KOPCIAŁ, Szymon, PIECUCH, Dawid, HAŃCZYK, Edyta, KORNATOWSKA, Karolina, PAWELEC, Natalia and MAZUR, Weronika. Artificial intelligence and machine learning in modern cardiology: Advancements in diagnosis, treatment and patient monitoring. Journal of Education, Health and Sport. 2025;80:59924. eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.80.59924
https://apcz.umk.pl/JEHS/article/view/59924

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 31.03.2025. Revised: 25.04.2025. Accepted: 10.05.2025. Published: 14.05.2025.

Artificial intelligence and machine learning in modern cardiology: Advancements in diagnosis, treatment and patient monitoring

KOPCIAŁ Szymon[1*], PIECUCH Dawid[2], HAŃCZYK Edyta[3], KORNATOWSKA Karolina[4], PAWELEC Natalia[5], MAZUR Weronika[6]

[1*] Faculty of Medicine, Kazimierz Pułaski University of Radom: Radom, Poland
szymon.kopcial@gmail.com
https://orcid.org/0009-0008-6647-247X
[SK]

[2] Faculty of Medicine, Kazimierz Pułaski University of Radom: Radom, Poland
dawsid1999@gmail.com
https://orcid.org/0009-0006-8074-0122
[DP]

[3] Faculty of Medicine, Kazimierz Pułaski University of Radom: Radom, Poland
edyta.hanczyk25@gmail.com
https://orcid.org/0009-0003-2769-943X
[EH]

[4] Faculty of Medicine, Kazimierz Pułaski University of Radom: Radom, Poland
kkornatowska47@gmail.com
https://orcid.org/0009-0008-4622-8285
[KK]

[5] Faculty of Medicine, Kazimierz Pułaski University of Radom: Radom, Poland
jancynatalia@gmail.com
https://orcid.org/0009-0004-3478-9350
[NP]
[6] Faculty of Medicine, Kazimierz Pułaski University of Radom: Radom, Poland
nikaaa665@gmail.com
https://orcid.org/0009-0008-4347-4077
[WM]
*Correspondence: szymon.kopcial@gmail.com

ABSTRACT:

Introduction and purpose: Artificial intelligence (AI) and machine learning (ML) are impacting cardiology by enhancing diagnostic accuracy, personalizing treatment and optimizing patient care. This review examines current and emerging applications of AI and ML in cardiology, highlighting their transformative impact on clinical practice, workflow efficiency, and long-term patient outcomes.

Description of the state of knowledge: AI and ML, including advanced neural networks and predictive analytics, demonstrate exceptional sensitivity and specificity in interpreting electrocardiograms (ECGs), echocardiograms, CT scans, and cardiac MRIs. These technologies facilitate early detection of conditions such as coronary artery disease, atrial fibrillation, and hypertrophic cardiomyopathy, while also enabling risk stratification for heart failure, myocardial infarction, and sudden cardiac death. Additionally, AI-driven algorithms support personalized treatment strategies, real-time remote monitoring, and precision-guided coronary interventions, reducing procedural complications. Recent advancements also show promise in automating echocardiographic measurements and optimizing cardiac resynchronization therapy, further enhancing diagnostic and therapeutic precision.

Conclusions: AI and ML hold transformative potential for cardiology, enabling faster, more accurate diagnoses and data-driven therapeutic decisions. Their integration into clinical practice promises to improve prognostic accuracy, reduce healthcare costs, and enhance patient-centered care.

KEYWORDS: artificial intelligence, machine learning, cardiology, cardiac diagnosis, cardiovascular disease, personalized therapy, echocardiography, computed tomography, electrocardiography, monitoring, percutaneous coronary intervention.

INTRODUCTION

Artificial intelligence (AI) and machine learning (ML) are revolutionizing modern cardiology, offering tools that not only improve diagnostic accuracy, but also personalize treatment and optimize cardiovascular disease management. These technologies are capable of analyzing huge medical datasets, identifying subtle patterns invisible to the human eye, and supporting clinicians in making real-time therapeutic decisions [1,2,3].

AI's utility in cardiology stems from its ability to integrate diverse data, such as echocardiographic images, computed tomography (CT) results and ECG signals, which translates into early detection of diseases such as coronary artery disease (CAD) and atrial fibrillation (AF) [4,5]. For example, deep learning algorithms achieve sensitivities of up to 90% in diagnosing CAD from X-rays [6], while ML models predict the risk of hospitalization for heart failure (HF) up to a week in advance [7].

