Artificial intelligence in cardiology

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Artificial intelligence (AI) holds great promise in cardiology for evaluating the results of diagnostic procedures, including X-ray imaging, electrocardiography, echocardiography, computed tomography, and magnetic resonance imaging. It can reveal abnormalities that were previously difficult for cardiologists to detect. In addition, AI can be used to predict the risk of complications. In the future, various types of medical AI will be used to treat cardiovascular diseases; however, AI itself will not be able to replace the physicians. Reports of randomized controlled trials confirming the benefits of cardiovascular AI are emerging. The strengths and weaknesses of medical AI need to be evaluated so that cardiologists can effectively use this technology to improve patient care.

Keywords: artificial intelligence, diagnostics, cardiology.

Conflict of interests: none declared.

Received: 21.06.2024
Accepted: 30.07.2024

For citation: Mamedov M.N., Savchuk E.A., Karimov A.K. Artificial intelligence in cardiology. International Journal of Heart and Vascular Diseases. 2024. 12(43): 4-8. DOI: 10.24412/2311-1623-2024-43-4-8

Introduction

The World Health Organization's Global Strategy for Digital Health 2020-2025 states that technological healthcare should be accessible to patients. The security and confidentiality of information, transparency of data processing, and strengthening trust in e-services are identified as priorities [1]. In Russia, more than 60 billion rubles have been invested for the federal project "Development of a network of national medical research centers and introduction of innovative medical technologies" for the period of 2019-2024 [2].

Innovative technologies in healthcare include artificial intelligence (AI), medical robotics, wearable

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devices for health monitoring, genome analysis and editing, virtual and augmented reality technologies, implantable devices and prostheses, drug delivery systems, bioprinting, and telemedicine.

AI is the imitation by a computer of human logic and thought processes to solve various tasks. Machine learning is one of the branches of AI and involves processes by which a computer acquires and recognizes data. The machine then makes assumptions based on the identified relationships.

AI is an assistant to scientists and doctors in various medical fields, including

- Electronic medical record management;
- Disease diagnosis;
- Pharmacological and surgical treatment planning;
- Personalized medical care;
- Health monitoring;
- Drug development;
- Conducting virtual consultations [3].

The first application of AI in medicine was described in 1976; it was the development of a computer algorithm to identify the causes of acute abdominal pain [4]. Since then, the range of AI applications has expanded considerably. The technology has also facilitated the early detection of conditions such as skin cancer and diabetic retinopathy, as well as image interpretation in the field of radiology. In addition to diagnostic imaging, data have been published on the application of AI in the manufacture of neuroprostheses for stroke patients using a brain-computer interface.

Cardiovascular diseases (CVD) are the subject of numerous studies using AI [5]. Several types of AI are being developed for various instrumental studies such as X-ray, electrocardiography (EKG), echocardiography (EchoCG), computed tomography (CT), and magnetic resonance imaging (MRI). It is expected that the use of AI in cardiology will be recommended in clinical practice as soon as substantial evidence is available [6].

The following is a brief review of published studies on the use of AI in the diagnosis of CVD.

Studies of artificial intelligence use in X-ray imaging

In the field of cardiology, the use of chest X-ray imaging is a fundamental tool in the process of differential diagnosis. Toba et al. developed an AI model that assumed hemodynamics based on chest radiography data using the scans of 657 patients with congenital heart disease [7].

A high correlation coefficient was observed between the ratio of pulmonary to systemic blood flow measured through the catheter and that obtained by AI from radiographic data. Matsumoto et al. developed an AI system for the differentiation of heart failure (HF) from normal findings using the chest X-ray scans [8].

By leveraging the transfer learning with the VGG16 model obtained from ImageNet, an AI was developed to differentiate between HF and the norm on 638 chest radiographs, achieving an accuracy of 82%. The sensitivity and specificity were 75% and 94%, respectively.

