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# ARTIFICIAL INTELLIGENCE IN CARDIOLOGY

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***Abstract***

*Significant progress in the field of Artificial Intelligence (AI) has been highlighted over the past decade. Its continuously evolving applications have found various uses in the medical field, focusing on prevention, screening, and treatment for a wide range of conditions, as well as anticipating their progression. In the field of cardiology, various AI models have proven their effectiveness in interpreting data from technologies such as electrocardiography and imaging, demonstrating their utility in interpreting echocardiography, nuclear magnetic resonance, as well as computer tomography. The integration of artificial intelligence into electrocardiogram (ECG) analysis not only improves the accuracy of diagnosis but also facilitates the recommendation of personalized and optimal treatment for each patient. Cardiovascular imaging has become an extremely advanced research field within AI, with echocardiography being an excellent method for non-invasive evaluation, both quantitatively and qualitatively, of cardiac function. The implementation of artificial intelligence in analyzing images obtained through nuclear magnetic resonance and computer tomography has also been successful in identifying specific conditions, such as myocardial ischemia or obstructive coronary artery disease.*

***Keywords:*** *artificial intelligence, echocardiography, valvopathies, coronary artery disease.*

***Rezumat***

*În decursul ultimului deceniu, s-au înregistrat progrese semnificative în domeniul inteligenței artificiale (IA). Aplicațiile sale în evoluție continuă au găsit diverse utilizări în domeniul medical, concentrându-se pe prevenție, screening și tratament pentru o gamă variată de afecțiuni, precum și în anticiparea evoluției acestora. În sfera cardiologiei, diferite modele de IA și-au demonstrat eficacitatea în interpretarea datelor provenite din tehnologii precum electrocardiografia și imagistica, dovedindu-și utilitatea și în interpretarea ecocardiografiei, rezonanței magnetice nucleare, precum și computer-tomografiei.*



# Internal Medicine

## General Reviews

*Integrarea inteligenței artificiale în analiza electrocardiogramei (ECG) nu doar îmbunătățește precizia diagnosticului, ci și facilitează recomandarea unui tratament personalizat și optim pentru fiecare pacient în parte. Imagistica cardiovasculară a devenit un domeniu de cercetare extrem de avansat în cadrul IA, ecocardiografia reprezentând o metodă excelentă pentru evaluarea non-invazivă, atât din perspectiva cantitativă, cât și calitativă, a funcției cardiace. Implementarea inteligenței artificiale în analiza imaginilor obținute prin rezonanța magnetică nucleară și computer-tomografie a obținut, de asemenea, succes în identificarea unor afecțiuni specifice, cum ar fi ischemia miocardică sau boala coronariană obstructivă.*
***Cuvinte cheie:*** *inteligență artificială, ecocardiografie, valvulopatii, boală coronariană*.

### Introduction

Cardiovascular diseases stand as the foremost contributor to both illness and mortality on a global scale. According to the World Health Organization's estimation, around 17.9 million individuals die annually due to such conditions, making up 31% of all global deaths.

Over the past decade, there has been a notable increase in the generation of medical data, with an estimated annual growth rate of around 48%. This rapid growth had a profound impact on the delivery of healthcare services, fundamentally altering the dynamics of the industry[1]. Information systems can now store massive amounts of data, process it intelligently, and arrive at rapid conclusions. The use of AI and associated tools, such as machine learning, presents a valuable solution, especially in the field of cardiology. These technologies can contribute to establishing accurate diagnoses, eliminating the subjective component of the physician. The capability to analyze complex and extensive data, a characteristic of machine learning, allows clinicians to provide usable solutions for precise prognoses[2,3].

The effectiveness of using AI in cardiology has been confirmed by various models used to anticipate the risk of specific conditions, through dynamic interpretation of data obtained through electrocardiography and echocardiography[4,5].

### Artificial Intelligence in Electrocardiography

Electrocardiography is among the most frequently used methods in medical practice,

being a simple, non-invasive, and financially accessible test. In conjunction with artificial intelligence, this method can have a significant impact on prevention, as well as in the areas of diagnosis, treatment, and prognosis[6].

