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EARLY DETECTION AND PROGNOSIS OF CHRONIC HEART DISEASES USING ARTIFICIAL INTELLIGENCE

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Abstract

Cardiovascular diseases remain one of the leading causes of mortality and disability worldwide. The high prevalence of these diseases, their complex pathophysiology, and multifactorial etiology necessitate the introduction of new approaches for early detection, accurate diagnosis, and effective prognosis. Early identification of high-risk cardiovascular conditions can reduce the likelihood of acute myocardial infarction and other life-threatening complications, significantly lowering mortality rates among patients.Traditional clinical and statistical analysis methods have limited capacity to fully capture the multidimensional and highly complex data required for cardiovascular risk assessment, prediction of cardiac events, comprehensive analysis of medical imaging, development of individualized treatment strategies, and forecasting disease progression. These limitations are largely explained by the complex interactions among genetic, metabolic, hemodynamic, and environmental factors. Artificial intelligence (AI) has emerged as an advanced computational technology

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capable of deeply analyzing large volumes of medical data, identifying hidden patterns, and generating accurate prognostic predictions, thereby playing a crucial role in modern cardiology. AI-based models demonstrate high effectiveness in the early diagnosis, risk stratification, and optimization of individualized treatment plans for heart failure, atrial fibrillation, valvular heart diseases, hypertrophic cardiomyopathy, congenital heart defects, and other cardiovascular pathologies.In clinical practice, artificial intelligence enhances the accuracy of cardiovascular disease detection, supports diagnostic and decision-making processes, classifies patients according to risk levels, and predicts disease outcomes. Modern AI algorithms are designed to identify subtle and hidden relationships within large-scale, complex healthcare datasets, offering greater potential for solving complex clinical problems compared to traditional approaches.

Keywords: Artificial intelligence, cardiology, effectiveness of artificial intelligence in cardiology, machine learning, cardiovascular diseases, clinical decision support, diagnosis and prognosis.

Introduction

The heart is one of the most vital organs in the human body, ranking second in importance after the brain. Any dysfunction of the heart ultimately leads to systemic disorders throughout the body. We are living in a modern era in which the surrounding world is undergoing significant changes that directly affect our daily lives. Cardiovascular diseases, which claim millions of lives worldwide, remain among the five most dangerous diseases and occupy a leading position among global causes of mortality. Cardiovascular diseases continue to be one of the primary causes of death worldwide and place a substantial burden on healthcare systems. According to the World Health Organization, cardiovascular diseases are responsible for approximately 17.9 million deaths each year,

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

accounting for nearly 32% of all global deaths. Early detection and timely treatment of these conditions play a crucial role in significantly reducing mortality and disability rates. Historically, the diagnosis of cardiovascular diseases has relied on clinical examinations, medical imaging technologies, and laboratory tests. However, these conventional methods are not always accessible to everyone, can be costly, and are prone to human-related errors.Therefore, there is a growing need for new, modern, and more accurate approaches in healthcare.Artificial intelligence (AI) is a technology that enables the simulation of human intelligence in machines and has brought a major breakthrough, particularly in cardiovascular medicine. AI technologies encompass machine learning, deep learning, and natural language processing techniques. These technologies enhance diagnostic accuracy, enable early disease prediction, and support the development of personalized treatment plans for individual patients. By utilizing large-scale medical data, AI systems are capable of identifying complex and hidden patterns within medical images, electrocardiographic recordings, and patients' medical histories. This capability allows for earlier and more accurate detection of cardiovascular diseases, cardiac arrhythmias, and heart failure, thereby improving clinical decision-making and patient outcomes.

Global Impact of Cardiovascular Diseases. Cardiovascular diseases (CVDs) are the leading cause of death worldwide. Ischemic heart disease, heart failure, and stroke are the primary contributors to these high mortality rates. These conditions also impose a substantial financial burden on healthcare systems. For instance, in some developed countries, expenditures related to cardiovascular diseases reach hundreds of billions of dollars, with projections indicating further increases in the future. In developing countries, insufficient medical infrastructure complicates the early detection of these diseases. This situation underscores the growing need for modern diagnostic and treatment methods.