EKG AI research

The automatic interpretation of electrocardiograms (EKG) is a widely utilized clinical practice, enabling the identification of arrhythmias and ST segment alterations. EKG AI is capable of identifying abnormalities that were previously challenging to discern with automated devices. Attia et al. state that the application of AI in EKG is capable of anticipating the emergence of atrial fibrillation (AF) during sinus rhythm [9]. Following the publication of a study in which the onset of AF was predicted by EKG-based AI in 180,922 cases (sensitivity 79%, specificity 79.5%), clinicians expressed interest in this method.

In a randomized controlled trial (RCT), Yao et al. evaluated the efficacy of EKG AI in detecting a decrease in ejection fraction (EF) [10]. A total of 22,641 cases were randomly in two groups (with and without EKG AI) to facilitate a comparison of the diagnostic rate for detecting reduced EF. In the cohort utilizing EKG AI, the incidence of identifying diminished EF rose by approximately 30%.

Other authors developed AI for diagnosing cardiac amyloidosis [11]. The model worked successfully in 3191 cases. The researchers also got better results when they combined this method with EchoCG.

Sawano et al. developed an AI using EKG data of 29,859 cases and found aortic regurgitation with a high area under the ROC-curve (AUC) of 0.80 [12]. In general, the development of EKG AI has progressed rapidly in recent years.

Echocardiographic studies using artificial intelligence

In recent years, automatic measurement of cardiac function, disease diagnosis and evaluating the prognosis with EchoCG AI are being developed. EchoNet-Dynamic is an automated AI for EchoCG [13].

Using three-dimensional (3D) CNN and semantic segmentation based on 10,030 EchoCG videos for training, an AI was developed that can be used to automatically measure the value of EF. The correlation coefficient between the EF value inferred by the AI and the value determined by EchoCG experts reached 0.9, corresponding to an AUC of 0.97.

Salte et al. developed an AI that measures global longitudinal strain using EchoCG video [14]. The correlation coefficient between the actual measured global longitudinal strain and the estimated global longitudinal strain of the AI reached 0.93, suggesting that the AI can reduce the examination time for EchoCG.

Ulloa Cerna et al. developed a highly accurate AI for predicting one-year prognosis (AUC 0.83) based on EchoCG video of 32,362 individuals [15]. Cardiologists using this model significantly improved predictive sensitivity by 13% in predicting one-year survival based on EchoCG video.

Shad et al. developed an AI that predicts postoperative right ventricular failure from preoperative EchoCG video recording, and its predictive performance showed an AUC of 0.73, which was higher than that of a group of clinical experts with an AUC of 0.58 [16].

Studies of artificial intelligence use in CT imaging

Coronary arteries (CA) CT is used to evaluate the status of the CA without invasive intervention. Many types of CT AI have been developed using analysis techniques such as 3D CNN.

Martin et al. reported that CT fractional flow reserve (FFR) was useful in predicting revascularization and major adverse cardiac events (MACE) [17]. In 159 cases, CT FFR could predict the occurrence of revascularization and MACE at one year with higher accuracy than conventional coronary CT angiography (odds ratio = 3.4).

Zeleznik et al. developed an AI to assess the rate of CA calcification from conventional CT data and predict cardiovascular events [18]. The AI assessed the rate of CA calcification from conventional (non-contrast) CT data in 20,084 cases. The Spearman correlation coefficient between the specialists' measurements and the estimated significance of the AI was 0.92. In addition, the AI-based calcification score was useful for predicting cardiovascular events (hazard ratio = 4.3).

Kumamaru et al. developed an AI that calculates fractional flow reserve from coronary CT data [19]. They used the CA CT scans from 921 cases. Automatic assessment of fractional blood flow reserve by CT AI can detect abnormal fractional blood flow reserve with an AUC of 0.78, sensitivity of 84.6% and a specificity of 62.6%.

MRI AI research

AI is used in the interpretation of cardiac MRI results.