The interpretation of electrocardiograms (ECG) requires a certain level of expertise, and the automatically generated diagnosis by ECG machines is often used in situations where a cardiologist specialist is not available[7].

However, the accuracy of conventional algorithms underlying ECG equipment is often below expectations. The integration of artificial intelligence in ECG (AI-ECG) can contribute to improving diagnostic accuracy, and some AI models have demonstrated diagnostic performance comparable to that of specialist doctors[5].

AI-ECG technology also facilitates the development of innovative devices. Devices such as the "implantable loop recorder" (ILR) and smartphones/smartwatches, whose recordings are not always reliable, can draw attention to the onset of a major-risk rhythm disorder. These can be used in high-risk groups for cardiovascular diseases, contributing to population screening. Thus, an essential aspect of AI-ECG lies in its ability to detect paroxysmal atrial fibrillation, identifying patients at risk of developing a stroke, and playing a significant role in the prevention process. This innovation proves effective in diagnosing ventricular arrhythmias and myocardial infarction, with promising expectations regarding the establishment and identification of phenotypes in cases of long QT syndrome[2,6].

Numerous studies have highlighted that AI-ECG provides more information compared to traditional ECG. Many of the models developed in these studies have demonstrated the ability to anticipate the development of hypertrophic cardiomyopathy, left ventricular dysfunction, and hypokalemia, considering other unmodifiable parameters such as age and gender[2].

## Artificial Intelligence in Echocardiography

### The Role of AI in Identifying Various Pathologies

The application of AI in echocardiography depends on its ability to autonomously interpret data and images, often exceeding the boundaries of human perception. In routine echocardiography, the considerable volume of information required for accurate diagnosis can be challenging for specialists to interpret within a short timeframe[8].

In this context, AI can provide an efficient solution for the rapid analysis of this information. As a result, there are an increasing number of clinical applications for AI in echocardiography, encompassing the detection of various conditions that include valvular heart disorders, coronary artery disease, hypertrophic cardiomyopathy, cardiac amyloidosis, cardiomyopathies, and cardiac masses. By integrating AI technology in this field, new horizons are opening for the rapid and accurate diagnosis and assessment of cardiac conditions, contributing to the prevention of cardiovascular diseases[9].

### 1. Valvular Heart Disease

AI's primary use in the field of valvular heart disorders has been to measure the severity of valvulopathies and to identify high-risk populations through echocardiographic analysis. AI algorithms have been successful in detecting the presence of valvulopathy in the initial image analysis. Furthermore, by integrating clinical information with imaging





data, AI has been able to identify new predictive factors for disease progression. This has the potential to improve patient management and outcomes[10,11].

In previous studies, researchers have developed highly accurate algorithms that utilize images to assess the severity of mitral and aortic valve diseases, identify the presence of prosthetic valves, and detect rheumatic heart disease.

These advancements have the potential to significantly transform the assessment and treatment of patients with valvular diseases. Further research in this area holds promise for improving patient outcomes and revolutionary clinical practice[10].

Sengupta et al. published an article involving approximately 2000 patients with aortic stenosis, AI was employed to assess echocardiographic measurements for determining disease severity and identifying high-risk subgroups. By analyzing higher-risk individuals, this approach has the potential to optimize the timing of surgical intervention for aortic valve replacement. Better patient outcomes and more effective use of healthcare resources may result from this[12].

In a different recent publication, a deep learning algorithm was introduced and demonstrated the ability to classify echocardiographic images, detect the presence of valvular heart disease, and accurately quantify the severity of the disease. These findings demonstrate how well an automated framework can assess, categorize, and quantify the severity of prevalent disorders in clinical practice. The framework was trained on widely accessible echocardiographic datasets. This highlights the potential of AI to enhance diagnostic accuracy and streamline clinical decision-making[8].

**2. Coronary Artery Disease**

In the management of subjects diagnosed with coronary artery disease, cardiac imaging plays a crucial role. An automated image processing algorithm was recently created with the goal of extracting geometric and kinetic information from stress echocardiography. This machine-learning model has shown impressive accuracy in classifying patients, with a specificity of 92.7% and a sensitivity of 84.4% in identifying those with severe coronary artery disease.