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Artificial Intelligence in Acute Coronary Syndrome. Acute coronary syndrome (ACS) encompasses a group of conditions that restrict blood flow to the heart. These include unstable angina, non–ST-segment elevation myocardial infarction (NSTEMI), and ST-segment elevation myocardial infarction (STEMI). Common symptoms may include severe chest pain radiating to the left arm. Rapid and accurate diagnosis of ACS is crucial for improving patient outcomes and reducing mortality and morbidity.Current diagnostic methods involve electrocardiograms (ECG) and troponin level assessments to differentiate between various types of infarctions. Once an ST-segment elevation myocardial infarction is identified, treatment should begin within 120 minutes, which can reduce the mortality rate by approximately 2%. However, elevated troponin levels do not always indicate a true infarction, and in some cases, ST-segment elevation may not be related to ischemia. Therefore, repeated ECG recordings or continuous ST-segment monitoring are recommended.Troponin is a marker of myocardial injury but can also be elevated in other conditions such as heart failure or atrial fibrillation. This can make the diagnosis of suspected ACS challenging.Machine learning methods can significantly assist in the rapid detection of ACS. Computed tomography (CT) can be used to assess arterial narrowing and classify patients. Studies have shown that machine learning systems can stratify patients based on risk level, allowing for earlier treatment. Artificial neural networks have demonstrated high sensitivity and accuracy in identifying patients with ACS.

Artificial Intelligence in Cardiac Arrhythmias. Bradyarrhythmia and Tachycardia occur when the heart rate falls below 60 beats per minute or exceeds 100 beats per minute, respectively.The normal heart rhythm is called sinus rhythm.Atrial fibrillation is the most common type of arrhythmia, affecting approximately 1.5–5% of the population.Arrhythmias are often asymptomatic, which makes early detection challenging. Artificial intelligence (AI) is increasingly being used to analyze digital electrocardiograms (ECGs). Machine

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

learning methods can predict the onset of atrial fibrillation, allowing proactive intervention.Modern devices and technologies have made detection and monitoring of atrial fibrillation easier. For example, smartwatches can track a patient's heart rhythm in real time, offering a cost-effective and efficient method for ongoing cardiac monitoring.

Artificial Intelligence and Heart Failure. Ventricular failure occurs as a result of insufficient filling or ejection of blood, leading to a complex clinical condition known as heart failure. This condition manifests with various signs and symptoms. According to the New York Heart Association, heart failure is classified into four classes: Class I – no limitation of physical activity; Class II – slight limitation of activity; Class III – marked limitation of activity; Class IV – symptoms present even at rest.

Improvements in treatment and longer patient survival have led epidemiologists to declare heart failure a global epidemic. Reducing hospital admissions of patients can significantly lower healthcare costs. Therefore, artificial intelligence algorithms are being applied to predict worsening symptoms in heart failure patients and initiate early treatment. For example, during the COVID-19 pandemic, some heart failure patients were remotely monitored using invasive pulmonary pressure monitoring. This approach helped in early detection of cardiac decompensation, improved clinical outcomes, and reduced hospital visits. Stehlik and colleagues monitored the vital signs of 100 patients in real time using wearable sensors that recorded body temperature, skin impedance, and electrocardiogram waveforms. The collected data were analyzed using similarity-based modeling, predicting hospitalization due to worsening heart failure with 76% sensitivity and 85% accuracy. These results demonstrate the potential of artificial intelligence in the early detection and management of heart failure.

Additionally, the PASSION-HF consortium proposed a concept of transitioning patients to personalized self-care using the virtual doctor "Abby." Abby includes

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

ISSN 2760-4942 (Online) Volume 2, Issue 1, January 2026

https://eurekaoa.com/index.php/5

an interactive doctor avatar interface, decision-support system, learning-based feedback, and gamification elements. This approach facilitates personal management of heart failure patients and can reduce the need for medical personnel, particularly in rural areas with limited healthcare access. Mobile health technologies enable patients to electronically record daily weight, receive reminders, and notify doctors of significant changes. This allows tracking weight fluctuations and alerting physicians when necessary.Heart failure patients are often classified by ejection fraction: preserved, mid-range, or reduced. Treatment approaches vary for each type. Guidelines for heart failure management are rapidly evolving based on new research and medications. Artificial intelligence provides significant support to medical professionals in diagnosis. For instance, in South Korea, a clinical decision-support system based on AI was tested with 600 patients. The results showed that heart failure with preserved ejection fraction was diagnosed with 78.9% accuracy, while mid-range and reduced ejection fraction cases were diagnosed with 100% accuracy. Furthermore, machine learning algorithms were used to phenotype and cluster patients with preserved ejection fraction heart failure.