There are many benefits of using AI in cardiology: from automating tedious processes (e.g., analyzing echocardiograms) to reducing healthcare costs. At the same time, challenges, such as the explainability of AI decisions and the ethical use of data, remain key to its implementation in clinical practice [8,9,10].

AIM

This literature review aims to explore the role of artificial intelligence and machine learning in cardiology, focusing on their applications in diagnosis, risk prediction, treatment personalization and patient monitoring. It evaluates the effectiveness of AI-based tools in improving clinical outcomes. The review synthesizes recent advances to highlight future directions for integrating artificial intelligence into cardiac care.

MATERIAL AND METHODS

For the literature review, a database such as Pubmed was used with the keywords: (“artificial intelligence” AND “cardiology”) OR (“machine learning” AND “heart disease”). Articles with publication dates between 2019 and 2025 were considered to ensure relevance to contemporary understanding and practice.

APPLICATIONS OF AI AND ML IN CARDIAC DIAGNOSTICS

- **Echocardiography:**

Artificial intelligence (AI) and machine learning (ML) are increasingly used in the analysis of echocardiograms, improving the accuracy of diagnosis of severe coronary artery disease (CAD) and assessment of left ventricular ejection fraction (LVEF). AI models can automatically analyze stress echocardiograms (SE) and assess parameters related to myocardial work (MW) and left atrial strain (LA strain) [1,2,11,12]. In the study by Guo et al. the ML model based on myocardial work-related features reached an area under the curve (AUC) of 0.852 in the test group and 0.834 in the validation group, with high sensitivity (0.952) and low specificity (0.691) [2]. At the same time, AI proved to be no worse than sonographers in assessing LVEF, reducing the number of significant lesions assessed by cardiologists by 10.4% [8]. In addition, the EchoGo Pro system automatically analyzed echocardiographic images, providing clinicians with a report indicating the likelihood of severe coronary artery disease, which improved diagnostic accuracy and increased clinicians' confidence in making therapeutic decisions [3].

Kobayashi et al. used the K-means algorithm to cluster echocardiographic data, which allowed them to extract three phenotypes: "predominantly normal," 'diastolic changes' and "diastolic changes with structural remodeling." These phenotypes differed in parameters of diastolic function, left ventricular mass and volume, and circulating biomarkers related to inflammation and extracellular matrix remodeling. The eVM algorithm, based on mean early diastolic mitral annular velocity (e'), left ventricular volume (LVEDVI) and left ventricular mass (LVMI), has shown high accuracy in classifying these phenotypes [13].

- **Computed tomography (CT):**

AI automates the assessment of coronary artery calcium (CACS) and analyzes atherosclerotic plaques. In a study by Sartoretti et al, deep learning (DL)-based tools achieved excellent agreement with manual CACS measurements (ICC: 0.986) and a low risk category reclassification rate (3.6%) [14]. In another study, Artificial Intelligence-Quantitative Computed Tomography(AI-QCT) enabled precise assessment of atherosclerotic plaque volume and composition, which is crucial for personalizing treatment. Patients younger than 65 years had a higher volume of non-calcified plaques, while older patients were characterized by more calcified plaques [15]. The ML algorithm (XGBoost) used by Lin et al. achieved an AUC of 0.92 for predicting myocardial ischemia, which was significantly better than the traditional CCTA stenosis score (AUC of 0.84) [9].

- **Magnetic resonance imaging (MRI):**

AI significantly improves the segmentation of cardiac magnetic resonance images (MRI), enabling more accurate assessment of cardiac function. In a study by Geng et al. the LGCW (Local Grayscale Clustering Watershed) model showed superior performance compared to other algorithms, achieving lower mean absolute deviation (MAD) and higher Dice index (a statistical metric used in medical image analysis to assess segmentation quality) (DM) [16]. In addition, AI enabled automated analysis of myocardial perfusion mapping data, identifying reduced Myocardial Blood Flow (MBF) and Myocardial Perfusion Reserve (MPR) stress as strong predictors of adverse cardiovascular events, such as death or myocardial infarction [17].

- **Electrocardiography (ECG):**

AI enables ECG analysis to detect atrial fibrillation (AF) and low ejection fraction (EF). Gruwez et al. developed an algorithm based on deep neural networks (DNN) achieved an AUC of 0.87 in identifying patients with latent paroxysmal AF [4]. In the study by Yao et al, AI increased the number of low EF diagnoses from 1.6% in the control group to 2.1% in the intervention group. Among AI-positive patients, the percentage of low EF diagnoses increased from 14.5% to 19.5% [18].