These results provide strong support for the use of AI in stress echocardiogram analysis, offering automated classifications and improving accuracy. Importantly, these findings highlight the need for AI in a context where stress echocardiography interpretation is acknowledged as a significant obstacle for experts[13].

In the realm of coronary artery disease, AI holds promise for differentiating between conditions that present with similar signs and

symptoms to acute coronary syndrome. A recent cohort study introduced a real-time system for interpreting echocardiograms, specifically aiming to distinguish Takotsubo syndrome from acute myocardial infarction. The model demonstrated comparable efficiency to experienced cardiologists in this task. However, further research is necessary before widespread application can be considered. Continued studies will help refine and validate the effectiveness of AI in accurately diagnosing and differentiating these conditions[8].

AI models have the potential to offer predictions regarding the recovery of the left ventricle following coronary syndromes. In a study, a method based on echocardiographic texture parameters was presented to evaluate the recovery of left ventricular function one year after myocardial infarction. Initial results showed promise, with an estimated prediction error of less than 30%. However, further research is warranted to validate these findings and assess the practical application of this approach in a clinical setting. Continued studies will help refine the AI model and determine its usefulness in predicting left ventricular recovery after coronary syndromes[13].

**3. Etiology of Determining Increased Thickness of the Left Ventricular Wall**

In cases where there is an observed increase in the thickness of the left ventricular wall, traditional echocardiography may not provide enough information to establish the underlying cause. This may necessitate the use of more advanced imaging methods. Assessing myocardial texture in routine echocardiography, performed solely through human interpretation, can pose a challenge. In a particular study, researchers utilized myocardial texture analysis using echocardiography to differentiate between three conditions: hypertrophic cardiomyopathy, hypertensive heart disease, and uremic cardiomyopathy. The findings revealed that patients with hypertrophic cardiomyopathy demonstrated the most uniform myocardial texture, which was significantly distinct from the textures observed in the other conditions. These findings support the potential of AI-based myocardial texture characteristics as a promising method for differentiating the etiology of left ventricular hypertrophy[4,14]).

Other researchers looked into the diagnostic value of a machine learning system that uses echocardiographic data to distinguish between physiological hypertrophy, which is often seen in athletes, and hypertrophic cardiomyopathy. According to the study, the AI model demonstrated high sensitivity and specificity when compared with standard parameters.

This finding raises the possibility that adding echocardiography images into machine learning algorithms can help differentiate between the normal physiological adaptations seen in athletes and the pathological patterns of hypertrophic remodeling seen in hypertrophic cardiomyopathy. These findings highlight the value of utilizing machine learning techniques with echocardiography for improved diagnostic accuracy in differentiating between these conditions[13,15].

Cardiac amyloidosis, which involves left ventricular hypertrophy, can sometimes present similar symptoms to hypertrophic cardiomyopathy. Although cardiac amyloidosis is associated with changes in cardiovascular imaging, single echocardiography results have not shown to be sensitive or specific enough to be used as gold standard diagnostics for this illness. A cohort study developed an AI algorithm that automatically evaluated the





thickness of the left ventricular wall in echocardiography and predicted the cause of left ventricular hypertrophy, whether it was cardiac amyloidosis or hypertrophic cardiomyopathy. The deep learning model accurately identified subtle changes in the geometric measurements of the left ventricular wall and the causes of hypertrophy, providing a more efficient clinical assessment for this group of patients[15].

In a separate study, researchers introduced a deep learning algorithm designed for the differential diagnosis of common causes of left ventricular hypertrophy, namely hypertensive heart disease, hypertrophic cardiomyopathy, and AL cardiac amyloidosis. The algorithm utilized a convolutional neural network model and relied on five standard ultrasound views (parasternal long-axis, parasternal short-axis, apical four-chamber, apical two-chamber, and apical three-chamber) for classification purposes. The study included a population divided into three stages: a training stage with 620 participants, a validation stage with 155 participants, and a testing cohort with 155 participants. In the testing cohort, the deep learning algorithm achieved impressive results, with area under the curve (AUC) values of 0.962 for hypertensive heart disease, 0.982 for hypertrophic cardiomyopathy, and 0.996 for AL cardiac amyloidosis. The overall diagnostic accuracy of the deep learning algorithm was significantly higher compared to that of echocardiography specialists. These findings support the notion that the implementation of artificial intelligence can enhance the diagnostic process for patients with left ventricular hypertrophy[9].