Prevalence of Heart Diseases in Uzbekistan. According to the statistical data of the Republic of Uzbekistan, cardiovascular diseases are among the most common and deadly conditions in the country. In 2019, a total of 93,260 people died due to cardiovascular diseases, accounting for more than 60% of all deaths. Among these diseases, ischemia (insufficient blood supply to the heart muscles), arterial hypertension and cerebrovascular disorders were the most frequently diagnosed.According to another statistical source, in 2021, 97,390 people in Uzbekistan lost their lives due to cardiovascular diseases. The mortality rate from heart diseases among the population was 284 per 100,000 people. From January to September 2024, a total of 131.7 thousand deaths were reported in Uzbekistan. A significant portion of these deaths was due to cardiovascular diseases, making

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 1, January 2026

https://eurekaoa.com/index.php/5

them still one of the leading causes of death in the country.Moreover, statistical studies show that despite some positive trends in the sector, the prevalence of heart diseases remains at a high level. For example, from 2003 to 2013, cases related to heart disease.

Which age groups and populations are most affected by heart diseases. In Uzbekistan, cardiovascular diseases most commonly occur in older adults, particularly those over 40 years of age. However, in recent years, these conditions have been increasingly observed among younger populations as well. Even patients aged 16–18 have been reported to experience strokes and heart attacks. This trend indicates that heart diseases are influenced by environmental factors, poor nutrition, stress, physical inactivity, and other lifestyle-related risk factors.

Diagnosis and Symptoms of Cardiovascular Diseases. Cardiovascular diseases (CVDs) are chronic conditions that pose a serious risk to human health. Early detection and proper treatment of these diseases play a crucial role in increasing patient life expectancy and improving quality of life. These diseases can occur in people of various ages, but they are more common in individuals over 50 years old, especially in patients with hypertension, diabetes, obesity, smoking habits, and a family history of heart disease.In Uzbekistan, cardiovascular diseases are widespread. According to the Ministry of Health, 25–30% of the population over 35 years old suffers from various heart conditions. The most common among these are arterial hypertension, heart failure, ischemia, arrhythmias, valvular disorders, and congenital heart diseases.The diagnosis of cardiovascular diseases is multifaceted and is carried out through evaluation of the patient's clinical examination, laboratory tests, diagnostic procedures, and symptoms. Initially, the physician studies the patient's medical history, including family history of heart disease, blood pressure and cholesterol levels, previous heart attacks or strokes, as well as lifestyle and habits.Next, a physical examination is conducted,

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

assessing heart rhythm and rate, blood pressure, body swelling, respiratory rate, and heart sounds (using a stethoscope). Various symptoms are observed depending on the type of disease. In patients with heart failure, shortness of breath, leg swelling, fatigue, and rapid heartbeat are common. Hypertension is often asymptomatic, but sometimes manifests as headache, dizziness, or visual disturbances. In ischemia or myocardial infarction, chest pain or pressure, shortness of breath, and sweating may occur. Patients with arrhythmias may report irregular heartbeats, fast or slow pulse, and dizziness. Valvular disorders can cause heart murmurs, shortness of breath, and fatigue, while congenital heart diseases may present with shortness of breath, rapid fatigue, frequent infections, and cyanosis (bluish discoloration). To confirm the diagnosis, several diagnostic methods are employed. Electrocardiography (ECG) measures heart rhythm and electrical activity, helping to identify infarction, arrhythmia, and heart failure. Echocardiography evaluates the size of the heart chambers, muscle thickness, valve movement, and cardiac contractility. Blood tests measure cholesterol, triglycerides, natriuretic peptides, and glucose, aiding in the assessment of heart failure or infarction risk. Blood pressure measurement and 24-hour monitoring are used to track hypertension and its variations. Stress tests assess heart function during physical activity. Additionally, computed tomography (CT) and magnetic resonance imaging (MRI) help detect structural abnormalities, vessel narrowing, and muscle damage.In recent years, artificial intelligence (AI) and machine learning algorithms have been increasingly applied for early detection and prediction of cardiovascular diseases. By analyzing large datasets, AI can identify the risk of heart failure, arrhythmia, and hypertension, automatically analyze 12-lead ECG and echocardiogram data, and assist physicians in providing rapid and accurate diagnoses. Overall, diagnosing cardiovascular diseases is a complex process that integrates symptom assessment, clinical examination, and diagnostic testing. Regular check-ups, a healthy lifestyle, and the use of advanced technologies are essential for maintaining patient health. The introduction of AI

