pre-evaluation. Although, the process demands experience, mature surgical skills, and a longer learning curve.[13]

In another application, Layoun et al. presented a case report of a male patient aged 24 with nonischemic cardiomyopathy of unknown etiology, a secondary mitral regurgitation, and an apical aneurysm. They created a computer tomography–derived 3-dimensional model of the patient's heart. It was crucial in directing the surgical approach to achieve the optimal result.[14] AI and 3D printing together, therefore, could revolutionize the field of cardiology, offering new possibilities for diagnosis, treatment, and care for patients in the context of cardiomyopathies. However, we must overcome significant challenges. Regulation, ethics, and data privacy are crucial examples of them.

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Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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