**4. Cardiomyopathies**

In the diagnosis of cardiomyopathies, supported by AI, ventricular segmentation, volume measurement, and automatic evaluation of heart function can be employed. The use of artificial intelligence in this context offers a significant advantage in terms of improving diagnostic efficiency, particularly in the early stages of certain cardiomyopathies. In some cases, structural signs that would be evident in echocardiography may not be detectable at this early stage[8,16].

The development of deep learning algorithms has allowed specific differentiation of cardiomyopathies through echocardiography. In a specific study, AI-assisted diagnosis was utilized to differentiate between cardiac sarcoidosis and the healthy state of subjects. The AI algorithm used echocardiography data for diagnosis, and the accuracy of this algorithm was found to be comparable to that of human experts interpreting echocardiograms[15].

**5. Cardiac Formations**

The precise diagnosis of the origin of cardiac

formations through echocardiography is often a crucial challenge, given the diversity of treatment options for different types of cardiac masses, such as thrombi, tumors, or vegetations. This may involve the need for additional tests, such as advanced imaging through magnetic resonance imaging (MRI), for a more detailed characterization. AI technology has the capability to classify and identify intracardiac masses. Previous studies have focused on using texture analysis in echocardiography to classify and segment these masses, which provides insights into the physiological characteristics of the cardiac tissues being examined. In recent research, the efficacy of using transesophageal echocardiography and an AI diagnostic algorithm to detect left atrial thrombi in atrial fibrillation patients was evaluated. The study discovered that when compared to the conventional method employed by human experts, the AI-based algorithm greatly increased the accuracy of diagnosing left atrial thrombi[13].

**Artificial Intelligence in MRI and CT**

Cardiac imaging represents a field with broad and promising perspectives. Artificial Intelligence (AI) technology has been implemented to enhance and reconstruct more qualitative and efficient images, including their segmentation. These algorithms are also used for analyzing contractile function, evaluating blood flow in the coronary artery, and assisting in computer-aided diagnosis[5,12].

**Artificial Intelligence in MRI**

An exemplary use of artificial intelligence in the field of magnetic resonance is observed in the treatment planning for atrial fibrillation. A remarkable aspect of progress in magnetic resonance is the elimination of the need for contrast enhancement. The Late Gadolinium Enhancement (LGE) method remains the gold standard for non-invasive myocardial characterization, identifying scarred or fibrotic areas. However, LGE involves the intravenous administration of contrast material, which requires caution in patients with impaired renal function. In a recent study, a method was described in which magnetic resonance techniques were guided by artificial intelligence, using a virtual native enhancement (VNE) from contrast-free images. This led to significantly superior image quality compared to LGE[2].

**Artificial Intelligence in CT**

Employing computed tomography scans, deep learning technology has been used to analyze coronary calcium scores. In the CONFIRM registry, which involved 13,054 participants, an algorithm was utilized to combine clinical variables with the coronary calcium score obtained from CT angiography. This integrated approach enabled a precise estimation of the pre-test probability of obstructive coronary artery disease. This technology has proven to accurately detect the disease based on CT angiographic imaging, surpassing clinician's visual assessment on reconstructed CT angiography images[1,12].

Radiomic algorithms can be utilized to characterize coronary lesions obtained through CT angiography. Through these intelligent radiomic algorithms, features of atheroma plaque and microcalcifications, as well as coronary inflammation, can be identified more precisely than through visual interpretation by clinicians[1,9].

By combining CT scanning with artificial intelligence, it is possible to achieve precise detection of myocardial scar tissue resulting

from myocarditis and myocardial infarction. Additionally, this collaborative approach allows for accurate assessment of left ventricular dilation and systolic function in patients with ventricular tachycardia[1].

**Discussions**

Although augmented reality and AI are separate technological approaches, their combination can be effectively utilized in the field of interventional cardiology. Virtual reality programs, for instance, are employed to plan structural interventions for cardiac diseases[5]. An FDA-approved application called True 3D can render a patient's specific anatomy in an interactive virtual reality format. Similar applications can also offer crucial information before or during procedures, displayed on multiple monitors[14].