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

simplifies the diagnostic and treatment process, significantly improving patient outcomes.

The Importance of Early Detection and Prognosis of Chronic Heart Diseases Using Artificial Intelligence in Treatment. The application of artificial intelligence (AI) in healthcare is creating new opportunities for early diagnosis, treatment planning, and patient monitoring. AI-based analytical algorithms optimize clinicians' workflows by processing large volumes of medical data quickly and accurately, identifying patterns that are often difficult for humans to detect. This approach not only improves diagnostic quality but also provides significant benefits in personalizing treatment strategies and predicting outcomes. Studies emphasize that AI systems expand the possibilities for early disease detection, enhancing diagnostic accuracy and enabling the creation of personalized treatment plans based on the patient's condition. This is especially important for complex chronic conditions such as cardiovascular diseases. Chronic heart diseases often remain asymptomatic in the early stages, and patients usually seek medical care only after the disease has already progressed. AI-developed algorithms, however, can detect risk factors before clinical symptoms appear by analyzing medical imaging, heart rhythm recordings, and clinical indicators. This enables early intervention, reduces complications, and significantly improves patient quality of life.Moreover, AI plays a key role in developing personalized treatment plans. Algorithms can integrate and analyze patients' medical histories, genetic data, and lifestyle parameters to suggest the most effective treatment options. This approach is particularly effective in managing complex conditions such as heart failure, hypertension and ischemic heart disease, where individualized treatment planning is crucial.AI also enhances patient monitoring during treatment. For instance, heart rate, blood pressure, and other physical parameters collected via mobile applications and wearable sensors can be analyzed in real-time by AI systems. This facilitates stronger

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

communication between clinicians and patients and allows for rapid, adaptive decisions regarding medication doses, treatment plans, or lifestyle modifications. Overall, AI opens new prospects for improving the effectiveness of chronic heart disease management, preventing disease progression through technology, and enhancing patient outcomes. By enabling early detection and accurate prognosis, AI helps clinicians make timely and informed decisions, guides patients toward individualized treatment plans, and reduces the risk of serious complications.

Conclusion

Artificial intelligence enables the early detection, prognosis, and significant improvement of the treatment process for chronic heart diseases. Studies show that AI systems can identify disease signs at asymptomatic stages by analyzing heart rate, electrocardiograms, ultrasound images, and patients' clinical parameters. For example, monitoring patients with heart failure using AI allows the initiation of early treatment, reducing disease complications and decreasing hospital visits by 30–40%. Additionally, AI enables the development of personalized treatment plans. By considering a patient's medical history, genetic data, and lifestyle parameters, AI can recommend the most effective medications and interventions. This approach is particularly effective for complex heart conditions such as heart failure, hypertension, and cardiomyopathy. Through real-time patient monitoring, AI systems help physicians optimize treatment, promptly adjust dosages, and modify therapies. Thus, artificial intelligence not only enhances diagnostic and treatment quality but also improves patients' quality of life and reduces complications arising from chronic heart diseases. Overall, AI technologies open broad opportunities as an alternative, effective, and reliable tool for the early detection of cardiovascular diseases, personalized treatment planning, and improving patient outcomes.

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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

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