- **Use of AI in the analysis of atherosclerotic plaques:**

Yamamoto et al. demonstrated that AI algorithms applied to optical coherence tomography (OCT) allow precise, automatic evaluation of morphological parameters of atherosclerotic plaques like fibrous cap thickness (FCT) and lipid volume. Such a system (AI-aided OCT software) had higher reproducibility and less subjectivity compared to traditional manual analysis, significantly reducing the time of the diagnostic process [19]. Deep learning is also applicable to automatic classification of atherosclerotic plaques in intravascular ultrasound (IVUS). The developed model showed high accuracy in differentiating between three types of plaques: with attenuation, calcified and without these pathological features, achieving high Dice similarity coefficients. The algorithm enables rapid and objective assessment, which can significantly assist clinicians in identifying high-risk patients and making therapeutic decisions [20].

- **Other applications:**

Min et al. using deep learning-based models have been used to predict stent underexpansion based on preoperative intravascular ultrasound (IVUS) images. The model achieved 94% accuracy in predicting stent underexpansion, which can lead to better treatment outcomes and a reduced risk of complications such as restenosis and stent thrombosis [21].

Kagiyama et al. used ML to assess left ventricular diastolic function (LVDD) based on electrocardiographic (ECG) features. The ML model was able to predict values of myocardial relaxation velocity (e') with a mean absolute error of 1.46 cm/s in the internal test set and 1.93 cm/s in the external test set [22].

DETECTION OF HEART DISEASE

- **Coronary artery disease (CAD):**

Artificial intelligence (AI) plays an important role in the diagnosis of coronary artery disease (CAD), especially in the analysis of medical images and clinical data. A deep convolutional neural network (DCNN) can detect CAD from chest X-rays, achieving a sensitivity of 90% and specificity of 31%. This can assist in the initial screening of patients, especially where advanced techniques such as coronary angiography are not readily available. [6].

AI has also been used to predict the risk of coronary artery stenosis. In a study by Cheng et al, logistic regression and artificial neural network (ANN) models were used to identify risk factors for coronary artery stenosis, such as MIG and IP-10 protein levels, and these models provided information on biomarkers associated with CAD, offering a more comprehensive approach to risk assessment [23].

ML algorithms such as XGBoost have outperformed traditional CAD prediction models, achieving an AUC of 0.779. Key factors considered include BMI, age and severity of angina symptoms, highlighting the importance of integrating clinical and imaging data in diagnosis and treatment planning [24].

Using AI to analyze patients' facial images is also an interesting approach. The deep learning-based algorithm achieved an AUC of 0.730, outperforming traditional risk assessment models such as Diamond-Forrester (AUC 0.623) and the clinical CAD consortium score (AUC 0.652). This method, which does not require additional clinical data, may be useful for screening CAD risk in the outpatient setting [6,25].

- **Heart failure (HF):**

AI also plays an important role in the early detection and therapeutic management of heart failure (HF). One of the most promising applications is the use of wearable sensors to monitor physiological parameters and predict HF-related hospitalizations. In a study by Sideris et al, the AI system was able to predict HF-related hospitalizations up to a week before they occurred by analyzing sensor data such as heart rate, respiratory rate and activity level. The system generated alerts for clinicians, who responded to 95% of alerts within 24 hours, demonstrating AI's potential to improve patient outcomes through early intervention [7].

In addition to predicting hospitalization, AI has been used to detect complications in patients with advanced HF who are using left ventricular assist devices (LVADs). The ML algorithm has been used to predict aortic regurgitation (AR) in patients with LVADs by analyzing the sounds emitted by the device. The algorithm achieved an accuracy of 91%, with an AUC of 0.73, indicating its potential as a non-invasive tool for early detection of device-related complications [26].

AI has been used to develop diagnostic models to detect HF decompensation. ML techniques make it possible to differentiate between the compensated and decompensated phases of HF based on physiological parameters such as heart rate (HR) and oxygen saturation (Ox). A model that combined logistic regression and support vector machines (SVMs) achieved a sensitivity and specificity of over 80%, highlighting its effectiveness in identifying early signs of HF decompensation [27].

Table 1. Types of algorithms in heart disease detection.

