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MODERN APPROACHES TO THE APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN CARDIOLOGY

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Abstract

Artificial Intelligence (AI) technologies are widely used in all fields of medicine, especially in cardiology. This article analyzes modern approaches of AI-based diagnostic, monitoring, and prediction systems in the detection and treatment of cardiovascular diseases. The results of scientific research in areas such as ECG analysis using AI algorithms, imaging diagnostics, clinical decision-making, and disease progression prediction in cardiology are presented.

Keywords

artificial intelligence, cardiology, diagnostics, machine learning, deep learning, electrocardiography.

KARDIOLOGIYADA SUN'IY INTELLEKT TEXNOLOGIYALARINING QO'LLANILISHI BO'YICHA ZAMONAVIY YONDASHUVLAR

Annotatsiya

Sun'iy intellekt (SI) texnologiyalari tibbiyotning barcha sohalarida, ayniqsa kardiologiyada keng qo'llanilmoqda. Ushbu maqolada SI asosidagi diagnostika, monitoring va bashorat qilish tizimlarining yurak-qon tomir kasalliklarini aniqlash va davolashdagi zamonaviy yondashuvlari tahlil qilingan. Kardiologiyada SI algoritmlari yordamida EKG tahlili, tasviriy diagnostika, klinik qaror qabul qilish hamda kasallik rivojlanishini bashorat qilish kabi yo'nalishlardagi ilmiy izlanishlar natijalari keltirilgan.

Kalit so'zlar

sun'iy intellekt, kardiologiya, diagnostika, machine learning, deep learning, elektrokardiografiya

СОВРЕМЕННЫЕ ПОДХОДЫ К ПРИМЕНЕНИЮ ТЕХНОЛОГИЙ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В КАРДИОЛОГИИ

Аннотация

Технологии искусственного интеллекта (ИИ) широко применяются во всех областях медицины, особенно в кардиологии. В данной статье проанализированы современные подходы систем диагностики, мониторинга и прогнозирования на основе ИИ в выявлении и лечении сердечно-сосудистых заболеваний. Представлены результаты научных исследований в таких направлениях, как анализ ЭКГ с помощью алгоритмов ИИ,

визуальная диагностика, принятие клинических решений и прогнозирование развития заболеваний в кардиологии.

Ключевые слова

искусственный интеллект, кардиология, диагностика, машинное обучение, глубокое обучение, электрокардиография.

Introduction

Cardiovascular diseases remain one of the most pressing problems of the global healthcare system. According to the World Health Organization, 17.9 million people die from cardiovascular diseases annually worldwide, which accounts for 32% of all deaths. According to statistics, this figure is expected to reach 23.6 million by 2030. Cardiovascular diseases are the main cause of mortality not only in developed countries, but also in developing countries[1].

One of the main problems in modern cardiology practice is the complexity of early detection of diseases and prediction of their development. Traditional diagnostic methods often allow for the detection of pathological changes in the cardiovascular system after significant disease progression. In addition, existing diagnostic methods significantly depend on the influence of the human factor in data analysis and decision-making.

The development of artificial intelligence (AI) technologies creates new opportunities for optimizing the processes of diagnosis and treatment in cardiology. Over the past decade, the improvement of machine learning and deep learning algorithms has led to a qualitatively new level of medical data processing, disease detection, and prediction systems. AI systems allow for fast and accurate analysis of large amounts of data, identification of complex relationships, and automation of decision-making processes.

In cardiology, AI technologies are mainly used in four areas: electrocardiographic diagnostics, visual diagnostics (echocardiography, CT, MRI), clinical decision-making systems, and disease progression prediction. In each direction, AI algorithms demonstrate higher accuracy and efficiency compared to traditional methods. For example, deep learning models allow detecting heart rhythm disturbances with an accuracy of up to 95% during ECG analysis.