Knott et al. reported on the prediction of cardiovascular events using AI that automatically assesses myocardial perfusion [20]. Myocardial perfusion reserve was assessed by using cardiac MRI scans in 1049 cases, indicating the importance of MRI AI in predicting cardiovascular events.

Zhang et al. developed a model to detect past myocardial infarction (MI) with a non-contrast MRI [21]. The MI was detected with a high accuracy of 99%.

Piccini et al. developed an AI to simulate expert assessment of cardiac MRI image quality using the scans of 424 cases [22]. The results of the regression analysis, assessing the performance of this AI, agreed very well with the conclusions of the experts.

Cardiovascular AI with GAN use

GAN is a fake image generation method that uses learned data to generate non-existent images [23].

GAN consists of two networks: a generator (generation network) and a discriminator (discrimination network), and the quality of images can be improved by competing these networks with each other. In recent years, GAN has been used in the development of cardiovascular AI. Miyoshi et al. developed an AI that interprets the degree of neointima coverage and the degree of yellow color on angioscopic images of 47 cases [24]. The reading accuracy of the AI improved from an AUC of 0.77 to 0.81 when vascular endoscopy data were supplemented with GAN.

Diller et al. used GAN to generate 100,000 cardiac MRI images from 303 cases of congenital heart disease [25]. GAN may be useful for imaging rare diseases.

The ethics of medical AI

There are several examples of potential misuse of AI, such as the collection of information for commercial purposes or the monitoring of personal behavior without consent. It has been noted that even in the absence of negative intent, the use of limited, poor quality, and unrepresentative data to analyze AI can lead to deepening biases and inequalities. Ethics are important in the development of medical AI. In other words, ensuring transparency, fairness, non-harm, accountability, and confidentiality are important in the ethics of medical AI [26].

The World Health Organization has identified the following ethical principles for AI:

- Protection of human autonomy;
- Supporting human welfare, safety, and the public interest;
- Ensuring transparency, clarity and understandability;
- Promoting responsibility and accountability;
- Ensuring inclusiveness and fairness;
- Promoting flexible and sustainable AI [27].

Rogers et al. reported on the need to familiarize patients and the public with the perspectives of medical AI [28].

It is also necessary to consider how medical AI will affect the doctor-patient relationship.

Will the AI replace the medical staff in cardiology practice?

AI for diagnostics (including wearable devices) in cardiology is expected to develop in the future. Although various types of medical AI have been developed for the treatment of CVD, they will never eliminate the need for physicians to be present. In Japan, the physician is primarily responsible for patient care, so the role of medical AI is still to assist the physician.

To date, several types of medical AI have been developed for diagnosis, while the development of AI for treatment is limited. RCTs, but not the AI predictions, are the gold standard for determining the best treatment protocols for specific conditions. Physicians will continue to play an important role in determining the best treatment for each patient. On the one hand, physicians should use AI to improve and verify diagnosis. On the other hand, physicians using AI should be aware that AI is vulnerable to some unrecognized data. If physicians fully understand the weaknesses of AI and use AI judiciously, we can expect an improvement in diagnostic accuracy. In a study based on a questionnaire survey of 1041 radiologists and residents, limited knowledge of AI was associated with fear of replacement, whereas intermediate to advanced knowledge of AI was associated with positive attitudes toward AI [29].

As cardiologists become more knowledgeable about AI, they will become more supportive of the use of AI and will be able to use AI more effectively in clinical practice.

Conclusion

Medical AI is developing rapidly, and the technologies developed have great prospects in cardiology practice. AI can be used in cardiology primarily for diagnostic purposes in the interpretation of techniques such as X-ray, EKG, EchoCG, CT and MRI. At the same time, limited AI developments are available for selected CVD treatments. Physicians will continue to play an important role in determining the optimal treatment for each patient. Overall, medical AI will not be able to replace the work of physicians. With a better understanding of the effectiveness of medical AI, cardiologists will be able to use it to improve the care of patients with various CVD.

Conflict of interests: none declared.

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