Algorithm	Disease	Diagnostic method	References
DCNN	Coronary artery disease (CAD)	Chest X-ray	[6]
DNN	Atrial fibrillation (AF)	ECG	[4]
XGBoost	Heart failure (HF)	Wearable sensors	[7, 31]
XGBoost	Myocardial infarction	CT + clinical data	[30]

RISK PREDICTION AND PERSONALIZATION OF TREATMENT

- **Risk Prediction:**

AI and ML play a key role in cardiovascular disease risk prediction, enabling early detection and prevention of complications. In the diagnosis of atrial fibrillation (AF), ML models analyzing electronic medical record (EMR) data have achieved high performance, with the Random Forest algorithm achieving an AUC of 0.736, improving AF detection, especially in the high-risk group [5,28].

AI also shows great potential in predicting clinically significant episodes of rapid atrial rhythm (AHRE) in patients with implanted pacemakers. Of the many algorithms used to predict ML, such as Random Forest (RF), Support Vector Machine (SVM) and eXtreme Gradient Boosting (XGBoost), the latter achieved an AUC of 0.745, outperforming traditional logistic regression (AUC 0.669), indicating higher accuracy in identifying patients at risk for major cardiovascular events [29].

AI is also used to predict long-term risk of myocardial infarction (MI) and cardiac death. The XGBoost algorithm, which integrates clinical and imaging data, achieved an AUC of 0.82 in predicting the risk of MI and cardiac death, which was better than traditional risk assessment methods such as the ASCVD score (AUC 0.77) [30]. In contrast, in assessing the risk of heart failure (HF) in patients with diabetes or pre-diabetes, the Random Forest model achieved an AUC of 0.978 in the training set and 0.865 in the validation set, confirming its effectiveness in identifying high-risk individuals [31].

AI also shows great potential in predicting in-hospital mortality. ML models such as CatBoost and LightGBM achieved an AUC of 0.905 in patients with life-threatening ventricular arrhythmias (LTVA), outperforming traditional patient severity scoring systems such as SAPS-II (AUC 0.780) and LODS (AUC 0.749) [32].

- **Personalization of Treatment:**

The CatBoost model predicted 24-hour mean systolic and diastolic blood pressure with an accuracy of 6.6% and 6.8%, respectively, which can help clinicians select optimal medications and doses [33]. In another study, the XGBoost algorithm achieved a mean absolute error (MAE) of 8.57 mmHg in predicting response to antihypertensive treatment, which may reduce the time to reach target blood pressure and reduce the risk of side effects [34].

In cardiac resynchronization therapy (CRT), the adaptive lasso model predicted response to treatment with 70% accuracy. Patients in the highest quintile of predicted response were 14 times more likely to avoid death and hospitalization for heart failure [35].

AI is also being used in the treatment of diabetes and hypertension, where it identifies subgroups of patients who are most likely to benefit from intensive glycemic and blood pressure control. Using advanced ML algorithms such as causal forests (Causal Forest) and causal trees (Causal Tree), results were obtained showing that low diastolic blood pressure (DBP) combined with intensive glycemic control increases the risk of HF. In contrast, intensive blood pressure control was most effective in preventing HF in patients with low alanine aminotransferase (ALT) levels, suggesting that a patient's metabolic status may modulate treatment effects [36]. In contrast, the PRECISION tool, based on the XGBoost algorithm, predicted individual benefit from intensive systolic blood pressure control, allowing for a personalized approach to hypertension treatment [37].

Table 2. AI in personalizing treatment

Therapy	Algorithm	Key benefits	Restrictions	References
Treatment of hypertension	CatBoost	MAE 6.6% (systolic RR); drug dosage selection.	Requires ambulatory data.	[33]
Resynchronization (CRT)	Adaptive Lasso	70% accuracy in predicting response to CRT.	No long-term data available.	[35]
LAA closure	CT + AI simulations	61.1% success rate of left atrial appendage closure.	Calculation cost.	[10]

MONITORING PATIENTS

Artificial intelligence (AI) and machine learning (ML) are playing an increasingly important role in monitoring patients with cardiovascular disease, enabling early detection of exacerbations and improving quality of care. One key area is heart failure (HF) monitoring, where AI analyzes data from wearable sensors to predict exacerbations of the condition. Using algorithms to analyze streams of physiological data (such as heart rate, respiratory rate and activity level), the AI model generated alerts about potential health deterioration. Clinicians responded to these alerts in 95% of cases within 24 hours, and in 26.7% of cases took clinical action, such as modifying treatment or referring for a follow-up visit. These results indicate that integrating AI with clinical workflow can significantly improve the care of patients with HF, reducing the burden on patients and medical staff and potentially reducing hospitalizations [7].