In addition, AI technologies allow personalizing cardiological services. Machine learning algorithms allow assessing the risk of disease development and choosing the optimal treatment tactics, taking into account the individual characteristics of each patient, medical history, genetic factors, and lifestyle. This allows to increase the effectiveness of treatment and reduce the risk of complications.

Research objective. The main goal of this study is to study and analyze modern approaches to the application of AI technologies in cardiology, assess their effectiveness, and determine their future prospects.

Materials and methods of research. This study was carried out through a systematic analysis of scientific articles, abstracts, and conference materials published in the Web of Science, PubMed, Scopus, and Google Scholar databases in 2019-2024. In the process of searching for data, such keywords and their combinations as "artificial intelligence in cardiology," "machine learning cardiology," "deep learning cardiovascular diseases," "SI-based cardiac diagnosis," "artificial intelligence heart disease prediction" were used.

As a result of the research, 487 scientific sources were identified. After the removal of duplicates and articles not directly related to the topic, 312 sources remained. In the process of selecting articles, attention was paid to the following criteria: the presence of an original research

or review article, the availability of a full text, publication in English, Russian, or Uzbek, the availability of information on the practical application of AI technologies in cardiology.

Of the selected articles, 156 were original research papers, 98 were systematic review articles, and 58 were meta-analyses. Of these, 15 sources containing the most important and relevant information were selected for in-depth analysis. To assess the quality of the selected articles, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) criteria were used.

When analyzing the original research work, special attention was paid to the following parameters: research design, patient contingent size, type of SI algorithms used, diagnostic accuracy indicators (sensitivity, specificity, predictive value), statistical analysis methods. In the study of meta-analyses and systematic reviews, the methodological quality of the research, the reliability of the results, and the possibility of generalization were assessed.

For the analysis of AI technologies used in cardiology, they were studied by dividing them into four main areas: electrocardiographic diagnostics, visual diagnostics, clinical decision-making systems, and disease progression prediction. The types of AI algorithms used in each area, their operating principles, and performance indicators were studied.

In the field of electrocardiographic diagnostics, the application of deep learning algorithms based on convolutional neural networks (CNN) and recurrent neural networks (RNN) architecture was studied. When analyzing ECG signals, the advantages and limitations of AI systems compared to traditional methods were assessed. Based on the data presented in the studies, the sensitivity and specificity of AI algorithms in detecting various heart rhythm disorders were analyzed.

In the direction of visual diagnostics, SI systems used in the analysis of echocardiography, CT, and MRI images were studied. In this direction, the effectiveness of semantic segmentation and object detection algorithms was assessed. Based on data from various studies, the accuracy indicators of SI systems in assessing the anatomy and function of the heart were compared[2-3].

In the area of clinical decision-making systems, the role of machine learning algorithms in the comprehensive analysis of various clinical data and the selection of optimal treatment tactics was studied. In this direction, the application of such algorithms as random forests, support vector machines, and gradient boosting was analyzed. The advantages and limitations of AI-based decision-making systems compared to traditional clinical protocols were assessed.

In the direction of predicting disease development, the effectiveness of deep learning and machine learning algorithms in creating various prediction models was studied. The accuracy indicators of SI systems used in assessing the risk of developing cardiovascular diseases and predicting the consequences of the disease were analyzed.

For statistical processing of the data collected during the study, SPSS 25.0 and Python 3.8 software were used. ROC-analysis (Receiver Operating Characteristic) and AUC (Area Under the Curve) indicators were used to assess the diagnostic accuracy of SI algorithms. Methods of meta-analysis were used to compare the results presented in various studies.

To assess the reliability of the obtained results, the Kappa coefficient and Bland-Altman analysis were used. The level of statistical significance was set at $p<0.05$. When presenting the research results, the guidelines STARD (Standards for Reporting Diagnostic Accuracy Studies) and TRIPOD (Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis) were followed[9].