A systematic review and meta-analysis of articles examining the application of artificial intelligence in detecting cardiovascular diseases from wearable devices have identified advanced AI models that show promise in this area. These models extend beyond arrhythmia detection, including atrial fibrillation (AF), and also encompass the prediction of various cardiovascular conditions such as diabetes, sleep apnea, anemia and valvular diseases[1,2,5].

An important aspect noted in the data analysis is the significant performance difference between models trained on public datasets, personal datasets, data collected from hospital devices, and data from wearable devices[17]. Data characteristics can vary considerably depending on collection methods (rest monitoring versus ambulatory monitoring) and specific settings (intensive care unit, hospitalized patient, outpatient, and general population) of data acquisition. This variety can influence the results and overall performance of AI models in detecting and prognosticating cardiovascular diseases[14].

For instance, there might be substantial differences in the incidence of cardiovascular diseases among various demographic groups, and the performance of a model can be greatly impacted by an imbalance between data relating to the disease and normal data. Therefore, using data gathered from a population group with characteristics comparable to the target group for which the AI model will be applied is crucial for constructing an artificial intelligence model. Instead of using data from hospital surroundings, it is preferable to use data from large general populations to establish a more universal model in digital healthcare[8,15].

However, a major issue with deep learning is its "black box" nature, making it challenging to understand how it works and the decision-making process. While deep learning models can provide high accuracy, their decisions

may be difficult for healthcare professionals to accept without proper interpretation[13]. Despite the existence of a small number of studies adopting strategies to use meaningful maps to improve interpretability, such approaches are still rare compared to models in the medical imaging field. Manual extraction of interpretable features from clinical or biosignal information known to human experts and integrating them into deep learning models can be a feasible alternative to improve AI interpretability[11].

Apart from the numerous benefits that artificial intelligence offers to the medical field, there is a propensity to misuse patient data for financial purposes. Together with the possible advantages of automation in learning, these problems must be acknowledged and addressed. It is appropriate that patients' express consent be obtained before making healthcare data publicly accessible.

However, by concentrating large amounts of data into artificial intelligence, there is a risk of cyberattacks and abusive use of data by private companies in exchange for them with insurance companies, raising concerns about patient information confidentiality and security[11,18].

## Limitations

Although there are notable advantages to implementing AI in cardiology and medicine in general, there are also certain limitations. Undoubtedly, AI can efficiently and accurately analyze images, additionally demonstrating the capability in saving time compared to specialist doctors. However, a series of essential limitations and problems may occur. AI models, sometimes known as "black boxes," are created by algorithms directly from raw data, which means that neither their developers nor any other human can comprehend how factors are integrated to produce predictions. This suggests that it may not always be easy to evaluate and validate clinically the outcomes produced by AI models[13].

The majority of research on artificial intelligence's therapeutic applications has been retrospective, and large-scale multicenter investigations are still needed to validate AI algorithms[7]. The application of AI in medicine raises important ethical and legal questions as well. In order to train AI models using machine learning methods, large databases and registries including sensitive patient data are frequently used in AI applications. Future research opportunities may be limited as a result of these concerns regarding the use of personal data and patients' reluctance to divulge information for AI applications[11,18].

## Conclusion

Cardiology has experienced a significant expansion in the use of AI technologies, which might completely transform patient treatment. AI systems are capable of accurately identifying, categorizing, diagnosing, and predicting cardiac abnormalities. They constitute a cost-effective solution to meet the expanding need for cardiac imaging and carry the potential of improved workflow efficiency, repeatability, and diagnostic accuracy. The application of AI in clinical practice must, however, overcome a number of challenges, including a lack of information on the technology and its effects on patient outcomes. To precisely evaluate the efficacy and accuracy of these algorithms and to comprehend how AI can impact clinical outcomes, more research in the form of prospective studies is essential. It is important to note that these technological advances are





not intended to replace the role of doctors and other healthcare professionals but rather to provide highly precise tools for disease detection, risk stratification, and optimization of individual patient management.

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