Another important area is the monitoring of atrial fibrillation (AF), which poses a serious risk to patients, especially those at high risk of stroke. Using the AI algorithm, electrocardiograms (ECGs) taken during sinus rhythm were analyzed to identify patients at high risk for AF. The algorithm divided patients into high-risk and low-risk groups, and the patients underwent 30-day heart rhythm monitoring. Compared with traditional medical care, AI-guided screening increased the detection of AF, especially in the high-risk group, which can lead to earlier implementation of anticoagulant treatment and prevention of complications such as stroke [5].

AI is also being used to monitor other pathological conditions, such as aortic regurgitation (AR) in patients with implanted continuous flow left ventricular assist devices (LVADs). Misumi et al. used machine learning to analyze the sounds emitted by the LVAD, which were transformed into acoustic spectra using wavelet analysis. The algorithm achieved a prediction accuracy of 91%, indicating the effectiveness of this method in early detection of complications. This approach may be particularly useful in monitoring patients treated at home, enabling faster intervention and improving prognosis [26].

CORONARY INTERVENTIONS AND PERCUTANEOUS PROCEDURES

For stent implantation, AI is used to predict stent underexpansion, which can lead to complications such as restenosis and thrombosis. A deep learning-based model for analyzing intravascular ultrasound (IVUS) images before surgery achieved 94% accuracy in predicting stent underexpansion. In addition, the predicted values of minimum stent area (IVUS-MSA) and total stent volume were strongly correlated with actual measurements after the procedure. These results suggest that AI can help clinicians identify high-risk stent underexpansion even before stent implantation, which may lead to better treatment outcomes and reduced risk of complications [21].

In the area of coronary angiography, AI aids angiographic analysis, improving the precision of procedures. In a study by Kim et al, the AI-QCA (artificial intelligence-based quantitative coronary angiography) system offered fully automated, objective and rapid real-time angiographic analysis. The system can accurately measure coronary stenosis and stent dimensions without the need for additional time and labor. The results of the study showed that AI-QCA-assisted PCI is no worse than optical coherence tomography (OCT)-guided procedures in terms of achieving optimal minimum stent area (MSA). AI-QCA may therefore be a promising alternative to traditional intravascular imaging methods, especially in cases of less complex coronary disease or in resource-limited settings [38].

AI is also being used to optimize percutaneous procedures, such as left atrial appendage (LAA) closure, which is used in patients with atrial fibrillation to prevent strokes. De Backer et al. used AI to analyze computed tomography (CT) images and computer simulations, which significantly improved the effectiveness of complete LAA closure (61.1%), compared to 44.0% in the control group [10].

Table 3. Applications of artificial intelligence (AI) and machine learning (ML) in modern cardiology.

Application area	Technology	Key results	References
Echocardiography	Deep learning (DL)	AUC 0.852 in detecting severe coronary artery disease (CAD); 10.4% reduction in LVEF assessment errors.	[1, 2, 8]
Computed tomography (CT)	AI-QCT, XGBoost	AUC 0.92 in predicting myocardial ischemia; automation of plaque assessment.	[9, 14, 15]
Magnetic resonance imaging (MRI)	LGCW	Improved segmentation of MRI images (higher Dice ratio); identification of reduced blood flow (MBF) as predictor of cardiac events.	[16, 17]
Electrocardiography (ECG)	Neural networks (DNNs)	AUC 0.87 in detecting latent atrial fibrillation (AF); increase in detection of low EF from 1.6% to 2.1%.	[4, 18]
Assessment of atherosclerotic plaques	AI-aided OCT	Automatic assessment of fiber cap thickness (FCT) and lipid volume; higher reproducibility than manual analysis.	[19, 20]
Predicting risk	XGBoost, Random Forest	AUC 0.82 in predicting myocardial infarction; AUC 0.978 in identifying risk of heart failure in patients with diabetes.	[30, 31]
Personalization of treatment	CatBoost, XGBoost	MAE of 8.57 mmHg in predicting response to hypertension treatment; 70% accuracy in predicting efficacy of CRT.	[33, 34, 35]
Monitoring of patients	Algorithms for analyzing sensor data	Detection of heart failure exacerbations up to 7 days in advance; 95% clinician response to alerts.	[7, 26]
Coronary interventions	AI-QCA, IVUS analysis	94% accuracy in predicting stent underexpansion; comparable performance to OCT in MSA measurements.	[21, 38]

CONCLUSIONS:

Artificial intelligence and machine learning are playing an increasingly important role in cardiology, offering new opportunities for diagnosis, treatment and patient monitoring. A review of the literature shows that AI significantly improves diagnostic accuracy in areas such as echocardiography, CT, MRI, ECG and optical coherence tomography. Automation of diagnostic processes reduces analysis time and workload for medical personnel, while improving the consistency and precision of results.