Research results and discussion. AI technologies in electrocardiographic diagnostics. The results of the conducted research showed that the effectiveness of deep learning algorithms in the analysis of ECG signals is significantly higher than traditional methods. Models based on

the CNN architecture achieved 96.7% sensitivity and 94.2% specificity in detecting arrhythmias[1]. In particular, AI algorithms demonstrated high accuracy in detecting atrial fibrillation and ventricular extrasystoles - 95.8% and 93.4% respectively. Models based on Long Short-Term Memory (LSTM) networks can predict dangerous heart rhythm disorders with an accuracy of 92.5%. This significantly reduces the time for providing emergency medical care and increases the chances of saving patients' lives[3].

Achievements in visual diagnostics. In the analysis of echocardiographic images, SI systems achieve 94.8% accuracy in measuring the size and wall thickness of the heart chambers. Semantic segmentation algorithms give corresponding results in 91.2% of cases when assessing left ventricular function compared to doctors. 3D CNN models showed particular effectiveness in the processing of CT and MRI images. In the detection of coronary artery stenosis, 89.7% sensitivity and 92.3% specificity are noted. AI algorithms achieve 90.5% accuracy in detecting myocardial fibrosis and cicatricial changes.

Decision-making systems based on machine learning allow for a comprehensive analysis of patients' clinical data, laboratory parameters, and visual examination results, increasing diagnostic accuracy to 87.6%. The Random Forests algorithm provides 88.9% accuracy in diagnosing coronary heart disease. Systems based on gradient boosting models provide correct recommendations in 85.4% of cases when selecting optimal drugs and adjusting doses. This will increase the effectiveness of treatment and reduce the risk of side effects [6-7].

Predicting disease progression. The effectiveness of deep learning algorithms in predicting disease progression deserves special attention. In assessing the risk of developing cardiovascular complications, SI models achieved an accuracy of 86.3%. Compared to the Framingham scale, AI systems have 23.5% higher accuracy. Machine learning algorithms can analyze patient data and predict the risk of heart attacks with an accuracy of 83.7%. This indicator is 18.9% higher than traditional risk scales. With the help of the XatSmart system, it will be possible to determine the risk of re-hospitalization in patients with heart failure with an accuracy of 82.4% [8-10].

Another important advantage of AI technologies is the ability to save time. Studies have shown that AI systems reduce the time for ECG analysis by 78.5% and the processing time of visual examination results by 65.3%. However, there are a number of problems in the widespread introduction of AI technologies. One of the main problems is the quality and standardization of data. The fact that the data obtained from different clinics are not in the same format affects the effectiveness of AI algorithms [11-12].

In addition, the issues of assessing the reliability and certification of AI systems are also relevant. In some cases, AI algorithms operate on the principle of a "black box," that is, the lack of transparency in the decision-making process causes distrust among doctors. Security and data confidentiality issues are also important. It is necessary to improve the legal framework for the protection and use of patient data. At the same time, issues of clearly defining the role of AI systems in clinical practice and defining the boundaries of doctors' responsibilities should also be addressed [13-15].

Conclusion

The results of a systematic analysis of the application of artificial intelligence technologies in the field of cardiology allow us to draw the following conclusions:

The introduction of AI technologies in cardiology leads to a qualitatively new level of diagnostic and treatment processes. Deep learning and machine learning algorithms achieve higher accuracy indicators compared to traditional methods in the detection and prediction of

cardiovascular diseases. ECG analysis showed an accuracy of more than 95%, visual diagnostics - about 90%.

AI systems allow not only to increase diagnostic accuracy, but also to save time and resources. It was noted that the time for processing and analyzing the results of visual examinations is reduced by 65-70%. This contributes to increasing the efficiency of doctors' work and reducing patient queues.

Improvement of clinical decision-making systems allows personalization of cardiological services. AI algorithms play an important role in choosing the optimal treatment tactics and predicting the development of the disease, taking into account the individual characteristics of each patient.

In the future, further improvement of AI technologies will allow raising the quality of cardiological services to a new level and significantly reducing mortality rates associated with cardiovascular diseases.

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