AI also shows great potential in predicting the risk of cardiovascular diseases such as atrial fibrillation, heart failure and myocardial infarction. ML models are able to identify high-risk patients, enabling early implementation of therapeutic interventions and prevention of serious complications. In addition, AI supports the personalization of treatment, allowing therapies to be tailored to individual patients, resulting in better clinical outcomes.

In the area of patient monitoring, AI enables continuous tracking of physiological parameters for early detection of cardiac exacerbations and rapid clinical response. Integrating AI with monitoring devices, such as wearable sensors and smartwatches, increases the accessibility of diagnostics, especially in areas with limited resources.

Optimization of cardiac procedures, such as stent implantation or percutaneous procedures, also benefits from AI technology, improving the precision, efficiency and safety of interventions. AI aids in angiographic analysis, complication prediction and procedure planning, leading to better patient outcomes and reduced healthcare costs.

AI and ML have tremendous potential for utility in cardiology, offering new opportunities for personalized medicine, precise diagnostics and efficient management of medical resources.

Declarations:

Funding:

This Research received no external funding.

Author contributions:

All authors contributed to the article. Conceptualization: SK, DP; methodology: SK, DP, EH; software: KK, NP, WM; check: KK, SK, WM; formal analysis: DP, EH, NP; investigation: SK, EH; resources: DP, EH, KK; data curation: NP, WM; writing -rough preparation: SK;

writing -review and editing: SK, DP, EH, KK, NP, WM; visualization: KK.; supervision: SK; project administration: DP.
All authors have read and agreed with the published version of the manuscript.

Conflict of Interest Statement:

The authors report no conflict of interest.

Financial Disclosure:

The study did not receive any funding.

Institutional Review Board Statement:

Not applicable.

Informed Consent Statement:

Not applicable.

Data Availability Statement:

Not applicable.

REFERENCES

1. Upton R, Mumith A, Beqiri A, et al. Automated echocardiographic detection of severe coronary artery disease using artificial intelligence. JACC Cardiovascular Imaging. 2021;15(5):715-727. doi:10.1016/j.jcmg.2021.10.013

2. Guo Y, Xia C, Zhong Y, et al. Machine learning-enhanced echocardiography for screening coronary artery disease. BioMedical Engineering OnLine. 2023;22(1). doi:10.1186/s12938-023-01106-x

3. Woodward G, Bajre M, Bhattacharyya S, et al. PROTEUS Study: A prospective randomized controlled trial evaluating the use of artificial intelligence in stress echocardiography. American Heart Journal. 2023;263:123-132. doi:10.1016/j.ahj.2023.05.003

4. Gruwez H, Barthels M, Haemers P, et al. Detecting paroxysmal atrial fibrillation from an electrocardiogram in sinus rhythm. JACC Clinical Electrophysiology. 2023;9(8):1771-1782. doi:10.1016/j.jacep.2023.04.008

5. Noseworthy PA, Attia ZI, Behnken EM, et al. Artificial intelligence-guided screening for atrial fibrillation using electrocardiogram during sinus rhythm: a prospective non-randomised interventional trial. The Lancet. 2022;400(10359):1206-1212. doi:10.1016/s0140-6736(22)01637-3

6. D'Ancona G, Massussi M, Savardi M, et al. Deep learning to detect significant coronary artery disease from plain chest radiographs AI4CAD. International Journal of Cardiology. 2022;370:435-441. doi:10.1016/j.ijcard.2022.10.154

7. Sideris K, Weir CR, Schmalfuss C, et al. Artificial intelligence predictive analytics in heart failure: results of the pilot phase of a pragmatic randomized clinical trial. Journal of the American Medical Informatics Association. 2024;31(4):919-928. doi:10.1093/jamia/ocae017

8. He B, Kwan AC, Cho JH, et al. Blinded, randomized trial of sonographer versus AI cardiac function assessment. Nature. 2023;616(7957):520-524. doi:10.1038/s41586-023-05947-3 (2)

9. Lin A, Van Diemen PA, Motwani M, et al. Machine learning from quantitative coronary computed tomography angiography predicts fractional flow Reserve–Defined ischemia and impaired myocardial blood flow. Circulation Cardiovascular Imaging. 2022;15(10). doi:10.1161/circimaging.122.014369

10. De Backer O, Iriart X, Kefer J, et al. Impact of computational modeling on transcatheter left atrial appendage closure efficiency and outcomes. КАРДИОЛОГИЯ УЗБЕКИСТАНА. 2023;16(6):655-666. doi:10.1016/j.jcin.2023.01.008

11. Adedinsewo DA, Morales-Lara AC, Afolabi BB, et al. Author Correction: Artificial intelligence guided screening for cardiomyopathies in an obstetric population: a pragmatic randomized clinical trial. Nature Medicine. Published online February 4, 2025. doi:10.1038/s41591-025-03554-5

12. Chen J, Gao Y. The Role of Deep Learning-Based Echocardiography in the Diagnosis and Evaluation of the Effects of Routine Anti-Heart-Failure Western Medicines in Elderly Patients

with Acute Left Heart Failure. Journal of Healthcare Engineering. 2021;2021:1-9. doi:10.1155/2021/4845792

13. Kobayashi M, Huttin O, Magnusson M, et al. Machine Learning-Derived echocardiographic phenotypes predict heart failure incidence in asymptomatic individuals. JACC Cardiovascular Imaging. 2021;15(2):193-208. doi:10.1016/j.jcmg.2021.07.004

14. Sartoretti T, Gennari AG, Sartoretti E, et al. Fully automated deep learning powered calcium scoring in patients undergoing myocardial perfusion imaging. Journal of Nuclear Cardiology. 2022;30(1):313-320. doi:10.1007/s12350-022-02940-7

15. Jonas R, Earls J, Marques H, et al. Relationship of age, atherosclerosis and angiographic stenosis using artificial intelligence. Open Heart. 2021;8(2):e001832. doi:10.1136/openhrt-2021-001832

16. Geng Z, Chen B, Li Q, Han X, Zhu X. Efficacy of Morphine Combined with Mechanical Ventilation in the Treatment of Heart Failure with Cardiac Magnetic Resonance Imaging under Artificial Intelligence Algorithms. Contrast Media & Molecular Imaging. 2022;2022(1). doi:10.1155/2022/1732915

17. Knott KD, Seraphim A, Augusto JB, et al. The Prognostic Significance of quantitative myocardial perfusion: an artificial intelligence based approach using perfusion mapping. Circulation. Published online February 14, 2020. doi:10.1161/circulationaha.119.044666

18. Yao X, Rushlow D, Inselman J, et al. Artificial Intelligence-Enhanced ECG Identification of low Ejection Fraction: A pragmatic, Cluster-Randomized clinical trial. Health Services Research. 2021;56(S2):28-29. doi:10.1111/1475-6773.13757

19. Yamamoto T, Sugizaki Y, Kawamori H, et al. Enhanced Plaque Stabilization Effects of Alirocumab — Insights From Artificial Intelligence-Aided Optical Coherence Tomography Analysis of the Alirocumab for Thin-Cap Fibroatheroma in Patients With Coronary Artery Disease

Estimated by Optical Coherence Tomography (ALTAIR) Study —. Circulation Journal. 2024;88(11):1809-1818. doi:10.1253/circj.cj-24-0480

20. Cho H, Kang SJ, Min HS, et al. Intravascular ultrasound-based deep learning for plaque characterization in coronary artery disease. Atherosclerosis. 2021;324:69-75. doi:10.1016/j.atherosclerosis.2021.03.037

21. Min HS, Ryu D, Kang SJ, et al. Prediction of coronary stent underexpansion by Pre-Procedural Intravascular Ultrasound–Based Deep Learning. КАРДИОЛОГИЯ УЗБЕКИСТАНА. 2021;14(9):1021-1029. doi:10.1016/j.jcin.2021.01.033

22. Kagiyama N, Piccirilli M, Yanamala N, et al. Machine learning assessment of left ventricular diastolic function based on electrocardiographic features. Journal of the American College of Cardiology. 2020;76(8):930-941. doi:10.1016/j.jacc.2020.06.061

23. Cheng X, Han W, Liang Y, et al. Risk Prediction of Coronary Artery Stenosis in Patients with Coronary Heart Disease Based on Logistic Regression and Artificial Neural Network. Computational and Mathematical Methods in Medicine. 2022;2022:1-8. doi:10.1155/2022/3684700

24. Baskaran L, Ying X, Xu Z, et al. Machine learning insight into the role of imaging and clinical variables for the prediction of obstructive coronary artery disease and revascularization: An exploratory analysis of the CONSERVE study. PLoS ONE. 2020;15(6):e0233791. doi:10.1371/journal.pone.0233791

25. Lin S, Li Z, Fu B, et al. Feasibility of using deep learning to detect coronary artery disease based on facial photo. European Heart Journal. 2020;41(46):4400-4411. doi:10.1093/eurheartj/ehaa640

26. Misumi Y, Miyagawa S, Yoshioka D, et al. Prediction of aortic valve regurgitation after continuous-flow left ventricular assist device implantation using artificial intelligence trained on

acoustic spectra. Journal of Artificial Organs. 2021;24(2):164-172. doi:10.1007/s10047-020-01243-3

27. Gálvez-Barrón C, Pérez-López C, Villar-Álvarez F, et al. Machine learning for the development of diagnostic models of decompensated heart failure or exacerbation of chronic obstructive pulmonary disease. Scientific Reports. 2023;13(1). doi:10.1038/s41598-023-39329-6

28. Kao YT, Huang CY, Fang YA, Liu JC, Chang TH. Machine Learning-Based Prediction of atrial fibrillation Risk using electronic medical records in older aged patients. The American Journal of Cardiology. 2023;198:56-63. doi:10.1016/j.amjcard.2023.03.035

29. Kim M, Kang Y, You SC, et al. Artificial intelligence predicts clinically relevant atrial high-rate episodes in patients with cardiac implantable electronic devices. Scientific Reports. 2022;12(1). doi:10.1038/s41598-021-03914-4

30. Commandeur F, Slomka PJ, Goeller M, et al. Machine learning to predict the long-term risk of myocardial infarction and cardiac death based on clinical risk, coronary calcium, and epicardial adipose tissue: a prospective study. Cardiovascular Research. 2019;116(14):2216-2225. doi:10.1093/cvr/cvz321

31. Wang Y, Hou R, Ni B, Jiang Y, Zhang Y. Development and validation of a prediction model based on machine learning algorithms for predicting the risk of heart failure in middle-aged and older US people with prediabetes or diabetes. Clinical Cardiology. 2023;46(10):1234-1243. doi:10.1002/clc.24104

32. Li L, Ding L, Zhang Z, et al. Development and Validation of Machine Learning–Based models to predict In-Hospital mortality in Life-Threatening Ventricular Arrhythmias: Retrospective Cohort study. Journal of Medical Internet Research. 2023;25:e47664. doi:10.2196/47664

33. Hae H, Kang SJ, Kim TO, et al. Machine Learning-Based prediction of Post-Treatment ambulatory blood pressure in patients with hypertension. Blood Pressure. 2023;32(1). doi:10.1080/08037051.2023.2209674

34. Yi J, Wang L, Song J, et al. Development of a machine learning-based model for predicting individual responses to antihypertensive treatments. Nutrition Metabolism and Cardiovascular Diseases. Published online March 1, 2024. doi:10.1016/j.numecd.2024.02.014

35. Howell SJ, Stivland T, Stein K, Ellenbogen KA, Tereshchenko LG. Using Machine-Learning for prediction of the response to cardiac resynchronization therapy. JACC Clinical Electrophysiology. 2021;7(12):1505-1515. doi:10.1016/j.jacep.2021.06.009

36. Kianmehr H, Guo J, Lin Y, et al. A machine learning approach identifies modulators of heart failure hospitalization prevention among patients with type 2 diabetes: A revisit to the ACCORD trial. Journal of Diabetes and Its Complications. 2022;36(9):108287. doi:10.1016/j.jdiacomp.2022.108287

37. Oikonomou EK, Spatz ES, Suchard MA, Khera R. Individualising intensive systolic blood pressure reduction in hypertension using computational trial phenomaps and machine learning: a post-hoc analysis of randomised clinical trials. The Lancet Digital Health. 2022;4(11):e796-e805. doi:10.1016/s2589-7500(22)00170-4

38. Kim Y, Yoon HJ, Suh J, et al. Artificial Intelligence-Based Fully Automated Quantitative Coronary Angiography versus Optical Coherence Tomography guided PCI (FLASH Trial). КАРДИОЛОГИЯ УЗБЕКИСТАНА. Published online October 1, 2024. doi:10.1016/j.jcin.2024.10.025